UL 83A

STANDARD FOR SAFETY

Fluoropolymer Insulated Wire

UL Standard for Safety for Fluoropolymer Insulated Wire, UL 83A

First Edition, Dated February 1, 2016

Summary of Topics

This revision of ANSI/UL 83A dated November 12, 2021 is being issued to update the title page to reflect the most recent designation as a Reaffirmed American National Standard (ANS). No technical changes have been made.

Text that has been changed in any manner or impacted by UL's electronic publishing system is marked with a vertical line in the margin.

The requirements are substantially in accordance with Proposal(s) on this subject dated September 10, 2021.

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UL 83A

Standard for Fluoropolymer Insulated Wire

First Edition

February 1, 2016

This ANSI/UL Standard for Safety consists of the First Edition including revisions through November 12, 2021.

The most recent designation of ANSI/UL 83A as a Reaffirmed American National Standard (ANS) occurred on November 12, 2021. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

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

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1 Scope

1.1 This Standard specifies the requirements for 600 V, single-conductor, fluoropolymer-insulated wires and cables in accordance with NFPA 70, National Electrical Code (NEC).

Note: *See Appendix A for the complete list of wire types covered by this Standard.*

1.2 Products for which this Standard provides requirements might have applications not described in the electrical code listed in 1.1.

2 General

2.1 Units of measure

2.1.1 Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information.

2.2 Reference publications

2.2.1 Any undated reference to a code or standard appearing in the requirements of this standard shall be interpreted as referring to the latest edition of that code or standard.

UL Standards

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

UL 2556
Wire and Cable Test Methods

ASTM (American Society for Testing and Materials) Standards

B3-13,
Standard Specification for Soft or Annealed Copper Wire

B8-11,
Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft

B33-10(2014),
Standard Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes

B160-10(2014),
Standard Specification for Nickel Rod and Bar

B172-10(2015),
Standard Specification for Rope-Lay-Stranded Copper Conductors Having Bunch-Stranded Members, for Electrical Conductors

B173-10(2015),
Standard Specification for Rope-Lay-Stranded Copper Conductors Having Concentric-Stranded Members, for Electrical Conductors

B174-10(2015),
Standard Specification for Bunch-Stranded Copper Conductors for Electrical Conductors

B355-11,
Standard Specification for Nickel-Coated Soft or Annealed Copper Wire

IEC (International Electrotechnical Commission) Standards

60228 (2004-11),
Conductors of insulated cables

NFPA (National Fire Protection Association) Publication

NFPA 70,
National Electrical Code (NEC)

2.3 Summary of requirements

2.3.1 As a guide to users of this Standard, a summary of requirements is provided in Appendix A.

3 Definitions

3.1 The following definitions apply in this Standard:

3.2 EQUIPMENT-GROUNDING CONDUCTOR – a conductor that is defined in the NEC, as "Grounding Conductor, Equipment".

3.3 ETFE – Ethylene tetrafluoroethylene

3.4 FEP – Fluorinated ethylene propylene

3.5 PFA – Perfluoroalkoxy

3.6 TFE – Polytetrafluoroethylene

3.7 THERMOPLASTIC – a polymeric material that can repeatedly be softened by heating and hardened by cooling and that in the softened state can be shaped through the application of force.

4 Construction

4.1 Conductors

4.1.1 General

4.1.1.1 Circuit and equipment-grounding conductors shall be of copper or of a nickel-based alloy.

4.1.2 Copper conductors

4.1.2.1 General

4.1.2.1.1 The requirements of 4.1.2.2 or 4.1.2.3 shall apply to solid conductors or the individual wires of stranded conductors prior to stranding.

4.1.2.2 Bare copper conductors

4.1.2.2.1 Each wire in a bare copper conductor shall comply with the requirements of ASTM B3.

4.1.2.3 Tin-coated copper conductors

4.1.2.3.1 Each wire in a tin-coated conductor shall comply with the requirements of ASTM B33. Overcoating of 2.08 mm^2 (14 AWG), 3.31 mm^2 (12 AWG), and 5.26 mm^2 (10 AWG) stranded copper conductor with a layer of tin shall be optional.

4.1.2.4 Nickel-base alloy conductors

4.1.2.4.1 Each wire in a nickel-base alloy conductor shall comply with the requirements of ASTM B160.

4.1.2.5 Nickel-coated copper conductors

4.1.2.5.1 Each solid copper conductor and each strand in a stranded copper conductor shall be protected against oxidation by a coating of nickel complying with ASTM B355.

4.1.3 Sizes and stranding

4.1.3.1 Sizes

4.1.3.1.1 Conductors shall be as shown in Table 1.

Note: *IEC conductor sizes are not recognized in the NEC, however, these sizes can be required for wires and cables intended for use outside of the codes. As a guide to users of this Standard, information on IEC conductors is provided in Appendix B.*

4.1.3.2 Stranding

4.1.3.2.1 General

4.1.3.2.1.1 The minimum number of wires (strands) in a conductor shall be in accordance with Table 2.

4.1.3.2.1.2 Copper strands smaller than 0.0127 mm^2 (36 AWG) shall not be used.

4.1.3.2.2 Compressed

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

4.1.3.2.3 Assembly of strands

4.1.3.2.3.1 A 19-wire combination round-wire unilay stranded conductor shall be round and shall consist of a straight central wire, an inner layer of six wires of the same diameter as the central wire, and an outer layer consisting of six wires with the same diameter as the central wire alternated with six wires with a diameter of 0.732 times the diameter of the central wire. No particular assembly of the individual wires of any other stranded conductor shall be required. However, simple bunching (untwisted strands) shall not be

used. The length of lay of the strands in a bunch-stranded conductor twisted as a single bunch shall not be greater than as indicated in Table 3. The direction of lay of the strands in a bunch-stranded conductor shall be left-hand.

4.1.3.2.4 Length and direction of lay

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

a) The direction of lay of the strands, members, or ropes in a 13.3 – 107 mm^2 (6 AWG – 4/0) conductor, other than a combination unilay or a compressed unilay or compressed unidirectional lay conductor, shall be reversed in successive layers. Rope-lay conductors with bunch-stranded or concentric-stranded members shall be either unidirectional or reversed. All unidirectional lays and the outer layer of reversed lays shall be in the left-hand direction.

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

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

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

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

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

4.1.4 Diameter and cross-sectional area

4.1.4.1 The nominal diameters of solid and stranded conductors are shown in Table 4 – Table 7. The minimum diameter for stranded conductors is 98 percent of the nominal. The maximum diameter is 101 percent of the nominal. The diameter shall be determined in accordance with the test, Conductor diameter, in UL 2556.

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

4.1.4.3 The nominal cross-sectional area, if required, shall be determined in accordance with the test, Cross-sectional area, in UL 2556.

4.1.4.4 Compressed unilay or compressed unidirectional lay copper conductors that are smaller in diameter than the requirement (0.98 x nominal in Table 5) for compressed concentric lay conductors shall be marked in accordance with 6.1.6.

4.1.5 Joints

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

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

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

4.1.6 Separator

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

4.2 Insulation

4.2.1 General

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

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

4.2.2 Repairs

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

4.2.3 Colored insulation

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

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

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

4.2.4 Thickness and centering

4.2.4.1 The average and minimum thickness of the insulation shall be as shown in Table 9 – Table 12. Compliance shall be determined in accordance with the test, Thickness, in UL 2556.

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

4.2.5 Physical properties of insulation

4.2.5.1 General

4.2.5.1.1 The tensile strength and ultimate elongation of the insulation, before and after aging, shall be as specified in Table 13.

4.2.5.2 Test requirement

4.2.5.2.1 Compliance with 4.2.5.1.1 shall be determined in accordance with the test, Physical properties (ultimate elongation and tensile strength), in UL 2556.

4.2.5.3 Evaluation of alternative insulation materials for use in this Standard (see Appendix C)

4.2.5.3.1 Alternative insulation materials for products shall be evaluated in accordance with the test, Dry temperature rating of new materials (long-term aging test), in UL 2556.

4.2.5.3.2 Materials having characteristics different from those specified in Table 13 shall be evaluated for the requested temperature rating in accordance with 5.15. To be evaluated, materials shall have an initial absolute minimum tensile strength of not less than 6.8 MPa (1000 lbf/in^2), and an absolute minimum elongation of 100 percent before aging.

4.2.5.3.3 The temperature rating and thickness of those materials having characteristics different from those specified in Table 13 shall be as required for the specific thermoplastic-insulated wire or cable type.

The electrical, mechanical, and physical characteristics of the wire or cable using these materials shall be such that the materials meet the specified requirements for the temperature rating.

4.2.5.3.4 Insulation material complying with 4.2.5.3.2 shall then be evaluated to establish requirements for its specific physical properties in Table 14.

4.3 Assemblies that include thermoplastic-insulated single conductors

4.3.1 When cabled into assemblies (length and direction of lay not specified), single-conductor wires that comply with the requirements in this Standard shall not be considered cables, and do not include overall coverings. An open, skeleton tape or wrap intended only to hold the assembly together shall be allowed. Such assemblies shall be allowed to include other single-conductor wires or cables not covered in this Standard. An assembly may contain a bare copper conductor – size is not specified – that is coated with tin or other metal shall be optional. A bare, coated copper conductor shall not be covered. The completed assembly shall meet the following requirements:

a) Assemblies in which a bare, coated copper conductor is included shall be tested for dielectric voltage-withstand as indicated in 5.17, except that immersion in water shall be for at least 1 hour.

b) Each assembly in which a bare conductor is not included shall either be tested as indicated in 5.17 (1 hour or longer immersion) or be spark tested as indicated in 5.16, with each layer in a multiple-layer assembly sparked separately.

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

4.4 Braids

4.4.1 Type FEPB wire in size 14 – 2 AWG shall be provided with a lacquer-coated glass braid applied over the insulation. The lacquer coating on the glass braid on size 14 – 2 AWG Type FEPB wires shall not reduce the ability of the finished wires to comply with the applicable flame test(s) in this Standard.

5 Test requirements

5.1 General

5.1.1 Every length of finished insulated conductor shall be capable of meeting the test requirements set out in 5.2 – 5.19, as applicable.

5.2 Conductor resistance

5.2.1 The direct-current resistance of the conductor shall not be greater than shown in Table 15 – Table 23 inclusive. For conductors for which the maximum resistance is not tabulated in Table 15 – Table 23 , the maximum resistance for a given size of the solid or stranded construction shall be determined by multiplying the maximum resistance tabulated in the tables for uncoated copper of the same size and construction by the ratio of 100 percent IACS (International Annealed Copper Standard) to the percent conductivity as shown in the applicable conductor standard.

5.2.2 A twisted conductor assembly shall not exceed the value tabulated in Table 15 – Table 23 as applicable, for a single conductor multiplied by whichever of the following factors is applicable:

a) Cabled in one layer: 1.02;

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

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

5.2.3 Compliance shall be determined in accordance with the test, DC resistance, in UL 2556.

5.3 Short-term insulation resistance at elevated temperature in water

5.3.1 The insulation of Type ZW, ZW-2, Z, PFA, PFAH, FEP, FEPB, and TFE wires shall result in the full range of sizes of finished wire having an insulation resistance of not less than 1000 megohms based on 1000 conductor feet or 304 megohms based on a conductor kilometer.

5.4 Long-term insulation resistance in water

5.4.1 Minimum acceptable value

5.4.1.1 The insulation on Type ZW-2 wire shall result in the full range of sizes of finished wire having an insulation resistance in tap water at 90°C (194°F) and the insulation on Type ZW wire shall result in the full range of sizes of finished wire having an insulation resistance in tap water at 75°C (167°F) of not less than 100 megohms based on 1000 conductor feet or 30.4 megohms based on a conductor kilometer.

5.4.2 Maximum acceptable rate of decrease

5.4.2.1 During the extended immersion, the maximum decrease in insulation resistance per week, as determined from a curve (derived from the best fit using the method of least squares representing the average of actual values), for every continuous period of 3 weeks during the latter half of the specified immersion time shall be not more than 4 percent if and while the insulation resistance is 3 GΩ•m (10 MΩ•1000 ft) or more, and shall be not more than 2 percent if the insulation resistance is less than 3 GΩ•m (10 MΩ•1000 ft), but more than the value indicated in 5.4.1.1.

5.4.2.2 Any coil that shows a greater percent decrease in insulation resistance than those indicated in 5.4.2.1 during the extended period of time in the water tank may be tested for additional one week periods in the water tank and judged on the basis of the results for every continuous period of 3 weeks during the last 6-week period in the water tank, provided that the final insulation resistance is not less than as specified in 5.4.1.1.

5.5 Capacitance and relative permittivity of wet rated ("W" type) wires

5.5.1 Specimens of finished wire immersed in water at the wet-rated temperature, 75°C, or 90°C, shall comply with each of the following, in accordance with the test, Capacitance and relative permittivity, in UL 2556:

a) The relative permittivity determined after immersion for 24 hours shall not be more than 4.

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

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

5.6 Flexibility at room temperature after aging

5.6.1 The insulation shall not show any cracks, either on the surface or internally, when wound around a mandrel of the diameter specified in Table 24, Column B, at room temperature, in accordance with the test, Flexibility at room temperature after aging, in UL 2556, after aging in an air oven as specified in Table 13.

5.7 Cold bend and cold impact

5.7.1 Cold bend

5.7.1.1 After conditioning at a temperature of -25 ±1°C for 4 hours, the insulation shall not show any cracks when tested in accordance with the test, Cold bend, in UL 2556, modified as indicated in 5.7.1.2. The mandrel diameter shall be as specified in Column B of Table 24. Conditioning at a temperature of -40 ±1°C shall be optional.

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

5.7.1.3 When the wire or cable is marked with the optional -40°C marking in accordance with 6.1.7, conditioning shall be carried out at a temperature of -40 ±1°C.

5.7.2 Cold impact (optional)

5.7.2.1 The insulation on at least 8 out of 10 complete cable specimens shall not crack or rupture when tested at -40°C in accordance with the test, Cold impact, in UL 2556.

5.8 Deformation

5.8.1 The thickness of 90°C rated insulations shall not decrease by more than 25 percent, respectively, when subjected to the load specified in Table 25 and tested at a temperature of 121 ±1°C in accordance with the test, Deformation, in UL 2556.

5.9 Flame and smoke

5.9.1 Vertical flame

5.9.1.1 When tested in accordance with the test, FV-1/Vertical Flame, in UL 2556, a specimen of a wire or cable shall not flame longer than 60 seconds following five 15 seconds applications of the test flame, the period between applications being 15 seconds. If any specimen shows more than 25 percent of the indicator flag burned away or charred (soot that can be removed with a cloth or the fingers and brown scorching area shall be ignored) after any of the five applications of flame, the wire or cable shall be judged capable of conveying flame along its length. If any specimen emits flaming or glowing particles or flaming drops at any time that ignite the cotton on the burner, wedge, or floor of the enclosure (flameless charring of the cotton shall be ignored), the wire or cable shall be judged capable of conveying flame to combustible materials in its vicinity.

5.9.2 FT1 (optional)

5.9.2.1 When tested in accordance with the test, FT1, in UL 2556, a finished conductor shall not convey flame or continue to burn for more than 60 seconds after five 15 seconds applications of the test flame. If more than 25 percent of the extended portion of the indicator is burned, the conductor shall be considered to have conveyed flame.

5.9.3 VW-1 (optional)

5.9.3.1 Vertical specimen

5.9.3.1.1 For a given size of a finished wire or cable to be marked VW-1, that size and 2.08 mm^2 (14 AWG) copper shall comply with the requirements of the horizontal flame test described in 5.9.3.2, and shall be judged not capable of conveying flame along its length or in its vicinity when tested in accordance with the test, FV-2/VW-1, in UL 2556. If any specimen shows more than 25 percent of the indicator flag burned away or charred (soot that can be removed with a cloth or the fingers and brown scorching area shall be ignored) after any of the five applications of flame, the wire or cable shall be judged capable of conveying flame along its length. If any specimen emits flaming or glowing particles or flaming drops at any time that ignite the cotton on the burner, wedge, or floor of the enclosure (flameless charring of the cotton shall be ignored), the wire or cable shall be judged capable of conveying flame to combustible materials in its vicinity. If any specimen continues to flame longer than 60 seconds after any application of the gas flame, the wire or cable shall be judged capable of conveying flame to combustible materials in its vicinity.

5.9.3.2 Horizontal specimen

5.9.3.2.1 Each size of a given construction of a finished wire that is marked VW-1, in addition to complying with 5.9.3.1, shall be capable of not conveying flame along its length or in its vicinity when a specimen is subjected to the test in FT2/FH/Horizontal flame, in UL 2556. The total length of the char in the specimen shall not exceed 100 mm (4 inches), and the dripping particles emitted by the specimen during or after the application of the flame shall not ignite the cotton on the floor of the enclosure, on the base of the burner, or on the wedge.

5.9.4 Vertical tray (optional)

5.9.4.1 PFA, PFAH, and Z insulated equipment-grounding conductors that are colored green in accordance with 6.1.6, and all No. 1/0 AWG and larger circuit and grounding conductors of the same types, are eligible to be marked (see 6.1.8.2) to indicate use in cable trays when the insulation does not exhibit damage that reaches the upper end of any of two sets of specimen, when subjected for the specified period to the test, Method 1 – Vertical Tray, in UL 2556.

5.9.5 FT4 vertical tray (optional)

5.9.5.1 Finished single conductors shall not exhibit charred material beyond a length exceeding 1.5 m from the flame impingement, when tested for the specified period in accordance with the test, Method 2-FT4, in UL 2556.

5.9.6 ST1 limited-smoke (optional)

5.9.6.1 General

5.9.6.1.1 When tested in accordance with the test, ST1 Limited Smoke, in UL 2556, each finished insulated single conductor shall meet the test criteria in 5.9.4 or 5.9.5. Limits are specified for each fire test to make the following tests equally acceptable for the purpose of quantifying the smoke. The cable manufacturer shall specify, for testing each ST1 (limited-smoke) cable construction, either the vertical flame exposure described in the Vertical-Tray Flame Test – Method 1-Vertical Tray, or in the Vertical-Tray Flame Test – Method 2-FT4 in UL 2556.

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

5.9.6.2 Vertical-tray flame exposure

5.9.6.2.1 Finished insulated single conductors shall exhibit the following properties when tested in accordance with the Vertical-Tray Flame Test – Method 1-Vertical Tray in UL 2556:

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

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

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

d) The values of cable damage height, total smoke released, and peak smoke release rate obtained from one set of specimens shall not differ by more than 15 percent from the values obtained from the second set of specimens. If any of the values differ by more than 15 percent between the two sets of specimens, a third set of specimens shall be tested as described in UL 2556. The values obtained from the third set of specimens shall be within the limits specified in a), b), and c).

5.9.6.3 FT4 vertical-tray flame exposure

5.9.6.3.1 Finished insulated single conductors shall exhibit the following properties when sets of specimen lengths are tested in accordance with the Vertical-Tray Flame Test – Method 2-FT4 in UL 2556:

a) The cable damage height for each set of specimens shall be less than 1.50 m when measured from the lower edge of the burner face.

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

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

d) The values of cable damage height, total smoke released, and peak smoke release rate obtained from one set of specimens shall not differ by more than 15 percent from the values obtained from the second set of specimens. If any of the values differ by more than 15 percent between the two sets of specimens, a third set of specimens shall be tested as described in UL 2556. The values obtained from the third set of specimens shall be within the limits specified in a), b), and c).

5.10 Weather resistance (optional)

5.10.1 To be marked SR, the insulation of Types ZW and ZW-2 shall retain at least 80 percent of their unconditioned tensile strength and elongation values, after conditioning in a specified weather-resistance apparatus for 720 hours.

5.10.2 Compliance shall be determined in accordance with the applicable requirements of the test, Physical Properties – Weather (sunlight) resistance, in UL 2556.

5.11 Oil resistance (optional)

5.11.1 Oil resistance at 60°C

5.11.1.1 To be marked PR I, the retention of tensile strength and elongation of the insulation shall not be less than 50 percent of the unconditioned value after immersion of the finished wire in IRM 902 oil for 96 hours at 100°C. Compliance shall be determined in accordance with the applicable requirements of the test, Oil resistance, in UL 2556.

5.11.1.2 Specimens of wire shall be immersed. After immersion for the specified length of time, each specimen shall be cut in half at the center of the U bend to provide two specimens for physical tests from each length immersed.

5.11.2 Oil resistance at 75°C

5.11.2.1 To be marked PR II, the retention of tensile strength and elongation of the insulation shall be not less than 65 percent of the unconditioned value after immersion of the finished wire in IRM 902 oil for 60 days at 75°C. Compliance shall be determined in accordance with the applicable requirements of the test, Oil resistance, in UL 2556.

5.11.2.2 Specimens of wire shall be immersed. After immersion for the specified length of time, each specimen shall be cut in half at the center of the U bend to provide two specimens for physical tests from each length immersed.

5.12 Gasoline and oil resistance (optional)

5.12.1 To be marked GR I or GR II, the retention of tensile strength and elongation of insulated conductors found to be in compliance with the requirements of 5.11.1 or 5.11.2, respectively, shall not be less than 65 percent after 30 days immersion in water saturated with equal volumes of iso-octane and toluene (ASTM Reference Fuel C) maintained at 23 ±1°C. Compliance shall be determined in accordance with the applicable requirements of the test, Gasoline resistance, in UL 2556.

5.12.2 Specimens of wet rated wire shall be immersed. After immersion for the specified length of time, each specimen shall be cut in half at the center of the U bend to provide two specimens for physical tests from each length immersed.

5.13 Durability of ink printing

5.13.1 The printing on the finished wire shall remain legible after being subjected to the test, Durability of ink printing, in UL 2556.

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

5.14 Color coating

5.14.1 Surface (ink or paint) coated thermoplastic-insulated wire shall comply with the requirements in 5.14.2 – 5.14.4, when tested in accordance with the test, Color coating, in UL 2556.

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

5.14.3 The coating shall not flake off of the surface of the insulation when samples of the wire are flexed at room temperature in the manner described in the test, Color coating, in UL 2556 both before and after the air-oven aging applicable to the insulation.

5.14.4 The surface coating shall not migrate when tested in accordance with the test, Color coating, in UL 2556.

5.15 Long-term aging of insulation

5.15.1 The absolute elongation of insulation material referenced in 4.2.5.3 shall be not less than 50 percent after being subjected to long-term aging in an air oven in accordance with the test, Dry temperature rating of new materials (long-term aging test), in UL 2556.

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

5.15.3 The applicable test duration and temperature shall be in accordance with Table 14.

5.16 A-C spark test

5.16.1 Every finished production length of single-conductor cable shall be subjected to one of the following:

a) To the a-c spark test in accordance with the test, Spark, in UL 2556. The test potential shall be as shown in Table 26; or

b) To the dielectric voltage-withstand in water test described in 5.17, and the insulation resistance in water test at 15°C described in 5.18.

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

5.17 Dielectric voltage-withstand in water

5.17.1 The insulation of single conductors, when tested in accordance with the test, Dielectric voltage-withstand – Method 1 (in water), in UL 2556 shall withstand, without breakdown, the application of 2000V ac, 6000V dc after immersion in water for not less than 1 hour before the test potential is applied.

5.18 Insulation resistance in water at 15°C

5.18.1 Following compliance with 5.17, while still immersed, the insulation of single conductors shall have an insulation resistance, corrected to 15°C, if necessary, of not less than 1000 megohms based on 1000 conductor feet or 304 megohms based on a conductor kilometer when tested at the prevailing water temperature. The apparatus and test method shall be in accordance with the test, Insulation resistance, in UL 2556. Unless the spark test specified in 5.16 is carried out, each length of finished cable shall be subjected to this test.

5.19 Electrical continuity

5.19.1 Each conductor shall be continuous when tested in accordance with either Method 1 or Method 2 described in the test, Continuity, in UL 2556.

6 Marking

6.1 Marking on product

6.1.1 General

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

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

6.1.1.3 Required markings are described in 6.1.2 – 6.1.5. Optional markings are described in 6.1.7 – 6.1.11.

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

6.1.2 Manufacturer's identification

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

6.1.3 Type designation

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

6.1.4 Conductor size

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

a) "mm^2 (AWG)";

b) "AWG (mm^2)";

c) "mm^2 (kcmil)";

d) "kcmil (mm^2)";

e) "AWG"; or

f) "kcmil".

6.1.4.2 For surface printing on products, the use of "mm2" in place of "mm^2" shall be permitted.

6.1.5 Voltage marking

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

6.1.6 Surface Color

6.1.6.1 An insulated conductor intended for use as an equipment-grounding conductor shall be finished to show the color green throughout the entire length and circumference of its outer surface with or without one or more straight or helical, broken (non-continuous) or unbroken yellow stripes. See 6.1.6.2 for details on stripes.

6.1.6.2 Stripes as specified in 6.1.6.1 shall be of even or varying width and shall occupy a total of 5 – 70 percent of the calculated circumference of the outer surface of the finished insulated conductor in the case of a yellow stripe(s) The width shall be measured perpendicular to each stripe.

6.1.7 Low-temperature marking (optional)

6.1.7.1 A wire or cable marked "(-40°)" shall meet the requirements for -40°C cold bend and cold impact specified in 5.7.

6.1.8 Flame test marking (optional)

6.1.8.1 General

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

a) "FT1": 5.9.2;

b) "VW-1": 5.9.3;

c) "CT": 5.9.4 or 5.9.5 (see 6.1.8.2 for applicability);

d) "FT4": 5.9.5 or 5.9.6, using the FT4 Vertical-Tray Flame exposure;

e) "ST1": 5.9.6;

6.1.8.2 Cable-tray use marking (optional)

6.1.8.2.1 Insulated conductors marked "CT" shall meet the requirements of either 5.9.4 or 5.9.5.

6.1.8.2.2 This marking shall be allowed on single circuit conductors of size 53.5 mm^2 (1/0 AWG) and larger, and equipment-grounding conductors of size 21.2 mm^2 (4 AWG) and larger.

6.1.9 Weather resistance (optional)

6.1.9.1 Wires or cables marked "SR" shall meet the requirements of 5.10. When marked "SR", the additional markings "Sunlight Resistant" or "Sun Res" shall be allowed.

6.1.10 Oil resistance (optional)

6.1.10.1 Wires or cables marked "PR I" shall meet the requirements of 5.11.1. Wires or cables marked "PR II" shall meet the requirements of 5.11.2.

6.1.11 Gasoline and oil resistance (optional)

6.1.11.1 Wires or cables marked "GR I" shall meet the requirements of 5.11.1 and 5.12. Wires or cables marked "GR II" shall meet the requirements of 5.11.2 and 5.12.

6.2 Marking on package

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

a) Manufacturer's identification;

b) Type designation;

c) Conductor size, in accordance with 6.1.4;

d) Voltage rating;

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

6.3 Month and year of manufacture

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

TABLES

Table 1
Conductor sizes and stranding

(See 4.1.3.1.1 and 6.1.3.1)

Wire type	Metal	Conductor size range		Assembly
		mm^2	AWG	
TFE and PFAH	Copper Nickel-based alloy[a]	2.08 – 107	14 – 4/0	Solid, bunch, concentric lay, compressed, 19-wire combination unilay, rope
FEP, FEPB, ZW and ZW-2	Copper	2.08 – 33.6	14 – 2	
PFA and Z	Copper	2.08 – 107	14 – 4/0	

[a] *The conductor shall be of nickel-based alloy complying with ASTM B 160-93 and having a tensile strength of 65,000 ±15,000 lbf/in^2 or 448 ±103 MN/m^2 or 44,816 ±10,342 N/cm^2 or 45.7 ±10.5 kgf/mm^2, an elongation of at least 35 percent, and a nominal volume resistivity of 66 ohm•cmil/ft at 20°C (68°F) or 0.110 ohm•m^2/m at 20°C (68°F)*

Table 2
Conductor stranding

(See 4.1.3.2.1.1)

Sizes of wire		Minimum acceptable number of strands	
mm^2	AWG	Combination unilay	All others
2.08 – 8.37	14 – 8	19[a]	7
13.3 – 33.6	6 – 2	19	7
42.4 – 107	1 – 4/0	19	19

[a] *Copper only.*

[b] *Conductors with a lesser number of strands shall be allowed, based on an evaluation for connectability and bending.*

Table 3
Length of lay of strands in a bunch-stranded conductor twisted as a single bunch[a]

(See 4.1.3.2.3.1)

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

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

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

Note: *Nominal strand configuration and number of wires are found in ASTM B174.*

Table 4
Diameters over solid conductors and cross-sectional area for all solid and stranded conductors

(See 4.1.4.1 and 4.1.4.2)

Size of conductor		Nominal diameter of solid conductor		Nominal cross-sectional area of conductor	
mm²	AWG	mm	mils	mm²	cmil
2.08	14 AWG	1.63	64.1	2.08	4110 cmil
3.31	12	2.05	80.8	3.31	6530
5.26	10	2.588	101.9	5.261	10380
8.37	8	3.264	128.5	8.37	16510
13.3	6	4.115	162.0	13.3	26240
21.2	4	5.189	204.3	21.2	41740
26.7	3	5.827	229.4	26.67	52620
33.6	2	6.543	257.6	33.6	66360
42.4	1	7.348	289.3	42.4	83690
53.5	1/0	8.252	324.9	53.5	105600
67.4	2/0	9.266	364.8	67.4	133100
85.0	3/0	10.40	409.6	85.0	167800
107	4/0	11.68	460.0	107	211600

Table 5
Diameters over round compressed concentric-lay-stranded conductors for Classes B, C, and D

(See 4.1.4.4)

Conductor size		Nominal diameter	
mm^2	AWG	mm	inches
2.08	14 AWG	1.80	0.071
3.31	12	2.26	0.089
5.26	10	2.87	0.113
8.37	8	3.61	0.142
13.3	6	4.52	0.178
21.2	4	5.72	0.225
26.7	3	6.40	0.252
33.6	2	7.19	0.283
42.4	1	8.18	0.322
53.5	1/0	9.19	0.362
67.4	2/0	10.3	0.405
85.0	3/0	11.6	0.456
107	4/0	13.0	0.512

Table 6
Diameters over round compressed unidirectional or unilay-stranded conductors for Class B

Conductor size		Nominal diameter	
mm^2	AWG	mm	inches
42.4	1 AWG	7.95	0.313
53.5	1/0	8.94	0.352
67.4	2/0	10.03	0.395
85.0	3/0	11.25	0.443
107	4/0	12.65	0.498

Table 7
Diameter over round concentric-lay-stranded conductors for Classes B, C, and D

Conductor size		Nominal diameter	
mm^2	AWG	mm	inches
2.08	14 AWG	1.85	0.0727
3.31	12	2.32	0.0915
5.26	10	2.95	0.116
8.37	8	3.71	0.146
13.3	6	4.67	0.184
21.2	4	5.89	0.232
26.7	3	6.60	0.260
33.6	2	7.42	0.292
42.4	1	8.43	0.332

Table 7 Continued on Next Page

Table 7 Continued

Conductor size		Nominal diameter	
mm²	AWG	mm	inches
53.5	1/0	9.45	0.372
67.4	2/0	10.62	0.418
85.0	3/0	11.94	0.470
107	4/0	13.41	0.528

Table 8
Strand and conductor dimensions for 19-wire combination round-wire unilay-stranded conductors

(See Appendix A)

Conductor size		Nominal strand dimensions								Nominal conductor diameter E = 3A + 2C	
		Large strand				Small strand					
		Diameter (A)		Cross-sectional area		Diameter (C)		Cross-sectional area			
mm²	AWG	mm	inch	mm²	cmil	mm	inch	mm²	cmil	mm	inch
2.08	14	0.4	0.0159	0.128	253	0.3	0.0117	0.069	137	1.80	0.071
3.31	12	0.5	0.0201	0.205	404	0.4	0.0147	0.109	216	2.29	0.090
5.26	10	0.6	0.0253	0.324	640	0.5	0.0185	0.173	342	2.87	0.113
8.37	8	0.8	0.0319	0.515	1018	0.6	0.0234	0.277	548	3.63	0.143
13.3	6	1.0	0.0402	0.818	1616	0.7	0.0294	0.437	864	4.55	0.179
21.2	4	1.3	0.0507	1.301	2570	0.9	0.0371	0.696	1376	5.74	0.226
26.7	3	1.4	0.0570	1.644	3249	1.1	0.0417	0.880	1739	6.45	0.254
33.6	2	1.6	0.0640	2.073	4096	1.2	0.0468	1.108	2190	7.26	0.286
42.4	1	1.8	0.0718	2.609	5155	1.3	0.0526	1.400	2767	8.15	0.321
53.5	1/0	2.1	0.0807	3.296	6512	1.5	0.0591	1.768	3493	9.14	0.360
67.4	2/0	2.3	0.0906	4.154	8208	1.7	0.0663	2.225	4396	10.26	0.404
85.0	3/0	2.6	0.1017	5.234	10343	1.9	0.0745	2.809	5550	11.53	0.454
107	4/0	2.9	0.1142	6.600	13042	2.1	0.0836	3.537	6989	12.95	0.510

Table 9
Thicknesses of insulation on Type FEP and FEPB wires

(See 4.2.4.1)

Wire type	Conductor size	Minimum thicknesses			
		Average		At any point	
		mils	mm	mils	mm
FEP	14 – 10 AWG	20	0.51	18	0.46
	9 – 2	30	0.76	27	0.69
FEPB	14 – 2 AWG	14[a]	0.36	13[a]	0.33

[a] *A lacquer-coated glass braid (see 4.4.1) is required over the insulation.*

Table 10
Thicknesses of insulation on Type TFE, PFA, and PFAH wires

Conductor size	Minimum thicknesses			
	Average		At any point	
	mils	mm	mils	mm
14 – 10 AWG	20	0.51	18	0.46
9 – 2	30	0.78	27	0.89
1 – 4/0	45	1.14	40	1.02

Table 11
Thicknesses of insulation on Type Z wire

Conductor size	Minimum thicknesses			
	Average		At any point	
	mils	mm	mils	mm
14 – 12 AWG	15	0.38	13	0.33
10	20	0.51	18	0.46
9 – 4	25	0.63	22	0.56
3 – 1	35	0.89	31	0.79
1/0 – 4/0	45	1.14	40	1.02

Table 12
Thicknesses of insulation on Type ZW, ZW-2 wire

(See Appendix A and Appendix C)

Conductor size	Minimum thicknesses			
	Average		At any point	
	mils	mm	mils	mm
14 –10 AWG	30	0.78	27	0.69
9 – 2	45	1.14	40	1.02

Table 13
Physical properties of insulation

(See 4.2.5.1.1, 4.2.5.3.2, 4.2.5.3.3, 5.6.1, and Table 14)

	Type							
	FEP	**FEPB**	**PFA**	**PFAH**	**TFE**	**Z**	**ZW**	**ZW-2**
Insulation material	FEP	FEP	PFA	PFA	TFE	ETFE	ETFE	ETFE
Temperature rating	90, 200 spec	90, 200 spec	90, 200 spec	90, 250 spec	250	90, 150 spec	90, 1500 spec	90, 1500 spec
Minimum properties								
Before aging								
Tensile strength, MPa (lbf/in^2)	17.2 (2500)	17.2 (2500)	17.2 (2500)	17.2 (2500)	27.6 (4000)	34.5 (5000)	34.5 (5000)	34.5 (5000)
Elongation, percent, minimum increase in distance between 25 mm (1 inch) gauge marks	200	200	200	200	175	100	100	100
After aging								
hours	168	168	96	168	60	168	168	168
Temperature, C (F)	232 (449)	232 (449)	260 (500)	287 (549)	260 (500)	180 (356)	180 (356)	180 (356)
Retention of tensile strength, percent	75	75	85	85	85	85 or 34.5 MPa (5000 lbf/in^2)	85 or 34.5 MPa (5000 lbf/in^2)	85 or 34.5 MPa (5000 lbf/in^2)
Retention of elongation, percent	75	75	85	85	85	75	75	75

[a] *The 45 percent applies only to samples aged in die-cut form.*

Table 14
Worksheet for determination of physical properties of insulation having characteristics different from those indicated in Table 13[a]

(See 4.2.5.3.4 and 5.15.3)

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

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

[b] *Values as determined in accordance with Annex D of UL 2556.*

Table 15
Maximum direct-current resistance at 20°C of solid conductors of bare copper

(See 5.2.1 and 5.2.2)

Size of conductor		Bare copper	
mm^2	AWG	Ohms per km	Ohms per 1000 ft
2.08	14	8.45	2.57
3.31	12	5.31	1.62
5.26	10	3.34	1.02
8.37	8	2.10	0.641
13.3	6	1.32	0.403
21.2	4	0.832	0.254
26.7	3	0.660	0.201
33.6	2	0.523	0.159
42.4	1	0.415	0.126
53.5	1/0	0.329	0.100
67.4	2/0	0.261	0.0795
85.0	3/0	0.207	0.0631
107	4/0	0.16	0.0500

Table 16
Maximum direct-current resistance at 20°C of bare copper conductors – concentric-stranded Classes B, C, and D; and compressed-stranded

Size of conductor		Bare copper	
mm^2	AWG	Ohms per km	Ohms per 1000 ft
2.08	14 AWG	8.62	2.62
3.31	12	5.43	1.65
5.26	10	3.41	1.04
8.37	8	2.14	0.653
13.3	6	1.35	0.411
21.2	4	0.848	0.259
26.7	3	0.673	0.205
33.6	2	0.534	0.163
42.4	1	0.423	0.130
53.5	1/0	0.335	0.102
67.4	2/0	0.266	0.0811
85.0	3/0	0.211	0.0643
107	4/0	0.167	0.0510

Note: *Nominal strand configuration and number of wires are found in ASTM B8 for copper conductors.*

Table 17
Maximum direct-current resistance at 20°C of copper conductors, concentric-stranded Class B with each strand coated with tin or a tin alloy and compressed-stranded Class B with each strand coated

Size of conductor			
mm^2	AWG	Ohms per km	Ohms per 1000 ft
2.08	14 AWG	8.96	2.73
3.31	12	5.64	1.72
5.26	10	3.55	1.08
8.37	8	2.23	0.680
13.3	6	1.40	0.428
21.2	4	0.882	0.269
26.7	3	0.700	0.213
33.6	2	0.555	0.169
42.4	1	0.440	0.134
53.5	1/0	0.349	0.106
67.4	2/0	0.277	0.0843
85.0	3/0	0.219	0.0669
107	4/0	0.172	0.0525

Note: *Nominal strand configuration and number of wires are found in ASTM B8 .*

Table 18
Maximum direct-current resistance at 20°C of copper conductors concentric-stranded Classes C and D with each strand coated with tin or a tin alloy and compressed-stranded Classes C and D with each strand coated

Size of conductor		Class C		Class D	
mm^2	AWG	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft
2.08	14 AWG	9.15	2.78	9.25	2.82
3.31	12	5.75	1.75	5.75	1.75
5.26	10	3.55	1.08	3.62	1.10
8.37	8	2.23	0.679	2.23	0.679
13.3	6	1.41	0.427	1.41	0.427
21.2	4	0.882	0.269	0.882	0.269
26.7	3	0.700	0.213	0.700	0.213
33.6	2	0.555	0.169	0.555	0.169
42.4	1	0.440	0.134	0.440	0.134
53.5	1/0	0.349	0.106	0.349	0.106
67.4	2/0	0.276	0.0844	0.276	0.0844
85.0	3/0	0.219	0.0669	0.219	0.0669
107	4/0	0.174	0.0530	0.174	0.0530

Note: *Nominal strand configuration and number of wires are found in ASTM B8.*

Table 19
Maximum direct-current resistance at 20°C of 19-wire combination round-wire unilay-stranded copper conductors

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

Table 20
Maximum direct-current resistance at 20°C of solid copper conductors coated with tin or a tin alloy

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

Table 21
Maximum direct-current resistance at 20°C of Class G and H stranded conductors

Size of conductor		Bare copper				Coated copper[a]			
		Class G		Class H		Class G		Class H	
mm^2	AWG	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft	Ohms per km	Ohms per 1000 ft
	AWG								
2.08	14	8.70	2.65	–	–	9.24	2.82	–	–
3.31	12	5.48	1.67	–	–	5.81	1.77	–	–
5.26	10	3.45	1.05	–	–	3.66	1.11	–	–
8.37	8	2.16	0.660	2.18	0.666	2.30	0.701	–	–
13.3	6	1.37	0.415	1.38	0.419	1.42	0.431	–	–
21.2	4	0.857	0.261	0.865	0.263	0.890	0.271	–	–
26.7	3	0.679	0.207	0.6866	0.209	0.707	0.215	–	–
33.6	2	0.539	0.164			0.560	0.170		
(No. of wires)		Class H only							
33.6	2 (133)			0.544	0.166			0.566	0.172
33.6	2 (259)			0.547	0.166			0.580	0.176
42.4	1	0.431	0.132	0.434	0.133	0.449	0.137	–	–
53.5	1/0	0.342	0.104	0.344	0.105	0.355	0.108	–	–
67.4	2/0	0.271	0.0826	0.272	0.0830	0.282	0.0860	–	–
85.0	3/0	0.215	0.0656			0.223	0.0681		
(No. of wires)		Class H only							
85.0	3/0 (259)			0.216	0.0659			0.0685	0.224
85.0	3/0 (427)			0.217	0.0662			0.0703	0.231
107	4/0 (259)			0.171	0.0522			0.0544	0.179
107	4/0 (427)			0.172	0.0525			0.0546	0.180
107	4/0	.170	.0520			.177	.0541		

[a] Each strand coated with tin.

Note: *Nominal strand configuration and number of wires are found in ASTM B173 .*