UL 719

STANDARD FOR SAFETY

Nonmetallic-Sheathed Cables

UL Standard for Safety for Nonmetallic-Sheathed Cables, UL 719

Thirteenth Edition, Dated September 8, 2015

SUMMARY OF TOPICS

This revision of ANSI/UL 719 dated March 18, 2022 includes changes to the following requirements:

> ***Low Temperature Unwind Test, 5.12.1, 5.12.2, 7.11.2.1 – 7.11.2.3, 7.11.3, 7.11.3.2 – 7.11.3.4, 7.11.4.1, Table 7 and Table 8***

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

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UL 719

Standard for Nonmetallic-Sheathed Cables

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This ANSI/UL Standard for Safety consists of the Thirteenth edition including revisions through March 18, 2022.

The most recent designation of ANSI/UL 719 as an American National Standard (ANSI) occurred on March 18, 2022. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

The Department of Defense (DoD) has adopted UL 719 on June 7, 1985. The publication of revised pages or a new edition of this Standard will not invalidate the DoD adoption.

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 These requirements cover nonmetallic-sheathed cables containing 2 – 4 thermoplastic-insulated circuit conductors, with a grounding conductor, in the constructions indicated in Table 1. These cables are intended for use in accordance with Article 334 and other applicable parts of the National Electrical Code, NFPA 70. Type NMC cable is for use in dry, moist, damp, and corrosive locations, and Type NM cable is for use in normally dry locations. Both types carry the suffix letter "-B" to designate the use of conductors with 90°C insulation.

1.2 A cable to which the designation "ST1" (signifying "limited smoke") is applied as a type-letter suffix complies with the test criteria for smoke release and for cable damage height stated in the Standard for Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables, UL 1685.

2 General

2.1 Units of Measurement

2.1.1 In addition to being stated in the inch/pound units that are customary in the USA, each of the requirements in this standard is also stated in units that make the requirement conveniently usable in countries employing the various metric systems (practical SI and customary). Equivalent– although not necessarily exactly identical – results are to be expected from applying a requirement in USA or metric terms. Equipment calibrated in metric units is to be used when a requirement is applied in metric terms.

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 83
Thermoplastic-Insulated Wires and Cables

UL 514B
Conduit, Tubing, and Cable Fittings

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

UL 1685
Standard for 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

B3-01
Standard Specification for Soft or Annealed Copper Wire

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

G21-13
Standard Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi

NFPA (National Fire Protection Association) Publication

NFPA 70
National Electric Code

3 Definitions

3.1 The following definitions apply in this Standard:

3.2 DIRECTION OF LAY – the longitudinal direction, designated as left-hand (counterclockwise) or right-hand (clockwise), in which the wires of a member or units of a conductor run over the top of the member or conductor as they recede from an observer looking along the axis of the member or conductor.

3.3 EQUIPMENT-GROUNDING CONDUCTOR – a conductor that is defined in the National Electrical Code and the Standard for Electrical Installations as "Grounding Conductor, Equipment".

3.4 GROUNDED CIRCUIT CONDUCTOR – a circuit conductor that is intentionally grounded.

3.5 LENGTH OF LAY – the length along the longitudinal axis of the conductor or assembly for any component to complete one revolution.

3.6 NYLON – a thermoplastic compound whose main characteristic constituent is polyamide.

3.7 POLYPROPYLENE – a thermoplastic compound whose characteristic constituent is polypropylene, the crystalline copolymer of ethylene and propylene.

3.8 PVC – a thermoplastic compound whose characteristic constituent is polyvinyl chloride or a copolymer of vinyl chloride and vinyl acetate.

3.9 ROOM TEMPERATURE – 25 ±10°C (77 ±18°F)

3.9.1 SIGNAL/CONTROL CONDUCTORS – conductors installed as Class 2 and Class 3 in accordance with Article 725 of the National Electrical Code (NEC).

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

4 Construction

4.1 Materials

4.1.1 Only materials that are acceptable for the particular use shall be employed in a cable.

4.2 Types of cables

4.2.1 A cable shall be one of the following types and shall comply in all respects with the applicable requirements for construction details, test performance, and marking.

4.2.2 Type NMC cable is required to comply with a flame test and to be resistant to moisture, fungi, and corrosion and also to have some degree of inherent protection against mechanical abuse.

4.2.3 Type NM cable is required to comply with a flame test, to be resistant to moisture, and to have some degree of inherent protection against mechanical abuse.

4.2.4 Each of the materials used for the insulation, spacers, fillers, jacket, and other nonmetallic parts of a Type NMC cable shall be resistant to fungi, moisture, and corrosion.

4.2.5 Polypropylene, PVC, and glass are known to be resistant to fungi and hence, are acceptable in this respect without exposure tests. Tests to determine the degree of resistance to fungi are to be made as indicated in the American Society for Testing and Materials (ASTM) the Standard for Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi, ASTM G21, on materials not known to have the requisite property. Cotton, paper, jute, hemp, and the like are not acceptable in the construction of Type NMC cable.

4.2.6 The requirement in 4.2.4 that the insulation used in the construction of a Type NMC cable be resistant to moisture is intended to indicate that the insulation be acceptable for use where it is only occasionally and temporarily exposed to dampness or wetness. It is not intended that the insulation be for use in wet locations.

4.3 Conductors

4.3.1 Only soft-annealed copper, copper-clad aluminum, or an acceptable aluminum alloy shall be used for the conductor or conductors in a cable. Soft-annealed copper shall comply with the Standard Specification for Soft or Annealed Copper Wire, ASTM B3. Solid aluminum conductors in size 12 – 8 AWG shall comply with the requirements for aluminum-wire stock (aluminum-alloy conductor material). All other aluminum conductors shall comply with the "Requirements for Aluminum Conductors of an 8000 Series Alloy", Section in the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581. Copper-clad aluminum conductors shall comply with the "Requirements for Copper-Clad Aluminum Conductors", Section in UL 1581. In a given cable, all conductors shall be of the same metal.

4.3.2 A copper circuit conductor shall not be smaller than 14 AWG and shall not be larger than 2 AWG. An aluminum or copper-clad aluminum circuit conductor shall not be smaller than 12 AWG and shall not be larger than 2 AWG. Signal/control conductors used within a Type NM-PCS cable shall be 18 or 16 AWG copper.

4.3.3 An 8 AWG or larger circuit conductor and a 6 AWG or larger grounding conductor shall be stranded. Conductors shall comply with the requirements in the "Conductors" Section of the Standard for Thermoplastic-Insulated Wires and Cables, UL 83 except as modified in this section.

4.3.4 A joint in a solid conductor or in one of the individual wires of a stranded conductor shall be made in a workmanlike manner and shall not increase the diameter of the solid conductor, the individual wire strand, or the overall stranded conductor. A joint shall not be made in a stranded conductor as a whole but shall be made by separately joining each individual wire. A joint shall be made only before coverings, if any, are applied to an insulated conductor. The insulation applied to such joints shall be equivalent to that removed and, if of PVC, shall have insulation-resistance (K = 4000 at 15.6°C or 60.0°F) and dielectric-withstand characteristics complying with the requirements for the thermoplastic-insulated wire.

4.4 Insulation

4.4.1 Both before and after assembly into finished cable, the insulation employed on the circuit conductors shall comply with (a) or (b) and the insulation employed on the control/signal conductor shall comply with (c):

a) THHN Construction – Jacketed insulation for a Type NM or NMC cable shall have a nylon or similar jacket and shall comply with the thickness and other applicable requirements for Type THHN thermoplastic-insulated wire without (see 6.2.4) any surface marking of "THHN", "-B", or any ampacity or temperature rating.

b) TW Construction – Insulation without a nylon jacket shall comply with the thickness requirements for a Type TW thermoplastic-insulated wire. The insulation material shall comply with (1) or (2):

1) For TYPE NM or Type NMC Cable – The insulation material shall be a dry-locations PVC that complies with the requirements for Type THHN insulation without any surface marking of the ampacity or temperature rating (the surface marking "-B" is optional on the insulation). The tensile strength and elongation are to comply with the “Physical properties of PVC insulation from Type TFN and TFFN fixture wires" Table in UL 1581. The deformation test is to be conducted at 121.0 ±1.0°C (249.8±1.8°F) with a decrease of not more than 50 percent in the thickness of the PVC insulation.

2) For TYPE NM only – Type NM is eligible to use a thermoplastic insulating material other than PVC. The performance and ratings of the material as insulation shall be determined by investigation and shall be:

i) Electrically comparable to the PVC insulation in Type THHN wire, and

ii) Mechanically comparable to the nylon or similarly jacketed PVC insulation of Type THHN wire, and

iii) In accordance with “Physical properties of insulation of thermoplastic other than PVC from Type NM cables” Table in UL 1581.

c) Insulated Signal/Control Conductors – The insulation material shall be a dry-location PVC that complies with the requirements for Type TFN insulation without any surface marking of the temperature rating. The tensile strength and elongation shall comply with the Physical properties of PVC insulation from Type TFN and TFFN fixture wires in Table 50.155 in UL 1581. The deformation test is to be conducted at 121.0 ±1.0°C (249.8 ±1.8°F) with a decrease of not more than 50 percent in the thickness of the PVC insulation. The force to be used is 300 grams for 18 AWG and 400 grams for 16 AWG conductors.

4.4.2 The grounding conductor shall be bare or shall be insulated (with or without a nylon jacket) in compliance with 4.4.1 and 4.6.3.

4.4.3 An insulation or jacket that is of material generically different from any insulation or jacket material specified in 4.4.1 or 4.7.1 for the construction (new material), or that is of material specified in 4.4.1 or 4.7.1 yet does not comply with the short-term tests applicable to the insulation or jacket material, shall be of a material and in thicknesses and with the temperature rating required for the specific nonmetallic-sheathed cable type. The material shall be evaluated for the requested temperature rating as described in the "Long-Term Aging", Section of the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581. Investigation of the electrical, mechanical, and physical characteristics of the cable using the material shall show the material to be comparable in performance to the insulation or jacket material specified in 4.4.1 or 4.7.1 for the required temperature rating. The investigation shall include tests such as crushing, impact, abrasion, deformation, heat shock, insulation resistance, and dielectric voltage-withstand.

4.5 Protective sheath in type NM cable

4.5.1 Except for cable on which a 30 mil or 0.76 mm jacket is used, a continuous, tight-fitting, protective sheath (not the nylon or similar jacket on a Type THHN conductor) of tough, nonmetallic material shall

cover either the insulation on each circuit conductor or the entire assembly of insulated conductors and (if any) the spacer, grounding conductor, or both in Type NM cable. The character, shape, and dimensions of the material used and the manner of application shall not damage the insulation either during manufacture of the cable or during the unwind test on the cable (see 7.11.1.1 – 7.11.4.1).

4.6 Assembly

4.6.1 General

4.6.1.1 At least two but not more than four circuit conductors, and an optional -PCS signal/control subassembly in accordance with 4.6.1A, shall be used in a Type NM cable. Two or three circuit conductors shall be used in a Type NMC cable. In a given cable all of the circuit conductors shall be of the same size.

4.6.1.2 One grounding conductor shall be used in every cable.

4.6.1A PCS Subassemblies

4.6.1A.1 A round or flat NM cable may employ a -PCS subassembly consisting of two 18 or 16 AWG signal/control conductors for use in Class 2 and Class 3 circuits with a thermoplastic jacket over the two 18 or 16 AWG conductors. The thermoplastic jacket shall be a minimum of 30 mils or 0.76 mm thick. The thermoplastic jacket shall meet the requirements of 5.2.

Exception: A flat NM cable may employ a -PCS subassembly consisting of two 18 or 16 AWG conductors for use in Class 2 and Class 3 circuits provided with an overall overall thermoplastic jacket that is a minimum of 60 mils or 1.52 mm thick where the -PCS subassembly is attached to the power conductor subassembly by a web or similar means. The thermoplastic jacket shall meet the requirements of 5.2.

4.6.2 Cabling Methods

4.6.2.1 In Type NM cables containing two circuit conductors, the circuit conductors shall either be laid parallel or shall be cabled with a length of lay that is not longer than indicated in Table 2. In Type NM cables containing more than two circuit conductors, the circuit conductors shall be cabled with a length of lay no longer than indicated in Table 2 except that, for sizes 14 – 10 AWG copper or 12 – 10 AWG aluminum or copper-clad aluminum, whether or not a binder is employed, the circuit conductors shall either be cabled with a length of lay which is not specified, shall be bundled together parallel to one another, or shall be laid parallel. In Type NMC cables, the circuit conductors shall be laid parallel. In a round cable, the direction of lay may be changed at intervals throughout the length of the cable. The intervals need not be uniform. In a cable in which the lay is reversed:

a) Each area in which the lay is right- or left-hand for not less than 5 complete twists (full 360° cycles) shall have the insulated conductors cabled with a length of lay that is not greater than indicated in Table 2, and

b) The length of each lay-transition zone (oscillated section) between these areas of right- or left-hand lay shall not exceed 1.8 times the maximum length of lay indicated in Table 2.

4.6.2.2 A flat NM-PCS cable shall consist of an NM cable where either (1) the NM cable is joined to the PCS subassembly by means of a web or similar method or (2) the power conductors and PCS subassembly are contained under the overall jacket. One of the following constructions is acceptable.

a) A flat NM-PCS cable may consist of an NM cable connected in parallel to a -PCS subassembly with an additional jacket of not less than 30 mils or 0.76 mm over the PCS subassembly as noted in 4.6.1A. There shall be no reduction in the overall jacket thickness when the PCS portion is separated from the circuit conductor portion.

b) A flat NM-PCS cable may also consist of an NM cable in parallel with the PCS subassembly.

4.6.2.3 A round NM-PCS cable shall consist of circuit conductors as described in 4.6.2.1 and a -PCS subassembly as described in 4.6.1A all within the overall NM cable jacket. The overall jacket shall not be less than 30 mils or 0.76 mm. The cabling of the circuit conductors and jacketed signal/control cables shall meet the requirements in 4.6.2.1.

4.6.3 Grounding conductor

4.6.3.1 The grounding conductor shall be entirely in one location in the cable – that is, it shall not be divided into two or more parts located separately or distributed helically. In a Type NMC cable, the grounding conductor shall be placed in the valley between two of the circuit conductors but shall not be directly between the circuit conductors. In either a two- or three-conductor flat Type NM cable, the grounding conductor shall be placed in the valley between two of the circuit conductors or directly between two of the circuit conductors. In a twisted assembly with two circuit conductors, the grounding conductor shall be cabled with the circuit conductors. In a twisted assembly with three or four circuit conductors, the grounding conductor shall be cabled with the circuit conductors or shall be placed in the center section of the assembly. In untwisted assemblies of three or four 14 – 10 AWG circuit conductors only, the grounding conductor shall be bundled along with the circuit conductors in no particular location. In all constructions in which a bare grounding conductor is used, this conductor shall be kept, by a wrap or other means, from coming into contact with any nylon jacket on a circuit conductor or with circuit-conductor insulation.

4.6.3.2 Where the equipment-grounding conductor provided in a cable is insulated (see 4.4.2), it shall be green throughout the entire length and circumference of its finished outer surface with or without one or more yellow stripes. No other conductor in the cable shall be green. Each yellow stripe shall be straight or helical, broken (non-continuous) or unbroken. See 6.2 for details on stripes.

4.6.3.3 The grounding conductor shall not be smaller than indicated in Table 4 or Table 5.

4.6.4 Fillers

4.6.4.1 Fillers shall be used in a cable if, in their absence, the finished cable would not have a smooth, firm exterior. All materials other than PVC or glass used as fillers in a Type NM cable shall be treated with a preservative and moisture-resistant compound. Fillers for use in a Type NMC cable may be integral with the jacket or may be separate (see 4.2.4 – 4.2.6).

4.7 Overall thermoplastic jacket

4.7.1 The assembled cable shall be enclosed completely by a snug-fitting overall jacket of PVC (NMC cable) or of PVC or other thermoplastic (NM cable). The jacket shall provide the cable with resistance to abrasion and the required flexibility. If it is applicable for the use, a jacket of a material other than PVC is acceptable on Type NM cable insulated with PVC or other thermoplastic material. A connector pull-out test is to be part of the evaluation of a cable jacketed with a material other than PVC. The test (a pull of 60 lbf or 267 N or 27.2 kgf applied for 5 minutes, with no more than 1/8 inch or 3 mm movement of the cable in the connector) is to be conducted as outlined under the heading "Connectors for Nonmetallic-Sheathed Cable" in the Standard for Conduit, Tubing, and Cable Fittings, UL 514B.

4.7.2 A composite thermoplastic jacket of nylon and PVC, may be provided on NM cable. The nylon is the outer most layer.

4.7.3 If a composite thermoplastic jacket is employed, each material, when separated, must comply with the physical properties values called out in 5.2.

5 Test Requirements

5.1 General

5.1.1 Every length of finished insulated conductor shall be capable of complying with the requirements of clauses 5.2 – 5.19 as applicable.

5.2 Physical properties of PVC and other materials

5.2.1 The physical properties of specimens of a PVC jacket prepared from finished cable shall comply with the requirements in the "Physical properties of NM Cable PVC[a] jacket" table in UL 1581, and a specimen of the nylon from the nylon/PVC composite jacket shall comply with the requirements in the “Physical properties of NM Cable Nylon jacket " Table 10 when tested in accordance with the "Physical Properties" Section in the Standard for Wire and Cable Test Methods, UL 2556. See 4.4.3 for the long-term evaluation of a jacket material not specified in 4.7.1 or not complying with the applicable short-term tests.

5.3 Jacket thickness requirements

5.3.1 The average and minimum thicknesses of jacket and, if a sheath is used, of jacket and sheath determined on specimens of finished cable shall not be less than indicated in Table 6 when prepared and measured in accordance with 7.3.

5.4 Separability test of cable parts

5.4.1 The circuit conductors, the insulation thereon, the grounding conductor, and any insulation or other covering on the grounding conductor shall be readily separable from one another and from the rest of the finished Type NMC or Type NM cable without damage to the insulation, covering, or any other part of the cable. The nylon and PVC of a composite jacket shall be separable from each other without damage to each other.

5.5 Continuity test requirements

5.5.1 Each circuit conductor and the grounding conductor shall be continuous throughout the entire length of finished cable. Finished cable shall be tested for continuity of each 14 – 10 AWG conductor by the cable manufacturer at the cable factory in accordance with 7.5.

5.6 Vertical flame

5.6.1 When tested in accordance with 7.6, a vertical specimen of finished Type NMC cable, of finished Type NM cable, and of the insulated circuit conductors shall not flame longer than 60 seconds following five 15 second applications of the test flame, the period between applications being 15 seconds. For an NM-PCS cable, a vertical specimen of (1) the finished cable, (2) the -PCS jacketed assembly, and (3) the individual insulated signal/control conductors shall not flame longer than 60 seconds following five 15 second 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.

5.7 Vertical-tray flame test

5.7.1 Any cable that is surface marked (see 6.1.12 and 6.1.13) for use in cable trays is acceptable where the insulation and overall covering do not exhibit damage that reaches the upper end of any sample after two sets of samples are separately installed in a vertical ladder type of cable tray and then are subjected to 20 minutes of flame as indicated under “UL Flame Exposure” or “FT4/IEEE 1202 Type of Flame Exposure” in the Standard for Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables, UL 1685, (smoke measurements are not applicable). See 5.7.2.

5.7.2 The results of this test are to be judged as specified in UL 1685. The results using cable containing two 14 or 12 AWG circuit conductors with a grounding conductor are representative of the performance of any of the constructions of Type NM or NMC cable that are covered in Table 1. Where the flat or round construction of 14 or 12 AWG cable is used in a set of specimens that complies with the fire test in Vertical-Tray Fire-Propagation and Smoke-Release Test, Section 5.8, qualifying that construction for the "ST1" (limited smoke) surface marking, the results of the Section 5.8 fire test also qualify both the flat and round constructions for use in cable trays without conduct of the vertical-tray flame test specified in this requirement.

5.8 Vertical-tray fire-propagation and smoke-release test

5.8.1 Each Table 1 construction of Type NM or NMC cable that is surface marked "ST1" in accordance with 6.1.14 shall comply with the limits for smoke release and cable damage stated in UL 1685 when sets of specimens as described in 7.8.1 are tested in either of the flame exposures described in UL 1685.

5.9 Tray-cables sunlight-resistance test

5.9.1 Any of the constructions of Type NM or NMC cable that are covered in Table 1 and are marked (see 6.1.13) for sunlight-resistant use in cable trays are acceptable for the sunlight-resistant aspect if the ratio of the average tensile strength and ultimate elongation of five conditioned specimens of the jacket to the average tensile strength and ultimate elongation of five unconditioned specimens of the jacket is 0.80 or more when the finished cable containing two 14 or 12 AWG circuit conductors is tested as outlined in the "Xenon-Arc Tests", Section in UL 1581 after 720 hours of xenon-arc exposure.

5.10 Dielectric voltage-withstand test

5.10.1 After immersion in water at room temperature for 24 hours and while still immersed, specimens of finished cable wound around a mandrel shall withstand for 60 seconds a 48 – 62 Hz essentially sinusoidal potential of 5000 V when tested in accordance with 7.9. The potential shall be applied from each circuit conductor separately, to the other conductor or conductors, the grounding conductor, and to the earth-grounded water and mandrel.

5.11 Tension and elongation test

5.11.1 Finished cable shall be capable of withstanding the application of a tension imparted by a weight that exerts 300 lbf or 1334 N or 136 kgf for 60 seconds without parting, opening up at any point, or showing a permanent elongation of more than 1 inch per 12 inches of original specimen length or more than 5 millimeters per 60 millimeters of original specimen length when tested in accordance with 7.10. The interior of the cable is not required to be examined.

5.12 Unwinding tests at low temperature

5.12.1 After cooling for 4 hours to −25.0 ±1.0°C (−13.0 ±1.8°F), each component of the finished cable shall remain undamaged as described in 5.12.2 after the low-temperature unwinding described in 7.11.1 – 7.11.4.1.

5.12.2 Any cable shall not exhibit inside and outside surface cracks, tears, splits, or other openings in the insulation, individual covering over the insulation (nylon jacket or protective sheath), or in the PVC jacket. Internal cracks are those within the thickness of the insulation or jacket as evidenced by slight depressions (checks) in the outer surface.

5.13 Crushing resistance test for flat cable

5.13.1 To crush finished flat cable containing two or three 14 or 12 AWG copper, or 12 or 10 AWG aluminum or copper-clad aluminum circuit conductors with a grounding conductor shall be when tested in accordance with 7.12:

a) An average of not less than 600 lbf or 2669 N or 272 kgf shall be needed when the crushing force is applied to the cable flatwise as indicated in 7.12.1.1 – 7.12.1.4, and

b) An average of not less than 1200 lbf or 5338 N or 544 kgf shall be needed when the crushing force is applied to the cable edgewise as indicated in 7.12.2.1 – 7.12.2.5.

5.14 Crushing resistance test for round cable

5.14.1 Finished round Type NM-PCS and NM cable that contains two circuit conductors with an insulated grounding conductor, or three or four circuit conductors with an insulated or bare grounding conductor, in which the conductors are twisted, and which does not comply with the separation requirement in 5.18.1 and all finished round Type NM cable in which the conductors are parallel, shall be tested for crushing resistance in accordance with the method described in the Crushing-Resistance Test of Round Type NM Cables Section of the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581. The cable is not acceptable if the average of the ten crushing trials is less than 1200 lbf or 5338 N or 544 kgf for a test length of round Type NM cable containing two circuit conductors with an insulated grounding conductor, or three or four 14 or 12 AWG circuit conductors.

5.15 Abrasion resistance test of jacket on flat cable

5.15.1 The jacket on finished flat cable containing two or three 14 or 12 AWG copper or 12 or 10 AWG aluminum insulated circuit conductors shall not wear through exposing the underlying protective sheath or conductor assembly in fewer than 70 complete cycles of abrasion against sharp steel edges. On a flat NM-PCS cable, the signal/control conductors shall be separated from the NM power conductor side and only the remaining NM cable is subjected to this test. The test is to be conducted as described in 7.14.

5.15.1.1 A composite jacket of nylon and PVC shall not wear through both layers exposing the underlying protective sheath or conductor assembly in fewer than 70 complete cycles of abrasion against sharp steel edges. The test is to be conducted as described in 7.14.

5.15.2 The jacket on one or more of the six specimens tested shall not be worn through in fewer than 70 complete strokes.

5.16 Pulling-though-joists test

5.16.1 Finished, flat, parallel cable containing two or three insulated 14 or 12 AWG copper or 12 AWG aluminum or copper-clad aluminum circuit conductors with a grounding conductor with or without the -PCS suffix; round Type NM with or without the -PCS suffix cable that contains two circuit conductors with an insulated grounding conductor, or three or four circuit conductors with a grounding conductor, fillers, or both, in which the conductors are twisted, and which does not comply with the separation requirements in 5.18.1; and all finished round Type NM cable with or without the -PCS suffix in which the conductors are parallel, shall each be constructed to withstand the low-temperature pulling through joists described in 7.15 without any opening occurring in the jacket that exposes the cable interior (see 7.15.6 and 7.15.7),

without reduction of the spacing between the circuit conductors in flat cable to a value less than indicated in Table 3 (see 5.16.2), without any change in the position of the grounding conductor that results in the metal of the grounding conductor touching the insulation on a circuit (see 5.16.2), and without physical damage to the insulation (see 5.16.2).

5.16.2 The 36-inch or 1-m section of the cable that shows the most scuffing, abrasion, twisting, disturbance, or a combination thereof of the conductor configuration is to be cut from each test length. These sections are to be examined at both ends for maintenance of the position of the circuit conductors in flat cable. If the adjacent-metal spacing between the circuit conductors in flat cable is less than indicated in Table 3, the spacing is to be recorded as not acceptable. The most severely scuffed, abraded, twisted, disturbed portion, or a combination thereof of each test length is to be cut from the 36 inch or 1 m section. The portion cut from the section is to be 6 – 8 inch or 150 – 200 mm long, with the scuffing, etc. occupying the center of its length. The jacket is to be slit longitudinally along both of the curved edges of the cable and, with the portion lying flat on a horizontal surface, the uppermost flat half of the jacket is to be lifted off to expose the interior of the cable. The cable interior is not to be disturbed while the jacket is slit and its upper half is removed. The interior of the portion is to be examined for maintenance of the position of the grounding conductor. Spacers and fillers may be removed from the flat cable during this examination. If any of the paper wrap on the circuit conductor has not kept the metal of the grounding conductor from touching the insulation on a circuit conductor, this result is to be recorded as not acceptable. The conductors are to be removed from each test length and the insulation on the conductors is to be examined. If the insulation on any conductor shows checking (as evidenced by a circumferential depression in the outer surface), cracking, splitting, tearing, shattering, or other physical damage, this result is to be recorded as not acceptable. If any of the three examinations described in this requirement show unacceptable results, no additional tests are to be performed but one additional 36 inch or 1 m section is to be cut and examined as described in this requirement from each cable test length from which unacceptable results were obtained. These additional section(s) are to be the severely scuffed, abraded, twisted, disturbed portions, or a combination thereof of the test lengths. The cable is not acceptable if unacceptable results are shown in any of the three examinations of any additional sections.

5.17 Flow test

5.17.1 Finished Type NMC cable and Type NM flat cable in which there are two or three 14 AWG copper or 12 AWG aluminum or copper-clad aluminum circuit conductors with a grounding conductor shall withstand an overload current of 40.0 A applied according to each of the two methods described in 7.16.1 and 7.16.2. Subsequently, the cable shall withstand a 48 – 62 Hz essentially sinusoidal rms potential of 5000 V applied for 60 seconds as indicated in 7.16.3.

5.18 Conductor separation requirements

5.18.1 Adjacent circuit conductors in finished cable shall be separated by at least the applicable metal-to-metal or center-to-center distance indicated in Table 3. Round Type NM cable that contains two circuit conductors with an insulated grounding conductor, or three or four circuit conductors with an insulated or bare grounding conductor, and complies with the crushing test referenced in Crushing Resistance Test for Round Type NM Cable, Section 5.14 and the Pulling-Through-Joists Test, Section 5.16 is not required to comply with the separation requirement.

5.19 Connector pull-out test requirements

5.19.1 A connector pull-out test is to be part of the evaluation of a cable jacketed with a material other than PVC. The test (a pull of 60 lbf or 267 N or 27.2 kgf applied for 5 minutes, with no more than 1/8 inch or 3 mm movement of the cable in the connector) when tested in accordance with 7.2.

6 Markings

6.1 Markings on product

6.1.1 All printing on the outer surface of finished cable or anywhere within a cable shall be legible and shall be repeated at the following intervals throughout the length of the cable:

a) Size shall be repeated at intervals that are not longer than a nominal 24 inches or 610 mm (maximum 25 inches or 635 mm).

b) The marking in 6.1.15 for identification of copper-clad aluminum shall be repeated at intervals that are not longer than 6 inches or 150 mm.

c) All information other than size and the identification of copper-clad aluminum shall be repeated at intervals that are not longer than 40 inches or 1016 mm.

6.1.2 An insulated conductor intended for use as a grounded circuit conductor shall be finished to show the color white or grey throughout the entire length and circumference of its outer surface, or shall be identified by three continuous straight or helical, unbroken white stripes on other than green insulation, along its entire length. See 6.1.4 for details on stripes. Straight stripes are to be placed a nominal 120 degrees apart. Where multiple grounded circuit conductors are used in a cable, no more than one shall employ white stripes. Where white or grey multiple grounded circuit conductors are used in a cable it is also appropriate to distinguish between them by the use of a raised tracer or one or more broken (non-continuous) or unbroken straight or helical stripes that are of a contrasting color other than green.

6.1.3 An insulated conductor intended for use as an ungrounded insulated circuit conductor shall be finished to show a color or combination of colors other than and in contrast with white, gray, or green. The outer surface so colored also complies with the intent of this requirement where it contains any one of the following throughout the length of the wire or cable in a color or combination of colors other than white, gray, or green:

a) One or more broken or unbroken straight or helical stripes.

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

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

The markings covered in this requirement shall not conflict or be confusable with any of the other markings required or otherwise covered in this Standard.

6.1.4 Stripes as specified in 4.6.3.2, 6.1.2, 6.1.3 shall be of even or varying width and shall occupy a total of 5 – 70 percent of the calculated circumference of the outer surface of the finished insulated conductor with no individual width less than 5 percent of that same circumference. The width shall be measured perpendicular to each stripe. Where broken stripes are appropriate, they shall consist of a series of identical marks and spaces, the length of each mark shall be at least 1/8 inch or 3 mm and the linear spacing between marks shall not be greater than 3/4 inch or 19 mm.

6.1.5 Finished cable shall have a durable marking on the outside surface of the cable consisting of the letters "NMC-B" or "NM-B" (no more than one type-letter designation shall be marked on any cable), the name of the cable manufacturer, that manufacturer's trade name for the product, or both, or any other acceptable distinctive marking by means of which the organization responsible for the product can readily be identified, the AWG size and number of the insulated circuit conductors, and the maximum working potential "600 volts" or "600 V". The color of the ink printing shall contrast with the background.

6.1.6 If the organization that is responsible for the cable is different from the actual manufacturer, both the responsible organization and the actual manufacturer shall be identified by name or by acceptable coding such as by trade name, trademark, the assigned electrical reference number, or the assigned combination of colored marker threads. The meaning of any coded identification shall be made available. A private labeler may also be identified.

6.1.7 Embossed (raised) lettering is acceptable on the overall jacket. Indent printing is acceptable if the thicknesses of the jacket are not reduced below the average and minimum at any point shown in Table 6 as being the thinnest acceptable. Ink printing is acceptable on the overall jacket.

6.1.8 If the organization responsible for the cable produces the cables covered in this standard in more than one factory, the marking mentioned in 6.1.5 shall include an identification of the factory. In the case of a colored thread or threads, the ply or the material of one or more of the threads used at each factory shall be different from the ply or material of the same color thread or threads used at every other factory. The organization responsible for the cable shall make available the meaning of the different plies and materials. The identifying marker for the finished cable shall not be located under the insulation.

6.1.9 The organization responsible for the insulated conductors, if other than the organization responsible for the finished cable, may use indelible ink printing on the surface of each of the insulated conductors as the means for its identification and the factory identification. Such printing is to appear in conjunction with the identification of the organization responsible for the cable and is to appear at the intervals mentioned in 6.1.1. The printing is to consist of an identification of the organization responsible for the circuit conductors followed by a hyphen and an identification of the factory (if the organization operates more than one). No other wording or identification of the organization responsible for the circuit conductors is to appear in the printing. Also, a statement is to appear on tags, and on all reels, cartons, and other packaging containing the circuit conductors to indicate that the conductors contained therein are intended for further processing.

6.1.10 The markings required in 6.1.5 – 6.1.9 may be accomplished by indent, raised, or ink printing. Ink printing is acceptable if the printing on specimens of the complete cable remains legible after being tested with a felt-faced weight as described in the "Durability Of Indelible-Ink Printing" test, of UL 1581.

6.1.11 A marker thread of glass is acceptable if the length of lay of the individual glass filaments in each basic strand does not exceed 1/3 inch or 8.5 mm. A longer length of lay is not acceptable because it alters the color of the thread.

6.1.12 The designation "for CT use" or "for use in cable trays" may be marked on the outer surface of finished Type NM or NMC cable of any of the Table 1 constructions if finished flat cable containing two 14 or 12 AWG circuit conductors with a grounding conductor complies with the flame-test requirements in Vertical-Tray Flame Test, Section 5.7, or if finished flat or round cable containing two 14 or 12 AWG circuit conductors with a grounding conductor complies with the fire-test requirements in Vertical-Tray Fire-Propagation and Smoke-Release Test, Section 5.8, but the cable that complies with Section 5.7 or 5.8 has not been tested for sunlight resistance or does not comply with the sunlight-resistance requirements in 5.9.1. Where the flame test referenced in 5.7.1 consisted of the FT4/IEEE 1202 Type of Flame Exposure, the cable may additionally be marked “FT4/IEEE 1202” or “FT4”; where used, this marking is to be spaced from the other cable markings required in this Standard.

6.1.13 The designation "sunlight-resistant, for CT use" or "sunlight-resistant, for use in cable trays" may be marked on the outer surface of finished Type NM or NMC cable of any of the Table 1 constructions if finished flat cable containing two 14 or 12 AWG circuit conductors with a grounding conductor complies with the flame-test requirements in Vertical-Tray Flame Test, Section 5.7, or if finished flat or round cable containing two 14 or 12 AWG circuit conductors with a grounding conductor complies with the fire-test requirements in Vertical-Tray Fire-Propagation and Smoke-Release Test, Section 5.8, and the cable that complies with Section 5.7 or 5.8 also complies with the sunlight-resistance requirements in 5.9.1. Where the flame test referenced in 5.7.1 consisted of the FT4/IEEE 1202 Type of Flame Exposure, the cable may

additionally be marked “FT4/IEEE 1202” or “FT4”; where used, this marking is to be spaced from the other cable markings required in this Standard.

6.1.14 The designation "ST1" (signifying "limited smoke") may be added to the outer surface of each finished Type NM or NMC cable of a Table 1 construction that complies with the UL 1685 fire-test requirements referenced in Vertical-Tray Fire-Propagation and Smoke-Release Test, Section 5.8, of this Standard.

6.1.15 The outer surface of the PVC insulation on each copper-clad aluminum conductor in a cable shall be durably and legibly printed at intervals of at least 6 inches or 150 mm throughout the entire length of the cable with the AWG size of the conductor and with one of the designations "AL (CU-CLAD)", "ALUMINUM (COPPER-CLAD)", "CU-CLAD AL", or "COPPER-CLAD ALUMINUM". In the case of a circuit conductor, one or more orange stripes of even or varying width are acceptable in place of or in addition to the word identification of the conductor metal. One or more orange stripes shall not be used on a grounding conductor. Wherever used, one or more orange stripes shall be straight and shall occupy a total width – the width shall be measured perpendicular to the longitudinal axis of each stripe, not necessarily around the conductor circumference – of 5 – 70 percent of the calculated circumference of the outer surface of the finished conductor and no less individual width than 5 percent of the calculated circumference of the finished outer surface. One or more orange stripes used in place of word identification of the conductor metal may be broken only by the AWG size designation. One or more orange stripes used in addition to word identification of the conductor metal may be broken only by the AWG size designation and the word identification of the conductor metal.

6.1.16 If signal/control conductors are present, an NM cable shall carry the suffix letters -PCS to designate the presence of Class 2 or 3 signal/control conductors.

6.1.17 For a round NM-PCS cable, the jacket over the signal/control conductors shall be marked with the following statement: "The conductors under this jacket are only for signal/control connections, not for circuit power." Additionally, the overall jacket of a round NM-PCS cable shall be marked to indicate the following: "This cable contains both signal/control and power conductors." These markings shall repeat every 24 inches or 610 mm.

6.1.18 For a flat NM-PCS cable construction utilizing a separate 60-mil or 1.52-mm jacketed signal/control conductor construction, the jacket over the signal/control conductors shall be marked with the following statement: "Conductors under this jacket are only for signal/control connections, not for circuit power." These markings shall repeat every 24 inches or 610 mm.

6.2 Markings on package

6.2.1 A tag on which the following information is indicated plainly (the sequence of the items is not specified) shall be tied to every shipping length of finished cable. However, where the cable is wound on a reel or coiled in a carton, it is appropriate for the tag to be glued, tied, stapled, or otherwise attached to the reel or carton instead of to the cable, or for the tag to be eliminated and the information printed or stenciled directly onto the reel or carton. Other information, where added, shall not confuse or mislead (see 6.2.4 – 6.2.6) and shall not conflict with these requirements. See 6.2.10 for date marking.

a) The maximum working potential: "600 V" or "600 volts".

b) The name of the cable manufacturer, that manufacturer's trade name for the cable, or both, or any other appropriate distinctive marking by means of which the organization responsible for the cable is readily identifiable. Where the organization that is responsible for the cable is different from the actual manufacturer, both the responsible organization and the actual manufacturer shall be identified by name or by appropriate coding such as by trade name, trademark, the assigned electrical reference number, or the assigned combination of colored marker threads. The meaning

of any coded identification shall be made available by the organization responsible for the cable. It is appropriate also to identify a private labeler; the means is not specified.

c) One and only one of the type-letter/suffix designations: Type NMC-B or Type NM-B (see 6.2.7).

d) The AWG size of the circuit conductors and the number of circuit conductors.

e) The colored-thread marker assigned to identify the organization responsible for the cable where the threads are used in the cable.

6.2.2 If the circuit conductors are of aluminum, the AWG size of such conductors followed by the word "aluminum" or the abbreviation "AL" shall appear in the marking on tags, reels, and cartons and also on the outside surface of the finished cable.

6.2.3 If a copper-clad aluminum conductor or conductors are used, the AWG size of the conductors, wherever the size appears (on the tag, reel, or carton, or on a PVC surface), shall be followed by one of the designations, "AL (CU-CLAD)", "ALUMINUM (COPPER-CLAD)", "CU-CLAD AL", or "COPPER-CLAD ALUMINUM". Tags, reels, and cartons for copper-clad aluminum cable shall have the following markings:

a) "Copper-clad aluminum shall be used only with equipment marked to indicate that it is for use with aluminum conductors. Terminate copper-clad aluminum with pressure wire connectors marked 'AL-CU' or 'CC-CU'".

b) For 12 – 10 AWG solid copper-clad aluminum "May be used with wire-binding screws and in pressure-plate and push-in spring-type connecting mechanisms that are acceptable for use with copper conductors."

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

6.2.4 No conductor type-letter designation and no current or temperature designation shall be included in the marking on the tag, reel, or carton or directly on or in a cable.

6.2.5 Wherever the type-letter/suffix designation for nonmetallic-sheathed cable appears – on tags, reels, or cartons, or on the product itself – no other letter, figure, or symbol shall appear in conjunction with the cable type letters.

6.2.6 The requirement in 6.2.5 is intended to indicate that a clear marking of the cable type-letter/suffix designation is required and that the use of letters, numerals, or other symbols in proximity to the type-letters is precluded where such use would be confusing in any way.

6.2.7 The markings on coils, reels, etc. of 2-conductor or 3-conductor flat 14 – 10 AWG Type NM-B cables that comply with 4.2.4 - 4.2.6, or on the tags attached thereto, may include the statement "also for use as Type NMC-B cable" if the added statement is separated from (and preferably follows) the items of required marking indicated in 6.2.1.

6.2.8 The provision in 6.2.7 is intended as a means of clarifying the possible use of the cable mentioned where uncertainty might result were the statement not employed. The added statement, wherever it appears, is not to be interpreted as providing an exception to the requirement in the first parentheses in 6.1.5 or in accordance with 6.2.1(c) – that is, a dual marking is not acceptable.

6.2.9 If a compact-stranded copper conductor is used, the AWG size of the conductor – wherever the size appears (on the tag, reel, carton, or on or in the cable or insulated conductor) – shall be followed by COMPACT COPPER or COMPACT CU. The word COMPACT may be abbreviated CMPCT. Tags, reels,

and cartons for compact-stranded copper wire shall have the following marking: "Terminate with connectors identified for use with compact-stranded copper conductors".

6.2.10 DATE OF MANUFACTURE – The date of manufacture by month and year (or in the sequence month, day, and year) shall be included among the tag, reel, or carton markings described in 6.2.1, or shall be included among the cable markings described in this Standard where legible on the outer surface of the cable. The date shall be shown in plain language, not in code.

6.2.11 The marking: "There are both signal/control circuits and power circuits in this cable. Do not use the signal/control conductors as circuit power conductors. The signal/control circuits are under jacket marked as such." shall be marked on the tag, reel, or carton of cable Type NM-PCS.

7 Test Methods

7.1 Conductor separation measurement

7.1.1 The method of measuring the conductor separation is not specified. When conclusive results are not obtained, specimens 4 inches or 100 mm long are to be cut from the finished cable. The insulated circuit conductors and the grounding conductor are one by one to be partially withdrawn (about 1/4 inch or 6 mm) from one end of the specimen (call this end A). This procedure leaves the other end (call it end B) of the specimen free of the metal conductors and insulation. At end B, the nonmetallic materials (any fillers and the overall jacket) are to be cut through cleanly and perpendicular to the longitudinal axis of the specimen without the cutting blade encountering the conductor insulation or metal. The insulated circuit conductors and the grounding conductor are one by one to be worked gently back into the specimen just far enough to make the ends of each conductor flush with the freshly cut nonmetallic materials at end B. The separation between centers of the metal circuit conductors is then to be measured (estimated to the nearest 1/64 inch or 0.5 mm) at end B by means of a machinist's scale calibrated in 64ths of an inch or in millimeters. The foregoing procedure often is not necessary for flat cable because the configuration of such cable can be kept undisturbed while cutting through the metal conductors and the nonmetallic materials simultaneously to obtain a cross section of the cable for the separation measurements.

7.2 Connector pullout test

7.2.1 A connector pull-out test is to be part of the evaluation of a cable jacketed with a material other than PVC. The test is to be conducted as outlined under the heading "Connectors for Nonmetallic-Sheathed Cable" in the Standard for Conduit, Tubing, and Cable Fittings, UL 514B .

7.3 Jacket thickness measurement

7.3.1 The minimum average thickness and the minimum thickness at any point of the overall covering on finished cable are to be determined by means of a pin-gauge dial micrometer, the presser foot of which exerts 25 ±2 gf on a specimen. The pin is to be 0.437 inch or 11.10 mm long and 0.043 inch or 1.09 mm in diameter, and the rectangular end of the presser foot that makes contact with a specimen is to be 0.043 inch or 1.09 mm wide and 0.312 inch or 7.92 mm long. Specimens 4 inches or 100 mm long are to be cut from the finished cable and the metal circuit and grounding conductors are to be withdrawn (not the insulation). The ends of each specimen are then to be cut off clean and square. The conductor insulation and any separable fillers are to be withdrawn carefully leaving only the jacket and any sheath. This procedure reduces deformation of components of the outer covering.

7.3.2 For flat cable, 16 measurements (each estimated to the nearest 0.1 mil or 0.001 mm) are to be made (see Figure 1) at both ends of each specimen. The specimen is to be placed on the pin and so located on the pin that the entire length of the presser foot makes contact with the pin. The presser foot is to be brought to rest gently on the specimen, and the reading (estimated to the nearest 0.1 mil or 0.001 mm) is to be taken immediately. The presser foot is not to be in contact with the specimen while the latter

is being rotated. The 16 measurements at each end of each specimen are to be averaged, and the smaller of the two averages for each specimen is to be compared with the average thickness specified in Table 6. If the average for a specimen is less than the average in Table 6, the cable is not acceptable.

7.3.3 For 2-, 3-, or 4-conductor round cable, one measurement (estimated to the nearest 0.1 mil or 0.001 mm) is to be made at the thinnest point at each end of the specimen on the outer covering at each of the impressions left by the withdrawn circuit conductors and insulation and any separable fillers. All of the measurements at each end of the specimen are to be averaged, and the smaller of the two averages for each specimen is to be compared with the average thickness specified in Table 6. If the average for a specimen is less than the average in Table 6, the cable is not acceptable.

7.3.4 The lowest single reading on either end of a specimen from 2-, 3-, or 4-conductor cable is to be rounded off to the nearest mil or 0.01 mm (this measurement may be from any point along the periphery of the specimen except that, in the case of a grounding conductor in a flat cable with integral jacket and fillers, an additional measurement is to be made as shown as 11 in the lower drawing of Figure 6) and compared with the minimum thickness at any point specified in Table 6. If the minimum for a specimen is less than the minimum in the table, the cable is not acceptable.

7.4 Preparation of specimens for physical property determination

7.4.1 The methods of preparation of samples, of selection and conditioning of specimens, and of making the measurements and calculations for ultimate elongation and tensile strength are indicated under the heading "Physical Properties of Insulation and Jacket", in UL 1581. A buffed and die-cut specimen may be used, or a complete specimen of jacket with all conductors, insulation, and other parts removed may be used.

7.5 Continuity testing

7.5.1 To determine whether or not a cable is continuous, it shall be tested as indicated in the Electrical tests for finished wire and cable, Apparatus Method 1 and Procedure Method 1 of the Standard for Wire and Cable Test Methods, UL 2556.

7.5.2 For the factory production continuity testing of a cable, the manufacturer may elect to substitute the continuous eddy-current procedure as indicated in the Electrical tests for finished wire and cable, Apparatus Method 2 and Procedure Method 2 of the Standard for Wire and Cable Test Methods, UL 2556.

7.6 Vertical flame test

7.6.1 Two specimens 18 inches or 455 mm long are to be cut from a sample length of the finished cable. The insulated conductors are to be removed from one specimen and tested individually. The other specimen is to be tested as a complete cable. Testing shall be done according to the test FV-1/Vertical Flame in the Standard for Wire and Cable Test Methods, UL 2556.

7.7 Vertical-tray flame test

7.7.1 Testing is to be performed as specified in the Standard for Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables, UL 1685.

7.8 Vertical-tray fire-propagation and smoke-release test

7.8.1 Specimens for the test specified in "UL Flame Exposure" section of the Standard for Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables, UL 1685 are to consist of the smallest, largest, and an intermediate size of each construction covered in Table 1 plus any other

size(s) in each construction that may be appropriate because of the cable geometry and materials. Only finished cable is to be tested.

7.9 Dielectric voltage-withstand test

7.9.1 The apparatus is to consist of an immersion tank; a set of metal mandrels, each a right-circular cylinder having a diameter equal to seven times the diameter or length of minor axis of the cable with which it is used; and a testing transformer, circuit breaker, and voltmeter as described in 7.9.2.

7.9.2 The test potential is to be supplied by a 48 – 62 Hz isolation transformer whose rms output potential is continuously variable from zero to at least 5000 V at a rate that is not greater than 500 V/s. With a specimen in the circuit, the output potential is to have a crest factor (peak voltage divided by rms voltage) equal to 95 – 105 percent of the crest factor of a pure sine wave over the upper half of the output range. The output voltage is to be monitored continuously by a voltmeter that:

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

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

The maximum current output of which the supply is capable is to enable routine testing of full reels of the cable without tripping of the output circuit breaker by the charging current.

7.9.3 A specimen of finished cable of a length for making seven or more turns around the applicable diameter of mandrel plus 28 inches or 711 mm is to be opened at each end so that the insulated circuit conductors extend 4 inches or 102 mm from the rest of the cable. The insulation is not to be damaged. At one end of the specimen, each of the circuit conductors and the grounding conductor are to be bared for 1 inch or 25 mm to facilitate connection to the testing circuit. The specimen of cable is then to be wound onto the mandrel starting at the center of the specimen and winding simultaneously toward each end. The ends are then to be secured so that no less than a 10 inches or 254 mm length of cable extends away from the mandrel at each end of the coil. The specimen and the mandrel on which it is wound are then to be immersed in tap water at room temperature for 24 hours. During the immersion, the ends of the coil are to extend at least 8 inches or 200 mm above the surface of the water, and the ends are not to become wet. After the coil has been immersed for 24 hours, and while it is still immersed, the potential is to be increased from zero at an essentially uniform rate in the range of 10 – 60 V/s. The increase is to continue in this manner until the voltage is 5000. If the 5000-V level is reached without breakdown, the voltage is to be held constant at that level for 60 seconds and is then to be reduced to near zero at an essentially uniform rate in the range of 10 – 60 V/s. The cable is not acceptable if, during any application of voltage, breakdown occurs in less than 60 seconds at 5000 V or while the voltage is being increased or decreased.

7.10 Tension and elongation test

7.10.1 The apparatus consists of a pair of clamps, a weight that exerts 300 lbf or 1334 N or 136 kgf, and a differential pulley or a block and tackle for raising the specimen weight gently and gradually. The clamping arrangement shall be such that the cable is securely held in place so that there is no slippage or breakage at the clamps.

7.10.2 A specimen of finished cable approximately 4-1/2 ft or 1.4 m long is to be secured in the clamps so that somewhat more than 36 inches or 900 mm of cable extends between the clamps. Two marks are to be placed on the cable 36 inches or 900 mm apart – penciled lines on the surface of the cable at such points are acceptable as markers.

7.10.3 The upper clamp is to be raised gently by means of the differential pulley or block and tackle until the weight is supported by the specimen and is a short distance from the floor. The method to be used is shown in Figure 2. The weight is to be supported in this manner for 60 seconds and then lowered to the

floor to release the tension. Sixty seconds after removal of the load, the distance between marks is to be measured again. The specimen is then to be examined for damage.

7.11 Unwinding tests at low temperature

7.11.1 Preparation of specimens

7.11.1.1 Two straight specimens at least 36 inches or 1 m long are to be cut from a sample length of finished cable without bending the cut ends of the conductors. This test need not be conducted on sizes larger than 10 AWG if the construction of the larger sizes is the same as for the smaller sizes.

7.11.2 Test equipment

7.11.2.1 A mandrel 3/4 ±1/64 inch or 19 ±0.4 mm in diameter is to be used for flat cable containing two or three 14, 12, or 10 AWG insulated circuit conductors. The diameter of the mandrel for any other cable is to be as indicated in Table 7 (inches) or in Table 8 (millimeters).

7.11.2.2 The apparatus for this test is to consist of mandrels of the diameters indicated in Table 7 or Table 8 and a dry-ice cabinet or mechanical refrigerator capable of sustained operation at a low temperature of −25.0 ±1.0°C (−13.0 ±1.8°F). An accurate thermometer or other means of continuous, accurate indication of the temperature in the cold chamber is to be provided, and its indications are to be clearly legible from outside the chamber.

7.11.2.3 Means are to be provided for securing the mandrels in a manner that makes it practical for the winding and unwinding operation to be conducted in the chamber at low temperature. There is to be space below the mandrels to enable the weighted specimens to hang freely without touching one another or the walls or floor of the chamber as they are wound and unwound. Space is to be provided for removal of the unwound specimens from the opened chamber and their separation from the mandrels for examination without damage or stress to the insulation in the course of the removal and separation.

7.11.2.4 Weights in accordance with Table 9 are to be provided.

7.11.3 Test method

7.11.3.1 The empty cold chamber is to be precooled to the low temperature before the test is begun.

7.11.3.2 While the specimens and the mandrels are at room temperature, one end of each specimen is to be secured to the mandrel, the assembly of mandrel and specimen is to be placed in the cold chamber, the weight indicated in 7.11.2.4 is to be attached to each specimen and each specimen is to be wound onto the mandrel for a minimum of five full turns with adjacent turns touching and ensuring that each coil of cable is in intimate contact with the mandrel. The chamber is then to be brought back to −25.0 ±1.0°C (−13.0 ±1.8°F). The weight indicated in 7.11.2.4 is to remain attached to each specimen throughout the cooling period and during the unwinding.

7.11.3.3 After the 4 hours, and while the chamber remains at the low temperature, five full turns of the specimens (with the weights attached) are to be unwound from the mandrels at a continuous the rate of 4 – 6 turns per minute. Without damaging the specimens, the weights are then to be detached and the specimens are to be removed from the chamber.

7.11.3.4 During the unwinding of the specimens, the temperature in the chamber shall not rise above −22.0°C (−7.6°F).

7.11.4 Results

7.11.4.1 Both specimens are to be cut open and their interiors examined for the damage described in 5.12.2.

7.12 Crushing resistance test for flat cable

7.12.1 Flatwise

7.12.1.1 The cable is to be crushed between a flat horizontal surface and the surface of a rigid cylinder 1/8 inch or 3.2 mm in diameter. The cylinder is to be a 3 1/2 inch or 90 mm length of steel drill rod 0.125 inch or 3.2 mm in diameter welded along the length of a steel bar that is also 3 1/2 inches or 90 mm long is T-shaped in cross section. The stem and cross of the tee are each to be approximately 1/8 inch or 3.2 mm thick, and the depth of the stem is to be about 1 inch or 25 mm from the cross to the free end of the stem.

7.12.1.2 A sample length of the finished flat cable is to be laid flat with the length of the cable at right angles to the longitudinal axis of the tee and a point on the cable directly under the drill rod at least 12 inches or 305 mm from one end of the cable.

7.12.1.3 The circuit conductors and the steel block and tee are to be connected to low-voltage indicators (buzzers or the like) and to power supplies. The steel block and tee are to be connected together. The indicators are to provide a signal whenever contact is established between one or more of the circuit conductors and the block or tee. The grounding conductor is to be out of the circuit. The cable, the apparatus, and the surrounding air are to be in thermal equilibrium with one another at a temperature of 23.0 ±2.0°C (73.4 ±3.6°F) during the test.

7.12.1.4 The head of a compression testing machine is to be started moving toward the bed at a rate of 0.50 ±0.05 in/min or 10 ±1 mm/min. The travel is to be continued until the drill rod pushes through the insulating materials of the cable to contact one or more of the circuit conductors, at which time the crushing force being exerted by the machine is to be noted and recorded and the downward direction of travel of the head is to be reversed. The crushing procedure is to be repeated at nine other locations. In five of the trials, the cable is to be positioned so that the grounding conductor is down. In the five remaining trials, the grounding conductor is to be up. The results of all ten trials are to be averaged. If the average is less than 600 lbf or 2669 N or 272 kgf for cable with two 14, 12, or 10 AWG insulated circuit conductors, the cable is not acceptable.

7.12.2 Edgewise

7.12.2.1 The cable is to be crushed edgewise between two flat, rigid, parallel, horizontal steel plates that are 2 inches or 50 mm wide. A previously untested sample of finished flat cable is to be used, with ten trials being made. For each trial, the cable – with its axis horizontal and its flat faces vertical – is to be gripped at points 3 inches or 75 mm to each side of the section of cable to be crushed and manually twisted by turning the cable 90 degrees in opposite directions. The flat faces thus remain vertical at the midpoint and the opposite flat faces are up and horizontal. For half of the trials, the samples are to be twisted in a clockwise direction and, for the other half, the samples are to be twisted in the opposite direction.

7.12.2.2 One of the steel plates is to be secured to the underside of the head of a compression machine whose head travels vertically, and the other is to be secured directly below the first on the bed of the machine. After being twisted as indicated in 7.12.2.1, the cable is to be placed on the bed plate with the length of the cable parallel to the 2 inch or 50 mm dimensions of the plate and the vertical flat faces of the cable at the center of the plate. The twist in the cable is to be maintained throughout the test either manually or by means of a jig.

7.12.2.3 The insulated conductors and the two steel plates are to be connected to low-voltage indicators (buzzers or the like) and to power supplies to provide a means for indicating a short circuit between conductors or between any conductor and the steel plates. The grounding conductor is to be out of the circuit. The cable, the apparatus, and the surrounding air are to be in thermal equilibrium with one another at a temperature of 23.0 ±2.0°C (73.4 ±3.6°F) during the test.

7.12.2.4 The head of the machine is to be started and moved toward the bed at the rate of 0.50 ±0.05 in/min or 10 ±1 mm/min. The travel is to be continued until contact is established between the insulated conductors or between one or more of the insulated conductors and one or both plates. The crushing force being exerted by the machine and the points between which the contact occurs are to be noted and recorded, and the downward direction of travel of the head is to be reversed. If the insulated conductors do not remain one above the other until a contact is established, or if the cable does not remain vertical at the center of the plates, the results of the trial are to be disregarded and a new trial is to be made at a different location.

7.12.2.5 The crushing procedure is to be repeated on nine other samples or at nine other locations at least 12 inches or 305 mm apart on the sample length of cable. The results of all ten trials are to be averaged. If the average is less than 1200 lbf or 5338 N or 544 kgf for cable with two 14, 12, or 10 AWG insulated conductors, the cable is not acceptable.

7.13 Crushing resistance test for round cable

7.13.1 Finished round Type NM cables are crush tested as described in the "Crushing-Resistance Test of Round Type NM Cables", Section of the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581.

7.14 Abrasion resistance test of jacket on flat cable

7.14.1 Six straight untwisted 15 inch or 380 mm specimens are to be cut from a sample length of finished cable. They are to be laid flat and parallel to one another on a flat horizontal steel plate and are to be individually secured in place at their ends. An abrasion tool consisting of a weighted solid steel right-circular cylinder across one face of which three straight parallel teeth are machined symmetrically about a diameter (see Figure 3) is to be supported above (not touching) the center of each specimen with its teeth perpendicular to the longitudinal axis of the specimen. The support is to minimize the play of the tool at the ends of each stroke during the abrasion process.

7.14.2 The plate on which the specimens are mounted is to be made to reciprocate horizontally in simple harmonic motion at 30 cycles per minute in the direction parallel to the longitudinal axes of the specimens. The stroke is to center on the abrasion tools, and the length of stroke is to be the 6 inches or 150 mm occupying the center portion of the specimens.

7.14.3 The test is to be started with the plate on which the specimens are mounted at rest at either end of the stroke and the stroke counter set at zero and for the beginning of a cycle. Weight is to be added to the top of each of the abrasion tools to make the combination of each tool and its added weight exert downward 3 lbf ±0.5 ozf or 13.34 ±0.14 N or 1.36 ±0.01 kgf. The abrasion tools are to be lowered gently onto the specimens and the plate is to be started reciprocating immediately. The action is to be continued without interruption until one or more of the tools wear through the outer covering on the cable or until 70 full cycles have been completed without any tool wearing through. An operator is to be present throughout the test to observe the wear, brush away accumulations of debris during the test that might influence the abrading action of the tools in subsequent tests, and to notice and record the number of strokes at which the jacket on each specimen wears through if it wears through.

7.15 Pulling-through-joists test

7.15.1 The joists are to be simulated by four straight, knot-free 6 inch or 150 mm or longer lengths of Douglas fir 2-by-4 kiln-dried lumber (actual cross section measures 1-1/2 inches by 3-1/2 inches or 38 mm by 89 mm). Both ends of each length are to be cut perpendicular to the long surfaces.

7.15.2 By means of a power wood auger, three holes, each 5/8 inch or 16 mm in diameter, are to be bored (at a speed of approximately 1800 r/min) through the broad faces of each length of 2 by 4 as shown in Figure 4. For NM cable, the size of the holes shall be 5/8 inch or 16 mm in diameter. For flat or round NM-PCS cable, the size of the holes to be drilled shall be 1 inch or 25.4 mm. The longitudinal axes of the holes are to be parallel and at an angle of 15 degrees to the horizontal, as shown in the end view, and 1 1/2 inches or 38 mm apart. No attempt is to be made to smooth or round the edges of the holes or to remove splintered wood, sawdust, or drilling chips from the holes.

7.15.3 As illustrated in Figure 4, an open, rigid, metal frame is to be provided on which four of the 2 by 4's are to be supported on edge (broad faces vertical) far enough above the bottom of the coil to achieve the 80 inch or 2 m dimension specified in 7.15.4 and approximately 8.5 ft or 2.6 m above the floor of the test room with their centerlines 16 inches or 406 mm apart and parallel to one another in a horizontal plane. The 2 by 4's are to be secured to the frame with all of their holes inclined in the same direction (longitudinal axes of holes parallel – see the four end views in Figure 5) and progressively offset a horizontal distance of 6 inches or 150 mm as shown in Figure 5, which is a view looking down from above the 2 by 4's.

7.15.4 A 250-ft or 75-m coil of finished cable, in its carton or other finished package, is to be placed flat on or close to the floor of the cold chamber. The inner circle is to be removed from the carton to make the inner end of the cable accessible. The cable is to be cooled in circulating air to a temperature of −20.0 ±2.0°C (−4.0 ±3.6°F) for 21 ±3 hours. The vertical distance between the bottom of the coil inside the cold chamber and a line perpendicular to the center of the 2 by 4's mentioned in 7.15.3 is to be 80 inches or 2 m. The horizontal distance between the first 2 by 4 and a line perpendicular to the center of the carton in which the cable is located, is to be 18 inches or 457 mm. After the cooling, the procedures described in 7.15.5 and 7.15.6 are to be carried out without delay and completed within 5 minutes.

7.15.5 One end of the coil of cable is to be threaded in succession through the holes labeled A, B, C and D in Figure 5 while the rest of the coil remains in the cold chamber. As soon as the cable has been threaded through the four holes, the end of the cable emerging from hole D is to be grasped securely by one or two people standing on the floor in a position such that the cable emerges from hole D at an angle of about 45° to the vertical. While maintaining this angle, they are to pull (hand-over-hand whenever possible) 50 ft or 15 m of the cable entirely through the holes until the end of this length of cable emerges from hole D. The cable is to be pulled through within 30 seconds, and no effort is to be made to uncoil, untwist, or otherwise straighten or adjust the cable except to remove kinks that would keep the cable from being pulled completely through the four holes. All of the pulling is to be done from beyond hole D, none from between the 2 by 4's.

7.15.6 As soon as 50 ft or 15 m of the cable emerges from hole D, that initial test length is to be cut off and set aside. The cable extending from hole D back through holes C, B, and A to the coil in the cold chamber is to be cut off and discarded. The lid of the cold chamber is to be closed long enough (about 10 minutes for a cold chamber with a lid on the top) so that the remainder of the coil can return to the test temperature. While the coil is recooling, the initial test length of the cable is to be examined for any tears, cracks, or other openings through the jacket that expose the underlying parts of the cable. If the cable is damaged is to be considered unacceptable.

7.15.7 A second 50 ft or 15 m length of the cable from the coil in the cold chamber, once it has been recooled to the test temperature, is to be pulled through holes E, F, G, and H as described in 7.15.5 and 7.15.6 without delay and completed within 5 minutes. A third (and final) 50 ft or 15 m length of the cable from the coil in the cold chamber, once it has been recooled to the test temperature, is to be pulled through holes I, J, K, and L as described in 7.15.5 and 7.15.6 without delay and completed within 5 minutes.

7.16 Flow test

7.16.1 An 11 ft or 3350 mm spacing of finished cable is to be laid flat and tested on a horizontal board. A second specimen is to be tested on two wooden blocks that are 2 by 2 inches or 51 by 51 mm in cross section and of any convenient length. As shown in Figure 6, the blocks are to be secured parallel to one another and with their outer faces 8 inches or 203 mm apart. The outer edge of each block is to be notched to accommodate a steel rod 1/16 inch or 1.5 mm in diameter. The cable is to be laid over the blocks and is to be bent down over the rods to form an inverted U. A weight that exerts 5 lbf or 22.2 N or 2.27 kgf is to be attached to each end of the specimen, and the circuit conductors are to be connected in series. The grounding conductor is not to be in the circuit.

7.16.2 A current of 40.0 A is to be passed through the circuit conductors at low voltage for 60 minutes, after which the specimens are to cool to room temperature undisturbed in still air.

7.16.3 The specimens are then to be coiled and immersed in tap water at room temperature, with the ends of the specimens projecting from the water. A 48 – 62 Hz essentially sinusoidal rms test potential of 5000 V is then to be applied between pairs of the circuit conductors and, separately, between each circuit conductor and the water. The potential is to be increased at an essentially uniform rate that:

a) Is not less than 100 percent of the voltage rating for the product in 60 seconds, and

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

The increase is to continue in this manner until the rms voltage reaches 5000. If this level is reached without breakdown, the voltage is to be held constant at 5000 for 60 seconds for each of the conductors tested and is then to be reduced to near zero at the rate mentioned above. The cable is not acceptable if breakdown occurs at less than 5000 V as the voltage is being increased or decreased or occurs in less than 60 seconds at 5000 V.

Tables

Table 1
Cables covered in this standard

(See 1.1, 5.7.2, 5.8.1, 5.9.1, 6.1.12 – 6.1.14, 7.8.1 and 7.11.2.2)

Type	Construction	Number of circuit conductors	Size of circuit conductors
NMC	flat	2 or 3	14 – 10 AWG copper or 12 – 10 AWG aluminum or copper-clad aluminum
NM	flat	2	14 – 2 AWG copper or 12 – 2 AWG aluminum or copper-clad aluminum
	flat	3	14 – 10 AWG copper or 12 – 10 AWG aluminum or copper-clad aluminum
	round	2, 3, or 4	14 – 2 AWG copper or 12 – 2 AWG aluminum or copper-clad aluminum
NM with -PCS	flat	2 or 3	14 – 10 AWG copper or 12 – 10 AWG aluminum or copper-clad aluminum and 18 – 16 AWG copper control/signal conductors
	round	2 or 3	

Table 2
Longest acceptable length of lay of cabled circuit conductors

(See 4.6.2.1 and 7.11.2.2)

AWG size of circuit conductors	Longest acceptable length of lay	
	inches	(mm)
14	5.0	(127)
12	5.5	(140)
10	6.0	(152)
8	8.5	(216)
6	10.5	(267)
4	11.5	(292)
2	13.0	(330)

Table 3
Minimum acceptable separation of circuit conductors

(See 5.16.1, 5.16.2, and 5.18.1)

AWG size of circuit conductors	Separation measured between adjacent surfaces of the metal circuit conductors		Separation measured between centers of the metal of the circuit conductors			
			ASTM Class B stranding or compressed stranding		Compact-stranded aluminum	
	inch	(mm)	inch	(mm)	inch	(mm)
14 – 10	1/8	(3.0)	–	–	–	–
8	–	–	21/64	(8.5)	5/16	(7.9)
6	–	–	13/32	(10.5)	25/64	(9.9)
4	–	–	29/64	(11.5)	7/16	(11.1)
2	–	–	33/64	(13.0)	1/2	(12.7)

Table 4
Grounding conductor in cable with copper conductors

(See 4.6.3.3)

Size of circuit conductors	Smallest acceptable grounding conductor in cables with 2, 3, or 4 circuit conductors
14 AWG	14 AWG
12	12
10, 8[a], 6[a]	10
4[a]	8
3[a], 2[a]	8

[a] These conductors are required to be stranded.

Table 5
Grounding conductor in cables with aluminum or copper-clad aluminum conductors

(See 4.6.3.3)

Size of circuit conductors	Smallest acceptable grounding conductor in cables with 2, 3, or 4 circuit conductors
12 AWG	12 AWG
10	10
(8 – 4)[a]	8
(3, 2)[a]	6[a]

[a] These conductors are required to be stranded.

Table 6
Thicknesses of outer covering on jacketed cables

(See 5.3.1, 6.1.7, 7.3.2, 7.3.3, and 7.3.4)

Type of cable	Construction of covering	Minimum acceptable average thickness				Minimum acceptable thickness at any point					
						At the grounding conductor		Elsewhere than at the grounding conductor			
		Thermoplastic		Thermoplastic and sheath		Thermoplastic		Thermoplastic		Thermoplastic and sheath	
		Mils	mm	Mils	mm	Mils	mm	Mils	mm	Mils	mm
NM	Thermoplastic jacket with no protective sheath	30	0.76	–	–	15	0.38	24	0.61	–	–
	Thermoplastic jacket over protective sheath	20	0.51	30	0.76	–	–	16	0.41	24	0.61
NMC	Thermoplastic jacket over 2 or 3, 14 – 10 AWG circuit conductors	30	0.76	–	–	15	0.38	24	0.61	–	–
NM	Composite jacket of nylon and PVC with no protective sheath	30 mils (0.76 mm) total consisting of 3 – 5 mils (0.076 – 0.127 mm) of nylon and 27 – 25 mils (0.684 – 0.634 mm) of PVC		–	–	15	0.38	24	0.61	–	–