UL 2592

STANDARD FOR SAFETY

Low Voltage LED Wire

UL Standard for Safety for Low Voltage LED Wire, UL 2592

First Edition, Dated March 9, 2015

Summary of Topics

This revision of ANSI/UL 2592 dated July 26, 2024 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 ULSE'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 May 24, 2024.

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UL 2592

Standard for Low Voltage LED Wire

Prior to the first edition, the requirements for the products covered by this standard were included in the Outline of Investigation for Low Voltage LED Wire, UL 2592.

First Edition

March 9, 2015

This ANSI/UL Standard for Safety consists of the First Edition including revisions through July 26, 2024.

The most recent designation of ANSI/UL 2592 as a Reaffirmed American National Standard (ANS) occurred on July 26, 2024. 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 ULSE at any time. Proposals should be submitted via a Proposal Request in the Collaborative Standards Development System (CSDS) at https://csds.ul.com.

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INTRODUCTION

1 Scope

1.1 These requirements cover single-conductor and multi-conductor, unjacketed, 18 – 10 AWG (0.807 – 5.16 mm^2), low voltage LED wire rated 105°C – 250°C (221°F – 482°F), and 300 or 600 volts, suitable for installation in dry and damp, or wet locations. These wires are for use with signs, outline lighting, and interior lighting where the wire is only connected to the output of the driver to the LED array, is only accessible during user servicing of the sign, and is not required to be additionally enclosed by the sign enclosure, in accordance with the Standard for Electrical Signs, UL 48.

1.2 Assemblies that include these wires and are intended for use as components of signs shall meet the requirements in the Standard for Electric-Sign Components, UL 879.

1.3 Wires that are surface marked "-EX" are for use as exposed runs between a cable tray and utilization equipment where the wires are continuously supported and protected against physical damage using mechanical protection such as struts, angles, or channels.

2 Units of Measurement

2.1 When a value for measurement is followed by a value in other units, the use of either value will provide equivalent results in the application of the requirement.

2.2 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 necessary exactly identical – results are to be expected from applying a requirement in USA or in metric terms. Equipment calibrated in metric units is to be used when a requirement is applied in metric terms.

3 Undated References

3.1 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.

CONSTRUCTION

4 Materials

4.1 Each material used in a wire shall be compatible with all of the other materials used in the wire.

5 Conductors

5.1 General

5.1.1 The conductor shall be stranded and shall be of soft-annealed copper. The conductor shall be 18 – 10 AWG (0.807 – 5.16 mm^2) in size. The conductor shall not be smaller in area than indicated in Table 5.1 and shall be continuous throughout without joints in the conductor as a whole. The conductor shall not be used where subjected to any temperature that exceeds that shown for the metal as shown in Table 5.2. The metal shall comply with the applicable ASTM specification as indicated in Table 5.2.

Table 5.1
Minimum cross-sectional area of conductor

AWG size of copper conductor	cmil (0.98 X nominal area)	mm^2
18	1,588	0.807
17	2,009	1.02
16	2,528	1.28
15	3,195	1.62
14	4,028	2.04
13	5,076	2.58
12	6,399	3.24
11	8,065	4.09
10	10,172	5.16

Table 5.2
Conductor – metal specifications

Conductor Metal	ASTM Reference	Temperature limit, °C (°F)
Copper, uncoated, each strand less than 0.015 inch (0.38 mm) in diameter	Standard Specification for Soft or Annealed Copper Wire, ASTM/ANSI B 3	150 (302)
Copper, uncoated, each strand at least 0.015 inch (0.38 mm) in diameter	Standard Specification for Soft or Annealed Copper Wire, ASTM/ANSI B 3	200 (392)
Copper, tin-coated, each strand less than 0.015 inch (0.38 mm) in diameter	Standard Specification for Soft or Annealed Copper Wire, ASTM/ANSI B 3	150 (302)
Copper, tin-coated, each strand at least 0.015 inch (0.38 mm) in diameter	Standard Specification for Soft or Annealed Copper Wire, ASTM/ANSI B 3	200(392)
Copper, silver-coated	Standard Specification for Silver-coated Soft or Annealed Copper Wire, ASTM/ANSI B 298	200 (392)
Copper, nickel-coated	Standard Specification for Nickel-coated Soft or Annealed Copper Wire, ASTM/ANSI B 355	250 (482)
Copper, nickel-coated, 27 percent minimum nickel coated copper	Standard Specification for Nickel-coated Soft or Annealed Copper Wire, ASTM/ANSI B 355	550 (1022)

5.1.2 The size of a conductor shall be verified either by determination of the dc resistance or by determination of the cross-sectional area as described in 5.1.4. Measurement of the dc resistance is to be as described in the DC resistance test in the Standard for Wire and Cable Test Methods, UL 2556. Determination of the conductor size by measurement of the direct-current resistance is the referee method in all cases. The dc resistance shall not be higher than the maximum indicated for the size in Table 5.3 or Table 5.4, as applicable.

Table 5.3
Maximum direct-current resistance of copper conductors ASTM Class C 19-strand concentric-lay conductors

AWG size of conductor (mm^2)	Uncoated				Coated			
	20°C (68°F)		25°C (77°F)		20°C (68°F)		25°C (77°F)	
	Ohms per 1000 feet	Ohms per kilo-meter	Ohms per 1000 feet	Ohms per kilo-meter	Ohms per 1000 feet	Ohms per kilo-meter	Ohms per 1000 feet	Ohms per kilo-meter
18 (0.807)	6.66	21.8	6.79	22.2	7.06	23.2	7.19	23.6
17 (1.02)	5.27	17.3	5.37	17.6	5.59	18.3	5.70	18.7
16 (1.28)	4.18	13.7	4.26	14.0	4.45	14.6	4.53	14.9
15 (1.62)	3.31	10.9	3.37	11.1	3.44	11.3	3.51	11.5
14 (2.04)	2.62	8.62	2.68	8.78	2.73	8.96	2.78	9.14
13 (2.58)	2.08	6.82	2.12	6.97	2.21	7.10	2.20	7.24
12 (3.24)	1.65	5.43	1.68	5.53	1.72	5.64	1.75	5.75
11 (4.09)	1.32	4.30	1.34	4.39	1.37	4.48	1.39	4.56
10 (5.16)	1.039	3.409	1.060	3.476	1.080	3.546	1.102	3.615

Table 5.4
Maximum direct-current resistance of single-bunch bunch-stranded copper conductors

AWG size of conductor (mm^2)	Uncoated				Coated			
	20°C (68°F)		25°C (77°F)		20°C (68°F)		25°C (77°F)	
	Ohms per 1000 feet	Ohms per kilo-meter	Ohms per 1000 feet	Ohms per kilo-meter	Ohms per 1000 feet	Ohms per kilo-meter	Ohms per 1000 feet	Ohms per kilo-meter
18 (0.807)	6.72	22.1	6.85	22.5	7.23	23.7	7.36	24.6
17 (1.02)	5.29	17.4	5.40	17.7	5.47	17.9	5.57	18.3
16 (1.28)	4.18	13.7	4.26	14.0	4.54	14.9	4.58	15.0
15 (1.62)	3.30	10.8	3.37	11.1	3.44	11.3	3.50	11.5
14 (2.04)	2.63	8.64	2.67	8.76	2.82	9.25	2.89	9.48
13 (2.58)	2.08	6.82	2.12	6.96	2.16	7.09	2.20	7.22
12 (3.24)	1.65	5.42	1.69	5.55	1.78	5.84	1.81	5.94
11 (4.09)	1.32	4.33	1.35	4.43	1.37	4.49	1.40	4.59
10 (5.16)	1.040	3.420	1.063	3.380	1.120	3.680	1.140	3.740

5.1.3 The resistance of a copper conductor measured at a temperature other than 20 or 25°C (68 or 77°F) is to be adjusted to the resistance at 20 or 25°C (68 or 77°F) by means of the applicable multiplying factor from Adjustment factors for dc resistance of conductors in the Standard for Wire and Cable Test Methods, UL 2556.

5.1.4 Where measured as the means of size verification (see 5.1.2), the cross-sectional area of the conductor shall not be smaller than the minimum area indicated for the size in Table 5.1. The cross-sectional area of the conductor is to be determined as the sum of the areas of its component round strands, with the individual strands measured as described in 5.1.5.

5.1.5 The diameter of each individual strand is to be measured over the tin or other metal coating by means of a micrometer caliper having flat surfaces on both the anvil and the end of the spindle and calibrated to read directly to at least 0.001 inch (0.01 mm). It is to be assumed that any one strand is practically constant in diameter throughout its length. Determination of the conductor size is to be in accordance with the Conductor diameter test in the Standard for Wire and Cable Test Methods, UL 2556.

5.1.6 No particular combination of the individual strands of a conductor is required; however, simple bunching (untwisted strands) shall not be used.

5.1.7 The individual strands used in making up a conductor are usually drawn to a specified diameter that does or does not correspond to the diameter of an established gauge number. The individual strands are not required to be all of the same diameter.

5.1.8 The length of lay of the strands in every layer of a concentric-lay-stranded conductor shall be 8 – 16 times the outside diameter of that layer. The direction of lay of the outer layer shall be left-hand. The length of lay shall be determined in accordance with the Length of Lay test in the Standard for Wire and Cable Test Methods, UL 2556.

5.1.9 The length of lay of the strands in a single-bunch bunch-stranded conductor shall not be greater than indicated in Table 5.5. The direction of lay shall be left-hand. The length of lay shall be determined in compliance with the method Length of Lay in the Standard for Wire and Cable Test Methods, UL 2556.

Table 5.5
Maximum length of lay of strands in a single-bunch bunch-stranded conductor

AWG (mm^2) size of conductor	Inches	(mm)
18 (0.807), 17 (1.02)	1-1/4	32
16 (1.28), 15 (1.62)	1-1/2	38
14 (2.04), 13 (2.58)	1-3/4	44
12 (3.24), 11 (4.09)	2	51
10 (5.16)	2-1/2	64

5.2 Metal coating

5.2.1 The individual strands of a copper conductor shall each have a continuous coating of tin or other metal or alloy if the conductor is insulated with a material that is capable of corroding unprotected copper.

5.3 Separator

5.3.1 A separator between the conductor and the insulation is not required, but shall be permitted to keep the insulation from penetrating between the strands of a stranded conductor. A separator shall be colored or opaque to make the separator clearly distinguishable from the conductor once the insulation is removed. The color shall be other than green or green and yellow and may be solid, striped, or in some other pattern.

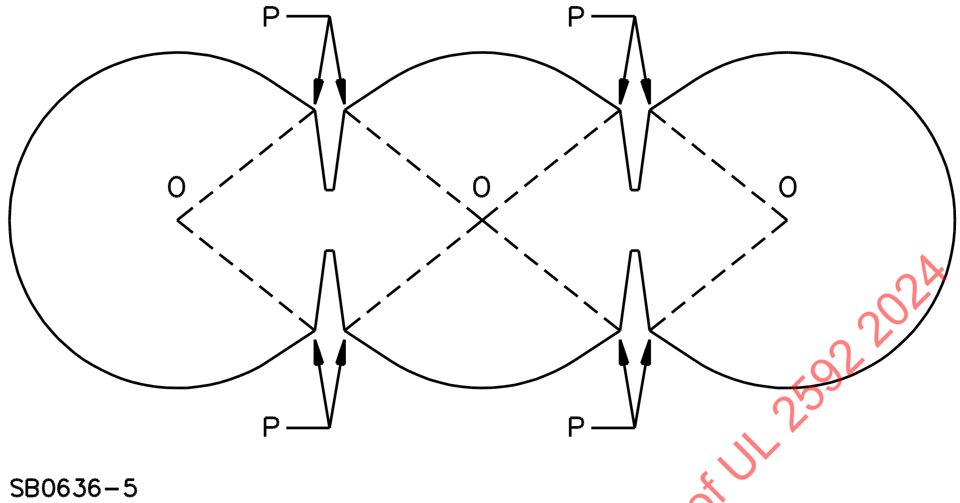
6 Insulation

6.1 The conductor shall be insulated for its entire length with one or more of the materials for which physical-properties limits are noted in Specific Materials in the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581 or with another such material evaluated for the use. The insulation shall be of a material that has a minimum, unaged tensile strength of 1200 lbf/in^2 (8.27 MPa). The insulation material shall have a temperature rating of 105°C (221°F), 125°C (257°F), 150°C (302°F), 200° C (392°F), or 250°C (482°F), shall be applied directly to the surface of the conductor or to the separator, if one is used, and shall comply with the requirements in Sections 9 – 24.

6.2 The applied insulation shall provide a circular cross section for the insulated conductor, and the conductor itself shall be centered in the applied material so that, when determined by the pin-gauge or optical method, the minimum thickness at any point of the applied material is not less than 90 percent of the average thickness of the material as determined by the difference method. For parallel constructions, measurements to determine the average thickness and to determine compliance with the minimum at any point requirement shall be made as shown in Figure 6.1. For rippable constructions, the minimum thickness at any point of the applied material is not less than 90 percent of the average thickness of the material as determined by the difference method after ripping. The average thickness of the insulation is not specified. The insulation thickness shall be determined in compliance with the Thickness test in the Standard for Wire and Cable Test Methods, UL 2556.

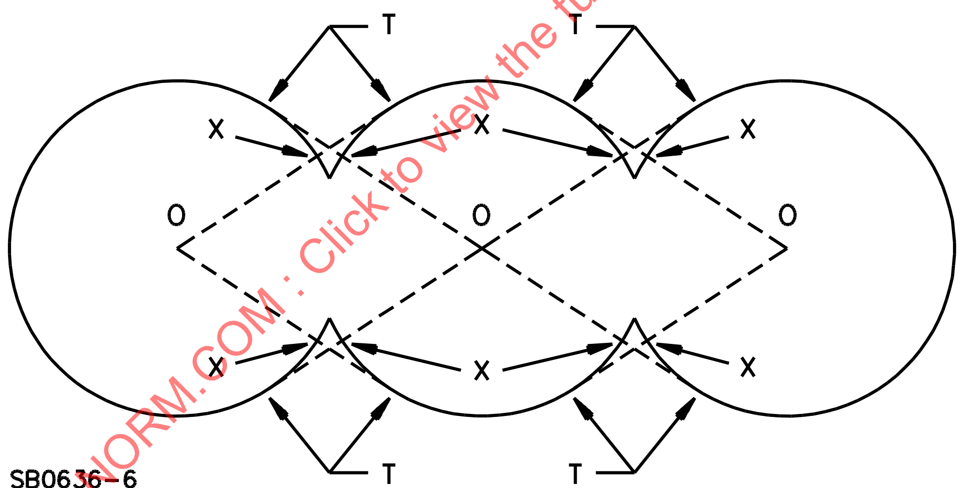
Figure 6.1

Definition of regions of valley slopes on which thickness measurements shall not be made on parallel constructions



Constructions with a cross-section having a definite point P at the outer end of each valley slope.

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



Constructions with a cross-section having a definite point to mark the outer end of each valley slope.

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

6.3 An insulation that is of material generically different from any insulation material referenced in the Index to insulation and jacket materials table in the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581, or that is as referenced in 6.1 yet does not comply with the short-term tests applicable to the material, shall be of a material and in thicknesses and with the temperature rating appropriate for the wire. The material shall be evaluated for the requested temperature rating as described in the Dry temperature rating of new materials (long-term aging test) test in the Standard for Wire and Cable Test Methods, UL 2556. Investigation of the electrical, mechanical, and physical characteristics of the wire using either material shall show the material to be comparable in performance to the insulation materials referenced in 6.1. The investigation shall include tests such as crushing, abrasion, deformation, heat shock, insulation resistance, and dielectric voltage-withstand.

7 Assembly

7.1 The construction shall consist of a single, insulated conductor, or 2 or more insulated conductors laid parallel.

PERFORMANCE

8 Samples

8.1 Test samples shall consist of single conductor and multi-conductor parallel cables. Rippable constructions shall be separated and additionally tested as a single conductor construction.

9 Physical Properties Tests

9.1 Specimens prepared from sample lengths of the insulation shall have physical properties that comply with Specific Materials in the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581 or with separately established values of physical properties. The samples are to be taken from the finished wire and the testing is to be conducted as indicated in 9.2.

9.2 The methods of preparation of samples, of selection and conditioning of specimens, and of making the measurements and calculations for ultimate elongation, tensile strength, and set shall be in accordance with the Physical properties (ultimate elongation and tensile strength) tests in the Standard for Wire and Cable Test Methods, UL 2556.

10 Routine Voltage Application Test

10.1 Finished wire shall be capable of withstanding without breakdown the application of a 48 – 62 Hz essentially sinusoidal potential after immersion in water at 24.0 ±3°C (75.2 ±5°F) for 1 hour and under the following conditions. Starting near zero, the applied potential shall be increased at the rate of approximately 500 V/s until the test voltage is equal to the test voltage indicated in Table 12.1, shall be held at that level, and then shall be reduced to zero. The total time for increasing, holding, and reducing the test voltage shall be 5 minutes.

10.2 Compliance of wire with the requirement in 10.1 is to be determined by using a voltage supply that complies with 12.3. The test potential is to be applied between the conductor of the wire and an electrode immersed in the water. For multi-conductor constructions, the test potential is to be applied between all conductors tied together and the water. Additionally, for multi-conductor constructions, the test potential is to be applied between adjacent conductors.

10.3 Throughout the test, including the 1-hour period of immersion prior to the application of the test potential, the two ends of the coil are to be kept at least 2 feet (610 mm) out of the water. Breakdown usually can be determined by a current rush resulting from the decreased resistance of the circuit, and is to be indicated by the tripping of a circuit breaker or by the illumination of a bank of lamps connected in series with the test coil. In some instances, breakdown can be noted by observing the flash at the point on the wire at which the rupture takes place.

11 Voltage Application at Elevated Temperature

11.1 A 10 foot coil of finished wire shall be capable of withstanding, without breakdown, the application of a 48 – 62 Hz essentially sinusoidal potential when the coil under test is placed in an oven at elevated temperature calculated as follows under the following conditions. Starting near zero, the applied potential shall be increased at the rate of approximately 500 V/s until the test voltage is equal to the test voltage indicated in Table 12.1, shall be held at that level, and then shall be reduced to zero. The total time for increasing, holding, and reducing the test voltage shall be 12 hours.

The oven temperature, T_{test}, shall be 102 percent of the desired temperature rating expressed on the Kelvin scale. This temperature shall be calculated, in °C, using the following formula (T_{test} shall be rounded to the nearest whole number):

$$T_{test}\left(°C\right) = 1.02 \times \left[273.15 + T_{rating}\left(°C\right)\right] - 273.15$$

The test temperatures applied for the most common temperature ratings are given in Table 11.1.

Table 11.1
Test temperature for dry temperature rating of new materials

See 11.1

Temperature rating, °C (°F)	60 (140)	75 (167)	80 (176)	90 (194)	105 (221)	125 (257)	150 (302)	180 (356)	200 (392)	250 (482)
Aging temperature, °C (°F)	67 (153)	82 (180)	87 (189)	97 (207)	113 (235)	133 (271)	158 (316)	189 (372)	209 (408)	260 (500)

11.2 Compliance of wire with the requirement in 11.1 is to be determined by using a voltage supply that complies with 12.3. The test potential is to be applied between the conductor and either a metallic braid applied around the wire for test purposes, or a graphite powder in which the wire is placed. For multi-conductor constructions, the test potential is to be applied between all conductors tied together and the braid or graphite powder. Additionally, for multi-conductor constructions, the test potential is to be applied between adjacent conductors.

11.3 Breakdown usually can be determined by a current rush resulting from the decreased resistance of the circuit, and is to be indicated by the tripping of a circuit breaker or by the illumination of a bank of lamps connected in series with the test coil. In some instances, breakdown can be noted by observing the flash at the point on the wire at which the rupture takes place.

12 Extended Voltage Application Test

12.1 When a specimen of finished wire is wound on a metal mandrel, the insulation shall be capable of withstanding for 1 hour without breakdown the application of a 48 – 62 Hz essentially sinusoidal potential as indicated in Table 12.1 and under the following conditions: starting near zero, the applied potential shall be increased at the rate of approximately 500 V/s until the required test value is reached. After an hour, the applied potential shall be reduced to zero.

Table 12.1
Test potential and mandrel diameter

Maximum working potential in volts	Test potential in volts rms	Diameter* of mandrel
600	2000	2 times the outer diameter of the wire
300	1500	2 times the outer diameter of the wire
* For parallel constructions, the minor diameter shall be used to determine the mandrel size.		

12.2 Compliance of wire with the requirements of 12.1 is to be determined by means of:

a) A voltage supply that complies with 12.3, and

b) A rigid, metal mandrel having the diameter indicated in Table 12.1.

12.3 The test potential is to be supplied by a 48 – 62 Hz supply whose potential is continuously variable from near zero to at least 10 kV rms at the rate of approximately 500 V rms/s. With a specimen in the circuit, the supply 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 supply range. The supply voltage is to be monitored continuously by a voltmeter that, 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 that has an overall accuracy that does not introduce an error exceeding 5 percent.

12.4 The wire shall be wound around the mandrel for 6 turns. Successive turns are to be in contact with each other. The wire is not to be twisted while being wound onto the mandrel. The free end of the wire is to adjust itself as the wire is being wound onto the mandrel.

12.5 The conductor is to be held in position at the ends by means of one or two turns of tape around the mandrel and conductor. The metal mandrel is to serve as one electrode and the conductor(s) in the wire is to serve as the other electrode. For multi-conductor constructions, the test potential is to be applied between all conductors tied together and the mandrel. Additionally, for multi-conductor constructions, the test potential is to be applied between adjacent conductors.

12.6 The test described in 12.1 – 12.6 shall also be conducted on samples which have been conditioned (two separate samples for each conditioning) as described below, except that the test voltage shown in Table 12.1 shall be increased by 6000 volts.

a) 720 hours weatherometer exposure as described in the Conditioning of specimens, Weather (sunlight) resistance test in the Standard for Wire and Cable Test Methods, UL 2556.

b) 7 day immersion in 75 minus 0, plus 5°C (167 minus 0, plus 9°F) water, immersed as described in the Short term insulation resistance, Method 1 (15°C in water) test in the Standard for Wire and Cable Test Methods, UL 2556 (wet locations only).

c) 4 hours at minus 25 ±3°C (minus 13 ±5°F) (samples wound around the mandrel specified in Cold Bend, Section 20, while at the low temperature.)

13 Extended Voltage Application After Immersion Test

13.1 After a finished wire is immersed in water for 1 hour, the insulation shall be capable of withstanding for a period of 4 hour without breakdown the application of a 48 – 62 Hz sinusoidal potential of 150 percent of the rated voltage of the wire. Starting near zero, the applied potential is to be increased at the rate of approximately 500 V/s until the required test value is reached. After 4 hour, the applied potential is to be reduced to zero.

13.2 Compliance of wire with the requirement in 13.1 is to be determined by means of:

a) A voltage supply that complies with 12.3, and

b) A 5-ft (1.5-m) length of 1/2 inch trade size rigid metal conduit having square-cut ends and standard conduit bushings threaded in place.

13.3 A 9-foot (2.7-m) sample of wire is to be immersed for all but about 6 inches (150 mm) at each end in water at 25.0 ±5.0°C (77.0 ±9.0°F) for 1 hour, after which the sample is to be removed and the surface moisture is to be wiped off with a clean, dry cloth. A 7-foot (2.1-m) specimen is then to be cut from the immersed part of the 9-foot (2.7-m) sample, and 1 inch (25 mm) of the insulation is to be removed from each end. This specimen is then to be centered lengthwise in a length of rigid metal conduit so that approximately 10 inches (250 mm) of the insulation extends beyond the conduit at each end. By means of electrical connections to one end of the conductor(s) and to the metal conduit, the sample is to be subjected to the test potential for 4 hours. During this test, any breakdown of the insulation or charring of the insulation is unacceptable.

14 Conductor Corrosion Test

14.1 Only bare copper conductors without a metal coating are required to be tested. One specimen of an insulated conductor is to be tested to, and meet the requirements of Copper corrosion test in the Standard for Wire and Cable Test Methods, UL 2556. The specimen is to be conditioned with the conductor in place, for the same time and temperature as described in the physical properties requirements for the specific insulation material.

15 Surface Leakage Test

15.1 After a finished wire is immersed in water for 30 minutes, the insulation shall be capable of withstanding for 1 minute without smoking, flaming, or flashover the application of a 48 – 62 Hz sinusoidal potential as of 1000 V. Starting near zero, the applied potential is to be increased at the rate of approximately 500 V/s until the required test value is reached. After 1 minute, the applied potential is to be reduced to zero.

15.2 Compliance of wire with the requirements in 15.1 is to be determined by using a voltage supply that complies with 12.3.

15.3 A length of the wire is to be immersed, except at the ends, in tap water at 24.0 ±3.0°C (75.2 ±5.4°F) for 30 minutes. After removal from the water, surface moisture is to be wiped off with a clean, dry cloth, and then two bands of 18 AWG bare, solid wire are to be wrapped tightly around the surface of the insulation, with a spacing between them 1/2 inch (12.7 mm) apart. Electrical connections are to be made to the two wire bands and the potential is then to be applied for 1 minute.

16 VW-1 Flame Test (Required)

16.1 The sample shall not convey flame along its length and shall not convey flame to combustible materials in its vicinity when the wire is subjected to the FV-2/VW-1 test in the Standard for Wire and Cable Test Methods, UL 2556. The sample length shall be at least 18 inches (450 mm).

16.2 Where any specimen shows more than 25 percent of the indicator flag burned away or charred after any of the five applications of the flame, the wire is judged to be capable of conveying flame along its length. Where any specimen emits flaming or glowing particles that at any time ignite the cotton, or continues to flame longer than 60 seconds after any application of the flame, the wire is judged capable of conveying flame to combustible materials in the vicinity.

17 Vertical-Tray Flame Test on Wire Optionally Marked "-VTR"

17.1 The construction of a cable is changed (and therefore the flame test is to be repeated) where different materials and/or different amounts of the same materials are introduced that affect the flame characteristics of the cable.

17.2 Wire of a given construction that is surface marked or designated with the suffix "-VTR" shall not exhibit char that reaches the upper end of any specimen [a maximum of 8 feet 0 inches (244 cm)] when sets of cable specimens as described in 17.3 are separately installed in a vertical ladder type of cable tray and are subjected to 20 minutes of flame as described under UL Flame Exposure (smoke measurements are not applicable) in the Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables, UL 1685.

17.3 Typically, the test specimens of this cable are two sets each of the smallest and largest constructions of cable that the manufacturer intends to produce in the construction. A tested size does not comply when the damage to the insulation and/or the overall cable jacket reaches the upper end of the individual cable length.

18 FT4/IEEE 1202 Flame Test on Wire Optionally Marked "FT4"

18.1 Finished wire that is surface marked or designated by a with the suffix "-FT4" shall not exhibit a char length in excess of 4 feet 11 inches (1.5 m) when each of the sets of specimens as detailed in 17.3 is tested as described under FT4/IEEE 1202 Type of Flame Exposure (smoke measurements are not applicable) in the Standard for Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables, UL 1685.

19 Sunlight Resistance

19.1 Specimens shall retain 80 percent of the unaged tensile and elongation values after the insulation is subjected to the described in the Conditioning of specimens, Weather (sunlight) resistance test in the Standard for Wire and Cable Test Methods, UL 2556 for a 720 hour exposure.

20 Cold Bend

20.1 The wire shall not crack when tested in accordance with Cold bend test in the Standard for Wire and Cable Test Methods, UL 2556 at minus 25 ±3°C (minus 13 ±5°F) and using the mandrel diameters shown in Table 20.1. The sample shall be wrapped around the mandrel in close turns as indicated in Table 20.1. For parallel constructions, the minor diameter shall be used to determine the mandrel size. For parallel constructions where the major diameter is greater than 0.625 inches (15.88 mm), the diameter of mandrel used shall be twice the minor diameter of the wire and the wire shall be wrapped in a U-bend around the mandrel.

Table 20.1
Mandrel diameter inches (mm)

Diameter of wire inches (mm)	Diameter of mandrel inches (mm)	Number of turns around mandrel
0 – 0.125 (0 – 3.12)	0.250 (6.35)	6
0.126 – 0.250 (3.20 – 6.35)	0500 (12.70)	6
0.251 – 0.375 (6.38 – 9.53)	0.750 (19.05)	6
0.376 – 0.500 (9.55 – 12.70)	1.000 (25.40)	6
0.501 – 0.625 (12.73 – 15.88)	1.250 (31.75)	6

21 U-Bend Test

21.1 General

21.1.1 Finished wire shall not break down electrically and shall not crack, erode, or track on its outside surface when a specimen of the wire is prepared and tested as described in 21.2 – 21.4.

21.2 Apparatus

21.2.1 A smooth, flat metal plate, approximately square in shape, is required.

21.3 Specimen

21.3.1 A specimen of the wire or wire shall be bent, in the form of a "U", around a mandrel having a diameter of 4 times the outside diameter of the specimen. For parallel constructions, the minor diameter shall be used to determine the mandrel size.

21.4 Procedure

21.4.1 The specimen shall be positioned over the horizontally supported plate, the bend of the "U" just touching the plate, the legs of the "U" being vertical. After not less than 30 or more than 45 minutes following the bending of the specimen, an ac voltage shall be applied and maintained for 6 hours between the specimen conductor(s) and the plate. The voltage applied shall be 0.1 kV per mil (3.9 kV per millimeter) of nominal insulation thickness, or the rated voltage of the wire, whichever is greater.

21.5 Examination

21.5.1 The wire is acceptable if there is no electrical breakdown and there is no visible cracking, erosion, or tracking of the outside surface. A change in color or glossiness or other appearance is not cause for rejection. If the specimen breaks down or shows cracking, erosion, or tracking, the test is to be repeated on each of two additional specimens. The wire is not acceptable if any of the two additional specimens break down or show cracking, erosion, or tracking. Visual examination is to be made with the unaided eye.

22 Impact Test for Wire Optionally Marked "-EX"

22.1 Wire marked "-EX " as indicated in 26.1 shall be capable of withstanding without contact between circuit conductors, the energy of a free-falling, flat-faced weight that impacts the cable at the point at which the cable is laid over a steel rod. The test shall be conducted and the results evaluated as described in 22.2 – 22.10. Flat cable shall be capable of withstanding the impact when tested with the broad and narrow faces laid over the rod (flatwise and edgewise using separate specimens).

22.2 The performance of a two conductor cable is to be tested on a finished cable containing two circuit conductors that are of identical size and shall be taken as representative of the performance of all other cables of the same construction containing the same or a larger number of conductors of the same or of a larger size.

22.3 A solid rectangular block of steel 4-3/4 inch (121 mm) long by 3 inch (76 mm) wide by 5 inch (127 mm) high, with its upper face 4-3/4 by 3 inch (121 by 76 mm) horizontal, is to be secured to a concrete floor, the building framework, or another solid support. A solid steel rod 3/4 inch (19 mm) in diameter and 4-3/4 inch (or 121 mm) long is to be bolted or otherwise secured to the upper face of the stationary block with the longitudinal axis of the rod in the same vertical plane as the longitudinal axis of the stationary block.