UL 4703

STANDARD FOR SAFETY

Photovoltaic Wire

UL Standard for Safety for Photovoltaic Wire, UL 4703

First Edition, Dated September 30, 2014

Summary of Topics

This revision of ANSI/UL 4703 dated August 11, 2020 is being issued to update the title page to reflect the most recent designation as a Reaffirmed American National Standard (ANS). No technical changes have been made.

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

The requirements are substantially in accordance with Proposal(s) on this subject dated May 15, 2020.

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UL 4703

Standard for Photovoltaic Wire

Prior to the first edition, the requirements for the products covered by this standard were included in the Outline of Investigation for Photovoltaic Wire, UL 4703.

First Edition

September 30, 2014

This ANSI/UL Standard for Safety consists of the First Edition including revisions through August 11, 2020.

The most recent designation of ANSI/UL 4703 as a Reaffirmed American National Standard (ANS) occurred on July 21, 2020. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

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

No Text on This Page

CONTENTS

INTRODUCTION

1 Scope 5
2 Units of Measurement 5
3 Undated References 5
4 Glossary 5

CONSTRUCTION

5 General 6
6 Conductors 6
6.1 General 6
7 Insulation 7
7.1 Thermoplastic Insulation (90°C Dry and Wet, 600 Volts) 7
7.2 Thermoset insulation and jacket (90, 105, 125, or 150°C dry and 90°C wet, 600, 1000, or 2000 volts) 8
8 Assemblies 11
8.1 Assemblies that include single conductors 11

PERFORMANCE

9 Details 11

MANUFACTURING AND PRODUCTION

10 Manufacturing and Production Tests 12

MARKING

11 On the Wire 13
12 On the Tag, Reel, or Carton 14

No Text on This Page

INTRODUCTION

1 Scope

1.1 This standard covers single-conductor, insulated and integrally or non-integrally jacketed, sunlight resistant, photovoltaic wire rated 90°C, 105°C, 125°C, or 150°C dry and, 90°C wet, 600, 1000, or 2000 V for interconnection wiring of grounded and ungrounded photovoltaic power systems as described in Article 690, Part IV, Wiring Methods, and other applicable parts of the National Electrical Code (NEC), NFPA 70.

2 Units of Measurement

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

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

4 Glossary

4.1 For the purpose of this standard the following definitions apply.

4.2 COMPOSITE INSULATION – A multiple-layer system of materials that fulfills the requirements for both electrical and mechanical integrity of the cable or wire.

4.3 CP – A thermoset compound whose characteristic constituent is chlorosulfonated polyethylene.

4.4 CPE – A thermoset compound whose characteristic constituent is chlorinated polyethylene.

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

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

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

4.8 NEOPRENE – A thermoset compound whose characteristic constituent is polychloroprene.

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

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

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

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

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

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

CONSTRUCTION

5 General

5.1 Only materials that are acceptable for the particular use shall be employed in a wire. Wires shall be made and finished with the degree of uniformity and grade of workmanship that are practicable in a well-equipped factory.

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

5.3 The wire shall consist of a single, insulated, stranded copper, or aluminum conductor, complying with the construction and materials requirements for Type RHW-2 in the Standard for Thermoset-Insulated Wires and Cables, UL 44, or for Type THW-2 in the Standard for Thermoplastic-Insulated Wires and Cables, UL 83, with the exceptions noted in Conductors, Section 6 and Insulation, Section 7. For wires rated greater than 90°C, see 9.2. For assemblies of these single conductor wires see 8.1.

6 Conductors

6.1 General

6.1.1 A copper conductor shall not be smaller than 18 AWG and shall not be larger than 2000 kcmil. An aluminum or copper-clad aluminum conductor shall not be smaller than 12 AWG and shall not be larger than 2000 kcmil. Only stranded conductors of copper, copper-clad aluminum, or an acceptable aluminum alloy shall be used in a wire. Conductors shall consist of materials complying with the:

a) Standard Specification for Soft or Annealed Copper Wire, ASTM B3,

b) Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft, ASTM B8,

c) Standard Specification for Tin-Coated Soft or Annealed Copper Wire for Electrical Purposes, ASTM B33,

d) Standard Specification for Rope-Lay-Stranded Copper Conductors Having Bunch-Stranded Members, for Electrical Conductors, ASTM B172,

e) Standard Specification for Rope-Lay-Stranded Copper Conductors Having Concentric-Stranded Members, for Electrical Conductors, ASTM B173,

f) Standard Specification for Bunch-Stranded Copper Conductors for Electrical Conductors, ASTM B174,

g) Standard Specification for Silver-Coated Soft or Annealed Copper Wire, ASTM B298,

h) Standard Specification for Nickel-Coated Soft or Annealed Copper Wire, ASTM B355,

i) Standard Specification for 8000 Series Aluminum Alloy Wire for Electrical Purposes-Annealed and Intermediate Tempers, ASTM B800,

j) Standard Specification for Concentric-Lay-Stranded Conductors of 8000 Series Aluminum Alloy for Subsequent Covering or Insulation, ASTM B801,

k) Standard Specification for Compact Round Stranded Copper Conductors Using Single Input Wire Construction, ASTM B835,

l) Standard Specification for Compact Round Stranded Aluminum Conductors Using Single Input Wire Construction, ASTM B836,

m) Standard Specification for Compressed Round Stranded Aluminum Conductors Using Single Input Wire Construction, ASTM B901,

n) Standard Specification for Compressed Round Stranded Copper Conductors, Hard, Medium-Hard, or Soft Using Single Input Wire Construction, ASTM B902,

o) Standard Specification for 19 Wire Combination Unilay-Stranded Aluminum Conductors for Subsequent Insulation, ASTM B786/B786M.

p) Standard Specification for 19 Wire Combination Unilay-Stranded Copper Conductors for Subsequent Insulation, ASTM B787/B787M,

q) Requirements for Copper-Clad Aluminum Conductors in the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581.

6.1.2 An aluminum conductor shall be of aluminum conductor material (ACM), AA 8000 series alloy. Copper-clad aluminum conductors shall comply with the Requirements for Copper-Clad Aluminum Conductors in the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581.

6.1.3 An 18 or 16 AWG copper conductor shall comply with the requirements for stranded fixture wire conductors in the Standard for Fixture Wire, UL 66 and shall employ a minimum of 7 strands. All other conductors shall comply with the requirements in the Standard for Thermoset-Insulated Wires and Cables, UL 44, or in the Standard for Thermoplastic-Insulated Wires and Cables, UL 83, except as modified in this Section.

6.1.4 Metric conductors in accordance with Conductors of insulated cables, IEC 60228, Class 2, 5, or 6 may be used instead of AWG sized conductors described in the Standard for Thermoset-Insulated Wires and Cables, UL 44, or in the Standard for Thermoplastic-Insulated Wires and Cables, UL 83. The size of these metric conductors shall be between 0.823 and 1013 mm^2. The next largest AWG size shall be used to determine the insulation and/or jacket thickness.

6.1.5 Refer to the table Conductor – metal specifications in the Standard for Appliance Wiring Material, UL 758, for the temperature limitations of the conductor material used.

7 Insulation

7.1 Thermoplastic Insulation (90°C Dry and Wet, 600 Volts)

7.1.1 The insulation shall be PVC that complies with the requirements for Type THW-2 as specified in the Standard for Thermoplastic-Insulated Wires and Cables, UL 83.

7.1.2 A thermoplastic insulation that is of a material generically different from PVC (new material), or that is a PVC material that does not comply with the short-term physical properties tests for Type THW-2 PVC insulation, shall be evaluated for the requested temperature rating as described in the Dry temperature

rating of new materials (long-term aging test), in the Standard for Wire and Cable Test Methods, UL 2556. Investigation of the electrical, mechanical, and physical characteristics of the wire using the material shall show the material to be comparable in the performance to the Type THW-2 PVC insulation. The investigation shall include tests such as crushing, impact, abrasion, deformation, heat shock, insulation resistance, and dielectric voltage withstand.

7.1.3 The average and minimum thickness of a thermoplastic insulation shall be as shown in Table 7.1. The method of preparing specimens, taking the measurements, and determining compliance shall be as specified in the Standard for Thermoplastic-Insulated Wires and Cables, UL 83.

Table 7.1
Minimum acceptable thicknesses of integral thermoplastic insulation and jacket

Conductor size(s)		Minimum average	Minimum at any point
Copper	Aluminum or copper-clad aluminum	mils (mm)	mils (mm)
18 – 10 AWG	12 – 10 AWG	75 (1.90)	68 (1.73)
8 – 2	8 – 2	95 (2.41)	86 (2.18)
1 – 4/0	1 – 4/0	110 (2.79)	99 (2.51)
250 – 500 kcmil	250 – 500 kcmil	125 (3.18)	112 (2.84)
550 – 1000	550 – 1000	140 (3.56)	126 (3.20)
1100 – 2000	1100 – 2000	170 (4.32)	153 (3.89)

7.2 Thermoset insulation and jacket (90, 105, 125, or 150°C dry and 90°C wet, 600, 1000, or 2000 volts)

7.2.1 The insulation and jacket materials shall be as shown in Table 7.2. A jacket may be thermoplastic if it complies with the requirements noted in 7.2.3.

Table 7.2
Insulation and jacket materials

Insulation	Jacket
EP	Required: CP, Thermoset CPE, NBR/PVC, Neoprene, XL, or PVC
XL	Optional: same materials as above
EPCV	Optional: same materials as above
CP, CPE	Optional: same materials as above
Composite construction of CP, CPE, EPCV, or XL, all over EP, EPCV, Silicone, or XL	Optional: same materials as above

7.2.2 The insulation and jacket shall comply with the requirements for Type RHW-2 as specified in the Standard for Thermoset-Insulated Wires and Cables, UL 44.

7.2.3 A thermoset insulation or jacket that is of a material generically different from those specified for Type RHW-2 (new material), or that is a material specified for Type RHW-2, but that does not comply with the short-term physical properties tests for Type RHW-2 insulation or jacket, shall be evaluated for the requested temperature rating as described in the Dry temperature rating of new materials (long-term aging test), in the Standard for Wire and Cable Test Methods, UL 2556. Investigation of the electrical, mechanical, and physical characteristics of the wire using the material shall show the material to be comparable in performance to the Type RHW-2 insulation or jacket. The investigation shall include tests

such as crushing, impact, abrasion, deformation, heat shock, insulation resistance, and dielectric voltage withstand.

7.2.4 The average and minimum thickness of a thermoset insulation not having a jacket shall be as shown in Table 7.3. The average and minimum thickness of the insulation under a jacket shall be as shown in Table 7.4. The average and minimum thickness of a thermosetting composite insulation without a jacket shall be as shown in Table 7.5. The average and minimum thickness of a thermoset jacket over other than EP insulation shall be as shown in Table 7.6. The average and minimum thickness of a thermoset jacket over EP insulation shall be as shown in Table 7.7. The method of preparing specimens, taking the measurements, and determining compliance shall be as specified in the Standard for Thermoset-Insulated Wires and Cables, UL 44.

Table 7.3
Minimum acceptable thicknesses of 600 V thermoset insulation not requiring a jacket

Conductor size(s)		mils (mm)	
Copper	Aluminum or copper-clad aluminum	Minimum average thickness of insulation	Minimum thickness at any point of insulation
18 – 10 AWG	12 – 10 AWG	60 (1.52)	54 (1.37)
8 – 2	9 – 2	75 (1.90)	68 (1.73)
1 – 4/0	1 – 4/0	95 (2.41)	86 (2.18)
250 – 500 kcmil	250 – 500 kcmil	110 (2.79)	99 (2.51)
550 – 1000	550 – 1000	125 (3.18)	112 (2.84)
1100 – 2000	1100 – 2000	140 (3.56)	126 (3.20)

Table 7.4
Minimum acceptable thicknesses of 600 V thermoset insulation having a jacket

Conductor size(s)		mils (mm)	
Copper	Aluminum or copper-clad aluminum	Minimum average thickness of insulation	Minimum thickness at any point of insulation
18 – 10 AWG	12 – 10 AWG	45 (1.14)	40 (1.02)
8 – 2	9 – 2	60 (1.52)	54 (1.37)
1 – 4/0	1 – 4/0	80 (2.03)	72 (1.83)
250 – 500 kcmil	250 – 500 kcmil	95 (2.41)	86 (2.18)
550 – 1000	550 – 1000	110 (2.79)	99 (2.51)
1100 – 2000	1100 – 2000	125 (3.18)	112 (2.84)

Table 7.5
Minimum acceptable thicknesses of 600 V composite insulation without a jacket

Size(s) of conductor		mils (mm)			
		Inner layer		Outer layer	
Copper	Aluminum or copper-clad aluminum	Minimum average thickness of insulation	Minimum thickness at any point of insulation	Minimum average thickness of insulation	Minimum thickness at any point of insulation
18 – 10 AWG	12 – 10 AWG	30 (0.76)	27 (0.69)	30 (0.76)	27 (0.69)
8	8	45 (1.14)	40 (1.02)	30 (0.76)	27 (0.69)
6 – 2	6 – 2	45 (1.14)	40 (1.02)	45 (1.14)	40 (1.02)
1 – 4/0	1 – 4/0	55 (1.40)	50 (1.27)	60 (1.52)	54 (1.37)
250 – 500 kcmil	250 – 500 kcmil	65 (1.65)	58 (1.47)	80 (2.03)	72 (1.83)
550 – 1000	550 – 1000	80 (2.03)	72 (1.83)	80 (2.03)	72 (1.83)
1100 – 2000	1100 – 2000	100 (2.54)	90 (2.29)	110 (2.79)	99 (2.51)

Table 7.6
Minimum acceptable thicknesses of jacket over other than EP insulation

Size(s) of conductor		mils (mm)	
Copper	Aluminum or copper-clad aluminum	Minimum average thickness of jacket	Minimum thickness at any point of jacket
18 AWG – 2000 kcmil	12 AWG – 2000 kcmil	30 (0.76)	24 (0.61)

Table 7.7
Minimum acceptable thicknesses of jacket over EP insulation

Size(s) of conductor		mils (mm)	
Copper	Aluminum or copper-clad aluminum	Minimum average thickness of jacket	Minimum thickness at any point of jacket
18 – 2 AWG	12 – 2 AWG	45 (1.14)	36 (0.91)
1 – 4/0	1 – 4/0	60 (1.52)	45 (1.14)
250 – 1000 kcmil	250 – 1000 kcmil	80 (2.03)	60 (1.52)
1100 – 2000	1100 – 2000	110 (2.79)	85 (2.16)

7.2.5 For 1000 and 2000 V rated constructions, the minimum average thickness of the insulation noted in Table 7.3 – Table 7.5 shall be increased by the amount shown in Table 7.8. For a composite insulation, the inner layer shall be the layer that is increased.

Table 7.8
Increase in thicknesses of non-composite insulation and the inner layer of a composite insulation for 1000 and 2000 V constructions

Size(s) of conductor		mils (mm)	
Copper	Aluminum or copper-clad aluminum	Minimum average thickness of insulation	Minimum thickness at any point of insulation
18 – 10 AWG	12 – 10 AWG	15 (0.38)	14 (0.36)
8 AWG – 1000 kcmil	8 AWG – 1000 kcmil	10 (0.25)	9 (0.23)
1100 – 2000	1100 – 2000	15 (0.38)	14 (0.36)

8 Assemblies

8.1 Assemblies that include single conductors

8.1.1 When cabled into assemblies (length and direction of lay not specified), single-conductor wires that comply with the requirements in this Standard shall not be considered cables, and do not include overall coverings. An open, skeleton tape or wrap intended only to hold the assembly together shall be allowed. Such assemblies shall be allowed to include other single-conductor wires or cables not covered in this Standard. An assembly shall be without a bare or covered aluminum conductor, but a bare copper conductor – size is not specified – that is coated with tin, a lead-base alloy, or other metal shall be optional. A bare, coated copper conductor shall not be covered. The completed assembly shall meet the following requirements:

a) Assemblies in which a bare, coated copper conductor is included shall be tested for Dielectric voltage-withstand in water in the Standard for Thermoset-Insulated Wires and Cables, UL 44, except that immersion in water shall be for at least 1 hour.

b) Each assembly in which a bare conductor is not included shall either be tested as indicated in the Dielectric voltage-withstand in water (1 hour or longer immersion) in UL 44 or be spark tested as indicated in the A-C spark test in UL 44, with each layer in a multiple-layer assembly sparked separately.

c) Each 2.08 – 8.37 mm^2 (14 AWG – 8 AWG) conductor in an assembly shall be individually tested for continuity in accordance with the Electrical continuity test in UL 44 after the assembly is completed.

PERFORMANCE

9 Details

9.1 90°C rated wire – For thermoplastic materials – all tests required for Type THW-2 in accordance with the Standard for Thermoplastic-Insulated Wires and Cables, UL 83. For thermoset materials – all tests required for Type RHW-2 single-conductor construction per the Standard for Thermoset-Insulated Wires and Cables, UL 44. In addition, the following requirements apply. Note that test requirements for 18 and 16 AWG sizes are the same as those for a 14 AWG wire.

a) The FV-1/Vertical flame test in the Standard for Wire and Cable Test Methods, UL 2556.

b) The Physical properties – Weather (sunlight) resistance in UL 2556. The sample shall retain a minimum of 80 percent of their initial tensile strength and elongation after being subjected to 720 hours of exposure.

c) The FV-2/VW-1 test (optional) in UL 2556. To be marked "VW-1" the wire must also comply with the Horizontal-Specimen flame test in UL 2556.