

**August 23, 2007**

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**SUBJECT 4703**

**OUTLINE OF INVESTIGATION**

**FOR**

**PHOTOVOLTAIC WIRE**

**Issue Number: 2**

**August 23, 2007**

***Summary of Topics***

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## INTRODUCTION

### 1 Scope

1.1 This Outline 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 Wiring Systems, Article 690, and other applicable parts of the National Electrical Code (NEC), NFPA 70.

## CONSTRUCTION

### 2 General

2.1 In addition to being stated in the inch/pound units that are customary in the USA, each of the requirements in this outline is also stated in units that make the requirement conveniently useable 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 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.

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

2.4 The wire shall consist of a single, insulated, stranded copper conductor, size 18 – 4/0 AWG, complying with the construction and materials requirements for single-conductor Type UF cable in the Standard for Thermoplastic-Insulated Underground Feeder and Branch-Circuit Cables, UL 493, or for Type USE-2 cable in the Standard for Service-Entrance Cables, UL 854, with the exceptions noted in 3.1 and 4.1, respectively. There are additional requirements for cables rated greater than 90°C. See 7.2.

### 3 Wire Similar to Type UF (90°C Dry and Wet, 600 Volts)

3.1 The thickness of the integral insulation / jacket shall be increased by 15 mils. The insulation / jacket on conductors sized 18 or 16 AWG shall meet the same thickness requirements as for 14 AWG. The size and construction of the 18 and 16 AWG stranded copper conductors shall comply with the requirements for Conductors in the Standard for Fixture Wire, UL 66. The insulation shall be rated for 90°C wet and dry.

3.2 Metric conductors in accordance with Conductors of insulated cables, IEC 60228, Class 5 may be used instead of AWG sized conductors described in Standard for Thermoplastic-Insulated Underground Feeder and Branch-Circuit Cables, UL 493 and Standard for Fixture Wire, UL 66. The size of the conductors shall be between 0.825 and 107 mm<sup>2</sup>. The next largest AWG size shall be used to determine the insulation and/or jacket thickness.

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#### 4 Wire Similar to Type USE-2 (90, 105, 125, or 150°C Dry and Wet, 600, 1000, or 2000 Volts)

4.1 For 600 volt rated constructions with insulations that do not require a jacket (see the Table for Acceptable Constructions of Single-Conductor Type USE-2 Cable in the Standard for Service-Entrance Cables, UL 854), the thickness of the insulation shall be increased by 15 mils or a jacket with a thickness of 30 mils shall be employed. For constructions that require a jacket as described in the Table for Acceptable Constructions of Single-Conductor Type USE-2 Cable in UL 854, the thickness of the jacket shall be increased by 15 mils. For constructions employing a composite insulation, the thickness of the outer insulation layer shall be increased by 15 mils. Also:

- a) Thermoplastic jackets may be employed.
- b) The insulation and jacket (if present) on conductors sized 18 – 16 AWG shall meet the same thickness requirements as for 14 AWG.
- c) The size and construction of the 18 and 16 AWG stranded copper conductors shall comply with the requirements for Conductors in the Standard for Fixture Wire, UL 66.

4.2 For 1000 and 2000 volt rated constructions, the thickness of the insulation determined in 4.1 shall be increased by 15 mils (14 – 10 AWG) and by 10 mils (9 – 1/0 AWG).

4.3 Metric conductors in accordance with Conductors of insulated cables, IEC 60228, Class 5, may be used instead of AWG sized conductors described in the Standard for Service-Entrance Cables, UL 854 and the Standard for Fixture Wire, UL 66. The size of the conductors shall be between 0.825 and 1013 mm<sup>2</sup>. The next largest AWG size shall be used to determine the insulation and/or jacket thickness.

#### MARKINGS

##### 5 On the Wire

5.1 A durable surface marking shall include the following:

- a) Identification of the organization responsible for the product. When the organization responsible for the product operates more than one manufacturing location, a distinctive identification for each location shall be provided.
- b) "PV Wire or Photovoltaic Wire".
- c) Size of conductor in AWG or mm<sup>2</sup>.
- d) Dry and wet temperature ratings.
- e) Voltage rating.
- f) "Sunlight Resistant" or "Sun Res".
- g) "-40C".

Additional markings may be surfaced marked as long as they are not confusing or misleading. The current carrying capacity shall not be marked on the wire.

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## 6 On the Tag, Reel, or Carton

6.1 The tag markings shall include the surface markings required in 5.1. In addition, the following information is required:

- a) Date of manufacture by month and year.
- b) "Photovoltaic module interconnection wire for use with or without a raceway in accordance with Wiring Systems, Article 690 in the National Electrical Code (NEC), NFPA 70" or equivalent.
- c) Nominal outside diameter.

Additional markings may be printed on the tag as long as they are not confusing or misleading. The current carrying capacity shall not be marked on the tag.

## TEST PROGRAM

### 7 Details

7.1 90°C rated cable – All tests for Type USE-2 single-conductor construction per the Standard for Service-Entrance Cables, UL 854 with the exception of the overload, crushing, and impact tests or per Type UF in accordance with the Standard for Thermoplastic-Insulated Underground Feeder and Branch-Circuit Cables, UL 493, as applicable. In addition, the following requirements apply:

- a) The Vertical Flame and FT 1 Tests in the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581.
- b) The Carbon-Arc and Xenon-Arc Tests in UL 1581.
- c) The VW-1 (Vertical-Specimen) Flame Test (optional) in UL 1581.
- d) The Flexibility at Low Temperature Test in UL 1581, except at –40°C.
- e) Physical Properties (conductors similar to Type UF, PVC only) – same as for Type THW-2 per the Standard for Thermoplastic-Insulated Wires and Cables, UL 83.
- f) The Long-Term Insulation Resistance Test in water (conductors similar to Type UF, PVC only) – same as for Type THW-2 per UL 83.
- g) Physical Properties of thermoplastic jacket over thermoset insulation (construction similar to Type USE-2) in Specific Materials in UL 1581, rated minimum 90°C.
- h) Durability of Indelible-Ink Printing in UL 1581.

7.2 Cable rated 105 to 150°C – In addition to the requirements specified in clause 7.1, the following requirements apply:

- a) Physical Properties – Unaged and oven aged specimens of insulation and jacket shall be in accordance with any of the materials described in Specific Materials in the Reference Standard for Electrical Wires, Cables, and Flexible Cords, UL 1581. For materials with a temperature rating other than that specified in the tables, or for those materials not described in Specific Materials in UL 1581, the requirements in Long-Term Aging, in UL 1581 shall be applied.

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b) Long-Term Insulation Resistance Test – In air, same as for Type RHH per the Standard for Thermoset-Insulated Wires and Cables, UL 44, except that the oven temperature shall be 113°C for 105°C rated cable, 133°C for cable rated 125°C, and 158°C for cable rated 150°C. Cables rated 1000 volts are required to comply with the insulation resistance values of cable rated 2000 volts.

c) Constructions which employ insulation and/or jacket materials not referenced in UL 854 for use on Type USE-2 shall be part of an additional investigation. The investigation of the electrical, mechanical, and physical characteristics of the cable using these material(s) shall show the material(s) to be comparable in performance to the insulation or jacket materials used on Type USE-2 cable. The investigation shall include tests such as crushing, impact, abrasion, deformation, heat shock, insulation resistance and dielectric voltage-withstand.

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