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# Standard Guide for Fire Prevention for Photovoltaic Panels, Modules, and Systems[1]

This standard is issued under the fixed designation E2908; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This guide describes basic principles of photovoltaic module design, panel assembly, and system installation to reduce the risk of fire originating from the photovoltaic source circuit.

1.2 This guide is not intended to cover all scenarios which could lead to fire. It is intended to provide an assembly of generally-accepted practices.

1.3 This guide is intended for systems which contain photovoltaic modules and panels as dc source circuits, although the recommended practices may also apply to systems utilizing ac modules.

1.4 This guide does not cover fire suppression in the event of a fire involving a photovoltaic module or system.

1.5 This guide does not cover fire emanating from other sources.

1.6 This guide does not cover mechanical, structural, electrical, or other considerations key to photovoltaic module and system design and installation.

1.7 This guide does not cover disposal of modules damaged by a fire, or other material hazards related to such modules.

1.8 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.9 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

E772 Terminology of Solar Energy Conversion

E2481 Test Method for Hot Spot Protection Testing of Photovoltaic Modules

2.2 *Other Standards and Documents:*

IEC 61215 Crystalline silicon terrestrial photovoltaic (PV) modules—Design qualification and type approval

IEC 61730 Photovoltaic (PV) module safety qualification

North American Board of Certified Energy Practitioners (NABCEP), Study Guide for Photovoltaic System Installers

NFPA 70 US National Electrical Code (article 690)

UL 1703 Standard for Flat-Plate Photovoltaic Modules and Panels

UL 1741 Inverters, Converters, and Controllers for Use in Independent Power Systems

## 3. Terminology

3.1 Definitions of terms used in this standard may be found in Terminology E772.

3.2 *Definitions:*

3.2.1 *ground fault, n*—a condition where there is an unintended electrical connection between the active PV circuit and ground.

## 4. Summary of Practice

4.1 Photovoltaic modules and panels should be designed to minimize the risk of fire and should be assembled with good quality-control practices.

[1] This test method is under the jurisdiction of ASTM Committee E44 on Solar, Geothermal and Other Alternative Energy Sources and is the direct responsibility of Subcommittee E44.09 on Photovoltaic Electric Power Conversion.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

4.2 Photovoltaic systems should be designed to minimize the risk of fire, and installed with fire safety in mind. Installers should be aware of PV-related fires that have occurred and the cause of those fires.

## 5. Significance and Use

5.1 Photovoltaic modules are electrical dc sources. dc sources have unique considerations with regards to arc formation and interruption, as once formed, the arc is not automatically interrupted by an alternating current. Solar modules are energized whenever modules in the string are illuminated by sunlight, or during fault conditions.

5.2 With the rapid increase in the number of photovoltaic system installations, this guide attempts to increase awareness of methods to reduce the risk of fire from photovoltaic systems.

5.3 This guide is intended for use by module manufacturers, panel assemblers, system designers, installers, and specifiers.

5.4 This guide may be used to specify minimum requirements. It is not intended to capture all conditions or scenarios which could result in a fire.

## 6. Arcing

6.1 *dc Arcing:*

6.1.1 An electrical arc can form where an electric potential exists between two neighboring conductors. Unlike ac arcs which may be extinguished during the alternating-cycle of current, a dc arc will be maintained indefinitely until interrupted. A dc arc will be sustained until the voltage potential is reduced, an arc-detection device disrupts the flow of current, or the effective distance between the conductors becomes too large to sustain the arc. Even once the arc is eliminated, the arc may have been sufficient to cause burning or ignition of surrounding materials.

6.1.2 An arc may propagate across the surface of the module (for example, along the gap between rows of cells) as materials are burned away.

6.1.3 The arc may extinguish and re-ignite under variable environmental conditions or with expansion and contraction of affected materials, and may also extinguish at night and restart the next day.

6.1.4 Common sources of arcs in PV modules:

6.1.4.1 Cracks in solar cells (crystalline or thin film).

6.1.4.2 Inadequate spacing between parts of different voltage potentials.

6.1.4.3 Improper bonding of interconnects to cells.

6.1.4.4 Improper bonding of interconnects to bus bar.

6.1.4.5 Improper bonding of bus bar to wiring terminal or connector.

6.1.4.6 Insufficient allowance for thermal expansion and contraction of materials, which leads to mechanical fatigue. Common examples include cell interconnects and expansion joints in conduits.

6.1.4.7 Insufficient strain relief between parts; especially field wiring terminations, solder joints, and internal conductors.

6.2 *ac Arcing:*

6.2.1 Both ac and dc circuits may be present in a solar photovoltaic system, and both circuits contain potential arc sources. A dc arc may be sustained over a larger distance and longer duration than an ac arc due to the one-directional flow of the dc current, which is not easily interrupted. The current in an ac arc always goes to zero twice per cycle.

## 7. PV Modules and Panels

7.1 *Design Against Arcing*—Modules shall be designed to reduce the risk of arcing.

7.1.1 Modules shall meet the spacing requirements of IEC 61730 or UL 1703 to reduce the occurrence of arcing under both normal operating conditions and fault conditions.

7.1.2 Materials and processes used in the manufacture of PV modules shall be designed to be durable and reliable over the entire service life of the PV module.

7.1.3 Failure mechanisms, such as mismatch of thermal expansion coefficients, metal fatigue, corrosion or vibration, shall be considered during the selection of materials, module lay-out, and assembly.

7.1.4 Material selection shall include consideration of the operating temperatures of the material and aging characteristics of the material.

7.2 *Design for Arc and Fire Suppression:*

7.2.1 Materials in close contact to potential arc sources, such as junction boxes, shall have a minimum arc and flammability rating in accordance with IEC 61730 or UL 1703. This helps to reduce the risk of fire in the event of an arcing event.

7.2.2 According to the 2011 National Electrical Code, an arc-detection device is required to disconnect the current flow in the event of arcing. Depending on the location of the device, it may protect an individual module or an entire string. Consideration shall be given to the reliability of such devices, to avoid nuisance trips and costly servicing.

7.3 *Operating Temperature:*

7.3.1 A PV module converts a portion of the sun's energy into electrical energy. The portion of the sun's energy that is not converted into electrical energy is either reflected, transmitted through the module, or transformed into heat energy. Therefore, a PV module usually operates at a temperature hotter than the surrounding ambient temperature.

7.3.2 *Operating Temperature Considerations*—The exact operating temperature of a module, and of any given component within a module, depends on a variety of factors.

7.3.2.1 *Environmental Factors*—Wind speed, wind direction, ambient temperature, solar irradiance, and cloud cover.

7.3.2.2 *Installation Factors*—Angle of installation, rack type, module spacing, location, wind obstructions, tracking versus non-tracking, ventilation, shading events.

7.3.2.3 *Module Factors*—Cell mismatch (leading to non-uniform heat generation), insulated sections (e.g. junction boxes), color, framing, transparency, material thermal conductivity, thermal convection characteristics, current-carrying limits of live parts.

7.3.3 *Shading*—Shading events can cause shaded cells to act as power sinks (resistors) as opposed to power generators.