Solar Photovoltaic Systems

What is PV?

• Solar Photovoltaic System
• The total components and subsystems that, in combination, convert solar energy into electrical energy suitable for connection to a utilization load.

PV Equipment

- Panels (modules)
- Inverters
- Conductors (cables)
- Combiner boxes
- Charge controllers
- Storage media (batteries)

Basic components of a Solar Photovoltaic System

Different configurations of PV installations
Where is PV Installed?

NEC 690.4 (A) Photovoltaic systems shall be permitted to supply a building or other structure in addition to any other electricity supply system(s).

Residential Rooftops

Commercial Rooftops

Shade Structures

Ground Mounted

Windows
**PV Installation Concerns**

- Utility compatibility and interaction
- Environment (e.g. indoor, rainproof, corrosion resistant)
- Maximum number of modules
- Fire exposure ratings
- Location on roof
- Effect on roof covering
- Wind and snow loading

**Items needed to Inspect PV?**

- Permits
- Plans
- Wiring
- Attachment
- Equipment
Plans (Electrical)

Electrical plan should be submitted that includes the following:
• Locations of main service or utility disconnect.
• Total number of modules, number of modules per string and the total number of strings.
• Make and model of inverter(s) and/or combiner box if used.
• One-line diagram of system.
• Specify grounding/bonding, conductor type and size, conduit type and size and number of conductors in each section of conduit.

Electrical plan should be submitted that includes the following:
• If batteries are to be installed include them in the diagram and show there locations and venting.
• Equipment cut sheets including inverters, modules, AC and DC disconnects and combiners.
• Labeling of equipment as required by Sections 690 and 705.
• Site diagram showing the arrangement of panels on the roof or ground, north arrow, lot dimensions, and the distance from property lines to adjacent buildings/structures (existing and proposed).

Plans (Structural)

Structural plan identifying support information for roof mounted systems including the following:
• The type of roof covering and the number of roofing layers installed.
• Type of roof framing, size of members and spacing.
• Weight of panels, support locations and method of attachment.
• Framing plan and details for any work necessary to strengthen the existing roof structure.
• Any relevant calculations (when required)

Structural plan identifying support information for roof mounted systems including the following:
• Location of PV equipment on the building
• Where an approved racking system is used, provide documentation showing the manufacturer of the rack system, maximum allowable weight the system can support, attachment method to the roof or ground and product evaluation information or structural design for the rack system.

Plans (Code Requirements)

• Site Plan – NEC 80.21 (Annex H), IBC 107.2.5, IRC R106.2
• One-Line Diagram – NEC 215.5
• Attachment Details – NEC 110.3(B), IBC 107.2.1, IRC R106.1.2
• Equipment Specifications – NEC 690.4(D)

Site Plan
Attachment

- The International Building Code (IBC) Sect 106.3 load supports
- Dead loading and wind loading of roof are covered in IBC 1603.1.4, 1603.1.8, 1604.2, 1606.2
Key Inspection Points

- Number of PV modules and PV model numbers match plans
- Array conductors and components are installed in a neat and workman like manner.
- PV array is properly grounded
- Electrical boxes are accessible and connections are suitable for environment
- Array is fastened and sealed according to attachment detail
- Conductors ratings and sizes match plans

Key Inspection Points

- Appropriate signs are properly constructed, installed and displayed, including:
  - Sign identifying PV power source system attributes at dc disconnect
  - Sign identifying ac point of connection.
  - Sign identifying switch for alternative power system.

Key Inspection Points

- Equipment ratings are consistent with application and installed signs on the installation, including:
  - Inverter has a rating as high as max voltage on PV Power Source sign.
  - DC-side OCPD’s are DC rated at least as high as max voltage on sign.
  - Switches and OCPDs are installed according to manufacturers specifications.

Key Inspection Points

Many 600Vdc switches require passing through the switch poles twice in a specific way
Key Inspection Points

• Equipment ratings are consistent with application and installed signs on the installation, including:
  Inverter is rated for the site ac voltage supplied and shown on the ac point of connection sign.
  OCPD connected to the ac output of the inverter is rated at least 125% of maximum current on sign, and is no larger than the maximum OCPD on the Inverter listing label.
  Sum of the main OCPD and the inverter OCPD is rated for not more than 120% of the busbar rating.

NEC Requirements - 690

Definitions:
Array
Building Integrated Photovoltaics
Interactive System
Inverter
Panel
Photovoltaic Output Circuit
Photovoltaic Source Circuit
Stand-Alone System

Building Integrated PV

Integration into the building structure or protective surfaces

Interactive System

Utility Grid
Inverter
Electrical Panel
Utility Meter
Solar Panels
690.3 Other Articles
Where the PV system is operated in parallel with a primary source(s) of electricity, the requirements in 705.14, 705.16, 705.32, and 705.143 shall apply.

690.4(A) Photovoltaic Systems
PV system(s) shall be permitted to supply a building or other structure in addition to any other electricity supply system(s).

690.4(B) Identification & Grouping
PV circuits (dc/ac) shall not be contained in the same raceway, cable tray, cable, outlet box, junction box, or similar fitting as conductors, feeders, or branch circuits of other non-PV systems, unless the conductors of the different systems are separated by a partition.
690.4(B) Identification & Grouping

(1) PV Source Circuits. …shall be identified at all points of termination, connection, and splices.

(2) PV Output and Inverter Circuits. …shall be identified at all points of termination, connection, and splices.

(3) Conductors of Multiple Systems. …of more than one PV system occupy the same … the conductors of each system shall be identified at all termination, connection, and splice points.

(4) Grouping. …of more than one PV system occupy the same junction box or raceway with a removable cover(s), the ac and dc conductors of each system shall be grouped separately by wire ties or similar means at least once, and then shall be grouped at intervals not to exceed 6 ft.

690.4(D) Equipment

Inverters, PV modules, combiners, charge controllers and ... shall be identified and listed for the application.

690.4(E) Wiring and Connections

The equipment and systems in 690.4(A) through (D) and all associated wiring and interconnections shall be installed only by qualified persons.

Article 100 Definition:
Qualified Person. One who has skills and knowledge related to the construction and operation of the electrical equipment and installations and has received safety training to recognize and avoid the hazards involved.

UL University PV Training Program

• The PV System Installer certification program was created to meet and exceed existing industry requirements through a working cooperation with leading PV industry stakeholders.
• PV training is geared towards licensed electricians, aims to satisfy a need to improve the safety and performance of PV systems through a more qualified workforce.
• ULU offers hands-on training that will be closely aligned with the knowledge and skills required for practitioners to perform safely and effectively.
• For more information on UL University and the PV System Installer certification program, visit www.uluniversity.us/certification.

UL Product Categories

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIUR</td>
<td>Circuit Breakers, Molded Case and Circuit-breaker Enclosures for Use in Photovoltaic Systems</td>
</tr>
<tr>
<td>IZMR</td>
<td>Fuseholders, Photovoltaic</td>
</tr>
<tr>
<td>JFGA</td>
<td>Fuses for Photovoltaic System</td>
</tr>
<tr>
<td>JDDZ</td>
<td>Cartridge Fuses, Nonrenewable (Intended for AC circuits only, unless also marked with DC voltage rating)</td>
</tr>
<tr>
<td>QIGU</td>
<td>Photovoltaic Modules &amp; Panels</td>
</tr>
<tr>
<td>QIKA</td>
<td>Photovoltaic Solar Trackers</td>
</tr>
<tr>
<td>QIKH</td>
<td>Photovoltaic Inverters</td>
</tr>
<tr>
<td>QIBP</td>
<td>Photovoltaic Charge Controllers</td>
</tr>
</tbody>
</table>
UL Product Categories

QIIO - Distributed Generation Power Systems Accessory Equipment
QIJL - Distributed Resource Power Systems
QIMS - Photovoltaic Mounting Systems, Mounting Devices, Clamping Devices and Ground Lugs (both mounting systems and clamping devices may be for bonding and/or mechanical loading)
QHYZ - AC Modules
QHZK - Building-integrated Photovoltaic Modules & Panels
QHZS - Distributed Generation Wiring Systems and Harnesses

Basic PV Standards

• UL 1703 - Flat Plate Photovoltaic Modules and Panels
• UL 1741 - Inverters, Converters, Controllers, and Interconnection System Equipment For Use With Distributed Energy Resources
• UL 2703 - Rack Mounting Systems
• UL 4703 - Photovoltaic Wire
• UL 8703 - Concentrator Photovoltaic Modules and Assemblies
• IEC 61730 - Addresses safe electrical and mechanical operation during their expected lifetime, prevention of electrical shock, fire hazards, and personal injury due to mechanical and environmental stresses
• ICC ES AC 365 - Building Integrated Photovoltaic Systems

690.4(F) Circuit Routing

• New requirements were added for visibility and roof marking of certain PV circuits
• Firefighting community has expressed concern about the safety of ventilating roofs where PV circuits are present
• Routing PV circuits along the building structural members will lower probability that the structural members will be compromised by the firefighting process during a fire
• When PV module system circuits are integrated into the roof, PV associated circuits are to be clearly marked on the surface of the roof as a visual aid for firefighters and other maintenance personnel

690.4(H) Multiple Inverters

A PV system shall be permitted to have multiple utility-interactive inverters installed in or on a single building or structure.
**690.4(H) Multiple Inverters**

Where the inverters are remotely located from each other, a directory in accordance with 705.10 shall be installed at each dc PV system disconnecting means, at each ac disconnecting means, and at the main service disconnecting means showing the location of all ac and dc PV system disconnecting means in the building.

---

**690.5 Ground-Fault Protection**

Grounded DC PV arrays shall be provided with DC ground fault protection per 690.5(A) through (C) to reduce fire hazard.

---

**Exception No. 1**

Ground-mounted or pole-mounted photovoltaic arrays with not more than two paralleled source circuits and with all dc source and dc output circuits isolated from buildings shall be permitted without ground-fault protection.

**Exception No. 2**

PV arrays installed at other than dwelling units where the equipment grounding conductors are sized in accordance with 690.45.

---

**690.5(A) Ground-Fault Detection and Interruption**

- Permits automatic opening of the grounded conductor of the faulted circuit
- If the grounded conductor is opened, all conductors of the faulted circuit shall be automatically and simultaneously opened.
- Manual operation of the PV DC disconnect shall not activate the GFP or result in the grounded conductors becoming ungrounded

---

**690.5(B) Isolating Faulted Circuits**

The faulted circuits shall be isolated by one of the two following methods:

1. The ungrounded conductors of the faulted circuit shall be automatically disconnected.
2. The inverter or charge controller fed by the faulted circuit shall automatically cease to supply power to output circuits.

---

**690.5 (C) Labels and Markings**

...shall appear on the utility-interactive inverter or be applied by the installer near the ground-fault indicator at a visible location, stating the following:

**WARNING**

Electric Shock Hazard

If a ground fault is indicated, normally grounded conductors may be ungrounded and energized
UL 1741 Overcurrent Protection

31.1 Inverters or charge controllers with direct photovoltaic inputs from a grounded photovoltaic array or arrays shall be provided with a ground-fault detector/interrupter (GFDI).

Exception No. 1: AC modules are not required to be provided with a GFDI.

Exception No. 2: Inverters or charge controllers without GFDI devices may be used when the unit includes the following markings.

UL 1741 Marking

The manual shall include the word:

"WARNING"

“This unit is not provided with a GFDI device. This inverter or charge controller must be used with an external GFDI device as required by the Article 690 of the National Electrical Code for the installation location.”

690.5(A) Ground-Fault Detection and Interruption.

- Ground Fault Detection & Interruption permits automatic opening of the grounded conductor of the faulted circuit
- If the grounded conductor is opened, all conductors of the faulted circuit shall be automatically and simultaneously opened.
- Manual operation of the PV DC disconnect shall not activate the GFP or result in the grounded conductors becoming ungrounded

UL 1741 Marking

31.10 An integral ground-fault detector/interrupter (GFDI) or a photovoltaic inverter intended for operation with a separate GFDI shall be marked in accordance with 64.15.

64.15 …, units with integral ground-fault detector/interrupter or separate devices having the same function shall be marked with the word “CAUTION” and the following or equivalent: “Risk of Electric Shock. Normally Grounded Conductors May Be Ungrounded and Energized When a Ground-Fault is Indicated.” If the separate device is not self-contained and is intended for installation in another enclosure, the device shall be provided with a label for fixing to the outside of the enclosure to indicate the caution statement.

690.6 Alternating-Current (ac) Modules

690.2 Alternating-Current (ac) Module (Alternating-Current Photovoltaic Module). A complete, environmentally protected unit consisting of solar cells, optics, inverter, and other components, exclusive of tracker, designed to generate ac power when exposed to sunlight.

Commentary
An ac PV module consists of a single integrated mechanical unit. Because there is no accessible, field-installed dc wiring in this single unit, the dc PV source-circuit requirements in this Code are not applicable to the dc wiring in an ac PV module.

690.6 Alternating-Current (ac) Modules

Micro-Inverter
PV Module
AC Module
**UL Category QHYZ AC Modules**

**USE AND INSTALLATION**

An AC module consists of a PV module and an integral static inverter that changes dc power to ac power. These modules are rated up to 600 V dc input; 10 kW, 120/240 V ac or less, single-phase output. AC modules are marked with the maximum size of dedicated branch circuit on which they may be installed and the maximum number of modules which may be connected in parallel.

**UL MARK**

The Listing Mark of UL on the product is the only method provided by UL to identify products manufactured under its Listing and Follow-Up Service. The Listing Mark for these products includes the UL symbol together with the word "LISTED," a control number, and the product name "Utility Interactive AC Module" or "Utility Interactive Inverter Module."

**Table 690.7 Voltage Correction Factors for Crystalline and Multicrystalline Silicon Modules (Partial)**

<table>
<thead>
<tr>
<th>Ambient Temperature (°C)</th>
<th>Factor</th>
<th>Ambient Temperature (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 to 20</td>
<td>1.02</td>
<td>76 to 68</td>
</tr>
<tr>
<td>19 to 15</td>
<td>1.04</td>
<td>67 to 59</td>
</tr>
<tr>
<td>14 to 10</td>
<td>1.06</td>
<td>58 to 50</td>
</tr>
<tr>
<td>9 to 5</td>
<td>1.08</td>
<td>49 to 41</td>
</tr>
<tr>
<td>4 to 0</td>
<td>1.10</td>
<td>40 to 32</td>
</tr>
<tr>
<td>-1 to -5</td>
<td>1.12</td>
<td>31 to 23</td>
</tr>
<tr>
<td>-6 to -10</td>
<td>1.14</td>
<td>22 to 14</td>
</tr>
<tr>
<td>-11 to -15</td>
<td>1.16</td>
<td>13 to 5</td>
</tr>
</tbody>
</table>

When open-circuit voltage temperature coefficients are supplied in the instructions for listed PV modules, they shall be used to calculate the maximum photovoltaic system voltage as required by 110.3(B) instead of using Table 690.7.

**690.7 Maximum Voltage**

- One- and Two-Family dwellings maximum is 600 volts.
- Other occupancies is unlimited.
690.8(A) Circuit Sizing

DC: The maximum current shall be the sum of parallel module rated short-circuit currents multiplied by 125 percent.

\[ 8.59 \times 1.25 = 10.7375 \text{ A maximum current} \]

Reason: PV output circuits can deliver output currents higher than the rated short-circuit currents for more than 3 hours near solar noon.

690.8(A)(3) Circuit Sizing

AC: The maximum current shall be the inverter continuous output current rating.

\[ 86 \]

690.8(B)(1) Ampacity

The circuit conductors and overcurrent devices shall be sized to carry not less than 125 percent of the maximum currents as calculated in 690.8(A).

690.8(A) Maximum Circuit Current

\[ 8.59 \times 1.25 = 10.7375 \text{ A maximum current} \]

690.8(B)(1) Conductor & OOCD Size

\[ 10.7375 \text{ Amps} \times 125\% = 13.42 \text{ Amps} \]

Informational Note 690.8(A)

Clarifies that when both 690.8(A) and 690.8(B) are applied, the 125% for calculation of maximum circuit current and the 125% for sizing of conductors and overcurrent devices, the resulting multiplication factor is 156%!!!!!!

690.8 Circuit Sizing and Current

Where a single overcurrent device is used to protect a set of two or more parallel-connected module circuits, the ampacity of each of the module interconnection conductors shall not be less than the sum of the rating of the single fuse plus 125 percent of the short-circuit current from the other parallel-connected modules.

690.9

OCPD for PV Array

When modules are shaded, back feeding is possible from other parallel strings
- Result – overheating of modules and wiring
Key – proper rated fuse, not exceeding modules’ max. fuse rating

WARNING
690.9 Overcurrent Protection

(C) Photovoltaic Source Circuits. Branch-circuit or supplementary-type OCPD’s shall be permitted to provide overcurrent protection in PV source circuits. OCPD’s allowed by this section shall be in one ampere size increments, starting at one ampere up to and including 15 amperes. Above 15 amperes ... shall be based on the standard sizes provided in 240.8(A).

690.9(D) Direct-Current Rating

Overcurrent devices, either fuses or circuit breakers, used in any DC portion of a PV power system shall be listed for use in DC circuits.

UL Category DIUR

• This category covers circuit breakers and circuit-breaker enclosures intended to provide overcurrent protection and disconnecting means in DC PV systems in accordance with Article 690 of the NEC.
• PV circuit breakers are rated up to 1000 V DC maximum and, unless otherwise marked, are not intended to be loaded to exceed 80% of the current rating.
• PV circuit breakers are intended for use in ambient temperatures between -20 and 50° C.

UL Category DIVQ

• 2-pole independent trip breakers and single-pole breakers with handle ties, rated 125/250 V DC, are suitable for use in line-to-line connected 3-wire DC circuits supplied from a system with a grounded neutral where the voltage to ground does not exceed 125 V.
• Multi-pole common trip circuit breakers rated 125/250 V or 125/250 V DC are suitable for use in a single-phase and a DC multi-wire circuit, with or without the neutral connected to the load, where the voltage to ground does not exceed 125 V.
• Listed circuit breakers are rated 600 V or less. A circuit breaker is marked AC or DC, or both AC and DC. A symbol (-), where used, represents AC.
UL Category JFGA

- ... are intended for use in PV systems. The voltage rating may be up to 1500 V DC (AC ratings are optional).
- ... are not intended to protect downstream inverter components, such as capacitors or the discharge of such capacitors back into the arrays or the array wiring. Such protection must be achieved by providing suitable separate capacitor fuses designed, intended and rated for that purpose.
- Fuses for PV systems are nonrenewable, are not current-limiting, and have a minimum interrupting rating of 10 kA. Time-delay ratings are optional.

UL Category JDDZ

These fuses are intended for use on AC circuits only, unless also marked with a DC voltage rating.

These fuses are suitable for branch circuit, feeder and service overcurrent protection in accordance with the NEC.

690.10 Stand-Alone Systems

(E) Back-fed Circuit Breakers. Plug-in type back-fed circuit breakers connected to a stand-alone inverter output in either stand-alone or utility-interactive systems shall be secured in accordance with 408.36(D).

690.10(E) Back-fed Circuit Breakers

Circuit breakers that are marked “line” and “load” shall not be backfed.

UL Category DIVQ

Line and load markings on a circuit breaker are intended to limit connections thereto as marked.

690.11 Arc-Fault Circuit Protection (Direct Current)

... dc source circuits, dc output circuits, or both, on or penetrating a building operating at a PV system maximum system voltage of 80 volts or greater, shall be protected by a listed (dc) AFCI, PV type, or other system components listed to provide equivalent protection. The PV arc-fault protection means shall comply with the following requirements:
690.11 continued...

1. **shall detect** and interrupt arcing faults resulting from a failure in the intended continuity of a conductor, connection, module, or other system component in the dc PV source and output circuits.

2. **shall disable or disconnect** one of the following:
   a. Inverters or charge controllers connected to the fault circuit when the fault is detected
   b. System components within the arcing circuit

3. **shall require** that the disabled or disconnected equipment be manually restarted.

4. **shall have** an annunciator that provides a visual indication that the circuit interrupter has operated. This indication shall not reset automatically.

**690.11 Arc-Fault Circuit Protection (Direct Current)**

Means shall be provided to disconnect all current-carrying dc conductors of a PV system from all other conductors in a building or other structure. A switch, circuit breaker, or other device shall not be installed in a grounded conductor if operation of that switch, circuit breaker, or other device leaves the marked, grounded conductor in an ungrounded and energized state.

**UL Category QIDC**

- Intended to mitigate the effects of arcing faults that may pose a risk of fire ignition under certain conditions if the arcing persists
- Intended for use in circuits rated 1000 V or less
- Intended for use in dc electrical systems that are supplied by a PV source
- Investigated to determine their ability to recognize and react to arcing faults
- Investigated to determine resistance to unwanted tripping

**690.13 All Conductors**

**Exception No. 1:** A switch or circuit breaker that is part of a ground-fault detection system required by 690.5, or that is part of an arc-fault detection/interruption system required by 690.11, shall be permitted to open the grounded conductor when that switch or circuit breaker is automatically opened as a normal function of the device in responding to ground faults.

**Exception No. 2:** A disconnecting switch shall be permitted in a grounded conductor if all of the following conditions are met:

1. The switch is used only for PV array maintenance.
2. The switch is accessible only by qualified persons.
3. The switch is rated for the maximum dc voltage and current that could be present during any operation, including ground-fault conditions.
690.14(C) Disconnecting Means
1. ...readily accessible location ... outside of a building or structure or inside nearest the point of entrance

690.14(C) Disconnecting Means
2. Each PV system disconnect shall be permanently marked to identify it as a PV system disconnect

690.14(C) Disconnecting Means
3. Each PV system disconnect shall be suitable for the prevailing conditions

690.14(C) Disconnecting Means
4. PV disconnects shall consist of not more than six switches or six circuit breakers mounted in a single enclosure, in a group of separate enclosures, or in or on a switchboard.

690.14(C) Disconnecting Means
5. PV disconnects shall be grouped with other disconnecting means for the system. PV disconnects shall not be required at the PV module or array location.

690.14(D) Utility-Interactive Inverters Mounted in Not-Readily-Accessible Locations
Utility-interactive inverters shall be permitted to be mounted on roofs or other exterior areas that are not readily accessible. These installations shall comply with (1) through (4):
Compliance with 110.26?

690.14(D)
Utility-Interactive Inverters

(1) A direct-current photovoltaic disconnecting means shall be mounted within sight of or in the inverter.

(2) An alternating-current disconnecting means shall be mounted within sight of or in the inverter.

690.14(D)
Utility-Interactive Inverters

(3) The ac output conductors from the inverter and an additional ac disconnect for the inverter shall comply with 690.14(C)(1).

690.14(D)
Utility-Interactive Inverters

(4) A plaque shall be installed in accordance with 705.10.

UL Category QIKH

- Some inverters need to be installed and operated with external transformer
- Some inverters need external output overcurrent protection
  - 125% of product output current rating unless specified in markings
- Refer to manufactures installation instructions
- Model ratings posted in UL’s online certifications directory

690.15
Disconnection of PV Equipment

Means shall be provided to disconnect equipment, such as inverters, batteries, charge controllers, and the like, from all ungrounded conductors of all sources.

If the equipment is energized from more than one source, the disconnecting means shall be grouped and identified.
690.15 Disconnection of PV Equipment

690.16(B) Fuse Servicing
A disconnecting means shall be installed on PV output circuits where fuses must be serviced that cannot be isolated from energized circuits.

The disconnecting means shall be within sight of, and accessible to, the location of the fuse or integral with fuse holder and shall comply with 690.17.

Where the disconnecting means are located more than 6 ft. from the overcurrent device, a directory showing the location of each disconnect shall be installed at the overcurrent device location.

Non-load-break-rated disconnecting means shall be marked “Do not open under load.”

690.16(B) Fuse Servicing

690.17 Switch or Circuit Breaker
The disconnecting means for ungrounded conductors shall consist of a manually operable switch(es) or circuit breaker(s) complying with all of the following requirements:

(1) Located where readily accessible
(2) Externally operable without exposing the operator to contact with live parts
(3) Plainly indicating whether in the open or closed position
(4) Having an interrupting rating sufficient for the nominal circuit voltage and the current that is available at the line terminals of the equipment

WARNING ELECTRIC SHOCK HAZARD. DO NOT TOUCH TERMINALS. TERMINALS ON BOTH THE LINE AND LOAD SIDES MAY BE ENERGIZED IN THE OPEN POSITION.

690.17 Switch or Circuit Breaker

Exception: A connector shall be permitted to be used as an ac or a dc disconnecting means, provided that it complies with the requirements of 690.33 and is listed and identified for the use.
690.17
Switch or Circuit Breaker
Listed and identified for the use.
The Recognized Component Mark does not provide evidence of listing or labeling, which may be required by installation codes or standards.

690.31(A)
Wiring Systems
All raceway and cable wiring methods included in this Code and other wiring systems and fittings specifically intended and identified for use on PV arrays shall be permitted.

Informational Note: PV modules operate at elevated temperatures when exposed to high ambient temperatures and bright sunlight.

690.31(B)
Single-Conductor Cable
Single-conductor cable type USE-2 and single-conductor cable listed and labeled as PV wire shall be permitted in exposed outdoor locations in PV source circuits for PV module interconnections within the PV array.

UL Category QHZS
Distributed Generation Wiring Systems and Harnesses

USE AND INSTALLATION
This category covers distributed generation wiring systems and harnesses intended for use with specific distributed generation equipment/devices such as photovoltaic modules, inverters, solar trackers, etc., as identified in the individual Listings.
The installation of these distributed generation wiring harnesses is intended to be in accordance with the NEC and any applicable building codes.

UL Category QHZS
Distributed Generation Wiring Harness

690.31(B)
Single-Conductor Cable

UL MARK
The Listing Mark will have one of the following product identities: "Distributed Generation Wiring Harness" (or "DG Wiring Harness"), "Distributed Generation Wiring System" (or "DG Wiring System"), "Photovoltaic Wiring Harness" (or "PV Wiring Harness") or "Photovoltaic Wiring System" (or "PV Wiring System").
690.31(E) Direct-Current Photovoltaic Source and Output Circuits Inside a Building

Where dc PV source or output circuits from a building-integrated or other PV system are run inside a building or structure, they shall be contained in metal raceways, Type MC metal-clad cable that complies with 250.118(10), or metal enclosures from the point of penetration of the surface of the building or structure to the first readily accessible disconnecting means.

690.31(E)(1) Beneath Roofs

Wiring methods shall not be installed within 10 in. of the roof decking or sheathing except where directly below the roof surface covered by PV modules and associated equipment. Circuits shall be run perpendicular to the roof penetration point to supports a minimum of 10 in. below the roof decking.

690.31(E)(2) Flexible Wiring Methods

FMC smaller than trade size 3/4 or Type MC cable smaller than 1 in. in diameter containing PV power circuit conductors is installed across ceilings or floor joists, the raceway or cable shall be protected by substantial guard strips that are at least as high as the raceway or cable. Where run exposed, other than within 6 ft. of their connection to equipment, these wiring methods shall closely follow the building surface or be protected from physical damage by an approved means.

690.31(E)(3) Marking or Labeling Required

The following wiring methods and enclosures that contain PV power source conductors shall be marked with the wording “Photovoltaic Power Source” by means of permanently affixed labels or other approved permanent marking:

(1) Exposed raceways, cable trays, and other wiring methods
(2) Covers or enclosures of pull boxes and junction boxes
(3) Conduit bodies in which any of the available conduit openings are unused
690.31(E)(4)
Marking and Labeling

The labels or markings shall be visible after installation. PV power circuit labels shall appear on every section of the wiring system that is separated by enclosures, walls, partitions, ceilings, or floors. Spacing between labels or markings, or between a label and a marking, shall not be more than 10 ft. Labels required by this section shall be suitable for the environment where they are installed.

690.31(F)
Flexible, Fine-Stranded Cables

Flexible, fine-stranded cables shall be terminated only with terminals, lugs, devices, or connectors in accordance with 110.14(A).

UL Category ZMVV

Stranded conductor Class — Connectors rated for use with stranded conductors are for the following strand configurations:
- Aluminum – Class B concentric, compressed, or compact, and SIW (single input wire)
- Copper-clad aluminum – Class B concentric or compressed, and Class C concentric
- Copper – Class B concentric or compressed, and Class C concentric

Wire connectors additionally rated for use with compact copper conductors are additionally marked “For compact-stranded copper conductors” or equivalent on the connector, or on or within the unit container.

Wire connectors additionally rated for use with other Class conductors, such as Class M, are marked with the additional class designation and number of strands on the connector, or on or within the unit container.

690.33 Connectors

The connectors permitted by Article 690 shall comply with 690.33(A) through (E).

(A) Configuration. The connectors shall be polarized and shall have a configuration that is noninterchangeable with receptacles in other electrical systems on the premises.

(B) Guarding. The connectors shall be constructed and installed so as to guard against inadvertent contact with live parts by persons.
690.33 Connectors
The connectors permitted by Article 690 shall comply with 690.33(A) through (E).

(C) Type. The connectors shall be of the latching or locking type. Connectors that are readily accessible and that are used in circuits operating at over 30 volts, nominal, maximum system voltage for dc circuits, or 30 volts for ac circuits, shall require a tool for opening.

(D) Grounding Member. The grounding member shall be the first to make and the last to break contact with the mating connector.

690.33 Connectors
The connectors permitted by Article 690 shall comply with 690.33(A) through (E).

(E) Interruption of Circuit. Connectors shall be either (1) or (2):
(1) Be rated for interrupting current without hazard to the operator.
(2) Be a type that requires the use of a tool to open and marked “Do Not Disconnect Under Load” or “Not for Current Interrupting.”

UL Category QIJQ2 Recognized Component
• ... must be part of the UL Listed PV module rather than for direct separate installation in the field.
• ... suitable for the termination of single, insulated, stranded copper USE-2 or PV wire.
• ... are intended to be used for interconnection of PV modules and panels.
• PV connectors are marked with:
  1. The manufacturer's name or trademark
  2. The current rating
  3. The voltage rating
  4. The statement “Do Not Disconnect Under Load”

UL Category QIJQ2 Recognized Component
• ... may consist of in-line connectors, panel-mounted connectors, distribution blocks and splitter connectors for the purpose of facilitating connections up to and including inverters, combiner boxes, and like devices in a PV system. They are not intended to be used on the output side of inverters and combiner boxes or to downstream system components from such devices.
690.35 Ungrounded Photovoltaic Power Systems

...shall be permitted to operate with ungrounded PV source and output circuits where the system complies with 690.35(A) through (G).

690.35 Ungrounded Photovoltaic Power Systems

(A) Disconnects. All photovoltaic source and output circuit conductors shall have disconnects complying with 690, Part III.

(B) Overcurrent Protection. All photovoltaic source and output circuit conductors shall have overcurrent protection complying with 690.9.

690.35 Ungrounded Photovoltaic Power Systems

(C) Ground-Fault Protection. All PV source and output circuits shall be provided with a ground-fault protection device or system that complies with (1) through (3):

1. Detects a ground fault.
2. Indicates that a ground fault has occurred
3. Automatically disconnects all conductors or causes the inverter or charge controller connected to the faulted circuit to automatically cease supplying power to output circuits.

690.35 Ungrounded Photovoltaic Power Systems

(D) The photovoltaic source conductors shall consist of the following:

1. Nonmetallic jacketed multiconductor cables
2. Conductors installed in raceways, or
3. Conductors listed and identified as Photovoltaic (PV) Wire installed as exposed, single conductors.

690.35 Ungrounded Photovoltaic Power Systems

(F) The PV power source shall be labeled with the following warning at each junction box, combiner box, disconnect, and device where energized, ungrounded circuits may be exposed during service:

WARNING
ELECTRIC SHOCK HAZARD.
THE DC CONDUCTORS OF THIS PHOTOVOLTAIC SYSTEM ARE UNGROUNDED AND MAY BE ENERGIZED. 

690.35 Ungrounded Photovoltaic Power Systems

...shall be permitted to operate with ungrounded PV source and output circuits where the system complies with 690.35(A) through (G).
690.42 Point of System Grounding Connection

The DC circuit grounding connection shall be made at any single point on the photovoltaic output circuit.

690.43 Equipment Grounding

The equipment grounding requirements for PV systems have been rearranged and revised for clarity and usability. Exposed non-current-carrying metal parts of module frames, equipment, and conductor enclosures shall be grounded in accordance with 250.134 or 250.136(A) regardless of voltage.

690.43 Equipment Grounding

(C) Structure as Equipment Grounding Conductor. Devices listed and identified for grounding the metallic frames of PV modules or other equipment shall be permitted to bond the exposed metal surfaces or other equipment to mounting structures. Metallic mounting structures, other than building steel, used for grounding purposes shall be identified as equipment-grounding conductors or shall have identified bonding jumpers or devices connected between the separate metallic sections and shall be bonded to the grounding system.

UL Category QIMS

USE AND INSTALLATION

PV mounting systems, mounting devices, clamping devices and ground lugs intended for use with specific PV modules and panels and specified module frames and mounting structures as identified in the individual certifications. Mounting systems and clamping devices may be investigated for mechanical mounting alone, or mechanical mounting and ground bonding as identified in the individual certifications. Ground lugs may be investigated for use with specific PV modules, specific PV module frames, or specific mounting-system rails.

690.43 Equipment Grounding

(E) Adjacent Modules. Devices identified and listed for bonding the metallic frames of PV modules shall be permitted to bond the exposed metallic frames of PV modules to the metallic frames of adjacent PV modules.

Concerns

• Dissimilar metals
• Exposed terminations

Follow the manufacturer’s installation instructions

690.45(A) Size of Equipment Grounding Conductors

Where protected by GFPE per 690.5, the minimum size for equipment grounding conductors shall be in accordance with 250.122.
690.45 Size of Equipment Grounding Conductors

(B) Ground-Fault Protection Not Provided. For other than dwelling units where ground-fault protection is not provided in accordance with 690.5(A) through (C), each equipment grounding conductor shall have an ampacity of at least two (2) times the temperature and conduit fill corrected circuit conductor ampacity.

690.47 Grounding Electrode System

(A) Alternating-Current Systems.

(B) Direct-Current Systems.

(C) Systems with Alternating-Current and Direct-Current Grounding Requirements.


2. Common Direct-Current and Alternating-Current Grounding Electrode


690.47 Grounding Electrode System

(C) Systems with Alternating-Current and Direct-Current Grounding Requirements.


- Sized on the larger of the ac GEC or the dc GEC per 250.166
- Not a substitute for ac equipment grounding conductors

2. Common Direct-Current and Alternating-Current Grounding Electrode

- Size per 250.166
- Not a substitute for ac equipment grounding conductors


- Unspliced, or irreversibly spliced
- The larger of 250.122 or 250.166
- Installed in per 250.64(E)

690.48 Continuity of Equipment Grounding Systems.

Where the removal of equipment disconnects the bonding connection between the grounding electrode conductor and exposed conducting surfaces in the PV source or output circuit equipment, a bonding jumper shall be installed while the equipment is removed.
690.53 Direct-Current Photovoltaic Power Source

A permanent label for the direct-current PV power source indicating items (1) through (5) shall be provided by the installer at the PV disconnecting means:

1. Rated maximum power-point current
2. Rated maximum power-point voltage
3. Maximum system voltage
4. Short-circuit current
5. Maximum rated output current of the charge controller (if installed)

690.56 Identification of Power Sources

(B) Facilities with Utility Services and PV Systems.
Buildings or structures with both utility service and a PV system shall have a permanent plaque or directory providing the location of the service disconnecting means and the PV system disconnecting means if not located at the same location.

690.64 Point of Connection

Point of connection shall be in accordance with 705.12.

705.12(A) Point of Connection

An electric power production source shall be permitted to be connected to the supply side of the service disconnecting means as permitted in 230.82(6). The sum of the ratings of all OCPD’s connected to power production sources shall not exceed the rating of the service.

705.12(D) Utility-Interactive Inverters

1. Output of a utility-interactive inverter shall be permitted to be connected to the load side of the service disconnecting means.
2. Where distribution equipment is fed simultaneously by a primary source(s) and one or more utility-interactive inverters, the interconnecting provisions for the utility-interactive inverter(s) shall comply with (D)(1) through (D)(7).
705.12(D) Utility-Interactive Inverters

3) The interconnection point shall be on the line side GFPE.

4) Equipment containing overcurrent devices in circuits supplying power to a busbar or conductor supplied from multiple sources shall be marked to indicate the presence of all sources.

UL 1741 Utility Interaction

Traditional Fire/Shock Requirements
20 Sections of Tests
Utility Interaction

• Testing per IEEE 1547, the Standard for Interconnecting Distributed Resources With Electric Power Systems and IEEE 1547.1, the Standard for Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems
• Utility-driven standards
• Power quality and synchronization back into the grid
• Anti-Islanding protection

Article 690 is not the only section of the NEC applicable to PV Installations

250.97 Bonding for Over 250 Volts

Where oversized concentric, or eccentric knock-outs are encountered “Listed Fittings” are required to provide a reliable bonding connection.
Other Code Requirements for PV Systems

R905.16 Photovoltaic modules/shingles. The installation of PV modules/shingles shall comply with the provisions of this section.

R905.16.1 Material standards. Photovoltaic modules/shingles shall be listed and labeled in accordance with UL 1703.

R905.16.2 Attachment. PV modules/shingles shall be attached in accordance with the manufacturer’s installation instructions.

2012 IRC PV Systems

M2302.2.1 Roof-mounted panels and modules. Where PV panels and modules are installed on roofs, the roof shall be constructed to support the loads imposed by such modules. Roof-mounted PV panels and modules that serve as roof covering shall conform to the requirements for roof coverings in Chapter 9. Where mounted on or above the roof coverings, the PV panels and modules and supporting structure shall be constructed of noncombustible materials or fire-retardant-treated wood equivalent to that required for the roof construction.
Where PV panels and modules are installed on roofs, the roof shall be constructed to support the loads imposed by such modules.

M2302.3 Photovoltaic panels and modules. Photovoltaic panels and modules shall be listed and labeled in accordance with UL 1703.

M2302.4 Inverters. Inverters shall be listed and labeled in accordance with UL 1741. Systems connected to the utility grid shall use inverters listed for utility interaction.

1505.8 Photovoltaic systems. Rooftop installed photovoltaic systems that are adhered or attached to the roof covering or PV modules/shingles installed as roof coverings shall be labeled to identify their fire classification in accordance with the testing required in Section 1505.1.

1507.17 Photovoltaic modules/shingles. The installation of PV modules/shingles shall comply with the provisions of this section.

1507.17.1 Material standards. PV modules/shingles shall be listed and labeled in accordance with UL 1703.
1507.17.3 Wind resistance. PV modules/shingles shall be tested in accordance with procedures and acceptance criteria in ASTM D 3161. PV modules/shingles shall comply with the classification requirements of Table 1507.2.7.1(2) for the appropriate maximum nominal design wind speed. PV modules/shingle packaging shall bear a label to indicate compliance with the procedures in ASTM D 3161 and the required classification from Table 1507.2.7.1(2).

1509.7 Photovoltaic systems. Rooftop mounted PV systems shall be designed in accordance with this section.

1509.7.1 Wind resistance. Rooftop mounted PV systems shall be designed for wind loads for component and cladding in accordance with Chapter 16 using an effective wind area based on the dimensions of a single unit frame.

1509.7.2 Fire classification. Rooftop mounted PV systems shall have the same fire classification as the roof assembly required by Section 1505.

1509.7.3 Installation. Rooftop mounted PV systems shall be installed in accordance with the manufacturer’s installation instructions.

1509.7.4 Photovoltaic panels and modules. PV panels and modules mounted on top of a roof shall be listed and labeled in accordance with UL 1703 and shall be installed in accordance with the manufacturer’s installation instructions.

1511.1 Solar photovoltaic panels/modules. Solar PV panels/modules installed upon a roof or as an integral part of a roof assembly shall comply with the requirements of this code and the International Fire Code.

1511.1.1 Structural fire resistance. The structural frame and roof construction supporting the load imposed upon the roof by the PV panels/modules shall comply with the requirements of Table 601.
601.2 Permits. PV Systems
Permits shall be obtained for refrigeration systems, battery systems and PV power systems as set forth in Sections 105.6 and 105.7.

605.11 Solar photovoltaic power systems. PV power systems shall be installed in accordance with Sections 605.11 through 605.11.4, the International Building Code and the NEC.

Exception: Detached, nonhabitable Group U structures including, but not limited to, parking shade structures, carports, solar trellises and similar structures shall not be subject to the requirements of this section.

605.11.1 Marking. The marking shall contain the words “WARNING: PHOTOVOLTAIC POWER SOURCE.”

605.11.3 Main service disconnect. The marking shall be placed adjacent to the main service disconnect in a location clearly visible from the location where the disconnect is operated.

605.11.2 Locations of DC conductors. Conduit, wiring systems, and raceways for PV circuits shall be located as close as possible to the ridge or hip or valley and from the hip or valley as directly as possible to an outside wall to reduce trip hazards and maximize ventilation opportunities. Conduit runs between sub arrays and to DC combiner boxes shall be installed in a manner that minimizes the total amount of conduit on the roof by taking the shortest path from the array to the DC combiner box. The DC combiner boxes shall be located such that conduit runs are minimized in the pathways between arrays. DC wiring shall be installed in metallic conduit or raceways when located within enclosed spaces in a building. Conduit shall run along the bottom of load bearing members.

605.11.4 Location of marking. Marking shall be placed on interior and exterior DC conduit, raceways, cable assemblies, junction boxes, combiner boxes and disconnects.

605.11.1.1 Materials. The materials used for marking shall be reflective, weather resistant and suitable for the environment. Marking shall be placed adjacent to the main service disconnect in a location clearly visible from the location where the disconnect is operated.

605.11.1.4 Location of marking. Marking shall be placed on interior and exterior DC conduit, raceways, cable assemblies, junction boxes, combiner boxes and disconnects.

605.11.3 Access and pathways. Roof access, pathways, and spacing requirements shall be provided in accordance with Sections 605.11.3.1 through 605.11.3.3.

Exceptions:
1. Residential structures shall be designed so that each photovoltaic array is no greater than 150 feet by 150 feet in either axis.
2. Panels/modules shall be permitted to be located up to the roof ridge where an alternative ventilation method approved by the fire chief has been provided or where the fire chief has determined vertical ventilation techniques will not be employed.
605.11.3.1 Roof access points.
Roof access points **shall be located in areas** that do not require the placement of ground ladders over openings such as windows or doors, and located at strong points of building construction in locations where the access point does not conflict with overhead obstructions such as tree limbs, wires, or signs.

605.11.3.2 Residential systems for one- and two-family dwellings.
Access to residential systems for one- and two-family dwellings **shall be provided** in accordance with Sections 605.11.3.2.1 through 605.11.3.2.4.

605.11.3.2.1 Residential buildings with hip roof layouts.
PV panels/modules installed on residential buildings with hip roof layouts **shall be located** in a manner that provides a 3-foot-wide clear access pathway from the eave to the ridge on each roof slope where PV panels/modules are located. The access pathway **shall be located** at a structurally strong location on the building capable of supporting the live load of fire fighters accessing the roof.

Exception: These requirements **shall not apply** to roofs with slopes of two units vertical in 12 units horizontal (2:12) or less.

605.11.3.2.2 Residential buildings with a single ridge.
PV panels/modules installed on residential buildings with a single ridge **shall be located in a manner that provides** two, 3-foot-wide access pathways from the eave to the ridge on each roof slope where PV panels/modules are located.

Exception: This requirement **shall not apply** to roofs with slopes of two units vertical in 12 units horizontal (2:12) or less.

Ridge roofs need two, 3-foot-wide access pathways from the eave to the ridge.
605.11.3.2.3 Residential buildings with roof hips and valleys.
PV panels/modules installed on residential buildings with roof hips and valleys shall be located no closer than 18 inches to a hip or a valley where panels/modules are to be placed on both sides of a hip or valley. Where panels are to be located on only one side of a hip or valley that is of equal length, the panels shall be permitted to be placed directly adjacent to the hip or valley.
Exception: These requirements shall not apply to roofs with slopes of two units vertical in 12 units horizontal (2:12) or less.

605.11.3.3.1 Access.
There shall be a minimum 6-foot-wide clear perimeter around the edges of the roof.
Exception: Where either axis of the building is 250 feet or less, there shall be a minimum 4-foot-wide clear perimeter around the edges of the roof.

605.11.3.3 Other than residential buildings.
Access to systems for occupancies other than one- and two-family dwellings shall be provided in accordance with Sections 605.11.3.3.1 through 605.11.3.3.3.
Exception: Where it is determined by the fire code official that the roof configuration is similar to that of a one- or two-family dwelling, the residential access and ventilation requirements in Sections 605.11.3.2.1 through 605.11.3.2.4 shall be permitted to be used.

605.11.3.2.4 Residential building smoke ventilation.
PV panels installed on residential buildings shall be located no higher than 3 feet below the ridge in order to allow for fire department smoke ventilation operations.
605.11.3.3.2 Pathways.
The PV installation shall be designed to provide designated pathways. The pathways shall meet the following requirements:
1. The pathway shall be over areas capable of supporting the live load of fire fighters accessing the roof.
2. The centerline axis pathways shall be provided in both axes of the roof. Centerline axis pathways shall run where the roof structure is capable of supporting the live load of fire fighters accessing the roof.
3. Shall be a straight line not less than 4 feet clear to skylights or ventilation hatches.
4. Shall be a straight line not less than 4 feet clear to roof standpipes.
5. Shall provide not less than 4 feet clear around roof access hatch with at least one not less than 4 feet clear pathway to parapet or roof edge.

605.11.3.3.3 Smoke ventilation.
The PV installation shall be designed to meet the following requirements:
1. Arrays shall be no greater than 150 feet by 150 feet in distance in either axis in order to create opportunities for fire department smoke ventilation operations.
2. Smoke ventilation options between array sections shall be one of the following:
   2.1. A pathway 8 feet or greater in width.
   2.2. A 4-foot or greater pathway and bordering roof skylights or smoke and heat vents.
   2.3. A 4-foot or greater pathway and bordering 4-foot by 8-foot “venting cutouts” every 20 feet on alternating sides of the pathway.

605.11.4 Ground-mounted PV arrays.
Ground-mounted PV arrays shall comply with Sections 605.11 through 605.11.2 and this section. Setback requirements shall not apply to ground-mounted, free-standing PV arrays. A clear, brush-free area of 10 feet shall be required for ground-mounted PV arrays.

C402.2.1.1 Roof solar reflectance and thermal emittance.
Low-sloped roofs, with a slope less than 2 units vertical in 12 horizontal, directly above cooled conditioned spaces in Climate Zones 1, 2, and 3 shall comply with one or more of the options in Table C402.2.1.1.
Exceptions: The following roofs and portions of roofs are exempt from the requirements in Table C402.2.1.1:
1. Portions of roofs that include or are covered by:
   1.1. Photovoltaic systems or components.
   1.2. Solar air or water heating systems or components.
   1.3. Roof gardens or landscaped roofs.
   1.4. Above-roof decks or walkways.
   1.5. Skylights.
   1.6. HVAC systems, components, and other opaque objects mounted above the roof.
2012 IGCC
PV Systems

610.1 Renewable energy systems requirements.
Buildings that consume energy shall comply with this section. Each building shall be equipped with one or more renewable energy systems in accordance with this section. Renewable energy systems shall comply with the requirements of Section 610.2 for solar photovoltaic systems, Section 610.3 for wind systems, or Section 610.4 for solar water heating systems, and Section 610.5 for performance monitoring and metering of these systems as approved by the code official. These systems shall be commissioned in accordance with the requirements of Section 611.

610.1.1 Building performance-based compliance.
Buildings and surrounding property or building sites where there are multiple buildings on the building site, that are designed and constructed in accordance with Section 601.3.1, performance-based compliance, shall be equipped with one or more renewable energy systems that have the capacity to provide not less than 2 percent of the total calculated annual energy use of the building, or collective buildings on the site.

610.1.2 Building prescriptive compliance.
Buildings ..., that are designed and constructed in accordance with Section 601.3.2, prescriptive compliance, shall be equipped with one or more renewable energy systems that have the capacity to provide not less than 2 percent of the total estimated annual energy use of the building, or collective buildings on the building site, with onsite renewable energy by calculation demonstrating that onsite renewable energy production has a rating of not less than 1.75 Btu/h (0.5 W) or not less than 0.50 watts per square foot of conditioned floor area, and using any single or combination of renewable energy generation systems meeting the requirements of Sections 610.2, 610.3, or 610.4.

610.2 Solar photovoltaic systems.
PV systems shall be sized to provide not less than 2 percent of the total estimated annual electric energy consumption of the building, or collective buildings on the building site in accordance with Section 610.1.1 or 610.1.2.

610.2.1 Limitation.
PV systems shall not be used to comply with Section 610.1 where building sites have total global insolation levels lower than 2.00 kWh/m²/day as determined in accordance with NREL SERI TR-642-761.

610.2.2 Requirements.
The installation, inspection, maintenance, repair and replacement of PV systems and system components shall comply with the manufacturer’s instructions, Section 610.2.2.1, the International Fire Code, the International Building Code and NFPA 70.

610.2.2.1 Performance verification.
PV systems shall be tested on installation to verify that the installed performance meets the design specifications. A report of the tested performance shall be provided to the building owner.

Jeff Fecteau
Sr. Regulatory Engineer
Underwriters Laboratories
(952) 838-5453
Jeffrey.Fecteau@ul.com