Report of Experiments of Minimum Gap and Flashing for Rack Mounted Photovoltaic Modules
Phase 4

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Introduction

The research described herein expands on previous work conducted over multiple phases of a broader project[1] to determine the effect of rack mounted photovoltaic (PV) modules on the fire rating of roof assemblies. In general, these earlier experiments demonstrated that the flame spread ratings of the roof are not maintained when PV modules are installed elevated above the roof. An initial study measured the surface temperature and incident heat flux of a noncombustible roof with a noncombustible PV module mock-up installed at 10, 5 and 2.5 inches above the roof. All three PV-to-rooftop gap configurations resulted in increased surface temperature and heat flux on the roof assembly as compared to these measurements without the PV module. The highest heat flux and surface temperature values were with the 5 in. gap.

In this phase (Phase 4) of the investigation, data for some methods to mitigate the flame propagation through the gap between the PV module and the rooftop were developed.

Objectives

The objectives of this phase of the investigation were to:

1. Determine the minimum PV-to-rooftop gap which may maintain the roof covering's original fire rating; and
2. Develop data on the effect of sheet metal flashing to block the passage of flames between the PV module and the roof assembly.

Samples

Commercially available PV modules and roof covering samples were acquired either through industry donation or purchased from local retailers.

For the PV-to-rooftop gap experiments PV modules were a Class C fire rated metal framed glass on polymer design. In addition, a PV surrogate module consisting of a noncombustible sheet was also used.

For the flashing experiments, PV modules were Class C fire rated metal frame glass on polymer design.

The test assemblies representing high roof slopes (5:12 ratio), and low slopes (xx:xx ratio) were constructed using Class A roof covering materials for the UL 790/ASTM E108 Spread of Flame tests as follows:

Steep Slope Roof

One type of steep slope assembly consisting of Class A 3-tab shingles secured to a ¾ in. oriented strand board (OSB) was used.

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[1] Effect of Rack Mounted Photovoltaic Modules on the Flammability of Roofing Assemblies, Dated September 30, 2009, Revised March 5, 2010

Low Roof Slope

Three types of low slope roof assemblies were used as described herein:
a. Rolled asphalt on 2 inch thick polyisocyanurate insulation mechanically fastened to a noncombustible deck;
b. Fire retardant single ply EPDM (60 mil) over 2 inch thick polyisocyanurate insulation board mechanically fastened to a noncombustible deck; and
c. TPO (60 mil) over 2 inch thick polyisocyanurate insulation board mechanically fastened to a noncombustible deck.

Experiments

Fire performance of the PV modules/surrogate on roof deck assemblies was investigated by Spread of Flame tests as described in UL 790 "Standard Test Methods for Fire Tests of Roof Coverings" and UL 1703 "Standard for Safety, Flat-Plate Photovoltaic Modules and Panels". In UL 790/ASTM E108 standard, Class A roof covering materials have flame propagation not exceeding 6 ft.

In the experiments, the PV module or the surrogate was mounted parallel to the roof surface.

PV-to-Rooftop Gap

In these experiments, the PV-to-rooftop gap was varied from 12 in. to 24 in.to determine the minimum gap at which the Class A rating of the roof covering materials was retained. Two experiments were conducted on high slope assemblies and four experiments were conducted on low slope assemblies.

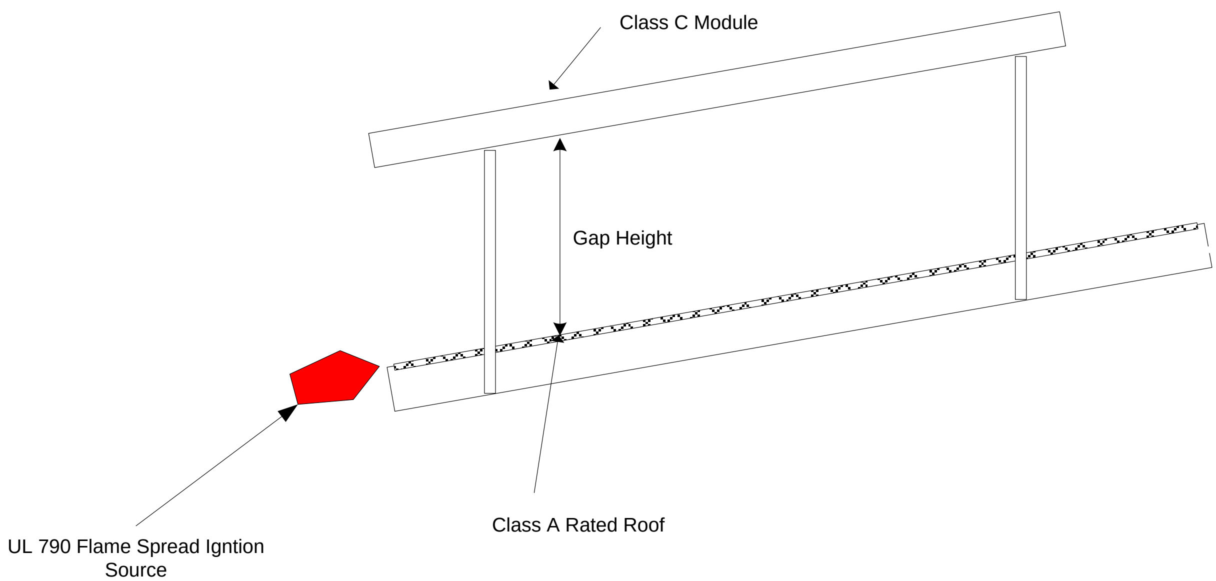

Figure 1 – Figure Illustrating Roof / PV Module Experiment Assembly With a Gap

Flashing

In these experiments, a Class C PV module was installed parallel to the roof surface, with a gap of 5 inches. A 26 AWG galvanized sheet metal flashing was placed from the top of the PV module to rooftop to either completely block the gap or to allow a ½ inch gap.

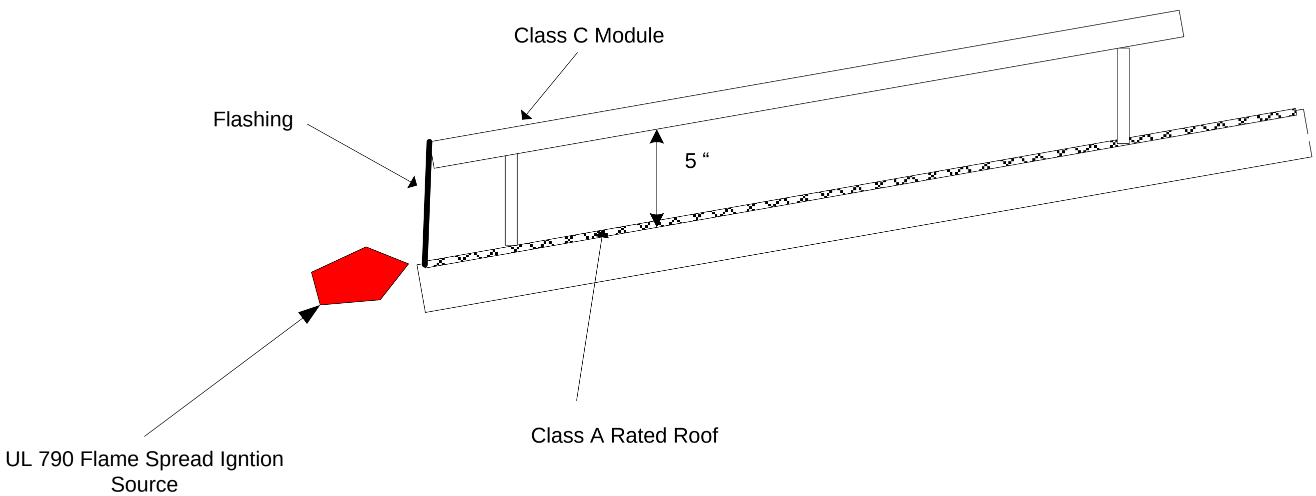

Figure 2 – Figure Illustrating Roof / PV Module Experiment Assembly With a Continuous Flashing

Results

PV-to-Rooftop Gap Experiments

Maximum flame spread distances and the corresponding time at which they occurred for the various roof assemblies experiments are listed in Table 1.

Table 1 - Summary of PV-to-Rooftop Gap Experiments

Roof Slope	Roof Covering	PV / Surrogate	Gap (in.)	Maximum Flame Distance (ft.)	Time for Maximum Flame Spread (Min:Sec)
Steep	3 tab shingles	Surrogate	12	5.25	9:36
Steep	3 tab shingles	Class C PV Module	12	4.5	8:26
Low	Rolled Asphalt	Surrogate	12	>6	2:33
Low	FR EPDM	Surrogate	16	>6	1:47
Low	FR EPDM	Surrogate	20	>6	1:53
Low	TPO	Surrogate	24	>6	5:16

With the steep slope, both the Class C and the surrogate PV modules had maximum flame spread less than 6 ft. at a gap of 12 inches. Thus, higher PV-to-rooftop gaps were not further investigated.

However, for the low slope roof tests, all the roof assemblies with the PV surrogate had flame spread distances exceeding 6 ft., even at gap distance of 24 inches. Thus, for these assemblies tests with Class C PV module was not conducted.

Post experiment photographs of a compliant steep slope and noncompliant low slope roof configuration are shown in Figures 1 and 2.

Figure 3 – Figure Illustrating Steep Slope Roof / PV Module Assembly 12" Gap Sample After Flame Spread Experiment

Figure 4 – Figure Illustrating Low Slope FR EPDM Roof / PV Surrogate Assembly 24" Gap After Flame Spread Experiment

Flashing Experiments

Maximum flame spread distances and the corresponding times at which they occurred for the roof assemblies are listed in Table 2.

Table 2 - Summary of Flashing Experiments

Roof Slope	Roof Covering	Flashing Opening (in.)	Roof Flame Spread		Module Flame Spread		Lateral Spread	
			Maximum Distance (ft.)	Time to Maximum Flame Distance (Min:Sec)	Maximum Distance (ft.)	Time to Maximum Flame Distance (Min:Sec)	Spread to Width of the Assembly	Time to Maximum Flame Distance (Min:Sec)
Steep	Shingle	0.5	0	*	0	*	No	*
Low	FR EPDM	0	0	*	0	*	No	*
Low	FR EPDM	0.5	0	6:13	3 1/2	6:32	Yes	7:14
Low	TPO	0.5	5 1/2	6:39	5 1/2	6:39	Yes	6:52
Low	Mod Bit*	0.5	3	8:02	5 1/2	8:02	Yes	9:11

Notes: * - No flame spread

The steep slope, 3 tab shingled roof assembly with ½ inch gap in the flashing between the PV module and roof assembly exhibited flame spread performance that met the criteria of a Class A roof.

The low slope PV module-roof assembly with a continuous flashing without an opening between the roof surface and the PV module (0 in. flashing opening) completely blocked the interstitial was successful in preventing the flames entering the opening between PV module and the roof top. Experiments on low slope roof assemblies with ½ inch opening provided by the flashing did not have flame spread longitudinally exceeding 6 ft. However, they had lateral flame spread that extended to the width of the test assembly.

Selected photographs of a flashing with the opening blocked, and a ½ in. opening are shown in Figures 3 and 4 respectively.

Figure 5 – Photograph of Flame with a the Opening Blocked by Flashing Installed on a Low Slope Roof Assembly

Figure 6 – Photograph of Flame with a ½ in. Flashing Opening Flashing Installed on Low Slope Roof Assembly

It may be observed from Figure 3 that when the flashing completely blocks the opening between the rooftop and the PV module, the flame is deflected above the panel; and when there is a ½ in. flashing opening (Figure 4), the flame extension between the rooftop and the PV module is limited longitudinally but tends to spread laterally.

SUMMARY OF FINDINGS

Although the experiments conducted for this report are not exhaustive, an analysis of the generated data point to the following key findings:

- A noncombustible representation of a PV module (i.e., PV surrogate) and a Class C PV module mounted 12 inches above a Class A shingled roof, when evaluated in a steep slope configuration, both exhibited no flame spread greater than 6 feet, no significant lateral flame spread, nor burning embers. These results are in conformance to Class A roof rating.

- A gap of 12 inches and up to 24 inches between a noncombustible representation of a PV module and various low slopes Class A membrane over insulation roofs generated flame spread distances greater than 6 feet. These results are not in conformance to a Class A roof rating.

- A metal flashing that completely blocked the opening between the rooftop and the PV module prevented flames from entering the interstitial space between an elevated PV module and the roof assembly surface. This result is in conformance with a Class A roof rating.

- A metal flashing with 1/2” opening between the rooftop and the PV module allowed flames to enter the interstitial space between an elevated PV module and various low slope roofs. The flames then propagated laterally to the edge of the roof. This result is not in conformance with Class A roof rating.

- A metal flashing with 1/2” opening between the rooftop and the PV module allowed flames to enter the interstitial space between an elevated PV module and a steep slope shingled roof. However, the flame spread did not exceed 6 feet; no significant lateral flame spread was observed; and no burning embers were emitted from the PV module or the roof assembly. These results are in conformance with a Class A roof rating.