Validation of 42” PV Module Setback on Low Slope Roof Experiments
Project 7

Project Number: – 11CA43479
File Number: IN15911
Date: November 30, 2012
Revised: December 12, 2012

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DISCLAIMER

Acknowledgments

The authors would like to acknowledge the following individuals / organizations for their contributions including guidance and support for this project:

Bill Brooks of Brooks Engineering
Larry Sherwood of Sherwood Associates
Joe Cain of Solar City
Andy Rosenthal of New Mexico State University

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Introduction

The research described herein expands on previous work conducted over multiple phases of a broader project[1,2,3,4,5] to determine the effect of rack mounted photovoltaic (PV) modules on the fire rating of roof assemblies. In general, the 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 room with a noncombustible PV module surrogate installed at 10, 5 and 2.5 inches above the roof. An analysis of the data indicated the 5 inch gap height to be the most critical of the three that were evaluated in terms of increased radiant flux and roof surface temperature. All three gap configurations increased the surface temperature and heat flux on the roof assembly higher than those measured in the absence of the PV module.

A subsequent second project further investigated rack mounted PV modules on roof decks to determine (1) the effect of PV modules mounted at angles (positive and negative) to steep and low sloped roofs, (2) the impact of PV modules mounted at zero clearance to the roof surface and with the ignition source directed in the plane of the roof or the plane of the PV surface, and (3) the heat release rate and transfer to roof surface of Class A, B, C brands and common materials such as leaf debris and excelsior (wood wool).

A third project investigated the critical flux for ignition of roofing and PV products. While the individual values varied, most were within the range of the flux values measured on the roof in the original experiments without the PV module in place.

Then a fourth project was undertaken to validate the performance of two approaches thought to mitigate the effect of rack mounted PV modules on the fire ratings of roofs - a minimum separation gap and a sheet metal flashing to block the passage of flames between the PV module and the roof assembly. A continuous flashing was determined to effectively block the passage of flame along the roof under a PV module. A minimum distance of 12 inches above a steep slope (shingled) roof was determined to sufficiently separate the two surfaces to maintain the roof's original fire rating. Experiments up to a height of 24 inches above a low slope roof resulted in flame spread in excess of the performance criteria for a Class A roof.

A fifth Project 5 described a series of experiments to investigate a modification of the current UL 1703 spread of flame test to (1) expose a PV module to flames originating from the UL790 (ASTM E108) ignition source, (2) allow those flames to generate on a representative roof section, and (3) observe the propagation of the flames underneath the candidate PV module being tested. Previous research within Project 1 had been conducted with the PV module

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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,

[2] Effect of Rack Mounted Photovoltaic Modules on the Fire Classification Rating of Roofing Assemblies, Dated January 30, 2012

[3] Characterization of Photovoltaic Materials – Critical Flux for Ignition / Propagation Phase 3 Dated January 16, 2012,

[4] Determination of Effectiveness of Minimum Gap and Flashing for Rack Mounted Photovoltaic Modules. Phase 4 Dated March 29, 2012

[5]Considerations of Module Position on Roof Deck During Spread of Flame Tests, Phase 5, Dated July 24, 2012

installed in a position where both the roof and the module were subjected to the ignition source with zero set back and with only modest set back distances (24 inches or less). The repositioning of the PV module was conducted to investigate an application of first item (roof) / second item (module) ignition sequence. This concept was investigated to refine the understanding of the effect of a rack mounted PV array on the fire rating of a Class A roof. Experiments were conducted on low and steep slope roofs.

In addition to the work described above, three additional projects resulted from discussions with PV and roofing industry stakeholders. These projects include:

- Project # 6 – A series of experiments to demonstrate generic installation details of PV and roofing systems. If compliant, these details can be documented and used by industry without the need for further evaluation. As of the date of this report, work under Project 6 had not begun.
- Project # 7 – As described in this report, this series of experiments was conducted to generate data in support of proposed changes to UL 1703, specifically, 42 inch setback of the PV module on low slope roofs.
- Project # 8 – Development of a burner designed to represent the flame spread along the roof surface. This burner could potentially replace the standard roof configurations described in the UL 1703 proposal improving the test protocol by eliminating variation of the burning roof deck. . As of the date of this report, work under Project 8 had not begun.

The results of this investigation (# 7) could be used to:

1. Validate performance of low slope roof test parameters as contained in a draft of a revised test method for consideration by the UL 1703 Standards Technical Panel (STP), and
2. Provide quantitative data to support the proposed standard revisions, specifically, 42 inch setback of the PV module on low slope roofs.

Samples

Commercially available PV modules and roofing product samples were acquired either through industry donation or purchased from local retailers. The PV modules were a Class C fire rated metal framed glass on polymer design. A surrogate representation of a PV module was simulated using a noncombustible sheet for some experiments.

UL 790/ASTM E 108 Class A rated roof deck assemblies consisted of:

- 60 mil LSFR EPDM (low slope, fire retardant, ethylene propylene diene monomer) over
- 4 inch thick polyisocyanurate insulation board mechanically fastened to a
- combustible deck.

Experiments

Fire performance of the PV modules on roof deck assemblies was investigated by Spread of Flame tests as being considered for proposal to the UL 1703 STP.

For these experiments, the objective was to conduct the experiments with the module subjected to a thermal exposure resulting primarily from the burning roof. This was accomplished by positioning the module at a distance beyond exposure of the test fixture ignition source, but within range of the flame progression along the surface of the roof. This setback distance was 42 in. with the PV module elevated 5 in. above the roof surface. A baseline experiment was conducted to establish the flame propagation along the roof's surface in the absence of a PV module.

Low Slope Results

Three experiments were conducted with the standard low slope roof as described in the current UL1703 proposal being considered by the UL1703 Standards Technical Panel. Maximum flame spread distances and the corresponding time at which they occurred for the various low slope roof assembly experiments are listed in Table 1.

The baseline experiment without a PV module present demonstrated a maximum flame spread distance along the roof of 5 ft., which is Class A compliant.

All of the PV / roof experiments were conducted with aluminum framed glass on polymer PV modules installed at a gap height of 5 in., an offset of 42 in and parallel to the roof (0° inclination). During two of the three experiments, the flame spread extended to a maximum of 3.5 ft. (Class A, compliant). A third roof / PV experiment was conducted resulting in a flame spread of 8 ft (Class A nonccompliant) where flame spread across the roof surface with both the module and the roof fully involved with flames extending beyond the deck.

Table 1 - Summary of Repositioning Experiments – Low Slope

						Roof															
			Gap		Module		Time of Roof Flame Spread														
System		System	Height	Slope	Offset	Ignition	0.5'	1.0'	2.0'	2.5'	3.0'	3.5'	4.0'	4.5'	5.0'	5.5'	6.0'	6.5'	7.0'		Class A
#	Slope	Notes	(in)	(in/in)	(in)	(sec)	(m:s)	(m:s)	(m:s)	(m:s)	(m:s)	(m:s)	(m:s)								Compliant
Experiments conducted November 5 2012																					
1	Low	PV	5	0.5/12	42	0:51	0:51	1:40	2:40	2:52	3:19	4:50									Yes
2	Low	PV	5	0.5/12	42	0:56	0:56	1:59	2:38	3:00	3:35	5:01									Yes
3	Low	Baseline	N/A	0.5/12	N/A	0:53	0:53	1:49	2:27	NR	3:03	3:26	3:54	4:44	7:22						Yes
4	Low	PV	5	0.5/12	42	0:42	0:42	1:34	2:06	NR	2:31	2:57	3:28	NR	4:17	4:28	4:37	4:42	4:49		No
NA = Not Applicable																					
NR = Not Recorded																					

Figure 1 – Figure Illustrating Flame Spread of System 1

Figure 2 – Figure Illustrating Flame Spread of System 2

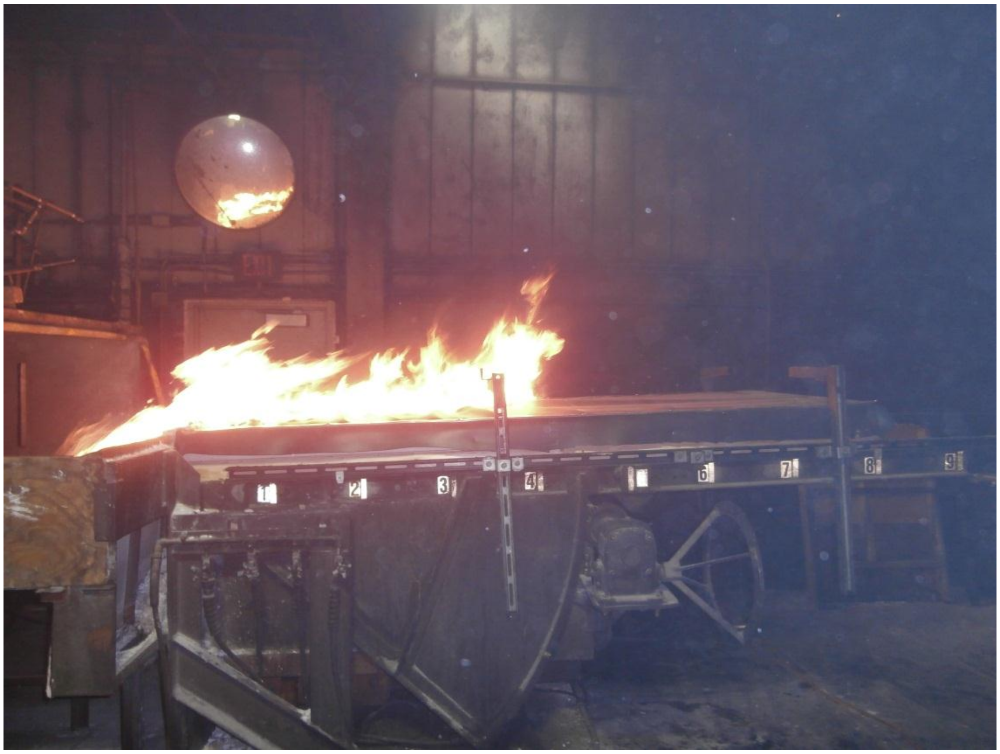

Figure 3 – Figure Illustrating Flame Spread of System 3 (No PV Module)

Figure 4 – Figure Illustrating Ignition of the Module and Roof of System 4

Summary and Recommendations

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:

- The low slope roof baseline (no PV) experiment exhibited a flame spread of 60 inches. This Class A compliant performance is consistent with previous flame spread experiments.
- Two of the PV / roof assembly experiments exhibited a flame spread of 42” (Class A compliant)
- One experiment conducted on the same assembly exhibited a flame spread of 96” (Class A noncompliant).
- This inconsistency can be compared to the critical flux determinations of roofing materials as investigated in the third project and reported in “Characterization of Photovoltaic Materials – Critical Flux for Ignition/Propagation, January 16, 2012.” The Critical heat flux for ignition is the lowest thermal load per unit area capable of initiating a combustion reaction on a given material (either flame or smolder ignition). In these experiments, the thermal conditions of the roof / PV assembly configuration are such that fire propagation along the roof and up under the module are at a critical stage.
- Observations of the ignition source flame and the flame emanating from the roof surface indicated the following influencing factors for the different experimental results:
    - During all of the experiments, the ignition source did not impinge directly onto either the roof surface or the PV module. The roof surface was ignited by radiant heat from the ignition flame. Upon ignition, flames propagated along the roof surface.
    - During two of the experiments, flames advanced along the roof up to the front of the module (42”), but did not advance further. The flame front was observed to be leaning in the direction of the forward end of the roof deck, opposite of the 12 mph airflow. This observation indicates that the diffusion flame at the roof / PV module interface was drawing combustion air from under the PV module.
    - During the experiment that resulted in a flame spread of 96”, the flame front demonstrated similar physiognomies as the previous experiments - advancing along the roof up to the roof / module interface. However, during this experiment, the flame front advancement paused temporarily at 42” until ignition of the module as indicated by flames observed along the leading edge of the PV module frame. The flames grew in intensity and extended under the module igniting the module substrate. Once this occurred, flames propagated along the module substrate and roof surfaces. This combination flame front grew quickly extending beyond the roof deck at which time the experiment was terminated by extinguishing the fire.

Recommendations

These experiments support the recommendations as previously suggested in Project 5, specifically regarding 42 inch between the edge of the flame test apparatus and the edge of the PV mounting system for low sloped roofs.

As previously noted in the report "Considerations of Module Position on Roof Deck During Spread of Flame Tests Phase 5":

> "Based on the research study findings, the repositioning approach of examining the first item ignited (roof) and then the second item ignited (PV), was a viable method for assessing the performance of a roof / PV combination. It was observed that this method was of such severity that currently commercially available PV Class C modules would likely have to be modified, or the installation details specified, in order to yield compliant results for both low and steep slope tests. It is important to note that the results of tests with the PVs present were fairly consistent with tests using a surrogate noncombustible PV.
>
> Consequently, the Research Team as well as a focus group present to observe some of these tests supported the following recommendations and suggestions to propose revisions to UL 1703 as follows:
>
> Spread-Of-Flame Tests to be conducted:
>
> - Individually with the module mounted on a noncombustible deck and oriented such that the ignition flame is directed on the top surface of the module or panel.
> - With the module installed on a steep slope and low slope roofs as an assembly and oriented such that the ignition flame is directed into the interstitial space below the module and above the roof. The module or panel installation shall be installed:
>   a. with a 36 inch (0.91 m) between the edge of the flame test apparatus and the edge of the PV mounting system for steep sloped roofs,
>   b. with 42 inch (1.07 m) between the edge of the flame test apparatus and the edge of the PV mounting system for low sloped roofs."

Collectively, the results of the experiments described in this report and those reported in the previous report "Considerations of Module Position on Roof Deck During Spread of Flame Tests Phase 5" validate a 42" offset of a PV module over low slope roofs as a critical point which differentiates performance of PV module design and installation details.