



Report on Spread of Flame and Burning Brand Performance of Generic Installations



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Bob Backstrom
Research Engineer, Fire Group, Corporate Research

Chad Fisher
Engineering Team Leader, Building Materials and Systems

Reviewed by:
Pravinray Gandhi, PhD PE
Director of Engineering Research, Corporate Research

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TABLE OF CONTENTS

Acknowledgments	3
Introduction	5
Purpose.....	5
Samples	5
Experiment Configurations	7
Modules Only	7
Steep slope – Burning Brand	7
Steep slope – Spread of Flame.....	8
Low slope – Spread of Flame	9
Baseline Tests Results.....	10
Module Only Results	10
Steep Slope PV / Roof Assembly Tests Results	10
Burning Brand	11
Spread of Flame.....	11
Low Slope PV / Roof Assembly Tests Results	12
Spread of Flame.....	12
Summary of Findings	13
Burning Brand	13
Spread of Flame.....	13

Introduction

The research described herein expands on previous work conducted over multiple phases of a broader project^{1,2,3,4,5,6} to determine the effect of rack mounted photovoltaic (PV) modules on the fire rating of roof assemblies. In general, the experiments demonstrated that the spread of flame ratings of the roof are not maintained when PV modules are installed elevated above the roof. Results from the work indicated that fire performance of roof mounted PV arrays is dependent on the system – roof, PV modules, racking and installation details (elevation, inclination to roof, proximity of modules etc.). Discussions with industry stakeholders led to an interest in developing generic installation details which meet the requirements of a new systems-level fire test in UL 1703. If these installations practices result in meeting the fire performance requirements, then they may be utilized by industry without the need for further evaluation.

Purpose

The purpose of this project was to examine examples of generic PV and racking system installation performance when subjected to the revised UL 1703 PV system fire test.

The results of this investigation may be used to provide quantitative data to support future standard revision proposals, specifically, a PV assembly including a module, rack and air deflection hardware mounted on a standardized roof configuration representing roofs with defined slopes. It may also be used to provide industry a set of installation practices that enable meeting the fire performance requirements.

Samples

The samples used in these experiments consisted of PV modules and roofing materials.

PV Modules

Commercially available PV modules and roofing product samples were acquired either through industry donation or purchased from local retailers. For this research the PV modules were aluminum framed with a glass superstrate and demonstrated a Class A SOF with fire exposure

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

⁶ Validation of 42" PV Module Setback on Low Slope Roof Experiments

on the top surface of the module. The manufacturer identified the modules as a Type 2 design. All experiments resulted in Class A fire performance, SOF < 6 feet.

Roofing Materials

UL 790/ASTM E 108 Class A rated low and steep slope roof deck assemblies were used in the experiments and consisted of:

- “Steep Slope”
 - a. Spread Of Flame experiments - bituminous sheet roofing material applied over a noncombustible deck
 - b. Burning Brand experiments - Class A shingles applied over 30 lb. felt and fastened to a combustible deck
- ‘Low Slope”
 - a. Spread Of Flame experiments – EPDM sheet roofing material applied over 4 inches of polyisocyanurate foam over a combustible deck

Experimental Configurations

The installation details used in the experiments were the result of meetings convened by Solar ABC’s with industry stakeholders. Low and steep slope PV / roof assemblies were investigated as follows:

Modules Only

Three spread of flame experiments were conducted on a PV module only in accordance with the revised UL 1703 test procedure. The PV module was positioned at the leading edge of the support carriage such that the ignition flame was directed over the exposed (superstrate) of the module.

Steep slope – Burning Brand

Four burning brand experiments were conducted with a PV mounted at a height of 5” above the roof. Two experiments were conducted with a Class A brand positioned on the surface of the PV module; and two experiments with a Class B brands positioned under the PV module and above the roof. Figure 1 provides an illustration of the burning brand positioned on the module top surface experiment. Figure 2 provides an illustration of the burning brand positioned on the roof surface below the module.



Figure 1 - Photograph of Brand Positioned Above Module



Figure 2 - Photograph of Brand Positioned Below the Module

Steep slope – Spread of Flame

A total of eight spread of flame experiments were conducted with a PV mounted on a steep slope roof:

- two experiments with the PV module installed at a height of 5" above the roof, equipped with a solid 0.187-inch (0.4712 mm, 26 gage) corrosion resistant steel barrier attached to the leading edge of the module (fire end) at 90° to the roof surface and with a 3/4" gap between the sheet metal and the roof;
- two experiments with the PV module installed at a height of 5" above the roof, equipped with a solid 0.187-inch (0.4712 mm, 26 gage) corrosion resistant steel barrier attached to the leading edge of the module (fire end) at 45° to the roof surface and with a 3/4" gap between the sheet metal and the roof;
- two experiments with the PV module installed at a height of 5" above the roof, equipped with a 1/16" screen attached to the downward slope edge of the module (fire end) at 45° to the roof surface and continuous from the module to the roof; and
- two experiments with the PV module installed at a height of 3" above the roof.

Low slope – Spread of Flame

A total of six spread of flame experiments were conducted with a PV module mounted on a low slope roof:

- two experiments with the PV module installed at a height of 8" above the roof and parallel (inclination of 0°) to the roof surface;
- two experiments with the PV module installed at a height of 8" above the roof and at an inclination of 5° to the roof surface; and
- two experiments with the PV module installed at a height of 5" above the roof and at an inclination of 5° to the roof surface.

Figure 3 provides an illustration of the digital level positioned on the module top surface experiment. Figure 4 provides an illustration of the ignition source and detached flame propagating along the roof surface toward the module.



Figure 3 - Photograph of 5° Inclination



Figure 4 - Photograph of Low Slope SOF at 5° Inclination

Baseline Tests Results

In accordance with the revised UL1703 test procedure, tests were conducted on low and steep slope roofs without PV. These results of these tests are considered baseline to establish the position of modules for the roof / PV assembly level tests. Spread of flame (SOF) results are shown in Table 1.

Table 1- Baseline SOF Results

	Test	Roof		SOF
Date	#	Slope	Test	ft (in)
10/21/2013	4	Steep	Baseline	5.5
10/21/2013	5	Steep	Baseline	5.75
10/21/2013	6	Steep	Baseline	5.75
1/31/2014	5	Low	Baseline	4.5 (56)
1/31/2014	6	Low	Baseline	5 (61)
1/31/2014	7	Low	Baseline	5 (61)

Module Only Results

In accordance with the revised UL1703 test procedure, tests were conducted on the PV module top surface. These results of these tests are considered to establish the module Type classification for the roof / PV assembly level tests. Spread of flame (SOF) results are shown in Table 2.

Table 2 - Module Only SOF Results

	Test	Roof	Test	Height	Module	Baffle / Angle			Module	SOF	Time	
					Angle		Angle					Position
Date	#	Type		(in)	To Roof	Baffle	Screen	To Roof	# of Modules	(ft)	(ft)	(min:sec)
1/29/2014	3	Noncomb	SOF	NA	0	NA	NA	NA	1	0	4	6:21
1/29/2014	4	Noncomb	SOF	NA	0	NA	NA	NA	1	0	6	9:22
1/29/2014	5	Noncomb	SOF	NA	0	NA	NA	NA	1	0	5.25	7:23

Fire exposure on the top of the module's surface resulted in Class A fire performance, SOF < 6 feet.

Steep Slope PV / Roof Assembly Tests Results

Spread of flame and burning brand tests were conducted in accordance with the revised UL1703 test procedure. Results of the burning brand tests are shown in Table 3 and spread of flame tests in Table 4.

Burning Brand

The results from the burning brand tests on steep slope are shown in Table 3.

Table 3 - Steep Slope Burning Brand Results

Solution		Test	Roof	Module		Height	Module Angle To Roof	Baffle / Angle		# of Modules	BB	Notes	
#	Date	#	Type	Test	Type	(in)	(°)	Baffle	Screen	(°)	For Experiment	Breach (Y/N)	
1	10/23/2013	7	Steep	BB	TBD	5	0	NA	NA	NA	1	No	Class A brand on PV surface
1	10/23/2013	8	Steep	BB	TBD	5	0	NA	NA	NA	1	No	Repeat of above
1	10/23/2013	9	Steep	BB	TBD	5	0	NA	NA	NA	1	No	Class B brand on roof surface
1	10/23/2013	10	Steep	BB	TBD	5	0	NA	NA	NA	1	No	Repeat of above

Both the Class A brand placed on the top of the module's surface and the Class B brand placed on the roof surface under the module resulted in compliant results – fire did not penetrate through the roof deck.

Spread of Flame (SOF)

The results from the spread of flame tests on steep slope are shown in Table 4,

Table 4 - Steep Slope Spread of Flame Results

Solution		Test	Roof	Module		Height	Module Angle To Roof	Baffle / Angle		Module	SOF	Notes		
#	Date	#	Type	Test	Type	(in)	(°)	Baffle	Screen	(°)	of Module Position (ft)	(ft)		
3	10/24/2013	17	Steep	SOF	TBD	5	0	Sheet metal	NA	90	1	4.75	3.5	3/4" Gap between roof & baffle
3	10/24/2013	18	Steep	SOF	TBD	5	0	Sheet metal	NA	90	1	4.75	3.5	Repeat of above
3b	10/24/2013	19	Steep	SOF	TBD	5	0	Sheet metal	NA	45	1	4.75	3.5	3/4" Gap between roof & baffle
3b	10/24/2013	20	Steep	SOF	TBD	5	0	Sheet metal	NA	45	1	4.75	3.5	Repeat of above
4	10/24/2013	21	Steep	SOF	TBD	5	0	NA	1/16	90	1	4.75	5.5	
4	10/24/2013	22	Steep	SOF	TBD	5	0	NA	1/16	90	1	4.75	5.25	Repeat of above
5	10/24/2013	23	Steep	SOF	TBD	3	0	NA	NA	0	1	4.75	5	
5	10/24/2013	24	Steep	SOF	TBD	3	0	NA	NA	0	1	4.75	5	Repeat of above

Experiments 17 and 18 were conducted with a sheet metal baffle attached to the PV module positioned perpendicular to the roof plane and terminated ¾ inch above the shingles. Experiments 19 and 20 were conducted with a sheet metal baffle attached to the PV module positioned 45° to the roof plane and terminated ¾ inch above the shingles. Experiments 21 and 22 were conducted with a ¼ inch by ¼ inch opening screen attached to the PV module positioned perpendicular to the roof plane and terminated directly on the shingle. Experiments 23 and 24 were conducted without either a baffle or screen but with the module installed 3 inches above the roof surface. All experiments resulted in Class A fire performance, SOF < 6 feet.

Low Slope PV / Roof Assembly Tests Results

Spread of flame tests were conducted in accordance with the revised UL1703 test procedure. Results of the spread of flame tests are shown in Table 5.

Spread of Flame (SOF)

The results from the spread of flame tests on steep slope are shown in Table 5.

Table 5 - Low Slope Spread of Flame Results

Solution #	Date	Test #	Roof Type	Test	Module		Baffle / Angle			# of Modules For Experiment	Module Position (ft (in))	SOF (ft)
					Height (in)	To Roof (°)	To Roof	Angle (°)	Screen			
2	2/3/2014	1	Low	SOF	8	0	NA	NA	NA	1	5 (60)	4.0
2	2/3/2014	2	Low	SOF	8	0	NA	NA	NA	1	5 (60)	5.0
2	2/3/2014	3	Low	SOF	8	5	NA	NA	NA	1	5 (60)	5.0
2	2/3/2014	4	Low	SOF	8	5	NA	NA	NA	1	5 (60)	4.5
2	2/3/2014	5	Low	SOF	5	5	NA	NA	NA	1	5 (60)	4.5
2	2/3/2014	6	Low	SOF	5	5	NA	NA	NA	1	5 (60)	4.5

Experiments 1 and 2 were conducted with the module installed 8 inches above the roof surface parallel to the roof surface without either a baffle or screen. Experiments 3 and 4 were conducted with the module installed 8 inches above the roof surface at 5° to the roof surface without either a baffle or screen. Experiments 5 and 6 with were conducted with the module installed 5 inches above the roof surface at 5° to the roof surface without either a baffle or screen. All experiments resulted in Class A fire performance, SOF < 6 feet.

Summary of Findings

Burning Brand

The burning brand results were reviewed and determined compliant with the performance criteria of 31.2.3 Burning-brand tests for steep sloped mounting systems as outlined in the October 25, 2013 revision of UL 1703.

Spread of Flame

The spread of flame results for the module only, steep slope PV / roof assembly and low slope PV / roof assembly were reviewed and determined compliant with the performance criteria of 31.2.2.2 For the Spread-of-Flame Tests.