Fire Classification Rating Testing of Stand-Off Mounted Photovoltaic Modules and Systems

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EXECUTIVE SUMMARY

The year 2013 marks a significant change for the fire classification rating approach for roof mounted stand-off photovoltaic (PV) modules and panels evaluated in accordance with American National Standards Institute/Underwriters Laboratories, Inc. (ANSI/UL) 1703, *Standard for Safety for Flat-Plate Photovoltaic Modules and Panels.* Prior to 2013, a PV module manufacturer could receive a fire classification rating based on tests of the module or panel alone. After the 2013 changes to ANSI/UL 1703, the fire classification rating approach takes into account the module or panel in combination with the mounting system and the roof covering products over which it is installed. The proposals that led to these changes were an outgrowth of research tests conducted and broad stakeholder forums held through a partnership between UL and the Solar America Board for Codes and Standards (Solar ABCs).

Throughout this report, ANSI/UL 1703-2012 (ANSI/UL, 2002) refers to versions of UL 1703 with a revision date of May 8, 2012 or earlier. ANSI/UL 1703-2013 refers to the new edition of UL 1703 that incorporates the new fire classification test described in this report.

Around 2009, it became apparent that fire and code officials and the solar industry had concerns about the installation of lesser class-rated PV modules (Class C) over higher class-rated roofs (Class A). Although both roof covering materials and PV modules received fire class ratings, little work had been done to investigate the interactions between them when systems composed of PV modules mounted in stand-off configuration over roofing systems are exposed to burning materials or flame. Specifically, it was necessary to investigate whether and how PV modules with Class B or C fire ratings may adversely affect the performance of Class A rated roofing systems. To investigate these concerns, Solar ABCs and UL conducted extensive tests on various combinations of PV designs and roof coverings, and explored some mitigation techniques.

During early research testing, various spread of flame test experiments were performed with Class A and Class C rated PV modules mounted in combination with Class A roof products and systems. The results in all cases showed flame propagation well beyond the ANSI/UL 1703-2012 Class A requirement of six feet within a fraction of the typical test time duration. Experiments were also performed to examine a burning item coming to rest between the PV and the roof, or the ignition of accumulated leaves or debris. Testing showed that Class A rated PV modules mounted at a typical five-inch gap height did not comply with Class A requirements when the burning brand was placed on the roof below the modules. When this test was performed using Class C modules, the test results were inconclusive. Finally, initial testing found mitigation techniques that showed promise in preventing the degradation of roof covering fire class rating by rack-mounted PV modules.

The research tests demonstrated that fire class rating of the PV module alone determined according to ANSI/UL 1703-2012 may not predict the fire performance of the PV module, mounting system, and roof assembly as a system. From a safety perspective, the objective of the work turned towards promoting stand-off-mounted PV systems with improved performance and developing a system-based test that would differentiate high performing from low performing designs. Thus, the stakeholders and investigation team decided to pursue the development of a new fire classification test for the PV module, the mounting components, and the roof assembly as a system.

During the steps towards development of a new fire classification test, the team considered the real world scenario in which the roof ignites first and then the flames develop and migrate underneath the PV panel to present a fire exposure challenge to the PV system. This concept of first to ignite, second to ignite sequence is well established in the fire protection community, and was proposed as the best way to properly evaluate a PV module in the presence of a roof covering. In all the research tests prior to this concept, the PV module was installed in a position where both the roof and the module were subjected to the ignition source with zero offset or with only modest offset distances (24 inches or less) from the flame source. At the beginning of these tests, the test flame was already extending well into the gap between the module and the roof. However, with a first to ignite, second to ignite test, the PV is installed for test with a setback such that the roof covering ignites first, the fire propagates along the roof, and then the PV module is exposed. This concept was tested in a number of validation tests.

These experiments led to a new fire classification test, which is a significant change from the previous PV module fire classification test procedure. In the new procedure, the module is tested mounted over representative roof covering systems and the performance of the entire system is the basis for the fire classification rating of the PV module with mounting system. In this manner, the new PV fire classification test provides a more useful rating than the previous PV module-only rating test.

The new requirements in ANSI/UL 1703-2013 include an optional characteristic testing of PVs, tested alone in a similar manner to ANSI/UL 1703-2012. This characterization was maintained because this information can prove useful in demonstrating grouping of PVs into “types” in an effort to satisfy the ANSI/UL 1703-2013 requirements for the classification rating as a system.

The new fire classification rating tests in ANSI/UL 1703-2013 involve the combination of the module or panel, the mounting system, and the roof covering system. Because each of these three components has many products in the marketplace, testing every possible combination of the three components could mean thousands of required tests. This is not practical and could stifle market innovation. In response, a number of considerations and provisions were written into the new standard to reduce the number of required tests. In addition, Solar ABCs, UL, industry, and stakeholders continue to explore and validate industry-wide solutions that may satisfy the new, revised ANSI/UL 1703-2013 fire classification requirements in an effort to reduce the industry’s testing burden.

Solar ABCs is a collaborative effort among experts to provide coordinated recommendations to codes and standards-making bodies for existing and new solar technologies. UL provides safety and performance testing and product certifications for thousands of materials and products. UL is also a leading safety standard development organization. UL was a pioneer in the evaluation and testing of roof covering materials (e.g., shingles) and PV modules.

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Bill Brooks has worked with utility-interconnected photovoltaic (PV) systems since the late 1980s. He is a consultant to the PV industry on a variety of performance, troubleshooting, and training topics. During the past 15 years, his training workshops have helped thousands of local inspectors, electricians, and installers understand and properly install PV systems. His field troubleshooting skills have been valuable in determining where problems occur so that training can focus on the issues of greatest need. He has written several important technical manuals for the industry that are now widely used in California and beyond. His experience includes work on technical committees for the *National Electrical Code*® Article 690. and IEEE utility interconnection standards for PV systems. In 2008, the Solar Energy Industries Association appointed him to Code Making Panel 4 of the *National Electrical Code.* He holds bachelor and master of science degrees in mechanical engineering from North Carolina State University and is a registered professional engineer in both North Carolina and California.

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Solar America Board for Codes and Standards

The Solar America Board for Codes and Standards (Solar ABCs) is a collaborative effort among experts to formally gather and prioritize input from the broad spectrum of solar photovoltaic stakeholders including policy makers, manufacturers, installers, and consumers resulting in coordinated recommendations to codes and standards making bodies for existing and new solar technologies. The U.S. Department of Energy funds Solar ABCs as part of its commitment to facilitate widespread adoption of safe, reliable, and cost-effective solar technologies.

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Background on Fire Classifications Rating of PV Modules and System

Roofing systems undergo a suite of tests described in Underwriters Laboratories (UL) 790—*Tests for Fire Resistance of Roof Covering Materials,* the test standard that determines the fire resistance properties of roofing. All roofing systems undergo these tests as required by local and model U.S. building codes. Roofing systems that demonstrate the highest resistance to ignition, burn through, and flame spread receive a Class A rating. Materials with lesser performance receive a Class B or C rating.

PV modules undergo safety testing to another standard, American National Standards Institute (ANSI)/UL 1703—*Standard for Safety for Flat-Plate Photovoltaic Modules and Panels* (ANSI/UL, 2002). Although this standard describes a suite of tests designed to stress the module physically, environmentally, and electrically, it also describes tests that result in a determination of a fire rating for each photovoltaic (PV) module or system. In ANSI/UL 1703-2012 and earlier versions, two tests were required, spread of flame and burning brand.

The spread of flame test applies a natural gas fueled flame and measures the potential for flames to spread across the surface. The burning brand test measures the potential for fire to penetrate from outside a roofing material (or, in the case of UL 1703-2012 tests, a PV module). The source of fire is a burning brand, a measured stack of dry wood that is ignited and burns with known properties.

These tests are a subset of UL 790 tests and resulted in a fire class rating for the module (Class A, B, or C). ANSI/UL 1703-2013 is the new version of this standard that includes the new fire classification test described in this report. The ANSI/UL 1703-2013 tests result in a system fire class rating for the module, mounting system, and roof covering (Class A, B, or C).

As a result of catastrophic wildfires, many jurisdictions, especially in California, increased the fire classification rating requirements for roof coverings. Where a Class B or C roof covering may have previously been allowed, many jurisdictions increased the requirement to a Class A roof covering. When presented with applications for rooftop solar installations, these jurisdictions began to question whether lesser class rated PV modules (Class C) installed over higher class rated roofs (Class A) would adversely affect the performance of Class A rated roofing systems. At this time, most PV modules were rated Class C.

When directed to UL's *Online Certification Directory* (White Book)(UL, 2007), the following provided guidance:

> Installation of modules on or integral to a building's roof system may or may not adversely affect the roof-covering materials' resistance to external fire exposure if the module has a lesser or no fire-resistance rating. Roof-covering materials will not be adversely affected when the modules have an equal or greater fire-resistance rating than the roof-covering material.

However, there was still ambiguity in the *Certification Directory* statement, so the solar industry and fire and code officials set out to clarify concerns about the most common residential PV roof installation—Class C rated PV modules mounted over Class A rated roofs. This effort illuminated the fact that there was a lack of fire test results on systems including PV modules in roof-mounted configurations. Industry representatives turned to UL to assist in bringing clarity to this concern.

Although roof covering materials and PV modules both received fire class ratings, little work had been done to investigate the interactions that may occur between them when burning materials or flame are imposed on systems composed of PV modules mounted in stand-off configuration over roofing systems. Specifically, it was necessary to investigate whether and how PV modules with Class B or C fire ratings may degrade the fire-resistance properties of Class A rated roofing systems using standard flammability test procedures and methods in a qualified laboratory. With funding from the U.S. Department of Energy, UL and the Solar America Board for Codes and Standards (Solar ABCs) developed a test plan to answer these questions.

In the Summer of 2009, Solar ABCs, in partnership with UL, designed and conducted specific tests to characterize the effects of stand-off mounted (elevated and parallel to roof surface) PV modules on the fire rating of Class A rated roofing systems. Staff members of UL's Corporate Research Division in Northbrook, Illinois, conducted all tests with assistance from representatives of Solar ABCs.

The tests included the "burning brand" and the "spread of flame" tests normally conducted on PV modules during ANSI/UL 1703-2012 certification of all PV modules, but with a major difference. During ANSI/UL 1703-2012 certification testing, fire and burning materials were applied to the top surface of the PV module only. The tests conducted for this study were designed specifically to impose fire between the module and roof covering (see Figure 1). Therefore, unlike ANSI/UL 1703-2012, which evaluates the properties of a PV module in isolation, the current tests were conducted to examine modules and roof coverings as a system when exposed to fire. Tests were designed to use the methods of UL 790 to evaluate different combinations of modules, stand-off heights, and roofing materials. These tests are reported in a Solar ABCs Interim Report (Rosenthal et al., 2010) and several UL Research Reports (Backstrom & Tabaddor, 2009a; Backstrom & Tabaddor, 2009b; Backstrom & Sloan, 2012a; Backstrom & Sloan, 2012b, Backstrom & Sloan, 2012c, Backstrom & Sloan, 2012d; Backstrom & Sloan, 2012e; Backstrom, 2013).

Figure 1. Example spread of flame test (this test is non-combustible roof with a simulated non-combustible PV module with 0-inch setback and a 10-inch gap.

The tests showed that the current fire classification rating of a module or panel may not in all cases predict the fire performance of the system including the module or panel, the mounting system, and the roof covering material. The results of testing demonstrated that any panel (even a noncombustible one) mounted at a range of gap heights (stand-offs) typical of many PV arrays will increase the temperature and heat flux present at the roof surface during the spread of flame test. The increased temperature and heat flux are the result of a "channeling effect" between the PV and the roof, through which the panel holds hot gases and flame close to the roof surface, not allowing them to dissipate as they do when not confined.

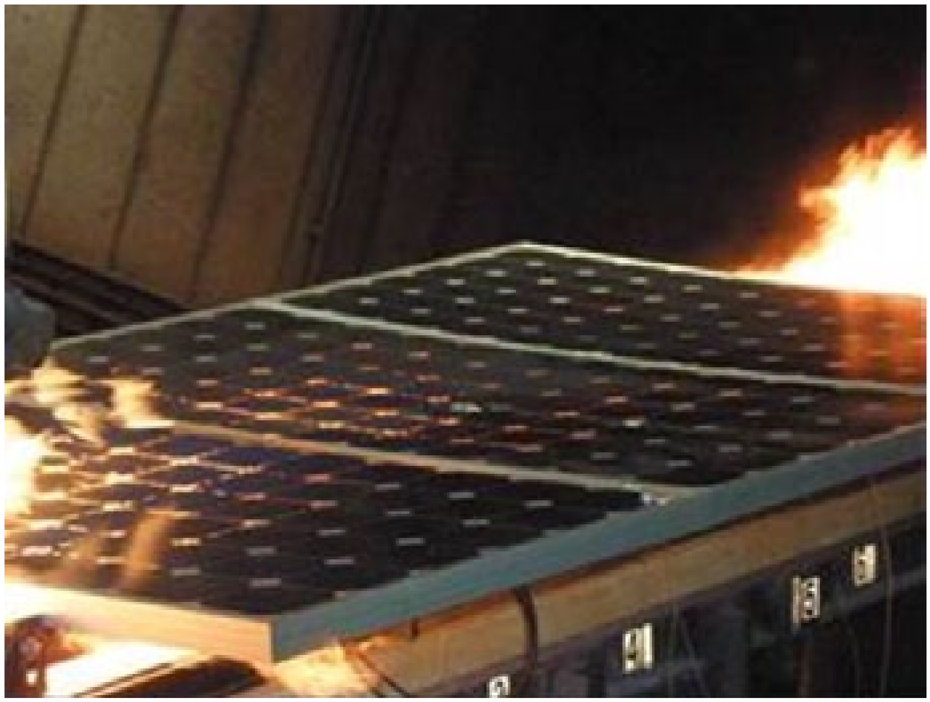

Figure 2. Spread of Flame Test showing failure to meet Class A requirements.

As a result of this "channeling effect," PV modules of any fire rating (Class A or C) mounted in a five-inch stand-off configuration will hold sufficient heat against the roof surface such that previously Class A rated roof coverings will no longer meet the Class A requirements during the UL 790 spread of flame test. The "channeling effect" shows the need for a systems approach to fire testing. Testing also determined that Class A rated PV modules mounted at a five-inch gap height prevented Class A rated roof coverings from meeting the Class A requirements of the burning brand test when the brand was placed on the roof below the modules, simulating a burning item coming to rest between the PV and the roof or the ignition of accumulated leaves or debris. This work will be discussed in further detail in the Burning Brand Tests Between Module and Roof section. When this test was performed using Class C modules, the test results were inconclusive. Finally, initial testing found mitigation techniques that show promise of preventing the degradation of roof covering fire class rating by rack-mounted PV modules. After completing this round of research, Solar ABCs and UL convened several meetings with a cross section of volunteer scientists and engineers from the PV industry, the enforcement community, other testing laboratories, and the National Institute of Standards and Technology.

From a safety perspective, the goal is that the installation of a stand-off mounted PV module and its mounting system does not degrade the fire class rating of the roof assembly. As the fire class rating of the PV module (determined according to ANSI/UL 1703-2012) is not a predictor of whether or not the fire class rating of the PV module and roof assembly as a system is changed from the fire classification rating of the roof assembly, additional work was required. In response, the stake-holders and investigation team decided to pursue the development of a new fire classification test for the PV module and roof assembly as a system.

TESTS TO DEVELOP AND VALIDATE NEW FIRE CLASSIFICATION RATING TEST

Burning Brand Tests Between Module and Roof

The burning brand test conducted in UL 790 and ANSI/UL 1703 is intended to evaluate roofing assemblies to resist the penetration of fire through the assemblies into spaces underneath, such as a cockloft or attic. There was general agreement that the burning brand test should continue to be conducted with the appropriate fire classification brand placed on top of the module and failure determined by whether the fire burns through the roof deck, as defined in UL 790.

However, the team considered the real world scenario of burning items coming to rest between the PV and the roof or the ignition of accumulated leaves or debris. This issue of a test with the burning brand placed between the module and the roof proved more controversial and warranted additional test work.

The objective of this set of experiments was to demonstrate the burning behaviors of the standard Class A and C roofing brands, as well as common materials that may collect between the PV modules and the roof surface, represented by excelsior (wood wool) and leaves. Temperatures of a noncombustible roof deck were measured directly under the burning item or material to illustrate the heat transfer to roofing materials (see Figure 3). In addition, the weight of the burning item or material and the peak heat release rate were also measured. These data were provided to contrast the different fuel packages. These experiments are described in detail in a UL research report (Backstrom & Sloan, 2012a).

Figure 3. Experimental setup with leaf debris over noncombustible deck.

The following is a summary of the results:

- Under similar wind conditions of 700 feet per minute (fpm), the Class A brand developed a significantly greater amount of energy than the Class C brand both in peak and total.
- The leaf debris and excelsior generated substantially less energy than the Class A brand, but significantly greater than an individual Class C brand. One significant challenge with the use of leaf debris or excelsior is an expected variation of energy generated due to the nature of the material.

Overall, the heat release rate and heat transfer to the roof surface of Class A and Class C brands did not demonstrate a direct correlation to common materials that may collect between PV modules and the roof surface, such as leaf debris and excelsior (wood wool). The Class A brand yielded significantly greater heat transfer than the leaf debris and wood excelsior, and the Class C brand yielded significantly less heat transfer than the leaf debris and wood excelsior. Although the Class B brand was not included in the experiments, the conclusion of these experiments is that the representation of materials likely to collect between the PV module and the roof surface is closest to the Class B brand in terms of heat release and heat transfer to the roof surface. Based on these experiments, the new standard test (in ANSI/UL 1703-2013) includes a Class B brand for the tests between the module and the roof.

Characterization of Photovoltaic Materials—Critical Flux for Ignition and Propagation

As the work began to develop a fire classification rating test for PV and roofing systems, attendees at stakeholder meetings as well as members of the UL 1703 Standards Technical Panel (STP) expressed concern about the number of tests that would be required to evaluate a seemingly insurmountable number of combinations of PV modules or panels, mounting systems, and low and steep slope roof systems and products. Although roof coverings may generally be grouped into low and steep sloped roofs, the number of manufacturers and types of roofing products are more than what can be reasonably evaluated by a PV manufacturer.

These experiments examined possible similarities of roofing materials and PV modules in an effort to extend PV/roofing system evaluation to a large number of roofing types while minimizing the amount of testing required. Critical flux for ignition was the parameter chosen to compare the different materials. Critical flux is a fundamental fire property of a material and is defined as the minimum level of incident radiant flux energy required for ignition, expressed as energy per unit area (kilowatts per square meter [kW/m^2] or watts per square centimeter [W/cm^2]). A UL Research Report describes these tests in detail (Backstrom & Sloan, 2012b).

The products tested were PV modules and roofing product samples either donated by industry or purchased from local retailers. The PV modules were metal framed glass on polymer design, representative of Class C fire classification rating (ANSI/UL 1703-2012 standard). The roofing products consisted of Class A steep slope 3-tab and architectural (laminate) roof shingles, base and cap sheets, ethylene propylene diene monomer (EPDM) and fire retardant (FR) EPDM membranes, and polyisocyanurate insulation boards. The samples tested included:

- composite or “stacks” cut from PV modules consisting of glass, encapsulant, and cell and backplane layers (three manufacturers),
- three-tab shingles (three manufacturers),

- architectural shingles (three manufacturers),
- base sheet (one manufacturer),
- cap sheet (two manufacturers),
- EPDM membrane (one manufacturer),
- FR EPDM membrane (one manufacturer),
- insulation board (one manufacturer), and
- FR insulation board (one manufacturer).

The experimental plan originally was designed to obtain the value of critical flux for ignition using the floor and radiant panel (FARP) apparatus, the lateral ignition and flame travel (LIFT) apparatus, and, finally, the cone calorimeter apparatus. The plan was to compare measured values from the different tests for the same roofing or PV product to gain an understanding of the influence of the test method and fixture on critical flux values.

Critical flux measurements are obtained directly from the FARP and LIFT experiments using the ASTM E648 and E1321 test protocols, respectively. In both of these test protocols, the flame front or propagation along the sample surface is directly related to the incident radiant flux exposure during the test. A calibration is conducted to establish the relationship between heat flux and distance. The critical flux is then determined from the point at which the flame front progresses. In this work, neither the FARP or the LIFT apparatus successfully determined critical flux values for either roofing or PV materials.

The cone calorimeter protocol (see Figure 4) using the ASTM E1354 procedure does not determine critical flux directly as a reported result from the test protocol. Rather, the test apparatus may be used to conduct experiments at multiple heat flux exposures in order to derive the critical flux by plotting heat flux vs. ignition times. This technique was used to develop critical flux values for both roofing and PV materials.

Figure 4. Cone calorimeter test apparatus (ASTM 1354).

An analysis of the data generated by the experiments carried out in this study point to the following key findings:

- The critical flux values for most of the roofing products was greater than the 14 kW/m^2 exposure measured on the surface of a noncombustible deck without PV. The critical flux values for all of the roofing products was less than the 41 kW/m^2 exposure measured on the surface of a noncombustible deck with PV installed with a five-inch gap.
- The critical flux for ignition of low slope roof products was found to be generally consistent, as was the critical flux for ignition of steep slope roof products.
- Crystalline silicon PV modules ignite at nearly identical critical flux values.

These test results supported the premise that, within limits, groupings of low slope roofing products, steep slope roofing products, and certain types of PV modules could be "represented" in a fire response test with an expectation of similar test results. This conclusion would later prove extremely helpful as the team began development of the new test protocol.

Test Concept of First to Ignite, Second to Ignite

To date in the research, almost all PV and roof system combinations were non-compliant when using the traditional UL 790 Class A methods and requirements. Although the critical flux experiments discussed above demonstrated that certain products could be grouped, the team was still challenged to develop a new test that would differentiate PV system performance. The concept of first to ignite, second to ignite items was proposed as the best way to properly test the PV module in the presence of a roof covering.

In all the tests previously reported, the PV module was installed in a position so that both the roof and the module were subjected to the ignition source with zero offset or with only modest offset distances (24 inches or less) from the flame source. At the beginning of the test, the test flame is already extending well into the gap between the module and the roof. However, the broad group of industry and stakeholders began to consider the likely real world scenario in which the roof ignites first and then the flames develop and migrate under the PV, presenting a typical fire exposure challenge to the PV, its mounting system, and the roof covering underneath. This approach became known as the first to ignite, second to ignite test, in which the roof covering is ignited and then that flame is used to test the PV module. This same concept is used in testing other products, for example, furniture (California Department of Consumer Affairs, 1991), mattresses (CPSC, 2006), and fuel packages (NFPA, 2013).

A series of experiments evaluated the first to ignite, second to ignite concept for testing a PV system, including a module or panel, mounting system, and roof covering (Backstrom & Sloan, 2012d). In these tests, a UL 790 ignition source created flames on a representative roof section and then the test engineers observed the propagation of flames underneath the PV module being tested.

Figure 5. Example experiment illustrating first to ignite, second to ignite concept with 48-inch offset (low slope roof with low slope FR EPDM, noncombustible PV surrogate, five-inch gap)

Commercially available PV modules and roofing product samples were either donated by industry or purchased from local retailers. The PV modules were an ANSI/UL 1703-2012 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.

The UL 790 (ASTM E108) Class A rated roof deck assemblies consisted of:

- three-tab shingles with 30 pound felt underlayment over nominal ½-inch plywood (Note: three manufacturers of shingles were used in the experiments); and
- 60 mil low slope FR EPDM over four-inch-thick polyisocyanurate insulation board mechanically fastened to a non-combustible deck.

Steep Slope Results

Ten experiments were conducted on steep slope roofs constructed using Class A rated, three-tab shingles produced by three different manufacturers. Maximum flame spread distances and the corresponding time at which they occurred for the various steep slope roof assembly experiments were recorded. Two baseline experiments without PV modules present were conducted on the shingles from manufacturer one, and single baseline experiments were conducted on shingles from manufacturers two and three. All baseline experiments without PV modules demonstrated flame spread along the roof surface of approximately four feet (UL 790 Class A compliant).

When a noncombustible PV surrogate was installed at a gap height of five inches and an offset of 36 inches, the flame spread along the roof extended to four feet (Class A compliant). When a noncombustible PV surrogate was also installed at a gap height of five inches and an offset of 24 inches, the flame spread along the roof extended to eight feet (Class A noncompliant). These results showed that a noncombustible PV would likely pass at a 36-inch offset but likely fail at a 24-inch offset. This suggested that the 36-inch offset may be a critical, and therefore ideal, test condition for achieving passing or failing results based on product or system design.

Figure 6. Spread of flame test with steep slope roof and PV module, 36-inch offset, five-inch gap, and 0° inclination.

Two experiments were conducted with aluminum framed, glass on polymer PV modules installed at a gap of five inches, an offset of 42 inches, and parallel to the roof (0° inclination). For the experiment conducted with shingles from manufacturer one, the flame spread was three-and-a-half feet (Class A compliant), and for the experiment conducted with shingles from manufacturer three, the flame spread was four feet (Class A compliant).

Two additional experiments were conducted with the modules installed at an offset of 36 inches. The experiment conducted with shingles from manufacturer one developed a flame spread of four feet (Class A compliant), and manufacturer three's product developed a flame spread of four and a half feet (Class A compliant). These results validated that some designs would likely pass the steep slope condition without redesign.

Low Slope Results

Six experiments were conducted with low slope roofs. The baseline experiment without a PV module present demonstrated a maximum flame spread distance along the roof of approximately five feet, which is Class A compliant.

A noncombustible PV surrogate was installed at a gap height of five inches and an offset of 48 inches. The flame spread along the roof extended under the PV module and the total spread of flame along the roof was eight feet (Class A noncompliant). The same configuration, but with an offset of 52 inches, exhibited a flame spread of eight-and-a-half feet (Class A noncompliant).

A series of experiments were conducted with PV modules installed at a gap height of five inches. With the module installed at an offset of 48 inches and parallel to the roof (0° inclination), the flame spread extended to eight feet (Class A noncompliant). Another experiment was conducted with the module offset at 48 inches, but with the module installed at a slight angle to the roof (10° inclination) resulting in a flame spread of four feet (Class A compliant). A final experiment was conducted with two modules at an angle to the roof (10° inclination), the first offset 24 inches and the second spaced 12 inches from the first. Flame spread across the roof surface with both modules fully involved with flames extending beyond the deck (Class A noncompliant). These tests and results are described in detail in a UL Research Report (Backstrom & Sloan, 2012d).

UL ran a separate set of experiments to generate data on a 42-inch setback of the PV module on low slope roofs (Backstrom & Sloan, 2012e). Three experiments were conducted with aluminum framed glass on polymer PV modules installed at a gap height of five inches, an offset of 42 inches, and parallel to the roof (0° inclination). During two of the three experiments, the flame spread extended to a maximum of three and a half feet (Class A compliant). A third roof/PV experiment was conducted resulting in a flame spread of eight feet (Class A noncompliant). In this experiment, flames spread across the roof surface with both the module and the roof fully involved, and flames extending beyond the deck.

Summary and Findings

Low Slope:

- The low slope roof baseline experiment (no PV) exhibited a flame spread of 60 inches.
- A noncombustible representation of a PV module or a Class C PV module mounted parallel to and at an elevation of five inches above the roof and at offsets of 48 and 52 inches resulted in flame spreads in excess of Class A performance requirements.
- A PV module mounted at a slight inclination (10°) to and at an elevation of five inches above the roof and at a 48-inch offset did comply with Class A requirements.
- A single experiment conducted with two modules angled to the roof (10° inclination), the first offset 24 inches and the second spaced 12 inches from the first did not comply with Class A requirements.
- The overall results of low slope tests with the PVs present were fairly consistent with tests using a surrogate noncombustible PV.

Steep Slope:

- The steep slope roof baseline experiments (no PV) exhibited a flame spread of 48 inches.
- A noncombustible representation of a PV module mounted parallel to and at an elevation of five inches above the roof with an offset of 42 inches complied with Class A requirements.
- Two experiments conducted with PV modules mounted parallel to and at an elevation of five inches above the roof with an offset of 42 inches complied with Class A requirements.
- Two experiments conducted with PV modules mounted parallel to and at an elevation of five inches above the roof with an offset of 36 inches complied with Class A requirements.
- An additional experiment was conducted with a noncombustible sheet mounted parallel to and at an elevation of five inches above the roof with an offset of 24 inches and did not comply with Class A requirements
- The overall results of steep slope tests with the PVs present were fairly consistent with tests using a surrogate noncombustible PV.

Recommendations

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 UL Research Team as well as a focus group present to observe some of these tests supported the following recommendations and suggestions for proposed revisions to ANSI/UL 1703-2012:

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 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:
    - o with 36 inches between the edge of the flame test apparatus and the edge of the PV mounting system for steep sloped roofs, and
    - o with 42 inches between the edge of the flame test apparatus and the edge of the PV mounting system for low sloped roofs.

NEW FIRE CLASSIFICATION TEST PROCEDURE

The proposed changes were put before the UL 1703 STP and underwent review, technical debate, and changes from the original proposal—all typical of most consensus standards development processes. The final result was a new fire classification test procedure (ANSI/UL 1703-2013), which is a significant change from the current PV module fire classification test procedure. In the new procedure, the module is tested mounted over representative roof covering systems and the performance of the entire system is the basis for the fire classification rating of the PV module with mounting system. With this approach, the new PV fire classification test is a measure of effects of the PV installation on the fire classification rating of the roof covering system and provides a more logical rating than the previous PV rating test.

Concerns About Multiple Configurations

The fire classification rating tests involve the module or panel, the mounting system, and the roof covering system. Because each of these three components has many products in the marketplace, testing every possible combination of the three components could mean thousands of required tests. This is not practical and could stifle market innovation. In response, a number of provisions were written into the new standard to reduce the number of required tests.

First, two representative roof covering systems were chosen—one for steep slope and one for low slope. Manufacturers must use these two representative roof covering systems for their tests.

Second, a type system was defined for PV modules. Types 1 and 2 modules have a tempered glass superstrate, polymeric encapsulant, polymeric substrate, and aluminum framing and meet minimum fire performance requirements. Type 3 modules or panels have tempered glass superstrate, polymeric encapsulant, tempered glass substrate, and no frame and meet minimum fire performance requirements. Additional types with different combinations of superstrate, encapsulant, substrate, and frame could be developed in the future. A test for one type module would apply to all other modules of the same type. Thus a mounting system manufacturer could test a Type 1 module with their mounting system and the results would apply to all other Type 1 modules with the same or similar installation instructions.

A module manufacturer may perform the module or panel characterization tests. Then a mounting system or module manufacturer performs the fire classification tests for a specific type of module or panel. Any other module or panel that meets the requirements for same type module or panel could receive the same fire classification rating. With this evaluation scheme, the required number of tests will be drastically reduced to a manageable number without excluding any products or system solutions from the marketplace.

Description of Proposed Test Procedure

PV Module or Panel Characterization

Initially, two characterization tests are described for PV modules and panels, tested independently of the mounting system. These tests are summarized in Table 1 and then each of the tests is described. A more detailed description including the actual requirements is included in ANSI/UL 1703-2013.

Table 1

Type Tests for Fire Performance of PV Modules or Panels Independent of Mounting System and Roof Covering

Test	Fire Performance Characteristics		
Spread of flame on top surface of module or panel	Flame spread less than 6 ft. in 10 minutes	Flame spread less than 8 ft. in 10 minutes	Flame spread less than 13 ft. in 4 minutes
Burning brand on surface of module or panel	A Brand	B Brand	C Brand
One test is required for each of the above required tests			

The spread of flame on top surface test is the same as the spread of flame test in ANSI/UL 1703-2012. The module or panel is mounted in the test apparatus such that the ignition flame is directed at the top surface of the module or panel. The flame spread is measured from the origin of the test flame apparatus.

The burning brand on surface of module or panel test is the same as the burning brand test in ANSI/UL 1703-2012. The module or panel fails the test if there are flaming or glowing brands blown off the test deck, the brand burns a hole in the module, or there is sustained flaming of the module or panel. The data from these characterization tests may be used towards certain tests required for the system fire classification rating.

System Tests

Five system tests are required to develop the fire classification rating for a PV module or panel with mounting system. These tests are summarized in Table 2 and then each of the tests is described. A more detailed description including the actual requirements is included in ANSI/UL 1703-2013.

Table 2

Required Tests for Fire Class Rating of PV Module or Panel With Mounting System in Combination With Roof Coverings

Test	Tests Over Representative Roof Coverings		
	Class A	Class B	Class C
Spread of flame on top surface of module or panel[a]	Flame spread less than 6 ft. in 10 minutes	Flame spread less than 8 ft. in 10 minutes	Flame spread less than 13 ft. in 4 minutes
Spread of flame at roof and module or panel interface over representative steep sloped roof	Pass	Pass	Pass
Spread of flame at roof and module or panel interface over representative low sloped roof	Pass	Pass	Pass
Burning brand on surface over representative steep sloped roof	A Brand	B Brand	C Brand
Burning brand between module or panel and representative steep sloped roof	Pass	Pass	Pass
[a] Requirement can be met with a type tested module or by performing the test on the top surface of a module or panel in the mounting system being qualified. For non-type tested products, the product must pass two consecutive tests for each required test.			
Two consecutive tests for each test must be passed unless not required by the terms of ANSI/UL 1703-2013, Sections 31.2.1.2, 31.2.2, or 31.2.3.			
For the purpose of ANSI/UL 1703-2013, Steep and Low Sloped Roof are defined in Section 31.2.1.1.			

Spread of Flame on Top Surface

This requirement can be met with either a type tested module or by performing the test on the top surface of a module or panel in the mounting system being qualified. For non-type tested products, the product must pass two consecutive tests for each required test.

Spread of Flame at Roof and Module or Panel Interface

This test measures the spread of flame in the interface between the module or panel, its racking system, and a representative roof system. The test is conducted over a representative steep sloped roof or a representative low slope roof, depending on the intended use of the module or panel. If installation is intended for both low and steep slope applications, then both tests must be conducted. The module is installed with an offset between the edge of the flame test apparatus and the edge of the PV mounting system. The offset distance is established as the average baseline of the low slope or steep slope roofing materials minus 12 inches, but no less than 36 inches. This application of the first item ignited, second item ignited concept is further described in the Test Concept of First to Ignite, Second to Ignite section. The system passes the test if the flame spread is less than six feet, measured from the origin of the test flame apparatus.

Burning Brand on Surface Over Representative Steep Sloped Roof

This test measures whether the Class A rated roof system still meets the Class A requirements in the presence of a PV module or panel with mounting system. The burning Class A brand is positioned on top of the module or panel. The system passes if there is no sustained flaming of the underside of the plywood deck and no flaming or glowing brands fall off the test deck. This performance criteria is different than the current burning brand test, in which a failure occurs if the brand burns through the module.

If the module or panel is designed only for low slope applications, this test is not required.

Burning Brand Between Module or Panel and Representative Steep Sloped Roof

This test is similar to the previous burning brand test, except that a Class B brand is placed between the module and the roof surface. The rationale for using a Class B brand is explained in the Burning Brand Tests Between Module and Roof section. The pass/fail criteria are the same as the previous burning brand test. If the module or panel is designed only for low slope applications or the module has a guarded perimeter protected with a wire screen or other similar means then this test is not required.

Considerations for UL 2703

The new fire classification test is being implemented first in ANSI/UL 1703-2013, which is a module safety standard. If the module or panel is fire rated, the installation, including the mounting system, will be considered to have a fire classification rating, Class A, B, or C.

UL Outline of Investigation 2703, *Mounting Systems, Mounting Devices, Clamping/ Retention Devices, and Ground Lugs for Use With Flat-Plate Photovoltaic Modules and Panels* (UL, 2010) addresses the mounting system. The intention is that the UL 2703 STP will consider and adopt complementary language in that standard to allow evaluation, certification, and labeling of mounting systems.

Industry Solutions

An Industry Solutions project is currently underway to identify and validate solutions that may satisfy the revised ANSI/UL 1703-2013 fire classification requirements through testing specific generic installation geometries that qualify as Class A. Test data analysis, along with details of construction and installation, will be summarized in a forthcoming UL Report. The report will be made public and shared with industry, authorities having jurisdiction, and other stakeholders. For installation assemblies that have been proven to meet Class A requirements, manufacturers could use this information as the basis for certification, and, consequently, installation approval. Ultimately, the data can be used as substantiation for code proposals. Use of industry solutions will also help reduce the number of tests required without excluding any product or system solution from the marketplace.

New Burner

Although the use of commercially available roof coverings in the spread of flame tests was found to be a viable way to evaluate PV fire performance, it has been recognized that variables are introduced because the flame spread performance of roof coverings vary widely. The standard attempts to address this variation by setting acceptable baseline ranges, but there is still variation. Consequently, a new proposal is being researched to replace the roof covering with a burner representative of the thermal stress of the roof fire to the underside of the PV module.

Developing this new burner requires a series of experiments of roofing materials to develop heat release and surface involvement data. These data will be used to design the "burner" test rig and to correlate the two methods. An oxygen consumption calorimeter will be assembled to capture and measure heat release characteristics during tests using the UL 790/1703 test fixture.

Based on these results, the UL researchers will develop a burner test rig and run a series of experiments to evaluate and validate the performance of the new burner. Once this is complete, the UL1703 and UL 2703 STPs will consider a revised fire classification test procedure using the new burner. This research and development is under way and is expected to be completely by the end of 2013.

CONCLUSIONS

UL has conducted research over a period of years to develop a new fire classification test that can more accurately evaluate the effects of a PV module or panel on the fire classification rating of roof coverings. This research has produced the following findings:

- For burning brand tests in which the brand is placed between the PV module and the roof surface, a Class B brand is the closet representation of actual materials likely to collect in this area.
- The critical flux values for ignition of low slope and steep slope roofing products and for crystalline silicon PV modules were found to be generally consistent for products in the same category (validating module 'typing' as a means to streamline testing requirements).
- The first to ignite (roof covering), second to ignite (PV) concept was demonstrated as a viable method for assessing the flammability performance of a system composed of PV, roof covering, and mounting hardware.

Based on these results, a Task Force of the UL 1703 STP developed a draft for a new fire classification test procedure. The new procedure requires the following tests be performed to derive the fire classification rating for the system:

- spread of flame test on the top surface of module or panel,
- spread of flame test at roof and module or panel interface over representative steep or low sloped roof,
- burning brand test on module surface over representative steep sloped roof, and
- burning brand test between the module or panel and representative steep sloped roof.

Following a series of stakeholder meetings and public comment periods, the proposal was revised and in July 2013 the UL STP voted unanimously to approve the new fire classification test procedure. In adopting the new procedure, the STP also recognized that further clarifications and refinements are needed. Some of these potential refinements may include:

- defining additional PV module types in order to address new and old products not currently covered by the existing 3 types, and
- adding flexibility for the standard baseline roof types that meet the 48-inch to 72-inch fire performance criteria. (Recent tests have shown challenges in choosing commercially available roof coverings (within the parameters of the new standard) that also satisfy the baseline requirement.)

In addition to any changes anticipated for ANSI/UL 1703-2013, the UL 2703 STP will consider incorporating the new Fire Classification Test Procedure into that standard. Beyond that, further research is needed in two areas—industry solutions (system tests thatå will help reduce the number of component tests otherwise required to determine system ratings) and completion of a new, calibrated burner flame source that will reduce variability and increase repeatability of tests using commercially available roof coverings.

ACRONYMS

ANSI	American National Standards Institute
EPDM	ethylene propylene diene monomer
FARP	floor and radiant panel
fpm	feet per minute
FR	fire retardant
kW/m^2	kilowatts per square meter
LIFT	lateral ignition and flame travel
PV	photovoltaic
Solar ABCs	Solar America Board for Codes and Standards
STP	Standards Technical Panel
UL	Underwriter Laboratories, Inc.
W/cm^2	watts per square centimeter

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