Flammability Testing of Standard Roofing Products

In the Presence of Standoff-mounted Photovoltaic Modules

A Solar ABCs Interim Report

Solar America Board for Codes and Standards

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Andrew Rosenthal, Larry Sherwood, Bill Brooks, Pravinray Ghandi, and Bob Backstrom

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Executive Summary

The object of these tests was to investigate whether and how the presence of standoff-mounted PV arrays may affect the fire class rating of common roof covering materials. In particular, these tests were initiated in response to questions from stakeholders about the language in the UL Guide Card that stated that PV modules may or may not reduce the fire class rating of roof coverings when modules of a lower rating are installed above a roof covering with a higher rating.

In the Summer of 2009, the Solar America Board for Codes and Standards (Solar ABCs) in partnership with Underwriters Laboratories Inc. (UL) designed and conducted tests to characterize the effects of stand-off mounted (elevated, parallel to roof surface) PV modules on the fire rating of Class A rated roofing systems. All tests were conducted by UL in Northbrook, IL, with assistance from representatives of Solar ABCs. Funding for this research was provided by the U.S. Department of Energy.

To assess flammability, "spread of flame" and "burning brand" tests were used. These are UL/ASTM standard tests that are conducted on all roofing systems (during UL 790 certification) as well as on all PV modules (during UL 1703 certification). However, flammability tests are ordinarily performed on either a roof covering or a PV module in isolation. The current tests applied fire and burning material to the roof covering while rack-mounted PV was present. Therefore, unlike UL1703 which evaluates the properties of a PV module in isolation, the current tests were conducted to examine combined effects of 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.

In all cases, when the burning brand was placed on top of either Class A or Class C modules (the standard test geometry from UL 1703) the roof system was found to remain compliant with Class A requirements. However, when the brand was placed on the Class A rated roof covering beneath Class C rated PV modules (a test geometry not defined in either UL 1703 or UL 790) the roof covering remained in compliance with Class A requirements in some cases and in some cases it did not. Multiple tests placing the brand on Class A-rated roof coverings beneath Class A rated PV modules resulted in the roof covering failing to meet the Class A requirements in all cases. Table E1 summarizes the results of the burning brand tests.

Table E1. Results of Burning Brand Tests

Roof Rating	PV Rating	Brand Size / Position	Fire Performance Result
A	C	Class A / PV	Compliant
A	C	Class A / Roof	2 Compliant/ 1 not compliant
C	C	Class C / Roof	Not compliant
A	A	Class A / Roof	Not compliant

During the spread of flame tests it was observed that any panel (even a noncombustible one) mounted at a range of gap heights (standoff) typical of many PV arrays increased the temperature and heat flux present at the roof surface when the flames were applied between the panel and roof. The increased temperature and heat flux are the result of a "channeling effect" through which the panel holds hot gases and flame closer to the roof surface not allowing them to dissipate as they do when not confined. Due to this effect, in all cases, the presence of either Class C or Class A modules mounted above Class A roof materials resulted in the roofing assemblies failing to meet the Class A spread of flame test requirements (i.e. flame spread of greater than 6 feet was observed). Table E2 summarizes the results of the spread of flame tests.

Table E2. Results of Spread of Flame Tests

Roof Rating	PV Rating	Flame Spread
A	C	Greater than 8 ft.
A	A	Greater than 8 ft.
C	C	Greater than 8 ft.
Noncombustible	C	Greater than 8 ft.
Noncombustible	A	Greater than 8 ft.

When comparing spread of flame test results for Class A versus Class C modules, both types were found to fail the tests with the same frequency. It should be noted that spread of flame test failures due to the "channeling effect" would not occur for building integrated PV arrays or arrays that mount directly onto the roof surface with no gap.

Though not part of the initial test plan, a few methods were examined for their potential to prevent the channeling effect observed in the spread of flame tests. Some of these experiments with noncombustible flashings and screening showed great promise, others none at all. Further tests to define and characterize mitigation methods will be conducted in the next phase of the effort.

The effect of varying the setback of the module leading edge from the leading edge of the roof was also studied. The greatest temperature rise was observed when the PV modules were placed in line with the leading edge of the roof. Increasing the setback distance resulted in lower surface temperature measured on the roof.

After completing this round of research, the Solar ABCs and UL convened two meetings with a cross section of volunteer scientists and engineers from the PV industry, the enforcement community, other nationally recognized testing laboratories, and the National Institute of Standards and Technology (NIST). The attendees at these meetings formed a working group that has provided extensive review of the tests that were performed, commented on interpretation of all results, reviewed and revised the content of this Interim Report, and, most importantly, determined and defined the specific tests and objectives for the next round of research. Description of the tests and objectives developed by the PV flammability working group for the next round of research is included in Appendix A.

Based on the current round of testing, reviews and comments by the PV flammability working group and the steering committee of the Solar ABCs, our recommendations are as follows:

1. At present, field experience and thorough review of fire incident data do not indicate an urgent need to revise current practice with regard to code requirements. A major task in the next round of research will be to quantify the potential risk identified by the test results.
2. Further investigation is required to refine the pass/fail criteria for a fire performance test for systems that includes roofing materials as well as the PV array. In addition, tests should be conducted to identify effective means of mitigating fire spread by this roof/PV system. (These tests are presented in Appendix A.)
3. Meetings should be held with fire safety authorities, the solar industry and other interested stakeholders to discuss these test results and determine future test requirements, as needed.
4. Results of these tests and of subsequent stakeholder meetings should be communicated to the UL 1703 Standards Technical Panel for their consideration regarding impact of these results on that test standard.

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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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1.0 General Background on Photovoltaics and Fire Safety

As the number of rooftop photovoltaic (PV) systems increases, questions and concerns about fire service response procedures for buildings with PV modules and systems have never been more prevalent. These questions and concerns fall into three categories.

First, in what ways are PV modules and systems designed and installed to prevent ignition of building fires? Modern qualification tests for PV modules are designed to ensure the integrity of PV modules in order to prevent failures that can result in arcing and fires. Similarly, system installation codes for PV (such as the *National Electrical Code*) are constantly updated to address the issue of preventing or controlling PV-initiated fires. Code compliant system designs require elements such as bypass diodes in modules and overcurrent devices in source circuits, as well as adherence to rigorously-developed design rules that specify wire protection, types and sizes, balance of system (BOS) and other component ratings, etc. to reduce the risk of PV-initiated fires.

Second, in what ways can PV systems be installed that protect public and first responder safety in the event of a structural fire and enable fighting a fire if one occurs? In April 2008, the California Department of Forestry and Fire Protection - Office of the State Fire Marshal (CAL FIRE-OSFM), published a guideline for PV installations specifically to address these safety concerns for all structures equipped with rooftop PV systems. It presented certain installation rules for PV systems that mandate necessary signage and specified setbacks and row spacing that ensure that firefighters can use well-developed fire fighting and suppression techniques. The California installation guideline is only the latest action by public safety professionals in this area.

Finally, can the presence of a rooftop PV system contribute to the intensity or spread of a structural fire? It is this third category that was the subject of a series of recent laboratory tests that are being reported in this Solar ABCs Interim Report. These tests were designed specifically to evaluate how PV and roof material interact as a system during exposure to fire and burning material.

1.1 The Role of Underwriters Laboratories in Fire Safety Testing

Underwriters Laboratories Inc. (UL) provides safety and performance testing for thousands of materials and products including both roof covering materials (e.g. shingles) and PV modules. Roofing systems undergo a suite of tests covered in 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 burning, burn through, and spreading of flames receive a Class A rating. Materials with less resistance receive a Class B or C rating. Discussion of requirements for these fire class ratings are presented later.

PV modules undergo safety testing to another standard, UL 1703 – *Flat Plate Photovoltaic Modules and Panels*. While this standard describes a suite of tests designed to stress the module physically, environmentally, and electrically, it also subjects modules to a specific subset of UL 790 that results in determination of a fire rating for each PV module.

2.0 Reasons for Conducting the Fire Safety Tests

The testing that is reported in this Interim Report was conducted in response to questions that arose during the development of the Cal Fire OSFM (Office of State Fire Marshall) *Solar Photovoltaic Installation Guidelines*. These questions were restated during discussions held in San Jose, CA on 20 March 2008 between members of the California Solar Energy Industries Association (CALSEIA) and Underwriters Laboratories (UL). CALSEIA requested the meeting to discuss three areas of concern that CALSEIA members had with UL listing requirements or documents. The three areas of concern were listing requirements for various mounting brackets, the need to develop new testing and listing for grounding lugs, and specific language about fire rating for roofs with rack mounted PV arrays contained in the UL Guide information referenced in the 2007 UL White Book.

Regarding the fire rating issue, the language of concern was:

> *Installation of modules on or integral to a building's roof system may 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.*

CALSEIA noted that fire officials had raised concern over the ambiguity in this statement with regard to the most common residential PV roof installation, Class C PV modules mounted over Class A rated roofs. This illuminated the fact that there was a lack of fire test results on systems including PV modules in roof-mounted configurations. Industry representatives requested that UL work to bring clarity to this concern.

In response, UL changed the language of the Guide Card as follows:

> *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.*

UL also agreed that additional testing was necessary to fully address the concerns expressed by fire officials and CALSEIA. Though roof covering materials and PV modules both receive 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 comprised of PV 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 ABCs developed a test plan to answer these questions.

2.1 Notes on UL 790 Flammability Testing

Throughout this paper, the experimental results of flammability testing as defined in UL 790, "Tests for Fire Resistance of Roof Covering Materials", will be discussed. Fire performance ratings are determined using three different fire tests described in UL 790: spread of flame test, intermittent flame test, and burning brand test. As stated above, PV modules also obtain fire class ratings. During UL 1703 testing, PV modules undergo a subset of the UL 790 tests that includes a burning brand test and spread of flame test. A general understanding of these tests is necessary to use this paper and interpret its results. (Note: for brevity, the intermittent flame test is not described below since it was not used during the testing reported in this Interim Report.)

The spread of flame test applies a natural gas fueled flame of approximately 3 feet in width driven by moving air at a velocity of 12 mph. and measures the potential for flames to spread across a surface. The intensity of the flame is controlled with greater intensity applied during the Class A test (1400°F) and reduced intensity during the Class C test (1300°F). During the Class A test, flame is applied for 10 minutes. The Class C test applies flame for 4 minutes. Either test is failed if the flame spreads beyond a specific maximum defined for each test (6 feet for Class A, 8 feet for Class B, 13 feet for Class C). The test also fails if fire spreads laterally to both edges of the 40-inch wide sample surface, burning or glowing material falls from the sample and continues to burn or glow or a combustible roof deck is exposed as a result of testing. During PV testing to UL 1703, the test fails if burn through of the PV module is observed.

As will be seen below, some of the spread of flame tests were conducted using noncombustible roof surfaces. It is important to understand that determination of fire class rating using the spread of flame test is based on the observed distance flame travels during the test and that ignition of the roof covering is not required for determination of results.

The burning brand test measures the potential for fire to penetrate from outside a roofing material (or, in the case of UL 1703 tests, a PV module) to the underside of a combustible roof deck. The source of fire is a burning brand, a measured stack of dry wood that is ignited and burns with known properties. The mass of the burning brand for Class A testing is 2000 grams (single brand) and for Class C testing the mass is 9.25 grams (20 brands). In the case of tests for roof coverings, a successful result is obtained if no sustained flame or burning is observed on the underside of the test deck and burning particles have not fallen to the floor and continued to burn. For PV module testing, all of the following conditions must occur for a successful result to be obtained: no part of the module falls to the floor in flames or while glowing, the brand does not burn through the module and through the roof covering below, and there is no sustained flaming of burning of the module itself.

3.0 Tests Conducted

In the Summer of 2009, the Solar America Board for Codes and Standards (Solar ABCs) in partnership with Underwriters Laboratories (UL) designed and conducted specific tests to characterize the effects of stand-off mounted (elevated, parallel to roof surface) PV modules on the fire rating of Class A rated roofing systems. All tests were conducted by staff members of UL's Corporate Research Division in Northbrook, IL, with assistance from representatives of Solar ABCs. The tests included the "burning brand" test and the "spread of flame" test normally conducted on PV modules during UL 1703 certification of all PV modules but with a major difference. During UL 1703 certification testing, fire and burning materials are 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. Therefore, unlike UL1703 which evaluates the properties of a PV module alone in isolation, the current tests were conducted to examine combined effects of modules and roof coverings as a system when exposed to fire and flame. Tests were designed to use the methods of UL 790 to evaluate different combinations of modules, stand-off heights, and roofing materials.

The test plan was initially designed to be conducted in two phases and, based on the results obtained, a subsequent third phase of testing was added. The objectives of the three test phases are described as follows:

Phase I (non-combustible panels mounted over non-combustible roof decks, limited tests using actual PV modules mounted over roof assemblies):

1. Establish baseline data of fire exposure on roof deck samples without PV according to UL 790
2. Determine the effects of stand-off height and leading edge setback on results of UL 790 testing with non-combustible materials.

Phase II (Class A and C fire rated PV modules mounted over standard roofing systems)

1. Determine the effects of varying PV installation parameters on Class A and C rated PV modules on UL 790 test results
2. Determine the impact of lesser fire rated PV modules on common roofing systems
3. Investigation of potential mitigation techniques.

Phase III (Class A and C fire rated PV modules mounted over standard roofing systems)

1. Validation of Phase II results
2. Further investigation of mitigation techniques.

4.0 Test Results

4.1 Phase I Test Results – Baseline Test and Tests with Noncombustible Materials

The first task of Phase I was selection of the different roofing products and PV modules that would be used during all subsequent tests. Five different roofing systems were selected for use: *asphalt impregnated fiberglass matt three tab shingle, asphalt impregnated fiberglass laminated mat or 'architectural' shingle, cedar shake shingle, 2" thick rigid Isocyanurate foam covered with a single ply of Ethylene propylene diene monomer (EPDM) membrane, asphalt-coated glass-fiber mat (felt) – Type G1 (ply sheets), and a Type G3 (granular surfaced).* The PV modules selected for testing were not identified or sorted by model or manufacturer. The only characteristic of the PV modules recorded during testing was each module's original fire class rating, either Class A or Class C.

All tests in Phase I were performed on a roof with a standard slope of 5:12 (23°) and with a noncombustible PV module mounted parallel to the roof surface. PV modules were mounted on adjustable, metal rods so that the stand-off height (called Gap in this report, the distance between the back of the module and the roof surface) could be selected. During the first round of testing, gap heights of 2.5, 5 and 10 inches were used. Roof mounts also enabled the adjustable placement of the module so that the distance between the leading edge of the roof and the leading edge of the module, the setback, was also selectable. During the first round of testing, setback lengths of 0, 12, and 24 inches were used. The test assembly was fitted with thermocouples, heat flux gauges, and bi-directional velocity probes to record experimental conditions during testing. Automated data acquisition equipment sampled data from all sensors at a 1 second rate during testing.

Phase I testing began with a series of spread of flame tests performed using noncombustible roof materials and noncombustible panels (in place of actual roofing systems and PV modules). This series of tests was designed to assess the influence of any noncombustible stand-off structure mounted above a roof surface on temperature rise and heat flux.

The first test used no panel above the roof covering (stated another way, the gap was infinite). This was conducted to provide a baseline of temperature rise and heat flux on the roof surface during flame exposure in the Class A spread of flame test of UL 790. Eleven tests then followed using the noncombustible panel mounted above the roof surface at various gap heights and setback distances from the roof's leading edge. These tests were conducted for five minutes.

The results of the first set of tests were consistent. When mounted to simulate PV modules, even noncombustible panels used during the spread of flame test, held hot gases closer and for longer distances near the roof surface. This "channeling effect" of hot gases significantly raised the temperature and heat flux at the roof surface making it more difficult for the roofing system to pass the spread of flame test. The magnitude of this effect was found to be a function of both gap height and setback distance. Increases in temperature and heat flux were greatest at 5 inch gap height and less at a gap height of 2 inches. At a gap height of 10 inches, there was less of a difference in temperature and heat flux at the roof surface compared with baseline. With regard to setback distance, the temperature rise was greatest with zero setback and least as setback distance was increased to 24 in.

The results of the first round testing indicated that worst case conditions occurred when gap height was 5 inches and setback was 0 inches. These conditions were used for the next round of testing. In this round, two spread of flame and two burning brand tests were conducted using actual PV modules and roof covering materials. All tests utilized Class C PV modules mounted over Class A shingle roofing.

For the two spread of flame tests, one test utilized vertical mounting rails (rails running up the slope of the roof) while the second test utilized horizontal mounting rails (rails running parallel to the roof's edge). Both spread of flame tests resulted in flames extending beyond the roof decking in excess of 8 feet before the ten minute requirement for Class A rating had been reached. That is, in both spread of flame test cases, the results of mounting Class C modules above Class A roof materials resulted in the roofing assemblies failing to meet requirements under the Class A spread of flame test.

For the two burning brand tests conducted during this round, the first evaluated the results of placing the burning brand on top of the module surface and allowing it to burn. The second evaluated the results of placing the burning brand on the roof surface beneath the PV module (within the 5 inch gap between module and roof). In the case of the burning brand test with Class A PV module mounted on a Class A roof system, the roof system was compromised (i.e. no longer met Class A requirements). In the case of the burning brand test with a Class C PV module mounted above a Class A roof material, the roof system was not compromised.

4.2 Phase II Test Results – Test Matrix of Different PV Modules and Roof Covering Materials

Phase II testing broadened the number of different combinations of PV modules and roofing systems subjected to UL 790 conditions. It had the dual goals of validating the early results from Phase I and of evaluating the possibly greater or lesser severity of flammability attainable by different combinations of PV and roof coverings. The Phase II tests used spread of flame and burning brand methods on a matrix of PV and roof covering combinations.

The spread of flame tests were performed with Class A and C fire rated PV modules mounted over Class A roof coverings (3 tab composition shingles, membrane, architectural shingles, and hot mopped), over Class C roof coverings (wood shake), and over noncombustible roof coverings. During all tests, the gap height was 5 inches and the setback distance was 0 inches. The result for every spread of flame test was flame propagation beyond the length of the roof deck (> 8 feet) and failure to conform to the requirements for Class A systems (< 6 feet).

One finding of the Phase II spread of flame tests has prompted much discussion among reviewers of this paper and bears comment. This regards the results for spread of flame tests involving noncombustible roof coverings. As mentioned above, the results of spread of flame tests conducted on noncombustible roof coverings with rack-mounted PV present was flame spread beyond 8 feet. Determination of fire class rating using the spread of flame test is based on the observed distance flame travels during the test. Thus, based on the standard criteria of the test, the tested systems comprised of noncombustible roof covering with rack-mounted PV failed to conform to Class A requirements. In no case did ignition of the roof covering occur, but this is not required for determination of results.

The burning brand tests were conducted with Class C fire rated PV modules mounted over Class A roof covering (3 tab composition shingle) and Class C roof covering (wood shake). The brand size was based on the roof fire rating – tests involving roofing products rated Class A utilized a Class A brand, tests involving roofing products rated Class C utilized a Class C brand. The Class C designation of the wood shakes was based on identification of such by the supplier and validation testing was not performed.

Results of tests placing the burning brand either on top of or beneath the Class C PV module over a Class A roof passed the requirements for Class A systems. The results of placing the burning brand directly on the Class C roof beneath a Class C module failed to conform to Class C requirements. And a test with the burning brand placed on the surface of a Class A roof material beneath the Class A module failed to conform to the requirements of the Class A system.

The influence of the set back of the leading edge of the modules from the leading edge of the roof was studied. The influence of the PV modules was highest when the PV modules were placed in line with the leading edge of the roof. The greater the distance of the leading edge of the PV from the leading edge of the roof, the lower will be the surface temperature of the roof.

4.3 Phase II and III Test Results - Mitigation Techniques

During Phase II and III testing, a few techniques for mitigating the impact of rack-mounted PV on the fire resistance properties of the roofing system were evaluated. These experiments were not designed to be completed before publication of this paper and were conducted to gain insight into future directions of this work. The mitigation techniques fell into three categories: the use of various configurations of flashings and screens to block fire from passing between module and roof, the use of increased setback of rack-mounted PV from the source of flames, and application of non-combustible panels to the back of the rack-mounted PV modules.

The mitigation methods showing the most promise will receive further tests to fully characterize their ability to mitigate effects of standoff-mounted PV on flammability properties of roof coverings.

5.0 Discussion

The object of these tests was to investigate whether and how the presence of standoff-mounted PV arrays may affect the fire class rating of common roof covering materials. In particular, these tests were initiated in response to questions from stakeholders about the language in the UL Guide Card that stated that PV modules may or may not reduce the fire class rating of roof coverings when modules of a lower rating are installed above a roof covering with a higher rating.

In preparing this study, the authors had many discussions with PV and fire safety professionals. In no case was anyone aware of a wind driven rooftop fire intensified by the presence of PV modules. The authors also conducted a review of fire incident data (National Fire Incident Reporting Systems) and found no record of any building fire in which wind driven flames or brands have travelled along a rooftop equipped with a rack-mounted PV array. In the case of recorded fire incident data, however, it should be noted that records often do not include details of this kind.

The results of testing demonstrated that any panel (even a noncombustible one) mounted at a range of gap heights (standoff) 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” 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.

As a result of this “channeling effect,” PV modules of any fire rating (Class A or C) mounted in a 5 inch standoff 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. Testing also determined that Class A rated PV modules mounted at a 5 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. When this test was performed using Class C modules, the test results were inconsistent.

Finally, initial testing found mitigation techniques that show promise of preventing the degradation of roof covering fire class rating by rack-mounted PV modules. These techniques will be tested further.

After completing this round of research, the Solar ABCs and UL convened two meetings with a cross section of volunteer scientists and engineers from the PV industry, the enforcement community, other nationally recognized testing laboratories, and the National Institute of Standards and Technology (NIST). The attendees at these meetings formed a working group that has provided extensive review of the tests that were performed, commented on interpretation of all results, reviewed and revised the content of this Interim Report, and, most importantly, determined and defined the specific tests and objectives for the next round of research. Description of the tests and objectives developed by the PV flammability working group for the next round of research is included in Appendix A.

6.0 Recommendations

PV flammability group recommendations for the next round of research are included in Appendix A. Based on the current round of testing, reviews and comments by the PV flammability working group and the steering committee of the Solar ABCs, our recommendations are as follows:

1. At present, field experience and a thorough review of fire incident data do not indicate an urgent need to revise current practice with regard to code requirements. A major task in the next round of research will be to quantify the potential risk identified by the test results.
2. Further investigation is required to refine the pass/fail criteria for a fire performance tests for systems that includes roofing materials as well as the PV array. In addition, tests should be conducted to identify effective means of mitigating fire spread by this roof/PV system. (These tests are presented in Appendix A.)
3. Meetings should be held with fire safety authorities, the solar industry and other interested stakeholders to discuss these test results and determine future test requirements, as needed.
4. Results of these tests and of subsequent stakeholder meetings should be communicated to the UL 1703 Standards Technical Panel for their consideration regarding impact of these results on that test standard.

Appendix A

Test Objectives and Test Plan Developed by the PV Flammability Working Group For the Next Round of Research by the Solar ABCs

RESEARCH OBJECTIVES

There are two main objectives for the next round of research.

The first objective of the next round of research will be to provide specific tests and procedures that can be applied to PV installations and components to verify that they will have no impact on the fire rating of the roof assemblies (with an emphasis on Class A rated roof assemblies).

The second will be to develop these tests and procedures into the form needed to serve as input for modifications to existing codes and standards such as UL1703, ICC, Model Codes, etc.

TEST PLAN

1. Conduct Class A Spread of Flame tests on Class C PV module mounted over Class A roofs to see if the roof assembly will routinely pass Class A Spread of Flame test. Conduct tests for three different geometries, different module types, and over non-combustible roof products.

2. Verify the Burning Brands Tests previously conducted in order to define when mitigation is required. Conduct tests for different brand locations, different module types, and different roof types including non-combustible roof products. Investigate potential caloric load of debris accumulated under solar array to determine which size burning brand is appropriate for placement between the PV modules and the roof assembly.

3. Conduct Class A Spread of Flame tests for modules at tilts that are not parallel to the roof surface in order to determine how their performance compares with tests conducted on modules parallel to the roof surface.

4. Perform research to quantify the potential risk identified by the test results. A fire protection research engineer, economist, or actuarial insurance consultant will be hired to conduct this research.

5. Test several Spread of Flame mitigation techniques in order to develop mitigation recommendations. Document all test methods for preparation of recommendations so that these may be added to existing standard.

6. Develop and test Burning Brand mitigation techniques in order to provide mitigation recommendations. Tests to be developed after Item 2 tests define when mitigation is required. Develop language for required maintenance and cleaning between module and roof assembly.

7. Conduct Spread of Flame test on a large array to learn if tests conducted on single modules scale accurately to arrays with many modules.

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