

Functional Performance Testing of ArcBox Solar Fire Safety Enclosure

A range of functional performance tests for the ArcBox were developed by experts in fire and PV safety and clearly demonstrate the effectiveness of the product in helping prevent dangerous DC connector arc faults from developing into a fire.

1.0 Background

ArcBox is a simple, low-cost, and innovative approach to reducing the fire risk associated with solar PV systems. The ArcBox enclosure simply snaps around a DC connector, protecting it in use. In the event that an arc fault occurs, it is safely contained and doesn't spread to combustible materials in or around the solar installation.

As a category-creating product, there are currently no established standards or test procedures for this specific device or for broader arc containment. Consequently, subject matter experts were consulted to devise a series of rigorous tests that could be carried out by independent fire testing laboratories.

2.0 Tests with Flat Roofing

INDEPENDENT TEST LABORATORY: Slovenian National Building and Civil Engineering Institute Fire Testing Laboratory (ZAG), April 2024

2.1 Test Design

PV fire incidents on flat roofs are technically complex and often poorly understood. The introduction of PV systems can alter fire dynamics, frequently exacerbating risks despite the use of fire-retardant roofing membranes. While individual components may carry relevant fire ratings, these ratings often fail to reflect real-world behaviour, as the complete system can behave quite differently during a fire.

To determine if installing an ArcBox can prevent the spread of fire, an independent functional performance test for a flat roof system was performed by ZAG fire test laboratory. Test rig construction and methodology was designed in collaboration with fire experts at ZAG in conjunction with:

- Tracy Bradford - Senior Lecturer in Fire Safety Engineering University of Central Lancashire
- Folkert van der Ploeg - Fire Investigator, Brandweer Twente, the Netherlands
- Prof. Ali Nadjai - Director of Fire Safety Engineering Research Technology University of Ulster

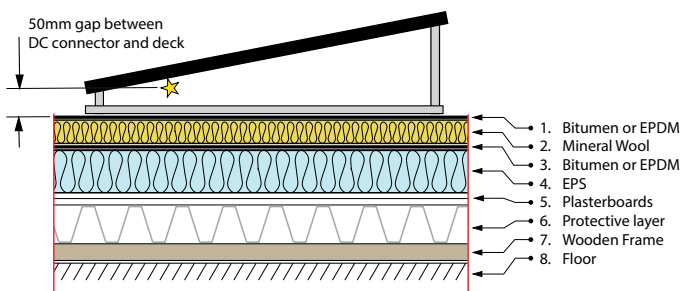


Figure 1. Flat roof test rig showing build up - layers 1-4 representing the roof, and 5-7 protecting the floor

Eight test scenarios were chosen as a broad representation of common industry practice, as shown in Table 1.

Membrane	Fire Retardant EPDM		Fire Retardant Bitumen	
	Layout	E-W	South	E-W
With ArcBox	Test 1	Test 7	Test 5	Test 3
Without ArcBox	Test 2	Test 8	Test 6	Test 4

Table 1- Test scenarios for flat roof functional assessment

Tests were performed using two common types of combustible flat roofing materials, fire retardant EPDM and Bitumen, with and without ArcBox and in two layouts corresponding to an East-West configuration and a South facing configuration.



Figure 2 - Flat roof solar configurations. South facing configuration



Figure 3: Flat roof solar configurations. East-West facing configuration

A DC connector was modified to allow it to slide freely on one side, with the corresponding mating half fixed. In this way a gap can be opened between conductors across which an arc can be maintained for the duration of the test.

A current of 35A was maintained in the circuit while continuous adjustments were made to the connector spacing to maintain an arc for the test period of five minutes. This time was chosen to be a plausible worst-case, being comfortably long enough for an arc of this energy to completely destroy the connector and self-extinguish.

The DC connectors were secured 50mm above the roofing membrane so that, in accordance with industry best practice, the connectors remained out of direct contact with the roofing membrane throughout the experiment.

2.2 Results

The ArcBox successfully prevented ignition from DC connector arc failures, thereby halting fire spread beneath the PV installation. This result was consistent across all scenarios.

Conversely, without the ArcBox, the same arcing events led to significant flaming, resulting in membrane ignition despite the deliberate elevation of the connector away from the deck. Once established, fire quickly spread across the area beneath the PV panels, as shown in Figures 4-6.



Figure 4 - E-W format test without ArcBox and high energy arc visible

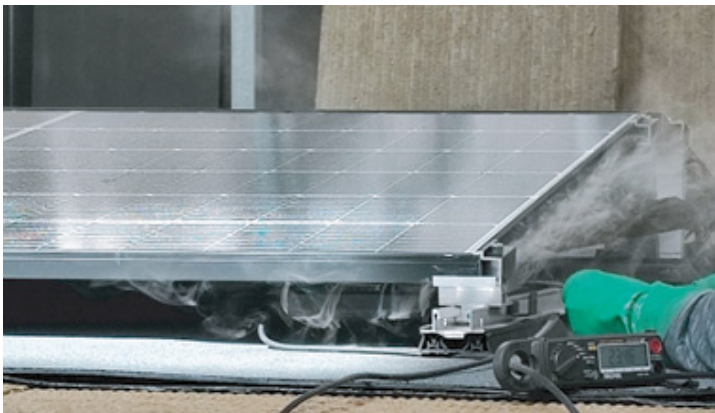


Figure 5 - E-W format test with ArcBox showing only smoke venting



Figure 6 - E-W format test without ArcBox showing rapid development of fire across the roof covering behind the panels

3.0 Tests with In-Roof Solar Mounting Systems

INDEPENDENT TEST LABORATORY: BDA Testing B.V. Netherlands Fire Safety and Security Laboratory, March 2023

3.1 Test Design

Roof-integrated solar, which replaces tiles or slates on the roof, results in cables and connectors in close proximity to combustible materials like tile support battens and rafters (timber), roofing membrane (polymer) and insulation (typically rigid polymer foam). Some in-roof mounting systems further increase the fuel available by adding combustible polypropylene mounting trays behind the solar panels to direct rain water runoff.

A series of tests were undertaken to assess the effectiveness of ArcBox at preventing the development of a fire from a DC connector fault in roof-integrated solar systems. The tests were developed in collaboration with:

- RJ de Jongh of KIWA BDA Testing B.V.
- Dr. Thomas Betts of Loughborough University

Two popular integrated solar systems were tested – a bespoke system with roof-integrated panels fitting directly above the tile battens and a second consisting of a plastic mounting tray supporting a standard solar panel.

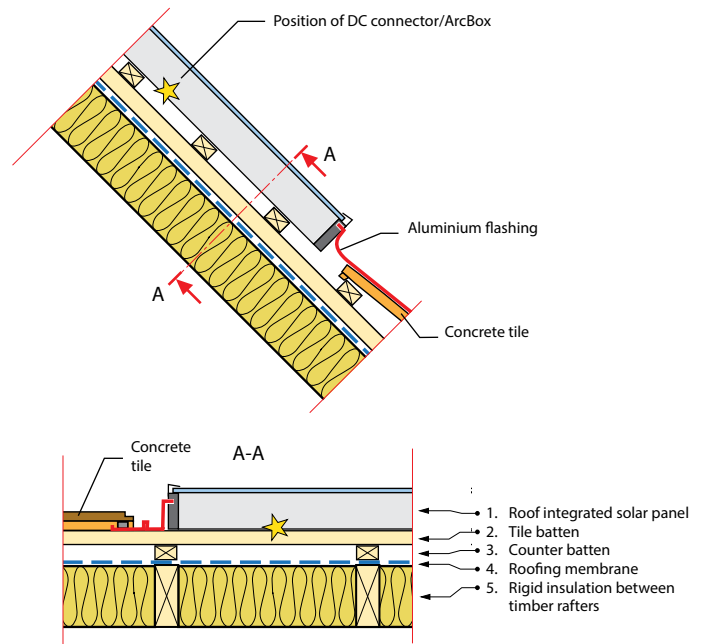


Figure 7 - Roof integrated solar test rig showing build up - bespoke panel system without plastic tray

The investigation was independently conducted at KIWA BDA Testing B.V, the Netherlands with the laboratory staff in full control of the experiment.

In all tests conducted, the solar systems were mounted on identical pitched roof constructions consisting of PIR rigid foam insulation boards sandwiched between 140x40mm rafters on a 600mm spacing, breathable membrane, 46x21mm counter battens fastened to the rafters and 46x21mm tile battens with spacing of 330mm.

As in the flat roof tests, the DC connector was modified to allow it to slide apart. A constant current was passed through the connector while adjusting positioning of the two halves to maintain arcing for a test period of five minutes.

3.2 Results

The test demonstrated that electrical arc caused by an electrical fault in a DC connector unprotected by an ArcBox will ignite nearby roofing materials and start a fire. By contrast, all tests performed with the DC connector in an ArcBox were safely contained and failed to initiate a fire in the surrounding roofing materials.

The plastic tray in-roof mounting system performed significantly worse. The tray itself quickly became involved in the fire and accelerated its spread, necessitating an early end to the testing for safety reasons.

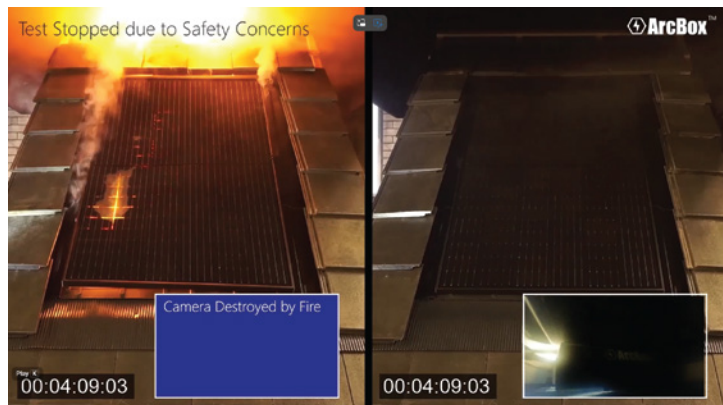


Figure 8 - LEFT test without ArcBox at 4 minutes - plastic tray mounting system - showing highly developed fire. RIGHT with ArcBox showing the containment of the arc and absence of fire.

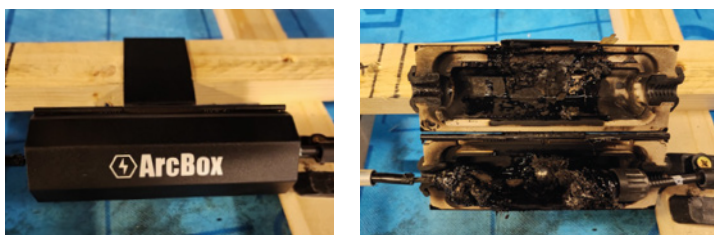


Figure 9 - ArcBox after test completion. LEFT - closed and showing intact roofing materials in the vicinity. RIGHT - opened and showing the almost complete destruction of the DC connector

4.0 Conclusions

The testing showed that DC solar connectors in a fault condition have the capacity to initiate large-scale fires for both roof-integrated solar and above-roof solar installations.

Developed in collaboration with respected fire experts, the experiments covered a challenging range of scenarios that place combustible construction materials in close proximity to the solar system. With tests performed by leading independent fire test laboratories, ArcBox proved its ability to contain and mitigate the risk of solar fires.