Insulation Manufacturers Association

Fire performance of thermal insulation products in end-use conditions

Comparative tests to assess the fire behaviour of a flat roof assembly with PIR and stone wool insulation products and a reinforced bituminous membrane below a PV system.

Summary document

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Insulation Manufacturers Association (IMA) is the Trade Association that represents both the polyisocyanurate (PIR) and polyurethane (PUR) insulation industry in the UK. Its members manufacture rigid insulation that provides around 40 per cent of the total thermal insulation market into the UK. IMA's membership comprises all of the major companies in the industry, including manufacturers of finished PIR and PUR insulation products, as well as suppliers of raw materials and associated services.

IMA represents the industry's views across all government and industry stakeholders and decision makers and promotes a positive and dynamic business environment for the PIR and PUR insulation industry in the UK.

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This document should be read alongside the full report from Fire Protection Association which can be found **here**

Contents

Executive summary

The Fire Protection Association (FPA) carried out two comparative fire tests on flat roof assemblies with identical reinforced bituminous roofing membranes, but with two different insulation products. Four PV panels were mounted above. The spread of fire on the roof surface and the fire penetration were assessed.

The tests were performed in an enclosed burn hall in order to minimise wind influence which could be expected if the tests were conducted outside.

A 15kW propane burner was applied below one PV panel for ten minutes to represent a localised fire starting below the PV system. After ten minutes the ignition burner was shut down and the fire was allowed to develop freely until it was extinguished at 21 minutes 50 seconds due to excessive temperatures in the facility's smoke scrubbing system.

Results show that the fire performance of the roof was similar for both the roof with PIR insulation and with stone wool insulation.

In both tests there was no fire penetration through the insulation to the air and vapour control layer (AVCL).

1 Introduction

Fire safety is a critical factor in the design and construction of buildings. PV systems are increasingly installed on roofs to support energy efficiency goals, reduce greenhouse gas emissions and lower energy costs for occupants. This makes it essential for regulators and insurers to have robust, independent research to support informed, risk-based decision-making.

PIR is the preferred thermal insulation material for many flat roof applications. Alongside its strong thermal performance, PIR insulation boards provide good mechanical stability and walkability, enabling the installation and maintenance of PV systems above the insulation and waterproofing layers. Architects, building owners, regulators and insurers therefore need confidence that, in the event of a fire involving PV systems, flat roof constructions incorporating PIR can continue to meet relevant fire safety objectives.

Insulation Manufacturers Association (IMA) commissioned the FPA to investigate how two different fire rated roof insulation products behave when a fire occurs under a PV array, mounted above a flat roof with reinforced bituminous membranes. The objective was to provide technical evidence of fire development on and within the roof assembly when exposed to a PV fire, rather than to qualify individual products against any particular standard.

Two insulation products commonly available on the UK market were selected: a PIR insulation product and a stone wool insulation product. Both were installed to achieve equivalent thermal performance, giving a nominal roof U-value of approximately 0.15 W/m²K. The remaining elements of the roof build-up and the PV configuration, were kept identical between tests so that observed differences could be attributed primarily to the insulation layer.

2 Fire scenario and test environment

Testing took place in a burn hall at the FPA research facility in Gloucestershire, UK. The enclosure was approximately 10 m by 10 m with a height of 5 m with a smoke extraction and scrubbing system and a fire suppression installation.

The tests simulated an external fire originating below an array of four PV panels mounted in east-west configuration above a flat roof. A 15kW propane gas burner according to CLC/TR50670 regulated by a mass flow controller was positioned beneath one PV panel to deliver 15kW exposure for ten minutes. After this ignition period, the gas supply was shut off and the fire was allowed to develop until it was extinguished after 21 minutes 50 seconds. This was in both tests necessary to prevent damage to the smoke scrubbing system.

Ventilation was provided by a smoke extraction system. For the incoming air vents in the side walls and a partially open roller shutter were available. The wind conditions on the test days influenced the direction of fire spread. In the PIR test the prevailing wind direction was from the east towards the west wall of the hall, whilst in the stone wool test the wind came from the south towards the roller shutter opening.

3 Roof and PV systems

Each roof assembly measured 7.4 m by 8.4 m and was constructed on a timber supporting frame. From the bottom up, the principal components mounted on a wooden roof frame were:

1. Wooden roof frame

2. Steel deck

Thickness – 0.7mm
Depth – 100mm
Primer
Lamellas for infill of outer ends of troughs to prevent airflow

3. Membrane below insulation

Bituminous air and vapour control layer (AVCL)

4. Insulation product (PIR insulation product / Stone wool insulation product)

PIR and stone wool with equivalent thermal performance to achieve a U-value of 0.15 kW/m^2 K.
PIR – Two layers of 80mm each = 160mm total (U-value 0.152 rounded to 0.15) Reaction to fire classification F in accordance with EN1350-1
Stone wool – Two layers of 150mm base layer + 105mm layer (Bonded together then bonded with a PU adhesive) Reaction to fire classification A1 in accordance with EN13501-1
The insulation materials were sourced from the UK market, and the brands are known to the test laboratory.

5. Membrane above insulation layer (Waterproofing layer)

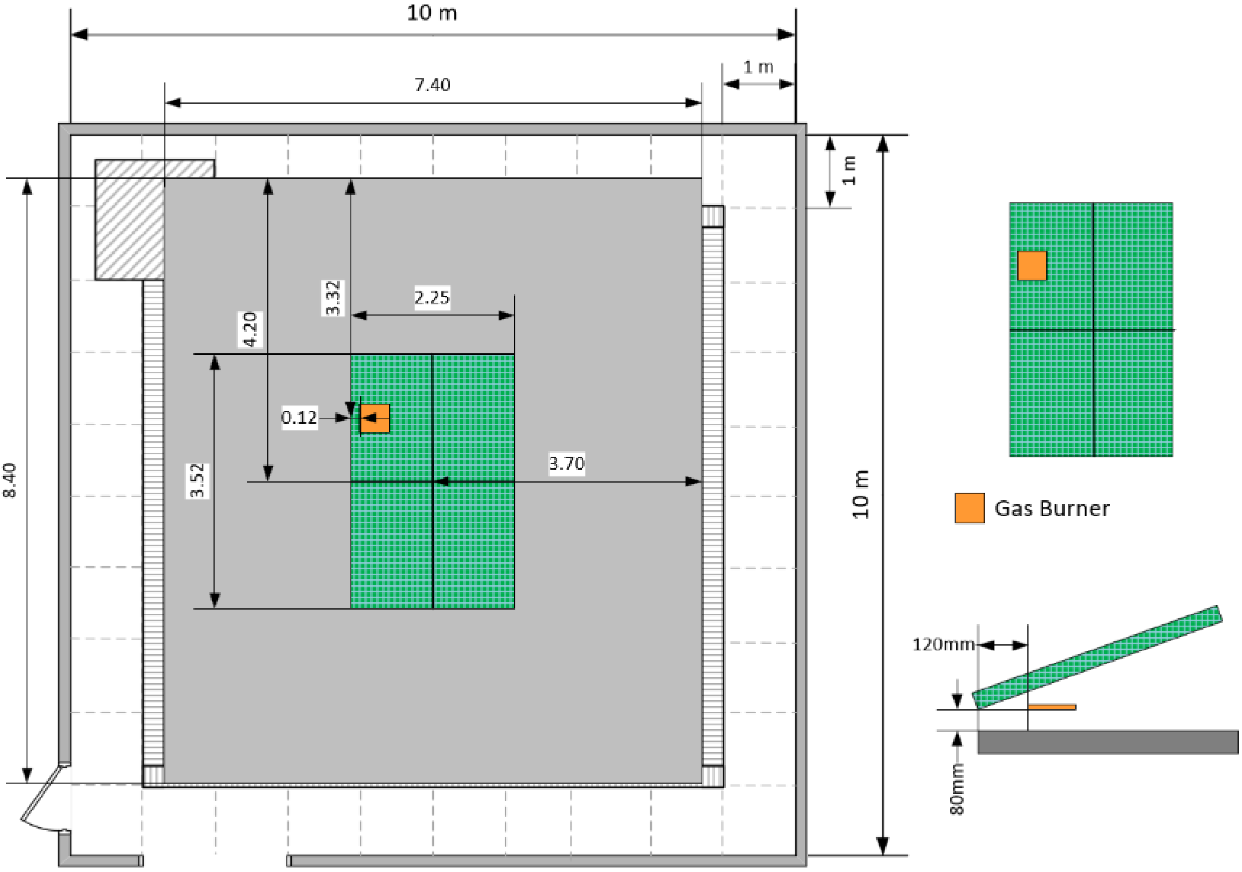
Bituminous self-adhesive underlayer
Torch-applied SBS elastomeric bitumen capping sheet

6. PV panels and mounting system

Mount – K2 D-DOME in East/West orientation
Modules – 4 x Solarwatt classic

The insulation materials and the other components for the roof assembly were sourced from the UK market and the brands known to the test laboratory.

Four foil-backed PV panels were mounted on a proprietary ballast frame in east–west configuration on the roof, covering approximately 2.25 m by 3.52 m. The gas burner was located beneath the centre one of the panels, close to the outer edge of the array (see figure).



PV solar panel and gas burner configuration

4 Instrumentation and measurements

Twenty thermocouples were installed for each test. Nine were located between the roof membrane and the top of the insulation at a distance of 50 cm to the PV array and nine between the underside of the insulation and the vapour control layer below the PV array. Two were placed within the burn hall to monitor hot-gas temperatures at 4 m and 4.5 m above the floor. A data logger recorded all temperatures throughout the tests. Three video cameras captured views from different positions within the hall.

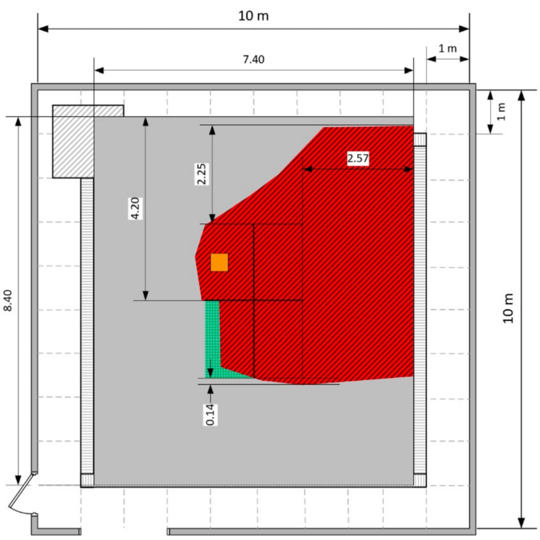
5 Recorded data and observations

Fire development and spread on the roofs

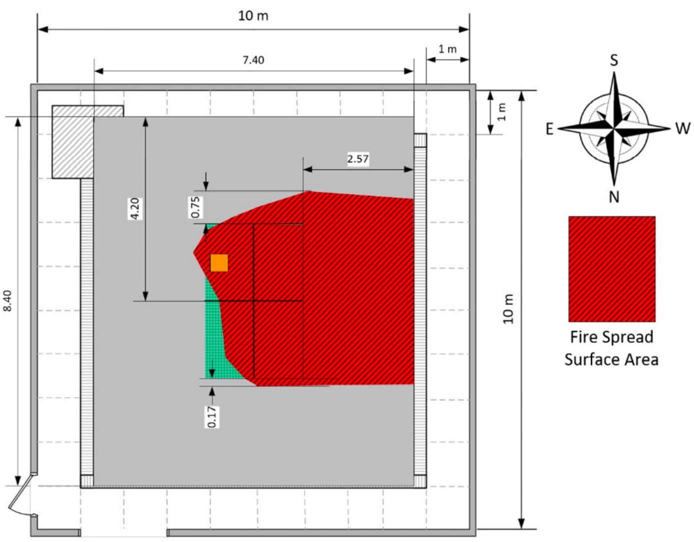
In the PIR test, the panel above the gas burner became fully involved in the fire after approximately six minutes. The opposite panel was fully involved at around seven minutes, coinciding with ignition of the roof surface near the array. The gas burner was turned off at ten minutes, by which time flames were observed on several panels. Fire subsequently spread across the roof cap sheet, with progressive involvement of the remaining panels and visible flaming over much of the western side of the roof. The test was extinguished at 21 minutes 50 seconds due to rising temperatures in the smoke cleaning system.

In the stone wool test, the panel above the gas burner became fully involved after about five minutes and the roof surface ignited shortly afterwards. The opposite panel ignited and became fully involved between seven and ten minutes. As in the PIR test, the gas supply was shut off after ten minutes but the fire continued to grow, with subsequent ignition of the remaining panels and significant lateral flame spread across the roof surface. Fire spread was influenced by the wind direction, with flames and smoke moving predominantly towards the south-west of the roof before test termination.

Post-test mapping of the charred and burned area on the cap sheet showed that in both tests the fire reached the full western edge of the roof, travelling approximately 2.57 m from the edge of the PV array. The total fire spread area, however, differed markedly: the north–south extent was about 0.92 m in the PIR test and about 2.39 m in the stone wool test, giving a noticeably larger affected area in the latter case.



Total fire spread across stone wool insulation roof assembly.



Total fire spread across PIR insulation roof assembly.

Temperatures in and below the insulation layers

Across both tests, thermocouples in the locations, which were closest to the ignition source and the main direction of fire spread, recorded the highest temperatures. In general, thermocouples at the upper interface of the insulation (between the membrane and insulation) showed higher peak temperatures than those at the lower interface (between the two insulation layers and the vapour layers).

The stone wool test showed higher recorded temperatures at most thermocouples within the roof assembly. One sensor recorded a peak temperature above 1200°C, which is assumed to be due to molten bitumen coming into direct contact with the thermocouple. Even excluding this local effect, maximum temperatures 50 cm from the PV array in the south direction were consistently higher in the stone wool test than in the equivalent locations in the PIR test.

Stone wool insulated roof

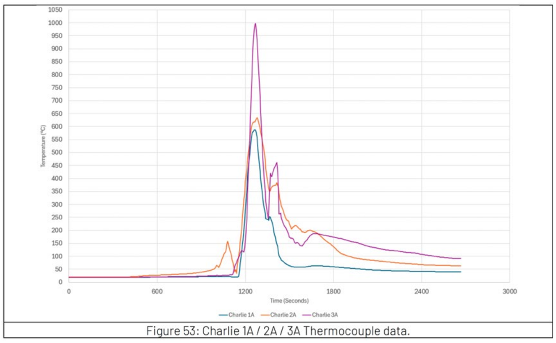


Figure 53: Charlie 1A / 2A / 3A Thermocouple data.

PIR Insulated roof

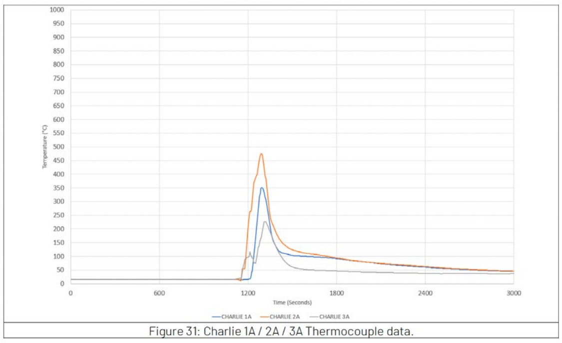


Figure 31: Charlie 1A / 2A / 3A Thermocouple data.

Temperatures between the roof membrane and the insulation layer

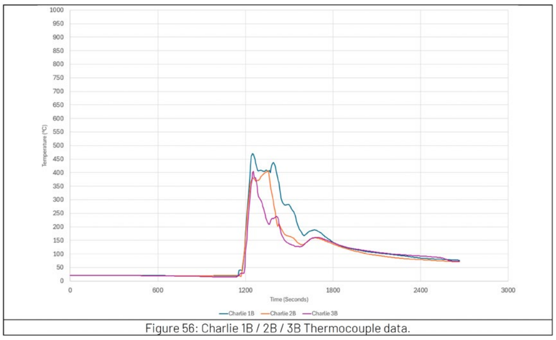


Figure 56: Charlie 1B / 2B / 3B Thermocouple data.

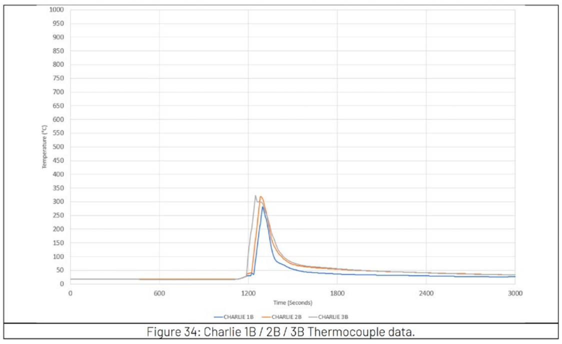


Figure 34: Charlie 1B / 2B / 3B Thermocouple data.

Temperatures below the insulation layers, 50 cm from the edge of the PV array, next to the burner position

6 Damage on and within the roof build-up

After the PIR test, examination of the roof revealed extensive damage and collapse of the PV panels above the ignition area, with charring and loss of the bituminous capping sheet across the main burned zone. The PIR insulation exhibited a charred layer beneath the burned membrane but retained uncharred material at depth. The pattern of damage was consistent with significant burning of the cap sheet and localised involvement of the insulation beneath, rather than full-depth burn-through.

After the stone wool test, the PV panels and capping sheet in the main burned area were also heavily damaged. The stone wool insulation beneath the burned zone showed a deep discoloured region and evidence that molten bitumen had penetrated between boards. This discoloured region extended further across the roof surface than in the PIR test, in line with the larger measured fire spread area on the membrane.

In both tests there was no fire penetration through the insulation layer nor was the AVCL damaged.

7 Summary and conclusions

The comparative tests were designed to examine the influence of two different insulation products on the fire behaviour of a flat roof assembly under a PV system, for a single ignition scenario and roof configuration. No formal acceptance criteria were defined, and the results should therefore be interpreted as comparative data rather than as a rating or approval of any specific product.

Under the conditions tested, both roofs experienced significant fire spread on the bituminous cap sheet following burning of the PV modules. In both cases, the fire reached the full western edge of the roof but did not consume the entire roof area before test termination. The damaged area on the surface of the roof insulated with PIR was smaller than that insulated with stone wool. In neither test was fire penetration of the full insulation layer observed and the air and vapour control layer remained fully intact. The roof with stone wool insulation showed generally higher measured temperatures within the roof assembly than the roof with PIR insulation. In both constructions, the highest temperatures were recorded in locations closest to the ignition source and in the direction of prevailing ventilation.

The findings are specific to the particular roof build-up, insulation, PV configuration, ignition source, ventilation conditions and test duration used. They do not on their own demonstrate how other roof systems, PV layouts or insulation products would behave, nor do they cover other relevant aspects such as internal fire spread, smoke production or structural performance. Nevertheless, the results provide a useful evidence base on the behaviour of the tested PIR and stone wool roof systems when exposed to a severe localised fire within a PV array.

When the results of these tests are reviewed in comparison with for example previous PU Europe testing (include link to factsheet) with single-ply membranes it is evident that insulation, whether PIR or stone wool can act as a mitigation layer for fire penetration through to the roof structure.

8 Limitations and disclaimer

The tests and this summary report relate only to the specific specimens tested. The products tested are commonly used products, readily available on the market. They do not constitute product certification or approval and must not be used as the sole basis for design decisions.

The FPA report on which this summary is based sets out detailed limitations, including the reliance on information supplied by the client, the absence of defined performance criteria and the need to consider all other aspects of building fire safety when assessing roof and PV system designs.

The full report from the Fire Protection Association can be found **here**

For more details on the benefits of PIR insulation please visit: insulationmanufacturers.org.uk

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