0151-L-20/4
4 February 2022

Additional test report

Comparative test on fire behaviour of flat roof waterproofing systems with different thermal insulation materials and equipped with identical photovoltaic systems

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Comparative test on fire behaviour of flat roof waterproofing systems with different thermal insulation materials and equipped with identical photovoltaic systems

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Date of order	24 November 2020
Project number	0151-L-20/4
Author	A.R. Hameete
Subject	comparative test on external fire exposure to roofs with different insulation materials in combination with identical photovoltaic (PV) arrays according to the principles of CLC/TR 50670

This test report is additional to the original test report issued as order number 0151-L-21/3, dated 4 February 2022.
The original test report remains valid and has not been replaced by this additional test report.

Contents

1 Introduction

By order of PU Europe, Kiwa BDA Testing B.V. has performed two comparative tests of fire behaviour of two roof waterproofing systems, consisting of the same roof waterproofing sheet and a different thermal insulation with a realistic PV panel array positioned on top of the roof. The roofs have been exposed to external fire exposure according to the principles of CLC/TR 50670:2016.

The aim of this investigation was to compare the fire spread on the surface and downwards between the two roof waterproofing systems when a burner is placed between the surface of the roof and the PV panel array and is ignited subsequently.

The two roof waterproofing systems have been built up as follows:

System A:

- supporting **trapezoidal steel deck** in combination with a vapour barrier consisting of a **PE foil**;
- mechanically fastened insulation, **MW** in combination with a **metal point fastener** fastening system;
- single layer roof waterproofing system with **PVC** roof waterproofing sheets connected by welding and fixed with a **metal point fastener** fastening system.

System B:

- supporting **trapezoidal steel deck** in combination with a vapour barrier consisting of a **PE foil**;
- mechanically fastened insulation, **PIR** in combination with a **metal point fastener** fastening system;
- single layer roof waterproofing system with **PVC** roof waterproofing sheets connected by welding and fixed with a **metal point fastener** fastening system.

The roof waterproofing systems have been tested including four PV modules in combination with an mounting system in east-west configuration.

In week 33 and week 34, 2021 all products have been delivered to the Twente Safety Campus.

This product has not been retested. This additional test report is no technical review of the original test report 0151-L-21/3, dated 21 December 2021.
By request of the principal the brand names of the products have been removed.

See annex III for drawing of the mounting system.

2 Test specimens

On 1 September 2021 the test specimens have been built up by members of PU Europe and supervised by Troned.

According to the prescription of the principal the test specimens, with dimensions 6000 mm × 6000 mm, have been built using the following products from the bottom up.

- Supporting deck : trapezoidal steel deck, 106 profile, thickness 0,75 mm; the open ends of the trapezoidal steel deck have been closed with MW

- Vapour barrier : PE foil, thickness 0,2 mm

- Thermal insulation (system A) : Mineral wool (MW), FM approved (two layers)
  - material : MW
  - type of facing : none
  - type of joint : butt joint
  - thickness per board : 130 mm
  - total thickness : 260 mm
  - product standard : EN 13162

- Thermal insulation (system B) : Polyisocyanurate foam (PIR), FM approved (one layer)
  - material : PIR
  - type of facing : multi-layer complex
  - type of joint : butt joint
  - thickness : 142 mm
  - product standard : EN 13165

- Top layer : Polyvinylchloride (PVC), FM approved
  - material : PVC
  - thickness : 1,5 mm
  - product standard : EN 13956

- Mounting system : east-west configuration

- PV modules : PV module, dimensions 1650 mm × 992 mm

3 Investigation

3.1 General information

The investigations have been performed in accordance with the principles of CLC/TR 50670:2016 – External fire exposure to roofs in combination with photovoltaic (PV) arrays – Test method(s).

The tests have been performed on actual roof waterproofing systems as mentioned in chapter 2, including a trapezoidal steel deck, vapour barrier, thermal insulation, a roof waterproofing sheet and PV panel arrays in east-west configuration, consisting of four PV modules (see photo 5 and photo 25 in annex I and drawing in annex III).

On 2 September 2021 the tests have been performed by Mr W.J.B. Middag and Mr A.R. Hameete of Kiwa BDA Testing B.V. at Twente Safety Campus in Enschede, and was witnessed by representatives of PU Europe and Troned and by Mr C.W. van der Meijden MSc of Kiwa BDA.

During and after the tests the temperatures have been measured with thermocouples which have been positioned on several positions halfway the thickness of the insulation and underneath the insulation above the steel deck. From these measurements graphs have been made. The positions of the sensors are shown on the drawing in annex II.

The fire spread on top of the surface has been measured by Kiwa BDA Testing B.V. The temperature measurements have been performed by Troned. The results of the temperature measurements during and after the test have been delivered afterwards by Troned.

The tests have been carried out outside. In consultation with the principal and in order to assess the fire performance of the roof during burning of the PV panels and after the PV panels had burnt down the fire has not been extinguished. During the tests the average windspeed was between 1 $m.s^{-1}$ and 1,5 $m.s^{-1}$. Because the wind direction changed during the test, no wind direction can be given. The main wind direction during test 1 was significantly different from the main wind direction during test 2.

At the start of test A (MW insulation) the ambient temperature was 20,2 °C and the humidity was 58,0%. The temperature in the middle of the insulation was 13,2 °C and on the steel roof deck was 17,4 °C.

At the start of test B (PIR insulation) the ambient temperature was 25,0 °C and the humidity was 46,2%. The temperature in the middle of the insulation was 36,0 °C and on the steel roof deck was 23,2 °C.

3.2 Test procedures

As defined in CLC 50670:2015, the gas burner was adjusted to provide a flow rate of (324 ± 20) $mg.s^{-1}$, generating a heat output of (15 ± 1) kW. After 10 minutes the gas flow has been shut down.

The gas burner has been made of a stainless tube with an external diameter of (15,0 ± 0,1) mm and an internal diameter of (13,0 ± 0,1) mm, ending in a square part with 265 mm side length. In the square part of the burner, 32 holes with a diameter of 1,3 mm have been drilled, 8 holes at each side. The holes have been oriented to the inside of the burner. Half of the holes have an upward inclination of 45° and half of the holes have a downward inclination of 45° with respect to the burner plane.
The gas supplied to the burner has been propane with a purity of 95% or higher.
The propane mass flow rate has been (324 ± 20) $mg.s^{-1}$, generating a heat output of (15 ± 1) kW. A mass flow controller has been used to ensure that the flow rate is maintained throughout the test.

The gas burner has been applied at lowest edge of the PV module between the backside of the module (exposed surface) and the top of the roofing system surface, centred in the module's width and placed at a distance of d2 = 120 mm from the lowest edge of the module. The burner has been positioned in parallel to the roofing system, with a distance of d1 = 80 mm measured from the underside of the burner to the test deck surface.
The PV module is to be installed with an inclination of 30° to the test deck or at the minimum module inclination as defined in the installation instructions if lower than 30°. The slope of the simulated roof deck (test deck) shall be 0°.

In this case the PV module has been installed with an inclination of 13° to the test deck. The slope of the simulated roof deck (test deck) has been set at 0°.

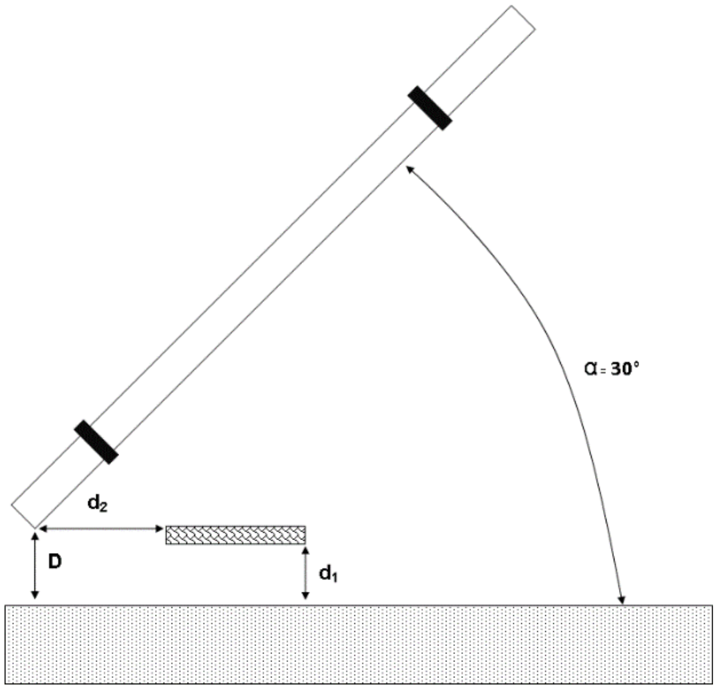


Figure 1: Position of the burner according CLC/TR 50670:2016
(This drawing is only an example from CLC/TR 50670)

3.3 External fire spread during the test

- The time when the sustained flaming has progressed left has been measured and recorded, every 200 mm until the edge of the test specimen. The measurement has been performed from the left side (seen from the side from which the burner has been positioned) of the projection of the gas burner on to the exposed specimen surface.
- The time when the sustained flaming has progressed right has been measured and recorded, every 200 mm until the edge of the test specimen. The measurement has been performed from the right side (seen from the side from which the burner has been positioned) of the projection of the gas burner on to the exposed specimen surface.
- The time when the sustained flaming has progressed forward has been measured and recorded., every 200 mm until the edge of the test specimen. The measurement has been performed from the front side (seen from the side from which the burner has been positioned) of the projection of the gas burner on to the exposed specimen surface.
- The time when the sustained flaming has progressed backward has been measured and recorded, every 200 mm until the edge of the test specimen. The measurement has been performed from the rear side (seen from the side from which the burner has been positioned) of the projection of the gas burner on to the exposed specimen surface.

In annex I a photo report of the test and the test results is given.

4 Results

4.1 Fire behaviour during the test, measured by Kiwa BDA Testing B.V.

Description	Result [min:s]							
	System A (MW)				System B (PIR)			
Roofing burning	1:02				1:04			
Fire extinguished	28:35				32:27			
Fire spread [mm] [1]	**left**	**right**	**forward**	**back ward**	**left**	**right**	**forward**	**back-ward**
▪ 200	1:45	2:25	2:04	1:07	2:20	2:06	1:59	3:16
▪ 400	2:54	3:40	2:28	2:18	2:42	2:42	2;21	4:12
▪ 600	3:49	3:56	2:50	3:07	3:33	3:01	2:25	4:21
▪ 800	4:11	4:50	3:27	3:19	4:54	3:23	2:33	4:39
▪ 1000	4:29	5:36	4:01	8:01	-[2]	3:43	2:45	5:00
▪ 1200	4:36	5:47	4:13	8:08	-[2]	3:52	2:51	5:23
▪ 1400	5:00	5:54	4:50	8:22	-[2]	3:57	2:59	5:28
▪ 1600	5:20	6:05	5:40	8:36	-[2]	4:05	3:09	-[2]
▪ 1800	-[2]	6:20	-[2]	8:47	-[2]	4:12	3:15	-[2]
▪ 2000	-[2]	6:33	-[2]	8:51	-[2]	4:19	3:33	-[2]
▪ 2200	-[3]	6:48	-[2]	-[3]	-[3]	4:25	3:54	-[3]
▪ 2400	-[3]	7:04	-[2]	-[3]	-[3]	4:41	4:04	-[3]
▪ 2600	-[3]	7:13	-[2]	-[3]	-[3]	4:57	-[2]	-[3]
▪ 2800	-[3]	7:29	-[2]	-[3]	-[3]	5:05	-[2]	-[3]
▪ 3000	-[3]	7:56	-[2]	-[3]	-[3]	5:17	-[2]	-[3]
▪ 3200	-[3]	8:42	-[2]	-[3]	-[3]	5:28	-[2]	-[3]
▪ 3400	-[3]	-[2]	-[2]	-[3]	-[3]	5:34	-[2]	-[3]
▪ 3600	-[3]	-[2]	-[2]	-[3]	-[3]	6:01	-[2]	-[3]

[1] Length of fire spread measured from the edge the projection of the gas burner on to the exposed specimen surface.
[2] Not been reached.
[3] End of test specimen.

4.2 Measurements made after the test, measured by Kiwa BDA Testing B.V.

Description	Results	
	System A (MW)	System B (PIR)
External fire spread / burnt length [1]		
▪ left	1735 mm	925 mm
▪ right	3255 mm	3695 mm
▪ forward	1795 mm	2485 mm
▪ backward	2045 mm	1515 mm

[1] Length of fire spread and damaged area measured from the edge the projection of the gas burner on to the exposed specimen surface.

4.3 Temperature measurements of system A (MW), measured by Troned

4.3.1 Temperature during the test

Highest temperature measured after	Results (sensor)	
	halfway insulation	underneath insulation
Start of the test	13,2 °C (27)	17,4 °C (1)
5 minutes	13,3 °C (27)	17,5 °C (1)
10 minutes	13,5 °C (25)	17,6 °C (1)
15 minutes	15,7 °C (25)	17,6 °C (1)
20 minutes	21,1 °C (25)	17,6 °C (1)
25 minutes	27,4 °C (26)	17,8 °C (1)
30 minutes	35,2 °C (26)	17,7 °C (1)

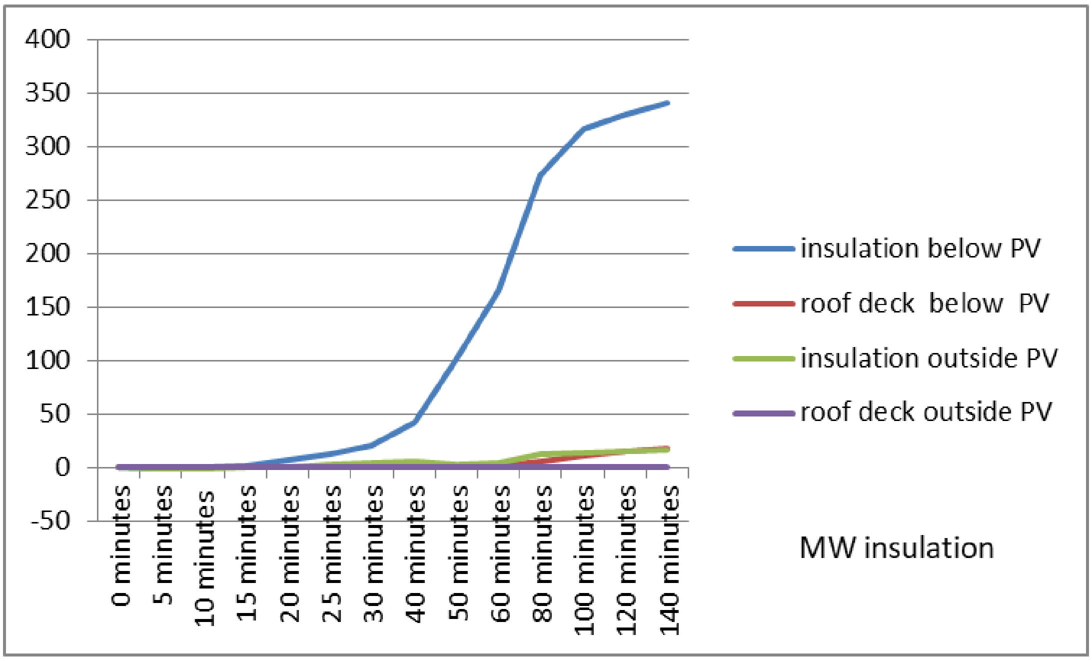
4.3.2 Temperature after the test

Highest temperature measured after	Results (sensor)	
	halfway insulation	underneath insulation
Start of the test	13,2 °C (27)	17,4 °C (1)
60 minutes	185 °C (26)	19,4 °C (3)
120 minutes	343 °C (26)	32,9 °C (4)
180 minutes	403 °C (29)	48,9 °C (4)
234 minutes	440 °C (29)	70,8 °C (4)

4.3.3 Temperature rise from start temperature during the test

System A MW insulation - [K]				
highest temperature rise after	sensors below PV array		sensors outside PV array	
	halfway insulation	underneath insulation (on steel deck)	halfway insulation	underneath insulation (on steel deck)
start temperature [°C]	12,8	17,2	13	17,5
0 minutes	0	0	0	0
5 minutes	-0,1	0,2	-0,1	0
10 minutes	0,3	0,3	-0,1	0,2
15 minutes	2,1	0,3	0,2	0,1
20 minutes	6,8	0,4	1,2	0,1
25 minutes	13,2	0,4	2,8	0,3
30 minutes	20,8	0,5	4,5	0,3
40 minutes	42,3	0,9	6,4	0,3
50 minutes	102,1	1,1	3,8	0,5
60 minutes	165,7	2,1	4,4	0,5
80 minutes	273,3	6,5	12,6	0,8
100 minutes	316,7	11	14,6	0,9
120 minutes	329,9	15,5	16,1	1,2
140 minutes	341,3	18,7	16,9	1,2

4.3.4 Graph of temperature rise during the test in K



4.4 Temperature measurements of system B (PIR), measured by Troned

4.4.1 Temperature during the test

Highest temperature measured after	Results (sensor)	
	halfway insulation	underneath insulation
▪ Start of the test	36,0 °C (34)	23,2 °C (1)
▪ 5 minutes	36,0 °C (34)	22,8 °C (1)
▪ 10 minutes	38,3°C (32)	22,4 °C (1)
▪ 15 minutes	106 °C (32)	23,1 °C (1)
▪ 20 minutes	151 °C (32)	22,4 °C (10)
▪ 25 minutes	154 °C (32)	22,6 °C (1)
▪ 30 minutes	147 °C (32)	23,6 °C (8)

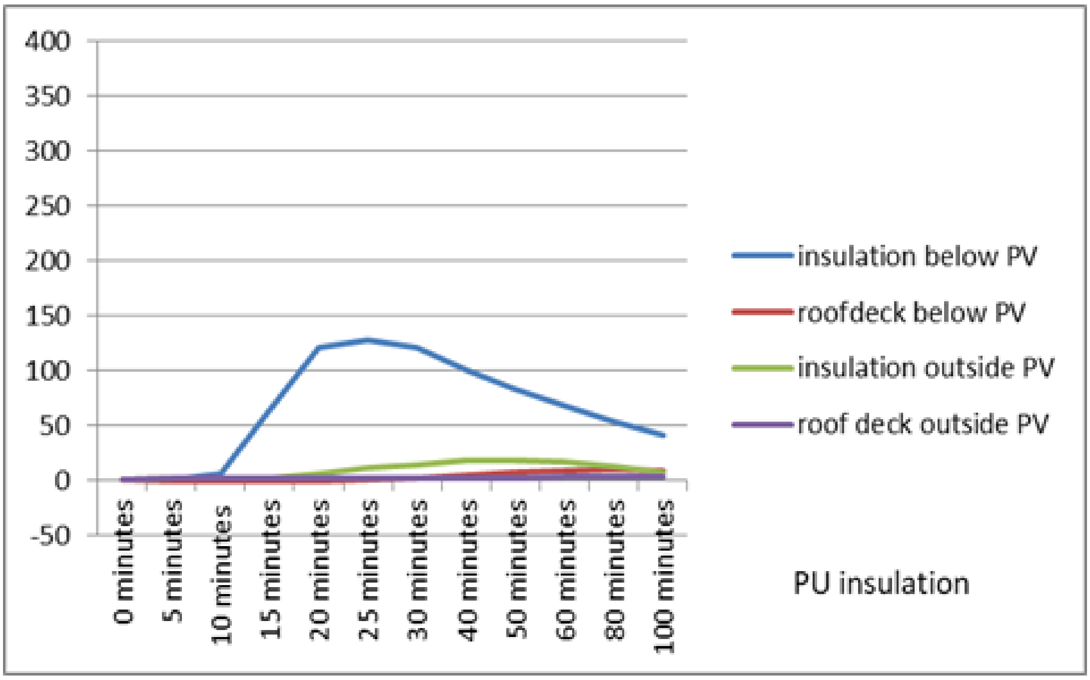
4.4.2 Temperature after the test

Highest temperature measured after	Results (sensor)	
	halfway insulation	underneath insulation
▪ Start of the test	36,0 °C (34)	23,2 °C (1)
▪ 60 minutes	94,8 °C (32)	30,8 °C (8)
▪ 105 minutes	65,0 °C (26)	30,2 °C (8)

4.4.3 *Temperature rise from start temperature during the test*

System B PIR insulation - [K]				
Highest temperature rise after	Sensors below PV array		Sensors outside PV array	
	halfway insulation	underneath insulation (on steel deck)	halfway insulation	underneath insulation (on steel deck)
Start temperature [°C]	27,1	21,9	33,9	21,2
0 minutes	0	0	0	0
5 minutes	0	-0,2	2	1,5
10 minutes	5,5	-0,3	1,9	1,3
15 minutes	64,1	-0,4	2,6	1,8
20 minutes	121,1	-0,3	5,4	2,1
25 minutes	127,9	0,1	11	1,3
30 minutes	121,1	1,3	14,4	1,7
40 minutes	100,8	4,8	17,9	1,6
50 minutes	82,9	7,4	18,4	2,4
60 minutes	68,6	8,7	16,6	3
80 minutes	52,6	10	12,3	3,3
100 minutes	41	8,5	7,7	3

4.4.4 *Graph of temperature rise during the test in K*



5 Discussion

During the test it becomes clear that the wind has a great influence on the spreading of the fire on the surface of the test specimen. If the wind turns to one side of the test specimen, the flames on the roof waterproofing sheet follows immediately and the fire spreads in the same direction. This counts for the test specimen with MW insulation as well as for the test specimen with PIR insulation.

A difference between the two test specimens is the temperature which has been reached in the insulation and underneath the insulation. In test specimen A (MW) the increasing of the temperature goes slower but continues longer compared to test specimen B (PIR) at which the increasing of the temperature goes quicker but continues shorter.

In test specimen A (MW) the fire has gone out after 28:35 (min:s).
After 30 minutes the temperature has reached 35 °C in the middle of the insulation. After approximately 4 hours the temperature has reached 440 °C in the middle of the insulation and is still increasing slowly. Overnight measurements on the steel deck showed a peak temperature of 190 °C.

In test specimen B (PIR) the fire has gone out after 32:27 (min:s).
After 23 minutes the temperature has reached 155 °C in the middle of the insulation, after this time the temperature is decreasing. After approximately 2 hours the highest temperature is 65 °C. After these two hours temperatures are decreasing further until they reached the ambient level again.

The total burnt area on the roof covering was comparable in both tests. For MW insulated roof the burnt area was slightly larger, but as the direction of flame spread on the PIR insulated roof was different, the fire reached the edge of the specimen on one side – therefore it can be assumed that the burnt area would have been larger if the distance from the PV panel array to the edge would have been the same as on the long side of the PV array.

For this investigation a burner has been used as defined in CLC/TR 50670.
The burner has been positioned below one of the PV panels in order to combine the effects of burning of the PV panels with the effects of the fire performance of roofs with different insulation products. In both test specimens a realistic roof construction has been used and an array of PV panels has been installed as in practice.

Remarks:

The results are only related to the investigated samples, products and/or systems. Kiwa BDA Testing B.V. is not liable for interpretations or conclusions that are made in consequence of the results obtained.

If sampling was not performed by Kiwa BDA Testing B.V., no judgement can be given with regard to the origin and representativeness of the samples.

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Gorinchem, 4 February 2022

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manager testing

Designated as Notified Body NB 1640 pursuant to the Construction Products Regulation (EU, No 305/2011)

Member

I Photo report of the test

System A (MW)

Photo 1
The steel deck has been fastened on wooden beams.

Photo 2
The vapour barrier has been applied and the insulation is mechanically fixed.

Photo 3
The roof waterproofing sheet is welded.

Photo 4
The PV modules have been positioned.

Photo 5
Overview of test specimen.

Photo 6
The gas burner has been ignited (time 10:11).

Photo 7
The roofing and PV module are burning (time 10:11).

Photo 8
The fire is spreading underneath the PV modules (time 10:13).

Photo 9
The fire is spreading backwards outside the PV modules (time 10:14).

Photo 10
The fire is spreading on the left side outside the PV modules (time 10:15).

Photo 11
The fire is spreading backwards again outside the PV modules (time 10:19).

Photo 12
The fire is almost gone out (time 10:26).

Photo 13
Overview of the burnt roof waterproofing sheet including PV modules.

Photo 14
Overview of the burnt roof waterproofing sheet.

Photo 15
Overview of the burnt section of the MW insulation (top layer).

Photo 16
Overview of the burnt section of the MW insulation (top layer and underlayer).

Photo 17
Overview of the burnt section of the MW insulation (underside of top layer).

Photo 18
Overview of the burnt section of the MW insulation (underlayer).

Photo 19
Detail of the burned vapour barrier.

System B (PIR)

Photo 20
The steel deck has been fastened on wooden beams.

Photo 21
The vapour barrier has been applied and the insulation is mechanically fixed.

Photo 22
The roof waterproofing sheet is fixed.

Photo 23
The roof waterproofing sheet is welded.

Photo 24
The PV modules have been positioned.

Photo 25
Overview of test specimen.

Photo 26
The gas burner has been ignited (time 15:03)

Photo 27
The roofing and PV module are burning (time 15:04).

Photo 28
The fire is spreading underneath the PV modules (time 15:06).

Photo 29
The fire is spreading backwards and on the left side, outside the PV modules (time15:08).

Photo 30
The fire is spreading forwards, outside the PV modules (15:09).

Photo 31
The fire is almost gone out (time 15:16).

Photo 32
Overview of the burnt roof waterproofing sheet including PV modules.

Photo 33
Overview of the burnt roof waterproofing sheet.

Photo 34
Overview of the burnt insulation.

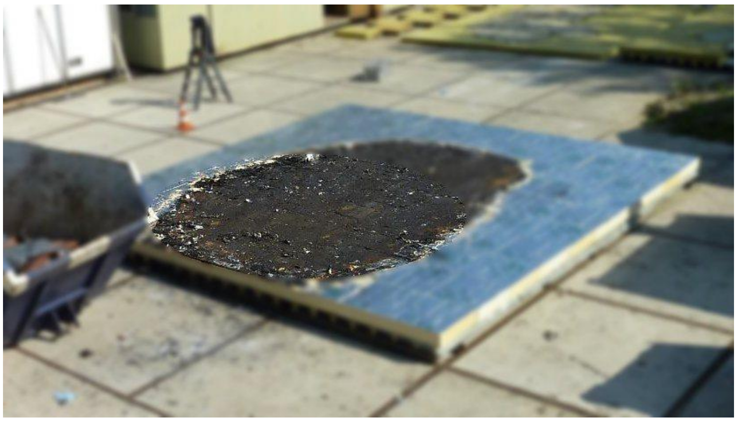
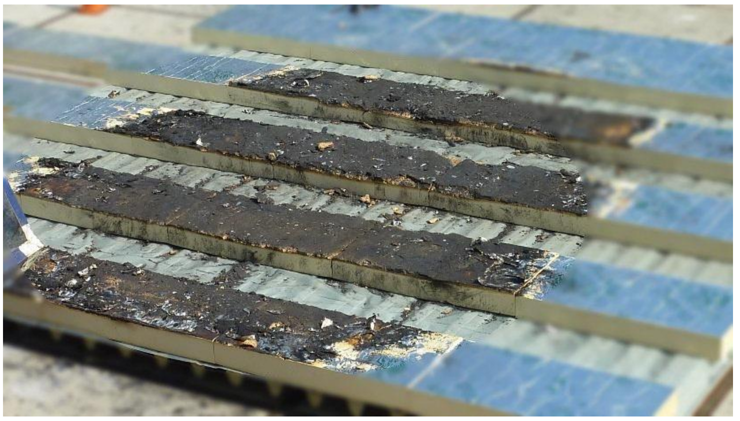
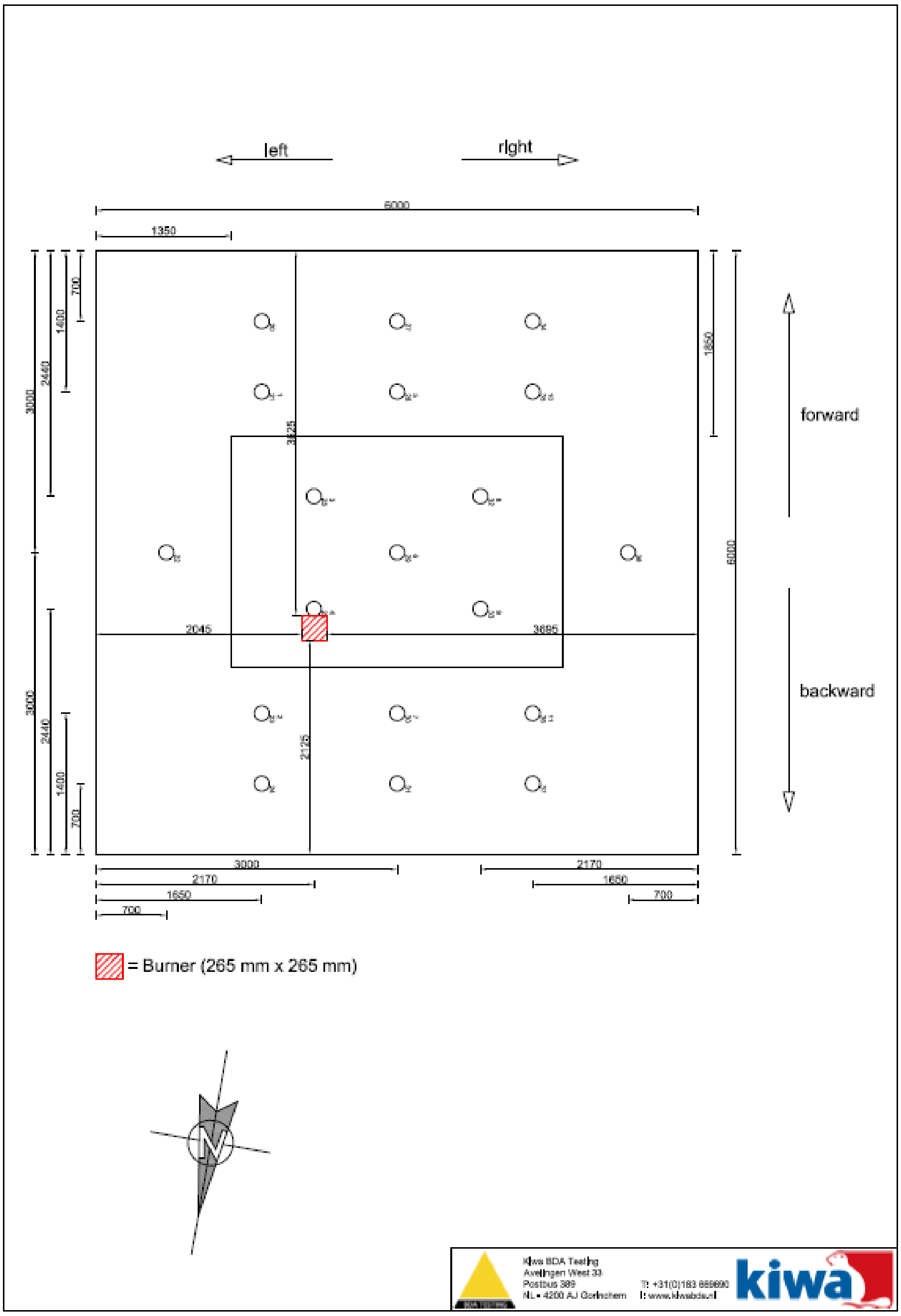


Photo 35
Overview of the burnt insulation and undamaged vapour barrier.

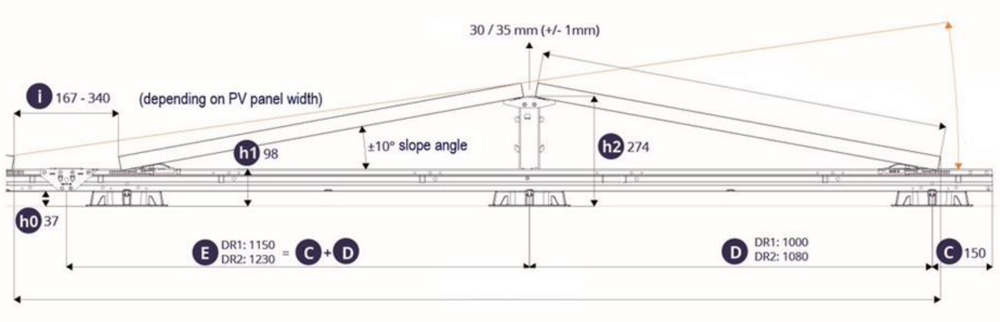


II Positions of the thermocouples and burner



III Mounting system

Side view



Top view