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Ministry of Housing, Communities and Local Government Final Research Report

Fire Performance of Cladding Materials Research – Appendix E Main experimental programme

Prepared for:	**Technical Policy Division, MHCLG**
Date:	**20 March 2020**
MHCLG Contract:	**CCZZ17A36**
Report Number:	**P111324-1019 (M9D12V2)**

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E1 Introduction

The authors of this report are employed by BRE Global. The work reported herein was carried out under a Contract placed by the Ministry of Housing, Communities and Local Government. Any views expressed are not necessarily those of the Ministry of Housing, Communities and Local Government.

This Appendix is part of a Main report and Appendices and should be read in conjunction with these.

This Appendix contains a description of the main experimental fires (Task 6) and the results.

E2 Main experimental programme

Details of the experimental methodology and the calibration exercise undertaken to ensure the procedures adopted produced a consistent and repeatable exposure consistent with the objectives of the research project are included in Appendices C and D.

E2.1 Experimental matrix

The original prioritised list of materials/products for the experimental programme is included as Table E1.

Table E1 – Initial prioritised list of materials/products for the experimental programme

Material/Product	Priority	Comment	Background
Calcium silicate board	-	Control panel for calibration purposes	Calibration
ACM with polyethylene (PE) core	-	100% PE core, 3 mm PE core and 0.5 mm aluminium facing	Calibration
FR ACM with PE and mineral core	-	3 mm FR PE core and two 0.5 mm outer aluminium facings	Calibration
Limited combustibility A2 ACM with mineral core	-	3 mm “A2” core and two 0.5 mm outer aluminium facings	Calibration
Aluminium honeycomb panels	1	Core size from 6-20 mm, claimed Class 0	Initial selection provided by MHCLG
HPL panels	2	Thicknesses range from 6-13 mm, Classification ranges from D-s2,d0 to B-s2,d0	Initial selection provided by MHCLG
Brick slip systems	3	Brick slip bonded to PUR foam insulation	Potential combustible substrate Potential organic content in brick slips
Reconstituted stone panels	4	Crushed stone and polyester binder	Potential combustible binders

All the materials identified above were included in the experimental programme. In addition, additional experiments for aluminium and zinc composite panels were requested by MHCLG. Unless specifically mentioned all samples provided came directly from the manufacturer. Table E2 summarises all the samples included in the experimental programme. The samples are identified generically. No information is provided on specific products or manufacturers.

Table E2 – Experimental programme

Sample ref.	Description	Manufacturer's stated RTF performance
S1	Aluminium honeycomb panels 4 mm thick with 0.7 mm aluminium face	A2-s1, d0
S2	Aluminium honeycomb panels 4 mm thick with 0.7mm aluminium face	A2-s1, d0
S3	High pressure laminate (HPL) panels 6 mm thick	B-s2, d0
S4	Aluminium honeycomb panels 4 mm thick with 0.7 mm aluminium face	A2-s1, d0
S5	High pressure laminate (HPL) panels 10 mm thick	B-s2, d0
S6	Aluminium honeycomb panels 25 mm thick	A2-s1, d0
S7	Wood composite HPL panels 6 mm thick	B-s2, d0
S8	Wood composite HPL panels 10 mm thick	B-s2, d0
S9	HPL PUR resin panels 6 mm thick	B-s2, d0
S10	HPL PUR resin panels 10 mm thick	B-s2, d1
S11	HPL phenolic panels 6 mm thick	B-s1, d0
S12	HPL phenolic panels 10 mm thick	B-s1, d1
S13	Zinc composite panels 4 mm thick	B-s1, d0
S14	Zinc composite panels 4 mm thick	B-s1, d0
S15	Copper composite panels 4 mm thick	B-s1, d0
S16	Copper composite panels 4 mm thick	B-s1, d0
S17	Zinc composite panels 4 mm thick	B-s1, d0
S18	Zinc composite panels 4 mm thick	B-s1, d0
S19	Reconstituted stone panels 6 mm thick	Class 0
S20	Reconstituted stone panels 10 mm thick	Class 1
S21	Brick slip system bonded to PUR insulation	B-s2, d0
S22	Brick slip system bonded to PUR insulation	B-s2, d0

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A summary of the construction detail for the samples i.e. positions of the vertical and horizontal joints, size of the cavity and the fixing mechanism is presented in Table E3. The precise location of the vertical joint was dependent on the width of the panel as supplied by the manufacturer.

Table E3 – Construction details for the samples

Sample ref.	Thickness (mm)	Vertical joint (measured from centre line) (m)	Horizontal joint measured from ground level (m)	Cavity (mm)	Fixing spacing (mm)
S1	4	0.5	2	50	300 (vertical) 400 (horizontal)
S2	4				
S3	6				
S4	4				
S5	10				
S6	25	0.5	2	140	M6x30 in the corners
S7	6	0.2	2	50	300 (vertical) 400 (horizontal)
S8	10				
S9	6	0.5	2	50	300 (vertical) 400 (horizontal)
S10	10				
S11	6	0.25	2	50	300 (vertical) 400 (horizontal)
S12	10				
S13	4	0	2	50	300 (vertical) 400 (horizontal)
S14	4				
S15	4				
S16	4				
S17	4				
S18	4				
S19	6	0.2	2	50	300 (vertical) 400 (horizontal)
S20	10				
S21	55-65	N/A	N/A	N/A	Mechanical fixings and cement-based adhesive
S22	55-65				

E2.2 Findings

Unless specifically mentioned all panels were sourced directly from the manufacturer.

E2.2.1 Sample S1 4 mm aluminium honeycomb panels

The panels for the first sample were sourced from an existing building. The first sample consisted of an aluminium panel with a bonded aluminium honeycomb core. The aluminium panels were installed onto 100 mm wide aluminium T-shaped rails positioned 400 mm apart. The panels were installed onto the rails using 25 mm long self-drill self-tap screws at 300 mm vertical centres. Figure E1 shows the material installed on the rig. A cavity of 50 mm was provided between the aluminium panels and the incombustible support (calcium silicate board) of the experimental rig. One vertical joint and one horizontal joint of approximately 10 mm were provided within the installation as shown in Figure E1.

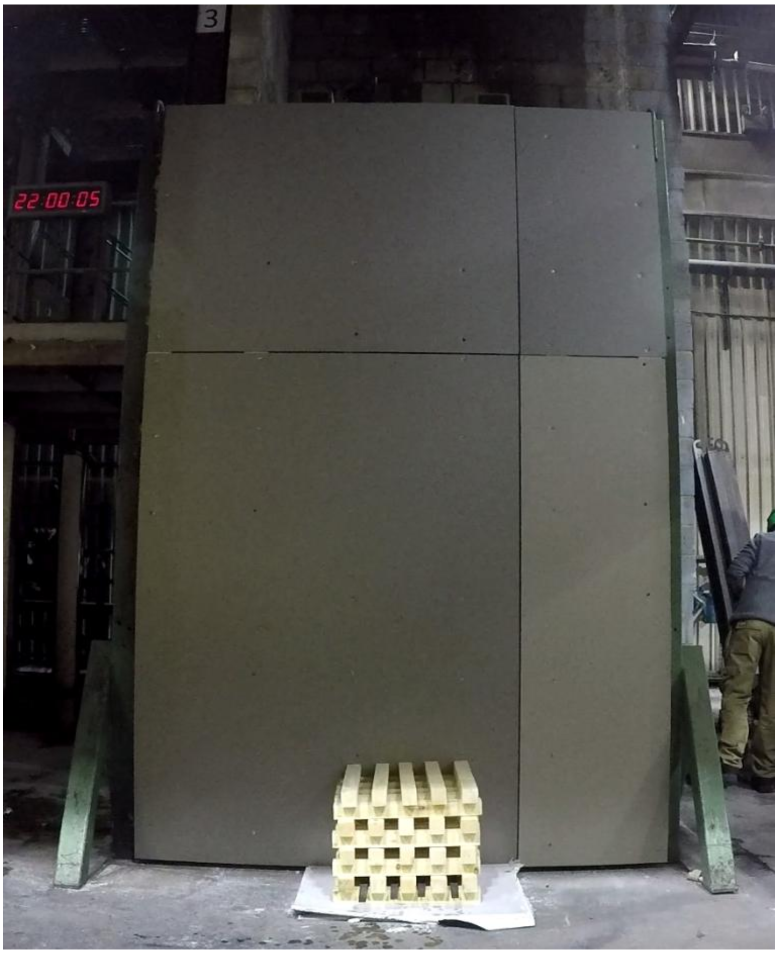
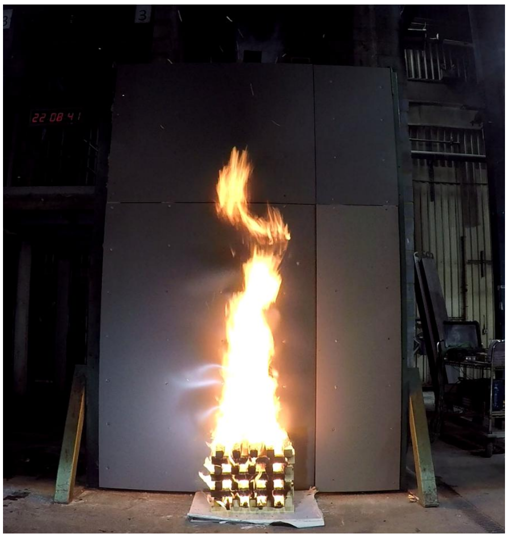
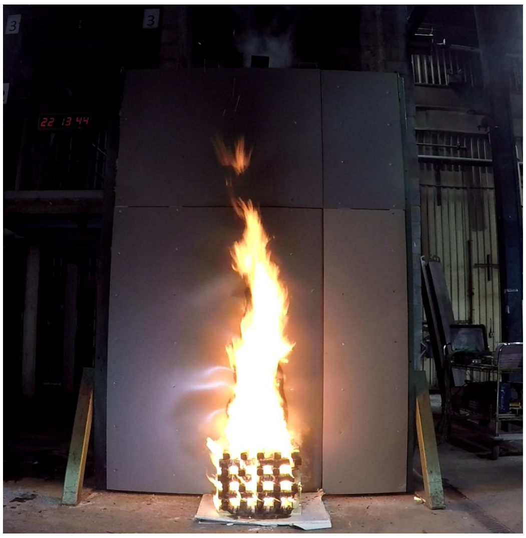


Figure E1 – Sample S1 aluminium honeycomb panels installed on the rig

Figure E2 shows photographs during the fire exposure at specified times.



5 minutes from ignition



10 minutes from ignition

20 minutes from ignition

25 minutes from ignition

Figure E2 – Photographs during the fire at 5, 10, 20, 25 minutes from ignition

No falling debris or burning droplets were observed during the fire. A discoloration of the panels was observed in the area of direct flame exposure.

Based on both measured values and visual observation after approximately 19 minutes of thermal exposure the fire breached the cavity. Delamination adjacent to the fire source and local flaming of the bonded honeycomb was observed for a short duration of time.

No significant vertical or horizontal flame spread on the surface of the aluminium honeycomb panels was observed.

Figure E3 shows the heat release rate as a function of time during the fire exposure, including the fire source. Based on the original crib calibrations and measured values from the calorimeter it is assumed that the peak heat release rate for the crib alone is approximately 300 kW [1].

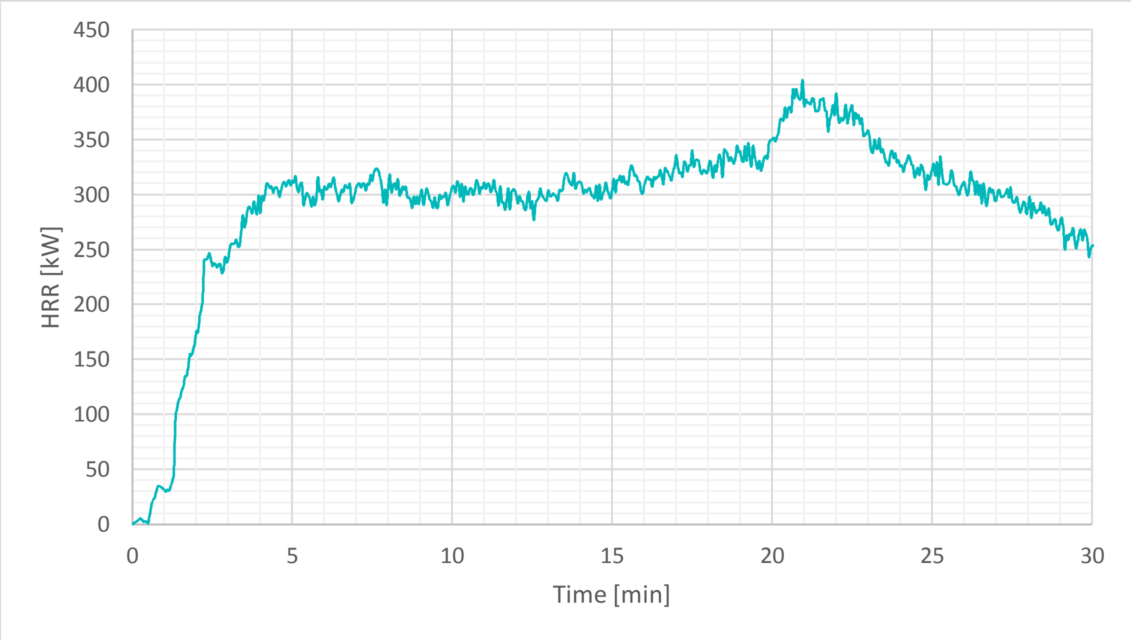


Figure E3 – Heat release rate measured during the fire, including the source

Figure E4 shows the heat flux recorded during the fire on the centre line at a height of 3.0 m from the ground.

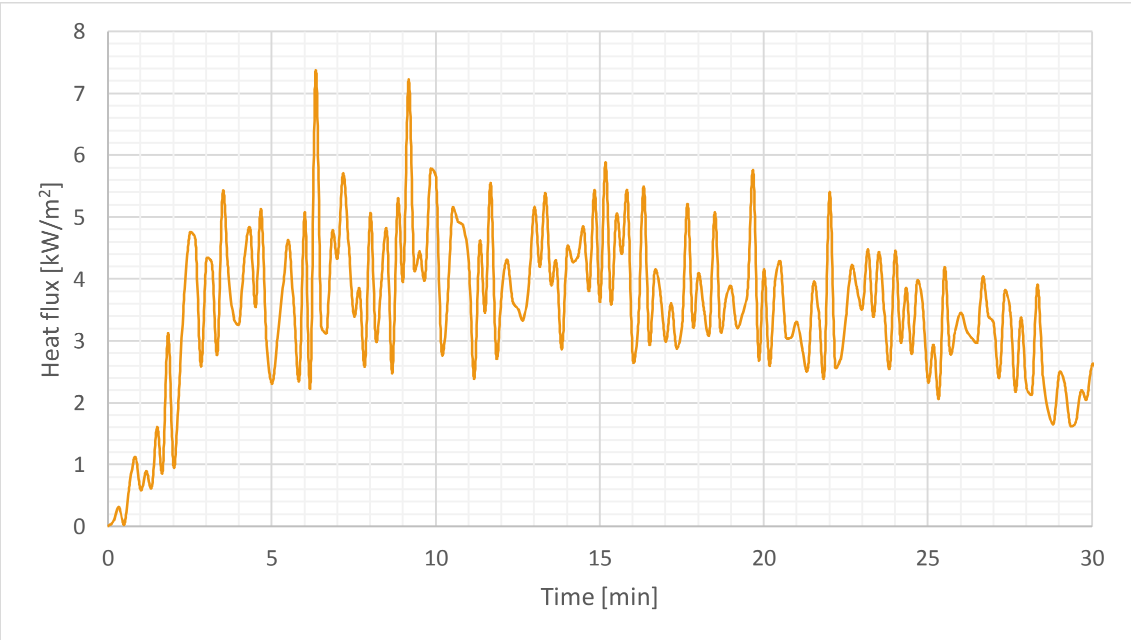


Figure E4 – Heat flux recorded during the fire at 3.0 m height

Table E4 shows the maximum external temperature, the maximum cavity temperature, maximum temperature at 3.0 m, time to peak heat release rate (HRR), peak HRR, maximum heat flux (HF) at 3.0 m and total heat release (THR) over a period of 30 minutes.

Table E4 – Summary of different measured parameters during the experiment

Max external temp [°C]	Max cavity temp [°C]	Max H=3.0m Temp [°C]	Time to peak HRR [min]	Peak HRR [kW]	Max H=3.0m Heat flux [kW/m^2]	THR [MJ]
788	1023	144	20.95	404.3	7.4	528.7

A summary of the visual observations is presented in Table E5.

Table E5 – Visual observations during the experiment

Burning droplets	Time to burn through (min)	Burn through	Area consumed [m^2]	Vertical flame spread	Horizontal flame spread
No	≈ 18	Yes	≈0.35	No	No

Figure E5 shows the sample after the fire. The aluminium honeycomb panels were consumed locally in the zone of direct flame impingement. Discoloration and distortion could be observed on the surface of the panels. On the vertical joint next to the fire source the delamination behaviour of the panels could be observed.

Figure E5 – Post fire observations

E2.2.2 Sample S2 4 mm aluminium honeycomb panels

The second non-ACM sample consisted of an aluminium panel with a bonded aluminium honeycomb core. This was a repeat of the previous fire experiment. The aluminium panels were cut to size and installed onto 100 mm wide aluminium T-shaped rails positioned 400 mm apart. The panels were installed onto the rails using 25 mm long self-drill self-tap screws at 300 mm vertical centres. Figure E6 shows the material installed on the rig. A cavity of 50 mm was provided between the aluminium panels and the incombustible support of the rig. One vertical joint and one horizontal joint of approximately 10 mm were provided within the installation as shown in Figure E6.

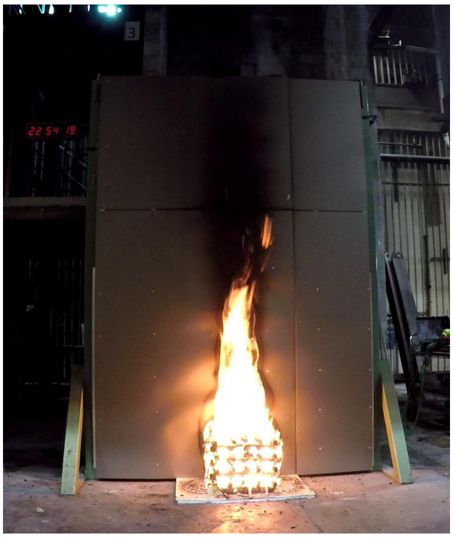
Figure E6 – Sample S2 aluminium honeycomb panels installed on the rig

Figure E7 shows photographs during the fire exposure at specified times.

5 minutes from ignition

10 minutes from ignition

20 minutes from ignition



25 minutes from ignition

Figure E7 – Photographs during the fire at 5, 10, 20 and 25 minutes from ignition

No falling debris or burning droplets were observed during the fire. Discoloration of the panels was observed in the area of direct flame exposure.

Based on both measured values and visual observation after approximately 23 minutes of thermal exposure the fire breached the cavity. Local delamination and local flaming of the bonded honeycomb was observed for a short duration of time next to the fire source.

No significant vertical or horizontal flame spread on the surface of the aluminium honeycomb panels was observed.

Figure E8 shows the heat release rate as a function of time during the fire exposure, including the fire source. Based on the original crib calibrations and measured values from the calorimeter it is assumed that the peak heat release rate for the crib alone is approximately 300 kW.

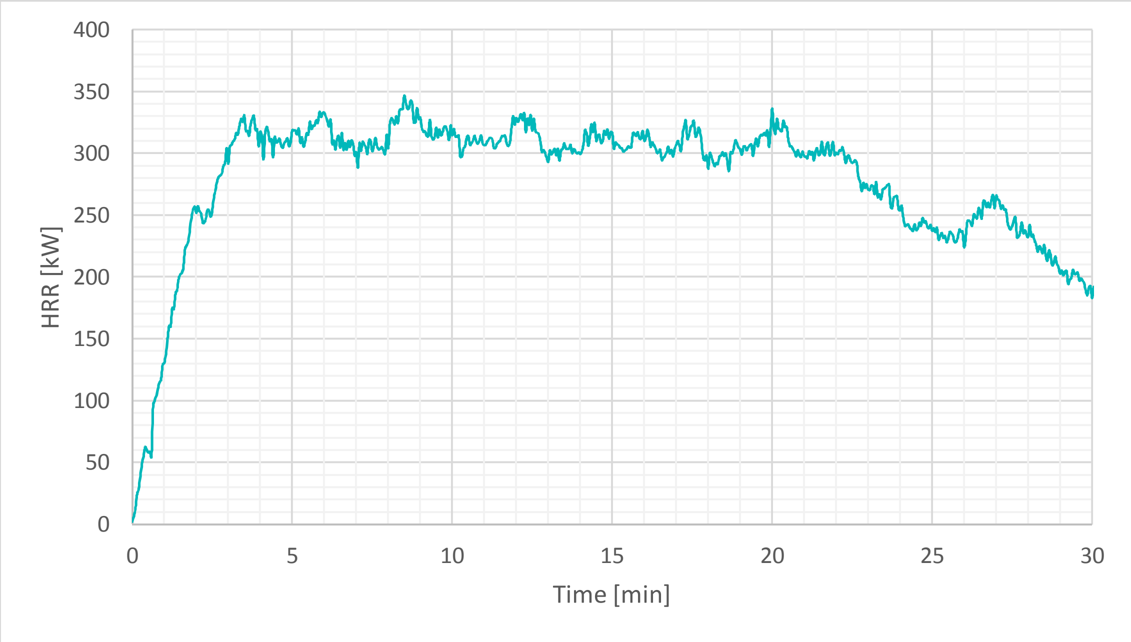


Figure E8 – Heat release rate measured during the fire, including the source

Figure E9 shows the heat flux on the centre line recorded during the fire at a height of 3.0 m from the ground.

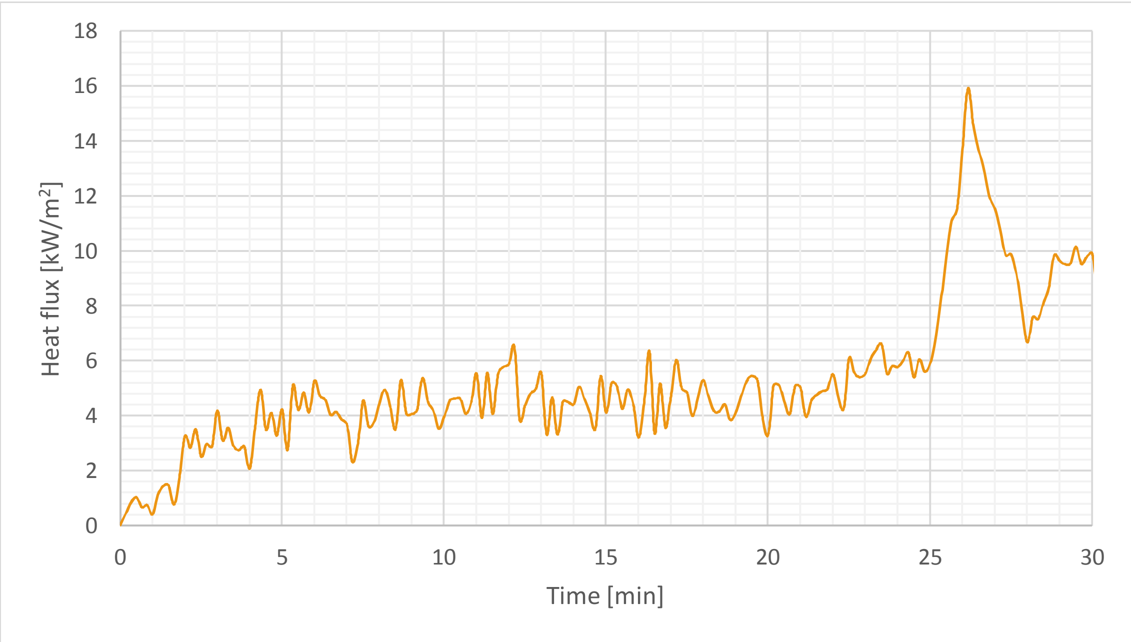


Figure E9 – Heat flux recorded during the fire at 3.0 m height

Table E6 shows the maximum external temperature, the maximum cavity temperature, maximum temperature at 3.0 m, time to peak heat release rate (HRR), peak HRR, maximum heat flux (HF) at 3.0 m and total heat release (THR) over a period of 30 minutes.

Table E6 – Summary of different measured parameters during the experiment

Max external temp [°C]	Max cavity temp [°C]	Max H=3.0m Temp [°C]	Time to peak HRR [min]	Peak HRR [kW]	Max H=3.0m Heat flux [kW/m^2]	THR [MJ]
885	940	147	8.5	346.8	15.9	504.1

A summary of the visual observations is presented in Table E7.

Table E7 – Visual observations during the experiment

Burning droplets	Time to burn through (min)	Burn through	Area consumed [m^2]	Vertical flame spread	Horizontal flame spread
No	23	Yes	≈0.32	No	No

Figure E10 shows the sample after the fire. The aluminium honeycomb panels were consumed locally in the zone of direct flame impingement. Discoloration and distortion could be observed on the surface of the panels. The aluminium honeycomb was visible and local delamination could be observed around the consumed edges of the panel.

Figure E10 – Post fire observations

E2.2.3 Sample S3 6 mm high pressure laminate (HPL) panels

The third sample was a high pressure laminate (HPL) with a fire-retardant wood-based fibre core, bonded with thermosetting resins at high pressures and temperatures. The 6 mm thick HPL panels were cut to size and installed onto 100 mm wide aluminium T-shaped rails positioned 400 mm apart. The panels were installed onto the rails using 25 mm long self-drill self-tap screws at 300 mm vertical centres. Figure E11 shows the material installed on the rig. A cavity of 50 mm was provided between the HPL panels and the incombustible support of the experimental rig. One vertical joint and one horizontal joint of approximately 10 mm were provided within the installation as shown in Figure E11.

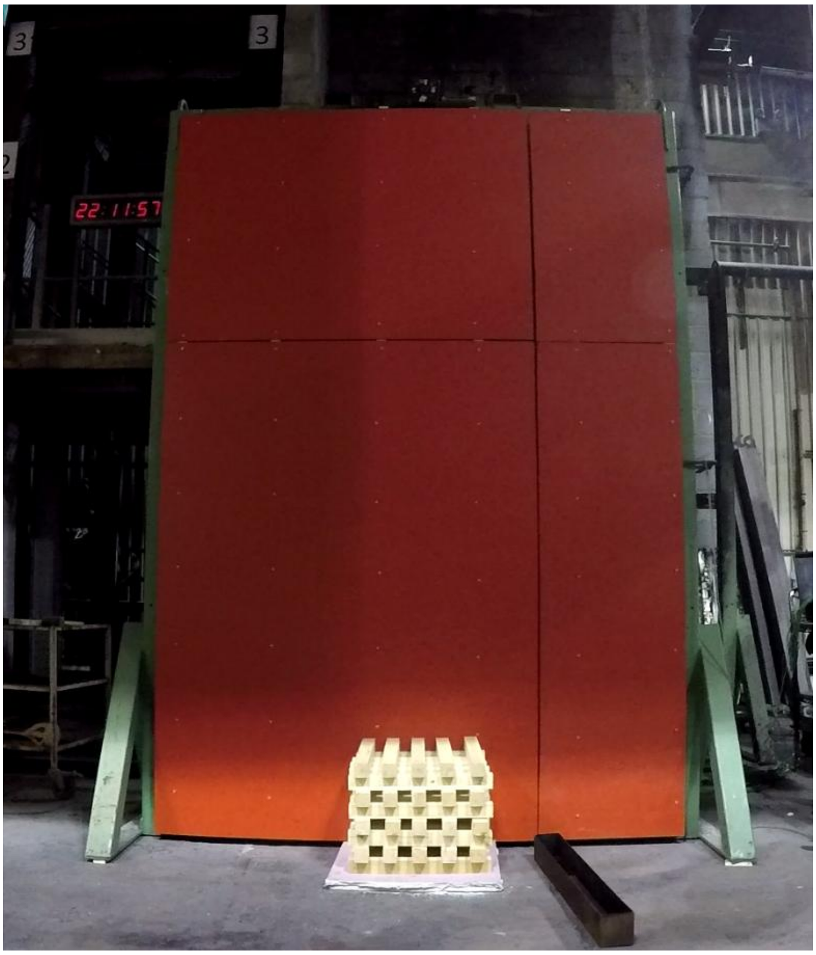


Figure E11 – Sample S3 HPL panels installed on the rig

Figure E12 shows photographs during the fire exposure at specified times.

5 minutes from ignition

10 minutes from ignition

20 minutes from ignition

25 minutes from ignition

Figure E12 – Photographs during the fire at 5, 10, 20 and 25 minutes from ignition

During the fire exposure no burning droplets were observed. Discoloration of the panels was observed in the area of direct flame exposure.

Based on both measured values and visual observation after approximately 9 minutes of thermal exposure the fire breached the cavity. Local cracks were observed on the surface of the panels. Detachment of parts of the panels in the area of direct flame impingement was observed during the experiment.

Localised sustained flaming was observed on the surface of the panels in the fire exposed area. Limited horizontal flame spread was recorded on the external surface of the panels in the area of direct heat exposure. The surface burning self-extinguished without direct flame exposure. No significant vertical or horizontal flame spread on the surface of the HPL panels was observed.

Figure E13 shows the heat release rate as a function of time during the fire exposure, including the fire source. Based on the original crib calibrations and measured values from the calorimeter it is assumed that the peak heat release rate for the crib alone is approximately 300 kW.

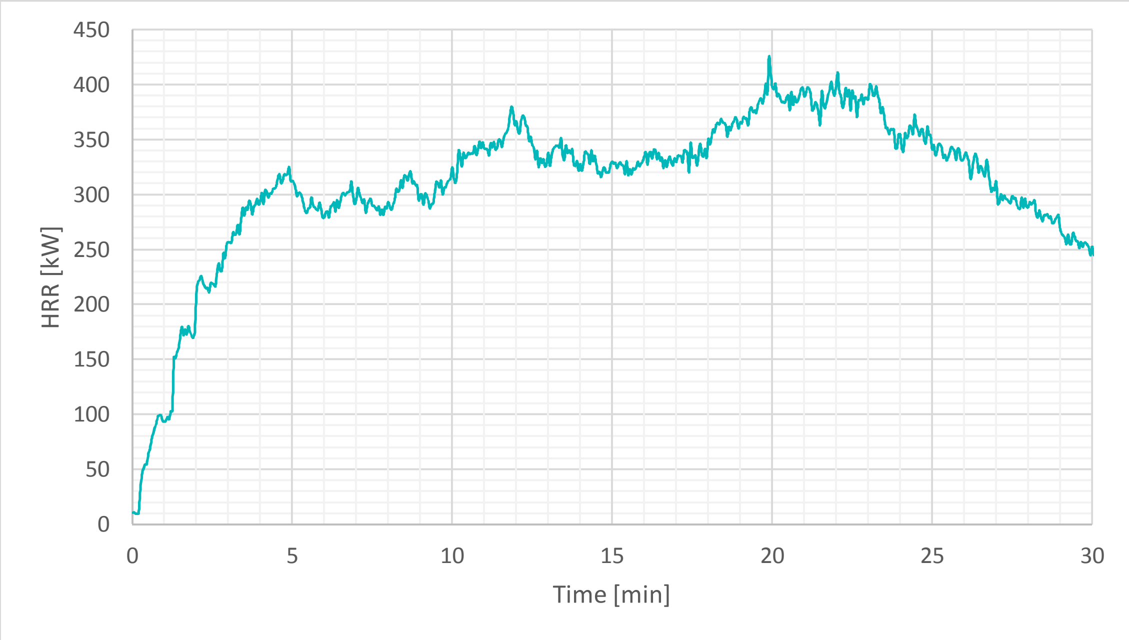


Figure E13 – Heat release rate measured during the fire, including the source

Figure E14 shows the heat flux on the centre line recorded during the fire at a height of 3.0 m from the ground. The maximum capability of the heat flux meter of 50 kW/m^2 was reached 11 minutes from ignition.

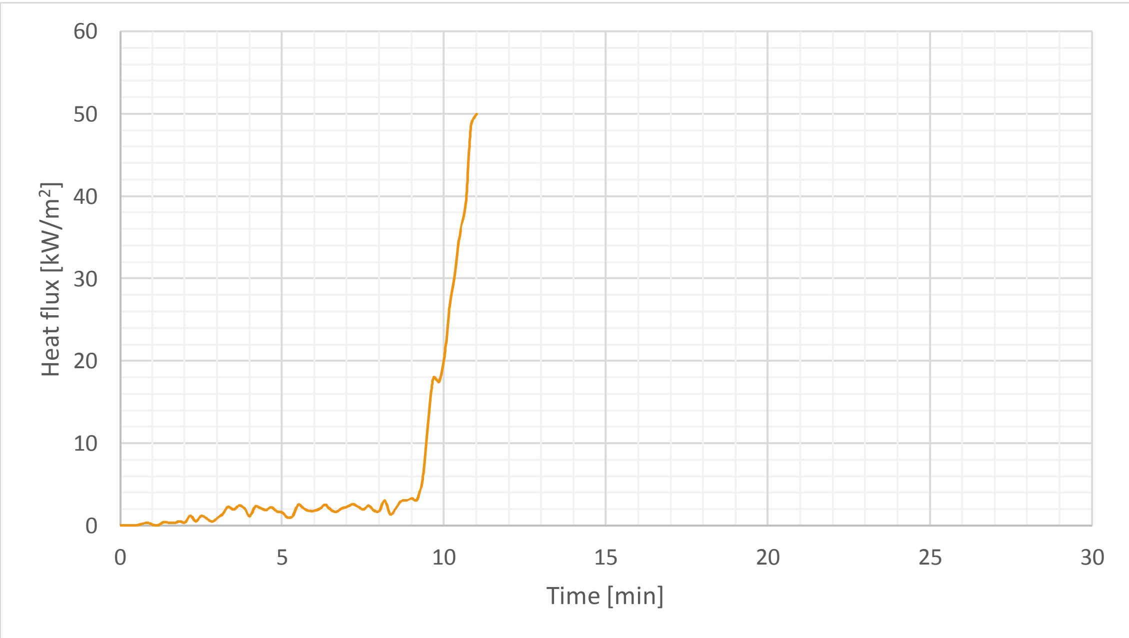


Figure E14 – Heat flux recorded during the fire at 3.0 m height

Table E8 shows the maximum external temperature, the maximum cavity temperature, maximum temperature at 3.0 m, time to peak heat release rate (HRR), peak HRR, maximum heat flux (HF) at 3.0 m and total heat release (THR) over a period of 30 minutes.

Table E8 – Summary of different measured parameters during the experiment

Max external temp [°C]	Max cavity temp [°C]	Max H=3.0m Temp [°C]	Time to peak HRR [min]	Peak HRR [kW]	Max H=3.0m Heat flux [kW/m^2]	THR [MJ]
843	892	286	19.9	425.5	50*	560.2

** Maximum measurement range of instrument*

A summary of the visual observations is presented in Table E9.

Table E9 – Visual observations during the experiment

Burning droplets	Time to burn though [min]	Burn through	Area consumed [m^2]	Vertical flame spread	Horizontal flame spread
No	≈9	Yes	≈0.98	Localised	Localised

Figure E15 shows the sample after the fire. The HPL panels were consumed locally in the zone of direct flame impingement. Discoloration and distortion could be observed on the surface of the panels. Detachment of parts of the panels could be observed after the fire. The panels had a brittle behaviour when exposed to fire. Localised cracks of the panels could be observed in the area of direct heating.

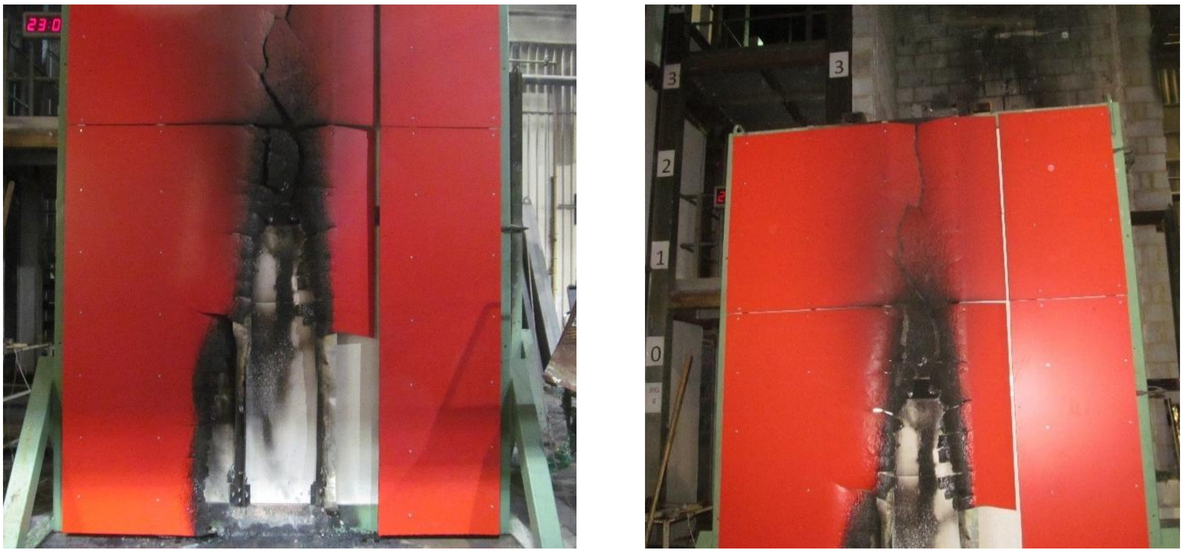


Figure E15 – Post fire observations

E2.2.4 Sample S4 4 mm aluminium honeycomb panels

The fourth sample was sourced by MHCLG and consisted of an aluminium sheet either side of a bonded aluminium honeycomb core with an overall thickness of 4 mm. The aluminium panels were cut to size and installed onto 100 mm wide aluminium T-shaped rails positioned 400 mm apart. The panels were installed onto the rails using 25 mm long self-drill self-tap screws at 300 mm vertical centres. Figure E16 shows the material installed on the rig. A cavity of 50 mm was provided between the aluminium panels and the incombustible support of the experimental rig. One vertical joint and one horizontal joint of approximately 10 mm were provided within the installation as shown in Figure E16.

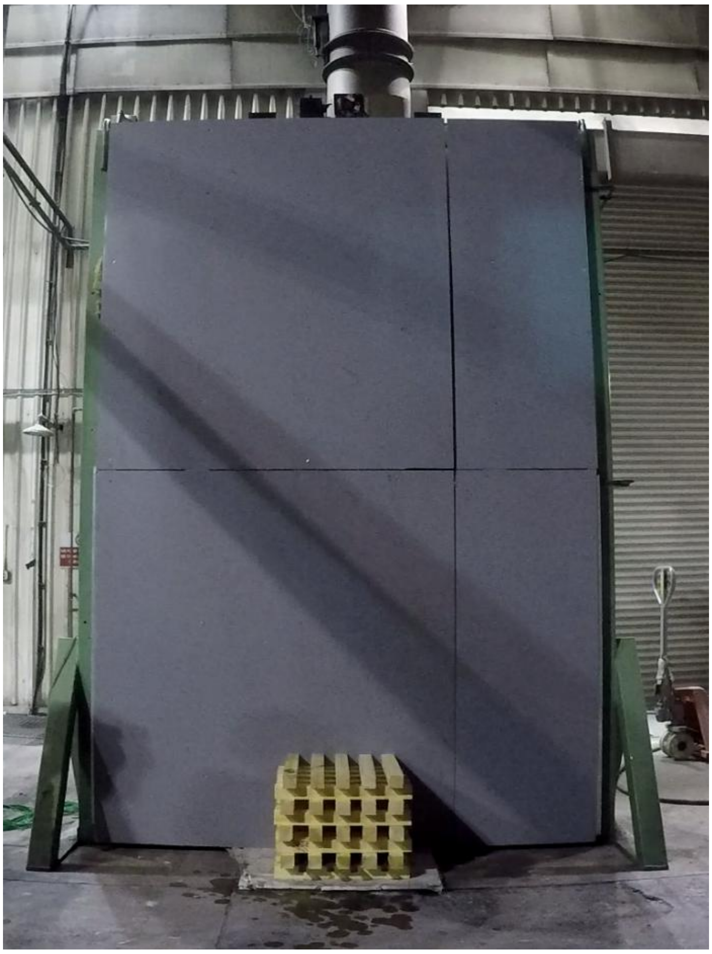


Figure E16 – Sample S4 aluminium honeycomb panels installed on the rig

Figure E17 shows photographs during the fire exposure at specified times.

5 minutes from ignition

10 minutes from ignition

20 minutes from ignition

25 minutes from ignition

Figure E17 – Photographs during the fire at 5, 10, 20 and 25 minutes from ignition

No falling debris or burning droplets were observed during the fire. Discoloration of the panels was observed in the area of direct flame exposure.

Based on both measured values and visual observation after approximately 22 minutes of thermal exposure the fire breached the cavity. Local delamination and local flaming of the bonded honeycomb was observed for a short duration of time.

No significant vertical or horizontal flame spread on the surface of the aluminium honeycomb panels was observed.

Figure E18 shows the heat release rate as a function of time during the fire exposure, including the fire source. Based on the original crib calibrations and measured values from the calorimeter it is assumed that the peak heat release rate for the crib alone is approximately 300 kW.

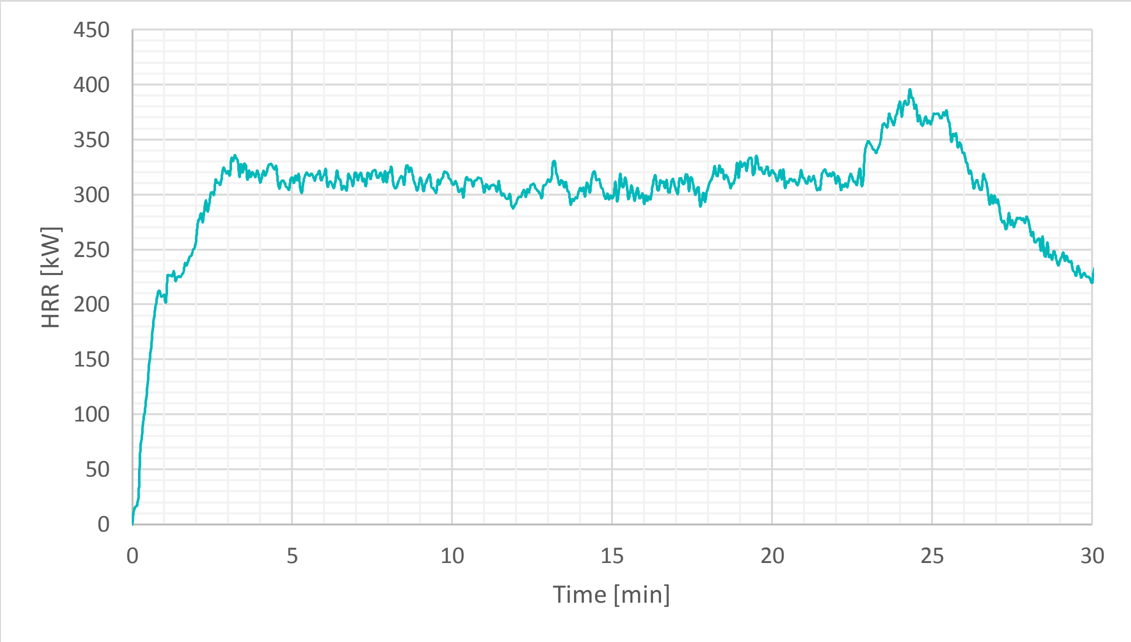


Figure E18 – Heat release rate measured during the fire, including the source

Figure E19 shows the heat flux on the centre line recorded during the fire at a height of 3.0 m from the ground.

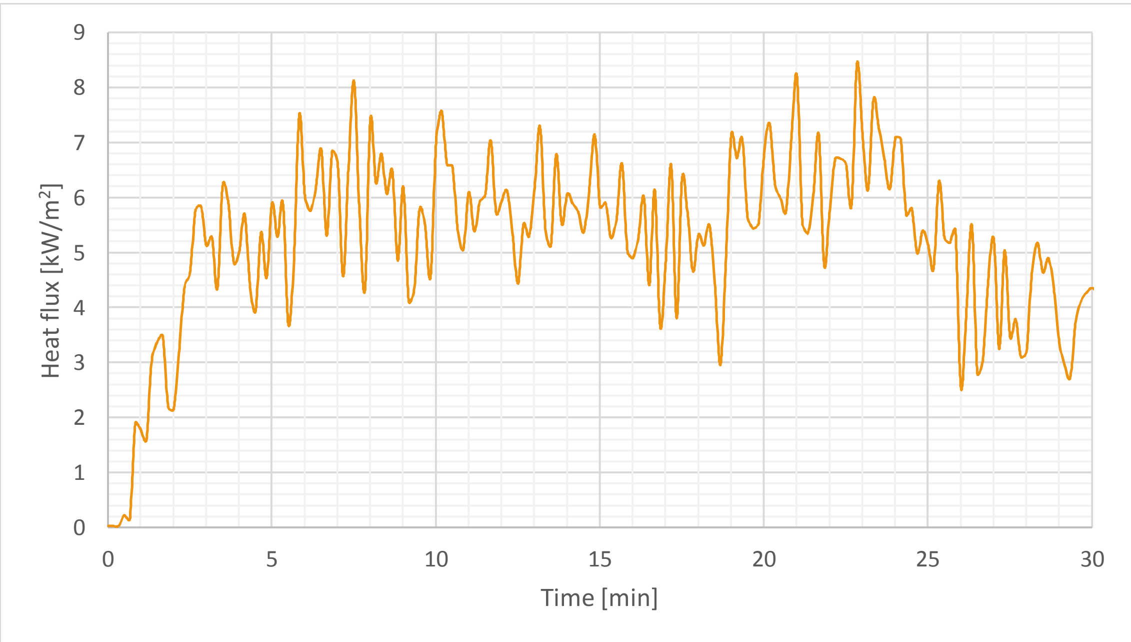


Figure E19 – Heat flux recorded during the fire at 3.0 m height

Table E10 shows the maximum external temperature, the maximum cavity temperature, maximum temperature at 3.0 m, time to peak heat release rate (HRR), peak HRR, maximum heat flux (HF) at 3.0 m and total heat release (THR) over a period of 30 minutes.

Table E10 – Summary of different measured parameters during the experiment

Max external temp [°C]	Max cavity temp [°C]	Max H=3.0m Temp [°C]	Time to peak HRR [min]	Peak HRR [kW]	Max H=3.0m Heat flux [kW/m^2]	THR [MJ]
801	917	191	24.3	396.1	8.4	544.3

A summary of the visual observations is presented in Table E11.

Table E11 – Visual observations during the experiment

Burning droplets	Time to burn though [min]	Burn through	Area consumed [m^2]	Vertical flame spread	Horizontal flame spread
No	≈22	Yes	≈0.33	No	No

Figure E20 shows the sample after the fire. The aluminium honeycomb panels were consumed locally in the zone of direct flame impingement. Discoloration and distortion could be observed on the surface of the panels. The aluminium honeycomb was visible and local delamination could be observed around the consumed edges of the panel.

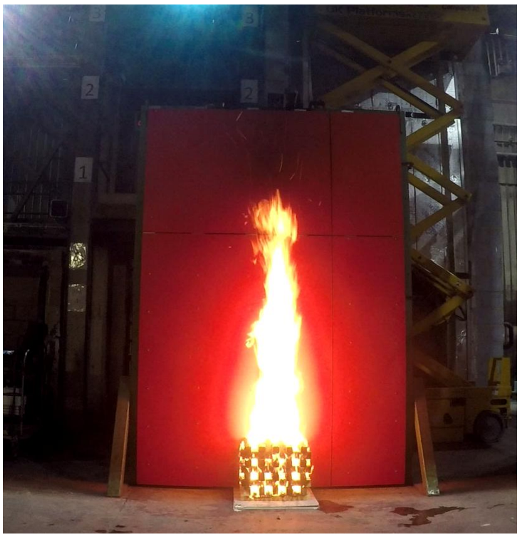
Figure E20 – Post fire observations

E2.2.5 Sample S5 10 mm HPL panels

The fifth sample was a high pressure laminate (HPL) with a fire-retardant wood-based fibre core, bonded with thermosetting resins at high pressures and temperatures. The 10 mm thick HPL panels were cut to size and installed onto 100 mm wide aluminium T-shaped rails positioned 400 mm apart. The panels were installed onto the rails using 25 mm long self-drill self-tap screws at 300 mm vertical centres. Figure E21 shows the material installed on the rig. A cavity of 50 mm was provided between the HPL panels and the incombustible support of the experimental rig. One vertical joint and one horizontal joint of approximately 10mm were provided within the installation as shown in Figure E21.

Figure E21 – Sample S5 HPL panels installed on the rig

Figure E22 shows photographs during the fire exposure at specified times.



5 minutes from ignition

10 minutes from ignition

20 minutes from ignition

25 minutes from ignition

Figure E22 – Photographs during the fire at 5, 10, 20, and 25 minutes from ignition

During the fire exposure no burning droplets were observed. Discoloration of the panels was observed in the area of direct flame exposure.

Based on both measured values and visual observation after approximately 20 minutes of thermal exposure the fire breached the cavity. Local cracks were observed on the surface of the panels. Detachment of small parts of the panels in the area of direct flame impingement were observed during the experiment.

Localised sustained flaming was observed on the surface of the panels in the fire exposed area. Limited horizontal flame spread was recorded on the external surface of the panels in the area of direct heat exposure. The surface burning self-extinguished without direct flame exposure.

No significant vertical or horizontal flame spread on the surface of the HPL panels was observed.

Figure E23 shows the heat release rate as a function of time during the fire exposure, including the fire source. Based on the original crib calibrations and measured values from the calorimeter it is assumed that the peak heat release rate for the crib alone is approximately 300 kW.

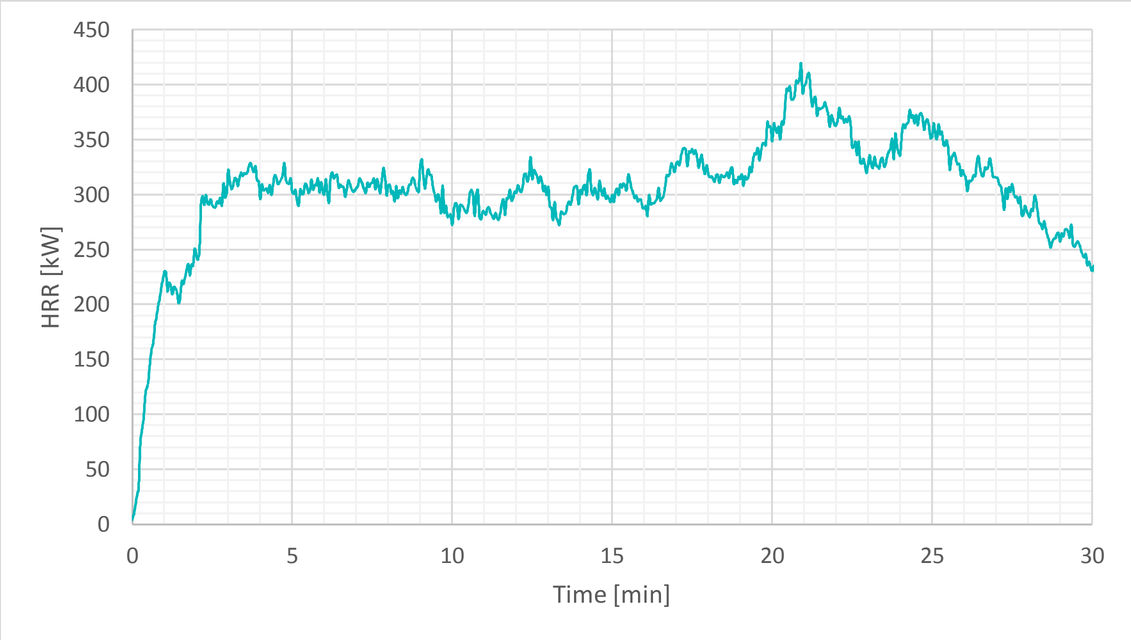


Figure E23 – Heat release rate measured during the fire, including the source

Figure E24 shows the heat flux on the centre line recorded during the fire at a height of 3.0 m from the ground.

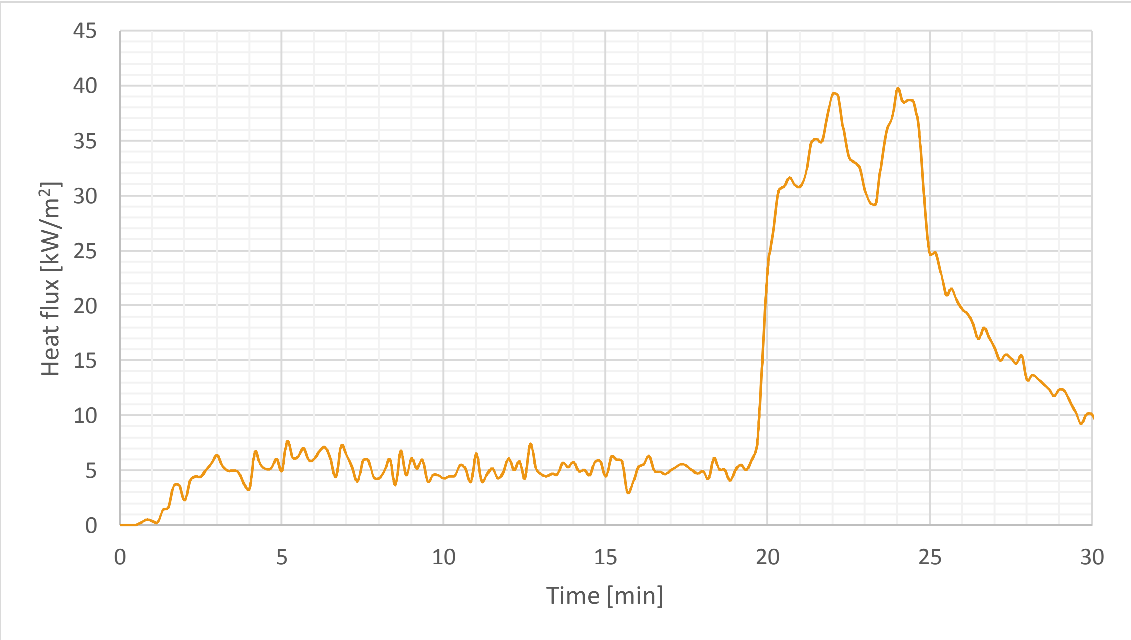


Figure E24 – Heat flux recorded during the fire at 3.0 m height

Table E12 shows the maximum external temperature, the maximum cavity temperature, maximum temperature at 3.0 m, time to peak heat release rate (HRR), peak HRR, maximum heat flux (HF) at 3.0 m and total heat release (THR) over a period of 30 minutes.

Table E12 – Summary of different measured parameters during the experiment

Max external temp [°C]	Max cavity temp [°C]	Max H=3.0m Temp [°C]	Time to peak HRR [min]	Peak HRR [kW]	Max H=3.0m Heat flux [kW/m^2]	THR [MJ]
856	1006	387	20.9	419.6	39.8	550.1

A summary of the visual observations is presented in Table E13.

Table E13 – Visual observations during the experiment

Burning droplets	Time to burn though [min]	Burn through	Area consumed [m^2]	Vertical flame spread	Horizontal flame spread
No	≈20	Yes	≈0.46	Localised	Localised

Figure E25 shows the sample after the fire. The HPL panels were consumed locally in the zone of direct flame impingement. Discoloration and distortion could be observed on the surface of the panels. Detachment of parts of the panels could be observed after the fire. The panels had a brittle behaviour when exposed to fire. Localised cracks of the panels could be observed in the area of direct heating.

Figure E25 – Post fire observations

E2.2.6 Sample S6 25 mm aluminium honeycomb panels

The sixth sample consisted of aluminium panels with a bonded aluminium honeycomb core with a total thickness of 25 mm. The aluminium faces had a thickness of 1 mm. A set of four brackets were installed onto each vertical aluminium T-shaped rail positioned 400 mm apart. The panels substructure consisted of aluminium mullions with rectangular section 50 mm × 50 mm and with vertical notches on all four sides. At the desired locations a set of single tapped blocks were installed inside the vertical notches and fixed in position with M6 x 30 mm bolts. The panels had pre-installed brackets in the four corners allowing for a direct fix to the mullions through the tapped blocks using a M6 × 30 mm bolt.

Figure E26 shows the material installed on the rig. A cavity of 140 mm was provided between the aluminium honeycomb panels and the incombustible support of the experimental rig. One vertical joint and one horizontal joint of approximately 15 mm were provided within the installation as shown in Figure E26.

Figure E26 – Sample S6 aluminium honeycomb panels installed on the rig

Figure E27 shows photographs during the fire exposure at specified times.

5 minutes from ignition

10 minutes from ignition

20 minutes from ignition

25 minutes from ignition

Figure E27 – Photographs during the fire at 5, 10, 20 and 25 minutes from ignition

No falling debris or burning droplets were observed during the fire. Discoloration of the panels was observed in the area of direct flame exposure.

Based on both measured values and visual observation after approximately 28 minutes of thermal exposure the fire breached the cavity in a localised area at the bottom of the panels. Local delamination and local flaming of the bonded honeycomb was observed for a short duration of time.

No significant vertical or horizontal flame spread on the surface of the aluminium honeycomb panels was observed.

Figure E28 shows the heat release rate as a function of time during the fire exposure, including the fire source. Based on the original crib calibrations and measured values from the calorimeter it is assumed that the peak heat release rate for the crib alone is approximately 300 kW.

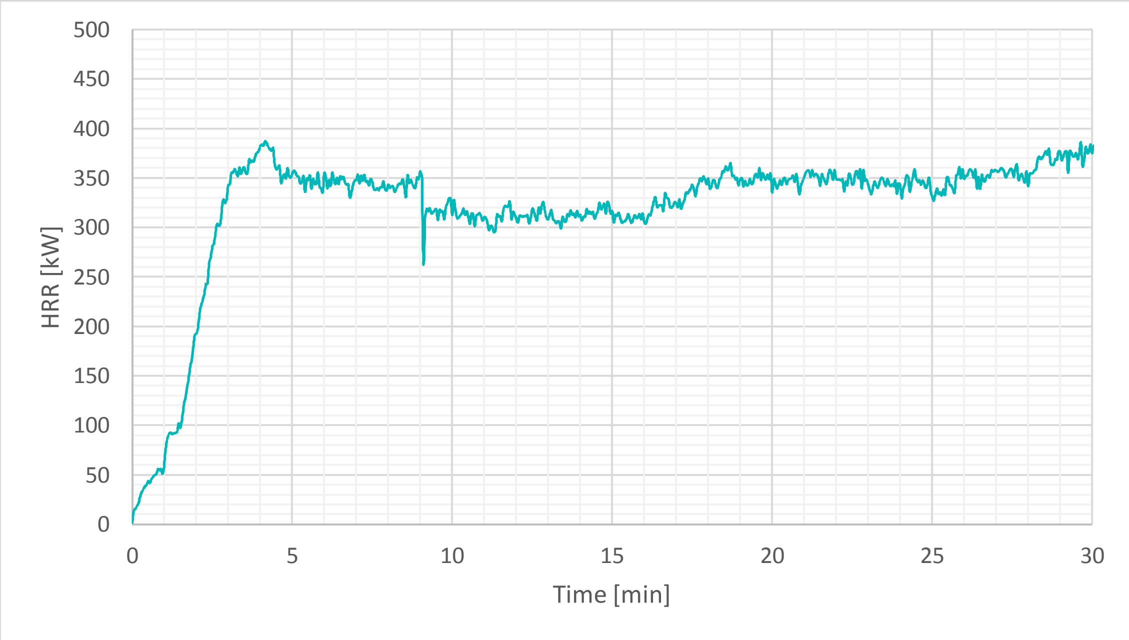


Figure E28 – Heat release rate measured during the fire, including the source

Figure E29 shows the heat flux on the centre line recorded during the fire at a height of 3.0 m from the ground.

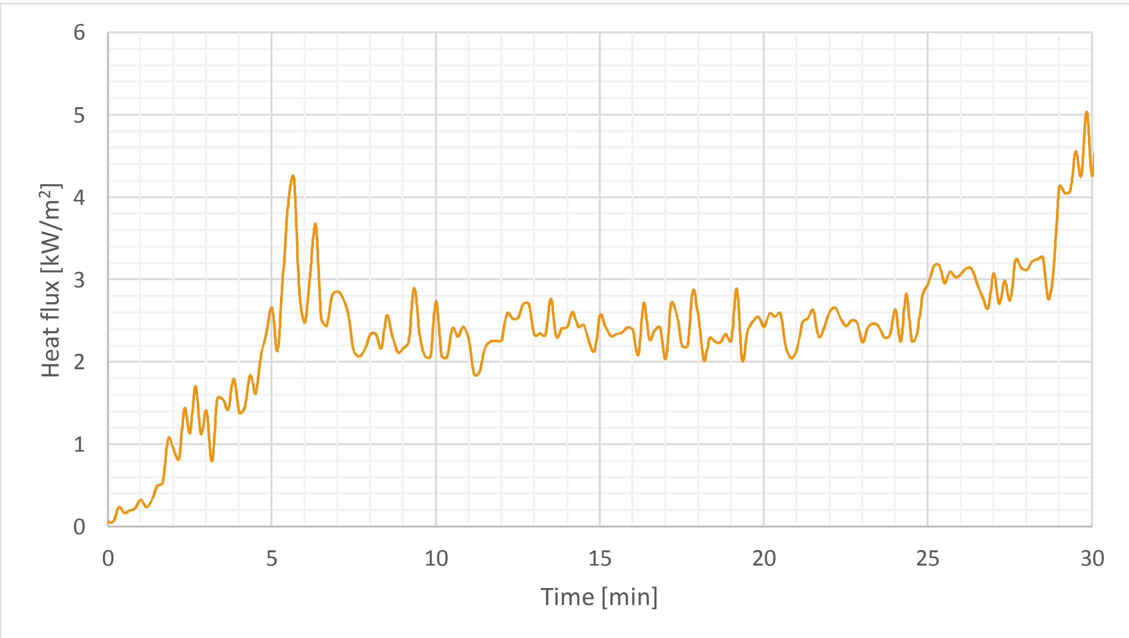


Figure E29 – Heat flux recorded during the fire at 3.0 m height

Table E14 shows the maximum external temperature, the maximum cavity temperature, maximum temperature at 3.0 m, time to peak heat release rate (HRR), peak HRR, maximum heat flux (HF) at 3.0 m and total heat release (THR) over a period of 30 minutes.

Table E14 – Summary of different measured parameters during the experiment

Max external temp [°C]	Max cavity temp [°C]	Max H=3.0m Temp [°C]	Time to peak HRR [min]	Peak HRR [kW]	Max H=3.0m Heat flux [kW/m^2]	THR [MJ]
852	275	83	4.15	387.4	5.2	576.9

A summary of the visual observations is presented in Table E15.

Table E15 – Visual observations during the experiment

Burning droplets	Time to burn though [min]	Burn through	Area consumed [m^2]	Vertical flame spread	Horizontal flame spread
No	≈28	Localised	≈0.21	No	No

Figure E30 shows the sample after the fire. The aluminium honeycomb panels were consumed locally in the zone of direct flame impingement. Discoloration and distortion could be observed on the surface of the panels. The aluminium honeycomb was visible and local delamination could be observed around the consumed edges of the panel.

Figure E30 – Post fire observations

E2.2.7 Sample S7 6 mm wood-based HPL panels

The seventh sample consisted of high pressure laminate (HPL) with a fire-retardant cellulose fibre core, bonded with thermosetting resins at high pressures and temperatures. Each panel consists of a high density bakelite core with a surface treated synthetic resin and an exterior PVDF (polyvinylidene difluoride) film. The 6 mm thick HPL panels were cut to size and installed onto 100 mm wide aluminium T-shaped rails positioned 400 mm apart. The panels were installed onto the rails using 25 mm long self-drill self-tap screws at 300 mm vertical centres. Figure E31 shows the material installed on the rig. A cavity of 50 mm was provided between the HPL panels and the incombustible support of the experimental rig. One vertical joint and one horizontal joint of approximately 10 mm were provided within the installation as shown in Figure E31.

Figure E31 – Sample S7 wood-based HPL panels installed on the rig

Figure E32 shows photographs during the fire exposure at specified times.

5 minutes from ignition

10 minutes from ignition

20 minutes from ignition

25 minutes from ignition

Figure E32 – Photographs during the fire at 5, 10, 20 and 25 minutes from ignition

During the fire exposure no burning droplets were observed. Discoloration of the panels was observed in the area of direct flame exposure. At the beginning of the experiment localised removal of surface material (spalling) was observed in the area of direct flame exposure.

Based on both measured values and visual observation after approximately 3 minutes of thermal exposure the fire breached the cavity. Local cracks were observed on the surface of the panels. Detachment of small parts of the panels in the area of direct flame impingement and central axis were observed during the experiment.

Localised sustained flaming was observed on the surface of the panels in the fire exposed area. Limited horizontal flame spread was recorded on the external surface of the panels in the area of direct heat exposure. The surface burning self-extinguished without direct flame exposure. No significant vertical or horizontal flame spread on the surface of the HPL panels was observed. Figure E33 shows the heat release rate as a function of time during the fire exposure, including the fire source. Based on the original crib calibrations and measured values from the calorimeter it is assumed that the peak heat release rate for the crib alone is approximately 300 kW.

Figure E33 – Heat release rate measured during the fire, including the source

Figure E34 shows the heat flux recorded on the centre line during the fire at a height of 3.0 m from the ground.

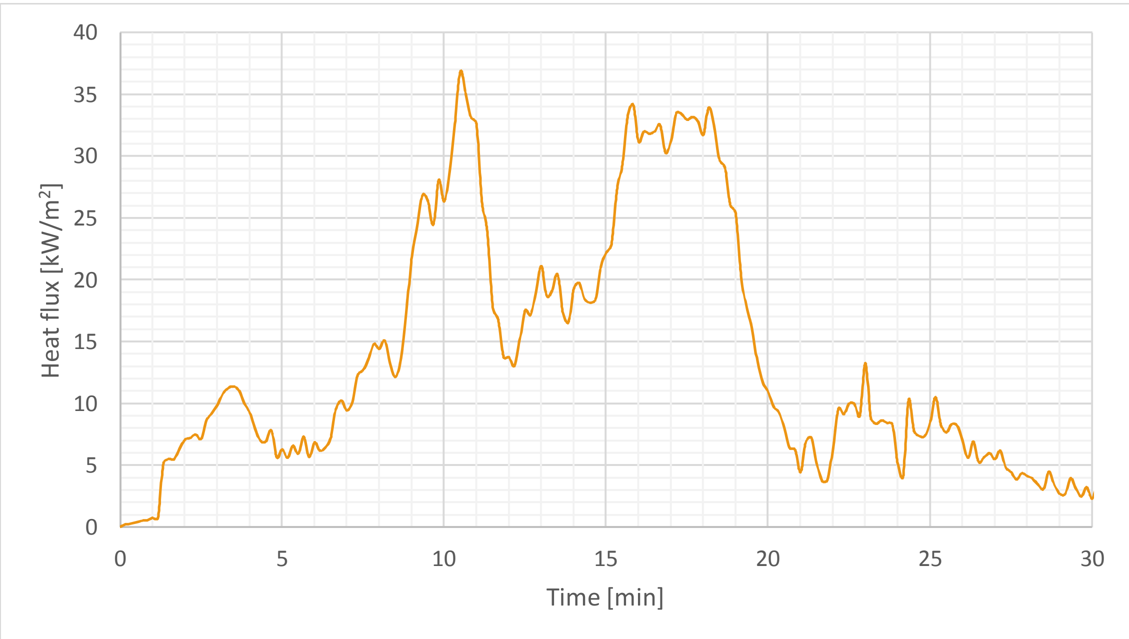


Figure E34 – Heat flux recorded during the fire at 3.0 m height

Table E16 shows the maximum external temperature, the maximum cavity temperature, maximum temperature at 3.0m, time to peak heat release rate (HRR), peak HRR, maximum heat flux (HF) at 3.0 m and total heat release (THR) over a period of 30 minutes.

Table E16 – Summary of different measured parameters during the experiment

Max external temp [°C]	Max cavity temp [°C]	Max H=3.0m Temp [°C]	Time to peak HRR [min]	Peak HRR [kW]	Max H=3.0m Heat flux [kW/m^2]	THR [MJ]
884.9	921	165	19.1	484.4	36.9	671

A summary of the visual observations is presented in Table E17.

Table E17 – Visual observations during the experiment

Burning droplets	Time to burn though [min]	Burn through	Area consumed [m^2]	Vertical flame spread	Horizontal flame spread
No	≈3	Yes	≈1.15	Localised	Localised

Figure E35 shows the sample after the fire. The HPL panels were consumed locally in the zone of direct flame impingement. Discoloration and distortion could be observed on the surface of the panels. Detachment of parts of the panels could be observed after the fire. The panels had a brittle behaviour when exposed to fire. Localised cracks of the panels could be observed in the area of direct heating.

Figure E35 – Post fire observations

E2.2.8 Sample S8 10 mm wood-based HPL panels

The eighth sample consisted of high pressure laminate (HPL) with a fire-retardant cellulose fibre core, bonded with thermosetting resins at high pressures and temperatures. Each panel consists of a high density bakelite core with a surface treated synthetic resin and an exterior PVDF film. The 10 mm thick HPL panels were cut to size and installed onto 100 mm wide aluminium T-shaped rails positioned 400 mm apart. The panels were installed onto the rails using 25 mm long self-drill self-tap screws at 300 mm vertical centres. Figure E36 shows the material installed on the rig. A cavity of 50 mm was provided between the HPL panels and the incombustible support of the experimental rig. One vertical joint and one horizontal joint of approximately 10 mm were provided within the installation as shown in Figure E36.

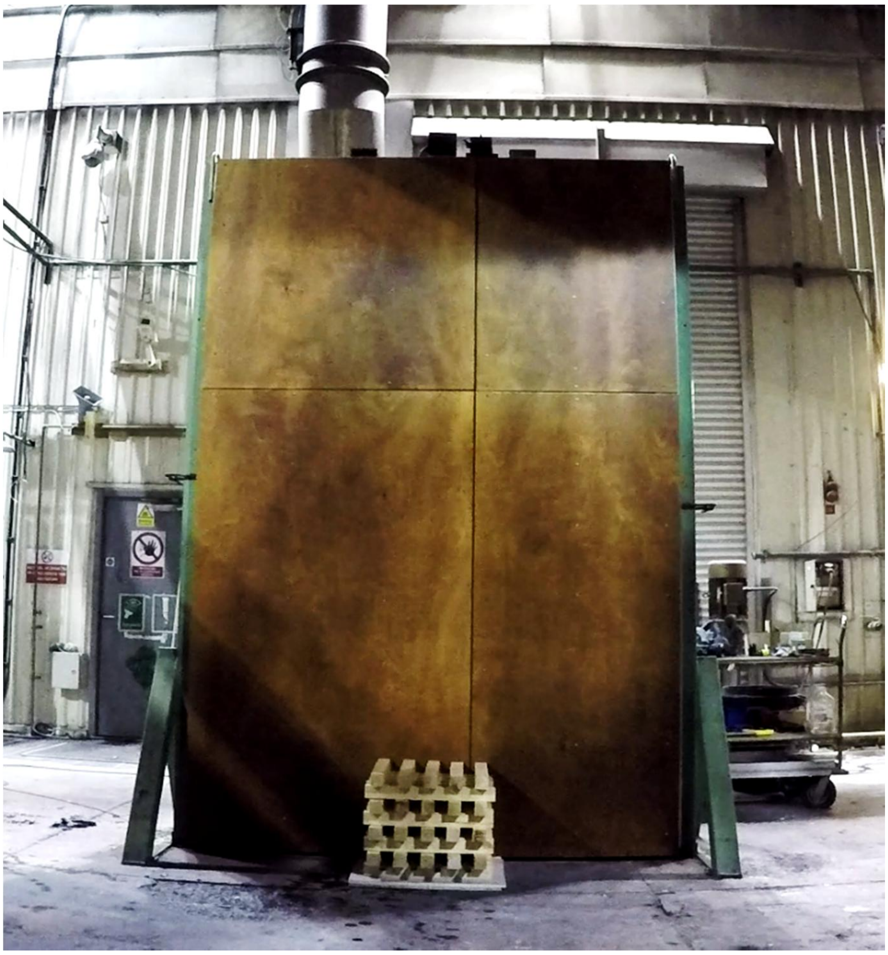


Figure E36 – Sample S8 wood-based HPL panels installed on the rig

Figure E37 shows photographs during the fire exposure at specified times.

5 minutes from ignition

10 minutes from ignition

20 minutes from ignition

25 minutes from ignition

Figure E37 – Photographs during the fire at 5, 10, 20 and 25 minutes from ignition

During the fire exposure no burning droplets were observed. Discoloration of the panels was observed in the area of direct flame exposure. At the beginning of the experiment localised removal of surface material (spalling) was observed in the area of direct flame exposure. Due to the restraint and thermal expansion the central panel tended to bend towards the fire source.

Based on both measured values and visual observation after approximately 12 minutes of thermal exposure the fire breached the cavity. Local cracks were observed on the surface of the panels. Detachment of small parts of the panels in the area of direct flame impingement along the central axis was observed during the experiment. Localised sustained flaming was observed on the surface of the panels in the fire exposed area. Limited horizontal flame spread was recorded on the external surface of the panels in the area of direct heat exposure. The surface burning self-extinguished without direct flame exposure.

No significant vertical or horizontal flame spread on the surface of the HPL panels was observed. Figure E38 shows the heat release rate as a function of time during the fire exposure, including the fire source. Based on the original crib calibrations and measured values from the calorimeter it is assumed that the peak heat release rate for the crib alone is approximately 300 kW.

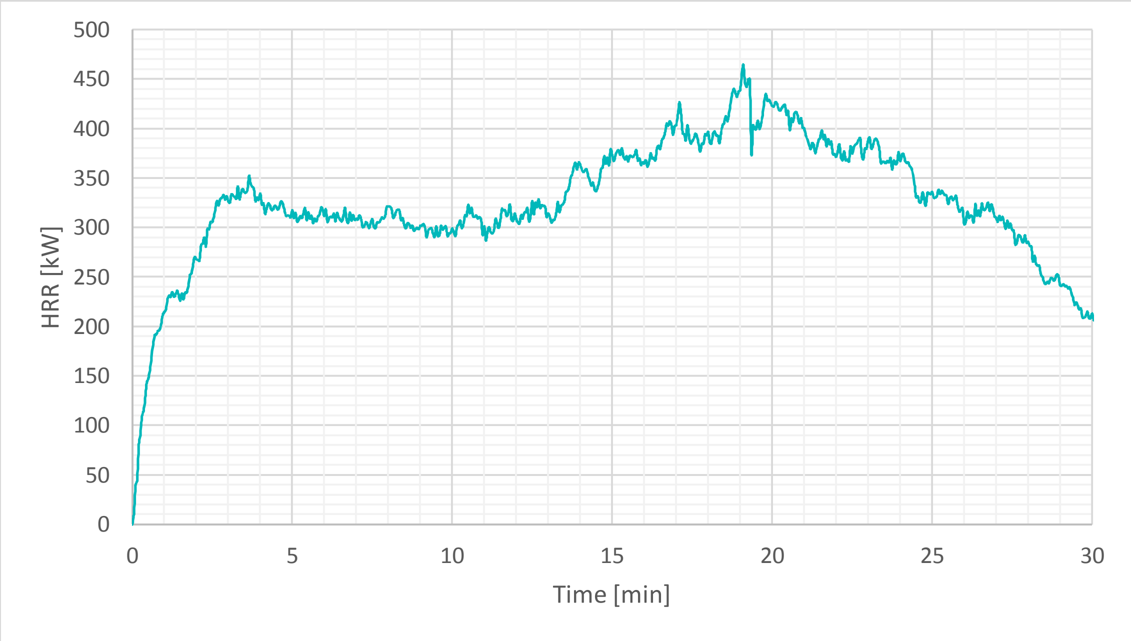


Figure E38 – Heat release rate measured during the fire, including the source

Figure E39 shows the heat flux on the centre line recorded during the fire at a height of 3.0 m from the ground.

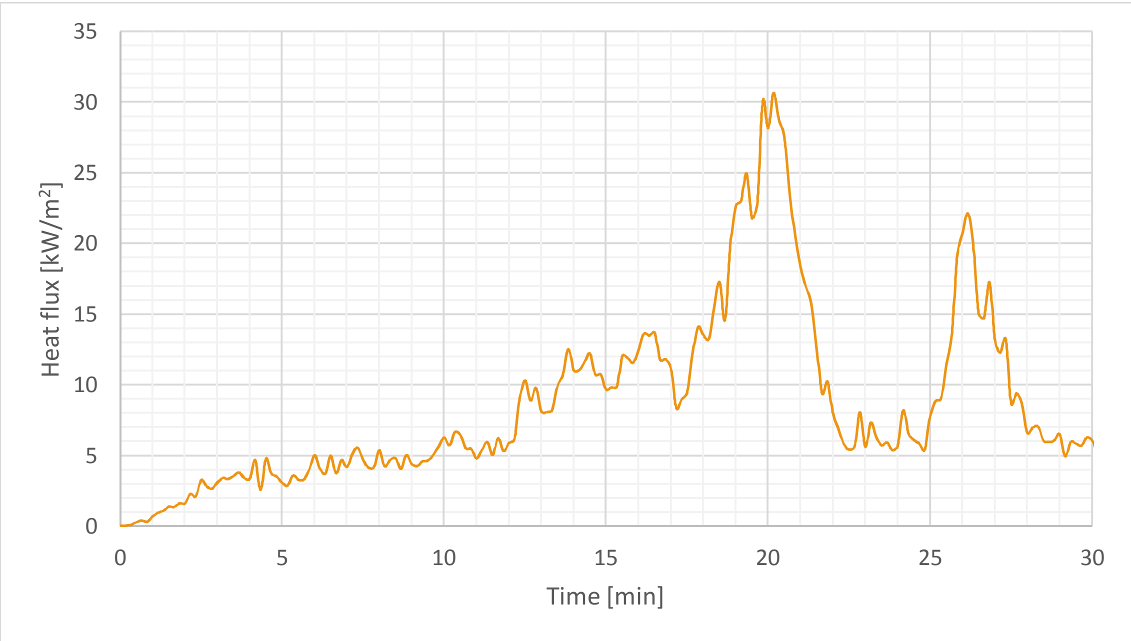


Figure E39 – Heat flux recorded during the fire at 3.0 m height

Table E18 shows the maximum external temperature, the maximum cavity temperature, maximum temperature at 3.0 m, time to peak heat release rate (HRR), peak HRR, maximum heat flux (HF) at 3.0 m and total heat release (THR) over a period of 30 minutes.

Table E18 – Summary of different measured parameters during the experiment

Max external temp [°C]	Max cavity temp [°C]	Max H=3.0m Temp [°C]	Time to peak HRR [min]	Peak HRR [kW]	Max H=3.0m Heat flux [kW/m^2]	THR [MJ]
884	884	148	19.1	464.6	30.7	587.7

A summary of the visual observations is presented in Table E19.

Table E19 – Visual observations during the experiment

Burning droplets	Time to burn though [min]	Burn through	Area consumed [m^2]	Vertical flame spread	Horizontal flame spread
No	≈12	Yes	≈1.0	Localised	Localised

Figure E40 shows the sample after the fire. The HPL panels were consumed locally in the zone of direct flame impingement. Discoloration and distortion could be observed on the surface of the panels. Detachment of parts of the panels could be observed after the fire. The panels had a brittle behaviour when exposed to fire. Localised cracks of the panels could be observed in the area of direct heating.

Figure E40 – Post fire observations

E2.2.9 Sample S9 6 mm HPL with PUR resin panels

The ninth sample consisted of high pressure laminate (HPL) with a fire-retardant wood fibre core, bonded with double-hardened acrylic polyurethane resins at high pressures and temperatures. The 6 mm thick HPL panels were cut to size and installed onto 100 mm-wide aluminium T-shaped rails positioned 400 mm apart. The panels were installed onto the rails using 25 mm long self-drill self-tap screws at 300 mm vertical centres. Figure E41 shows the material installed on the rig. A cavity of 50 mm was provided between the HPL panels and the incombustible support of the experimental rig. One vertical joint and one horizontal joint of approximately 10 mm were provided within the installation as shown in Figure E41.

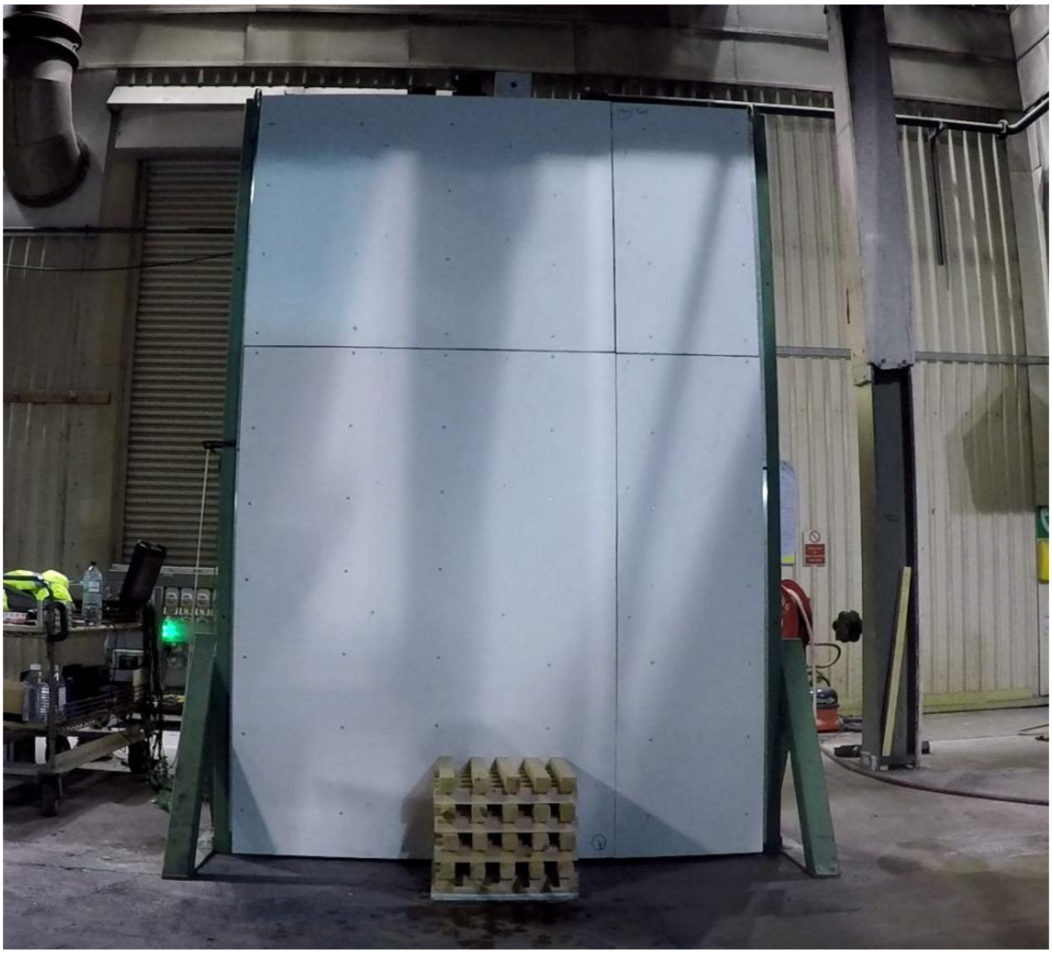
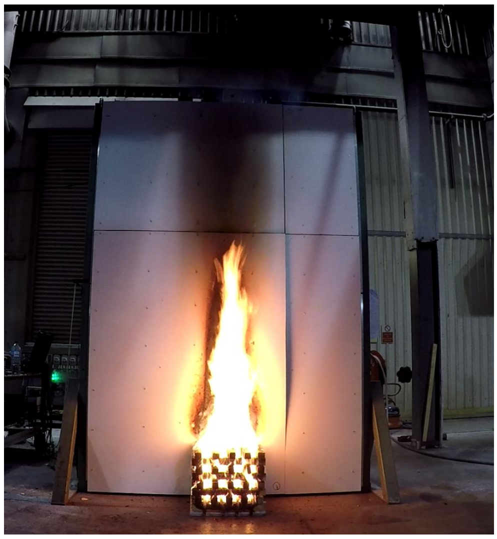


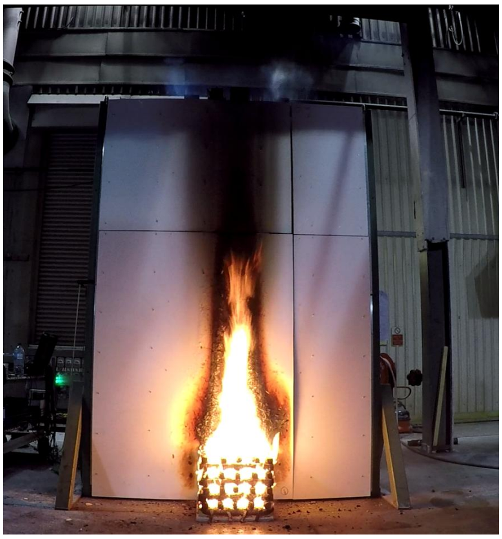
Figure E41 – Sample S9 HPL with PUR resin panels installed on the rig

Figure E42 shows photographs during the fire exposure at specified times.

5 minutes from ignition



10 minutes from ignition



20 minutes from ignition

25 minutes from ignition

Figure E42 – Photographs during the fire at 5, 10, 20 and 25 minutes from ignition

During the fire exposure no burning droplets were recorded. Discoloration of the panels was observed in the area of direct flame exposure. At the beginning of the experiment localised removal of surface material (spalling) was observed in the area of direct flame exposure. Due to the restraint and thermal expansion the central panel tended to bend towards the fire source.

Based on both measured values and visual observation after approximately 11 minutes of thermal exposure the fire breached the cavity. Local cracks were observed on the surface of the panels. Detachment of small parts of the panels in the area of direct flame impingement along the central axis was observed during the experiment.

Localised sustained flaming was observed on the surface of the panels in the fire exposed area. Limited horizontal flame spread was observed on the external surface of the panels in the area of direct heat exposure. The surface burning self-extinguished without direct flame exposure.

No significant vertical or horizontal flame spread on the surface of the HPL panels was observed.

Figure E43 shows the heat release rate as a function of time during the fire exposure, including the fire source. Based on the original crib calibrations and measured values from the calorimeter it is assumed that the peak heat release rate for the crib alone is approximately 300 kW.

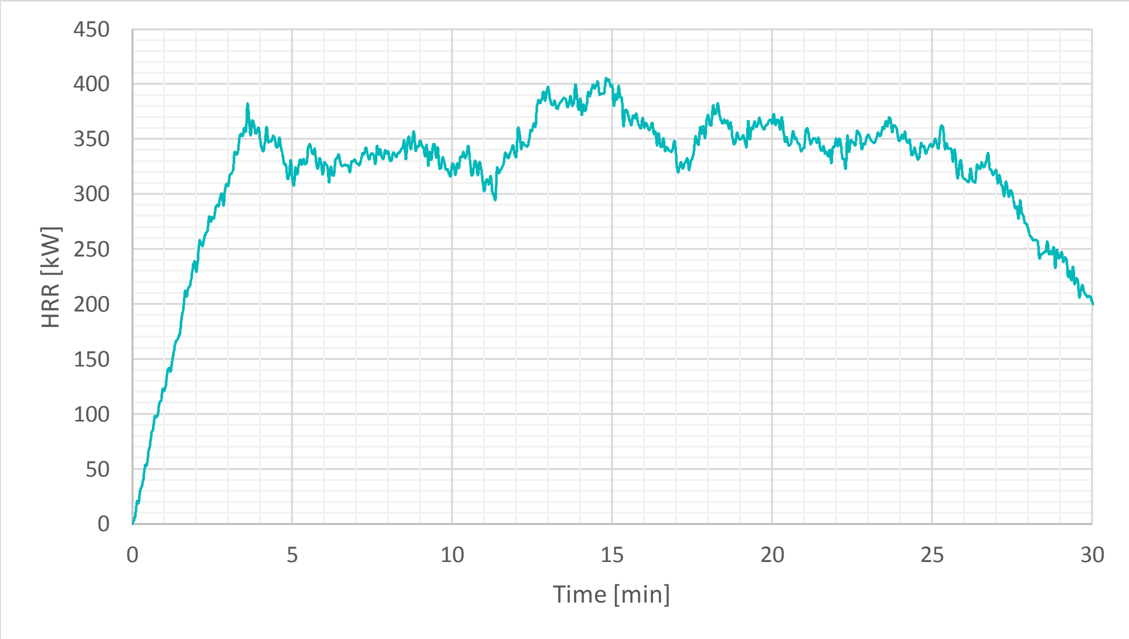


Figure E43 – Heat release rate measured during the fire, including the source

Figure E44 shows the heat flux recorded on the centre line during the fire at a height of 3.0 m from the ground.

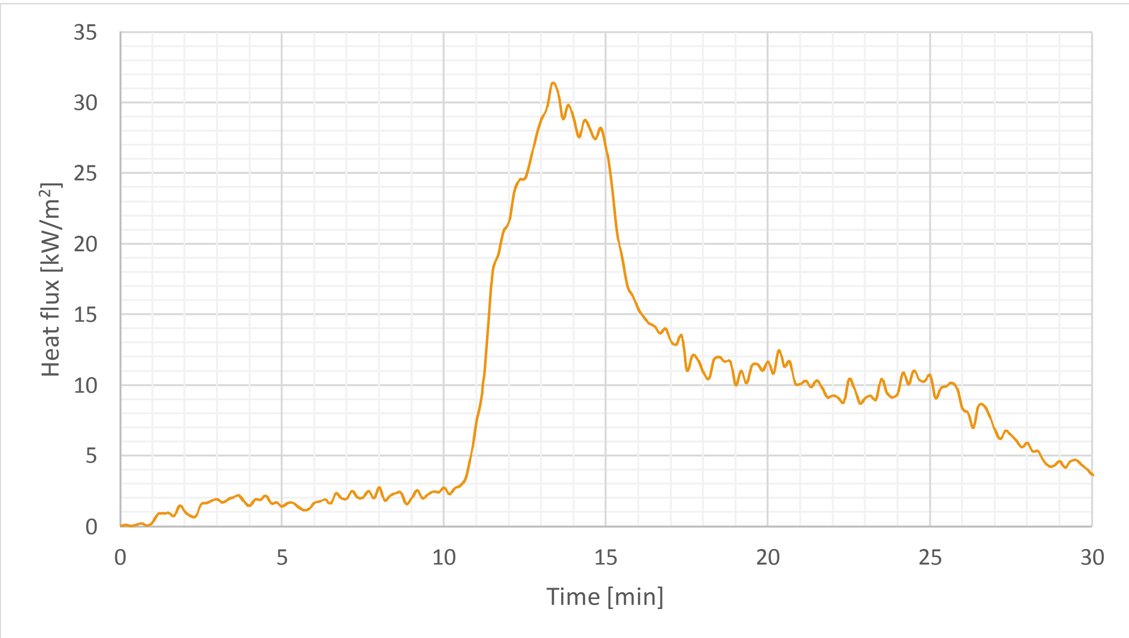


Figure E44 – Heat flux recorded during the fire at 3.0 m height

Table E20 shows the maximum external temperature, the maximum cavity temperature, maximum temperature at 3.0 m, time to peak heat release rate (HRR), peak HRR, maximum heat flux (HF) at 3.0 m and total heat release (THR) over a period of 30 minutes.

Table E20 – Summary of different measured parameters during the experiment

Max external temp [°C]	Max cavity temp [°C]	Max H=3.0m Temp [°C]	Time to peak HRR [min]	Peak HRR [kW]	Max H=3.0m Heat flux [kW/m^2]	THR [MJ]
870	944	228	14.8	405.4	31.4	577.8

A summary of the visual observations is presented in Table E21.

Table E21 – Visual observations during the experiment

Burning droplets	Time to burn though [min]	Burn through	Area consumed [m^2]	Vertical flame spread	Horizontal flame spread
No	≈11	Yes	≈0.72	Localised	Localised

Figure E45 shows the sample after the fire. The HPL panels were consumed locally in the zone of direct flame impingement. Discoloration and distortion could be observed on the surface of the panels. Detachment of parts of the panels could be observed after the fire. The panels had a brittle behaviour when exposed to fire. Localised cracks of the panels could be observed in the area of direct heating.

Figure E45 – Post fire observations

E2.2.10 Sample S10 10 mm HPL with PUR resin panels

The tenth sample consisted of high pressure laminate (HPL) with a fire-retardant wood fibre core, bonded with double-hardened acrylic polyurethane resins at high pressures and temperatures. The 10 mm thick HPL panels were cut to size and installed onto 100 mm wide aluminium T-shaped rails positioned 400 mm apart. The panels were installed onto the rails using 25 mm long self-drill self-tap screws at 300 mm vertical centres. Figure E46 shows the material installed on the rig. A cavity of 50 mm was provided between the HPL panels and the incombustible support of the experimental rig. One vertical joint and one horizontal joint of approximately 10 mm were provided within the installation as shown in Figure E46.

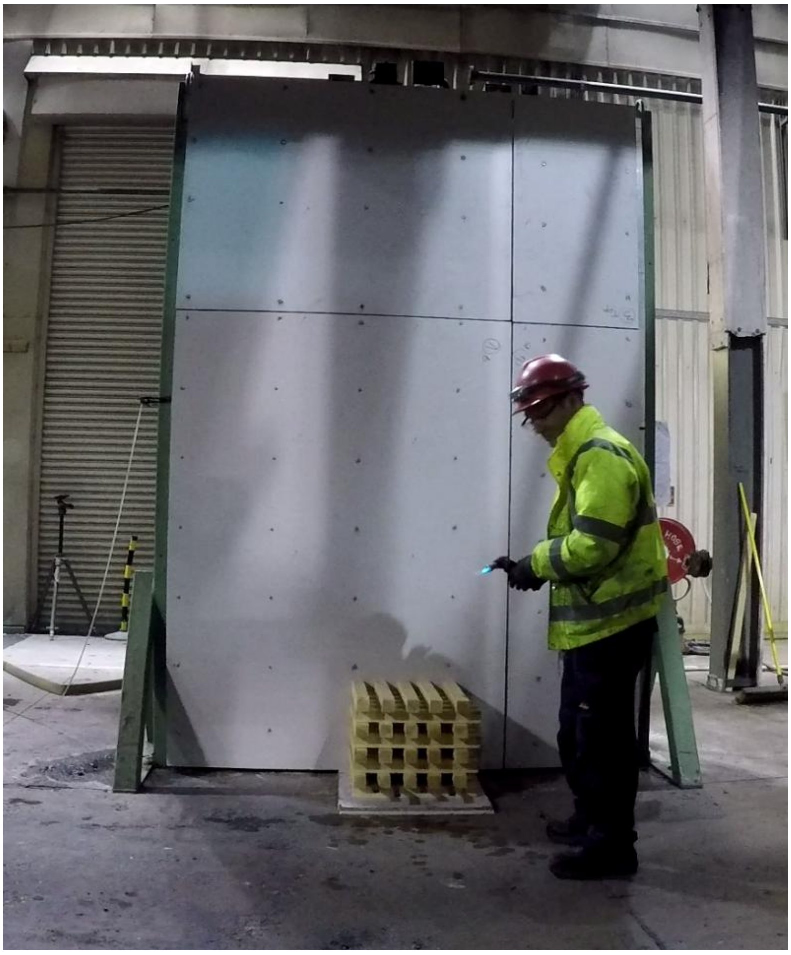
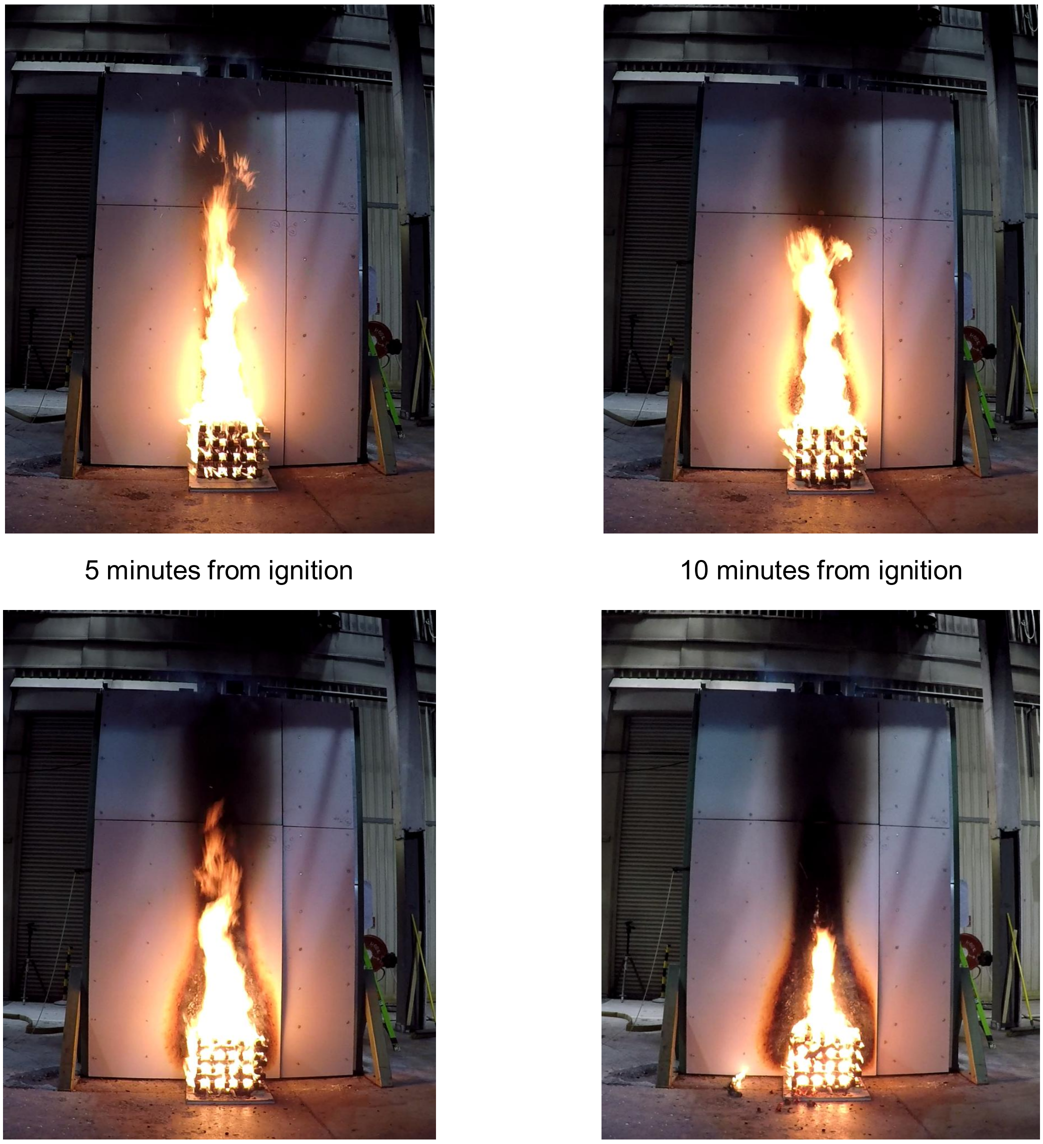


Figure E46 – Sample S10 HPL with PUR resin panels installed on the rig

Figure E47 shows photographs during the fire exposure at specified times.



5 minutes from ignition

10 minutes from ignition

20 minutes from ignition

25 minutes from ignition

Figure E47 – Photographs during the fire at 5, 10, 20 and 25 minutes from ignition

During the fire exposure no burning droplets were observed. Discoloration of the panels was observed in the area of direct flame exposure. At the beginning of the experiment localised removal of surface material (spalling) was observed in the area of direct flame exposure. Due to the restraint and thermal expansion the central panel tended to bend towards the fire source.

Based on both measured values and visual observation after approximately 22 minutes of thermal exposure the fire breached the cavity. Local cracks were observed on the surface of the panels. Detachment of small parts of the panels in the area of direct flame impingement and central axis was observed during the experiment.

Localised sustained flaming was observed on the surface of the panels in the fire exposed area. Limited horizontal flame spread was recorded on the external surface of the panels in the area of direct heat

exposure. The surface burning self-extinguished without direct flame exposure. No significant vertical or horizontal flame spread on the surface of the HPL panels was observed.

Figure E48 shows the heat release rate as a function of time during the fire exposure, including the fire source. Based on the original crib calibrations and measured values from the calorimeter it is assumed that the peak heat release rate for the crib alone is approximately 300 kW.

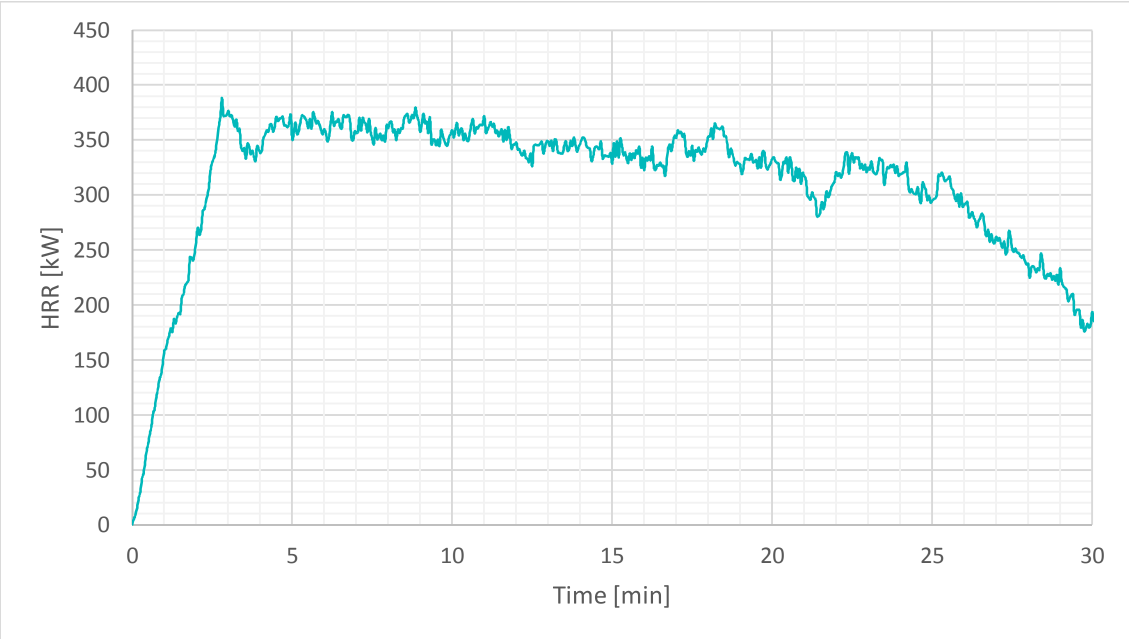


Figure E48 – Heat release rate measured during the fire, including the source

Figure E49 shows the heat flux on the centre line recorded during the fire at a height of 3.0 m from the ground.

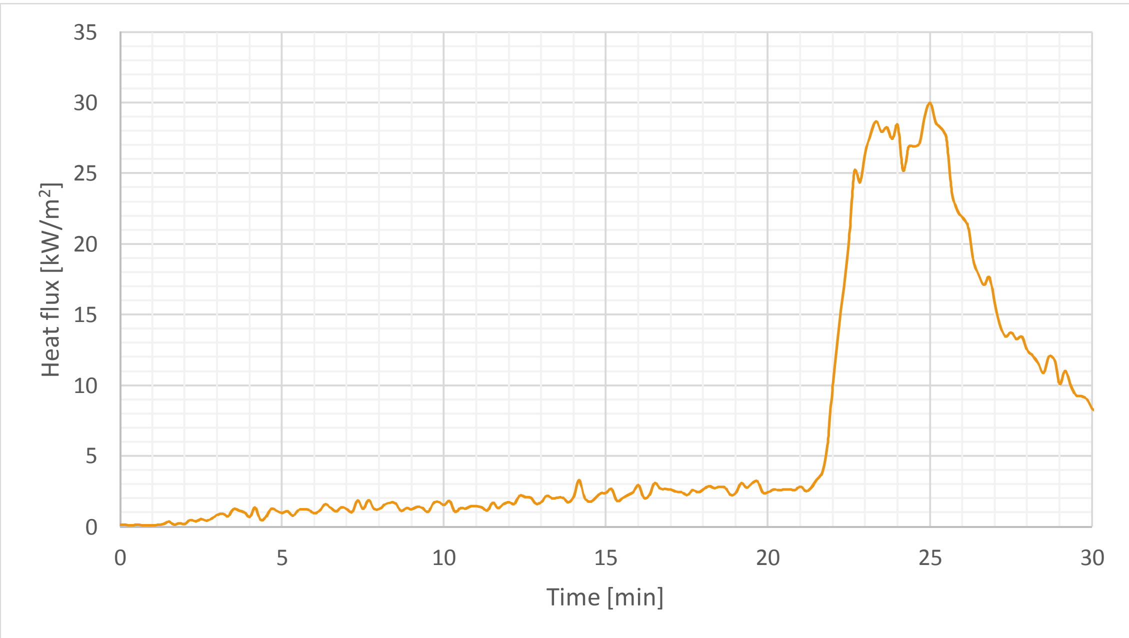


Figure E49 – Heat flux recorded during the fire at 3.0 m height

Table E22 shows the maximum external temperature, the maximum cavity temperature, maximum temperature at 3.0 m, time to peak heat release rate (HRR), peak HRR, maximum heat flux (HF) at 3.0 m and total heat release (THR) over a period of 30 minutes.

Table E22 – Summary of different measured parameters during the experiment

Max external temp [°C]	Max cavity temp [°C]	Max H=3.0m Temp [°C]	Time to peak HRR [min]	Peak HRR [kW]	Max H=3.0m Heat flux [kW/m^2]	THR [MJ]
847	975	214	2.8	388	30	564

A summary of the visual observations is presented in Table E23.

Table E23 – Visual observations during the experiment

Burning droplets	Time to burn though [min]	Burn through	Area consumed [m^2]	Vertical flame spread	Horizontal flame spread
No	≈22	Yes	≈0.47	Limited	Limited

Figure E50 shows the sample after the fire. The HPL panels were consumed locally in the zone of direct flame impingement. Discoloration and distortion could be observed on the surface of the panels. Detachment of parts of the panels could be observed after the fire. The panels had a brittle behaviour when exposed to fire. Localised cracks of the panels could be observed in the area of direct heating.

Figure E50 – Post fire observations

E2.2.11 Sample S11 6 mm HPL phenolic panels

The eleventh sample consisted of high pressure laminate (HPL) with a fire-retardant wood fibre core, bonded with double-hardened acrylic polyurethane resins at high pressures and temperatures. The 6 mm thick HPL panels were cut to size and installed onto 100 mm wide aluminium T-shaped rails positioned 400 mm apart. The panels were installed onto the rails using 25 mm long self-drill self-tap screws at 300mm vertical centres. Figure E51 shows the material installed on the rig. A cavity of 50 mm was provided between the HPL panels and the incombustible support of the experimental rig. One vertical joint and one horizontal joint of approximately 10 mm were provided within the installation as shown in Figure E51.

Figure E51 – Sample S11 HPL phenolic panels installed on the rig

Figure E52 shows photographs during the fire exposure at specified times.

5 minutes from ignition

10 minutes from ignition

20 minutes from ignition

25 minutes from ignition

Figure E52 – Photographs during the fire at 5, 10, 20 and 25 minutes from ignition

During the fire exposure no burning droplets were observed. Discoloration of the panels was observed in the area of direct flame exposure. At the beginning of the experiment localised removal of surface material (spalling) was observed in the area of direct flame exposure.

Based on both measured values and visual observation after approximately 12 minutes of thermal exposure the fire breached the cavity. Local cracks were observed on the surface of the panels. Detachment of small parts of the panels in the area of direct flame impingement and central axis was observed during the experiment.

Localised sustained flaming was observed on the surface of the panels in the fire exposed area. Limited horizontal flame spread was recorded on the external surface of the panels in the area of direct heat

exposure. The surface burning self-extinguished without direct flame exposure. No significant vertical or horizontal flame spread on the surface of the HPL panels was observed.

Figure E53 shows the heat release rate as a function of time during the fire exposure, including the fire source. Based on the original crib calibrations and measured values from the calorimeter it is assumed that the peak heat release rate for the crib alone is approximately 300 kW.

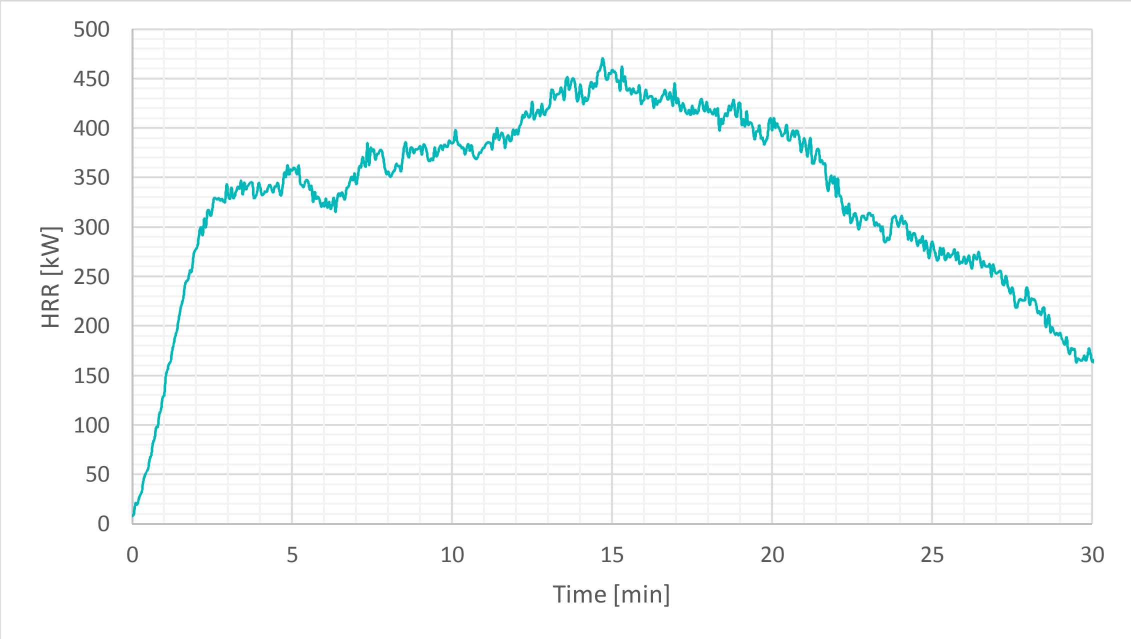


Figure E53 – Heat release rate measured during the fire, including the source

Figure E54 shows the heat flux on the centre line recorded during the fire at a height of 3.0 m from the ground.

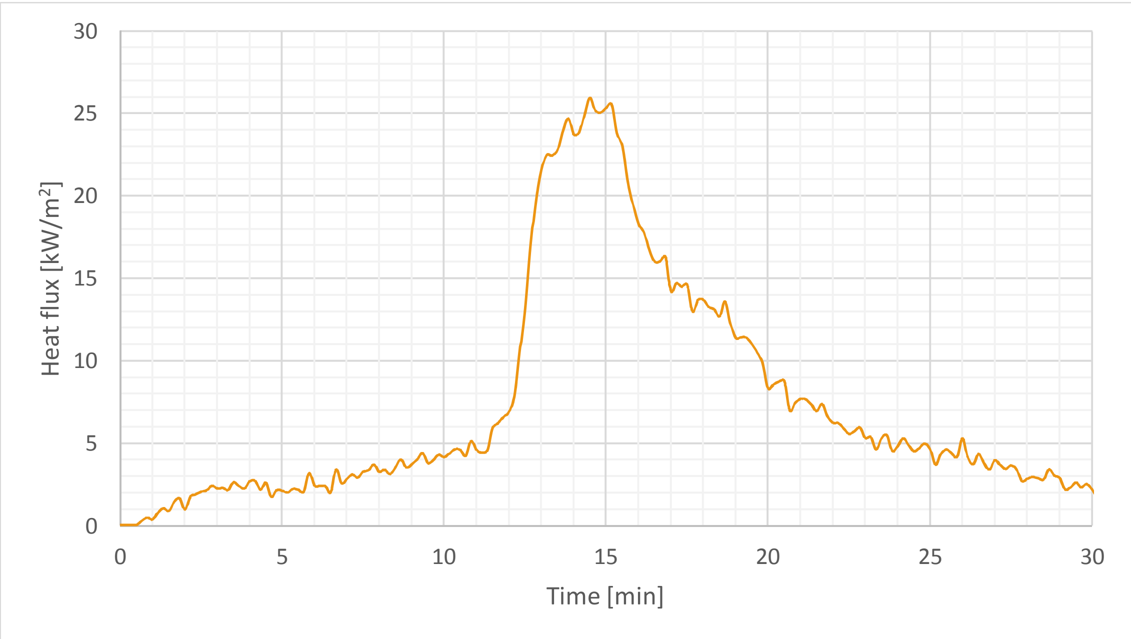


Figure E54 – Heat flux recorded during the fire at 3.0 m height

Table E24 shows the maximum external temperature, the maximum cavity temperature, maximum temperature at 3.0 m, time to peak heat release rate (HRR), peak HRR, maximum heat flux (HF) at 3.0 m and total heat release (THR) over a period of 30 minutes.

Table E24 – Summary of different measured parameters during the experiment

Max external temp [°C]	Max cavity temp [°C]	Max H=3.0m Temp [°C]	Time to peak HRR [min]	Peak HRR [kW]	Max H=3.0m Heat flux [kW/m^2]	THR [MJ]
871	913	198	14.7	471	26	604

A summary of the visual observations is presented in Table E25.

Table E25 – Visual observations during the experiment

Burning droplets	Time to burn though [min]	Burn through	Area consumed [m^2]	Vertical flame spread	Horizontal flame spread
No	≈12	Yes	≈0.80	Limited	Limited

Figure E55 shows the sample after the fire. The HPL panels were consumed locally in the zone of direct flame impingement. Discoloration and distortion could be observed on the surface of the panels. Detachment of parts of the panels could be observed after the fire. The panels had a brittle behaviour when exposed to fire. Localised cracks of the panels could be observed in the area of direct heating.

Figure E55 – Post fire observations

E2.2.12 Sample S12 10 mm HPL phenolic panels

The twelfth sample consisted of high pressure laminate (HPL) with a fire-retardant wood fibre core, bonded with double-hardened acrylic polyurethane resins at high pressures and temperatures. The 10 mm thick HPL panels were cut to size and installed onto 100 mm wide aluminium T-shaped rails positioned 400 mm apart. The panels were installed onto the rails using 25mm long self-drill self-tap screws at 300 mm vertical centres. Figure E56 shows the material installed on the rig. A cavity of 50 mm was provided between the HPL panels and the incombustible support of the experimental rig. One vertical joint and one horizontal joint of approximately 10 mm were provided within the installation as shown in Figure E56.

Figure E56 – Sample S12 HPL phenolic panels installed on the rig

Figure E57 shows photographs during the fire exposure at specified times.

5 minutes from ignition

10 minutes from ignition

20 minutes from ignition

25 minutes from ignition

Figure E57 – Photographs during the fire at 5, 10, 20 and 25 minutes from ignition

During the fire exposure no burning droplets were observed. Discoloration of the panels was observed in the area of direct flame exposure. At the beginning of the experiment localised removal of surface material (spalling) was observed in the area of direct flame exposure.

Based on both measured values and visual observation after approximately 21 minutes of thermal exposure the fire breached the cavity. Local cracks were observed on the surface of the panels. Detachment of small parts of the panels in the area of direct flame impingement and central axis were observed during the experiment.

Localised sustained flaming was observed on the surface of the panels in the fire exposed area. Limited horizontal flame spread was recorded on the external surface of the panels in the area of direct heat

exposure. The surface burning self-extinguished without direct flame exposure. No significant vertical or horizontal flame spread on the surface of the HPL panels was observed.

Figure E58 shows the heat release rate as a function of time during the fire exposure, including the fire source. Based on the original crib calibrations and measured values from the calorimeter it is assumed that the peak heat release rate for the crib alone is approximately 300 kW.

Figure E58 – Heat release rate measured during the fire for the HPL panels, including the source

Figure E59 shows the heat flux on the centre line recorded during the fire at a height of 3.0 m from the ground.

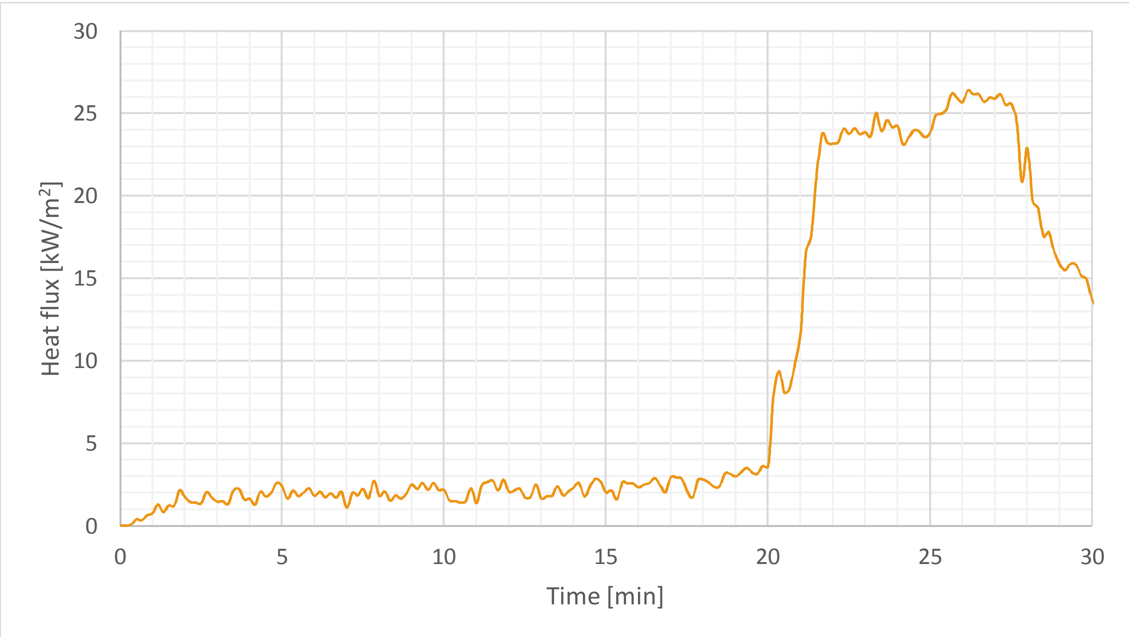


Figure E59 – Heat flux recorded during the fire at 3.0 m height

Table E26 shows the maximum external temperature, the maximum cavity temperature, maximum temperature at 3.0 m, time to peak heat release rate (HRR), peak HRR, maximum heat flux (HF) at 3.0 m and total heat release (THR) over a period of 30 minutes.

Table E26 – Summary of different measured parameters during the experiment

Max external temp [°C]	Max cavity temp [°C]	Max H=3.0m Temp [°C]	Time to peak HRR [min]	Peak HRR [kW]	Max H=3.0m Heat flux [kW/m^2]	THR [MJ]
866	918	203	22	423	26	559

A summary of the visual observations is presented in Table E27.

Table E27 – Visual observations during the experiment

Burning droplets	Time to burn though [min]	Burn through	Area consumed [m^2]	Vertical flame spread	Horizontal flame spread
No	≈21	Yes	≈0.82	Limited	Limited

Figure E60 shows the sample after the fire. The HPL panels were consumed locally in the zone of direct flame impingement. Discoloration and distortion could be observed on the surface of the panels. Detachment of parts of the panels could be observed after the fire. The panels had a brittle behaviour when exposed to fire. Localised cracks of the panels could be observed in the area of direct heating.

Figure E60 – Post fire observations

E2.2.13 Sample S13 4 mm zinc composite panels with FR core

The thirteenth sample consisted of zinc composite material with a mineral fire-retardant core. The zinc composite panels were cut to size and installed onto 100 mm wide aluminium T-shaped rails positioned 400 mm apart. The 4 mm thick panels were installed onto the rails using 25 mm long self-drill self-tap screws at 300 mm vertical centres. Figure E61 shows the material installed on the rig. A cavity of 50 mm was provided between the zinc composite panels and the incombustible support of the experimental rig. One vertical joint and one horizontal joint of approximately 10 mm were provided within the installation as shown in Figure E61.

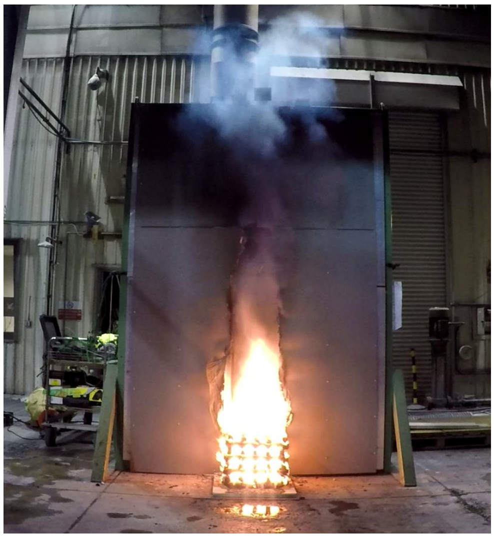
Figure E61 – Sample S13 zinc composite panels with mineral fire-retardant core installed on the rig

Figure E62 shows photographs during the fire exposure at specified times.

5 minutes from ignition

10 minutes from ignition

20 minutes from ignition



25 minutes from ignition

Figure E62 – Photographs during the fire at 5, 10, 20 and 25 minutes from ignition

After 4 minutes of fire exposure the core of the panels expanded and came out through the exposed joints and sealed them for a short duration. The zinc external face of the composite panels started to melt after approximately 6 minutes in the area of direct flame impingement. Based on both measured values and visual observation after approximately 7 minutes of thermal exposure the fire breached the cavity.

Localised flaming on the consumed edges of the panels was observed. After 20 minutes of fire exposure the amount of smoke released increased.

No significant falling debris and burning droplets were observed during the fire. No significant vertical or horizontal flame spread on the surface of the zinc composite panels was observed.

Figure E63 shows the heat release rate as a function of time during the fire exposure, including the fire source. Based on the original crib calibrations and measured values from the calorimeter it is assumed that the peak heat release rate for the crib alone is approximately 300 kW.

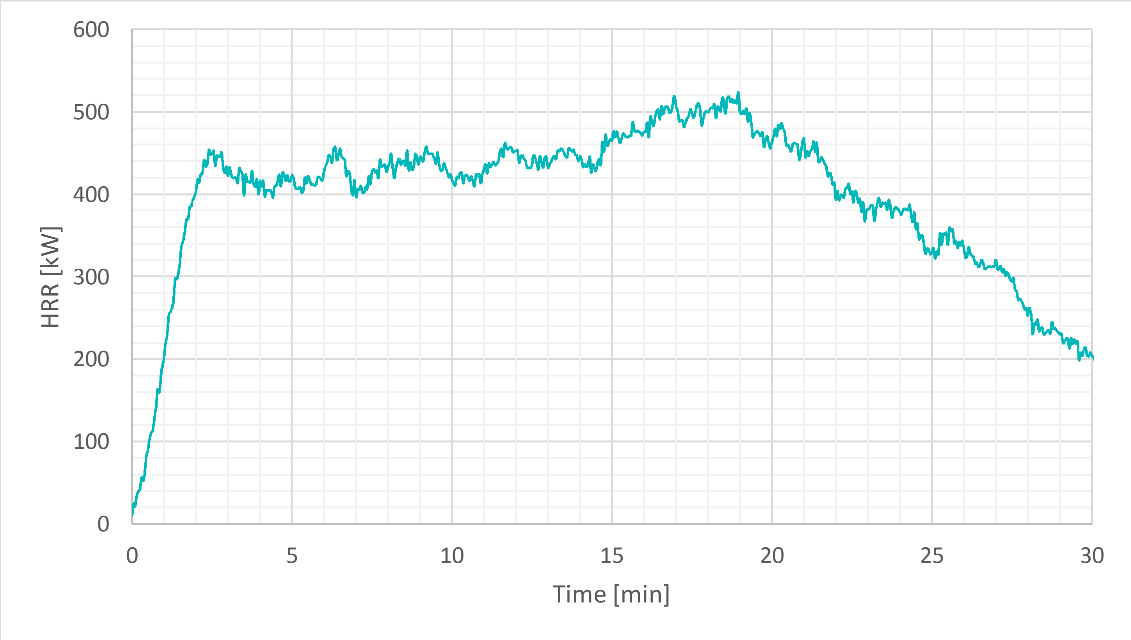


Figure E63 – Heat release rate measured during the fire for the zinc panels, including the source

Figure E64 shows the heat flux recorded during the fire at a height of 3.0 m from the ground.

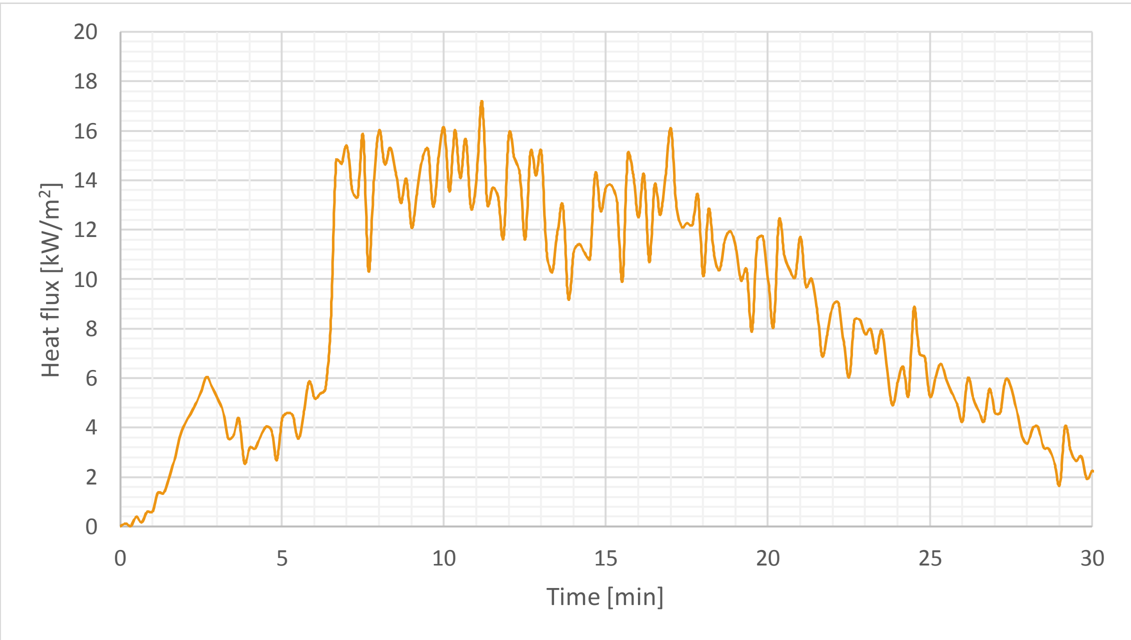


Figure E64 – Heat flux recorded during the fire at 3.0 m height

Table E28 shows the maximum external temperature, the maximum cavity temperature, maximum temperature at 3.0 m, time to peak heat release rate (HRR), peak HRR, maximum heat flux (HF) at 3.0 m and total heat release (THR) over a period of 30 minutes.

Table E28 – Summary of different measured parameters during the experiment

Max external temp [°C]	Max cavity temp [°C]	Max H=3.0m Temp [°C]	Time to peak HRR [min]	Peak HRR [kW]	Max H=3.0m Heat flux [kW/m^2]	THR [MJ]
877	849	148	19.0	524	17	716

A summary of the visual observations is presented in Table E29.

Table E29 – Visual observations during the experiment

Burning droplets	Time to burn though [min]	Burn through	Area consumed [m^2]	Vertical flame spread	Horizontal flame spread
Not significant	≈6	Yes	≈0.75	Limited	Limited

Figure E65 shows the sample after the fire. The zinc composite panels were consumed locally in the zone of direct flame impingement. Discoloration and distortion could be observed on the surface of the panels.

Figure E65 – Post fire observations

E2.2.14 Sample S14 4 mm zinc composite panels with FR core

The fourteenth sample consisted of zinc composite material with a mineral fire-retardant core. The zinc composite panels were cut to size and installed onto 100 mm wide aluminium T-shaped rails positioned 400 mm apart. The 4 mm thick panels were installed onto the rails using 25 mm long self-drill self-tap screws at 300 mm vertical centres. Figure E66 shows the material installed on the rig. A cavity of 50 mm was provided between the zinc composite panels and the incombustible support of the experimental rig. One vertical joint and one horizontal joint of approximately 10 mm were provided within the installation as shown in Figure E66.

Figure E66 – Sample S14 zinc composite panels with mineral fire-retardant core installed on the rig

Figure E67 shows photographs during the fire exposure at specified times.

5 minutes from ignition

10 minutes from ignition

20 minutes from ignition

25 minutes from ignition

Figure E67 – Photographs during the fire at 5, 10, 20 and 25 minutes from ignition

After 5 minutes of fire exposure the core of the panels expanded and came out through the exposed joints and sealed them for a short duration. The zinc external face of the composite panels started to melt after approximately 6 minutes in the area of direct flame impingement. Based on both measured values and visual observation after approximately 6 minutes of thermal exposure the fire breached the cavity.

Localised flaming on the consumed edges of the panels was observed. After 22 minutes of fire exposure the amount of smoke released increased.

No significant falling debris and burning droplets were observed during the fire. No significant vertical or horizontal flame spread on the surface of the zinc composite panels was observed.

Figure E68 shows the heat release rate as a function of time during the fire exposure, including the fire source. Based on the original crib calibrations and measured values from the calorimeter it is assumed that the peak heat release rate for the crib alone is approximately 300 kW.

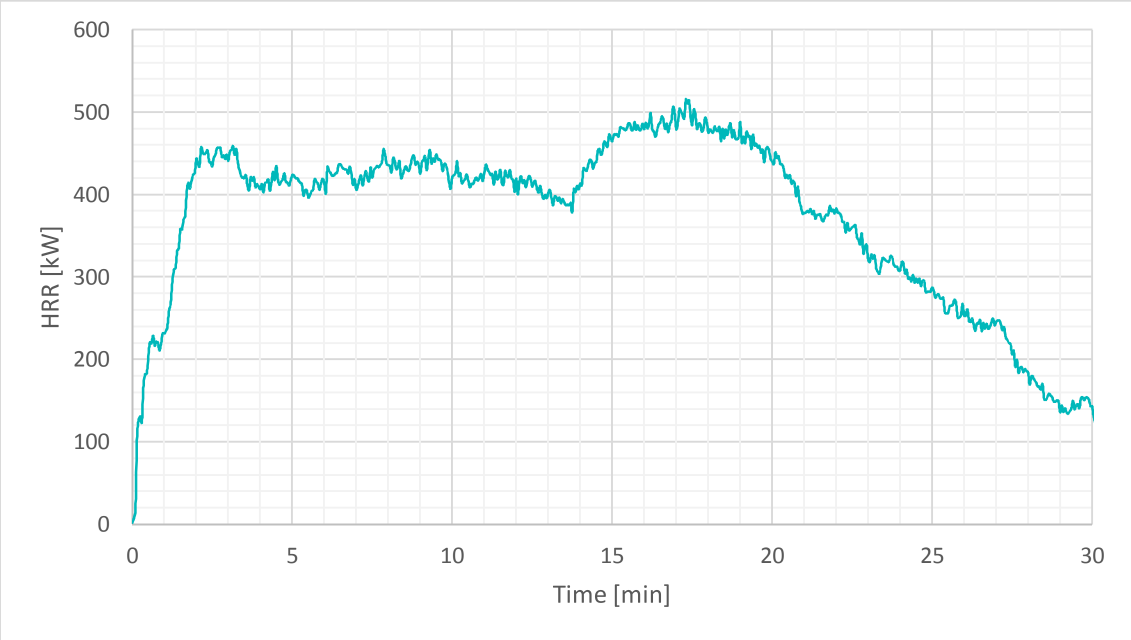


Figure E68 – Heat release rate measured during the fire, including the source

Figure E69 shows the heat flux recorded on the centre line during the fire at a height of 3.0 m from the ground.

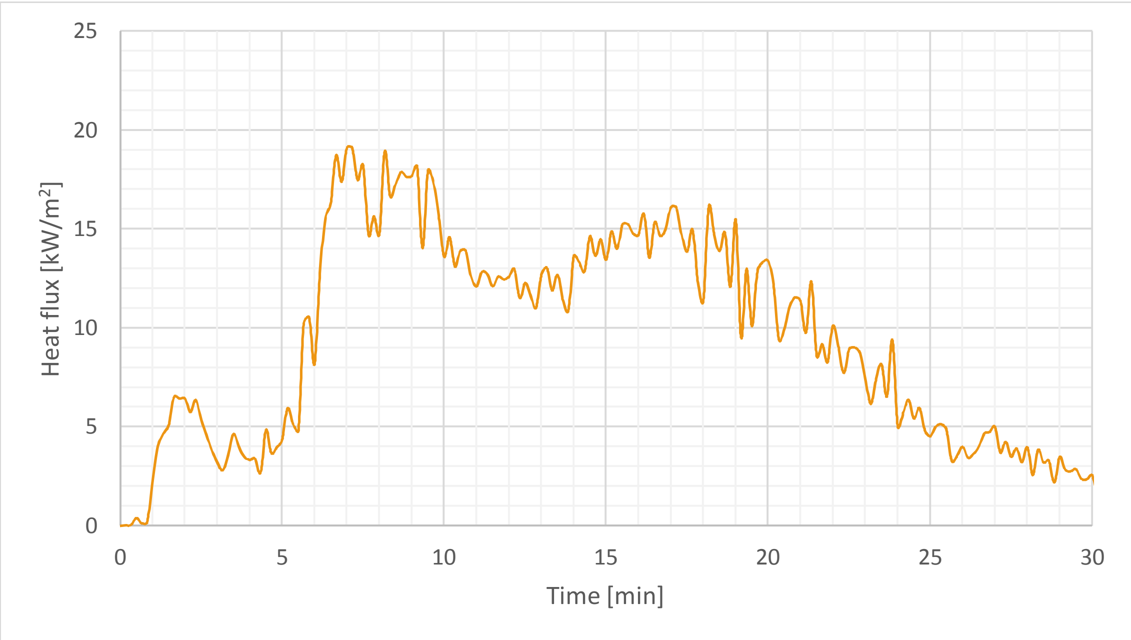


Figure E69 – Heat flux recorded during the fire at 3.0 m height

Table E30 shows the maximum external temperature, the maximum cavity temperature, maximum temperature at 3.0 m, time to peak heat release rate (HRR), peak HRR, maximum heat flux (HF) at 3.0 m and total heat release (THR) over a period of 30 minutes.

Table E30 – Summary of different measured parameters during the experiment

Max external temp [°C]	Max cavity temp [°C]	Max H=3.0m Temp [°C]	Time to peak HRR [min]	Peak HRR [kW]	Max H=3.0m Heat flux [kW/m^2]	THR [MJ]
903	839	174	17	515	19	674

A summary of the visual observations is presented in Table E31.

Table E31 – Visual observations during the experiment

Burning droplets	Time of burn though [min]	Burn through	Area consumed [m^2]	Vertical flame spread	Horizontal flame spread
Not significant	≈6	Yes	≈1.0	Limited	Limited

Figure E70 shows the sample after the fire. The zinc composite panels were consumed locally in the zone of direct flame impingement. Discoloration and distortion could be observed on the surface of the panels.

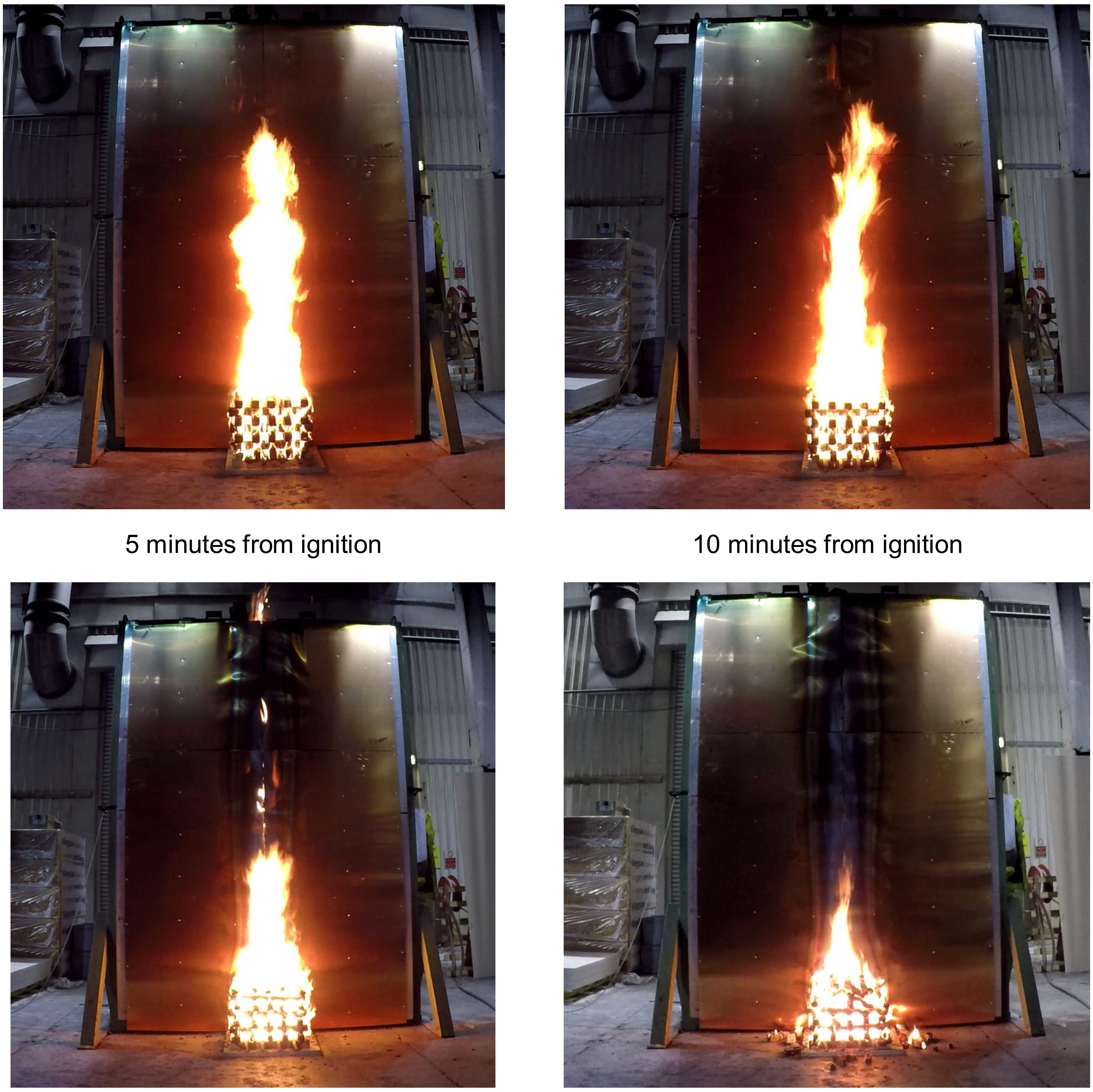
Figure E70 – Post fire observations

E2.2.15 Sample S15 4 mm copper composite panels with FR core

The fifteenth sample consisted of copper composite material with a mineral fire-retardant core. The copper composite panels were cut to size and installed onto 100 mm wide aluminium T-shaped rails positioned 400 mm apart. The 4 mm thick panels were installed onto the rails using 25 mm long self-drill self-tap screws at 300 mm vertical centres. Figure E71 shows the material installed on the rig. A cavity of 50 mm was provided between the zinc composite panels and the incombustible support of the experimental rig. One vertical joint and one horizontal joint of approximately 10mm were provided within the installation as shown in Figure E71.

Figure E71 – Sample S15 copper composite panels with mineral fire-retardant core installed on the rig

Figure E72 shows photographs during the fire exposure at specified times.



5 minutes from ignition

10 minutes from ignition

20 minutes from ignition

25 minutes from ignition

Figure E72 – Photographs during the fire at 5, 10, 20 and 25 minutes from ignition

After 12 minutes of fire exposure the central vertical joint opened due to the thermal expansion of the panels. No breakthrough of the copper faces of the panels was observed.

Based on both measured values and visual observation after approximately 15 minutes of thermal exposure the fire breached the cavity due to the panel movement. Flames were observed on the central vertical joint and coming out from the open cavity at the top of the rig. Distortion and further movement of the panels was observed.

No falling debris, burning droplets or panels consumption were observed during the fire. No vertical or horizontal flame spread on the surface of the copper composite panels was observed.

Figure E73 shows the heat release rate as a function of time during the fire exposure, including the fire source. Based on the original crib calibrations and measured values from the calorimeter it is assumed that the peak heat release rate for the crib alone is approximately 300 kW.

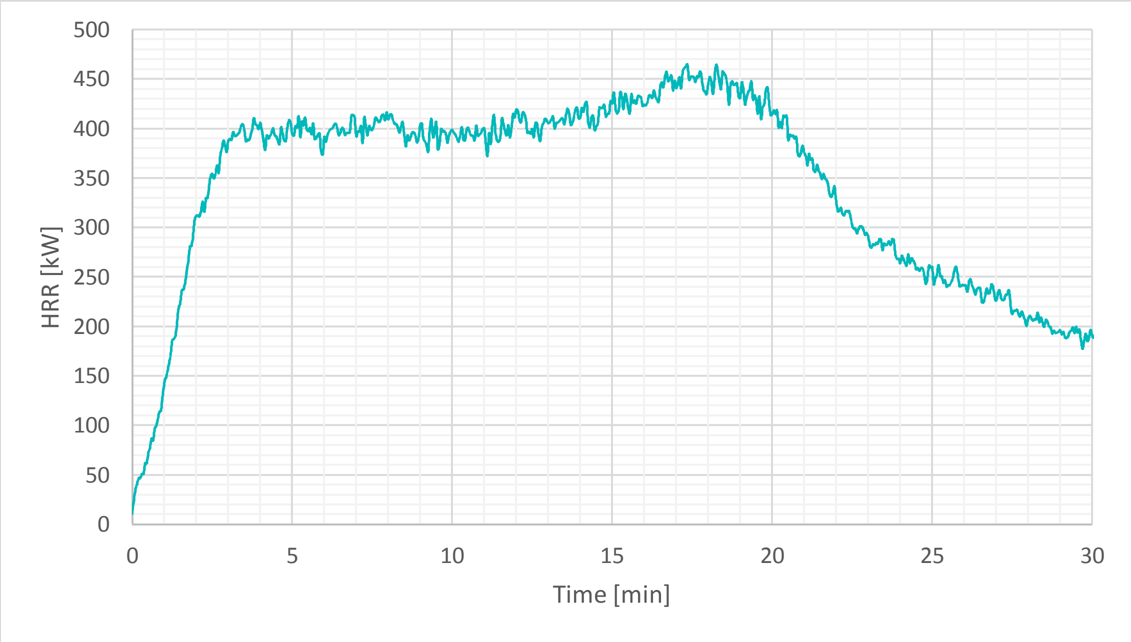


Figure E73 – Heat release rate measured during the fire for the copper panels, including the source

Figure E74 shows the heat flux recorded on the centre line during the fire at a height of 3.0 m from the ground. The maximum capability of the heat flux meter of 50 kW/m² was reached 18 minutes after ignition.

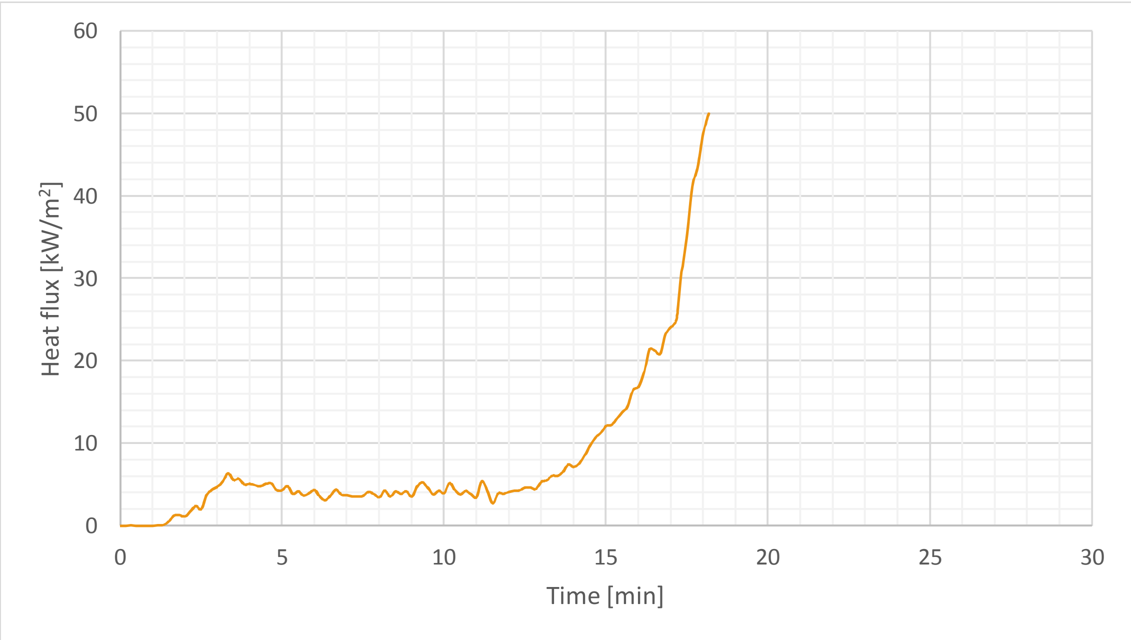


Figure E74 – Heat flux recorded during the fire at 3.0 m height

Table E32 shows the maximum external temperature, the maximum cavity temperature, maximum temperature at 3.0 m, time to peak heat release rate (HRR), peak HRR, maximum heat flux (HF) at 3.0 m and total heat release (THR) over a period of 30 minutes.

Table E32 – Summary of different measured parameters during the experiment

Max external temp [°C]	Max cavity temp [°C]	Max H=3.0m Temp [°C]	Time to peak HRR [min]	Peak HRR [kW]	Max H=3.0m Heat flux [kW/m^2]	THR [MJ]
894	953	201	17	465	50	621

A summary of the visual observations is presented in Table E33.

Table E33 – Visual observations during the experiment

Burning droplets	Time of burn though [min]	Burn through	Area consumed [m^2]	Vertical flame spread	Horizontal flame spread
No	Cavity fire after ≈15	No, cavity fire due to the joint opening	≈0 panels ≈0.5 core	No	No

Figure E75 shows the sample after the fire. Discoloration and distortion could be observed on the surface of the panels. No breakthrough of the copper faces was recorded after the fire. The copper faces were peeled away after the fire and it was found that the mineral core present inside the panels, on the central axis, had been consumed in the area of direct flame impingement.

Figure E75 – Post fire observations

E2.2.16 Sample S16 4 mm copper composite panels with FR core

The sixteenth sample consisted of copper composite material with a mineral fire-retardant core. The copper composite panels were cut to size and installed onto 100 mm wide aluminium T-shaped rails positioned 400 mm apart. The 4 mm thick panels were installed onto the rails using 25 mm long self-drill self-tap screws at 300 mm vertical centres. Figure E76 shows the material installed on the rig. A cavity of 50 mm was provided between the zinc composite panels and the incombustible support of the experimental rig. One vertical joint and one horizontal joint of approximately 10 mm were provided within the installation as shown in Figure E76.

Figure E76 – Sample S16 copper composite panels with mineral fire-retardant core installed on the rig

Figure E77 shows photographs during the fire exposure at specified times.

5 minutes from ignition

10 minutes from ignition

20 minutes from ignition

25 minutes from ignition

Figure E77 – Photographs during the fire at 5, 10, 20 and 25 minutes from ignition

After 8 minutes of fire exposure the central vertical joint opened due to the thermal expansion of the panels. No breakthrough of the copper faces of the panels was observed.

Based on both measured values and visual observation after approximately 10 minutes of thermal exposure the fire breached the cavity due to the panel movement. Flames were observed on the central vertical joint and coming out from the open cavity at the top of the rig. Distortion and further movement of the panels was observed.

No falling debris, burning droplets or panels consumption were observed during the fire. No vertical or horizontal flame spread on the surface of the copper composite panels was observed.

Figure E78 shows the heat release rate as a function of time during the fire exposure, including the fire source. Based on the original crib calibrations and measured values from the calorimeter it is assumed that the peak heat release rate for the crib alone is approximately 300 kW.

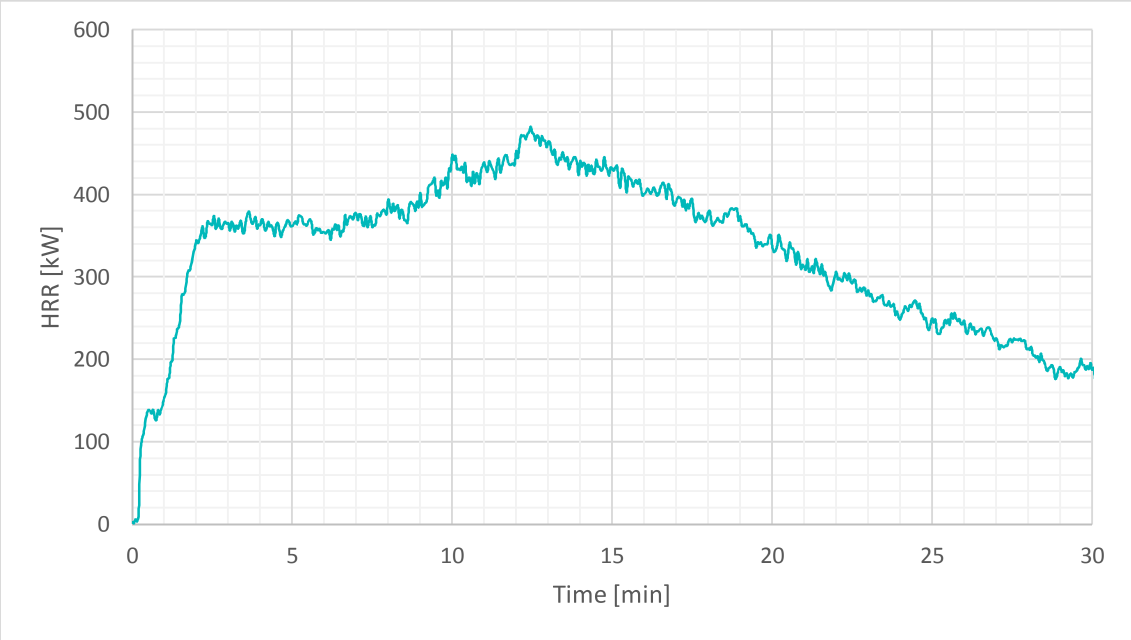


Figure E78 – Heat release rate measured during the fire for the copper panels, including the source

Figure E79 shows the heat flux on the centre line recorded during the fire at a height of 3.0 m from the ground. The maximum capability of the heat flux meter of 50 kW/m^2 was reached 12 minutes after ignition.

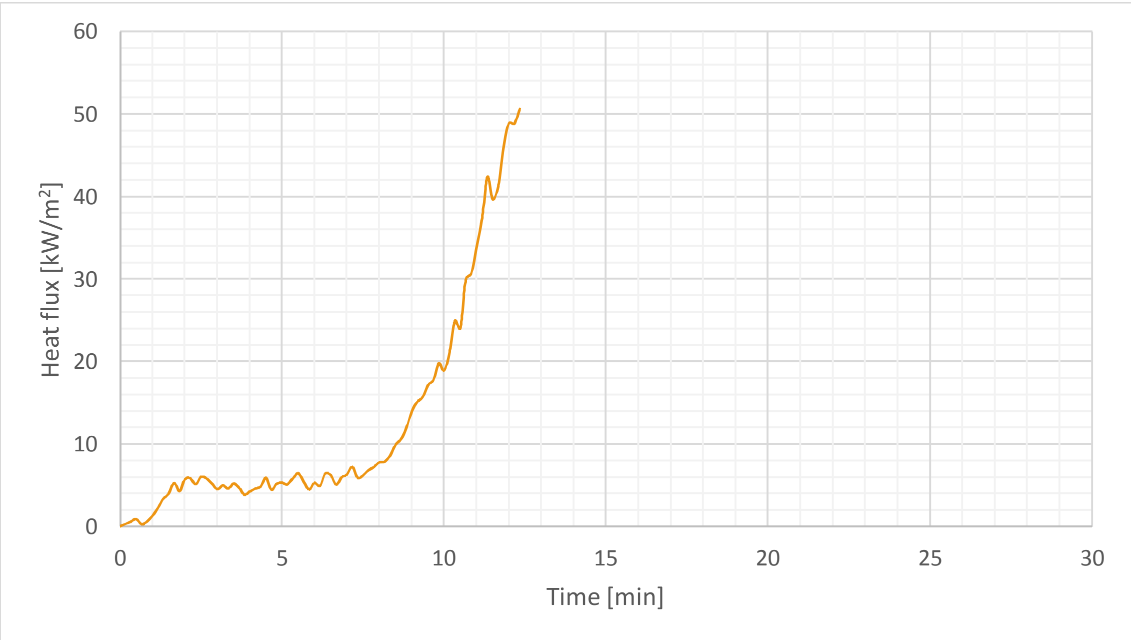


Figure E79 – Heat flux recorded during the fire at 3.0 m height

Table E34 shows the maximum external temperature, the maximum cavity temperature, maximum temperature at 3.0 m, time to peak heat release rate (HRR), peak HRR, maximum heat flux (HF) at 3.0 m and total heat release (THR) over a period of 30 minutes.

Table E34 – Summary of different measured parameters during the experiment

Max external temp [°C]	Max cavity temp [°C]	Max H=3.0m Temp [°C]	Time to peak HRR [min]	Peak HRR [kW]	Max H=3.0m Heat flux [kW/m^2]	THR [MJ]
888	877	250	12	482	51	600

A summary of the visual observations is presented in Table E35.

Table E35 – Visual observations during the experiment

Burning droplets	Time to burn though [min]	Burn through	Area consumed [m^2]	Vertical flame spread	Horizontal flame spread
No	Cavity fire after ≈8	No, cavity fire due to the joint opening	≈0 panels ≈0.4 core	No	No

Figure E80 shows the sample after the fire. Discoloration and distortion could be observed on the surface of the panels. No consumption of the copper faces was recorded after the fire exposure. The copper faces were peeled away after the fire and it was found that the mineral core present inside the panels, on the central axis, had been consumed in the area of direct flame impingement.

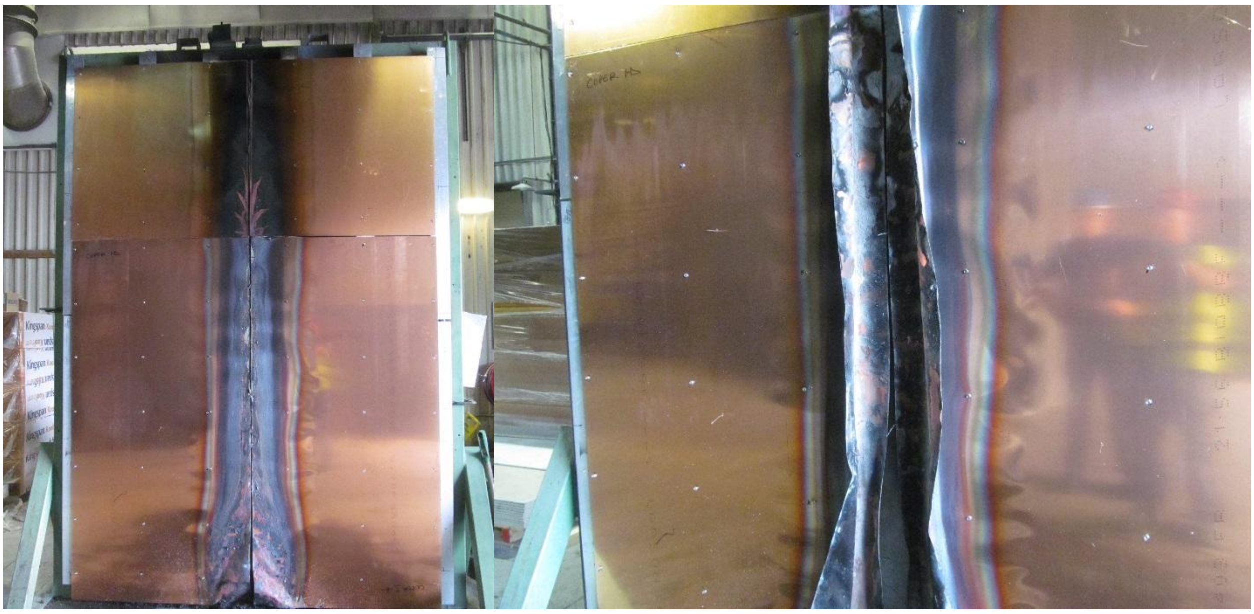


Figure E80 – Post fire observations

E2.2.17 Sample S17 4 mm zinc composite panels with FR core

The seventeenth sample consisted of zinc composite material with a mineral fire-retardant core. The zinc composite panels were cut to size and installed onto 100 mm wide aluminium T-shaped rails positioned 400 mm apart. The 4 mm thick panels were installed onto the rails using 25 mm long self-drill self-tap screws at 300 mm vertical centres. Figure E81 shows the material installed on the rig. A cavity of 50 mm was provided between the zinc composite panels and the incombustible support of the experimental rig. One vertical joint and one horizontal joint of approximately 10 mm were provided within the installation as shown in Figure E81.

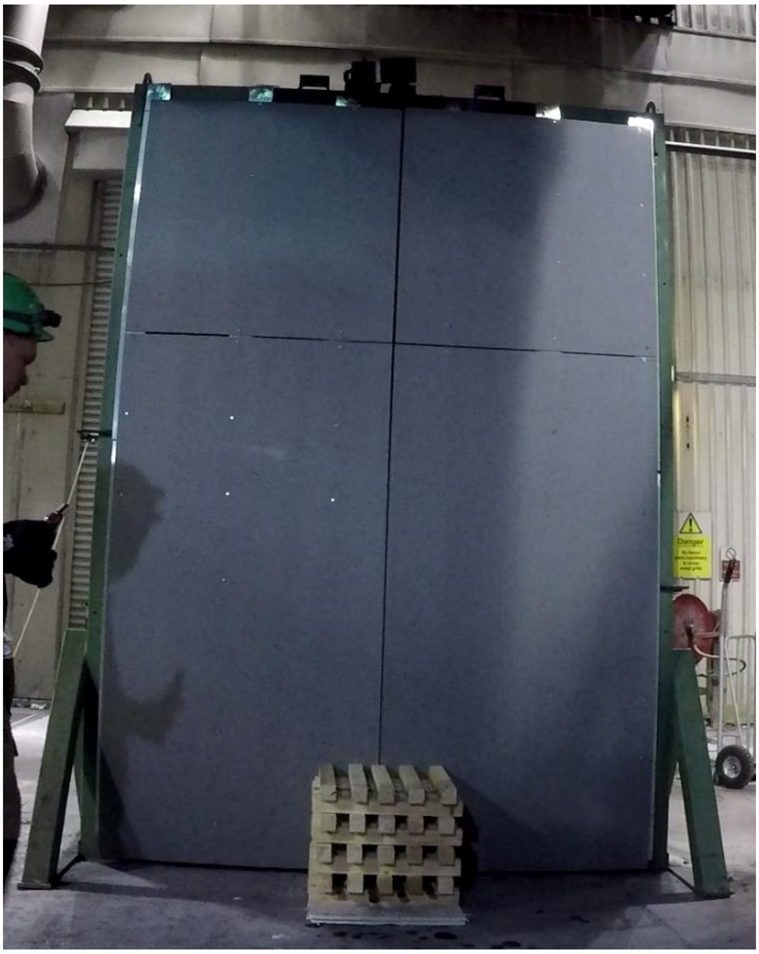
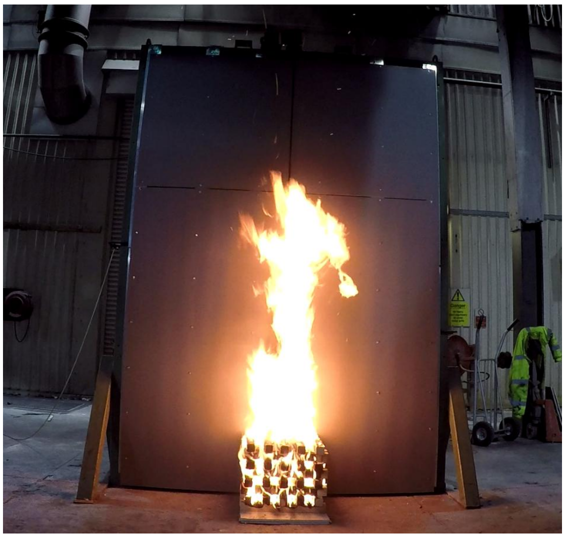


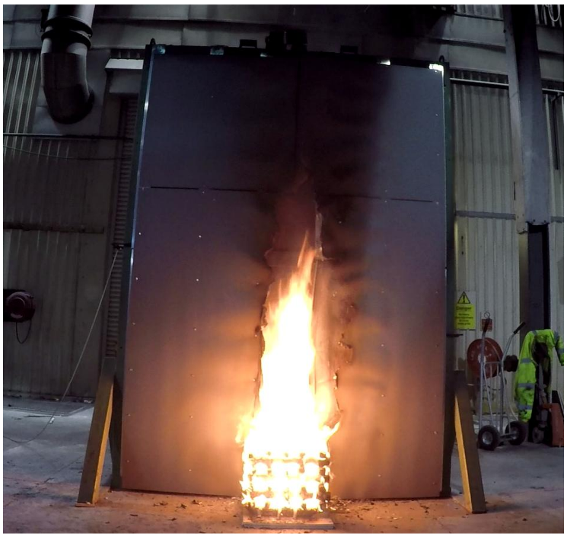
Figure E81 – Sample S17 zinc composite panels with mineral fire-retardant core installed on the rig

Figure E82 shows photographs during the fire exposure at specified times.



5 minutes from ignition

10 minutes from ignition



20 minutes from ignition

25 minutes from ignition

Figure E82 – Photographs during the fire at 5, 10, 20 and 25 minutes from ignition

After 5 minutes of fire exposure the core of the panels expanded and came out through the exposed joints and sealed them for a short duration. The zinc external face of the composite panels started to melt after approximately 6 minutes in the area of direct flame impingement. Based on both measured values and visual observation after approximately 6 minutes of thermal exposure the fire breached the cavity.

Localised flaming on the consumed edges of the panels was observed. After 21 minutes of fire exposure the amount of smoke released increased.

No significant falling debris and burning droplets were observed during the fire. No significant vertical or horizontal flame spread on the surface of the zinc composite panels was observed.

Figure E83 shows the heat release rate as a function of time during the fire exposure, including the fire source. Based on the original crib calibrations and measured values from the calorimeter it is assumed that the peak heat release rate for the crib alone is approximately 300 kW.

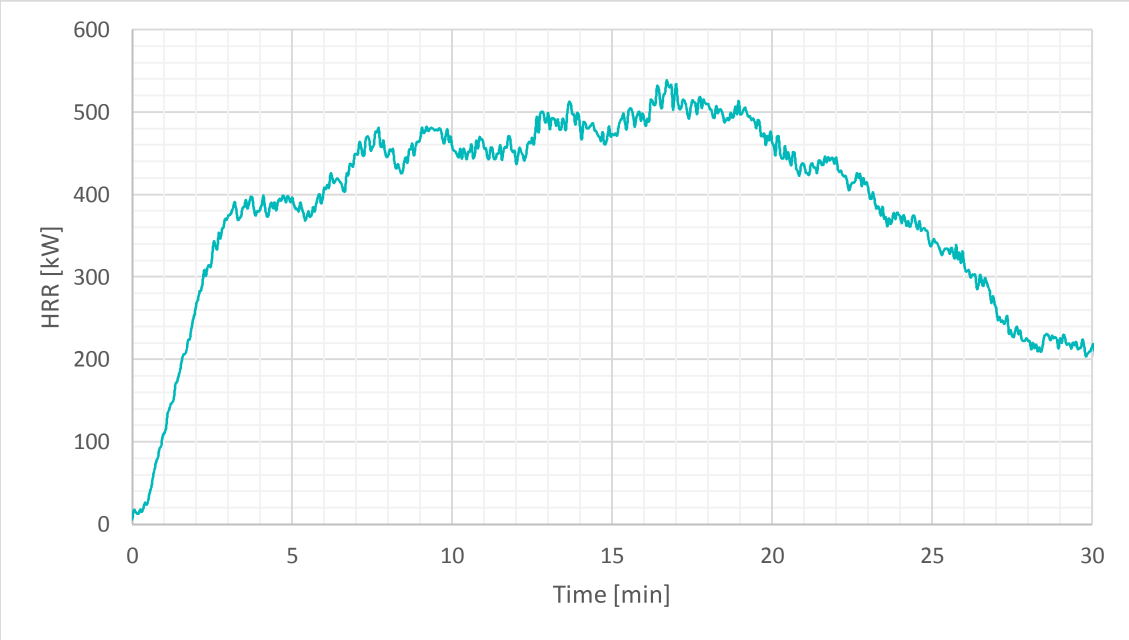


Figure E83 – Heat release rate measured during the fire for the zinc panels, including the source

Figure E84 shows the heat flux recorded on the centre line during the fire at a height of 3.0 m from the ground.

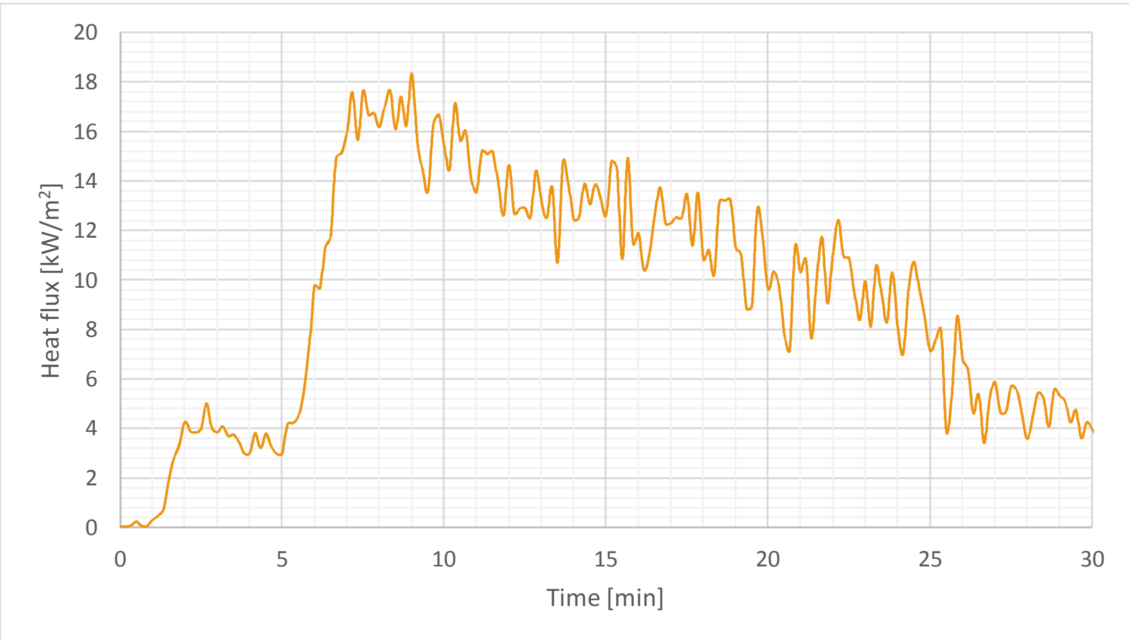


Figure E84 – Heat flux recorded during the fire at 3.0 m height

Table E36 shows the maximum external temperature, the maximum cavity temperature, maximum temperature at 3.0 m, time to peak heat release rate (HRR), peak HRR, maximum heat flux (HF) at 3.0 m and total heat release (THR) over a period of 30 minutes.

Table E36 – Summary of different measured parameters during the experiment

Max external temp [°C]	Max cavity temp [°C]	Max H=3.0m Temp [°C]	Time to peak HRR [min]	Peak HRR [kW]	Max H=3.0m Heat flux [kW/m^2]	THR [MJ]
857	903	219	17	539	18	702

A summary of the visual observations is presented in Table E37.

Table E37 – Visual observations during the experiment

Burning droplets	Time to burn though [min]	Burn through	Area consumed [m^2]	Vertical flame spread	Horizontal flame spread
Not significant	≈6	Yes	≈1.15	Limited	Limited

Figure E85 shows the sample after the fire. The zinc composite panels were consumed locally in the zone of direct flame impingement. Discoloration and distortion could be observed on the surface of the panels.

Figure E85 – Post fire observations

E2.2.18 Sample S18 4 mm zinc composite panels with FR core

The eighteenth sample consisted of zinc composite material with a mineral fire-retardant core. The zinc composite panels were cut to size and installed onto 100 mm wide aluminium T-shaped rails positioned 400 mm apart. The 4 mm thick panels were installed onto the rails using 25mm long self-drill self-tap screws at 300 mm vertical centres. Figure E86 shows the material installed on the rig. A cavity of 50 mm was provided between the zinc composite panels and the incombustible support of the experimental rig. One vertical joint and one horizontal joint of approximately 10 mm were provided within the installation as shown in Figure E86.

Figure E86 – Sample S18 zinc composite panels with mineral fire-retardant core installed on the rig

Figure E87 below shows photographs during the fire exposure at specified times.

5 minutes from ignition

10 minutes from ignition

20 minutes from ignition

25 minutes from ignition

Figure E87 – Photographs during the fire at 5, 10, 20 and 25 minutes from ignition

After 6 minutes of fire exposure the core of the panels expanded and came out through the exposed joints and sealed them for a short duration. The zinc external face of the composite panels started to melt after approximately 9 minutes in the area of direct flame impingement. Based on both measured values and visual observation after approximately 10 minutes of thermal exposure the fire breached the cavity.

Localised flaming on the consumed edges of the panels was observed. After 20 minutes of fire exposure the amount of smoke released increased.

No significant falling debris and burning droplets were observed during the fire. No significant vertical or horizontal flame spread on the surface of the zinc composite panels was observed.

Figure E88 shows the heat release rate as a function of time during the fire exposure, including the fire source. Based on the original crib calibrations and measured values from the calorimeter it is assumed that the peak heat release rate for the crib alone is approximately 300 kW.

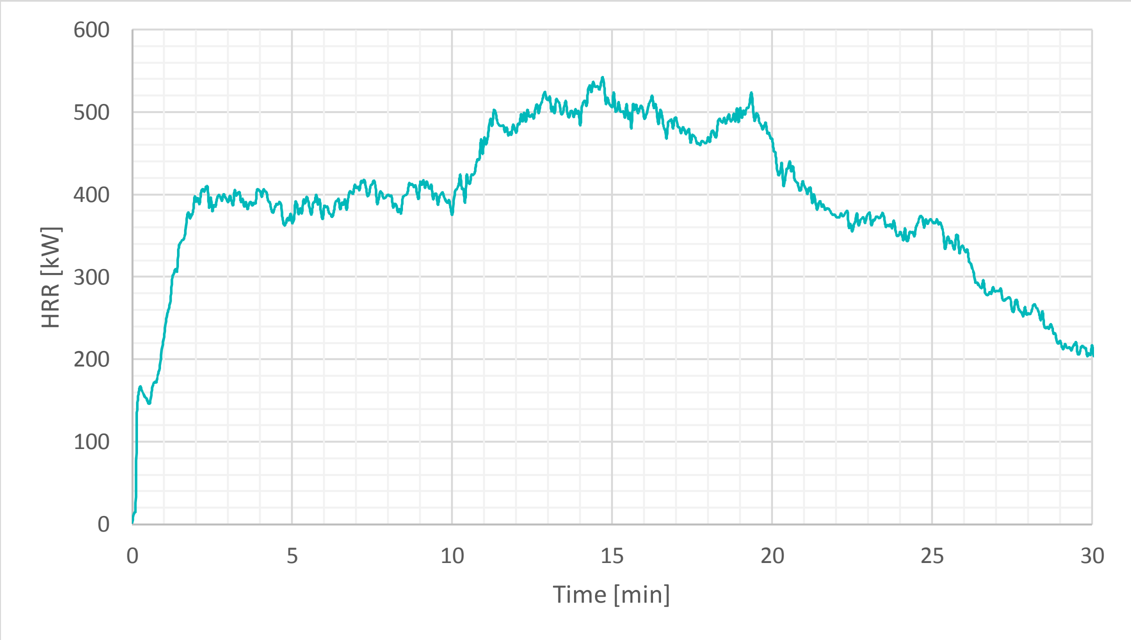


Figure E88 – Heat release rate measured during the fire for the zinc panels, including the source

Figure E89 shows the heat flux recorded on the centre line during the fire at a height of 3.0 m from the ground.

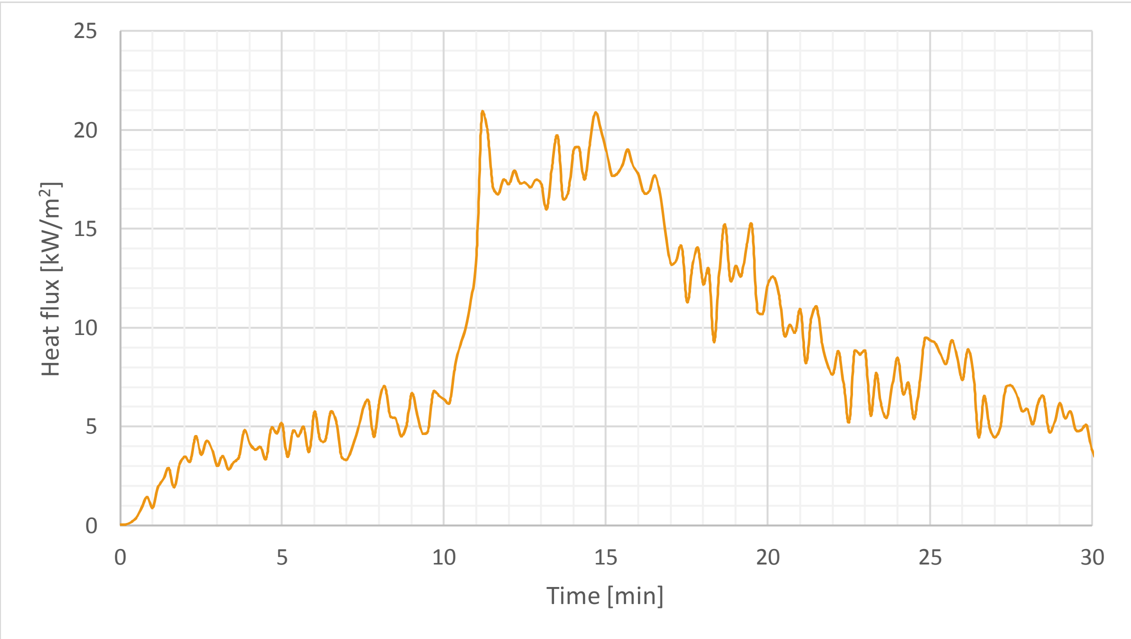


Figure E89 – Heat flux recorded during the fire at 3.0 m height

Table E38 shows the maximum external temperature, the maximum cavity temperature, maximum temperature at 3.0 m, time to peak heat release rate (HRR), peak HRR, maximum heat flux (HF) at 3.0 m and total heat release (THR) over a period of 30 minutes.

Table E38 – Summary of different measured parameters during the experiment

Max external temp [°C]	Max cavity temp [°C]	Max H=3.0m Temp [°C]	Time to peak HRR [min]	Peak HRR [kW]	Max H=3.0m Heat flux [kW/m^2]	THR [MJ]
879	971	172	15	542	21	708

A summary of the visual observations is presented in Table E39.

Table E39 – Visual observations during the experiment

Burning droplets	Time of burn though [min]	Burn through	Area consumed [m^2]	Vertical flame spread	Horizontal flame spread
Not significant	≈10	Yes	≈0.75	Limited	Limited

Figure E90 shows the sample after the fire. The zinc composite panels were consumed locally in the zone of direct flame impingement. Discoloration and distortion could be observed on the surface of the panels.

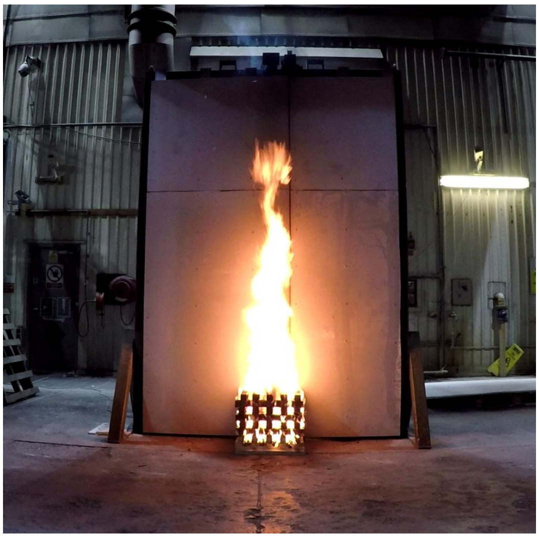
Figure E90 – Post fire observations

E2.2.19 Sample S19 7 mm reconstituted stone panels

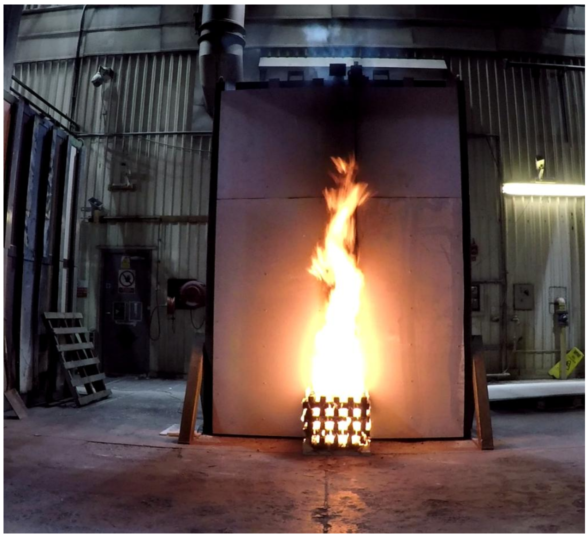
The nineteenth sample consisted of reconstituted stone material made of crushed stone bound together with adhesive. The reconstituted stone panels were cut to size and installed onto 100 mm wide aluminium T-shaped rails positioned 400 mm apart. The 7 mm thick panels were installed onto the rails using 25 mm long self-drill self-tap screws at 300 mm vertical centres. Figure E91 shows the material installed on the rig. A cavity of 50 mm was provided between the reconstituted stone panels and the incombustible support of the experimental rig. One vertical joint and one horizontal joint of approximately 10 mm were provided within the installation as shown in Figure E91.

Figure E91 – Sample S19 reconstituted stone panels installed on the rig

Figure E92 shows photographs during the fire exposure at specified times.



5 minutes from ignition



10 minutes from ignition

20 minutes from ignition

25 minutes from ignition

Figure E92 – Photographs during the fire at 5, 10, 20 and 25 minutes from ignition

After 15 minutes of fire exposure the central vertical joint opened due to the thermal expansion of the panels. No breakthrough of the reconstituted stone panels was recorded.

Based on both measured values and visual observation after approximately 16 minutes of thermal exposure the fire breached partially inside the cavity due to the panel movement. Intermittent flames were observed on the vertical joint. Surface intermittent flaming was observed on the face of the panels in the area of direct flame impingement.

No falling debris, burning droplets or panels consumption were observed during the fire. No significant vertical or horizontal flame spread on the surface of the reconstituted stone panels was observed.

Figure E93 shows the heat release rate as a function of time during the fire exposure, including the fire source. Based on the original crib calibrations and measured values from the calorimeter it is assumed that the peak heat release rate for the crib alone is approximately 300 kW.

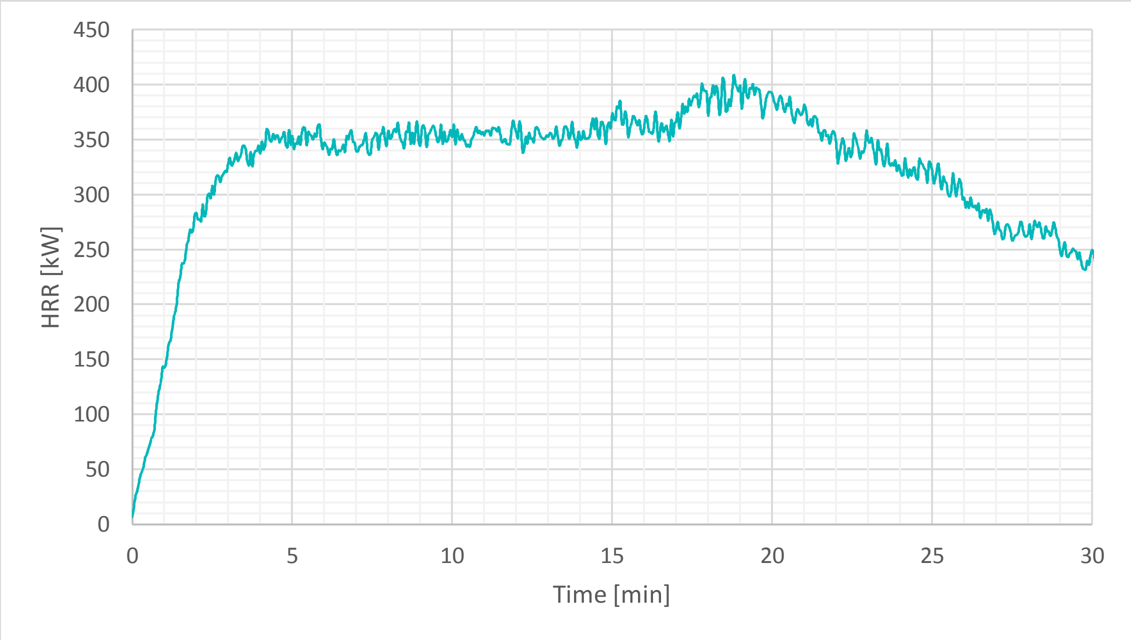


Figure E93 – Heat release rate measured during the fire, including the source

Figure E94 shows the heat flux recorded on the centre line during the fire at a height of 3.0 m from the ground.

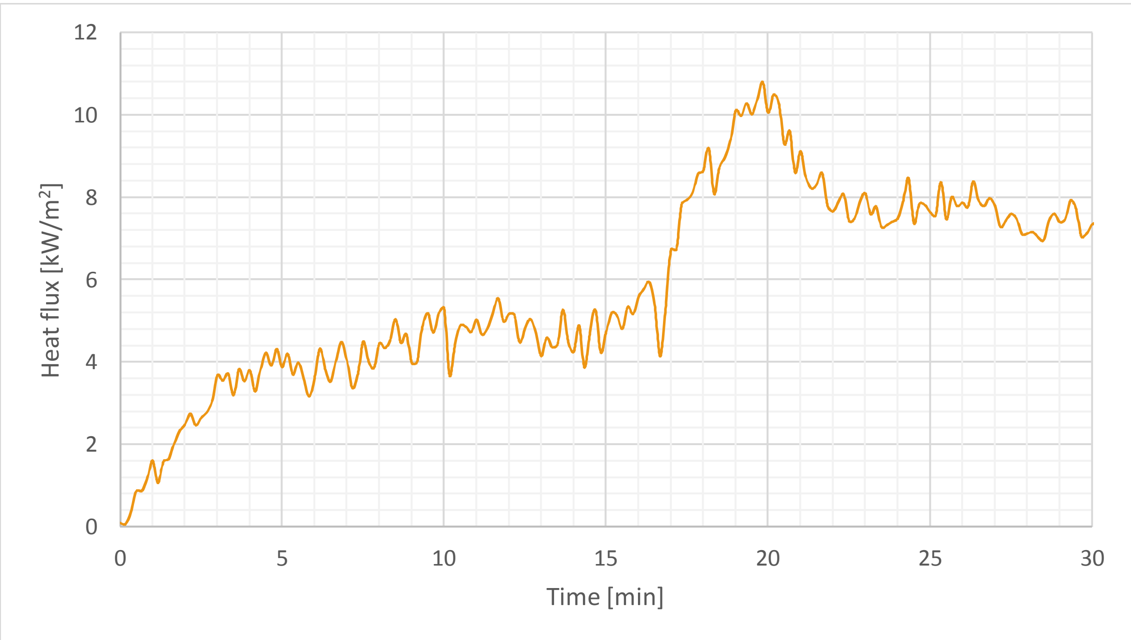


Figure E94 – Heat flux recorded during the fire at 3.0 m height

Table E40 shows the maximum external temperature, the maximum cavity temperature, maximum temperature at 3.0 m, time to peak heat release rate (HRR), peak HRR, maximum heat flux (HF) at 3.0 m and total heat release (THR) over a period of 30 minutes.

Table E40 – Summary of different measured parameters during the experiment

Max external temp [°C]	Max cavity temp [°C]	Max H=3.0m Temp [°C]	Time to peak HRR [min]	Peak HRR [kW]	Max H=3.0m Heat flux [kW/m^2]	THR [MJ]
891	330	139	19	409	11	589

A summary of the visual observations is presented in Table E41.

Table E41 – Visual observations during the experiment

Burning droplets	Time to burn though [min]	Burn through	Area consumed [m^2]	Vertical flame spread	Horizontal flame spread
No	16	No - cavity fire due to the joint opening	≈0 panels	Not significant	Not significant

Figure E95 shows the sample after the fire. Discoloration and distortion could be observed on the surface of the panels in the central axis area and next to the vertical joint. No breakthrough of the reconstituted stone panels was recorded after the fire exposure.

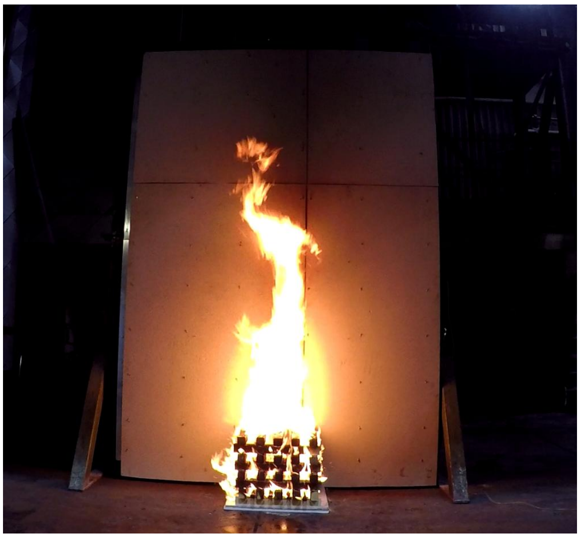
Figure E95 – Post fire observations

E2.2.20 Sample S20 10 mm reconstituted stone panels

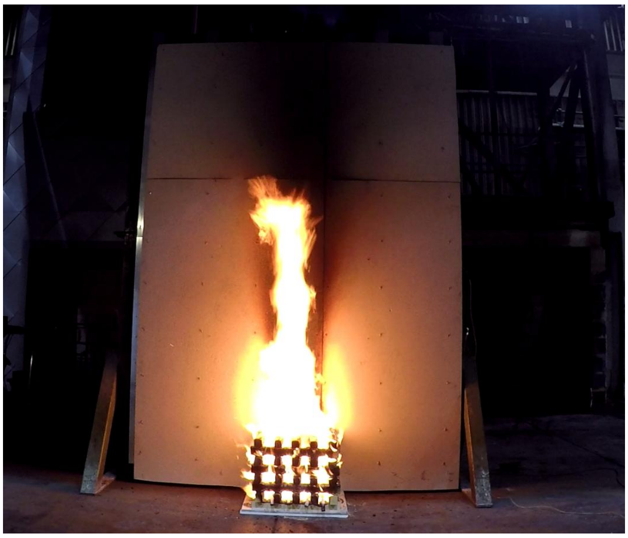
The twentieth sample consisted of reconstituted stone material made of crushed stone bound together by adhesive. The reconstituted stone panels were cut to size and installed onto 100 mm wide aluminium T-shaped rails positioned 400 mm apart. The 10 mm thick panels were installed onto the rails using 25 mm long self-drill self-tap screws at 300 mm vertical centres. Figure E96 shows the material installed on the rig. A cavity of 50 mm was provided between the reconstituted stone panels and the incombustible support of the experimental rig. One vertical joint and one horizontal joint of approximately 10 mm were provided within the installation as shown in Figure E96.

Figure E96 – Sample S20 reconstituted stone panels installed on the rig

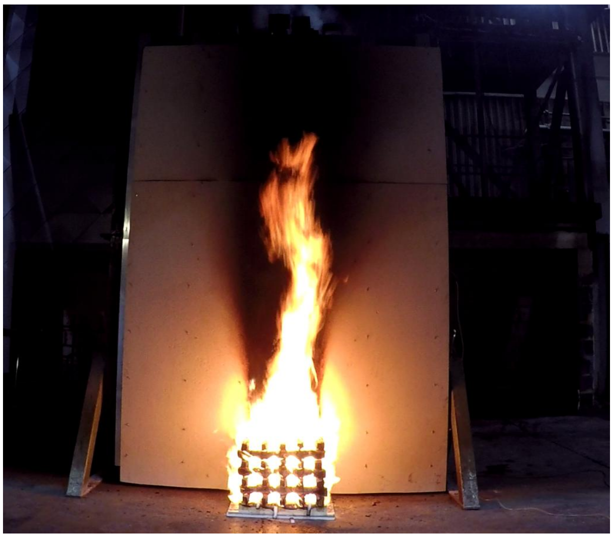
Figure E97 shows photographs during the fire exposure at specified times.



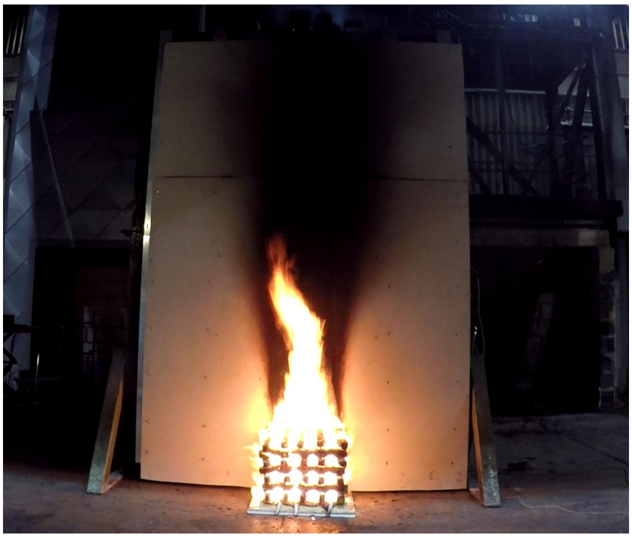
5 minutes from ignition



10 minutes from ignition



20 minutes from ignition



25 minutes from ignition

Figure E97 – Photographs during the fire at 5, 10, 20 and 25 minutes from ignition

Discoloration was observed in the area of direct flame impingement. No breakthrough of the reconstituted stone panels was observed.

No falling debris, burning droplets or panels consumption were observed during the fire. No vertical or horizontal flame spread on the surface of the reconstituted stone panels was observed.

Figure E98 shows the heat release rate as a function of time during the fire exposure, including the fire source. Based on the original crib calibrations and measured values from the calorimeter it is assumed that the peak heat release rate for the crib alone is approximately 300 kW.

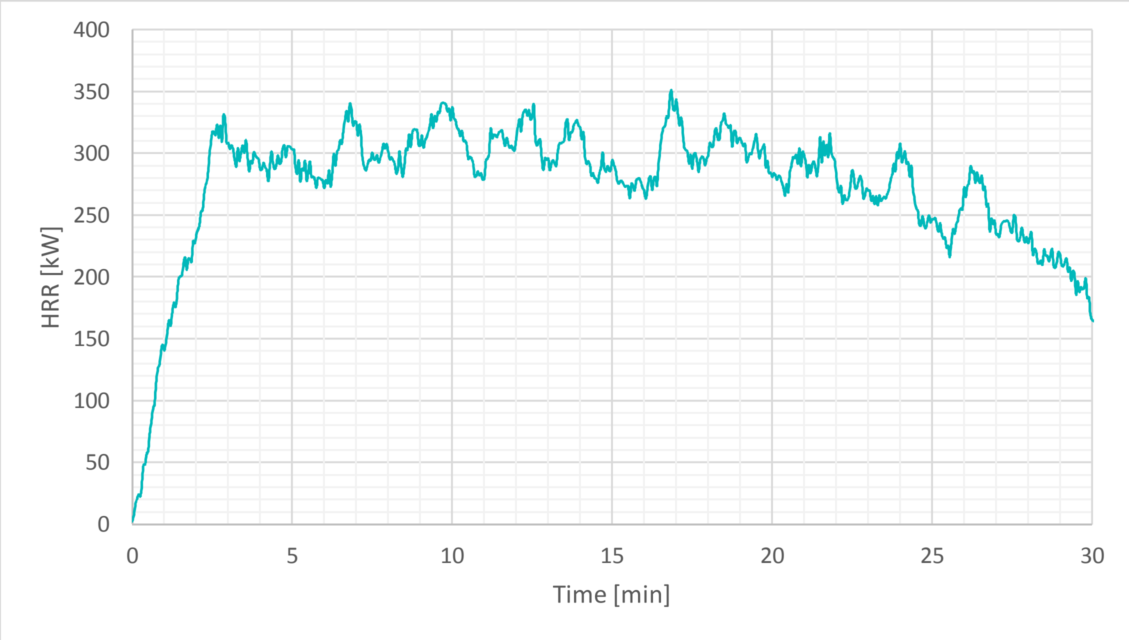


Figure E98 – Heat release rate measured during the fire, including the source

Figure E99 shows the heat flux recorded on the centre line during the fire at a height of 3.0 m from the ground.

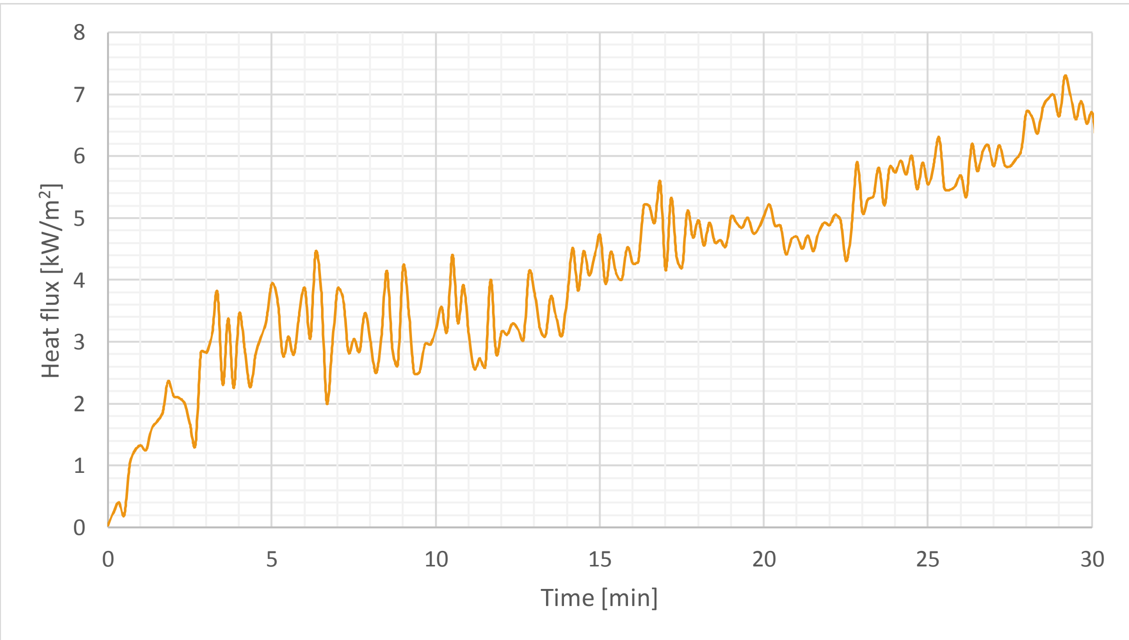


Figure E99 – Heat flux recorded during the fire at 3.0 m height

Table E42 shows the maximum external temperature, the maximum cavity temperature, maximum temperature at 3.0 m, time to peak heat release rate (HRR), peak HRR, maximum heat flux (HF) at 3.0 m and total heat release (THR) over a period of 30 minutes.

Table E42 – Summary of different measured parameters during the experiment

Max external temp [°C]	Max cavity temp [°C]	Max H=3.0m Temp [°C]	Time to peak HRR [min]	Peak HRR [kW]	Max H=3.0m Heat flux [kW/m^2]	THR [MJ]
823	310	114	17	351	7	495

A summary of the visual observations is presented in Table E43.

Table E43 – Visual observations during the experiment

Burning droplets	Time of burn though [min]	Burn through	Area consumed [m^2]	Vertical flame spread	Horizontal flame spread
No	No	No	≈0 panels	No	No

Figure E100 shows the sample after the fire. Discoloration and smoke damage were observed on the surface of the panels in the central axis. No breakthrough of the reconstituted stone panels was recorded after the fire exposure.

Figure E100 – Post fire observations

E2.2.21 Sample S21 brick slip system bonded to PUR insulation

The twenty first sample was a system with an overall thickness of approximately 60 mm comprising 40-45 mm of PUR insulation and 15-20 mm brick. The brick slips were cut to size and installed onto a substrate comprising 12 mm thick fibre cement building board. The fibre cement building board was installed on to the aluminium T-shaped rails of the rig using 50 mm self-drill, self-tap screws. A 50 mm cavity was provided between the fibre cement building board and the incombustible substrate of the rig. The panels were fixed to the fibre cement building board using Spax screws with white collars and cement based adhesive as supplied by the manufacturer. The fixing positions are cast within each panel during manufacture and are evenly distributed, located in joints between the brick slips. PU foam is applied around the perimeter of every component to fully seal the system. Pointing of the joints was carried out six days after installation. Figure E101 shows the material installed on the rig.

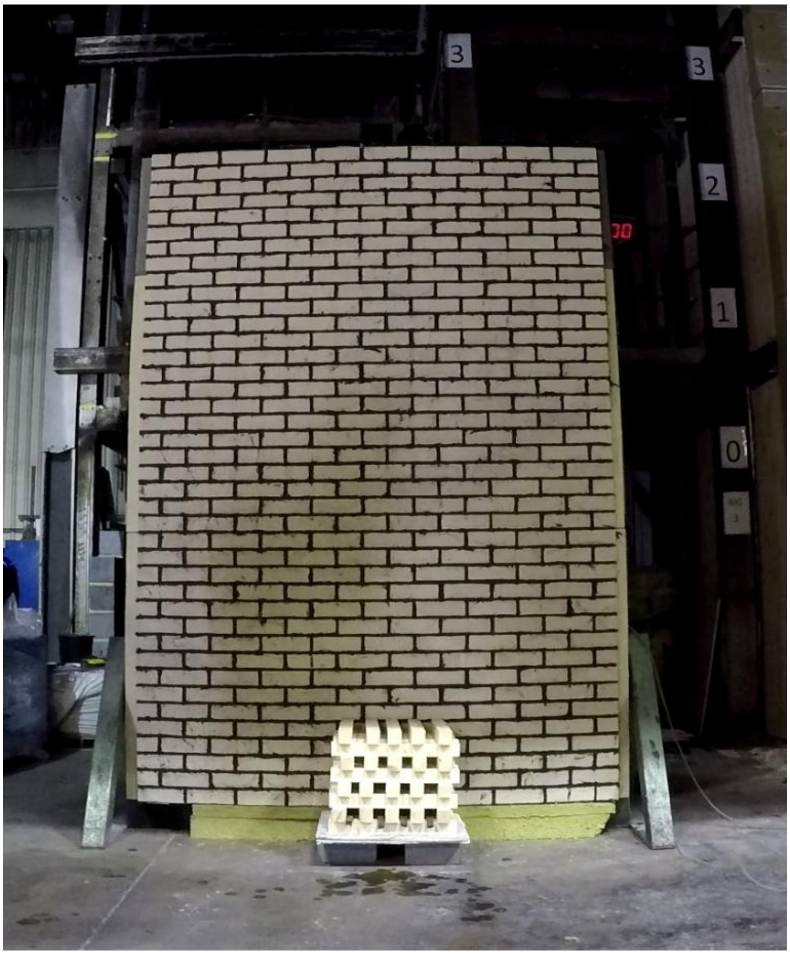


Figure E101 – Sample 21 brick slip system installed on the rig

Figure E102 shows photographs during the fire exposure at specified times.

5 minutes from ignition

10 minutes from ignition

20 minutes from ignition

25 minutes from ignition

Figure E102 – Photographs during the fire at 5, 10, 20 and 25 minutes from ignition

Discoloration was observed in the area of direct flame impingement. No breakthrough of the brick slip system was recorded.

After approximately 20 minutes of fire exposure hot gases were observed escaping through the mortar joints, next to fire source. In the area of direct flame impingement, the gases self-ignited and burned for a short duration.

No falling debris or burning droplets were observed during the fire. No vertical or horizontal flame spread on the surface of the brick slip system was observed.

Figure E103 shows the heat release rate as a function of time during the fire exposure, including the fire source. Based on the original crib calibrations and measured values from the calorimeter it is assumed that the peak heat release rate for the crib alone is approximately 300 kW.

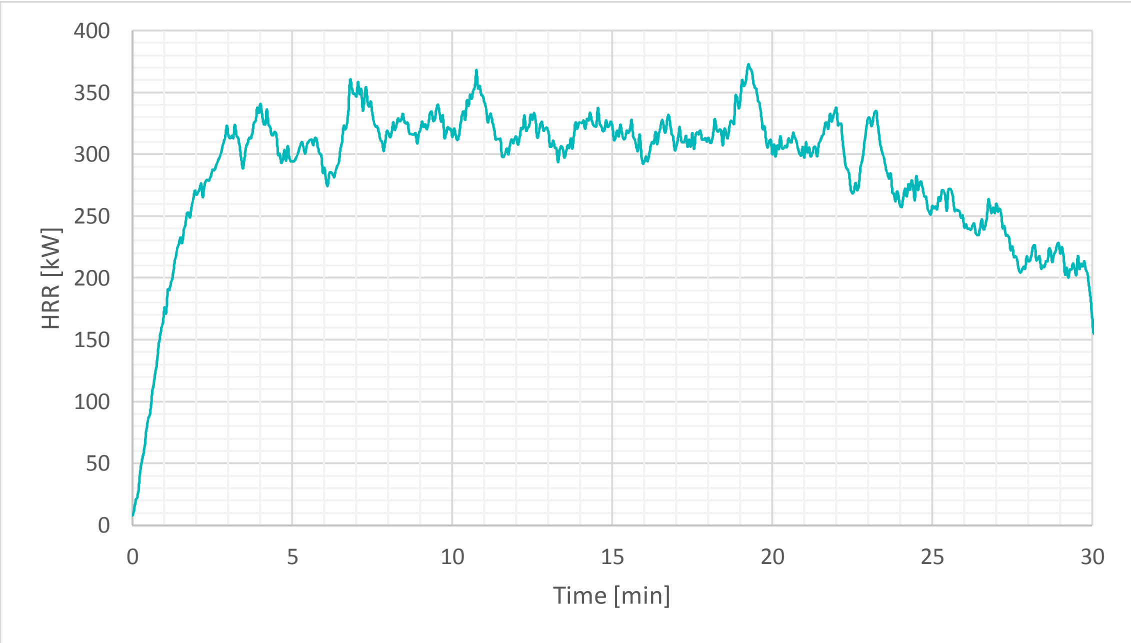


Figure E103 – Heat release rate measured during the fire, including the source

Figure E104 shows the heat flux recorded on the centre line during the fire at a height of 3.0m from the ground.

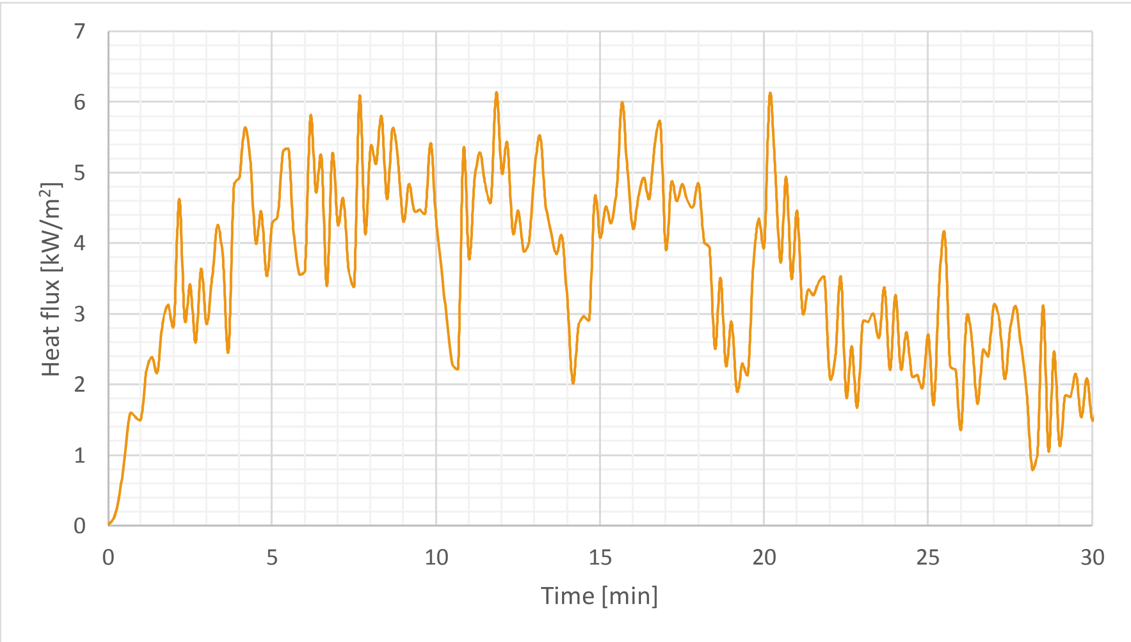


Figure E104 – Heat flux recorded during the fire at 3.0 m height

Table E44 shows the maximum external temperature, the maximum cavity temperature, maximum temperature at 3.0 m, time to peak heat release rate (HRR), peak HRR, maximum heat flux (HF) at 3.0 m and total heat release (THR) over a period of 30 minutes.

Table E44 – Summary of different measured parameters during the experiment

Max external temp [°C]	Max cavity temp [°C]	Max H=3.0m Temp [°C]	Time to peak HRR [min]	Peak HRR [kW]	Max H=3.0m Heat flux [kW/m^2]	THR [MJ]
823	45	128	19	373	6	521

A summary of the visual observations is presented in Table E45.

Table E45 – Visual observations during the experiment

Burning droplets	Time of burn though [min]	Burn through	Area consumed [m^2]	Vertical flame spread	Horizontal flame spread
No	No	No	≈0 panels	No	No

Figure E105 shows the sample after the fire. Discoloration and smoke damage were observed on the surface of the panels in the central axis. No breakthrough of the brick slip panels was recorded after the fire exposure.

Figure E105 – Post fire observations

E2.2.22 Sample S22 brick slip system bonded to PUR insulation

The twenty second was a system with an overall thickness of approximately 60 mm comprising 40-45 mm of PUR insulation and 15-20 mm brick. The brick slips were cut to size and installed onto a substrate comprising 12 mm thick fibre cement building board. The fibre cement building board was installed on to the aluminium T-shaped rails of the rig using 50 mm self-drill, self-tap screws. A 50 mm cavity was provided between the fibre cement building board and the incombustible substrate of the rig. The panels were fixed to the fibre cement building board using Spax screws with white collars and cement based adhesive as supplied by the manufacturer. The fixing positions are cast within each panel during manufacture and are evenly distributed, located in joints between the brick slips. PU foam is applied around the perimeter of every component to fully seal the system. Pointing of the joints was carried out six days after installation. Figure E106 shows the material installed on the rig.

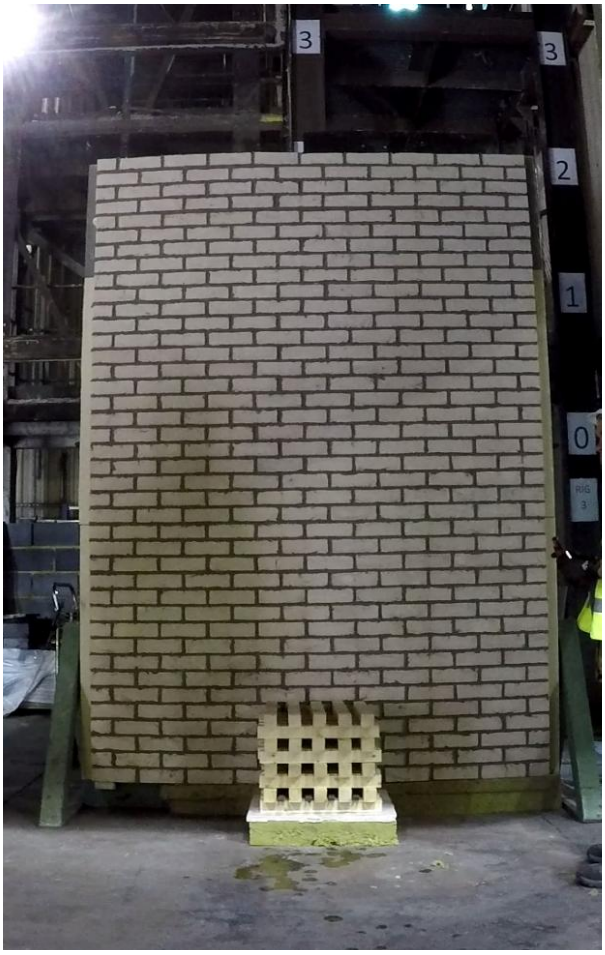
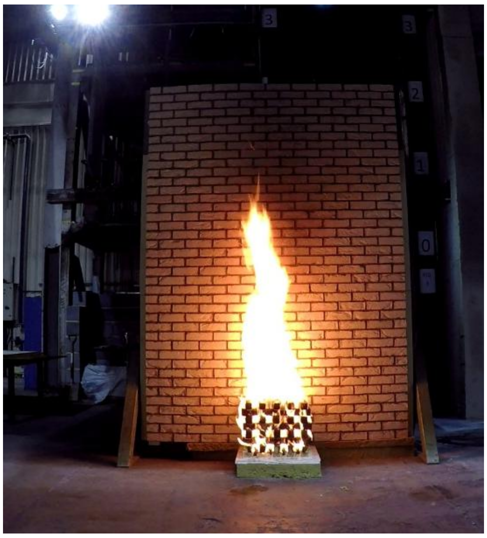


Figure E106 – Sample 22 brick slip system installed on the rig

Figure E107 shows photographs during the fire exposure at specified times.



5 minutes from ignition

10 minutes from ignition

20 minutes from ignition

25 minutes from ignition

Figure E107 – Photographs during the fire at 5, 10, 20 and 25 minutes from ignition

Discoloration was observed in the area of direct flame impingement. No breakthrough the brick slip system was observed.

After approximately 19 minutes of fire exposure hot gases were observed escaping through the mortar joints, next to fire source. In the area of direct flame impingement, the gases self-ignited and burned for a short period.

No falling debris or burning droplets were observed during the fire. No vertical or horizontal flame spread on the surface of the brick slip system was observed.

Figure E108 shows the heat release rate as a function of time during the fire exposure, including the fire source. Based on the original crib calibrations and measured values from the calorimeter it is assumed that the peak heat release rate for the crib alone is approximately 300 kW.

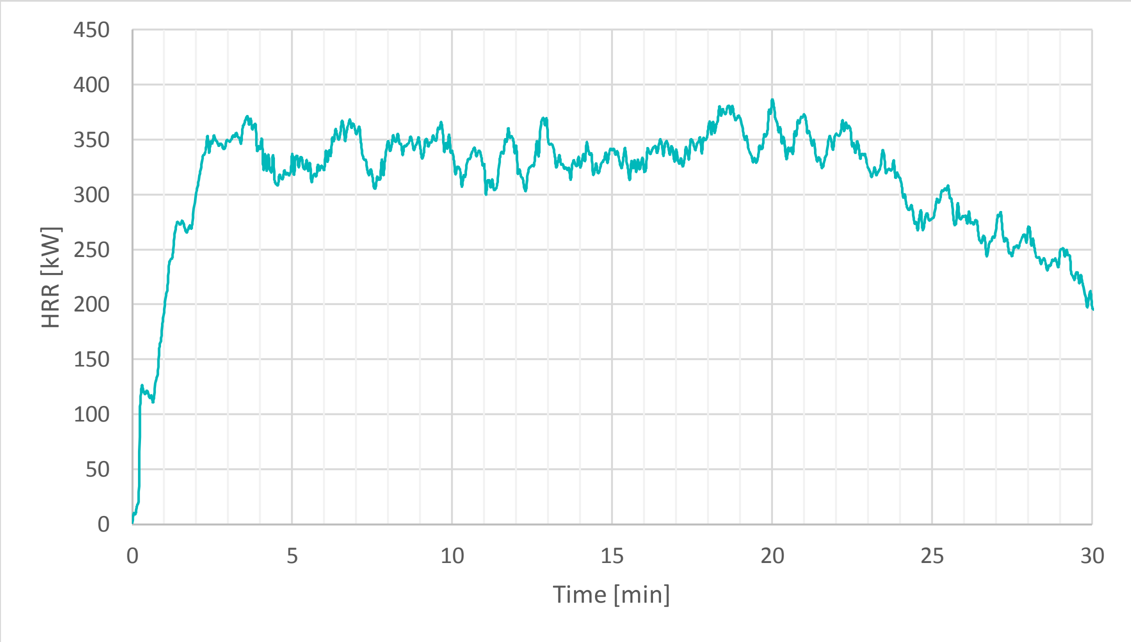


Figure E108 – Heat release rate measured during the fire, including the source

Figure E109 shows the heat flux recorded on the centre line during the fire at a height of 3.0 m from the ground.

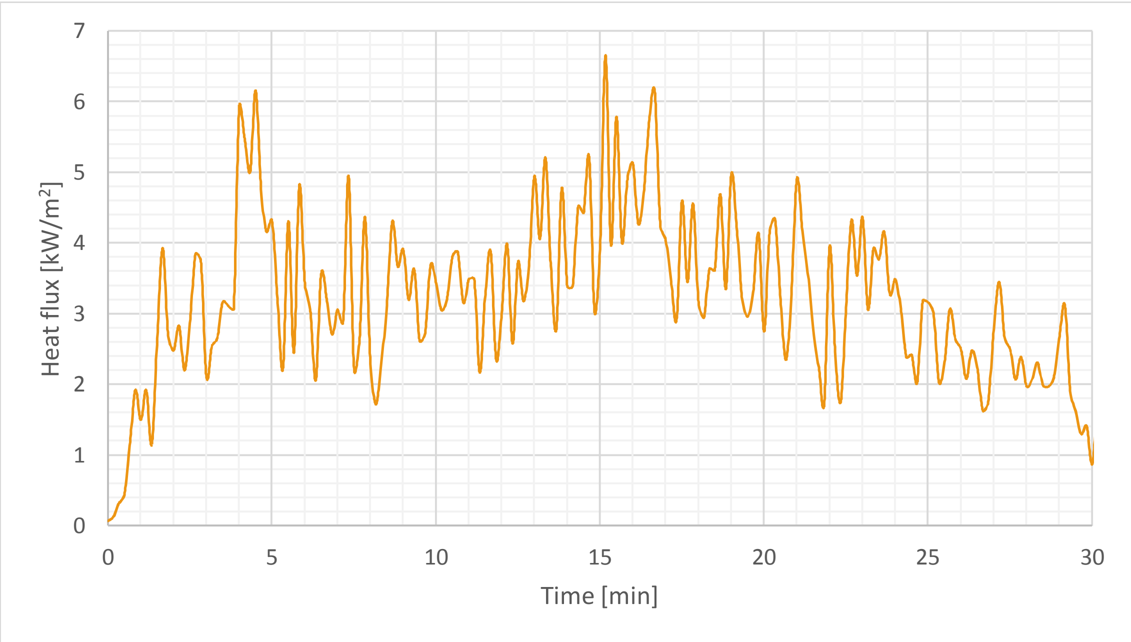


Figure E109 – Heat flux recorded during the fire at 3.0 m height

Table E46 shows the maximum external temperature, the maximum cavity temperature, maximum temperature at 3.0 m, time to peak heat release rate (HRR), peak HRR, maximum heat flux (HF) at 3.0 m and total heat release (THR) over a period of 30 minutes.

Table E46 – Summary of different measured parameters during the experiment

Max external temp [°C]	Max cavity temp [°C]	Max H=3.0m Temp [°C]	Time to peak HRR [min]	Peak HRR [kW]	Max H=3.0m Heat flux [kW/m^2]	THR [MJ]
850	36	75	20	387	7	565

A summary of the visual observations is presented in Table E47.

Table E47 – Visual observations during the experiment

Burning droplets	Time of burn though [min]	Burn through	Area consumed [m^2]	Vertical flame spread	Horizontal flame spread
No	No	No	≈0 panels	No	No

Figure E110 shows the sample after the fire. Discoloration and smoke damage were observed on the surface of the panels in the central axis. No breakthrough of the brick slip panels was recorded after the fire exposure.

Figure E110 – Post fire observations

E3 Next stage

The next stage of the project was to carry out a detailed analysis of the experimental results.

E4 Reference for Appendix E

[1] British Standards Institution. BS EN ISO 1716, Reaction to fire tests for products. Determination of the gross heat of combustion (calorific value), BSI London, 2018.

Appendix E1 Temperature measurements for the experimental fires

This Appendix presents the measured external and cavity temperatures on the central axis of the experimental rig for all the samples. The location and designated number of the installed thermocouples is illustrated in Figure E111.

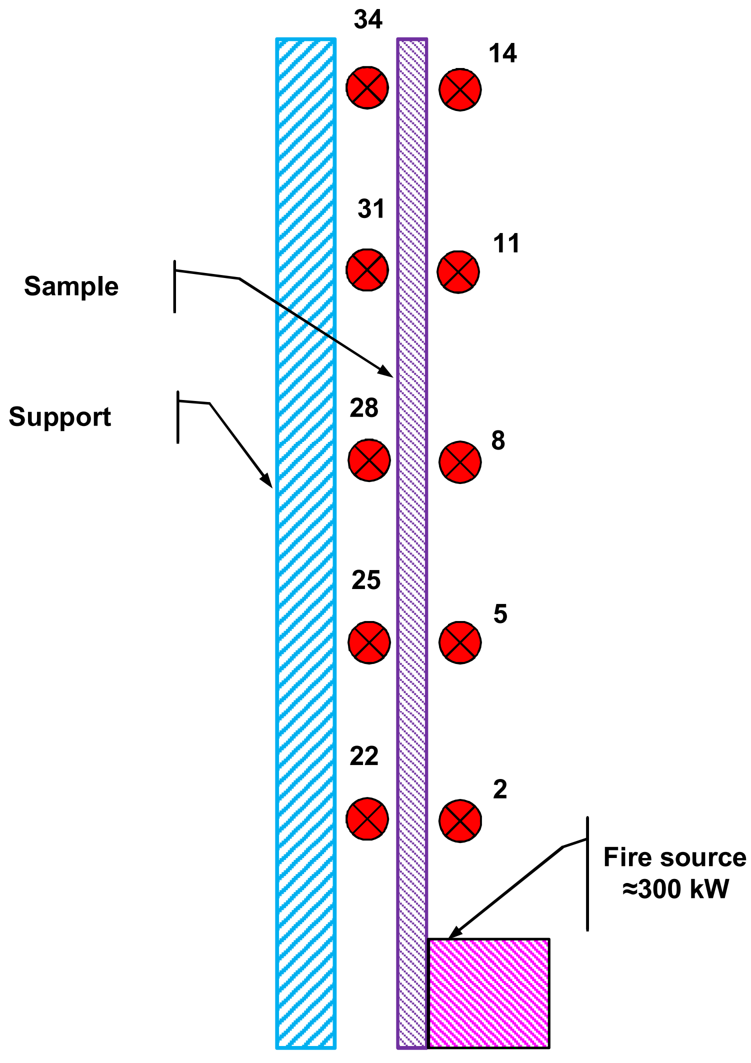


Figure E111 – Thermocouple locations for the samples

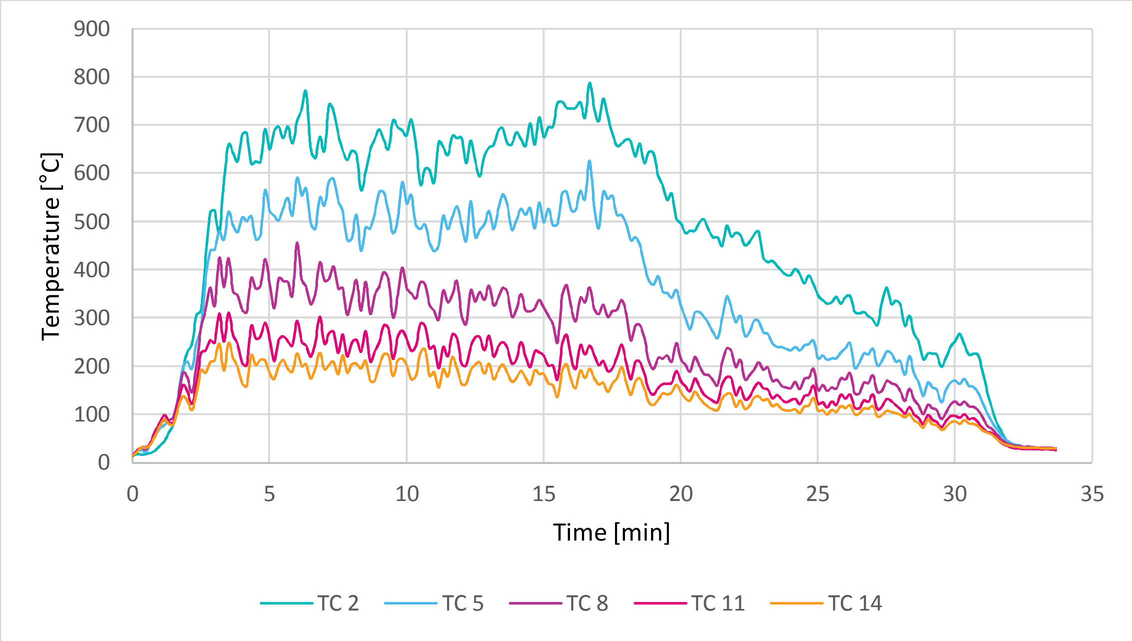


Figure E112 – Temperatures measured on the external central axis for S1

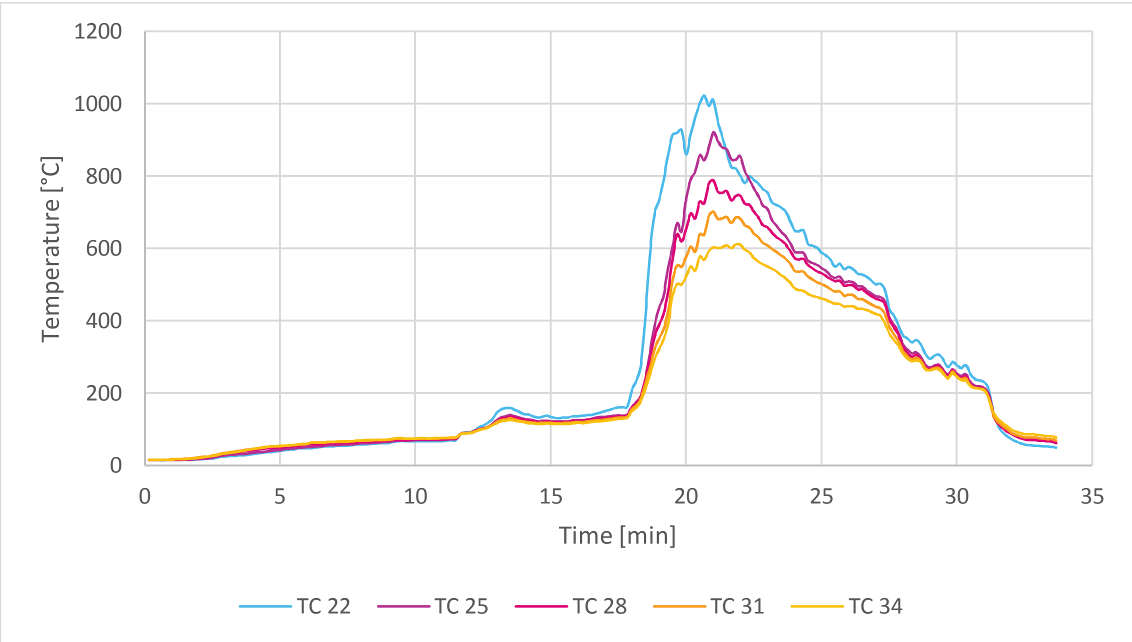


Figure E113 – Temperatures measured on the cavity central axis for S1

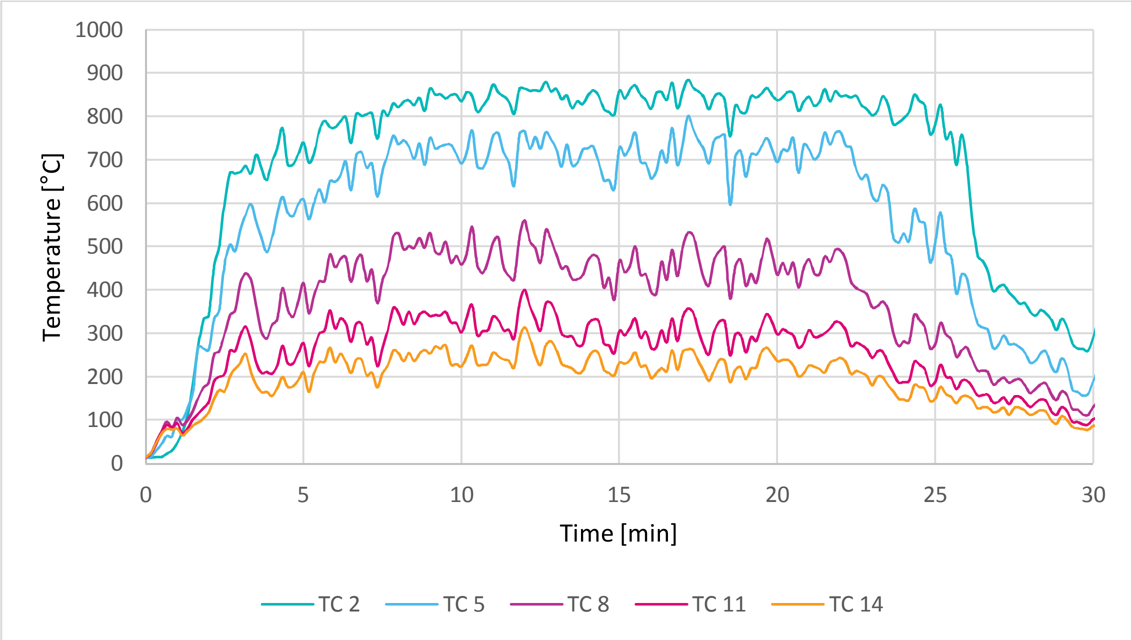


Figure E114 – Temperatures measured on the external central axis for S2

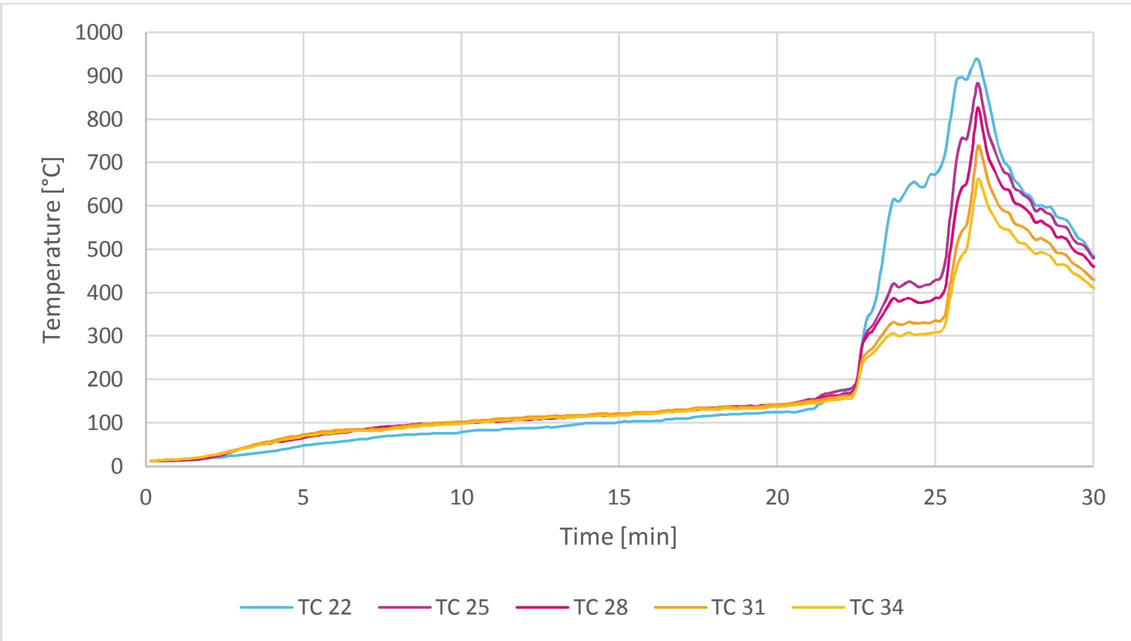


Figure E115 – Temperatures measured on the cavity central axis for S2

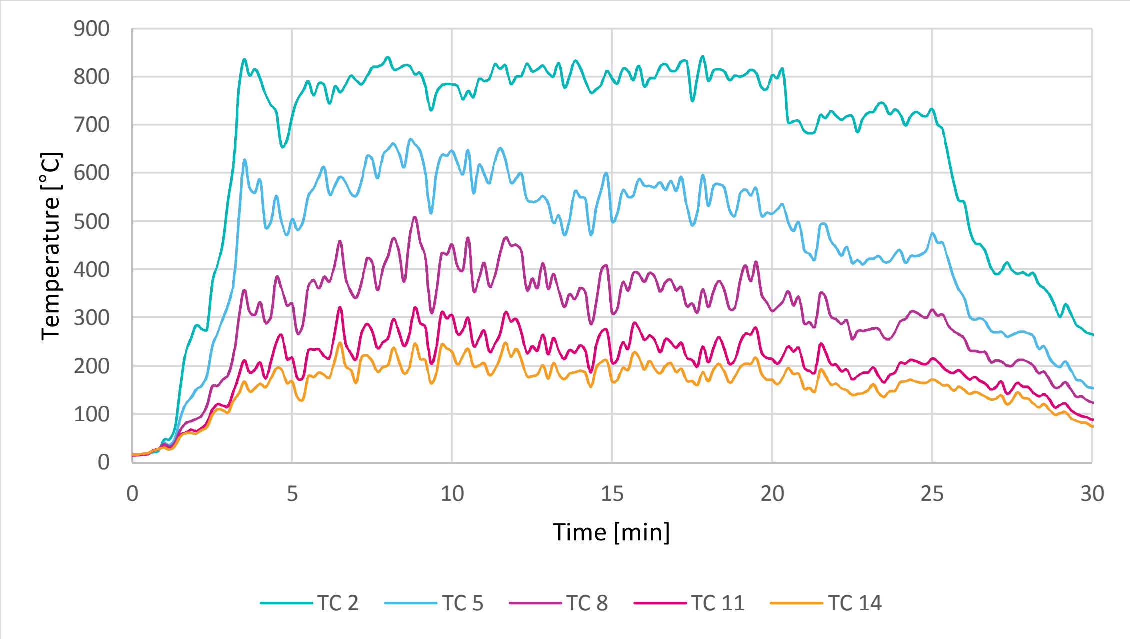


Figure E116 – Temperatures measured on the external central axis for S3

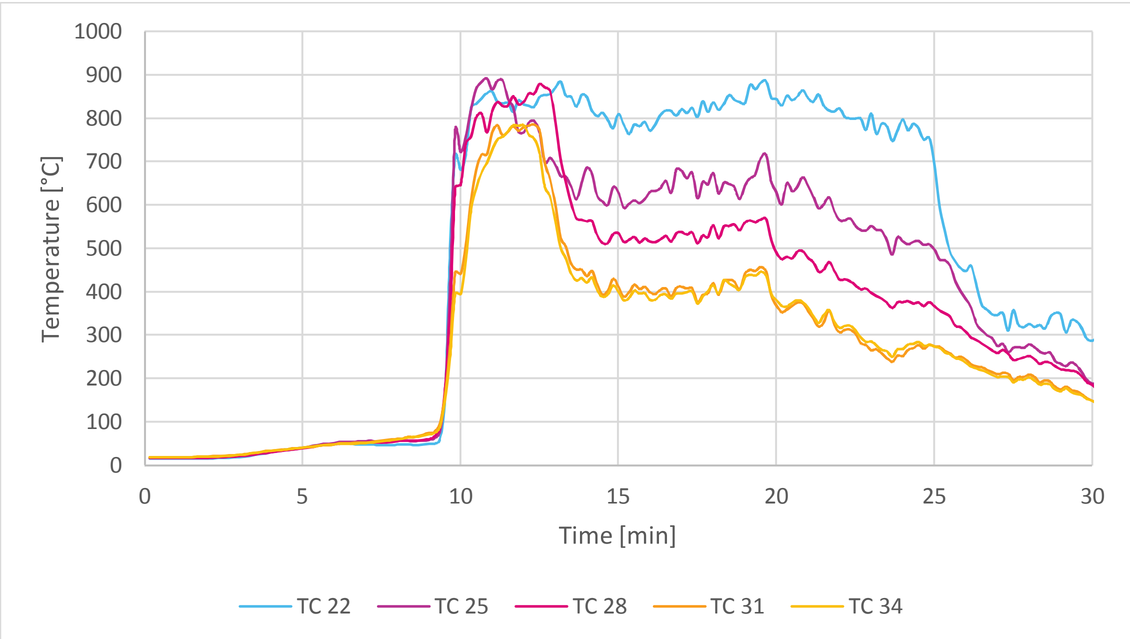


Figure E117 – Temperatures measured on the cavity central axis for S3

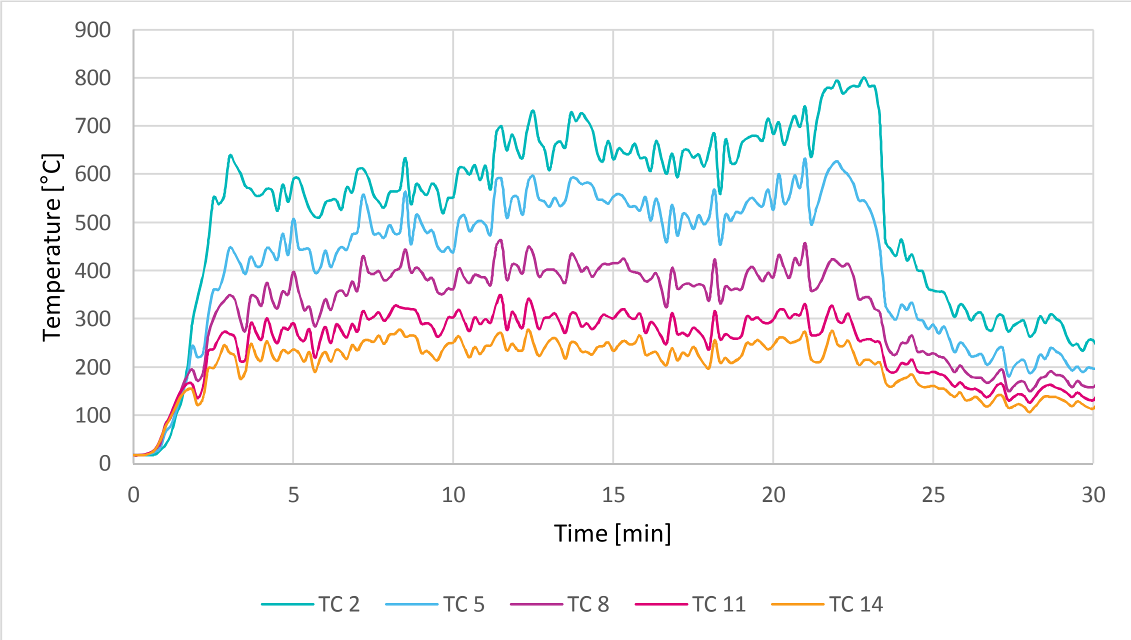


Figure E118 – Temperatures measured on the external central axis for S4

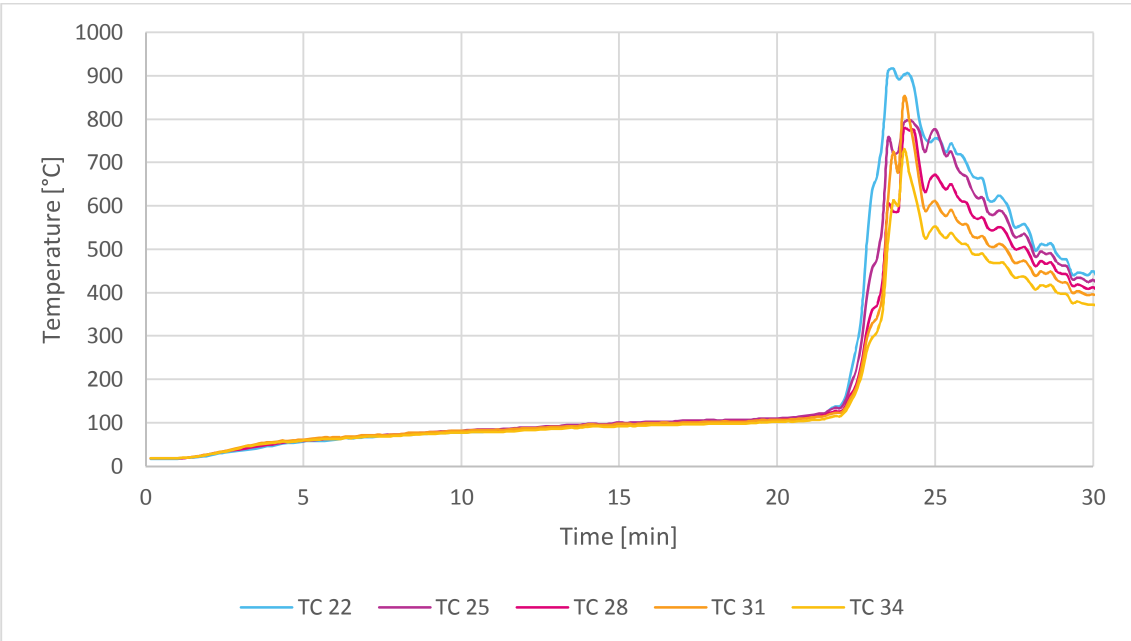


Figure E119 – Temperatures measured on the cavity central axis for S4

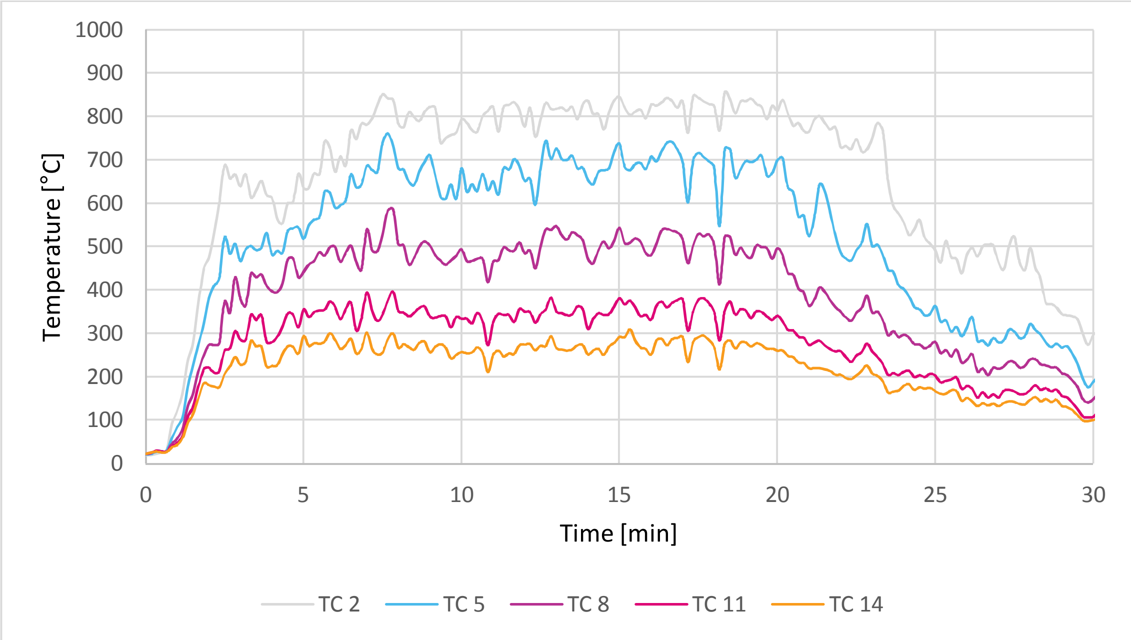


Figure E120 – Temperatures measured on the external central axis for S5

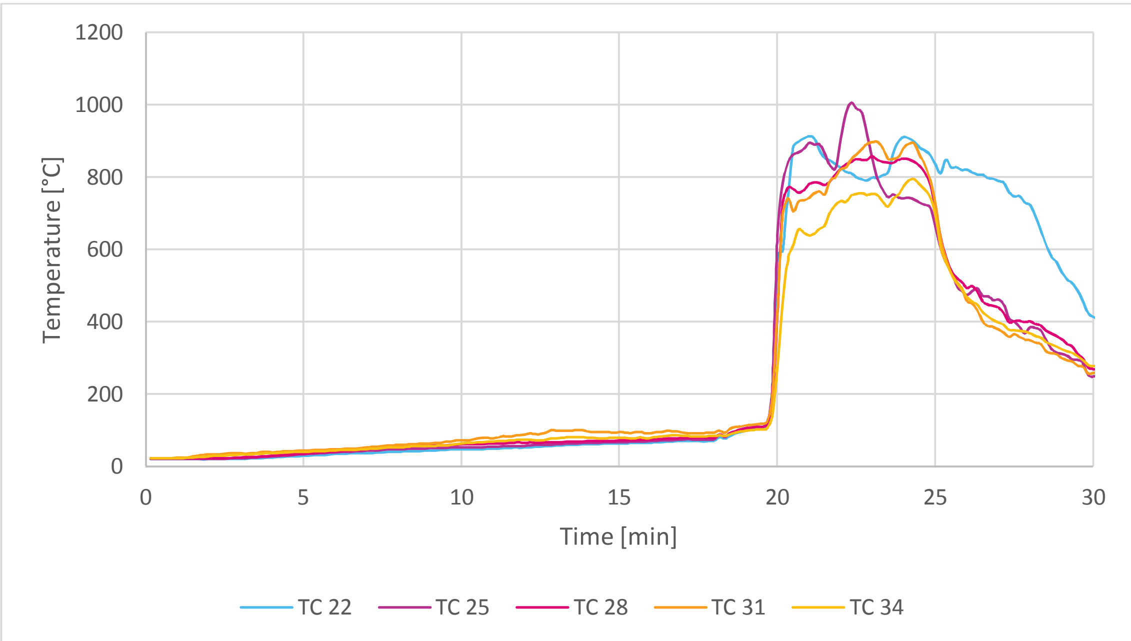


Figure E121 – Temperatures measured on the cavity central axis for S5

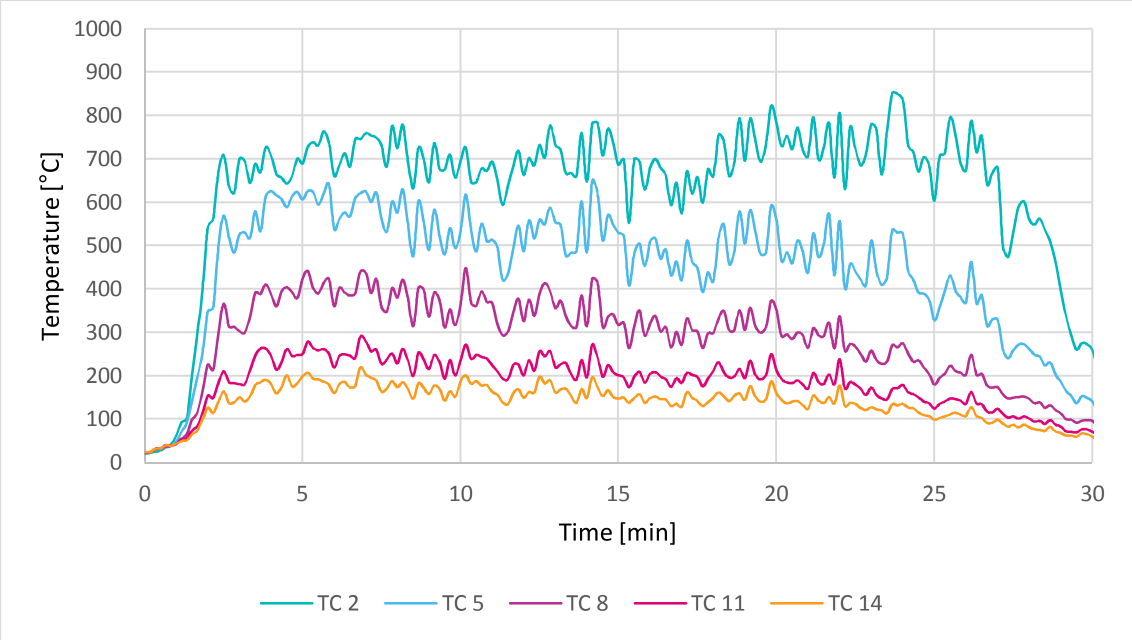


Figure E122 – Temperatures measured on the external central axis for S6

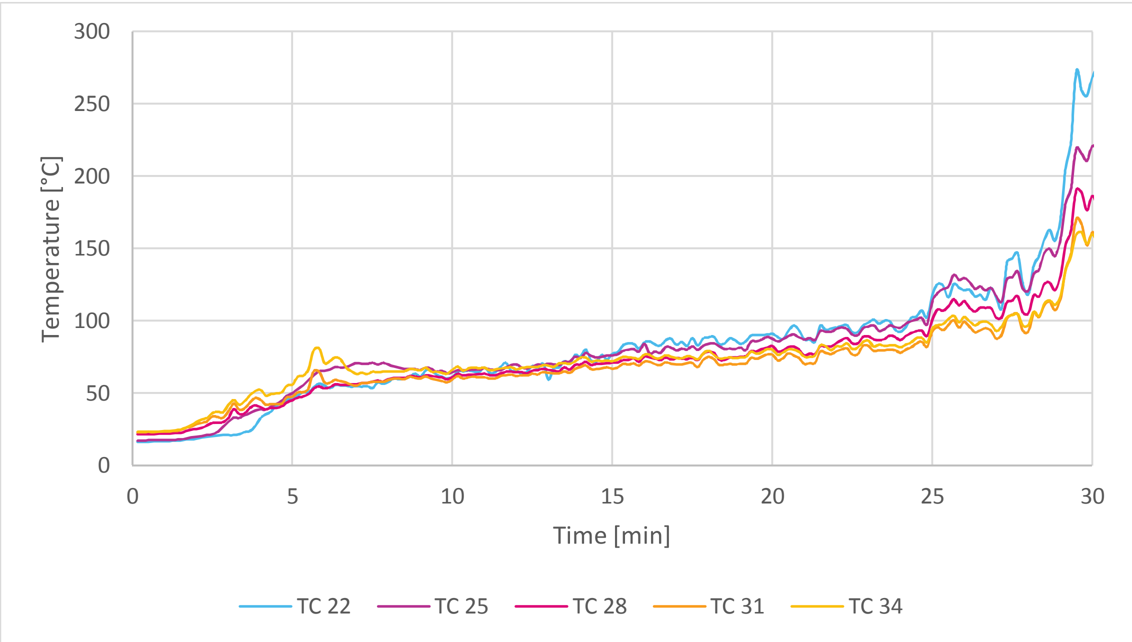


Figure E123 – Temperatures measured on the cavity central axis for S6

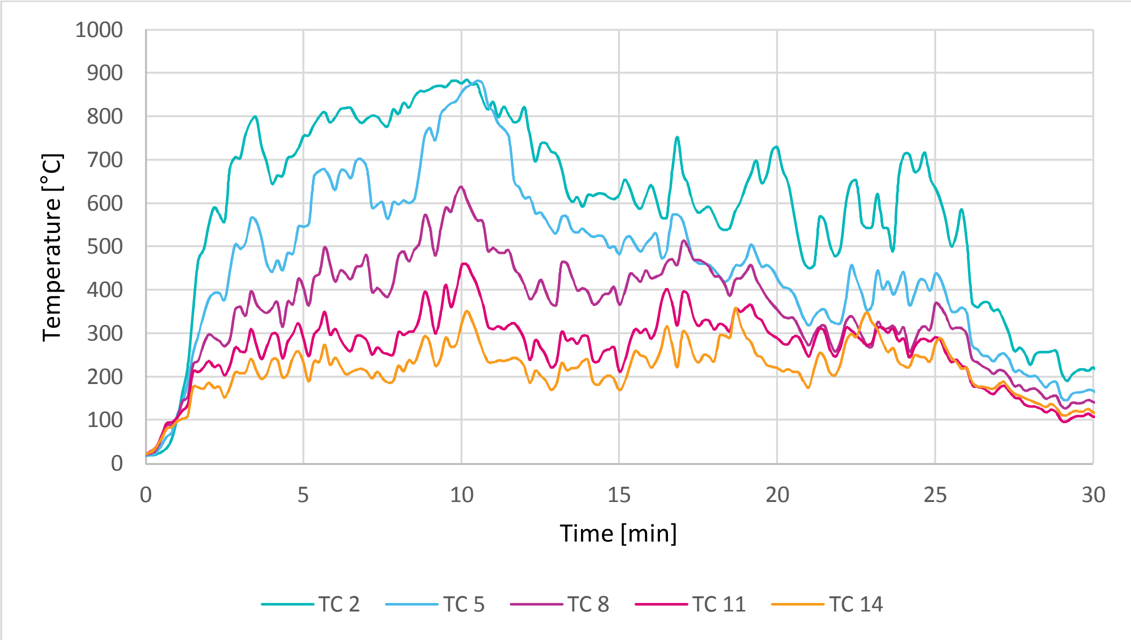


Figure E124 – Temperatures measured on the external central axis for S7

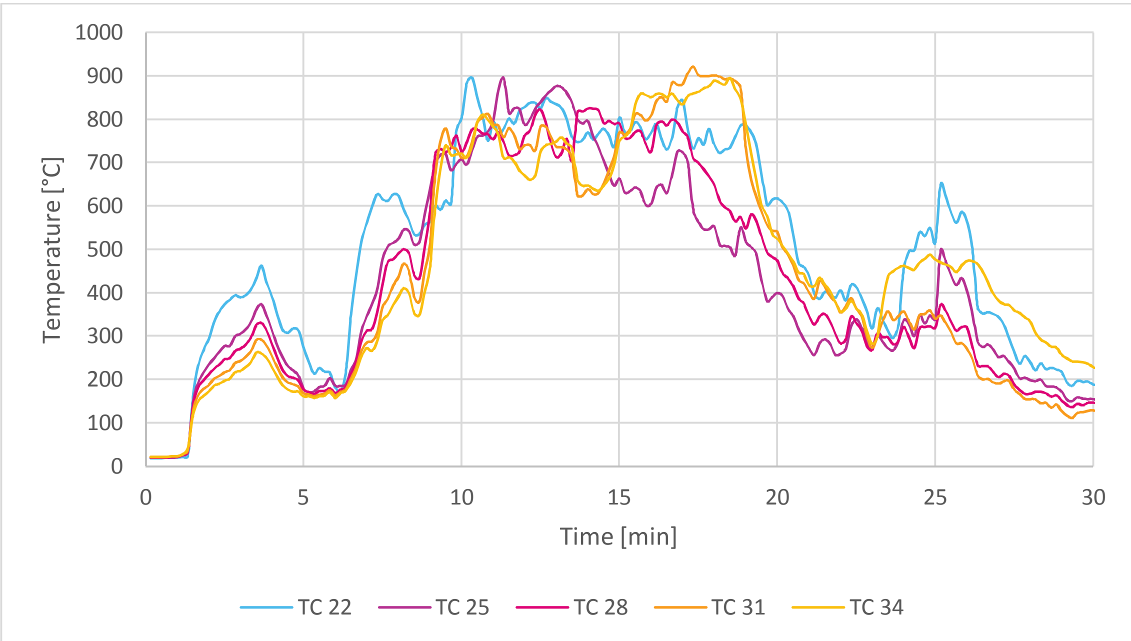


Figure E125 – Temperatures measured on the cavity central axis for S7

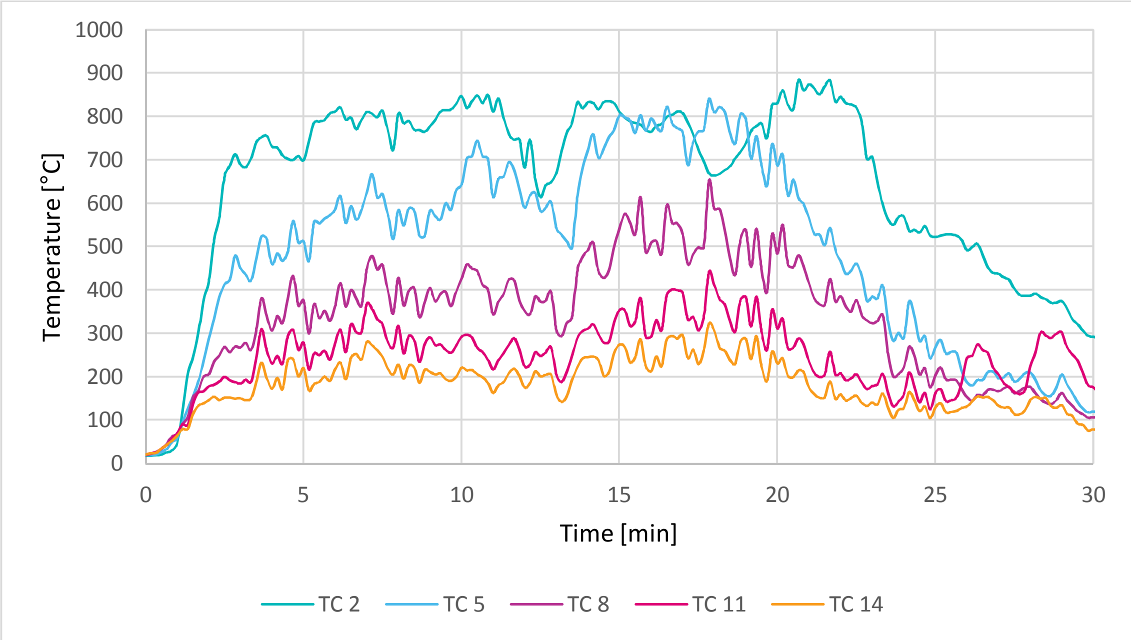


Figure E126 – Temperatures measured on the external central axis for S8

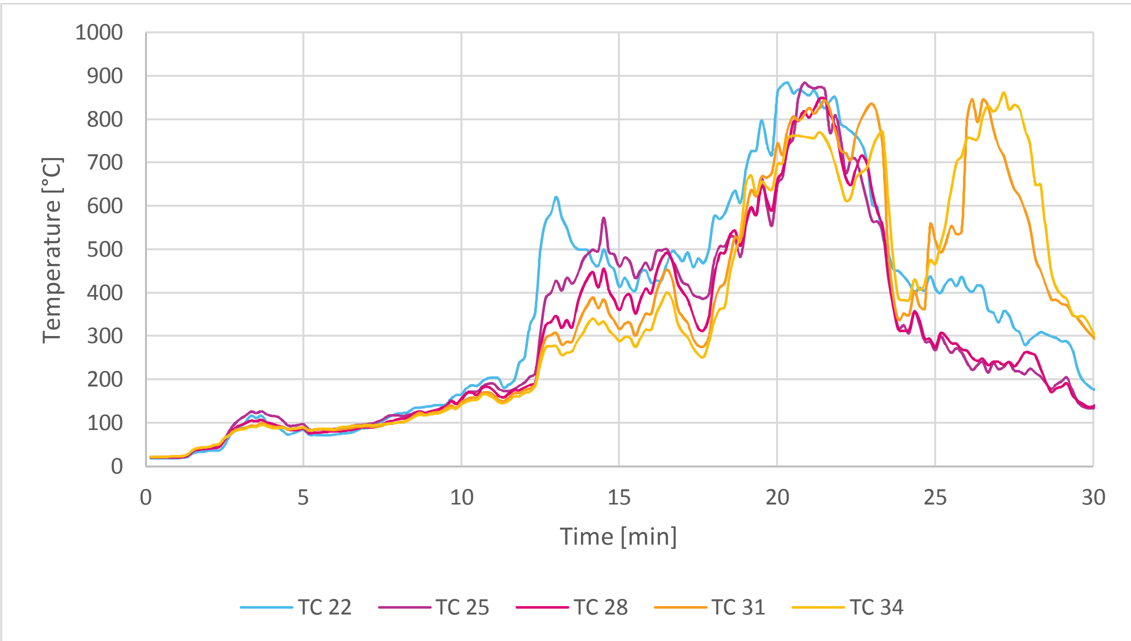


Figure E127 – Temperatures measured on the cavity central axis for S8

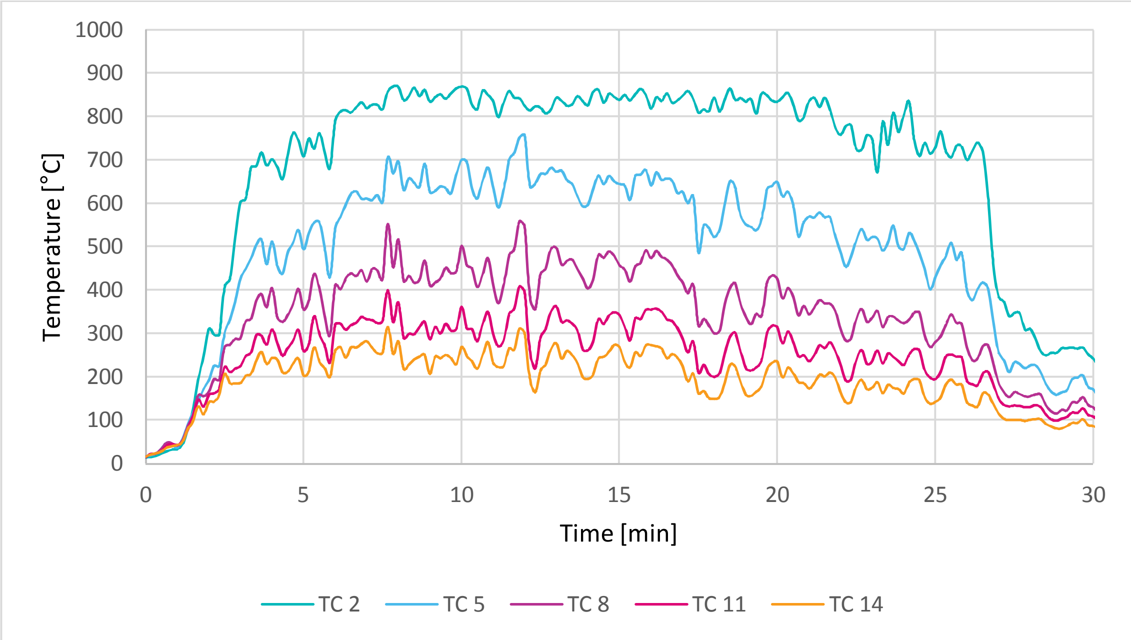


Figure E128 – Temperatures measured on the external central axis for S9

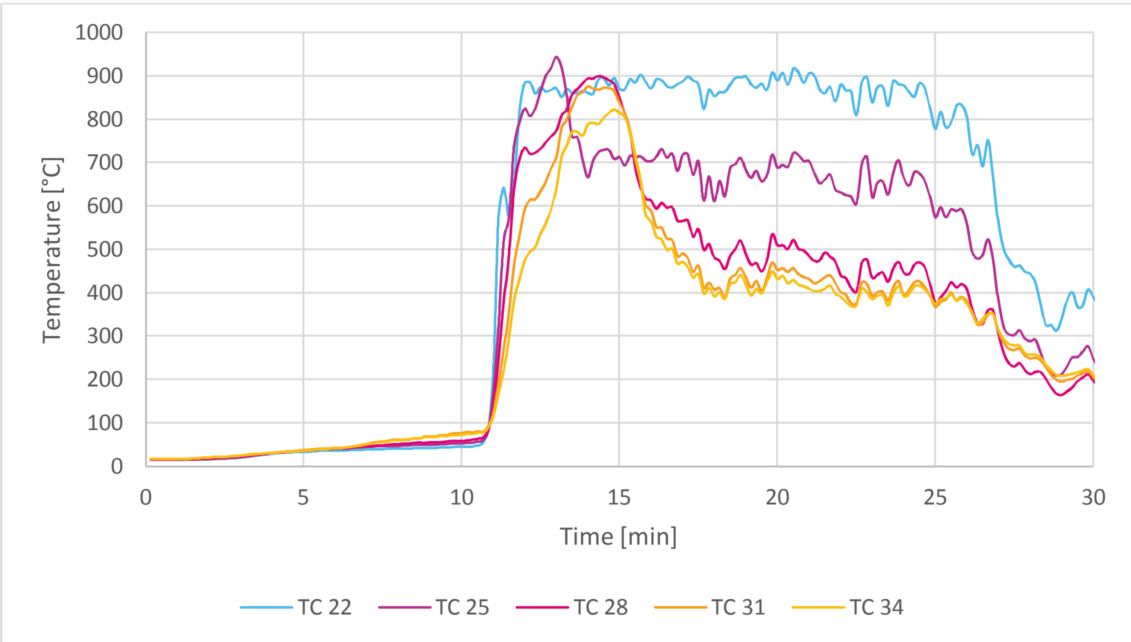


Figure E129 – Temperatures measured on the cavity central axis for S9

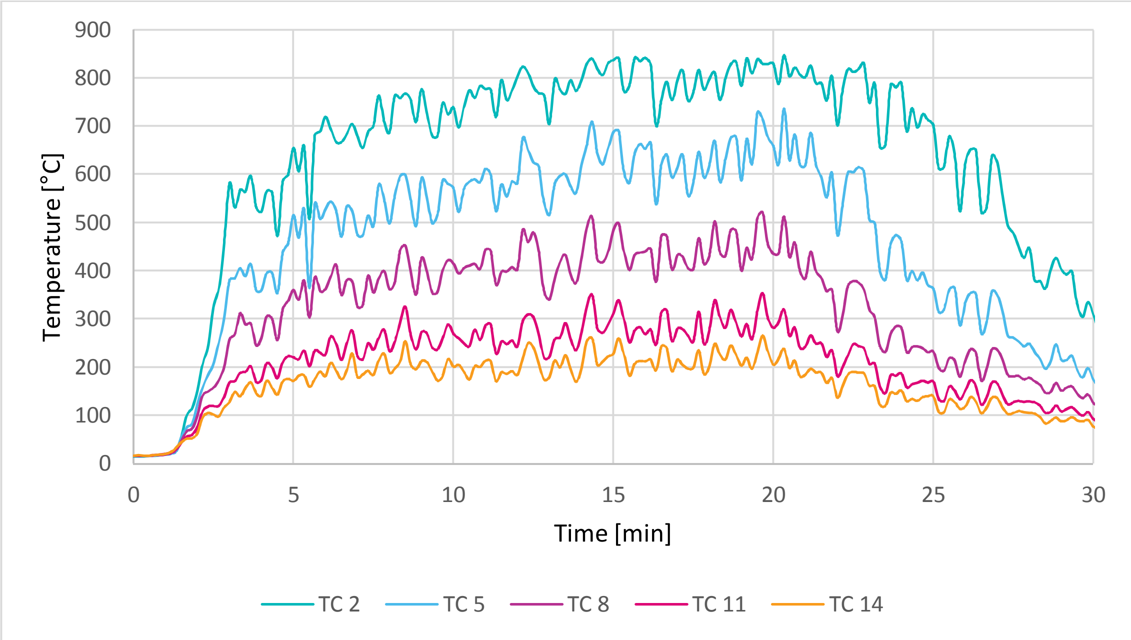


Figure E130 – Temperatures measured on the external central axis for S10

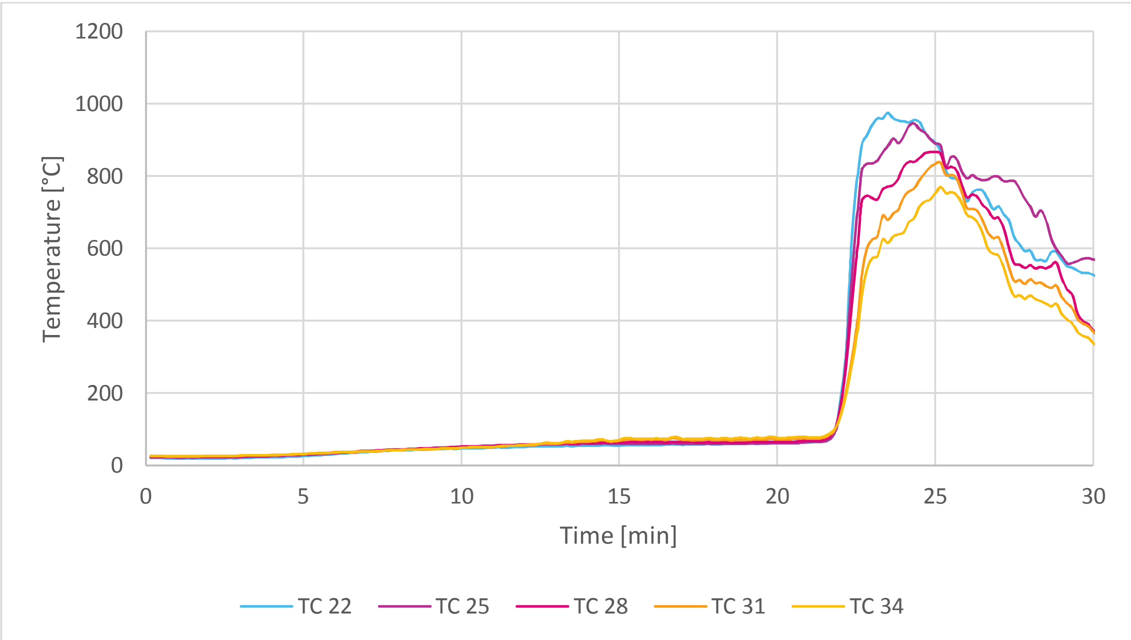


Figure E131 – Temperatures measured on the cavity central axis for S10

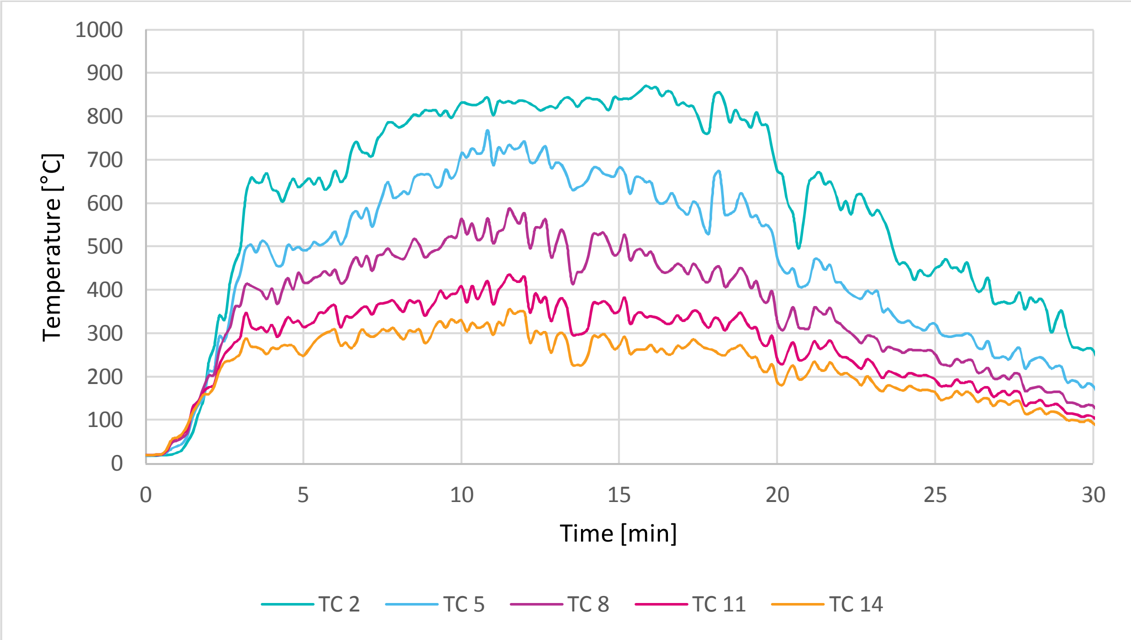


Figure E132 – Temperatures measured on the external central axis for S11

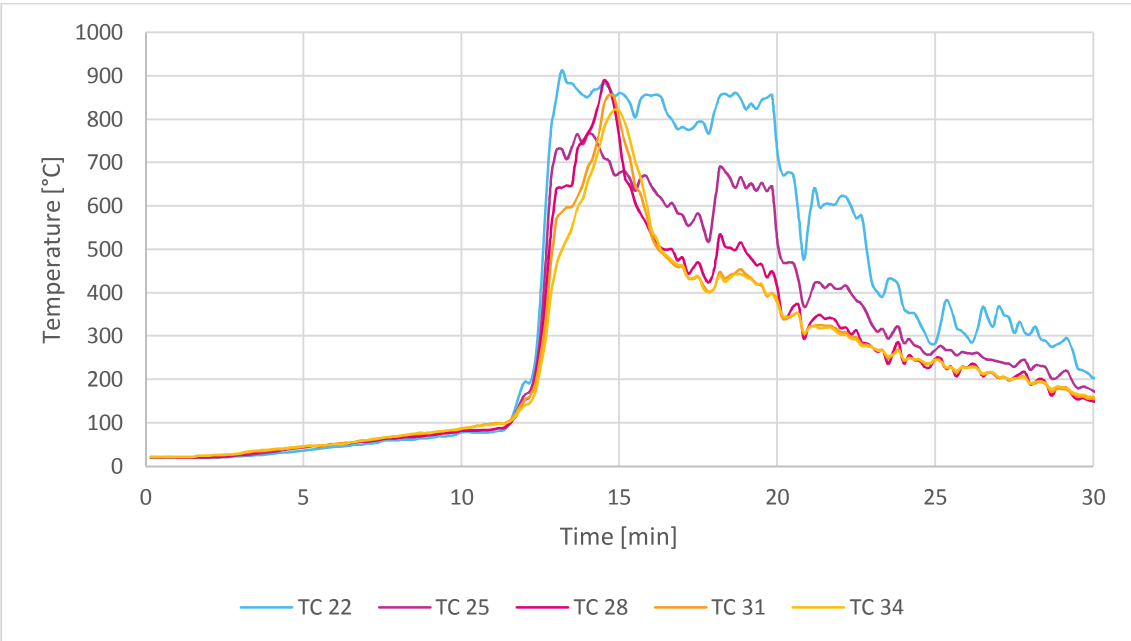


Figure E133 – Temperatures measured on the cavity central axis for S11

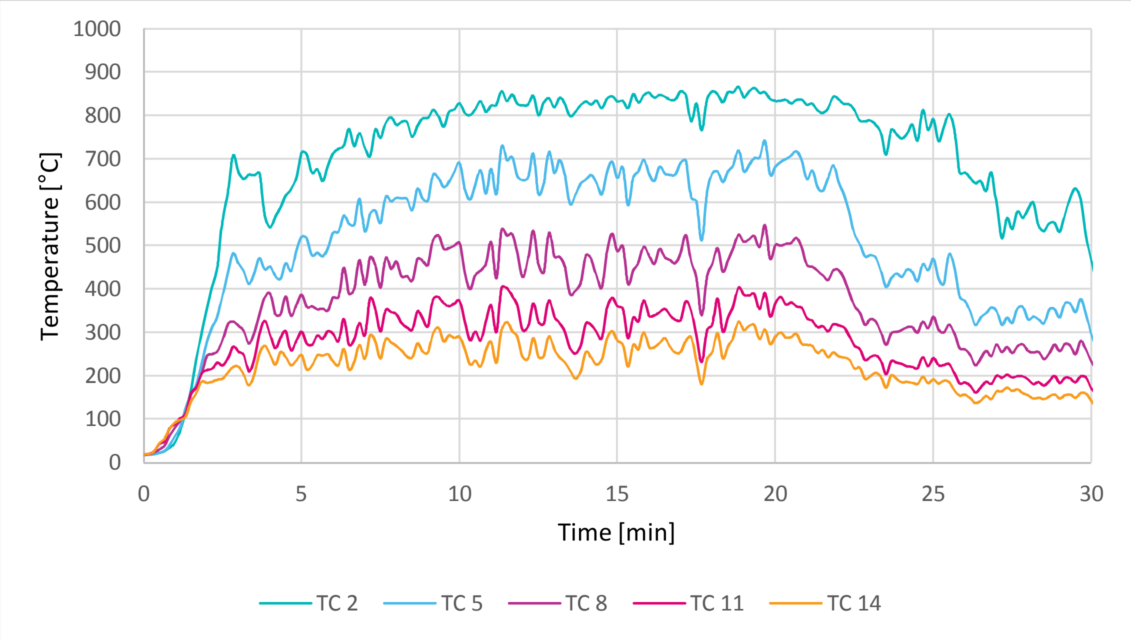


Figure E134 – Temperatures measured on the external central axis for S12

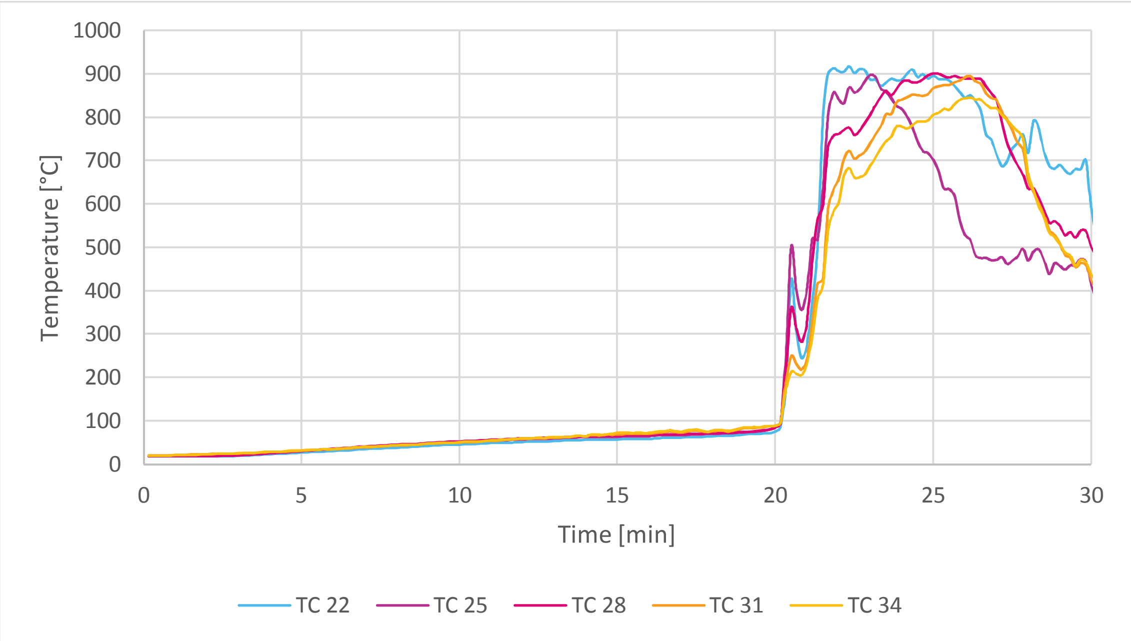


Figure E135 – Temperatures measured on the cavity central axis for S12

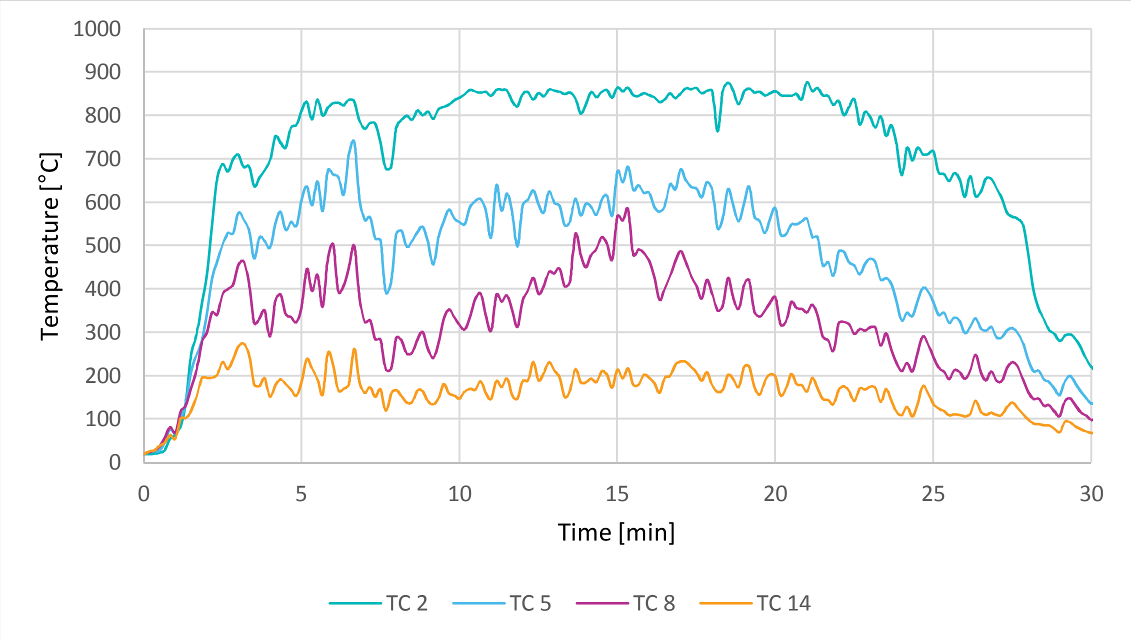


Figure E136 – Temperatures measured on the external central axis for S13

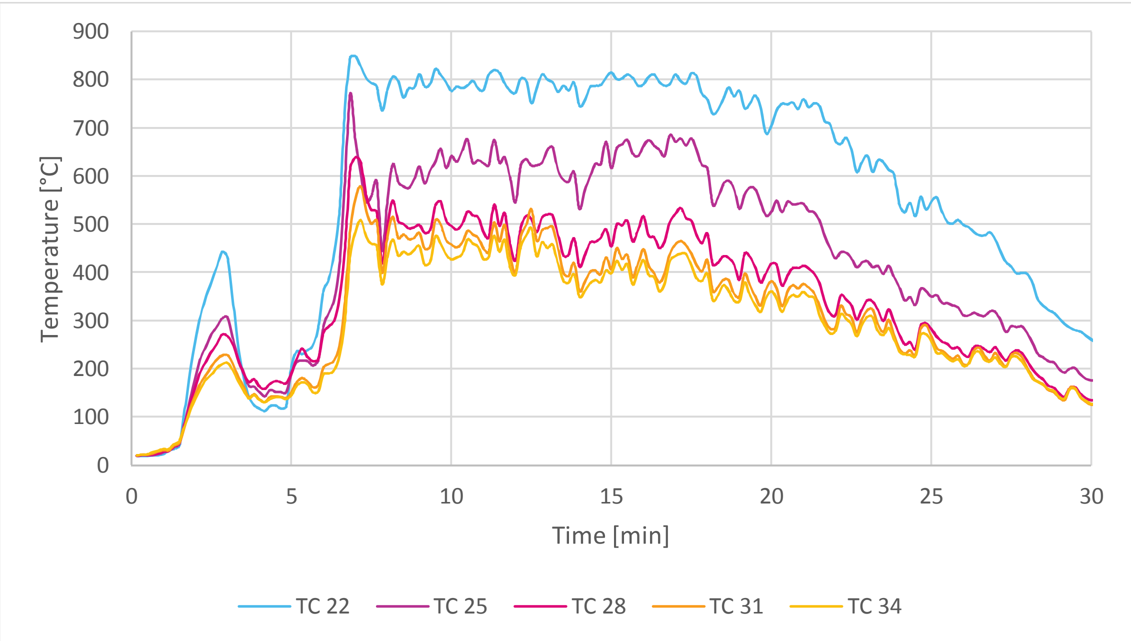


Figure E137 – Temperatures measured on the cavity central axis for S13

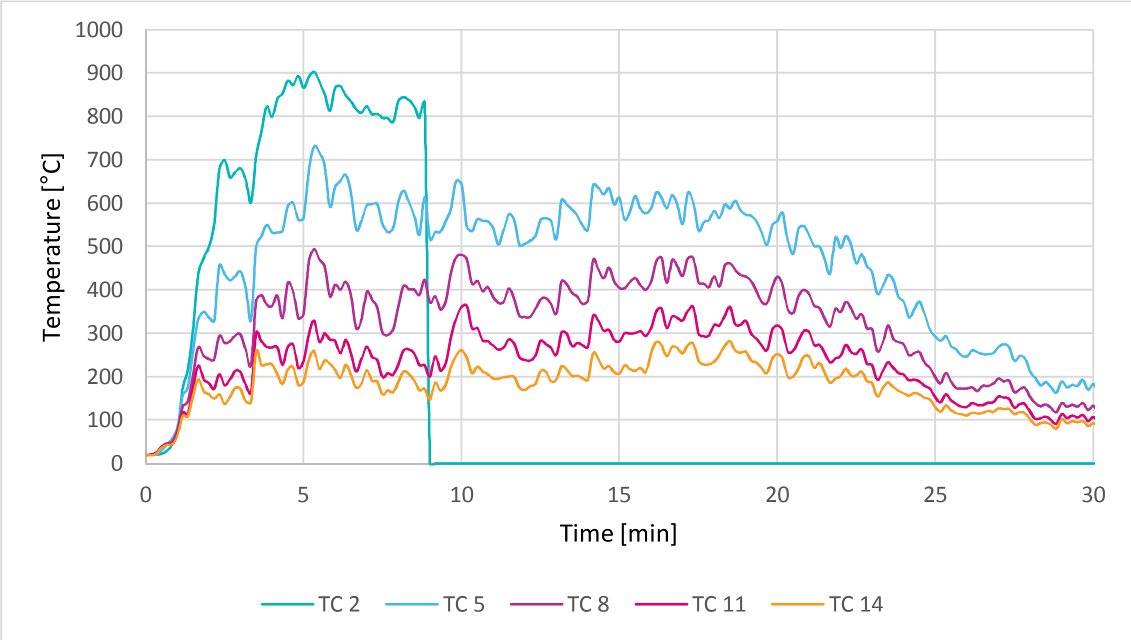


Figure E138 – Temperatures measured on the external central axis for S14

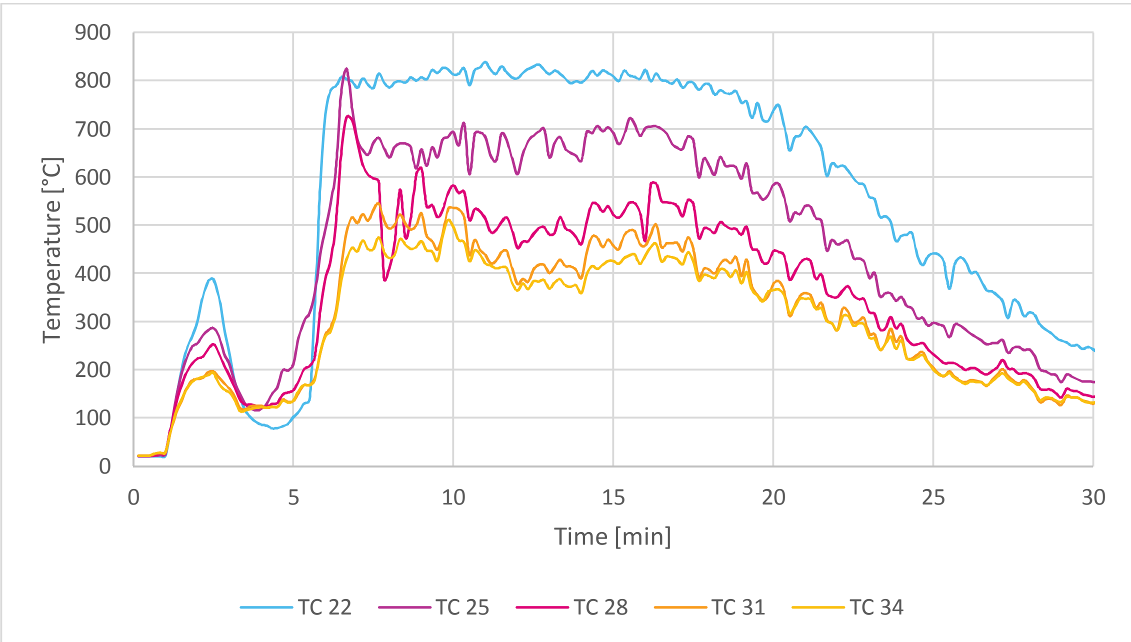


Figure E139 – Temperatures measured on the cavity central axis for S14

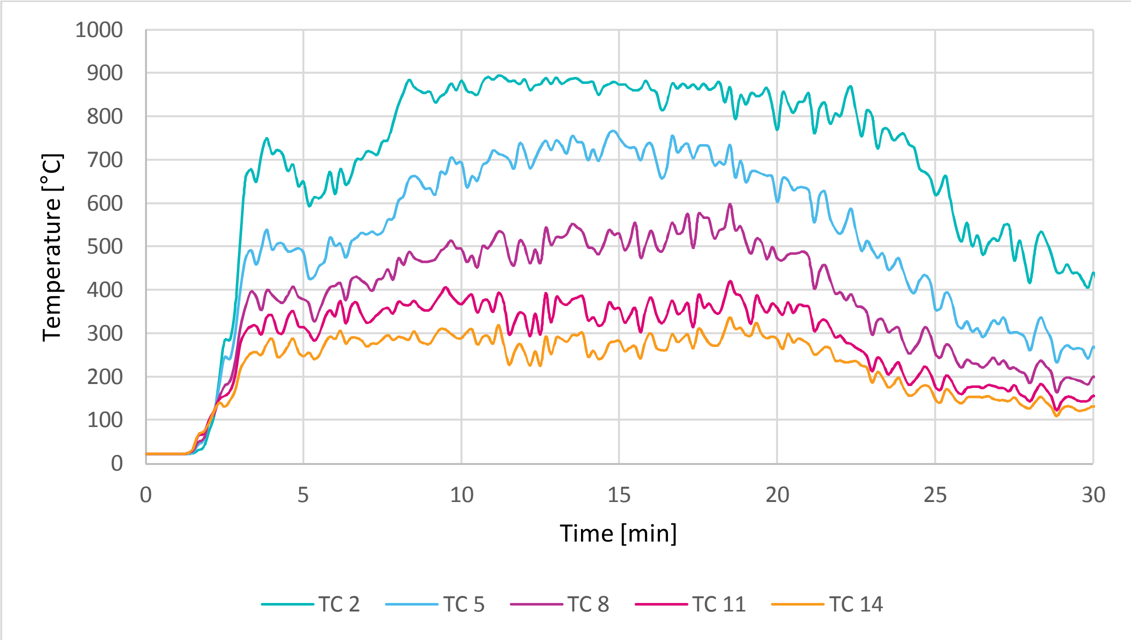


Figure E140 – Temperatures measured on the external central axis for S15

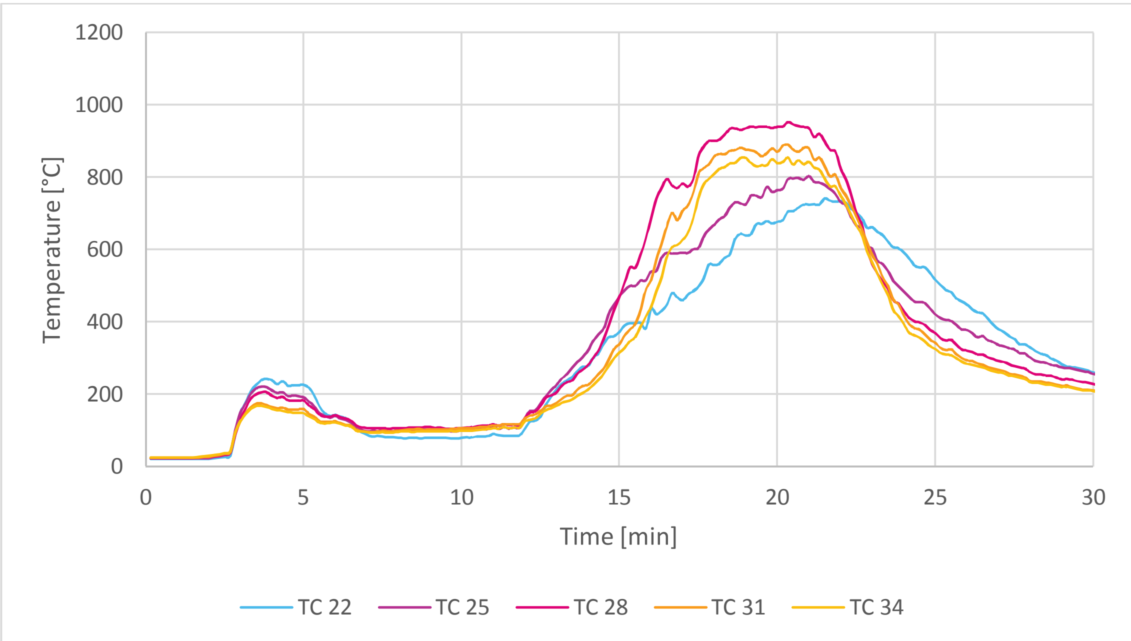


Figure E141 – Temperatures measured on the cavity central axis for S15

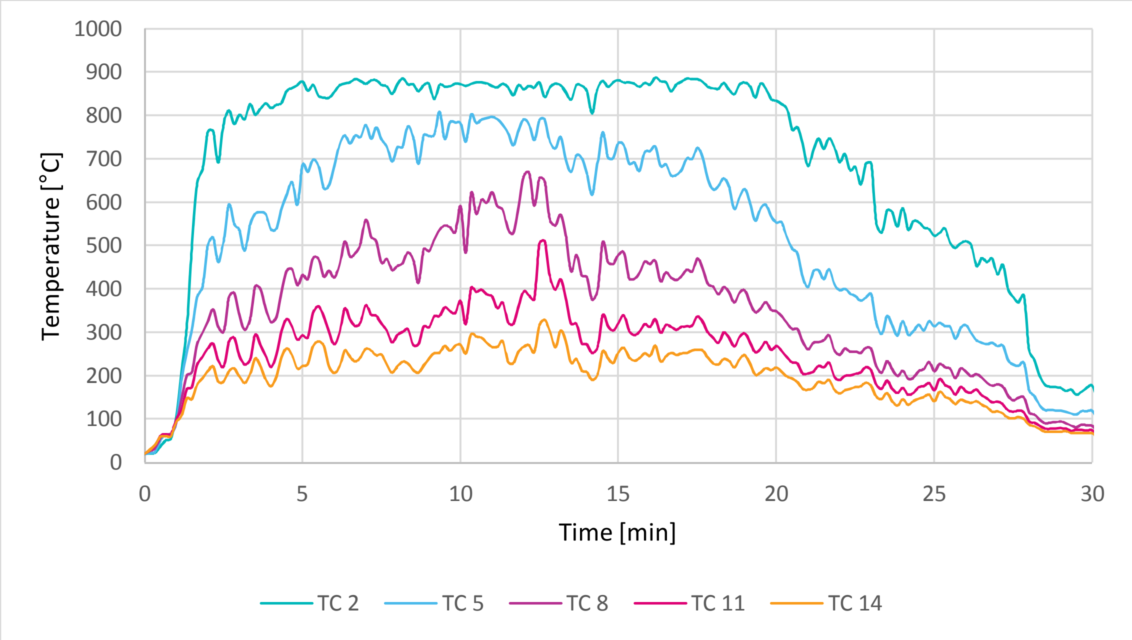


Figure E142 – Temperatures measured on the external central axis for S16

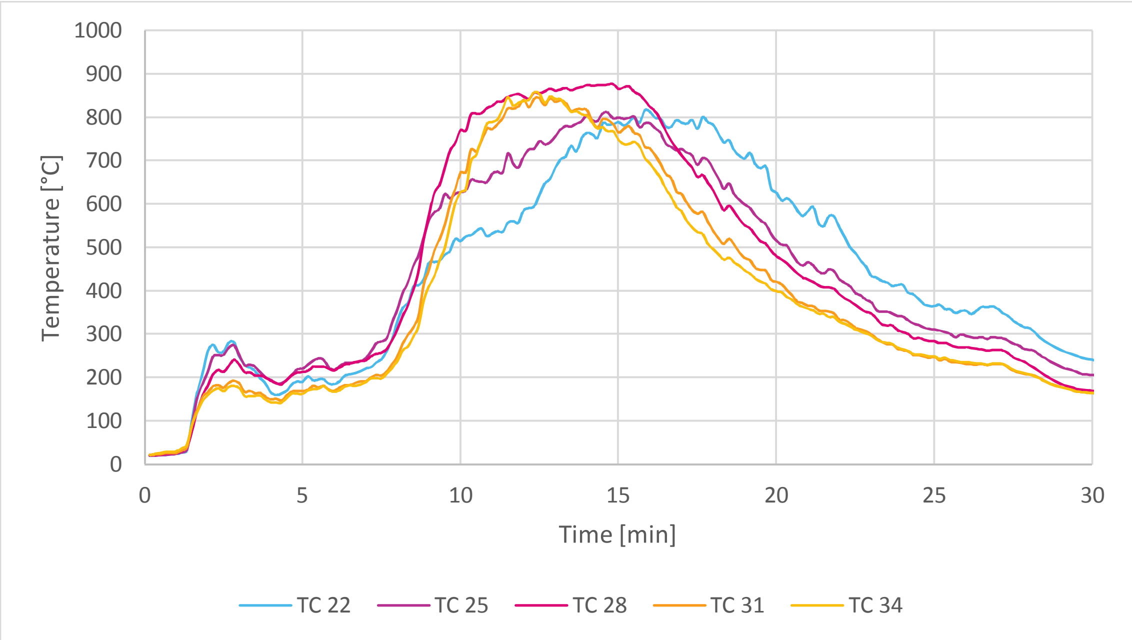


Figure E143 – Temperatures measured on the cavity central axis for S16

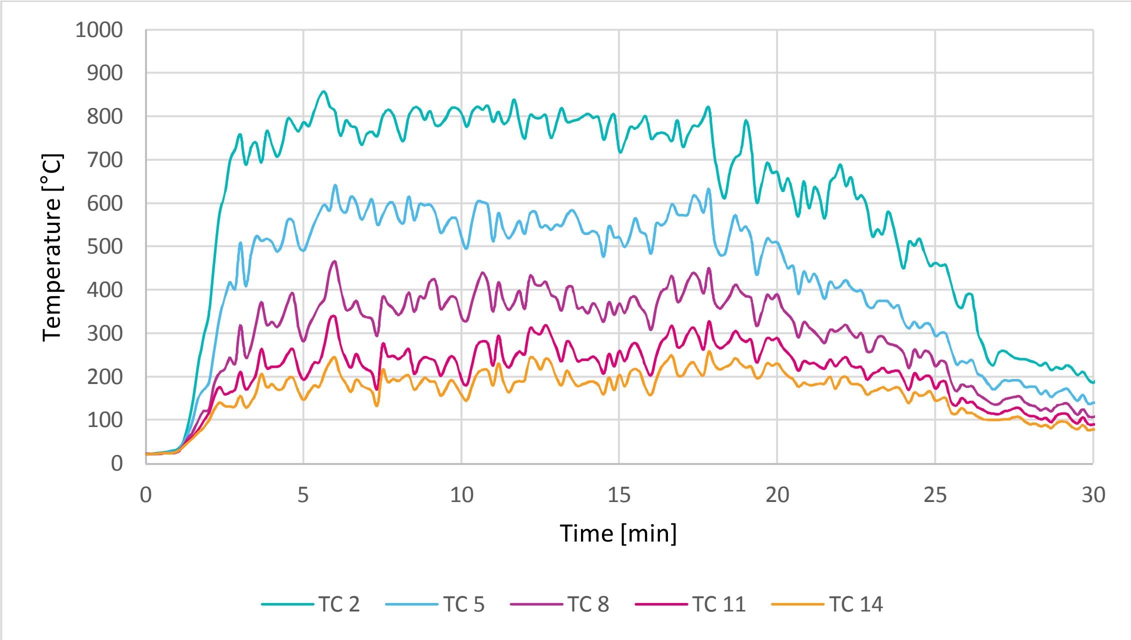


Figure E144 – Temperatures measured on the external central axis for S17

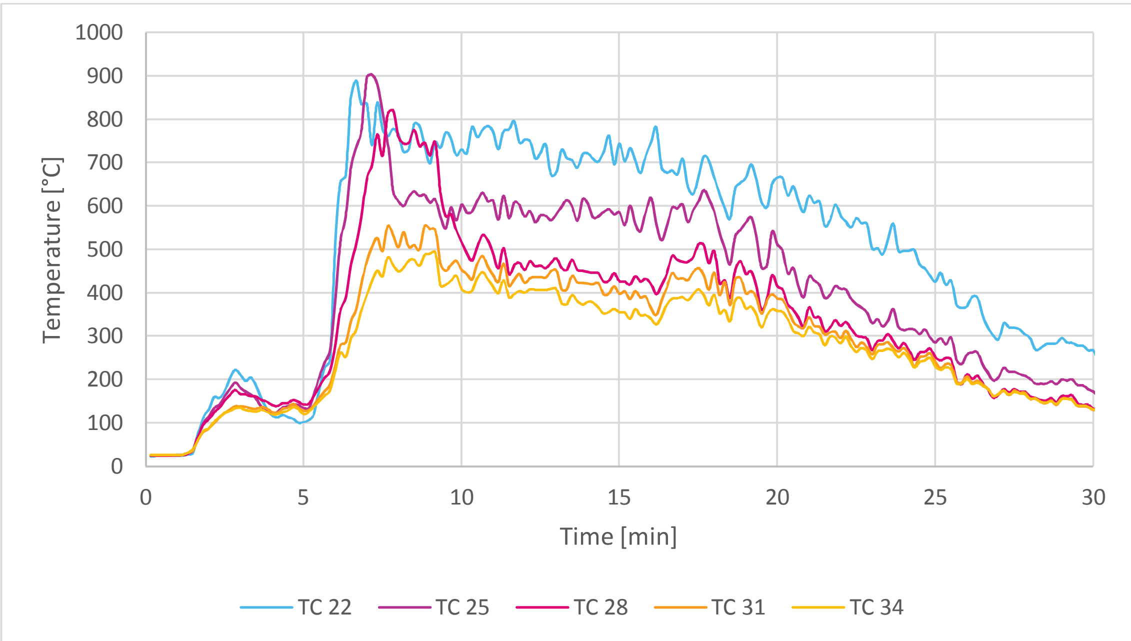


Figure E145 – Temperatures measured on the cavity central axis for S17

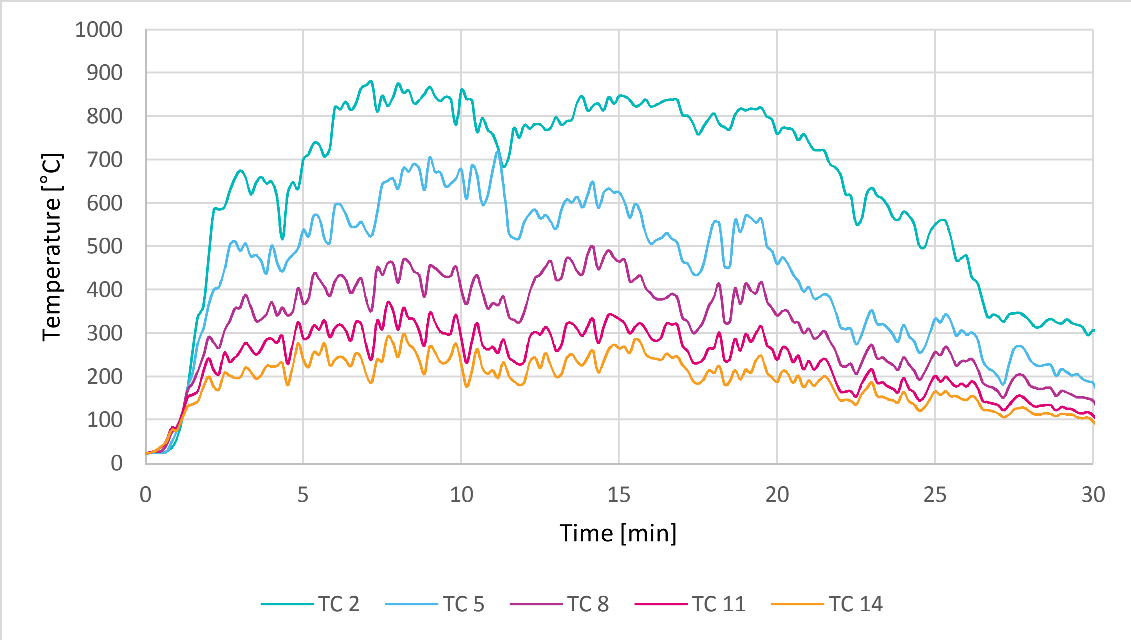


Figure E146 – Temperatures measured on the external central axis for S18

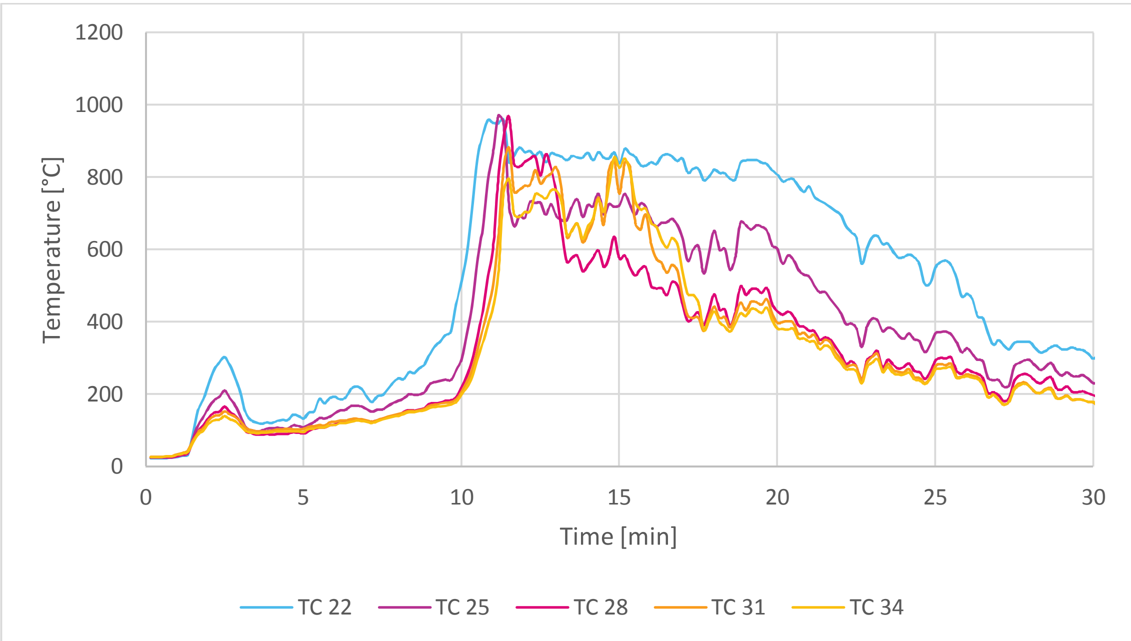


Figure E147 – Temperatures measured on the cavity central axis for S18

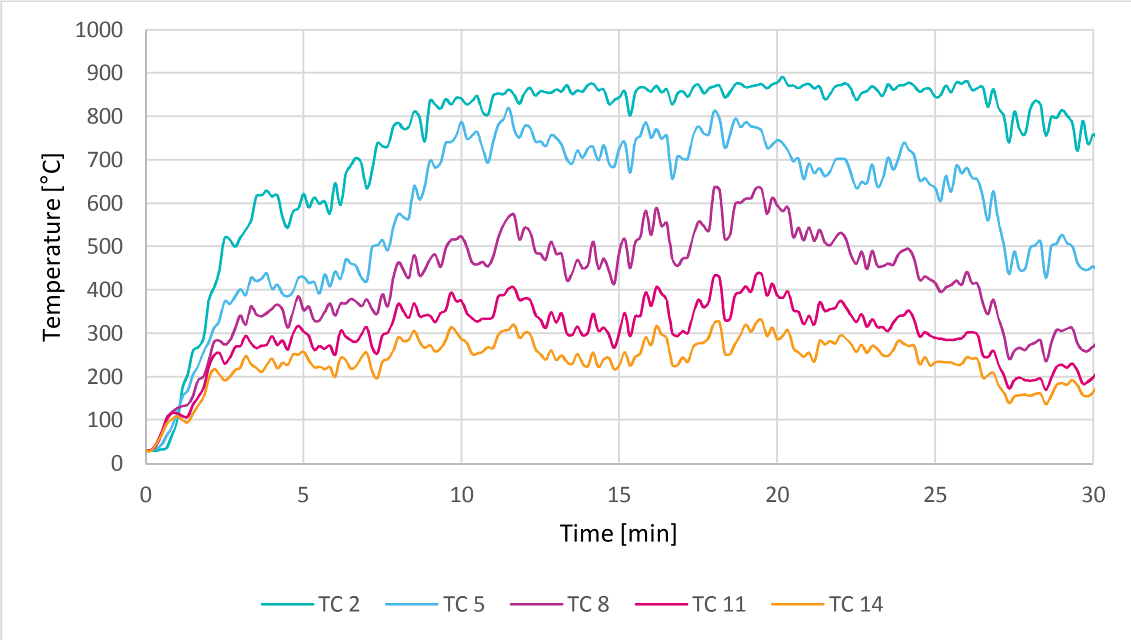


Figure E148 – Temperatures measured on the external central axis for S19

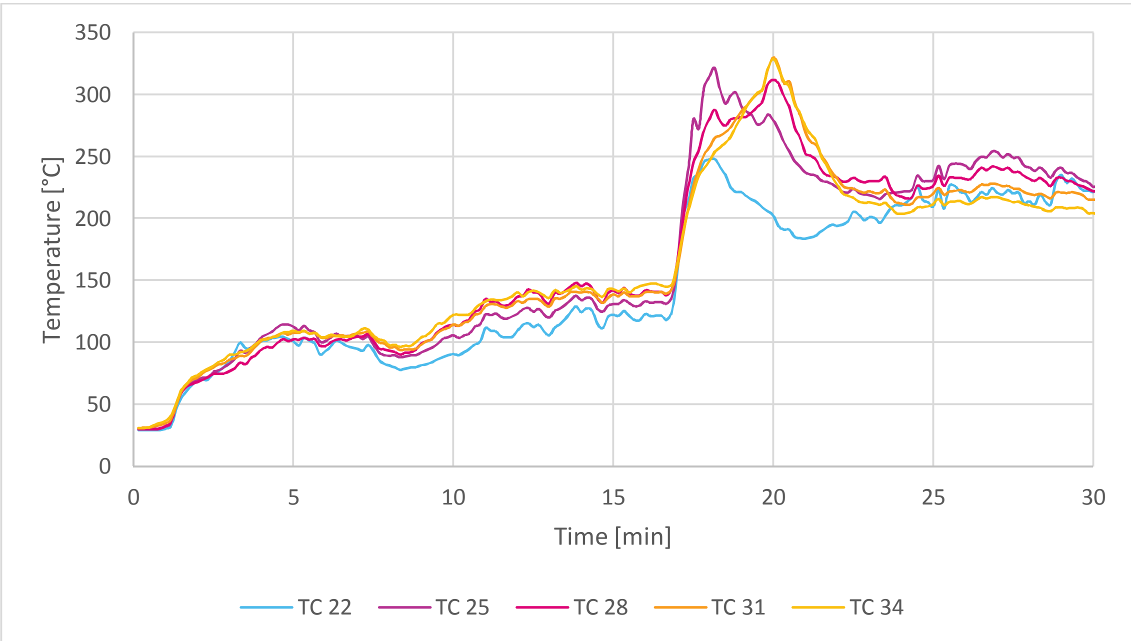


Figure E149 – Temperatures measured on the cavity central axis for S19

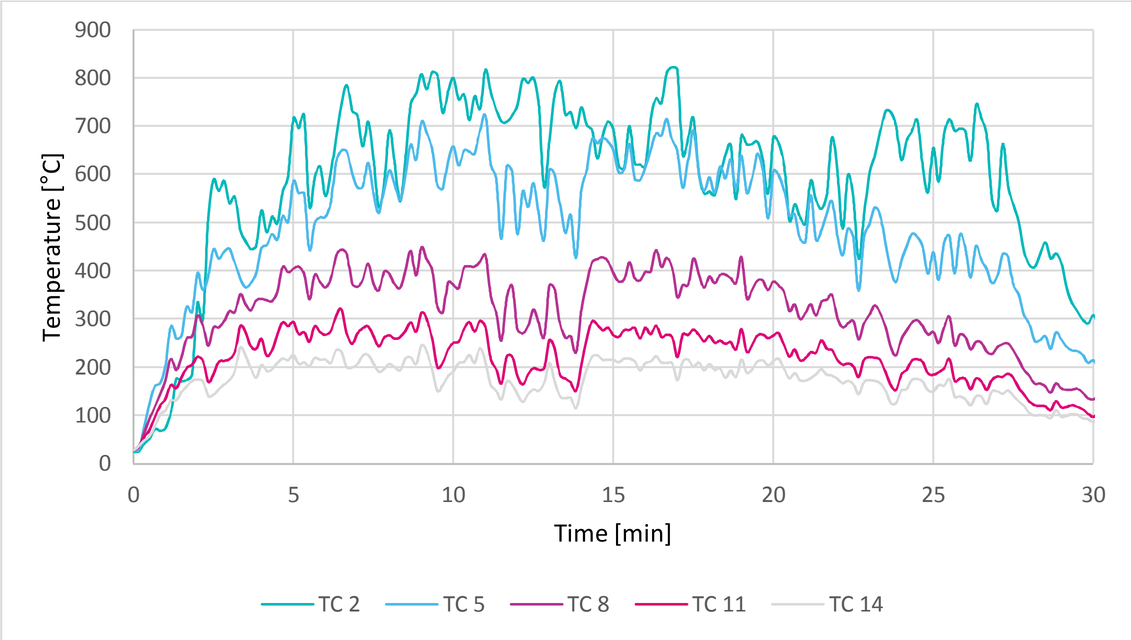


Figure E150 – Temperatures measured on the external central axis for S20

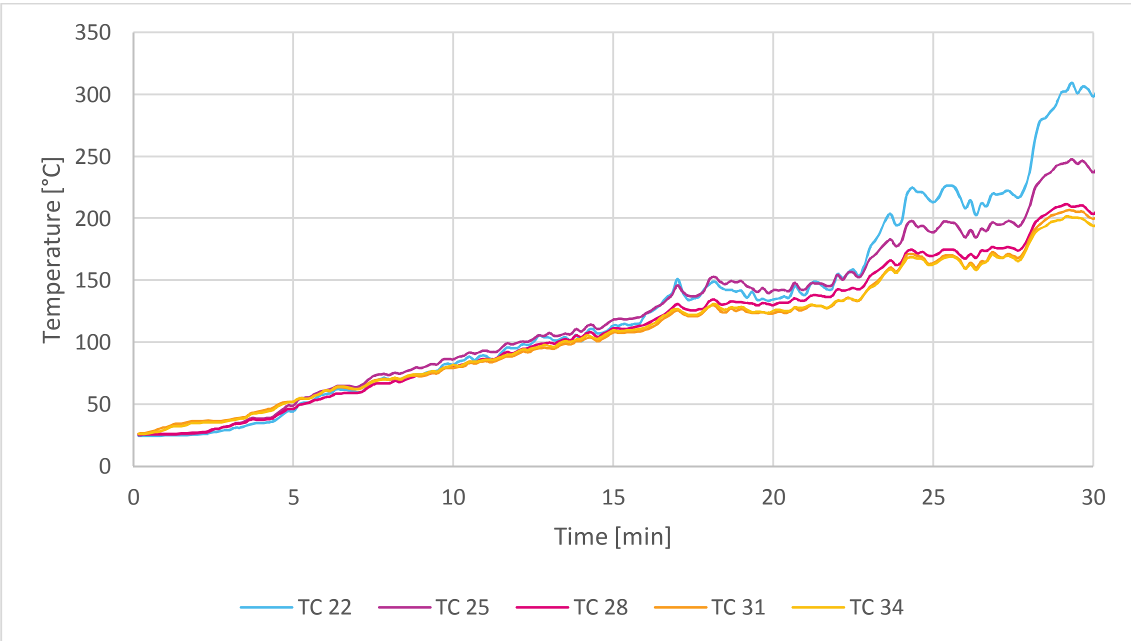


Figure E151 – Temperatures measured on the cavity central axis for S20

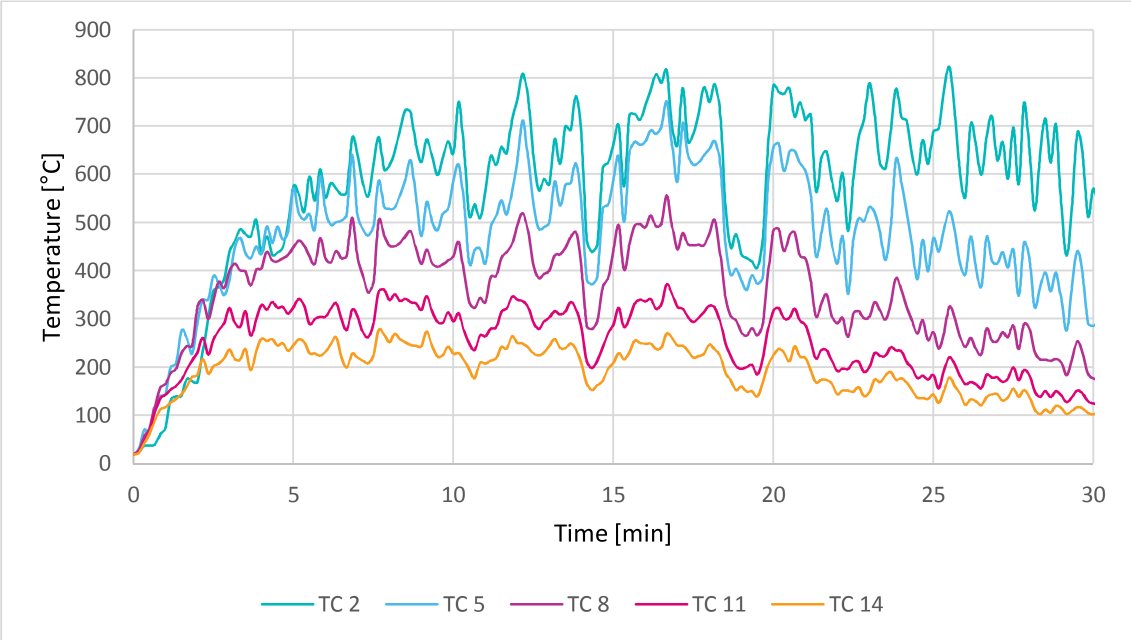


Figure E152 – Temperatures measured on the external central axis for S21

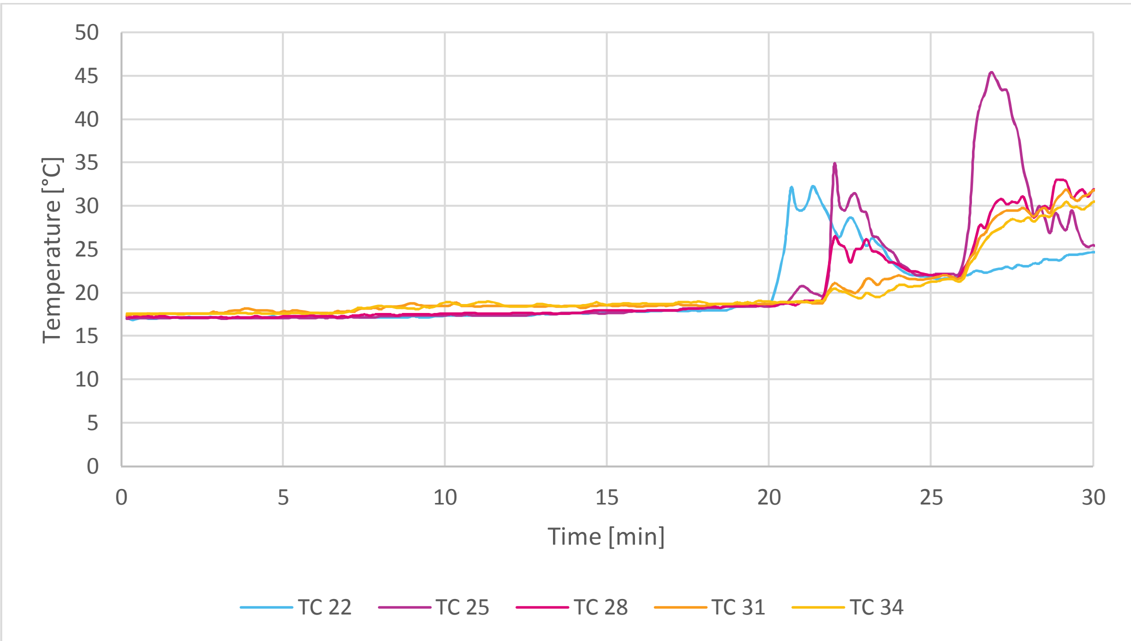


Figure E153 – Temperatures measured on the cavity central axis for S21

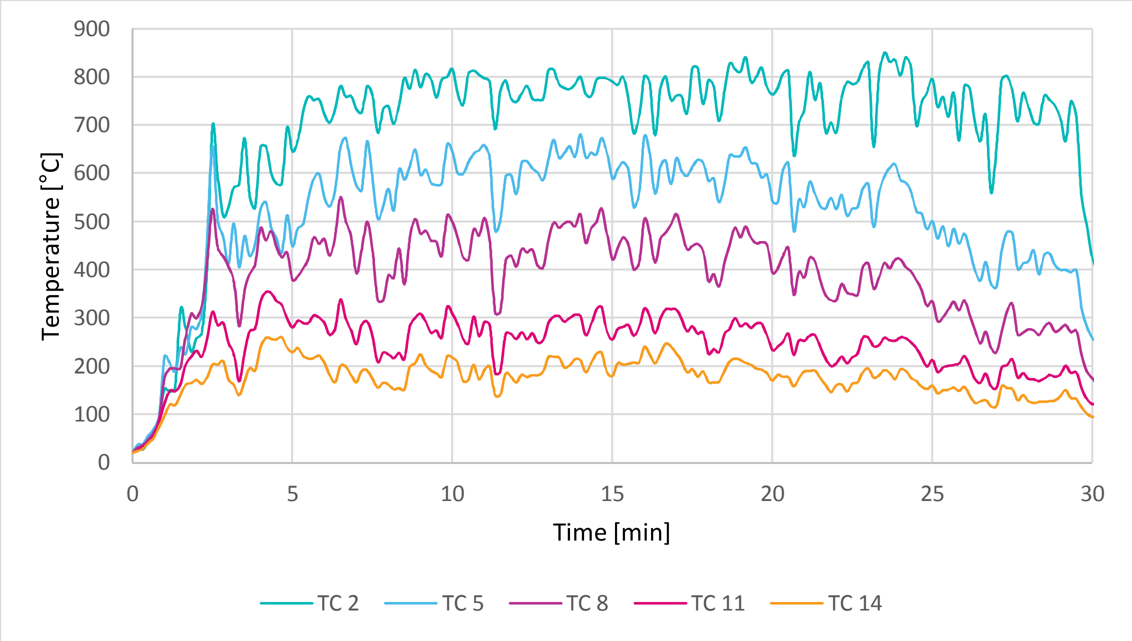


Figure E154 – Temperatures measured on the external central axis for S22

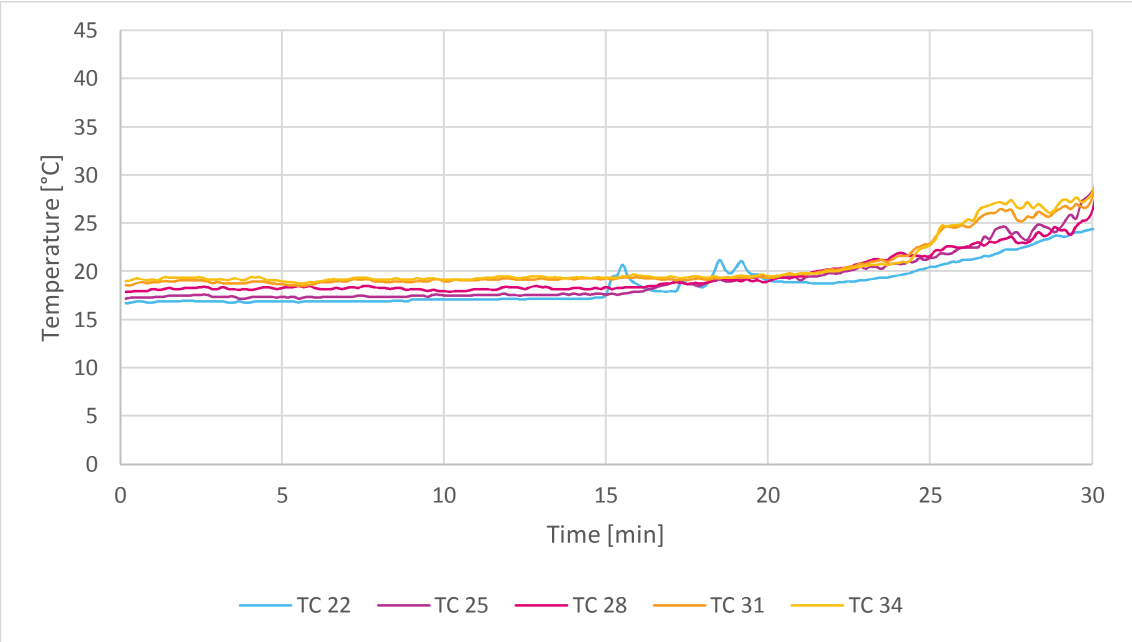


Figure E155 – Temperatures measured on the cavity central axis for S22

Report Ends