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Ministry of Housing, Communities and Local Government Final Research Report

Fire Performance of Cladding Materials Research – Appendix G Supplementary experimental work

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BRE Global Ltd
Watford, Herts
WD25 9XX

Customer Services 0333 321 8811

From outside the UK:
T + 44 (0) 1923 664000
F + 44 (0) 1923 664010
E enquiries@bre.co.uk
www.bre.co.uk

Prepared for:
Ministry of Housing, Communities and Local Government
Technical Policy Division
2 Marsham Street
Westminster
London
SW1P 4DF

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G1 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 relates to additional work requested by MHCLG (Additional Task). It contains a description of the supplementary experimental fires and the results, together with analysis and assessment of the results.

G1.1 Original (main) experimental programme

Table G1 summarises all the samples included in the original (main) experimental programme. The samples are identified generically. The manufacturer's declared reaction to fire (RTF) performance is included for reference. No information is provided on specific products or manufacturers. The detailed results are included in Appendix E.

Table G1 – Original (main) 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

G2 Supplementary experimental programme

Details of the experimental methodology and the calibration exercise are included in Appendix C and Appendix D, respectively. The supplementary fire experiments were conducted in accordance with the same methodology.

G2.1 Experimental matrix for the supplementary fires

Table G2 summarises all the samples included in the supplementary experimental programme. The samples are identified generically. No information is provided on specific products or manufacturers.

Table G2 – Supplementary experimental programme

Sample ref.	Description	Manufacturer's stated RTF performance
S23	High pressure laminate (HPL) panels 6 mm thick	D-s2, d0 [1]
S24	High pressure laminate (HPL) panels 10 mm thick	C-s2, d0 [1]
S25	High pressure laminate (HPL) panels 6 mm thick	C-s1, d0 [2]
S26	High pressure laminate (HPL) panels 10 mm thick	C-s1, d0 [2]
S27	Cedar wood cladding 19 mm thick	No classification declared
S28	Cedar wood cladding 19 mm thick	No classification declared

As shown in Table G2, six additional experimental fires were conducted for untreated timber and standard (non FR) grade HPLs. Two separate sources of the standard (non FR) grade HPL samples were procured for this supplementary work to increase the range of types of HPL samples from different manufacturers. The specification sought through procurement from the first source was standard (non FR) exterior grade HPL with thicknesses of 6mm and 10mm and a manufacturer's declared reaction to fire performance of class D-s2, d0[1]; the specification sought through procurement from the second source was standard (non FR) interior grade HPL with thicknesses of 6mm and 10mm and a declared reaction to fire performance of class C- s1, d0. In the experimental programme, the samples were subject to identical conditions in terms of the overall geometry and the location of the ignition source.

A summary of the construction details for the samples such as positions of the vertical and horizontal joints, size of the cavity and the spacing of the fixings is presented in Table G3. The precise location of the vertical joint was dependent on the width of the panel as supplied by the manufacturer or distributer.

Notes: -

1. According to the manufacturer, these HPL panels are marketed as class D standard (non FR) grade suitable for external use. Examination of the classification report supplied by the manufacturer shows that the reaction to fire classification D – s2, d0 is the worst performance achieved from testing and classifying a range of different types of standard exterior grade HPL panels when fixed to timber battens. After further investigation it was established that the 6mm thick panel achieves

a reaction to fire classification D – s2, d0 (Note: the parameters used for determining the classification indicate that the total heat release rate measured in the BS EN 13823 test method exceeds the class C limit by 4%) and is of a different type from the 10mm thick panel which achieves a reaction to fire classification C – s2, d0.

2. These specific HPL panels were included in this experimental research to provide an increased range of reaction to fire performances for comparative purposes. However, it should be noted that S25 and S26 were classified in accordance with the product standard EN 438 ("High pressure decorative laminates (HPL) sheets based on thermosetting resins (usually called laminates)") as compact laminates of standard grade suitable for moderate and heavy use – they were not exterior grade panels.

Table G3 – Construction details for the additional samples

<table>
<tr><th>Sample ref.</th><th>Thickness (mm)</th><th>Vertical joint (measured from centreline) (m)</th><th>Horizontal joint (measured from ground level) (m)</th><th>Cavity (mm)</th><th>Fixing spacing (mm)</th></tr>
<tr><td>S23</td><td>6</td><td>0.5</td><td>2</td><td rowspan="6">50</td><td rowspan="4">300 (vertical)
400 (horizontal)</td></tr>
<tr><td>S24</td><td>10</td><td>0.5</td><td>2</td></tr>
<tr><td>S25</td><td>6</td><td>0</td><td>2</td></tr>
<tr><td>S26</td><td>10</td><td>0</td><td>2</td></tr>
<tr><td>S27</td><td>19</td><td>0.25</td><td>N/A</td><td rowspan="2">140 (vertical)
400 (horizontal)</td></tr>
<tr><td>S28</td><td>19</td><td>0.25</td><td>N/A</td></tr>
</table>

G3 Findings

Samples S23 and S24 were sourced directly from the manufacturer. Samples S25 and S26 were sourced from a commercial distributer and the timber cladding material (S27 and S28) was sourced from a commercial timber merchant.

G3.1 Sample S23 6 mm high pressure laminate (HPL) panels (Class D)

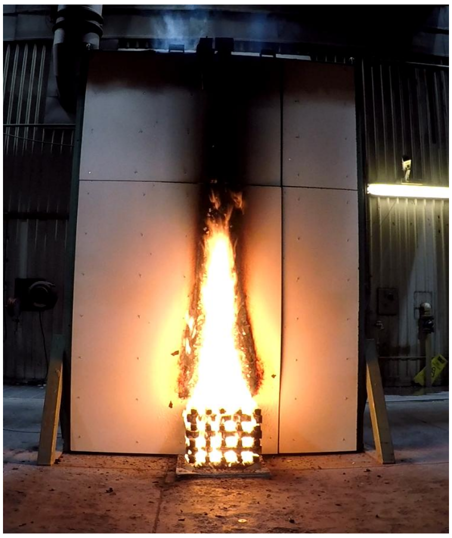
The sample for the first additional experiment (twenty third sample) consisted of high pressure laminate (HPL) panels of natural fibres impregnated with phenolic resin and coated on the outside with acrylic resin. The 6 mm thick HPL panels were cut to size and installed onto 100 mm wide aluminium T-shaped 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 G1 shows the material installed on the rig. A cavity of 50 mm was provided between the HPL panels and the non-combustible support of the experimental rig (calcium silicate board). One vertical joint and one horizontal joint were provided within the installation shown in Figure G1.

Figure G1 – Sample S23 HPL panels installed on the rig

Figure G2 shows photographs during the fire experiment at specified times.

5 minutes from ignition

10 minutes from ignition



20 minutes from ignition

25 minutes from ignition

Figure G2 – 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 impingement.

The fire breached the cavity after approximately 11 minutes of thermal exposure based on both measured values and visual observation. Localised 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 flame impingement. The surface flaming self-extinguished without direct flame exposure.

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

Figure G3 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 is approximately 300 kW. Figure G4 shows the measured value of heat flux on the centre line of the rig 3 m from the ground.

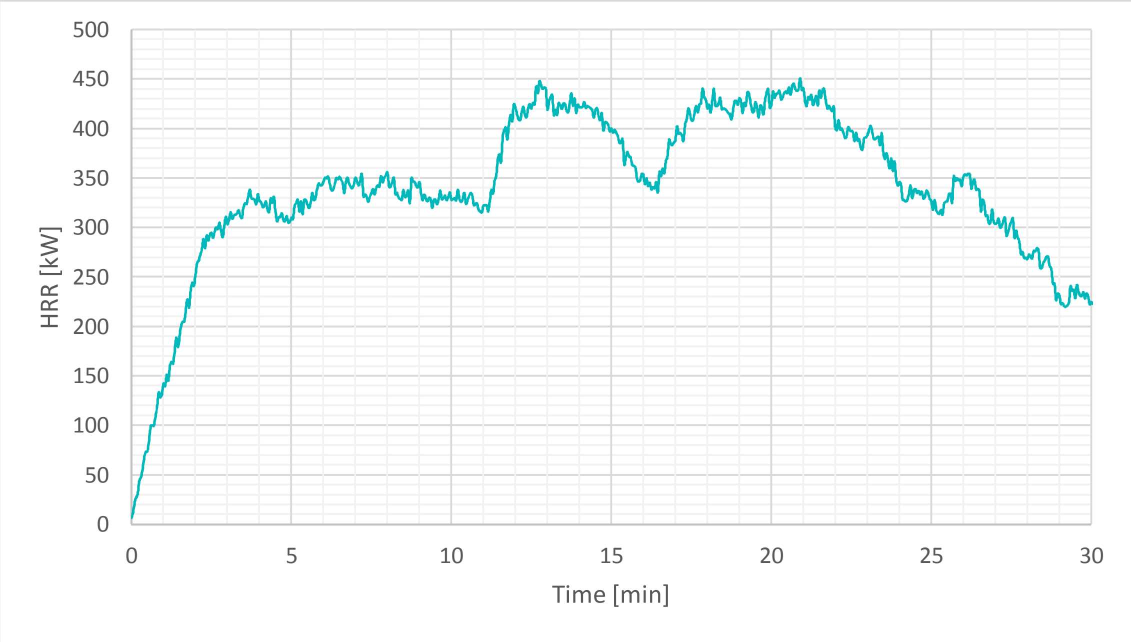


Figure G3 – Heat release rate measured during the fire, including the fire source

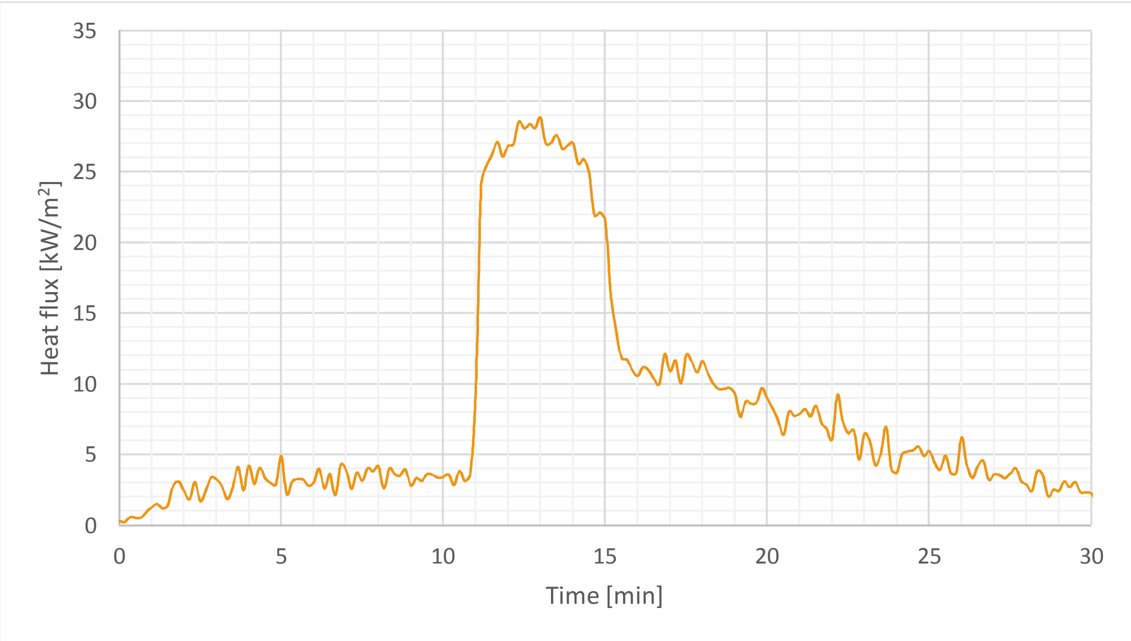


Figure G4 – Heat flux recorded during the fire at 3.0 m height

Table G4 shows the maximum external temperature, the maximum cavity temperature, maximum temperature at 3.0 m, time to peak heat release rate (HRR), peak HRR and total heat release (THR) over a period of 30 minutes.

Table G4 – 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	928	282	21	451	29	615

A summary of the visual observations is presented in Table G5.

Table G5 – Visual observations during the experiment

Burning droplets	Burn through	Time to burn through [min]	Area consumed [m^2]	Vertical flame spread	Horizontal flame spread
No	Yes	≈11	≈0.69	Localised	Localised

Figure G5 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 charred parts of the panels was observed after the fire. The panels became brittle after exposure to fire. Localised cracks could be observed in the area of direct heating on the panels.

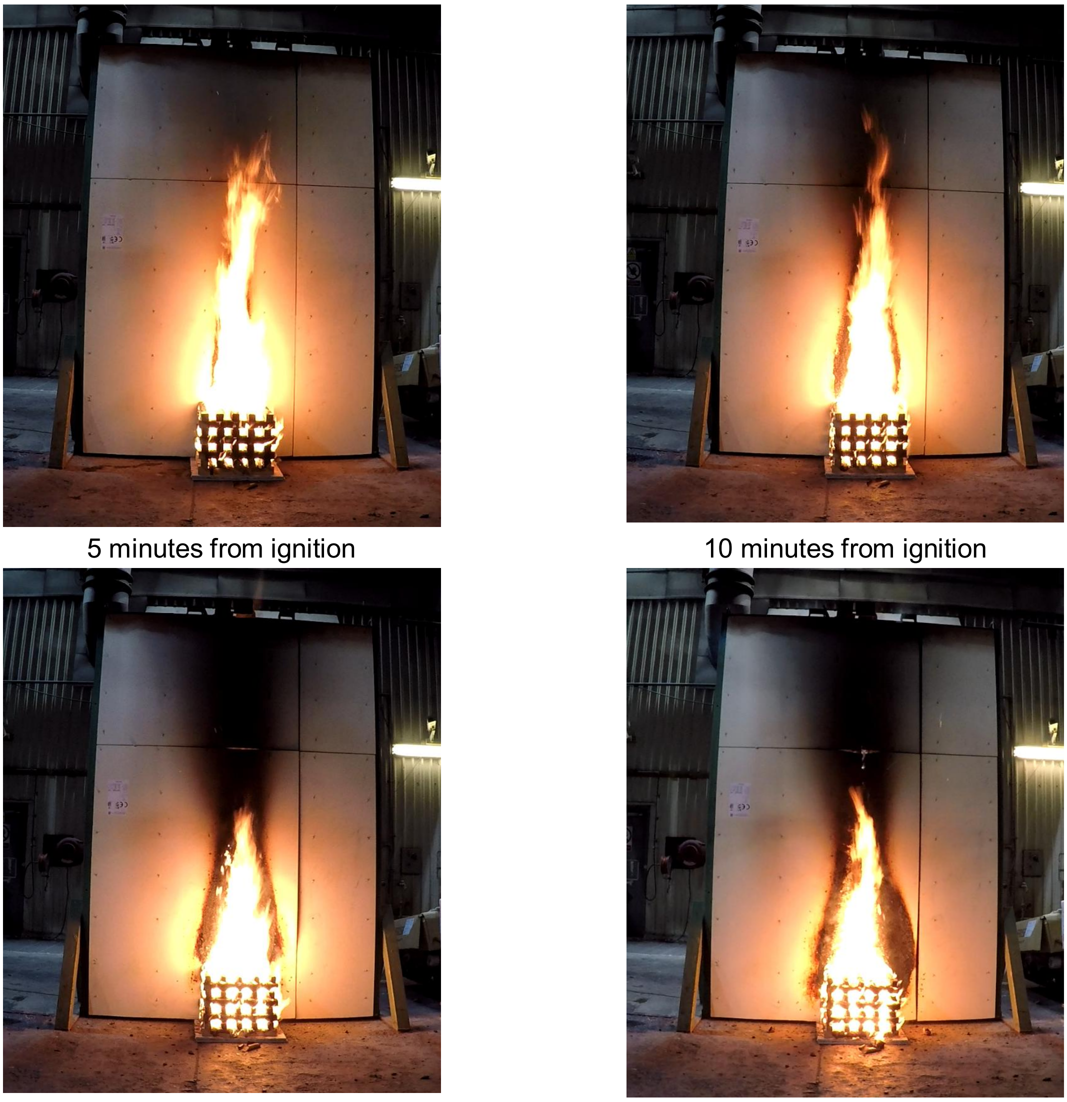
Figure G5 – Post fire observations

G3.2 Sample S24 10 mm high pressure laminate (HPL) panels (Class C)

The sample for the second additional experiment (twenty fourth sample) consisted of high pressure laminate (HPL) panels of natural fibres impregnated with phenolic resin and coated on the outside with acrylic resin. 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 G6 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 were provided within the installation shown in Figure G6.

Figure G6 – Sample S24 HPL panels installed on the rig

Figure G7 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 G7 – 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. Due to the restraint and thermal expansion the central panel tended to bend towards the fire source.

The fire breached the cavity after approximately 17 minutes of thermal exposure based on both measured values and visual observation. Localised cracks were observed on the surface of the panels. Detachment of small parts of the panels in the area of direct flame impingement and on 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 G8 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 is approximately 300 kW.

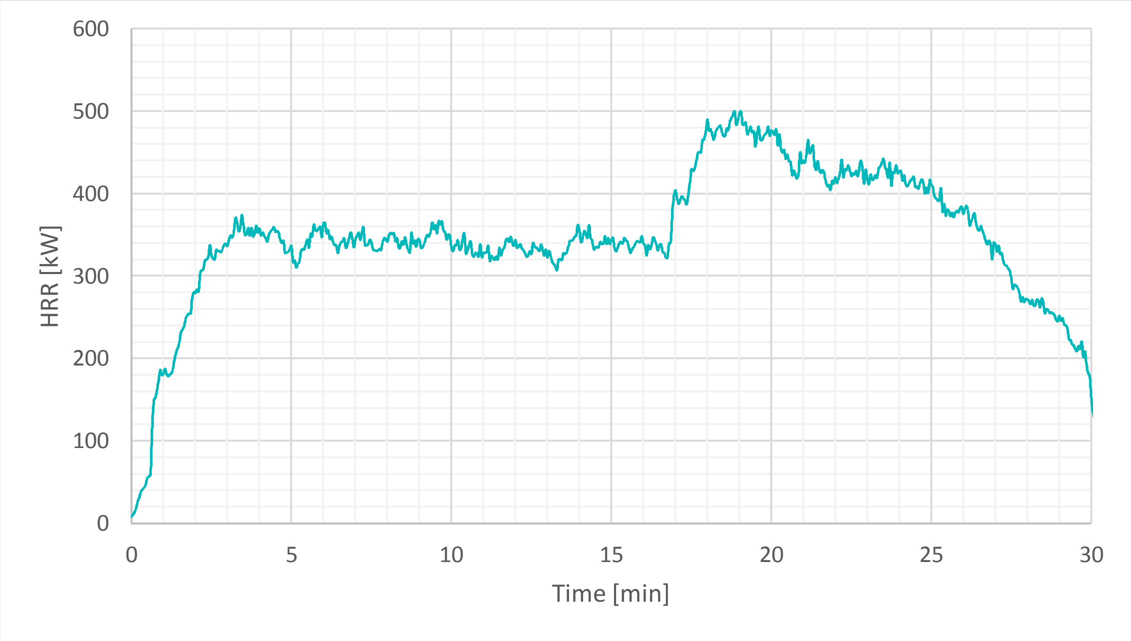


Figure G8 – Heat release rate measured during the fire, including the source

Figure G9 shows the heat flux on the centre line recorded during the fire at a height of 3.0 m from the ground.

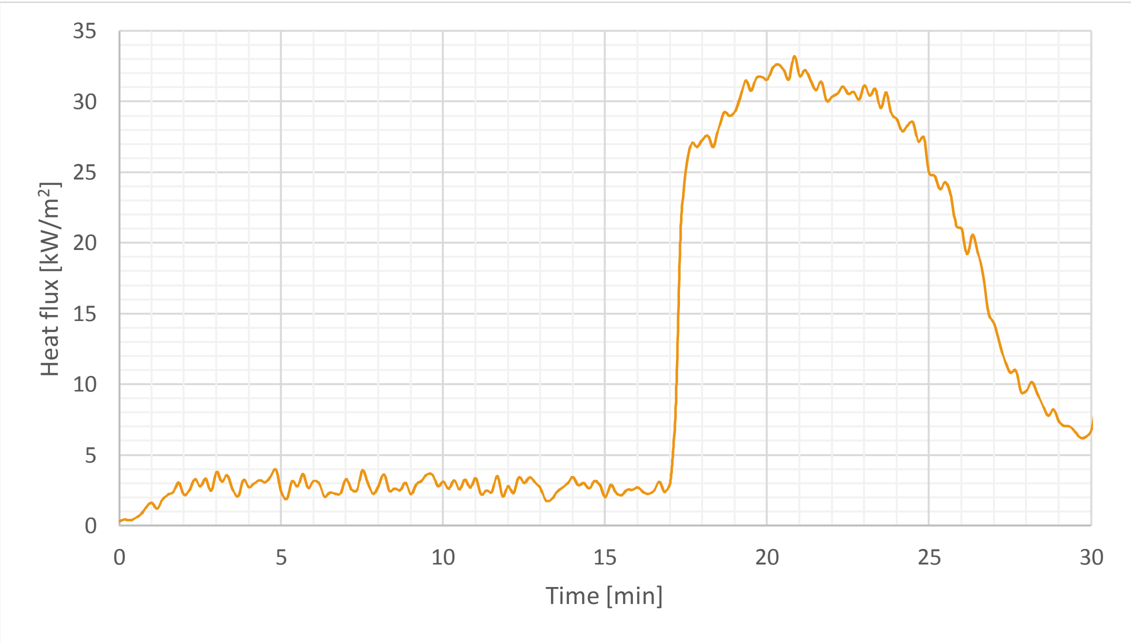


Figure G9 – Heat flux recorded during the fire at 3.0 m height

Table G6 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 at 3.0 m and total heat release (THR) over a period of 30 minutes.

Table G6 – 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]
876	954	267	19	500	33	627

A summary of the visual observations is presented in Table G7.

Table G7 – Visual observations during the experiment

Burning droplets	Burn through	Time to burn through [min]	Area consumed [m^2]	Vertical flame spread	Horizontal flame spread
No	Yes	≈17	≈0.47	Localised	Localised

Figure G10 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 charred parts of the panels was observed after the fire. The panels became brittle after exposure to fire. Localised cracks could be observed in the area of direct heating on the panels.

Figure G10 – Post fire observations

G3.3 Sample S25 6 mm high pressure laminate (HPL) panels (Class C)

The sample for the third additional experiment (twenty fifth sample) consisted of high pressure laminate (HPL) with a wood fibre core, bonded with thermosetting resins at high pressures and temperature. The classification report provided by the supplier states that the product is intended for internal wall and ceiling finishes. 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 G11 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 were provided within the installation as shown in Figure G11.

Figure G11 – Sample S25 HPL panels installed on the rig

Figure G12 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 G12 – 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 4 minutes of thermal exposure the fire breached the cavity through the vertical joint present. Localised cracks were observed on the surface of the panels. Detachment of small parts of the panels in the area of direct flame impingement and on the central axis was observed during the experiment.

Sustained flaming was observed on the surface of the panels in the fire exposed area. Horizontal flame spread was observed on the external surface of the panels. After 15 minutes of exposure the fire spread inside the cavity beyond the aluminium rails positioned next to the centreline. At the end of the experiment the horizontal fire spread observed was relatively symmetrical, approximatively 600 mm from the centreline. The surface burning self-extinguished without direct flame exposure. Vertical and horizontal flame spread on the surface of the HPL panels was observed as shown in the figure above.

Figure G13 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 is approximately 300 kW.

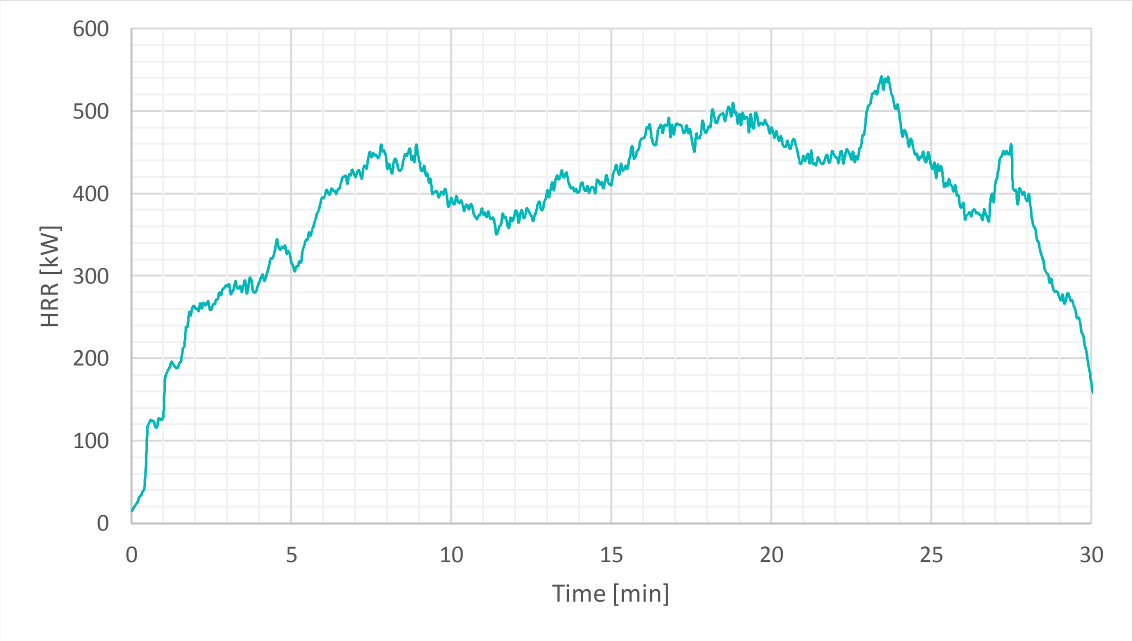


Figure G13 – Heat release rate measured during the fire, including the source

Figure G14 shows the heat flux on the centre line recorded during the fire at a height of 3.0 m from the ground.

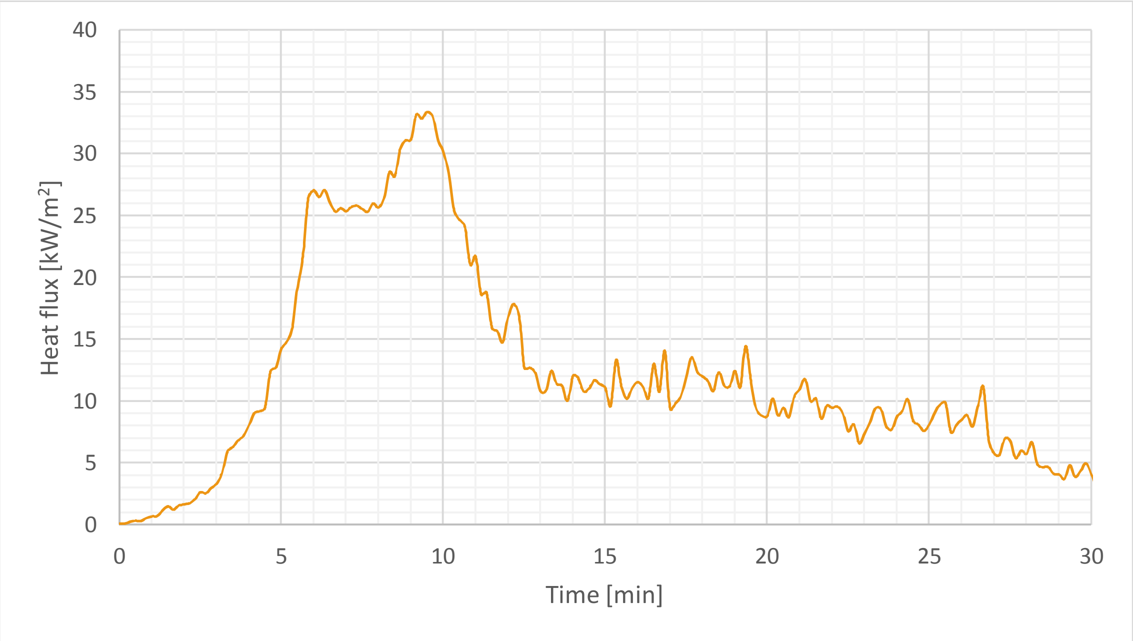


Figure G14 – Heat flux recorded during the fire at 3.0 m height

Table G8 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 at 3.0 m and total heat release (THR) over a period of 30 minutes.

Table G8 – 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]
914	989	366	23	542	33	699

A summary of the visual observations is presented in Table G9.

Table G9 – Visual observations during the experiment

Burning droplets	Burn through	Time to burn through [min]	Area consumed [m^2]	Vertical flame spread	Horizontal flame spread
No	Yes, through vertical joint	≈4	≈3.1	Localised	Localised

Figure G15 shows the sample after the fire. The HPL panels were consumed over an area of approximately 3.1 m^2. Discoloration and distortion could be observed on the remaining surface of the panels. Detachment of charred parts of the panels could be observed after the fire. The panels became brittle after exposure to fire. Localised cracks could be observed in the area of direct heating on the panels. At the end of the 30 minutes period the crib was extinguished, and some localized flaming continued on the surface of the panel for a short duration.

Figure G15 – Post fire observations

G3.4 Sample S26 10 mm high pressure laminate (HPL) panels (Class C)

The sample for the fourth additional experiment (twenty sixth sample) consisted of high pressure laminate (HPL) with a wood fibre core, bonded with thermosetting resins at high pressures and temperature. The classification report provided by the manufacturer states that the product is intended for internal wall and ceiling finishes. 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 G16 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 were provided within the installation shown in Figure G16.

Figure G16 – Sample S26 HPL panels installed on the rig

Figure G17 shows photographs during the fire exposure at specified times.


5 minutes from ignition


10 minutes from ignition


20 minutes from ignition

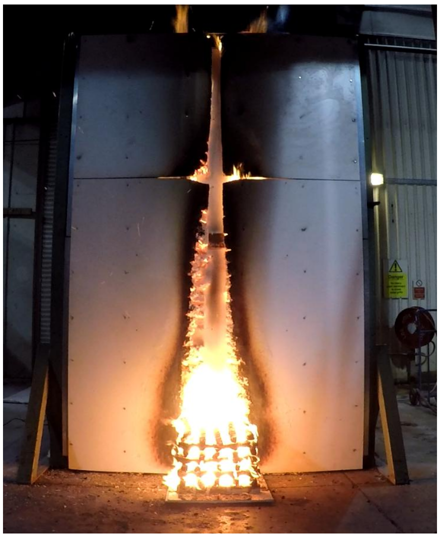

25 minutes from ignition

Figure G17 – 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 5 minutes of thermal exposure the fire breached the cavity through the vertical joint present. Localised 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.

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. After 23 minutes of exposure, the fire spread inside the cavity beyond the aluminium rails positioned next to the centreline. The surface burning self-extinguished. Vertical and horizontal flame spread on the surface of the HPL panels was observed as shown in the figure above.

Figure G18 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 is approximately 300 kW.

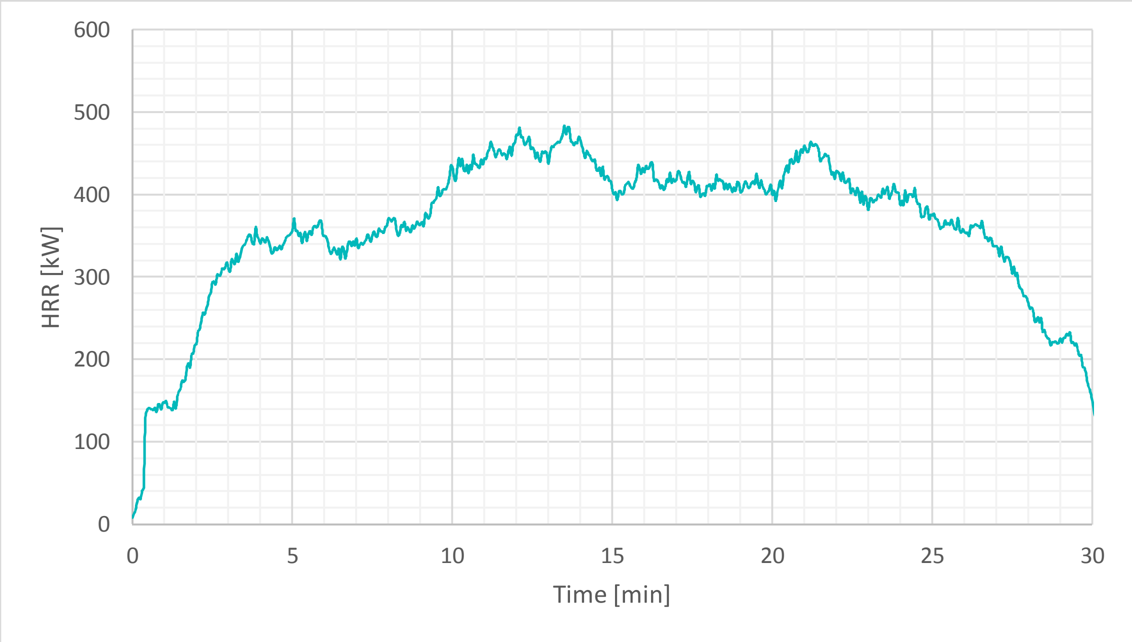


Figure G18 – Heat release rate measured during the fire, including the source

Figure G19 shows the heat flux on the centre line recorded during the fire at a height of 3.0 m from the ground and the maximum recording capacity of the instrument.

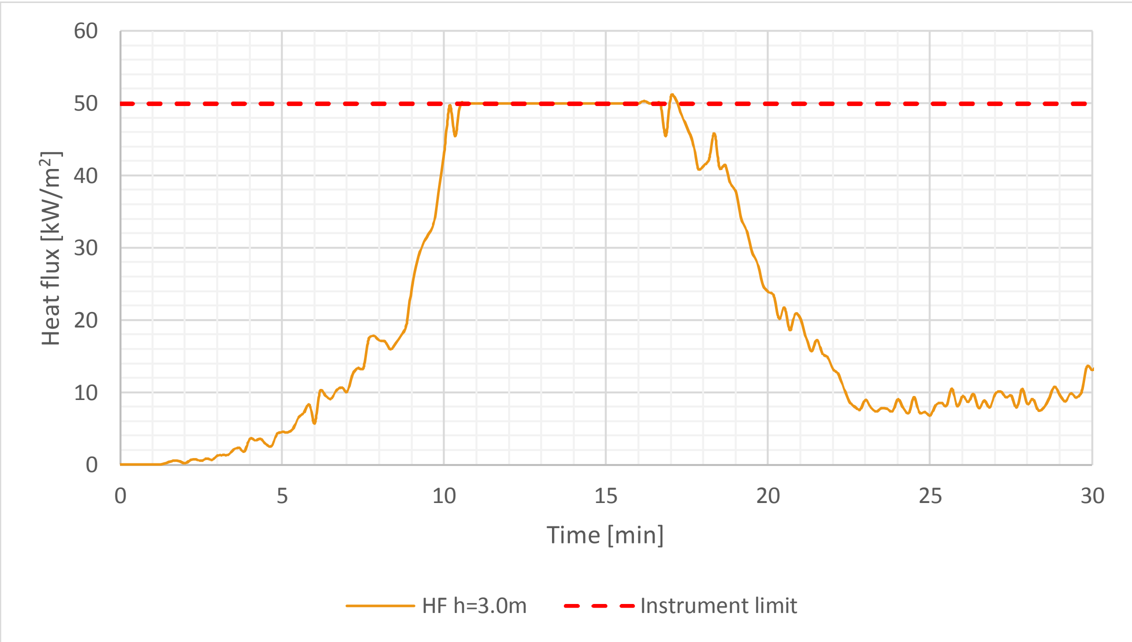


Figure G19 – Heat flux recorded during the fire at 3.0 m height

Table G10 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 at 3.0 m and total heat release (THR) over a period of 30 minutes.

Table G10 – 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]
887	1001	324	14	484	51	653

A summary of the visual observations is presented in Table G11.

Table G11 – Visual observations during the experiment

Burning droplets	Burn through	Time to burn through [min]	Area consumed [m^2]	Vertical flame spread	Horizontal flame spread
No	Yes, through vertical joint	≈5	≈1.4	Localised	Localised

Figure G20 shows the sample after the fire. The HPL panels were consumed over an area of approximately 1.4 m^2. Discoloration and distortion could be observed on the remaining surface of the panels. Detachment of charred 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. At the end of the 30 minutes period the crib was extinguished, and flaming in the cavity continued for a short duration.

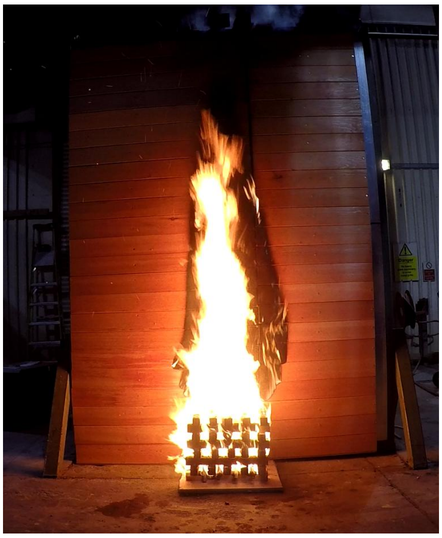
Figure G20 – Post fire observations

G3.5 Sample S27 19 mm x 140 mm cedar wood cladding

The sample for the fifth additional experiment (twenty seventh sample) consisted of untreated cedar wood. The timber slats were of a tongue and groove type with a thickness of 19 mm, a width of 140 mm and a cross sectional profile as shown in Figure G21. The density of the timber was 355 kg/m^3 as measured. The timber slats were cut to size (0.8 m and 1.3 m lengths) 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 140 mm vertical centres. Figure G21 shows the material installed on the rig and the profile of the tongue and groove joint. A cavity of 50 mm was provided between the timber cladding and the incombustible support of the experimental rig. One vertical joint was provided within the installation shown in Figure G21. The measured moisture content of the timber cladding prior to the fire was between 13% and 15%.

Figure G21 – Sample S27 timber cladding a) installed on the rig (left) and b) cross sectional profile of tongue and groove (right)

Figure G22 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 G22 – Photographs during the fire at 5, 10, 20, and 25 minutes from ignition

After approximately 3 minutes of fire exposure, the surface of the timber cladding ignited. The average gas temperature measured in the ignition area prior to the surface burning was approximately 360°C. Once the timber cladding had charred, self-extinguishment of the burning surface occurred.

Based on both measured values and visual observation, after approximately 14 minutes of thermal exposure the fire breached the cavity. The fire spread both vertically and horizontally on the surfaces of both the cavity facing and external faces of the timber cladding. Detachment of small parts of the timber cladding in the area of direct flame impingement was observed during the experiment. After 17 minutes of fire exposure, flames were observed coming out from the vertical joint present. Sustained flaming was observed on the surface of the timber cladding in the fire exposed area. After approximately 23 minutes of exposure, the timber cladding was fully consumed in the area of direct flame impingement. Sustained flaming and smouldering was observed on the surface in the area of direct flame exposure after the fire source had been removed. Some vertical and horizontal flame spread on the surface of the timber cladding was observed. During the fire exposure no burning droplets were observed.

Figure G23 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 is approximately 300 kW.

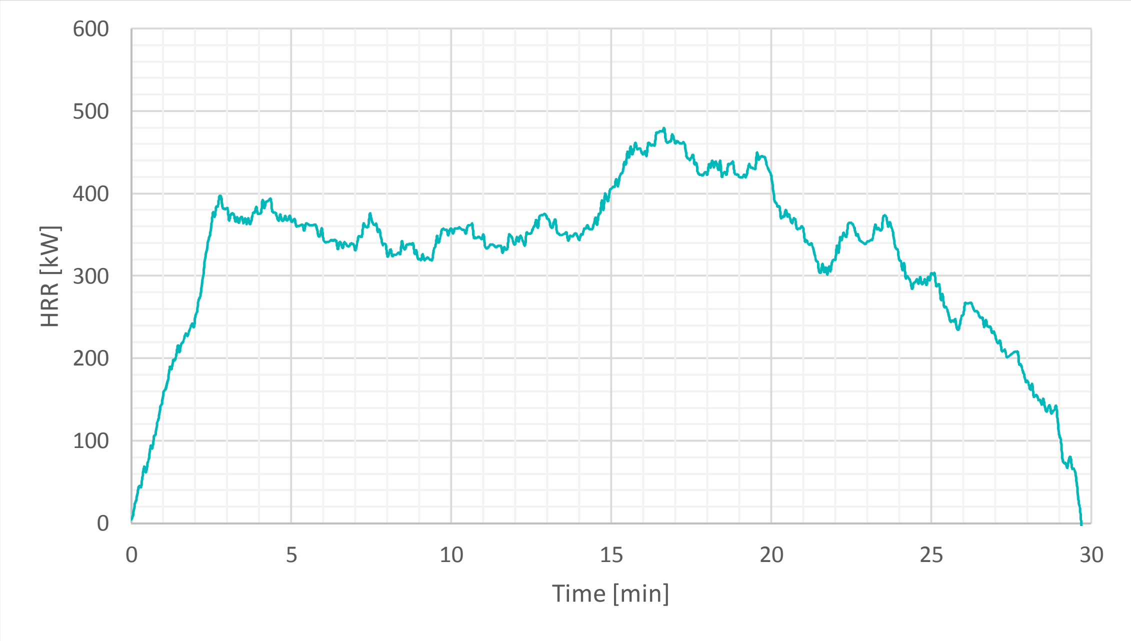


Figure G23 – Heat release rate measured during the fire, including the source

Figure G24 shows the heat flux on the centre line recorded during the fire at a height of 3.0 m from the ground and the maximum recording capacity of the instrument.

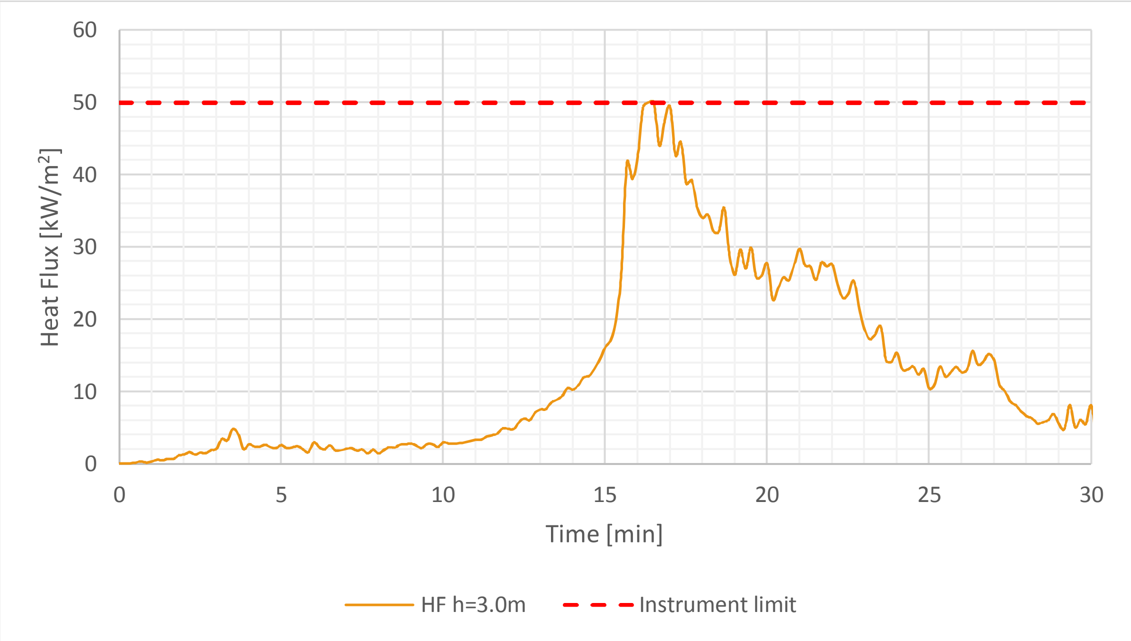


Figure G24 – Heat flux recorded during the fire at 3.0 m height

Table G12 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 at 3.0 m and total heat release (THR) over a period of 30 minutes.

Table G12 – 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]
926	882	214	17	479	50	581

A summary of the visual observations is presented in Table G13.

Table G13 – Visual observations during the experiment

Burning droplets	Burn through	Time to burn through [min]	Area consumed [m^2]	Vertical flame spread	Horizontal flame spread
No	Yes	≈14	≈1.65	Localised	Localised

Figure G25 shows the sample after the fire. The timber cladding was consumed over an area of approximately 1.65 m^2. Discoloration and charring can be observed on the remaining surface of the panels. Detachment of charred parts of the timber cladding was observed after the fire. At the end of the 30 minutes period the crib was extinguished, and some localised flaming and charring continued for a short duration.

Figure G25 – Post fire observations

G3.6 Sample S28 19 mm x 140 mm cedar wood cladding

The sample for the final additional experiment (twenty eighth sample) was a repeat of sample twenty seven and consisted of untreated cedar wood. The timber slats were of a tongue and groove type with a thickness of 19 mm, a width of 140 mm and a cross sectional profile as shown in Figure G21. The density of the timber was 355 kg/m^3 as measured. The timber slats were cut to size (0.8 m and 1.3 m lengths) 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 140 mm vertical centres. Figure G26 shows the material installed on the rig. A cavity of 50 mm was provided between the timber cladding and the incombustible support of the experimental rig. One vertical joint was provided within the installation shown in Figure G26. The measured moisture content of the timber cladding prior to the fire was between 13% and 15%.

Figure G26 – Sample S28 timber cladding installed on the rig

Figure G27 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 G27 – Photographs during the fire at 5, 10, 20, and 25 minutes from ignition

After approximately 2 minutes 50 seconds of fire exposure, the surface of the timber cladding ignited. The average gas temperature measured in the ignition area prior to the surface burning was approximately 360°C. Once the timber cladding has been charred, self-extinguishment of the burning surface occurred.

Based on both measured values and visual observation, after approximately 21 minutes of thermal exposure, the fire breached the cavity. The fire spread both vertically and horizontally on the surfaces of both the cavity facing face and the external faces of the timber cladding. Detachment of small parts of the timber cladding in the area of direct flame impingement was observed during the experiment. Sustained flaming was observed on the surface of the timber cladding in the fire exposed area. After approximately 26 minutes of exposure, the timber cladding was fully consumed in the area of direct flame impingement. Sustained flaming and smouldering were observed on the surface in the area of direct flame exposure after the fire source had been removed. Some vertical and horizontal flame spread on the surface of the timber cladding was observed. During the fire exposure no burning droplets were observed.

Figure G28 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 is approximately 300 kW.

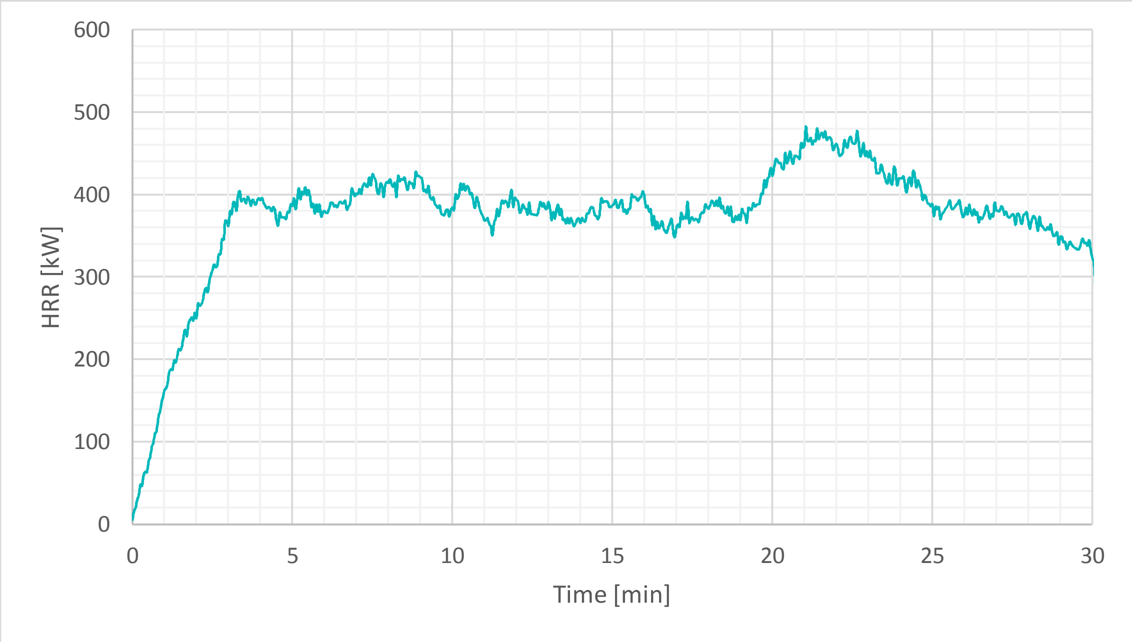


Figure G28 – Heat release rate measured during the fire, including the source

Figure G29 shows the heat flux on the centre line recorded during the fire at a height of 3.0 m from the ground.

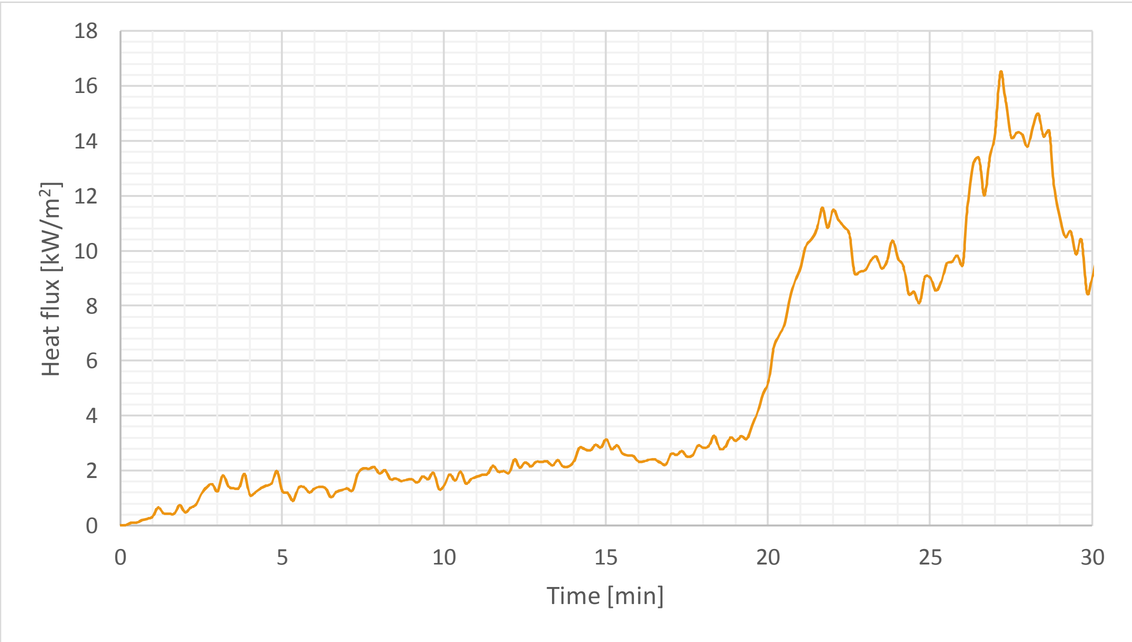


Figure G29 – Heat flux recorded during the fire at 3.0 m height

Table G14 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 at 3.0m and total heat release (THR) over a period of 30 minutes.

Table G14 – 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/m²]	THR [MJ]
915	674	153	21	483	17	674

A summary of the visual observations is presented in Table G15.

Table G15 – Visual observations during the experiment

Burning droplets	Burn through	Time to burn through [min]	Area consumed [m²]	Vertical flame spread	Horizontal flame spread
No	Yes	≈21	≈0.72	Localised	Localised

Figure G30 shows the sample after the fire. The timber cladding was consumed over an area of approximately 0.72 m^2. Discoloration and charring could be observed on the remaining surface of the panels. Detachment of charred parts of the timber cladding could be observed after the fire.

Figure G30 – Post fire observations

G4 Analysis of experimental results

The approach to analysis of performance is related to the extent to which the panels may contribute to fire growth in a realistic scenario. When considering the performance of those products included in the experimental programme, the contribution needs to be viewed alongside:

- The base level of heat release provided by the ignition source.
- The measured/observed performance for a product/material representing an unacceptable level of risk.

The base level provided by the crib ignition source against a non-combustible backing on the experimental rig was measured during the calibration process and is summarised in Table G16.

Table G16 – Base level results for crib ignition source and non-combustible board

Parameter	Value
Peak heat release rate (kW)	300
Time to peak heat release (min)	6
Total heat release (MJ)	450
Peak measured heat flux on centre line 3 m from ground (kW/m^2)	8

One of the primary objectives of this project identified by MHCLG was to establish if there were any other materials on the market that would provide a similar level of hazard to Aluminium Composite Material (ACM) with a polyethylene (PE) core. As part of the calibration process undertaken for this project, a series of fire experiments were conducted on various types of ACM (see Appendix D). The assessment criteria adopted in this project are related to the measured and observed performance of the ACM panels with a PE core when subjected to the same thermal exposure and under the same conditions. The reference values are summarised in Table G17 based on average values for the two PE ACM panels evaluated during the calibration process.

Table G17 – Summary of experimental results for ACM panels with PE core

Parameter	Value
Peak heat release rate (kW)	1459
Time to peak heat release rate (min)	21
Total heat release (MJ)	1061
Peak measured heat flux on centre line 3 m from ground (kW/m^2)	100*

* above range of instrument

From the above it can be seen that the peak HRR for the PE ACM samples are almost five times that of the base level provided by the crib ignition source indicating a significant contribution to fire development from the material panel itself. This was supported by the visual evidence which showed both vertical and horizontal flame spread.

An increase in heat release rate over and above that provided by the ignition source indicates a contribution from the sample to the overall energy produced. This can be either a short-term increase which may represent, for example, the contribution from a surface coating which is ignited in the early stages and then consumed over a short period of time or may occur at a later time and be maintained for a longer duration which would be indicative of a contribution from the core or bulk of the material. The duration of the assessment for this programme was 30 minutes for every fire experiment corresponding to the time from ignition to almost complete combustion of the timber crib ignition source. Where there was an increase in the peak heat release rate but no corresponding increase in the total heat release this would be indicative of a localised contribution from the sample in the region of the ignition source often accompanied by a breakthrough of fire into the cavity.

The clearest quantitative assessment of a breakthrough of the panel and/or a fire within the cavity is the peak measured heat flux at the top of the panel corroborated by a significant temperature rise within the cavity between the panel and the non-combustible substrate. All measured values need to be considered alongside the observed behaviour. In many cases the breakthrough of the fire into the cavity space indicated by a rise in the temperature of the thermocouples within the cavity on the centre line and a subsequent rise in the peak measured heat flux can be confirmed from visual observation of flaming within the cavity.

G5 Discussion

Based on the methodology and analysis described above, the behaviour of each of the samples has been considered in relation to:

- Overall contribution to fire growth.
- Potential for development of a cavity fire incident.

The performance will be related to the relative performance of the PE ACM panels investigated during the calibration process.

G5.1 Contribution to fire growth

Figure G31 shows the measured HRR for all the individual samples (S23 to S28) compared to the base value for the crib fire source.

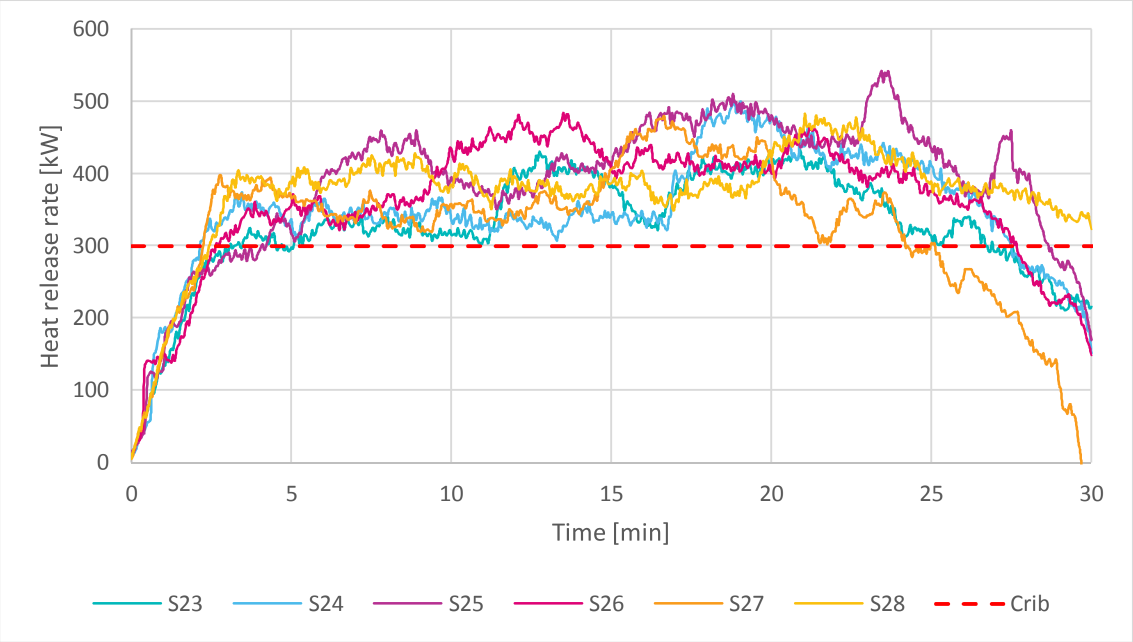


Figure G31 – Heat release rate for all samples showing base value of crib

It can be seen from the figure that there is some differentiation between the samples. All the HPL samples are in the same general area showing a contribution up to approximately 200 kW above the base level. The contributions of the timber cladding panels are lower than for the HPL panels but not significantly different. Figure G32 shows the values in Figure G31 compared with the results of the two PE ACM samples evaluated as part of the calibration process.

The heat release rate for any given material or product is dependent on the area burning as a function of time. As can be seen from the earlier results, there was a difference between the extent of damage or area burnt between the two nominally identical timber cladding systems, S27 and S28. In these cases, the variations measured are potentially a function of the efficiency of the fixings into the supporting framework, the studs.

As can be seen from the experimental results, in the case of two of the HPL panels, S25 and S26 (class C – s1, d0; intended for internal use) and one of the timber cladding systems, S27, the fire spread up the full height of the experimental rig consuming the samples. This means that the fire has sustained vertical fire spread beyond the area of direct flame contact produced by the crib ignition source. In each of these cases, the extent of lateral or horizontal fire spread appears to have been constrained by the metal framing system to which the samples were fixed. This suggests that the results in these experiments are particularly sensitive to the mounting and fixing arrangements and in the case of the HPL samples, the location of the vertical joint relative to the crib ignition source. The vertical joint on the centreline of the crib ignition source appears to represent the worst case in terms of penetration of the fire into the cavity.

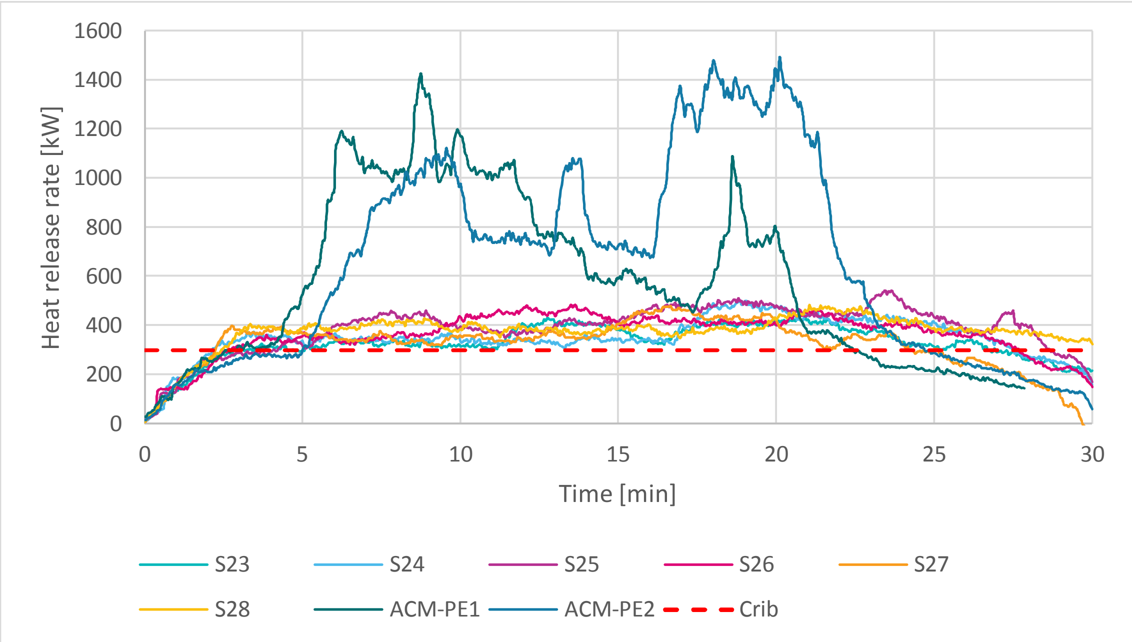


Figure G32 – Heat release rate for all samples showing base value of ignition source and comparison with PE ACM samples

Based on a consideration of Figure G32 and a review of the video evidence, it can be concluded that none of the samples included in the experimental programme exhibit fire performance which is comparable to the fire growth and fire spread of the PE ACM samples when subjected to the same fire exposure and experimental methodology which underpins this project.

Figure G33 shows the measured total heat release excluding the fire source (≈ 450 MJ) for all the tested samples in comparison with the PE ACM.

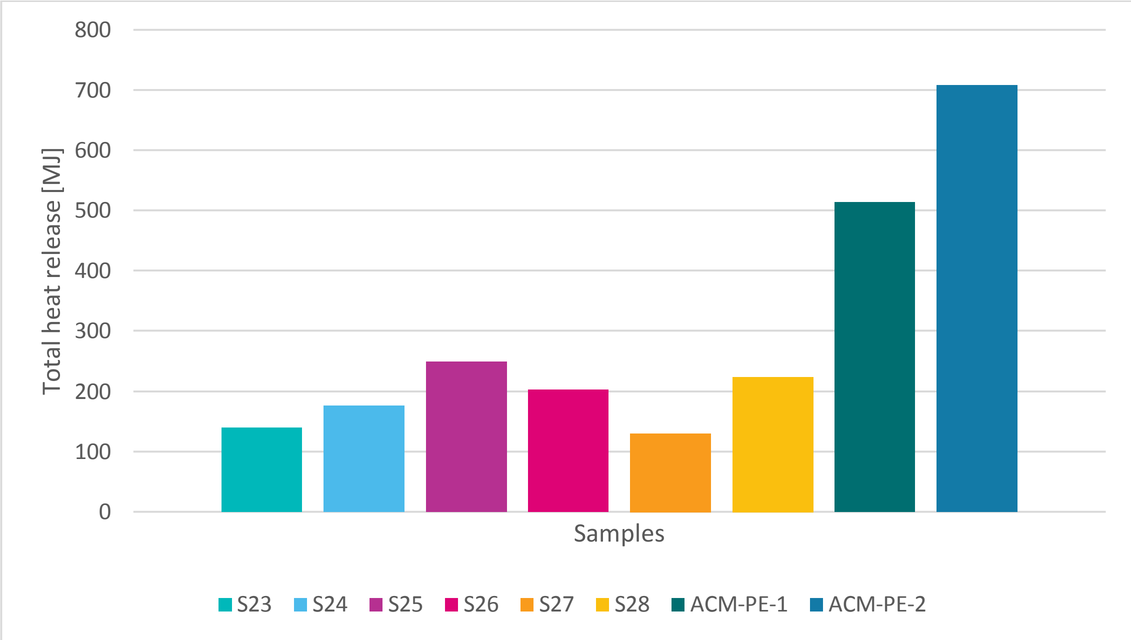


Figure G33 – Total heat release for all samples compared with PE ACM samples

G5.2 Cavity fire performance

For real cavity systems, it is necessary to consider not only the potential impact of fire growth on the external surface of the panel but also the potential impact of the fire breaking through the panel and exposing the back face and other surfaces within the cavity.

Figure G34 shows the measured value of heat flux on the centre line at a height of 3 m from the ground for all samples. The baseline contribution of the ignition source is indicated on the figure as a constant value of 4 kW/m².

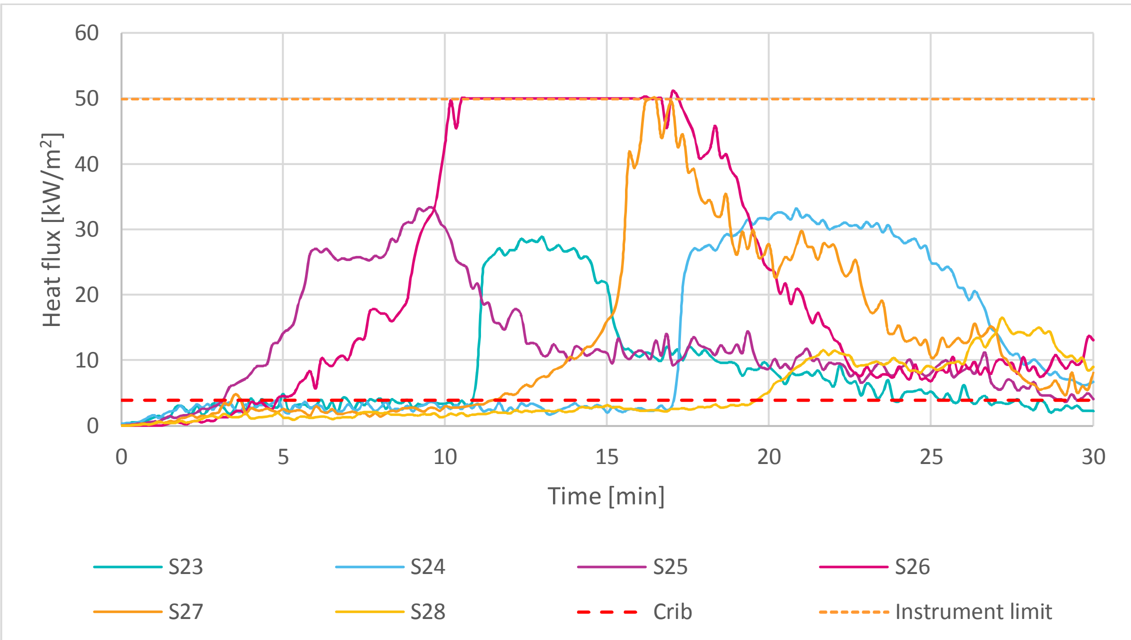


Figure G34 – Measured heat flux for all samples at 3 m from the ground on the centre line

Figure G34 shows a significant difference in the heat flux measurements at the top of the rig for all samples. The values of 50 kW/m² and the termination of the readings are where the maximum capacity of the heat flux meter was exceeded. The primary use of the heat flux measurements was in quantifying the time for the fire to break through into the cavity. The assessment of the heat flux measurements need to consider the issue of break through both in terms of time to breach the cavity and the intensity of the cavity fire once a breach has occurred and the potential impact on any materials contained within the space behind the front panel. The time to break through can be assessed in relation to the measured values and the observed behaviour. The severity of any subsequent fire within the cavity can be related to the temperature measured within the cavity and to some extent, the peak heat flux measured at the top of the sample. As with the assessment of the contribution to fire development, it is important to consider the results relative to the results from a material with a known level of performance. Figure G35 shows the measured values alongside the results from the two PE ACM samples considered as part of the calibration process. The values of 100 kW/m² and the termination of the readings for the two PE ACM calibration samples are where the maximum capacity of the heat flux meter was exceeded. Based on the anticipated fire growth and flame spread for the ACM PE samples used in the calibration programme, a heat flux meter with a higher range (up to 100 kW/m²) was used. For all the other samples, where the fire growth and flame spread was anticipated to be lower, a heat flux meter with a lower range (up to 50 kW/m²) was used to improve the sensitivity of the measurements.

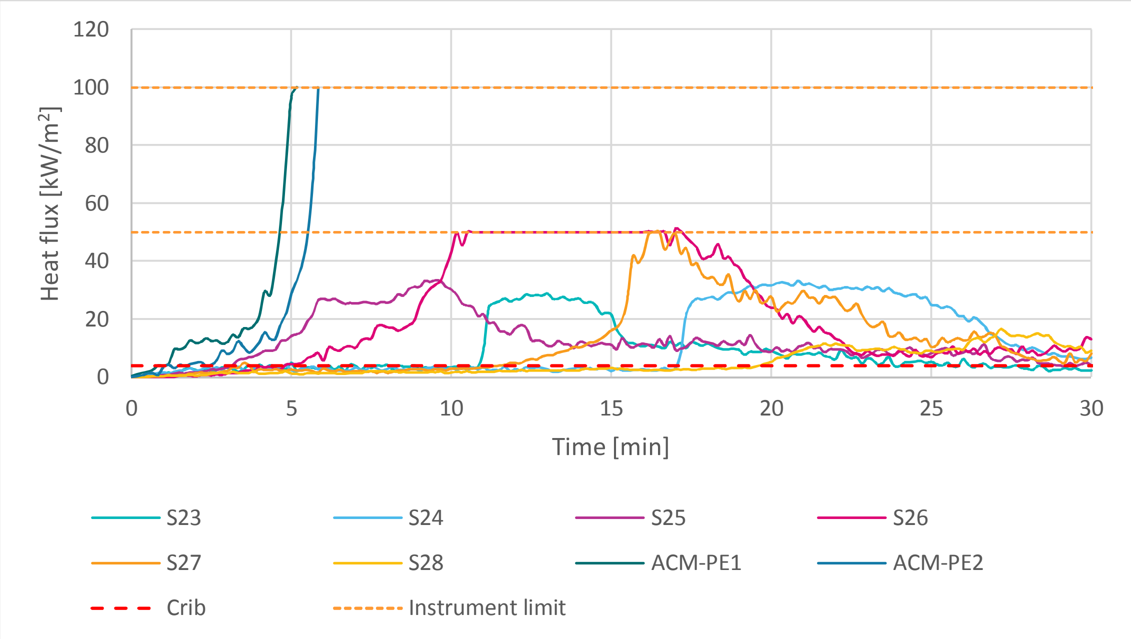


Figure G35 – Measured heat flux for all samples at 3 m from the ground on the centre line

The relative contribution of each sample in relation to both fire growth (peak HRR) and break through into the cavity (peak heat flux) is illustrated in Figure G36. Figure G37 shows the measured peak heat flux and the time to burn through of the panels.

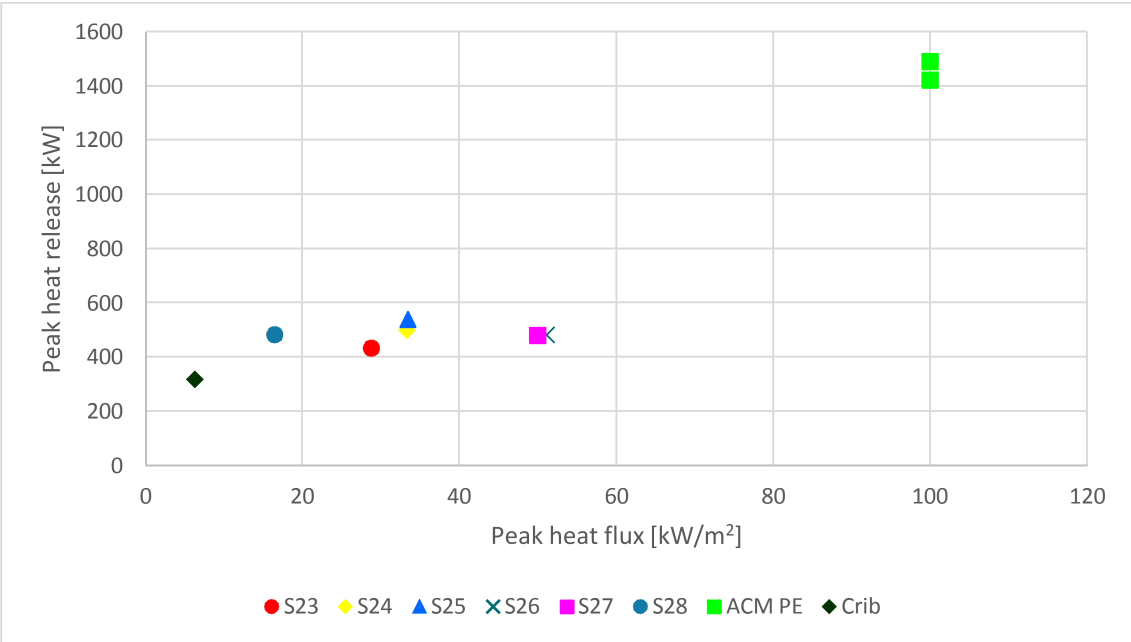


Figure G36 – Results related to measured peak heat release rate and measured peak heat flux including PE ACM panels used for calibration

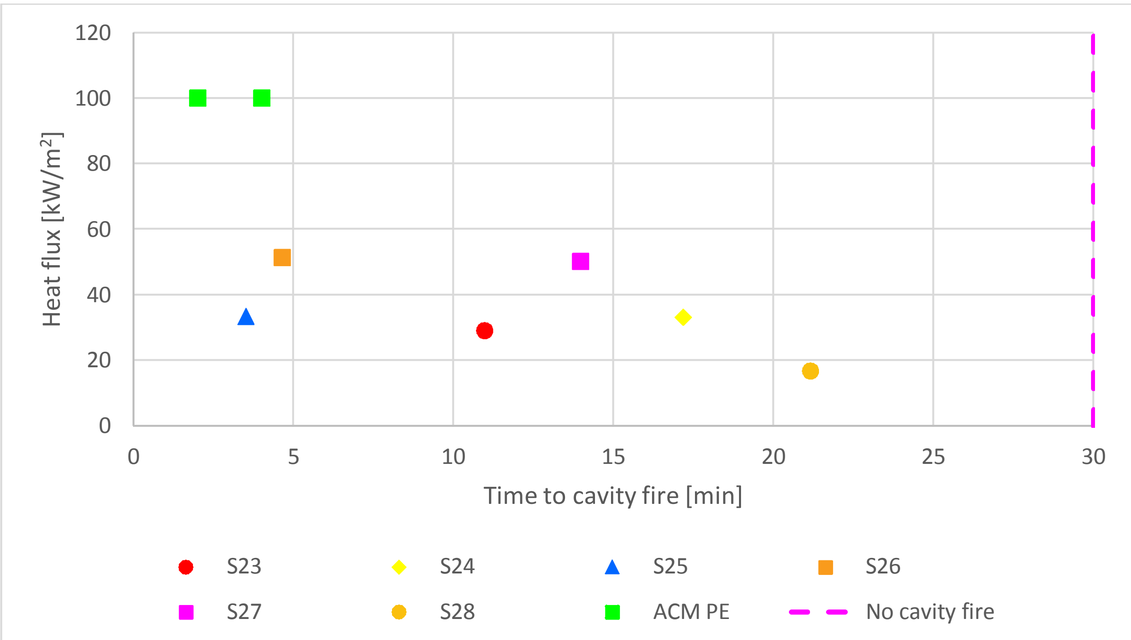


Figure G37 – Comparison of measured peak heat flux and time to burn through of the panels

G6 Conclusions

The following conclusions are based on the results and observations of the supplementary experimental programme in accordance with the methodology described in previous Appendices. The project only considered the external cladding panels in isolation from other components of the cladding system. Based on the measured and observed behaviour of the samples, a comparison with the measured and observed behaviour of the PE ACM panels when subject to the same experimental procedure as part of the calibration process and a consideration of the potential hazard based on contribution to fire growth and the potential hazard associated with a cavity fire, the following conclusions can be drawn:

- None of the samples investigated shows the same or a similar type of fire performance to that of PE ACM panels, whether in relation to contribution to fire growth, fire spread or potential issues with breakthrough and initiation of cavity fires. The samples included in the supplementary experimental programme had an indicative (based on information directly from the manufacturer or the distributer's website) reaction to fire performance of Class C or D (European classification) (HPLs) or no classification declared (untreated timber).

- There is no evidence for any of the samples investigated to indicate that the products represent a similar hazard to the PE ACM panels.

- The results for the HPL samples classified C – s1, d0 and intended for internal use and one of the timber cladding samples exhibited sustained vertical fire spread beyond the area of direct flame contact produced by the crib ignition source. In each of these cases, the extent of horizontal (or lateral) fire spread appears to have been constrained by the metal framing system to which the samples were fixed. This suggests that the results in these experiments are particularly sensitive to the mounting and fixing arrangements and in the case of the HPL samples, the location of the vertical joint relative to the crib ignition source. The vertical joint on the centreline of the crib ignition source appears to represent the worst case in terms of penetration of the fire into the cavity.

Based on the detailed results from the work carried out in this project, it is recommended that further work is conducted to establish the impact of the joint location on the outcome from the experiments as well as the relationship between some of the materials/products in conjunction with different types of insulation in the cavity. This work would require both intermediate and large-scale investigation to establish the impact of variables such as insulation type, thickness and cavity depth on an intermediate scale and then large-scale tests to validate the impact of scale. This further analysis should include metal composite materials and standard and FR HPL panels.

Appendix G1 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 additional samples. The location and designated number of the installed thermocouples is illustrated in Figure G38.

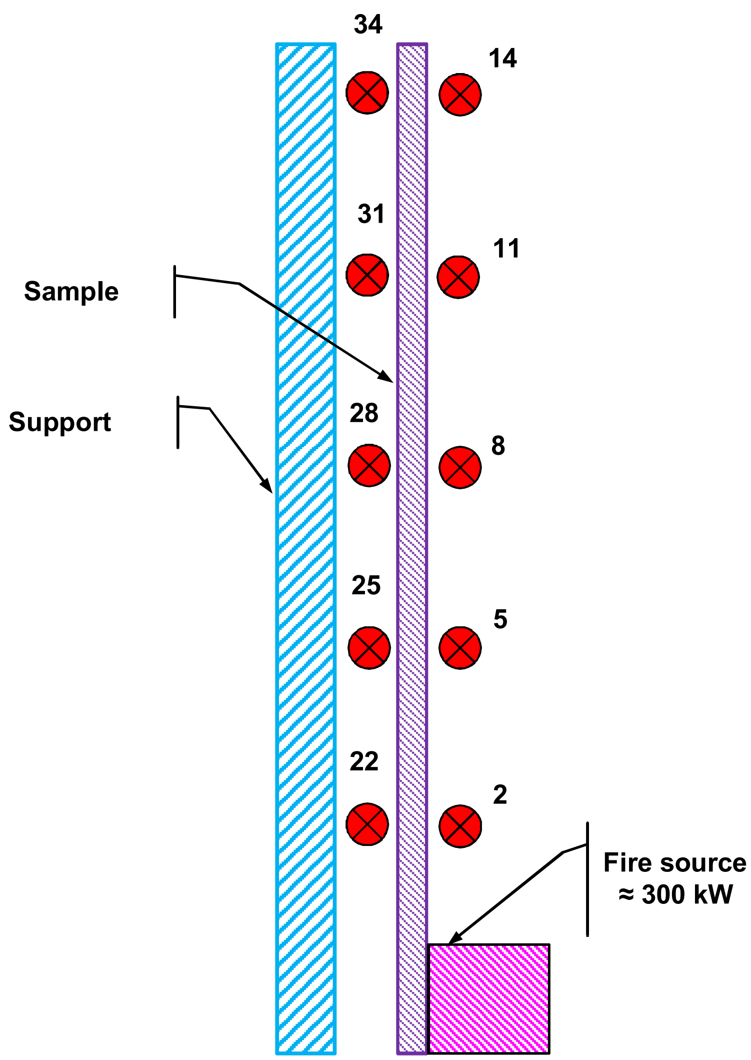


Figure G38 – Thermocouple locations for the samples

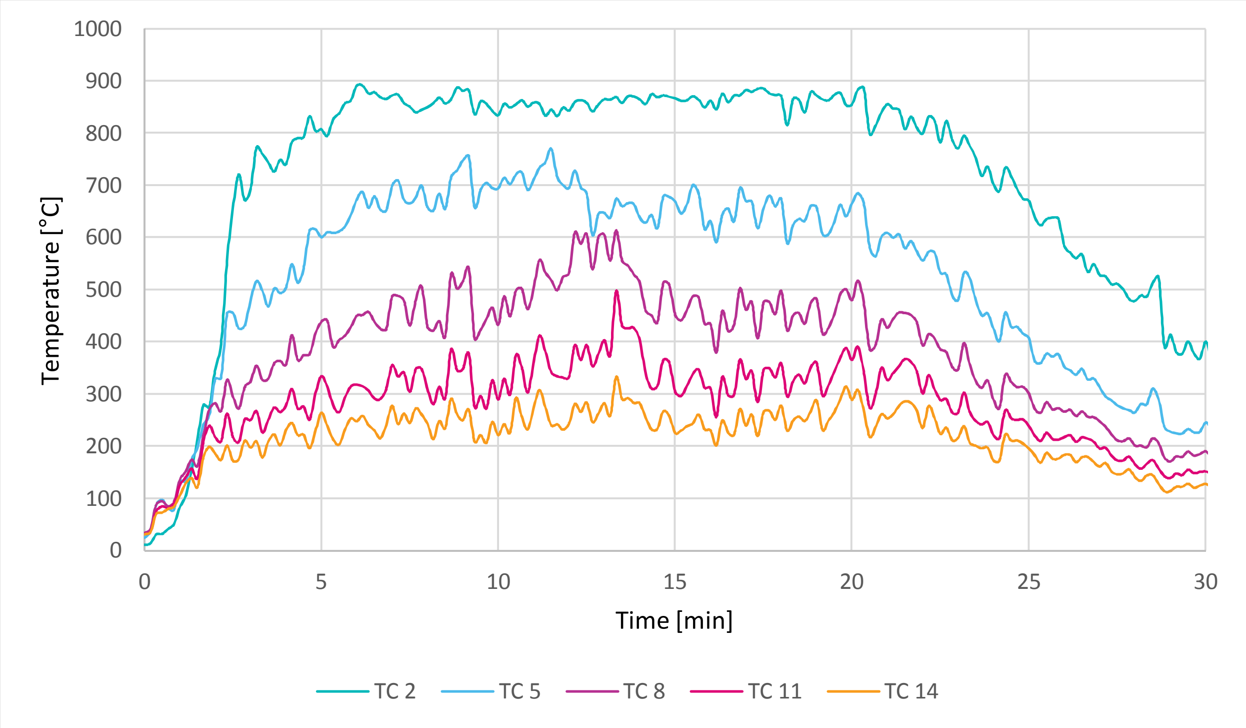


Figure G39 – Temperatures measured on the external central axis for S23

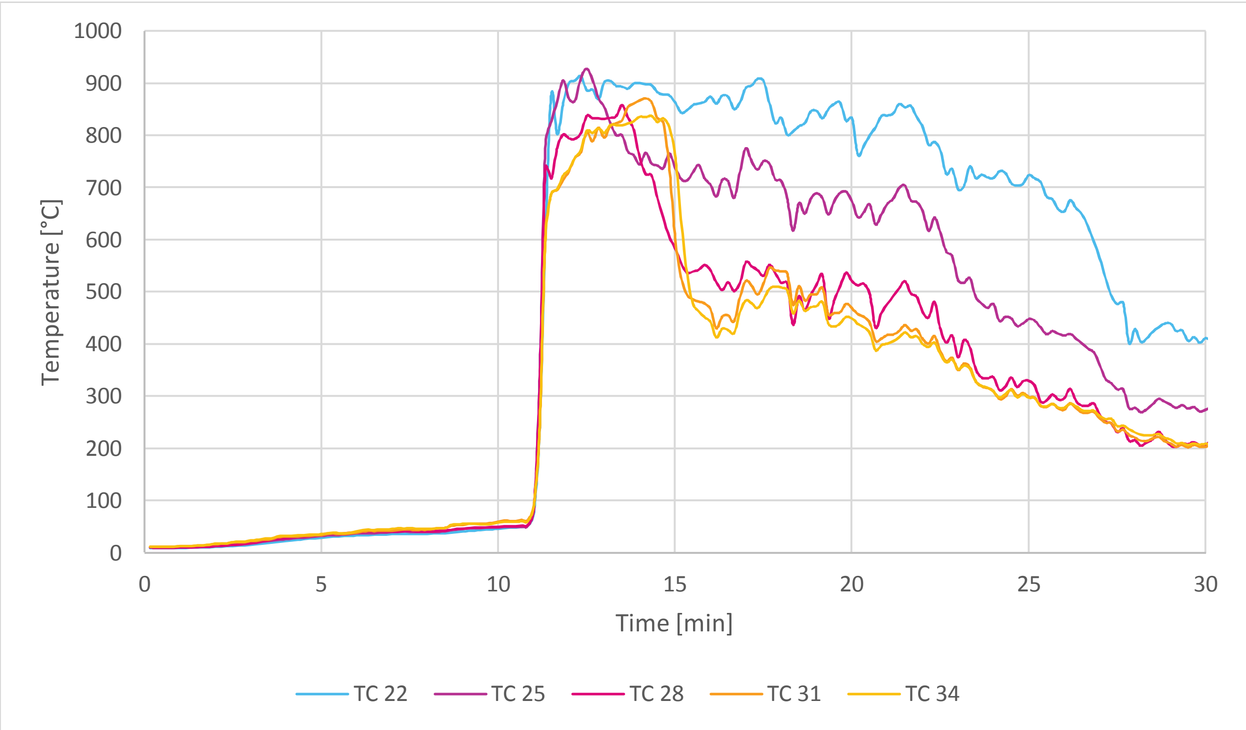


Figure G40 – Temperatures measured on the cavity central axis for S23

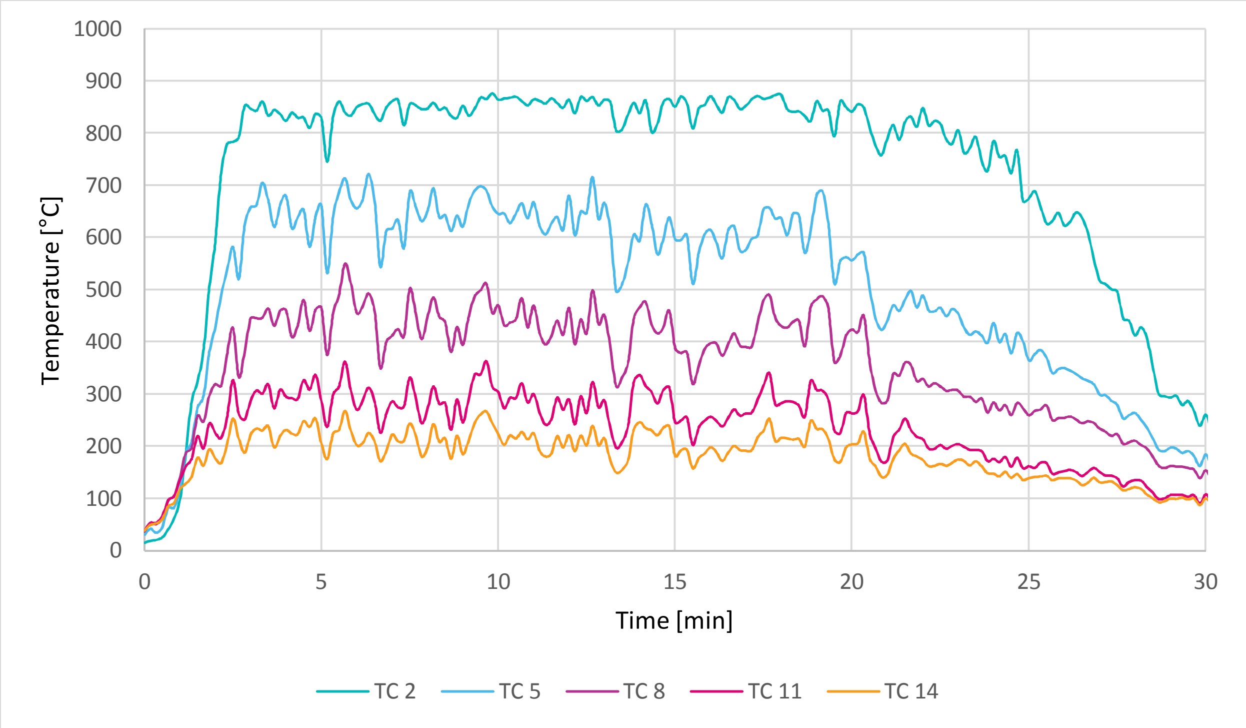


Figure G41 – Temperatures measured on the external central axis for S24

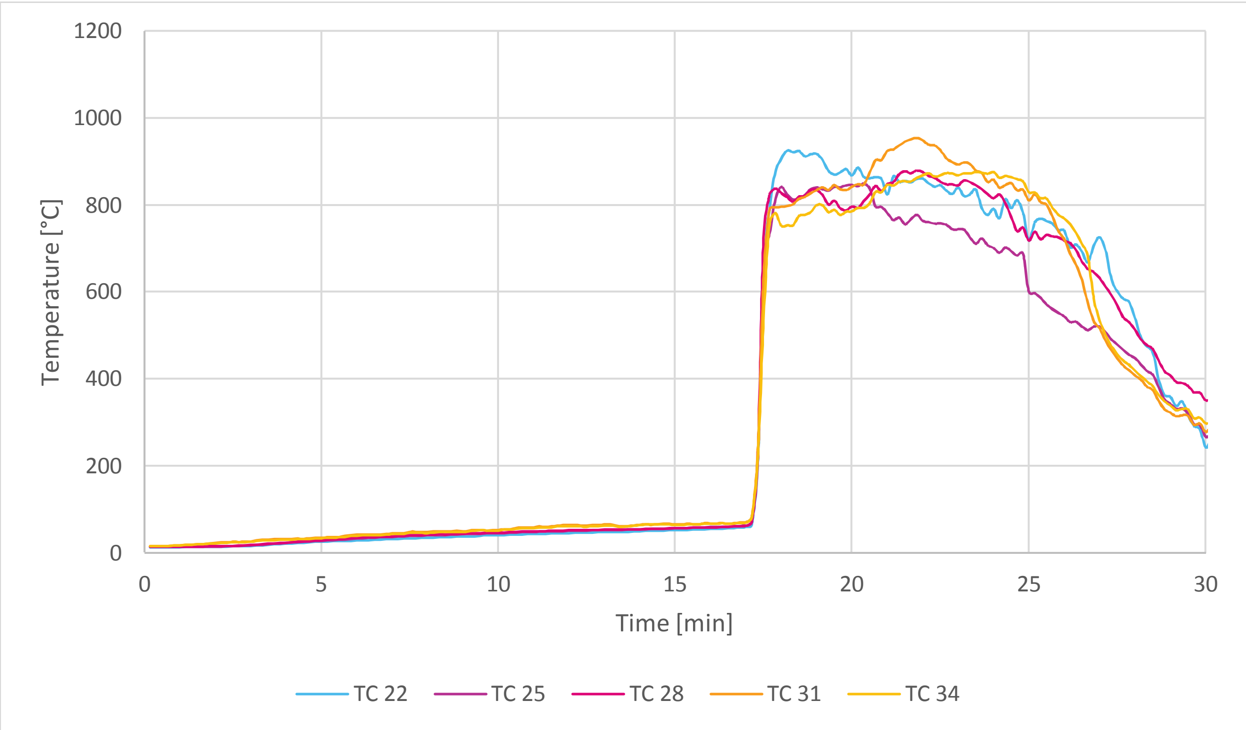


Figure G42 – Temperatures measured on the cavity central axis for S24

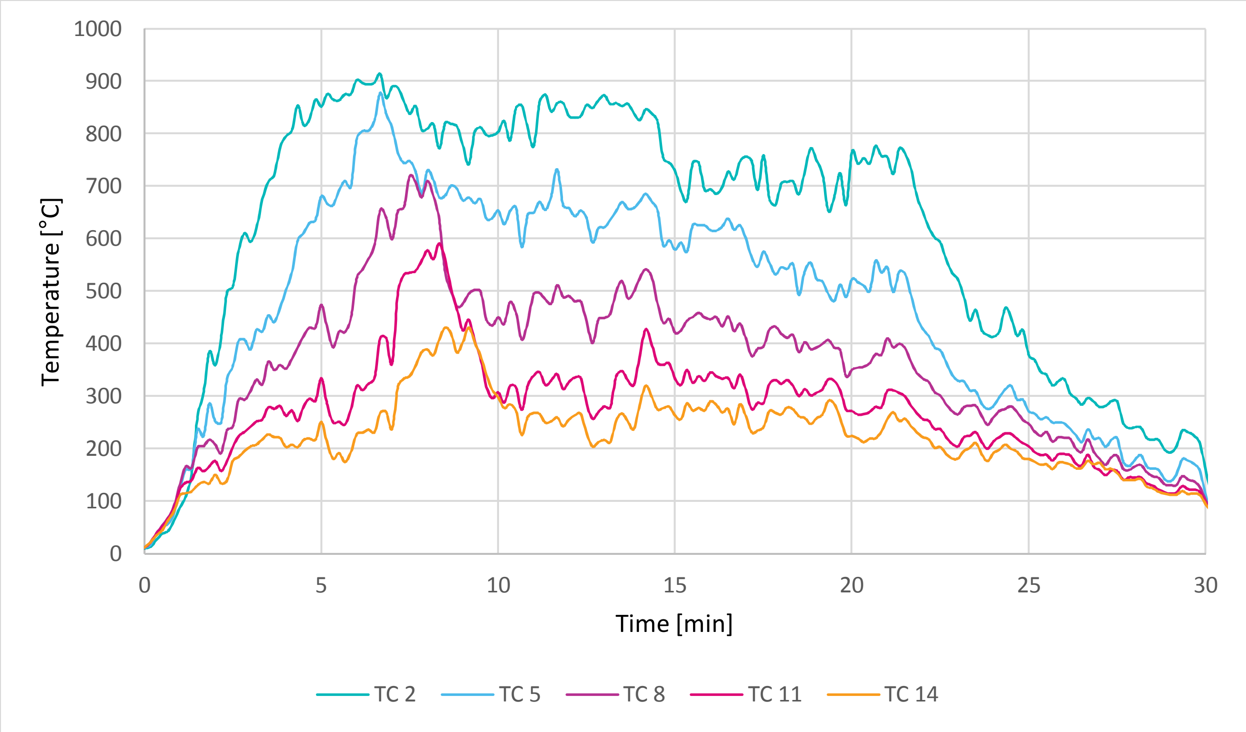


Figure G43 – Temperatures measured on the external central axis for S25

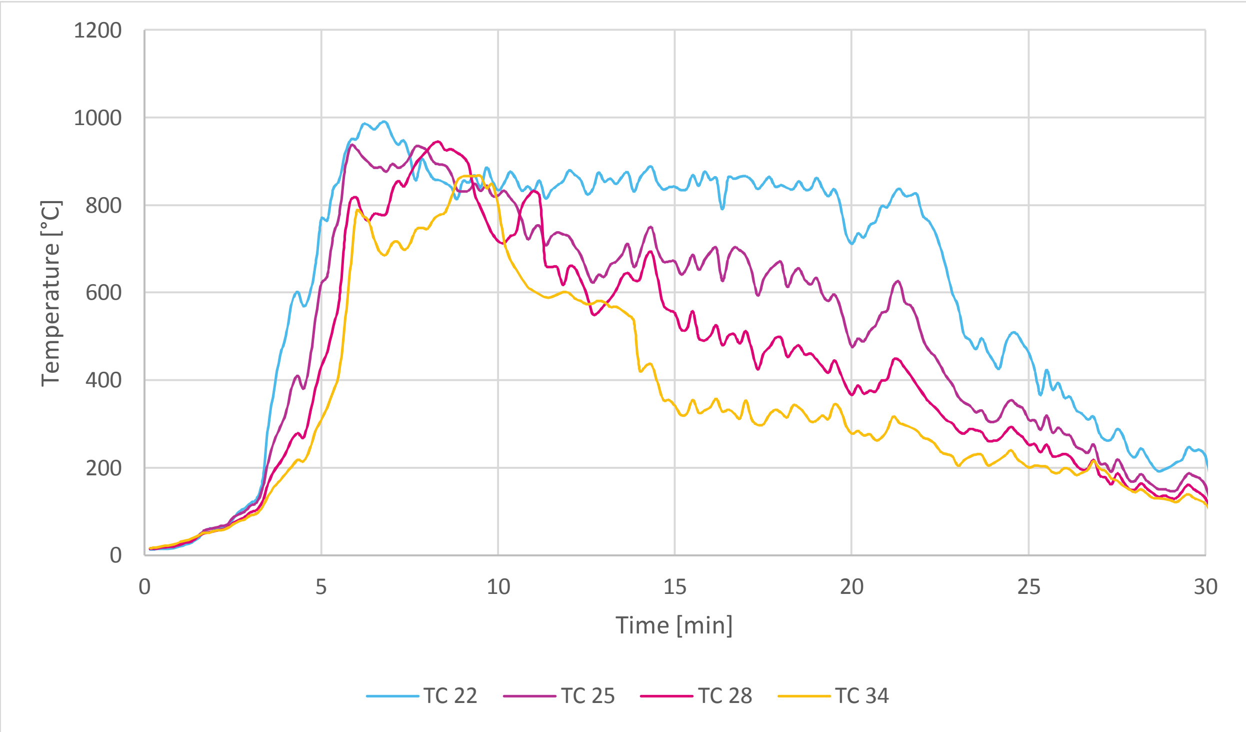


Figure G44 – Temperatures measured on the cavity central axis for S25

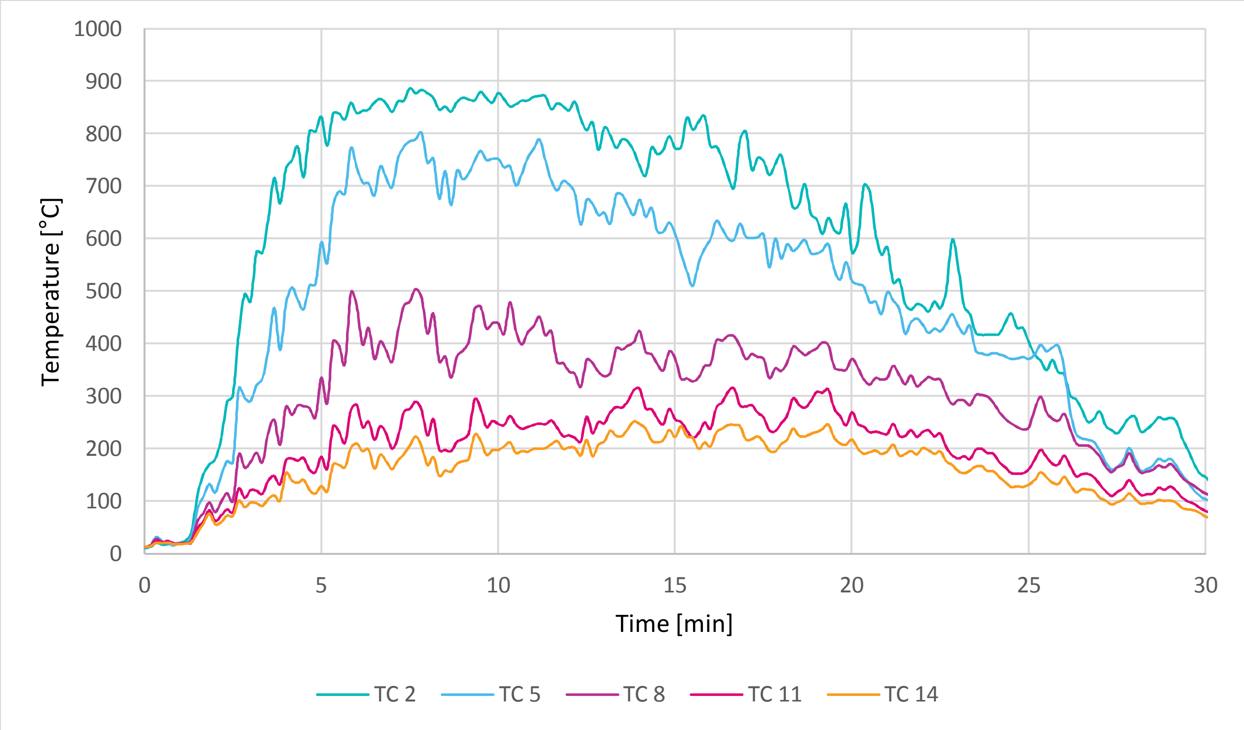


Figure G45 – Temperatures measured on the external central axis for S26

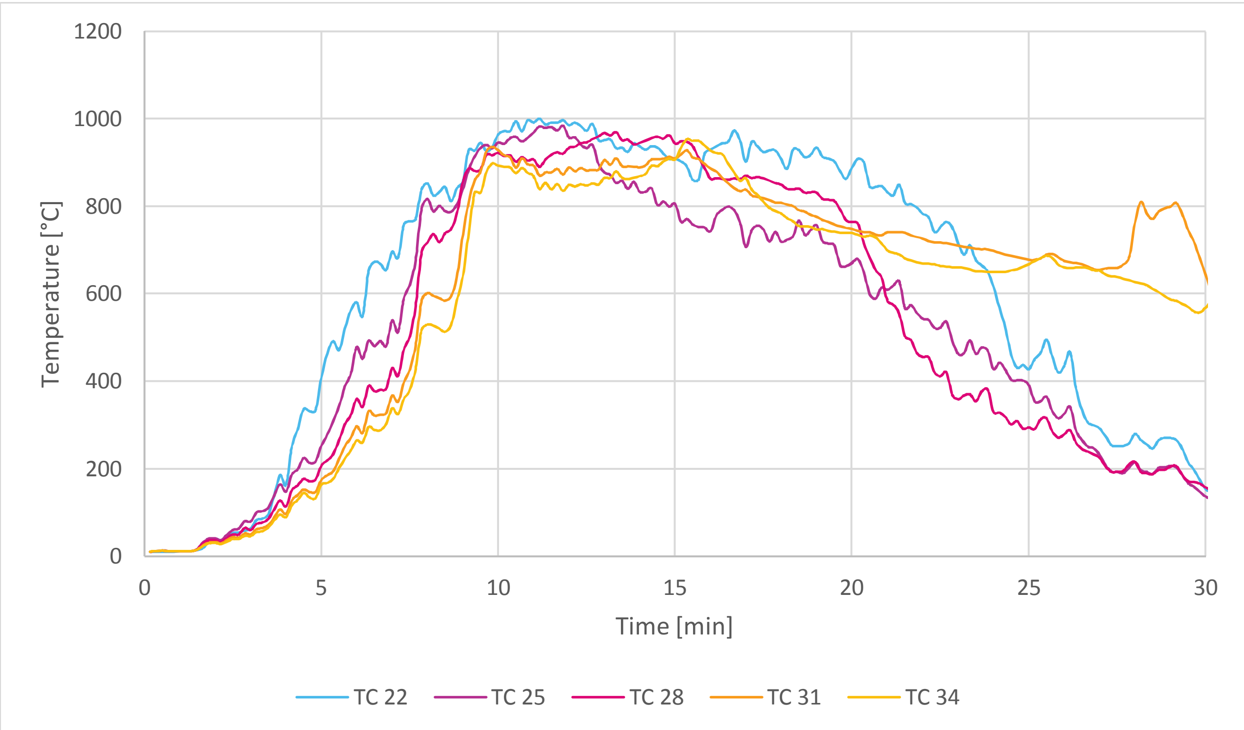


Figure G46 – Temperatures measured on the cavity central axis for S26

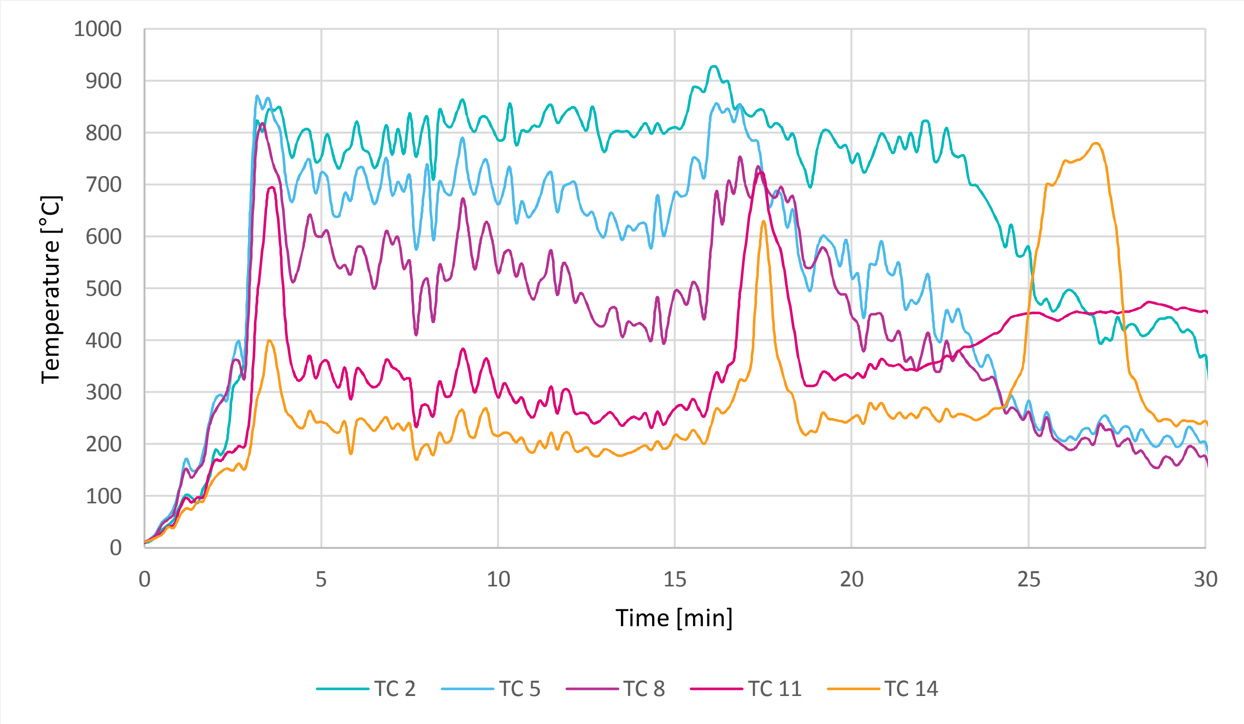


Figure G47 – Temperatures measured on the external central axis for S27

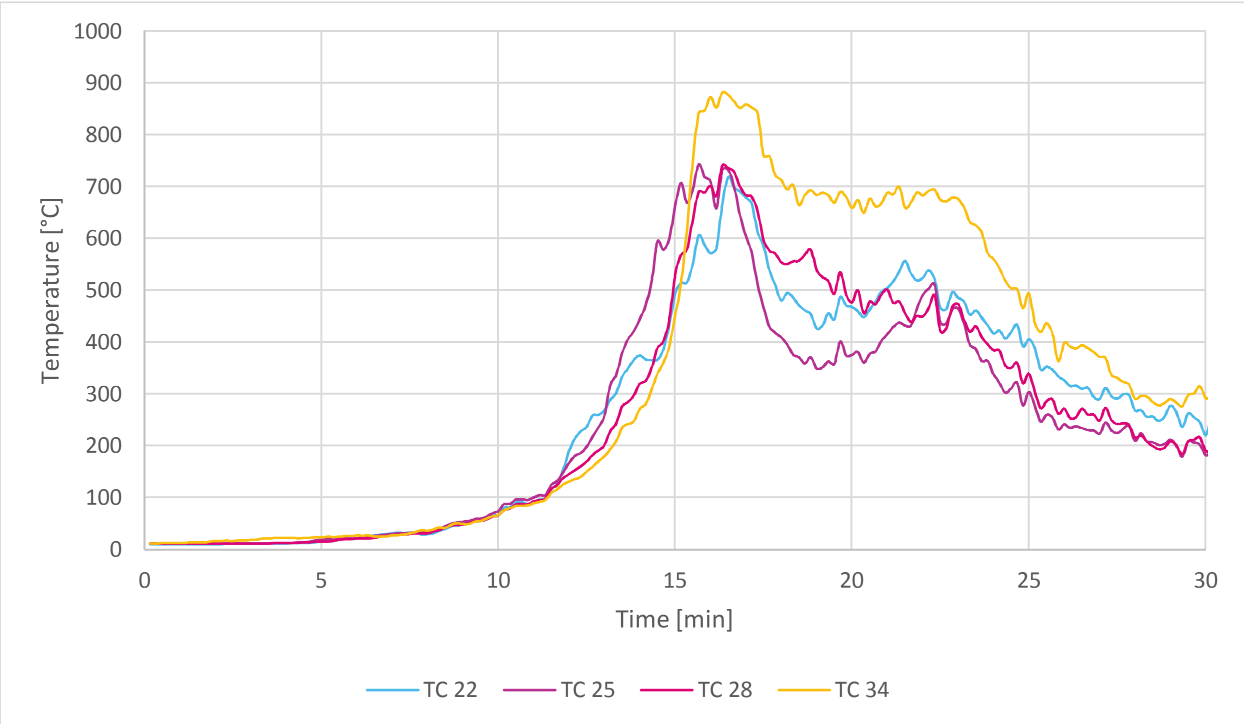


Figure G48 – Temperatures measured on the cavity central axis for S27

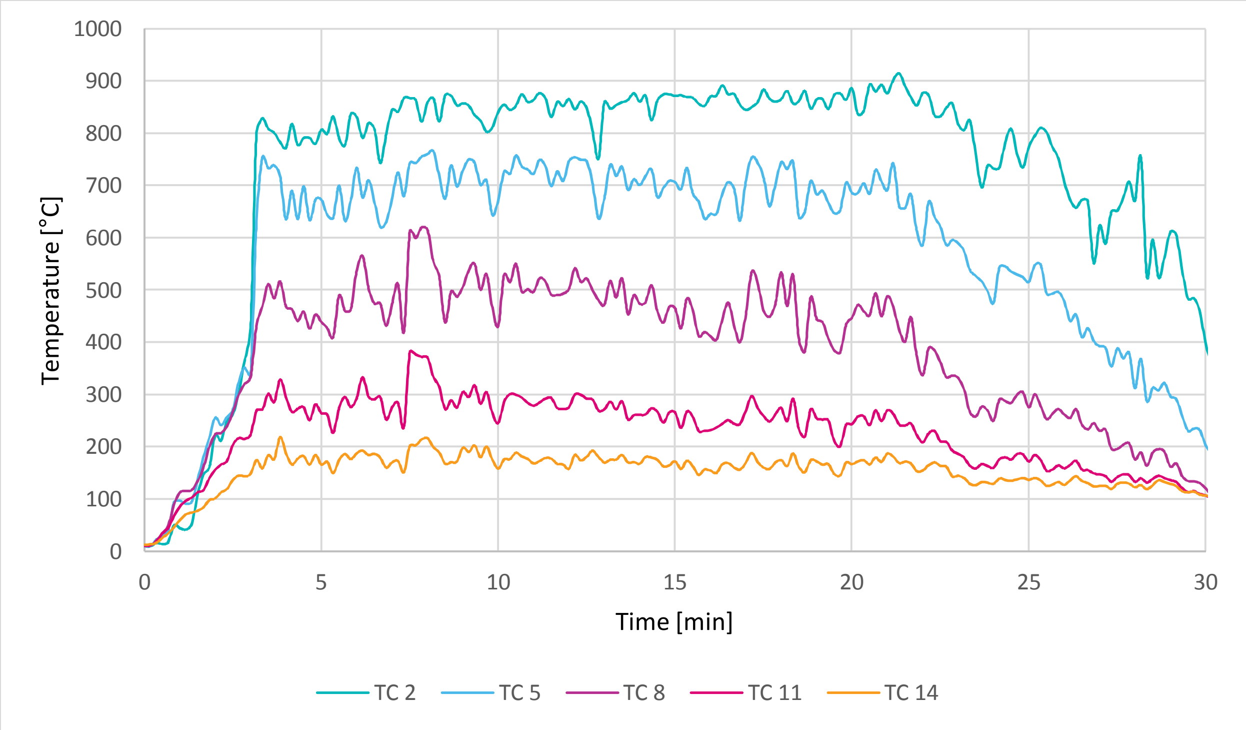


Figure G49 – Temperatures measured on the external central axis for S28

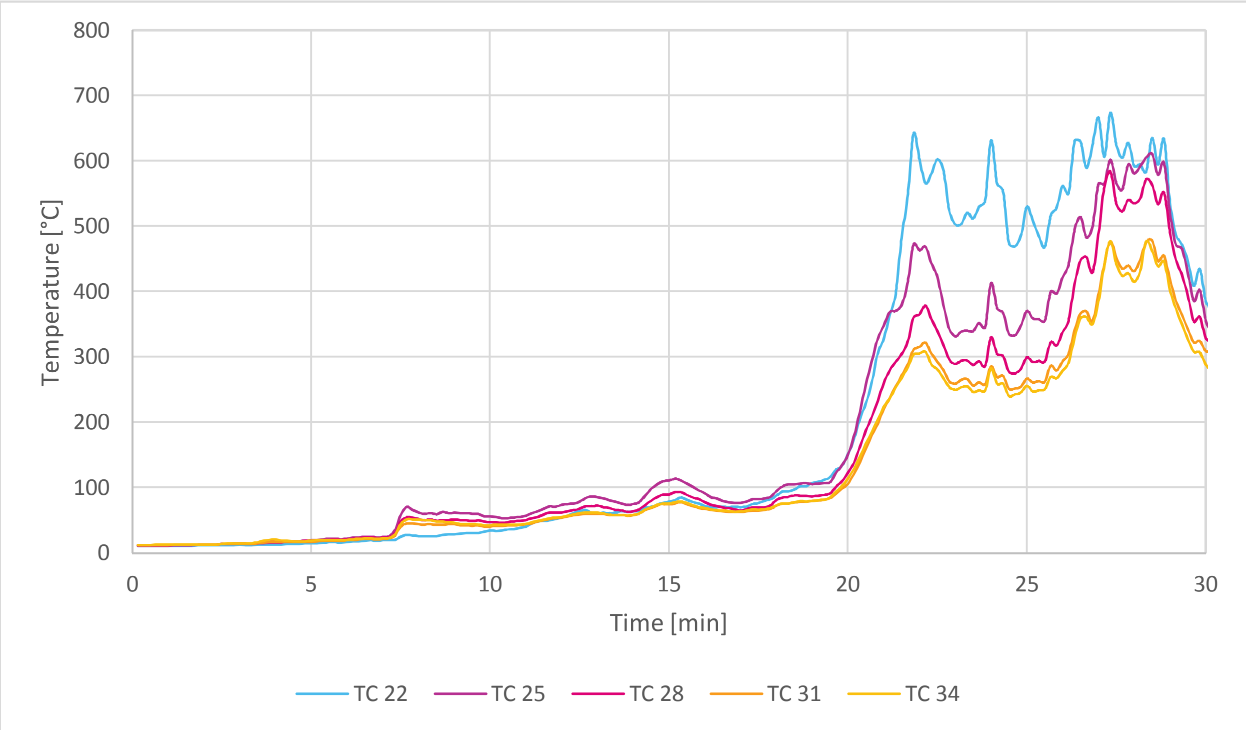


Figure G50 – Temperatures measured on the cavity central axis for S28

Report Ends