Intermediate-scale Cladding Fire Tests On Various Cladding Types

Fire Testing Report

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	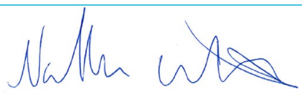	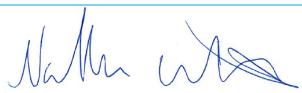
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Contents

Tables

1 Introduction

Cladding Safety Victoria (CSV) have engaged CSIRO to collaboratively design and undertake a series of intermediate fire test on various types of cladding.

The intermediate scale cladding fire tests are experiments (not complying to a particular test standard) applying a fire source in the range of 100-300 kW to a cladding specimen ~ 1.5 m wide x ~ 2.6 m high. The experimental arrangement was significantly modified from ISO 13785:2002 Part 1.

The cladding materials tested include:

1. Sandwich panel with PIR core (ISP-01, CSIRO Specimen Number FE3153-10).
2. Sandwich panel with EPS core (ISP-02, CSIRO Specimen Number FE3153-11).
3. Wood Polymer Composite with ~53-56 mass% wood, with balance being mostly Polyethylene (WPC-01, CSIRO Specimen Number FE3153-8).
4. Wood Polymer Composite with ~90-95 mass% wood, similar in composition to Masonite or high-density fibre board (WPC-02, CSIRO Specimen Number FE3153-3).

In this report the term Wood Polymer Composite (WPC, also known as wood plastic composite) is used to refer to composite materials made of wood fibre / wood flour and thermoplastic polymer. Such materials are also referred to as Timber Composite Panel or Timber Composite Cladding (TCC) by industry and the test sponsor. These terms can be used interchangeably to refer to this type of material.

The cladding materials have been sourced from commercially available products. As the testing has been conducted on behalf of CSV, and not on behalf of the product suppliers/manufacturers, the cladding materials tested have been described generically in terms of material composition, they have not been identified by product trade name or supplier/manufacturer throughout this report.

The scope of work is set out in CSV Statement of Work - Work Package Instruction # 04, Dated November 2023.

The CSV statement of work requires CSIRO to undertake a “Stage 1 – Technical Review and Scoping” which developed and agreed the test method and specimens to be tested. This stage was documented in CSIRO Report Number FE3153-RPT-01. This report was only issued as a draft to CSV for discussion and agreement and is not provided as a public report. Some aspects of the test method and test specimens were varied from “Stage 1” during the course of the test program as directed/agreed by CSV. Full details of the test program and specimens are detailed in this report (FE3153-RPT-03).

The following other CSIRO reports relate to this test report:

- CSIRO Report number: FE3153-RPT-03, “Cone Calorimeter Tests on Cladding Materials at 50 kW/m^2 in Accordance With AS/NZS 3837:1998”
- CSIRO Report number: XC3991, “Identification of Building Cladding Material”. This presents FTIR, TGA and DSC Material Characterisation test results on Cladding materials

The above test reports present cone calorimeter testing and material characterisation testing on the two sandwich panel core types, on seven different types of WPC (from which two were selected for intermediate scale testing) and two types of timber products for comparison/reference.

The following conventions have been used in descriptions/observations of tests in this report.

- Height – All descriptions of height are height from laboratory floor level (unless otherwise stated). In this test the bottom of the installed cladding is 400 mm above floor level and the top of the installed cladding is 3000 mm above floor level.
- Left and right – left means the left side of the specimen when viewed standing facing the front of the specimen from the front of the test hood.
- Panel numbering – Panel number 1 is the panel installed on the left-hand side or lower panel closed to ground level. Panel Number 2 is the panel installed on the right-hand side.

Table 1. Test laboratory, Sponsor and dates

Test Laboratory:	CSIRO, Infrastructure Technologies, Gate 6, 71 Normanby Road, Clayton, VIC
Test Sponsor	Cladding Safety Victoria
Dates of Tests	HRR Calibration tests – 12/06/2024, 27/08/2024 & 24/10/2024 Characterisation tests – 14/06/2024 Test 1 – 17/06/2024 Test 2 – 18/06/2024 Test 3 – 19/06/2024 Test 4 – 23/06/2024 Test 5 – 24/06/2024 Test 6 – 25/06/2024 Test 7 – 26/06/2024 Test 8 – 30/06/2024 Test 9 – 01/07/2024 Test 10- 03/07/2024 Test 11 – 24/10/2024 Test 12 – 27/10/2024 Test 13 – 27/10/2024

A team of at least two CSIRO staff, present at all times, was required to monitor and control the tests.

External test witnesses present for each test varied but were a limited number of CSV and RMIT University staff.

2 Limitations

This report is subject to the following limitations (other assumptions and limitations may be stated throughout the report):

1. This test method is specifically designed in collaboration with and for CSV. The tests are intended to provide information and knowledge relating to the fire behaviour of the cladding systems tested. The results may not be directly applicable to other cladding materials, systems or test arrangements.
2. The test method details provided in this report are developed by CSIRO and CSV. Any use of these methods must include reference and acknowledgment to CSIRO and the test sponsor.
3. The intermediate scale cladding fire tests are experiments (not complying to a particular test standard) applying a localised external fire source in the range of 100-300 kW to a cladding specimen ~ 1.5 m wide x ~ 2.6 m high. The experimental arrangement was partially based on ISO 13785:2002 Part 1.
4. The intermediate scale testing does not represent a large ignition source such as a post flashover internal fire (given internal sprinkler protection) or external fires of ~ 1 MW or larger.

5. The results of these fire tests may be used to directly assess fire hazard, but it should be recognized that a single test method will not provide a full assessment of fire hazard under all fire conditions.
6. These test results only relate to the behaviour of the specimen of the element of construction under the specimen installation details and conditions of the test. They are not intended to be the sole criteria for assessing the potential fire performance of the element in use, and they do not necessarily reflect the actual behaviour under all fire conditions.
7. This report does not address any variations to the specimen from the details tested. Any variation with respect to materials of construction, size, construction details, loads, stresses, edge or end conditions is not addressed by this report.
8. This set of intermediate-scale cladding fire tests are intended to be fire scenario-based experiments to observe the reaction of the cladding system in response to a localized external fire source and provide test data to inform general cladding fire risk assessment. They are not tests in accordance with any specific test standard, and pass/fail criteria from other test standards should not be directly applied.
9. The FTIR gas analysis system was rented from supplier and was provided with all gas analysis equipment and software pre-calibrated by supplier. CSIRO did not undertake any calibration checks except to sample/measure a known calibration gas mixture of CO and CO2, which the FTIR correctly measured to within +/- 5%. FTIR gas analysis can be subject to miss identification or cross measurement of different gas species which may have overlapping IR absorbance spectra. Therefore, CSIRO does not provide a stated measurement uncertainty or accuracy for the FTIR gas concentration measurements presented within this report.
10. Where Methane and Ethylene concentrations have been identified and measured by FTIR gas analyser it is possible that this may be miss identification of other gases such as unburnt (or partially burnt) propane from the gas burner.
11. Reaction to fire testing includes numerous combined/simultaneous measurements and the behaviour of materials when subject to replicate testing can be subject to variability. It is not practical to quantifying and state the uncertainty and/or repeatability of measurements obtained from this reaction to fire test. The HRR calibration test results indicate that HRR measurement is generally accurate within ±5 %. Where replicate testing of the same specimen has been provided this may provide an indication of repeatability.
12. TGA/FTIR testing and calculation of wood %mass composition in WPC specimens is presented in CSIRO Report number: XC3991. The measurement of wood %mass composition is an approximate/indicative measurement which was found to match relatively well with information from WPC suppliers. CSIRO is not able to provide a stated measurement uncertainty or accuracy for these measurements.

3 Definitions

Table 2. Definitions

Acronymn / Phrase	Definition
BMT	Bare metal Thickness
C2H4	Ethylene
C_3H_4O	Acrolein
CH2O	Formaldehyde
CH_4	Methane
CO	Carbon Monoxide
CO2	Carbon Dioxide
CSIRO	Commonwealth Science and Industrial Research Organisation
CSV	Cladding Safety Victoria
DIN	German Institute for Standardization
DSC	Differential Scanning Calorimetry
EPS	Expanded polystyrene
EPS-FR	Expanded polystyrene with fire retardant additive, typically Hexabromocyclododecanen (HBCD)
FR - PB	fire resistant plasterboard
FR- Plasterboard	fire resistant plasterboard
FTIR	Fourier-transform infrared spectroscopy
FTT	Fire Testing Technology (test equipment supplier)
HBCD	Hexabromocyclododecane
HBr	Hydrogen Bromide
HCl	Hydrogen Chloride
HCN	Hydrogen cyanide
HF	Hydrogen Fluoride
HRR	Heat Release Rate, a unit of energy release per unit time (kW or MW)
HRRPUA	Heat Release rate per unit area (kW/m2)
IR	Infrared
ISO	International Organization for Standardization
ISP	Insulated Sandwich Panel
LPG	Liquid Propane Gas
MIMS	Mineral Insulated Metal Sheathed, Thermocouple
NATA	The National Association of Testing Authorities (NATA) is the recognised national accreditation authority for analytical laboratories and testing service providers in Australia.
NCC	National Construction Code
NH_3	Ammonia
NO	Nitrogen monoxide
NO2	Nitrogen Dioxide
PIR	Polyisocyanurate
PPE	Personal Protective equipment
PPM	Parts per million
PU	Polyurethane

RMIT	Royal Melbourne Intitute of Technology
SO2	Sulphur dioxide
STP	Standard atmospheric temperature and pressure conditions
TCC	Timber composite cladding (refer to WPC)
TGA	Thermo-gravimetric analysis
TOC	Total organic Carbon (TOC)
WPC	Wood Polymer Composite

4 Test Specimens

4.1 Specimen materials

4.1.1 CLADDING

The following table details the different cladding specimens tested in this series. The cladding material ID is used identify each of the 4 cladding types tested in this report in an abbreviated form. The CSIRO specimen number is the same specimen number used for cone calorimeter and materials characterization testing on these materials which is presented in separate CSIRO test reports.

Table 3 Cladding specimens

Cladding material ID	CSIRO Specimen number	Description	
ISP-01	FE3153-10	Product name	Not Disclosed
		Manufacturer or Supplier	Not Disclosed
		Material composition[1]	Steel faced insulated sandwich panel. Core material = Polyisocyanurate (PIR) Steel facing material = 0.5 mm thick steel sheet with white surface coating on front at rear of panels.
		Size and Shape	Insulated sandwich panel with tung and groove edge joints. Panel width = 1100 mm Panel thickness = 100 mm Panel length = cut to suit test installation
		Colour	Core = light yellow Steel facings = white
		Density[2]	Core = 40.0 kg/m^3
		Fire retardants	No additional fire retardant additives identified[3].
ISP-02	FE3153-11	Product name	Not Disclosed
		Manufacturer or Supplier	Not Disclosed
		Material composition[1]	Steel faced insulated sandwich panel. Core material = expanded polystyrene with fire retardant (EPS-FR) Steel facing material = 0.4 mm thick steel sheet with white surface coating on front at rear of panels.
		Size and Shape	Insulated sandwich panel with tung and groove edge joints. Panel width = 1200 mm Panel thickness = 100 mm Panel length = cut to suit test installation

		Colour	Core = White Steel facings = white
		Density[2]	Core = 13.4 kg/m^3
		Fire retardants	Core Assumed to be Hexabromocyclododecane (HBCD)[4]
WPC-01	FE3153-3	Product name	Not Disclosed
		Manufacturer or Supplier	Not Disclosed
		Material composition	Wood polymer composite cladding panels, with ~90-95 mass% wood [5]. Product information indicated very low (<5%) mass% paraffin wax. Visually appears similar to Masonite or high-density fibre board.
		Size and Shape	Cladding panel with board joint/groove profile on external face . Panel width = 1196 mm Panel thickness = ~9.7 mm Panel length = 2.6 m (cut to suit test installation)
		Colour	Dark Brown
		Density (measured by CSIRO)	1.04 kg/m^3
		Fire Retardants	Note determined [6, 7].
WPC-02	FE3153-8	Product name	Not Disclosed
		Manufacturer or Supplier	Not Disclosed
		Material composition (determined based on FTIR and TGA testing by CSIRO)	Wood polymer composite cladding boards, with ~53-56 mass% wood, with balance being mostly Polyethylene [5]. The cladding boards had an external ~ 100% polyethylene shell with less than 1 mm thickness
		Size and Shape	Cladding board with shiplap profile. Board width = 156 mm Board thickness = ~7.9 mm Due to profile, front face of board is ~ 21 mm from supporting battens or studs
		Colour	WPC Core = Dark Grey WPC < 1mm external polymer shell = Brown
		Density (measured by CSIRO)	1.3 kg/m^3
		Fire Retardants	Note determined [6, 8] Note – based on mass % of wood and polyethylene, if fire retardants are present, they would be expected to be at low mass % CSIRO FTIR and TGA analysis does not directly verify the presence of Magnesium Hydroxide or Aluminium Hydroxide in the WPC specimens.

Table Notes

1. Determined based on product information and CSIRO inspection.
2. Measured by CSIRO.
3. PIR has intrinsic thermosetting and char forming characteristics.
4. HBCD fire retardant is typical for EPS-FR. CSIRO has not conducted testing to verify HBCD presence or quantify amount for EPS-FR core.
5. Determined based on FTIR and TGA testing by CSIRO
6. CSIRO FTIR and TGA analysis does not directly verify the presence of Magnesium Hydroxide or Aluminium Hydroxide or other fire-retardant additives in WPC specimens. Particularly where such fire retardants may be present in low mass %.
7. For WPC-01, based on the very high mass % of wood, it is not expected that the is any significant quantity of fire retardant additives for this WPC.
8. For WPC-02, based on mass % of wood and polyethylene, if fire retardants are present, they would be expected to be at low mass %

4.1.2 OTHER MATERIALS

The test sponsor instructed that the façade cavity behind the cladding was not to include sarking or thermal insulation and was to generally consist of non-combustible products (other than the cladding material). This approach was intended to observe the performance of the cladding material without contribution from cavity materials during testing.

The following other materials were installed/used as part supporting test rig and installed façade specimen systems tested. Note that not all of these products were installed in every test – see specimen installation section for further details.

Table 4. Other Materials/product details

Product	Trade name	Manufacturer	Description	Nominal Density
Sealant	[redacted]	[redacted]	Polyurethane construction sealant. Grey in colour	1.25 kg/L
Backing rod	[redacted]	[redacted]	Closed cell polyethylene foam backing rod/gap filler. 10 mm diameter. White in colour	Not measured.
13 mm Fire resistant plasterboard	[redacted]	[redacted]	13 mm thick paper faced fire resistant plasterboard. Gypsum plaster with glass fibre re-enforcement. Note – Plaster board is not non-combustible but may be used wherever a non-combustible material is required (NCC DtS). Based on test results the paper facing of the plaster board is not considered to have contributed to fire spread (in most cases the paper facing within the specimen cavity had been previously burnt during characterisation tests and/or previous specimen tests.	10.5 kg/m^2

Product	Trade name	Manufacturer	Description	Nominal Density
12 mm Plywood	[redacted]	[redacted]	2400 x 1200 x 12mm Non Structural Plywood	Not determined.
Mineral wool blanket	[redacted]	[redacted]	25 mm thick white mineral wool blanket. Non-Combustible	96 kg/m^3
Rockwool cavity batts	[redacted]	[redacted]	Non-combustible rockwool insulation batts, 100 mm thick x 1.2 m long x 168 mm wide.	75 kg/m^3
Steel studs	[redacted]	[redacted]	Steel stud. 1.15 BMT. 92 mm width. 36 mm depth, Various Lengths	1.52 kg/m
Steel stud track	[redacted]	[redacted]	Steel stud track. 1.15 BMT. 92 mm width. 36 mm depth, Various Lengths	
Steel Battens	[redacted]	[redacted]	Steel Top Hat 50 x 50mm High x 1.15 BMT. Various Lengths	1.93 kg/m
Steel channel capping	[redacted]	[redacted]	Zincalume coated Steel “C” Channel. 0.4 mm thick x 100mm x 50 mm. Various lengths	Not determined.
Aluminum angle	[redacted]	[redacted]	Various widths/heights. Thicknesses ranged from 1.4 mm to 1.6 mm. These were used to cover (cap) the bottom edge of the installed specimen for some tests with the aluminium angle width extending to the front face of the installed cladding. Where needed, larger width aluminium angle products were cut to the required width.	Not determined
Plasterboard screws 8G x Various lengths	[redacted]	[redacted]	Bugle head plasterboard screws. 8G x various lengths including 30 mm , 50 mm and 75 mm	Not determined.
Hex head Metal screws	[redacted]	[redacted]	Hex Head Metal self tapping screw 12G x various lengths including 35 mm and 50 mm	Not determined.
Button head metal screws	[redacted]	[redacted]	Zenith 8G x 32mm Galvanised Button Head Metal Screws. Class 3G Galvanised	Not determined.
150 mm Bugle head screws	[redacted]	[redacted]	Bugle head 4G - 8 x 150mm Class 3 Galvanised Bugle Batten Screws - 100 Pack	Not determined.

Product	Trade name	Manufacturer	Description	Nominal Density
150 mm screws Hex Hed	[redacted]	[redacted]	14-14 x 150 mm Hex Head self drilling metal screws	Not determined.
250 mm screws	[redacted]	[redacted]	8 - 7 x 250mm Landscaping Construction Screw	Not determined.
Steel angle plaster trim	[redacted]	[redacted]	Zincalume coated 28 x 2400mm Utility Angle Plaster Trim. 0.3 mm thick steel angle	
Steel "L" flashing	[redacted]	[redacted]	Zincalume coated Steel angle, 0.4 mm thick and either 50mm x50 mm or 100mm x 50 mm. Cut to 1.5 m lengths and trimmed to required width to be inserted into joint edges of ISP and partially cover the ISP core with an ~ 20 mm width of ISP core remaining exposed.	Not determined.

4.2 Specimen Installation

The cladding system test specimens were supported by a specimen support frame to simulate an external wall cavity behind the cladding, the cladding support frame and to provide a fire-resistant backing. The specimen support frame consisted of:

- Back wall – 1.5 m wide x 3.0 m high
- Two wing walls – 1.0 m wide x 3.0 m high each

See Section 5 for details of specimen support frame.

Each cladding system test specimen was installed to a back wall over an area of 2.6 m wide x1.5 m wide (or 1.3 m wide for some tests). They were all installed so that the bottom edge of the cladding system was 400 mm above the test lab floor.

Generally:

- Where cladding was installed oriented horizontally, cladding was installed directly to supporting studs (without battens),
- Where cladding was installed oriented vertically, cladding was installed to supporting studs with horizontal battens.

Multiple back walls were constructed so that multiple test specimens could be prepared simultaneously in batches to increase test preparation efficiency and reduce time between tests. The test specimens were installed on the back walls outside of the test hood prior to testing (in other areas of CSIRO Clayton Laboratories). Each specimen mounted to back wall was then lifted into position under the test hood and the two wing walls were screw fixed (hex head metal screws) to each side of the back wall.

The following table summarises the specific installation details for each test.

Table 5. Summary of specimen installation details for each test.

Test No	Cladding Material	Sample size	Installation detail
Test 01	WPC-01 (~90-95% wood) With open cavity	2600 mm x 1500 mm	• Vertical studs and horizontal battens located within wall cavity to support cladding. • WPC-01Cladding panels installed vertically with external groove profile oriented vertical. Two cladding panels, one ~ 1.2 m wide x 2.6 m high and one ~0.3 m wide x 2.6 m high, were installed with a vertical but joint between the two panels. The vertical but joint was on the right side of specimen. • Cladding was screwed battens with button head metal screws located at 300 mm centres along each batten • Bottom edge of cladding covered by 35 x 35 x 1.4 mm Aluminium angle, located against the bottom edge of the cladding panels and against the front face of the FR-plasterboard (covering the bottom 400 mm of studs/cavity). Aluminium angle was screw fixed through FR-plasterboard into each steel stud behind with hex head metal screws • A 140 mm deep open air cavity created by the studs and battons between cladding and fire-rated plasterboard lining of backwall. • No insulation, sarking or other materials installed to cavity. The top of the cavity (at top of specimen) remained open. • Left and right edges of cladding were butted against the wing walls. • ~ 150 mm wide strips of 13 mm thick FR-Plasterboard were positioned on the wing walls with the 13 mm thick edges butted against the front face of the cladding, and fixed with plaster screws, to seal the edges of the cladding
Test 02	WPC 01 (~90-95% wood) With open cavity	2600 mm x 1500 mm	Same as for Test 01
Test 03	WPC-02 (~53-56% wood) With open cavity	2600 mm x 1500 mm	• Vertical studs and horizontal battens located within wall cavity to support cladding. • WPC-02 Cladding boards with shiplap profile installed vertically with external groove profile oriented vertical. • First cladding board installed at Left side backwall with board edge butted against wing wall. Left side of first cladding board was screwed to battens with button head metal screws so the button heads were exposed on front of cladding. The right side of first cladding board was screwed to battens with button head metal screws located withing shiplap groove so that the next board would cover the screw heads. • The left side of next cladding board was clipped into the shiplap profile of the previous board, with only the left side of the next cladding board being screw fixed to battens by button head screws located in shiplap groove. This installation process was repeated until cladding boards were installed across entire width of specimen. • Bottom edge of cladding covered by 50 x 50 x 1.6 mm Aluminium angle trimmed so that the edge capping the cladding was level with front of cladding (~46 mm wide). The angle was located against the bottom edge of the cladding panels and against the front face of the FR-plasterboard (covering the bottom 400 mm of studs/cavity). Aluminium angle was screw fixed through FR-plasterboard into each steel stud behind with hex head metal screws • A 140 mm deep open air cavity created by the studs and battens between cladding and fire-rated plasterboard lining of backwall. • No insulation, sarking or other materials installed to cavity. The top of the cavity (at top of specimen) remained open. • Left and right edges of cladding were butted against the wing walls. • ~150 mm wide strips of 13 mm thick FR-Plasterboard were positioned on the wing walls with the 13 mm thick edges butted against the front face of the cladding, and fixed with plaster screws, to seal the edges of the cladding

Test No	Cladding Material	Sample size	Installation detail
Test 04	WPC-01 (~90-95% wood) No Cavity	2600 mm x 1500 mm	Installed the same as for Test 1 except for the following changes • 2 x 13 mm layers of FR Plasterboard were screw fixed (plaster board screws) to battens covering the 2.6 m H x 1.5 m W area where cladding was to be mounted • WPC-01Cladding panels were screw fixed (Hex head metal screws) with the rear face of the cladding panels in contact with the FR Plasterboard so that there was no cavity directly behind the cladding panels. • WPC-01 cladding panels were oriented and sized the same as test 01 with screw fixings at 300 mm spacing along each batten (screwed through the 2 x plasterboard layers behind cladding and into the steel studs) • Bottom edge of cladding covered by 60 x 50 x 1.6 mm Aluminium angle, located against the bottom edge of the cladding panels and against the front face of the FR-plasterboard (covering the bottom 400 mm of studs/cavity). Aluminium angle was screw fixed through FR-plasterboard into each steel stud behind with hex head metal screws • No insulation, sarking or other materials installed behind cladding. • Left and right edges of cladding were butted against the wing walls. • ~ 150 mm wide strips of 13 mm thick FR-Plasterboard were positioned on the wing walls with the 13 mm thick edges butted against the front face of the cladding, and fixed with plaster screws, to seal the edges of the cladding n.
Test 05	WPC-01 (~90-95% wood) Cavity barrier	2600 mm x 1500 mm	Installed the same as for Test 1 except for the following changes • WPC-01 cladding panels were oriented, sized and fixed the same as test 01, except the vertical butt joint between the two panels was located on Left side. • Cladding installed with studs & Battens behind resulting in a 140 mm wide air cavity behind, same as for Test 01, Except that a cavity barrier detail was installed to the cavity at the top of the specimen. • 92 mm wide steel stud sections were cut to correct length and inserted horizontally between the vertical studs located directly between the top most Batten and the Back wall. This was then screw fixed into place (hex head metal screws)both from the front/top of the batten and from the rear of the Backwall. This was installed prior to the cladding. This was intended to provide support to rockwool cavity barrier • During cladding install, Rockwool cavity batts were located at the top of the cavity directly above the top most batten with the 168 mm batt width oriented horizontally. As cladding was screwed in place the rockwool was compressed to seal the top of the cavity between the rear of the cladding and the back wall. • The bottom edge of the cladding specimen was capped with aluminium angle same as for Test 01. • Two 13 mm thick FR-Plasterboard strips ranging from 100-150 mm wide were positioned on the wing walls with ~ 100 mm wide strips of mineral wool blanket compressed between the edges of the plasterboard strips butted against the front face of the cladding, and fixed with plaster screws, to seal the edges of the cladding. (Note mineral wool was added to improve protective seal at edge of cladding, However, premature edge burning edges of the installed cladding was not observed in any of the previous tests.
Test 06	ISP-01 (PIR) Vertical Uncapped edges No additional screw fixing to panel joints Open cavity	2600 mm x 1500 mm	• Vertical studs and horizontal battens located within wall cavity to support cladding. • Two ISP-01 Cladding panels installed vertically tung and groove panel joint oriented vertical. The outside edges of the two panels were cut longitudinally so that the vertical tung and groove panel joint was located at the centreline of the specimen. • The panel with the "Male" panel joint was located on the left side of the specimen and was installed first. Single 150 mm bugle head screws located at the panel joint groove fixing at a slight ~10° angle through both the front and rear ISP metal facings into each Batten. This was

Test No	Cladding Material	Sample size	Installation detail
			located so that the heads of these screws would be hidden when the female profile of the next panel joint was pushed into place. • The 2nd ISP panel with female panel joint profile was pushed into place. The interlocking joint profile was used to retain this edge of the 2nd panel without any additional fasteners along this edge. • 150 mm Hex head screws were installed along the outer vertical edge of the two panels with a single screw at each batten location fixing through both the front and rear ISP metal facings into each Batten. These screws were located ~ 30 mm from the outer edge of the panels so that the screw heads were covered by mineral wool blanket specimen edge protection (when installed • There was no other screw fixing of the ISP panels along panel joints etc. • An ~ 10 mm bead of sealant was applied along the external surface of the vertical tung and groove panel joint. • Bottom edge of cladding covered by 125 mm wide x 1.6 mm Aluminium strip with 25 x 25 x 1.6 mm aluminium angle overlapping the rear edge of the strip located against the bottom edge of the cladding panels and against the front face of the FR-plasterboard (covering the bottom 400 mm of studs/cavity). Hex head metal screws were driven through the Aluminium angle and aluminium strip into the steel batten located directly above the rear edge of this aluminium capping. Screws were located at ~ 370 mm spacing. This created an ~ 6 mm air gap between the base of the ISP panel and the aluminium capping. • Backing rod was compressed ~ 10 mm in from the front of the above air gap and a bead of sealant was applied to seal this gap. was screw fixed through FR-plasterboard into each steel stud behind with hex head metal screws • A 140 mm deep open air cavity was created by the studs and battons between cladding and fire-rated plasterboard lining of backwall. • No insulation, sarking or other materials installed to cavity. The top of the cavity (at top of specimen) remained open. • The cut, uncapped Left and right edges of cladding were butted against the wing walls. • Two 13 mm thick FR-Plasterboard strips ranging from 100-150 mm wide were positioned on the wing walls with ~ 100 mm wide strips of mineral wool blanket compressed between the edges of the plasterboard strips butted against the front face of the cladding, and fixed with plaster screws, to seal the edges of the cladding. • The cut, uncapped top edges of the ISP panel were left with the core material exposed.
Test 07	ISP-02 (EPS) Vertical Uncapped edges No additional screw fixing to panel joints Open cavity		Installation detail was the same as for Test 06 except that ISP-02 with EPS core was installed.
Test 08	ISP-01 (PIR) Horizontal Capped edges Additional screw fixing to panel joints Open cavity	2600 mm x 1300 mm	Note - All ISP was obtained cut to 2.6 m lengths as it was originally intended to install all ISP tests with panels oriented vertically. After observation of Test 06 and Test 07, CSV requested Test 08 and Test 09 to be installed with ISP oriented horizontally. To do this the 2.6 m long panels were cross cut in half, resulting in 1.3 m wide specimens (rather than 1.5 m wide). • Only Vertical studs (no horizontal battens) located within wall cavity to support cladding. • Three ISP-01 Cladding panels, 1.3 m long, installed horizontally with tung and groove panel joints oriented horizontally. The 3rd (top) panel

Test No	Cladding Material	Sample size	Installation detail
			was cut to longitudinally to a width of 400 mm to achieve installed specimen height of 2.6 m. • The bottom panel was installed first with the "Male" panel joint facing upwards. Single 150 mm bugle head screws were located at the panel joint groove fixing at a slight ~10° angle through both the front and rear ISP metal facings into stud. This was located so that the heads of these screws would be hidden when the female profile of the next panel joint was pushed into place. • The 2nd ISP panel with female panel joint profile facing down was pushed into place. The interlocking joint profile was used to retain this edge of the 2nd panel without any additional fasteners along this edge. 150 mm bugle head screws were used to fasten along top panel joint goove of 2nd panel same as for 1st panel. • The 3rd (400 mm wide) ISP panel with female panel joint profile facing down was pushed into place. • Steel channel capping was installed to cover the ISP core along the top, bottom and both sides of the installed specimen. This was screw fixed (button head metal screws) at 300 mm spacing from the external (front) side through the capping and into the steel external side ISP facing only. • Hex head metal screws were applied at the left and right sided of the installed ISP Panels with screws locate ~ 30 mm from the panel edge fastening through the steel capping, through both the front and rear ISP facings and into the steel stud behind. Three hex head metal screws were used at left and right sides of panels 1 and 2. Two hex head metal screws were used at left and right sides of panel 3 • Button head metal screws were installed at 300 mm spacing along the external/front face of each panel tung and groove joint so that the screws fastened the overlapping external/front metal facings together • There was no other screw fixing of the ISP panels from the rear/cavity side as this side was not accessible. • A ~ 10 mm bead of sealant was applied along the external surface of the Horizontal and groove panel joints. • No aluminium angle installed to bottom edge of the specimen as the steel capping encapsulated the bottom edge • A 92 mm deep open air cavity was created by the studs between cladding and fire-rated plasterboard lining of backwall. • No insulation, sarking or other materials installed to cavity. The top of the cavity (at top of specimen) remained open. • The cut, uncapped, left and right edges of cladding were butted against the wing walls. • To fill the 100 mm gap between the edges of the specimen and the wing walls, rockwool cavity batt was compressed into the gap level with the front of the specimen. A 2.4 m long steel angle plaster trim was screw fixed (plaster screws) to each wing wall level with the front of the installed specimen to retain plasterboard strip. A 150 mm wide FR plasterboard strip was placed over the rockwool filled gap, covering the gap and overlapping the edge of the specimen by 50 mm. Mineral wool blanket was compressed between the plasterboard and the 50 mm overlapped, edge of the specimen. ~ 5 x 250 mm screws where driven through the covering plasterboard strips, through the rockwool and into the Backwall (not through the ISP) to retain the protective filler in place.
Test 09	ISP-02 (EPS) Horizontal Capped edges Additional screw fixing to panel joints	2600 mm x 1300 mm	Installation detail was the same as for Test 08 except that ISP-02 with EPS core was installed.

Test No	Cladding Material	Sample size	Installation detail
	Open cavity		
Test 10	ISP-01 (PIR) Vertical Capped edges Additional screw fixing to panel joints Open cavity	2600 mm x 1500 mm	Installation detail was the same as for Test 06 except that: • Steel channel capping was installed to cover the ISP core along the top, bottom and both sides of the installed specimen same as for Test 08, and • Button head metal screws were installed at 300 mm spacing along the external/front face of each panel tung and groove joint same as for Test 08. ISP-02 with EPS core was installed.
Tests 11	ISP-01 (PIR) Horizontal Steel flashing partially covering core at panel joints Capped edges Additional screw fixing to panel joints Open cavity	2600 mm x 1500 mm	Installation detail was the same as for Test 08 except that: • ISP cut to a panel length of 1.5 m was procured to enable the total installed specimen width to be 1.5 m wide. • Prior to installing ISP, Steel “L” flashing was inserted along the male and female tong a groove profile panel edges so as to partially cover the internal core along these edges, leaving an ~ 20 m width of exposed core between the steel “L” flashing and the rear (cavity side) rolled edge of the rear facing steel joint profile. These Steel L Flashings were screw fixed with Button head metal screws at 300 mm (inset ~ 25 mm from the rolled joint profile) by driving the screws through from the external steel face of the ISP into the Steel “L” flashing inserted into the core. • As the installed specimen was 1.5 m wide there was no gap between the edges of the installed specimen and the wing walls. The edges of the specimen were protected by installing plasterboard strip and mineral wool blanket strip same as for Test 06.
Test 12	ISP-02 (EPS) Horizontal Steel flashing partially covering core at panel joints Capped edges Additional screw fixing to panel joints Open cavity	2600 mm x 1500 mm	Installation detail was the same as for Test 11 except that ISP-02 with EPS core was installed.
Tests 11	ISP-01 (PIR) Horizontal Steel flashing partially covering core at panel joints Capped edges Additional screw fixing to panel joints Open cavity	2600 mm x 1500 mm	Test 11 was a repeat of Test 10. The installation detail was the same as for Test 10.

The specimen materials and installation details tested were as instructed by CSV.

The cladding specimens are installed as a single flat wall (to the back wall only) rather than a right-angle wing wall arrangement (as per ISO 13785-1).

The ~250 mm height gap between the fire source and the bottom of the installed panel has been included:

1. To simulate the bottom edge of cladding at openings in the wall such as windows, doors or balcony overhangs.
2. A 250 mm gap between fire source and test panel is specified in ISO 13785:2002 Part 1.
3. The 250 mm gap enabled the selected fire source to achieve direct flame impingement and heat exposure to the specimen panel base.
4. A gap significantly higher than 250 mm would not enable the test rig to fit beneath the test hood without reducing the total height of installed cladding panel.

[redacted] polyurethane sealant was selected for the sealant to be used following reasons:

1. This is type of sealant product is commonly used on cladding panel installations.
2. The fire performance of sealant caulking can differ significantly between fire resistant sealant, silicone based sealants and PU based sealants.
3. PU based sealants can have poor fire performance and may potentially support localized fire spread on the sealant along the vertical joint in the test. However, due to the limited quantity of caulking sealant typically installed to buildings, fire spread limited to caulking/sealant does not typically present an undue risk to life safety or exit.
4. The intention is to test the fire behavior of the sandwich panels, not the sealant. However, sealant has been installed to joints for the test so as to represent the installation to the actual building.
5. When the tongue and groove joint is pressed together it achieves a metal-on-metal seal with minimal gaps and no exposed core on the exposed side of the joint.

The ~ 1.5-1.6 mm thick aluminium bottom edge channel detail was selected for the following reasons:

1. Channels or transoms would typically be installed to seal the exposed edge of sandwich panel cladding.
2. A broad variety of different channel/transom details could be used on different building designs. However the 1.5 mm thick capping channel selected is typical of cool room installations.
3. The type of material and thickness of material may impact the likelihood of exposure of the sandwich panel core at the base of the specimen during the test. Aluminium, is more likely to melt away and expose the core compared to steel.
4. 1.5 mm thick aluminium capping has been selected and a reasonable worst case which will be likely to melt away and expose the core to some degree during tests. The same capping type will be used for tests on all typed of sandwich panel so differences in the performance of the exposed core can be observed.

CSV Stated the following reasoning for installing steel flashing to partly cover the sandwich panel core internal to sandwich panel joints:

- It was observed that some ISP cladding panels can have a more pronounced, overlapping rolled tung and groove panel joint profile, as per x below. In these joint profiles the width of exposed core material can sometimes be significantly less than the total panel width, due to the rolled steel facings at the panel edge.
- The sandwich the panels that were obtained for this series of testing, had edge where the width of core material expose at the panel edges was the majority of the core width.

- CSV requested for tests 11-13 that steel flashing be inserted to panel joints to reduce the exposed core at panel edges to ~ 20 % in order to simulate the exposed area of core typical of the joint profile shown in Fig 1 below
- It is acknowledges that this inserted flashing does not fully simulate all aspects of the fire performance of the joint and fixing profile shown in Fig 1 below. This inserted flashing was applied to tests 11-13 as panel products with the edge provide shown in Fig 1 below were not obtained at the time of testing

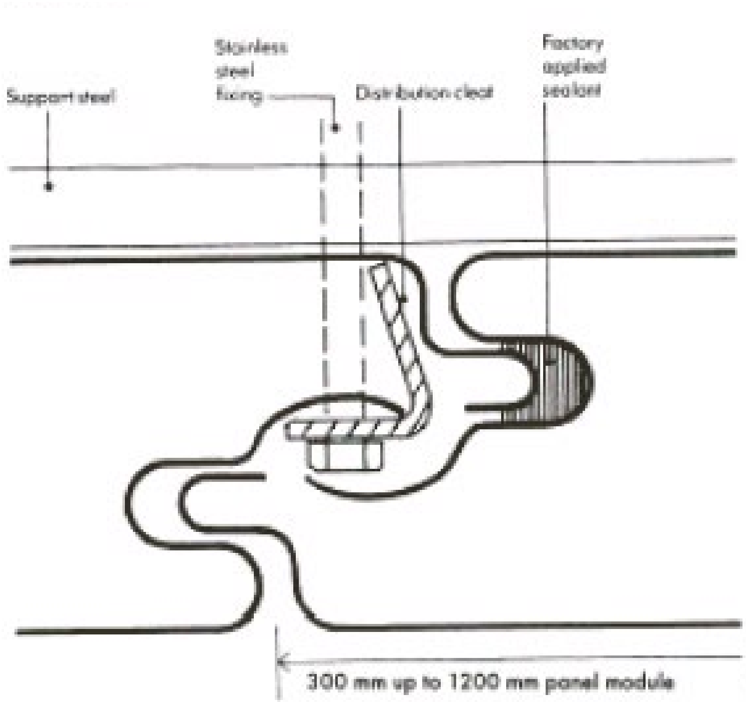


Figure 1. More pronounced, overlapping rolled tung and groove panel joint profile observed for some cladding insulated panels (not tested)

Figure 2. ISP-01 (PIR) sandwich panel joint profile with Steel "L" flashing installed to edge joints.

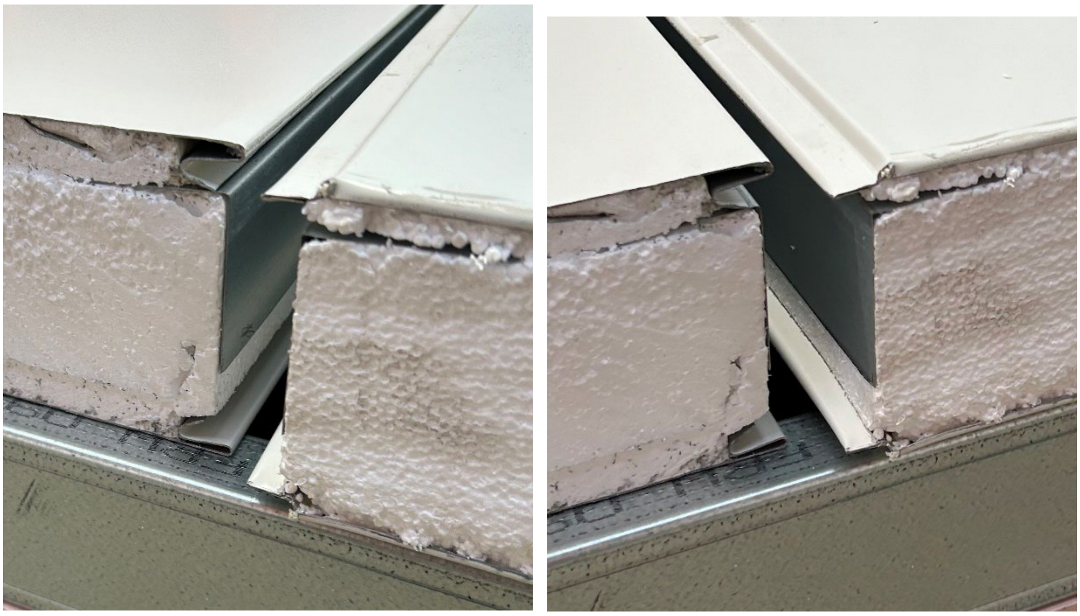


Figure 3. ISP-02 (EPS) sandwich panel joint profile with Steel "L" flashing installed to edge joints.

4.3 Specimen conditioning

All specimens were prepared and stored indoors within the CSIRO test lab at dry ambient laboratory conditions from the time they were received until the time they were tested (which varied from 2 weeks to >1 month). All specimens were observed to be unaffected by weathering or excess moisture or water exposure. No conditioning of test specimens at a prescribed controlled environmental temperature and humidity was undertaken as this was not practical given the size of the specimens.

5 Test Equipment

5.1 CSIRO Intermediate scale fire test hood

The intermediate scale fire tests were conducted at CSIRO Fire Laboratory, North Clayton, Melbourne.

Tests were conducted within a fire test hood of 2.4 m x 2.4 m perimeter. The bottom edge of the test hood is 2.2 m above laboratory floor level and the height at which the hood begins to diagonally slope to the exhaust point is 3.15 m above lab floor level.

The exhaust hood and exhaust duct are installed with instrumentation for collecting products of combustion and measuring HRR and smoke (see below for more details). The combustion gases that enter the hood, pass through a wet scrubber pollution control system to remove smoke and gas contaminants before being released into the atmosphere.

The test exhaust hood is capable of fire sizes up to at least 1 MW.

Exhaust flow rate is adjustable from ~0.0-3.0 m^3/s at STP.

For all HRR calibration, Characterization and Specimen tests the test hood was operated in the range 2.0-2.5 m^3/s at STP.

At the time of these tests the hood is capable of testing specimens up to a maximum size of ~ 2 m wide x 3 m high.

5.2 Specimen support frame

5.2.1 BACK WALL AND WING WALLS

The cladding system test specimens were supported by a specimen support frame to simulate an external wall cavity behind the cladding, the cladding support frame and to provide a fire-resistant backing.

The Specimen support frame was designed as 'C' shaped structure that consists of:

- A back/rear wall 1500 mm internal width x 3000 mm high. The purpose of the back wall is to provide a fire-resistant supporting wall to mount the sample test panel system.
- Two wing walls 1000 mm internal width x 3000 mm high. The purpose of the two wing walls is to:
  - Minimize air entrainment from sides and direct air entrainment to the ignition source from the front. This promotes ignition source flames to impinge directly upon the base of the installed cladding panels (rather than flames rising directly upwards or leaning outwards and not impinging directly on panels).
  - Provide stability against the test rig tipping over when fully assembled.
- The back wall and wing walls are constructed using 92mm (1.15 BMT) steel stud and track wall framing fixed at 600 c/c spacing. The exposed sides of these frames were lined with:
  - 1 x layer 12 mm plywood. This provides bracing and enables easy screw fixing at any location into the plywood.
  - 2 x layers 13 mm fire resistant plasterboard.
- The specimen support frame stands on the laboratory floor within the test hood.
- The specimen cladding systems were installed to the rear wall only (not to the wing walls).
- The wing walls are screw fixed to each side of the back wall. The wing walls were detachable so that multiple back walls can be pre-installed with cladding specimens (In batches) away from the test hood area and then each back wall with specimen installed is lifted into position within the test hood and the wing walls re-attached for each test.

Although the paper facing of the fire-resistant plasterboard is combustible, FR Plasterboard was used to line the inside of the rig, due to the following:

- The paper facing will be burnt away in area of direct fire source impingement during fire source calibration tests (final fire source test will be repeated to show results without any paper facing interaction).
- In CSIRO's experience of past testing, the paper facing is unlikely to enhance fire spread and it represents a very small fuel load.
- FR plasterboard is readily available and easy to work. Calcium silicate board is less readily available and is harder to work with.
- Both CSV and CSIRO agreed to proceed with FR plasterboard rather than Calcium silicate board, or any other non-combustible board lining.

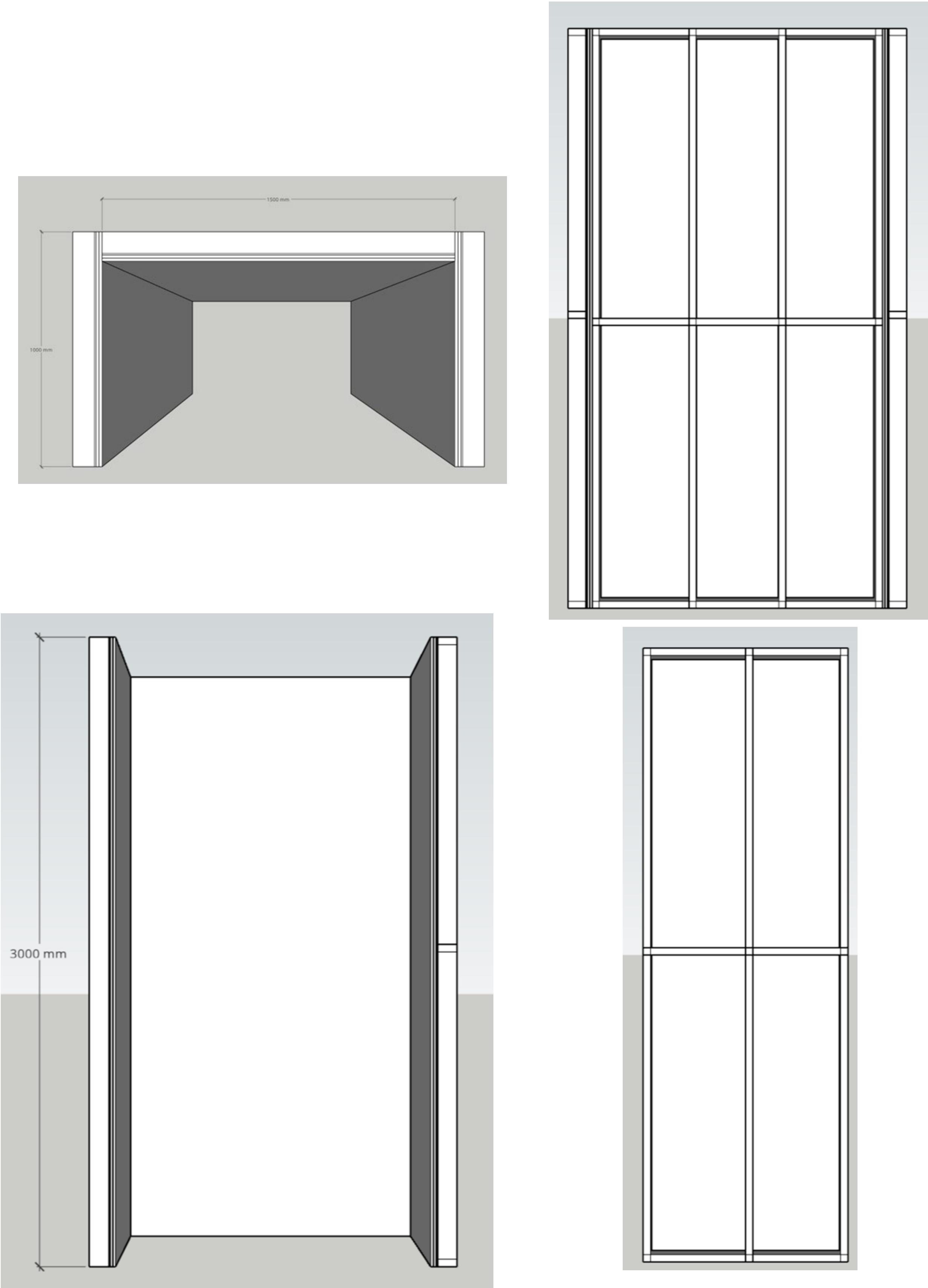


Figure 4. Specimen support back and wing walls plan, Rear elevation, Side elevation and front elevation (clockwise from top left)

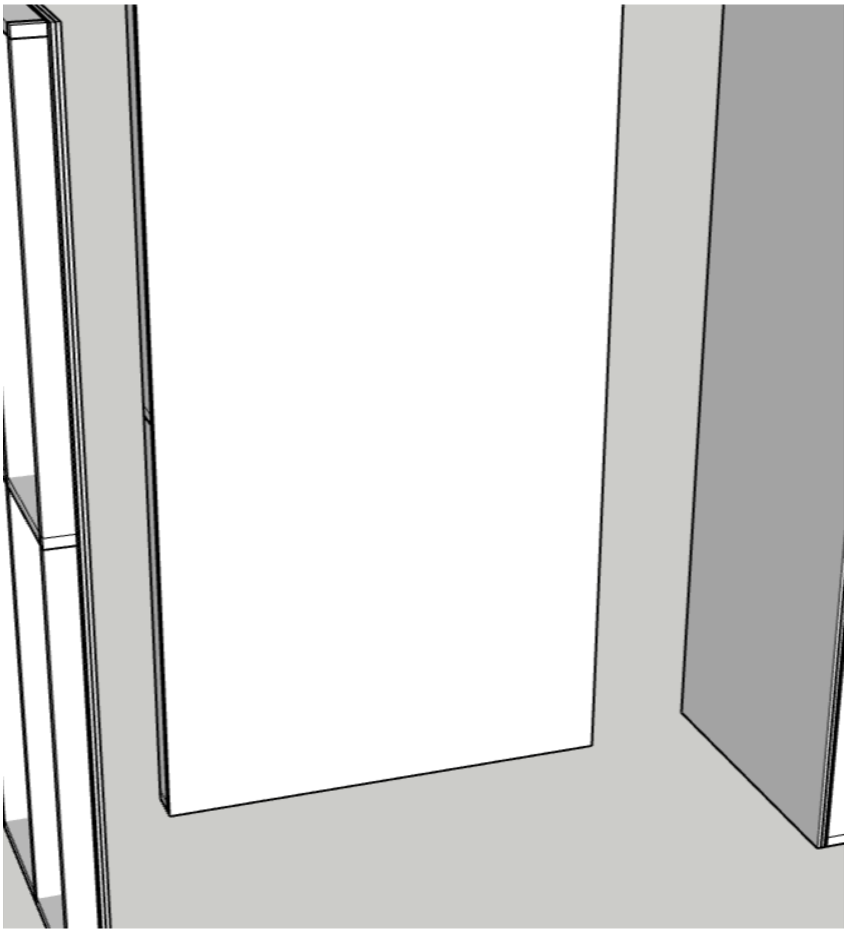


Figure 5 Back wall with wing walls detached.

Fire source characterization tests were conducted on the bare plasterboard wing and back walls without studs, battens or test specimens installed in front of the plasterboard..

5.2.2 SPECIMEN SUPPORT STUDS AND BATTENS

The specimen cladding was installed with a supporting cavity framework of studs and battens (in front of the plasterboard lined back wall) to simulate the cavity behind the cladding on the subject building. This includes:

- Four evenly spaced 92 mm wide steel studs (1.15 BMT) screw fixed to the plasterboard & plywood lining of the back wall.
- Four 50 mm deep steel top hat battens evenly spaced at 800 mm centers directly behind the specimen panels, Screw fixed to the steel studs. The bottom top hat is 400 mm above lab floor level. The Battens are only installed for cladding which is oriented vertically. In this case the cladding is directly screw fixed to the battens.
- Where specimens are oriented horizontally, no battens were installed and the cladding was directly screw fixed to the studs.
- The 2.6 m high section of cladding is installed with the bottom of the cladding 400 mm above the floor (at the bottom Batten height)
- Two layers of 13 mm FR Plasterboard are screw fixed across the bottom 400 mm x 1.5 m wide section of studs, entirely enclosing from lab floor level to bottom of cladding, to prevent flame penetration though this area into the wall cavity.

- The bottom of the cladding for each specimen test is installed with representative capping. This enables this feature to be directly exposed to flame impingement and the performance of the cladding bottom edge capping to be evaluated in the test.
- No combustible insulation or sarking was specified to be installed within the wall cavity.

The specimen support frame and installed panel arrangement (for vertical ISP specimens) are shown in the figures below.

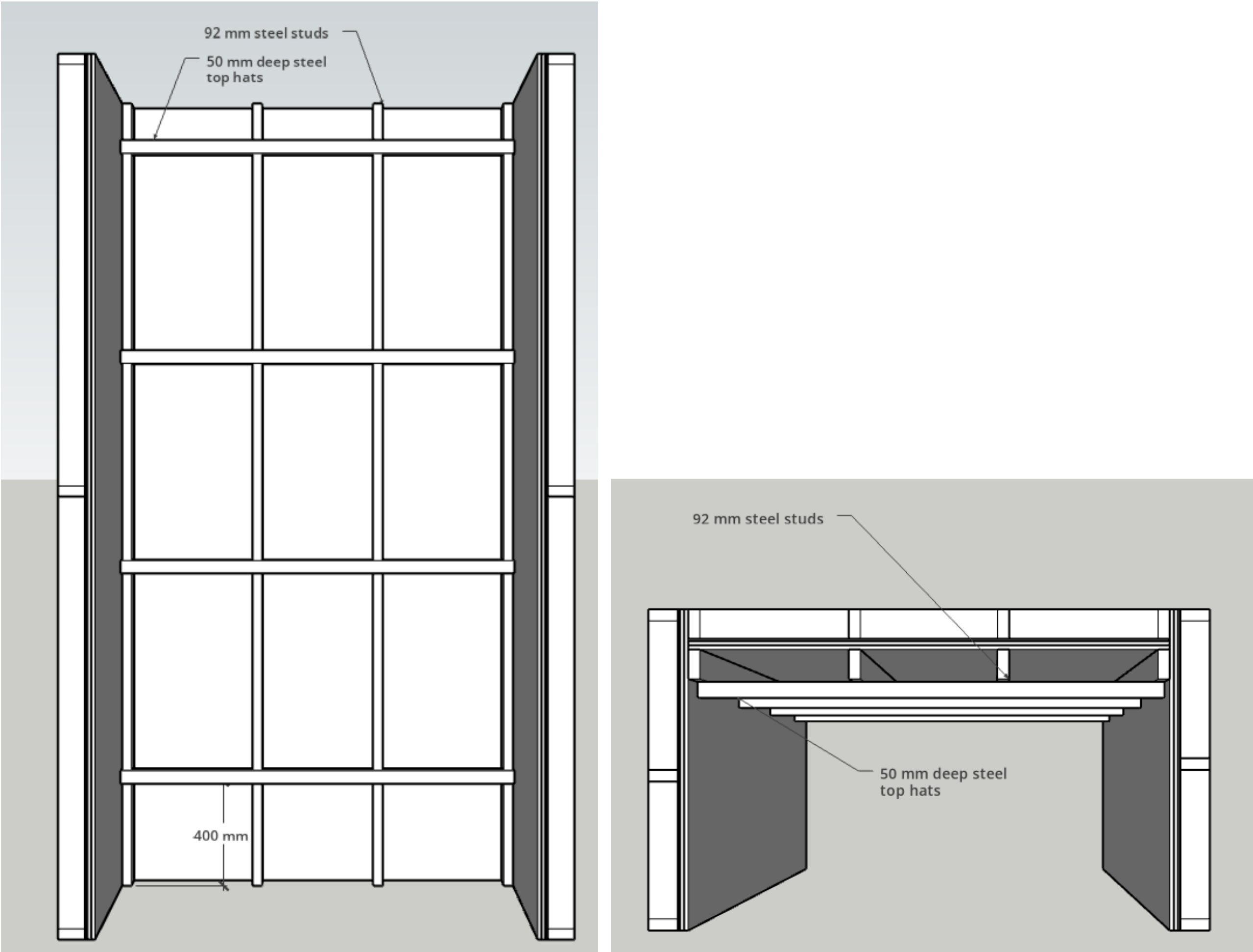


Figure 6. Front and top views of specimen support frame showing steel studs and top hat locations without specimen installed.

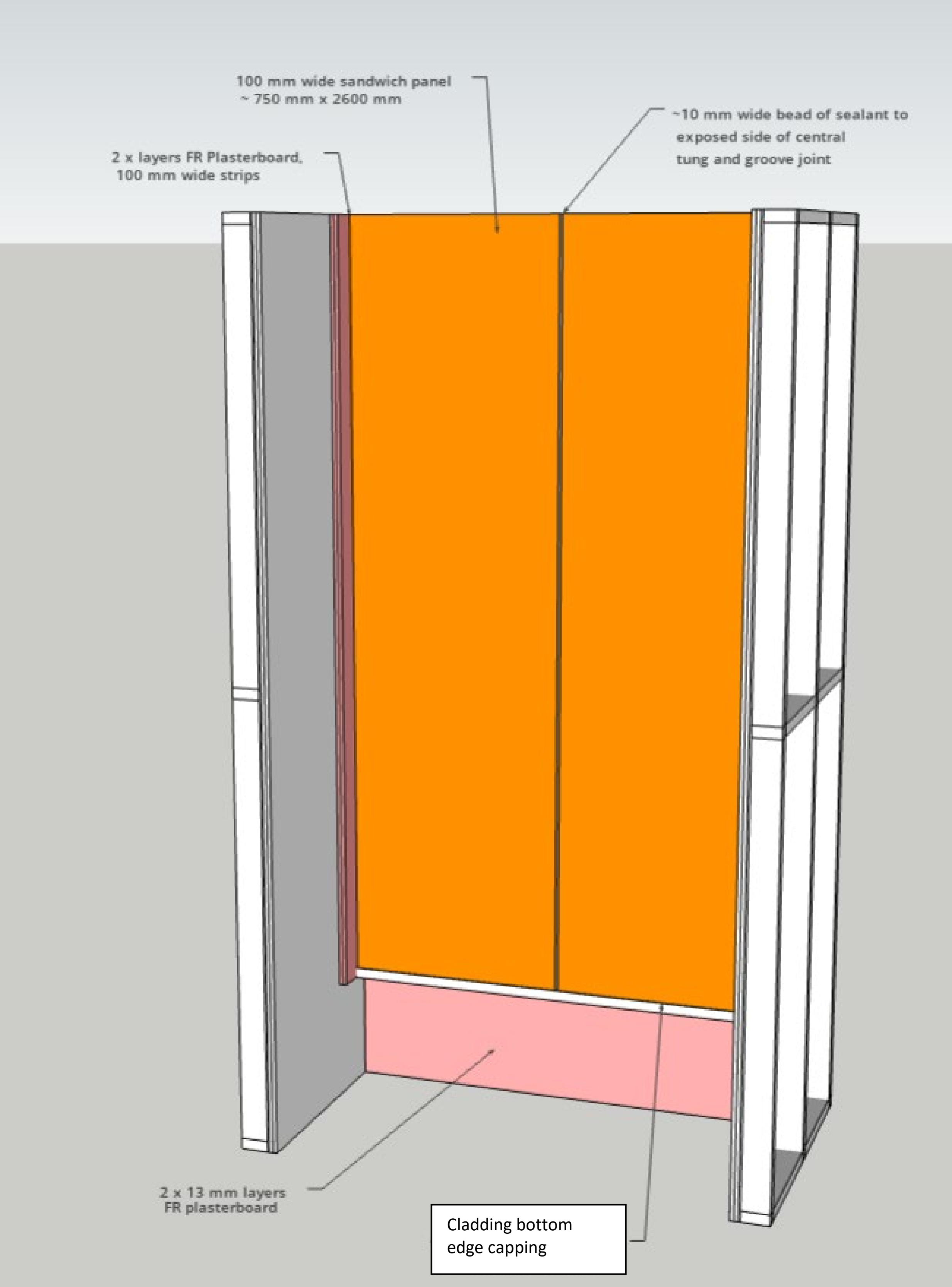


Figure 7. 3-Dimensional drawing of sandwich panel specimen installed to test rig

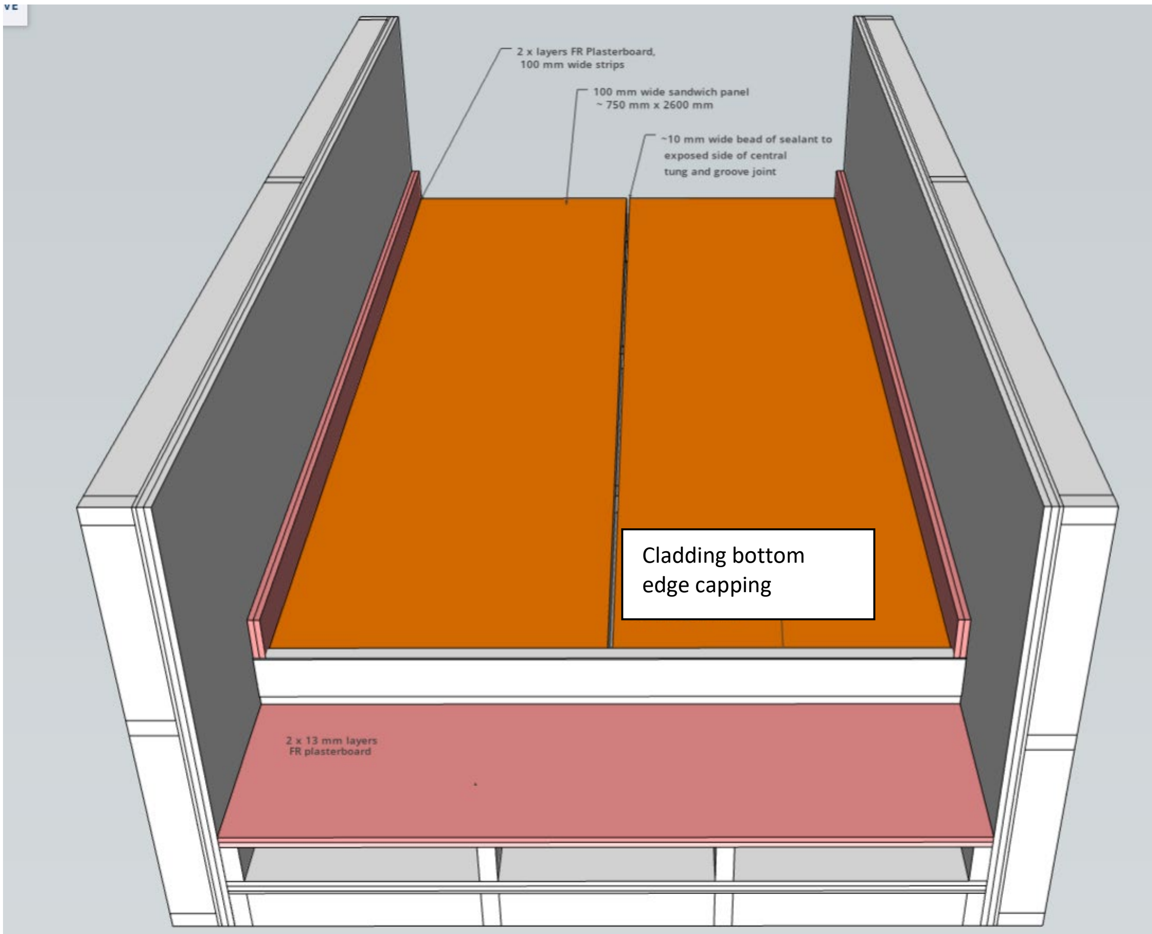


Figure 8. Bottom view of sandwich panel specimen installed to test rig

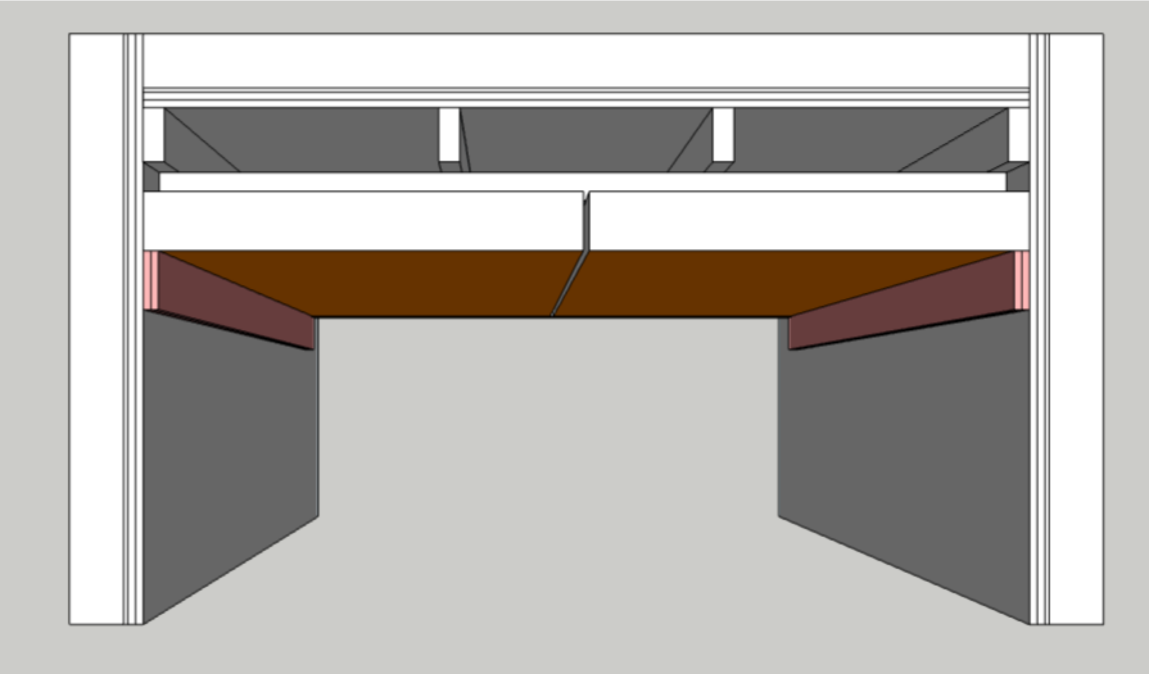


Figure 9. Top view of sandwich panel installed to test rig

5.3 Specimen lifting rig

Building and testing each specimen individually and sequentially within the test hood (which has limited space/height) is the conventional way that CSIRO has done similar past intermediate -scale fire tests where there is only 1-3 tests to be completed. Time required to build, instrument, cure sealants prior to test and demolish after test would typically limit such a sequential testing rate to approximately 1 test every 1-2 weeks.

Pre-preparing batches of specimens external to the test hood was more efficient for a large series of repeat tests and enabled multiple tests to be completed per week, once testing commenced.

As the test hood has a lower edge height of 2.2 m and the test specimens have a standing height of ~ 3 m. the specimens were not be able to be wheeled into the test hood in an upright orientation.

Instead, the specimens where pre-built on the rear wall support frame laying horizontally. The specimen rear wall was then wheeled into the test hood in a horizontal orientation, without the wing walls attached, and then lifted/tilted up into a vertical standing orientation. The wing walls where then attached which stabilizes/supports the specimen in the test rig in its vertical/standing test orientation.

The specimen rear walls installed with 100 mm thick steel faced sandwich panel are estimated to have a mass of ~250 kg (due mainly to the mass of the supporting frame and layers of plasterboard and plywood). The same rear wall panel specimens fitted with a 75 mm thick Hebel aerate concrete façade would be estimated to have a mass of ~ 350 kg. The wing walls not fitted with any cladding are estimated to have a mass of ~ 65kg each.

It was not appropriate or safe to do repeat manual handling to lift/tilt up to 12 rear wall test specimens in/out of the test hood without a mechanical lifting aid.

CSIRO has designed and built a lifting frame which was permanently located within the test hood for the duration of the tests and used to lift the specimens in and out of the test hood. The wing walls when detached from the back wall were left standing, leaning and clamped against the side of the lifting frame during specimen replacement. Wing walls where re-used for multiple tests and simply re-lined with FR plasterboard when the plasterboard became too degraded after multiple tests.

The following figure illustrates the lifting frame – for mor details see plans in Appendix A of this report.

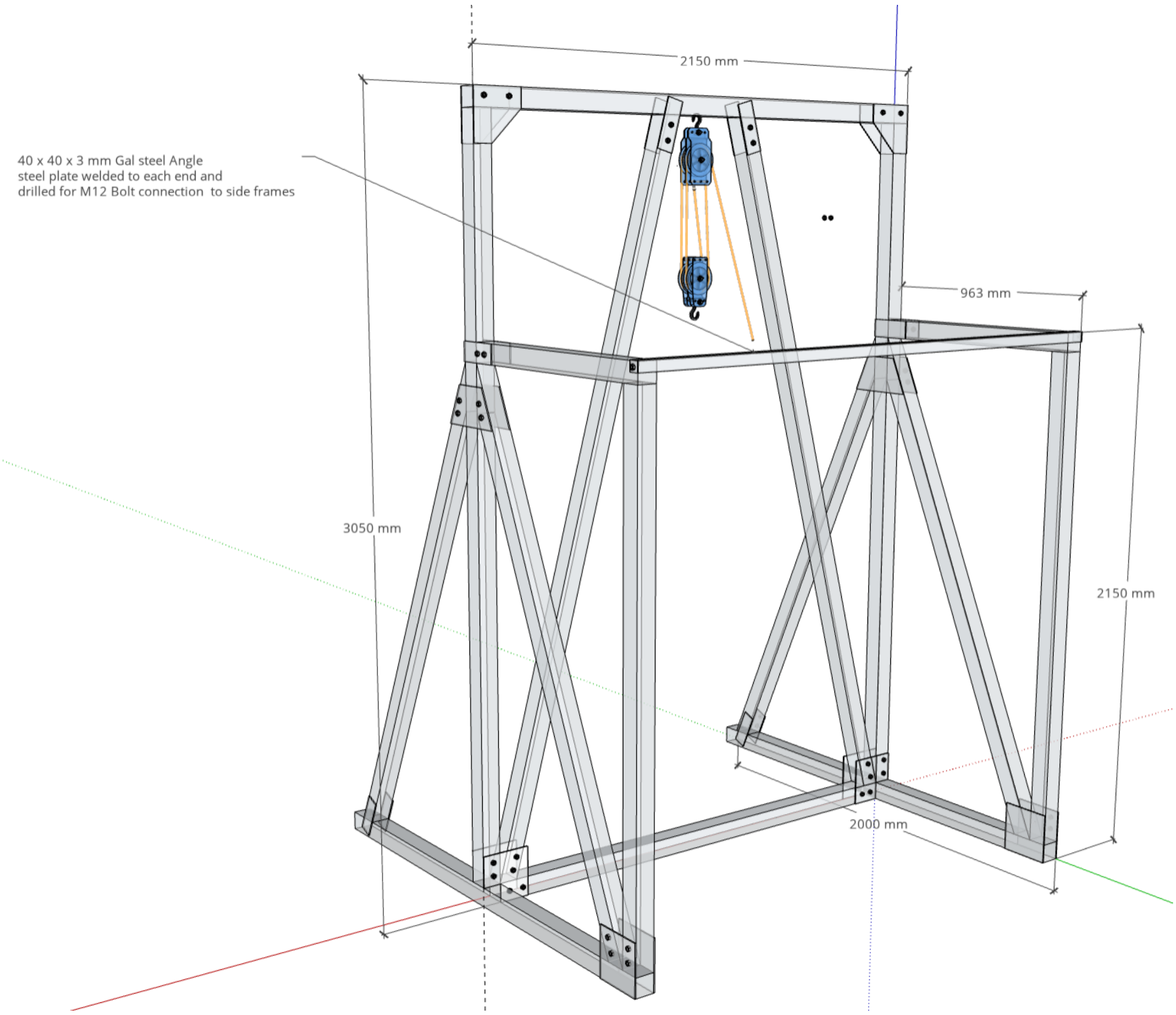


Figure 10. Specimen lifting frame

5.4 Mass flow-controlled propane burner fire ignition source

The fire ignition source was intended to simulate potential localized external fires at the base of a building exterior or on an external balcony.

The ISO 13784-1 gas burner ignition source was used. It has a surface area of 1200 mm x 100 mm (total area of 0.12 m^2). The ISO 13784-1 standard specifies a 100 kW burner output applied for a period of 30 min (or until the upper edge of the test specimen is extensively flaming). However, CSV requested the HRR and duration settings to be as follows:

1. A burner output of 100 kW is to be applied for the first 15 minutes of the test
2. The burner output will then be increased and sustained at 300 kW for a further 25 minutes.
3. The above provides a total test gas burner duration of 40 minutes.
4. The burner will be turned off prior to this if the total HRR is estimated to significantly exceed 1 MW or the measured temperatures within the scrubber pollution control system approach an unsafe operating temperature for this equipment.

The above burner outputs were selected by CSV on the following basis:

- The same burner HRR and duration setting have been applied by CSV in similar fire testing previously performed at other labs and this enables direct comparison to these previous tests.
- A constant 100 kW burner HRR may not reasonably represent all credible localized external ignition sources for a building which may be larger of the order of 300 kW (or more). A peak fire source size

larger than 100 kW has been considered to reasonably challenge the fire performance of the test specimens.
- The proposed burner outputs are the same as for the ISO 9705 room corner test.
- The application of 2 progressively increased burner outputs may enable observation of any different fire behavior when exposed to fires of different sizes.
- The total test time of 40 minutes was considered to provide a conservatively long fire exposure duration for a localized external ignition source.

The gas burner propane flow rate (from which the propane burner output in term of HRR is calculated) was controlled and measured by a Bronkhurst Propane gas mass flow controller.

The propane gas burner system includes the main gas burner (detailed above), a smaller pilot ignition burner (which is < 10 kW) and a gas burner control system. The pilot burner has a spark igniter and a flame ionization detection rod. The control system requires the pilot burner to be ignited first and used to ignite any propane released from the main burner. The control system requires the pilot burner to operate for the duration of the main burner operation. If the flame ionization rod detects that the pilot burner has gone out, then the control system shuts of the propane supply to both burners.

5.5 Instrumentation

5.5.1 HEAT RELEASE RATE

Heat Release Rate (HRR) is measured by oxygen consumption calorimeter via test hood exhaust duct mounted instruments and sampling using the oxygen consumption calorimeter principles as stated in ISO 9705. The key instruments included:

- Gas sampling from exhaust duct with continuous measurement of Oxygen, Carbon dioxide and Carbon Monoxide gas concentrations.
- Exhaust gas temperature measurement
- Exhaust flow differential pressure measurement

From the above measurements exhaust flow rate and HRR is calculated.

The sampling location for the above instruments was from the exhaust duct, ~ 8.5 m from the exhaust opening at the top of the test hood. This sampling location was located ~ 4.5 m downstream along a straight 400 mm ID section of the exhaust duct.

5.5.2 SMOKE MEASUREMENT

A white light smoke measurement system was located at the exhaust duct HRR sampling location. The smoke meter is manufactured by FTT to comply with DIN 50055 and ISO 9705. It consists of a white light source which passes a beam of light across the exhaust duct to a light receiver sensor on the opposite side of the duct. The smoke optical density and smoke extinction coefficient is directly related to the ratio of the intensity of light with smoke vs the intensity of light with no smoke. The smoke production rate is related to both the smoke extinction coefficient and the flow rate of exhaust gas.

The smoke meter light source and receiver were mounted within an anvil support system which kept them aligned and not impacted by thermal expansion of the exhaust duct as it is heated by exhaust gas.

5.5.3 TEMPERATURE AND HEATFLUX INSTRUMENTS

Type K, 1.5 mm diameter, stainless steel sheathed mineral insulated metal sheathed (MIMS) thermocouples were used for all temperature measurements.

Hukseflex SBG01 water cooled heat flux meters having a range of 0-100 kW/m^2 (manufacture states they will operate safely and measure correctly up to 150% of stated range) measuring total heat flux (convective and radiant heat combined) were used for all heat flux measurements.

The following table summarises all the thermocouples and heat flux meter locations used in these tests.

Table 6. Temperature and heat flux instrument summary table.

Inst. No	type	Horizontal location	Vertical location (mm above floor level)	Used in Characterisation tests	Used in Specimen tests
HF1	Water cooled total Heat flux meter (0-100 kW)	Centre	650 mm	Yes	No
HF2		Centre	1650 mm	Yes	No
HF3		Centre	3000 mm (top of specimen)	Yes - installed at 2650 mm high for characterisation tests.	Yes
TC1	External thermocouples ~30 mm in front of external face of cladding. Located near central vertical panel joint. Located 30 mm in front of plasterboard for characterisation tests	Centre	400 mm	Yes	Yes
TC2		Centre	900 mm	Yes	Yes
TC3		Centre	1400 mm	Yes	Yes
TC4		Centre	1900 mm	Yes	Yes
TC5		Centre	2500 mm	Yes	Yes
TC6		Centre	3000 mm	Yes	Yes
TC7	Air cavity thermocouple 25 mm between insulation and rear face of panels	Centre	900 mm	No	Yes
TC8		Centre	1900 mm	No	Yes
TC9		Centre–	2900mm	No	Yes
TC10	Sandwich panel core thermocouple embedded 50 mm deep into core	Centre (100 mm to right of vertical panel joint)	900 mm	No	Yes
TC11		Centre (100 mm to right of vertical panel joint)	1900 mm	No	Yes
TC12		Centre (100 mm to right of vertical panel joint)	2400 mm	No	Yes

Fire source characterization tests

Tests to characterize the ignition source thermal exposure will be applied to the specimen support frame (without the specimen or steel studs and top hats installed and with the bare plasterboard representing an essentially non-combustible reference surface). These tests will have the following instrumentation:

- Six Type K 1.5 mm diameter MIMS thermocouples measuring gas temperatures ~ 30 mm from the surface of the back wall plasterboard at the locations shown in the figure below.
- Three water cooled heat flux meters measuring total heat flux (convective and radiant heat combined) at the surface of the back wall at the locations shown in the figure below.

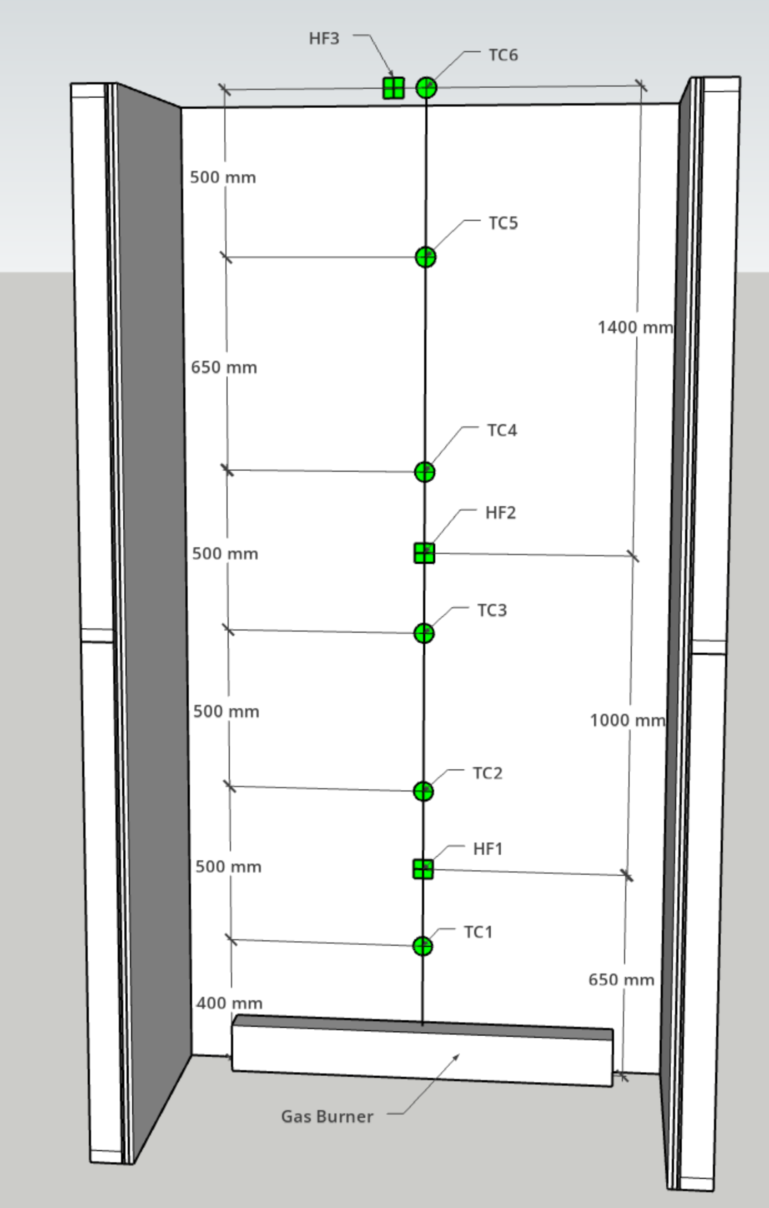


Figure 11. Instrumentation for ignition source characterisation tests

Specimen tests

Specimen tests will have the following instrumentation:

- Six Type K 1.5 mm diameter MIMS thermocouples measuring air temperatures ~ 30 mm in front of the external face of specimen sandwich panel along the exposed panel joint at the locations shown in the figure below.
- Three Type K 1.5 mm diameter MIMS thermocouples measuring sandwich panel core temperature, inserted 50 mm deep into core from rear face of panels at heights as per Table 6 at the vertical center of the installed specimens (~ 100 mm to right of vertical panel joint)
- Three Type K 1.5 mm diameter MIMS thermocouples measuring air cavity temperature, inserted 50 mm into the sandwich panel core from the rear face of panels at following heights as per Table 6 at the vertical center of the installed specimens
- One water cooled heat flux meter measuring total heat flux (convective and radiant heat combined) at centrally at the top of the installed specimen at the location shown in the figure below).

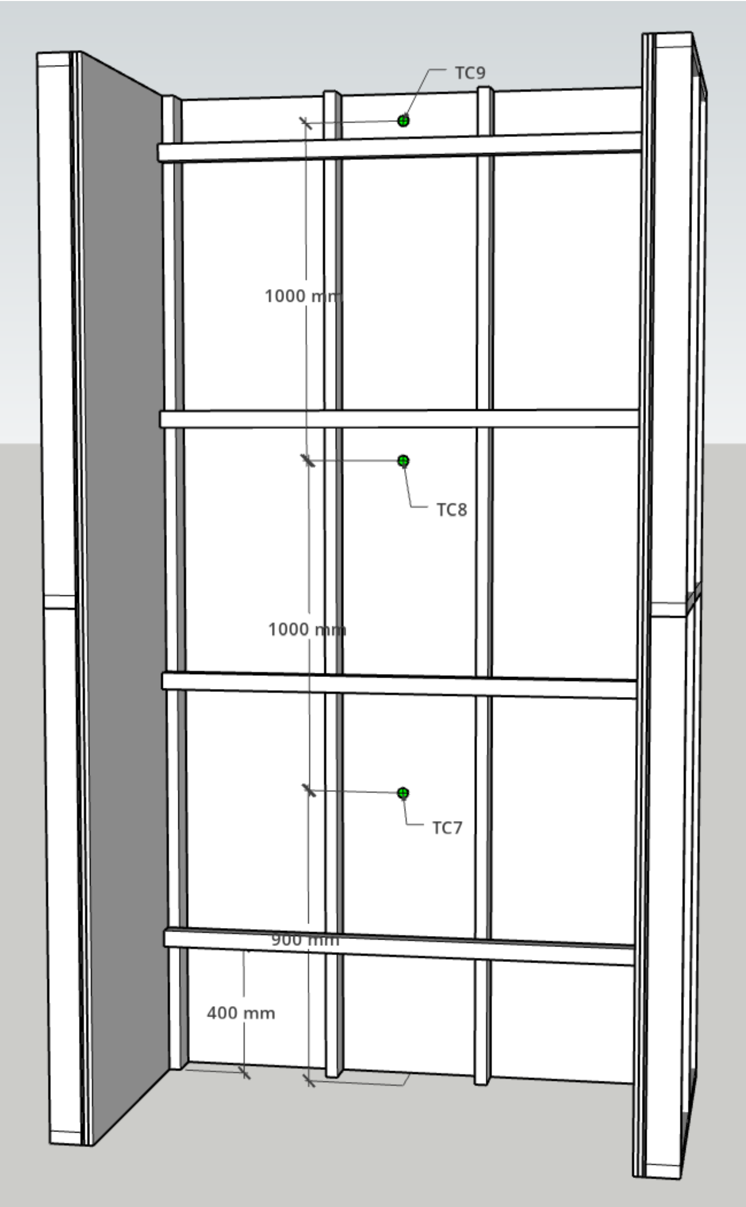


Figure 12. Instrumentation within cavity for specimen tests. Note – 3 x thermocouples which will penetrate rear skin of sandwich panel into centre of core are not shown in this drawing

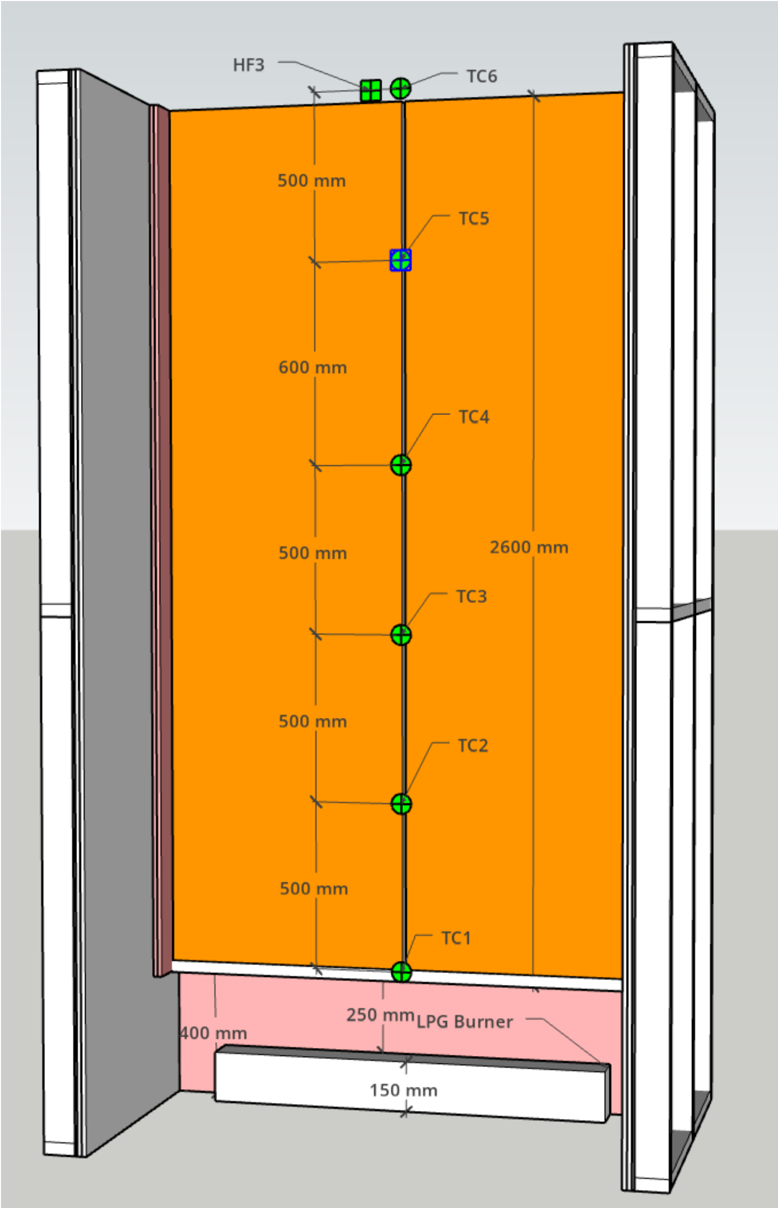


Figure 13. External face instrumentation for specimen tests

5.5.4 DATA ACQUISITION

Dataloggers were used to record and store all test instrument data for the duration of each test at a sampling period not exceeding 2 s intervals.

5.5.5 FTIR GAS ANALYSIS

A Fourier transform infrared (FTIR) gas analysis system was used to sample and measure toxic gas species concentrations.

A Gasmet DX4000 portable FTIR Gas analysis system and heated gas sample system was used. It had the following specifications:

Spectrometer	
Resolution	4/8 cm^{-1}
Detector	Thermoelectrically cooled MCT
Beamsplitter	Antireflection coated ZnSe
Wave number range	900 - 4 200 cm^{-1}
Gas sample cell	
Path length	Multi-pass, path length 5.0 m
Material	Goldcoated aluminum
Mirrors:	Fixed, protected gold coating
Volume	0.4 liters
Temperature	180 °C, maximum
Heated gas sample system	
Controlled operating temperature of filter, flexible sample tubes and pump	180 °C
Sample flow rate	2 liters per minute
Soot filter	2 µm, ceramic filter (heated to 180 °C)
Construction/components	Sample probe = 4 mm OD stainless steel tube, ~ 0.5m long Heated filter housing = stainless steel housing with ceramic filter Flexible heated sample lines = 4 mm OD Teflon tube with external heated sleave. The tube from filter to pump was 1 m long. The tube from pump to FTIR spectrometer was 1 m long Pump = Stainless steel with Teflon diaphragms.

The FTIR gas analyser was located with the probe sampling from ~ 1 m down stream from the HRR sampling equipment. The stainless-steel probe was inserted to sample from the center of the duct.

The FTIR gas analyser was connected to a laptop using “Calcmet” analysis and control software for the FTIR. Prior to any test measurements:

1. the FTIR was heated and purged with high purity Nitrogen prior to test measurements to ensure stable operating conditions, then
2. FTIR Background reference scans were recorded using high purity Nitrogen gas purge rather than air sampled from the sample probe.

The FTIR analyser can be set to measure multiple different gas species simultaneously at various different scan/logging rates.

CSIRO requested the system to be set up (by the supplier) to measure the gas species and measurement ranges listed in the table below. The scan/logging rate for all tests was set to 20 s intevals.

The Key toxic gas species for fires listed below are as recommended by ISO 19702 and EN 17084 (standards for FTIR measurement of toxic gases in fire testing). The other gas species listed were also measured.

Table 7. Gas species and measurement ranges specified for FTIR gas analysis.

Gas Species		Specified gas measurement range (0 to max value below)	Volumetric concentration measurement units
Key toxic gas species for fires			
Carbon dioxide	CO_2	10	Vol%
Carbon monoxide	CO	1	Vol%
Sulphur dioxide	SO2	500	PPM
Acrolein	C_3H_4O	500	PPM
Nitrogen monoxide	NO	500	PPM
Nitrogen Dioxide	NO2	500	PPM
Hydrogen Chloride	HCl	500	PPM
Hydrogen cyanide	HCN	500	PPM
Hydrogen Bromide	HBr	500	PPM
Hydrogen Fluoride	HF	500	PPM
Other gas species			
Formaldehyde	CH2O	500	PPM
Ammonia	NH_3	500	PPM
Total organic Carbon (TOC)	-	2,000	PPM
Methane	CH_4	500	PPM
Ethylene	$C2H_4$	500	PPM

5.6 Video and photography

All ignition source characterization tests and specimen tests were video recorded and still photographs taken of key events.

Photos were taken to document the specimen installation prior to testing.

Photos were taken to document the extent of specimen damage and fire spread post test..

5.7 Suppression and safety

Portable CO2 extinguishers and fire hose (water) were available immediately at the test hood location. It is not intended that the tests should be suppressed unless conditions become potentially unsafe for the test laboratory or test observers (at which point the test would be exhibiting a combination of flames extending above the top of the specimen, and pollution control scrubber temperature approaching unsafe levels.

Test operators must use suitable PPE which may include:

- Safety boots,

- Heat resistant gloves,
- Heat/flame resistant clothing,
- Safety glasses and/or,
- P2 face mask/respirator.

A team of at least two CSIRO staff present at all times was required to monitor and control the test. External test witnesses were limited maximum of 4 people and were located at a safe observer location outside of the test hood.

6 Test method

6.1 HRR Calibration Tests

Prior to undertaking the characterisation tests or a series of specimen tests, HRR Calibration tests were undertaken to check the Heat Release Rate (HRR) Oxygen consumption calorimeter measurement for the test hood was working correctly and within required accuracy.

6.1.1 METHYLATED SPIRITS POOL FIRE

This method is an alcohol fuel tray calibration test burning a measured mass of fuel with known heat of combustion.

A3 sized trays are placed on the floor at the centre of the hood. The number of trays used may be varied. The surface area of a single A3 tray is 0.125 m^2.

Approximately 2-8 L of denatured industrial grade methylated spirits is evenly distributed between the trays. The total mass of fuel used is measured and recorded.

The trays are ignited and the HRR vs time is measured by Oxygen consumption calorimeter. Where 4 x A3 trays are used this pool fire is typically expected to produce an approximate HRR of ~340 kW (stated in AS 4391) which typically increases over the duration of the burn time due to heating of the tray, until all fuel is consumed.

The total heat released based on total mass of fuel consumed, Q_{mass} (MJ) is calculated by:

$$Q_{mass} = \Delta h_C \times m_{fuel}$$

Where:

- Q_{mass} (MJ) = total heat released based on mass of fuel consumed
- Δh_C(MJ/kg) = Net heat of combustion of Methylated Spirits (26.8 MJ/kg)
- m_{fuel}(kg) = total mass of fuel consumed.

The total heat released based on oxygen consumption calorimeter, Q_{O2} (MJ), is calculated as the integral of the area beneath the measured HRR vs time curve.

The difference between Q_{mass} and Q_{O2} should be within ±5 %.

6.1.2 PROPANE GAS BURNER

This method applies the mass flow controlled propane burner HRR calibration test method generally in accordance with ISO 9705-1:2016 Section 9, with the following modifications:

- The ISO 13784-1 propane gas burner (1.2 x 0.1 m area), as this was the ignition source used in the specimen tests, instead of the standard ISO9705 square propane burner (0.17 x 0.17 m square area).
- The tests were generally applied with the propane burner located centrally under the test hood with the plasterboard lined specimen support frame back and wing walls installed.
- The propane burner was operated in a series of steady/set outputs of 0 kW, 100kW, 300 kW, 100 kW, 0 kW. The duration of steady state burner operation at each output was a maximum of 10 minutes, however in some cases durations shorter than 10 minutes were applied but were

sufficient to demonstrate that the Oxygen consumption calorimeter measurement of HRR was reasonable and accurate.

6.2 Characterisation Tests

Characterisation tests were conducted on the specimen support structure lines with FR Plasterboard (no specimen installed) to determine the following:

a) The exposure conditions in terms of gas temperatures and incident heat flux to the surface area of the fire-resistant plasterboard wall (from the fire source) and
b) The direct flame impingement area on the fire-resistant plasterboard wall.

The characterisation tests applied the following procedure:

- Tests were applied to the bare FR plasterboard clad back wall and wing walls (without the supporting specimen studs and top hats installed and without the specimens installed
- Instrumentation and datalogging was as per Section 5 of this report
- The fire source was as per Section 5.4 of this report
- The rear wall and wing walls were allowed to cool to near ambient temperatures before repeating any characterisation test. The FR plasterboard was not required to be replaced between repeat tests and it maintained its integrity.

The following two characterisation tests were performed

1. Short characterisation test – this applied the propane burner at 100 kW for 2 minutes followed by 300 kW for a further 2 minutes. The purpose was to provide a short test to check that all instruments operated correctly and give a preliminary indication if the fire exposure achieved prior to doing the long characterisation test.
2. Long characterisation test - this applied the propane burner at 100 kW for 15 minutes followed by 300 kW for a further 25 minutes, as specified for specimen tests

6.3 Specimen Tests

A total of thirteen specimen tests were completed which included four types of cladding specimen with different installation details. See Section 4.

The following outlines the general specimen test procedure.

1. The specimen and specimen support frame were installed and located under the test hood
2. Instrumentation was installed.
3. All instrumentation must be logged and checked prior to start of test to confirm all instrumentation is working.
4. All gas analysis equipment was turned on, warmed up and calibrated or reference background scans undertaken within the required period prior to the start of test
5. Instrumentation was started logging base-line ambient conditions at least 2 minutes prior to the start of test and continued logging for at least 5 minutes after the completion of each test.
6. Each test applied the ignition source as detailed in Section 5.5 of this report.
7. The test was only ended early if:
    a. The fire size became unsafe or was at risk of damaging exhaust scrubber equipment. (if the fire continued to burn at an elevated HRR then it was suppressed with a fire hose reel), or
    b. Agreed by CSV.
8. Each test continue after the ignition source had been turned off until all visible signs of specimen flaming or combustion had ceased.

9. Video and still photos recorded all significant visual events during each test
10. Upon end of test, post test photos will be immediately taken of the specimen.
11. The specimen was allowed to cool (typically at least 2-3 hours).
12. Any debris which had fallen away from the test specimen wall was removed and then the remaining test specimen was removed from the test hood as a complete rear wall panel (to make way for the next test specimen).
13. The removed test specimen was disassembled, layer by layer, taking photos of any significant damage or evidence of burning within the layers/cavity.

6.4 Acceptance Criteria

No pass/fail acceptance criteria are defined for these tests.

This set of intermediate-scale cladding fire tests are intended to be fire scenario-based experiments to observe the reaction of the cladding system in response to a localized external fire source and provide test data to inform general cladding fire risk assessment.

They are not tests in accordance with any specific test standard, and pass/fail criteria from other test standards should not be directly applied.

7 Results

Photos of all tests are shown in Appendix C .

Graphs of all test measurements are shown in Appendix B .

7.1 HRR calibration tests

7.1.1 METHYLATED SPIRITS POOL FIRE

Results for the two methylated spirits pool fire calibration tests are given below and measurement graphs in Appendix B.

Table 8. Methylated spirits pool fire calibration test results

Test Number	Test date	Total fuel tray area	Mass burnt (kg)	Total heat released (MJ)	Total heat Released (MJ)	Variation (%)	peak HRR (kW)
20240606 Metho CAL	6/06/2024	4 x A3	3.16	84.69	84.77	0.10%	343
20240827 Metho CAL	27/08/2024	4 x A3	3.14	84.15	82.67	-1.76%	336

7.1.2 PROPANE GAS BURNER

Propane burner calibration tests were conducted on 12/06/2024, 27/08/2024 & 24/10/2024. Results are given in Graphs in Appendix B

7.2 Characterisation Tests

Results for the two Characterisation tests are given below and measurement graphs in Appendix B.

Due to the height of the pilot burner above the main gas burner, the dimensions of the main gas burner, and propane being heavier than air, it typically took ~ 10 s for the main gas burner to ignite after the mass flow controller was turned up from 0 kW to 100 kW for most of the characterisation and specimen tests.

The following table compares the main results between characterisation tests.

Table 9. Characterisation Tests arrangement and corresponding exposure conditions

Test No.	Burner exposure (100 kW and 300 kW) (s)	Heat Flux at 650 mm (kW/m²)	Heat Flux at 1650 mm (kW/m²)	Heat Flux at 2500 mm (kW/m²)	Peak Heat Flux at 3050 mm (kW/m²)	TC1 400 mm (°C)	TC2 900 mm (°C)	TC3 1400 mm (°C)	TC2 1900 mm (°C)	TC5 2500 mm (°C)	TC6 3000 mm (°C)
Test 01 -Short characterisation	100 kW: 0-120 s	Peak: 49 Ave: 30	Peak: 13 Ave: 6	Peak: 8 Ave: 4	Peak: 9 Ave: 5	Peak: 738 Ave: 648	Peak: 561 Ave: 467	Peak: 344 Ave: 284	Peak: 219 Ave: 182	Peak: 153 Ave: 129	Peak: 123 Ave: 101
	300 kW: 120-240 s	Peak: 67 Ave: 57	Peak: 69 Ave: 44	Peak: 37 Ave: 18	Peak: 38 Ave: 19	Peak: 806 Ave: 766	Peak: 871 Ave: 833	Peak: 857 Ave: 774	Peak: 695 Ave: 616	Peak: 519 Ave: 433	Peak: 386 Ave: 319
Test 02 -Short characterisation	100 kW: 900-1200 s	Peak: 52 Ave: 23	Peak: 12 Ave: 5	Peak: 6 Ave: 3	Peak: 8 Ave: 4	Peak: 737 Ave: 647	Peak: 528 Ave: 399	Peak: 326 Ave: 229	Peak: 208 Ave: 147	Peak: 140 Ave: 104	Peak: 110 Ave: 85
	300 kW: 1200-2400 s	Peak: 77 Ave: 48	Peak: 49 Ave: 26	Peak: 32 Ave: 14	Peak: 34 Ave: 13	Peak: 810 Ave: 764	Peak: 884 Ave: 763	Peak: 855 Ave: 665	Peak: 714 Ave: 507	Peak: 539 Ave: 346	Peak: 395 Ave: 266

Note:

- Peak heat flux and temperature data were collected throughout the entire heating process using the 100 kW and 300 kW propane burners. The transition period between 100 kW and 300 kW was not included in the calculation.
- Average temperature and heat flux values were calculated for the entire heating duration, where the HRR was stabilized at both the 100 kW and 300 kW exposures.

Discussion:

- The heat flux values, and temperature data collected from both long and short characterisation tests show similar trends with comparable peaks and averages (e.g., heat flux at 650 mm, temperature at TC1). These consistent results indicate the test fire exposure conditions are repeatable.
- At 100 kW the persistent flame height was ~ 600-700 mm and the intermittent flame height was ~900 mm with very intermittent narrow flames up to ~ 1500 mm (all heights above lab floor level).
- At 300 kW the persistent flame height was ~ 1000-1100 mm and the intermittent flame height was ~1500-2000 mm, with very intermittent narrow flames up to ~ 3000 mm (all heights above lab floor level).
- The flames from the gas burner were observed to directly imping upon the back wall in the region of persistent flame height.

Figure 14. Burner at 100 kW.

Figure 15. Burner at 300 kW.

7.3 Specimen Tests

Video recordings were taken for each test. A copy of the video is available upon request from the test sponsor or by contacting Cladding Safety Victoria. The video of the test should be viewed in conjunction with the contents of this report.

7.3.1 SUMMARY RESULTS

This section provides an overarching summary and comparison of all specimen test results as follows:

- Figure 16 in this report section compares the measured HRR vs time for all tests on WPC-01 and WPC-02.
- Figure 17 in this report section compares the measured HRR vs time for all tests on ISP-01 and ISP-02
- Table 10 in this report section provides a summary of the fire behaviour for each of the cladding specimen types for the various tests. In Table 10, tests which were on similar specimens, and which achieved similar results and fire behaviour are grouped together to make presentation and comparison of results simpler.
- Table 11 in this report section provides a summary of the maximum/peak fire test measurements for HRR, heat flux, temperatures, smoke production rate, and also the time and size of sustained flaming above top of specimens.

In Tables 9 and 10 the following definitions have been used to categorise the “size” of sustained flaming above the top of specimens”

- Large sustained flaming – Flames that grew to extend more than half the width of the specimen at the top of the specimen and where the difference between the measured total HRR (specimen and burner combined) and the burner HRR setting at the time of this sustained flaming was significantly more than 100 kW.
- Small-Medium sustained flaming – Flame which did not extend more than ~ 1/3rd the width of the specimen at the top of the specimen and where the difference between the measured total HRR (specimen and burner combined) and the burner HRR setting at the time of this sustained flaming was ~ 100 kW or less.

Note:

- Due to the proximity of the test hood to the top of the specimen it was not possible to measure sustained flame height above specimen.
- The above categorisation is only intended to provide a description of observed size of sustained flames above top of specimen. It is not intended to directly predict likelihood of continued vertical fire spread for larger extents of cladding.

Table 12 in this section provides a comparative ranking of tested specimens/installations from worst to best fire test performance based on fire growth rate and peak HRR. In determining this ranking CSIRO considered the following:

- For tests which exceeded 1 MW, the peak HRR was limited either due to limited vertical extent/ fuel load of installed specimen (ISP-02 EPS) or suppression with water (WPC-01 and WPC-2 with cavities).
- For tests which exceeded 1 MW it is considered very likely that vertical fire spread would occur if a larger vertical extent of cladding system was installed and no water suppression was applied. Therefore, it was considered best to rank these tests in terms of time to exceed 1 MW.
- For tests which did not exceed 1 MW the peak HRR was limited by a combination of:
    - The burner being turned off early (in the case of WPC-01 in Tests 4 and 5),
    - The limited vertical extent/fuel load installed (ISP-02 EPS),
    - The encapsulation and fire behaviour of the specimen.

- Therefore, for tests which did not exceed 1 MW, it was considered best to rank these tests in terms of Peak HRR and burner exposure HRR at time of peak HRR.
- Note that for tests which did not exceed 1 MW, it is still possible the tested cladding specimens might support vertical fire spread if installed in a larger vertical extent.
- This report simply presents the test results and a comparative ranking of fire performance of the tested cladding systems. It does not directly assess risk of vertical fire spread for systems installed to actual buildings.

Further detailed test results for each individual test are provided in:

- Test observations for each specific test are provided in the further report sections below.
- Test measurement graphs for each test are provided in Appendix B.
- Photos for each test are provided in Appendix C

The following is a summary of any instrumentation issues or failures for the series of tests.

- For tests on sandwich panels the majority of flaming at top of specimen occurred either at the top of the exposed core or from the top of the rear cavity. In these cases, flames were mostly located behind the front face of the heat flux meter. Therefore, heat flux meter measurements for these tests to not measure heat flux from flames at these locations.
- The thermocouples within the cavity were located at the centre width of the specimen and therefore do not measure the peak cavity temperatures where flaming within cavity may have occurred away from the thermocouple locations. This is particularly the case for tests where small/medium sustained flaming occurred at the top of the cavity as these tended to be located at the side of the specimen rather than at the centre.
- For Test 04 the FTIR Gas analyser measured concentrations of toxic species was lower than expected based on other similar WPC-01 tests. It is suspected that a Nitrogen purge (required for background scan immediately prior to test) may not have been turned off prior to starting the test and that this appears to have diluted the pumped sample. Measured FTIR toxic gas species concentrations for Test 04 have been provided in this report but the above limitation should be considered.
- For Test 05 the FTIR gas analyser pump was not turned on so no toxic species concentration measurement by FTIR was recorded for this test.
- For Test 04 onwards, the CO concentration measured by the test hood gas analyser appeared to be subject to a fairly constant linear drift increase during the period of each test. This does not impact the measured HRR. CO was also measured by FTIR, which did not drift significantly over the period of each test.
- For Test 06, TC-10 within core, failed at ~ 2200 s.
- For Test 12, TC-12 within core, failed shortly after start of test.
- For some tests on ISP specimens where the burner was run for the full 40 minutes, the datalogger was temporarily halted after HRR had returned to ~ 0 kW to save the Key test data, the datalogger was then restarted to log the cool down temperatures in the core and cavity. This resulted in a short gap in the measured test data.

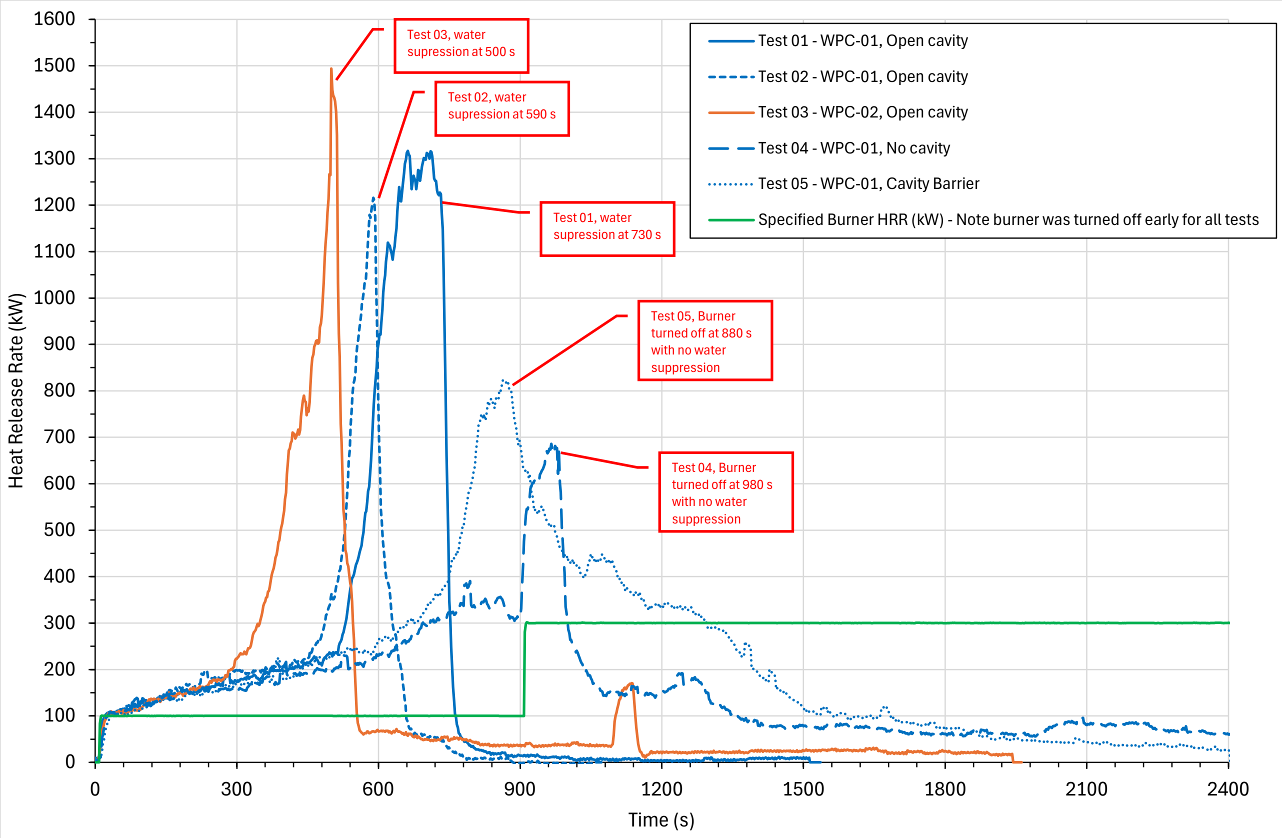


Figure 16. Comparison of measured HRR for all tests on WPC-01 and WPC-02

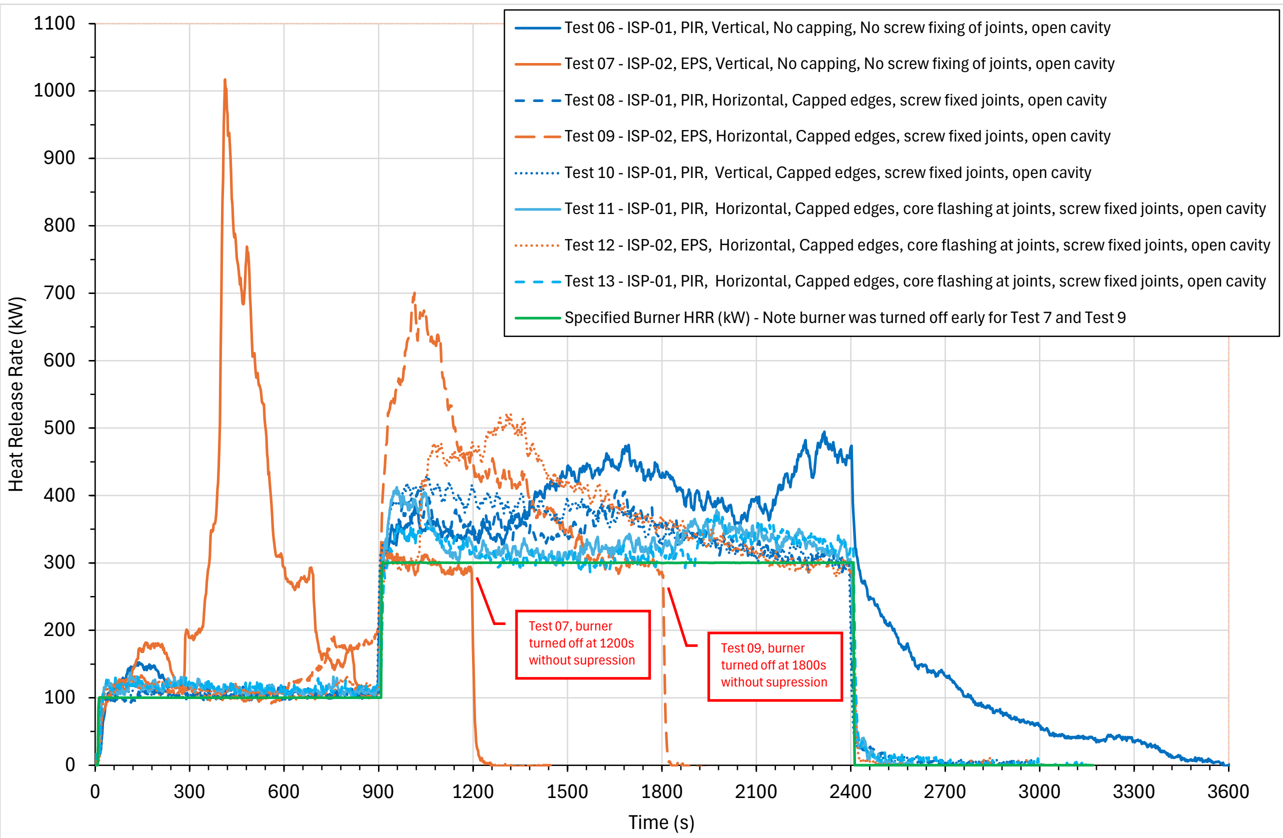


Figure 17. Comparison of measured HRR for all tests on ISP-01 and ISP-02

Table 10. Summary of specimen test results and observed fire behaviour

Test Numbers	Cladding system	Time to sustained flames above top of specimen (s)	Key behaviour
Test 01 Test 02	WPC-01 (~90-95% wood) With open cavity	Test 1 = 530 s from front face, 570 s from cavity Test 2 = 490 s from front face, 540 s from cavity	• Large sustained flaming above top of specimen from both front face and top of cavity occurred during 100 kW burner application. • Both tests suppressed water during planned 100 KW burner stage of test • Both tests steadily increased in HRR to ~ 200 kW at 420 s (7 min) due to slowly growing burning area on front face of cladding. • After 420 flames burnt through the cladding/aluminium capping and penetrated the cavity. The fire growth rate then increased due to burning within the cavity. • Test 1 exceeded 1 MW at 610s, Test 2 exceeded 1 MW at 570 s • Fire hose suppression of fire within cavity was difficult requiring fire hose to be inserted into cavity and cladding to be pulled away. • The cladding in area of burner impingement/flame spread had charred (similar to timber) and had burnt through exposing cavity in central inverted “V” shape ~ 0.5 m wide at base and ~ 2.0 m high. • Aluminium capping at base of cladding at melted away over a centrale width of ~450 mm
Test 3	WPC-02 (~53-56% wood) With open cavity	410 s from front face, 350 s from cavity	• Large sustained flaming above top of specimen from both front face and top of cavity occurred during 100 kW burner application. • Lab needed to suppress test with water during planned 100 KW burner stage of test. • The fire growth rate was slightly faster compared to WPC-01. • Flames appeared to penetrate into cavity faster than for WPC-01, with sustained flaming above top from cavity occurring before sustained flaming above top from front face. • The shiplap cladding profile had an approximately 15 mm air gap between the rear of the cladding and the steel battens. This gap was initially shielded by a 1.6 mm thick aluminium angle at the base, which melted away, exposing the gaps to direct burner flames. • HRR increased steadily to ~ 200 kW at 300 s (5 min) due to steadily growing burning area on front face of cladding. • After 300 s flames burnt through the cladding/aluminium capping and penetrated the cavity. The fire growth rate then increased due to burning within the cavity. • Test 3 exceeded 1 MW at 480 s • Fire hose suppression of fire within cavity was difficult requiring fire hose to be inserted into cavity and cladding to be pulled away. The Cladding material continued to smoulder and produce smoke during suppression significantly more compared to WPC-01 • The cladding in area of burner impingement/flame spread had charred on the surface but also became softened (partially thermoplastic). The cladding had burnt through in central inverted “V” shape ~ 0.9 m wide at base and ~ 1.5 m high with partially burnt/softened strips of cladding board remaining loosely hanging in this area. • After initial water suppression, softened cladding boards fell to laboratory floor and continued to smoulder and eventually re-ignited.
Test 04	WPC-01	620 s from front face	• Large sustained flaming above top of specimen occurred during both the 100 kW and 300 kW burner application. • Gas burner turned off at 980s and cladding fire left to burn out without water suppression.

Test Numbers	Cladding system	Time to sustained flames above top of specimen (s)	Key behaviour
	(~90-95% wood) No Cavity (Plasterboard directly behind)		• The absence of a cavity resulted in a slower fire growth rate compared to WPC-01 with cavity. • Test steadily increased to ~350 KW at the end of the 900 s (15 min) 100 KW burner application • Upon turning the burner up to 300 kW the total HRR increased to 600 kW and continued to increase to 680kW at 980 s (80 s after turning burner up). At this time the burner was turned off without water suppression. • At the time the burner was turned off the cladding had burnt away in an inverted "V" shape ~1.5 m wide at base and ~2.5 m high. • Upon turning the burner off, the cladding continued to burn at the edges and top of the area of burnt away cladding. The HRR initially reduced rapidly to 200 kW within 60 s, but then decayed slowly until all flaming self-extinguished at 3120 s (52 min). at this time a fire hose was applied to supress any smouldering/glowing embers. • After 420 flames burnt through the cladding/aluminium caping and penetrated the cavity. The fire growth rate then increased due to burning within the cavity. • Test 1 reached a peak HRR of 680 kW at the time the 300 KW burner was turned off.
Test 05	WPC-01 (~90-95% wood) Cavity with cavity barrier at top	510 s from front face	• Large sustained flaming above top of specimen occurred during the 100 kW burner application. • 100 kW Gas burner turned off at 880s and cladding fire left to burn out without water suppression. • The cavity with cavity barrier at top resulted in slower fire growth rate than for tests 1 and 2 (cavity without barrier), but faster fire growth rate than Test 4 (no cavity). • Test steadily increased to ~250 KW at 540 s (9 min). at this time the cladding started to burn through exposing the cavity in a small area at base of cladding. • From 600 s (10 min) the fire growth rate increase as the area of cladding burn through steadily increased, which increased ventilation and burning within the cavity. However the cavity barrier prevented flames from venting out the top of the cavity. • At 880s the HRR was 820 kW with large flames above top of specimen. The 100 kW burner was turned off at this time, without water suppression and the specimen fire. was allowed to decay. • At the time the burner was turned off, the cladding had burnt away exposing cavity in an Inverted "V" shape ~ 1 m wide at base and reaching top of specimen • The specimen fire decay rate after turning burner off was initially slower compared to Test 3 due to continued burning both on the front face and within the cavity. • By 1380 s(23 min) the HRR reduced to 200 kW and the cladding had mostly burnt away except for ~ 100-200 mm wide flaming strips of cladding remaining at each side of the specimen. • These continued to at a slower decay rate until all flaming ceased at 2340s (39 min) and the cladding had been entirely consumed except for glowing embers.
Test 06	ISP-01 (PIR) Vertical Uncapped edges No additional screw fixing to panel joints	1370 s (22:50 min:s) from top edge of uncapped core.	• Large sustained flaming above top of specimen from top of uncapped sandwich panel core occurred during 300 kW burner application. • Gas burner continued for full 40 min test duration • At ~ 2 minutes during to 100 kw burner exposure the test produced a HRR of ~ 150 kW. This appeared to be when a section of aluminium capping at bottom of cladding melted exposing a small area of PIR to burning. However from ~ 4 min to 15 min (rest of 100 KW burner exposure) the HRR was not significantly greater than 100 kW and the specimen did not appear to contribute significant HRR. The vertical panel joint did not open to expose the core during this period.

Test Numbers	Cladding system	Time to sustained flames above top of specimen (s)	Key behaviour
	Open cavity		• At 16 min (960 s) within 1 min of turning burner up to 300 kW, the vertical external steel skin joint had started to open, with the PIR core being exposed to flames and ventilation. The PIR char formation appeared to have an impact on controlling the fire growth and the total HRR remained stable at ~ 350 kW until 1370 s • From 1370 s the flames had spread on PIR core behind external steel skin and started venting from uncapped top of specimen. From this time until the burner was turned off at 40 min (2400 s) the HRR increased between 350-495kW. • When burner was turned off at 40 min the HRR reduced to 300 kW. The PIR core continued to burn with a steadily decreasing HRR until the majority of the PIR was consumed or charred and flaming ceased at ~ 3600 s (1 hour). During this period charred segments of PIR core periodically fell to the lab floor • Post test the steel facing skins remain in place but were open along the vertical joint with a gap of ~ 50-100 mm.
Test 07	ISP-02 (EPS) Vertical Uncapped edges No additional screw fixing to panel joints Open cavity	310 s from top edge of uncapped core	• Large sustained flaming above top of specimen from uncapped core occurred during 100 kW burner application. • Gas burner was turned off at 1200 s as all EPS core had been consumed. • At ~(120-240s) (2-4 min) during 100 kw burner exposure the test produced a HRR of ~ 175 kW. This appeared to be when a section of aluminium capping at bottom of cladding melted exposing the bottom of the of EPS to burning. • At 310 the flames had spread on EPS core behind external steel skin and started venting from uncapped top of specimen. • From ~ 390 s the external vertical steel skin joint started to open with flames emerging from the vertical joint. At this time there were large flames emerging from the uncapped top of the sandwich panel • By 412 s the test had reached a peak of 1017 kW which was limited by the available amount of EPS starting to burn out • From 420 s some flaming molten EPS started falling to burner or lab floor below and continue to burn. However the majority of EPS appeared to burn within the sandwich panel core. • By 840 s the available EPS had mostly burnt away and the test HRR reduced to 100 kW (the burner output). • The gas burner was turned up to 300 kW at 900 s (15 min). However there was no further burning or contribution to HRR from the specimen so the burner was turned off at 1200 s. • Post test the steel facing skins remained in place but were open along the vertical joint with a gap of ~ 50-100 mm. All EPS was consumed.
Test 08 Test 10 Test 11 Test 13	ISP-01 (PIR) Test 8, 11 &12 Horizontal Test 10 Vertical Capped edges Additional screw fixing to panel joints Open cavity Test 11 and Test 13 had Steel	Test 08 = 1600 s from cavity Test 10 = 1205 s from cavity Test 11 = 2100 s from cavity Test 13 = 2160 s from cavity	• Small-medium sustained flaming above top of specimen from cavity occurred during 300 kW burner application. Flaming above top of specimen was significantly reduced compared to Test 06 due to steel capping covering PIR core edges. Size of flames above top of specimen were limited in height and width and only occurred on the left ~ 1/3rd width of specimen • Gas burner continued for full 40 min test duration • During the 100 kW burner phase of the tests the specimens did not appear to contribute any significant burning. The fixing of panel joints and capping remained in tact without gaps opening • During the 300 kW phase of the tests the front face fixing of panel joints and capping remained in tact without gaps opening. There was only minor/localised flaming at some joints/capping at on front face which appeared to possibly be a combination of sealant burning and combustible pyrolysis gas from the core squeezing out though limited locations of fixed joints and capping. • As the 300 kW burner phase of the test progressed, the amount of smoke/fumes venting from the top of the rear cavity steadily increased. It was not possible to observe if rear skin panel joints were opening to form gap (due to location within cavity) but these joints were not screw fixed. • The fumes at top of cavity eventually became intermittent small flames above top of cavity followed by sustained small-medium flames above top of cavity.

Test Numbers	Cladding system	Time to sustained flames above top of specimen (s)	Key behaviour
	flashing partially covering core at panel joints		• When burner was turned off at 40 min the HRR reduced rapidly to ~ 0 kW. No flaming of the specimen continued except for the small flames at the top of the cavity which steadily decayed then stopped after ~ 2-5 minutes from turning the burner off. • Post test the steel skins and edge capping remained in place with no opening of the joints. ~ 60-70% of the PIR core was heavily charred.
Test 09	ISP-02 (EPS) Horizontal Capped edges Additional screw fixing to panel joints Open cavity	720 s from cavity	• Small-medium sustained flaming above top of specimen from cavity. Limited to right 1/3rd width of specimen) occurred during 100 kW burner application. This became large sustained flaming across entire width of specimen from top of cavity during 300 kW burner application. • Gas burner continued for shorter 30 min test duration as all EPS appeared to have been consumed by 30 minutes. • During the first 10 minutes of 100 kW burner phase of the test the specimens did not appear to contribute any significant burning. During the first 2-4 minutes there was a period of increased smoke from the front of the specimen which appeared to be due to the painted surface. • As the 100 kW burner phase of the test progresses the amount of smoke and fume vented from the top of the cavity increased until it eventually became intermittent small flames followed by sustained small/medium flames on right 1/3rd width of top of cavity from 720 s (12 min). • There was no significant flaming on front face of specimen during 100 kW burner phase of test. • Within 60 s of turning the burner up to 300 kW flaming at the top of the cavity increased to large sustained flamed across the entire width of the cavity. The test reached a peak of 700 kW at 1000 s. (16:40 min:s) • During 300 kW burner phase of test there was minor/localised flaming at some joints/capping at on front face which appeared to possibly be a combination of sealant burning and combustible pyrolysis gas from the core squeezing out though limited locations of fixed joints and capping. • It was not possible to observe if rear skin panel joints were opening to form gap (due to location within cavity) but these joints were not screw fixed. • From ~ 1140 s(19 min) the rate of burning/flaming of the specimen started to steadily reduce as the specimen appeared to start burning out of EPS. • By 1560 s (26 min) all flaming of the specimen, including flaming at the top of the cavity, had ceased. • The fixing of front face panel joints and capping remained in tact without gaps opening through the entire test. There was no molten EPS which dripped to the burner or floor below test specimen. All EPS appears to have been consumed within the sandwich panel core area. • The gas burner was turned off at 30 minutes. There was no continued flaming of the specimen upon turning the burner off. • Post test the steel skins and edge capping remained in place with no opening of the joints. ~100% of the EPS core had been consumed.
Test 12	ISP-02 (EPS) Horizontal Steel flashing partially covering core at panel joints	1020 s from cavity	• Large sustained flaming above top of specimen from cavity occurred during 300 kW burner application. No sustained flaming above top of specimen during 100 kW • Gas burner continued for full 40 min test duration • During the 100 kW burner application the specimen did not appear to contribute any significant burning and there was no flaming at the top of the cavity. During the first 2-4 minutes there was a period of increased smoke from the front of the specimen which appeared to be due to the painted surface.

Test Numbers	Cladding system	Time to sustained flames above top of specimen (s)	Key behaviour
	Capped edges Additional screw fixing to panel joints Open cavity		• Immediately after turning the burner up to 300 KW the amount of smoke/fumes venting from rear cavity began increasing. These became sustained flames above top of cavity at 1020 s (17 min). these flames were initially located at left side of cavity but 1100 s had spread to be across the majority of the width of the cavity. • The test reached a peak of 520 kW at 1320 s (22 min) • During 300 kW burner phase of test there was minor/localised flaming at some joints/capping at on front face which appeared to possibly be a combination of sealant burning and combustible pyrolysis gas from the core squeezing out though limited locations of fixed joints and capping. • From ~ 1380 s (23 min) the rate of burning/flaming of the specimen started to steadily reduce as the specimen appeared to start burning out of EPS. • By 3100 s (35 min) all flaming of the specimen, including flaming at the top of the cavity, had ceased. • The fixing of front face panel joints and capping remained in tact without gaps opening through the entire test. There was no molten EPS which dripped to the burner or floor below test specimen. All EPS appears to have been consumed within the sandwich panel core area. • The gas burner was turned off at 40 minutes. There was no continued flaming of the specimen upon turning the burner off. • Post test the steel skins and edge capping remained in place with no opening of the joints. ~100% of the EPS core had been consumed

Table 11. Summary of the maximum/peak fire test measurements

Test No.	Specimen	Burner exposure (100 kW and 300 kW) (s)	Time of suppression with water (Time or No suppression)	HRR		Sustained flames above top from external face of cladding	Sustained flames above top from within cavity	Maximum size of sustained flaming	Heat Flux at 3050 mm		External Temperature at top of specimen		Cavity temperature at top of specimen		Smoke production rate	
				Peak (kW)	Time (s)	Yes/No/Time	Yes/No/Time		Peak (kW/m²)	Time (s)	Peak (°C)	Time (s)	Peak (°C)	Time (s)	Peak (m²/s)	Time (s)
Test 1	WPC-01, (~90-95% wood), With open cavity	100 kW: 0 - 676 s	730 s	1316	662	Yes-530 s	Yes – 570 s	Large	114	728	971	712	958	690	4.2	746
Test 2	WPC-01, (~90-95% wood), With open cavity (Repeat of Test 1)	100 kW: 0 - 573 s	589 s	1215	589	Yes – 490 s	Yes – 540 s	Large	66	589	791	593	830	615	2.4	663
Test 3	WPC-02, (~53-56% wood), With open cavity	100 kW: 0 - 474 s	495	1494	500	Yes – 410 s	Yes – 350 s	Large	36	456	739	498	867	512	14.4	614
Test 4	WPC-01, (~90-95% wood), No Cavity (Plasterboard directly behind)	100 kW: 0 – 982 s	No suppression	685	966	Yes – 620 s	N/A	Large	76	966	866	972	112	982	2.0	1418
Test 5	WPC-01, (~90-95% wood), Cavity with cavity barrier at top	100 kW: 0 – 874 s	No suppression	824	866	Yes – 510 s	N/A	Large	94	888	958	840	134	1464	0.6	674
Test 6	ISP-01 (PIR), Vertical, Uncapped edges, No additional screw fixing to panel joints, Open cavity	100 kW: 0 – 900 s 300 kW: 900 – 2,400 s	No suppression	495	2316	No	Yes - 1370 s from uncapped top of core	Large	79	2288	785	2288	1054	1736	12.7	1672
Test 7	ISP-02 (EPS), Vertical, Uncapped edges No additional screw fixing to panel joints Open cavity	100 kW: 0 - 900 s 300 kW: 900 – 1,200 s	No suppression	1017	412	No	Yes – 310 s from uncapped top of core	Large	5.9	188	298	510	369	510	18.2	400
Test 8	ISP-01 (PIR), Horizontal, Capped edges, Additional screw fixing to panel joints, Open cavity	100 kW: 0 - 900 s 300 kW: 900 s – 1,800 s	No suppression	408	1026	No	Yes – 1600 s	Small/ Medium	15	2066	322	2062	832	1680	7.6	1334
Test 9	ISP-02 (EPS), Horizontal, Capped edges, Additional screw fixing to panel joints, Open cavity	100 kW: 0 - 900 s 300 kW: 900 – 1,800 s	No suppression	700	1014	No	Yes – 720 s	Large	17	1270	382	1360	683	1136	11.9	1210
Test 10	ISP-01 (PIR), Vertical, Capped edges Additional screw fixing to panel joints Open cavity	100 kW: 0 - 900 s 300 kW: 1500 – 2,400 s	No suppression	429	1050	No	Yes – 1205 s	Small/ Medium	18	970	409	980	262	1660	6.1	1034
Tests 11	ISP-01 (PIR), Horizontal, Capped edges Additional screw fixing to panel joints Steel flashing partially covering core at panel joints, Open cavity	100 kW: 0 - 900 s 300 kW: 1500 – 2,400 s	No suppression	412	958	No	Yes – 2100 s	Small/ Medium	19	1028	406	1030	67	1044	2.8	980
Test 12	ISP-02-EPS, Horizontal, Capped edges Additional screw fixing to panel joints Steel flashing partially covering core at panel joints, Open cavity	100 kW: 0 - 900 s 300 kW: 1500 – 2,400 s	No suppression	520	1320	No	Yes – 1020 s	Large	17	1970	384	2230	264	1264	9.0	1380
Test 13	ISP-01 (PIR), Horizontal, Capped edges Additional screw fixing to panel joints Steel flashing partially covering core at panel joints, Open cavity	100 kW: 0 - 900 s 300 kW: 1500 – 2,400 s	No suppression	370	1970	No	Yes – 2160 s	Small/ Medium	18	1480	407	1760	87	2310	3.6	1996

Table 12. Comparative ranking of tested specimens/installations from worst to best fire test performance based on fire growth rate and peak HRR.

Cladding system	Test numbers	Time to exceed 1 MW	Peak HRR for tests which did not exceed 1 MW	Peak HRR occurred during 100kW or 300kW burner exposure	Comment
ISP-02 (EPS) Uncapped edges, No additional screw fixing to panel joints, Open cavity	Test 07	412 s	>1000 kW	100 kW	Peak HRR of 1017kW at 412 s due to EPS starting to burn out.
WPC-02 (~53-56% wood) With open cavity	Test 3	480 s	>1000 kW	100 kW	Supressed with water
WPC-01 (~90-95% wood) With open cavity	Test 01 Test 02	Test 1 = 610 s Test 2 = 570 s	>1000 kW	100 kW	Supressed with water
WPC-01 (~90-95% wood) Cavity with cavity barrier at top	Test 05	-	824 kW	100 kW	Peak HRR at 980s due burner turned off without water suppression
ISP-02 (EPS) Capped edges, Additional screw fixing to panel joints, Open cavity	Test 9	-	700 kW	300 kW	Peak HRR at 1014 due to EPS starting to burn out. Test 9 and Test 04 had similar fire growth rates and peak HRR and are ranked approximately equal
WPC-01, (~90-95% wood), No Cavity (Plasterboard directly behind)	Test 04	-	685 kW	300 kW	Peak HRR at 980s due burner turned off without water suppression Test 9 and Test 04 had similar fire growth rates and peak HRR and are ranked approximately equal
ISP-02 (EPS) Steel flashing partially covering core at panel joints, Capped edges, Additional screw fixing to panel joints	Test 12	-	520 kW	300 kW	Peak HRR at 1000s due to EPS starting to burn out.
ISP-01 (PIR) Uncapped edges, No additional screw fixing to panel joints, Open cavity	Test 06	-	495 kW	300 kW	No water suppression. Burner off at 40 min
ISP-01 (PIR) Capped edges, Additional screw fixing to panel joints, Open cavity. Test 11 and Test 13 had Steel flashing partially covering core at panel joints	Test 08 Test 10 Test 11 Test 13	-	370-429 kW	300 kW	No water suppression. Burner off at 40 min

Note – all Test HRR measurements in table above include contribution from both the specimen and the gas burner.

7.3.2 SPECIMEN TEST 1– WPC-01, (~90-95% WOOD), WITH OPEN CAVITY

The observations for Test 1 are summarised in the table below.

Table 13. Specimen Test 1 observations

Time (sec)	Observations
00	Pilot burner started prior to start of test Main LPG burner mass flow controller started at 100kW setting at t = 0 s (start of test).
~10	LPG from main burner reaches pilot burner and ignites
30	Flames distributed evenly underneath of the WPC cladding. The flames are steady at a height of 700 mm with intermitted flames reaching 1400 mm.
60	Flames are steady at a height of around 1000 mm, with intermittent flames reaching 1700 mm. A small amount of white smoke is visible at the bottom of the cladding. No significant changes are observed from 60 to 150 s.
150	Intermittent flames reach a height of 2100 mm from ground level. Flames are clearly visible at the external bottom edge of the cladding, growing slowly in height.
200	Flames can be seen increased horizontally at the bottom edge of the cladding. No significant changes in flames since the start of heating, except for the gradual vertical growth of flames on external face of cladding.
300	Flames from the external face of cladding increase in size both vertically and horizontally. The black charred surface of the cladding is visible behind the flames.
400	Flames increase in size, burning steadily at a height of 1900 mm, with intermittent flames reaching 2400 mm.
420	A small gap (brunt through cladding) is visible in the middle area of face of the cladding above the burner. Flames spread upward externally and horizontally. The aluminium L shaped capping at the bottom of the cladding starts melting.
510	Flames grow larger. Flames from the cavity are visible through the middle gap of the cladding. Steady flames reach the full height of the specimen.
530	Sustained flames above specimen from front face of specimen
550	Flames spread, igniting most of the middle area of the cladding and contributing to the flame height. Flames reach the full height of the cladding. A gap is visible at the bottom edge, with cavity fire clearly seen. The gap increases vertically to around 500 mm from the bottom edge of the cladding.
570	Sustained flames above specimen from both the cavity and the front face of specimen. Flames are visible at the top of the cladding, coming from the rear cavity. Flames increase in size. The bottom gap on face of specimen widens, splitting the middle of the cladding. Cavity fire grows larger.
600	Flames within the cavity are steady, visible through the gap burnt through the cladding and from the top edge of the cavity. Charred material starts falling to the floor/burner. The gap widens and the cavity fire remains steady.
610	Measure HRR reaches 1 MW
620	Flames at the middle bottom of the cladding reduce as the WPC chars and burns away. The cavity fire spreads across the top, and flames remain steady on the cladding's surface. The cladding gap widens to 900 mm, with visible flames in the cavity. The bottom 400 mm is burnt out.
640	Flames appear at the bottom and top of the cladding. The bottom section is burnt away, creating a 500 mm horizontal and 1300 mm vertical gap. Flames spread from the top edge of the cavity to the top of the cladding. A second vertical gap forms up to 500 mm high.
676	Sustained flames on the cladding surface and top continue as HRR rises to 1300 kW. The 100 kW burner is turned off. The cladding bottom edge is fully burnt, with red char falling and piling up. The cavity fire remains strong and visible. External flames persist after the burner is off.
730	Water suppression commenced. Scrubber temperature exceeds 130°C, risking smoke exhaust failure. Fire hose water is used to suppress the test. A gap in the cladding runs from the bottom to the top of the cladding. External flames are easily extinguished, but cavity flames persist and need more effort to put out. Fire hose has to be inserted into cavity and some charred cladding pulled away to suppress.

Time (sec)	Observations
	Immediately Prior to suppression - The cladding in area of burner impingement/flame spread had charred (similar to timber) and had burnt through exposing cavity in central inverted "V" shape ~ 0.5 m wide at base and ~ 2.0 m high. Aluminium capping at base of cladding at melted away over a centrale width of ~450 mm
778	External and cavity flames are fully extinguished. Charred areas, gaps, and unburnt areas are clearly visible.

Post test damage observations.

The following damage observations are after suppression where some charred cladding had to be pulled away during suppression.

- The cladding in area of burner impingement/flame spread had charred (similar to timber) and had burnt through exposing cavity in central inverted "V" shape ~ 1100 mm at base and extending to top of cladding..
- From the bottom edge of the cladding to 1500 mm, the middle cladding is burnt away, exposing the fire rated plasterboard. The width of burnt away area is approximately 900 mm.
- From 1500 mm to the top edge of the cladding, the burnt area narrows to around 200 to 300 mm.
- The far left and right areas of the cladding remain unburnt.

Discussion of test

The test results showed significant flame propagation and a sustained cavity fire, which greatly contributed to the HRR. The peak HRR observed was 1300 kW (at time of suppression HRR was still rapidly increasing).

Initially, fire growth on the external face only was gradual/steady. However, the fire growth rate significantly increased once flames penetrated into the cavity.

The cavity fire played a crucial role in the HRR, facilitating vertical fire spread. Even after the burner was turned off, flames persisted, demonstrating substantial vertical and horizontal propagation, particularly as the burn through area of the cladding increased to provide more air to the cavity burning

The application of a water extinguisher effectively suppressed flames on external surface; however, extinguishing the cavity fire required additional effort.

7.3.3 SPECIMEN TEST 2– WPC-01, (~90-95% WOOD), WITH OPEN CAVITY (REPEAT OF TEST 1)

Test 2 was a repeat of Test 2.

The results and observations for Test 2 are very similar to Test 1 with the following minor differences:

- Time to sustained flames above top of specimen from front face = 490 s.
- Time to sustained flames above top of specimen from cavity = 540 s.
- Measure HRR reached 1 MW at 570 s
- Time of suppression with water = 589 s. Note that Test 1 was suppressed late at a time when exhaust and scrubber temperatures had significantly exceeds safe operating limits. For test 2 it was decided to suppress the Test 2 at an earlier time to reduce risk of damage to exhaust and scrubber equipment. However, Test 2 exhibited similar growth rate and behaviour to Test 1 up to the time of suppression.
- The peak HRR for test 2 was 1200 kW (at time of suppression HRR was still rapidly increasing).

7.3.4 SPECIMEN TEST 3 – WPC-02, (~53-56% WOOD), WITH OPEN CAVITY

The observations for Test 3 are summarised in the table below.

Table 14. Specimen Test 3 observations

Time (sec)	Observations
00	Pilot burner started prior to start of test. Main LPG burner mass flow controller started at 100 kW setting at t = 0 s (start of test).
~10	LPG from main burner reaches pilot burner and ignites, starting the test.
30	Flames distribute evenly underneath the WPC cladding. Intermittent flames reach up to 1400 mm from ground level.
90	Sustained flames appear at the bottom edge front face of WPC 02 cladding, with intermittent flames reaching 1900 mm on the front face.
150	Surface flames on front face become clearly visible over a larger area of the bottom edge, with intermittent flames reaching 2400 mm. Flames reach a height of 2100 mm from ground level, growing slowly.
285	The bottom aluminium capping melts, allowing flames to enter the cavity. Red char/embers is clearly visible at the bottom edge. Flames increase in size, mainly vertically, with intermittent flames reaching the top edge of the cladding.
350	Sustained flames above top of specimen from cavity Top internal cavity fire is visible on the left-hand side of the panel. Sustained external flames develop along the vertical extent of the external walls.
410	Sustained flames above top of specimen from front face. External flames reach and sustain at the top of the sample. The central bottom part of the sample burns away, creating a gap that supplies air to the internal cavity. Cladding boards have surface char but also soften and slump in a partially thermoplastic manner
480	Measure HRR reaches 1 MW
474	Sustained flames continue the external face and top of the panel. Heat Release Rate (HRR) rapidly increases to 1494 kW. The 100 kW burner is turned off. The bottom edge of the cladding is fully burnt out, with red embers and softened cladding falling and accumulating at the base. The cavity fire remains strong and clearly visible. After shutting down the burner, external flames persist. Additional red chars fall to the floor. Immediately prior to suppression: The cladding in area of burner impingement/flame spread had charred on the surface but also became softened (partially thermoplastic). The cladding had burnt through in central inverted “V” shape ~ 0.9 m wide at base and ~ 1.5 m high with partially burnt/softened strips of cladding board remaining loosely hanging in this area.
495	Water suppression commenced. The scrubber temperature exceeds 100°C, posing a risk of smoke exhaust system failure. Water from a fire hose reel is applied to suppress the test. A gap is clearly visible from the bottom to the top edge of the cladding in the middle area. External flames are easily extinguished, while cavity flames persist and require more effort. Fire hose suppression of fire within cavity was difficult requiring fire hose to be inserted into cavity and cladding to be pulled away. The Cladding material continued to smoulder and produce smoke during suppression significantly more compared to WPC-01.
510	Both external and cavity flames are fully extinguished. The top cavity fire remains strong and requires extra effort to extinguish. Burned/softened areas, gaps, and unburnt areas are clearly visible.
1090	After initial water suppression, softened cladding boards fell to laboratory floor and continued to smoulder and eventually re-ignited. These were supressed again with further application of hose reel.

Post test damage observations.

The following damage observations are after suppression where some charred/softened cladding had to be pulled away during suppression.

- Black char/burnt is clearly visible with the size of around 1000 mm wide spreading from the bottom edge to the top of the cladding.
- From the bottom edge of the cladding to 1100 mm, the middle cladding is burnt away, exposing the fire rated plasterboard. The width of burnt away area is approximately 800 mm.

- From 1500 mm to the top edge of the cladding, the burnt area narrows to around 200 to 300 mm.
- The far left and right areas of the cladding remain unburnt.

Discussion of test

The test results showed significant flame propagation and a sustained cavity fire, which greatly contributed to the HRR. The peak HRR observed was 1494 kW. (at time of suppression HRR was still rapidly increasing).

Initially, fire growth on the external face only was gradual/steady. However, the fire growth rate significantly increased once flames penetrated into the cavity.

The penetration of flames into the cavity and subsequent rapid fire growth occurred at an earlier time compared to WPC-01 (Tests 1 and 2). The following three factors may have contributed to this:

1. WPC-02 had a shiplap cladding profile which resulted in an approximately 15 mm air gap between the rear of the cladding and the steel battens. This gap at bottom edge of cladding was initially capped by a 1.6 mm thick aluminium angle at the base, which melted away, exposing the gaps to direct burner flames. WPC-01 had a flat rear profile which was screwed directly to steel battens with the bottom edge also capped by a 1.6 mm thick aluminium angle at the base.
2. WPC-02 was individual 156 mm vertical boards with a shiplap joint between boards and exhibited partial thermoplastic behaviour (softening). It is possible that as the material softened gaps may have opened between boards allowing flames to penetrate earlier (this was not possible to observe trough the gas burner flames). WPC-01 was installed in larger continuous sheets within only 1 single vertical butt joint which was off centre on the specimen
3. In cone calorimeter testing (CSIRO Report number: FE3153-RPT-03) WPC-01 performed similar to natural thin (~ 9 mm) timber, However WPC-02 had a faster HRRPUA growth rate and peak HRRPUA. This may have increased the rate of fire spread within cavity once the cavity was penetrated by flames.

Cavity fire spread had a critical impact on fire growth.

The application of a water extinguisher effectively suppressed flames on external surface; however, extinguishing the cavity fire required additional effort.

Compared to WPC-01, WPC-02 exhibited:

- Significantly high amounts of smoke production and toxic gas production.
- Thermoplastic behaviour with softened boards slumping and falling to floor during suppression.
- Increased smouldering and re-ignition during and after initial water suppression.

7.3.5 SPECIMEN TEST 4 – WPC-01, (~90-95% WOOD), NO CAVITY (PLASTERBOARD DIRECTLY BEHIND)

The test observations for Test 4 are summarised in the table below.

Table 15. Specimen Test 4 observations

Time (sec)	Observations
00	Pilot burner started prior to start of test. Main LPG burner mass flow controller started at 100 kW setting at t = 0 s (start of test).
~10s	LPG from main burner reaches pilot burner and ignites, starting the test.
130	Flames distributed evenly underneath of the WPC cladding. Intermittent flame reaching up to 1400 mm from ground level. Sustained flames appear at bottom edge of the WPC 01.
210	Flames increase in size. No cavity flames are observed (due to direct fixing of cladding to plasterboard without cavity). External flames are clearly visible, growing both horizontally and vertically.
380	Flames increase in size, with intermittent flames reaching the top of the cladding.
480	Flames on the external cladding reach up to 1500 mm from the bottom. External cladding flames continue to grow and spread vertically.

Time (sec)	Observations
620	Sustained flames above test specimen from front face of cladding.
870	The bottom part of the cladding burns away, creating a gap up to 1000 mm high from the bottom of the cladding. Sustained flames spread to the top of the cladding.
900	The LPG burner is increased to 300 kW. Larger flames are immediately visible at the top of the cladding. Flames grow in size, but there is no significant contribution from the bottom area of the cladding due to the material having burned away.
980	The LPG burner is turned off without any water suppression. Flame size reduces but remains sustained in the top part of the cladding. The burned area is clearly visible up to 1500 mm from the bottom edge. Flames continue spreading vertically. The burned area keeps expanding upward, leaving a larger gap before flames start to reduce in size.
1020	Flames significantly reduce in size, with minor flames at the bottom edge of the cladding. Red char accumulates at the bottom of the cladding. Smaller external flames are visible at the top. The burned area increases up to 1700 mm from the bottom. Smaller flames spread horizontally to the bottom edge.
1410	Flames at the top of the cladding self-extinguish first due to fuel depletion, while flames at the bottom sustain due to radiant heat from the red char on the ground.
2010	Flames on both sides of the cladding remain and spread upward, gradually reducing in size and fully extinguishing around 45 minutes after starting the test.
3136	The test ends. The char at the ground level is extinguished/cooled down using water. Small amounts of fire hose reel water applied to remaining cladding to suppress any continued smouldering.

Post test damage observations (reported before applying water).

- Black char areas are clearly visible. The burned area extends from the bottom edge to the top of the cladding, covering up to 80 percent of the entire cladding, with only small, unburned areas remaining in the top left and right corners.
- Hot char has accumulated at the bottom of the cladding on the ground level.

Discussion of test

- The absence of a cavity resulted in a significantly slower fire growth rate compared to Tests 1 and 2.
- Upon the ignition of burner at 100 kW, the HRR gradually/steadily increased ~350 KW at the end of the 900 s (15 min) 100 KW burner application.
- The total HRR slightly reduced to 300 kW during the last ~ 2 minutes of 100 kW burner application due to the burnout of the bottom portion of the cladding (in the area of direct burner flame impingement.
- Upon turning the burner off, the cladding continued to burn at the edges and top of the area of burnt away cladding. The HRR initially reduced rapidly to 200 kW within 60 s, but then decayed slowly until all flaming self-extinguished at 3120 s (52 min). at this time a fire hose was applied to supress any smouldering/glowing embers..

7.3.6 SPECIMEN TEST 5 – WPC-01, (~90-95% WOOD), CAVITY WITH CAVITY BARRIER AT TOP

The observations for Test 5 are summarised in the table below.

Table 16. Specimen Test 5 observations

Time (sec)	Observations
00	Pilot burner started prior to start of test. Main LPG burner mass flow controller started at 100 kW setting at t = 0 s (start of test).
~10	LPG from main burner reaches pilot burner and ignites, starting the test.
60	Flames distribute evenly at the bottom edge of the cladding with intermittent flame up to 1400 mm from ground level.

Time (sec)	Observations
120	Flames increase in size, with intermittent flames reaching up to 1900 mm. Small visible external flames are seen on the cladding surface.
240	Flames sustain on the external surfaces, with the flame height increasing to 2400 mm from the ground level. External surface flames grow in size.
390	Flame size spreads to the top of the cladding, with external surface flames increasing in size and spreading both vertically and horizontally.
510	Sustained flames above top of specimen from front face of cladding External flames continue from the bottom edge to the top of the cladding. The aluminium capping at bottom of cladding starts melting in centre. Strong burning is observed.
540	Cladding starts to burn through in small area at base directly above burner forming a small gap where burner flames penetrate into cavity. No flaming at top of cavity and cavity barrier remains sealed.
570	The middle gap/opening of the cladding increases in size and height, and the cavity fire becomes clearly visible. The bottom part of the cladding starts burning out. No flaming at top of cavity and cavity barrier remains sealed
720	The bottom part of the cladding burns out, reducing the added fuel to the total HRR. Flames slightly disconnect from the burner to the top part of the cladding due to the burnout of the bottom part. External flames are very strong from 900 mm above ground level to the top of the cladding, with contribution from the cavity fire. No flaming at top of cavity and cavity barrier remains sealed.
880	100 kW burner is turned off. At the time the burner was turned off, the cladding had burnt away exposing cavity in an Inverted "V" shape ~ 1 m wide at base and reaching top of specimen. Burning continues at the external surface around the edges of the remaining cladding and also within the cavity. The cavity barrier remains in place at top with cavity flames spilling around it through the burnt out opening in the centre of the cladding.
1200	Flames sustain at the right and left parts of the cladding until burnout. The top rockwool remains intact. Char drops and accumulates at ground level.
1380	The HRR reduced to 200 kW and the cladding had mostly burnt away except for ~ 100-200 mm wide flaming strips of cladding remaining at each side of the specimen
1560	Minor flames sustain with almost 100% of the cladding area burnt away.
2340	All flaming ceased and the cladding had been almost entirely consumed except for glowing embers

Post test damage observations (reported before applying water).

- Almost 100% area of the cladding is burnt away,
- The rockwool cavity barrier remained in place.
- Hot char has accumulated at the bottom of the cladding on the ground level.

Discussion of test

The test results highlight the minimal effect of the top barrier using rockwool in the later stages of the test once the cavity fire has developed. The sustained burning behaviour of WPC is highlighted with the following key points:

- The HRR increase gradually from 100 kW to 300 kW after 700 s of burning with 100 kW LPG demonstrating the contribution of the external flames due to the burning of WPC.
- Between 700 s to 800 s, the HRR rapidly increased due to burning though of the cladding in a central area starting at base, resulting in ventilation and burning within cavity. However the cavity barrier remained in place sealing the top of the cavity and reducing the fire growth rate to some degree.
- The HRR peaked at around 820 kW due to the burner being turned off at 880s.
- After switching of the of 100 kW burner, the Cladding kept burning at edges of front face and within cavity with fire spreading gradually horizontally. However the HRR gradually decayed.
- The cavity barrier using rockwool clearly contributed to reduce fire growth rate compared to Test 1 and Test 2. However, the fire growth rate was faster compered to test 4 (no cavity). For Test 5, the cavity fire still significantly contributed to the HRR, adding up to 700 kW in total. The cavity barrier

had less effect on HRR once the cladding had burnt through in a significant area, permitting ventilation into the cavity.

- For Test 05 with cavity barrier, an increased amount of horizontal fire spread on the cladding was observed compared to prior tests.

7.3.7 SPECIMEN TEST 6 – ISP-01 (PIR), VERTICAL, UNCAPPED EDGES, NO ADDITIONAL SCREW FIXING TO PANEL JOINTS, OPEN CAVITY.

The observations for Test 6 are summarised in the table below.

Table 17. Specimen Test 6 observations

Time (sec)	Observations
00	Pilot burner started prior to start of test. Main LPG burner mass flow controller started at 100 kW setting at t = 0 s (start of test).
~10	LPG from main burner reaches pilot burner and ignites, starting the test.
120	HRR of ~ 150 kW is measured with 100 kW burner HRR. There was also some increased smoke produced form the area of burner impingement at this time. This appeared to be when a section of aluminium capping at bottom of cladding melted exposing a small area of PIR to burning. It may also have been some contribution to burning from the paint on the steel facing and the sealant. Intermittent flames reach up to 1400 mm from the ground level, with black smoke rising to the exhaust hood. The burning PIR is not visible except for black smoke and external flames. The HRR peaks at 150 kW,
240	The burning and smoke production from the base of the specimen has reduced and the HRR is ~ 100 kW. For the rest of the 100 KW burner exposure until 900 s the specimen does not appear to significantly burn or produce HRR.
900	Burner increased to 300 kW. After increasing the burner to 300 kW, the flame height remains constant at around 1400 mm from the ground level, with intermittent flames reaching up to 2400 mm.
960	within 1 min of turning burner up to 300 kW, the vertical external steel skin joint had started to open, with the PIR core being exposed to flames and ventilation. The PIR char formation appeared to have an impact on controlling the fire growth and the total HRR remained stable at ~ 350 kW
1080	Intermittent flames reach the full height of the cladding, maintaining a constant height of around 1400 mm. Flames are visible from the bottom of the cladding, and the HRR peaks at 380 kW before gradually reducing to 330 kW around 1300 s.
1300	The HRR increases gradually with more black smoke emerging from the left side of the cladding. A gap at the bottom edge of the metal sheet allows flames from the inner PIR to become visible, increasing the HRR. The highest flame height is observed in the middle of the cladding due to this gap.
1370	Sustained flames above top of specimen from the uncapped PIR core edge at top of specimen Flames from the top core are visible, sustained, and growing larger on the left side of the cladding. Flames from the middle gap at the bottom reach up to 2400 mm from the ground level.
1700	The HRR reaches approximately 460 kW before gradually reducing. Flames at the bottom mainly burn inside the metal sheet with minimal external visibility. Sustained flaming from core at tope of specimen continues.
2200	The HRR reduces and fluctuates around 400 kW. The bottom flames are primarily from the burner, while the top flames originate from the core. The middle gap at the panel skin joints increases in size, with flames behind the metal skin visible from the middle to the top of the cladding.
2300	Flames at the bottom burn inside the cladding, with charred PIR falling and accumulating on top of the burner. The middle gap in the cladding enlarges, and bigger flames emerge from the middle, the HRR to approximately 495 kW.
2400	300 kW burner turned off without water suppression. HRR reduced to 300 kW. The PIR core continued to burn with a steadily decreasing HRR. Black char sits on top of the burner tray with small flames. Flames persist in the middle and top core, visible

Time (sec)	Observations
	through the gap between the panel steel skin vertical joint. The HRR reduces significantly, and the cladding is left to cool naturally. Post-test damage is then assessed.
3600	Flaming ceases. The PIR core continued to burn with a steadily decreasing HRR until the majority of the PIR was consumed or charred and flaming ceased at ~ 3600 s (1 hour). During this period charred segments of PIR core periodically fell to the lab floor Post test the steel facing skins remain in place but were open along the vertical joint with a gap of ~ 50-100 mm

Post test damage observations (reported before applying water).

- The external metal sheets are deformed, creating a permanent and visible gap between the panel joints of ~ 50-100 mm.
- Removal of the external skins revealed that >95% of PIR core had been consumed. With only a small amount of uncharred PIR core remaining in the top right corner of the specimen.

Discussion of test

- The aluminium capping at base of sandwich panel melted away in the centre base of specimen during the 100 kW burner exposure exposing the PIR core at bottom to burner flames.
- The PIR thermosetting and char forming behaviour controlled the rate of burning to some degree
- The Steel facing of the sandwich panel provided a degree of encapsulation of the core.
- However the lack of steel capping to exposed core edges of sandwich panels and the lack of fixings to the vertical joint result in eventual burning of most of the core.
- During the initial 15 minutes of heating with a 100 kW burner, the burning of PIR was minimal, contributing only an additional 50 kW to the peak HRR. This low contribution was due to the protective effects of the metal sheet encasing the PIR, which delayed the onset of significant burning.
- From 200 to 900 s, the HRR remained around 100 kW, indicating that only a minor amount of PIR was burning.
- Upon increasing the burner output to 300 kW, the PIR core began to burn more noticeably, resulting in a temporary rise of HRR by up to 100 kW. However, this increase was followed by a reduction to approximately 330 kW before experiencing another peak. This pattern indicates a progressive burning behaviour where the PIR core burns, forms a protective char layer, then the char degrades/falls away.
- The uncapped top of the sandwich panel and melted aluminium capping at bottom significantly increased the burning rate of the core. The cavity acted as a chimney, drawing in air and sustaining the combustion process. After switching off the 300 kW burner, burning of the core within the steel sheet persisted and slowly decayed over a significant time.

7.3.8 SPECIMEN TEST 7 – ISP-02 (EPS), VERTICAL, UNCAPPED EDGES, NO ADDITIONAL SCREW FIXING TO PANEL JOINTS, OPEN CAVITY

The observations for Test 7 are summarised in the table below.

Table 18. Specimen Test 7 observations

Time (sec)	Observations
00	Pilot burner started prior to start of test. Main LPG burner mass flow controller started at 100 kW setting at t = 0 s (start of test).
~10	LPG from main burner reaches pilot burner and ignites, starting the test.
60	Burner flames distribute evenly at the bottom of the panel. No flaming of specimen is visible, but minor black smoke is being produced in the area of burner flame impingement.

Time (sec)	Observations
120 - 240	From 120-240 s the aluminium capping at the bottom edge of the sandwich panel started to melt away in the central area above the gas burner. The bottom edge of the EPS core started to burn producing an increased amount of black smoke and a HRR of ~ 175 kW. The flame height is constant at 900 to 1400 mm, with intermittent flames reaching up to 1900 mm. The external flames then reduce in size.
285	Flames are reduced and only visible at the bottom of the cladding, remaining constant at around 900 mm. The flames from the burner appear to mostly be penetrating into the core of the sandwich panel behind the front metal skins
310	Large sustains flaming above the top of the specimen from the top of the EPS core. Burner flames are penetrating into the bottom of the cladding behind the front steel skin, with intermittent flames between 900 to 1400 mm..
390	A significant amount of black smoke is observed again. The external vertical steel skin joint started to open with flames emerging from the vertical joint. At this time there were large flames emerging from the uncapped top of the sandwich panel. There is a significant increase in flame size at the top of the cladding. The HRR dramatically increases from 200 to 1000 kW within just 100 s.
412	The test had reached a peak of 1017 kW which was limited by the available amount of EPS starting to burn out The flame at the top of the cladding has reached a maximum and distributes across entire width of specimen. At the bottom, the flame height remains around 900 mm, with intermittent flames within 900 to 1400 mm. The whole surface of the metal turns black. A significant amount of black smoke is emitted from the bottom of the cladding.
420	Some flaming molten EPS started falling to burner or lab floor below and continue to burn. However the majority of EPS appeared to burn within the sandwich panel core
600	The flame size reduces significantly, especially at the top of the cavity. Larger flames are seen at the bottom of the cladding, with the flame at the top mainly on the right-hand side. The flame size at the top of the cladding continues to reduce.
840	The available EPS appears to have fully burnt away and the test HRR reduced to 100 kW (the burner output). There is no visible flaming of the specimen. Only flames from the burner.
900	The burner is turned up to 300 kW. However no further significant burning of the specimen can be observed. The flames appear to be entirely from the burner.
1200	The burner is shut down. There is no further burning of the specimen. Upon turning off the burner

Post test damage observations

- The EPS core was ~ 100% consumed.
- The metal surface shows black and white areas, indicating the paint has been burnt.
- The vertical joint between the two steel external facings has opened with an ~ 50 mm gap.

Discussion of test

- The Aluminium capping at base of sandwich panel started to melt away allowing flames to penetrate and expose the EPS Core at base at an early stage from ~ 2 min onwards during the 100 kW burner exposure.
- The EPS thermoplastic behaviour and characteristics resulted significantly faster fire growth compared to the similar fire test 6 on PIR core sandwich panel.
- Shortly after 5 minutes of exposure to 100 kW burner the fire had spread within the EPS core behind the steel skins with flames venting from the top of the sandwich panel. The fire sized continued to grow from this point until it began to burn out of EPS fuel shortly after 7 minutes.
- No steel capping to exposed core edges of sandwich panels and the no fixings to the vertical joint resulted in fire exposure and fire spread on the EPS core at an early stage.

7.3.9 SPECIMEN TEST 8 – ISP 01 – ISP-01 (PIR), HORIZONTAL, CAPPED EDGES, ADDITIONAL SCREW FIXING TO PANEL JOINTS, OPEN CAVITY

The test observations for Test 8 are summarised in the table below.

Table 19. Specimen Test 8 observations

Time (sec)	Observations
00	Pilot burner started prior to start of test. Main LPG burner mass flow controller started at 100 kW setting at t = 0 s (start of test).
~10	LPG from main burner reaches pilot burner and ignites, starting the test.
60 – 900 s	Burner flames distribute evenly underneath the cladding, sustaining between 400 to 900 mm above ground level, with intermittent flames reaching up to 1400 mm. During the 15 min 100 kW burner exposure a small amount of black smoke emerges is produced by the cladding, and the external metal sheet slightly deforms. However there is no observed flaming of the specimen during this period and the HRR remains steady around 100 kW. The screw fixed steel front face panel joints and steel edge capping remain intact with no gaps opening up. A small amount of smoke is venting from the top of the cavity during the later half of this period
900	The Burner is turned up to 300 kW. The flame height at the front of the specimen increased to flame height typical of 300 kW burner with initially no significant flaming contribution from specimen. The amount of smoke venting from the top of the cavity increases
1000	The HRR has increased to ~ 400 kW. There is a small amount of flaming occurring at the joint between panels 1 and 2. The joints and capping have remained in tact and not opened up significant gaps, however it appears the flaming may be due to a combination of sealant burning and possible pyrolysis gas from core squeezing out through joints.
1100	The HRR drops to ~ 350 kW and remains relatively steady before increasing back to 400 kW at 1650 s.
1200	Intermittent small/medium flaming is visible venting from centre of top of cavity.
1440	Intermittent small/medium flaming is visible venting from mostly now from left of top of cavity. Intermittent means flames a visible for less than 10 s. However during this period the intermittent flaming stops/starts constantly.
1600	Small/medium flames venting mostly from left of top of cavity have become sustained
1650	The HRR peaks again at around 400 kW with sustained flames at the top of the cladding. The HRR steadily reduces to 300 kW by 2400 s. flames persist.
2400	Sustained flames venting from top of cavity on left side continue prior to turning burner off. The 300 kW burner is shut down. After burner shutdown there is no visible flaming anywhere on the specimen except for small sustained flames which continue to vent from left and centre at top of cavity.
2550	The sustained flames venting from top of cavity steadily decrease from the time the burner is turned off until flames cease venting from top of cavity at 2550 s.

Post test damage observations.

- The external steel facings were blackened with soot and the paint has be burnt/flaked away in the lower half of the specimen
- The fixings, steel capping and steel panel joints remained in tact with no gaps/holes having formed.
- Removing the steel capping and external steel skins revealed that ~70% pf the PIR core had been heavily charred. ~ 30% of the PIR core remained uncharred located in the top right corner and right side of specimen.

Discussion of test

Inclusion of the steel capping and screw fixings to front face joints significantly increased the encapsulation/protection of the PIR core. This resulted in the following compared to Test 06:

- Reduced peak HRR during 300 kW burner exposure
- A reduction in the size/extent of sustained flaming above the top of the specimen

- Reduced extent of charring/consumption of PIR core.

Small/medium flaming still did occur above the top of the specimen during the 300 kW exposure. Thes flames were venting from the rear cavity. It appeared that fumes from the PIR core were able to vent from joints in rear cavity which did not have screw fixings and these fumes eventually ignited either within the cavity or near the top of the cavity where they were exposed to air.

7.3.10 SPECIMEN TEST 9 – ISP-02 (EPS), HORIZONTAL, CAPPED EDGES, ADDITIONAL SCREW FIXING TO PANEL JOINTS, OPEN CAVITY.

The observations for Test 9 are summarised in the table below.

Table 20. Specimen Test 9 observations

Time (sec)	Observations
00	Pilot burner started prior to start of test. Main LPG burner mass flow controller started at 100 kW setting at t = 0 s (start of test).
~10	LPG from main burner reaches pilot burner and ignites, starting the test.
60	Burner flames distribute evenly underneath the cladding, sustaining heights between 400 and 900 mm above ground level, with intermittent flames reaching up to 1400 mm.
120-240	During the first 2-4 minutes there was a period of increased smoke from the front of the specimen and the HRR also slightly increased ~150 kW. This appeared to be due to the painted surface burning and possibly a small area of the EPS behind steel facing exposed to burner pyrolyzing with fumes squeezing our joins at bottom of panel and burning. The capping and joints remained in tact with no gaps forming. After 240 s the HRR retuned to ~ 100 kW and
240	The HRR has reduced back to 100 kW and there is no significant fuming or smoking of specimen from front face. There is smoke/fumes venting from top of cavity which appears to be steadily increasing.
480	No significant changes are observed except sealant between panels melting on front face.
724	As the 100 kW burner phase of the test progresses the amount of smoke and fume vented from the top of the cavity increased until it eventually became intermittent small flames rapidly followed by sustained small/medium flames on right 1/3rd width of top of cavity from 720 s (12 min). The HRR has increased to ~170 -180 kW. The flaming at top of cavity remains small/medium for the remainder of the 100 kW burner exposure period. There is no significant flaming from the specimen on the front face during this period
900	The burner output is increased to 300 kW.
960	Within 60 s of turning the burner up to 300 kW flaming at the top of the cavity increased to large sustained flamed across the entire width of the cavity
1000	The HRR peaks at 700 kW with flames at the top of the cladding growing larger and distributing along the width. There is no significant flaming from the specimen on the front face and the joints and caping on the front face are intact and have not formed gaps. There is flaming at the base of the specimen but it is not possible to determine if this is only due to the gas burner or if the EPS is venting and contributing at base of specimen.
1200	The specimen appears to be starting to burn out of EPS as fuel. The HRR drops to around 420 kW. The flames at the top of the cladding reduce in size.
1320	A small amount of flaming occurs at side capping edges of specimen on left and right sides. This appears to be EPS fumes squeezing through caping joints and igniting. The capping and joints remain in tact
1560	All flaming of the specimen, including flaming at the top of the cavity, had ceased. The fixing of front face panel joints and capping remained in tact without gaps opening through the entire test. There was no molten EPS which dripped to the burner or floor below test specimen. All EPS appears to have been consumed within the sandwich panel core area.
1800	The 300 kW burner is turned off. There is no flaming of the specimen immediately after the burner is turned off. There is no continued flaming of the specimen immediately upon turning the burner off.

Time (sec)	Observations
	No EPS has dripped onto the burner or the floor below the specimen. It appears that all EPS was consumed within the metal skins

Post test damage observations

- The external steel facings were blackened with soot and the paint has been burnt/flaked away in the lower half of the specimen
- The fixings, steel capping and steel panel joints remained in tact with no gaps/holes having formed.
- Removing the steel capping and external steel skins revealed that ~100% of the EPS core had been consumed with only a very small amount of charred material collected at the bottom of the specimen skin/capping..

Discussion of test

Inclusion of the steel capping and screw fixings to front face joints significantly increased the encapsulation/protection of the EPS core. This resulted in the following compared to Test 07:

- Reduced fire growth rate and peak HRR

However, the following fire behaviour did still occur:

- Small/medium flaming still did occur above the top of the specimen venting from cavity during the 100 kW burner exposure.
- Flaming at venting from top of cavity increased to large-sustained flames during the 300 kW burner exposure.
- This flaming continued until ~ 100% of the EPS core was consumed.
- These flames were venting from the rear cavity. It appeared that fumes from the EPS core were able to vent from joints in rear cavity which did not have screw fixings and these fumes eventually ignited either within the cavity or near the top of the cavity where they were exposed to air.

This test on EPS core with steel capping resulted in a significantly higher peak HRR and faster growth rate compared to similar test 8 on PIR core with steel capping.

7.3.11 SPECIMEN TEST 10 – ISP-01 (PIR), VERTICAL, CAPPED EDGES, ADDITIONAL SCREW FIXING TO PANEL JOINTS, OPEN CAVITY

The results and observations for Test 10 are very similar to Test 8 (which was essentially the same type of specimen and installation except for panels being horizontal in test 8). The following were the main minor difference.

- Sustained small/medium flaming from top of cavity started at 1205 s.

Post test damage observations

- The external steel facings were blackened with soot and the paint has be burnt/flaked away in the lower half of the specimen
- The fixings, steel capping and steel panel joints remained in tact with no gaps/holes having formed.
- Removing the steel capping and external steel skins revealed that ~60-70% of the PIR core had been heavily charred. ~ 30% of the PIR core remained uncharred located in the top right corner and right side of specimen.

Discussion of test

Test behaviour and results were very similar as for Test 8.

7.3.12 SPECIMEN TESTS 11 AND 13– ISP 01 – ISP-01 (PIR), HORIZONTAL, CAPPED EDGES, ADDITIONAL SCREW FIXING TO PANEL JOINTS, STEEL FLASHING PARTIALLY COVERING CORE AT PANEL JOINTS, OPEN CAVITY

The results and observations for Tests 11 and 13 are very similar to tests Test 8 and 10. The following were the main minor differences.

- Test 11, Sustained small/medium flaming from top of cavity started at 2100 s.
- Test 13, Sustained small/medium flaming from top of cavity started at 2160 s.

Post test damage observations

- The external steel facings were blackened with soot and the paint has be burnt/flaked away in the lower half of the specimen
- The fixings, steel capping and steel panel joints remained in tact with no gaps/holes having formed.
- Removing the steel capping and external steel skins revealed that ~60-70% of the PIR core had been heavily charred. ~ 30% of the PIR core remained uncharred located in the top right corner and right side of specimen.
-

Discussion of test

Test behaviour observed from exterior and test results were very similar as for Test 8 and Test 10.

The internal steel flashings were still located at panel joints (due to screw fixing to steel skin). However, these flashings (applied to PIR core) did not impact the test results (in terms of HRR and amount of core charring) noticeably compared to Test 10.

7.3.13 SPECIMEN TEST 12 – ISP-02-EPS, HORIZONTAL, CAPPED EDGES, ADDITIONAL SCREW FIXING TO PANEL JOINTS, STEEL FLASHING PARTIALLY COVERING CORE AT PANEL JOINTS, OPEN CAVITY.

The test observations for Test 12 are summarised in the table below.

Table 21. Specimen Test 12 observations

Time (sec)	Observations
00	Pilot burner started prior to start of test. Main LPG burner mass flow controller started at 100 kW setting at t = 0 s (start of test).
~10	LPG from main burner reaches pilot burner and ignites, starting the test.
60	Burner flames distribute evenly underneath the cladding, sustaining heights between 400 and 900 mm above ground level, with intermittent flames reaching up to 1400 mm. A small amount of black smoke emerges from the cladding, gradually increasing, and the external metal sheet slightly deforms. The HRR increases up to 150 kW before gradually reducing back to 100 kW. Small flames observed come out from the bottom steel cap.
120-240	During the first 2-4 minutes there was a period of increased smoke from the front of the specimen. This appeared to be due to the painted surface burning and possibly a small area of the EPS behind steel facing exposed to burner pyrolyzing with fumes squeezing our joins at bottom of panel and burning. The capping and joints remained in tact with no gaps forming. However the HRR during this period did not significantly increase beyond 125 kW.
300	No flaming on the specimen front face has occurred. The steel capping and facing joints have remained in tact with not gaps opening. Fumes/smoke have started to vent from the top of the rear cavity.
300-900	The behaviour of the specimen remains stable for the remainder for the 100 kW burner exposure. Only the fumes/smoke venting from the top of rear cavity steadily increases over this period
800	The HRR fluctuates slightly around 120 kW. Significant amount of white smoke is observed from top left edge of the cladding.

Time (sec)	Observations
900	The burner output is increased to 300 kW. For the first 100 seconds after turning the burner up the HRR remains at ~ 300 kW and there is no visible flaming of the specimen. The fumes/smoke venting from the rear cavity significantly increase during this time.
1020	Sustained flames vent from the top of the cavity. These flames were initially located at left side of cavity.
1064	Sustained flaming above top of cavity increases and is located at both left and right sides of cavity.
1260	Small flames occur at left and right side edge capping of specimen from front face. This appears to be fumes from EPS squeezing out through joins and burning. The Steel capping and external facing joints are still intact with no gaps opening.
1100	Sustained flaming above top of cavity increases and is located across most of width of cavity. The HRR has increased to ~ 460 kW
1320	The HRR peaks at ~520 kW with sustained large flemes venting from top of cavity and small flaming occuring from some areas of edge capping at bottom of the cladding and from right edge of the cladding. After this time the HRR starts gradually decreasing with sustained flames at top of cavity gradually decreasing. This indicates that the specimen is gradually burning out of EPS.
1920	Flames at top left of cavity of the cladding disappears, while the flame and top right of cavity remaining with small size.
2100	Flames above the top cavity of the cladding cease. The HRR continue declining and reach 300 kW at 2148 second, indicating no additional EPS burning.
2400	The 300 kW burner is shut down. There is no continued flaming of the specimen immediately upon turning the burner off. No EPS has dripped onto the burner or the floor below the specimen. It appears that all EPS was consumed within the metal skins.

Post test damage observations

- The external steel facings were blackened with soot and the paint has been burnt/flaked away in the lower half of the specimen
- The fixings, steel capping and steel panel joints remained intact with no gaps/holes having formed.
- Removing the steel capping and external steel skins revealed that ~100% of the EPS core had been consumed with only a very small amount of charred material collected at the bottom of the specimen skin/capping.

Discussion of test

When compared against Test 9 (EPS with steel edge capping and screw fixed front face joints but no steel flashing at core joints), it is concluded that installing steel flashing partially covering core at panel joints for test 12 appeared to have the following impacts on results:

- Sustained flaming above top of specimen venting from cavity did not occur during the 100 kW burner exposure for Test 12 (it did for Test 9).
- Large sustained flaming above top of specimen venting from cavity did occur during the 300 kW burner exposure for both tests 12 and 9.
- The peak HRR and time during 300 kW burner exposure for test 12 (520 kW at 1320 s) was improved compared to Test 9 (700 kW at 1000 s). This indicated that the internal steel flashing at panel joints appeared to have slowed the rate of burning of the EPS core within the test specimen compared to Test 9.
- However, in both tests the specimen continued to burn until all the EPS core was consumed.
- The internal steel flashings were still located at panel joints (due to screw fixing to steel skin)

8 Conclusion

Cladding Safety Victoria (CSV) have engaged CSIRO to design and undertake a series of intermediate fire test on various types of cladding.

The intermediate scale cladding fire tests are experiments (not complying to a particular test standard) applying a fire source in the range of 100-300 kW to a cladding specimen ~ 1.5 m wide x ~ 2.6 m high. The experimental arrangement was significantly modified from ISO 13785:2002 Part 1

Key conclusions from this series of tests are:

1. The following tested specimen systems all exceeded 1 MW HRR and were ranked as having the worst fire performance in terms of rate of fire growth compared to all specimens tested:
    a. ISP-02 (EPS) with no steel capping or screw fixing of joints, >1MW at 412 s.
    b. WPC-02 (~53-56% wood) with open cavity, > 1MW at 480 s.
    c. WPC-01 (~90-95% wood) with open cavity, > 1 MW at 570-610 s
2. ISP-01 (PIR) with steel capping and screw fixing to front steel facing joints had the best fire performance in terms of rate of fire growth and peak HRR have a peak HRR ranging from 370 kW - 430 kW during the 300 kW burner exposure.
3. All specimens tested, except for ISP-01 (PIR) with steel capping and screw fixing to front steel facing joints, resulted in large sustained flaming above the top of the specimen.
4. ISP-01 (PIR) with steel capping and screw fixing to front steel facing joints, resulted in small/medium sustained flaming above the top of the specimen
5. The presence of a cavity behind wood polymer composite cladding significantly increased the fire growth rate. Once ignition source flames penetrated into the cavity, fire spread within the cavity was enhanced.
6. Eliminating the cavity by installing the WPC directly to plasterboard significantly reduced the fire growth rate. Installing a cavity barrier at the top of the cavity behind the WPC had a less significant reduction to fire growth rate as fire within the cavity still occurred with flames spilling around the cavity barrier once the cladding had burnt through in a central area up to the cavity barrier.
7. Installing steel capping and screw fixing to the steel front facing joints has a significant impact in reducing fire growth rate for both ISP-01 (PIR) and ISP-02 (EPS), as this enhanced the encapsulation of the combustible core material and limited ventilation to core and emission of combustible fumes to the outside of the panels.
8. For sandwich panels it was not possible/practical to install screw fixings to rear steel facing panel joints within the rear cavity. Fumes were emitted from these rear cavity joints resulting in sustained flaming venting from the top of the cavity for EPS core ISP and PIR core ISP.
9. PIR core ISP generally had better fire performance in terms of fire growth rate and peak HRR compared to EPS core ISP.
10. WPC-02 (~53-56% wood) with open cavity had slightly worse fire performance in terms of fire growth rate compared to WPC-01 (~90-95% wood) with open cavity.
11. WPC-02 (~53-56% wood) produced significantly more smoke and toxic gas than WPC-01 (~90-95% wood).
12. WPC-02 (~53-56% wood) behaved partially thermoplastic (softening and slumping when exposed to fire) and had a higher propensity for continued smouldering and re-ignition after water suppression compared to WPC-01 (~90-95% wood). WPC-01 (~90-95% wood) appeared to behave similar to thin (~ 9 mm) 100% natural wood in terms or charring and fire behaviour.
13. This set of intermediate-scale cladding fire tests are intended to be fire scenario-based experiments to observe the reaction of the cladding system in response to a localized external fire source and provide test data to inform general cladding fire risk assessment. They are not tests in accordance with any specific test standard, and pass/fail criteria from other test standards should not be directly applied.

14. This report presents the test results and a comparative ranking of fire performance of the tested cladding systems, exposed to the specified test fire source. These test results alone, do not directly assess the risk of vertical fire spread for systems installed to actual buildings.

Appendix A Specimen Lifting frame details

- All sections to be Galvanised steel 75 x 75 x 3 mm SHS
- 4 mm thick galvanised steel bolting plates to be welded to SHS as shown in exploded view and plates and connecting sections to be pre- drilled for M12 bolting with 100 mm long galvanised steel bolts
- Centre lifting point to be fitted with welded steel eyelet or steel rod bent and welded to underside of lifting point to receive 1 Tonne chain block
- Maximum cladding panel mass to be lifted is 330 kg
- Stress calculations on frame with above steel SHS dimension indicate design provides a factor of safety = 5.
- Total length of 75 x 75 x 3 mm SHS ~ 35 m plus allowance for wastage.

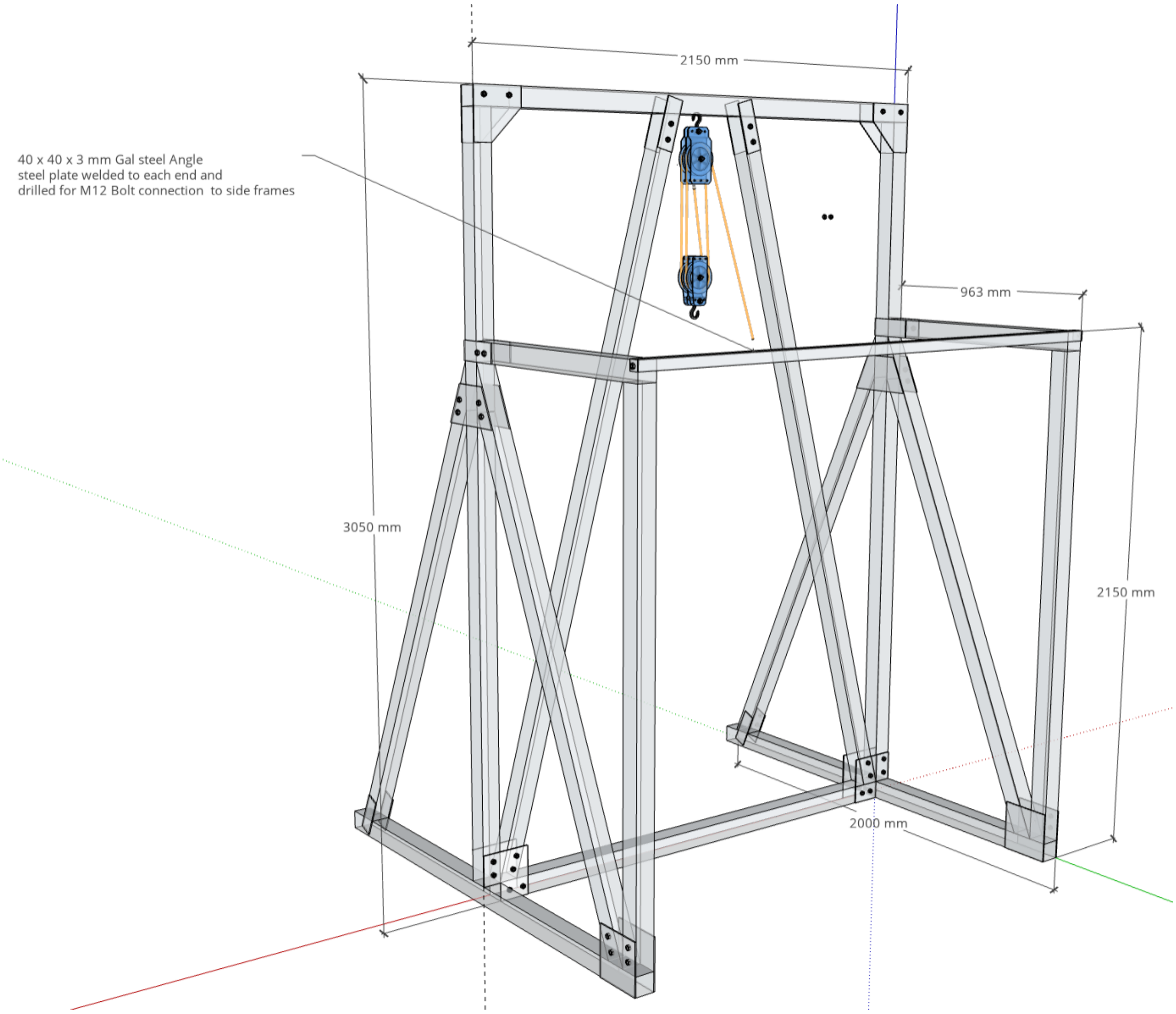


Figure 18 – 3D view

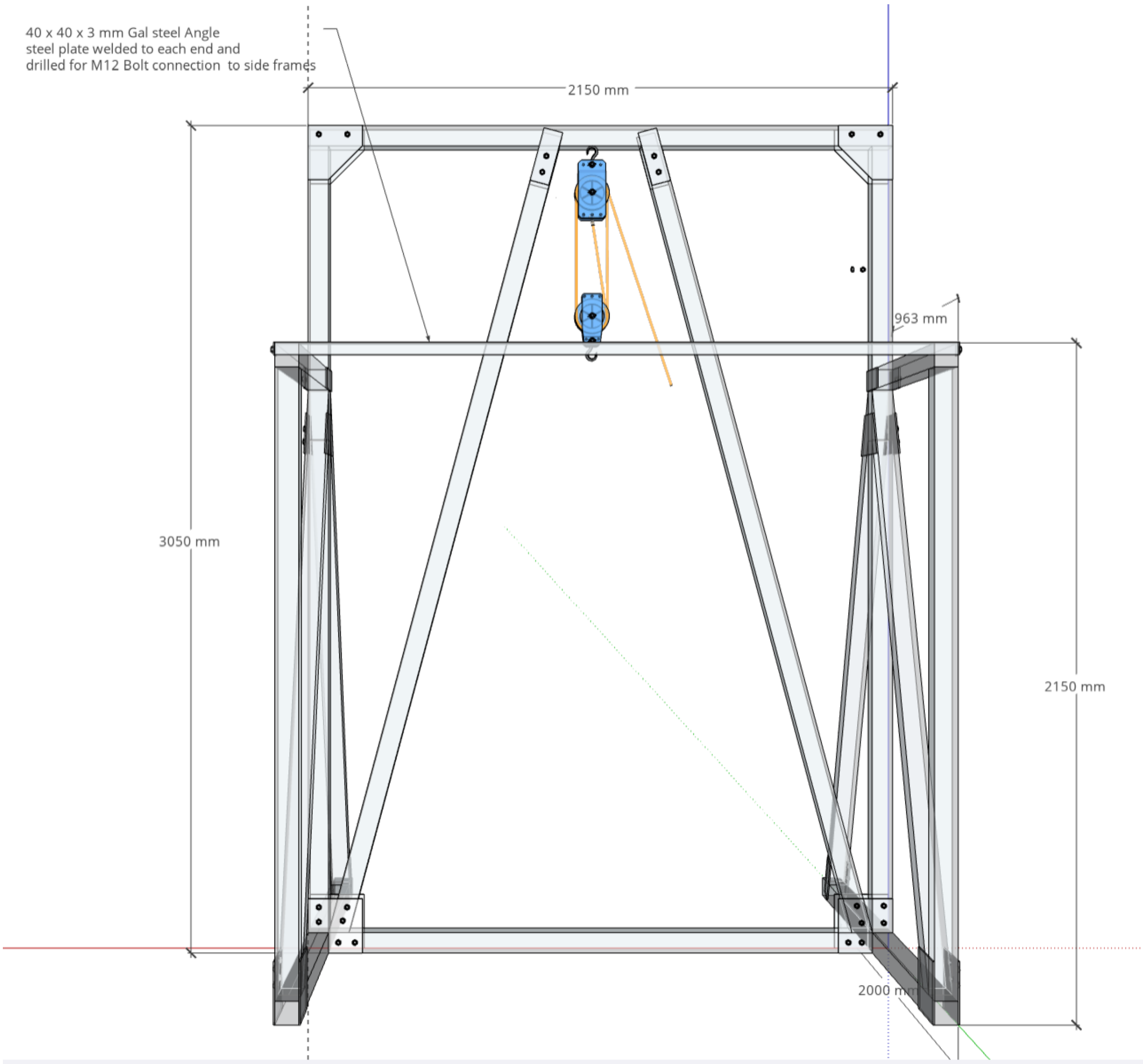


Figure 19. Front View

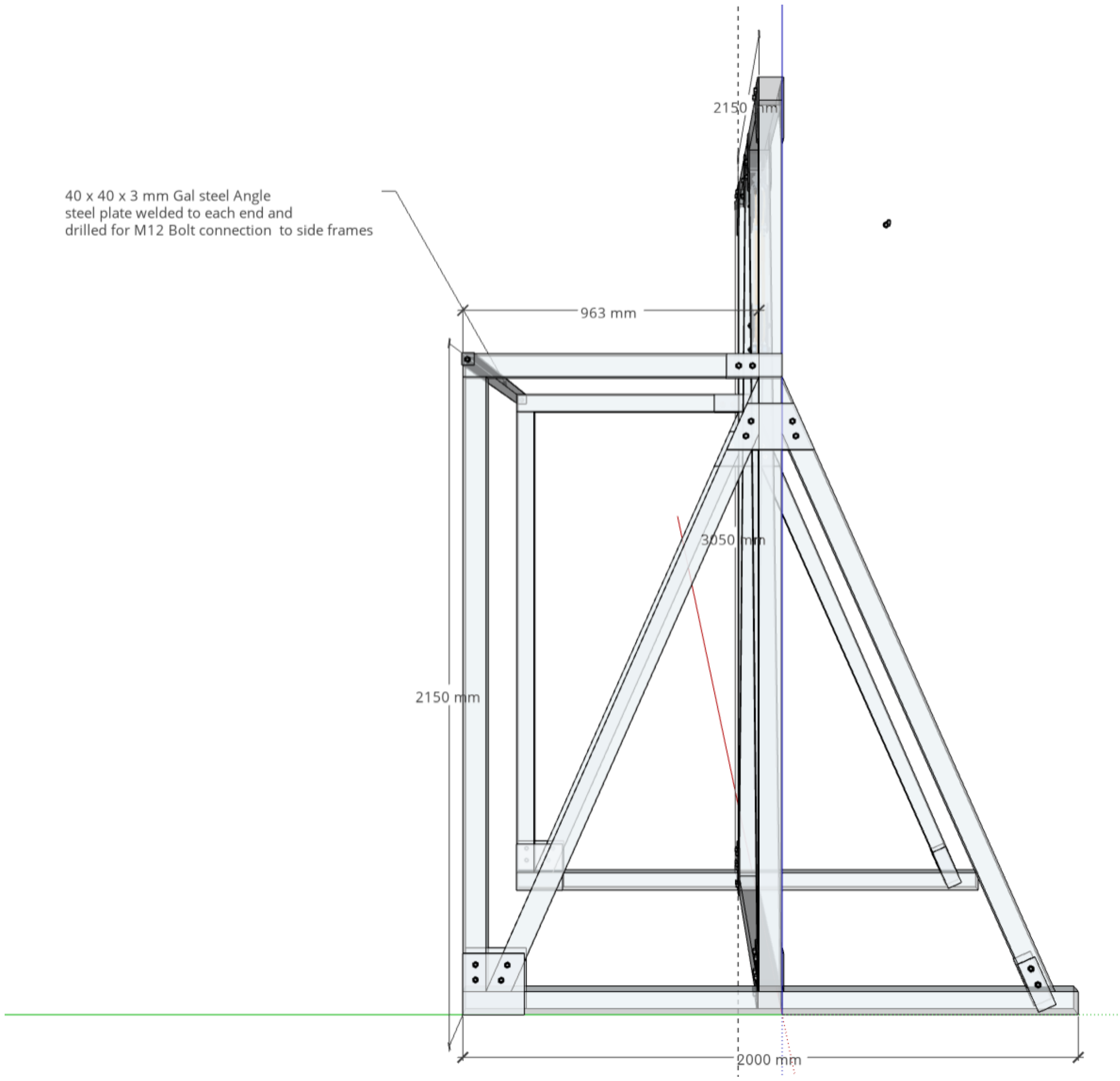


Figure 20. Side view

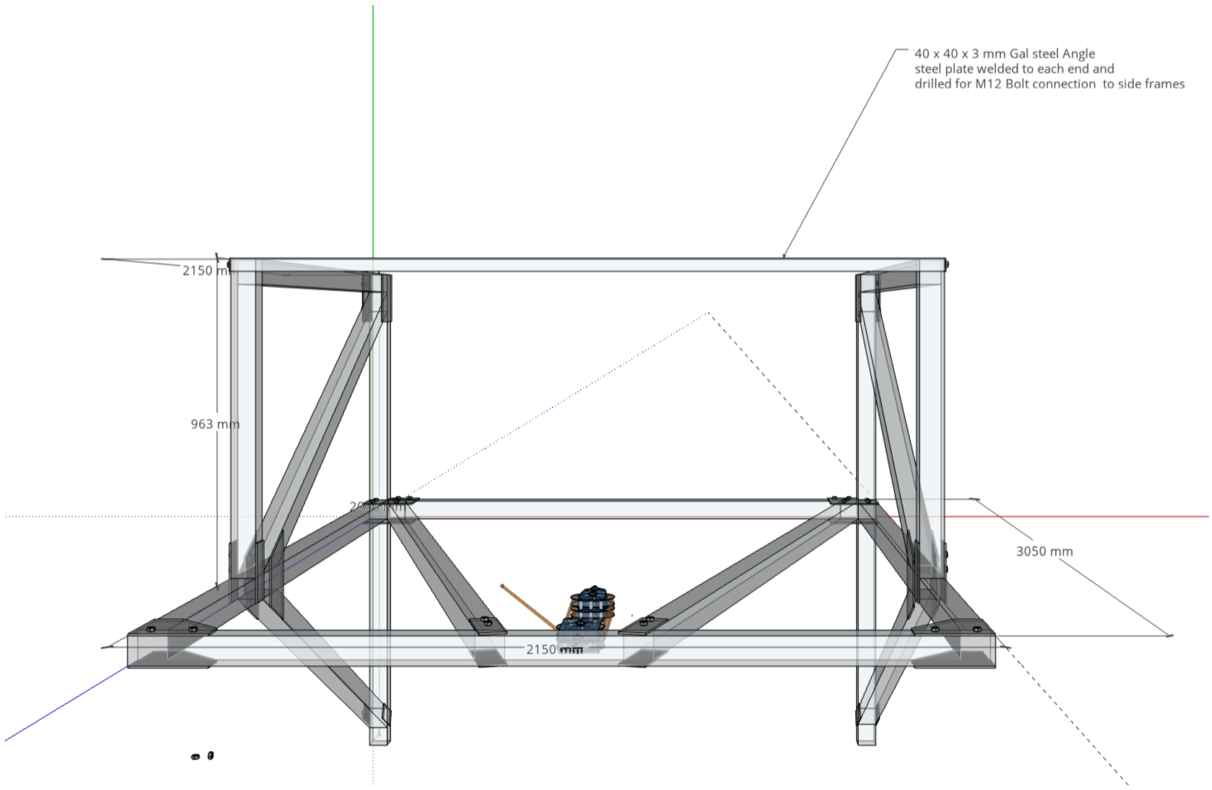


Figure 21. Top View

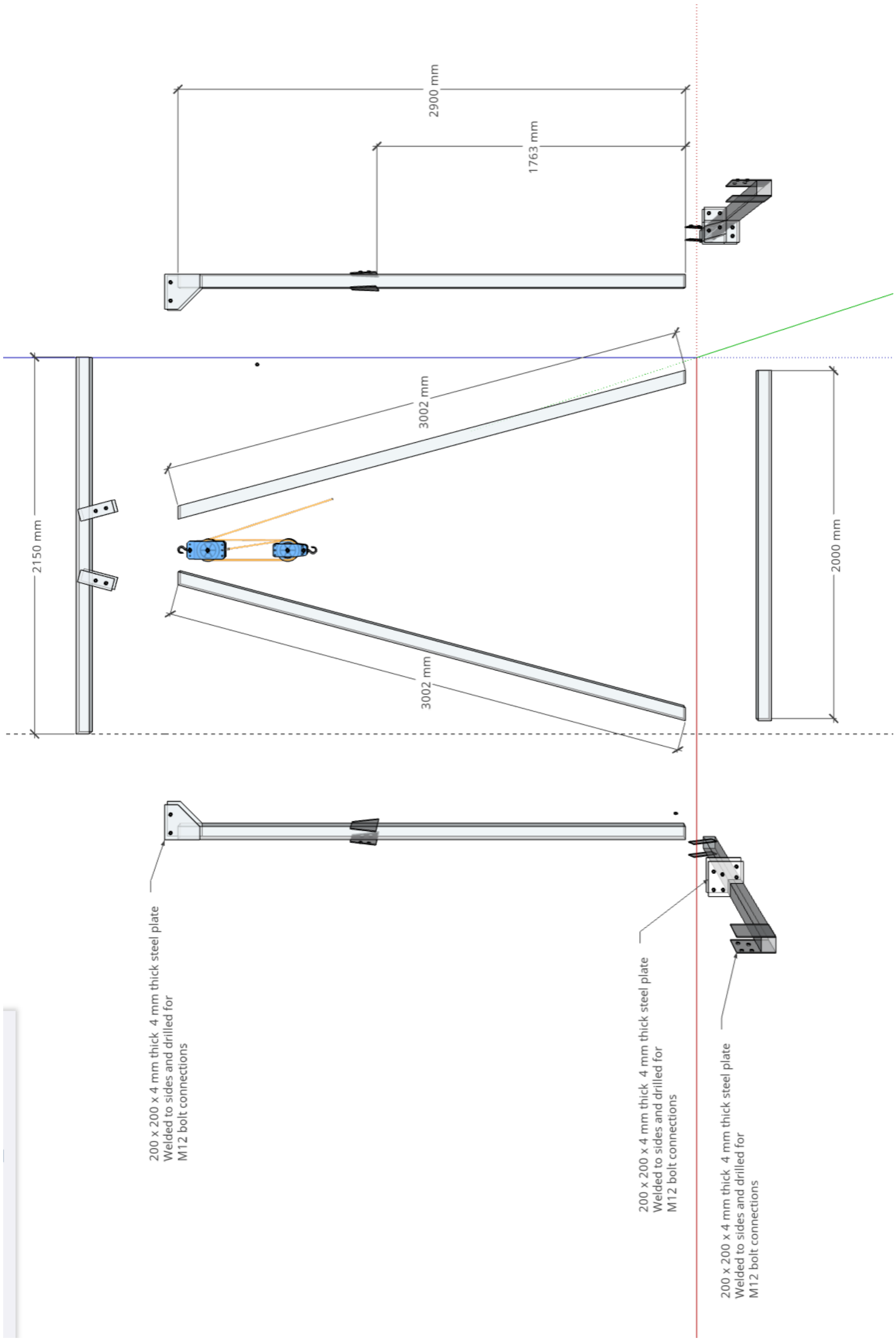


Figure 22 Front exploded view

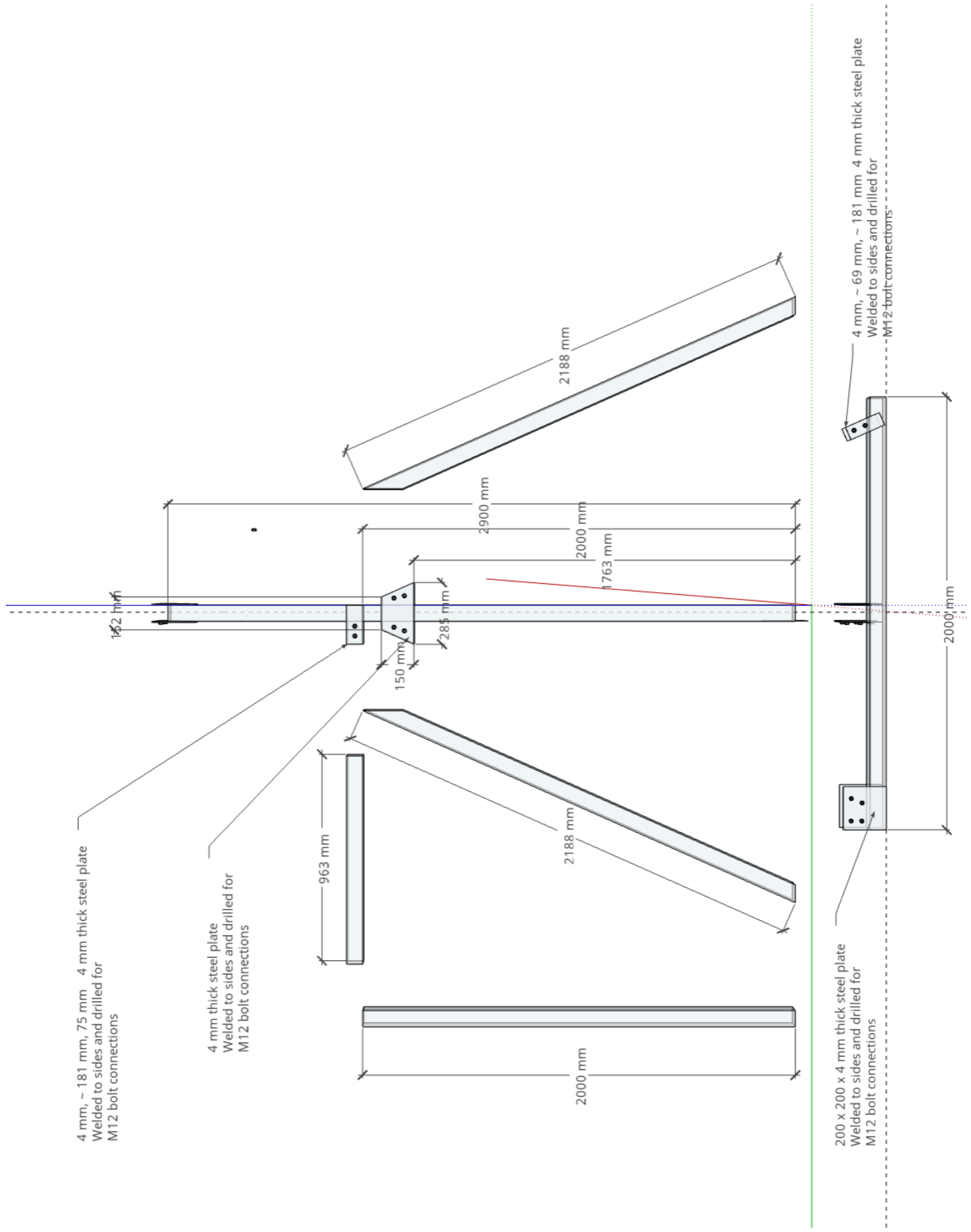


Figure 23 Side exploded view

Appendix B Test Measurement graphs

B.1 HRR Calibration tests

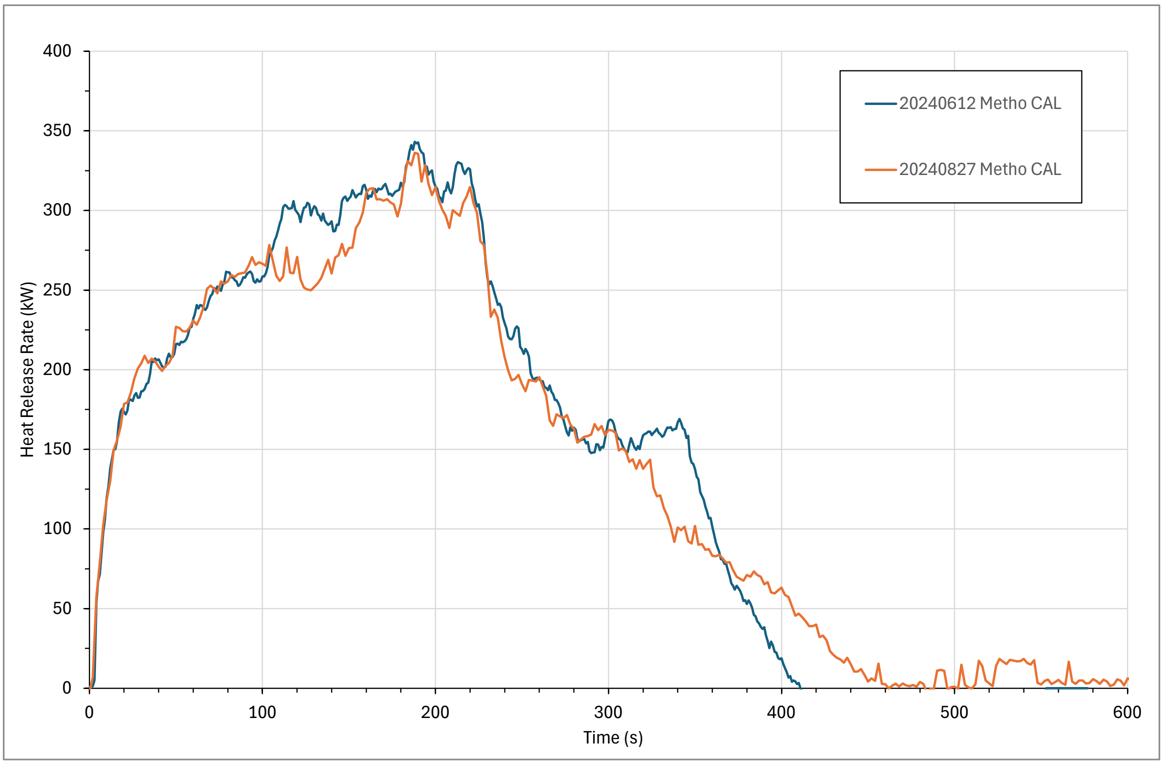


Figure 24. Methylated spirits pool fire calibration test HRR.

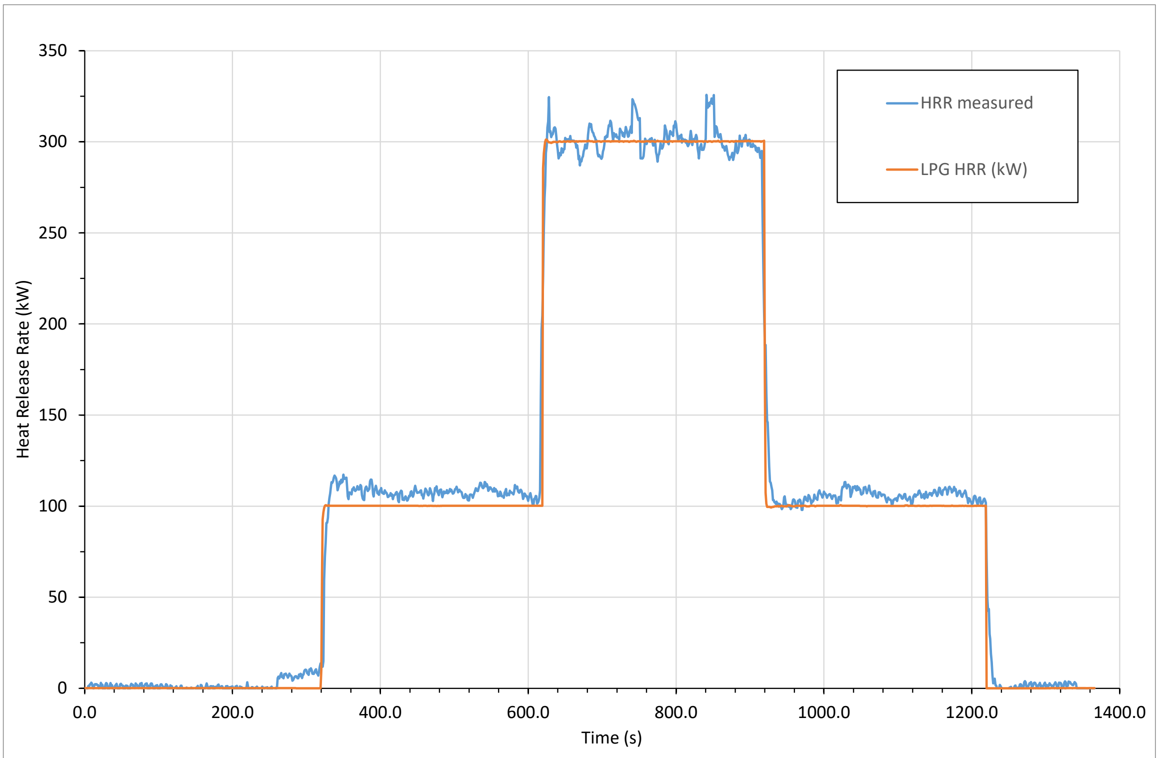


Table 22. Propane Burner calibration conducted on 12/06/2024

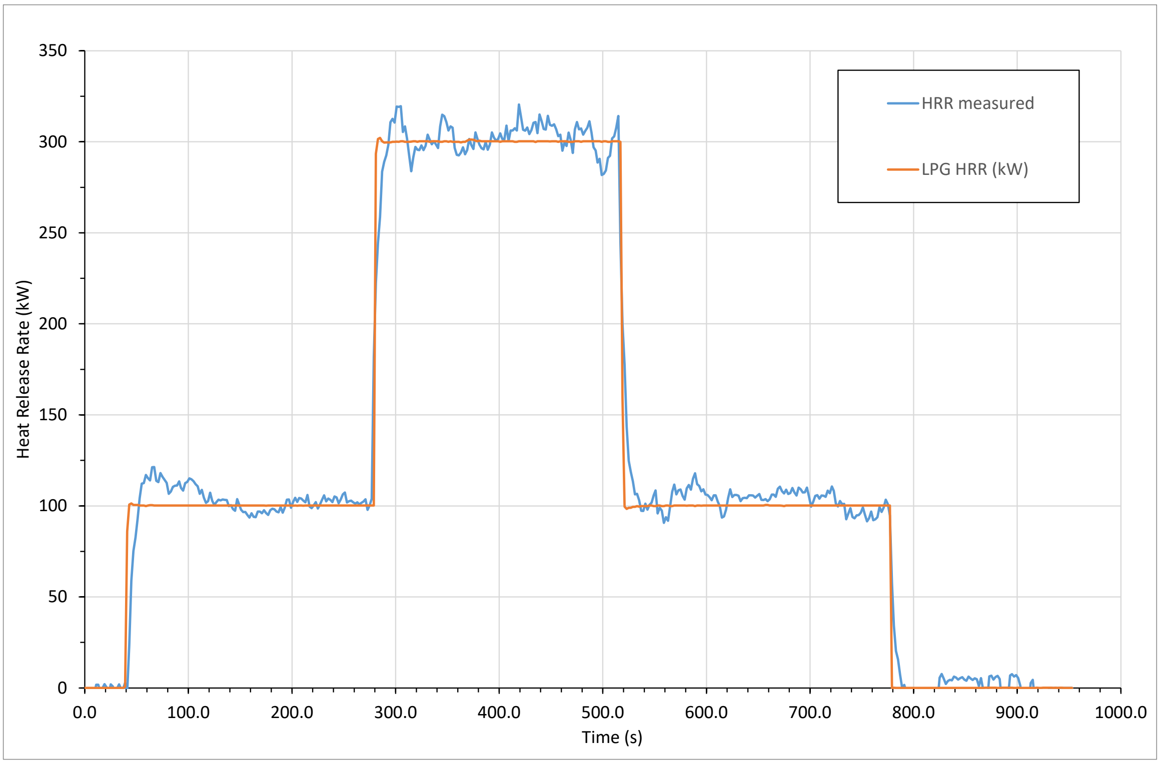


Table 23. Propane Burner calibration conducted on 27/08/2024

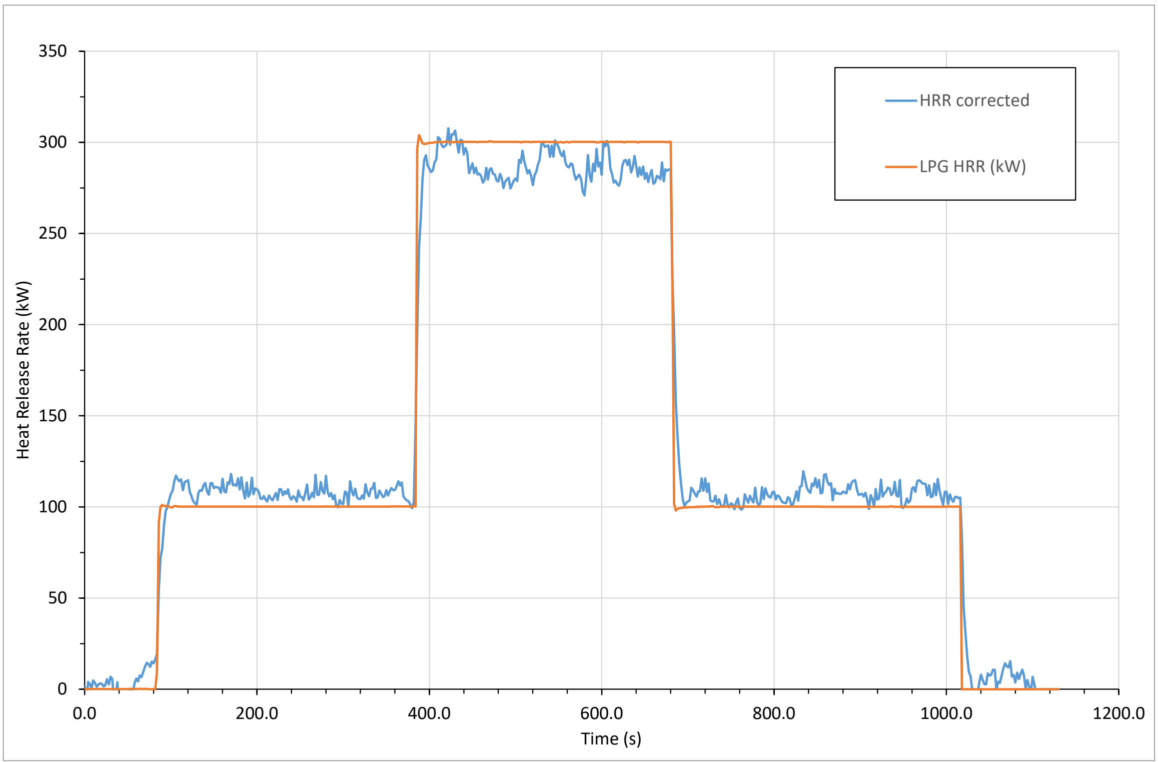


Table 24. Propane Burner calibration conducted on 24/10/2024

B.2 Short Characterisation test

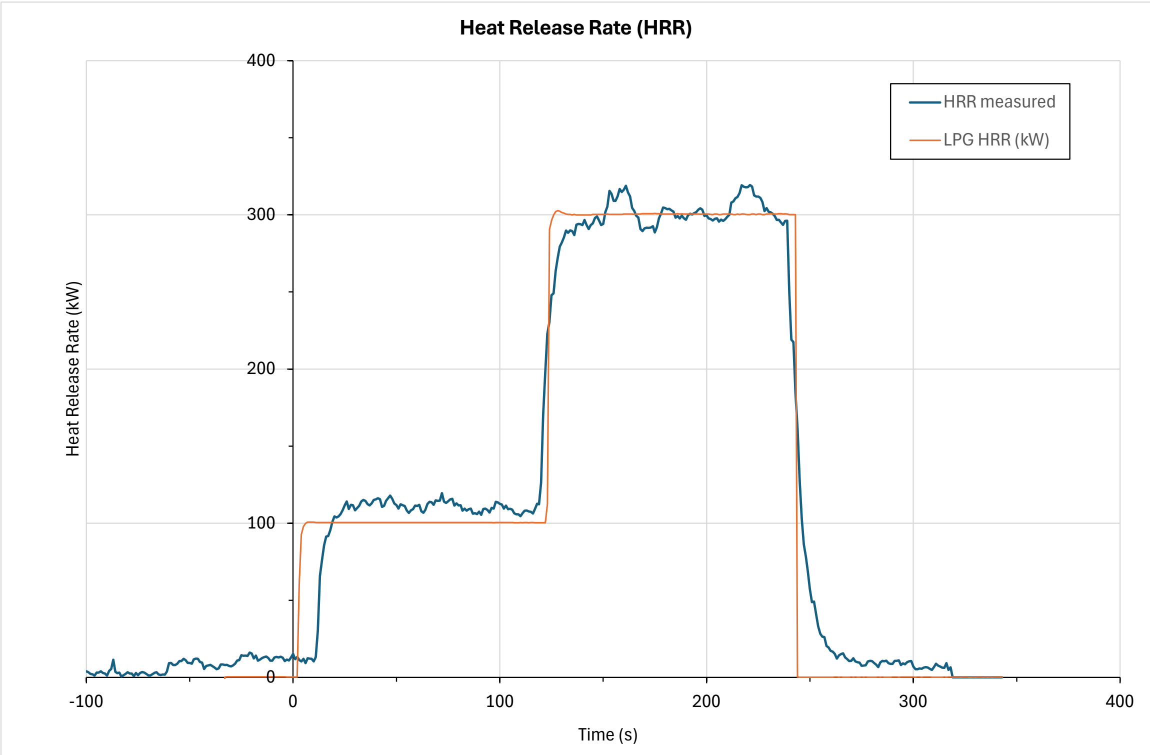


Figure 25. Short characterisation test – HRR vs time.

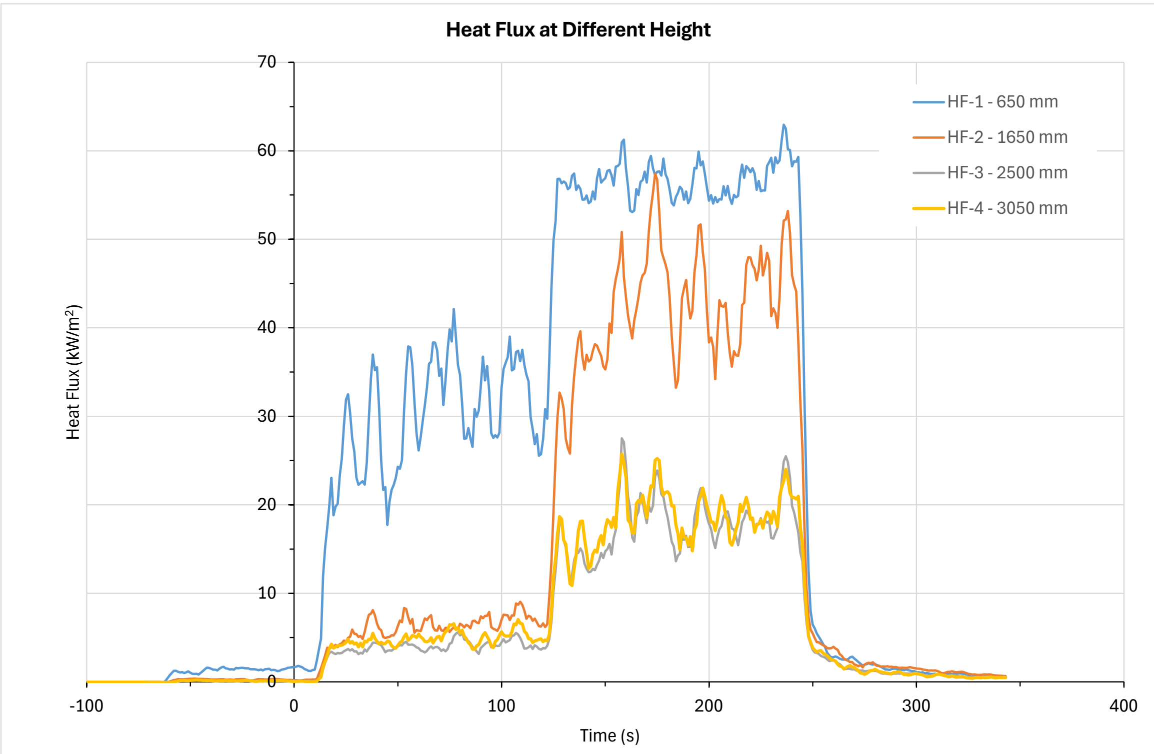


Figure 26. Short characterisation test – Heat flux at different locations.

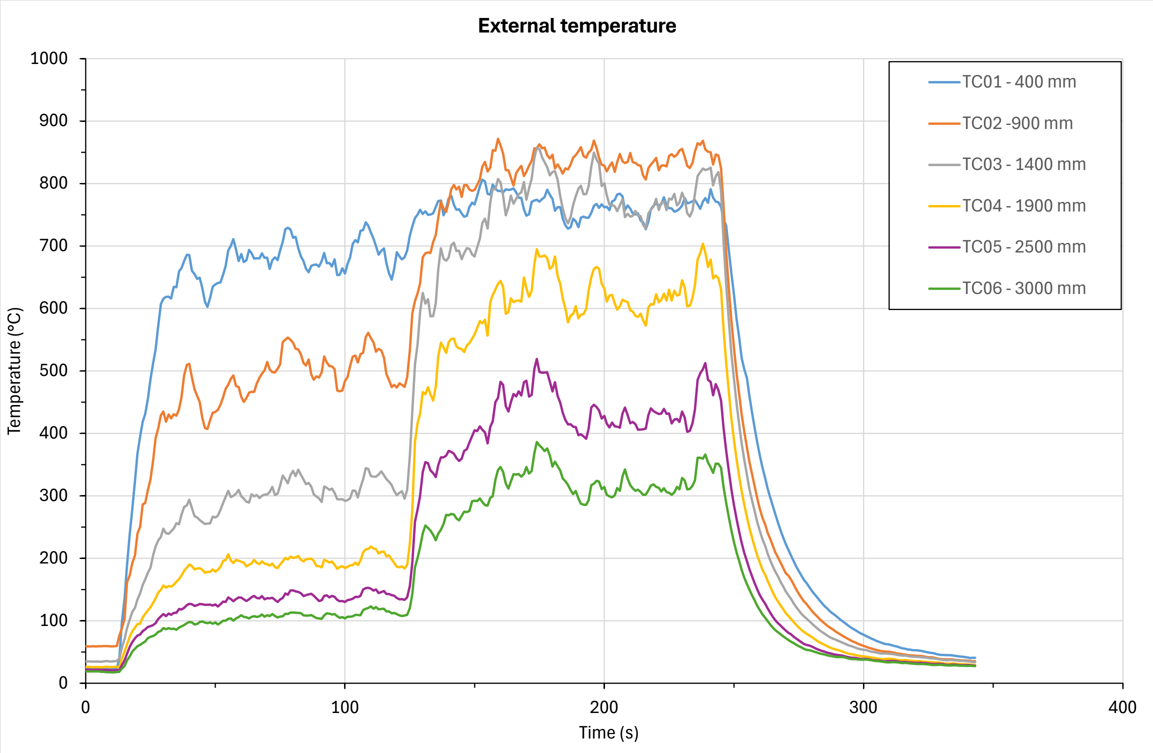


Figure 27. Short characterisation test – External face temperatures at various heights (TC01 to TC06)

B.3 Long Characterisation test

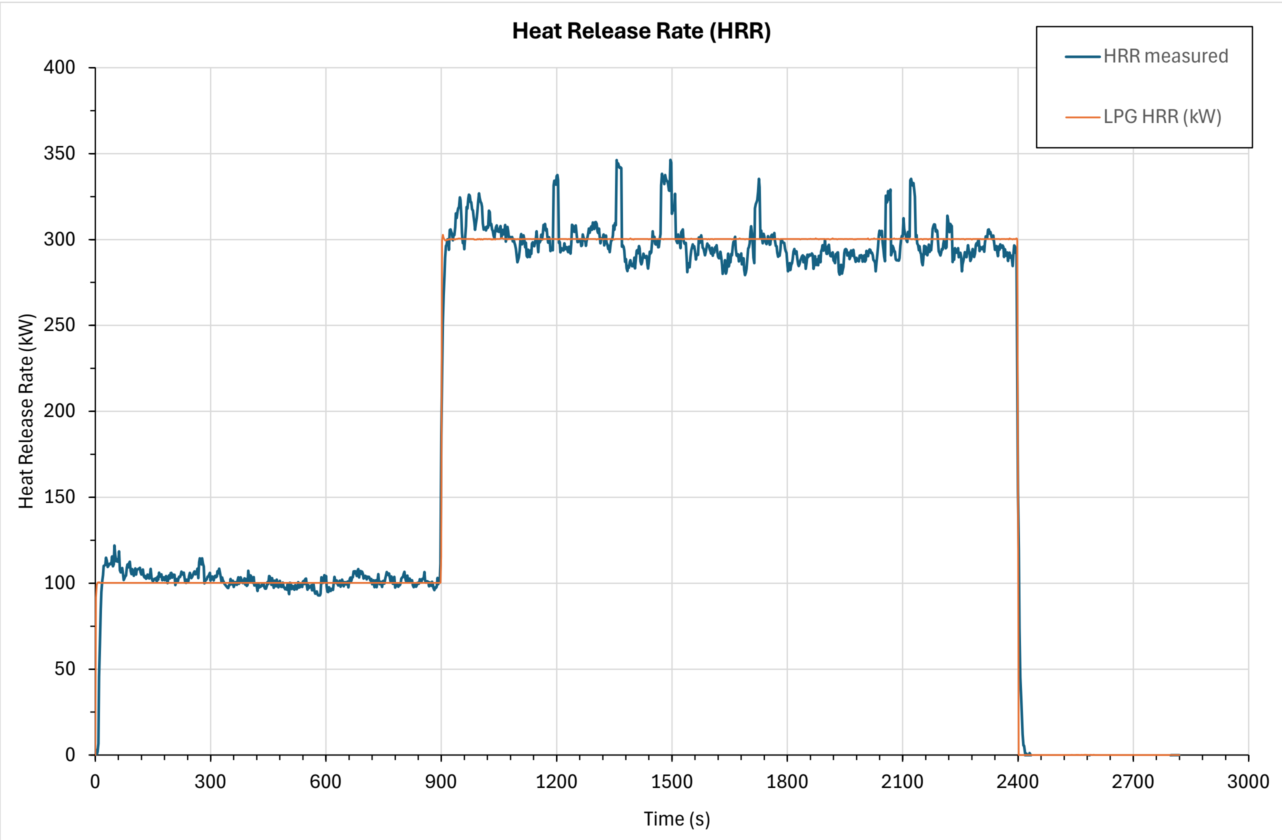


Figure 28. Long characterisation test – HRR vs time

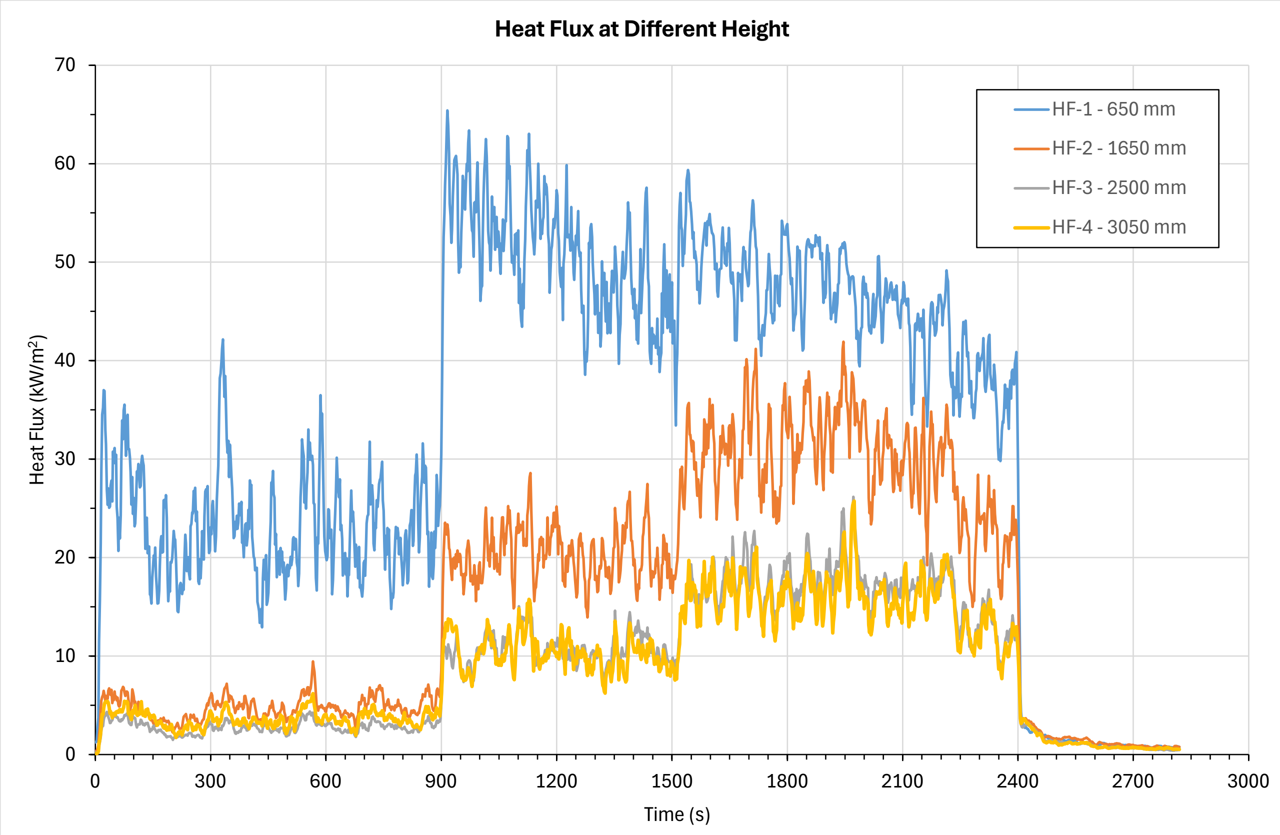


Figure 29. Long characterisation test – Heat flux at different height (kW/m^2)

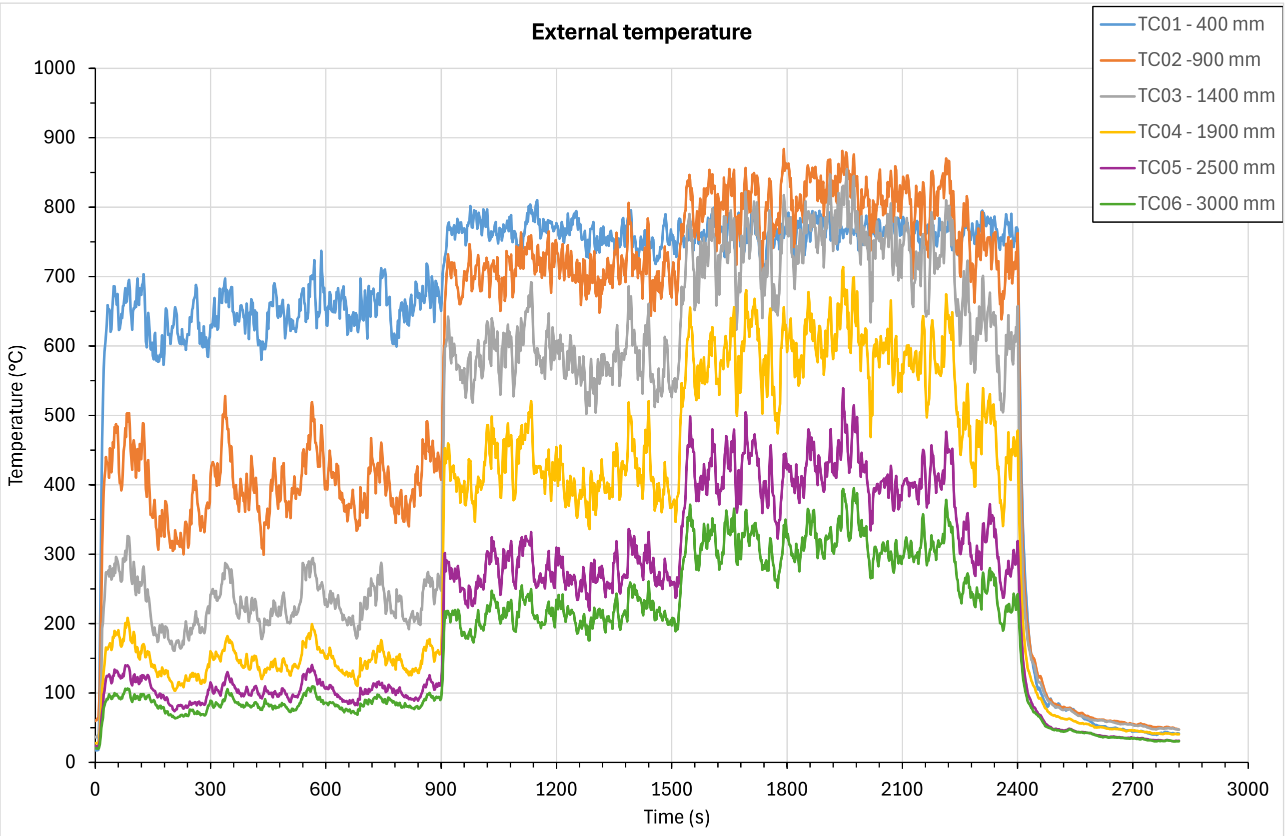


Figure 30. Long characterisation test – External face temperatures at various heights (TC01 to TC06)

B.4 Test 1 – WPC-01

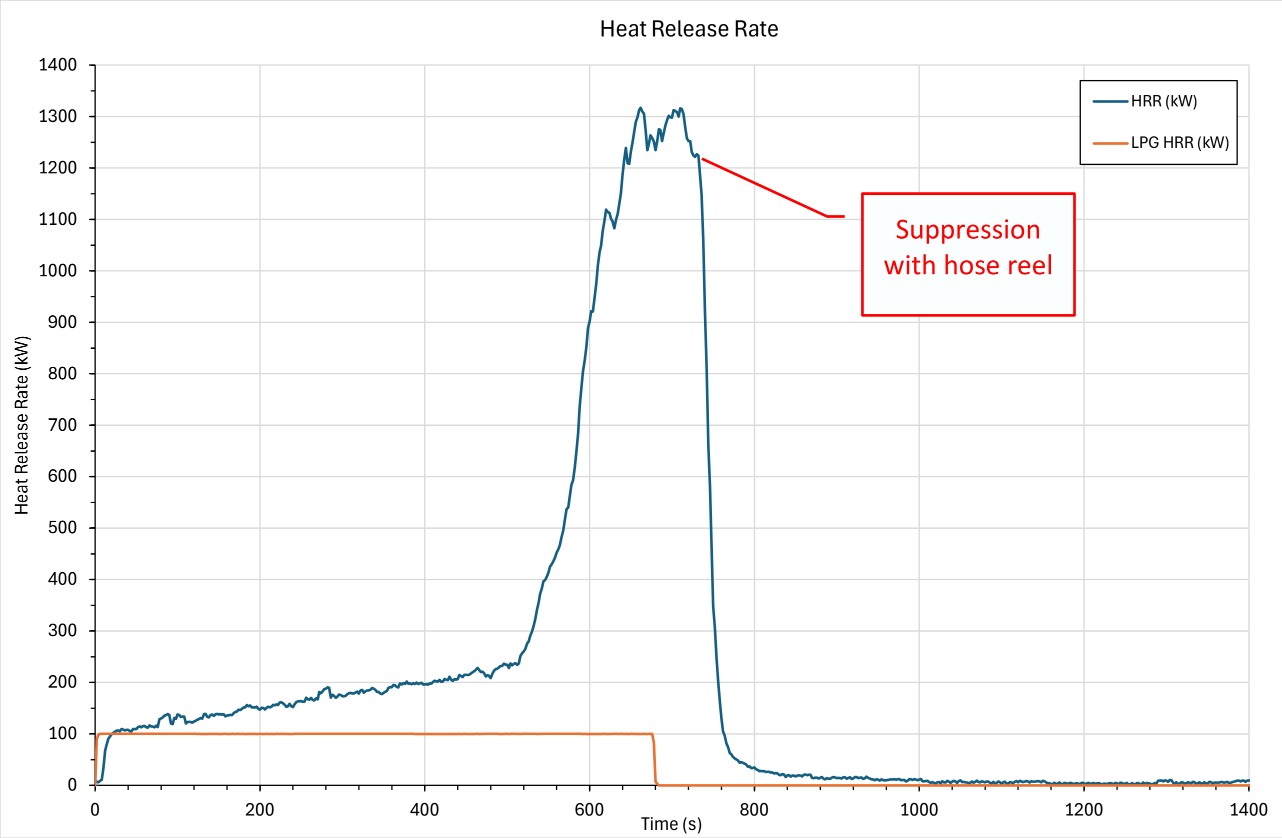


Figure 31. Test 1 – HRR (kW)

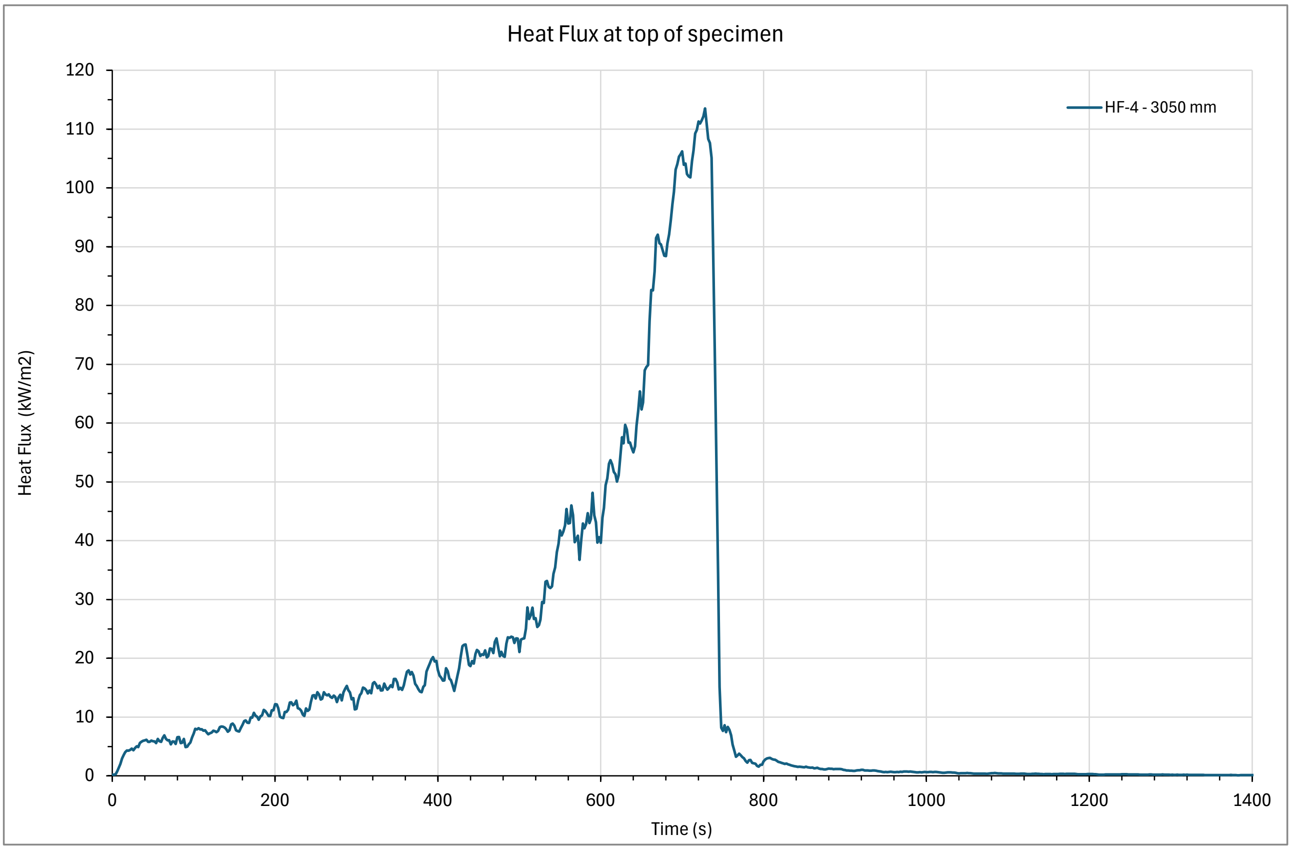


Figure 32. Test 1 – Heat flux (kW/m^2) above 3050 mm from the ground level.

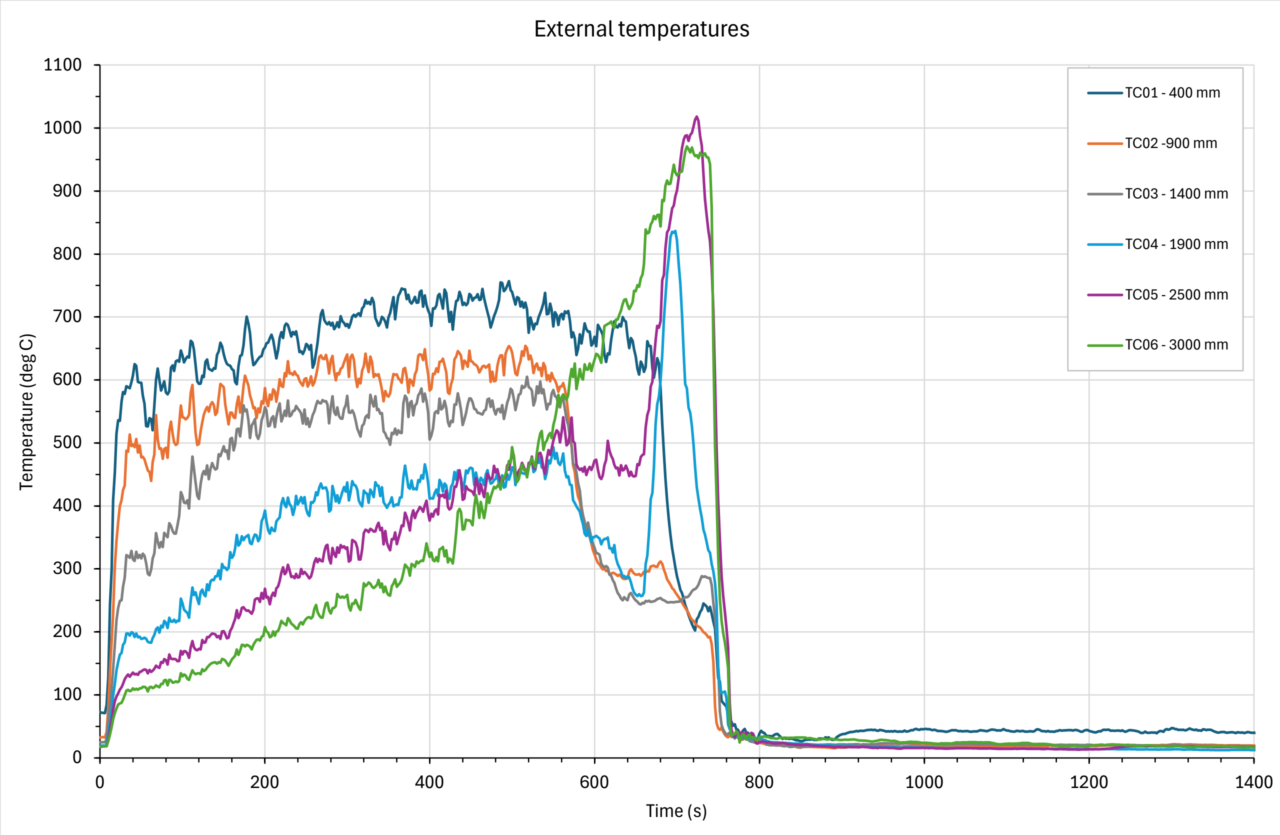


Figure 33. Test 1 – External face temperatures at various heights (TC01 to TC06)

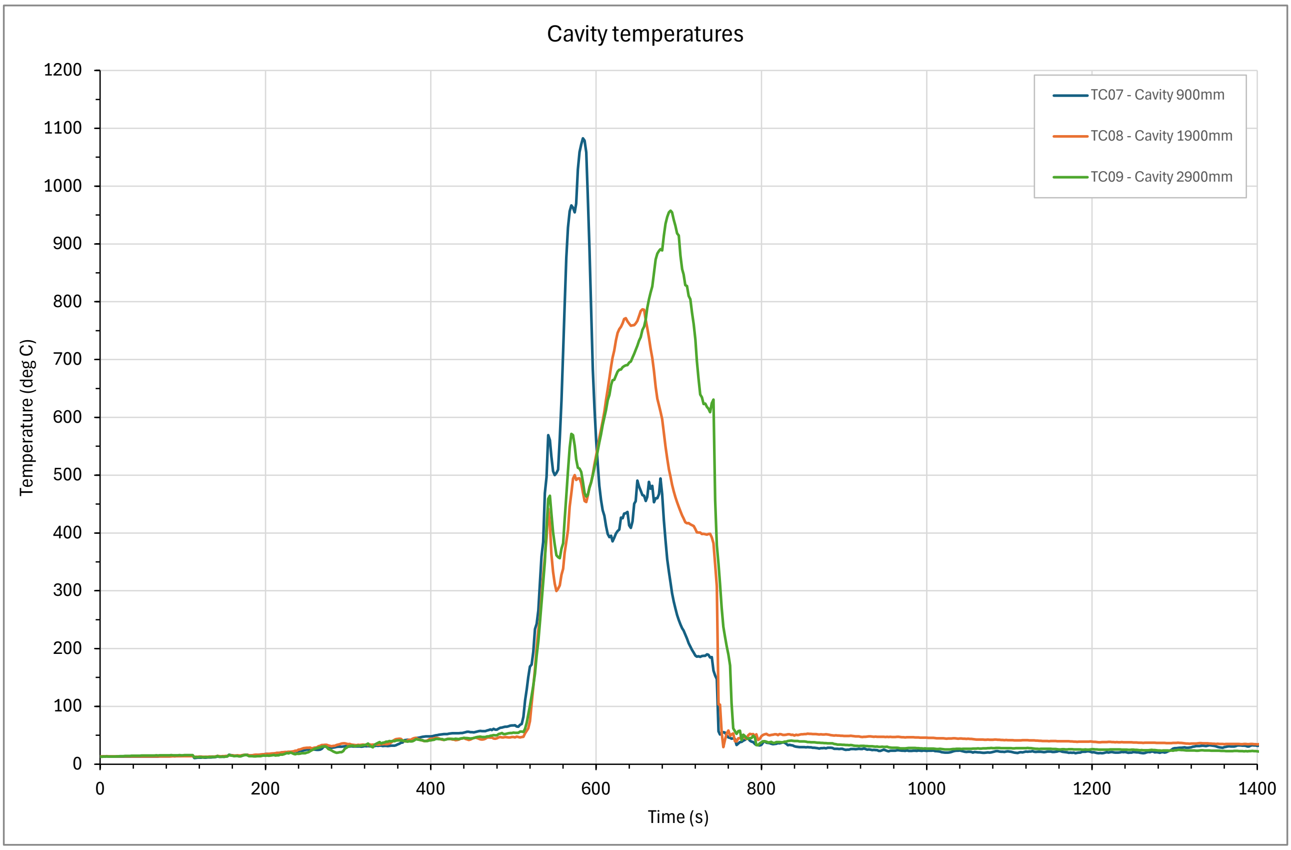


Figure 34. Test 1 – Temperatures within air cavity at 900 mm (TC07), 1,900 mm (TC08), 3,000 mm (TC09) above ground level

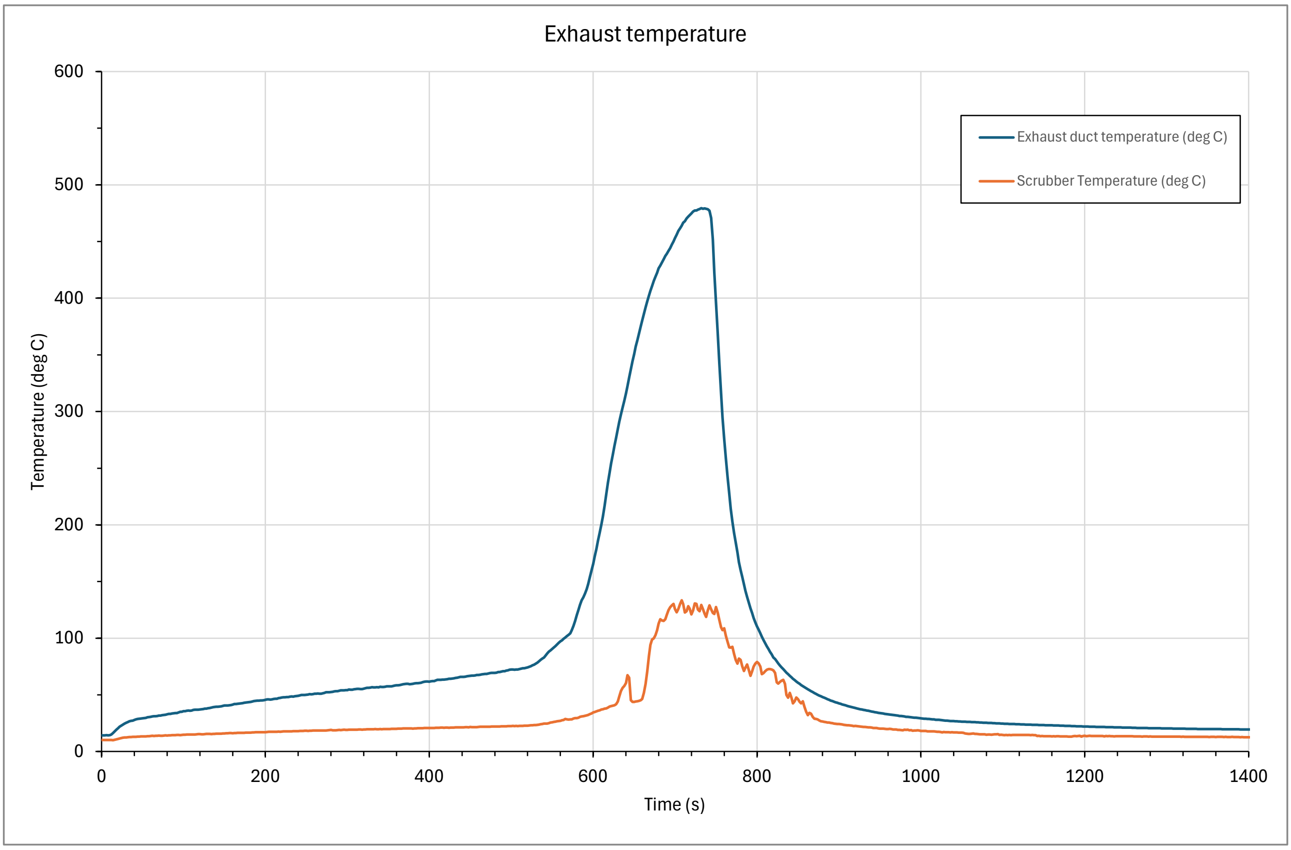


Figure 35. Test 1 – Test Hood exhaust temperatures

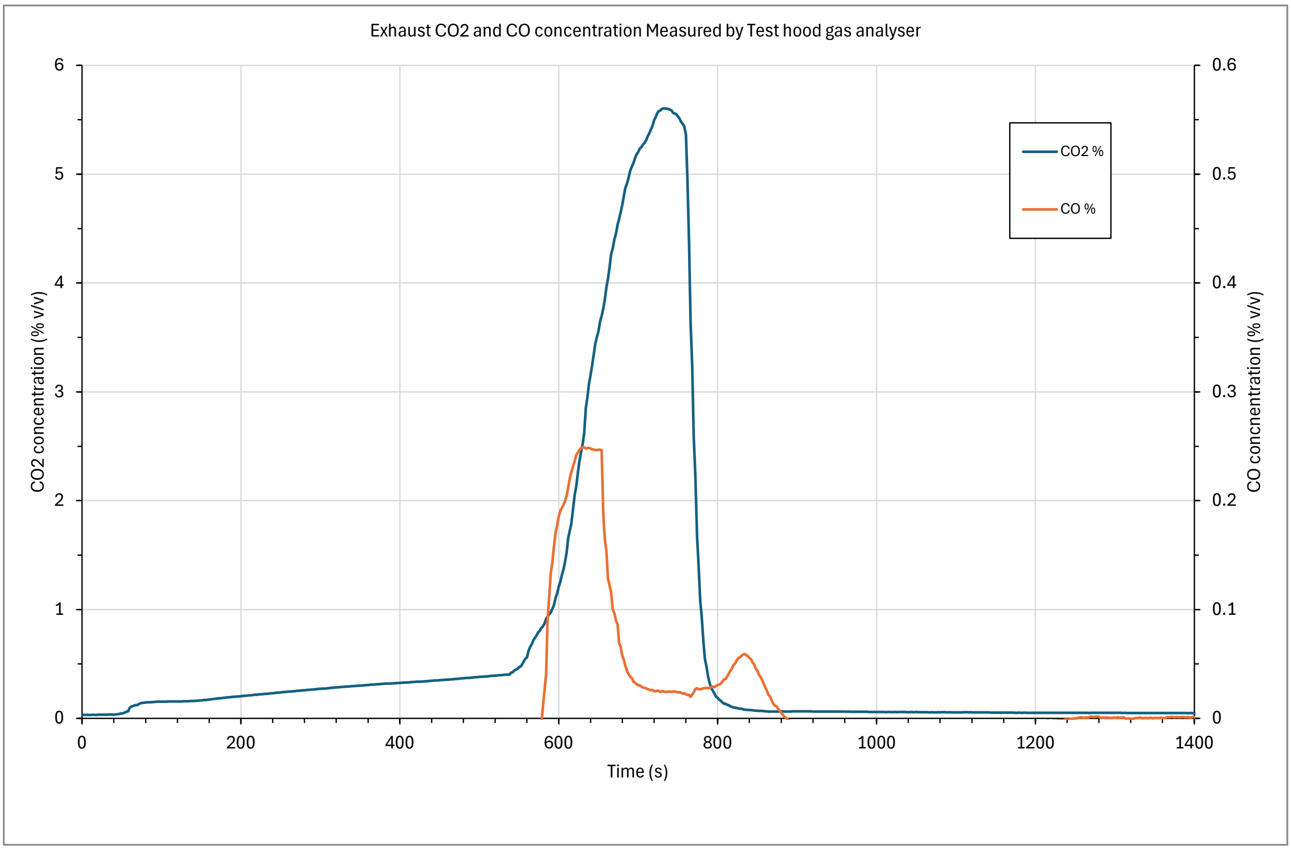


Figure 36. Test 1 – CO and CO2 concentration measured by test hood gas analyser

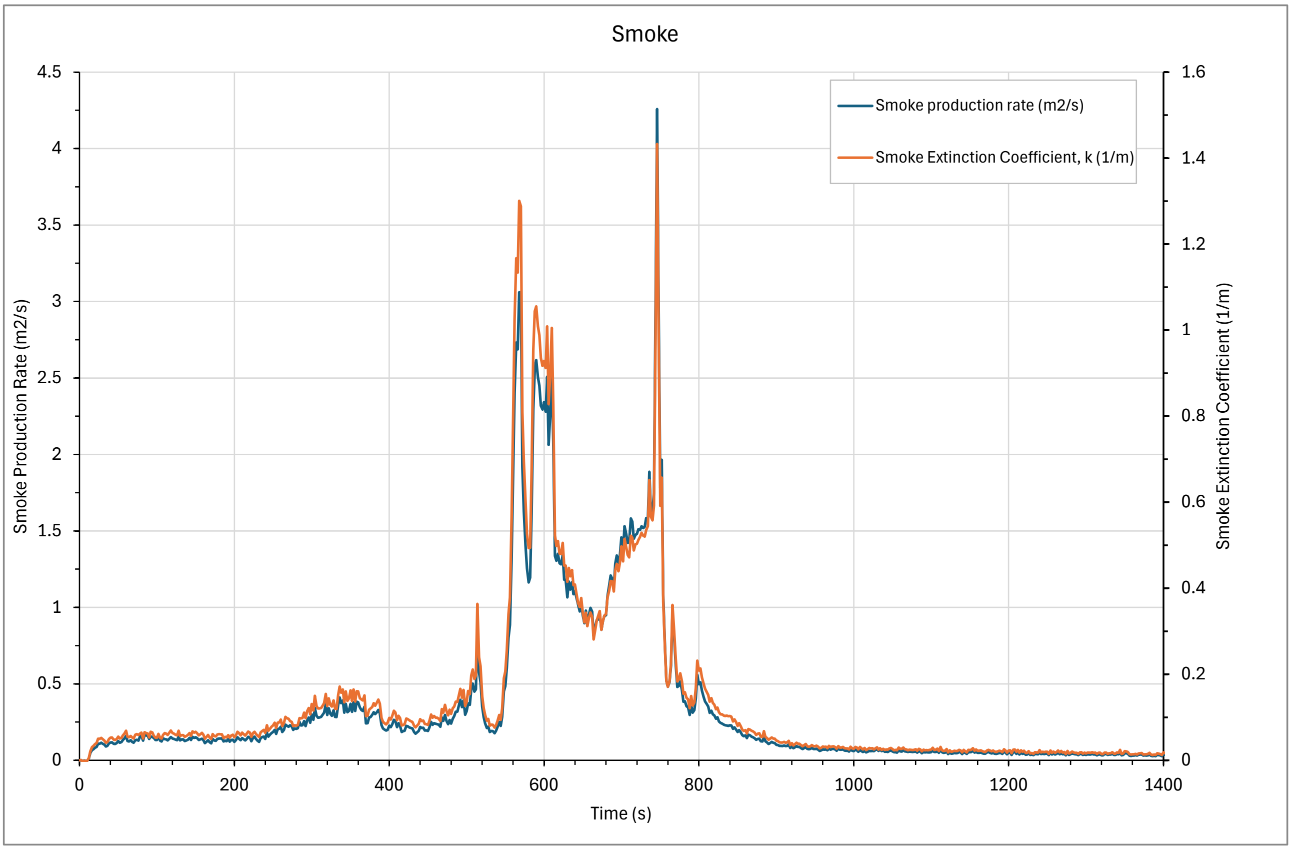


Figure 37. Test 1 – Smoke production rate

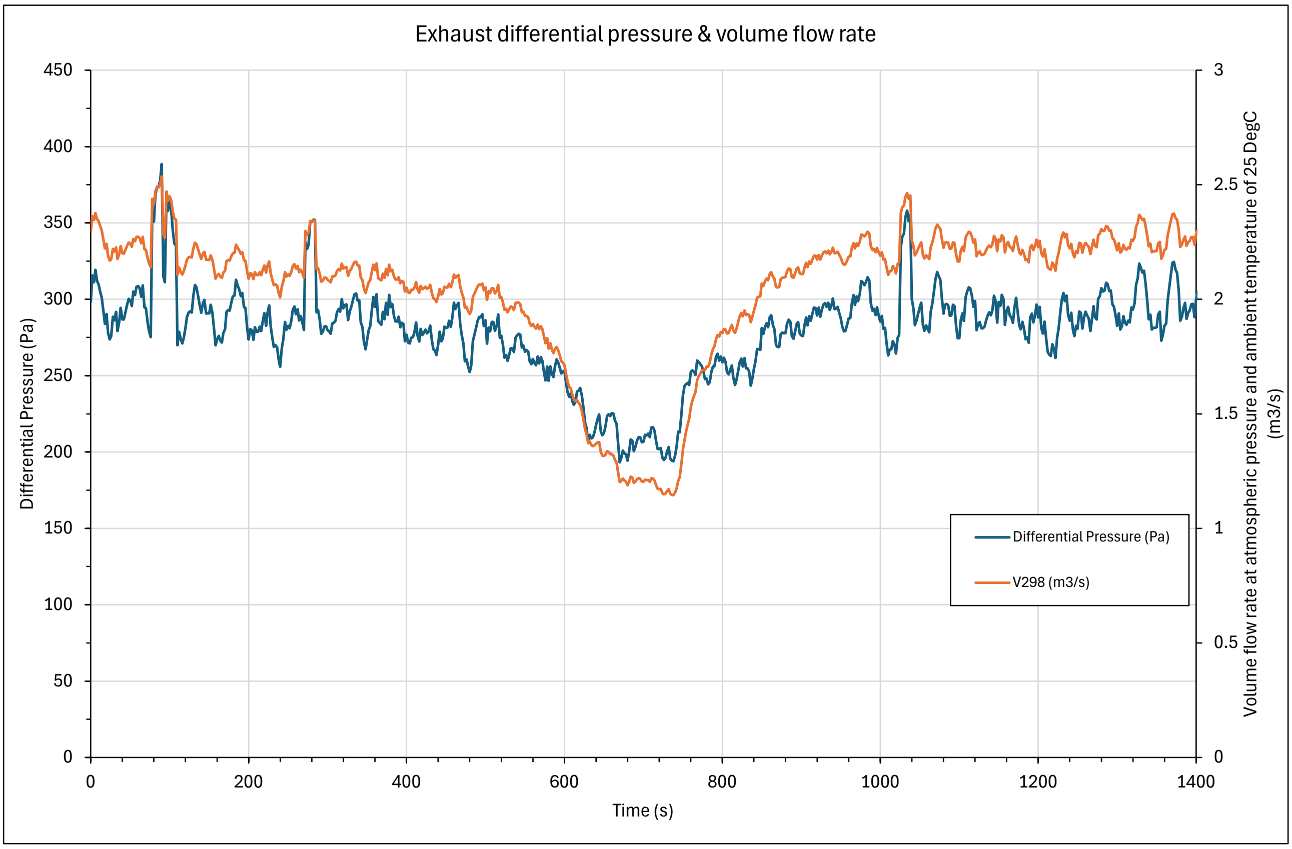


Figure 38. Test 1 – Test hood exhaust flow rate

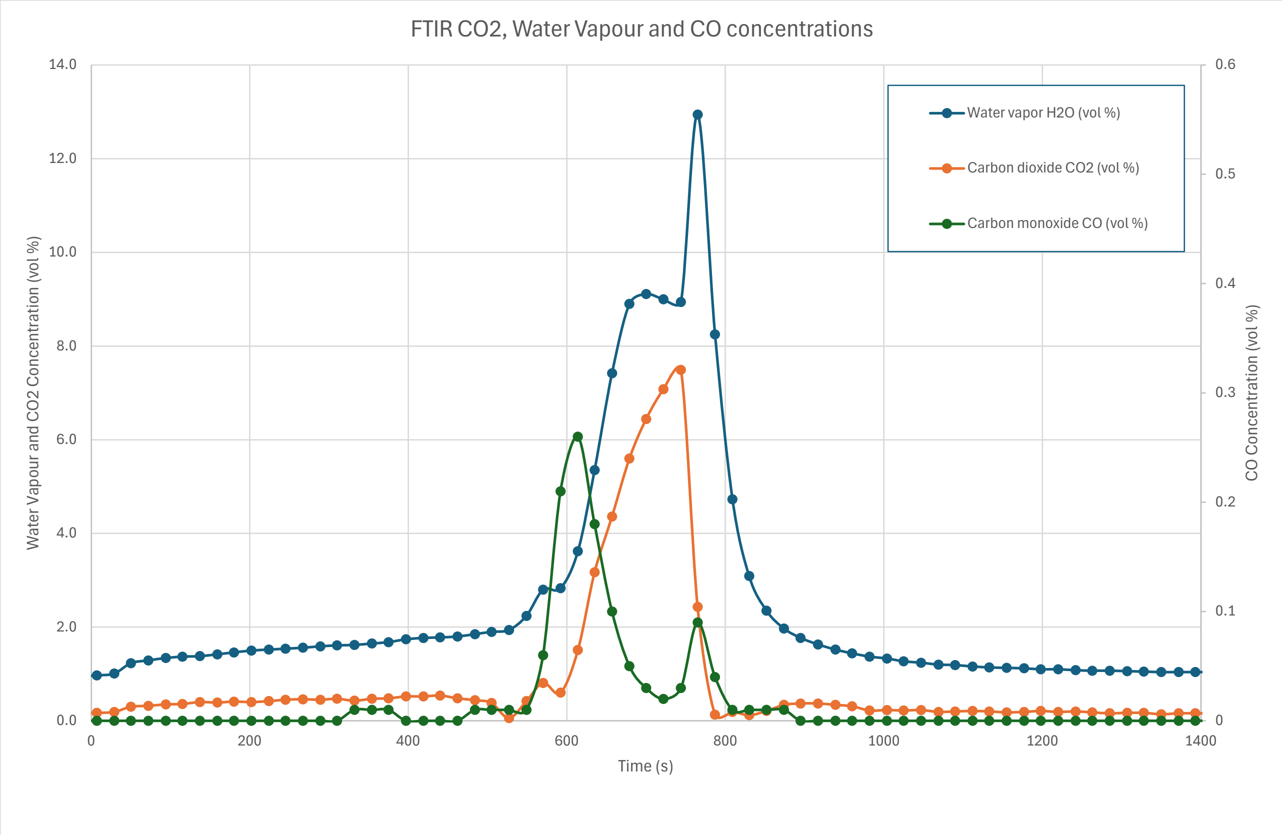


Figure 39. Test 1 – CO and CO_2 concentration recorded by FTIR.

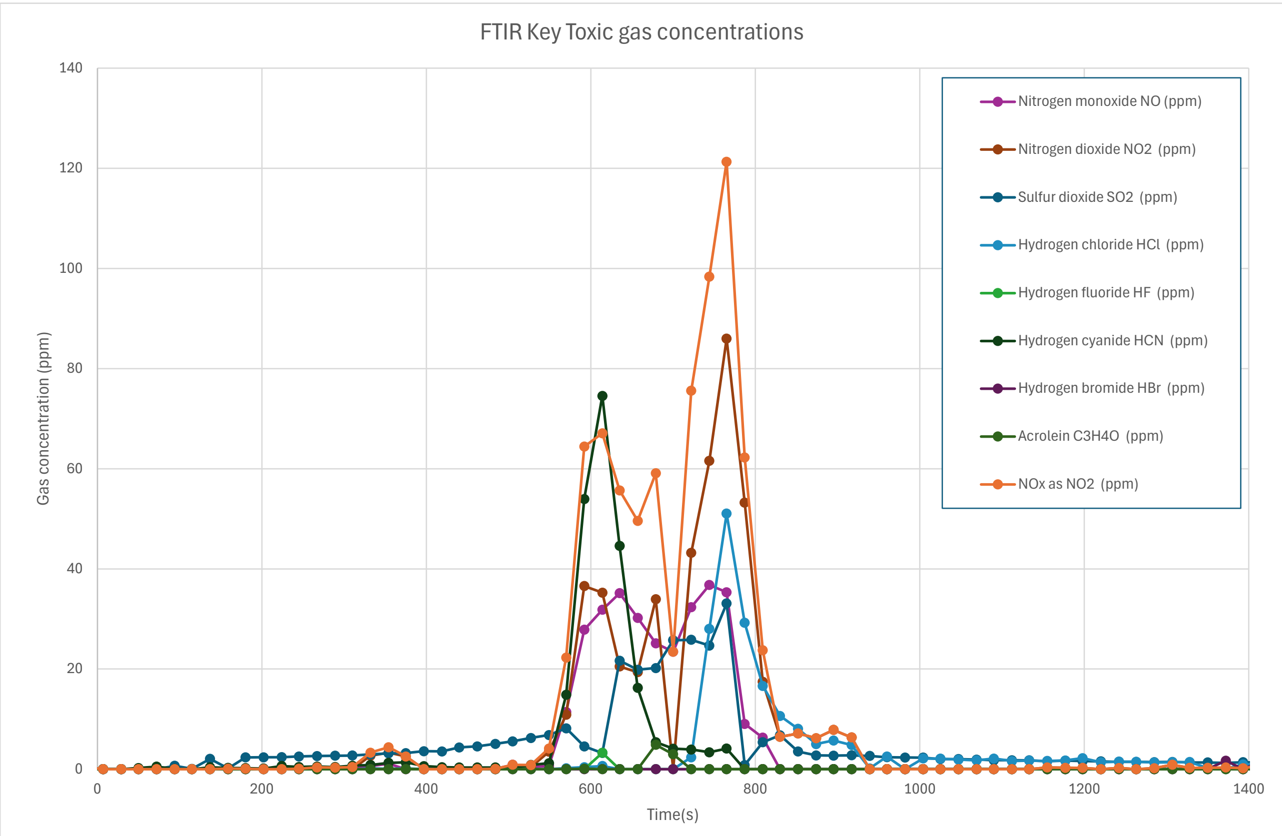


Figure 40. Test 1 – Key Toxic Species concentration recorded by FTIR.

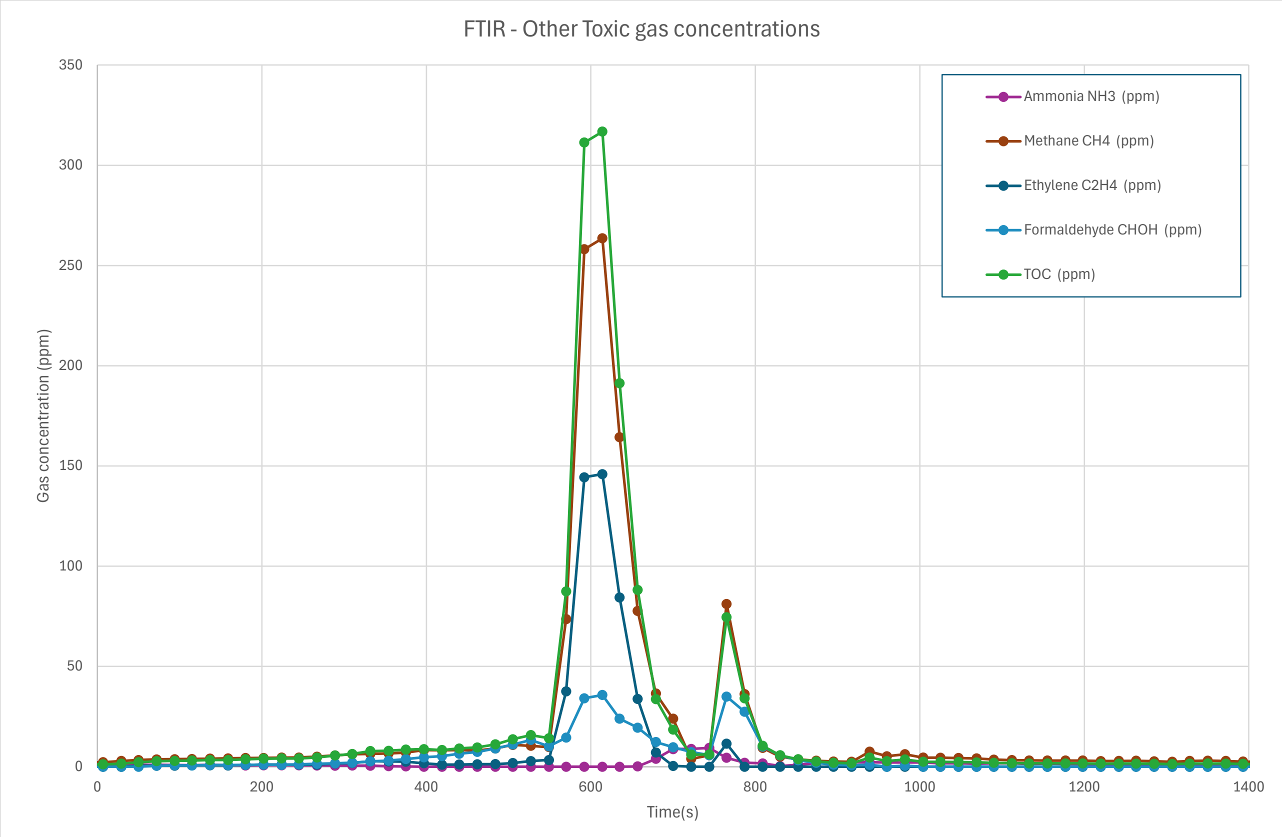


Figure 41. Test 1 – Other Toxic Species concentration recorded by FTIR.

B.5 Test 2 – WPC-01

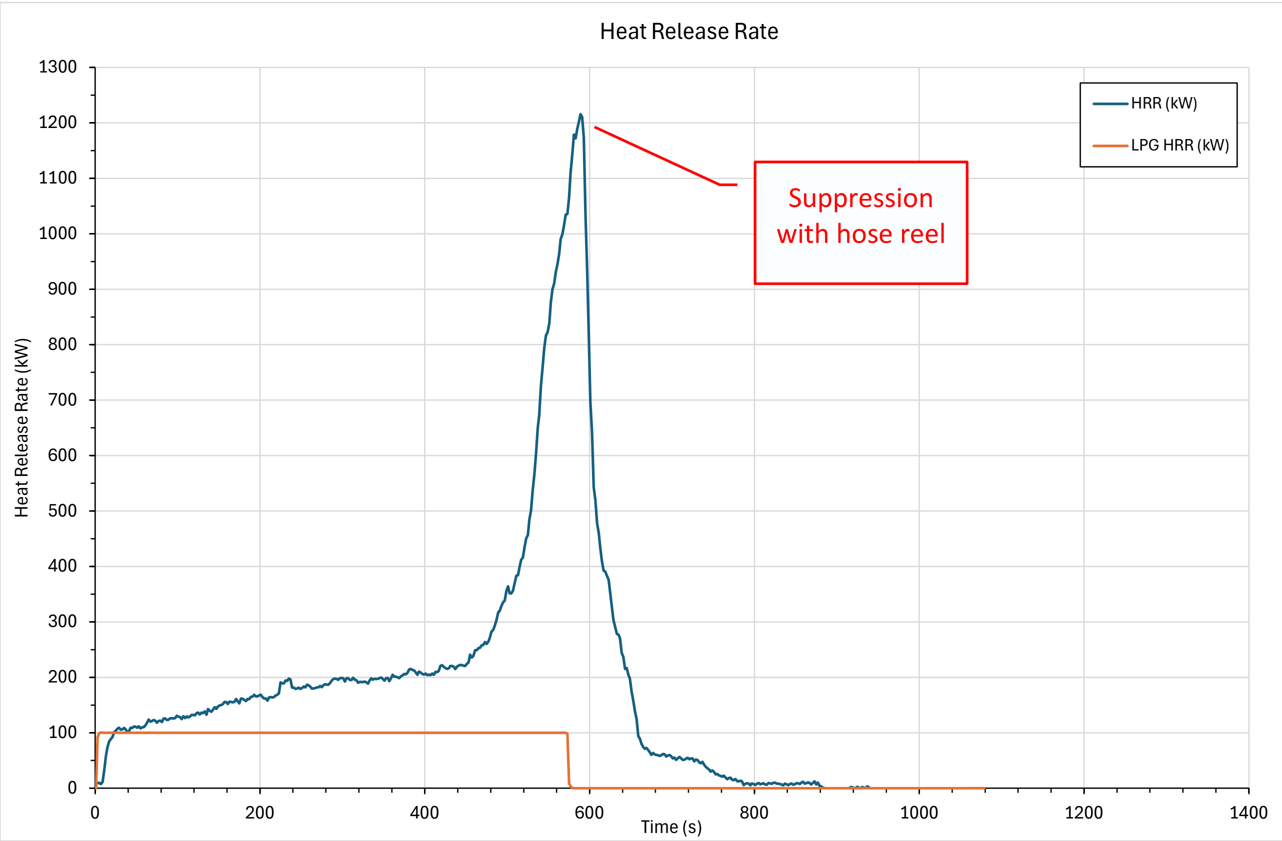


Figure 42. Test 2 – HRR (kW)

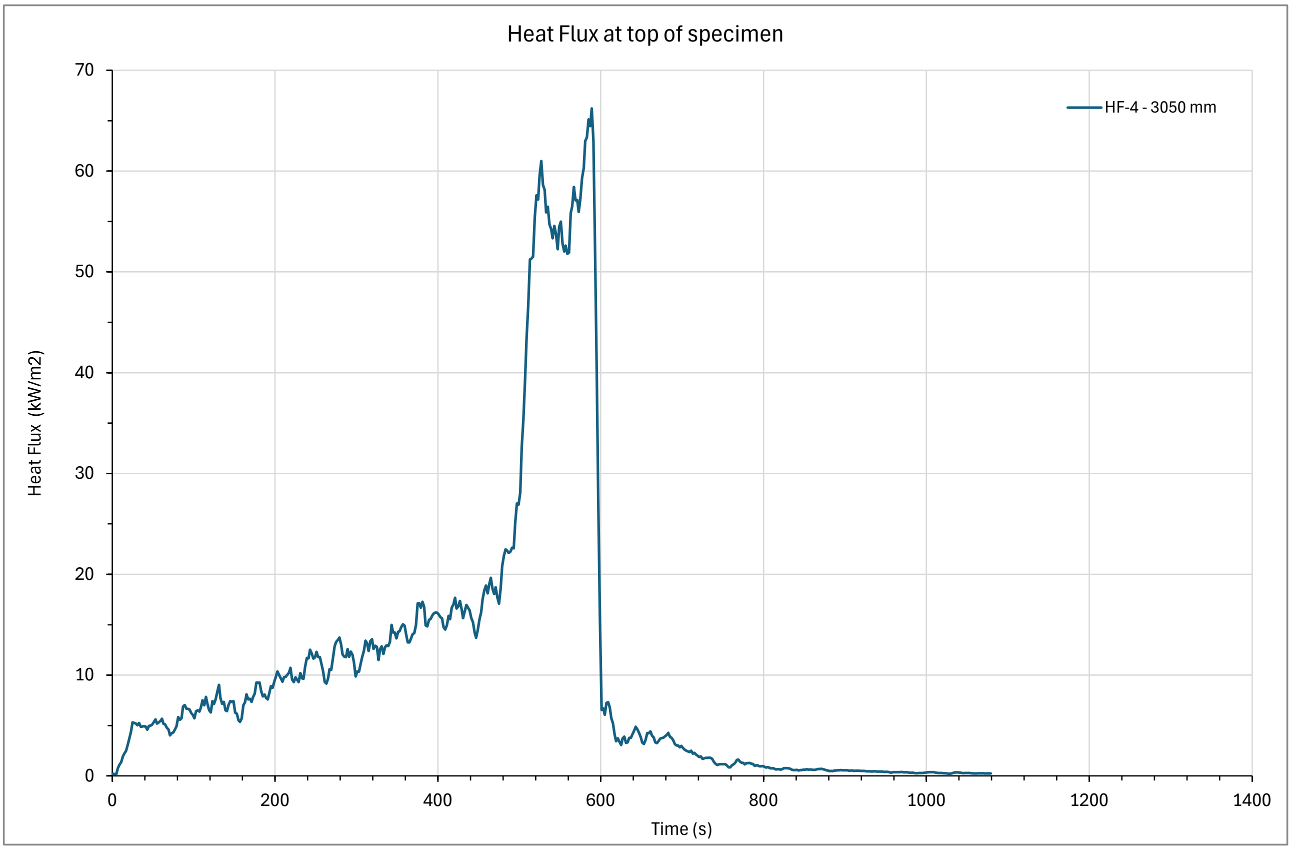


Figure 43. Test 2 – Heat flux (kW/m^2) above 3050 mm from the ground level.

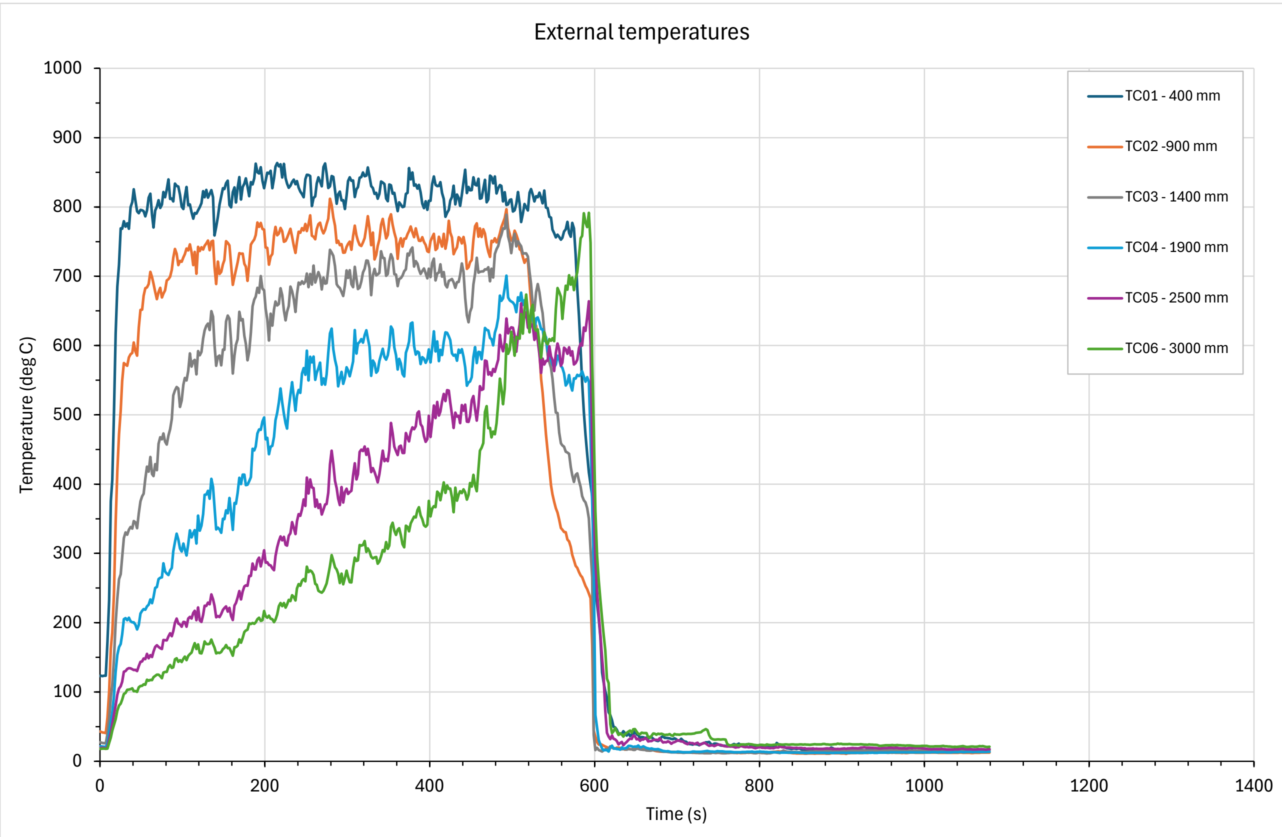


Figure 44. Test 2 – External face temperatures at various heights (TC01 to TC06)

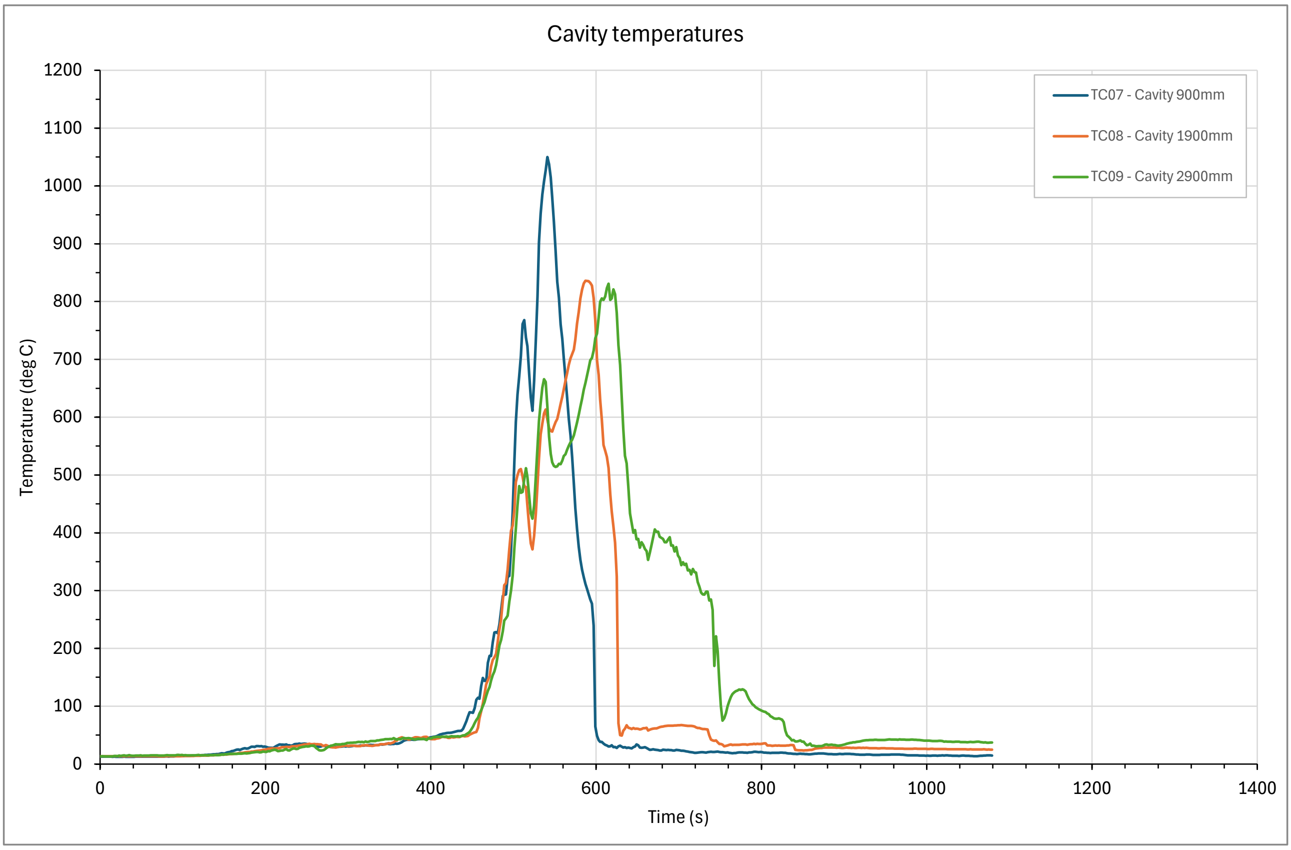


Figure 45. Test 2 – Temperatures within air cavity at 900 mm (TC07), 1,900 mm (TC08), 3,000 mm (TC09) above ground level

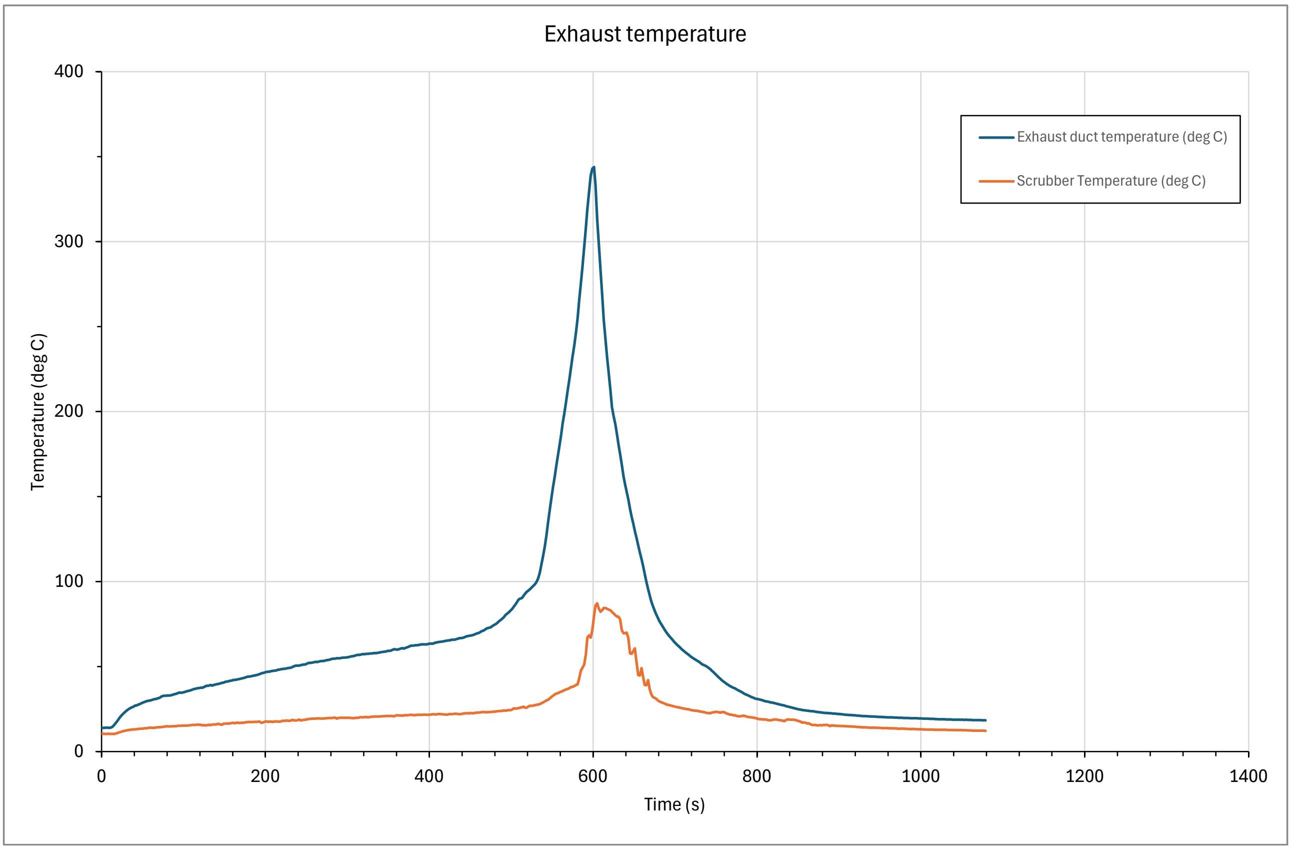


Figure 46. Test 2 – Test Hood exhaust temperatures

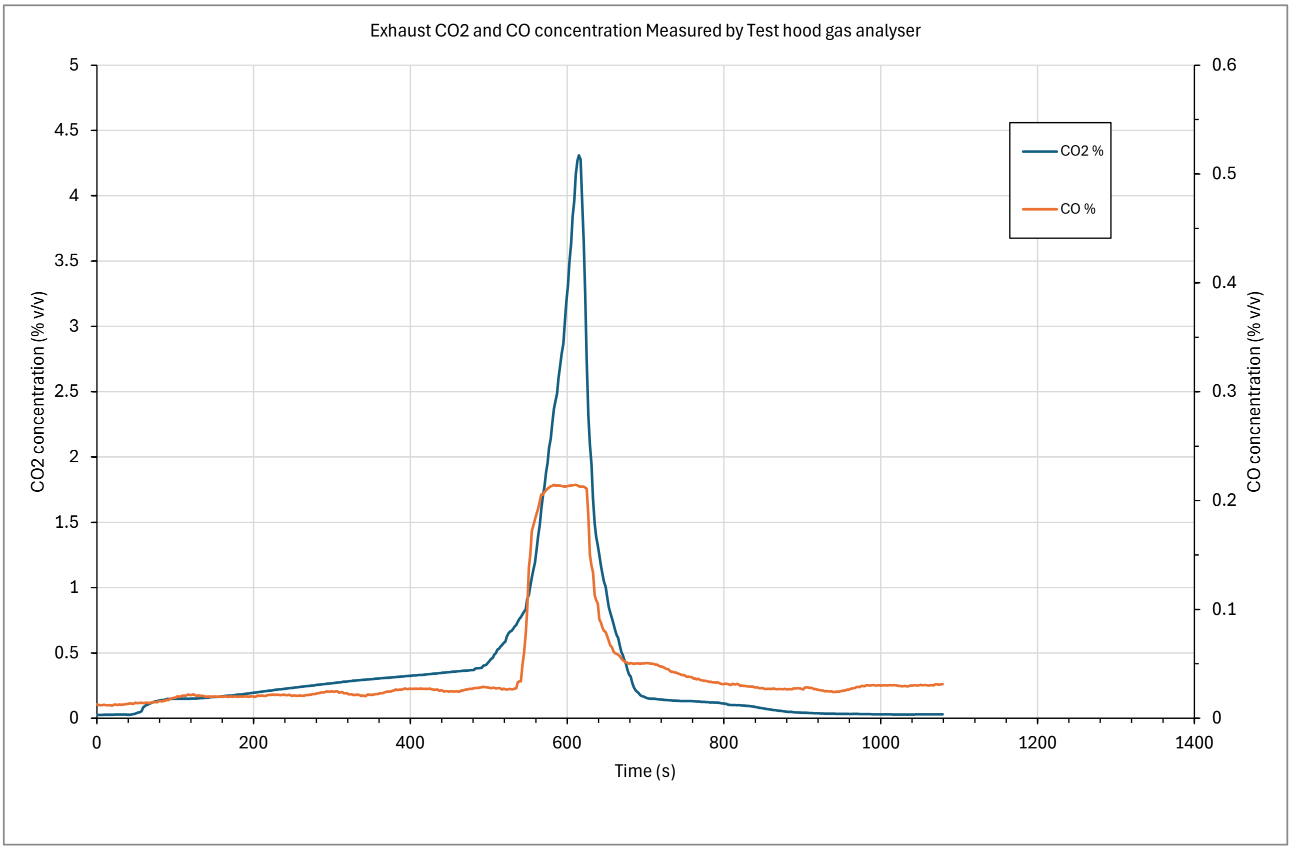


Figure 47. Test 2 – CO and CO2 concentration measured by test hood gas analyser

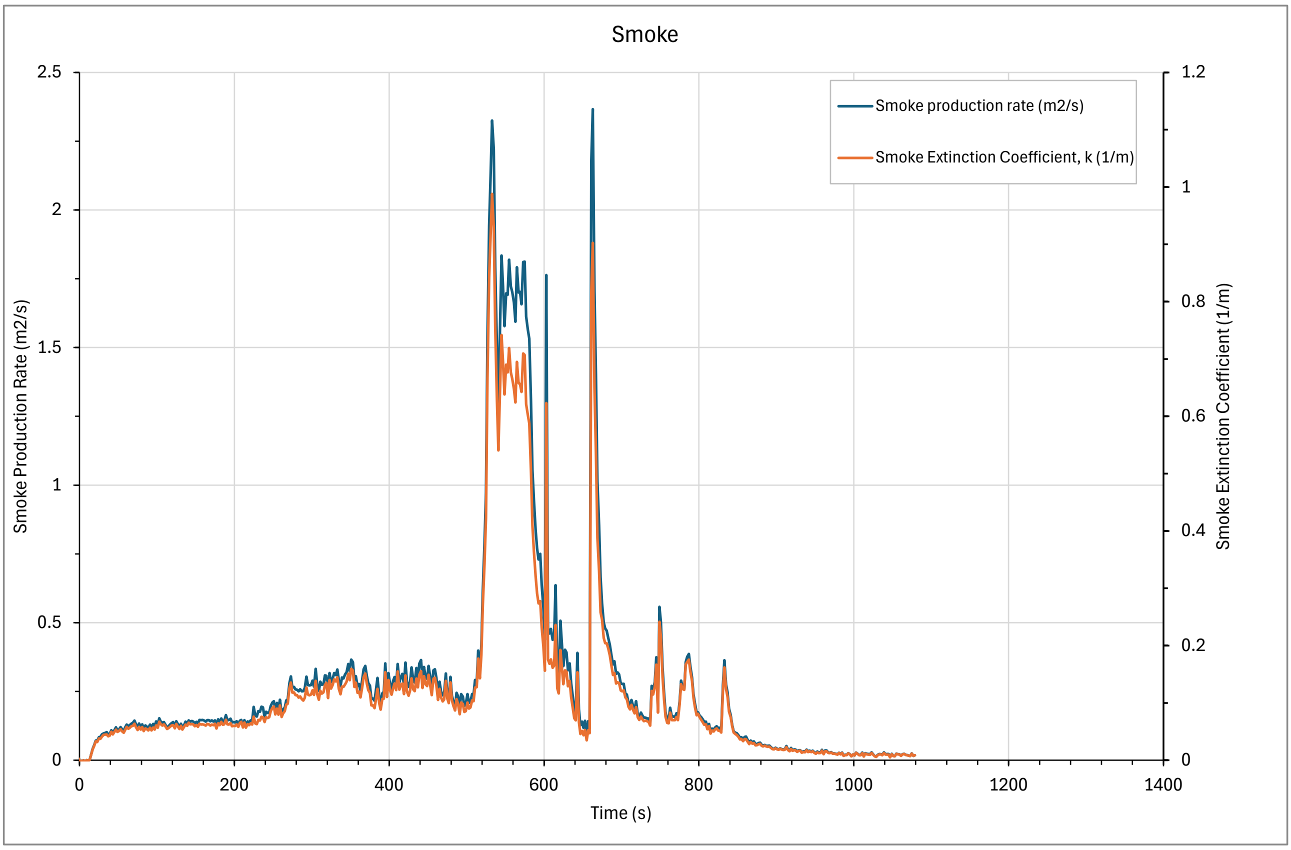


Figure 48. Test 2 – Smoke production rate

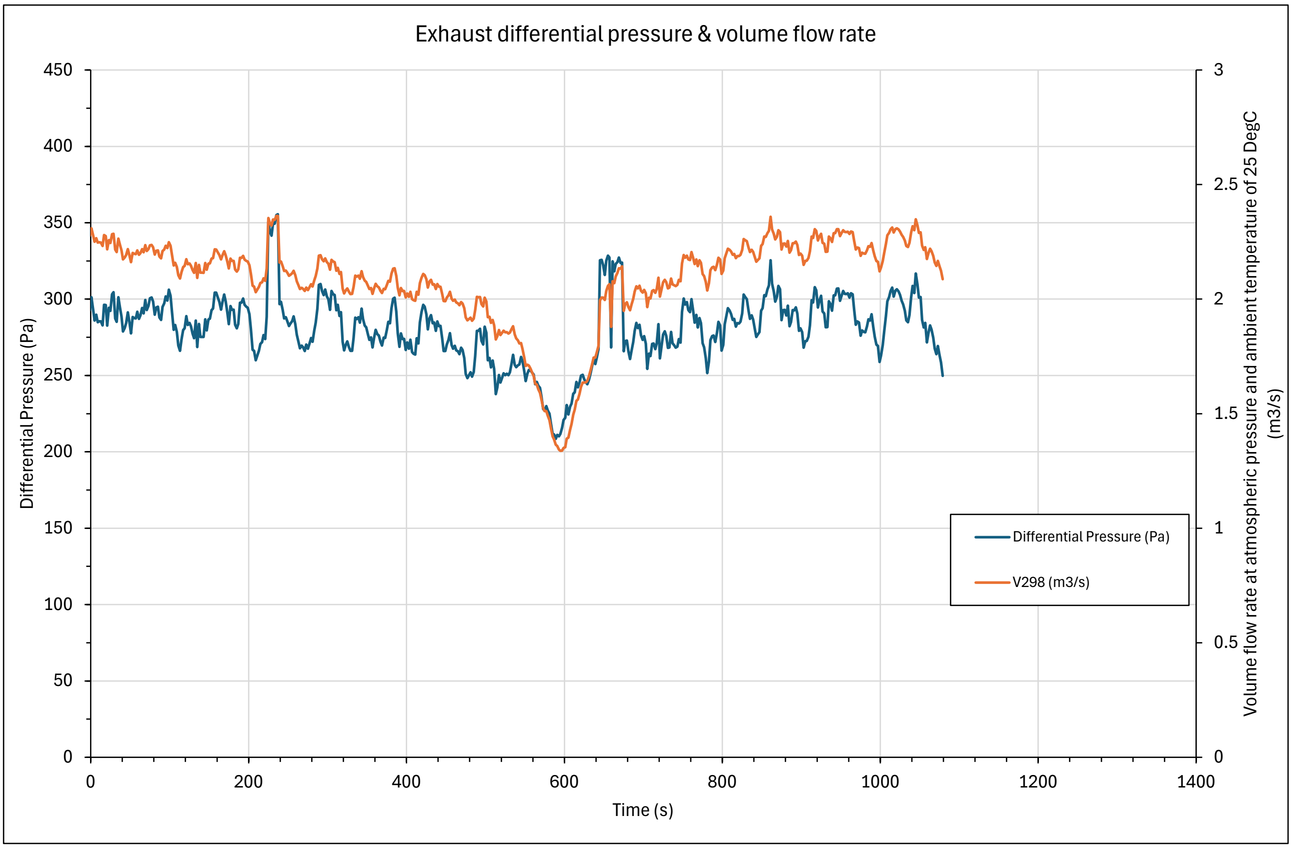


Figure 49. Test 2 – Test hood exhaust flow rate

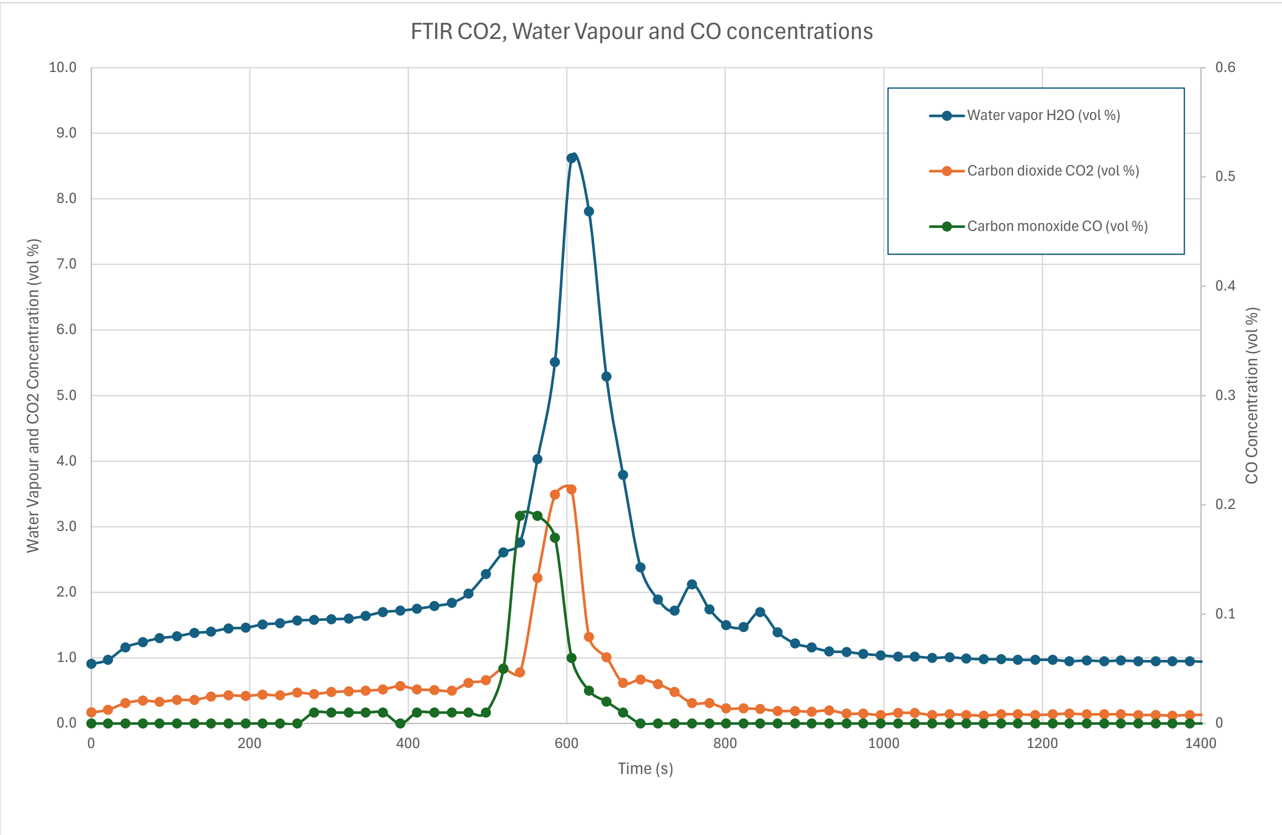


Figure 50. Test 2 – CO and CO2 concentration recorded by FTIR.

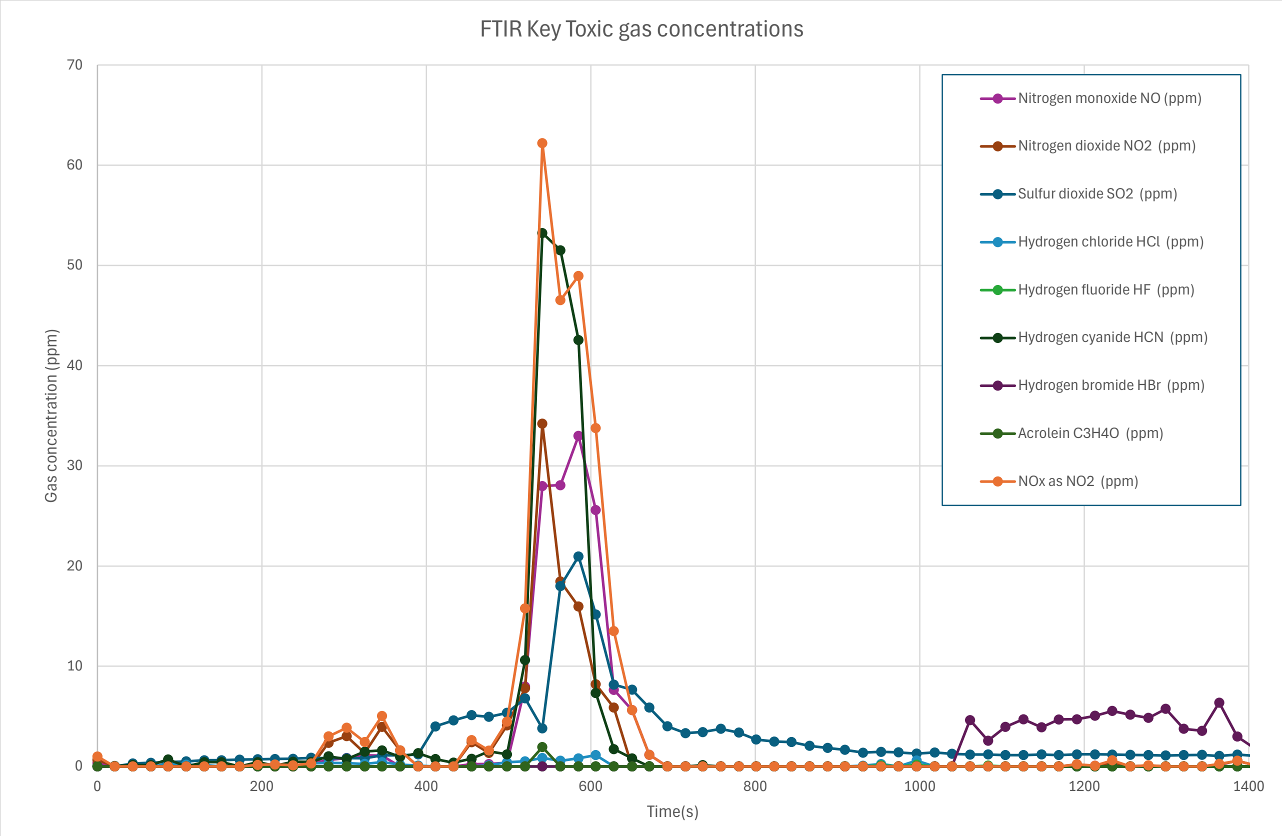


Figure 51. Test 2 – Key Toxic Species concentration recorded by FTIR.

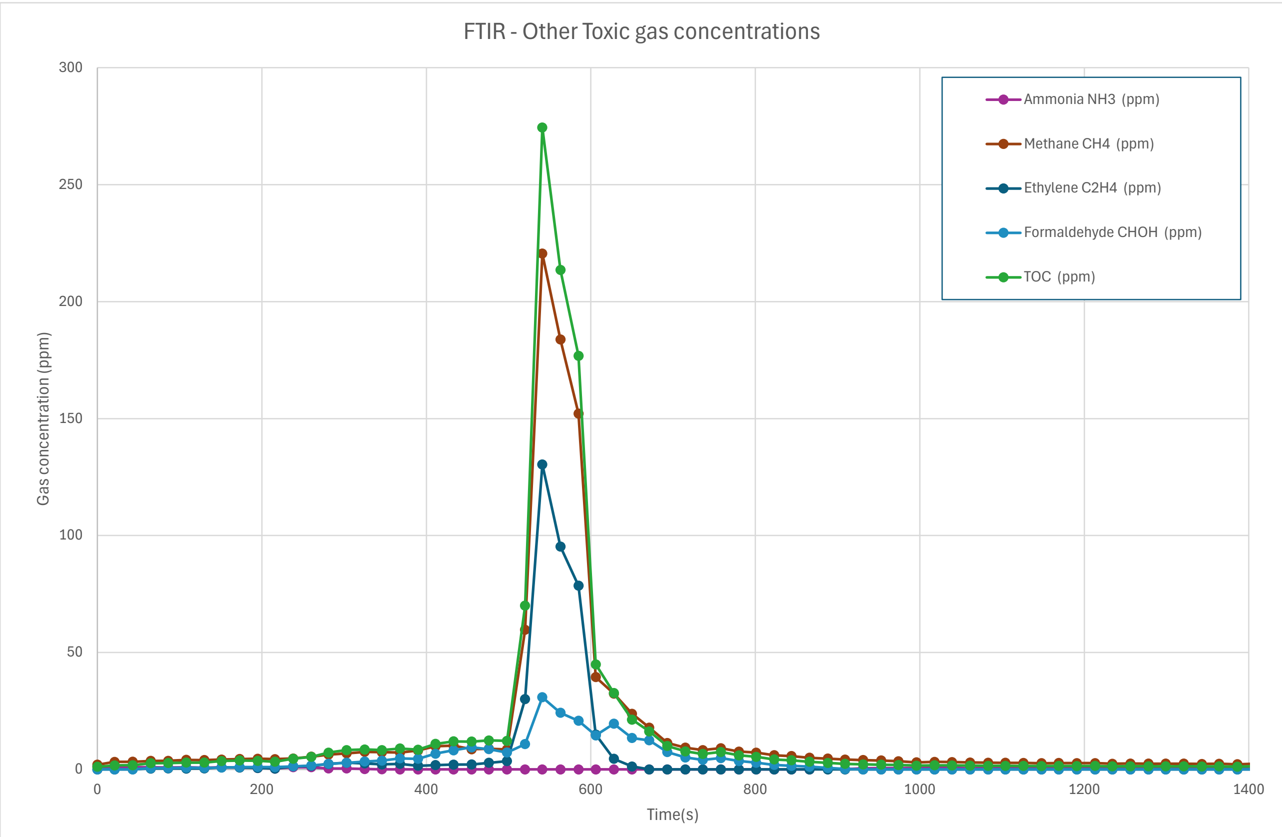


Figure 52. Test 2 – Other Toxic Species concentration recorded by FTIR.

B.6 Test 3 – WPC-02

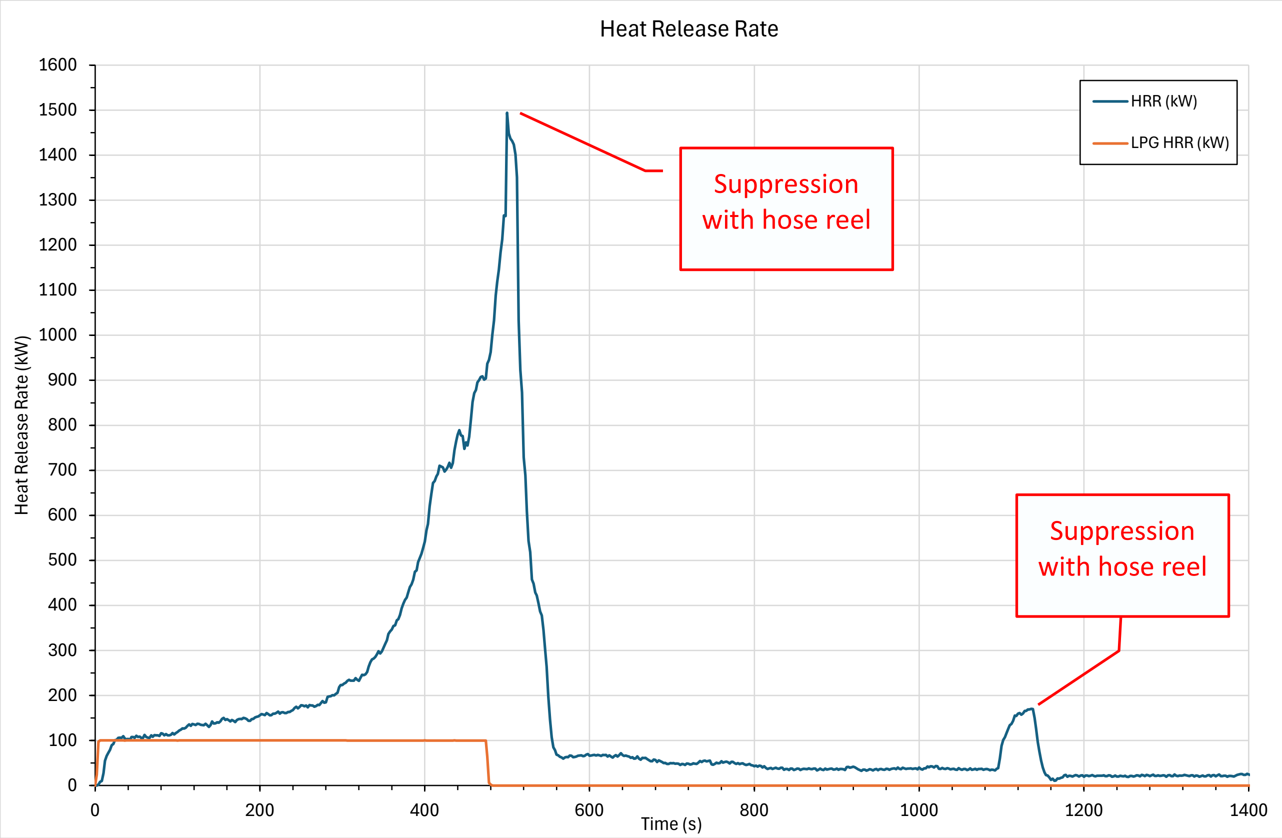


Figure 53. Test 3 – HRR (kW)

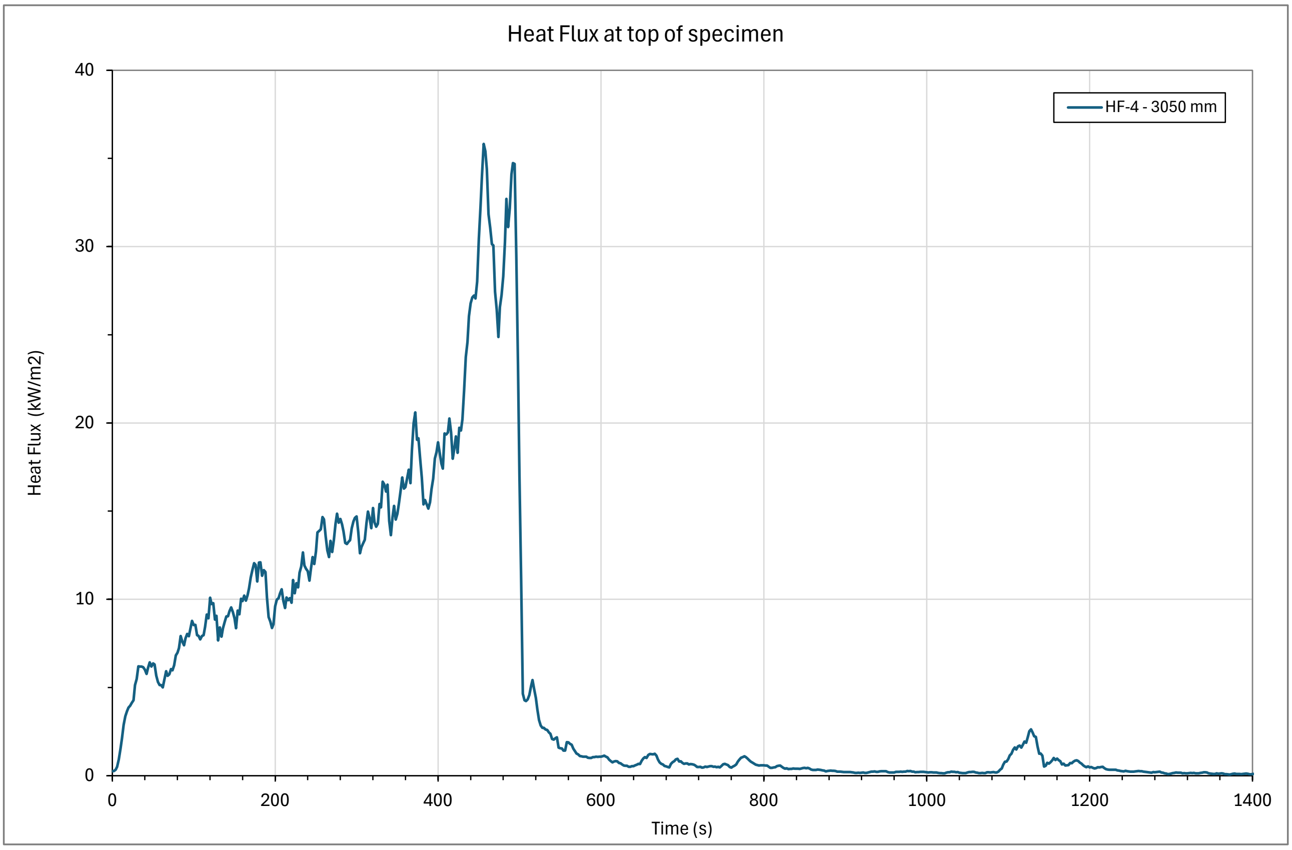


Figure 54. Test 3 – Heat flux (kW/m²) above 3050 mm from the ground level.

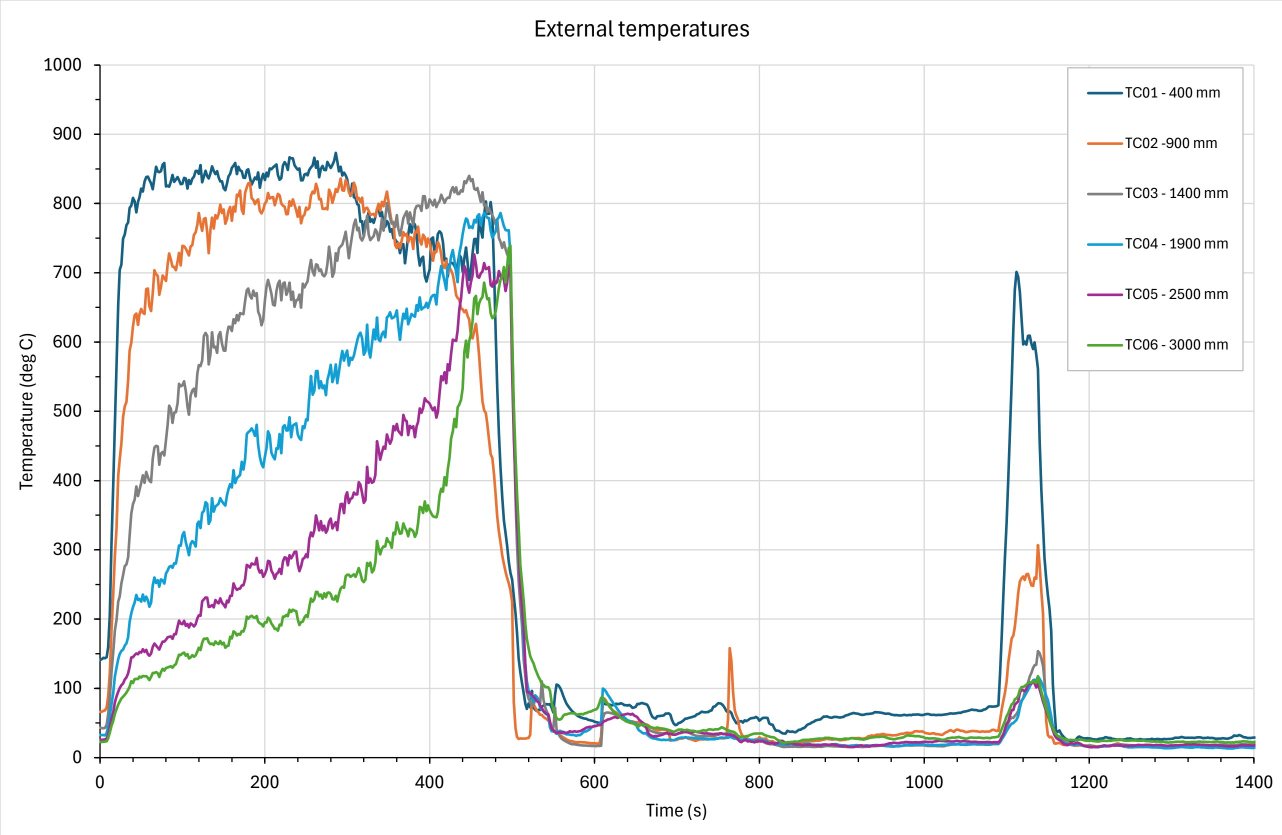


Figure 55. Test 3 – External face temperatures at various heights (TC01 to TC06)

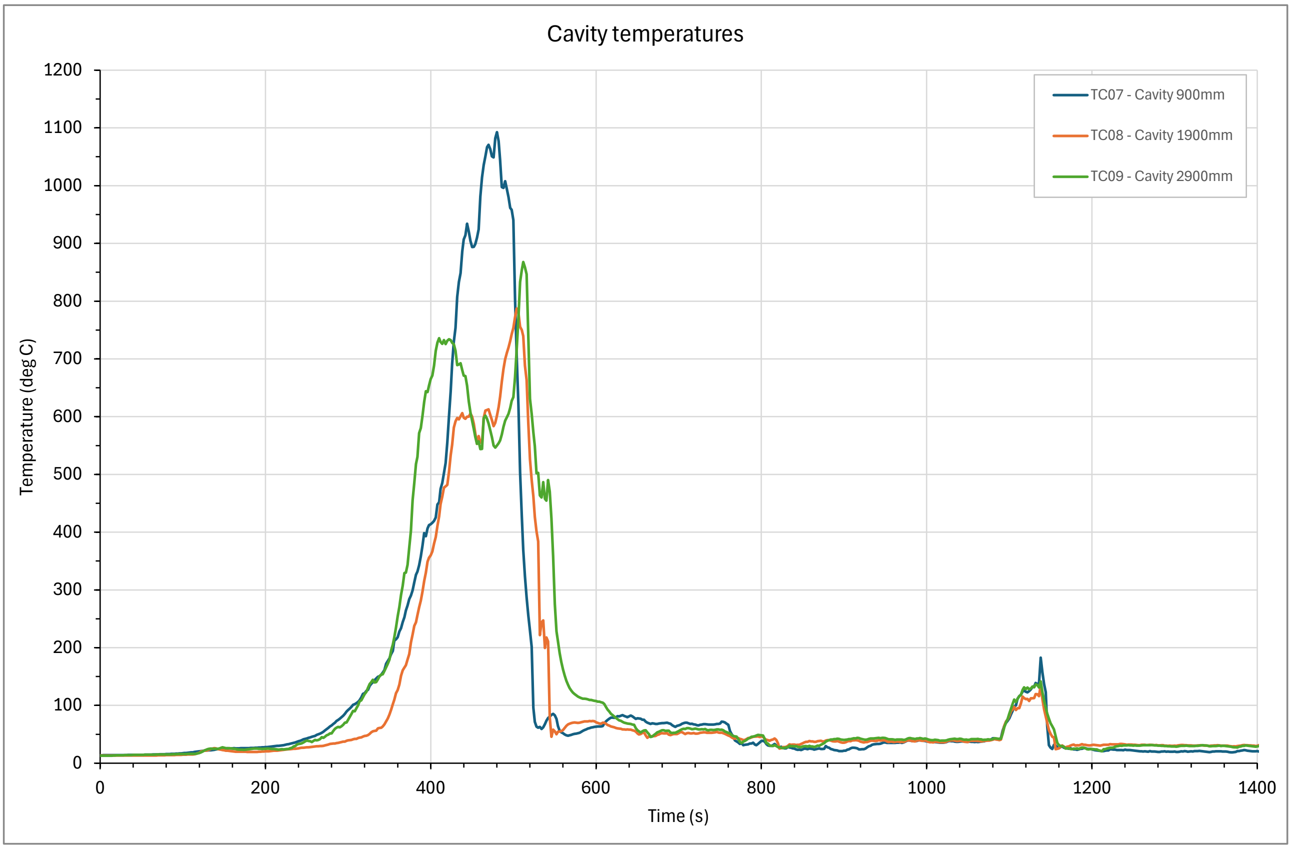


Figure 56. Test 3 – Temperatures within air cavity at 900 mm (TC07), 1,900 mm (TC08), 3,000 mm (TC09) above ground level

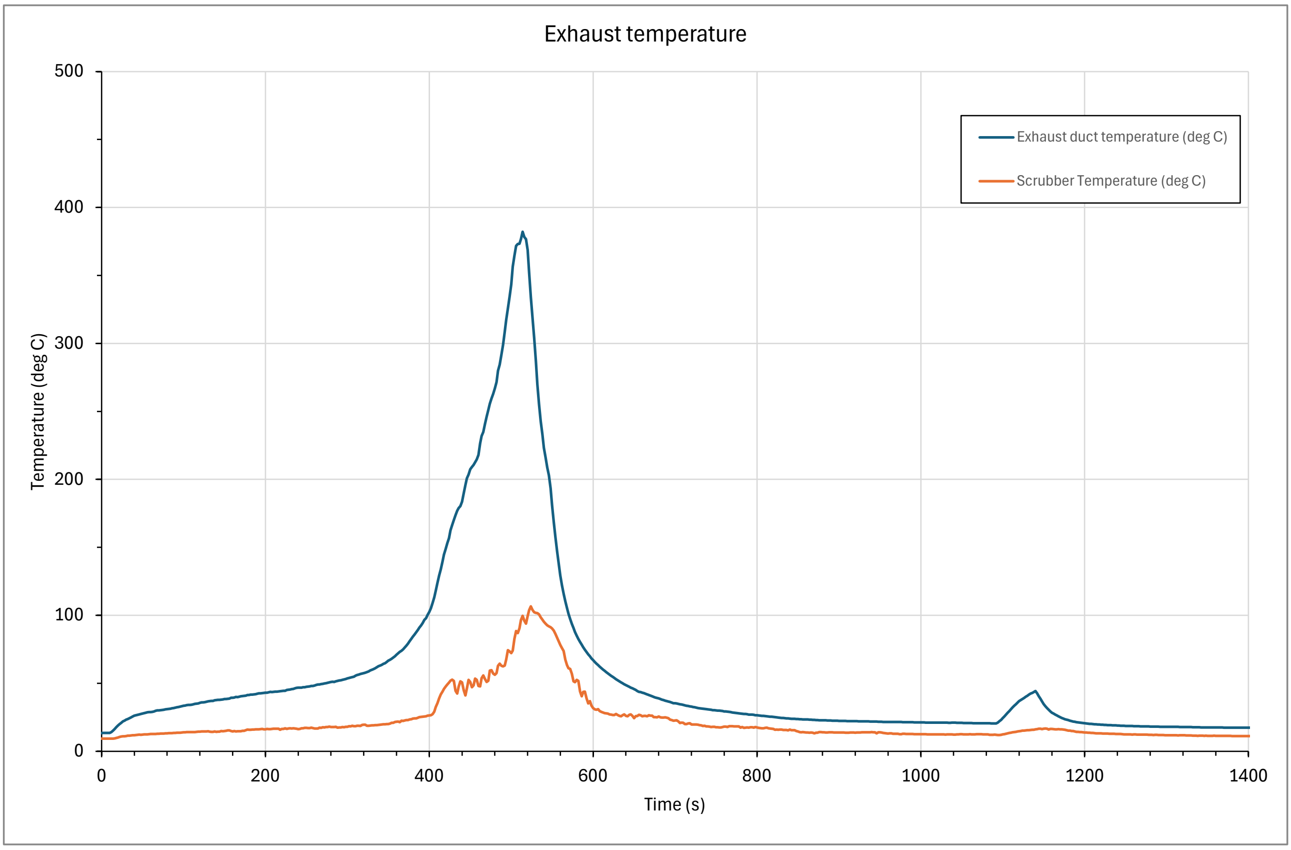


Figure 57. Test 3 – Test Hood exhaust temperatures

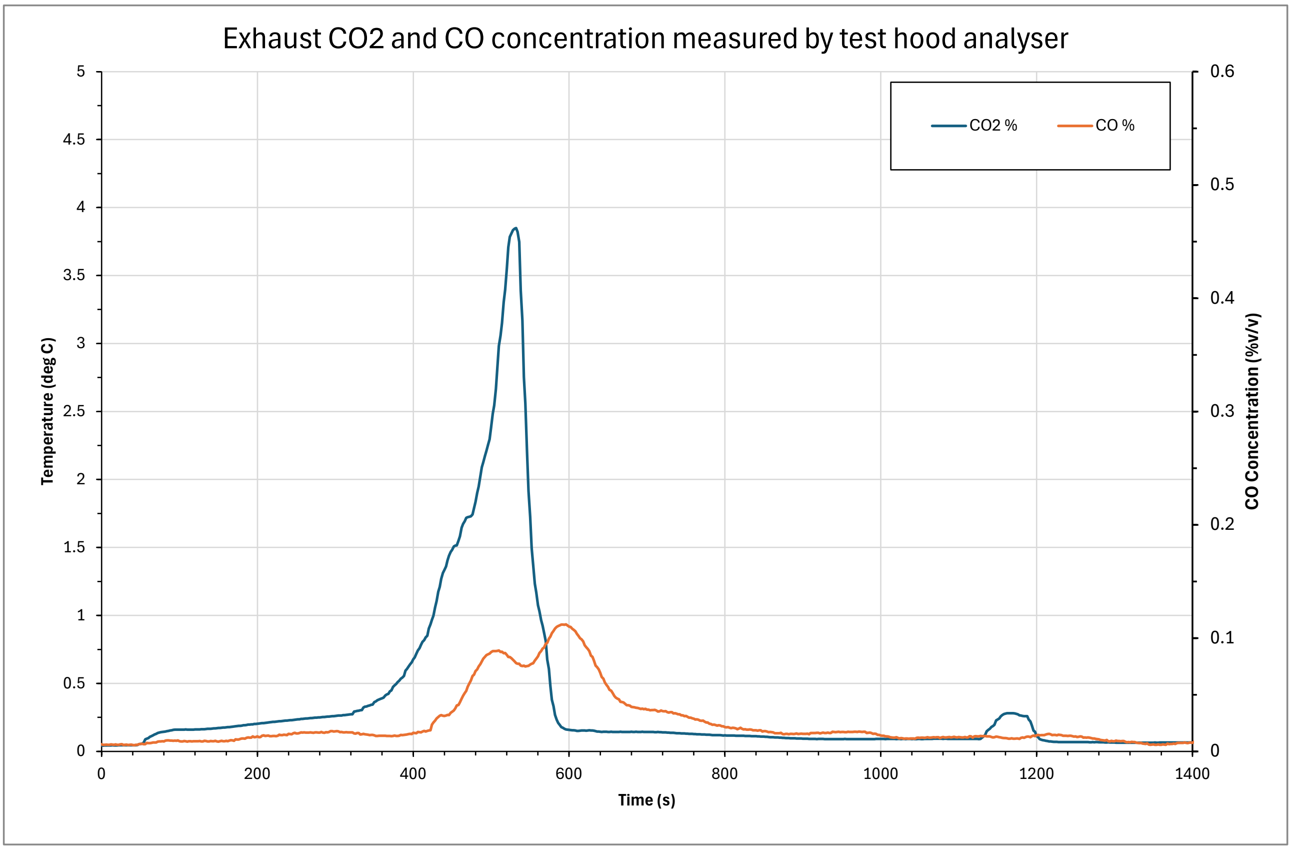


Figure 58. Test 3 – CO and CO2 concentration measured by test hood gas analyser

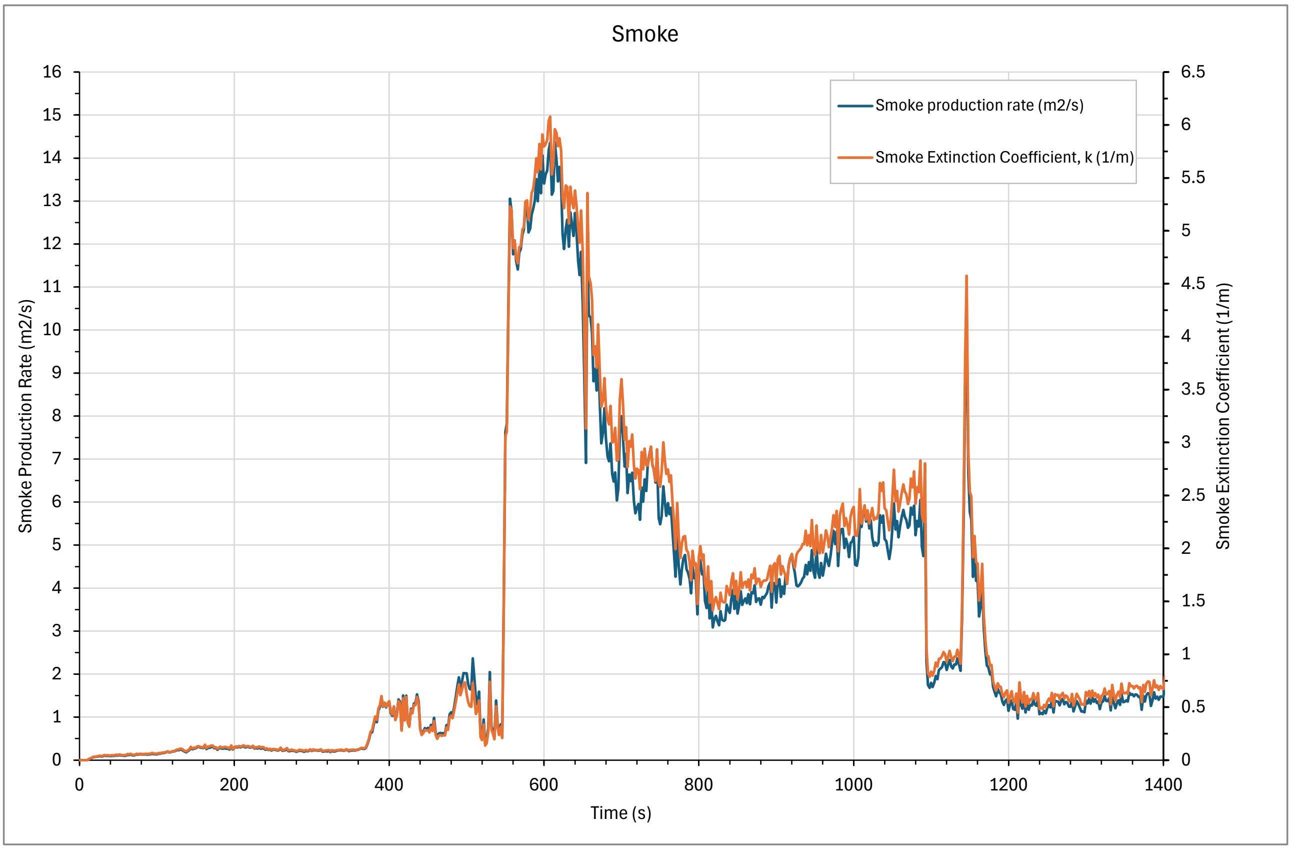


Figure 59. Test 3 – Smoke production rate

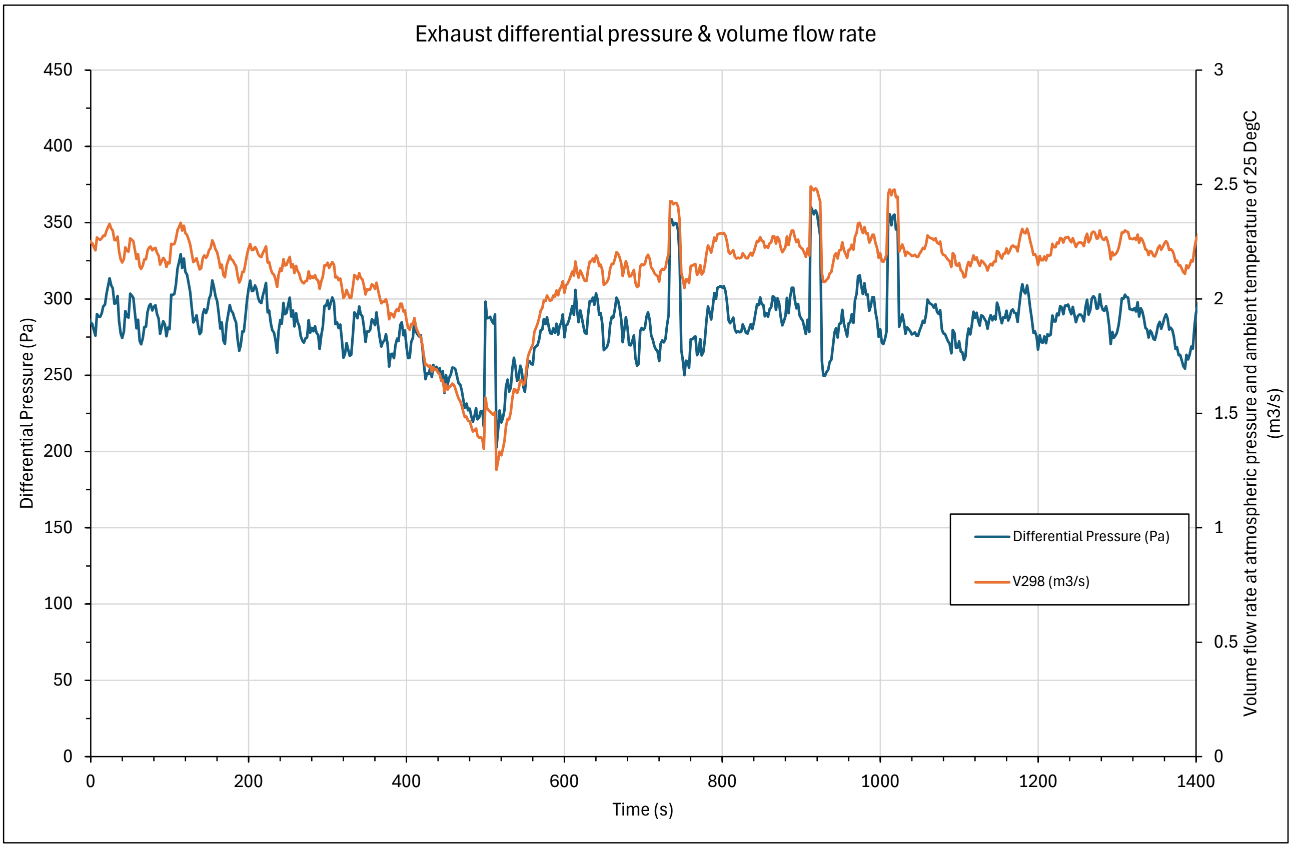


Figure 60. Test 3 – Test hood exhaust flow rate

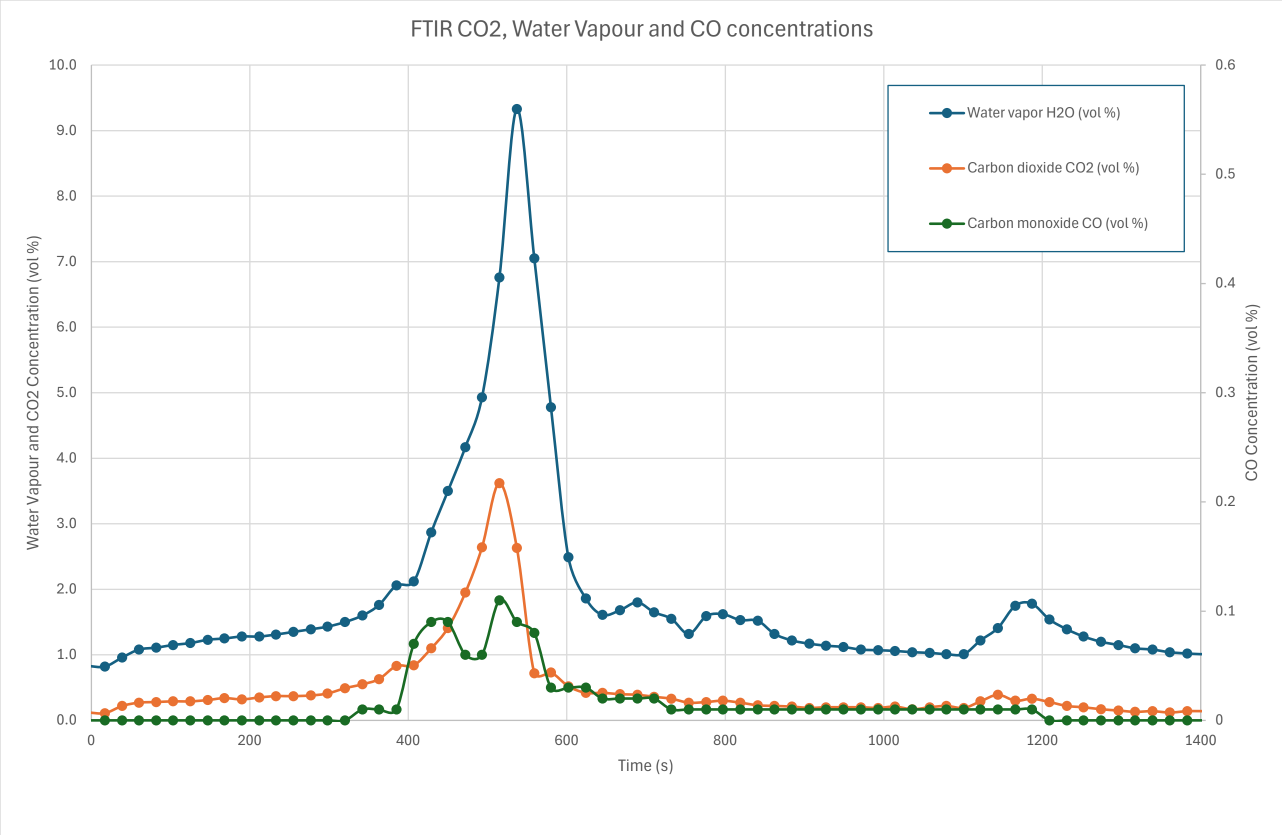


Figure 61. Test 3 – CO and CO2 concentration recorded by FTIR.

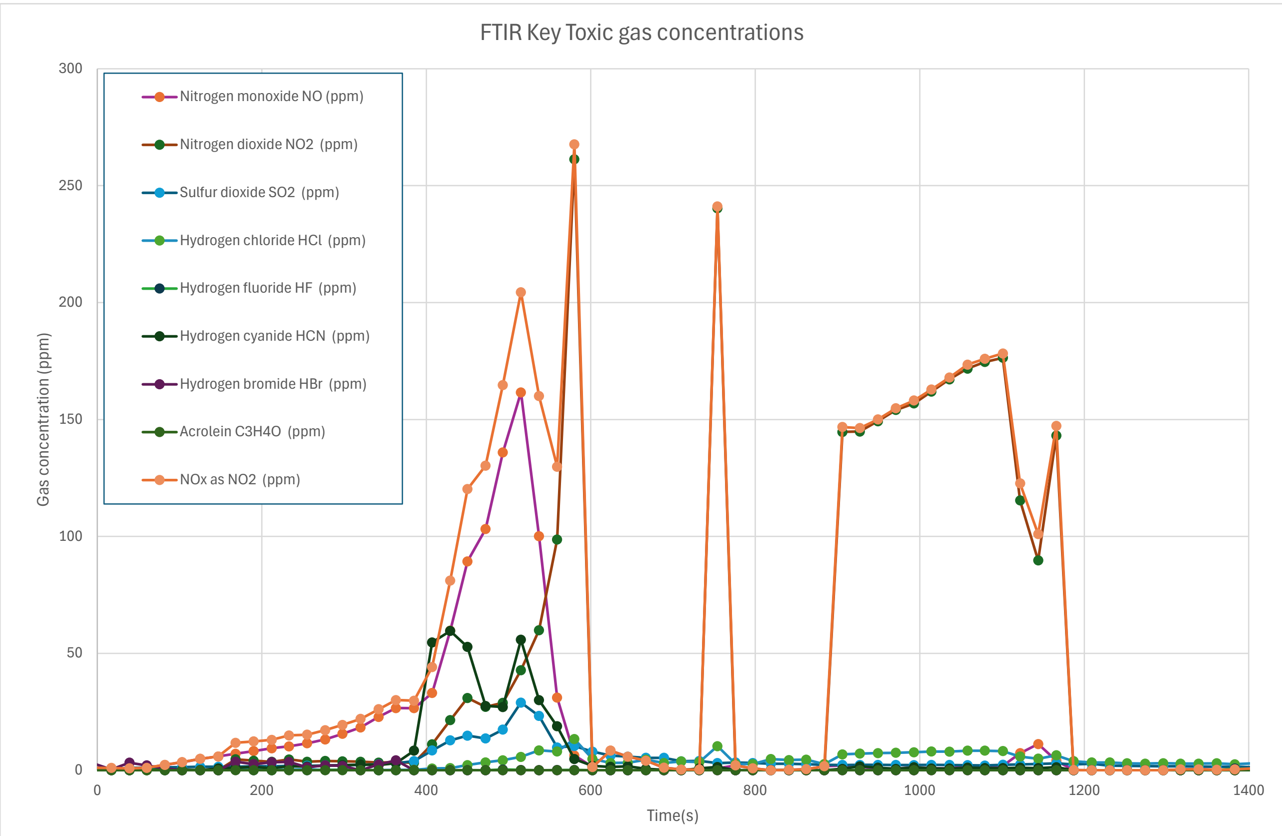


Figure 62. Test 3 – Key Toxic Species concentration recorded by FTIR.

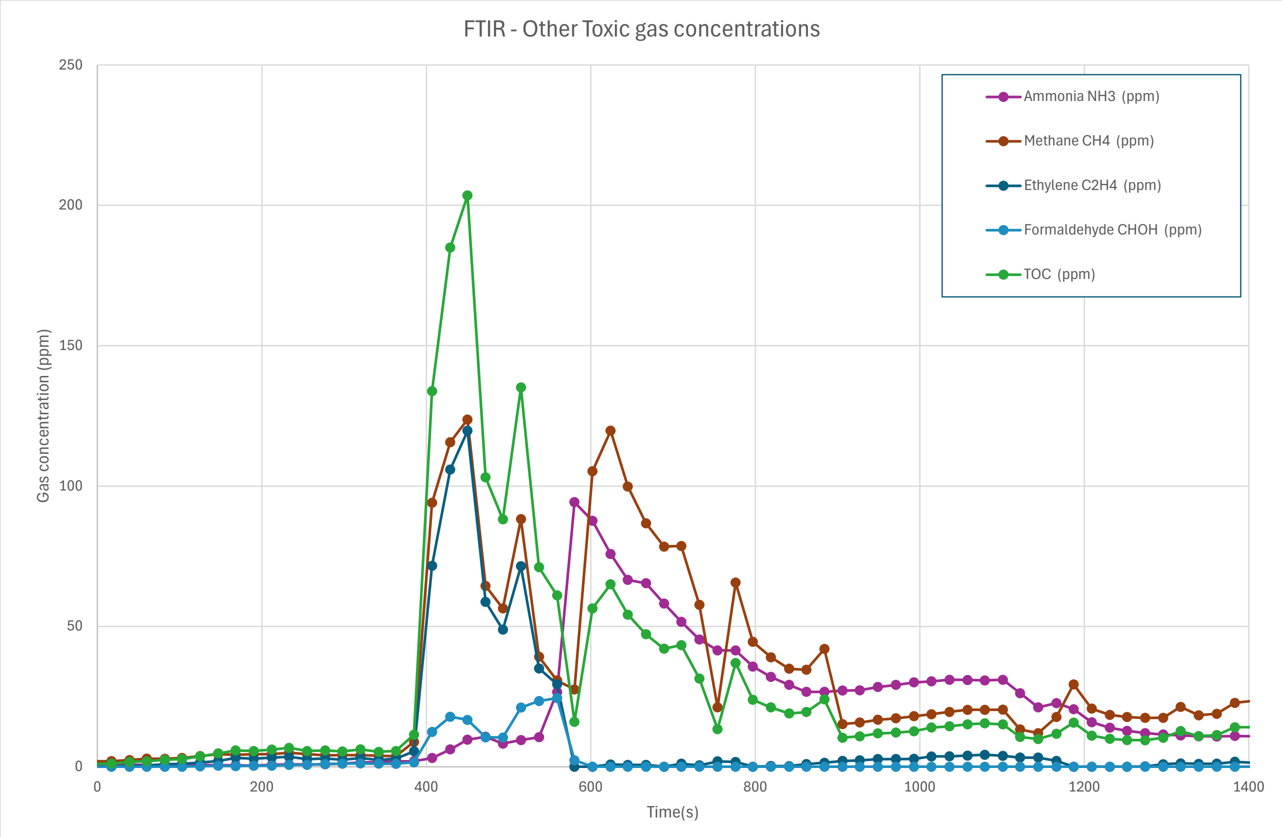


Figure 63. Test 3– Other Toxic Species concentration recorded by FTIR.

B.7 Test 4 – WPC-01

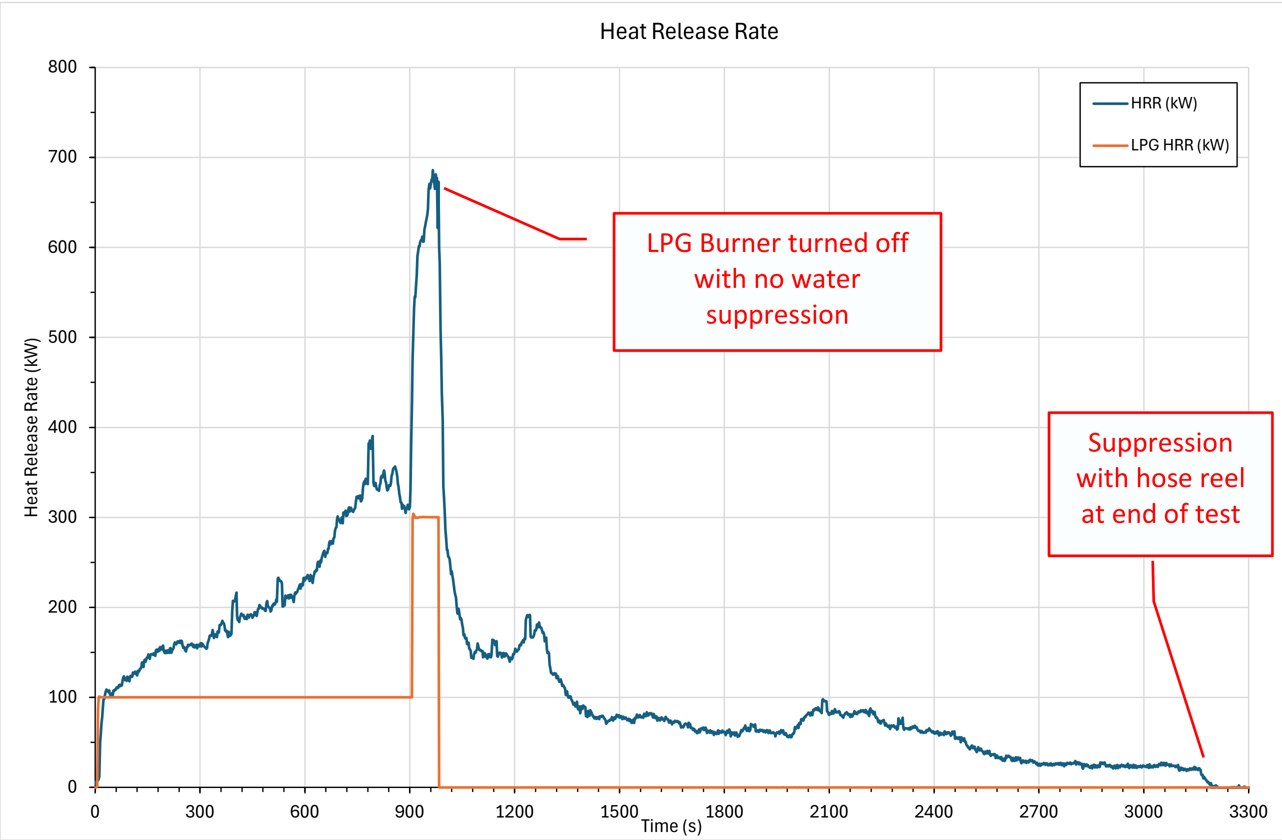


Figure 64. Test 4 – HRR (kW)

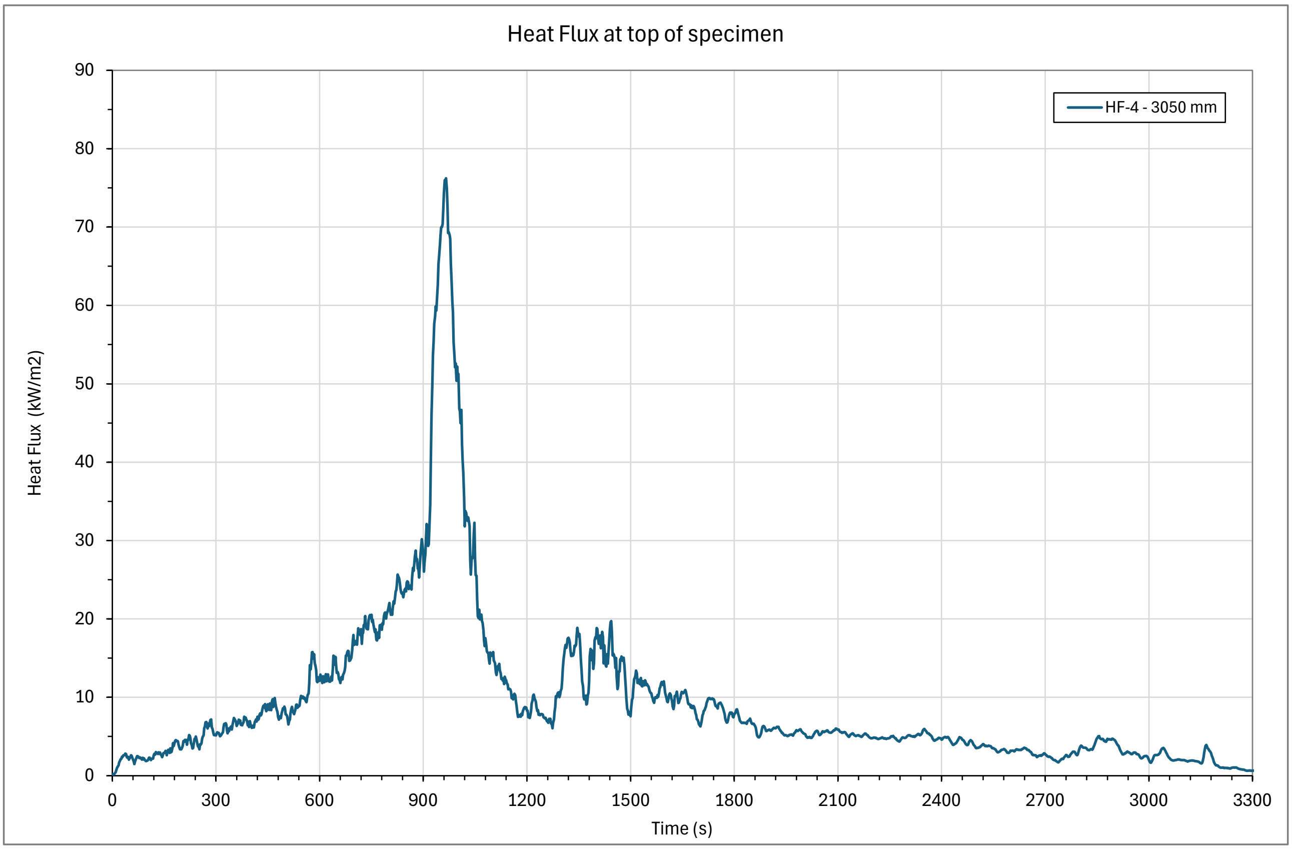


Figure 65. Test 4 – Heat flux (kW/m²) above 3050 mm from the ground level.

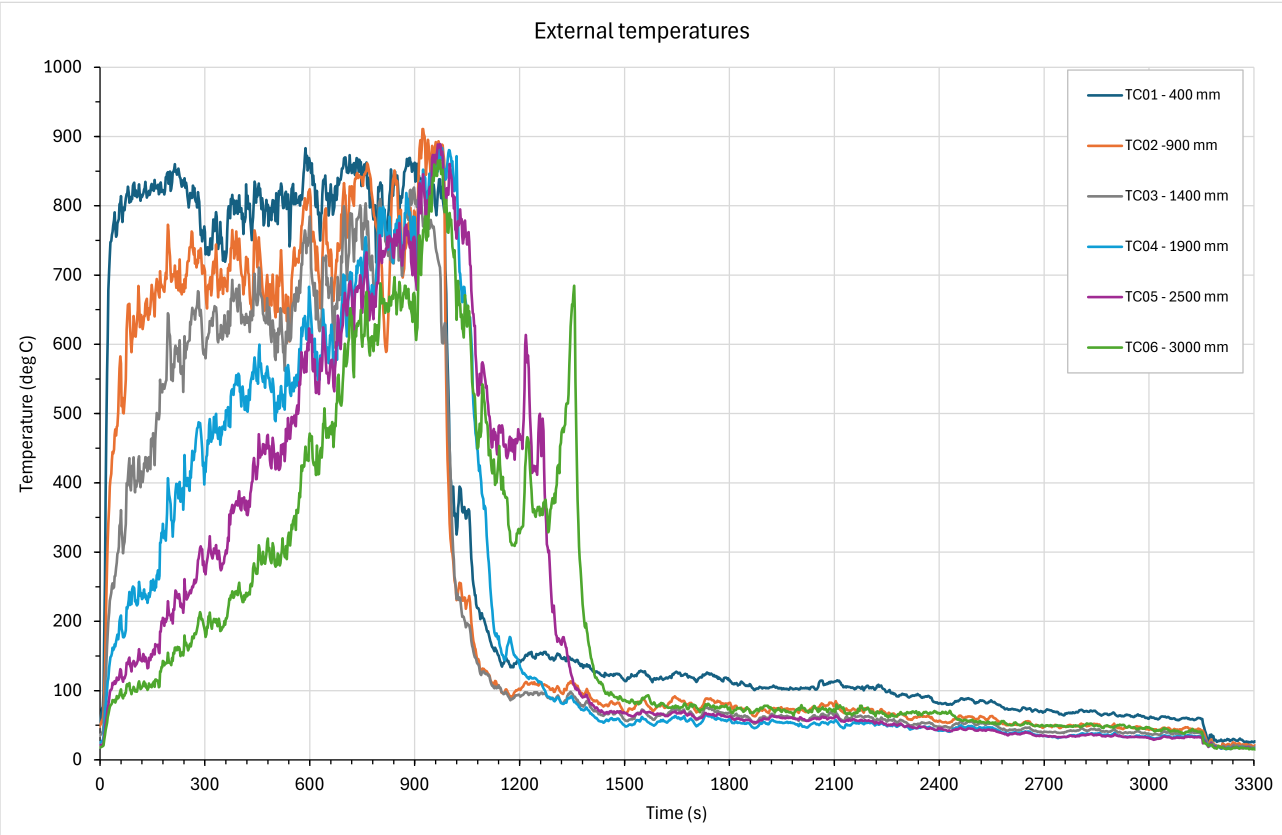


Figure 66. Test 4 – External face temperatures at various heights (TC01 to TC06)

Note – no cavity thermocouples installed for Test 4.

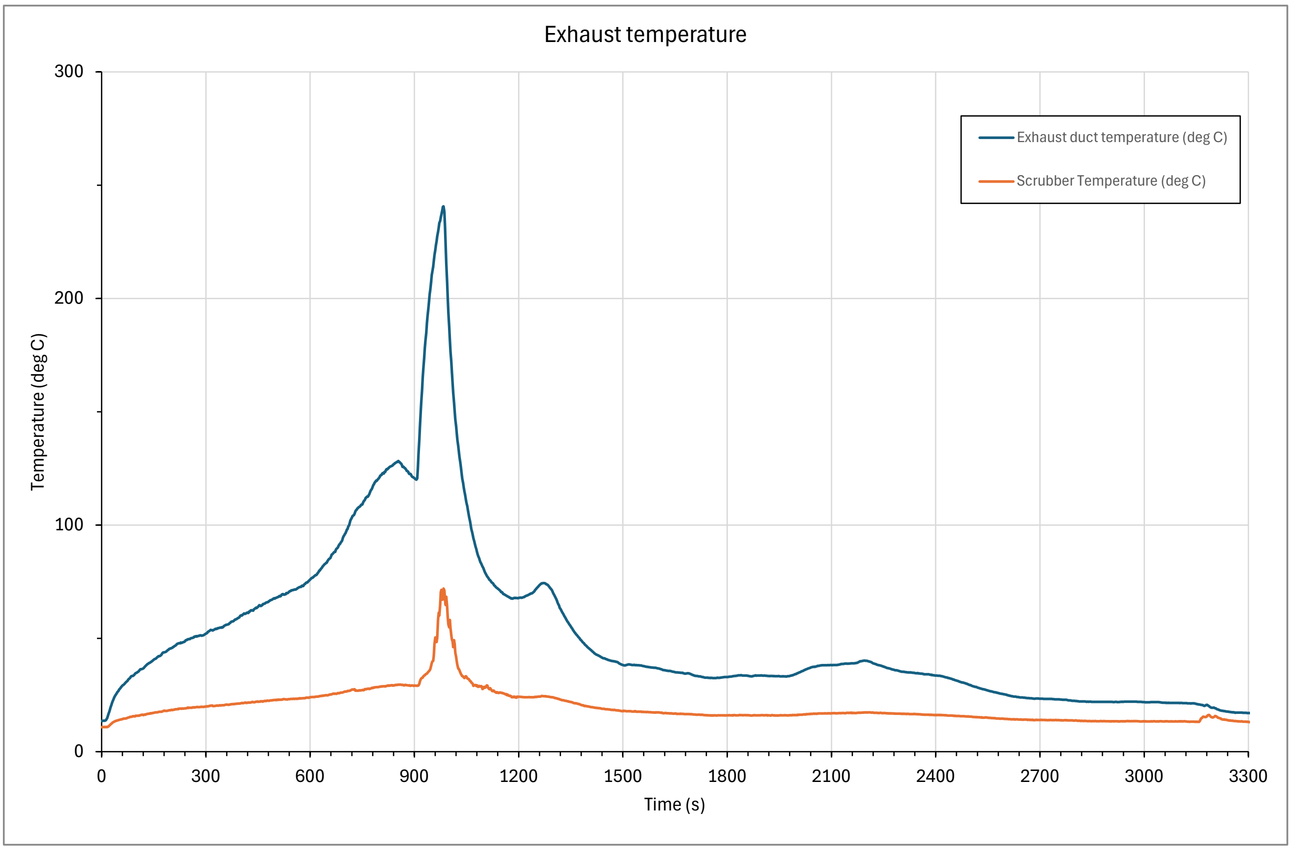


Figure 67. Test 4 – Test Hood exhaust temperatures

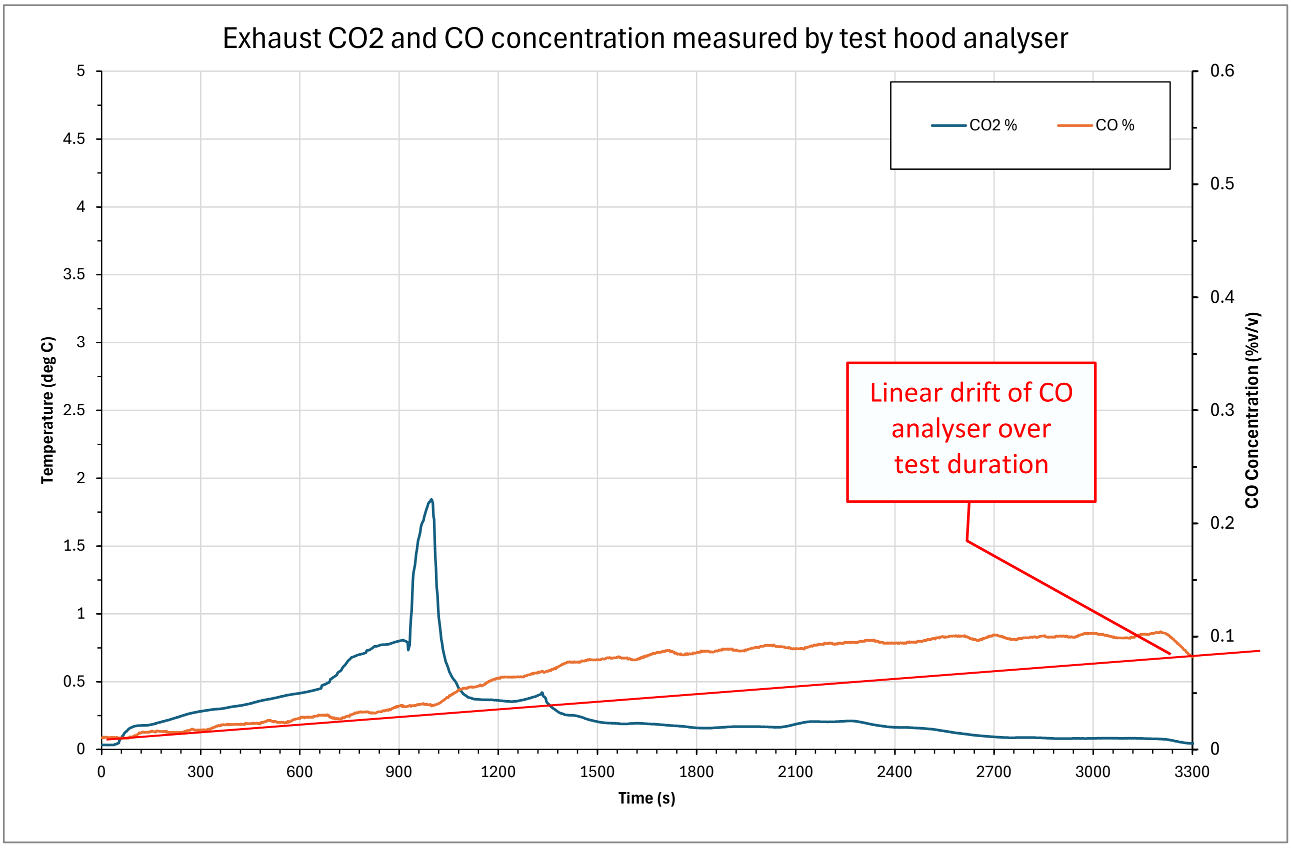


Figure 68. Test 4 – CO and CO2 concentration measured by test hood gas analyser

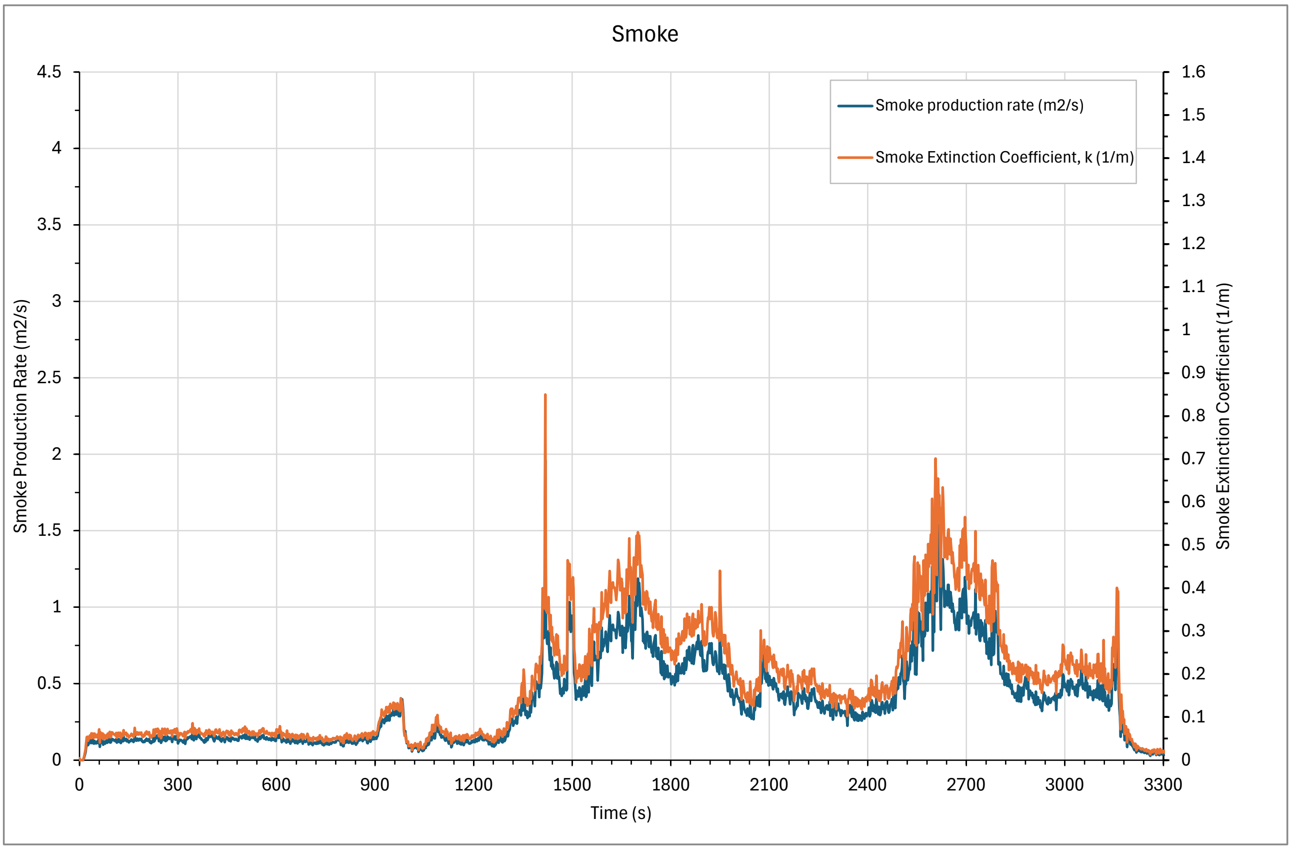


Figure 69. Test 4 – Smoke production rate

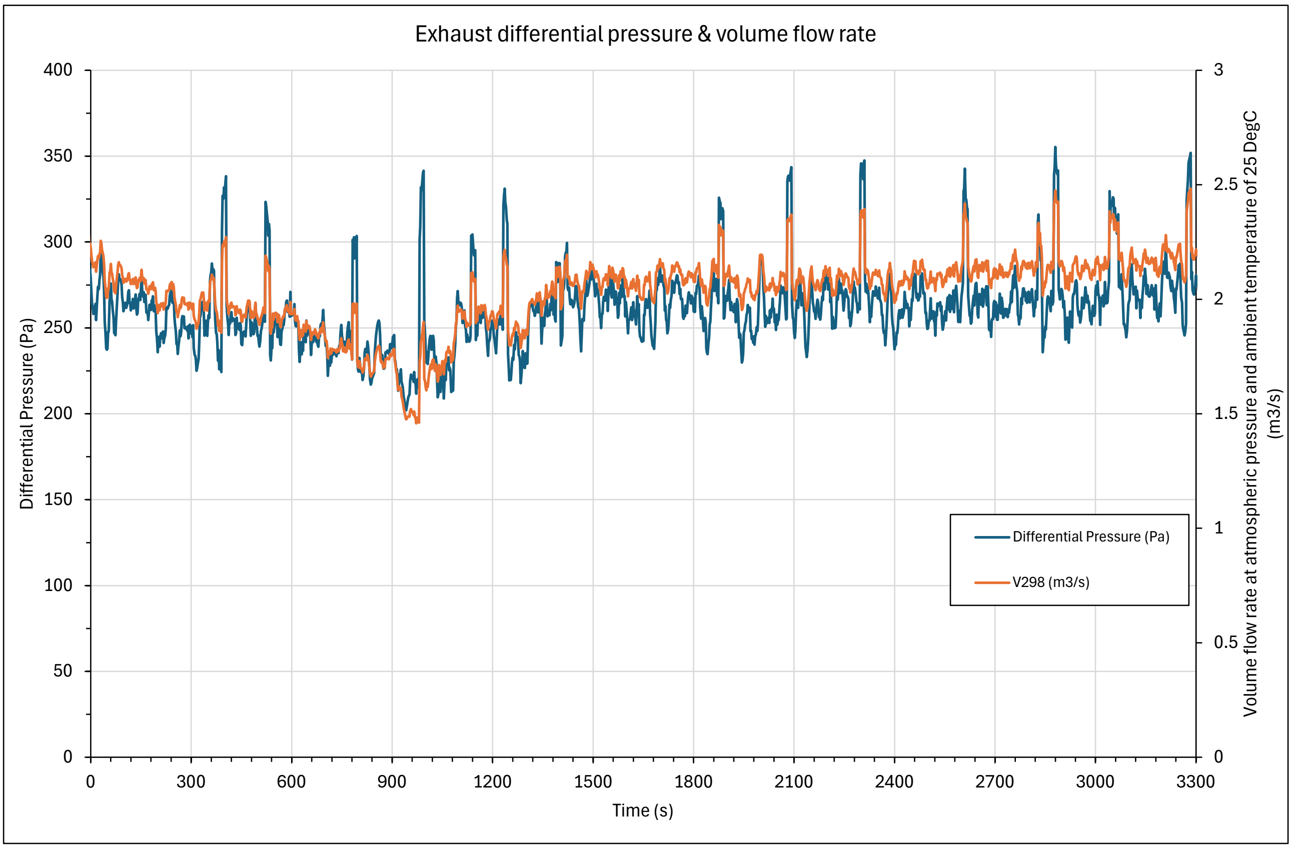


Figure 70. Test 4 – Test hood exhaust flow rate

Note that the FTIR Gas analyser measured concentrations of toxic species for Test 4 is lower than expected based on other similar WPC-01 tests. It is suspected that a Nitrogen purge (required for background Scan immediately prior to test) may not have been turned prior to starting the test and that this appears to have diluted the pumped sample.

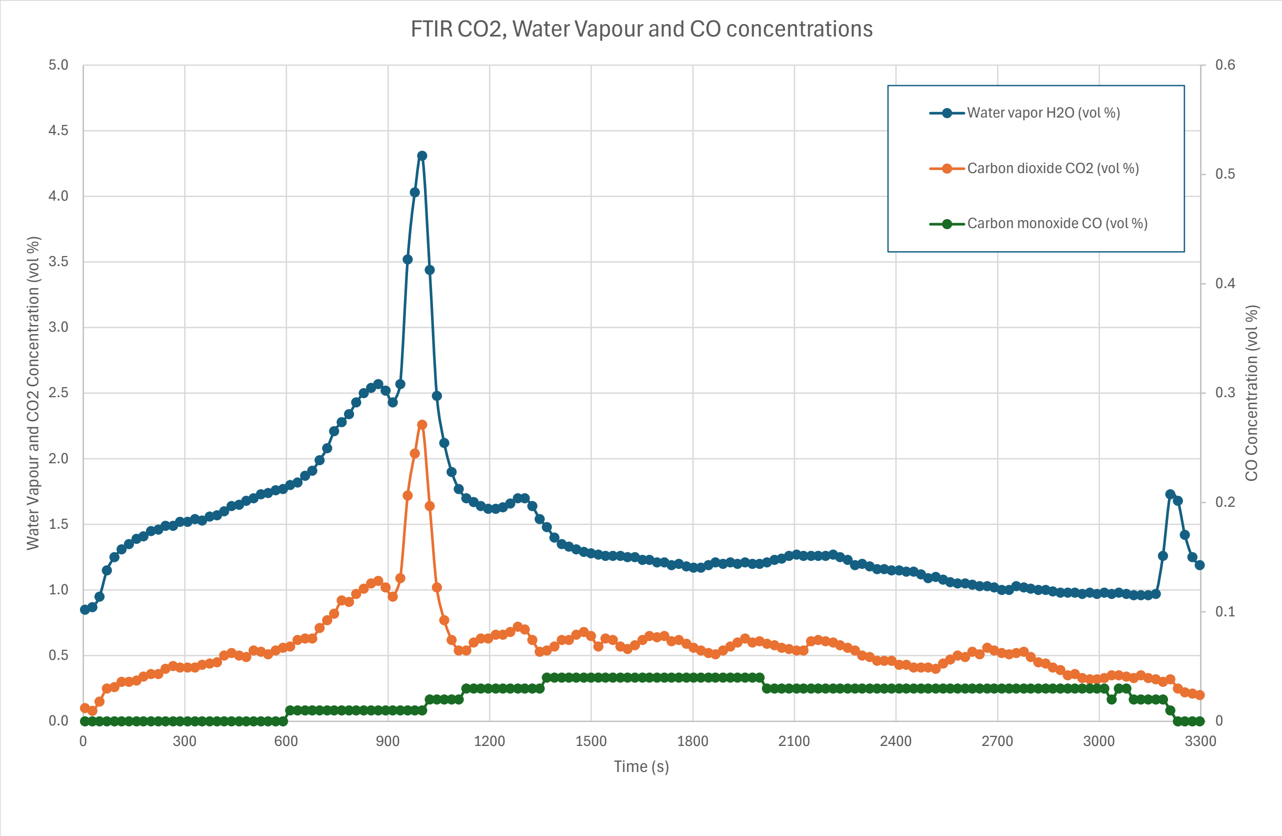


Figure 71. Test 4 – CO and CO2 concentration recorded by FTIR.

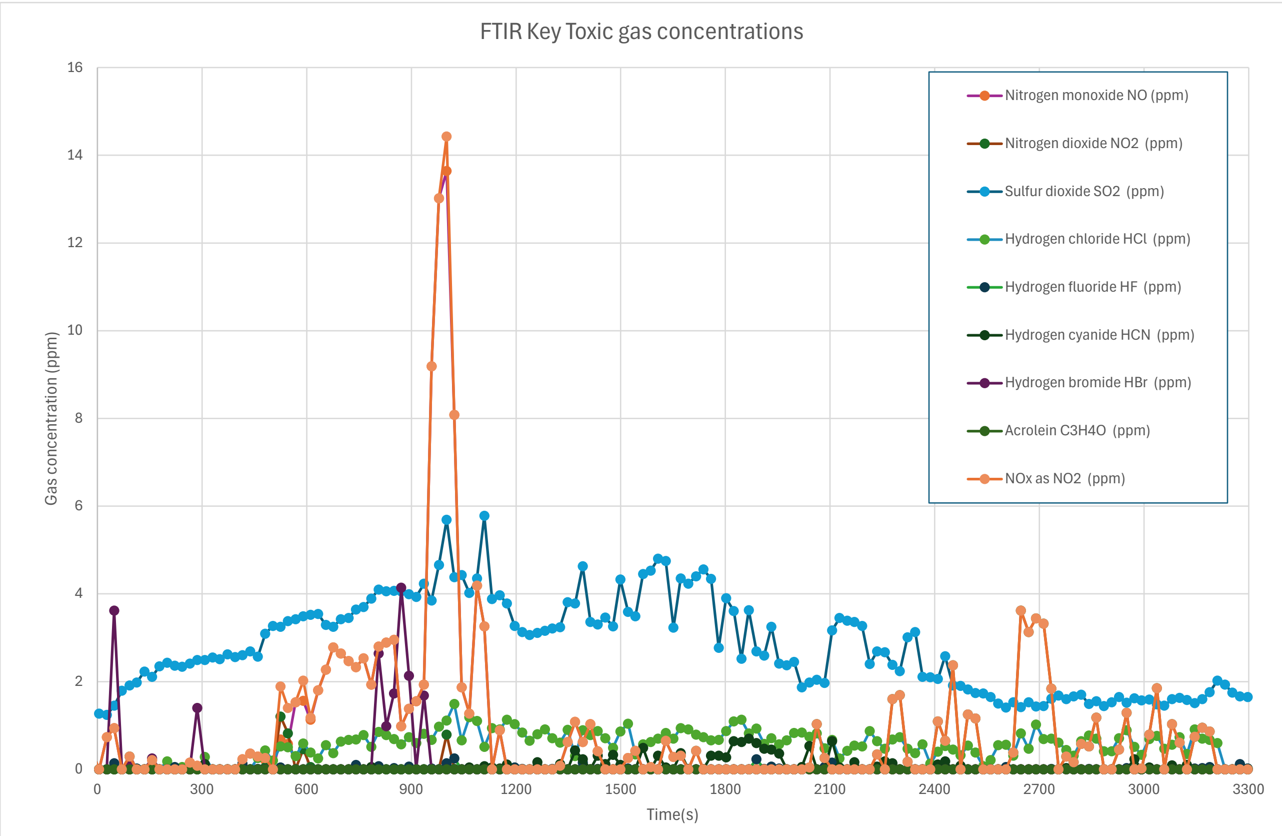


Figure 72. Test 4 – Key Toxic Species concentration recorded by FTIR.

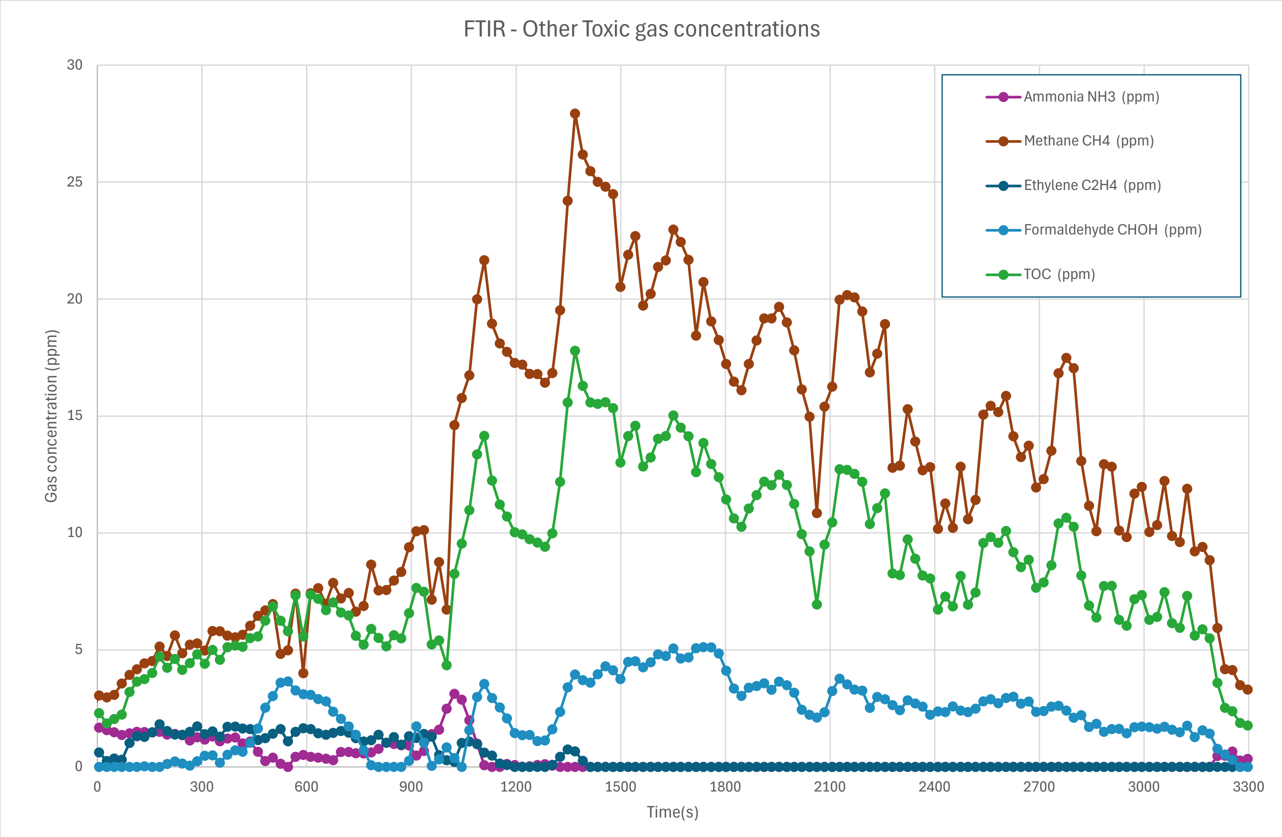


Figure 73. Test 4– Other Toxic Species concentration recorded by FTIR.

B.8 Test 5 – WPC-01

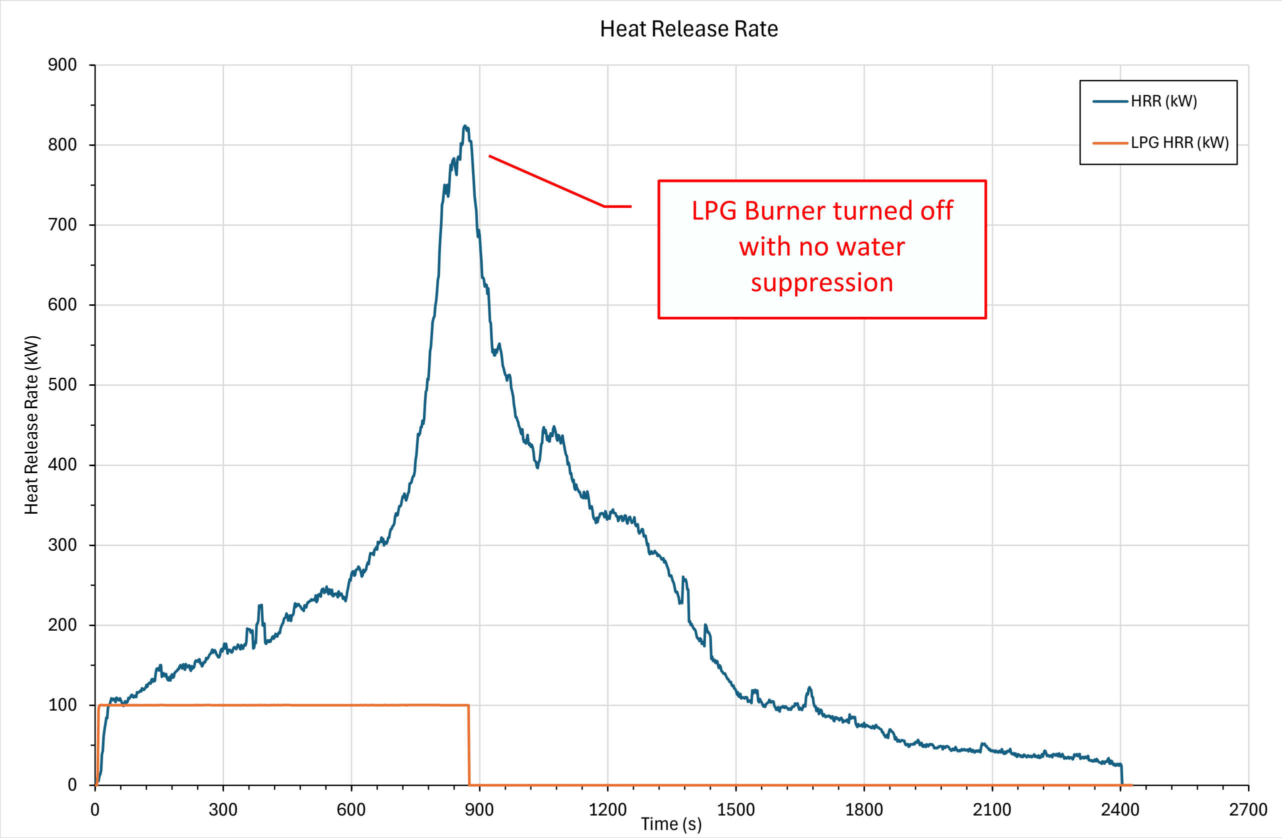


Figure 74. Test 5 – HRR (kW)

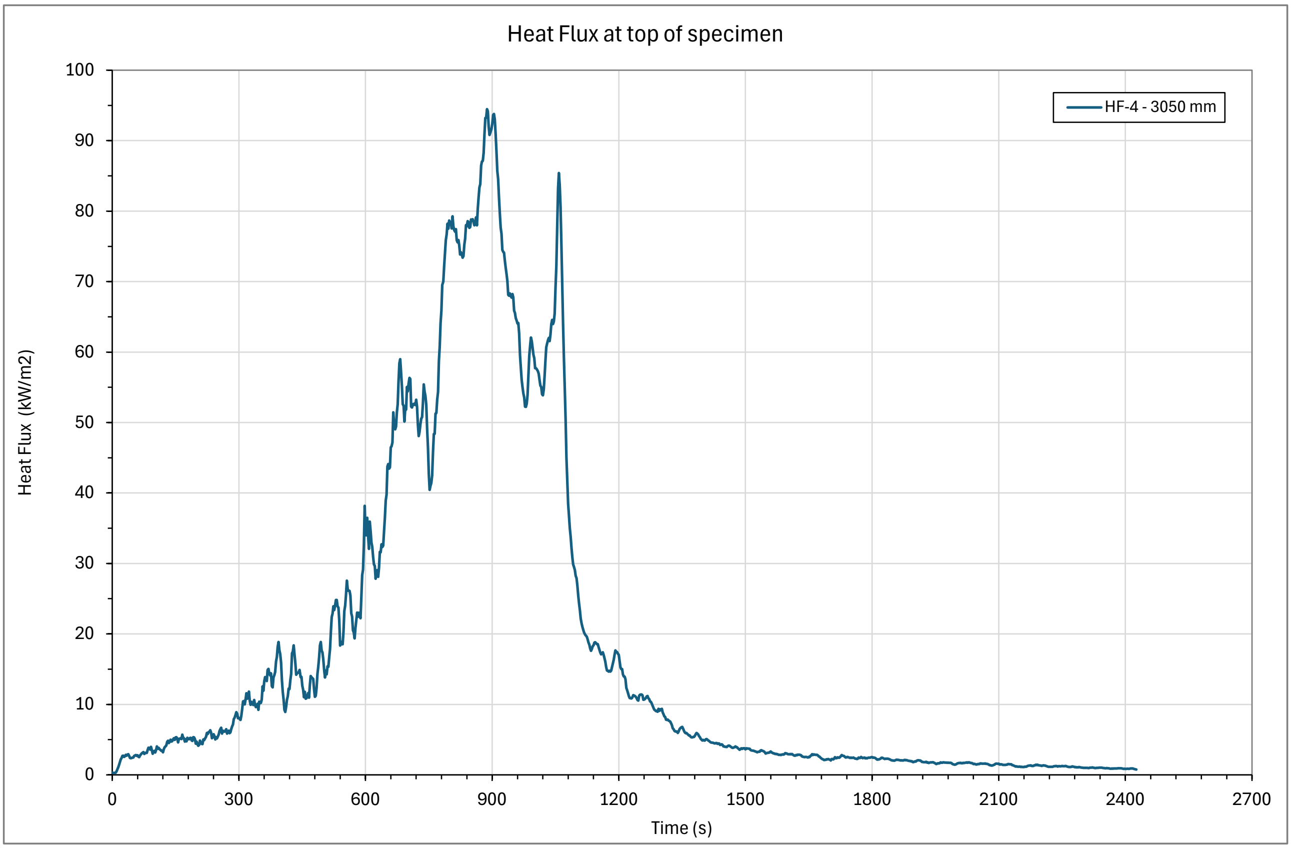


Figure 75. Test 5 – Heat flux (kW/m²) above 3050 mm from the ground level.

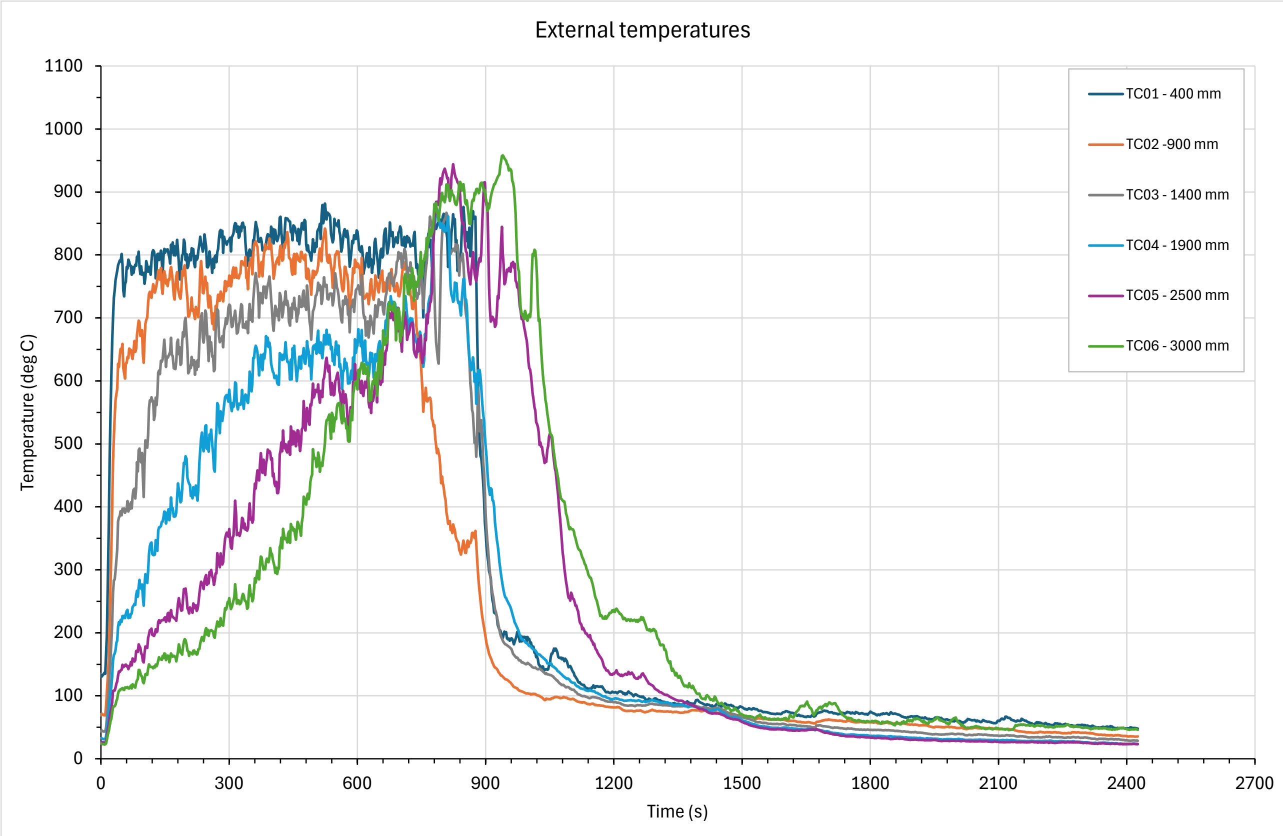


Figure 76. Test 5 – External face temperatures at various heights (TC01 to TC06)

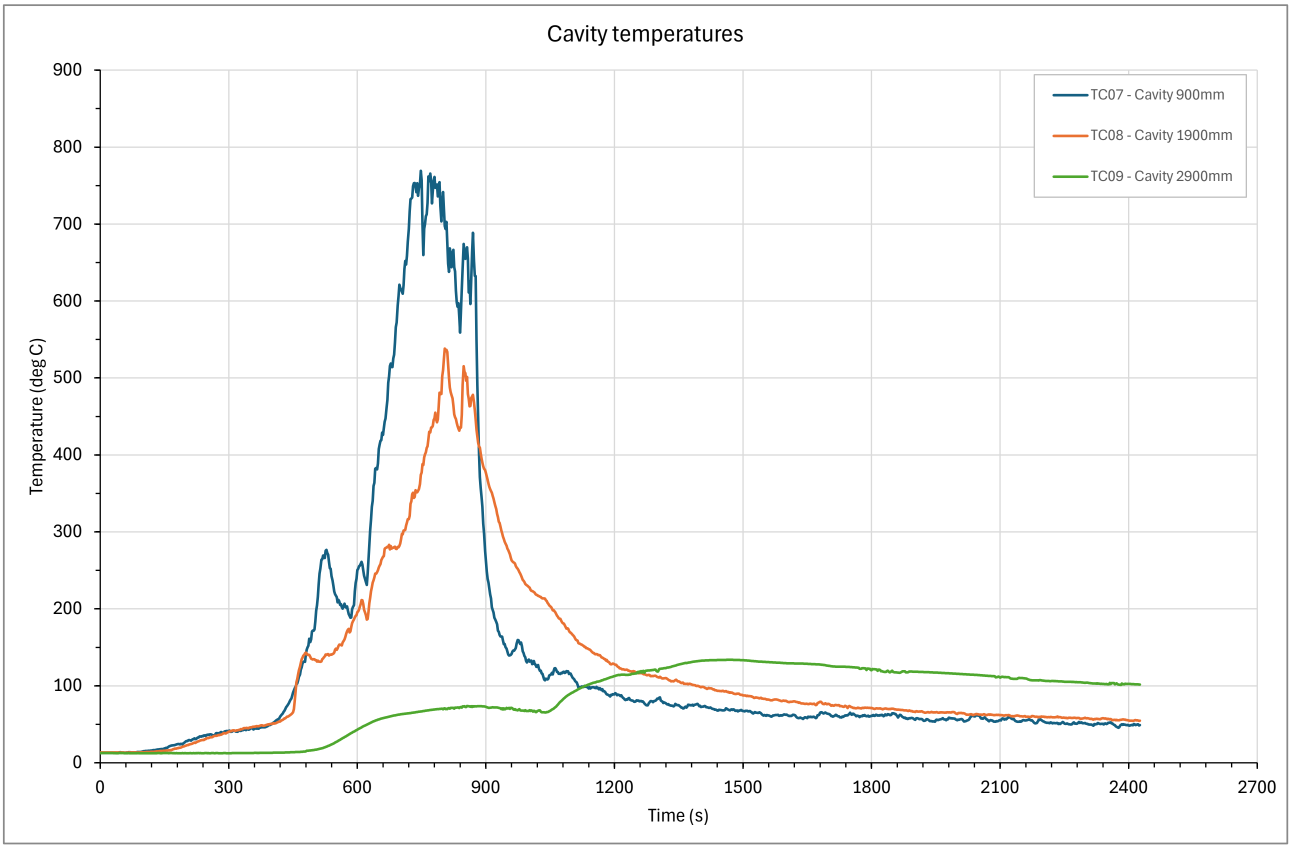


Figure 77. Test 5 – Temperatures within air cavity at 900 mm (TC07), 1,900 mm (TC08), 3,000 mm (TC09) above ground level

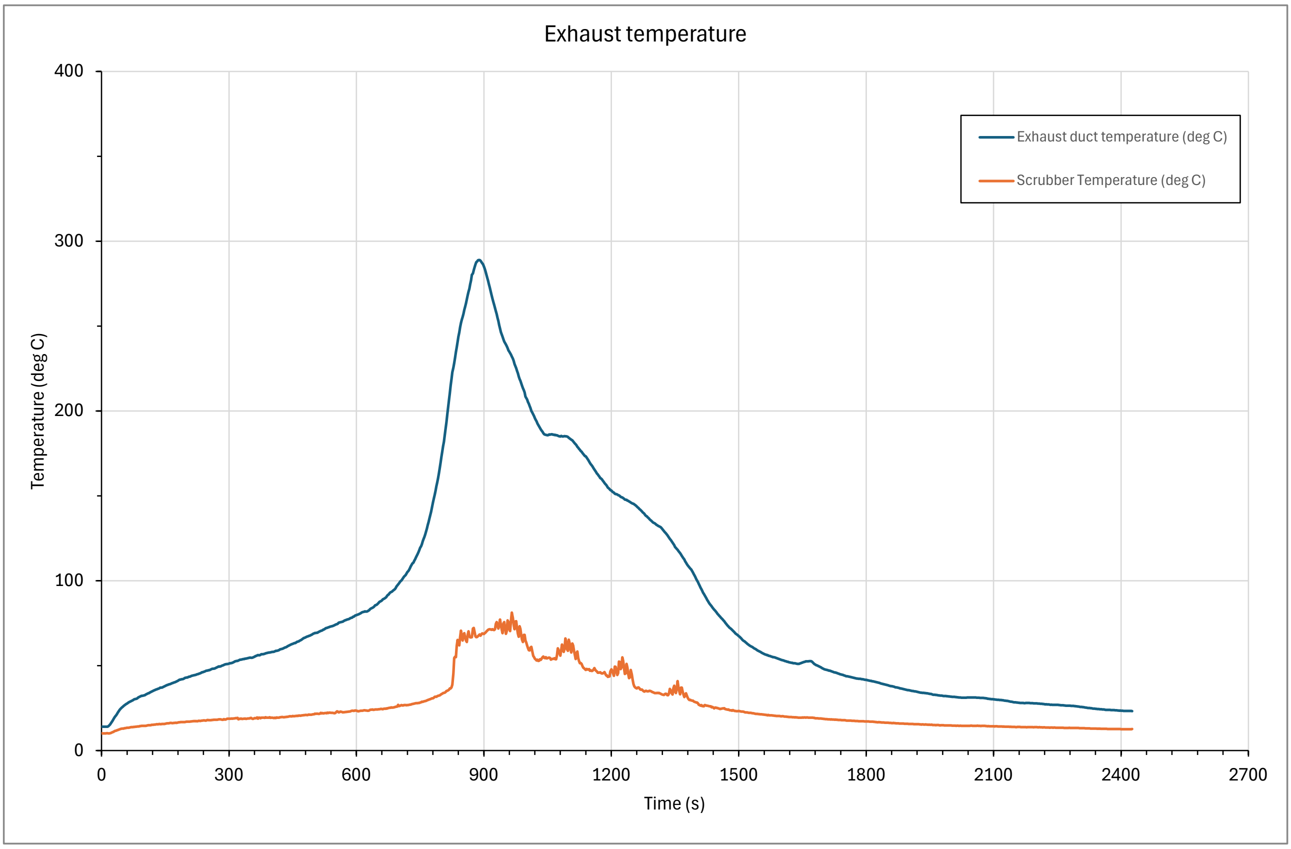


Figure 78. Test 5 – Test Hood exhaust temperatures

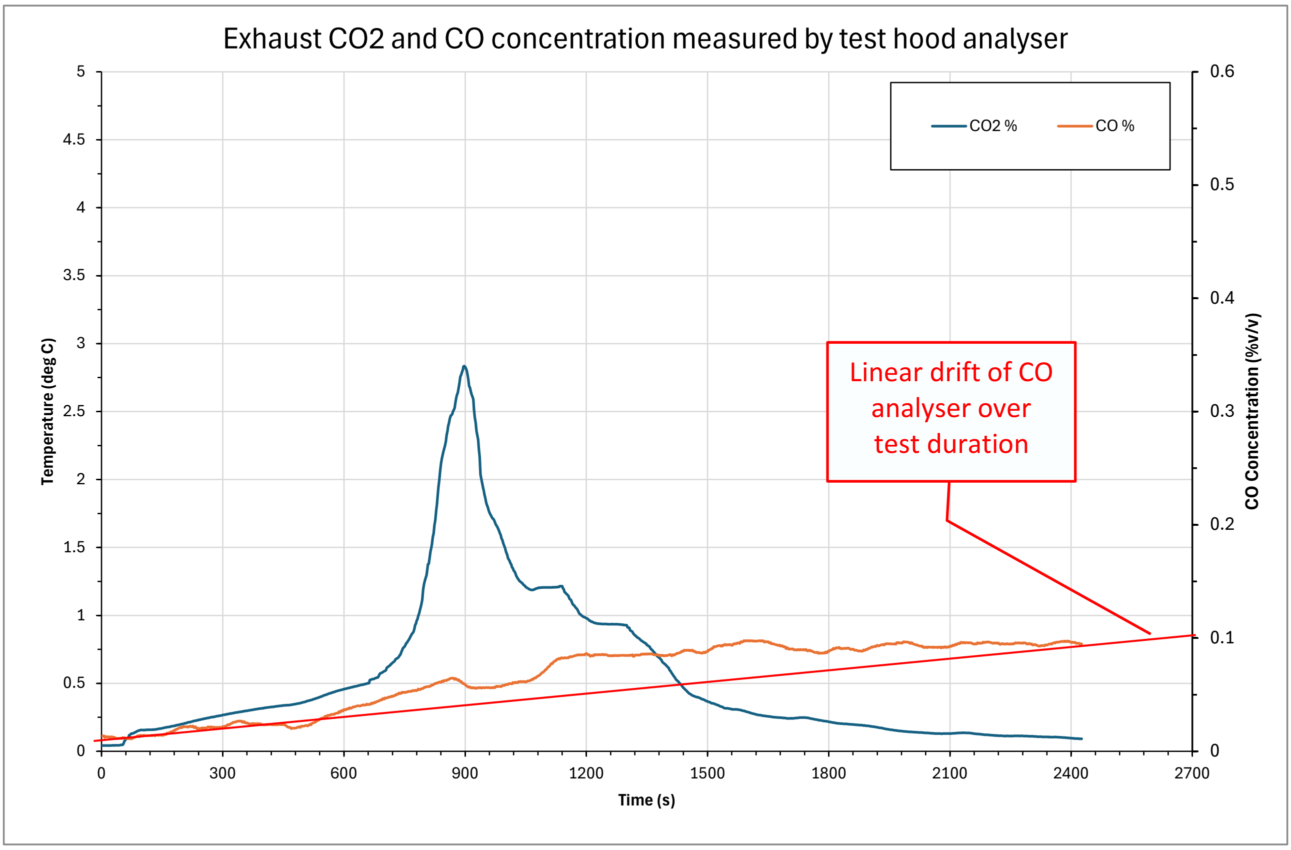


Figure 79. Test 5 – CO and CO2 concentration measured by test hood gas analyser

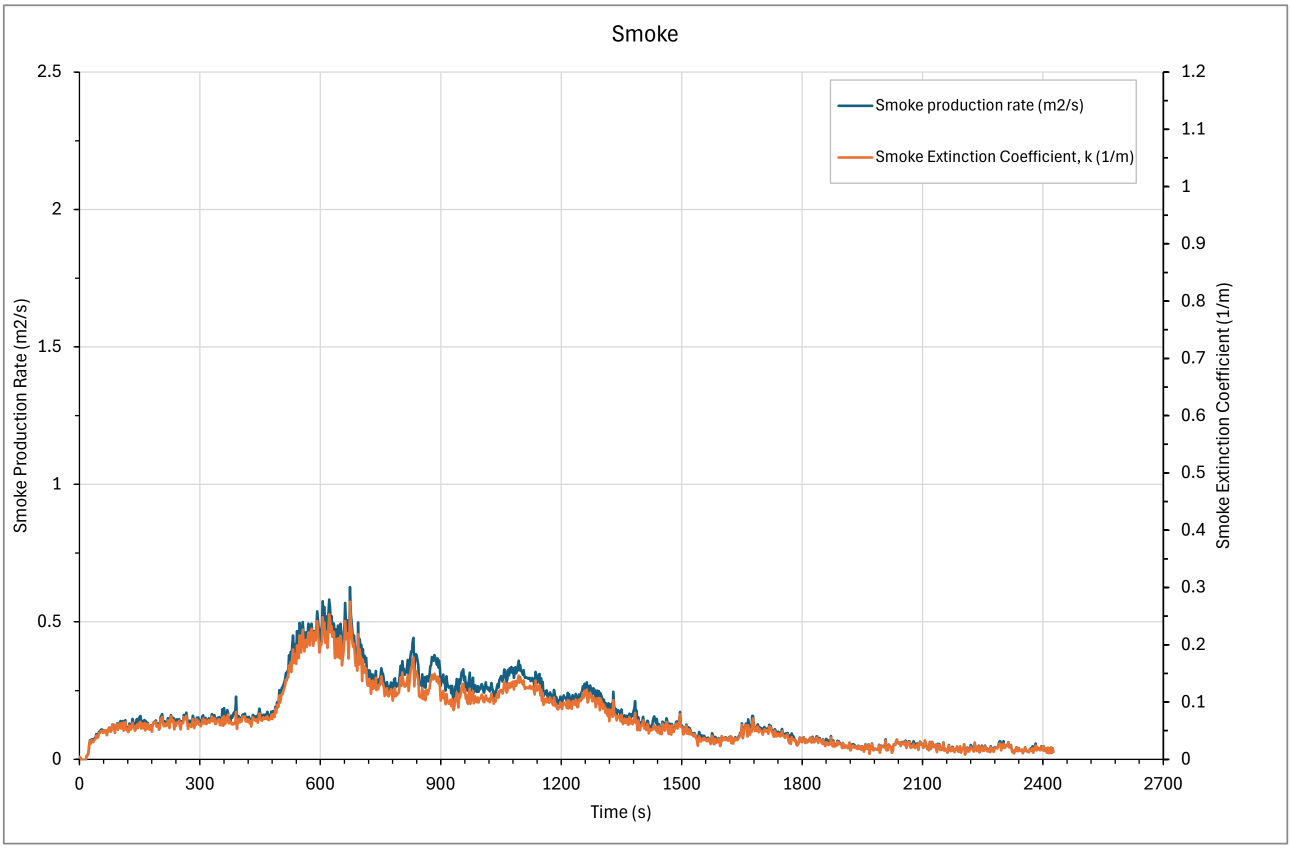


Figure 80. Test 5 – Smoke production rate

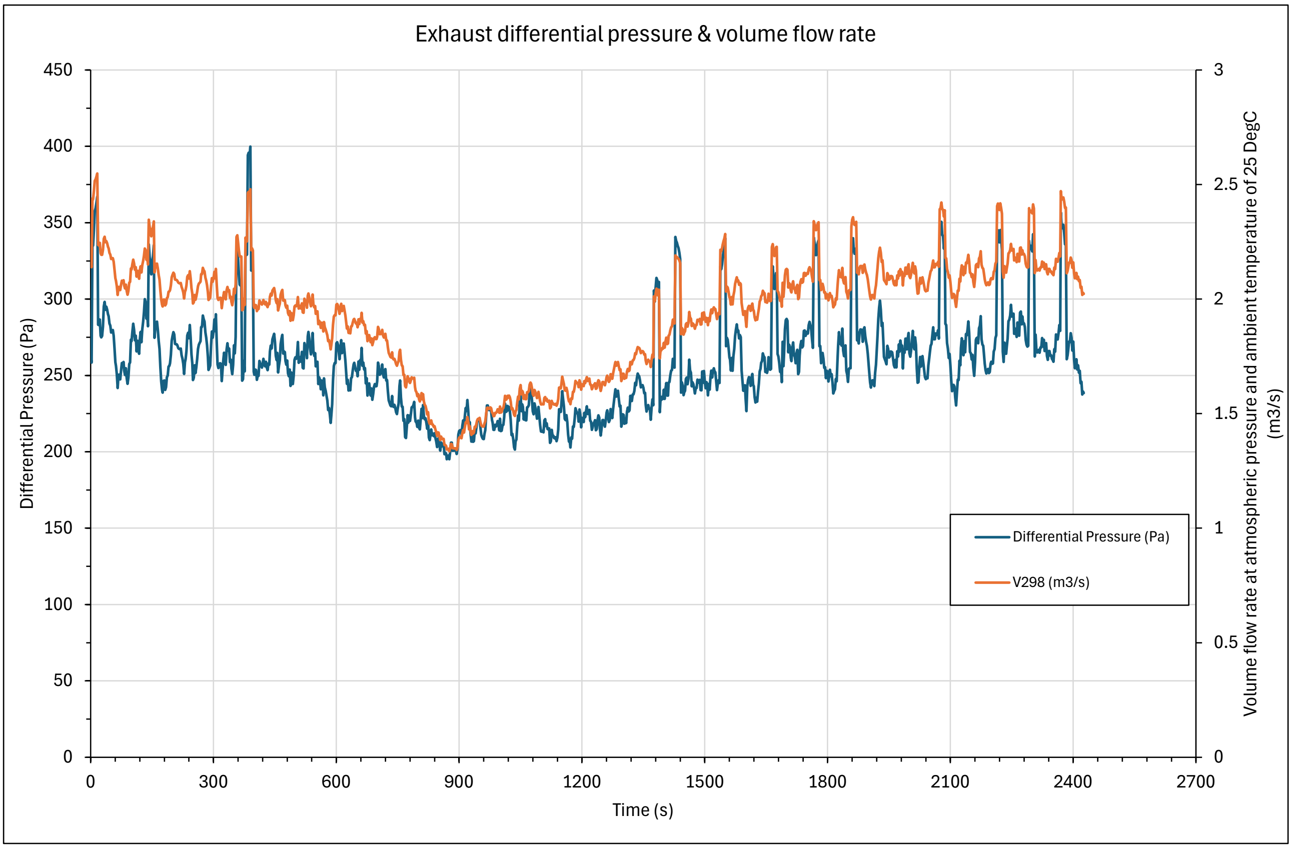


Figure 81. Test 5 – Test hood exhaust flow rate

Note that the FTIR Gas analyser sample pump was not turned on for Test 5, so No FTIR gas analyser data was collected for this test

B.9 Test 6 – ISP-01-PIR Vertical Panel

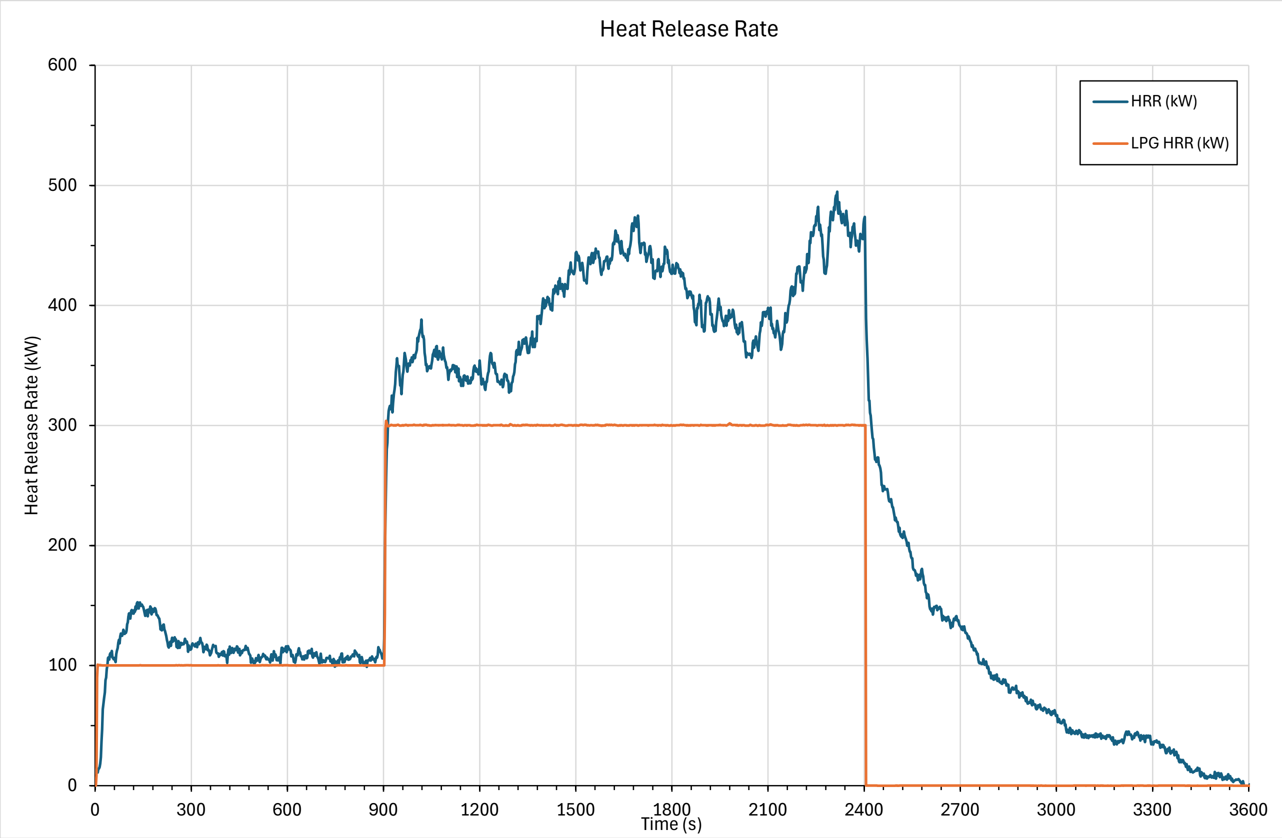


Figure 82. Test 6 – HRR (kW)

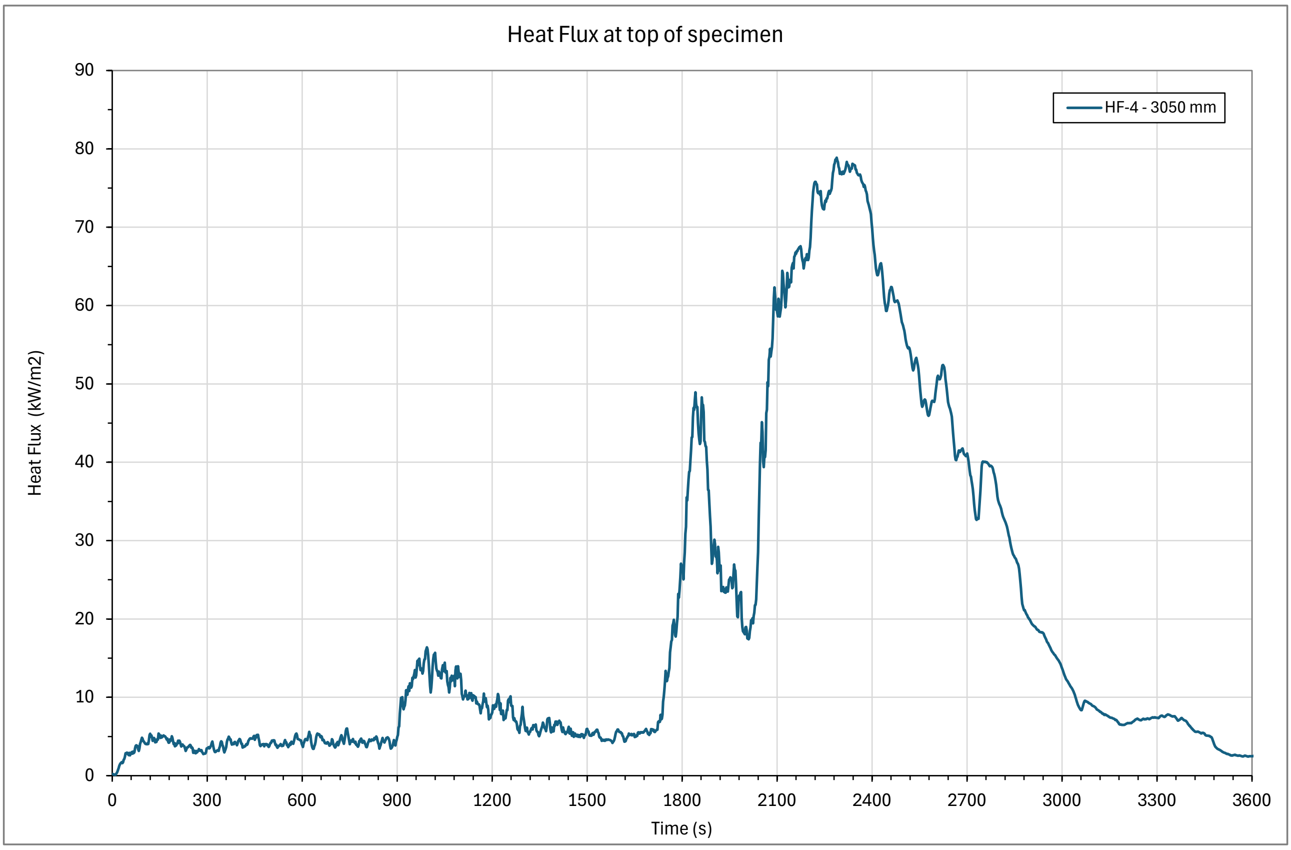


Figure 83. Test 6 – Heat flux (kW/m²) above 3050 mm from the ground level.

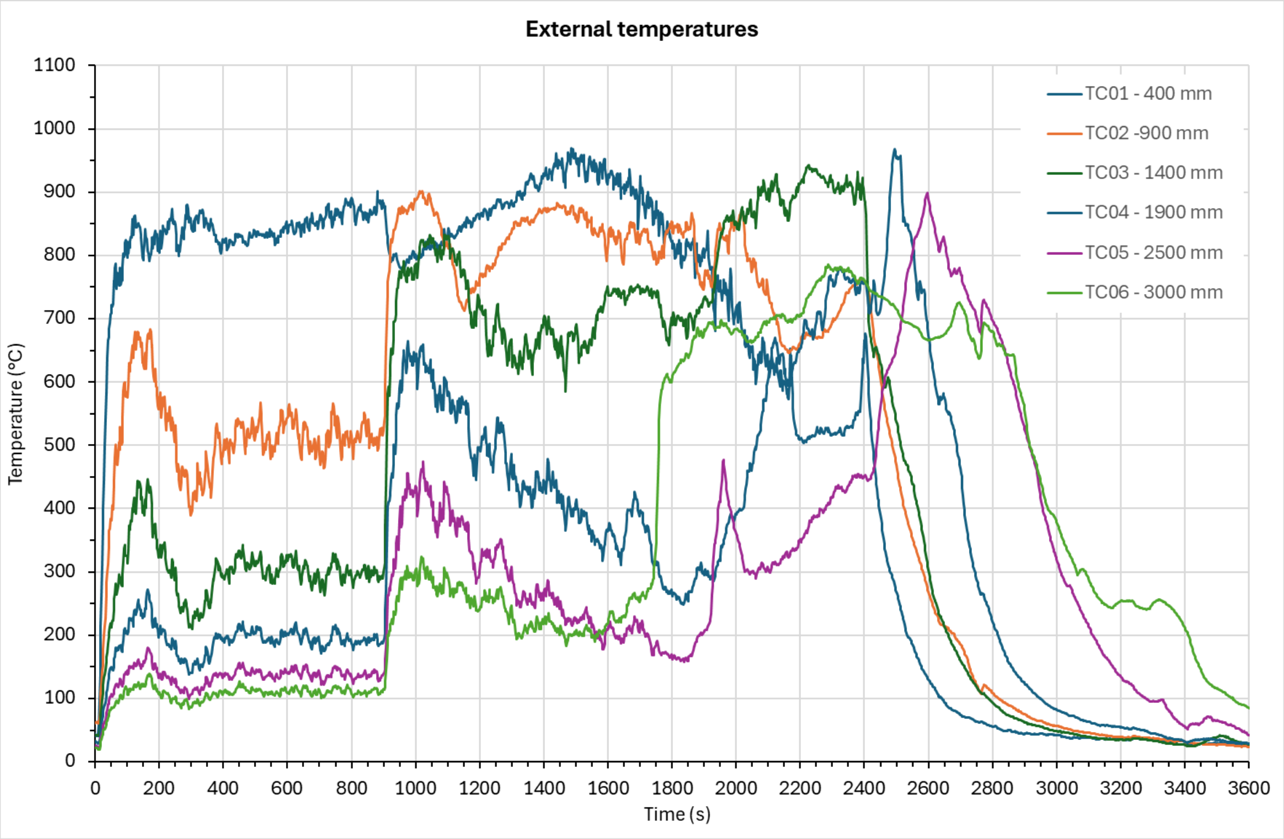


Figure 84. Test 6 – External face temperatures at various heights (TC01 to TC06)

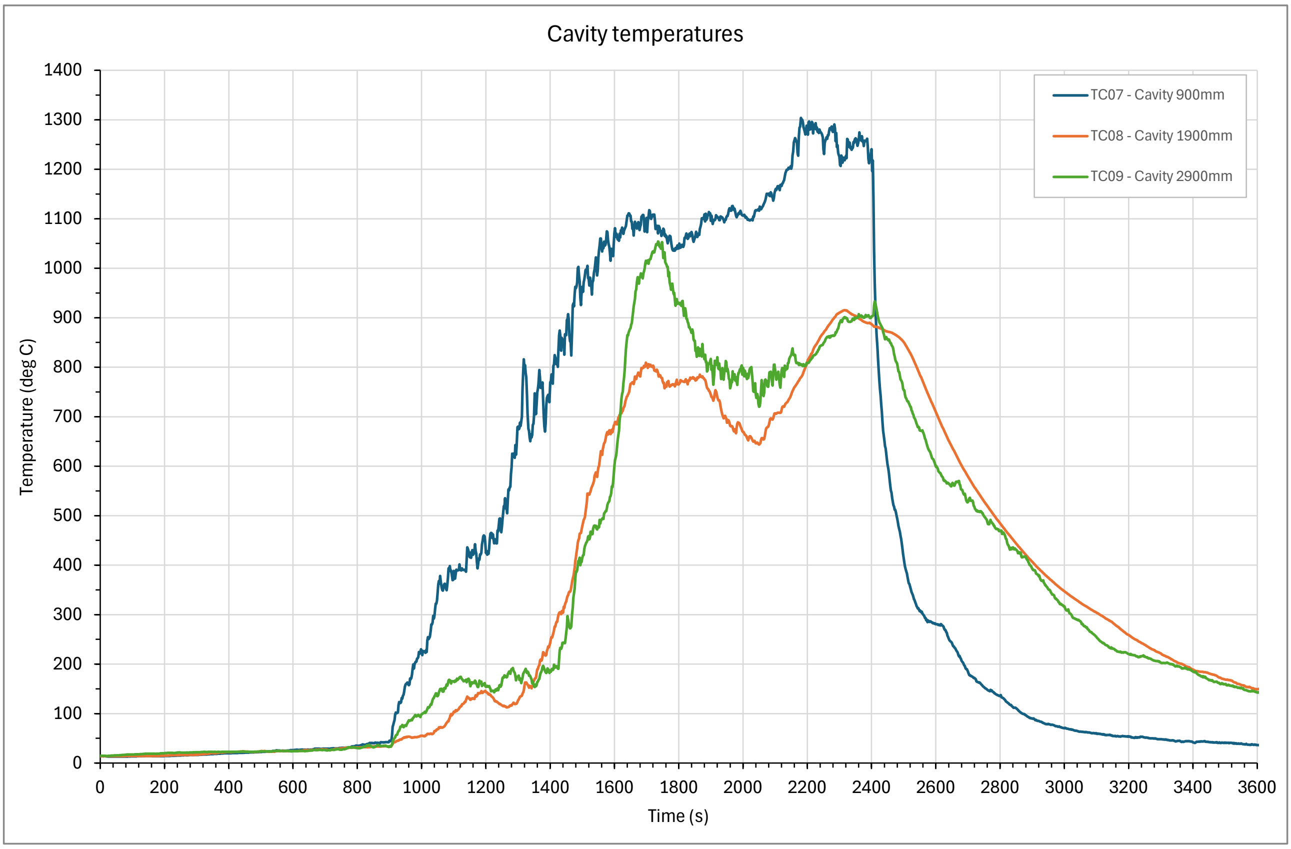


Figure 85. Test 6 – Temperatures within air cavity at 900 mm (TC07), 1,900 mm (TC08), 3,000 mm (TC09) above ground level

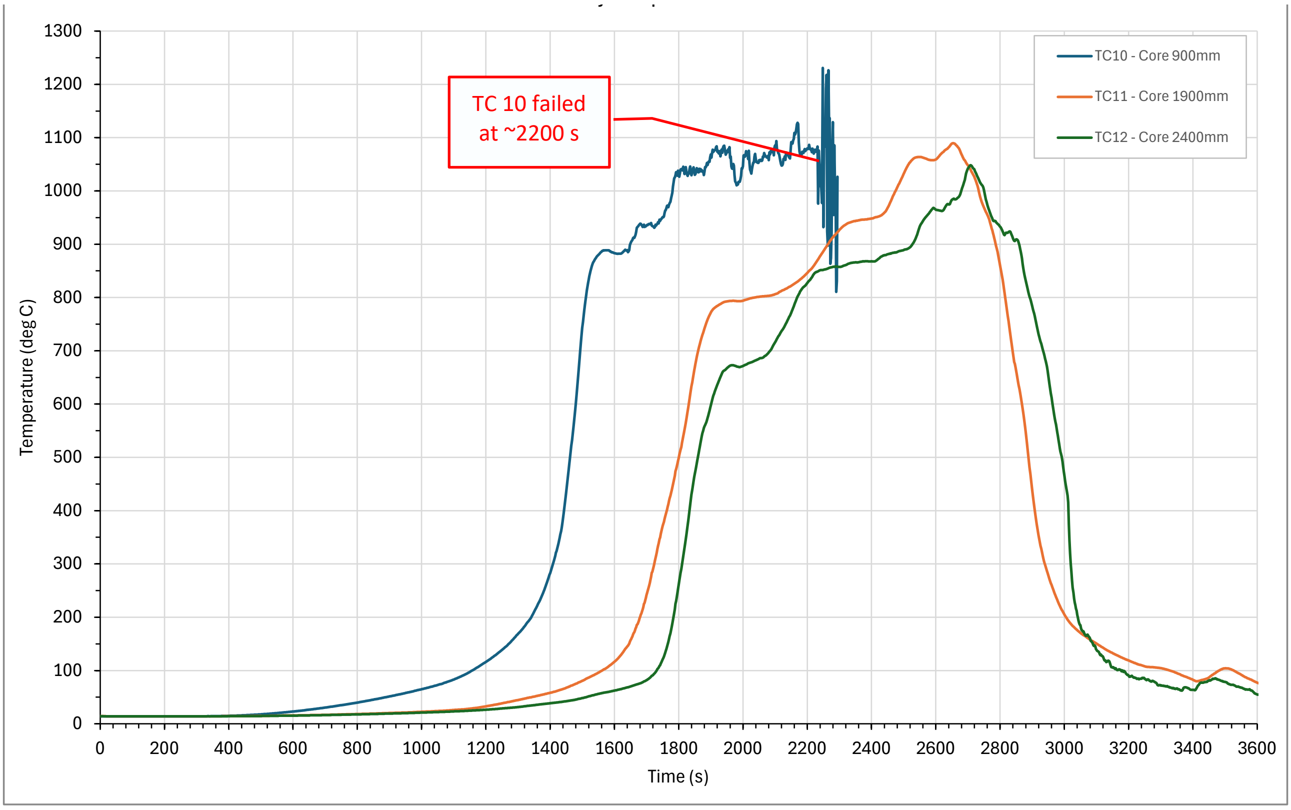


Figure 86. Test 6 – Temperatures within core at 900 mm (TC10), 1,900 mm (TC11), 2,400 mm (TC12) above ground level

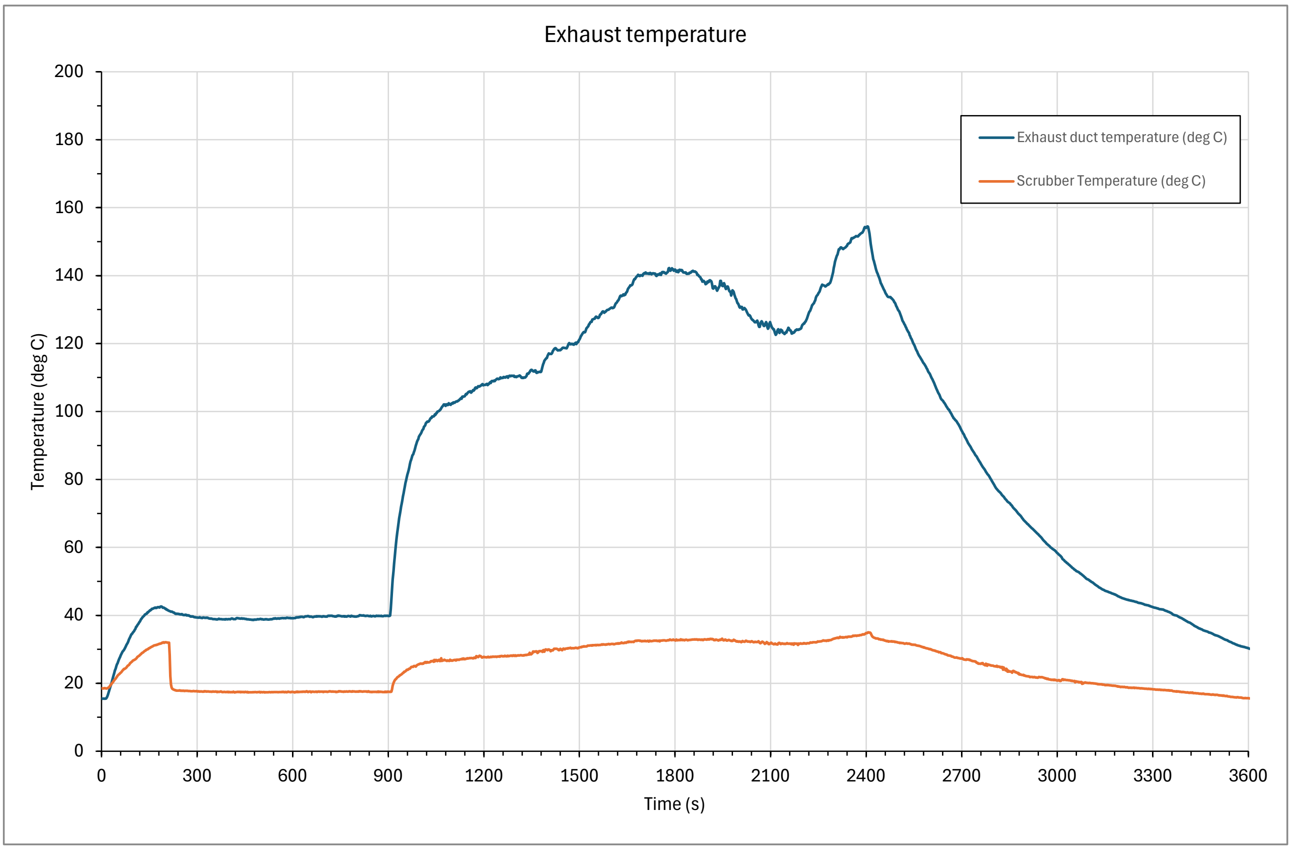


Figure 87. Test 6 – Test Hood exhaust temperatures

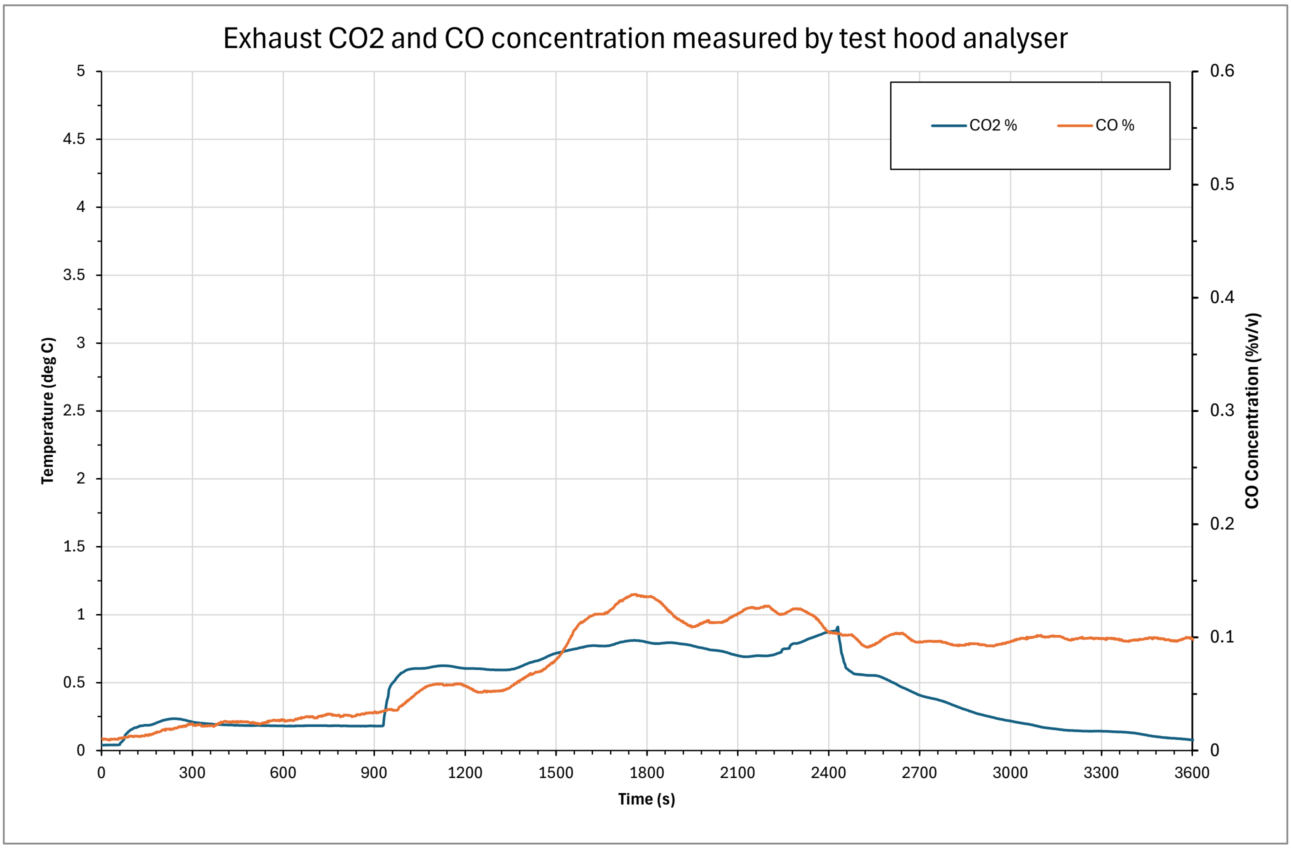


Figure 88. Test 6 – CO and CO2 concentration measured by test hood gas analyser

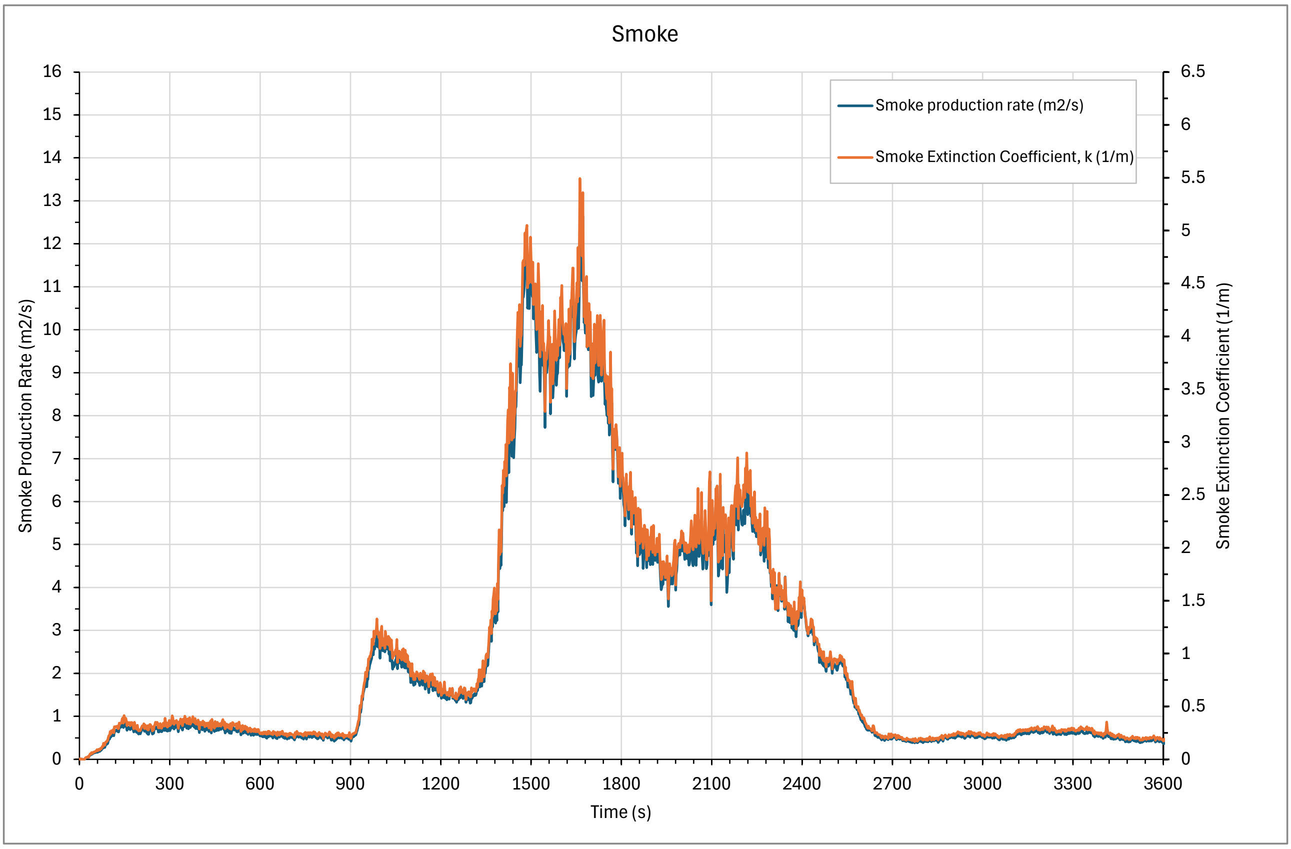


Figure 89. Test 6 – Smoke production rate

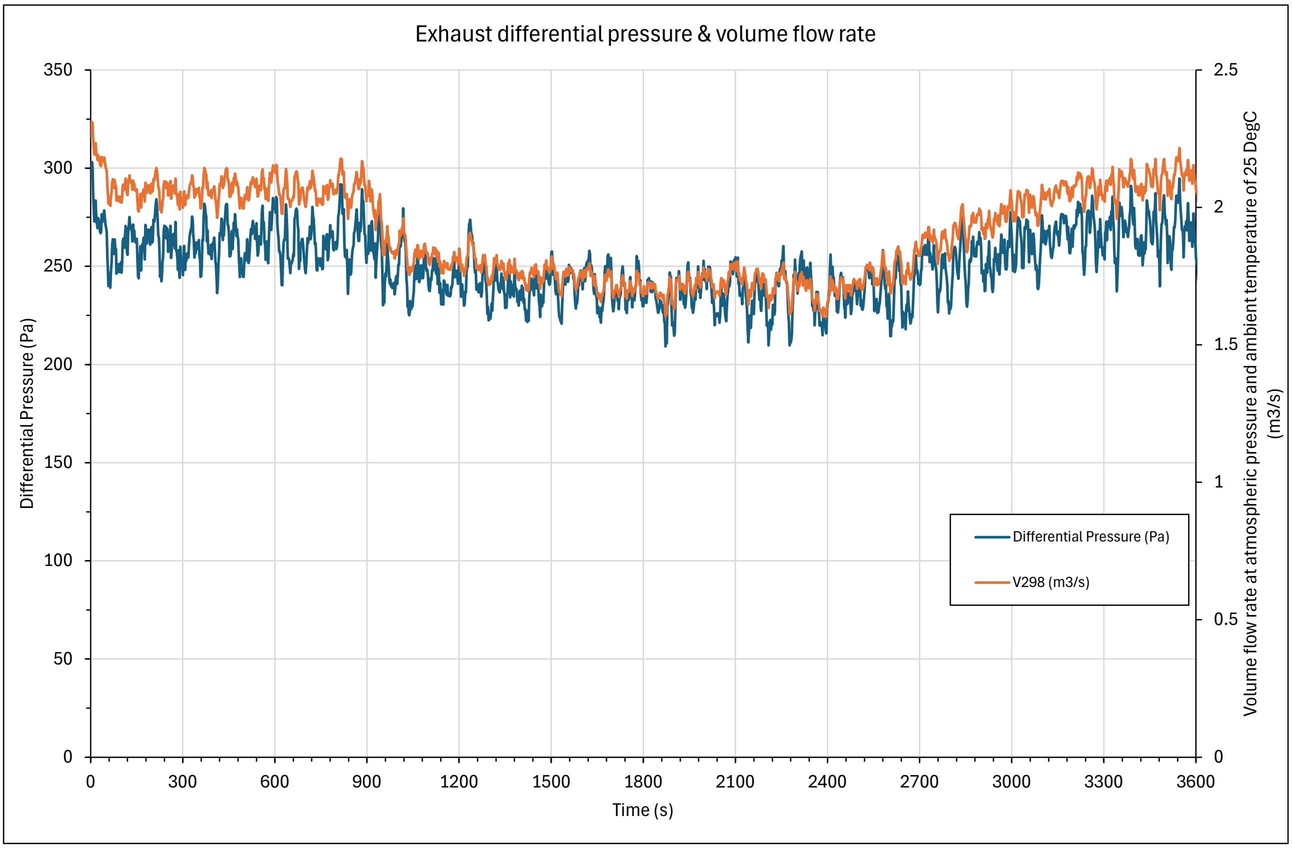


Figure 90. Test 6 – Test hood exhaust flow rate

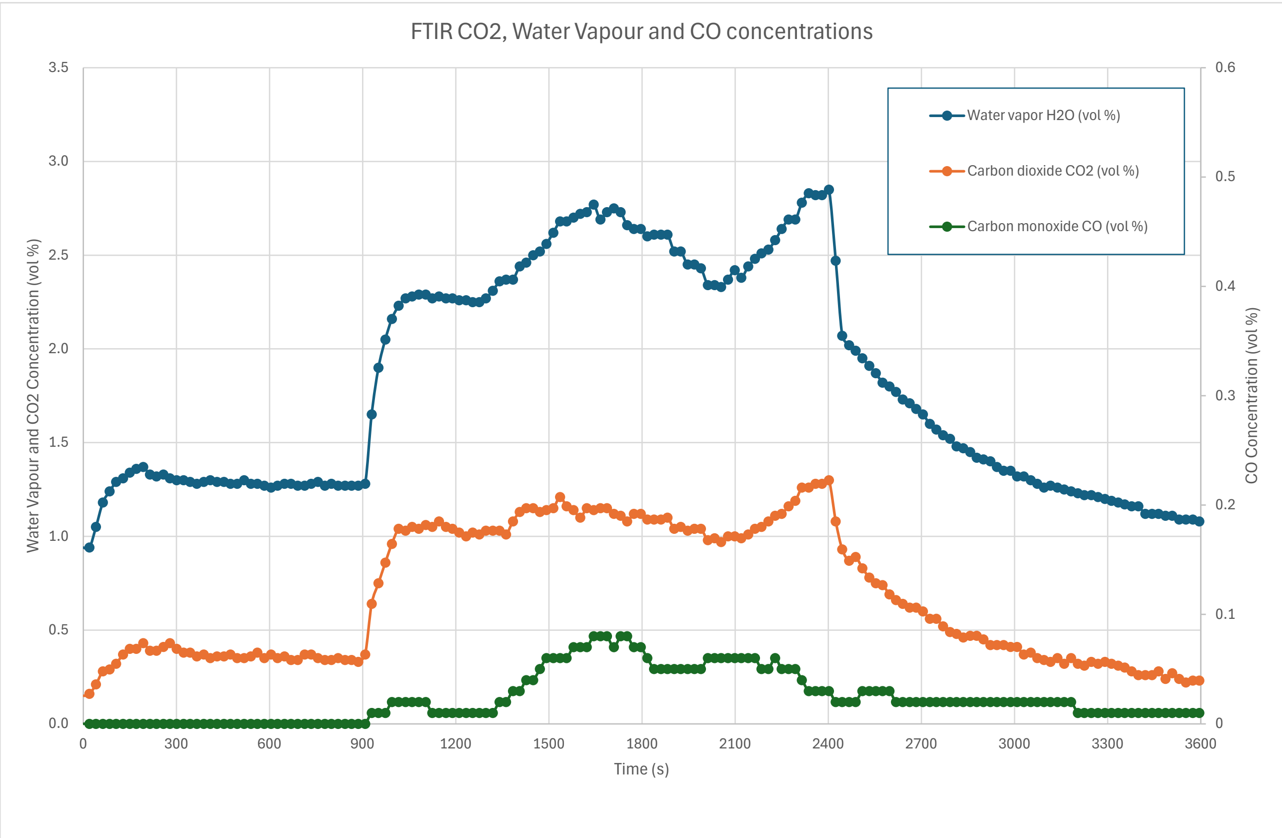


Figure 91. Test 6 – CO and CO2 concentration recorded by FTIR.

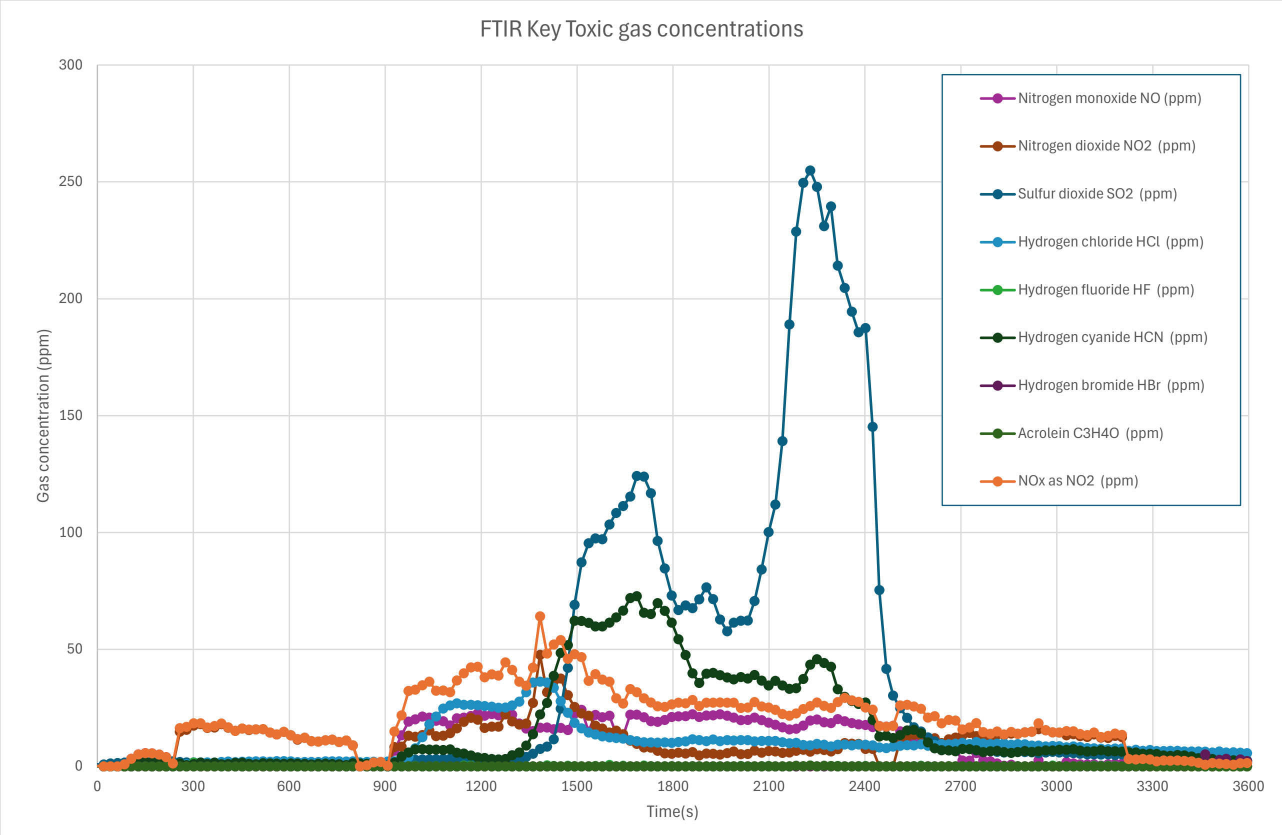


Figure 92. Test 6 – Key Toxic Species concentration recorded by FTIR.

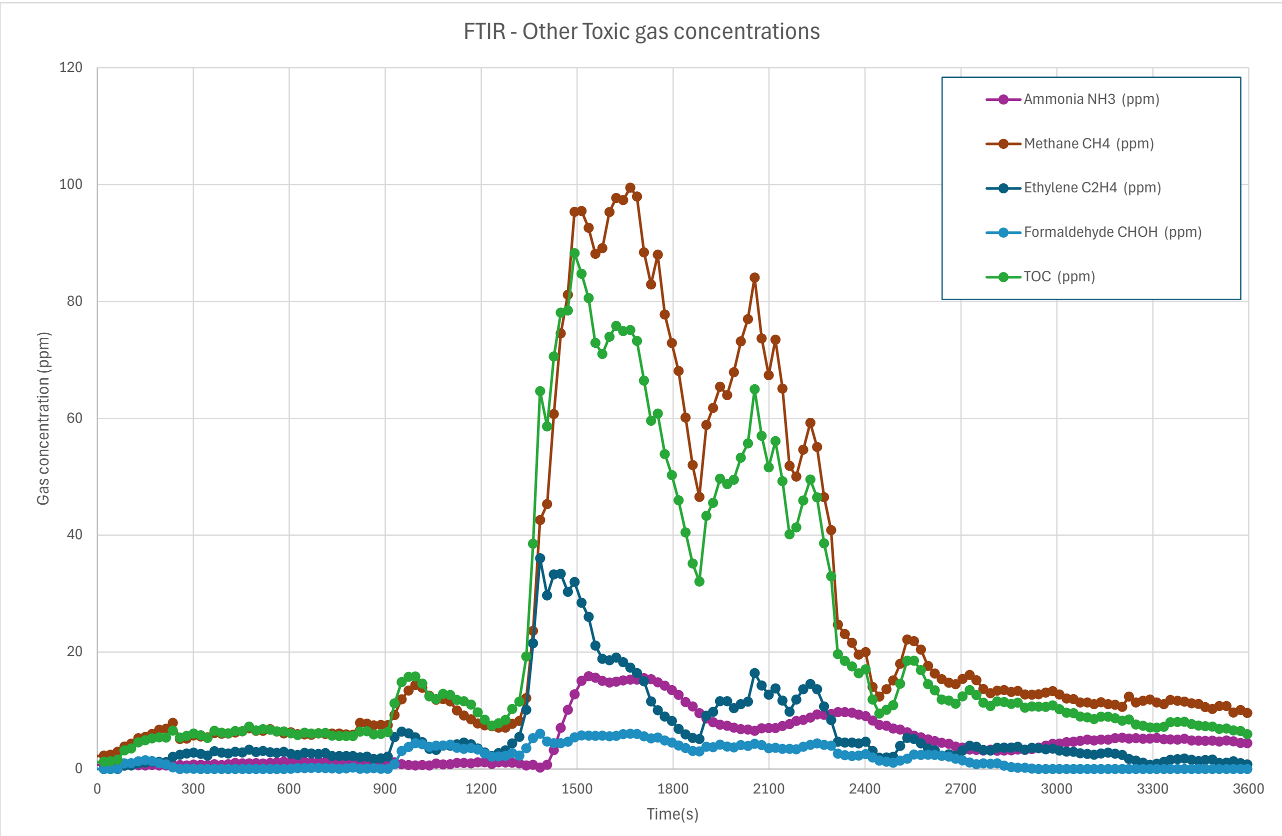


Figure 93. Test 6– Other Toxic Species concentration recorded by FTIR.

B.10 Test 7 – ISP-02-EPS Vertical Panel

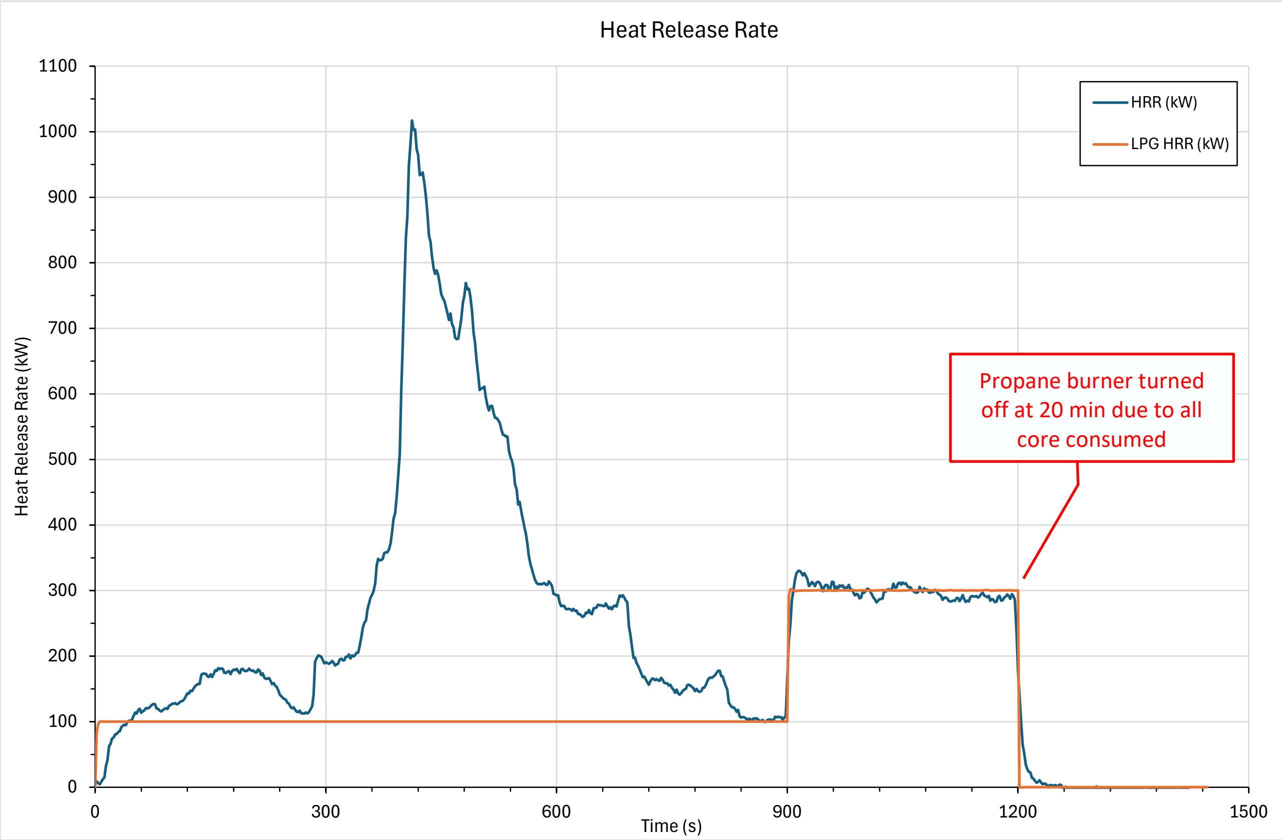


Figure 94. Test 7 – HRR (kW)

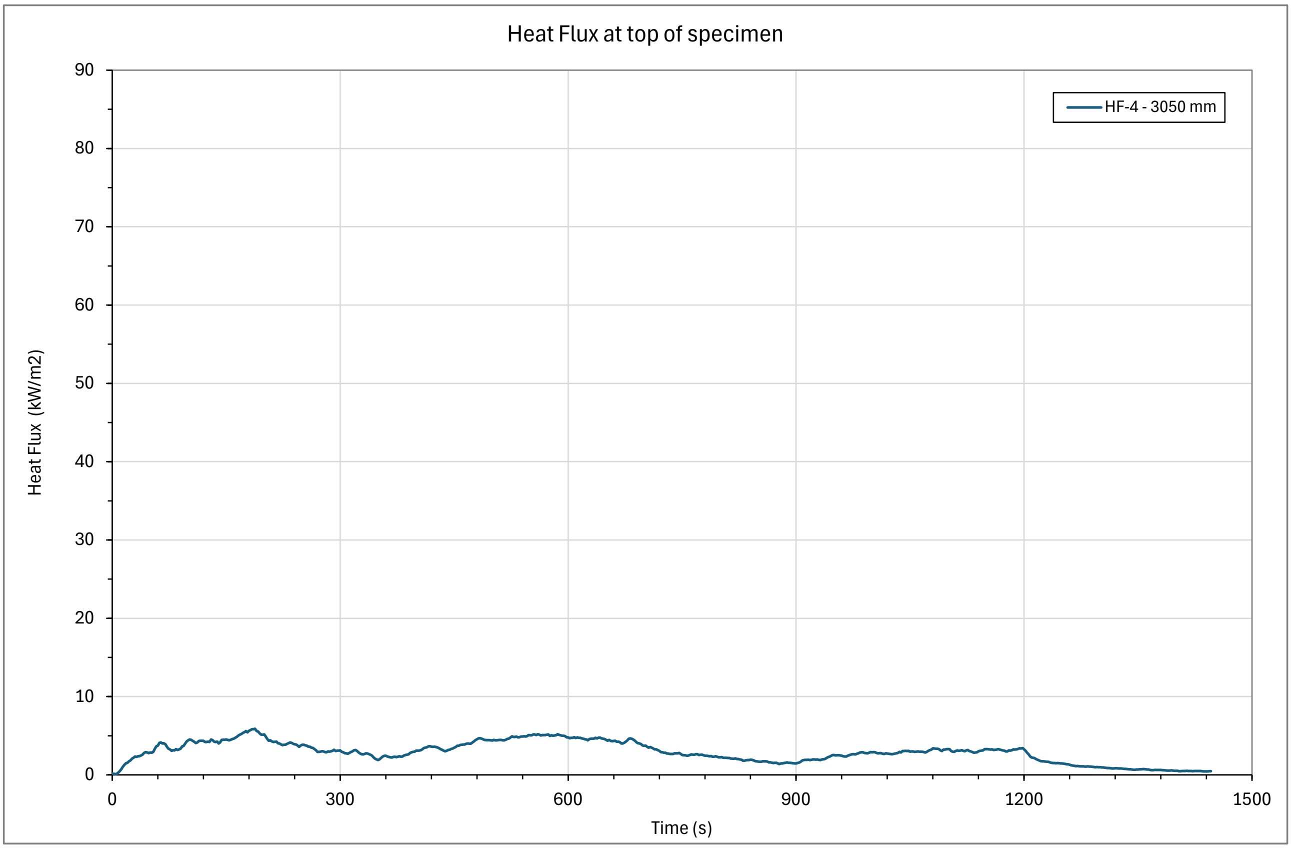


Figure 95. Test 7 – Heat flux (kW/m²) above 3050 mm from the ground level.

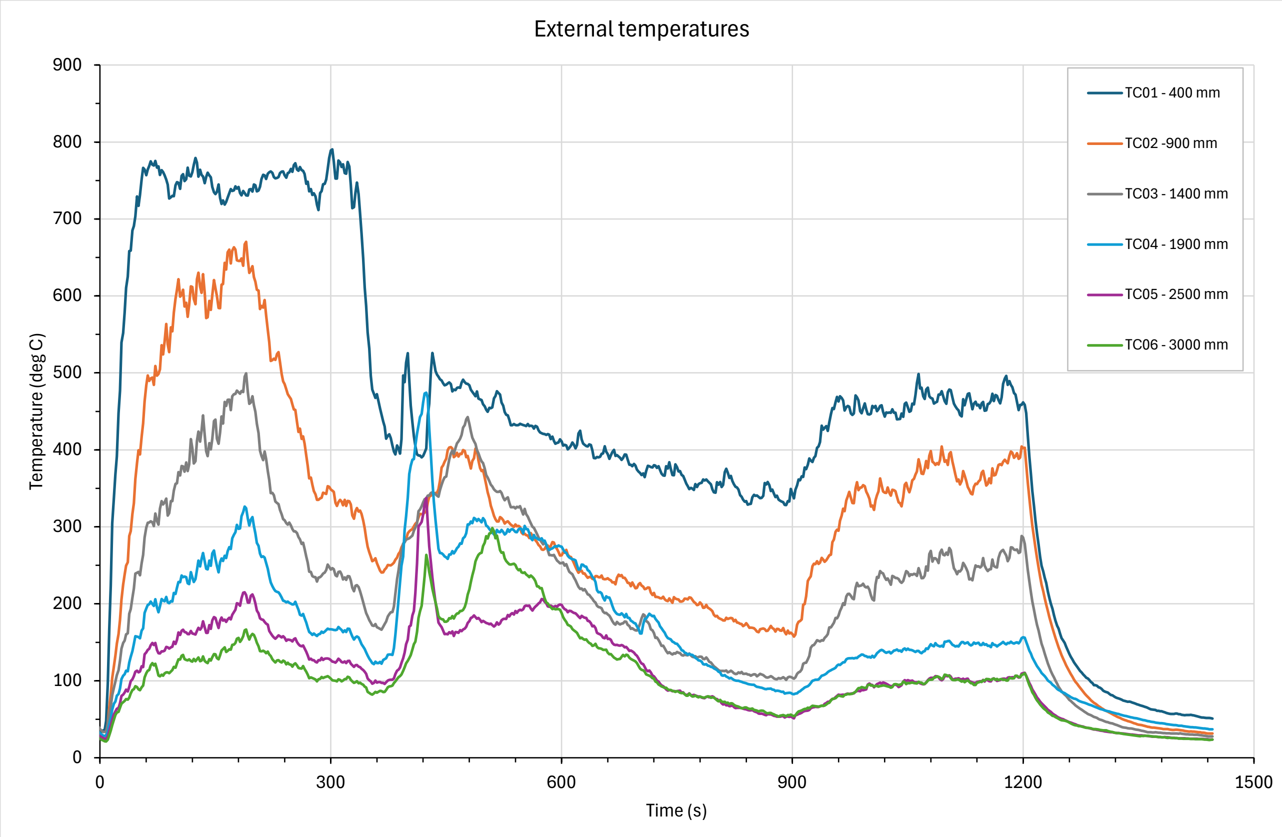


Figure 96. Test 7 – External face temperatures at various heights (TC01 to TC06)

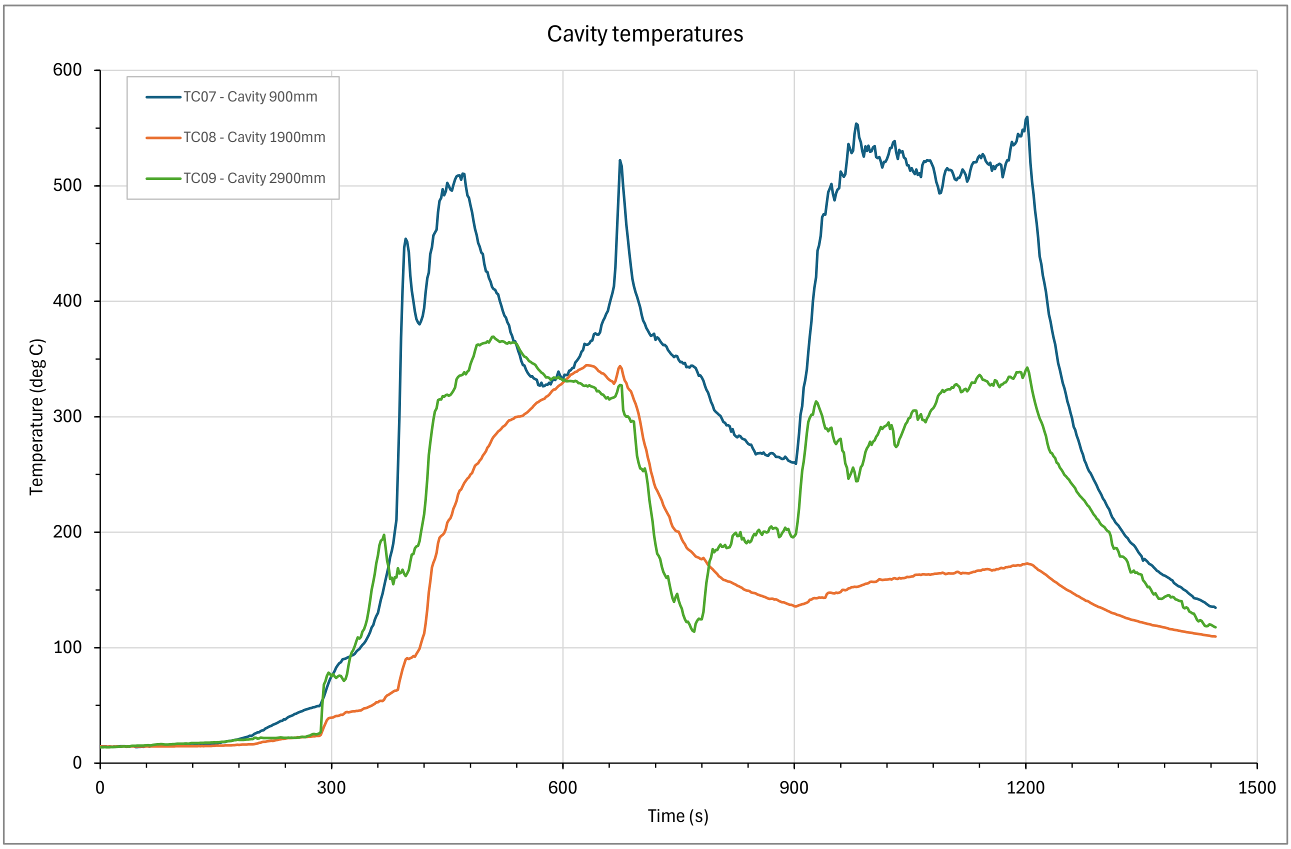


Figure 97. Test 7 – Temperatures within air cavity at 900 mm (TC07), 1,900 mm (TC08), 3,000 mm (TC09) above ground level

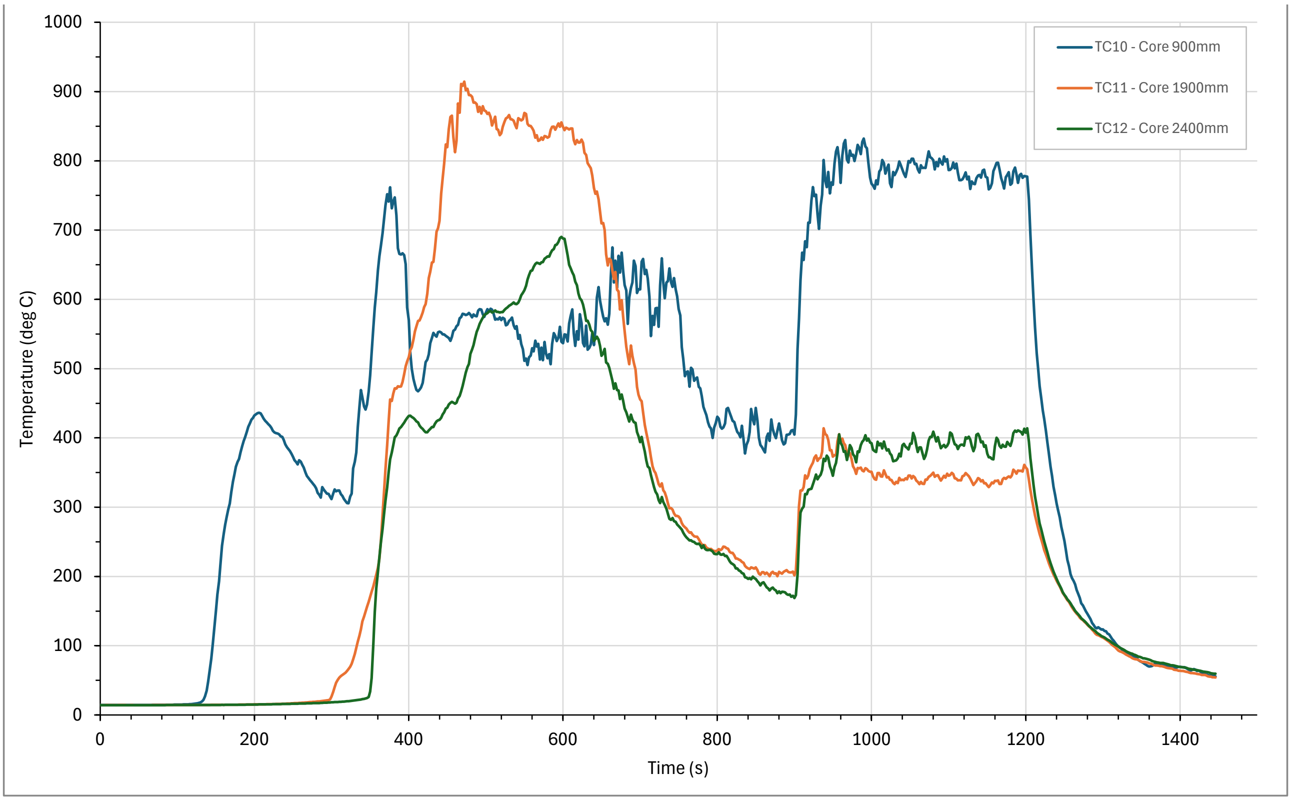


Figure 98. Test 7 – Temperatures within core at 900 mm (TC10), 1,900 mm (TC11), 2400 mm (TC12) above ground level

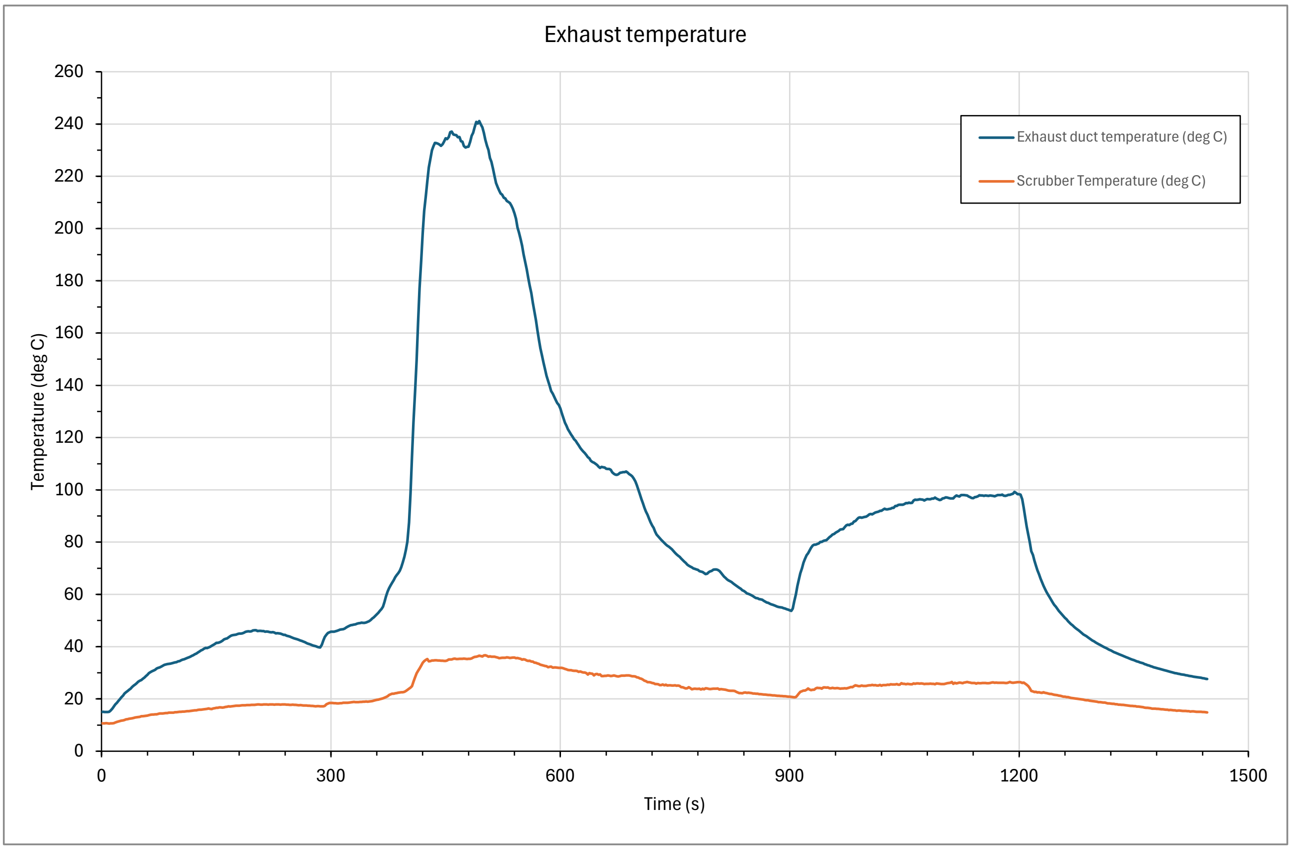


Figure 99. Test 7 – Test Hood exhaust temperatures

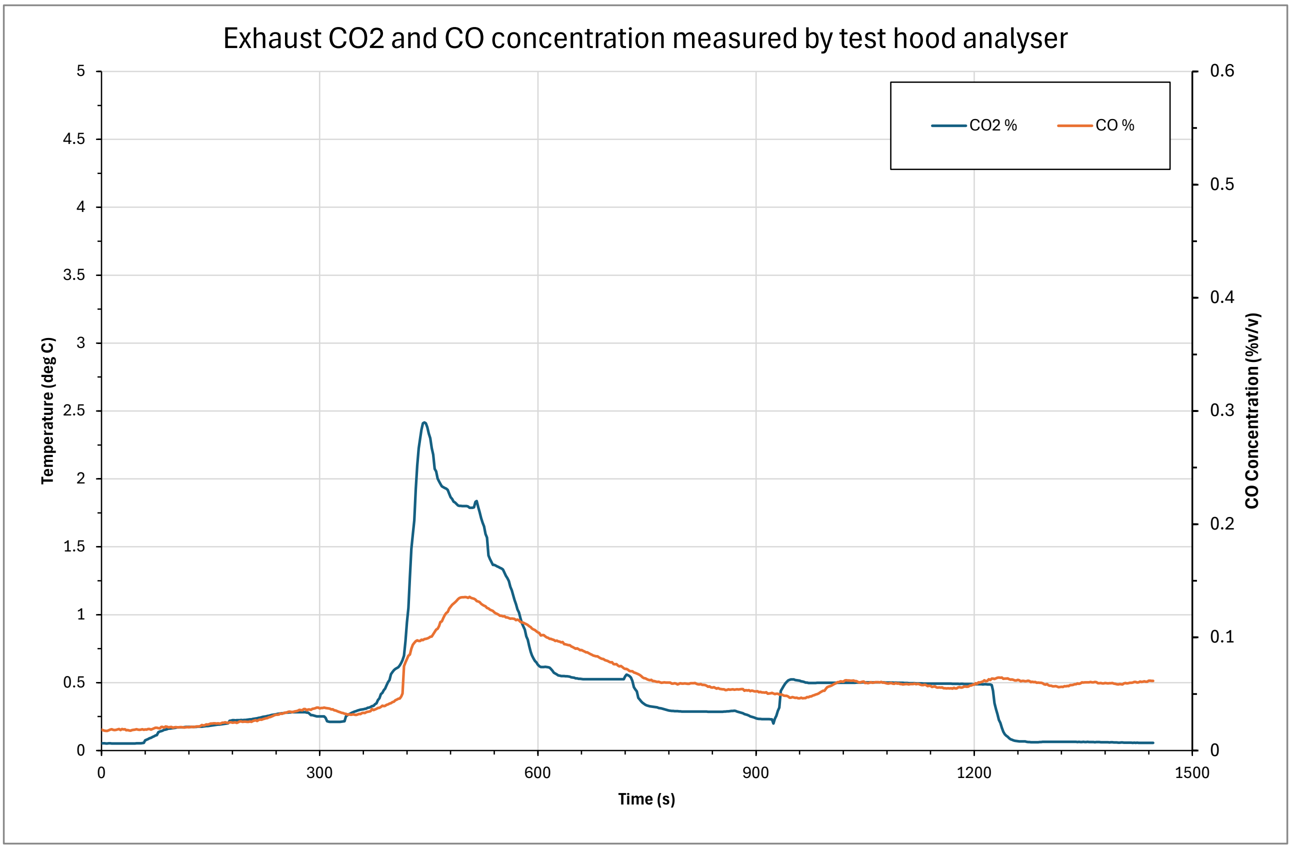


Figure 100. Test 7 – CO and CO2 concentration measured by test hood gas analyser

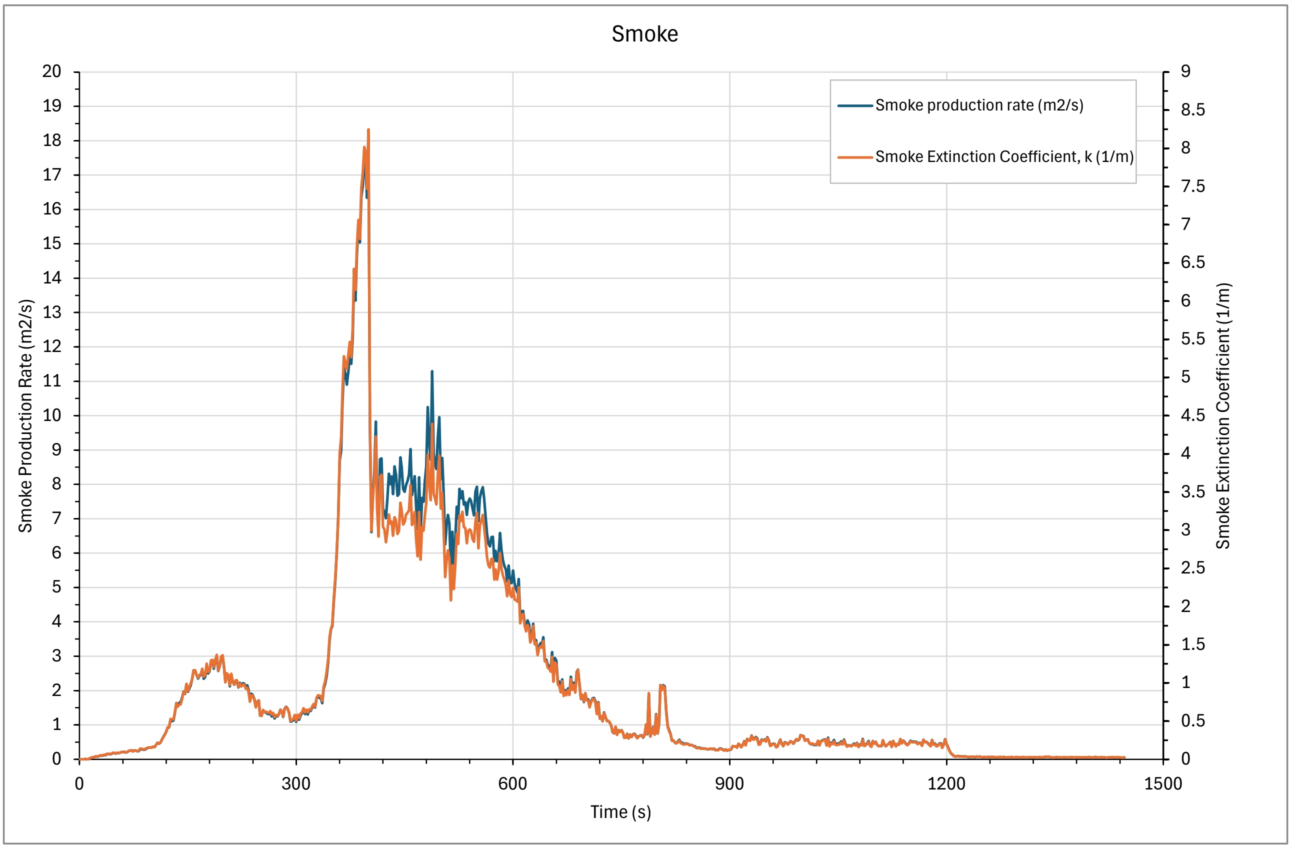


Figure 101. Test 7 – Smoke production rate

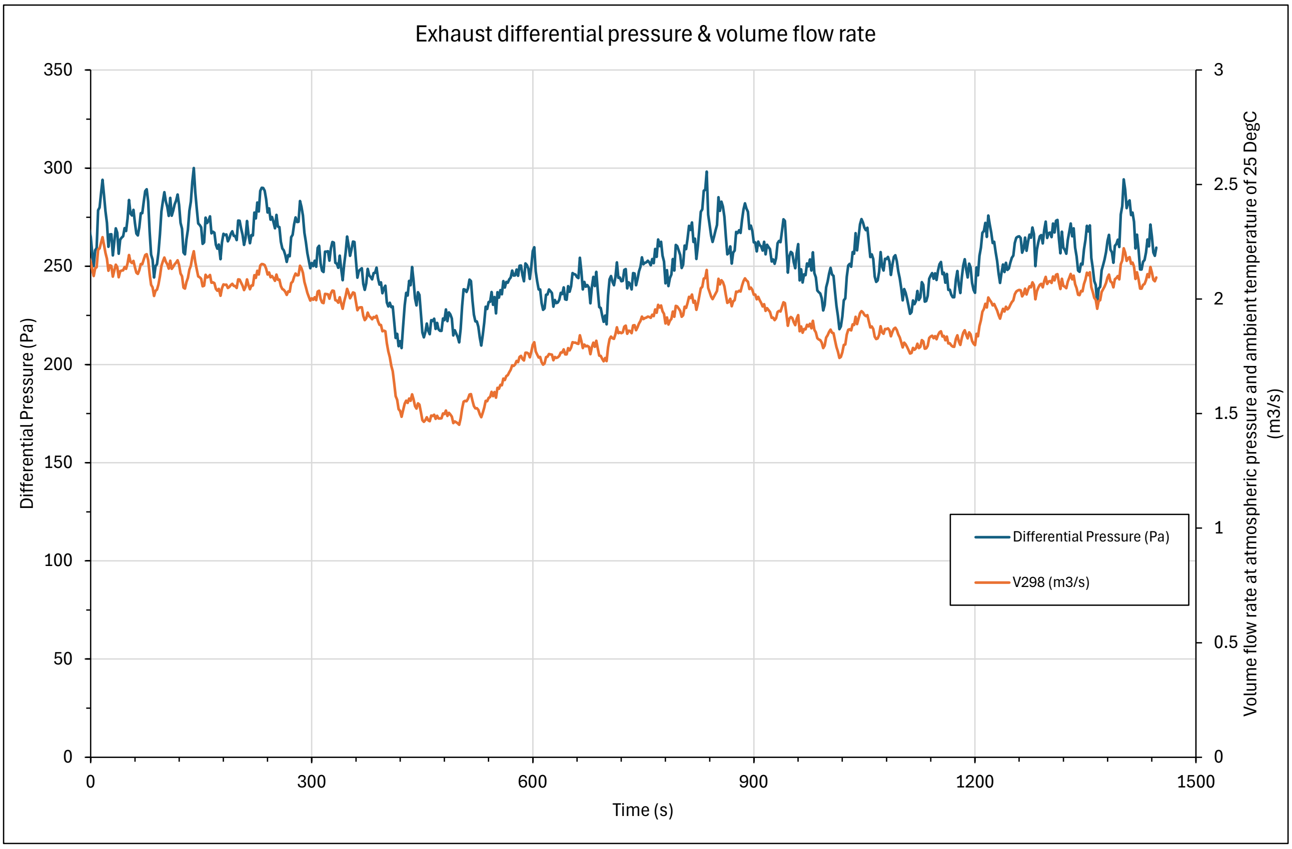


Figure 102. Test 7 – Test hood exhaust flow rate

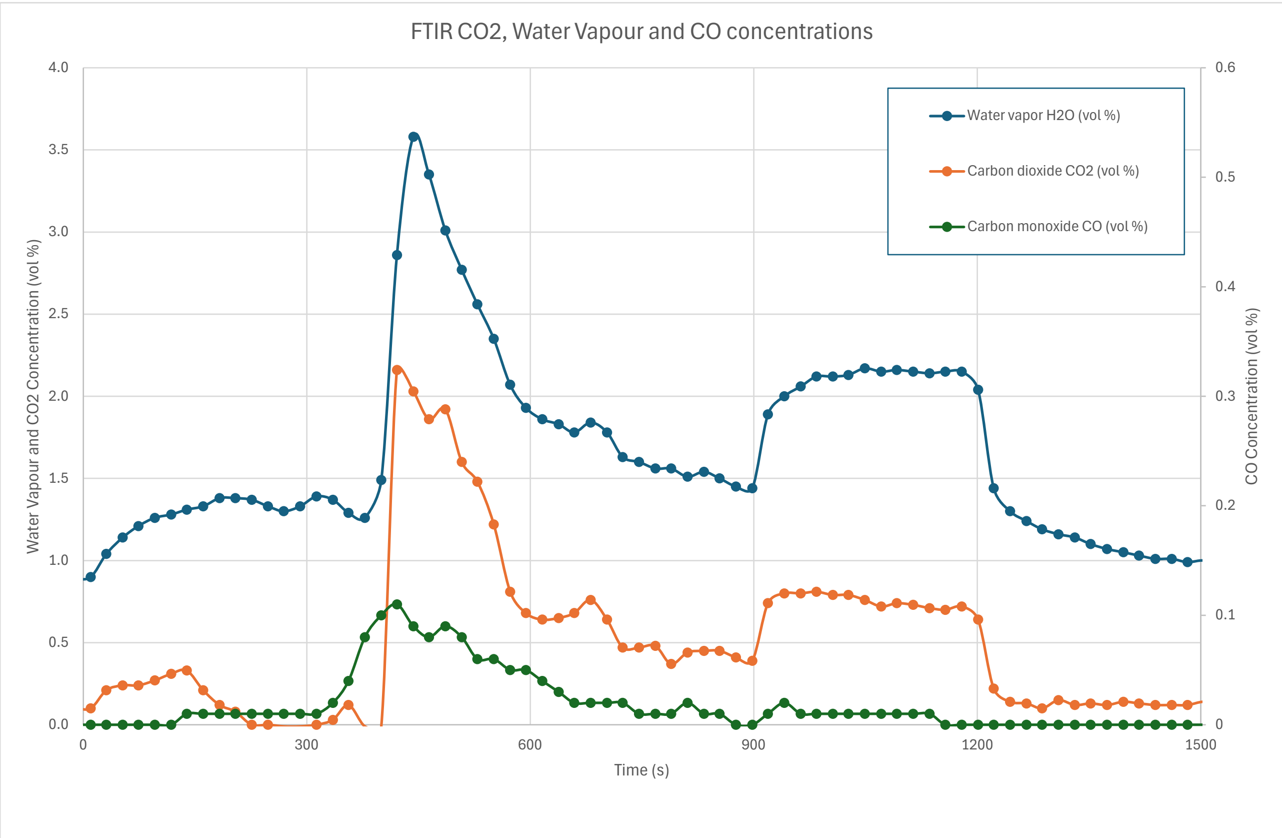


Figure 103. Test 7 – CO and CO2 concentration recorded by FTIR.

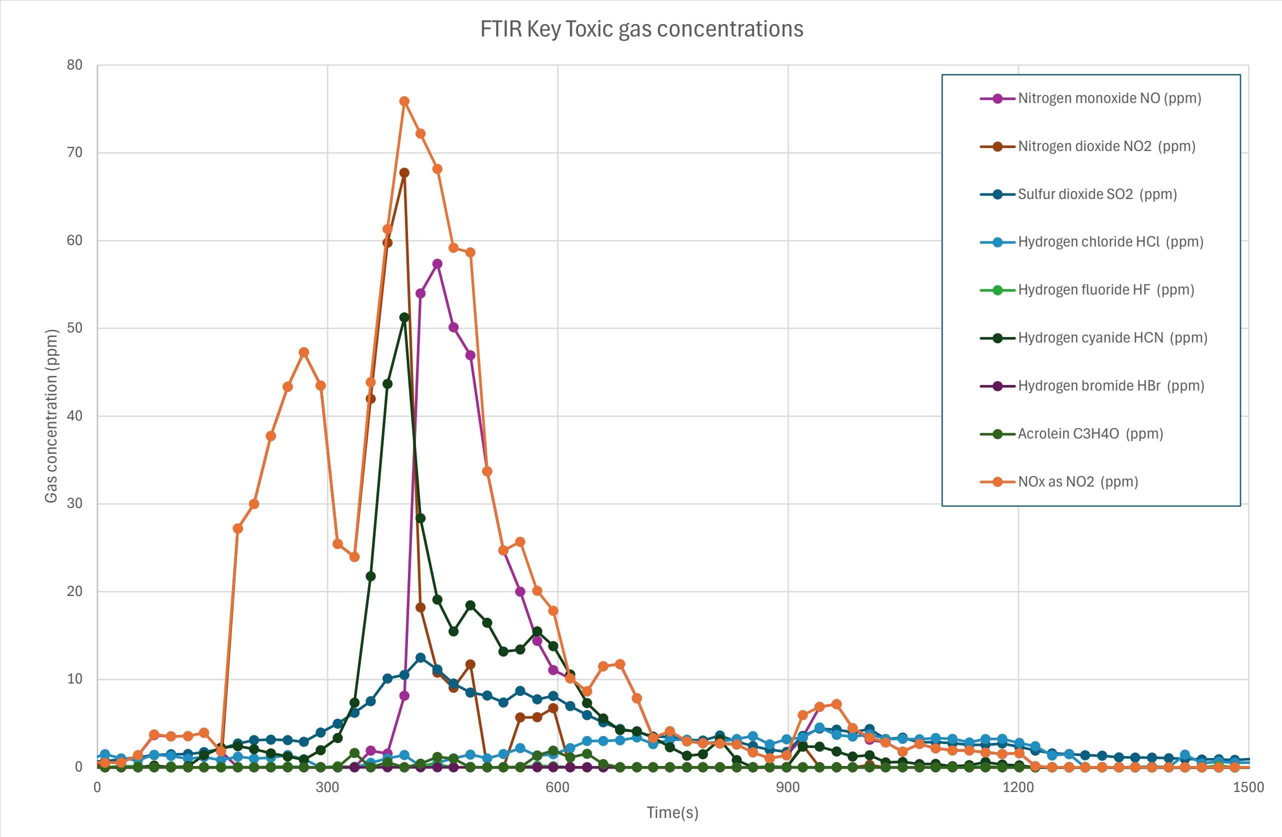


Figure 104. Test 7 – Key Toxic Species concentration recorded by FTIR.

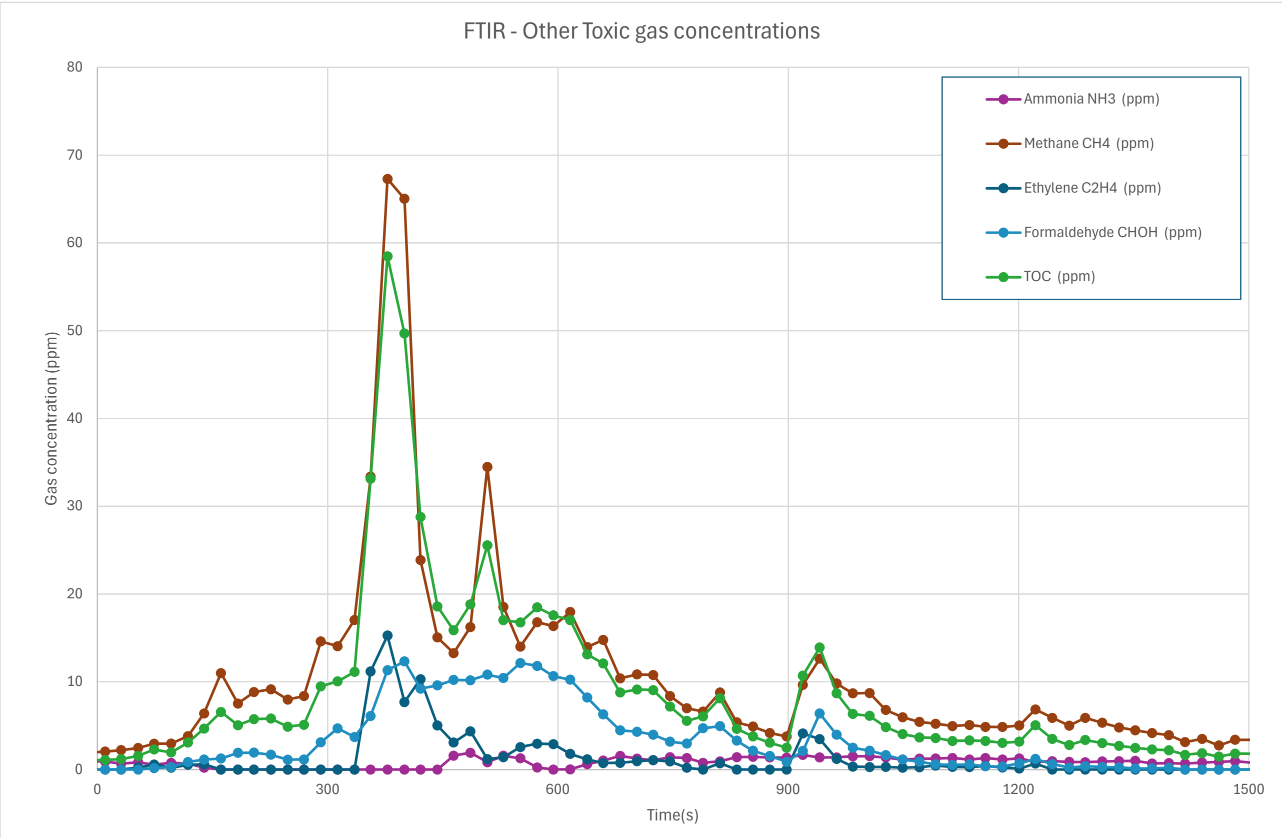


Figure 105. Test 7– Other Toxic Species concentration recorded by FTIR.

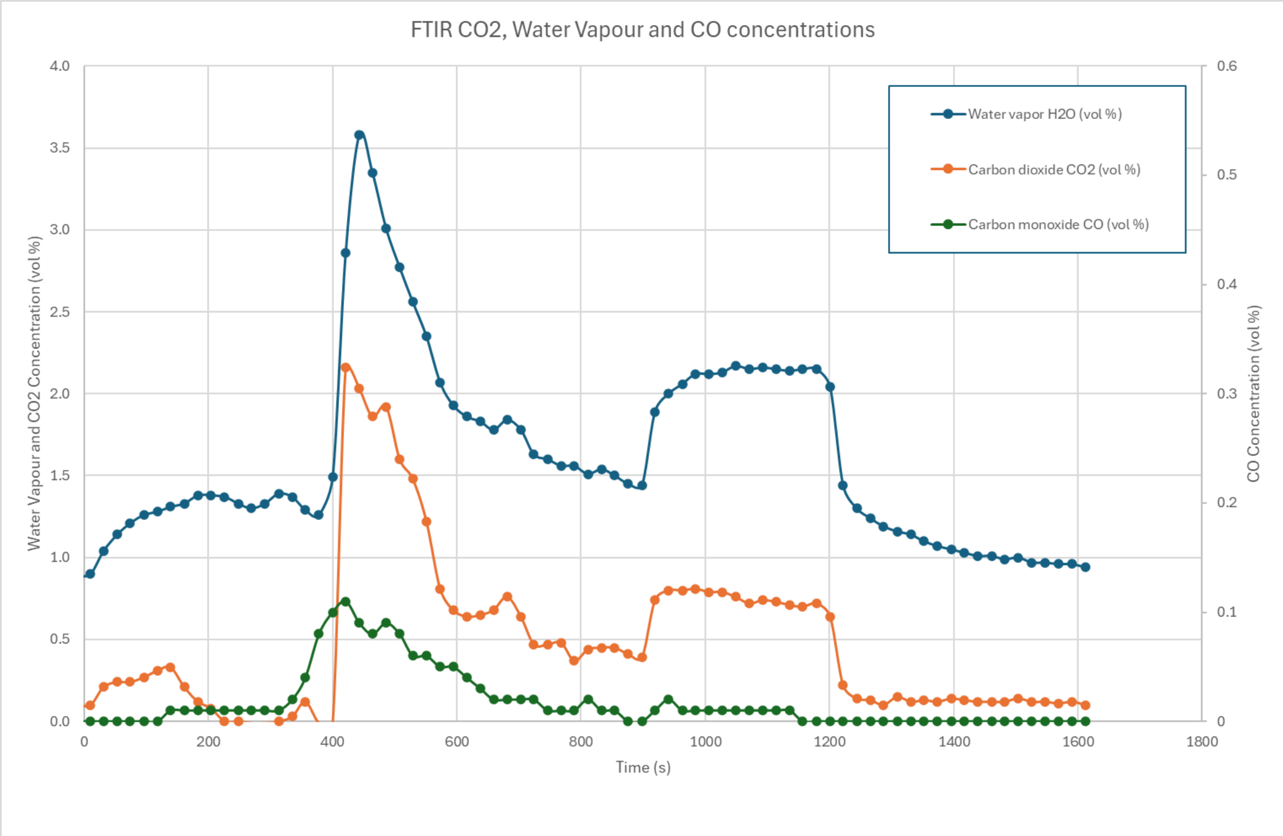


Figure 106. Test 7 – Gas concentration recorded by FTIR.

B.11 Test 8 – ISP-01-PIR Horizontal with steel capping

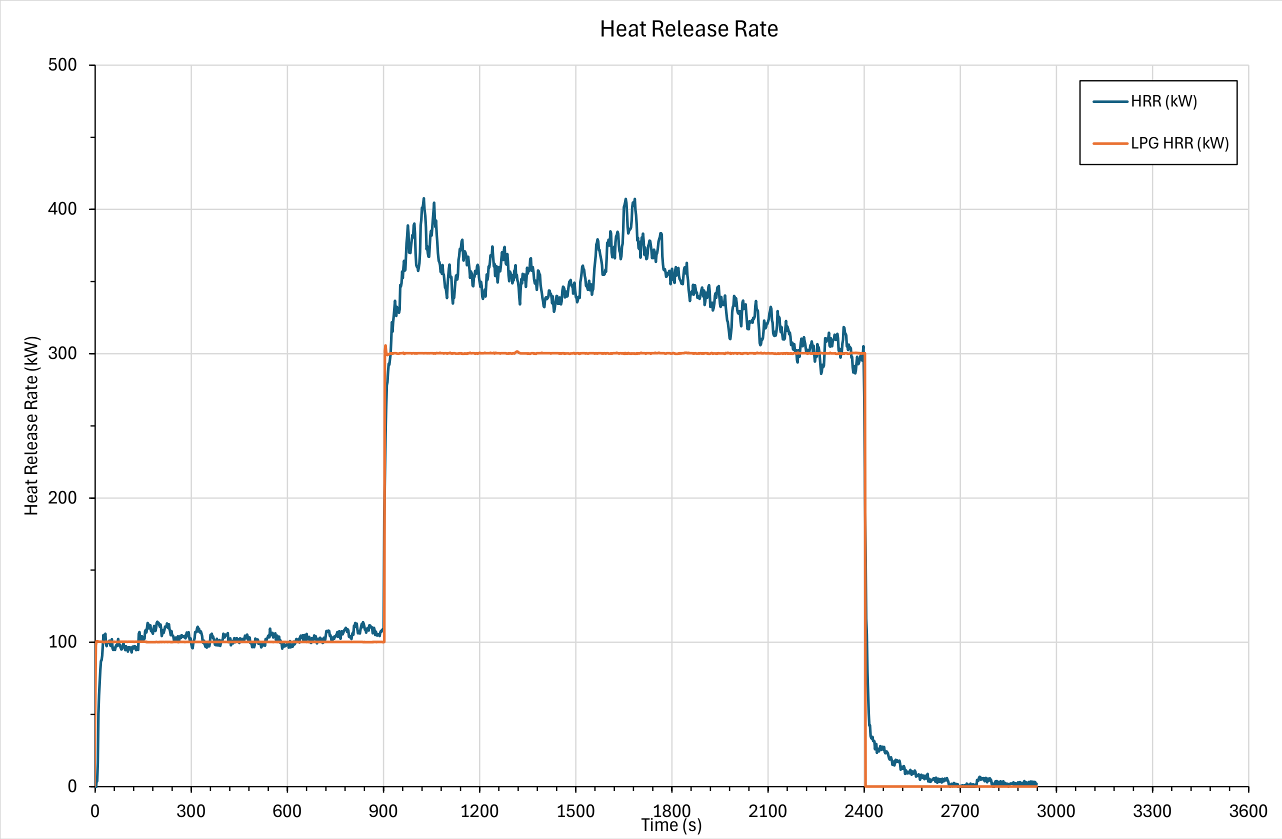


Figure 107. Test 8 – HRR (kW)

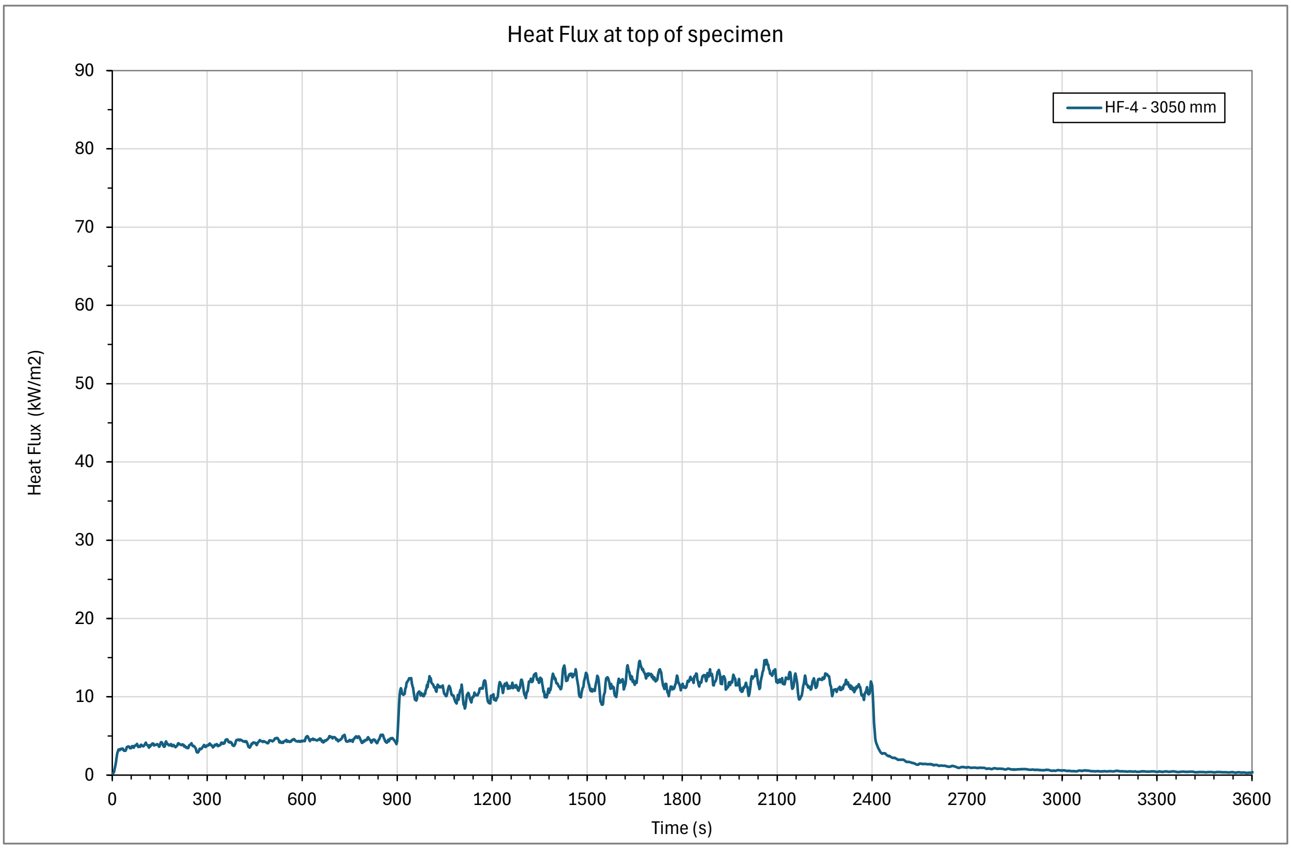


Figure 108. Test 8 – Heat flux (kW/m^2) above 3050 mm from the ground level.

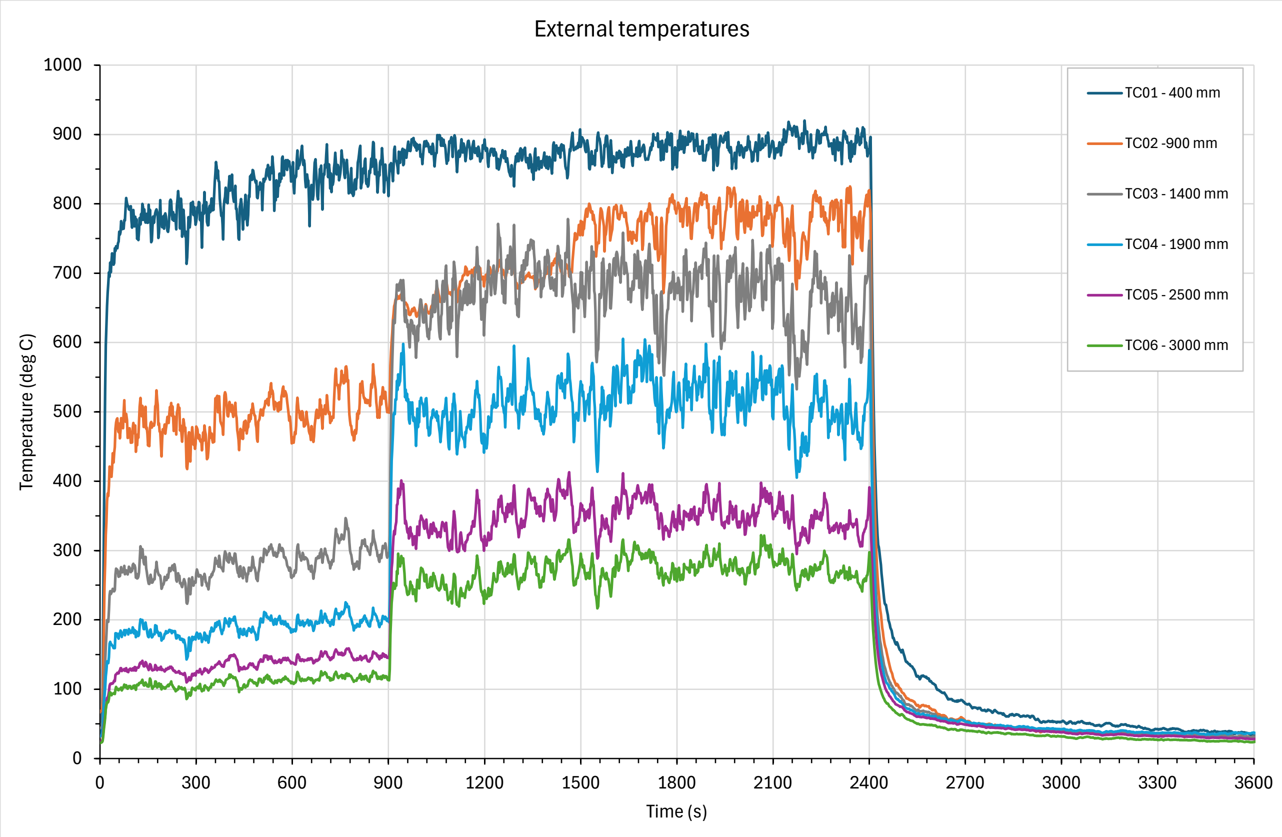


Figure 109. Test 8 – External face temperatures at various heights (TC01 to TC06)

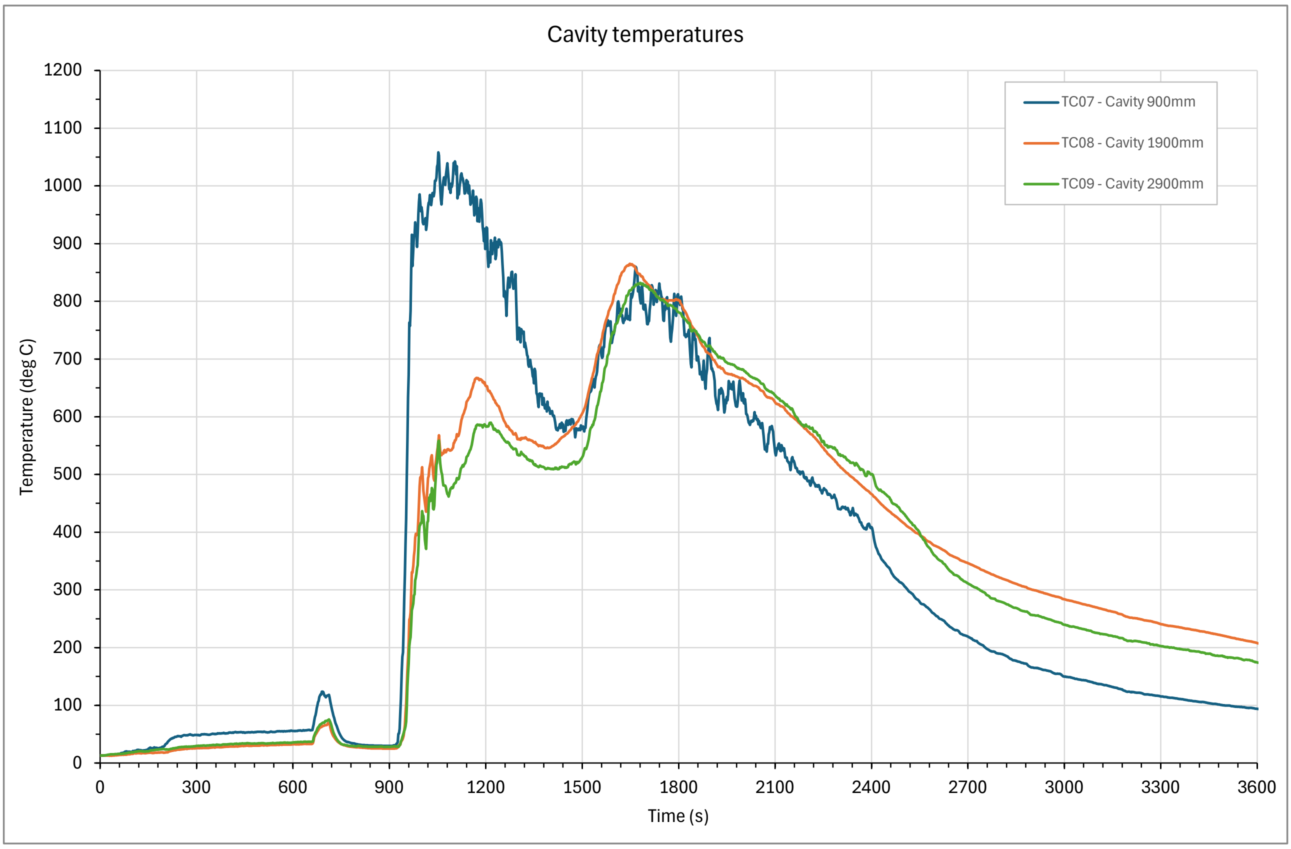


Figure 110. Test 8 – Temperatures within air cavity at 900 mm (TC07), 1,900 mm (TC08), 3,000 mm (TC09) above ground level

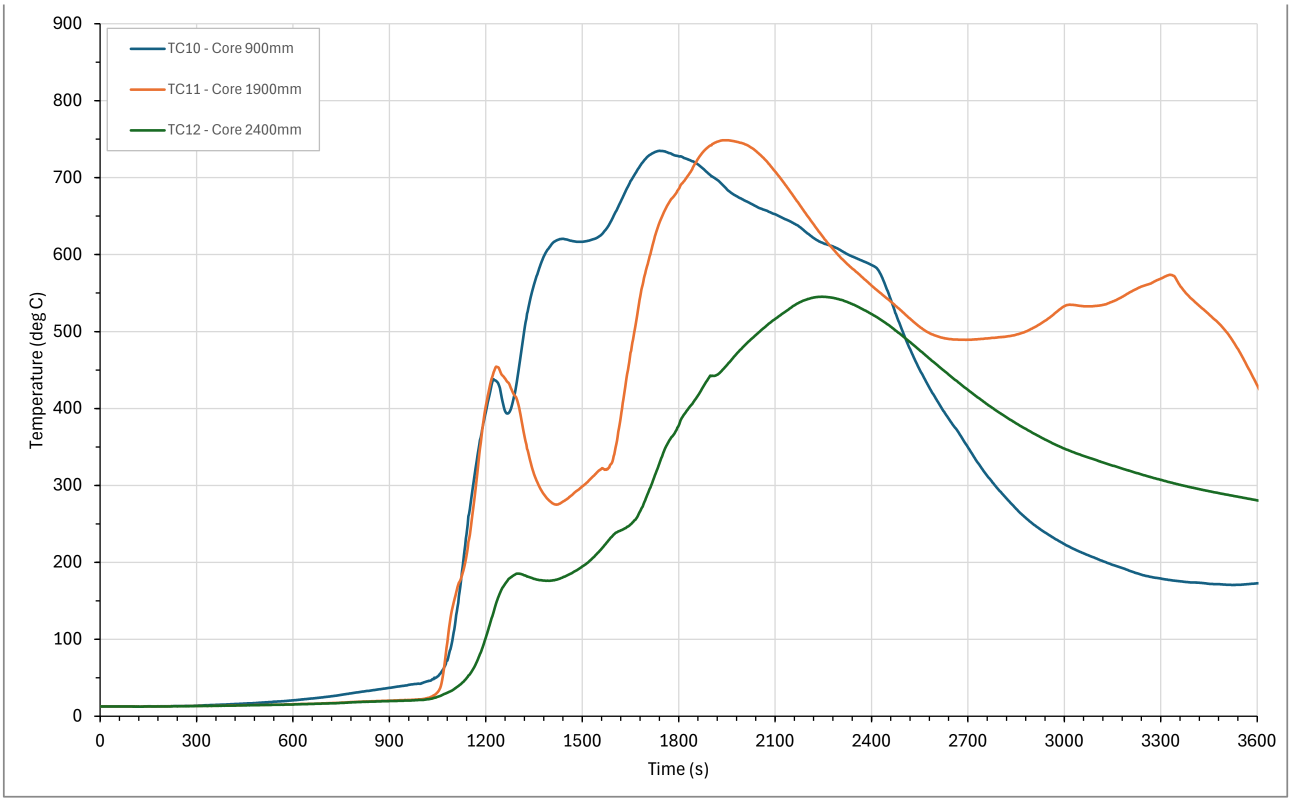


Figure 111. Test 8 – Temperatures within core at 900 mm (TC10), 1,900 mm (TC11), 2400 mm (TC12) above ground level

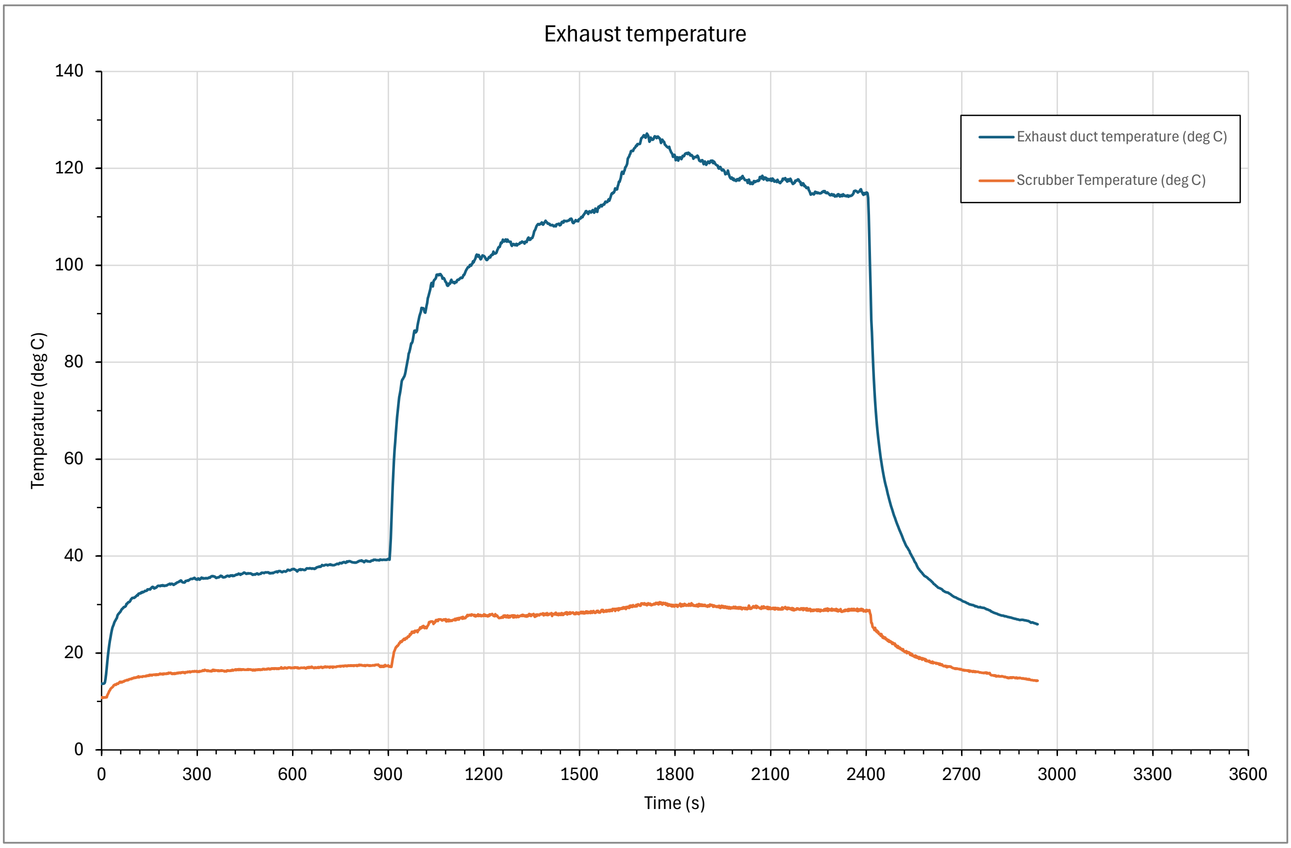


Figure 112. Test 8 – Test Hood exhaust temperatures

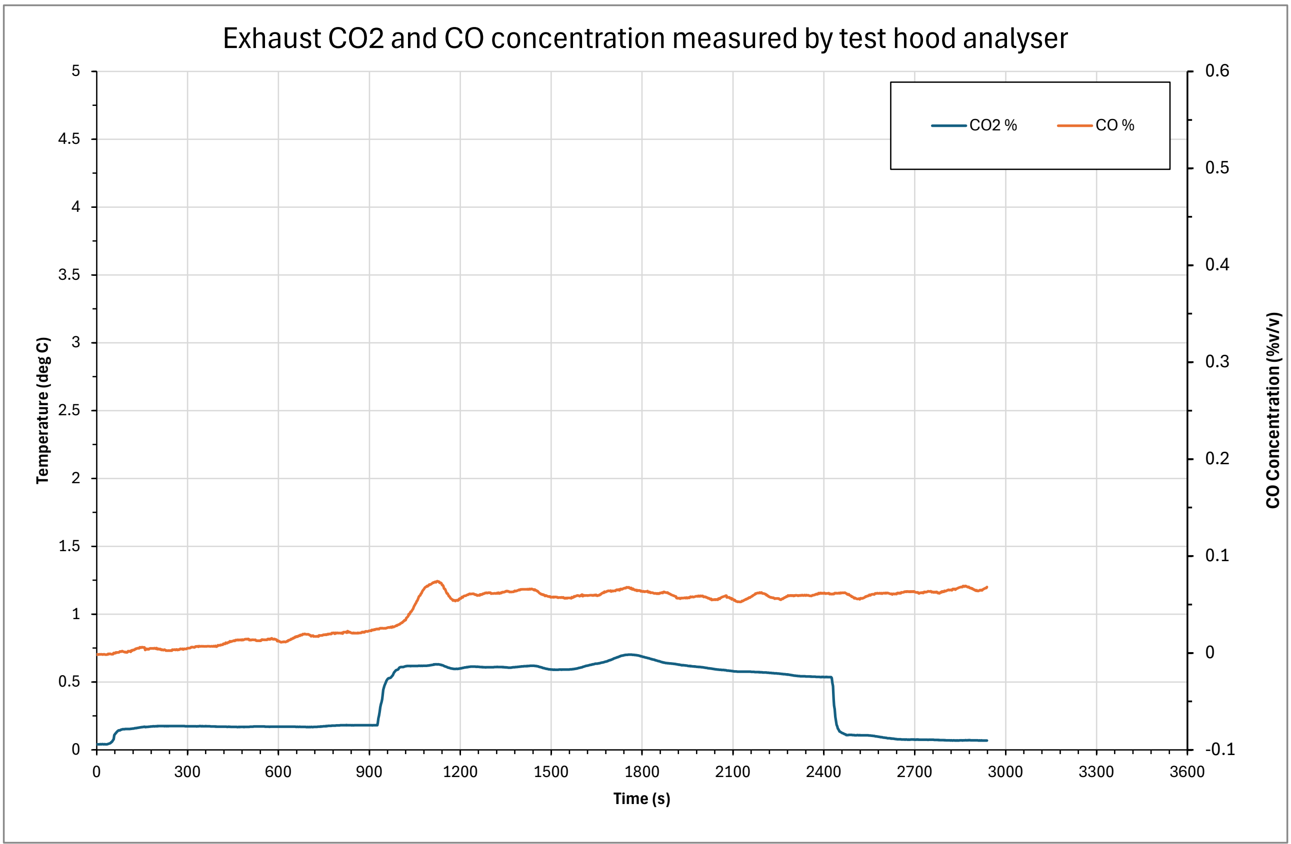


Figure 113. Test 8 – CO and CO2 concentration measured by test hood gas analyser

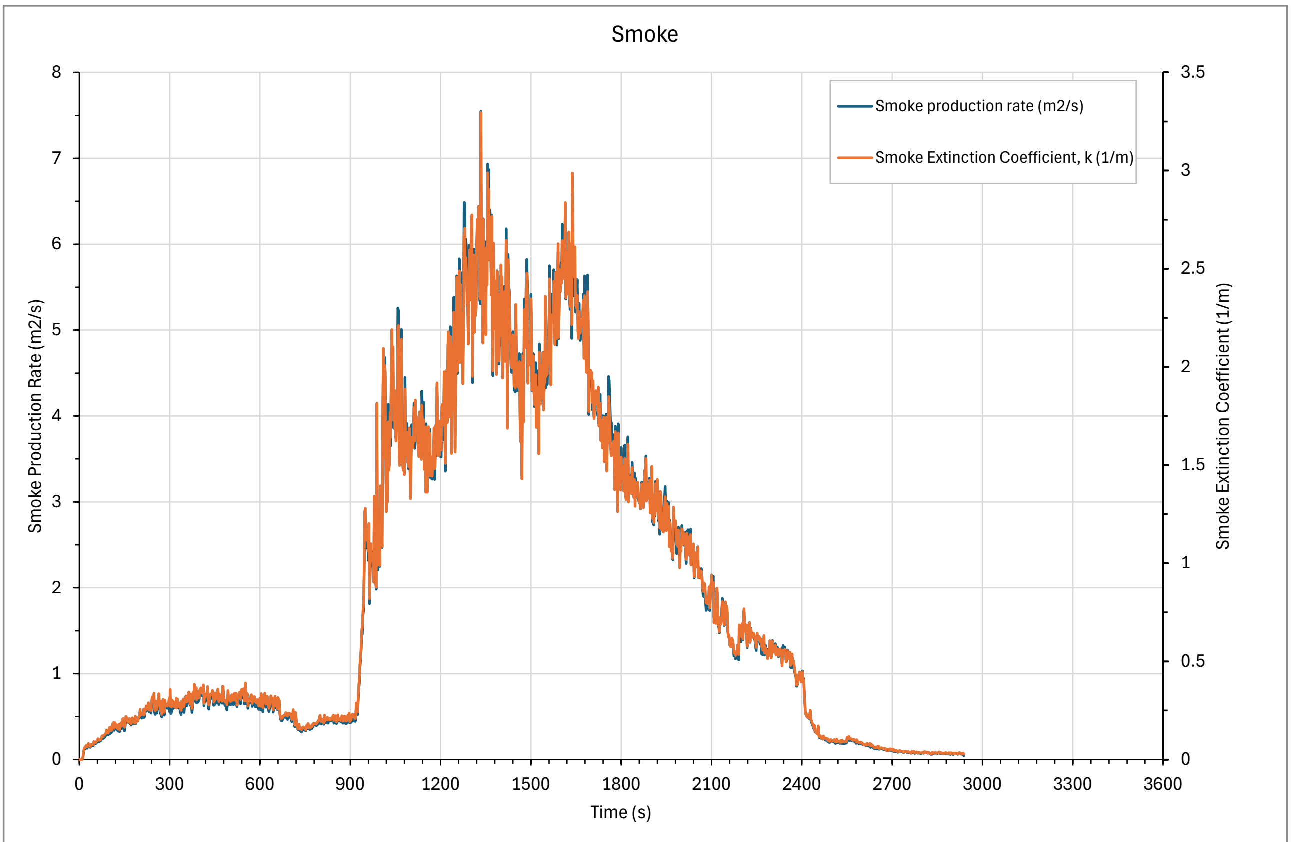


Figure 114. Test 8– Smoke production rate

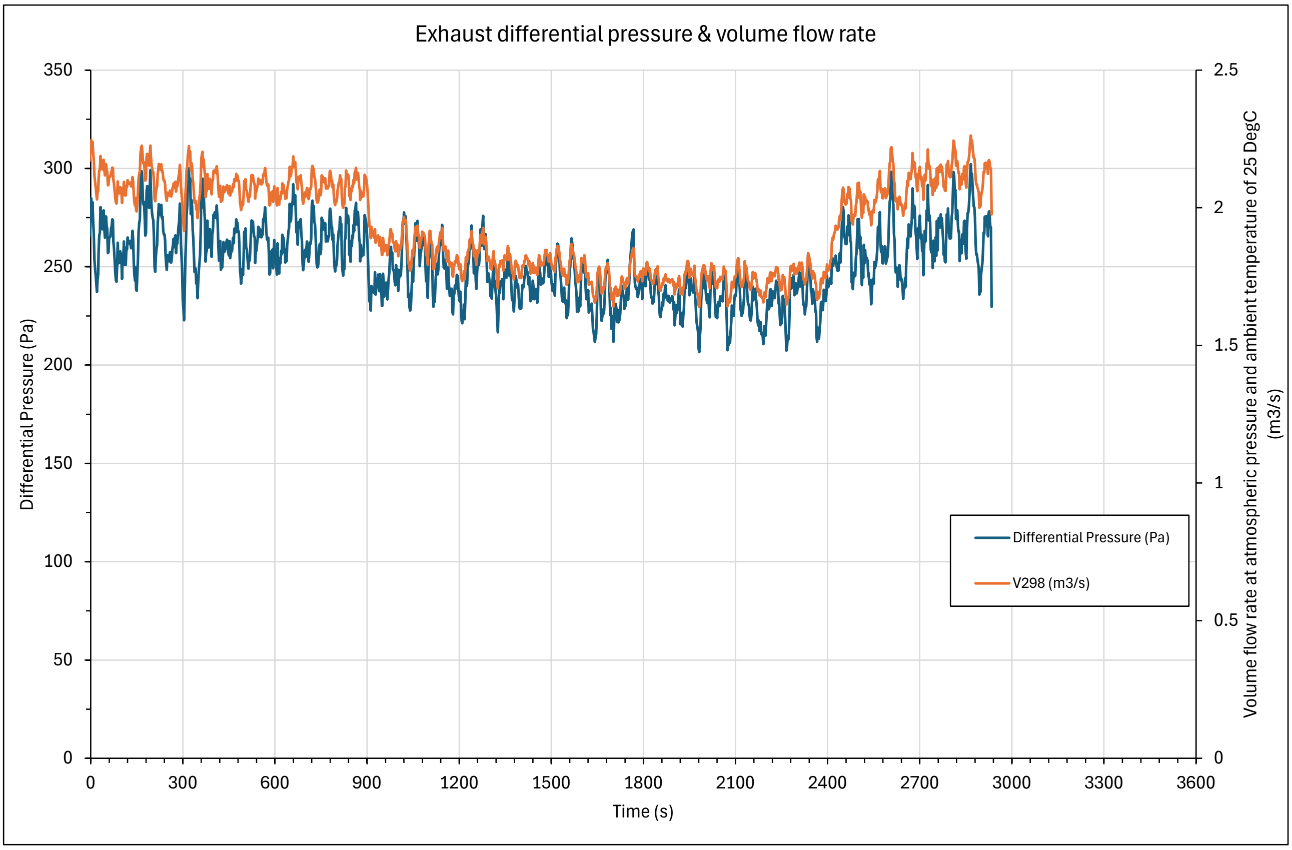


Figure 115. Test 8 – Test hood exhaust flow rate

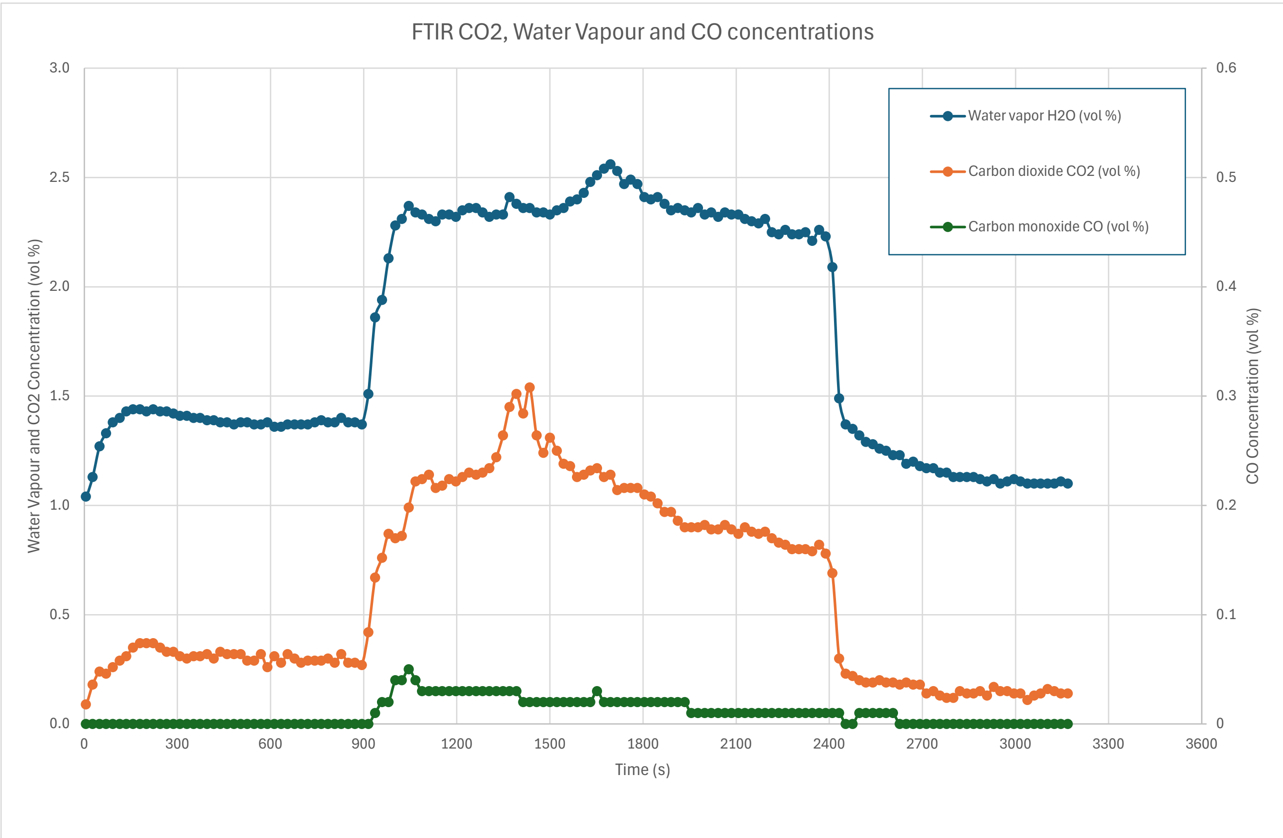


Figure 116. Test 8 – CO and CO2 concentration recorded by FTIR.

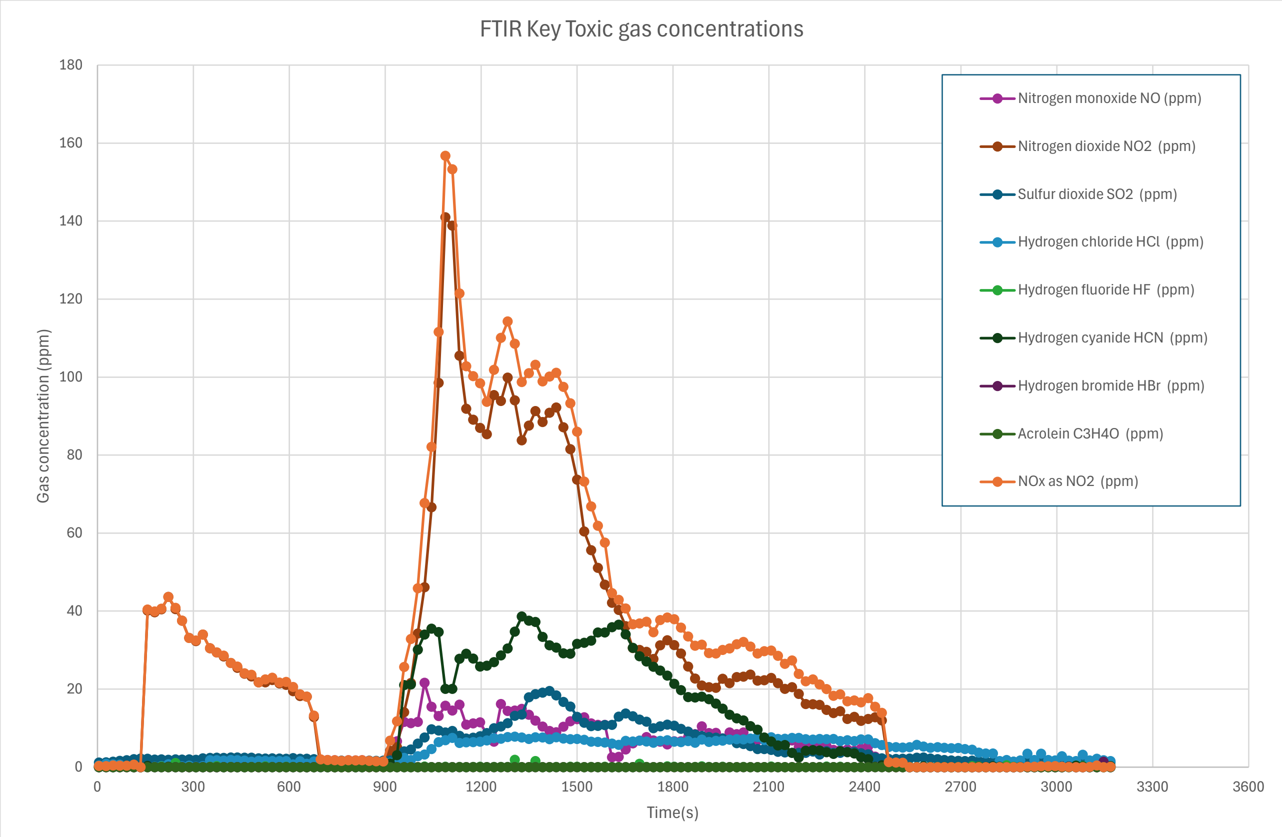


Figure 117. Test 8 – Key Toxic Species concentration recorded by FTIR.

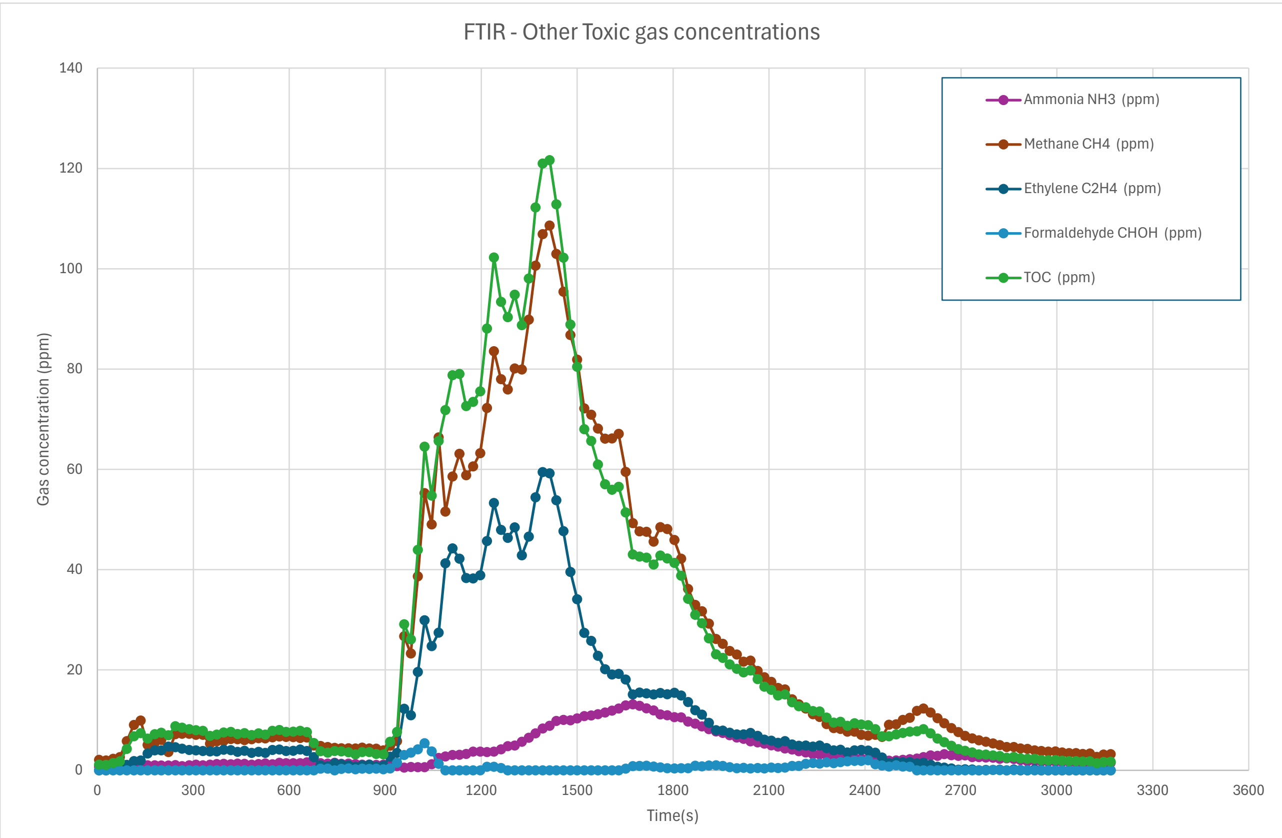


Figure 118. Test 8– Other Toxic Species concentration recorded by FTIR.

B.12 Test 9 – ISP-02-EPS Horizontal with steel capping

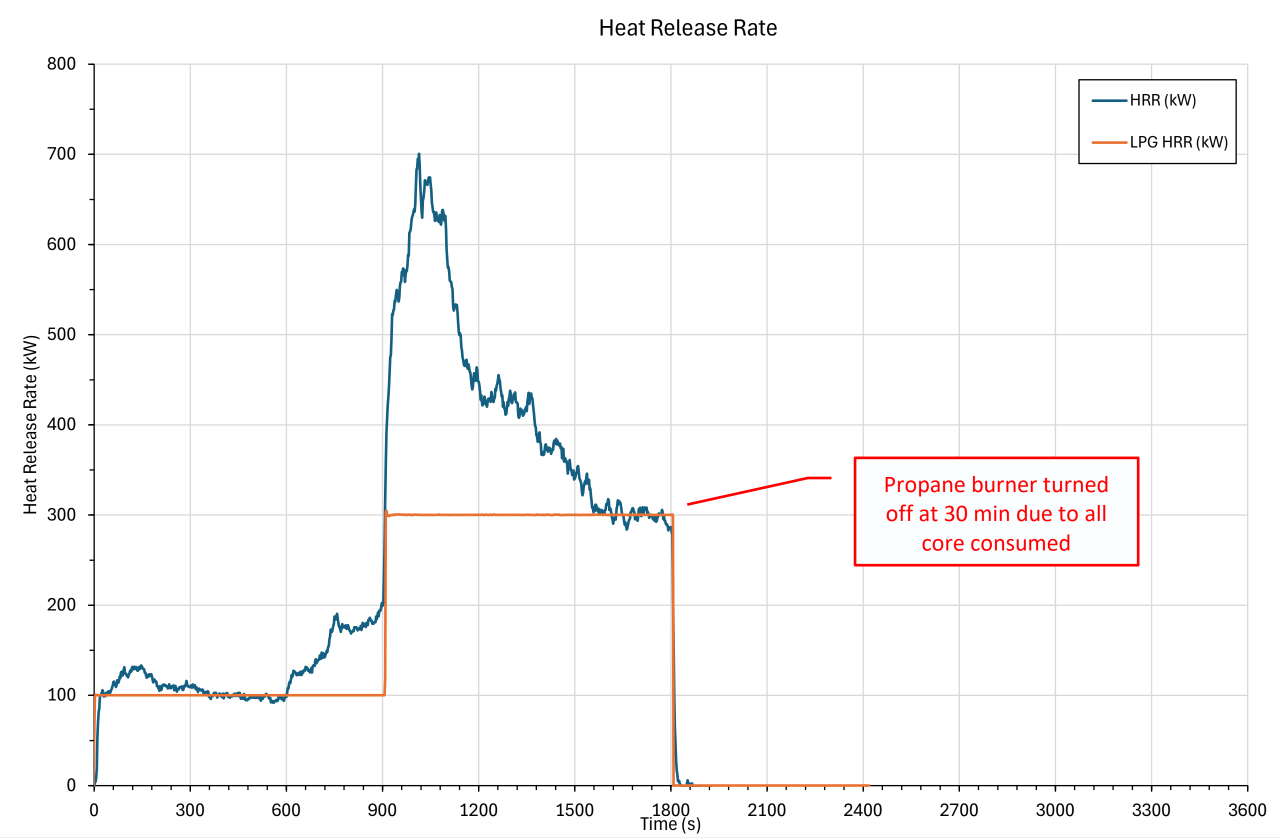


Figure 119. Test 9 – HRR (kW)

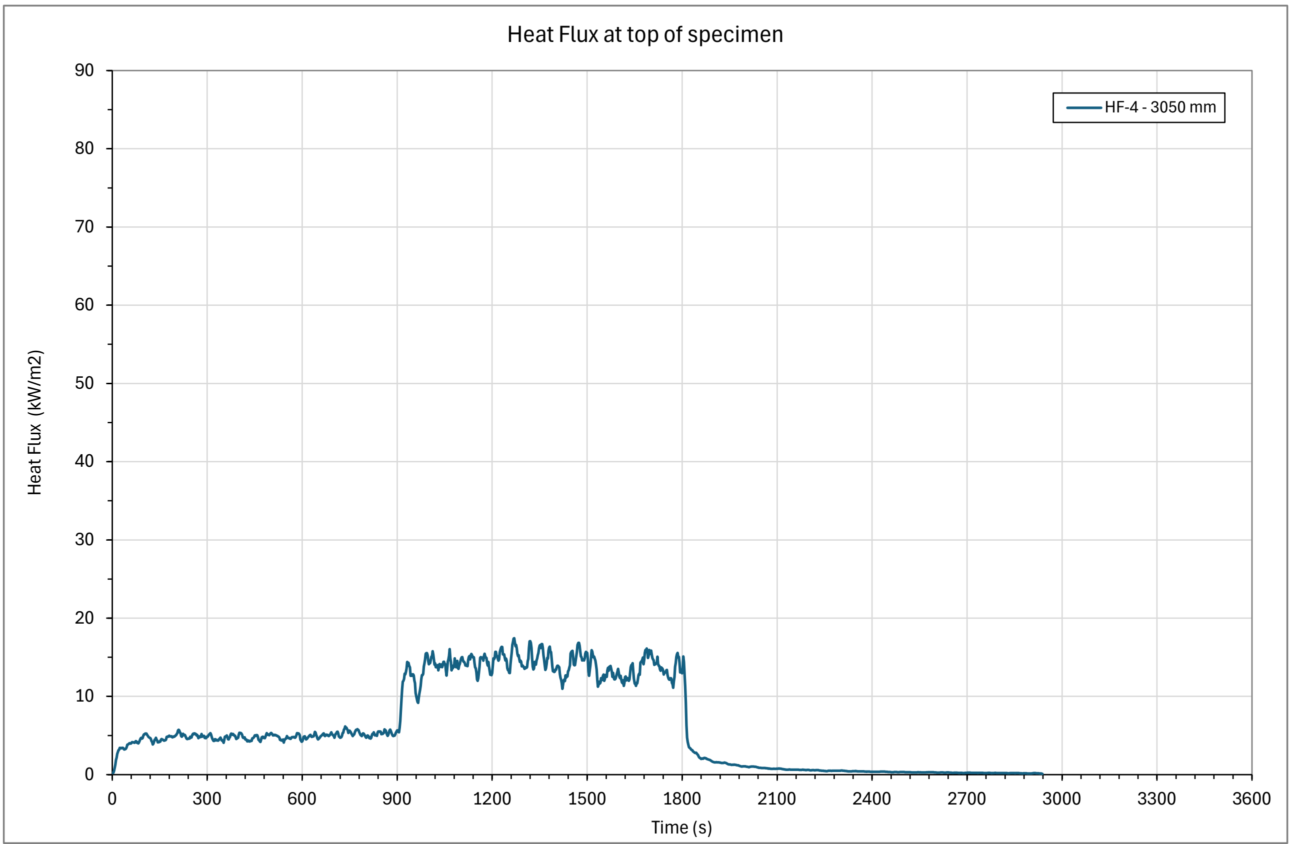


Figure 120. Test 9 – Heat flux (kW/m²) above 3050 mm from the ground level.

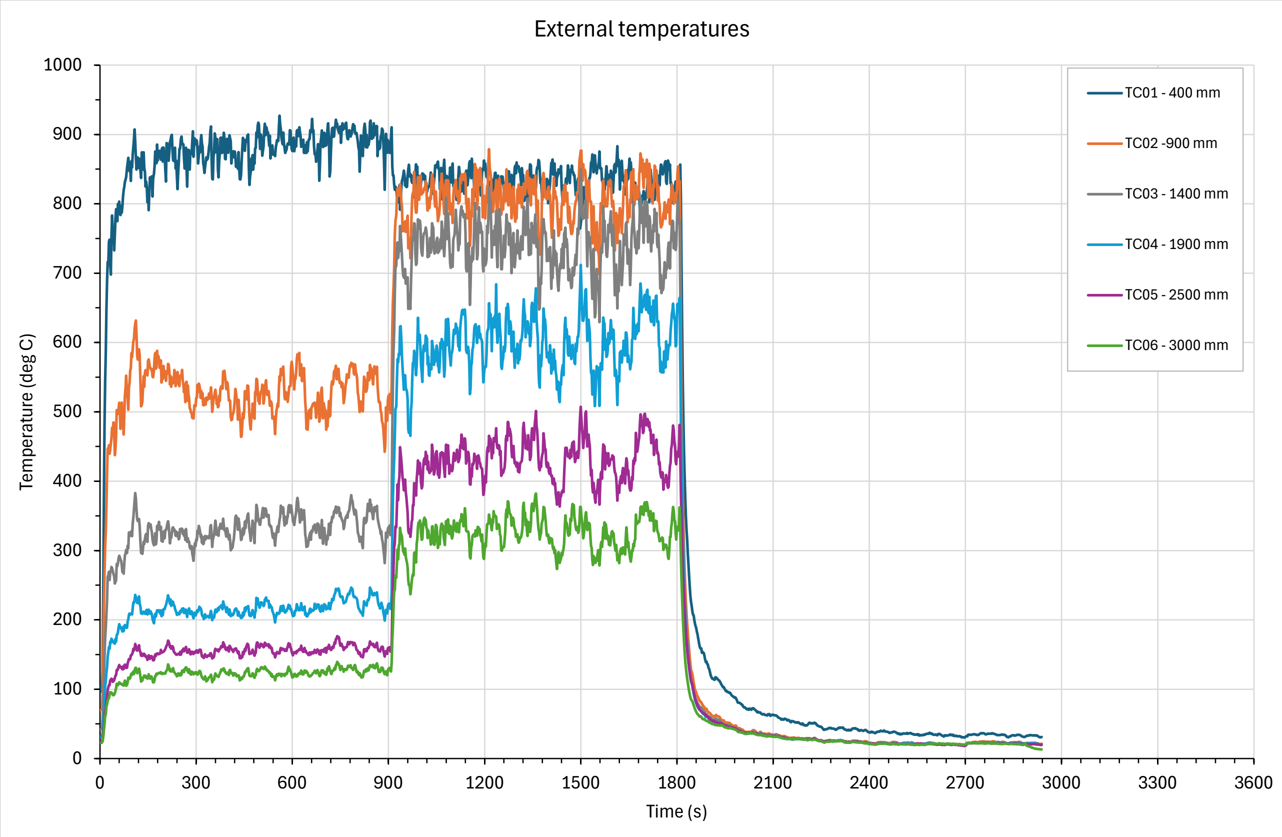


Figure 121. Test 9 – External face temperatures at various heights (TC01 to TC06)

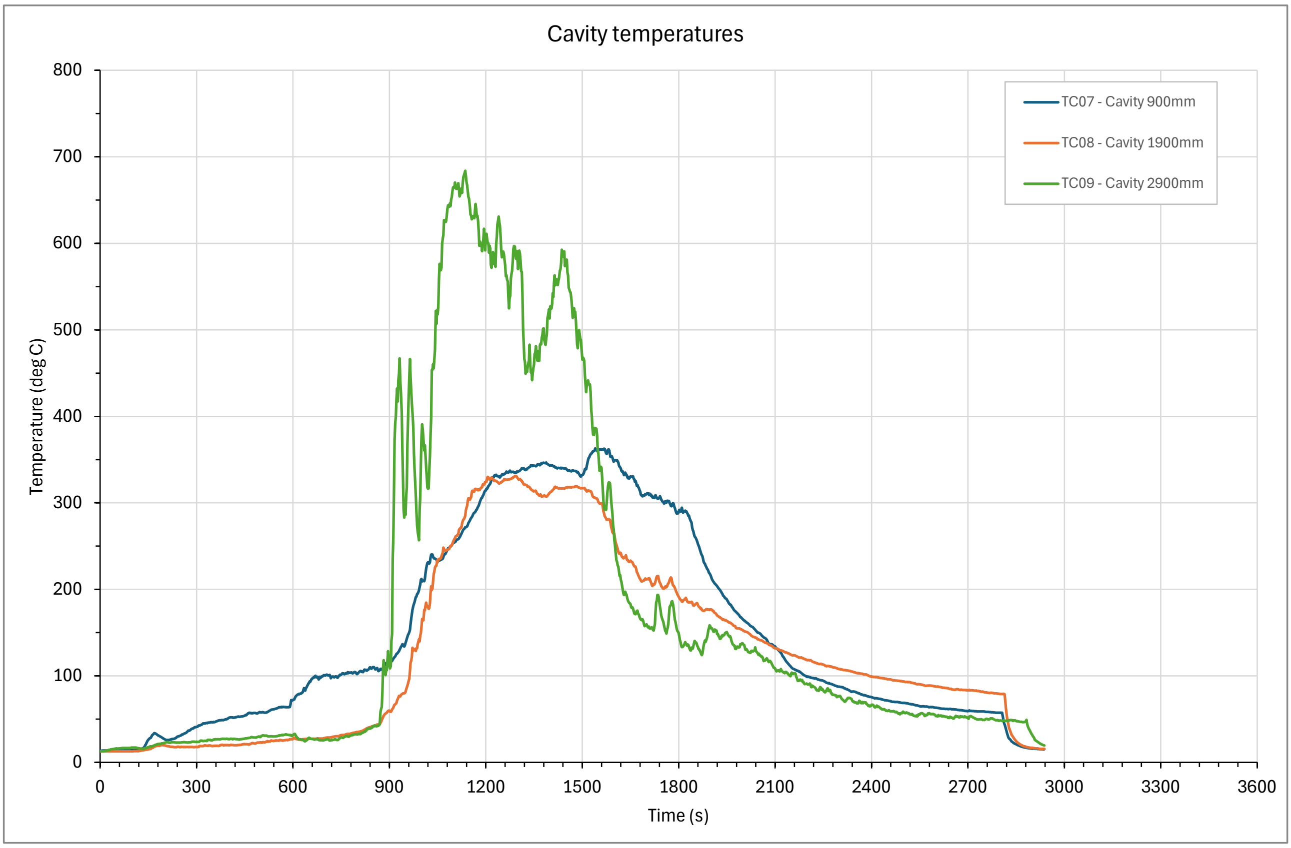


Figure 122. Test 9 – Temperatures within air cavity at 900 mm (TC07), 1,900 mm (TC08), 3,000 mm (TC09) above ground level

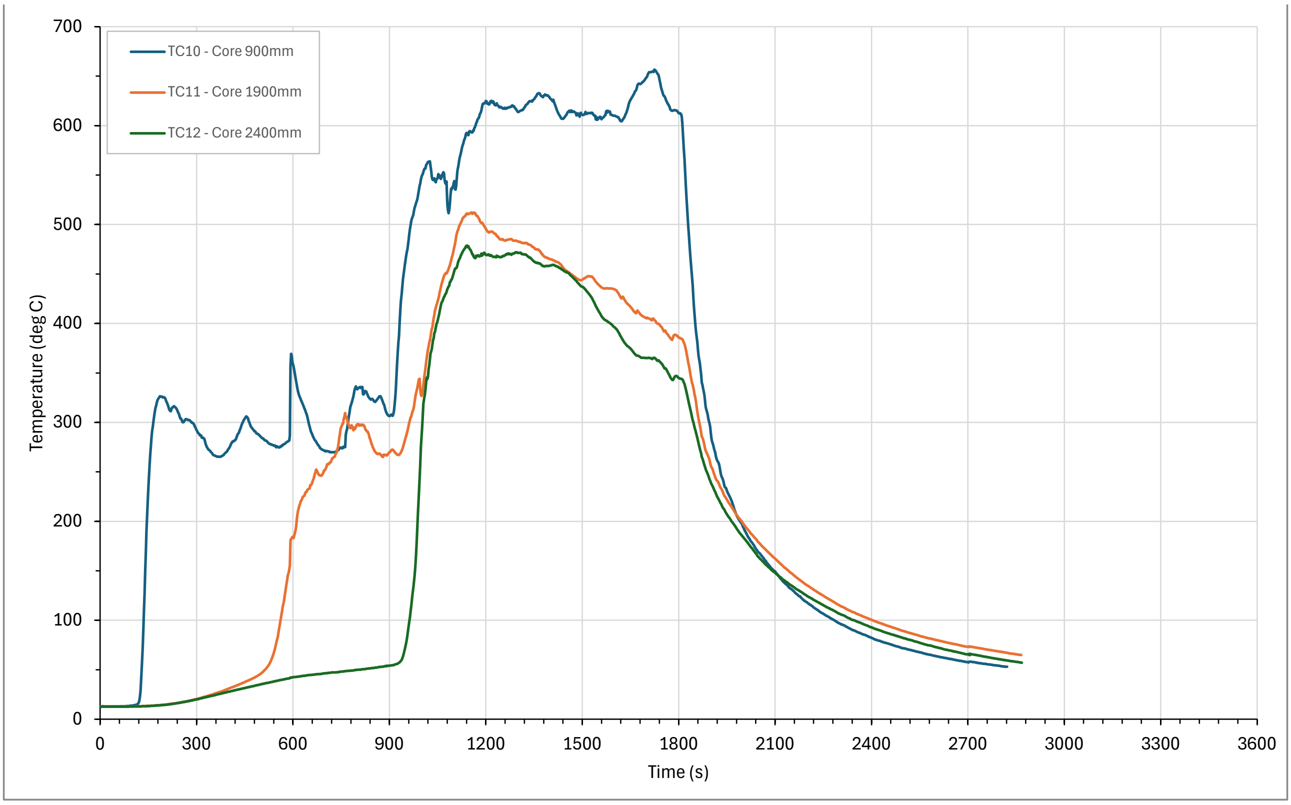


Figure 123. Test 9 – Temperatures within core at 900 mm (TC10), 1,900 mm (TC11), 2400 mm (TC12) above ground level

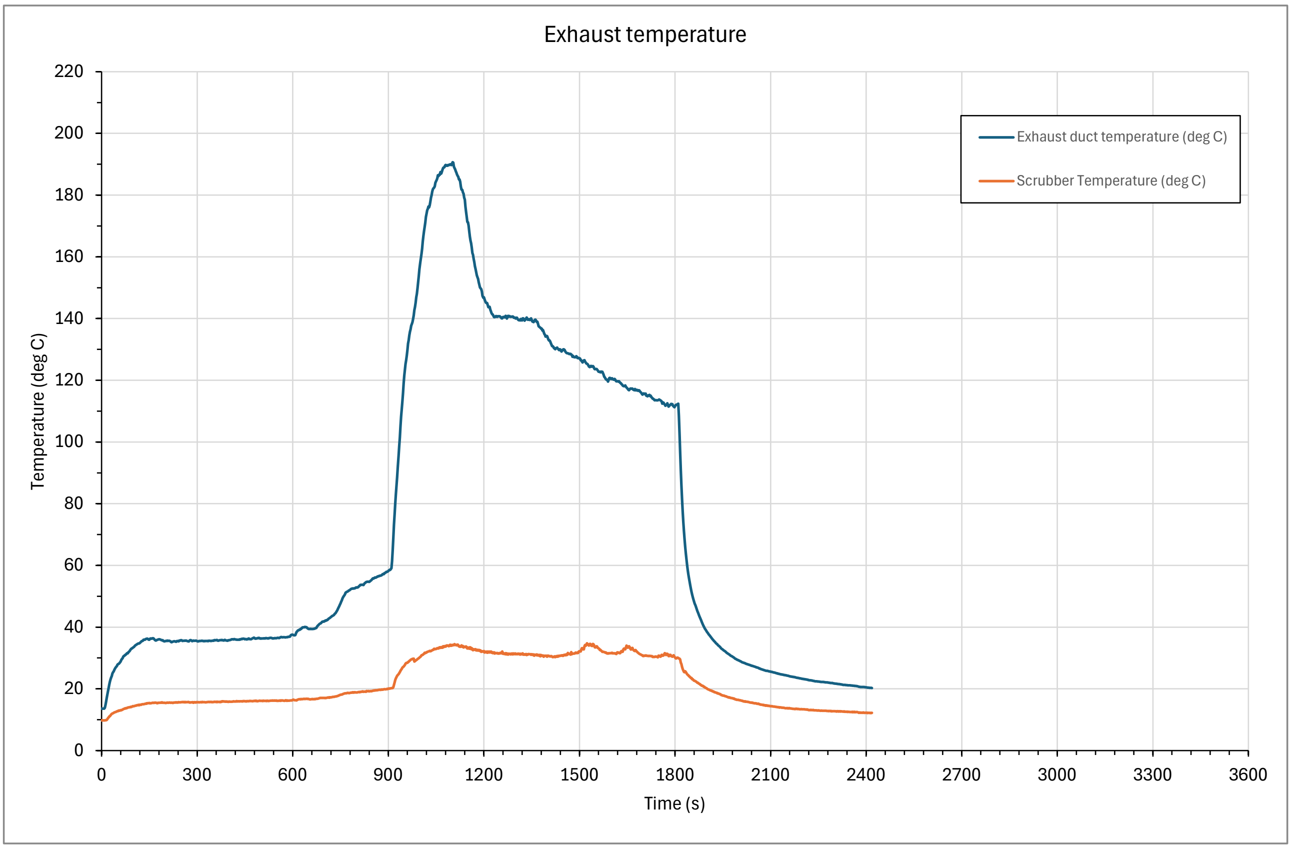


Figure 124. Test 9 – Test Hood exhaust temperatures

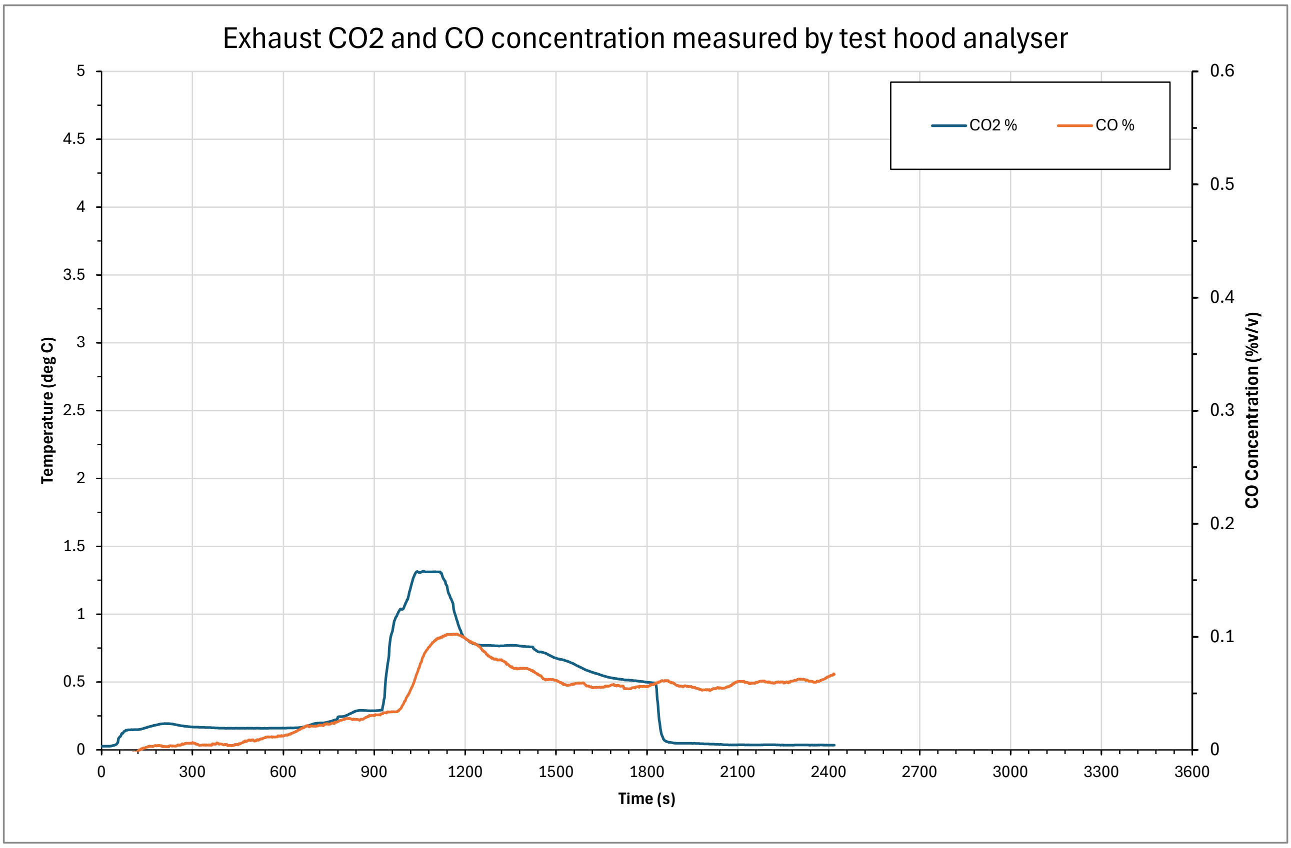


Figure 125. Test 9 – CO and CO2 concentration measured by test hood gas analyser

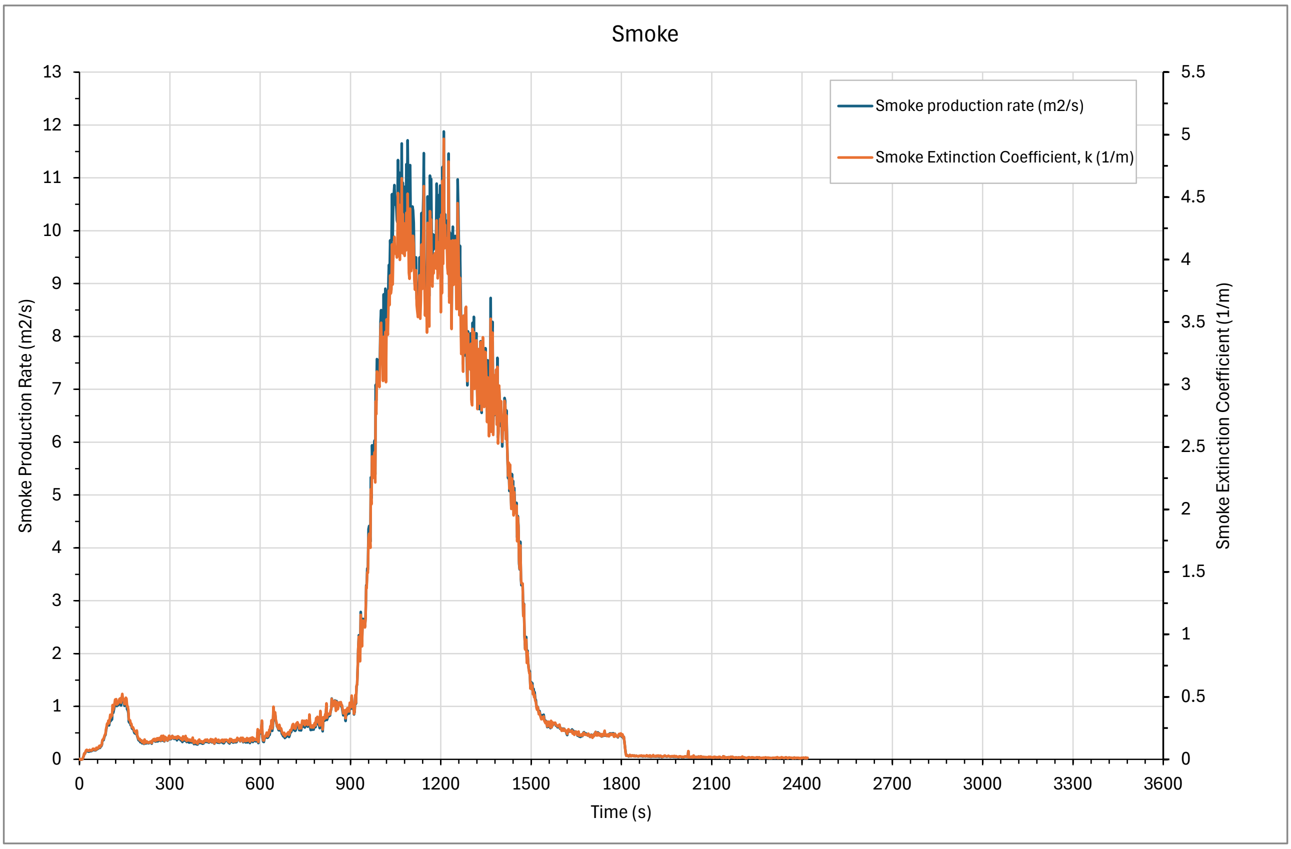


Figure 126. Test 9– Smoke production rate

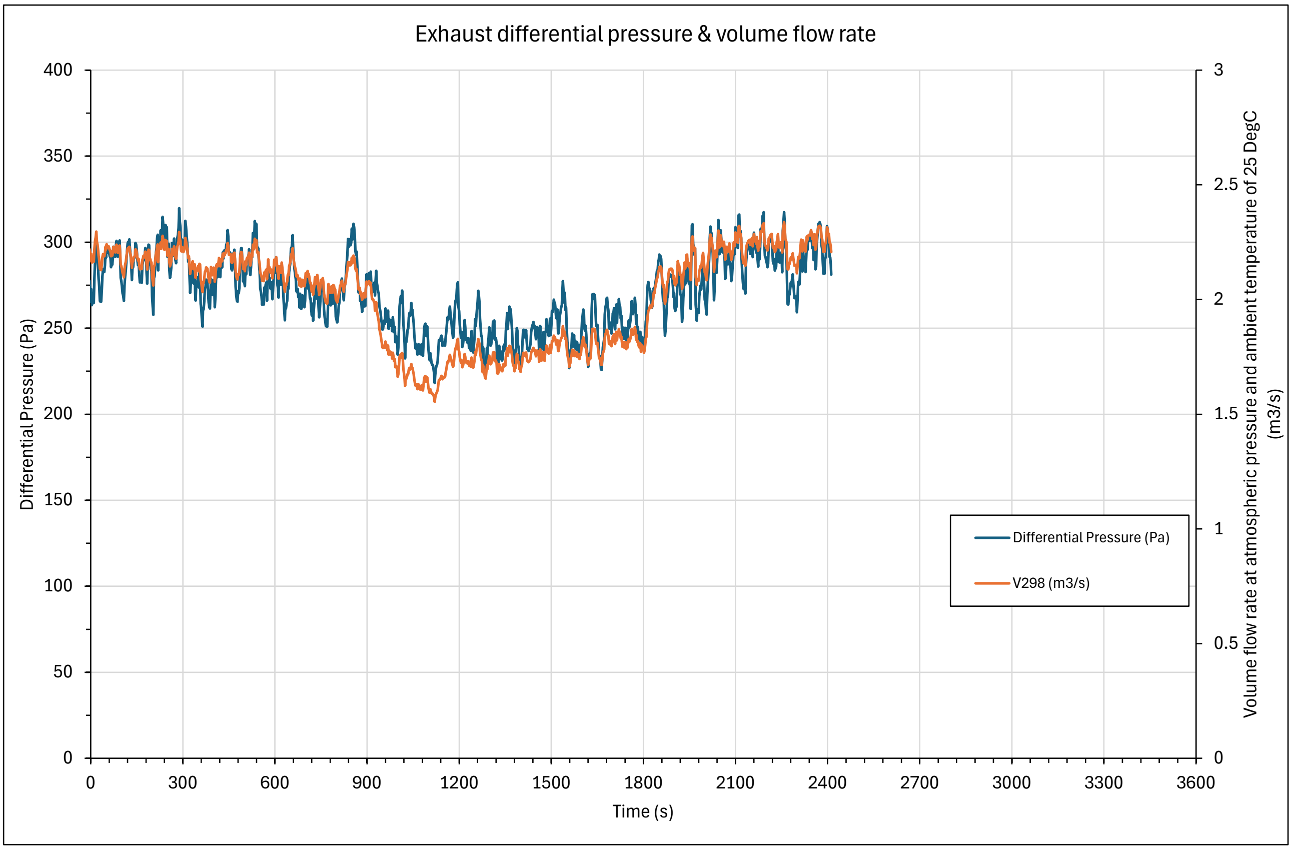


Figure 127. Test 9 – Test hood exhaust flow rate

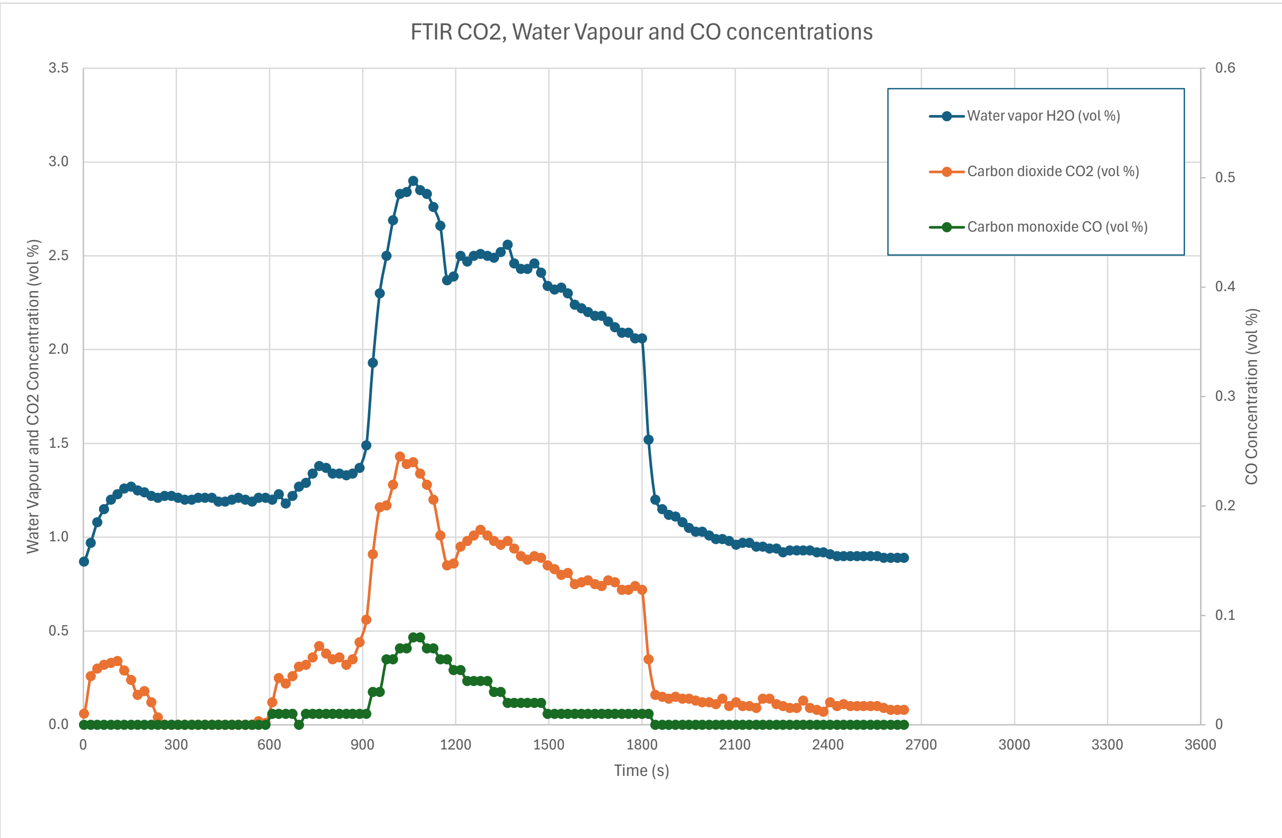


Figure 128. Test 9 – CO and CO2 concentration recorded by FTIR.

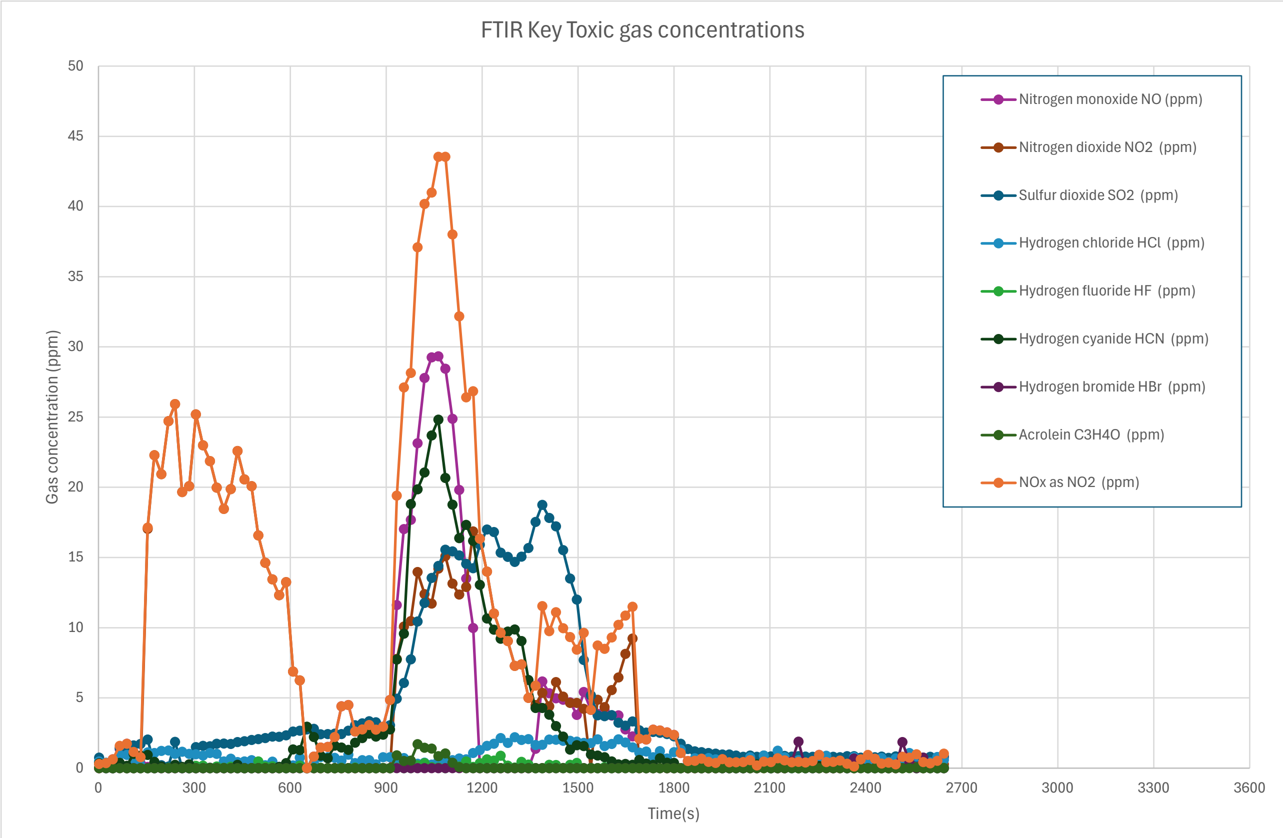


Figure 129. Test 9 – Key Toxic Species concentration recorded by FTIR.

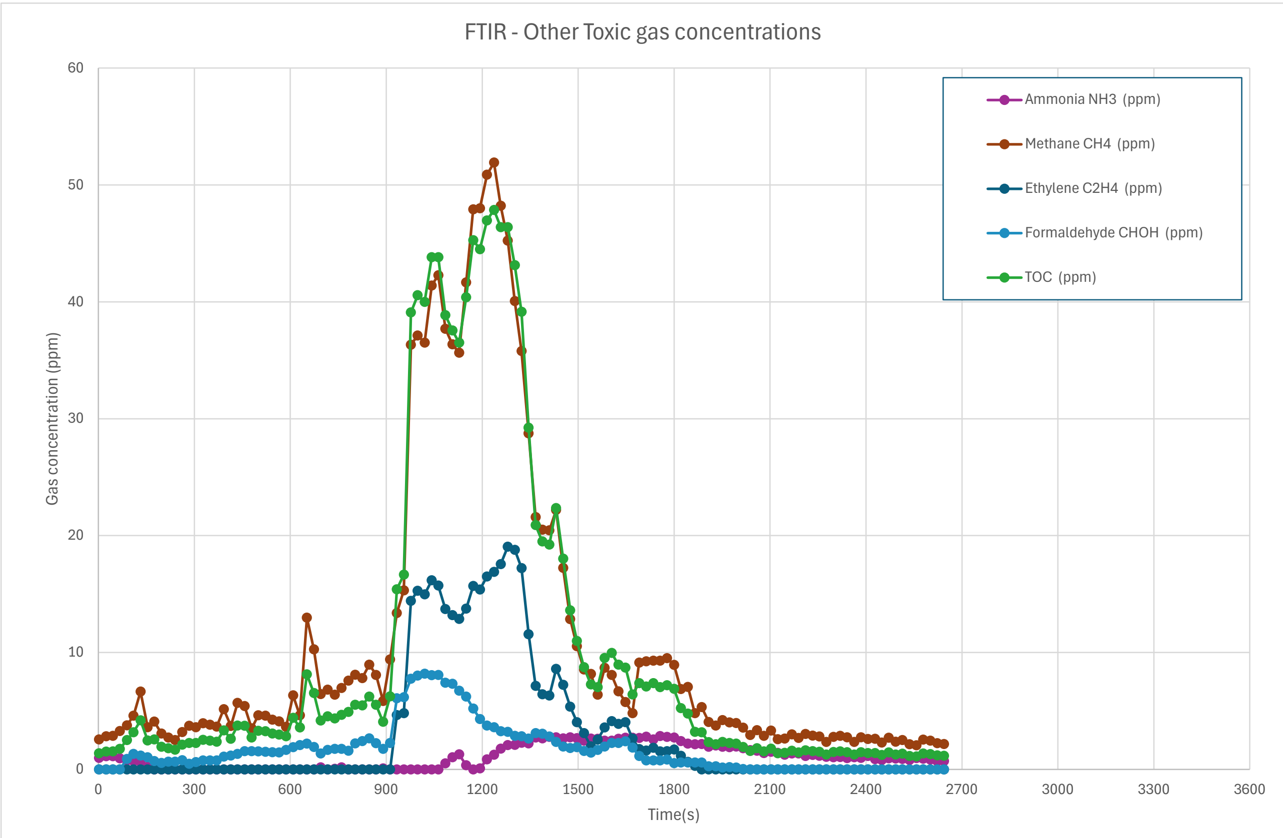


Figure 130. Test 9 – Other Toxic Species concentration recorded by FTIR.

B.13 Test 10 – ISP-01-PIR Vertical with steel capping

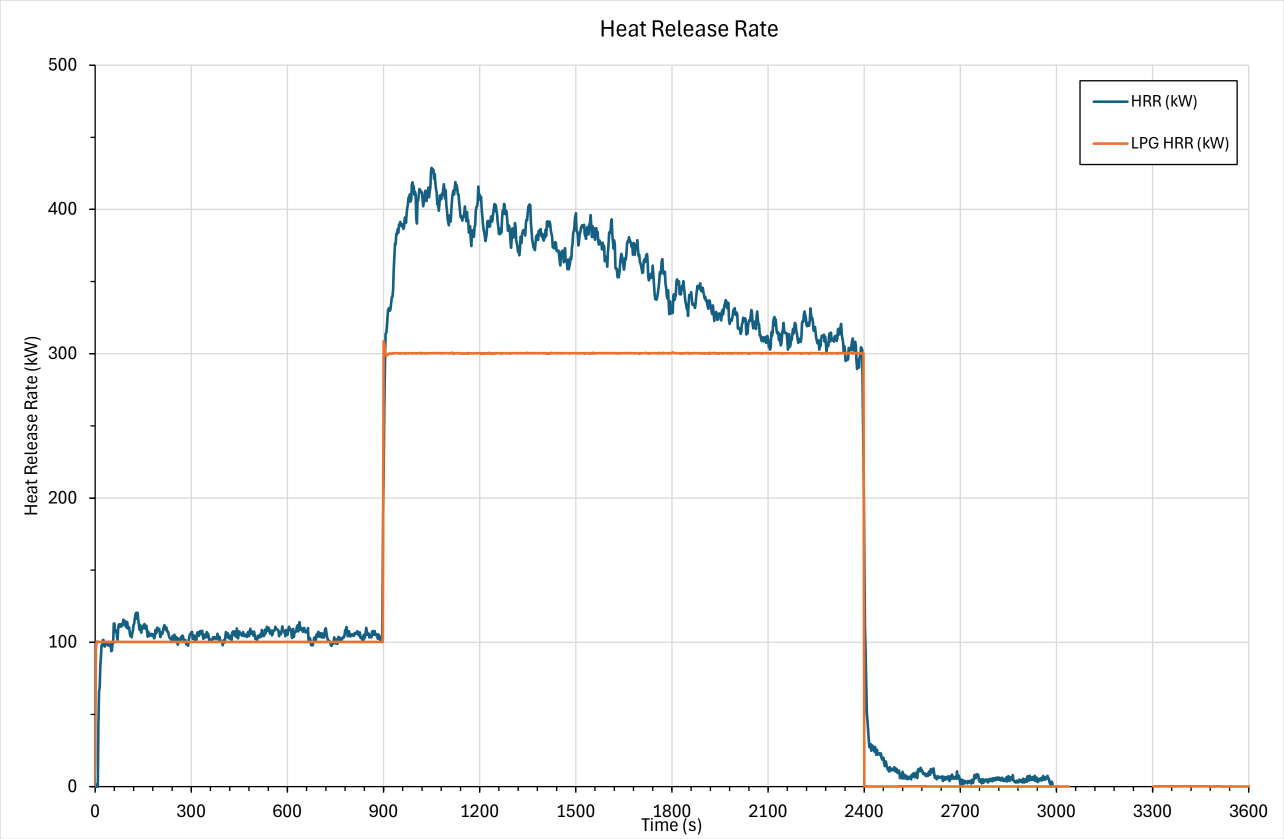


Figure 131. Test 10 – HRR (kW)

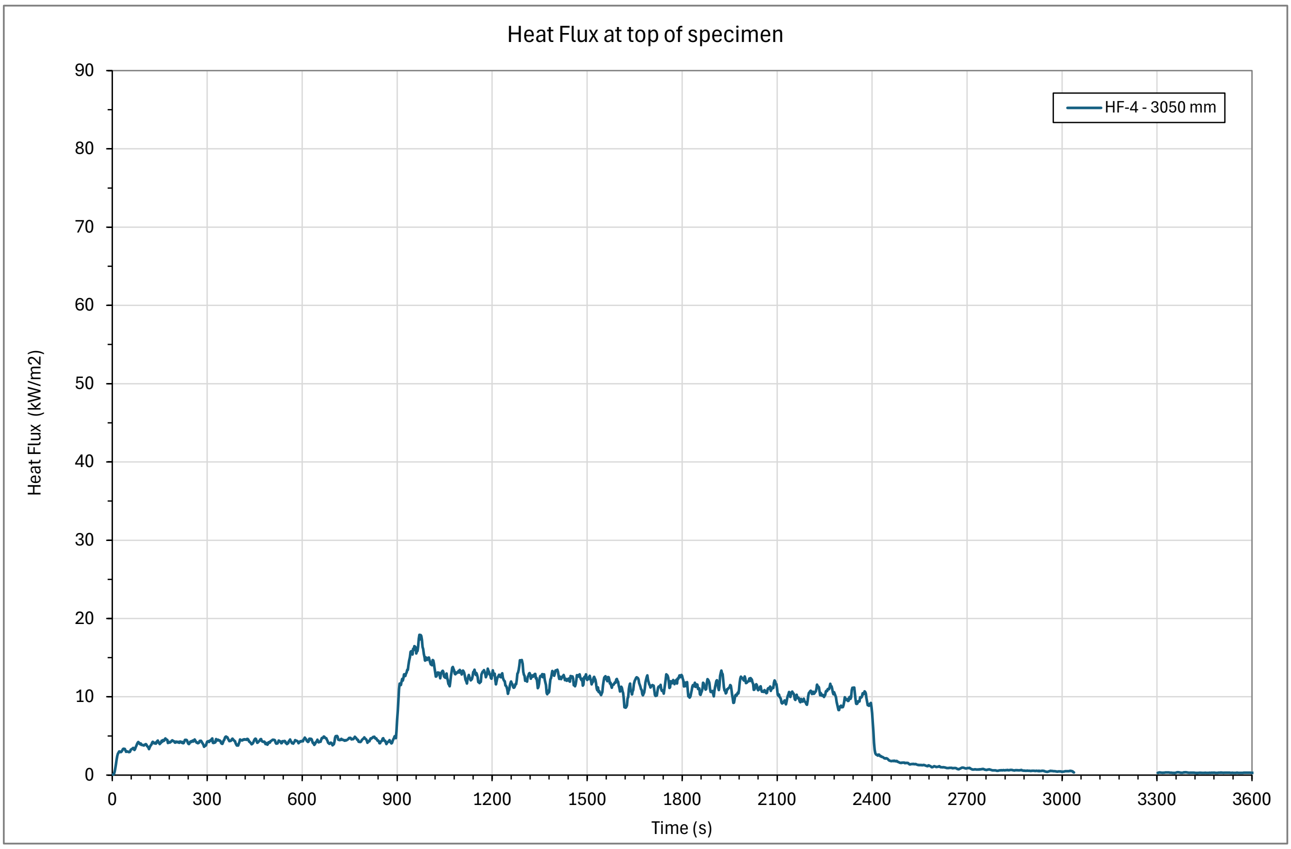


Figure 132. Test 10 – Heat flux (kW/m^2) above 3050 mm from the ground level.

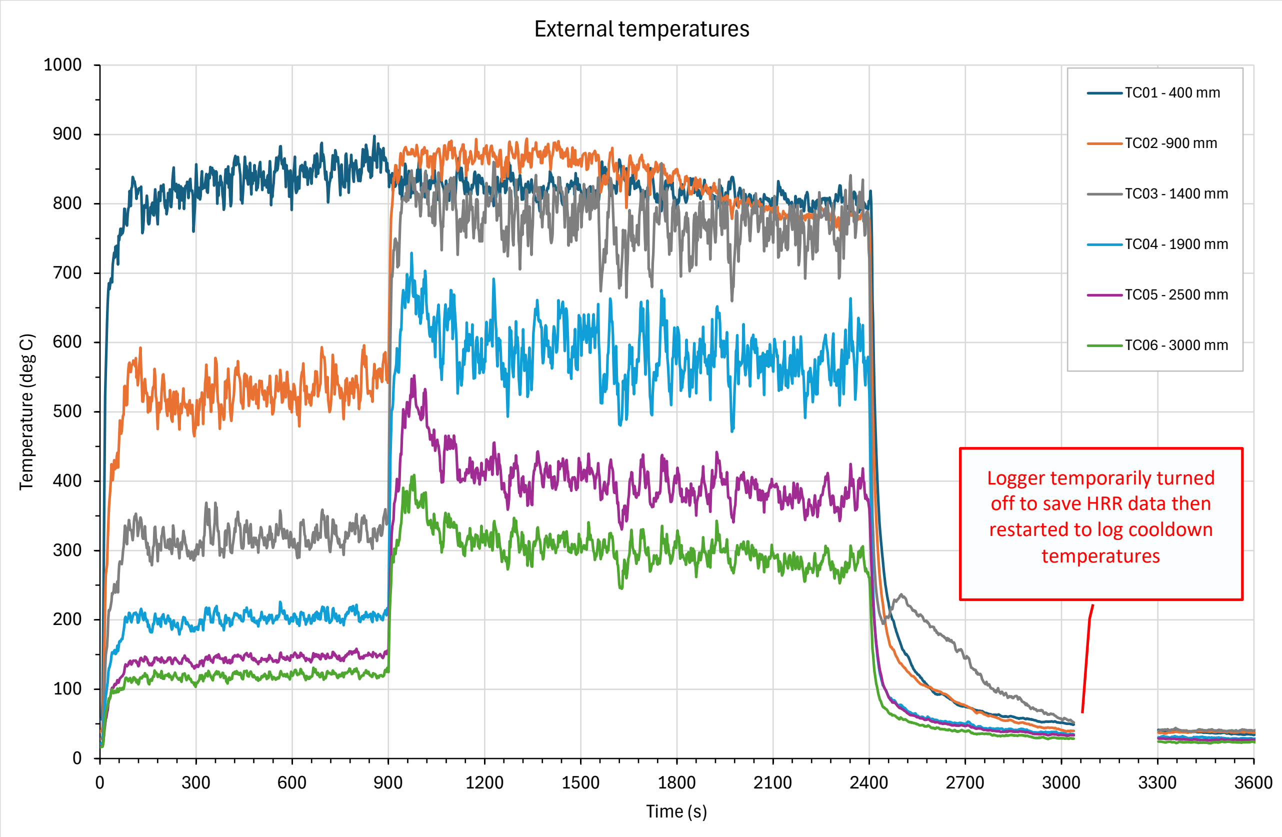


Figure 133. Test 10 – External face temperatures at various heights (TC01 to TC06)

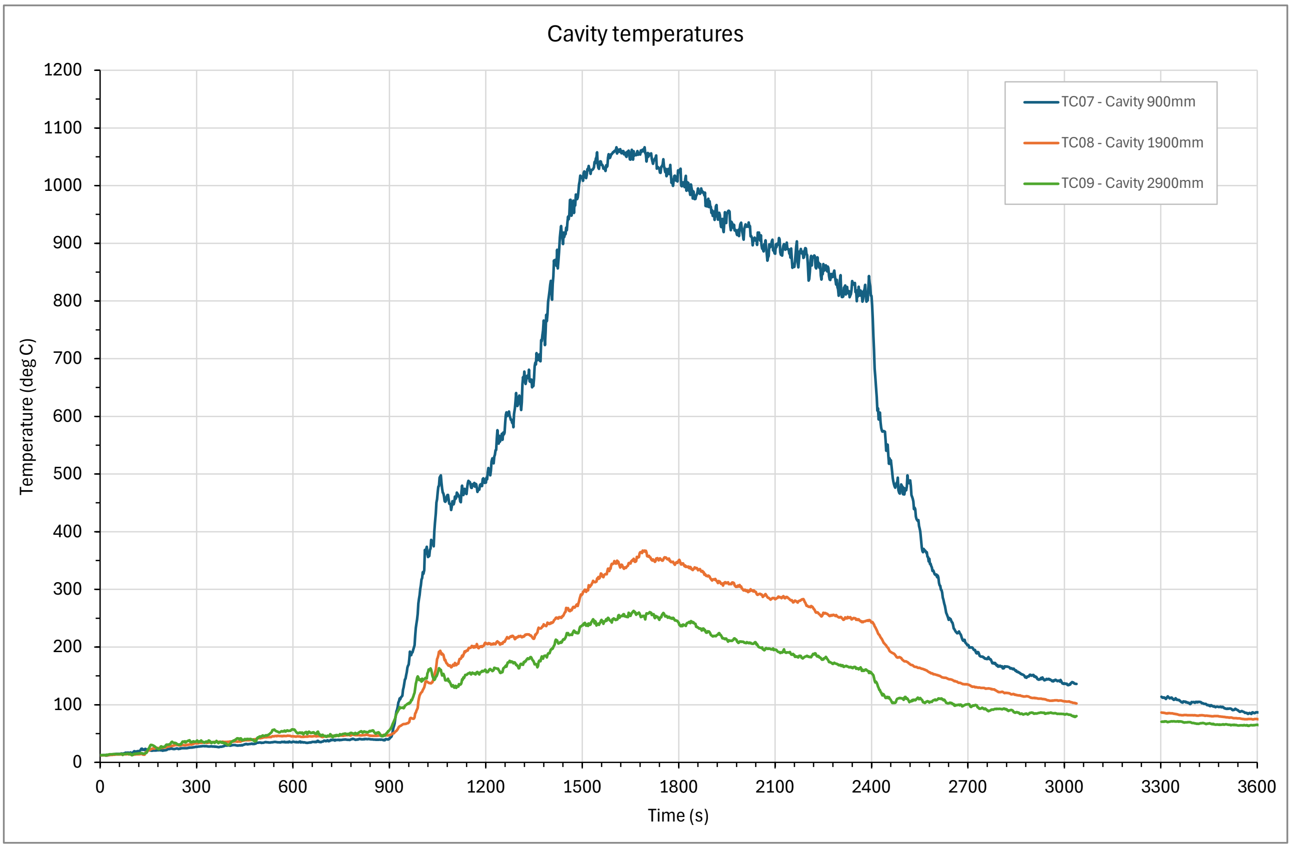


Figure 134. Test 10 – Temperatures within air cavity at 900 mm (TC07), 1,900 mm (TC08), 3,000 mm (TC09) above ground level

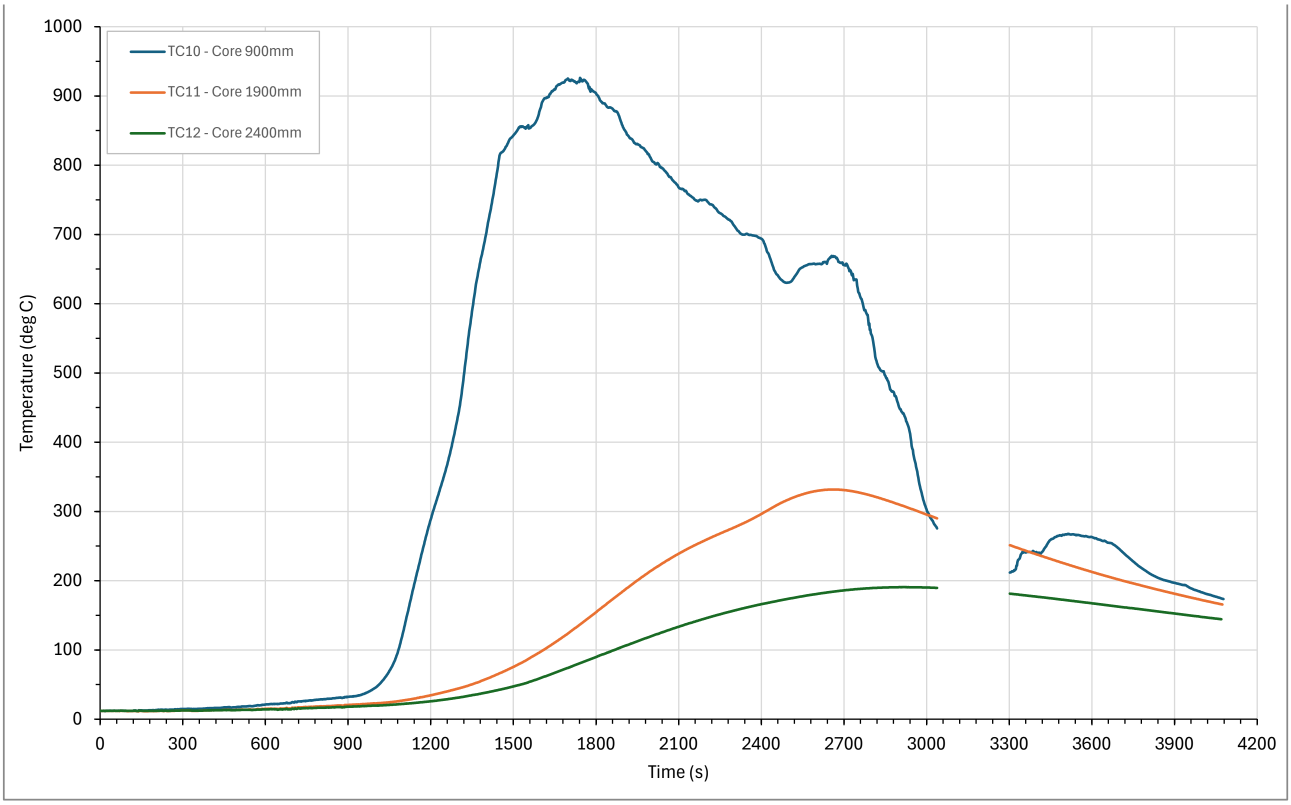


Figure 135. Test 10 – Temperatures within core at 900 mm (TC10), 1,900 mm (TC11), 2400 mm (TC12) above ground level

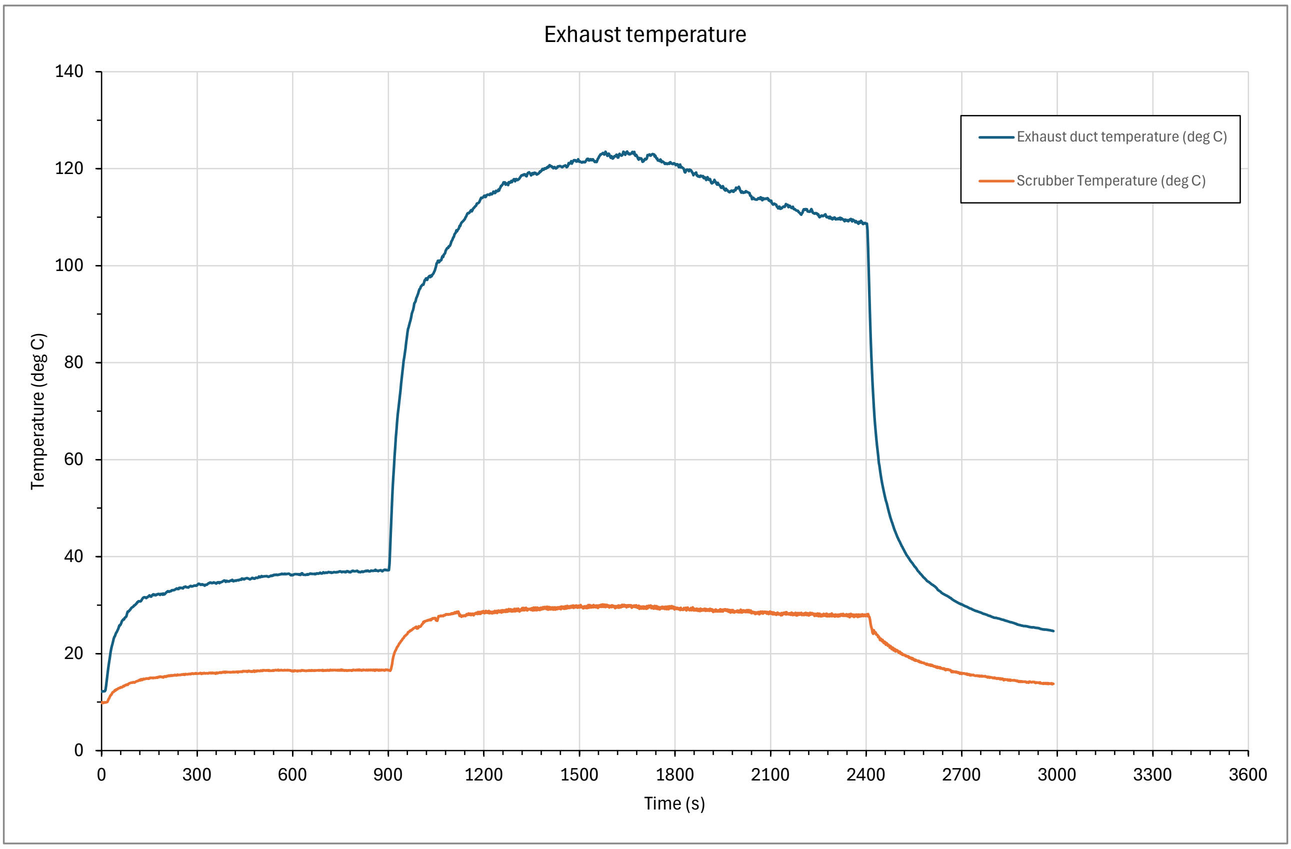


Figure 136. Test 10 – Test Hood exhaust temperatures

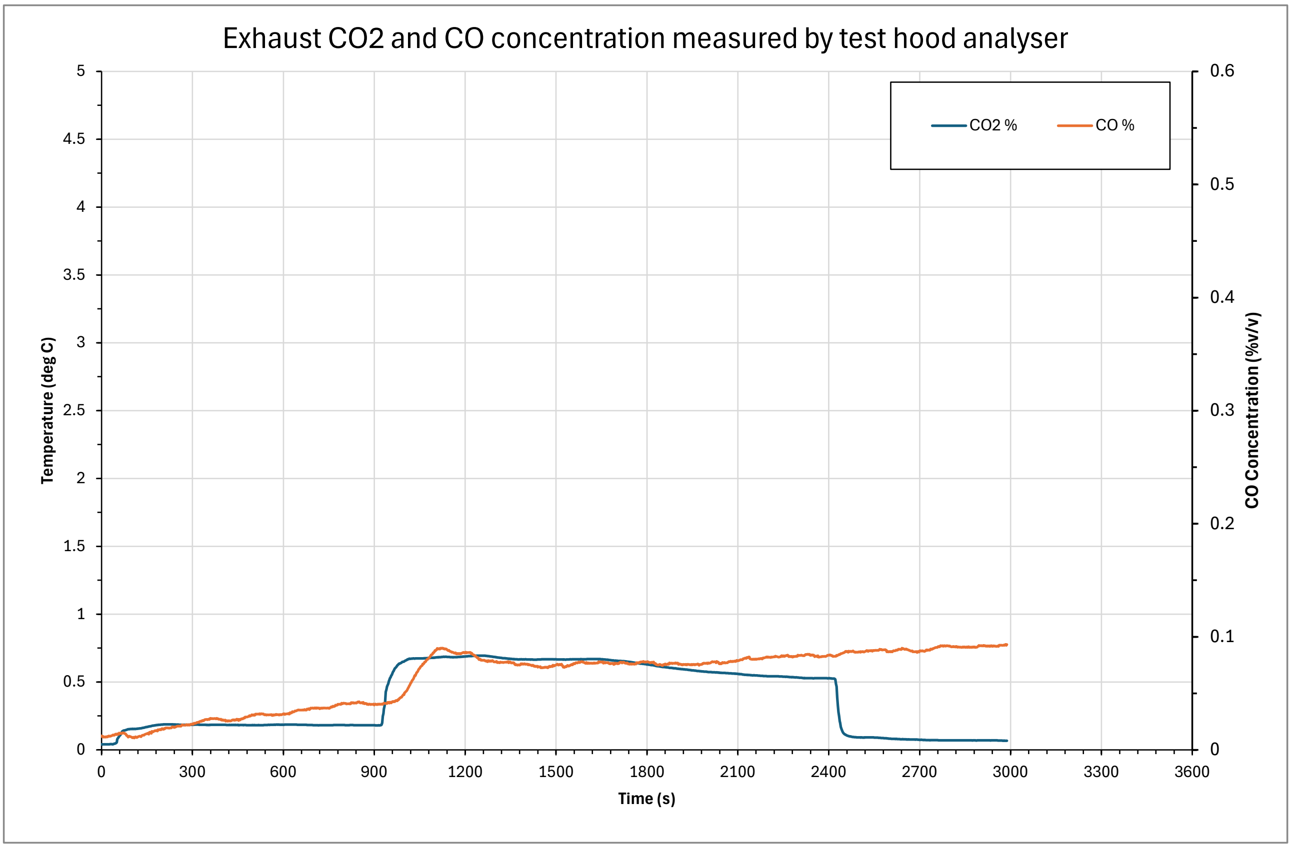


Figure 137. Test 10 – CO and CO2 concentration measured by test hood gas analyser

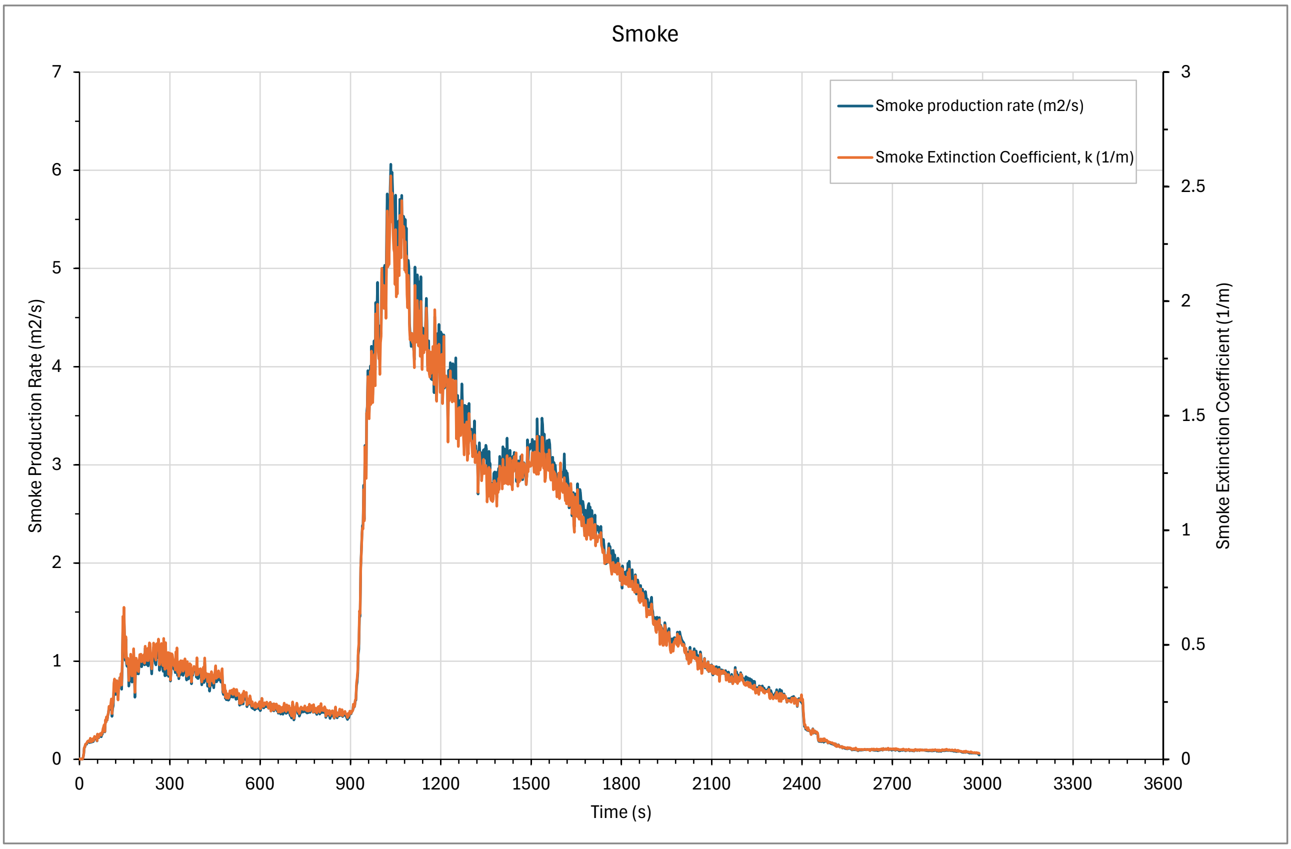


Figure 138. Test 10– Smoke production rate

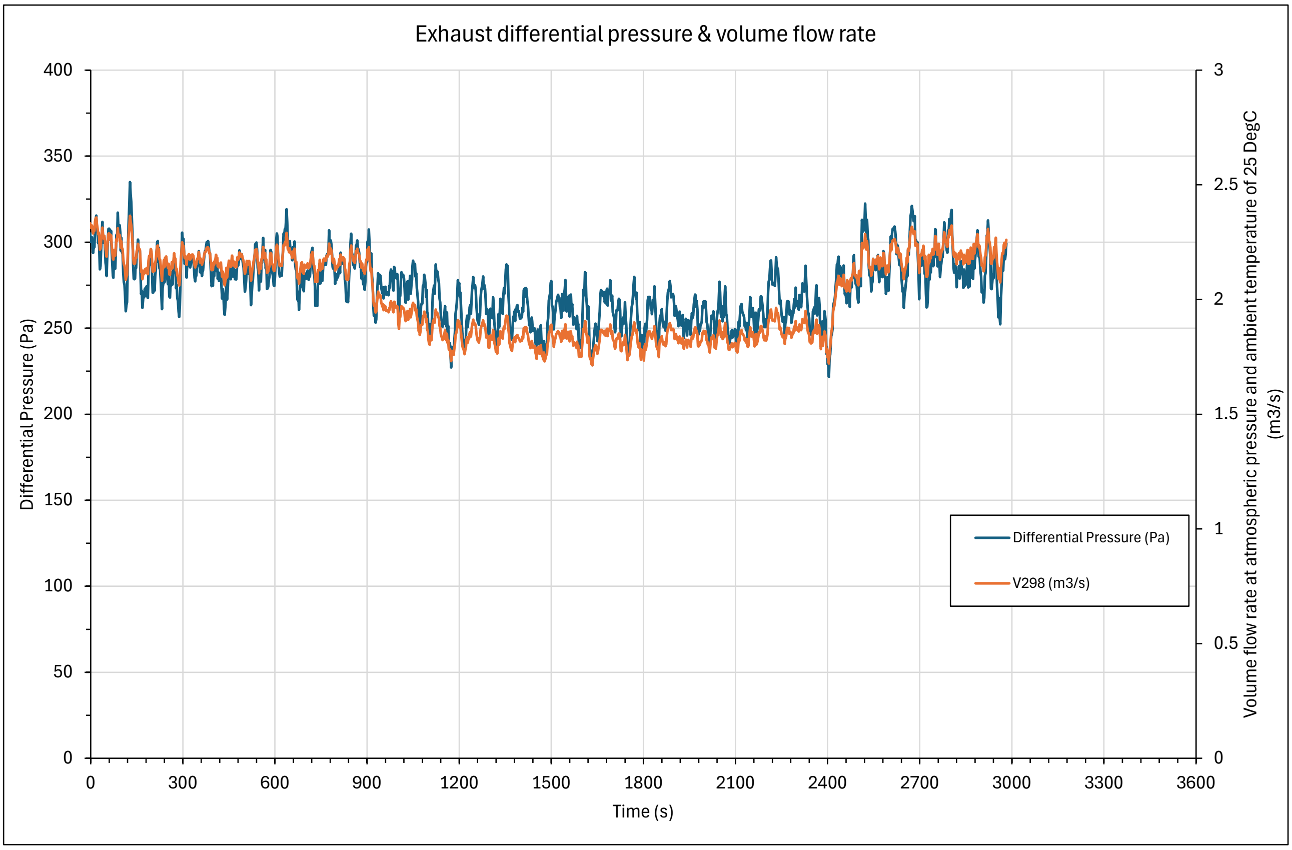


Figure 139. Test 10 – Test hood exhaust flow rate

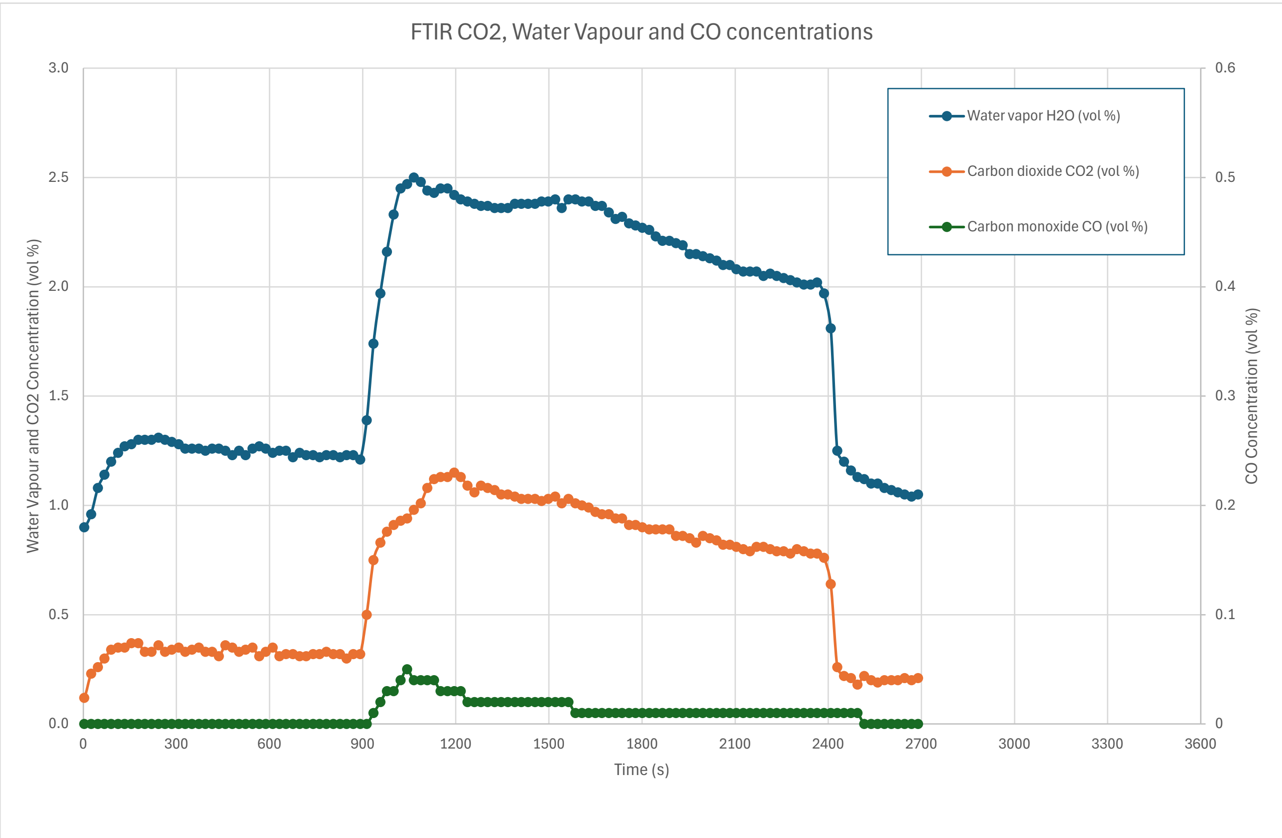


Figure 140. Test 10 – CO and CO2 concentration recorded by FTIR.

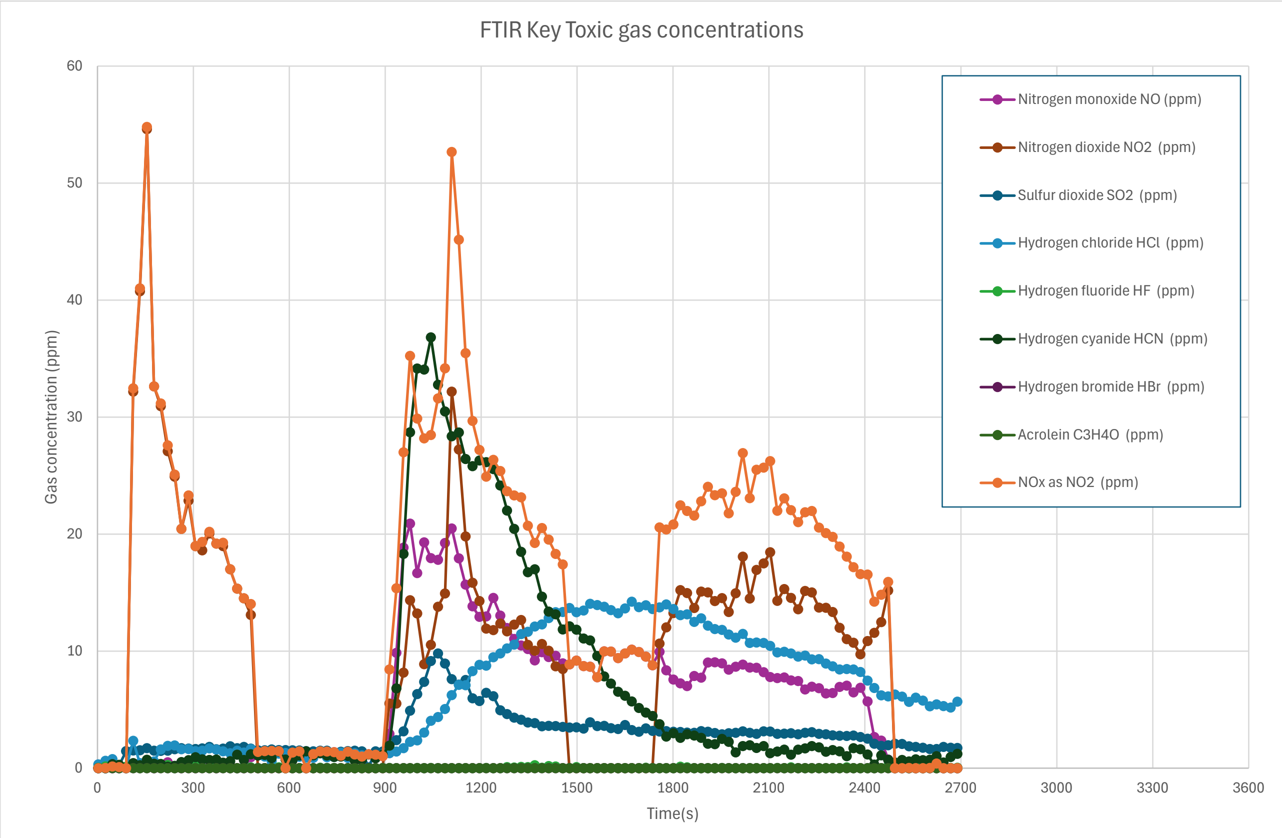


Figure 141. Test 10 – Key Toxic Species concentration recorded by FTIR.

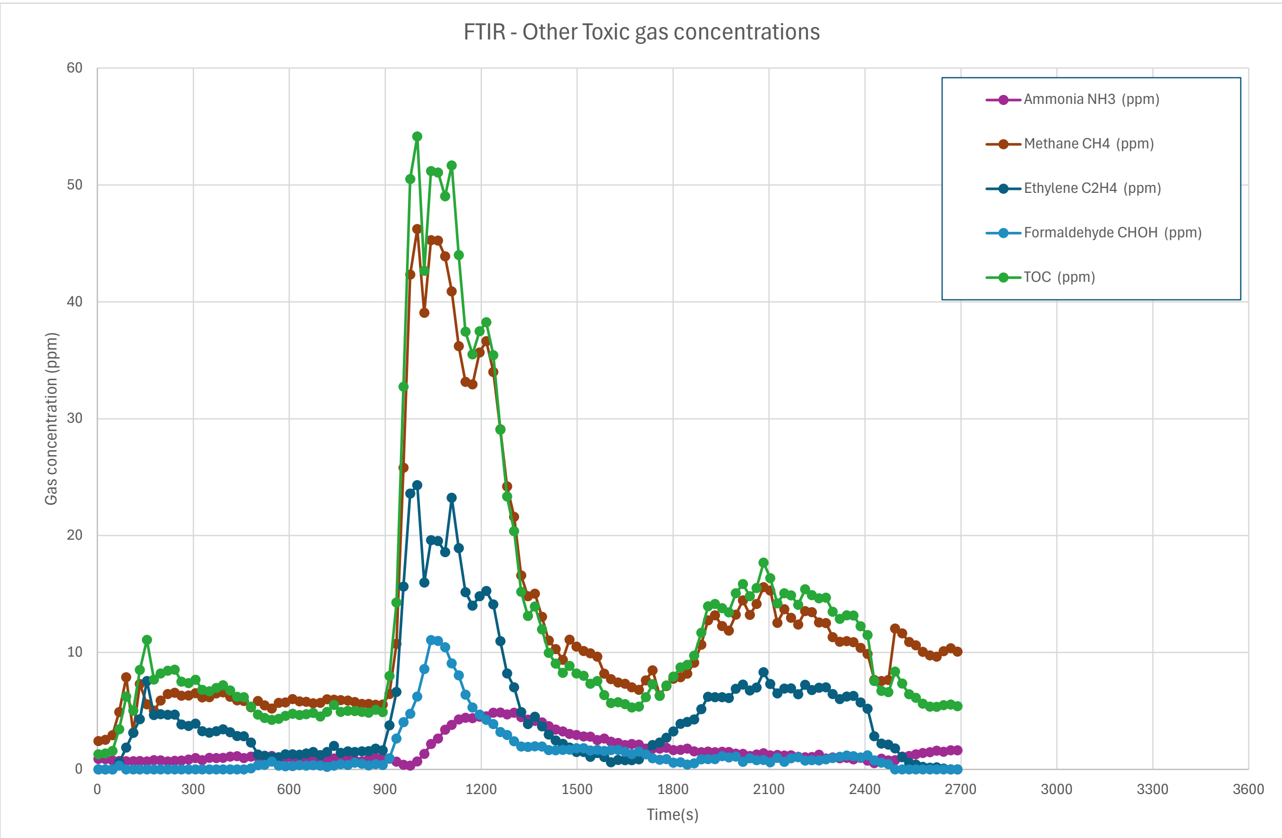


Figure 142. Test 10 – Other Toxic Species concentration recorded by FTIR.

B.14 Test 11 – ISP-01-PIR Horizontal with steel capping & internal joint flashing

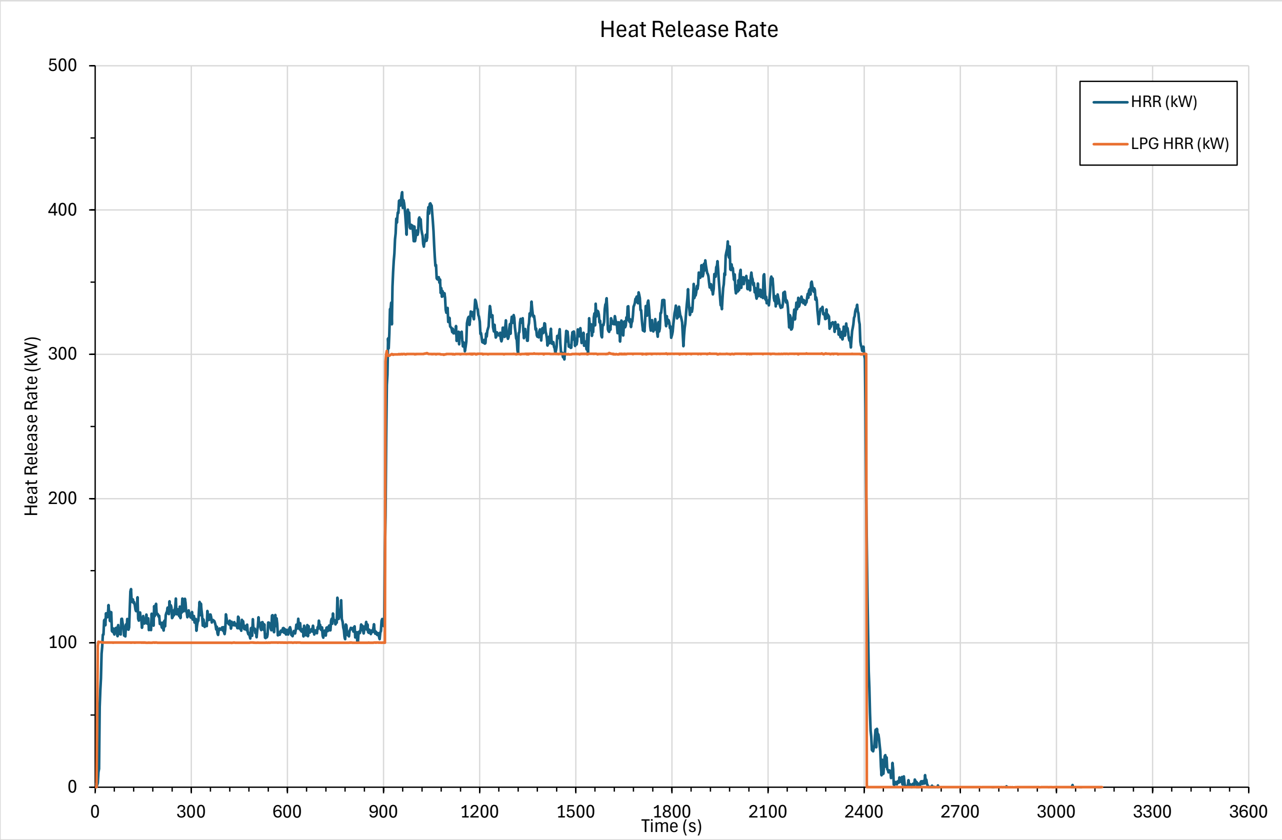


Figure 143. Test 11 – HRR (kW)

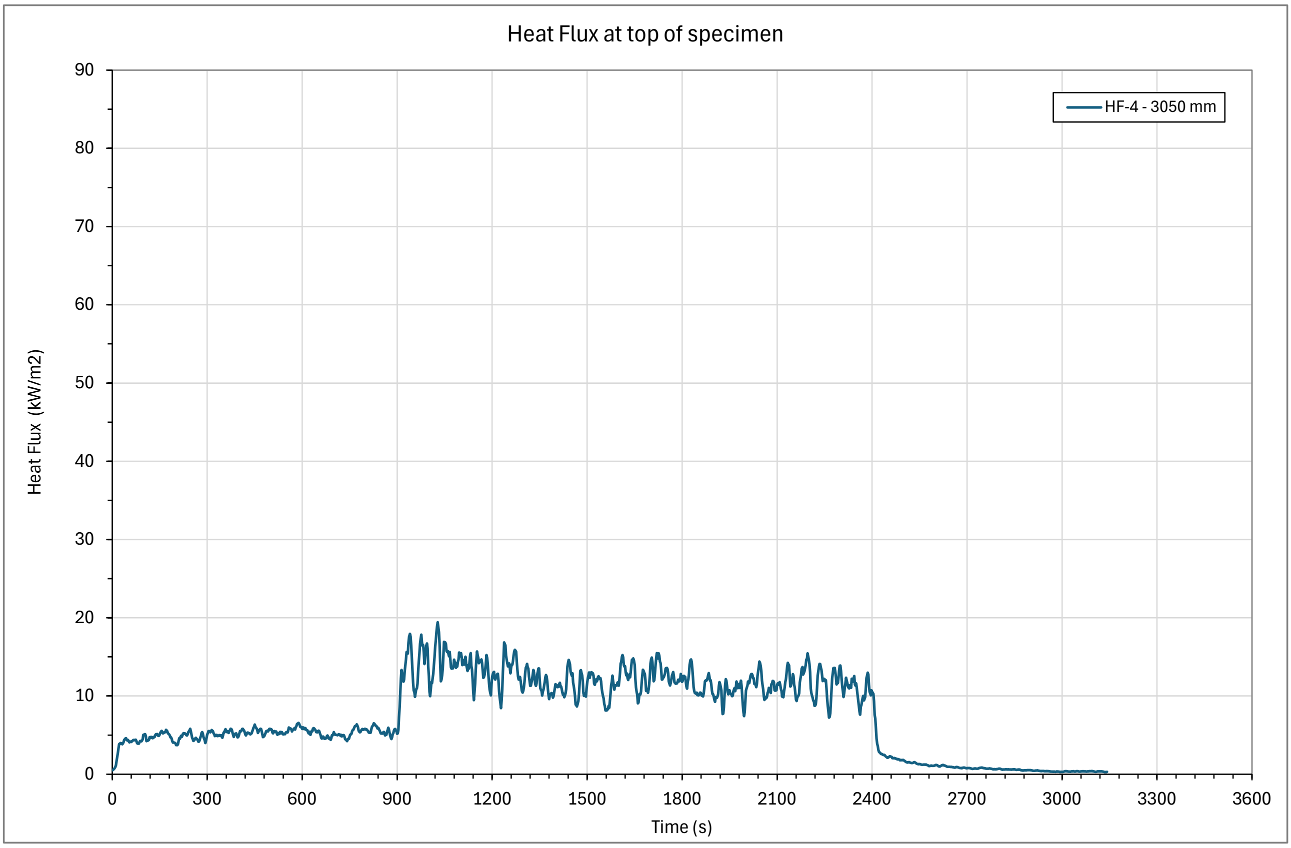


Figure 144. Test 11 – Heat flux (kW/m^2) above 3050 mm from the ground level.

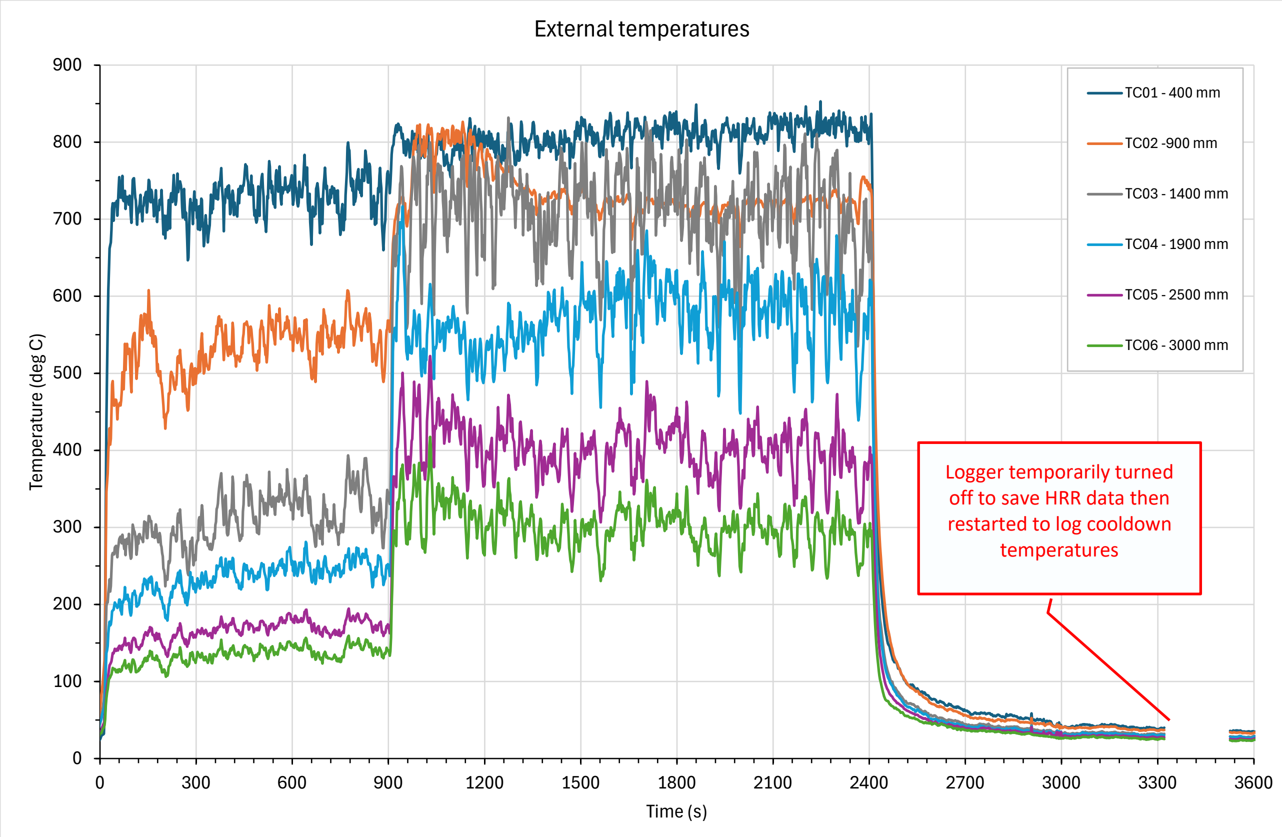


Figure 145. Test 11 – External face temperatures at various heights (TC01 to TC06)

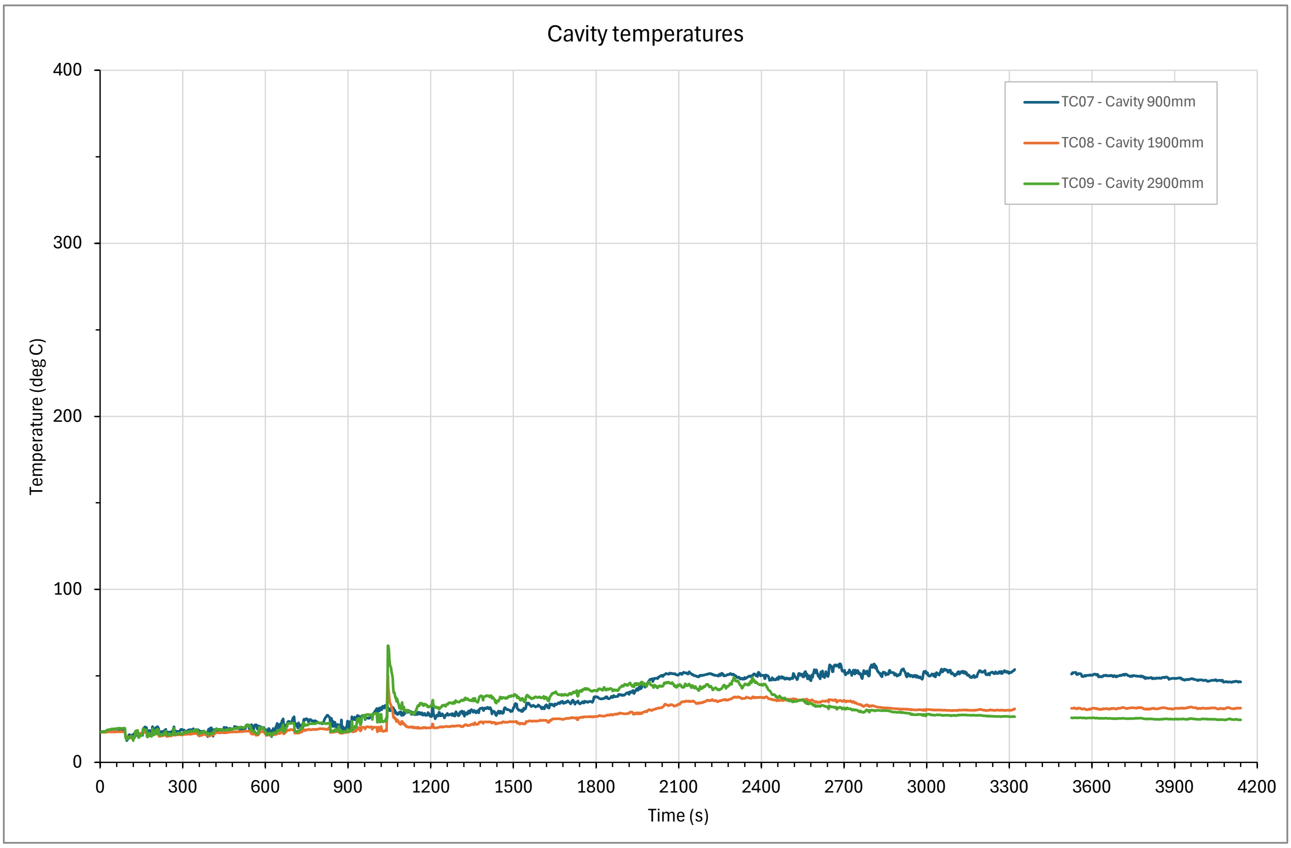


Figure 146. Test 11 – Temperatures within air cavity at 900 mm (TC07), 1,900 mm (TC08), 3,000 mm (TC09) above ground level

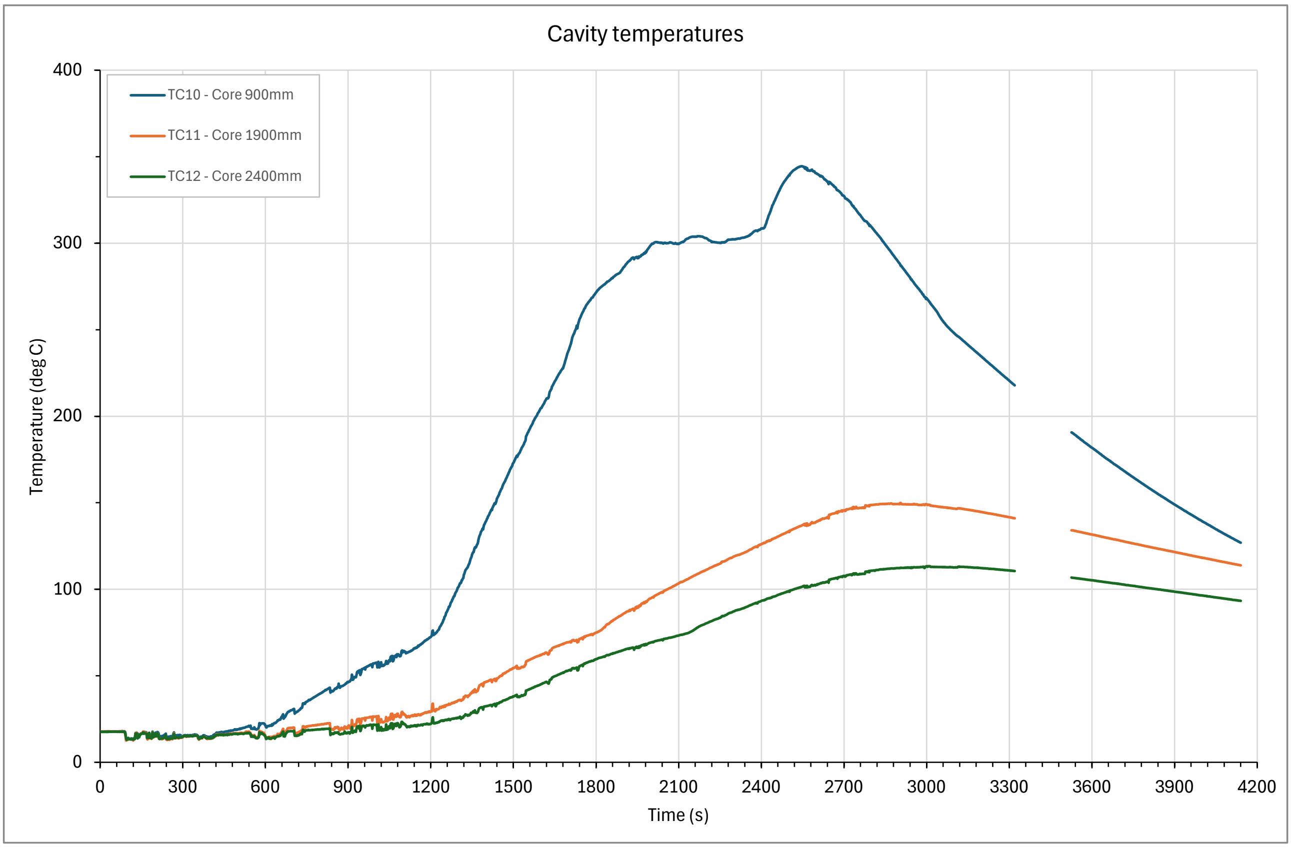


Figure 147. Test 10 – Temperatures within core at 900 mm (TC10), 1,900 mm (TC11), 2400 mm (TC12) above ground level

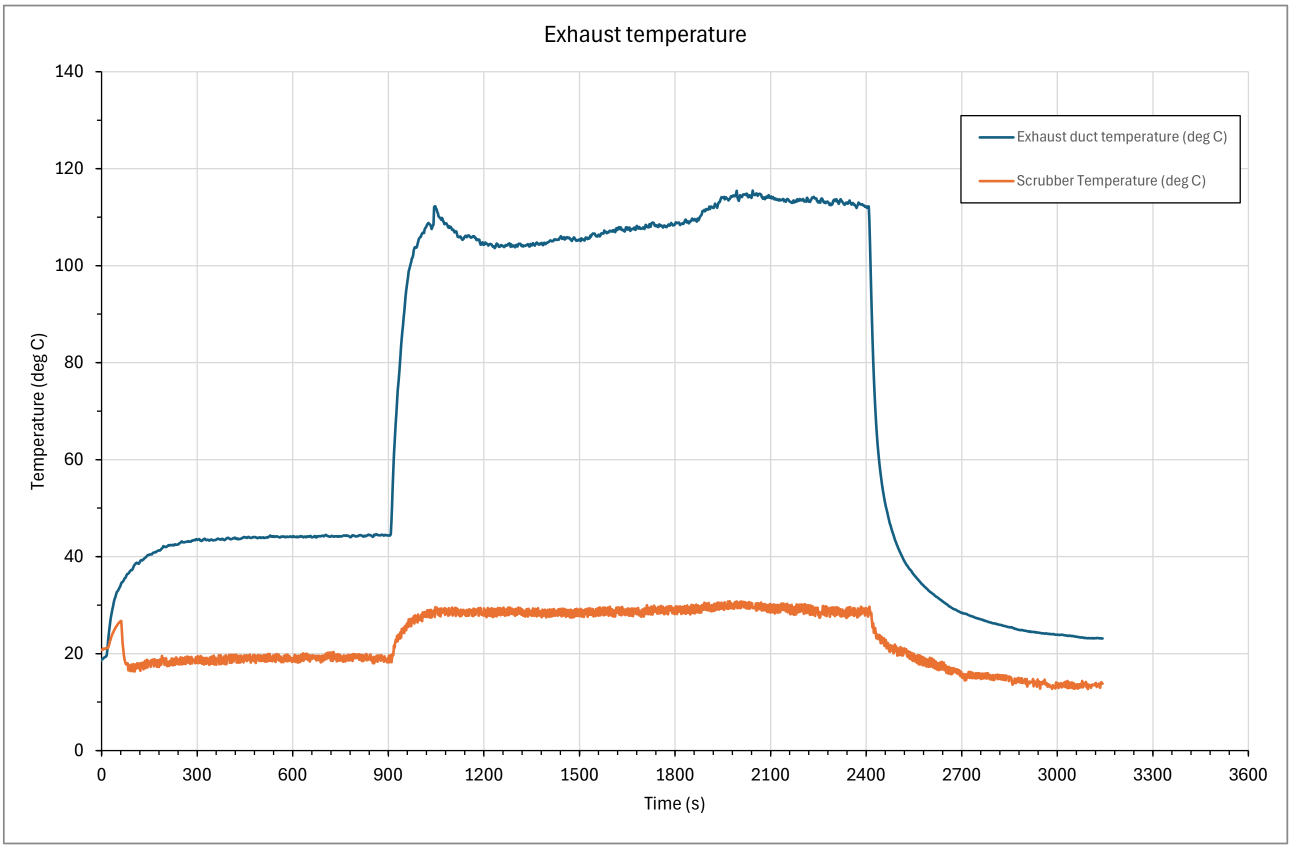


Figure 148. Test 11 – Test Hood exhaust temperatures

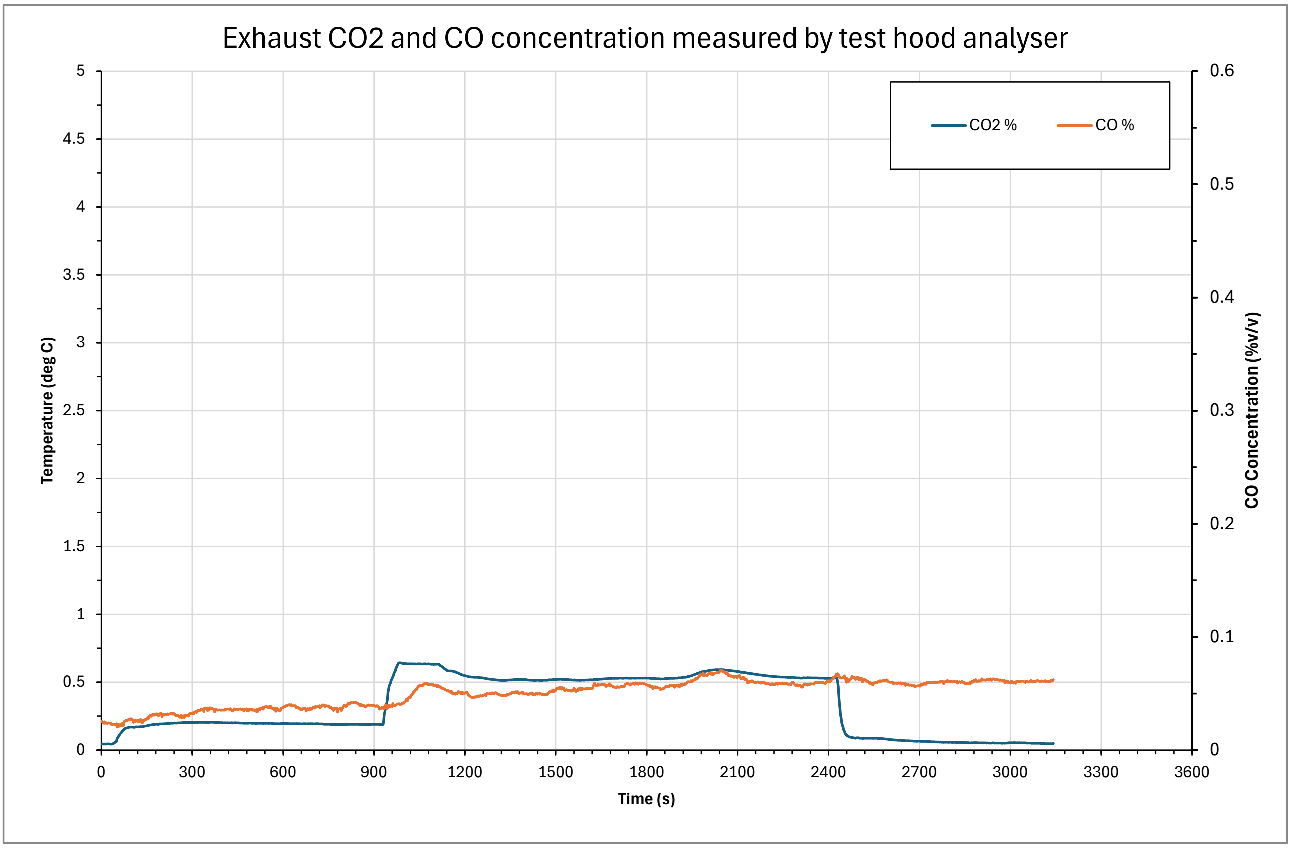


Figure 149. Test 11 – CO and CO2 concentration measured by test hood gas analyser

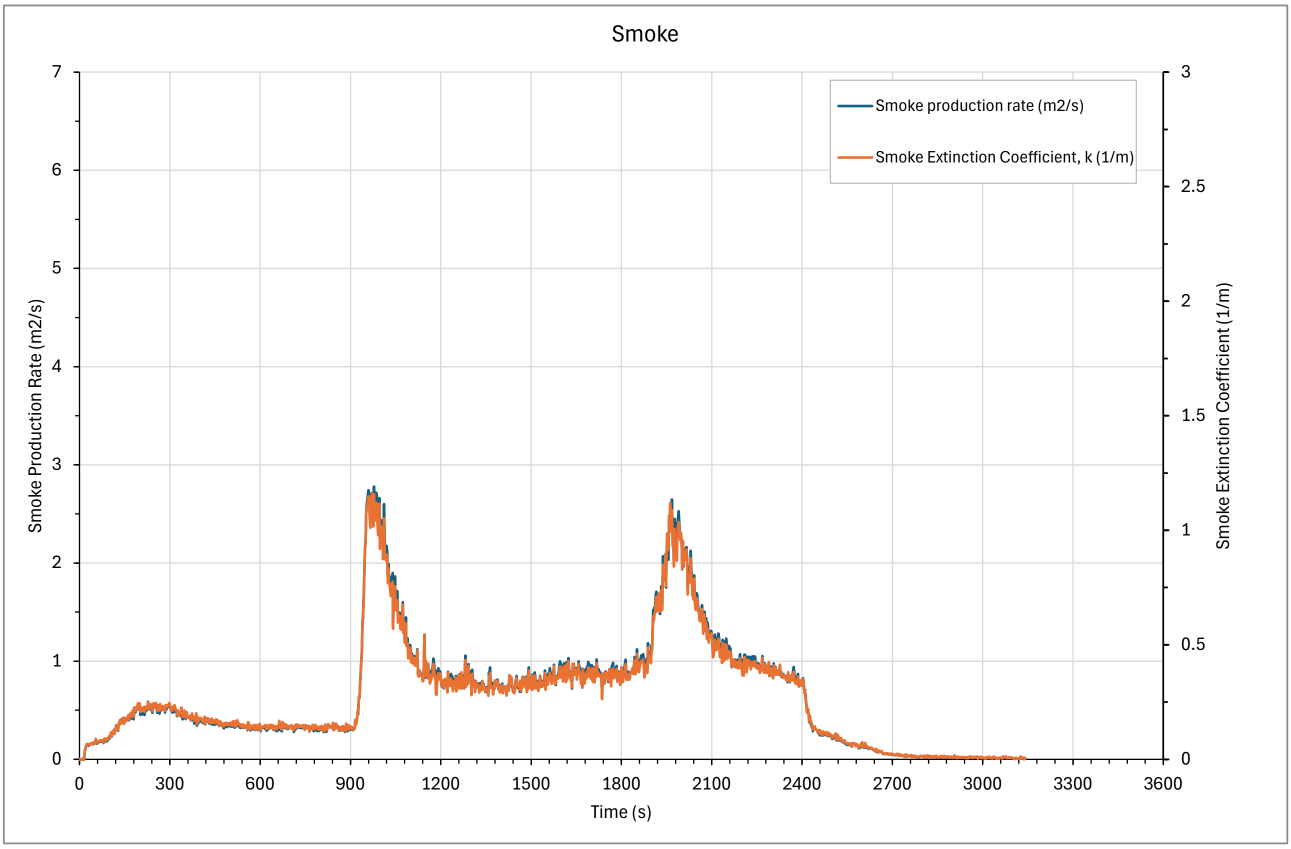


Figure 150. Test 11– Smoke production rate

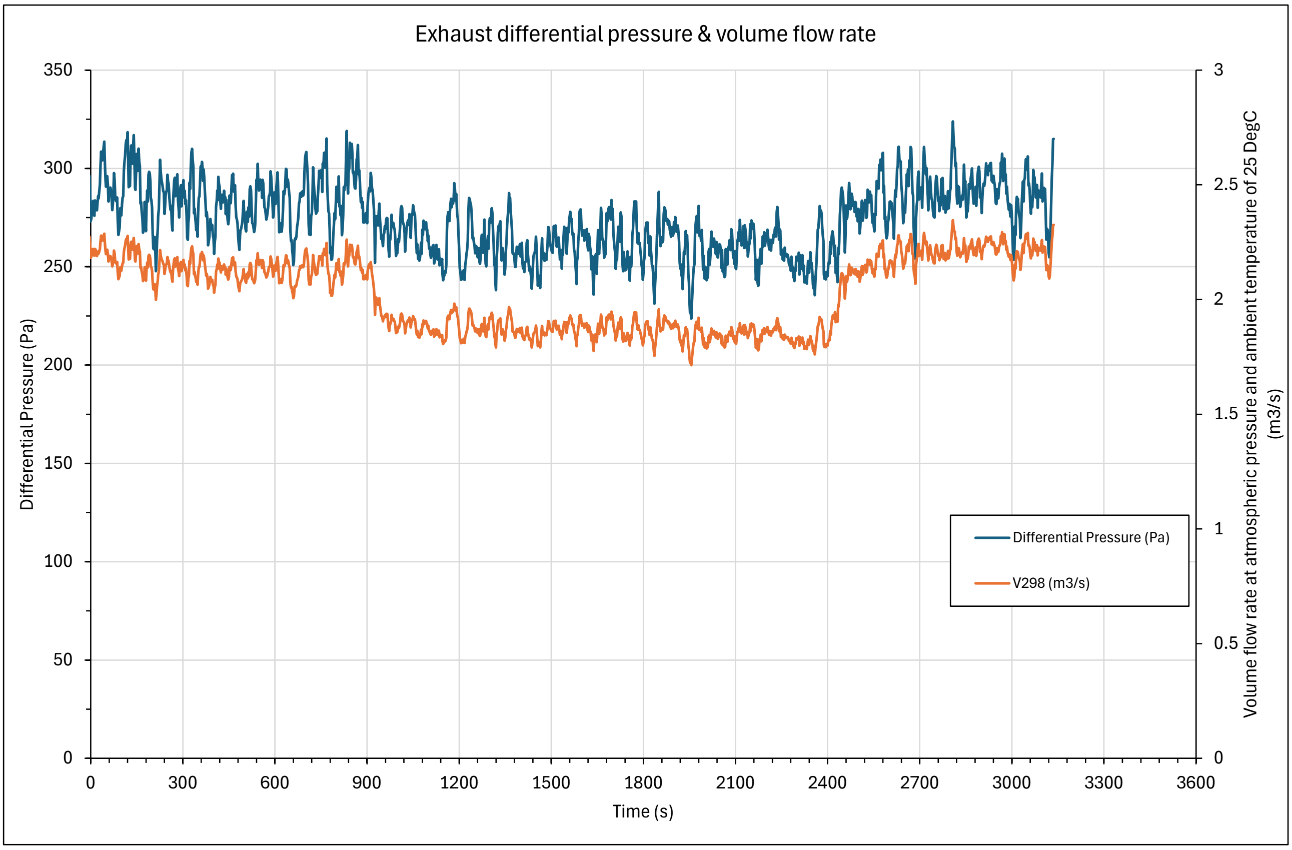


Figure 151. Test 11 – Test hood exhaust flow rate

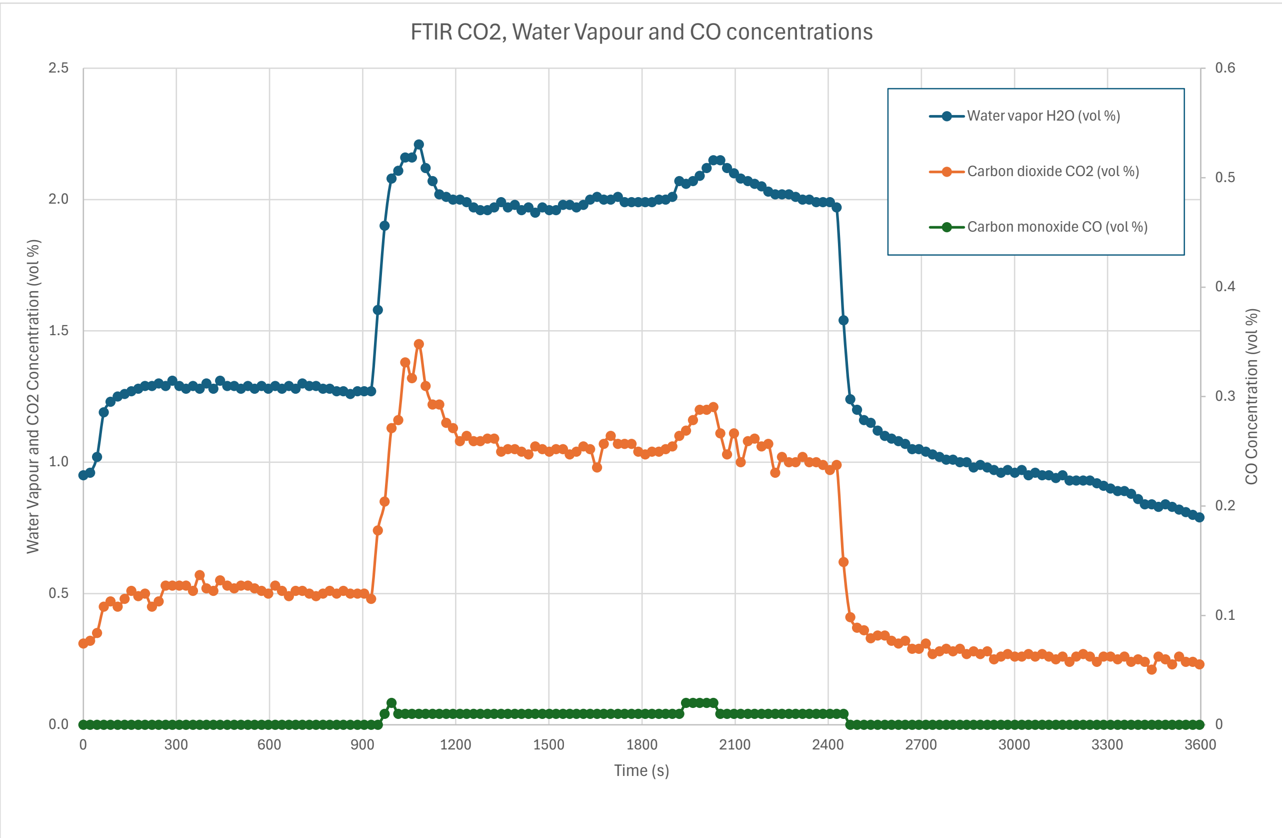


Figure 152. Test 11 – CO and CO2 concentration recorded by FTIR.

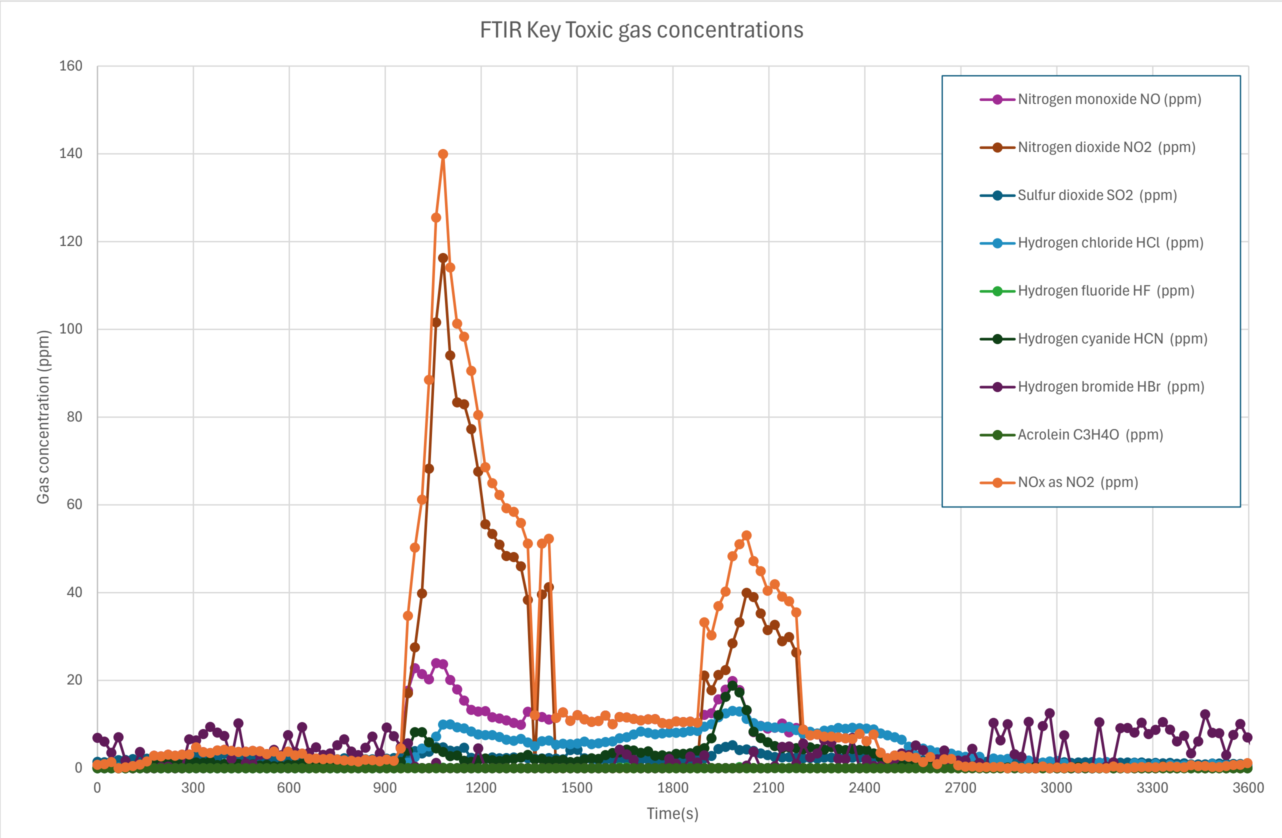


Figure 153. Test 11 – Key Toxic Species concentration recorded by FTIR.

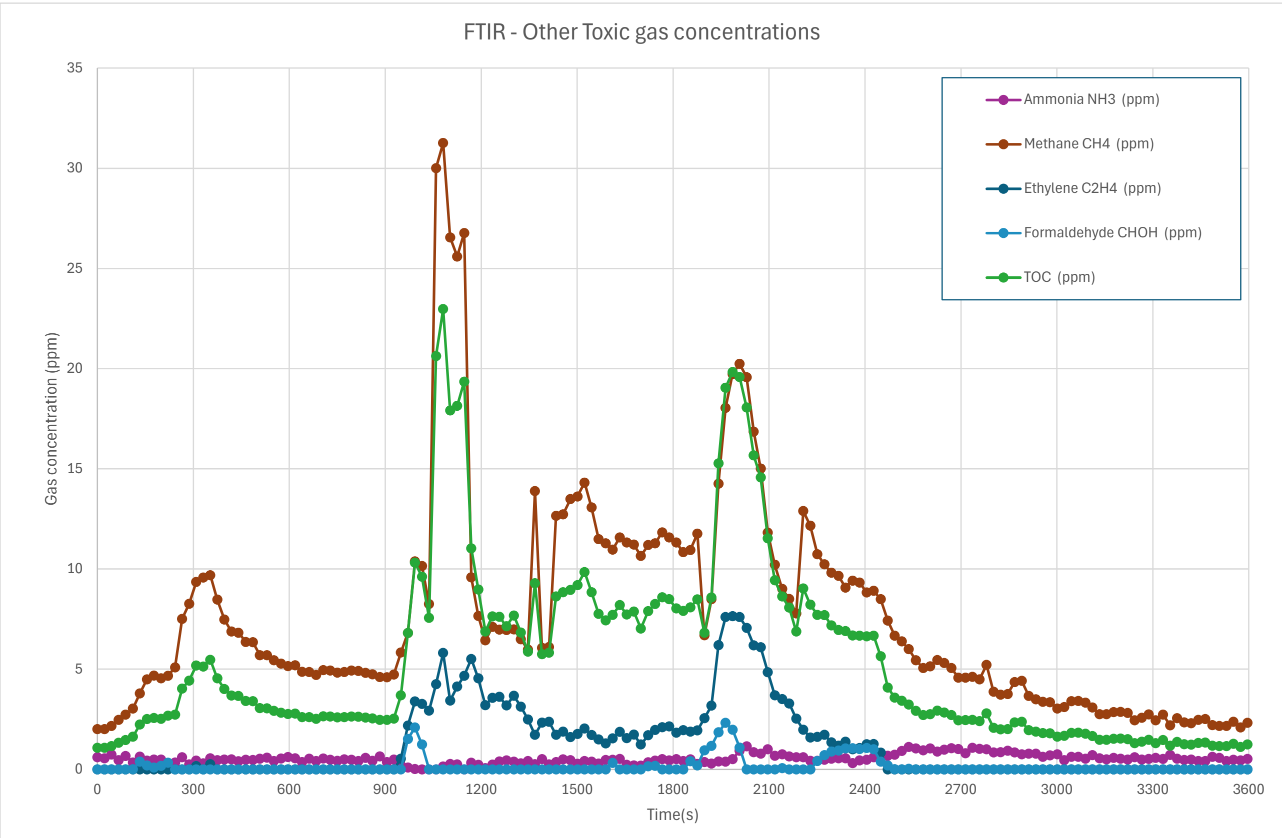


Figure 154. Test 11 – Other Toxic Species concentration recorded by FTIR.

B.15 Test 12 – ISP-02-EPS Horizontal with steel capping & internal joint flashing

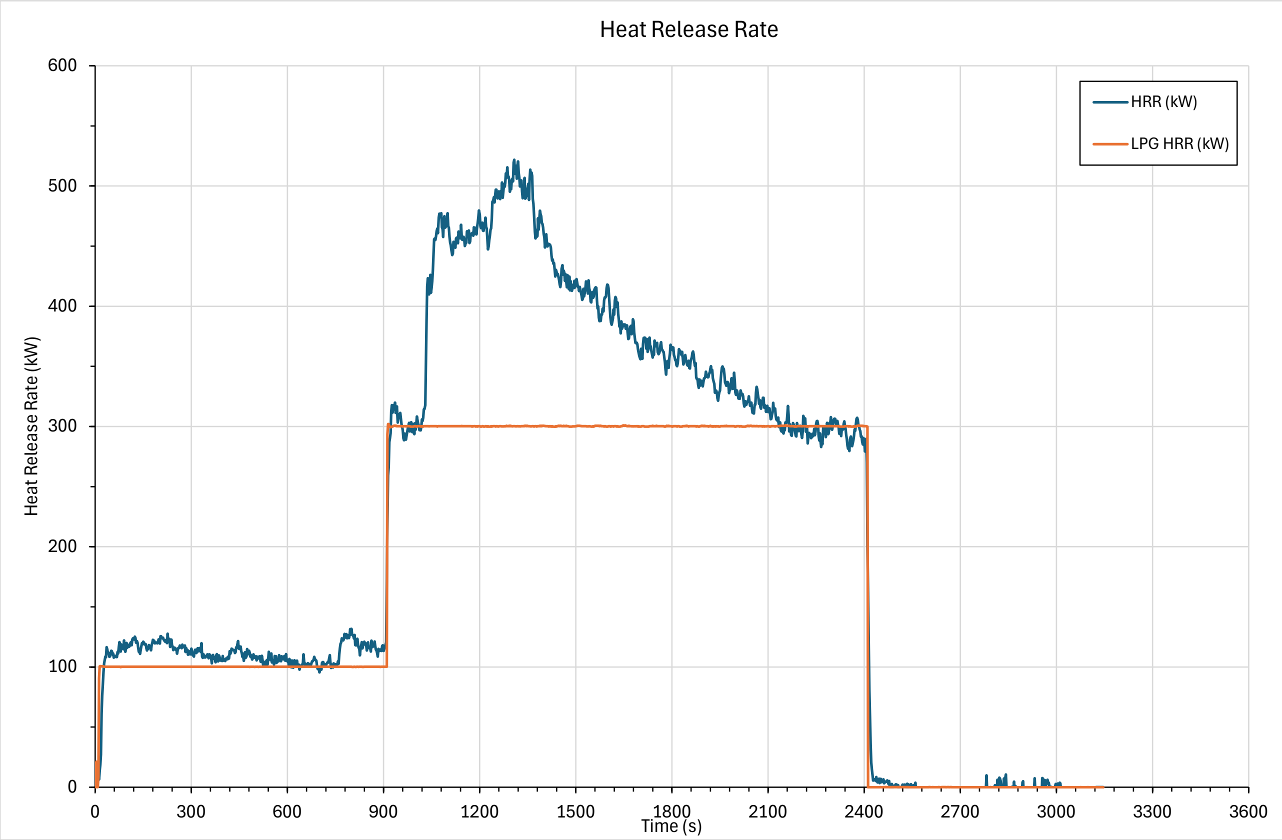


Figure 155. Test 12 – HRR (kW)

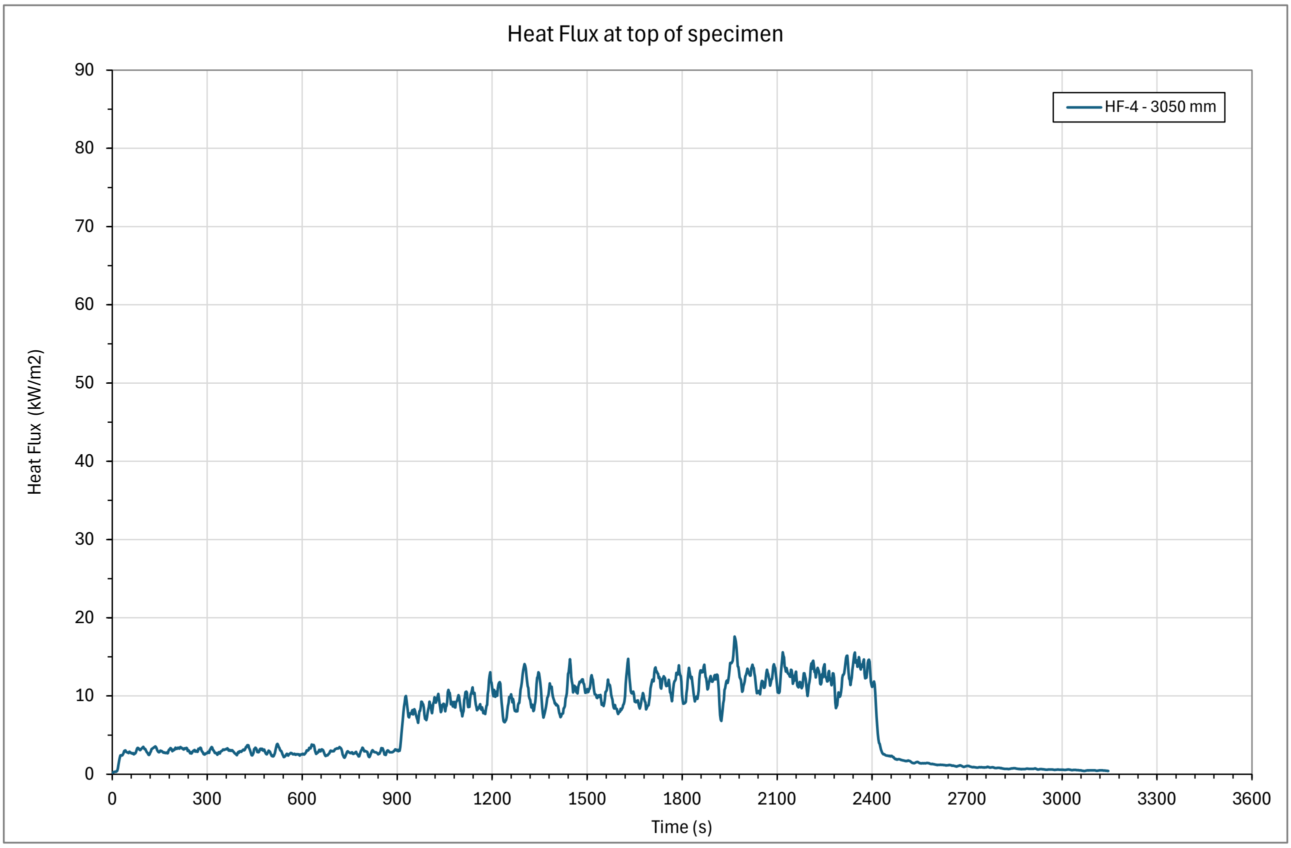


Figure 156. Test 12 – Heat flux (kW/m²) above 3050 mm from the ground level.

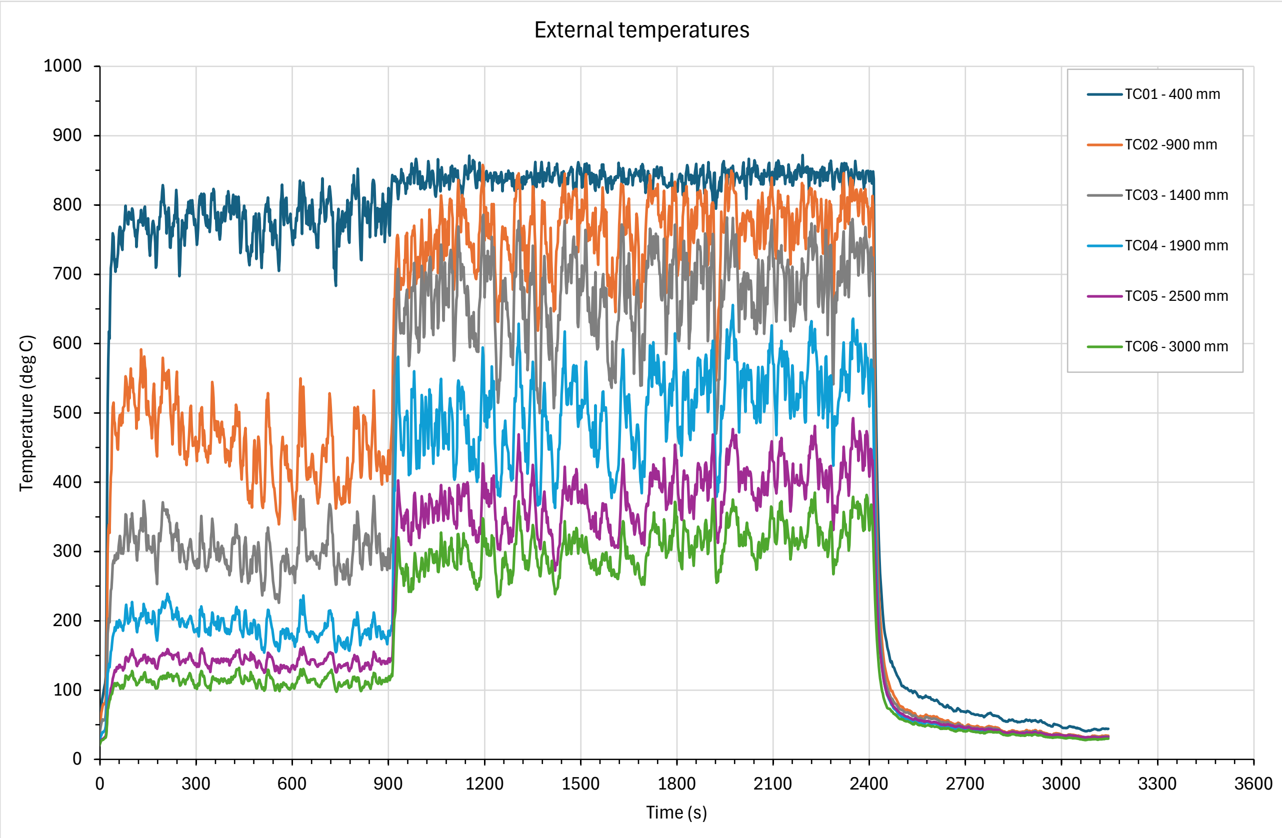


Figure 157. Test 12 – External face temperatures at various heights (TC01 to TC06).

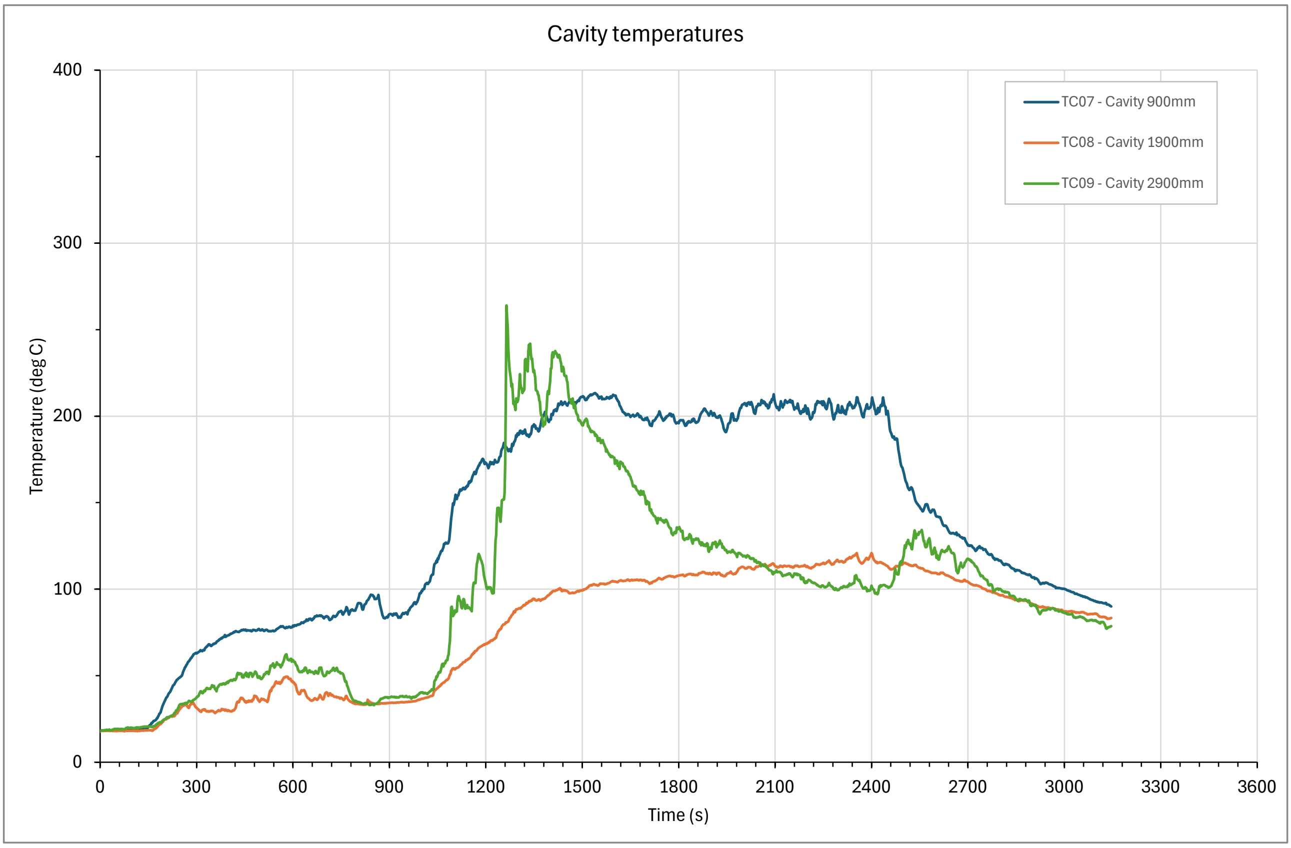


Figure 158. Test 12 – Temperatures within air cavity at 900 mm (TC07), 1,900 mm (TC08), 3,000 mm (TC09) above ground level

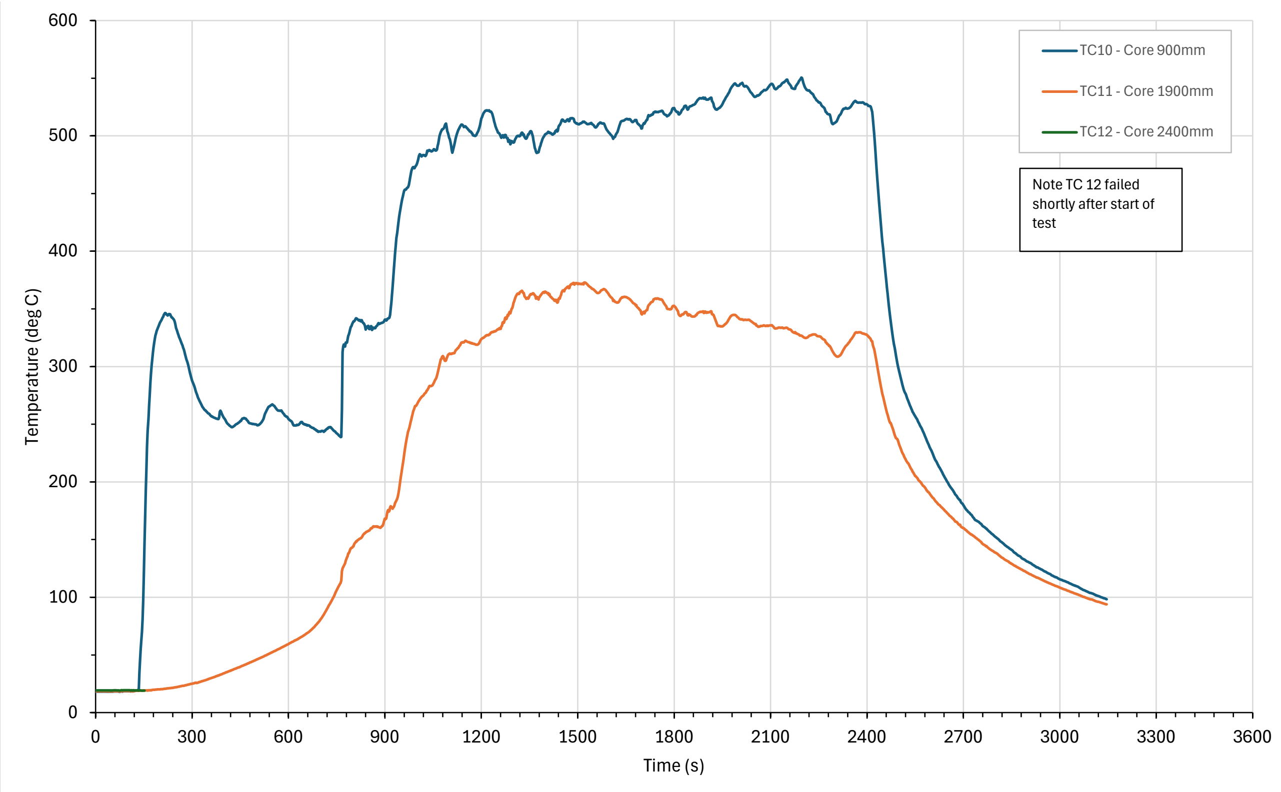


Figure 159. Test 12 – Temperatures within core at 900 mm (TC10), 1,900 mm (TC11), 2400 mm (TC12) above ground level. Note: TC 12 failed shortly after start of test.

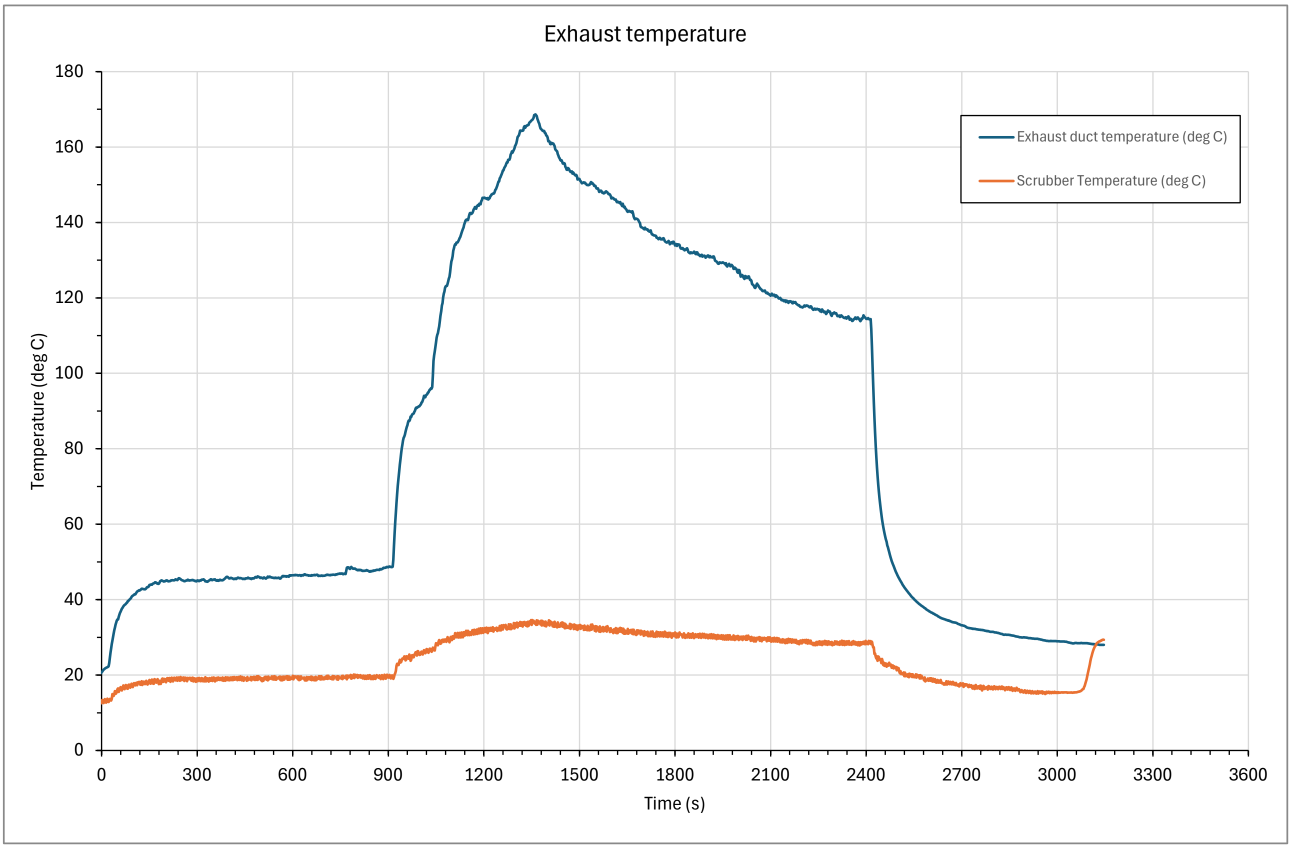


Figure 160. Test 12 – Test Hood exhaust temperatures

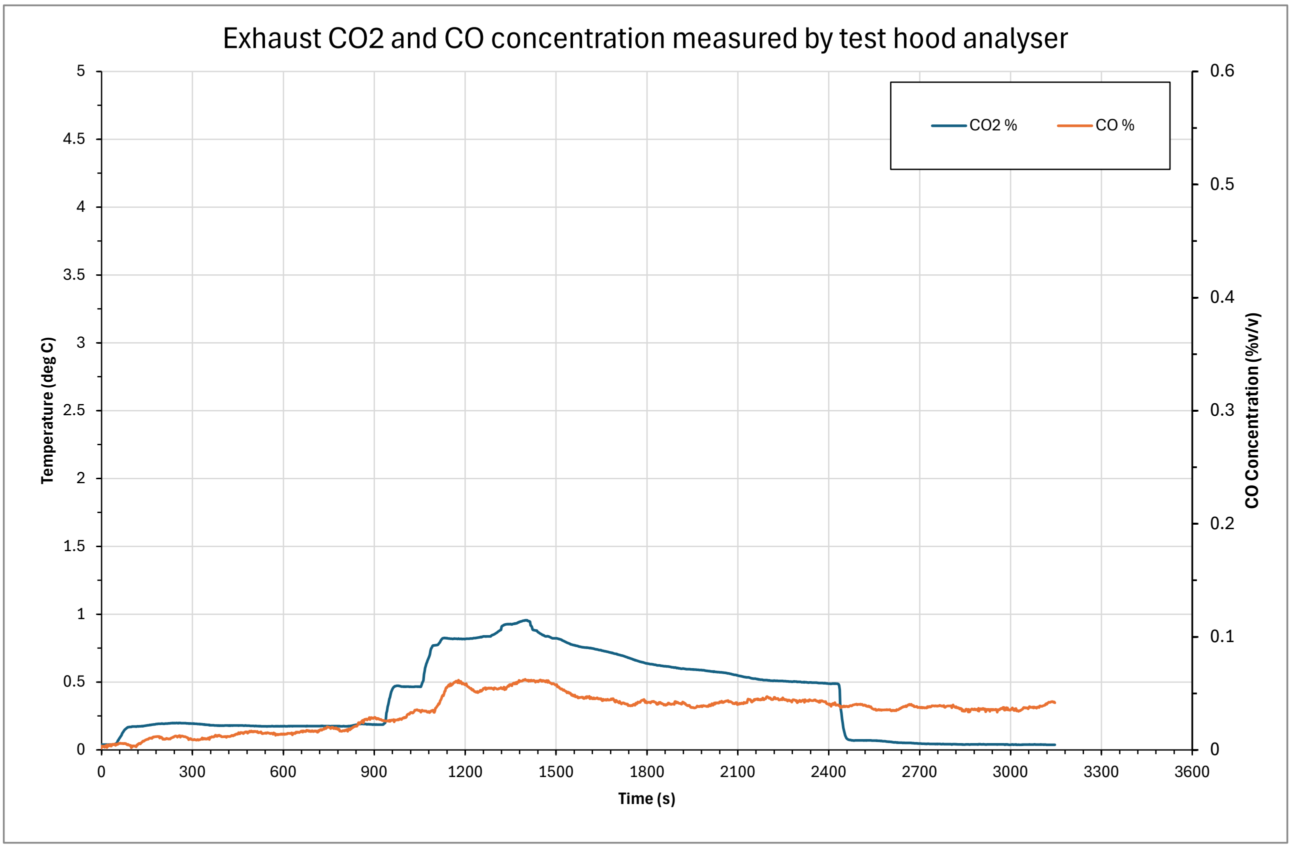


Figure 161. Test 12 – CO and CO2 concentration measured by test hood gas analyser

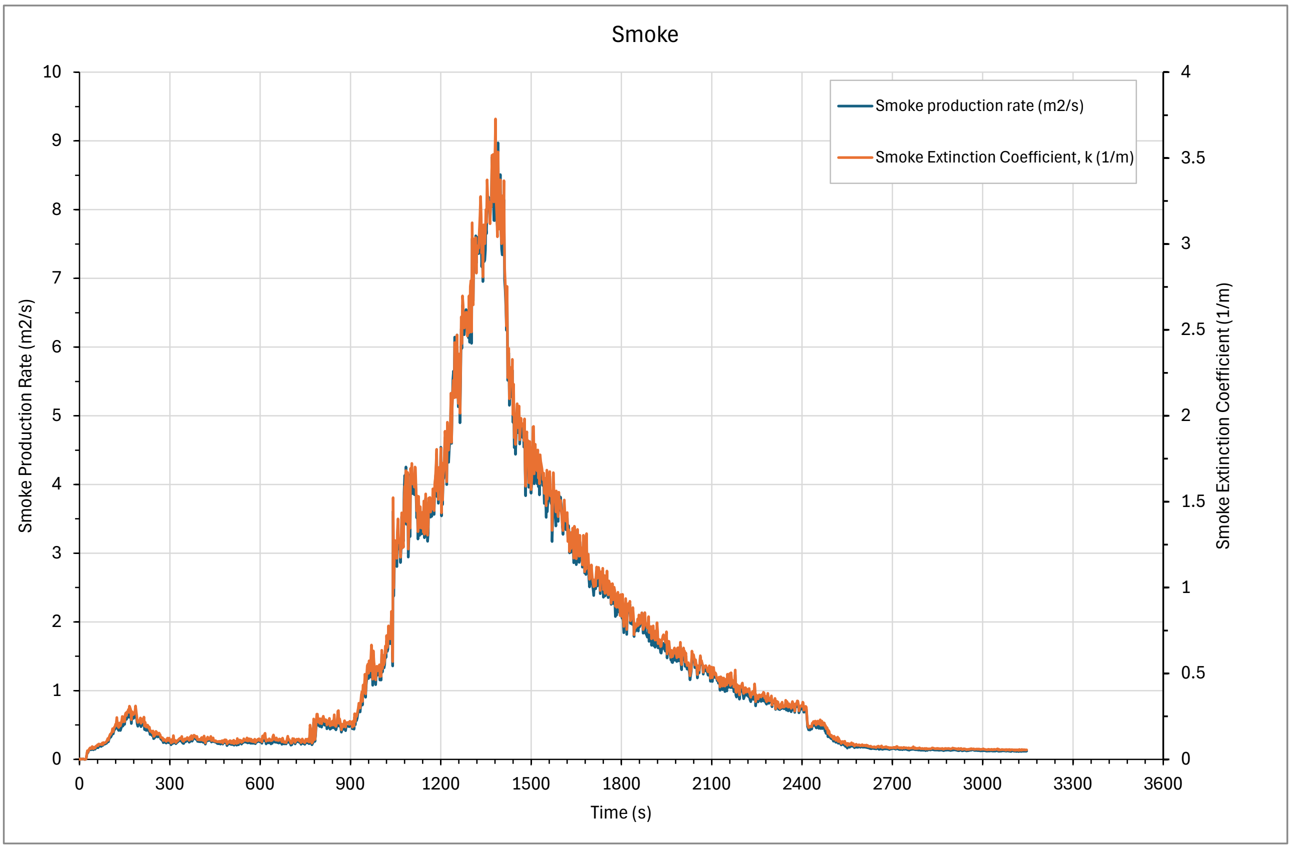


Figure 162. Test 12– Smoke production rate

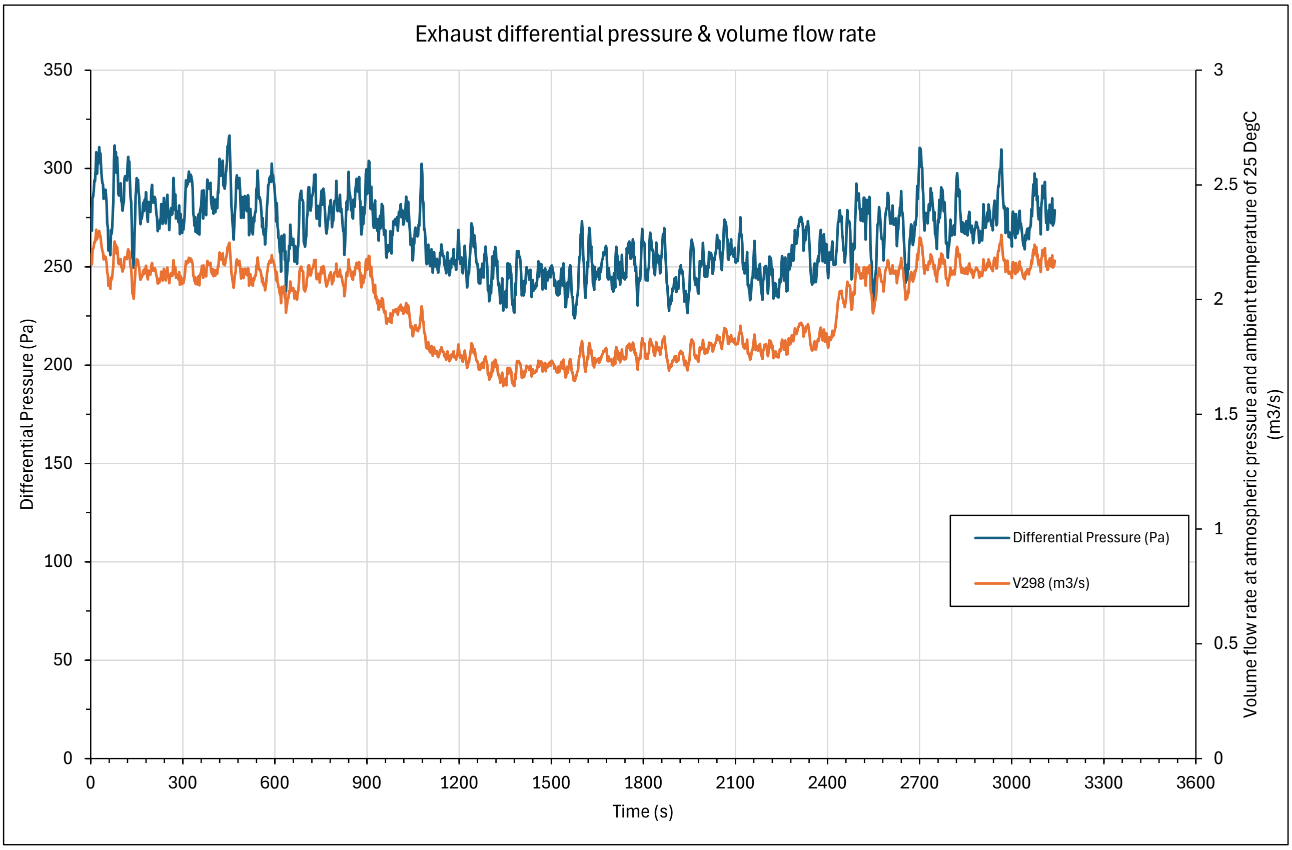


Figure 163. Test 12 – Test hood exhaust flow rate

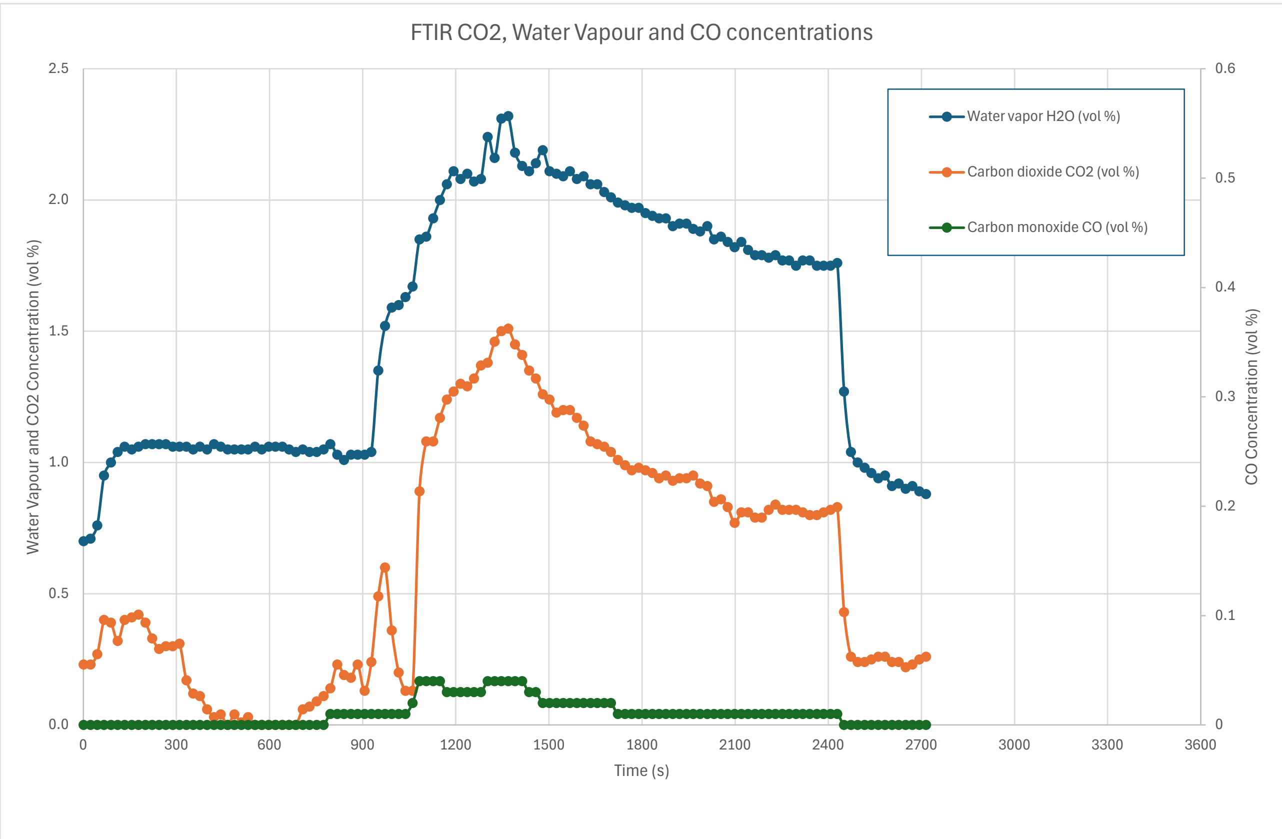


Figure 164. Test 12 – CO and CO2 concentration recorded by FTIR.

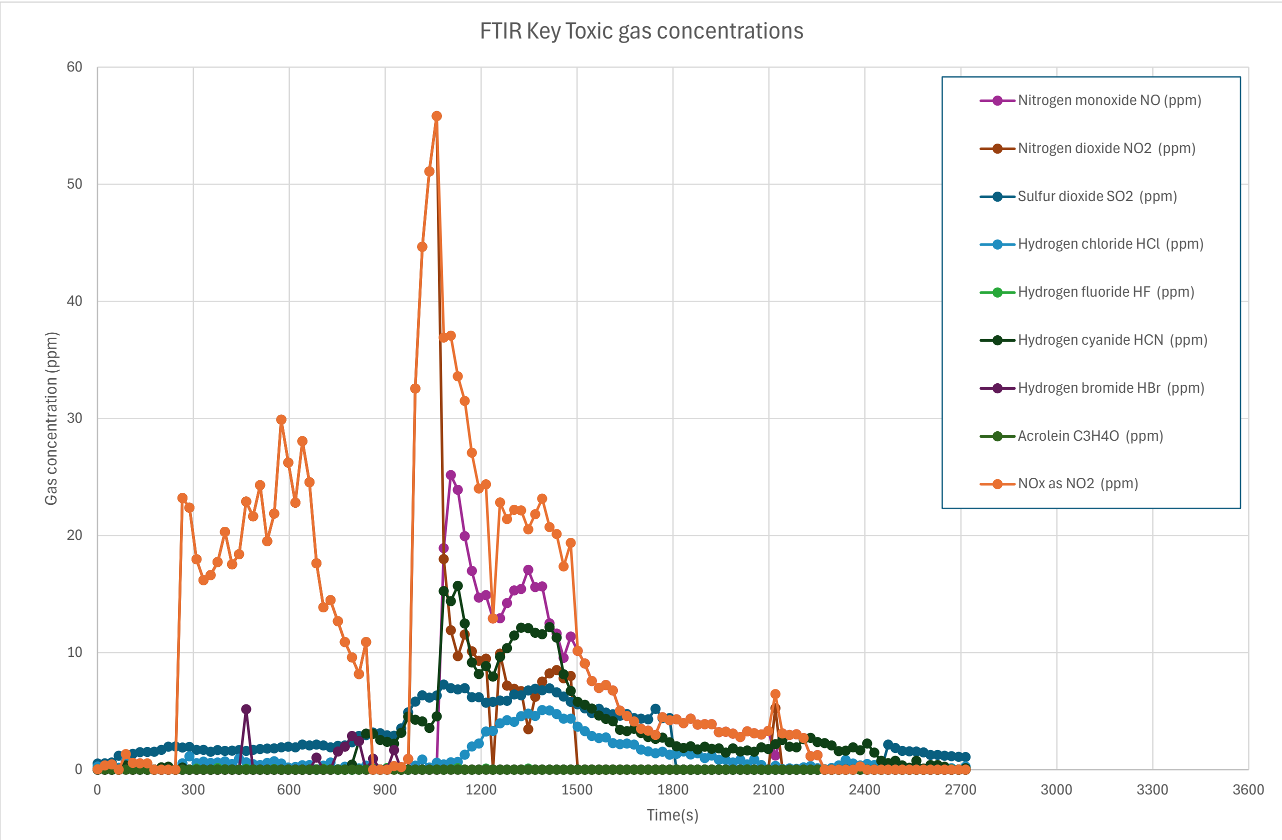


Figure 165. Test 12 – Key Toxic Species concentration recorded by FTIR.

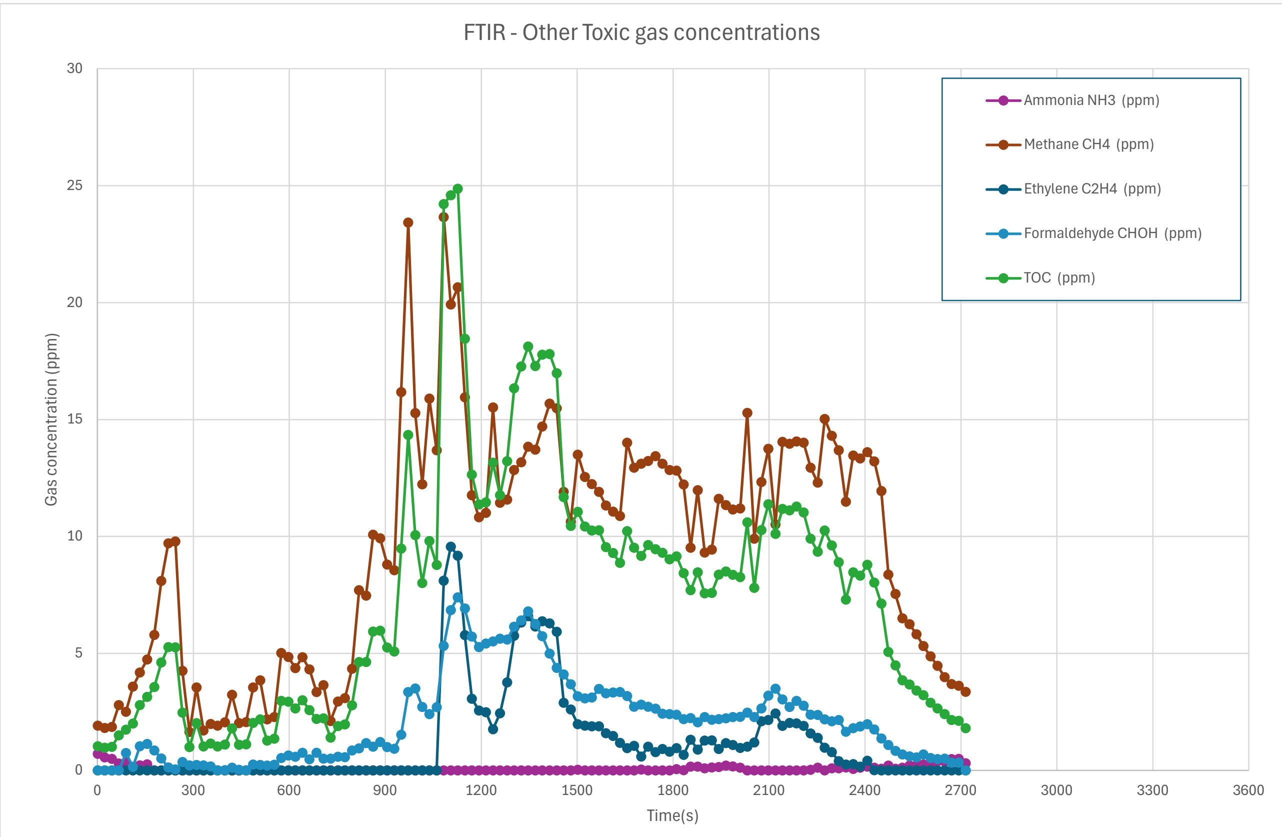


Figure 166. Test 12 – Other Toxic Species concentration recorded by FTIR.

B.16 Test 13 – ISP-01-PIR Horizontal with steel capping & internal joint flashing

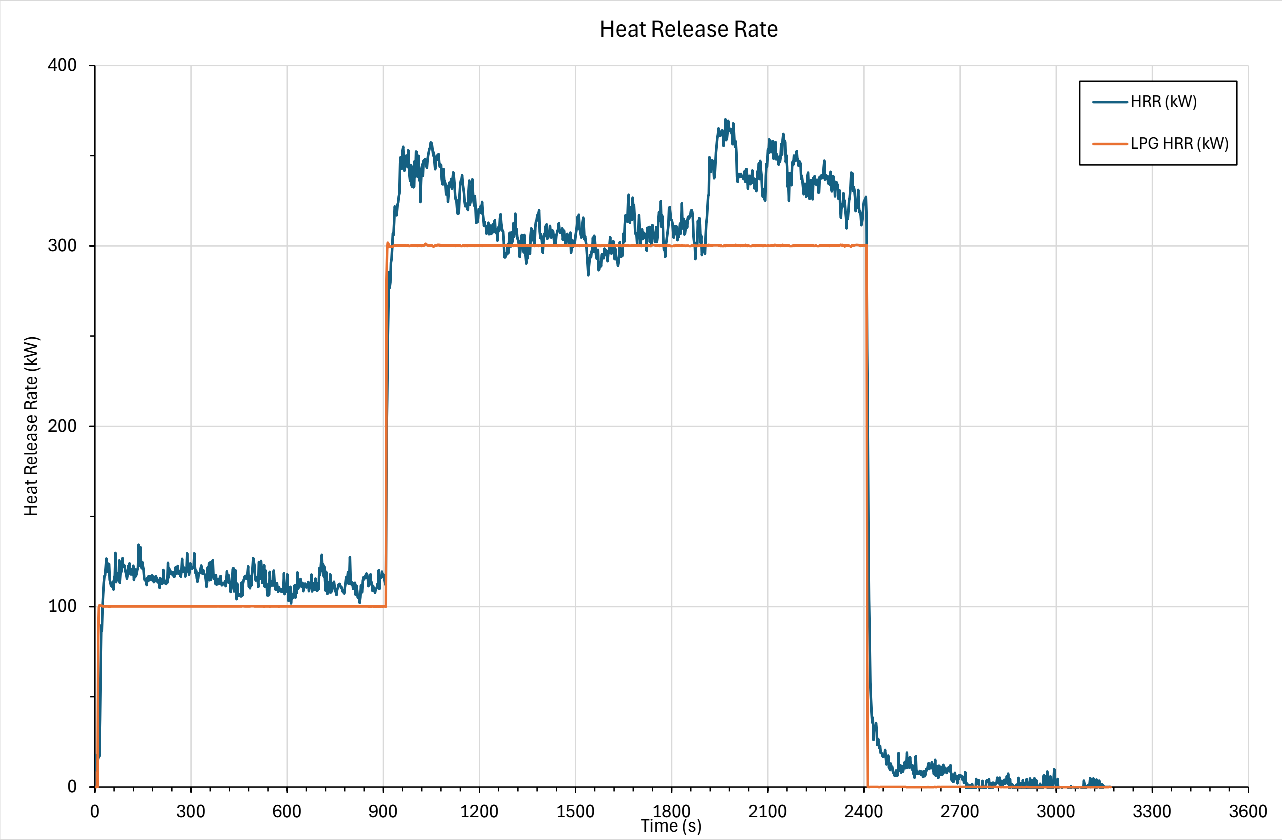


Figure 167. Test 12 – HRR (kW)

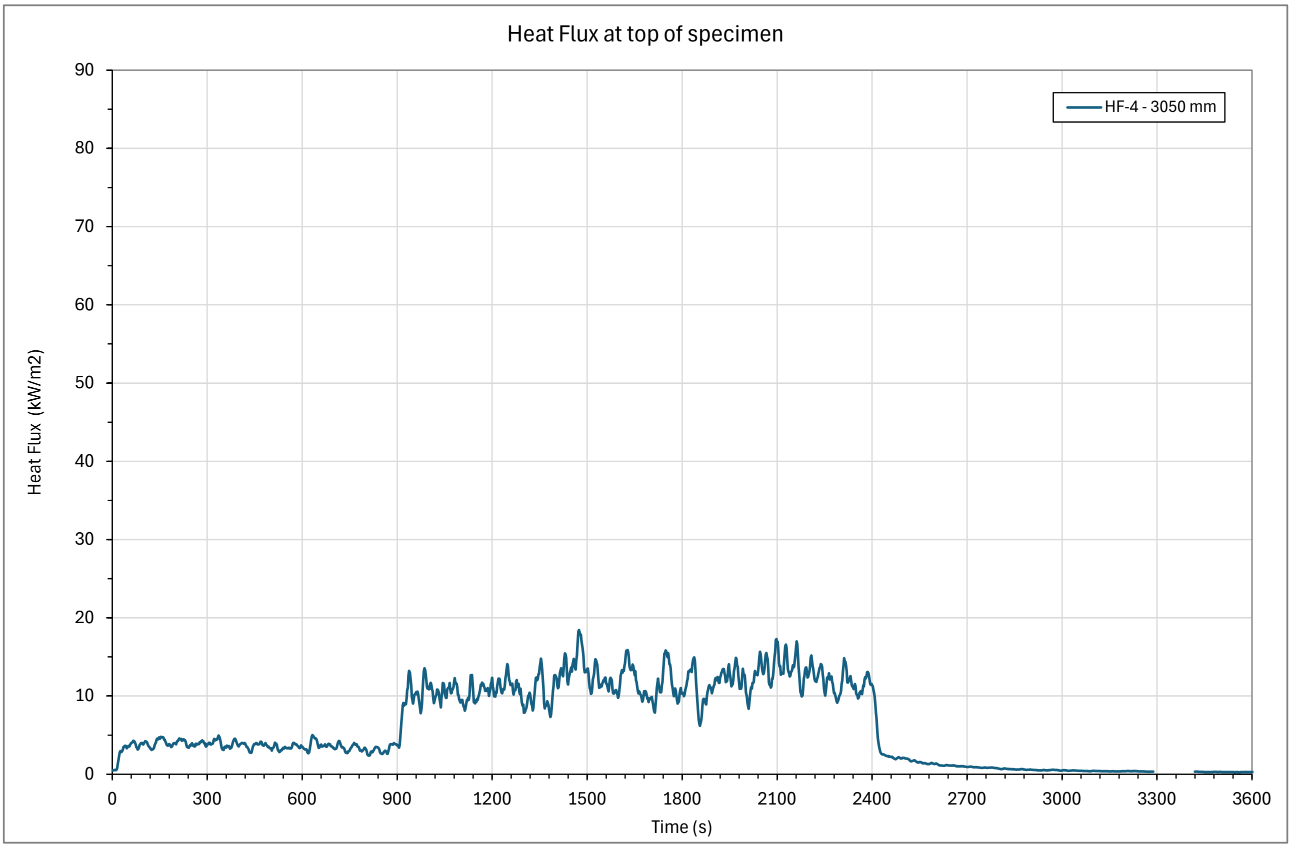


Figure 168. Test 12 – Heat flux (kW/m^2) above 3050 mm from the ground level.

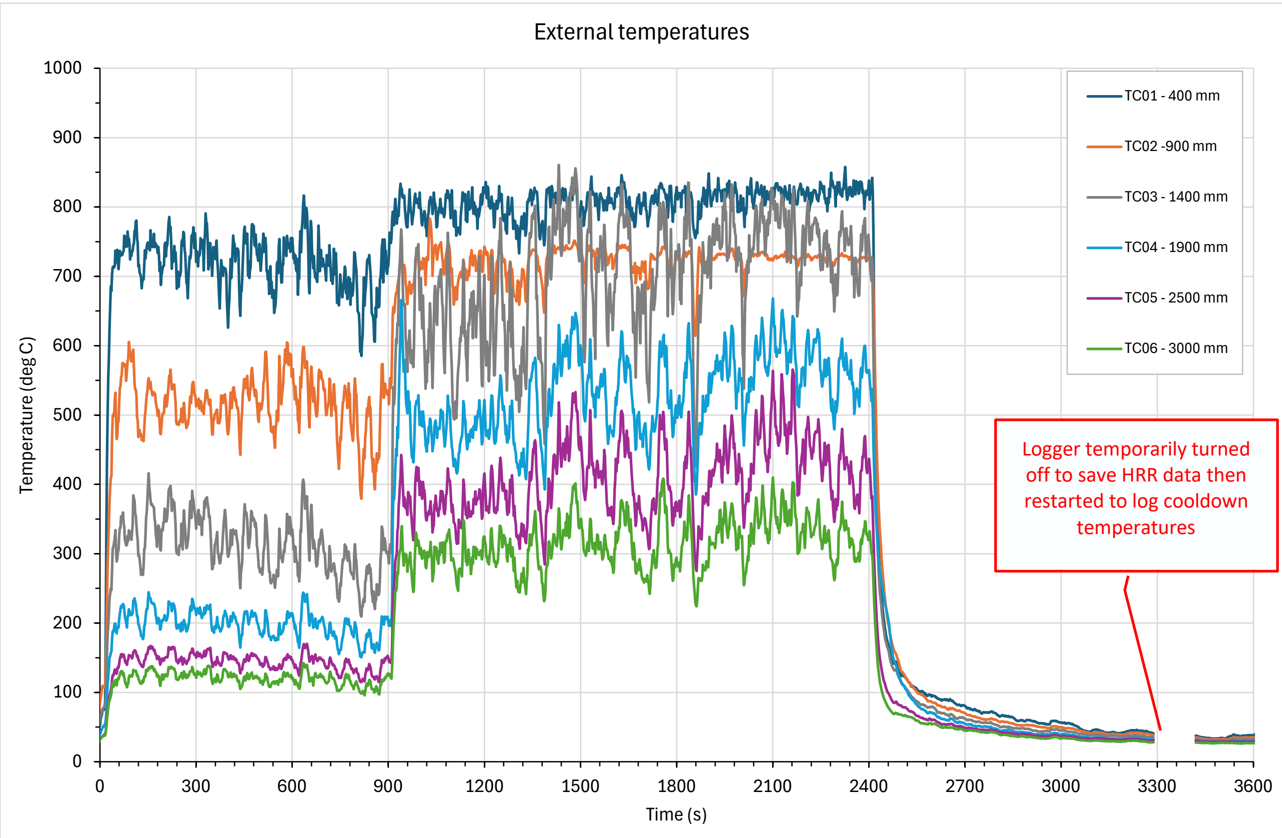


Figure 169. Test 12 – External face temperatures at various heights (TC01 to TC06).

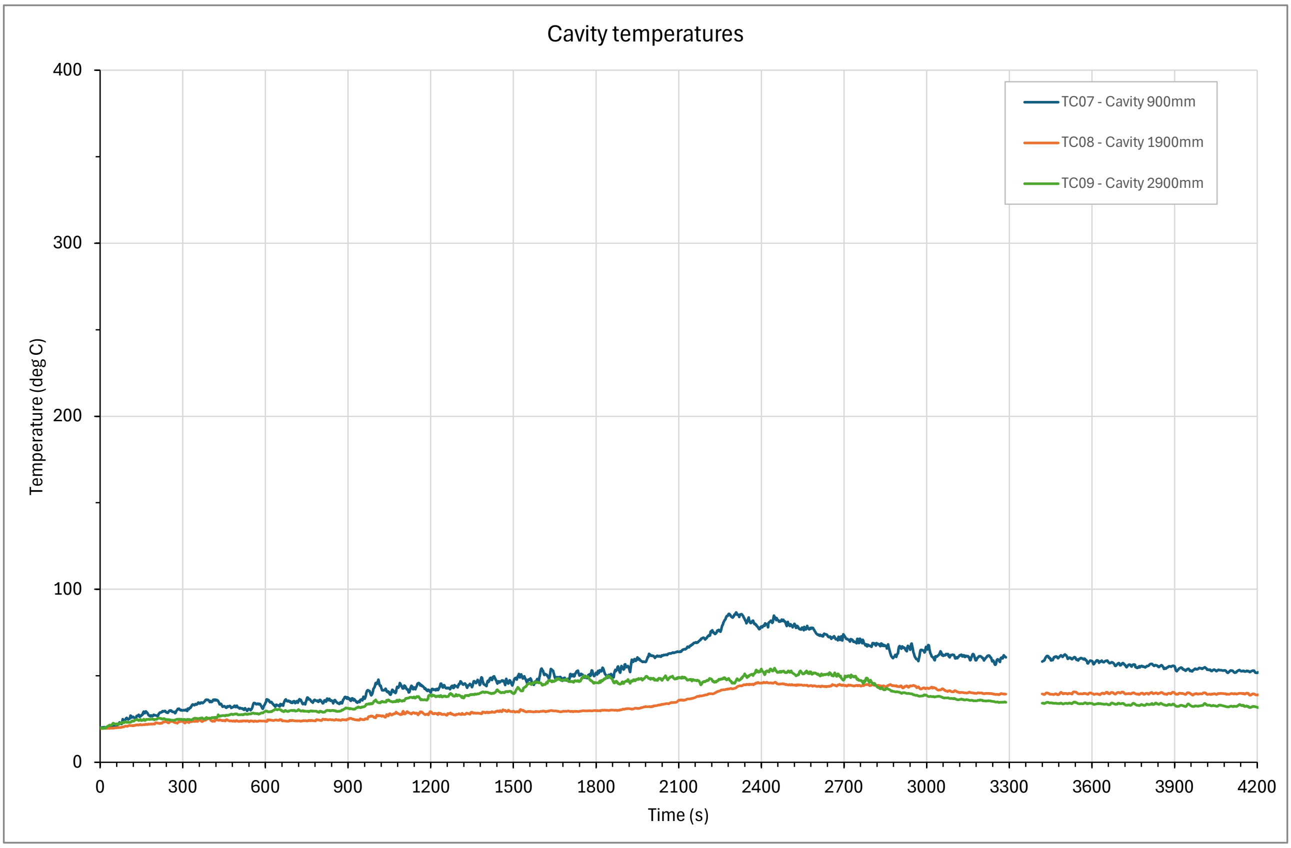


Figure 170. Test 12 – Temperatures within air cavity at 900 mm (TC07), 1,900 mm (TC08), 3,000 mm (TC09) above ground level

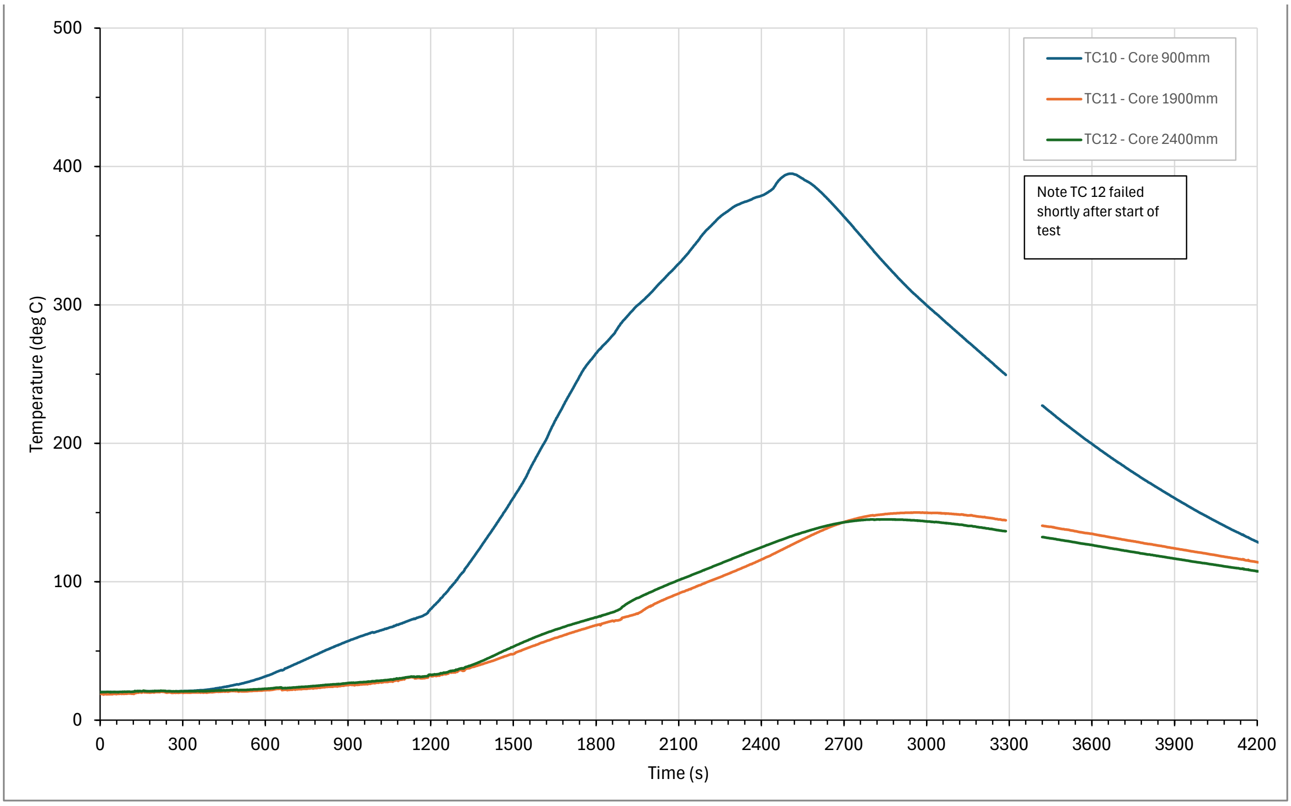


Figure 171. Test 12 – Temperatures within core at 900 mm (TC10), 1,900 mm (TC11), 2400 mm (TC12) above ground level. Note: TC 12 failed shortly after start of test.

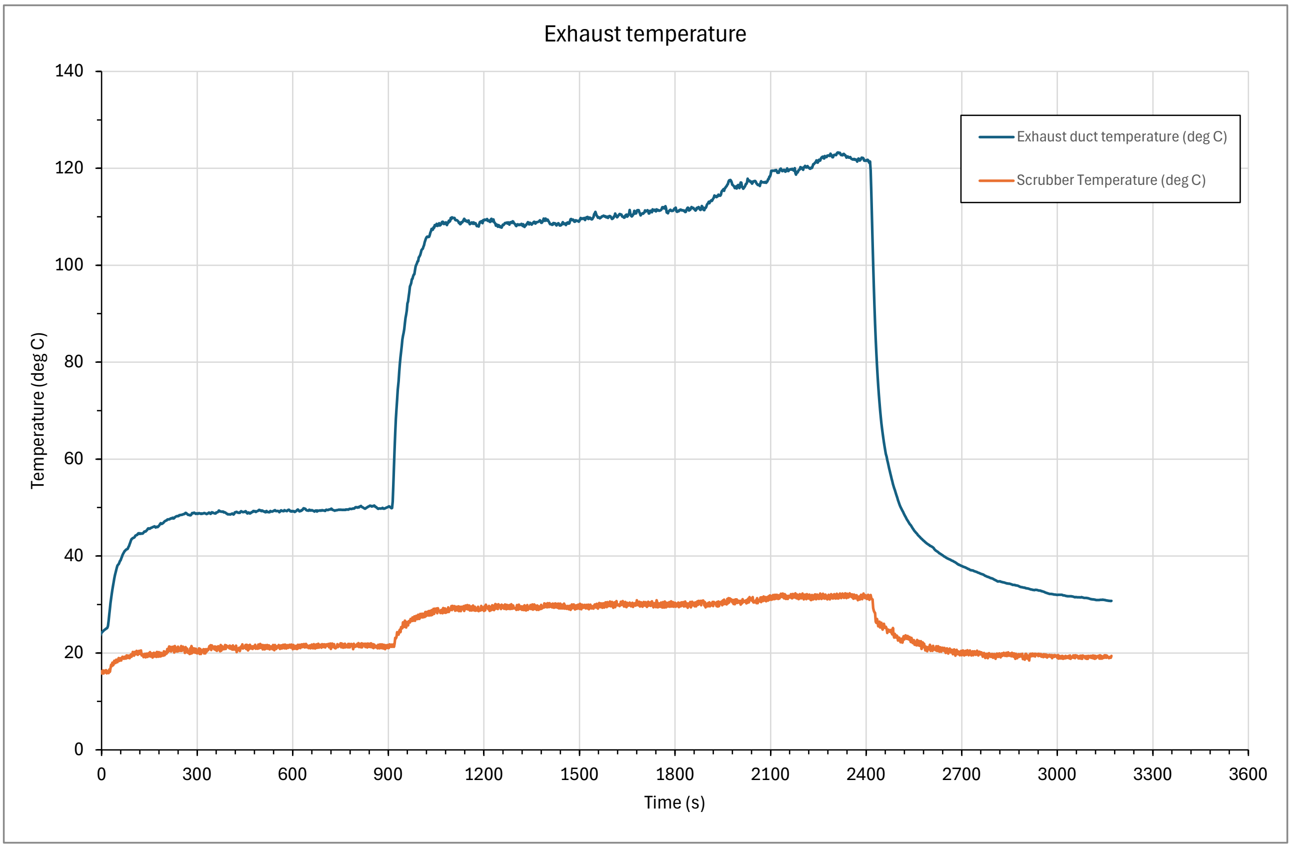


Figure 172. Test 12 – Test Hood exhaust temperatures

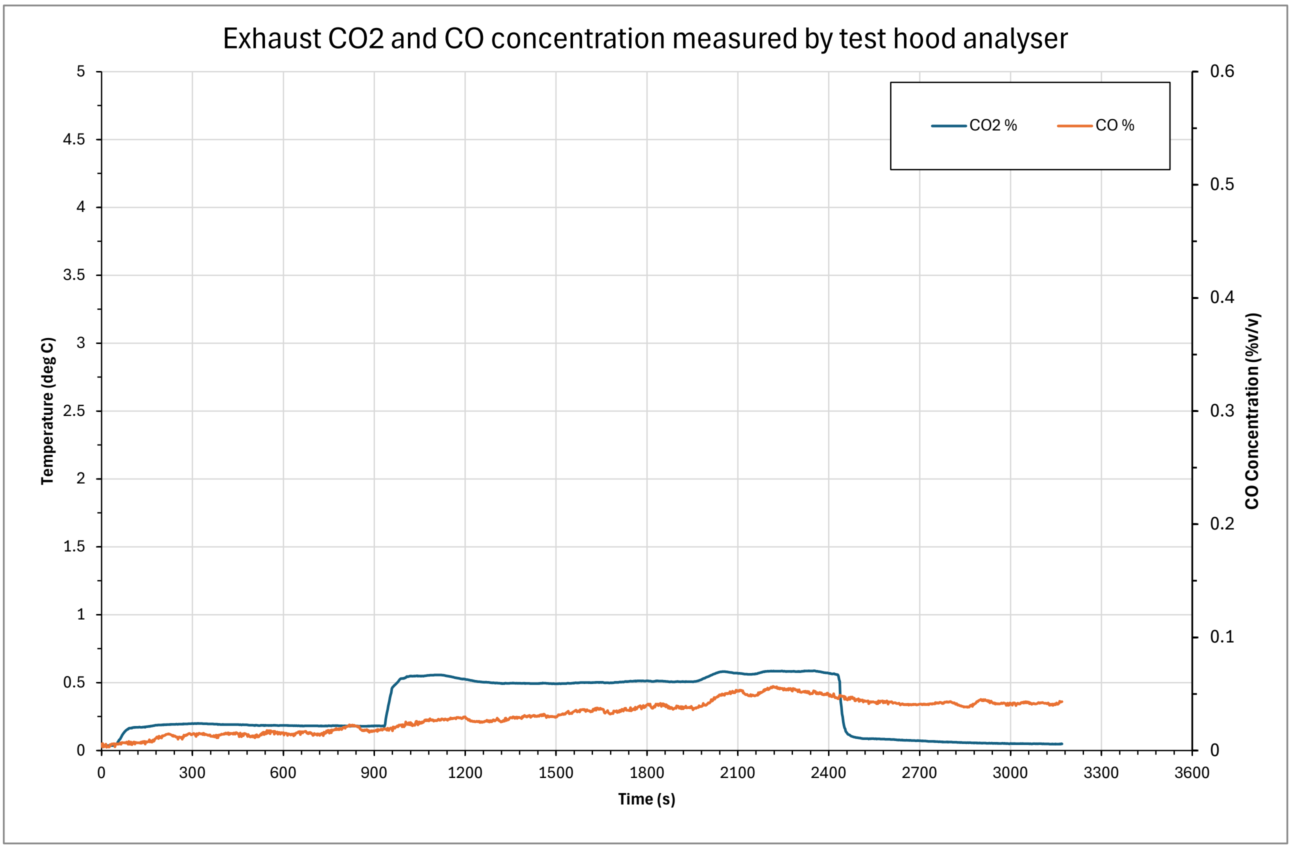


Figure 173. Test 12 – CO and CO2 concentration measured by test hood gas analyser

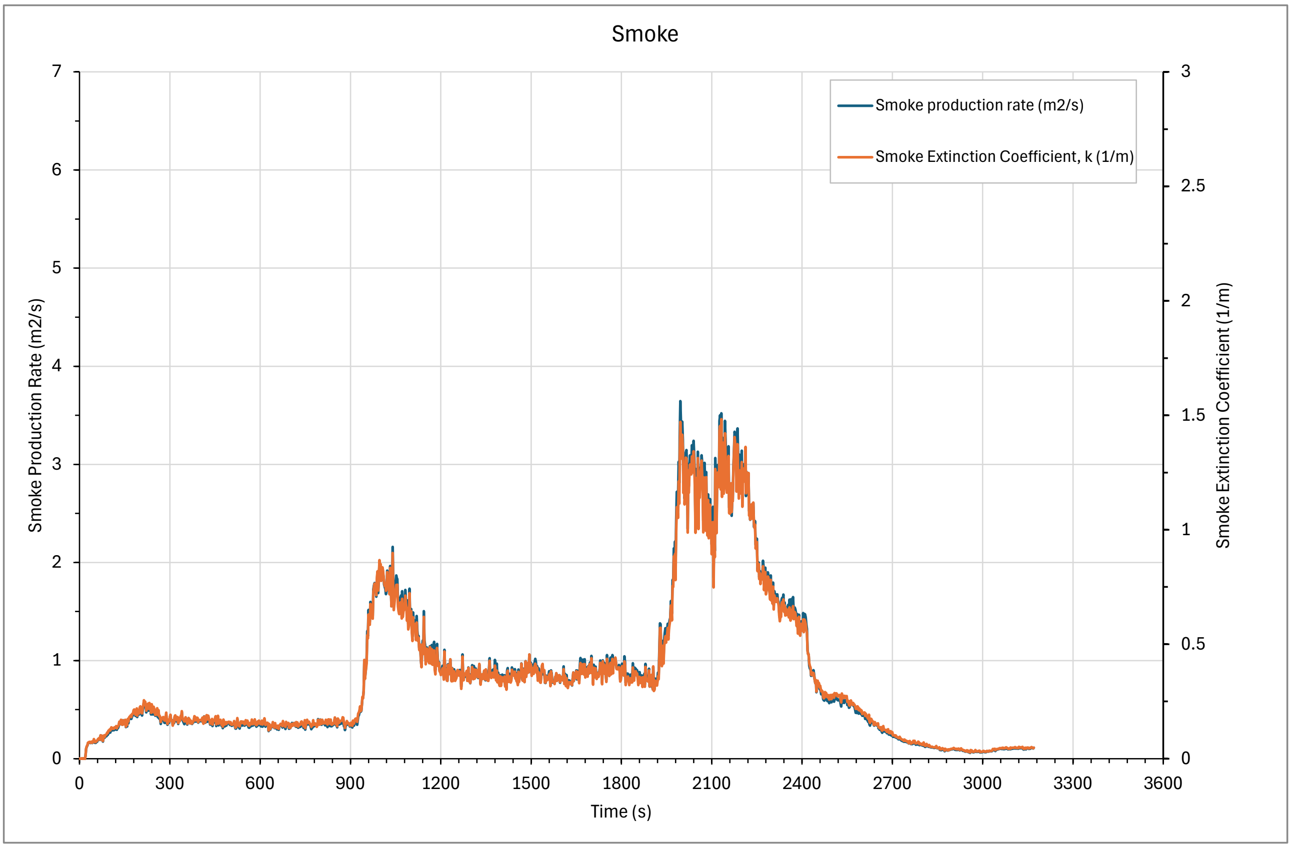


Figure 174. Test 12– Smoke production rate

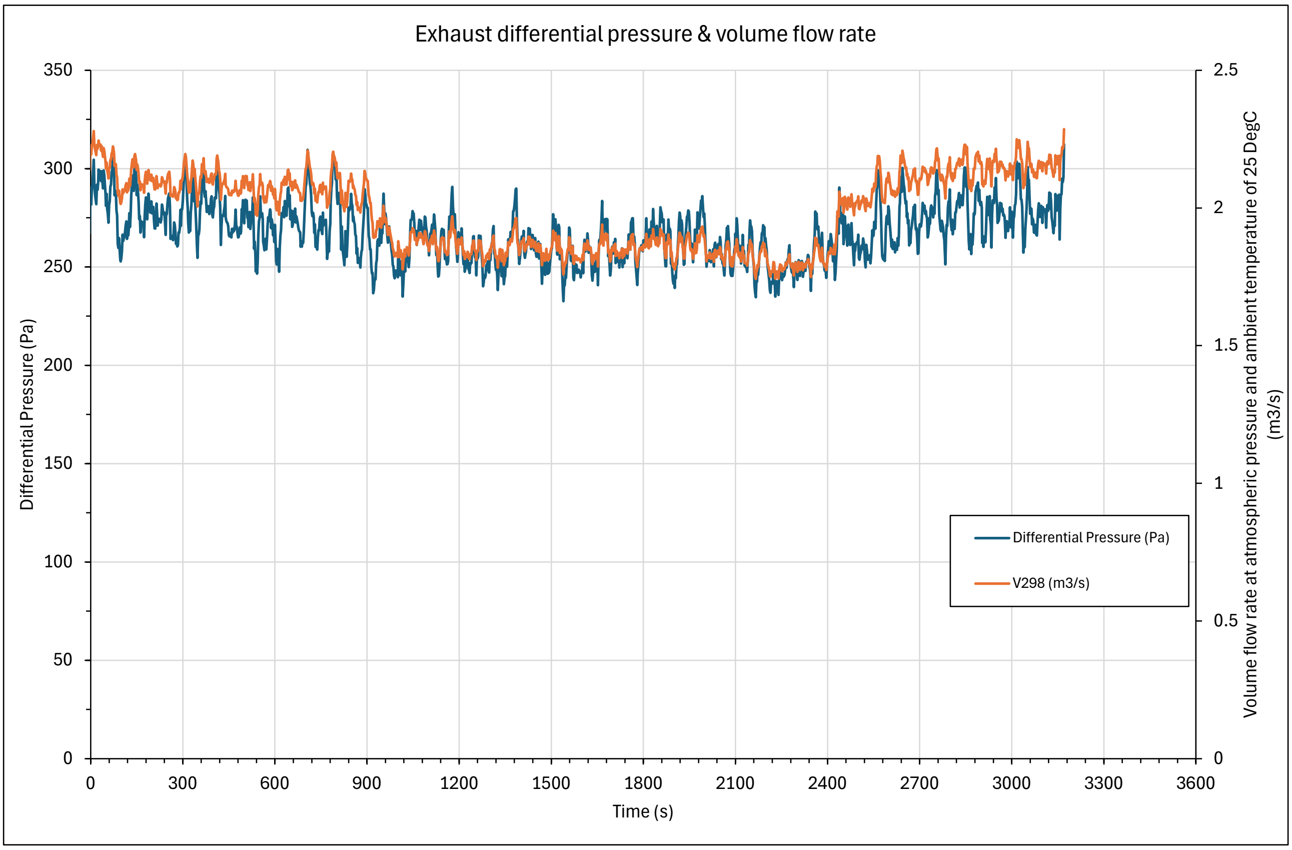


Figure 175. Test 12 – Test hood exhaust flow rate

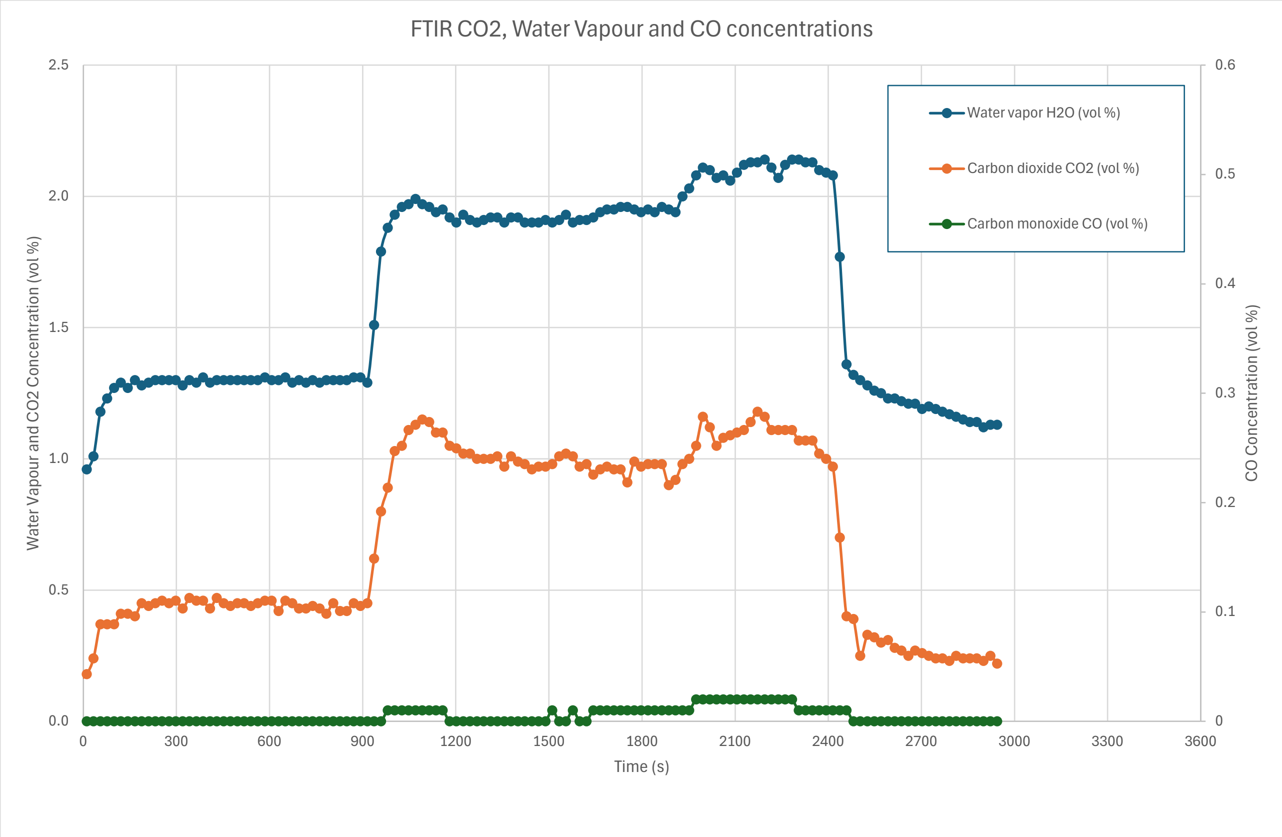


Figure 176. Test 12 – CO and CO2 concentration recorded by FTIR.

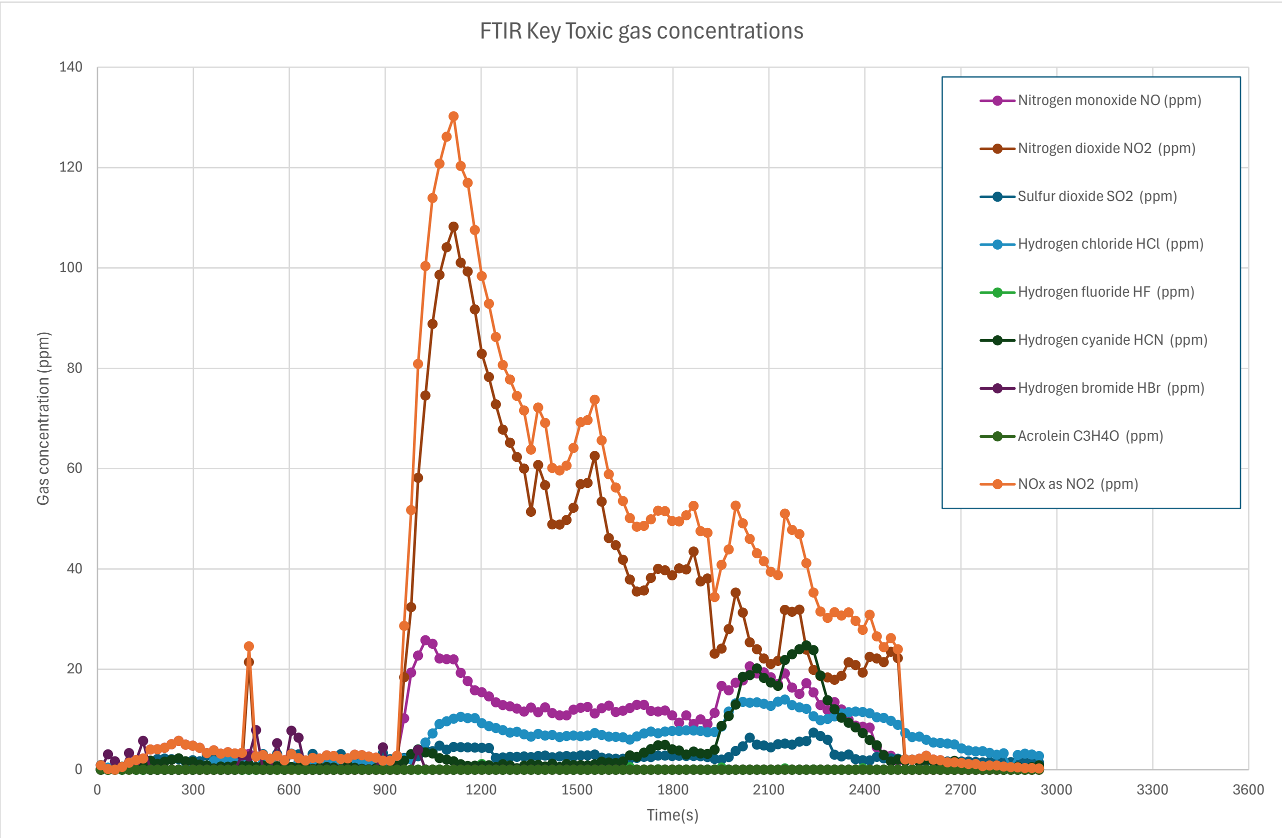


Figure 177. Test 12 – Key Toxic Species concentration recorded by FTIR.

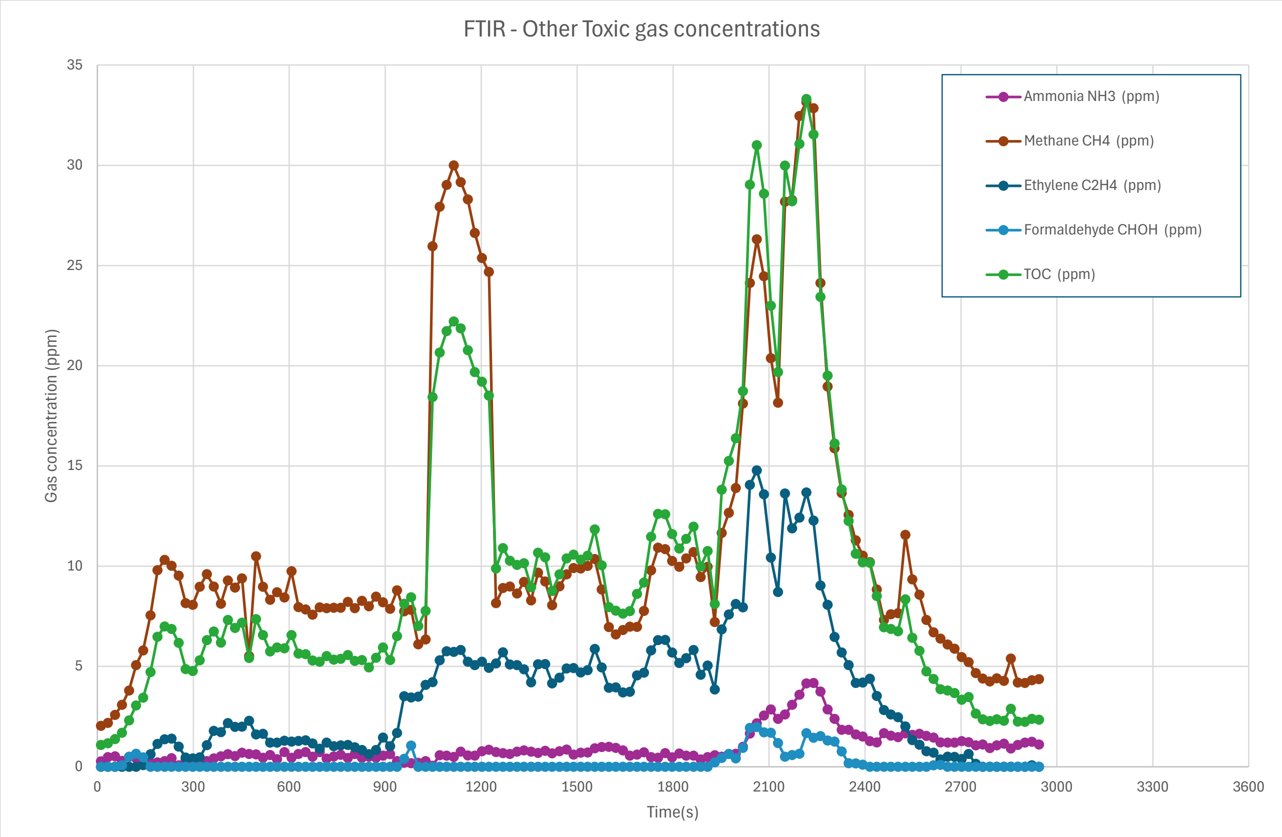


Figure 178. Test 12 – Other Toxic Species concentration recorded by FTIR.

Appendix C Photos

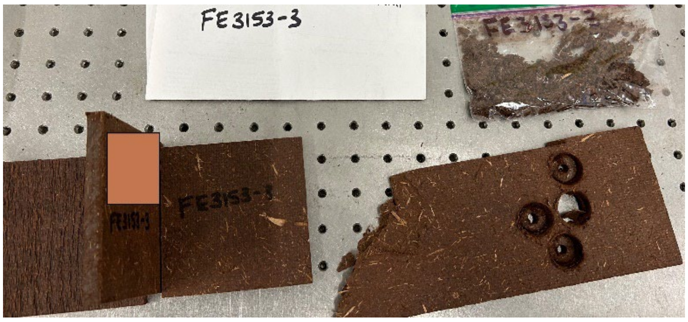
C.1 Test hood, equipment & Instrumentation

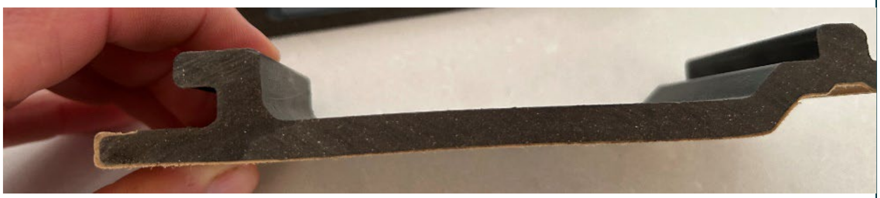
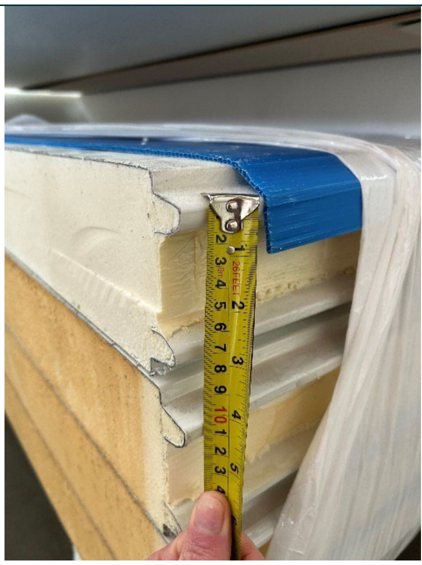
Photo No	Photo	Description
1		CSIRO Intermediate scale fire test hood prior to installation of the support frame

2		Lifting rig and wing walls installed within test hood
3		Instrumentation installed to rear wall and wing walls supporting test specimens

4		CSIRO Intermediate scale fire test hood exhaust duct instrumentation and FTIR gas analysis equipment

C.2 Cladding specimens

5	 	Cladding material ID: WPC-01 CSIRO Specimen number: FE3153-3 ~90-95% wood

6	   	Cladding material ID: WPC-02 CSIRO Specimen number: FE3153-8 ~53-56% wood, with balance being mostly Polyethylene. The cladding boards had an external ~ 100% polyethylene shell with less than 1 mm thickness
7	 	Cladding material ID: ISP-01 PIR Core CSIRO Specimen number: FE3153-10

8	 	Cladding material ID: ISP-02 EPS Core CSIRO Specimen number: FE3153-11

C.3 Characterisation tests

9	 	Long characterisation test, Burner at 100 kW
10	 	Long characterisation test, Burner at 300 kW

C.4 Test 1, WPC-01

11	 	Test 1 WPC-01 installation to steel battens and aluminium capping along bottom edge.

12		Test 1 WPC-01 prior to test
13		Test 1, WPC-01 at ~ 60s

14		Test 1, WPC-01 at ~ 300s
15		Test 1, WPC-01 at ~ 600s

16		Test 1, WPC-01 at ~ 680s
17		Test 1, WPC-01 fire hose reel applied at 730s

18		Test 1, WPC-01 Post test damage
19	 	Test 1, WPC-01 Post test damage

C.5 Test 2, WPC-01

20		Test 2, WPC-01 Prior to test
21	 	Test 2, WPC-01 Prior to test

22		Test 2, WPC-01 at 180s
23		Test 2, WPC-01 at 200s

24		Test 2, WPC-01 at 400s
25		Test 2, WPC-01 at 500s

26		Test 2, WPC-01 at 580s Burner turned off just prior to suppression with fire hose reel.
27		Test 2, WPC-01 post test damage

C.6 Test 3, WPC-02

28		Test 3, WPC-02, Installation
29		Test 3, WPC-02, Installation

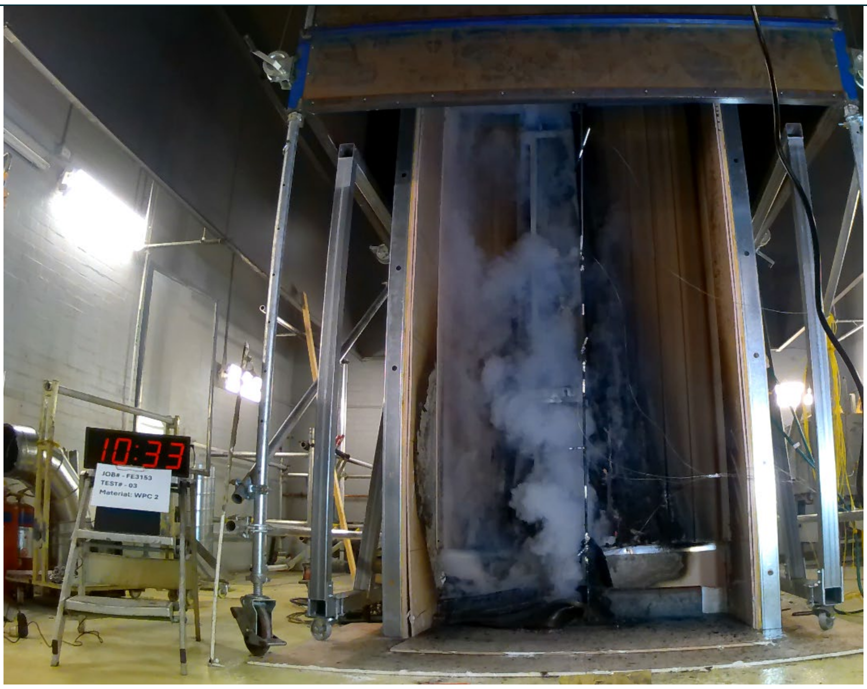
30		Test 3, WPC-02, Installation
31		Test 3, WPC-02, Installation

32		Test 3, WPC-02, at 83 s
33		Test 3, WPC-02, at 190 s

34		Test 3, WPC-02, at 350 s
35		Test 3, WPC-02, at 390s

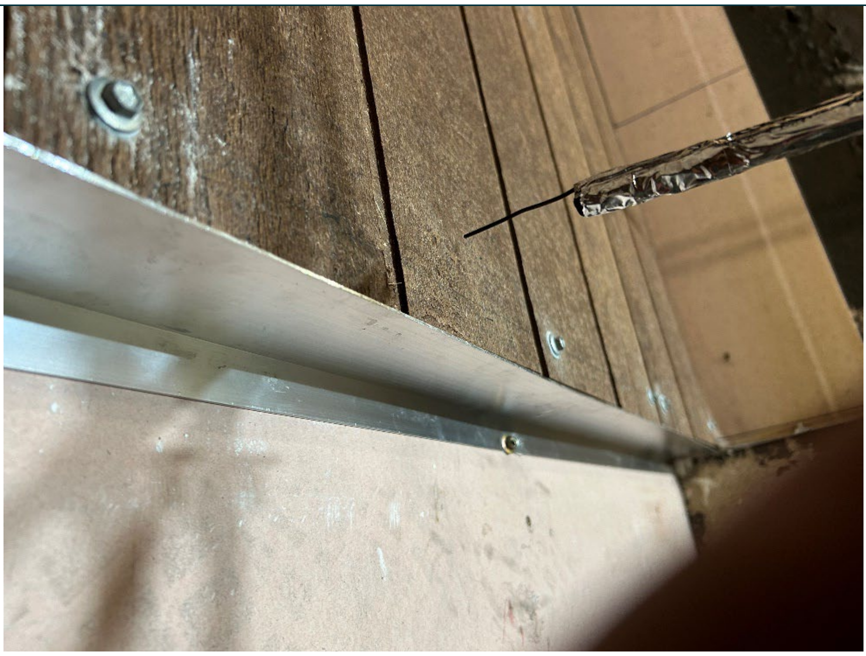
<table>
<tr>
<td>36</td>
<td>

</td>
<td>Test 3, WPC-02, at 484s, Burner turned off just prior to suppression with fire hose reel.</td>
</tr>
</table>

37		Test 3, WPC-02, post-test damage after suppression with fire hose reel.
38		Test 3, WPC-02, Softened cladding material slumps and falls to floor after suppression and continues smouldering

39		Test 3, WPC-02, Softened cladding on floor re-ignites. This was then suppressed with further water.
40		Test 3, WPC-02, post test damage.

C.7 Test 4, WPC-01

41		Test 4, WPC-01, fixed directly to 2 layers of 13 mm FR plasterboard with no cavity. Photo shows bottom edge of specimen prior to installing aluminium capping along bottom edge.
42		Test 4, WPC-01, Aluminium capping installed o bottom edge of specimen

43		Test 4, WPC-01, Prior to test
44		Test 4, WPC-01 at 120s

45		Test 4, WPC-01 at 260s
46		Test 4, WPC-01 at 540s

47		Test 4, WPC-01 at 660s
48		Test 4, WPC-01 at 780s

49		Test 4, WPC-01 at end of 100 kW burner exposure
50		Test 4, WPC-01 at 53 s after turning burner up to 300 kW

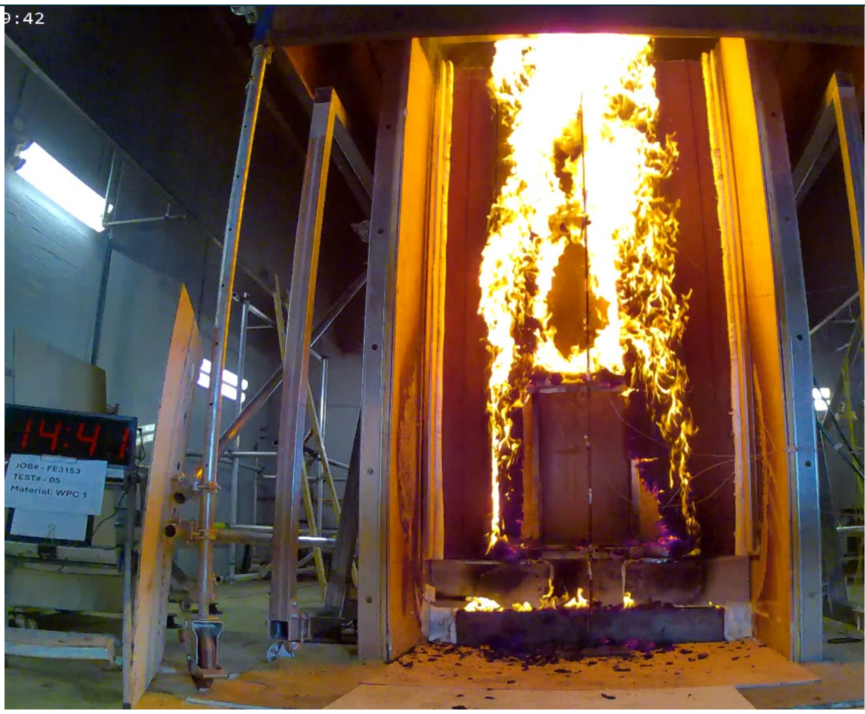
51		Test 4, WPC-01 after burner turned off
52		Test 4, WPC-01 after burner turned off
53		Test 4, WPC-01 after burner turned off. Flames have just ceased and only glowing embers

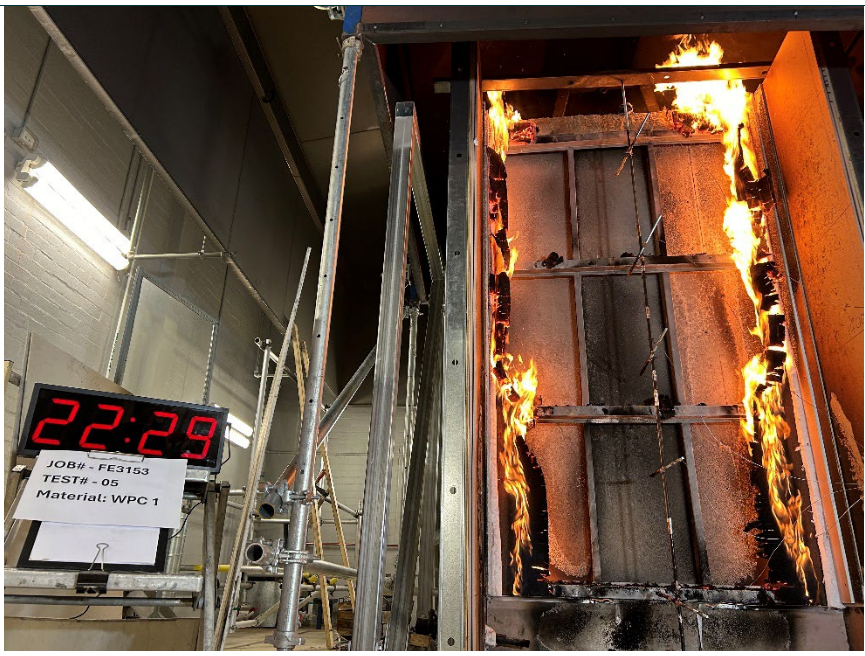
C.8 Test 5, WPC-01

54		Test 5, WPC-01 with cavity barrier installed to top of cavity
55		Test 5, WPC-01 prior to test

<table>
<tr><td>56</td><td>
</td><td>Test 5, WPC-01</td></tr>
<tr><td>57</td><td>
</td><td>Test 5, WPC-01</td></tr>
</table>

58		Test 5, WPC-01
59		Test 5, WPC-01

60		Test 5, WPC-01 at 12:50 (770 s)
61		Test 5, WPC-01 immediately after 100 kW burner turned off.

62		Test 5, WPC-01
63		Test 5, WPC-01

64		Test 5, WPC-01
65		Test 5, WPC-01 Post test damage

C.9 Test 6 – ISP-01 PIR, Vertical, No steel capping

66		Test 6, ISP-01 PIR, No steel capping
67		Test 6, ISP-01 PIR, No steel capping

68		Test 6, ISP-01 PIR, No steel capping
69		Test 6, ISP-01 PIR, No steel capping

70		Test 6, ISP-01 PIR, No steel capping
71		Test 6, ISP-01 PIR, No steel capping

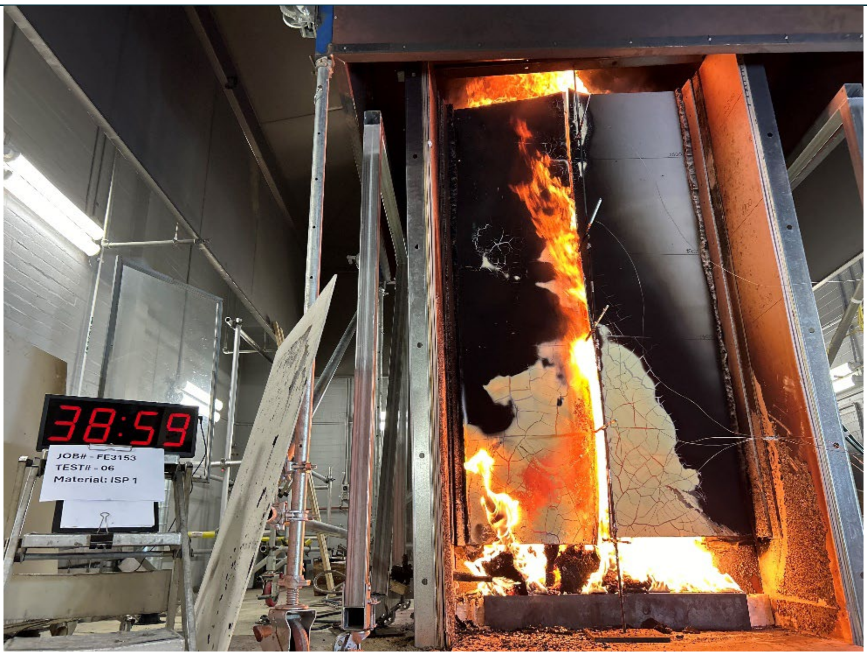
72		Test 6, ISP-01 PIR, No steel capping
73		Test 6, ISP-01 PIR, No steel capping

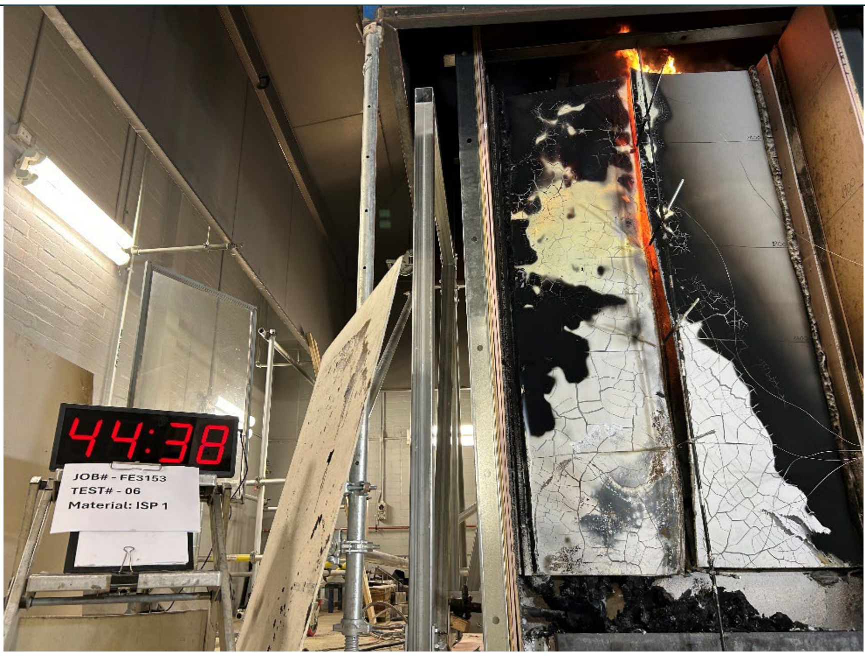
74		Test 6, ISP-01 PIR, No steel capping
75		Test 6, ISP-01 PIR, No steel capping

76		Test 6, ISP-01 PIR, No steel capping
77		Test 6, ISP-01 PIR, No steel capping

78		Test 6, ISP-01 PIR, No steel capping
79		Test 6, ISP-01 PIR, No steel capping

80		Test 6, ISP-01 PIR, No steel capping
81		Test 6, ISP-01 PIR, No steel capping

82		Test 6, ISP-01 PIR, No steel capping
83		Test 6, ISP-01 PIR, No steel capping

84		Test 6, ISP-01 PIR, No steel capping
85		Test 6, ISP-01 PIR, No steel capping

86		Test 6, ISP-01 PIR, No steel capping
87		Test 6, ISP-01 PIR, No steel capping

88		Test 6 Post test dismantle. Viewed from bottom Note damage to plaster board is due to storage in outdoor rain post test
89		Test 6 Post test dismantle. Viewed from top.

90		Test 6 Post test dismantle. External skins removed

C.10 Test 7 – ISP-02 EPS, Vertical, No Steel capping

91		Test 7, ISP-02 EPS, No steel capping

92		Test 7, ISP-02 EPS, No steel capping Aluminium capping, backing rod and sealant to base of specimen
93		Test 7, ISP-02 EPS, No steel capping Aluminium capping to base of specimen viewed from underneath

94		Test 7, ISP-02 EPS, No steel capping
95		Test 7, ISP-02 EPS, No steel capping

96		Test 7, ISP-02 EPS, No steel capping
97		Test 7, ISP-02 EPS, No steel capping

98		Test 7, ISP-02 EPS, No steel capping
99		Test 7, ISP-02 EPS, No steel capping

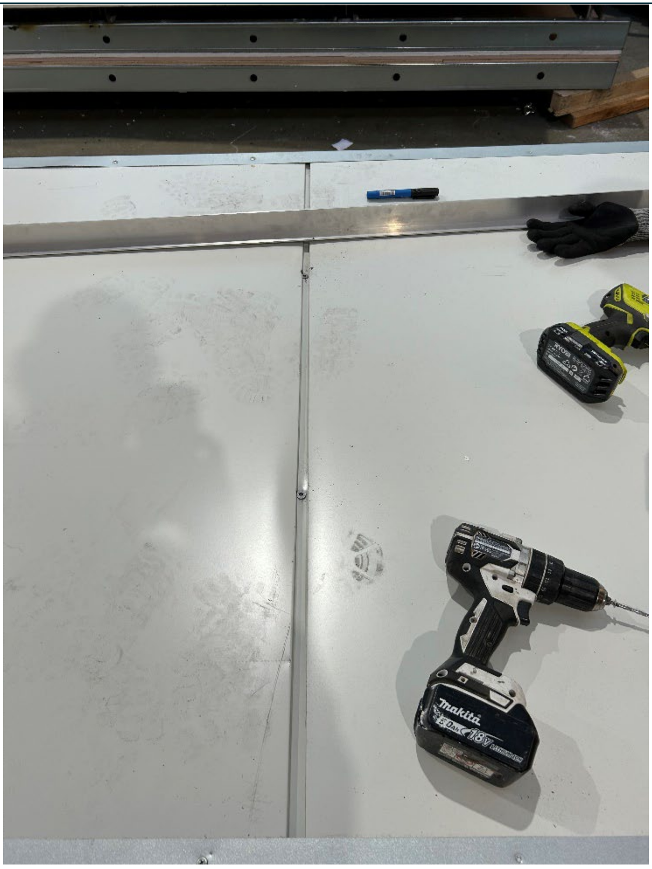
100		Test 7, ISP-02 EPS, No steel capping
101		Test 7, ISP-02 EPS, No steel capping

102		Test 7, ISP-02 EPS, No steel capping
103		Test 7, ISP-02 EPS, No steel capping

104		Test 7, ISP-02 EPS Post test prior to removing external skin
105		Test 7, ISP-02 EPS Post test external skin removed showing ~100% EPS consumed.

C.11 Test 8 – ISP-01, PIR Horizontal with steel capping

106		Test 8 – ISP-01 PIR with steel capping install
107		Test 8 – ISP-01 PIR with steel capping install

108		Test 8 – ISP-01 PIR with steel capping install
109		Test 8 – ISP-01 PIR with steel capping install

110		Test 8 – ISP-01 PIR with steel capping install
111		Test 8 – ISP-01 PIR with steel capping install

112		Test 8 – ISP-01 PIR with steel capping install
113		Test 8 – ISP-01 PIR with steel capping install

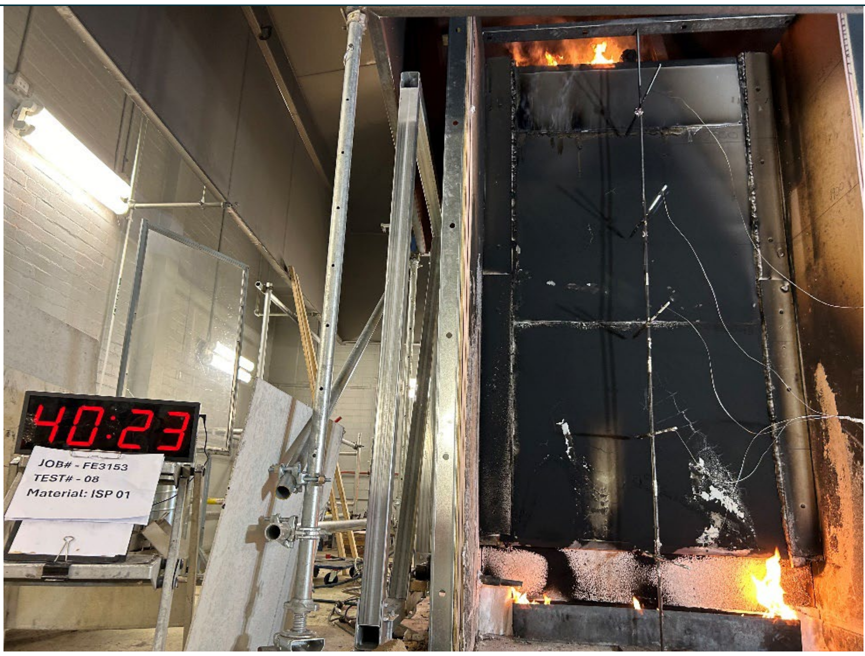
114		Test 8 – ISP-01 PIR with steel capping
115		Test 8 – ISP-01 PIR with steel capping

116		Test 8 – ISP-01 PIR with steel capping
117		Test 8 – ISP-01 PIR with steel capping

118		Test 8 – ISP-01 PIR with steel capping
119		Test 8 – ISP-01 PIR with steel capping

120		Test 8 – ISP-01 PIR with steel capping
121		Test 8 – ISP-01 PIR with steel capping

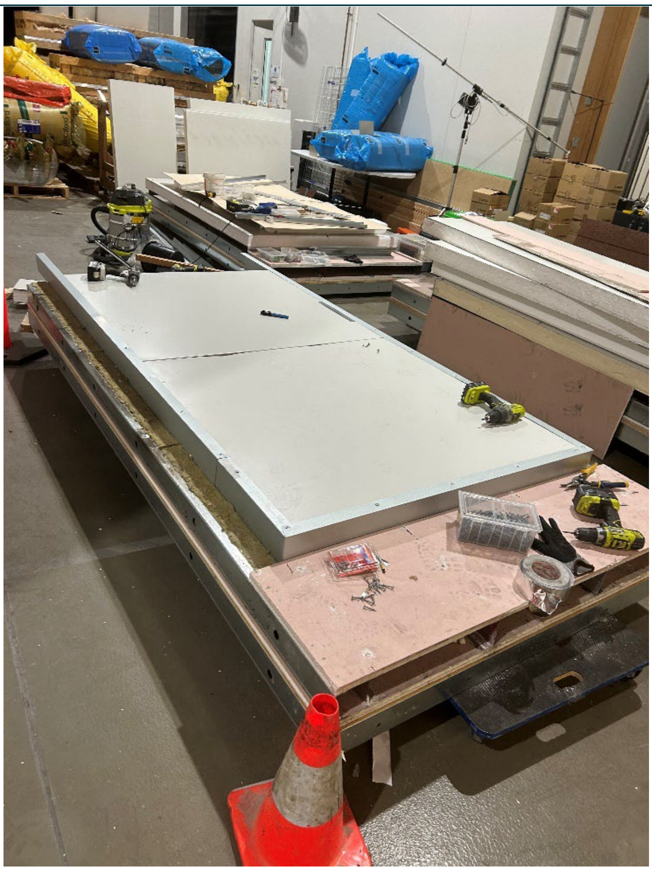
122		Test 8 – ISP-01 PIR with steel capping
123		Test 8 – ISP-01 PIR with steel capping

124		Test 8 – ISP-01 PIR with steel capping
125		Test 8 – ISP-01 PIR with steel capping

126		Test 8 – ISP-01 PIR with steel capping
127		Test 8 Post test dismantle. Viewed from bottom Note damage to plaster board is due to storage in outdoor rain post test

128		Test 8 Post test dismantle. Viewed from top.
129		Test 8 Post test dismantle. Steel edge capping and External skins removed

C.12 Test 9 – ISP-02 EPS, Horizontal with steel capping

130		Test 9 ISP-02 EPS, Horizontal with steel capping. Install
131		Test 9 ISP-02 EPS, Horizontal with steel capping. Install

132		Test 9 ISP-02 EPS, Horizontal with steel capping. Install
133		Test 9 ISP-02 EPS, Horizontal with steel capping. Install

134		Test 9 ISP-02 EPS, Horizontal with steel capping.
135		Test 9 ISP-02 EPS, Horizontal with steel capping.

136		Test 9 ISP-02 EPS, Horizontal with steel capping.
137		Test 9 ISP-02 EPS, Horizontal with steel capping.

138		Test 9 ISP-02 EPS, Horizontal with steel capping.
139		Test 9 ISP-02 EPS, Horizontal with steel capping.

140		Test 9 ISP-02 EPS, Horizontal with steel capping.
141		Test 9 ISP-02 EPS, Horizontal with steel capping.

142		Test 9 ISP-02 EPS, Horizontal with steel capping.
143		Test 9 ISP-02 EPS, Horizontal with steel capping.

144		Test 9 Post test dismantle. Viewed from bottom Note damage to plaster board is due to storage in outdoor rain post test
145		Test 9 Post test dismantle. Steel edge capping and External skins removed

C.13 Test 10 – ISP-01 PIR, Vertical with steel capping

146		Test 10 ISP-01 PIR, Vertical with steel capping. Prior to install of steel capping
147		Test 10 ISP-01 PIR, Vertical with steel capping.

148		Test 10 ISP-01 PIR, Vertical with steel capping.
149		Test 10 ISP-01 PIR, Vertical with steel capping.

150		Test 10 ISP-01 PIR, Vertical with steel capping.
151		Test 10 ISP-01 PIR, Vertical with steel capping.

152		Test 10 ISP-01 PIR, Vertical with steel capping.
153		Test 10 ISP-01 PIR, Vertical with steel capping.

154		Test 10 ISP-01 PIR, Vertical with steel capping.
155		Test 10 ISP-01 PIR, Vertical with steel capping.

156		Test 10 ISP-01 PIR, Vertical with steel capping.
157		Test 10 ISP-01 PIR, Vertical with steel capping.

158		Test 10 ISP-01 PIR, Vertical with steel capping.
159		Test 10 Post test dismantle. Viewed from bottom Note damage to plaster board is due to storage in outdoor rain post test

160		Test 10 Post test dismantle. Steel edge capping and External skins removed

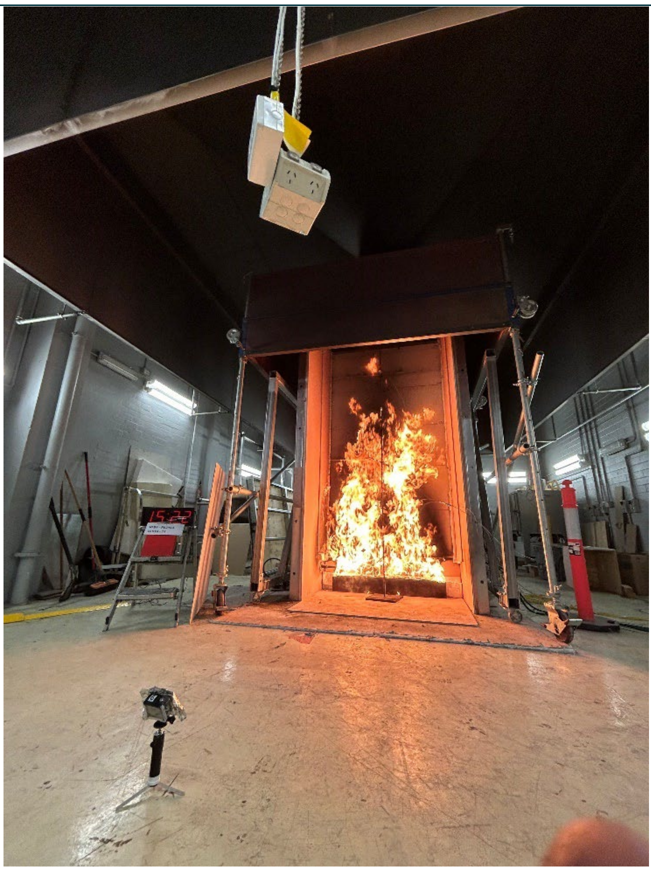
C.14 Test 11 – ISP-01 PIR, Horizontal with steel capping and partial steel flashing internal to joints

161		Test 11 ISP-01 PIR Horizontal with steel capping and partial steel flashing internal to joints

162		Test 11 ISP-01 PIR Horizontal with steel capping and partial steel flashing internal to joints
163		Test 11 ISP-01 PIR Horizontal with steel capping and partial steel flashing internal to joints

164		Test 11 ISP-01 PIR Horizontal with steel capping and partial steel flashing internal to joints
165		Test 11 ISP-01 PIR Horizontal with steel capping and partial steel flashing internal to joints

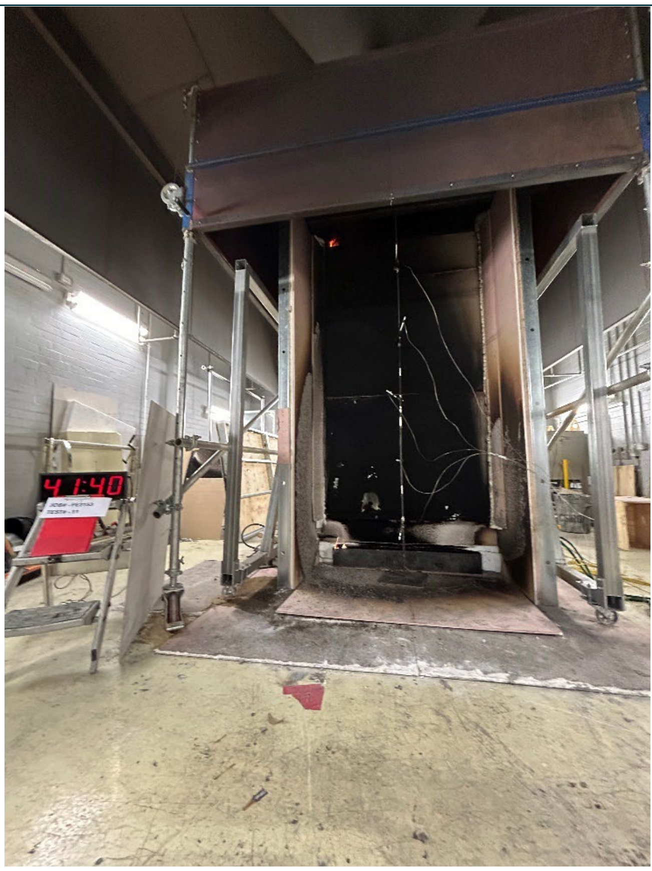
166		Test 11 ISP-01 PIR Horizontal with steel capping and partial steel flashing internal to joints
167		Test 11 ISP-01 PIR Horizontal with steel capping and partial steel flashing internal to joints

168		Test 11 ISP-01 PIR Horizontal with steel capping and partial steel flashing internal to joints
169		Test 11 ISP-01 PIR Horizontal with steel capping and partial steel flashing internal to joints

170		Test 11 ISP-01 PIR Horizontal with steel capping and partial steel flashing internal to joints
171		Test 11 ISP-01 PIR Horizontal with steel capping and partial steel flashing internal to joints

172		Test 11 ISP-01 PIR Horizontal with steel capping and partial steel flashing internal to joints
173		Test 11 ISP-01 PIR Horizontal with steel capping and partial steel flashing internal to joints

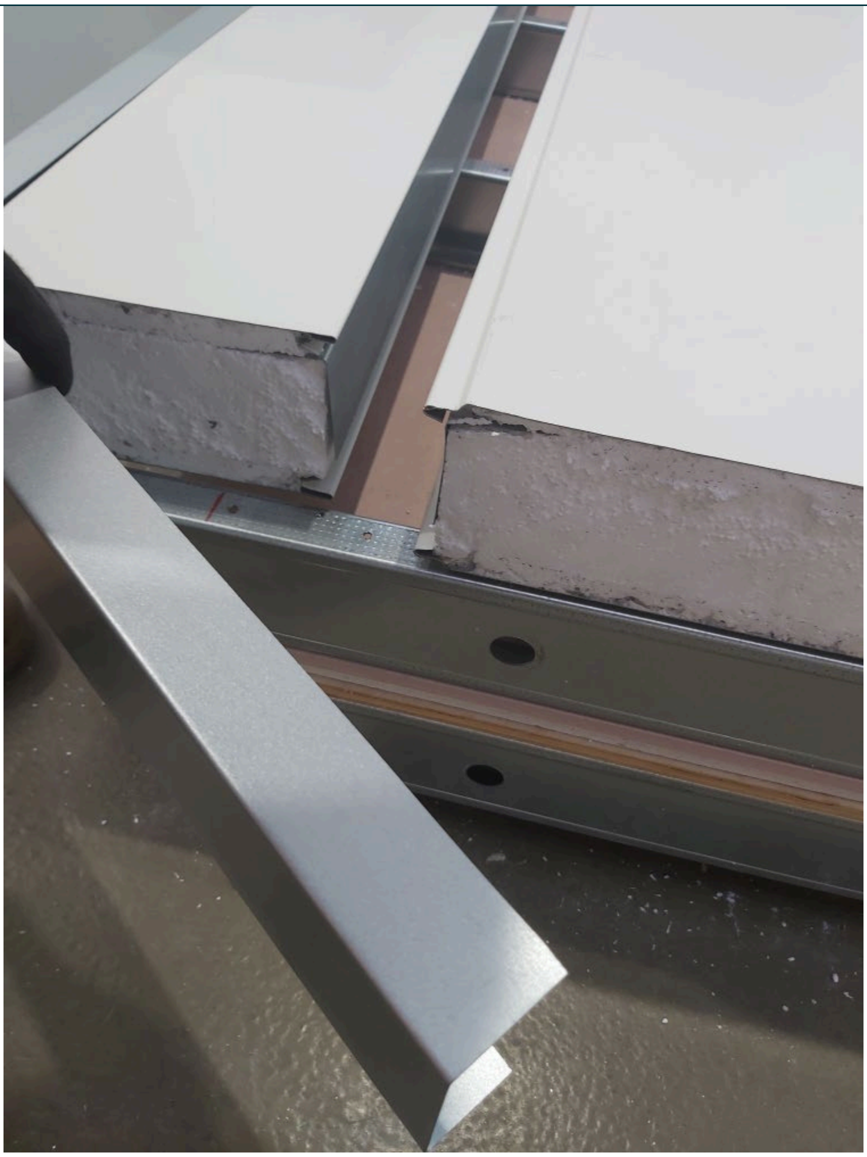
174		Test 11 ISP-01 PIR Horizontal with steel capping and partial steel flashing internal to joints
175		Test 11 ISP-01 PIR Horizontal with steel capping and partial steel flashing internal to joints

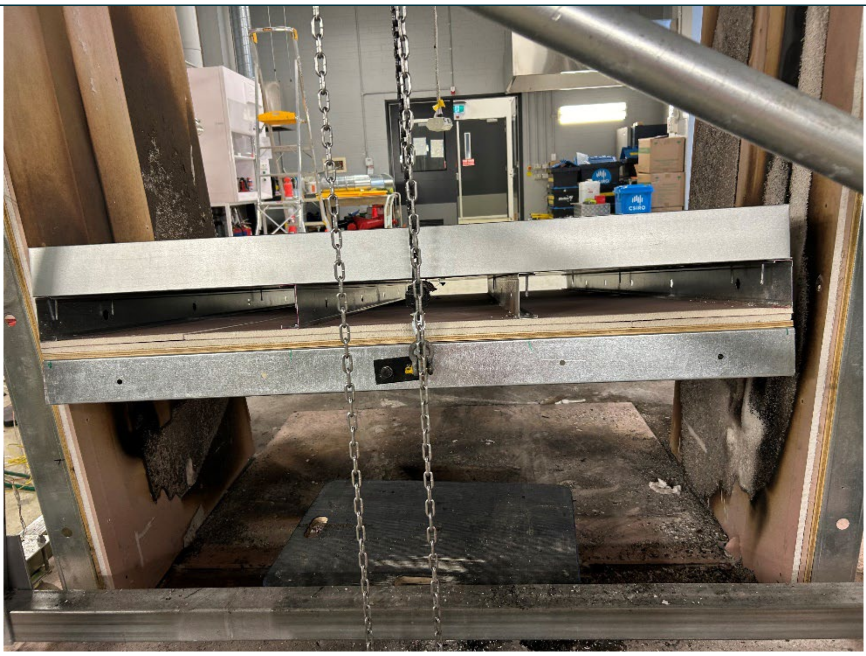
176		Test 11 ISP-01 PIR Horizontal with steel capping and partial steel flashing internal to joints
177		Test 11 ISP-01 PIR Horizontal with steel capping and partial steel flashing internal to joints

178	 	Test 11 Post test dismantle. Steel edge capping and External skins removed

C.15 Test 12 – ISP-02 EPS Horizontal with steel capping and partial steel flashing internal to joints

179		Test 12 – ISP-02 EPS Horizontal with steel capping and partial steel flashing internal to joints

180		Test 12 – ISP-02 EPS Horizontal with steel capping and partial steel flashing internal to joints
181		Test 12 – ISP-02 EPS Horizontal with steel capping and partial steel flashing internal to joints

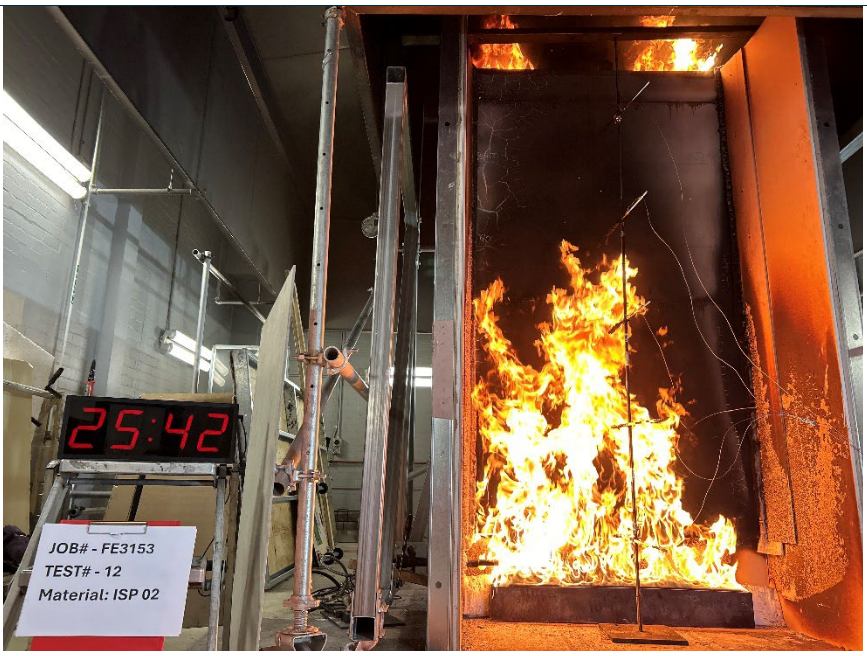
182		Test 12 – ISP-02 EPS Horizontal with steel capping and partial steel flashing internal to joints
183		Test 12 – ISP-02 EPS Horizontal with steel capping and partial steel flashing internal to joints

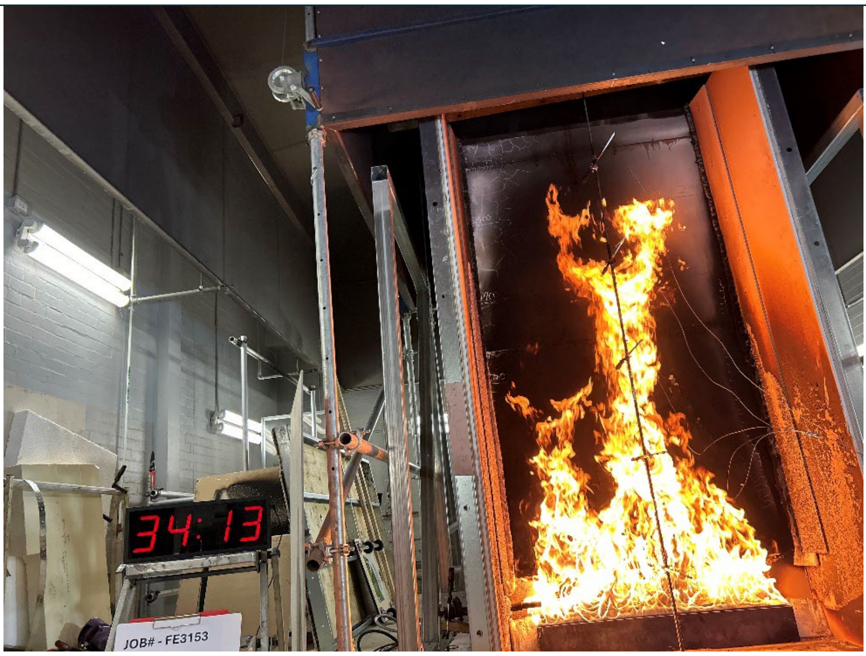
184		Test 12 – ISP-02 EPS Horizontal with steel capping and partial steel flashing internal to joints
185		Test 12 – ISP-02 EPS Horizontal with steel capping and partial steel flashing internal to joints

186		Test 12 – ISP-02 EPS Horizontal with steel capping and partial steel flashing internal to joints
187		Test 12 – ISP-02 EPS Horizontal with steel capping and partial steel flashing internal to joints

188		Test 12 – ISP-02 EPS Horizontal with steel capping and partial steel flashing internal to joints
189		Test 12 – ISP-02 EPS Horizontal with steel capping and partial steel flashing internal to joints

190		Test 12 – ISP-02 EPS Horizontal with steel capping and partial steel flashing internal to joints
191		Test 12 – ISP-02 EPS Horizontal with steel capping and partial steel flashing internal to joints

192		Test 12 – ISP-02 EPS Horizontal with steel capping and partial steel flashing internal to joints
193		Test 12 – ISP-02 EPS Horizontal with steel capping and partial steel flashing internal to joints

194		Test 12 – ISP-02 EPS Horizontal with steel capping and partial steel flashing internal to joints
195		Test 12 – ISP-02 EPS Horizontal with steel capping and partial steel flashing internal to joints

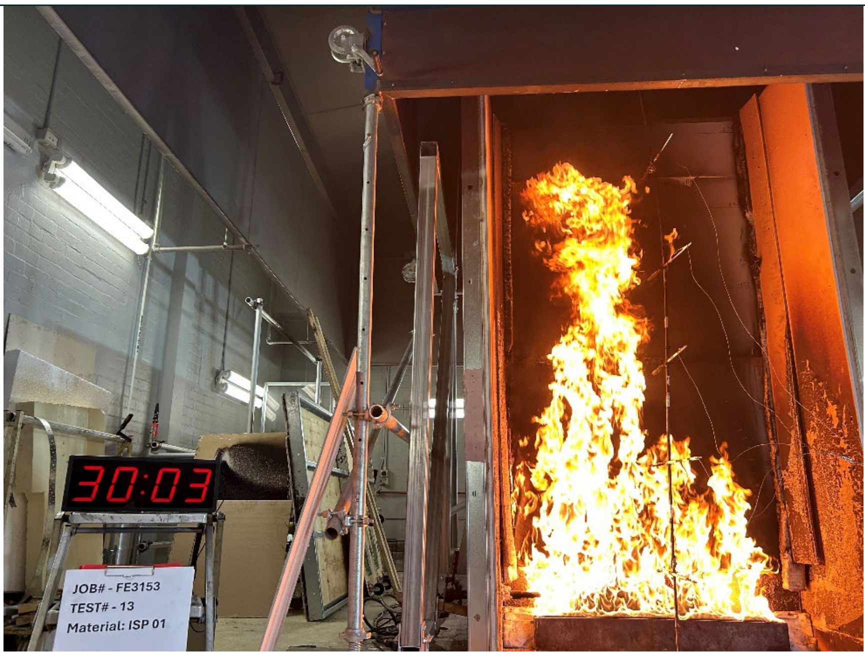
196		Test 12 – ISP-02 EPS Horizontal with steel capping and partial steel flashing internal to joints
197		Test 12 Post test dismantle. Steel edge capping and External skins removed

C.16 Test 13 – ISP-01 PIR, Horizontal with steel capping and partial steel flashing internal to joints

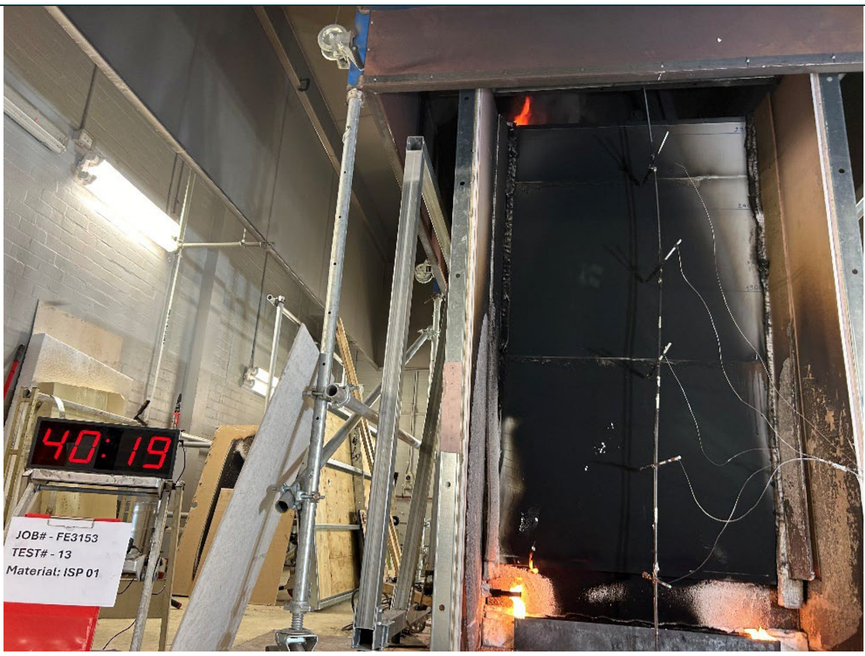
198		Test 13 – ISP-01 PIR, Horizontal with steel capping and partial steel flashing internal to joints
199		Test 13 – ISP-01 PIR, Horizontal with steel capping and partial steel flashing internal to joints

200		Test 13 – ISP-01 PIR, Horizontal with steel capping and partial steel flashing internal to joints
201		Test 13 – ISP-01 PIR, Horizontal with steel capping and partial steel flashing internal to joints

202		Test 13 – ISP-01 PIR, Horizontal with steel capping and partial steel flashing internal to joints
203		Test 13 – ISP-01 PIR, Horizontal with steel capping and partial steel flashing internal to joints

204		Test 13 – ISP-01 PIR, Horizontal with steel capping and partial steel flashing internal to joints
205		Test 13 – ISP-01 PIR, Horizontal with steel capping and partial steel flashing internal to joints

206		Test 13 – ISP-01 PIR, Horizontal with steel capping and partial steel flashing internal to joints
207		Test 13 – ISP-01 PIR, Horizontal with steel capping and partial steel flashing internal to joints

208		Test 13 – ISP-01 PIR, Horizontal with steel capping and partial steel flashing internal to joints
209		Test 13 – ISP-01 PIR, Horizontal with steel capping and partial steel flashing internal to joints

210		Test 13 – ISP-01 PIR, Horizontal with steel capping and partial steel flashing internal to joints
211		Test 13 – ISP-01 PIR, Horizontal with steel capping and partial steel flashing internal to joints
212		Test 13 Post test dismantle. Steel edge capping and External skins removed

LAST PAGE OF REPORT

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