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BRE Global Client Report

BS 8414-1:2015 + A1:2017 test referred to as DCLG test 5.

Prepared for: DCLG

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Version history

14/08/2017	Issue 1.1	Amendment to section 7.1.3.
12/09/2017	Issue 1.2	Amendment to section 4.4.

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Table of Contents

1 Introduction

This report is one of a series, commissioned by the Department for Communities and Local Government (DCLG) intended to establish how different types of Aluminium Composite Material (ACM) panels in combination with different types of insulation behave in a fire.

Following the fire at Grenfell Tower in London on 14 June 2017, the Government established an Independent Expert Advisory Panel to advise on immediate measures that should be put in place to help make buildings safe. On 6 July the Independent Expert Advisory Panel recommended a series of full scale BS 8414 tests be carried out in order to help building owners make decisions on any further measures that may need to be put in place.

This series of tests includes 6 combinations of cladding systems. The detailed design of each test specimen was carried out by a cladding company appointed by DCLG. The design of the cladding systems have been reviewed by the Independent Expert Advisory Panel and other industry bodies to ensure that they are representative of the systems that are in common use on buildings, including the way they are fixed. The cladding systems have been or will be installed by a Company appointed by DCLG and each one has been or will be independently assessed during the installation to ensure that it meets the design specification.

The six test specimens incorporate each of the three common types of ACM panel, with core filler materials of unmodified polyethylene, fire retardant polyethylene and limited combustibility mineral. The two insulation materials specified for use in the testing are rigid polyisocyanurate foam (PIR) or stone wool.

The test method, BS8414 Part 1:2015 + A1:2017[1] describes a method of assessing the behaviour of non-load bearing external cladding systems, rain screen over cladding systems and external wall insulation systems when applied to the face of a building and exposed to an external fire under controlled conditions. The fire exposure is representative of an external fire source or a fully developed (post-flashover) fire in a room, venting through an opening such as a window aperture that exposes the cladding to the effects of external flames.

This report applies to the cladding system as detailed. The report only covers the details as tested. It is important to check that the cladding system tested relates to the end use application when installed on a building. Such checks should be made by a suitably competent person.

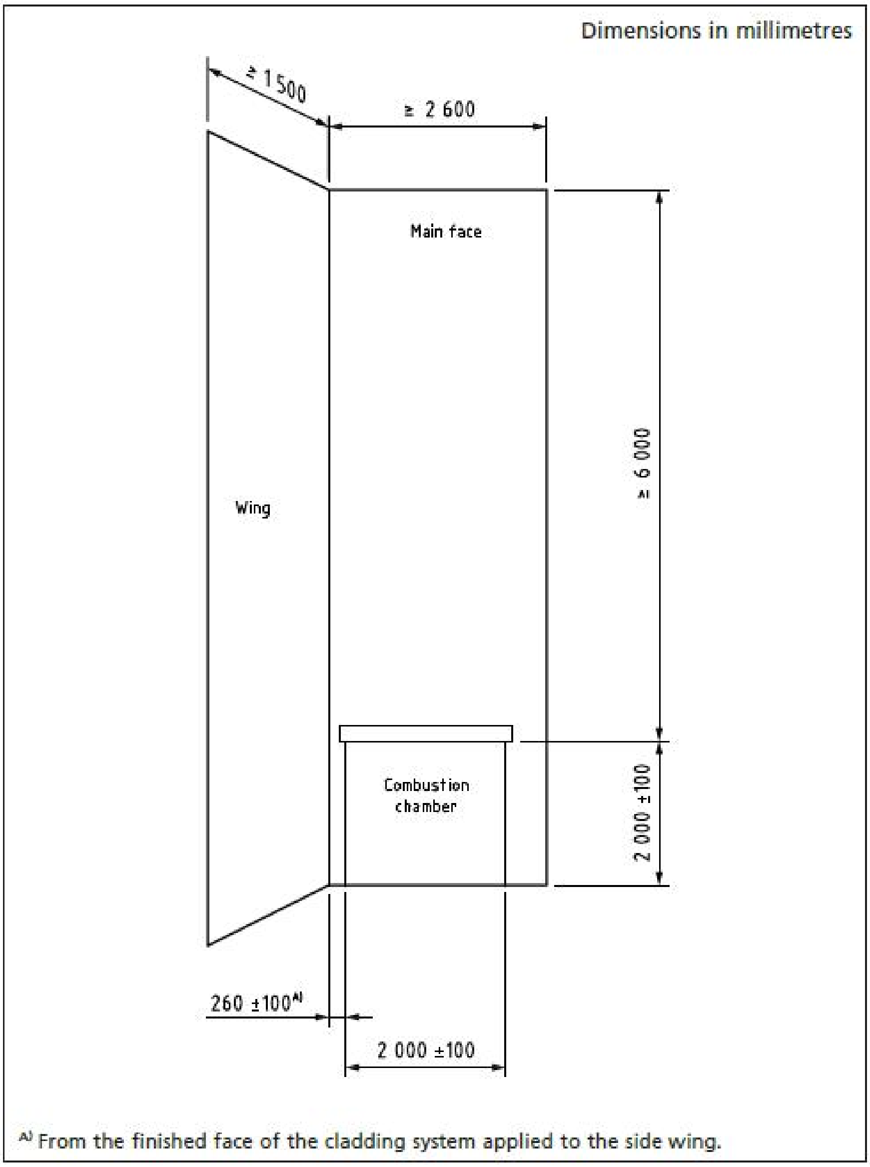
All measurements quoted in this report are nominal unless stated otherwise.

2 Details of test carried out

Name of Laboratory:	BRE Global Ltd.
Laboratory Address:	Bucknalls Lane, Garston, Watford, Hertfordshire, WD25 9XX.
Test reference:	DCLG test 5
Date of test:	06/08/2017
Sponsor:	Department for Communities and Local Government
Sponsor address:	2 Marsham Street, London, SW1P 4DF.
Method:	The test was carried out in accordance with BS 8414-1:2015 + A1:2017
Deviations:	None

3 Details of test apparatus used

The product was installed to wall number 1 of the BS 8414-1 BRE Global test facility. This apparatus is defined in the test Standard[1] and consists of a masonry structure with a vertical main test wall and a vertical return wall at a 90º angle to and at one side of the main test wall. See *Schematic 1*. The main wall includes the combustion chamber.



Schematic 1. Test apparatus dimensions as specified by test Standard[1].

Note: The test apparatus may be constructed left- or right-handed.

4 Description of the system

4.1 Installation of specimen

BRE was not involved in the design, installation, procurement or specification of the materials and cladding system that was submitted for testing. The tested system was defined by the Test Sponsor.

4.2 Description of substrate

The test specimen was installed to wall number 1 of the BRE Global Cladding Test Facility. This is a multi-faced test rig constructed from steel with a masonry finish onto which the cladding system was applied.

4.3 Description of product

Figures 13-17 were provided by the Test Sponsor to show the design and detailing of the installed system.

The tested cladding system build up is given in order from the masonry substrate to the external finish:

- 90mm-high×64mm-wide×113mm-deep×4mm-thick aluminum 'L'-shaped brackets fixed with a single 90mm-long×ϕ8mm stainless steel screw anchor and plastic plug – see *Figures 8&9;*
- 100mm-thick rigid polyisocyanurate (PIR) foam insulation boards (supplied 2400mm×1200mm and cut to size) with aluminium foil facings on both sides – see *Figure 7*;
- 120mm-wide×60mm-deep×2mm-thick aluminum 'T'-section framing and 40mm-wide×60mm-deep×2mm-thick aluminum 'L'-section framing – see *Figure 10*;
- 75mm-wide×160mm-deep stone wool vertical cavity barriers (stated integrity/insulation performance: 90/30mins), with 10mm compression – see *Figure 3*;
- 75mm-wide×125mm-deep stone wool with intumescent horizontal cavity barriers (stated integrity/insulation performance: 90/30mins) – see *Figure 4*;
- 4mm-thick front face Aluminum Composite Material (ACM) panels, with a white finish – see *Figure 12*.

The densities of the insulation and the cavity barriers have been determined and are reported in *Appendix A*.

The 4mm-thick ACM panels consisted of, from outward face in:

- 0.5mm-thick aluminium sheet;
- 3.0mm-thick limited combustibility mineral filler;
- 0.5mm-thick aluminium sheet.

The filler between the aluminium sheets was screened using the BS EN ISO 1716:2010[3] test methodology. The results are given in *Appendix B*.

4.4 Installation sequence

Onto the masonry support structure the 90mm-high×64mm-wide×113mm-deep×4mm-thick aluminium 'L'-shaped brackets were fixed in position on low density polyethylene isolation pads (5mm-thick), with a single 90mm-long×ϕ8mm stainless steel screw anchor and plastic plug – see *Figures 8&9*. On the main face the horizontal spacing between the brackets varied between 340mm and 500mm – *Figure 3*. On the wing wall the horizontal spacing between the brackets was 645mm as specified in the manufacturer's details. The vertical spacing between the brackets was 960mm and where horizontal cavity barriers were present a spacing of 410mm was used - see *Figure 3&4.*

The system included vertical and horizontal cavity barriers – see *Figure 4*. On the main face, two 75mm-wide×160mm-deep stone wool vertical cavity barriers, with 10mm compression, were fixed in position with a clear distance of 1950mm between them. The vertical cavity barriers were skewered to ¾-depth on steel brackets fixed into the masonry wall with one 70mm-long×ϕ4mm anchor. Two steel brackets were used for each length of 1200mm of stone wool cavity barrier. The vertical cavity barriers were trimmed to fit - see *Figure 6*.

On the wing wall, one 75mm-wide×160mm-deep stone wool vertical cavity barrier, with 10mm compression, was fixed in position at the edge of the system, approximately 1350mm from the external face of the main wall – see *Figure 3*. Once installed in position the stone wool vertical cavity barriers were compressed by the ACM panels to fully close the 50mm ventilated cavity.

A pre-fabricated, welded window pod constructed from 5mm-thick aluminium was fixed onto the edge of the combustion chamber opening with eight (two on top, three on both vertical edges) 90mm-long×ϕ8mm stainless steel screw anchor and plastic plugs – see *Figure 5*.

A set of four 75mm-wide×125mm-deep intumescent horizontal cavity barriers were butted up to the continuous vertical barriers (see *Figures 4-7*) and fixed in rows at approximate (top-top) heights of:

- 0m above the combustion chamber opening,
- 2395mm above the first cavity barrier,
- 2330mm above the second cavity barrier,
- and close to the top of the ventilated system (1635mm above the third cavity barrier, 6360mm above the combustion chamber opening).

The horizontal cavity barriers were fixed through the entire depth on face turned steel brackets –see *Figure 5*. Two steel brackets were used per length of 1200mm of stone wool cavity barrier, each fixed into the masonry wall with one 70mm-long×ϕ4mm anchor, positioned above the cavity barrier. The horizontal intumescent cavity barriers were installed with a maximum gap of 25mm to the back face of the panel in accordance with the manufacturer's recommendation.

The 100mm-thick foil-faced PIR insulation panels (supplied in 2400mm×1200mm panels and cut to fit) were installed in position through the substructure bracket fixing systems and fixed to the support structure (masonry wall) with five 125mm-long×ϕ8mm plastic anchors and four 140mm-long×ϕ8mm stainless steel anchors per full size panel - see *Figure 7*. The insulation panels were installed with the long edge orientated vertically. All the gaps between the insulation panels and at the intersection with the cavity barriers or aluminium brackets were sealed with aluminium tape as recommended by the manufacturer - see *Figure 10*.

After the insulation was fixed in position, the 120mm-wide×60mm-deep×2mm-thick aluminium 'T'-section and 40mm-wide×60mm-deep×2mm-thick 'L'-section framing were installed at horizontal spacings of 480mm – see *Figure 10*. The horizontal spacing between successive sections of aluminium 'T'-section or 'L'-section framing was 970mm. The aluminum vertical rails, with a typical length of 2300mm, were positioned 10mm inside the thermal insulation with each rail fixed to the brackets with 2×4.8×16mm self-drilling, self-tapping, stainless steel screws. The aluminum rails were installed with a 30mm gap at the floor levels to allow for structural movement – see *Figure 6*. Three brackets supported each section of rail: the middle bracket was fixed while the top and bottom brackets were connected with movement holes – see *Figures 8&9*.

The external ACM panels of the system were installed on to the rail substructure with one fixed point (ϕ6mm hole) in the middle and twenty (per full size panel) oversize (ϕ8.5mm holes) fixings into the rail substructure, at 450mm horizontal spacings and 375mm vertical spacings. A nominal gap of 20mm was provided between the panels to maintain the ventilation of the cavity – see *Figure 11.* The measured gaps after installation varied between 18mm and 25mm. The full size ACM panel dimensions measured 950mm-wide×2310mm-high.

In accordance with the requirements of the test Standard[1], the cladding system measured:

Requirement	Actual measurement
≥6000mm above the top of the combustion chamber	6497mm
≥2400mm width across the main wall	2585mm
≥1200mm width across the wing wall	1340mm
260mm (±100mm) wing wall-combustion chamber opening	255mm
2000mm x 2000mm (±100mm) combustion chamber opening	2000mm×1960mm

4.5 Test conditions

Test Date: 06/08/17

Ambient Temperature: 19°C

Wind speed: < 2 m/s

Frequency of measurement: Data records were taken at five second intervals.

Thermocouple locations *(Figure 2)*:

Level 1 – External (50mm in front of the finished face).

Level 2 – External (50mm in front of the finished face).

Level 2 – Midpoint of cavity between panel and insulation.

Level 2 – Midpoint of insulation layer.

5 Test results

5.1 Temperature profiles

Figures 18-21 provide the temperature profiles recorded. *Figure 12* shows the system before the test.

Parameter	Result
T_s, Start Temperature	19˚C
t_s, Start time	105 seconds after ignition of crib.
Peak temperature / time at Level 2, External	565˚C at 1380 seconds after t_s.
Peak temperature / time at Level 2, Cavity	215˚C at 1055 seconds after t_s.
Peak temperature / time at Level 2, Insulation	141˚C at 890 seconds after t_s.

5.2 Visual observations

Table 1: Visual Observations – refer to *Figure 1*.
Height measurements are given relative to the top of the combustion chamber.
Unless otherwise specified, observations refer to the centre line above the combustion chamber.

Time* (mins:secs)	t_s (seconds)	Description
00:00		Ignition of crib.
01:20		The flames from the combustion chamber are impinging on the cladding system.
01:45	0	Start time (ts) criteria achieved: External temperature 2.5m above the top of the combustion chamber in excess of 219°C (=200°C+Ts).
02:10	25	Flame tips to top of panels 1C&1D.
02:25	40	Flame tips to height of Level 1 thermocouples.
02:30	45	A small amount of distortion can be observed at the base of panels 1C&1D.

Time* (mins:secs)	t_s (seconds)	Description
02:40	55	Discolouration and slight distortion of panels 1C&1D up to mid-height. A small amount of paint detachment can also be observed from the base of the panels up to mid-height, in the joint area.
02:50	65	Flame tips to the base of panels 2C&2D.
04:40	175	Discolouration and slight distortion of panels 2C&2D at the base.
04:50	185	Discolouration of panels 1C&1D up to the top horizontal joint.
06:40	295	Slight distortion of wing wall panel 1A.
07:00	315	Slight discoloration of wing wall panel 1A, near the intersection with the main wall.
07:20	335	Discoloration and paint detachment of panel 1C, up to approximately 2000mm above the combustion chamber, at the vertical junction with panel 1B.
07:35	350	Flame tips to mid-height of panels 2C&2D.
08:20	395	Sporadic burning droplets observed (sustained flaming less than 10 seconds).
09:00	435	Increased production of burning droplets at the base of the cladding system (sustained flaming longer than 20 seconds). The PIR insulation is visible through the flames, in the central section where ACM panels 1C&1D have been consumed. At this point the flames are observed entering the cavity behind the remaining sections of panels 1C&1D.
09:40	475	PIR insulation is burning where ACM panels 1C&1D have been consumed.
09:50	485	Discoloration and distortion can be observed on the wing wall from the top of panel 0A to the base of panel 2A.
10:00	495	Discoloration and paint detachment up to mid-height of panels 2C&2D.
10:05	500	Flickering flames from the horizontal junction above panels 1C&1D.
10:10	505	Increased production of burning droplets from above the combustion chamber. Sustained pool fire at the base of the cladding system.

Time* (mins:secs)	t_s (seconds)	Description
11:00	555	Flame tips up to the top of panels 2C&2D.
12:20	635	Increased loss of material on panels 1C&1D has exposed a greater area of PIR insulation directly above the combustion chamber. An increased production of burning droplets and debris. Detachment of larger components from the system is observed.
14:00	735	Consumption at the base of panels 2C&2D. The central “T”-shaped aluminium rail is exposed.
14:50	785	Discoloration at the base of panels 3C&3D.
15:20	815	Increased consumption at the base of panels 2C&2D to expose the horizontal cavity barrier.
15:30	825	Flaming from the PIR insulation above the horizontal cavity barrier at the base of panels 2C&2D. Flames entering the cavity behind panels 2C&2D.
16:00	855	Flaming from the edges of partially consumed panels.
17:00	915	The majority of panels 1C&1D have been consumed. The length of the intermittent flames is relatively constant at the base of panels 3C&3D.
17:30	945	Flickering flames are observed in the horizontal joint above panels 2C&2D.
18:00	975	Flaming from the vertical junction between panels 2C&2D.
18:10	985	Detachment of small sections of debris from panel 1D.
19:10	1045	Flaming from the vertical junction between panels 1D&1E.
19:45	1080	Area of discolouration on wing wall panels (0A, 1A&2A) has increased.
21:20	1175	Detachment of small sections from panels 2C&2D.
22:10	1225	Intermittent flaming from the vertical junction between panels 2C&2D.
22:30	1245	Detachment of several sections from panel 2C.
23:00	1275	Distortion of remaining sections of panels 2C&2D away from cladding system.

Time* (mins:secs)	t_s (seconds)	Description
23:40	1315	Frequent flaming along the horizontal and vertical junctions between panels: 2C, 2D, 3C&3D.
24:20	1355	Frequent flaming along the vertical junction between panels 2B and 2C.
24:30	1365	Flaming at the horizontal junction between panels 1B&2B.
25:00	1395	Sustained flaming at the top of panels 2C&2D.
25:20	1415	Flickering flames at the horizontal junction between wing wall panels 1A&2A.
26:40	1495	Flaming at the vertical junction between main-wing wall panels 1A&1B.
27:00	1515	Detachment of several sections from panel 2D.
28:15	1590	Detachment of a larger section from panel 2D.
28:55	1630	The upper part of panel 1B is consumed. Flaming from PIR insulation.
29:59	1694	Detachment of the remaining section of panel 1B. PIR insulation is exposed.
30:00	1695	Fuel load extinguished. The monitoring procedure continued for an additional 30 minutes.
30:50	1745	Flickering flaming from PIR insulation across full surface where exposed on the main face.
32:00	1815	Significantly reduced flaming from the insulation, isolated locations on the main wall.
33:35	1910	Small intermittent flaming is present at the horizontal junction between wing panels 1A&2A. Small intermittent flaming is present at the exposed face of panel 2B. Small intermittent flaming is present at the base of the vertical junction between main-wing panels 1A&1B. Small intermittent flaming is present on the exposed insulation (top location of panel 1C). Glowing parts of exposed insulation are visible at location of panels 1C&1D.

Time* (mins:secs)	t_s (seconds)	Description
38:40	2215	Flaming from exposed PIR insulation has ceased. Small flaming present at the top and base of the vertical junction between main-wing wall panels 1A&1B.
51:00	2955	All visible flaming has ceased.
60:00	3495	No significant visible changes since the last observation. Test terminated.

*Time from point of ignition.

6 Analysis of fire performance and classification

The primary concerns given in BR 135[2] when setting the performance criteria for these systems are those of fire spread away from the initial fire source and the rate of fire spread.

In order for a classification to BR 135[2] to be undertaken, the cladding system must have been tested to the full test duration requirements of BS 8414-1[1] without any early termination of the test. If the test criterion is met, then the performance of the system under investigation is evaluated against the following three criteria;

- External fire spread
- Internal fire spread
- Mechanical performance

Failure due to external fire spread is deemed to have occurred if the temperature rise above T_s (the mean temperature of the thermocouples at level 1 during the 5 minutes before ignition) of any of the external thermocouples at level 2 exceeds 600°C for a period of at least 30 seconds within 15 minutes of the start time (t_s).

Failure due to internal fire spread is deemed to have occurred if the temperature rise above T_s of any of the internal thermocouples at level 2 exceeds 600°C for a period of at least 30 seconds within 15 minutes of the start time (t_s).

No failure criteria are defined for mechanical performance. However, BR 135[2] notes that ongoing system combustion following extinguishing of the ignition source shall be included in the test and classification reports together with details of any system collapse, spalling, delamination, flaming debris and pool fires. The nature of the mechanical performance should be considered as part of the overall risk assessment when specifying the system.

The cladding system was tested in accordance with BS 8414-1[1] without any early termination of the test and can therefore be evaluated against the performance criterion of BR 135[2].

Parameter	**Results**	
	Fire spread test result time, t_s (min)	**Compliance with parameters in Annex A BR135:2013**
External fire spread	>15 minutes	Compliant
Internal fire spread (Cavity)	>15 minutes	Compliant
Internal fire spread (Insulation)	>15 minutes	Compliant
Mechanical performance	See section 5.2	

7 Post-test damage report

7.1 Summary

The cladding system was significantly damaged up to the height of the third horizontal cavity barrier – see *Figures 22-33*. The extent of the damage increased from black discolouration of the ACM panels at the edges of the flame damage zone to complete consumption of panels, rail substructure, substantial charring and detachment of the insulation across the full width of the combustion chamber opening up to a height of approximately 4600mm – see *Figures 22-33*. The wing wall was less severely damaged than the main wall with slight insulation charring adjacent to the main wall up to a height of approximately 4600mm above the combustion chamber, one area (<0.05m^2) of partial panel consumption, and significant panel discolouration and distortion below the height of the third cavity barrier which reduced in severity towards the top of the cladding system – see *Figures 24-32.*

7.1.1 ACM panels

On the main wall, approximately 70% of the ACM panels directly above the combustion chamber, up to the height of the third cavity barrier, were consumed – see *Figures 22&23*. With reference to *Figure 1*:

- 100% consumption of panel 1C.
- 85% consumption of 1D.
- 78% consumption of 2C.
- 25% consumption of panel 2D.

Smaller areas of panel consumption on the main wall to panel 1B which had almost completely detached from the cladding system – see *Figures 22&23.*

Significant discolouration and distortion was sustained by panels: 2B (85%), 2C (100% of remaining panel), 2D (40% - immediately adjacent to the area of panel consumption a damaged strip with an area approximately 0.9m^2 was present) – see *Figures 22, 23&27.*

On the wing wall, there was one area, approximately 1800mm above the height of the combustion chamber and 150mm from the main wall, of partial panel consumption (<0.05m^2) – see *Figure 26.*

Significant discolouration and distortion was sustained by panels: 0A (75%), 1A (80%), 2A (50%) and 3A (5%) – see *Figures 24-29*. The damaged area tapered, in the direction of the main wall, from within 100mm of the outer edge of the wing wall (approximately 1300mm above the height of the combustion chamber) to the wing-main wall junction at the top of panel 2A.

7.1.2 'T' and 'L' rail substructure

Damage to the rail substructure was most severe on the main wall with the five sections spaced evenly across the combustion chamber opening sustaining significant consumption below the height of the third cavity barrier – see *Figures 30-33*. At 500mm intervals from the edge of the combustion chamber adjacent to the wing wall the following damage occurred:

- 'T'-section: complete consumption from the combustion chamber opening to the height of the second cavity barrier. A further 200mm of partial consumption, 300mm above the second cavity barrier and significant distortion and discolouration to the height of the third cavity barrier.
- 'L'-section: complete consumption from the combustion chamber opening to a height approximately 1300mm above the second cavity barrier. Significant discolouration and distortion to the height of the third cavity barrier.

- 'T'-section: complete consumption from the combustion chamber opening to a height approximately 2100mm above the second cavity barrier. Partial consumption of the remaining rail up to the height of the third cavity barrier.
- 'L'-section: complete consumption from the combustion chamber opening to the height of the second cavity barrier and above this, with the exception of a partially consumed 200mm-long section at the height of the cavity barrier, to a height 600mm above the second cavity barrier.
- 'T'-section: partial consumption in the region 1200mm-1900mm above the combustion chamber opening. Significant distortion 600-1200mm above the top of the combustion chamber and 1900mm-second cavity barrier.

Above the height of the third cavity barrier, the five main wall rails sustained minor discolouration – see *Figure 33*.

The corner section of railing ('L'-section fixed to 'T'-section) at the main-wing wall junction was partially consumed, on the main wall face, in the region 500mm-1900mm above the combustion chamber opening – see *Figure 31*. The remaining corner section, specifically the 'L'-section on the main wall face, between the first and second cavity barriers was discoloured and distorted. Between the second and third cavity barriers the 'L'-section was fully consumed up to a height 800mm above the second cavity barrier – see *Figure 32.* The 'T'-section on the wing wall was partially consumed in the region 300mm-500mm above the second cavity barrier.

Damage to the rail substructure on the wing wall was far less severe – see *Figures 30-33.* Between the first and second cavity barrier, the 'L'-rail at the centre of panel 1A sustained five isolated areas of dark discolouration – see *Figure 31.* Between the second and the third cavity barrier, two isolated areas of dark discolouration were observed approximately at mid-height – see *Figure 32.* The rail substructure above this suffered minor discolouration and, at the outside edge of the vertical cavity barrier (full-height, main and wing wall) no damage was visible - see *Figures 30-33*.

7.1.3 PIR insulation

On the main wall face, at the location of panel/s (refer to *Figure 1)*:

- 1C&1D, charring (80-100mm char depth) of the insulation occurred across the full area, approximately 0.4m^2 of exposed blockwork due to detachment/consumption of insulation – see *Figure 22, 30&31*.
- 2C, charring (typically 40mm-deep) of the insulation occurred in decreasing severity between the second and third cavity barrier. The foil face of the insulation remained intact in an approximately 0.3m^2 patch in the top left corner – see *Figure 32.*
- 2D, charring (typically 40mm-deep) of the insulation occurred in decreasing severity between the second and third cavity barrier. The foil face of the insulation remained intact in a rectangular patch approximately 1.4m^2 which started in the top right corner, spanned the 'L'-section across ¾ panel width and down to a height 400mm above the second cavity barrier – see *Figure 32.*
- 1B-2B, charring of the insulation ranged from 30mm-depth at 1B to a peak of 75mm-depth at the mid-height of 2B– see *Figures 31&32.*
- 3B-3D, light discolouration of the foil facing was the extent of the damage – see *Figure 33*.
- 0E-3E, damage to the insulation was not observed beyond the vertical cavity barrier – see *Figures 30-33*.

On the wing wall face, beneath panel (refer to *Figure 1)*:

- 1A, the foil facing was consumed and the insulation charred to a depth of 60mm in an area approximately 300mm-wide×500mm-high in a position directly adjacent to the main wall and approximately 1200mm above the first horizontal cavity barrier. Significant discolouration and blistering of the foil facing covering the remaining area between the centrally supporting 'L'-rail and the main wall occurred. To the left of the centrally supporting 'L'-rail the insulation sustained minor discolouration – see *Figure 31*.

- 2A, the foil facing was blistered and discoloured between the central 'L'-section and the main wall. Minor discolouration and blistering was the extent of damage to the remainder of the insulation panel – see *Figure 32*.
- 3A, minor discolouration to the foil facing was the extent of damage – see *Figure 34.*

7.1.4 Horizontal (intumescent) cavity barriers

The first row horizontal intumescent cavity barrier directly above the combustion chamber was exposed to a significant fire load and there is evidence of activation, however; some of the material appears to have been consumed or detached during the test – see *Figure 31*. A 1300mm-long section of cavity barrier detached from the wing wall edge of the combustion chamber following consumption of the aluminium window pod. The section of cavity barrier at the outside edge, beneath panel 1E, displays the initial signs of activation – see *Figure 31*. On the wing wall, activation of the cavity barrier filled the void across ¾-width (from ¼ width to the main wall). Partial activation of the remaining ¼-width of cavity barrier occurred at the outside edge of the wing wall – see *Figure 31*.

The second row horizontal cavity barrier shows evidence of activation but by test termination all expanded material directly in line with the combustion chamber opening had been consumed and the barrier had started to slump – see *Figures 32&34.* The section of cavity barrier at the outside edge, beneath panel 2E, displays the initial signs of activation. On the wing wall, full width activation of the cavity barrier is evident: from the outside edge to ¾-width the intumescent material fills the void, towards the main wall the intumescent material has detached and deteriorated – see *Figure 32.*

The third row horizontal cavity barrier expanded to fill the void from ¼-width (from outside edge to main wall) on the wing wall to the outside edge of the combustion chamber opening on the main wall – see *Figure 33*. The section of cavity barrier at the outside edge, beneath panel 3E, is undamaged and has not activated. Partial activation on the wing wall cavity barrier occurred in the ¼-width furthest from the main wall.

The fourth row horizontal cavity barrier shows the early signs of activation except for the outside edge of the main wall which appeared undamaged – see *Figure 33*.

7.1.5 Vertical (compression) cavity barriers

From the height of the combustion chamber opening to the height of the second horizontal cavity barrier, the vertical cavity barrier on the inside edge of the main wall (adjacent to the wing wall), was significantly discoloured – see *Figure 35*. Between the second and third cavity barrier discolouration of the vertical barrier reduced and was minimal beyond this point – see *Figures 32*.

The vertical cavity barrier on the outside edge of the combustion chamber opening was discoloured along the inside edge but remained intact and prevented fire spread to the outside edge of the main wall.

Fire spread within the cavity did not appear to have reached the vertical cavity barrier at the outside edge of the wing wall– see *Figures 30-33.*

8 Reference

1. BS 8414-1:2015 + A1:2017, 'Fire performance of external cladding systems – Part 1: Test method for non-load bearing external cladding systems applied to the masonry face of the building', British Standards Institution, London, 2015.

2. Colwell, S and Baker, T. BR 135, "Fire performance of external thermal insulation for walls of multistorey buildings", Third Edition, published by IHS BRE press, 2013.

3. BS EN ISO 1716:2010 (*"Reaction to fire tests for products. Determination of the gross heat of combustion (calorific value)",* British Standards Institution, London, 2010.

9 Figures

9.1 Diagrams of finished face of the cladding system

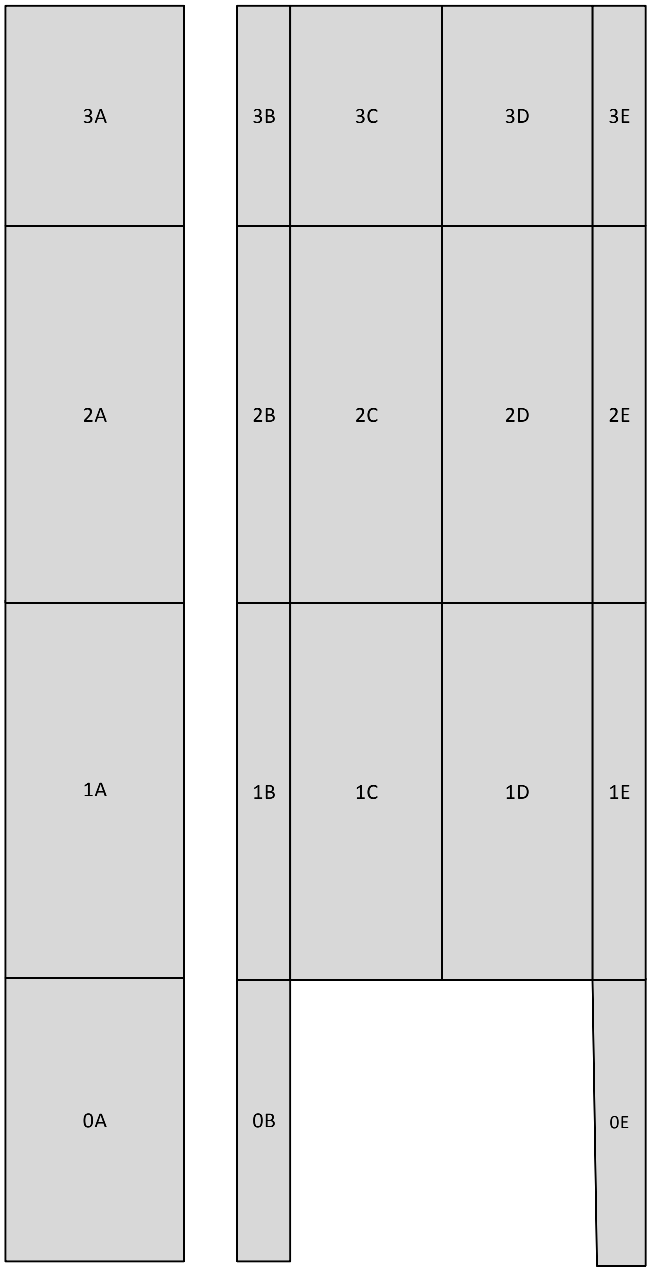


Figure 1. Layout of panels and labelling system used for reporting purposes. Not to scale.

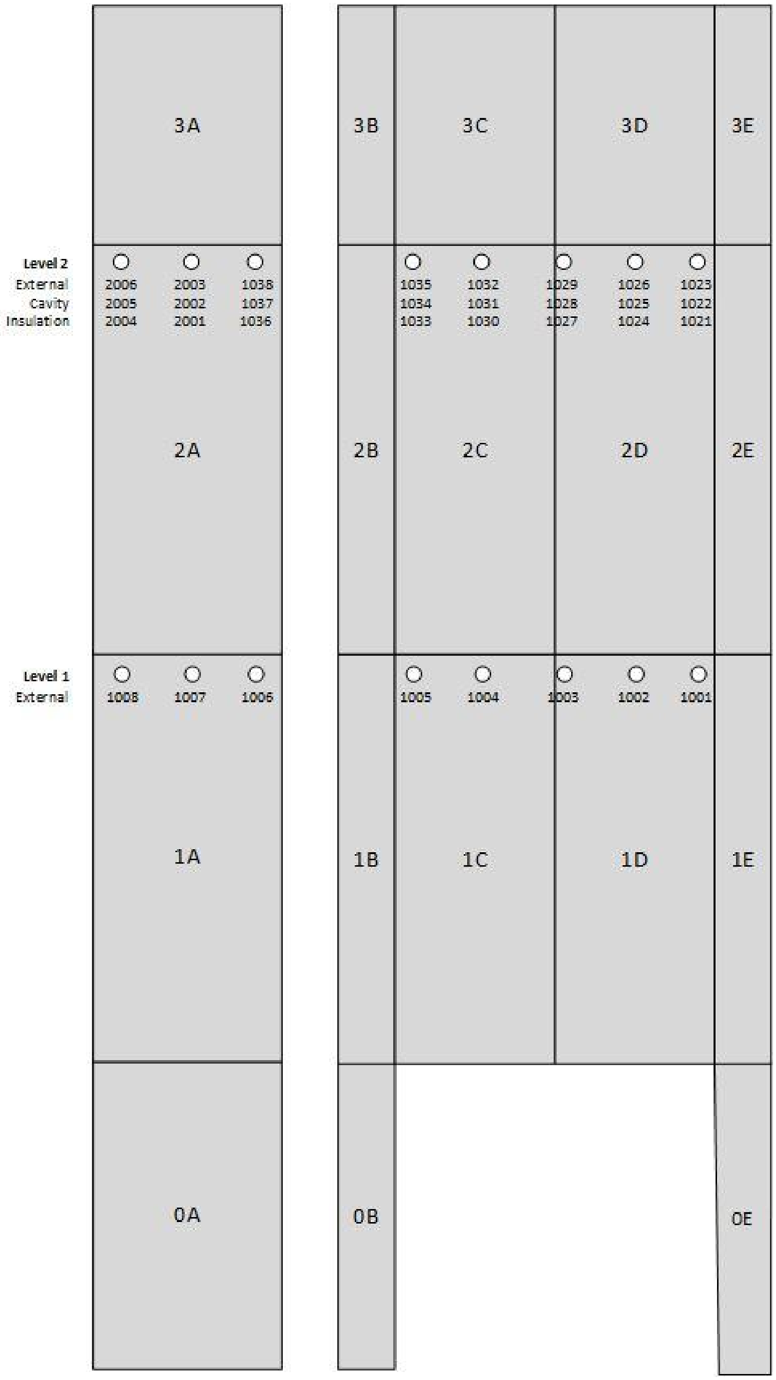


Figure 2. TC positions and panel labelling system (0A – 3E). Not to scale.

9.2 Installation photographs

Figure 3. Location of ‘L’ brackets (partially visible) and vertical cavity barriers.

Figure 4. Horizontal intumescent cavity barriers fitted between vertical cavity barriers.

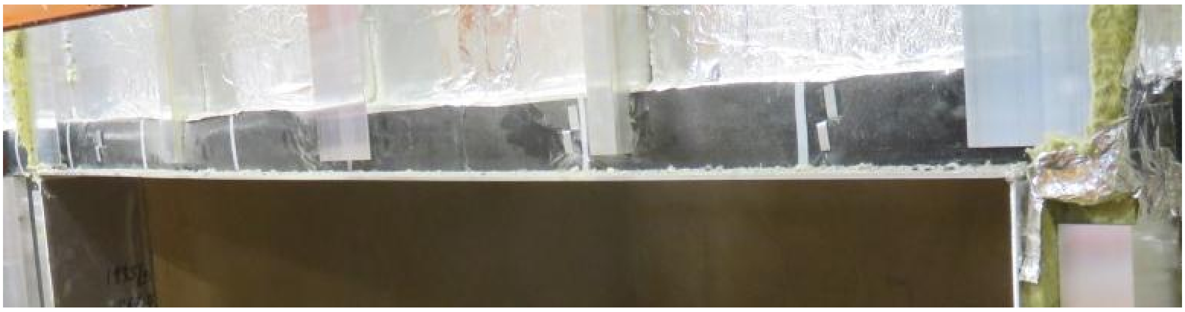


Figure 5. Horizontal intumescent cavity barriers fixed through the entire depth on face turned steel brackets, fitted above window pod.

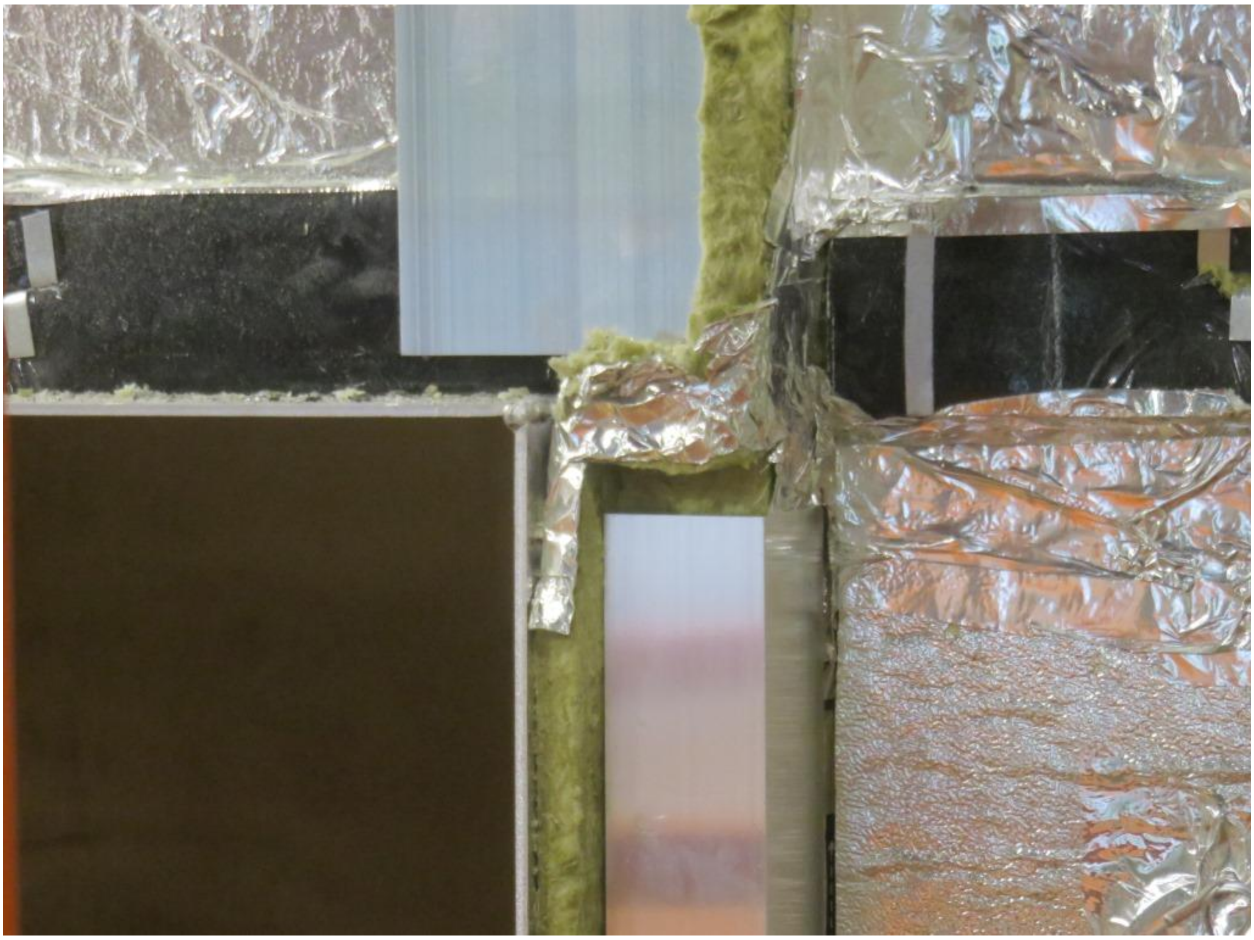


Figure 6. Vertical cavity barrier cut to fit under ‘T’-rail.

Figure 7. Installed cavity barriers and PIR insulation panels.

Figure 8. Example of aluminium rail fixed to ‘L’ bracket through movement holes.

Figure 9. Example of aluminium rail fixed to ‘L’ bracket through fixed holes.

Figure 10. Completed installation of railing substructure visible on main wall.

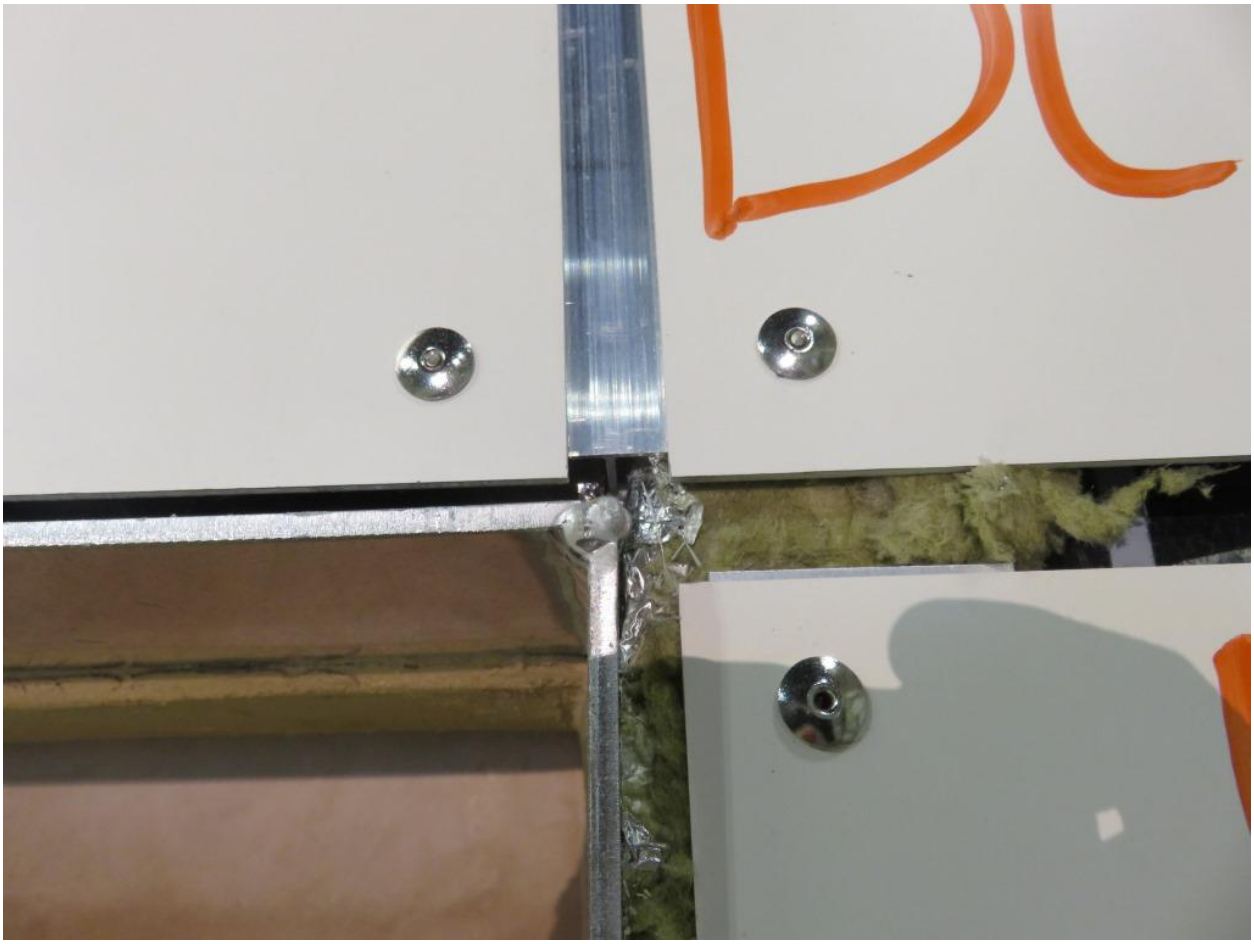


Figure 11. Detail at corner of combustion chamber opening. Panels riveted in place with nominal 20mm vertical gap for ventilation purposes.

Figure 12. Completed installation prior to test.

9.3 System drawings

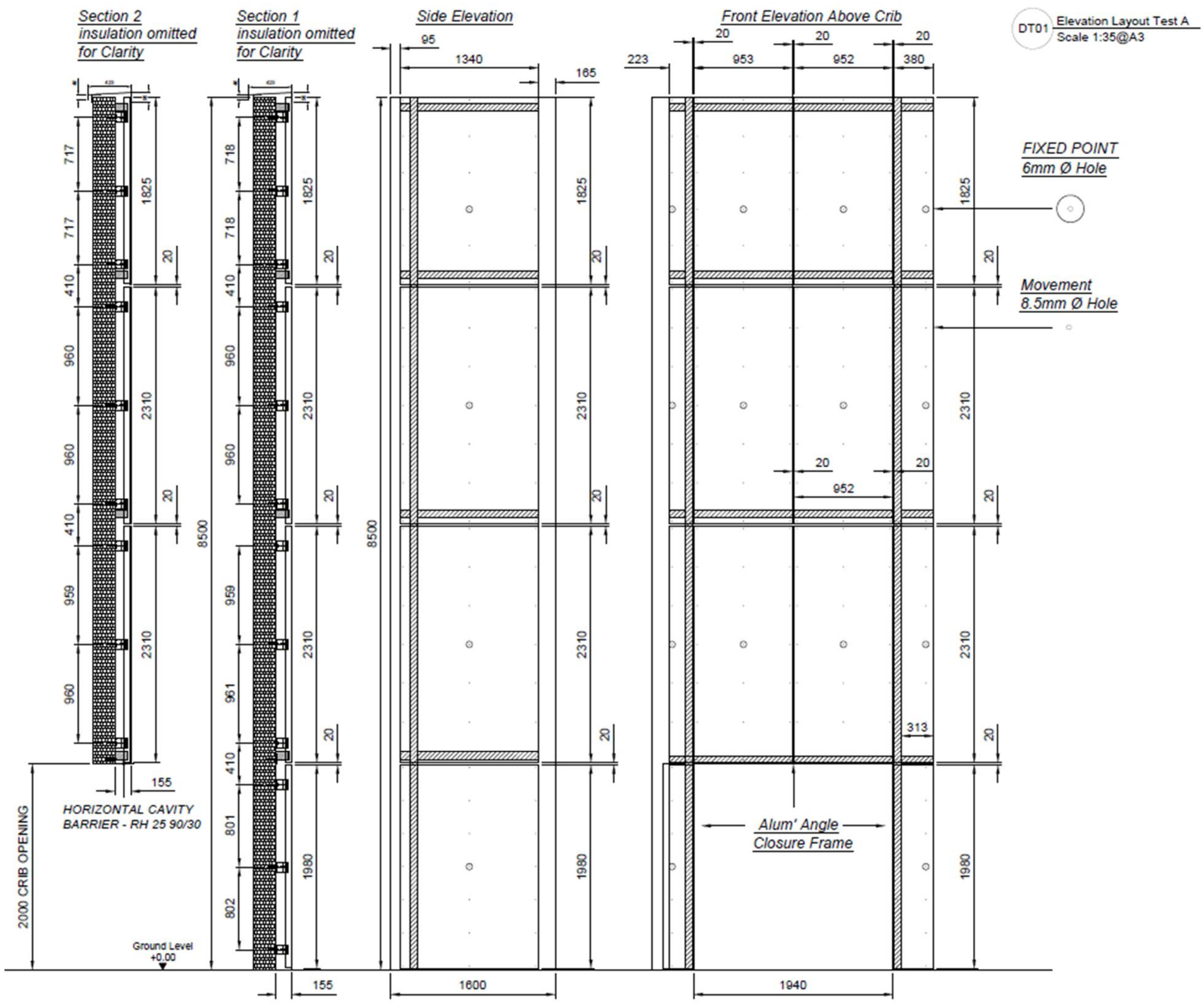


Figure 13. Front elevation, side elevation and vertical sections for the system (supplied by the Test Sponsor)

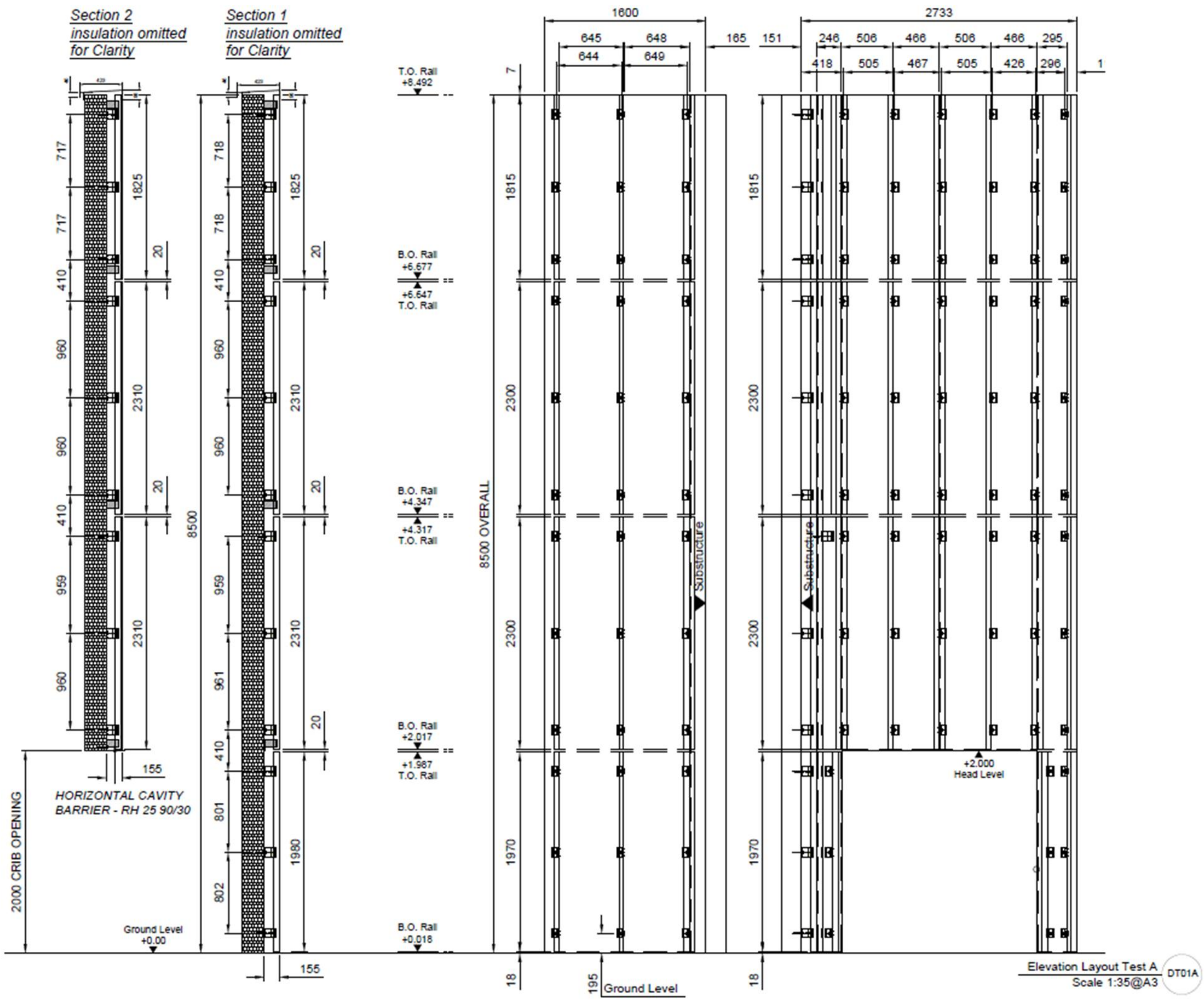


Figure 14. Front elevation, side elevation and vertical sections for the substructure system (supplied by the Test Sponsor).

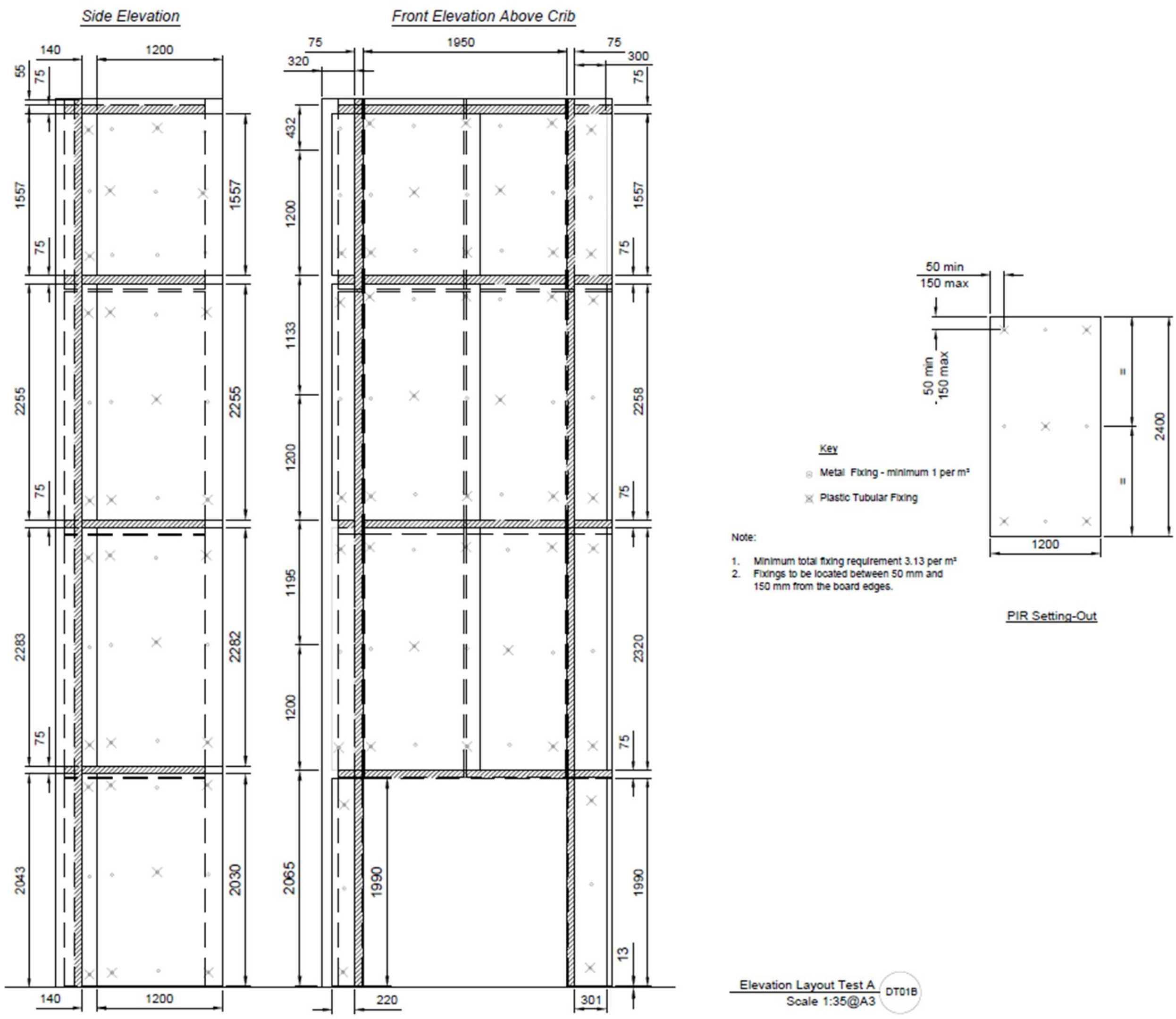


Figure 15. Front elevation, side elevation for the insulation panels installation (supplied by the Test Sponsor).

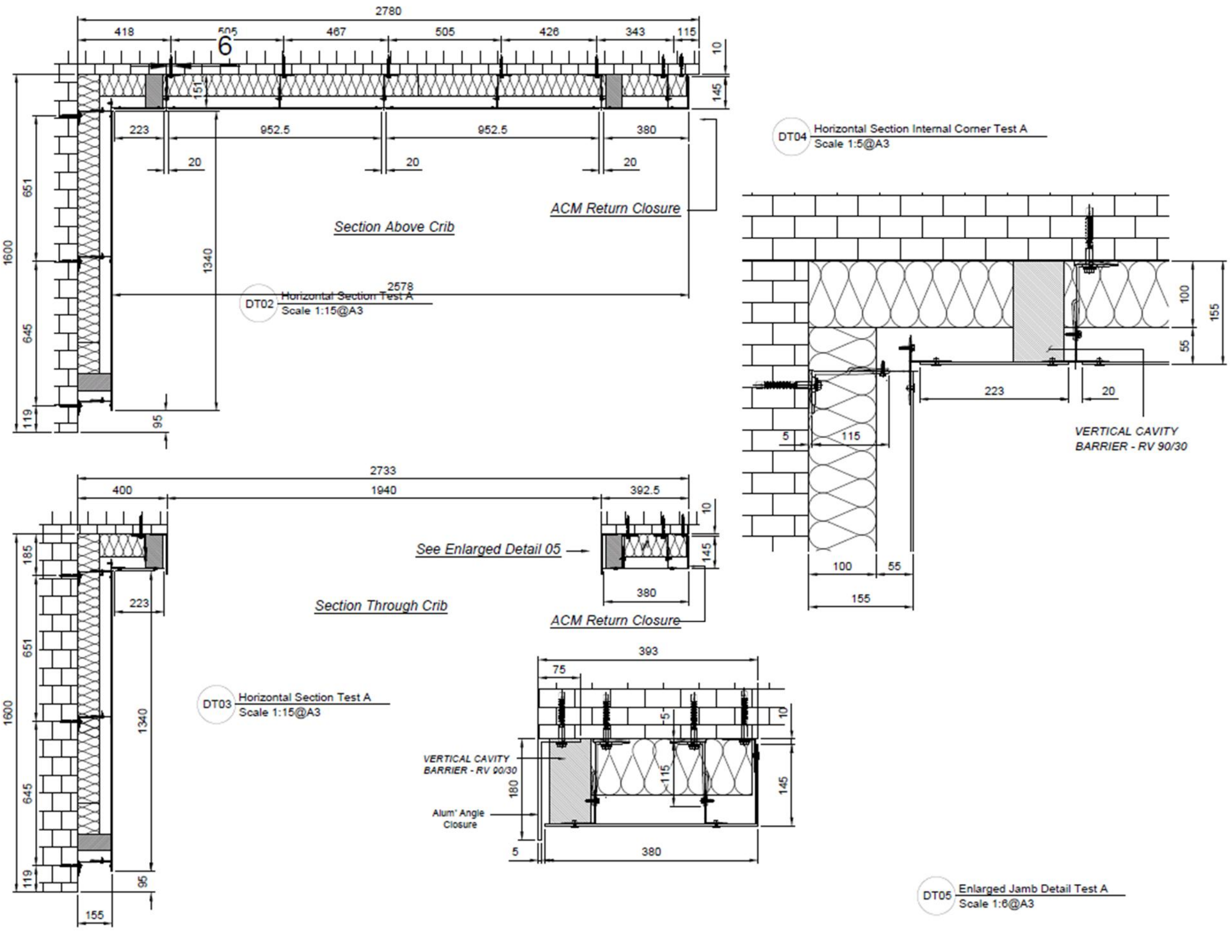


Figure 16. Horizontal section through and above the combustion chamber, and installation details for the system (supplied by the Test Sponsor).

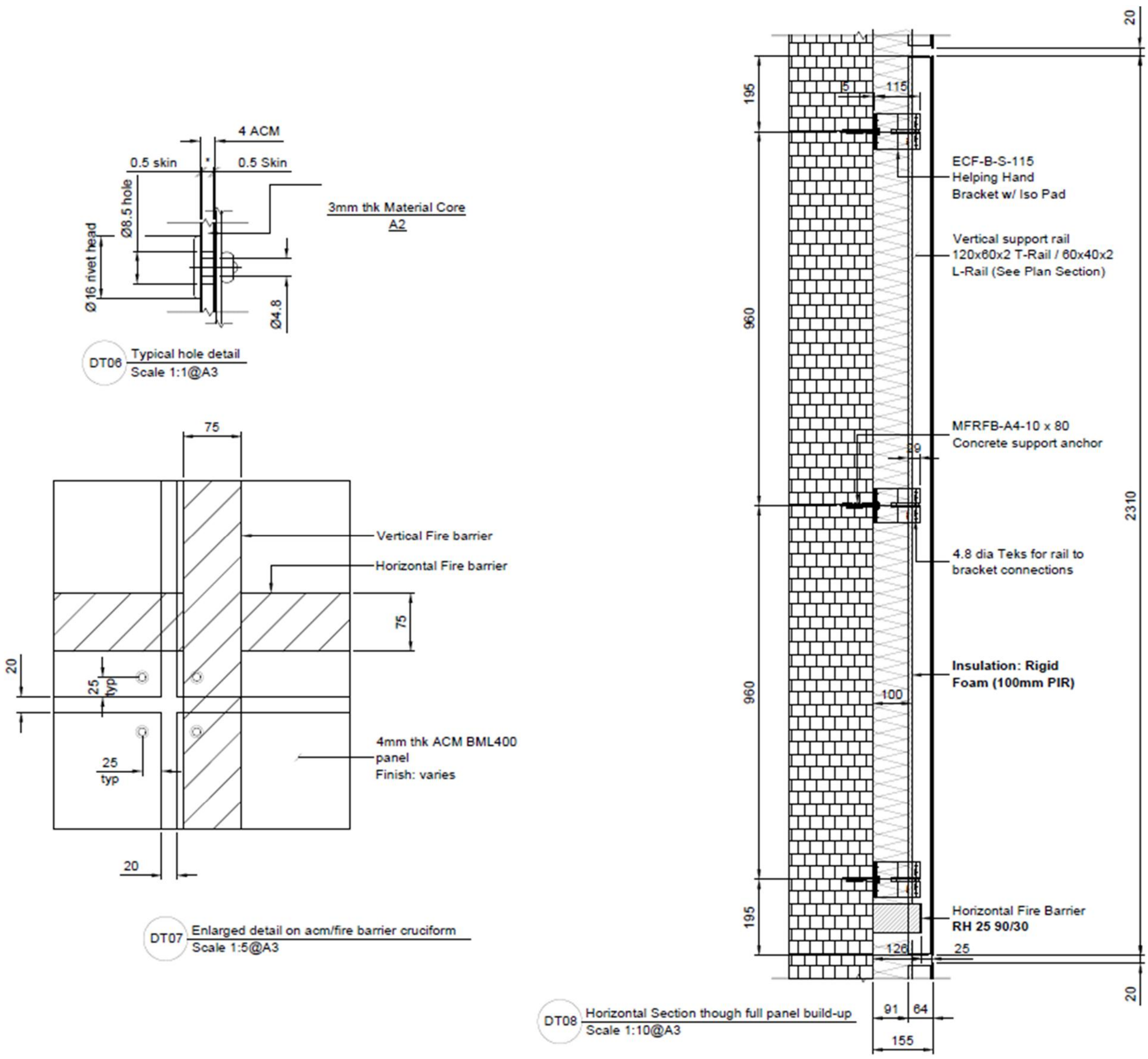


Figure 17. Vertical section through the cladding system, ACM panel detail and vertical and horizontal cavity barriers intersection (supplied by the Test Sponsor).

9.4 Temperature data

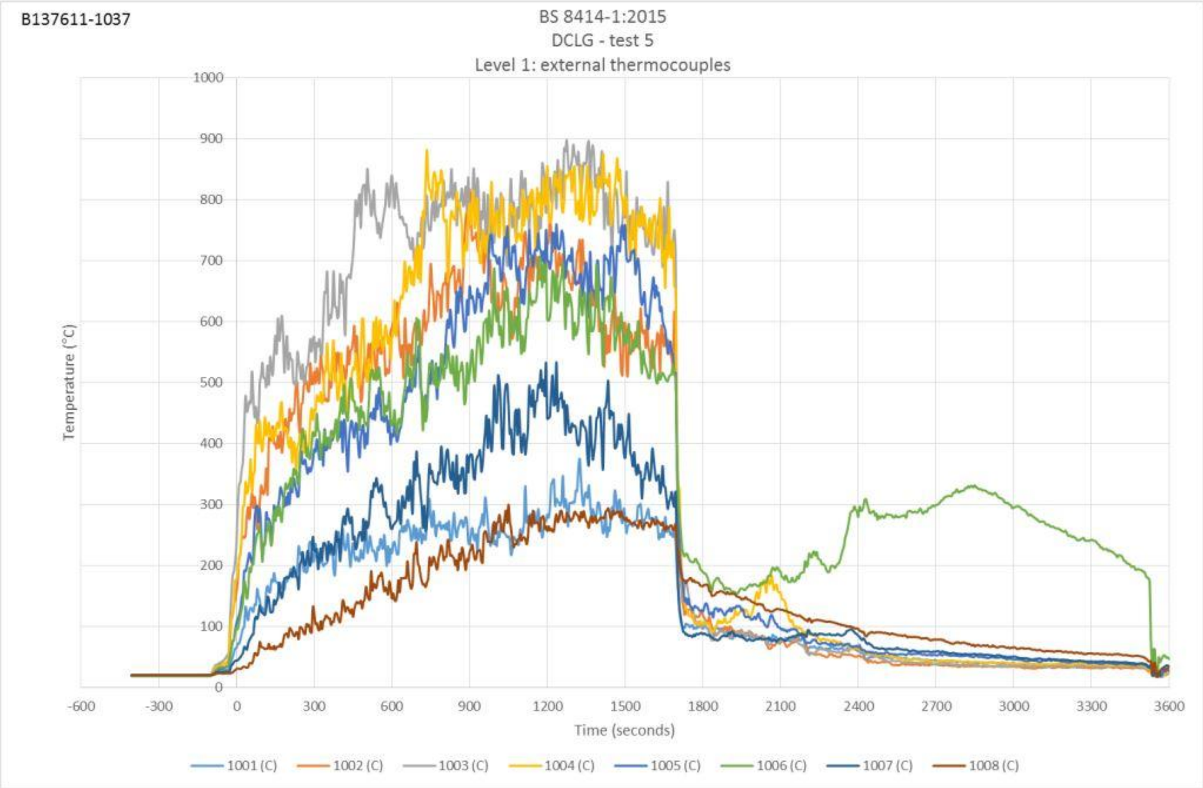


Figure 18. Level 1 external thermocouples.

t_s=105s after ignition of the crib.

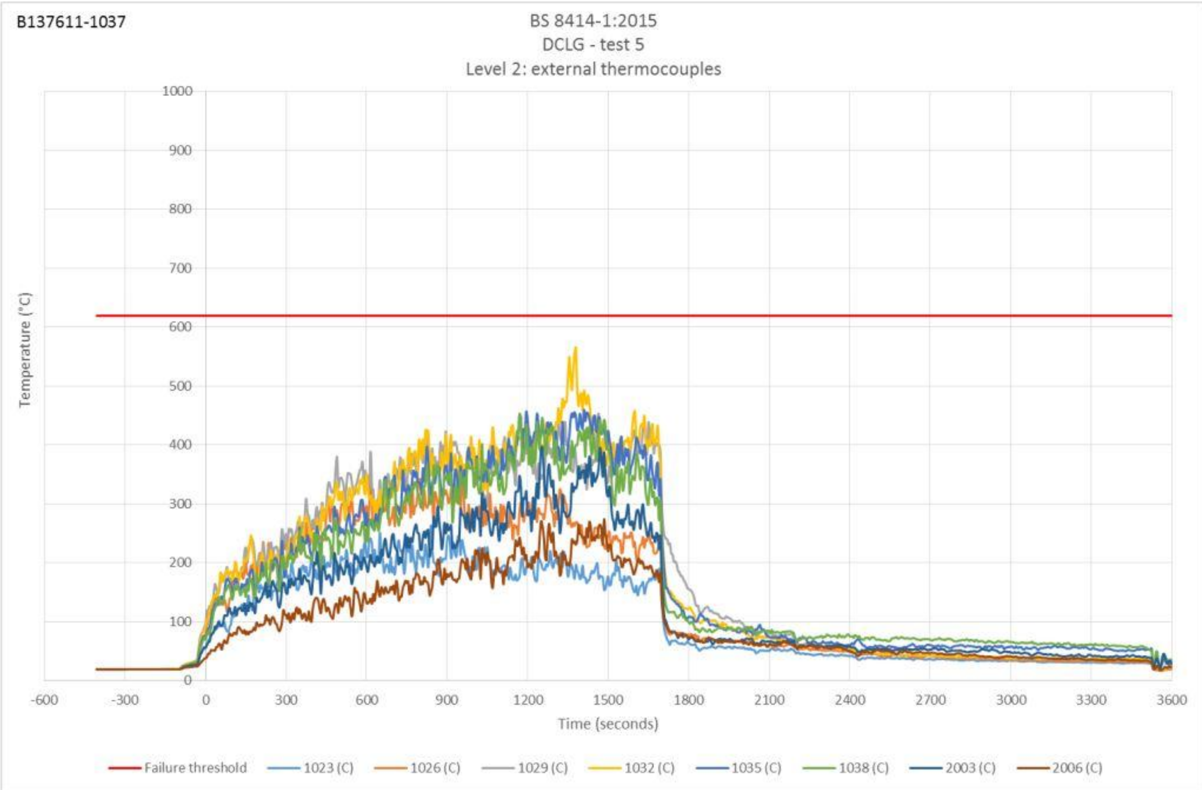


Figure 19. Level 2 external thermocouples.

t_s=105s after ignition of the crib.

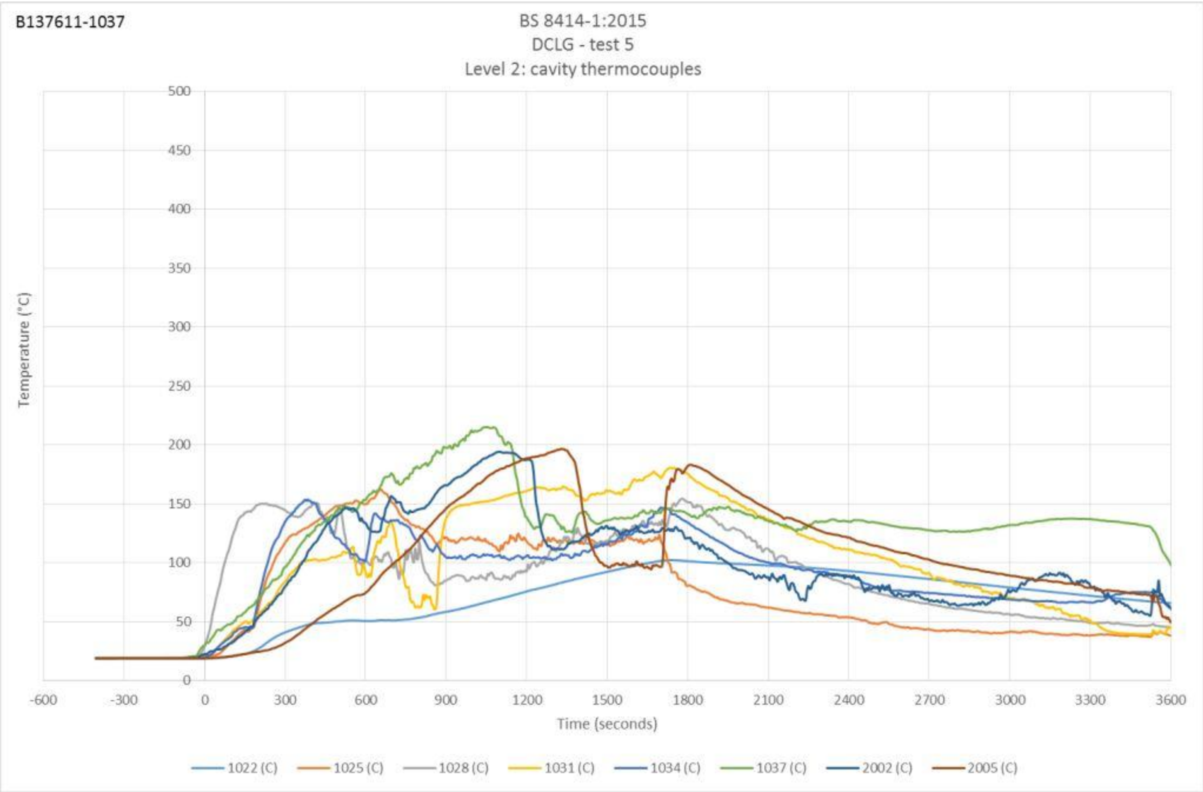


Figure 20. Level 2 cavity thermocouples.

t_s=105s after ignition of the crib.

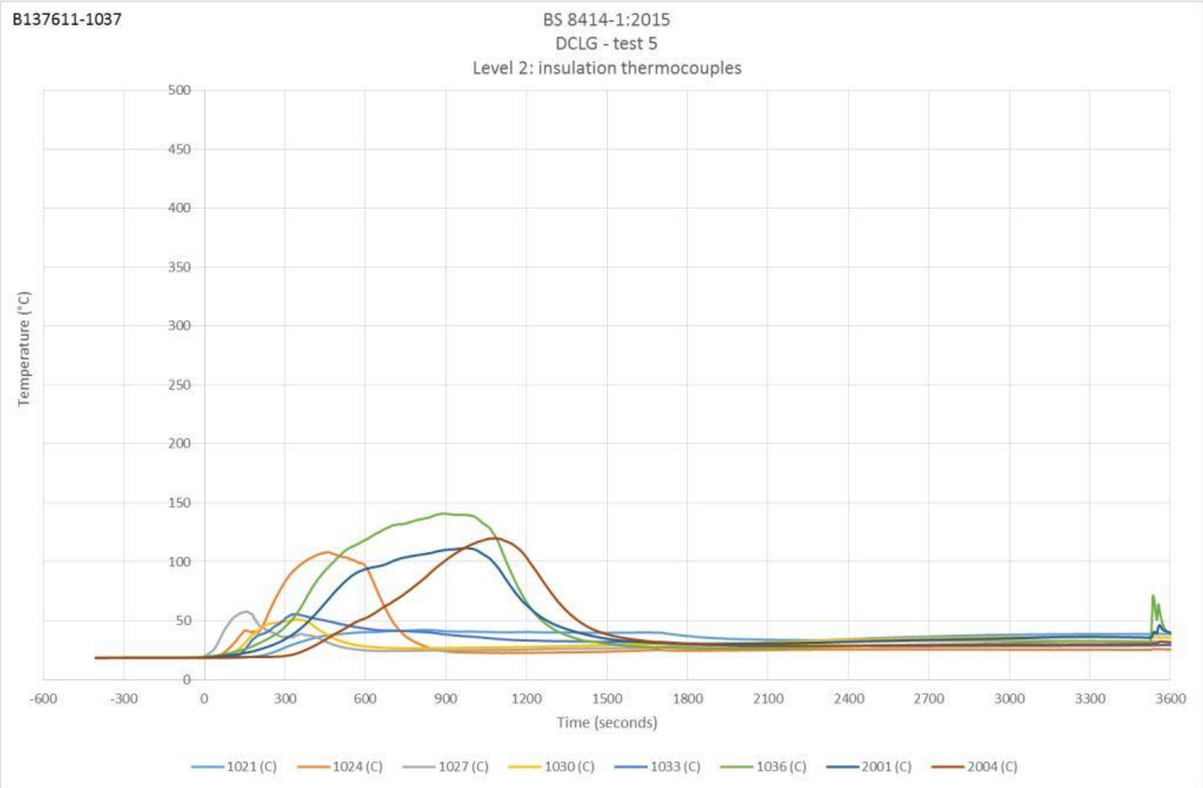


Figure 21. Level 2 insulation thermocouples.

t_s=105s after ignition of the crib.

9.5 Post-test photographs

Figure 22. Full height photograph of system post-test – general.

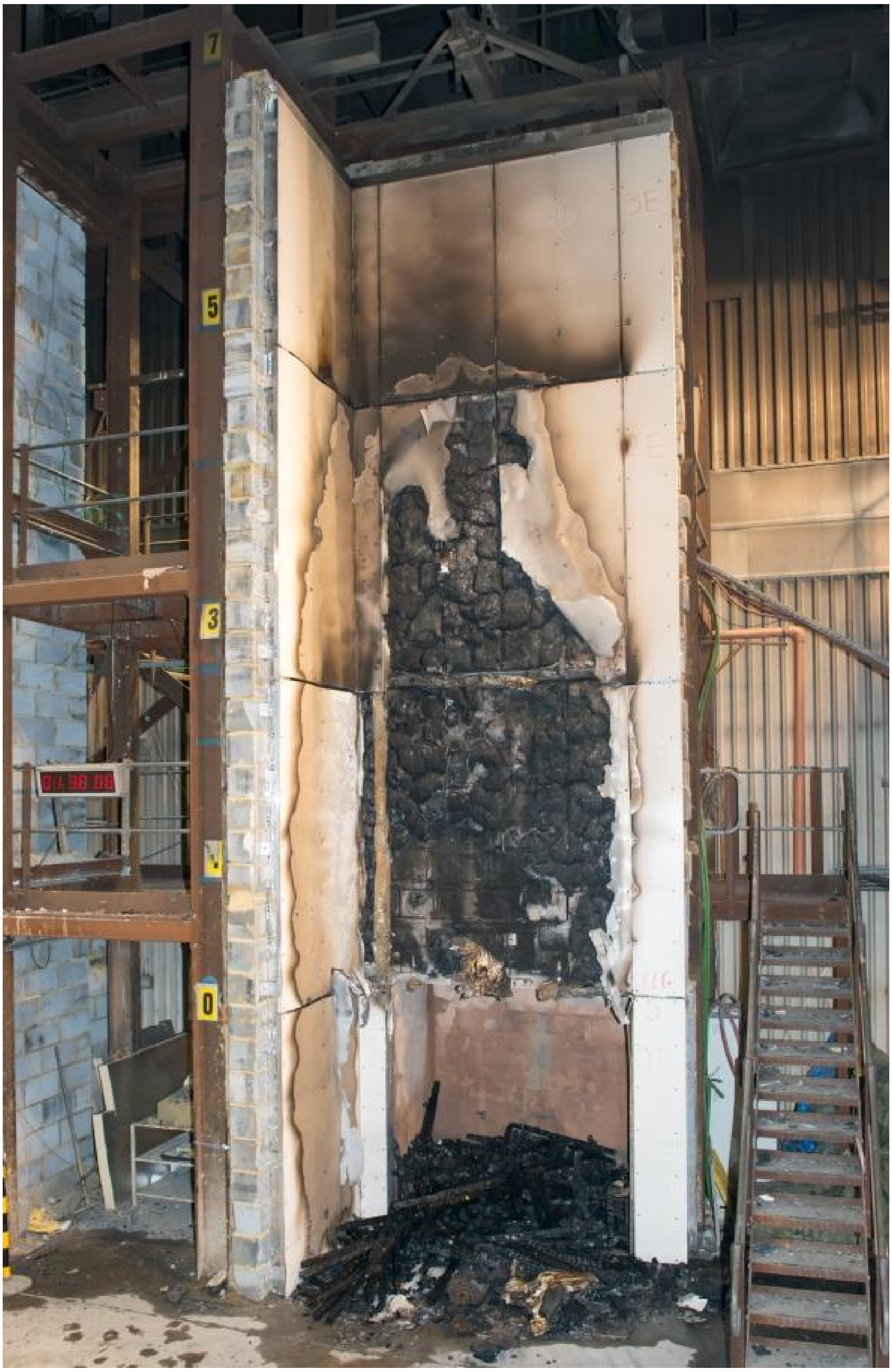


Figure 23. Full height photograph of system following post-test damping down procedures.

Figure 24. Photograph of system post-test – wing wall.

Figure 25. First row ACM panels (directly above combustion chamber).

Figure 26. Close up view of partial panel consumption on the wing wall.

Figure 27. Second row ACM panels (approximately 2300mm-4600mm above combustion chamber).

Figure 28. Third row ACM panels (approximately 4600mm-6500mm above combustion chamber).

Figure 29. Distortion and delamination of ACM panel 1A – note some filler material remains intact.

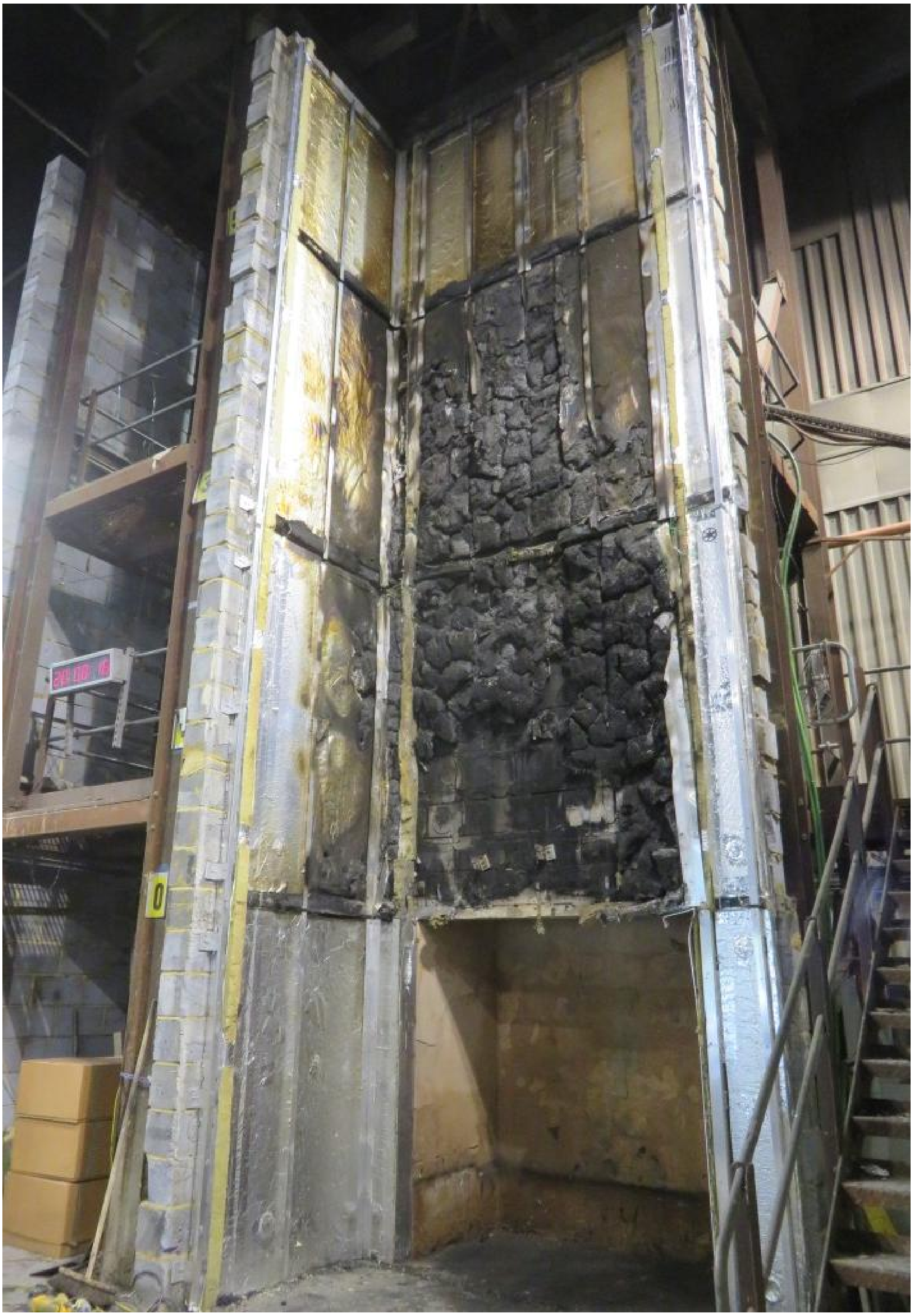


Figure 30. Full height photograph of system following removal of ACM panels.

Figure 31. Damage to cladding system beneath ACM panels directly above combustion chamber.

Figure 32. Damage to cladding system beneath ACM panels between the second and third horizontal cavity barrier (approximately 2400-4700mm above combustion chamber).

Figure 33. Damage to cladding system beneath ACM panels between the third and fourth horizontal cavity barrier (approximately 4700-6400mm above the combustion chamber).

Figure 34. Close up of second cavity barrier in line with the combustion chamber opening.

Figure 35. Close up of vertical cavity barrier adjacent to the wing wall directly above the combustion chamber (photograph taken during the 30-60 minute test period).

Appendix A – Material densities

Representative samples of the construction materials were taken during construction.

The free moisture content ($W_1 – W_2$) of the samples expressed as a percentage of the dried weights (W_2), and density (kg/m^3) are given in *Table 2.*

Table 2: Conditioning and material information.

Sample Material	Oven drying temperature	Moisture content by dry weight (%)	Density (kg/m^3)
PIR insulation	105 ± 5ºC	2.6	30.9
Vertical cavity barrier	105 ± 5ºC	0.4	78.9
Horizontal cavity barrier	105 ± 5ºC	0.5	88.0

Appendix B – ACM panel screening test results

The screening test indicates whether the core or filler of the ACM panel used as part of the cladding system has properties which indicate flame retardant properties based on testing in BS EN ISO 1716:2010[3]. As the purpose of this testing was to quickly and reliably screen the core material, the full procedures set out in the BS EN ISO 1716:2010 (*"Reaction to fire tests for products. Determination of the gross heat of combustion (calorific value)"* test standard have not been followed as they are unnecessary to confirm which type of panel has been used. These results should therefore be considered to provide a high degree of certainty as to the type of panel screened.

The result indicates the performance achieved for the core in terms of a category

- **Category 1** means that the result is in line with the requirements for a material of limited combustibility (Calorific potential ≤3 MJ/kg)
- **Category 2** means that the result does not achieve the requirements of category 1 but that it does have some limited flame retardant properties (Calorific potential > 3MJ/kg and ≤35MJ/kg)
- **Category 3** means that the result does not achieve the requirements of Category 1 or 2 and that it has no flame retardant properties (Calorific potential >35MJ/kg)

DCLG Advice - ***The Department's view is that cladding material found to be in either Category 2 or Category 3 in the screening test would not meet the requirements for limited combustibility set out in Approved Document B guidance.***

The samples were taken from aluminium composite material panels that were part of the cladding system tested and they had the following characteristics:

Overall dimensions (H×W mm)	Total thickness including Al facings (mm)	Code
2310×953	4.0	CT005-01 CT005-02 CT005-03

The ambient conditions in the testing room, prior to the test, were:

Ambient temperature (°C)	Relative humidity of the air (%)
22.7	52.3

Test results:

Test No.	Calorific value (MJ/kg)	Category	Standard deviation (%)
1	2.3560	CAT 1	0.09
2	2.4782	CAT 1	
3	2.5469	CAT 1	

Report Ends