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# BRE Global Client Report

**BS 8414-1:2015 + A1:2017 test referred to as DCLG test 3.**

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## Version History

| | | |
|---|---|---|
| 08/08/2017 | Issue 1.1 | Amendment to section 7.1.1. |
| 12/09/2017 | Issue 1.2 | Amendment to section 4.4. |

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# 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.

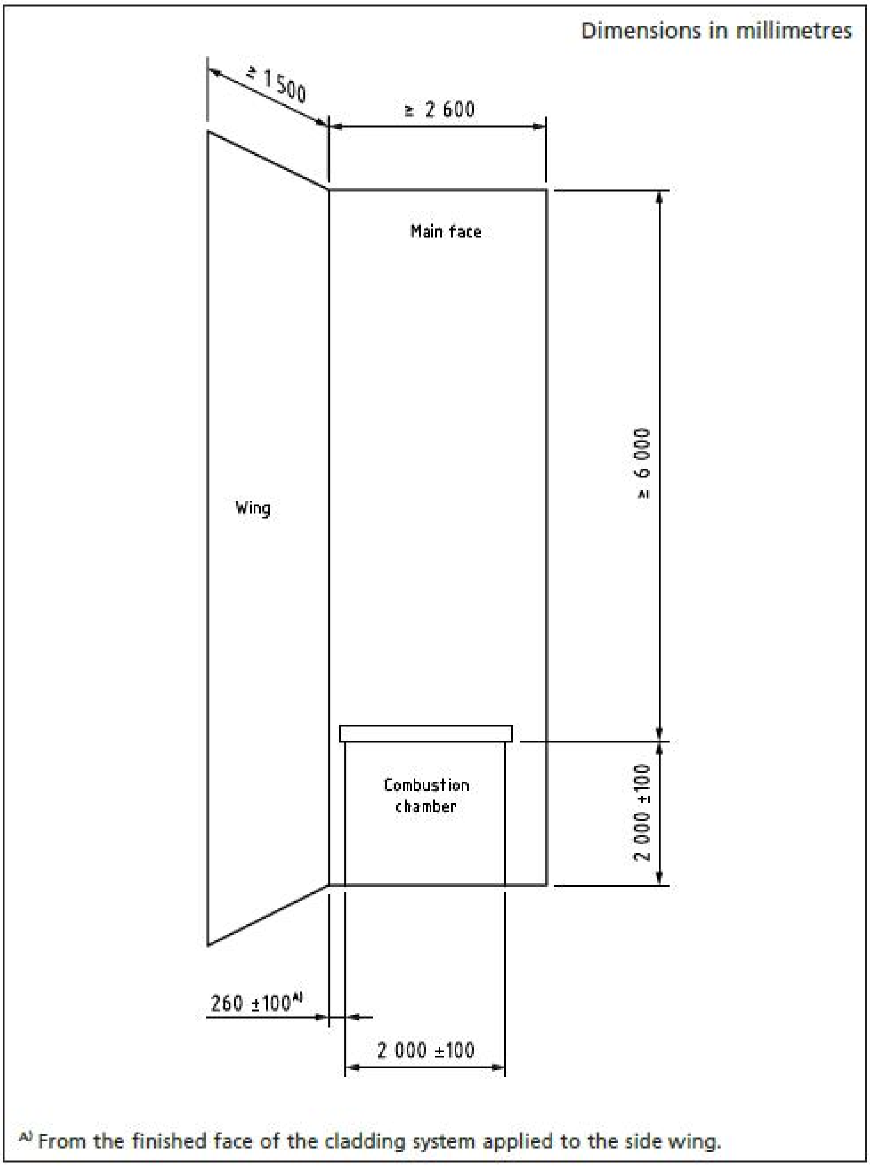
All measurements quoted in this report are nominal unless stated otherwise.

## 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 3 |
| **Date of test:** | 30/07/2017 |
| **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 15-19* 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 10&11;*
- 100mm-thick rigid polyisocyanurate (PIR) foam insulation boards (supplied 2400mm×1200mm and cut to size) with aluminium foil facings on both sides – see *Figures 7&8*;
- 120mm-wide×60mm-deep×2mm-thick aluminum 'T'-section framing and 40mm-wide×60mm-deep×2mm-thick aluminum 'L'-section framing – see *Figure 12*;
- 75mm-wide×160mm-deep stone wool vertical cavity barriers (stated integrity/insulation performance: 90/30mins), with 10mm compression – see *Figures 3-5*;
- 75mm-wide×125mm-deep stone wool with intumescent horizontal cavity barriers (stated integrity/insulation performance: 90/30mins) – see *Figures 3-8*;
- 4mm-thick front face Aluminum Composite Material (ACM) panels, with a white finish – see *Figure 13-14*.

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 fire retardant polyethylene (PE) 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. On the main face the horizontal spacing between the brackets varied between 340mm and 500mm. 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. 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 2120mm between them. The vertical cavity barriers above the combustion chamber were installed with an offset towards the main wall edges of approximately 70mm – see *Figure 5*. 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 – see *Figure 3&4*.

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. Once installed in position the stone wool vertical cavity barriers were compressed by the ACM panels to fully close the 50mm ventilated cavity. *Figure 3&4* demonstrate the installed 'L' brackets and vertical cavity barriers.

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 *Figures 5&6*. The window pod extended 180mm perpendicular to the masonry wall so that it extended approximately 30mm beyond the front face of the finished cladding system.

A set of four 75mm-wide×125mm-deep intumescent horizontal cavity barriers were butted up to the continuous vertical barriers 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 *Figures 5, 6 & 8*. 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 8*. The insulation panels were installed with the long edge orientated vertically - see *Figures 8&9*. 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 9*.

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. The horizontal spacing between successive sections of aluminium 'T'-section or 'L'-section framing was 970mm as shown in *Figure 12*. 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. 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 10&11*.

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 13*. The measured gaps after installation varied between 18mm and 20mm. 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 | 2650mm |
| ≥1200mm width across the wing wall | 1350mm |
| 260mm (±100mm) wing wall-combustion chamber opening | 225mm |
| 2000mm x 2000mm (±100mm) combustion chamber opening | 2000mm×1960mm |

## 4.5 Test conditions

**Test Date:** 30/07/17

**Ambient Temperature**: 19.7°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 20-23* provide the temperature profiles recorded. *Figure 14* shows the system before the test.

| Parameter | Result |
|---|---|
| $T_s$, Start Temperature | 20˚C |
| $t_s$, Start time | 110 seconds after ignition of crib. |
| Peak temperature / time at Level 2, External | 877˚C at 1395 seconds after $t_s$. |
| Peak temperature / time at Level 2, Cavity | 225˚C at 1395 seconds after $t_s$. |
| Peak temperature / time at Level 2, Insulation | 102˚C at 590 seconds after $t_s$. |

**Note:** The data reported in this table relates to the period up to the point of test termination. The test was terminated at 1402s. The last reported data points are at 1400s.

## 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. |
| 01:40 | | The flames from the combustion chamber are impinging on the cladding system. |
| 01:45 | | Flame tips to mid-height of panels 1C&1D. |
| 01:50 | 0 | Start time ($t_s$) criteria achieved: External temperature 2.5m above the top of the combustion chamber in excess of 220˚C (=200˚C+$T_s$). |
| 02:15 | 25 | Flame tips to top of panels 1C&1D. |
| 02:20 | 30 | Flame tips to height of Level 1 thermocouples. |

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| Time* (mins:secs) | $t_s$ (seconds) | Description |
|---|---|---|
| 02:25 | 35 | A small amount of distortion can be observed at the bottom of 1C&1D panels. |
| 02:55 | 65 | Discolouration and slight distortion of panels 1C&1D up to mid-height. A small amount of paint detachment can also be observed at the base of the panels. |
| 03:15 | 85 | Flame tips to mid-height of panels 2C&2D. |
| 03:25 | 95 | Detachment of paint up to mid-height of panels 1C&1D. |
| 04:00 | 130 | Sporadic flame tip height to the top of panels 2C&2D. |
| 04:20 | 150 | Detachment/consumption of paint layer to the top of panels 1C&1D to reveal ‘shiny’ exposed metal surface. Tapers from a width of approximately 1.5m directly above the combustion chamber. |
| 04:30 | 160 | Discolouration and detachment of the paint at the base of panels 2C&2D. |
| 05:20 | 210 | No significant visual change since the last observation. Flame tips continuously at mid-height of panels 2C&2D with sporadic emissions to the top of panels 2C&2D. Paint detachment has spread to approximately 400mm above the base of panels 2C&2D. |
| 06:00 | 250 | A small amount of burning droplets from the system can be observed, with a self-sustained burning duration less than 5 seconds. |
| 06:40 | 290 | Discolouration and detachment of the paint to a height of approximately 1m above the base of panels 2C&2D. Flame movement towards wing wall (panel 1A). |
| 07:07 | 317 | A small amount of burning droplets from the system can be observed, with a self-sustained burning duration of approximately 5 seconds. |
| 07:15 | 325 | Sporadic flame tip height to the Level 2 thermocouples. |
| 07:45 | 355 | Detachment/consumption of paint layer from directly above the combustion chamber (approximately 1.8m-width) to mid-height of panels 2C&2D with a width of approximately 1.5m at the horizontal panel junction. |
| 08:05 | 375 | Increased quantity of burning droplets from the system can be observed, with a self-sustained burning duration longer than 20 seconds. |
| 08:30 | 400 | Continued release of burning droplets. |

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| Time* (mins:secs) | $t_s$ (seconds) | Description |
|---|---|---|
| | | Dark discolouration to panel 1A, directly adjacent to wing wall, 100mm-above the height of the combustion chamber in an oval shape approximately 1m-high x 250mm-wide. |
| 09:00 | 430 | Sustained pool fire at the base of the cladding system. |
| 09:15 | 445 | Sporadic flame tips to mid-height of panels 3C&3D. |
| 09:30 | 460 | Increased production of burning droplets and melting of the aluminium at the base of panels 1C&1D.<br><br>Full-width destruction/detachment of paint layer directly above the combustion chamber tapering to a height approximately 1.75m above the base of panels 2C&2D. Near full-height discolouration on panel 1A with increased width to approximately 500mm. |
| 09:45 | 475 | Flame tips frequently up the height of the Level 2 thermocouples. Sporadic flame tips to top of the cladding system. |
| 10:00 | 490 | Flames can be observed in the cavity behind panels 1C&1D. |
| 10:45 | 535 | Melting of aluminium to the top of panels 1C&1D. |
| 11:20 | 570 | Melting of aluminium at the base of panels 2C and 2D. |
| 11:45 | 595 | Flame emission from the lower half of the vertical joint between panels 2C&2D. |
| 12:30 | 640 | Significant discolouration of panel 1A spreading onto wing wall panels above and below. Discolouration to the top of panels 2C&2D. |
| 13:15 | 685 | Increased rate of flaming droplet emission and growth of pool fire at the base of cladding system. |
| 13:30 | 700 | Approximately 85% removal of panels 1C&1D. |
| 14:00 | 730 | The central 'T'-shaped aluminium rail forming the substructure for panels 1C&1D has fully melted. |
| 14:30 | 760 | Increased discolouration and distortion of the wing wall. |
| 15:10 | 800 | No increase in fire size since the last observation: flaming full width and height for approximately 2.5m above the combustion chamber (full-width), sporadic flame tips to height of Level 2 thermocouples. |

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| Time* (mins:secs) | $t_s$ (seconds) | Description |
|---|---|---|
| | | Significant detachment directly above the combustion chamber – possibly a section of cavity barrier. |
| 15:45 | 835 | Sporadic full-height flaming along vertical junction between panels 2C&2D. |
| 17:20 | 930 | The central ‘T’-shaped aluminium rail forming the substructure for panels 2C&2D is damaged and partially melted. |
| 18:50 | 1020 | Discolouration of panels on the wing wall from ground level to top of panel 3A. Discolouration at the base of panels 3C&3D. |
| 19:45 | 1075 | Sporadic flaming off the edge of panel 1E. |
| 20:15 | 1105 | Significant detachment (approximately 300mm×300mm) from panel 2C. |
| 20:30 | 1120 | Continuous flaming from the top of the vertical junction between panels 2C&2D. |
| 21:45 | 1195 | Continuous flaming from the base of the vertical junction between panels 3C&3D. |
| 22:00 | 1210 | Continuous flaming from the horizontal junction between panels 1A&2A directly adjacent to the main wall.<br><br>Movement of flames towards the wing wall. |
| 22:30 | 1240 | Burning droplets from the wing wall adding to the substantial pool fire at the base of the cladding system. |
| 22:50 | 1260 | Significant detachment (approximately 300mm×300mm) from panel 2C.<br><br>Panel 2D has peeled away from the cladding system allowing further fire spread beneath. |
| 22:55 | 1265 | Further significant detachment (similar size) from panel 2C. |
| 23:00 | 1270 | Flame tips frequently to the top of the cladding system. |
| 23:20 | 1290 | Intermittent flaming is observed coming out through the joints, from the cavity behind the 3C&3D panels. |
| 24:00 | 1330 | Sporadic flaming off the top of the cladding system. |
| 24:30 | 1360 | Increased rate of flaming droplets from the wing wall. |

| Time* (mins:secs) | $t_s$ (seconds) | Description |
|---|---|---|
| 24:50 | 1380 | A significant contribution to the fire development is observed from the wing wall.<br>Additional large detachment from the vicinity of panel 2C. |
| 25:00 | 1390 | Flame tips extending beyond 1m off the top of the cladding system at the main-wing wall junction. |
| 25:05 | 1395 | Continued flame emission higher than 1m off the top of the cladding system. |
| 25:12 | 1402 | Test terminated. |

*Time from point of ignition.

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# 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.

In accordance with BS 8414-1[1] (and reported above in *Section 5*), the test of this cladding system was terminated after 25 minutes and 12 seconds from ignition of the fire load (timber crib) due to flame spread above the test apparatus. Therefore this cladding system failed to meet the minimum test duration as detailed in BS 8414-1[1]. A classification to BR 135[2] is therefore not possible for this cladding system.

The Level 2 thermocouples reached 600°C at 1190s. Although the Level 2 thermocouple recordings did not exceed a 600°C temperature rise above $T_s$, for a minimum of 30s, within 15mins from test start time ($t_s$), failure to achieve the minimum test duration, due to flame spread off the top of the cladding system, prevents classification to BR 135[2].

# 7 Post-test damage report

## 7.1 Summary

The cladding system was significantly damaged across the full height – see Figures *24-34*. 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 and substantial charring of the insulation across the full width of the combustion chamber opening up to a height of approximately 4600mm – see *Figures 24-34*. The wing wall was less severely damaged than the main wall with slight insulation charring associated with small areas of panel consumption, and significant panel discolouration and distortion below the height of the third cavity barrier (approximately 4700mm above the combustion chamber) which reduced in severity towards the top of the cladding system – see *Figures 30, 32 & 34*.

### 7.1.1 ACM panels

On the main wall, approximately 80% of the ACM panels directly above the combustion chamber, up to the height of the third cavity barrier, were consumed – see *Figures 24, 26 & 27*. With reference to *Figure 1*:

- 100% consumption of panels 1C and 1D.
- 90% consumption of panel 2C – small section approximately 400mm×500mm (0.2m$^2$) remained in the top left corner.
- 40% consumption of panel 2D – panel consumption tapered from approximately 600mm inside the outer edge at the base, to the top left corner (centre line of the combustion chamber).

Smaller areas of panel consumption on the main wall to panels: 1B (75%), 1E (10%) and 2B (10%) – see *Figures 24, 26 & 27.*

Significant discolouration and distortion was sustained by panels: 3B (100%), 3C (75% - top right corner furthest from wing wall remained relatively undamaged) and 2D (25% - immediately adjacent to the area of panel consumption a damaged strip with an area approximately 0.6m$^2$ was present) – see *Figures 24, 26 & 27.*

On the wing wall, smaller, oval areas of panel consumption (approximately 350mm-wide×1100mm-high(0.39m$^2$) and (300mm-wide×1000mm-high (0.3m$^2$)) were visible directly adjacent to the main wall towards the base of panels 1A and 2A respectively – see *Figures 24-27*.

Significant discolouration and distortion was sustained by panels: 0A (90%), 1A (90%), 2A (60%) and 3A (25%) – see *Figure 24-27*. The damaged area tapered, in the direction of the main wall, from the outer edge of the wing wall (approximately 1.5m above the height of the combustion chamber) to the wing-main wall junction at the top of the cladding system.

### 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 – see *Figures 28, 29 and 31*. 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 a height approximately 100mm above the second cavity barrier. A further 800mm of significantly damaged rail extended beyond this.

- ‘L’-section: complete consumption from the combustion chamber opening to a height approximately 1000mm above the second cavity barrier. A further 400mm of significantly damaged rail extended beyond this.
- ‘T’-section: complete consumption from the combustion chamber opening to a height approximately 1900mm above the second cavity barrier. A further 400mm of damaged rail extended beyond this.
- ‘L’-section: complete consumption from the combustion chamber opening to the height of the second cavity barrier. A further 800mm of significantly damaged rail extended beyond this.
- ‘T’-section: complete consumption from a height of 600mm above the combustion chamber opening to a height approximately 300mm below the second cavity barrier. The remaining sections of ‘T’ rail between the first and second cavity barrier were significantly damaged and distorted.

Damage to the rail substructure on the wing wall was far less severe – see *Figures 28, 30, 32 & 34.* Between the first and the second cavity barrier, the ‘L’-rail adjacent to the main wall was charred and distorted – see *Figure 30.* The ‘L’-rail at the centre of panel 1A sustained isolated areas of dark discolouration. Between the second and the third cavity barrier, isolated areas of lighter discolouration were observed on the lower 1m of the ‘L’-rails at the centre and main wall edge of panel 2A – see *Figures 32.* The rail substructure above this, and at the outside edge (full-height) of the vertical cavity barrier was undamaged *Figures 28, 30, 32 & 34*.

### 7.1.3 PIR insulation

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

- 1C&1D, charring (50-90mm char depth) of the insulation occurred across the full area – see *Figure 29*.
- 2C, charring occurred at the base (40mm char-depth) which decreased towards the top of the panel (10mm char-depth). The foil face of the insulation remained intact in an approximately 500m$^2$ patch in the top left corner – see *Figure 31.*
- 2D, charring occurred at the base (40mm char-depth) which reduced to surface charring approximately 1000mm above the second cavity barrier. Approximately 50% of the foil face of the insulation remained intact, the majority of which was positioned to the right of the centrally supporting ‘L’-rail -– see *Figure 31*.
- 3C&3D, light discolouration of the foil facing was the extent of the damage – see *Figure 33*.
- 0B-3B and 0E-3E, damage to the insulation was not observed beyond the vertical cavity barrier – see *Figures 28, 29, 31 & 33*.

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

- 1A, the foil facing was consumed and the insulation charred in an area approximately 200mm-wide×400mm-high in a position directly adjacent to the main wall and approximately 400mm 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 was undamaged – see *Figure 30*.
- 2A, the foil facing was consumed and the insulation charred in an area approximately 200mm-wide×400mm-high in a position directly adjacent to the main wall and approximately 250mm above the second horizontal cavity barrier. Blistering of the foil facing was most concentrated within a 300mm-radius of the exposed insulation. Minor discolouration to the foil facing 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.*

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### 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. There is evidence of activation, however; significant destruction and detachment occurred during the test – see *Figure 26*. A 1m-long section of cavity barrier detached from the centre line of the combustion chamber following consumption of the aluminium window pod. The section of cavity barrier at the outside edge, beneath panel 1E, is undamaged and has not activated – see *Figure 29*. On the wing wall, successful activation of the cavity barrier to fill the void occurred between the centrally supporting 'L'-rail and the main wall – see *Figure 30*. Partial activation occurred on the side of the centrally supporting 'L'-rail furthest from the main wall.

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 – see *Figures 29 & 31.* The section of cavity barrier at the outside edge, beneath panel 2E, is undamaged and has not activated. On the wing wall, full width activation of the cavity barrier is evident: to the outside of the centrally supporting 'L'-rail the intumescent material fills the void, towards the main wall the intumescent material has started to detach and deteriorate – see *Figure 32*.

The third row horizontal cavity barrier has expanded to fill the void from mid-width on the wing wall to approximately ¾-width of the main wall – see *Figures 33 & 34*. The final ¼-width at the outside edge of the main wall demonstrates partial activation up to the vertical cavity barrier, beyond this the intumescent barrier is undamaged and has not activated. Partial activation on the wing wall cavity barrier occurred on the side of the centrally supporting 'L'-rail furthest from the main wall.

The fourth row horizontal cavity barrier demonstrates the initial stages of activation across the full width of the wing wall and up to the vertical cavity barrier at the outside edge of the main wall– see *Figure 33*.

### 7.1.5 Vertical (compression) cavity barriers

The fire damage to the cladding system on the main wall was contained within the bounds of the vertical cavity barriers across the combustion chamber opening – see *Figure 28*. The cavity barriers remained intact despite significant charring and discolouration along the inside edges running parallel to the vertical edges of the combustion chamber.

Fire spread within the cavity did not reach the vertical cavity barrier at the outside edge of the wing wall– see *Figures 30, 32 & 34*.

# 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

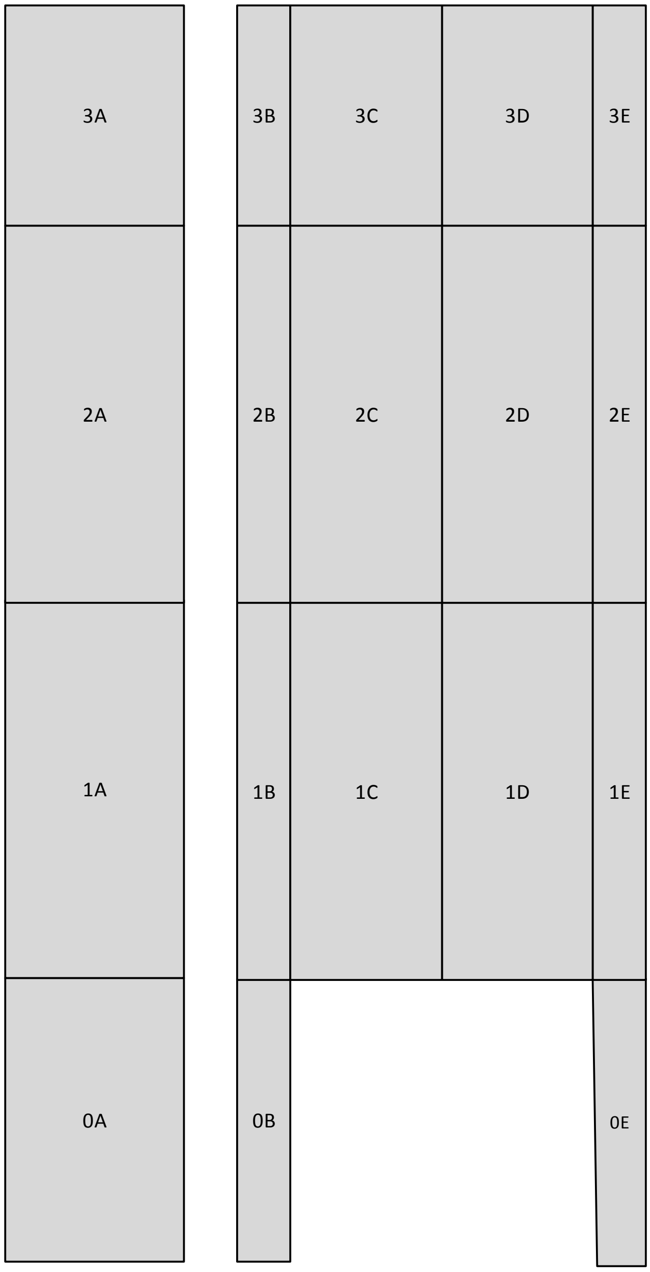


Figure 1. Layout of panels and labelling system used for reporting purposes. Not to scale.

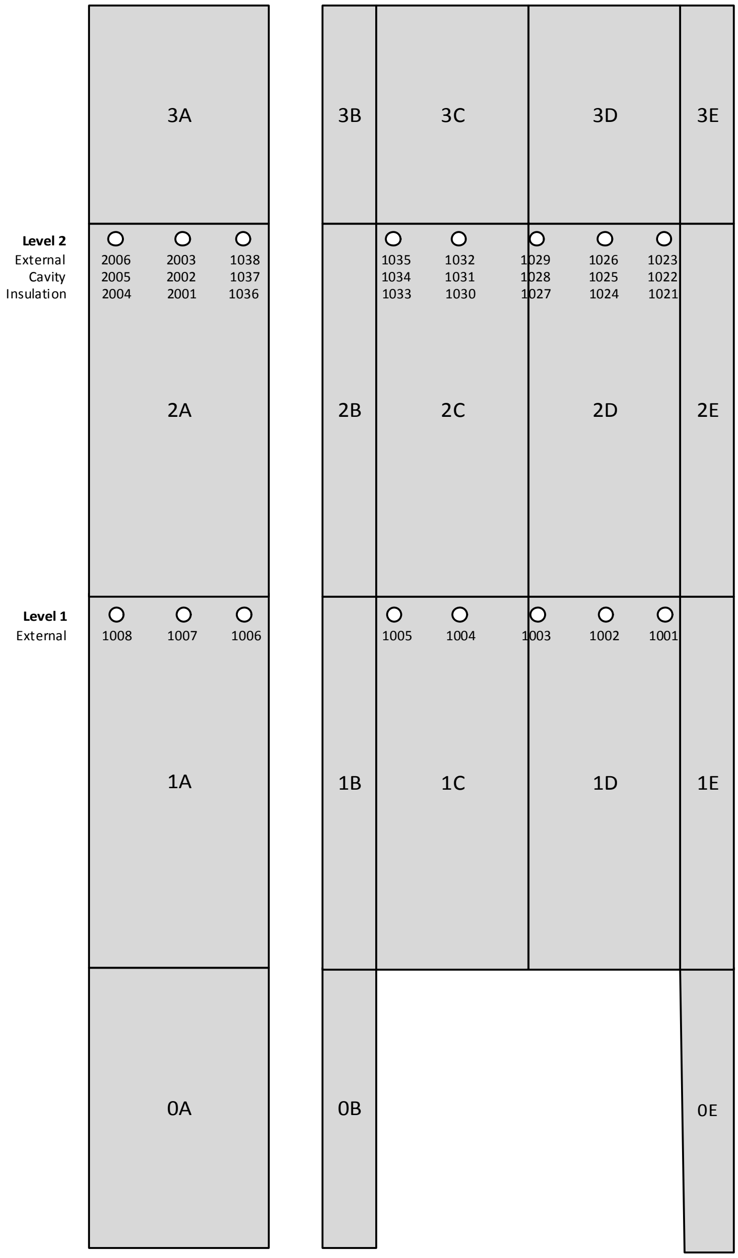


Figure 2. TC positions and panel labelling system (0A – 3E). Not to scale.

## 9.2 Installation photographs

Figure 3. Location of ‘L’ brackets (partially visible), cavity barriers and PIR insulation panels.


Figure 4. Horizontal intumescent cavity barriers fixed through the entire depth on face turned steel brackets, fitted between vertical cavity barriers.

Figure 5. Vertical cavity barrier staggered at the height of the combustion chamber opening.

Figure 6. Installed window pod lining combustion chamber.


Figure 7. Installed cavity barriers. PIR insulation panels cut to fit and skewered onto ‘L’-brackets.

**Note**: Insulation panels have not yet been fixed to masonry.

Figure 8. Insulation fixings applied and ‘L’-rail embedded into panel.

Figure 9. Joints and fixings covered with aluminium tape.

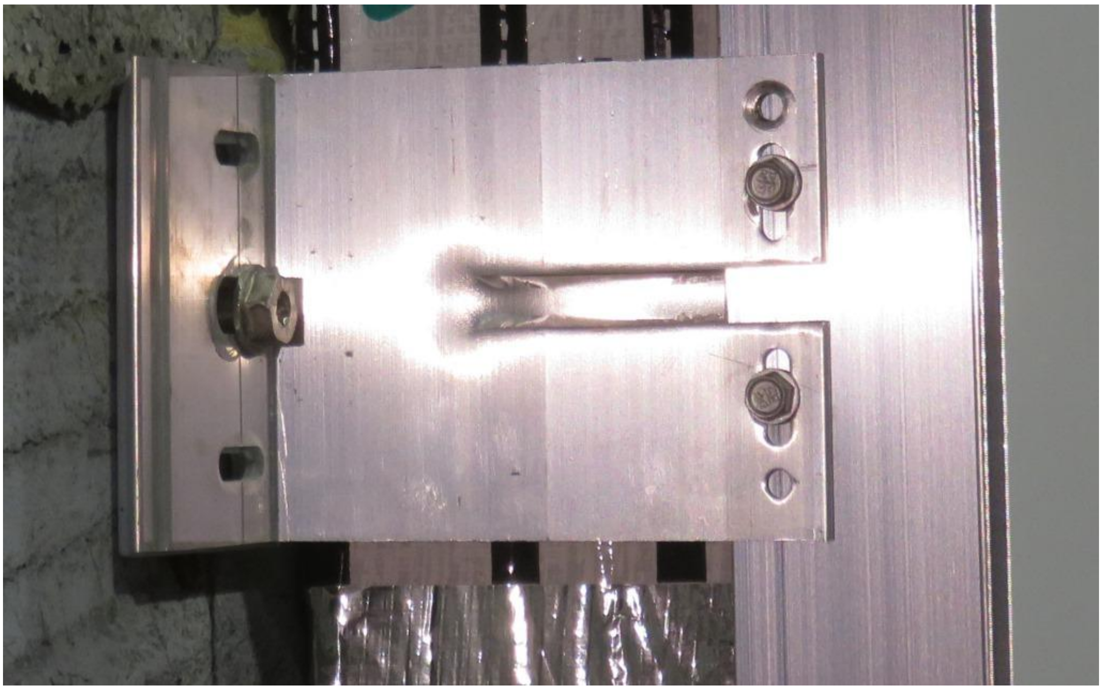

Figure 10. Example of aluminium rail fixed to ‘L’ bracket through movement holes.

Figure 11. Example of aluminium rail fixed to ‘L’ bracket through fixed holes.

Figure 12. Completed installation of railing substructure visible on main wall.

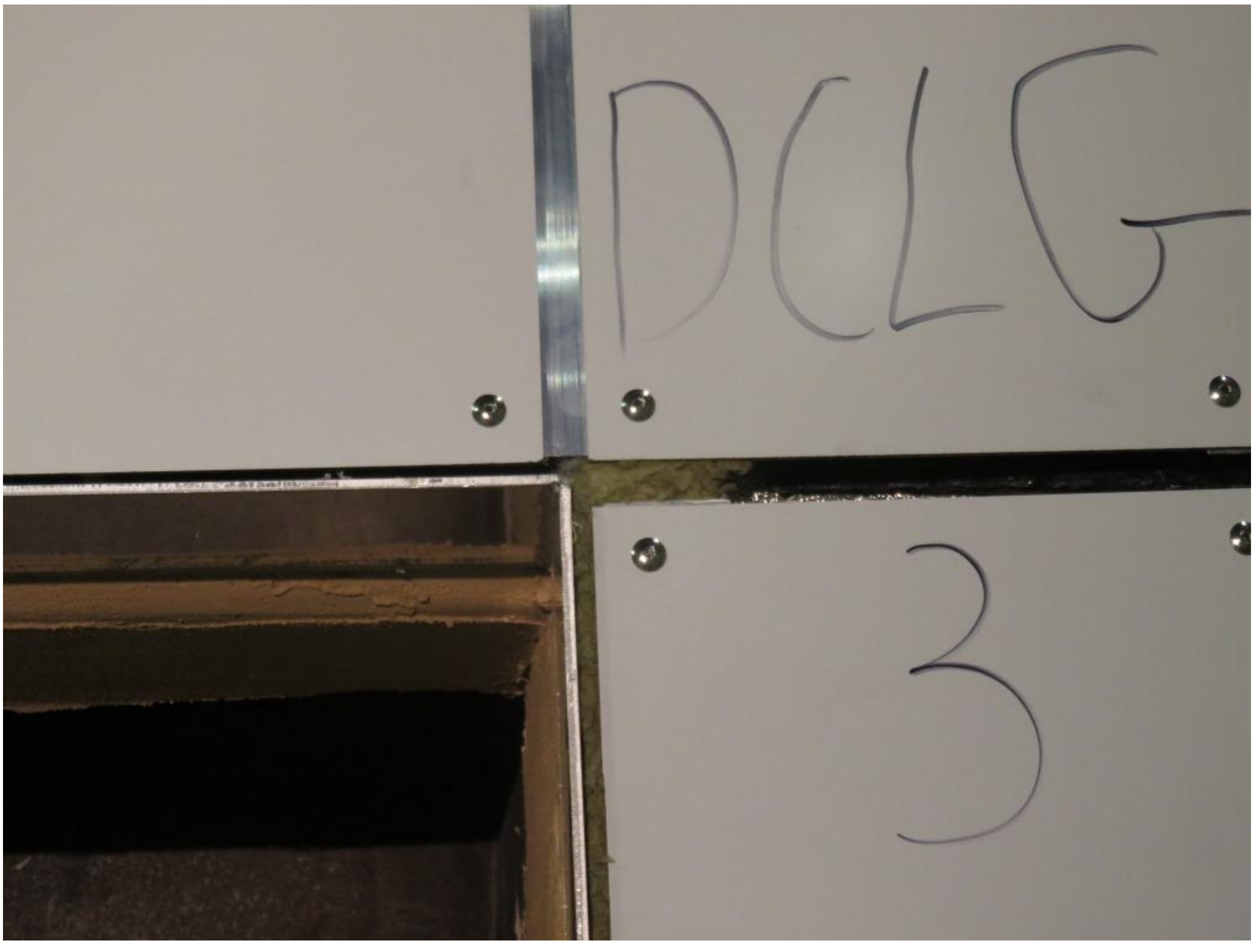


Figure 13. Detail at corner of combustion chamber opening. Panels riveted in place with nominal 20mm vertical gap for ventilation purposes.


Figure 14. Completed installation prior to test.

## 9.3 System drawings

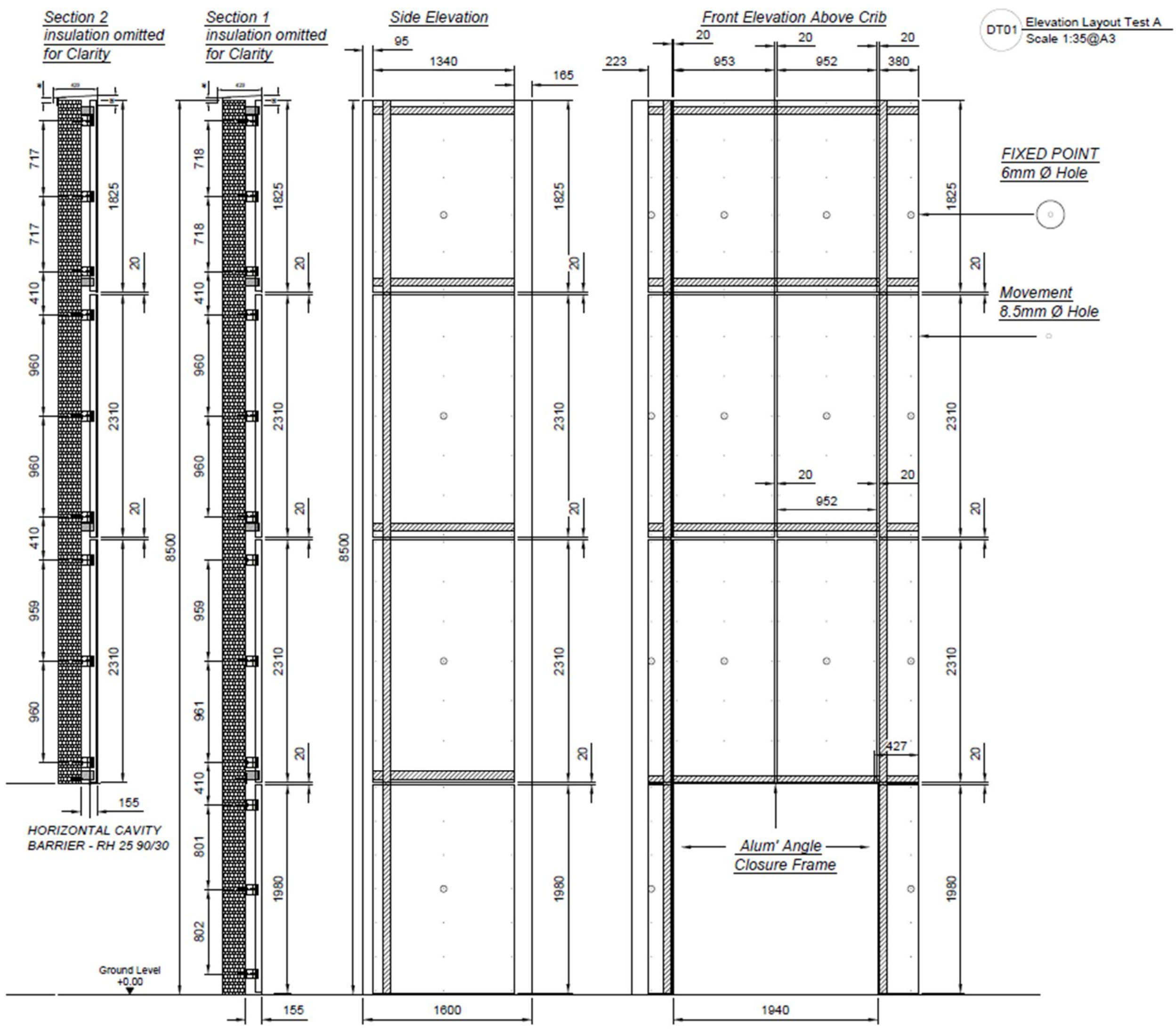


Figure 15. Front elevation, side elevation and vertical sections for the system (supplied by the Test Sponsor).

**Note:** The vertical cavity barriers above the combustion chamber were installed with an offset towards the main wall edges of approximately 70mm – see also *Figure 5*.

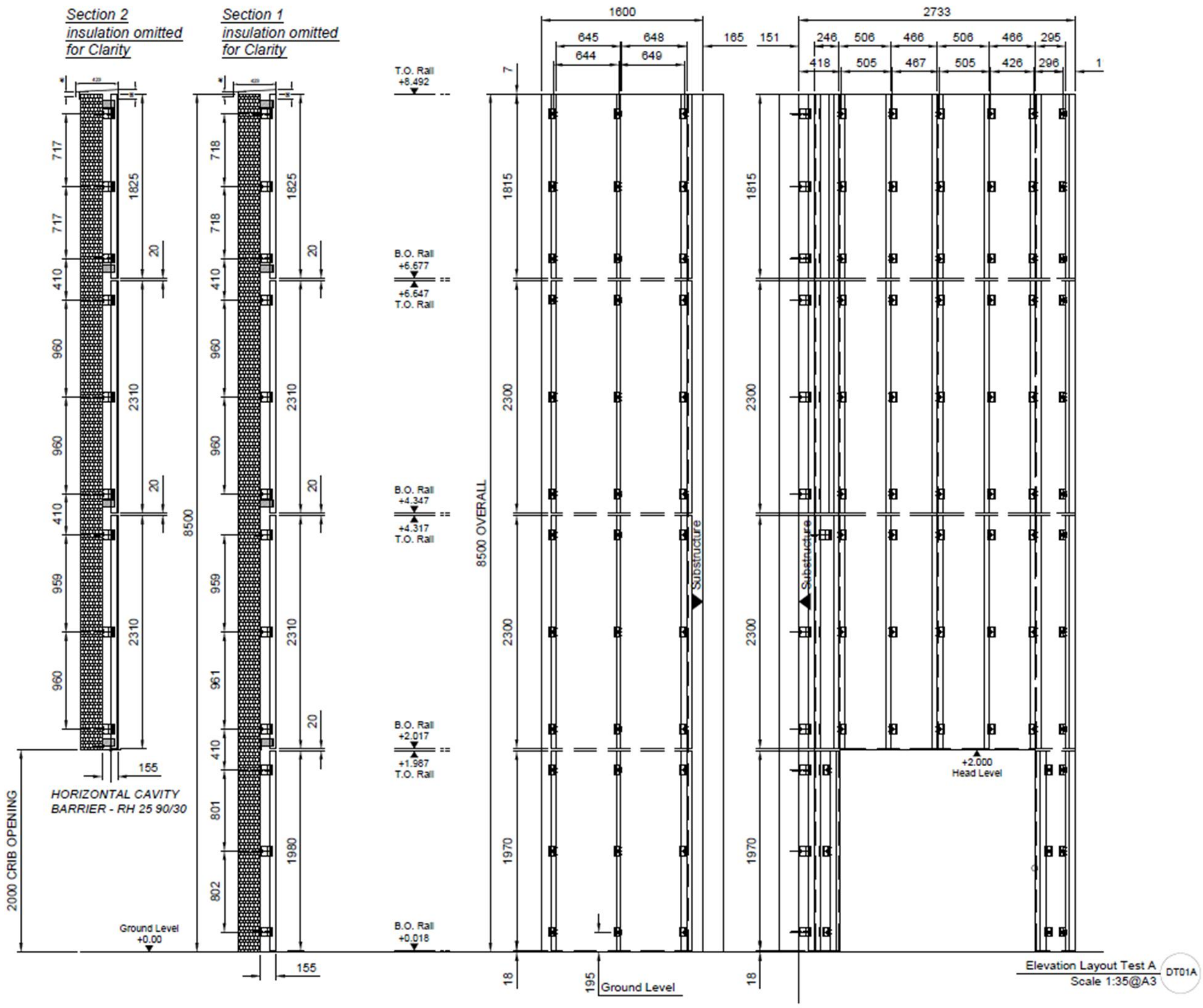


Figure 16. Front elevation, side elevation and vertical sections for the substructure system (supplied by the Test Sponsor).

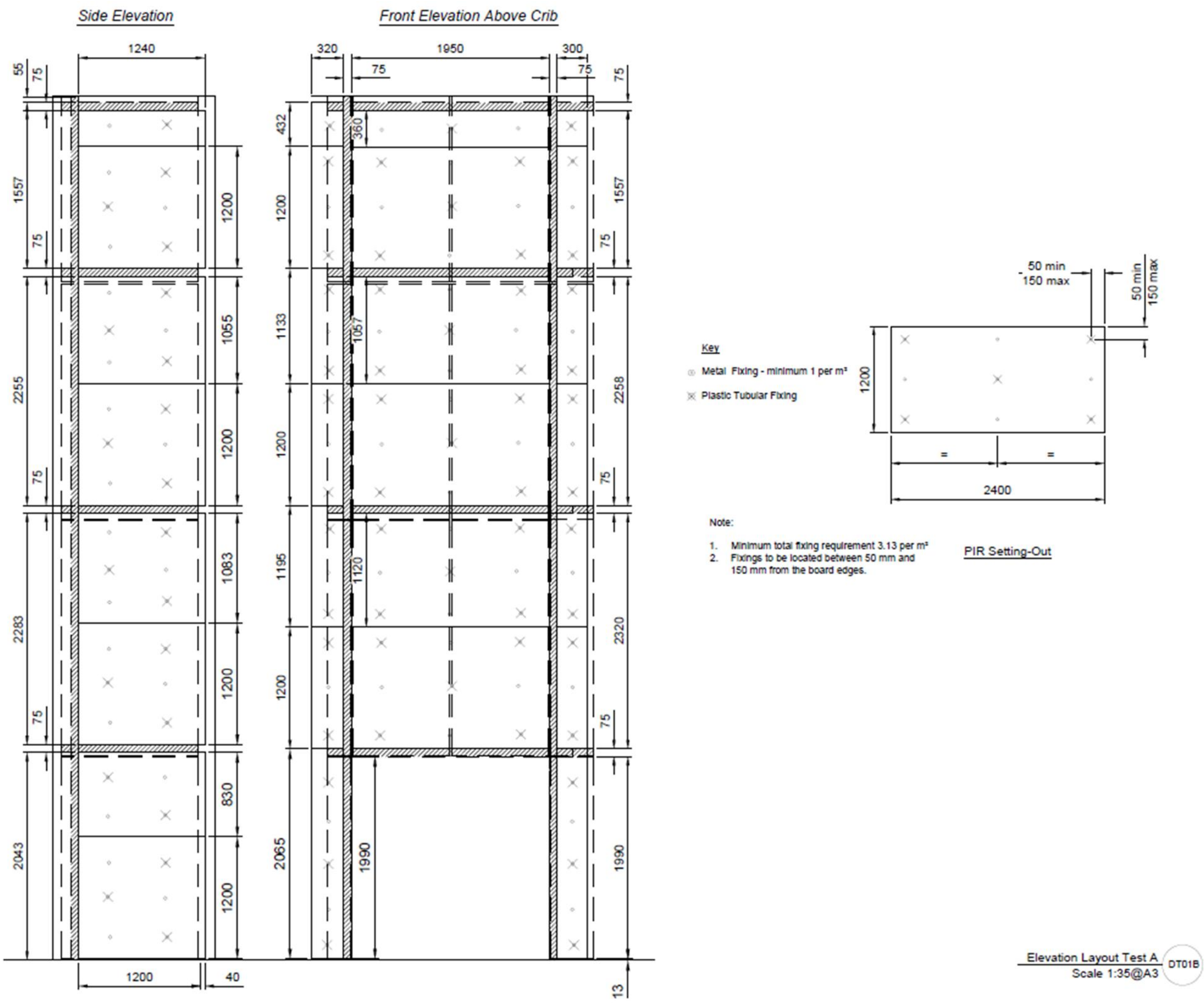


Figure 17. Front elevation, side elevation for the insulation panels installation (supplied by the Test Sponsor).

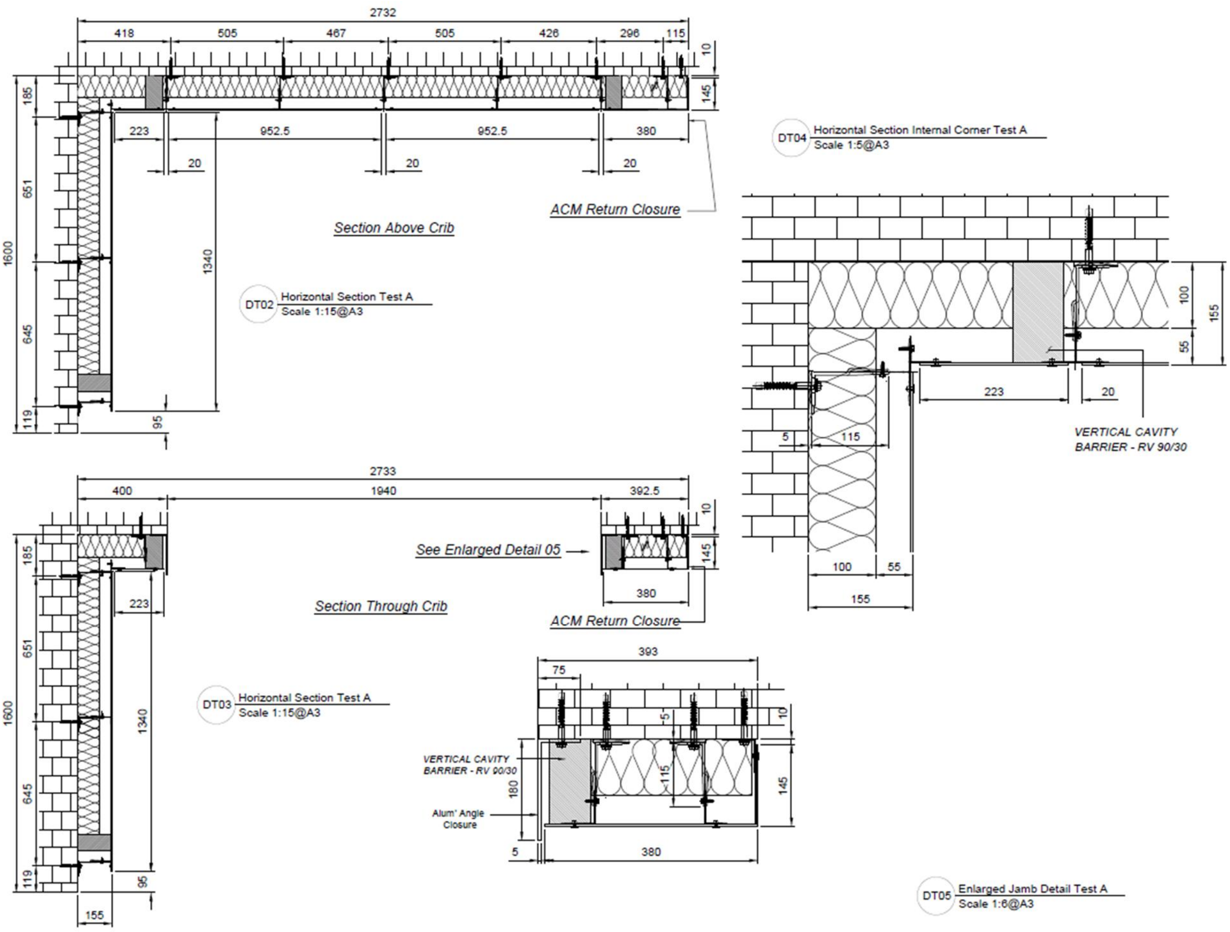


Figure 18. Horizontal section through and above the combustion chamber, and installation details for the system (supplied by the Test Sponsor).

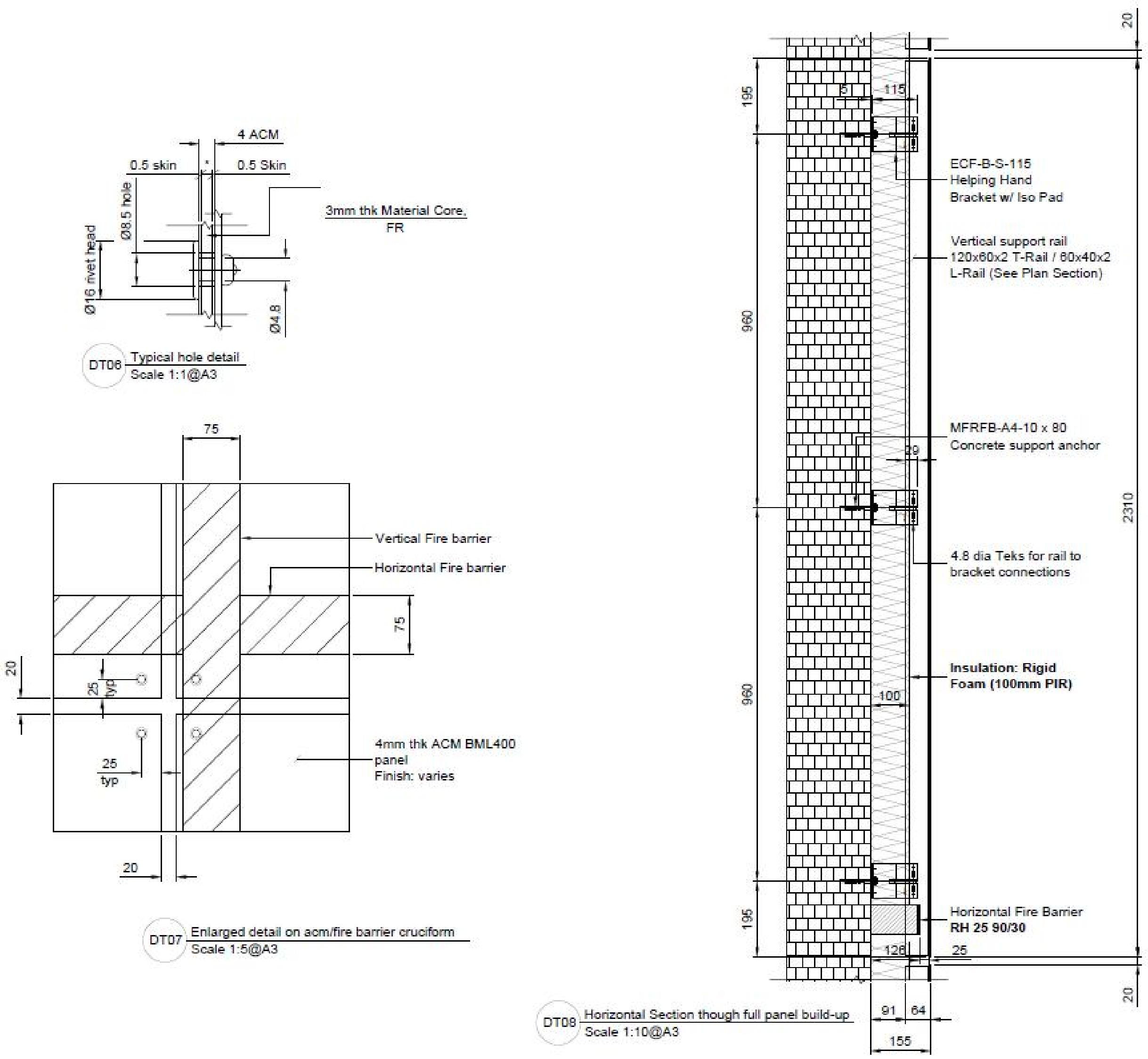


Figure 19. Vertical section through the cladding system, ACM panel detail and vertical and horizontal cavity barriers intersection (supplied by the Test Sponsor).

## 9.4 Temperature data

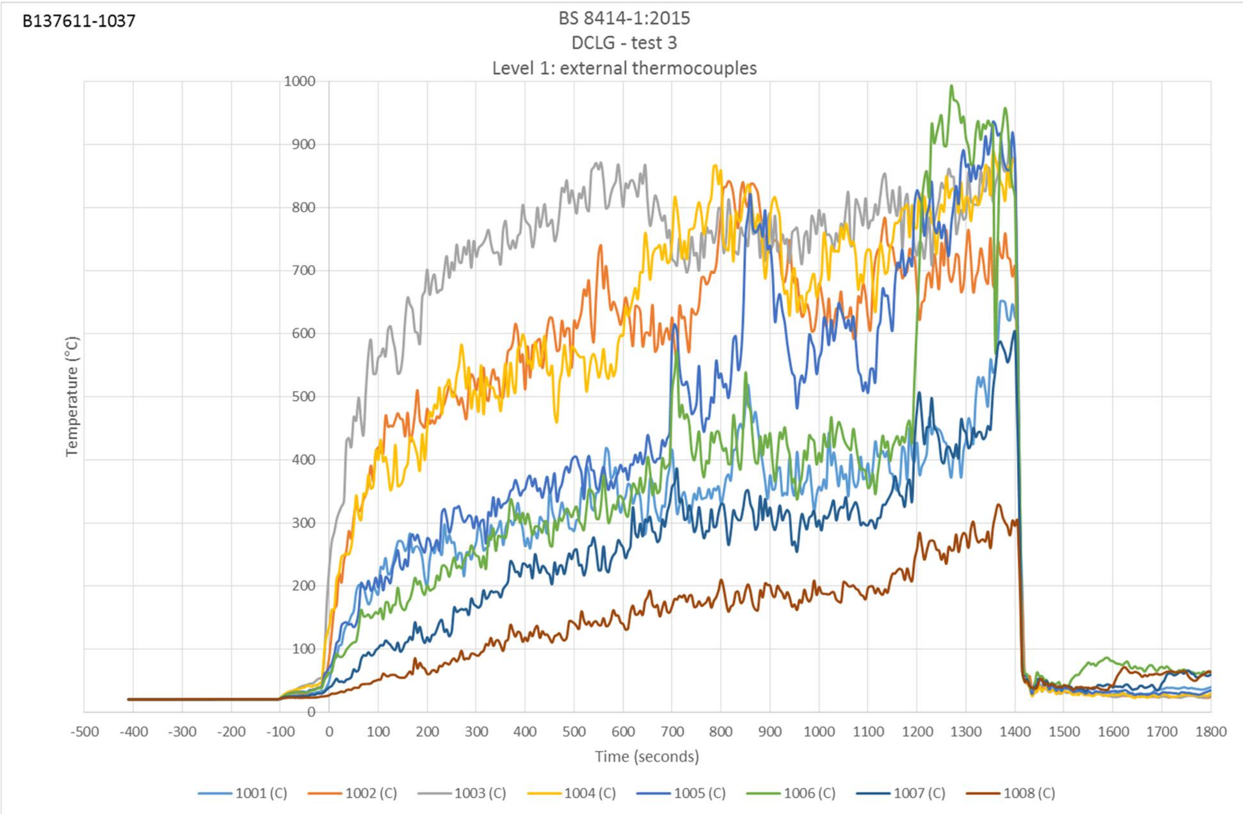


Figure 20. Level 1 external thermocouples.

$t_s$=110s after ignition of the crib.

**Note:** Test terminated after 1402s.

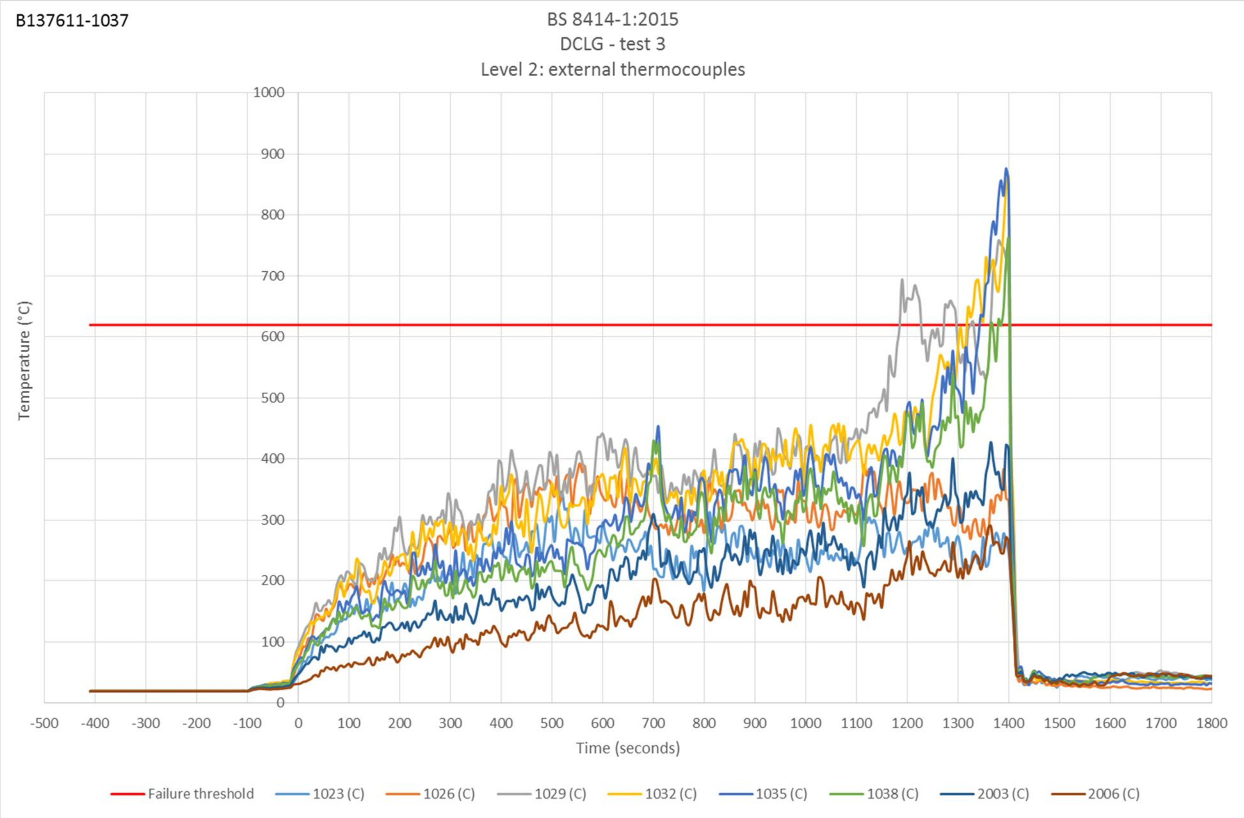


Figure 21. Level 2 external thermocouples.

$t_s$=110s after ignition of the crib.

**Note:** Test terminated after 1402s.

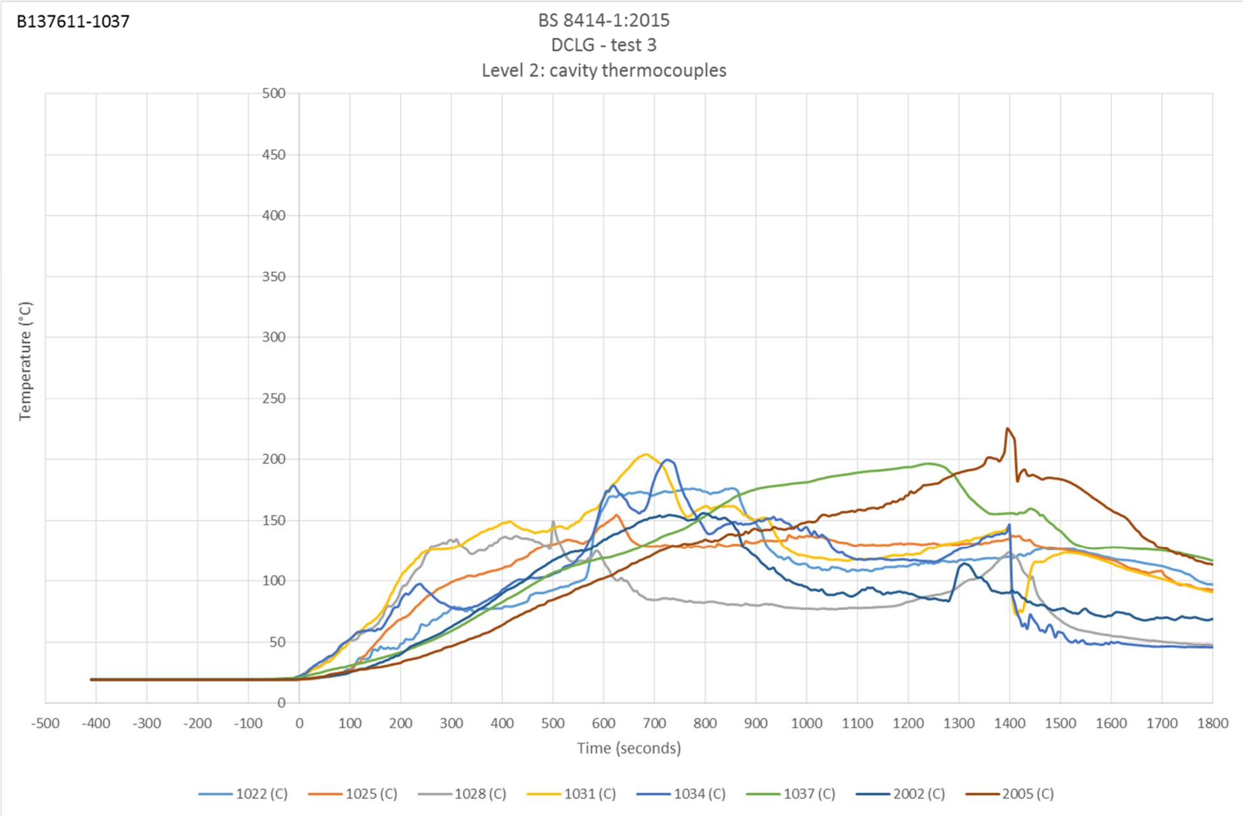


Figure 22. Level 2 cavity thermocouples.

$t_s$=110s after ignition of the crib.

**Note:** Test terminated after 1402s.

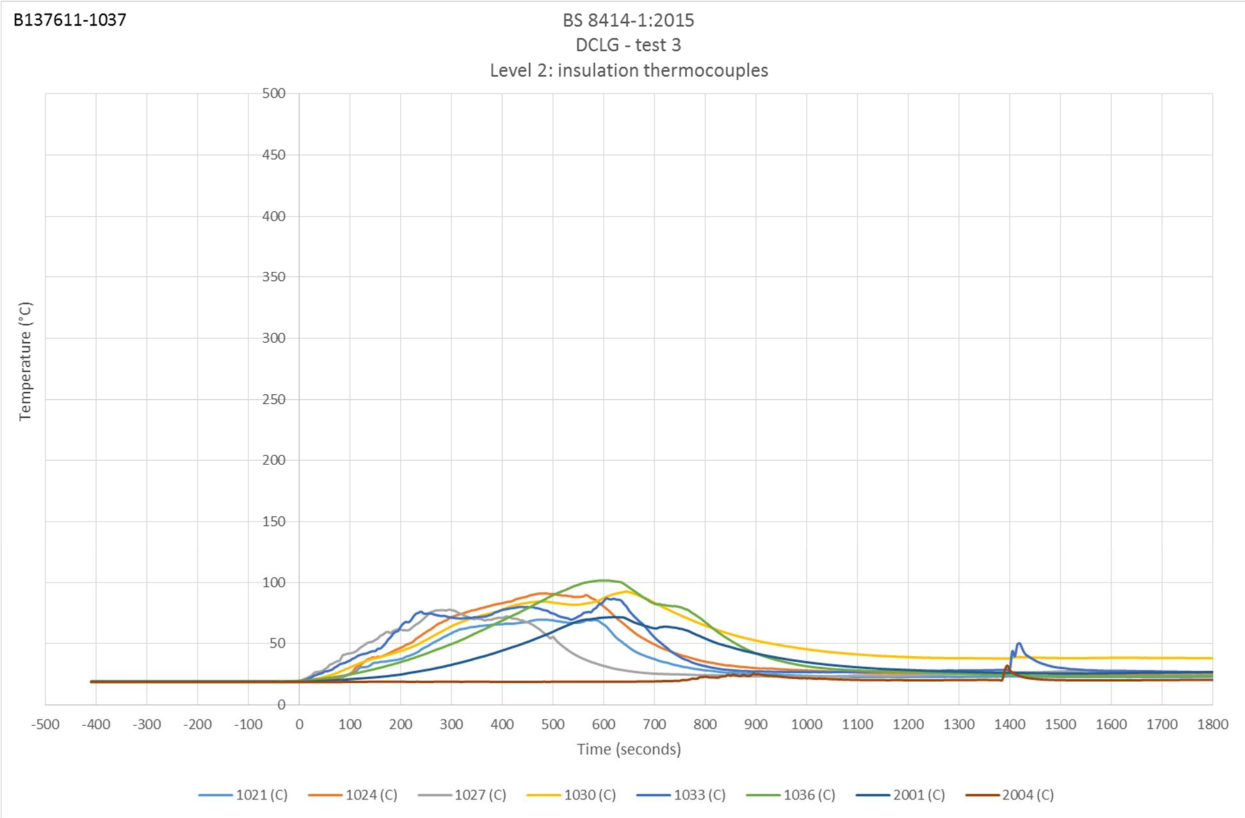


Figure 23. Level 2 insulation thermocouples.

$t_s$=110s after ignition of the crib.

**Note:** Test terminated after 1402s.

## 9.5 Post-test photographs

Figure 24. Full height photograph of system after test termination – general.

**Note:** Test terminated after 1402s.

Figure 25. Full height photograph of system after test termination – wing wall.

**Note:** Test terminated after 1402s.

Figure 26. First row ACM panels (directly above combustion chamber).

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

Figure 28. Full height photograph of system following removal of ACM panels.

**Note**: 500mm-wide×800mm-high section of absent insulation, located immediately above the combustion chamber, removed post-test.

Figure 29. Damage to cladding system beneath ACM panels directly above the combustion chamber.

**Note**: 500mm-wide×800mm-high section of absent insulation, located immediately above the combustion chamber, removed post-test.

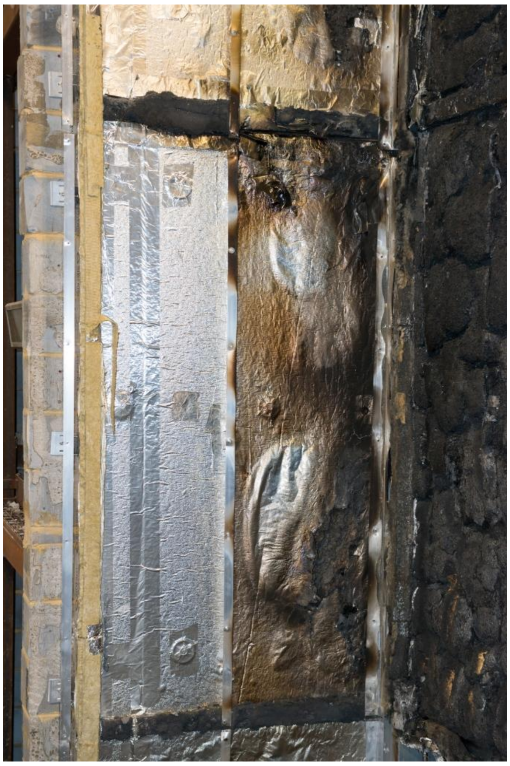

Figure 30. Damage to cladding system beneath ACM panels on wing wall between the first and second horizontal cavity barrier (approximately 0-2400mm above the height of the combustion chamber).

Figure 31. Damage to cladding system beneath ACM panels between the second and third horizontal cavity barrier (approximately 2400-4700mm above combustion chamber).

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

Figure 33. Damage to cladding system beneath ACM panels between the third and fourth horizontal cavity barrier (approximately 4700-6360mm above the combustion chamber).

Figure 34. Damage to cladding system beneath ACM panels on wing wall between the third and fourth horizontal cavity barrier (approximately 4700-6360mm above the height of the combustion chamber).

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## **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 | 3.9 | 30.4 |
| Vertical cavity barrier | 105 ± 5ºC | 0.5 | 79.9 |
| Horizontal cavity barrier | 105 ± 5ºC | 0.3 | 80.5 |

## **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 | CT003-01<br>CT003-02<br>CT003-03 |

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

| Ambient temperature (°C) | Relative humidity of the air (%) |
|---|---|
| 23.9 | 48.8 |

Test results:

| Test No. | Calorific value (MJ/kg) | Category | Standard deviation (%) |
|---|---|---|---|
| 1 | 13.8608 | CAT 2 | 0.09 |
| 2 | 13.6737 | CAT 2 | |
| 3 | 13.8129 | CAT 2 | |





Report Ends