

Window Refurbishment Pilot Scheme at Crescent House, London –Acoustics Testing, Airtightness Testing, Smoke Audit and Thermography Survey

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Introduction

A testing programme including acoustic testing, airtightness testing, air permeability testing, smoke investigations and thermographic survey was carried out to determine the performance of the window systems once installed within the front façade of Crescent House, London. The purpose of the testing is to provide indicative performance characteristics of each installed window system.

The first set of tests (as above) was carried out on 13th and 14th February 2023 on the original window configuration to provide 'baseline' data, which are provided in this report and once each of the subsequent three proposed systems are installed performance comparisons can be made against the initial results.

Work programme: (The following scope of works was agreed by the client)

BRE understands that the customer does not consider it practical to remove the windows from site to enable laboratory testing, which would be the preferred method for establishing performance in terms of accuracy, and instead requested BRE to undertake measurements on-site. The following work programme was agreed with the customer to assess each of the different parameters. The process will be repeated for each installed window system/iteration as instructed.

Acoustic Testing- unattended noise monitoring

To undertake the measurement process BRE Acoustics will require two sound level meters to be set up to run at the same time. One sound level meter will be installed on a tripod within the room that the window system serves, with the other sound level meter/microphone installed externally to the window at a position not closer than 1.5 m from the façade.

The two sound level meters shall be set to measure synchronously for a period of one week for each installed window system. Once the measurements have been averaged for each position a level difference between the two sound level meters can be provided through a desktop analysis of the results.

We will require access to the interior of the property and access to the external façade directly outside the window of interest to position the externally located microphone on the façade via access provided.

Noise measurements should be undertaken at times representative of normal activity in the locale (for example, not during periods of reduced traffic such as school holidays).

Desktop analysis and report

Analyse the measured external & internal noise levels to provide information concerning the performance of each window system installed and tested.



Airtightness tests carried out in accordance with CIBSE TM23:2022 of the whole apartment and smoke investigation and smoke audit.

1. Carry out an Airtightness test of the whole apartment.
2. Carry out an Airtightness test of the whole apartment with all windows temporarily sealed (taped), as discussed with the client, to establish a base line reading. The testing would be repeated following removal of the temporary sealing applied to establish the air leakage rate through the windows.

The test involves raising the internal pressure of the apartments in steps up to around 50Pa compared to the ambient pressure outside using a fan/blower door airtightness testing kit (usually mounted in the front door). The air flow rate required to achieve the different test pressures is used to determine the air leakage rate of the two test conditions. Once we are maintaining a positive pressure in the apartment, we can identify potential leakage paths around the windows by applying smoke. At points of leakage, the smoke will be pushed through gaps to help to identify areas of potential weakness to the client.

The smoke used for building envelope testing produces a non-toxic oil-based smoke (vapour), on completion of testing the smoke can be vented from the building, leaving no signs that a test has been carried out.

Air permeability testing of the different window types

The air permeability tests of the different window types within the apartment will be carried out based on the methods in BS EN 14351-1:2006 +A1:2010 Clause 4.14, and the National Application Document BS 6375-1:2015. The test methods will be BS EN 1026:2016 for air permeability. BS 6375-1:2015 will be used to assess the results.

Thermographic Survey of the different window types

BRE will carry out a Thermographic Survey of the different window types within the apartment as installed based on the methods in BS EN 13187 and BRE infrared thermography guide BR176. BRE will use a portable infrared camera with digital picture storage so that any thermal anomalies identified during the survey can be recorded and analysed later. Analysis of the recorded survey data will take place at BRE where the results will be collated and presented in report form with a description and location of any thermal abnormality identified using thermographic and corresponding visual images.



Instrumentation

The equipment used to conduct the tests is identified in **Table 1**, below.

Instrument number	Equipment description	Manufacturer	Type	Serial Number	Calibrate date
3110	Calibrator	B&K	4231	2175848	11/2023
6153	Sound Level Meter	NOR	140	1402786	07/2024
6468	Sound Level Meter	NOR	140	1403085	07/2024
5613	Minneapolis Fan	Energy conservatory	BD4	CE753	20/05/2023
5614	Manometer	Energy conservatory	DG700	2897.4.700	20/05/2023
4955	Barometer	Druck	DPI705	70536731	20/05/2023
4898	Thermometer	Testo	925	33757089/807	20/05/2023

Table 1: Equipment list

The gain of the real time analyser was adjusted to give a reading 113.9 dB at 1 kHz using the Bruel & Kjaer Type 4231 calibrator prior to use. All equipment is calibrated in accordance with BRE procedures, using reference equipment calibrated by a UKAS accredited laboratory.



Acoustic Testing details

Test dates and personnel

The measurements detailed in this report were undertaken with two sound level meters monitoring sound pressure levels between the 13th and 20th February 2023, the equipment was deployed by Mr M Coleman and Mr E Nichols of BRE Acoustics.

Test method

Two sound level meters were set to run at the same time (synchronous) and left unattended for the duration. Both sound level meters were installed on tripods within the room that the window system serves, one was set to measure internal noise levels whilst the microphone of the other sound level meter was positioned externally to the window at a position not closer than 1.5 m from the façade.

The two sound level meters were set to measure 15-minute periods synchronously for a period of one week. The 15-minute measurements are then averaged over each hour of the day to provide a suitably reduced dataset for this large measurement period, from which six random time periods were selected for further analysis.

Once the measurements have been averaged for each hour and each position, level differences (D) in third octave bands (50 Hz to 5 kHz) between the two sound level meters are provided in a graph for the averaged differences.

The single figure value is derived from these third octave values (between 100 Hz and 3.15 kHz) and provides information for the overall base level performance of the installed original window system.

Test element installation

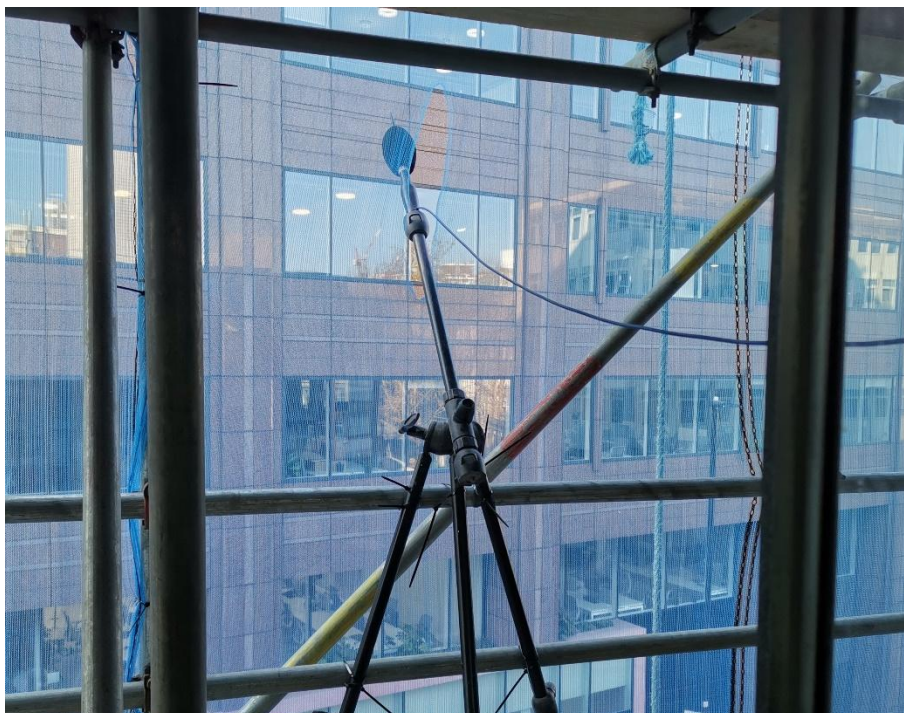
The test specimen window system was the originally installed window system, with no alterations.

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Photographs



Photograph 1: Two sound level meters set up internally with window system under test.



Photograph 2: External microphone located at external façade.



Test numbers and test results

Test number, specimen type and sound insulation performance presented as as a level difference (D), are presented in **Table 2**, below. Randomly selected hourly periods were used for the analysis.

Test number	Test element	Selected measurement details	Difference (D)
L152-001	Original window system	Tuesday 14 th Feb – 12pm to 1pm	33.7 dB
L152-002		Wednesday 15 th Feb – 1am to 2am	33.8 dB
L152-003		Thursday 16 th Feb – 9am to 10am	33.6 dB
L152-004		Friday 17 th Feb – 3am to 4am	33.8 dB
L152-005		Saturday 18 th – 5pm to 6pm	33.6 dB
L152-006		Sunday 19 th – 8am to 9am	33.8 dB

Table 2: Measurement details with test numbers and difference (D) results for each hour of logarithmically averaged 15-minute measurements.

Test number	Test element	Measurement details	Overall Difference (D)
L152-007	Original window system	Logarithmically averaged overall performance for selected hourly results in Table 2.	33.7 dB

Table 3: Test number and difference (D) test result from the logarithmically averaged hourly results in Table 2.



Frequency f [Hz]	D 1/3 octave [dB]
50	4.5
63	15.5
80	18.0
100	17.6
125	15.8
160	18.2
200	17.4
250	18.8
315	20.3
400	21.5
500	22.7
630	23.1
800	23.5
1000	21.5
1250	21.2
1600	22.4
2000	24.0
2500	24.6
3150	23.2
4000	22.8
5000	23.4

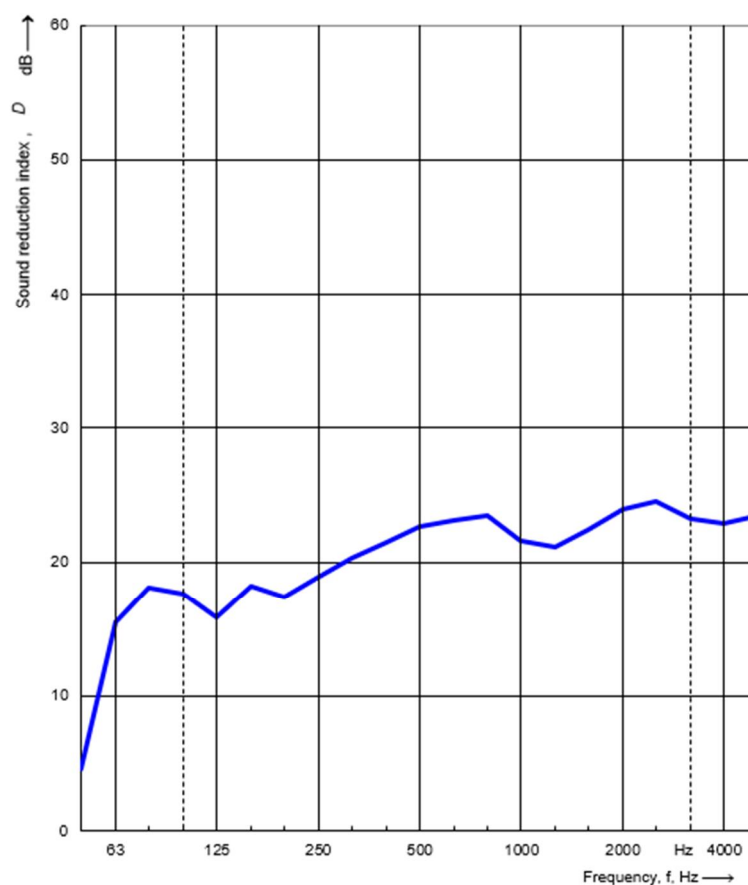


Figure 1: 1/3rd octave band performance data from 50 Hz to 5 kHz – showing the upper and lower band limits (100 Hz and 3.15 kHz) used for the single figure calculations in Tables 2 & 3

Airtightness Testing

Test Conditions

The apartment was tested as a whole by mounting the test equipment (blower door) within a hallway door serving the space under test, see Figure 2. All internal doors wedged opened to allow airflow through entire area under test, as required by CIBSE TM23:2022.

The apartment was also tested with a range of sealed configurations (see Table 4) to highlight areas of air leakage. The testing was undertaken by inducing both a positive and negative pressure across the building envelope and the results averaged.



Figure 2: Test set-up showing the blower door mounted in the front door.



Test results

The airtightness test on the whole apartment was conducted in accordance with the requirements of CIBSE TM23:2022

The envelope areas were calculated from supplied drawings.

The airtightness test results are presented in Table 4, below.

Test Number sealed/unsealed parts of building envelope.	Envelope Area m ²	Airtightness Result Negative	Airtightness Result Positive
Test 1 - Whole Apartment (bathroom extract sealed for all tests)	141.71	7.47 m ³ .hr ⁻¹ .m ⁻² @50Pa 9.90 Air Change per hour @50Pa	8.79 m ³ .hr ⁻¹ .m ⁻² @50Pa 11.65 Air Change per hour @50Pa
Test 2 - Whole Apartment with kitchen window sealed	141.71	7.13 m ³ .hr ⁻¹ .m ⁻² @50Pa 9.46 Air Change per hour @50Pa	8.54 m ³ .hr ⁻¹ .m ⁻² @50Pa 11.32 Air Change per hour @50Pa
Test 3 - Whole Apartment with kitchen and bathroom window sealed	141.71	5.93 m ³ .hr ⁻¹ .m ⁻² @50Pa 7.86 Air Change per hour @50Pa	7.50 m ³ .hr ⁻¹ .m ⁻² @50Pa 9.94 Air Change per hour @50Pa
Test 4 - Whole Apartment with kitchen, bathroom and main window sealed	141.71	3.84 m ³ .hr ⁻¹ .m ⁻² @50Pa 5.09 Air Change per hour @50Pa	5.58 m ³ .hr ⁻¹ .m ⁻² @50Pa 7.40 Air Change per hour @50Pa
Test 5 - Whole Apartment with kitchen, bathroom, main window, and service cupboard sealed	141.71	3.32 m ³ .hr ⁻¹ .m ⁻² @50Pa 4.40 Air Change per hour @50Pa	5.31 m ³ .hr ⁻¹ .m ⁻² @50Pa 7.03 Air Change per hour @50Pa

Table 4: Airtightness Test Results on 13/02/2023



Air Permeability Testing

The two windows were tested for air permeability using the test equipment (blower door) as in Figure 2 and methodically sealing off other known leakage within the apartment allowing the airflow through each window to be taken. The testing was undertaken by inducing both a positive and negative pressure across the windows and the results averaged.

Test Conditions

Internal Temperature 11.4 °C External Temperature 8.8 °C Barometric Pressure 1035.4 mbar

Test Results

Tables 5 to 10 show the air permeability test results for the individual windows tested when tested with a positive and negative pressure difference along with the average test result.

Kitchen window - 1540mm width x 798mm height

Pressure Differential (Pa)	Air flow per unit area of the specimen m ³ /h.m ²
50	-0.34

Table 5: Air permeability under negative pressure

Pressure Differential (Pa)	Air flow per unit area of the specimen m ³ /h.m ²
50	0.25

Table 6: Air permeability under positive pressure

Pressure Differential (Pa)	Average air flow per unit area of the specimen m ³ /h.m ²
50	0.30

Table 7: Average of air permeability under positive and negative pressure differential (see Figure 3 classification graph, at 50Pa)



Main window - 5334mm width x 3454mm height

Pressure Differential (Pa)	Air flow per unit area of the specimen m ³ /h.m ²
50	-2.09

Table 8: Air permeability under negative pressure

Pressure Differential (Pa)	Air flow per unit area of the specimen m ³ /h.m ²
50	1.92

Table 9: Air permeability under positive pressure

Pressure Differential (Pa)	Average air flow per unit area of the specimen m ³ /h.m ²
50	2.01

Table 10: Average of air permeability under positive and negative pressure differential (see Figure 3 classification graph, at 50Pa)



Figure 3 shows the air permeability classification graph from BS 6375-1:2015, and red circle shows where kitchen window 1540mm width x 798mm height and the green circle shows where the Main Window 5334mm width x 3454mm height results fit on the graph.

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BS 6375-1:2015+A1:2016

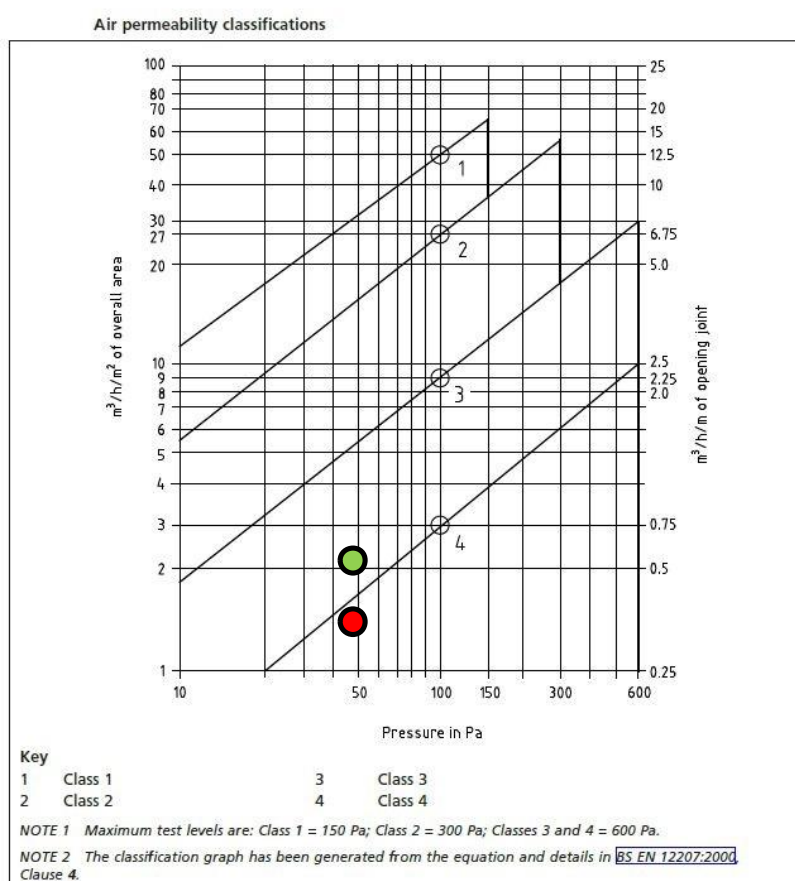


Figure 3: Air permeability classification graph.



Smoke audit locations

The smoke audit was carried-out by pressurising the apartment to a pressure of 50Pa using a fan/blower door airtightness testing kit, once a positive pressure was maintained, areas of leakage through the building envelope were investigated by applying smoke. The smoke was pushed through gaps in the building fabric to identify the air leakage paths.

Figure 4 below, and Figure 5 on the following page, show the areas tested for air leakage and locations of the smoke audit within the apartment.

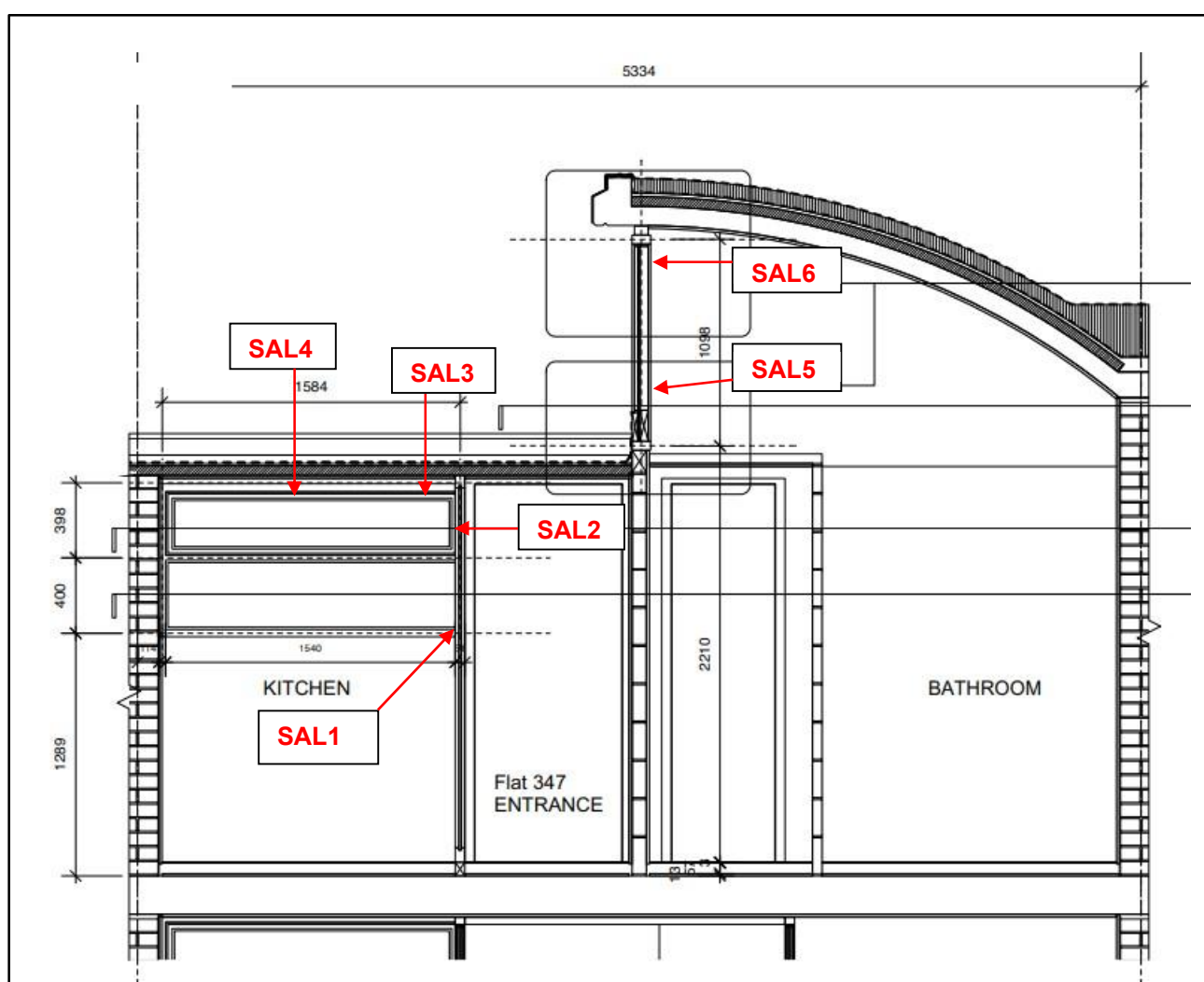


Figure 4: Rear of apartment - Smoke Audit Locations (SAL)

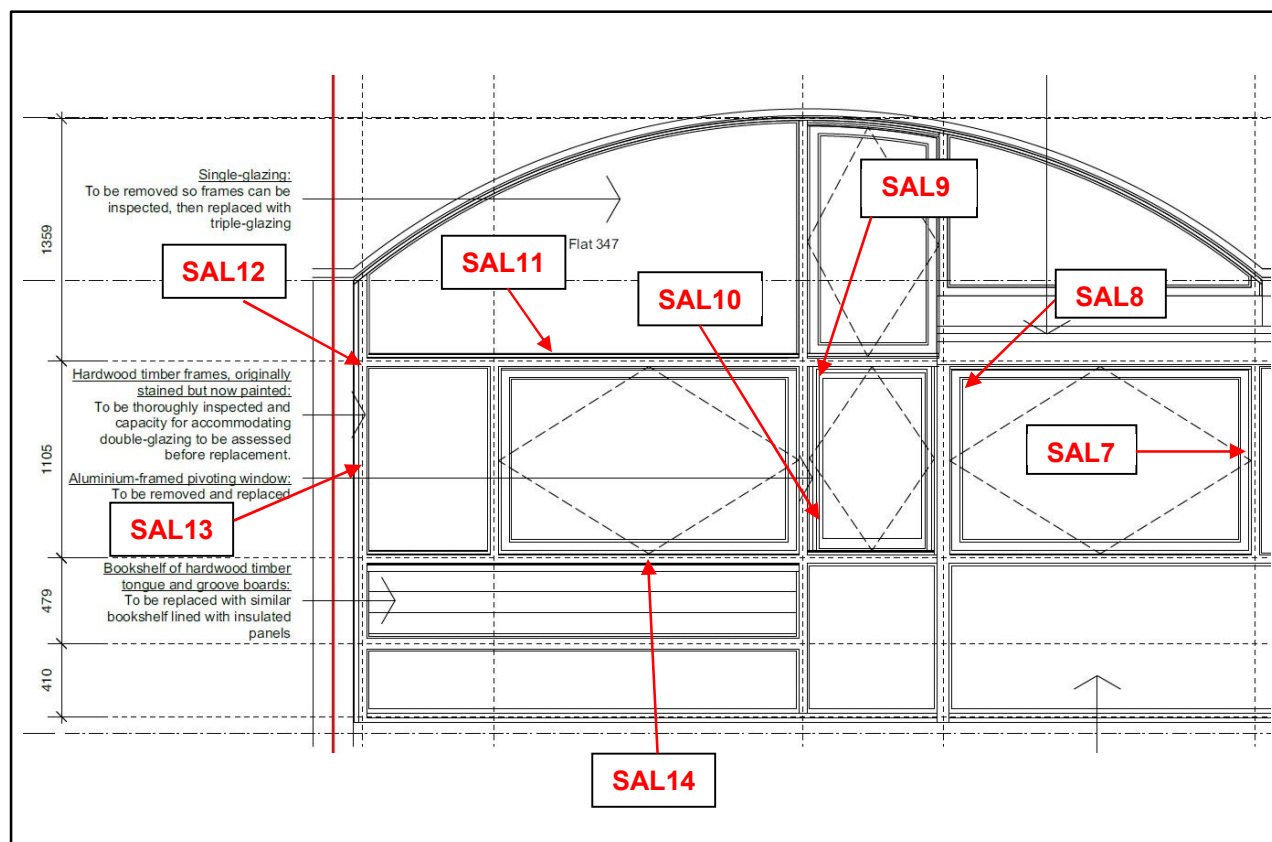


Figure 5: Front of apartment - Smoke Audit Locations (SAL)



Smoke audit findings

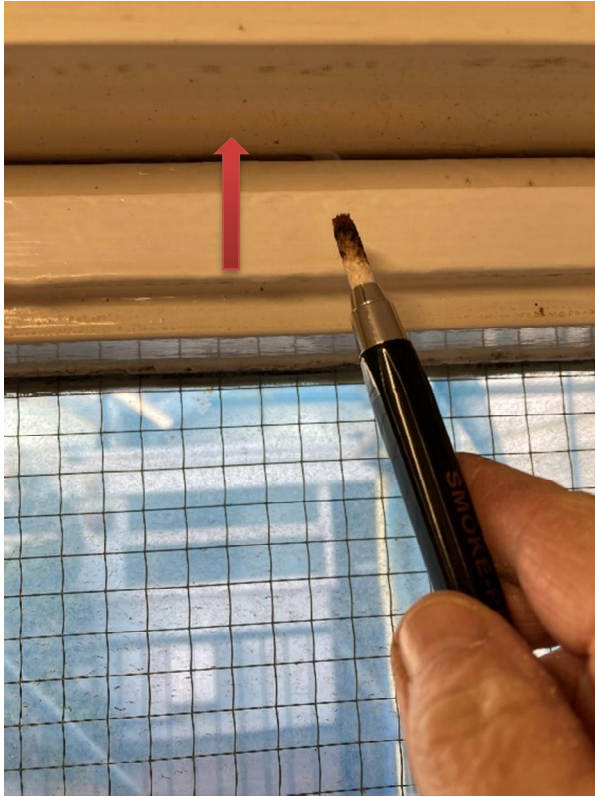


Photograph 3: Air Leakage - kitchen window (SAL1)



Photograph 4: Air Leakage - kitchen window (SAL2)

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Photograph 5: Air Leakage - kitchen window (SAL3)



Photograph 6: Air Leakage - kitchen window (SAL4)

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Photograph 7: Air Leakage – bathroom louvre (SAL5)



Photograph 8: Air Leakage – bathroom flue (SAL6)

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Photograph 9: Air Leakage – main window frame (SAL7)



Photograph 10: Air Leakage – window frame (SAL8)

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Photograph 11: Air Leakage - window frame (SAL9)



Photograph 12: Air Leakage - window frame (SAL10)

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Photograph 13: Air Leakage - window frame (SAL11)



Photograph 14: Air Leakage - window frame (SAL12)

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Photograph 15: Air Leakage - window frame (SAL13)



Photograph 16: Air Leakage - window frame (SAL14)



Thermographic Survey

The following section presents the findings of the thermographic survey of the apartment.

Date of survey: 15th February 2023

Time of survey: 8am

The survey was carried out using an Infrared camera according to BS EN 13187: 1999 and BRE Report 176.

A digital image was taken alongside an infrared image at survey locations around the apartment (*see figures 6 and 7*)

Images were taken to highlight areas of conductive heat loss, structural defects, air leakage and thermal bridging within the building fabric, see Figures 8 to 16 THL1-THL8.

The temperature scale on the side of the images has been adjusted to highlight any anomalies and therefore may not reflect the exact temperature of all objects in the image.

The survey was conducted at a suitable time to ensure that the solar loading effects of the sun are eliminated and to help with attaining a minimum temperature difference between internal and external temperatures of at least 10°C. See Table 11 for the environmental conditions during the survey.

Survey Parameters (Environmental Conditions)	
Cloud cover	50%
Average external air temperature	8.8 °C
Wind speed / direction	1.1 m/s SW
Average internal surface temperature	20.5 °C

Table 11: Environmental conditions during thermographic survey

The images obtained during the thermographic survey are presented in Figures 6 to 7.

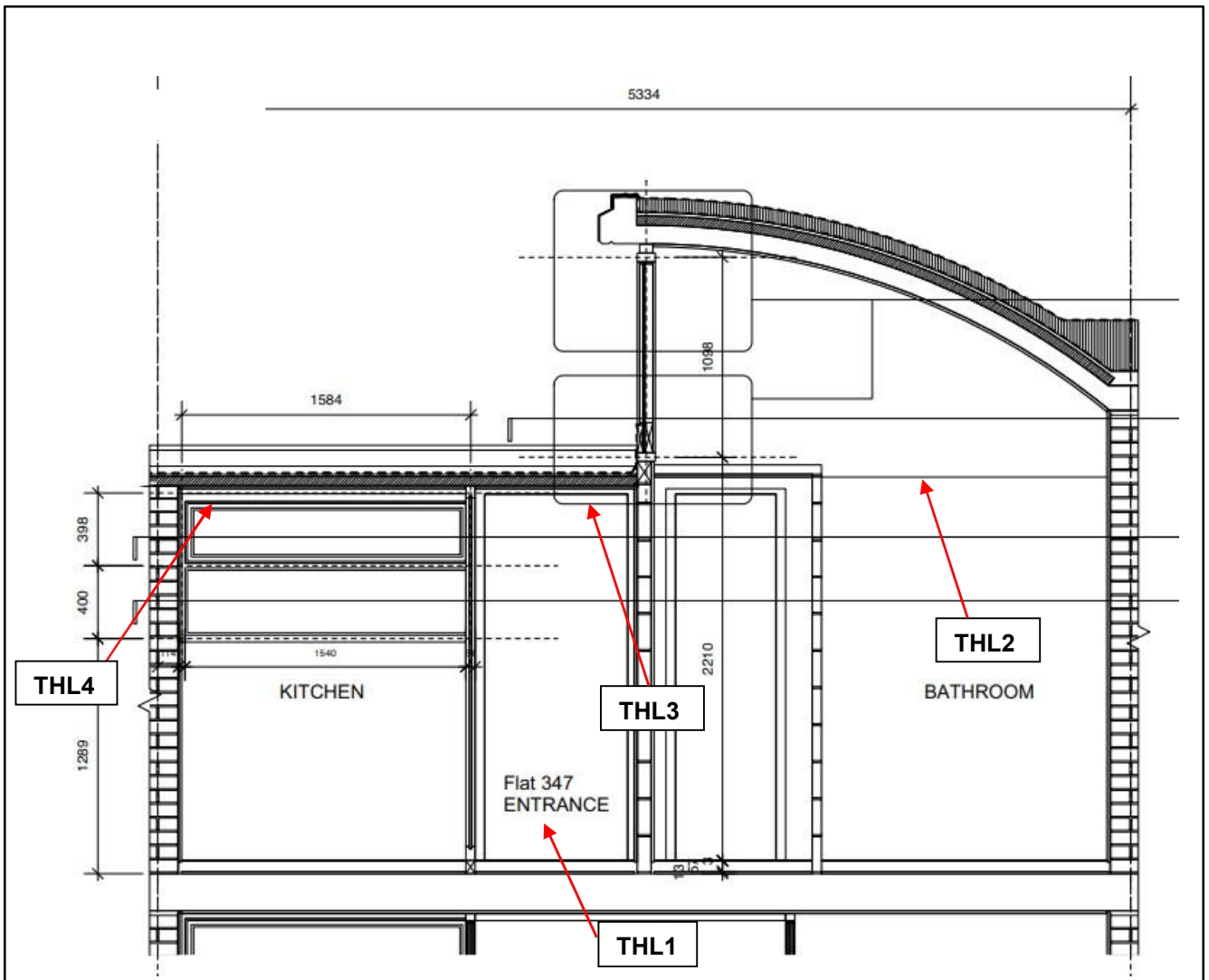


Figure 6: Plan of Thermal images Locations (THL) taken from ground floor level.

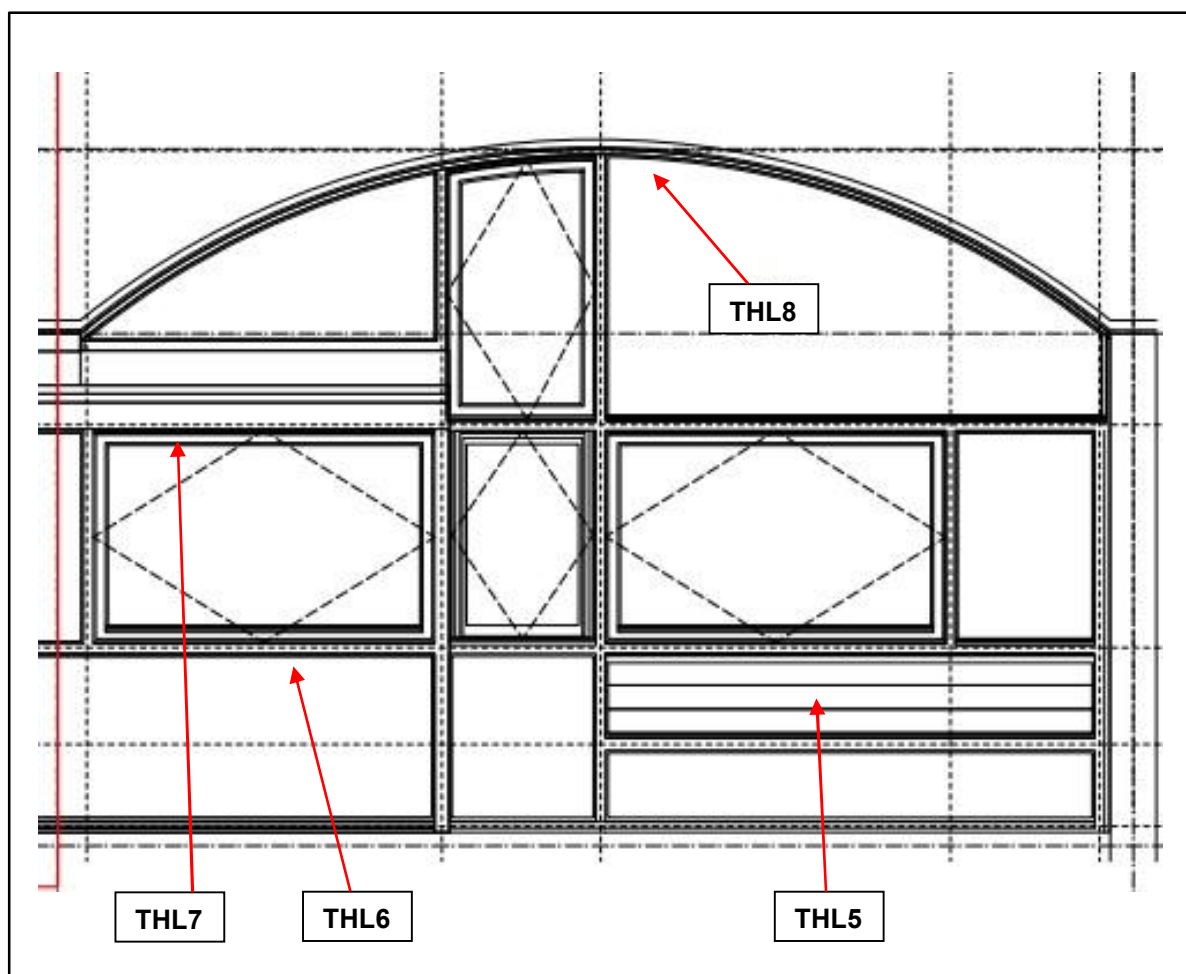


Figure 7: Plan of Thermal images Locations (THL) taken from ground floor level.

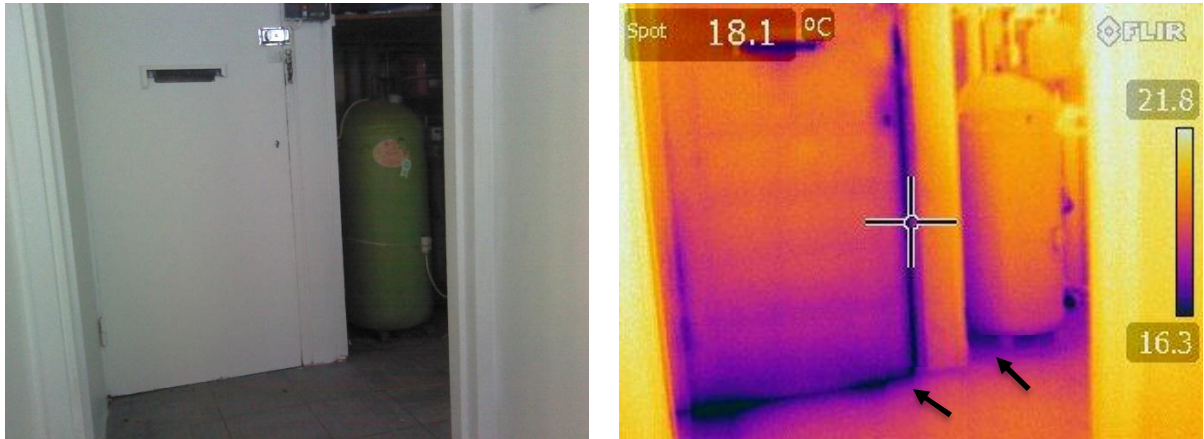


Figure 8: Thermal Image entrance heat loss highlighted Location THL1 (see Figure 6)

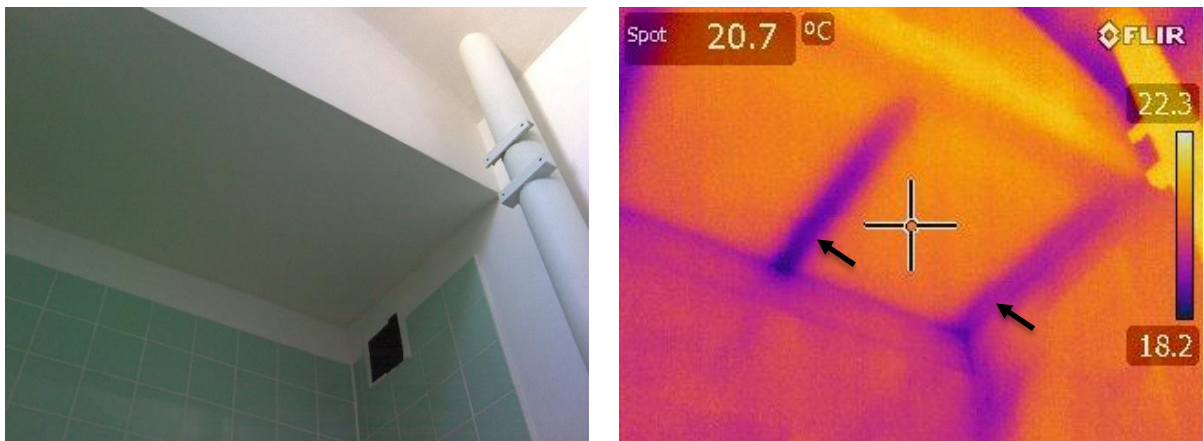


Figure 9: Thermal Image bathroom, heat loss highlighted THL2.

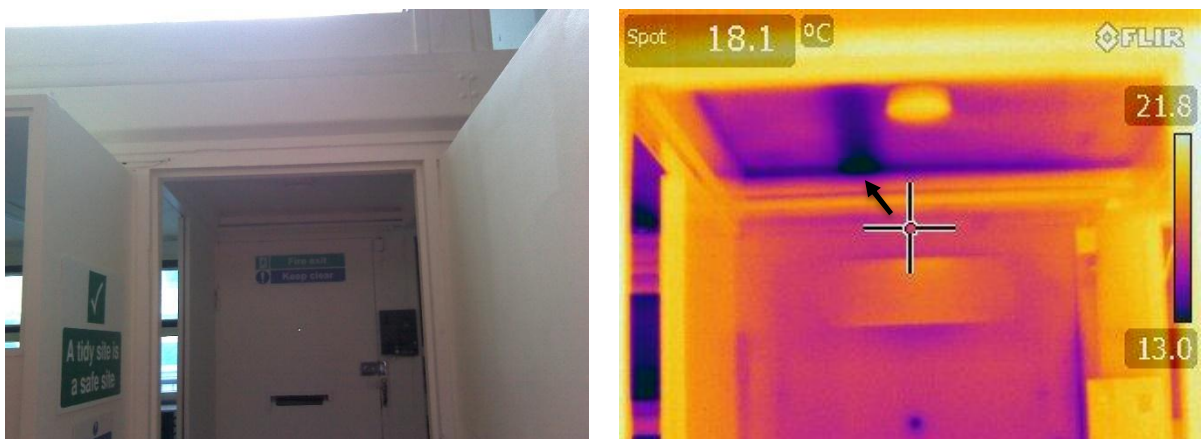


Figure 10: Thermal Image Hall, heat loss highlighted THL3.

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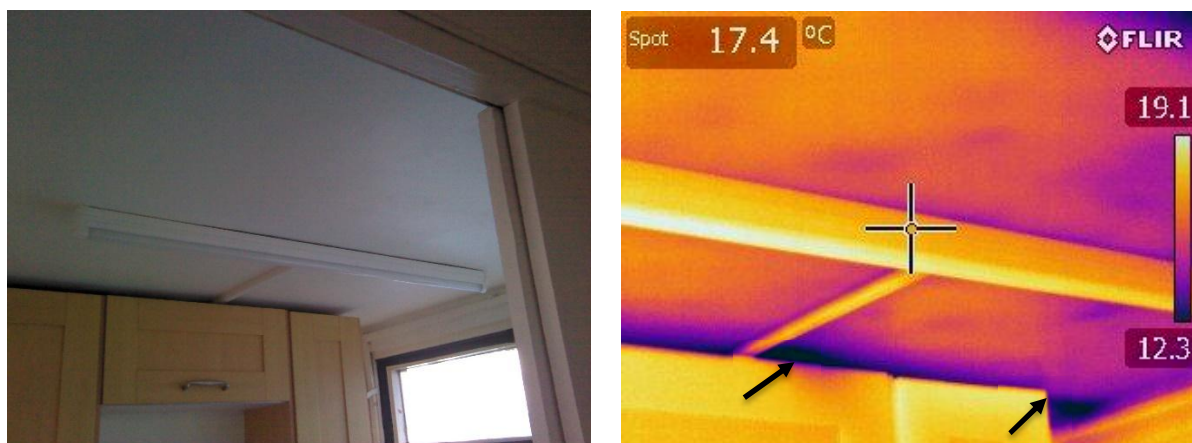


Figure 11: Thermal Image kitchen - heat loss highlighted Location THL4

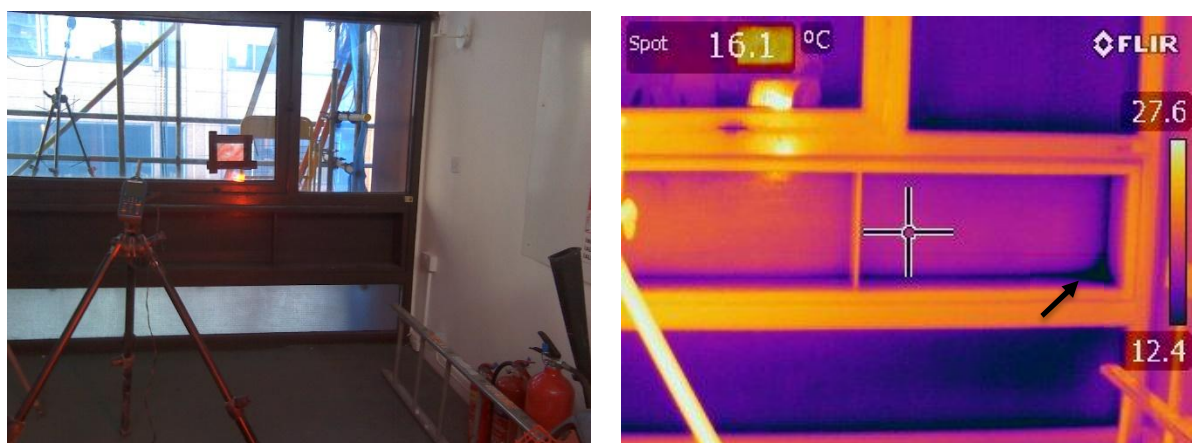


Figure 12: Thermal Image shelving - heat loss highlighted Location THL5 (see Figure 7)

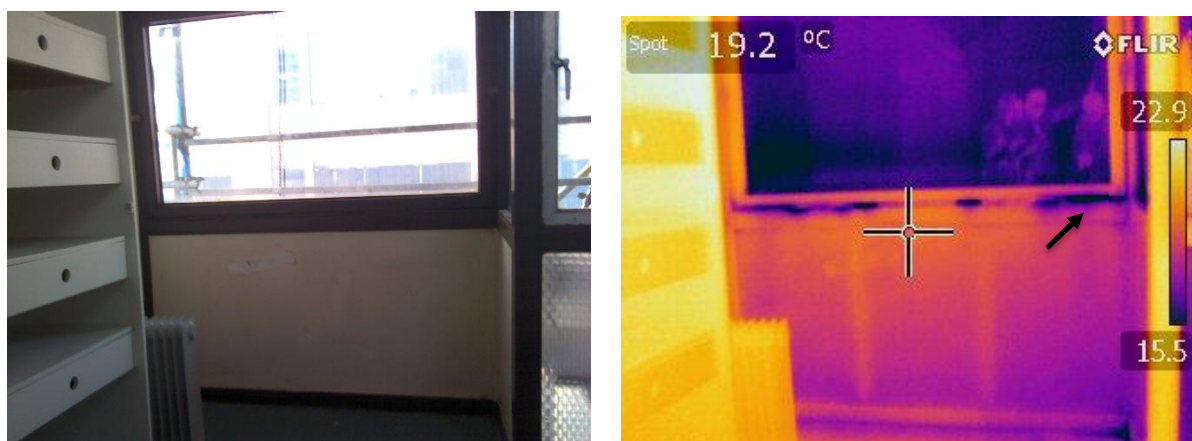


Figure 13: Thermal Image front window - heat loss highlighted Location THL6

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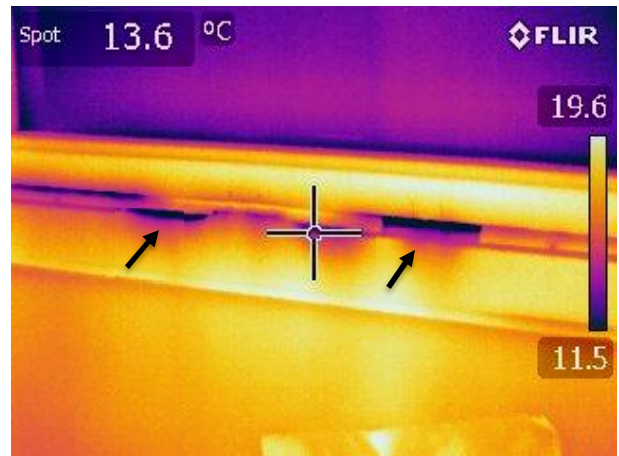
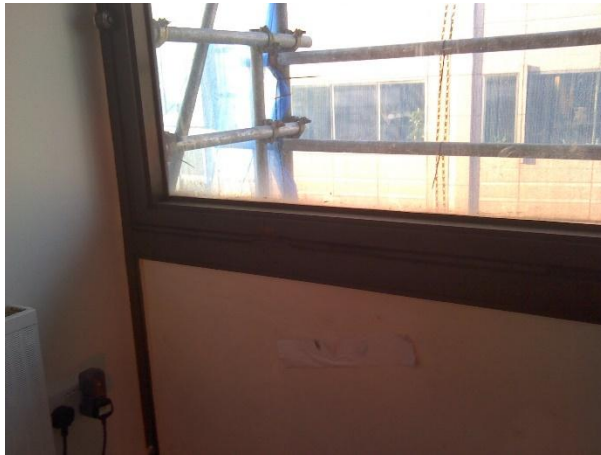


Figure 14: Thermal Image - close up of front window - heat loss highlighted Location THL6



Figure 15: Thermal Image - front window reveal - heat loss highlighted Location THL7

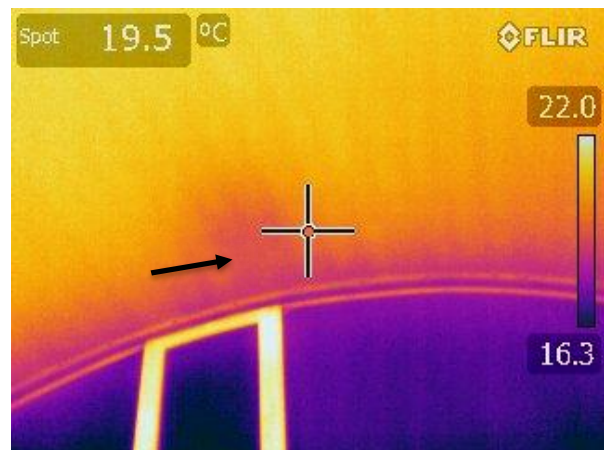
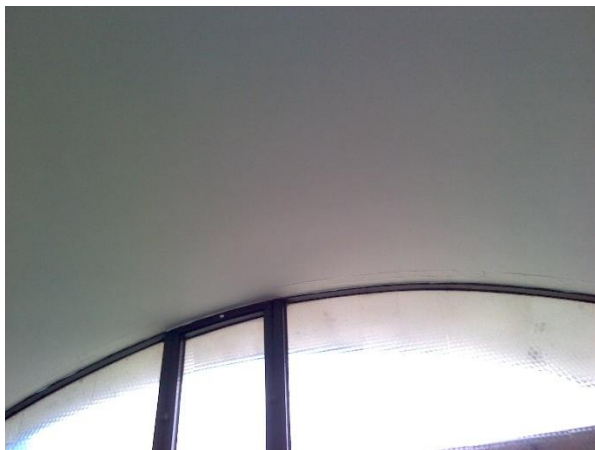


Figure 16: Thermal Image - front window roofline - heat loss highlighted Location THL8



Conclusion

This report presented the baseline results and outcomes for the acoustics testing, airtightness testing, smoke audit and thermography survey undertaken at Crescent House prior to works being undertaken to the building envelope.

The airtightness testing coupled with the smoke audit showed significant air leakage paths around the door penetrations, pipe work and window frames which would also be likely to contribute to the acoustic performance.

The thermography survey generally highlighted localised potential heat loss around the door penetrations, pipe work and window frames.

Once post-works measurements and surveys are undertaken, the outcomes presented in this report shall be used to evaluate any performance improvements that have been made.