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Investigation into the *in situ* thermal performance of 2 static caravans - Assessing the change in heat loss behaviour due to thermally superior replacement windows.

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Introduction

The purpose of this investigation is to assess the *in situ* thermal performance of upgraded replacement windows and door installed into a static caravan located at the Blue Dolphin Holiday Park, Filey, North Yorkshire.

Two static caravans were supplied by Camden Group to the research team within the Centre for the Built Environment (CeBE) Group at Leeds Beckett University for an initial 1 week period. One caravan (Unit 10) was to be tested over the entire period as a control, with no interventions made to the van; the second van (Unit C05) was due to be tested for 2 nights in its original state followed by a further 2 nights with its original windows and door replaced with higher specification replacements. Supply issues with the door resulted in this test programme being extended and a 3-stage test being performed. Details of the tests are outlined below in Table 1.

Date	Action
16-Mar-2015	Install & set-up test equipment
	Initial airtightness tests
	Commence coheating stage 1
18-Mar-2015	Replacement of windows in Unit C05
	Thermal imaging
	Airtightness test of C05 with replacement windows
	Download coheating stage 1 data
	Commence coheating stage 2
20-Mar-2015	Replacement of door in Unit C05
	Thermal imaging
	Airtightness test of C05 with replacement door
	Download coheating stage 2 data
	Commence coheating stage 3
24-Mar-2015	Download coheating stage 3 data
	Uninstall test equipment

Table 1: Test Programme

During the test period measurements of the internal and external temperatures were recorded, along with the power consumption required to maintain that temperature difference. These measurements enabled a metric for the whole caravan heat loss to be determined, namely the heat loss coefficient (HLC) in W/K. Additionally, the heat flow through a number of different fabric elements (glazed elements, roof, walls and floor) was also measured in W/m². The value of undertaking both sets of measurements is that a comparison can be made between the two datasets. Consequently, any changes in performance pre- and post-intervention should be reflected in both sets of measurements (power consumption and aggregate elemental heat flow), thus providing a degree of cross-validation between the two sets of results obtained.

Thermal Imaging

Method

Thermal imaging was performed at various stages throughout the investigation using a Flir B620 Infra-Red Thermal Imaging Camera. Images contained within this section were captured under a natural pressure differential between the inside and outside of the caravans. A selection of thermal images captured under depressurisation is included in the Airtightness section of this report. A full list of all the thermal images captured during this investigation can be found in Appendix 2 - Images 16-Mar-2015 3 & 4.

Discussion

Figure 1 & Figure 2 show the original and replacement windows in C05. In both examples the thermal images were captured on arrival at the site (on the 18th and 20th March respectfully) prior to any other access being gained to the caravan that morning. Additionally, both sets of thermal images were set to a temperature span of 5 °C to allow better direct comparisons to be made between them. The difference in surface temperature, and hence heat loss, due to the replacement glazing is stark; the surface temperatures of the original glazing were the lowest observable temperatures in the images, indicating the maximum heat loss and the first or most likely areas to foster surface condensation.

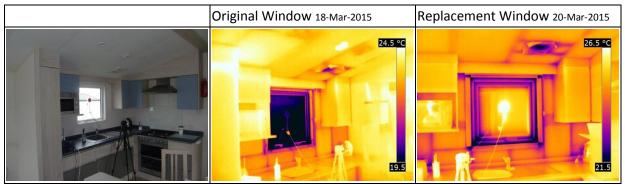
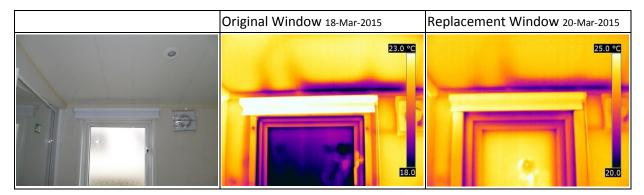


Figure 1: C05 Kitchen window – original and replacement



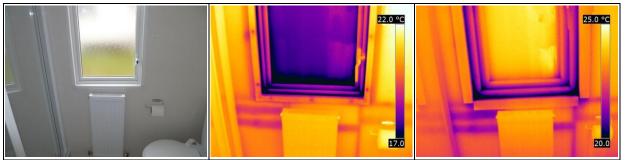


Figure 2: C05 Bathroom window – original and replacement

What is also noticeable in Figure 1 & Figure 2 is the surface temperature of the opaque elements and window frames. The window frames on the original windows are consistently cooler than the structural timber within the walls and ceiling. In contrast, the replacement frames display frame surface temperatures much closer to that of the areas of the plane elements with timber beneath.

The difference between the original window performance and the replacement glazing can be seen most clearly on caravan C05, where the window adjacent to the door was replaced prior to the door being upgraded. Figure 3 displays some difference between the 2 types of glazing when viewed from the outside, although variations in atmospheric conditions and reflection prevent any accurate analysis.

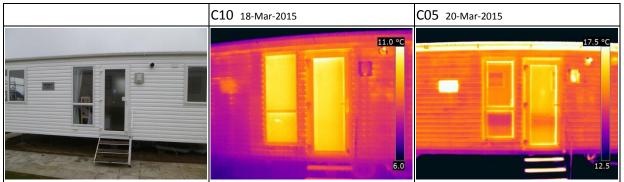


Figure 3: Doors and adjacent window showing difference in external surface temperature

Figure 4 shows the same door and adjacent window in C05, but with the images captured from within the caravan. Taken immediately after the image in Figure 3, the internally captured thermal images in Figure 4 show around a 3.5 °C difference in surface temperature between the original glazing in the door and that of the replacement glazing in the adjacent window.



Figure 4: Internal images of C05 original door with adjacent window replaced – 20-Mar-2015

The thermal imaging surveys conducted throughout the investigation also indicated numerous point and repeated thermal bridges around the entire envelopes of both caravans. Analysis of these thermal anomalies do not fall within the remit of this investigation, so are not expounded upon, but provide a substantial amount of information should a more in-depth study of the thermal performance of the caravans be conducted. All the thermal images taken during this investigation are presented in Appendices 2, 3 and 4.

Airtightness

Method

Air tightness tests were performed on the caravans in accordance with the method outlined by the Airtightness Testing and Measurement Association (ATTMA) for the testing of building envelopes (ATTMA, 2010). The tests were undertaken using an Energy Conservatory Minneapolis 3 Blower Door with a DG700 dual-channel pressure gauge.

For the purposes of the tests all accessible purpose-provided ventilation, in both caravans, was temporarily sealed; some inaccessible vents (such as below the boiler and a presumed similar outlet beneath the kitchen units) were not sealed. The results were obtained using depressurisation only (rather than the usual mean of pressurisation and depressurisation), due to the door lifters in the caravan door frames making placement of the blower door frame within the narrow caravan door frame difficult. Some air leakage detection was performed under depressurisation, utilising the thermal camera to identify cooler infiltrating air.

Results

Table 2 summarises the results of the air pressurisation tests performed on both caravans.

Caravan	Date	Air Permeability	Air Leakage Rate	Correlation coefficient
		m³/(h.m²) @ 50 Pa	ach⁻¹ @ 50 Pa	r ²
C05	16-Mar-2015	5.23	8.37	0.999
C05	18-Mar-2015	5.73	9.17	0.999
C05	20-Mar-2015	5.54	8.88	0.999
C10	16-Mar-2015	5.52	8.84	0.998

Table 2: Airtightness test results

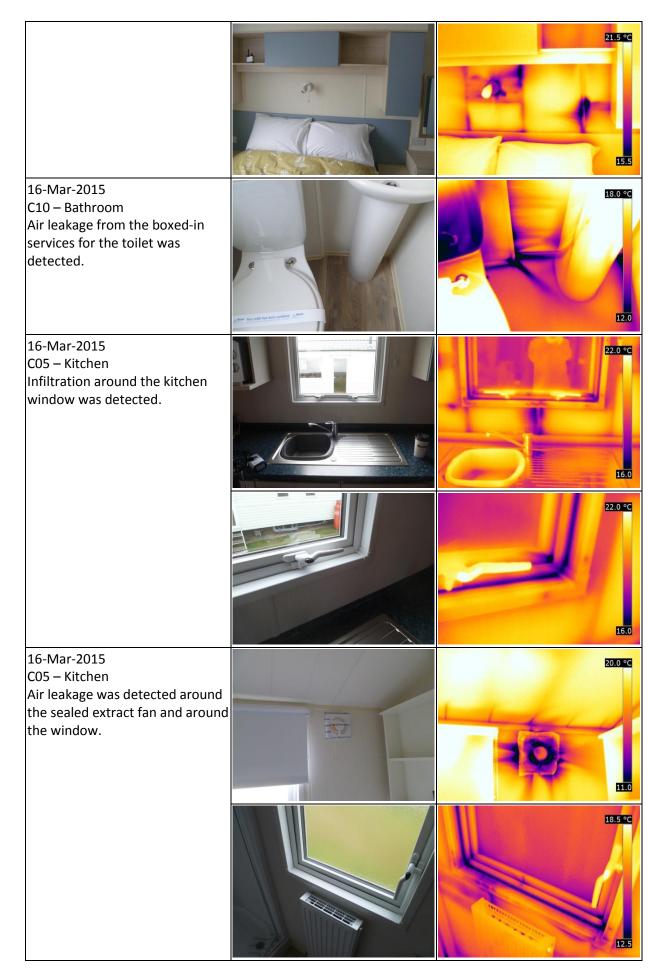
The initial increase in air leakage following the fitting of the replacement windows in C05 was partly due to difficulties in re-fitting the window surrounds, resulting in a number of these being left unfinished. During the 3rd test of C05, some of these surrounds had been re-fitted but many were still left unfinished.

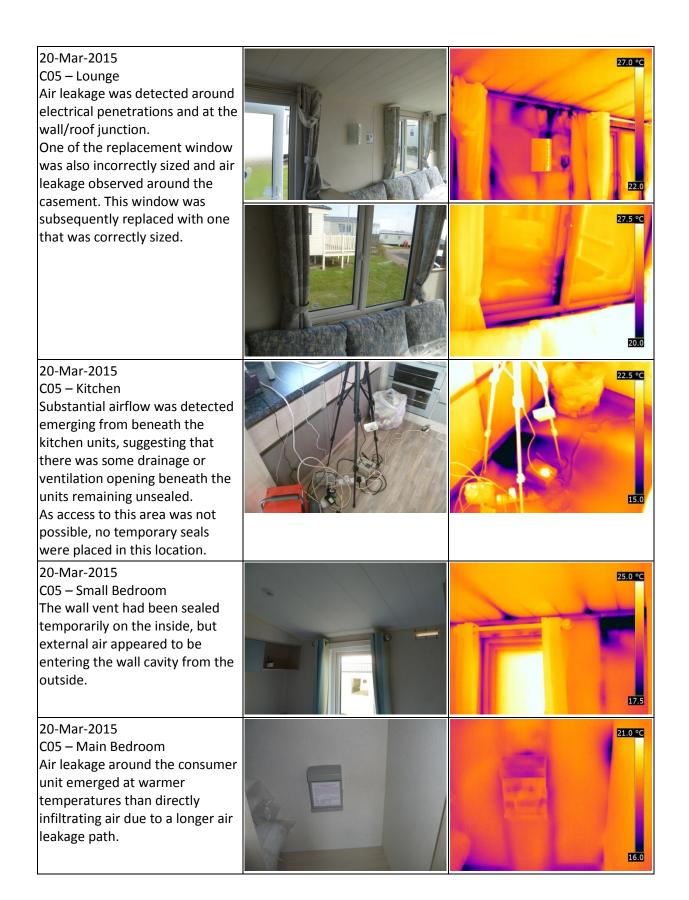
Air leakage paths

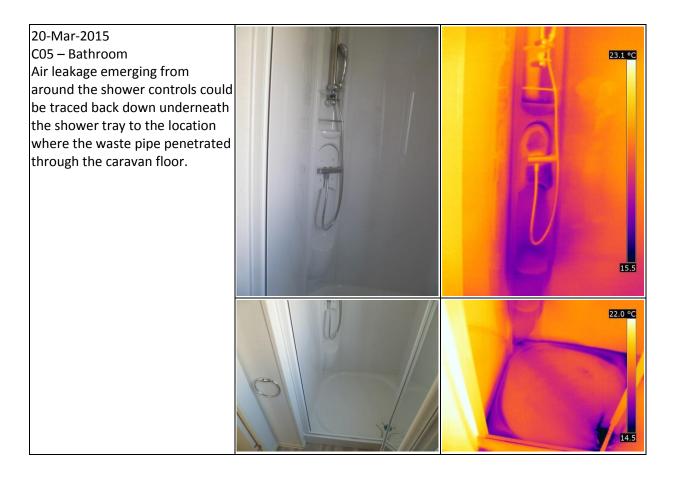
In general, both vans achieved a reasonable standard of airtightness, better than the minimum standard of 10 m³/(h.m²) @ 50 Pa that is contained within Part L of the Building Regulations (NBS, 2013). Air leakage was detected around many junctions and penetrations, particularly those which were inaccessible or obscured from vision, with both vans displaying very similar patterns and points of air leakage. Table 3 shows just a few of the leakage paths detected and, as with the thermal imaging surveys, analysis of these do not fall within the remit of this investigation. However, they provide a substantial amount of information should a more in-depth study of the thermal performance of the caravans be conducted. All of the thermal images taken during this investigation under caravan depressurisation are presented in Appendices 2 and 4.











Actual ventilation rate

Although pressurisation tests provide a value for air permeability or air leakage, the value obtained does not represent a real background ventilation rate, since under normal conditions the internal/external pressure differential will be far less than 50 Pa and in buildings is typically around 3 to 6 Pa (Modera et al., 2009). Furthermore, the blower-door test is a single measurement, whereas background ventilation varies with pressure, temperature and wind conditions, and so is most usefully quoted as an annual average figure. In dwellings, the air leakage rate can be approximated to the natural annual average background ventilation rate by simply dividing the air change rate measured at 50Pa (n_{50}) by 20. This empirical procedure is commonly known as the $n_{50}/20$ '*rule of thumb*'. The origin of this '*rule of thumb*' is usually attributed to Kronvall and Persily (cited by Sherman in 1987). As this '*rule of thumb*' was originally devised based upon a large number of results obtained in North American dwellings, the research team were sceptical whether this rule could equally be applied to caravans.

In order to be able to determine whether the $n_{50}/20$ 'rule of thumb' is likely to be applicable to the test caravans, CO₂ tracer gas decay measurements were undertaken in caravan CO5 during test period 1. Instead of introducing CO₂ artificially into the caravans using some type of CO₂ dispersion device, as is usual in domestic properties, the measurements were undertaken following a period when the researchers had been working in the van for some time (during this period CO₂ levels will have been elevated above the external background level). The actual air change rate was then determined using the CO₂ decay method described within Roulet and Foradini (2002). The results obtained using this method, illustrated by Figure 5 and Table 4, suggest that in the test caravans a figure of n/40 is more applicable to approximate the actual ventilation rate during the tests. This figure has also been used to determine the heat loss attributable to ventilation and has been used in subsequent energy calculations contained within this report (for instance, see Table 7).

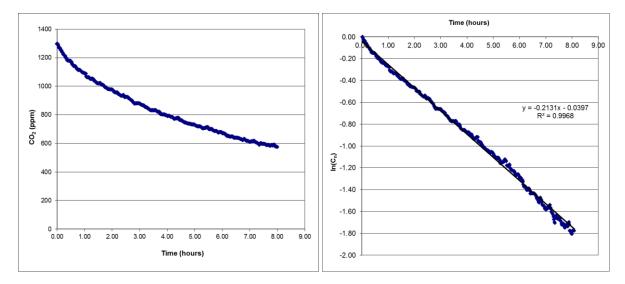


Figure 5: CO₂ decay curves for caravan CO5 stage 1 test



	Based on pressure test (n/20)	Based on CO₂ decay
Approximated background ventilation rate (ach ⁻¹)	0.42	0.21
Ventilation heat loss (W/K)	11.6	5.8

Coheating Tests

Method

A simplified version of a coheating test was used to obtain an estimate of the steady-state aggregate fabric and ventilation heat loss from a whole dwelling. The metric which quantifies this heat loss is the heat loss coefficient (HLC), which is the power input in Watts required to maintain a one Kelvin temperature difference between the internal and external environment (Δ T). The HLC is expressed in units W/K.

A modified version of Leeds Beckett University's Coheating Test Method (Johnston et al., 2013) was used to measure the heat loss from the entire thermal envelope of caravans C05 and C10. The coheating test method was modified to account for the short time period that was available to the research team. Typically, coheating tests are undertaken during a time period of 10 - 21 days. This enables the analysis procedure to more confidently account for thermal storage and release due to the building's thermal mass, external power input resulting from solar radiation, and the effect of wind speed.

As the test caravans have low thermal mass it is reasonable to assume that a coheating test can be undertaken over a shorter time period than that of typical dwellings. However the shorter time period precludes an accurate estimation of the contribution of solar radiation to the heating power input to the caravan using multiple regression analysis. Thus, data used in the estimation of the HLC is from a time period thought not to be influenced by direct or previously stored solar radiation (22:00 – 05:59 inclusive). In addition, the data points used in a coheating regression analysis are usually the mean of a 24 hour time period. However, due to the limited test period and the fact that any thermal lag between a change in Δ T and resultant change in heating power is likely to be minimal (due to the low thermal mass of the caravans), coheating data was aggregated into hourly mean time intervals.

Each caravan was heated using electric resistance point heaters controlled by thermostatic temperature controllers. The temperature controllers in both caravans were set to maintain an internal temperature of 22 °C. Power input to the heaters was measured as well as the internal and external temperature and net radiation. Data was recorded at one minute intervals throughout the entire testing period.

Results

Caravan C05

Test period 1 (original glazing)

Figure 6 shows the hourly mean power and environmental conditions measured during test period 1 for caravan C05. The decrease in power input to the caravan observed in the first day of testing (16/03/15) is due to a reduction in power required to charge the thermal mass of the caravan following the commencement of heating (approximately 4 hours prior to the start of data logging); thus data from the first night of test period 1 (16/03/15) is excluded from the HLC analysis. The result is only one night of data available for the coheating analysis (17/03/15). The suppression of power input resulting from solar radiation and higher external temperatures is highly evident and justifies the use of overnight data in the coheating analysis. It can also be seen that overnight any

change in ΔT results in a change in power input during the same one hour time period; this indicates low thermal mass and suggests that the use of one hour aggregated data in the coheating analysis is both appropriate and acceptable.

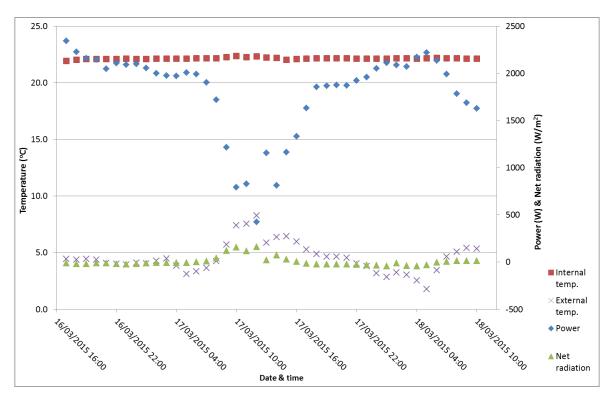


Figure 6: Caravan C05 power and environmental conditions measured during test period 1 (hourly means)

Figure 7 illustrates the power input and environmental conditions during the coheating analysis of test period 1. It is evident that a gradual external temperature decrease results in a gradual increase in power input to the caravan to maintain the ΔT throughout the test period.

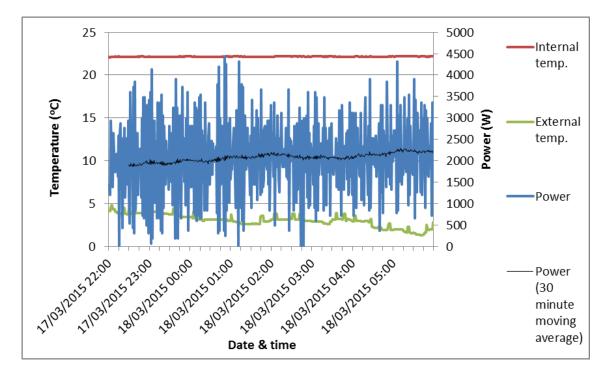




Figure 8 provides the coheating analysis of caravan C05 during test period 1. The coheating test produced an estimate of the HLC of 108.7 (±0.5) W/K (slope of the regression line). The low thermal mass of the caravan is evident by the strong relationship between mean hourly power demand and ΔT (r² of 0.91). This relationship provides confidence that reasonable estimate of the HLC can be obtained over a short time period.

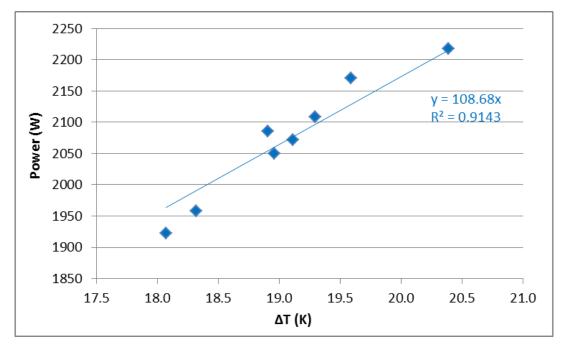


Figure 8: Coheating test 1 analysis for caravan C5 (regression forced through origin)

Test period 2 (replacement windows)

Figure 9 shows the hourly mean power and environmental conditions measured during test period 2 of caravan C05. As the fabric of the caravan remained heated throughout the period of the window replacement on 18/03/15, charging of the thermal mass was complete prior to the first night coheating analysis period. As a result, two nights of coheating data were available for analysis (18 & 19/03/15). It can be seen in Figure 9 that power input into the caravan remained reasonably stable during the coheating analysis periods. There was a reduction in internal temperature in the daytime of 19/03/15 as minor alterations to the internal window trims of the caravan were made. A partial solar eclipse caused the temporary reduction in net radiation measured on the morning of 20/03/15.

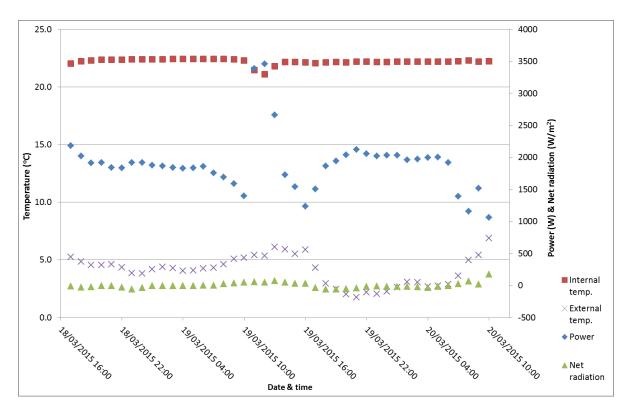
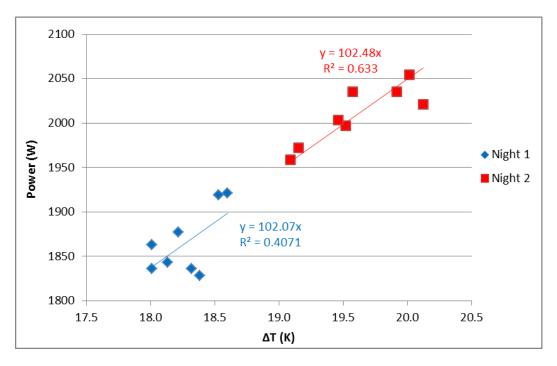
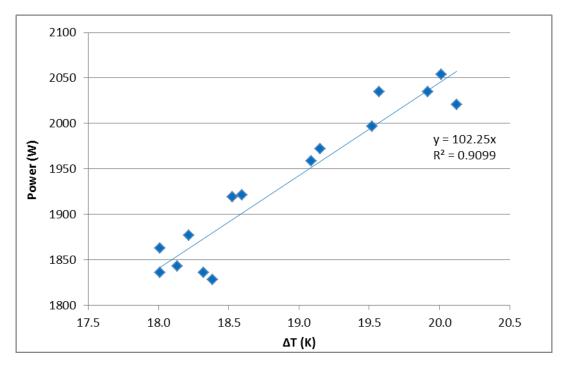


Figure 9: Caravan C05 power and environmental conditions measured during test period 2 (hourly means)

Figure 10 shows the coheating analysis for the two successive nights during test period 2. It can be seen that there is good consistency between the HLC measured on successive nights. The HLCs measured suggest that the minor alterations did not have a measureable difference on the thermal performance of the caravan. The cause of the outliers during night 1 corresponds with a reduction in wind speed during the final two hours of the test.







To increase the power of the coheating test analysis, both nights' data are included in the regression analysis to produce the HLC for test period 2; this is displayed in Figure 11.



Figure 11 provides the coheating analysis of caravan C05 during test period 2. It is clear that there is a strong relationship between the mean hourly power demand and ΔT (r^2 of 0.91). The coheating test produced an estimate of the HLC of 102.3 (±0.3) W/K. This represents a reduction in HLC of 6.5 W/K (5.9%) from test period 1. As the airtightness of the caravan remained almost unchanged following test period 1, this reduction can primarily be attributed to the installation of the replacement windows.

Test period 3 (replacement windows and door)

Figure 12 shows the hourly mean power and environmental conditions measured during test period 3 of caravan C05. As the fabric of the caravan remained heated throughout the period of the door replacement on 20/03/15, charging of the thermal mass was complete prior to the first night coheating analysis period. As a result, four nights coheating data were available for analysis (20, 21, 22 & 23/03/15). Test period 3 was characterised by the greatest diurnal fluctuations in external temperature and the greatest changes in net radiation. The influence that these changes in external temperature and net radiation have on the power input to the caravan to maintain the ΔT can be clearly seen in Figure 12.

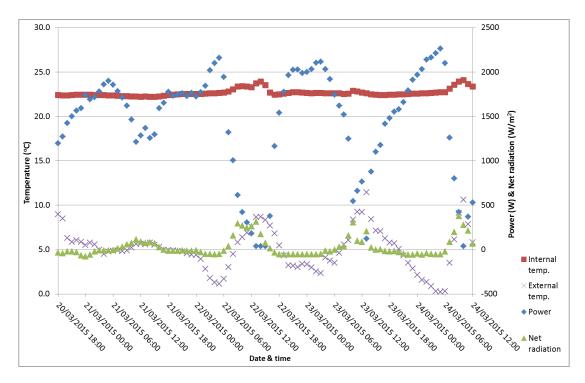




Figure 13 shows the coheating analysis for the four successive nights during test period 3. It can be seen that there is poor consistency between the HLC measured across the test period.

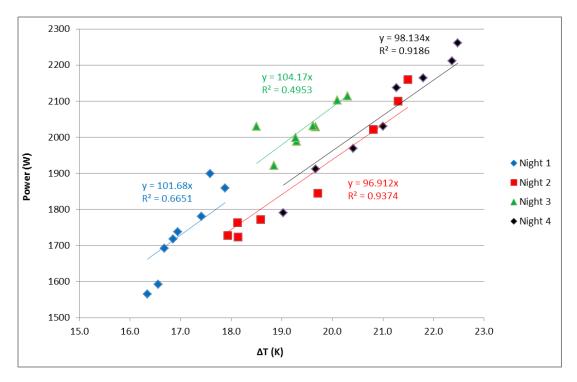


Figure 13: Individual nights coheating test 3 analysis for caravan C05 (regression forced through origin)

Figure 14 shows the relationship between nightly HLC estimates and mean wind speed measured¹ during the test period. The higher wind speed measured during night 1 and night 3 correlate with the higher HLCs measured and the poorer relationship between power input and ΔT measured (lower r² value). It is reasonable to assume that the many ventilation points through the caravan structure mean that it is susceptible to increased ventilation heat loss and wind-washing of the insulation during periods of high wind speeds.

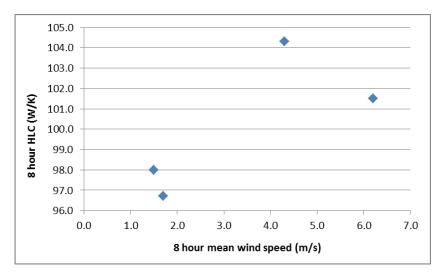


Figure 14: Wind speed vs. nightly HLC for caravan C05 during test period 3

Figure 15 shows the mean wind speed measured during each nightly coheating test period throughout the test programme. The wind speeds measured during night 1 and night 3 of test period 3 were in excess of the other two test periods. To ensure a more suitable comparison between previous test periods these nights have been excluded from the coheating analysis of test period 3.

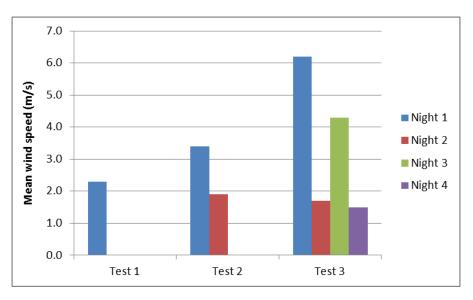


Figure 15: Mean wind speed during each nightly coheating test throughout the test programme

¹ Wind speed data obtained from Weather Underground (<u>http://www.wunderground.com/</u>) at RAF Topcliffe, North Yorkshire; 73 km WSW from test location. This location was the closest to the test site with trustworthy hourly wind speed measurements available. As this data is secondary, its veracity cannot be verified. In addition the distance from the location means that its suitability for use in analysis should be treated with caution.

Figure 16 provides the coheating analysis of caravan C05 during test period 3 using data obtained from night 2 and night 4 only. The coheating test produced an estimate of the HLC of 97.6 (±0.6) W/K. This represents a reduction in HLC of 11.1 W/K (11.4%) from test period 1. There is a high degree in confidence with the HLC estimate due to the very strong correlation between power input and ΔT (r² of 0.94). Unfortunately, it was not possible to measure change in airtightness that may have occurred following the installation of the new door. Assuming that the airtightness of C05 did not significantly change when the door was replaced, the reduction in HLC from test period 1 can primarily be attributed to the installation of the replacement windows and door.

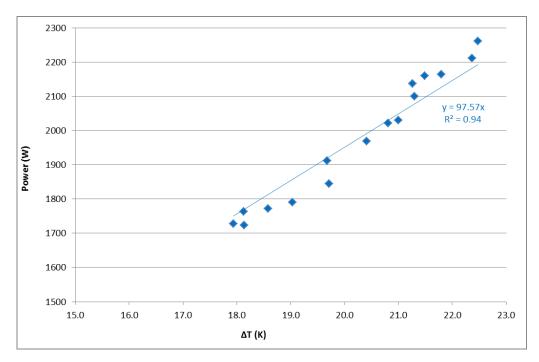
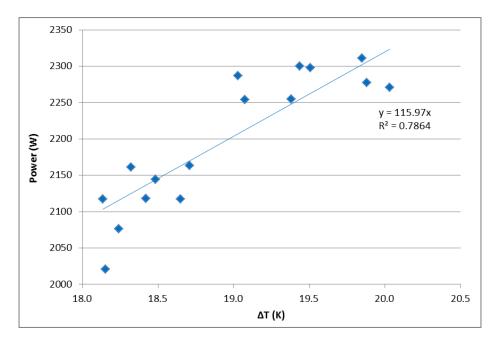


Figure 16: Coheating test 3 analysis for caravan C05 (regression forced through origin)

Caravan C10

Due to a malfunction of the energy metering equipment in caravan C10, it was not possible to estimate a HLC for test period 1; the issue with the logging equipment was resolved prior to test period 2. Caravan C10 did not have any glazing replaced, thus the HLC estimate for test period 2 is for the caravan in its original condition. The coheating analysis for caravan C10 is provided in Figure 17. The coheating test produced an estimate of the HLC of 116 (±0.6) W/K. There is a reasonable degree in confidence with the HLC estimate due to the correlation between power input and ΔT (r^2 of 0.79).





Coheating test summary and conclusions

Table 5 summarises the coheating test results from the test programme. The installation of replacement windows and door to caravan C05 resulted in a HLC reduction of 11.1W/K, which equates to 10.2%. As no significant change in airtightness was measured, the improvement is primarily attributed to an improvement in the fabric thermal performance of the caravan; this is supported by the *in situ* U-value measurements presented in the following section of this report.

Caravan	HLC (W/K)								
	Original glazing	Replacement windows & door							
C05	108.7 ± 0.5	102.3 ± 0.3	97.6 ± 0.6						
C10	116 ± 0.6	n/a	n/a						

Table 5: Summary of coheating test results

The change in HLC is measured against a baseline HLC estimated with data from only one night; however there is a reasonably high degree of confidence that the HLC is reasonably accurate as successive test phases demonstrated good agreement between HLC estimates over differing nights (excluding nights of high wind speed). The coheating tests suggest that the caravans are highly susceptible to wind-washing and increased ventilation heat loss (even with all accessible purpose provided ventilation sealed). The limited data available meant that it was not possible to normalise the HLCs for wind speed. It is suggested that future testing of caravans should involve greater monitoring of wind conditions and be undertaken over a substantially longer time period. Due to the mobile nature of caravans it could be feasible to conduct fabric performance testing within a controlled environment. By undertaking fabric tests within a controlled environment it would allow faster, more accurate and more precise measurements of fabric heat loss to be obtained. Such testing could also be used to develop fabric integrity standards or a fabric performance labelling scheme for such caravans.

In situ U-value Measurement

The primary purpose of the thermal performance measurements was to measure the change in fabric heat loss of caravan C05 resulting from the installation of replacement windows and door. To confidently ascribe any change in thermal performance of the caravan to a change in thermal performance of the windows and door, rather than due to a change in the thermal performance of any other thermal element, *in situ* U-value measurements of the caravan's thermal elements were undertaken.

Method

The thermal transmittance of a building element (U-value) is defined in ISO 7345 as the *"Heat flow rate in the steady-state divided by area and by the temperature difference between the surroundings on each side of a system"* (ISO, 1987, p.3). U-values are expressed in units W/m²K. ISO 9869 (ISO, 2014) describes the method in which *in situ* U-value measurements of thermal elements are typically undertaken. For a lightweight thermal element the minimum measurement period to comply with ISO 9869 is three successive nights where the U-value does not differ by more than \pm 5%. Due to the short test duration, it was not possible to continue measurement until this condition was met; thus the values presented are not to the ISO 9869 standard. Despite this, other aspects relating to the measurement and analysis of the *in situ* U-values were undertaken in accordance with ISO 9869.

To reduce the influence of solar radiation on the results and provide a valid comparison with the coheating tests, *in situ* U-values were calculated from measurements of heat flux density and ΔT obtained overnight (22:00 – 05:59 inclusive) using Equation 1 contained within ISO 9869.

$$U = \frac{\sum_{j=1}^{n} q_j}{\sum_{j=1}^{n} (T_{ij} - T_{ej})}$$
 Equation 1

Where: U = in situ U-value ($W/m^2 K$)

q = heat flux density (W/m²) $T_{(i)}$ = internal air temperature (K) $T_{(e)}$ = external air temperature (K)

The U-values presented are the mean of the U-values measured during each night of each test period. The error associated with each *in situ* U-value presented is considered to be \pm 10%.

In situ measurements of heat flux density, from which *in situ* U-values are derived, were obtained using Hukseflux HFP01 heat flux plates (HFPs) installed on the following thermal elements of each test caravan:

- Window glazing centre pane (4 no.)
- Door glazing centre pane
- External wall
- Roof
- Floor

Results

Table 6 provides a summary of the *in situ* U-value measurements obtained during each test period.

Leastion	Concern	In	situ U-value (W/	m²K)
Location	Caravan	Test 1	Test 2	Test 3
Window 1	C5	2.61	1.39	1.41
(centre pane)	C10	2.66	2.82	n/a
Window 2	C5	2.54	1.33	1.34
(centre pane)	C10	2.51	2.50	n/a
Window 3	C5	2.55	1.33	1.36
(centre pane)	C10	2.63	2.70	n/a
Window 4	C5	2.57	1.32	1.36
(centre pane)	C10	2.57	2.76	n/a
Door	C5	2.61	2.74	1.41
(centre pane)	C10	2.72	2.74	n/a
Wall	C5 (stud)	0.76	0.73	0.74
vvan	C10	0.44	0.41	n/a
Roof	C5	0.26	0.24	0.24
	C10	0.26	0.29	n/a
Floor	C5	0.56	0.58	0.55
FIUUI	C10	0.76	0.75	n/a

Table 6: In situ U-values measured in each caravan during each test period

There was a high level of consistency between *in situ* glazing centre pane U-values measured across both caravans (mean 2.60 W/m²K, SD 0.06 W/m²K) in test period 1. The *in* situ U-values of nonglazed thermal elements in each caravan remained reasonably consistent across each of the test periods, this supports the assertion made in the coheating analysis that the reduction in HLC of caravan C05 is primarily due to the installation of replacement glazing and door. In addition, the mean *in situ* window centre pane U-value in caravan C05 reduced from 2.57 W/m²K to 1.37 W/m²K following the installation of the replacement windows. Figure 18 illustrates the reduction in mean *in situ* window centre pane U-value that was measured across the test periods.

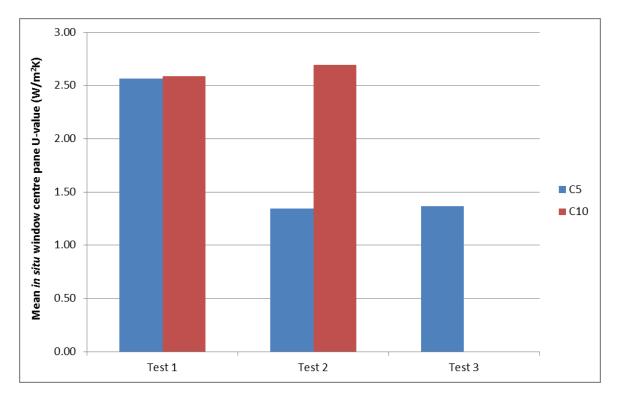




Table 7 provides very approximate estimates of the total heat loss from the caravans for each stage of testing based on the values listed in Table 6 and a number of additional assumptions, not least that the elemental *in situ* U-values obtained were only based on single placements of heat flux sensors. Unfortunately, extending the heat flux measurement to provide fully representative samples of each individual thermal element in each caravan was beyond the scope of this project. The assumptions used in calculating the total heat loss are detailed below.

- The external wall U-value used is based on the assumption that the stud fraction is 10% of the overall external wall area.
- The window/door U-values used are based upon the measured centre-pane values.
- The values used for thermal bridging equate to the default values used with Part L of the Building Regulations for timber- frame housing.
- The heat loss due to ventilation has been calculated based upon the measured pressurisation test results of each caravan, rather than an actual ventilation rate over the test periods.

The results obtained from undertaking the heat loss calculations are detailed within Table 7. In all of the tests, the total heat loss coefficient values listed in Table 7 show a reasonable and consistent correlation with the measured whole caravan heat loss detailed within Table 5. Both sets of results appear to verify the measurements made using the alternative technique. It should be noted that it is the general trend that is of importance here, rather than the estimated values.

 Table 7: Approximate HLC based on *in situ* U-value measurement and estimates of thermal bridging and ventilation heat loss.

		C	LO	C05 - S	Stage 1	C05 - 5	Stage 2	C05 - S	itage 3
		Apparent		Apparent		Apparent		Apparent	
Detail	Area	U-value	Heat Loss	U-value	Heat Loss	U-value	Heat Loss	U-value	Heat Loss
	m²	W/m ² K	W/K	W/m ² K	W/K	W/m ² K	W/K	W/m ² K	W/K
Ground Floor	38.4	0.76	29.0	0.56	21.5	0.58	22.3	0.55	21.1
Roof	37.6	0.28	10.5	0.26	9.8	0.24	9.2	0.24	9.2
Walls	47.2	0.48	22.9	0.48	22.9	0.48	22.9	0.48	22.9
Windows	9.9	2.62	26.0	2.57	25.5	1.37	13.6	1.37	13.6
Door	1.3	2.73	3.4	2.61	3.3	2.74	3.5	1.41	1.8
Total	134.5		91.8		82.9		71.4		68.5
Thermal									
Bridging	m	W/mK		W/mK		W/mK		W/mK	
Openings	75.9	0.15	11.4	0.15	11.4	0.15	11.4	0.15	11.4
Junctions	47.6	0.15	7.1	0.15	7.1	0.15	7.1	0.15	7.1
Total	123.5		18.5		18.5		18.5		18.5
		ach⁻¹@50Pa		ach ⁻¹ @50Pa		ach⁻¹@50Pa		ach ⁻¹ @50Pa	
Ventilation H	eat Loss	8.84	5.6	8.37	5.3	9.17	5.8	8.88	5.7
Total (Heat Los	s Coeffici	ent)	116.0		106.8		95.7		92.7

Conclusions

The magnitude of the HLC reduction calculated from the *in situ* U-value measurements is comparable to that measured by the coheating tests. The *in situ* U-value measurements also support the findings obtained from the coheating tests, where the reduction in the measured HLC can be attributed to the installation of the replacement glazing and doors, rather than due to any change in thermal performance of the other thermal elements.

The installation of the replacement windows in caravan C05 resulted in a reduction of mean *in situ* window centre pane U-value (for the 4 windows and door investigated) from 2.57 W/m²K to 1.37 W/m²K.

Summary

This report has outlined the results of a number of fabric performance tests that were undertaken on two static caravans located at the Blue Dolphin Holiday Park, Filey, North Yorkshire. The tests were undertaken in order to assess the impact that the installation of upgraded replacement windows and doors would have on the *in situ* thermal performance of the caravans.

Due to slight differences in the orientation of the two caravans, it is to be expected that there will be some natural variation between the measured fabric thermal performance of each caravan. The coheating test measurements indicate a small difference in fabric thermal performance between the caravans prior to any upgrade measures, with caravan C10 obtaining an HLC of 116 \pm 0.6 W/K and caravan C10 obtaining an HLC of 108.7 \pm 0.5 W/K. This small difference in performance is also reflected in the pressurisation test results, with caravan C10 obtaining an air permeability of 5.52 m³/(h.m²) @ 50 Pa compared to 5.23 m³/(h.m²) @ 50 Pa for caravan C05. The observed difference in air permeability between the caravans will account for some of the observed difference in the coheating test results. Following replacement of the original windows and door installed in caravan C05 with higher performance glazing and door units, the heat loss coefficient of this caravan reduced to 97.6 \pm 0.6 W/K. This equates to an absolute difference in heat loss coefficient of 11.1 W/K, representing a reduction in heat loss coefficient in excess of 10%.

The results of the coheating tests also suggest that both caravans are highly susceptible to wind washing and increased ventilation heat loss (even when all of the accessible purpose provided ventilation openings are sealed). It is suggested that any future testing of caravans should involve greater monitoring of wind conditions and be undertaken over a substantially longer time period. Due to the mobile nature of caravans it could be feasible to conduct fabric performance testing within a controlled environment. By undertaking fabric tests within a controlled environment it would allow faster, more accurate and more precise measurements of fabric heat loss to be obtained and add to any evaluation of interventions (such as this investigation). Such testing could also be used to develop fabric integrity standards or a fabric performance labelling scheme for such caravans.

A series of *in situ* heat flux density measurements was also undertaken on the caravans. These measurements revealed that there was a high level of consistency between *in situ* glazing centre pane U-values measured across both caravans in test period 1 (mean 2.60 W/m²K, SD 0.06 W/m²K), whilst the *in* situ U-values of the non-glazed thermal elements in each caravan remained reasonably consistent across each of the test periods. These results confirm that the reduction in the HLC of caravan C05 measured during the coheating tests is primarily due to the installation of the replacement glazing and door. In addition, the *in situ* heat flux density measurements undertaken in caravan C05 revealed a significant reduction in the mean *in situ* window centre pane U-value following the installation of the replacement windows. From test period 1 to test period 3, the centre pane U-value reduced by almost 50%, from 2.57 W/m²K to 1.37 W/m²K.

Thermal imaging undertaken internally also revealed that the replacement window surfaces were noticeably warmer than the original windows. As moisture generation within the caravans will condense most rapidly on the coolest surfaces, this raised window surface temperature is likely to result in a reduction in formation of surface condensation on the glazing units. It is suspected that there is also a reduction in thermal bridging around the window frames, due to the removal of the aluminium strip around the perimeter of the original window frames. However, additional work would be required to be undertaken to confirm this.

The results obtained from the *in situ* heat flux density measurements were also used to determine a whole van heat loss coefficient using an *in situ* U-value methodology. If this methodology is compared with the whole van *in situ* heat loss measurement method, comparable results are obtained.

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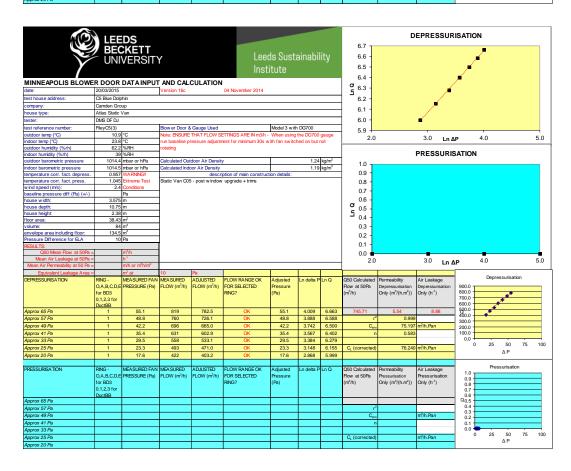
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nppiox 20 F a													ΔΡ

Appendix 1 - Blower door spread sheets

		DS								D	EPRESSUR	RISATION
		VERSIT	Y			ds Sust itute	ainabi	lity	6.7 6.6 - 6.5 - 6.4 -			1
MINNEAPOLIS BLOWE	R DOOR	DATA INPUT	AND CAL	CULATION	1				0.4 -			
date:	16/03/2015		Version 16c		04 November 2014				<u> </u>		_	
test house address:	C5 Blue Dold	ohin							6.2			
company:	Camden Gro								1		, pr	
house type:	Atlas Static								6.1 -			
tester:	DMS DF								6.0 -		- -	
test reference number:			Blow er Door &	Gaune Used		Model 3 wit	h DG700					
outdoor temp (°C)	9.3	er.			ETTINGS ARE IN m3/h				5.9 +			
indoor temp (°C)	19.1				ment for minimum 30s v				2.0		^{3.0} Ln 2	∆P 4.0 5.0
outdoor humidity (%rh)	66	%RH	rotating									
indoor humidity (%rh)	51	%RH	_								PRESSURIS	SATION
outdoor barometric pressure		mbar or hPa		tdoor Air Densit	у			5 kg/m ³	1.0 -			
indoor barometric pressure		mbar or hPa	Calculated Ind	oor Air Density			1.20) kg/m ³				
temperature corr. fact. depress.	0.966				iption of main construc	tion details:			0.9 -			
temperature corr. fact. press.	1.035		Static Van CO	5 - pre window	upgrade				0.8 -			
wind speed (m/s):	0.2		-						0.7 -			
baseline pressure diff (Pa) (+/-) house width:	3.575	Pa	-						0.6 -			
house width:	3.5/5		-						- a			
house depail.	2.38		-						5 0.5			
floor area:	38.43		1						0.4			
volume:		m ³	1						0.3 -			
envelope area including floor:	134.5	m ²							0.2 -			
Pressure Difference for ELA	10	Pa	1						0.2			
RESULTS:									0.1 -			
Q50 Mean Flow at 50Pa =		m³/h							0.1 -		-	
Q50 Mean Flow at 50Pa = Mean Air Leakage at 50Pa =		m ³ /h h ⁻¹									3.0 ln/	AP 4.0 5.0
Q50 Mean Flow at 50Pa = Mean Air Leakage at 50Pa = Mean Air Permeability at 50 Pa =		m³/h h*1 mh or m*h/m²	-						0.0		^{3.0} Ln <i>L</i>	ΔP 4.0 5.0
OS0 Mean Flow at 50Pa = Mean Air Leakage at 50Pa = Mean Air Permeability at 50 Pa = Equivalent Leakage Area =		m³/h h ⁻¹ mħ or m³ħ/m² m² at	10	Pa					0.0 +			
Q50 Mean Flow at 50Pa = Mean Air Leakage at 50Pa = Mean Air Permeability at 50 Pa =	RING -	m ² /h h ⁻¹ m ⁴ h or m ³ h/m ² m ² at MEASURED FAN		Pa ADJUSTED	FLOW RANGE OK	Adjusted	Ln delta F	² Ln Q	0.0 - 2.0 Q50 Calculated	Permeability	Air Leakage	Depressurisation
OS0 Mean Flow at 50Pa = Mean Air Leakage at 50Pa = Mean Air Permeability at 50 Pa = Equivalent Leakage Area =	O,A,B,C,D,E	m ² /h h ⁻¹ m ⁴ h or m ³ h/m ² m ² at MEASURED FAN	10 MEA SURED FLOW (m³/h)	Pa ADJUSTED FLOW (m³/h)	FOR SELECTED	Pressure	Ln delta F	Ln Q	0.0 - 2.0 Q50 Calculated Flow at 50Pa	Depressurisation	Air Leakage Depressurisation	Depressurisation
OS0 Mean Flow at 50Pa = Mean Air Leakage at 50Pa = Mean Air Permeability at 50 Pa = Equivalent Leakage Area =	O,A,B,C,D,E for BD3	m ² /h h ⁻¹ m ⁴ h or m ³ h/m ² m ² at MEASURED FAN					Ln delta F	Ln Q	0.0 - 2.0 Q50 Calculated		Air Leakage	Depressurisation
OS0 Mean Flow at 50Pa = Mean Air Leakage at 50Pa = Mean Air Permeability at 50 Pa = Equivalent Leakage Area =	O,A,B,C,D,E for BD3 0,1,2,3 for	m ² /h h ⁻¹ m ⁴ h or m ³ h/m ² m ² at MEASURED FAN			FOR SELECTED	Pressure	Ln delta F	Ln Q	0.0 - 2.0 Q50 Calculated Flow at 50Pa	Depressurisation	Air Leakage Depressurisation	Depressurisation
OS0 Mean Flow at 50Pa = Mean Air Leakage at 50Pa = Mean Air Permeability at 50 Pa = Equivalent Leakage Area =	O,A,B,C,D,E for BD3	m ² /h h ⁻¹ m ⁴ h or m ³ h/m ² m ² at MEASURED FAN			FOR SELECTED	Pressure	Ln delta F 3.976	2 Ln Q 6.577	0.0 - 2.0 Q50 Calculated Flow at 50Pa	Depressurisation	Air Leakage Depressurisation	Depressurisation
GGO Mean Flow at 50Pa = Mean Air Leakage at 50Pa = Mean Air Permeability at 50 Pa Equivalent Leakage Area = DEPRESSURISATION	O,A,B,C,D,E for BD3 0,1,2,3 for DuctBB	m ² /h h ⁻¹ m ² n or m ² h/m ² m ² at MEA SURED FAN PRESSURE (Pa)	FLOW (m ³ /h)	FLOW (m ³ /h) 718.1 671.8	FOR SELECTED RING?	Pressure (Pa)			0.0 - 2.0 Q50 Calculated Flow at 50Pa (m ² /h)	Depressurisation Only (m ³ /(h.m ²))	Air Leakage Depressurisation Only (h ⁻¹)	Depressurisation
OSO Mean Flow at SOPa = Mean Air Leakage at SOPa = Mean Air Primeability at SO Pa = Equivalent Leakage Area = DEPRESSURISATION	O,A,B,C,D,E for BD3 0,1,2,3 for DuctBB 1	m ² /h h ⁻¹ m ⁻¹ or m ² h/m ² m ² at MEA SURED FAN PRESSURE (Pa) 53.3	FLOW (m ³ /h) 744	FLOW (m ³ /h) 718.1	FOR SELECTED RING? OK	Pressure (Pa) 53.3	3.976	6.577	0.0 - 2.0 Q50 Calculated Flow at 50Pa (m ² /h) 703.01	Depressurisation Only (m ² /(h.m ²)) 5.23 0.999	Air Leakage Depressurisation Only (h ⁻¹)	Depressurisation 800.0 700.0 400.0 500.0 500.0 300.0 200.0 500.0 300.0 5
250 Muan Flow at 50Pa = Mean Ar Leakaga at 50Pa = Mean Ar Leakaga at 50Pa = Equivalent Leakaga Area = DEPRESSURISATION	O,A,B,C,D,E for BD3 0,1,2,3 for <u>DuctBB</u> 1 1	m ⁷ /h h ⁻¹ m ² at MEA SURED FAN PRESSURE (Pa) 53.3 47.3	FLOW (m ³ /h) 744 696	FLOW (m ³ /h) 718.1 671.8	FOR SELECTED RING? OK OK	Pressure (Pa) 53.3 47.3	3.976 3.857	6.577 6.510	0.0 2.0 Q50 Calculated Flow at 50Pa (m ² /h) 703.01	Depressurisation Only (m ² /(h.m ²)) 5.23 0.999	Air Leakage Depressurisation Only (h ⁻¹) 8.37	Depressurisation
Alexan Cisto Mann Flava et 60% a Mann A'r Eudwage et 60% a Mann A'r Eudwage et 60% a Equivalent Leakage Area = DePRESSURISA TON Approx 65 Pe Approx 65 Pe Approx 67 Pa Approx 67 Pa	O,A,B,C,D,E for BD3 0,1,2,3 for DuctBB 1 1 1	m ⁷ /h h ⁻¹ mh or m ⁷ h/m ⁷ m ⁷ at MEASURED FAN PRESSURE (Pa) 53.3 47.3 42.3	FLOW (m ³ /h) 744 696 646	FLOW (m³/h) 718.1 671.8 623.5	FOR SELECTED RING? OK OK OK	Pressure (Pa) 53.3 47.3 42.3	3.976 3.857 3.745	6.577 6.510 6.435	0.0 2.0 2.0 050 Calculated Flow at 50Pa (m ² /h) 703.01 r ² C _{anv}	Depressurisation Only (m ² /(h.m ²)) 5.23 0.999 69.799	Air Leakage Depressurisation Only (h ⁻¹) 8.37	Depressurisation 700.0 600.0 600.0 600.0 600.0 600.0 600.0 8
CSD Man Flow at 60th Man A Leakage at 60th Man A Phrmebility at 60 th Equivalent Leakage Area = DEPRESSURISATION Approx 65 Pls Approx 67 Pls Approx 49 Pls Approx 41 Pls	O,A,B,C,D,E for BD3 0,1,2,3 for DuctBB 1 1 1 1	m ² /h h ¹ mh or m ² l/m ² m ² at MEASURE (Pa) 53.3 47.3 42.3 35.8	FLOW (m³/h) 744 696 646 590	FLOW (m ³ /h) 718.1 671.8 623.5 569.5	FOR SELECTED RING? OK OK OK	Pressure (Pa) 53.3 47.3 42.3 35.8	3.976 3.857 3.745 3.578	6.577 6.510 6.435 6.345	0.0 2.0 2.0 050 Calculated Flow at 50Pa (m ² /h) 703.01 r ² C _{anv}	Depressurisation Only (m²/(h.m²)) 5.23 0.999 69.799 0.586	Air Leakage Depressurisation Only (h ⁻¹) 8.37	Depressurisation 700.0
CSD Man Flow at 50Ps Main Ar Landage at 50Ps Main Ar Permeability at 50 Ps Esurvient Landage Area = DEPressUritSA TON Approx 65 Pa Approx 65 Pa Approx 45 Pa Approx 45 Pa Approx 41 Pa Approx 41 Pa	O,A,B,C,D,E for BD3 0,1,2,3 for DuctBB 1 1 1 1	m ² /h h ⁻¹ m ² or m ² N/m ² m ² at m ² N/m ² m ² at NesSURE (Pa) 53.3 47.3 47.3 42.3 36.8 30.7	FLOW (m³/h) 744 696 646 590 537	FLOW (m ³ /h) 718.1 671.8 623.5 569.5 518.3	FOR SELECTED RING? OK OK OK OK	Pressure (Pa) 53.3 47.3 42.3 35.8 30.7	3.976 3.857 3.745 3.578 3.424	6.577 6.510 6.435 6.345 6.251	0.0 + 2.0	Depressurisation Only (m²/(h.m²)) 5.23 0.999 69.799 0.586	Air Leakage Depressurisation Only (h ⁻¹) 8.37 m ² /h.Pan	Depressurisation 700.0 600.0 600.0 600.0 600.0 600.0 600.0 8
CSD Man Flow at 60th CSD Man Flow at 60th Man Ar Internetability at 60 th Envirolment Leakage Area = DEPRESSURISA TON Approx 65 Pa Approx 65 Pa Approx 67 Pa	0,A,B,C,D,E for BD3 0,1,2,3 for <u>DuctBB</u> 1 1 1 1 1 1 1 1 1	m ² /h h ⁻¹ m ¹ or m ² /m ² m ² at MEASURED FAN PRESSURE (Pa) 53.3 47.3 42.3 36.8 30.7 25.5	FLOW (m³/h) 744 696 646 590 537 487	FLOW (m³/h) 718.1 671.8 623.5 569.5 518.3 470.0	FOR SELECTED RING? OK OK OK OK OK	Pressure (Pa) 53.3 47.3 42.3 35.8 30.7 25.5	3.976 3.857 3.745 3.578 3.424 3.239	6.577 6.510 6.435 6.345 6.251 6.153	0.0 + 2.0	Depressurisation Only (m²/(h.m²)) 5.23 0.999 69.799 0.586	Air Leakage Depressurisation Only (h ⁻¹) 8.37 m ² /h.Pan	Depressurisation 00.0
CSD Man Flow at 60th CSD Man Flow at 60th Man Ar Internetability at 60 th Envirolment Leakage Area = DEPRESSURISA TON Approx 65 Pa Approx 65 Pa Approx 67 Pa	0,A,B,C,D,E for BD3 0,1,2,3 for <u>DuctBB</u> 1 1 1 1 1 1 1 1 1 1 8	m ² /h h ¹ mh or m ² Nm ² m ² at MEASURED FAN PRESSURE (Pa) 53.3 47.3 42.3 35.8 30.7 25.5 20 MEASURED FAN	FLOW (m ² /h) 744 696 646 590 537 487 487 417 MEA SURED	FLOW (m³/h) 718.1 671.8 623.5 569.5 518.3 470.0	FOR SELECTED RING? OK OK OK OK OK	Pressure (Pa) 53.3 47.3 42.3 35.8 30.7 25.5	3.976 3.857 3.745 3.578 3.424 3.239	6.577 6.510 6.435 6.345 6.251 6.153 5.998	0.0 + 2.0	Depressurisation Only (m²/(h.m²)) 5.23 0.999 69.799 0.586	Air Leakage Depressurisation Only (h ⁻¹) 8.37 m ² /h.Pan	Depressurisation 00.0
CSD Man Flow at 60th a Main At Charlong at 60th a Eurivent Lankage Area = DEPRESSURISATION Approx 65 Pa Approx 25 Pa Approx 25 Pa	O,A,B,C,D,E for BD3 0,1,2,3 for DuctBB 1 1 1 1 1 1 1 1 1 8 RNG - O,A,B,C,D,E	m ² /h h ¹ mh or m ² Nm ² m ² at MEASURED FAN PRESSURE (Pa) 53.3 47.3 42.3 36.8 30.7 25.5 20	FLOW (m ³ /h) 744 696 646 590 537 487 417	FLOW (m ³ /h) 718.1 671.8 623.5 569.5 518.3 470.0 402.5	FOR SELECTED RING? OK OK OK OK OK FLOW RANGE OK FOR SELECTED	Pressure (Pa) 53.3 47.3 42.3 35.8 30.7 25.5 20 Adjusted Pressure	3.976 3.857 3.745 3.578 3.424 3.239 2.996	6.577 6.510 6.435 6.345 6.251 6.153 5.998	0.0 - 2.0 2.0 2.0 2.0 2.0 2.0 2.0 2.0	Depressurisation Only (m²/(h.m²)) 5.23 0.999 69.799 0.586 70.935 Permeability Perssurisation	Air Leakage Depressurisation Only (h ⁻¹) 8.37 m ² /h.Pa <i>n</i> Air Leakage Pressurisation	Depressurisation 00000 0000 0000 0000 0000 0000 0000 0000 0000
CSD Man Flow at 60th a Main At Charlong at 60th a Eurivent Lankage Area = DEPRESSURISATION Approx 65 Pa Approx 25 Pa Approx 25 Pa	0,A,B,C,D,E for BD3 0,1,2,3 for DuctBB 1 1 1 1 1 1 1 1 1 1 1 1 1 0,A,B,C,D,E for BD3	m ² /h h ¹ mh or m ² Nm ² m ² at MEASURED FAN PRESSURE (Pa) 53.3 47.3 42.3 35.8 30.7 25.5 20 MEASURED FAN	FLOW (m ² /h) 744 696 646 590 537 487 487 417 MEA SURED	FLOW (m ² /h) 718.1 671.8 623.5 569.5 518.3 470.0 402.5 ADJUSTED	FOR SELECTED RING? OK OK OK OK OK FLOW RANGE OK	Pressure (Pa) 53.3 47.3 42.3 35.8 30.7 25.5 20 Adjusted	3.976 3.857 3.745 3.578 3.424 3.239 2.996	6.577 6.510 6.435 6.345 6.251 6.153 5.998	0.0 4 2.0 2.0 2.0 2.0 2.0 2.0 2.0 7 703.01 7 7 7 7 7 7 7 7 7 7 7 7 7	Depressurisation Only (m ² /(h.m ²)) 5.23 0.999 69.799 0.586 70.935 Permeability	Air Leakage Depressurisation Only (h ⁻¹) 8.37 m ² /h.Pan ^{m²/h.Pan Air Leakage}	Depressurisation 00.0 0.0
CSD Man Flow at 60th a Main At Charlong at 60th a Eurivent Lankage Area = DEPRESSURISATION Approx 65 Pa Approx 25 Pa Approx 25 Pa	0.A.B.C.D.E for BD3 0.1,2,3 for <u>DuctBB</u> 1 1 1 1 1 1 1 1 1 1 0.A.B.C.D.E for BD3 0.1,2,3 for	m ² /h h ¹ mh or m ² Nm ² m ² at MEASURED FAN PRESSURE (Pa) 53.3 47.3 42.3 35.8 30.7 25.5 20 MEASURED FAN	FLOW (m ² /h) 744 696 646 590 537 487 487 417 MEA SURED	FLOW (m ² /h) 718.1 671.8 623.5 569.5 518.3 470.0 402.5 ADJUSTED	FOR SELECTED RING? OK OK OK OK OK FLOW RANGE OK FOR SELECTED	Pressure (Pa) 53.3 47.3 42.3 35.8 30.7 25.5 20 Adjusted Pressure	3.976 3.857 3.745 3.578 3.424 3.239 2.996	6.577 6.510 6.435 6.345 6.251 6.153 5.998	0.0 - 2.0 2.0 2.0 2.0 2.0 2.0 2.0 2.0	Depressurisation Only (m²/(h.m²)) 5.23 0.999 69.799 0.586 70.935 Permeability Perssurisation	Air Leakage Depressurisation Only (h ⁻¹) 8.37 m ² /h.Pa <i>n</i> Air Leakage Pressurisation	Depressurisation 000.0
CSD Man Flow at 50Ps - Main Ar Lendage at 50Ps - Main Ar Permeability at 50 Ps - Exuivent Lankage Area - DEPRESSURISA TON Approx 65 Ps - Approx 75 Ps - Approx 41 Ps - Approx 41 Ps - Approx 25 Ps - Approx 26 Ps - Approx 20 Ps - Ps -	0,A,B,C,D,E for BD3 0,1,2,3 for DuctBB 1 1 1 1 1 1 1 1 1 1 1 1 1 0,A,B,C,D,E for BD3	m ² /h h ¹ mh or m ² Nm ² m ² at MEASURED FAN PRESSURE (Pa) 53.3 47.3 42.3 35.8 30.7 25.5 20 MEASURED FAN	FLOW (m ² /h) 744 696 646 590 537 487 487 417 MEA SURED	FLOW (m ² /h) 718.1 671.8 623.5 569.5 518.3 470.0 402.5 ADJUSTED	FOR SELECTED RING? OK OK OK OK OK FLOW RANGE OK FOR SELECTED	Pressure (Pa) 53.3 47.3 42.3 35.8 30.7 25.5 20 Adjusted Pressure	3.976 3.857 3.745 3.578 3.424 3.239 2.996	6.577 6.510 6.435 6.345 6.251 6.153 5.998	0.0 - 2.0 2.0 2.0 2.0 2.0 2.0 2.0 2.0	Depressurisation Only (m²/(h.m²)) 5.23 0.999 69.799 0.586 70.935 Permeability Perssurisation	Air Leakage Depressurisation Only (h ⁻¹) 8.37 m ² /h.Pa <i>n</i> Air Leakage Pressurisation	Depressurisation 00.0
CSD Man Flow at 60th CSD Man Flow at 60th Man A Leaking at 60th The Man A P Internability at 0 th Equivalent Leakings A rea = DEPRESSURISA TON Approx 65 Pa Approx 65 Pa Approx 65 Pa Approx 20 Pa PRESSURISA TON PRESSURISA TON	0.A.B.C.D.E for BD3 0.1,2,3 for <u>DuctBB</u> 1 1 1 1 1 1 1 1 1 1 0.A.B.C.D.E for BD3 0.1,2,3 for	m ² /h h ¹ mh or m ² Nm ² m ² at MEASURED FAN PRESSURE (Pa) 53.3 47.3 42.3 35.8 30.7 25.5 20 MEASURED FAN	FLOW (m ² /h) 744 696 646 590 537 487 487 417 MEA SURED	FLOW (m ² /h) 718.1 671.8 623.5 569.5 518.3 470.0 402.5 ADJUSTED	FOR SELECTED RING? OK OK OK OK OK FLOW RANGE OK FOR SELECTED	Pressure (Pa) 53.3 47.3 42.3 35.8 30.7 25.5 20 Adjusted Pressure	3.976 3.857 3.745 3.578 3.424 3.239 2.996	6.577 6.510 6.435 6.345 6.251 6.153 5.998	0.0 - 2.0 2.0 250 Calculated Flow at 50Pa (m ² /h) 703.01 C ₁ (corrected) Cost Calculated Flow at 50Pa (m ² /h)	Depressurisation Only (m²/(h.m²)) 5.23 0.999 69.799 0.586 70.935 Permeability Perssurisation	Air Leakage Depressurisation Only (h ⁻¹) 8.37 m ² /h.Pa <i>n</i> Air Leakage Pressurisation	Depressurisation 000.0
CSD Man Flow at 50Ps Main Ar ManaPart 450Ps Main Ar Permeability at 50 Ps Exuivert Lankage at 50Ps Exuivert Lankage Area DEPRESSURISA TION Approx 65 Ps Approx 25 Ps Approx 65 Ps Approx 65 Ps	0.A.B.C.D.E for BD3 0.1,2,3 for <u>DuctBB</u> 1 1 1 1 1 1 1 1 1 1 0.A.B.C.D.E for BD3 0.1,2,3 for	m ² /h h ¹ mh or m ² Nm ² m ² at MEASURED FAN PRESSURE (Pa) 53.3 47.3 42.3 35.8 30.7 25.5 20 MEASURED FAN	FLOW (m ² /h) 744 696 646 590 537 487 487 417 MEA SURED	FLOW (m ² /h) 718.1 671.8 623.5 569.5 518.3 470.0 402.5 ADJUSTED	FOR SELECTED RING? OK OK OK OK OK FLOW RANGE OK FOR SELECTED	Pressure (Pa) 53.3 47.3 42.3 35.8 30.7 25.5 20 Adjusted Pressure	3.976 3.857 3.745 3.578 3.424 3.239 2.996	6.577 6.510 6.435 6.345 6.251 6.153 5.998	0.0 2.0 2.0 2.0 Calculated Flow at 50Pa (m ² /h) 703.01 r ² C _{ent} 0.0 C ₄ (corrected) C ₄ (corrected) C ₅ C ₄ (corrected) C ₅ C ₆ (corrected) Flow at 50Pa (m ² /h) C ₄ (corrected) C ₅ C ₆ (corrected) C ₆ (corrected) C ₆ (corrected) C ₇	Depressurisation Only (m²/(h.m²)) 5.23 0.999 69.799 0.586 70.935 Permeability Perssurisation	Air Leakage Depressurisation Only (h*) <u>8:37</u> m ³ /h.Pan Mir Leakage Pressurisation Only (h*)	Depressurisation 0000 ••••••••••••••••••••••••••••••••••••
CSD Man Flow at 60th a Main A fue dissing at 60th a Main A ir Permeability at 60 th a Envirolent Leakage A rea = DEPRESSURISA TION Approx 65 Pa Approx 65 Pa Approx 65 Pa Approx 20 Pa Reprox 20 Pa Reprox 20 Pa Approx 65 Pa	0.A.B.C.D.E for BD3 0.1,2,3 for <u>DuctBB</u> 1 1 1 1 1 1 1 1 1 1 0.A.B.C.D.E for BD3 0.1,2,3 for	m ² /h h ¹ mh or m ² Nm ² m ² at MEASURED FAN PRESSURE (Pa) 53.3 47.3 42.3 35.8 30.7 25.5 20 MEASURED FAN	FLOW (m ² /h) 744 696 646 590 537 487 487 417 MEA SURED	FLOW (m ² /h) 718.1 671.8 623.5 569.5 518.3 470.0 402.5 ADJUSTED	FOR SELECTED RING? OK OK OK OK OK FLOW RANGE OK FOR SELECTED	Pressure (Pa) 53.3 47.3 42.3 35.8 30.7 25.5 20 Adjusted Pressure	3.976 3.857 3.745 3.578 3.424 3.239 2.996	6.577 6.510 6.435 6.345 6.251 6.153 5.998	0.0 - 2.0 2.0 Calculated Fow at 50Pa (m ² /h) 703.01 7 C ₁ (corrected) C ₅ Calculated Fow at 50Pa (m ² /h)	Depressurisation Only (m²/(h.m²)) 5.23 0.999 69.799 0.586 70.935 Permeability Perssurisation	Air Leakage Depressurisation Only (h ⁻¹) 8.37 m ² /h.Pa <i>n</i> Air Leakage Pressurisation	Depressurisation 000.0
CSD Man Flow at 50Ps Man Ar Lendage at 50Ps Man Ar Permetability at 50 Ps Equivalent Landage Area DEPRESSURISA TION Approx 65 Pa Approx 75 Pa Approx 25 Pa Approx 26 Pa Approx 27 Pa Approx 65 Pa Approx 66 Pa Approx 67 Pa Approx 67 Pa Approx 67 Pa Approx 77 Pa Approx 67 Pa	0.A.B.C.D.E for BD3 0.1,2,3 for <u>DuctBB</u> 1 1 1 1 1 1 1 1 1 1 0.A.B.C.D.E for BD3 0.1,2,3 for	m ² /h h ¹ mh or m ² Nm ² m ² at MEASURED FAN PRESSURE (Pa) 53.3 47.3 42.3 35.8 30.7 25.5 20 MEASURED FAN	FLOW (m ² /h) 744 696 646 590 537 487 487 417 MEA SURED	FLOW (m ² /h) 718.1 671.8 623.5 569.5 518.3 470.0 402.5 ADJUSTED	FOR SELECTED RING? OK OK OK OK OK FLOW RANGE OK FOR SELECTED	Pressure (Pa) 53.3 47.3 42.3 35.8 30.7 25.5 20 Adjusted Pressure	3.976 3.857 3.745 3.578 3.424 3.239 2.996	6.577 6.510 6.435 6.345 6.251 6.153 5.998	0.0 2.0 2.0 2.0 Calculated Flow at 50Pa (m ² /h) 703.01 r ² C _{ent} 0.0 C ₄ (corrected) C ₄ (corrected) C ₅ C ₄ (corrected) C ₅ C ₆ (corrected) Flow at 50Pa (m ² /h) C ₄ (corrected) C ₅ C ₆ (corrected) C ₆ (corrected) C ₆ (corrected) C ₇	Depressurisation Only (m²/(h.m²)) 5.23 0.999 69.799 0.586 70.935 Permeability Perssurisation	Air Leakage Depressurisation Only (h*) <u>8:37</u> m ³ /h.Pan Mir Leakage Pressurisation Only (h*)	Depressurisation 00.0 ••••••••••••••••••••••••••••••••••••
GSD Mann Flow at 60th a Mann Flow at 60th a Mann Ar Permeability at 60th a Enviroim 1 carlsogn at 60th a Enviroim 1 carlsogn at 60th a Enviroim 1 carlsogn Area a DEFRESSURIA TION Approx 65 Pa Approx 65 Pa Approx 65 Pa Approx 40 Pa Approx 41 Pa Approx 40 Pa Approx 40 Pa Approx 65 Pa	0.A.B.C.D.E for BD3 0.1,2,3 for <u>DuctBB</u> 1 1 1 1 1 1 1 1 1 1 0.A.B.C.D.E for BD3 0.1,2,3 for	m ² /h h ¹ mh or m ² Nm ² m ² at MEASURED FAN PRESSURE (Pa) 53.3 47.3 42.3 35.8 30.7 25.5 20 MEASURED FAN	FLOW (m ² /h) 744 696 646 590 537 487 487 417 MEA SURED	FLOW (m ² /h) 718.1 671.8 623.5 569.5 518.3 470.0 402.5 ADJUSTED	FOR SELECTED RING? OK OK OK OK OK FLOW RANGE OK FOR SELECTED	Pressure (Pa) 53.3 47.3 42.3 35.8 30.7 25.5 20 Adjusted Pressure	3.976 3.857 3.745 3.578 3.424 3.239 2.996	6.577 6.510 6.435 6.345 6.251 6.153 5.998	0.0 2.0 050 Calculated (m ² h) 703.01 r ² C ₂ (corrected) 050 Calculated (m ² h) 050 Calculated (m ² h)	Depressurisation Only (m²/(h.m²)) 5.23 0.999 69.799 0.586 70.935 Permeability Perssurisation	Ar Leskage Depressiriation Cely (h ⁻¹) 8.37 m ³ /h.Pan m ³ /h.Pan Ar Leskage Pressureation Cely (h ⁻¹)	Depressurisation 000.0
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MINNEAPOLIS BLOWE						ituto			6.6 -			
date:	18/03/2015	DATAINFUT	Version 16c	COLATION	04 November 2014				g 6.5 -			7
test house address:	C5 Blue Dolp	hin	T CTORRET TOO		of noreinder 2014				_			· /
company:	Camden Gro								6.4 -			🛋 🚽
house type:	Atlas Static										1	
tester:	DMS DF								6.3 -		1	
test reference number:	FileyC5(2)		Blow er Door 8	Gauge Used		Model 3 with	DG700				1	
outdoor temp (°C)	6.9	° C			ETTINGS ARE IN m3/h -			naune	6.2 +			
indoor temp (°C)	17.4	°C			ment for minimum 30s w				2.0		3.0 Ln 2	AP 4.0 5.0
outdoor humidity (%rh)	89.2	%RH	rotating									
indoor humidity (%rh)	49.8	%RH							4		PRESSURI	SATION
outdoor barometric pressure	1023.2	mbar or hPa		tdoor Air Densit	У			kg/m ³	1.0 -			
indoor barometric pressure	1023.2	mbar or hPa	Calculated Inde	oor Air Density			1.22	kg/m³	0.9			
temperature corr. fact. depress. temperature corr. fact. press.	0.964	WARNING! Extreme Test	Static Van CO	descr 5 - post w indow	iption of main construc	tion details:						
wind speed (m/s):	2.8		Static Van Cos	5 - post window	/ upgrade				0.8 -			
baseline pressure diff (Pa) (+/-)	2.0	Pa	ł						0.7 -			
house width:	3.575		t						0.6 -			
house depth:	10.75		1						0 0.5 -			
house height:	2.38	m	1						5			
floor area:	38.43		Ι						0.4 1			
volume:	84		1						0.3 -			
envelope area including floor:	134.5		1						0.2 -			
Pressure Difference for ELA	10	Pa										
			+						01			
RESULTS:			İ						0.1 -			
Q50 Mean Flow at 50Pa =		m³/h	İ						0.0		-	
Q50 Mean Flow at 50Pa = Mean Air Leakage at 50Pa =		m³/h h-1									^{3.0} Ln <i>L</i>	∆p 4.0 5.0
Q50 Mean Flow at 50Pa = Mean Air Leakage at 50Pa = Mean Air Permeability at 50 Pa =		m ³ /h h ⁻¹ m/h or m ³ h/m ²	10	Pa			1		0.0		^{3.0} Ln <i>L</i>	2P
Q50 Mean Flow at 50Pa = Mean Air Leakage at 50Pa =	RING -	m³/h h-1	10 MEASURED	Pa ADJUSTED	FLOW RANGE OK	Adjusted	Ln delta P	Ln Q	0.0	Permeability	3.0 Ln Z	AP 4.0 5.0 Depressurisation
Q50 Mean Flow at 50Pa = Mean Air Leakage at 50Pa = Mean Air Permeability at 50 Pa = Equivalent Leakage Area =	RING - O,A,B,C,D,E	m²/h h² m²h or m²h/m² m² at MEASURED FAN	20		FLOW RANGE OK FOR SELECTED	Adjusted Pressure	Ln delta P	Ln Q	0.0 -	Permeability Depressurisation		Depressurisation
Q50 Mean Flow at 50Pa = Mean Air Leakage at 50Pa = Mean Air Permeability at 50 Pa = Equivalent Leakage Area =	O,A,B,C,D,E for BD3	m²/h h² m²h or m²h/m² m² at MEASURED FAN	MEASURED	ADJUSTED			Ln delta P	Ln Q	0.0 - 2.0 Q50 Calculated		Air Leakage	Depressurisation
Q50 Mean Flow at 50Pa = Mean Air Leakage at 50Pa = Mean Air Permeability at 50 Pa = Equivalent Leakage Area =	O,A,B,C,D,E for BD3 0,1,2,3 for	m²/h h² m²h or m²h/m² m² at MEASURED FAN	MEASURED	ADJUSTED	FOR SELECTED	Pressure	Ln delta P	Ln Q	0.0 - 2.0 Q50 Calculated Flow at 50Pa	Depressurisation	Air Leakage Depressurisation	Depressurisation 900.0 800.0 700.0
Q50 Mean Flow at 50Pa = Mean Air Leakage at 50Pa = Mean Air Primeability at 50 Pa = Equivalent Leakage Area = DEPRESSURISATION	O,A,B,C,D,E for BD3 0,1,2,3 for DuctBB	m²/h h² m/h or m²h/m² m² at MEASURED FAN PRESSURE (Pa)	MEASURED FLOW (m ³ /h)	ADJUSTED FLOW (m ³ /h)	FOR SELECTED RING?	Pressure (Pa)			Q50 Calculated Row at 50Pa (m ² /h)	Depressurisation Only (m ³ /(h.m ²))	Air Leakage Depressurisation Only (h ⁻¹)	Depressurisation 900.0 600.0
OSO Mean Flow at SOPa = Mean Air Leakage at SOPa = Mean Air Permebility at SO Pa = Equivalent Leakage Area = DEFRESSURISATION	O,A,B,C,D,E for BD3 0,1,2,3 for DuctBB 1	m ² /h h ⁻¹ m ¹ or m ² h/m ² m ² at MEASURED FAN PRESSURE (Pa) 58.8	MEA SURED FLOW (m ³ /h) 860	ADJUSTED FLOW (m ³ /h) 828.6	FOR SELECTED RING? OK	Pressure (Pa) 58.8	4.074	6.720	0.0	Depressurisation Only (m ³ /(h.m ²)) 5.73	Air Leakage Depressurisation	Depressurisation 900.0 9
Q50 Mean Flow at 50Pa = Mean Air Leakage at 50Pa = Mean Air Purability at 50 Pa = Equivalent Leakage Area = DEFRESSURISATION Approx 65 Pa Approx 65 Pa	O,A,B,C,D,E for BD3 0,1,2,3 for <u>DuctBB</u> 1	m ² /h h ⁻¹ m/h or m ² h/m ² m ² at MEASURED FAN PRESSURE (Pa) 58.8 53.4	MEA SURED FLOW (m ³ /h) 860 806	ADJUSTED FLOW (m ³ /h) 828.6 776.6	FOR SELECTED RING? OK OK	Pressure (Pa) 58.8 53.4	4.074 3.978	6.720 6.655	Q50 Calculated (m ³ /h) 770.23	Depressurisation Only (m ³ /(h.m ²)) 5.73 0.999	Air Leakage Depressurisation Only (h ⁻¹) 9.17	Depressurisation 900.0 9000.0 9000.0 900.0 900.0 900.0 900.0 900.0 900.0 900.0
250 Mean Flow at 50Pa Mean Air Leokage at 50Pa Mean Air Leokage at 50Pa Benerative Strategies at 50Pa Equivalent Leokage Area = DEPRESSURSATION Approx 65 Pa Approx 57 Pa Approx 57 Pa	O,A,B,C,D,E for BD3 0,1,2,3 for DuctBB 1 1 1	m ² /h h ⁻¹ m ² h or m ² h/m ² m ² at MEASURED FAN PRESSURE (Pa) 58.8 53.4 48	MEA SURED FLOW (m³/h) 860 806 762	ADJUSTED FLOW (m ³ /h) 828.6 776.6 734.2	FOR SELECTED RING? OK OK OK	Pressure (Pa) 58.8 53.4 48	4.074 3.978 3.871	6.720 6.655 6.599	0.0	Depressurisation Only (m ² /(h.m ²)) 5.73 0.999 76.870	Air Leakage Depressurisation Only (h ⁻¹)	Depresuriation 900.0 900
250 Mean Flow at 50Pa Mean Air Haralagan et 50Pa Mean Air Permeability at 50 Pa Explorater Loakage Artes = DERESSURGATION Approx 65 Pa Approx 65 Pa Approx 49 Pa Approx 49 Pa	O,A,B,C,D,E for BD3 0,1,2,3 for DuctBB 1 1 1 1	m7/h h ⁻¹ m7 or m7b/m7 m7 at MEASURED FAN PRESSURE (Pa) 58.8 53.4 48 43.4	MEA SURED FLOW (m³/h) 860 806 762 726	ADJUSTED FLOW (m ³ /h) 828.6 776.6 734.2 699.5	FOR SELECTED RING? OK OK OK	Pressure (Pa) 58.8 53.4 48 43.4	4.074 3.978 3.871 3.770	6.720 6.655 6.599 6.550	Q50 Calculated (m ³ /h) 770.23	Depressurisation Only (m ³ /(h.m ²)) 5.73 0.999	Air Leakage Depressurisation Only (h ⁻¹) 9.17	Depressurisation 900.0 9000.0 9000.0 900.0 900.0 900.0 900.0 900.0 900.0 900.0
CEO Mean Flow at 50th a Mean Air Permeability at 50th a Equivalent Leakaga of 50th a Equivalent Leakaga Arra a DEPRESSURISA TON Approx 65 Pa Approx 65 Pa Approx 47 Pa Approx 41 Pa Approx 41 Pa Approx 41 Pa	0,A,B,C,D,E for BD3 0,1,2,3 for DuctBB 1 1 1 1 1 1	m²/h h² ¹ m² at m² h/m² m² at m² h/m² m² at m² h/m² MEASURE (Pa) 58.8 53.4 48 43.4 39	MEA SURED FLOW (m ³ /h) 860 806 762 726 673	ADJUSTED FLOW (m ³ /h) 828.6 776.6 734.2 699.5 648.4	FOR SELECTED RING? OK OK OK OK	Pressure (Pa) 58.8 53.4 48 43.4 39	4.074 3.978 3.871 3.770 3.664	6.720 6.655 6.599 6.550 6.475	0.0 =- 2.0 G50 Calculated Row at 50Pa (m ⁷ /h) 770.23 r ² C _{em}	Depressurfaction Only (m²/(h.m²)) 5.73 0.999 76.870 0.583	Air Leakage Depressurisation Only (h ⁻¹) 9.17 m ³ /h.Pa <i>n</i>	Depressurisation 90.0 90.0 90.0 90.0 90.0 90.0 90.0 90.
250 Mean Row at 50Pa Mean Ar Hermeability at 50 Pa Expirate Lankage at 50Pa Expirate Lankage Area = DEFRESSURISATION Approx 65 Pa Approx 65 Pa Approx 67 Pa Approx 67 Pa Approx 71 Pa Approx 37 Pa Approx 37 Pa Approx 37 Pa	O,A,B,C,D,E for BD3 0,1,2,3 for DuctBB 1 1 1 1 1 1 1 1 1 1	m ⁷ /h h ¹ m ¹ or m ² h/m ² m ² at MEASURED FAN PRESSURE (Pa) 58.8 53.4 48 43.4 39 33.4	NEASURED FLOW (m³/h) 860 806 762 726 673 620	ADJUSTED FLOW (m ² /h) 828.6 776.6 734.2 699.5 648.4 597.4	FOR SELECTED RING? OK OK OK OK OK	Pressure (Pa) 58.8 53.4 48 43.4 39 33.4	4.074 3.978 3.871 3.770 3.664 3.509	6.720 6.655 6.599 6.550 6.475 6.393	Q50 Calculated (m ³ /h) 770.23	Depressurisation Only (m ² /(h.m ²)) 5.73 0.999 76.870	Air Leakage Depressurisation Only (h ⁻¹) 9.17 m ³ /h.Pa <i>n</i>	Depressurisation 900.0 9
CEO Mean Flow at 50th a Mean Air Permeability at 50th a Equivalent Leakaga of 50th a Equivalent Leakaga Arra a DEPRESSURISA TON Approx 65 Pa Approx 65 Pa Approx 47 Pa Approx 41 Pa Approx 41 Pa Approx 41 Pa	0,A,B,C,D,E for BD3 0,1,2,3 for DuctBB 1 1 1 1 1 1	m²/h h² ¹ m² at m² h/m² m² at m² h/m² m² at m² h/m² MEASURE (Pa) 58.8 53.4 48 43.4 39	MEA SURED FLOW (m ³ /h) 860 806 762 726 673	ADJUSTED FLOW (m ³ /h) 828.6 776.6 734.2 699.5 648.4	FOR SELECTED RING? OK OK OK OK	Pressure (Pa) 58.8 53.4 48 43.4 39	4.074 3.978 3.871 3.770 3.664	6.720 6.655 6.599 6.550 6.475	0.0 =- 2.0 G50 Calculated Row at 50Pa (m ⁷ /h) 770.23 r ² C _{em}	Depressurfaction Only (m²/(h.m²)) 5.73 0.999 76.870 0.583	Air Leakage Depressurisation Only (h ⁻¹) 9.17 m ³ /h.Pa <i>n</i>	Depressurisation 900.0
250 Mean Row at 50Pa Mean Ar Hermeability at 50 Pa Exprimentality at 50 Pa Exprimentality at 50 Pa Expransion S7 Pa Approx 65 Pa Approx 65 Pa Approx 40 Pa Approx 41 Pa Approx 20 Pa Approx 20 Pa	0,A,B,C,D,E for BD3 0,1,2,3 for <u>DuctBB</u> 1 1 1 1 1 1 1 1 1 1	m²/h h² mh or m²h/m² m² at MEASURED FAN PRESSURE (Pa) 58.8 53.4 48 43.4 39 33.4 26.2	MEASURED FLOW (m³/h) 860 806 762 726 673 620 534	ADJUSTED FLOW (m ² /h) 828.6 776.6 734.2 699.5 648.4 597.4 514.5	FOR SELECTED RING? OK OK OK OK OK OK OK	Pressure (Pa) 58.8 53.4 48 43.4 39 33.4 26.2	4.074 3.978 3.871 3.770 3.664 3.509 3.266	6.720 6.655 6.599 6.550 6.475 6.393 6.243	0.0 = 2.0 0.0 = 2.0 050 Calculated Flow at 50Pa (m ⁷ /h) 770.23 r ² C _{em} n C ₄ (corrected)	Depressurfsation Only (m²/(h.m²)) 5.73 0.999 76.870 0.583 78.673	Air Leakage Depressurisation Only (h ⁻¹) 9.17 m ³ /h.Pa <i>n</i>	Depressurisation 900.0
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250 Mean Row at 50Pa Mean Ar Hermeability at 50 Pa Exprimentality at 50 Pa Exprimentality at 50 Pa Expransion S7 Pa Approx 65 Pa Approx 65 Pa Approx 40 Pa Approx 41 Pa Approx 20 Pa Approx 20 Pa	0,A,B,C,D,E for BD3 0,1,2,3 for DuctBB 1 1 1 1 1 1 1 1 8 1 8 1 8 1 8 1 8 1 8	m²/h h² mh or m²h/m² m² at MEASURED FAN PRESSURE (Pa) 58.8 53.4 48 43.4 39 33.4 26.2	MEASURED FLOW (m³/h) 860 806 762 726 673 620 534	ADJUSTED FLOW (m ² /h) 828.6 776.6 734.2 699.5 648.4 597.4 514.5	FOR SELECTED RING? OK OK OK OK OK OK OK	Pressure (Pa) 58.8 53.4 48 43.4 39 33.4 26.2	4.074 3.978 3.871 3.770 3.664 3.509 3.266	6.720 6.655 6.599 6.550 6.475 6.393 6.243	0.0 = 2.0 0.0 = 2.0 050 Calculated Flow at 50Pa (m ⁷ /h) 770.23 r ² C _{em} n C ₄ (corrected)	Depressurfsation Only (m²/(h.m²)) 5.73 0.999 76.870 0.583 78.673	Air Leakage Depressurisation Only (h ⁻¹) 9.17 m ³ /h.Pa <i>n</i>	Depressurisation 900.0 000.0 900.0
250 Mean Row at 50Pa Mean Ar Hermeability at 50 Pa Exprimentality at 50 Pa Exprimentality at 50 Pa Expransion S7 Pa Approx 65 Pa Approx 65 Pa Approx 40 Pa Approx 41 Pa Approx 20 Pa Approx 20 Pa	O.A.B.C.D.E for BD3 0.1,2,3 for DuctBB 1 1 1 1 1 1 1 1 1 1 1 1 0.A.B.C.D.E for BD3 0.J.2,3 for	m ² /h h ² m ³ nr m ² h/m ² MEASURED FAN PRESSURE (Pa) 58.8 53.4 48 43.4 39 33.4 26.2 MEASURED FAN	MEASURED FLOW (m ² /h) 860 806 762 726 673 620 534 MEASURED	ADJUSTED FLOW (m ² /h) 828.6 776.6 734.2 699.5 648.4 597.4 514.5 814.5 ADJUSTED	FOR SELECTED RING? OK OK OK OK OK FLOW RANGE OK FOR SELECTED	Pressure (Pa) 58.8 53.4 48 43.4 39 33.4 26.2 Adjusted Pressure	4.074 3.978 3.871 3.770 3.664 3.509 3.266	6.720 6.655 6.599 6.550 6.475 6.393 6.243	0.0 +	Depressurisation Only (m ² /(h.m ²)) 5.73 0.999 76.870 0.583 78.673 Permeability Pressurisation	Air Leakage Depressurisation Only (h ⁻¹) 9.17 m ² /h.Pa <i>n</i> Air Leakage Pressurisation	Depressurisation 90.0 0
CED Mean Flow at 50% a Mean Art Art Permeability at 50% a Exclusion at 50% a Exclusion at 50% a DEPRESSURISA TON Approx 65 Pa Approx 65 Pa Approx 40 Pa Approx 20 Pa Approx 20 Pa Approx 20 Pa Approx 20 Pa	0,A,B,C,D,E for BD3 0,1,2,3 for DuctBB 1 1 1 1 1 1 1 1 1 1 8 ING - 0,A,B,C,D,E for BD3	m ² /h h ² m ³ nr m ² h/m ² MEASURED FAN PRESSURE (Pa) 58.8 53.4 48 43.4 39 33.4 26.2 MEASURED FAN	MEASURED FLOW (m ² /h) 860 806 762 726 673 620 534 MEASURED	ADJUSTED FLOW (m ² /h) 828.6 776.6 734.2 699.5 648.4 597.4 514.5 814.5 ADJUSTED	FOR SELECTED RING? OK OK OK OK OK FLOW RANGE OK FOR SELECTED	Pressure (Pa) 58.8 53.4 48 43.4 39 33.4 26.2 Adjusted Pressure	4.074 3.978 3.871 3.770 3.664 3.509 3.266	6.720 6.655 6.599 6.550 6.475 6.393 6.243	0.0 +	Depressurisation Only (m ² /(h.m ²)) 5.73 0.999 76.870 0.583 78.673 Permeability Pressurisation	Air Leakage Depressurisation Only (h ⁻¹) 9.17 m ² /h.Pa <i>n</i> Air Leakage Pressurisation	Depressurisation 900.0 000.0 900.0 <
201 Mean Row at 50Ps Mean Ark Heatinge at 50Ps Man Ark Heatinge at 50Ps Man Ark Heatinge at 50Ps DefreeSsUrisAnton	O.A.B.C.D.E for BD3 0.1,2,3 for DuctBB 1 1 1 1 1 1 1 1 1 1 1 1 0.A.B.C.D.E for BD3 0.J.2,3 for	m ² /h h ² m ³ nr m ² h/m ² MEASURED FAN PRESSURE (Pa) 58.8 53.4 48 43.4 39 33.4 26.2 MEASURED FAN	MEASURED FLOW (m ² /h) 860 806 762 726 673 620 534 MEASURED	ADJUSTED FLOW (m ² /h) 828.6 776.6 734.2 699.5 648.4 597.4 514.5 814.5 ADJUSTED	FOR SELECTED RING? OK OK OK OK OK FLOW RANGE OK FOR SELECTED	Pressure (Pa) 58.8 53.4 48 43.4 39 33.4 26.2 Adjusted Pressure	4.074 3.978 3.871 3.770 3.664 3.509 3.266	6.720 6.655 6.599 6.550 6.475 6.393 6.243	0.0 4 2.0 2.0 2.0 2.0 2.0 2.0 2.0 2.0	Depressurisation Only (m ² /(h.m ²)) 5.73 0.999 76.870 0.583 78.673 Permeability Pressurisation	Air Leakage Depressurisation Only (h ⁻¹) 9.17 m ² /h.Pa <i>n</i> Air Leakage Pressurisation	Depressurisation 900.0 0 800.0 0 900.0 0 900.0 0 900.0 0 900.0 0 900.0 0 900.0 0 900.0 0 900.0 0 900.0 0 900.0 0 900.0 0 90.0 0
CED Mean Flow at 50% a Mean Ar Vermeability at 50% a Equivalent Leskage Area 50% a Equivalent Leskage Area 50% a DEPRESSURISA TON Approx 65 Pa Approx 25 Pa Approx 25 Pa Approx 25 Pa Approx 25 Pa Approx 25 Pa Approx 65 Pa Approx 65 Pa	O.A.B.C.D.E for BD3 0.1,2,3 for DuctBB 1 1 1 1 1 1 1 1 1 1 1 1 0.A.B.C.D.E for BD3 0.J.2,3 for	m ² /h h ² m ³ nr m ² h/m ² MEASURED FAN PRESSURE (Pa) 58.8 53.4 48 43.4 39 33.4 26.2 MEASURED FAN	MEASURED FLOW (m ² /h) 860 806 762 726 673 620 534 MEASURED	ADJUSTED FLOW (m ² /h) 828.6 776.6 734.2 699.5 648.4 597.4 514.5 814.5 ADJUSTED	FOR SELECTED RING? OK OK OK OK OK FLOW RANGE OK FOR SELECTED	Pressure (Pa) 58.8 53.4 48 43.4 39 33.4 26.2 Adjusted Pressure	4.074 3.978 3.871 3.770 3.664 3.509 3.266	6.720 6.655 6.599 6.550 6.475 6.393 6.243	0.0 4 2.0 2.0 2.0 2.0 2.0 2.0 2.0 2.0 2.0 2.0	Depressurisation Only (m ² /(h.m ²)) 5.73 0.999 76.870 0.583 78.673 Permeability Pressurisation	Air Leakage Depressurisation Only (h*) <u>9.17</u> m ³ /h.Pa <i>n</i> Mir Leakage Pressurisation Only (h*)	Depressurisation 900.0 0.0 900.0
CSD Mean Row at 50Ps Man Ark Harmability at 50Ps Man Ark Permeability at 50 Ps Eguinate Lesiage Area = DEFRESSURSATION Approx 65 Ps Approx 41 Ps Approx 41 Ps Approx 20 Ps Approx 20 Ps RESSURSATION RESSURSATION RESSURSATION	O.A.B.C.D.E for BD3 0.1,2,3 for DuctBB 1 1 1 1 1 1 1 1 1 1 1 1 0.A.B.C.D.E for BD3 0.J.2,3 for	m ² /h h ² m ³ nr m ² h/m ² MEASURED FAN PRESSURE (Pa) 58.8 53.4 48 43.4 39 33.4 26.2 MEASURED FAN	MEASURED FLOW (m ² /h) 860 806 762 726 673 620 534 MEASURED	ADJUSTED FLOW (m ² /h) 828.6 776.6 734.2 699.5 648.4 597.4 514.5 814.5 ADJUSTED	FOR SELECTED RING? OK OK OK OK OK FLOW RANGE OK FOR SELECTED	Pressure (Pa) 58.8 53.4 48 43.4 39 33.4 26.2 Adjusted Pressure	4.074 3.978 3.871 3.770 3.664 3.509 3.266	6.720 6.655 6.599 6.550 6.475 6.393 6.243	0.0 = 2.0 2.0 2.0 2.0 2.0 2.0 2.0 2.0	Depressurisation Only (m ² /(h.m ²)) 5.73 0.999 76.870 0.583 78.673 Permeability Pressurisation	Air Leakage Depressurisation Only (h ⁻¹) 9.17 m ² /h.Pa <i>n</i> Air Leakage Pressurisation	Depressurisation 900.0 0.0 900.0 0.0 900.0 0.0 900.0 0.0 900.0 0.0 900.0 0.0 900.0 0.0 900.0 0.0 900.0 0.0 900.0 0.0 900.0 0.0 900.0 0.0 900.0 0.2 900.0 0.2 900.0 0.0 900.0 0.0 900.0 0.0 900.0 0.0 900.0 0.0 900.0 0.0 900.0 0.0 900.0 0.0 900.0 0.0 900.0 0.0 900.0 0.0 900.0 0.0 900.0 0.0 900.0 0.0 900.0 0.0 900.0 0.0 900.0 0.0 900.0
CED Mean Flow at 50% Mean Ar was at 50% Man Ar Permeability at 50% Equivalent Leakage Arma Equivalent Leakage Arma DEPRESSURISA TON	O.A.B.C.D.E for BD3 0.1,2,3 for DuctBB 1 1 1 1 1 1 1 1 1 1 1 1 0.A.B.C.D.E for BD3 0.J.2,3 for	m ² /h h ² m ³ nr m ² h/m ² MEASURED FAN PRESSURE (Pa) 58.8 53.4 48 43.4 39 33.4 26.2 MEASURED FAN	MEASURED FLOW (m ² /h) 860 806 762 726 673 620 534 MEASURED	ADJUSTED FLOW (m ² /h) 828.6 776.6 734.2 699.5 648.4 597.4 514.5 814.5 ADJUSTED	FOR SELECTED RING? OK OK OK OK OK FLOW RANGE OK FOR SELECTED	Pressure (Pa) 58.8 53.4 48 43.4 39 33.4 26.2 Adjusted Pressure	4.074 3.978 3.871 3.770 3.664 3.509 3.266	6.720 6.655 6.599 6.550 6.475 6.393 6.243	0.0 4 2.0 2.0 2.0 2.0 2.0 2.0 2.0 2.0 2.0 2.0	Depressurisation Only (m ² /(h.m ²)) 5.73 0.999 76.870 0.583 78.673 Permeability Pressurisation	Air Leakage Depressurisation Only (h*) <u>9.17</u> m ³ /h.Pa <i>n</i> Mir Leakage Pressurisation Only (h*)	Depressurisation 900.0 900.0 900.0
200 Mean Row at 50% a Mean Ark Harmshilly at 50% a Man Ark Permetability at 50 M a Egynheait Leakage Area = DEFRESSURISATION	O.A.B.C.D.E for BD3 0.1,2,3 for DuctBB 1 1 1 1 1 1 1 1 1 1 1 1 0.A.B.C.D.E for BD3 0.J.2,3 for	m ² /h h ² m ³ nr m ² h/m ² MEASURED FAN PRESSURE (Pa) 58.8 53.4 48 43.4 39 33.4 26.2 MEASURED FAN	MEASURED FLOW (m ² /h) 860 806 762 726 673 620 534 MEASURED	ADJUSTED FLOW (m ² /h) 828.6 776.6 734.2 699.5 648.4 597.4 514.5 814.5 ADJUSTED	FOR SELECTED RING? OK OK OK OK OK FLOW RANGE OK FOR SELECTED	Pressure (Pa) 58.8 53.4 48 43.4 39 33.4 26.2 Adjusted Pressure	4.074 3.978 3.871 3.770 3.664 3.509 3.266	6.720 6.655 6.599 6.550 6.475 6.393 6.243	0.0 - 2.0 0.50 Calculated (m ² /h) 770.23 r ² C _{an} 0.50 Calculated (m ² /h) 0.50 Calculated	Depressurisation Only (m ² /(h.m ²)) 5.73 0.999 76.870 0.583 78.673 Permeability Pressurisation	Ar Leskage Depressuriation Only (h ⁻¹) 9.17 m ² /h.Pan Ar Leskage Pressuriation Coly (h ⁻¹)	Depressurisation 900.0 0 900.0
CED Mean Flow at 50th Mean Ar Warmability at 50th Mean Ar Permeability at 50 h Equivalent Leakage Arma Equivalent Leakage Arma DEPRESSURISA TON	O.A.B.C.D.E for BD3 0.1,2,3 for DuctBB 1 1 1 1 1 1 1 1 1 1 1 1 0.A.B.C.D.E for BD3 0.J.2,3 for	m ² /h h ² m ³ nr m ² h/m ² MEASURED FAN PRESSURE (Pa) 58.8 53.4 48 43.4 39 33.4 26.2 MEASURED FAN	MEASURED FLOW (m ² /h) 860 806 762 726 673 620 534 MEASURED	ADJUSTED FLOW (m ² /h) 828.6 776.6 734.2 699.5 648.4 597.4 514.5 814.5 ADJUSTED	FOR SELECTED RING? OK OK OK OK OK FLOW RANGE OK FOR SELECTED	Pressure (Pa) 58.8 53.4 48 43.4 39 33.4 26.2 Adjusted Pressure	4.074 3.978 3.871 3.770 3.664 3.509 3.266	6.720 6.655 6.599 6.550 6.475 6.393 6.243	0.0 = 2.0 2.0 2.0 2.0 2.0 2.0 2.0 2.0	Depressurisation Only (m ² /(h.m ²)) 5.73 0.999 76.870 0.583 78.673 Permeability Pressurisation	Air Leakage Depressurisation Only (h*) <u>9.17</u> m ³ /h.Pa <i>n</i> Mir Leakage Pressurisation Only (h*)	Depressurisation 900.0 900.0 900.0



Appendix 2 - Images 16-Mar-2015



Leeds Sustainability Institute

- Camden Group: Site Visit Images 16-Mar-2015
- Researchers: Dominic Miles-Shenton, David Farmer
- Site Address: C05 & C10, Holly Bank Blue Dolphin Holiday Park Filey North Yorkshire YO14 9PU



C05



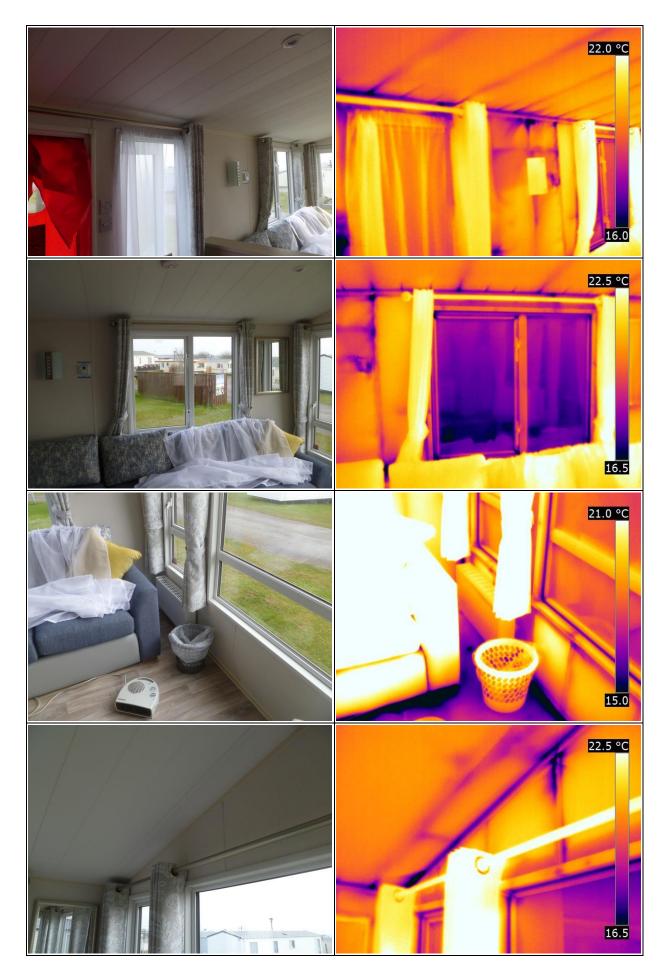
Pressurisation Test Results (depressurisation only):

	Air Permeability	Air Leakage Rate	Correlation coefficient
	m³/(h.m²) @ 50 Pa	ach-1	r ²
C05	5.23	8.37	0.999
C10	5.52	8.84	0.998

Images:

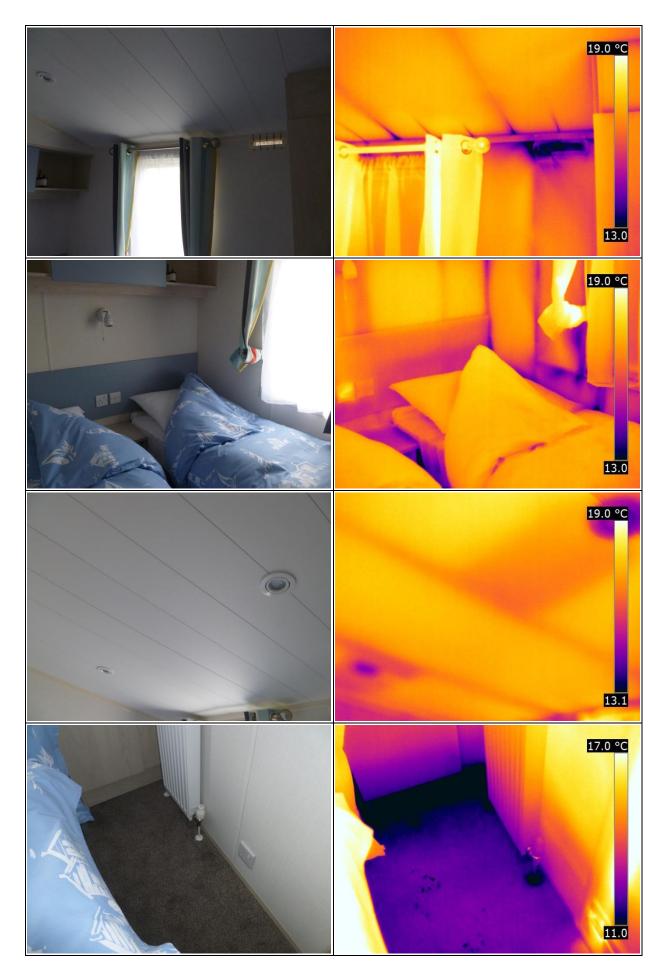


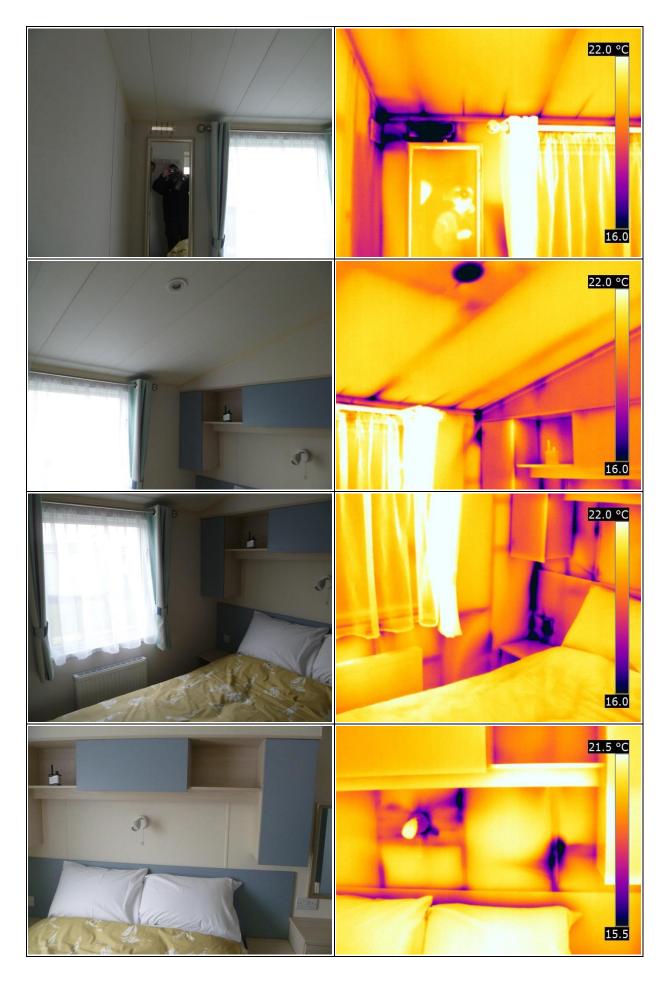




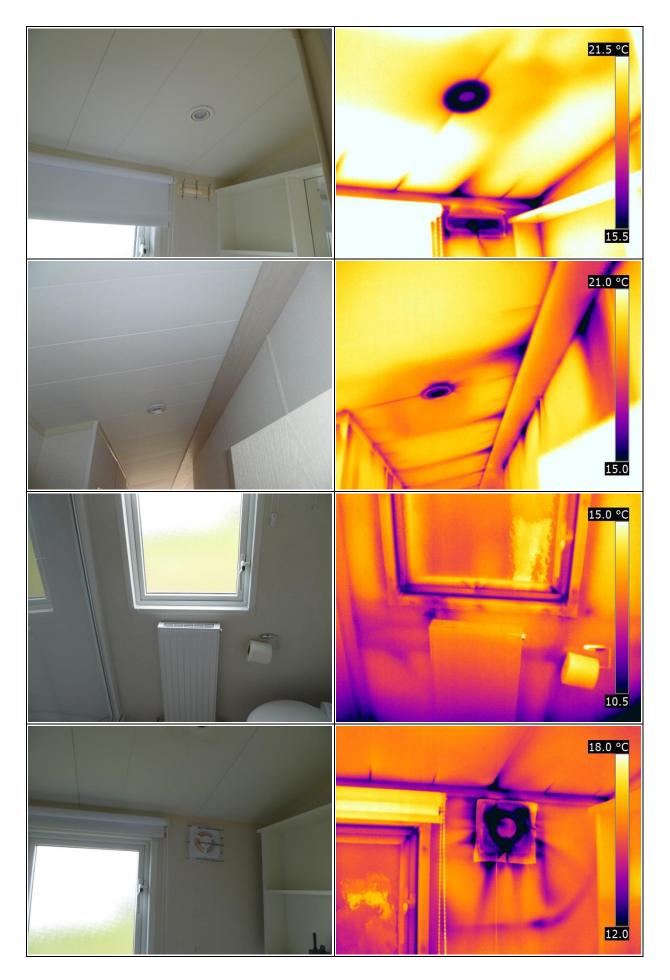


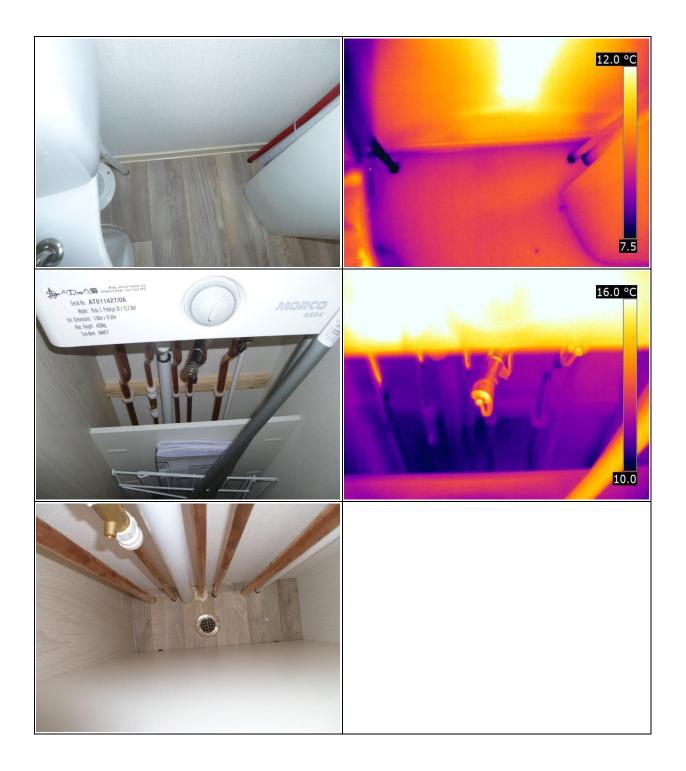
Leeds Sustainability Institute





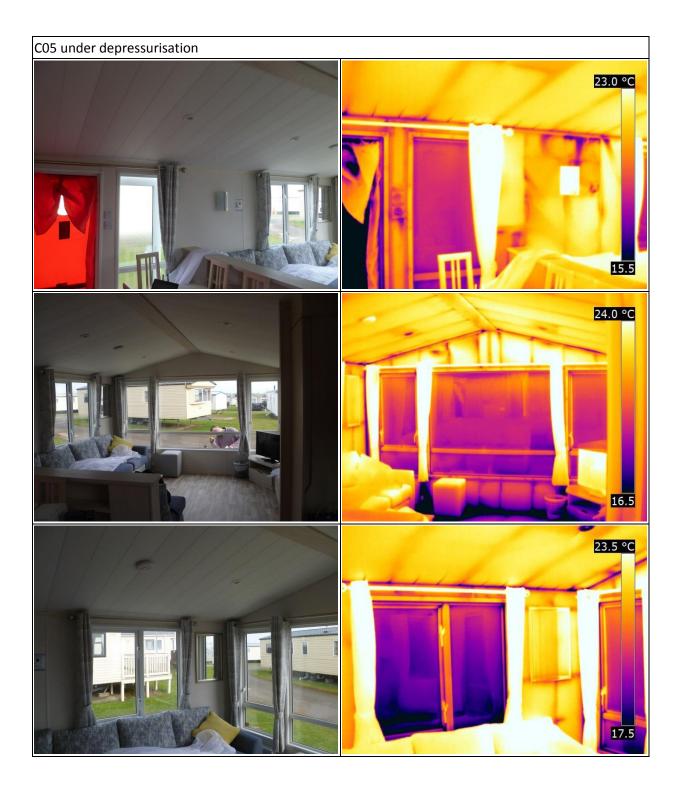








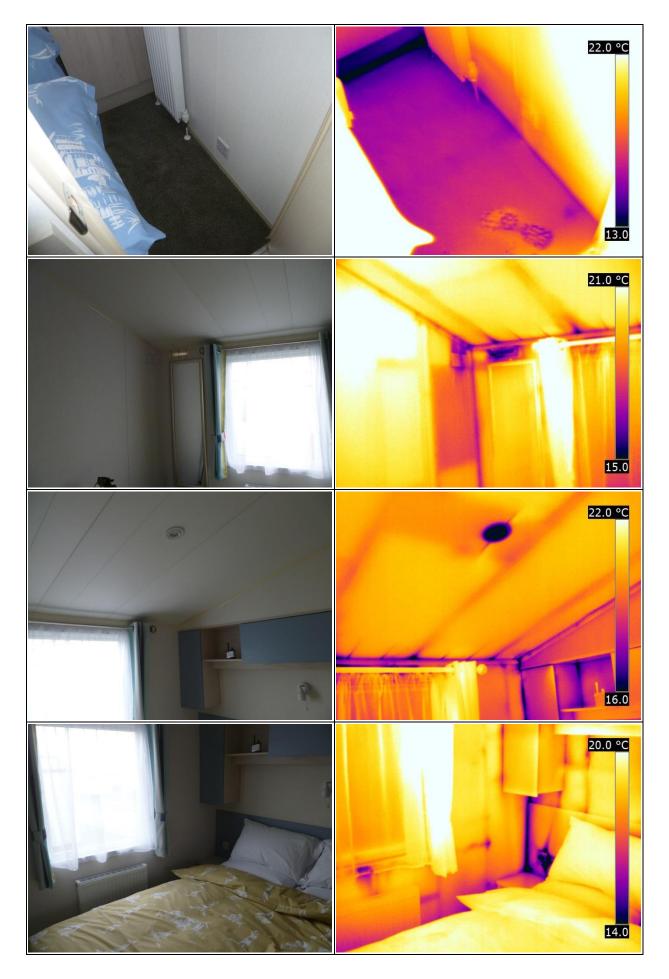




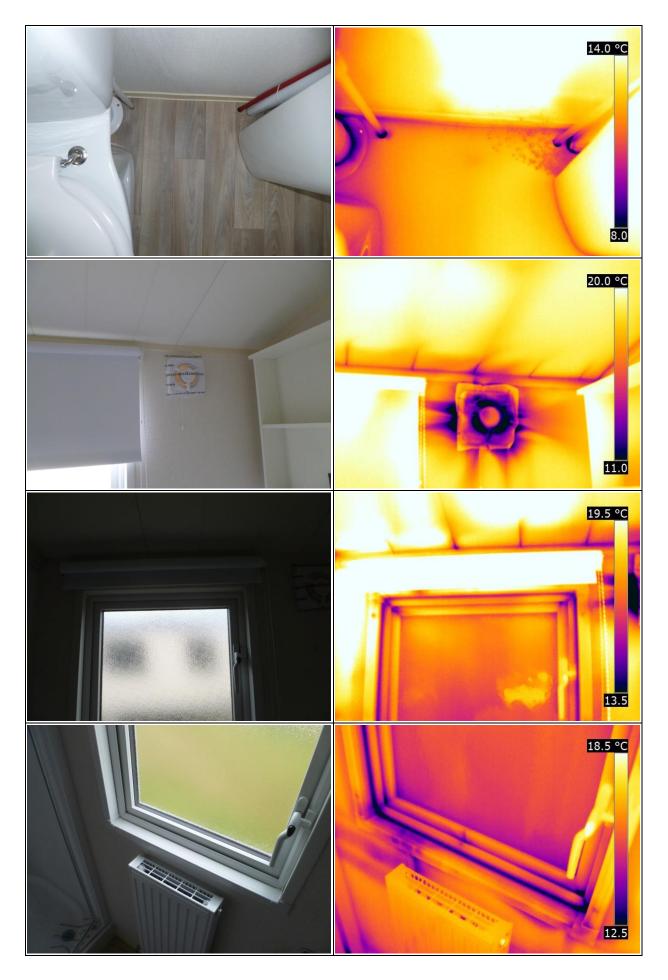






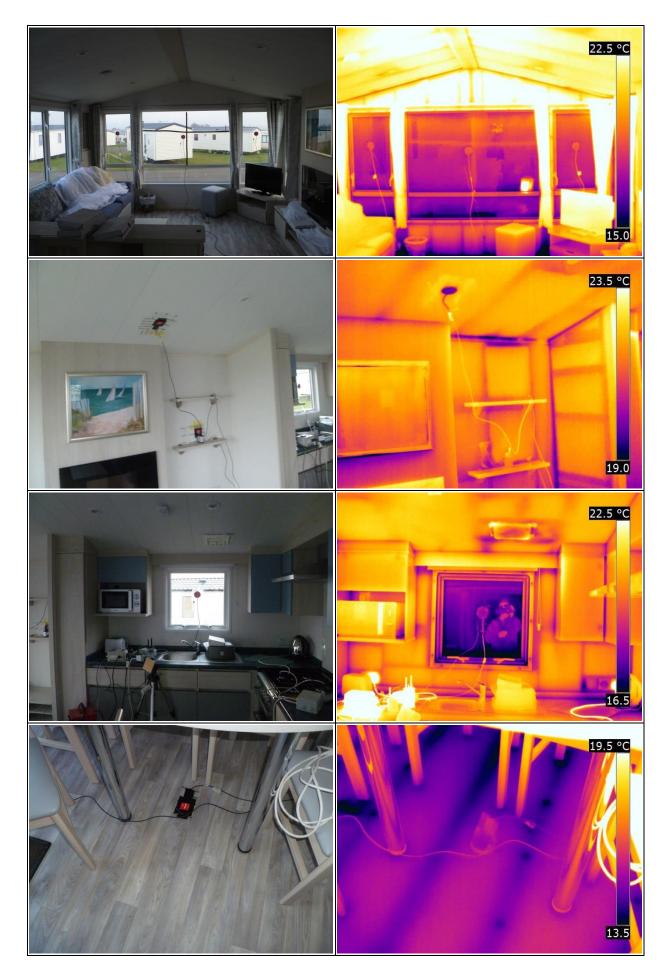














Appendix 3 - Images 18-Mar-2015



Leeds Sustainability Institute

- Camden Group: Site Visit Images 18-Mar-2015
- Researchers: Dominic Miles-Shenton, David Farmer

Site Address: C05 & C10, Holly Bank Blue Dolphin Holiday Park Filey North Yorkshire YO14 9PU

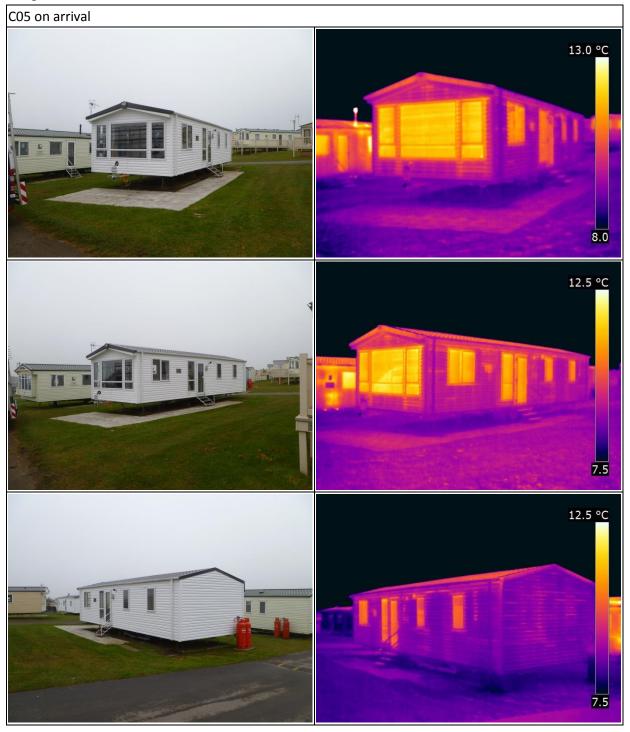
Pressurisation Test Result 18-Mar-2015 (depressurisation only):

	Air Permeability	Air Leakage Rate	Correlation coefficient
	m³/(h.m²) @ 50 Pa	ach ⁻¹	r ²
C05	5.73	9.17	0.999

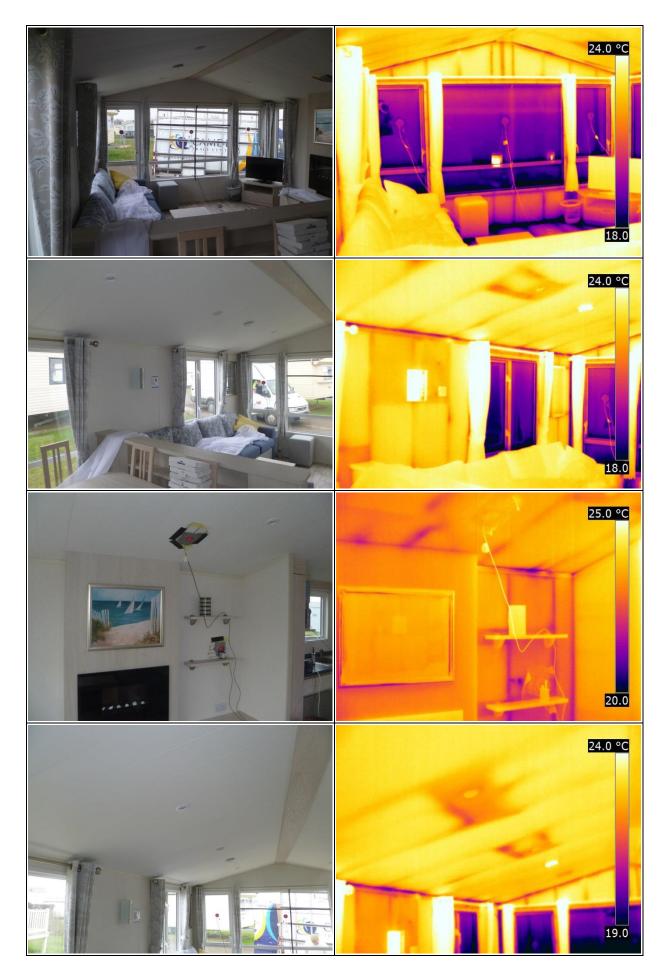
Previous pressurisation Test Results 16-Mar-2015 (depressurisation only):

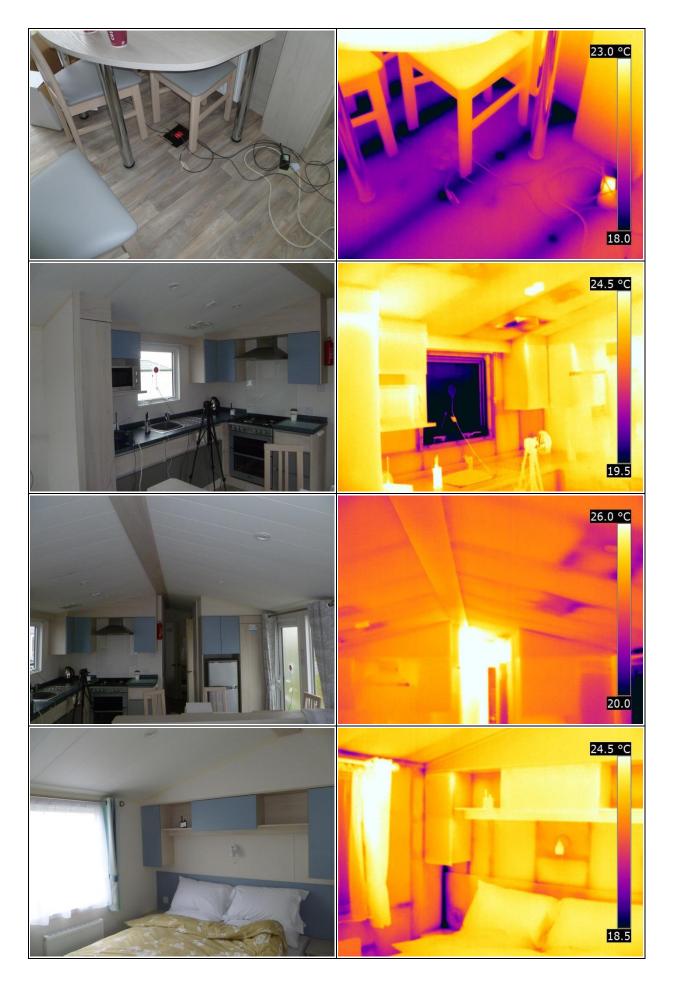
	Air Permeability	Air Leakage Rate	Correlation coefficient
	m³/(h.m²) @ 50 Pa	ach ⁻¹	r ²
C05	5.23	8.37	0.999
C10	5.52	8.84	0.998

Images:





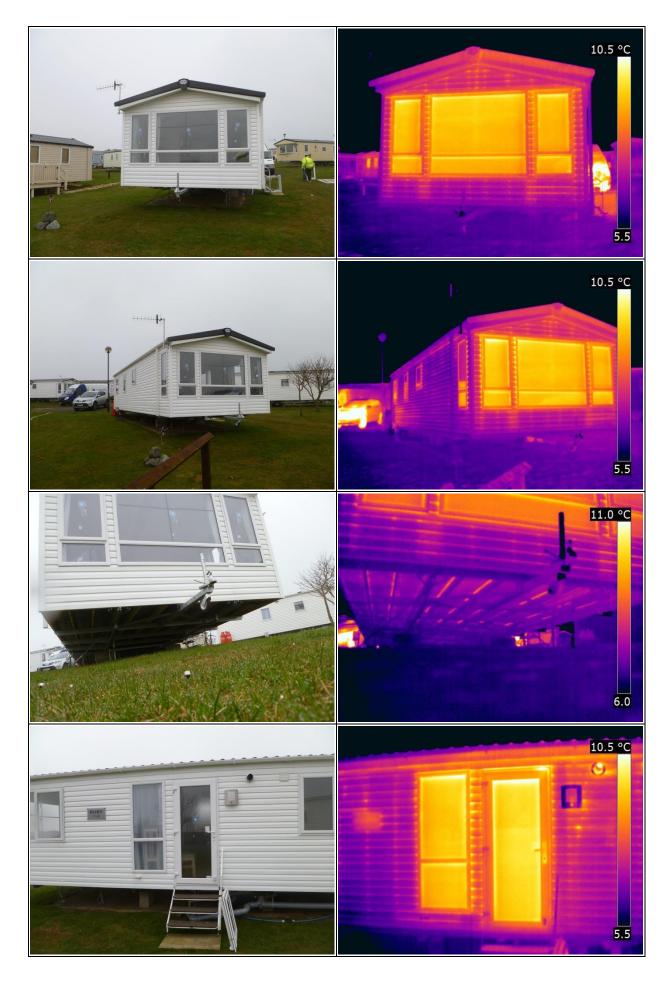


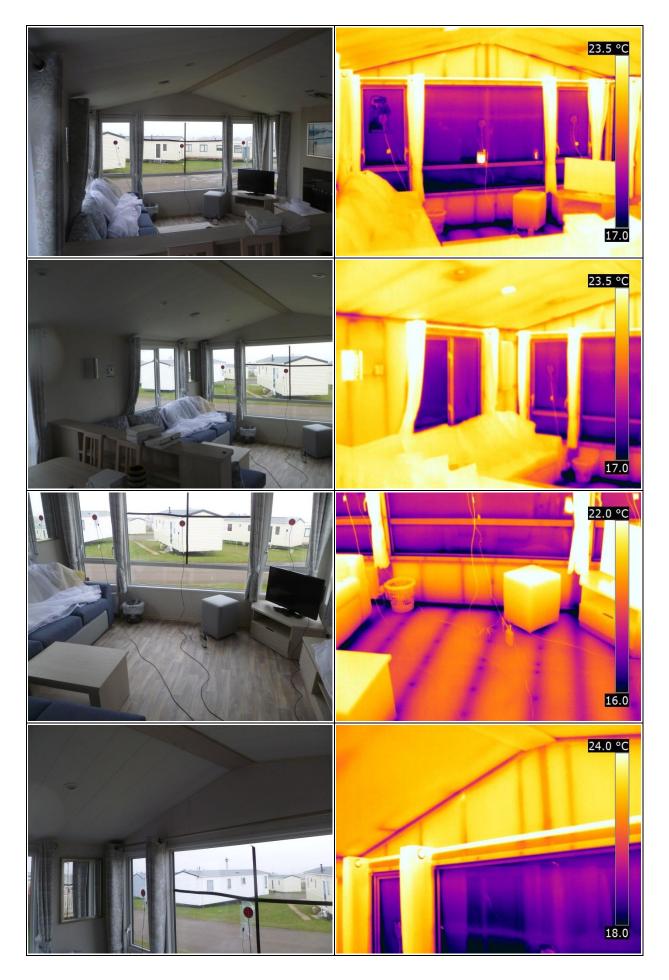


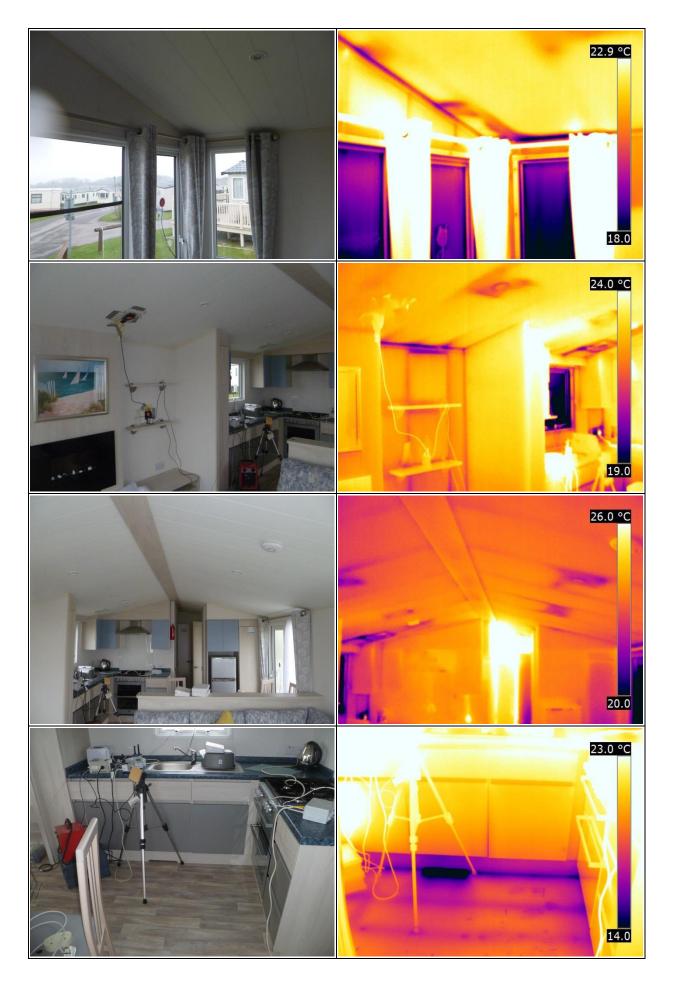






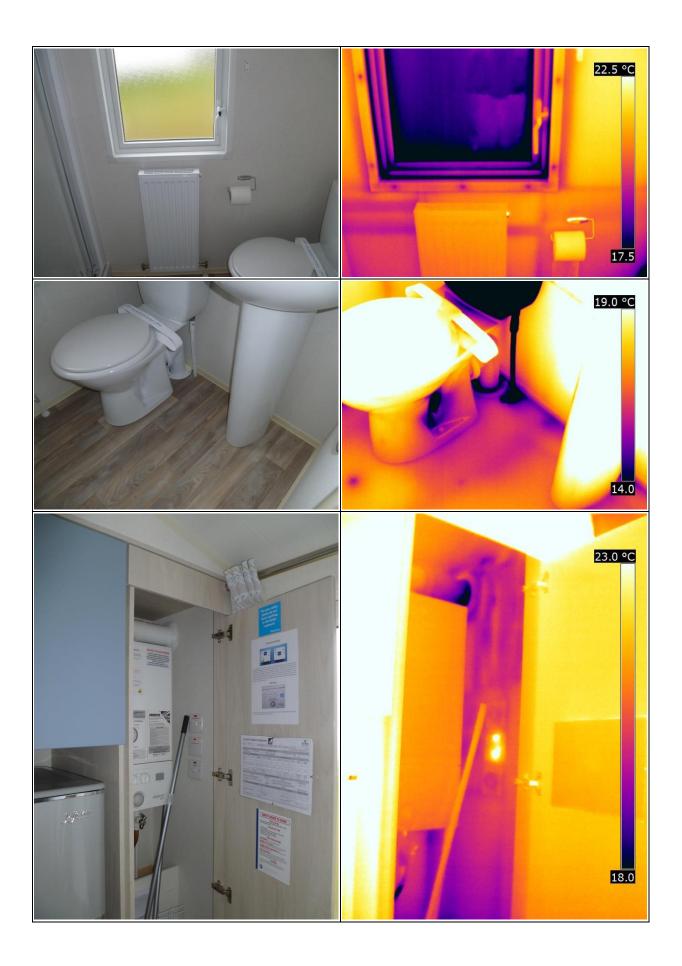




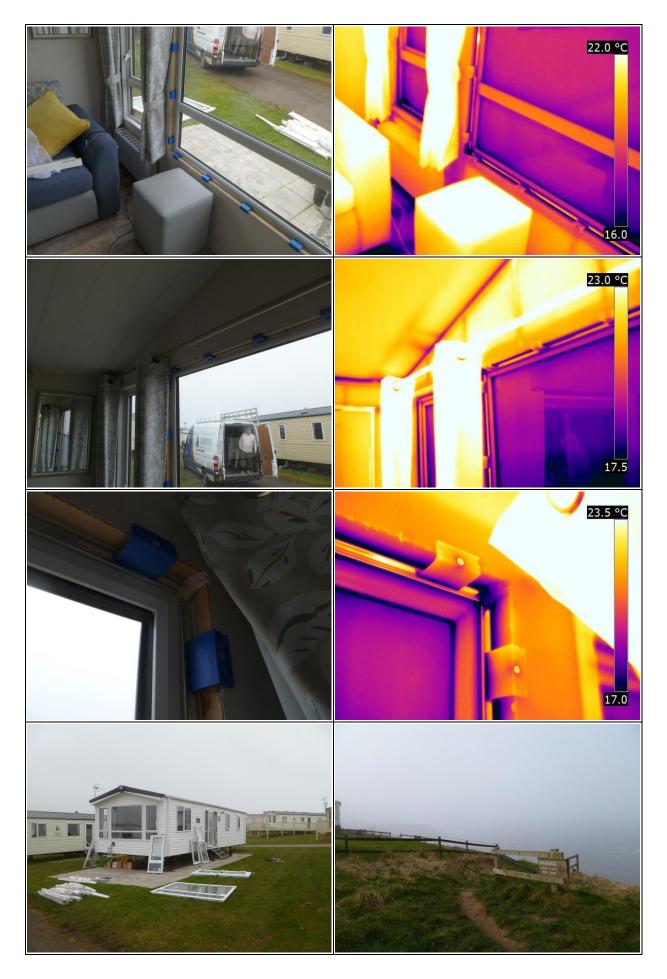


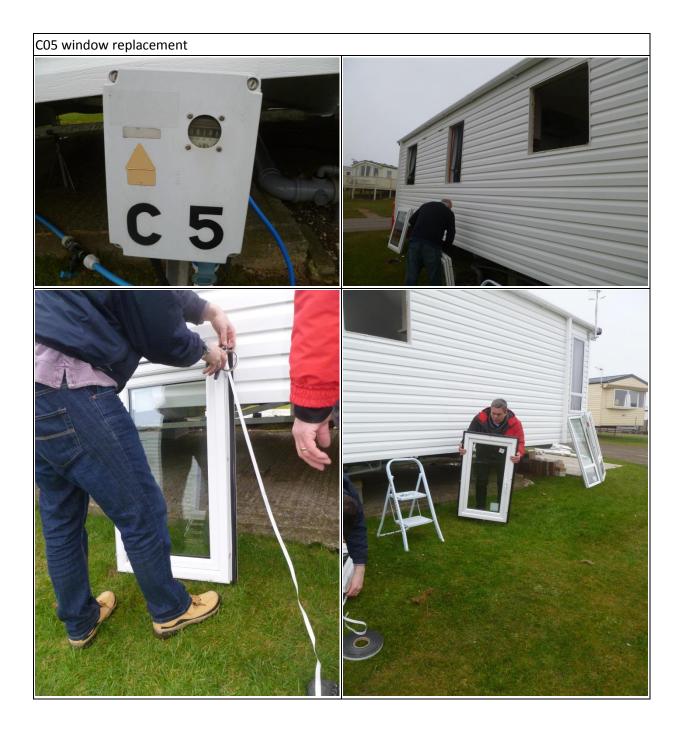






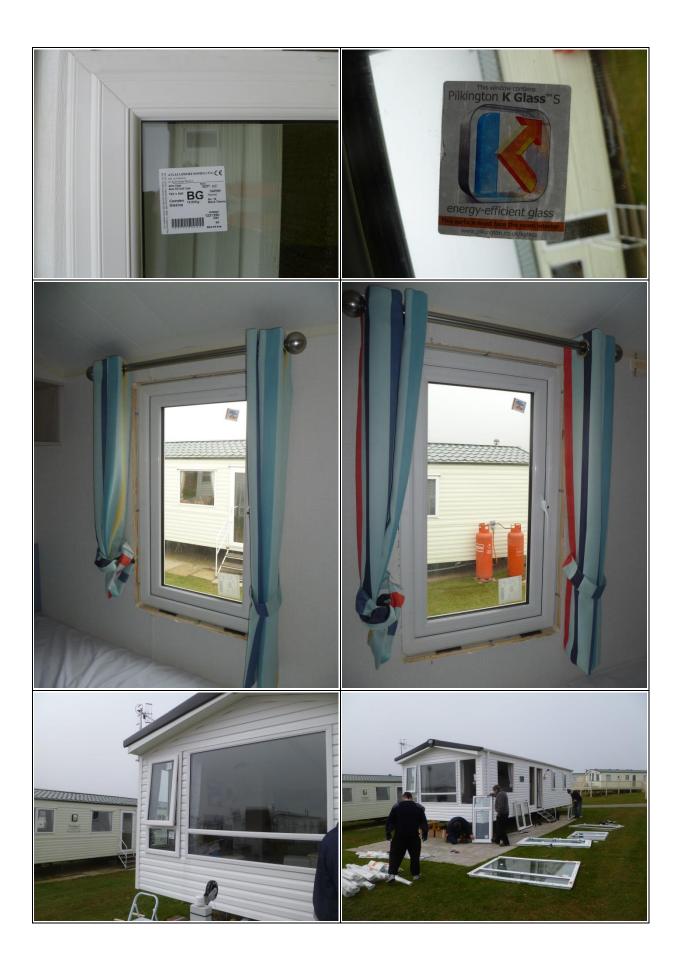






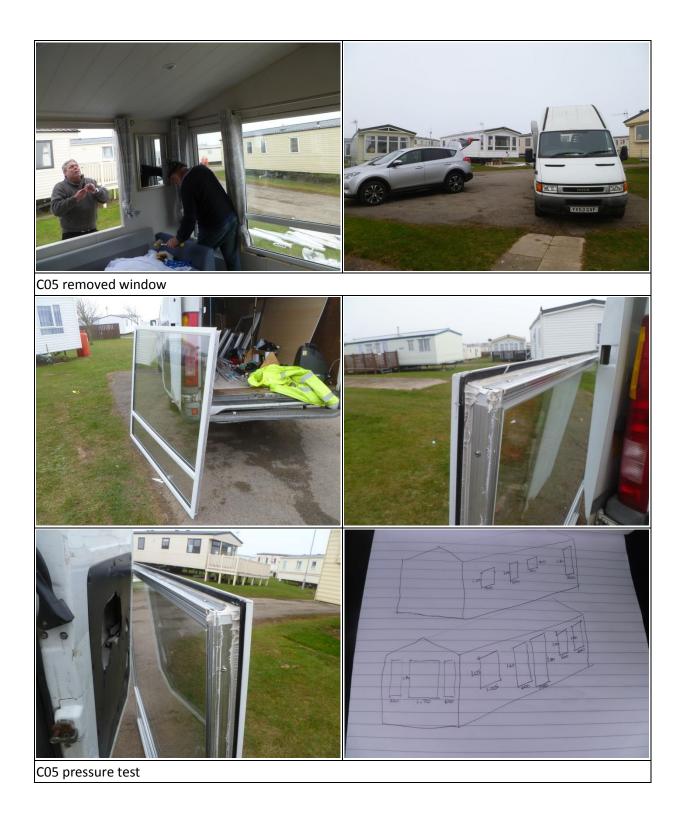
















Appendix 4 - Images 20-Mar-2015



Camden Group: Site Visit Images 20-Mar-2015

Researchers: Dominic Miles-Shenton, David Farmer, Prof. David Johnston

Site Address: C05 & C10, Holly Bank Blue Dolphin Holiday Park Filey North Yorkshire YO14 9PU

Pressurisation Test Result 20-Mar-2015 (depressurisation only):

	Air Permeability	Air Leakage Rate	Correlation coefficient
	m³/(h.m²) @ 50 Pa	ach ⁻¹	r ²
C05	5.54	8.88	0.999

Previous pressurisation Test Results (depressurisation only):

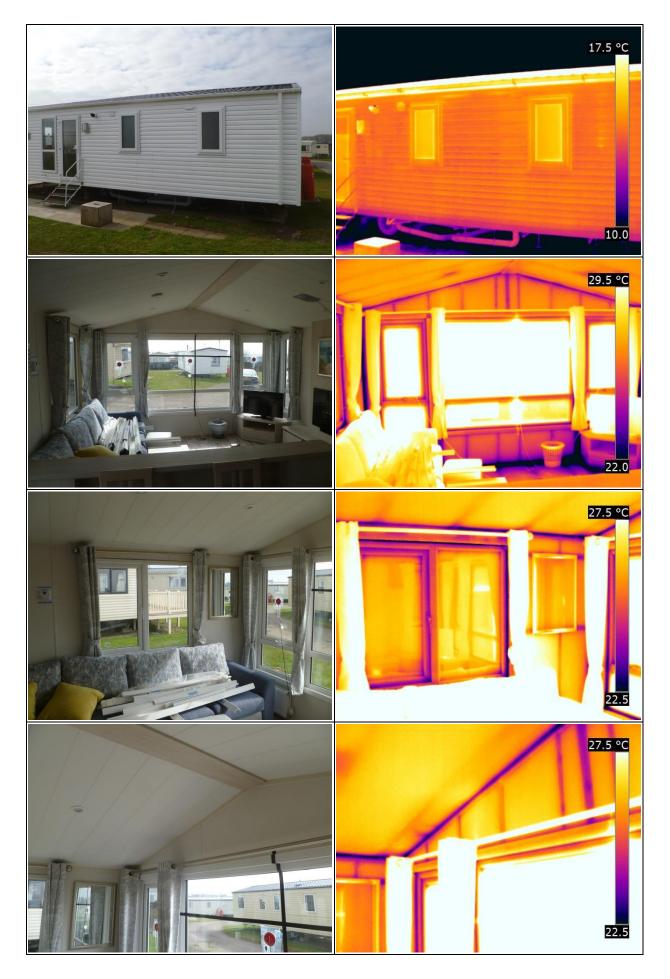
	Date	Air Permeability	Air Leakage Rate	Correlation coefficient
		m³/(h.m²) @ 50 Pa	ach-1	r ²
C05	16-Mar-2015	5.23	8.37	0.999
C05	18-Mar-2015	5.73	9.17	0.999
C10	16-Mar-2015	5.52	8.84	0.998



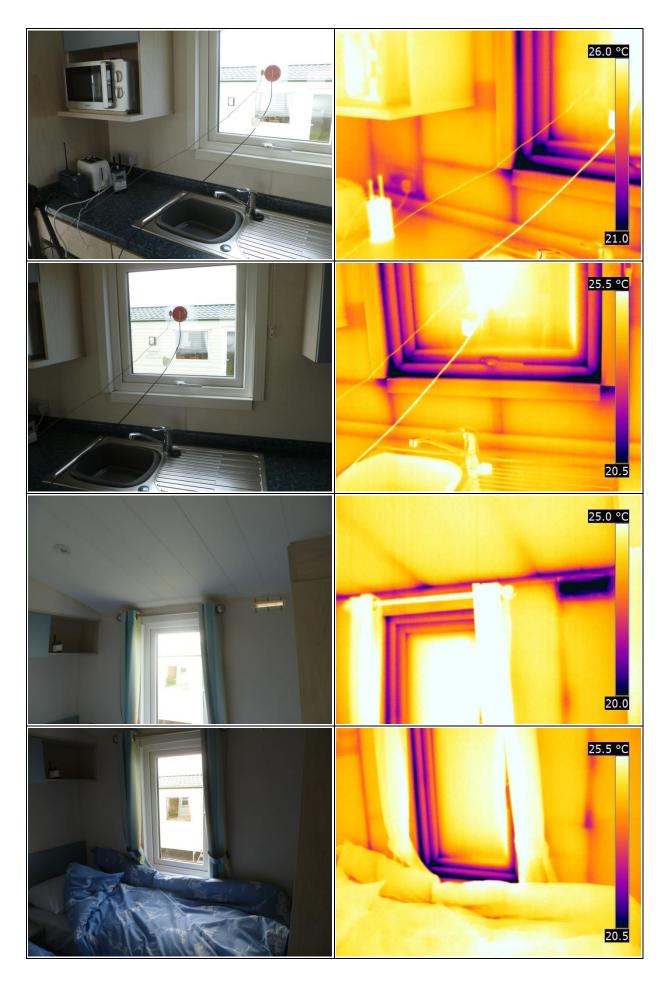
Direct comparison of the original door and a replacement window in C05:

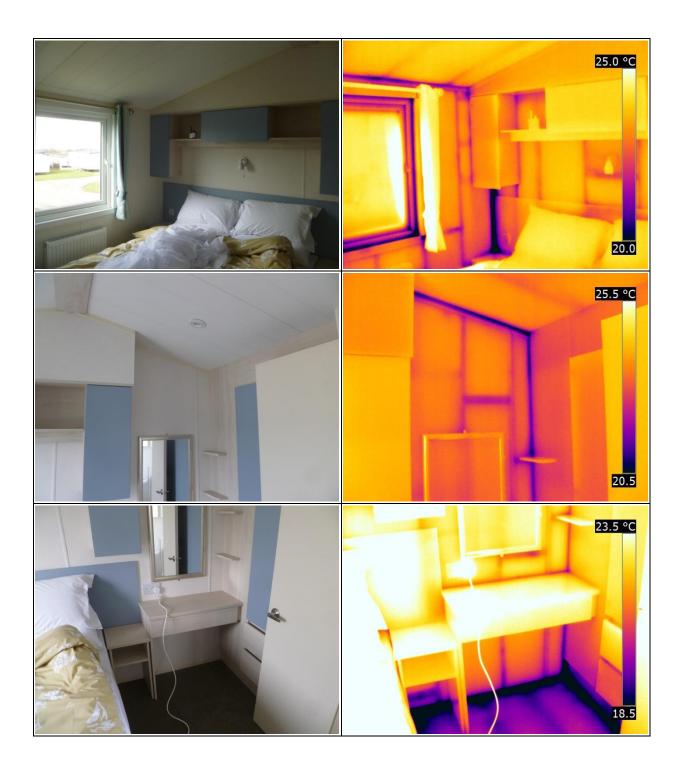
Images:





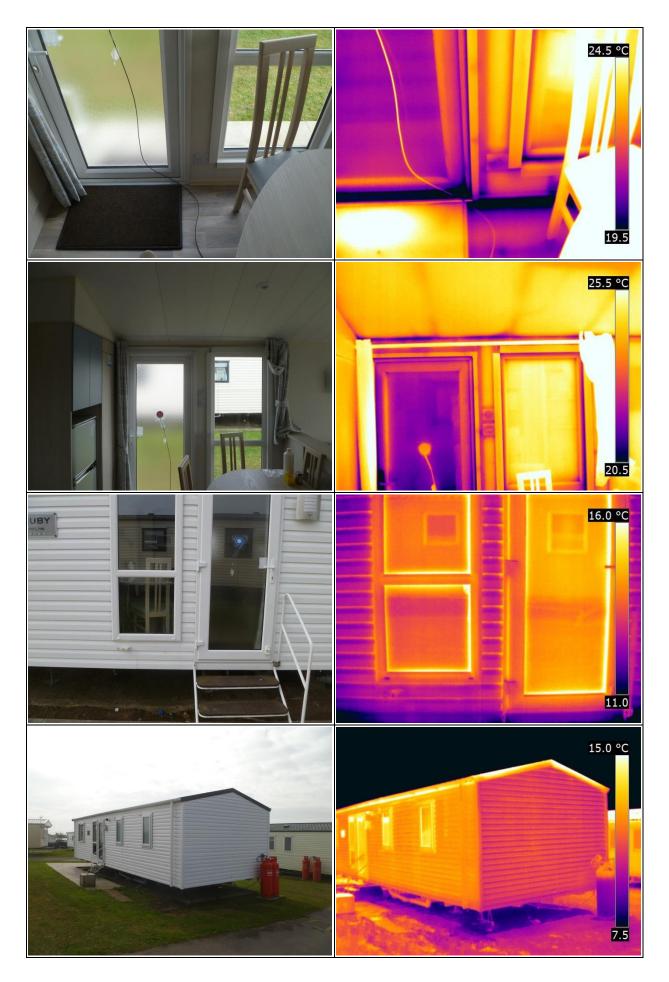




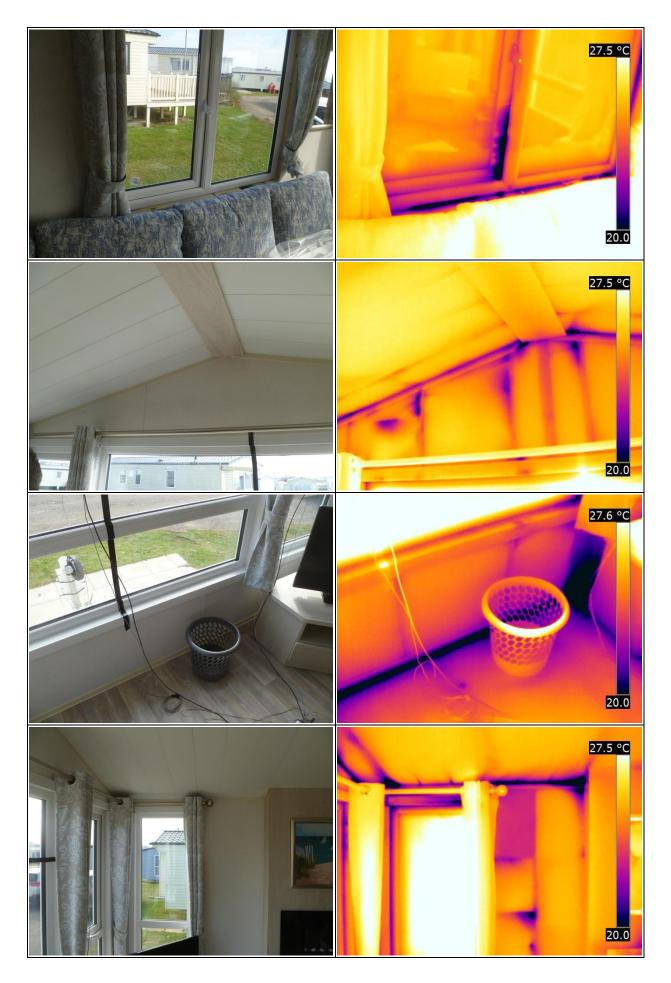


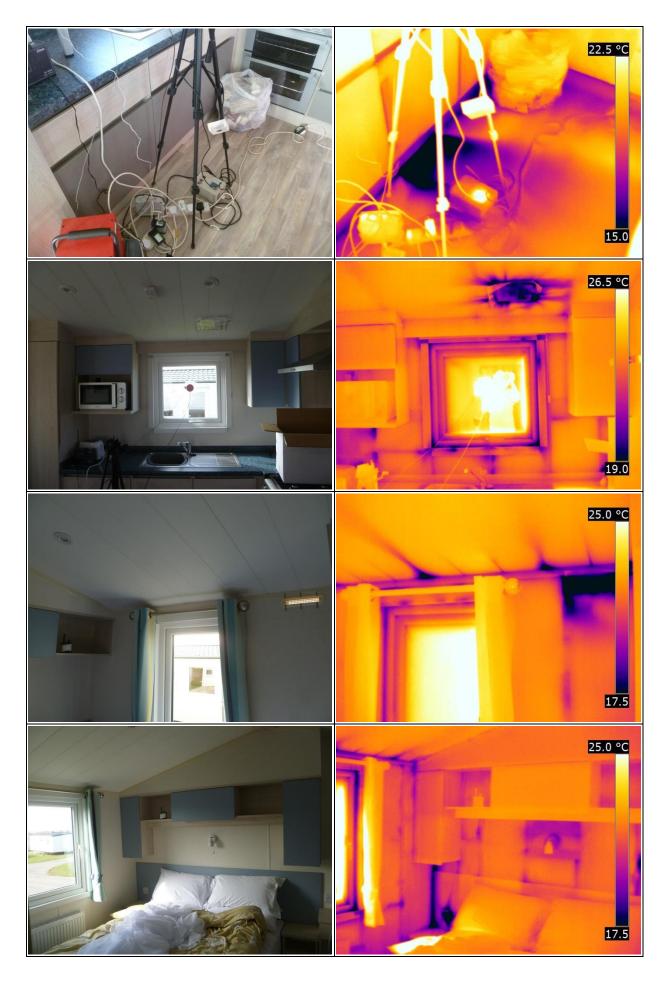




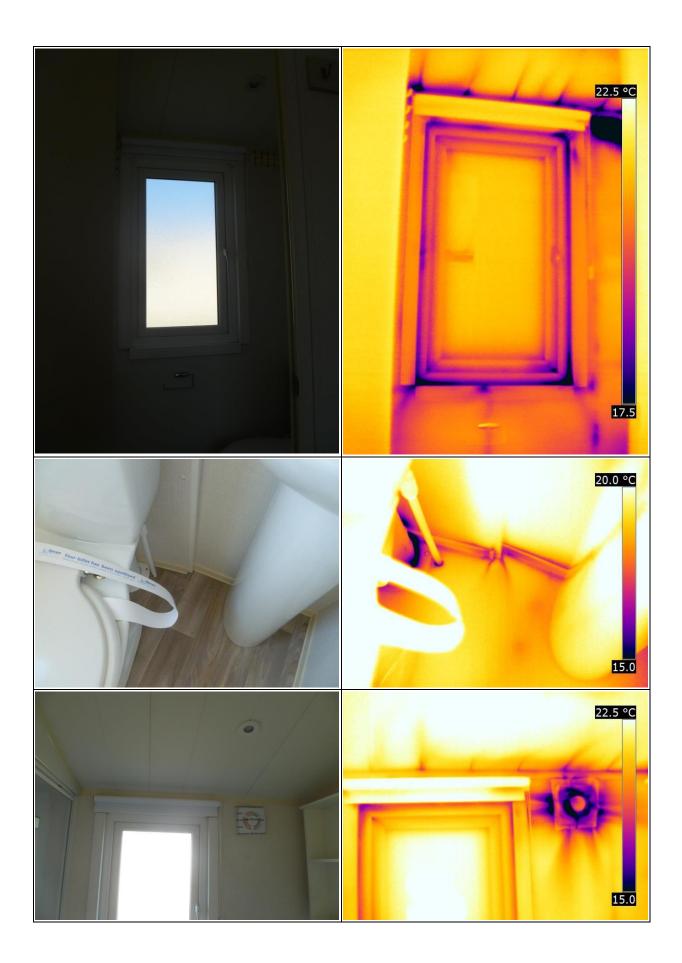
















C05 Door and mullion window replacement

