Innovate UK Innovation Voucher project – Oxypod® device test

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October 2015

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Introduction

1 This report presents the results of the *in situ* testing that was undertaken at the Salford Energy House on the Oxypod® device. The Oxypod® is an award winning deaerator device that is designed to improve the efficiency of wet central heating systems by removing the amount of dissolved air in the circulating hot water. The system works by pumping the circulating hot water from the central heating system down into the device. Due to the shape of the device, the velocity of the water flowing through the device increases whilst the pressure reduces, creating a vortex within the device. This results in the water imploding in on itself, which forces any entrapped air within the water to bubble up through the device and exit via the air vent at the top of the device.

2 It has been claimed that by the manufacturer of the device that the Oxypod® could save up to 30% per year on their central heating fuel bill by installing such a device (Oxypod, 2015). However, there is no published evidence available on a directly comparable test both pre- and post-installation of an Oxypod® to enable such claims to be substantiated. Given this, this project was undertaken to investigate whether such claims could be substantiated by undertaking a directly comparable test both with and without the Oxypod® device installed.

3 Testing of the Oxypod® device was undertaken for the Goodwin Development Trust as part of an Innovate UK Innovation Voucher. The tests were undertaken by the Centre for the Built Environment (CeBE) Group within the Leeds Sustainability Institute at Leeds Beckett University in collaboration with the University of Salford, Manchester.

Purpose of the test

4 The *in situ* testing was undertaken to compare, under controlled conditions, the performance of a gas-fired condensing combination boiler, and the wet central heating system served by this boiler, both with and without the Oxypod® device installed.

5 All of the tests were undertaken at the Salford Energy House, at the University of Salford, Manchester. The Salford Energy House is a typical fully functional 1919 solid brick walled two bedroom two storey end-terrace dwelling that has been constructed within an environmental chamber. The house has been deliberately located within an environmental chamber, as this enables the climatic conditions surrounding the house to be controlled and monitored over a set period of time.

6 The Salford Energy House comprises a living room and kitchen/dining area on the ground floor, and has two bedrooms and a bathroom located on the first floor. The layout of the dwelling is illustrated in Figure 1. Further details regarding the Salford Energy House can be obtained from the following link: http://www.salford.ac.uk/built-environment/research/research-centres/applied-buildings-and-energy-research-group/energy-house.

7 The tests reported here were deliberately designed to be undertaken at the Salford Energy House with no occupancy. This environment was chosen as it enables a direct comparison to be made of between the performance of the gas-fired condensing combination boiler and the wet central heating system with the Oxypod® device installed and the performance of both of these systems with the Oxypod® device bypassed (effectively uninstalled). Such replication of the test conditions would not be possible to be achieved in the field, due to the natural variability of the external weather conditions and variations in occupant behaviour.

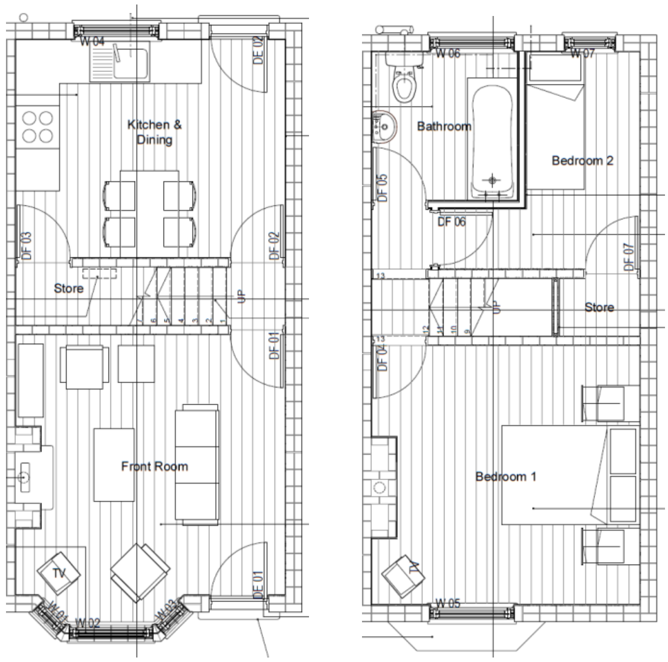


Figure 1 Layout of the Salford Energy House.

Details of the installed space heating system

8 Space heating within the Salford Energy House is provided via a 26kW Viessmann Vitodens 200-W B2B wall-mounted gas-fired modulating condensing combination boiler, which is located on the external wall in the kitchen (see Figure 2). The boiler feeds a conventional wet central heating system with six column radiators (see Figure 3). The radiators are located in the kitchen, hall, living room, bathroom, bedroom 1 and bedroom 2. The radiators are fed via two separate space heating circuits; one for the kitchen, hall and living room, and the second circuit for the bathroom, bedroom 2 and bedroom 1.

9 Control of the space heating system is provided via a wall-mounted Danfoss Link™ CC panel. The panel is located on the external wall in the kitchen (see Figure 4) and acts as an electronic programmer and thermostat. The panel is linked to six electronic living connect® TRV's located on the bottom corner of the wall-mounted radiators (see Figure 5). The TRV's enable the temperature in each room of the house to be controlled separately.

10 The Oxypod® was installed on the primary flow to the boiler (see Figure 6). A bypass loop was also installed on the boiler primary flow to enable the space heating circuit to be operated either with or without the Oxypod® device operating. The Oxypod® device was also installed in advance of any of the tests commencing to ensure that the hot water circulating in the system was identical.

Figure 2 Gas-fired condensing combination boiler.

Figure 3 Column radiator located in the kitchen.

Figure 4 Danfoss Link™ CC panel.

Figure 5 Danfoss electronic living connect® TRV.

Figure 6 Oxypod® device installed *in situ* on the primary flow to the boiler.

Test method

11 Testing of the Oxypod® device was separated into three distinct stages. These were as follows:

a) **Stage 1 (Preliminary test) –** A preliminary test on the space heating system was undertaken following the installation of the Oxypod® device to ensure that the bypass loop was operational and that no significant drop in pressure was experienced in the wet central heating system as a consequence of the de-aeration process. If a significant drop in pressure in the wet central heating system had been experienced, then it is likely that the boiler would have automatically switched off, nullifying the test period. During this preliminary test, the chamber surrounding the Salford Energy House was maintained at ~3°C and the existing wet central heating system was programmed to run continuously for 24 hours from 12:00 on 10th September 2015 until 11:59 on the 11th September 2015. Although the space heating system within the Energy House can be controlled via the wall-mounted Danfoss Link™ CC panel, this was not used during any of the test periods. Instead, temperature control was achieved by manually adjusting each of the TRV's. In the living room, the head of the electronic TRV was adjusted to maintain a living room temperature of ~21°C, whilst all of the heads on the electronic TRV's in the remaining rooms were manually adjusted to maintain a room temperature of ~18°C. The bypass loop was also activated during this test period, enabling the water from the wet central heating system to pass through the Oxypod® device. Following the preliminary test run, the space heating system was programmed to switch off and the dwelling was left to cool down naturally for a period of 12 hours (until 23:59 on the 11th September 2015). A cool down period of 12 hours was chosen as it was deemed to be sufficiently long enough to enable the thermal mass within the Energy House to discharge. This was based upon previous experiments conducted within the Energy House. During this cool down period, the de-aerated water within the wet central heating system was drained off and the system refilled with fresh naturally aerated water.

b) **Stage 2 (Test period 1) –** This test was undertaken to determine the performance of the existing wet central heating as installed, with the Oxypod® device bypassed. During this test, the bypass loop was closed (Oxypod® not operating) and no adjustments were made to any of the electronic TRV's or to the chamber temperature surrounding the Energy House. The wet central heating system was programmed to run continuously for 24 hours from 00:00 on the 11th September to 23:59 on the 12th September 2015. Following this test, the dwelling was left to cool down naturally for 12 hours (until 11:59 on the 13th September 2015). The same length of cool down time period was used prior to the commencement of tests 1 and test 2 to ensure that the chamber and house temperatures were comparable when each test commenced.

c) **Stage 3 (Test period 2) –** This test was undertaken to determine the performance of the existing wet central heating with the Oxypod® device installed and operational. During this test, the Oxypod® device was activated via the bypass loop and the same process identified within Test 1 was repeated.

12 The following parameters were measured during each of the test stages:

a) Internal air temperature in the kitchen, hall, living room, bedroom 1, bedroom 2 and bathroom.

b) Globe temperature in the kitchen, living room, bedroom 1, bedroom 2 and bathroom.

c) Environmental chamber air temperature.

d) Surface temperature at the geometric centre of each of the six radiators.

e) Total heat output from each of the six radiators.

f) Total heat output from the boiler.

g) Total gas consumption of the boiler.

h) Flow and return temperatures to the boiler.

i) Flow and return temperatures for each radiator.

j) Flow rate to the boiler.

k) Flow rate from each radiator.

13 Data was recorded over the period 00:00 on the 11th September to 23:59 on the 14th September 2015. All of the parameters were logged at one minute intervals.

Internal room and external chamber air temperatures

14 The internal room air temperatures measured over each of the test periods are illustrated in Figure 7. It can be seen from Figure 6, that there is a high degree of consistency in the internal air temperatures measured in each room between test period 1 and test period 2, with the exception of bedroom 2. Closer analysis and comparison of the data on a room-by-room basis for each test period confirms that this is the case (see Figure 8 to Figure 13 and Table 1).

	Mean internal room air temperature (°C)	
	Test period 1	**Test period 2**
Living room	21.5	21.5
Hall	17.5	17.5
Kitchen	17.4	17.4
Bedroom 1	17.5	17.5
Bathroom	17.7	17.0
Bedroom 2	17.8	17.7

Table 1 Mean internal room air temperatures over the test periods.

15 In terms of bedroom 2, analysis of the data indicates a mean internal air room temperature difference of ~0.8°C between test period 1 and test period 2 (see Figure 13). Unfortunately, it was only once the tests were complete, that this difference in air temperature was discovered. Thermal images of the radiator undertaken after completion of the tests with the space heating system switched back on revealed an uneven surface temperature distribution within the column radiator, with the bottom of the radiator being almost 30°C warmer than the top of the radiator (see Figure 14). Investigations revealed that this difference in temperature was caused by an air pocket which had lodged in the top of the radiator. Once the radiator had been bled, the surface temperature of the radiator increased and the heat became more evenly distributed (see Figure 15). The reason for the existence of the air pocket within the radiator during test period 2 is thought to have been caused by a 'microleak' through a loose radiator bleed valve supporting nut that was observed on the end of the radiator. Unfortunately, the reasons why the air entered the radiator in test period 2 rather than in test period 1, is not known and could not be established using the non-destructive testing methods available to the research team during the testing periods. The microleak appeared to occur between the first and second hours of test period 2. As the Oxypod was the only variable that had altered between the two test periods, it suggests that the process of deaeration may be responsible, possibly due to the reduction in pressure in the system.

16 The impact that the slightly lower air temperature recorded in bedroom 2 has had on the comparability of the two test periods is likely to be minimal for four reasons. First of all, the difference in the air temperature measured between each test period is small (average of ~0.8°C). Secondly, bedroom 2 represents only a small proportion of the overall dwelling floor area and volume, therefore any difference in air temperature experienced within this room will have minimal impact on the air temperatures experienced throughout the rest of the dwelling. Thirdly, as all of the internal doors were open during both test periods, there will have been some movement of air between the rooms which will have reduced the impact that the slightly lower surface temperature of the radiator in bedroom 2 will have had on the test. Finally, although there was air within the radiator during test period 2, the top of the radiator was still able to obtain a surface temperature of ~39°C during the test, so heat will still have been provided to this room.

17 To investigate whether the small difference in the internal air temperature measured within bedroom 2 during test period 2 is likely to be important, the internal room air temperature data has also been used to devise a simple arithmetic mean internal air temperature for the dwelling. This data reveals very little difference (mean of 0.12°C over the entire test period) between the mean internal air temperatures experienced during each test period (see Figure 16). If the temperature data is used to produce a floor area weighted mean internal air temperature for each test period, then the difference reduces event further (mean of 0.05°C over the entire test period).

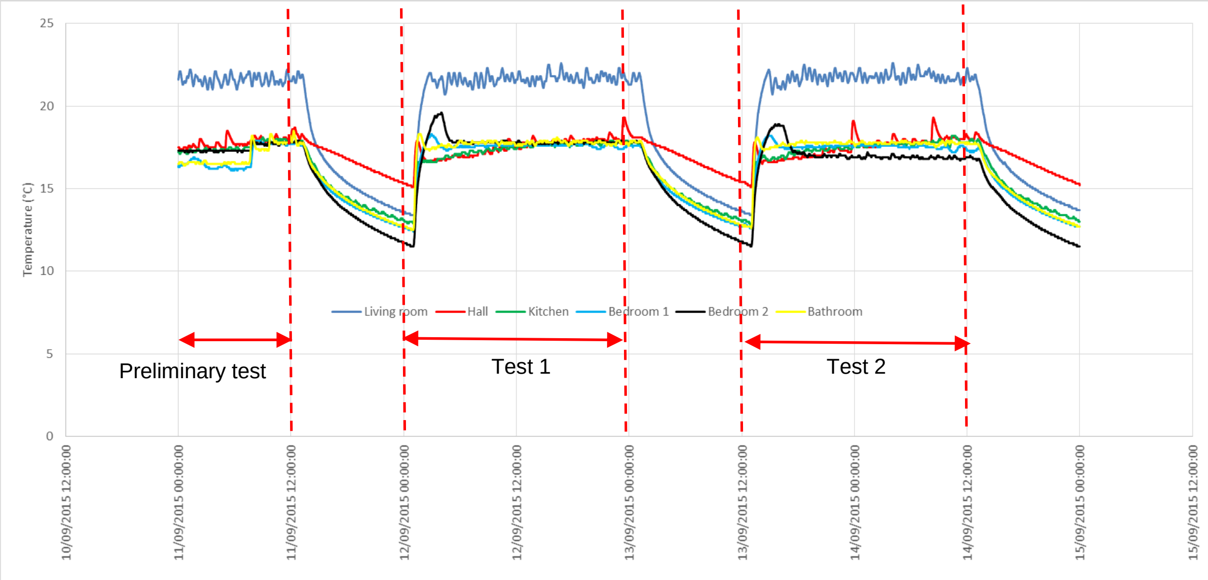


Figure 7 Internal room air temperatures during the entire testing period.

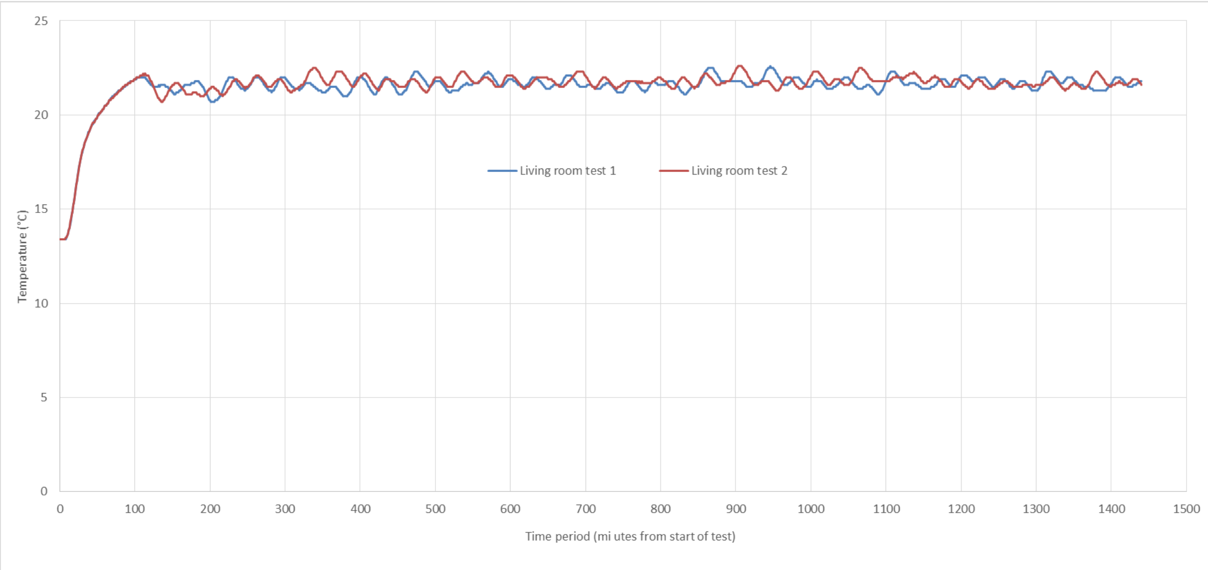


Figure 8 Living room air temperatures during test period 1 and 2.

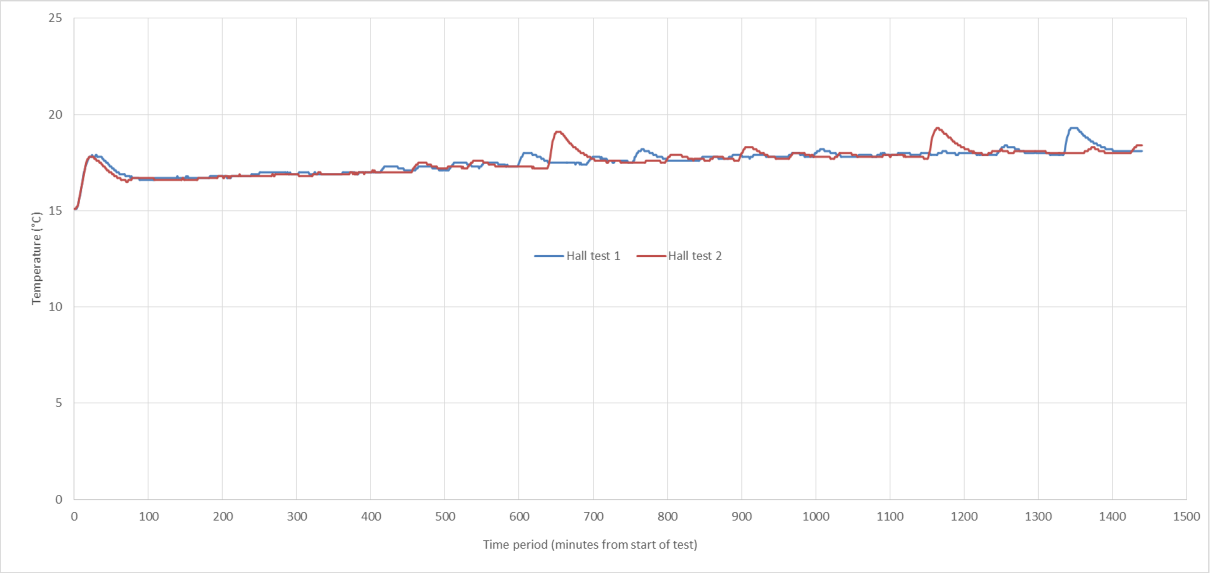


Figure 9 Hall air temperatures during test period 1 and 2.

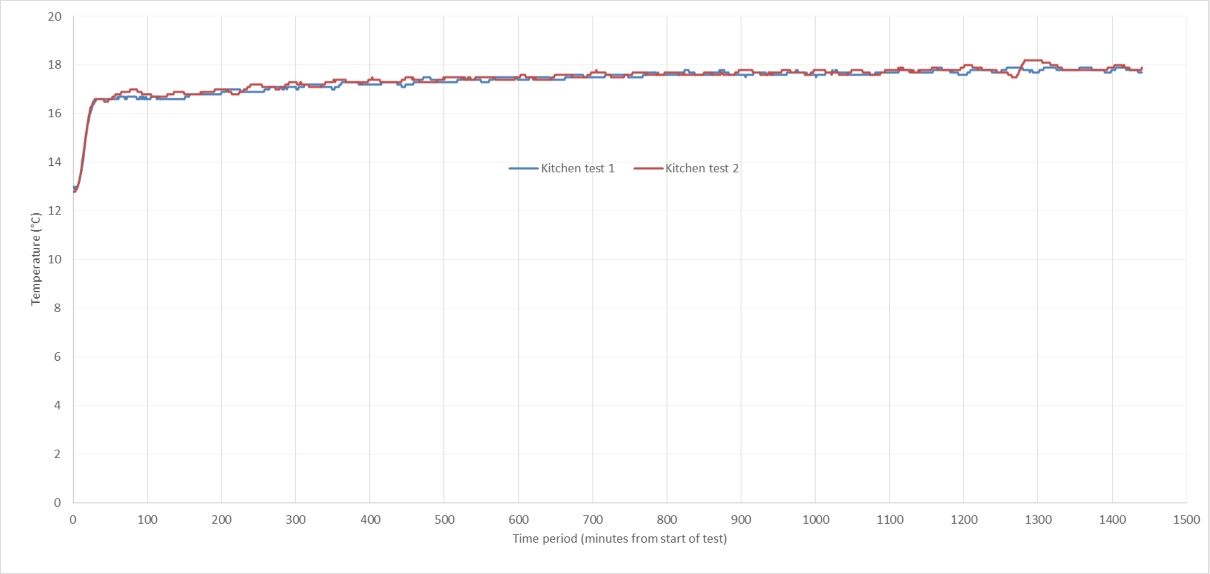


Figure 10 Kitchen air temperatures during test period 1 and 2.

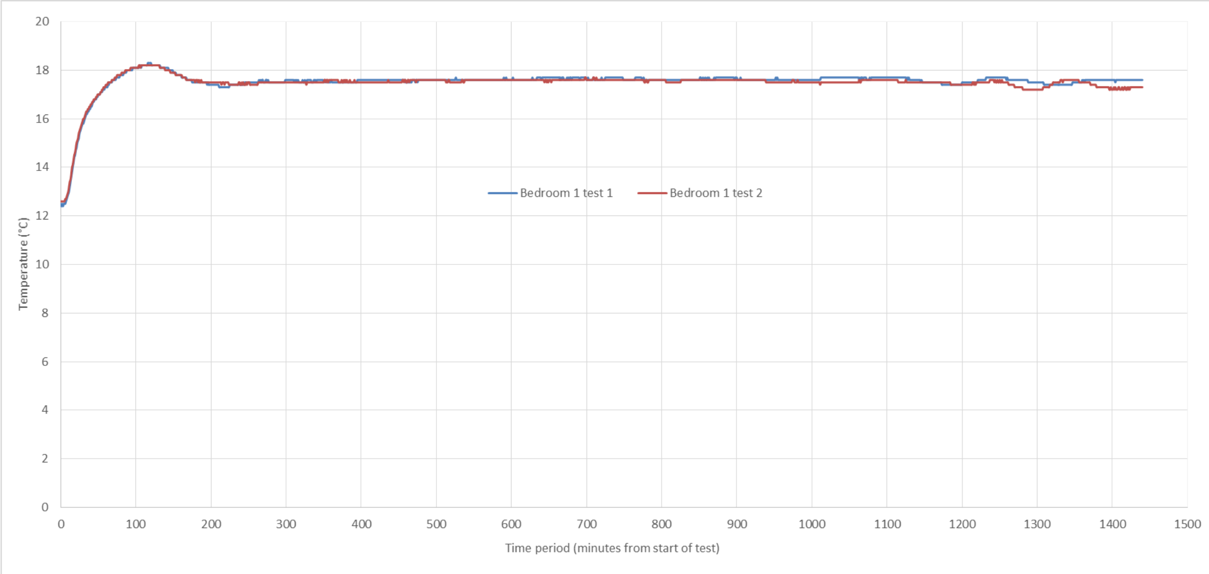


Figure 11 Bedroom 1 air temperatures during test period 1 and 2.

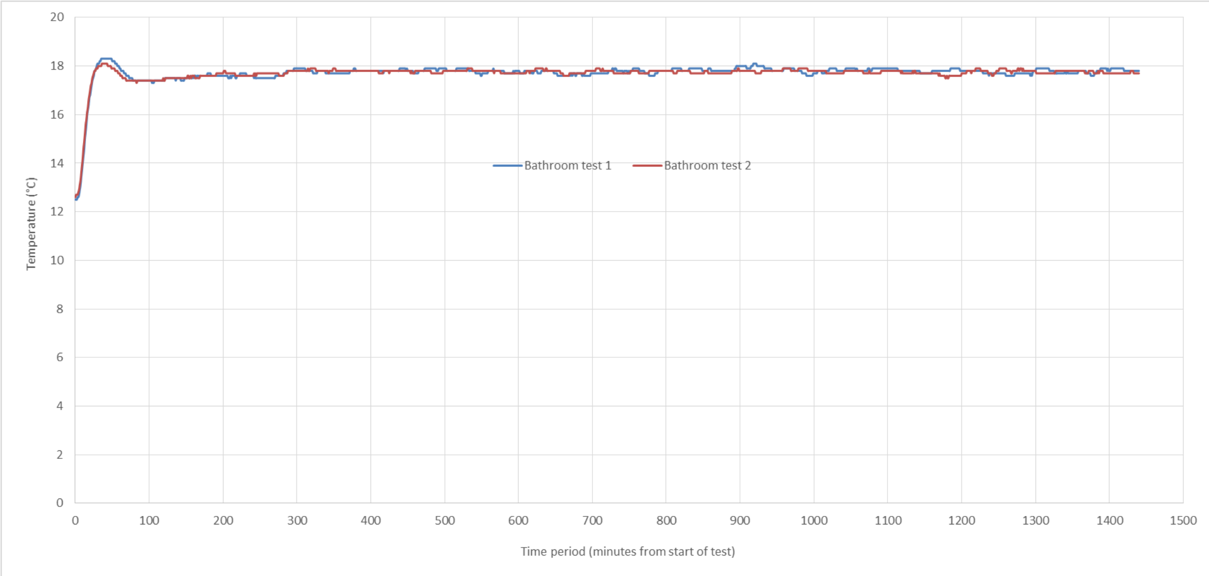


Figure 12 Bathroom air temperatures during test period 1 and 2.

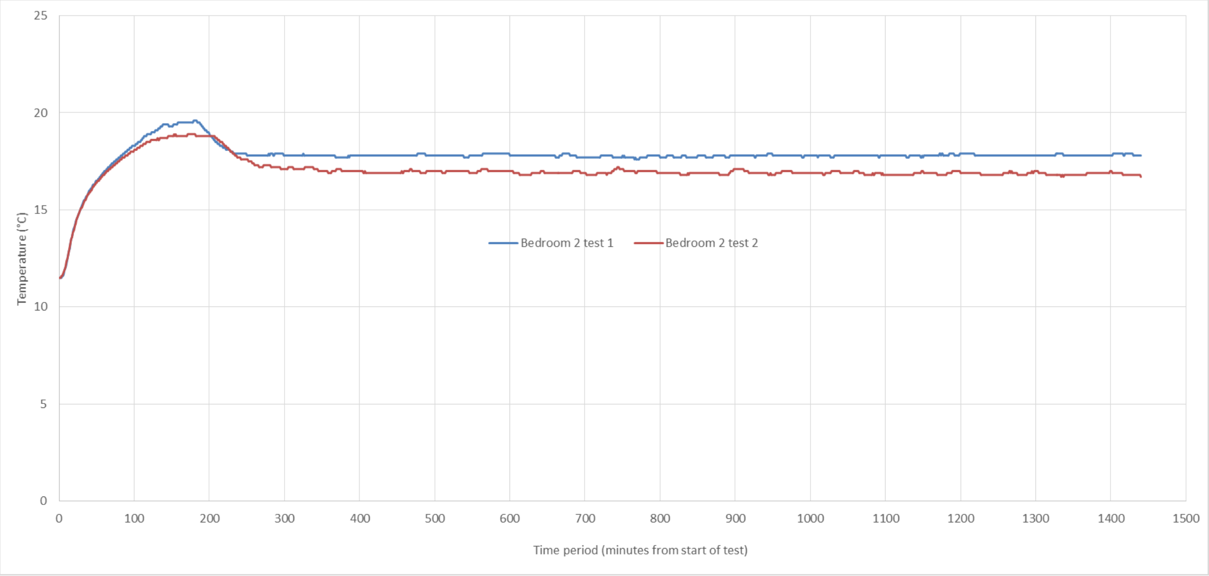


Figure 13 Bedroom 2 air temperatures during test period 1 and 2.

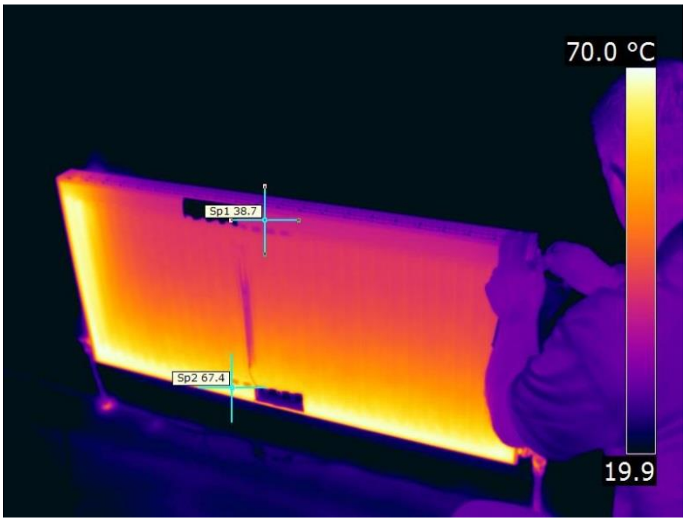


Figure 14 Thermal image of bedroom 2 radiator post testing.

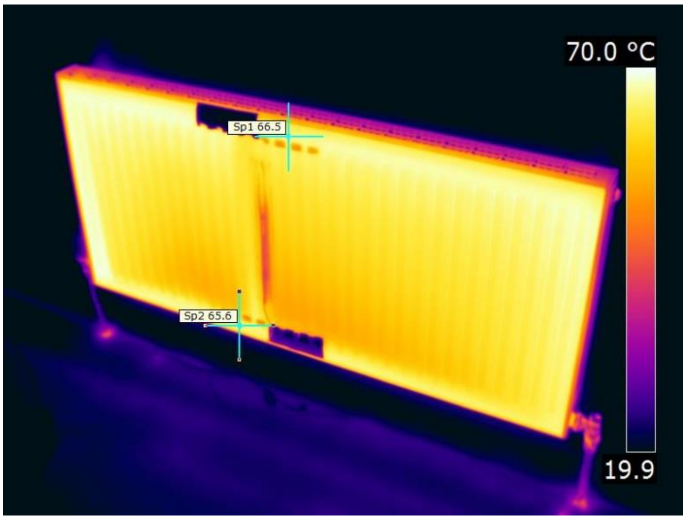


Figure 15 Thermal image of bedroom 2 radiator once bled post testing.

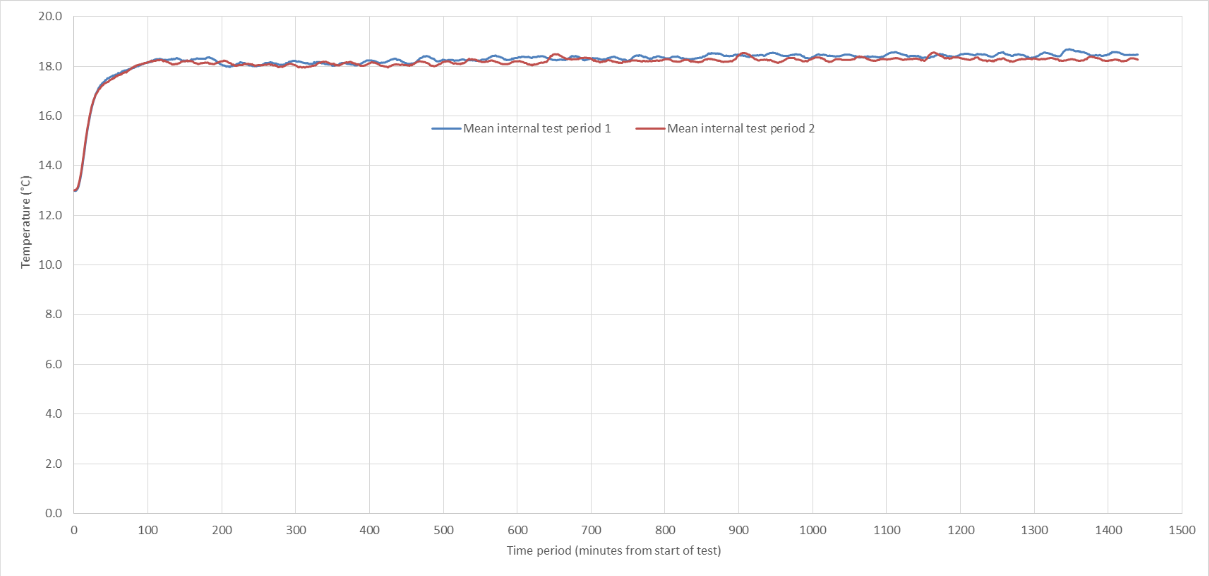


Figure 16 Mean internal air temperature (simple arithmetic mean) during test period 1 and 2.

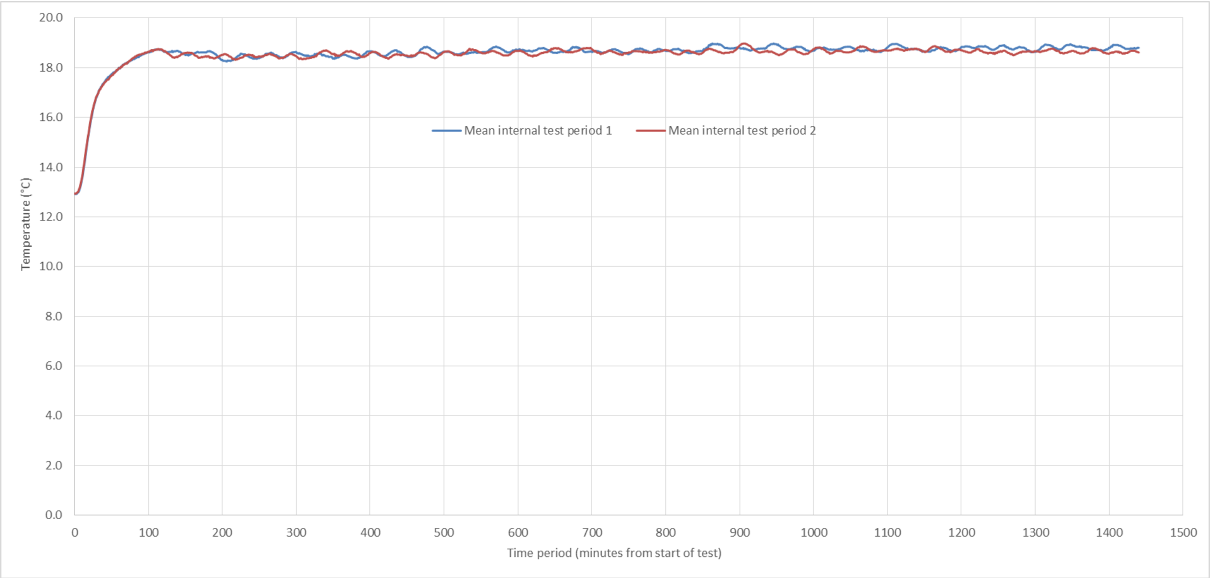


Figure 17 Mean internal air temperature (floor area weighted) during test period 1 and 2.

18 With respect to the external chamber, the air temperatures measured over both test periods are illustrated in Figure 18. It can be seen that there is a high degree of consistency in the chamber air temperatures measured between test period 1 and test period 2. Closer analysis and comparison of the data on a temperature measurement location-by-location basis confirms that this is the case (see Figure 19, Figure 20, Figure 21 and Table 2). In addition, if the three separate chamber air temperatures are used to produce a simple arithmetic mean chamber air temperature for each test period and the results compared (see **Figure 22**), there is very little difference in the air temperatures measured between each test period.

	Mean air temperature (°C)	
	Test period 1	**Test period 2**
Front	3.5	3.5
Gable	2.8	2.8
Rear	2.5	2.5

Table 2 Mean external chamber air temperature over the test periods.

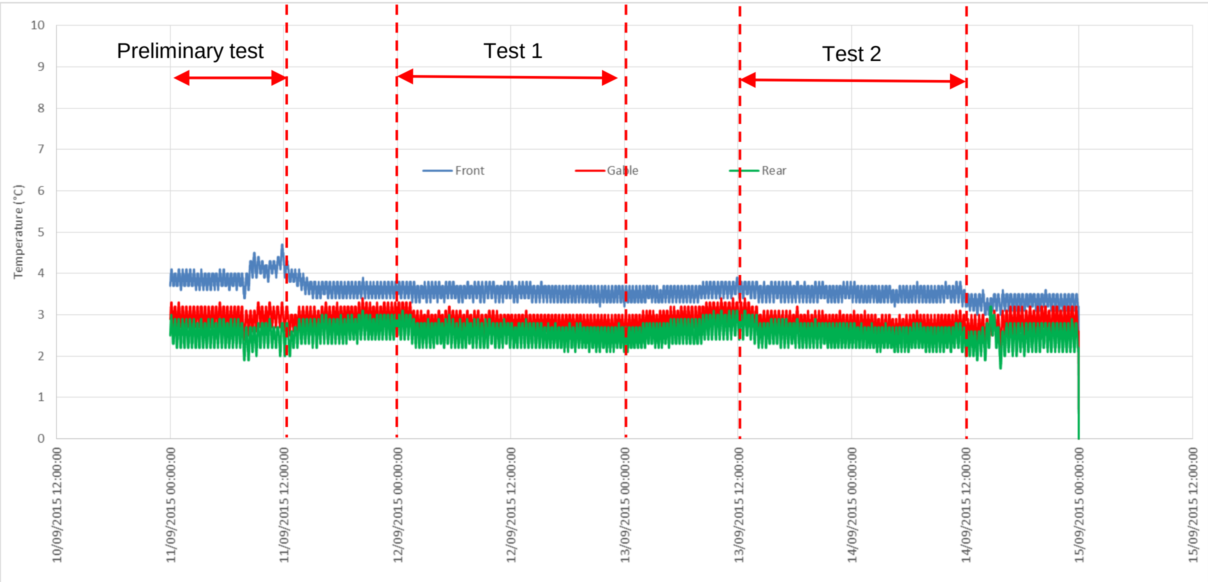


Figure 18 External chamber air temperatures during the entire testing period.

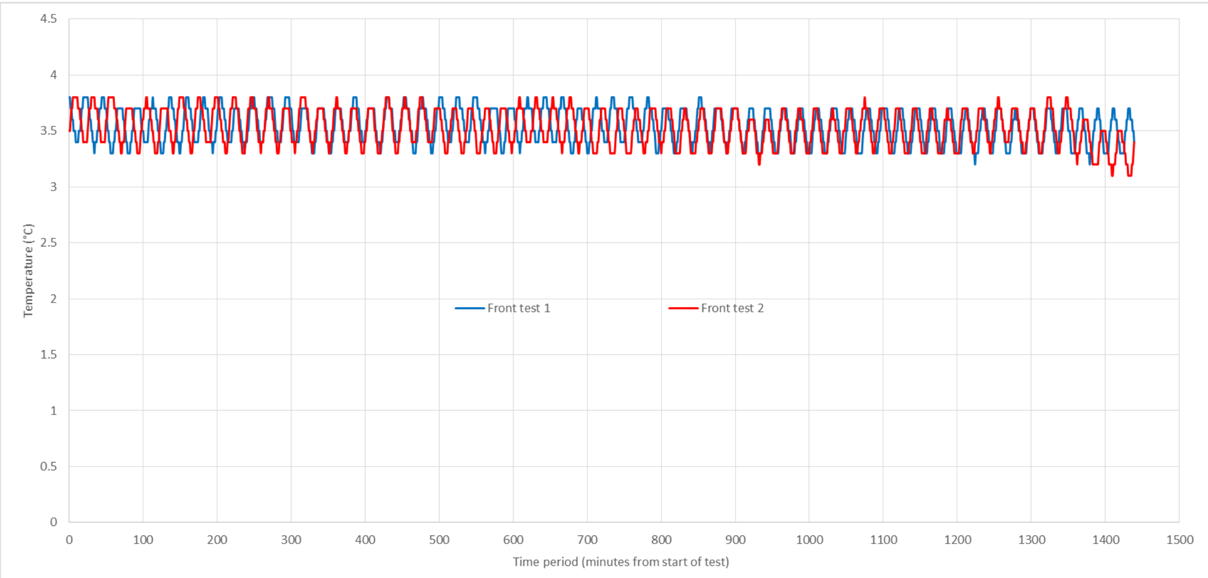


Figure 19 Front elevation external chamber air temperatures during test period 1 and 2.

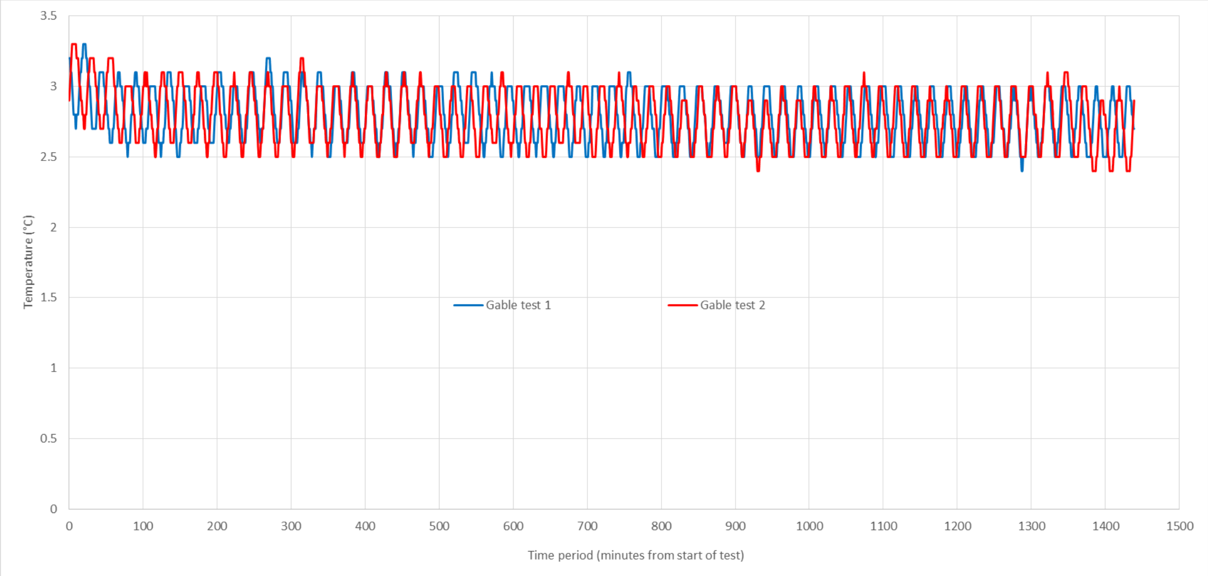


Figure 20 Gable elevation external chamber air temperatures during test period 1 and 2.

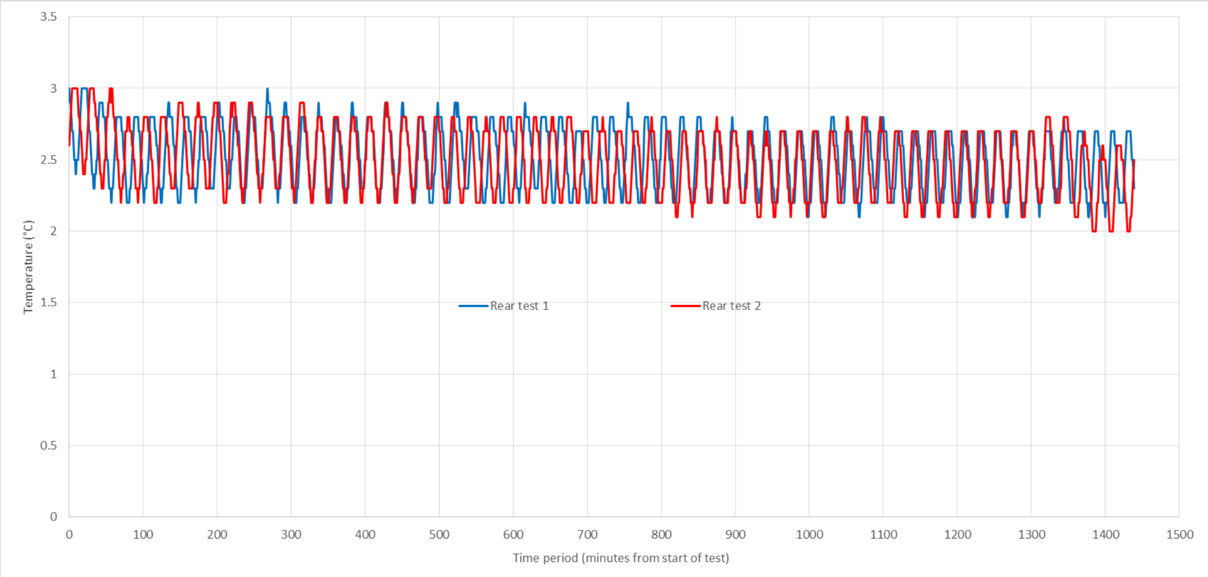


Figure 21 Rear elevation external chamber air temperatures during test period 1 and 2.

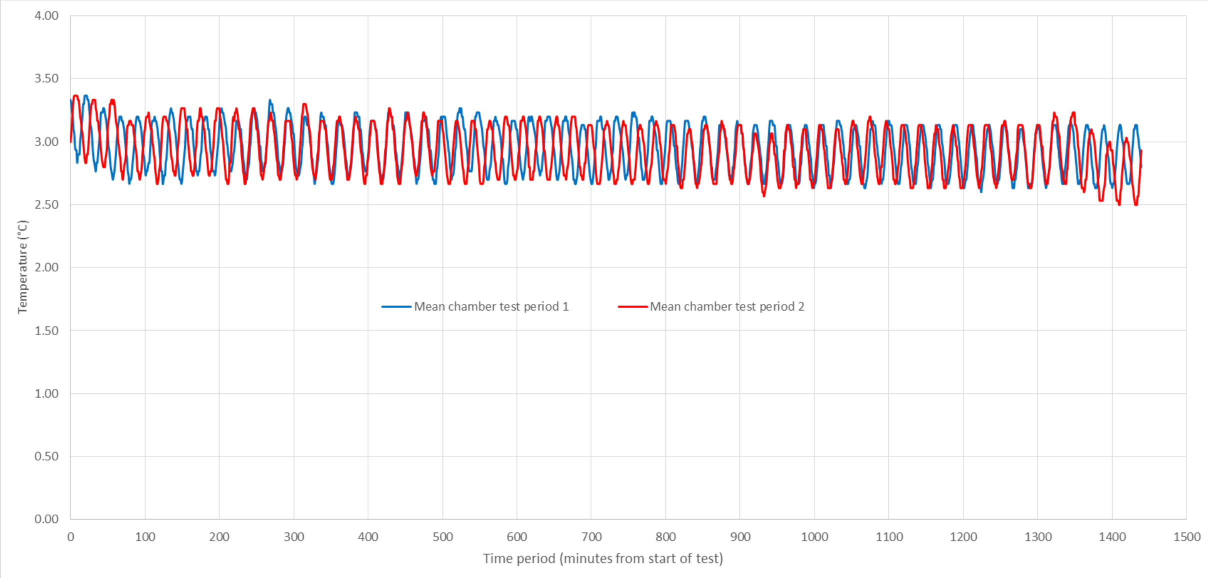


Figure 22 Mean external chamber air temperature during test period 1 and 2.

In summary, the analysis of the internal room and external air chamber temperature data reveals that despite the existence of air within bedroom 2 radiator during test period 2, both tests were undertaken under very similar temperature conditions. This means that it is possible to directly compare the surface temperature and gas consumption figures for both test periods with one another without any corrections having to be made to account for differing conditions within each test period.

Internal globe temperatures

19 In addition to the internal air temperatures, the globe temperature was also measured in the living area, kitchen, bedroom 1, bedroom 2 and the bathroom. The globe temperature was measured to ascertain whether the operation of the Oxypod® device is likely to have any positive impact on thermal comfort. The globe temperatures measured over each test period are illustrated in Figure 23 to Figure 27 and Table 3.

20 It can be seen from the Figures that there is a high degree of consistency in the globe temperatures measured in the living area, kitchen and the bathroom, suggesting that there is little impact on thermal comfort between the two test periods. As expected, the globe temperature measured in bedroom 2 is lower during the majority of test period 2 due to the air pocket within the radiator located within this room, whilst in bedroom 1, the globe temperature is very similar for the majority of the test period. However, during the initial heat-up period, lower globe temperatures were measured in bedroom 1 when the Oxypod® device was operational despite the starting globe temperature point being higher. Conversely, higher globe temperatures were measured in bedroom 2 when the Oxypod® device was operational despite the starting globe temperature point being lower. Unfortunately, as globe temperature is dependent upon a number of parameters; namely the amount of radiation, the air temperature and the air velocity within the room, it has not been possible to ascertain the reasons for the differences in globe temperature based upon the limited amount of measurements that were undertaken during both test periods.

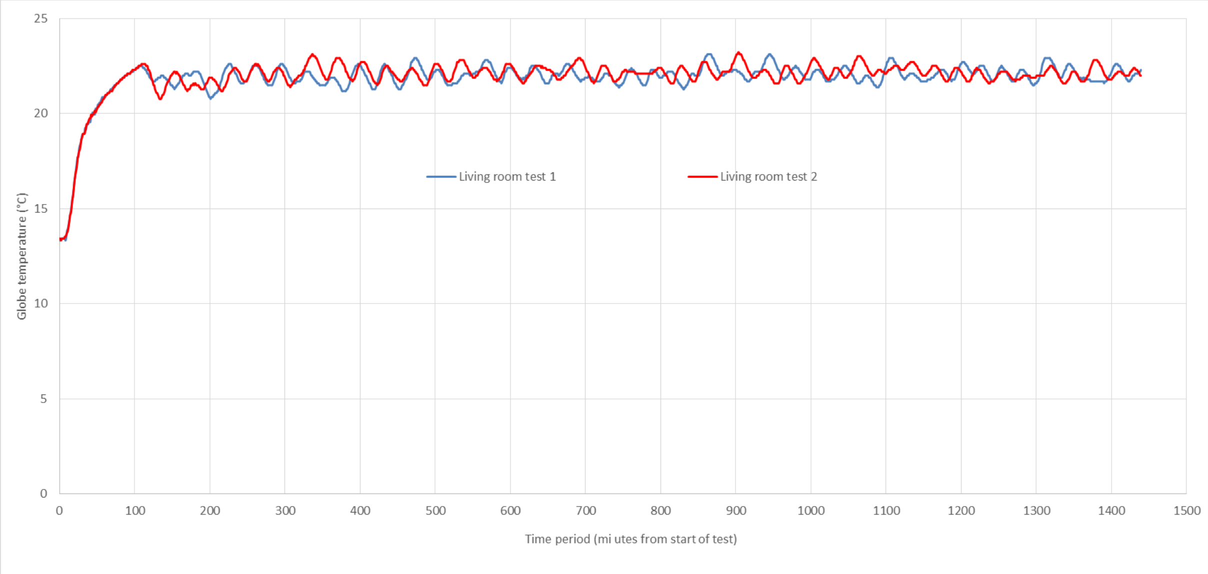


Figure 23 Globe temperature of the living room during test period 1 and 2.

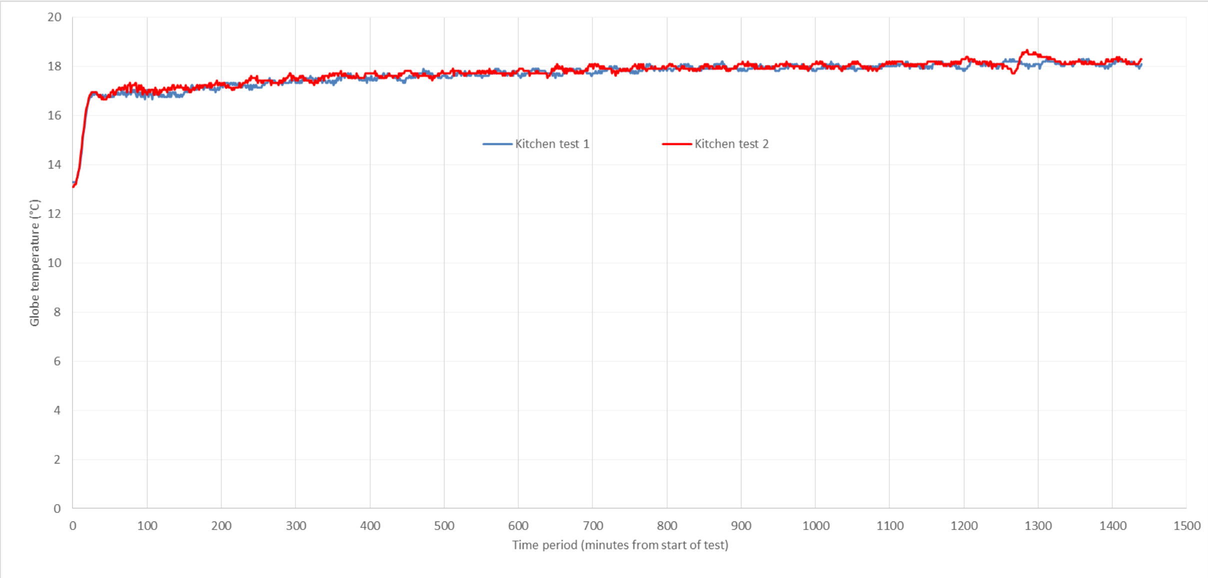


Figure 24 Globe temperature of the kitchen during test period 1 and 2.

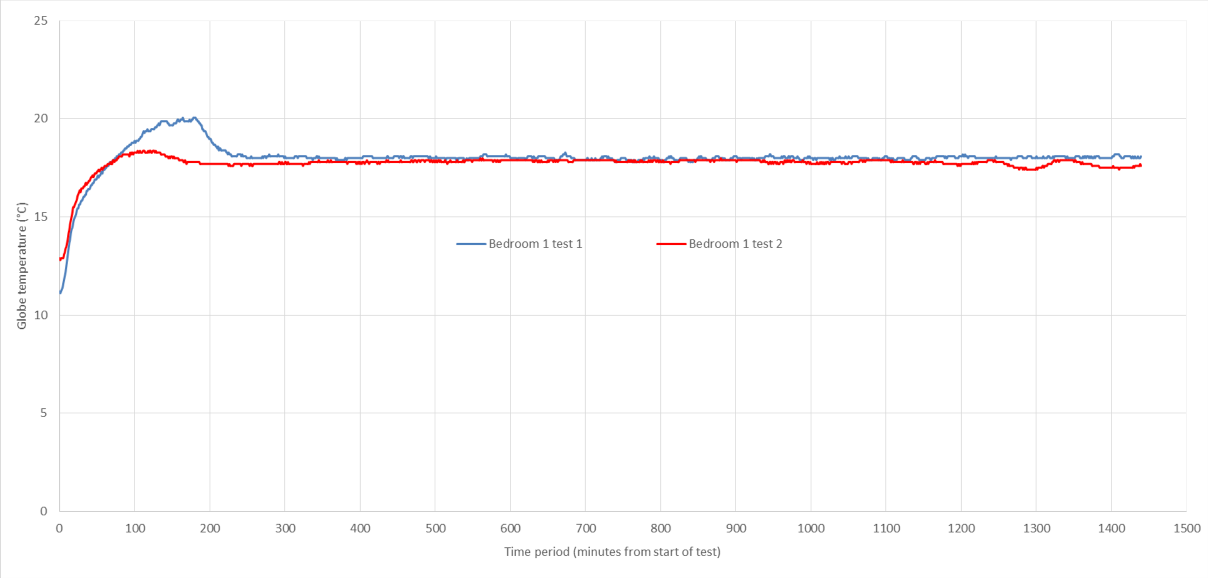


Figure 25 Globe temperature of bedroom 1 during test period 1 and 2.

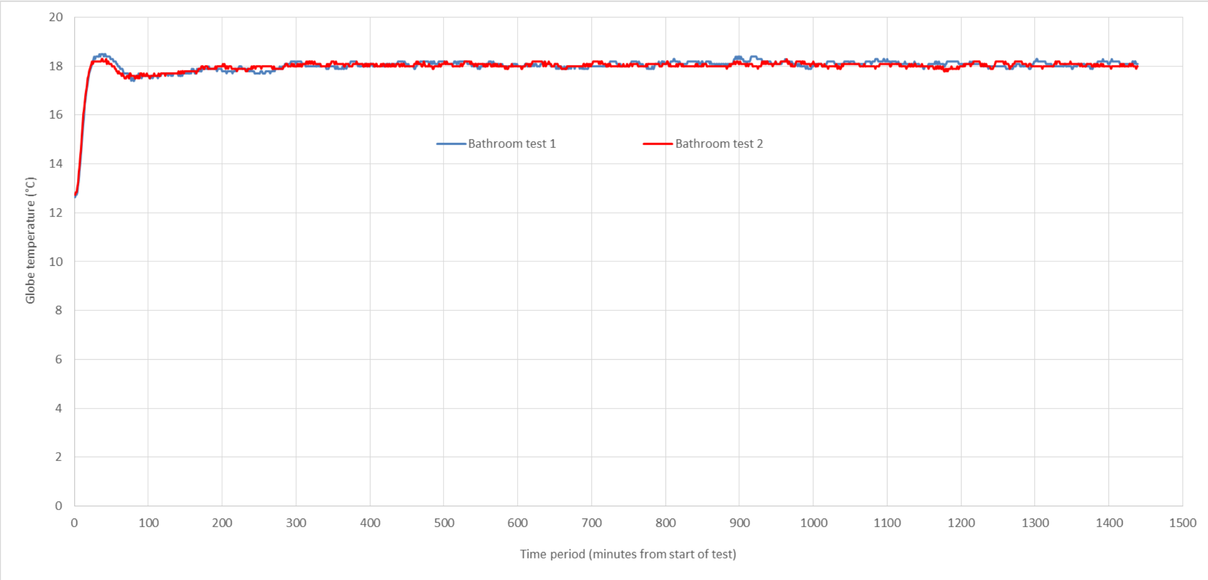


Figure 26 Globe temperature of the bathroom during test period 1 and 2.

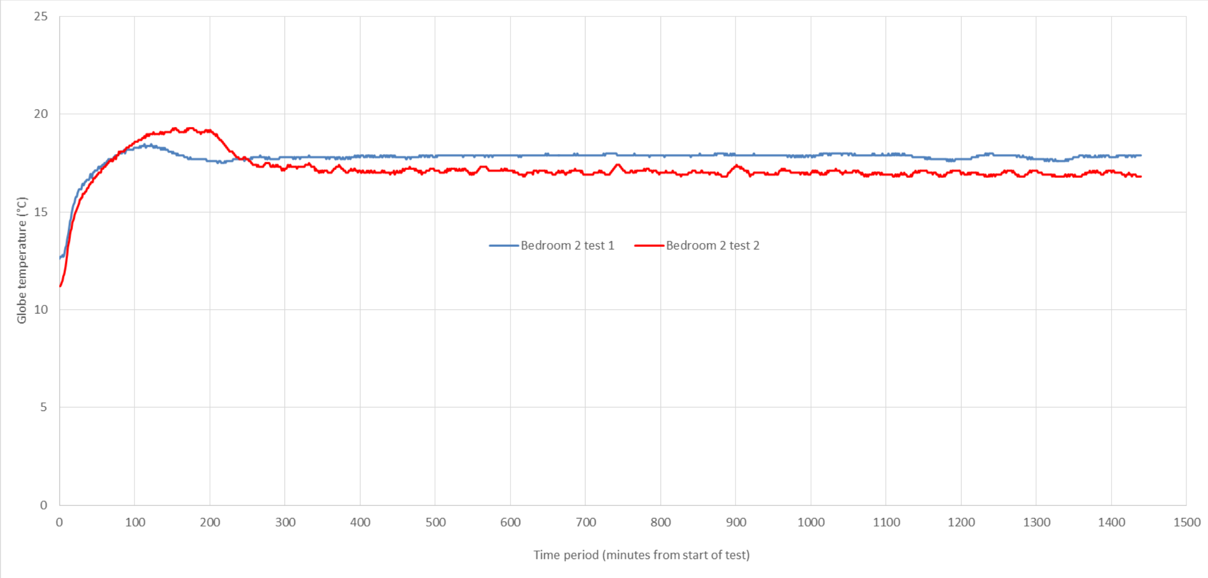


Figure 27 Globe temperature of bedroom 2 during test period 1 and 2.

	Mean internal globe temperature (°C)	
	Test period 1	**Test period 2**
Living room	21.9	21.9
Hall	-	-
Kitchen	17.7	17.7
Bedroom 1	18.0	17.7
Bathroom	18.0	18.0
Bedroom 2	17.8	17.2

Table 3 Mean internal globe temperatures over the test periods.

Radiator surface temperatures

21 The surface temperatures of each radiator measured over each test period are detailed within Figure 28 to Figure 33. As the surface temperature of the radiator will be dependent upon the temperature of the water entering the radiator, which is controlled by the TRV, along with the amount of heat lost to the room (these should be the same between each test period), then it would be expected that there would be little variation in the surface temperatures measured between each test period. However, it can be seen from the data that there is some variation in the surface temperatures measured across a number of the radiators for short periods of time, primarily in the living area and hall, where the surface temperature measured during one test period far exceeds that measured during the other test period. It is likely that this variation is being caused by slight differences in the way in which the TRV is reacting to the internal temperature within the room. For the kitchen, bedroom 1 and the bathroom, the surface temperatures measured are broadly comparable with one another between each test period. The only exception relates to bedroom 2, where the surface temperature of the radiator is consistently lower during test period 2 due to the existence of the entrapped air. Analysis of the data reveals that the air appears to have entered this radiator at the beginning of test period 2, probably within the first hour, following the initial heat-up period.

22 The mean internal surface temperature of each radiator over each test period has also been calculated and is presented in Table 4. It is clear from this data that there is very little difference in the average surface temperatures between each test period, apart from in bedroom 2 where there is an average difference in surface temperature of 5°C. Despite this difference in surface

temperature, the radiator still maintained a mean surface temperature of 32.5°C during test period 2, so still made a significant contribution to heating this room.

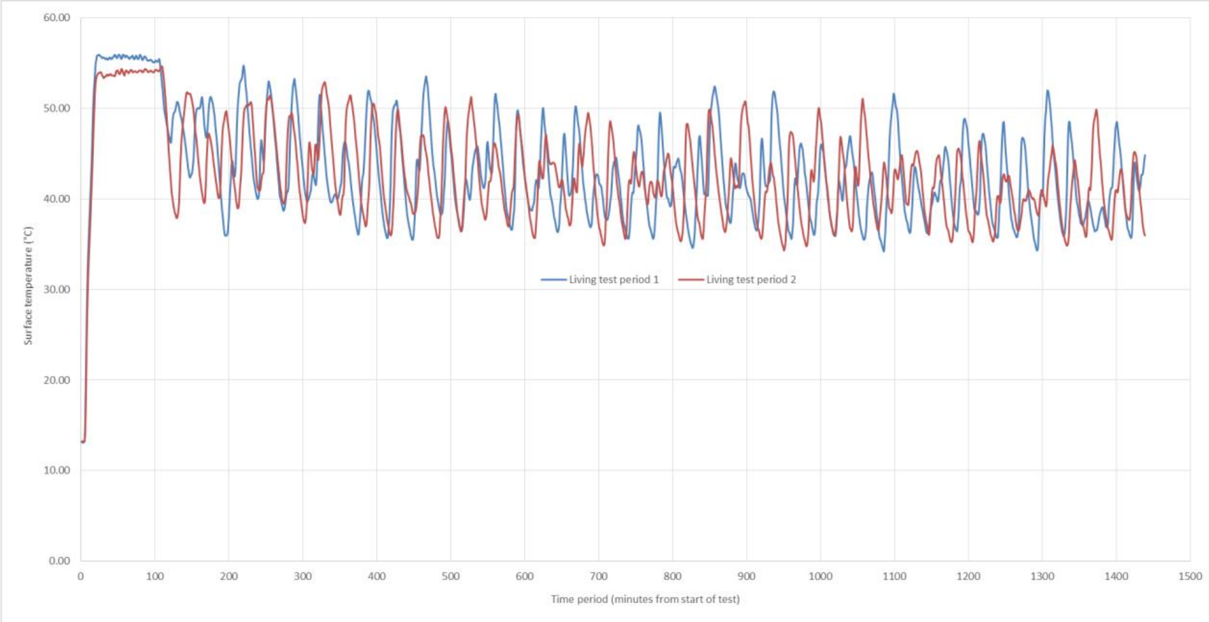


Figure 28 Surface temperature of the living room radiator.

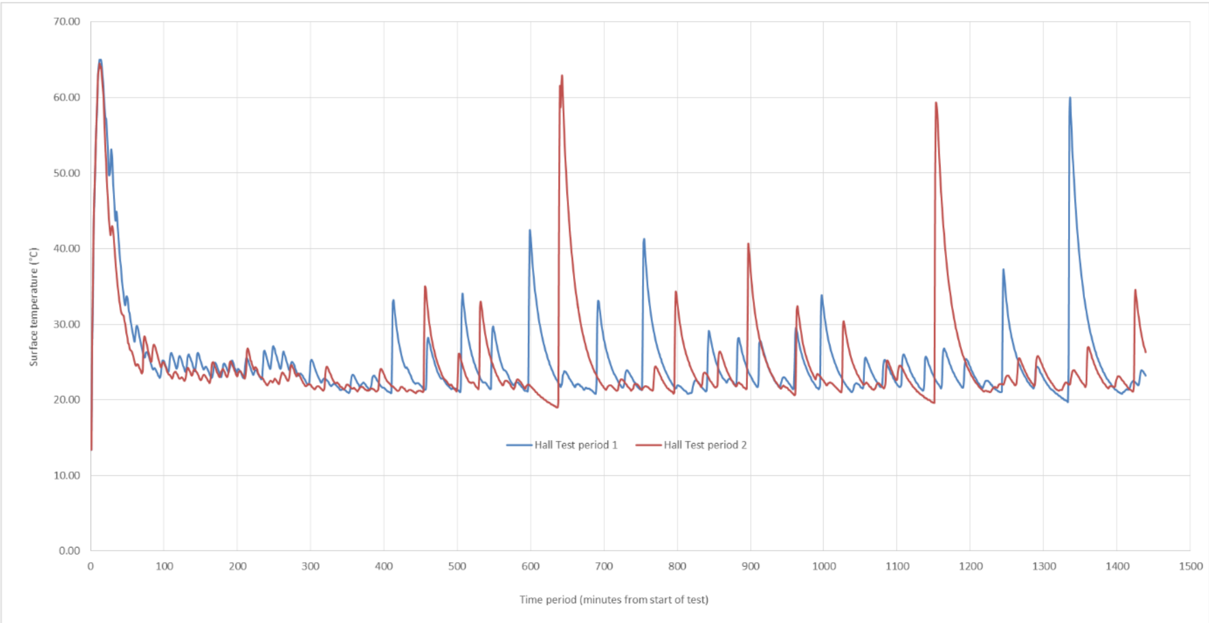


Figure 29 Surface temperature of the hall radiator.

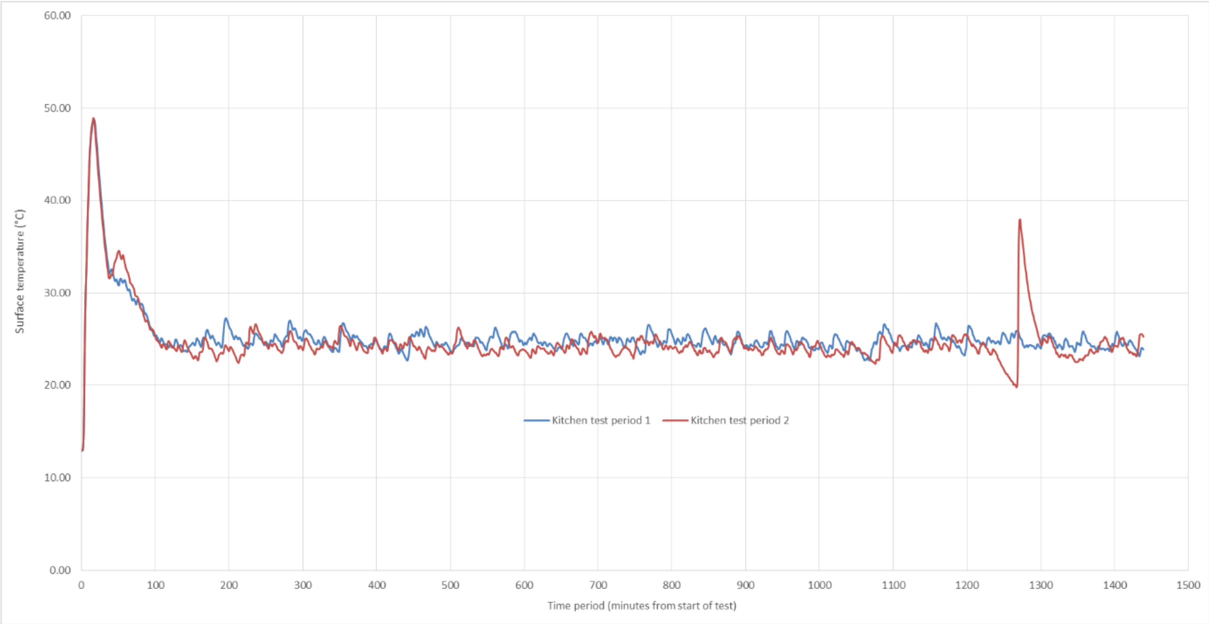


Figure 30 Surface temperature of the kitchen radiator.

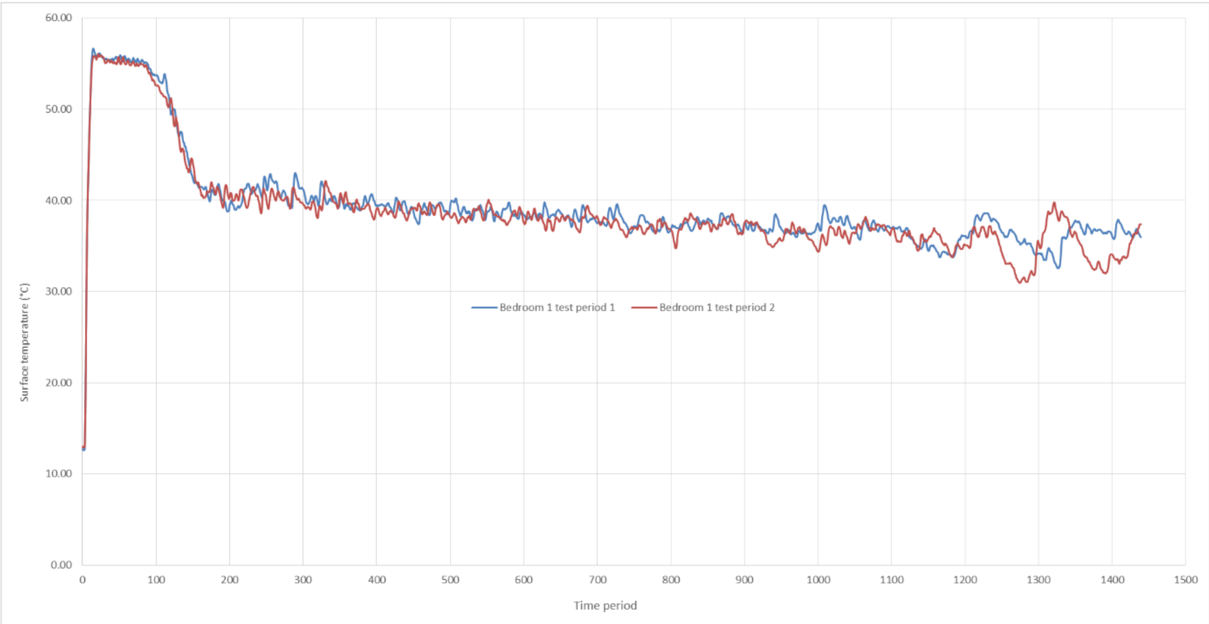


Figure 31 Surface temperature of bedroom 1 radiator.

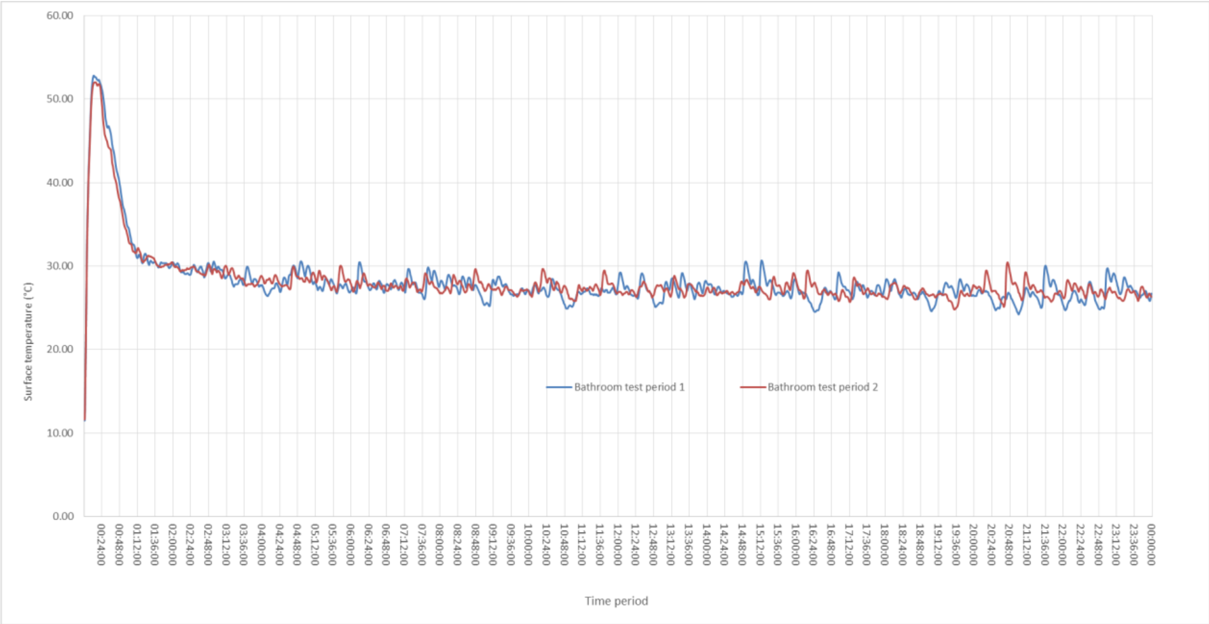


Figure 32 Surface temperature of the bathroom radiator.

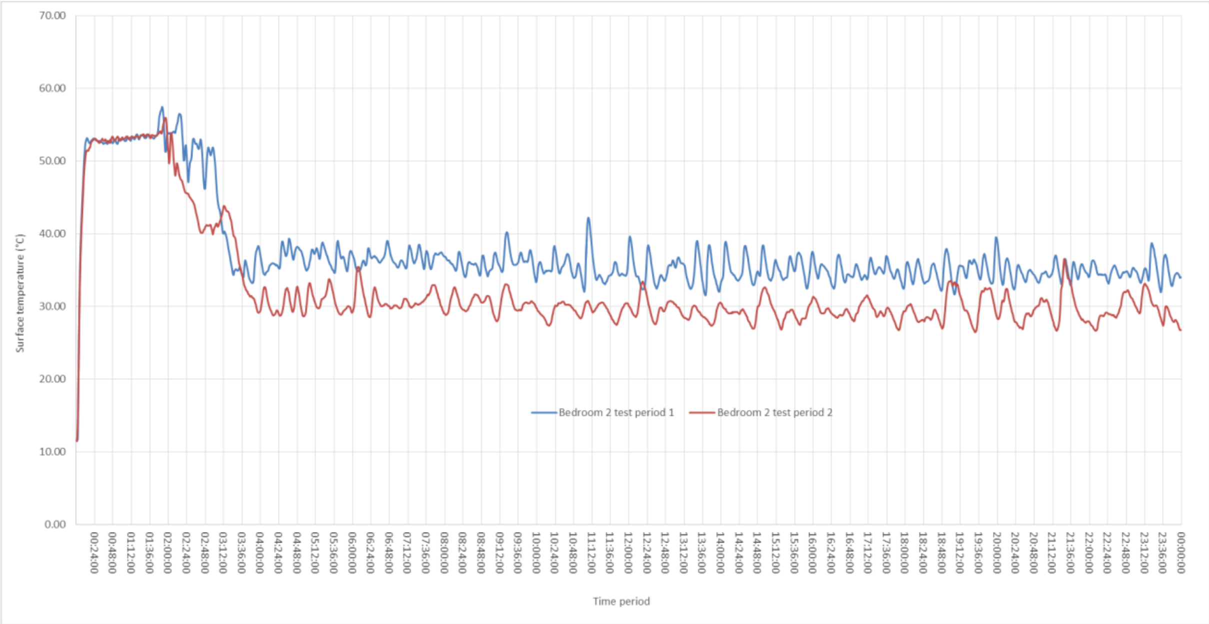


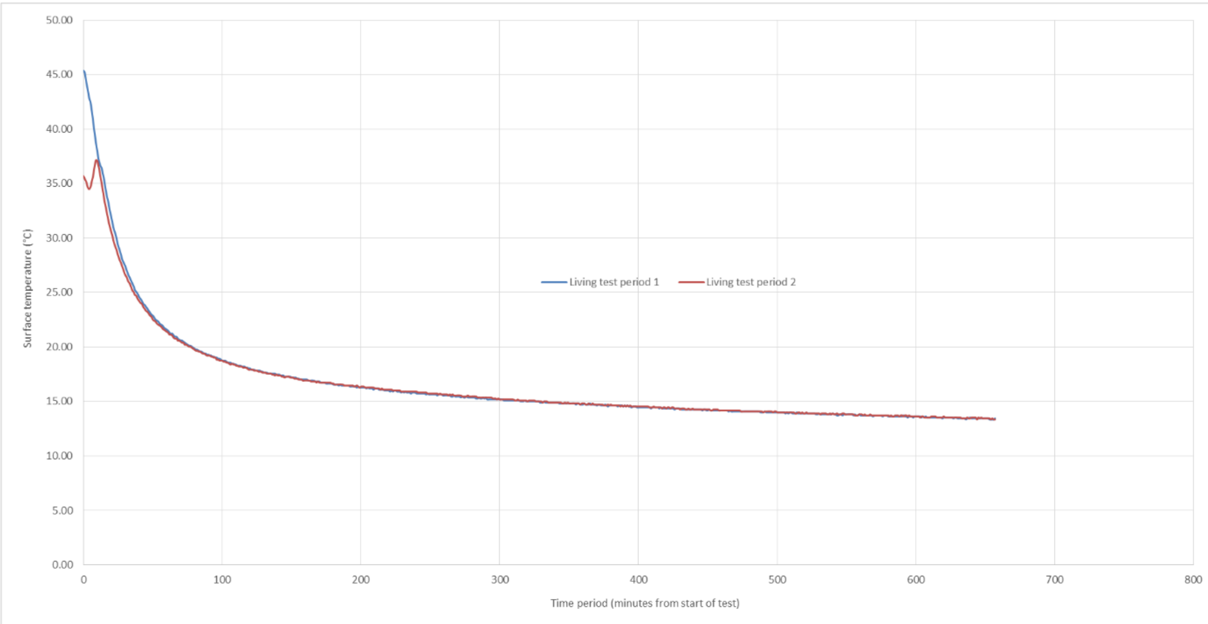
Figure 33 Surface temperature of bedroom 2 radiator.

	Mean surface temperature of radiator (°C)	
	Test period 1	**Test period 2**
Living room	43.1	42.8
Hall	25.2	24.9
Kitchen	25.3	24.8
Bedroom 1	39.3	38.8
Bathroom	28.2	28.2
Bedroom 2	37.5	32.5

Table 4 Mean surface temperature of radiators over the test periods.

Radiator surface temperatures during cool down

The surface temperatures of each radiator were also measured during the 12 hour cool down period following each test (see



23 Figure 34 to Figure 39). This data has also been analysed to determine whether there is any difference in the rate at which the radiator surface temperature cools down following each test period. It is clear from Figures 34 to Figure 39 that in the main there is little observable difference in the rate at which the surface temperature of the radiator reduces during the cool down period. The only occasion where there are some slight differences in the rate of cool down are in the bathroom and bedroom 2 where the surface temperature drops slightly quicker during test period 2. The reason for this is most likely attributable to the slightly lower surface temperatures that were experienced in both of these rooms at the time when the test period finished. Despite this, the surface temperature of the radiator in both of these rooms stabilises to a very similar value following the full 12 hour cool down period.

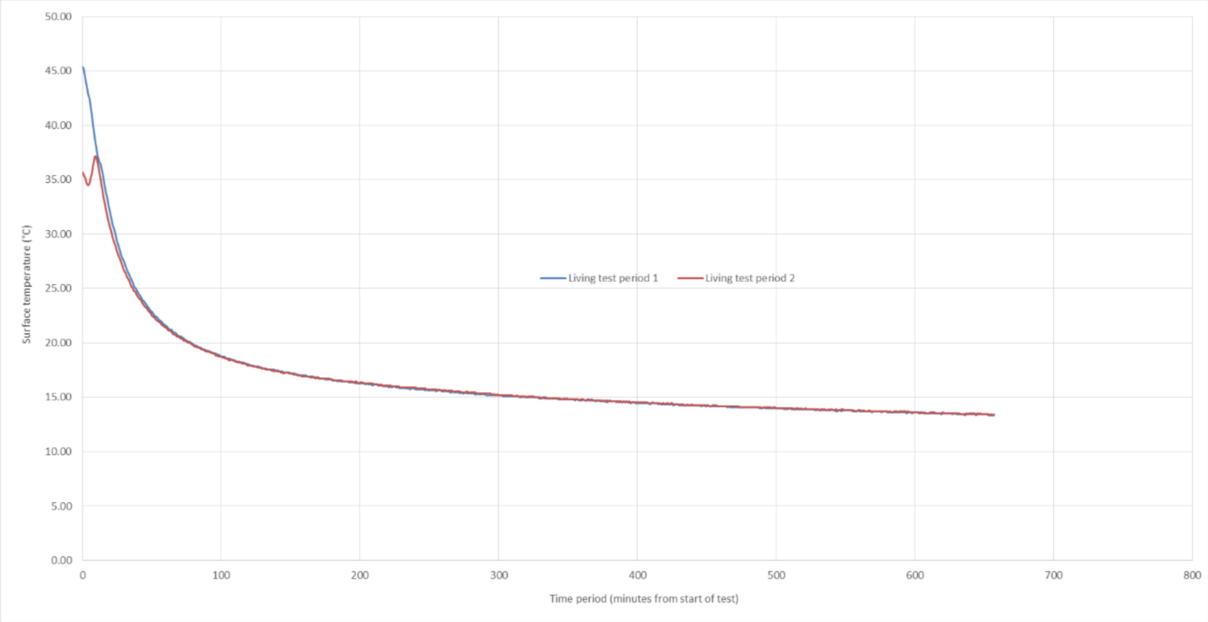


Figure 34 Surface temperature of the living room radiator during the cool down periods.

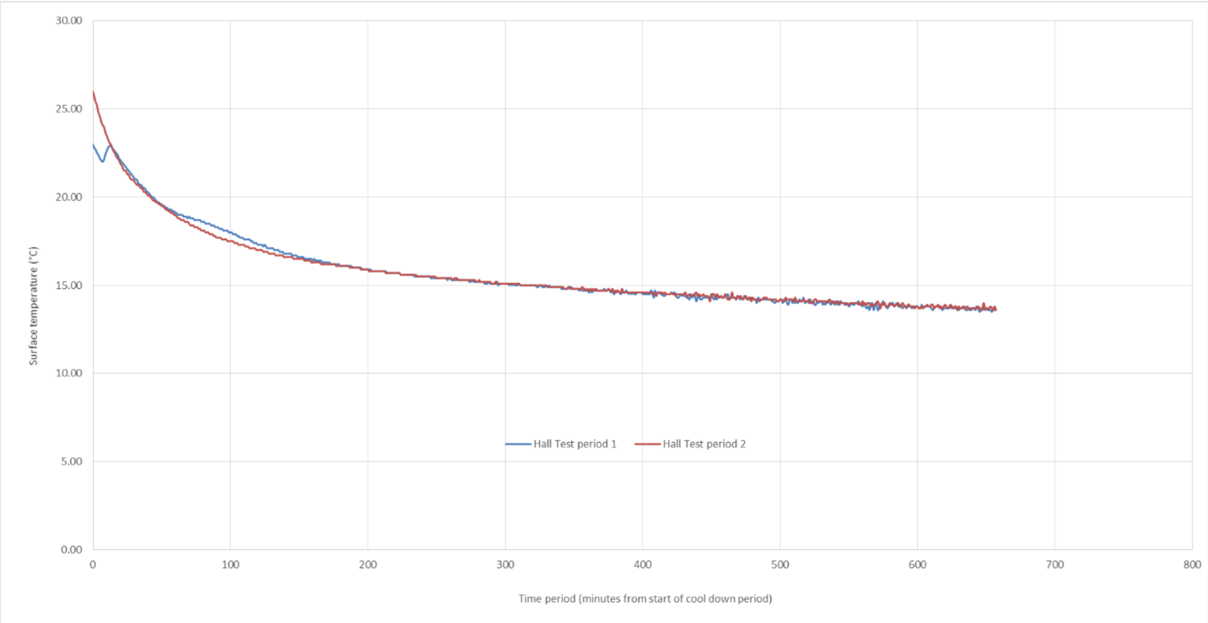


Figure 35 Surface temperature of the hall radiator during the cool down periods.

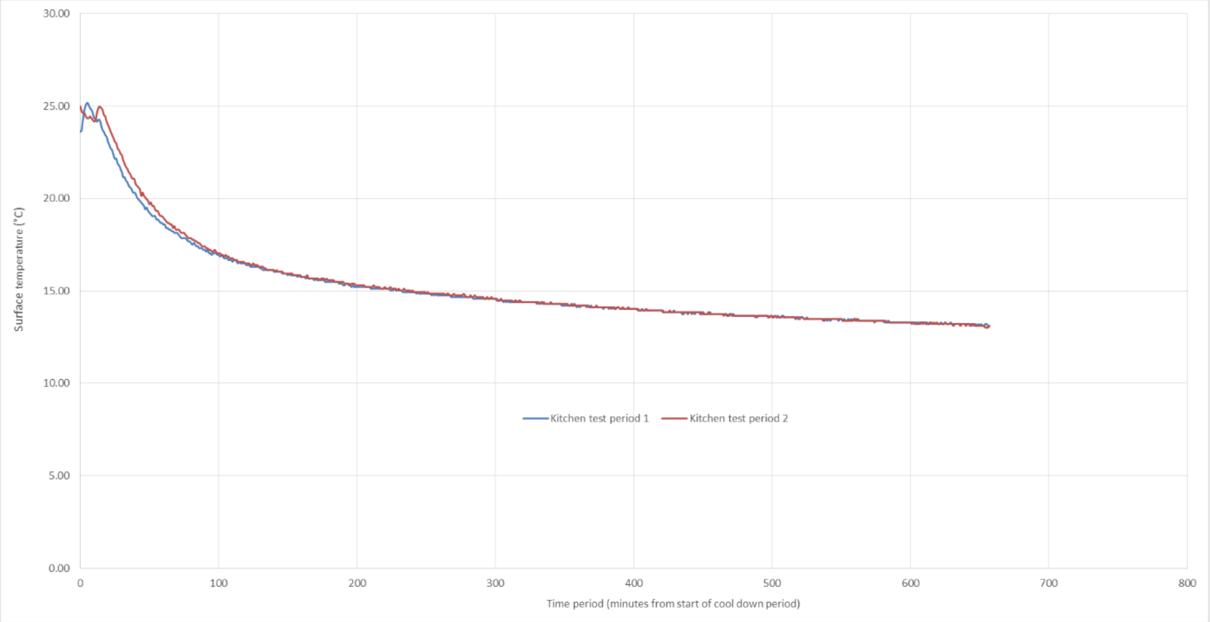


Figure 36 Surface temperature of the kitchen radiator during the cool down periods.

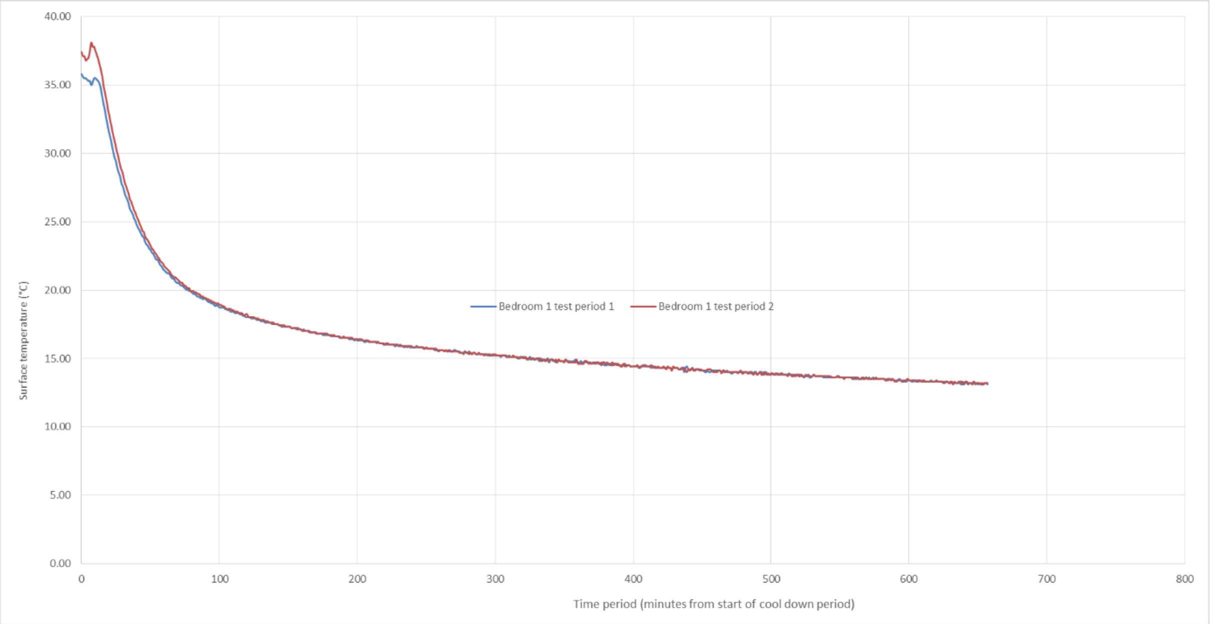


Figure 37 Surface temperature of the bedroom 1 radiator during the cool down periods.

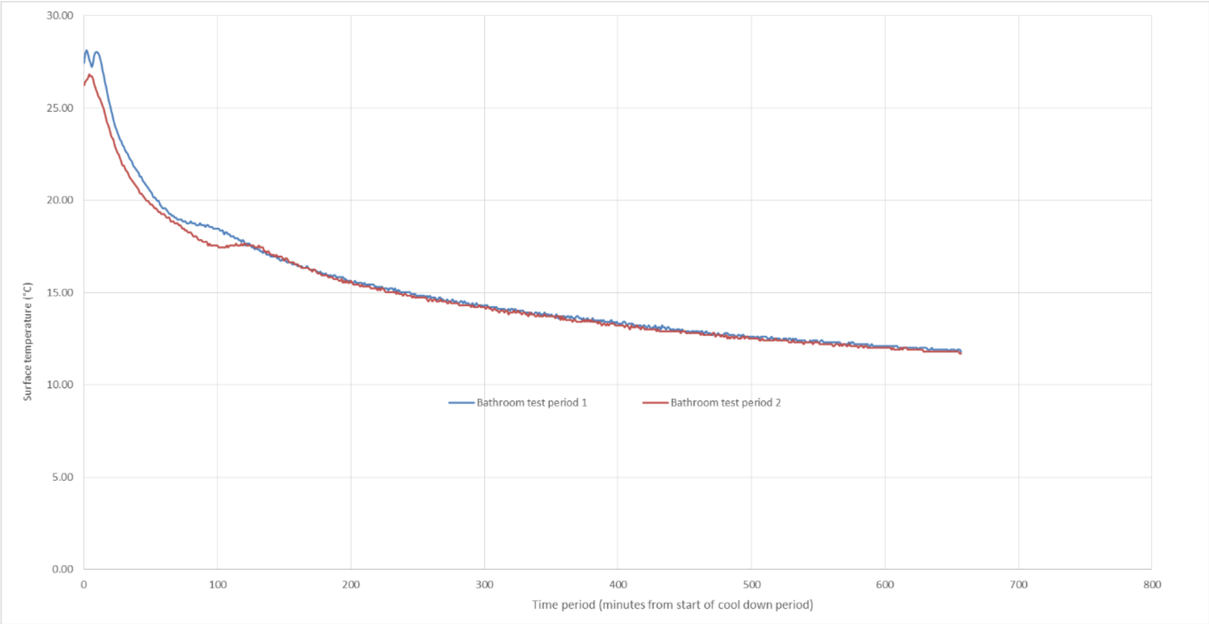


Figure 38 Surface temperature of the bathroom radiator during the cool down periods.

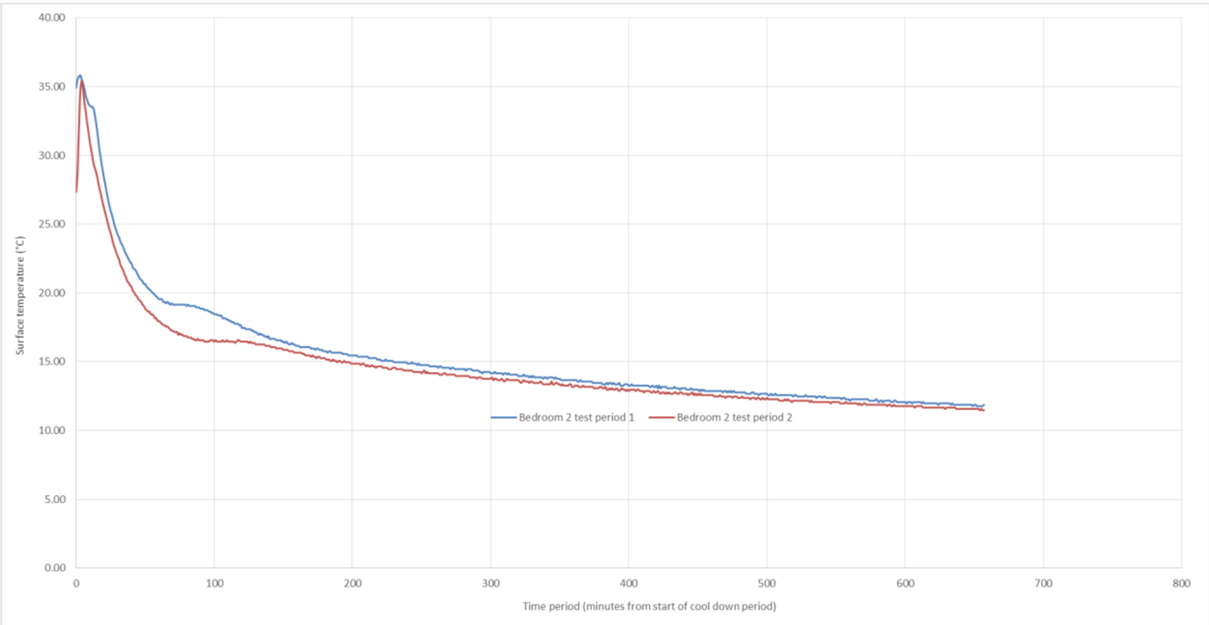


Figure 39 Surface temperature of the bedroom 2 radiator during the cool down periods.

Heat output from the radiators

24 Total heat output from all six radiators was measured using a Zenner Zelsius C5-IUF heat meter with class 2 measurement accuracy. Although this device is capable of accurately measuring the heat output from the radiators when the Oxypod® device is not operating (i.e. when naturally aerated water is circulated around the wet central heating system), it is not known how accurate the measurements are likely to be when the water within the central heating circuit is de-aerated by the Oxypod® device. As the Oxypod® device is designed to remove dissolved gases from the circulating hot water, the reduction in these gases will result in an increase in the specific heat capacity of the water within the central heating circuit. As it was not possible to either measure the specific heat capacity of a sample of the central heating circuit water following test period 2, or measure the amount of dissolved gas removed from the central heating circuit, it is not known what change in the specific heat capacity of the water, if any, is likely to have occurred during test period

2. If the specific heat capacity of the water did increase, then the heat meters will underestimate the amount of heat delivered, i.e. test period 2 may actually be using more heat than is actually being measured. Consequently, caution should be exercised when considering the results discussed below, as it has not been possible to make any corrections have been made to the recorded heat meter readings.

25 The total heat output from each the individual radiators for each test period is illustrated in Figure 40. It is clear that during test period 2, less heat is output from the radiator located in bedroom 2 (as to be expected due to the entrapped air pocket), but there is also very slightly less heat output from the radiators located in the kitchen, bedroom 1 and the hall. This appears to be counter intuitive, as it would not have been surprising to see the heat output from the kitchen (directly below bedroom 2), bedroom 1 (across the hall from bedroom 2) and hall radiator increase slightly to compensate for the slight reduction in the heat output from the radiator located in bedroom 2.

26 The reasons for the slightly lower heat output from the kitchen (0.6 kWh), bedroom 1 (0.5 kWh) and hall (0.1 kWh) radiator in test 2 are not easy to decipher and cannot be related to any discernible difference in the measured internal room air temperature or the radiator surface temperature. An analysis of the flow and return temperatures and the accumulative flow rates associated with the kitchen and bedroom 1 radiators (see Figure 41, Figure 42, Figure 44 and Figure 45) indicates that there is no noticeable difference in the flow and return temperatures or flow rates between the two test periods. In terms of the hall, there are some distinct periods where the flow and return temperatures vary considerably between the two test periods (see Figure 43), there is very little difference in the flow between the two test periods (see Figure 46).

27 Taking into account the reduced output from the radiator in bedroom 2, the overall aggregate reduction in the heat output from the radiators in test period 2 is 2.8 kWh less than that measured during test period 1 (representing a reduction of 4%), although a significant proportion of this reduction (more than half; 1.6 kWh) can be attributed to the lower output from the radiator located in bedroom 2. This suggests that the Oxypod® device is capable of maintaining a comparable overall mean internal temperature and surface radiator temperatures for a slightly reduced overall heat output.

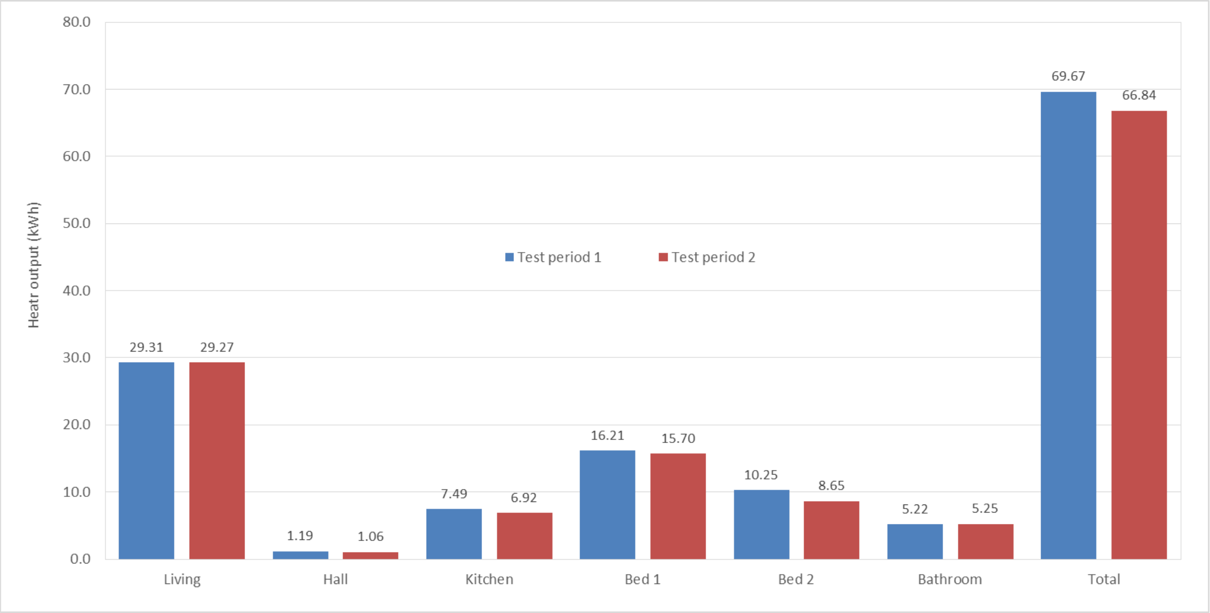


Figure 40 Heat output from each of the radiators.

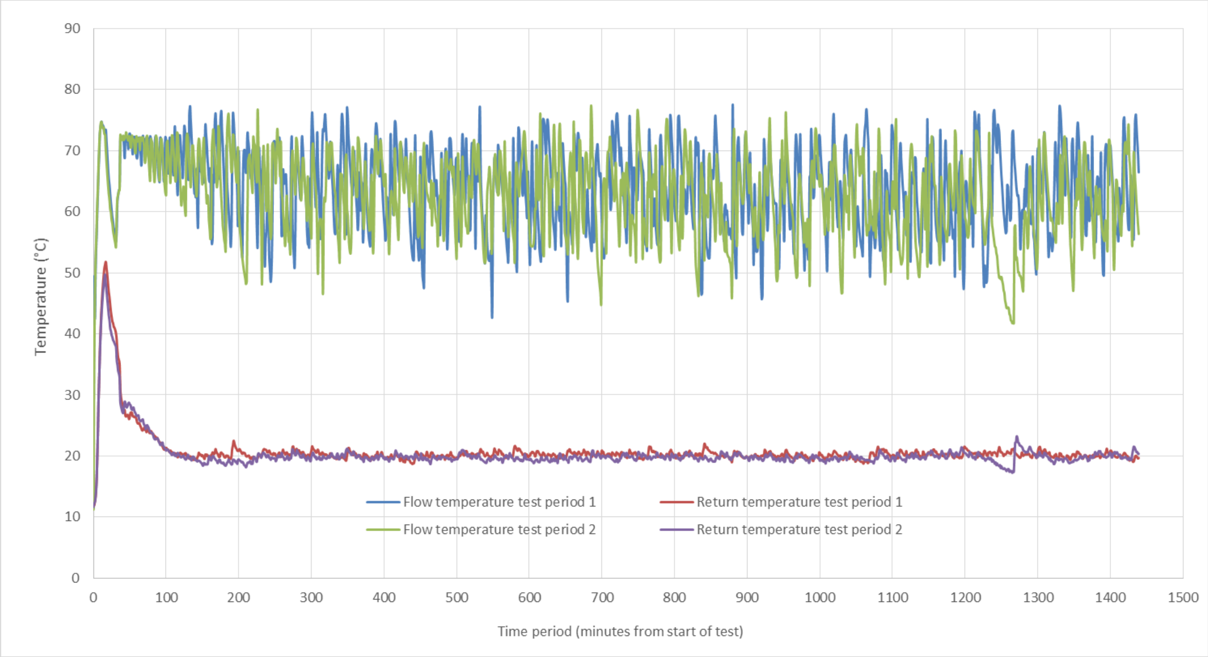


Figure 41 Flow and return temperatures for the kitchen radiator during test periods 1 and 2.

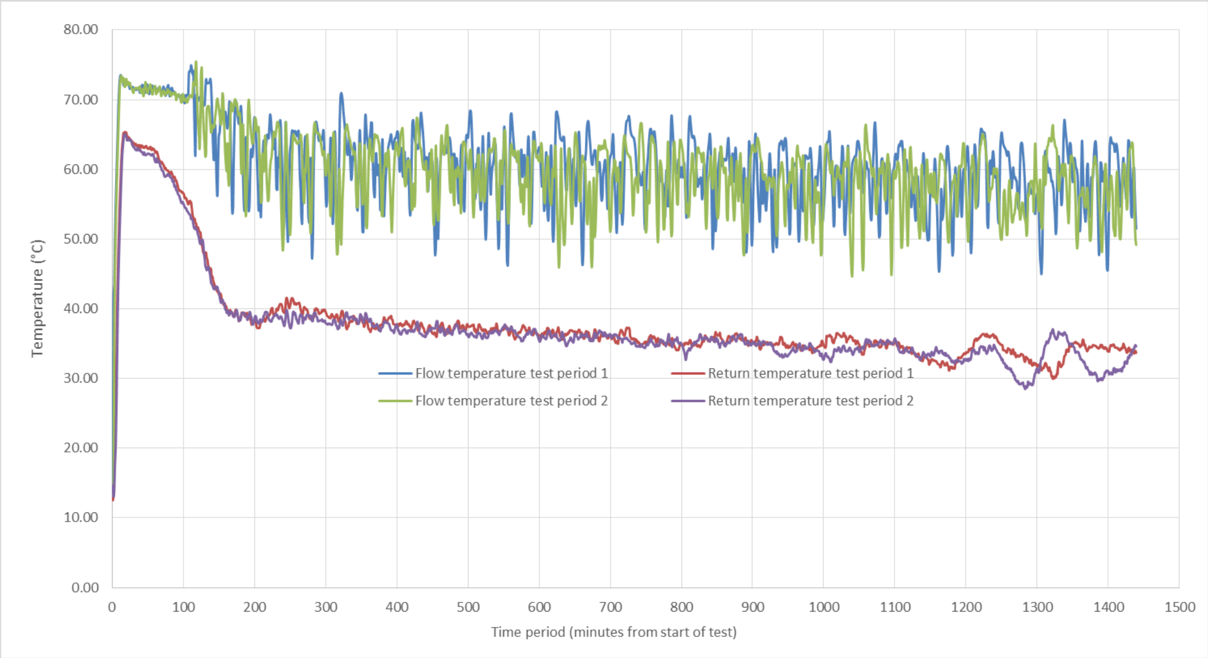


Figure 42 Flow and return temperatures for bedroom 1 radiator during test periods 1 and 2.

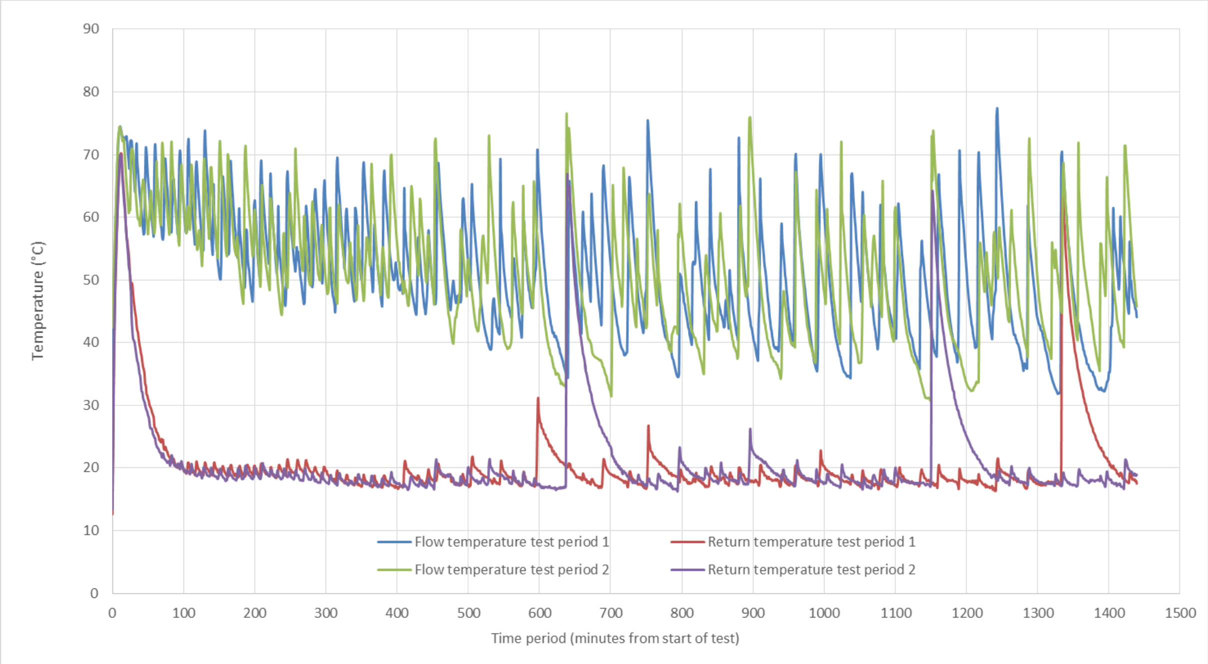


Figure 43 Flow and return temperatures for the hall radiator during test periods 1 and 2.

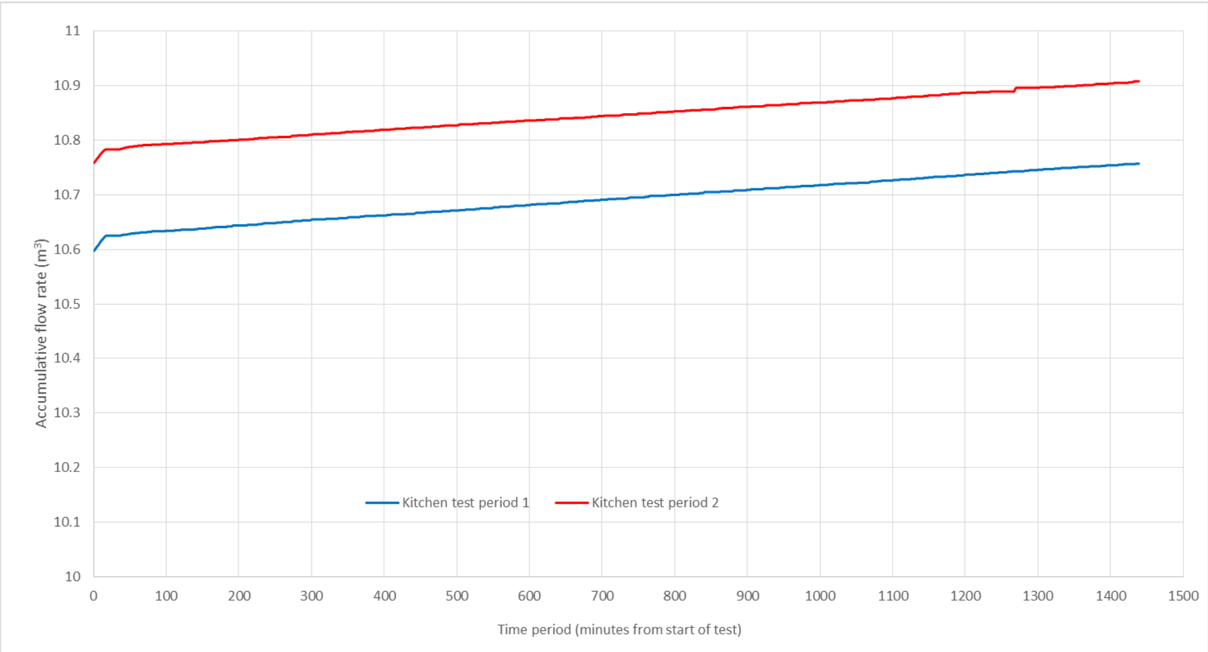


Figure 44 Accumulative flow rate for kitchen during test periods 1 and 2.

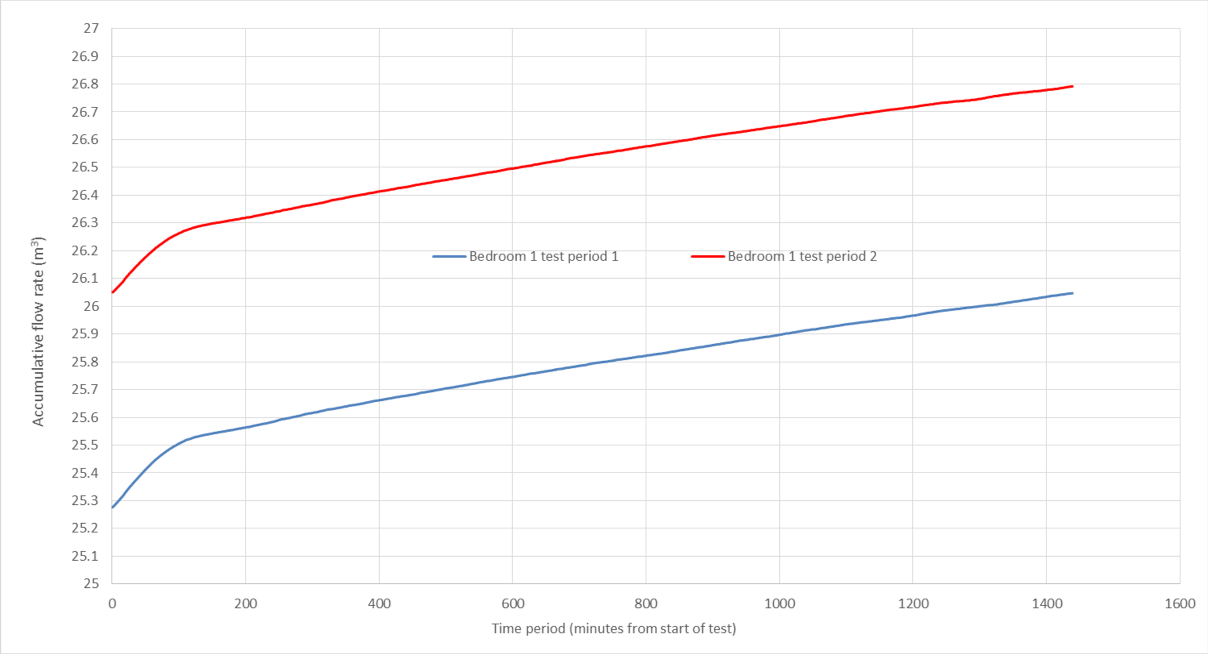


Figure 45 Accumulative flow rate for bedroom 1 during test periods 1 and 2.

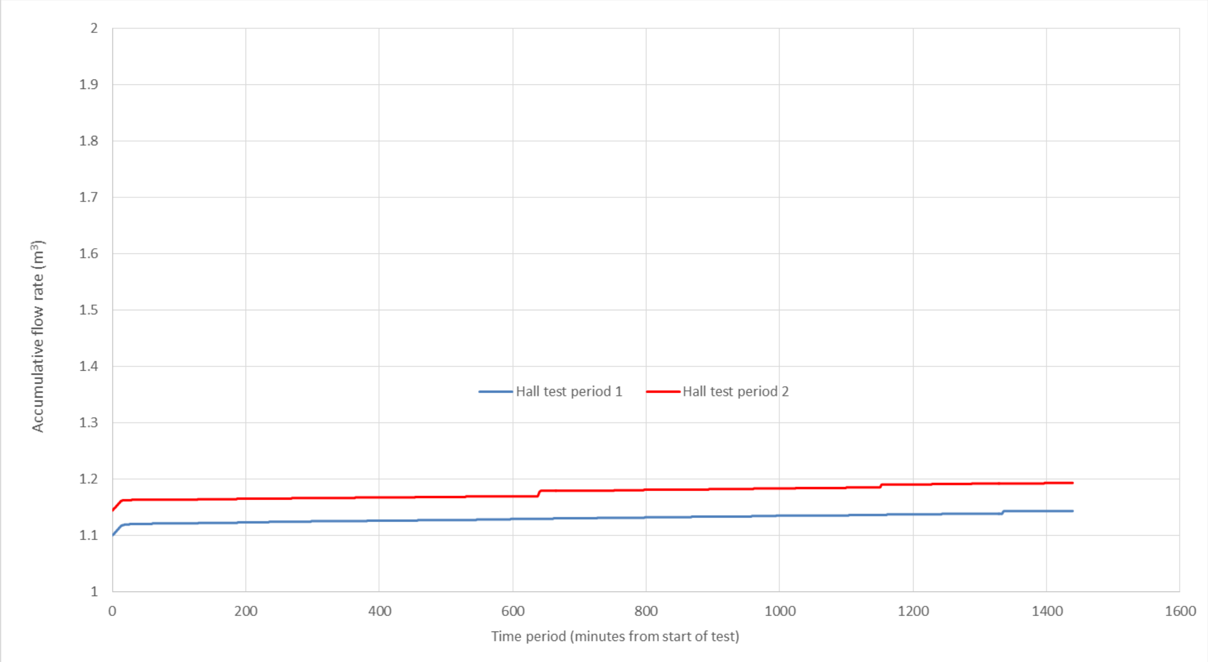


Figure 46 Accumulative flow rate for the hall during test periods 1 and 2.

Heat output from the boiler

28 Total heat output from the boiler was also measured using a Zenner Zelsius C5-CFM heat meter. As previously discussed in paragraph 28, caution should be exercised when interpreting the results discussed below due to the potential inaccuracies associated with measuring heat flow when the Oxypod® device is operating.

29 In terms of the total heat output from the gas-fired condensing combination boiler, during test period 1 the heat output was 91.9 kWh and during test period 2 the heat output was 88.7 kWh. This represents a difference in heat output of 3.2 kWh (3.5%) between these two test periods. Almost all of this heat (2.8 kWh) can be attributed to differences in the heat output from the radiators between

the test periods. The remaining 0.4 kWh of heat, representing ~0.5% of the total measured, is so small that it is not possible to be confident that this represents a reduction in heat output that can be attributed to the installation of the Oxypod® device. Instead, it may simply be a consequence of the natural variation in performance of the Energy House and wet central heating system[1].

30 If the total heat output from the gas boiler is compared against the aggregate heat output from all of the radiators located in the dwelling, then the efficiency of the installed wet central heating system circuit can be obtained. During test period 1, the efficiency of this circuit was calculated as being 75.8% and during test period 2 the efficiency was calculated as being 75.4%. This suggests that the installation of the Oxypod® device in this case has had no impact on the efficiency of the installed wet central heating system. Interestingly, the results indicate that during both test periods, almost 25% of the heat delivered by the boiler is not delivered to the individual rooms via the radiators, but is instead lost through the wet central heating system distribution pipework. As some of this pipework is located within the heated envelope of the test dwelling, then some of this heat will be termed 'useful' heat and will be used to heat various different parts of the dwelling. However, in other instances, such as where the pipework is located in the ventilated underfloor void, the majority of the heat emitted by the pipework will not be termed 'useful' and will instead be lost to the external environment, in this case the environmental chamber. Unfortunately, it was not possible within either test period to determine how much of this heat from the wet central heating distribution system is deemed to be 'useful'.

Total gas consumption of the boiler

31 The total amount of gas and hence primary energy used by the gas boiler was also measured. During test period 1, the total primary energy used by the boiler was 115.7 kWh, whilst for test period 2 the total primary energy usage was 115.1 kWh, representing a difference in gas consumption of 0.5%. If these figures are combined with the total heat output figures for the boiler, then the efficiency of the gas boiler during each test period can be determined. During test period 1, the efficiency of the boiler was calculated as being 79.4% and during test period 2 the efficiency of the boiler was slightly lower at 77.0%. This suggests that the installation of the Oxypod® device has had a small detrimental impact on the efficiency of the gas-fired combination condensing boiler.

32 A closer analysis of the data has been undertaken to determine the possible reasons for this reduction in the efficiency of the boiler. This analysis indicates that when the Oxypod® device is operating, the heat output is more variable and there are a number of large spikes in the heat output that do not occur when the device is bypassed (see Figure 47). In the majority of cases, these spikes in heat output correspond with the higher surface temperatures measured in the hall (see Figure 29). Another interesting observation from the data is that the majority of the lower heat output points occur when the Oxypod® device is operating. This suggests that the boiler is switching on and off more frequently (short cycling) when the Oxypod® device is used. Short cycling the boiler will have an adverse effect on gas consumption. Hence, this could explain the reason why the boiler is slightly less efficient when the Oxypod® device is operating. Further work would be neededto establish if this is likely to be the case.

33 An analysis of the boiler flow and return temperatures and flow rates has also been undertaken (see Figure 48 and Figure 49). This reveals that when the Oxypod® device is operational, there is no obvious difference in the flow rate from the boiler, however, there are some subtle differences in the flow and return temperatures between each test period.

[1] In two identical tests undertaken on the Energy House over a 24 hour period using the dwellings wet central heating system, the total gas consumption measured varied by less than 1%.

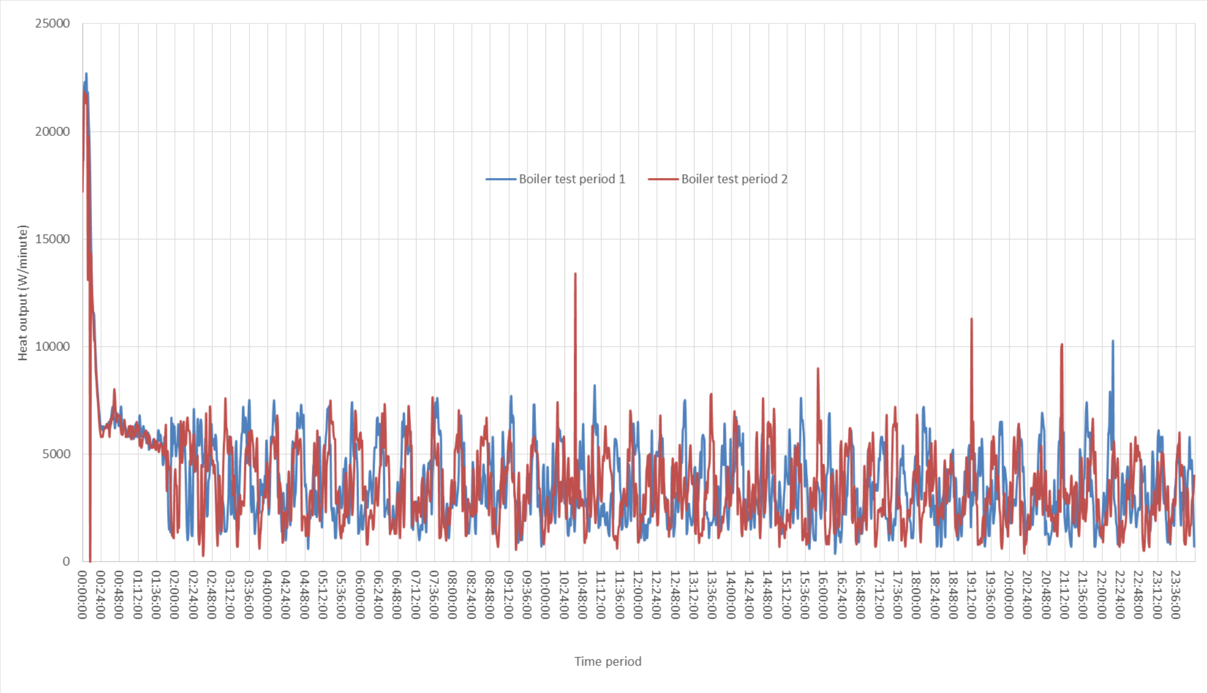


Figure 47 Heat output from the boiler during test period 1 and 2.

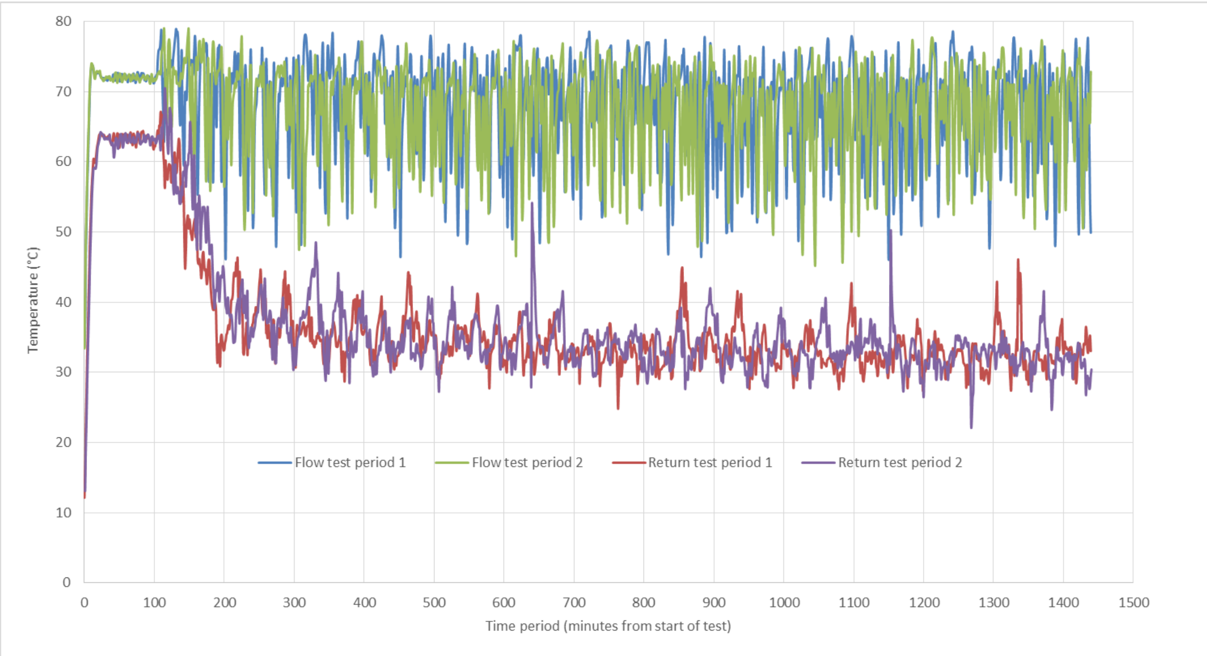


Figure 48 Flow and return temperatures from the boiler during test period 1 and 2.

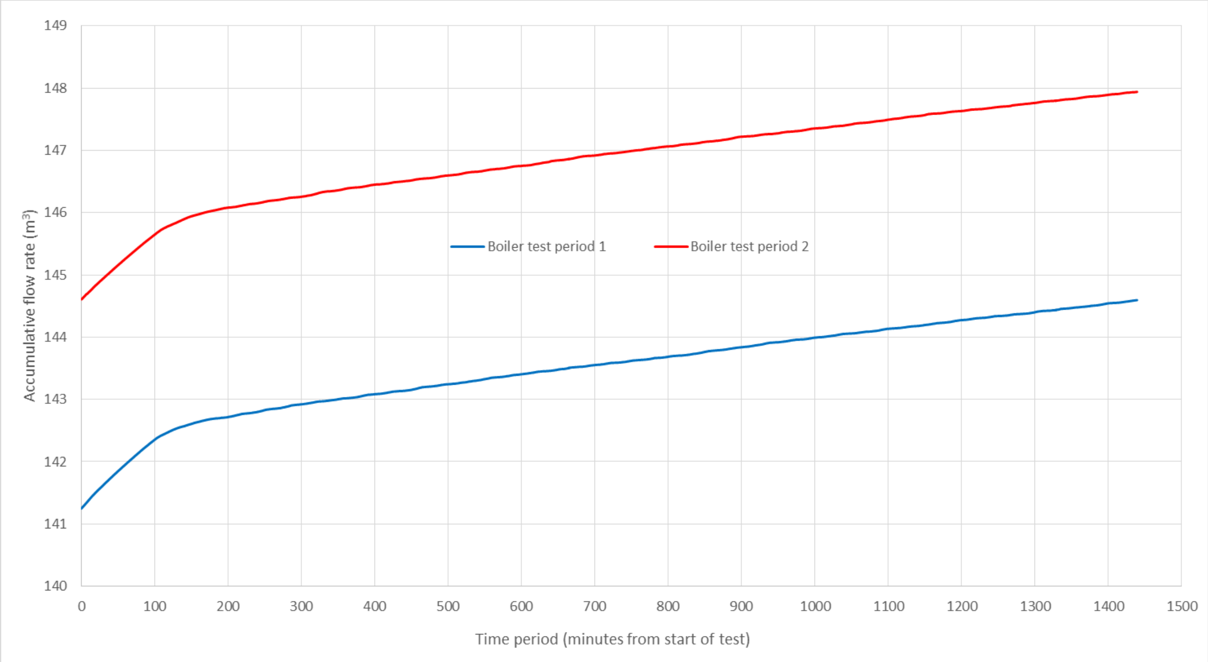


Figure 49 Accumulative flow rate from the boiler during test periods 1 and 2.

Summary

34 This report has outlined the results of a series of *in situ* tests undertaken on the Oxypod® device which was installed in the wet central heating circuit of the Salford Energy House. The *in situ* testing was undertaken in order to establish whether the inclusion of the Oxypod® device within the wet central heating system circuit has any impact upon the performance of this circuit or the gas-fired condensing combination boiler that supplies heat to this circuit. It should be noted that a degree of caution is required when interpreting the heat output results obtained from the heat meters when the Oxypod® device is operational, as it is not known what impact the device has on the accuracy of the heat flow measurement. In addition, the results are based upon two test periods only – one with and one without the Oxypod® device operational. It is advised that further tests are undertaken to establish whether the results reported within this report can be replicated.

35 Analysis of the data revealed that although there were some very small differences in one of the individual room temperatures measured between the tests (bedroom 2), caused by entrapped air within the radiator, the scale of the temperature difference was such that it was felt to have a negligible impact on the overall test results. Consequently, it has been possible to directly compare the results obtained from test period 1 with those obtained from test period 2.

36 Most importantly, the measurements revealed that although a marginally lower overall heat output was required from the boiler (3.5%) to maintain very similar internal temperature conditions when the Oxypod® device was operational, this reduction in heat output does not necessarily translate into a corresponding reduction in overall gas consumption for the boiler. The reason for this appears to relate to the fact that when the Oxypod® device is operating, the boiler short cycles more frequently, and in doing so, is slightly less efficient (result in a reduction in efficiency of ~2.5%). In consequence, any small reductions in overall heat output from the boiler that are obtained when the Oxypod® device is operational are more or less out weighted by the fact that the boiler is producing heat less efficiently. Therefore, the overall reduction is gas consumption achieved by utilising the Oxypod® device is only of the order of 0.5%. This figure is so small that it is not possible to be confident that this represents an actual reduction in gas consumption that can be attributed to the installation of the Oxypod® device. Instead, it may simply be a consequence of the natural variation in performance of the Energy House and wet central heating system.

37 It is also interesting to note that results have highlighted that installation of the Oxypod® device has had no impact on the efficiency of the wet central heating system circuit installed in the Energy House. However, the data reveals that the efficiency of this circuit was calculated as being ~75% during both test periods. This indicates that in the Energy House, ~25% of the heat delivered by the

boiler is not delivered to the individual rooms via the radiators, but is instead lost through the wet central heating system distribution pipework.

38 Based upon the results of this work, it is suggested that the following tests are undertaken on the Oxypod® device:

a) A repeat of the test identified within this report. The repeat test would be able to establish whether the results reported within this report can be replicated, or are simply a consequence of the natural variation in performance of the Energy House and wet central heating system. The repeat test would also be able to clarify whether the microleak experienced in the bedroom 2 radiator did have an adverse effect on the results obtained.

b) A repeat of the test identified within this report but with a smaller output boiler installed within the Salford Energy House. This test will be able to determine if the Oxypod® device is sensitive to the boiler being correctly sized for the application in question.

c) Longitudinal testing of the Oxypod® device where the wet central heating system would be programmed to run for a much longer period of time than was the case in the test identified within this report. This test will be able to determine if it takes a much longer period of operation for the Oxypod® device to realise any potential energy and efficiency savings.

d) A repeat of the test identified within point (c) above but with the central heating system programmed to run based upon a standard occupancy regime. This test will be able to quantify the performance of the Oxypod® device under realistic occupancy conditions. The external chamber conditions could also be varied to reflect external weather conditions.

Acknowledgments

39 The authors gratefully acknowledge the assistance, help and support provided by Mo Benjaber and Richard Fitton (both of the University of Salford) for enabling the tests to be undertaken within the Salford Energy House, setting up the tests and for recording the test data.

References

Oxypod (2015) Oxypod benefits. Available from: http://www.oxypod.me/benefits> [Accessed: 23rd September, 2015]