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# BRE Test Report

## BRE Testing of Room Heaters

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# 1 Introduction

## 1.1 Objectives

The aim of this test programme was to provide temperature and energy performance data indicative of the operation of Fischer dynamic storage heaters in a typical UK environment. Fischer also wanted comparative data between different types of storage heaters and also a typical gas boiler/radiator installation for a better understanding of the differences in internal temperature control and energy performance.

BRE made it clear that product testing in a laboratory environment cannot provide an accurate representation of product performance in daily usage, where there are a number of parameters that are continuously changing, some in a random manner. The usefulness of product testing in a laboratory environment is that it permits the comparison of different products. This comparison, however, is only accurate when the products are operated in the laboratory test mode or usage pattern, and therefore may be of limited value in actual usage.

BRE understood that Fisher would like to obtain a better understanding of the storage heater performance and would also like to have comparative data for the Fisher range of products.

On this basis, BRE proposed a series of tests to be carried out in a purpose built 'apartment' in one of the BRE environmental chambers.

## 1.2 Test method and programme

The test programme was based on an apartment built inside a temperature controlled environmental chamber at BRE's main Garston site.

The test room walls were constructed so that the thermal resistance of their walls was similar to typical solid walled UK houses.

The apartment consisted of two rooms and a central corridor and was heated using the heaters under test to constant temperature levels while the environmental chamber was maintained at a lower constant temperature. The amount of heat energy required to maintain the specified room temperature for each test cycle indicated the measure of performance of the heating system, while the temperature profile within the apartment indicated the measure of temperature control of the heating system.

## 2 Test method

Whilst a specific standard exists for the measuring of performance of household electric thermal storage room heaters (BS EN 60531:2000), the scope of the testing requested by Fischer is the measuring of performance in a simulated typical actual residence.

For this reason BRE implemented an experimental method based on a controlled laboratory test.

The test method was based on a two room 'apartment' constructed inside a temperature controlled test chamber. The two rooms each measured approximately 2.4 x 3.6m and were 2.4m in height. They were constructed very precisely using prepared engineering drawings so that both test rooms were identical in terms of dimensions and thermal properties.

The construction was designed to 'mimic' the thermal transmittance of a solid 210mm thick brick wall using lightweight materials (U-value around 2.1 W/Km$^2$). This avoided using 'wet' construction methods and the risk of dissimilar thermal properties due to differences in drying out resulting in varying moisture levels in the walls.

Each room included a double glazed window of approximate dimensions 1 m x 0.7 m with a U-value of approximately 2.5 W/m$^2$K.

The central corridor between the rooms included a motorised damper of approximate dimensions 0.6 m x 0.6 m to enable the simulation of door openings to the apartment during the test.

The basis of each test was to maintain a constant air temperature difference between the environmental chamber and the interior of the test apartment by cooling the environmental chamber and heating the interior of the test rooms. The tests were repeated for a number of different heating systems, namely two different types of Fischer dynamic storage heaters, two different types of alternative storage heaters, and one domestic gas boiler central heating installation. The following test sequence was proposed (Table 1).

**Table 1 Proposed test schedule for each heater type (x 5)**

| Test | Apartment temperature | Environmental chamber temperature | Time schedule | Duration |
|---|---|---|---|---|
| 1 | **25°C** | **5°C** | **24 hours**<br>**(steady state)** | **Approx. 48 hours** |
| 2 | **21°C**<br>**16°C** | **10°C**<br>**-1°C** | **16 hours**<br>**8 hours** | **Approx. 72 hours** |

A critical aspect of the tests is that the conditions within the environmental chamber were repeatable from one set of tests to the next. This is the specific reason for carrying out the tests within the chamber rather than outdoors with variable conditions.

An array of temperature sensors in each room of the apartment and the environmental chamber were used to measure air temperature and wall surface temperature at appropriate locations. These were connected to a PC based data acquisition system for automatic data capture and recording. Air temperature in the apartment was be based on a mixture of dry bulb (DBT) and dry resultant temperature (DRT) sensors so that the effect of temperature variations within the heated space could be evaluated.

The power input to the heating system (whether electrical or gas), including the power of any auxiliary devices such as fans or pumps, was measured and recorded.

## 2.1 Monitoring and data analysis

Measured parameters were recorded continuously to a PC. Data analysis was undertaken using Microsoft Excel.

The key reported information includes:

- The calculated percentage difference in power input to the heating systems over the test cycle.
- Room air, wall surface and external air temperature and energy input.

## 2.2 Test chamber construction

The test rooms were constructed using a made-up sandwich panel comprising chipboard, expanded polystyrene and plasterboard. Test room inside dimensions are stated in Table 2. Photographs or relevant details are shown in Appendix B. Thicknesses and thermal resistance values are stated in Table 3.

Each test room was erected on an insulated base comprising a total thickness of 150 mm extruded polystyrene (XPS) insulation panels. The floor panels had tongue and grooved joints which were sealed using flexible sealant to prevent air leaks. The room walls were supported in shallow grooves in the floor insulation to allow precise positioning of the walls and allow the joints to be made air tight by applying silicone sealant to the base of the grooves before inserting the wall panels. The test room ceilings were 200 mm thick PIR insulation panels with all joints sealed internally with silicone sealant and taped externally to ensure airtightness.

Table 2 Dimensions of test room internal surfaces

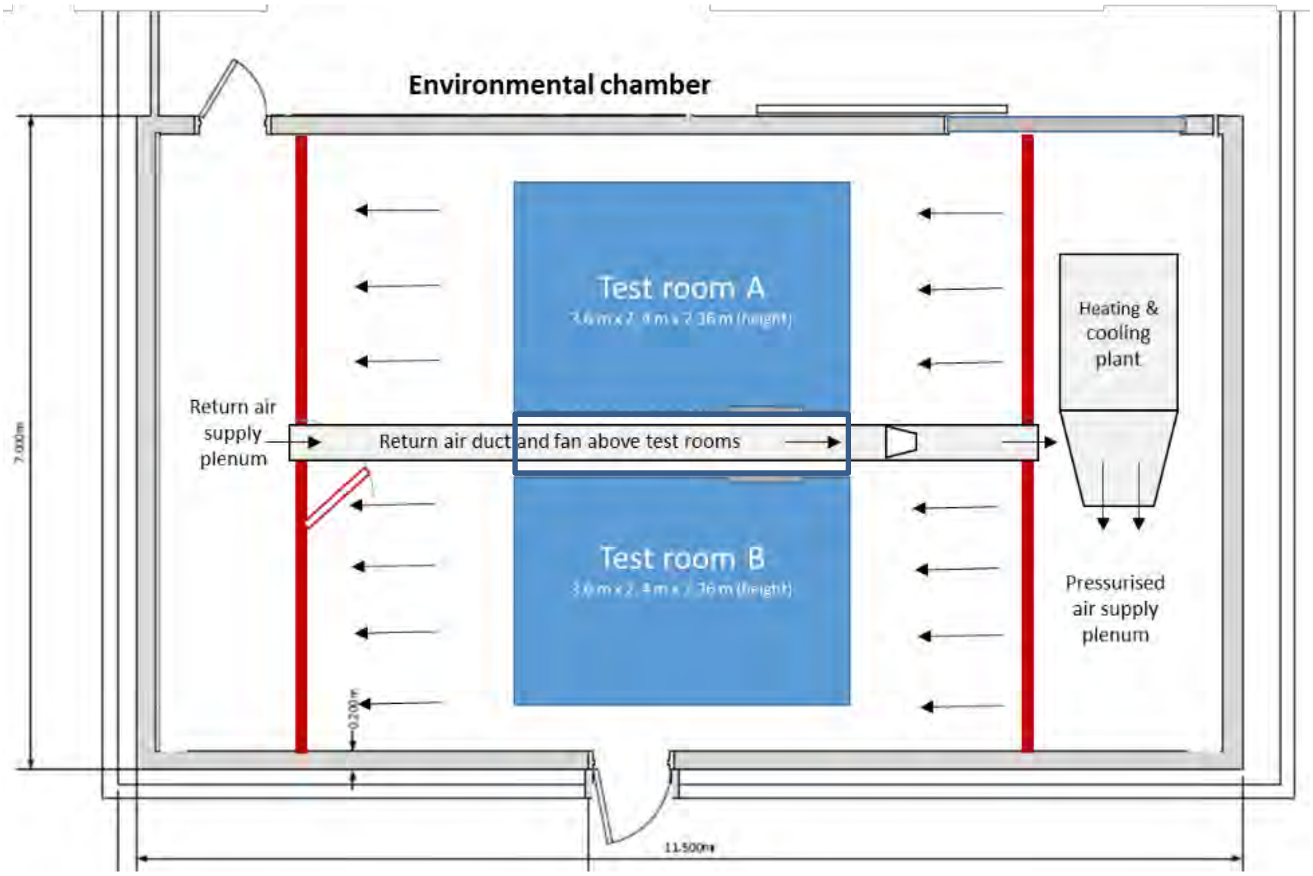
| Surface | Length (m) | Height (m) | Area ($m^2$) |
|---|---|---|---|
| Wall 1 | 3.6 | 2.34 | 8.42 |
| Wall 2 | 2.4 | 2.34 | 5.62 |
| Wall 3 | 2.4 | 2.34 | 5.62 |
| Wall 4 | 3.6 | 2.34 | 8.42 |
| Floor/ceiling | 3.6 | 2.4 | 8.64 |

Table 3 Thickness and thermal resistance of test room panels

| Test room thermal properties | Thermal conductivity | Thickness | R value |
|---|---|---|---|
| | W/m/k | m | $m^2$.K/W |
| P5 chipboard | 0.12 | 0.02 | 0.17 |
| EPS | 0.04 | 0.002 | 0.05 |
| PB | 0.16 | 0.0125 | 0.08 |
| Ceiling insulation | 0.026 | 0.2 | 7.69 |
| Floor insulation | 0.033 | 0.15 | 4.55 |

The test rooms were positioned symmetrically near the centre of the environmental chamber, see Figure 1. To ensure equal temperatures around the test rooms a temperature control system for the environmental chamber was installed to provide a laminar airflow across the chamber. A full height and width supply air plenum was constructed on the right hand side of the chamber and a similar return air plenum was installed on the left hand side. To ensure an even air distribution the plenums had a porous fabric face. Air was returned from the return plenum to the supply plenum by an overhead duct with inline fan, see Figure 1.

The environmental chamber air temperature was controlled by a PID controller and thyristor in the heating and cooling unit with an air temperature sensor in the air supply discharge within the supply air plenum.




Note: Arrows denote direction of air flow.

Figure 1 Schematic of environmental chamber and test rooms

## 2.3 Instrumentation and data logging

Room dry bulb air temperature (DBT) and dry resultant (globe) temperature (DRT) was measured using PT100 sensor probes in each test room at two locations 1.2 m above the floor and on a centre line running through the centre line of each room. The sensors were attached to telescopic probes (one set on the same pole as the room heater control sensor) and had a pole mounted fan blowing room air downwards on to the sensors and radiant heat shields to minimise radiant heating effects from the electric heat mats.

Type T thermocouples were also installed on poles in the room to determine whether there was a variation in room air temperature, for example due to stratification effects. Additional thermocouples were also attached on each wall at two heights and on the room side and outside surfaces. All of the temperature sensors were connected to an Anville Instruments Series 400 data acquisition system and Windows PC for displaying and recording the data at 30 second intervals. Prior to start of the tests all temperature sensors were calibrated by placing inside a small insulated wind tunnel with a calibrated reference instrument.

## 2.4 Test programme

Following initial testing and discussions with Fischer, the test schedule in Table 1 was modified as indicated in Table 4.

**Table 4 Revised test schedule for each heater type (x 5)**

| Test | Apartment temperature | Environmental chamber temperature | Time schedule | Duration |
|---|---|---|---|---|
| 1 | **21°C** | **5°C** | **24 hours**<br>**(steady state)** | **Approx. 48 hours** |
| 2 | **21°C**<br>**16°C** | **10°C**<br>**5°C** | **16 hours**<br>**8 hours** | **Approx. 72 hours** |

# 3 Test results

## 3.1 Principal test programme events

**Table 4** below details the dates of the principal stages of the project including the testing phases.

**Table 4 Dates of principal events in test programme**

| System | Description | Test | Test Dates |
|---|---|---|---|
| **1** | Fischer | Steady state | 16/12/16 to 19/12/16 |
| **1** | Fischer | Day / night operation | 09/12/16 to 12/12/16 |
| **2** | Fischer Premier | Steady state | 26/01/17 to 29/01/17 |
| **2** | Fischer Premier | Day / night operation | 01/02/17 to 04/02/17 |
| **3** | Premier storage heater | Steady state | 09/02/17 to 12/02/17 |
| **3** | Premier storage heater | Day / night operation | 14/02/17 to 17/02/17 |
| **4** | Standard storage heater | Steady state | 24/02/17 to 27/02/17 |
| **4** | Standard storage heater | Day / night operation | 01/03/07 to 04/03/17 |
| **5** | Gas central heating | Steady state | 11/05/2017 to 14/05/2017 |
| **5** | Gas central heating | Day / night operation | 17/05/07/ to 20/05/17 |

## 3.2 Test results – Steady state operation – Temperature control

These tests were carried out with the environmental chamber at a constant temperature of 5°C and the apartment at a constant temperature of 21°C. However System 3 and System 4 are both storage type heaters and by their very nature these heaters are not designed to maintain a constant temperature. Therefore, although the heaters were set for a temperature set point of 21°C, they actually fluctuated between ‘day’ and ‘night’ temperature values. There were no door openings programmed for the steady state test.

Charts summarising the principal measurements for the steady state operation tests are shown in Figure 3 to Figure 7. The charts show a selection of the room and chamber temperatures measured on the test rig. The test start and end times (for data collection) and key temperature parameters are summarised in Table 5 to Table 9.

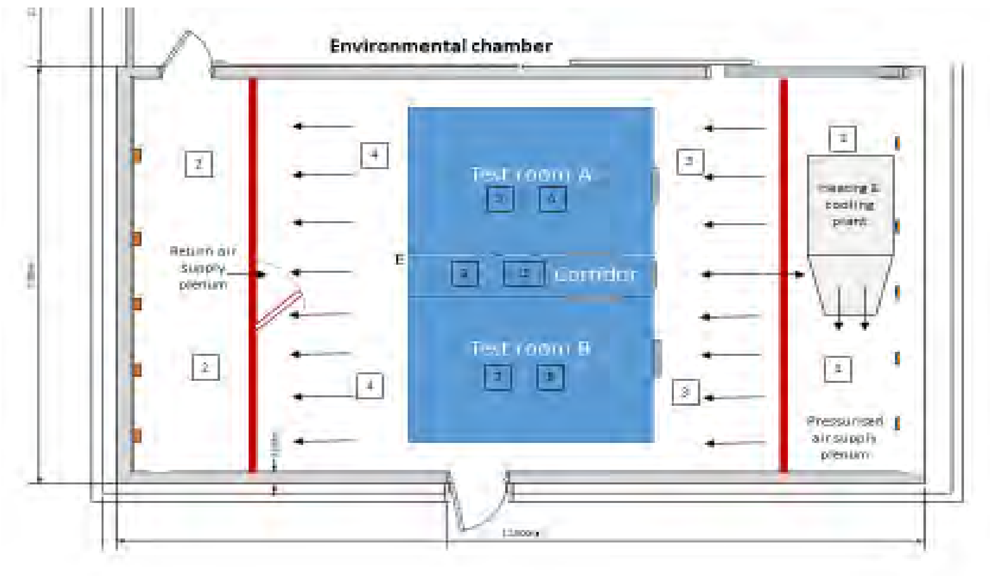



Figure 2: Test rig showing temperature locations

| Legend | Description | Ref |
|---|---|---|
| | | |
| Supply Plenum A & B | Air temperature in supply plenum before entering chamber measured at 4 points | **1** |
| Return Plenum A & B | Air temperature in return plenum after leaving chamber measured at 4 points | **2** |
| Chamber Supply A & B | Air temperature in chamber measured at 4 points before passing over apartment | **3** |
| Chamber return A & B | Air temperature in chamber measured at 4 points after passing over apartment | **4** |
| Room A Globe temperature | Globe temperature measured on pole in centre of room A | **5** |
| Room A Dry bulb temperature | Dry bulb temperature measured on pole in centre of room A | **6** |
| Room B Globe temperature | Globe temperature measured on pole in centre of room B | **7** |
| Room B Dry bulb temperature | Dry bulb temperature measured on pole in centre of room B | **8** |
| Corridor Globe temperature | Globe temperature measured on pole in centre of corridor | **9** |
| Corridor Dry bulb temperature | Dry bulb temperature measured on pole in centre of corridor | **10** |

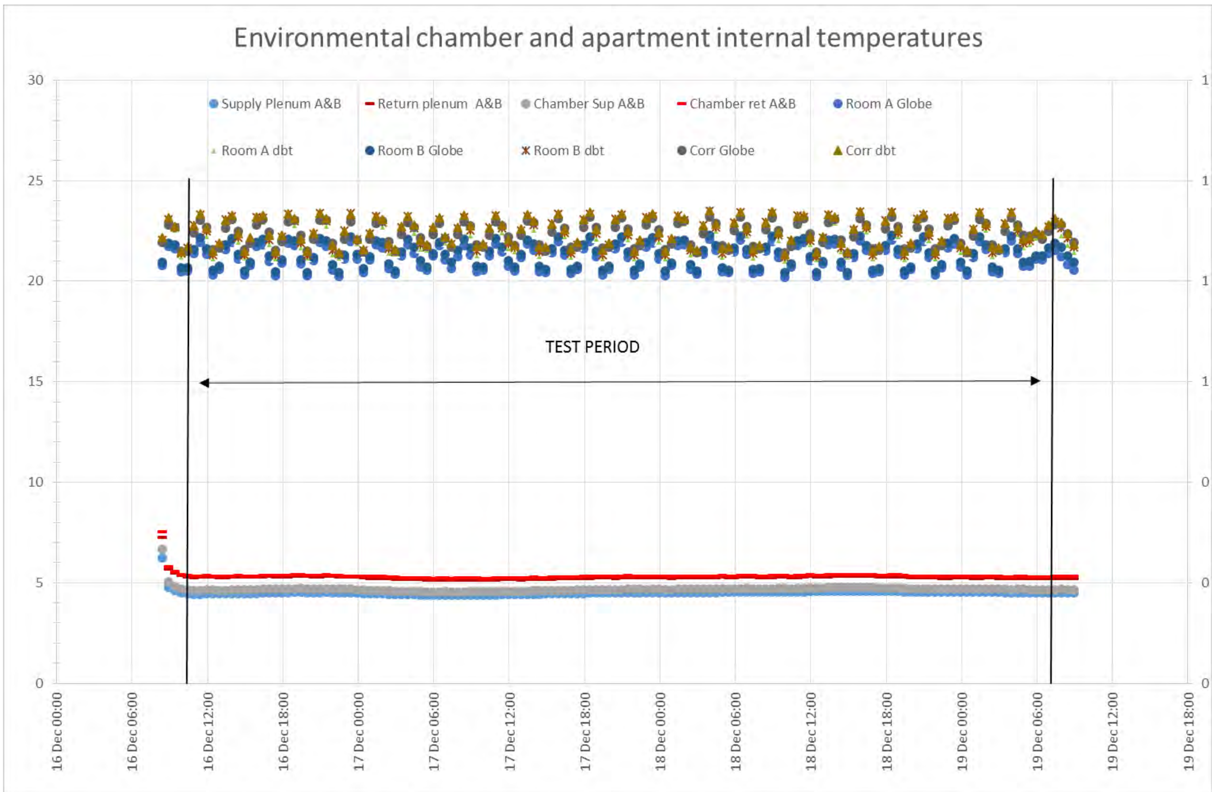



Figure 3: Steady state test temperatures for System 1

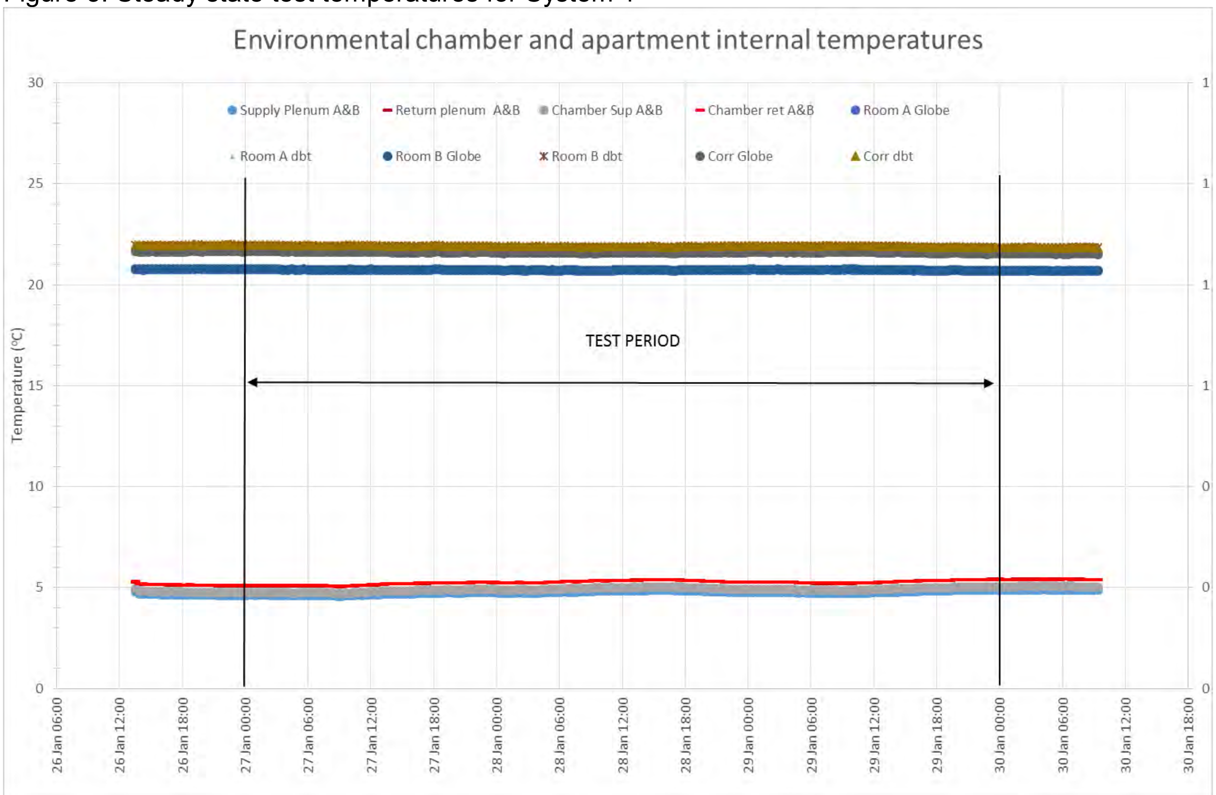



Figure 4: Steady state test temperatures for System 2

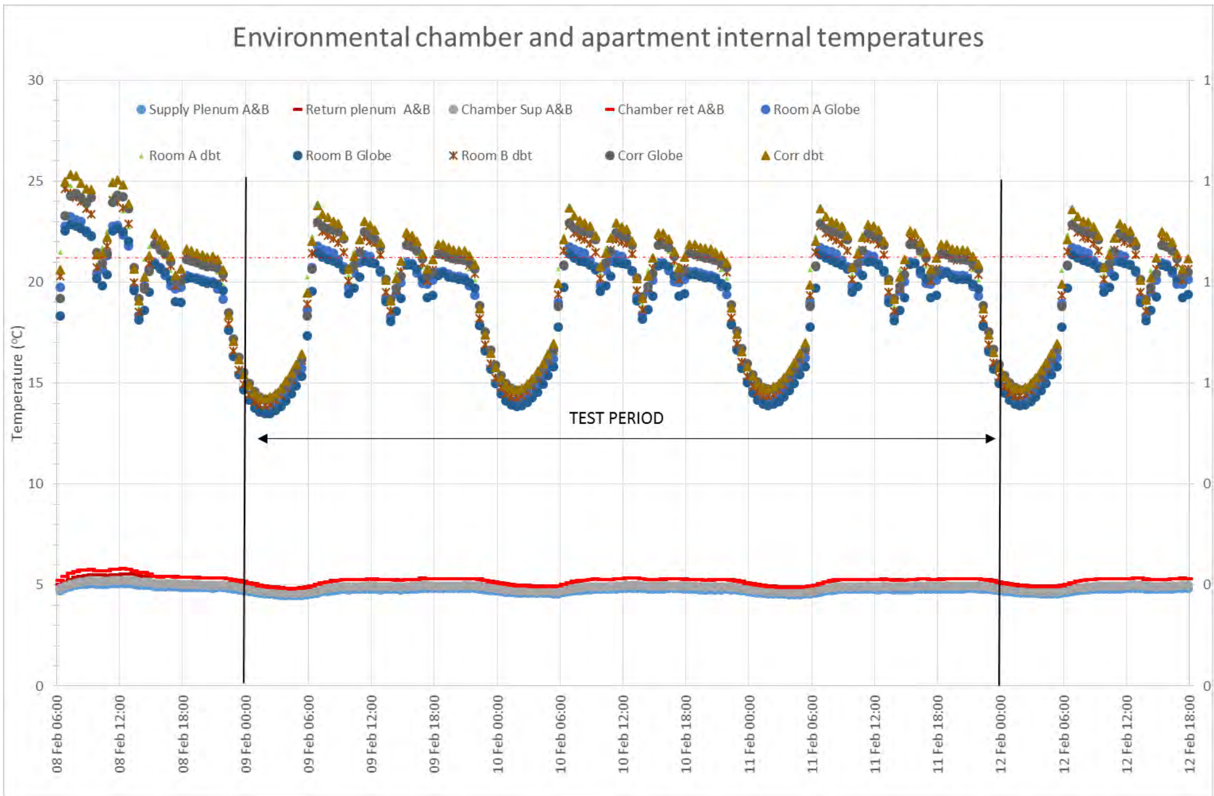



Figure 5: Steady state test temperatures for System 3

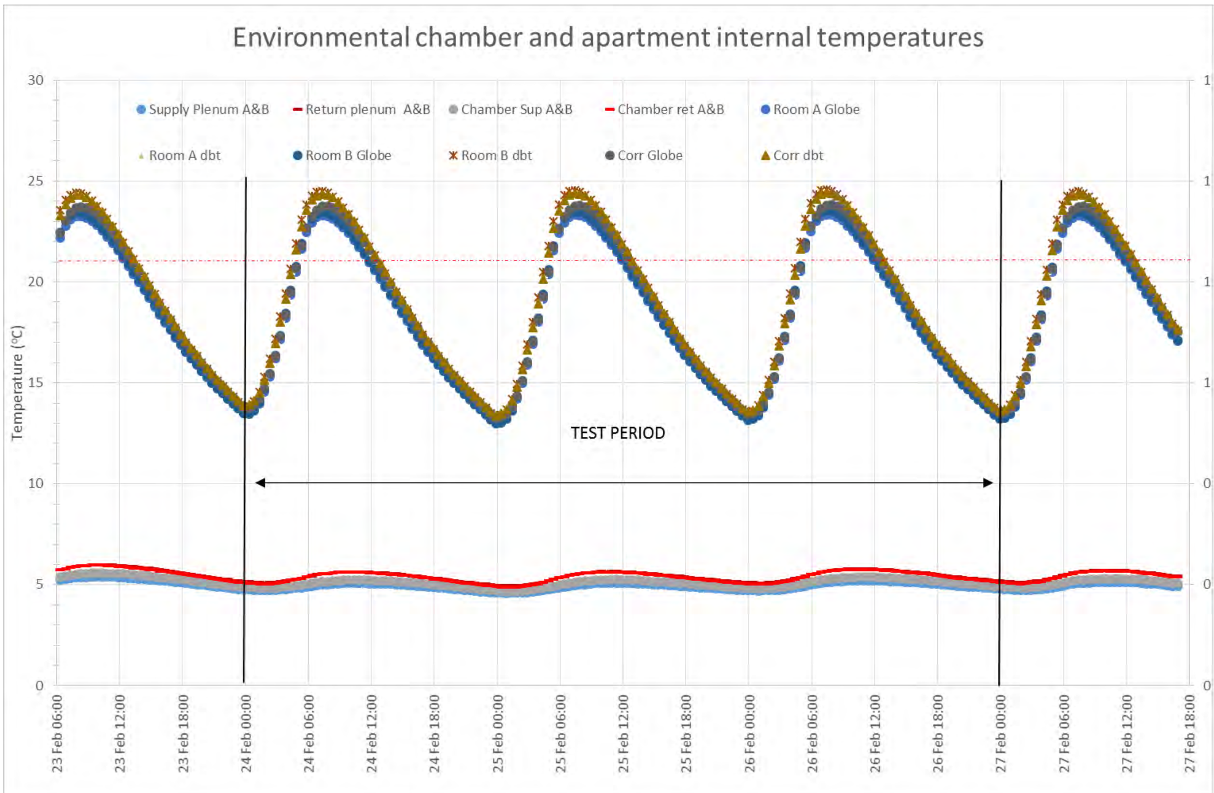



Figure 6: Steady state test temperatures for System 4

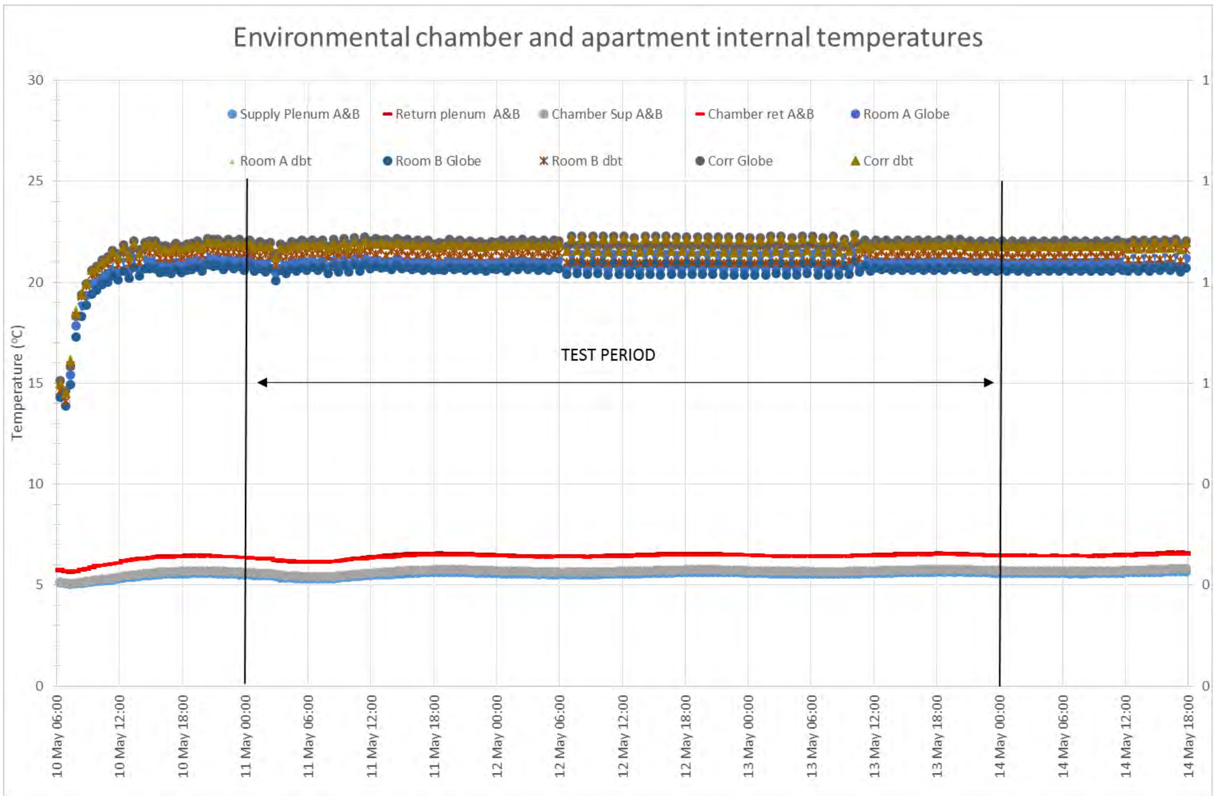



Figure 7: Steady state test temperatures for System 5

Table 5 System 1: Summary of temperatures over steady state test period

| SYSTEM 1 | Room A Dry bulb temp | Room B Dry bulb temp | Corridor Dry bulb temp | Room A Wall ext temp | Room A Wall int temp | Room B Wall int temp | Room A Average pole temp | Room B Average pole temp | Corridor Average pole temp | Chamber supply temp | Chamber return temp |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Mean T (°C)* | 22.21 | 22.36 | 22.46 | 7.74 | 18.08 | 17.94 | 22.32 | 23.13 | 22.76 | 4.49 | 5.33 |
| *Minimum (°C)* | 20.91 | 21.07 | 21.20 | 7.55 | 17.27 | 17.25 | 20.90 | 21.54 | 21.27 | 4.35 | 5.20 |
| *Maximum (°C)* | 23.47 | 23.62 | 23.62 | 8.35 | 18.91 | 18.65 | 23.74 | 24.74 | 24.03 | 4.90 | 5.93 |
| *Range (°C)* | 2.56 | 2.56 | 2.42 | 0.80 | 1.64 | 1.40 | 2.85 | 3.21 | 2.76 | 0.55 | 0.73 |
| *Median (°C)* | 22.24 | 22.39 | 22.50 | 7.74 | 18.10 | 17.95 | 22.37 | 23.13 | 22.88 | 4.50 | 5.33 |
| *Mode (°C)* | 23.11 | 23.49 | 21.37 | 7.73 | 17.37 | 18.52 | 23.32 | 24.42 | 23.73 | 4.52 | 5.32 |
| *Standard deviation* | 0.78 | 0.79 | 0.73 | 0.08 | 0.48 | 0.42 | 0.83 | 0.93 | 0.80 | 0.06 | 0.06 |

Table 6 System 2: Summary of temperatures over steady state test period

| SYSTEM 2 | Room A Dry bulb temp | Room B Dry bulb temp | Corridor Dry bulb temp | Room A Wall ext temp | Room A Wall int temp | Room B Wall int temp | Room A Average pole temp | Room B Average pole temp | Corridor Average pole temp | Chamber supply temp | Chamber return temp |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Mean T* | 21.82 | 21.92 | 21.91 | 7.83 | 17.95 | 17.42 | 22.22 | 22.47 | 22.02 | 4.73 | 5.24 |
| *Minimum* | 21.72 | 21.83 | 21.80 | 7.60 | 17.86 | 17.28 | 22.06 | 22.30 | 21.81 | 4.55 | 5.05 |
| *Maximum* | 21.91 | 22.03 | 22.05 | 8.02 | 18.04 | 17.96 | 22.39 | 22.96 | 22.32 | 4.89 | 5.42 |
| *Range* | 0.20 | 0.20 | 0.25 | 0.42 | 0.18 | 0.68 | 0.32 | 0.66 | 0.51 | 0.34 | 0.37 |
| *Median* | 21.82 | 21.92 | 21.91 | 7.86 | 17.95 | 17.42 | 22.22 | 22.47 | 22.02 | 4.75 | 5.25 |
| *Mode* | 21.84 | 21.92 | 21.92 | 7.88 | 17.96 | 17.42 | 22.21 | 22.45 | 22.02 | 4.75 | 5.11 |
| *Standard deviation* | 0.03 | 0.03 | 0.04 | 0.09 | 0.03 | 0.03 | 0.05 | 0.05 | 0.06 | 0.08 | 0.09 |

Table 7 System 3: Summary of temperatures over steady state test period

| SYSTEM 3 | Room A Dry bulb temp | Room B Dry bulb temp | Corridor Dry bulb temp | Room A Wall ext temp | Room A Wall int temp | Room B Wall int temp | Room A Average pole temp | Room B Average pole temp | Corridor Average pole temp | Chamber supply temp | Chamber return temp |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Mean T* | 19.62 | 19.35 | 19.87 | 7.44 | 16.06 | 15.52 | 19.72 | 19.53 | 19.21 | 4.73 | 5.17 |
| *Minimum* | 14.12 | 13.88 | 14.23 | 6.41 | 12.05 | 11.58 | 14.32 | 14.13 | 13.94 | 4.45 | 4.79 |
| *Maximum* | 23.82 | 23.79 | 24.35 | 7.98 | 18.34 | 17.80 | 24.89 | 24.29 | 24.19 | 4.88 | 5.38 |
| *Range* | 9.70 | 9.91 | 10.12 | 1.57 | 6.30 | 6.22 | 10.57 | 10.16 | 10.26 | 0.43 | 0.59 |
| *Median* | 20.96 | 20.59 | 21.18 | 7.72 | 17.13 | 16.60 | 20.95 | 20.62 | 20.30 | 4.78 | 5.26 |
| *Mode* | 14.13 | 20.93 | 21.55 | 7.79 | 17.29 | 17.24 | 22.08 | 22.06 | 20.68 | 4.79 | 5.26 |
| *Standard deviation* | 2.91 | 2.92 | 3.01 | 0.49 | 2.08 | 2.03 | 2.83 | 2.86 | 2.79 | 0.10 | 0.16 |

Table 8 System 4: Summary of temperatures over steady state test period

| SYSTEM 4 | Room A Dry bulb temp | Room B Dry bulb temp | Corridor Dry bulb temp | Room A Wall ext temp | Room A Wall int temp | Room B Wall int temp | Room A Average pole temp | Room B Average pole temp | Corridor Average pole temp | Chamber supply temp | Chamber return temp |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Mean T* | 18.86 | 18.90 | 18.85 | 7.51 | 15.65 | 15.20 | 19.14 | 19.30 | 18.31 | 4.91 | 5.36 |
| *Minimum* | 13.26 | 13.26 | 13.31 | 6.29 | 11.33 | 10.98 | 13.42 | 13.54 | 12.92 | 4.57 | 4.88 |
| *Maximum* | 24.54 | 24.60 | 24.45 | 8.66 | 19.94 | 19.44 | 24.83 | 25.17 | 23.68 | 5.21 | 5.77 |
| *Range* | 11.28 | 11.34 | 11.14 | 2.38 | 8.60 | 8.46 | 11.42 | 11.64 | 10.77 | 0.64 | 0.90 |
| *Median* | 18.56 | 18.62 | 18.58 | 7.50 | 15.46 | 15.01 | 18.84 | 19.02 | 18.09 | 4.92 | 5.37 |
| *Mode* | 24.50 | 13.80 | 24.36 | 8.47 | 19.85 | 19.30 | 16.05 | 25.03 | 23.52 | 5.06 | 5.06 |
| *Standard deviation* | 3.70 | 3.71 | 3.66 | 0.72 | 2.83 | 2.79 | 3.71 | 3.80 | 3.49 | 0.17 | 0.25 |

Table 9 System 5: Summary of temperatures over steady state test period

| SYSTEM 5 | Room A Dry bulb temp | Room B Dry bulb temp | Corridor Dry bulb temp | Room A Wall ext temp | Room A Wall int temp | Room B Wall int temp | Room A Average pole temp | Room B Average pole temp | Corridor Average pole temp | Chamber supply temp | Chamber return temp |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Mean T* | 21.59 | 21.39 | 21.81 | 8.73 | 17.94 | 17.12 | 22.16 | 21.68 | 22.45 | 5.55 | 6.42 |
| *Minimum* | 20.25 | 20.11 | 20.74 | 8.40 | 17.12 | 16.44 | 20.33 | 20.05 | 20.44 | 5.29 | 6.13 |
| *Maximum* | 22.41 | 22.17 | 22.40 | 9.09 | 18.54 | 17.54 | 23.39 | 22.70 | 24.07 | 5.85 | 6.56 |
| *Range* | 2.17 | 2.06 | 1.66 | 0.69 | 1.42 | 1.10 | 3.06 | 2.65 | 3.64 | 0.56 | 0.43 |
| *Median* | 21.71 | 21.47 | 21.86 | 8.75 | 18.01 | 17.16 | 22.33 | 21.83 | 22.66 | 5.56 | 6.44 |
| *Mode* | 22.20 | 21.94 | 22.22 | 8.76 | 18.17 | 17.26 | 22.68 | 22.09 | 22.87 | 5.60 | 6.43 |
| *Standard deviation* | 0.53 | 0.48 | 0.37 | 0.09 | 0.34 | 0.23 | 0.77 | 0.60 | 0.64 | 0.09 | 0.09 |

The above charts and tables demonstrate the different abilities of the various temperature control and heating systems to maintain a constant temperature within the apartment. The most precise temperature control is maintained by System 2 with a range of approximately ± 0.1°C around the control set point. Systems 2 and 5 utilised the same controller but with different heating systems (electric and gas) and this maintained a range of approximately ± 1.1°C around the control set point. Due to the inherent day/night operation of the storage heaters, Systems 3 and 4 operated with a temperature range of approximately +3°C and - 7°C around the control set point. The range of temperatures in the apartments for the different systems is shown comparatively for steady state operation in Figure 8.

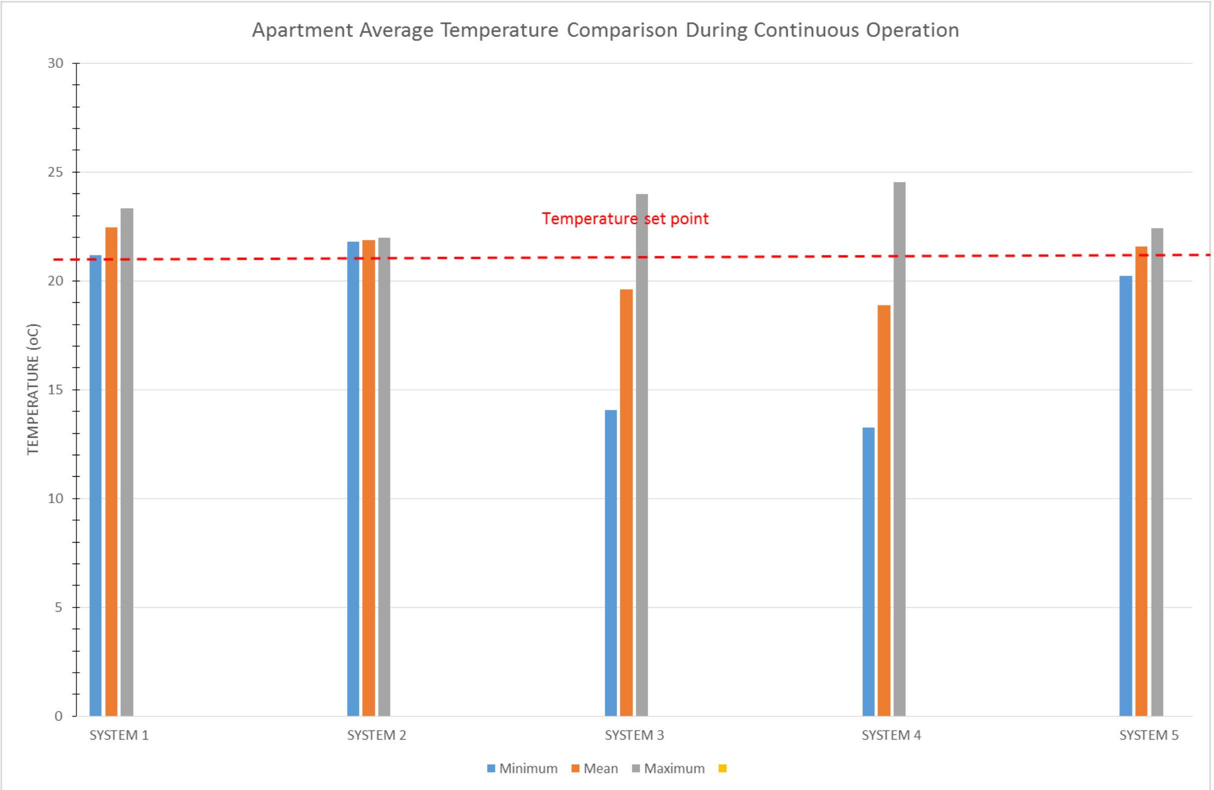



Figure 8: Apartment temperatures for steady state operation

## 3.3 Test results – Day/night operation – Temperature control

These tests were carried out with the environmental chamber running at a constant temperature of 10°C from 07:00 to 21:00 (day) and at 5°C from 21:00 to 07:00 (night). The apartment heating systems were also set for day/night operation with a temperature set point of 21°C during the day and 17°C during the night. The motorised damper was programmed to open once an hour during the day.

Charts summarising the principal measurements for the steady state operation tests are shown in Figure 9 to Figure 13. The charts show room and chamber temperatures. The test start and end times (for data collection) and key temperature parameters are summarised in Table 10 to Table 14.

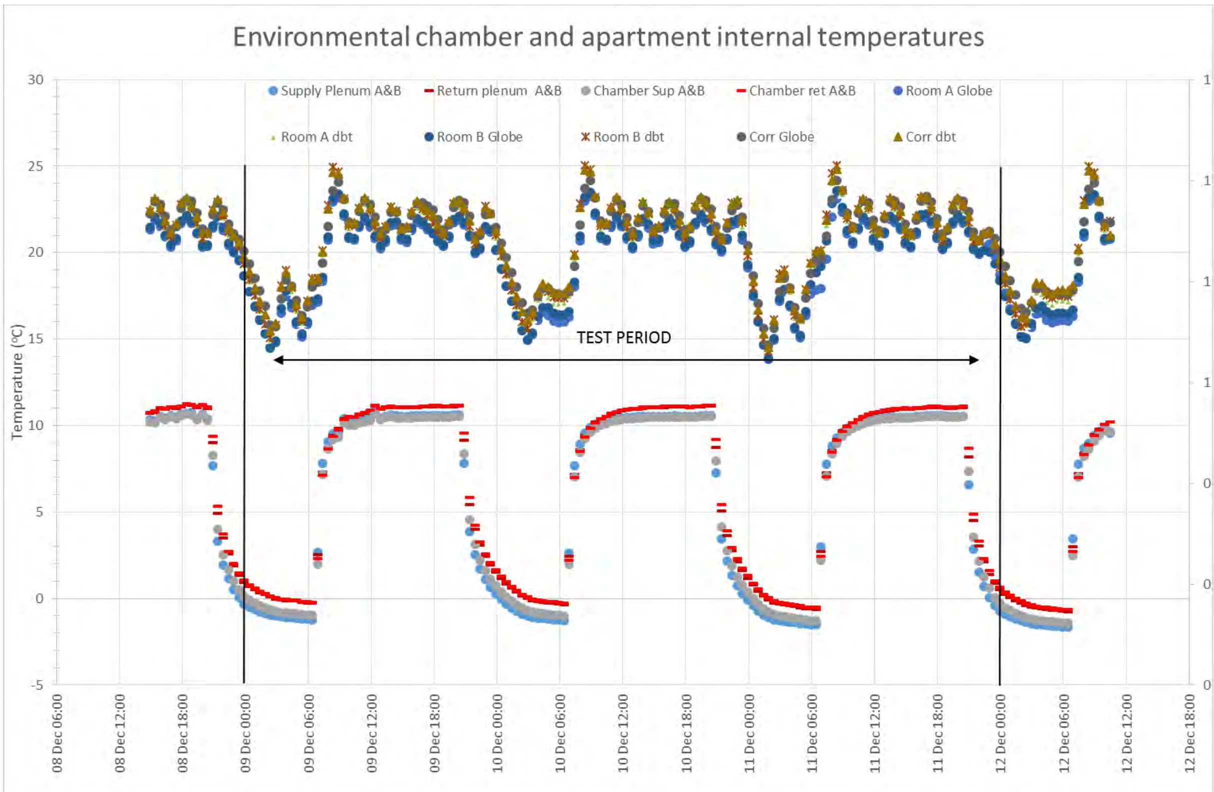



Figure 9: Day/night test temperatures for System 1

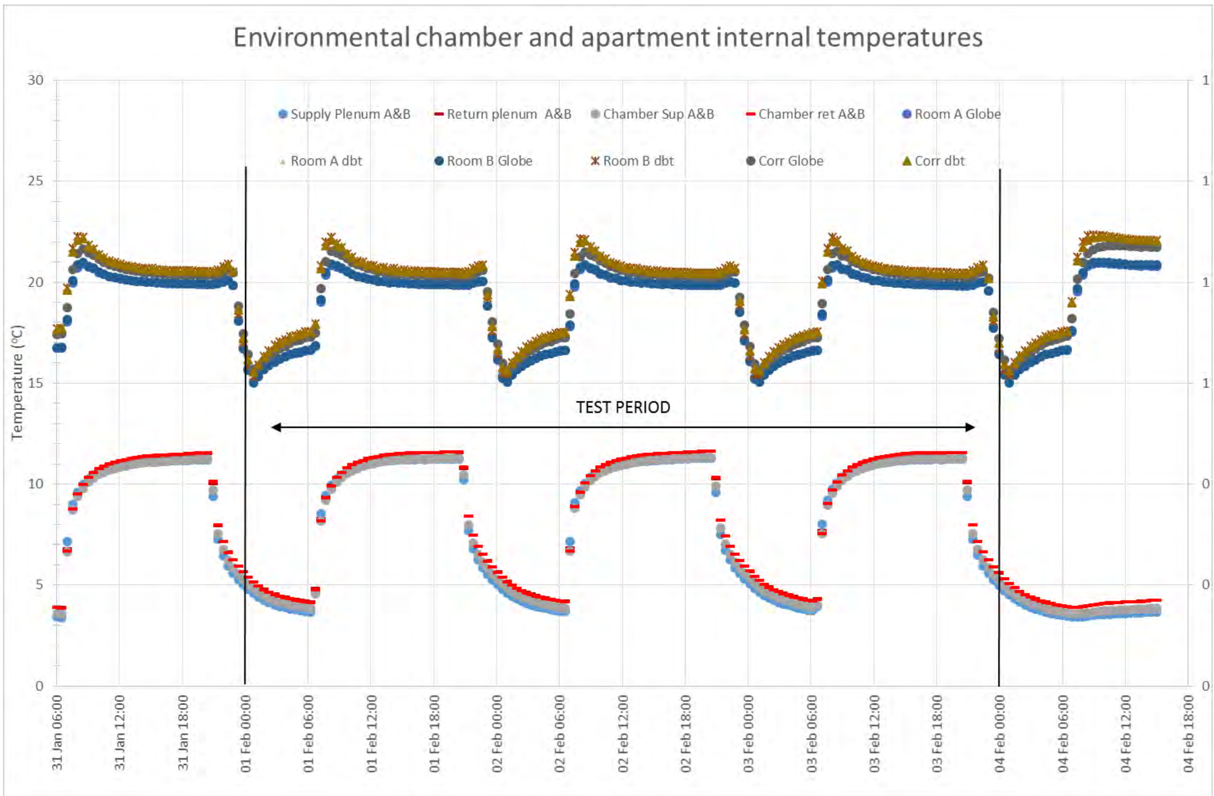



Figure 10: Day/night test temperatures for System 2

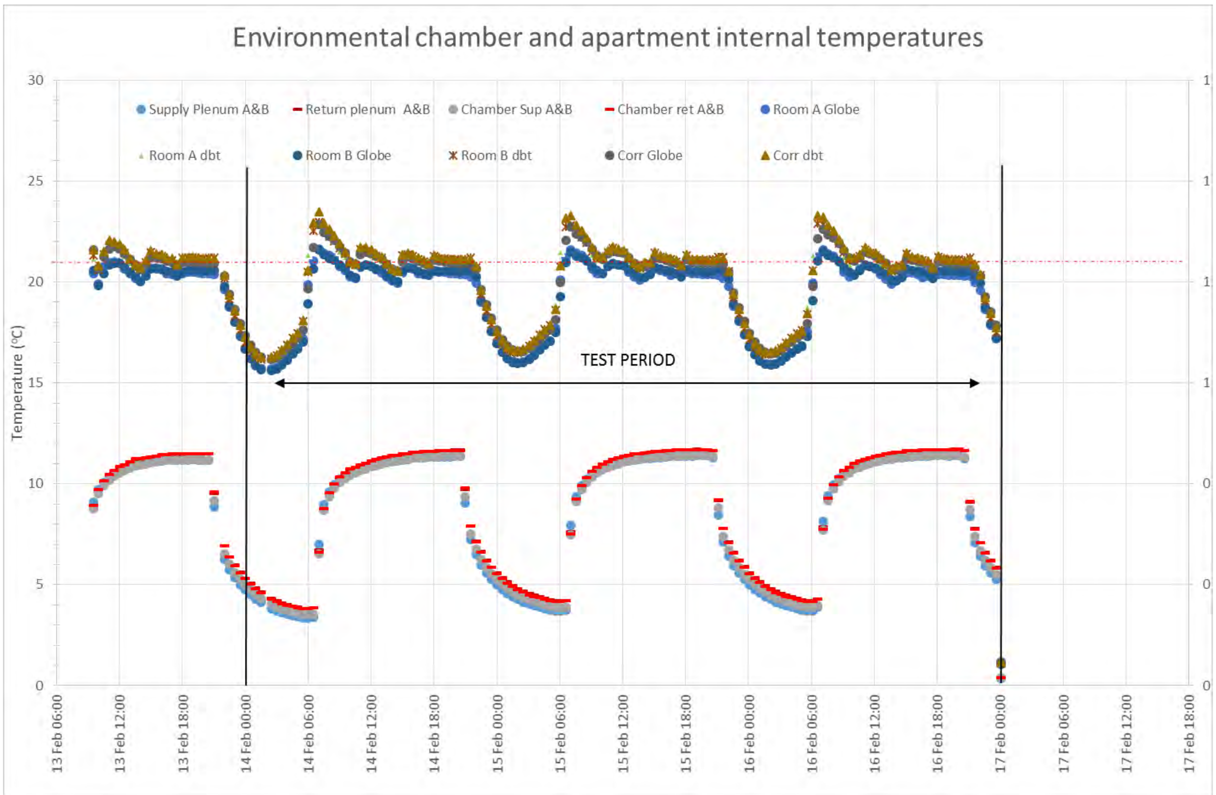



Figure 11 : Day/night test temperatures for System 3

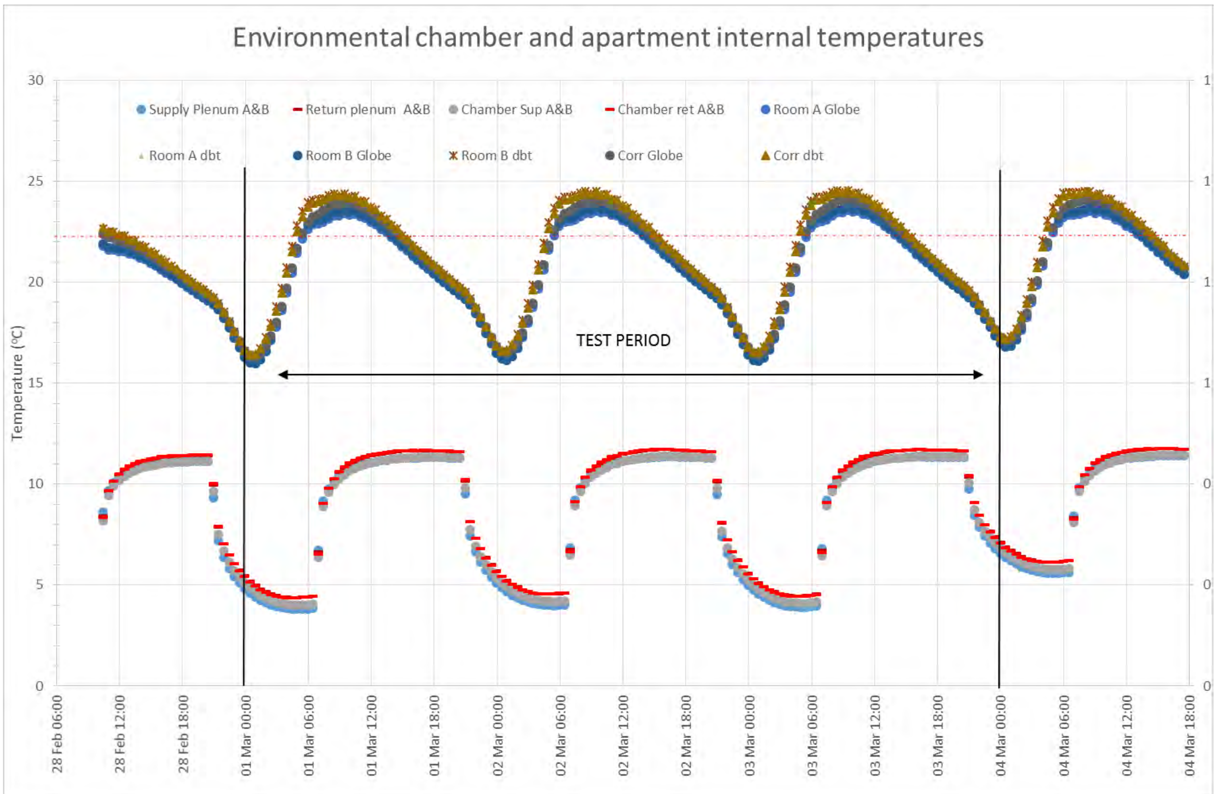



Figure 12: Day/night test temperatures for System 4

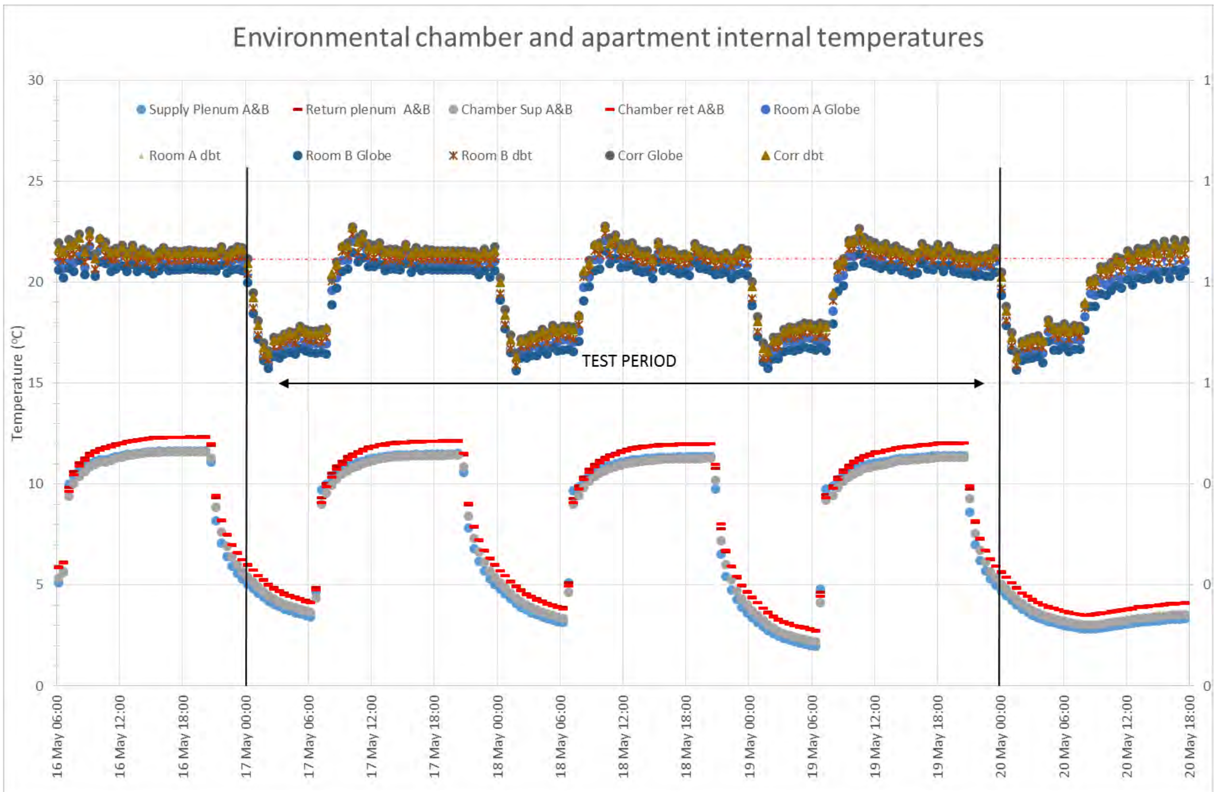



Figure 13: Day/night test temperatures for System 5

Table 10 System 1: Summary of temperatures over day/night test period

| SYSTEM 1 | | Room A Dry bulb temp | Room B Dry bulb temp | Corridor Dry bulb temp | Room A Wall ext temp | Room A Wall int temp | Room B Wall int temp | Room A Average pole temp | Room B Average pole temp | Corridor Average pole temp | Chamber supply temp | Chamber return temp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NIGHT | Mean T (°C) | 18.52 | 18.66 | 18.87 | 4.35 | 14.83 | 14.60 | 18.78 | 19.34 | 19.33 | -0.06 | 1.24 |
| | Minimum (°C) | 14.06 | 14.15 | 14.44 | 2.12 | 11.44 | 11.28 | 14.21 | 14.52 | 14.47 | -1.55 | -0.53 |
| | Maximum (°C) | 23.04 | 23.14 | 23.14 | 12.62 | 19.38 | 19.28 | 23.25 | 24.28 | 23.82 | 10.52 | 11.36 |
| | Range (°C) | 8.98 | 8.99 | 8.70 | 10.50 | 7.94 | 7.99 | 9.04 | 9.76 | 9.34 | 12.07 | 11.89 |
| | Median (°C) | 18.22 | 18.36 | 18.47 | 3.36 | 13.98 | 13.65 | 18.46 | 19.06 | 18.92 | -0.86 | 0.30 |
| | Mode (°C) | 17.75 | 21.13 | 17.68 | 2.48 | 12.82 | 13.06 | 18.81 | 21.35 | 17.20 | -1.21 | -0.20 |
| | Standard deviation | 2.26 | 2.25 | 2.20 | 2.39 | 2.34 | 2.31 | 2.26 | 2.32 | 2.24 | 1.87 | 2.18 |
| | | | | | | | | | | | | |
| DAY | Mean T (°C) | 22.03 | 22.18 | 22.29 | 11.56 | 18.66 | 18.53 | 22.20 | 22.83 | 22.67 | 10.08 | 10.40 |
| | Minimum (°C) | 17.25 | 17.53 | 17.83 | 2.29 | 12.94 | 13.04 | 17.34 | 18.36 | 18.22 | -1.42 | -0.48 |
| | Maximum (°C) | 25.19 | 25.44 | 25.19 | 12.76 | 19.82 | 19.63 | 25.94 | 26.60 | 25.02 | 11.13 | 11.34 |
| | Range (°C) | 7.94 | 7.91 | 7.36 | 10.47 | 6.88 | 6.59 | 8.61 | 8.24 | 6.80 | 12.55 | 11.82 |
| | Median (°C) | 22.12 | 22.24 | 22.39 | 12.42 | 18.97 | 18.81 | 22.28 | 22.84 | 22.87 | 10.50 | 11.00 |
| | Mode (°C) | 22.64 | 21.24 | 22.47 | 12.56 | 19.34 | 19.14 | 22.81 | 21.43 | 23.83 | 10.55 | 11.10 |
| | Standard deviation | 1.22 | 1.24 | 1.16 | 1.91 | 1.19 | 1.17 | 1.27 | 1.32 | 1.24 | 1.24 | 1.56 |

Table 11 System 2: Summary of temperatures over day/night test period

| SYSTEM 2 | | Room A Dry bulb temp | Room B Dry bulb temp | Corridor Dry bulb temp | Room A Wall ext temp | Room A Wall int temp | Room B Wall int temp | Room A Average pole temp | Room B Average pole temp | Corridor Average pole temp | Chamber supply temp | Chamber return temp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NIGHT | Mean T (°C) | 17.78 | 17.85 | 17.85 | 7.78 | 15.09 | 14.66 | 18.06 | 18.29 | 17.95 | 4.80 | 5.36 |
| | Minimum (°C) | 15.10 | 15.11 | 15.48 | 5.99 | 13.32 | 12.98 | 15.15 | 15.29 | 15.36 | 3.37 | 3.84 |
| | Maximum (°C) | 20.99 | 21.06 | 21.00 | 12.87 | 18.18 | 17.87 | 21.45 | 21.67 | 21.34 | 11.28 | 11.62 |
| | Range (°C) | 5.90 | 5.96 | 5.52 | 6.88 | 4.86 | 4.89 | 6.30 | 6.37 | 5.98 | 7.92 | 7.78 |
| | Median (°C) | 17.32 | 17.38 | 17.35 | 6.96 | 14.24 | 13.79 | 17.65 | 17.88 | 17.52 | 4.23 | 4.75 |
| | Mode (°C) | 17.54 | 17.55 | 17.50 | 6.41 | 18.08 | 13.36 | 17.88 | 18.06 | 17.73 | 3.67 | 4.18 |
| | Standard deviation | 1.72 | 1.72 | 1.68 | 1.72 | 1.68 | 1.70 | 1.70 | 1.73 | 1.68 | 1.42 | 1.51 |
| | | | | | | | | | | | | |
| DAY | Mean T (°C) | 20.79 | 20.86 | 20.81 | 12.11 | 18.02 | 17.65 | 21.14 | 21.39 | 20.83 | 10.75 | 10.98 |
| | Minimum (°C) | 17.47 | 17.54 | 17.51 | 6.01 | 14.28 | 13.84 | 18.03 | 18.19 | 17.80 | 3.37 | 3.84 |
| | Maximum (°C) | 22.21 | 22.40 | 22.22 | 12.92 | 18.42 | 18.03 | 23.06 | 23.08 | 22.21 | 11.31 | 11.66 |
| | Range (°C) | 4.74 | 4.86 | 4.71 | 6.91 | 4.14 | 4.19 | 5.03 | 4.89 | 4.41 | 7.95 | 7.82 |
| | Median (°C) | 20.61 | 20.66 | 20.62 | 12.67 | 18.16 | 17.82 | 20.90 | 21.15 | 20.68 | 11.10 | 11.41 |
| | Mode (°C) | 20.46 | 20.53 | 20.46 | 12.85 | 18.15 | 17.82 | 20.75 | 21.02 | 20.60 | 11.22 | 11.57 |
| | Standard deviation | 0.59 | 0.60 | 0.59 | 1.25 | 0.56 | 0.60 | 0.61 | 0.60 | 0.50 | 0.91 | 1.07 |

Table 12 System 3: Summary of temperatures over day/night test period

| SYSTEM 3 | | Room A Dry bulb temp | Room B Dry bulb temp | Corridor Dry bulb temp | Room A Wall ext temp | Room A Wall int temp | Room B Wall int temp | Room A Average pole temp | Room B Average pole temp | Corridor Average pole temp | Chamber supply temp | Chamber return temp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NIGHT | Mean T (°C) | 18.24 | 18.26 | 18.36 | 7.84 | 15.40 | 14.90 | 18.41 | 18.53 | 18.01 | 4.81 | 5.34 |
| | Minimum (°C) | 16.11 | 16.10 | 16.22 | 6.01 | 13.50 | 12.96 | 16.29 | 16.33 | 15.89 | 3.33 | 3.78 |
| | Maximum (°C) | 23.77 | 24.00 | 24.40 | 13.09 | 18.50 | 18.60 | 24.49 | 24.56 | 24.17 | 11.38 | 11.69 |
| | Range (°C) | 7.67 | 7.91 | 8.18 | 7.08 | 5.00 | 5.64 | 8.20 | 8.24 | 8.27 | 8.06 | 7.92 |
| | Median (°C) | 17.47 | 17.52 | 17.57 | 7.09 | 14.56 | 14.08 | 17.70 | 17.90 | 17.28 | 4.26 | 4.75 |
| | Mode (°C) | 16.50 | 16.48 | 16.60 | 6.48 | 14.02 | 13.43 | 16.69 | 16.78 | 16.37 | 3.69 | 4.15 |
| | Standard deviation | 1.93 | 1.93 | 1.93 | 1.72 | 1.61 | 1.69 | 1.91 | 1.89 | 1.83 | 1.45 | 1.53 |
| | | | | | | | | | | | | |
| DAY | Mean T (°C) | 21.24 | 21.33 | 21.44 | 12.32 | 18.37 | 18.01 | 21.29 | 21.56 | 21.02 | 10.84 | 11.05 |
| | Minimum (°C) | 20.11 | 20.23 | 20.34 | 6.40 | 17.62 | 16.76 | 20.00 | 20.43 | 19.62 | 3.37 | 3.84 |
| | Maximum (°C) | 23.40 | 23.49 | 24.11 | 13.12 | 19.08 | 18.82 | 23.73 | 23.88 | 23.48 | 11.40 | 11.72 |
| | Range (°C) | 3.29 | 3.26 | 3.77 | 6.72 | 1.46 | 2.07 | 3.73 | 3.45 | 3.86 | 8.04 | 7.88 |
| | Median (°C) | 21.06 | 21.20 | 21.25 | 12.84 | 18.41 | 18.12 | 21.11 | 21.45 | 20.90 | 11.19 | 11.48 |
| | Mode (°C) | 20.83 | 21.16 | 21.07 | 13.05 | 18.36 | 18.15 | 21.06 | 21.57 | 20.68 | 11.38 | 11.69 |
| | Standard deviation | 0.61 | 0.58 | 0.66 | 1.17 | 0.24 | 0.35 | 0.65 | 0.57 | 0.55 | 0.93 | 1.07 |

Table 13 System 4: Summary of temperatures over day/night test period

| SYSTEM 4 | | Room A Dry bulb temp | Room B Dry bulb temp | Corridor Dry bulb temp | Room A Wall ext temp | Room A Wall int temp | Room B Wall int temp | Room A Average pole temp | Room B Average pole temp | Corridor Average pole temp | Chamber supply temp | Chamber return temp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NIGHT | Mean T (°C) | 19.46 | 19.49 | 19.40 | 8.10 | 16.36 | 15.88 | 19.83 | 19.94 | 18.92 | 5.04 | 5.61 |
| | Minimum (°C) | 16.36 | 16.34 | 16.37 | 6.67 | 14.04 | 13.56 | 16.65 | 16.64 | 16.00 | 3.80 | 4.35 |
| | Maximum (°C) | 24.22 | 24.25 | 24.12 | 12.97 | 19.48 | 18.96 | 24.52 | 24.81 | 23.40 | 11.32 | 11.63 |
| | Range (°C) | 7.86 | 7.91 | 7.75 | 6.30 | 5.43 | 5.40 | 7.87 | 8.18 | 7.39 | 7.52 | 7.28 |
| | Median (°C) | 18.81 | 18.83 | 18.77 | 7.34 | 16.21 | 15.73 | 19.12 | 19.15 | 18.37 | 4.29 | 4.80 |
| | Mode (°C) | 16.48 | 16.56 | 16.51 | 7.04 | 14.26 | 13.72 | 16.95 | 16.90 | 16.27 | 3.91 | 4.44 |
| | Standard deviation | 2.54 | 2.56 | 2.46 | 1.59 | 1.67 | 1.66 | 2.60 | 2.69 | 2.32 | 1.55 | 1.59 |
| | | | | | | | | | | | | |
| DAY | Mean T (°C) | 22.63 | 22.66 | 22.66 | 12.72 | 19.66 | 19.28 | 22.80 | 23.01 | 22.19 | 10.88 | 11.17 |
| | Minimum (°C) | 19.58 | 19.59 | 19.63 | 7.43 | 17.65 | 17.31 | 19.76 | 19.77 | 19.27 | 3.87 | 4.45 |
| | Maximum (°C) | 24.57 | 24.61 | 24.59 | 13.39 | 20.93 | 20.51 | 24.80 | 25.11 | 24.04 | 11.39 | 11.77 |
| | Range (°C) | 4.99 | 5.02 | 4.96 | 5.97 | 3.28 | 3.20 | 5.04 | 5.34 | 4.77 | 7.53 | 7.33 |
| | Median (°C) | 23.02 | 23.06 | 23.07 | 13.12 | 19.84 | 19.44 | 23.15 | 23.40 | 22.50 | 11.25 | 11.61 |
| | Mode (°C) | 24.34 | 24.23 | 24.24 | 13.34 | 20.69 | 20.31 | 24.55 | 24.76 | 23.83 | 11.32 | 11.68 |
| | Standard deviation | 1.59 | 1.60 | 1.56 | 1.03 | 0.95 | 0.93 | 1.61 | 1.69 | 1.46 | 0.87 | 1.01 |

Table 14 System 5: Summary of temperatures over day/night test period

| SYSTEM 5 | | Room A Dry bulb temp | Room B Dry bulb temp | Corridor Dry bulb temp | Room A Wall ext temp | Room A Wall int temp | Room B Wall int temp | Room A Average pole temp | Room B Average pole temp | Corridor Average pole temp | Chamber supply temp | Chamber return temp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NIGHT | Mean T (°C) | 18.74 | 18.49 | 18.86 | 7.80 | 15.87 | 15.04 | 19.19 | 18.61 | 19.19 | 4.26 | 5.16 |
| | Minimum (°C) | 15.59 | 15.54 | 15.98 | 5.17 | 13.43 | 12.86 | 15.57 | 15.39 | 15.79 | 1.93 | 2.68 |
| | Maximum (°C) | 21.94 | 21.59 | 21.89 | 13.37 | 19.15 | 18.39 | 22.85 | 22.01 | 22.90 | 11.52 | 12.12 |
| | Range (°C) | 6.35 | 6.06 | 5.91 | 8.20 | 5.72 | 5.53 | 7.28 | 6.62 | 7.11 | 9.59 | 9.45 |
| | Median (°C) | 17.77 | 17.48 | 17.80 | 7.21 | 14.58 | 13.71 | 18.47 | 17.76 | 18.46 | 3.86 | 4.70 |
| | Mode (°C) | 17.79 | 21.21 | 17.32 | 5.41 | 14.52 | 13.43 | 18.28 | 17.67 | 18.58 | 3.46 | 4.39 |
| | Standard deviation | 1.94 | 1.91 | 1.90 | 1.91 | 1.93 | 1.92 | 2.00 | 1.94 | 1.97 | 1.66 | 1.81 |
| | | | | | | | | | | | | |
| DAY | Mean T (°C) | 21.15 | 20.86 | 21.24 | 12.43 | 18.38 | 17.59 | 21.63 | 21.04 | 21.71 | 10.98 | 11.39 |
| | Minimum (°C) | 16.27 | 16.07 | 16.66 | 5.26 | 13.77 | 13.02 | 16.28 | 15.93 | 16.38 | 1.96 | 2.68 |
| | Maximum (°C) | 23.02 | 22.70 | 22.95 | 13.43 | 19.69 | 18.94 | 23.98 | 23.11 | 24.07 | 11.54 | 12.15 |
| | Range (°C) | 6.75 | 6.63 | 6.29 | 8.17 | 5.92 | 5.92 | 7.70 | 7.19 | 7.69 | 9.59 | 9.47 |
| | Median (°C) | 21.41 | 21.15 | 21.52 | 13.07 | 18.86 | 18.15 | 21.84 | 21.30 | 21.92 | 11.28 | 11.83 |
| | Mode (°C) | 21.43 | 21.21 | 21.61 | 13.20 | 18.79 | 18.32 | 22.10 | 21.43 | 22.22 | 11.35 | 11.94 |
| | Standard deviation | 1.17 | 1.17 | 1.14 | 1.38 | 1.30 | 1.37 | 1.20 | 1.18 | 1.20 | 0.85 | 1.13 |

The above charts and tables demonstrate the different abilities of the various temperature control and heating systems to maintain a constant temperature within the apartment during day/night operation. The change in external temperature results in less precise temperature control with a range of between 3°C and 9°C around the control set point. In this scenario the day/night operation of the storage heaters was not a disadvantage. The frequency of the average temperatures in the apartments over half hour intervals is shown in Figures 13 to 17.

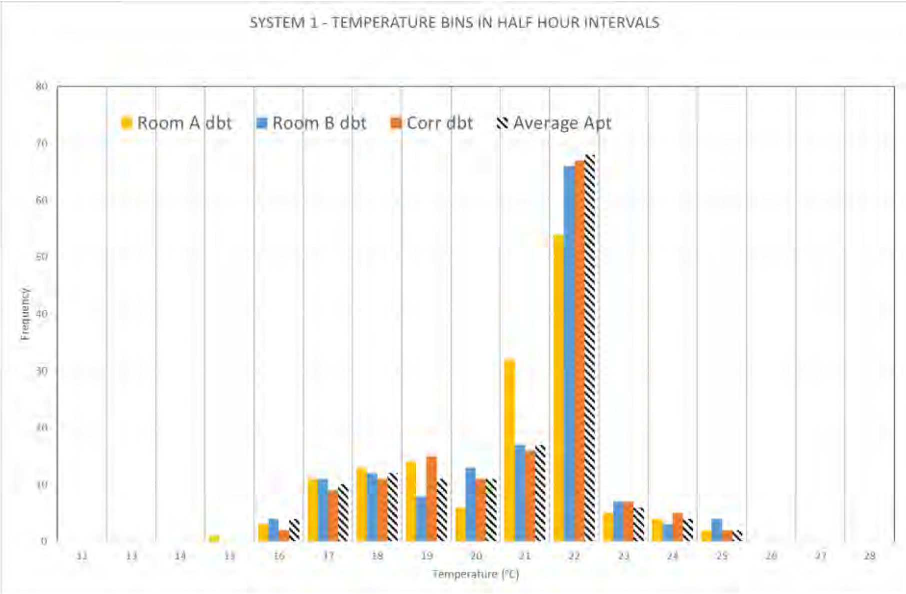



Figure 14: Temperature distribution for System 1 day/night operation

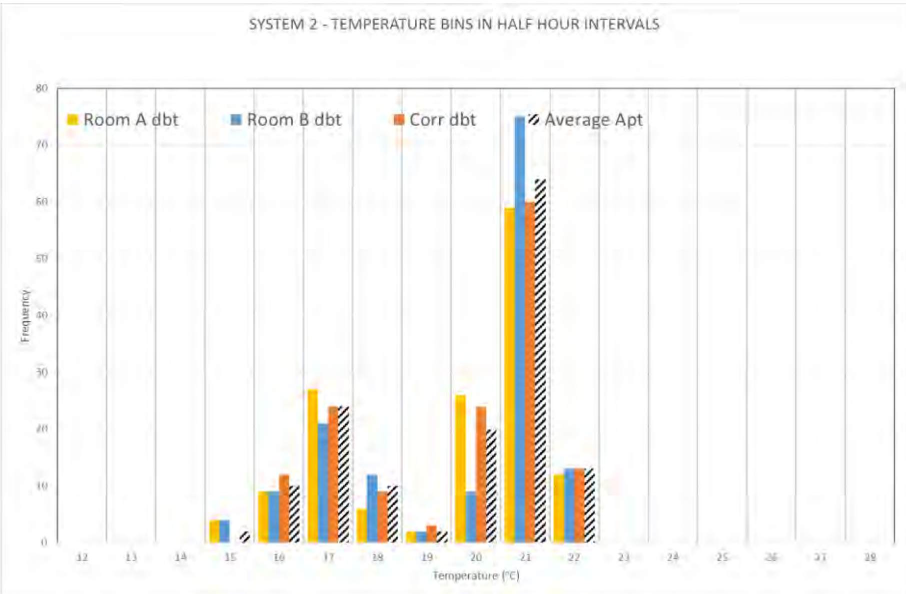



Figure 15: Temperature distribution for System 2 day/night operation

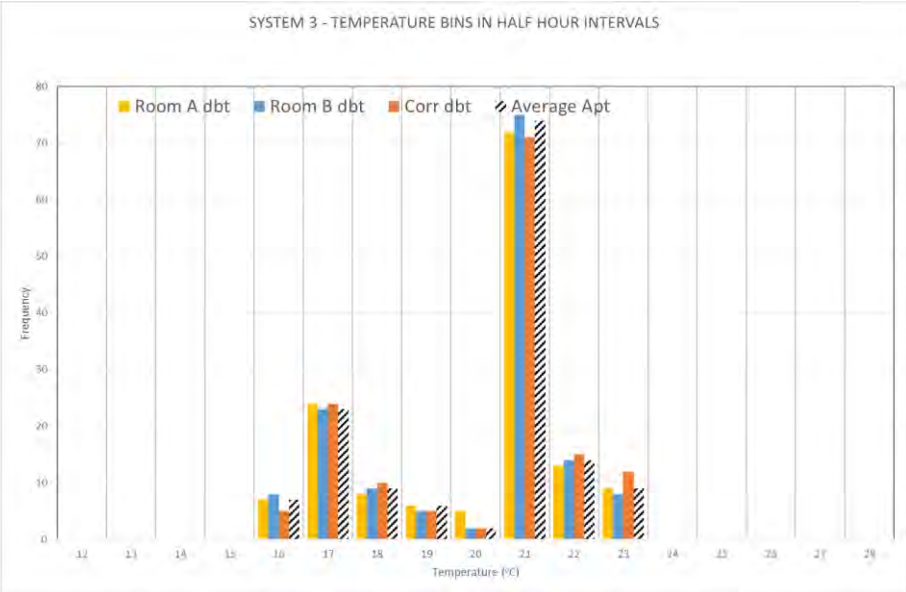



Figure 16: Temperature distribution for System 3 day/night operation

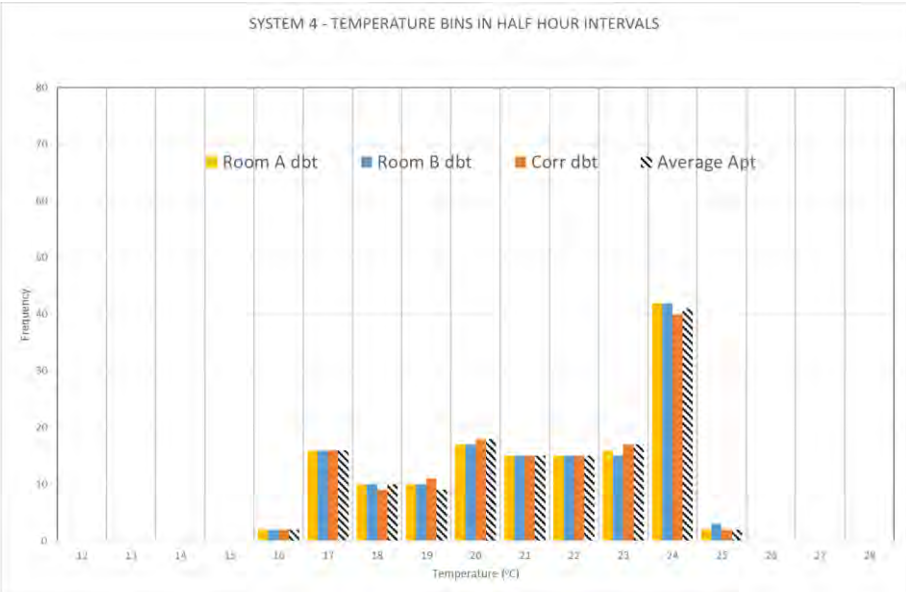



Figure 17: Temperature distribution for System 4 day/night operation

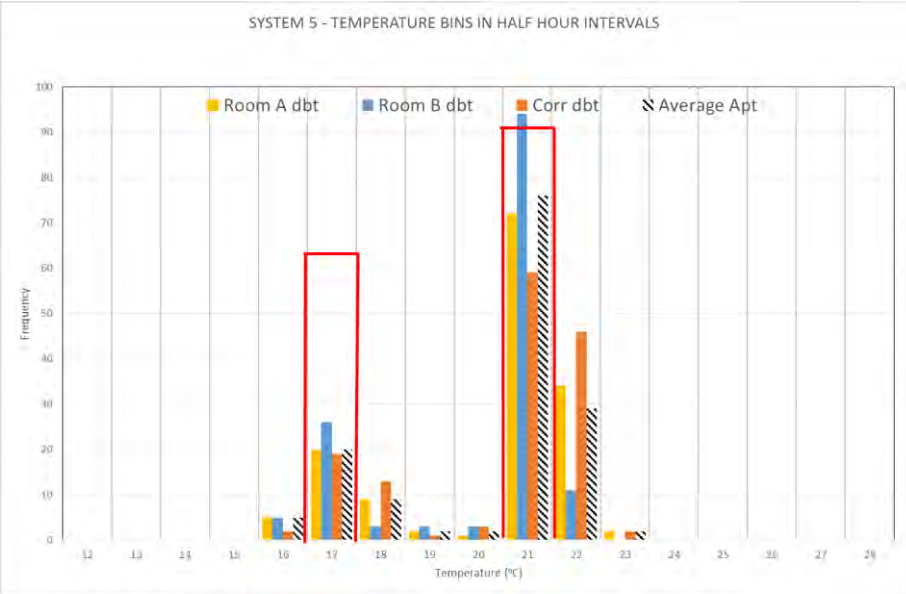



Figure 18: Temperature distribution for System 5 day/night operation

## 3.4 Test results – Power input to the heating systems

During the tests the electrical power input to the heaters in Systems 1 to 4 was measured and recorded, as was the gas supply to System 5.

Charts summarising the principal measurements for the steady state tests are shown in Figure 19 to Figure 22, while similar charts for the unsteady state (day/night operation) are shown in Figure 23 to Figure 26. The combined results are shown in Figure 27 to Figure 30.

The charts demonstrate two separate trends in power consumption, one for the electric heaters, Systems 1 to 4, and one for the gas central heating, System 5.

The data for the charts is presented in Table 15 and Table 16.

The different temperature distribution in the apartment arising from the different control strategies applied by the various heating systems does not permit direct comparison of the test results in a meaningful manner. Hence in order to provide a precise comparison of the power input to the apartment over the different test periods, the values of the power are normalised by dividing the power by the temperature difference between the interior and the exterior of the apartment, over the test period.

Table 15: Power and temperature data for steady state operation

| System number | Apartment temperature | External temperature | Delta T | Energy | Average Power | Average Power/Delta T |
|---|---|---|---|---|---|---|
| | (°C) | (°C) | (°C) | (kWh) | (W) | (W/°C) |
| | | | | | | |
| **1** | 22.75 | 4.89 | 16.91 | 93.91 | 1293.80 | 72.43 |
| **2** | 21.89 | 4.97 | 16.91 | 88.32 | 1226.66 | 72.53 |
| **3** | 19.61 | 4.96 | 14.66 | 76.06 | 1056.42 | 72.07 |
| **4** | 18.87 | 5.15 | 13.72 | 70.07 | 973.25 | 70.92 |
| **5** | 21.60 | 6.00 | 15.59 | 122.84 | 1706.08 | 109.40 |

Table 16: Power and temperature data for unsteady state operation

| System number | Apartment temperature | External temperature | Delta T | Cumulative Power | Average Power | Average Power/Delta T |
|---|---|---|---|---|---|---|
| | (°C) | (°C) | (°C) | (kWh) | (W) | (W/°C) |
| | | | | | | |
| **1** | 21.14 | 6.01 | 15.12 | 77.04 | 1070.03 | 70.75 |
| **2** | 19.54 | 8.43 | 11.11 | 55.39 | 769.27 | 69.25 |
| **3** | 20.06 | 8.51 | 11.56 | 57.47 | 798.15 | 69.06 |
| **4** | 21.31 | 8.64 | 12.67 | 65.94 | 915.90 | 72.29 |
| **5** | 20.08 | 8.50 | 11.59 | 88.79 | 1233.22 | 106.42 |

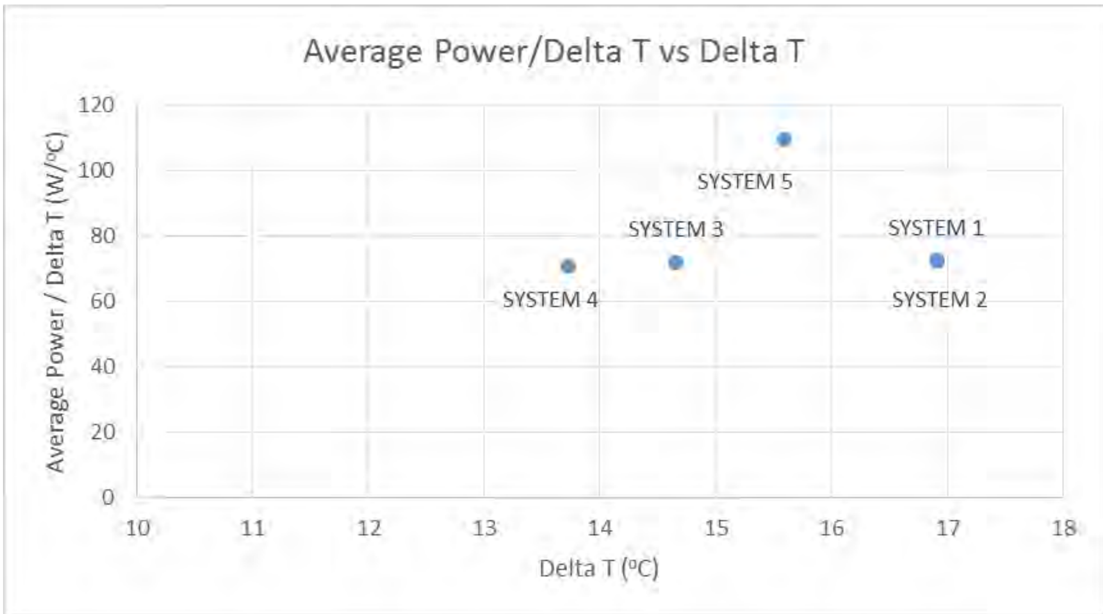



Figure 19: Steady State Average Power/Delta T vs Delta T

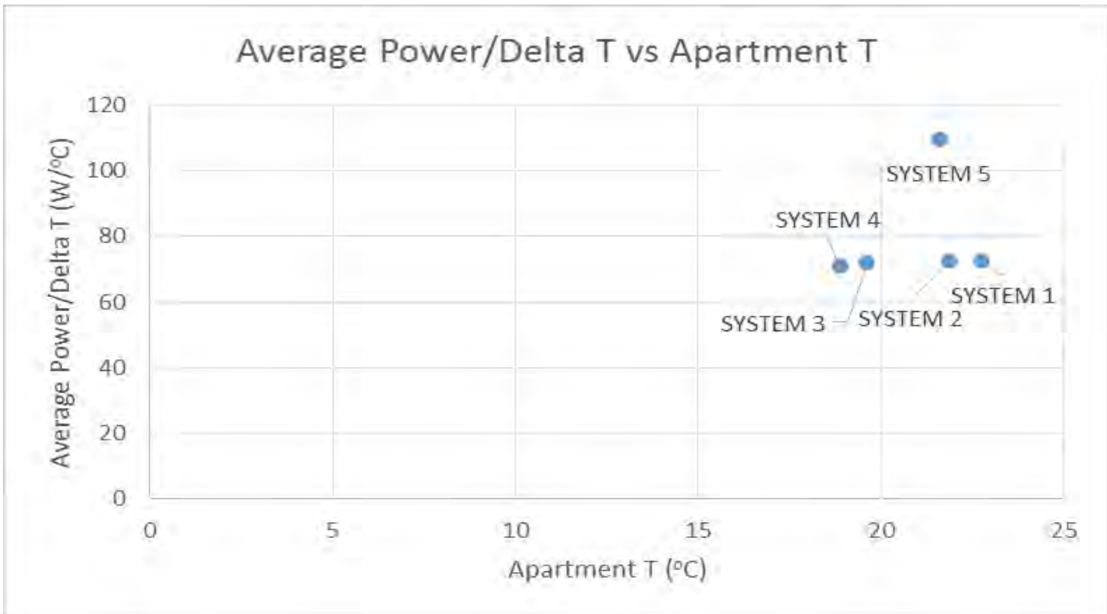



Figure 20: Steady State Average Power/Delta T vs Apartment T

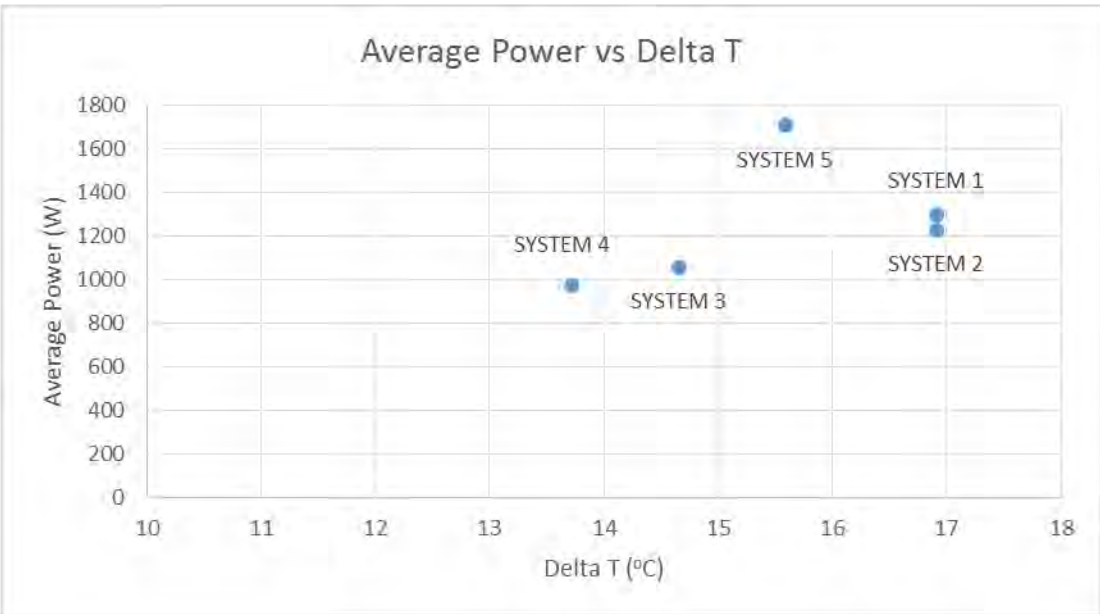



Figure 21: Steady State Average Power vs Delta T

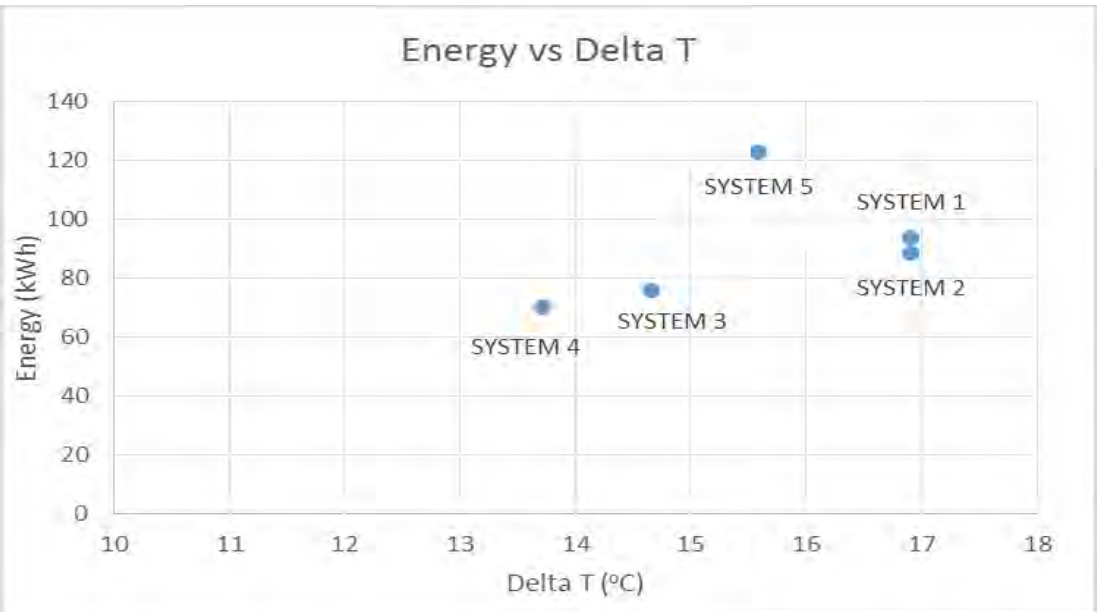



Figure 22: Steady State Energy vs Delta T

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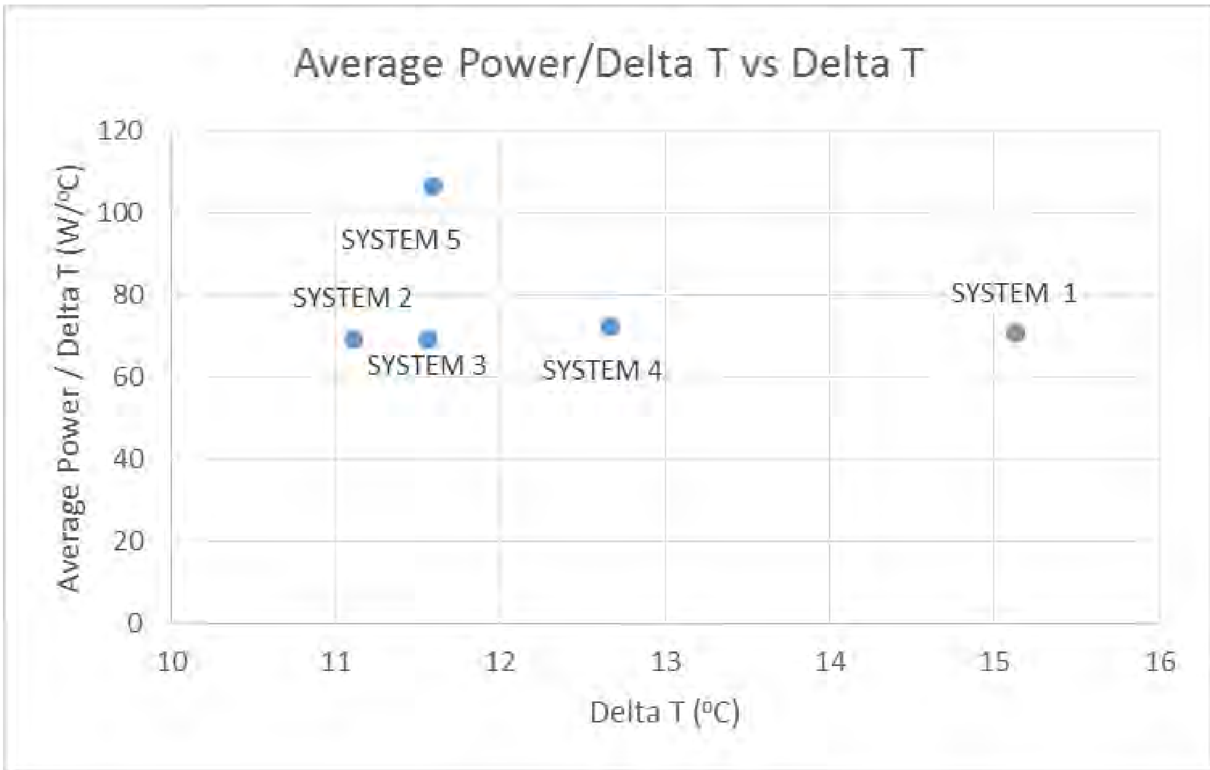


Figure 23: Unsteady State Average Power/Delta T vs Delta T

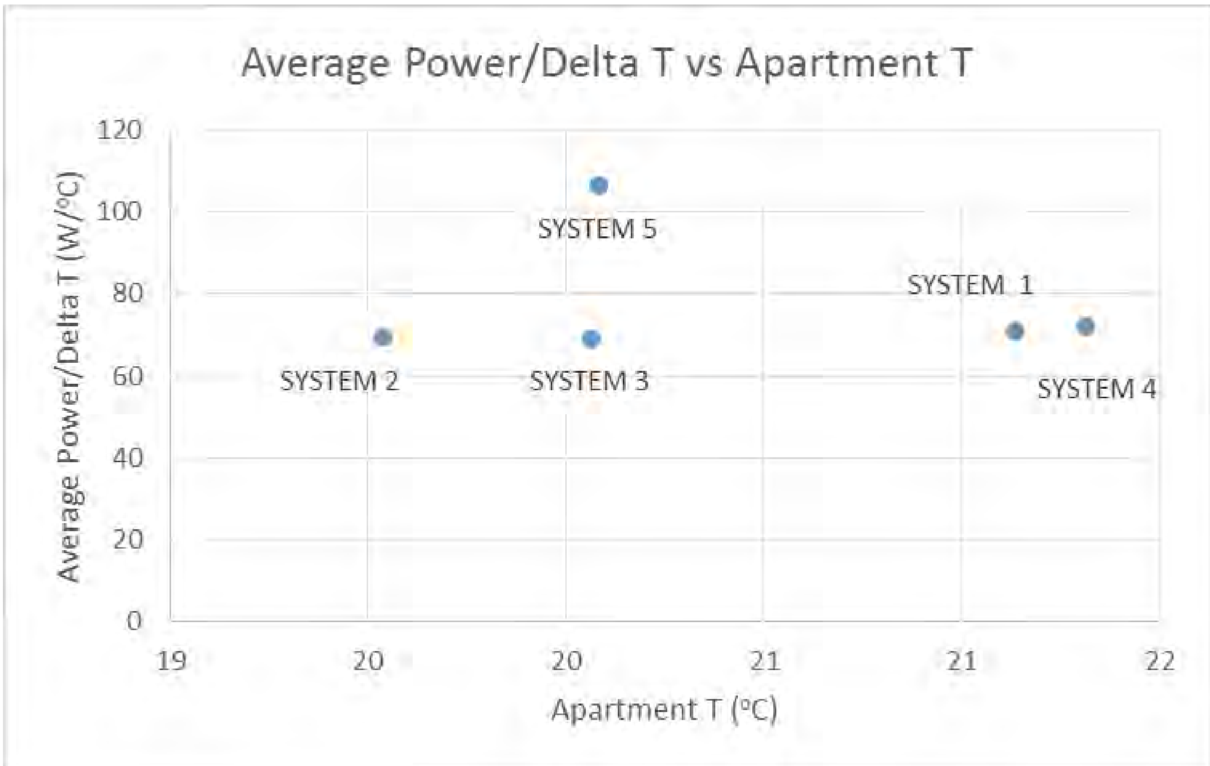


Figure 24: Unsteady State Average Power/Delta T vs Apartment T

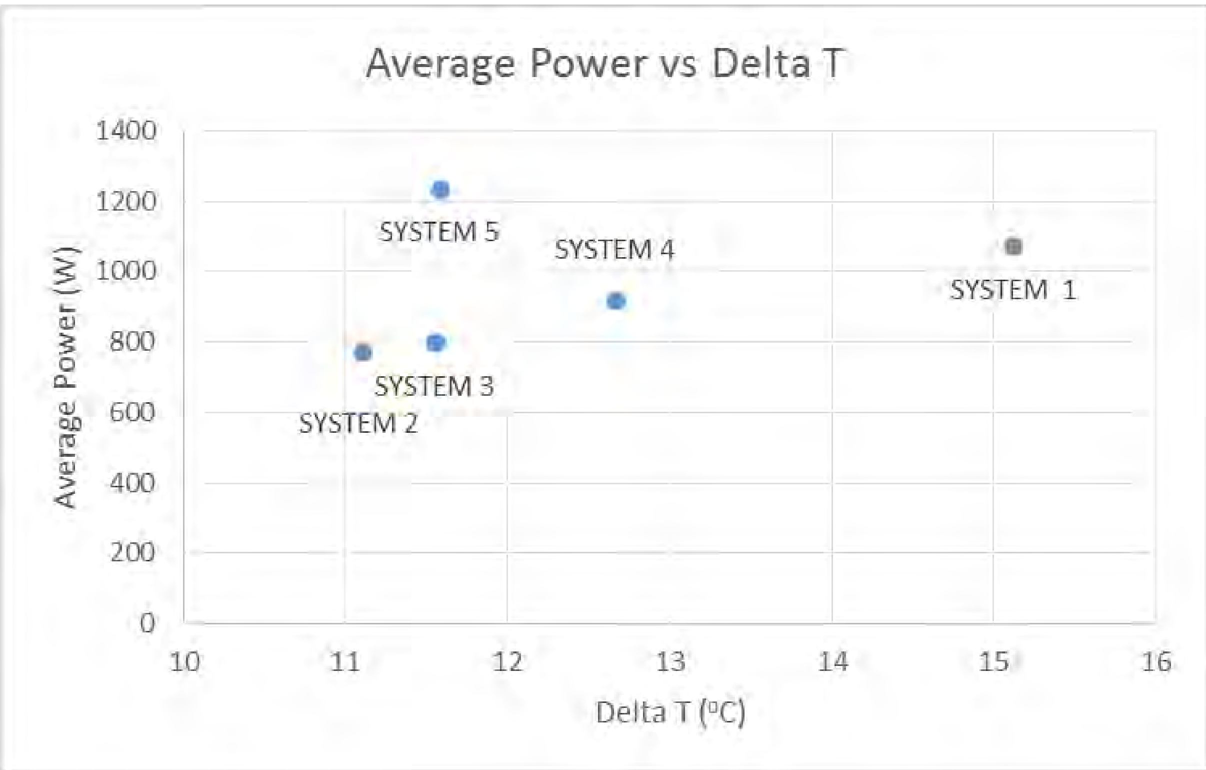


Figure 25: Unsteady State Average Power vs Delta T

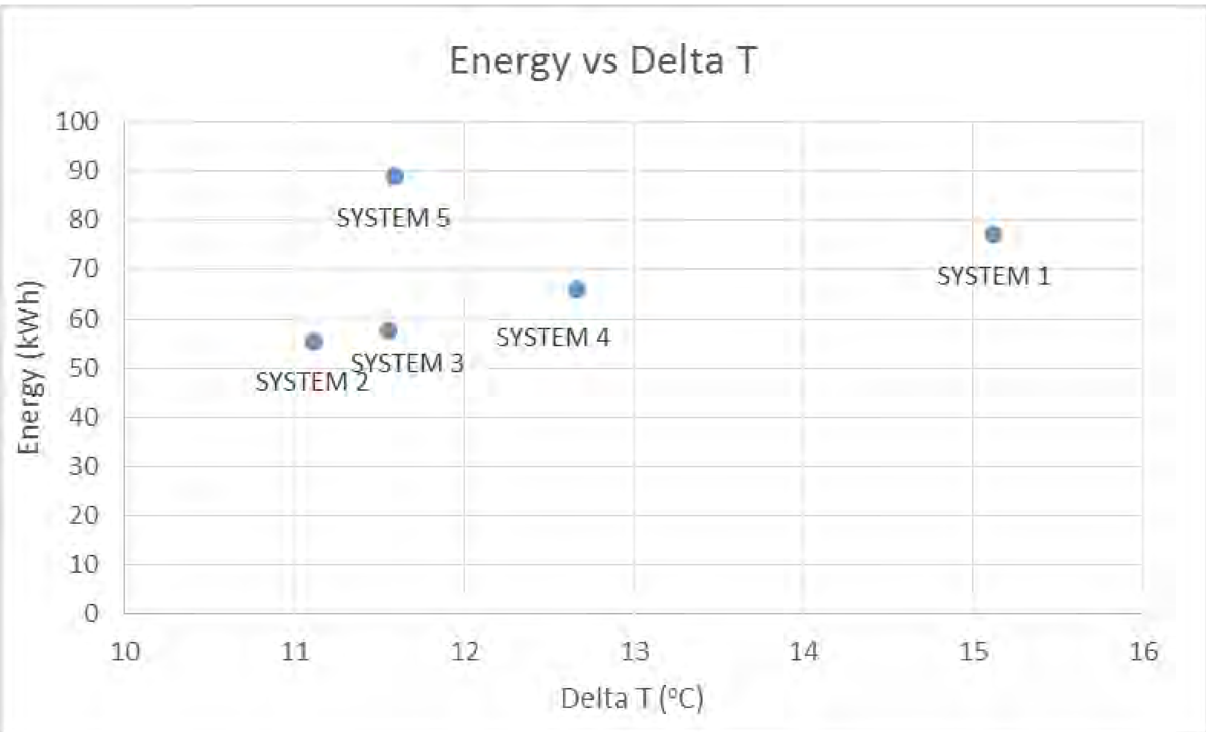


Figure 26: Unsteady State Energy vs Delta T

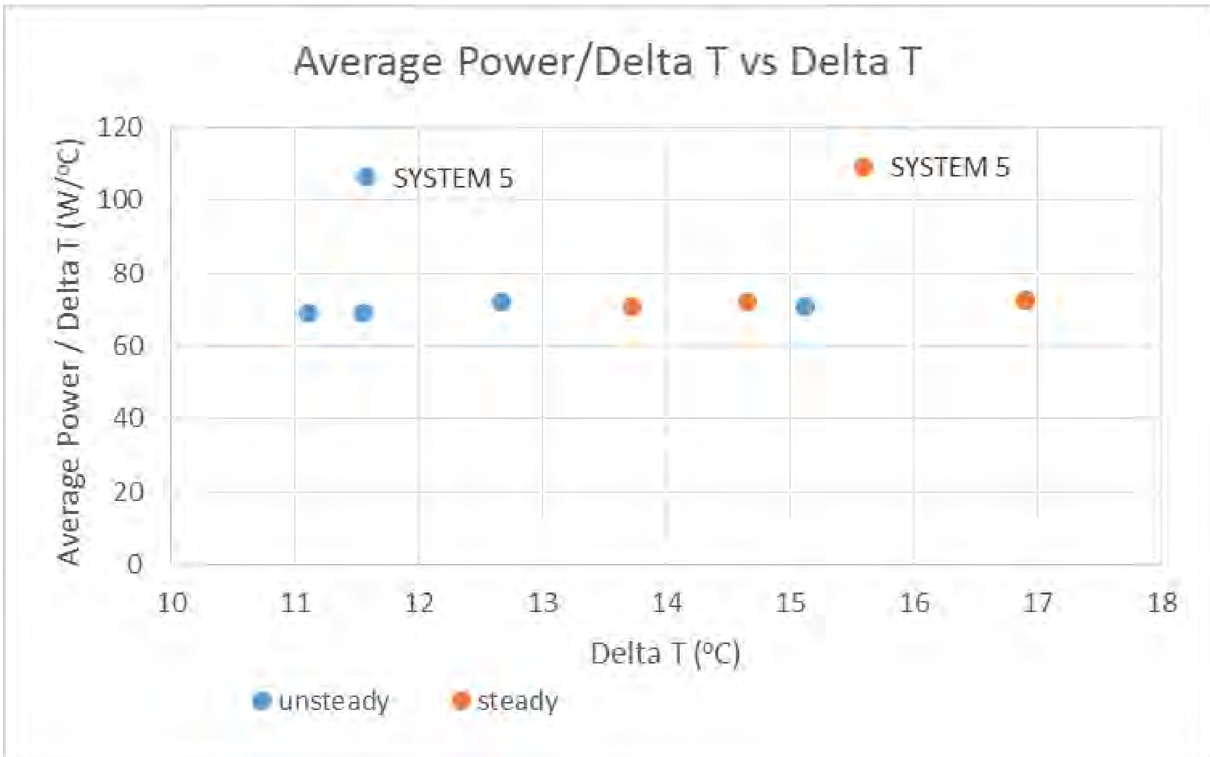


Figure 27: Average Power/Delta T vs Delta T for all tests

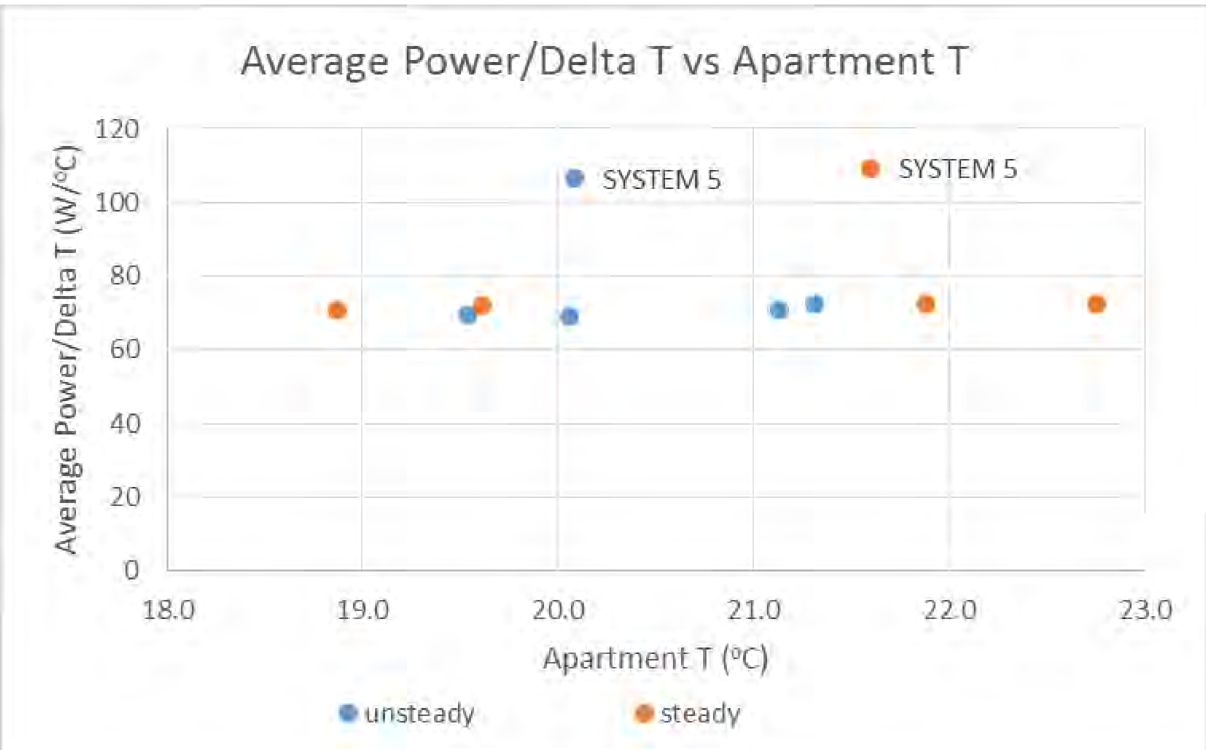


Figure 28: Average Power/Delta T vs Apartment T for all tests

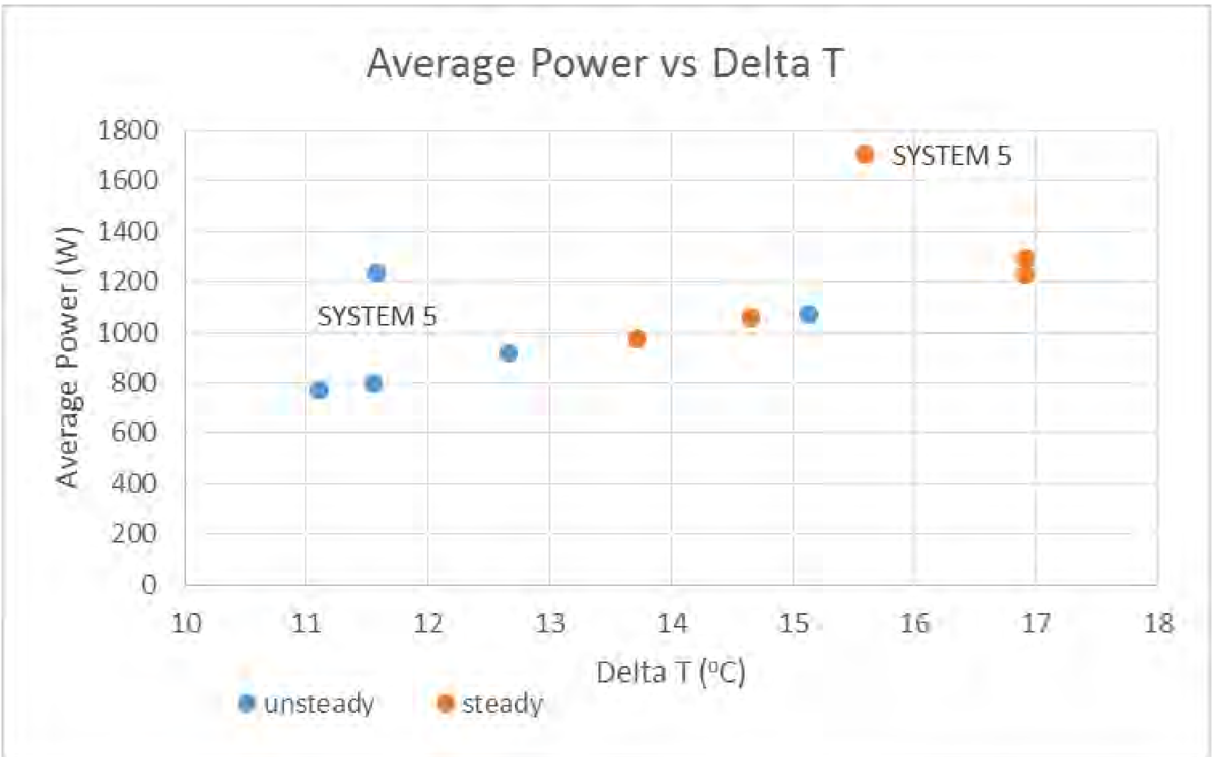


Figure 29: Average Power vs Delta T for all tests

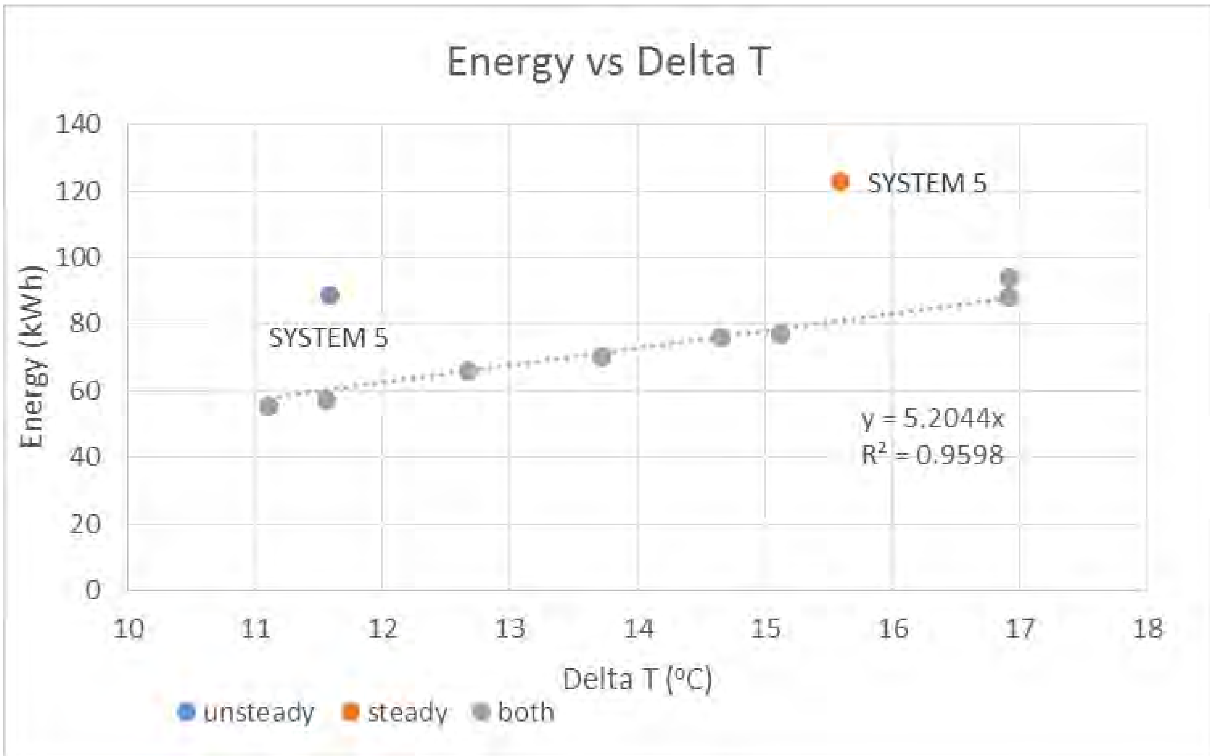


Figure 30: Energy vs Delta T for all tests

The different temperature and power data for Systems 1 to 4 result from the different control strategy implemented by the heaters. Figure 31 to Figure 38 show the power profiles for the four electrical heaters for one day of the test period for both the steady state and the day / night operation. Figure 31 shows that System 1 implements a switching type control which results in the power pulsing between 0 and 3 kW. Figure 32 shows that System 2 has a much tighter control band with the power maintained steadily between 1.2 and 1.8 kW over the typical day. System 3 is closer to conventional storage heater operation, with the maximum power of approximately 4kW drawn over the night period, and a minimal trickle power of approximately 600 W supplied over the day period, as shown in Figure 33. Figure 34 displays the power for a conventional storage heater with power only drawn over the night period. Similar behaviour is exhibited by the four systems over the day/night operating tests and this can be seen in Figure 35 to Figure 38.

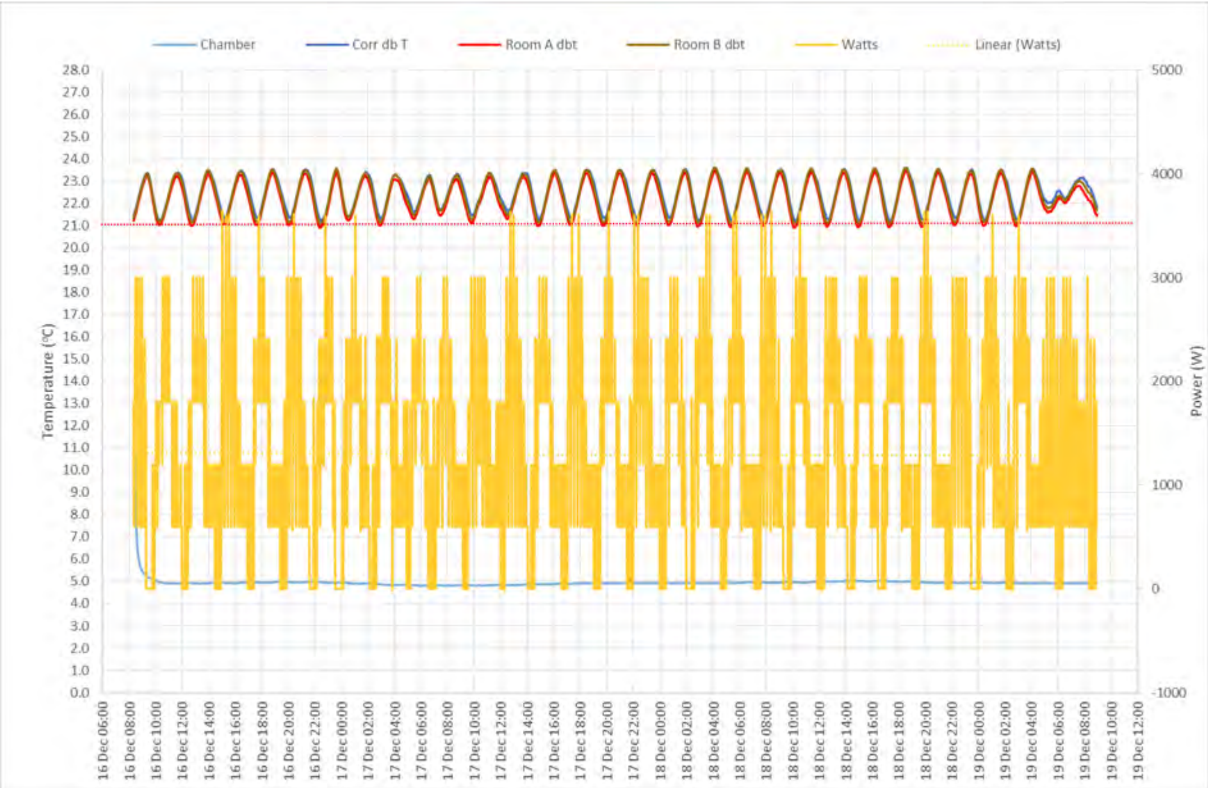


Figure 31: Power profile for System 1 steady state operation

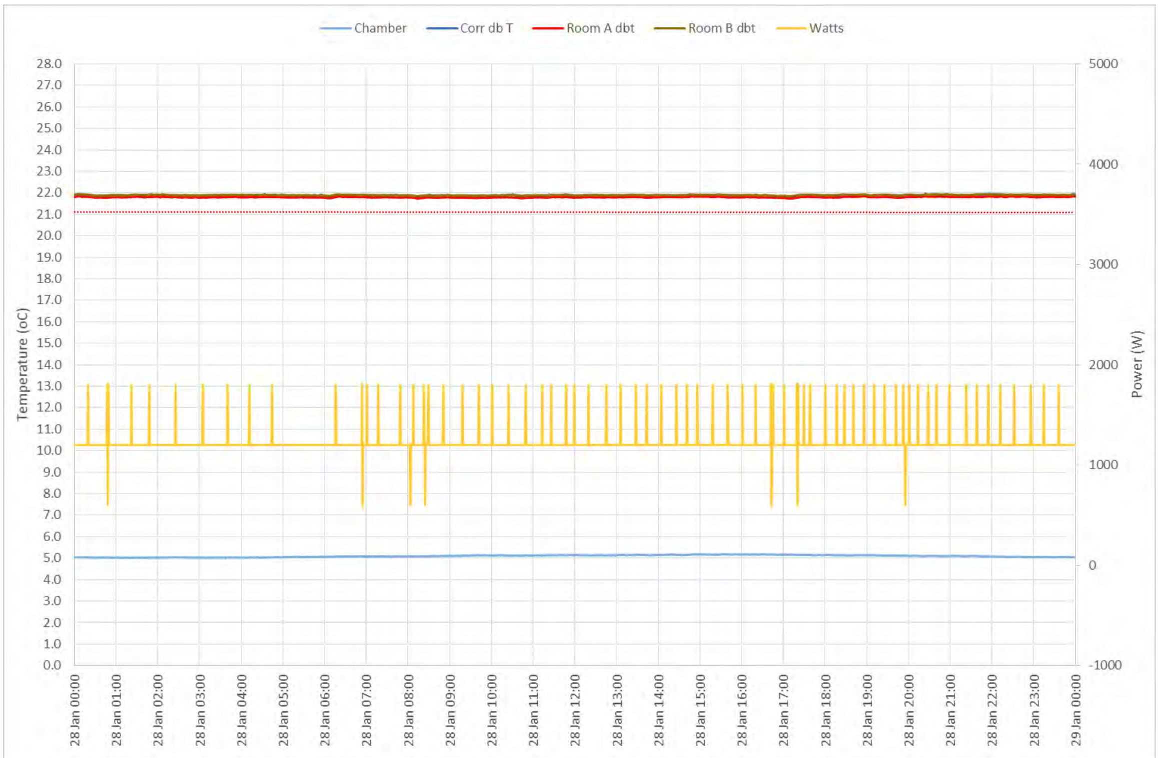


Figure 32: Power profile for System 2 steady state operation

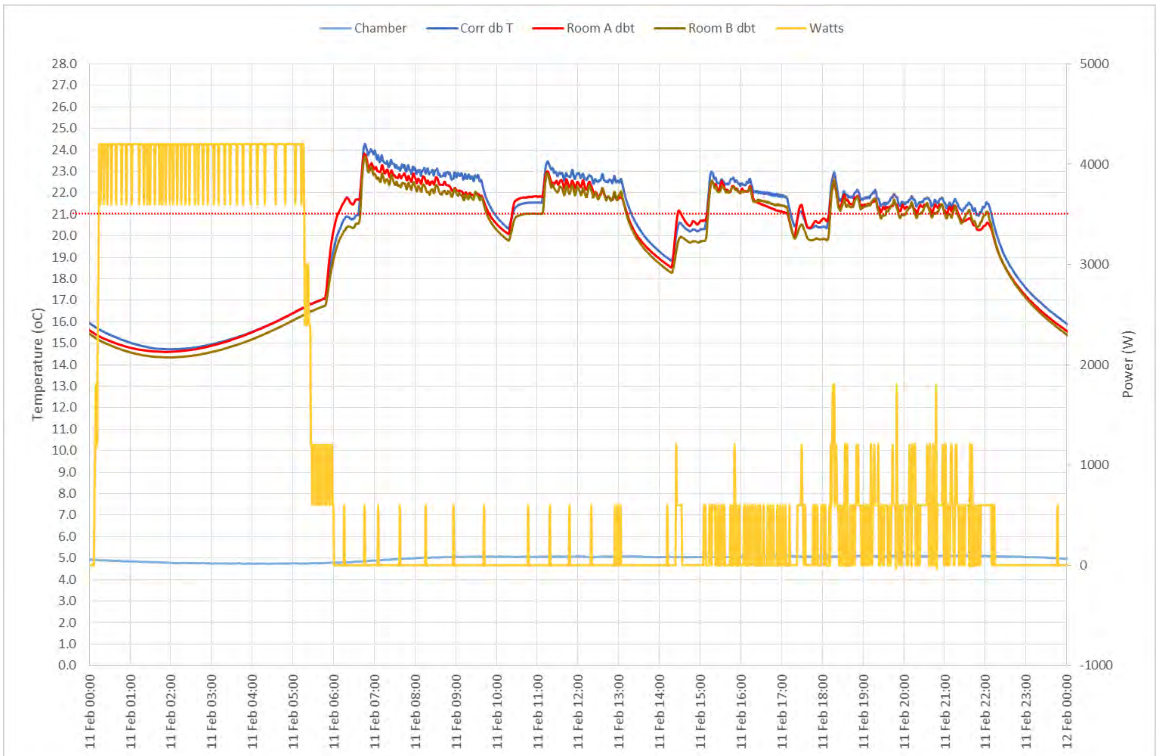


Figure 33: Power profile for System 3 steady state operation

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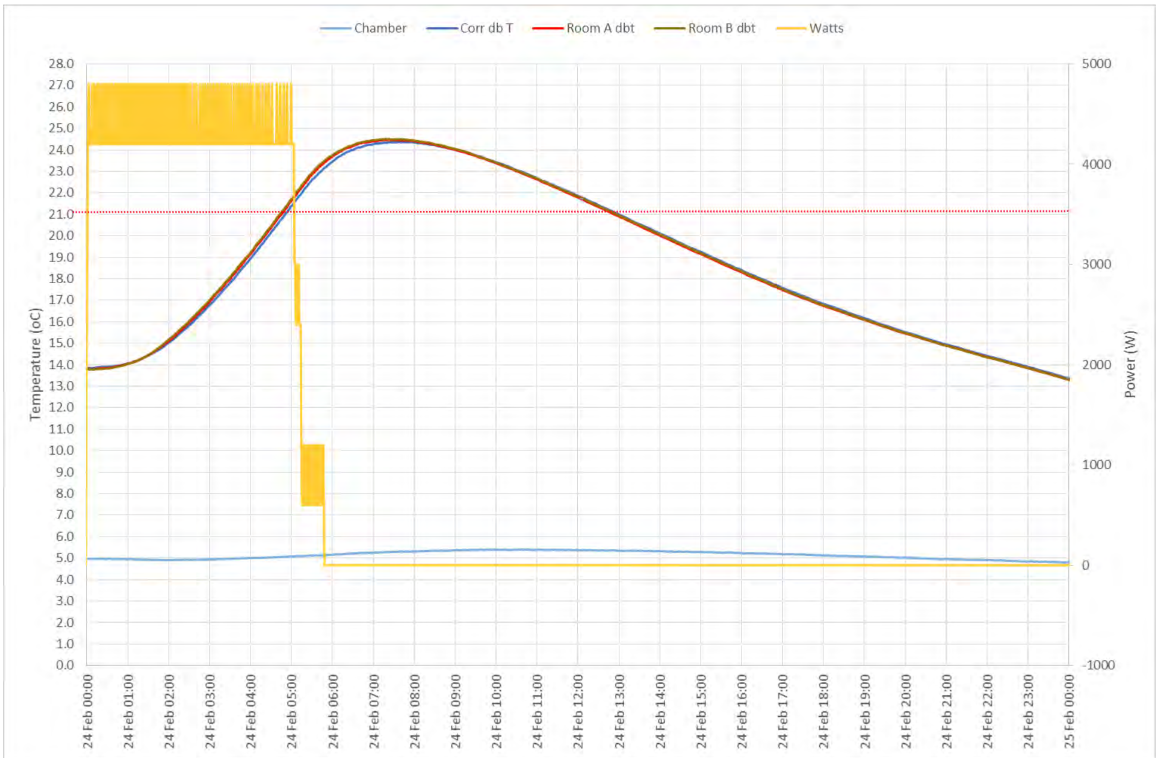


Figure 34: Power profile for System 4 steady state operation

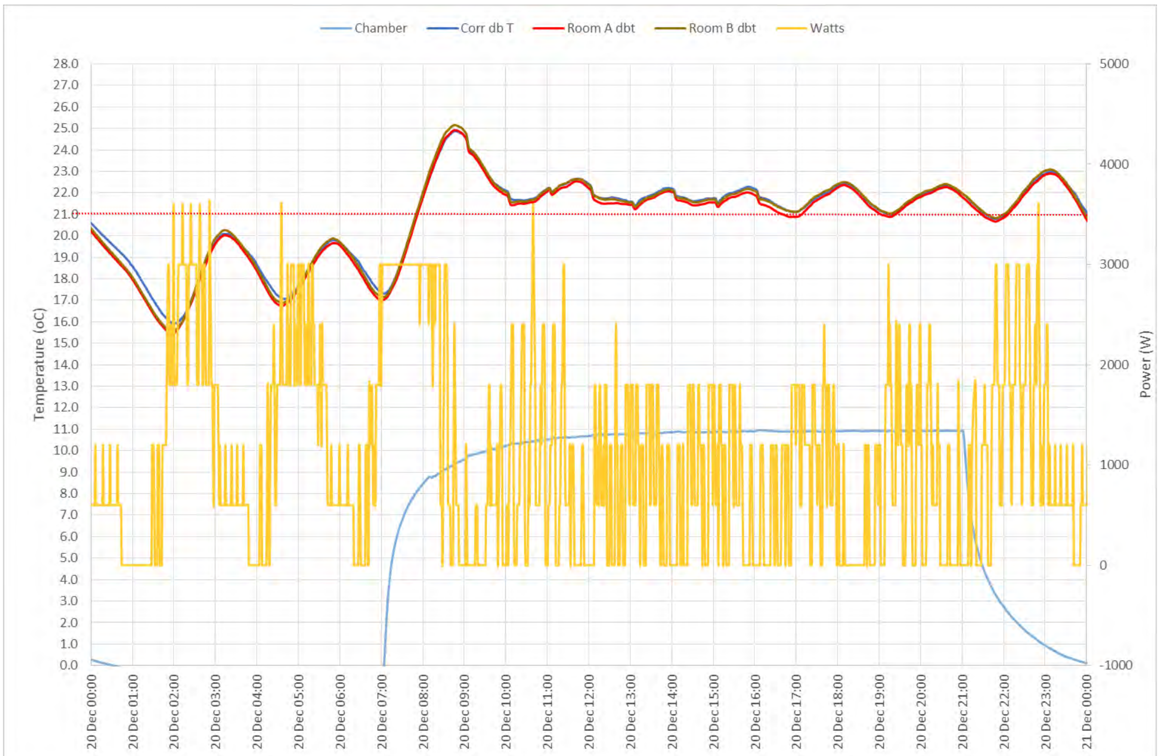


Figure 35: Power profile for System 1 day/night operation

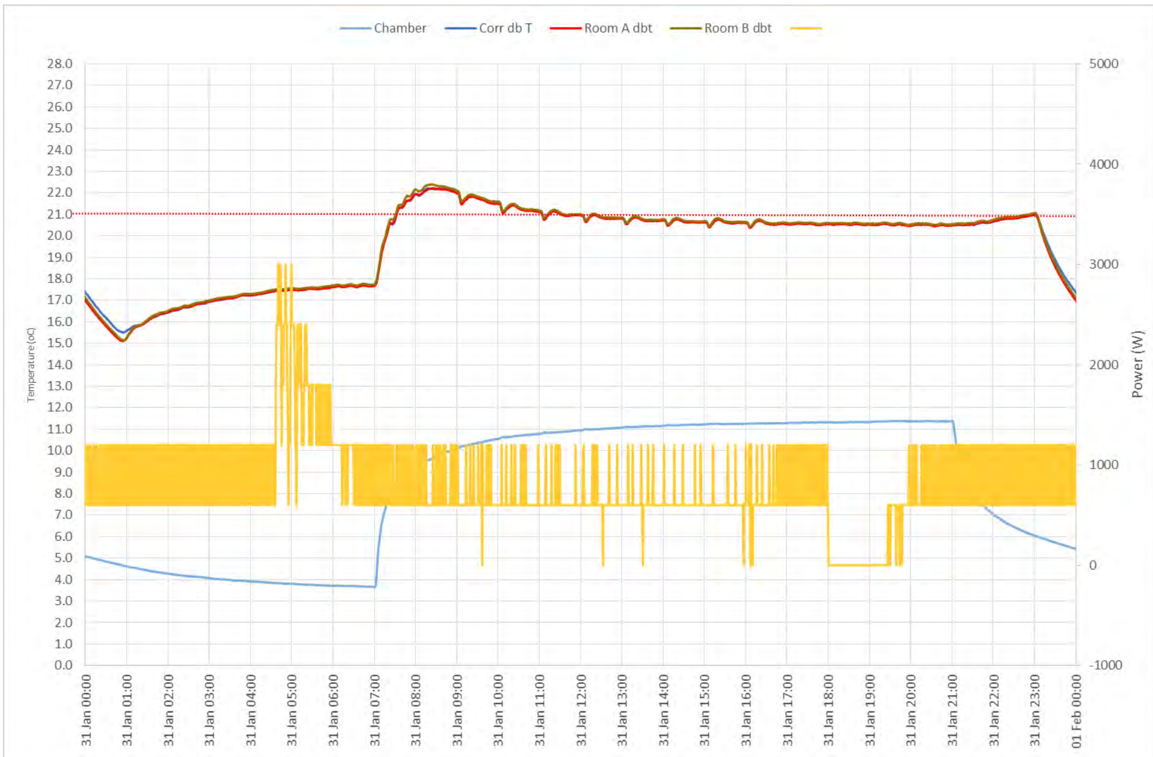


Figure 36: Power profile for System 2 day/night operation

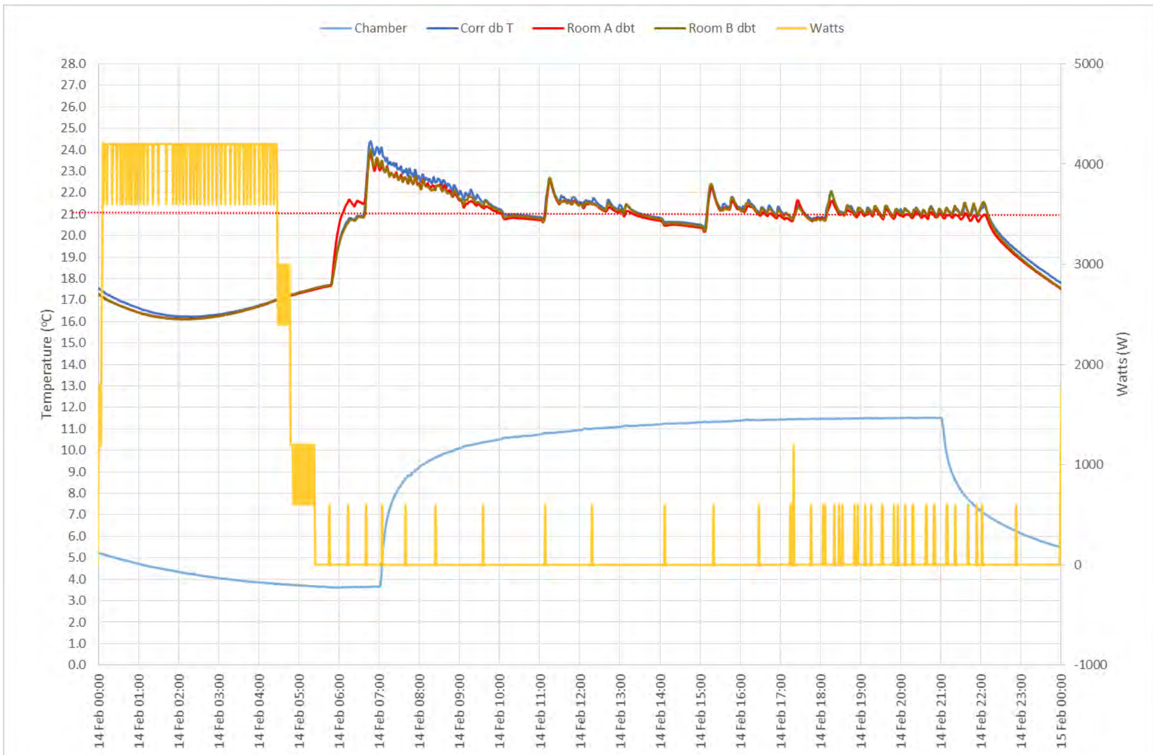


Figure 37: Power profile for System 3 day/night operation

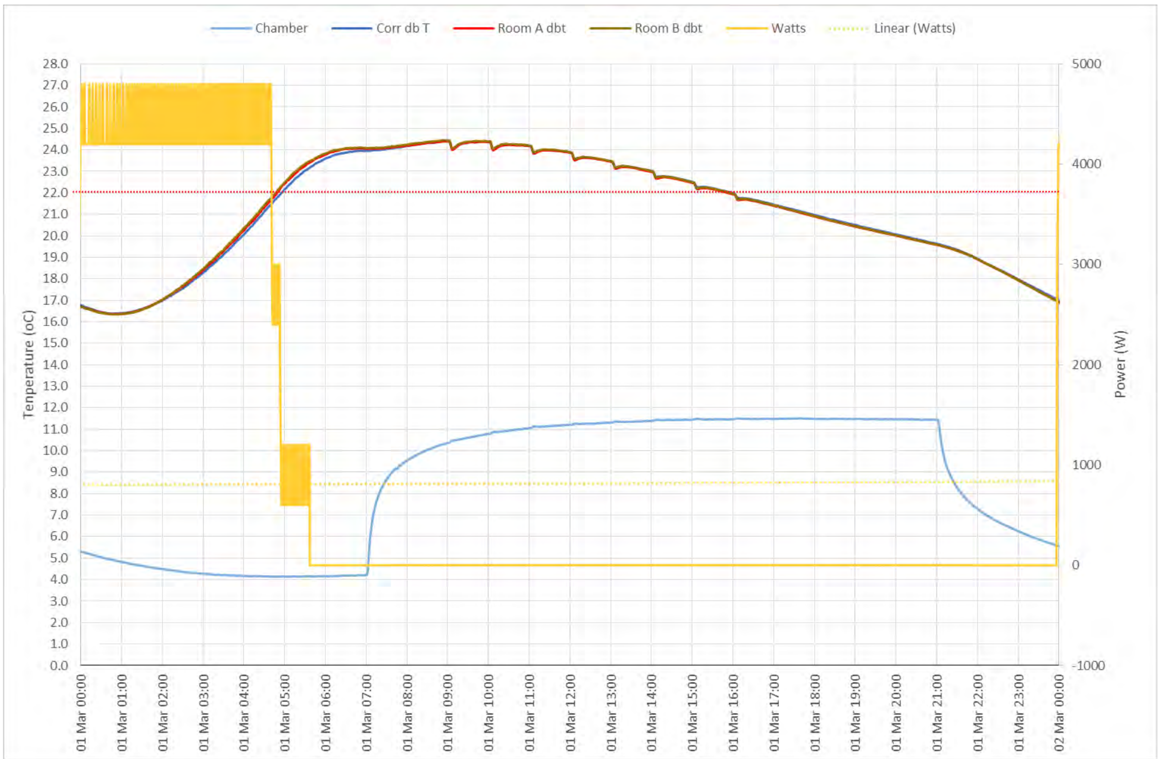


Figure 38: Power profile for System 4 day/night operation

# 4 Analysis of test results

## 4.1 Temperature Control – steady state operation

The different systems tested have different abilities to maintain the set-point temperature within the heated space. Figure 3 to Figure 7 show the different temperature characteristics for the five systems for steady state operation, i.e. in circumstances where the occupant desires to maintain a constant temperature in the apartment twenty four hours a day. Systems 3 and 4 are storage type heaters, and the controls are not set up to maintain the same temperature throughout the day, but incorporate a night set back. It can be seen that this results in a certain amount of over-heating and under-heating through the day.

The numerical data in Table 5 to Table 9 demonstrates the extent of the different temperature control capabilities. The range is a measure of the temperature band maintained in the apartment over the test period, and Table 6 clearly shows that System 2 maintained the tightest temperature control, as also evidenced by the straight line plot in Figure 4, with a temperature variation in the apartment of the order of just ±0.1°C.

System 1 and System 5 are also able to maintain a steady temperature within the apartment, but these systems operate with a temperature variation in the apartment of the order of ±1.0°C. It is interesting to note that although these systems are completely different, the same control module was used on both systems, and this produced the same level of temperature control.

The storage heaters used for System 3 and System 4 had a temperature swing of between 10 and 11°C over twenty four hours, with temperatures down to 10°C and up to 24°C.

The range of temperatures in the test apartment over the steady state test period is shown in Figure 8

## 4.2 Temperature control – day/night operation.

Figure 9 to Figure 13 show the different temperature characteristics for the five systems for day/night operation, i.e. in circumstances where there are two different temperature set-points in the apartment for day and night respectively. Again the figures show that the temperature control for System 2 is the most precise, with a limited amount of overshooting the set-point when heating up the apartment in the mornings,

Whilst the basic storage heater in System 4 had a very limited amount of temperature control, the other four systems maintained the temperatures in the apartment in accordance with the desired profile.

Figure 11 and Figure 13 show that Systems 3 and 5 maintained a more precise temperature profile than System 1 (Figure 9). The latter profile shows regular peaks indicative of frequent switching on and off of the heater.

The numerical data in Table 10 to Table 14 show the temperature data for the different systems over the day and the night periods. The systems with the smallest range, and therefore the tightest temperature control over this profile, are Systems 2 and 3.

### 4.3 Power consumption

Figure 27 presents the Average Power/Delta T for the ten tests. It is clear that for the electric heaters (Systems 1 to 4), the average power drawn is directly related to the temperature difference between the inside and the outside of the apartment, and that this is of the order of 71 W/°C for this specific apartment.

In the case of the gas heating system, System 5), the average power drawn is of the order of 108 W/°C for this specific apartment, which represents an increase of approximately 50% over the electric heaters. The power consumption for the gas system is based on the conversion of the volume of gas measured by the meter into energy using the average calorific value over the test period for gas supplied in the test region.

## 5 Conclusions

A total of five different heating systems were tested in an apartment rig set up within an environmental chamber which ran at steady state conditions and at a temperature profile that simulated day / night operation.

The five heating systems consisted of

System 1.
The Fischer Future Heat dynamic storage heaters which are an innovative type of storage heater with the main innovation being the nature of the thermal storage within the heater, as well as the microprocessor control of the heater which offers considerable functionality.

System 2.
The Fischer Premium dynamic storage heaters which are also an innovative type of storage heater with a different but also innovative thermal storage and a different form of microprocessor controller.

System 3.
The Dimplex Quantum storage heaters which are a more conventional form of storage heater as regards the nature of the thermal storage with high thermal mass. The control is slightly less conventional with a high power charge up time at night but a low power top up heat available during the day, and a small fan for better control of heat output.

System 4.
The Creda storage heaters which are a conventional form of storage heaters that charge up during the night and discharge heat from the thermal store during the day

System 5.
A typical gas boiler / radiator central heating set up with TRVs on the radiators and the Fischer micro-processor controller operating the boiler.

A number of conclusions can be drawn from the data presented above.

1. The temperature control within the apartment varied considerably from system to system. The most precise temperature control is maintained by System 2 for both steady state and day / night

operation. Precise temperature control provides maximum energy efficiency since unnecessary overheating consumes additional power and may also cause discomfort. System 3 also demonstrated very good temperature control for day / night operation.

2. The precise temperature control of System 2 is an outcome of the precise power control exercised by the heater controller. Figure 32 and Figure 36 show how the power consumption for this heater type is maintained within a very narrow band, showing the ability of the controller to regulate the power to this heater very accurately. This might also have been helped by the fact that the temperature sensor on this heater was located at the bottom of the heater, sensing the convection air current that passed over the heater.

3. Systems 1 and 2 did not demonstrate the characteristic behaviour of storage heaters, in that they did not absorb energy over night to release this energy during the day. This has the advantage of generally better temperature control, particularly for System 2.

4. For both steady state and day / night operation, all four electrical systems draw power at between 69 and 74W per degree temperature difference between the inside of the apartment and the outside, with an average value of 71.4 W per degree. This represents a range of -3% and +4% around the average, within the limits of experimental error, and cannot be attributed to any difference in efficiency between the electrical heating systems.

5. The gas central heating system under test drew an average of 108 W per degree temperature difference which represents power consumption of approximately 50% more than electric heating (based on gas consumption). This is due to the specific inefficiencies of the system installed in relation to the test apartment, and cannot be quoted as a general figure to represent the difference in efficiency between gas central heating and electric heating. Actual figures will differ from installation to installation, even for the same boiler, and may be higher or lower.

6. The performance of the Fischer storage heaters demonstrates that, possibly as an outcome of the dynamic nature of the storage element, the maximum power demand is not coinciding with the reduced overnight Economy 7 tariff. This indicates that additional savings could be obtained by setting the day / night temperatures with different time settings to ensure possibly slightly earlier heating up times overnight

7. Gas central heating with an appropriate thermostat and TRVs can provide efficient temperature control

8. If the lack of precise temperature control of conventional storage heaters had to be compensated for by increasing temperatures in the apartment to ensure a minimum temperature of say 21°C for 24 hour operation this would increase the operating cost of the conventional storage heaters and result in overheating at certain times of day. The adjusted values are shown in Table 17.

9. Gas central heating with an appropriate thermostat and TRVs can provide efficient temperature control.

Table 17: Power consumption in apartment with steady state operation and temperature settings adjusted to **maintain a minimum value of 21°C at all times**.

| System number | Apartment temperature | External temperature | Delta T | Cumulative Power for 1 day | Average Power | Average Power/Delta T |
|---|---|---|---|---|---|---|
| | (°C) | (°C) | (°C) | (kWh) | (W) | (W/°C) |
| | | | | | | |
| **1** | 22.47 | 5.00 | 17.47 | 30.37 | 1265.29 | 72.43 |
| **2** | 21.10 | 5.00 | 16.10 | 28.03 | 1167.80 | 72.53 |
| **3** | 30.70 | 5.00 | 25.70 | 44.46 | 1852.31 | 72.07 |
| **4** | 32.28 | 5.00 | 27.28 | 46.43 | 1934.69 | 70.92 |
| **5** | 22.34 | 5.00 | 17.34 | 45.53 | 1897.02 | 109.40 |

# Appendix A Types of Heating System Installed

System 1. Fischer Future Heat electric dynamic storage heaters

Model Type 65/60 1100W

Model Type 65/60 1100W

Model Type 47/00 600W

System 2. Fischer Premier electric dynamic storage heaters

Model Premier 1000W Serial Number PT2065400008

Model Premier 1000W Serial Number PT2065400018

Model Premier 500W Serial Number PT2059900004

System 3. Dimplex Quantum storage heaters

Model QM 070 Serial Number 0x0F00102AE0 Output 700W Input 1560W including 630W boost

Model QM 070 Serial Number 0x1000101475 Output 700W Input 1560W including 630W boost

Model QM 050 Serial Number 0x1003400C7C Output 500W Input 1100W including 430W boost

System 4. Creda Newera storage heaters

Model TSR6AW 0.85kW

Model TSR12AW 1.7kW

Model TSR12AW 1.7kW

System 5. Gas central heating with Glow-worm 12hxi high efficiency condensing boiler, radiators with TRVs.

## Appendix B Photographs

Figure 39: Fischer storage heater in Room B

Figure 40: Fischer storage heater in corridor

Figure 41: Fischer storage heater in Room A

Figure 42: Fischer Premier heater in Room B

Figure 43: Fischer Premier heater in corridor

Figure 44: Fischer Premier heater in Room A

Figure 45: Dimplex Quantum heater in Room B

Figure 46: Dimplex Quantum heater in corrridor

Figure 47: Dimplex Quantum heater in Room A

Figure 48: Radiator in Room B

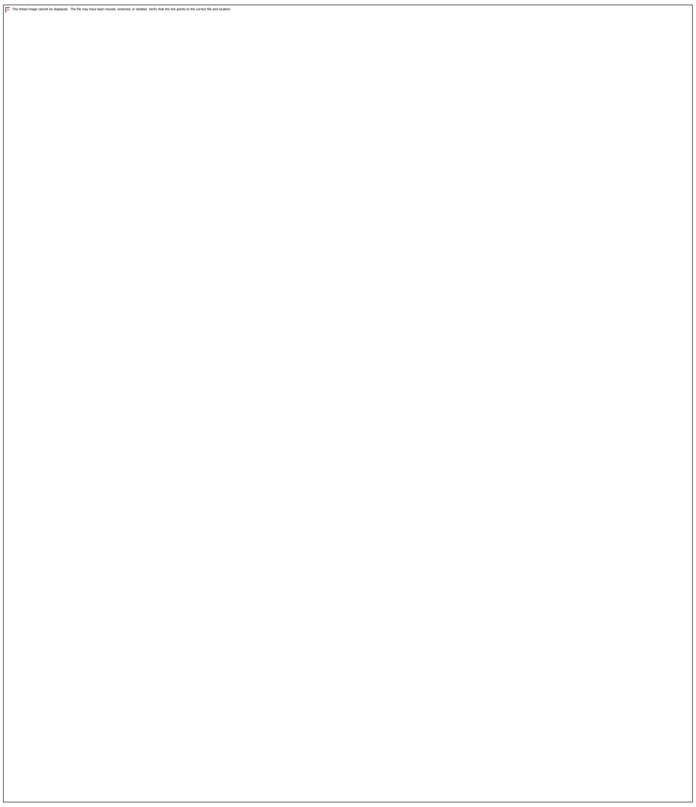

Figure 49: Radiator in corridor

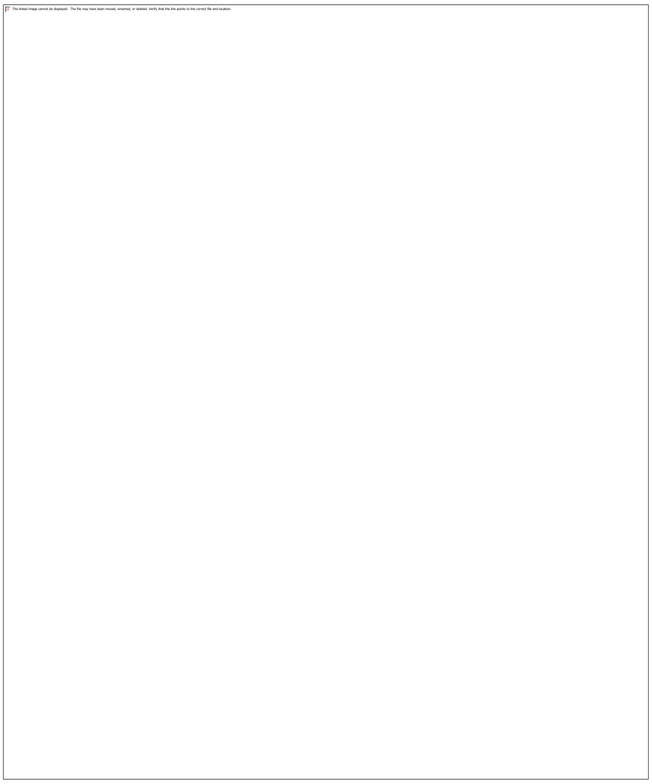

Figure 50: Radiator in Room A

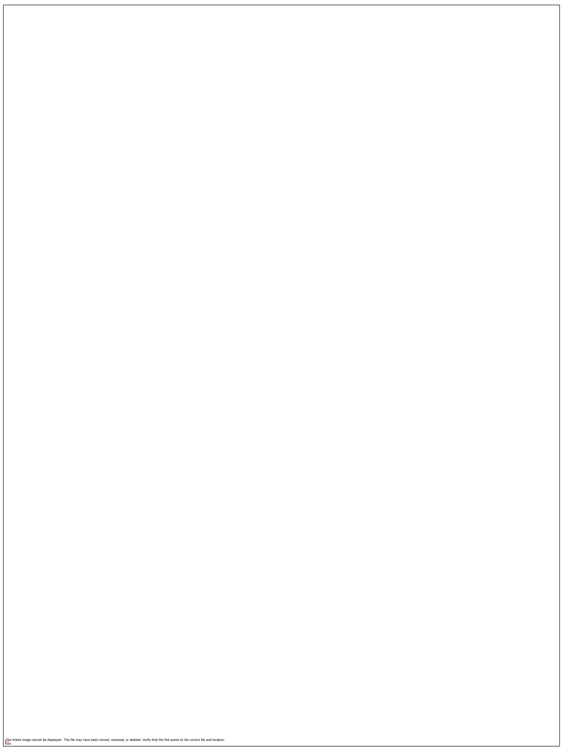

Figure 51: Controller for Fischer storage heater and gas boiler

Figure 52: Gas boiler installation


Report Ends