Electric radiator test

Final Report 56161/1

Carried out for
Cornwall Heating Solutions Ltd
& Bright Heating

By Calum Maclean

27 June 2012



Electric radiator test

Carried out for:

Cornwall Heating Solutions Ltd & Bright Heating
Southwest Heating Solutions
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SUMMARY

This report details tests carried out on an electric radiator supplied by Cornwall Heating Solutions, part reference S201 (16/131-12). The tests were conducted during the period 9 to 16 May 2012.

The objectives were to determine the heater performance when subjected to the tests below, as requested by the client

1. Determine stability of temperature control and power consumption when subjected to cooling loads of 50% of nominal maximum heater output at a nominal room temperature of 21°C for 16 hours
2. Determine stability of temperature control and power consumption when set to a temperature of 16°C at the same control conditions for the cooling load in test 1 for 8 hours.
3. Determine stability of temperature control and power consumption when subjected to cooling loads of 25% of nominal maximum heater output at a nominal room temperature of 21°C for 3 hours

Tests 1 and 2 combined represent a daytime heater operation followed by a night set back condition.

The heating measured during the three tests was:

Test 1 – 1026W (16.416kWh over 16 hours)– With a cooling load balance of 99.7%
Test 2 – 430W – (3.440kWh over 8 hours)- With a balance cooling load of 99.7%
Test 3 – 526W – (1.578kWh over 3 hours)- With a balance cooling load of 99.0%

The balance is the ratio between the heating and cooling measured within the test chamber. This balance between heating and cooling is due to a combination of the test device stability, rig control stability and measurement tolerances, and taking account of these tolerances the heating load is equivalent to the cooling load.

The range of control of the room temperature at the reference temperature globe achieved by the heater was:

Test 1 – 0.48°C
Test 2 – 0.44°C
Test 3 – 0.54°C

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1 INTRODUCTION

This report details tests carried out on a Cornwall Heating Solutions Ltd heater, part reference S201 (16/131-12). The tests were requested by Cornwall Heating Solutions Ltd and were conducted during the period 9 to 16 May 2012.

2 OBJECTIVES

The objectives were to determine the heater performance when subjected to the tests below, as requested by the client

4. Determine stability of temperature control and power consumption when subjected to cooling loads of 50% of nominal maximum heater output at a nominal room temperature of 21°C for 16 hours
5. Determine stability of temperature control and power consumption when set to a temperature of 16°C at the same control conditions for the cooling load in test 1 for 8 hours.
6. Determine stability of temperature control and power consumption when subjected to cooling loads of 25% of nominal maximum heater output at a nominal room temperature of 21°C for 3 hours

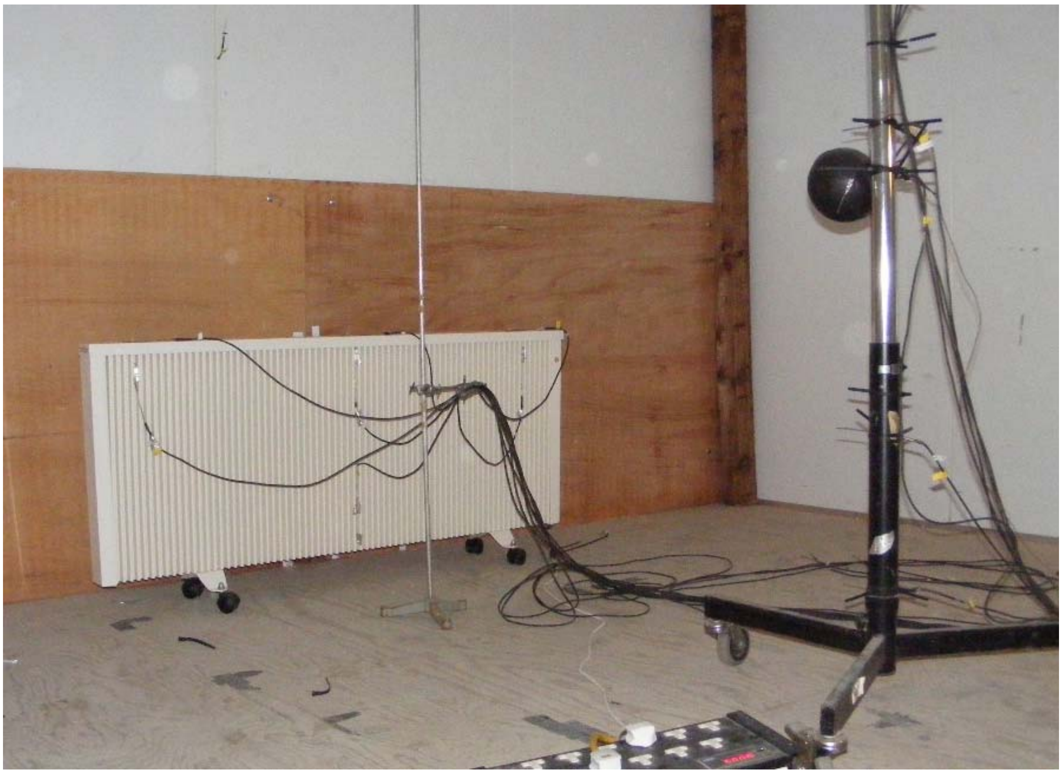
Tests 1 and 2 combined represent a daytime heater operation followed by a night set back condition.

3 ITEM SUPPLIED FOR TESTING

The item supplied consisted of a Cornwall Heating Solutions heater, part reference S201 (16/131-12) with a nominal stated output of 2000W at 230V. A thermostat dial positioned on one edge of the radiator had a switch below to turn the item on and off and an indicator light above to show when the radiator was operating. The thermostat had indications on it for a range of 1 to 6. The Thermostat was set at a position found to correspond to a control air temperature of approximately 21°C for tests 1 and 3. A different thermostat position was used for test 2 which corresponded to 16°C.

The radiator is shown in Figure 1 as installed in the test chamber with measurement probes attached

Figure 1 Test item as installed in test chamber



4 INSTRUMENTATION

Table 1 Instrumentation used during testing

Description	Identifier	Calibration due
Yokogawa WT210 power meter	988	25 April 2013
Seimens Magflo meter	203	03 May 2013
Agilent 34970A data-logger 1	Logger 6	22 November 2013
Agilent 34970A data-logger 2	Logger 7	
Platinum resistance thermometers	Channel nos: 11 to 18, 20, 21 to 25, 27 and 28	
Thermocouples	Channel nos: 1, 8 to 13, 16, 18 and 19	

5 SCOPE OF WORK AND TEST METHOD

The general methodology used was taken from the BSRIA generic test method for electrical and nonstandard radiators. This incorporated principles and methods from BS EN 60675:1995 “Household electric direct acting room heaters. Methods for measuring performance”

The BSRIA method document is included as Appendix A of this report and includes descriptions and diagrams of the test chamber and position of temperature probes.

Clauses referred to below are those within the BSRIA method document (Appendix A).

Tests were conducted as detailed in clauses 3.1.2 ‘Stability of room temperature’ (in this case at nominal initial radiator thermostat set point of 21°C for tests 1 and 3 and 16°C for test 2 as requested by the client).

Prior to tests commencing, a calibration of the chilled ceiling characteristic was conducted to determine the control temperatures required for applied heating loads. At the same time data was collected to verify that the balance between heating and cooling load was within 5% under fixed conditions, using non-modulating resistance heaters controlled by means of a variable resistor.

In addition to the air temperature probes, positioned vertically in the centre of the room, eight resistance thermometers were attached to and around the radiator, as shown in Figure 2.

The radiator was supplied at UK National grid voltage, which while being at nominal 230V was actually 240V during tests.

6 RESULTS

The results for the three tests conducted are outlined below and are split into two main parts:

1. The tables of the average conditions within the test chamber
2. The graphical representations of the temperatures and power consumption during each test

The heating measured during the three tests was:
Test 1 – 1026W (16.416kWh over 16 hours)– With a cooling load balance of 99.7%
Test 2 – 430W – (3.440kWh over 8 hours)- With a balance cooling load of 99.7%
Test 3 – 526W – (1.578kWh over 3 hours)- With a balance cooling load of 99.0%

The balance is the ratio between the heating and cooling measured within the test chamber. This balance between heating and cooling is due to a combination of the test device stability, rig control stability and measurement tolerances, and taking account of these tolerances the heating load is equivalent to the cooling load.

The range of control of the room temperature at the reference temperature globe achieved by the heater was:

Test 1 – 0.48°C
Test 2 – 0.44°C
Test 3 – 0.54°C

The globe temperature is taken as the mean radiant temperature and used in determining measurements of comfort conditions.

Because of local convective air currents the globe temperature T_g typically lies between the air temperature T_a and the true mean radiant temperature T_r . The faster the air moves over the globe thermometer the closer T_g approaches T_a. If there is zero air movement $T_g = T_r$.

The air movement in the centre of the chamber will be relatively slow, as it is driven by natural convection T_g will therefore approach T_r.

6.1 STABILITY OF ROOM TEMPERATURE

The stability of the room temperature was determined for each of the three tests. The globe temperature was measured at 1.1m from the floor and was used to determine the stability of room temperature during each test.

Mean heat output was determined from the integrated power consumption (kWh) over the test period.

The mathematical standard deviation (STDev) is included below for the room reference temperatures.

Table 2 Mean room temperatures for test 1

Parameter	Measured value	STDev
Actual cooling ratio [1](%)	48.2	
Mean heat output over 16 hour period (Watt) from integrated kWh	1026.6	
Mean cooling load over 16 hour period (Watt)	1023.4	
Mean room temperature 0.3m (°C)	21.11	0.21
Mean room temperature 0.5m (°C)	21.13	0.22
Mean Globe temperature 1.1m (°C)	21.08	0.15
Mean room temperature 1.2m (°C)	21.07	0.23
Mean Globe temperature 1.5m (°C)	21.05	0.24
Mean room temperature 2.0m (°C)	21.01	0.23
Mean room temperature 2.2m (°C)	20.82	0.24
Amplitude at Globe	0.48	

Note: 1. As a proportion of the average measured running output of 2128 W

Table 3 Mean room temperatures for test 2

Parameter	Measured value	STDev
Actual cooling ratio [1] (%)	20.2	
Mean heat output over 8 hour period (Watt) from integrated kWh	429.9	
Mean cooling load over 8 hour period (Watt)	428.4	
Mean room temperature 0.3m (°C)	16.04	0.18
Mean room temperature 0.5m (°C)	16.11	0.19
Mean Globe temperature 1.1m (°C)	16.12	0.14
Mean room temperature 1.2m (°C)	16.08	0.19
Mean Globe temperature 1.5m (°C)	16.08	0.19
Mean room temperature 2.0m (°C)	16.10	0.19
Mean room temperature 2.2m (°C)	15.97	0.19
Amplitude at Globe	0.44	

Note: 1. As a proportion of the average measured running output of 2128 W

Table 4 Mean room temperatures for test 3

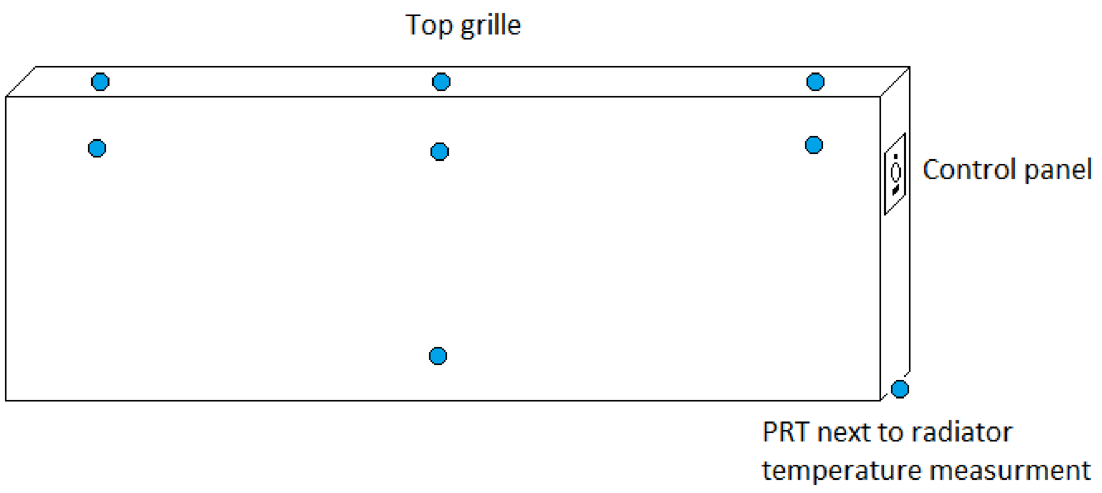
Parameter	Measured value	STDev
Actual cooling ratio [1] (%)	24.7	
Mean heat output over 3 hour period (Watt) from integrated kWh	526.4	
Mean cooling load over 3 hour period (Watt)	520.9	
Mean room temperature 0.3m (°C)	21.09	0.21
Mean room temperature 0.5m (°C)	21.15	0.24
Mean Globe temperature 1.1m (°C)	21.11	0.18
Mean room temperature 1.2m (°C)	21.12	0.26
Mean Globe temperature 1.5m (°C)	21.12	0.27
Mean room temperature 2.0m (°C)	21.07	0.27
Mean room temperature 2.2m (°C)	20.95	0.29
Amplitude at Globe	0.54	

Note: 1. As a proportion of the average measured running output of 2128 W

Peak instantaneous radiator output was 2257 W from the three tests. Generally the instantaneous output switched between zero and 2050 W to 2200 W when the heater was modulating.

Plotted data is shown for the whole test period. A two hour period is shown to give an indication of the switching frequency of the heater thermostat under the steady state load condition during the first two hours of test 1.

Figure 2 Surface temperature positions

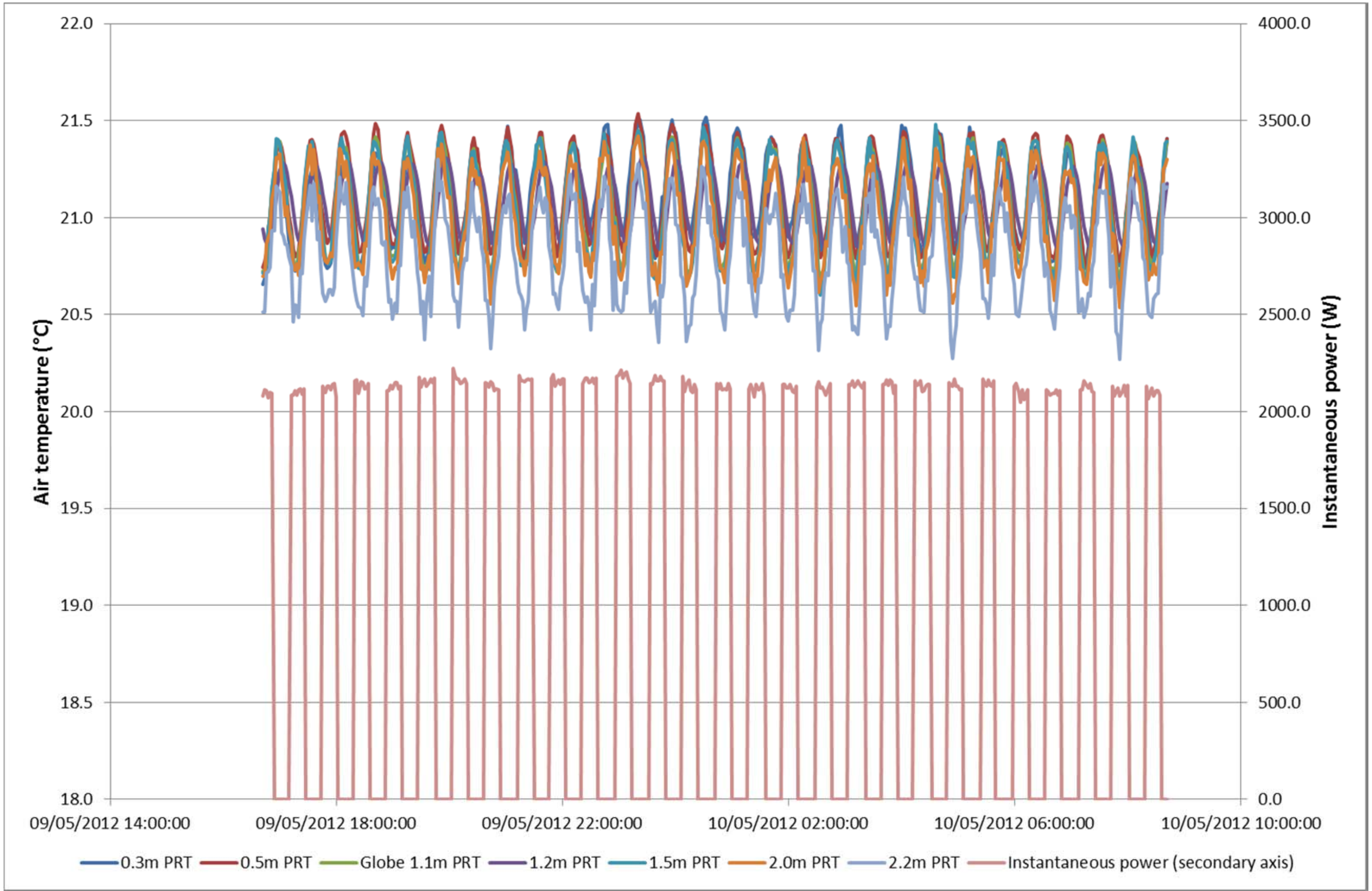


Key; Blue circles show the PRT placement on the radiator during the tests

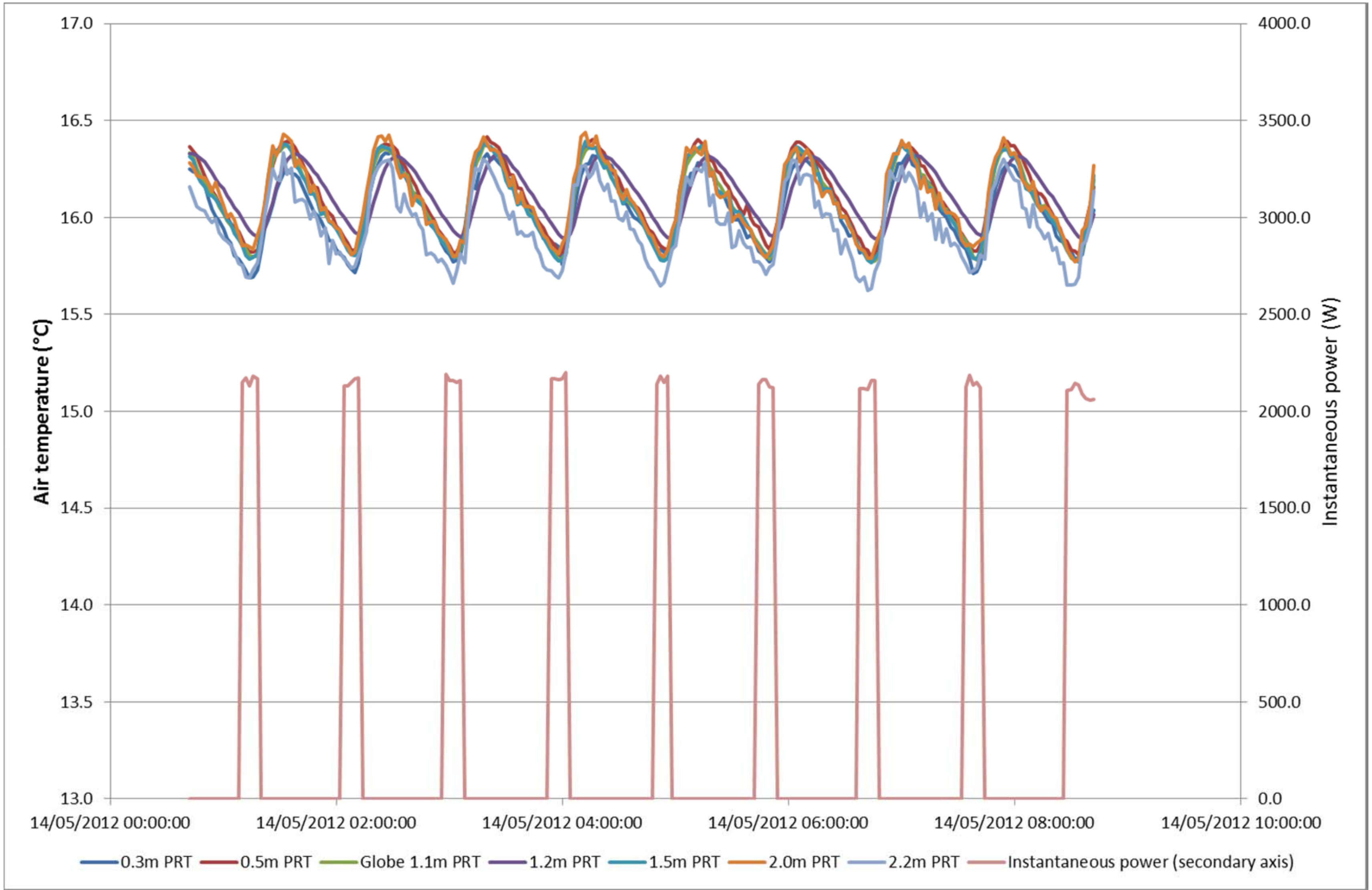
Table 5 Mean radiator temperatures

Parameter	Test 1	Test 1 STDev	Test 2	Test 2 STDev	Test 3	Test 3 STDev
Mean front lower temperature (°C) (1 PRT)	36.2	2.5	23.5	2.5	31.0	2.7
Mean front upper temperature (°C) (3 PRTs)	52.2	4.0	30.6	3.9	40.7	4.3
Mean grille/air off temperature (°C) (3 PRTs)	49.0	3.7	29.3	3.8	39.2	4.0
Mean air temperature beside radiator measurement device (°C) (1 PRT)	22.6	0.4	16.7	0.3	21.7	0.3

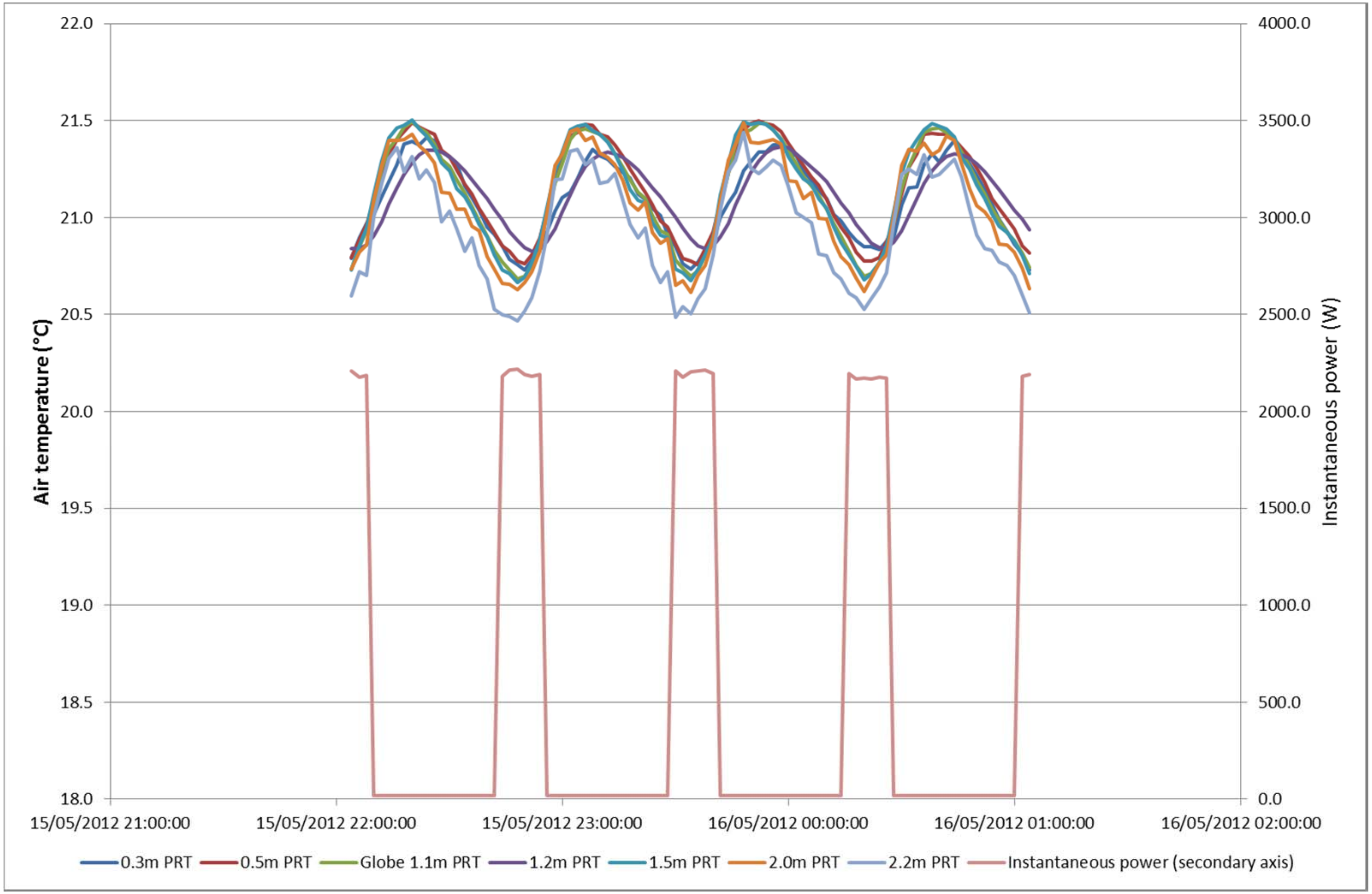
6.2 16 HOUR CHART OF AIR TEMPERATURE AND INSTANTANEOUS POWER FOR TEST 1



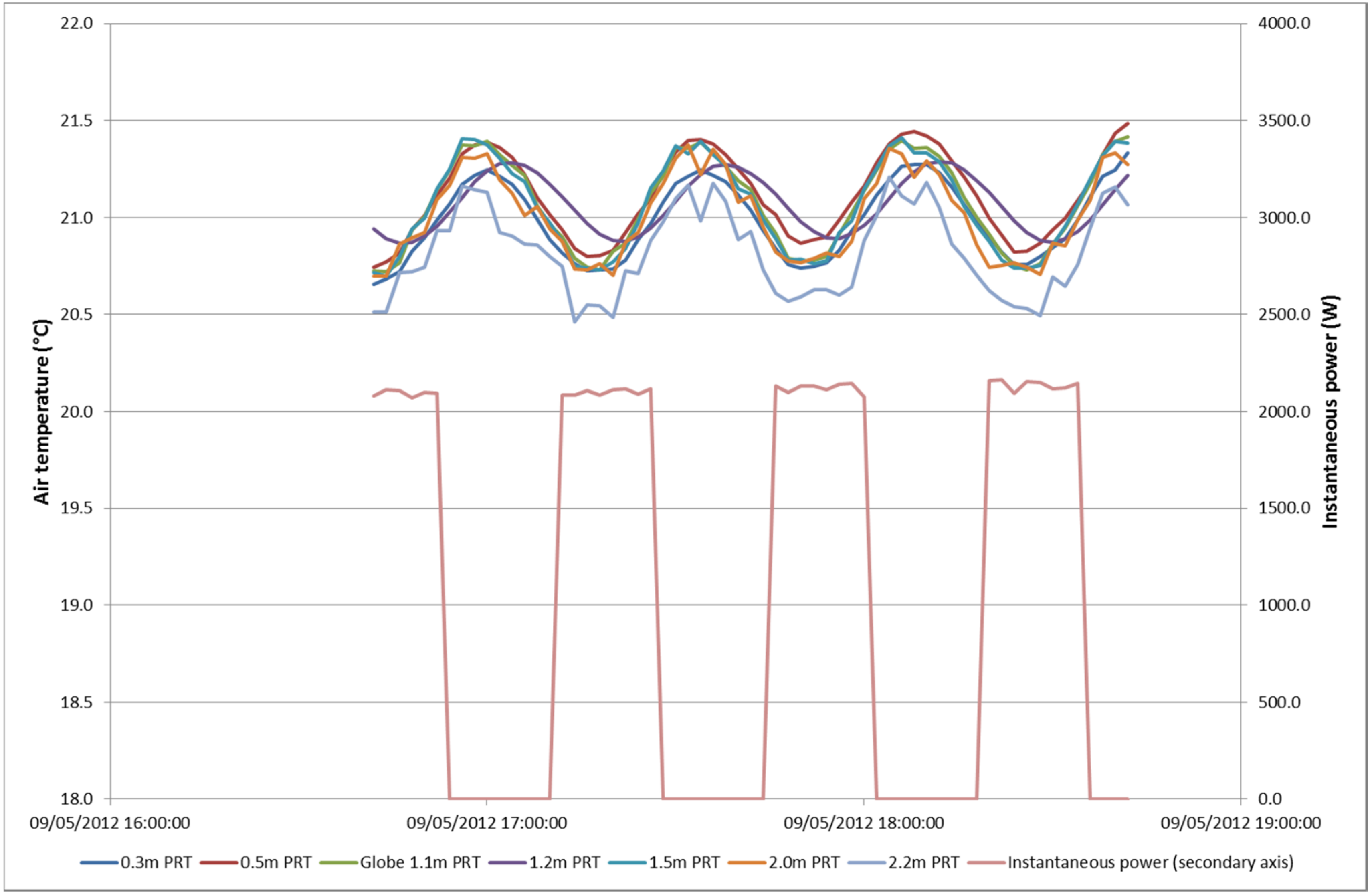
6.3 8 HOUR CHART OF AIR TEMPERATURE AND INSTANTANEOUS POWER FOR TEST 2



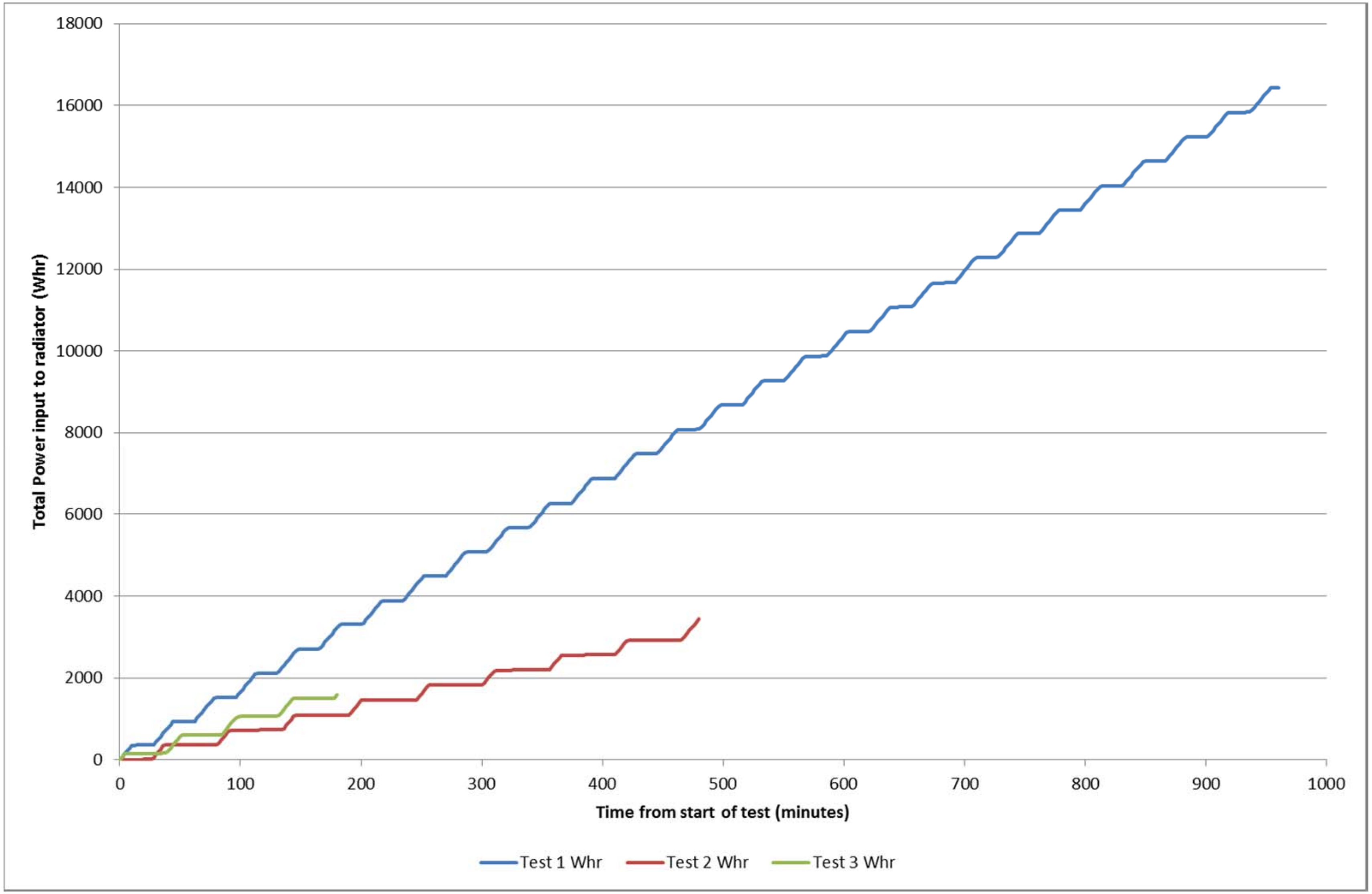
6.4 3 HOUR CHART OF AIR TEMPERATURE AND INSTANTANEOUS POWER FOR TEST 3



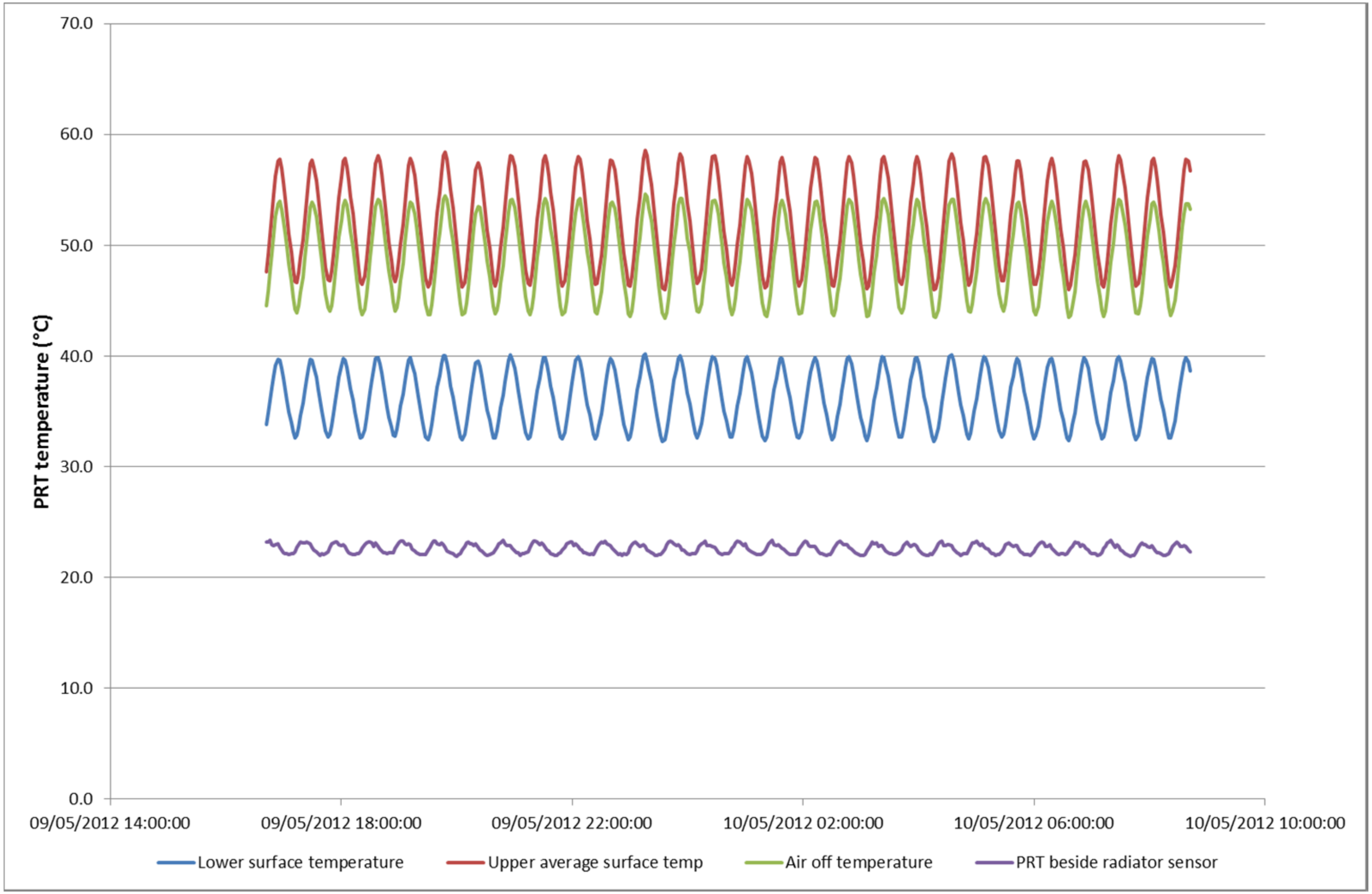
6.5 2 HOUR CHART OF TEST 1 TO SHOW FREQUENCY OF RADIATOR THERMOSTAT



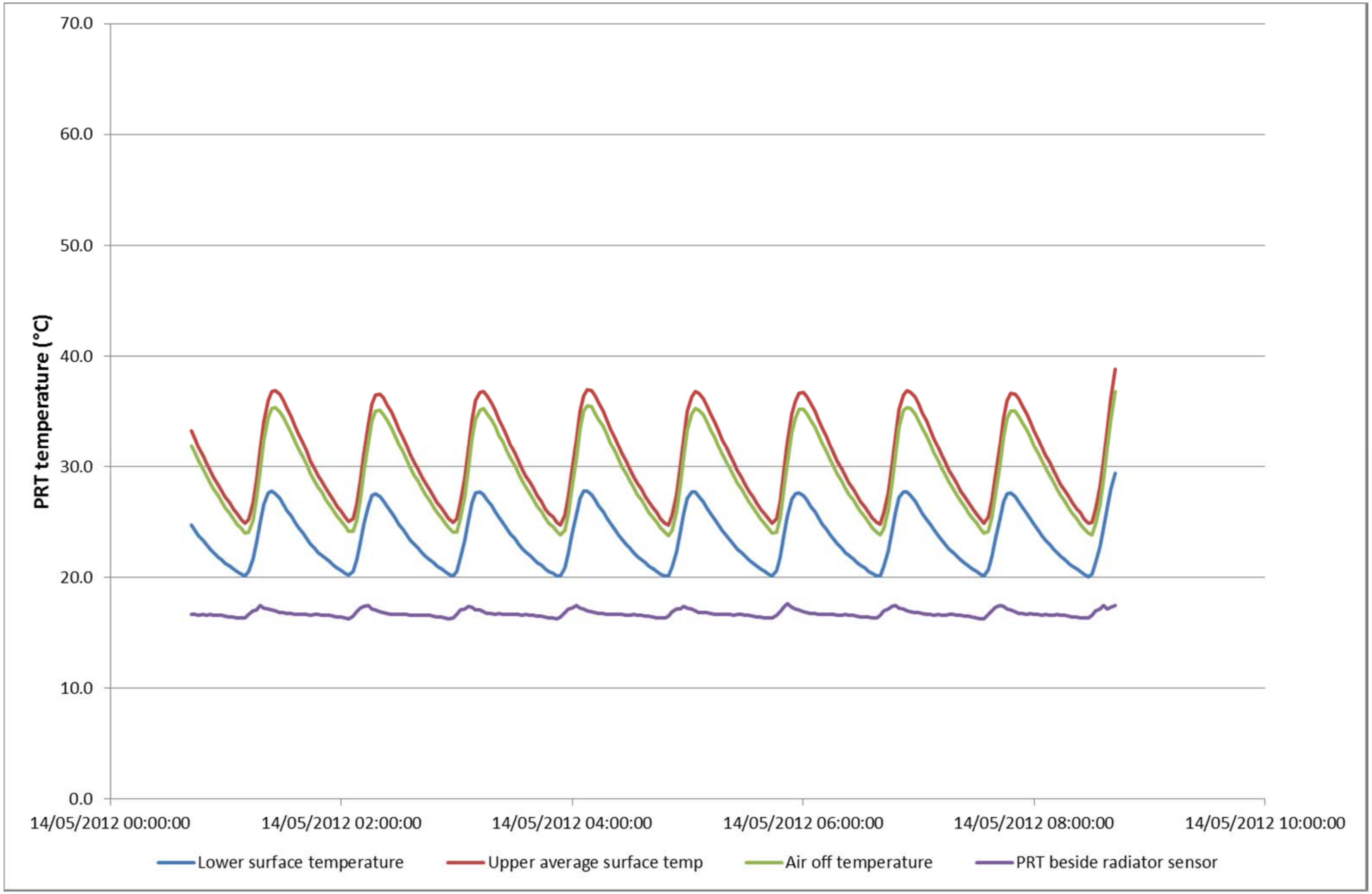
6.6 POWER CONSUMPTION FOR THREE TESTS



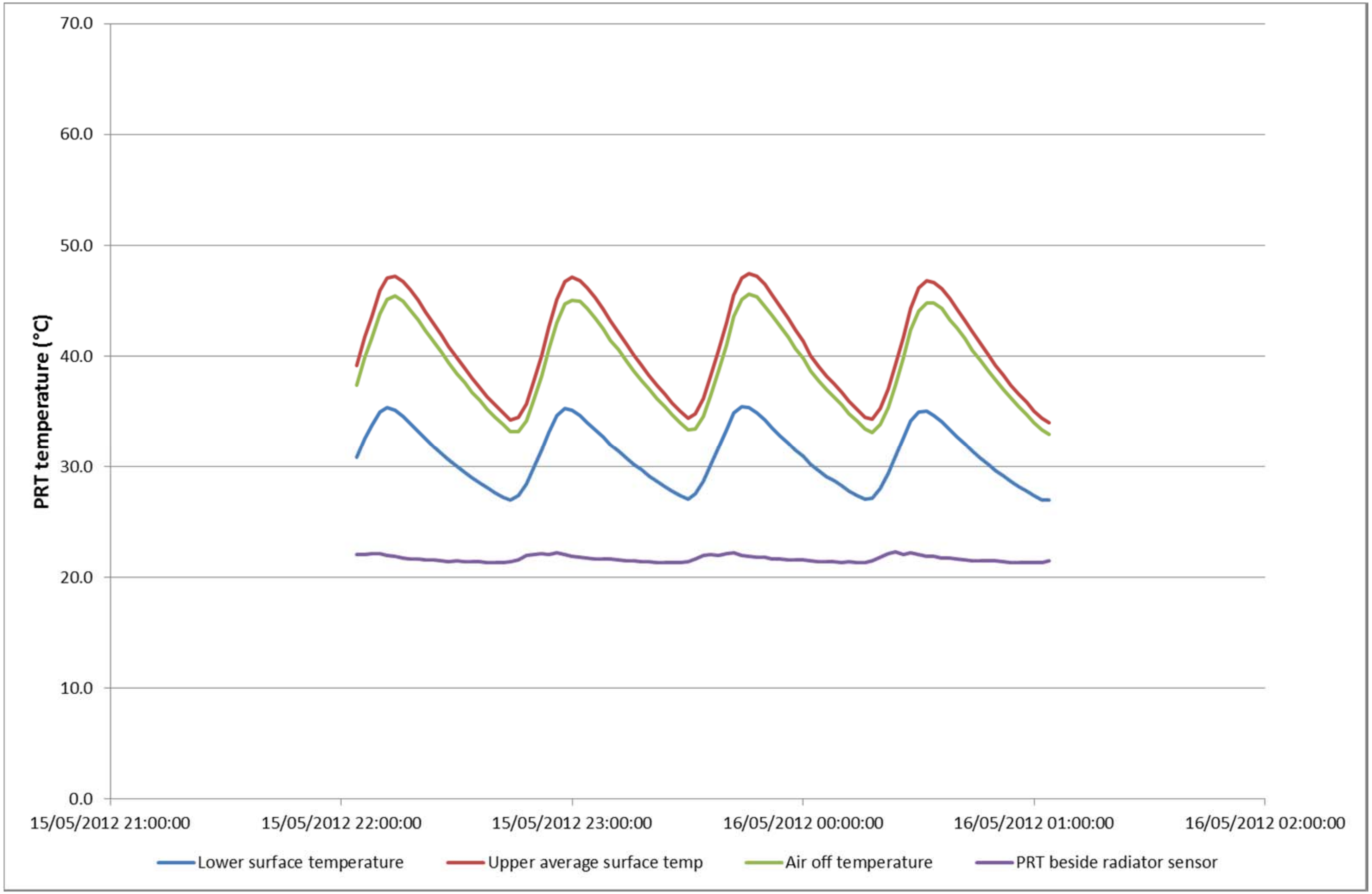
6.7 RADIATOR TEMPERATURES FOR TEST 1



6.8 RADIATOR TEMPERATURES FOR TEST 2



6.9 RADIATOR TEMPERATURES FOR TEST 3



7 CALCULATIONS AND OBSERVATIONS

Cornwall Heating Solutions Ltd requested that a calculation be made to determine the equivalent outside air temperature to obtain the same heat loss in the test chamber as obtained using the cold panels.

This was calculated using:

Outside temperature = Internal temperature – (Heat into radiator / (u-value x surface area))

For test 1, with load of 1027 Watts, internal temperature of 21^{o}C, chamber U value 0.19 W.m^{-2}.°C^{-1}and surface area 75.2m^{2}

t_o= 21-(1027/(0.19*75.2))
t_o=21-(1027/14.288)
t_o=21-71.9
t_o= -50.9 ^{o}C

For test 2, with load of 429.9 Watts, internal temperature 16^{o}C, chamber U value 0.19 W.m^{-2}.°C^{-1}and surface area 75.2m^{2}

t_o= 16-(429.9/(0.19*75.2))
t_o=16-(429.9/14.288)
t_o=16-30.1
t_o= -14.1^{o}C

As can be seen above, the large variations in calculated equivalent outside air temperature around the test chamber for different loads mean that in practice, to obtain a reliable estimate of the size of heater required to meet specific internal design temperatures will need the particular U values (thermal transmittance) and surface areas of the property the product will be installed in.

Any simplistic calculations also assume a sealed space with no air leakage and the theoretical outside temperatures above relate only to the test chamber installation.

Some examples are given below for different surface areas and constructions to illustrate the effect.

Example 1 – Flat with only heat loss from the 4 walls.
Average u-value for room – 0.3 W.m^{-2}.°C^{-1}
Whole house surface area – 100 m^{2}
Test 1 heat into radiator – 1027 W
Calculated outside temperature: -13°C with internal temperature of 21°C

Example 2 – Detached house – average whole house U-value.
Average u-value for room – 0.5 W.m^{-2}.°C^{-1}
Whole house surface area – 200 m^{2}
Test 1 heat into radiator – 1027 W
Calculated outside temperature: 10.7°C with internal temperature of 21°C

Example 3 – Detached house – better whole house U-value.
Average u-value for room – 0.3 W.m^{-2}.°C^{-1}
Whole house surface area – 200 m^{2}
Test 1 heat into radiator – 1027 W
Calculated outside temperature: 3.9°C with internal temperature of 21°C

APPENDIX: A ELECTRIC RADIATOR GENERIC TEST METHOD

Test method - free standing electric heating

Contract: **Version 7**

Date: **November 2010**

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BACKGROUND

The test method described has been drafted by BSRIA in response to creating an acceptable procedure for testing electrical radiators. It is envisaged that this method may eventually be adopted by European Standards bodies.

DEFINITIONS

Radiator	Device with internal electric element used for space heating
Cooling load	Cooling load for the radiator to work against, simulating building heat loss
Room temperature	Air temperature within a black globe mounted at a height of 1.5m in the room centre
Thermostat	Device controlling the operating temperature of the radiator
Surface temperature	Temperature measured on the radiator surface
Temperature stratification	Variations in temperature from floor to ceiling of the test chamber
Emissivity	The relative ability of the radiator surface to emit heat by radiation
Thermal imaging camera	A device that detects and produces an image of thermal radiation in the infra red spectrum
Thermocouple	A temperature measuring probe consisting of two dissimilar metals that produce an EMF when subjected to changes in temperature
Cooling device	A device used to provide the cooling load e.g.chilled water fan coil or cooled ceiling panel
PRT	A platinum resistance thermometer, having a variable resistance with changing temperature.

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FIGURES

Figure 1 Basic room dimensions and layout 7

1 PURPOSE

This test method applies to stand-alone room heating supplied by electrical radiators and is intended for heating duty only. The testing process will determine the room heating capacity and the intrinsic ability of the radiator to maintain a level of control within a standard space. This information will enable effective simulation (modelling) of a proposed installation in order to predict comfort and seasonal energy use.

Stand-alone radiators can be of many types with differing thermal response, innovative control mechanisms and of varied architectural form. This test method defines the protocol needed to assess their surface temperatures and hence suitability for use in spaces occupied by vulnerable people.

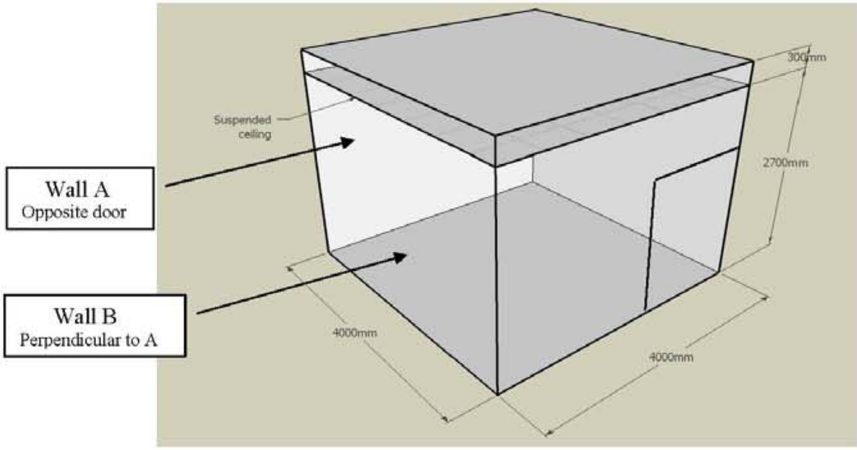
The test method does not provide for an associated rating scheme. It is limited to providing robust and repeatable test data arising from a controlled set of applied loads.

2 TEST EQUIPMENT

2.1 THE TEST ROOM

The tests will be carried out in a closed cuboid-shaped room with internal dimensions of 4 m x 4 m x 3 m in height. Dimensions will have a tolerance not exceeding ± 0.05 m. This room is illustrated in Figure 1.

Figure 1 Basic room dimensions and layout



The test room will be constructed using 100 mm Urethane insulation with steel finish materials in a fabricated sheet form with U-value of not more than 0.19 W/m^2K). The test room shall be airtight to a standard of 0.5 m^3/Hr @ 50 Pa when testing in accordance with ATTMA TS1; this is sufficient to prevent any significant flow from or to the ambient air outside. The test room shall be placed within a second larger environmental room, to minimise heat transfer through its surfaces.

Temperature shall be controlled within both inner and outer rooms. Temperatures in the outer room will be maintained at 20ºC ± 0.5 K.

A cooling load within the inner room shall be provided using a water-cooled ceiling. This should be located 300 mm from the roof and have an extended cold surface of up to 16 m^2. The capacity of the cooling device will be adjusted by changing the chilled water temperature and / or flow rate of the coolant. The temperature of the cooled surface in all places shall be within 5 K of the mean of the incoming and outgoing fluid temperatures.

Electrical supply to the radiator unit inside the room shall be controlled such that the voltage delivered will be 220 VAC ± 5 VAC. The energy supplied to the unit will be measured such that the accuracy of the delivered energy can be assured to within ± 1 %.

The room will be supplied with temperature measurement probes and associated data logging equipment that delivers an uncertainty of not greater than 0.2 K with an in-air time constant not greater than 1 minute. In particular the room temperature referred to throughout the test method shall be that temperature measured at the geometric centre of the room i.e. at a height of 1.5 m.

2.2 TEST UNITS

Units for test shall be selected by the test house manufacturers' production line.

Three units from the production line will be tested in order to confirm the quality of the production line.

The test unit shall be installed using its supplied fittings and in the orientation specified by the manufacturer. For radiators not intended to be affixed to a wall the unit will be placed such that the nearest part of the unit is 0.1 m ± 0.01 m from Wall A shown in Figure 1.

For units supplied with remote room temperature sensors the supplied sensor will be fitted to the geometric centre of Wall B shown in Figure 1 or in the position specified by the manufacturer.

If the radiator does not have its own integrated thermostat a platinum resistance thermometer (PTR) conforming to BS EN 14597:2005 will be mounted in the geometric centre of Wall B at a distance of 0.01 m ± 1 mm from the surface. The PRT shall have a time constant in air of not greater than 1 minute. The PRT shall be connected to a suitable controller operating simple on / off control of the radiator with a dead band set at 0.5 K ± 0.1 K.

3 TEST METHOD

3.1 ROOM TEMPERATURE RISE TIME

3.1.1 Radiator fully cold

The test will be conducted with the test radiator in an 'unused' condition i.e. with the radiator in an ambient temperature throughout its structure.

In this test the time taken for the radiator to raise the temperature of the test room from 15 to 25°C is reported.

The test method is as follows:

- The room will be cooled to 15°C with the test radiator switched off. This will be achieved by supplying a cooling load equivalent to 66 % of the maximum stated output of the radiator at a room temperature of 20°C.

- This will be applied and the time taken for the room temperature measured in the geometric centre of the room to rise from 15 to 25°C will be determined. It may be necessary to use an additional balance load radiator to maintain the pre-conditioning temperature of 15°C. This will be switched off when the test unit is switched on.- This test shall be conducted 3 times and an average of all 3 tests will be taken as the room temperature rise time. Using this data the energy used to heat the room will be calculated.

- The following variables will be logged every 1 –minute:

- Air on temperature (within 100 mm of air inlet)
- Air off temperature (within 25 mm of air outlet)
- Mean radiant room temperature. This will be taken as the temperature of a black globe placed in the middle of the test room 1.5 m vertically off the floor
- Wall temperature (a thermocouple will be placed centrally on each of the four walls)
- Power drawn by the radiator
- Temperature stratification. PRTs will be arranged at the centre of the room at heights from the floor of 0.5 m, 1 m, 1.5 m, 2 m, 2.5 m, and 3 m

Additional options

Surface temperature measurement. Three magnetic adhesive probes can be used on the surface of the radiator to measure surface temperature of the radiator unit. A thermal imaging camera will be used to locate the areas of maximum surface temperature and the stick-on PRTs will be located in these areas.

3.1.2 Radiator in warmed condition

The test shall be undertaken as in 3.1.1 with the exception that the Radiator shall have been allowed to operate in its normal condition with a 66 % load at 20°C for a period not less than 24 hours immediately prior to this test.

3.2 WARMING UP TIME OF THE RADIATOR (BASED ON TEST 10 OF STANDARD BS EN 60675:1995)

In this test the warming up time of the surface of the radiator is determined.

The time taken for the surface of the radiator to attain 90 % of its ultimate surface temperature under steady state conditions is measured. The temperature rise of the hottest point of the external surfaces or air outlet grilles (whichever reaches steady conditions first) is used as a reference for the ultimate surface temperatue as long as it is representative of the surface temperature rise. This point shall be located using a thermal imaging camera. It is considered that steady conditions have been attained when the temperature rise over a one-hour period does not vary more than 2°C.

The test method is as follows:

- With no power being drawn by the radiator a cooling load is applied to the test room to decrease the room temperature to 18°C.
- This cooling load is then adjusted to be 66 % of the maximum output of the radiator at a room temperature of 20°C.
- The thermostat on the radiator is set to maximum to ensure that the radiator draws maximum power for the duration of the test.
- The time taken for the radiator to attain 90 % of the temperature rise under steady conditions is measured.
- This test shall be conducted 3 times and an average of all 3 tests will be taken as the surface temperature rise time.

The following variables will be logged every minute:

- Air on temperature (within 100 mm of air inlet)
- Air off temperature (within 25 mm of air outlet)
- Average room temperature. This will be taken as the temperature of a black globe placed in the middle of the test room 1.5 m vertically off the floor.
- Wall temperature (a thermocouple will be placed centrally on each of the four walls)
- Power drawn by the radiator (kWh over test period)
- Surface temperature probes. Two magnetic stick-on PRTs will be placed on the hottest areas of each external surface of the radiator. A thermal imaging camera will be used to locate these areas
- Temperature stratification. PRTs will be arranged at the centre of the room at heights from the floor of 0.5 m, 1 m, 1.5 m, 2 m, 2.5 m, and 3 m

3.3 STABILITY OF ROOM TEMPERATURE (BASED ON TEST 11 OF STANDARD BS EN 60675:1995)

The purpose of this test is to evaluate the ability of the radiatorto retain effective control when the load in the room varies. The thermostat is set to give 20°C at 80 % of full output and then the applied load is varied without subsequently adjusting the thermostat.

The temperature inside the test room is measured for three different load ratios that are obtained by changing the cooling load, without changing the setting of the ambient temperature thermostat. For this test the thermostat is adjusted to achieve a room temperature of 20°C. Measurements are taken when the average room temperature is judged to be stable over a 2-hour period (20 ± 0.3°C).

The test method is as follows:

- The first measurement is made with the ambient temperature thermostat set to give a temperature in the test room of 20°C at a load ratio of 80 (± 5) %. If the ratio is not attainable due to the capacity of the device used to provide the cooling load, the highest possible energy ratio is used, in accordance with Equation 1.

$$Energy\ Ratio = \frac{Cooling\ Load\ (W)}{Maximum\ \text{Radiator}\ Output\ (W)}$$ Equation 1

- The capacity of the cooling device is then decreased to give a load ratio of (50 ± 5) % and the second measurement is taken.
- - The third measurement is made with a low load ratio. The low load ratio is 20 (± 5) %, subject to a minimum of 250 W

- For each load ratio the amplitude of the room temperature oscillation is measured. This is taken as the average difference between the maximum and minimum room temperature, for each oscillation, over the 2-hour period of stability.

- The drift is determined from the average room temperature at the high and low energy ratios using the formula given in Equation 2:

$$D = (t_B - t_A) \times \frac{60}{A - B}$$ Equation 2

where

D	is the drift
t_A	is the average room temperature at the high energy ratio
t_B	is the average room temperature at the low energy ratio
A	is the measured power output/cooling load at the high energy ratio
B	is the measured power output/cooling load at the low energy ratio

In the formula, '60' is the difference between the ratios of 80 % and 20 %. If the average room temperature at the energy ratio of 50 % does not fall between t_A and t_B, the formula is not applicable and the maximum difference of the three values is stated as the drift.

The amplitude and the drift are stated to the nearest 0.1 K

This method is generally in accordance with BS EN 60675:1995 Calc of drift

- The following variables will be logged everyminute;

- Air on temperature (within 100 mm of air inlet)
- Air off temperature (within 25 mm of air outlet)
- Average room temperature. This will be taken as the temperature of a black globe placed in the middle of the test room 1.5 m vertically off the floor
- Wall temperature (a thermocouple will be placed centrally on each of the four walls)
- Power drawn by the radiator. For a valid test this should remain constant throughout each test period
- Surface temperature probes. Two magnetic adhesive PRTs will be placed on each external surface of the radiator
- Temperature stratification. PRTs will be arranged in the centre of the room at heights from the floor of 0.5 m, 1 m, 1.5 m, 2 m, 2.5 m, and 3 m

Additional options

- *Surface temperature measurement*. Three magnetic adhesive PRTs can be used on the surface of the radiator to measure surface temperature of the radiator unit. A thermal imaging camera will be used to locate the areas of maximum surface temperature and the stick on PRTs will be located in these areas.

3.4 EFFECT OF RADIANT HEAT (BASED ON TEST 15 OF STANDARD BS EN 60675:1995)

A dull-black painted plywood board approximately 20 mm thick, having a width of 1.5 m and a height of 1 m, shall be positioned vertically on the floor symmetrically in front of the radiator at a distance of 1m from it.

Thermocouples shall be fixed on the board, with the distance between adjacent thermocouples being not more than 00.1 m. A thermocouple protected against heat radiation is placed behind the board at a horizontal distance of 0.2 m from the centre.

The thermostat on the radiator is set to attain 20°C. The cooling load is adjusted to be 66% of the maximum output of the radiator.

Temperatures are measured when steady conditions are established. The temperature rises are calculated, being the difference between the temperature of the thermocouple on the board and the protected thermocouple.

The following temperature rises of the board are stated, rounded to the nearest 1 K:

- The temperature rise distribution;
- The highest and lowest temperature rises;
- The average temperature rise;
- The lowest and the average temperature rise of the central part of the board over a width of 0.5 m

During the period when measurements are made, the ambient temperature of the room is to be maintained within 0.5 K. Before commencement of the test it will be ensured that the board is at equilibrium with the room temperature. The board will only be placed in front of the radiator once the radiator has reached its maximum surface temperature. This maximum surface temperature will be maintained throughout the test.

The following variables will be logged everyminute:

- Air on temperature (within 100 mm of air inlet)
- Air off temperature (within 25 mm of air outlet)
- Average room temperature. This will be taken as the temperature of a black globe placed in the middle of the test room 1.5 m vertically off the floor
- Wall temperature (a thermocouple will be placed centrally on each of the four walls)
- Power drawn by the radiator
- Surface temperature probes. Three PRTs will be placed on the surface of the radiator facing the plywood board. They will be placed at each horizontal third of the outward facing area of the radiator. Their positions will be such that they will be located half along the vertical plane of the radiator
- Surface temperature thermocouples on the plywood board

The board may also be positioned to measure the effect of radiant heat from the sides of the radiator. Also, if the top of the radiator is higher than 1m above the floor, the board may be positioned vertically.

Additional options

- *Emmissivity measurement.* The emmissivity of the surface of the radiator will be found. In order to find the emmissivity a standard technique using a thermal imaging camera will be applied.
- *Thermal images* of the radiator shall be taken when power is being drawn and maximum surface temperatures have been attained. This illustrates the surface temperature distribution on the radiator.

3.5 24-HOUR TEMPERATURE MAINTENANCE TEST WITH VARYING SIMULATED HEAT LOSS

The purpose of the test is to investigate how effectively the electric radiator maintains 20°C within the test room when subjected to varying loads. The maximum and minimum temperatures, the corresponding cooling loads and standard deviation of temperature will be reported.

In this test heat loss variations from a typical domestic room with similar dimensions to the test room are simulated over a 24-hour period. In order to achieve this an electric actuator is used to change the flow rate of chilled water through a cooling device simulating heat loss from the test room.

The test method is as follows:

- The thermostat on the electric radiator is set to attain 20°C.
- The test room is then maintained at a steady state temperature of 20°C balanced against an initial cooling load of 1 kW.
- Over a period of 24 hours the voltage across the mechanical actuator is varied, changing the flow rate through the cooling device and therefore the cooling load applied to the room. This simulates the effect of changing outdoor temperatures. The flow rates vary so that, with the test room maintained at 20°C, the maximum cooling load will be 1 kW and the minimum-cooling load will be 100 W.
- Throughout the 24-hour period the cooling load will vary so as to reflect changing outside temperatures throughout a typical day.

The following variables will be logged every minute:

- Air on temperature (3 PRTs placed below the radiator)
- Air off temperature (3 PRTs placed above the radiator)
- Average room temperature. This will be taken as the temperature of a black globe placed in the middle of the test room 1.5 m vertically off the floor
- Wall temperature (a thermocouple will be placed centrally on each of the four walls)
- Power drawn by the radiator
- Surface temperature probes. Two PRTs will be placed on each external surface of the radiator
- Temperature stratification. PRTs will be arranged at the centre of the room at heights from the floor of 0.5 m, 1 m, 1.5 m, 2 m, 2.5 m, and 3 m
- Cooling load applied to the test room

Additional options

- *Comparison test.* The test will be conducted with another electrical or wet radiator. In the case of a wet radiator a Thermostatic Radiator Valve (TRV) will be set to 20ºC to regulate the power output.