Report

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Radiator testing

Report 53246/1 Edition 2

This report supersedes Report Number 53246/1 dated September 2009

09 March 2011

Carried out for: **Industrias Royal Termic S.L.**
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PREFACE

This report supersedes Report Number 53246 dated September 2009.

The following amendment/s has been made:

Edition 2 of Report 53246 has been issued due to the addition of Appendix C as requested by the Client.

Appendix C, by BSRIA's Engineering Director, Mike Smith, contains a summary of the testing, intended to help the Client's customers understand the testing done. There have been no changes to the main body of the Report.

This change does not affect the overall results or conclusions of the report as originally issued.

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1 OVERVIEW

Industrias Royal Termic S.L. contacted BSRIA in order to determine the performance of the Rointe K Series radiator. This report summarises the findings of the testing done on an electric radiator Rointe K Series at BSRIA's laboratories in Bracknell.

2 TESTS

The purpose of this test was to determine the performance of the radiator. It was intended to determine how effectively the radiator achieved and maintained a temperature of 20± 2°C in the test chamber, when a cooling load of 700 W was applied.

2.1 THE TEST FACILITY

The testing was done in an environmental chamber at BSRIA. The chamber is built within an exterior building to enable control of the environmental parameters. During the testing, the external chamber temperature was kept at 21°C, to minimise heat transfer.

Figure 1 External and internal chambers at BSRIA

The internal chamber dimensions are 3x 4 x 3 m height. The test room has been constructed using 100 mm Urethane insulation with steel finish materials in a fabricated sheet form
(U value=0.19 $W.m^{-2}.K^{-1}$)

2.2 CHILLED CEILING CALIBRATION/COOLING LOAD

The cooling load was achieved through a chilled ceiling.

2.2.1 Chilled ceiling calibration

The chilled ceiling was set so that it would provide a cooling load of 700 W when the room temperature was 21°C. To do so, the chilled ceiling was tested beforehand. A set of 8 DIN man were connected in the room connected to a Eurotherm controller, which was set to maintain 21°C in the chamber. The temperatures of the water flow and return to the chilled ceiling, as well as the water flowrate were measured under steady state conditions, therefore the cooling power could be calculated by the formula:

$$Cooling\,(kW) = 4.186 kJ.kg^{-1}.K^{-1}.(\Delta Twater).Q(kg.s^{-1})$$

(Assuming water density= 1 $kg.m^{-3}$)

Three different tests were done in order to calibrate the ceiling. The supply water temperature was modified (by the water storage tank) and the cooling data is presented in the table below:

Date	Test	Water in tank set to: (°C)	Water in chilled ceiling (°C)	Water out chilled ceiling (°C)	Flow ($l.s^{-1}$)	Average cooling power (W)
27-28 July 2009	1	14	13.9	14.7	0.146	498
28 July 2009	2	11	10.9	12.2	0.152	731
28-29 July 2009	3	9	8.9	10.3	0.151	882

Interpolating the results, the temperature the tank should be set to so that the cooling power is 700 W when the room is at 21°C should be 11.4°C.

With the chilled water set at 11.4°C the test was repeated this time with the Rointe series K Radiator. The radiator power was maintained at 700 W (using a Variable Voltage Power Supply). The room temperature (measured at the globe in the middle of the room at 1.5 m height) was 19.8°C.

This difference between the room temperature using the DIN men and using the radiator can be explained by the very rapid response of the DIN men when varying the heating load and by the fact that the radiator temperature sensor is in the radiator and not in the middle of the room as the Eutotherm's was. Therefore the supply water was modified, as shown in the table below, increased again (aiming to achieve 21°C in the room). The following table shows the tests carried out in order to adjust these parameters with the radiator.

Date	Test	Water in tank set to: (°C)	Water in chilled ceiling (°C)	Water out chilled ceiling (°C)	Flow ($l.s^{-1}$)	Radiator power (W)	Average cooling power (W)	Walls (W)	Imbalance (W)	Room Temperature (°C)
29/7/09	1	11.4	11.1	12.3	0.152	697	737	23	73	20.2
31/7/09	2	12.0	11.9	13.0	0.152	696	709	40	60	20.9
03/8/09	3	13.0	12.9	13.9	0.152	692	667	43	23	21.2

Therefore, the water in the tank was set to 13^0C for the performance test of the radiator.

2.3 PERFORMANCE TEST

The purpose of this test was to determine the performance of the radiator. It was intended to determine how effectively the radiator achieved and maintained a temperature of 21°C in the test chamber, when a cooling load of 700 W was applied.

The chamber was previously cooled down to 15°C. The radiator thermostat was set to 21°C and the power consumption of the radiator was monitored during the heating period and over 24 hours.

During this test the following variables were monitored:

- Oil temperature (see Figure 3)
- Air on temperature (see Figure 2)
- Air off temperature (see Figure 3)
- Air centre of radiator
- Globe temperature at 1.5 m
- Radiator surface temperatures (see Figure 2) 2 sides
- Lower, middle and upper part of the central element
- An extra PRT was placed next to the radiator's own temperature probe
- Wall temperatures and heat loss through chamber walls
- Relative humidity
- Temperature stratification in the room

Figure 2 Probes on the radiator

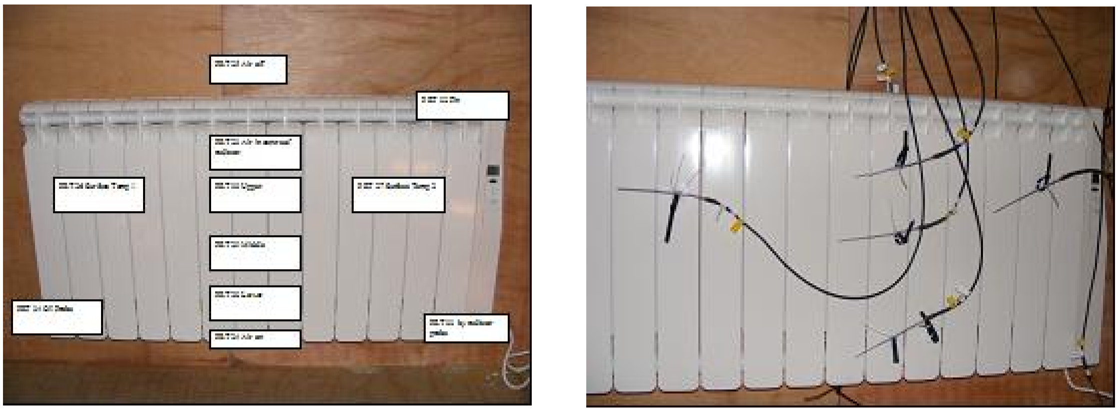
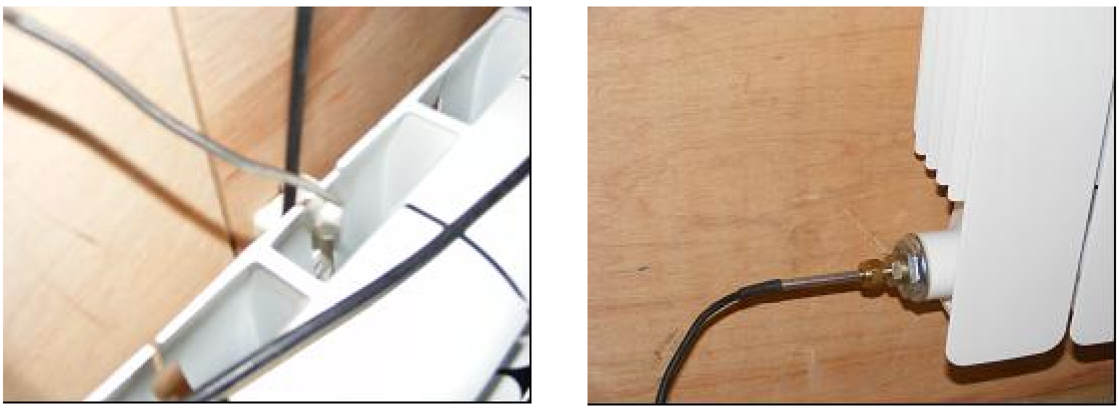


Figure 3 Detail of "air off" probe and oil probe connection



2.4 THERMOGRAPHY

A thermography survey was carried out under the same conditions as the previous test, over a period of 24 hours. The results were logged every 30 seconds and are shown in the accompanying video (5 images per second). A representative selection of the results are shown in Appendix B.

2.5 VOLTAGE TEST

The Client's specifications for the radiator (i.e. maximum power consumption of the radiator) referred to a different voltage than the one applied during testing at BSRIA's laboratories (which is supplied by the National Grid). To explain the difference in the results achieved, BSRIA carried out a voltage test. The radiator thermostat was set at 30°C, to achieve the maximum power output (kW) from the radiator. A Variac was connected to the power meter and the voltage was set to different values and the maximum power form the radiator measured.

The results are presented in Figure 4.

Figure 4 Voltage test results

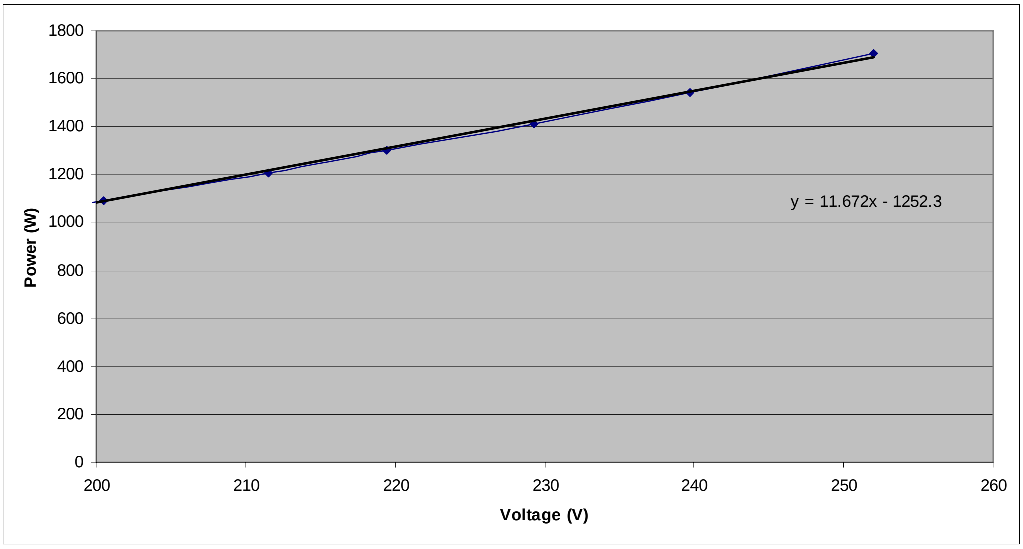


Table 1 Comparison of Voltage /Power results

Conditions	Applied Voltage	Measured
Client's specification	230	1430
Measured at BSRIA	230	1432
Average voltage during test (*)	244	1629
According to equation	244	1595 (derived)

* For power higher than 1400 W

As a cross check, data recorded in the test (see Figures 5 and 6) has been processed for measured power above 1400 W and the result is shown in row 4 of Table 1. This agrees closely with the value of 1595 W derived from the equation from the voltage test.

3 INSTRUMENTATION

3.1 TEMPERATURE

Platinum resistance thermometers (PRT) were used to monitor air temperatures and for measurement of surface temperatures. The PRTs were connected to a multi-channel microprocessor based data acquisition system. Resistance signals generated by the PRTs were converted in the processor, by applying the appropriate relationship, into units of temperature (°C). Data was transmitted directly to a p.c., firstly to enable more comprehensive on-screen monitoring, and secondly for data analysis within a spreadsheet and a graphical presentation software.

3.2 ELECTRICAL AND THERMAL LOADS

The electrical power consumption of the internal heat sources was measured using a kilowatt-hour meter.

3.3 RADIANT TEMPERATURE

Radiant temperatures were measured using a PRT with the sensing junction positioned at the centre of a 100 mm blackened sphere. The PRT signal was treated by the same processor as that used for temperature measurements of the control parameters.

3.4 THERMAL IMAGING CAMERA

The thermography test was done using a FLIR Therma CAM PM595. The camera had a range between –40 to 500°C, sensitivity 0.1°C at 30°C and a spectral Range –7.5 to 13**µm**

3.5 CALIBRATION

All equipment significant to measurements is regularly serviced and maintained according to the manufacturers' instruction and is regularly calibrated in accordance with BSRIA's quality requirements. Operated by our test engineers, a rigid system is in force, which records the calibration history of each instrument and prompts re-calibration prior to each work programme.

4 RESULTS

The results for the performance test are presented in the Figures 5 to 11 below. The environmental chamber was cooled down until it reached 15^0C and the radiator was connected at 10:27 a.m. on 5 August 2009.

Table 1 and 2 show the average results for the test and the test parameters.

Table 2 Performance test results

Total Wh during test	13490
Time since radiator was switched on	24 hours
Average Power during test (W)	560

Table 3 Performance test parameters

Water temp In room	Water temp out room	Flow meter 2	Total Cooling (W)	Fabric Gains (W)	Total Heating Av. (W)	Balance (W)	Room temp 1.5 m (Globe)
12.9	13.7	0.151	-518	-9	560	33	19.4

The average balance over the test is 33 W. This implies that a small amount of heat if being lost from the Chamber. The mode of operation of the radiator is for short periods at full power, which will take the radiator temperature slightly above the average value- the consequence will be a short-term transient heat loss from the Chamber,

Nevertheless, the relative magnitude of the imbalance is less than 6% of the average power and it is considered to be within experimental limits.

Figure 5 Instantaneous power consumption of the radiator during performance test

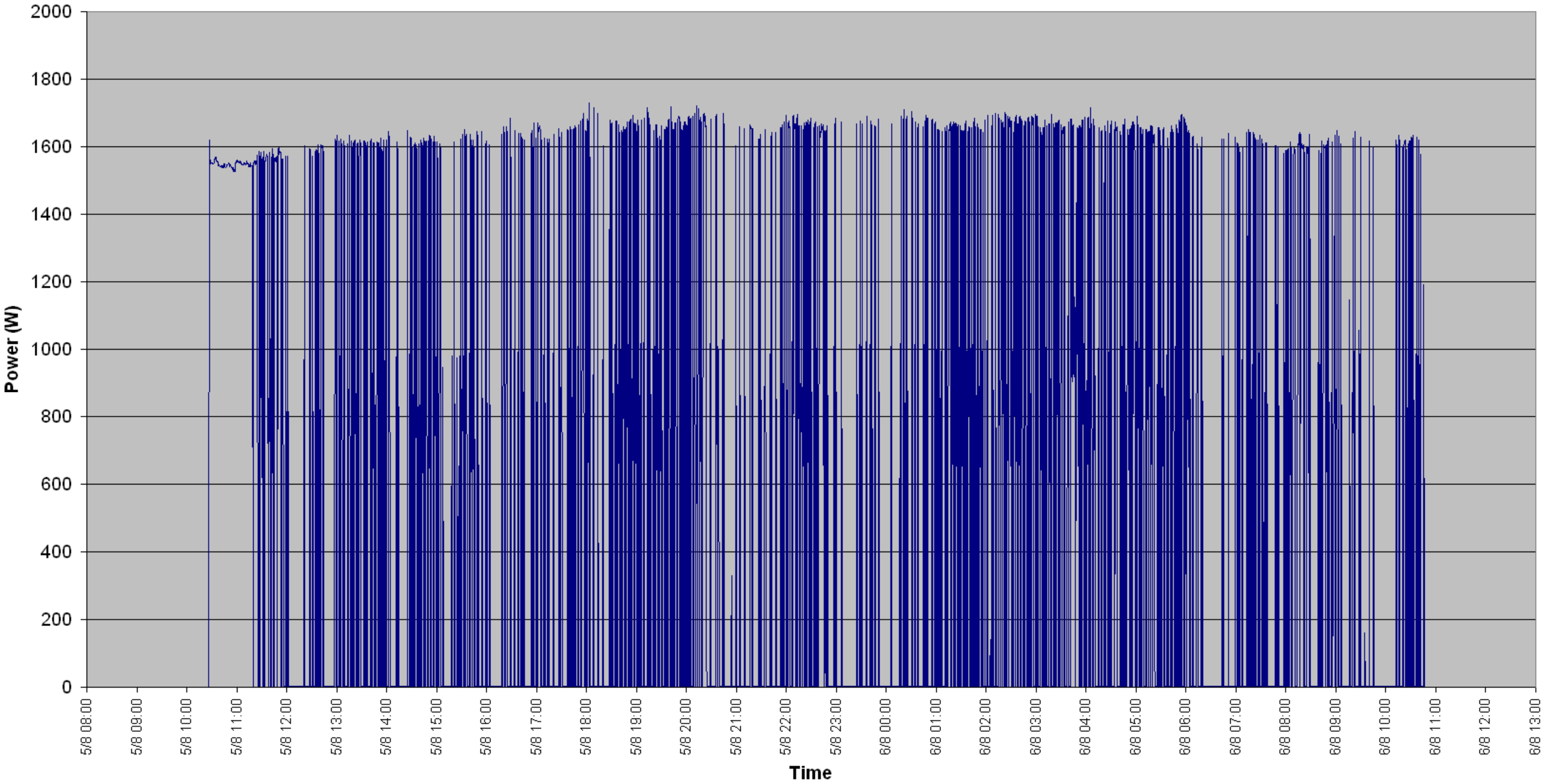


Figure 6 Cumulative power consumption during performance test

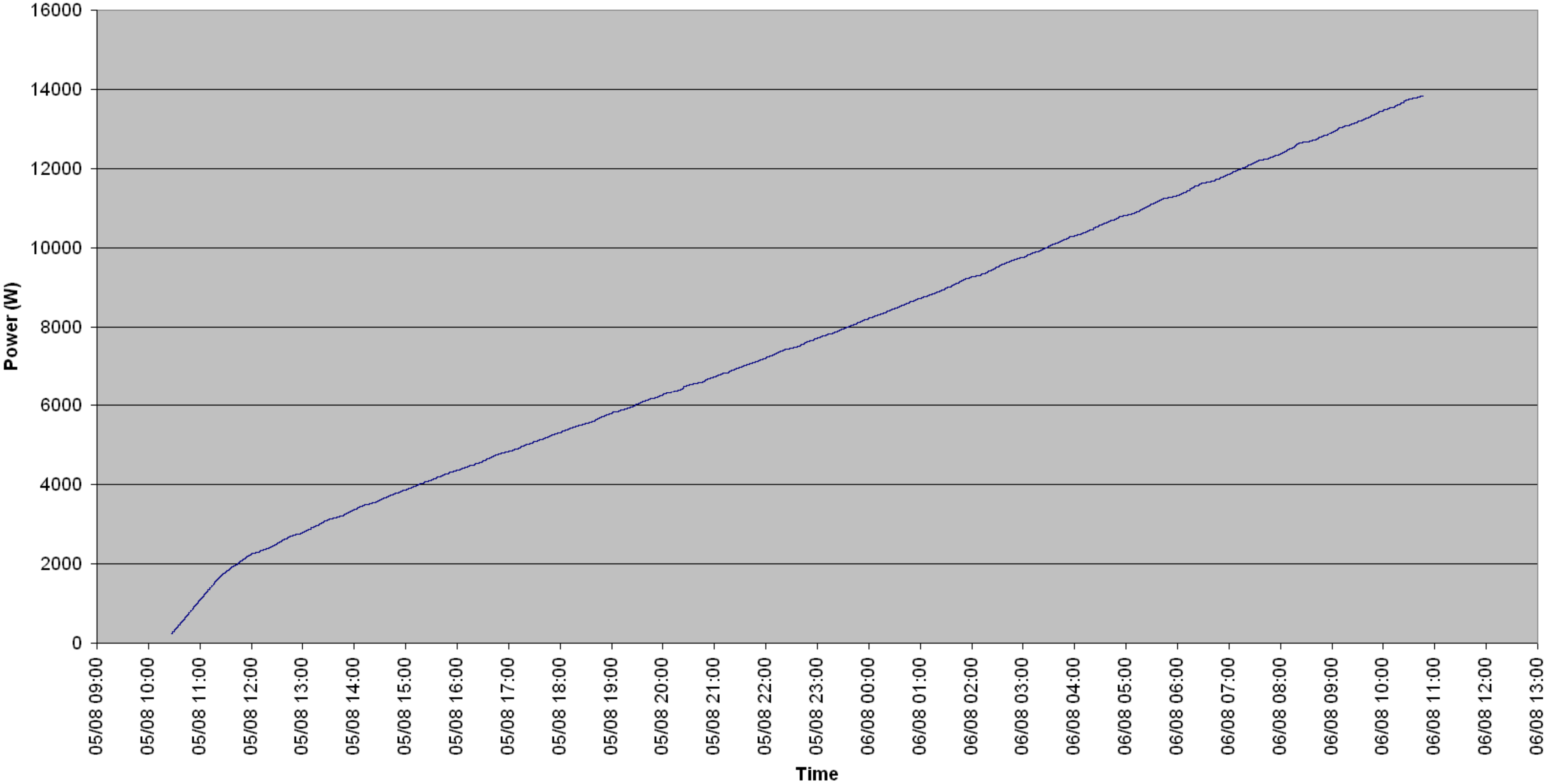


Figure 7 Voltage during performance test

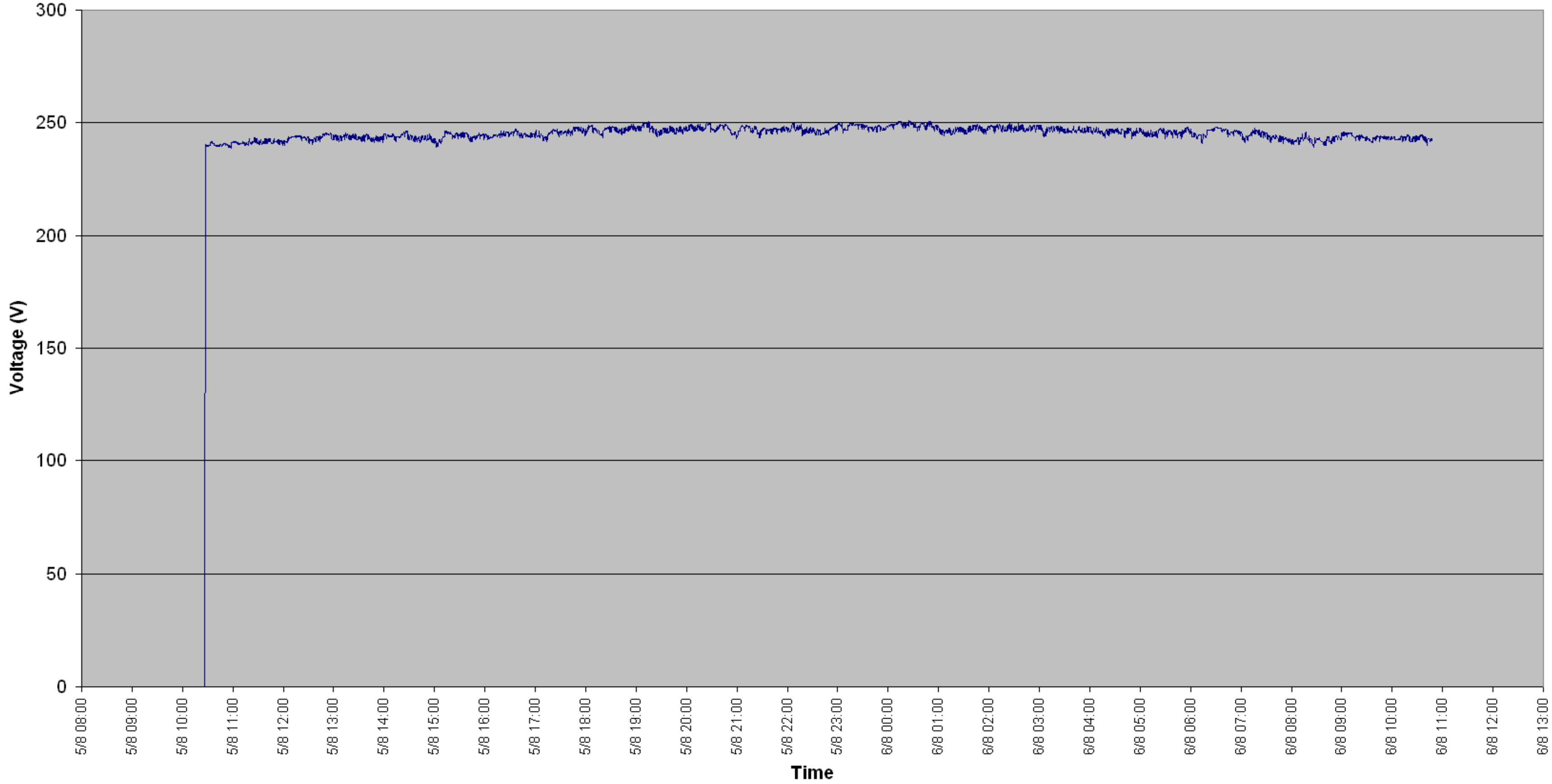


Figure 8 Current during performance test

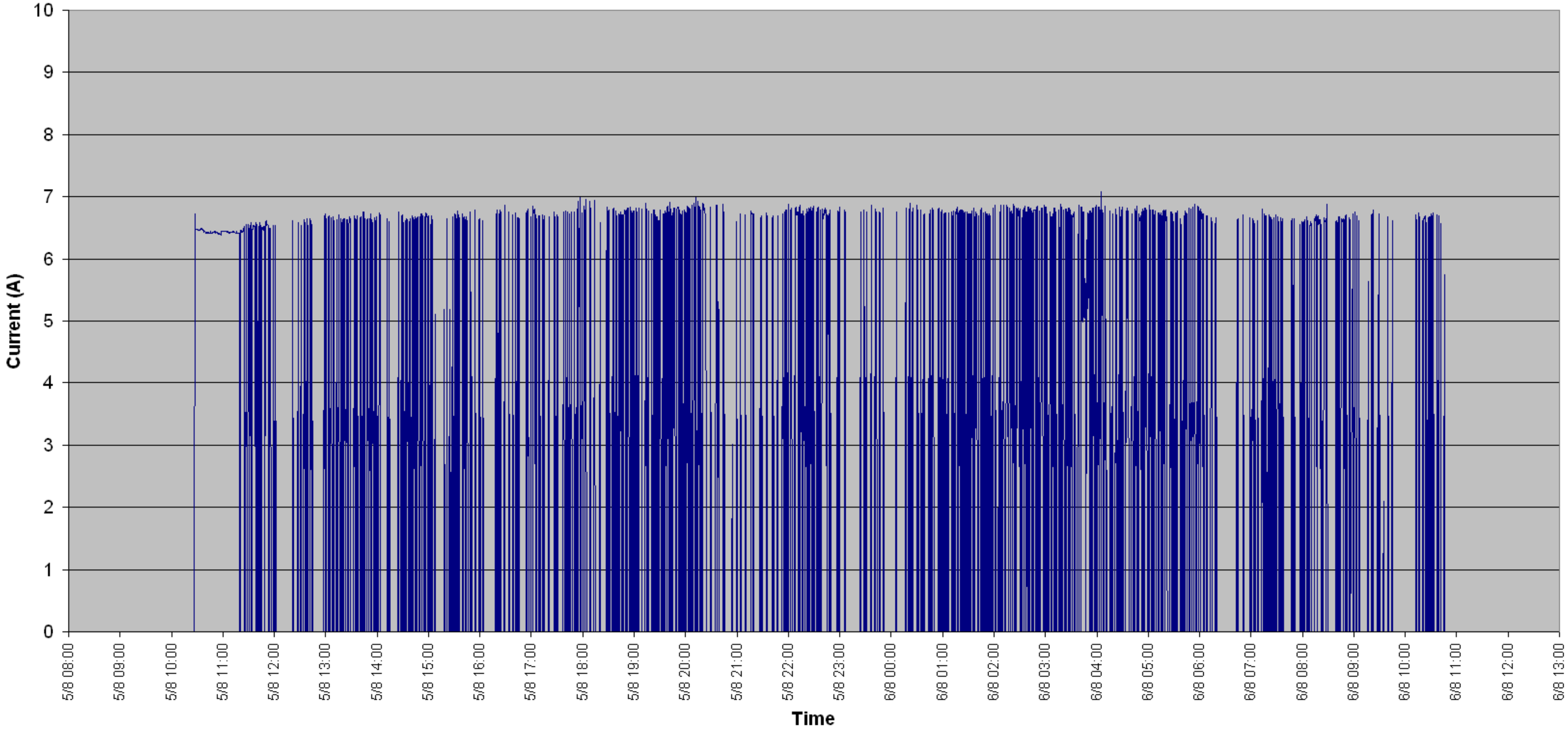


Figure 9 Cooling load

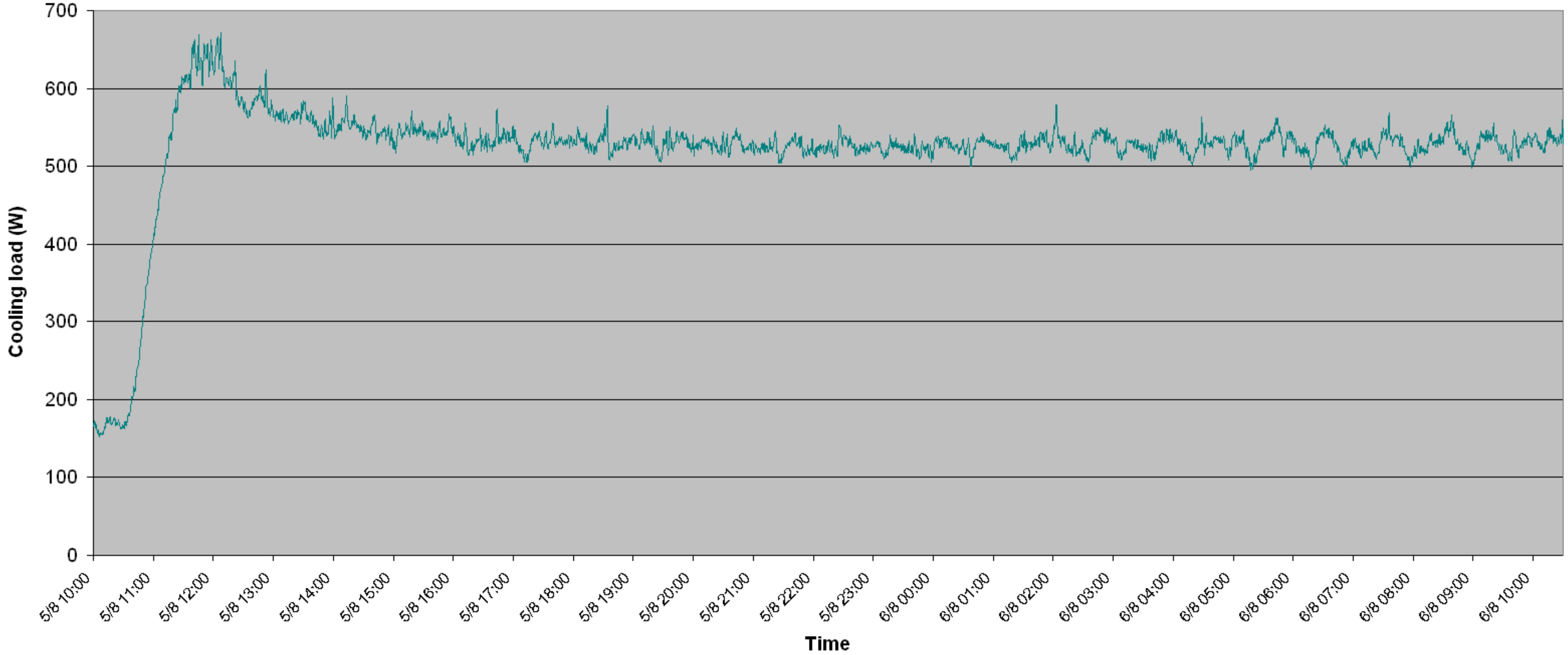


Figure 10 Radiator air temperatures

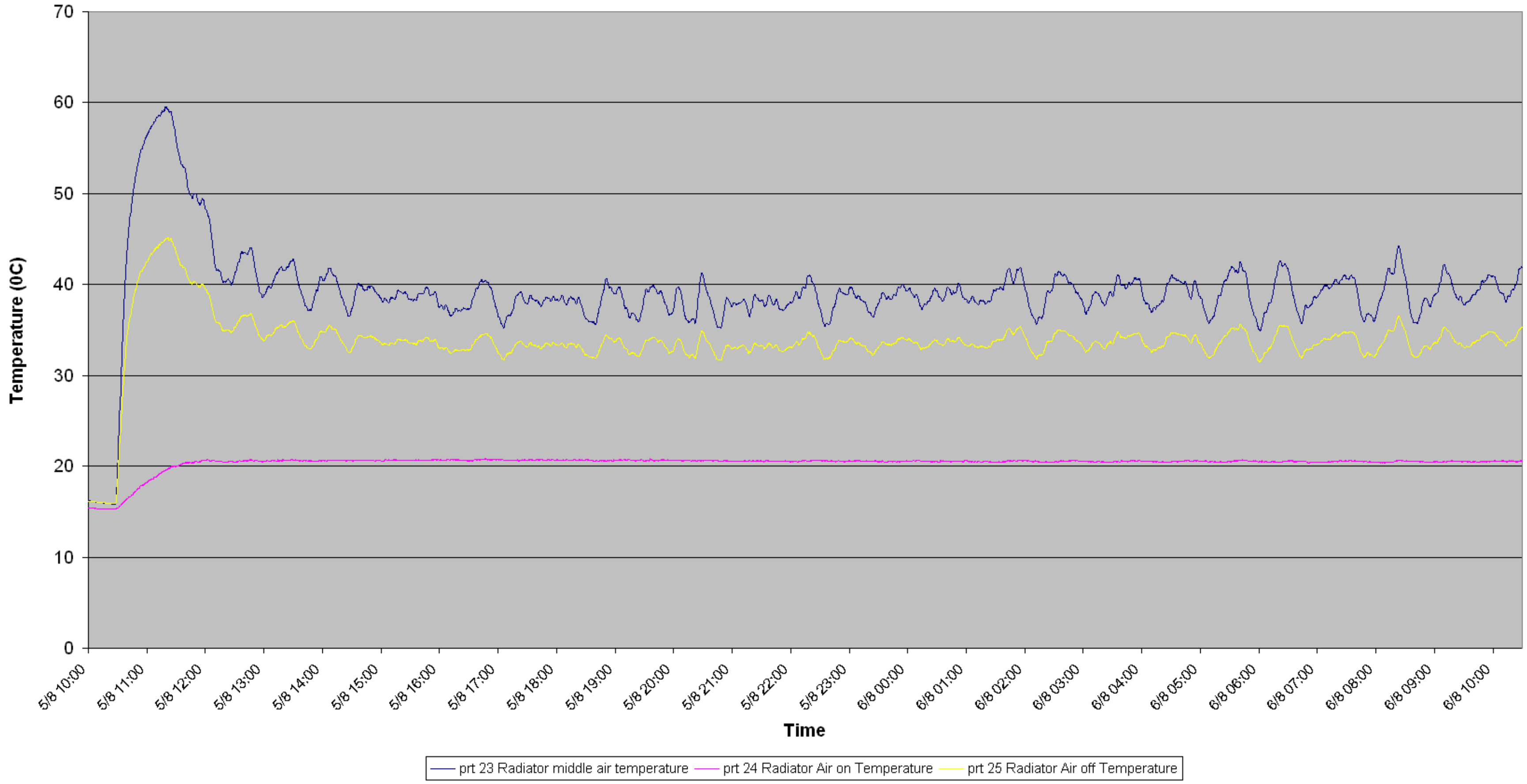


Figure 11 Room temperatures (Pole) and Relative Humidity (%)

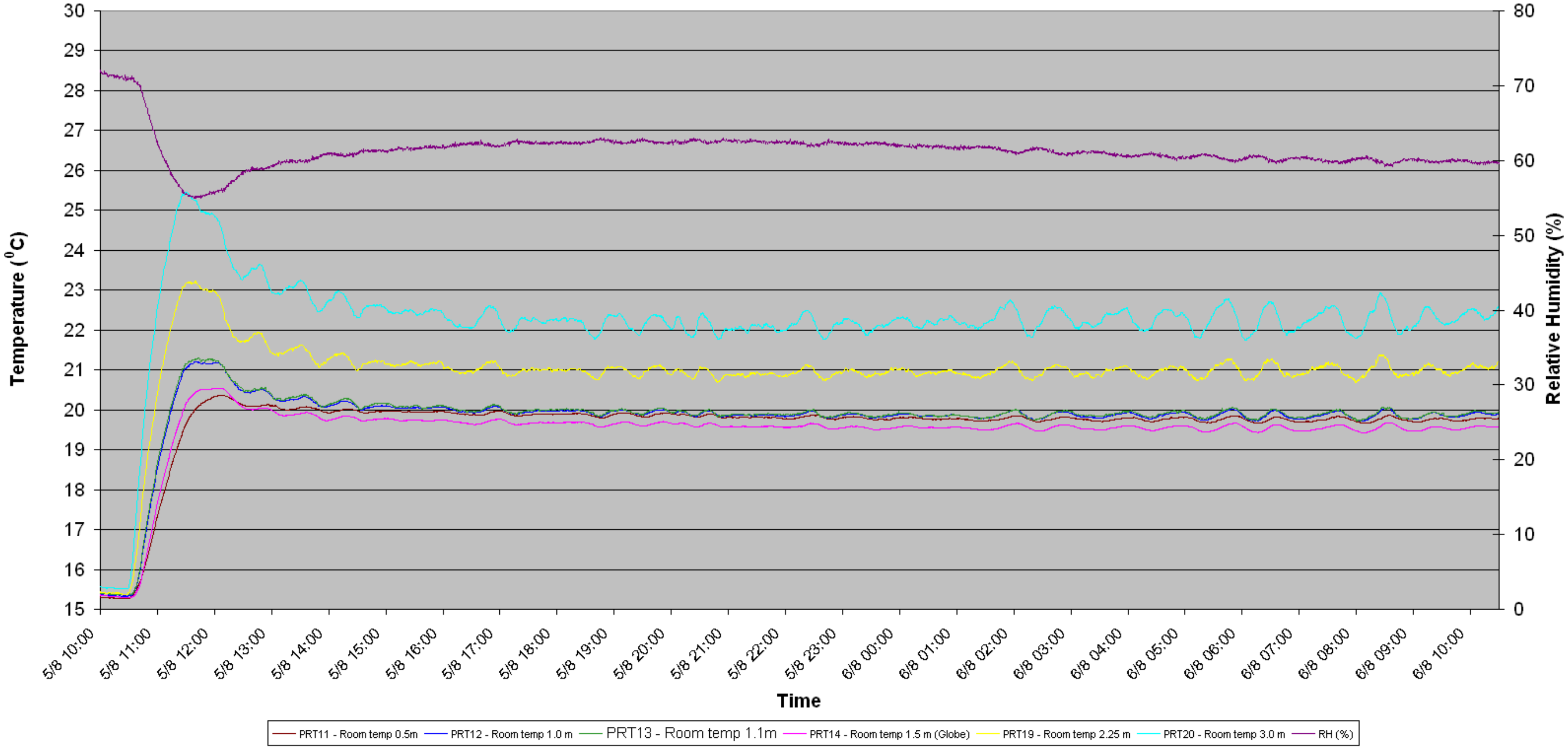
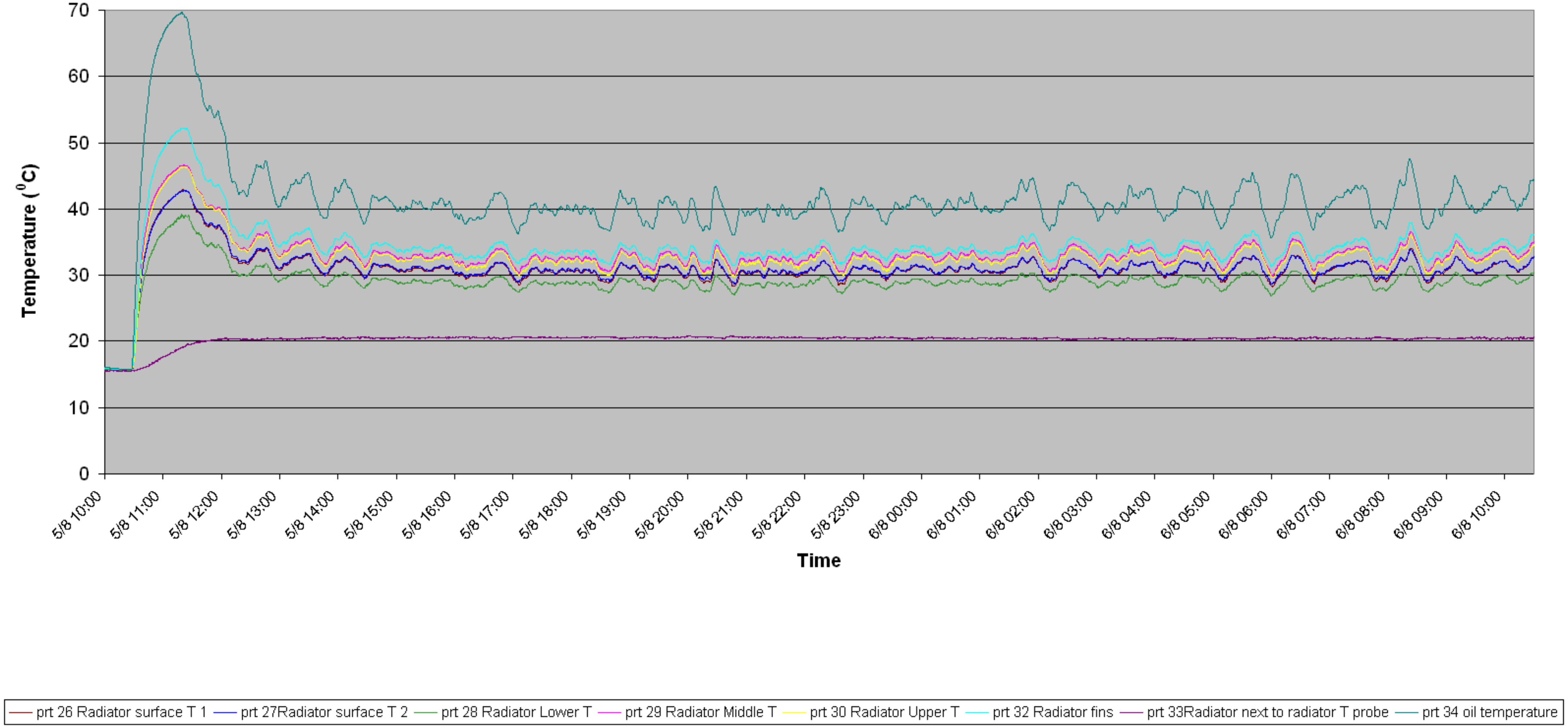


Figure 12 Radiator temperatures



Results show a difference between the calibration of the chilled ceiling tests and the performance test. The same cold-water temperature was applied to the chilled ceiling, but the results show an average cooling power of 518 W versus 667 on the calibration test.

This can be explained by the difference in the radiator's drawn power. When the radiator's consumption was forced to be 700 W, the room achieved 21.2°C. During the performance test, when the radiator's thermostat was regulating the temperature of the room, the average power consumption of the radiator was 562 W, therefore the temperature in the room was lower.

During the calibration test of the ceiling (Test 3) the average room temperature was 21.2°C whereas during the performance test, the room temperature achieved 19.5°C. Nevertheless, this is still within the room control temperature of 20 ±2°C.

Table 4 Comparison of tests

Test	Description	Radiator Power (W)	Room temperature (°C)	Cooling load (W)	Balance (W)	W/°C
Chilled ceiling	Radiator supplied through Variac (thermostat not controlling)	700	21.2	667	33	85.4
Performance test	Radiator connected directly to main supply (thermostat controlling	562	19.5	518	41	86

During starting of the radiator, some of the surface temperatures went over 43.5°C for over 30 minutes (Radiator Upper T and middle T) and therefore go over the recommended limit established by the NHS (National Health Service) for radiator surface temperatures. The fin temperature also goes over 43°C, but this is not a surface that can be reached by a user.

For the performance test, the total Wh for a radiator Rointe Series K was 13490Wh over 24 hours, which is equivalent to an average power during of 560 W.

APPENDICES

Appendix: A Sensor list and calibration factors

Sensor	C_0	C_1
PRT16 - Water temp out room	-0.1362	1.0010
PRT17 - Water temp In room	-0.1477	0.9999
PRT21 - Water in chilled ceiling	-0.1306	0.9994
PRT22 - Water out chilled ceiling	-0.1764	0.9997
TCT3 - External chamber wall 1	0.1289	1.0077
TCT4 - Ext Chamber 2	-0.2510	1.0080
TCT5 - Water tank 1	-0.5676	1.0074
TCT7 - Loft temperature	-0.9725	1.0082
TCT9 - Ext Chamber roof	-1.1627	1.0098
TCT10 - Internal chamber void in ceiling	-1.1303	1.0111
TCT11 - Internal chamber floor	-0.9267	1.0107
TCT12 - Internal chamber 1	-0.9171	1.0117
TCT3 - External chamber 1	0.1289	1.0077
TCT14 - Internal chamber 2	-0.8946	1.0122
TCT15 - Rear space of rig	-0.8738	1.0120
TCT16 – Internal chamber 4	-0.5987	1.0139
TCT17 - Air off heater 1	-0.2699	1.0135
TCT18 - Internal chamber 3	0.1381	1.0126
TCT19 - External chamber 4	0.4267	1.0136
TCT20 - External chamber 3	0.7426	1.0117
Flow meter 2	-0.0620	15.6250
PRT11 - Room temperature 0.5 m	-0.1777	1.0009
PRT12 - Room temperature 1.0 m	-0.1620	1.0003
PRT13 - Temperature 1.1 m	-0.1283	1.0001
PRT14 - Room temperature 1.5 m	-0.1472	0.9998
PRT19 - Room temperature 2.5 m	-0.1579	0.9987
PRT20 - Room temperature 3.0 m	-0.1623	1.0009
PRT23 - Radiator middle air temperature	-0.3091	1.0040
PRT24 - Radiator air on temperature	-0.2847	1.0024
PRT25 - Radiator air off temperature	-0.1899	0.9994
PRT26 - Radiator surface T 1	-0.2103	1.0043
PRT27 - Radiator surface T 2	-0.2050	1.0000
PRT28 - Radiator lower T	-0.1433	1.0007
PRT29 - Radiator middle T	-0.1492	1.0008
PRT30 - Radiator upper T	-0.1325	0.9995
PRT32 - Radiator fins	-0.1333	0.9991
PRT33 - Radiator next to radiator T probe	-0.4201	1.0024
PRT4 - Oil temperature	-0.3234	1.0075
Vaisala probe	-45.0000	6250

Appendix: B Thermography results

This appendix shows the thermography results every 15 minutes up to 4.5 hours and then every hour up to 24 hours. The complete video is edited in the accompanying CD.

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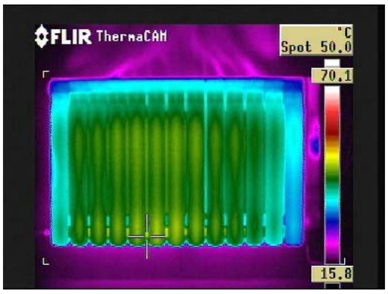

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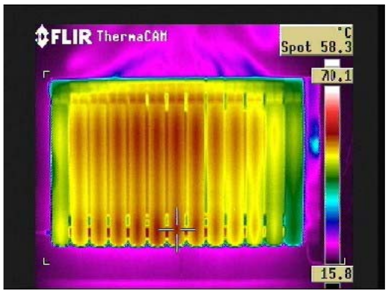

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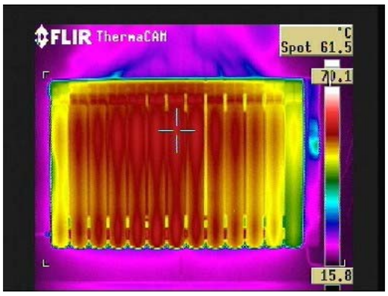

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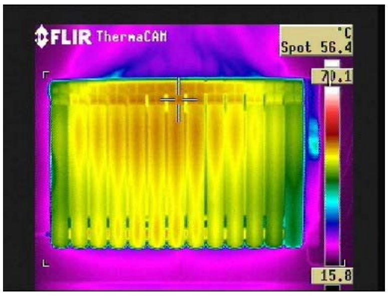

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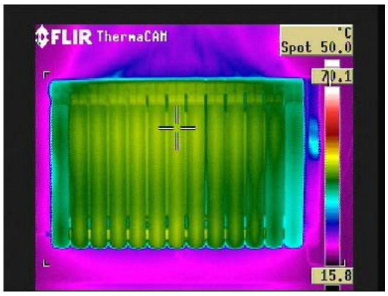

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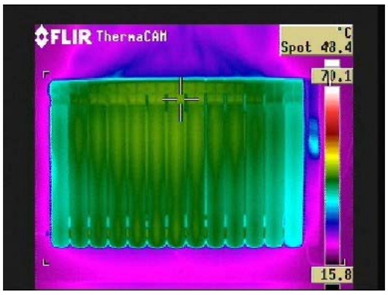

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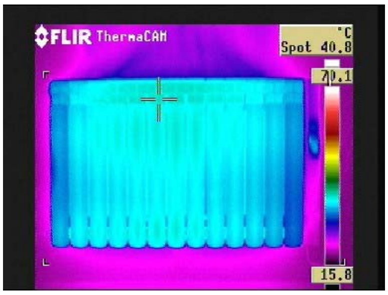

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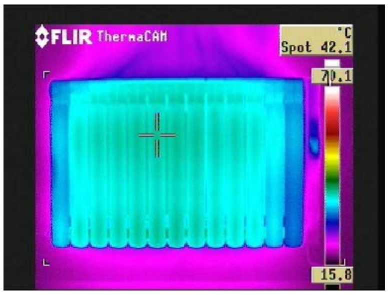

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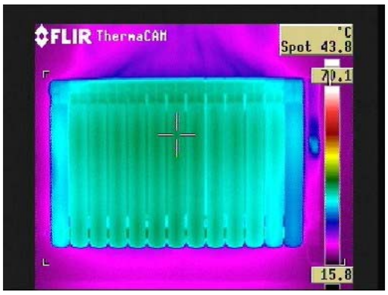

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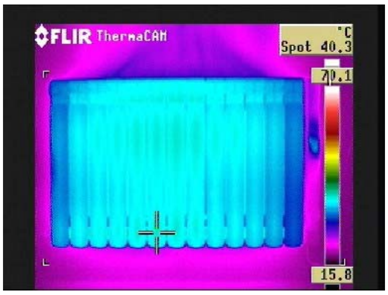

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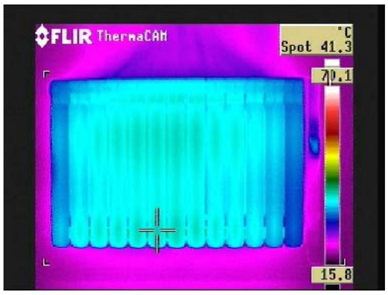

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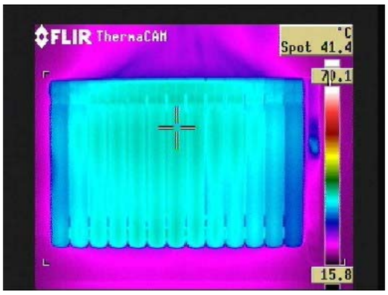

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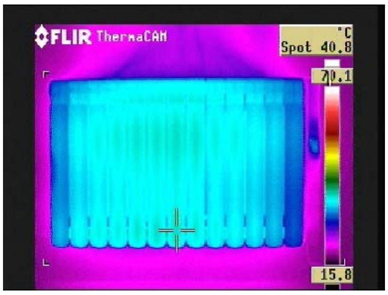

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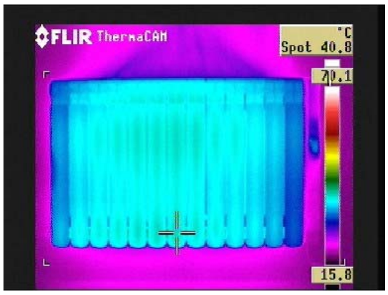

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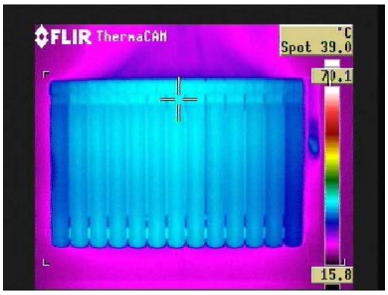

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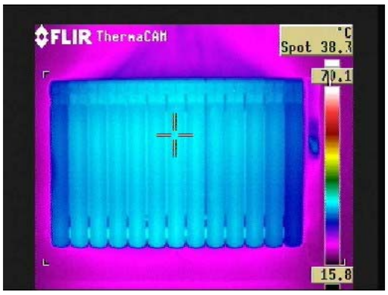

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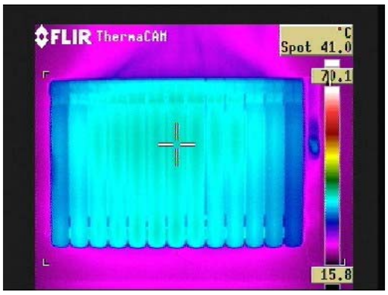

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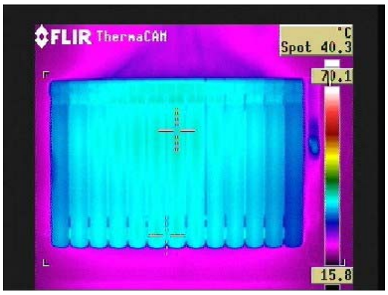

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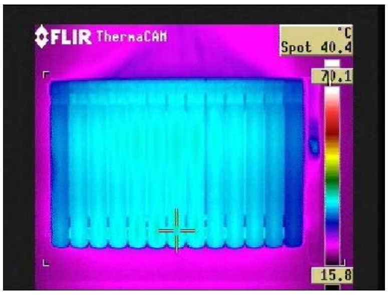

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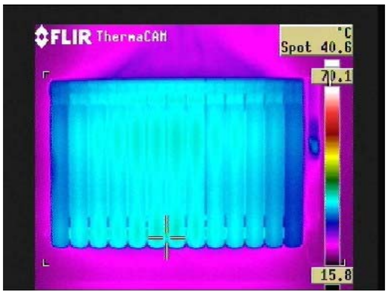

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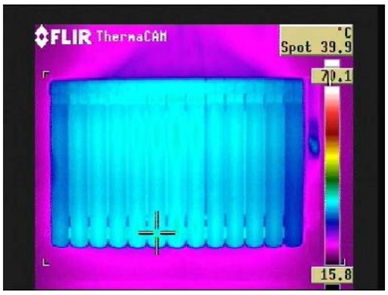

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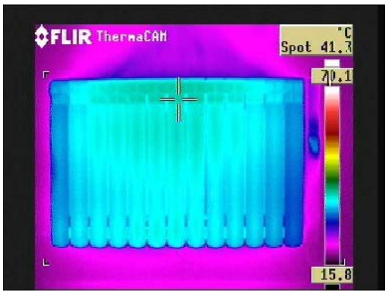

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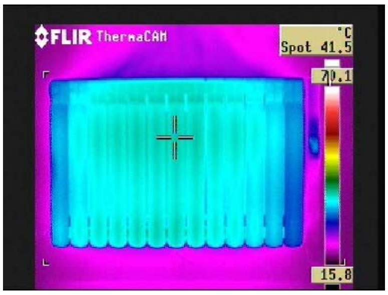

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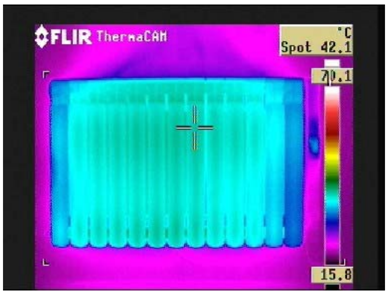

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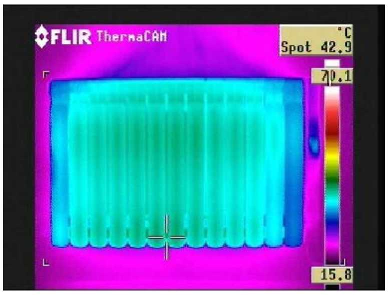

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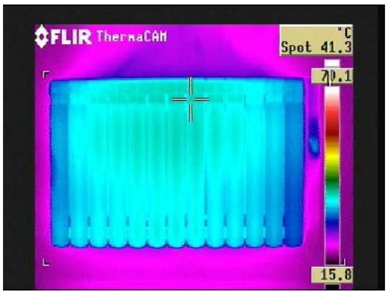

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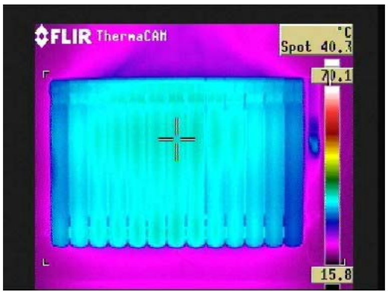

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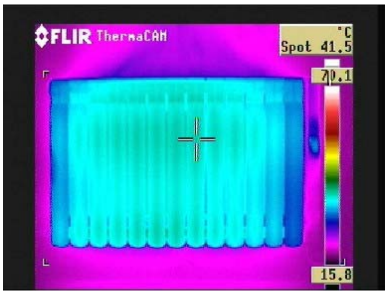

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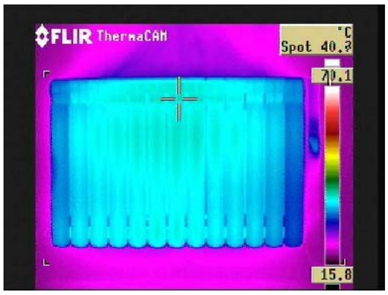

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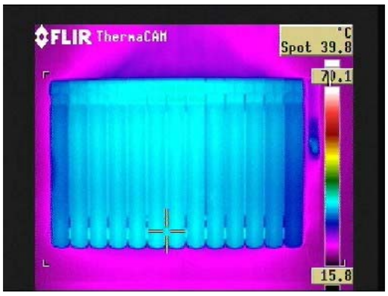

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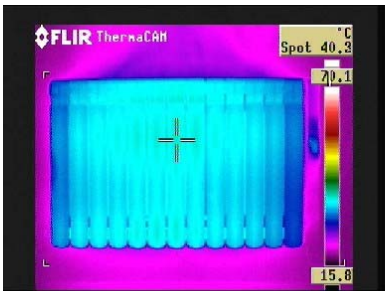

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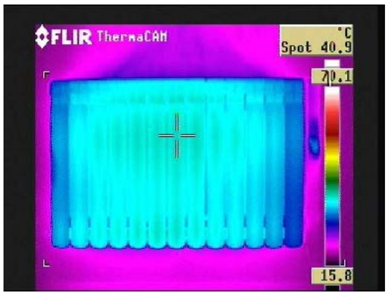

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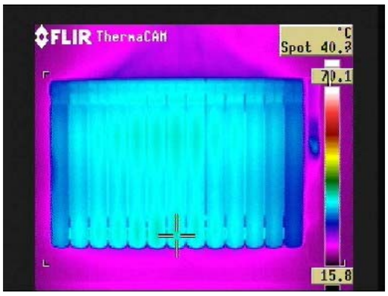

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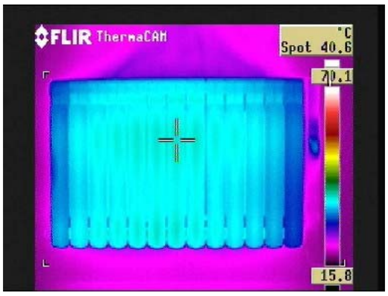

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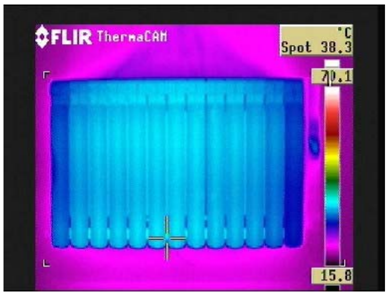

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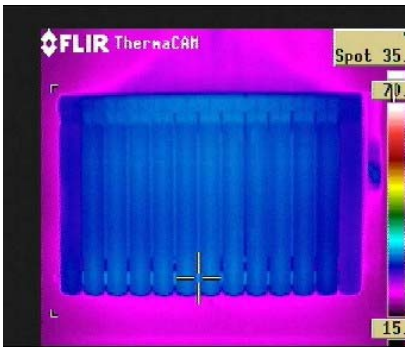

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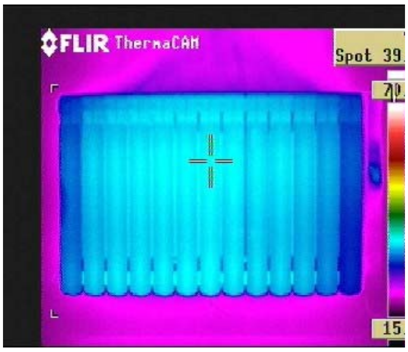

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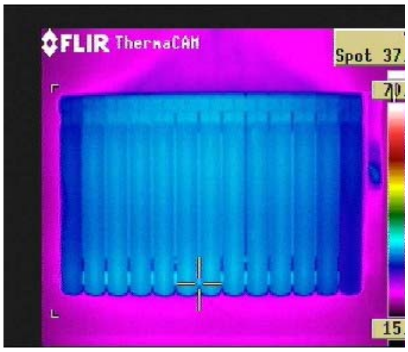


24:00

Appendix: C Summary output from technical report 53246/1

Electric radiator testing

This test simulates the heating of a 3m(W)x4m(B),3m(H) room with the radiator control thermostat set to 21ºC.

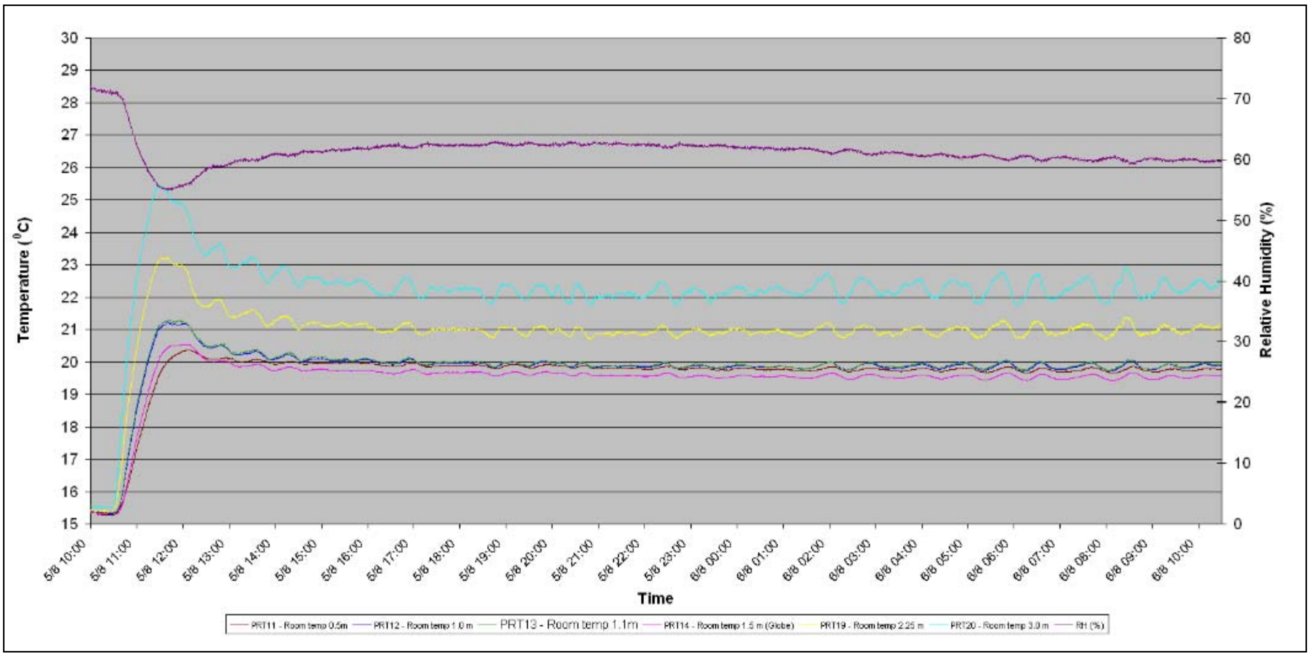
Performance test

The purpose of this test was to demonstrate the temperature stability of the radiator controls. It was intended to show how effectively the radiator achieved and maintained a temperature of 20± 2°C in the test chamber, when a fixed cooling load was applied. Note that the cooling load was approximately 40% of the full load capability of the radiator.

Performance test results

Total energy consumed during test with optimizer control system	13490 Wh
Test duration	24 hours
Average power during test	560 W

Chart 1 Room temperatures (°C) at various heights in centre of room and Relative Humidity (%) at a single point



CONCLUSIONS

The name plate of the test unit states capacity as 1400W at 230 V. The measured full load power of test unit was 1432 W when 230 V was applied; the test cooling load was an average of 518 W plus small losses from the room of 42 W during the test and the unit consumed an average of 560W per hour over the 24 hour period.

Scrutiny of the chart shows a rapid rise of temperature from 15 °C to 21 °C (during which the unit ran at full output) and then the controls maintained the temperature at a notional setting of 21 °C. The temperature measured in the centre of the room, 1.1 m above the floor level (head height for a person sitting down) was 20 °C with a variation of only +/- 0.25 °C over 10 hours.

Note that the rate of increase of temperature during room warm up is a complex mix of the maximum power output of the unit, the thermal characteristics of the room and the cooling load and in particular, the radiative and convective component of the unit heat output. A bigger radiator would have warmed the room quicker.

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