

The image features a dark blue background on the left side, which transitions into a white background on the right. The dark blue area is filled with a complex, abstract pattern of thin, light yellow lines that curve and overlap, creating a sense of motion and depth. The word "bre" is printed in a bold, lowercase, yellow sans-serif font on the left side of the blue area.

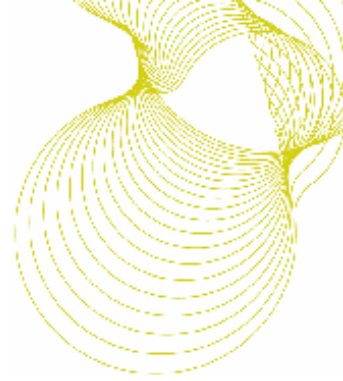
bre

**Before and after tests on  
a heat pump coil coated  
with Bronz-Gold**

Prepared for: Sam Newsham  
Bronz-Glow UK Ltd

07 January 2010

Test report number 258-133



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**Prepared by**

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Position: Senior Consultant  
Date: 07 January 2009

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**Approved on behalf of BRE**

Name: David Butler  
Position: Manager HVAC Engineering and Building Diagnostics  
Date: 07 January 2009

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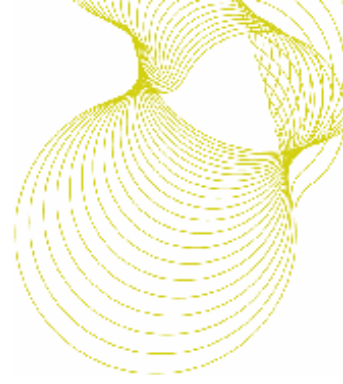
**Test Engineer**

Name: Richard Kemp  
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Date: 07 January 2009

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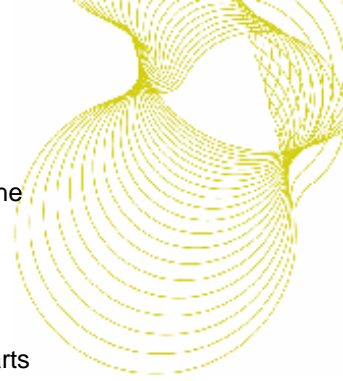
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## 1 Introduction

This report details the results of performance rating tests of an air to water heat pump prior to and after the application of Bronz Gold coil coating on the external unit air coil, for Bronz-Glow Ltd at BRE during November 2009 to January 2010. The tests were to determine the effect of the coil coating on the Coefficient of Performance (COP) and heating capacity of the heat pump. The tests were carried out according to the requirements of BS EN 14511: 2007 Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling, Parts 1 to 3.

## 2 Details of tests carried out

A standard Mitsubishi PUHZ-W50VHA-BS air to water heat pump including the associated controllers was supplied by Bronz Glow for the tests. Tests were carried out in BRE's heat pump test facility according to the requirements of BS EN 14511: 2007 Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling, Parts 1 to 3. A method statement for the tests is shown in Appendix A.

### 2.1 Details of heat pump tested

**Air to Water Heat Pump**  
 MODEL PUHZ-W50VHA-BS (C)  
 SERVICE REF. PUHZ-W50VHA-BS

Approved product

Microgeneration Certification Scheme sponsored by BERR

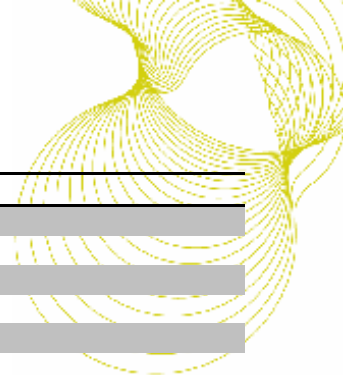
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MCS HP0002 EN14511

RATED HEATING CAPACITY (min. -max.)	5.00 (1.50-5.00)	5.00 (1.50-5.00)
COP	3.13	4.10
RATED CURRENT A	7.1	5.4
MAX. CURRENT A	13	
RATED CONDITION °C	A2/W35	A7/W35
~/N 230V 50Hz	R410A	1.7kg
64 kg IP24	SERIAL NO.	99U00606
HP PS 4.15MPa	YEAR OF MANUFACTURE	2009.09
LP PS 2.3MPa		

**MITSUBISHI ELECTRIC CORPORATION**  
 MANUFACTURER MITSUBISHI ELECTRIC CORPORATION, SHIZUOKA WORKS  
 18-1, OSHIKA 3-CHOME, SURUGA-KU, SHIZUOKA CITY, JAPAN  
 MADE IN JAPAN  
 BF79G965L04



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**Model of heat pump: PUIZ-W50VHA-BS**

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**Serial number: 99U00606**

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**Refrigerant type: R410A**

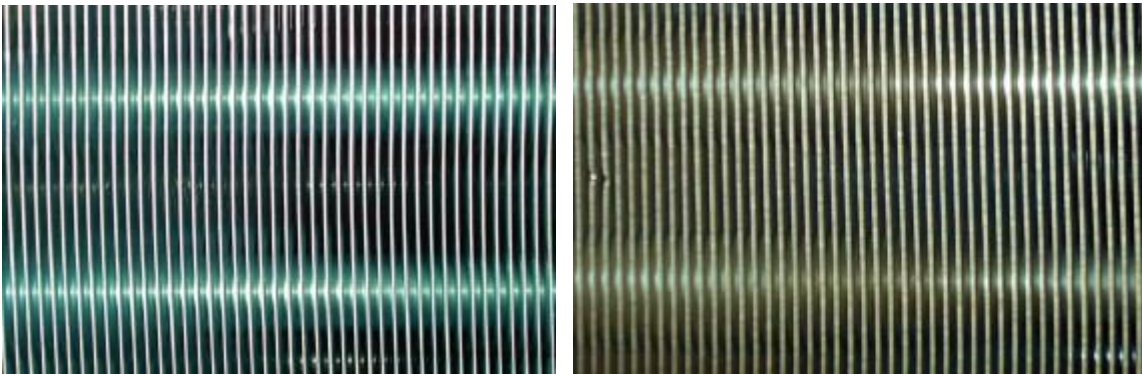
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**Nominal refrigerant charge: 1.7kg**

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The unit was supplied with a separate interface unit PAC-IF011B-E and flow temperature controller. Close up photographs of the external coil before and after application of the coating are shown in **Figure 1**.

**Figure 1 Evaporator coil before (left) and after application of coil coating**

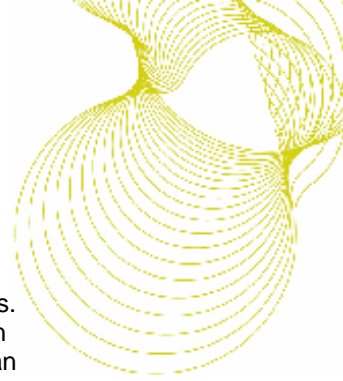


## 2.2 Test Rig

The tests were undertaken in a specially designed test facility at BRE's main Garston site. A photograph of the PUIZ-W50VHA-BS heat pump in the test chamber is shown in **Figure 2**.

**Figure 2 Heat pump in BRE heat pump test chamber prior to application of coil coating**





### 2.3 Test conditions

Two tests were carried out on the heat pump before and after the coil coating was applied. These conditions, taken from EN 14511:2007, are reproduced in **Table 1** below.

Most air to water heat pumps would not undergo a defrost cycle during the standard rating condition tests. The application rating conditions would normally be at sufficiently low temperature for frosting to occur on the evaporator coil and hence the unit would initiate defrost cycles during the tests. This test condition can therefore be used to assess any potential effect of the coil coating on the frost formation and defrost characteristics of the heat pump.

**Table 1 Heat pump test conditions**

	Outdoor heat exchanger		Indoor heat exchanger	
	Air inlet dry bulb temperature °C	Air inlet wet bulb temperature °C	Water inlet temperature °C	Water outlet temperature °C
Test 1 – Standard rating condition	7	6	30	35
Test 2 – Application rating condition	2	1	*	35

\* at flow rate determined during the standard rating condition tests

### 3 Test results

Summary of tests undertaken:

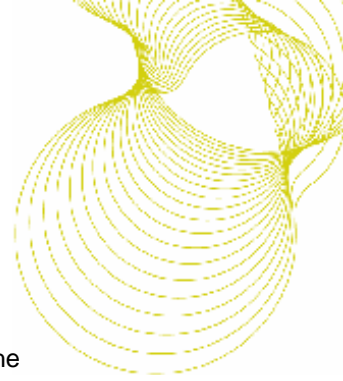
Test	Date	Result	
		COP	Heating capacity (W)
Before coil coating • A7/W35 • A2/W35	17 November 2009 20 November 2009	4.38 3.45	5290 5560
After coil coating • A7/W35 • A2/W35	16 December 2009 05 January 2010	4.30 3.36	5180 5380

#### Note:

During transport back to the testing lab after coil coating, the unit sustained some minor casing damage and minor coil damage.

We cannot say whether this affected any of the results, but it must be taken into consideration never the less.





### 3.1 Tests carried out prior to application of coil coating

#### 3.1.1 Standard rating condition capacity and COP test

Test requirement: BS EN14511:2007-3

The rating conditions were as specified in BS EN14511:2007-2 Table 9.

Since the heat pump did not initiate a defrost during the first 35 minutes of the data collection period or the equilibrium and preconditioning periods, the test was designated a steady state test

(see EN 14511-3 4.4.4.6).

Date of test: 17 November 2009

Total duration of test: 105 mins

Data collection period: 35 mins

Data recording interval: 10 seconds

**Figure 3** shows a graph of the key measured values.

As per the methodology for a steady state test, heating capacity and effective power were based on the integrated values and elapsed time over the 35 minute data collection period.

The mean measured values and calculated ratings for the data collection period are shown in **Table 2**.

The mean, minimum and maximum measured values and their deviations from the set values for the preconditioning, equilibrium and data collection periods are shown in **Table 3**.

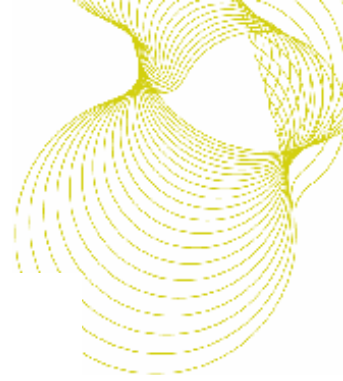
None of the deviations exceed the maximum allowable deviations.

**Table 2 Measured values for the data collection period**

<i>Parameter</i>	<i>Measured value (mean for duration of test data collection period)</i>	<i>Units</i>
Water inlet temperature	30.06	°C
Water outlet temperature	35.00	°C
Water flow rate	0.257	l/s
Air inlet dry bulb temperature	7.09	°C
Air inlet wet bulb temperature	6.12	°C
Electrical power input (whole unit)	1196	W
Voltage	230.2	V
Internal static pressure	14.9	kPa
Effective power input*	1209	W
Heating capacity#	5290	W
COP	4.38	W/W

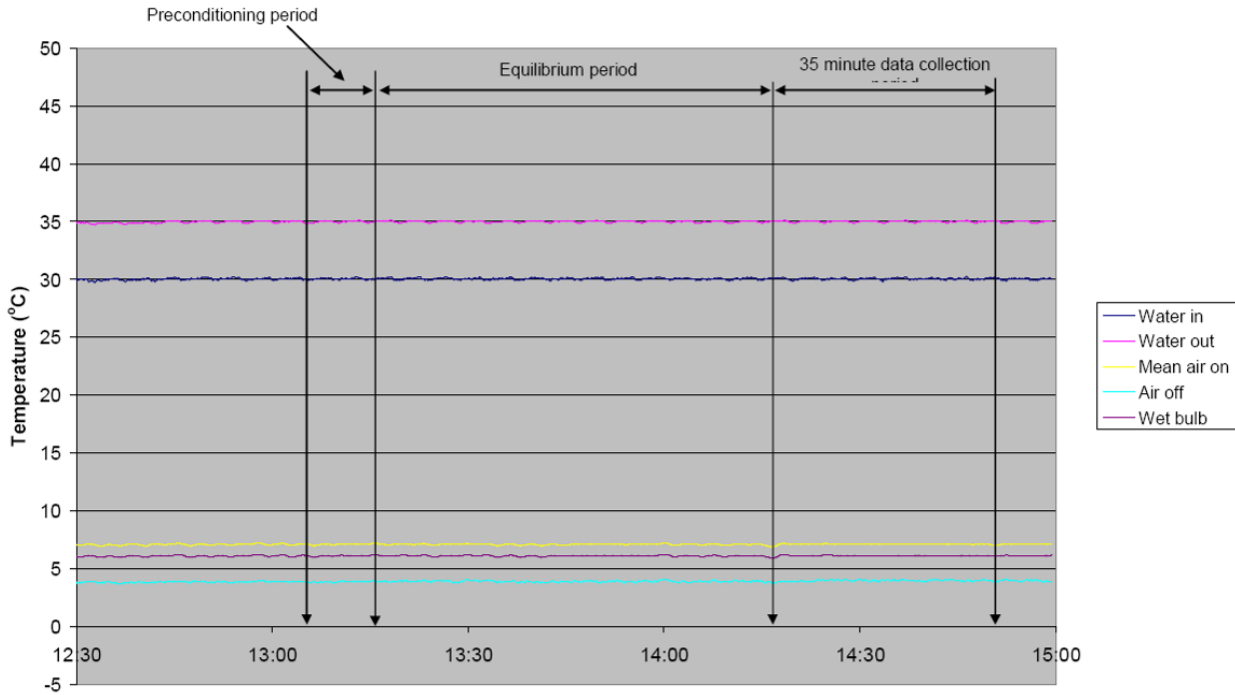
\*Pump was not integral with the unit

#Rounded to three significant figures



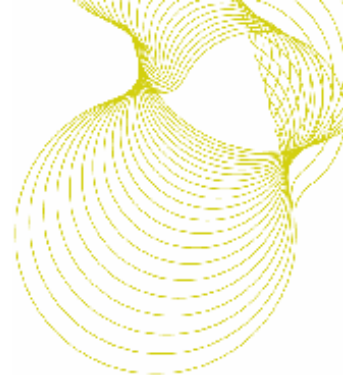
**Figure 3 Heat pump standard rating test duration and recorded parameters**

7db/6wb rating test before coating application (17 November 2009)



**Table 3 Heat pump rating test recorded and set values – preconditioning, equilibrium and data collection periods**

	Recorded value	Set value	Deviation	Allowed deviation	Units
Mean dbt	7.09	7.00	0.09	±0.30	°C
Min dbt	6.88	7.00	-0.12	±1.00	°C
Max dbt	7.20	7.00	0.20	±1.00	°C
Mean wbt	6.12	6.00	0.12	±0.30	°C
Min wbt	5.90	6.00	-0.10	±1.00	°C
Max wbt	6.23	6.00	0.23	±1.00	°C
Mean water inlet	30.06	30.00	0.06	±0.20	°C
Min water inlet	29.83	30.00	-0.17	±0.50	°C
Max water inlet	30.25	30.00	0.25	±0.50	°C
Mean water outlet	35.00	35.00	0.00	±0.30	°C
Min water outlet	34.85	35.00	-0.15	±0.60	°C
Max water outlet	35.13	35.00	0.13	±0.60	°C
Mean supply voltage	230.2	230	0.15	±9.20	volts
Min supply voltage	229.0	230	-1.00	±9.20	volts
Max supply voltage	230.8	230	0.78	±9.20	volts



### 3.1.2 Application rating condition capacity and COP test

Test requirement: BS EN14511:2007-3

The rating conditions were as specified in BS EN14511:2007-2 Table 9.

Since the heat pump initiated a defrost during the equilibrium and/or the first 35 minutes of the data collection period, the test was designated a transient test (see EN 14511-3 4.4.4.7).

Date of test: 20 November 2009

**Total duration of test: 264 mins**  
**Data collection period: 180 mins**  
**Data recording interval: 10 seconds**

Figure 4 shows a graph of the key measured values.

As per the methodology for a transient test, heating capacity and effective power were based on the integrated values and elapsed time over two complete cycles during the data collection period.

The mean measured values and calculated ratings for the two complete cycle period is shown in Table 4.

The mean, minimum and maximum measured values for the preconditioning, equilibrium and data collection periods were all within the tolerances specified in BS EN14511:2007-3.

**Table 4 Measured values for the complete heating / defrost cycles**

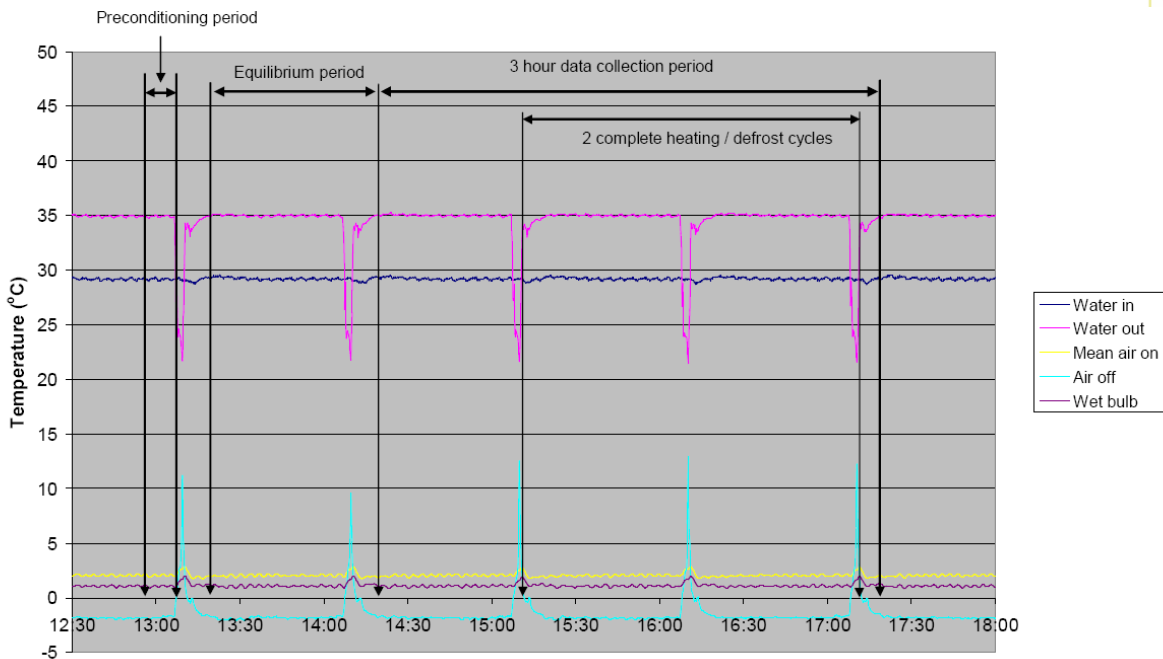
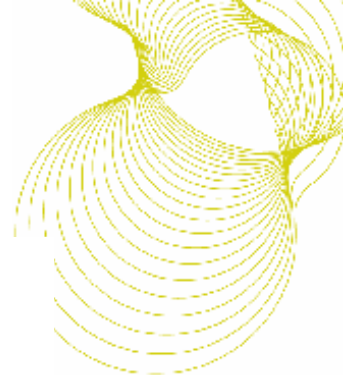
<i>Parameter</i>	<i>Measured value (mean for duration of test data collection period)</i>	<i>Units</i>
Water inlet temperature	29.21	°C
Water outlet temperature	34.37	°C
Water flow rate	0.259	l/s
Air inlet dry bulb temperature	2.08	°C
Air inlet wet bulb temperature	1.14	°C
Electrical power input (whole unit)	1601	W
Voltage	229.6	V
Internal static pressure	14.9	kPa
Effective power input*	1614	W
Heating capacity#	5560	W
COP	3.45	W/W

\*Pump was not integral with the unit

#Rounded to three significant figures

**Figure 4 Heat pump application rating test duration and recorded parameters**

2db/1wb rating test before coating application (20 November 2009)



### 3.2 Tests carried out after the application of coil coating

#### 3.2.1 Standard rating condition capacity and COP test

Test requirement: BS EN14511:2007-3

The rating conditions were as specified in BS EN14511:2007-2 Table 9.

Since the heat pump did not initiate a defrost during the first 35 minutes of the data collection period or the equilibrium and preconditioning periods, the test was designated a steady state test (see EN 14511-3 4.4.4.6).

Date of test: 16 December 2009

Total duration of test: 105 mins

Data collection period: 35 mins

Data recording interval: 10 seconds

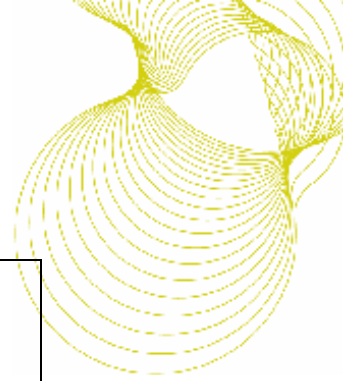
**Figure 5** shows a graph of the key measured values.

As per the methodology for a steady state test, heating capacity and effective power were based on the integrated values and elapsed time over the 35 minute data collection period.

The mean measured values and calculated ratings for the data collection period are shown in **Table 5**.

The mean, minimum and maximum measured values and their deviations from the set values for the preconditioning, equilibrium and data collection periods are shown in **Table 6**.

None of the deviations exceed the maximum allowable deviations.

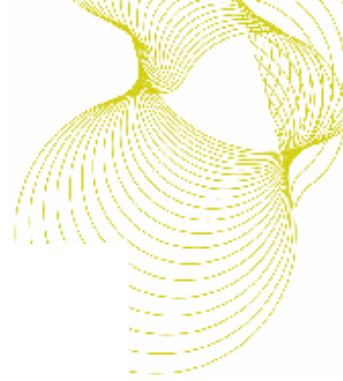


**Table 5 Measured values for the data collection period**

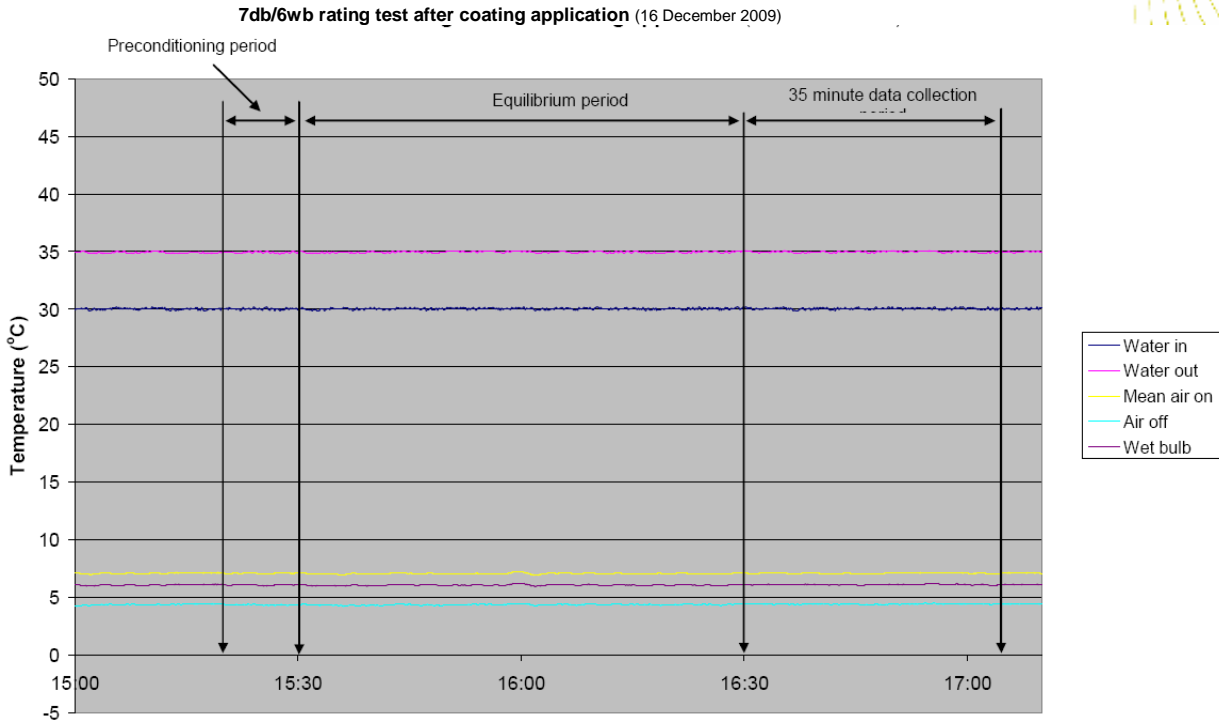
<i>Parameter</i>	<i>Measured value (mean for duration of test data collection period)</i>	<i>Units</i>
Water inlet temperature	30.05	°C
Water outlet temperature	34.96	°C
Water flow rate	0.254	l/s
Air inlet dry bulb temperature	7.08	°C
Air inlet wet bulb temperature	6.10	°C
Electrical power input (whole unit)	1191	W
Voltage	230.6	V
Internal static pressure	14.9	kPa
Effective power input*	1203	W
Heating capacity#	5180	W
COP	4.30	W/W

\*Pump was not integral with the unit

#Rounded to three significant figures

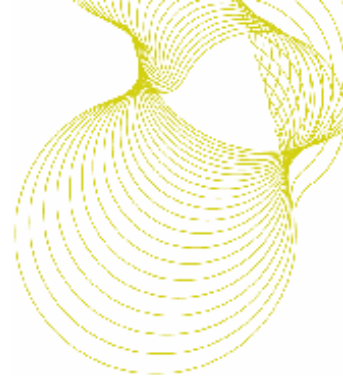


**Figure 5 Heat pump standard rating test duration and recorded parameters**



**Table 6 Heat pump rating test recorded and set values – preconditioning, equilibrium and data collection periods**

	Recorded value	Set value	Deviation	Allowed deviation	Units
Mean dbt	7.06	7.00	0.06	±0.30	°C
Min dbt	6.92	7.00	-0.08	±1.00	°C
Max dbt	7.22	7.00	0.22	±1.00	°C
Mean wbt	6.08	6.00	0.08	±0.30	°C
Min wbt	5.93	6.00	-0.07	±1.00	°C
Max wbt	6.24	6.00	0.24	±1.00	°C
Mean water inlet	30.04	30.00	0.04	±0.20	°C
Min water inlet	29.84	30.00	-0.16	±0.50	°C
Max water inlet	30.23	30.00	0.23	±0.50	°C
Mean water outlet	34.96	35.00	-0.04	±0.30	°C
Min water outlet	34.80	35.00	-0.20	±0.60	°C
Max water outlet	35.08	35.00	0.08	±0.60	°C
Mean supply voltage	230.6	230	0.61	±9.20	volts
Min supply voltage	228.4	230	-1.65	±9.20	volts
Max supply voltage	231.5	230	1.53	±9.20	volts



### 3.2.2 Application rating condition capacity and COP test

Test requirement: BS EN14511:2007-3

The rating conditions were as specified in BS EN14511:2007-2 Table 9.

Since the heat pump initiated a defrost during the equilibrium and/or the first 35 minutes of the data collection period, the test was designated a transient test (see EN 14511-3 4.4.4.7).

<b>Date of test:</b>	<b>05 January 2010</b>
<b>Total duration of test:</b>	<b>264 mins</b>
<b>Data collection period:</b>	<b>180 mins</b>
<b>Data recording interval:</b>	<b>10 seconds</b>

**Figure 6** shows a graph of the key measured values.

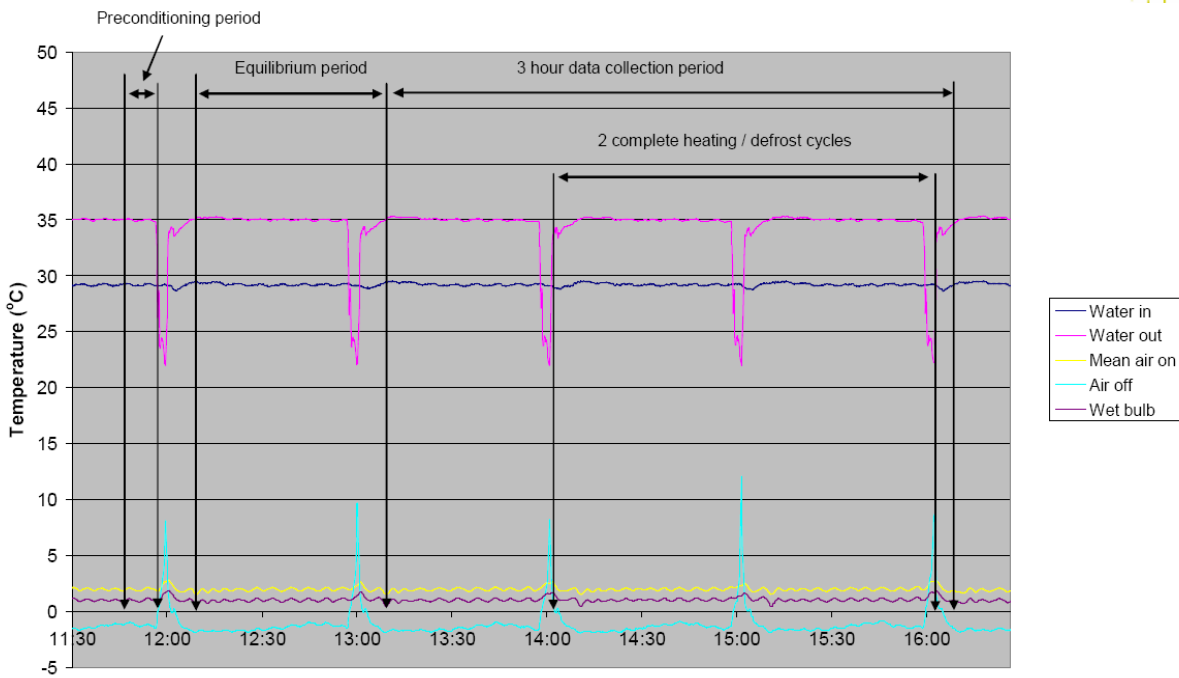
As per the methodology for a transient test, heating capacity and effective power were based on the integrated values and elapsed time over two complete cycles during the data collection period.

The mean measured values and calculated ratings for the complete cycle period is shown in **Table 7**.

The mean, minimum and maximum measured values for the preconditioning, equilibrium and data collection periods were all within the tolerances specified in BS EN14511:2007-3.

**Figure 6 Heat pump application rating test duration and recorded parameters**

2db/1wb rating test after coating application (05 January 2010)

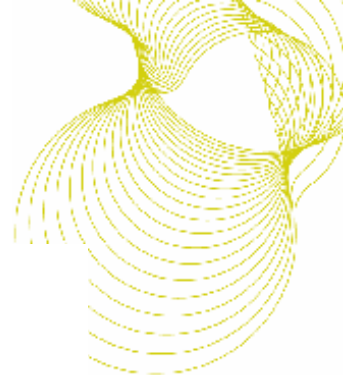


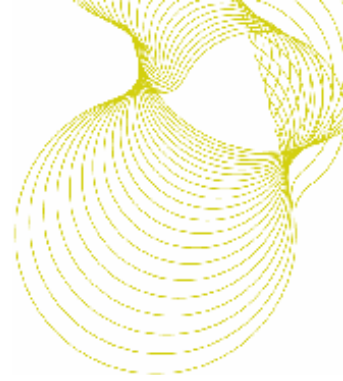
**Table 7 Measured values for the two complete heating / defrost cycles**

<i>Parameter</i>	<i>Measured value (mean for duration of test data collection period)</i>	<i>Units</i>
Water inlet temperature	29.22	°C
Water outlet temperature	34.30	°C
Water flow rate	0.254	l/s
Air inlet dry bulb temperature	1.98	°C
Air inlet wet bulb temperature	1.05	°C
Electrical power input (whole unit)	1590	W
Voltage	229.9	V
Internal static pressure	14.9	kPa
Effective power input*	1603	W
Heating capacity#	5380	W
COP	3.36	W/W

\*Pump was not integral with the unit

#Rounded to three significant figures





## Appendix A - Test Methodology for air to water heat pumps

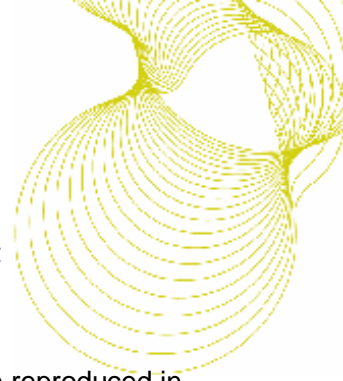
Air to water heat pump tests to BS EN14511:2007 Parts 1-3 *Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling.*

### BRE staff

The project team at BRE will be led by David Butler and will include staff from BRE's Building Technology Group.

The table below summarises the main project team structure and main responsibilities:

<i>Name / qualifications</i>	<i>Grade</i>	<i>Role in the project and competence</i>
David Butler BTech, MSc, FInstR	Project Manager	Overall project management and quality control. Over ten years experience running HVAC related test and consultancy projects at BRE. Technical Expert to the Carbon Trust for ECA ETL chiller applications and compliance testing.
Dr Michael Swainson PhD, BSc	Principal Consultant	Jointly responsible with David Butler for technical supervision of tests and analysis of results. Dr Swainson is highly experienced in HVAC performance testing. Has advised the Carbon Trust on air to air heat pump testing and is currently carrying out heat pump sensitivity testing for the EST.
Richard Kemp PhD, BSc	Senior Consultant	HVAC engineering specialist. Recent Post Graduate HVAC research experience and experience of a range of HVAC testing at BRE.
Arron Perry BEng (Hons)	Senior Engineer	Setup and commissioning of test rig and instrumentation calibration. Over 5 years experience of HVAC testing and specialist test rig development. Familiar with UKAS accredited test and calibration procedures at BRE (for building air tightness pressurisation tests).



### Rating capacity test - BS EN14511:2007-3

The heating capacity will be determined in accordance with the direct method at the water heat exchanger by measurement of the water volume flow rate and inlet and outlet temperatures, taking into account the specific heat capacity and density of the water.

The rating conditions will be as specified in BS EN14511:2007-2 Table 9. These conditions are reproduced in Table A1.

**Table A1 Standard rating conditions for air to water heat pump tests**

	Outdoor heat exchanger		Indoor heat exchanger	
	Air inlet dry bulb temperature °C	Air inlet wet bulb temperature °C	Water inlet temperature °C	Water outlet temperature °C
Test 1 – Standard rating condition	7	6	30	35
Test 2 – Application rating condition	2	1	*	35

\* at flowrate determined during the standard rating condition tests

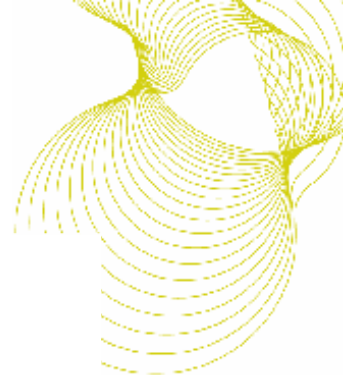
The calorimeter test method will be used (BS EN14511:2007-3 Annex A) by balancing the cooling and dehumidifying effect at the outdoor-side with an equal amount of heat and water input (humidification). The heat pump will be installed in a test chamber with heating and cooling coils, a humidifier and room air circulation fans.

For test conditions at which frost occurs on the heat pump outdoor coil the heat pump may undergo periodic defrosts. During defrosts the heat pump will produce a heating effect and this will be balanced by an equal amount of cooling.

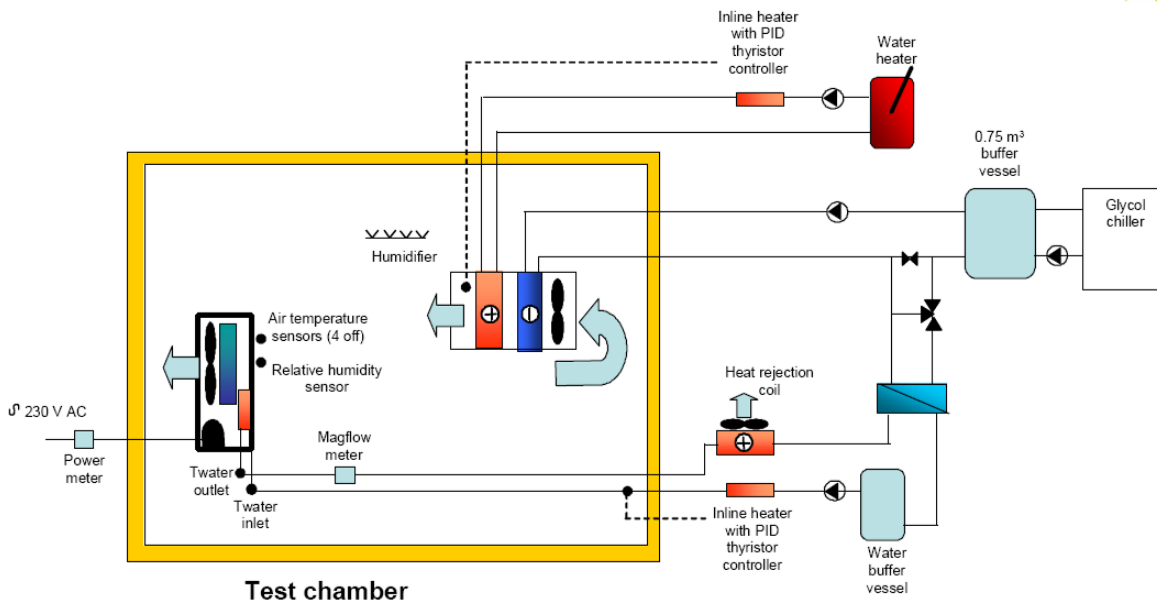
A sketch of the test apparatus is shown in Figure A1.

The size of the test chamber is 4.6 x 3.33 x 4.6 m (height) which exceeds the minimum recommended dimensions in BS EN14511:2007-3

Table A.1 for the size of heat pumps being tested. The test chamber also meets the requirements of BS EN14511:2007-3 clause 4.2.1.2 which requires that the room air flow is arranged to avoid short circuiting between the inlet and outlet of the heat pump and that the room air velocity does not exceed the air velocity through the heat pump air inlet.



**Figure A1 Test apparatus for air to water heat pump rating tests**



The following formula will be used to determine heating capacity and COP:

**Effective power input,  $P_E$**

$P_E$  = total power input of unit excluding pump plus proportional power input of pump power (Watts)

**Proportional power input for pump** - where no liquid pump is provided with the heat pump this is added to effective power input.

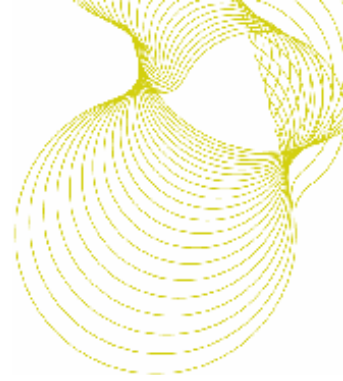
$$= (q \times \Delta P_i) / \eta_f \text{ (Watts) (see BS EN 14511-3 clause 4.1.6.2)}$$

Where:

$q$  = nominal water flow rate ( $m^3/s$ )

$\Delta P_i$  = measured internal static pressure difference (Pa)

$\eta_f$  = 0.3 (by convention)



**Proportional power input for pump** - where a liquid pump is integral to the heat pump only a fraction of the pump power is included in the effective power.

$$= (q \times \Delta P_e) / \eta \text{ (Watts)}$$

Where:

$q$  = nominal water flow rate ( $\text{m}^3/\text{s}$ )

$\Delta P_e$  = measured available external static pressure difference (Pa)

$\eta$  = 0.3 (by convention)

**Heating capacity,  $P_H$**

$$P_H = q \times \rho \times c_p \Delta T \text{ (Watts)}$$

(To be stated to 2 decimal places, maximum 3 significant figures)

Where:

$q$  = water volume flow rate

$\rho$  = density of water

$c_p$  = specific heat of water

$\Delta T$  = difference between water inlet and outlet temperatures

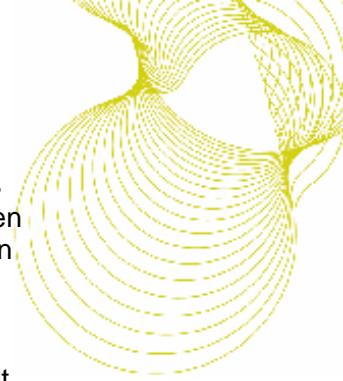
**Coefficient of performance, COP**

COP = ratio of heating capacity to effective power input of unit  
(To be stated to 3 significant figures)

**Duration of test and frequency of measurements**

The duration of the test will be in accordance with the requirements of BS EN 14511-3 clause 4.4.4 and Annex C. Each test will consist of a three consecutive periods:

1. Preconditioning period – minimum duration of 10 minutes once the deviations of the set values are no more than the maximum permissible deviations stated in see BS EN 14511- 3 Table 4.
2. Equilibrium period - minimum duration of 1 hour. Deviations of the set values must be no more than the maximum permissible deviations stated in see BS EN 14511-3 Table 4.
3. Data collection period - 35 minute duration. Deviations of the set values must be no more than the maximum permissible deviations stated in see BS EN 14511-3 Table 4.



The above assumes that the heat pump does not undergo a defrost and that the outdoor coil is free from frost at the start of the equilibrium period. Should frosting of the outdoor coil occur then the test will be designated a transient test and the test duration and periods will be as defined in BS EN 14511-3 Annex C. This should not normally happen at the standard rating conditions stated in Table A1.

All transducers and sensors will be measured by a Hewlett Packard 3852A data acquisition unit and PC used for data recording and graphical display. The data sampling time will be 10 seconds.

### Parameter measurement sensors and accuracy

Air temperature at the inlet to the heat pump outdoor unit will be measured according to BS EN 14511-3 clause 4.2.2.4. Four sensors will be distributed evenly at the air intake (additional sensors will be used if less than one sensor per m<sup>2</sup>). The sensors will be positioned approximately 150 mm from the surface of the heat exchanger surface and will be shielded to minimise radiative effects.

Wet bulb temperature at the air inlet is calculated from measured air temperature and relative humidity.

The measurement uncertainties will not exceed the values specified in BS EN 14511-3 Table 1.

The sensors used by BRE, including their uncertainties are specified in Table A2.

**Table A2 Sensor calibration details and uncertainties**

<i>Parameter</i>	<i>Instrument</i>	<i>Calibration</i>	<i>Uncertainty</i>
Heating water flow rate	Danfoss Magflo sensor type Mag1100, head type MAG3000	Labcal Ltd (UKAS)	± 0.5%
Heating water inlet and outlet temperature	Matched pair PT100 1/10 <sup>th</sup> DIN probes	In-situ 6 point water bath calibration with Hewlett Packard Digital Quartz Thermometer type 2804A (ASAP Calibration services Ltd (UKAS))	± 0.05°C
Internal static pressure difference	Omega Differential Pressure Transmitter Type PX760 s/n E21761	BRE Calibration Services (tracable to UKAS reference instrument)	± 0.05%
Air inlet temperature (Measured at 5 locations to BS EN14511-3 clause 4.2.2.4)	PT100 1/10 <sup>th</sup> DIN probes	In-situ 6 point water bath calibration with Hewlett Packard Digital Quartz Thermometer type 2804A (ASAP Calibration services Ltd (UKAS))	± 0.05°C
Air inlet relative humidity	Vaisala HMP230 humidity transmitter	BRE Calibration Services (tracable to UKAS reference instrument)	± 1.1%
Air inlet wet bulb temperature	Calculated from dry bulb air temperature and relative humidity		< ± 0.2°C
Electrical power and voltage	Hioki 3333 Power HiTester AC power analyser	Manufacturer supplied calibration certificate (March 2009)	± 0.1%
Voltage stabiliser	Claude Lyons TS 2.5		± 0.5%