# Mitsubishi PUHZ-W90VHA air to water heat pump tests

Prepared for:
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## Contents

# 1 Introduction

This report details the results of performance rating tests of a Mitsubishi PUHZ-W90VHA air to water heat pump carried out at BRE for Mitsubishi Electric Europe during April to May 2007.

The tests were carried out according to the requirements of BS EN 14511: 2004 Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling, Parts 1 to 4. Note that BS EN 14511 supersedes BS EN 255 which has been withdrawn.

A series of hot water cylinder heat up tests were also carried out with the heat pump. Although there is no BS EN standard for these tests relevant parts of BS EN 14511: 2004 were used as a guide. The hot water cylinder was a proprietary product supplied by Gledhill Water Storage Ltd.

The tests were carried out in BRE's HVAC test facility's environmental chamber.

# 2 Details of tests carried out

The performance of a Mitsubishi PUHZ-W90VHA air to water heat pump, supplied by Mitsubishi Electric Europe, was obtained by testing at BRE to the requirements of BS EN 14511: 2004 Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling, Parts 1 to 4.

## 2.1 Details of heat pump tested

| | |
|---|---|
| Model of heat pump | PUHZ-W90VHA |
| Serial number | 6ZU06217 |
| Refrigerant type | R410A |
| Nominal refrigerant charge | 3.5 kg |

## 2.2 Tests carried out – heat pump rating

These tests were carried out to the requirements of BS EN14511: 2004. The test conditions are shown in **Table 1**.

The heat pump did not incorporate its own heating water pump. However, the internal static pressure drop across the heat pump was measured for the two flow rates used in the tests and the proportional power input for a pump calculated according to BS EN14511 (Clause 4.1.6.2) and taken into account in the calculation of COP.

**Table 1 Heat pump rating tests**

| | Outdoor heat exchanger | | Indoor heat exchanger | |
|---|---|---|---|---|
| Test number<br>(each test repeated for compressor speed 7 and 4) | Air inlet dry bulb temperature<br>°C | Air inlet wet bulb temperature<br>°C | Water inlet temperature<br>°C | Water outlet temperature<br>°C |
| Test 1 & 2<br>*Standard rating condition* | 7 | 6 | 30 | 35 |
| #Test 3 & 4 | 2 | 1 | 30* | 35 |
| #Test 5 & 6 | -5 | - | 30* | 35 |
| Test 9 & 10 | 7 | 6 | 40* | 45 |
| #Test 11 & 12 | 2 | 1 | 40* | 45 |
| #Test 13 & 14 | -5 | - | 40* | 45 |
| Test 17 & 18 | 7 | 6 | 50* | 55 |
| #Test 19 & 20 | 2 | 1 | 50* | 55 |
| #Test 21 & 22 | -5 | - | 50* | 55 |
| Test 25 & 26 | 12 | 10 | 30* | 35 |
| Test 27 & 28 | 12 | 10 | 40* | 45 |
| Test 29 & 30 | 12 | 10 | 50* | 55 |

*Nominal water inlet temperature. Test was performed at the water flow rate obtained during the standard rating tests (Test 1 and 2).

#These application rating tests were carried out under coil frosting conditions. The tests were therefore defined as transient capacity tests and were carried out in accordance with BS EN 14511-3: 2004 clause 4.5.3.2.

## 2.3 Tests carried out – hot water cylinder heat up

These tests were carried out with a proprietary hot water cylinder supplied by Gledhill Water Storage Ltd.

Before the start of each test the hot water cylinder was pre-charged with water at 12°C. The heat pump was then allowed heat up the tank until a temperature sensor inserted in the manufacturer fitted sensor pocket approximately half way up the tank registered a value of 55°C.

| Test number (each test repeated for compressor speed 7 and 4) | Outdoor heat exchanger | |
|---|---|---|
| | Air inlet dry bulb temperature °C | Air inlet wet bulb temperature °C |
| Test 1 & 2 | 7 | 6 |
| #Test 3 & 4 | 2 | 1 |
| #Test 5 & 6 | -5 | - |
| Test 9 & 10 | 12 | 10 |
| Test 11 & 12 | 20 | 16 |
| Test 13&14 | 25 | 18 |

#These tests were carried out under coil frosting conditions.

## 2.4 Test rig

The tests were carried out in a large environmental test room with internal measurements of 6 x 9 x 4.5 m (height). A temporary compartment constructed from insulation panels was built around the heat pump to provide a thermal buffer for the low temperature tests. The general arrangement of the apparatus is shown in **Figure 1**. A general view of the heat pump in the test chamber is shown in **Figure 3** and the inlet and outlet temperature senors positions and flow meter are shown in **Figure 4**.

Cooling of the test room was provided by the heat pump and a cooling coil supplied by an external glycol chiller. Fine temperature control was provided by an electric heating coil and fan and a PID controller. Humidification was provide by a Stulz ultrasonic humidifier with PID controller and Vaisala relative humidity sensor.

The heat pump heat output was rejected to an external water cooling system with chilled water injection. High stability temperature control was achieved through incorporation of two water buffer vessels and an inline electric water heater with PID control.

The voltage supplied to the heat pump was stabilised at 230 VAC using a Claude Lyons type TS 2.5 adjustable voltage stabiliser.

The arrangement of the apparatus for the hot water cylinder heat up tests is shown in **Figure 2**.

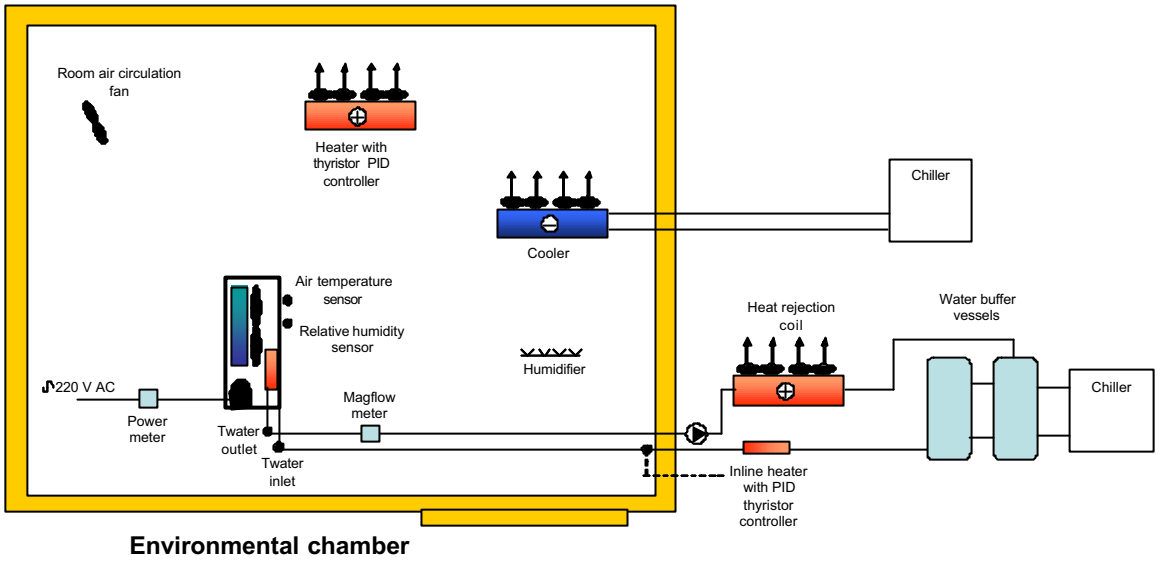



**Figure 1 Schematic of test room and test apparatus – heat pump rating tests**

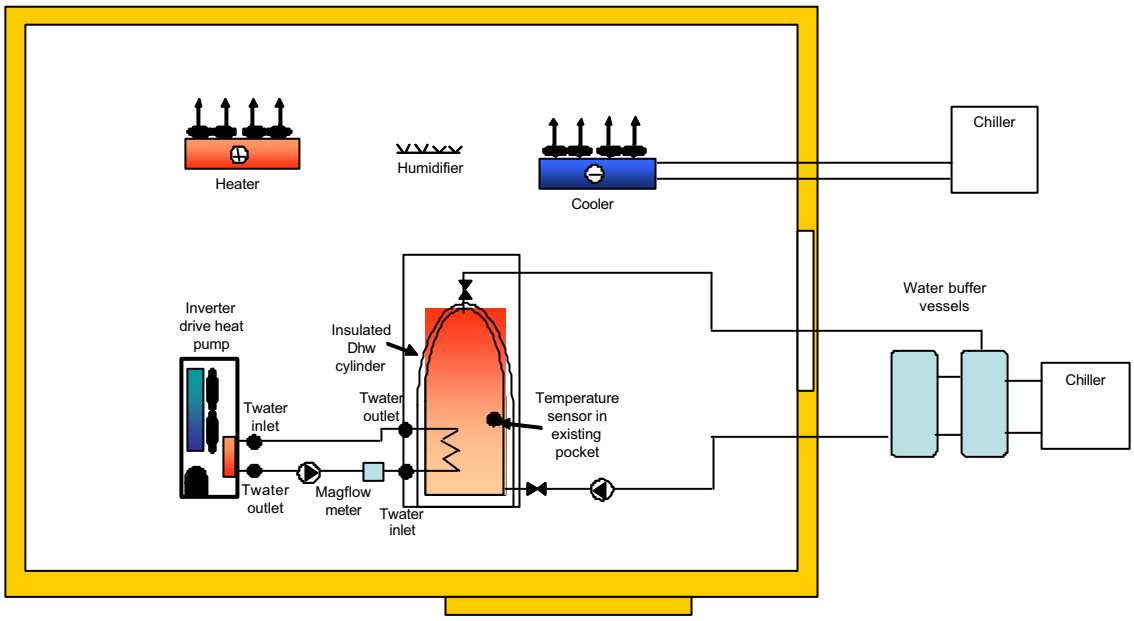



**Figure 2 Schematic of test room and test apparatus – hot water cylinder heat up tests**

**Figure 3 General of heat pump in test chamber**

**Figure 4 Inlet and outlet temperature sensors and flow meter**

## 2.5 Parameter measurement sensors and accuracy

| *Parameter* | *Instrument* | *Calibration* | *Uncertainty* |
|---|---|---|---|
| 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$^{th}$ DIN probes | In-situ 6 point temperature calibration in water bath with Hewlett Packard Digital Quartz Thermometer type 2804A (BRE Calibration Services (UKAS)) | ± 0.05°C |
| Hot water cylinder temperature | PT100 1/10$^{th}$ DIN probe inserted in existing temperature sensor pocket | In-situ 6 point temperature calibration in water bath with Hewlett Packard Digital Quartz Thermometer type 2804A (BRE Calibration Services (UKAS)) | ± 0.05°C |
| Internal static pressure difference | Crane Universal Perfactor type PFCV and PSW200 transducer | BRE Calibration Services (UKAS) | ± 0.9 kPa |
| Air inlet temperature | PT100 1/10$^{th}$ DIN probes | In-situ 6 point temperature calibration in water bath with Hewlett Packard Digital Quartz Thermometer type 2804A | ± 0.05°C |
| Air inlet relative humidity | Vaisala HMP230 humidity transmitter | BRE Calibration Services (UKAS) | ± 1.1% |
| Electrical power and voltage | Yokogawa WT110 digital AC power analyser | TER Instruments Ltd (UKAS) | ± 0.1% |
| Voltage stabiliser | Claude Lyons TS 2.5 | | ± 0.5% |

**Table 2 Sensor calibration details and uncertainties**

# 3 Test results

The following definitions and formula have been used, in accordance with BS EN 14511: 2004:

**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**

= (q x ?$P_i$ ) / ? (Watts) (see BS EN 14511-3 clause 4.1.6.2)

Where:

q = nominal water flow rate

?$P_i$ = measured internal static pressure difference

? = 0.3 (by convention)

**Heating capacity, $P_H$**

$P_H$ = q x ? x $c_p$ ?T (Watts)

Where:

q = water volume flow rate

? = density of water

$c_p$ = specific heat of water

?T = difference between water inlet and outlet temperatures

**Coefficient of performance, COP**

COP = ratio of heating capacity to effective power input of unit

All tests carried out under evaporator coil frosting conditions were defined as transient capacity tests and were carried out in accordance with BS EN 14511-3: 2004 Clause 4.5.3.2. The electrical power input and the heating capacity were determined on the basis of their integrated values over the same data collection period. The data collection period contained either one, two or three complete heating and defrost cycles depending on how many complete cycles could fit into a three hour data collection period.

The hot water cylinder heat pump tests were based on heating the hot water cylinder from 12°C to 55°C. The electrical power input and the heat input to the water cylinder were determined on the basis of their integrated values over the test duration.

## 3.1 Heat pump rating tests

The test results are summarised in **Table 3**. Detailed test result sheets and graphs for each test are contained in Appendix A.

The test result sheets also contain an assessment of the variations in the measured temperatures. These variations were less than the maximum values allowed by BS EN 14511-3:2004.

**Table 3 Heat pump rating test results – summary table**

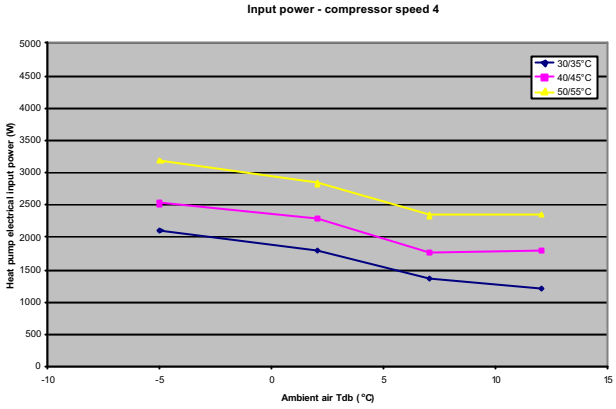
| *Test* | *Inlet/outlet water temperature* | *Air dry bulb / wet bulb temperature* | *Compressor speed step* | *Date of test* | *Power input* | *Heat output* | *COP* |
|---|---|---|---|---|---|---|---|
| 1 | 30/35°C | 7/6°C | 7 | 16/2/07 | 2350.0 | 8800.5 | 3.74 |
| 2 | 30/35°C | 7/6°C | 4 | 19/2/07 | 1370.4 | 5842.7 | 4.26 |
| 3 | 30/35°C | 2/1°C* | 4 | 1/3/07 | 1790.5 | 5775.7 | 3.23 |
| 4 | 30/35°C | 2/1°C* | 7 | 22/2/07 | 2861.2 | 8005.3 | 2.80 |
| 5 | 30/35°C | -5°C* | 4 | 14/3/07 | 2112.5 | 5797.3 | 2.74 |
| 6 | 30/35°C | -5°C* | 7 | 15/3/07 | 3178.3 | 7784.1 | 2.45 |
| 9 | 40/45°C | 7/6°C | 4 | 20/2/07 | 1756.6 | 6134.7 | 3.49 |
| 10 | 40/45°C | 7/6°C | 7 | 20/2/07 | 3056.1 | 9290.5 | 3.04 |
| 11 | 40/45°C | 2/1°C* | 4 | 27/2/07 | 2281.7 | 5989.4 | 2.62 |
| 12 | 40/45°C | 2/1°C* | 7 | 28/2/07 | 3554.2 | 8296.3 | 2.33 |
| 13 | 40/45°C | -5°C* | 4 | 8/5/07 | 2521.8 | 5578.6 | 2.21 |
| 14 | 40/45°C | -5°C* | 7 | 15/3/07 | 3916.1 | 8048.0 | 2.06 |
| 17 | 50/55°C | 7/6°C | 4 | 21/2/07 | 2339.6 | 5911.2 | 2.53 |
| 18 | 50/55°C | 7/6°C | 7 | 21/2/07 | 3832.8 | 8901.3 | 2.32 |
| 19 | 50/55°C | 2/1°C* | 4 | 5/3/07 | 2832.4 | 5978.8 | 2.11 |
| 20 | 50/55°C | 2/1°C* | 7 | 8/3/07 | 4245.6 | 8245.6 | 1.96 |
| 21 | 50/55°C | -5°C* | 4 | 9/5/07 | 3181.5 | 5284.2 | 1.66 |
| 22 | 50/55°C | -5°C* | 7 | 27/3/07 | 4840.3 | 7281.5 | 1.50 |
| 25 | 30/35°C | 12/10°C | 4 | 29/3/07 | 1209.9 | 5923.3 | 4.90 |
| 26 | 30/35°C | 12/10°C | 7 | 30/3/07 | 2083.2 | 9050.9 | 4.34 |
| 27 | 40/45°C | 12/10°C | 4 | 2/4/07 | 1802.4 | 6440.9 | 3.57 |
| 28 | 40/45°C | 12/10°C | 7 | 31/3/07 | 2719.3 | 9015.6 | 3.32 |
| 29 | 50/55°C | 12/10°C | 4 | 3/4/07 | 2343.7 | 6329.1 | 2.7 |
| 30 | 50/55°C | 12/10°C | 7 | 3/4/07 | 3943.0 | 9824.2 | 2.49 |

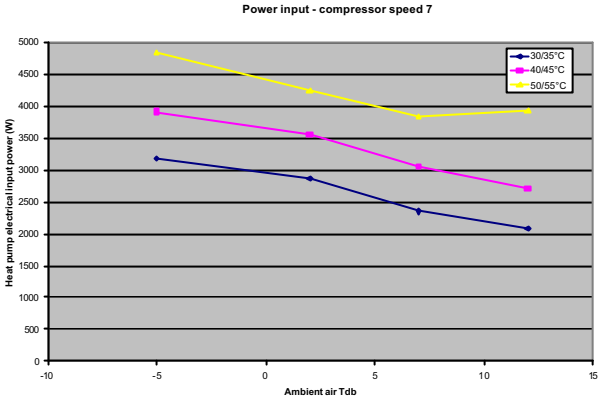
*At the 2/1°C and -5°C conditions the evaporator coil frosted-up and a transient test method was employed (see BS EN 14511-3 Clause 4.5.3.2.)

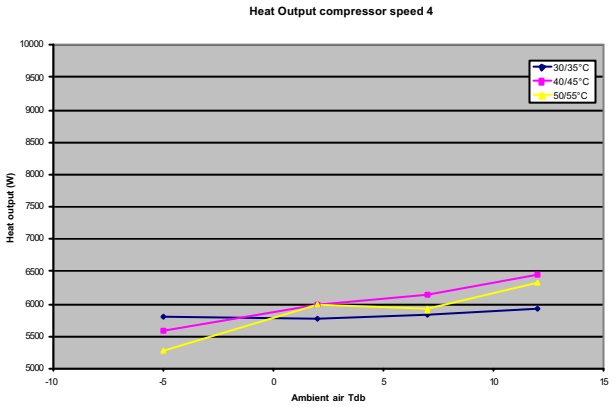
Note the standard rating tests are carried out at 7/6°C. The water flow rates determined during these tests were used for the other outdoor air temperature conditions (application rating tests).

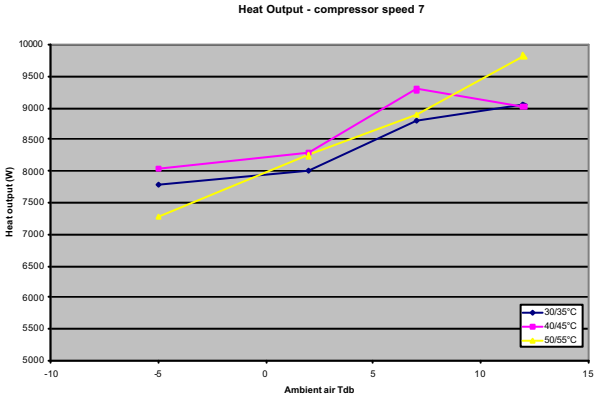
The test results are also summarised graphically in **Figure 5**.

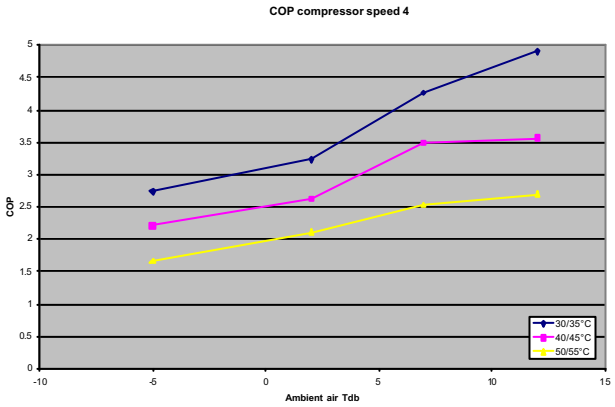
**Figure 5 Heat pump rating tests – summary graphs**

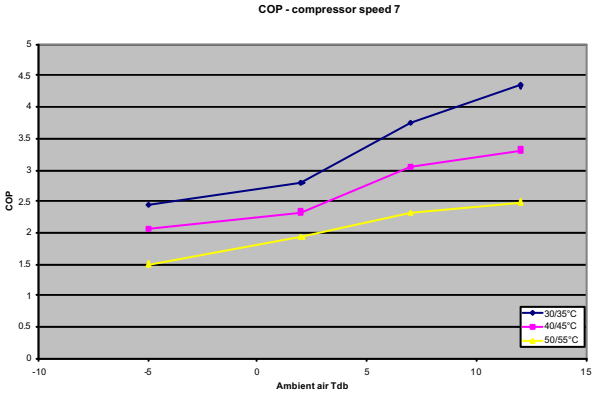



**Compressor speed 4** **Compressor speed 7**

## 3.2 Hot water cylinder heat up tests

The test results are summarised in **Table 4**. Detailed test result sheets for each test are contained in Appendix B.

**Table 4 Hot water cylinder heat up tests – summary table**

| *Test* | *Air dry bulb / wet bulb temperature* | *Compressor speed step* | *Time to heat tank from 12°C to 55°C (secs)* | *Mean heat pump COP* | *Total power consumed by heat pump (kWh)* | *Total heat supplied to the tank (kWh)* | *Date of test* |
|---|---|---|---|---|---|---|---|
| | | | *Mean of 2 tests* | | | | |
| 1 | 7/6°C | 7 | 3338 | 2.87 | 2.62 | 7.53 | 27/7/07 |
| 2 | 7/6°C | 4 | 5013 | 3.16 | 2.37 | 7.50 | 27/7/07 |
| 3* | 2/1°C | 7 | 3876 | 2.06 | 3.66 | 7.54 | 30/4/07 |
| 4 | 2/1°C | 4 | 4529 | 2.70 | 2.80 | 7.57 | 30/4/07 |
| 5 | -5°C | 7 | 4188 | 1.79 | 4.24 | 7.57 | 1/5/07 |
| 6 | -5°C | 4 | 5502 | 2.00 | 3.81 | 7.62 | 2/5/07 |
| 9 | 12/10°C | 7 | 3334 | 3.18 | 2.35 | 7.48 | 11/4/07 |
| 10 | 12/10°C | 4 | 4932 | 3.63 | 2.07 | 7.50 | 10/4/07 |
| 11 | 20/16°C | 7 | 3375 | 3.65 | 2.06 | 7.52 | 12/4/07 |
| 12 | 20/16°C | 4 | 4530 | 4.25 | 1.77 | 7.51 | 3/5/07 |
| 13 | 25/18°C | 7 | 3417 | 4.09 | 1.82 | 7.45 | 19/4/07 |
| 14 | 25/18°C | 4 | 4736 | 4.90 | 1.51 | 7.39 | 20/4/07 & 3/5/07 |

*Test 3 - 1 test carried out