

Australian/New Zealand Standard™

## Heat pump water heaters—Performance assessment

### Part 1: Air source heat pump water heaters



## **AS/NZS 5125.1:2014**

This Joint Australian/New Zealand Standard was prepared by Joint Technical Committee CS-028, Solar Water Heaters. It was approved on behalf of the Council of Standards Australia on 25 July 2014 and on behalf of the Council of Standards New Zealand on 11 July 2014.

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# Australian/New Zealand Standard™

## Heat pump water heaters—Performance assessment

### Part 1: Air source heat pump water heaters

Originated as AS/NZS 5125.1:2010.  
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## PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee CS-028, Solar Water Heaters, to supersede AS/NZS 5125.1:2010. The performance evaluation procedure defined in this Standard has been designed to provide a means of evaluating the annual task performance of air source heat pump water heating systems. The main purpose of this revision is to introduce a performance test for assessing performance against minimum performance requirements for heat pump water heaters.

Testing of solar and heat pump water heating systems under outdoor conditions was specified in AS 2984—1987, *Solar water heaters—Method of test for thermal performance—Outdoor test method* (obsolescent Standard). Outdoor testing requires a long test period (8–10 weeks) due to the need to obtain stable inputs for a range of operating conditions. The major drawback of outdoor testing is that the tests must be repeated for every variation of system configuration offered by the supplier. The procedure defined in this Standard overcomes the time and cost limitations of using the outdoor test method in AS 2984.

The performance characteristics determined using this Standard are for the purpose of modelling annual performance in AS/NZS 4234, *Heated water systems—Calculation of energy consumption*, using the TRNSYS simulation program or equivalent software.

Statements expressed in mandatory terms in notes to figures and tables are deemed to be requirements of this Standard.

The terms ‘normative’ and ‘informative’ have been used in this Standard to define the application of the appendix to which they apply. A ‘normative’ appendix is an integral part of a Standard, whereas an ‘informative’ appendix is only for information and guidance.

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## STANDARDS AUSTRALIA/STANDARDS NEW ZEALAND

**Australian/New Zealand Standard****Heat pump water heaters—Performance assessment****Part 1: Air source heat pump water heaters**

## SECTION 1 SCOPE AND APPLICATION

**1.1 SCOPE**

This Standard specifies the test conditions and test procedures for determining the energy performance characteristics of single-circuit air source heat pump water heaters. It applies to both stand-alone heat pump water heaters and heat pumps with the condenser integral with a storage tank. The variation of coefficient of performance (COP) and electric power used as a function of operating conditions are determined so that the results can be used in annual performance calculations of heat pump applications for sanitary hot water supply applications.

This Standard also specifies methods of testing and reporting the energy performance characteristics of electrical driven heat pumps using a single refrigeration circuit and having one evaporator and one condenser. Products with two evaporators that operate exclusively may also be tested in each mode.

The energy performance of a heat pump is determined by operating the product under a range of controlled environmental conditions and measuring the electrical power input and the thermal energy output in the form of hot water where the condenser is integral with a storage tank. Slightly different test procedures are specified for stand-alone and integral heat pump configurations.

This Standard also specifies a method for a 24 h tapping hot water load test for heat pumps to simulate domestic hot water usage behaviour under a range of controlled environmental conditions to determine a range of energy performance characteristics.

NOTE: This Standard uses the daily load profile of AS/NZS 4234.

**1.2 APPLICATION**

This Standard only addresses residential sanitary hot water supply.

This Standard does not apply to the testing of—

- (a) multiple split-system heat pumps;
- (b) units designed for dual heating and cooling tasks; or
- (c) heat pump water heater—solar boosted.

**1.3 REFERENCED DOCUMENTS**

The following documents are referred to in this Standard:

AS

3498 Authorization requirements for plumbing products—Water heaters and hot-water storage tanks

AS/NZS

4234 Heated water systems—Calculation of energy consumption

4692 Electric water heaters

4692.1 Part 1: Energy consumption, performance and general requirements

IAPWS

IAPWS-95 The IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use

NZBC New Zealand Building Code

## 1.4 DEFINITIONS

For the purpose of this Standard, the definitions below apply.

### 1.4.1 Auxiliary boosting

The use of gas and electrical energy in a heat pump water heater to directly heat the water by mean of a gas burner and/or electrical resistive heating unit.

### 1.4.2 Electrical power input

Total electrical power supplied to the heat pump while operating.

### 1.4.3 Heat pump water heater

A water heater using vapour compression cycle and incorporating a compressor, an evaporator and a condenser that delivers heat to the water either directly or indirectly.

#### 1.4.3.1 Heat pump water heater—solar boosted

A heat pump water heater with an evaporator collecting latent energy and sensible heat from the atmosphere and solar energy.

#### 1.4.3.2 Heat pump water heater—air source

A heat pump water heater with an evaporator collecting latent energy and sensible heat from the atmosphere.

### 1.4.4 Integral heat pump

Heat pump water heater with the condenser connected as an integral part of the tank or mounted inside the tank. Heat is delivered to the water in the tank by free convection over the tank wall or condenser tubing inside the tank.

### 1.4.5 Moving average

Average of a specified interval of a data set such as a test point period. Some data records are reused in overlapping averages or test point periods.

### 1.4.6 Recharge period

Period during which the water is being heated.

### 1.4.7 Recharge rate

Rate at which the heat pump delivers energy to the tank.

### 1.4.8 Stand-alone heat pump

Heat pump water heater without storage. Heat is delivered to water flowing through the condenser.

#### 1.4.8.1 Recirculating stand-alone heat pump

Stand-alone heat pumps that require recirculation of water in order to reach the required final temperature in a storage tank.

**1.4.8.2 Once-through stand-alone heat pump**

Stand-alone heat pump that delivers water at the required final temperature (usually 60°C or higher) in one pass through the heat pump.

**1.4.9 Standby electrical power**

Electrical power supplied to the heat pump when the compressor is not operating.

**1.4.10 Test point period**

Data monitoring period corresponding to a change of 5 K to 5.5 K in average tank temperature.

**1.4.11 Thermal capacity**

Thermal power output of heat pump

**1.4.12 Thermostat cut in**

Time at which the heat pump controller or thermostat activates to heat the storage tank to a specified water temperature.

**1.4.13 Thermostat cut out**

Time at which the heat pump controller or thermostat deactivates after heating the storage tank to a specified water temperature.

**1.5 NOTATION**

Symbols used in this Standard are listed below.

|                      |                                                                                                       |
|----------------------|-------------------------------------------------------------------------------------------------------|
| $a_i$                | = coefficients determined by curve fitting <i>COP</i> test data ( $i = 0, 1, 2, \text{ or } 3$ )      |
| <i>COP</i>           | = coefficient of performance                                                                          |
| $COP_{\text{daily}}$ | = coefficient of performance averaged over the 24-hour tapping cycle                                  |
| $C_{\text{pt}}$      | = inner tank wall specific heat (kJ/kg.K)                                                             |
| $C_{\text{pw}}$      | = water specific heat (temperature dependent) (kJ/kg.K)                                               |
| $d_i$                | = inner diameter of pipe insulation (m)                                                               |
| $d_o$                | = outer diameter of pipe insulation (m)                                                               |
| $E_1$                | = cumulative electrical energy input at the start of test point period or 24-hour tapping cycle (kWh) |
| $E_2$                | = cumulative electrical energy input at the end of test point period or 24-hour tapping cycle (kWh)   |
| $E_{\text{HP}}$      | = daily electrical energy consumption of heat pump (kWh)                                              |
| $h_i$                | = internal convective heat transfer coefficient for pipe (W/m <sup>2</sup> K)<br>= 1000               |
| $h_o$                | = external convective heat transfer coefficient for pipe (W/m <sup>2</sup> K)<br>= 20                 |
| $k$                  | = thermal conductivity for pipe insulation material (W/m.K)                                           |
| $L$                  | = pipe length (m)                                                                                     |
| $\dot{m}(t)$         | = measured mass flow rate of water (kg/s)                                                             |

|                     |                                                                                                                                                |
|---------------------|------------------------------------------------------------------------------------------------------------------------------------------------|
| $M_e$               | = water equivalent mass of tank and contents (kg)                                                                                              |
|                     | $= M_w + \frac{M_t C_{pt}}{C_{pw}}$                                                                                                            |
| $\dot{m}_{HP}$      | = calculated mass flow rate of water flowing between heat pump and tank (kg/s)                                                                 |
| $M_{hw}$            | = mass of hot water withdrawn from tank (kg)                                                                                                   |
| $M_t$               | = mass of inner tank wall in contact with the water (kg)                                                                                       |
| $M_w$               | = mass of water in tank (kg)                                                                                                                   |
|                     | $= \rho V$                                                                                                                                     |
| $N$                 | = length of test point period (min)                                                                                                            |
| $p_i$               | = coefficients determined by curve fitting <i>Power</i> test data ( $i = 0, 1, 2, \text{ or } 3$ )                                             |
| $P_{loss}$          | = rate of heat loss from connecting piping (kW)                                                                                                |
|                     | $= \frac{\pi d_i L (\overline{T_p} - \overline{T_a}) / 1000}{\frac{1}{h_i} + \frac{d_i}{2k} \ln(d_o / d_i) + 1 \frac{1}{h_o} \frac{d_i}{d_o}}$ |
| $P_{mix}$           | = electrical power input to tank mixing pump (if used) (kW)                                                                                    |
| <i>Power</i>        | = total electric power input (kW)                                                                                                              |
| $Q$                 | = thermal capacity of heat pump (kW)                                                                                                           |
| $Q_{HP}$            | = daily useful energy output (MJ)                                                                                                              |
| $Q_{HPe}$           | = quantity of energy withdrawn for a tapping event (MJ)                                                                                        |
| $Q_{loss}$          | = tank standing heat loss (see AS/NZS 4692.1) (kWh/d)                                                                                          |
| $t$                 | = time(s)                                                                                                                                      |
| $T(t)$              | = temperature at time $t$ after step change of temperature ( $^{\circ}\text{C}$ )                                                              |
| $T_1$               | = initial temperature before step change ( $^{\circ}\text{C}$ )                                                                                |
| $T_2$               | = final temperature after step change ( $^{\circ}\text{C}$ )                                                                                   |
| $\overline{T}_a$    | = air dry bulb temperature averaged over test point period ( $^{\circ}\text{C}$ )                                                              |
| $\overline{T}_{dp}$ | = dew point temperature averaged over test point period ( $^{\circ}\text{C}$ )                                                                 |
| $T_{HPin}$          | = temperature of water into heat pump (from tank) ( $^{\circ}\text{C}$ )                                                                       |
| $T_{HPout}$         | = temperature of water from heat pump (to tank) ( $^{\circ}\text{C}$ )                                                                         |
| $\overline{T}_{hw}$ | = time-average of temperature of hot water withdrawn from tank ( $^{\circ}\text{C}$ )                                                          |
| $T_{hw}(t)$         | = temperature of water withdrawn from tank, as a function of time ( $^{\circ}\text{C}$ )                                                       |
| $\overline{T}_{in}$ | = time-average of temperature of water supplied to tank ( $^{\circ}\text{C}$ )                                                                 |
| $T_{in}(t)$         | = temperature of water supplied to tank, as a function of time ( $^{\circ}\text{C}$ )                                                          |
| $T_{in0}$           | = nominal temperature of water supplied to tank ( $^{\circ}\text{C}$ )                                                                         |
|                     | = 14 (for T2 test condition) or 9 (for low temperature test conditions)                                                                        |
| $\overline{T}_p$    | = water temperature in connecting pipes averaged over test point period ( $^{\circ}\text{C}$ )                                                 |

|                      |                                                                                                                              |
|----------------------|------------------------------------------------------------------------------------------------------------------------------|
| $T_t$                | = average tank water temperature (mass weighted mean of all tank segments) (°C)                                              |
| $\overline{T_t}$     | = average tank water temperature ( $T_t$ ) averaged over test point period (°C)                                              |
| $T_{tci}$            | = average tank temperature ( $T_t$ ) after second preconditioning tapping for 24-hour tapping cycle (°C)                     |
| $T_{tco}$            | = average tank temperature ( $T_t$ ) at the thermostat cut-out after third preconditioning tapping for 24-hour tapping cycle |
| $T_{t,1}$            | = average tank water temperature ( $T_t$ ) at start of test point period or 24-hour tapping cycle (°C)                       |
| $T_{t,2}$            | = average tank water temperature ( $T_t$ ) at end of test point period or 24-hour tapping cycle (°C)                         |
| $\overline{T_w}$     | = water temperature ( $T_w$ ) averaged over test point period (°C)                                                           |
|                      | <i>Stand-alone heat pump—</i>                                                                                                |
|                      | $T_w$ = mean of inlet and outlet water temperatures                                                                          |
|                      | <i>Integral heat pump—</i>                                                                                                   |
|                      | $T_w$ = mass weighted mean of temperature for tank segments adjacent to condenser coil                                       |
| $\overline{T_{wi}}$  | = water inlet temperature averaged over test point period (°C)                                                               |
| $\overline{T_{wet}}$ | = air wet bulb temperature averaged over test point period (°C)                                                              |
| $UA$                 | = tank heat loss rate per unit of temperature difference (kW/K)                                                              |
|                      | = $\frac{Q_{loss}}{24 \times 55}$                                                                                            |
| $V$                  | = static volumetric capacity of water storage tank (m <sup>3</sup> )                                                         |
| $V_{hw}$             | = delivered hot water volume equivalent at 45°C (L)                                                                          |
| $\dot{V}_{rr}$       | = standardized volumetric recharge rate (L/h)                                                                                |
| $\Delta t$           | = time interval between consecutive sample(s)                                                                                |
| $\Delta t_{rr}$      | = recharge time (h)                                                                                                          |
|                      | = time interval from end of second preconditioning tapping until next thermostat cut-out                                     |
| $\rho$               | = water density (temperature dependent) (kg/m <sup>3</sup> )                                                                 |
| $\tau$               | = sensor time constant (s)                                                                                                   |
| $\omega_X$           | = uncertainty in the value of parameter X                                                                                    |

## SECTION 2 TEST CONDITIONS

### 2.1 SCOPE OF SECTION

This Section specifies requirements for the test chamber for testing the product under controlled air temperature and humidity conditions. Product installation and sensors that are to be added to the product are also specified.

### 2.2 TEST CHAMBER

The heat pump shall be installed in a test chamber that can maintain the air temperature and humidity conditions specified in Table 2.1 with stability limits specified in Table 2.2. A minimum of the four test conditions specified in Table 2.1 shall be used. Additional tests may be used if requested by the manufacturer (e.g. additional low temperature tests to quantify heat pump defrosting).

**TABLE 2.1**  
**DRY BULB TEMPERATURE AND DEW POINT**  
**TEMPERATURE TEST CONDITIONS**  
**DURING A TEST POINT PERIOD**

| Test condition | Dry bulb temperature<br>°C | Dew point temperature<br>°C |
|----------------|----------------------------|-----------------------------|
| 1              | <10 (see Note)             | $T_a - 2.5$ to $T_a - 1.5$  |
| 2              | 18 to 20                   | 11 to 14                    |
| 3              | 30 to 34                   | 14 to 18                    |
| 4              | 31 to 35                   | 22 to 25                    |

NOTE: If low temperature performance is claimed (Section 5) the selection of test condition 1 may affect the temperature limit that is allowed in the annual performance evaluation (below which a performance penalty applies).

If a defrost cycle is observed during a test, the test shall be repeated at a higher dry bulb temperature with the specified dew point temperature until operation without a defrost cycle is achieved. The performance analysis shall only consider data collected during test point periods where no defrost cycle occurs.

NOTE: A defrost cycle is often indicated by abrupt changes of power consumption of the unit.

**TABLE 2.2**  
**VARIATION OF DRY BULB TEMPERATURE AND**  
**DEW POINT TEMPERATURE ABOUT THE**  
**AVERAGE DURING TEST POINT PERIOD**

| Parameter             | Allowed variation of one minute average conditions during test point period |
|-----------------------|-----------------------------------------------------------------------------|
| Dry bulb temperature  | $\pm 1$ K                                                                   |
| Dew point temperature | $\pm 0.5$ K                                                                 |

NOTE: The variations in Table 2.2 are deviations from the average for a test point period, not deviations of the average for a test point period from the ranges given in Table 2.1. For example, if the average air conditions of a test point period are 8.5°C dry bulb temperature and 6.3°C dew point temperature then the allowed variation of the one minute average for dry bulb temperature is 7.5°C to 9.5°C and for dew point temperature is 5.8°C to 6.8°C. All test point period averages shall fall in the ranges given in Table 2.1.

## 2.3 PRODUCT INSTALLATION

The equipment to be tested shall be installed in accordance with the manufacturer's installation instructions and to requirements in Appendix A. Piping between stand-alone heat pumps and the storage tank shall be as short as practicable and shall be insulated in accordance with the manufacturer's recommendations.

## 2.4 STAND-ALONE HEAT PUMP OPERATION

A stand-alone heat pump shall be tested to the requirements of Section 3 when connected to an insulated storage tank with a volumetric capacity of 250 L or the minimum tank size specified by the manufacturer whichever is larger.

The storage tank shall be mixed during testing. This may be achieved by plumbing the hot return to the bottom of the tank or by the use of a tank mixing pump that circulates water from the top to the bottom of the tank at a flow rate of more than two tank volumes per hour (see Paragraph A3.4).

NOTE: Water flow rate through the condenser during performance testing should be within 20% of the value specified in the manufacturer's installation manual.

## 2.5 SENSORS AND MEASUREMENTS

### 2.5.1 Temperature sensors

A minimum of six temperature sensors shall be inserted into the storage tank as specified in Appendix A. For stand-alone heat pumps temperature sensors shall also be inserted into the supply and return lines within 300 mm of the heat pump fittings.

### 2.5.2 Electrical power

The electrical power used by the heat pump compressor, fan(s), water pump (if used) and controls shall be measured during the operation of the heat pump as specified in Appendix A.

If the water pump is not integral with the heat pump its electrical power shall be measured separately and reported in Table F3.1.

The electrical power used by any pump to mix the storage tank during the test shall be measured separately from the heat pump electrical power measurement. The energy added by the mixing pump to the tank shall be subtracted from the energy accumulated in the tank when determining the heat pump thermal output power.

### **2.5.3 Stand-by electrical power**

The stand-by electrical power used by the heat pump fan(s), water pump (if used) and controls shall be measured for test condition two as defined in Table 2.1 and Table 2.3.

### **2.5.4 Stand-alone heat pump flow rate**

The flow rate of the water between the stand-alone heat pump and storage tank shall be measured during the operation of the heat pump as specified in Appendix A. If it is not possible to install a water flow meter, the flow rate shall be calculated using Equation 4.6 from the measured temperature difference between the heat pump inlet and outlet and the energy change within the storage tank.

## SECTION 3 TEST PROCEDURE

### 3.1 SCOPE OF SECTION

This Section specifies the measurement and test procedures for determining the performance of stand-alone and integral heat pump water heaters.

### 3.2 TEST CONDITIONS

#### 3.2.1 General

The heat pump shall be operated under constant air conditions (as set out in Table 2.1 and Table 2.2) and data shall be recorded while the tank is heated from the minimum to maximum temperatures specified in Table 3.1.

**TABLE 3.1**  
**WATER TEMPERATURE TEST CONDITIONS**

| Test condition | Water temperature at start of test | Water temperature at end of test        |
|----------------|------------------------------------|-----------------------------------------|
| 1              | <10°C                              | Maximum heat pump operating temperature |
| 2              | <15°C                              | Maximum heat pump operating temperature |
| 3              | <25°C                              | Maximum heat pump operating temperature |
| 4              | <25°C                              | Maximum heat pump operating temperature |

#### 3.2.2 Maximum heat pump operating temperature during test

The maximum heat pump operating temperature during each test condition shall be the maximum temperature to which the heat pump controller could require the heat pump to operate under the test condition.

NOTE: The maximum heat pump operating temperature is usually meant to satisfy both water heating requirements and *Legionella* control.

*Legionella* control requirements for Australia are specified in AS 3498. *Legionella* control requirements for New Zealand are specified in Clause G12 of the NZ Building Code and specific methods to meet these requirements are specified in the acceptable solutions G12/AS1 and G12/AS2.

### 3.3 TEST POINT PERIOD

A test point period shall consist of a period of time during which the mass weighted average tank temperature changes by 5 K to 5.5 K. The test chamber air conditions during the test point period shall satisfy the conditions specified in Table 2.1 and Table 2.2, however average air conditions may vary between test point periods for the same test condition. The tank temperature intervals used for different test point periods may overlap.

NOTE: For example, during one test point period the tank temperature may change from 10°C to 15°C and the next might be from 13°C to 18°C.

### 3.4 MEASUREMENTS

During the heat pump operation, one minute averages of the following variables shall be determined by recording each variable at a minimum rate of ten readings per minute:

- (a) Dry bulb temperature.
- (b) Dew point temperature, wet bulb temperature or relative humidity.

- (c) Tank core temperatures (minimum of six sensors, see Appendix A).
- (d) Water inlet temperature to the heat pump (for stand-alone heat pump only).
- (e) Water outlet temperature of the heat pump (for stand-alone heat pump only).
- (f) Water flow rate between heat pump and storage tank (stand-alone heat pump only, see Clause 2.5.4).
- (g) Electrical power input to heat pump (total power consumed).
- (h) Electrical power input to the condenser water circulation pump where such a pump is separate from the heat pump.

## SECTION 4 CALCULATIONS

### 4.1 SCOPE OF SECTION

This Section specifies the calculations of thermal capacity and the coefficient of performance.

NOTE: Guidance on errors is given in Appendix D.

### 4.2 SELECTION OF TEST POINT PERIODS

A test point period is a sequence of  $N$  one minute average records during which the average tank water temperature changes by 5 K to 5.5 K. A moving average 5 K interval may be used to generate a sequence of partially overlapping test point periods.

The set of test point periods used for the *COP* and *Power* correlation (Clause 4.5) shall satisfy the following distribution of test point periods:

- (a) At least one test point period with an average tank water temperature within  $\pm 5$  K of the start and stop test temperatures.
- (b) At least three test point periods in each 10 K band in the range of the start and stop temperatures.
- (c) The overlap of the average tank water temperature for successive test point periods shall be less than 3 K.

### 4.3 THERMAL CAPACITY

The heat pump thermal capacity ( $Q$ ) for each test point period is given by Equation 4.1:

$$Q = \frac{M_e C_{pw} (T_{t,2} - T_{t,1})}{N \times 60} + UA (\bar{T}_t - \bar{T}_a) - P_{\text{mix}} + P_{\text{loss}} \quad \dots 4.1$$

where

- $Q$  = thermal capacity of heat pump (kW)
- $C_{pw}$  = water specific heat at temperature  $\bar{T}_t$  (kJ/kg.K)
- $M_e$  = water equivalent mass of tank and contents (kg)
- $N$  = length of test point period (min)
- $P_{\text{mix}}$  = electrical power input to the tank mixing pump (if used) (kW)
- $P_{\text{loss}}$  = rate of heat loss from the connecting piping (kW)
- $\bar{T}_a$  = air dry bulb temperature averaged over test point period ( $^{\circ}\text{C}$ )
- $\bar{T}_t$  = average tank water temperature ( $T_t$ ) averaged at start of test point period ( $^{\circ}\text{C}$ )
- $T_{t,1}$  = average tank water temperature ( $T_t$ ) at start of test point period ( $^{\circ}\text{C}$ )
- $T_{t,2}$  = average tank water temperature ( $T_t$ ) at end of test point period ( $^{\circ}\text{C}$ )
- $UA$  = tank heat loss rate per unit of temperature difference (kW/K)