



BSI Standards Publication

# Laboratory tests to determine the heating and electrical performance of heat-led micro-cogeneration packages primarily intended for heating dwellings



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## Foreword

This Publicly Available Specification (PAS) has been developed by the Energy Saving Trust in collaboration with the British Standards Institution (BSI). The technical authorship has been undertaken by Gastec at CRE Ltd through a development process managed by the Energy Saving Trust, with sponsorship from the Department for Environment, Food, and Rural Affairs (DEFRA) through the Housing Energy Efficiency Best Practice Programme which is operated by the Energy Saving Trust.

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This Publicly Available Specification does not purport to include all the provisions that may be needed to form the basis of a contract. Users are responsible for its correct application.

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This Publicly Available Specification is not to be regarded as a British Standard.

To comply with this specification, the user shall comply with all its requirements.

**Compliance with this Publicly Available Specification does not in itself confer immunity from legal obligations.**

## Introduction

The purpose of PAS 67 is to determine by measurement, under a variety of load conditions, the data needed to calculate the energy performance of a micro-cogeneration package. It is restricted to packages whose function is the production of heat and electricity and whose control is by heat demand. The tests are designed to be reproducible.

Micro-cogeneration units (also known as micro combined heat and power units) require a substantially different test procedure from that for boilers, and the laboratory tests specified in PAS 67 have been designed to take account of these differences.

The results obtained from testing to the requirements of PAS 67 are not intended for use as a direct comparative assessment of micro-cogeneration packages. However, the results obtained from testing to the requirements of PAS 67 can be fed forward to procedures to calculate one or more indices of performance, such as an estimation of annual system energy requirements and system efficiencies, which could be utilized as part of a heating system design and for comparative assessments.

PAS 67 contains a number of testing modes and regimes (see Table 2) and manufacturers are cautioned to consider carefully how their packages are to be used when choosing the modes and regimes under which they wish their product to be tested.

It is recommended that the units offered for test conform to all relevant directives prior to submission for testing in accordance with PAS 67.

*NOTE Attention is drawn to Directive 2004/8/EC on the promotion of cogeneration, which excludes micro-cogeneration units from the need to meet the minimum thermal efficiency requirements that are specified in the Hot-Water Boiler Directive, 92/42/EEC [1] (commonly referred to as the BED, the Boiler Efficiency Directive).*

## 1 Scope

This Publicly Available Specification (PAS) specifies a comprehensive set of test conditions for determining the heating and electrical performance of heat-led micro-cogeneration packages that are primarily intended for use in dwellings. The PAS is suitable for testing those micro-cogeneration packages with a thermal output up to 70 kW (252 MJ/hr); the full output test may also be suitable for packages up to 400 kW (1440 MJ/hr).

For the category of micro-cogeneration package that provides space and water heating in which the domestic hot water (DHW) is provided wholly from within the package (CombiPK), the DHW test conditions described in this PAS are only applicable for packages with less than 15 litres of water storage.

For CombiPK packages with hot water storage of 15 litres or more, the DHW test has not been yet been developed and this will be considered for the next revision of the PAS. However, CombiPK packages with hot water storage of 15 litres or more can be tested using all other PAS 67 tests (full output, partial output and standby tests). The PAS results can be input to the procedure to calculate annual energy performance, such as "*Method to evaluate the annual energy performance of micro-cogeneration heating systems in dwellings*" [2] which for these products, until the PAS is revised, treats the DHW load as additional space heating load. This enables the estimation of the annual energy performance and derivation of the single index of performance for product comparison.

A reporting format for the test results is also specified.

*NOTE PAS 67 is not intended to deliver an evaluation of the annual energy performance of a product directly, but provides the data from which it may be calculated. It is intended to produce test results and other information that can be used in a separate method of calculation of annual energy performance of the micro-cogeneration package. An estimate of annual energy performance is necessary for the SAP (The UK Government's Standard Assessment Procedure for Energy Rating of Dwellings) [3] and other energy rating schemes. The document "Method to evaluate the annual energy performance of micro-cogeneration heating systems in dwellings" [2] specifies such a method. An extension of the annual energy performance method is used to derive a single index of performance for product comparison, similar in principle to SEDBUK (Seasonal Efficiency of Domestic Boilers in the UK) [4] already used for boilers.*

## 2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

**BS 845-1:1987**, *Methods for assessing thermal performance of boilers for steam, hot water and high temperature heat transfer fluids – Part 1: Concise procedure*

**BS 845-2:1987**, *Methods for assessing thermal performance of boilers for steam, hot water and high temperature heat transfer fluids – Part 2: Comprehensive procedure*

**BS 1566-1:2002**, *Copper indirect cylinders for domestic purposes – Open vented copper cylinders – Part 1: Requirements and test methods*

**BS EN 13203-2:2006**, *Gas-fired domestic appliances producing hot water – Appliances not exceeding 70 kW heat input and 300 litres water storage capacity – Part 2: Assessment of energy consumption*

**BS EN 304:1992**, *Heating boilers – Test code for heating boilers for atomizing oil burners*

**BS EN 437:2003**, *Test gases – Test pressures – Appliance categories*

**BS EN 60751:1996**, *Industrial platinum resistance thermometer sensors*

**Directive 2004/8/EC** of the European Parliament and of the Council of 11 February 2004 on the promotion of cogeneration based on a useful heat demand in the internal energy market and amending Directive 92/42/EEC.

**Directive 2004/108/EC** of the European Parliament and of the Council of 15 December 2004 on the approximation of the laws of the Member States relating to electromagnetic compatibility and repealing Directive 89/336/EEC

**Engineering Recommendation G83-1**, *Recommendations for the connection of small scale embedded generators (up to 16A per phase) in parallel with Public Low-Voltage Distribution Networks*

**UKAS M3003, Edn 2 2007**, *The Expression of Uncertainty and Confidence in Measurement*

### 3 Terms and definitions

For the purposes of this PAS the following terms and definitions apply:

- 3.1 case loss**  
heat lost from all surfaces (whether by radiation, natural or forced ventilation) of the micro-cogeneration package to the surroundings, including that from the flue pipe
- 3.2 cogeneration**  
simultaneous generation in one process of thermal energy and electrical and/or mechanical energy
- 3.3 cogeneration unit**  
unit that is capable of cogeneration
- 3.4 CombiPK**  
category of micro-cogeneration package for providing space and water heating in which Domestic Hot Water (DHW) service is provided wholly from within the package
- 3.5 condensing micro-cogeneration unit**  
micro-cogeneration unit designed to make use of the latent heat released by the condensation of water vapour in the products of combustion and to allow the condensate to leave the package in liquid phase  
*NOTE Units not so designed, or without the means to remove the condensate in liquid phase, are “non-condensing micro-cogeneration units”.*
- 3.6 DHW storage tank**  
tank used for the storage of domestic (sanitary) hot water

- 3.7 flow water temperature**  
temperature of the water leaving the micro-cogeneration package and entering the test rig
- 3.8 flue loss**  
sensible and latent thermal energy lost from a micro-cogeneration package via the flue pipe and the condensate drain
- 3.9 flue pipe**  
conduit by which gaseous products of combustion are transported to outside the building
- 3.10 full output**  
heat output for space heating as determined by the full output test
- 3.11 gross calorific value (CV)**  
(also known as the **higher calorific value** or **higher heating value**)  
quantity of heat produced by the complete combustion of a unit of weight or volume of a fuel at a constant reference temperature and pressure, with the constituents of the fuel being taken at reference conditions and the products of combustion being brought back to the same conditions
- 3.12 heat output during the heat demand time**  
output to space heating produced by the package recorded during the heat demand times as defined in Table 7
- 3.13 HeatPK**  
category of micro-cogeneration package for providing space heating only (no domestic hot water service)
- 3.14 island mode**  
operation of a micro-cogeneration package whilst not connected to a public electricity supply network
- 3.15 mean surface temperature**  
mean temperature of the surface of the micro-cogeneration unit at any location over a prescribed time period (see B.2)
- 3.16 micro-cogeneration unit**  
condensing or non-condensing cogeneration unit defined by Directive 2004/8/EC as a maximum electrical output power below 50 kW<sub>e</sub>
- 3.17 micro-cogeneration package (see 6.1)**  
micro-cogeneration unit with associated equipment, excluding any flue pipe over and above the minimum specified by the manufacturer for the safe operation of the micro-cogeneration package  
*NOTE See 6.2 for a list of associated equipment.*
- 3.18 nominal rated heat output**  
rate of heat output (expressed in kW) of the micro-cogeneration package, declared by the manufacturer that can be maintained indefinitely over successive 24 hour periods
- 3.19 power analyser**  
meter capable of measuring electrical power and energy that makes true allowance for the voltage, current and power factor (phase angle) as relevant, of an alternating current (AC) or direct current (DC)

- 3.20 primary circuit**  
circuit by which hot water flows out of the micro-cogeneration package and cooled water is returned
- 3.21 proximate**  
analysis of solid fuel in terms of moisture, ash, volatile matter and (by difference) fixed carbon
- 3.22 RegPK**  
category of micro-cogeneration package for providing space and water heating, intended for connection to a separate DHW storage tank of standard specification
- 3.23 return water temperature**  
temperature of the water returning to the micro-cogeneration package from the test rig
- 3.24 SEDBUK (Seasonal Efficiency of Domestic Boilers in the UK)**  
method used to determine the average annual installed efficiency of gas and oil boilers in dwellings in the UK, used both for SAP [3] and product endorsement purposes
- 3.25 synchronous mode**  
operation of a micro-cogeneration package connected to a public alternating current (AC) electricity distribution network and capable of exporting electrical power to it
- 3.26 system circulator**  
circulator of sufficient capacity to pump the central heating (CH) water around the distribution circuit of size proportional to the thermal output of the package
- 3.27 test laboratory**  
location where micro-cogeneration packages are tested
- 3.28 test mode**  
load pattern applied during test to the micro-cogeneration package, as defined in 6.3
- 3.29 test regime**  
set of test modes conforming to one of the options shown in Table 2
- 3.30 thermal store**  
any vessel used to store the heat output from the micro-cogeneration unit and thus assist the micro-cogeneration package in serving the instantaneous heat demand of the space heating and/or DHW load
- NOTE This could be a purpose designed storage vessel containing water used in the space heating system or it could be the storage vessel conventionally used for DHW, or a combination of the two.*
- 3.31 view factor**  
fraction of the total energy emitted by one surface that is directly incident on another surface (see B.3)

## 4 Abbreviations

- 4.1 AC**  
Alternating Current
- 4.2 CH**  
Central Heating
- 4.3 CV**  
Gross Calorific Value (see 3.11)
- 4.4 DC**  
Direct Current
- 4.5 DHW**  
Domestic Hot Water
- 4.6 LPG**  
Liquefied Petroleum Gas

## 5 Symbols

For the purposes of this PAS the following symbols apply. All values are based upon the use of the gross calorific value of the fuel.

| Symbol              | Unit                             | Designation                                                                                                                                                                                                     |
|---------------------|----------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $\rho_{\text{air}}$ | kg/m <sup>3</sup>                | density of air through grill (see B.4.1)                                                                                                                                                                        |
| $\sigma$            | Wm <sup>-2</sup> K <sup>-4</sup> | Stefan-Boltzmann constant (equal to $5.67 \times 10^{-8}$ Wm <sup>-2</sup> K <sup>-1</sup> )                                                                                                                    |
| $A$                 | m <sup>2</sup>                   | total surface area of the component (see B.3)                                                                                                                                                                   |
| $C$                 | –                                | constant for convection (see B.3)                                                                                                                                                                               |
| $d_i$               | litre/min                        | flow rate for individual draw-off (tapping), see Table 11                                                                                                                                                       |
| $D$                 | litre/min                        | single specific rate of hot water draw-off (tapping) as specified by the manufacturer                                                                                                                           |
| $E_{\text{in}}$     | MJ                               | total electrical energy input to the package over the 24 hour test period, as recorded on the “import” register of the power analyser                                                                           |
| $E_{\text{inact}}$  | MJ                               | actual total electrical energy input to the package during the standby loss test as recorded on the “import” register of the power analyser                                                                     |
| $E_{\text{out}}$    | MJ                               | <i>NOTE This is likely to be over a period of more than 24 hours</i><br>total electrical energy output from the package over the 24 hour test period as recorded on the “export” register of the power analyser |
| $E_{\text{outact}}$ | MJ                               | actual total electrical output from the package during the standby loss test period as recorded on the “export” register of the power analyser                                                                  |
| $F$                 | –                                | <i>NOTE This is likely to be over a period of more than 24 hours</i><br>view factor (see 3.31)                                                                                                                  |
| $F_{23}$            | kW                               | loss due to sensible heat in the dry flue gases; BS 845-2:1987, Clause 8.2.22                                                                                                                                   |
| $F_{24}$            | kW                               | energy flow rate in flue gas from sensible and latent heat in moisture in fuel; BS 845-2:1987, Clause 8.2.23                                                                                                    |
| $F_{28}$            | kW                               | energy flow rate within any condensate collected from the flue or micro-cogeneration package drain; BS 845-2:1987, Clause 8.2.27                                                                                |
| $F_{53}, F_{54}$    | kW                               | energy flow rates within un-burnt flue gases; BS 845-2:1987, Clause 8.2.21                                                                                                                                      |

| Symbol                                                               | Unit              | Designation                                                                                                                                                                                                                                                                                                                       |
|----------------------------------------------------------------------|-------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $J(T)$                                                               | kJ/kg             | specific enthalpy of water at $T$ °C in the range 10 °C to 240 °C<br><i>NOTE This is evaluated from</i><br>$J(T) = A + BT + CT^2 + DT^3 + ET^4$<br>Where the following numerical values apply<br>$A = 0.167853$<br>$B = 4.18587$<br>$C = -1.46789 \times 10^{-4}$<br>$D = 9.38153 \times 10^{-7}$<br>$E = 8.36764 \times 10^{-9}$ |
| $J(T_{\text{spaceflow}})$                                            | kJ/kg             | specific enthalpy of the central heating water sent out to the system                                                                                                                                                                                                                                                             |
| $J(T_{\text{spacereturn}})$                                          | kJ/kg             | specific enthalpy of the returning central heating water                                                                                                                                                                                                                                                                          |
| $J(T_{\text{thermalstore}})$                                         | kJ/kg             | specific enthalpy at mean temperature from measurements taken at different locations of a thermal store at a particular time $t$                                                                                                                                                                                                  |
| $H_{\mu\text{chp}}$                                                  | MJ                | energy content of the micro-cogeneration package                                                                                                                                                                                                                                                                                  |
| $H_{\text{thermalstore}}$                                            | MJ                | energy content of the thermal store                                                                                                                                                                                                                                                                                               |
| $H_s$                                                                | kJ/m <sup>3</sup> | Gross (higher) calorific value of the dry test gas at 15 °C, 1013.25 mbar                                                                                                                                                                                                                                                         |
| $H_{\text{soil}}$                                                    | kJ/kg             | Gross (higher) calorific value of the test oil or other liquid fuel                                                                                                                                                                                                                                                               |
| $H_{\text{ssolid}}$                                                  | kJ/kg             | Gross (higher) calorific value of the test solid fuel                                                                                                                                                                                                                                                                             |
| $L_{1\text{gr}}$                                                     | %                 | loss due to sensible heat in the dry flue gases (as defined within BS 845-1:1987)                                                                                                                                                                                                                                                 |
| $L_{2\text{gr}}$                                                     | %                 | loss due to enthalpy in the water vapour in the flue gases (as defined within BS 845-1:1987)                                                                                                                                                                                                                                      |
| $L_{3\text{gr}}$                                                     | %                 | loss due to un-burnt flue gases (as defined within BS 845-1:1987)                                                                                                                                                                                                                                                                 |
| $M_{\text{oil}}$                                                     | kg                | measured mass of oil or other liquid fuel over the 24 hour test period                                                                                                                                                                                                                                                            |
| $M_{\text{solid}}$                                                   | kg                | measured mass of solid fuel over the 24 hour test period                                                                                                                                                                                                                                                                          |
| $M_{\text{thermalstore}}$                                            | kg                | mass of water contained within thermal store                                                                                                                                                                                                                                                                                      |
| $m_{\text{spacewater}}$                                              | kg/sec            | flow rate of central heating water through the micro-cogeneration package                                                                                                                                                                                                                                                         |
| $N$                                                                  | –                 | constant for convection (see B.3)                                                                                                                                                                                                                                                                                                 |
| $n$                                                                  | –                 | number of tappings (Clause 12.7, DHW only test)                                                                                                                                                                                                                                                                                   |
| $p_a$                                                                | mbar              | atmospheric pressure at time of test                                                                                                                                                                                                                                                                                              |
| $p_g$                                                                | mbar              | gas pressure at the meter                                                                                                                                                                                                                                                                                                         |
| $p_s$                                                                | mbar              | saturated vapour pressure of water                                                                                                                                                                                                                                                                                                |
| $Q_{\text{balance}}$                                                 | MJ                | total measured energy input minus total measured energy output of micro-cogeneration package                                                                                                                                                                                                                                      |
| $Q_{\text{case}}$                                                    | MJ                | total energy loss from the case (estimated)                                                                                                                                                                                                                                                                                       |
| $q_{\text{com}}$                                                     | W                 | rate of energy released at time $t$ from the component                                                                                                                                                                                                                                                                            |
| $Q_{\text{DHW}}$                                                     | MJ                | total energy to DHW                                                                                                                                                                                                                                                                                                               |
| $Q_{\text{DHWpump}}$                                                 | kJ                | total power demand as indicated by the pump power meter over 1 hour                                                                                                                                                                                                                                                               |
| $Q_{\text{DHWrigloss}}$                                              | kJ                | total energy “supplied to/lost from” RegPK DHW test circuit over 1 hour during assessment of standing loss                                                                                                                                                                                                                        |
| $Q_{\text{DHWtankloss}}$                                             | kJ                | total power demand as indicated by the heater power meter over 1 hour                                                                                                                                                                                                                                                             |
| $q_{\text{DHWpipelossinst}}$                                         | W                 | Average instantaneous rate of energy “supplied to/lost from” RegPK DHW pipework test circuit during assessment of standing loss                                                                                                                                                                                                   |
| $q_{\text{DHWriglossinst}}$                                          | W                 | Average instantaneous rate of energy “supplied to/lost from” RegPK DHW storage tank and pipework test circuit during assessment of standing loss                                                                                                                                                                                  |
| $q_{\text{fan}}$                                                     | kW                | rate of energy loss from the case by forced convection (usually a fan)                                                                                                                                                                                                                                                            |
| $Q_{\text{fuel}}$                                                    | MJ                | total energy of fuel consumed                                                                                                                                                                                                                                                                                                     |
| $Q_{\text{fuelact}}$                                                 | MJ                | actual total energy of fuel consumed during the standby loss test                                                                                                                                                                                                                                                                 |
| <i>NOTE This is likely to be over a period of more than 24 hours</i> |                   |                                                                                                                                                                                                                                                                                                                                   |

| Symbol                                      | Unit           | Designation                                                                                                                                                                                                                           |
|---------------------------------------------|----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $Q_{\text{flue}}$                           | MJ             | total energy loss from flue (estimated)                                                                                                                                                                                               |
| $Q_{\text{flueuf}}$                         | MJ             | energy loss from flue under fire                                                                                                                                                                                                      |
| $q_{\text{flueppsingle}}$                   | MJ             | energy loss associated with single pre-purge or post purge from flue                                                                                                                                                                  |
| $Q_{\text{fluepptotal}}$                    | MJ             | total energy loss associated with pre-purge and post purge from flue<br>Equals $\sum_0^{24}$                                                                                                                                          |
| $Q_{\text{fuelfull}}$                       | MJ             | total energy of fuel consumed during the 24 hour full output test                                                                                                                                                                     |
| $Q_{\text{space}}$                          | MJ             | total energy to space heating                                                                                                                                                                                                         |
| $Q_{\text{spacedt}}$                        | MJ             | energy output to space heating recorded as produced by the package during the heat demand times as defined in Table 7                                                                                                                 |
| $spht_{\text{air}}$                         | kJ/(kg.K)      | mean specific heat of air through grill (default value 1.05)                                                                                                                                                                          |
| $spht_{\text{water}}$                       | kJ/(kg.K)      | specific heat of water<br><br><i>NOTE Used when evaluating the energy content of water under Domestic Hot Water (DHW) tests (12.7). This is defined within BS EN 13203-2, Clause 5.2.2.2 as 4.1868 kJ/(kg.K)</i>                      |
| $T_{\text{coldwater}}$                      | °C             | temperature of the water at the inlet to DHW production                                                                                                                                                                               |
| $T_{\text{ContentDHW}}$                     | °C             | weighted mean instantaneous temperature of DHW tank                                                                                                                                                                                   |
| $T_{\text{DHW}}$                            | °C             | instantaneous temperature of DHW                                                                                                                                                                                                      |
| $T_{\text{g}}$                              | °C             | gas temperature at the meter                                                                                                                                                                                                          |
| $t_{\text{dur}}$                            | seconds        | test period of the test for standby losses with a duration of <ul style="list-style-type: none"> <li>• an integral number of re-heat cycles, and;</li> <li>• at least two re-heat cycles; and</li> <li>• at least 24 hours</li> </ul> |
| $t_{\text{i}}$                              | mins           | tapping duration of the useful water                                                                                                                                                                                                  |
| $T_{\text{r}}$                              | °C             | ambient temperature                                                                                                                                                                                                                   |
| $T_{\text{pwater}}$                         | °C             | temperature of the water returning to the pump °C                                                                                                                                                                                     |
| $T_{\text{pair}}$                           | °C             | mean temperature of the air measured 35 mm above and below the pump °C                                                                                                                                                                |
| $T_{\text{primflowDHW}}$                    | °C             | temperature 75 mm ( $\pm 25$ mm) from the point where the primary flow pipework is connected to the mCHP unit                                                                                                                         |
| $T_{\text{primretDHW}}$                     | °C             | temperature 75 mm ( $\pm 25$ mm) from the point where the primary return pipework is connected to the mCHP unit                                                                                                                       |
| $T_{\text{xyzDHW}}$                         | °C             | temperature at any point xyz measured during a DHW test.                                                                                                                                                                              |
| $T_{\text{s}}$                              | °C             | mean surface temperature of any component at time $t$                                                                                                                                                                                 |
| $T_{\text{spaceflow}}$                      | °C             | temperature of the central heating water sent out to the system                                                                                                                                                                       |
| $T_{\text{spacereturn}}$                    | °C             | temperature of the returning central heating water                                                                                                                                                                                    |
| $T_{\text{thermalstore(at } t=0\text{h})}$  | °C             | average of the representative temperatures of defined locations of a thermal store at the beginning of the 24 hour period                                                                                                             |
| $T_{\text{thermalstore(at } t=24\text{h})}$ | °C             | average of the representative temperatures of defined locations of a thermal store at the end of the 24 hour period                                                                                                                   |
| $T_{\text{ventin}}$                         | °C             | temperature of the ambient air into micro-cogeneration unit case through the grill                                                                                                                                                    |
| $T_{\text{ventout}}$                        | °C             | average temperature of the warmed air exiting from the discharge vents                                                                                                                                                                |
| $U_{\text{grill}}$                          | m/s            | mean velocity of air through grill                                                                                                                                                                                                    |
| $V$                                         | m <sup>3</sup> | measured volume of the test gas over the 24 hour test period                                                                                                                                                                          |

## 6 Micro-cogeneration packages, test modes and test regimes

### 6.1 Category of micro-cogeneration package

For testing purposes, the manufacturer shall categorise the package as one of the following:

- a) HeatPK – micro-cogeneration package for the provision of space heating only - no domestic hot water service, i.e. a system for meeting the space heating demand only.
- b) CombiPK – micro-cogeneration package for the provision of space and water heating, in which the DHW service is provided wholly from within the package, i.e. a system acting as an alternative for a combination boiler providing both space heating and domestic hot water.

*NOTE* Provision of the domestic hot water (DHW) may utilise either a DHW storage tank or heat exchange coils within the package.

The DHW test conditions described in this PAS are only applicable for packages with less than 15 litres of water storage.

For CombiPK packages with water storage of 15 litres or more, the DHW test has not yet been developed. However, CombiPK packages with water storage of 15 litres or more can be tested using all other PAS 67 tests (full output, partial output and standby tests) and the PAS results fed forward to the procedure to calculate annual energy performance, “*Method to evaluate the annual energy performance of micro-cogeneration heating systems in dwelling*” [2] which will allow for DHW performance.

- c) RegPK – micro-cogeneration package for the provision of space and water heating, in which the DHW storage tank is outside the package but connected to it, i.e. a system acting as an alternative for a regular boiler. In this category the DHW storage tank is not part of the package and shall be supplied by the test laboratory (see 6.2). It is expected that the DHW storage tank will be a cylinder. For PAS 67, the DHW storage tank provided by the laboratory will be a cylinder to BS 1566 as specified in 6.2 e).

The manufacturer shall specify and supply the DHW storage tank thermostat which shall be recorded in 8.1.

*NOTE* Any micro-cogeneration unit in which any DHW storage tank, internal or external, to the package is expected to operate also as a thermal store, should be tested under category CombiPK.

### 6.2 Composition of the micro-cogeneration package to be tested

The micro-cogeneration package shall consist of the following items. Each item shall be provided by the manufacturer except where otherwise indicated:

- a) a micro-cogeneration unit;
- b) declaration in accordance with Results Table 1 in Clause 13;
- c) thermal store(s) as specified by the manufacturer (if required);
- d) a full set of installation, commissioning and operating instructions, as provided for the normal installation in dwellings;

- e) items according to category declared in 6.2 b):

1) HeatPK:

If a thermal store is to be used it shall be included within the package tested. The manufacturer shall define the control strategy so as to maintain the temperature of water at T2 (see 6.2 f and Figure A.1).

2) CombiPK:

The manufacturer shall define the control strategy so as to maintain the temperature of water at T2 (see 6.2 f and Figure A.1) and T4 (see 6.2 f and Figure A.2).

*NOTE 1 Figure A.1 shows the arrangement for space heating tests for all package categories.*

3) RegPK:

The manufacturer shall define the control strategy so as to maintain the temperature of water at T2 [see 6.2 f) and Figure A.1].

The DHW storage tank, provided by the test laboratory, shall have a nominal volume of 117 litres, and shall conform to the minimum standard defined within BS 1566 (Ref 7, type G). The manufacturer shall provide instructions to fit and operate the thermostat to the DHW storage tank such that the set point of the DHW draw-off is  $60 \pm 5$  °C.

*NOTE 2 A temperature of DHW draw-off of 60°C may require a bespoke setting on the DHW tank thermostat, which may or may not correspond to 60 °C.*

*NOTE 3 Figure A.1 shows the arrangement for space heating tests for all package categories.*

- f) An internal control system identical to that of production models of the package intended to be placed on the market under the declared unique package identifier, (see Manufacturer's Declaration, Results Table 1) and sufficient information to enable the test laboratory to control the package in such a way as to deliver the heat output required for the various tests.

This information shall include values and timing of signals (from genuine or artificial origin) that would be received from a typical installation. For example, signals from a room thermostat, DHW tank thermostat, external thermostat, programmer or any other devices that communicate heat demand from the building. These signals will represent the call for heat within the dwelling and control the heat output from the package;

*NOTE The performance of micro-cogeneration packages will be dependant on the functionality of the internal control system and following the above requirements is intended to ensure that the performance of the installation in the laboratory replicates that likely to occur in a real installation.*

- g) the minimum effective length of flue pipe specified in the installation instructions;
- h) in the case of equipment to be tested in synchronous mode, any power conversion and conditioning equipment to enable compliance with the electrical conditions specified in 10.5;

- i) a detailed description of how the thermal energy content of the package can be determined at the beginning and end of any 24 hour test period, to allow compliance with 10.8;
- j) flow and return connections and valves as specified by the test laboratory that will enable the package to be connected to the test rigs specified in Annex A;
- k) details of the recommended values for  $T_{\text{spacereturn}}$  and  $T_{\text{spaceflow}}$  and space heating and DHW flow rates that would allow the test laboratory to comply with the minimum temperatures defined within Clause 12.

### 6.3 Test modes and test regimes

6.3.1 The test modes are as follows:

- a) *Continuous operation* – requires compliance with continuous operational criteria (see Table 1 for the relevant output test clauses). The heat produced by the package shall be relatively uniform and as a minimum comply with the minimum hot period defined within Tables 7 and 8 as appropriate, delivered over the 24 hour period.
- b) *Uni-modal operation* – requires compliance with certain operational criteria during the heating period 07:00 to 23:00 (see Table 1 for the relevant output test clauses). The heat produced by the package shall be relatively uniform and as a minimum comply with the minimum hot period defined within Table 7 and Table 9 as appropriate, delivered over the 16 hour period.
- c) *Bi-modal operation* – requires compliance with certain operational criteria during the heating periods 06:00 to 09:00 and 15:00 to 23:00 (see Table 1 for the relevant output test clauses). The heat produced by the package shall be relatively uniform and as a minimum comply with the minimum hot period defined within Tables 7 and 10 as appropriate, delivered during the morning and evening on periods.
- d) *Domestic Hot Water only* – production of hot water in accordance with 12.7.
- e) *Standby Losses* – the package shall be tested in standby mode (see 12.6).

Table 1 Relevant clause numbers for each test mode

| Test mode            | Clause number           |                 |                 |
|----------------------|-------------------------|-----------------|-----------------|
|                      | Full Output test (100%) | 30% Output test | 10% Output test |
| Continuous operation | 12.2                    | 12.3.2          | 12.4.2          |
| Uni-modal operation  | 12.2                    | 12.3.3          | 12.4.3          |
| Bi-modal operation   | 12.2                    | 12.3.4          | 12.4.4          |
| Standby mode         | 12.6                    |                 |                 |
| DHW only             | 12.7                    |                 |                 |

**6.3.2** Manufacturers shall choose a test regime from Table 2. The manufacturer's operating instructions supplied to customers with the package shall confirm that the test regime(s) chosen is appropriate to assess how the package will perform after installation in accordance with the manufacturer's design and installation instructions.

*NOTE The manufacturer should give careful consideration as to how the results may be treated in any higher level procedures before choosing which test mode and regime to follow. Different test regimes may lead to different performance results, and further calculations are necessary to determine the overall annual energy performance and carbon emissions in any particular building.*

Table 2 **Definitions of test regimes**

| Regime | Applicable test modes              |                     |                     |
|--------|------------------------------------|---------------------|---------------------|
|        | Full output test (100%) (see 12.2) | 30% test (see 12.3) | 10% test (see 12.4) |
| 1      | Continuous                         | Continuous          | Continuous          |
| 2      | Continuous                         | Uni-modal           | Uni-modal           |
| 3      | Continuous                         | Bi-modal            | Bi-modal            |
| 4      | Continuous                         | Uni-modal           | Bi-modal            |

**6.3.3** Manufacturers shall choose whether the package is to be tested at any of the supplementary operational conditions (see 6.4 and 12.5).

## 6.4 Supplementary partial output tests

As well as the full output, 30% output, and 10% output tests, supplementary partial-output tests may be carried out at 90%, 80%, 70%, 60%, 50%, 40% and 20%, under the conditions specified in 12.5. Supplementary tests are optional, but may be included and certified as part of the same group of tests. Where supplementary tests are to be carried out, the test mode for each one shall be as defined in Table 3, e.g. if regime 1 has been chosen from Table 2, then the test mode shall be chosen from the row labelled regime 1 in Table 3.

*NOTE Supplementary test results will enable a more reliable curve of performance (a graph of thermal efficiency and net electrical output versus partial output) to be produced. The performance curve will be required in order to calculate annual performance data and the additional points that are established through supplementary partial output tests will reduce the errors of interpolation. For example, it may be beneficial to carry out a test close to the partial output at which the highest ratio of electrical power generation to heat is obtained.*

Table 3 **Test modes for permitted supplementary partial output tests under each regime**

| Regime | Permitted supplementary partial output tests |      |      |           |           |           |           |
|--------|----------------------------------------------|------|------|-----------|-----------|-----------|-----------|
|        | 90%                                          | 80%  | 70%  | 60%       | 50%       | 40%       | 20%       |
| 1      | Cont                                         | Cont | Cont | Cont      | Cont      | Cont      | Cont      |
| 2      | N/A                                          | N/A  | N/A  | Uni-modal | Uni-modal | Uni-modal | Uni-modal |
| 3      | N/A                                          | N/A  | N/A  | N/A       | N/A       | Bi-modal  | Bi-modal  |
| 4      | Cont                                         | Cont | Cont | Uni-modal | Uni-modal | N/A       | N/A       |

Cont = Continuous

N/A = Not allowed

## 7 Test laboratory conditions adjacent to the micro-cogeneration unit

The ambient air temperature in the test laboratory shall be  $20\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ . The maximum air velocity adjacent to the package shall be 0.5 m/s, except where the air velocity is inherently generated by the package. The package shall at all times be shaded from sunlight. The laboratory temperature, humidity and pressure shall be recorded hourly during the test at a height of 1.5 m and between 1 m and 3 m horizontally away from the micro-cogeneration unit. The thermometer shall be protected from direct radiation from the micro-cogeneration unit. The averages shall be reported in Results Table 2 (Clause 13). Wherever possible, relative humidity shall be controlled between 50% and 70%.

## 8 Records for future package surveillance

### 8.1 General

The manufacturer and test laboratory shall together compile a technical file that accurately defines the package and the conditions under which the package was tested.

### 8.2 Manufacturer

The manufacturer shall provide:

- a) manufacturer's declaration (see Results Table 1 in Clause 13);
- b) a set of functional drawings that accurately define all the physical attributes of the package;
- c) a set of functional data, including information as specified in 6.2 f), that accurately and completely defines any control system used within the package. If the manufacturer operates a transparent system in accordance with an approved quality scheme (for example BS EN ISO 9001 [5]), this shall be the manufacturer's own code number (for example the ABC Ltd micro-cogeneration control program Version 7.16). This code number may in turn call up a number of further references detailing the commercial software with which such a control program might have been written. In the absence of such a rigorous scheme, the manufacturer shall provide the appropriate logic trees, ladder diagrams or electronic programs and shall include all time constants for proportional, integral and differential controls (where applicable).

*NOTE The information will not be analysed by the test laboratory but will act as a permanent record of the control strategy used by the package at the time of test.*

### 8.3 Manufacturer and test laboratory

The manufacturer and test laboratory together shall provide:

- a) the test declaration (see Results Table 7 in Clause 13);
- b) a set of functional data, including information as specified in 6.2 f), that accurately and completely defines how the package and the control system were set up for all laboratory tests. This shall be set at a sufficient level of detail to allow reliable and unambiguous replication of the test procedure in another test laboratory.

*NOTE This would be similar to that required for compliance with the Gas Appliances Directive [6] and certainly greater than generally recorded for the testing of boilers to the Boiler Efficiency Directive [1]. This is particularly important with respect to the setting or unusual adjustment of controls, for example pressure switches.*

### 8.4 Test laboratory

The test laboratory shall provide:

- a) the test results (see Results Tables 2, 3, 4, 5 and 6 in Clause 13);
- b) the details and condition under which the package was tested, including any additional equipment used by the test laboratory with particular reference to 6.2 e) and 6.2 f);
- c) any additional comments relating to the tests to allow reproducible surveillance testing.

## 9 Actions of the test laboratory upon acceptance of micro-cogeneration package

The test laboratory shall assess the package to ensure that all components of the micro-cogeneration package are accurately specified. Details of the equipment shall be recorded in the technical file (see Clause 8).

## 10 Testing principles

### 10.1 Introduction

The total measured energy flowing into the micro-cogeneration package during any 24 hours shall be compared with the measured energy flowing out of the package. All timed events (for example the beginning or end of a measurement period) shall be carried out within  $\pm 15$  seconds of the time stated within PAS 67.

*NOTE This is required due to the relative complexity of micro-cogeneration packages when compared with boilers. The following sub-clauses detail the appropriate techniques.*

The expression of uncertainty in measurements shall be in accordance with UKAS M3003, 2007.

### 10.2 Test fuels

All the calculations shall be determined using gross calorific values.

Test fuels and their input rates shall be determined by the following techniques, as appropriate.