**PAS 67:2013**

*Incorporating corrigendum No. 1*

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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# Contents

**Summary of pages**
This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 62, an inside back cover and a back cover.

 

# Foreword

## Publishing information

This PAS was sponsored by the Energy Saving Trust (EST). Its development was facilitated by BSI Standards Limited and it was published under licence from The British Standards Institution. It came into effect on 28 June 2013.

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This PAS is not to be regarded as a British Standard. It will be withdrawn upon publication of its content in, or as, a British Standard.

The PAS process enables a specification to be rapidly developed in order to fulfil an immediate need in industry. A PAS may be considered for further development as a British Standard, or constitute part of the UK input into the development of a European or International Standard.

## Supersession

This PAS supersedes PAS 67:2008, which is withdrawn.

## Use of this document

It has been assumed in the preparation of this British Standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

## Presentational conventions

The provisions of this standard are presented in roman (i.e. upright) type. Its requirements are expressed in sentences in which the principal auxiliary verb is "shall".

*Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.*

## Contractual and legal considerations

This publication 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.

**Compliance with this PAS does not 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 in which all heat is usefully employed. The tests are designed to be reproducible.

Micro-cogeneration unit (MCG) (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 used for calculating one or more indices of performance, such as estimating annual system energy requirements and system efficiencies. This could be utilized as part of a heating system design and also for comparative assessments.

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

*NOTE 1 Attention is drawn to Directive 2004/8/EC [2] on the promotion of cogeneration, which excludes MCGs from the need to meet the minimum thermal efficiency requirements that are specified in the hot-water boiler Directive, 92/42/EEC [3], commonly referred to as the Boiler Efficiency Directive (BED).*

*NOTE 2 This PAS has been and will be affected by particular editions and revisions of the UK Building Standard Assessment Procedure (SAP) which is being reviewed by the government with increasing frequency and with respect to the corresponding Annual Performance Method. This does not affect the validity of the tests contained within this PAS but users and potential users might wish to understand the latest regulatory procedure before embarking upon large test programmes.*

# 1 Scope

This PAS specifies a 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 applicable for:

- testing micro-cogeneration packages that provide space and water heating with a thermal output up to 70 kW (252 MJ/h); or
- testing micro-cogeneration units (MCGs) designed to produce electricity and simultaneously heat a domestic hot water storage tank (DHWPK).

The full output test might also be suitable for packages up to 400 kW (1 440 MJ/h).

This PAS also specifies a reporting format (Results Tables) for the test results.

This PAS does not cover how to evaluate the annual energy performance of a MCG, but it is intended that the data obtained through testing to PAS 67 can be used for these purposes.

*NOTE 1 A suitable method that can be used to evaluate the annual energy performance of a MCG is given in* Method to evaluate the annual energy performance of micro-cogeneration heating systems in dwellings *[1]. This method 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.*

*NOTE 2 An estimate of annual energy performance is necessary for the SAP (The UK Government's Standard Assessment Procedure for Energy Rating of Dwellings) [4] and* *other energy rating schemes. The document* Method to evaluate the annual energy performance of micro-cogeneration heating systems in dwellings *[1] 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 Seasonal Efficiency of Domestic Boilers in the UK (SEDBUK) [5] already used for boilers.*

# 2 Normative references

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

## Standard references

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 1566-1:2002+A1:2011, *Copper indirect cylinders for domestic purposes – Part 1: Open vented copper cylinders – Requirements and test methods*

BS EN 304:1992+A2:2003, *Heating boilers – Test code for heating boilers for atomizing oil burners*

BS EN 437:2003+A1:2009, *Test gases – Test pressures – Appliance categories*

BS EN 483:1999+A4:2007, *Gas-fired central heating boilers – Type C boilers of nominal heat input not exceeding 70kW*

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

BS EN 60751:2008, *Industrial platinum resistance thermometers and platinum temperature sensors*

## Other references

[N1] UKAS M3003, Edition 2, 2007. *The Expression of Uncertainty and Confidence in Measurement.*

[N2] 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.* (see Energy Networks Association).

[N3] Engineering Recommendation G59/2, *Recommendations for the connection of generating plant to the distribution systems of licensed distribution network operators* (see Energy Networks Association).

# 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 (MCG)**
MCG 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 MCGs".*

**3.6 domestic hot water (DHW) storage tank**
tank used for the storage of domestic (sanitary) hot water

**3.7 domestic hot water production kit (DHWPK)**
category of micro-generation package for providing only domestic hot water (DHW) service

**3.8 flow water temperature**
temperature of the water leaving the micro-cogeneration package and entering the test rig

**3.9 flue loss**
sensible and latent thermal energy lost from a micro-cogeneration package via the flue pipe and the condensate drain

**3.10 flue pipe**
conduit by which gaseous products of combustion are transported to outside the dwelling

**3.11 full output**
heat output for space heating as determined by the full output test

**3.12 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

**3.13 heat output during the heat demand time**
output to space heating produced by the package recorded during the heat demand times

**3.14 HeatPK**
category of micro-cogeneration package for providing space heating only (no domestic hot water service)

**3.15 island mode**
operation of a micro-cogeneration package whilst not connected to a public electricity supply network

**3.16 mean surface temperature**
mean temperature of the surface of the MCG at any location over a prescribed time period

**3.17 micro-cogeneration unit (MCG)**
(also known as micro-combined heat and power units)

condensing or non-condensing cogeneration unit as a maximum electrical output power below 50 $kW_e$

*NOTE This definition is based on the definition given in Directive 2004/8/EC [2].*

**3.18 micro-cogeneration package**
MCG 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 1 See **6.2** for a list of associated equipment.*

*NOTE 2 For the purposes of this PAS, micro-cogeneration packages are referred to as "packages"*

**3.19 nominal rated heat output (NHRO)**
rate of heat output (expressed in kW) of the micro-cogeneration package, declared by the manufacturer that can be maintained indefinitely over successive 24 h periods

**3.20 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)

**3.21 primary circuit**
circuit by which hot water flows out of the micro-cogeneration package and cooled water is returned

**3.22 proximate**
analysis of solid fuel in terms of moisture, ash, volatile matter and (by difference) fixed carbon

**3.23 RegPK**
category of micro-cogeneration package for providing space and water heating, intended for connection to a separate DHW storage tank

**3.24 return water temperature**
temperature of the water returning to the micro-cogeneration package from the test rig

**3.25 Seasonal Efficiency of Domestic Boilers in the UK (SEDBUK)**
method used to determine the average annual installed efficiency of gas and oil boilers in dwellings in the UK, used both for SAP [4] and product endorsement purposes

**3.26 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

**3.27 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

**3.28 test laboratory**
location where micro-cogeneration packages are tested

**3.29 test mode**
load pattern applied during test to the micro-cogeneration package

*NOTE Test modes include continuous operation, uni-modal operation, bi-modal operation, standby mode and DHW only, which are defined in **6.3**.*

**3.30 test regime**
set of test modes

**3.31 thermal store**
any vessel used to store the heat output from the MCG and thus assist the micro-cogeneration package in serving the instantaneous heat demand of the space heating and/or DHW load

*NOTE A thermal store 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.*

**3.32 view factor**
fraction of the total energy emitted by one surface that is directly incident on another surface

# 4 Abbreviations

For the purposes of this PAS, the following abbreviations apply.

| Abbreviation | Full term |
|---|---|
| AC | alternating current |
| APM | annual performance method |
| CH | central heating |
| CV | gross calorific value |
| DV | direct current |
| DHW | domestic hot water |
| DHWPK | domestic hot water production kit |
| LPG | liquefied petroleum gas |
| NHRO | nominal-rated heat output |
| SEDBUK | Seasonal Efficiency of Domestic Boilers in the UK |

# 5 Symbols

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

| Symbol | Unit | Designation |
|---|---|---|
| $r_{air}$ | $kg/m^3$ | density of air through grill |
| $\Sigma$ | $Wm^{-2}K^{-4}$ | Stefan-Boltzmann constant (equal to $5.67 \times 10^{-8}$ $Wm^{-2}K^{-4}$) |
| $A$ | $m^2$ | total surface area of the component |
| $C$ | – | constant for convection |
| $d_i$ | L/min | flow rate for individual draw-off (tapping) |
| $D$ | L/min | single specific rate of hot water draw-off (tapping), as specified by the manufacturer |

| Symbol | Unit | Designation |
|---|---|---|
| $E_{in}$ | MJ | total electrical energy input to the package over the 24 h test period, as recorded on the import register of the power analyser |
| $E_{inact}$ | MJ | actual total electrical energy input to the package during the standby loss test as recorded on the import register of the power analyser<br>*NOTE 1 This is likely to be over a period of more than 24 h.* |
| $E_{out}$ | MJ | total electrical energy output from the package over the 24 h test period as recorded on the export register of the power analyser |
| $E_{outact}$ | MJ | actual total electrical output from the package during the standby loss test period as recorded on the export register of the power analyser<br>*NOTE 2 This is likely to be over a period of more than 24 h.* |
| $F$ | – | view factor (see **3.31**) |
| $F_{23}$ | kW | loss due to sensible heat in the dry flue gases (as defined in BS 845-2:1987, **8.2.22**) |
| $F_{24}$ | kW | energy flow rate in flue gas from sensible and latent heat in moisture in fuel (as defined in BS 845-2:1987, **8.2.23**) |
| $F_{28}$ | kW | energy flow rate within any condensate collected from the flue or micro-cogeneration package drain (as defined in BS 845-2:1987, **8.2.27**) |
| $F_{53}$, $F_{54}$ | kW | energy flow rates within unburnt flue gases (as defined in BS 845-2:1987, **8.2.21**) |
| $J(T)$ | kJ/kg | specific enthalpy of water at $T$ °C in the range 10 °C to 240 °C<br>*NOTE 3 This is evaluated from:* $(T) = A + BT + CT^2 + DT^3 + ET^4$ *where the following numerical values apply:* $A = 0.167853$; $B = 4.18587$; $C = –1.46789 \times 10^{-4}$; $D = 9.38153 \times 10^{-7}$; $E = 8.36764 \times 10^{-9}$ |
| $J(T_{spaceflow})$ | kJ/kg | specific enthalpy of the central heating water sent out to the system |
| $J(T_{spacereturn})$ | kJ/kg | specific enthalpy of the returning central heating water |
| $J(T_{thermalstore})$ | kJ/kg | specific enthalpy at mean temperature from measurements taken at different locations of a thermal store at a particular time, $t$ |
| $H_{\mu chp}$ | MJ | energy content of the micro-cogeneration package |
| $H_{thermalstore}$ | MJ | energy content of the thermal store |
| $H_s$ | kJ/m$^3$ | gross (higher) calorific value of the dry test gas at 15 °C, 1 013.25 mbar |
| $H_{soil}$ | kJ/kg | gross (higher) calorific value of the test oil or other liquid fuel |
| $H_{ssolid}$ | kJ/kg | gross (higher) calorific value of the test solid fuel |

| Symbol | Unit | Designation |
|---|---|---|
| $L_{1gr}$ | % | loss due to sensible heat in the dry flue gases (as defined in BS 845-1:1987, **6.3.1**) |
| $L_{2gr}$ | % | loss due to enthalpy in the water vapour in the flue gases (as defined in BS 845-1:1987, **6.3.2**) |
| $L_{3gr}$ | % | loss due to unburnt flue gases (as defined in BS 845-1:1987, **6.3.3**) |
| $M_{oil}$ | Kg | measured mass of oil or other liquid fuel over the 24 h test period |
| $M_{solid}$ | Kg | measured mass of solid fuel over the 24 h test period |
| $M_{thermalstore}$ | Kg | mass of water contained within thermal store |
| $m_{spacewater}$ | kg/sec | flow rate of central heating water through the micro-cogeneration package |
| $N$ | – | constant for convection |
| $N$ | – | number of tappings |
| $p_a$ | mbar | atmospheric pressure at time of test |
| $p_g$ | mbar | gas pressure at the meter |
| $p_s$ | mbar | saturated vapour pressure of water |
| $Q_{balance}$ | MJ | total measured energy input minus total measured energy output of micro-cogeneration package |
| $Q_{case}$ | MJ | total energy loss from the case (estimated) |
| $q_{com}$ | W | rate of energy released at time, *t,* from the component |
| $Q_{DHW}$ | MJ | total energy to DHW |
| $Q_{DHWpump}$ | kJ | total power demand as indicated by the pump power meter over 1 h |
| $Q_{DHWrigloss}$ | kJ | total energy supplied to/lost from RegPK DHW test circuit over 1 h during assessment of standing loss |
| $Q_{DHWtankloss}$ | kJ | total power demand as indicated by the heater power meter over 1 h |
| $q_{DHWpipelossinst}$ | W | average instantaneous rate of energy “supplied to/lost from” RegPK DHW pipework test circuit during assessment of standing loss |
| $q_{DHWriglossinst}$ | W | average instantaneous rate of energy “supplied to/lost from” RegPK DHW storage tank and pipework test circuit during assessment of standing loss |
| $q_{fan}$ | kW | rate of energy loss from the case by forced convection (usually a fan) |
| $Q_{fuel}$ | MJ | total energy of fuel consumed |
| $Q_{fuelact}$ | MJ | actual total energy of fuel consumed during the standby mode test<br>*NOTE 4 This is likely to be over a period of more than 24 h.* |
| $Q_{flue}$ | MJ | total energy loss from flue (estimated) |

| Symbol | Unit | Designation |
|---|---|---|
| $Q_{flueuf}$ | MJ | energy loss from flue under fire |
| $q_{flueppsingle}$ | MJ | energy loss associated with single pre-purge or post-purge from flue |
| $Q_{flueptotal}$ | MJ | total energy loss associated with pre-purge and post-purge from flue equals $\sum_0^{24} q_{flueppsingle}$ |
| $Q_{fuelfull}$ | MJ | total energy of fuel consumed during the 24 h full output test |
| $Q_{space}$ | MJ | total energy to space heating |
| $Q_{spacedt}$ | MJ | energy output to space heating recorded as produced by the package during the heat demand times |
| $spht_{air}$ | kJ/(kg×K) | mean specific heat of air through grill (default value 1.05) |
| $spht_{water}$ | kJ/(kg ×K) | specific heat of water<br>*NOTE 5 Used when evaluating the energy content of water under DHW tests (**12.7**). This is defined in BS EN 13203-2, **5.2.2.2** as 4.1868 kJ/(kg×K)* |
| $T_{coldwater}$ | °C | temperature of the water at the inlet to DHW production |
| $T_{ContentDHW}$ | °C | weighted mean instantaneous temperature of DHW tank |
| $T_{DHW}$ | °C | instantaneous temperature of DHW |
| $T_g$ | °C | gas temperature at the meter |
| $t_{dur}$ | s | test period of the test for standby mode |
| $t_i$ | min | tapping duration of the useful water |
| $T_r$ | °C | ambient temperature |
| $T_{pwater}$ | °C | temperature of the water returning to the pump |
| $T_{pair}$ | °C | mean temperature of the air measured 35 mm above and below the pump |
| $T_{primflowDHW}$ | °C | temperature 75 mm (±25 mm) from the point where the primary flow pipework is connected to the MCG unit |
| $T_{primretDHW}$ | °C | temperature 75 mm (±25 mm) from the point where the primary return pipework is connected to the MCG unit |
| $T_{xyzDHW}$ | °C | temperature at any point, xyz, measured during a DHW test |
| $T_s$ | °C | mean surface temperature of any component at time, *t* |
| $T_{spaceflow}$ | °C | temperature of the central heating water sent out to the system |
| $T_{spacereturn}$ | °C | temperature of the central heating water returning from the system |
| $T_{thermalstore(at\ t=0h)}$ | °C | average of the representative temperatures of defined locations of a thermal store at the beginning of the 24 h period |

| Symbol | Unit | Designation |
|---|---|---|
| $T_{thermalstore(at\ t=24h)}$ | °C | average of the representative temperatures of defined locations of a thermal store at the end of the 24 h period |
| $T_{ventin}$ | °C | temperature of the ambient air into MCG case through the grill |
| $T_{ventout}$ | °C | average temperature of the warmed air exiting from the discharge vents |
| $U_{grill}$ | m/s | mean velocity of air through grill |
| $V$ | $m^3$ | measured volume of the test gas over the 24 h test period |

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

## 6.1 Category of micro-cogeneration package

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

a) HeatPK – micro-cogeneration package for the provision of space heating only, no DHW 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 DHW;

*NOTE 1 The performance of the package in winter mode (i.e. the simultaneous provision of both central heating and DHW) may be evaluated by the separate measurement of performance in central heating mode and DHW mode followed by use of a higher level programme (for example the APM) to combine these values.*

*NOTE 2 Provision of the DHW may utilize either a DHW storage tank or heat exchange coils within the package.*

*NOTE 3 The DHW test conditions described in this PAS for CombiPK require either that the thermal state of the MCG package be determined at the beginning or end of the 24 h test periods or that the package can demonstrate equilibrium by repeated 24 h testing.*

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.

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

*NOTE 4 Any MCG 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.*

d) DHWPK micro-generation package for the provision of water heating alone.

## 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 MCG;

b) declaration in accordance with Results Table 1 (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):

*NOTE Figure A.1 shows the arrangement for space heating tests for HeatPK, CombiPK and RegPK package categories.*

1) for a 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 temperature measurement device, T2 [see **6.2**f) and Figure A.1].

2) for a 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 temperature measurement device, T4 [see **6.2**f)] and Figure A.2).

3) for a RegPK:

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

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

*NOTE 1 A temperature of DHW draw-off of 60 °C might require a bespoke setting on the DHW tank thermostat, which might or might not correspond to 60 °C.*

*NOTE 2 Figure A.1 shows the arrangement for space heating tests for all package categories.*

4) DHWPK:

The manufacturer shall define the control strategy so as to maintain the temperature of water at temperature measurement device, T2 [see **6.2**f)] and Figure A.1 or a corresponding location in Figure A.3;

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 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 or follow the electrical demand. If electrically led, the package shall contain such devices to limit system operation in the event of their being no demand for heat energy either externally to the micro-generation package or internally to the package for storage for future use. No device being tested according to PAS 67 shall by design discard heat to its surroundings. If the package is designed to receive functional instructions from a remote computer via the internet, this shall be permitted but a record of these instructions shall be provided to the test laboratory. This information shall include values and timing of signals (from genuine or artificial origin) that would be received from a typical installation;

*NOTE 1 For example, signals from a room thermostat, DHW tank thermostat, external thermostat, programmer or any other devices that communicate heat demand from the dwelling. These signals will represent the call for heat within the dwelling and control the heat output from the package.*

*NOTE 2 The performance of micro-cogeneration packages is dependent on the functionality of the internal control system and these requirements are 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 h 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 $T_{spacereturn}$ and $T_{spaceflow}$ and space heating and DHW flow rates that would allow the test laboratory to comply with the minimum temperatures defined within Clause **12**;

l) apparatus to simulate the electrical current that will control any modulation of the package, where called upon the design of the package.

## 6.3 Test modes and test regimes

**6.3.1** The test modes shall be as follows:

a) *Continuous operation* – requires compliance with continuous operational criteria (see Table 1 for the relevant output test subclauses). The heat produced by the package shall be relatively uniform and, as a minimum, conform to the minimum hot period defined in Table 8 and Table 9, as appropriate, delivered over the 24 h 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 subclauses). The heat produced by the package shall be relatively uniform and as a minimum conform to the minimum hot period defined in Table 8 and Table 10 as appropriate, delivered over the 16 h 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 subclauses). The heat produced by the package shall be relatively uniform and, as a minimum, conform to the minimum hot period defined in Table 8 and Table 11 as appropriate, delivered during the morning and evening on periods.

d) *Domestic hot water only* – hot water shall be produced in accordance with **12.7**.

e) *Standby mode* – the package shall be tested in standby mode (see **12.6**).

Table 1 **Relevant subclause for each test mode**

| Test mode | Subclause | | |
|---|---|---|---|
| | Full (100%) Output test | 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 be appropriate to assess how the package will perform after installation in accordance with the manufacturer's design and installation instructions.

*NOTE 1 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 test regime to follow. Different test regimes might lead to different performance results, and further calculations are necessary to determine the overall annual energy performance and carbon emissions in any particular dwelling.*

Table 2 **Definitions of test regimes for output tests**

| Test regime | Output test | | |
|---|---|---|---|
| | Full (100%) (see **12.2**) | 30 % (see **12.3**) | 10 % (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 |
| 5 A) | DHW only | | |

A) This test regime is included as it is the principal test required for packages producing DHW alone. Packages submitted under this test regime should be tested in accordance with at least two EU taping cycles, one of which should be Table 12.

**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 might be carried out at 90%, 80%, 70%, 60%, 50%, 40%, 30% and 20% under the conditions specified in **12.5**. Supplementary tests are optional, but might be included and reported as part of the same group of tests.

Where supplementary tests are to be carried out, the test mode for each package shall be in accordance with Table 3. The test regime shall be selected on the basis of the test regime selected in Table 2, whereby the test regime numbers are the same.

*NOTE 1 If test regime 1 has been chosen from Table 2, then the test mode is chosen from the row labelled test regime 1 in Table 3.*

*NOTE 2 Supplementary test results 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 is required in order to calculate annual performance* *data and the additional points that are established through supplementary partial output tests reduces the errors of interpolation. For example, it might 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 **Definitions of test regimes for supplementary partial output tests**

| **Test regime** | **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 |

*NOTE Cont = Continuous, N/A = Not allowed*

## 6.5 Range-rated appliances

*NOTE Some manufacturers may wish to test range-rated packages where the total nominal-rated heat output (NRHO) is adjusted to meet the maximum heat demand of the dwelling in which it is to be installed.*

The manufacturers shall provide within the installation instructions precise details on how the maximum heat demand of the dwelling is to be evaluated and how the MCG is to be adjusted to meet this. The method by which this adjustment can be made shall be made available to installers and not to the householder. In principle each adjustment within the range shall be considered to produce a separate package requiring completion of a full set of PAS 67 test work.

Packages where the ratio of NRHO is two or less can be linearly interpolated to obtain intermediate values.

*EXAMPLE The conditions under which a package comprising a MCG unit of 1.5 $kW_e$ and 6 kW fixed output main burner, plus a supplementary burner that can be either permanently off or adjusted (range-rated) to give maximum outputs of between 6 kW to 18 kW is tested are shown in Table 4.*

Table 4 **Example of test conditions of package with adjustable heat output**

| **NRHO** | **Test Output** | **Heat output in 24 h** |
|---|---|---|
| kW | % | MJ |
| 6 | 100 | 518.4 |
| | 30 | 155.5 |
| | 10 | 51.8 |
| 12 | 100 | 1 036.8 |
| | 30 | 311.0 |
| | 10 | 103.7 |
| 24 | 100 | 2 073.6 |
| | 30 | 622.1 |
| | 10 | 207.4 |

The installer shall be provided with instructions on how to adjust the package for dwellings of maximum heat demand of 6 kW, 12 kW or 24 kW. As the NRHO varies by a factor of four, all three packages shall be tested. If the manufacturer permitted intermediate settings (by way of the example 15 kW) the performance of the package at this output might be determined by interpolation.

# 7 Test laboratory conditions adjacent to the MCG

The ambient air temperature in the test laboratory shall be 20 °C ± 5 °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 MCG. The thermometer shall be protected from direct radiation from the MCG. The averages of each condition shall be reported in Results Table 2 (Clause **13**).

*NOTE Wherever possible, relative humidity should be controlled between 50% and 70%.*

# 8 Records for future package surveillance

## 8.1 General

The manufacturer shall compile a technical file, in conjunction with the test laboratory, that accurately defines the package and the conditions under which the package was tested in accordance with **8.2** to **8.4**.

## 8.2 Manufacturer

The manufacturer shall provide to the test laboratory:

a) the 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 this shall be the manufacturer's own code number (e.g. the ABC Ltd. micro-cogeneration control program Version 7.16). This code number might 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 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 1 The information is not to be analysed by the test laboratory but can act as a permanent record of the control strategy used by the package at the time of test.*

*NOTE 2 Users of this PAS are advised to consider the desirability of quality system assessment and registration against the appropriate standard in the BS EN ISO 9000 series by an accredited third-party certification body.*

## 8.3 Manufacturer and test laboratory

The manufacturer shall provide the following in conjunction with the test laboratory:

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 defines how the package and the control system were set up for all laboratory tests.

*NOTE 1 This data would be similar to that required for compliance with the Gas Appliances Directive 90/396/EEC [6] at the time of publication and certainly greater than generally recorded for the testing of boilers to the Boiler Efficiency Directive [3]. This is particularly important with respect to the setting or unusual adjustment of controls, for example pressure switches.*

*NOTE 2 This functional data should be set at a sufficient level of detail to allow reliable and unambiguous replication of the test procedure in another test laboratory.*

### 8.4 Test laboratory

The manufacturer shall obtain the following from the test laboratory:

a) the test results (see Results Tables 2, 3, 4, 5 and 6 in Clause **13**);

b) the details and conditions 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 that could allow reproducible surveillance testing.

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

The manufacturer shall request that the test laboratory assesses 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 General

The total measured energy flowing into the micro-cogeneration package during any 24 h period 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 ±15 s of the specified time .

*NOTE This is required due to the relative complexity of micro-cogeneration packages when compared with boilers. The techniques to be used to determine this are specified in **10.2** to **10.10**.*

The expression of measurement uncertainties shall be in accordance with UKAS M3003, 2007 [N1].

### 10.2 Test fuels

#### 10.2.1 General

All the calculations shall be determined using gross CVs.

Test fuels and their input rates shall be determined by the techniques specified in **10.2.2** to **10.2.7**.

#### 10.2.2 Second and third family gas

For second and third family gas, this shall be the reference test gas listed in BS EN 437.

*NOTE 1 Second and third family gases are usually natural gas or LPG.*

*NOTE 2 The test gas should be selected taking into account the eventual geographical destination of the package.*

The energy input from the test fuel ($Q_{fuel}$) used shall be calculated from the equation:

$$Q_{fuel} = H_s \times V \times (p_a + p_g - p_s)/1\,013.25 \times 288.15/(273.15 + T_g)/1\,000 \quad (1)$$

where:

1 013.25 is the standard reference pressure of gas in mbar;

288.15 is the standard reference temperature of gas in K;

273.15 is the temperature of gas at 0 °C in K;

1 000 is the conversion from kJ to MJ;

*NOTE 1 If a dry gas meter is used,* $p_s = 0$.

*NOTE 2 Test work on MCGs of gas input in excess of 70 kW (252 MJ/h) may be carried out using locally or nationally distributed line gas.*

Sampling of the second and third family gas shall take place at periods not exceeding 6 h and the gross CV of the line gas shall not vary during the test by more than 0.5%. The CV shall be measured and reported to an uncertainty of <0.5%.

*NOTE 3 A method for calculating the performance for units fuelled by LPG from the results obtained when tested with natural gas has yet to be developed.*

### 10.2.3 Gas from a bespoke source

For gas produced from a bespoke source, e.g. from a bio-gas plant, the micro-cogeneration package shall be tested on a representative sample of the gas. Full analysis shall be made by gas liquid chromatography. This shall be reported in full for all chemical species contributing >0.5% by volume. Energy input shall be reported as a gross value. The frequency and uncertainty of the analysis shall be such that $Q_{fuel}$ shall be reported to an uncertainty of <0.8%.

The energy input from the test fuel ($Q_{fuel}$) used shall be calculated from the equation:

$$Q_{fuel} = H_s \times V \times (p_a + p_g - p_s)/1\,013.25 \times 288.15/(273.15 + T_g)/1\,000 \quad (2)$$

where:

1 013.25 is the standard reference pressure of gas in mbar;

288.15 is the standard reference temperature of gas in K;

273.15 is the temperature of gas at 0 °C in K;

1 000 is the conversion from kJ to MJ.

*NOTE If a dry gas meter is used,* $p_s = 0$.

### 10.2.4 Hydrogen

For hydrogen, the gas shall be of a chemical composition agreed between the manufacturer and the test laboratory.

*NOTE Levels of carbon monoxide and other hetero atom gases (e.g. odorant) should be typical of those stipulated in the micro-cogeneration package manufacturer's installation instructions.*

A full analysis shall be made by suitable gas liquid chromatography. This shall be reported in full for all chemical species contributing >0.5% by weight. Energy input shall be reported as a gross value. The CV shall be measured and reported to an uncertainty of <0.5%.

The energy input from the test fuel ($Q_{fuel}$) used shall be calculated from the equation:

$$Q_{fuel} = H_s \times V \times (p_a + p_g - p_s)/1\,013.25 \times 288.15/(273.15 + T_g)/1\,000 \quad (3)$$

where:

1 013.25 is the standard reference pressure of gas in mbar;

288.15 is the standard reference temperature of gas in K;

273.15 is the temperature of gas at 0 °C in K;

1 000 is the conversion from kJ to MJ.

*NOTE If a dry gas meter is used, $p_s = 0$.*

### 10.2.5 Mineral oil

In the case of oil this shall be:

a) kerosene conforming to BS EN 304; or

b) gas-oil conforming to BS EN 304.

The CV of oil shall be measured calorimetrically or calculated in accordance with BS EN 304:1992, 4.1.2.1 and 4.1.2.2. The quantity of oil used shall be determined using the technique specified in BS EN 304:1992, 4.1.1. Energy input shall be reported as a gross value. The CV shall be measured and reported to an uncertainty of <0.5%.

The energy input from the test fuel ($Q_{fuel}$) used shall be calculated from the equation:

$$Q_{fuel} = H_{soil} \times M_{oil}/1\,000 \qquad (4)$$

where:

1 000 is the conversion from kJ to MJ.

*NOTE Values cannot be assumed as in some editions of BS EN 304 such generic values can have excessive uncertainty.*

### 10.2.6 Other liquid fuels, principally bio-oils

For other liquid fuels, the micro-cogeneration package shall be tested on a representative sample of the fuel. The manufacturer's declaration shall be accompanied by a letter explaining the nature of the fuel, its compatibility (where appropriate) with existing mineral oil standards (as described in BS EN 304), and the percentage of the fuel derived from fossil fuel sources and that derived from renewable sources. This shall be in detail to enable the carbon emissions (kg$CO_2$/MJ, or kg$CO_2$/kWh) to be calculated from an appropriate published standard, for example the Government's Standard Assessment Procedure for Energy Rating of Dwellings [4].

A full analysis (including where appropriate "proximate") shall be made. This shall be reported in full for all chemical species contributing >0.5% by weight. Energy input shall be reported as a gross value. The CV shall be measured and reported to an uncertainty of <0.5%.

The energy input from the test fuel ($Q_{fuel}$) used shall be calculated from the equation:

$$Q_{fuel} = H_{soil} \times M_{oil}/1\,000 \qquad (5)$$

where:

1 000 is the conversion from kJ to MJ.

*NOTE Where a biofuel is sold as a direct replacement for one of the mineral fuels listed in **10.2.5**, it is necessary to repeat the full test programme using the biofuel if the manufacturer requires the performance to be assessed for the biofuel. A method for calculating the performance for units fuelled by a biofuel sold as a direct replacement for a mineral fuel from the results obtained when tested with the mineral fuel has yet to be developed.*

### 10.2.7 Other fuels, including unconventional fuel and solid fuel

In the case of any other type of fuel, the micro-cogeneration package shall be tested on a representative sample of the fuel. A full analysis (including where appropriate "proximate") shall be made by a suitable method. This shall be recorded in full within the laboratory test reports for all chemical species contributing more than 0.5% by weight. Energy input shall be reported as a gross value. The CV shall be measured and reported to an uncertainty of <0.5%.

The energy input from the test fuel ($Q_{fuel}$) used shall be calculated from the equation:

$$Q_{fuel} = H_{ssolid} \times M_{solid}/1\,000 \qquad (6)$$

where:

1 000 is the conversion from kJ to MJ.

## 10.3 System circulator (where present)

Space heating water shall be passed through the micro-cogeneration package under the action of the test rig circulator. Where the package contains an internal system circulator the latter shall be disconnected unless this will cause the package to malfunction. Where disconnection is not possible the electrical output of the micro-cogeneration package shall be reported at the input/output terminals in accordance with **10.5**, i.e. will be net of the power required by this circulator. No attempt shall be made to adjust the recorded power input/output of the package to make allowance for the power consumed by the circulator.

*NOTE Conventionally, the energy associated with any system circulator has been (from a regulatory perspective) associated with the heat distribution system not with the heating appliance. However, some micro-cogeneration packages may be unconventional in requiring either a special internal circulator and/or a circulator of large duty. The above requirement, **10.3**, is intended to ensure that the test report accurately reflects reality.*

## 10.4 Measurement of energy output

### 10.4.1 Total energy to space heating, $Q_{space}$

The total energy to space heating ($Q_{space}$) of the micro-cogeneration package shall be determined by using the appropriate apparatus arrangement shown in Annex A for the category of micro-cogeneration package as defined in **6.1** and calculated from the equation:

$$Q_{space} = \sum_{0}^{24} m_{spacewater} \times \{J(T_{spaceflow}) - J(T_{spacereturn})\}/1\,000 \qquad (7)$$

where:

$J(T_{spaceflow})$ is the enthalpy of the central heating water sent out to the system;

$J(T_{spacereturn})$ is the enthalpy of the returning central heating water;

1 000 is the conversion of kJ to MJ.

The measurement uncertainty of ($Q_{space}/Q_{fuel}$) from the micro-cogeneration package (expressed as a percentage, when calculated in accordance with UKAS M3003 [N1]), shall be within the appropriate values given in Table 5.

Table 5 **Maximum permitted measurement uncertainties**

| Micro-cogeneration package output | Uncertainties |
|---|---|
| Full (100%) output | ±1.0% |
| 30% to 90% (nominal) | ±1.5% |
| <30% (nominal) | ±2.0% |

NOTE *These are maximum uncertainties and not permitted percentage point errors.*

For CombiPK for each test mode as defined in **6.3.1**, the package shall be maintained in such a condition that DHW is readily available in the quantities and temperatures specified in the DHW test (see Table 2).

For RegPK for test modes continuous, uni-modal and bi-modal operation as defined in **6.3.1**a), b) and c), the DHW storage tank shall be isolated.

The micro-cogeneration package shall be configured for testing in accordance with Figure A.1 or Figure A.3. The volume of water contained within those parts of the test rig supplied by the test laboratory shall be less than 20 + (0.1 × $Q_{space}$) L.

*NOTE The volume of water is controlled by the five components, shown in Figure A.1 and Figure A.3, of T1, CH control valve, CH flow sensor, bypass control valve and T2.*

## 10.4.2 Domestic hot water (DHW), $Q_{DHW}$

### 10.4.2.1 General

For CombiPK, the DHW shall be measured using the test rig shown in Figure A.2 and the test method described in **12.7.1**.

For RegPK, the DHW shall be measured using the test rig shown in Figure A.3 and the test method described in **12.7.2**.

The water at point T3 shall be maintained at 10 °C ±2 °C. Water temperatures shall be determined using the apparatus described in BS EN 13203-2.

*NOTE The technique described within BS EN 13203-2:2006, (Figure B.3, Example of temperature measurement device) would be suitable.*

The temperature of the drawn-off water shall be recorded using a platinum resistance thermometer whose tip is located centrally within the tapping pipework.

For RegPK, the location shall be 75 mm ±25 mm distant from the point where the DHW pipework is connected to the top of the DHW tank.

For CombiPK, the location shall be 300 mm ±25 mm from the outlet of the package.

For CombiPK, where the DHW tank is fitted with a heat transfer device (typically a coil), the temperature of the heat transfer fluid (typically water) leaving the device returning to the MCG shall be determined by a securely affixed surface thermocouple (typically as described in **B.1.2.3**) capable of measuring the temperature of the heat transfer fluid at that point to an accuracy of ±2 °C. These shall be mounted as close by as possible to the wall of the DHW tank, and no further than 50 mm.

*NOTE This might entail entering the case of the micro-cogeneration package.*

### 10.4.2.2 CombiPK estimation of standing heat loss from DHW test rig

The apparatus used shall be as shown in Figure A.2 and the test method described in **10.4.2.3**.

*NOTE No estimation is necessary of the standing heat loss from the DHW test rig, as required for the RegPK test.*

### 10.4.2.3 RegPK estimation of standing heat loss from DHW test rig

For package type, RegPK, the length of each interconnection flue pipe between the MCG and DHW tank shall not exceed 1.5 m. The pump power shall lie in the range 30 W to 95 W. The whole of the primary circuit (excluding the MCG itself) linking the package and the DHW storage tank shall be insulated to such a level that both together (i.e. $q_{DHWriglossinst}$) shall have a maximum thermal loss of <200 W when measured at a difference between tank and ambient temperature of 45 K, as determined by the following method.

*NOTE 1 This heat loss value <200 W can be challenging to achieve. The DHW tank will probably require two insulating jackets, the second (outer) jacket being fitted after connection of all instrumentation and pipework. The electric boiler requires a high level of insulation and the interconnection flue pipe between the DHW tank and MCG needs to be insulated along its length with at least 32 mm thickness of foamed nitrile rubber, U value <0.038 W/(m.K) at 40 °C or equivalent. The laboratory test rig pump should not be insulated.*

The temperature of the metal surface of the DHW storage tank (i.e. the surface under any primary insulation) shall be recorded at least every 5 min throughout the DHW test procedures using self-adhesive thin film temperature resistant devices conforming to BS EN 60751 (Class A). These shall be mounted on the surface of the cylinder in a vertical plane containing the axis of the cylinder that lies at 90° to the plane containing the cold water feed connection and the axis of the cylinder, located at seven points. The seven points shall be located at a distance in from the point of lowest water level at the bottom of the tank as specified in Table 6 and as shown in Figure A.4. These temperatures shall be used to calculate a weighted mean instantaneous tank temperature, $T_{ContentDHW}$, using the weighting factors specified in Table 6 for the seven thermocouples.

Table 6 **Positions and weighting factors for the evaluation of $T_{ContentDHW}$**

| **Distance in from the point of lowest water level at the bottom of the tank**<br>Mm | **Thin film temperature resistance devices** | **Weighting factor** |
|---|---|---|
| 900 | TC7 | 0.14 |
| 650 | TC6 | 0.28 |
| 400 | TC5 | 0.19 |
| 300 | TC4 | 0.11 |
| 200 | TC3 | 0.11 |
| 100 | TC2 | 0.11 |
| 5 | TC1 | 0.06 |

$T_{ContentDHW}$ is derived from the temperature recorded by each thermocouple weighted by the corresponding weighting factor and shall be calculated from the equation:

$$T_{ContentDHW} = (TC1 \times 0.06) + (TC2 \times 0.11) + (TC3 \times 0.11) + (TC4 \times 0.11) + (TC5 \times 0.19) + (TC6 \times 0.28) + (TC7 \times 0.14) \quad (8)$$

$T_{ContentDHW}$ and other points in this series, identified as $T_{xyzDHW}$, shall be evaluated and/or recorded at a frequency of at least 5 min during each and every test. Mean $T_{xyzDHW}$ shall be evaluated by using the simple arithmetic mean over the 24 h of a DHW test.

Two further thermocouples shall be located within the DHW primary circuit at a distance of 75 mm ±25 mm from the point where the primary flow and return pipework is connected to the MCG unit. These shall be called $T_{primflowDHW}$ and $T_{primretDHW}$, respectively.

The heat loss procedure shall be based on the use of an auxiliary electric boiler, pump and power meters similar to items 6 and 7 in Figure 16 of BS EN 483:1999+A4:2007, which provides a typical example.. The auxiliary electric boiler shall be installed to replace the micro-cogeneration package in Figure A.3 and the pump shall be installed in the return pipework as shown in Figure A.5.

*NOTE 2 Care should be taken to exclude any power internally consumed by the electric power meters themselves or the electric boiler control system and pump.*

With the water circulating continuously the auxiliary electric boiler shall be adjusted so as to obtain a temperature for $T_{ContentDHW} – T_r$ of 45 K ±5 K (i.e. the temperature of the DHW tank is 45 K ±5 K above laboratory temperature). At steady state, indicated by a change of <0.2 K over a 1 h period for any individual thermocouple, the total electrical power input shall be recorded over a period of 1 h.

The test shall be repeated with $T_{ContentDHW} – T_r$ reduced to 25 K ±5 K.

The total heat loss at each differential temperature, $Q_{DHWrigloss}$ (kJ), shall be calculated from the equation:

$$Q_{DHWrigloss} = Q_{DHWtankloss} + [Q_{DHWpump} - 3.6 \times \{9.5 + 0.44 \times (T_{pwater} - T_{pair})\}] \quad (9)$$

where:

| | |
|---|---|
| $Q_{DHWtankloss}$ | is the total power demand as indicated by the heater power meter in kJ over 1 h; |
| $Q_{DHWpump}$ | is the total power demand as indicated by the pump power meter in kJ over 1 h; |
| $T_{pwater}$ | is the temperature of the water returning to the pump °C; |
| $T_{pair}$ | is the mean temperature of the air measured 35 mm above and below the pump °C; |
| 9.5 W | is the electrical energy supplied to the pump not assumed to enter the water circuit; |
| 0.44 | is a correction factor to allow for electrical energy supplied to the pump, which is assumed, lost from the pump housing and thus does not enter the water circuit. This is applicable to pumps in the range of 30 to 95 W. |

$q_{DHWriglossinst}$ shall be reported in Results Table 3 in Clause **13**.

where:

$$q_{DHWriglossinst} = Q_{DHWrigloss}/3.6$$

and where:

3.6 is the conversion to kJ.

A graph shall be drawn of $q_{DHWriglossinst}$ vs ($T_{ContentDHW} – T_r$); the straight line shall be drawn such that it passes through the origin. The experimental apparatus shall be considered satisfactory if the value of $q_{DHWriglossinst}$ at 45 K is <200 W.

The heat loss procedure shall be repeated with the two ends of the primary interconnection pipework directly connected, i.e. with the DHW tank isolated. The graphical procedure shall then be repeated. The temperature shall be taken as that of $T_{primflowDHW}$. A value of a new heat loss factor $q_{DHWpipeslossinst}$ shall be reported at each of 45 K ±5 K and 25 K ±5 K. This shall also be recorded in Results Table 3 in Clause **13**.

## 10.5 Electrical input and output $E_{in}$ and $E_{out}$

The electrical input and output of the package shall be determined using a power analyser, and shall be of the voltage, current and frequency declared by the manufacturer. The power analyser selected shall measure power, voltage, current, power factor and calculate energy. The voltage of the package, at the input/output terminals, shall be maintained by the test laboratory at the manufacturer's declared voltage, ±2.0% or ±1.0 v, whichever is greater. Electrical energy shall be measured with an accuracy of ±2.0%. The power analyser shall have separate import and export registers.

The electrical test conditions shall be dependent upon the electrical connection stated in the installation instructions, i.e. island mode or synchronous mode.

Synchronous mode micro-cogeneration packages shall be tested when operating synchronously with a suitable public access.

*NOTE 1 This test method is suitable for micro-cogeneration packages that permit local synchronous operation. See Engineering Recommendation, G83-1 [N2] or G59/2 [N3].*

In the case of a single-phase micro-cogeneration package, the electrical connection shall be 230 V at 50 Hz.

In the case of a three-phase micro-cogeneration package, the electrical connection shall be 400 V at 50 Hz, either three wire or four wire.

A micro-cogeneration package shall only be tested in synchronous mode if it is able to demonstrate compliance with the EMC Directive (2004/108/EC) [7].

For all synchronous mode packages, exported electricity shall be reported for inclusion in Results Table 2 in Clause **13**, if the following is met:

a) the exported electrical energy has a level of harmonics acceptable to the electrical distribution system in the country of destination and a power factor within the bounds 0.95 (lead or lag) electrical energy;

b) the cogeneration package has been assessed as compliant with:

   1) relevant EMC standards, for example; BS EN 55014-1:2006+A2:2011, BS EN 55014-2:1997+A2:2008, CISPR 14-2:1997, BS EN 61000-3-2:2006+A2:2009, BS EN 61000-3-3:2008;

   2) the local recommendations for the connection of micro-cogeneration packages (up to 16 A per phase) in parallel with public low-voltage distribution networks, which in the UK is Engineering Recommendation G83-1 [N2].

*NOTE 2 Any power conversion equipment necessary to ensure compliance of any exported electricity with the EMC Directive (2004/108/EC) [7] and/or relevant EMC standards should be within the package.*

Island mode micro-cogeneration packages shall be tested connected to an electrical system as specified by the manufacturer of the package. The electrical system shall be capable of providing a voltage and frequency that is the same as that at which the micro-cogeneration package exports electrical power.

*NOTE 3 In the UK electrical output from tests in island mode cannot be credited in the* Method to evaluate the annual energy performance of micro-cogeneration heating systems in dwellings *[1] and* The Government's Standard Assessment Procedure for Energy Rating of Dwellings 2009 (SAP) *[4].*

*NOTE 4 This arrangement is also suitable for micro-cogeneration packages unable to demonstrate compliance with legislation pertaining to synchronous operation.*

## 10.6 Case losses, $Q_{case}$

The total energy loss from the case shall be evaluated from measurements of the micro-cogeneration package surfaces and laboratory temperatures. For packages where parts have very different time versus temperature profiles, an appropriate range of surface temperatures shall be recorded and integrated to determine the loss.

Where the MCG is fitted with cooling fans which might have the effect of increasing case loss and might operate intermittently, the increased losses shall be quantified.

*NOTE 1 A process for estimating the rate of energy loss from a hot surface is detailed in Annex B.*

*NOTE 2 $Q_{case}$ is the sum of the case losses (see Annex B).*

## 10.7 Flue losses $Q_{flue}$

The total energy loss from the flue shall be evaluated from a measurement of flue temperature, excess air level (derived from flue $CO_2$ or $O_2$ content) and quantity of liquid condensate, if any. The flue loss calculation used shall pertain to the chemical composition of the flue gas produced.

*NOTE 1 Particular care should be taken with this calculation where the test fuel (e.g. natural gas) has been chemically modified within the MCG unit.*

*NOTE 2 A process for determining this loss when the burner is under continuous firing and during pre- and post-purges is detailed in Annex C.*

*NOTE 3 Flue losses during intermittent firing cycles could be difficult to determine accurately and test laboratories should apply only a reasonable degree of effort to this measurement.*

*NOTE 4 The flue loss calculation for non-standard flue gases (i.e. other than arising from natural gas, propane, butane etc.) can be complicated and will require a return to fundamental scientific principles, but is essential if valid results are to be obtained.*

## 10.8 Assessment of change (if any) in energy content of package from start to finish of 24 h test

### 10.8.1 General

*NOTE To ensure the accuracy of the tests, it is essential to know the thermal energy content of the micro-cogeneration package at the beginning and end of every 24 h test programme. The difference is then taken into account in the energy balance equation.*

The test laboratory shall be requested to either:

a) determine any change in the energy content of any store and the appliance (see **10.8.2**); or

b) repeat 24 h tests until there is no significant change of the thermal content of the package from the beginning to the end of a 24 h test period (see **10.8.3**).

The choice of procedure shall be determined by the relative complexity of the two approaches. A record of this decision process shall be placed within the product data file (see Clause **8**).

### 10.8.2 Calculation of the energy content of the micro-cogeneration package at the beginning and end of individual tests (excluding the DHW cylinder under test option RegPK, see 12.7)

*NOTE 1 This approach requires the fitting of the micro-generation package with several thermocouples in locations to be agreed with the test laboratory to best determine the energy content as detailed in this subclause. Such an approach avoids* *the need for extended test work but requires a full understanding of the thermal mass of different parts of the package. Obtaining this understanding and analysing the results might be labour intensive.*

The energy content of any thermal store shall be determined at the beginning and the end of the test period. Each thermal store shall be provided with sufficient accessible locations from where the representative temperature of the thermal store can be measured.

The energy difference shall be calculated from the equation:

$$\Delta H_{\text{thermalstore}} = H_{\text{thermalstore(at t=0)}} - H_{\text{thermalstore(at t=24)}} \quad (10)$$

For each water store (without change of state), the energy difference shall be calculated from the equation:

$$\Delta H_{\text{thermalstore}} = M_{\text{thermalstore}} \times \{J(T_{\text{thermalstore (at t=0h)}}) - J(T_{\text{thermalstore (at t=24h)}})\}/1\,000 \quad (11)$$

where:

| | |
|---|---|
| $M_{\text{thermalstore}}$ | is the mass of water within the store; |
| $T_{\text{thermalstore(at t=0h)}}$ | is the average of the representative temperatures of defined locations of a thermal store at the beginning of the 24 h period; |
| $T_{\text{thermalstore(at t=24h)}}$ | is the average of the representative temperatures of defined locations of a thermal store at the end of the 24 h period; |
| 1 000 | is the conversion of kJ to MJ. |

The energy content of the MCG shall be determined either at the beginning and end of the test or a quantitative assessment made of the error in the test results arising from different starting and finishing conditions.

The change in energy content shall be calculated from the equation:

$$\Delta H_{\mu\text{chp}} = H_{\mu\text{chp(at t=0)}} - H_{\mu\text{chp (at t=24)}} \quad (12)$$

where:

$H_{\mu\text{chp}}$ is the energy content of the MCG at the beginning and end of the 24 h period.

*NOTE 2 When evaluating the energy content of the MCG, attention should be paid to the substantive parts of any chemical reactors, burner or engine. For the MCG alone, to minimize the scope for energy imbalance errors, it is desirable to operate the micro-cogeneration package for several hours prior to the start of any 24 h test so that the micro-cogeneration package is operating in a similar fashion to that which it is likely to be operating in towards the end of the test itself. It is unlikely that this period will be <4 h.*

The sum of $\Delta H_{\text{thermalstore}}$ and $\Delta H_{\mu\text{chp}}$ shall be no more than 0.5% of $Q_{\text{fuel}}$ during a 24 h full output test.

*NOTE 3 By the nature of many micro-cogeneration packages, this assessment is more critical than for a conventional boiler.*

### 10.8.3 Ensuring equilibrium in package condition from start to finish of 24 h test

*NOTE 1 This approach requires the micro-generation package to be operated for successive days until it reaches equilibrium. Such an approach requires additional time on any test rig and will consume additional test fuel but avoids the need to; understand the thermal mass of the components of the package; enter the package to install thermocouples; and evaluate thermal content.*

The individual 24 h tests shall be repeated until the energy flows $Q_{\text{fuel}}$, $E_{\text{in}}$, $Q_{\text{space}}$, individually vary by no more than 2.5% between successive 24 h periods.

*NOTE 2 This might take three days or four days.*

*NOTE 3 Further details of the procedure are given in **12.7.4**b).*

The value of $Q_{balance}$ shall then be evaluated using the technique contained within **10.9** on the assumption that $\Delta H_{thermalstore}$ and $\Delta H_{\mu chp}$ both equal zero.

## 10.9 Energy balance

The energy balance shall be calculated for each and every 24 h space heating test period from the equation:

$$Q_{balance} = (Q_{fuel} + E_{in}) - (Q_{space} + E_{out} + Q_{flue} + Q_{case} + Q_{DHW} + \Delta H_{thermalstore} + \Delta H_{\mu chp}) \quad (13)$$

where:

$Q_{balance}$ is the total measured energy input minus the total measured energy output.

Details of this energy balance shall be reported in Results Table 2 in Clause **13**.

$Q_{fuel}$ and $Q_{flue}$ shall be evaluated on a gross basis.

When expressed as a percentage of $Q_{fuel}$, the absolute value of $Q_{balance}$ shall not exceed the discrepancy limits specified in Table 7.

Table 7 **Permitted percentage discrepancy for $Q_{balance}$**

| **Output test** | **Permitted discrepancy % for $Q_{balance}$ expressed as $Q_{balance}/Q_{fuel}$** |
|---|---|
| Full (100%) to >90% | 2.0% |
| 90% to >60% | 3.0% |
| 60% to >30% | 4.0% |
| ≤30% | 6.0% |
| DHW | See **12.7** for procedure |

*NOTE The permitted discrepancy for $Q_{balance}$ can be positive or negative.*

Any test where the $Q_{balance}$ is calculated to be larger than the permitted discrepancy shall be repeated with suitable improvements and/or modifications to the test conditions in order to meet the discrepancy limits specified in Table 7.

## 10.10 Instrumentation and laboratory procedures

The measurement uncertainty to confidence limits of 95% on each of the measured results shall be reported in Results Table 6 in Clause **13**.

The test laboratory procedures shall meet the measurement uncertainty requirements specified within ±2% as calculated in accordance with UKAS M3003 [N1].

# 11 Data to be recorded

*NOTE 1 It is anticipated that at some point in the future correction factors will be applied to the data to adjust to standard conditions. Currently there is no agreed method for doing this.*

For each and every 24 h period of the test, the following information shall be recorded:

a) total electrical energy input, $E_{in}$;

b) total electrical energy output, $E_{out}$;

c) total fuel consumed, $Q_{fuel}$;

d) total energy to space heating, $Q_{space}$;

e) total energy to space heating during the precise heat demand times, as defined in Table 7, $Q_{spacedt}$;

f) total energy to DHW, $Q_{DHW}$;

g) mean $T_{primflowDHW}$, mean $T_{primretDHW}$ and mean $T_{ContentDHW}$ for the last day of the DHW test;

h) $T_{ContentDHW}$ at the beginning and end of the last day of the DHW test;

i) total case losses (estimated), $Q_{case}$;

j) total flue losses (estimated), $Q_{flue}$;

k) total change in energy content of package, $\Delta H_{thermalstore} + \Delta H_{\mu chp}$;

l) energy balance calculated in **10.9**, $Q_{balance}$;

For each test, the following data shall be recorded to enable the test laboratory to review the operation of the package:

1) hourly electrical energy input/output for each of the 24 h;

2) hourly fuel usage for each of the 24 h;

3) hourly energy to space heating;

4) hourly energy to DHW.

*NOTE 2 The terms "input" and "output" refer to movement across the boundary of the micro-cogeneration package, except where otherwise specified.*

The test report shall contain, as a minimum, the information specified in Clause **13** and shall be presented in the form of Results Tables 1, 2, 3, 4, 5, 6 and 7.

*NOTE 3 Additional data may be collected during this test programme, at the request of the manufacturer.*

# 12 Test conditions

*NOTE The test conditions are summarized in Table 8. Detailed requirements for the test conditions are given in the relevant subclauses of Clause **12**.*

## 12.1 Test sequence

The tests shall be carried out in the sequence in which they are laid out in **12.2** to **12.7**. If the test results fall outside the declared limits for any particular test, then that test shall be abandoned and repeated.

*NOTE 1 For packages submitted as RegPK, the flow and return to the DHW storage tank should be isolated during the space heating and standby losses tests.*

*NOTE 2 In an attempt to help understanding of the 24 h test period, Table 8 summarizes the test conditions. The entries shown in the second column (by way of example only) are the total MJ produced by a notional 100 MJ/h (27.78 kW) heat–to-water micro-cogeneration package.*

Table 8 **Summary of test conditions**

| Test | Energy Example to aid understanding | Min. return water temp.A) | Heat demand timesB) | Heating period | | Subclause |
|---|---|---|---|---|---|---|
| | | | | Min. hot period C) | Defined period | |
| | MJ | °C | | min | min | |
| Full | 100 | 60 | Continuous | 1 440 C) | 1 440 | **12.2** |
| 30% | | | | | | |
| Continuous | 30 | 30 | Continuous | 13 | 45 | **12.3.2** |
| Uni-modal | 30 | 30 | 07:00–23:00 | 10 | 30 | **12.3.3** |
| Bi-modal | 30 | 30 | 06:00–09:00 and 15:00–23:00 | 10 | 30 | **12.3.4** |
| 10% | | | | | | |
| Continuous | 10 | 30 | Continuous | 4 | 45 | **12.4.2** |
| Uni-modal | 10 | 30 | 07:00–23:00 | 3 | 30 | **12.4.3** |
| Bi-modal | 10 | 30 | 06:00–09:00 and 15:00–23:00 | 3 | 30 | **12.4.4** |

A) The temperatures listed are the minimum temperatures specified in the relevant subclause, but in individual cases they might be higher, dependent on the manufacturer's installation instructions, (see **6.2**d) and the relevant subclauses).

B) It is a requirement that each specified time of day (i.e. 06:00, 07:00, 09:00, 15:00 and 23:00) accurate to ±15 s (see **10.1**).

c) The minimum hot periods are the minutes within the defined period during which the flow water temperature needs to exceed the return water temperature by the differential specified in the subclause specified in the column headed "Subclause". The minimum hot periods are not to be presumed to be coupled to burner operational times.

D) For packages which cannot operate continuously for 24 h (for example, where the equipment contains self-checking software), the reported values shall reflect the maximum performance of the package for a 24 h period when operated in its conventional fashion.

For a test to be valid for CombiPK, the results shall conform to the reproducibility requirements of both the CH and DHW tests, detailed as follows.

For a CombiPK with a DHW store of <15 L, conformity is required with the relevant subclause of **12.2**, **12.3**, **12.4** and **12.7.4**a).

For a CombiPK with a DHW store >15 L, conformity is required with the relevant subclause of **12.2**, **12.3**, **12.4** and **12.7.4**b).

## 12.2 Full output test

### 12.2.1 General

The results of the full output test, $Q_{space}$, shall be within ±10% of the nominal rated heat output declared by the manufacturer in Results Table 1 in Clause **13**.

*NOTE 1 The full output test is a test of the package at its nominal rated heat output for space heating.*

The time used for measurement shall be either:

a) a full test period of 24 h (default option); or

b) where the manufacturer declares that the package operates at steady state for this entire period and this can be confirmed by the test laboratory, a reduced test period of 4 h.

*NOTE This reduction in test period is included as an energy saving option. In the event of any doubt regarding the scaling of the results, the full test period should be used.*

The relevant results required by Results Table 1 shall then be evaluated by multiplying the measured energy flows by a factor of six. This option is restricted to measurements in accordance with **6.3.1**a), b) or c)**.**

The return water temperature, T1 (Figure A.1), $T_{spacereturn}$, shall depend upon the heating system to which the package is intended to be connected.

### 12.2.2 Conventional heat emitters

Where the installation instructions offer the option of conventional heat emitters (designed to operate with a mean water temperature 50 °C above room temperature), the return water T1 temperature shall be at least 60 °C or at the minimum temperature stipulated in the operating instructions, whichever is the higher, and the flow water temperature T2 shall be at least 10 °C above this.

The return water flow rate shall be kept constant during the whole 24 h and shall be separately recorded to an accuracy of ±1%.

### 12.2.3 Low temperature heat emitters

Where the installation instructions require the use of only low temperature heat emitters then T1 shall be at the highest return temperature permitted within the installation instructions. These manufacturer's instructions shall also contain details of the sizing instructions for such low temperature emitters and these instructions shall be compatible ±10% with regard to oversize factor with the over-sizing and other design factors specified in Table 8.

*NOTE Further details are available from* The Heat Emitter Guide for Domestic Heat Pumps *[8].*

Such micro-cogeneration packages shall have a notice prominently displayed alongside the flow and return connections stipulating the maximum temperatures (°C) at which the connections are to be operated. The return water flow rate shall be kept constant during the whole 24 h, and shall be separately recorded to an accuracy of within ±1%.

*NOTE In this and subsequent tests, care should be taken that the package does not suffer a perturbation during the test period, for example arising from momentary loss of laboratory voltage.*

Table 9 **Over-sizing factors for fan assisted radiators, standard radiators and fan coil units for a variety of water temperatures with reference to a product with a mean temperature above room temperature of 50 °C**

| Flow<br>°C | Return<br>°C | Fan assist | Radiator | Fan coil |
|---|---|---|---|---|
| 35 | 30 | 4.3 | 6.8 | 5 |
| 40 | 34.3 | 3.1 | 4.3 | 3.5 |
| 45 | 38.6 | 2.4 | 3.1 | 2.6 |
| 50 | 42.9 | 2 | 2.4 | 2.1 |
| 55 | 47.1 | 1.7 | 1.9 | 1.7 |
| 60 | 51.4 | 1.4 | 1.6 | 1.5 |

*NOTE 1 Data for under-floor screed and aluminium under-floor panels refer to maximum flue pipe spacing (PS) in mm.*

*NOTE 2 The manufacturers' instructions should also require compliance with the maximum flue pipe inter-spacing for underfloor heating listed in the reference document, The Heat Emitter Guide for Domestic Heat Pumps [8]*

## 12.3 The 30% output test

### 12.3.1 General

The 30% output test is a test of the package for 24 h with a suitable space heating demand, such that the space heating output shall be equivalent to 30% of the space heating output produced during the full output test (see **12.2**). A maximum deviation of ±2 percentage points shall be permitted, i.e. the unit shall be tested with an actual heat output of between 28% and 32% of the full output test figure over the whole period.

*NOTE 1 For example, a unit with full output heat production of 100 MJ should be tested to produce a nominal 30 MJ during the 24 h test period. Actual heat output should be in the range 28 MJ to 32 MJ.*

Heat output during the heat demand time shall also be reported in Results Table 2 in Clause **13**. Each specified time of day (i.e. 06:00, 07:00, 09:00, 15:00 and 23:00) shall be accurate to ±15 s.

The 30% of space heating output can be achieved by utilizing the information supplied in **6.2**f) for the internal control system and in accordance with the recommendations of the manufacturer. This procedure shall be reported in accordance with [see **8.3**b)] and shall be recorded as part of the declarations and test results (see Clause **13** and Results Table 5).

*NOTE 2 Examples of actions the test laboratory can take to control the package to deliver the heat output required include:*

*a) adjusting the upper and lower switching temperatures that control water temperature; and/or*

*b) reducing the temperature of the thermostat used by the householder to define the temperature of the water leaving the micro-cogeneration package; and/or*

*c) introducing a timed operational test regime, i.e. using a suitably designed timer (or several timers, if required) connected to the input terminals of the room thermostat and/or other inputs that have similar control functions; and/or*

*d) adjusting a simulated room and/or external thermostats.*

*NOTE 3 Three operational modes are detailed (see **12.3.2**, **12.3.3** and **12.3.4**) to demonstrate that the package can maintain customer comfort when operating to a declared pattern as detailed in Table 8.*

*NOTE 4 The attention of both the test laboratory and manufacturer is drawn to the manufacturer's declaration within Results Table 1 in Clause **13**.*

### 12.3.2 Packages described as being suitable for continuous operation

The return water temperature, $T_{spacereturn}$, shall be at or above 30 °C, or at the minimum temperature specified in the operating instructions, whichever is the higher, for the whole 24 h. The temperature of the flow water, $T_{spaceflow}$, shall be at least 5 °C above the return water temperature for not less than 13 min out of every sequential 45 min period during the 24 h heating period.

### 12.3.3 Packages described as being suitable for uni-modal operation

The return water temperature $T_{spacereturn}$ shall be at or above 30 °C, or at the minimum temperature specified in the operating instructions, whichever is the higher, during the heating period. The temperature of the flow water, $T_{spaceflow}$, shall be at least 5 °C above the return water temperature for not less than 10 min out of every sequential 30 min period during the heating period 07:00 to 23:00.

### 12.3.4 Packages described as being suitable for bi-modal operation

Return water temperature, $T_{spacereturn}$, shall be at or above 30 °C, or at the minimum temperature specified in the operating instructions, whichever is the higher, during the heating periods. The temperature of the flow water, $T_{spaceflow}$, shall be at least 5 °C above the return water temperature for not less than 10 min out of every sequential 30 min, during the heating periods 06:00 to 09:00 and 15:00 to 23:00.

## 12.4 The 10% output test

### 12.4.1 General

The 10% output test is a test of the package for 24 h with a suitable space heating demand, such that the space heating output shall be equivalent to 10% of the space heating output produced during the full output test (see **12.2**). A maximum deviation of ±2 percentage points shall be permitted, i.e. the above unit shall be tested with an actual heat output of between 8% and 12% of the full output test figure over the whole period.

*NOTE 1 For example, a unit with full output heat production of 100 MJ should be tested to produce a nominal 10 MJ during the course of the 24 h. Actual heat output should lie in the range 8 MJ to 12 MJ.*

Heat output during the heat demand time shall also be reported in Results Table 2 in Clause **13**. Each specified time of day (i.e. 06:00, 07:00, 09:00, 15:00 and 23:00) shall be accurate to ±15 s.

The 10% of space heating output can be achieved by utilizing the information supplied in **6.2**f) for the internal control system and applying it in accordance with the recommendations of the manufacturer. This procedure shall be reported in accordance with **8.3**b) and shall be recorded as part of the declarations and test results (see Results Table 5 and Clause **13**).

*NOTE 2 Examples of actions the test laboratory can take to control the package to deliver the heat output required include:*

*a) adjusting the upper and lower switching temperatures that control water temperature; and/or*

*b) reducing the temperature of the thermostat used by the householder to define the temperature of the water leaving the micro-cogeneration package; and/or*

*c) introducing a timed operational test regime, i.e. using a suitably designed timer (or several timers, if required) connected to the input terminals of the room thermostat and/or other inputs that have similar control functions; and/or*

*d) adjusting a simulated room and/or external thermostats.*

*NOTE 3 Three operational modes are detailed (see **12.4.2**, **12.4.3** and **12.4.4**) to demonstrate that the package can maintain customer comfort when operating to a declared pattern as detailed in Table 8.*

*NOTE 4 The attention of both the test laboratory and manufacturer is drawn to the manufacturer's declaration within Results Table 1 in Clause **13**.*

### 12.4.2 Packages described as being suitable for continuous operation

The return water temperature, $T_{spacereturn}$, shall be at or above 30 °C, or at the minimum temperature specified in the operating instructions, whichever is the higher, for the whole 24 h. The temperature of the flow water, $T_{spaceflow}$, shall be at least 5 °C above the return water temperature for not less than 4 min out of every sequential 45 min period, during the 24 h heating period.

### 12.4.3 Packages described as being suitable for uni-modal operation

The return water temperature, $T_{spacereturn,}$ shall be at or above 30 °C, or at the minimum temperature specified in the operating instructions, whichever is the higher, during the heating period. The temperature of the flow water, $T_{spaceflow}$, shall be at least 5 °C above the return water temperature for not less than 3 min out of every sequential 30 min period during the period 07:00 to 23:00.

### 12.4.4 Packages described as being suitable for bi-modal operation

The return water temperature, $T_{spacereturn,}$ shall be at or above 30 °C, or at the minimum temperature specified in the operating instructions, whichever is the higher, during the heating periods. The temperature of the flow water, $T_{spaceflow}$, shall be at least 5 °C above the return water temperature for not less than 3 min out of every sequential 30 min, during the heating periods 06:00 to 09:00 and 15:00 to 23:00.

## 12.5 Supplementary test at other output values (optional)

### 12.5.1 General

The supplementary tests are tests of the package for 24 h with a suitable space heating demand, such that the space heating output shall be equivalent to X% of the space heating output produced during the full output test (see **12.2**), where X% is one of the values permitted within Table 3. A maximum deviation of ±2 percentage points shall be permitted, from any chosen value of X%, i.e. the value shall be (X ± 2)% of the full output figure.

The X% of space heating output shall be achieved by utilizing the information supplied in **6.2**f) for the internal control system and applying it in accordance with the recommendations of the manufacturer. This procedure shall be reported in accordance with **8.3**b) and shall be recorded as part of the declarations and test results (see Results Table 5 and Clause **13**).

*NOTE 1 Examples of actions the test laboratory can take to control the package to deliver the heat output required include:*

*a) adjusting the upper and lower switching temperatures that control water temperature; and/or*

*b) reducing the temperature of the thermostat used by the householder to define the temperature of the water leaving the micro-cogeneration package; and/or*

*c) introducing a timed operational test regime, i.e. using a suitably designed timer (or more if required) connected to the input terminals of the room thermostat and/or other inputs that have similar control functions; and/or*

*d) adjusting a simulated room and/or external thermostats.*

*NOTE 2 Three operational modes are detailed (see **12.5.2, 12.5.3** and **12.5.4**) to demonstrate that the package can maintain customer comfort when operating to a declared pattern.*

At the same time the package flow and return temperature criteria shall be as follows.

a) For outputs greater than X = 30%, the average flow temperature shall be in excess of that calculated by linear interpolation of the average flow temperature chosen at X = 30% and that chosen at X = 100%.

b) For outputs of X less than 30%, the return temperature shall be that value chosen at X = 30%.

c) Heat output during the heat demand time shall also be reported in Results Table 2 in Clause **13**. Each specified time of day (i.e. 06:00, 07:00, 09:00, 15:00 and 23:00) shall be accurate to within ±15 s.

### 12.5.2 Packages described as being suitable for continuous operation

The flow water temperature, $T_{spaceflow}$, shall be at least 5°C above the return water temperature for the period defined as the minimum hot period within the defined period given in Table 10).

Table 10 **Heating periods for continuous operation**

| Percentage of reference output, X | Minimum hot period | Defined period | Times |
|---|---|---|---|
| % | min | min | |
| 40, 50, 60, 70, 80, 90 | 13 | 45 | 00:00 – 24:00 |
| 20 | 4 | 45 | 00:00 – 24:00 |

### 12.5.3 Packages described as being suitable for uni-modal operation

The flow water temperature, $T_{spaceflow}$, shall be at least 5°C above the return water temperature for the period defined as the minimum hot period within the defined period given in Table 11a.

Table 11a **Heating periods for uni-modal operation**

| Percentage of reference output, X | Minimum hot period | Defined period | Times |
|---|---|---|---|
| % | min | min | |
| 40, 50, 60 | 10 | 30 | 07:00 – 23:00 |
| 20 | 3 | 30 | 07:00 – 23:00 |

### 12.5.4 Packages described as being suitable for bi-modal operation

The flow water temperature, $T_{spaceflow}$, shall be at least 5°C above the return water temperature for the period defined as the minimum hot period within the defined period (see Table 11b).

Table 11b **Heating periods for bi-modal operation**

| Percentage of reference output, X | Minimum hot period | Defined period | Times |
|---|---|---|---|
| % | min | min | |
| 40 | 10 | 30 | 06:00 – 09:00 and 15:00 – 23:00 |
| 20 | 3 | 30 | 06:00 – 09:00 and 15:00 – 23:00 |

## 12.6 Test for standby losses

### 12.6.1 General

The test to determine standby losses ($Q_{fuel} + E_{in} – E_{out}$ ) shall be carried out under conditions where the package is "ready for service", meaning that the nominal rated heat output (see **12.2**) shall be supplied from the micro-cogeneration package within 0.5 h of a call for heat. This condition shall be called standby mode (for the purposes of the test for standby losses).

In the case of a CombiPK package, "ready for service" also requires readiness for hot water draw-off, for which purpose any internal hot water shall be heated and maintained at service temperature (see Table 12).

### 12.6.2 Preparation of the package

The micro-cogeneration package shall be filled with cold water and then started. A sufficient interval shall be allowed to elapse for any internal hot water or other energy store to be heated to the upper temperature limit at which it is controlled. The time interval shall be determined by observing the substantive drop in energy consumption (either primary fuel or electricity) that might be expected as the package enters standby mode.

### 12.6.3 Reheat cycle

After entering standby mode a preliminary investigation shall be carried out to determine the length and characteristics of any reheat cycle, and a readily identifiable point of the cycle that can be used to delimit test measurements identified. A reheat cycle shall be defined as the time to return to the same thermal condition and may be taken as the time interval from a substantive reduction (or increase) in energy input to the next substantive reduction (or increase).

*NOTE 1 Discussions should be held between the test laboratory and the manufacturer as to the most appropriate method of determining entry into the standby mode, the expected nature of any reheat cycle and the most identifiable point on the reheat cycle that can be used to delimit the test period. It may be necessary for the laboratory to undertake a pre-test to determine this.*

*NOTE 2 A reheat cycle should not be confused with the small change (typically a few watts) in energy demand arising from small fluctuations in laboratory conditions or as a result of cycling of intelligent controls or safety software.*

### 12.6.4 Test

If it has been established that there is an identifiable reheat cycle, the test period shall be started and finished at the same point on the reheat cycle. The duration of the test shall be:

- an integral number of reheat cycles as defined in **12.7.2** or **12.7.4**;
- at least two reheat cycles; and
- at least 24 h.

During the test period, the instantaneous rates of fuel consumption, electrical input and electrical output shall be recorded every 5 min and the data examined at convenient intervals to determine the cyclic nature (if any) of the previous values.

*NOTE This data might be expected to show substantive rises, falls, and rises again in energy consumption for a period (a few seconds, minutes, or even hours) under the action of a thermostat and/or timer.*

If there is no reheat cycle that can be detected by a significant variation in energy input, then the test shall start 30 min after the package enters standby mode and continue for exactly 24 h.

No space heating water shall be drawn from space heating connections, nor shall any DHW be drawn off during the test period, but any DHW storage tank within the micro-cogeneration package shall be maintained at its service temperature. In the case of the RegPK package the DHW tank shall be isolated.

The duration of the test, $t_{dur,}$ shall be measured in seconds. The individual quantities, $Q_{fuelact}$, $E_{inact}$ and $E_{outact,}$ recorded over the whole duration of the test shall be entered in Results Table 4 in Clause **13**. These values shall be scaled to give equivalent 24 h values for $Q_{fuel}$, $E_{in}$ and $E_{out}$ by applying the multiplication factor (86 400÷$t_{dur}$) in Results Table 4 and entered into Results Table 2 in Clause **13**.

During these tests an estimate shall be made of case losses according to the procedure detailed within **10.6**. This shall be reported at the end of Results Table 2.

## 12.7 DHW-only test

*NOTE This test is applicable to RegPK , CombiPK and DHWPK.*

### 12.7.1 Producing 100 L/day of DHW

*NOTE 1 The test for the production of DHW only is a test of the package for 24 h to include only the DHW tapping cycle in accordance with Table 12.*

*NOTE 2 Subclause* ***12.7*** *is based upon European Commission Mandate M/324 [9] and its further interpretation within BS EN 13203-2, although test conditions are restricted to tapping cycle No 2.*

The test shall be carried out using the 23 tappings specified in Table 12 and with the energy equivalent of a total volume of 100.2 L at 60 °C per day at a cold feed of $T_{coldwater,}$ 10 °C ± 2 °C.

Table 12 **EU reference tapping cycle number 2**

| **Draw off number (i)** | **Start time** | **Energy** | **Type (ref M324 [9])** | **$\Delta T$ desired to be achieved during tapping** | **Minimum $\Delta T$ = start of counting energy** | **Flow rate for individual tapping, $d_i$** |
|---|---|---|---|---|---|---|
| | h/min | MJ | | K | K | L/min |
| 1 | 07.00 | 0.378 | Small | N/A | 15 | ≥3 |
| 2 | 07.15 | 5.040 | Shower | N/A | 30 | ≥6 |
| 3 | 07.30 | 0.378 | Small | N/A | 15 | ≥3 |
| 4 | 08.01 | 0.378 | Small | N/A | 15 | ≥3 |
| 5 | 08.15 | 0.378 | Small | N/A | 15 | ≥3 |
| 6 | 08.30 | 0.378 | Small | N/A | 15 | ≥3 |
| 7 | 08.45 | 0.378 | Small | N/A | 15 | ≥3 |
| 8 | 09.00 | 0.378 | Small | N/A | 15 | ≥3 |
| 9 | 09.30 | 0.378 | Small | N/A | 15 | ≥3 |
| 10 | 10.30 | 0.378 | Floor cleaning | 30 | 0 | ≥3 |
| 11 | 11.30 | 0.378 | Small | N/A | 15 | ≥3 |
| 12 | 11.45 | 0.378 | Small | N/A | 15 | ≥3 |
| 13 | 12.45 | 1.134 | Dish washing 1 | 45 | 0 | ≥4 |
| 14 | 14.30 | 0.378 | Small | N/A | 15 | ≥3 |
| 15 | 15.30 | 0.378 | Small | N/A | 15 | ≥3 |
| 16 | 16.30 | 0.378 | Small | N/A | 15 | ≥3 |
| 17 | 18.00 | 0.378 | Small | N/A | 15 | ≥3 |
| 18 | 18.15 | 0.378 | Household cleaning | N/A | 30 | ≥3 |
| 19 | 18.30 | 0.378 | Household cleaning | N/A | 30 | ≥3 |
| 20 | 19.00 | 0.378 | Small | N/A | 15 | ≥3 |
| 21 | 20.30 | 2.646 | Dish washing 3 | 45 | 0 | ≥4 |
| 22 | 21.15 | 0.378 | Small | N/A | 15 | ≥3 |
| 23 | 21.30 | 5.040 | Shower | N/A | 30 | ≥6 |
| **Total** | | **21.042** | | | | |

*NOTE N/A = not applicable*

The manufacturer shall request that the laboratory uses the minimum flow rates defined in Table 12 or a single higher flow rate of D, which shall be 6 L/min or higher, as declared by the manufacturer, whilst still meeting the temperature criteria, as shown in Table 12. The flow rate used shall be recorded in Results Table 1 in Clause **13**.

*NOTE 3 The definition of D in PAS 67 is slightly different to the definition in BS EN 13203-2 since it is expected that most micro-cogeneration packages will draw hot water from a water store.*

The energy content of the DHW drawn off $Q_{DHW}$ (MJ) shall either:

a) be calculated from the equation:

$$Q_{DHW} = \frac{spht_{water}}{1000} \times \sum_{i=1}^{n} \int_{0}^{ti} d_i \cdot \Delta T_i(\mathrm{t})\, dt \qquad (14)$$

where:

| | |
|---|---|
| $n$ | is the number of tappings; |
| $d_\mathrm{i}$ | is the water rate delivered in L/min; |
| $t_\mathrm{i}$ | is the tapping duration of the useful water, in min; |
| $\Delta T_\mathrm{i}$ | is the instantaneous temperature rise during the tapping, in K from a $T_{\mathrm{coldwater}}$ of 10 °C ± 2 °C; |
| $spht_{\mathrm{water}}$ | is the specific heat of water. |

*NOTE 4 The approach given in **12.7.1** is consistent with BS EN 13203-2.*

or:

b) $Q_{DHW}$ shall be evaluated using a real time calculation of instantaneous water enthalpies employing the approach in accordance with **10.4.1**.

The energy of the DHW drawn off shall be compared to the values given in Table 12.

*NOTE 5 All patterns define a 24 h measurement cycle and within that cycle the starting times and the total energy content (in MJ equivalent of hot water tapped) of each tapping are defined.*

When these tapping rates result in a tapping period of less than 15 s, the flow rate shall be decreased such that the tapping period is 15 s ±1 s.

If, by design of the package, the test cannot be carried out with these low flow rates, the minimum flow rate for the ignition of the package shall be taken.

*NOTE 6 For each individual delivery, the allowable deviation is 0.018 MJ for each L/min of flow rate for that individual delivery (tapping).*

The required accuracy for each draw-off shall be ±0.036 MJ or ±2%, whichever is the greater, with a tolerance on the total energy content of the DHW drawn off, $Q_{DHW}$, of ±3%. All data shall be measured and reported over the full 24 h test duration (see Clause **11**). The minimum change in temperature shall be met, where required.

During all DHW draw tests an estimate shall be made of case losses according to the procedure detailed within **10.6**. This shall be reported within Results Table 2.

### 12.7.2 RegPK

All times reported shall be EU tapping cycle clock times in accordance with Table 12.

The micro-cogeneration package shall be filled with cold water and then started. The time at which it is started shall be recorded as event 1.

The time at which the cylinder thermostat ceases to call for heat shall be recorded as event 2. Event 3 shall be recorded as the earlier of:

a) the time at which the micro-cogeneration package stops burning fuel after event 2;

b) 1 h after event 2.

Immediately after event 3, a shower draw-off shall be carried out as for *i* = 23 in Table 12. The conclusion of the draw-off shall be recorded as event 4.

The first test period of 24 h shall commence at 2.5 h after event 4. This time shall be 00:00 for the purposes of the draw-off schedule defined in Table 12.

The test shall be carried out according to the demand schedule given in Table 12. $T_{ContentDHW}$ shall be calculated at 00:00 and 24:00 for the first test period.

The second test period of 24 h shall immediately follow the first period. For the purposes of the draw-off schedule defined in Table 12, time 00:00 of the second period shall be defined as time 24:00 of the first period. The second 24 h test shall be completed according to Table 12. $T_{ContentDHW}$ shall be calculated at 00:00 and 24:00 for the second test period.

At the option of the manufacturer, third and subsequent 24 h test periods may be carried out in like manner, each test period following the last with no interval between.

The test shall be considered valid if the difference between $T_{ContentDHW}$ at 00:00 and 24:00 of the final 24 h test period does not exceed 2 K. The data for the final 24 h test period shall be reported as the DHW test results in Results Table 3 in Clause **13** and as a chart of $T_{ContentDHW}$ vs time for each 24 h test period used for reporting in accordance with Clause **13**.

*NOTE In the event of difficulties in meeting the criteria, it may be useful for the manufacturer to compare the records of the individual DHW tank temperatures during recovery following successive shower draw-offs timed at 21:30. It may be that the tank thermostat specified by the manufacturer has excessive differential.*

### 12.7.3 Producing alternative quantities of DHW per day

Subject to agreement between the manufacturer and the test laboratory, the package shall additionally be tested at other daily DHW demands, as defined within BS EN 13203-2.

*NOTE 1 A summary of the daily DHW demand for each tapping cycle is listed in this subclause and are also shown in more detail in Tables 12, 12a, 12b and 12c.*

Packages submitted within the category DHWPK (i.e. tested for DHW production alone) shall be tested according to at least three of the draw-off patterns specified in Table 12a) and to two of the other tapping cycles selected by the manufacturer from Table 13.

*NOTE 2 This is to allow accurate prediction of package performance under a range of conditions.*

*NOTE 3 These draw-off patterns were originally defined with EU CEN Mandate M324 [9]; and in light of this is retained as the definitive reference point.*

The data shall be reported using additional sheets of Results Table 3 (for RegPK) and Results Table 4 (for CombiPK and DHWPK).

Table 12a) **EU reference tapping cycle number 1**

| Draw off number (i) | Start time | Energy | Type (ref M324 [9]) | $\Delta T$ desired to be achieved during tapping | Minimum $\Delta T$, start of counting energy | Flow rate for individual tapping, $d_i$ |
|---|---|---|---|---|---|---|
| | | MJ | | K | K | L/min |
| 1 | 07:00 | 0.378 | Small | N/A | 15 | ≥3 |
| 2 | 07:30 | 0.378 | Small | N/A | 15 | ≥3 |
| 3 | 08:30 | 0.378 | Small | N/A | 15 | ≥3 |
| 4 | 09:30 | 0.378 | Small | N/A | 15 | ≥3 |
| 5 | 11:30 | 0.378 | Small | N/A | 15 | ≥3 |
| 6 | 11:45 | 0.378 | Small | N/A | 15 | ≥3 |
| 7 | 12:45 | 1.134 | Dishwashing | 45 | 0 | ≥4 |
| 8 | 18:00 | 0.378 | Small | N/A | 15 | ≥3 |
| 9 | 18:15 | 0.378 | Household cleaning | N/A | 30 | ≥3 |
| 10 | 20:30 | 1.512 | Dishwashing | 45 | 0 | ≥4 |
| 11 | 21:30 | 1.890 | Large | N/A | 30 | ≥4 |
| **Total** | | **7.560** | | | | |

*NOTE N/A = not applicable*

Table 12b) **EU reference tapping cycle number 3**

| Draw off number (i) | Start time | Energy | Type (ref M324 [9] | ΔT desired, to be achieved during tapping | Minimum ΔT = start of counting energy | Flow rate for individual tapping, $d_i$ |
|---|---|---|---|---|---|---|
| | | MJ | | K | K | L/min |
| 1 | 07:00 | 0.378 | Small | N/A | 15 | ≥3 |
| 2 | 07:05 | 5.040 | Shower | N/A | 30 | ≥6 |
| 3 | 07:30 | 0.378 | Small | N/A | 15 | ≥3 |
| 4 | 07:45 | 0.378 | Small | N/A | 15 | ≥3 |
| 5 | 08:05 | 12.978 | Bath | 30 | 0 | ≥10 |
| 6 | 08:25 | 0.378 | Small | N/A | 15 | ≥3 |
| 7 | 08:30 | 0.378 | Small | N/A | 15 | ≥3 |
| 8 | 08:45 | 0.378 | Small | N/A | 15 | ≥3 |
| 9 | 09:00 | 0.378 | Small | N/A | 15 | ≥3 |
| 10 | 09:30 | 0.378 | Small | N/A | 15 | ≥3 |
| 11 | 10:30 | 0.378 | Floor cleaning | 30 | 0 | ≥4 |
| 12 | 11:30 | 0.378 | Small | N/A | 15 | ≥3 |
| 13 | 11:45 | 0.378 | Small | N/A | 15 | ≥3 |
| 14 | 12:45 | 1.134 | Dishwashing | 45 | 0 | ≥4 |
| 15 | 14:30 | 0.378 | Small | N/A | 15 | ≥3 |
| 16 | 15:30 | 0.378 | Small | N/A | 15 | ≥3 |
| 17 | 16:30 | 0.378 | Small | N/A | 15 | ≥3 |
| 18 | 18:00 | 0.378 | Small | N/A | 15 | ≥3 |
| 19 | 18:15 | 0.378 | Household cleaning | N/A | 30 | ≥3 |
| 20 | 18:30 | 0.378 | Household cleaning | N/A | 30 | ≥3 |
| 21 | 19:00 | 0.378 | Small | N/A | 15 | ≥3 |
| 22 | 20:30 | 2.646 | Dishwashing | 45 | 0 | ≥4 |
| 23 | 21:00 | 12.978 | Bath | 30 | 0 | ≥10 |
| 24 | 21:30 | 0.378 | Small | N/A | 15 | ≥3 |
| **Total** | | **41.958** | | | | |

*NOTE N/A = not applicable*

Table 12c) **EU reference tapping cycle number 4**

| Draw off number (i) | Start time | Energy | Type (ref M324 [9]) | $\Delta T$ desired to be achieved during tapping | Minimum $\Delta T$ = start of counting energy | Flow rate for individual tapping, $d_i$ |
|---|---|---|---|---|---|---|
| | | MJ | | K | K | L/min |
| 1 | 07:00 | 0.378 | Small | N/A | 15 | ≥3 |
| 2 | 07:15 | 6.552 | Shower | N/A | 30 | ≥6 |
| 3 | 07:26 | 0.378 | Small | N/A | 15 | ≥3 |
| 4 | 07:45 | 15.912 | Bath | 30 | 0 | ≥10 |
| 5 | 08:01 | 0.378 | Small | N/A | 15 | ≥3 |
| 6 | 08:15 | 0.378 | Small | N/A | 15 | ≥3 |
| 7 | 08:30 | 0.378 | Small | N/A | 15 | ≥3 |
| 8 | 08:45 | 0.378 | Small | N/A | 15 | ≥3 |
| 9 | 09:00 | 0.378 | Small | N/A | 15 | ≥3 |
| 10 | 09:30 | 0.378 | Small | N/A | 15 | ≥3 |
| 11 | 10:00 | 0.378 | Small | N/A | 15 | ≥3 |
| 12 | 10:30 | 0.378 | Floor cleaning | 30 | 0 | ≥4 |
| 13 | 11:00 | 0.378 | Small | N/A | 15 | ≥3 |
| 14 | 11:30 | 0.378 | Small | N/A | 15 | ≥3 |
| 15 | 11.45 | 0.378 | Small | N/A | 15 | ≥3 |
| 16 | 12:45 | 2.646 | Dishwashing | 45 | 0 | ≥4 |
| 17 | 14:30 | 0.378 | Small | N/A | 15 | ≥3 |
| 18 | 15:00 | 0.378 | Small | N/A | 15 | ≥3 |
| 19 | 15:30 | 0.378 | Small | N/A | 15 | ≥3 |
| 20 | 16:00 | 0.378 | Small | N/A | 15 | ≥3 |
| 21 | 16:30 | 0.378 | Small | N/A | 15 | ≥3 |
| 22 | 17:00 | 0.378 | Small | N/A | 15 | ≥3 |
| 23 | 18:00 | 0.378 | Small | N/A | 15 | ≥3 |
| 24 | 18:15 | 0.378 | Household cleaning | N/A | 30 | ≥3 |
| 25 | 18:30 | 0.378 | Household cleaning | N/A | 30 | ≥3 |
| 26 | 19:00 | 0.378 | Small | N/A | 15 | ≥3 |
| 27 | 20:30 | 2.646 | Dishwashing | 45 | 0 | ≥4 |
| 28 | 20:46 | 15.912 | Bath | 30 | 0 | ≥10 |
| 29 | 21:15 | 0.378 | Small | N/A | 15 | ≥3 |
| 30 | 21:30 | 15.912 | Bath | 30 | 0 | ≥10 |
| **Total** | | **68.652** | | | | |

*NOTE N/A = not applicable*

Table 13 **Summary of the daily DHW demand for tapping cycles and source documentation**

| Reference Table within BS EN 13203-2 | Reference Tapping Cycle Number within BS EN 13203-2 | Reference Table within PAS 67 | Energy MJ/day | DHW draw off (Volume) L/day |
|---|---|---|---|---|
| 2 | 1 | 12a | 7.560 | 36.0 |
| 3 | 2 | 12 | 21.042 | 100.2 |
| 4 | 3 | 12b | 41.958 | 199.8 |
| 5 | 4 | 12c | 68.652 | 325.0 |

### 12.7.4 DHW test for CombiPK and DHWPK

#### 12.7.4.1 General

The micro-cogeneration package shall be filled with cold water and then started. A sufficient interval shall be allowed to elapse for any internal hot water store to be heated to the upper temperature limit at which it is controlled. If there is no visible indication of the time at which the micro-cogeneration package becomes ready to offer a full hot water delivery service then the advice of the manufacturer shall be sought to establish an adequate heating up time.

For those packages being tested to Table 2 the package shall be operated to undertake a shower draw-off as for $i = 23$ in Table 12. The conclusion of the shower draw-off shall be recorded as event 1.

The first test period of 24 h shall commence at 2.5 h after event 1. This is time 00:00 for the purposes of the draw-off schedule defined in Table 12. The test shall be carried out according to the demand schedule given in Table 12 or the selected tapping cycle demand schedule, as selected from table 13

The second test period shall immediately follow the first period. For the purposes of the draw-off schedule defined in Table 12, time 00:00 of the second period shall be defined as 24:00 of the first period. The second 24 h test shall be completed according to Table 12 or the selected tapping cycle demand schedule as selected from.

In the event of the temperature anywhere within the tank exceeding 95 °C, the package shall cease operation such that the transfer of heat from the micro-generation unit to the tank ceases.

Where different tapping cycles are requested the initial draw off may be different, although event i shall always be the last draw-off from the previous day, i.e. for cycle 1 (Table 12a) this is Large (1.89MJ), for cycle 3 (Table 12b) this is Small (0.378MJ) and for cycle 4 (Table 12c) this is Bath (15.9132MJ).

#### 12.7.4.2 For packages with a water content of <15 L

The procedure detailed within **12.7.4.1** shall be repeated for a third day. The test shall be considered valid if between 00:00 and 24:00 on the second day (penultimate day), and the same times on the third day (final day), none of the quantities of $Q_{fuel}$, $Q_{DHW}$, $E_{out}$ and $E_{in}$ differ by more than 2.5% (of the larger value) between the two days. If this difference is exceeded, the tests shall be repeated for a fourth day (an additional day). If the level of repeatability is still not within 2.5%, the micro-cogeneration package under test shall be considered incompatible with this test procedure and the DHW test results shall not be entered in Results Table 2 in Clause **13**.

#### 12.7.4.3 For packages with a water content of greater than 15 L

The procedure detailed within **12.7.4.1** shall be repeated for a third and successive days, until the test can be considered valid, by meeting the following conditions.

a) Between 00:00 and 24:00 on the second day (penultimate day) and the same times on the third day (final day), none of the individual quantities of $Q_{fuel}$, $Q_{DHW}$, $E_{out}$ and $E_{in}$ shall differ by more than 2.5% (of the larger value) between the two days. If this difference is exceeded, the tests shall be repeated for a fourth or further successive day. This process shall be repeated until two days do not vary by more than 2.5%.

   *NOTE 1 This requirement ensures no gross discrepancy in system heat content.*

The instantaneous temperatures at the start and end of the first and last draw-offs of the day shall not vary by more than ±2.0 °C between successive days.

*NOTE 2 This requirement ensures no gross temperature difference between the top of the tank on successive days. This requirement also ensures no gross change in tank stratification from day to day.*

b) Between 00:00 and 24:00 on the second day (penultimate day) and the same times (and at the same instantaneous fuel combustion rates) on the third day (final day), the temperature of the return ($T_{primretDHW}$) of any heat transfer fluid between the micro-generation unit and any heat store as determined within **10.4.2** shall be within ±3 °C. If this difference is exceeded, the tests shall be repeated for a fourth or further successive day. This process shall be repeated until two days do not vary by more than this figure.

*NOTE 3 It is appreciated that even at equilibrium there could be slight differences in the timings of firing of the micro- cogeneration unit between successive days. In this instance the similarity of rate of fuel combustion may take priority.*

*NOTE 4 This requirement ensures no gross temperature difference between the bottom of the tank on successive days or the level of convective heat transfer to the tank contents. This effectively ensures that the tank contents are under comparable conditions.*

If these levels of repeatability are not demonstrated, the micro-cogeneration package under test shall be considered incompatible with this test procedure and the DHW test results shall not be entered in Results Table 2 in Clause **13**.

*NOTE 5 This test option allows MCG package manufacturers to test and place on the market a closely integrated bespoke system to optimize the performance of the MCG unit, hot water storage and, optionally, the production of central heating water.*

# 13 Declarations and test results

## 13.1 General

The manufacturer shall request that a final report is prepared by the test laboratory including the declarations and results using the same format, wording and units as shown in Results Tables 1, 2, 3, 4, 5, 6 and 7, along with a copy of a chart of $T_{ContentDHW}$ vs. time for each of the 24 h test periods of the RegPK DHW test (see **12.7.2**).

*NOTE 1 The results are reported relative to the gross CV of the fuel because of the complexity of the packages and the need to demonstrate closure of the energy balance.*

*NOTE 2 The Results Tables 1, 2, 3, 4, 5, 6 and 7 are available in a spreadsheet workbook as a download from the BRE website.*

*NOTE 3 The workbook includes individual worksheets for each PAS 67 Results Table, with some high level consistency checks on the input data. The PAS 67 results are linked in the spreadsheet to worksheets that perform the calculations for the* Method to evaluate the annual energy performance of micro-cogeneration heating systems in dwellings *[1]. The calculator determines the heating plant emission rate and SAP intermediate results for a heat-led micro co-generation package for a dwelling in the UK.*

Results Table 1 **PAS 67:2013 manufacturer's declaration of package characteristics**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | **Manufacturer's name** | | | | | | |
| 2 | **Brand name** | | | | | | |
| 3 | **Package name** | | | | | | |
| 4 | **Unique package identifier**<br>Shall not be the same as for any other package previously submitted for a PAS 67 test by the same manufacturer | | | | | | |
| 5 | **Software/control package** | | | | | | |
| 6 | **Description of micro-cogeneration package**[a] | | | | | | |
| 7 | **Nominal rated heat output, kW** | | | | | | |
| 8 | **Nominal max. electrical output, kVA** | | | | | | |
| 9 | **Electrical specification** [b] | | | | | | |
| 10 | **Prime mover** [c] | | | | | | |
| 11 | **Test fuel** [d] | | | | | | |
| 12 | **Condensing or non-condensing** | | | | | | |
| 13 | **Presence of system circulator within the package** | | **Present:**<br>Yes or No | | **Nominal rating in W** | | |
| | | | **Disconnected for test**:<br>Select Yes or No | Select here | | | |
| 14 | **Volume of DHW storage vessel within package (if present) (L)** | | | | | | |
| 15 | **DHW supply pressure requirements and flow rate for individual hot water tappings – specify whether Table 12 rates or declared *D* (L/min)** | **Maximum pressure** | barg | | **DHW flow rate:**<br>Select Table 12 or *D* | Select here | |
| | | **Minimum pressure** | barg | | **If *D* selected: declare flow rate for *D*** | | L/min |
| 16 | **Describe any internal flow rate control within the package** | | | | | | |
| 17 | **Category of package** | | **Select RegPK, HeatPK or CombiPK** | Select here | | | |
| 18 | **Test electrical mode** | | **Select: Synchronous or Island Mode** | Select here | | | |
| 19 | **Test regime selected** | | **Select 1, 2, 3, or 4** | Select here | | | |
| 20 | **Suitable for installation in a dwelling**[e] **with a design heat loss of** | | **Minimum design heat loss** | | kW | | |
| | | | **Maximum design heat loss** | | kW | | |

[a] This shall be a brief description of the micro-cogeneration package and its function. It shall include the flue type as specified within PD CEN/TR 1749:2009.

[b] This shall be 230V 50Hz synchronous single phase, 400V 50Hz synchronous three phase (3 wire or 4 wire), or DC (to be declared) volts.

[c] This shall be internal combustion engine, Stirling engine, fuel cell, or other (If other, the manufacturer is permitted a definition of up to six words.)

[d] A full description including reference to relevant standard, as in accordance with **10.2** Where fuel is unconventional a full description should be attached to the report.

[e] This should correspond to the manufacturer's advice given to a designer of a heating system for a dwelling, who shall select heating plant of suitable size to meet the heat demand. The information is not needed to carry out the laboratory tests, but is needed if the test results are to be used in the method to evaluate the annual energy performance (see "Scope") for the purpose of calculating a seasonal performance index. The design heat loss is the instantaneous heat loss in kW from the dwelling when the temperature differential between inside and outside is 20.4 K. The plant size ratio is the nominal rated heat output of the micro-cogeneration package divided by the design heat loss. For domestic boilers (other than combination boilers), the plant size ratio is commonly in the range 1.5 to 1.8. For further information see *Method to evaluate the annual energy performance of micro-cogeneration heating systems in dwellings* [1], 1.3.3 and 2.5.

I the undersigned declare that:

- the micro-cogeneration package submitted for test in accordance with PAS 67 is representative of the micro-cogeneration package type and the packages to be produced from the production of this package type;
- no PAS 67 test results have previously been declared for a micro-cogeneration package with the unique package identifier above;
- the contents of Results Table 1 are accurate.

| | |
|---|---|
| **Signed** | **Date** |
| **Name** | **Position** |
| **Name of manufacturer** | |

## Results Table 2 **PAS 67:2013 laboratory test results**

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NOTE 1 The minimum number of tests to be completed are the mandatory tests for the selected regime. | | | | | | | | | | | | | | | | | | |
| NOTE 2 The grey shaded cells are entries required by the '*Method to evaluate the annual performance of micro-cogenerating heating systems in dwellings [1]*'. | | | | | | | | | | | | | | | | | | |
| NOTE 3 Please ensure that there are no data input error messages in Column U of this worksheet. | | | | | | | | | | | | | | | | | | |
| **Manufacturer's name:** | | | Copied from Table 1 | | | | | | | | | | | | | | | |
| **Unique package identifier:** | | | Copied from Table 1 | | | | | | | | | | | | | | | |
| **Test regime:** | | | Select Regime 1, 2, 3 or 4 | | | Select here | | | | | | | | | | | | |
| **Category of package:** | | | Select RegPK, HeatPK , CombiPK or DHWPK | | | Select here | | | | | | | | | | | | |
| **System circulator** | | | Does the package have system circulator? Yes or No | | | Select here | Was the circulator operational during space heating tests? | | | Select here | | Was the circulator operational during DHW tests? Yes or No circulator present | | | | | | |
| **Electrical mode** | | | Select Synchronous or Island | | | | | | | | | | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| | | | | $Q_{fuel}$ | | $Q_{space}$ | $Q_{spacedt}$ (or $Q_{DHW}$ for test T22 and T23)[2] | | | $E_{out}$ | $E_{in}$ | $Q_{flue}$ | $Q_{case}$ | $\Delta H_{thermalstore} + \Delta H_{\mu chp}$ | | Laboratory test conditions (averages) | | |
| **Test No.** | **Output Test** | **Test mode** | **Test regimes** | **Fuel IN (Gross)** | **Average gross calorific value measured during the test** | **Energy output to space heating** | **Energy output during heat demand time**[1] | **Average $T_{spacereturn}$** | **Average $T_{spaceflow}$** | **Electrical output** | **Electrical input** | **Flue loss (gross basis)** | **Case loss** | **Change in energy content** | **$Q_{balance}$** | **Temperature** | **Relative humidity** | **Pressure** |
| | | | | MJ for 24 h | kJ/m³ or kJ/kg (declare units) | MJ for 24 h | MJ for 24 h | °C during operational period | °C during operational period | MJ for 24 h | MJ for 24 h | MJ for 24 h | MJ for 24 h | MJ for 24 h | MJ | ° C | % | mbar |
| T1 | 100% | Continuous | 1/2/3/4 | | | | | | | | | | | | | | | |
| T2 | 90% | Continuous | 1/4; optional | | | | | | | | | | | | | | | |
| T3 | 80% | Continuous | 1/4; optional | | | | | | | | | | | | | | | |
| T4 | 70% | Continuous | 1/4; optional | | | | | | | | | | | | | | | |
| T5 | 60% | Continuous | 1; optional | | | | | | | | | | | | | | | |
| T6 | 60% | Uni-modal | 2/4; optional | | | | | | | | | | | | | | | |
| T7 | 50% | Continuous | 1; optional | | | | | | | | | | | | | | | |
| T8 | 50% | Uni-modal | 2/4; optional | | | | | | | | | | | | | | | |
| T9 | 40% | Continuous | 1; optional | | | | | | | | | | | | | | | |
| T10 | 40% | Uni-modal | 2; optional | | | | | | | | | | | | | | | |
| T11 | 40% | Bi-modal | 3; optional | | | | | | | | | | | | | | | |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T12 | 30% | Continuous | 1 | | | | | | | | | | | | | | | |
| T13 | 30% | Uni-modal | 2/4 | | | | | | | | | | | | | | | |
| T14 | 30% | Bi-modal | 3 | | | | | | | | | | | | | | | |
| T15 | 20% | Continuous | 1; optional | | | | | | | | | | | | | | | |
| T16 | 20% | Uni-modal | 2; optional | | | | | | | | | | | | | | | |
| T17 | 20% | Bi-modal | 3; optional | | | | | | | | | | | | | | | |
| T18 | 10% | Continuous | 1 | | | | | | | | | | | | | | | |
| T19 | 10% | Uni-modal | 2 | | | | | | | | | | | | | | | |
| T20 | 10% | Bi-modal | 3/4 | | | | | | | | | | | | | | | |
| T21 | Standby | | 1/2/3/4 | | | | 0 | | | | | | | | | | | |
| T22 | DHW | CombiPK, RegPK and DHWPK | | | | | | | | | | | | | | | | |
| T23 | DHW | CombiPK, RegPK and DHWPK | optional | | | | | | | | | | | | | | | |

1 The operational period refers to the hours during which minimum water temperature criteria apply e.g. bi-modal 06:00 to 09:00, and 15:00 to 23:00.

2 For DHW test, Column 8 shall contain the energy content for the DHW draw-off.

Results Table 3 **PAS 67:2013 additional domestic hot water laboratory test results (RegPK only)**

NOTE 1 The grey shaded cells are entries required by the '*Method to evaluate the annual energy performance of micro-cogeneration heating systems in dwellings*' [1]

NOTE 2 The average power consumption marked ‡ is after the deduction from pump contribution.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Manufacturer's name:** | Copied from Table 1 | | | | | | | | | | |
| **Unique package identifier:** | Copied from Table 1 | | | | | | | | | | |
| | **Electric boiler results** | | **24 h DHW results** | | | | | **24 h DHW optional results** | | | |
| | **Mean temperature during test** | | **Temperatures** | | | | | **Temperatures** | | | |
| | **Primary pipes** | **Cylinder and primary pipes** | Start | End | 24 h average | (End – Start) x weighting | Weighting fraction | Start | End | 24 h average | (End – Start) x weighting |
| **Nominal temperature rise 45 K** | °C | °C | °C | °C | °C | | | °C | °C | °C | |
| Cylinder surface top (TC7) | n/a | | | | | 0.0000 | 0.14 | | | | 0.0000 |
| Cylinder surface height 650 mm (TC6) | n/a | | | | | 0.0000 | 0.28 | | | | 0.0000 |
| Cylinder surface height 400 mm (TC5) | n/a | | | | | 0.0000 | 0.19 | | | | 0.0000 |
| Cylinder surface height 300 mm (TC4) | n/a | | | | | 0.0000 | 0.11 | | | | 0.0000 |
| Cylinder surface height 200 mm (TC3) | n/a | | | | | 0.0000 | 0.11 | | | | 0.0000 |
| Cylinder surface height 100 mm (TC2) | n/a | | | | | 0.0000 | 0.11 | | | | 0.0000 |
| Cylinder surface height 5 mm (TC1) | n/a | | | | | 0.0000 | 0.06 | | | | 0.0000 |
| Primary flow ($T_{primflowDHW}$) | | n/a | n/a | n/a | | | | n/a | n/a | | |
| Primary return ($T_{primretDHW}$) | | n/a | n/a | n/a | | **Sum = 0.0 K** | **These sums shall be within 2 K** | n/a | n/a | | **Sum = 0.0 K** |
| Ambient ($T_r$) | | | n/a | n/a | | | | n/a | n/a | | |
| | | | **Calibration data for the APM** | | | | **Value** | | | | |
| **Nominal temperature rise 25 K** | | | Temperature rise for primary pipes and cylinder | | | | | | | | |
| Cylinder surface top (TC7) | n/a | | Temperature rise for primary pipes and cylinder | | | | | | | | |
| Cylinder surface height 650 mm (TC6) | n/a | | Temperature rise for primary pipes | | | | | | | | |
| Cylinder surface height 400 mm (TC5) | n/a | | Temperature rise for primary pipes | | | | | | | | |
| Cylinder surface height 300 mm (TC4) | n/a | | Primary pipe loss gradient | | | | | | | | |
| Cylinder surface height 200 mm (TC3) | n/a | | Primary pipe and cylinder loss gradient | | | | | | | | |
| Cylinder surface height 100 mm (TC2) | n/a | | Cylinder loss gradient | | | | | | | | |
| Cylinder surface height 5 mm (TC1) | n/a | | **Calculated data for the APM** | | | | **BS EN 13203-2:2006 Tapping cycle No 2** | **BS EN 13203-2:2006 Tapping cycles No 1, 3 or 4** | | | |
| Primary flow ($T_{primflowDHW}$) | | n/a | Cylinder residual heat adjustment | | | | | | | | |
| Primary return ($T_{primretDHW}$) | | n/a | Cylinder temperature rise for 24 h test | | | | | | | | |
| Ambient ($T_r$) | | | Primary pipe temperature rise for 24 h test | | | | | | | | |
| | Power | Power | Primary pipe loss for 24 h test | | | | | | | | |
| Average power (at nominal rise 45 K) ‡ in Watts ($q_{DHWpipelossinst}$ and $q_{DHWriglossinst}$) | | | Cylinder loss heat for 24 h test | | | | | | | | |
| Average power (at nominal rise 25 K) ‡ in Watts ($q_{DHWpipelossinst}$ and $q_{DHWriglossinst}$) | | | Primary pipe and cylinder heat loss | | | | | | | | |
| | | | Primary pipe and cylinder heat loss | | | | | | | | |

Results Table 3a **PAS 67:2013 additional domestic hot water laboratory test results (CombiPK and DHWPK)**

| NOTE 1 The grey shaded cells are entries required by the '*Method to evaluate the annual energy performance of micro-cogeneration heating systems in dwellings*' [1] | |
|---|---|
| **Manufacturer's name:** | Copied from Table 1 |
| **Unique package identifier:** | Copied from Table 1 |

| | | First draw off | Final draw off | Difference | First draw off | Final draw off | Difference | First draw off | Final draw off | Difference | First draw off | Final draw off | Difference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | °C | | K | °C | | K | °C | | K | °C | | K |
| Mean delivered water temperature | | | | | | | | | | | | | |
| Primary return ($T_{primretDHW}$) | | | | | | | | | | | | | |

| | | Day 1 | Day 2 | Difference Day 1–Day 2 | | Day 2 | Day 3 | Difference Day 2 – Day 3 | | Day 3 | Day 4 | Difference Day 3 – Day 4 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MJ in 24 h | | MJ | % | MJ in 24 h | | MJ | % | MJ in 24 h | | MJ | % |
| $Q_{fuel}$ | | | | | | | | | | | | | |
| $Q_{DHW}$ | | | | | | | | | | | | | |
| $E_{out}$ | | | | | | | | | | | | | |
| $E_{in}$ | | | | | | | | | | | | | |

Results Table 4 **PAS 67:2013 standby losses test results**

| | | | | |
|---|---|---|---|---|
| **Manufacturer's name:** | | Copied from Table 1 | | |
| **Unique package identifier:** | | Copied from Table 1 | | |
| | | | | |
| **Actual test measurements** | | **Symbol** | **Units** | **Value** |
| 1 | Actual length of test period | $t_{dur}$ | s | |
| 2 | Actual total energy of fuel consumed | $Q_{fuelact}$ | MJ | |
| 3 | Actual total electrical energy input | $E_{inact}$ | MJ | |
| 4 | Actual total electrical energy output | $E_{outact}$ | MJ | |
| 5 | Was it possible to detect cyclic nature of reheat cycle: Yes or No | Select here | | |
| 6 | If Yes to 5 above – number of integral reheat cycles in the actual test period | – | – | |
| 7 | Description of the identifiable point on the reheat cycle at the beginning and end of the test period | | | |
| | | | | |
| **Calculated values for Results Table 2** | | **Symbol** | **Units** | **Value** |
| 8 | Total energy of fuel consumed over a 24 h test period. | $Q_{fuel}$ | MJ | |
| 9 | Electrical energy input to the package over a 24 h test period. | $E_{in}$ | MJ | |
| 10 | Electrical energy output from the package over a 24 h test period. | $E_{out}$ | MJ | |

Results Table 5 **PAS 67:2013 recording of control settings to achieve output results**

| | | | | |
|---|---|---|---|---|
| NOTE: The entries in the table should be in sufficient detail such that a different competent test laboratory could repeat the tests and achieve a similar operational performance as the test laboratory making this declaration within the uncertainties required by PAS67. | | | | |
| | | **Manufacturer's name:** | Copied from Table 1 | |
| | | **Unique package identifier:** | Copied from Table 1 | |
| 1 | 2 | 3 | 4 | |
| **Test No.** | **Output Test** | **Test mode** | **Test regime** | **Description of method used to achieve partial output of the package** 1) |
| T1 | 100% | Continuous | 1/2/3/4 | |
| T2 | 90% | Continuous | 1/4; optional | |
| T3 | 80% | Continuous | 1/4; optional | |
| T4 | 70% | Continuous | 1/4; optional | |
| T5 | 60% | Continuous | 1; optional | |
| T6 | 60% | Uni-modal | 2/4; optional | |
| T7 | 50% | Continuous | 1; optional | |
| T8 | 50% | Uni-modal | 2/4; optional | |
| T9 | 40% | Continuous | 1; optional | |
| T10 | 40% | Uni-modal | 2; optional | |
| T11 | 40% | Bi-modal | 3; optional | |
| T12 | 30% | Continuous | 1 | |
| T13 | 30% | Uni-modal | 2 or 4 | |
| T14 | 30% | Bi-modal | 3 | |
| T15 | 20% | Continuous | 1; optional | |
| T16 | 20% | Uni-modal | 2; optional | |
| T17 | 20% | Bi-modal | 3; optional | |
| T18 | 10% | Continuous | 1 | |
| T19 | 10% | Uni-modal | 2 | |
| T20 | 10% | Bi-modal | 3 or 4 | |
| T24 | Standby | | 1/2/3/4 | |
| T25 | DHW | CombiPK, RegPK and DHWPK | | |
| T26 | DHW | CombiPK, RegPK and DHWPK | | |

1) To be completed for each of the tests recorded in Results Table 2

Results Table 6 **PAS 67:2013 measurement uncertainties**

| | | | |
|---|---|---|---|
| **Manufacturer's name:** | Copied from Table 1 | | |
| **Unique package identifier:** | Copied from Table 1 | | |
| **Test regime selected:** | **Regime 1, 2, 3 or 4** | Select here | |
| **Category of package:** | **RegPK, HeatPK, CombiPK or DHWPK** | Select here | |
| **Electrical connection** | **Synchronous or Island** | Select here | |
| **Measured value** | **Maximum uncertainty at 95% confidence** 1) | **Measured value** | **Maximum uncertainty at 95% confidence** 2) |
| **Water temperature,** °C | | **Electrical energy,** MJ | |
| **Flue Gas temperature,** °C | | **Current,** A | |
| **Water mass flow rate,** kg/h | | **Voltage,** V | |
| **Fuel flow rate,** $m^3$/h or kg/h 3) | | **Lab. air temp,** °C | |
| **Gross CV fuel,** kJ/$m^3$ or kJ/kg 4) | | **Air humidity,** % | |
| | | $CO_2$, % | |
| 2) Under conditions of test 3) Declare units 4) Declare units | | | |

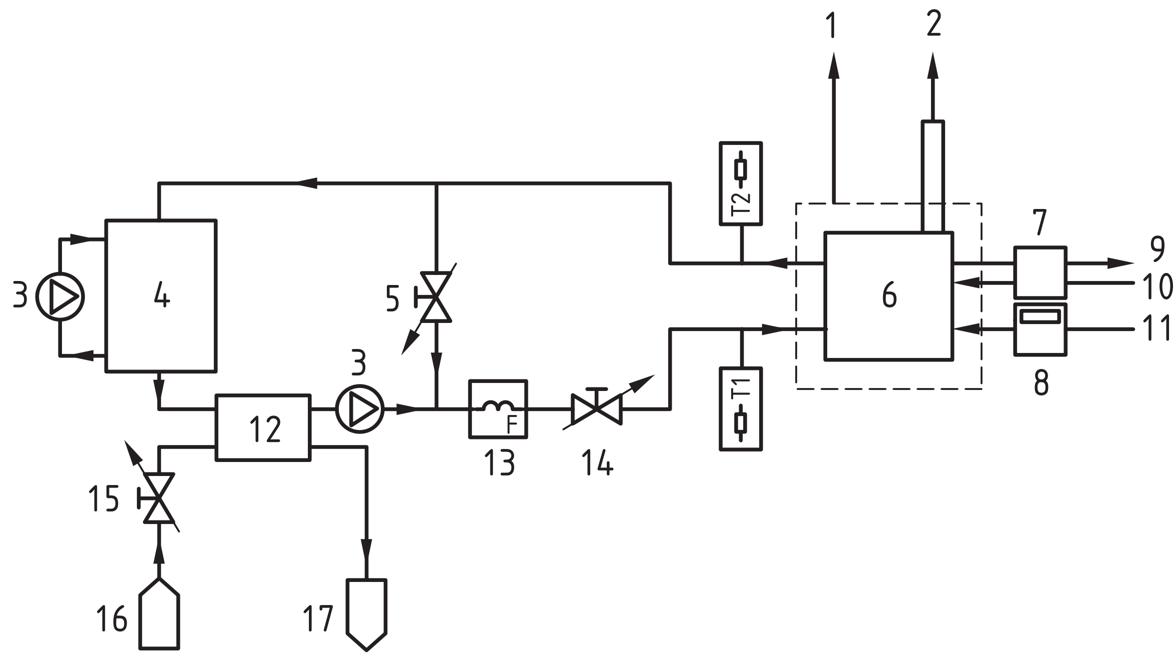
Results Table 7 **PAS 67:2013 test declaration**

| | |
|---|---|
| **Manufacturer's name:** | Copied from Table 1 |
| **Unique package identifier:** | Copied from Table 1 |
| **Test laboratory declaration:**<br>The contents of Results Tables 2, 3, 4, 5 and 6 are a true representation of the thermal and electrical performance as measured in accordance with PAS 67.<br>The signals used to control the micro-cogeneration package (e.g. from a room thermostat, cylinder thermostat, programmer) are as representative as possible of those expected to occur in a typical installation. Time constants have been recorded of any proportional, integral or differential controls such that on/off periods and levels of modulation witnessed during the tests are broadly in accordance with expected behaviour in real locations whilst meeting the required test criteria. | |
| **Signed:** | **Date:** |
| **Name:** | **Position:** |
| **Name of test laboratory:** | |
| **Address of test laboratory:** | **Address where tests carried out** |
| **Date when test started:** | **Date when test completed:** |
| | |
| **Manufacturer's Declaration** | |
| The package tested was not modified either before or during the test programme.<br>The signals used to control the micro-cogeneration package (e.g. from a room thermostat, cylinder thermostat, programmer) are as representative as possible of those expected to occur in a typical installation. Time constants have been recorded of any proportional, integral or differential controls such that on/off periods and levels of modulation witnessed during the tests are broadly in accordance with expected behaviour in real locations whilst meeting the required test criteria. | |
| **Signed:** | **Date:** |
| **Name:** | **Position:** |

# Annex A (normative) Typical arrangements for micro-cogeneration packages

Figure A.1, Figure A.2 and Figure A.3 give typical arrangements of a MCG and its associated components for the test set-up.

Figure A.1 **Space heating tests for HeatPK, CombiPK and RegPK packages**




**Key**

1. $Q_{case}$ total energy loss from the case
2. $Q_{flue}$ total energy loss from flue
3. Pump
4. Buffer vessel
5. By pass control valve
6. Micro-cogeneration package
7. Power meter
8. Gas meter [5)]
9. $E_{out}$ total electrical energy output
10. $E_{in}$ total electrical energy input
11. $Q_{fuel}$ total energy of fuel consumed

12 Heat exchanger

13. CH flow sensor
14. CH control valve
15. CH cooling valve
16. Water inlet
17. Drain

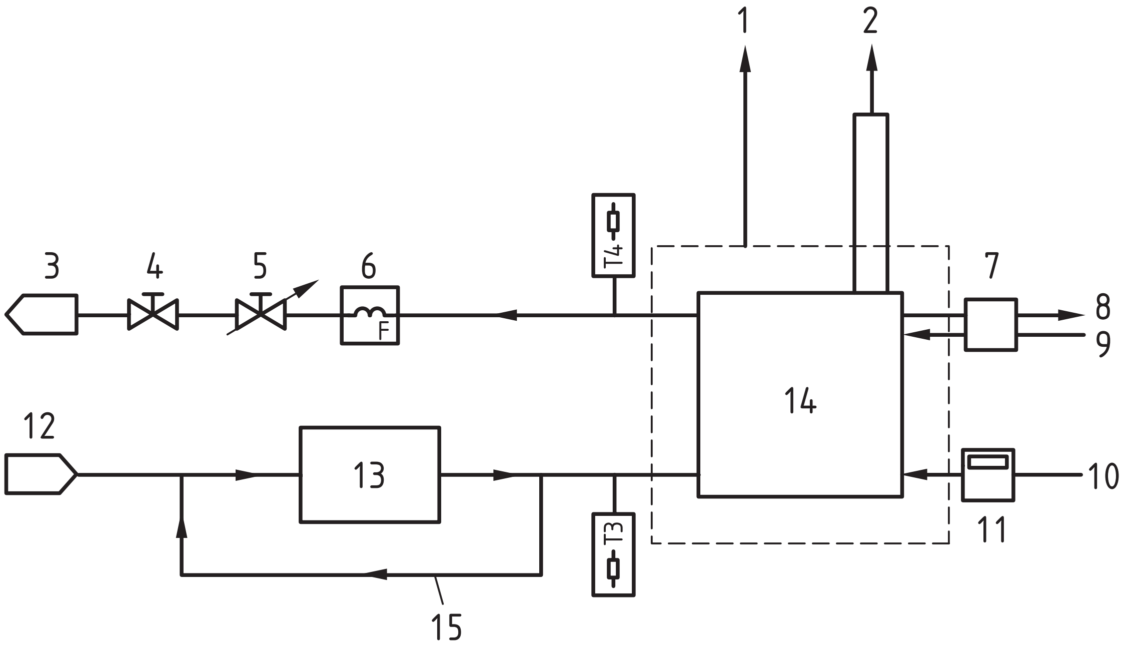
T1 temperature measurement device used to read $T_{spacereturn}$

T2 temperature measurement device used to read $T_{spaceflow}$

*NOTE The water flow rate through the package is* $m_{spacewater}$.

5) For fuels other than gas an appropriate technique specified with **10.2** Shall be adopted to determine $Q_{fuel}$

Figure A.2 **Domestic hot water (DHW) test for CombiPK packages with <15 L storage**




**Key**

1. $Q_{case}$ total energy loss from the case
2. $Q_{flue}$ total energy loss from flue
3. Drain
4. Tapping valve
5. DHW control valve
6. DHW flow sensor
7. Power meter
8. $E_{out}$ total electrical energy output
9. $E_{in}$ total electrical energy input
10. $Q_{fuel}$ total energy of fuel consumed
11. Gas meter [A)]
12. Water inlet
13. Water conditioning unit
14. Micro-cogeneration package
15. Spillback line [B)]

T3 temperature measurement device used to read $T_{coldwater}$

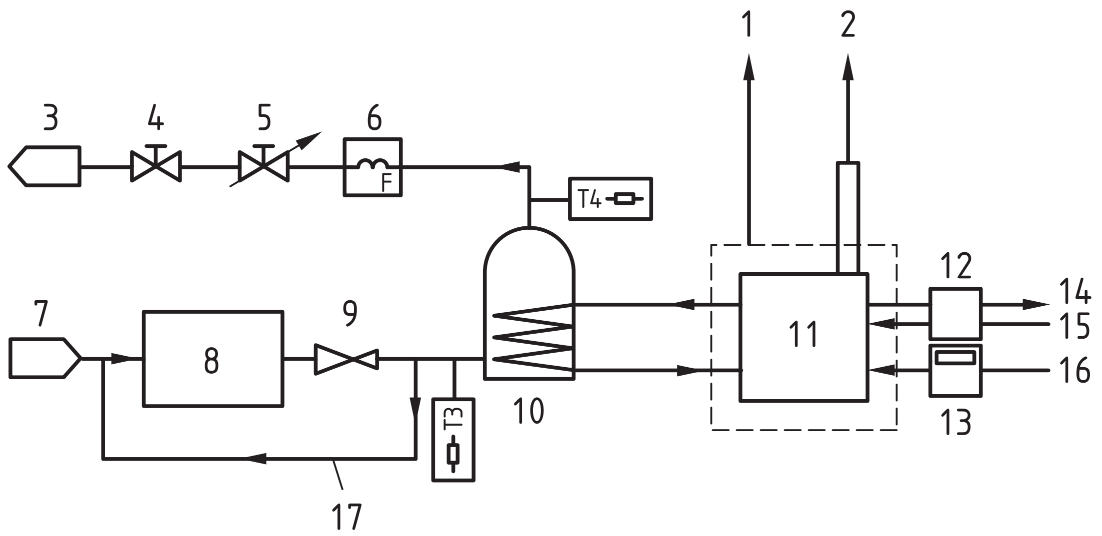
T4 temperature measurement device used to read $T_{DHW}$

*NOTE 1 Points T3 ($T_{coldwater}$) and T4 ($T_{DHW}$) correspond with the input and output temperature measuring devices in BS EN 13203-2:2006, Figure B.3.*

A) For fuels other than gas an appropriate technique specified within **10.2** shall be adopted to determine $Q_{fuel}$.

B) The spillback line is to ensure constant water temperature at T3 ($T_{coldwater}$) under all conditions.

Figure A.3 **Domestic hot water (DHW) test for RegPK, DHWPK and CombiPK packages of more than 15 L storage**




**Key**

1 $Q_{case}$ total energy loss from the case
2. $Q_{flue}$ total energy loss from flue
3. Drain
4. Tapping valve
5. DHW control valve
6. DHW flow sensor
7. Water inlet
8 Water conditioning unit
9. Pressure regulator
10. DHW storage
11. Micro-cogeneration package
12. Power meter
13. Gas meter [A)]
14. $E_{out}$ total electrical energy output
15. $E_{in}$ total electrical energy input
16. $Q_{fuel}$ total energy of fuel consumed
17. Spillback line [B)]
T3 temperature measurement device used to read $T_{coldwater}$
T4 temperature measurement device used to read $T_{DHW}$

*NOTE 1 Connections to central heating test circuit not shown.*

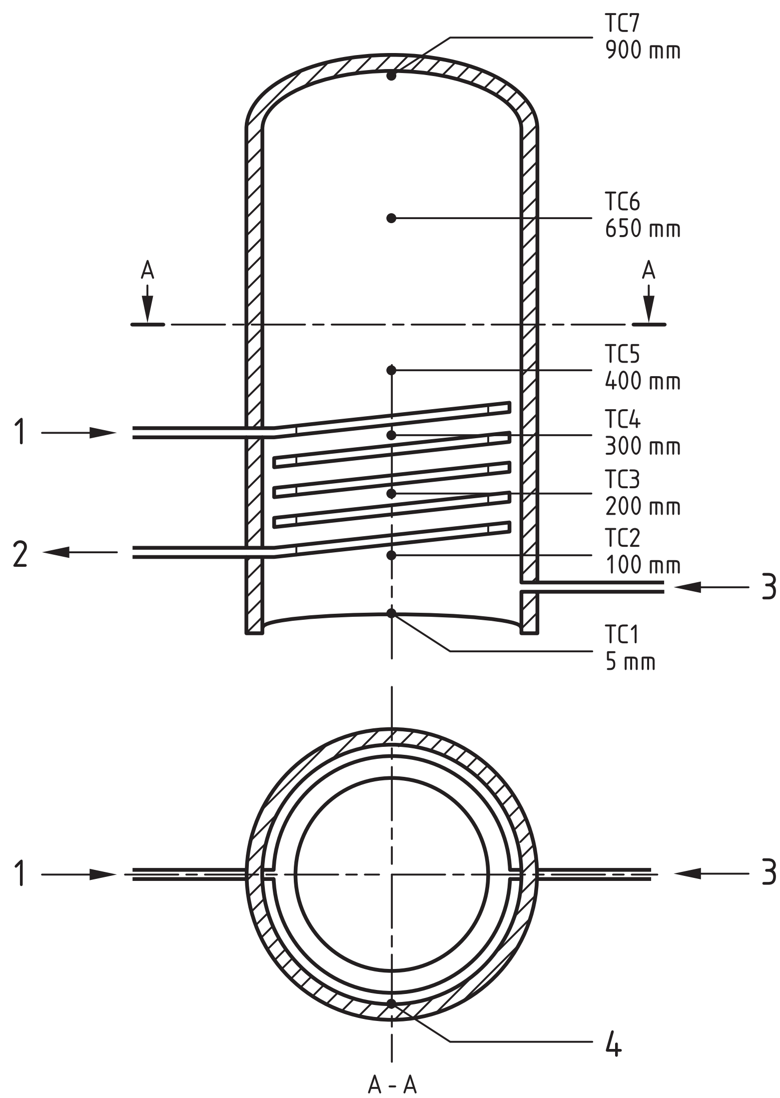
*NOTE 2 Points T3 ($T_{coldwater}$) and T4 ($T_{DHW}$) correspond with the input and output temperature measuring devices in BS EN 13203-2:2006, Figure B.3.*

A) For fuels other than gas an appropriate technique specified within **10.2** shall be adopted to determine $Q_{fuel}$.

B) The spillback line is to ensure constant water temperature at T3 ($T_{coldwater}$) under all test conditions.

Figure A.4 **Cross-section and plan of basic arrangement of thin film temperature resistance devices used to determine the thermal condition of the DHW tank used for RegPK**

Dimensions in millimetres

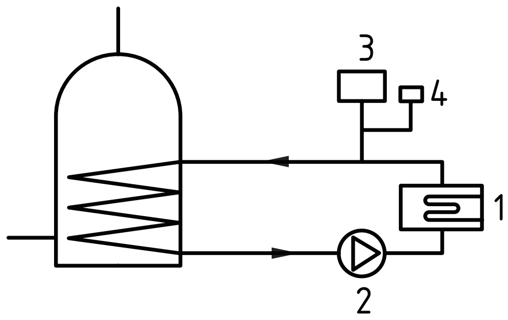



**Key**

1. Flow from package
2. Return to package
3. Cold water inlet
4. Thin film resistance devices positioned at 90° relative to cold water inlet labelled TC1 to TC7

Figure A.5 **Basic arrangement for the estimation of standing heat loss from the DHW test rig**




**Key**

1. Auxiliary electric boiler
2. Pump
3. Insulated expansion vessel
4. Bottle vent

# Annex B (informative) Method to determine case losses

*NOTE The case losses associated with a micro CHP package can be very small, of the order of 1-2% of full output as measured in kilowatts. Proportional effort should therefore be applied to the determination of case losses in light of the small effect that this is likely to have in the overall energy balance validation.*

## B.1 Direct method of measuring the energy to space from the case of the package arising from natural convection and radiation

### B.1.1 General

This annex is for the evaluation of a rate of energy emitted from the surface of a component, $q_{com}$. This excludes energy loss from forced convection, which is discussed in **B.4**. These values will need to be integrated over each 24 h test period. The time interval between measurements is to be determined by the test laboratory following consideration of the variation of surface temperature with time. Low and constant surface temperatures will permit longer intervals.

The estimation of the energy loss from a micro-cogeneration package requires division of the package into a series of components of simple geometry (e.g. cuboids, DHW tanks), the surface area and average temperature of which can be assessed. The energy loss of the package is then the sum of the energy losses from each component.

### B.1.2 Measurement of component surface temperature

#### B.1.2.1 General

The surface temperature of each of the component's exterior surfaces is measured against ambient temperature. In order to accurately measure the mean surface temperature it is essential that a sufficient number of temperature measurement points are chosen on each surface so that the measurement points give a reasonably good estimate of the mean temperature of that surface. However, as surface losses are a small component of the overall heat balance, the effort attributed to the determination of such values should be proportionate.

*NOTE 1 As an indication of proportionality it is a suggested that a package of surface area 3 $m^2$ making allowance for reasonable symmetry require no more than 20 measurements points.*

If the component construction is symmetrical in relation to flue ways and other construction, and also in respect of front, back and side walls, then it is permissible to measure only the temperature of one side wall and one half of the other surfaces. Guidance on choosing the specific measurement points is given in **B.1.2.2**.

*NOTE 2 It may be necessary to undertake a preliminary temperature survey and a physical survey to check that the temperature profiles of the surfaces are symmetrical.*

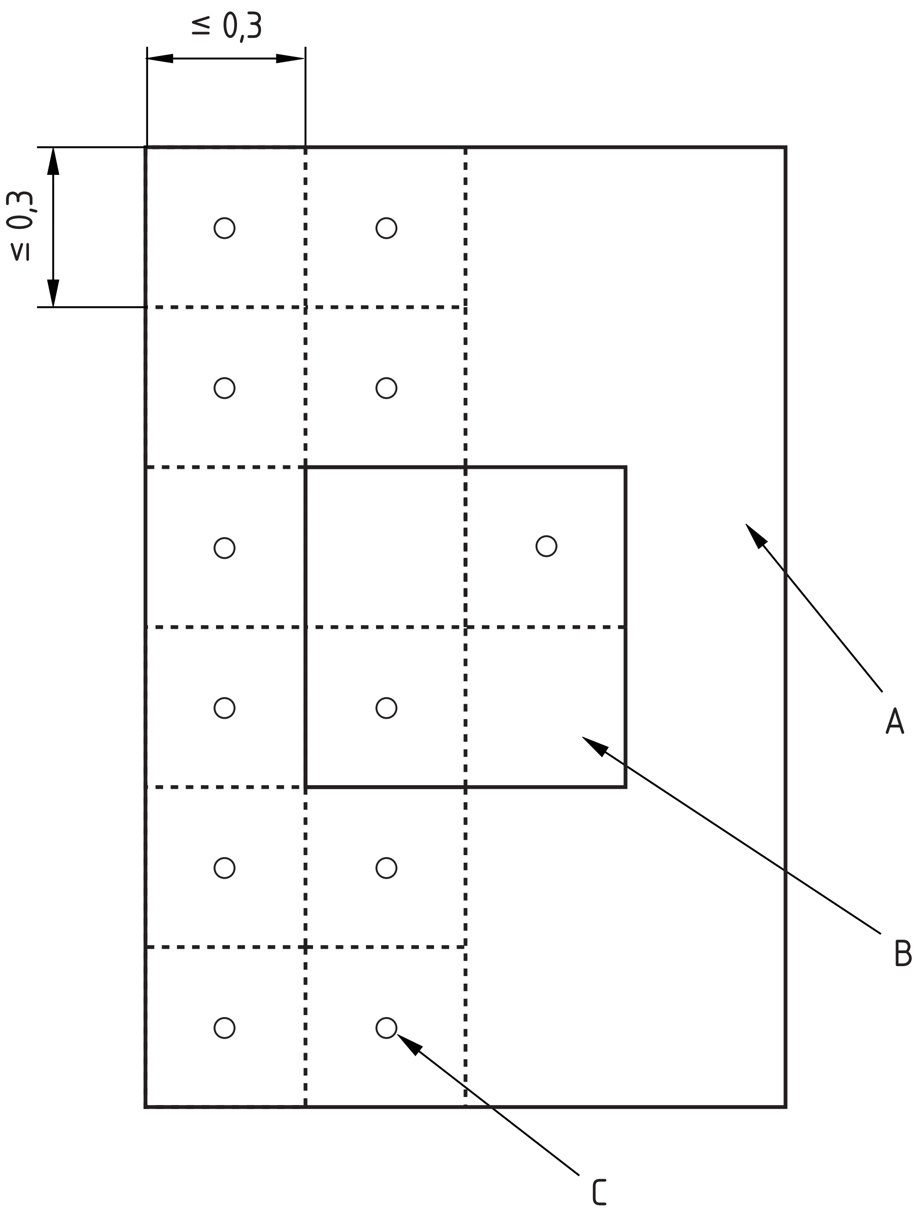
If the construction is not symmetrical or has significant differences then all independent surfaces should be measured separately and more measurement points should be taken, as detailed in **B.1.2.2**.

The mean surface temperature should be given as a weighted mean surface temperature. The calculation is based on the values of separate measurement points and their representing surface area, as detailed in Figure B.1 and related text.

Figure B.1 **Example of location of surface temperature points on component**

Dimensions in metres




**Key**

A Component front

B Door

C Measurement point

### B.1.2.2 Selection of measurement points

If the component has a symmetrical temperature profile, divide the component's back, front, top and side external surfaces into two identical surface areas by a vertical line. The mean surface temperature of only one half of the back, front and top surfaces and only one of the side wall surfaces are measured. Each surface area to be measured is further subdivided into smaller areas not exceeding 0.3 m × 0.3 m and at least one measurement point is needed for each of these smaller areas. The temperature measurement is made at the symmetrical centre point of the surface areas that it is representing.

If the component is not symmetrical in respect of temperature, geometry and flue ways or surfaces then each of the component's surfaces is subdivided into small areas not exceeding 0.3 m × 0.3 m and at least one measurement point is required for each 0.3 m × 0.3 m area. The temperature measurement is made at the symmetrical centre point of the surface area that it is representing.

The mean surface temperature of the component is calculated based on area-weighted temperature measurement points as detailed in **B.3**. A typical example of the positioning of the measurement points is given in Figure B.1.

#### B.1.2.3 Installing temperature probes to the component surface

Thermocouples (typically Type K, 1 mm or less diameter) should be installed such that the actual surface temperature measurements meet the uncertainty requirements of ±2 °C. Use either commercially available adhesive patch thermocouples, or a glue to ensure a good contact is made between the thermocouple and the component surface.

## B.2 Calculation of mean surface temperatures

### B.2.1 Step 1

Calculate the mean surface temperature of each individual external surface of the component (e.g. top, front). For each of these external surfaces calculate the mean value of the readings over the test period of each thermocouple measurement point and weight by the actual surface area that the measurement point represents. A typical calculation is detailed in **B.3.2**.

### B.2.2 Step 2

Calculate the mean temperature of the component from the calculated mean of each of the individual external surfaces from step 1 and weight by the actual surface area of the individual surface of the component that it represents (e.g. front, top). A typical calculation is detailed in **B.3.3**.

## B.3 Calculation of energy output from mean surface temperature

### B.3.1 General

The energy output $q$ (in W) from the surface area $A$ is calculated as an approximation by assuming the rate of energy release to be due to radiation and convection according to the equation B1.

$$q_{com} = A \times [\sigma F\{(T_s + 273.15)^4 - (T_r + 273.15)^4\} + C(T_s - T_r)^N] \quad \text{(B.1)}$$

where:

| | |
|---|---|
| $q_{com}$ | is the rate of energy released at time, $t$, from the component (W); |
| $A$ | is the total surface area of the component ($m^2$); |
| s | = $5.67 \times 10^{-8}$ W $m^{-2}K^{-4}$ (Stefan-Boltzmann's constant); |
| $F$ | is the view factor; |
| $T_s$ | is the mean surface temperature (°C) at time $t$; |
| $T_r$ | is the ambient temperature (°C); |
| $C$ and $N$ | are constants for convection. |

The following values should be attributed to the above variables, unless there is definite knowledge as to their unsuitability in particular circumstances:

- N = 1.36 (turbulent flow assumed);
- F = 0.8;
- C = 1.2 W $m^{-2}$ K.

### B.3.2 Example 1: Determination of mean local temperatures

This example is based on the following factors: a top surface having four measurement points; two measurement points have an area of 0.3 m × 0.3 m, i.e. 0.09 $m^2$, and mean temperature values of 60 °C and 55 °C, respectively, over the test period. The other two measurement points have an area of 0.25 m × 0.25 m, i.e. 0.062 5 $m^2$, and mean temperature values of 50 °C and 55 °C, respectively, over the test period. The mean value of the temperature of the surface would be calculated as follows:

$$\mathit{Mean\ value} = \frac{(60\times 0.09)+(55\times 0.09)+(50\times 0.0625)+(55\times 0.0625)}{(0.09\times 2)+(0.0625\times 2)} = 55.45°\text{C} \quad \text{(B.2)}$$

*NOTE If the actual surface areas of the measurement points are all of the same area, then the mean temperature of the surface may be calculated as the arithmetic mean of the individual readings of each measurement point.*

### B.3.3 Example 2: Calculation of mean surface temperature for the component

The individual mean calculated surface temperatures from example 1 are given in column 2 of Table B.1, and the corresponding surface area of each of the component sides is given in column 3. Column 4 is the weighted value and is calculated by multiplying the value in column 2 by the value in column 3 for each of the component surfaces. The mean value for the surface temperature of the component is calculated by dividing the total weighted value by the total surface area.

Table B.1 **Example of calculation of mean surface temperature**

| **Service components** | **Mean calculated value of temperature** °C | **Surface area** $m^2$ | **Weighted value** |
|---|---|---|---|
| Top | 65 | 0.75 | 48.75 |
| Front | 70 | 1.50 | 105.00 |
| Back | 60 | 1.50 | 90.00 |
| Each side | 55 | 2.00 | 110.00 |
| Totals | | 5.75 | 353.75 |
| Mean value for components | 61.5 | Mean value = $\frac{\text{Total weighted value}}{\text{Total surface area}}$ | |

## B.4 Direct method of measuring the energy to space from the case of the package arising from forced convection, usually a fan

Some micro-cogeneration packages may contain cooling fans or other means of forced convection. The energy loss arising from this should be evaluated and added to that arising from natural convection and radiation. An example of a possible technique is given below for a package that has a fan that draws cooling air through a grill and discharges the air through a number of gaps in the case of the package.

Measure the mass flow of air through the grill using a velocity probe, and measure the air temperature at a point alongside the probe. Use the following equation to calculate the energy removed from the micro-cogeneration package:

$$q_{fan} = (T_{ventout} - T_{ventin}) \times U_{grill} \times r_{air} \times spht_{air} \times A_{grill} \quad (B.3)$$

where:

- $q_{fan}$ is the rate of energy loss from the case by forced convection (kW);
- $T_{ventout}$ is the average temperature of the air from the discharge vents (°C);
- $T_{ventin}$ is the temperature of the air in through the cooling grill (°C);
- $A_{grill}$ is the cross sectional area of the grill in the plane of measurement of the mean velocity of the air;
- $U_{grill}$ is the mean velocity of air through the grill (m/s);
- $spht_{air}$ is the mean specific heat of air through the grill {kJ/(kg.K)} {Default value 1.005 kJ/(kg.K)};
- $r_{air}$ is the density of air through the grill (kg/m$^3$) represented by: 28.964 × 101.325 /{(273.15 + $T_{ventin}$) x 8 314}

where:

101.325 is the standard reference pressure of gas in mbar;

273.15 is the temperature of gas at 0 °C in K.

In the event of multiple fans or grills, the energy loss associated with each fan or grill should be evaluated separately and the heat flows summed up.

## B.5 Calculation of total energy loss due to radiation and natural and forced convection

Total energy loss from the case is then the sum of the energy loss from all of the components (identified 1 to *x*) from radiation, natural and forced convection integrated over the 24 h test period.

$$Q_{case} \sum_0^{24} \sum_1^{x} q_{com} + \sum_0^{24} \sum_1^{x} q_{fan} \quad (B.4)$$

# Annex C (informative) Direct method of measuring the energy loss from exhaust gases and condensate

*NOTE The case losses associated with a micro CHP package can be very small, of the order of 5-15% of full output as measured in kilowatts. Proportional effort should therefore be applied to the determination of case losses in light of the small effect that this is likely to have in the overall energy balance validation.*

## C.1 Non-condensing products

### C.1.1 General

This technique is suitable for MCGs without a liquid condensate discharge.

Flue losses, over a 24 h period, comprise the sum of flue losses whilst the unit is burning and during pre-and post-combustion purges.

### C.1.2 Energy lost with the flue gas whilst burning fuel, $Q_{\mathrm{flueuf}}$

The integrated loss should be evaluated using the equation:

$$Q_{flueuf} = (L_{1gr} + L_{2gr} + L_{3gr}) \times Q_{fuel} \div 100 \quad \text{(C.1)}$$

where:

$L_{1gr}$ is the loss due to sensible heat in the dry flue gases, BS 845-1:1987, **6.3.1** (%);

$L_{2gr}$ is the loss due to enthalpy in the water vapour in the flue gases, BS 845-1:1987, **6.3.2** (%);

$L_{3gr}$ is the loss due to unburnt flue gases, BS 845-1:1987, **6.3.3** (%);

100 is the conversion factor from percent to fraction;

All values are determined according to the detailed procedures laid down in BS 845-1:1987.

## C.2 Energy lost from the flue whilst the micro-cogeneration package is subject to pre-purge or post-purge cycles, $Q_{\mathrm{flueppTotal}}$

### C.2.1 General

Each purge will produce a loss, $q_{\mathrm{flueppsingle}}$. These losses will require considerable analytical thought and will probably require the estimation of mass flows and associated temperatures during these periods.

### C.2.2 Total energy loss from the flue

This is the sum of the energy loss whilst burning fuel $Q_{\mathrm{flueuf}}$ and those associated with pre and post-purge. It can be calculated using the following equation:

$$Q_{flue} = Q_{flueuf} + \sum_{0}^{24} q_{flueppsingle} \quad \text{(C.2)}$$

## C.3 Condensing products

### C.3.1 General

This technique is suitable for condensing MCGs.

### C.3.2 Energy lost with the flue gas whilst burning fuel, $Q_{\mathrm{flueuf}}$

The integrated energy loss should be evaluated using the equation:

$$Q_{fluent} = \left\{ \left( F_{23} + F_{24} + F_{28} + F_{53} + F_{54} \right) \times 86.4 \right\} \times \frac{Q_{fuel}}{Q_{fuelfull}} \quad \text{(C.3)}$$

where:

$F_{23}$ is the loss due to sensible heat in the dry flue gases (kW), BS 845-2:1987, **8.2.22**;

$F_{24}$ is the energy flow rate in flue gas from sensible and latent heat in moisture in fuel (kW) BS 845-2:1987, **8.2.23**;

$F_{28}$ is the energy flow rate within any condensate collected from the flue or micro-cogeneration package drain (kW) BS 845-2:1987, **8.2.27**;

| | |
|---|---|
| $F_{53}$ and $F_{54}$ | are the energy flow rates within unburnt flue gases (kW) BS 845-2:1987, **8.2.21**; |
| $Q_{fuel}$ | is the total fuel consumed during the test (MJ); |
| $Q_{fuelfull}$ | is the total fuel consumed during the 24 h full output test (MJ); |
| 86.4 | is the conversion factor from kW to MJ per 24 h. |

*NOTE The mixed units are to ensure an appropriate conversion of units as contained within BS 845.*

### C.3.3 Energy lost from the flue, $Q_{flueppttotal}$, whilst the micro-cogeneration package is subject to pre- or post-purge cycles

Each purge will produce a loss, $q_{flueppsingle}$. These losses will require considerable analytical thought and will probably require the estimation of mass flows and temperatures during these periods.

### C.3.4 Total energy loss from the flue

Total energy loss is the sum of the energy loss whilst burning fuel $Q_{flueuf}$ and the loss associated with pre and post-purge. See equation C.4

$$Q_{flue} = Q_{flueuf} + \sum_{0}^{24} q_{flueppsingle} \quad \text{(C.4)}$$

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