Technical Papers supporting SAP 2009

SAP

Analysis of results from energy performance tests on combi boilers

Reference no.	STP09/B04
Date last amended	26 March 2009
Date originated	29 October 2008
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Summary

A series of detailed efficiency and hot water performance tests have been carried out on two gas and two oil-fired combi boilers. The test programme had several purposes, the main ones being to compare energy performance with manufacturers' claims, to ascertain hot water performance separately from space heating, and to inform future changes to the treatment of boilers in SEDBUK and the SAP.

Conclusions are that, as has been found on previous occasions, there are significant discrepancies between efficiency figures obtained from independent tests and those used by manufacturers to support applications for entries in the Boiler Efficiency Database. The hot water results will assist the separation of space heating and water heating efficiencies in SAP and pave the way for direct acceptance of test data when it becomes more widely available under the Eco-design of Energy Using Products Directive (EuP). In this set of tests the hot water performance of oil-fired combi boilers was found to be unexpectedly poor. For gas boilers the tests indicated that current assumptions about reject water and "keep hot" features should be revised.

Two alternative approaches to evaluation of the energy performance of boilers in SAP were analysed, the first being use of SEDBUK (based on European standard test methods) and the second being the Annual Performance Method in conjunction with PAS-67 tests (designed primarily for micro-cogeneration plant). Not surprisingly, different results were obtained from these widely different approaches, and it was found that equivalent annual efficiencies obtained via SEDBUK/SAP gave overall results 3% to 4% lower than by APM/SAP.

Contents

1 Introduction

A series of detailed efficiency and hot water performance tests have been carried out on two gas and two oil-fired combi boilers. The objectives were:-

- To monitor the energy performance of boilers placed on the market in fulfilment of Defra's responsibilities under the Boiler (Efficiency) Regulations 1993 and BED[1].
- To verify boiler test efficiencies quoted by manufacturers. Significant discrepancies have previously been found between results from independent tests and those claimed by manufacturers when applying for entries in the Boiler Efficiency Database[2].
- To improve knowledge of the hot water performance of combi boilers. This will inform proposed changes to SAP[3].
- To support possible revisions to SEDBUK, especially for oil combi boilers. Test data is wanted to compare with key assumptions used in the SEDBUK theory and its use within the SAP.
- To provide further data to evaluate the Energy Balance Validation[4] (EBV) procedure.
- To examine SAP results obtained from treating a boiler as if it were a micro-cogeneration package (using the PAS-67[5] tests and Annual Performance Method[6]) and compare them with those obtained by use of SEDBUK.
- To determine the HPER[7] for a boiler of known SEDBUK value. This will be used as a comparator and minimum standard for other heating technologies in the MCS scheme.

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[1] Boiler Efficiency Directive (Council Directive 92/42/EEC on efficiency requirements for new hot-water boilers fired with liquid or gaseous fuels)

[2] See www.boilers.org.uk

[3] The government's Standard Assessment Procedure for Energy Rating of dwellings

[4] ENERGY BALANCE VALIDATION: Investigation of the residual energy of thermal efficiency tests on gas and oil boilers

[5] PAS 67: Laboratory tests to determine the heating and electrical performance of heat-led micro-cogeneration packages primarily intended for heating dwellings

[6] Method to evaluate the annual energy performance of micro-cogeneration heating systems in dwellings – see http://projects.bre.co.uk/sap2005/supporting-technical-documents.html

[7] The Heating Plant Emission Rate in a dwelling measured in $kgCO_2/kWh$, being the annual average for heating and hot water service

2 Description of the project

A series of efficiency tests have been carried out on natural gas and oil-fired condensing combi boilers. Tests completed were:

(a) Efficiency at full-load, part-load and minimum controlled rate (where applicable). Part-load efficiencies were determined by direct and indirect methods (as given in BS EN 277, 483, 304 and 677).

(b) Hot water draw-off performance in accordance with BS EN 13203.

(c) Electricity power measurements.

(d) Standby loss measurements.

(e) Daily performance at 0, 10%, 30% and 100% load levels in accordance with PAS-67 (two gas boilers only).

The test programme was carried out by Gastec at CRE Ltd using their dedicated automated test rig. Gastec was required to (a) purchase the boilers, (b) test the boilers (c) deliver a suitable report of test results, (d) store the boilers in good condition for a period of 6 months following the final test, and (e) dispose of the boilers on confirmation they are no longer to be retained.

3 Selection of Boilers

Four boilers were selected for test as shown in table 1. Although no market data was available, those selected were believed to be among the market leaders. The oil-fired boilers were selected in consultation with OFTEC and were assumed to be market leaders in the bespoke and contract markets. The boilers are referred to here as A, B, C and D.

Table 1 Boiler details

Boiler	Fuel	Type	Output kW	SEDBUK equation
A	Gas	Instantaneous with keep-hot	27	104
B	Gas	Instantaneous with keep-hot	28	104
C	Oil	Storage	26.5	202
D	Oil	Storage	23.5	203

Combi boiler C is described in the boiler efficiency database as an instantaneous unit, and as such it uses SEDBUK equation 202. Checks on the appliance confirm it has a heat exchanger with a water capacity 16 litres connected directly to a primary store with a capacity of 32 litres. The boiler has been incorrectly classified in the boiler database and should use SEDBUK equation 203.

4 Space heating efficiency results

4.1 Comparison of test efficiency values

Manufacturers quoted results[8] are described as "Manufacturers'" and the results from this series of tests are described as "DEFRA".

Figure 1 shows DEFRA results of full-load efficiency at a flow and return of 80/60°C as required by BS EN 677 and BS EN 304. Additional data at lower temperatures (60/40° and 50/30° for gas, and 50/30° and 40/30° for oil) is given to determine efficiency characteristics.

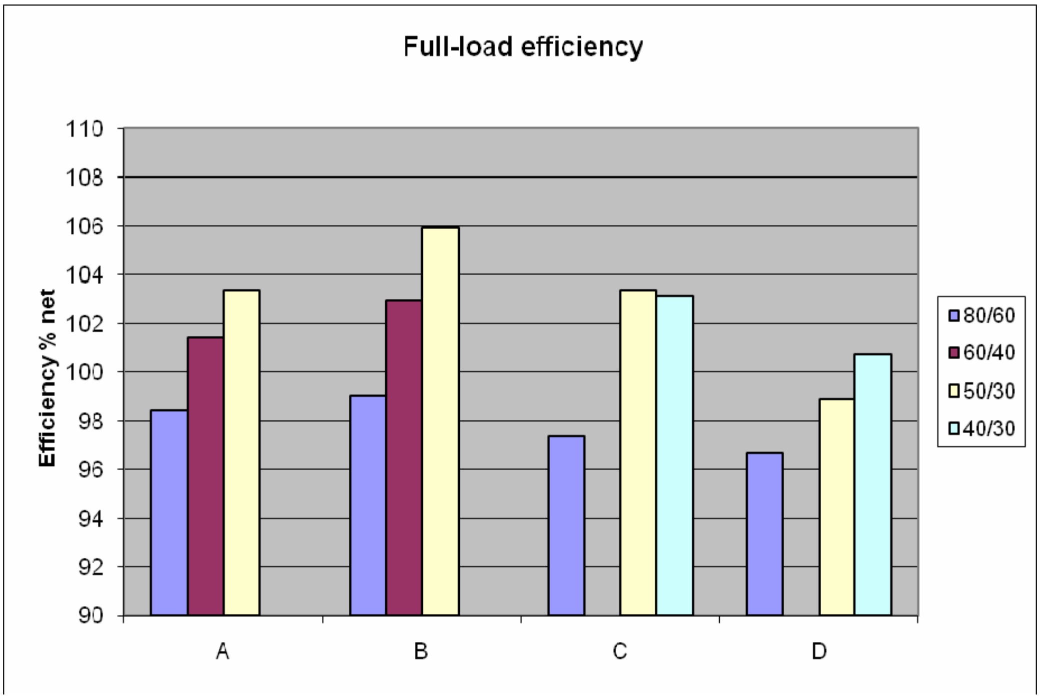

Figure 1: Full-load efficiency under different temperature regimes

[8] Source data supplied by manufacturers to the Boiler Efficiency Database

Figure 2 shows DEFRA results of part-load efficiency (30%) and also for gas boilers at minimum controlled rate. Oil boilers are fixed rate (non-modulating). Results are shown using both direct and indirect methods as given in as given in BS EN 483, 304 and 677.

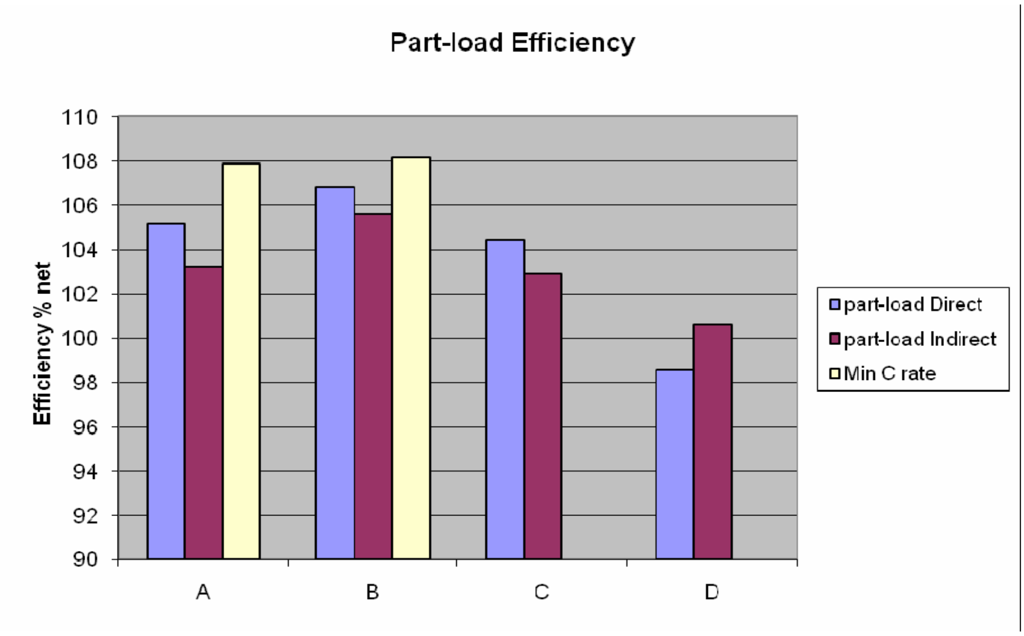

Figure 2: Part-load efficiency using direct and indirect methods

Table 2 shows the manufacturers' full and part-load efficiency values and compares them to the results of these DEFRA tests on "off-the-shelf" boilers.

Table 2 Comparison of Efficiency data (% net)

Boiler	Fuel	Manufacturers		DEFRA		
		Full-load %	Part-load %	Full-load %	Part-load – Direct %	Part-load – Indirect %
A	Gas	97.8	109.7	98.4	105.2	103.2
B	Gas	99.9	107.0	99.0	106.8	105.6
C	Oil	99.9	102.9	97.4	100.4	102.9
D	Oil	96.1	101.2	96.7	98.6	100.6

Table 3 shows the offset (%points efficiency) for each boiler test result. The offset is defined as the DEFRA independent value minus the manufacturer's value. So a negative value indicates the manufacturer's value is overestimated relative to the independent value.

Table 3 Comparison of Efficiency data (% net) - offsets				
Boiler	**Fuel**	**full-load offset**	**part-load offset direct method**	**part-load offset indirect method**
A	Gas	0.6	-4.6	-6.5
B	Gas	-0.9	-0.2	-1.4
C	Oil	-2.6	-2.5	0
D	Oil	0.6	-2.6	-0.6
Average		-0.6	-2.5	-2.1

The independent DEFRA efficiency results are generally lower than quoted by the manufacturer. Clearly this is a very small sample and cannot be considered significant on its own. A further report (now issued as "*A meta-analysis of boiler test efficiencies to compare independent and manufacturers' results*", reference STP09/B05) takes this data set together with other independent data sets and compares them with manufacturer's claimed values.

4.2 SEDBUK comparison

The full and part-load efficiency results are consistent with previous observations that manufacturer's results are generally higher than those from independent tests. SEDBUK efficiencies in the Boiler Efficiency Database are based on the manufacturer's efficiency data. However, the SEDBUK procedure limits the maximum efficiencies that can be used in the formulae, preventing excessive and unrepresentative values from being used in the SAP.

Table 4 shows a comparison of the manufacturers versus DEFRA SEDBUK values. SEDBUK values have been calculated using both direct and indirect part-load efficiency data. The offsets are reduced slightly compared to test efficiency data but the claimed higher SEDBUK values in the range 1-2% affects whether a boiler lies in the same SEDBUK band. Manufacturers' test results have been used to claim each boiler is in the SEDBUK "A" band, but if the independent test results were used only one out of the four boilers would be placed in the "A" band.

Table 4 Comparison of SEDBUK values and offsets							
Boiler	**Fuel**	**SEDBUK equation**	**Manuf's SEDBUK %**	**DEFRA SEDBUK %**		**Offset direct method**	**Offset Indirect method**
				Direct method	**Indirect method**		
A	Gas	104	90.2	89.60	88.72	0.6	1.5
B	Gas	104	91.1	90.63	90.09	0.5	1.0
C	Oil	202 and 203?	92.2	89.86	87.41	2.3	4.8
D	Oil	203	90	88.91	89.86	1.1	0.1
Average			**90.88**	**89.75**	**89.02**	**1.1**	**1.9**

4.3 Energy Balance Validation method (EBV)

The EBV method has been introduced to improve the quality of data that is accepted for entries in the Boiler Efficiency Database.

Table 5 shows that most results are acceptable, using the criteria of maximum acceptable residuals of -2% and -4% net for full-load and part-load respectively. Surprisingly, two of the full-load efficiency measurements fall just outside this limit.

Table 5 EBV results for combi test boilers				
Boiler	**Test**	**Measured Efficiency %net**	**Estimated Efficiency (from losses) %net**	**Residual value % gross**
A	Full-load 80/60°C	98.4	96.2	-1.94
B	Part-load 30°C return	107.8	107.0	-0.73
C	Full-load 80/60°C	99.0	95.9	-2.8
	Part-load 30°C return	108.2	107.8	-0.37
A	Full-load 80/60°C	97.4	95.5	-1.73
B	Full-load 50/30°C	103.5	101.4	-1.98
C	Full-load 80/60°C	96.7	94.2	-2.25
	Full-load 50/30°C	98.9	97.2	-1.57

5 Hot water test results

5.1 EN 13203 tests

Figure 3 show the results of hot water draw-off test in accordance with BS EN 13203-2:2006. The test results are based on the tapping cycle No.2 of table 3, which is based on a volume of 100 litres of water at 60°C (50K rise). This is equivalent to a total energy drawn-off of 5.845kWh over a 24 hour period.

The efficiency values are based on gross CV (calorific value) so that they can be compared to SEDBUK values. (BS EN13203 uses net values.) The fuel efficiency values are based on fuel (gas or oil) input only. The figure also shows the effect on efficiency of including the additional electrical input over the test period (not part of EN13203). This does not take account of the carbon intensity of electricity, which must be evaluated separately.

The gas-fired combi boilers include a “keep-hot” facility and tests were completed both with and without this facility active. The oil-fired combi boilers have hot water stores which remain hot in normal operation.

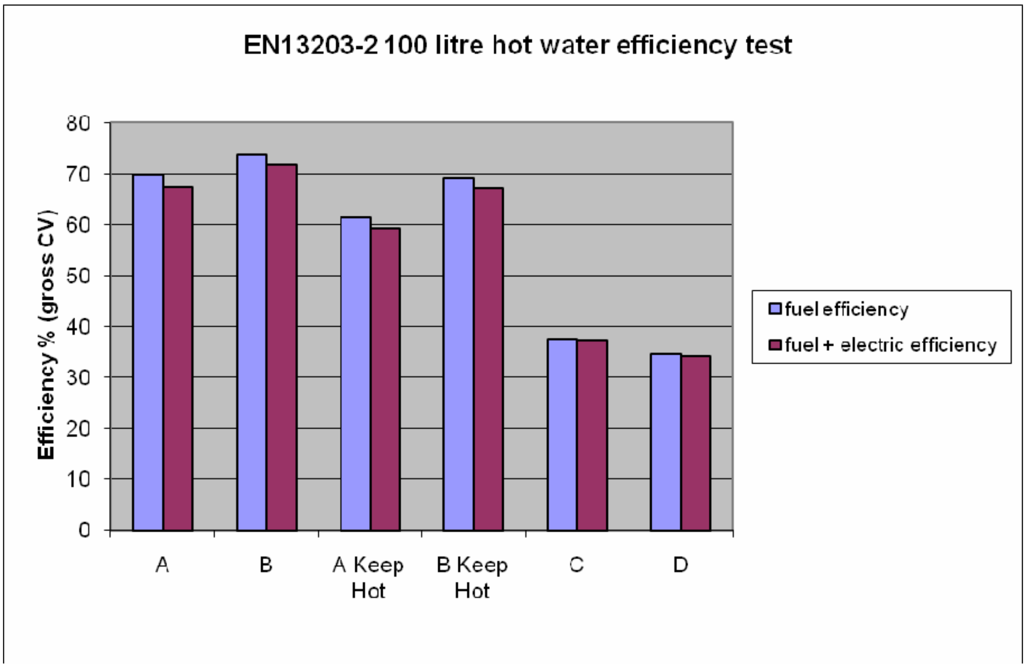

Figure 3: Hot water efficiency test results

A difficulty with storage combi boilers is that the amounts of heat in the store at the start and beginning of a test may differ substantially. To examine the possible variation, the storage combi boilers were tested over 3 consecutive days with the store temperature recorded at at the beginning and end of each day at four points, equally spaced vertically. The following table shows the unadjusted and adjusted hot water efficiencies over three consecutive days.

Table 6 – Domestic hot water efficiency results over three consecutive days (% net)				
	Day 1	Day 2	Day 3	Average[9]
Oil storage combi C				
Unadjusted	36.7%	38.0%	36.0%	36.9%
Adjusted for change in store temperature	36.5%	34.9%	39.4%	37.0%
Change (% points)	-0.2%	-3.1%	+3.4%	+0.1%
Oil storage combi D				
Unadjusted	39.7%	41.5%	39.5%	40.2%
Adjusted for change in store temperature	39.0%	38.3%	39.5%	39.0%
Change (% points)	-0.7%	-3.2%	0%	-0.8%

The adjustments due to a net gain or loss of heat in the store over a day can be as much as 3.4 percentage points. Over three days this reduced to 0.8 percentage points or less.

The adjustment for day three is not smaller than for day one, suggesting that the extra days do not necessarily reduce the energy difference between the start and end of the test. An estimate of the heat content of the store at the beginning and end of the test is essential.

The data used in figure 3 is the adjusted efficiency over three days. These results indicate that instantaneous gas combis with a keep-hot facility achieve DHW efficiencies of around 70% (gross CV). This efficiency is reduced by around 5-10 percentage points if a keep-hot facility is active.

The oil storage combi boilers (whose stores are maintained hot continuously over a 24 hour period) have much lower DHW efficiencies (around 35%) due to the very significant standby losses (see below)

5.2 Standby Losses

The EN13203 results provide overall efficiency, but it is also necessary to establish the losses from the system and see how they compare to assumptions in SEDBUK and the SAP.

Figure 4 shows the energy input required for each unit to remain hot with no draw-off. This is sometimes referred to as standby loss (as used in PAS-67) but this is quite different to the standby loss described as part of the indirect part-load efficiency calculation method. The results shown for gas boilers are with the “keep-hot” active.

[9] Based on (sum of heat in) ÷ (sum of heat out) for the three days

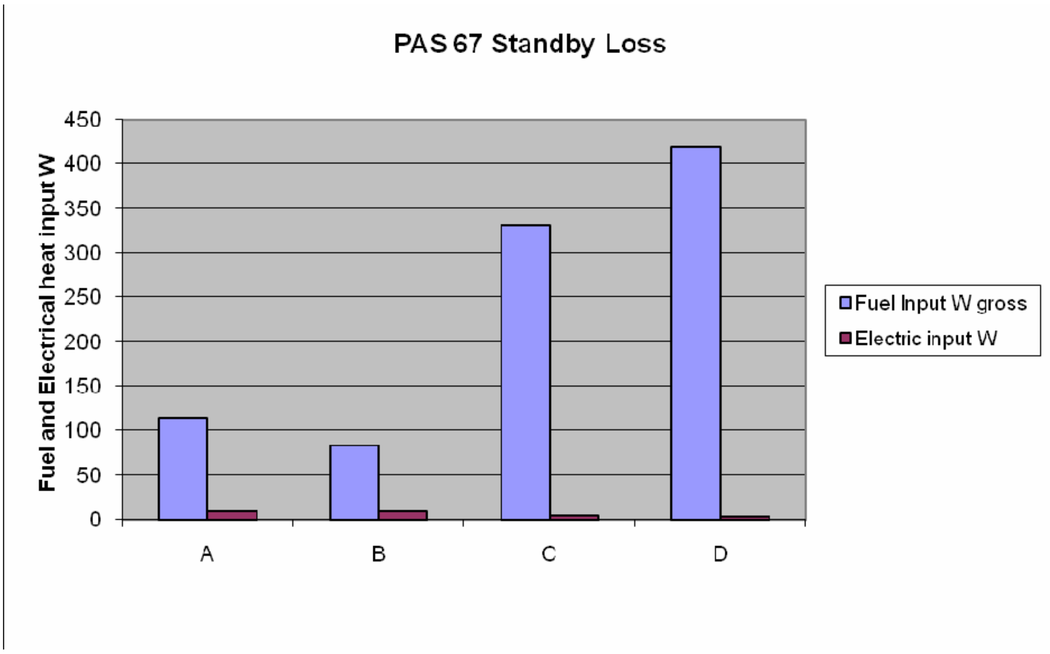

Figure 4: Heat input required to keep hot at 0% hot water load

These results have been obtained using the procedure given in PAS-67. At the time the tests were carried out, the procedure used was to simply record the energy input over 24 hours without consideration of the boiler operating cycles.

Further analysis shows that cycle time can have a significant effect on the results. Table 7 shows this effect. The standby condition cycle time was estimated from electrical data. The gas boilers fire at relatively short intervals for a short period of time to keep the appliance and a small volume of water hot. The oil-fired boilers have a large store and the boiler firing intervals are much longer. Therefore when testing these boilers knowledge of the cycle time is essential to ensure the standby loss is accurately determined over a whole number of complete cycles.

Table 7 Adjusted standby heat loss using cycle time at 0% hot water load.

Boiler	**Measured fuel heat input W**	**Estimated standby cycle time (hours)**	**Adjusted fuel heat input W**
A	115.4	1.3	118
B	84.0	0.56	82
C	331. 8	No data	-
D	420.2	4.9	411

Table 8 shows the measured standby loss values with the estimated equivalent annual fuel consumption and compares it to what is assumed in the SAP.

SAP also assigns 900kWh/yr and 600kWh/yr to an un-timed or timed keep-hot facility at a fuel-to-heat conversion efficiency equal to the SEDBUK value. The heat loss from the store is calculated in SAP from the store size and insulation thickness. The insulation level assumed in the SAP calculations of Table 8 is 25mm of foam.

Table 8 Fuel required to keep appliance hot at 0% hot water load compared to SAP assumptions

	PAS-67 Standby Loss W	**Annual equivalent[10] kWh/yr**	**SAP kWh/yr**
A	118	1034	1000 [11]
B	82	718	1000 [11]
C	331.8	2907	617 [12]
D	411	3600	770 [13]

Combi boiler C is incorrectly classified as an oil instantaneous boiler in the boiler efficiency database. In fact it is a primary storage combi boiler. The total water content is 48.5 litres; 16 for the heat exchanger and 32.5 for the primary store. The effect of incorrect classification is to ignore the standby storage heat losses of 617 kWh/yr and include a combi heat loss of 1000 kWh/yr.

The standby heat loss from the two oil storage combi boilers tested is considerably greater than assumed in the SAP. Possible reasons for this include the shape of the store and actual insulation thickness and properties. SAP assumes a cylindrical shape whereas the stores of these boilers actually resemble a rounded rectangular box shape.

Changes to SAP to take account of these significantly higher losses will be required. This could be arranged by an additional constant loss and/or a factor dependent on water content. Further data on storage combi appliances is required, which should include test data on gas-fired storage units that have similar characteristics to oil-fired units.

[10] Left column x 365 x 24 x 0.001
[11] = 900 / (SEDBUK = 0.90)
[12] = SAP table 2 x Table 2a x table 2b x volume x days/yr = 0.024 x 1.3524 x 0.9663 x 48.5 x 365 / (SEDBUK = 0.90)
[13] = SAP table 2 x Table 2a x table 2b x volume x days/yr = 0.024 x 1.1748 x 0.9102. x 74 x 365 / (SEDBUK = 0.90)

5.3 Influence of Keep-hot facility

The effect of the keep-hot facility of the two gas combi boilers on losses can be evaluated in two ways:

1) The difference between the EN13203:2 results with and without the keep-hot facility active. This applies only to the heat load provided by schedule No. 2 of EN13203:2; ie 100 litres water warmed by 50K.

2) The annual heat required by the keep-hot facility with zero hot water load; ie the standby loss.

SAP assigns 600kWh (at the fuel-to-heat conversion efficiency equivalent to the SEDBUK value) to a combi boiler without a keep-hot facility to represent the energy lost in rejected warm water. SAP also assigns 900kWh/yr and 600kWh/yr to an un-timed or timed keep-hot facility (at the fuel-to-heat conversion efficiency equal to the SEDBUK value.)

Table 8 compares the test results with assumptions in the SAP. It shows surprisingly large differences between the fuel consumed by the keep-hot facility at zero litres/day and 100 litres/day. Further examination of boiler firing times confirmed that these large differences are correct. It shows that when hot water is drawn fairly regularly throughout the day, as in the EN13202:2 No. 2 schedule, relatively little energy is wasted. It is concluded that heat losses resulting from the use of a a keep-hot facility are significantly influenced by the hot water load. Further test data using different EN13203:2 draw-off schedules are required to understand the characteristics.

It is concluded that SAP considerably overestimates the consumption of the keep-hot facility for these two boilers at a consumption of 100 litres/day.

Table 9 Comparison of laboratory and SAP data for a keep-hot facility.

Boiler	Domestic hot water efficiency (% net)		Fuel consumption of the keep-hot facility.			SAP additional combi loss
	Keep-hot status		(% of active)[14] EN13023 (100 litres/day)	Heat required at 100 litres/day	Heat required at zero load	
	Inactive	Active	%	kWh/yr	kWh/yr	kWh/yr
B	81.7	76.9	6.2%	179	1034	1000[15]
A	77.4	68.1	13.7%	414	718	1000

5.4 Influence of rejected water

Domestic hot water from a combi boiler with keep-hot inactive takes time to warm up since the water and metal in the appliance cools after each draw-off. The keep-hot system will minimise this but EN13203:2 specifies minimum temperature requirements for most of the draw-offs in

[14] As consumption is inversely proportional to efficiency, keep hot consumption (%) = (1 - efficiency(inactive) ÷ efficiency(active)

[15] 900 / (SEDBUK = 0.9)

the schedule. If not up to temperature, water is rejected until the minimum temperature is achieved.

With the facility active, as expected virtually none of the hot water is wasted (see Table 9). With the facility inactive a surprisingly small amount is wasted; mostly in the first water draw off.

The assumed losses in SAP (called additional combi losses in SAP) are very much higher than the measured figures for these two boilers.

Table 9 Comparison of rejected water data by keep-hot status

Boiler	Water rejected and status of keep-hot facility				
	Inactive % of heat output	Active % of heat output	Inactive heat requirement (kWh/yr)[16]	Active heat requirement (kWh/yr)	SAP assumption (kWh/yr)
B	0.07%	0.03%	<2	<1	600
A	0.70%	0.09%	15	<2	600

[16] ie, before the boiler efficiency is applied.

6 PAS-67 tests

6.1 PAS-67 applied to boilers

Two of the boilers were tested under PAS-67 as if they were micro-cogeneration packages. The principles of PAS-67 are not limited to any particular heating technology and the tests can be applied to a wide range of heat generators intended for use within a single dwelling.

The Annual Performance Method (APM) for assessing micro co-generation systems was applied to the test data obtained. The APM produces intermediate results required by SAP and the HPER (annual average CO_2 emissions per kWh heat). The latter is a single indicator to compare co-generation systems by taking into account the fuel used and electricity produced or generated. The HPER for a boiler of known SEDBUK value is needed for use as a comparator and minimum standard for other heating technologies in the MCS scheme.

The APM results are shown below in Figure 5.

Micro-cogeneration annual performance data produced by the Annual Performance Method **Annual results reported for:** Manufacturer's name: Boiler A Unique package identifier: Boiler A Selected test regime: number 3 Package type: CombiPK Electricity mode: Syncronous Fuel: Mains gas				
Intermediate results for SAP	R=0.5	R=1	R=1.5	R=4
2.13.1 Annual heat generated for space heating kWh	51608.2	38146.5	27578.1	10390.2
2.13.2 Annual heat generated for water heating kWh	1957.3	1957.3	1957.3	1957.3
2.13.3 Annual auxilary heat requirement kWh	31513.2	3414.3	129.1	0.0
2.13.4 Heat efficiency in the heating season % gross	88.8	90.1	91.0	85.0
2.13.5 Heat efficiency in the summer season % gross	61.3	61.3	61.3	61.3
2.13.6 Electricity consumed in the heating season kWh_e	118.2	97.1	82.3	68.4
2.13.7 Electricity consumed in the summer season kWh_e	33.8	33.8	33.8	33.8
2.13.8 Number of days operating at 16 hours insteads of 9 hours	0	0	0	0
2.13.9 Number of days operating at 24 hours insteads of 9 hours	0	0	0	0
2.13.10 Number of days operating at 24 hours insteads of 16 hours	0	0	0	0
Seasonal rating				
Heating plant emission rate kg of CO_2 per kWh_h	0.295	0.234	0.218	0.237

Micro-cogeneration annual performance data produced by the Annual Performance Method **Annual results reported for:** Manufacturer's name: Boiler B Unique package identifier: Boiler B Selected test regime: number 3 Package type: CombiPK Electricity mode: Syncronous Fuel: Mains gas				
Intermediate results for SAP	R=0.5	R=1	R=1.5	R=4
2.13.1 Annual heat generated for space heating kWh	58868.8	43513.2	31457.9	11851.9
2.13.2 Annual heat generated for water heating kWh	1962.0	1962.0	1962.0	1962.0
2.13.3 Annual auxilary heat requirement kWh	35946.7	3894.6	147.2	0.0
2.13.4 Heat efficiency in the heating season % gross	88.3	90.3	91.9	85.2
2.13.5 Heat efficiency in the summer season % gross	69.2	69.2	69.2	69.2
2.13.6 Electricity consumed in the heating season kWh_e	335.6	271.0	222.9	153.9
2.13.7 Electricity consumed in the summer season kWh_e	27.8	27.8	27.8	27.8
2.13.8 Number of days operating at 16 hours insteads of 9 hours	0	0	0	0
2.13.9 Number of days operating at 24 hours insteads of 9 hours	0	0	0	0
2.13.10 Number of days operating at 24 hours insteads of 16 hours	0	0	0	0
Seasonal rating				
Heating plant emission rate kg of CO_2 per kWh_h	0.297	0.235	0.216	0.236

Figure 5: APM results for the two gas boilers (keep-hot active)

6.2 Heating Plant Emission Rate (HPER)

HPER varies with plant size ratio. For boilers a plant size ratio of 1.5 is typical and for the two gas combi boilers the HPER is 0.220 and 0.219 respectively. This suggests a target for other heat generators (such as co-generation units) of 0.220 or lower.

6.3 SEDBUK/SAP and APM/SAP routes

The section compares the performance as determined via the APM/SAP and SEDBUK/SAP route for the two gas combi boilers. The APM intermediate results are those that would be required for a SAP assessment if the APM method were applicable to boilers.

For boiler A the heating season efficiency is 91.0% (gross) and summer efficiency 61.3% (net) giving an annual efficiency of 87.2 %(gross)[17]. This will include losses attributable to the keep-hot function. For boiler B the annual efficiency would be 89.2 (gross)%.

The SEDBUK value for boilers is only part of the information required on its performance to be used in the SAP. Other factors like storage heat losses and heat in rejected water are also included.

The SEDBUK values are 90.2% and 91.1% for boiler A and B respectively. SAP includes a 900 kWh/yr "combi loss" for combi boilers with an un-timed keep-hot facility; the case for both boilers. For an average heating requirement of 14,000 kWh/yr, this corresponds to an annual efficiency of 84.2%[18] and 85.6% for boilers A and B respectively.

Thus for an average heating requirement the SEDBUK/SAP route is 3 and 4 percentage points lower than the APM/SAP route for boilers A and B respectively. This reduction is principally due to assumptions SAP makes concerning the relative fuel consumption due to the use of keep-hot facilities. In APM/SAP the consumption due to the keep-hot facility is implicit in the laboratory results used by the APM.

6.4 Electrical consumption

In the APM any electrical consumption due to the electrical components in the boiler is included in the intermediate data. (This is in addition to the central heating system pump.) For an average dwelling this equates to 42kWh/yr and 99kWh/yr for boilers A and B respectively. As a comparison, SAP assigns 45kWh/yr for the fan consumption over the whole year.

[17] (1÷ (0.09/0.613 + 0.91/0.91)) where 0.09 is the summer hot water consumption expressed as fraction of the annual.

[18] = (14000 / 14900) x 0.902

7 Conclusions and recommendations

1. The full-load and part-load efficiencies from DEFRA tests on these 4 combi boilers are lower than those claimed by the manufacturers. This is consistent with previous experience in carrying out independent tests.
2. SEDBUK values based on DEFRA tests are on average 1-2% lower than quoted by manufacturers, but the offsets are less than those applicable to the full-load and part-load efficiencies due to the effects of capping in the SEDBUK formulae.
3. The EN13203:2 hot water tests show the instantaneous gas combi boilers to have hot water efficiencies of around 70% (gross) with the keep-hot feature inactive. When the keep-hot is active efficiency is reduced by 5-10%.
4. The EN13203:2 hot water tests on oil-fired storage combis have hot water efficiencies of around 35% (gross). This very low figure is due to the very significant standby losses; ie 300-400W, compared with around 80-100W for gas instantaneous units.
5. The standby loss was determined using the procedure in PAS-67. These tests confirm that it is important to take account of the re-heat cycle time so that an integral number of cycles is measured within the test period.
6. The heat losses from the oil combi boilers are 3-4 times greater than that assumed in SAP. Changes to the default losses for these appliances in SAP are recommended.
7. SAP assumes 900kWh/year for keep-hot losses, whereas actual values obtained for the two gas instantaneous combi boilers are at least 50% lower.
8. The EN13203:2 tests on the two gas instantaneous combi boilers show very low levels of rejected water (under 1% in energy terms) when operated without the keep-hot active for the No. 2 schedule. This is much lower than assumed in SAP (28%). It is recommended that SAP should make use of EN13203 test data, when available, which should provide improved results relative to SAP default values.
9. The two gas combi boilers when tested following the PAS-67 method and analysed by the APM showed HPER values of 0.220 and 0.219 kg CO_2 per $kWh_{heat.}$ This suggests a target (in order to have improved performance relative to a gas condensing boiler) for co-generation packages of 0.220 kg CO_2 per kWh_h.
10. A comparison of using the SEDBUK/SAP and APM/SAP routes for measuring the performance of a gas combi boiler was completed. For an average annual heating requirement this suggests the SEDBUK/SAP route gives 3-4% lower equivalent efficiencies than the APM/SAP route. This reduction is principally due to assumptions SAP makes concerning the consumption of the keep-hot facility. In the APM/SAP route the consumption due to the keep-hot facility is implicit in the laboratory results.
11. The oil combi boiler C is incorrectly classified in the boiler database as an instantaneous unit using SEDBUK equation 202. It should use equation 203 (for a storage combination boiler). The effect of the misclassification is to include extra losses attributable to rejected warm water but exclude the storage losses. It is not possible

quantify the impact of the misclassification without doing a full SAP calculation due to the complex interaction of heat gains from hot water on space heating consumption.

It is recommended that this is corrected in the boiler database and that classification checks are carried out on other oil instantaneous combi boilers.

12. Large hot water stores can introduce errors in the EN13203 tests due to unknown changes in the heat content of the store during the test. Repeating the tests of number of consecutive days has shown that that the error does not necessarily reduce with repeated days. It is still necessary to estimate the heat content at the beginning and end of the test by making temperature measurements and make adjustments for the heat imbalance.