Laboratory tests on domestic gas and oil boilers

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Summary

A series of detailed efficiency and hot water performance tests have been carried out on six gas and six oil-fired combi boilers. The purposes of the test programme were to compare energy performance with manufacturers' claims, to ascertain the hot water performance of gas storage combis, to determine surface heat losses from oil boilers, and to confirm planned changes to the treatment of boilers in SEDBUK and the SAP.

These independent tests have shown that the efficiency values of gas boilers are generally similar to those used by manufacturers to support applications for entries in the Boiler Efficiency Database. This is contrary to earlier independent tests, where results were significantly lower. For oil-fired boilers, however, the efficiencies obtained are in all cases lower than manufacturers' claims.

When translated into SEDBUK values for the boiler efficiency database, both oil and gas boiler results remain within the same efficiency band with one exception. All boilers would retain their “A” rating under SEDBUK 2005 except one oil-fired boiler. The oil-fired boilers were, on average, 1-2% lower than the SEDBUK efficiencies claimed.

Surface heat losses from the oil-fired boilers have been determined to provide data to support recent changes to SEDBUK equations for SAP 2009. Results of these tests have been compared with results using an alternative electrical method.

The hot water efficiency results (EN13203) for gas storage combi boilers were higher than the unexpectedly low figures obtained in a previous test programme on oil-fired storage combis. However, results are somewhat lower than instantaneous units with or without the “keep-hot” facility in operation.

The results for gas storage combis show that the algorithms in SAP significantly underestimate storage heat loss from the store's volume, type (primary or secondary) and insulation thickness. This is consistent with previous results for oil storage combis. Future changes to SAP are required to deal with this underestimate and to encourage manufacturers to provide hot water performance data.

Contents

1 Introduction

A series of performance tests have been carried out on six gas and six oil-fired boilers. Full and part-load efficiency tests have been carried out on all the boilers. Some boilers have also been subjected to hot water tests to EN13203 and heat-loss tests using the surface temperature method. The objectives were:-

- To monitor the energy performance of boilers placed on the market in fulfilment of DECC'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 gas-fired storage combi boilers. This will inform proposed changes to SAP[3].
- To support recent changes to SEDBUK, especially for oil boilers. Further test data will be used to compare with key assumptions used in the SEDBUK theory and its use within the SAP.
- To obtain actual efficiency measurements for two boilers operated on LPG (G31 propane).
- To provide further data to support the Energy Balance Validation[4] (EBV) procedure.

[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] Hayton J, Energy Balance Validation: Investigation of the residual energy of thermal efficiency tests on gas and oil boilers, STP09/B02, February 2009, BRE

2 Description of the project

A series of efficiency tests have been carried out on natural gas and oil-fired condensing boilers. The range of tests undertaken was:-

(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) Standing heat loss measurements using the surface temperature method.

(e) Regular gas boilers were tested using both natural gas (G20) and LPG (G31).

Table 1 shows the boiler tests undertaken and the numbers of boilers tested.

Activity/test	Storage combi nat gas	Combi nat gas	Regular nat gas	Regular LPG	Regular Oil
Efficiency at full-load, part-load and minimum controlled rate (both direct and indirect methods)	2	2	2	2	6
Hot water tests to EN 13203 (2)	2	-	-	-	-
Standing heat loss using surface temperature method	-	-	-	-	6
Electrical power measurements	2	2	2	2	6

Table 1 test programme

The test programme was carried out by Enertek Ltd using their dedicated automated test rigs. Enertek 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 8 months following the final test, and (e) dispose of the boilers on confirmation they are no longer to be retained.

For the purposes of this contract, GL Industrial Services (formerly Advantica Certification Services and now part of BSI), a Notified Body under the Boiler Efficiency Directive (and the Gas Appliance Directive) certified Enertek's efficiency results by conducting appropriate witness testing. GL also verified that all test procedures were in accordance with the relevant requirements and that the results are of equivalent quality to those from a Notified Body.

3 Selection of Boilers

Twelve boilers were selected for test as shown in Table 2. They are referred to here as A to L. The initial criterion for boiler selection was that, where possible, market leaders should be selected. However in previous years some current market leaders have already been tested, and therefore the opportunity was taken to test other products with anticipated reasonable sales figures. The oil-fired boilers were selected after consultation with OFTEC..

Table 2 Boiler details

Boiler	Fuel	Type	Output kW	SEDBUK equation
A	Natural Gas (G20)	Storage combi	30	106
B	Natural Gas (G20)	Storage combi	24	106
C	Natural Gas (G20)	Instantaneous with keep-hot	24	104
D	Natural Gas (G20)	Instantaneous with keep-hot	18	104
E	Natural Gas and LPG (G31)	Regular	14	102
F	Natural Gas and LPG (G31)	Regular	26	102
G	Oil	Regular	36	201
H	Oil	Regular	24	201
I	Oil	Regular	25	201
J	Oil	Regular	25	201
K	Oil	Regular	19	201
L	Oil	Regular	26	201

4 Space heating efficiency results

4.1 Comparison of test efficiency values

Manufacturers quoted results[5] are described as “Manufacturers’” and the results from this series of tests are described as “DECC”.

Figures 1 (gas) and 2 (oil) shows the manufacturers’ full -load efficiency values and compares them with the results of these DECC tests on “off-the-shelf” boilers.

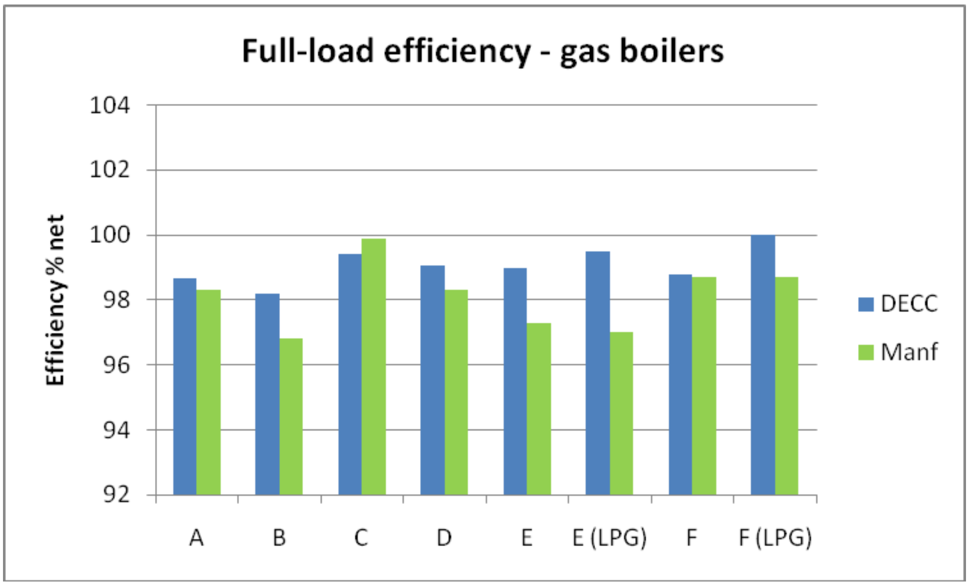

Figure 1: Full-load efficiency at 80/60°C– gas boilers

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

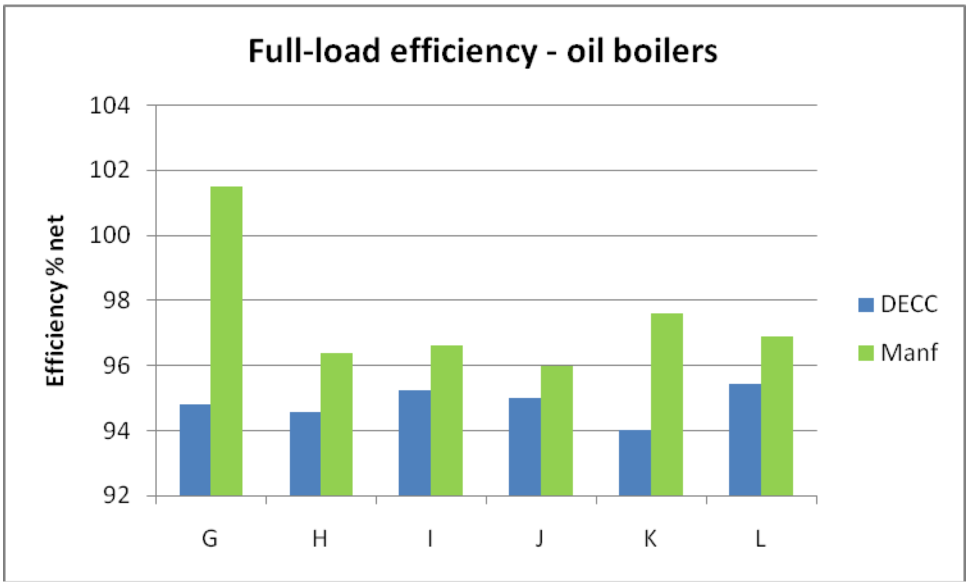

Figure 2: Full-load efficiency at 80/60ºC– oil boilers

Figures 3 (gas) and 4 (oil) shows the manufacturers' part -load efficiency values and compares them with the results of these DECC tests on "off-the-shelf" boilers. Results are shown using both direct and indirect methods as given in as given in BS EN 483, 304 and 677.

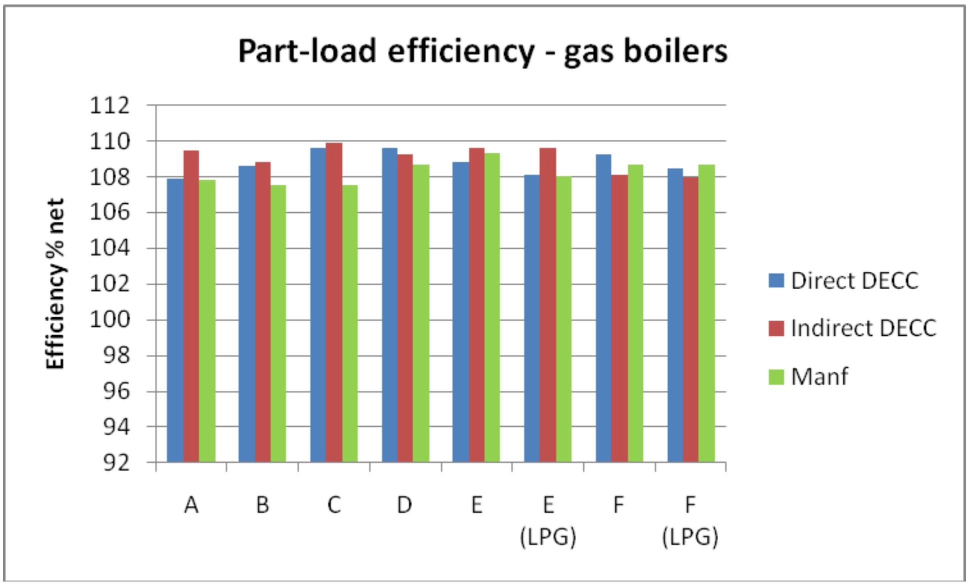

Figure 3: Part-load efficiency– gas boilers

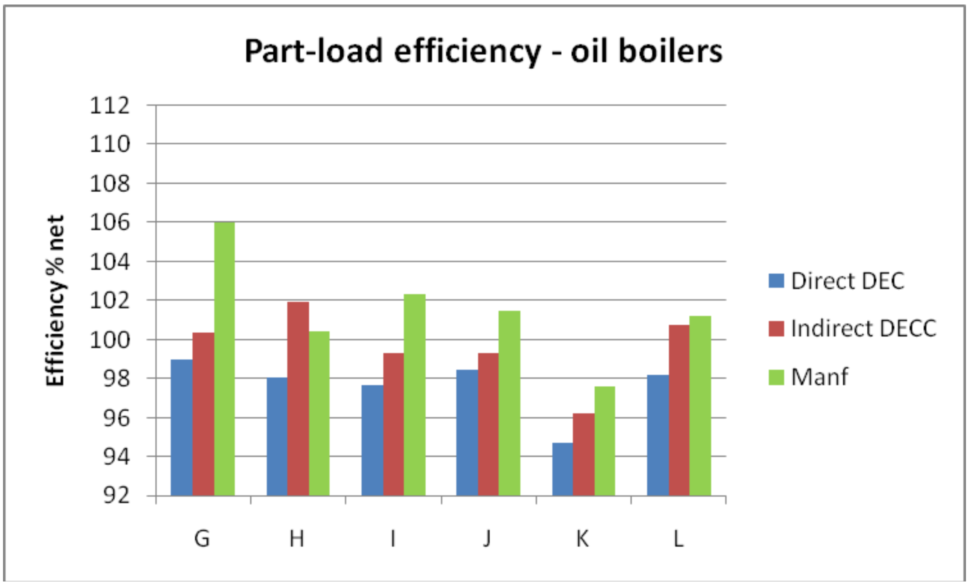

Figure 4: Part-load efficiency– oil boilers

Table 3 shows the offset (% points efficiency) for each boiler test result. The offset is defined as the DECC 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	G20	0.4	0.0	1.7
B	G20	1.4	1.1	1.3
C	G20	-0.5	2.1	2.4
D	G20	0.8	0.9	0.5
E	G20	1.7	-0.5	0.3
E (LPG)	G31	2.5	0.1	1.6
F	G20	0.1	0.5	-0.6
F (LPG)	G31	1.3	-0.2	-0.7
G	C2	-6.7	-7.0	-5.7
H	C2	-1.8	-2.4	1.5
I	C2	-1.4	-4.6	-3.0
J	C2	-1.0	-3.1	-2.2
K	C2	-3.6	-2.9	-1.4
L	C2	-1.5	-3.0	-0.4
Average	G20 &	1.0	0.5	0.8
Average oil	C2	-2.7	-3.8	-1.9
Average all		-0.6	-1.4	-0.3

The independent DECC efficiency results show that whilst the oil boiler efficiencies are generally lower than quoted by the manufacturer, the gas efficiencies are slightly higher than quoted by the manufacturer. Compared with a recent analysis of a much larger sample[6] this sample shows that gas boiler results are generally higher (based on heat to water efficiencies) than claimed by manufacturers. For oil boilers the reverse is true and in line with the previous analysis.

4.2 SEDBUK comparison

Figure 5 shows a comparison of the manufacturers versus DECC SEDBUK values (based on SAP2005). SEDBUK values have been calculated using both direct and indirect part-load efficiency data. All boilers in this series of tests were in SEDBUK efficiency band "A", and based on these DECC tests all but one (K) would retain that banding. Oil boiler G, has an exceptionally high claimed efficiency but based on DECC tests it has an efficiency similar to other oil boilers.

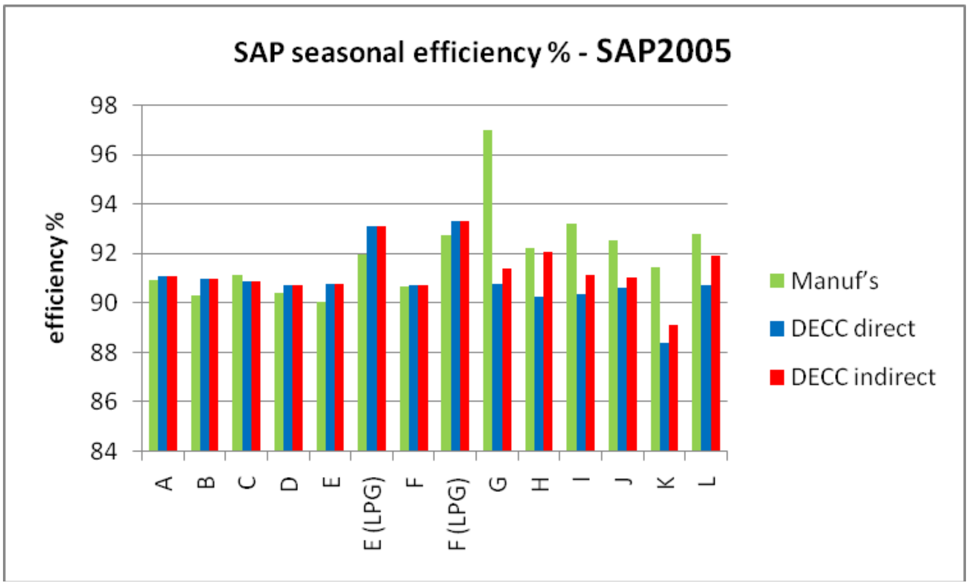

Figure 5 Seasonal efficiency based on SAP2005

Figure 6 uses the same boiler efficiency data but instead uses SAP2009 to calculate seasonal efficiency. Gas boilers (both G20 and G31) have 1-2% lower efficiencies. Using DECC results all natural gas boilers would fall into SEDBUK band "B" whilst LPG (G31) boilers would remain in band "A". Oil boiler efficiencies only reduce slightly and 5 remain in band "A" and one (K) falls to band "B".

The manufacturers results for boiler E using LPG are based on actual tests using LPG whereas the manufacturers results for boiler F using LPG are based on tests for natural gas and then derated by 2.2% points as given in BS EN677. The DECC tests confirm the higher actual efficiency using LPG (G31) compared to natural gas (G20).

[6] Hayton J, A meta-analysis of boiler test efficiencies to compare independent and manufacturers' results, STP09/B05, March 2009, BRE

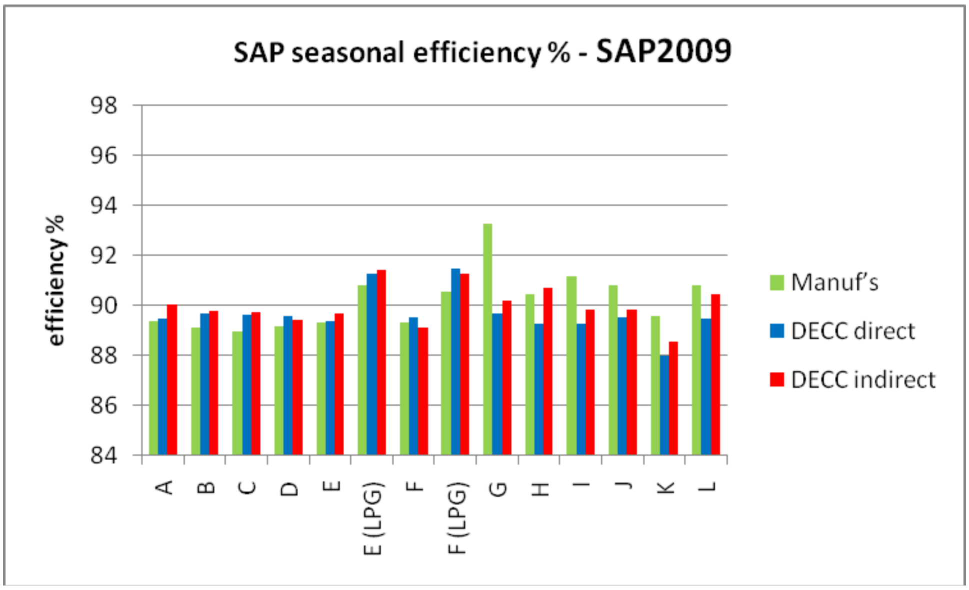

Figure 6 Seasonal efficiency based on SAP2009

4.3 Energy Balance Validation method (EBV)

The EBV method was introduced to improve the quality of data that is accepted for entries in the Boiler Efficiency Database (see ref 4).

Figures 7 and 8 show the calculated residuals for gas (G20 and G31) and oil fired (C2) boilers. Results are shown for full-load tests at both at 50/30ºC and 80/60ºC and part-load tests using both direct and indirect test methods. The results show that the residuals are almost always negative and fall within the acceptable range, using the criteria of maximum acceptable residuals of -2% and -4% net for full-load and part-load respectively.

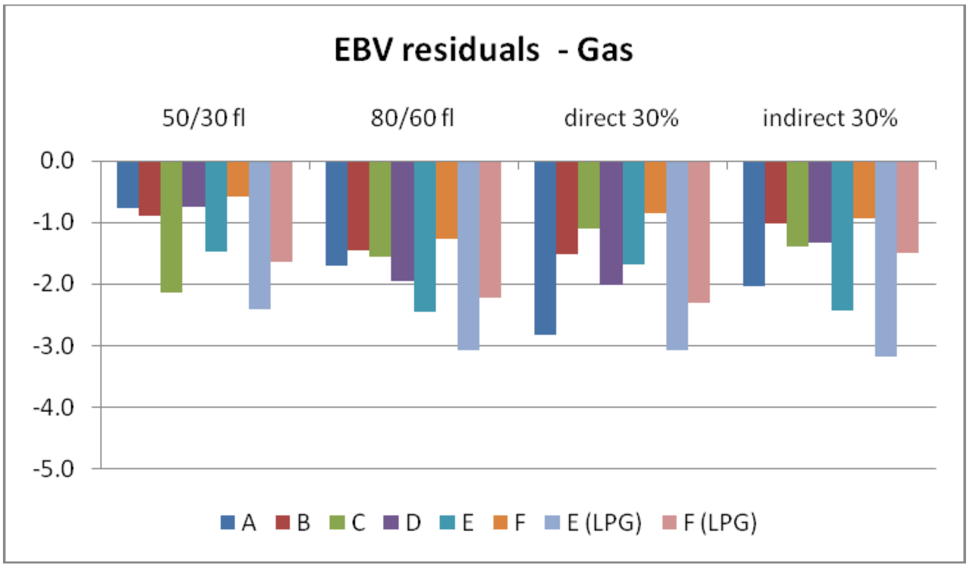

Figure 7 Calcuated residuals – gas boilers

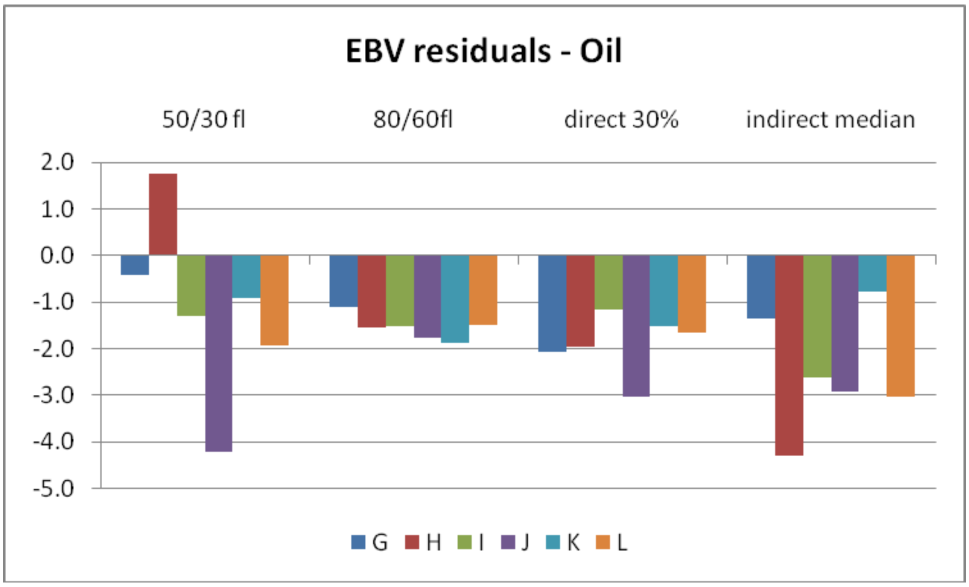

Figure 8 Calculated residuals – oil boilers

4.4 Oil boiler heat losses

This test programme included the determination of standing heat losses from each of the oil boilers. This was required to further support the equations used in SEDBUK. Previously the equations were based on a number of assumptions since test data was not available. This current data provides evidence to support changes which have been introduced in SAP2009.

The data collected are the heat losses based on surface temperature measurements of the boiler when operated under steady-state conditions. The test procedure is given in BS EN304 and uses a number of surface temperatures on each face of the boiler to estimate the overall emission heat loss. The average surface temperature is used with standard heat loss coefficients to determine heat loss. Table 4 shows the individual losses from each surface, the total and the proportion relative to boiler heat input. This data is used to support recent changes to SAP2009[7].

[7] Hayton J, Revision to the SEDBUK procedure for oil boilers, STP09/B03, March 2009, BRE

	G	H	I	J	K	L
TOP	9.45	16.90	20.40	35.80	26.73	18.04
LHS	25.38	31.00	24.43	24.97	38.32	20.09
RHS	22.16	27.56	28.81	22.14	32.70	10.57
FRONT	8.10	22.17	19.02	40.07	16.34	16.90
BACK	35.09	39.16	64.86	70.28	12.01	31.25
BASE	48.12	45.67	26.89	76.81	7.94	35.47
TOTAL	148.29	182.47	184.41	270.07	134.04	132.32
BOILER HEAT INPUT	41450	28040	28270	24730	20100	27160
LOSS AS %	0.358	0.651	0.652	1.092	0.667	0.487

Table 4 Heat losses (W) based on surface temperature method (EN304)

As part of the test programme, the heat losses from these boilers based on the "electrical method" (also from EN304) were obtained. Rather than using the oil fuel to heat the boiler, an external electrical heat source is used. Table 5 and Figure 9 shows a comparison of the two methods. The surface temperature method is carried out during a steady state test with the boiler flow and return at 80/60ºC and a nominal ambient temperature of 20ºC. This corresponds to a mean water temperature above ambient of 50ºC. The "electrical" test method is usually carried out with a mean temperature rise above ambient of 30ºC. Therefore for comparison data has been adjusted (using the approximate adjustment method given in EN304) so that losses can be compared at 30ºc temperature rise.

	G	H	I	J	K	L
Surface temperature method (50ºC rise)	148	183	184	270	134	132
Electrical method (30ºC rise)	128	169	153	173	111	93
Surface temperature method (**estimated** 30ºC rise)	78	97	97	143	71	70

Table 5 Heat losses (W) – comparison of test methods

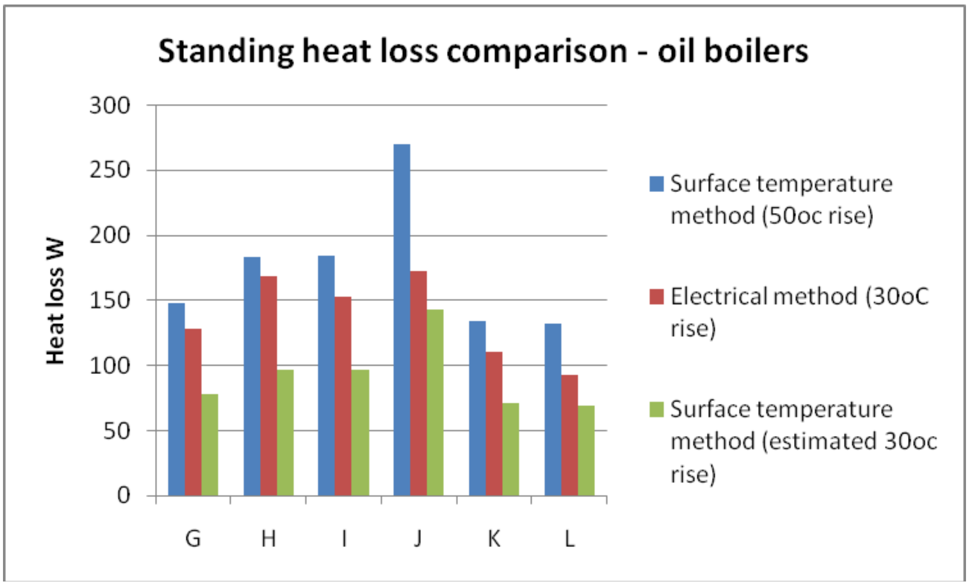

Figure 9 Heat losses (W) – comparison of test methods

5 Hot water test results

5.1 EN 13203 tests

Figure 10 show the results of hot water draw-off tests in accordance with BS EN 13203-2:2006[8]. The test results are based on the tapping cycles No.2 and No 3 of table 3, which are based on volumes of 100 and 200 litres of water at 60°C (50K rise). This is equivalent to a total energy drawn-off of 5.845kWh and 11.655kWh 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 calorific values.) The fuel efficiency values are based on fuel (gas or oil) input only.

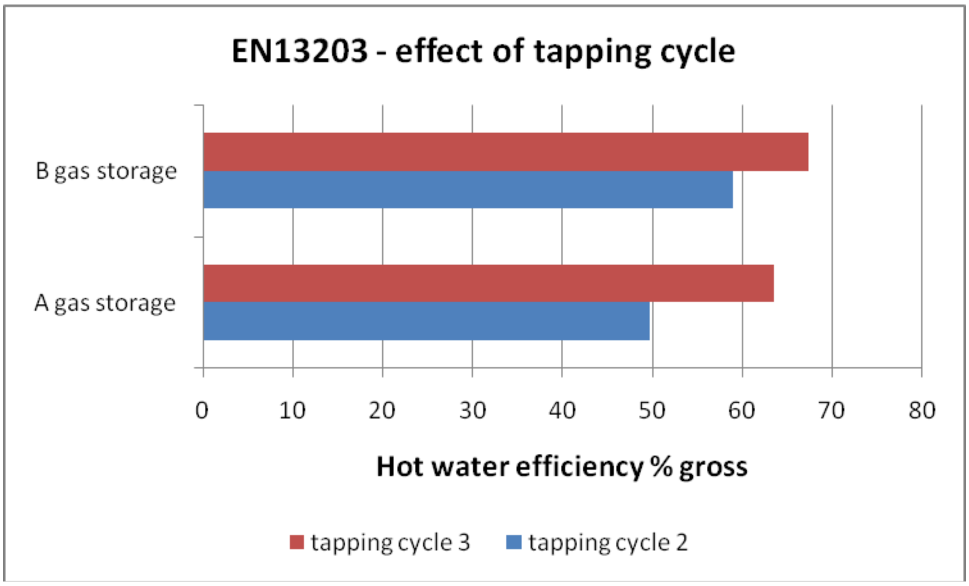

Figure 10 EN13203 efficiency results

A further comparison is shown in Figure 11 which compares these current results (gas storage combis A and B) with those obtained previously for gas instantaneous combis, and oil storage combis. The gas-fired combi boilers include a “keep-hot” facility (KH) 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.

[8] 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.

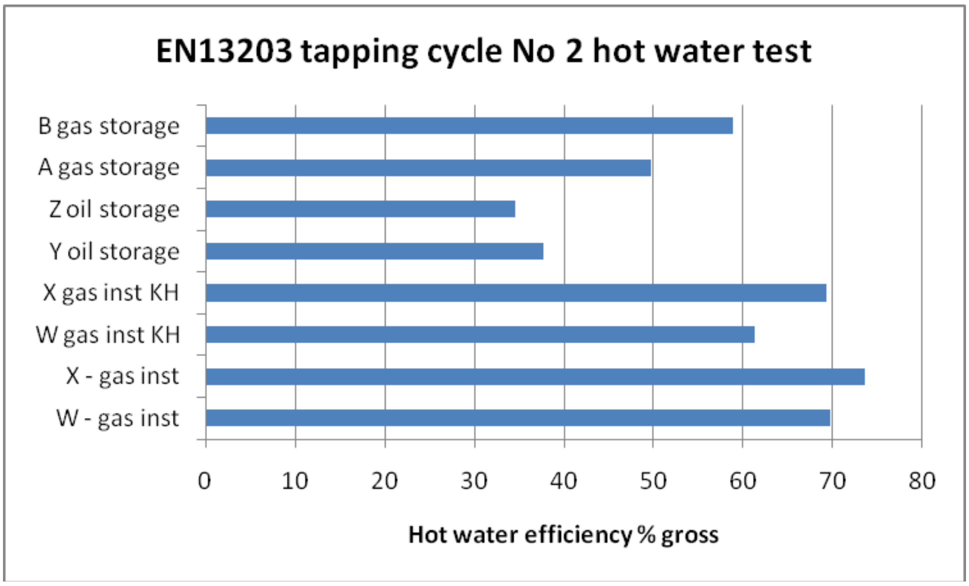

Figure 11: Current and previous hot water efficiency test results

A difficulty with estimating efficiency of storage combi boilers is that the amounts of heat in the store at the start and beginning of a test may differ substantially. To check this, temperatures at the start and end of the 24 hour test period were recorded at 7 heights on the store surface. Figures 12 and 13 show these temperatures for storage combis A and B.

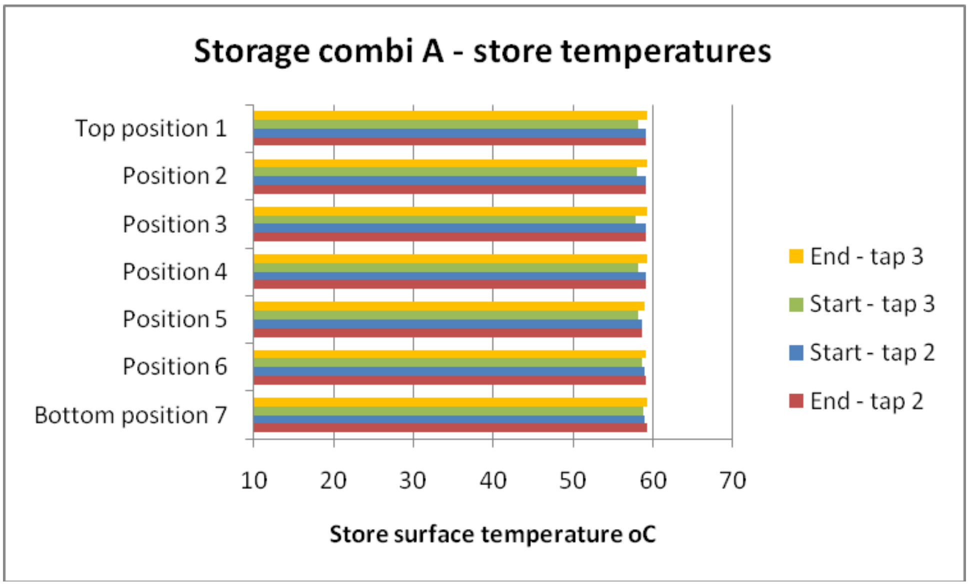

Figure 12: Store temperatures - A

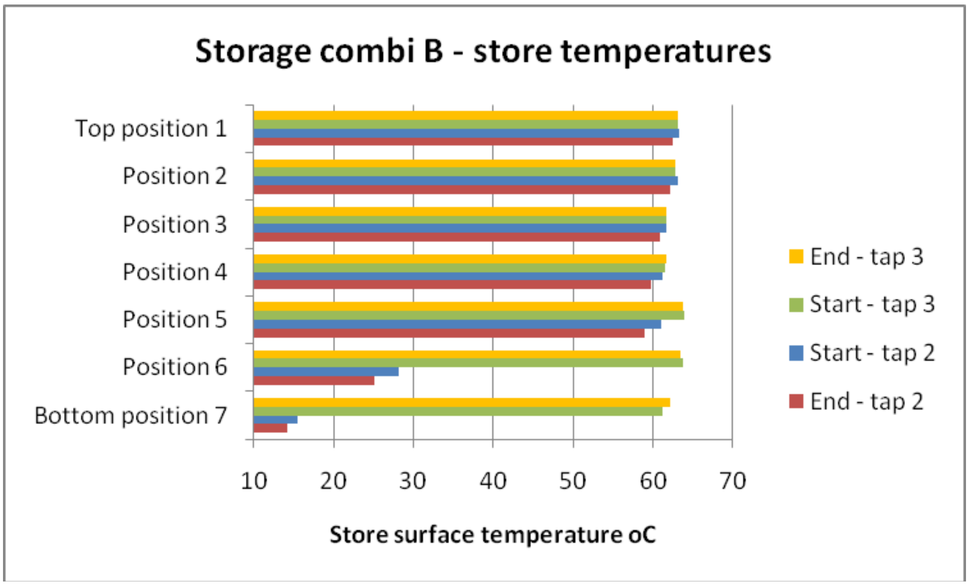

Figure 13: Store temperatures – B

5.2 Treatment of storage combis in SAP 2009 9:90

This section examines how the current test results compare with the results of previous tests[9] on gas instantaneous combis and oil storage boilers and the potential consequences when assessed in SAP 2009..

SAP 2009 introduced the use of hot water performance data to aid the energy assessment of a dwelling and its installed heating system. There are three possible options:

- provide no hot water performance data
- provide hot water performance for tapping cycle number 2
- provide hot water performance for tapping cycles numbers 2 and 3 .

The conclusions from previous tests generally led to the expectation of an improvement in performance of gas instantaneous combi boilers if they were to be supported by hot water performance data and assessed under SAP 2009. The conclusions for oil storage boilers were different, showing that either the efficiency was overestimated or the hot water storage heat loss was underestimated in SAP (derived from storage volume and insulation thickness)

The current tests on two natural gas storage combi boilers were carried out to try and resolve the matter. As mentioned in section 5.1 the average temperature of the store at the start and end of the test may differ and could have a significant impact on the measured efficiency over the 24-hour measurement window. To account for this the energy delivered is altered by the following:

Store adjustment = Change in store temperature during the test x 4.18 x volume of store[10]

[9] Shiret AR, Analysis of the results from energy performance tests on combi boilers, STP09/B04, March 2009, BRE

The test results and calculations are shown in Table 6 and the SAP 2009 optional results are shown in rows E and F. The adjustment in the useful heat delivered due to the change in energy content of the store is at most 2.2% but more typically less than 0.5%.

	Storage combi A		Storage combi B	
	Tapping cycle 2	Tapping cycle 3	Tapping cycle 2	Tapping cycle 3
Test results				
A. Useful heat delivered (kJ)	21096	42092	21130	42116
B. Net heat input (kJ)	38258	59661	32301	56297
Calculated results				
C. Change in store's energy (kJ)	-12	-180	732	-39
D. Store adjusted useful heat delivered (kJ) = A + C	21084	41912	21862	42077
E. Useful heat delivered – as required by EN13203 (kJ)	21042	41958	21042	41958
F. Net heat input (corrected) (kJ) = B x E ÷ D	37813	59726	31088	56137
% of water wasted by volume	2.15	0.98	1.3814	0.83

Table 6 Required data for SAP 2009

Three performance indicators are derived in SAP:

a) SAP hot water efficiency:

η_s= (useful energy delivered + storage heat loss) ÷ (fuel used)

This is not the same as the usual test hot water efficiency:

η = (useful energy delivered) ÷ (fuel used).

b) Storage heat loss before the SAP hot water efficiency is applied

c) Proportion of energy rejected because the water is too hot or too cold.

The Tables 7 and 8 show the SAP parameters calculated using the current laboratory test data for the following three cases:

- Hot water performance not supported by hot water results (defaults apply based on store volume and insulation thickness and efficiency value inferred from full load space heating efficiency)

[10] The factor 4.18 is the specific heat capacity of water in KJ/litre/degK

- Hot water performance supported by tapping cycle 2 results (the efficiency is inferred from efficiency of space heating at full load and storage heat loss is calculated from the hot water results and the inferred efficiency).
- Hot water performance supported by tapping cycles 2 and 3 results (both efficiency and heat loss are calculated from hot water results).

	SAP hot water efficiency (gross)	SAP storage heat lost over 24 hours	Proportion of energy rejected
No performance data	81.3%	1.824 kWh	0%
Only tapping cycle 2	87.0%	4.378kWh	1%
Tapping cycle 2 & 3	87.9%	4.426 kWh	0.5%

Table 7 SAP 2009 results for gas storage combi A, 47 litre store

	SAP efficiency (gross)	Storage heat lost over 24 hours	Proportion of energy rejected
No performance data	81.5%	1.135 kWh	0%
Only tapping cycle 2	86.8%	2.438kWh	0.7%
Tapping cycle 2 & 3	75.5%	1.335 kWh	0.4%

Table 8 SAP 2009 results for gas storage combi B, 115 litre store

Tables 9 and 10 show the resultant hot water efficiency (i.e. the energy content of the hot water divided by the fuel required) as estimated by SAP for a range of hot water consumptions and for three cases of performance supported by (i) no hot water results, (ii) tapping cycle 2 results and (iii) tapping cycles 2 and 3 results.

Occupancy or tapping cycle	Litres/day of water warmed by 37K	Storage combi A hot water efficiency		
		Hot water performance data used		
		None	Tap cycle 2	Tap cycle 2&3
1 person	61	47.9%	32.6%	32.7%
2 person	86	54.4%	39.8%	40.0%
3 person	111	58.8%	45.3%	45.6%
No 2 (4 person)	135	61.9%	49.6%	49.9%
No 3 (9 person)	270	70.2%	63.2%	63.6%

Table 9 Hot water performance predicted by SAP for storage combi A

Occupancy or tapping cycle	Litres/day of water warmed by 37K	Storage combi B hot water efficiency		
		Hot water performance data used		
		None	Tap cycle 2	Tap cycle 2&3
1 person	61	56.9%	44.7%	49.7%
2 person	86	62.3%	52.1%	55.2%
3 person	111	65.8%	57.2%	58.7%
No 2 (4 person)	135	68.2%	61.0%	61.2%
No 3 (9 person)	270	74.2%	71.6%	67.6%

Table 10 Hot water performance predicted by SAP for Storage combi B

As expected, increasing the volume of the hot water leads to higher efficiencies due to the lower relative impact of store heat loss.

Ideally, to encourage the provision of hot water performance data by manufacturers, the efficiency supported by tapping cycle 2 data should be higher than that not supported by any data. Similarly, if supported by data from both tapping cycles 2 and 3 the efficiency should be higher than tapping cycle 2 alone (otherwise there is no encouragement to carry out more than one hot water test). However, the efficiencies for using tapping cycle 2 alone and both tapping cycles 2 and 3 are very similar for 4-person occupancy. For lower occupancy levels the tapping cycles 2 and 3 give a higher efficiency; for higher occupancy (nine persons) the reverse is true.

However, the efficiencies inferred from no data are highest, which suggests that the default arrangements in SAP 2009 are too optimistic. This was the case for oil storage combi boilers[11] though not for instantaneous natural gas combi boilers. Referring to Tables 7 and 8, the biggest difference in the results between using no data and using tapping cycle 2 and 3 data (the best data provision) is in the value of storage heat loss. The SAP heat loss assuming no hot water performance data is provided is 42% and 58% of the measured value inferred from tapping cycle 2 and 3.

This is consistent with the oil storage combi results (table 11) and suggests the algorithms in SAP underestimate storage heat loss from the store's volume, type (primary or secondary) and insulation thickness. The likely explanation is that, originally, the algorithms were developed to estimate losses from a separate indirect cylinder. The under estimate will be offset considerably by the lower beneficial heat gains in space heating, providing the boiler is installed in the heated space.

[11] Shiret AR, Analysis of the results from energy performance tests on combi boilers, STP09/B04, March 2009, BRE

Occupancy or tapping cycle	Litres/day of water warmed by 37K	Oil storage combi Y hot water efficiency		Oil storage combi Z hot water efficiency	
		Hot water performance data used			
		None	Tap cycle 2	None	Tap cycle 2
1 person	61	41.9%	19.8%	42.2%	20.3%
2 person	86	49.1%	25.6%	49.6%	26.2%
3 person	111	54.2%	30.5%	54.8%	31.2%
Tap cycle 2 (4 person)	135	58.0%	34.6%	58.6%	35.4%
Tap cycle 3 (9 person)	270	68.8%	49.8%	69.6%	50.9%

Table 11 Hot water performance predicted by SAP for oil storage combi Y and Z

Another way of comparing the performance is to compare the storage heat loss shown in. Table 12. The bold value is the best estimate and is taken as the correct value. Note these losses are not the same as keeping the store hot, but the average storage loss over 24 hours during a tapping cycle. The default storage heat loss is underestimated in SAP by between 17% and 71%.

Boiler	Hot water performance data provided	Heat loss (W)	Under estimated by
Gas storage boiler A	None	76.0	59%
Gas storage boiler A	Tapping cycle 2	182.4	
Gas storage boiler A	Tapping cycle 2 &3	**184.4**	
Gas storage boiler B	None	47.3	17%
Gas storage boiler B	Tapping cycle 2	102.8	
Gas storage boiler B	Tapping cycle 2 &3	**56.9**	
Oil storage boiler Y	None	111.1	71%
Oil storage boiler Y	Tapping cycle 2	**386.3**	
Oil storage boiler Z	None	112.6	70%
Oil storage boiler Z	Tapping cycle 2	**378.9**	

Table 12 Water storage heat loss

It is concluded that the assumptions underlying the hot water storage algorithms in SAP (gas and oil) substantially under estimate the storage heat loss in combi boilers and need re-examining; preferably with results from more gas and oil storage combis. Possible reasons include underestimating the heat losses from the pipework and connections within the boiler; overestimating the combustion efficiency; and underestimating the start up losses. Results from more boilers would help to develop a better model in the next update of SAP.

In the interim a change to the temperature factor in SAP Table 2b is recommended for SAP 2009. The worst case is underestimated by 71% and to correct this in SAP the temperature factor (table 2b) needs to be multiplied by 3.5 (i.e 386.3/111.1 rounded up to the nearest 0.1)

Unless changes are made, manufacturers will be discouraged from providing supporting hot water performance data for storage combis, as without it they may achieve better performance under SAP 2009. Options to consider include:

- Setting a higher default storage heat loss by multiplying the temperature factor in table 2b by 3.5 for storage combi boilers;
- Requiring manufacturers always to provide hot water data for combi boilers on the database (new entries only);
- For new entries in the database and all existing entries, change the heat loss field such that it better matches the expected heat losses. This would achieve the same outcome as the first option above.

6 Electrical power measurements

Figure 14 shows the electrical power measurements for all boilers tested under different conditions. All gas boilers except boiler E had an integral pump fitted. For gas boilers with modulating burners, the power consumption (excluding the pump) was reduced by 30 - 65% in going from full to minimum heat input rate. All oil-fired boilers were regular units and were not fitted with a circulation pump. The higher power consumption of oil-fired boilers is due to the oil burner with integral oil pressure pump.

In SAP 2009 Table 4f, the annual electrical consumption for the fan in a gas boiler is 45 kWh/year and for integral oil pressure pump is 100 kWh/year (i.e. oil 120% greater). From these tests the average instantaneous electrical consumption when the boiler is firing was 38 watts for gas boilers and 144 watts for oil boilers. (i.e. oil 280% greater). This indicates that boiler electrical power consumption should be reviewed in any future SAP update.

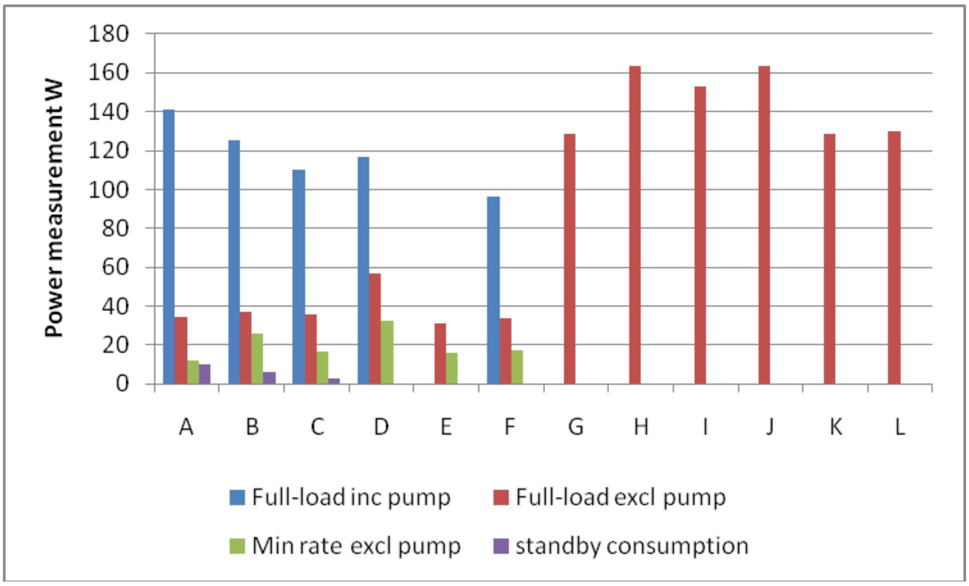

Figure 14 Electrical power (spot measurements) under different conditions

7 Conclusions and recommendations

1. The full-load and part-load efficiencies from DECC tests on the 6 gas boilers are slightly higher than those claimed by the manufacturers. Those from the 6 oil-fired boilers are lower than claimed. All boilers have efficiencies significantly above those required by the BED.

2. SEDBUK values (using SAP2005) based on DECC tests are similar to those claimed for the gas boilers, but on average are 1-2% lower than those quoted for oil boilers by their manufacturers. Despite this only one oil-fired boiler (K) would lose its SEDBUK(2005) band "A" status if DECC test data were used in the calculation.

3. If SAP2009 is used to calculate SEDBUK values from DECC results, the efficiencies fall by around 1-2% and natural gas units would then fall into SEDBUK band “B”. LPG units would remain in band “A”. All but one of the oil-fired boilers would retain their “A” band rating.

4. The Energy Balance Validation method has been used to check the consistency of full and part-load efficiency results. It shows that the residuals are mostly negative but fall within an acceptable range, using the criteria of maximum (negative) acceptable residuals of -2% and -4% net for full-load and part-load respectively.

5. Heat loss data using the surface temperature method for oil-fired boilers shows heat losses in the range 0.36 to 1.1% of net heat input. This data supports the changes introduced to SEDBUK equations in SAP2009.

6. Tests carried out on two regular boilers fired on LPG (G31) show an increase in SEDBUK efficiencies of around 2% when compared with similar test results on the same boilers using natural gas.

7. The EN13203:2 hot water tests on tapping cycle No.2 (100litres/day) show the storage gas combi boilers to have hot water efficiencies of 49-59% (gross). This is considerably better than hot water efficiencies obtained previously for oil-fired storage combis, which were in the range 35-38%.

8. The improved EN13203:2 hot water test efficiencies of gas-fired storage combis compared with oil-fired units is due to their much lower standby losses; i.e. 100-150W, compared with around 330-400W for oil storage units.

9. However the heat losses from the gas storage combi boilers derived from physical properties of the store are underestimated in SAP by 20%-60%. A similar, but larger, under estimate was previously reported for oil storage combi boilers[12]. It is recommended that this issue is examined fully in the next update of SAP, and possibly solved in the interim by multiplying the temperature factors of Table 2b in SAP for storage combi boilers by 3.5

10. The underestimate has the effect of discouraging manufacturers from providing hot water performance data for storage combis, as SAP results will be worse than using the default figures. Other incentives could be provided; e.g. only allowing new entries for combis if hot water performance data is provided. Alternatively new entries without such data could be down-graded by changing the heat loss field or insulation thickness field in the database to compensate for the SAP underestimate.

11. The average electrical power consumption of oil boilers excluding any central heating pump is significantly greater than an equivalent gas boiler due to the use of an oil pump. These tests indicate that the additional electricity used by oil boilers compared to gas is underestimated in SAP, and it is recommended that SAP 2009 Table 4f is reviewed.

[12] Shiret AR, Analysis of the results from energy performance tests on combi boilers, STP09/B04, March 2009