Combination Boilers and Low Flow Fittings.

Report commissioned by the Environment Agency. All errors and omissions are the responsibility of the author. www.environment-agency.gov.uk/savewater

Introduction

This desk-top study for the Environment Agency looks at the compatibility of water-saving fittings with gas fired combi boilers which represent about 70% of new boiler purchases in the UK[1]. The concern is that flow rates may be too low to initiate the firing of combi boilers or that the minimum boiler power will be too high for the required duty, causing temperatures to fluctuate. Oil fired combis are not considered as they use a hot water store and so behave more like a regular boiler for the purpose of this study.

Definition

Combination, or 'combi', boilers have the capability to provide domestic hot water directly. By comparison a *regular* boiler provides domestic hot water indirectly by heating a storage cylinder. Some combis include a small hot water store of up to 15 litres and some manufacturers offer *storage combis,* which include a built in hot water store of 15 litres or more. Multipoint water heaters also provide instantaneous hot water, but not central heating, and so are subject to some of the same issues as combis.

Older combi boilers and multipoint water heaters are likely to incorporate relatively basic controls and water output temperature will to some extent be linked to flow rate. Some older boilers do not modulate but switch between a high and low setting.
In general:

$$\Delta T = 14.3 \times P/Q$$

where ΔT is the temperature rise in degrees Celsius, P is the boiler output power to hot water in kW and Q is the flow rate in litres/minute[2]. In practice, if the power is constant, as flow reduces the water temperature increases until a thermostat turns the boiler off.

The majority of modern combi boilers will modulate continuously down to between 25 or 30% of full output and so can work at the lower flow rates typical of many aerating showers but may have problems with very low flow taps, see table 2. Because the modulation range is similar for most boilers, more powerful boilers will not modulate to as low a level as smaller ones unless they have an unusually wide range of modulation. It is thought that the turn-down of older boilers is likely to be closer to 50% of rated output rather than the 30 or 25% of newer boilers.

[1] The Society of British Gas Industries, SBGI.
[2] Whilst calculated from first principles ($E=MC\Delta T$) the results were checked against manufactures' published boiler performance.

Some boilers include a small hot water store, which reduces the delay and *water rejection*[3] before hot water is delivered. This will allow the use of very low flow fittings such as spray taps since the water is delivered from storage and the boiler cuts in as the store temperature drops rather than in response to flow.

Low flows

Whilst most ordinary taps and showers can be adjusted over a wide range of flow rates, water saving devices typically have a regulated or restricted output to limit the maximum flow rate. This leads to two possible problems:

1. Most combi boilers use some sort of flow sensor to start the burner and typically these require at least 2-3 litres per minute before the burner will cut in. There can be insufficient flow to start the boiler.

2. Once the boiler is firing, the water temperature achieved will be related to the flow rate and boiler power. At low flows the water may get too hot causing the boiler to cycle under the control of its thermostat.

Figure 1 shows flow rate against boiler output. For simplicity we will assume that water is delivered at the required temperature rather than at a higher temperature and mixed with cold water at the tap or shower[4]. The critical situation is in summer where the required temperature rise may as low as 27°C[5] (42 – 15°C). For example if we wish to use a 6 litre per minute showerhead then the boiler output needs to modulate down to 11.3 kW. Hence most modulating combis could achieve this flow rate with a modulation of 30% - a 35 kW boiler would modulate to 10.5 kW.

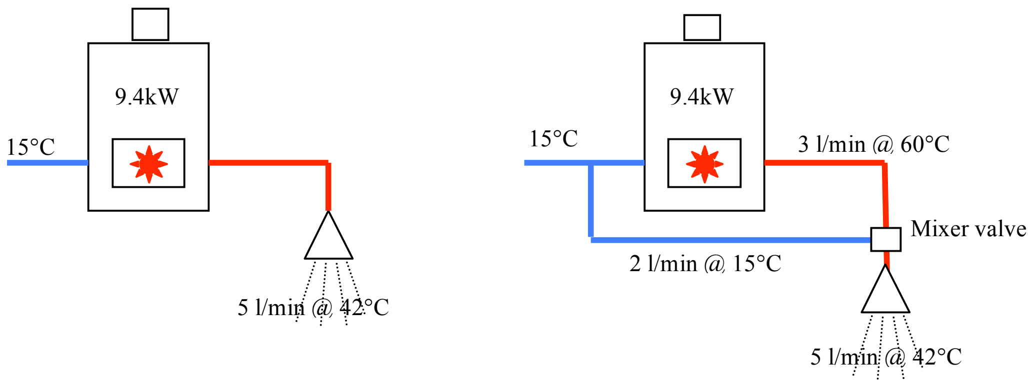

Figure 1. Illustration showing the simplification used for the graphs and tables in this paper and the equivalent situation of boiler water mixed with cold.

[3] The cold water drawn off and wasted as the boiler warms up.
[4] In energy terms this is the same provided that the cold-water temperature to the boiler is the same as the cold water temperature to the mixer.
[5] Boiler performance is typically quoted at cold water supply temperatures of 10°C Winter and 15°C Summer. This is considered a reasonable estimate but at the time and place of writing (14th June 2007, HR2 8SE) the incoming mains water temperature is 14°C which is close to this assumed maximum. To address this table 2 includes a column for 20°C incoming mains.

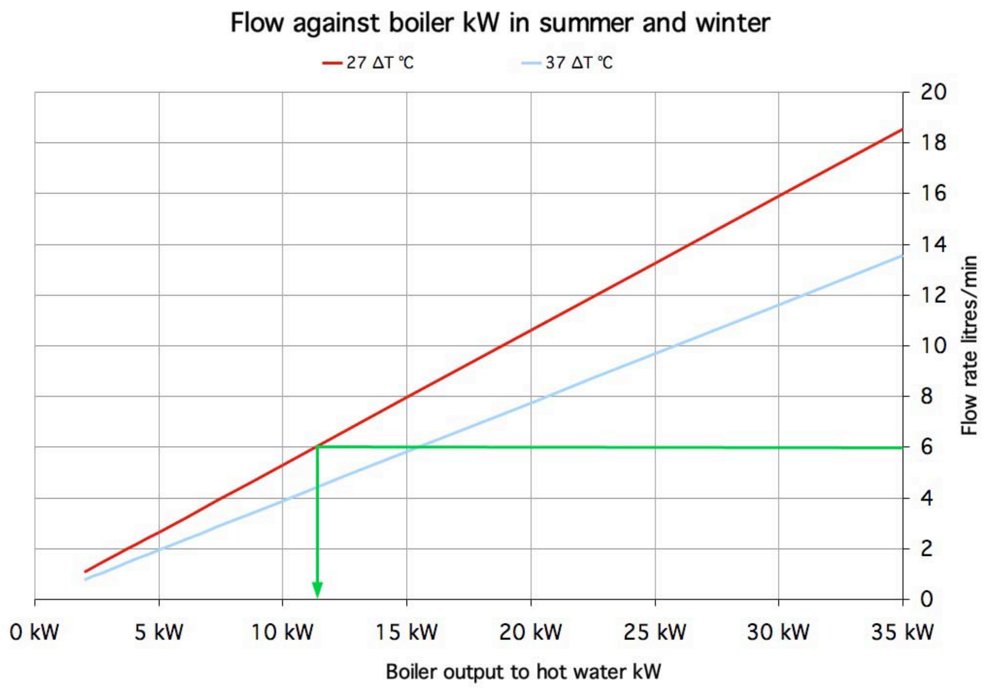

Figure 2. Graph of flow rate against boiler output for assumed summer and winter mains water temperatures of 15 and 5 °C

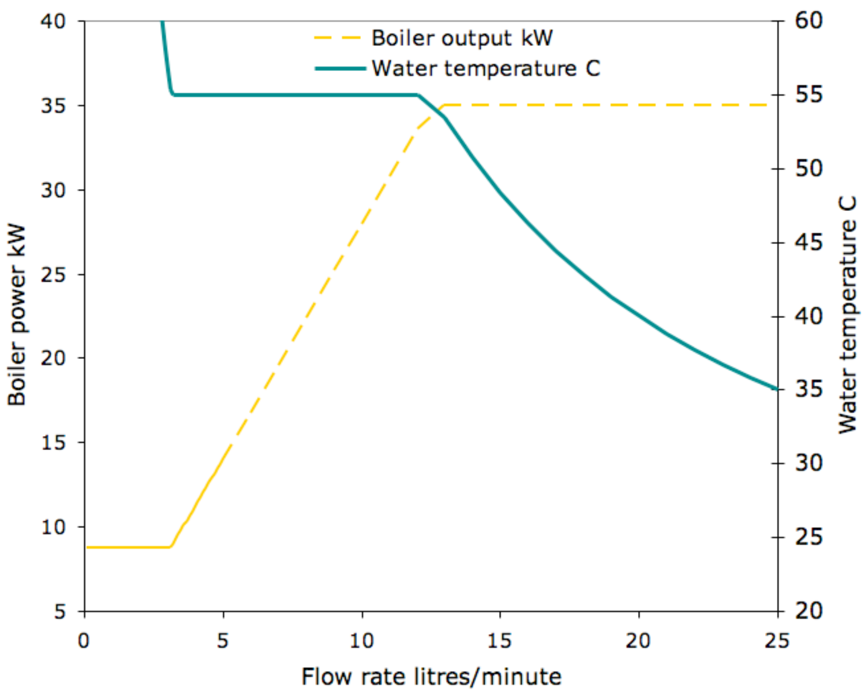

Figure 3. Graph showing (theoretical) water temperature variation with flow rate for a 35kW boiler modulating to 25% of rated output. The hot water temperature is set to 55°C and the boiler maintains this within the modulation range. As this hot water must be mixed with cold, the final flow rate from the tap will be higher.

Flow rates for water efficient fittings

Table 1 shows some typical flow rates for water efficient fittings alongside the required boiler output to ensure stable temperature without cycling[6].

Fitting	Flow litres/min	Boiler output for 15°C mains, 42°C shower	Notes
Spray tap	1.7	3.2 kW	Instantaneous combi not suitable
Very low flow shower	4.0	7.5 kW	Possible with smaller modulating combis up to about 25kW
Lowest flow aerator[7]	5.0	9.4 kW	OK with most modulating combis
Tap aerator or efficient shower	6.0	11.3 kW	OK with most modulating combis
Aerating shower	8.0	15.1 kW	OK with all modulating combis surveyed
Highest flow water saver shower	9.5	17.9 kW	OK with all modulating combis

Table 1. Required boiler output for a range of water efficient fittings.

Typically the smallest available combi is 24kW and in many dwellings the available gas supply limits the maximum to 35kW[8] although a very small number of combis up to 48kW are available[9]. Since the majority of combis will modulate down to 25-30% table 2 shows the range of minimum stable flow rates that should be achievable with available boilers at summer water temperatures.

Boiler	Minimum boiler output	Minimum flow for 27°C ΔT, litres/minute (15°C mains)	Minimum flow for 22°C ΔT, litres/minute[10] (20°C mains)	Notes
24kW, modulation down to 25%	6.0 kW	3.2	3.9	OK except for spray taps
24kW, modulation down to 30%	7.2 kW	3.8	4.7	OK except for spray taps
35kW, modulation down to 25%	8.8 kW	4.6	5.7	OK except for spray taps
35kW, modulation down to 30%	10.5 kW	5.6	6.8	Possible problem with lowest flow fittings in summer
(48kW, modulation down to 30%)	(15 kW)	(7.6)	(9.4)	Not compatible with low flow fittings - uncommon

Table 2. Minimum flow rates for commonly available boiler sizes including up to 20°C incoming mains water temperatures.

6 These are boundary conditions so boiler output should be less or flows slightly higher to prevent cycling.
7 Neoperl 5 l/min PCA aerator. 3 l/min was available but is discontinued.
8 Personal communication Bruce Young BRE.
9 Two models found on www.sedbuk.com
10 20°C mains water is included in this table as the 15°C consensus may be an underestimate.

Water pressure

Combi boilers typically require around 1 bar dynamic pressure to overcome the pressure drop within them and so provide sufficient flow rate. This may leave insufficient pressure for some flow regulated or aerating showers and taps, which are designed to operate at around 1 bar dynamic pressure.

Thermostatic mixers

Thermostatic mixing valves can be problematic with older boilers that use high-low controls rather than linear modulation. Modern modulating boilers are not thought to cause problems with thermostatic mixer valves provided the required flow is within the range that the boiler can supply.

Conclusions

With so many boilers available from many manufacturers it was not possible to carry out a detailed survey. Nor was it possible to test actual boilers to check that theory matches practice but the following conclusions are offered as a starting point for discussion and testing.

1. Regulated spray taps will only be compatible with a combi that contains some storage and only if the boiler is activated by store temperature rather than flow rate.

2. Older combi boilers and multi-point water heaters may not be compatible with low flow taps and showers. Boiler cycling may occur at very low flow rates, which will result in significant fluctuations in temperature.

3. Modern modulating combis should be compatible with all but the lowest flow fittings although larger boilers may be problematic with the lowest flow fittings.

4. Storage combis solve the low flow problem and *water rejection* but introduce a standing heat loss and increase the boiler cost. The SEDBUK rating does not currently measure heat loss but the SAP does include a table[11] to estimate it.

5. It is possible that innovative designs using temperature sensing combined with high thermal capacity heat exchanger or a small hot water store could operate at lower flows[12]. This might also be advantageous for utilising pre-warmed solar water.

Acknowledgement

Whilst all errors are my own, I would like to acknowledge the generous help of the following:

Brian Anderson BRE Scotland (SAP); John Beer, Technical Manager SBGI (also Martin Searle and Gordon Anderson); Alan Clarke, energy consultant; John Griggs, BRE; Chris Lawton, Chair of the Solar Trade Association; John Walker, Imagination Solar; John Thomason, Manager, Atmos Heating Systems; John Willoughby, energy consultant; Bruce Young, BRE/MTP; Plus the technical help lines of boiler manufacturers particularly Vaillant and Worcester Bosch.

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[11] SAP 2005 table 3a.

[12] Personal communication John Thomason Atmos Heating Systems.

Appendix A

Theoretical temperature versus flow graphs for a range of boilers set to 42°C output.

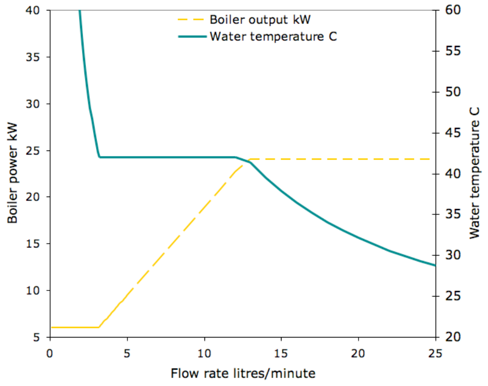

Figure 4. 24kW, modulation to 25%

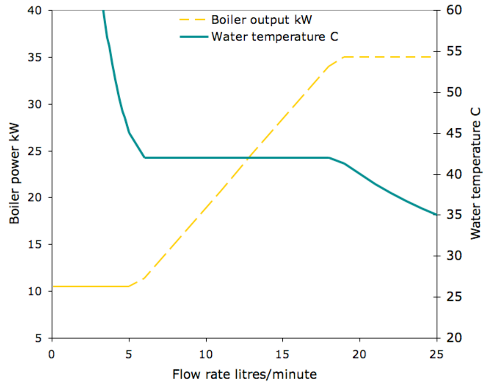

Figure 7. 35kW, modulation to 30%.

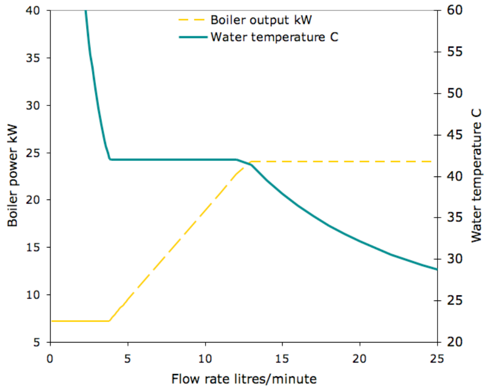

Figure 5. 24kW, modulation to 30%.

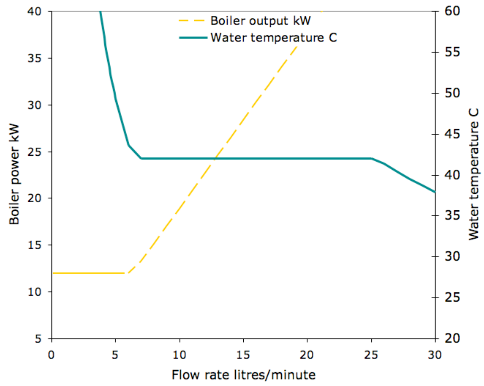

Figure 8. 48kW, modulation to 25%.

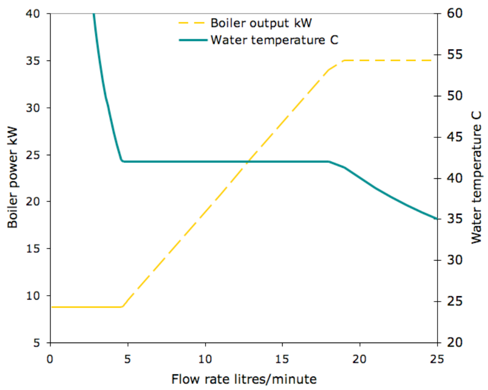

Figure 6. 35kW, modulation to 25%.

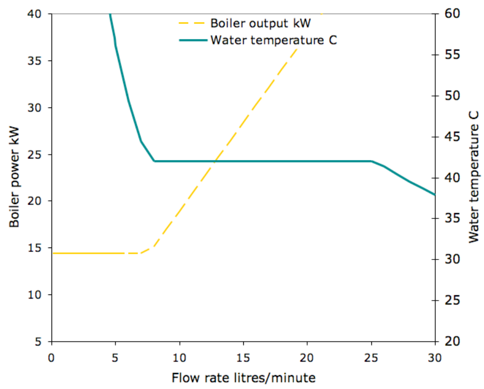

Figure 9. 48kW, modulation to 30%.