FIELD TESTS OF FUEL EFFICIENCY MAGNETS

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List of symbols

T_f average temperature at the flow header, °C
T_r average temperature at the return header, °C
f average water flow rate through the boiler, $l\,s^{-1}$
Q_g total calorific value of gas used over a period t of intermittent firing, MJ
q_g average rate of gas consumption (MJs^{-1}) over a period t of intermittent firing
Q_{max} total calorific value of gas used over a period t of continuous firing, MJ
q_{max} average rate of gas consumption (MJs^{-1}) over a period t of continuous firing
Q_h total useful heat output over a period t, MJ
L average boiler load factor; total firing time/ total plant running time or $Qg/Qmax$
q_s rate of total boiler losses during stand-by as ratio of q_{max}
e_b full-load boiler efficiency
e_u seasonal boiler efficiency

Background

A previous paper (1) reported measurements made on a range of devices purporting to reduce boiler fuel consumption. The majority of these were electronic devices which exercised control over boiler switching and replaced normal thermostatic boiler control. Amongst the devices tested, however, was a system comprising permanent magnets which were attached to the fuel line. The magnets were claimed to improve boiler efficiency by "ionising" the fuel and improving combustion efficiency.

Field experiments were conducted to test the effect of all these devices on boiler efficiency. This was felt to be the key issue since, if the devices reduced fuel consumption only at the expense of heat input to the building, this effect could be achieved by simple manipulation of existing controls. If the devices offered any added value, they needed to demonstrate an ability to reduce fuel consumption whilst maintaining heat output.

With the exception of one of the electronic devices, which achieved some improvement in boiler efficiency by running the system at very low temperatures, none of the devices had any discernible effect on efficiency.

Following the publication of these results, representations were received from the manufacturer and distributor of the magnets tested. It was claimed that this device had not been subject to a fair test on two counts. Firstly it was claimed that two magnets rather than one should have been used on the size of fuel pipe at that site. Secondly it was asserted that insufficient time (the experiment was conducted over two weeks) had been allowed for the effect of the magnets to be seen. A considerable "settling in" period was normally required.

Following negotiations it was agreed to re-test the magnets with the cooperation and assistance of the distributor and the manufacturer. A site was identified (described below) and visited by the distributor and the managing director of the manufacturing company. The boiler installation was inspected and approved as were the details of the experimental procedure. The main feature insisted upon was that the magnets would be allowed to operate for a period of four weeks following a period during which measurements would be made to establish the normal boiler characteristics. It was agreed that the magnets would be fitted by the distributor. The distributor was invited to attend all site visits by the experimenters and offered access to all data collected.

Experiment

The experiment was conducted at a light industrial building on an industrial estate in Cornwall. The chosen boiler was a wall mounted Gloworm Spacesaver 40BR MkII gas-fired unit rated at 11.72 kW output and 15.03 kW input. It provided heating to adjoining office space under simple time-clock control. Hot water from the boiler circulated through a number of steel radiators fitted with thermostatic radiator valves. Gas was supplied to the boiler via a 15mm copper pipe.

The aim of the experiment was to measure the heat output to the circulating water and the simultaneous gas consumption. Heat output was determined by measuring the water flow and return temperatures, T_f and T_r, along with the rate of water flow, f.

Gas consumption was measured directly using a suitable dedicated gas meter on the boiler supply line.

When averaged over a suitable period, these data allow the mean efficiency of the boiler to be deduced. Control over the operation of the system was exercised by the boiler thermostat and the thermostatic radiator valves as normal. The load on the system would be very variable and the efficiency figures obtained would therefore relate to boiler operation under part load. It is shown in the next section how the effects of variation in load factor can be largely eliminated and boiler full load efficiency, e_b, deduced from these measurements.

Instrumentation installed for the purpose of these measurements comprised a Kent MK20M hot water meter to measure water flow from the boiler, platinum resistance thermometers to measure flow, return, flue gas and ambient external air temperature and a UGI gas meter to measure fuel supply to the boiler. A schematic of the experimental installation is shown in figure 1.

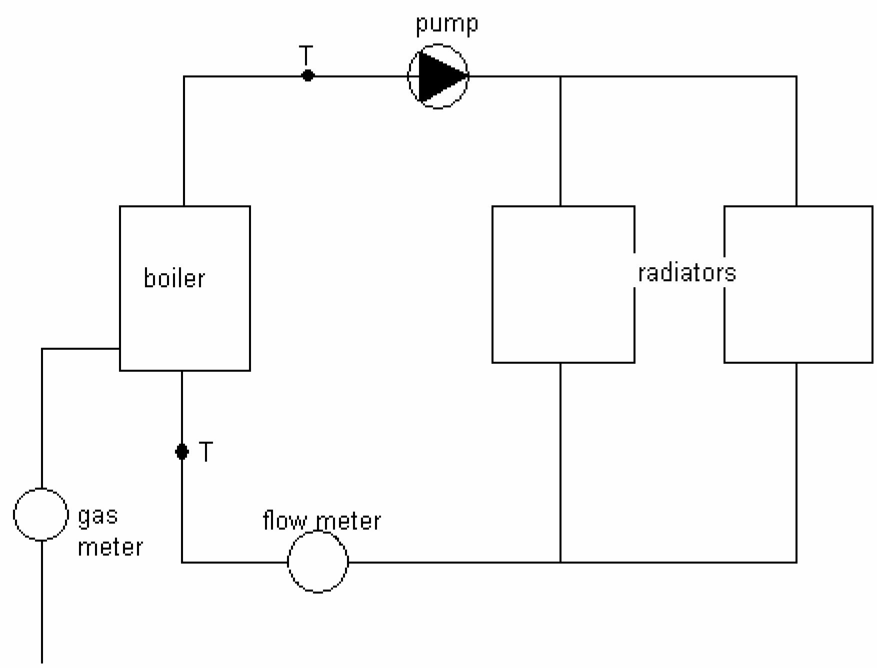

Figure 1 Schematic of the system monitored. Points labelled T indicate the location of Platinum resistance elements used to measure flow and return temperatures

The gas and water meters were fitted with pulse heads to allow the flows to be monitored automatically. Daily average calorific values of the gas supplied were obtained from Transco and the information used to convert gas volumes to heat energy content.

The platinum resistance elements measuring boiler flow and return temperatures were tightly attached to the pipework with nylon cable ties. A heat conducting compound was used to ensure good thermal contact and an insulating sleeve of 25mm neoprene was wrapped around the sensors to insulate them from the effect of ambient air temperature. A further ceramic coated platinum resistance element was inserted into the outlet of the balanced flue to measure flue gas temperature. External air temperature was measured with a platinum resistance thermometer mounted on an external north facing wall.

The resistance thermometers and the outputs from the two flow meters were connected to a Datataker 100L electronic data logger. This unit provides automatic conversion of resistance thermometer voltages to degrees centigrade. The logger was programmed to record the averages of repeated 20 second samples of temperature every 15 minutes. Pulses from the flow meters were totalled over the same interval.

The complete temperature measurement system, including the logger, junction box and all cabling exactly as installed, was calibrated by immersing the sensors simultaneously in a water bath at various temperatures. Regression fits to the data obtained from this calibration were used to correct the measured values of boiler flow and return temperature for differences between the two sensors employed. Calibration data are shown in Figure A1 in the appendix.

Measurement history

Measurements originally commenced on 10th February 1997 but difficulty was experienced with the hot water meter which was not suitable for use at the temperatures experienced. This was replaced with the type indicated above and measurements recommenced on 25th February 1997. Data were collected on the performance of the boilers prior to the installation of the magnets. The magnets were installed by the distributor on 13th March 1997. Data were then collected for a period of twenty nine days with the magnets in place. On 10th April 1997 the magnets were removed and logging continued for a further thirty three days without the magnets. The experiment terminated on the 13th May 1997.

Theory

Boiler efficiency calculated as a simple ratio of heat output to gas input over a given period includes the effect of periods of non-firing as the boiler cycles off under thermostatic control. During these periods heat is lost from the boiler fabric which has to be made up during the next firing cycle. Thus efficiency calculated in this way, so-called seasonal efficiency, varies according to the load on the boiler and the consequent variability in the length of the non-firing periods. During the course of these experiments, which were conducted towards the end of the heating season, a steady reduction in seasonal efficiency was recorded.

Theory developed elsewhere (1), and similarly in (2-6), relates seasonal efficiency to full load efficiency and load factor according to:

$$e_u = e_b - (1/L - 1)\, q_s \quad \text{.....................1}$$

Thus, for the combustion over a period t of a quantity of gas with calorific value Qg, the predicted heat output is

$Q_h = e_u \; Q_g$ 2

substituting for e_u yields,

$Q_h = e_b Qg - (1/L - 1) \, q_s \, Q_g$ 3

and since $L = Q_g \, / \, Q_{max}$

$Q_h = Q_g(e_b + q_s) - Q_{max} \, q_s$ 4

It is also instructive to substitute $Q_g = L \, t \, q_{max}$ for the last occurrence of Q_g in equation 3, giving

$Q_h = Q_g \, e_b - q_s \, q_{max} \, (1 - L) \, t$ 5

From which it may be seen that the useful heat obtained from a boiler operating at part load is the calorific value of the gas consumed multiplied by the boiler full-load efficiency, less the calorific value of the gas consumed in meeting stand-by losses during periods of non-firing. The reduction in seasonal efficiency at low load factor, *L*, clearly arises from the increased proportion of total gas consumption accounted for by that required to meet standing losses at low total heat output.

Results

Figures 2 and 3 show heat produced, Q_h, and gas consumed, Q_g, corresponding to the boiler operating without and with the magnets respectively. The quantities plotted are the daily averages of the heat and gas energy values over all fifteen minute intervals for which the boiler flow temperature, T_f, exceeded 40°C. This selection was made specifically to exclude extended periods when the boilers were not operating, e.g. at night and over weekends. This also ensured that results were only analysed within the calibrated range of the sensors monitoring boiler flow and return temperatures. Figure 4 shows the two data sets plotted on the same graph.

Equation 3 allows the full load efficiency, e_b, to be deduced from daily average measurements of Q_h and Q_g. Load factor was deduced by comparing the recorded daily gas consumption with that which would have been consumed had the boiler been firing continuously at the manufacturer's declared rated input. The boiler standing loss rate, q_s, was ascribed a value of 0.05 of full rated input in line with data reported in the literature (1,2 and 7). Figure 5 shows the average deduced values of full load efficiency for each of the four measurement periods. Experiments 1 and 4 correspond to the periods when the magnets were not fitted, and 2 and 3 to those when they were. The standard deviations on each mean value are indicated in the form of error bars. The first impression is that the magnets have made no difference to boiler efficiency and this impression is confirmed by appropriate statistical analysis.

The mean value of boiler full load efficiency for all data without the magnets is:

0.675 with a standard deviation of 0.0246.

For the data corresponding to the magnets fitted the mean value is

0.691 with a standard deviation of 0.0281.

To assess the significance of these results we note that the standard deviation of the difference between two quantities a and b with standard deviations s_a and s_b is

$$s_{a-b} = \sqrt{(s_a^2 + s_b^2)}$$

and the value of the Student's t $= (a - b) / s_{a-b}$

We take as the null hypothesis that the application of the magnets has not improved the full load efficiency of the boiler, i.e.; h_0: ($e_b$magnets - $e_b$nomagnets) =0, and the alternative, h_1: ($e_b$magnets > $e_b$nomagnets)

Calculation the value of t gives

$$t = (0.691 - 0.675) / \sqrt{(0.0281^2 + 0.0246^2)}$$

$t = 0.43$

Reference to standard statistical tables reveals that the value of t required for rejection of the "no effect" hypotheses would be 2.08 at the 95% confidence level. Thus the value of t obtained does not allow rejection of the null hypothesis. The alternative hypothesis, that the magnets have improved full-load efficiency, is therefore rejected .

Discussion

In these experiments the magnets failed to show any improvement in boiler efficiency within the limits of probability stated above. This confirms the results obtained earlier (1).

Since these magnets were installed by the distributor and since the design of the experiment conformed to the requirements of the distributor and the manufacturer it may be concluded that they represent a fair test. The distributor attended site on two occasions during the experiment. No representations were made concerning any experimental deficiencies and no comments have been received since communicating the results of the tests directly to the distributor.

It may be concluded that this device did not exercise any beneficial effect on the operation of a gas fired boiler.

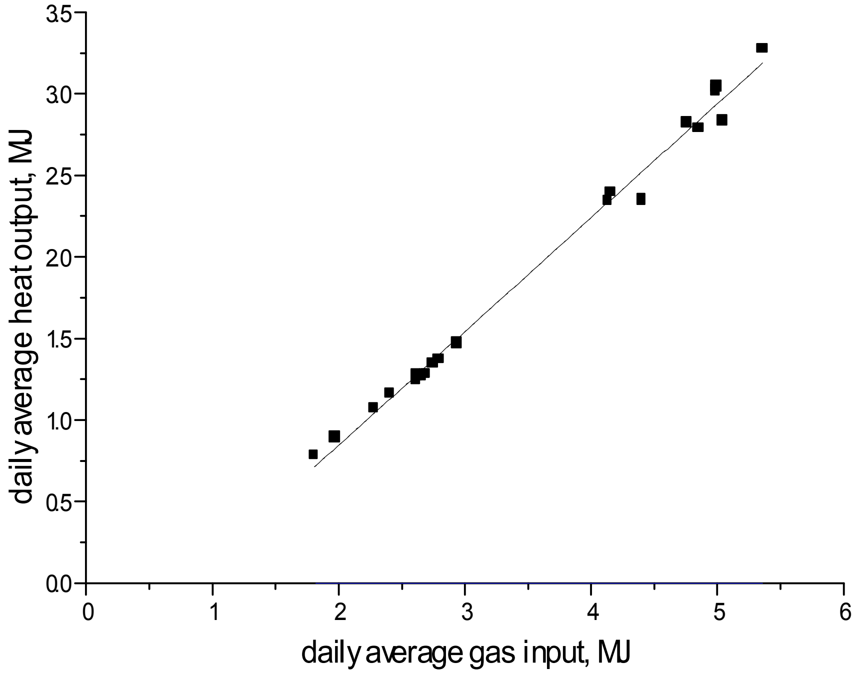

Figure 2 Daily average heat output vs. gas input (for all fifteen minute periods when T_f exceeded 40 °C) for the boiler operating without magnets

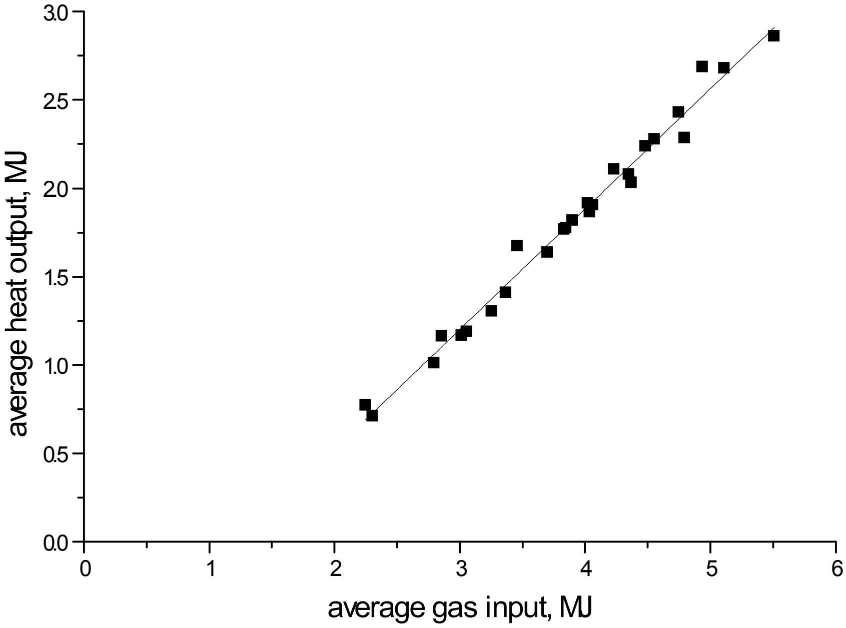

Figure 3 Daily average heat output vs. gas input (for all fifteen minute periods when T_f exceeded 40 °C) for the boiler operating with magnets.

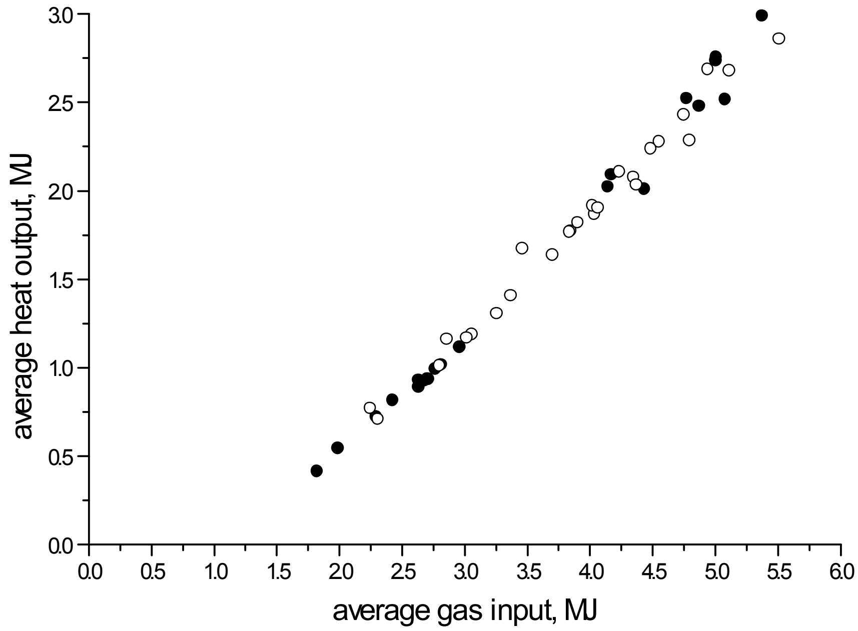

Figure 4 Combined plot of figures 2 and 3. Data relating to boiler running with magnets are shown as open circles.

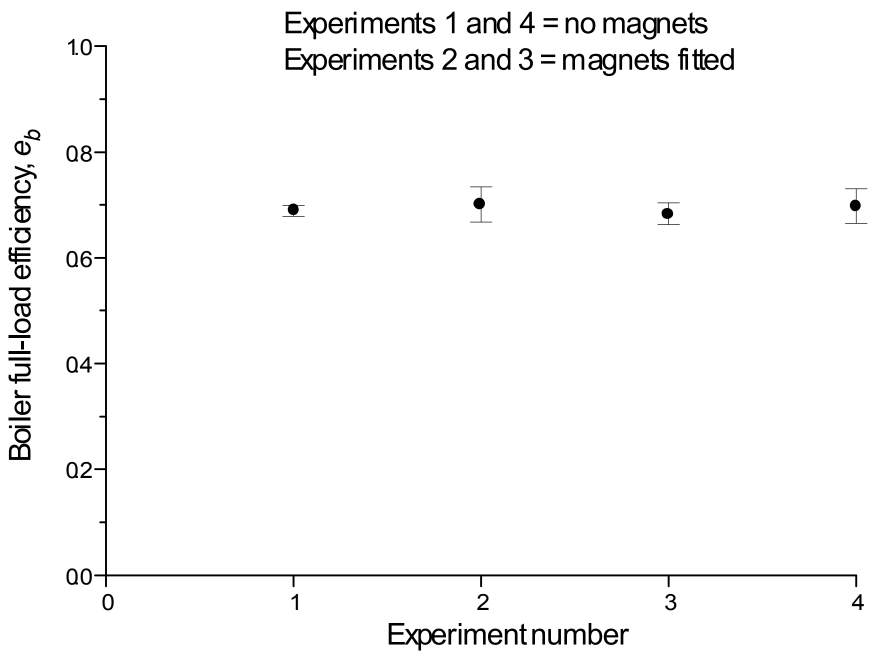

Figure 5 Mean values of deduced boiler full-load efficiency, standard deviations show as vertical bars.

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Appendix

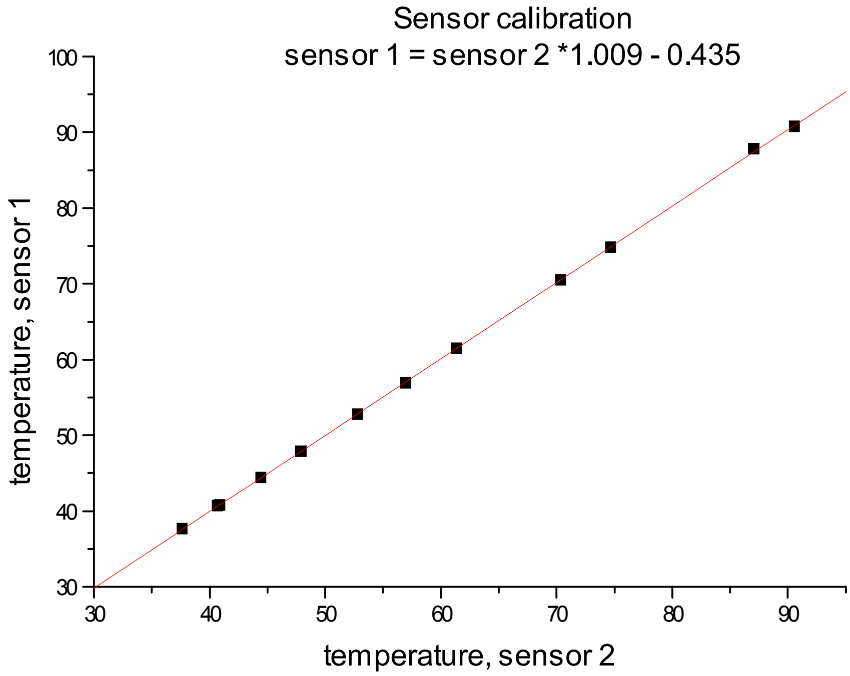

Figure A1 Calibration curve derived from water bath tests on the two sensors used to monitor boiler flow and return temperatures.