Observations on the Aquastan Tadpole Device Tests

A Report from TUV NEL for

Aquastan Heating Ltd

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A Report from TUV NEL for

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1 INTRODUCTION

The Tadpole is a device produced by Aquastan Heating Ltd[1] for fitting into central heating systems. Its purpose is to reduce the amount of dissolved air in the central heating water and as a consequence a number of benefits are claimed:-

- the boiler fuel demands are significantly reduced,
- the need for corrosion inhibitors is reduced,
- heat transfer in the boiler and the radiators is enhanced,
- the need for radiator bleeding is reduced and
- problems of knocking and vibration are reduced.

Alpha Heating Innovation[2] (AHI) was evaluating the device to establish whether AHI should recommend the addition of a Tadpole to its central heating systems. Following discussion between Aquastan Heating and TUV NEL, TUV NEL agreed to witness the testing of the Tadpole at AHI and to prepare a short report providing an independent opinion on the experimental set up and the measurements, instrumentation and data logging arrangements. This work was funded as a Consultancy by the National Measurement System (NMS) Measurements for Innovators (MFI) Scheme.

2 THE DESIGN OF THE TADPOLE DEVICE

A cross-section of the Tadpole is shown in Figure 1. Water returning from the radiators enters the small chamber through the connection at the top left and exits through the connection at the bottom of the tank to connect with the central heating pump in the combi boiler. The chamber is approximately 150 mm dia and 200 mm high over the domed ends. The central deaerator pipe extends from an automatic air vent above the Tadpole to approximately 10 mm above the water exit from the Tadpole.

Figure 1 Cross-section through a Tadpole

It would appear that the principle of operation is that water leaves the bottom of the Tadpole in a spiral vortex, similar to bathwater draining from a bath. The vortex action will tend to separate air from the water and the air bubbles will float to the top of the deaerator tube and out of the system via the automatic air vent.

3 EFFICIENCY OF A HEATING SYSTEM

The thermal efficiency, η_{th}, of a heating system can be expressed as:

$$\eta_{th} = \frac{\text{Energy output}}{\text{Energy input}} \tag{1}$$

In steady state operation the rates of energy in and out may be used in this expression. In a central heating system, where water is heated in a boiler, the energy flows are given by:

Energy input, E_i*:* Energy supplied in the gas, oil or electricity to the boiler plus electricity supplied to run the pump and fan.

Energy output, E_o*:* (Mass flowrate of water, $\dot{M}$) x (specific heat of water, C_p) x (temperature drop between the heating flow and heating return water, ΔT)

That is:

$$E_o = \dot{M}\, C_p\, \Delta T \tag{2}$$

The only reliable way of determining the thermal efficiency of a system is to undertake tests where all these parameters are measured in steady state.

Factors that can be expected to influence the behaviour of a central heating system include:

Water flowrate: If the flowrate is high, the heat transfer coefficients on the water side will be increased, but the water temperature rise through the boiler may be less because of the reduced residence time and vice versa. The practical consequence of this is that if the water flowrate is reduced the water entering the radiators may be hotter. The flowrate will be affected by the system resistance which is dependent on the thermostatic valves on the radiators and items in the circuit such as the Tadpole device, if fitted.

Coefficient of specific heat: If the value of C_p is low, less heat will be carried in the water for a given temperature rise and flowrate. The presence of air in the water may affect the value of C_p.

Temperature difference: If the temperature difference is measured between the water flow and return temperatures the correct value of heat output can be calculated. If the heat output is inferred from room temperature, radiator surface temperature or other indicators, considerable uncertainty will be introduced into the heat output determination. A modern combi boiler is influenced by a number of control systems including the room thermostat, the maximum water temperature setting in the boiler and the control system for modulating the gas burner. The interaction of these systems is not straightforward especially when changes to the heating circuit are made.

Further uncertainties are introduced in dynamic systems where transients in one system under test may differ from the transients in a modified version of the system.

In particular the rate at which the system warms and cools may change and alter the demands on the system.

The tests at AHI did not measure sufficient data to accurately determine the efficiency of the circuit, although indications of efficiency were obtained. Specifically the flowrate was not measured. This had two consequences:

- the heat output from the boiler could not be calculated and
- the effect of the Tadpole on the water flowrate was not known.

To illustrate an accurate way of determining how a Tadpole affects a heating system an ideal test rig and test procedure is described in the following section.

4 IDEAL TESTS OF THE TADPOLE

As this report will highlight, the manner in which the Tadpole device affects the operation of a domestic heating system is not clear. If the Tadpole is simply an efficient deaerator then the results would be expected to differ from those obtained. A test rig is therefore described which would help determine the way in which a Tadpole functions. The key feature of this test rig is that (1) instrumentation is installed to allow thermal efficiency to be calculated and (2) the measurements taken allow the operation of the tadpole to be understood.

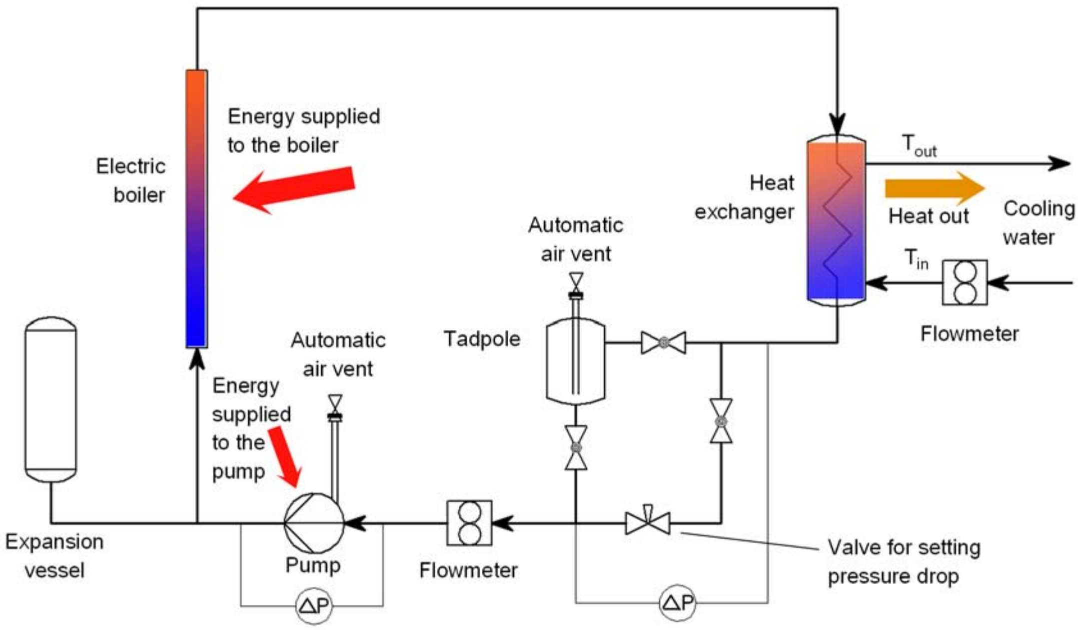

Figure 2 Ideal Test Rig

Figure 2 shows a test rig in which the energy supplied to the boiler and circulating pump can be directly measured and the heat taken out of the system by the heat exchanger can also be directly measured from the temperature change in the cooling water, the cooling water flowrate and a knowledge of the specific heat of the water. The volume of water circulating through the electric boiler would be arranged to be similar to a typical domestic central heating system. This test rig would enable tests to be conducted on the Tadpole device in various ways.

1. Firstly the Test Rig would be filled with deaerated water and the system bled from the highest points in the system. The deaerated water would be obtained by boiling distilled water for a period. The rig would then be run at different steady state settings with the Tadpole isolated from the system and the heat out at the heat exchanger monitored. With a knowledge of the heat exchanger heat transfer area the heat transfer coefficients with deaerated water and subsequently with normal water could be calculated.

2. The Tadpole would then be included in the system and any differences for steady state operation monitored. The pressure drop across the Tadpole would also be monitored.

3. If the Tadpole pressure drop was significantly different from the pressure drop recorded when the Tadpole was isolated, some further testing would be performed without the Tadpole but with the same pressure drop set by the setting valve.

4. The system would then be drained and filled with ordinary tap water and the system run with the Tadpole isolated. Air vented by the automatic air vent on the circulating pump would be measured and the heat transferred to the cooling water noted for various steady state operating conditions. These tests would be conducted until no further air was being released by the automatic air vent on the circulating pump.

5. Test 4 would be repeated but with the Tadpole in the system and air vented by both automatic air vents would be monitored.

6. Tests 4 and 5 would be repeated but in a way more representative of the typical transient cycling of a domestic central heating system.

With such tests it should be possible to isolate the effects that a Tadpole device has on a central heating system. In particular the tests would be independent of the weather and the system energy inputs and outputs could be compared directly. The specific conclusions that could be drawn include:

- The effect of the Tadpole on flowrate in the circuit
- The effect of the Tadpole on pressure loss and pressure at pump inlet (which influences flowrate)
- The effect of the Tadpole on circuit thermal efficiency with deaerated and normal water

These results cannot be determined explicitly from the tests at AHI, but indicative results were obtained and these are described in the next section.

5 TADPOLE TESTS CARRIED OUT BY ALPHA HEATING INNOVATION

Initially AHI fitted a Tadpole to a combi boiler system in its laboratory but no difference in boiler performance was found. However, the combi boiler was not attached to a conventional central heating system and it was concluded that any benefits were more likely to be found in a more typical domestic central heating system. AHI uses a converted cottage, known as the Bistro, as a company canteen and this building has a central heating system with 11 radiators similar to many domestic installations. A Tadpole was plumbed into the radiator return pipe to the combi boiler such that it could either be part of the system or it could be bypassed simply by adjusting three valves. The system has been run with and without the Tadpole for periods of a week at a time and the boiler fuel consumption was apparently improved when the Tadpole was in the system. The test arrangement when the Tadpole was included is shown in Figure 3.

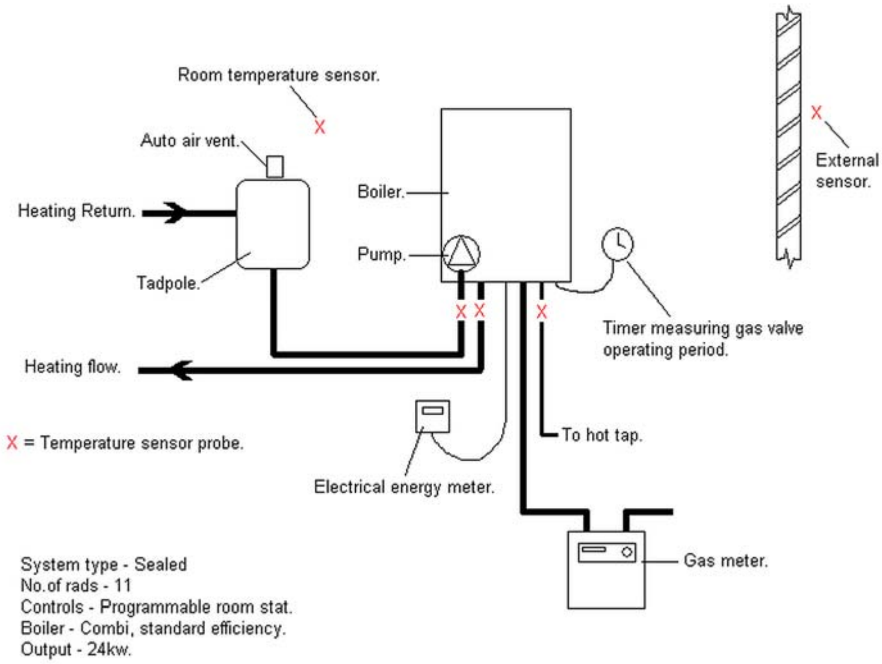

Figure 3 Alpha Heating Innovation Tadpole Test Arrangement (Courtesy of Alpha Heating)

Key features of the test setup and instrumentation are:

- The room temperature sensor was a bare thermocouple located in the small downstairs toilet where the combi boiler was located. This downstairs toilet had a small radiator without a thermostatic valve.
- The outdoor temperature sensor was a bare thermocouple outside the building located below the boiler balanced flue where it was unlikely to be affected by hot flue gases.
- The other ten radiators around the building all had thermostatic valves. The room temperature was not recorded in the space heated by these radiators.
- The temperature sensors indicated in Figure 3 were monitored every two minutes by a PC fitted with a data acquisition unit.
- The programmable room thermostat was located in the main upstairs room in the building. The daytime temperature was set to 21 °C and the night time temperature was set to 10 °C. The buttons for altering the settings of the room thermostat were disabled.
- Calibration certificates were not provided for the thermocouples but it was assumed they were functioning correctly.
- The flow rate in the heating circuit was not measured

- The readings on the gas meter, the electricity meter and the timer measuring the total gas valve operating period were noted at the beginning and end of test periods.

AHI supplied data for four tests conducted over four weeks from 28 January 2008. Each test started on the Monday afternoon and finished on the Friday afternoon exactly 4 days later. Before the first test started the system was drained and filled and pressurised to approximately 1 barg and the same water was used throughout the test series. The first and third tests were undertaken with the Tadpole isolated from the heating circuit and the second and fourth tests included the Tadpole. Indoor and outdoor air temperatures were only recorded during the third and fourth weeks.

6 SOME OBSERVATIONS ON THE DESIGN OF THE TADPOLE

The significant difference between the Tadpole air venting arrangement and the automatic air vent already installed on the combi boiler circulating pump inlet appeared to be that the latter air vent was connected to the periphery of the vortex that would tend to form at the circulating pump inlet whereas the Tadpole air vent was connected to the centre of the assumed vortex leaving the Tadpole.

A puzzling feature of the Tadpole is that although its stated purpose is to remove air from a central heating system, air will always be trapped in the Tadpole chamber when the central heating system is first filled with water. In the Alpha Bistro installation the radiator return pipe is from the upper floor down to the combi boiler and so when the central heating system is filled and bled from the upper floor radiators the Tadpole will fill with water to the top of the inlet connection. Air will remain in the dome at the top of the Tadpole tank. It is probably more common for the radiator return pipe to be under the floor below the combi boiler and so when it is connected to the Tadpole inlet there is not a way for air to be bled from Tadpole above the bottom of the deaerator pipe and so the Tadpole tank will be almost completely full of air. During operation water falling into the Tadpole from the inlet connection will entrain air in the tank and so in time air will escape but it might take many days for this to happen. It may be that having some air in the tank provides some additional compliance in a system and this might be the mechanism by which a Tadpole can reduce knocking in some central heating systems

A simple way of ensuring that air does not fill the Tadpole tank would be to drill a small hole (perhaps 1 mm dia) through the deaerator pipe just inside the upper dome. The Tadpole automatic air vent would then be able to remove the air in the Tadpole tank when the system is being filled.

7 ASSESSING CENTRAL HEATING SYSTEMS WITH MINIMAL DATA

7.1 Introduction

The energy used by a heating installation can provide an indication of a system's performance but UK weather is notoriously variable not only from season to season but from day to day. Consequently any changes in the energy used may simply be arising from variations in the weather over different periods. The Carbon Trust has addressed this issue in a Technology Guide[3], which introduces the concept of degree days described in the following section.

7.2 Degree Days

Heating degree days are a measure of the severity and duration of cold weather below 15.5 °C. The colder the weather in a given month, the larger the degree-day value for the month. 15.5 °C is taken as the baseline temperature and is the ambient temperature at which additional building heating is assumed to be unnecessary.

The degree days parameter is obtained by taking the difference between this baseline and the mean of the maximum and minimum outdoor temperatures for each day and summing over the number of days of interest. For example, if the mean temperature is 7.5 ºC for day 1 and 10.0 ºC for day 2, the degree days total over the two days would be:

$$(15.5 - 7.5) + (15.5 - 10.0) = 13.5 \quad (3)$$

The formulae for heating degree days, D_h, are given in Table 1 where T_{base} is the baseline temperature, 15.5 °C, T_{min} is the minimum outdoor temperature in a 24 hour period and T_{max} is the maximum outdoor temperature in the same 24 hour period. The formula to use is the first one in the list that matches the data for a given day.

TABLE 1 FORMULAE FOR CALCULATING DEGREE DAYS
(Taken from reference [4])

Condition	Formula used
$T_{min}>T_{base}$	$D_h=0$
$(T_{max}+T_{min})/2>T_{base}$	$D_h=(T_{base}-T_{min})/4$
$T_{max}>=T_{base}$	$D_h=(T_{base}-T_{min})/2-(T_{max}-T_{base})/4$
$T_{max}<T_{base}$	$D_h=T_{base}-(T_{max}+T_{min})/2$

Monthly values are freely available for every area in the UK from the Carbon Trust[5]. It is also possible to obtain weekly degree day data[6], but this usually incurs a charge. Table 2 lists data for 15 months for the South East region which covers Kent and Sussex. The data is based on meteorological records at Gatwick Airport.

TABLE 2 SOUTH EASTERN REGION DEGREE DAYS DATA FOR 2007 AND 2008[5]

Month	Degree days	
	2007	**2008**
Jan	268	271
Feb	258	296
Mar	260	280
Apr	124	
May	109	
Jun	38	
Jul	31	
Aug	39	
Sep	67	
Oct	166	
Nov	248	
Dec	332	

7.3 Central Heating System Performance

In order to evaluate a gas central heating system, for example, the gas meter reading is noted at the beginning of each month and the energy used in the previous month calculated. The energy data can then be plotted against the degree days for the corresponding months as shown in Figure 4. For many systems a straight line can be fitted through the data. The intercept on the vertical axis is an indication of the base load energy requirement for the system when space heating is not required.

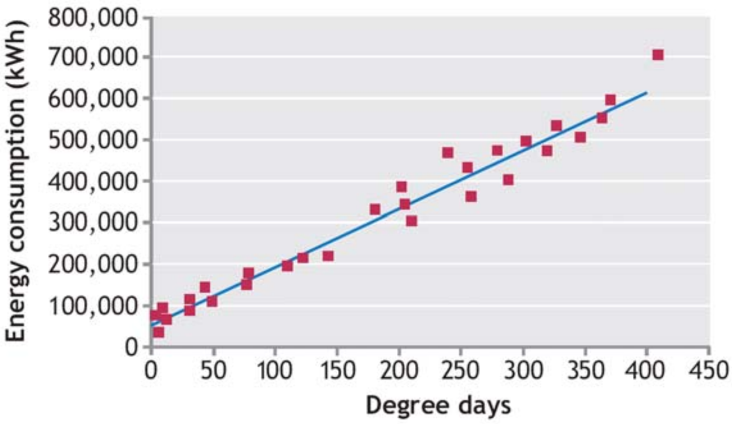

Figure 4 Example of Energy Consumption versus Degree Days plot for a large heating system taken from Reference [3].

If an improvement is made to the heating system then it can be expected that the new data will tend to fall on a line below the previous line. The difference between the two lines would be an indication of the magnitude of the improvement.

Graphs like Figure 4 take many months to plot and results are needed much more quickly for the Tadpole. One way to produce data more quickly is to take gas and electricity meter readings more frequently, such as daily at the same time. The corresponding degree day value can then be calculated, which can be done for the Alpha Bistro installation using the readings from the outdoor thermocouple.

Graphs similar to Figure 4 could then be plotted for the Alpha Bistro system running with and without the Tadpole and a view formed on the energy saved with the Tadpole.

An underlying assumption in this degree day approach is that the pattern of daily, weekly and/or monthly use does not vary significantly.

For the Tadpole tests in the Alpha Bistro system there are sufficient short term data to improve on the degree day approach.

8 ASSESSING THE TADPOLE IN THE ALPHA BISTRO INSTALLATION

8.1 Theory – Improved Calculation

The Alpha Bistro system has been described in the introduction. The biggest difficulty in any system like this is deciding whether the variations in the results with and without the Tadpole are caused by the Tadpole or by other factors.

From the examination of the installation it was apparent that the outdoor weather has a major influence on the heating demand placed on the heating system. However, the heat losses from a building are not only determined by the outdoor temperature but also by the interior temperature. The programmable controller for the Bistro system was located in the main upstairs room and was programmed to a set temperature of 21 °C during the working day and 10 °C at night time and at the weekend. This room is likely to experience greater heat losses through the walls, roof and windows than other rooms in the building and consequently the difference between the temperature in this room and the outdoor temperature is probably a good measure of the heat load on the central heating system. Unfortunately the interior temperature monitored by the temperature data acquisition system was the air temperature in the downstairs toilet where the combi boiler was located. There are no data on how closely the air temperature in the downstairs toilet follows that in the upstairs room. However, it can be inferred from Figure 6 below that the downstairs toilet is approximately 2 °C warmer than the upstairs room during the daytime when the upstairs room should be controlled at 21 °C. During the Consultancy visit to Alpha it was recommended that the indoor temperature thermocouple be transferred to the upstairs room alongside the programmable controller.

If it is assumed that the downstairs toilet temperature does broadly follow the upstairs temperature then the existing Tadpole performance data can be re-evaluated by attempting to discern whether weather effects are biasing the results.

The rate of heat loss from the Bistro building, assuming that the ventilation losses are small, can be approximated to an electrical analogy as shown in Figure 5. T_r is a representative room air temperature inside the building, T_a is the ambient air temperature outside the building, R is the overall thermal resistance of the building fabric, C is the thermal capacitance of the building fabric and T_w is a representative average temperature of the building fabric. As the interior and exterior temperatures vary there will be a lag in the temperature in the structure as heat is stored and released. However, over a full day, if the interior and exterior temperature cycles do not change significantly, the amount of heat stored and released in the building fabric will be similar. Consequently, to a first approximation, the heat lost from the building, Q, can be derived over the period of the experimental data collection t_{expt} from Equation 4:

$$Q = \int_0^{t_{expt}} \frac{(T_r - T_a)}{R} dt \qquad (4)$$

where t is time.

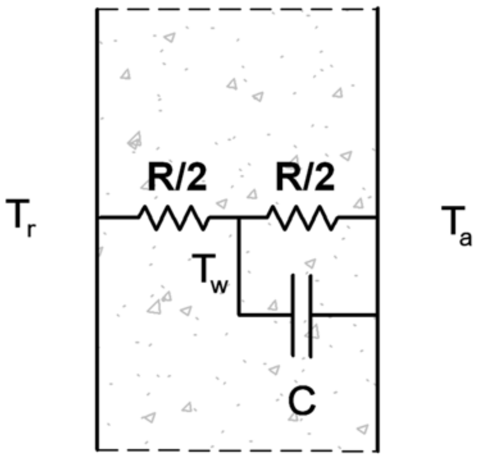

Figure 5 Electrical Analogy for Heat Losses from the Alpha Bistro Building

The building thermal resistance, R, is not known but it could be estimated from the measured results. However, on the assumption that it has not changed during the period of the Tadpole tests then it can be set to an arbitrary value of 1 and the weather effects can be compared for the tests with and without the Tadpole installed.

8.2 Examination of the Data for Weather Effects – Improved Calculation

The Tadpole test data was contained in a spreadsheet supplied by AHI[7]. The summary table of the results given in the spreadsheet are reproduced in Table 3.

TABLE 3 BISTRO TADPOLE TEST RESULTS

					Change in energy used	
Week starting	**Test condition**	**Burner On Time**	**Electricity Usage**	**Gas Usage**	**Gas**	**Elec-tricity**
28th Jan	**Without Tadpole***	40.75 Hrs	5.53 kWh	2260 ft³		
4th Feb	**With Tadpole**	37.5 Hrs	5.10 kWh	1980 ft³	-12.4%	-7.8%
11th Feb	**Without Tadpole**	48.5 Hrs	6.40 kWh	2580 ft³		
18th Feb	**With Tadpole**	37.25 Hrs	5.09 kWh	2070 ft³	-19.8%	-20.5%

* Drained and refilled system before the test series started

The tests lasted for 96 hours starting on the Monday afternoon of the given date and finishing on the Friday afternoon. The burner on time was the total time the burner was on during these 4 day periods. Indoor and outdoor temperatures were only monitored during the tests starting on 11th and 18th February and so it is these tests that are examined in greater detail.

Figure 6 shows the indoor and outdoor temperatures recorded during these two tests. Unfortunately the ambient air temperature thermocouple was accidentally moved during the test with the Tadpole on the 21st February and it subsequently measured indoor temperature. This can be seen by the jump in the curve.

A search on the internet revealed that historical weather data at 30 minute intervals could be obtained for Gatwick Airport from Reference [8]. This included ambient air temperature to the nearest 1 °C. The Gatwick data was downloaded for 21st and 22nd February and the ambient air temperature data have been added to Figure 6 after adjusting the time axis so that the overlapping periods of the Bistro and Gatwick data fitted each other. It can be seen that the fit is reasonably good. The missing Bistro data was therefore replaced by the appropriate Gatwick data to obtain Figure 7. A close examination of the data in Figure 7 shows that the indoor temperatures fall more quickly at night when the outside air temperature is lower thus indicating greater heat losses from the building.

With complete sets of data Equation 4 could then be applied to the data at 2 minute intervals over the 96 hours of the tests without the Tadpole and the 96 hours of the tests with the Tadpole. The results obtained were so similar that the calculation was also done for each 24 hour period, Table 4.

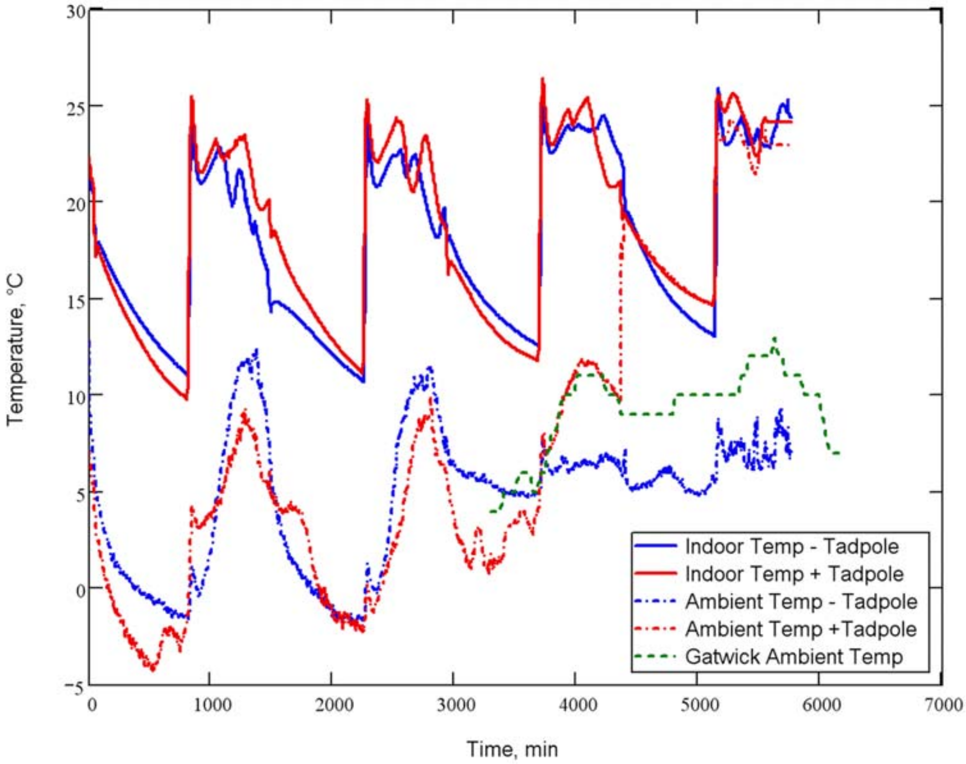

Figure 6 Variation of Indoor and Ambient Temperature with Time for the 4 day periods starting 11th February (without Tadpole) and 18th February (with Tadpole)

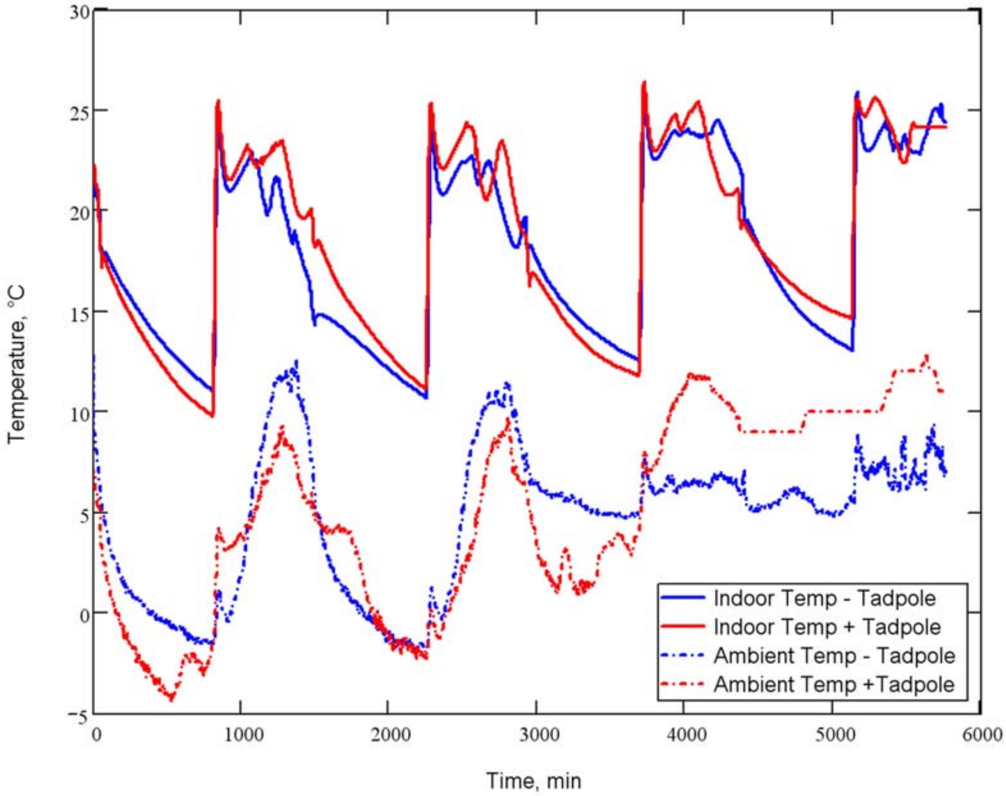

Figure 7 Variation of Indoor and Ambient Temperatures with Time over the 4 day periods starting 11th February (without Tadpole) and 18th February (with Tadpole)

TABLE 4 RESULTS FROM APPLYING THE EQUATION $Q = \int_0^{t_{\exp t}} \frac{(T_r - T_a)}{R} dt$ **TO THE BISTRO TADPOLE DATA**

Test Configuration	Q				
	Full 4 Days °C hr	**First Day °C hr**	**Second Day °C hr**	**Third Day °C hr**	**Last Day °C hr**
Test without Tadpole	1276	334	322	306	316
Test with Tadpole	1277	377	372	294	235

Table 4 shows that while the weather effects on individual days were very different from one test to the other, the overall effects of the weather on the two tests were almost identical. Referring to the values in Table 3 and Table 4 for weeks commencing 11 February and 18 February, it can be seen that the total heat loss indicated by parameter Q is, by coincidence, approximately the same for these weeks (1,276 and 1,277 °C hr respectively), but the gas volume supplied is significantly different (2,580 ft^3 without Tadpole and 2,070 ft^3 with Tadpole). The conclusion, therefore, must be that the reduction observed in the gas and electricity consumption for the two sets of data are not as a result of the weather.

8.3 Degree Day Calculations

It is unfortunate that the indoor and outdoor temperatures are not available for the weeks of 28th January and 4th February because while the overall results for the tests listed in Table 3 are similar for the two tests with the Tadpole on the weeks of 4th February and 18th February the results for the tests without the Tadpole for the weeks of 28th February and the 11th February differ significantly. However, it is possible to gain an idea of the weather effects using the approach described in Section 7 with maximum and minimum temperatures for Gatwick Airport over the relevant periods downloaded from Reference [8]. The Degree Days were calculated using the equations in Table 1. All the maximum and minimum temperatures were less than the base temperature of 15.5 °C and consequently the fourth equation in the Table was used. The experiments lasted four days starting partway through the first of five days and finishing partway through the fifth day. Therefore the total degree day figures for each experiment used half the values calculated for the first and last days and the full values for the intervening three days. The values calculated are listed in Table 5.

TABLE 5 DEGREE DAY VALUES FROM GATWICK AIRPORT DATA FOR THE RELEVANT PERIODS OF THE ALPHA BISTRO TADPOLE TESTS

Date	Test	Degree Days
28 January 2008	Without Tadpole	39
4 February 2008	With Tadpole	36.5
11 February 2008	Without Tadpole	42.25
18 February 2008	With Tadpole	42.75

The Degree Days for the last two tests are very similar as would be expected from the calculations for the full four days listed in Table 4 but the Degree Days for the earlier tests differ both from the later tests and each other and so weather influences on the combi boiler energy consumption could be expected. A graph similar to Figure 4 has been plotted in Figure 8 using the Alpha Bistro results. On the assumption that the Alpha Bistro installation supplies little domestic hot water then when no central heating is required there should be minimal gas used by the combi boiler. Consequently least squares straight lines have been fitted to the data passing through the graph origin. The straight lines indicate that on average the Alpha Bistro installation will use approximately 15% less gas during particular weather conditions when a Tadpole is fitted compared to the baseline case when a Tadpole is not fitted.

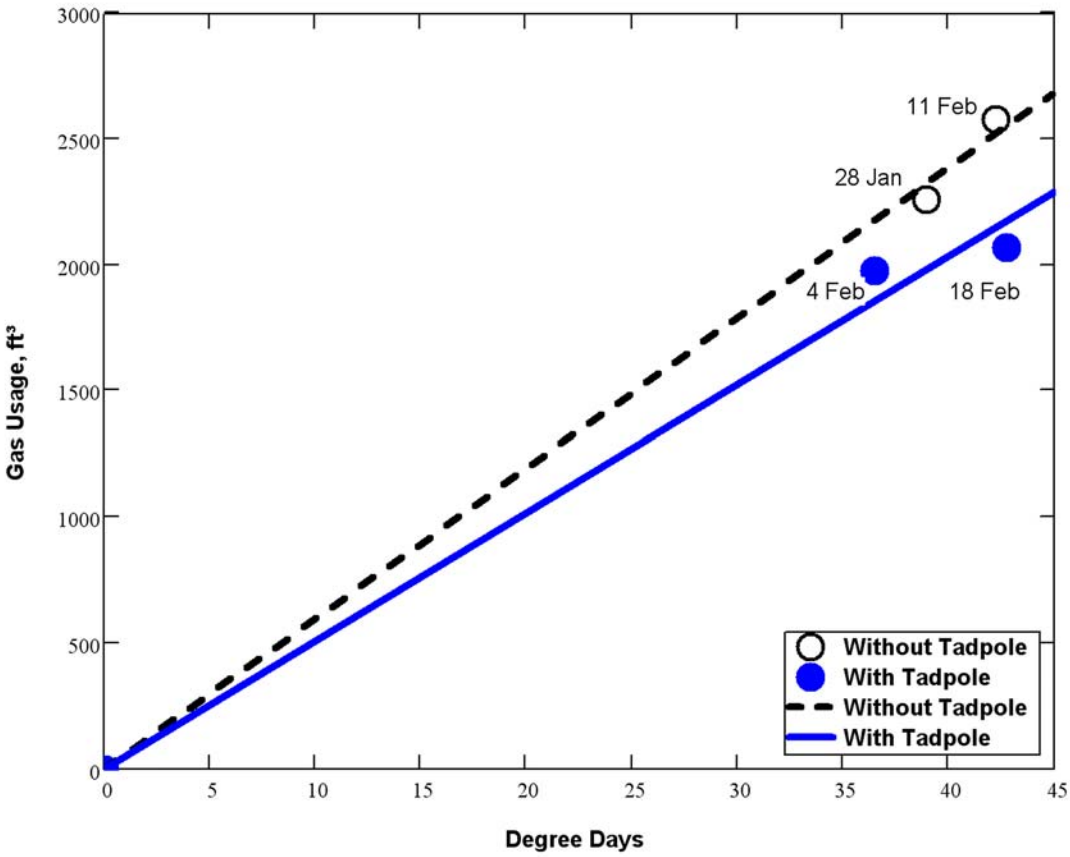

Figure 8 Alpha Bistro Tadpole Test Gas Usage versus Gatwick Airport Degree Days

8.4 Examination of the Data for Other Effects

The tests performed over the four weeks used the same water in a sealed pressurised system. If the Tadpole simply deaerated the water this would have happened in the second week and the results for the third week when the Tadpole was isolated from the system would be expected to be similar to the second and fourth weeks when the Tadpole was part of the system. The circuit was pressurised and so any leakages would be out of the system rather than air being able to leak into the system.

The effect of dissolved air on the heat transfer in a combi boiler and the radiators is not clear. In larger systems in power stations and process plant, deaeration systems are used to avoid corrosion and air in the plant rather than for optimising the heat transfer performance. It can be surmised that less dissolved air would alter the heat transfer but it would need specific tests to demonstrate whether this is the case and to what extent.

It is possible that the flow resistance of the central heating circuit is increased when the Tadpole is incorporated. This would tend to reduce the circulation flowrate which would give the water more time to rise in temperature as it flows through the boiler. The radiators would then run slightly hotter in line with anecdotal evidence. This possibility could be readily checked by measuring the pressure drop in the pipework either side of the Tadpole with and without the Tadpole isolated. A further check would be to replace the Tadpole with a pipe having a restriction in it that provided the same pressure drop as the Tadpole.

9 MEASUREMENT ISSUES

Various measurement issues have been raised above and these are summarised here:

1. The quantity of air trapped in the Tadpole chamber when it is plumbed into a system is not known. This could be resolved by arranging for the Tadpole automatic air valve to bleed the chamber via a small hole in the deaerator pipe.
2. The Bistro building indoor temperature should be measured in a more representative location than the downstairs toilet beside the boiler. A better location would be near the central heating programmable controller in the Bistro main upstairs room.
3. The outdoor thermocouple was not shielded from thermal radiation and it may be giving biased measurements during particular weather conditions.
4. To make up for gaps in the Tadpole test measurements weather data from Gatwick Airport have been used. The airport is approximately 30 miles from Alpha Heating Innovation and the weather is unlikely to be identical at the two locations.
5. The assumption has been made that the Alpha Bistro installation supplies little domestic hot water.
6. The pressure drop across the Tadpole is unknown as is the pressure drop across the pipework bypassing the Tadpole when the Tadpole is isolated.
7. The pressure rise across the central heating pump is unknown. The magnitude of this compared with the pressure loss across the Tadpole would be informative.

Additional measurement issues:

1. The amount of air removed from the water in the sealed system is unknown. This could be done simply by connecting the Tadpole air valve to a deflated bag, for example. At the end of the test the volume of the bag could be measured. Similarly the amount of air removed by the air valve in the combi boiler could be measured and compared with the air removed by the Tadpole.
2. The water flowrate through the boiler is unknown. If flowrate was included in the data measurements and the radiator supply and return temperatures were

known then the heat transferred to the building could be readily calculated and compared with the gas and electricity supplies.

3. Likewise a flowmeter and thermocouples in the domestic hot water would clarify how much heat has been delivered by the boiler as hot tap water.

A measurement uncertainty analysis has not been carried out and thus the magnitude of the error bounds on the calculated results cannot be given. The calculations performed above contain many uncertainties and assumptions and so the error bounds must be significant.

Insufficient measurements have been carried out to know how the mechanisms by which the Tadpole affects the Alpha Bistro system.

10 CONCLUSIONS

1. The test results for the Aquastan Heating Tadpole taken over the period 28 January 2008 until 22 February 2008 by Alpha Heating Innovation have been examined. The data referred to tests on the central heating system in a cottage used as canteen facilities by Alpha Heating Innovation staff.
2. There was insufficient data to be able to compare the heat delivered by the system with the energy supplied to the system. However, by assuming that little domestic hot water was supplied and by augmenting the outdoor temperature measurements with ambient air temperature measurements from Gatwick Airport, 30 miles away, inferences could be made about the heat delivered by the system.
3. Using the inferred heat demands on the system the Tadpole device apparently reduced the energy supplied to the central heating boiler by approximately 15% for a given heat demand. However it cannot be concluded from this that the efficiency of the system has improved by 15%, since only explicit measurements of energy input and output can define efficiency. The energy output calculation requires data on water flow rate and boiler water inlet and outlet temperature.
4. The mechanism by which this improvement came about was not clear. It cannot simply be a matter of deaerating the water because if that was the case the results would have been better for the week when the Tadpole was isolated in between the tests when the Tadpole was included in the system. If the Tadpole causes an increased pressure drop, which is having an influence on the system performance then an alternative flow resistance could provide the same pressure drop more economically.
5. The Tadpole construction means that it introduces air into the system when it is plumbed into the system. A simple modification could ensure this air was removed.
6. The effectiveness of the Tadpole at removing air could be measured directly and compared with the air removed by the automatic air valve on the boiler by collecting the air from each automatic air valve.
7. The use of degree days has been described for inferring system performance with minimal data. Where appropriate internal and outdoor temperatures are available a better method for inferring system performance has been described. The best way for determining the system performance would be to measure the boiler delivery water flowrates and the temperatures of the boiler

supply and return water flows and directly calculate the useful heat supplied by the boiler.

8. The uncertainties associated with each measurement should be estimated to in order to derive an uncertainty figure for the improvement provided by the Tadpole device.
9. An ideal test rig and a series of tests have been proposed that would circumvent the limitations in the Tadpole tests and clarify the way in which a Tadpole affects a domestic central heating system.
10. A full understanding of how the Tadpole works is required in order to produce a design and installation guide which would ensure effective results in each application.

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