

IT TRALEE

Subsequent Testing of Tadpole Product in an oil Fired open vent gravity fed Central Heating System

Report

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1.0 Introduction

Tadpole Energy re approached Dr. James Prendergast and Mr. Chris O' Donoghue of the Department of Mechanical and Manufacturing Engineering in the Institute of Technology Tralee, Co. Kerry, Ireland in June 2010 with the aim of independently testing the Tadpole unit used in domestic central heating systems. The objectives of the subsequent tests carried out were to:

- a) Evaluate dissolved oxygen and its re introduction into a central heating system over a period of time, with the system controlled by a clock timer simulating winter running of a typical domestic system.
- b) Evaluate the recovery rate of hot water in the system with and without the Tadpole unit installed
- c) Evaluate various parameters with and without the Tadpole unit installed and the system controlled by an air thermostat.

2.0 The Tadpole Device

The Tadpole unit tested is as shown in figure 1 and fitted in accordance with company instructions.



Figure 1 Domestic Tadpole

The Tadpole is a unique energy saving device which can deliver considerable energy savings when installed in a domestic heating system. The Tadpole is a cylindrical device which is placed up stream of the pump on the return to the boiler and is easily installed. The Tadpole by virtue of its design creates a vortex within the cylinder which allows entrained air and dissolved oxygen to be easily vented from the heating system providing an oxygen free system which as a result is more efficient in terms of energy usage, hot water regeneration

and higher radiator temperatures. Also by eliminating oxygen from the system the Tadpole reduces the incidence of corrosion.

3.0 Test Site Description

The test site that was chosen was a three bed roomed semi-detached house in the Tralee area. The house was built circa 1900 of stone construction without wall insulation. The house had a 150 mm thick insulation in attic areas and a mix of double glaze PVC and single glaze timber windows.



Figure 2 Test Site

4.0 Heating System Description

The central heating system was fuelled by an oil-fired outside boiler, housed in a shed approximately 10 metres horizontally from the header tank/hot water cylinder. The house was used as a guest house and the heating system retrofitted with that in mind. The oil boiler was used to heat the hot water cylinder (which could also be heated from a separate wrap around boiler/fire place or by using an immersion heater). The boiler was set to 90 °C the maximum setting on the boiler thermostat and kept at that setting for the all the tests. The boiler specification was as follows.

Table 1 Oil fired boiler specification.

Make	Firebird Boiler
Model	RS Balanced Flue Popular 90
Heat Output	14 to 26 kW

Max Operating Pressure	3 bar
Max Operating Temperature	90 C

The system contained 8 radiators of varying sizes, 4 upstairs and 4 downstairs. The system was open vent gravity fed from a header tank located in the attic. The boiler was controlled by its own thermostat/clock timer for the first two tests and a combination of its own stat and a wall mounted air stat for the final test. During the tests specific radiators were always in the fully on position. The system contained one Danfos circulating pump which was located on the return from radiators beside the boiler as shown in figure 1. The room and radiator sizes are shown in Table 2 below.

Table 2 Radiator and Room sizes.

Description	Room Size (m ²)	Radiator Size (m ²)
Sitting Room	5.3 x 3.4	1.4 x 0.49 (single)
Living Room	4.1 x 2.9	1.19 x 0.49 (double)
Dining Room	4.1 x 2.9	0.95 x 0.49 (single)
Hallway	5.6 x 1.8	1.19 x 0.51 (single)
Bedroom 1	2.7 x 1.8	0.52 x 0.51 (single)
Bedroom 2	5.3 x 3.4	1.42 x 0.51 (single)
Bedroom 3	4.1 x 3.4	1.27 x 0.51 (single)
Bathroom	2.6 x 2.5	1.42 x 0.43 (single)

A schematic of the system with positions of radiators can be seen in Figure 3:

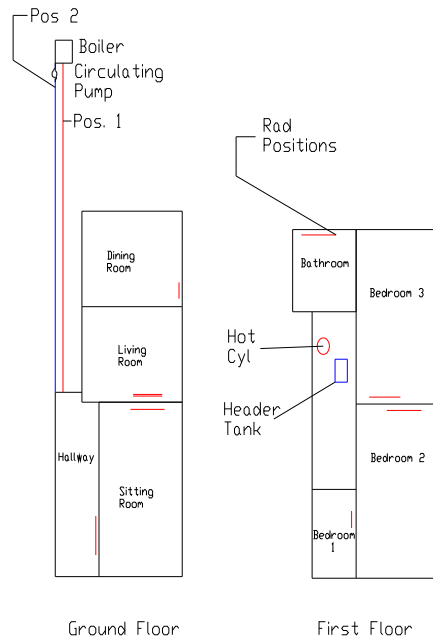


Figure 3 Schematic of test site central heating system.

5.0 Heating System Control

When the heating system was switched on the power up sequence was very repeatable regardless of whether or not the Tadpole was installed. The boiler and pump were wired to come on together in the first two tests and controlled by a programmable clock timer as in figure 4 (a). The last of the tests utilised a bi metallic room thermostat installed in room 2. This was set at 20 °C and was an off the shelf unit, figure. 4 (b). This stat controlled the boiler function in conjunction with the boiler mounted stat and the pump was kept running continuously for the duration of this test.



Figure 4 (a) Clock Timer.

Figure 4 (b) Wall mounted Thermostat.

6.0 Tests Conducted

Test methodologies and results are documented in sections 6.1 to 6.3.

6.1 Dissolved Oxygen Test

The main objective of this test was to replicate the typical running of domestic heating system during the winter periods. The primary parameter that was being evaluated in this test was the reduction in the level of Dissolved Oxygen as the system ran for a period of over a week. The hand held device used for measuring the level of Dissolved Oxygen sampled at intervals from the return was an WTW Oxi 96 and can be seen in figure 5.



Figure 5 WTW Oxi 96 DO Meter.

The cycle programmed by the clock timer was 2 hours on in the morning and 5 hours on in the evening.

Measured levels of Dissolved Oxygen (D.O.) in the system in conjunction with the return temperature are plotted against time as can be seen in figure 6. The overall trend of levels of D.O. in the system reduced over the duration of the test to a level of 0.5 Parts Per Million (PPM) after 186 hours of operation. On a daily basis D.O. levels followed an inverse trend to that of the return temperature.

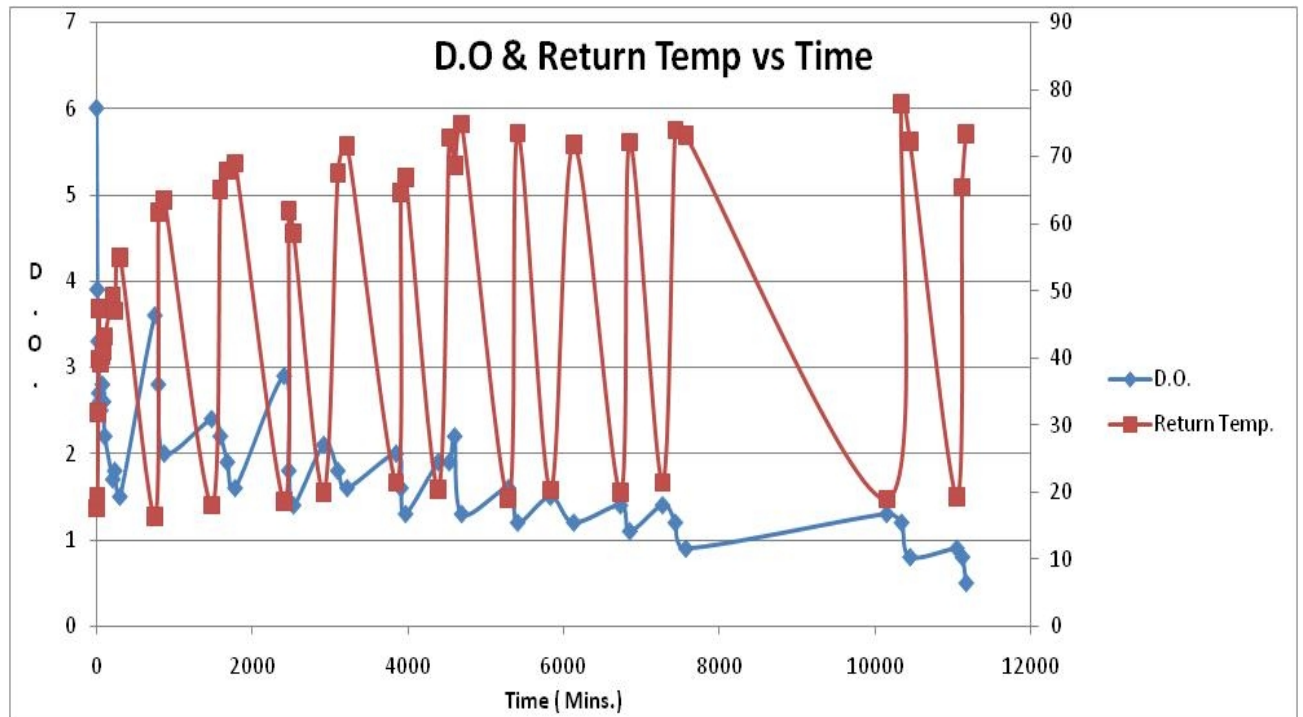


Figure 6 Dissolved Oxygen and Return Temperature against Time.

The large gap in the results towards the end of the test was due to an issue with the D.O. meter which was rectified. Basically the head of the meter picked up some dirt and had to be cleaned and this was done in a special cleaning solvent.

6.2 Hot Water Recovery

The objective of this test was to measure system recovery after 40 litres of hot water were removed from the hot water cylinder. The hot water recovery was measured at the top middle and bottom of the hot water cylinder and all the radiators were shut off for the test. This was done with the Tadpole unit in the system and compared to that without the Tadpole in place.

The results are shown in figures 7 and 8.

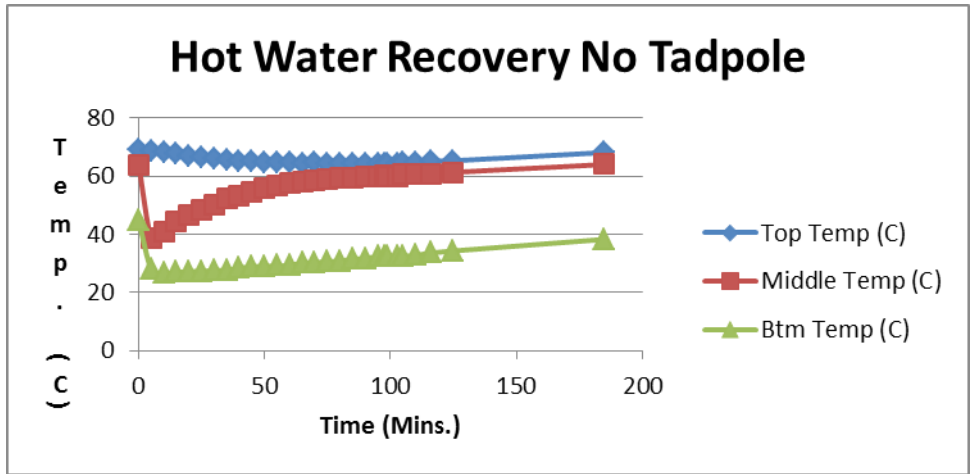


Figure 7 Hot Water Recovery rate with out Tadpole in system.

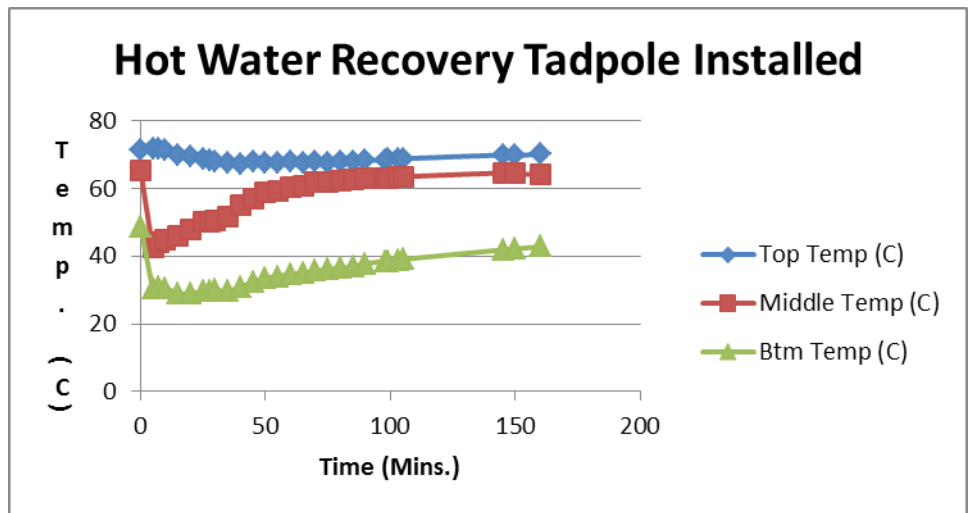


Figure 8 Hot Water Recovery rate with Tadpole in system.

The analysis of the data from the plots in figures 7 and 8 is shown in Table 3.

Note: There was no appreciable difference in average outside temperature for the days recovery tests were carried out (Met Eireann) and consequently there was no difference in the storage water feeding the hot water cylinder after the hot water was drawn off.

Table 3 Analysis of Hot Water recovery rate.

	Temperature Top of Tank	Temperature Middle of Tank	Temperature Bottom of Tank	Tadpole In/Out
Time 0	71.3	65.2	48.8	In
Time 0	69.2	63.8	44.7	Out
Time 150 Mins	69.7	64.4	42.2	In
Time 150 Mins	66.7	63.6	36.3	Out

0 Mins Difference	+2.1 C	+1.4 C	+4.1 C	
150 Mins Difference	+3.0C	+0.8 C.	+5.9 C	
Difference Across Tank	+0.9 C	-0.6 C	+1.8 C	

Across the hot water tank over the 150 minutes there was a cumulative increase in recovery temperature of +2.1 C in favour of the Tadpole installed in the heating system.

From the figures 7 and 8 there was also a faster rate of recovery with the Tadpole installed and this is seen in Table 4 where the temperature at the centre of the tank was analysed.

Table 4 Analysis of Hot Water heating rate.

Time	Temperature	Tadpole in/Out
25 Mins	48.2 C	Out
50 Mins	55.9 C	Out
25 Mins	50.1 C	In
50 Mins	58.8 C	In
Rate of Rise Over 25 Mins	7.7 C	Out
Rate of Rise Over 25 Mins	8.7 C	In

During the period from 25 to 50 minutes the hot water cylinder got 1 degree hotter with the Tadpole installed.

6.3 Tests conducted controlling the system using Air Thermostat

This series of tests involved controlling the heating system (boiler) using a bi metallic air thermostat set at 20 °C in bedroom 2. (Boiler thermostat was also set at 90 °C). Room 2 was sealed during the tests. No entry was allowed during duration in order to eliminate abnormal air flow and draughts. This could have interfered with the functioning of the air thermostat. The tests were carried out with and without the Tadpole installed for periods of up to 2 days. It was noted that all other radiators except those in rooms 2 were shut off. The parameters measured were as follows

- a) Outside Air Temperature
- b) Boiler duty cycle

6.3.1 Boiler Duty Cycle

Measurement of boiler running time was achieved using a counter unit directly connected to the electrical feed to the boiler and also timing the on and off cycles using a watch through both tests as seen in figure 11(a) and 11(b).



Figure 11 (a) Counter measuring on time Figure 11 (b) Watch measuring boiler cycle

The boiler duty cycle is calculated at any time throughout the operation of the boiler by clocking the on time, the subsequent off time and using the simple formula below to calculate the boiler on time as a percentage.

$$\text{Boiler on time \%} = \frac{\text{time boiler on}}{\text{time boiler on} + \text{time boiler off}} \times 100$$

The counter method was chosen to indicate the energy requirement in getting the system up to continuous running. For the first 103 minutes of test without the Tadpole installed the boiler was on for 61.6 minutes. The average external temperature for the same period was 12.97 °C. For the first 100 minutes of test with the Tadpole installed, the boiler was on for 54.27 minutes with an average external temperature of 8.58 °C.

The boiler duty cycle time during continuous running using boiler on time formula above was calculated and results are as follows:

Tadpole not installed at 266 minutes of test - **Boiler on time** was 37.5 % with an external temperature of 13.5° C at that time.

Tadpole installed at 269 minutes of test – **Boiler on time** was 37.86% with an external temperature of 3.9 °C at that time.

6.3.2 Summary of results with system controlled by air thermostat

The percentage on time in getting the system up to temperature with the Tadpole installed was 54.27 % as against 59.8 % without the Tadpole in the system. External temperature was 4.39 °C lower during this **start up phase** during the test with Tadpole installed.

Continuous running delivered a 37.86 % boiler on duty cycle with the tadpole as against a 37.5% value for test without Tadpole. During this period the test with the Tadpole installed ran with an average lower external temperature of 9.6 ° C.

6.3.3 Application of Degree Days

When the system was controlled using an air stat and during continuous running after the start up phase the outside temperature was very low. On average this was 3.9 degrees C compared to 13.5 degrees C without the Tadpole installed. Compensation in the form of degree days was applied in order to compare the test results. Degree days can be calculated from www.degreedays.net

Test	Tadpole in system	No Tadpole	Factor
Degree Days	3.6	8.8	2.4

Table 6 Degree Day results

Applying the principle of degree days the tests with the Tadpole installed should consume 2.4 times more energy than the tests without the unit installed.

As seen in section 6.3.1 the boiler on time with Tadpole installed was 37.86 %. When factor of 2.4 is applied a boiler on time of 15.775 % results. The difference between boiler on times results in 21.75% energy saving in favour of the test with Tadpole installed.

7.0 Conclusions and Recommendations

The three series of tests conducted and documented in this report took place between June 2010 and November 2010.

The first test was designed to analyse the level of D.O. in an open vent central heating system, replicated normal running and was found to have reduced to an inert level of 0.5 PPM after just over a week running the system 2 hours in the morning and 5 hours in the evening. The level of oxygen was continuing to decline and would presumably still reach lower levels over time. It is interesting to note that the level of D.O. fluctuated daily and in an inverse manner to the temperature of the water in the heating system.

The objective of the second test was to examine the performance of the rate of hot water recovery in the central heating system in question. Tests were carried out with the Tadpole unit installed and without the Tadpole in the system. 40 litres of hot water were drawn off when the system had got up to full heat and the temperature at three locations, on the cylinder was recorded. As the hot water cylinder was very well insulated, external temperature was not seen to be a factor in this test. It was shown from these tests that the hot water tank recovered to higher cumulative temperature of 2.1 ° C with the Tadpole in the system. It was also shown that when the rise after draw off was examined during the period of 25 to 50 minutes of test the Tadpole performed better by 1 ° C over that 25 minute period.

Finally the third test was conducted to examine the performance of the heating system with the Tadpole in and out of the system and control via the boiler thermostat set at 90 ° C and a room thermostat located in room 2 set at 20 ° C. The parameters that were examined here were:

- a) Outside Air Temperature
- b) Boiler duty cycle
- c) Degree day compensation

It is very important to note here that the average external temperature was 9.6 ° C colder during the test with the Tadpole installed.. However neglecting compensation for the 9.6 ° C external temperature difference across the tests, boiler cycle was considerably more efficient with Tadpole in place in the start-up phase and very slightly higher in the continuous running phase.

A degree day comparison is applied as in section 6.3.4. This concept enables a compensation factor to be applied to overcome the influence that the difference in outside temperatures between tests, has on tests results. When this factor is taken into account, the tests with the heating system controlled by air stat, give a 21.75% saving in energy consumption in favour of the test with Tadpole unit installed.