

IT TRALEE

Testing of Tadpole for Removal of Oxygen from Water in a Domestic Central Heating System

Report

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Contents

Section

- 1.0 Introduction
- 2.0 The Tadpole Device
- 3.0 Test Site and Heating System Description
- 4.0 Tests Conducted
- 5.0 Results
- 6.0 Subsequent Testing
- 7.0 Summary of Tadpole Test Results
- Appendix A. Corrosion Process (Central Heating Systems)

1.0 Introduction

Tadpole Energy Ltd approached the Department of Mechanical and Manufacturing Engineering in the Institute of Technology, Tralee, Co. Kerry, Ireland in late 2009 with the objective of independently testing the Tadpole Deaerator used in domestic central heating systems. The primary aim of the tests carried out was to evaluate the ability of Tadpole to remove Dissolved Oxygen to an inert level in a typical domestic central heating system compared to the base line, i.e. no Tadpole unit in the system.

2.0 The Tadpole Device

The product tested was the Tadpole unit which can be seen in in figure 1 below.



Figure 1
Tadpole Unit

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 product 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 incidences of corrosion.

3.0 Test Site and Heating system Description

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

The central heating system was fuelled by an oil fired boiler heating the radiators. The boiler thermostat was set to 90 °C the maximum and kept at that setting for the tests. The system was open vent gravity fed from a header tank located in the attic.

The system was controlled by the boiler thermostat and there was no temperature control in any of the living spaces. The system contained one pump which was located on the return beside the boiler as shown in figure 2.



Figure 2
Boiler and Pump Layout

4.0 Tests Conducted

In all two main tests were carried out:

Test 1: This was a baseline test (designated as BL in all the graphs). This test consisted of flushing the system and starting up without any Tadpole unit.

Test 2: This test consisted of testing the system with the Tadpole installed.

The primary parameter that was being evaluated in all tests was the reduction in the level of Dissolved Oxygen as the system ran. Dissolved Oxygen is regarded as one of the main factors associated with internal corrosion of system components (Appendix A). The tests conducted involved periodic measurement and recording of Dissolved Oxygen(DO).

Prior to any testing the system was allowed to cool down for a minimum of 24 hours and all the water drained from the system at the boiler. The system was then refilled and emptied and any necessary plumbing carried out to install the Tadpole. The system was then filled from the bottom up through the return to prevent large air pockets from forming in the radiators and the hot water cylinder coil bled. The hot water cylinder was also flushed to ensure that the cylinder retained no heat from previous tests. The pump was then run on its own for 20 minutes and a cold bleed performed on the radiators again.

5.0 Results

The Tadpole unit used in this test was evaluated to determine the effectiveness of venting dissolved gases from the heating system. The gas of most concern in any heating system is oxygen as it is related to the cause of many common problems in the domestic heating system. Problems such as air pockets causing non uniform heating of radiators, corrosion of radiators, knocking of pipes and cavitation of pumps etc. can all be linked to systems in which air is trapped. Of the problems listed above the removal of oxygen to an inert level ($\leq 0.5PPM$) will significantly reduce the incidence of blocked pipes and radiator replacement due to corrosion residue. According to the Energy Saving Trust in the UK tests in laboratories and homes indicate that the efficiency of heating systems can fall by as much as 15% where corrosion residue is present in the system.

The Dissolved Oxygen (D.O.) was tested by taking small samples at regular intervals from the flow to the radiators and testing the water immediately using an WTW Oxy 96 D.O. meter capable of reading to 0 PPM (Parts per Million). To ensure accuracy of D.O. measurements the samples were cooled to 40 °C.

The system baseline is shown in figure 3 and the behaviour is what would be typically expected with a rapid decline in D.O. as the temperature increased followed by a levelling off at 1.2 PPM as shown. The initial D.O. value was 7.7 ppm and this decreased rapidly as seen below when the system was heating up. The test was terminated after 1140 minutes (19 Hours) as the rate of decrease had declined significantly and it was unlikely that further testing would have yielded a further significant decrease.

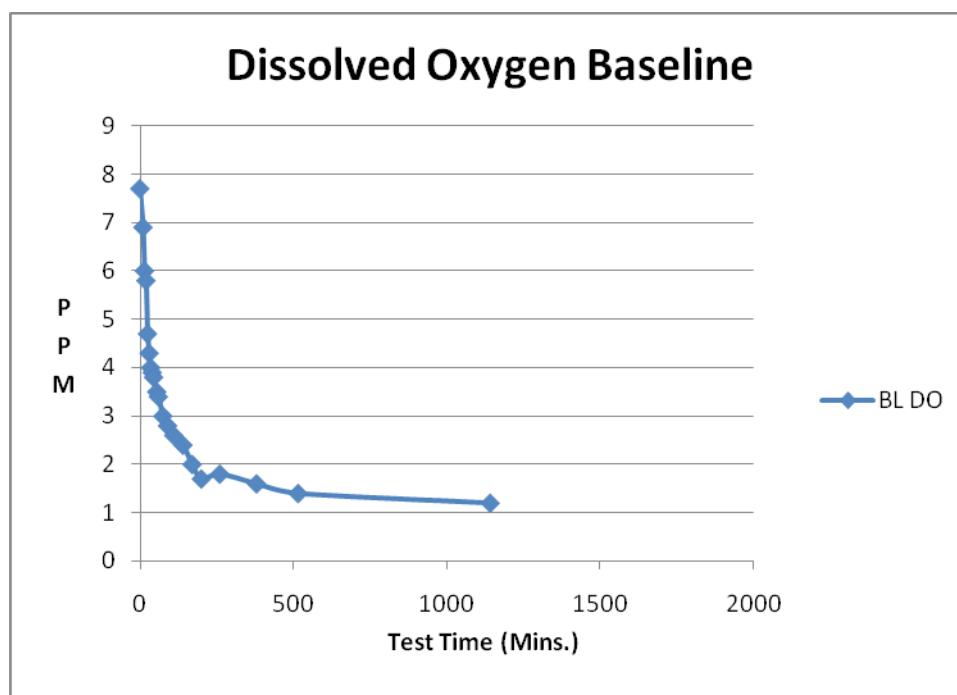


Figure 3 Baseline Dissolved Oxygen Curve

The data for the Tadpole is shown in figure 4 and again the trend is similar showing a rapid decrease initially but reducing to 0.8 PPM after 350 minutes and reaching 0.2 PPM after 1230 minutes (20.5 hours) from its initial value of 7.2 PPM.

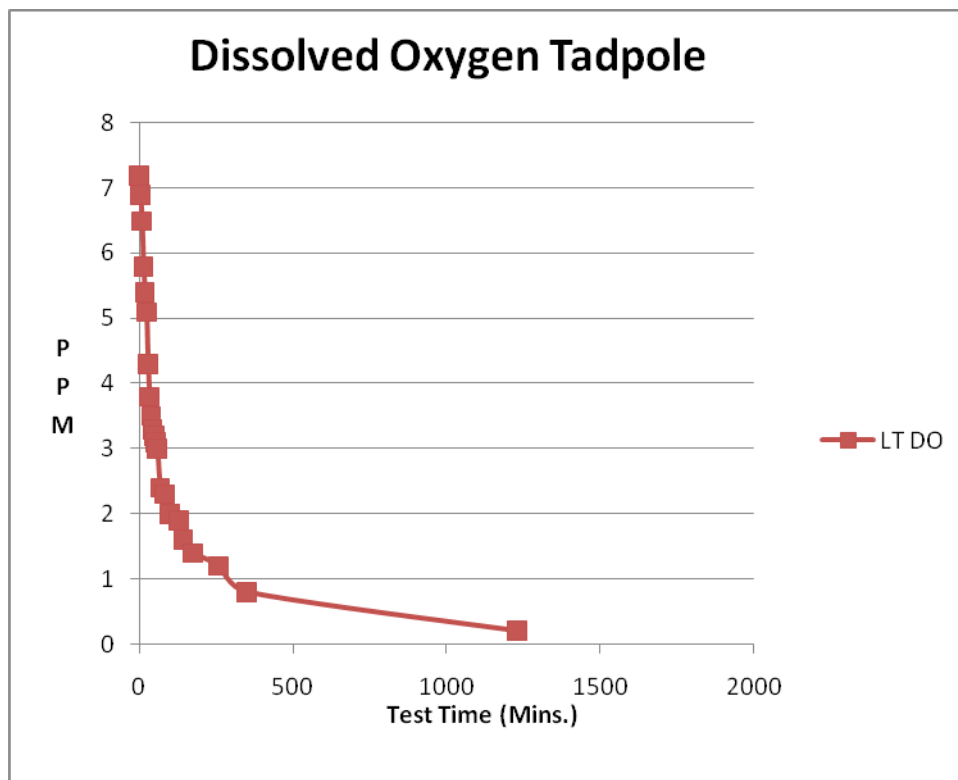


Figure 4 Tadpole Dissolved Oxygen

When the 2 curves are superimposed (figure 5) on each other the rate of decrease can be seen. In a time interval of 300 minutes it can be seen that Tadpole had the largest rate of decrease of dissolved oxygen. As the test continued the Tadpole continued to outperform the baseline and on completion of the tests the Tadpole system reached a PPM value of 0.2 as opposed to a value of 1.2 for the baseline all of which would aid in inhibiting corrosion.

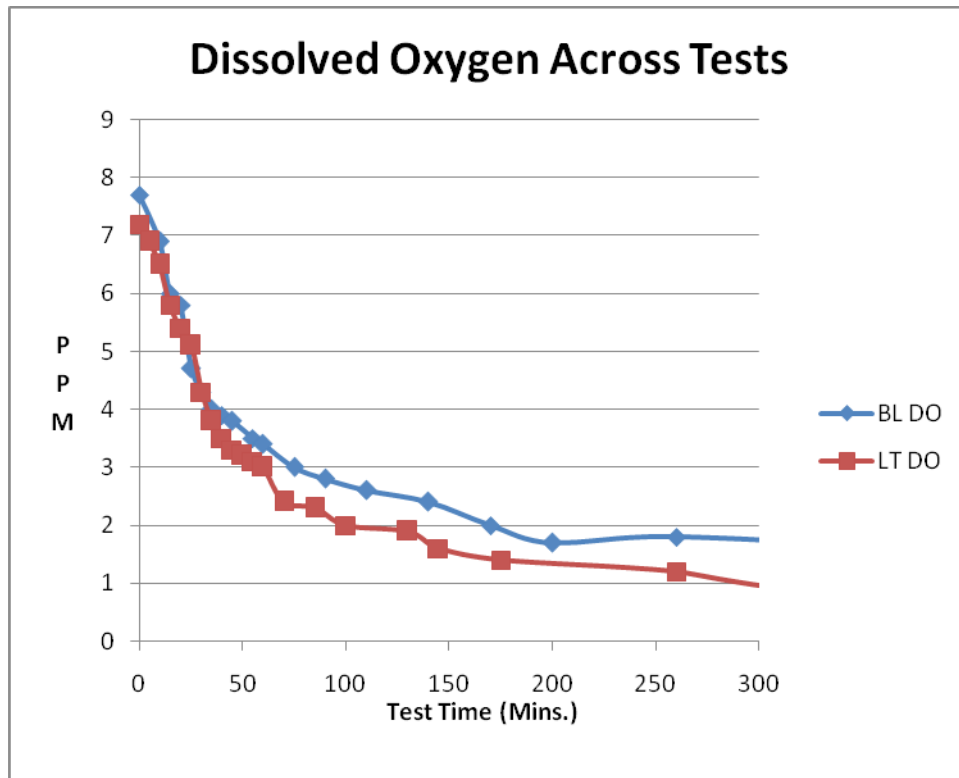


Figure 5 Oxygen Comparison Across Tests

6.0 Subsequent Testing

The objectives of the subsequent tests carried out between June and November 2010 were to evaluate the reintroduction of dissolved oxygen to the water during the normal cycling of a domestic central heating system and Tadpoles ability to reduce and maintain the level of oxygen at an inert level The system was controlled by a clock timer simulating winter running of a typical domestic system. The Tadpole unit tested is as shown in figure 6 and fitted in accordance with company instructions.



Figure 6 Domestic Tadpole unit.

6.1 Tests Conducted

The main objective of this test was to replicate the typical running of domestic central 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 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 as well as return temperature were plotted against time as can be seen in figure 7.

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.

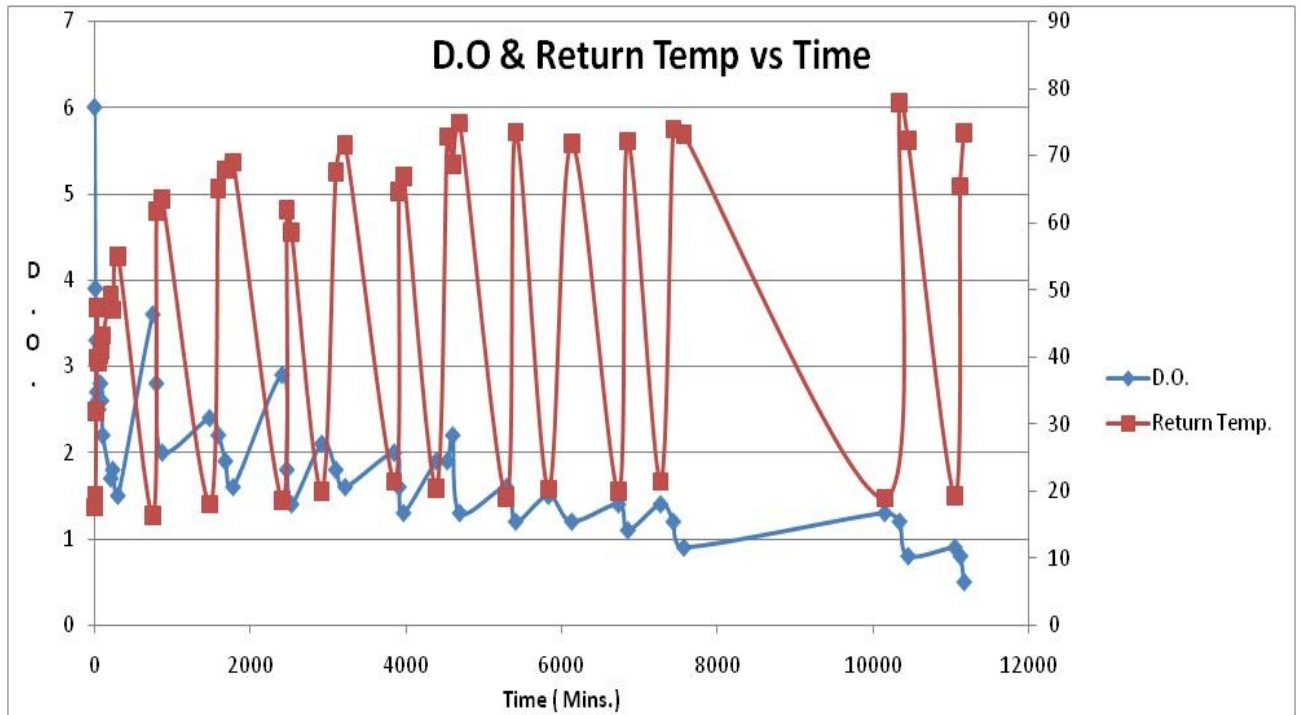


Figure 7 Dissolved Oxygen and Return Temperature against Time.

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 Conclusions

The test was designed to analyse the level of D.O. in an open vent central heating system replicating normal winter running and was found to have reduced the Oxygen to a level of 0.5 PPM after just over a week of running the system 2 hours in the morning and 5 hours in the evening. 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.

7.0 Summary of Tadpole Test Results

7.1 Tests

The Tadpole has been independently tested using an open vent oil fired central heating system firstly under constant operation on the boiler thermostat and secondly using an air thermostat and time clock to control the boiler cycle.

7.2 Conclusion of Results

With the boiler thermostat controlling the heating system and the system running constantly it was found that the levels of dissolved oxygen in the system reduced much quicker and reached an inert level of 0.2 ppm, with the Tadpole installed as opposed to 1.2 ppm for the system without the Tadpole installed. This would greatly reduce the incidence of corrosion and increase system life whereas at the level of 1.2 ppm without Tadpole corrosion would persist reducing the efficiency of the heating system by as much as 15%.

With the boiler thermostat and the system timer controlling the system, the performance was found to be excellent. The timer for these tests was set to 2 hours on in the morning and 5 hours in the evening. The system with Tadpole installed reached an inert level of 0.5 ppm in just over one week running at this cycle at which point the corrosive effects of Oxygen would have ceased. The reduction of oxygen was continuing to decline and would presumably reach still lower levels over time.

In summary the systems with the Tadpole installed outperformed the base system in terms of removal of Oxygen. More importantly boiler efficiency would be improved leading to savings in fuel, electricity and extension of the life of the system.

Appendix A (Corrosion)

Corrosion occurs whenever a gas or liquid chemically attacks an exposed surface usually a metal and it is accelerated by warm temperatures. Normally corrosion products such as rust stay on the surface and can protect it from further corrosion and removing these deposits re-opens the surface and corrosion continues. Traditional heating systems consist of iron in radiators, a heating fluid, water and generally run at temperatures in excess of 45 °C. so all the ingredients for corrosion are present and this generally occurs in the radiators. Corrosion or rusting has a significant economic cost. It has been estimated that the cost of corrosion is over 1% of the world's economy and that a quarter of the steel produced in the USA goes towards replacing rusted material.

The rusting process is a complex one but in its simplest form it involves the formation of a hydrated oxide such as $\text{Fe}(\text{OH})_3$ or $\text{FeO}(\text{OH})$. The process requires the presence of water, oxygen and an electrolyte. If any one of these are absent then no significant amount of corrosion will occur.

Rusting is a redox reaction involving the loss and gain of electrons between reactants. An electrochemical cell is created with impurity sites in the iron acting as cathodes for the reduction of O_2 gas and a region of the metal surface acting as the anode where the oxidation of iron occurs. The process is complex and will depend on the prevailing conditions such as the temperature, amount of impurities, quantity of oxygen in the water and a small amount of O_2 will initiate a regenerative corrosion process. The rust then forms a coating that can slow further corrosion if left undisturbed by the weather or other influences.

In a heating system the oxidation of the iron (corrosion) is usually localised in surface pits and crevices which would normally allow the formation of adherent rust over the surface which in other conditions would slow the corrosion process down. However in a heating system the adherent rust can be flushed away and further corrosion can occur in the same place in the radiator.

The removal of oxygen from the heating water to a level below 0.5 PPM, generally regarded as inert, should remove the incidence of corrosion from the heating system. This would have the effect of reducing ongoing maintenance due to rusting of radiators, blocked pipes etc. According to the Energy Saving Trust in the UK tests in laboratories and homes indicate that the efficiency of heating systems can fall by as much as 15% where magnetites created by corrosion are present in the system.