Control Schemes for OpenTherm Boilers: Energy Efficiency and Carbon Savings in Domestic Heating

Martin O'Hara and Philip Smith
Danfoss Randall Limited, Ampthill Road, Bedford, MK42 9ER, England

Abstract: This paper presents results of system testing with an OpenTherm modulating-condensing boiler and 3 types of room controllers; mechanical, electronic on/off and modulating. The results of measurements of energy consumption (gas and electricity), carbon emissions and comfort level are presented from tests in a controlled laboratory “test house”. The results suggest that many of the benefits of a modulating boiler are lost if the controls are not updated to match the boiler performance, however, energy efficiency may be improved by as much as 14%, with a similar reduction in carbon dioxide emissions, if the controls are upgraded on an existing OpenTherm boiler from mechanical to modulating control.

Introduction

There has been a lot of talk about how much energy will be saved by using a modulating boiler compared to a conventional non-modulating boiler, however, no-one to our knowledge has examined how the control scheme will effect the heating system performance. In this paper we have looked at the efficiency and carbon emissions that are achieved if a modulating (OpenTherm) boiler is used with older controls such as a mechanical thermostat and an electronic on/off thermostat. These are then compared with a modulating control (OpenTherm) thermostat to identify what benefits an “optimised” modulating boiler and control can offer.

Background

There will be many situations where an installer or home owner will decide to upgrade their heating boiler for an OpenTherm modulating type to gain the energy benefits that modulating boiler can offer over a condensing non-modulating boiler. However, many of the installers and home owners may not appreciate that their controls should also be updated to match the newer boiler, and why would they when there is little available evidence on the effect the control might have on the system. It was this lack of measured data on the benefits of a improved control scheme on the energy efficiency of a heating system that prompted Danfoss to investigate the impact that controls alone can have on the overall heating system performance.

Laboratory Controlled “Test House”

Danfoss Randall have a laboratory controlled “test house”. This consists of a 20 cubic metre single brick room with plastered internal lining (comfort house) surrounded by 50 cubic metres of controlled temperature air-flow (annular space) which represents the outside air temperature. The test house has a 1.3kW radiator to provide heat from the boiler to the room and a hydronic load dump allowing up to 25kW of additional load to be drawn from the boiler under room control (this load dump represents the rest of the house). The boiler is installed in a separate part of the laboratory hence does not contribute directly to the heating. Consequently, although operating on a single controlled room (as is typical in a UK dwelling), there is a “real life house” draw of energy from the system.

The above system allows the effect of control alone to be accurately monitored as we are able to set-up repeatable external temperature and system load on the same boiler with the same radiator in the same test room. The only difference between each system test run is the controller we use to determine the system activity.
UK Winter Weekend Profile

The tests presented here all had the same profile on the system. The annular space (external temperature) is maintained at 10°C, the test room is allowed to cool to 15°C before commencing run and the room control set for 20°C. The run is a single 12 hour operation representing a weekend profile, turning the system on once and then controlling at a fixed temperature; a single start-up and then constant control. The total system load is 13kW.

Controller Results

The OpenTherm protocol is designed to operate with a 2-wire on/off signal in situations where a modulating controller which implements the OpenTherm protocol is not available. Consequently it is not unlikely that simple 2-wire on/off controllers are being used in some installations to control an OpenTherm modulating boiler. As the interface to the boiler is a 2-wire only system, we determined to use 2-wire on/off controllers only when comparing to the OpenTherm controller.

Mechanical Room Control

A simple 2-wire electro-mechanical thermostat (bells type) was used to control the OpenTherm boiler, this has a relatively high swing in the comfort temperature of ±1°C as shown in the comfort plot. The speed of the controller is limited by the reaction rate of the bellows and is observed to be relatively slow in the system.

Electronic Room Control

The 2-wire electronic on/off controller has a microprocessor operating a PI control algorithm inside the product and as can be seen from the comfort plot, provides better control and comfort level than the mechanical controller. The electronic sensing element also reacts faster than the mechanical controller and consequently uses less energy to provide the same comfort level, with less variation about the set-point temperature (±0.6°C).
Modulating (OpenTherm) Room Control

The modulating control gives the best level of comfort over the test sequence. This results in the lowest level of energy consumption and lowest carbon dioxide emissions. The speed of response is significantly better than either of the other two controllers as the controller and boiler are interacting, hence even small changes in the room are communicated to the boiler (observed variation in comfort level less than ±0.3°C).
Discussion

As expected, having a modulating controller operating a modulating boiler provides the optimum system efficiency. Although improvements over the mechanical thermostat can be obtained using a faster reacting electronic thermostat, this electronic controller, despite its relative intelligence over the mechanical controller, has no information over what the boiler is doing and hence can not optimise its demands to meet the boiler capability.

The OpenTherm controller will not only communicate to the boiler what the room demand is, but will receive information from the boiler to assist it in optimising the load demand it requests. Hence although controlling on a single room, it will know that the system demand is greater than the room alone and the control algorithms adapt to the boiler load as well as the room conditions.

Summary

There are significant savings to be made by improving the control scheme used for a modulating-condensing boiler. Switching from a simple mechanical thermostat to an electronic version gives an improvement of over 10% in both energy cost reduction and carbon emissions saving. There is almost a further 5% saving available by installing the optimum system control for an OpenTherm boiler by utilising an OpenTherm controller.

<table>
<thead>
<tr>
<th>Control</th>
<th>Energy Cost (€)</th>
<th>Energy Saving (%)</th>
<th>Carbon Emissions (kg CO₂)</th>
<th>Carbon Saving (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical On/Off</td>
<td>3.92</td>
<td>-</td>
<td>15.18</td>
<td>-</td>
</tr>
<tr>
<td>Electronic On/Off</td>
<td>3.51</td>
<td>10.4</td>
<td>13.58</td>
<td>10.5</td>
</tr>
<tr>
<td>Modulating</td>
<td>3.36</td>
<td>14.3</td>
<td>12.91</td>
<td>15.0</td>
</tr>
</tbody>
</table>

The results above are from tests with Danfoss control products, however, tests have been conducted with other manufacturers on/off control products and similar differences obtained.

Conclusion

It is clear that only changing the boiler in a domestic heating system from non-modulating to modulating will not optimise the potential energy and carbon savings. The results here show that the controls similarly need to be changed and that for optimum performance a modulating OpenTherm room controller should be used with a modulating OpenTherm boiler.

Danfoss Room Controllers

Danfoss offer a range of room control products including mechanical, electronic on/off and soon to be released modulating (OpenTherm) controllers. The controllers are based around the principle of “simple to operate” for the user, hence all the intelligence is hidden and the occupier has the same interface regardless of the underlying control scheme. Consequently whether using chrono-proportional control for optimum efficiency on a non-modulating boiler or OpenTherm control protocol on a modulating boiler, the user only has to set the comfort level and let the room controller optimise their energy savings.