Assessing the heating energy use through varying set-point and set-back temperatures in a whole house test facility

Colin Timmins, BEAMA, January 2019

Summary

Test were carried out looking at the effects of varying the set-point temperatures and times of operation of the system in comparison to the system running under the same control regime but to the standard time and temperature profile defined in the SAP methodology.

The tests were carried out independently by the University of Salford and commissioned by BEAMA Heating Controls, the UK association for manufacturers of controls used in heating and hot water systems and for wider control of the internal environment of residential buildings.

Two tests were carried out on a system with a Programmable Room Thermostat compared to a baseline of a system operating to the SAP profile:

- Setting back the heating overnight and during the daytime rather than turning it off
- Lowering temperatures and reducing operating times to save energy

The results of the tests are summarised below:

Test	Cost difference from baseline
Setting back the heating rather than turning it off	+ 3%
Lowering temperatures and reducing operating times to save energy	-16%

The conclusions are that setting back the heating to 16oC overnight and during the daytime results in a higher energy cost than just turning it off, and that using a Programmable Room Thermostat to reduce heating system operating times and temperatures can allow occupants to obtain a significant reduction in their heating cost. The latter would also be true for smart controls, but both depend on occupants' lifestyle.

Introduction

Central heating systems in the UK are traditionally understood to be operated through an on/off heating regime with the temperature set at a single 'comfort' level on a room thermostat. When time control of heating system first became widespread it would invariably provide the ability to set two heating periods, one in the morning and one in the afternoon/evening and this format of heating is still commonly adopted. The 2011 'Energy Follow up Survey' done for the Department of Energy and Climate Change reported that 70% of people with central heating have their heating come on twice

per day, and the Standard Assessment Procedure (SAP) energy calculation methodology follows this by assuming a heating pattern of two hours in the morning and seven hours in the afternoon/evening.

The increasing application of programmable room thermostats, which allow occupants to set a variety of times and set-point temperatures, means that users have greater flexibility in how they heat their home. In addition to this, a variety of 'smart' controls can learn from occupancy patterns and preferences to automatically reduce times of heating operation or set-point temperatures.

However, there is little information on the potential energy savings that such actions can have on the energy use of the heating system. Even allowing for the fact that such changes will, by their nature, be specific to the occupants' lifestyle it would be helpful to have a technical analysis of the impact of changing the time and temperature of operation on the heating energy use.

As part of research commissioned by BEAMA Heating Controls and carried out independently by the University of Salford to look at energy savings from temperature controls, two additional tests were carried out. These focus on the effects of varying the set-point temperatures and times of operation of the system in comparison to the system running under the same control regime but to the standard time and temperature profile defined in the SAP methodology. This report details the process and results of these two additional tests.

The Salford Energy House test facility

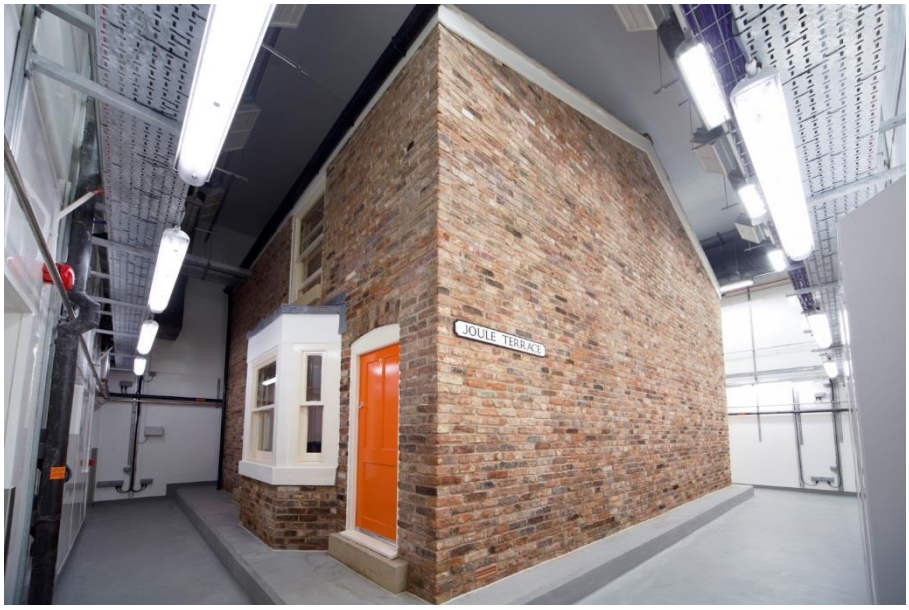

Figure 1: The Salford University Energy House

The Salford Energy House, Figure 1, is a full-sized test house, built within an environmental chamber. It is a test facility that bridges the gap between laboratory-based product testing and outdoor field trials, which may or may not include occupants. The house is a traditionally constructed Victorian end-terraced building, with a conditioning void to represent a neighbouring property. It has solid brick walls, suspended timber floors, lath and plaster ceilings and single glazed windows. In its base state it is un-insulated but for the purposes of these tests 100mm of loft insulation was fitted in the loft. It has a wet central heating system with radiators fed by a gas condensing combination boiler. All of this

can be changed to suit the testing requirements. The conditioning void uses the same construction techniques and can be environmentally controlled to reflect different heating behaviours. The house is a traditional UK 'two-up, two-down' Victorian solid wall property of a type that currently number approximately 6.6 million in the UK.

The external environment surrounding a dwelling makes a significant difference to how much energy is required to heat the building. The chamber can recreate a range of external weather conditions: Temperature can be controlled from -12oC to +30oC (with an accuracy of ±0.5oC). This controlled environment allows for consistent temperatures to be used, which is particularly useful for validating approaches such as whole house heat tests.

The advantage offered by the Energy House is that it allows for the effect of heating controls to be accurately measured as it is effectively a real house with a real heating system within a laboratory. Not having the intervention of real users that you would find in a field trial means that the technical potential for savings can be measured. While individual householders will use their controls in different ways, and have differing lifestyles that smart controls can adapt to, these tests allow us to measure the effect that controls can have on the system (which makes sense from the perspective of an energy performance calculation) while also gaining insights on how to help occupants achieve the full savings potential from their heating controls.

Test method

The test was set up with the heating system controlled by a programmable room thermostat and TRVs and the following were monitored:

- Temperature and humidity of each room
- Temperature of radiators
- Boiler flow and return temperatures
- Boiler flow rate
- Gas consumption
- Electricity consumption

The external temperature (in the climatic chamber) was set to 5°C, which is the average UK temperature in the winter months. Test were carried out over a 24-hour period starting at 00:00 with the settings and heating patterns maintained before each test started to allow the test facility to reach a repeatable state.

Three tests were carried out (including the baseline test) and these are described below:

Test 1 – Baseline test

The programmable room thermostat was set to maintain 21°C in the living room, with the TRVs maintaining 18°C in other rooms. The heating system was set to operate on the following time profile:

- On at 06:30
- Off at 09:00
- On at 15:30
- Off at 23:00

This profile equates to the assumed SAP profile where the dwelling is at set-point temperature for 2 hours in the morning and 7 hours in the afternoon and evening. A 'warm-up' period of 30 minutes was added to each 'on' period to match this, and was agreed with BRE who produce the SAP methodology.

Test 2 - Setting back the heating rather than turning it off

The programmable room thermostat was set to maintain 21°C in the living room during 'on' periods and 16°C during off periods, with the TRVs maintaining 18°C in other rooms. The heating system was therefore set to operate on the following time profile:

- 16°C at 00:00
- 21°C at 06:30
- 16°C at 09:00
- 21°C at 15:30
- 16°C at 23:00

This profile was set to answer the question of whether it is better to turn the heating system down rather than fully off when not needed. The premise behind this is that with the system fully off, it takes more energy to heat the fabric of the building up again in order to reach comfort temperatures. This is particularly relevant for buildings such as the test house, which has solid brick walls that are insulated, where the thermal mass of the building is significant and likely to cool down relatively quickly.

Test 3 – Lowering temperatures and reducing operating times to save energy

The programmable room thermostat was set to maintain varying temperatures in the living room, with the TRVs maintaining a maximum of 18°C in other rooms. The heating system was therefore set to operate on the following time profile:

- 12°C at 00:00
- 18°C at 07:30
- 12°C at 09:30
- 18°C at 16:30
- 21°C at 18:00
- 12°C at 11:00

This profile was to reflect occupants using the functionality of the programmable room thermostat to vary the heating system operation away from the standard SAP profile in order to reduce energy consumption. Hence the profile includes less heating hours (7.5 hours rather than 9), lower set-point temperatures for the morning and afternoon when occupants are likely to be more active (18°C rather than 21°C) and a reduced set-back temperature of 12°C.

Results

The full results from the tests are shown in Table 1 below:

Test	Energy use, gas and electricity[1] (kWh)	Cost[2]	Cost difference from baseline
1. Baseline test	69.10	£3.02	-
2. Setting back the heating rather than turning it off	71.12	£3.12	+ 3%
3. Lowering temperatures and reducing operating times to save energy	58.20	£2.55	-16%

Table 1 – Collected results[1]

Analysis and conclusions

There are two clear conclusions that can be drawn from these tests results:

1. **Setting back the heating to 16°C overnight and during the daytime results in a higher energy cost than just turning it off.** Given the heavyweight, poorly insulated nature of the test house this seems to disprove the theory that extra energy would be needed to warm the structure up if you allow the building to fully cool down, at least during average winter external temperatures. Given that the cost increase is only 3%, however, it might be sensible for householders who are in all day to maintain a setback temperature particularly if there are vulnerable occupants – even if budgets are tight.
2. **Using a Programmable Room Thermostat to reduce heating system operating times and temperatures can allow occupants to obtain a significant reduction in their heating cost**. This may be self-evident but having some data and examples of steps to take could add weight to this neglected aspect of energy efficiency advice. A crude analysis of the calculated savings that would be expected with these changes (hours of operation against delta T) indicates that the savings observed in this test might be slightly lower that the calculations would predict but a more detailed analysis is needed to confirm this. The potential for savings can be extended to smart controls although both will depend greatly on the lifestyle of the occupants.

[1] *1 - Calculated using http://www.energylinx.co.uk/gas_meter_conversion_meters.html with default settings (Correction Factor = 1.02264, Calorific Value = 40.0)
*2 - Based on British Standard monthly direct debit tariff (4.274p per kWh gas, 12.797p per kWh electric) not including standing charge (24.439p per day gas, 15.979p per day electric) - Prices taken on 07/05/2013 from: http://www.britishgas.co.uk/products-and-services/gas-and-electricity/our-energy-tariffs/clear-and- simple/clear-and-simple-rates.html