Assessing the energy savings from Thermostatic Radiator Valves in a whole house test facility

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Summary

A series of tests were carried out to establish the energy saving benefits of Thermostatic Radiator Valves (TRVs).

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. The tests were also carried out in close co-operation with BRE, who manage the energy performance calculation methodology, SAP, on behalf of the UK Government.

The tests were set up to measure the overheating that would occur in a residential building over the course of a heating season if TRVs were not present. The resulting energy savings from heating were compared.

The results of the tests are summarised below:

Outside temperature	Energy saving from using TRVs
-4°C	Baseline
5°C	14%
7°C	19%
9°C	18%
12°C	28%
15°C	41%

Given that the average UK outside temperature during the heating season is 7.6°C, it is concluded that the average energy saving potential for TRVs in homes is 18% of the heating costs.

Introduction

Around 80% of homes in the UK are heated by wet central heating systems with radiators, and analysis by eu.bac[1] and others are that around 8 million such homes don't have Thermostatic Radiator Valves (TRVs).

TRVs are fitted to a radiator where it connects to the pipework, replacing the manual valve that would be used to set up the system. They independently monitor the temperature of the room they are in and automatically adjust the heat output of the radiator in response to this so that a comfortable temperature is maintained. Without this addition to the usual central (boiler) control there is the potential for individual rooms to overheat and waste energy.

The forthcoming implementation of the 2018 review of the Energy Performance of Buildings Directive requires that all Member States implement a mandatory requirement for TRVs to be installed when boilers are replaced. This is due to be implemented in the UK through a revision to Part L of the Building Regulations that will be carried out early in 2019.

It is therefore timely to have robust data on the energy saving potential of TRVs both to emphasise the economic benefits of adding TRVs to new and refurbished heating systems, and to encourage consumers to make such a change to their existing system to reap the benefits straight away.

This research was commissioned by BEAMA Heating Controls and carried out independently by the University of Salford in their Energy House facility. BRE, who manage the energy performance calculation methodology, SAP, on behalf of the UK Government provided the specification for the tests which ensured the integrity of the proposed approach. This also ensured that the subsequent data could be used to amend and update the savings value calculated by SAP for TRVs.

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. Without the intervention of real users that you would find in a field trial it also allows the technical potential for savings to be measured. It is well known that householders tend to use their heating controls in a sub optimal way, therefore we can measure the effect that controls should be having (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.

The Salford Energy House test facility

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

[1]https://www.eubac.org/cms/upload/downloads/position_papers/White_Paper_on_Room_Temperature_Controls_-_eu.bac_July_2017_FINAL.pdf

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.

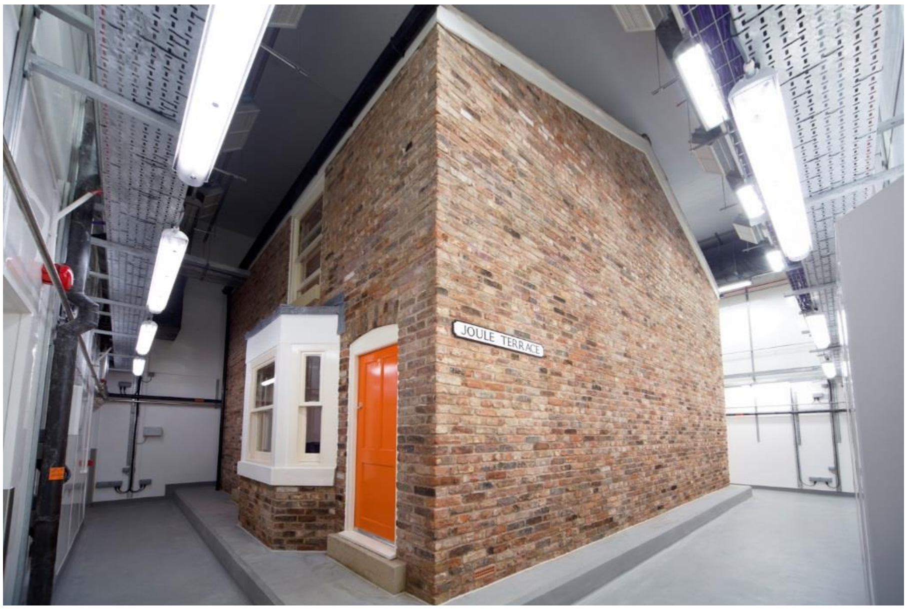

Figure 1: The Salford University Energy House

Test method

The principle behind the test was for the heating system to be set up so that it delivers the heat load for the building on the design day. The only control on the system would be a room thermostat in the living room – no TRVs were installed on any radiators. The radiators were sized using the CIBSE guidance document on heating system design and installation, and the system was balanced so that, at the design-day external temperature, the system was maintaining steady state temperatures in all rooms, in accordance with the internal temperatures defined in SAP. The external temperature was progressively increased with the expectation that the rooms other than the living room would increase in temperature (the living room remaining under control of the room thermostat) due to the reduced heat load on the system at higher external temperatures. The tests were then repeated with all radiators (except the one in the living room) controlled by TRVs.

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

Eleven tests were carried out under different external temperature conditions as below:

Test 1: Baseline test at -4°C

Test 2: 4.5°C without TRVs

Test 3: 4.5°C with TRVs

Test 4: 6.5°C without TRVs

Test 5: 6.5°C with TRVs

Test 6: 8.9°C without TRVs

Test 7: 8.9°C with TRVs

Test 8: 11.7°C without TRVs

Test 9: 11.7°C with TRVs

Test 10: 14.6°C without TRVs

Test 11: 14.6°C with TRVs

The boiler thermostat was set to 70°C and the boiler timer set to a 14-hour heating session for each test. Internal doors were all open except for the living room door which was kept shut. Simulated internal gains were added to the property during the tests, with the value of these specified by BRE.

The internal temperatures were intended to be 21°C in the living room and 18°C elsewhere in accordance with the assumed temperatures in the SAP calculation methodology. However, this proved to be impossible to consistently maintain in the baseline test due to practical difficulties in achieving these temperatures in a conventional system with very low flow volumes required in the balancing process.

The reason for this problem is the difference between the SAP model (which uses the 18°C baseline) and the CIBSE guidance document on heating system design and installation (which uses 21°C). The Salford test house system has been sized according to the CIBSE guidelines and, to achieve the 18°C, the lockshield valves were be tightened right down to the very end of their adjustment. It was therefore agreed with BRE to use higher internal temperatures of 24°C in the living room and 21°C in other rooms, which would maintain the important differential in temperatures but not affect the result given that starting at higher internal temperatures could only make the recorded overheating effect more conservative. The neighbouring property was set to an average of 22.5°C.

Results

The full results from the tests are shown in Table 1 below while table 2 summarises the savings from TRVs at each external temperature.

Chamber temp	Test	Total Energy Consumption				Non Living Areas Average temp
		kWh	£*2	kg CO_2e*3	% Savings	°C
Chamber at –4°C	Without TRVs	73.48	2.85	13.79	0.00%	21.39
Chamber at 4.5°C	Without TRVs	49.27	1.92	9.27	0.00%	22.59
	With TRVs	42.31	1.65	7.98	14.11%	20.75
Chamber at 6.5°C	Without TRVs	42.62	1.66	8.02	0.00%	22.32
	With TRVs	34.41	1.35	6.50	19.24%	20.96
Chamber at 8.9°C	Without TRVs	32.76	1.28	6.18	0.00%	22.93
	With TRVs	26.84	1.05	5.08	18.10%	21.16
Chamber at 11.7°C	Without TRVs	25.54	1.00	4.82	0.00%	22.64
	With TRVs	18.46	0.73	3.50	27.71%	21.27
Chamber at 14.6°C	Without TRVs	17.18	0.68	3.26	0.00%	22.82
	With TRVs	10.22	0.41	1.96	40.52%	21.61

Table 1 – Collected results[2]

Outside temperature	Energy saving from using TRVs
-4°C	Baseline
5°C	14%
7°C	19%
9°C	18%
12°C	28%
15°C	41%

Table 2 – Summary of energy savings from TRVs.

[2] *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 (3.80p per kWh gas, 12.98p per kWh electric) not including standing charge (26.01p per day gas, 26.01p per day electric) - Prices taken on 12/04/2016 from: https://www.britishgas.co.uk/products-and-services/gas-and-electricity/our-energy-tariffs
*3 - Carbon Trust energy and carbon Conversion factors 2014, published September 2014.

Analysis and conclusions

This test process replicates the situation in houses that only have a central temperature control and no TRVs. What should be strongly emphasised is the fact that the average temperature rise in the non-living areas are relatively modest, about 2 – 3^{O}C, which is unlikely to stimulate discomfort or compensatory action by occupants (even allowing for the fact that these rooms may be largely unoccupied) yet the energy savings from TRVs to avoid this overheating are substantial.

Reducing overheating means that less flow is required by the radiators and there is less heat load on the boiler. As a result the boiler fires less often and uses less energy.

Heating systems are, by necessity, designed to keep the house warm at a reasonable minimum outside Winter temperature. However, for most of the time the outside temperature will be above this minimum. In the UK the average outside temperature across the heating season (the months when the heating system will be used[3]) is an outside temperature of 7.7^{o}C[4].

The average energy saving potential for TRVs is therefore assumed to be 18%.

The savings potential would be higher in any scenario where the radiators were oversized and, as previously noted, it should be noted that the temperatures tested in the Energy House will provide a conservative assessment.

These savings represent a robust and thorough independent test process and correspond with other studies that have been done across Europe. For example:

- The European Standard covering the impact of control types[5] assesses that changing from a simple Manual Radiator Valve (MRV) to a TRV equals a 20% saving in heating energy (and that upgrading a TRV more than 20 years old equals a 7% saving in heating energy.)
- IMI Hydronic commissioned a study from TU Dresden to assess the potential savings from TRVs based on a computer simulation. This produced a range of figures showing savings of 8 – 28% depending on the energy efficiency of the building, type of boiler and whether it is a high or low temperature heating system.
- Simulation work done for the manufacturer Danfoss[6] assessed that savings of approximately 36% were possible for the installation of TRVs in individual dwellings.

We therefore conclude that these results should be taken with a high level of confidence. The installation of TRVs, accompanied by practical advice to householders on how to use them (the provision of which is already a requirement for installers under the Building Regulations) should be expected to yield significant energy savings across the UK housing stock.

[3] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/274772/4_Main_heating_systems.pdf
[4] Table U1: Mean external temperature https://www.bre.co.uk/filelibrary/SAP/2012/SAP-2012_9-92.pdf
[5] EN 15316-4-2:2008 Heating systems in buildings. Method for calculation of system efficiencies.
[6] Energy efficiency related to the change of thermostatic radiator valves - Prof. Dr.-Ing. Hirschberg (2016)