Low temperature heating systems in existing homes

Benefits and technology solutions

October 2022

Introduction

With rising energy prices, many householders are looking for ways to improve the energy efficiency of their home. Heating typically accounts for 60-70% of domestic energy use[1] and is the obvious place to start. Significant energy savings are possible, but heating systems are complex and require a number of interactions to optimise their efficiency.

There is growing awareness that reducing the temperature of the water that flows through radiators in heating systems can lead to improvements in efficiency. The Government's 2018 'Boiler Plus' review introduced load compensation and weather compensation controls as options when combination boilers are installed in existing buildings, and also looked at how heating systems are commissioned. Even so, there is limited understanding outside of the heating industry of how these measures can deliver energy savings, or of how they can be applied as retrofit energy saving measures in their own right.

This paper seeks to provide an overview of why operating an existing heating system at lower temperatures has the potential to improve the efficiency of that system. It also uses data from laboratory tests to describe how the use of advanced heating controls and/or better system set-up can overcome some of the pitfalls and deliver the highest possible savings all year round.

This paper has been put together by BEAMA and HHIC, with technical input from their respective membership.

[1] United Kingdom housing energy fact file 2013 – Department of Energy and Climate Change

1. Background

1.1 What do we mean by heating system temperatures?

Most heating systems in UK homes are made up of a gas boiler and radiators connected with pipes as shown in figure 1. Hot water from the boiler is pumped through the 'flow' pipework (shown in red) into radiators, which transfer heat from the water into each room. Water from the radiators, which is then at a lower temperature, passes back through the 'return' pipework (shown in blue) into the boiler to be reheated and recirculated.

Typically, the design flow temperature of a domestic heating system has been around 75/80°C with a return temperature of 55/60°C.

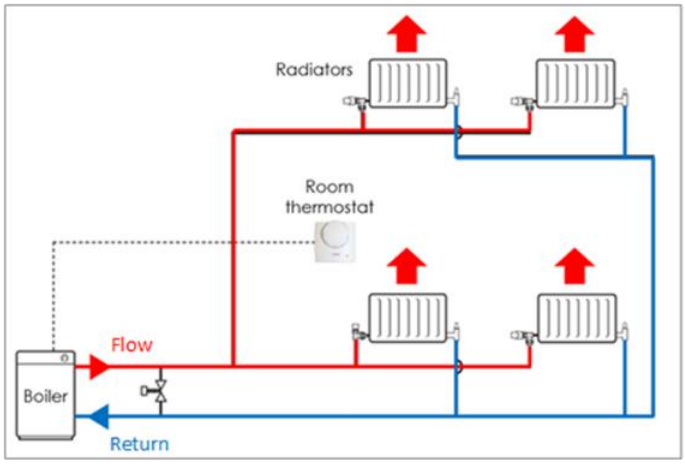

Figure 1 – Flow and return temperatures in a typical UK wet heating system

1.2 How do lower temperatures improve efficiency?

The more efficiently a boiler operates, the less gas it will use to keep your home warm. Most modern boilers are 'condensing boilers', which operate with greater efficiency when the return temperature from the heating system is lower. There is a pronounced increase in efficiency once the return temperature goes below 55°C and the boiler goes into 'condensing mode' (see figure 2).

Lower return temperatures should therefore directly result in lower fuel bills. A system with a flow temperature of 55°C and a return temperature of 45°C would be more economical than one at 75°C/65°C operating temperatures for example.

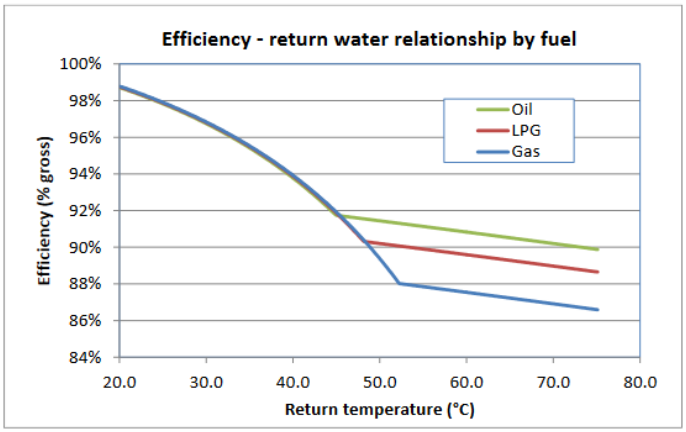

Figure 2 - Theoretical relationship between boiler efficiency and return water temperature (Source: BRE Consultation Paper – CONSP:02)

1.3 Can all existing heating systems operate at lower temperatures?

Heating systems need to be powerful enough to provide enough heat into your home to keep it warm during the coldest Winter weather that you might reasonably expect. So, while the heating system may be designed to keep the house warm when the temperature outside is as low as -3°C, it will usually be operating when less heat is needed. Average outside temperatures in the UK heating season (the months

when heating systems are used) range from 4.2°C in December to 10.6°C in October[2], meaning that the heating system needs to provide 35% less heat in December and 61% less heat in October, on average, compared to the design output.

As the amount of heat provided by the heating system is largely determined by the temperature of the water flowing through the system, the system could potentially operate at a lower temperature much of the time – still satisfying the heat requirements but with improved boiler efficiency.

1.4 Factors to be considered for operating an existing heating system at lower temperatures

To get the benefits of low temperature operation in an existing system there are some important factors to be taken into consideration. These are described below.

1.4.1 The system must still be able to provide enough heat at colder temperatures.

Many boilers have high outputs, in that they can provide more heat than is needed for central heating even when outside temperatures are at below zero temperatures; the type of conditions that the system must be designed to cope with. This is particularly true of combination boilers which are designed for the hot water load (which is much higher than the heating load), or in circumstances where a home has been insulated after the boiler was installed.

To ensure gas boilers are as efficient as possible they are designed so they can modulate their output both in hot water and heating mode. Modulation ranges of between 1-10 are not uncommon, meaning that a 30kW maximum heat output could automatically adjust down to as low as 3kW. The boiler's built-in ability to do this, when combined with Boiler Plus compliant controls such as a load compensation system, generally ensure that, while the maximum output of the boiler may be more than the heating system actually needs, it is rarely, if at all, going to operate at this output in central heating mode. Many boilers are also supplied as "variable output", meaning the installer can tailor the maximum central heating output to the needs of the property and system, whilst not affecting the larger hot water output required of a combination boiler.

It is not just the boiler output that is important. The heat output of radiators into each room is also determined by the size of the radiator plus the temperature of the water going through them. Most existing heating systems have been designed to give a high performance using a higher flow temperature, so reducing the flow temperature will mean that the existing radiators cannot provide enough heat in colder weather, as they do not have a large enough surface area. It may be the case that some radiators were oversized when they were installed, or that the later addition of insulation to the building allows the radiators to always deliver enough heat at low temperature operation. Research carried out for BEIS shows that this is only likely to be the case in 10 – 26% of existing homes[3] (with flow temperatures between 55C and 60C). If insulation measures could be further improved then this potential for low temperature (condensing) operation can also be improved[3b]

[2] Source Table U1 in BRE Standard Assessment Procedure version 10.2: https://bregroup.com/sap/sap10/

[3] Heat distribution systems, Research investigating the current state of heat distribution systems in homes. BEIS (2021) https://www.gov.uk/government/publications/heat-storage-and-distribution-systems-hds

1.4.2 Higher flow temperatures deliver quicker warm up times.

UK heating systems are operated intermittently, with the majority of households turning their system on twice a day[4]. As buildings cool down when the heating is off, this means that more energy is needed when it is turned back on to warm the structure before a comfortable air temperature can be maintained.

Systems designed for high temperature operation but operated at a lower temperature can take a significant time to get the temperature up to the desired setpoint. Figure 3 shows a test carried out in the University of Salford Energy House[5]. In this test, at an average December outside temperature, the boiler took 7 hours to reach the living room set-point temperature when its flow temperature was 55°C, compared to 1 hour when its flow temperature was set to 75°C. Despite the increased efficiency there is a point at which the low temperature operation will result in higher fuel costs if longer operating times are needed to meet the occupants needs.

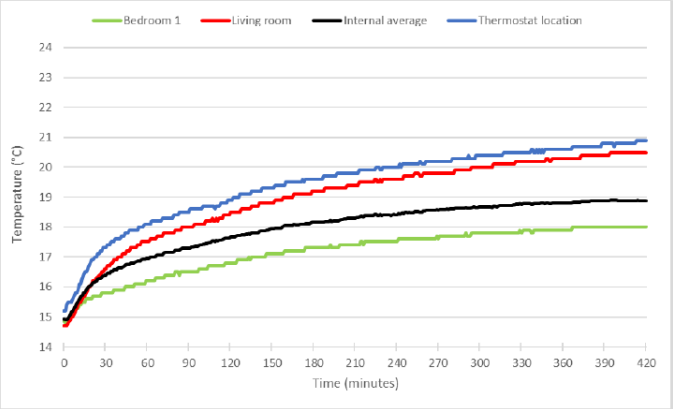

Figure 3 – Room temperatures measured over 7 hours with a constant flow temperature of 55°C when the outside temperature was 4.2°C.

Operating an existing heating system at lower flow temperatures will deliver efficiency benefits but ensuring that it always delivers both low running costs and comfortable living conditions can be a complex challenge. Fortunately, there are technical solutions available to overcome these challenges. These are described below.

2. Technology solutions to deliver low temperature heating benefits

New building regulations coming into force from June 2022[6] will require that any new heating system is designed for low temperature operation. It is also true that there is likely to be a general move towards low temperature heating systems as they deliver better efficiency both with current boilers and with future low carbon systems such as heat pumps or hydrogen boilers.

Boiler Plus legislation introduced through the building regulations in 2018[7] introduced options for the addition of heating control technologies that can get a current high temperature system to operate with low temperatures when it is possible to do so. This means that fuel bills will be reduced, and the system will automatically provide enough heat when needed to maintain comfort.

The sections below outline technology solutions that can be applied in existing homes as retrofit measures. The first is the addition of load or weather compensation (as included in the Boiler Plus legislation) and the other is through set up and commissioning of the system

[4] Energy Follow Up Survey: Heating patterns and occupancy, BEIS 2021 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1018727/efus-heating-patterns-occupancy.pdf
[5] https://www.beama.org.uk/resourceLibrary/salford-tests-on-load-and-weather-compensation-.html
[6] https://www.gov.uk/government/publications/conservation-of-fuel-and-power-approved-document-l
[7] https://www.gov.uk/government/consultations/heat-in-buildings-the-future-of-heat

2.1 Room thermostats that incorporate either load compensation or weather compensation can deliver both efficient operation and user comfort.

Tests carried out at the University of Salford[8] show that these controls can deliver savings of around 12% if communicating directly with the boiler, and 10% if such communications are not available in a retrofit situation. This is by optimising an existing high temperature heating system towards low temperature operation when suitable.

Figure 4 shows the flow and return temperature of a boiler controlled with a 'Class V'[9] load compensating room thermostat. This control ensures that comfort levels will be maintained but the efficiency of the boiler optimised. You can see from the graph that the return temperature (in blue) remains below 50°C at all times – this is the crucial factor in making sure that the boiler stays in its efficient condensing mode.

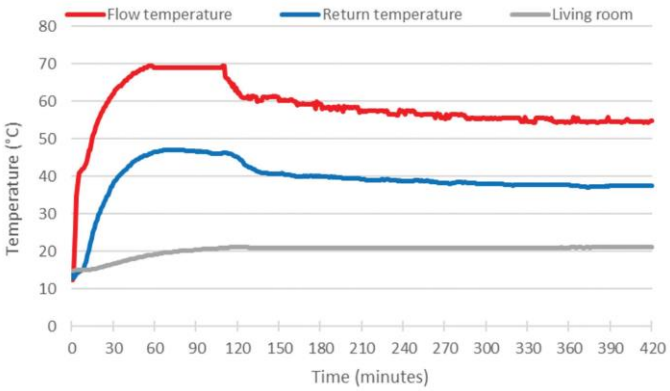

Figure 4 – Flow and return temperature of a heating system controlled by Class V load compensation.

A further factor at play, as mentioned earlier in this paper, is that most modern boilers have the facility to 'modulate', or turn down, their flow temperature. Under control of load or weather compensation, the boiler modulates the flow temperature so that, once the setpoint temperature is reached, the flow temperature reduces to the minimum needed to maintain the set-point. This ensures the boiler operates more efficiently as shown in figure 4.

2.2 Allowing installers the time to set boilers up correctly can lead to better efficiency outcomes.

Figure 5 shows the flow and return temperature of a real boiler installation where the boiler has been set up and balanced[10] correctly against a calculated heat loss for the building. The boiler operates at a high temperature under control of a standard on/off room thermostats but is still operating efficiently in condensing mode.

The boiler does not modulate to reduce its flow temperature and the on/off operation may not be as beneficial for occupant comfort, so adding load compensation or weather compensation controls to a system set up in this way will deliver additional savings. However, it does show the importance of how systems are set up and how using a skilled heating installer can be the quickest path to an improvement in boiler efficiency. It should also be noted that there are technology solutions available to

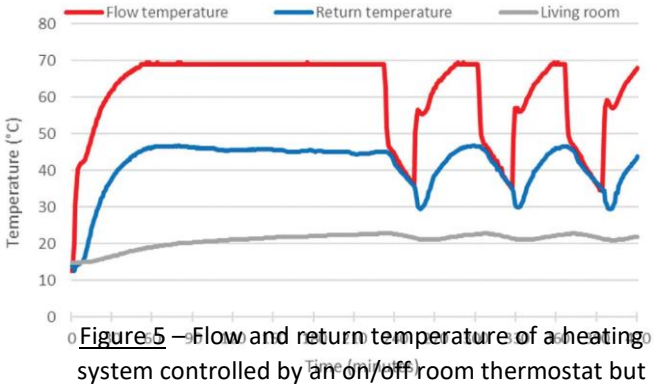

Figure 5 – Flow and return temperature of a heating system controlled by an on/off room thermostat but correctly set up and balanced.

[8] https://www.beama.org.uk/resourceLibrary/salford-tests-on-load-and-weather-compensation-.html
[9] https://www.beama.org.uk/resourceLibrary/temperature-control-classes-from-eu-energy-labelling-regulation-for-space-heaters.html
[10] https://www.hhic.org.uk/uploads/5ACCA2408554F.pdf

ensure that a heating system remains balanced, such as thermostatic radiator valves with integral automatic balancing functionality.

Conclusions

There is the potential for very real energy saving benefits from operating heating systems at lower temperatures. It is the 'return temperature' of the water coming back from the radiators into the boiler that determines the efficiency of the boiler, with lower return temperatures leading to better efficiencies. There are also energy saving benefits when the boiler can modulate down to run at a lower flow temperature.

A limiting factor for low temperature operation in existing homes can be the physical size of the radiators that were initially designed (sized) for higher temperature operation. Also, extra running time may be needed for the heating system to get the house up to comfort temperature, which can offset the efficiency gains to some extent. Both of these factors are more pronounced in colder weather, although the impact can be reduced by improved insulation of the building.

Room thermostats that incorporate load or weather compensation can deliver the energy saving benefits of low temperature operation when added to existing heating systems while also maintaining comfort year-round – overcoming the limitations referred to above. Effective set up and balancing of the heating system by a trained installer will ensure more efficient operation of a boiler in all circumstances, and when combined with load or weather compensation will deliver optimal energy performance and significantly lower fuel bills.