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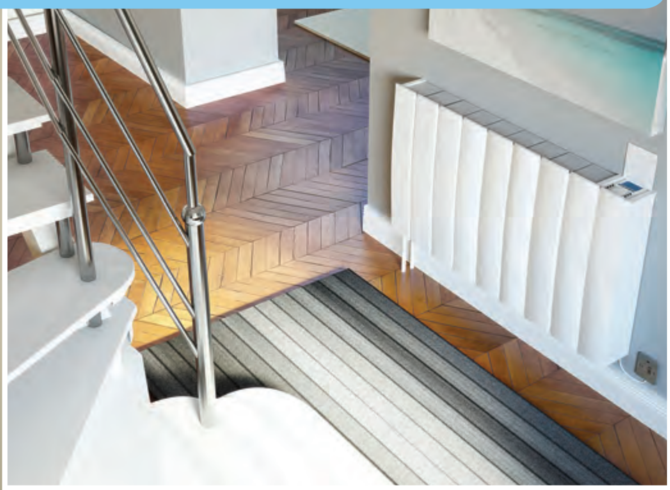
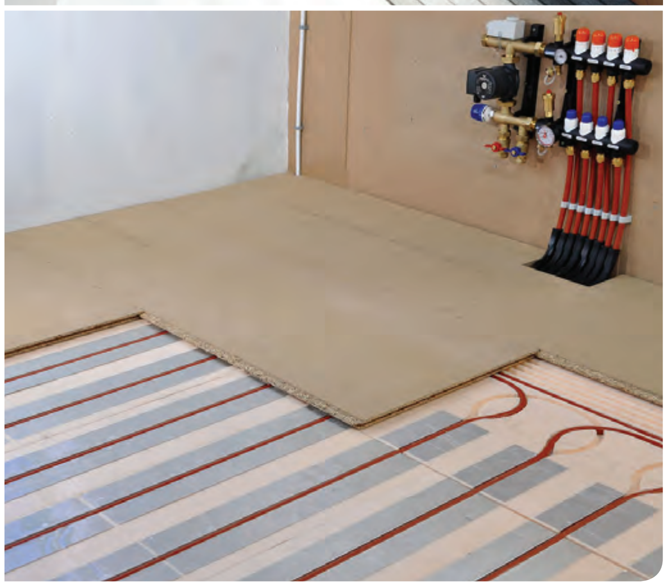
Design of low-temperature domestic heating systems

A guide for system designers and installers

Bruce Young, Alan Shiret, John Hayton and Will Griffiths





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- The Association of Controls Manufacturers (TACMA)
- Underfloor Heating Manufacturers' Association (UHMA)

Front cover photographs:
Stelrad Compact K3 radiator (left)
Dimplex SmartRad® intelligent fan convector (top right)
Hep2O underfloor heating system by Wavin (bottom right)

Back cover photograph:
Hep2O underfloor heating system by Wavin

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Executive summary

Low-temperature heating systems can improve energy efficiency and hence reduce fuel consumption and CO_2 emissions. There is growing interest in low-temperature hydronic central heating systems, ie those where water is used as the medium to distribute heat around the building and in which the water leaving the heat generator is limited to a lower temperature than in normal system design. This BRE Trust Report is aimed as a guide for those who wish to install low-temperature heating systems in dwellings, and concentrates on the calculations and other conditions necessary to ensure that low-temperature operation can be achieved.

It became apparent during the preparation of this guide that there is no generally well-established and understood design method for low-temperature domestic heating systems. Instead of simply gathering information on current practice, the authors found it necessary to engage in extensive debate about many of the technical parameters governing system sizing, configuration and selection of components. Some of these have not been fully resolved. In particular, leading designers should give more attention to:

- selection of a representative external temperature for heat loss calculations
- allowance for building exposure
- suitable heat loss calculators, conforming to stated rules
- refined intermittency factors, perhaps using the advanced method set out in BS EN 12831:2003
- evaluation of emitter responsiveness, especially for emitters with fans
- temperature-limiting controls, and modulation by reference to an upper temperature limit.

The last item (controls) is especially important, as it is the water temperature at the heat generator that is the principal determinant of efficiency when low-temperature heating system designs are contemplated. Further development of standard design and operating practices (especially for controls) for low-temperature heating systems will be necessary before such systems can be recognised as a mature option capable of providing energy savings in all cases.

1 The benefits and technical aspects of low-temperature heating

1.1 Introduction

There is growing interest in low-temperature hydronic central heating. This is taken to mean systems able to provide a full heating service while the mean temperature of the water in circulation is 50°C or lower. Interest is prompted by the development of high-output heat emitters (such as extended-surface and fan-assisted radiators) as well as perimeter and underfloor heating (UFH) emitters able to provide plentiful heat for well-insulated new homes with a low heat demand. The widespread adoption of condensing boilers capable of operating continuously at lower temperatures, and the recent focus on heat pumps, has raised interest further. Low-temperature operation raises the efficiency of both boilers and heat pumps. However, little has been done to help designers and installers (who are often designers too, for domestic systems) to produce such systems. This report has therefore been written to provide guidance to system designers and installers by demonstrating the effect of installation of such systems. It provides a design process and highlights the critical issues regarding implementation in practice, where an example design, installation and commissioning checklist is provided for assistance (Appendix A).

1.2 What is low-temperature heating?

In this guide a low-temperature heating system means one in which the hot water leaving the heat generator is always supplied at a lower temperature than that of a traditional central heating system, even on the 'design day' (ie a day with cold weather conditions chosen for calculating the maximum heat losses from the building). The definition does not include heating systems in which the water temperature is lower only some of the time, such as those with weather compensation or load compensation controls, nor does it include UFH in which a thermostatic mixing valve is used to blend water at a high temperature with cooler water before entering the UFH system floor*.

Low-temperature heating systems should not be confused with low-surface-temperature (LST) radiators, which are installed to protect vulnerable occupants. The conditions for low-temperature heating system operation are NOT achieved by selecting LST radiators. The need for LST radiators is reduced or eliminated in a low-temperature heating system, as high water temperatures should not occur.

Low-temperature heating requires a different system design, mainly to ensure that the heat emitters (radiators, fan-assisted radiators† or convectors, or UFH pipes) can deliver the same amount of heat at the lower temperature as a traditional system would have done at normal temperature. The emitters must be sized correctly to ensure they are capable of doing this. The design procedure explained here is limited to hydronic heating systems in dwellings of the UK. The key parameter governing low-temperature design is the mean water temperature (MWT), ie the average of the flow and return temperatures at the heat generator (a boiler, heat pump or micro combined heat and power (micro-CHP) unit). This determines the heat output from emitters in individual rooms.

* Underfloor systems may still use a mixing valve, but only as a protection device.

† Fan-assisted radiators, fan coil units and fanned convectors deliver most of the heat by forced convection and are described generically as convectors in this guide.

1.3 Efficiency improvement potential

Most types of heat generator operate more efficiently when the water passing through them is at a lower temperature. When the efficiency of the heat generator is higher the fuel consumed to produce the same amount of heat is lower, and hence the energy consumption, CO_2 emissions and fuel costs are also lower. These are benefits that persist over the whole lifetime of the heat emitters, typically 20 years.

In the case of boilers, the efficiency rises more sharply as the flue gas temperature drops below the dew point because condensation of flue gas vapour occurs. Efficiency is affected mainly by the return water temperature. Figures 1 and 2 show how the theoretical efficiency of typical condensing gas and oil boilers rises as the return water temperature is reduced. Low-temperature operation is practicable only for condensing boilers.

Figure 1 includes part-load and full-load efficiency range bars for 1250 condensing modulating gas boilers that were tested in accordance with the Boiler (Efficiency) Regulations[1] and are listed within the Product Characteristics Database (PCDB) that supports the National Calculation Methodology for energy rating of dwellings (SAP[2]). These laboratory measurements (allowing for measurement uncertainty) support the theoretical predictions.

In the case of heat pumps the seasonal performance factor is affected both by the flow temperature and the difference between source and sink temperatures. The sink temperature for a heat pump in a hydronic heating system is the flow temperature. Figures 3 and 4 show how the efficiencies of typical heat pumps rise as the flow temperature is reduced. Note that the efficiency is a seasonal value for space heating only, without hot water service, calculated in accordance with BS EN 15316-4-2:2008[3], which is utilised within SAP. The data used are sourced from the SAP PCDB for a heat pump selected from the 90th percentile when ordered from the best to worst performing; most heat pumps will perform better than this. It is assumed the heat pump systems include weather-compensating controls, which reduce the effect of low-temperature heating systems.

The efficiency characteristics of micro-CHP cannot be generalised in a single graph as many design types are possible. It may not be feasible for micro-CHP with an engine or fuel cell to heat water to a lower temperature, and if it did so there may be no performance benefit. However, some micro-CHP units include an auxiliary burner that behaves in a similar way to a boiler and would have performance characteristics resembling those shown in Figures 1 or 2. Before the benefit of low-temperature heating with micro-CHP can be assessed, evidence will be needed from the designer of the product to show how efficiency varies with water temperature.

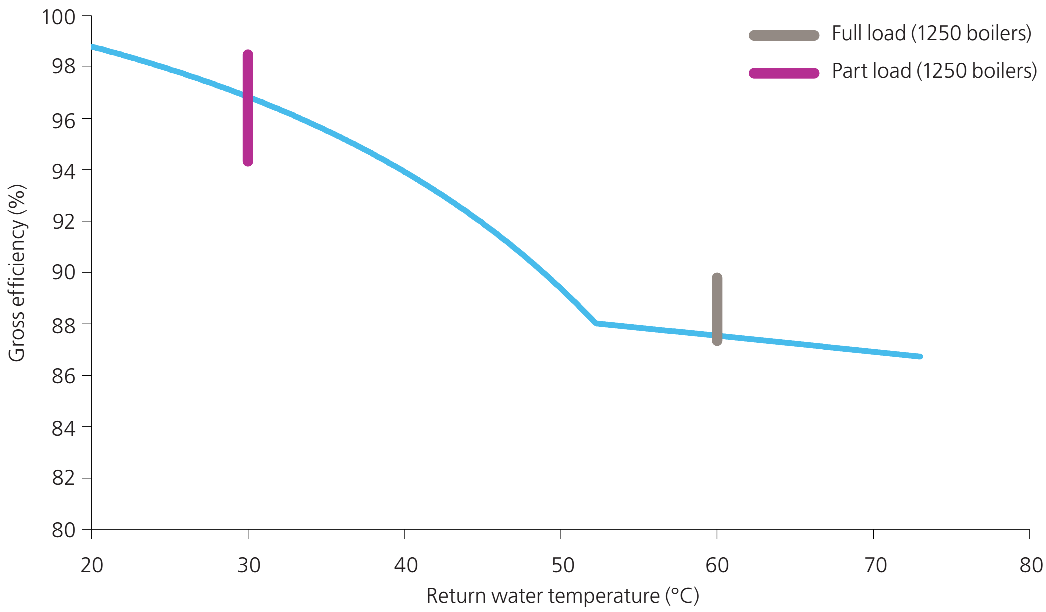

Figure 1: Typical modern condensing gas boiler: efficiency vs. return temperature relationship

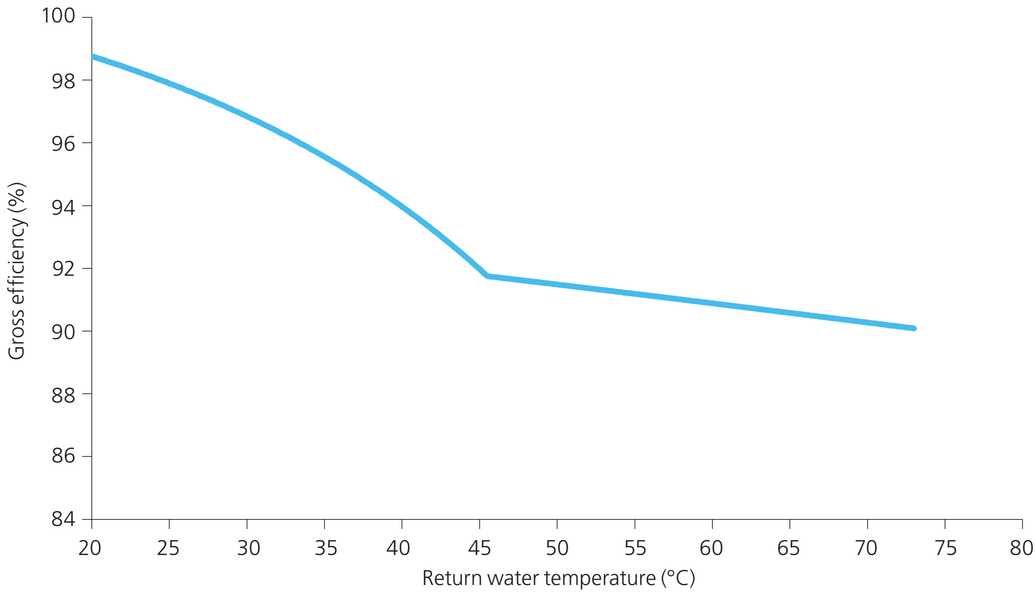

Figure 2: Typical modern condensing oil boiler: efficiency vs. return temperature relationship

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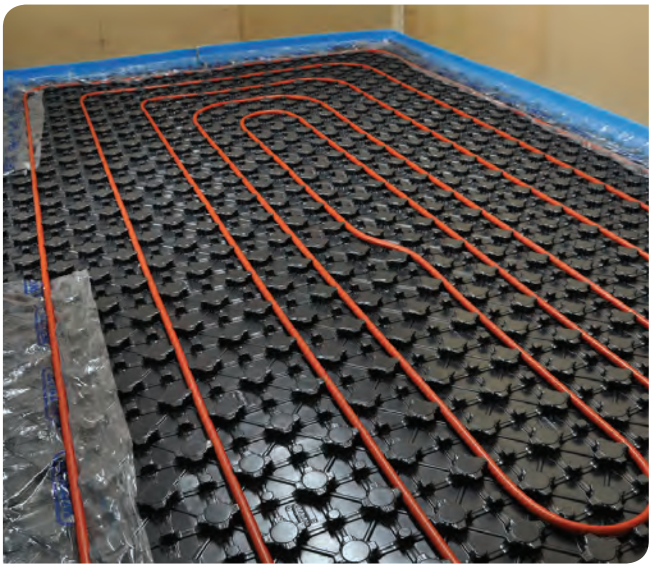

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