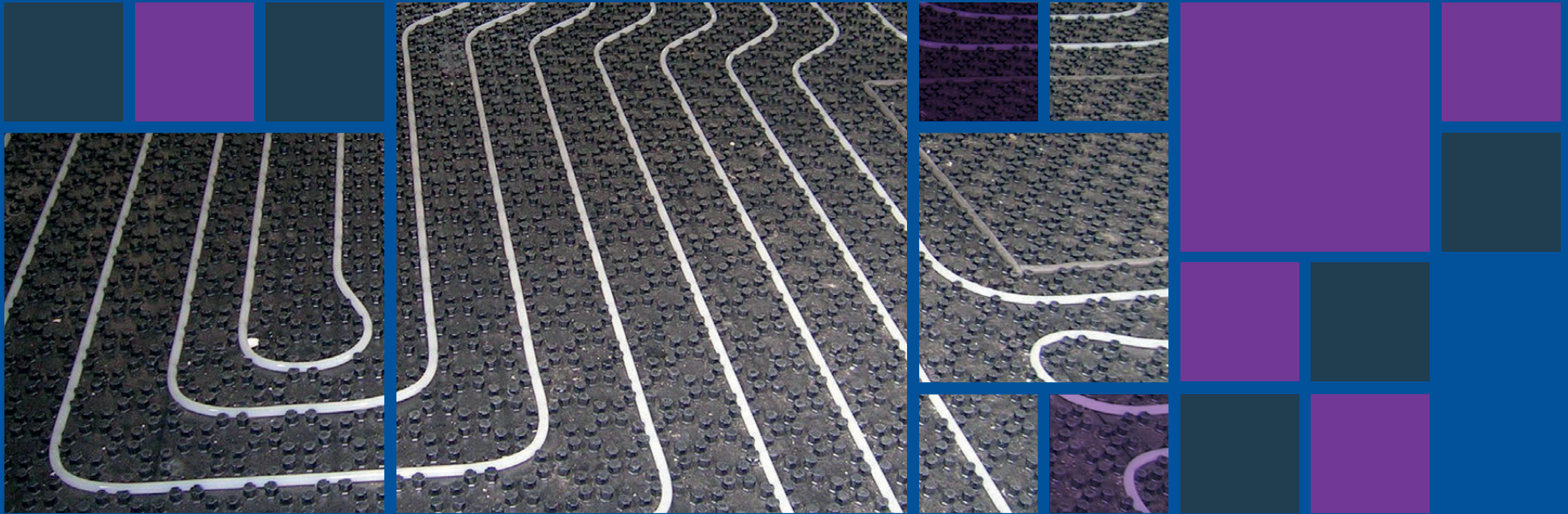


# Underfloor heating

A guide for house builders



Guide

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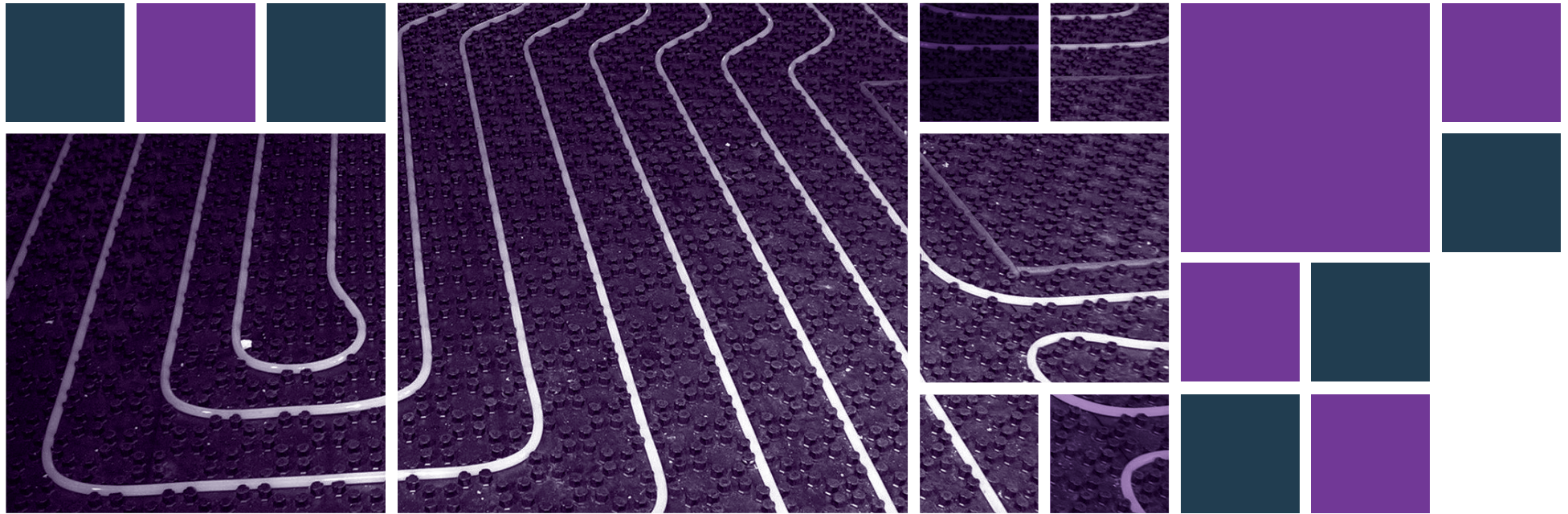
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# Underfloor heating

A guide for house builders



September 2016

# The NHBC Foundation

The NHBC Foundation, established in 2006, provides high-quality research and practical guidance to support the house-building industry as it addresses the challenges of delivering 21st-century new homes. To date, it has published more than 70 reports on a wide variety of topics, including the sustainability agenda, homeowner issues and risk management.

The NHBC Foundation is also involved in a programme of positive engagement with the government, academics and other key stakeholders, focusing on the current and pressing issues relevant to house building.

To find out more about the NHBC Foundation, please visit [www.nhbcfoundation.org](http://www.nhbcfoundation.org). If you have feedback or suggestions for new areas of research, please contact [info@nhbcfoundation.org](mailto:info@nhbcfoundation.org).

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# Foreword

The number of new homes with underfloor heating has increased in recent years. This is not surprising as underfloor heating brings several advantages. It frees up wall space, allowing more flexibility in furniture layouts, which is particularly useful in smaller apartments. Equally it has advantages in housing for elderly people where there is a need to maintain constant warm temperatures. It also works well with energy efficient condensing boilers and heat pumps. But, as with any unfamiliar technology, some problems have been encountered as plumbers and house builders have begun installing underfloor heating for the first time.

This guide has been prepared to help in particular smaller companies who have not yet developed great experience of installing underfloor heating systems. It draws on the design expertise of BSRIA, for which the NHBC Foundation is very grateful, as well as NHBC's practical experience of underfloor heating systems installed in new homes. The resulting good practice guidance is presented simply and clearly with helpful illustrations.

What are the key lessons? Obviously good design and installation are essential, but it is just as important to ensure that underfloor heating systems are properly commissioned. As we have found through NHBC Foundation research and guidance on other energy-related technologies, meticulous care and attention during commissioning is vital if systems are to work efficiently and deliver the intended benefits without unwelcome problems occurring.

It is equally important that homeowners and residents are inducted into the use of their particular system and understand how to get the best from it. It is likely that it will need to be operated in a different way from other heating systems to which they have become accustomed in the past. Settings may need to be different, and the heating may need to come on earlier and run for a longer period, albeit using less power than other systems. Clearly the objective must be an effective and economic heating system that delivers trouble-free warmth and comfort for years to come.

Hopefully, house builders and their contractors will derive benefit from this guidance, and it will help to improve the quality of underfloor heating installations, as well as the satisfaction of the residents.

**Rt Hon Nick Raynsford**  
Chairman, NHBC Foundation





# 1 Introduction

The energy efficiency of new homes in the UK has steadily improved over the last 40 years, to meet the challenging standards set in Building Regulations.

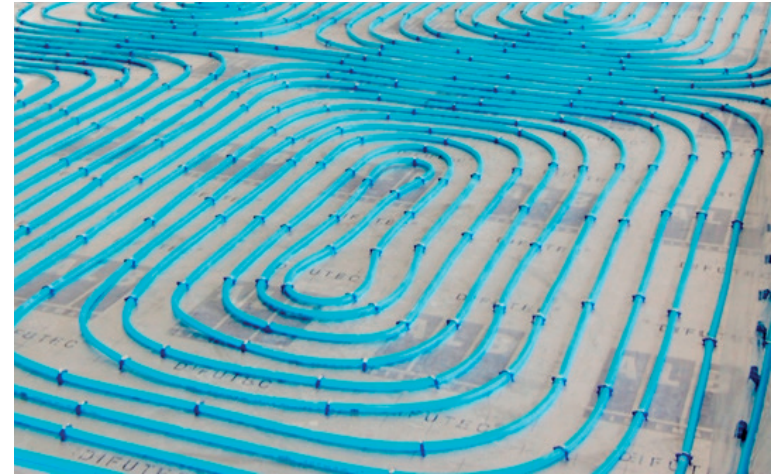
This has been achieved by a combination of improved levels of insulation and more airtight construction to minimise heat losses, and passive design measures such as large south-facing windows to maximise heat gains. Alongside these changes, central heating has become universal, allowing people to maintain their homes at warmer temperatures.

The requirement to reduce the CO<sub>2</sub> emissions that arise from the use of gas, electricity and other fuels in homes has also led to the development of new fuel-efficient systems and technologies for space heating and domestic hot water (DHW) systems. All gas and oil boilers in new homes are of the condensing type, and heat pumps are increasingly being specified. These are both low temperature heat sources.

The combination of lower demand for space heating and greater fuel efficiency of low temperature heat sources has led to the development of lower temperature heat emitter systems. One such system is underfloor heating, which can be installed with a wide range of floor constructions, finishes and heating sources.

Underfloor heating is, however, a relatively new technology and several factors must be considered when specifying and incorporating this within the design of a home.

This publication provides guidance for designers and house builders on the design, installation and commissioning of underfloor heating systems.



**Figure 1** Underfloor heating loops laid out uniformly over an insulation layer

## What is underfloor heating?

Underfloor heating uses the floor surface within a home as a heat emitter, and is an alternative to the use of conventional radiators. Hot water pipework loops are embedded into the floor construction as part of the 'wet' central heating system.

To limit discomfort to residents, and to protect floor finishes from damage, BS EN1264-2<sup>[1]</sup> limits the maximum temperature of the floor surface to 29°C. It should be noted that lower maximum temperatures are required for certain flooring materials.

With the entire floor area being used as the heat emitter, the relatively low temperature of the floor is sufficient to provide as much heat output as smaller radiators with much higher surface temperatures.

Underfloor heating is especially suited to applications where the demand for space heating is low and constant, such as in retirement housing. It may be less well suited for homes that are only occupied intermittently, for example when residents are not normally home during working hours.

An alternative to 'wet' underfloor heating is an electric system, where heating cables are embedded into the floor. Electric underfloor heating is very rarely used as the main heating system in new homes. This is because the high CO<sub>2</sub> emissions associated with mains grid electricity make compliance with the Building Regulations very difficult to achieve. However, it is sometimes used in limited areas such as bathrooms. This guide therefore focuses on 'wet' underfloor heating systems.

## Energy efficiency

Due to the large surface area of the emitter, water can be circulated through the distribution system at a relatively low temperature (around 40°C) compared to radiators (generally above 55°C). This makes the system particularly compatible with low temperature heat sources such as condensing boilers and heat pumps.

More than 50% of the heat emitted by underfloor heating is radiant. Radiant heat is transmitted directly to objects (and people) from the emitter and not by first warming the air in the room. Radiators, despite their name, emit most of their heat through convection – they heat the surrounding air which then rises, drawing in cooler air from lower down in the room.

This means that a larger proportion of the heat emitted through underfloor heating is utilised to provide warmth to people directly and relatively less heat is used to warm the air first. This allows for underfloor heating to be effective at lower thermostat settings (by 1-2°C) to achieve the same level of comfort as radiators.

Because of the lower temperature of the heat emitter, the lower proportion of convective heat output, and the positioning of the emitter at floor level, underfloor heating produces a temperature profile closer to the ideal for thermal comfort. Radiators, on the other hand, produce stratification – the collection of warm air at high level, and cooler air at low level within a room. Where stratification occurs, a significant proportion of the heat output is wasted, as it goes towards heating air above the heads of the residents. This is illustrated in Figure 2.

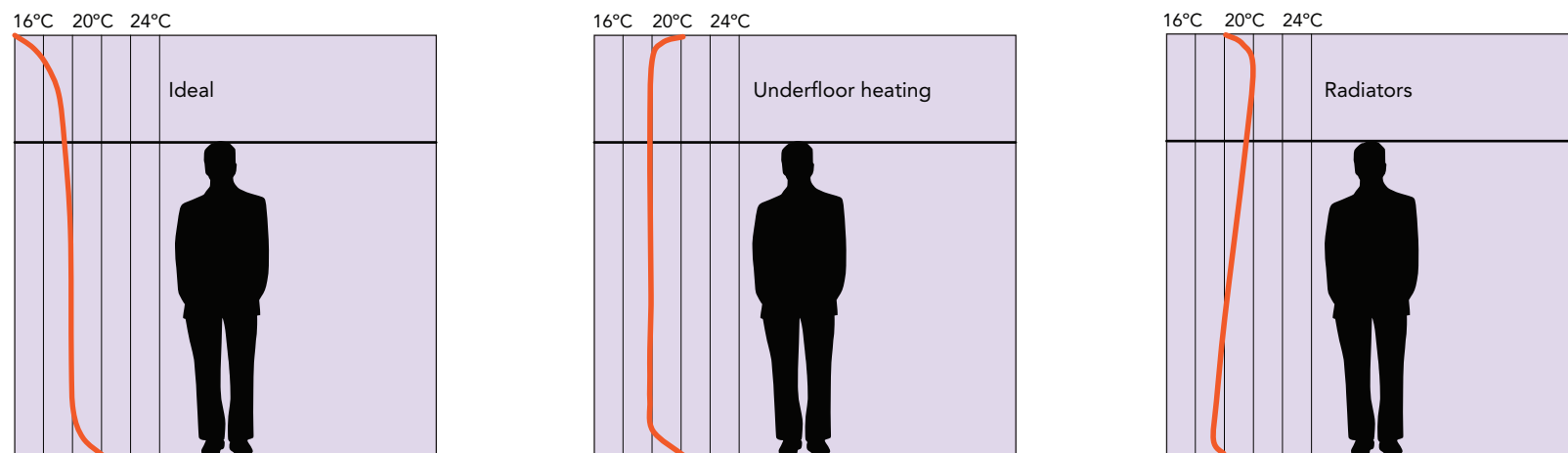


Figure 2 Comfort profiles

## What are the benefits of underfloor heating?

### Low temperature heat sources

Condensing boilers and heat pumps work more efficiently when supplying water at the lower temperatures used in underfloor heating systems.

### Low and constant space heating load

Underfloor heating is most effective in well-insulated homes with low space heating demand.

Where underfloor heating loops are embedded in the screed, there is a time lag between heat being supplied to the loops and the room becoming noticeably warmer. Also, the floor retains heat and emits it into the room for some time after the system is switched off. This helps stabilise temperatures, which is particularly suitable for uniform occupancy patterns, such as those found in retirement housing.

Where underfloor heating is installed in a timber floor, the overall response time is reduced as heat is dissipated into the room directly. Less heat is stored within the structure and so the room cools down more quickly when there is no input of heat. This application tends to be more suited to homes where the demand for heating is intermittent.

### Comfort

The entire area of the floor is heated at a low, steady rate by circulating relatively low temperature hot water.

Compared with radiators, underfloor heating causes less stratification. The temperature profile for underfloor heating is the closest to what is regarded ideal for resident comfort (as shown in Figure 2).

### Design flexibility

With underfloor heating there is no need to adjust furniture layouts to suit radiators, which generally need to be located under windows to counter cool draughts.

Additionally, as the floor surface itself is heated, materials such as stone and tile (which residents may otherwise consider to have a cold feel), may be more acceptable as floor finishes.

### Health and safety

The temperature of the floor surface is much lower than that of traditional radiators. This eliminates the risk of injuries caused by contact with a hot surface. This may be a significant consideration for more vulnerable residents such as children and the elderly.

The convection currents that move warm air around a room with radiators also have a tendency to circulate dust and dust mites, particularly in rooms with carpets. This tendency, which can be harmful to people with allergies, is reduced with underfloor heating.

### Maintenance

Underfloor heating loops should have no joints, with all connections for maintenance located above the floor finish at the manifolds, making the installation relatively robust against leaks.

## What to watch out for:

### Risk of damage

Although the risk of leaks from the pipework loops is low, they are concealed within the floor construction. This makes them potentially vulnerable to puncture during construction or subsequent building work that involves screwing or drilling into the floor. The layout of the system must therefore be clearly and accurately communicated by the installer (see Figure 3).

### Lower responsiveness

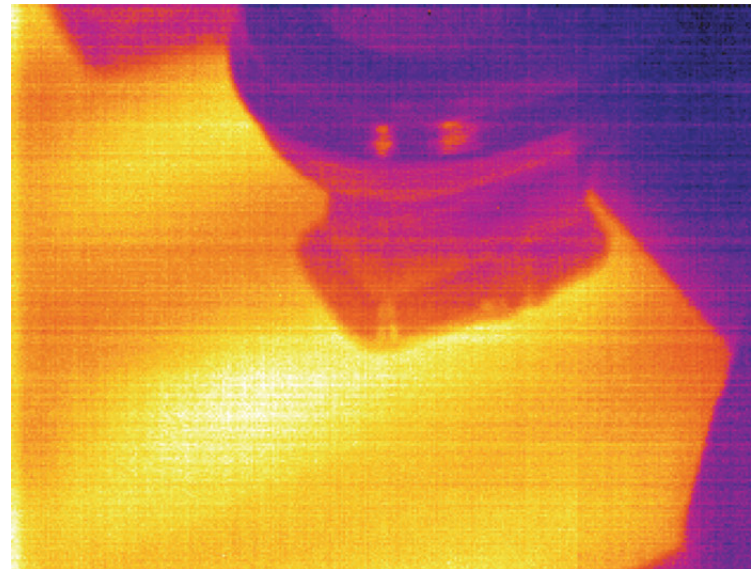
In screeded floors, there is a time lag between the space heating coming on and the room becoming noticeably warmer. It is important to communicate the implications of this to residents and give consideration when selecting the space heating controls.

### Obstructions to heat transfer

It is generally not possible to know the residents' final floor finish preferences (for example additional carpets and rugs) or furniture layouts before they move in. There is, however, a risk of the heat output from the floor being reduced as a result of these obstructions. Residents should be made aware, through the handover information, of how their choices could impact the performance of the heat emitter.

### Inflexibility of installation

The layout of the underfloor heating loops should take into account the overall layout of the home, especially plumbing, sanitary ware and other installations that involve penetrating the floors. Changes to pipework loops made at a later stage are likely to be highly disruptive.



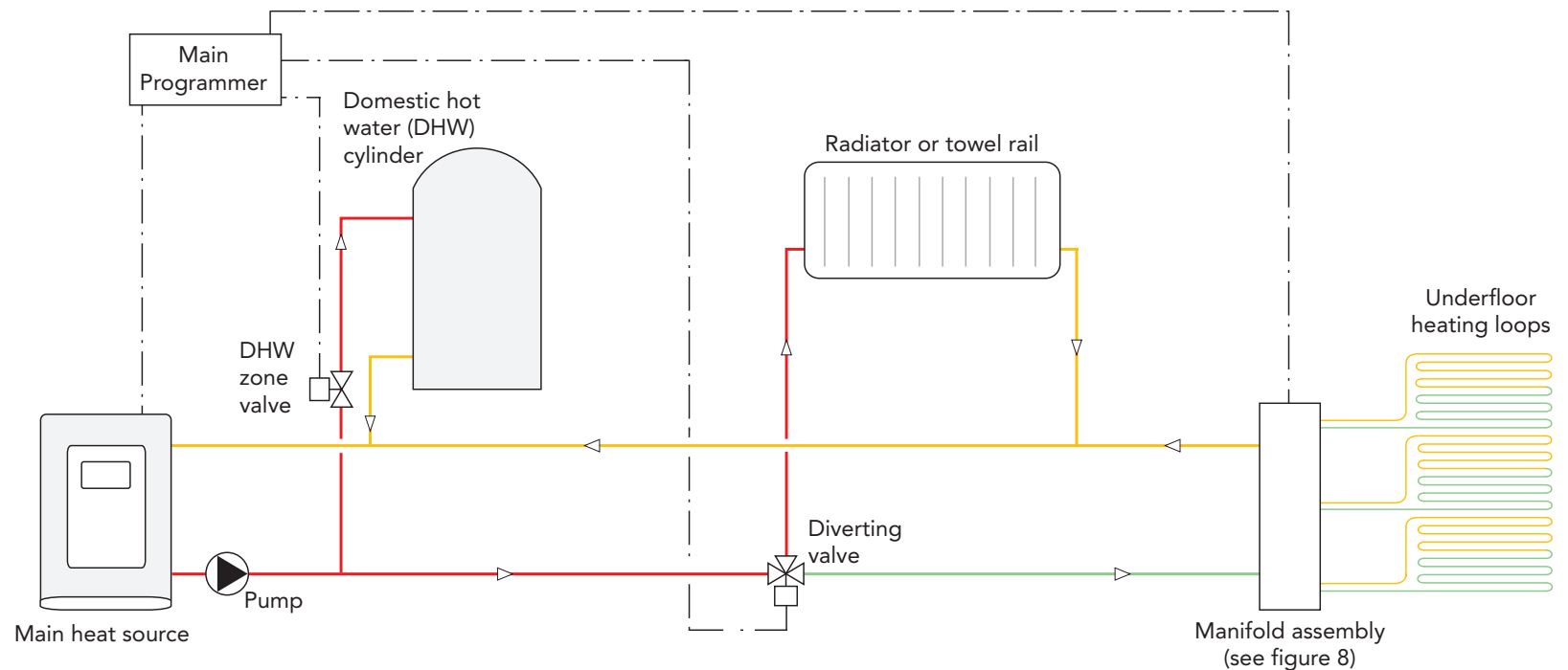
**Figure 3** Underfloor heating pipework loops running under WC – this may result in damage and leakage if the fixing screws are too close to the loops

## 2 Key considerations

An underfloor heating system manufacturer should be consulted early in the design process, for specific guidance on:

- The floor construction and finishes proposed
- The layout and spacing of the heating loops to meet the heating demand of the home, taking account of the floor construction
- Installation of the system, including standards for workmanship and commissioning.

All installations must incorporate certain key components. These should ideally be designed and specified as an integrated package by the system manufacturer so that all of the components are compatible. A diagram of these key components is shown in Figure 4, and they are discussed in the following sections.



**Figure 4** Key components within a typical domestic heating system that incorporates underfloor heating

## Main heat source

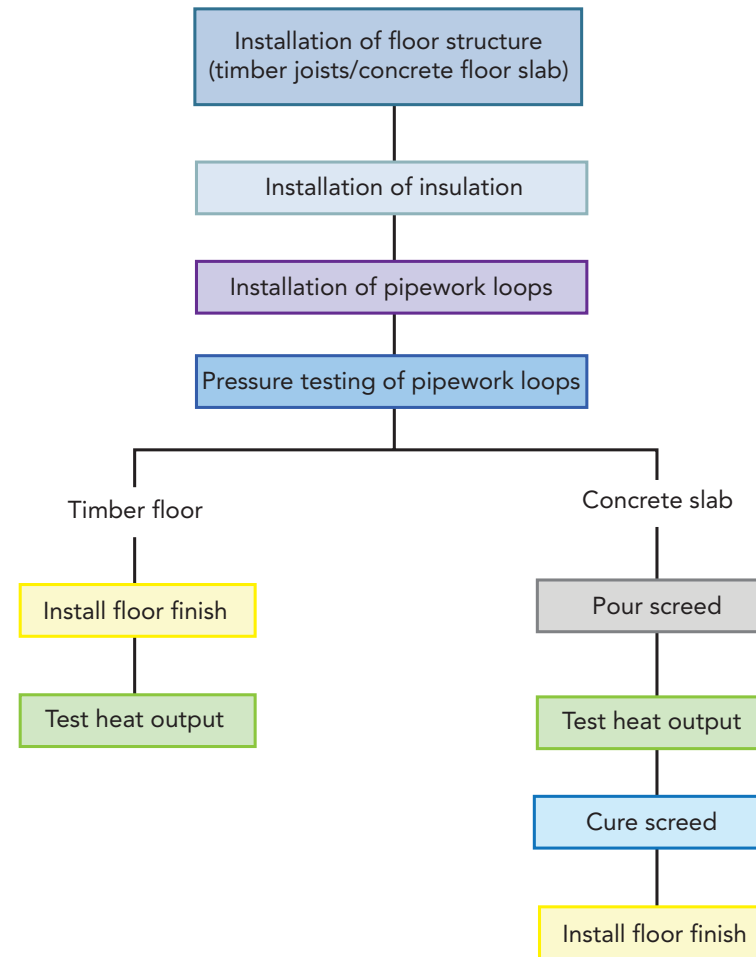
While underfloor heating can be installed with most heat sources, specific considerations must be made to ensure system efficiency and safety. Guidance is given in Section 3.

## Design and installation

The floor construction should be designed and installed to ensure efficient heat transfer into the rooms and minimise any heat losses. Floor finishes should also be protected from potential damage. Typical installation stages for both timber floor and concrete slab construction are shown in Figure 5.

## Guidance for residents

Underfloor heating systems may be new and unfamiliar to many users and so controls that are intuitive should be selected. Guidance material and handover procedures should be clear and easy to understand for a non-technical audience.



**Figure 5** Installation stages for underfloor heating

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## 3 Main heat source

Underfloor heating requires hot water input at relatively low temperatures from the main heat source, typically 35 to 45°C. This can be achieved either at source or externally through mixing valves.

There are no specific restrictions to the type of heat source that can be used to provide underfloor heating. However, as noted previously, some heat sources, including condensing boilers and heat pumps, are more efficient when supplying heat at lower temperatures.

### Underfloor heating and domestic hot water (DHW)

The temperature at which water is required for underfloor heating is lower (35 to 45°C) than that required for DHW (over 60°C).

Where the same main heat source provides space heating and DHW, the different temperatures can be achieved by either of the following means:

- Modulating temperatures at main heat source – This is done by setting up the controls integral to the main heat source.
- Modulating temperatures outside main heat source – Hot water is supplied at the temperature required to heat DHW, and reduced for distribution through the underfloor heating using mixing valves.

### Gas and oil boilers

In order to meet the efficiency requirements set out in Building Regulations guidance, all gas or oil boilers specified in new homes are of the condensing type. A condensing boiler has a large (or a second) heat exchanger, to recover heat that would otherwise be wasted in the flue gases. This improves the overall fuel efficiency of the boiler. The benefit from this heat recovery is maximised when the temperature of the water returning to the boiler is low as is the case with underfloor heating.

### Biomass boilers

Biomass boilers are unable to modulate water supply temperatures at source. Where these are installed with underfloor heating, a mixing valve arrangement is used to reduce the temperature of water supplied to the underfloor heating loops. Also, biomass boilers are generally installed with a buffer vessel to reduce on/off cycling of the boiler.

## Heat pumps

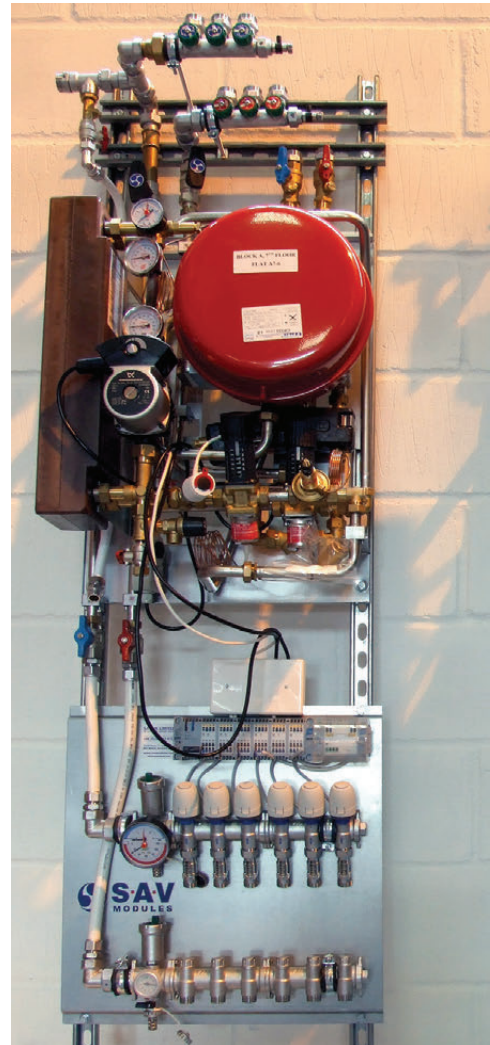
Heat pumps take heat from a relatively low temperature source such as outside air, the ground or a water body, and convert it to a higher temperature, generally using electricity. Their efficiency is measured by the ratio of heat output to the power needed to drive the entire process, called its Coefficient of Performance (COP).

The COP of a heat pump is higher when the difference in temperature between the heat source and the heat supply is low. This makes heat pumps particularly suitable for use with underfloor heating, where the supply temperatures are low.

## Community heating systems

Best practice guidance for community heating schemes, including CIBSE/ADE CP1<sup>[6]</sup> recommends that the primary return temperature should be designed to be as low as possible. In addition to improving the operational efficiency of the heating plant, low return temperatures help reduce peak flow rates, which in turn help reduce pipe sizes and associated costs for infrastructure.

Underfloor heating lends itself naturally to low return temperatures and supports efficient design of community heating systems. In a community heating system, the temperature of the water circulated is generally high in order to meet both the space heating and DHW demand. In most cases a Heat Interface Unit (HIU) is installed in each home, from where hot water is supplied to the underfloor heating manifolds and DHW circuit.



**Figure 6** Heat Interface Unit (HIU) with built-in underfloor heating manifolds



## 4 System distribution

### Primary pipework

The primary pipework supplies hot water from the main heat source to the DHW cylinder, radiators and underfloor heating system manifolds.

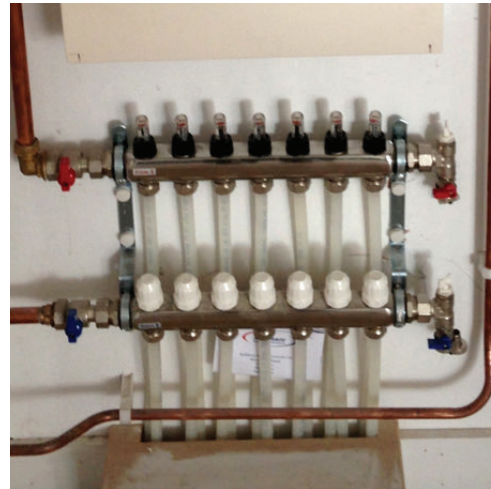
While it may be argued that heat losses from primary pipework contribute to meeting the space heating demand within homes, this happens in an uncontrolled manner, possibly resulting in overheating of some areas. Overheating is a particular problem when the primary flow temperature exceeds 40°C, and when uninsulated primary pipework loses heat into enclosed corridors where heat can accumulate over time.

Building Regulations guidance only requires that primary pipework to the DHW cylinder is insulated. However, best practice would be to minimise heat losses by insulating all primary pipework. Figure 7 shows an installation where primary pipework to the underfloor heating manifolds has been insulated and Figure 8 shows one where the insulation has been omitted.

There can also be some heat losses from the underfloor heating manifolds, which can contribute to overall system inefficiencies. This can be addressed by insulating the manifolds or placing them inside an insulated enclosure (see Figure 13). However, some manufacturers' components may not be suitable for operating inside an insulated enclosure.



**Figure 7** Well-insulated primary pipework at connection with manifolds



**Figure 8** Uninsulated primary pipework at connection with manifolds

### Manifold assemblies

Manifold assemblies comprise supply and return ports that take hot water through underfloor heating loops to individual rooms or heating zones. These can have between two and twelve ports, each port connected to one underfloor heating loop. Generally one port is allocated per heated room, but for large rooms, two or more ports may be required.

As each room is generally served by its own port on the manifold, temperature control can be achieved on a per-room basis. This enables the space heating to be programmed and operated in the most energy efficient manner, for example by heating different rooms on different schedules.

Manifold assemblies include pumps, sensors and valves that regulate temperatures and pressure in the system. They are generally pre-assembled and provided by system manufacturers with integrated controls, however, they can also be assembled on site.

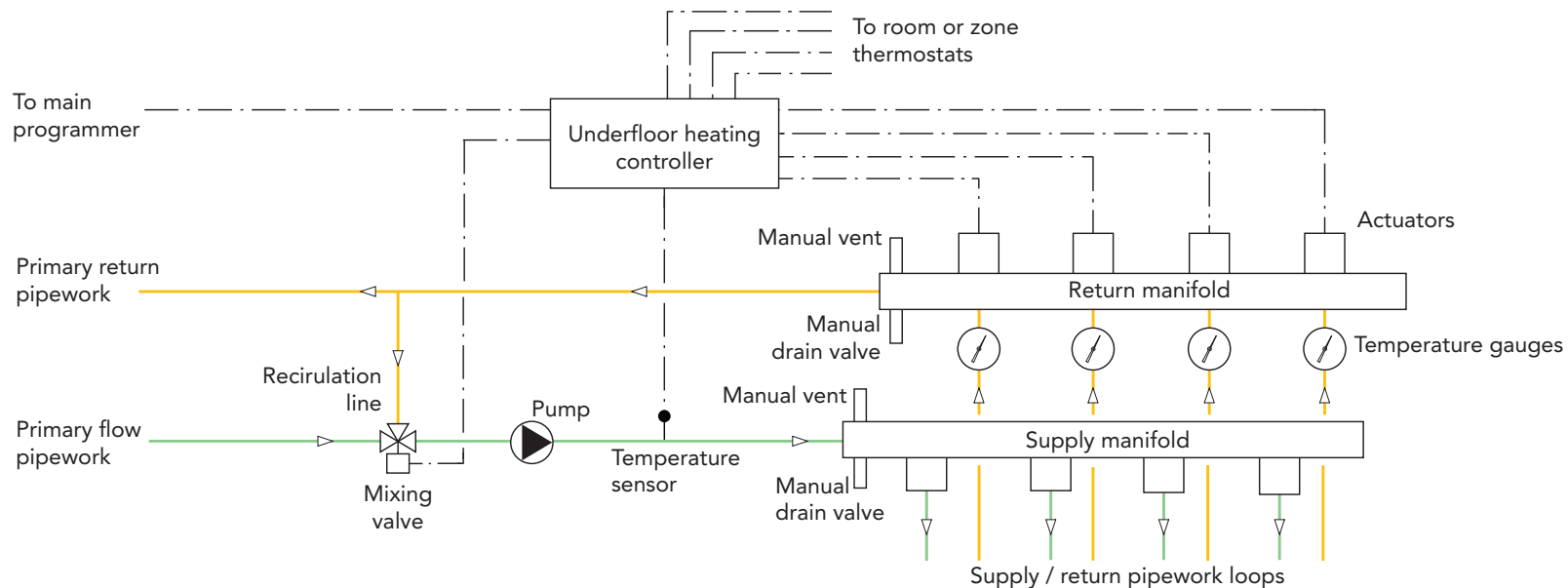
The schematic in Figure 9 lists the key components within a manifold assembly. This is a generic arrangement and there may be minor variations, for example depending on whether the main heat source can modulate supply temperatures.

In a typical domestic underfloor heating installation, hot water is supplied from the main heat source through the **primary flow pipework** to the **supply manifold**, which has ports leading to individual underfloor heating **supply pipework loops**. The **return pipework loops** carry water back from the heated rooms or zones to the **return manifold**. The return ports are fitted with **actuators**, which regulate the supply of

hot water in the corresponding supply loop, to achieve the temperature set points for all rooms (or zones) controlled by **room or zone thermostats**. **Temperature gauges** are often fitted onto each individual return loop to aid commissioning, repairs and maintenance.

To maintain the required flow in the underfloor heating network, a **pump** is connected to the manifold assembly. Where the hot water supply temperature for underfloor heating is not modulated at the heat source, a **recirculation line** diverts water from the return loop, to mix with hot water from the primary pipework at the **mixing valve**, controlled by a **temperature sensor** to achieve supply temperatures. The remaining water is circulated back through the **primary return pipework**.

**Manual vents and drains** are installed at both supply and return manifolds to aid commissioning.



**Figure 9** Typical modular manifold assembly

## Location of manifolds

Manifolds should be located to enable easy access for initial installation and commissioning as well as subsequent repairs and maintenance work. They should also be located centrally within the home, to facilitate a simple layout of supply and return pipework loops. Pipe runs between heating zones and manifolds should be kept to a minimum.

Concentrating a high density of supply and return pipework within the same area should also be avoided where possible, for ease of installation and to avoid local build-up of heat. Where this is unavoidable, for example adjacent to the manifolds, insulation may be installed to limit overheating and damage to floor finishes.

In single-storey homes including apartments, only one manifold is likely to be required. In multi-storey homes, one manifold is generally installed per storey, and these are generally vertically stacked to reduce primary pipework runs.

In homes where there is the potential for high heat loss from corridors, for example when these lead on to an external door, underfloor heating may need to be provided in these areas. When underfloor heating is provided in corridors, it should be via a dedicated pipework loop, controlled separately from other rooms.

## Maintaining water flow

The pipework loops leading to and from the manifolds must be kept free of any sharp bends that could restrict the free flow of water. Where 90° bends are required, metal formers should be used to prevent twisting and constriction.

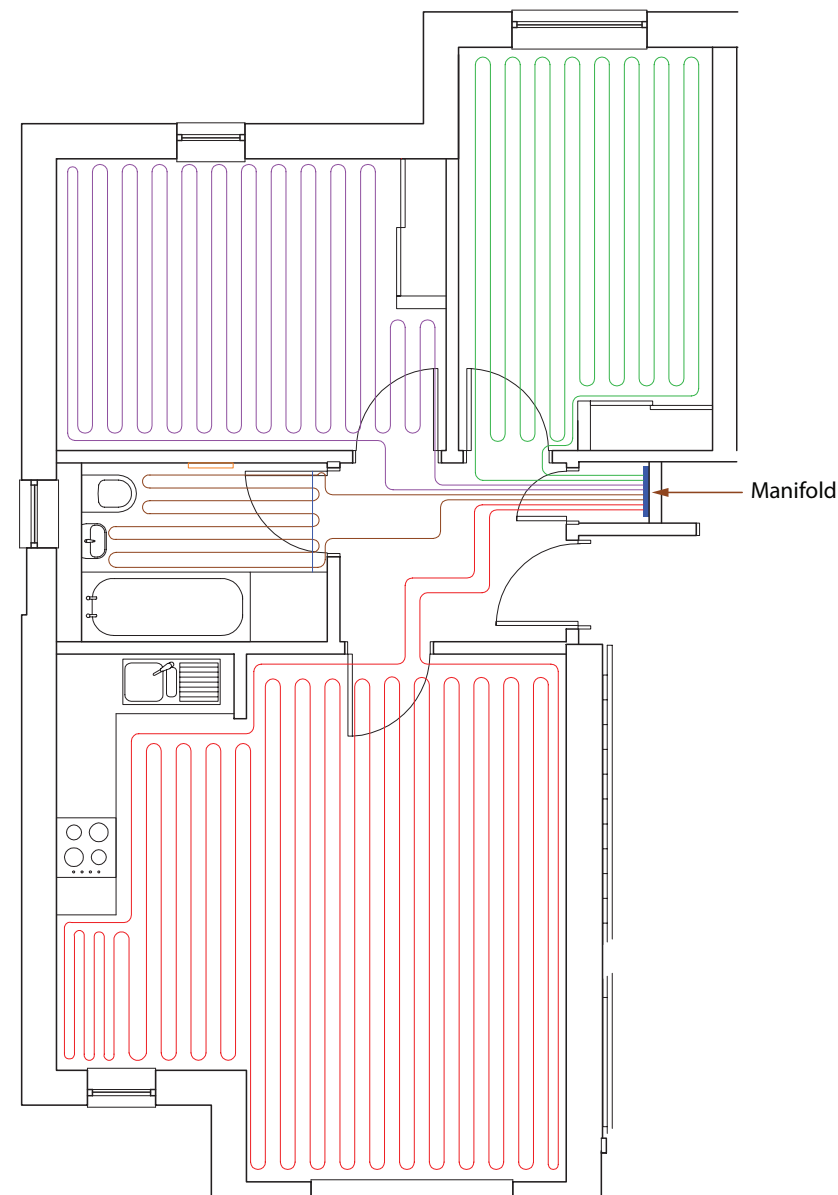


Figure 10 Typical layout for an apartment

## Preventing leaks

Where the pipework loops are installed in screed, it is important to ensure that all joints between the manifold and pipework loops are accommodated above the level of screed. No joints should be embedded in the screed, as this would restrict access for repairs and maintenance.



**Figure 11** Pipework joint embedded in screed – this will be difficult to reach for repairs in the event of a leak developing

## Secure fixing

Manifolds must be securely fastened on a wall at a reasonable height from the floor to ensure any bends in the pipework loops can be accommodated without obstructing flow.



**Figure 12** Manifold installation not secured onto wall – this could cause damage to both the wall and the components of the assembly

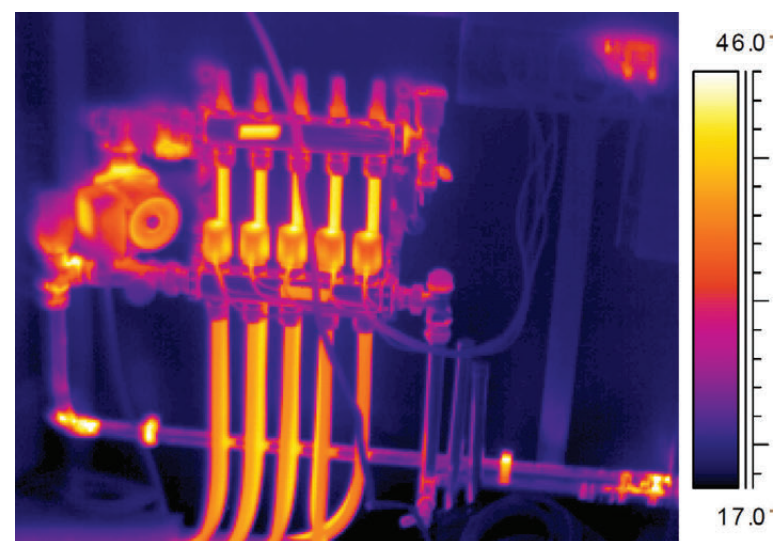


**Figure 13** Manifold installed in a dedicated casing fixed to the wall. This can also have a cover made of insulating material to limit heat losses. These should be designed by the system manufacturer to prevent any risk of overheating of components

## Insulating around the manifolds

As discussed previously, primary pipework to the manifolds should normally be insulated to prevent heat losses from the system and unwanted gains into surrounding spaces.

Heat gains from the underfloor heating pipework loops should also be considered, even though the temperature of hot water circulating in these loops is relatively low (see Figure 14). Where there is a high concentration of loops within the same area, such as corridors or immediately adjacent to manifolds, it is recommended that the pipework is insulated. This can be done by incorporating insulated sleeves as shown in Figure 16.



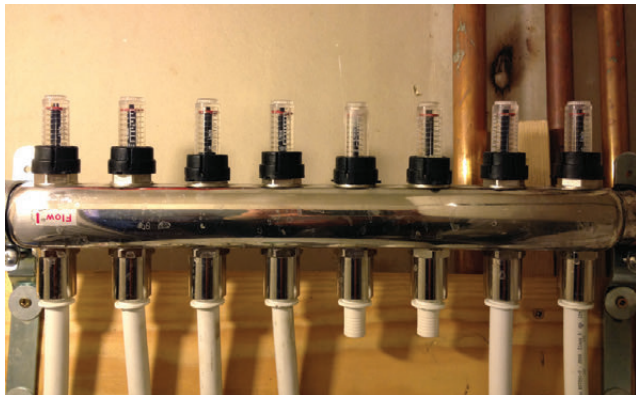
**Figure 14** Uninsulated underfloor heating loops can result in inefficiency and local overheating

## Labelling

To enable effective inspection, commissioning, maintenance and repairs of the underfloor heating installation, it is important to be able to identify the rooms to which individual ports of the manifold are connected. The labelling should reflect the room in the home (main bedroom, en-suite bathroom etc.) and not just the heating zones as per design schematics (room 1, room 2 etc.)



**Figure 16** Insulation sleeves can be fitted over underfloor heating loops



**Figure 15** Unlabelled manifolds make it difficult to commission and repair installations



**Figure 17** Labelling of manifold ports should relate to the installation

## 5 The floor as a heat emitter

To ensure that the underfloor heating system is capable of heating the rooms to the desired temperature, the following need to be considered:

- The area of heat emitter available, taking into account permanent obstructions
- Heat loss calculations carried out on a room-by-room basis
- The floor construction, finish and coverings.

### Layout of pipework loops

Guidance on the design and sizing of the system is provided in BS EN 1264<sup>[1-5]</sup>. There are five parts to this standard and all guidance from the system manufacturers should be in accordance with these.

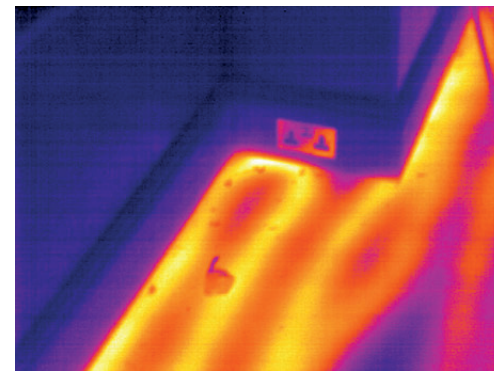
An undersized system, i.e. one where the heat output will not be sufficient to meet the space heating demand, cannot be compensated for by increasing the flow temperatures within the system. This is because the surface temperature of the floors must not exceed a maximum.

The supply temperatures and layout of the underfloor heating loops must therefore be determined taking into account the thermal performance and space heating demand of the specific home.

To achieve an even temperature distribution across the entire floor, the spacing of the pipework should be even. Spacing may, however, be locally reduced around the external perimeter of rooms, to compensate for the additional heat loss that occurs. Edge insulation of the floor is required to prevent heat losses from the floor to the walls.



**Figure 18** Surface temperatures across the floor of the same room not uniform due to incorrect commissioning



**Figure 19** Underfloor heating loops running to the edge of the floor and below skirting board. This may result in unnecessary heat losses

## Heat output of emitter

There are several factors that can prevent the entire floor area being available as an effective emitter. While it is not possible to predict with certainty the areas that will be obstructed by movable furniture, there are some obstructions that can be accounted for at early design stages. The following should be taken into account when laying out pipework loops:

### Kitchens, bathrooms and utility rooms

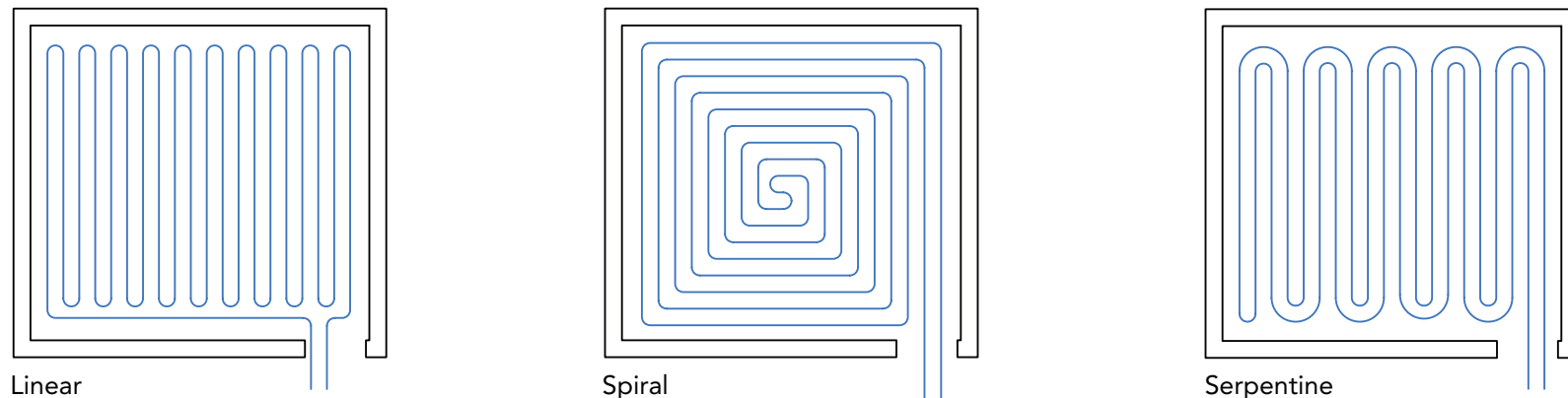
The areas under fixed storage and fittings such as showers and baths must not be included in the available heat emitter area, as no useful heat output occurs in these areas. The density of pipework loops installed within these rooms should not be increased to compensate for the area of emitter lost, as the surface temperatures of the floor must not exceed the maximum. Supplementary heating, where required, may be provided through towel rails or other means.

### Lift voids

New homes may incorporate features allowing flexibility in internal layouts by identifying locations in internal floors for future installation of through-the-floor lifts. In such cases it is important to account for the demarcated area by not including it as available heat emitter area and ensuring that no heating pipework loops are installed there.

### Skirting boards

Pipework loops should not extend right to the edge of the floors and under the skirting boards (see Figure 19). This is to prevent heat from being lost in the space between the internal plasterboard and wall, which may not be well-sealed or airtight.



**Figure 20** Underfloor heating pipework loops can be laid out in several patterns, depending on the fixing methods and shape of the room. The most appropriate layout for a particular application should be confirmed by the system manufacturer



## Insulating the floor

Floors must be insulated to minimise downward heat losses from the underfloor heating installation. The thickness of insulation should take into account the floor finish material and the resistance to heat that it will offer.

Where underfloor heating pipes are installed within screed, the thickness of the screed layer will also affect the proportion of heat flow transferred upwards or downwards.

### Ground floors

Insulation levels required to comply with Building Regulations are likely to be sufficient to limit downward heat loss from underfloor heating loops.



**Figure 21** Mineral wool can also be used to insulate under diffuser plates in timber floors. The plates should be prevented from sagging so that thermal contact is maintained with the floor finish

A rule of thumb is that the resistance value of the insulation layer should be at least 10 times the resistance value of the floor finish. The insulation type and thickness should be confirmed by calculations, taking into account the specific shape and size of the floor.

### Intermediate floors

Building Regulations do not normally require floors within homes or between homes to be insulated to prevent heat loss. However, where underfloor heating is installed, insulation will need to be incorporated to direct heat flow upwards.

To comply with Building Regulations, intermediate floors are required to meet standards for sound attenuation. Any floor constructions proposed by underfloor heating manufacturers must therefore take both requirements into consideration.



**Figure 22** Insulation left over metal heat diffuser panels will compromise heat transfer and should be cleared prior to installation of floor finish

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## 6 Installing underfloor heating

Underfloor heating can be used with concrete floors, timber floors, floating floors and acoustic floors.

Underfloor heating loops should be installed when all external doors and windows have been installed and the home is watertight. This is to ensure that the installation is protected from damage due to frost in the pipework loops during cold weather.

The installation should be pressure tested prior to the floor finish being installed, so that any remedial works can be carried out without causing disruption.

### Concrete floors

Where underfloor heating is installed over a concrete floor (in-situ slab, precast plank or beam and block), the insulation layer is applied over the concrete structure and the pipework loops are fixed on top of this. These loops are then embedded in a layer of screed, which effectively heats up as one mass to transfer heat evenly through the floor finish.

Pipework fixings should be carefully selected to maintain the integrity of the insulation and other materials. The use of foil-backed insulation can help address this risk.

The strength and composition of the screed will affect both installation and drying out times. Further guidance is available in BSRIA / Concrete Society publication IEP 11/2003<sup>[7]</sup>.

If the area of the floor exceeds 40m<sup>2</sup>, expansion joints should be incorporated to prevent cracking.

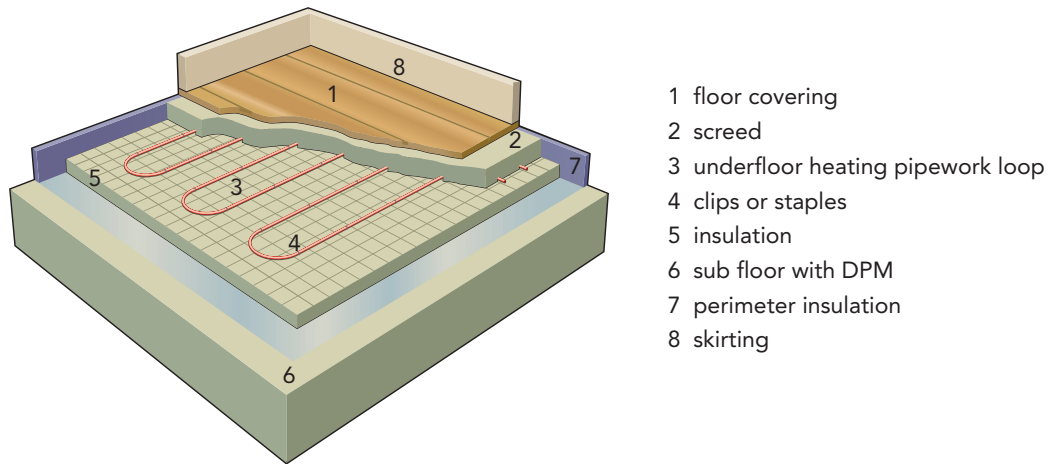
Pipework loops should be charged with water and pressurised before the screed is poured to ensure that the pipework has no constrictions as the screed sets.

Underfloor heating should not be used to dry out the screed as the increase in temperature could lead to cracking.

The following lists some considerations for the installation of underfloor heating over a concrete floor:

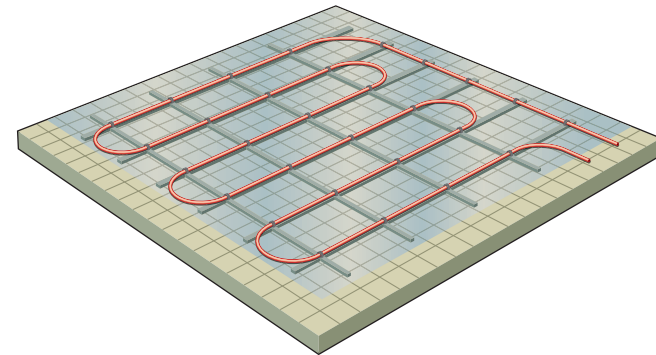
- The fixing of the rails, clips, staples or mesh should not damage the insulation. A protective membrane can be installed over the insulation layer.
- Adequate time should be allocated for drying out the screed, taking into account its thickness.
- Joints between insulation boards should be properly taped to prevent seepage of screed. Self-sealing clips with flanges that cover holes made by puncturing the insulation may also be used.
- Prior to pouring screed, edge insulation must be installed along the perimeter of the floor.

There are several ways in which the underfloor heating pipework loops can be fixed to the insulation in concrete floors with screed as shown in Figures 23 to 26.

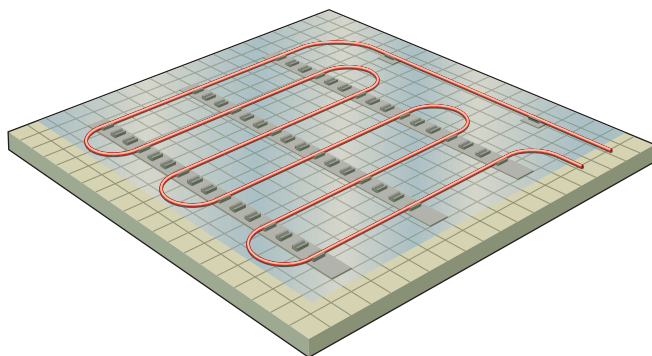


- 1 floor covering
- 2 screed
- 3 underfloor heating pipework loop
- 4 clips or staples
- 5 insulation
- 6 sub floor with DPM
- 7 perimeter insulation
- 8 skirting

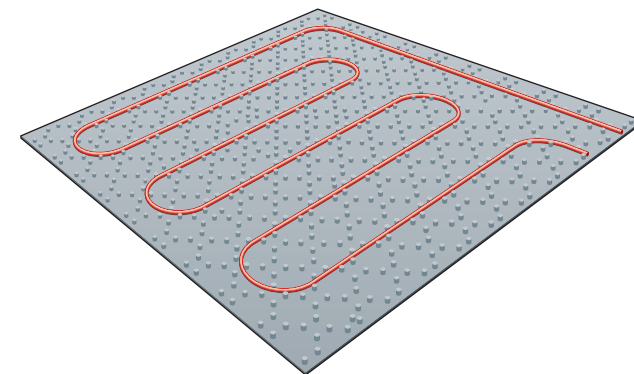
**Figure 23** Concrete floor – pipework loops fixed with **clips or staples**



**Figure 25** Concrete floor – pipework loops fixed to a **metal mesh** over insulation. The mesh potentially strengthens the screed, however, overall installation time may increase



**Figure 24** Concrete floor – pipework loops fixed with plastic clips to a **metal rail** over insulation



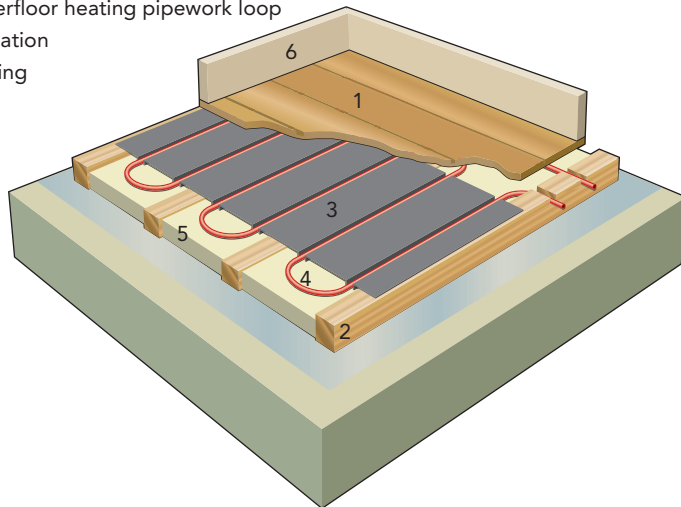
**Figure 26** Concrete floor - pipework loops over a **castellated panel**, which could also be of an insulating material

## Timber floors

In timber floors, the underfloor heating loops may be installed between floor joists in a linear layout in two ways:

- Inserted within pre-formed metal diffuser plates, which are in direct contact with the floor finish, to ensure even heat transfer to the floor finish surface (Figure 27).
- Embedded in a layer of lightweight screed over the insulation between joists (Figure 28). This is not very common and care must be taken to ensure there are no gaps between the insulation and joists for the screed to flow into.

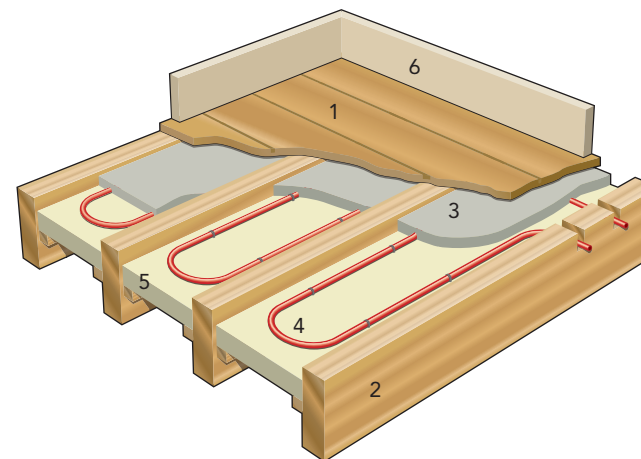
- 1 floor covering
- 2 timber battens
- 3 diffuser plate
- 4 underfloor heating pipework loop
- 5 insulation
- 6 skirting



**Figure 27** Underfloor heating loops with metal diffuser plates over rigid or mineral wool insulation between timber battens

The following lists some considerations for the installation of underfloor heating in a timber floor:

- Insulation between floor joists should be installed as close to the underside of the plates or the heating loops as possible and prior to the installation of the heating loops. The plates should not sag and should have good contact with the floor finish.
- Insulation should never be installed over the heating loops.
- The top surface of the diffuser plate should be clean before the floor finish is installed.
- When using tiles as the final floor finish, additional layers of plywood or tile backer board may be required to create a rigid base. The effect of these on the thermal resistance of the structure must be considered.

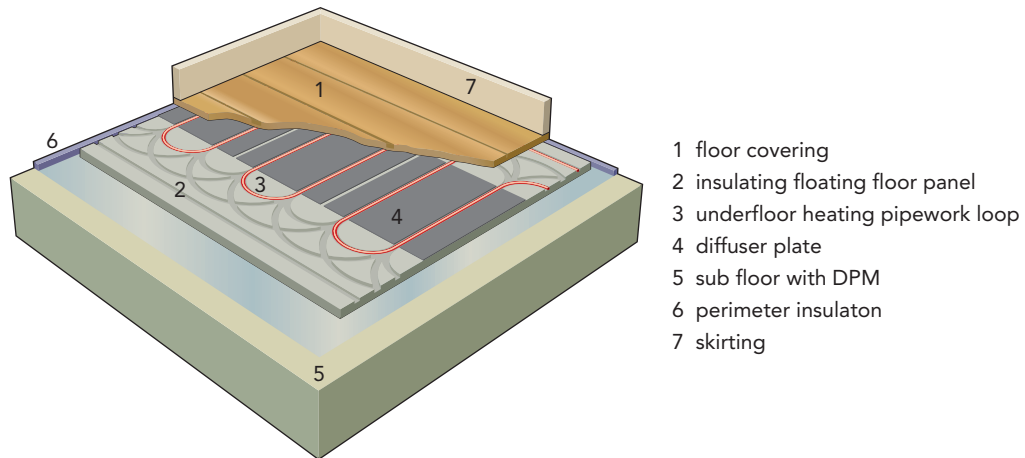


- 1 floor covering
- 2 timber joists
- 3 screed
- 4 underfloor heating pipework loop
- 5 insulation
- 6 skirting

**Figure 28** Underfloor heating loops embedded in lightweight screed over rigid insulation boards between timber joists

## Floating floors

Floating floor installations can be achieved using a layer of rigid insulation with pre-moulded tracks for the underfloor heating pipework loops. The floor finish is laid on top of the insulation but not fixed to it.

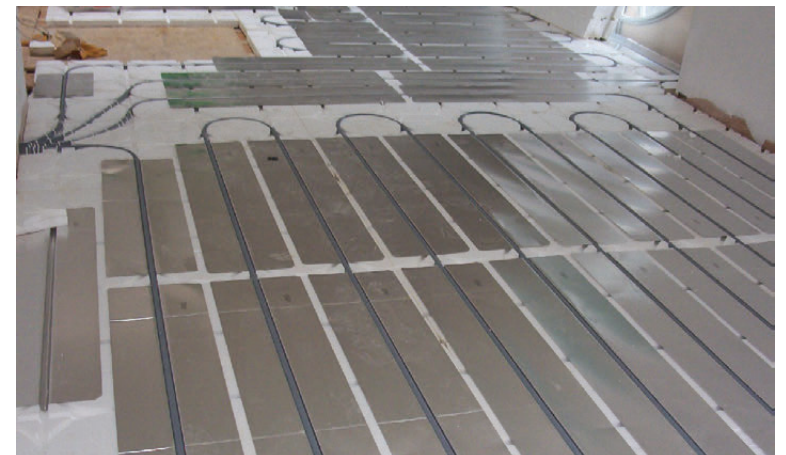


- 1 floor covering
- 2 insulating floating floor panel
- 3 underfloor heating pipework loop
- 4 diffuser plate
- 5 sub floor with DPM
- 6 perimeter insulaton
- 7 skirting

**Figure 29** Underfloor heating loops in pre-moulded tracks with a floating floor on top

The following lists some considerations for the installation of underfloor heating in a floating floor:

- Floating floor panels should be laid across the floor taking into account the intended pipework loop layout.
- The boards should be staggered to avoid corner joints between four adjacent panels.
- Standard panels may need to be cut into smaller sections to cover the entire floor, however, very small sections along the floor perimeter should be avoided.
- To maintain an even floor thickness, in sections where underfloor heating will be omitted, such as under baths, the level should be maintained by replacing the panels with plywood or chipboard.

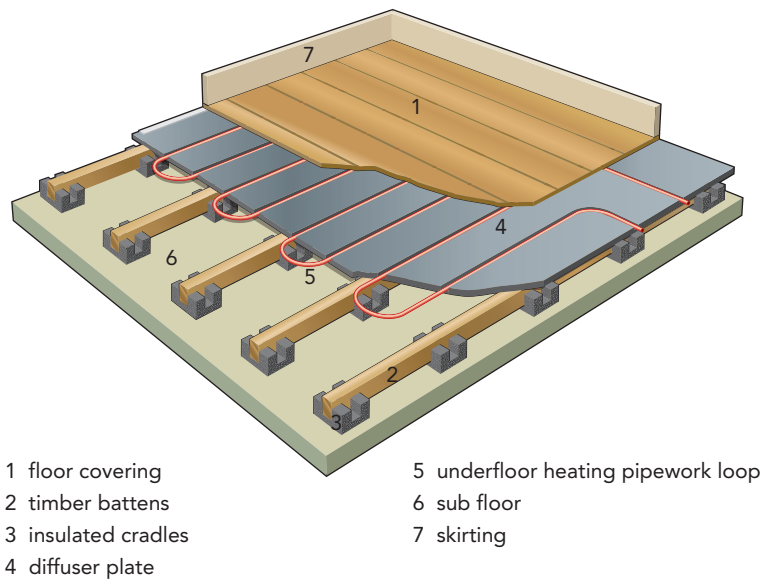


**Figure 30** Underfloor heating loops in rigid pre-moulded tracks with metal spreader plates to ensure even heat transfer

## Acoustic floors

A cradle and batten system can be used where acoustic insulation needs to be provided between homes, usually in apartment buildings. The pipework loops are laid into profiled diffuser plates or foil-covered profiled insulation panels. If diffuser plates are used, these must offer adequate insulation to minimise downward heat loss, even if additional insulation is incorporated for sound.

Good contact should be established between the pipework loops, diffuser plate or foil-covered panels, and the layers comprising the floor finish. Special consideration should be given to limiting sagging of panels between joists.



**Figure 31** Acoustic floor made of a cradle and batten system for sound insulation between homes

## Floor finishes

Underfloor heating works well with a wide range of floor finishes, however, different materials have different thermal properties. The system must therefore be designed from the outset taking into account the specific floor finishes to ensure adequate heat output.

Thin, lightweight floor finishes (such as timber and laminates) enable a fast response time as these do not absorb much heat and it is transferred rapidly into the room. These are therefore suitable for varying occupancy patterns where rooms are expected to be heated quickly.

Denser finishes (such as stone and ceramic tiles) take slightly longer to heat up and transmit heat but they retain this heat and remain warmer for longer. This provides a more stable temperature profile which is more suitable for a relatively constant occupancy.

### Stone and ceramic tile

Hard surfaces such as stone and ceramic tiles transfer heat more effectively than softer finishes such as carpet.

Rigid materials are at risk of developing cracks as the screed below expands and contracts, either as a result of the screed drying out or as the underfloor heating pipes expand and contract. To counter this, decoupling membranes can be used when laying stone and ceramic tiles. These must be appropriate for use with underfloor heating and approved by the system manufacturer. Flexible adhesives can also be used to further prevent cracks in the floor finish from expansion/contraction of the screed.

### Timber

Natural timbers are prone to cracking due to thermal expansion and contraction when used over underfloor heating loops and care should be taken when specifying board width and thickness.

Engineered hardwood flooring boards comprise a top layer of real wood combined with a cross-ply base laminate. When used with underfloor heating, engineered hardwood boards are more stable than solid timber boards and less susceptible to damage.

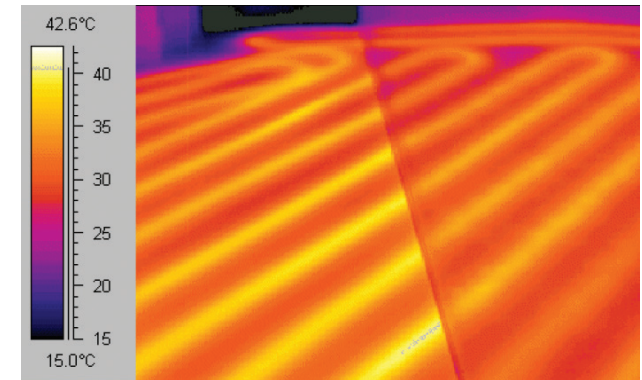
### Carpet

Carpets generally have a higher thermal resistance than other floor finishes and this can affect the output of heat from the system. Care should be taken with the selection of underlay with minimal thermal resistance. Felt or polyurethane underlays are generally unsuitable and should not be used.

### Vinyl and laminates

Laminates and synthetic vinyl work well with underfloor heating since they generally have a lower thermal resistance than carpets.

When used with screeded floors, these finishes are generally glued onto appropriate underlay over the screed surface. When used with timber floors, it may be necessary to overlay the decking with an additional layer of plywood before laying the vinyl or laminate.



**Figure 32** The temperature of the floor has been slightly reduced where a rug had been placed by residents.

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## 7 Programmers and controls

In order to achieve energy efficiency and comfort in homes, controls for installations with underfloor heating should be set up so that:

- the temperature settings for separate zones can be optimised, and
- there are no conflicts between space heating and DHW demands.

Building Regulations guidance sets out recommendations for the minimum standards of controls that must be incorporated in new homes. Guidance throughout the UK recommends that:

- For homes up to 150m<sup>2</sup> there must be provision to maintain at least two separate zones at different temperature settings, of which one must be the living room.
- For homes larger than 150m<sup>2</sup>, in addition to the above, there must also be provisions to separately switch the heating in these zones on or off.
- The exception is for single-storey homes where the living room forms the predominant proportion of the home (>70% in area) where there can be only one temperature zone.

Good practice would be to install one thermostat for each room in the home. In addition to maximising comfort for the users, this arrangement will facilitate the most energy efficient operation of the heating system.

Some room thermostats are programmable, enabling time and temperature control in individual rooms, however, time control is normally effected at the central controller.

### Controls on the main heat source

The main heat source should have integral controls to cap the temperature of the hot water output for health and safety purposes.

#### Gas and oil boilers

Modern gas and oil boilers can be set up to modulate output temperatures depending on whether there is a demand for space heating or DHW, with priority given to DHW. This means that when there is demand for DHW, the output from the boiler would be at a higher temperature. At all other times, the output would be at a lower temperature.

#### Heat pumps

Where a heat pump is providing both space heating and DHW, a hot water cylinder will be installed. This cylinder may be connected to another heat source, for example an electric immersion heater, to provide top-up heating.

Controls should be set up to prioritise DHW so that water is provided at the higher temperature only when there is demand for it. This will ensure that the heat pump operates predominantly in the space heating mode and therefore with a higher COP.

#### Biomass boilers

These boilers are unable to modulate the temperature of the hot water output, so it is generally set above 60°C to meet the DHW demand. The temperature of hot water to the underfloor heating pipework is therefore reduced by mixing valves as part of the manifold assembly.



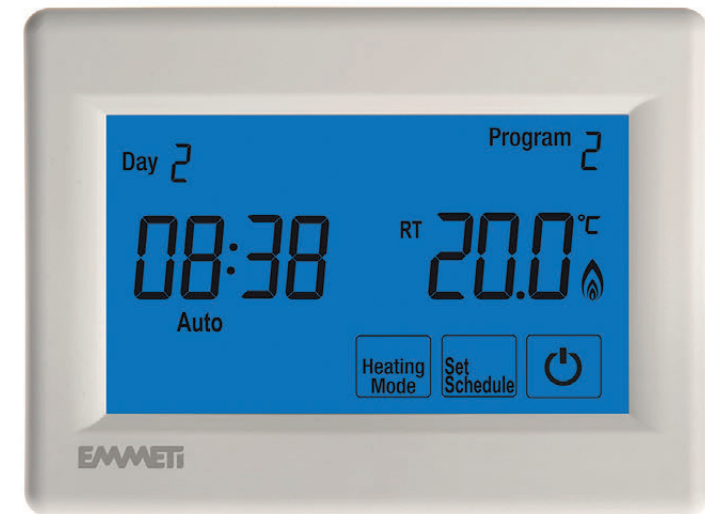
## Main programmer settings

### Time and temperature

The main programmer is an electronic controller with integral timers that allow residents to programme the time and temperature settings of the heating system. Space heating and DHW can generally be programmed separately. The thermostats in individual rooms or zones control space heating temperatures, based on the setup of the home.

### Night setback

Depending on the type of underfloor system it may take a several hours to restore comfort conditions if the system has become completely cold. Building Regulations guidance states that for floors with thick screed (>65mm), the main programmer should have a setting for an automatic setback temperature during the heating season.



**Figure 33** Touch screen programmer with 7-day, 6+1 day or 5+2 day options

## 8 Testing

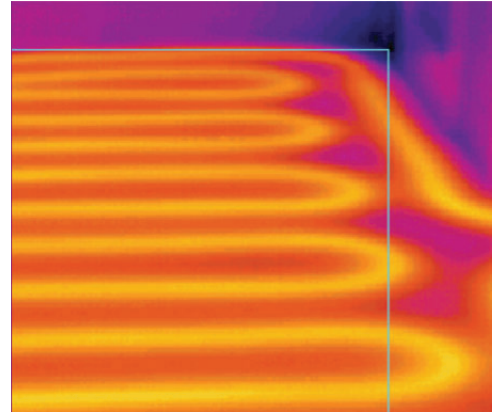
### Testing the installation

After the underfloor heating loops have been laid, the installation should be subjected to a pressure test at two times the working pressure, to meet the requirements set out in BS EN 1264-4<sup>[4]</sup>. This standard requires testing at a minimum pressure of 6 bar, however, underfloor heating suppliers recommend testing up to twice this pressure, maintained for 24 hours.

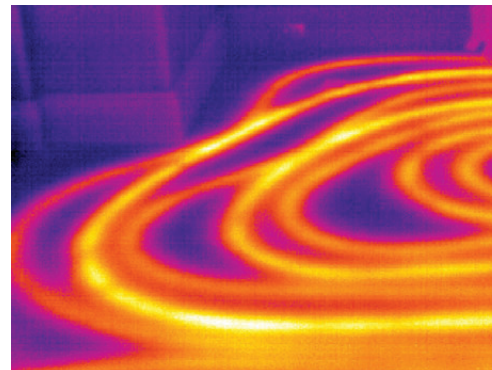
### Inspecting the quality of installation

A very effective way of checking the quality of the underfloor heating installation (and also to create a record of the position of the pipework within the floor) is to carry out a thermographic survey, preferably immediately after commissioning.

A thermal imaging camera provides a colour video image of a surface, where the colour indicates the temperature. This can indicate the routes of the pipework and any problem areas, and also provide an accurate record of floor surface temperatures to compare with the design specification.



**Figure 34** Evenly laid out underfloor heating loops embedded within screed layer, inspected prior to laying of floor finish



**Figure 35** Underfloor heating loops installed without consideration for spacing or fixing method



**Figure 36** Thermography is a simple way to inspect underfloor heating installations

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## 9 Commissioning and maintenance

### Water treatment

Underfloor heating pipes are made of plastic and therefore are not at risk of corrosion. However, metal pipework may be used in other parts of the overall system, for example at the boiler heat exchangers, manifolds, pumps and control valves. The entire system will therefore need to be subject to conventional water treatment regimes, including inhibitors and biocides. The compatibility of water treatment chemicals with all the materials that form part of the system must be confirmed.

### Heating plant

There are no specific requirements for commissioning and maintenance of boilers and heat pumps in systems with underfloor heating beyond those that would normally apply.

### Manifolds

Manifolds should be checked annually for signs of leaks. If these cannot be cured by tightening the fittings, the manifold may need to be dismantled and the washers or seals replaced. The operation of manifold valves should be checked and the indicated flows compared with the commissioning record.

Some manifolds incorporate a temperature gauge on the return giving an indication of the temperature drop through each loop. This can be used to determine if the output of the circuit is correct and is also used to balance the system during commissioning.

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# 10 Handover

Underfloor heating is relatively new in homes in the UK and some aspects of its operation are different to the radiators most people are used to. To ensure the comfort of residents, it is beneficial to engage with them early in the design process where possible.

However, a significant proportion of new housing in the UK is built speculatively or rented, so it is not possible for designers and contractors to interact with the residents. Handover material should take into account the types of residents to whom the homes will be handed over and also provide sufficient information to subsequent residents.

## Guidance

In order to demonstrate compliance with Building Regulations, information needs to be provided to residents to enable them to use the systems installed in their homes effectively. In addition to including manufacturers' manuals for products, it is important to provide simply-presented information relating to the specific installation and how it is set up.

Where underfloor heating is installed, the following information should be included:

### Heating zones

A clear diagram should be included to indicate how the property is split into control zones.

### Programmings and thermostats

An image of the controls interface, both for the programmer and thermostat, should be included, showing what various indicators represent and how the programme can be changed.

It would be beneficial to include a table to note the set points and programme at the time of handover and for residents to record any alterations.

### Responsiveness of system

A key difference between underfloor heating and a conventional radiator is how quickly the residents perceive the system to be taking effect. Although there are clear benefits to the even distribution of heating within the home, it is important to ensure residents understand that the system may be operating at its maximum setting even though the floor should not be noticeably warm.

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## References

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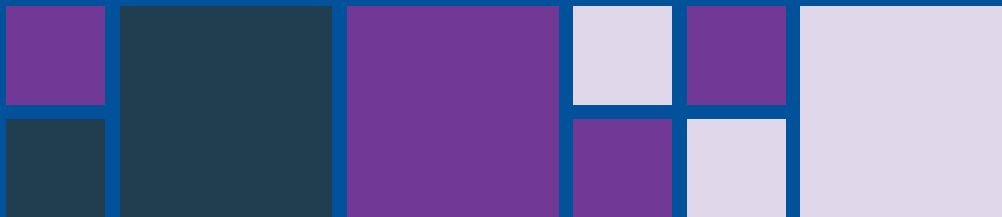
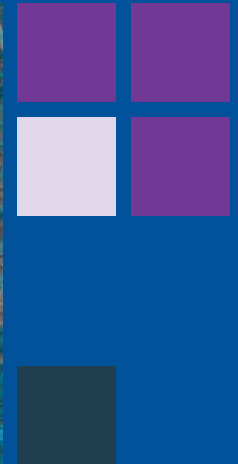
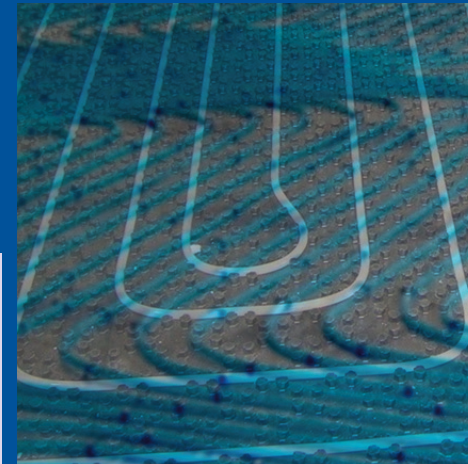




# Underfloor heating

A guide for house builders

This NHBC Foundation guide is intended to give house builders and designers a broad understanding of the benefits of underfloor heating and the issues surrounding its design and installation. It covers 'wet' underfloor heating systems installed in a variety of floor constructions and discusses system controls, testing, commissioning and maintenance.



The NHBC Foundation, established in 2006, provides high quality research and practical guidance to support the house-building industry as it addresses the challenges of delivering 21st century new homes.

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