# Underfloor Heating

## Underfloor Heating Installation

## Training Manual

*David Lowe.*

# Supporting Bodies and Documents.

**BSRIA.** (Building Services Research and Information Association)

A non-profit organisation formed in 1955 in Bracknell, BSRIA offer a vast range of advice, testing and consultancy services to the building and construction industry.

BSRIA's main objective is to improve the efficiency of buildings not only in terms of energy, but also to increase the lifespan of buildings by testing and ensuring the quality of the products and materials used to build them.

**BSI.** (British Standards Institute)

British Standards Institute was founded in London in 1901. Originally named the Engineering Standards Committee, this body writes and produces technical standards and management systems across a wide spectrum of products and services. BSI sets out how tasks are to be performed such as testing, development and manufacture. This is to help ensure a 'standard' level of quality and certification may be granted once these standards have been met.

**BEAMA.** (British Electrotechnical and Allied Manufacturers' Association)

BEAMA work between government offices and manufacturers of electrical infrastructure products and systems across the whole electrical industry. They ensure their members are kept up to date with the latest regulations, standards, and codes of practice.

Safety is key and so all electrical components within a UFH system have to be manufactured to an acceptable standard. With easy access to BEAMA's technical bulletins, regulatory updates and advice, these standards can easily be met.

**Planning Portal**

The government planning portal contains all the latest building regulations for England, Wales and R.O.I. available for free download.

Scotland conforms to building standards which are accessible from as is Northern Ireland who comply with N.I technical booklets B through to V. Although set out differently, the content is generally the same.

**Energy Saving Trust**

The Energy Saving Trust was formally established in November 1992. It was formed, in response to the Ofgas 1991 proposal to increase energy efficiency in the use of natural gas, and to the global June 1992 Earth Summit call to reduce greenhouse gas emissions and prevent global warming and climate change.

The trusts main goals are to achieve the sustainable use of energy and to cut carbon dioxide emissions. Their website is packed with free downloadable information and documents to support the industry.

# Underfloor Heating – A Brief History

Underfloor heating is by no means modern. It is believed to have been developed initially in ancient Asia in around 5,000 BC.

This early system was known as the '*Ondol'*.

Fuel was fed in at one end providing heat to a stove for cooking and the hot air would then pass through and around a cavity beneath the whole floor where it would be flued out to atmosphere. Earlier, smaller versions were in an area of the dwelling similar to a 'Yorkshire range'

Around 100 BC, The Romans are said to have introduced the hypocaust to Britain. This was very similar to the earlier ondol system, but the hypocaust had a bronze ventilator in the dome of the roof. When the room was hot enough, the ventilator would be lowered allowing the hot air to escape thus cooling the room to a level where the vent could be closed again, allowing the room to warm.

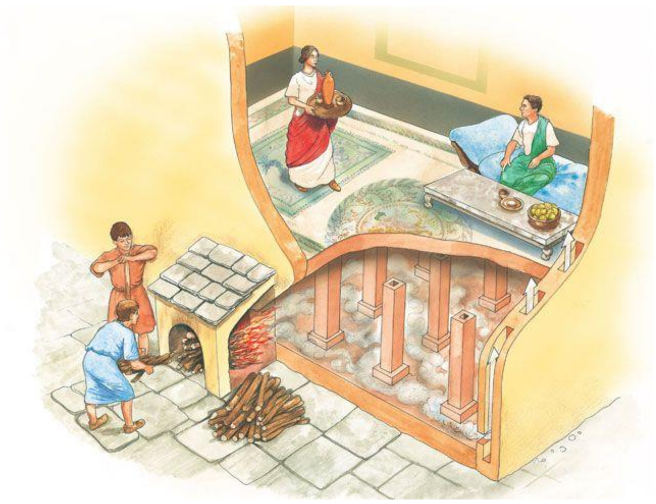
It wasn't until early to mid-20$^{th}$ century that hydronic or wet underfloor heating systems were developed. These used steel pipework and some of these systems are still in use today almost 100 years later.

Hydronic or 'wet' underfloor heating systems were primarily used to heat larger buildings such as churches, schools and even the houses of parliament but in post war Germany, the first domestic systems were installed.

In the 1960s electric underfloor heating was created which works on the similar principle to the electric blanket. Being electric, these systems were and still are, comparatively expensive to run. However, modern electric systems are still installed today but usually in small areas such as bathrooms – one benefit being that they are extremely low profile and have little effect upon floor height.

There has been little change to the principles of underfloor heating other than the introduction of ultra – flexible plastics used in pipework and more efficient control with the use of manifolds, actuators, and thermostats.

Due to constant research and development, there are now more solutions available offering greater flexibility in system design and allowing solutions for almost any situation.



*Hypocaust*

# Module 1

# Underfloor Heating Principles

# Module 1

## Underfloor Heating Principles.

Underfloor heating is a straight forward concept, but to better appreciate the principles of UFH and central heating systems in general, we need to understand the three methods of heat transfer which are:

### Conduction

Conduction is the transfer of heat through a solid, or semi solid medium (or material). Some materials transfer heat better than others – these are called *'conductors'*. Poor carriers of heat are called *'insulators'.*

In a screeded floor, heat is *'conducted'* from the pipe loops, through the screed and floor finish, up into the room. Consider a metal handled saucepan on a hob, it would be too hot to pick up. This is because heat from the burner has conducted through the metal of the pan and up the handle. Using an oven mitt would enable the pan to be picked up safely. This is because the oven mitt is an *'insulator'*

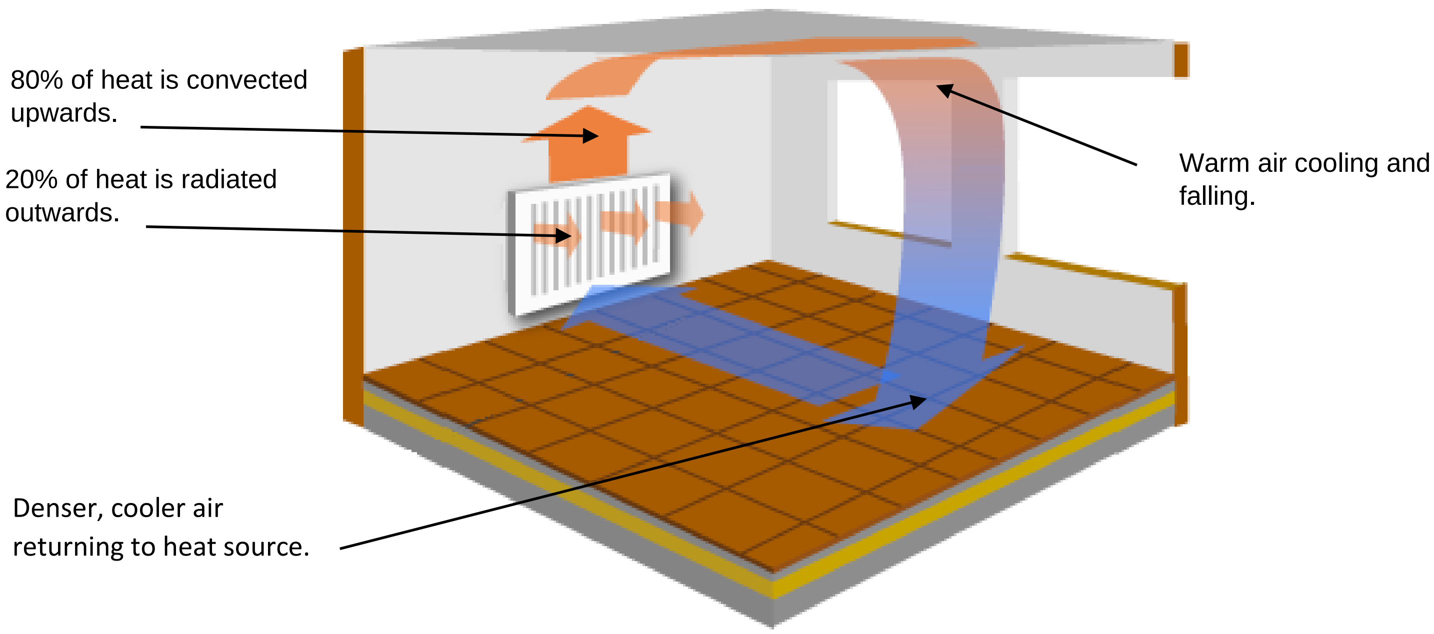

*Conduction*

### Convection

Convection is the transfer of heat through gases or liquids. In a conventional heating system, what we call radiators are actually convectors as around 80% of the heat they emit is convected upwards, and the remaining 20% radiated.

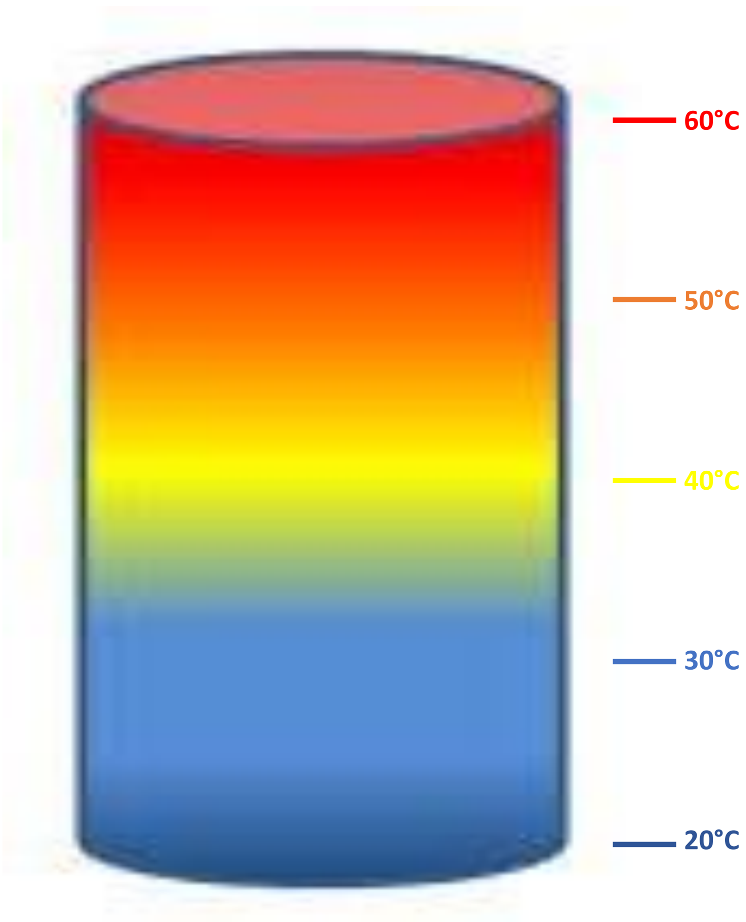
When heat is applied to a gas or liquid, the molecules within begin to vibrate then move apart releasing heat energy. This makes the gas or liquid less dense and the warmer molecules will begin to move upwards eventually being replaced by the cooler molecules from below. This will create two conditions.

Through gases or air, a convection current will be created. Radiators rely upon this process to distribute heat around the room as shown below.




*Convection through air*

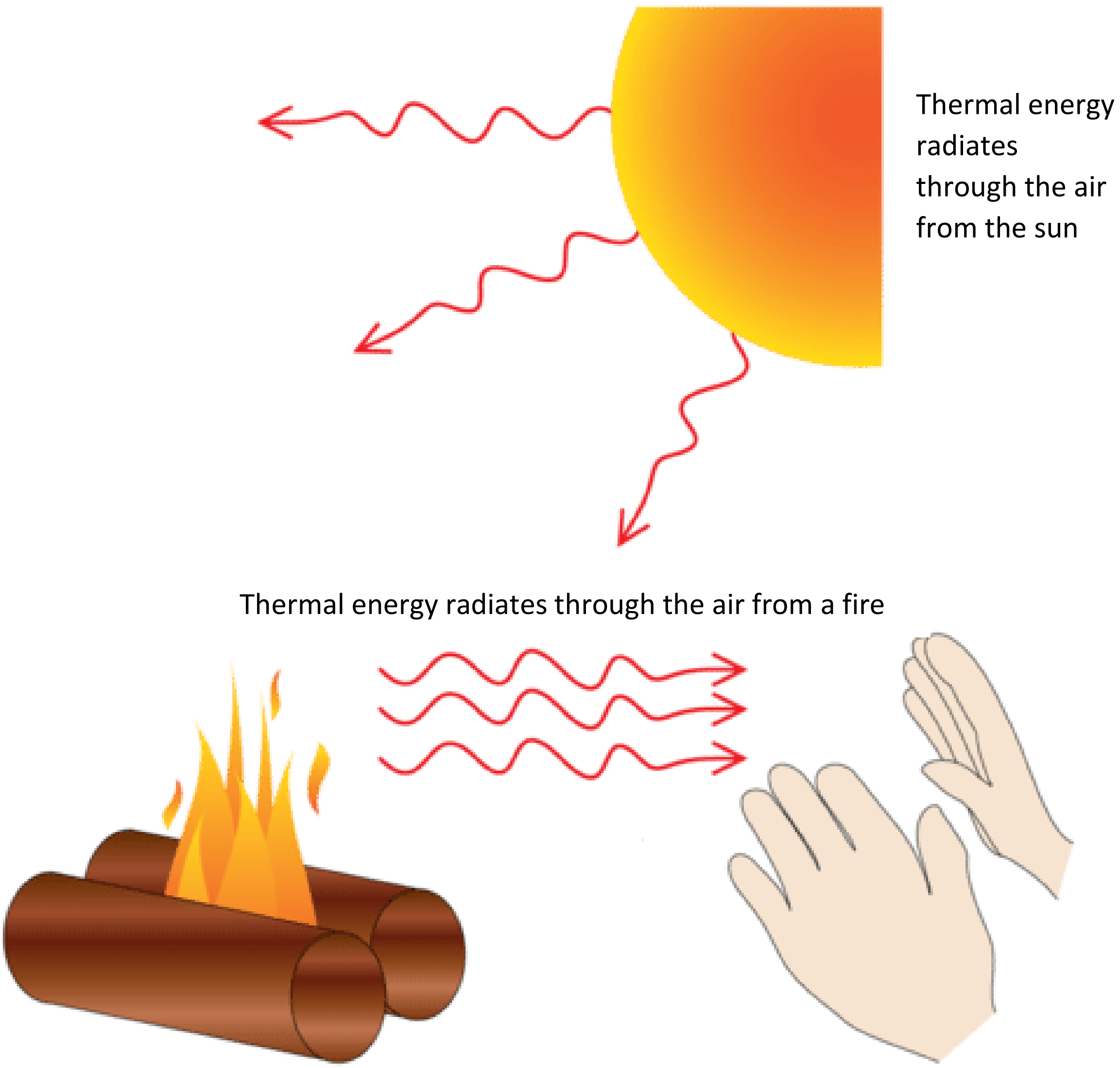
The diagram below shows that convection in liquids, can create what is known as *stratification*. This is where warmer, less dense molecules will settle at the top of the liquid contained, with gradually cooler molecules layered beneath. A great example of this is a domestic hot water cylinder which will feel hot at the top and cooler at the bottom.




*Convection through liquids*

**Radiation.**

Radiation is the ‘mediumless’ transfer of heat through electro-magnetic radiation. This is in the same way as the sun keeps us warm or how the microwave oven cooks a potato. This heat is radiated through the air and on a hot day can be seen as shimmering over such as road surfaces or on rooftops. The different colours we see through a thermal imaging camera show the various levels of heat radiated from a surface.




*Radiation*

# Radiators vs Underfloor Heating.

Now it is understood how heat energy can be distributed, it is easier to understand the differences between radiators and underfloor heating. It is fair to say that both systems have their own features and benefits.

## Radiator Systems

The main purpose of any central heating system is to achieve and maintain ideal comfort conditions which are usually 21°C for most rooms and around 23°C for bathrooms.

We are already aware that a radiator uses mainly convection to heat a room. It is because of this that radiators need to run at a temperature in the region of 80°C to create a convection current strong enough to reach the opposite end of the room. This makes conventional radiators unsuitable for many heat pumps.

Whilst convection is taking place, dust and other allergens which can aggravate chest conditions become airborne during the heating cycle. This also settles across the room increasing the need for dusting. The frequency of decorating will also rise as much of the dust will collect where the walls join the ceiling. Also, wall staining can appear directly above radiators

When siting furniture, care must be taken so as not to cover radiators with such as a sofa which would impede heat delivery into the room. Covering with curtains can also have the same effect.

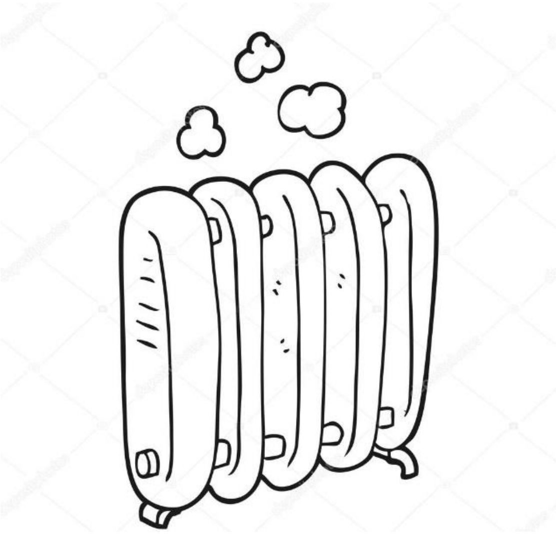
Decorating can become more laborious in terms of having to remove radiators to paper or paint behind, then refilling once refitted.

Radiator systems can be prone to mechanical damage. For example, exposed flow and return pipework being hit by vacuum cleaners. Pipework that is boxed in can also look unsightly.

Bearing in mind the 80°C operating temperatures, there is a risk of burns from the radiators surface and its pipework especially to younger children and the elderly. This is why in nursing homes and schools, LST (low surface temperature) radiators tend to be installed, the problem with LST's is their larger size.

Internal corrosion can cause radiators to 'pin-hole' causing damage to carpets which can result in insurance claims. This is often encountered following a power-flush.

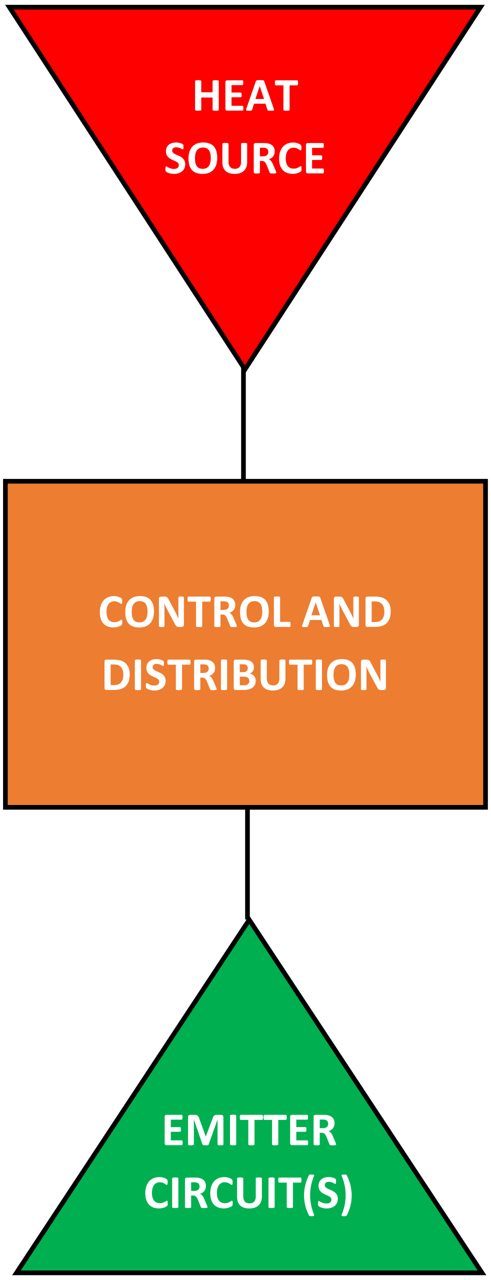
Larger sized radiators can be heavy to lift and hang which is a common problem when trying to fix to dot and dab walling.



## Underfloor Heating

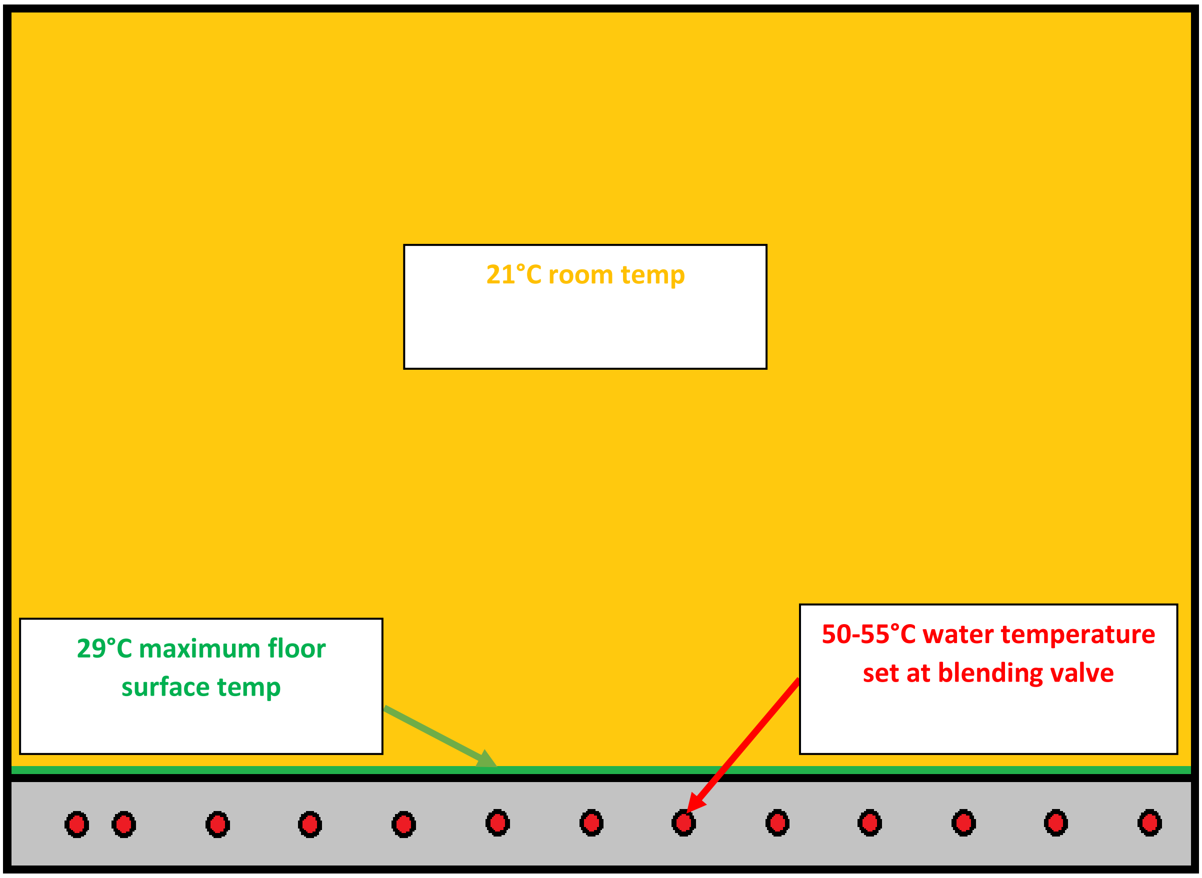
Underfloor heating consists of three basic sections – The heat source to warm the water, which in most cases, will be a gas boiler.

The warm water needs to be told where and when it is needed and at what temperature. This is performed via the control and distribution section, which then circulates as required, the water through the third section, the emitter circuits.



## Temperatures.

For a UFH system to achieve and maintain ideal comfort conditions, certain temperatures which are outlined below need to be met and sustained.




What the diagram explains is that with a blending valve temperature of 50-55°C, the system should produce a floor surface temperature of 29°C maximum, resulting in an air temperature of 21°C. These ‘ideal’ temperatures are may differ slightly from the actual design specification.

## Features and Benefits

It’s Clean – less risk of allergies due to airborne dust from convection.

More energy efficient – due to lower temperature of circa 50ºC, energy savings of around 25% can be achieved, and boilers are in condensing mode for longer.

Lower internal water temperature – this also can reduce wear and tear on the boiler.

Frees up more floor and wall space – no large radiators or cabinets to make rooms look smaller.

No need to redecorate so often – due to no dirt from the air settling around radiator tops.

More flexibility in siting furniture – there is no issue of covering radiators with sofas leading to cold rooms.

Safer – no hot surfaces that can burn especially the elderly or younger children.

Low maintenance – owing the concealment of the systems, there is less risk of mechanical damage e.g. upright vacuum cleaners on pipes.

Warm floors – with setback being a feature of many modern controls, the floor is always at a comfortable temperature.

Much more suited to human comfort conditions – The experience of UFH is much more comparable to outside warmth.

*Radiator convection staining*

## Heat Sources

At the heart of every central heating system is the heat source which can take many forms. Most common is the boiler which is usually fuelled by natural gas but can also be fired by LPG, oil, solid fuel or even electricity.

Boilers coupled with radiators need to produce a flow temperature of around 80°C to create sufficient convection to heat the entire room space.

Underfloor heating uses a pipe network integrated into the entire floor area as the heat emitter. This means a much larger output area and with most of the heat being radiated from the floor up, operating temperature can be considerably lower in the region of 50°C.

Oil boilers are generally problem free when coupled with underfloor heating as are biomass boilers being that most of them are now able to fully modulate.

Many solid fuel (anthracite) boilers don't have such precise temperature control and so extra provision for the latent heat produced must be accommodated by such as a heat dump or buffer vessel.

Heatpumps which have a lower maximum output temperature than boilers do work well with underfloor heating, and the number of air source heatpump installs is rising.

It is however, imperative that in all cases, heat source compatibility must be determined at the onset of any UFH project. The manufacturer may err on the side of caution, but it is always better to be safe than sorry as any rectification can prove costly.

## Boilers

### Conventional Systems

Earlier heating systems tended to be open vented and fired either by free-standing, wall-mounted or back-boiler units which had cast iron heat exchangers. While these older systems will work with underfloor heating, it makes sense at least to convert from open vented to a sealed system. Many of these systems are y-plan or s-plan.

Most modern gas boilers will work fine with underfloor heating as they produce outputs way above the lesser needs of an underfloor heating system and as a result do not have to work so hard. Therefore, underfloor heating is more efficient than radiators, with energy savings in the region of 15%. The service life of boilers will also be prolonged.

Condensing boilers are an excellent heat source for UFH. Condensing boilers are at their peak efficiency when condensing and under part load. The lower operating temperatures (50°C) of UFH will easily facilitate this.

A condensing boiler will start to condense when the return water is below 55°C and so with return temperatures of UFH being between 40 and 45°C, the boiler should be in condensing mode almost constantly, contributing to a highly efficient heating system.

### Combination Boilers

The 1970s saw the introduction of combination boilers to the UK although some boilers dated back to the 1960’s. As the name suggests, the combi-boiler combines instantaneous hot water and central heating in one unit.

Two main benefits of combi-boilers are that they are more efficient than conventional systems. This is because they use lightweight aluminium alloy or stainless-steel plate heat exchangers. ‘Size for size’ these have a much higher output when compared to cast iron water jackets.

There is also no requirement for storage of hot or cold water. This can release extra space in bathrooms and loft spaces. While free standing models do exist, most combi’s are wall mounted.

Some twenty years later, combi boiler technology improved with the advent of condensing combi boilers which utilise spent flue gases which pass through a second heat exchanger warming the water as it returns to the boiler. This adds around 10% efficiency.

### System Boilers

System boilers contain all that is required to provide heat to a hot water cylinder and to the central heating including the pump, expansion vessel with all relevant valves and connections.

### Heat Only Boilers

Heat only boilers are very similar to conventional boilers and these have just the basic internals. Usually, the ancillaries such as pump and expansion system are purchased separately. While this allows a more bespoke layout, considerably more work and materials are required.

### Solid Fuel Boilers

Solid fuel appliances such as wood burners and biomass boilers are becoming popular in the modern home, so one must bear in mind that solid fuel is an uncontrollable heat source. As such, some manufacturers will not confirm compatibility, so it is vital to ensure suitability from the onset.

Solid fuel systems usually require a thermal store which provides domestic hot water and acts as a buffer for the heating circuit giving almost instant heating response. While this may allow the installation of UFH, it will add expense to the project.

# Other Heatsources

## Heat Pumps

Both ground and air source heat pumps work under the same principle by extracting low grade heat from a medium usually the ground or air then converting it to a higher, more usable temperature via a refrigeration cycle.

Ground source heat pumps extract heat energy from the ground via appropriately sized ground loops. These loops are buried at around a metre deep. The ground loops are sometimes laid in lakes then weighed down.

The loops contain a water/glycol mix. This mixture is then transferred to the refrigerant via a plate heat exchanger.

Air source heat pumps extract energy from the air using fan coils then in the same way as ground source heat pumps, convert this to a higher temperature using refrigeration.

Both ground and air source heat pumps utilise plate heat exchangers to pass this higher temperature to the heat emitter circuits.

One consideration with all types of heatpumps, is that they produce a maximum heat output temperature of 50-55°C which would not be sufficient for some underfloor heating products such as spreader plates.

Owing to constant product development, some heatpumps are reputed to be able to reach higher temperatures. There are dual compressor heatpumps and some which work in conjunction with a purposely designed condensing boiler. Nevertheless, these output temperatures must be ascertained at the design stage.

## Electric Boilers


Electric boilers are available which are the perfect solution where a suitable primary flow and return is not easily accessible.

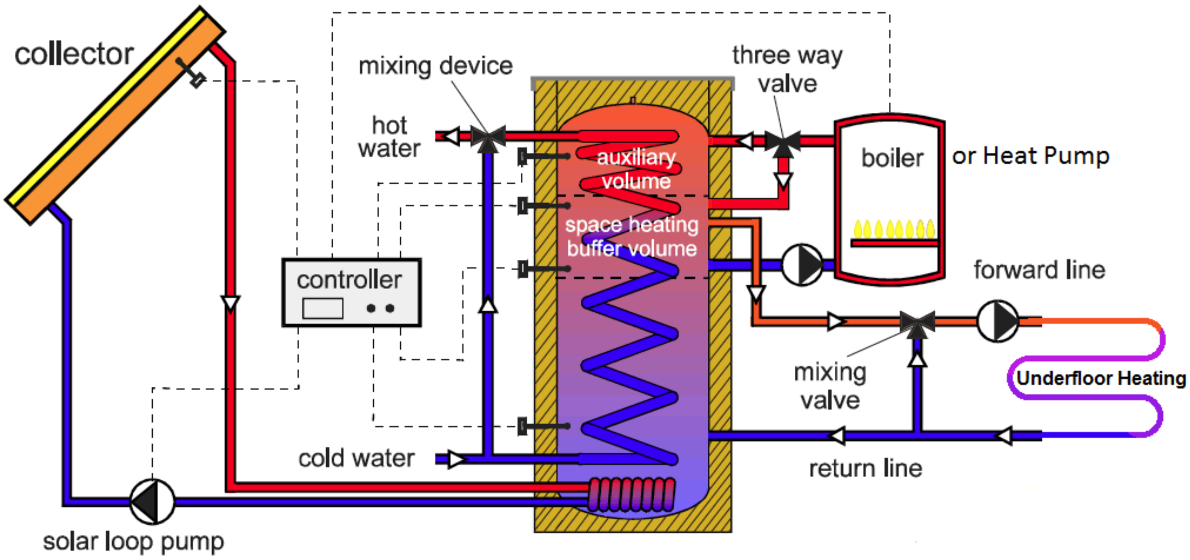
A 3kW electric boiler exists which will heat up to 38m² and plugs into a standard 3 pin socket and so is totally plug and play.

Inside the boiler is a 3kW heater with full overheat protection, expansion vessel, 2 port stainless steel manifold, an A rated pump, a temperature and pressure relief valve, and a pressure gauge. Internal temperature is controlled electronically with time and temperature set by an RF programmable room thermostat.

### Solar Thermal Combi-System

With the ever-rising costs of gas and electricity, more alternative methods of heating are becoming available as technology develops and progresses. *Solar-Thermal Combi* systems for example as shown below.

*Solar-Combi system.*




The solar combi system is solar thermal water heating combined with space heating. Solar collectors supply heat to the bottom coil of a thermal store. There is also a second coil through which mains cold water flows up through a blending valve at the top, then out to the hot taps.

Solar thermal alone will not provide the heat required within the cylinder, so a supplementary heat source boosts the stored water temperature up to around 80°C. This higher temperature ensures that the mains cold water will be hot enough and at the same time provide a buffer for the heating circuit.

The supplementary heat source can be a heat pump or boiler as pictured or either electric.

*Supplementary Heat Sources*

# Module 1

## Phase Test Questions

1. State the three methods of heat transfer.

2. State the ideal comfort temperatures for;

    a. Living rooms.

    b. Bathrooms.

3. What is the normal water temperature range circulated around a UFH system?

4. State the maximum floor surface temperature for a UFH system.

5. Name the three sections of an underfloor heating system.

# Module 2

# Floor Construction and Finishes.

# Module 2

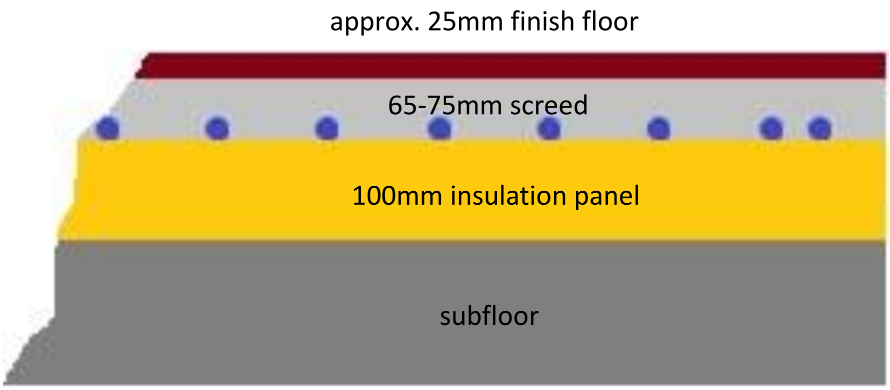
## Floor Construction and Finishes

There are four main types of floor construction which apply to UFH systems.

- Solid/screed floor
- Timber/intermediate floor
- Floating floor
- Low profile

## Solid Floors

Solid or screeded floors are best suited to new build and are rarely retro fitted. This is owing to the height of the finished floor once installed. This can add around 200mm to the floor height as below.




## Screed Types

There are many different types of screed available from dry mix screeds to liquid screeds and 'biscuit-mix' screeds. Screed compositions vary infinitely as do their characteristics which means thicknesses and drying times also differ.

Drying times may also be affected by weather conditions. Colder or damper air can delay setting. Admixes are available to speed up the curing process but must be compatible with the screed. The heating system must **not** be used to dry out the screed unless proven acceptable by the screed manufacturer.
Owing to different curing times, handover of the completed screed should be the responsibility of the screed company.

**BS EN 1264-4.1.2.8.6.2 states;**

***Laying***

*'When laying the screed, the temperature of the screed and the temperature of the room shall not fall below 5°C.*

### Ordinary 'dry mix' screed

The most common type of screed used with UFH is a semi-dry mix of sand and cement mixed to the same ratio as bricklaying mortar (3-4 parts sand to 1 part cement). Latex may be added to aid floating and improve finishing.

It is vital that the screed is properly compacted to ensure maximum contact with the pipe which will give better heat transfer. The optimum depth for this type of screed is 65-75mm, with a maximum of 90mm. It is normally finished with a wooden float.

### Liquid anhydrite screed

Liquid screeds can usually be laid at lesser depths of between 40 and 50mm. Some of the more modern composite liquid screeds can be laid as low as 25mm and are rapid curing.

Liquid screed or anhydrite screed is a compound usually of calcium sulphate and water with benefits being that this screed type is comparatively self-levelling and requires little work to achieve a good quality finish – some screeds become the floor finish once they have been sealed and polished.

Anhydrite screed costs around 25% more than standard ready mixed screed per $m^2$, but it can be laid at a lower thickness and being easier to lay, installation costs can be lower.

While liquid screeds are becoming more popular, due to their higher water content there is potential *laitance* occurring. Wet screeds should be avoided as these are only suitable for levelling and are likely to crack when used with UFH.

### Laitance

Laitance is the most common cause of failure in flooring installations. It is a layer which is formed on the surface of the screed after curing. It is a mixture of tiny particles of cement and fine aggregates that rise to the surface with too high a water content. Therefore, the screed must be properly cured and prepared prior to laying any floor covering.

### Biscuit mix or 'pug screed'

The structural ability of the joists must comply with building regulation part A to take the extra weight increase.

This system is best suited for use with air source heat pumps as the dry screed mix can give an output in the region of $100Wm^2$ at a relatively low water temperature which makes it ideal for heatpumps.

A standard installation for this system assuming the joists are deep enough would be to fix batons to the sides of the joists (about 70mm from the top of the joist) then a 50mm foiled faced insulation such as P.I.R. is cut and placed onto the batons, the pipe work is then clipped direct to the insulation and the screed can be installed on top, level with the joists.

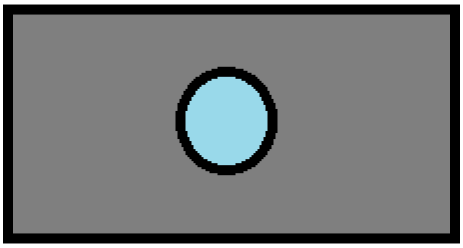
Regardless of the screed type or composition, before laying, the pipes will be fixed using the specified method and as designed by the manufacturer. Once fixed, the pipes shall be filled with water, bled and charged to a pressure of six bar for one hour.

During this time the system will be monitored for evidence of any significant pressure drop. If no pressure drop is evident, the results will be recorded, then the screed may be laid.

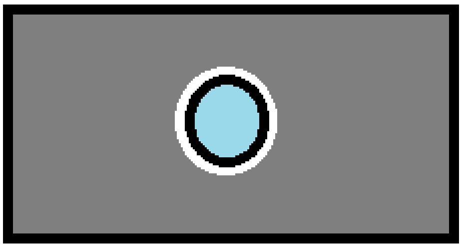
The pipework will be left under pressure while the screed is laid and should remain at six bar until the screed has fully set.

The reason for leaving the pipes under pressure while the screed cures is not only to identify potential leaks, but also to slightly expand them which simulates the expansion that occurs during system operation.

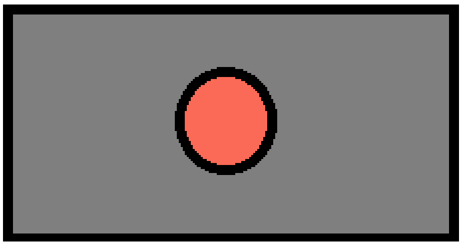
Once the pipes are depressurised, they will return to their original size which will create a tiny void around which will allow the pipes to expand freely as the warm water passes through during heating as demonstrated below;



*The pipe is pressurised to 6 bar and left under pressure until the screed cures*



*After the screed has cured, on depressurisation, the pipes will contract to their original size leaving a small void which will facilitate thermal expansion*



*Owing to the void created, when the system is running the pipe can expand into it thus preventing the screed from cracking on heating.*

## Screeded Systems Layer by Layer

### Damp-proof Membrane

Damp-proof membrane of a minimum 1200 gauge or 300$\mu$m is first laid to prevent moisture rising upwards by capillary attraction from the sub-floor.

The edges would normally be turned up around perimeters and taped along with any joints or overlaps.

### Insulation Layer

Insulation levels within building are of key importance as the better insulated the building, the more efficient and cost effective to run the heating system will be. At its simplest, the more insulation in a building, the lower its heating bills, and the colder the climate, the more important a high standard of insulation becomes.

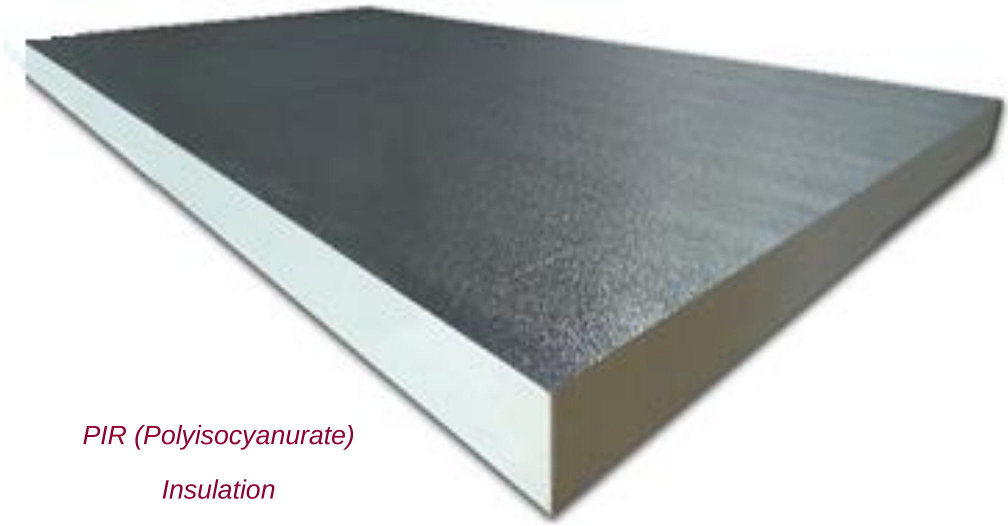
UK regulations, namely Part L1A & L1B (conservation of fuel and power) and Part E (Resistance to the passage of sound), have progressively required higher insulation standards and its simplest and most effective to achieve a high standard of insulation during building or major renovation work.

In practice, even a building insulated to well above the current legislation requirement will always need some level of heating; first because there needs to be some passage of air from the outside to maintain freshness and second, because insulation does not itself create warmth, it simply helps to retain it.

With UFH, a high proportion of the warmth is radiant, with little generation of convection currents, not only does it feel more comfortable, but there is much more warmth being used where it is needed.

Because the warmth passes into the room from the floor, it is important to prevent downward heat losses into the ground or the floor below. In a new building that meets the regulations, there will always be an adequate level of floor insulation, but if a building is being refurbished and no extra insulation is provided, this may not be the case.

There are many different insulation products available, manufactured from many different materials. PIR *(Polyisocyanurate)* is a popular choice as it is light, and easy to work with. Expanded polystyrene slabs can also be used but to provide adequate insulation values, these tend to be twice the thickness of their PIR alternative which can prove difficult in achieving the correct floor heights.



*PIR (Polyisocyanurate)*

*Insulation*

*EPS (Expanded polystyrene)*

*Insulation*

Shown below is **BS1264-4** table showing minimum accepted heat conduction resistance of insulation in various constructions. This would normally be determined at the design stage.

**Table 1 – System Insulation**

**Minimum heat conduction resistance of system-insulating layers below the pipes of heating/cooling systems (m²°K)/W**

| | heated room below or adjacent | unheated or Intermittent heated room below, adjacent or directly on the ground *) | external air temperature below or adjacent | | |
|---|---|---|---|---|---|
| | | | external design temperature<br>ϑd ≥ 0 °C | external design temperature<br>0 °C > ϑd ≥ -5 °C | external design temperature<br>-5 °C > ϑd ≥ -15 °C |
| heat conduction resistance Rλins | 0.75 | 1.25 | 1,25 | 1.50 | 2.00 |
| *) with ground water level ≥ 5m below the supporting base, the value should be increased. | | | | | |

It is good practice to keep the insulation panels as tight as possible. All joints should also be staggered and then taped.

## Vapour Barrier

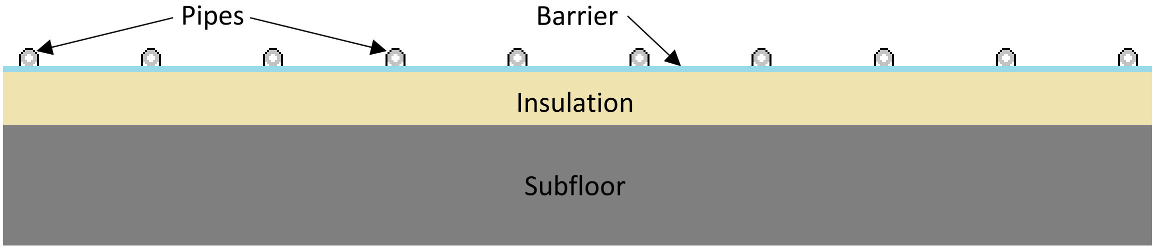
**BS EN 1264-4.1.2.3 states;**

*"Prior to laying the screed, the insulation layer shall be covered with a protective layer consisting of a polyethylene film of at least 0.15mm thickness, with a minimum of 80mm overlaps, or with another product of equivalent function."*

The moisture barrier helps prevent the insulation layer from absorbing moisture from the screed, which would reduce the efficiency of the insulation and can have a detrimental effect of fixing the floor finish.

As with liquid screeds, the barrier must be as water tight as possible to prevent contamination and damage of the insulation. Some liquid screeds (anhydrite) can react with the insulation causing 'bubbling' of the screed.

Being that pipe matrix overlays are manufactured as interlocking sheets; a barrier is not always required but check with the panel manufacturer first.



## Edge Expansion Strip

Edge expansion strip is used in all solid/screed floors and serves two purposes:

- It forms an insulation barrier around the floor slab and therefore prevents heat loss to perimeter walls
- It fills the expansion gap around the slab, allowing the floor to expand and contract

The edge expansion strip should be provided around the perimeter of the room including any internal walls. It should be placed along the walls prior to the laying of the screed. Any excess edge expansion strip above the slab can easily be trimmed once the screed has cured.

**BS EN 1264-4.1.2.2.2 states;**

*"Prior to the laying of the screed, a peripheral insulating strip (edge joint) shall be placed along the walls and other building components penetrating the screed and firmly secured to the supporting base, e.g. door frames, pillars, and risers*

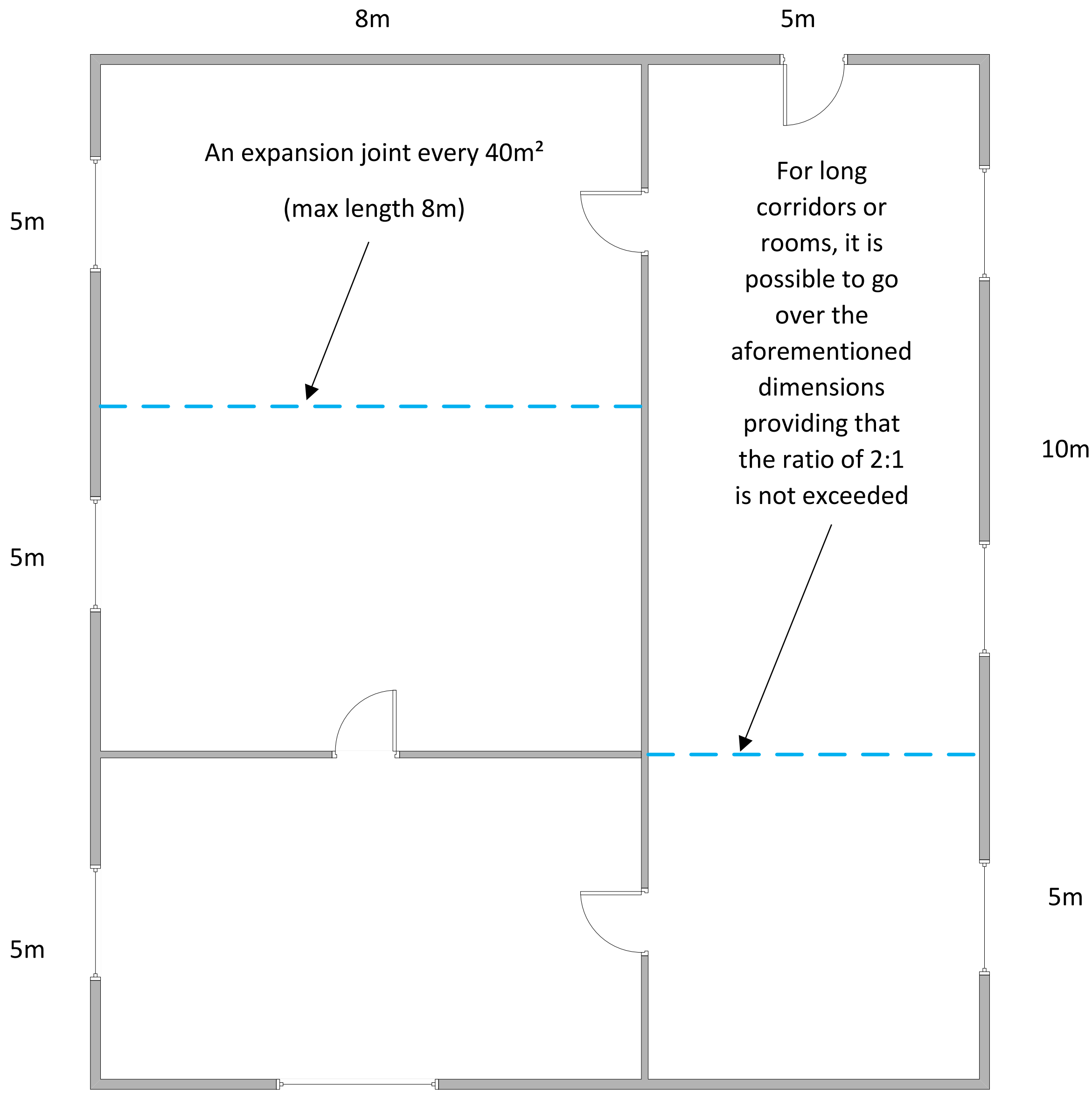
*The peripheral insulating strip shall rise from the supporting base up to the surface of the finished floor and permit a movement of the screed of at least 5mm"*

*Edge Expansion*

## Expansion

**BS1264-4.1.2.8.5 States;**

*"For heating screeds intended for the application of stone or ceramic coverings, joint areas shall not exceed 40m² with a maximum length of 8m. In the case of rectangular rooms, joint areas can exceed these dimensions but maximum to the length relation of 2:1. Any irregular areas shall have joints; the intended purpose is to have only rectangular dimensions above specified"*

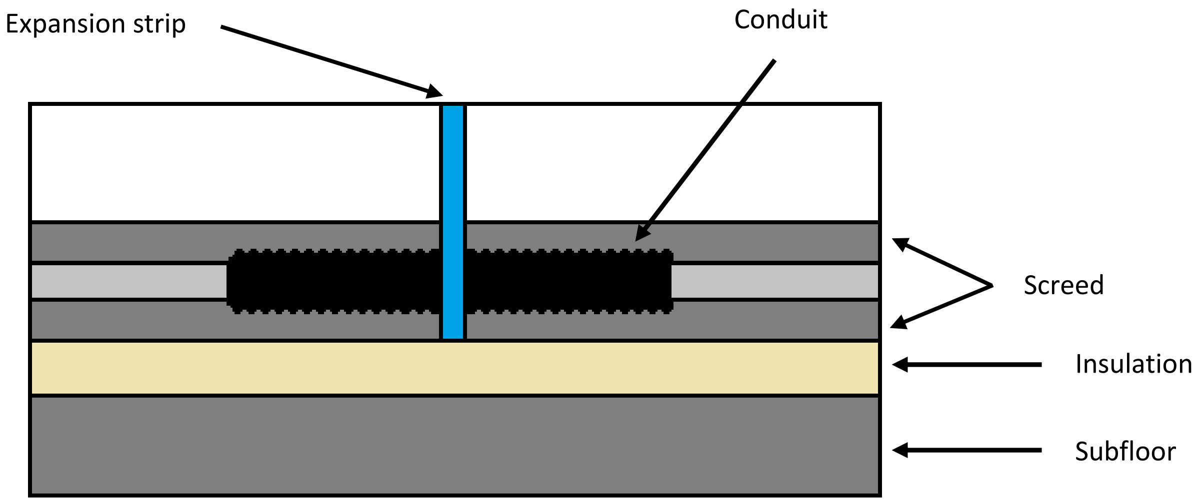



*Placing of expansion Joints*

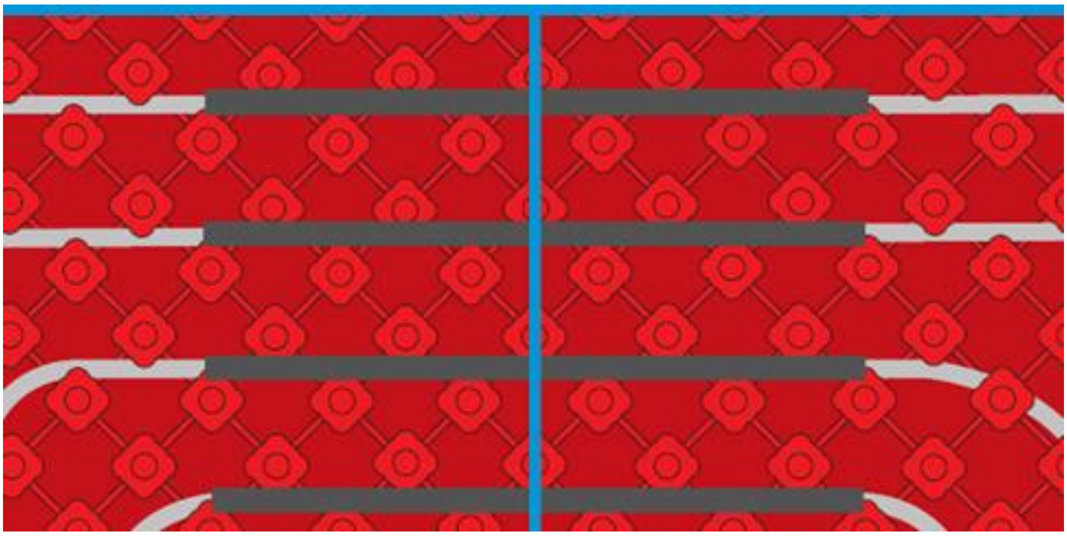
### Day Joints

On larger areas it may not be possible to complete all the screeding in the day, so a day joint must be included. The screed would be laid upto the expansion strip which is laid in the same way as an expansion joint, then work would continue the following day from the expansion strip without leaving a weak point which could open when the system is running.

The expansion or day joint is constructed by sleeving the pipe with flexible conduit then passing it through a length of expansion strip as below. The conduit is a cut as a single length to extend 400mm either side of the expansion strip.




*Day Joint*



*Example of day joint in red plate*

## Pipe Fixing Systems

There are three main types of fixing system for screeded floors.

- Staples
- Clip Rail
- Pipe Matrix Overlay

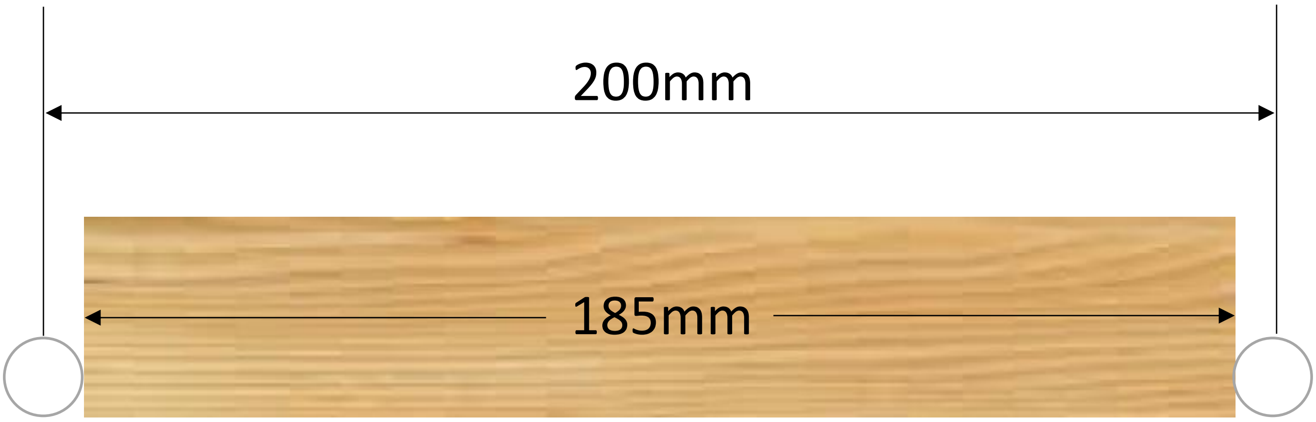
### Staples

The staple system is perhaps the most common of the above systems and has an optimum heat output of 76W/m² with pipes centred at a standard 200mm.

Once the insulation and the vapour barrier has been properly laid, then the pipe is simply stapled to the insulation in the pre-designed layout and at the correct pipe centres which would normally be 200mm.

Staple systems lend themselves very well to irregular room shapes. A more bespoke pattern can easily be achieved such as the circular layout of a converted windmill.

Pipe centres can be maintained simply by using a timber offcut as a guide placed between the pipes as below.




Staples can be fixed by hand for smaller areas, but it is more quickly done using a staple 9 is recommended that the pipes be stapled at a spacing of every 500mm.

*Fixing with staple gun*

Wherever the pipes are exposed such as connections to the manifold or where they may pass through an internal wall, mechanical protection must be in place. This is usually provided by sleeving the pipes at these points using flexible conduit cut to a length of 400mm. Specially made bend formers are also available.

## Clip Rails

Clip rails also have a 76W/m² optimum heat output at the same, standard 200mm spacings. They are plastic rails which are clipped together, and hand stapled directly on to the insulation panels. The first rail is laid at a maximum of 800mm from the perimeter to allow sufficient space for looping back and returning to the manifold as required, further rails are then spaced and clipped 1m apart ready to accommodate the pipe which clips into the preformed channels. It is good practice to staple the pipes where they return back and forth.

The rails give more uniform spacing than staples and are normally laid in a serpentine pattern although the spiral pattern is possible by positioning the rails in a cruciform layout.


*Clipping the rails to the insulation*

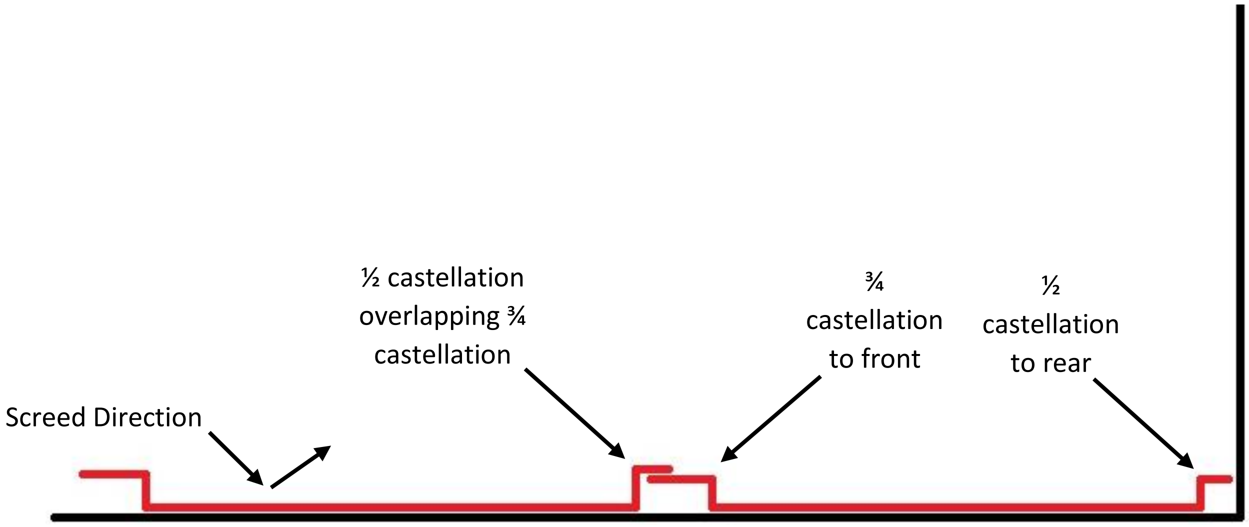
*Clipping the pipe into the rails*

### Pipe Matrix Overlays

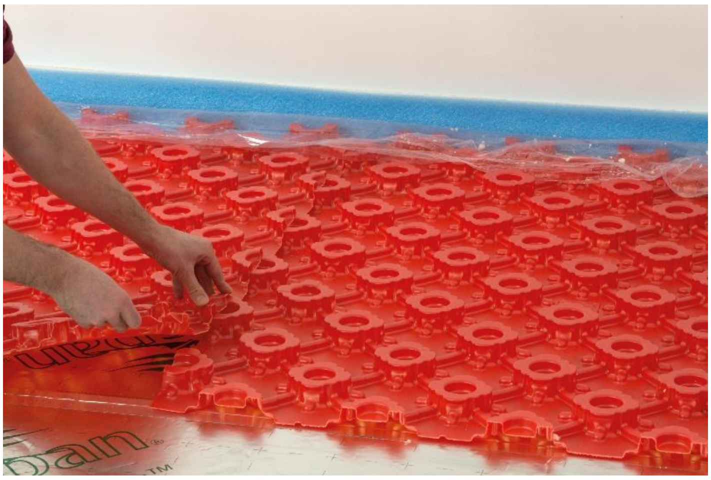
With pipe spacings possible of 100mm, an optimum heat output of upto 91W/m² can be achieved, and as a result, pipe matrix overlays tend to be the most efficient solid floor solution. They are typically made from vacuum formed polystyrene sheet and have a matrix of raised castellations which not only hold the pipe down, but also help to form the pipe layout which results in a very neat, kink-free pattern once the pipe is laid.

The castellations also reduce the required screed volume by up to 15%. The overlays or plates are laid straight on top of the insulation. Unlike staples and clip rail, pipe matrix overlays remove the need for a moisture barrier cutting installation time.

The sheets are overlapped in such a way as to prevent lifting when applying liquid screed as shown in the simplified drawing below.




*Panel layout*



*Laying the panels*

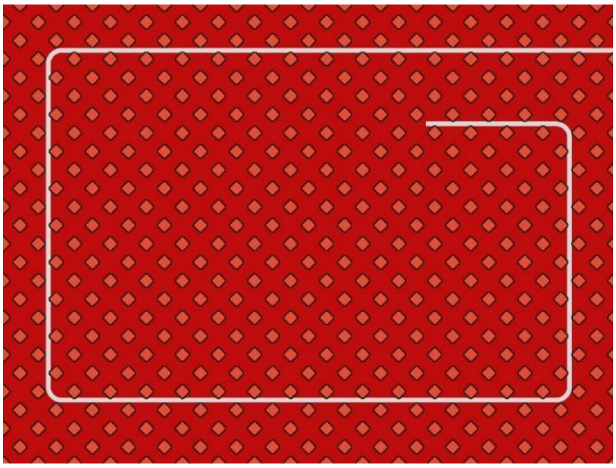
The panels may be cut using a small angle grinder. Lawn edging shears also work well, however, cutting may be reduced by overlapping the panels further. After the panels are laid, the pipe is simply 'walked' in to the pre-designed layout as shown below.

*Laying the pipe*

The plates help protect the pipe from mechanical damage. This is because the pipe is held flush with the top of the castellations as below.

*Pipework in situ.*

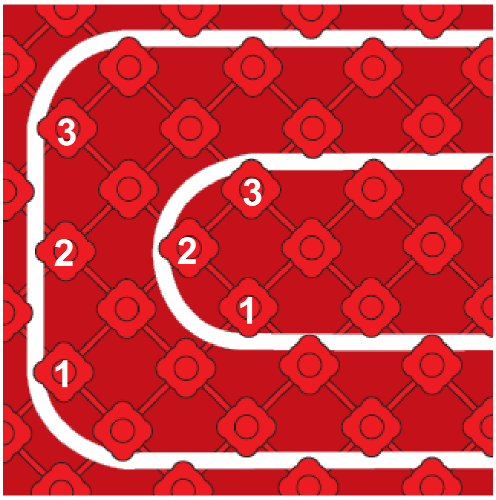
The flow is normally laid around the perimeter first, because the hotter pipe will help compensate for potentially higher heat loss on perimeter walls. When laying the pipe, loop in to the centre leaving sufficient space to allow a path back to the manifold. When looping in, double the final pipe spacing so to achieve 200mm centres, loop in at 400mm as demonstrated below.



The castellations hold the pipe well and incorporate a safe method of bending the pipe without kinking. This is done by adhering to the following bend radius details as below.

A 90° bend should be passed around no less than two of the panel castellations and a 180° bend around a minimum of three as shown below.


*90° Bend*




*180° Bend*

Failure to follow these guidelines can result in damage being caused to the pipe and any damaged pipe must be replaced.

When fitting the pipe, especially at the corners, there is a potential for the panels to lift slightly which, if liquid screed is applied, the screed may be able to get underneath the panels causing them to lift and possibly float so it is good, common practice to either weigh down the panels especially at the edges before the screed is laid, or to staple the sheet down to the insulation where necessary. In any case, if the panels are overlapped in the correct manner as previously shown, then lifting of the panels will be much less likely.

*Pipe matrix overlay*

## Timber/intermediate floor systems

Timber or intermediate floors (sometimes known as suspended) are generally of a joisted construction and are commonly found as upper floors in domestic buildings.

The underfloor heating system is normally installed between the joists but before the floorboards are laid.

The suspended system relies upon two crucial factors to be able to work at its best which are;

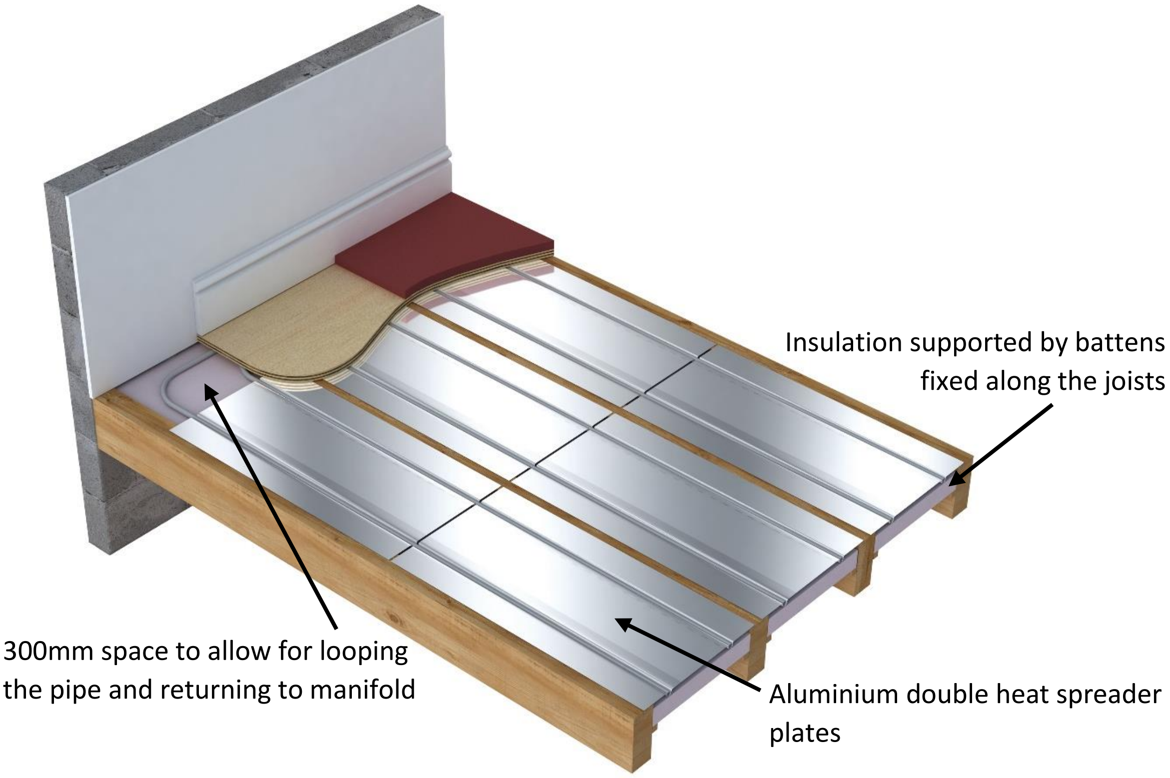
- Effective insulation to prevent downward heat loss
- Good contact between the plates and underside of the floor to ensure an efficient spread of heat

There are numerous solutions available that will serve suspended systems very well. However, the characteristics of each one must be understood as different projects will require a certain floor system for ease of installation and to give the best output.

The various solutions are outlined below;

- Spreader plates fitted from above (FFA)
- Spreader plates fitted from below (FFB)
- Low profile between joists
- Modular heating panel
- Biscuit mix or 'pug screed'

### Spreader plates (FFA)




*Suspended Double Heat Spreader Plates.*

Fit from above double heat spreader plates are the most common suspended solution. The plates are made from sheet aluminium and are fixed between the joists and the pipe 'clips' into them.

Insulation is fitted from above between the joists and must comply with the following regulations/standards.

- Parts E and L of building regulations for England, Wales and R.O.I.
- Scottish building standards sections 5 and 6
- Northern Ireland technical booklets F1 and G

To satisfy the above regulations, mineral (wool) or board based (P.I.R.) insulation is acceptable but consideration must be given to any electrical cables between the joists as covering them with insulation will reduce the current carrying capacity of the cables so expert advice should be sought.

Once adequate insulation has been fitted, the spreader plates are fixed to the joists ensuring a gap of 10mm all around to avoid the plates colliding and distorting as well as preventing noise on warming up as they expand. A gap of 300mm is left at either end of the room to allow for looping back and ease of connection at the manifold.

Should the plates require cutting, some are pre-scored and can be simply snapped across. Others may be scored using a sharp knife then snapped across with the pipe grooves uppermost which are cut using a hacksaw. Care must be taken when cutting and handling the plates especially when cut as there will be sharp edges.

If there is a falling risk, relevant PPE such as a harness will have to be worn which can restrict the installers movement. Other trades will need to be informed that the plates are not structural and so if entry to the room/zone is unavoidable, to be careful when in the vicinity. In key areas, temporary boards may be fixed to protect the plates.

This system has a comparatively lower optimum heat output of 52 Wm² and to achieve this, requires a higher blending valve temperature of 60°C. Many heatpumps with a maximum output temperature of 50 to 55°C, would struggle to achieve this and so heat source compatibility must be ascertained at the onset. FFA spreader plates are not suitable for engineered beams as the joists need to be notched at the ends where returning and looping back.

## Spreader Plates (FFB)

If the floor deck is already down, then one option is to install fit from below spreader plates. Timing is of the essence with FFB as it is important where possible to fit the system before any other services are installed. If services are already installed, then it can make access difficult.

Fit from below spreader plates are fitted to the underside of the floor and are screwed or tacked to the underside of the floor as seen above.

Once the panels are fixed, 15mm pipe is cabled through the web of the joists then carefully pulled back and clipped into the panels. Care must be taken so as not to damage the pipe when feeding through so help is essential. Once all circuits have been fitted and connected then the system will be filled, bled, then charged to a pressure of 6 bar for one hour.

FFB spreader plate systems have the same flow temperature and output as FFA spreader plates and so may not be suitable for many heat pumps.

Once the pressure test is satisfied, the insulation will be fixed as tightly as possible up to the panels and pipework.

### Low profile between joists

Many UFH manufacturers produce low profile panels intended for retro-fitting. It has been discovered that this system can also be easily adapted to work very well as a suspended floor solution as shown in the image below.

Battens are fitted along the joists and a plinth of 18mm MDF or plywood to finish 22mm below the top of the joists. The full panel can then be measured and cut to the exact size to fit between the joists which is a benefit when in some properties especially older buildings, joist centres are rarely uniform.

*Low Profile Between the Joists*

Another benefit of this system is that it will emit up to 65Wm² from a blending valve temperature of 50°C which means that it is compatible with heat pumps.

*(as previously noted, confirm heat source compatibility at the beginning of every project.)*

### Modular Heating Panel

A unique product exists which is known as the modular heating panel. The panel is constructed from moulded expanded polystyrene factory fitted with 10mm pipe and covered with a reflective aluminium foil to spread the heat.

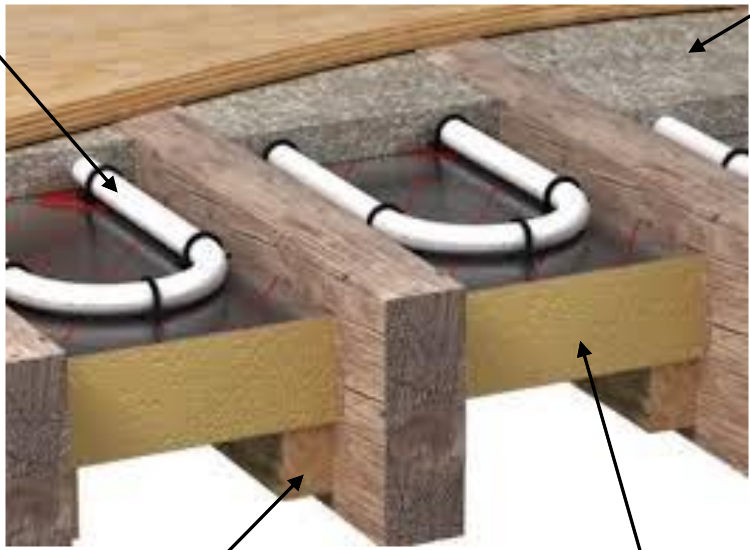

Sometime ago, there wasn't a suitable UFH product that could produce enough heat within suspended applications fired by heatpumps.

A product known as the modular heating panel was developed to overcome this. The panels are an 'all in one' solution where all components of the panels are factory assembled. They have a high output of 76W/m² at 50`C.

The panels can either be fitted from above or below. Fitting from above requires the joists being battened and plinthed prior to laying the plates. When fitting from below they are simply fixed to the underside of the floor using 40mm wood screws with washers taking care to avoid the puncturing the integral pipes.

One benefit of the MHP system is that there are no long pipes to feed through the joists thus reducing pipe damage as the panels are linked using standard push-fit fittings. As the panels are connected together, the system is pressure tested to 18 bar to ensure that all joints are properly made and are water-tight. It is recommended that no more than three panels be linked together before returning to the manifold.

## Biscuit mix screed




Biscuit mix screed although not so commonly found, is a highly efficient system producing upto 100W/m² and as a result works well with heatpumps.

When laid at a thickness of 20mm, a square metre of biscuit mix screed will weigh around 20 kilos, so the use of this system is subject to the joists having sufficient structural strength. It makes perfect sense to consult a structural engineer at the design stage to ensure compliance with building regulations part A.

The joists are battened along to a depth of around 70-75mm. This will accommodate an insulation thickness of 50mm leaving a depth of 20-25mm for the screed to be laid once the pipes have been fixed.

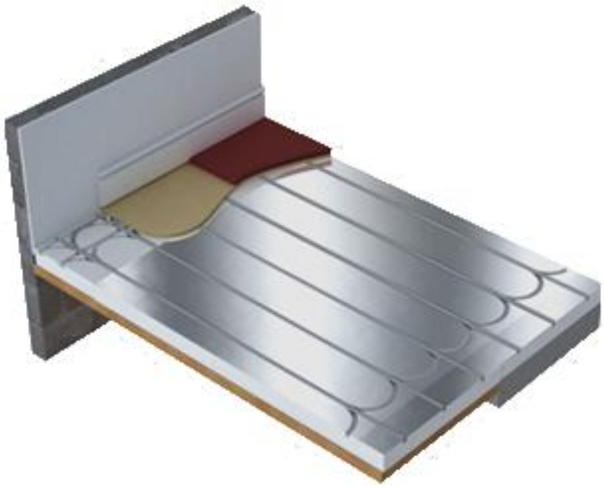
The screed is a mix of sand and cement same as normal screed but at a different ratio of 8 to 10 parts sand to 1 cement. It is recommended to lay a moisture barrier on top to prevent any moisture penetrating the floor boards fixed above.

Another solution for suspended applications is reflective foil which is similar to 'bubble wrap'. It consists of a layer of bubbled film with aluminium bonded to it which is then coated with polyethylene for protection. It is laid over the joists and fixed with special clips which also hold the pipes.

## Floating Floor

The floating floor system consists of high density polystyrene panels usually 50mm thick and emit up to 65W/m². They are pre-grooved to accept aluminium spreader plates. These plates spread the heat from the pipes up through the floor above and up in to the room. Some panels have factory fixed aluminium foil which speeds up the installation process. The thickness of the panels provide insulation, reducing downward heat loss.

*Floating floor with spreader plates*



*Floating floor with aluminium foil*

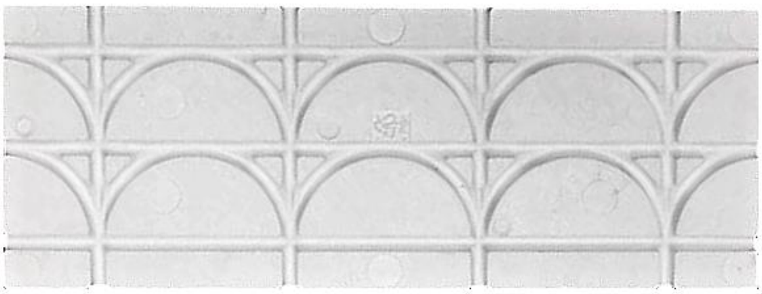
Floating floors are generally used where there are structural weight limitations or moisture issues and screed would not be suitable. They can be retro fitted onto existing solid or timber floors however, there will be a considerable increase in finished floor height.

A benefit of the floating floor system is that due to the 50mm thickness, the panels will offer some sound proofing when laid on upper floors.

The panels have end returns which allow the pipes to loop back and return to the manifold. The end return panels are also made from polystyrene.

The single heat spreader plates are cut to size in the normal way, laid into the panels and the pipes are then fixed into them.

The pre-foiled panels are simply laid, with the joints staggered and taped, and the pipe pressed into the grooves. Both types of panel are easily cut using a hand saw.



*End return panel*

## Low Profile Overlays

There is a misconception that UFH cannot easily be fitted retrospectively, and up until a few years ago this was most certainly the case. Most UFH manufacturers now produce a low-profile system that can be laid directly on top of existing timber or concrete floors.

The thicknesses of low-profile overlays can range anywhere between 15 and 25mm thick. They can be split into two categories – lightweight and heavyweight.

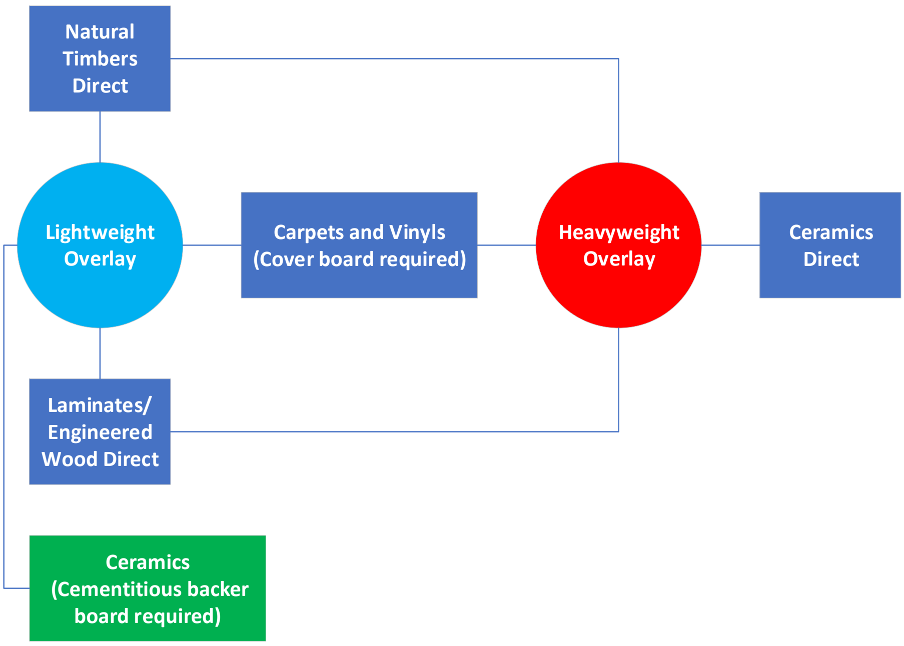
Both types use end returns and can produce up to 79W/m².

The lightweight panels are laid in as much the same way as floating floor, but the heavyweight panels are butt-jointed using polyurethane glue and cut using a power saw or jigsaw.

*Lightweight overlay*

*Heavyweight overlay*

The lightweight panels are made from high density expanded polystyrene and the heavyweight from a gypsum-based compound and each are chosen dependent upon the application and final floor covering as demonstrated below.




*Choosing low profile systems*

Owing to the premise that the system is low profile, thinner pipe is normally used with some using pipe at a diameter as low as 10 or 12mm. A result of this is, individual circuit lengths tend to be shorter with for example, 12mm pipe having a maximum circuit length of 80m. This can be an issue on larger areas as more circuits would have to be managed, so deeper panels are available e.g. with 15mm pipe allowing a maximum circuit length of 100m.

Being that these systems will raise the floor level slightly, extra care must be taken on retro installing where hollow doors are fitted. On many internal doors, the top and bottom rails may be thinner than the increase in floor height so when trimming the door to fit, the integrity of the door can be compromised.

*Heavyweight Overlay Installation*

*Lightweight Overlay Installation*

## Floor coverings and UFH

In modern homes especially, there is a myriad of floor coverings available and it must be understood that not all coverings are suitable, and that some work better or differently to others. This is not to say that most covering materials will work well with UFH, but in all cases suitability must be ascertained prior to commencing any installation project

Of all the commercially available floor products, the most common are...

- Carpets
- Vinyls (tile or sheet)
- Ceramics
- Wooden (laminates, engineered. or natural timber)

### Carpets

Carpets are insulators and so to be suitable for underfloor heating, they must have as low a thermal resistance as possible. This means that the heat should pass through the floor as effectively as possible. A maximum combined tog rating of 2.5 tog is usually specified with a 1 tog limit on the special UFH underlay.

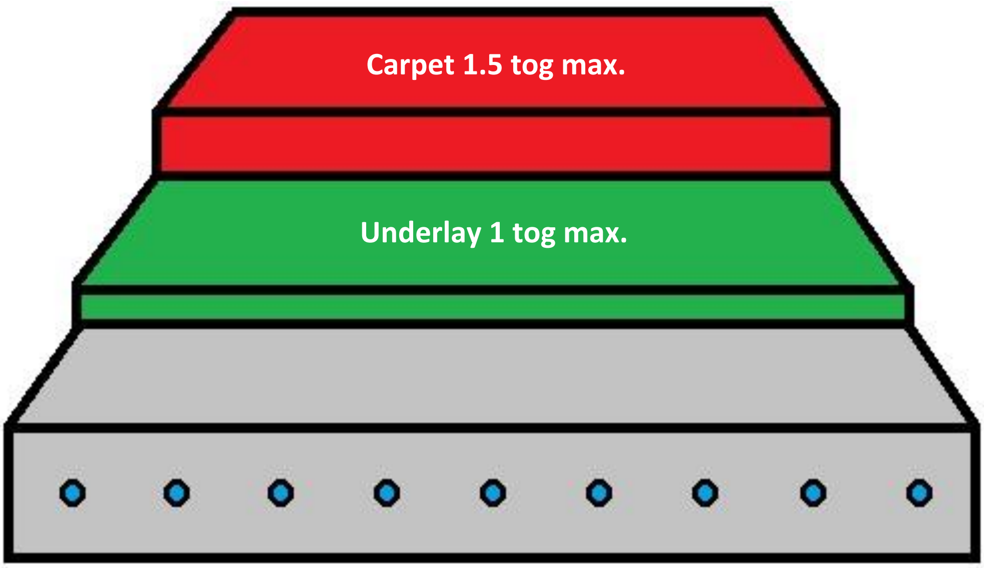
**B.S. 1264 4.1.5 Floor coverings states;**

*Thermal Resistance of Floor Coverings is to be taken into consideration regarding heat transfer calculations and should be verified on installation.*

*Prior to lying of the floor covering, the floor covering installer shall verify the suitability for lying the floor covering on the screed.*

*The floor coverings are stored and installed according to the relevant standards and the manufacturer's instructions.*

As a rule, 80% wool 20% nylon carpets have a tog rating of between 1.0 and 2.0 which means a combined tog rating of 2.0 to 3.0. Many flooring suppliers have dedicated areas for UFH and most already have great knowledge of UFH so at the design stage, the supplier should be consulted first so a suitable carpet can be chosen.



### Vinyls

When selecting vinyl floor coverings, the design floor temperature requires special consideration. Certain vinyls when exposed to too high a temperature, can become damaged. This is because the adhesive can melt, and the vinyl soften to such a degree that they weaken becoming more susceptible to damage.

It has been known that some LVT (luxury vinyl tile) products can fade directly above the UFH pipes due to too high a temperature. For this reason, most manufacturers specify a maximum contact temperature of 27°C which is controlled with floor probes.

For a vinyl floor product and adhesive to be suitable for UFH, they must both be able to withstand a contact temperature of 40°C. This may seem high but means that if the materials have been tested to this higher temperature, then under normal operating conditions, the strength and durability of the covering will not be compromised. It is required that a 10mm layer of marine ply be fixed below the vinyl on some systems which will also provide some mechanical protection. Owing to the typically high heat losses in conservatories, the laying of vinyls is not recommended.

*Sheet Vinyl*

*Installation of luxury vinyl tile (LVT)*

## Ceramics

Ceramic floor coverings exist across a wide range of applications and all have their own features and benefits and due to individual characteristics, certain types should be avoided. Epoxy compound tiles can be prone to warping when exposed to warm temperatures.

Most ceramics however are suitable but should be affixed using a UFH compatible flexible adhesive and any debris or laitance should be cleared first.

Ceramic tiles have high thermal conductivity so work well with UFH and are fixed using flexible tile adhesive. While this allows some movement of the tiled floor, it will not eliminate the risk of cracking from the screed below so a decoupling membrane such as Schluter Ditra or Dunlop Procover should be fitted.


*Schluter Ditra Mat Decoupling Membrane*

Stone flags work well with underfloor heating but consideration must be given to the slower response times on cooling and heating, Ceramics may also be laid on floating and low-profile overlay solutions providing that a support layer be fitted such as James Hardie backer board which not only adds strength, but also has excellent thermal transmission qualities.

*James Hardie Backer Board*

Marble has good thermal conductivity although is slightly slower than tiles to warm up. Marble does have an attractive finish.

*Marble tiles*

Slate is highly conductive and works well with underfloor heating. It is also a hard-wearing floor finish making it ideal for areas of high foot-traffic.

*Slate tiles*

### Wooden floors

Wooden floors – both natural and man-made provide a rustic appearance and work very well with UFH. Natural wood planks will expand at different rates and in different directions, but this adds to the rusticity of the floor finish enhanced by small gaps that will open and close with the changes in atmosphere.

*Natural timber floor*

Laminate flooring is a good partner for UFH. Being man-made, it is very stable indeed and less likely to move with temperature changes. It has a highly waterproof hard-wearing finish with the appearance of natural wood, ceramic tile or natural stone. The panels can easily be laid in all domestic areas.

*Laminate floor*

A cost-effective alternative to natural timber with the stability of a laminate is engineered wood flooring. This product is made up of two layers consisting of a birch plywood base and a thick veneer of hardwood on top.

*Engineered timber floor*

# Module 2

## Phase Test Questions

1. What are the four main types of floor construction which apply to UFH systems?

2. Which British standard applies to underfloor heating?

3. What is the recommended depth for ordinary dry mix screed?

4. What is the purpose of a vapour barrier?

5. List the three main pipe fixing methods for screeded floors.

6. What would be the best course of action should the pipe be kinked while fitting.

7. List five suspended floor applications.

8. List two suspended solutions for heatpumps.

9. State three applications for floating floor.

10. Name the most suitable retro-fit system.

11. What is the maximum permissible tog rating of carpets.

12. For a vinyl floor covering to be compatible with UFH what is the maximum temperature that it must withstand?

# Module 3

# UFH Systems.

# Module 3

## UFH Systems

Underfloor heating system types fall into three main categories in terms of area covered and how they are controlled. The types are;

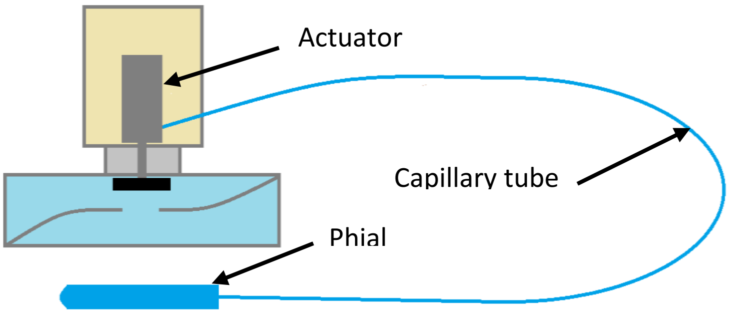
- Single or one zone systems
- Extension systems
- Full house systems

### Single/one zone system

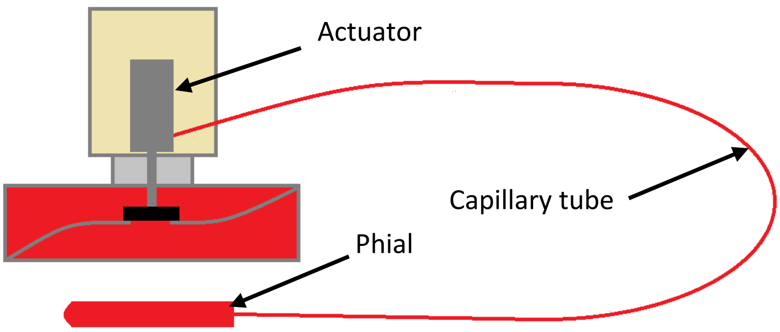
This system is usually installed in smaller areas up to 5m² in such as conservatories, bathrooms or single room applications. The system is generally an adaptation of an existing heating system. While the system usually works in unison with the existing system it can be zoned to run independently.

Owing to the differences between radiators and UFH, the temperature of the underfloor heating system must be set and maintained at a lower temperature. This is done using a temperature limiting valve (TLV).

The TLV has a phial containing an alcohol or spirit-based liquid which when warmed expands up a capillary tube to an actuator adjusting the valve down, thus reducing or stopping the flow to the floor circuit which allows the water within to cool.




*Temperature limiting valve open calling for heat*




*Temperature limiting valve closed temperature satisfied*

The valve body is connected to the supply or flow to the circuit. The phial is also clamped to the flow and the pipe must be metallic for quick response. If the flow and return are plastic, then a section of approximately 200mm must be removed and replaced with metallic pipe.

These smaller systems are often sold as a single room pack with all components required to complete the project.

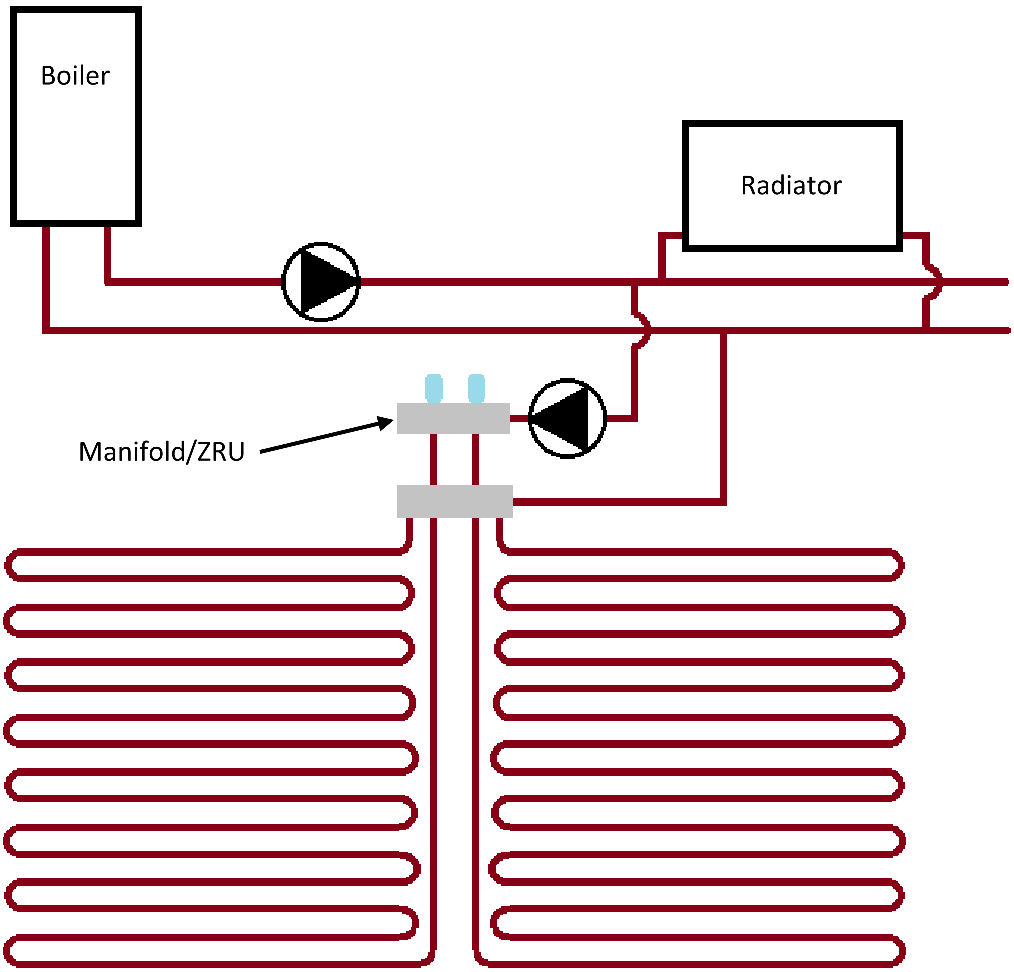
Slightly larger systems are the *ground floor only* and the *extension systems* which cover up to 30m²

### Ground floor only

This is a very popular choice of system layout with UFH installed downstairs with radiators upstairs. The UFH normally has individually controlled zones and runs independently to the radiator circuit.

### Extension system

For such as a house extension or a small multi-zone project, an extension system would be utilised. Same as the ground floor only system, the extension system consists of multiple circuits with independently controlled zones and is usually an add on to an existing system.




*Extension system*

Each separate circuit can either be controlled through a manifold as above or by the use of a ZRU or zonal regulation unit.

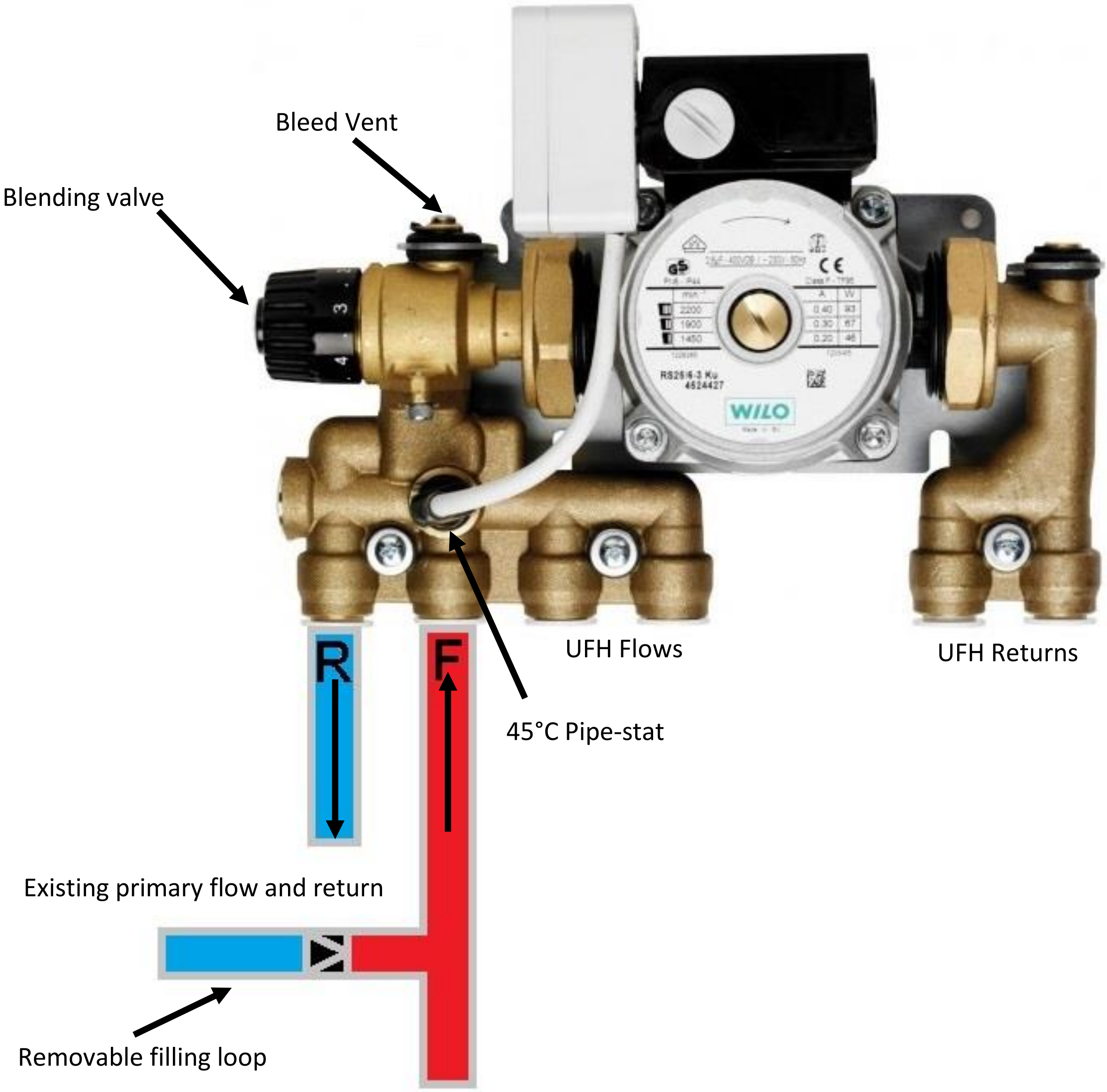
### Manifold

The manifold has two bars or headers, one flow and one return. On the flow header are flow regulators which indicate flow rates, and on the return header are balancing valves to allow adjustment to optimise flow, and in turn heat output.

Usually fitted on to the balancing valves are electro-thermic actuators which open and close the individual circuits depending upon heat demand. Connected to the manifold is also a pump pack with thermostatic blending valve and isolators.

### ZRU/Zonal regulation unit

This device is a single casting with integral blending valve and pump. The ZRU can be single or multi-port covering around 10m² per port up to 30m². The ZRU is designed to simplify adaption of an existing radiator system and can be zoned to allow independent running but in its simplest form is simply connected to flow and return and a 230V supply.



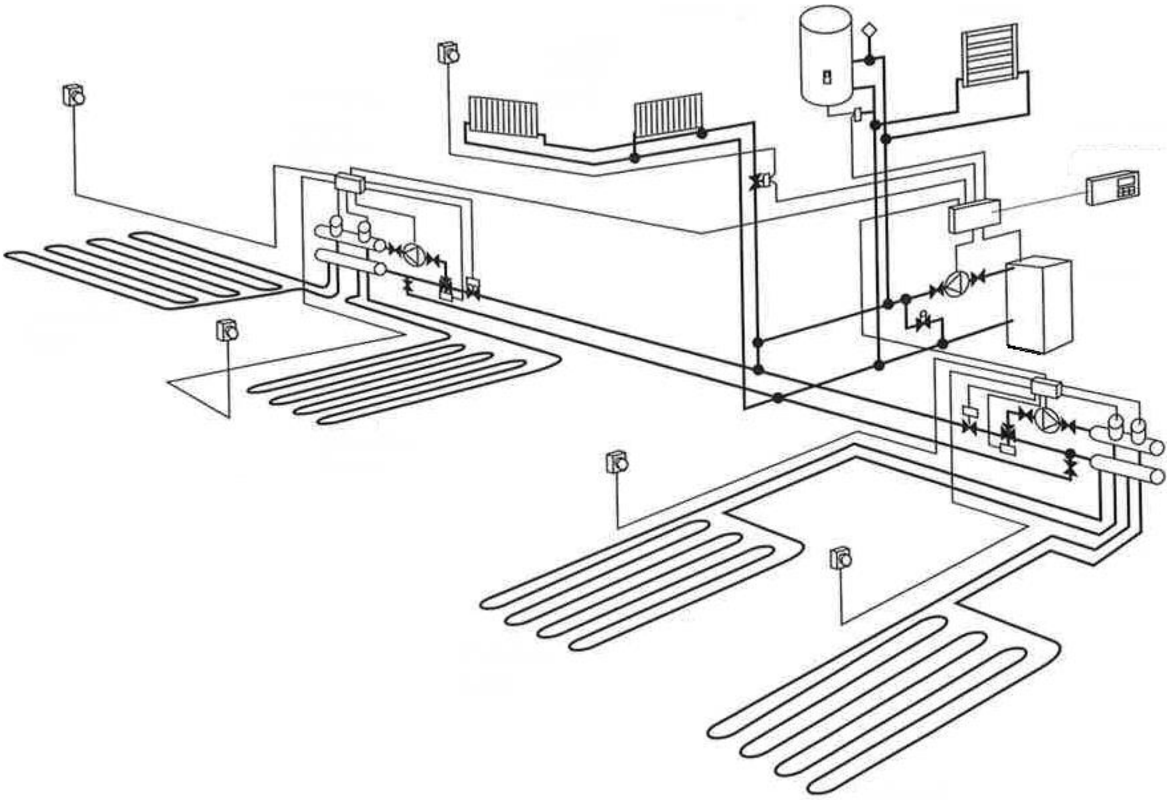

*Zonal Regulation Unit*

The zonal regulation unit works in the following way;

Water from the heating system is circulated into the flow, past the pipe stat and straight out of the return and back to the boiler.

As the water temperature rises and reaches 45°C, the pipe stat will switch on the pump allowing the water to circulate through the underfloor heating circuits via the thermostatic blending valve.

## Full house system



The term 'full house' system may imply that the whole house is heated by UFH but in fact it means that every individual zone can have time and temperature set independent of the others giving total control, and part L compliance. For example, if a spare room is not in use then the room can be isolated from the rest of the system, or if only one area of the house is occupied then all other zones may be isolated.

It is also normal for a towel rail heater to be fitted in bathrooms with UFH due to the shortfall in floor area. Each level of the building heated by UFH, will have at least one manifold and wiring centre.

## Pipe Layouts

It cannot be stressed enough that the pipework layout is a critical element of the system. If the pipework layout is incorrect, then the system will not work efficiently if at all and if the floor is then screeded, rectification can prove costly in terms of money and reputation.

Even if the design is carried out by the manufacturer, the design engineer will rely upon accurate information being given and the estimate or design can only match the standard of data provided so in simple terms, *'the more the better'* it also ensures a quicker estimate or design turnaround.

Considering that no two projects are the same, it is important that the appropriate configuration be chosen due to the many influencing factors which are;

- Heated surface area (circuit lengths and quantities)
- Heat requirement
- Distance of collection lengths
- Uneven heat requirements (peripheral areas)
- Insulation levels
- Heat source

In a normal modern well insulated dwelling fired by a gas boiler, it is normal for 15mm pipe to be laid at 200mm centres (subject to the particular UFH floor product) with a maximum circuit length of 100m.

In buildings with poor insulation, excessive heat loss, heavily glazed or buildings heated by heat pumps, the pipe spacings may have to be brought closer together which can rule out the use of some systems such as floating floor with which the spacings are pre-set during manufacture of the panels.

If the system is fired by a gas boiler and the homeowner is considering a heat pump, then it may be a good idea to reduce the pipe spacings which will future proof the UFH system.

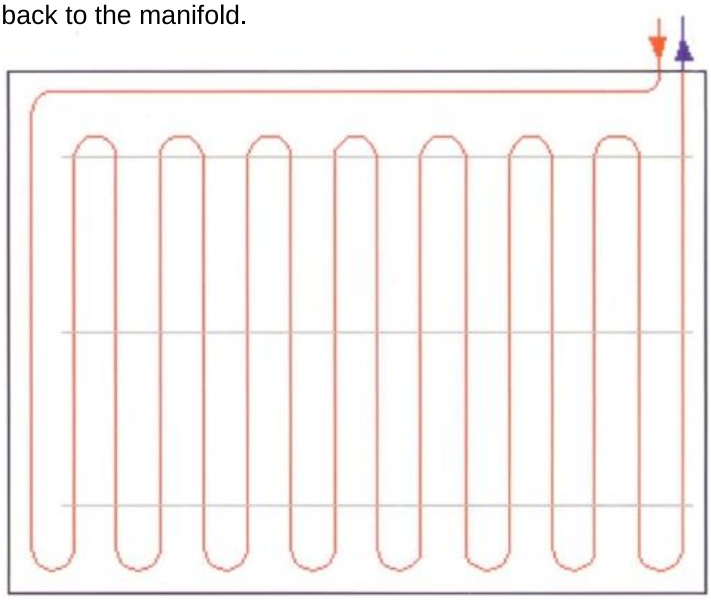
### Pipe Configurations

There are two main configurations which are;

- Series, meander or serpentine pattern
- Spiral, snail, or bifilar pattern

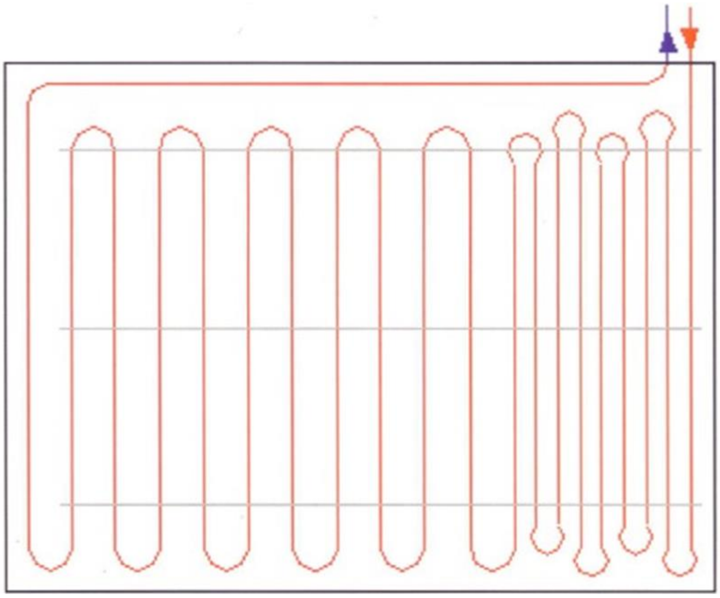
### Series Pattern

The series pattern is the most simple layout. To help compensate for potential heat losses through external walls, the flow from the manifold is usually taken around the perimeter to the furthest point away before looping back to the manifold.



*Series pattern (standard)*

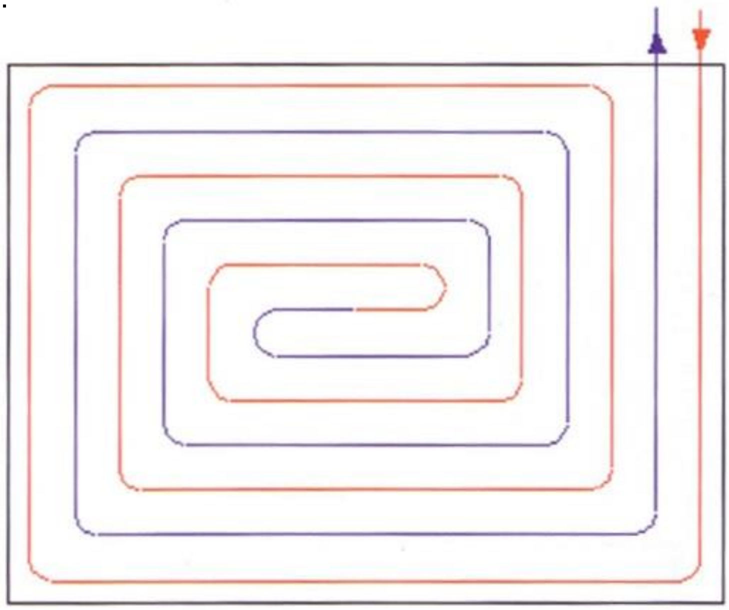
In areas of excessive heat losses such as patio doors, if the floor product will allow then the pipes can be fixed closer together to compensate as below. However, while the air temperature will be stable it can increase the floor temperature which may create issues with some coverings.



*Series pattern (modified)*

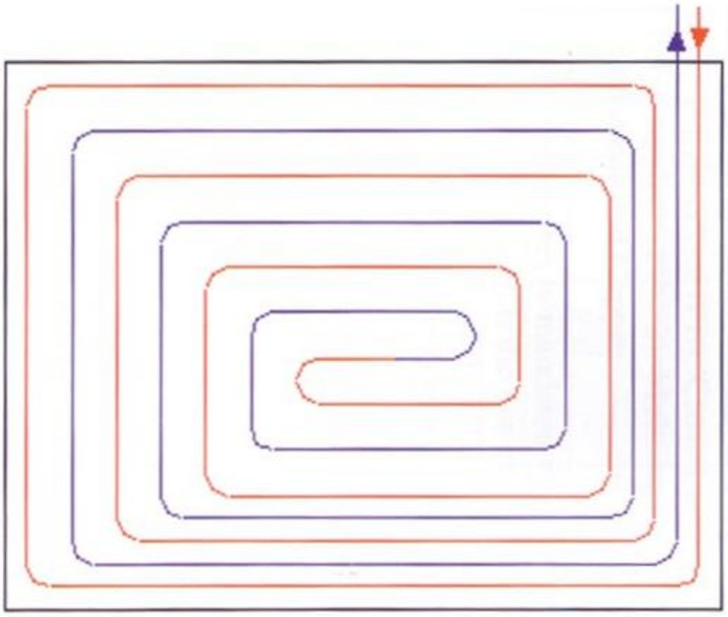
## Spiral Pattern

The spiral pattern is the most efficient and would normally be chosen where the UFH floor product will allow. This is because the flows and returns are alternate which results in a more even heat spread and faster response.



*Spiral pattern (standard)*

The spiral pattern can also be laid in a modified layout as below.



*Spiral pattern (modified)*

# Module 3

## Phase Test Questions

1. List the three main classifications of UFH system and the surface areas they normally serve.

2. How is the water temperature normally controlled in a single zone system?

3. Name two methods of controlling an extension system.

4. How would the UFH system be supported in a bathroom with little floor area?

5. List 4 factors which affect the layout of a UFH system.

6. List the two main pipe configurations.

# Module 4

# UFH System Components.

# Module 4

## UFH System Components

### Manifolds

The manifold consists of two headers, one for flow and one for return.

It is simply a distribution device which on instruction from the time clocks and thermostats, actuators on the manifold open specific ports allowing warm water to and through the emitter circuits via a common flow and return from the heat source.

The main benefit of the manifold is that each of the ports allow individual control of each zone meaning unused zones can be turned down saving energy.

Manifolds generally range from single port upto 12 with the option of adding a maximum of two more ports using extension kits.

Also available are sectional manifolds which are assembled by the installer port by port. The sectional manifold is good for the merchant in that the components are stocked rather than many different sizes of manifold. However, the increased number of joints although perfectly reliable when correctly made, can be a concern with some installers.

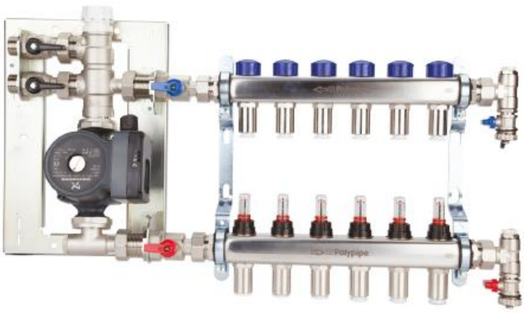
Depending on the manufacturer, flow and return headers can either be top or bottom mounted.

There is a premium quality manifold available which has a first-fix bracket which supports the weight of the pump and the blending valve. It also allows pressure testing of both the input and output sides of the manifold without fitting the pump pack. This can protect against premature start-up of the system before screeds have cured.

### Modern Manifolds

Todays manifolds are usually coupled to a pump and blending valve and are manufactured from brass, stainless steel or plastic composite as below.

*Brass*



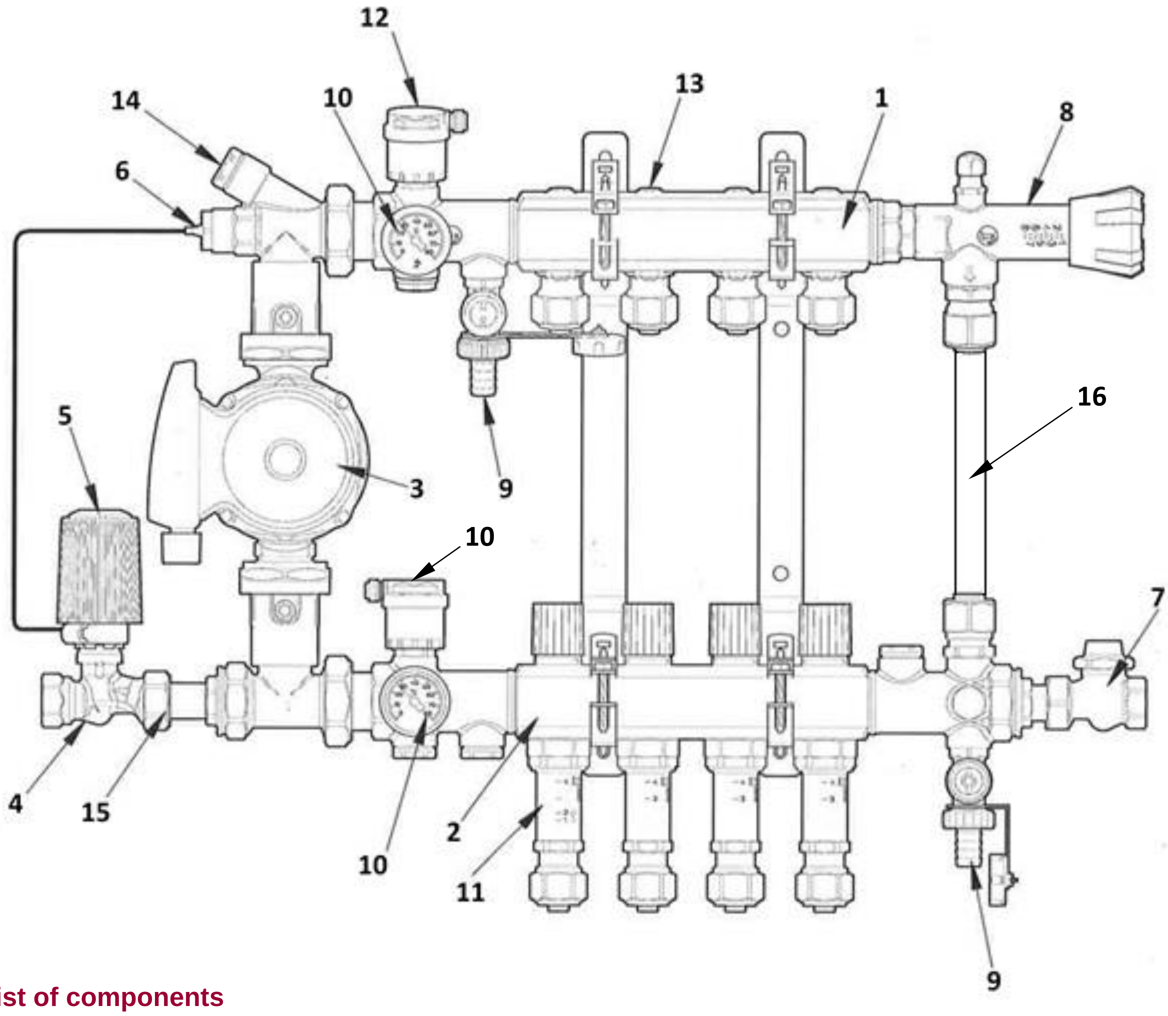
*Stainless steel*

*Plastic composite*

If the maximum output of the heat source (e.g. heat pump) cannot not exceed the heat requirements of the UFH system, then a blending valve may not be necessary but check with both manufacturers of the heat source and UFH system first.

There are subtle differences between manifolds, although most work in the same way. While normally, temperature is controlled by a thermostatic mixing valve, there are some older manifolds still fitted which employ an injector valve to govern the supply temperature as shown below;

### Injector Valve Manifold




### List of components

| | |
|---|---|
| 1 Flow header | 9 Drain cock |
| 2 Return header | 10 Temperature gauges |
| 3 Pump | 11 Flow meters |
| 4 Injector valve | 12 Automatic air vent |
| 5 Thermostatic head | 13 Balancing valve |
| 6 Sensor probe | 14 Sensor pocket |
| 7 Lockshield valve | 15 Extension piece |
| 8 Differential valve | 16 Bypass |

The most differing feature of this manifold is the inlet temperature control. The manifold utilises an injector valve (4) which works in the same way as the temperature limiting valve seen earlier.

The working principles of the manifold can be seen explained over the page.

When the system is in operation, water enters the injector valve (4), and is drawn up by the pump (3) where the water passes over the temperature probe (6). The water is then pumped into the flow header (1) and out to the floor circuits via the regulating valves (13). It enters back through the flow meters (11), returning to the boiler through the lock shield valve (7). The manifold has a bypass between flow and return with a differential valve fitted (8).

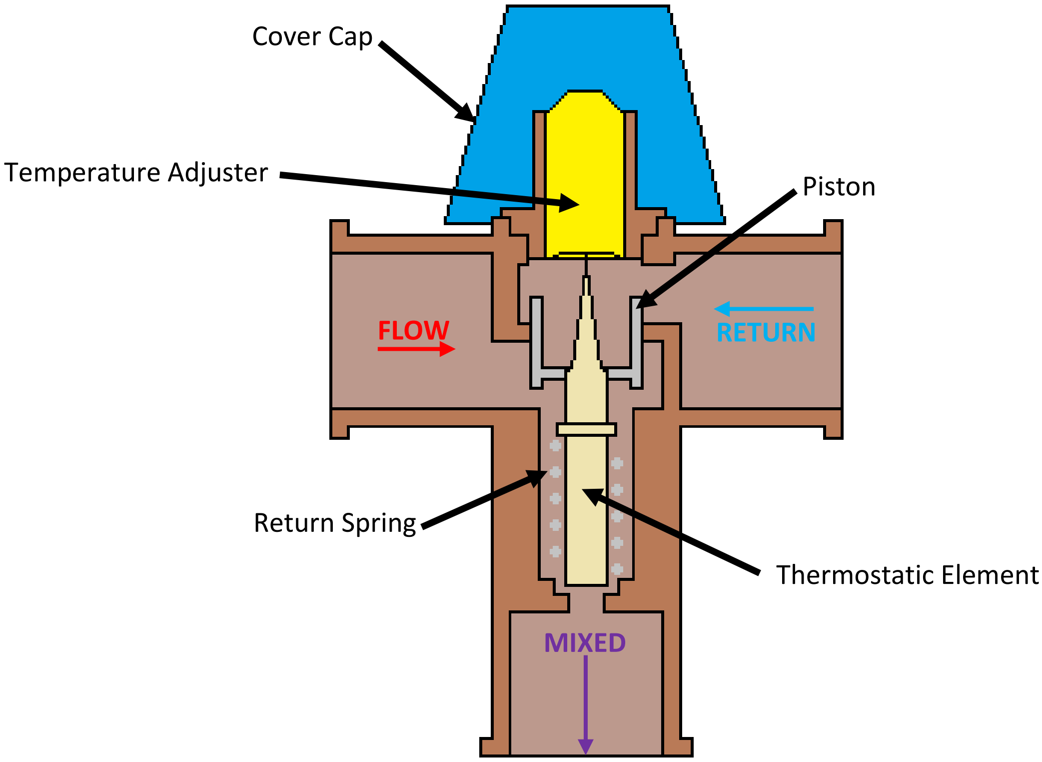
This type of manifold will give years of good service, but there is a potential risk of the sensor liquid leaking out and if this happens, the injector valve will open allowing water of around 80°C to enter the floor loops. It is rarely produced today, because of preference to the more modern blending valve manifold.

A concern with the injector valve manifold is that should the capillary tube or temperature probe become damaged and the thermal liquid leak out, the valve would automatically open fully allowing water at 70-80°C to enter any open floor circuits.

### Blending Valve

The blending valve works exactly like a TMV for domestic hot water. It has inside a thermostatic element which reacts to water temperature and moves a piston up or down maintaining the set point temperature.

In this case, if the valve is set to 50°C, then the temperature will be maintained by varying the ratio of hot (flow) and cold (return) water. If the temperature tries to increase above this set point, the element will expand allowing more cold and less hot water through thus lowering the temperature of the mixed water. When the temperature falls, the element will contract permitting more hot water and less cold water to reach the set temperature. As a safety feature, if the cold water supply fails then the temperature will carry on increasing and the element will expand into the fully closed position.




So, it can be seen that with the in-built overheat protection, blending valves are favoured over injector valves for UFH water temperature control.

Inside most blending valves there is a gauze strainer which can block especially in mixed systems causing the temperature or flow rates to drop so this can be removed for cleaning. Most valves can be set to the specified temperature and locked. Further adjustment is rarely necessary once set.

*Blending valves*

### Automatic flow control (AFC)

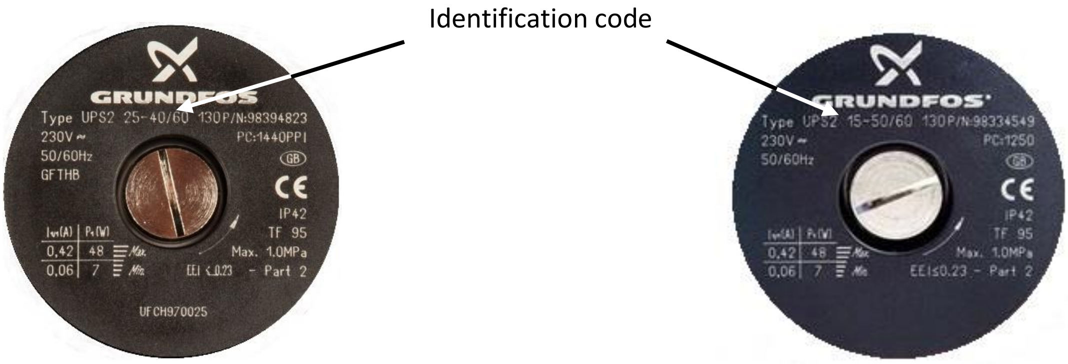
UFH flow rates can be controlled by a new technology known as automatic flow control. The flow rate is directly set at the valve and once set, no further adjustment is necessary. This makes for easier set up of the manifold, and the automatic flow control maintaining stable flow rates will result in increased system efficiency and lower energy costs.

*AFC Cartridge.*

### Pump

When the water is delivered to the manifold, in most cases, the existing heating pump will not be powerful enough to supply the UFH system, especially if the flow and returns to the manifold are too long. For this reason, a secondary pump is fitted on the manifold to distribute the water through the relevant circuits. This pump is normally fitted with the blending valve as part of the pump pack.

The UFH pump is very similar in appearance to a standard domestic circulator, the main difference being that the UFH pump has a 25mm bore and standard domestic circulators are normally 15mm.

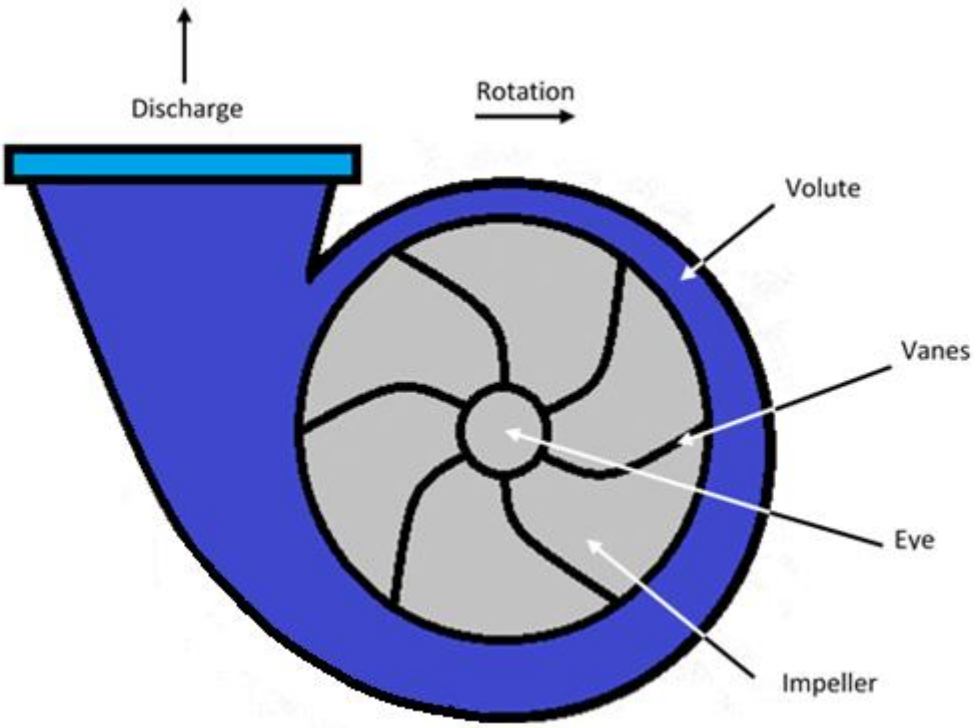



*UFH pump*　　　　*Domestic circulator*

Grundfos pumps have an easy to classify code number system as shown below;

15=bore of the pump body - 50/60 is the maximum head in decimetres. So, a 15-50/60 has a 15mm bore and will produce a maximum head of 5-6 metres.

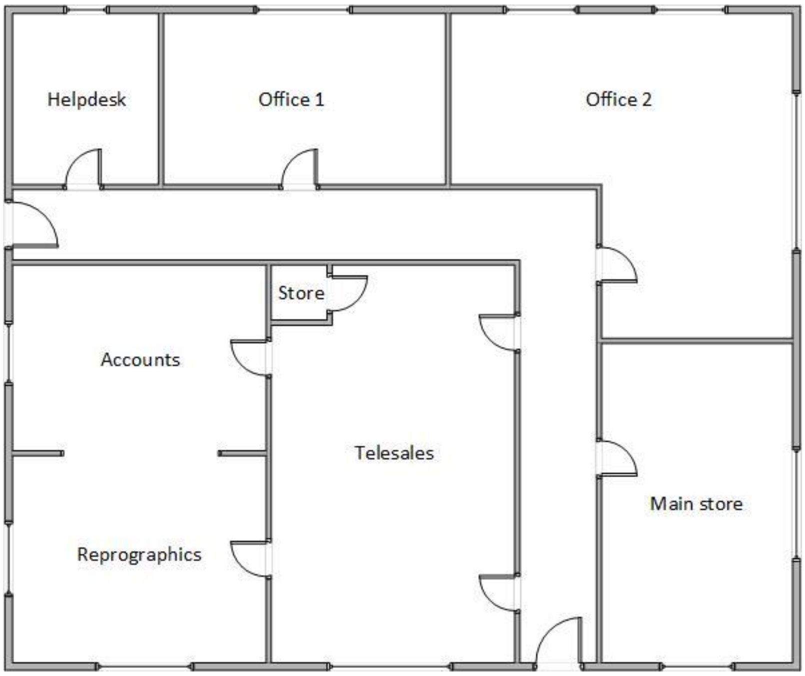
The pump is the centrifugal type. The water enters the pump inlet port or ‘eye’ into the centre of a spinning impeller, which by centrifugal force, the water is expelled out of the outlet or discharge port and circulated around the system.




*Centrifugal pump*

**Manifold Position.**

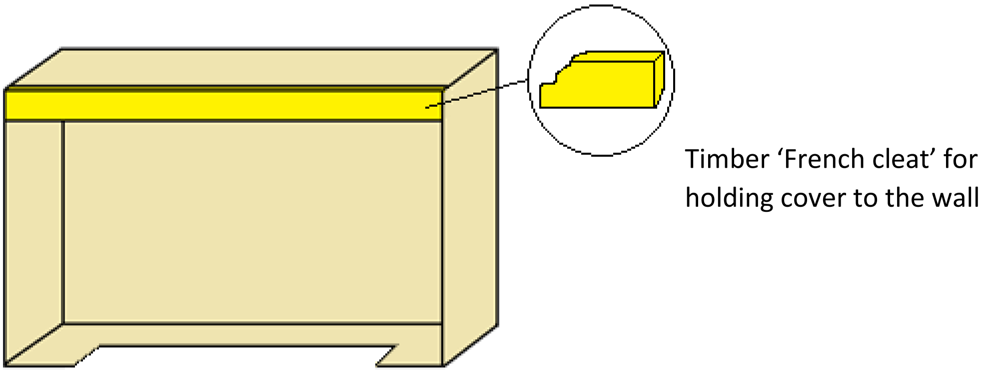
The pump pack and manifold need to be sited as centrally in the building as possible. This is to ensure that the connection lengths from manifold to zone will not be too excessive as this will impair efficiency.




The drawing above shows a typical office block. It was originally planned as there was an abundance of space, to site the manifold in the helpdesk but this would mean long connection lengths from there to office 2 and the main store. A result of this would be longer heat up times, unwanted heat emitted in the corridors which would also be a waste of energy. For these reasons, the store cupboard in telesales was chosen as it was the most central. It is imperative that the manifold position is decided at the design stage.

Another consideration once the location is decided upon, is the mounting height. 300mm is ideal so connection lengths will not be excessive, but not too low to risk kinking the pipes when making manifold connections. In all cases the manifold needs to be as accessible as possible to enable easy installation and maintenance/servicing. Corner connection elbows may be used where space is limited.

Even though the manifold is usually sited within an existing cupboard, it is good practice to box it in to protect against possible mechanical damage from the contents of the cupboard. There are a few companies who manufacture generic and bespoke cabinets specifically for UFH, but a removeable cover can easily be made.




*Rear View of Manifold Cover*

# Controls

Any heating system regardless of type relies upon correctly matched and specified controls to achieve maximum efficiency, and to comply with current regulations.

Thermostats can be supplied in different voltages from 24V to 230V. They can communicate by RF (radio frequency) or can be hard wired.

There is a type to suit everyone from simple dial type to programmable to smart controls which usually work in conjunction with a mobile device.

For maximum efficiency, heating controls have one or a combination of features built in to ensure fast, accurate sensing and switching. These are outlined below.

## Setback

This feature helps retain some of the heat within the building structure thus reducing energy usage.

Consider a heating regime of ‘on at 07:00, – off at 08:30’ then on at 16:00, and off at 21:30.

During the heating hours, normal set point temperature will be maintained e.g. 21°C. Out of these hours when heating is not required, rather than simply shut down, the system will continue to run but at around 4° lower, in this case 17°C. This is called the setback temperature.

The air temperature will be comfortably cooler, but when the heating is required, the setpoint temperature will be achieved much sooner, requiring much less energy as the heating only has to increase by 4°C as opposed to 15°C had the system shut off altogether.

To simplify this theory, imagine two winter coats, one hung up outside and the other on a working radiator. Choosing the coat hung up outside, the body will take longer, and require more energy to reach a comfortable temperature than if the coat on the radiator was to be selected.

## Optimised time control

Optimum start

Bearing in mind the afore-mentioned daily heating schedule, the occupant has an alarm clock set for 08:00 am. It has been assumed that it will take one hour to reach the desired temperature and so the heating has been set to come on at 7:00 am. It may only require 30 minutes to reach temperature, so this means the system has been operating unnecessarily for 30 minutes and wasting energy. During warmer days the system may not have to come on as early so with optimum start, the programmer will learn these changes and will automatically adjust to suit all varying conditions.

Optimum stop

The same applies when the system shuts down. With warmer outside air temperatures, the programmer will switch off sooner because the thermostat senses that the inside air will still be at a comfortable level for some time after the system has stopped. These features can be incorporated into the control device individually or be combined together.

## Weather compensation

Weather compensation, often referred to as ‘weather comp’ consists of an external sensor which is fitted outside of the building, located at high level and north facing. The sensor detects differences in the outside air temperature and adjusts the flow temperature to compensate creating a much smoother room temperature. This works very well with more modern boilers as most are fully modulating and condensing boilers will be more efficient owing to the lowered return temperature.

### T.P.I (Time Proportional and Integral)

Time proportional and integral or T.P.I, is a feature of modern thermostats which manages the current air temperature, set-point temperature and boiler firing time.

At the beginning of each heating cycle, the boiler will run constantly until the set-point temperature is almost reached. This is called the proportional band which is usually set at 1-2º C below set-point.

As heat demand is variable, the thermostat will reduce the boiler firing time to suit and will further reduce as the room temperature gets closer to its set-point. This reduces the boiler firing time and saves energy.

TPI will work with most boilers. Although this may sound rather complicated, TPI thermostats are relatively straight forward to operate as it is the firmware within that does the work.

There is also a facility for the thermostats to 'learn' each heating cycle and make the necessary adjustments automatically.

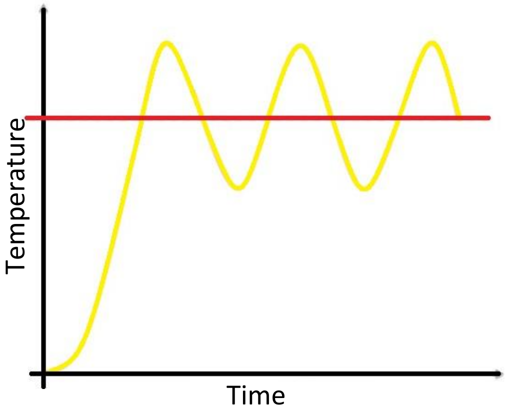
### Open Therm

Open Therm thermostats work only with modulating gas appliances subject to compatibility.

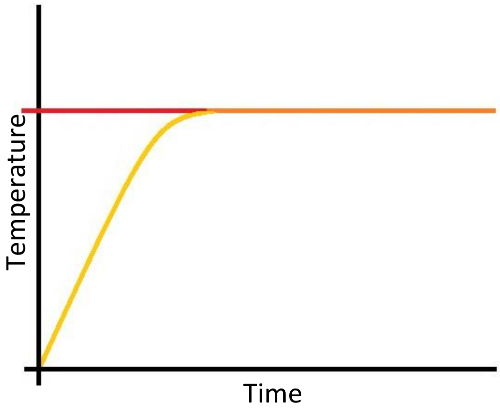
TPI thermostats, when in their proportional band, cycle the boiler on and off reducing its operating time to maintain the set-point temperature.

Open therm uses a system of two-way communication between the boiler and temperature controller which instead of cycling the boiler on and off, reduces the burner pressure which in turn lowers the heat output.

Because of these lower flow and return temperatures, the boiler will be in condensing mode for much longer, and the room temperature will be much smoother as shown on the graphs below below.




**On/Off Thermostat**




**Modulating Thermostat**

## Smart Controls

Becoming more popular are smart controls which give more accurate control resulting in a much more efficient system. These are usually connected to the internet and can be controlled either in the home or remotely using an app on a tablet or phone.  Some of these controls are compatible with home automation systems such as control 4 or can even work via virtual assistant devices like Alexa™.

Although these high-tech controls sound complicated, most are relatively simple to set up and operate.


*Smart controls*

## Commercial Properties.

Underfloor heating is very well suited to larger areas although generally, larger diameter pipes such as 18 or 20mm are used to allow longer individual circuits reducing the number of manifold connections. The pipes are normally connected using Euro-cone compression connectors. Temperature is usually controlled by fixed water temperature or setpoint control.

On the mixing valve is a floating action motor which drives an actuator. The actuator adjusts the valve to the required flow temperature and can adjust anywhere between and including fully open and closed according to thermostat settings. This can also be coupled with an external sensor for weather compensation.

## System Efficiency

There are four main design elements that will ensure system efficiency.

- Flow and return differential ($\Delta t$) of 5-10°C measured at manifold flow and return headers. This will demonstrate correct balancing and that all the heat energy is properly dissipated.
- Ideal room temperature should be set at around 21°C and kept as stable as possible to eliminate unnecessary boiler firing.
- The thermal resistance of the floor coverings must be kept as low as possible to ensure that the maximum amount of heat is radiated up into the room. Carpet and underlay must have a combined TOG rating of 2.5 tog. Floor covering types must be decided upon as part of the design process as they must be suitable for UFH. This must be passed on to future home owners so that if they change the floor coverings they choose a product that will not impede the heating process.
- It is pointless producing great heat outputs if the building cannot retain the heat, so it is imperative that the building is properly insulated to standard or regulations if not better.

# Pipework

The plumber/heating engineer will come across several different pipe materials which fall into three main categories these are;

- Metallic
- Elastomeric
- Composite

## Metallic

The most common pipe material used in plumbing is copper.

The raw material is placed into a furnace for melting at temperatures up to and around 1300°C. Once molten, it is poured into a casting pipe which will eventually become the tubing. Once it has cooled and solidified, the pipe is then rolled to the desired diameter then cut to length ready for packing. Early UFH systems used soft copper

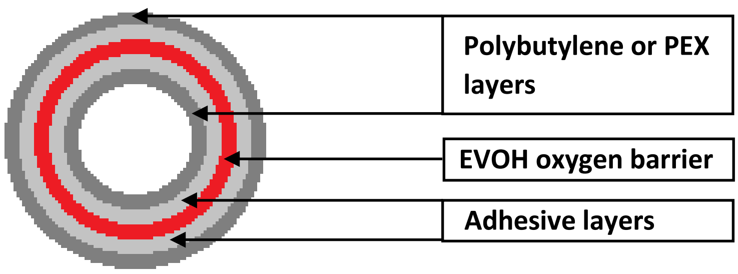
## Elastomeric

Elastomeric or plastic pipe is a much more lightweight than metal and so is easier to handle and to work with. The most common types of plastic pipe are PEX (polyethylene) or polybutylene.

Plastic pipe whether PEX or polybutylene is also known as barrier pipe, this is because it is made up of 5 layers incorporating a central layer of ethylene vinyl alcohol (EVOH) providing an oxygen barrier.

In their singular state, the polymers are micro porous meaning that water cannot leak out through the walls, but air can get in catalysing internal corrosion of any metallic components. An oxygen barrier can prevent this.

The main pipe material and the oxygen barrier do not bond well together, and so adhesive layers are needed which make up the five layers as below.

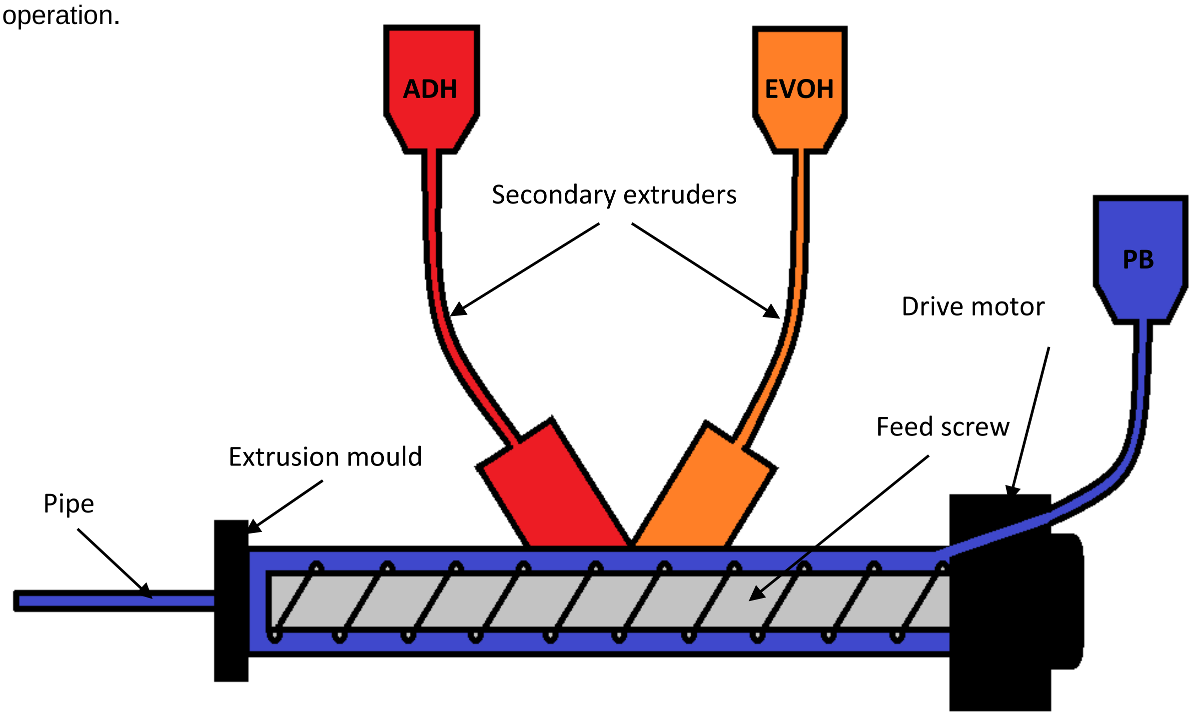



*Cross section of barrier pipe*

Plastic pipe is made by feeding grains of raw material through a heated screw at around 300°C. The molten material is then moulded it then leaves the mould and can be pushed or pulled through temperature-controlled water baths to the required size by a process known as extrusion. Multi-layer pipes are manufactured similarly by co-extrusion.

### Co-Extrusion

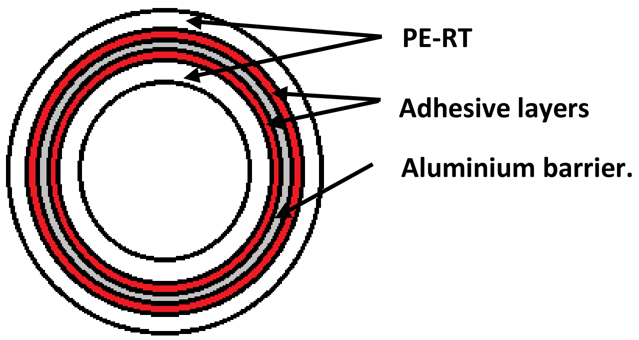
In mono-extrusion, solid plastic pellets are gravity fed into a forming mechanism, where heated feed screws melt and feed the material into a die. By contrast, coextrusion involves multiple extruders forming the different layers as one single material. Sometimes five or more materials are used in a single cycle, with each extruder delivering the precise amount of molten plastic needed for the operation.




*Co-extrusion*

## Composite

Composite pipe sometimes known as *Alu-Pex, MCP, or MLCP,* was developed in the 1970's and has a typical diameter of 16mm. This pipe composition has many benefits over metal and plastic as a pipe material and combines useful attributes from both. It is made up of five layers as below.




Composite pipe has the rigidity of metallic pipe but being fed from a coil can be fed through joists almost as easy as plastic.

Bends can be formed quickly and easily and due to the centre layer being aluminium, whichever shape is bent, it will be retained. This reduces the number of fittings required and as a result speeds up installation with a potential cost reduction.

Due to its smooth internal bore, composite pipe is also more hydraulically efficient than metal pipe and so less susceptible to pressure drop across the entire pipe network.

The aluminium core also provides an oxygen barrier and reduces the rate of thermal expansion encountered with plastics.

The pipe may be jointed using push-fit, press-fit or euro-cone compression connectors with press-fit being the most popular due to their strength.

Pipes are available in many diameters such as 12mm, 15mm, 16mm, and 18mm.

Coil lengths vary from 25m, 50m, 80m, 100m, 120m, 150m, 200m, 300m, and 500m.

Shorter coils of pipe can be laid manually but owing to their weight, larger coils such as 500m would be fitted from a decoiler.

### Pipe Optimisation

A question which is often asked is why are so many different pipe lengths available, even above the maximum circuit length?

The answer is simply to minimise wastage as ultra-flexible underfloor heating pipe cannot be used for domestic hot and cold water or standard central heating. This is because of the different composition of the pipe.

To better explain this, consider two circuits of 55m each. The nearest single coil length to 55m is 80m. This means that with 25m wastage left over from each of the circuits there will be 50m total unusable waste.

There is a 120m coil available, which means that would be the optimum length. A 120m coil used for both circuits will result in only 10m wastage. Also, when using a 500m coil with a decoiler, there will only be one waste length at the very end of the coil so, again minimising wastage.

### Fixing the pipe

Pipe must be fixed in accordance with manufacturers guidelines. This will support a warranty of up to 50 years. The two main stipulations are that he pipe must be in one continuous length from flow to return and free of kinks.

If the pipe is kinked when laying, then the whole length must be renewed.

Some manufacturers will permit a repair to an existing installation, but any fittings used must be accessible and recorded on a drawing. Testing afterwards may have to be carried out to a higher pressure. Always contact the manufacturer for support in the first instance.

Pipe is generally fixed down at 200mm centres and spaced at 500mm but check with manufacturer's instructions first.

If the pipe is being laid in cold temperatures, then the pipe coil may be kept in a warm environment prior to opening which will make the pipe easier to work with. On testing, if the air temperature was likely to fall to freezing then anti-freeze should be added then drained and after testing.

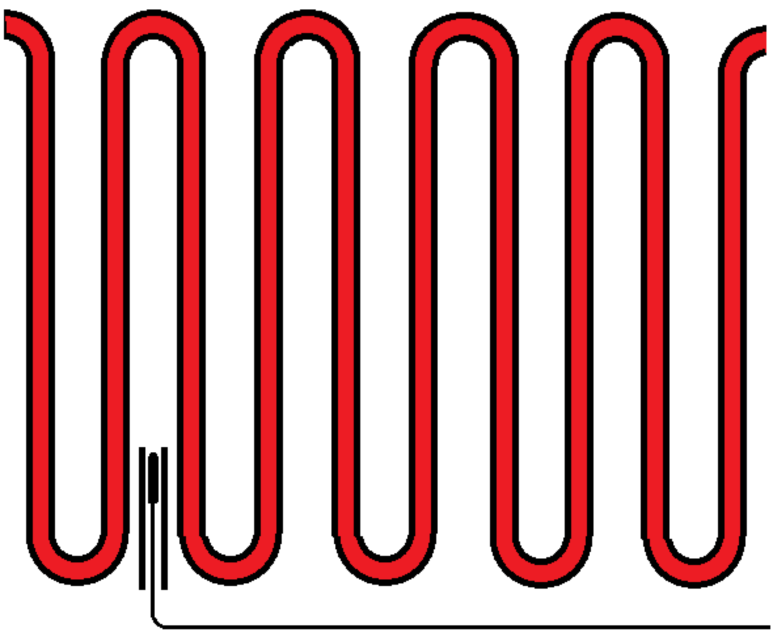
Where possible UFH pipe must be kept away from mains cold water pipes so as not to allow the cold water temperature to approach and exceed 25°C to remove the risk of legionella.

Where electrical cables are concerned, they must be protected from excess temperature. This is because when cables are warmed their current carrying capacity is reduced so they should not be allowed to reach 30°C it would be good practice to consult an electrical specialist if this temperature is reached.

It is vital that the electrician be kept informed of all work being carried out that may affect their own work.

As previously mentioned in module three, some floor coverings have a maximum temperature for underfloor heating which can be limited using a floor probe.

This should be fitted between flow and return in a conduit sleeve to allow easy removal if required.



*Floor Probe*

# Module 4

## Phase Test Questions

1. Name two devices that can control the temperature of water entering the manifold.

2. Where is the ideal location for the manifold?

3. What is the typical mounting height for the manifold and why?

4. Name three main control features which ensure an energy efficient system.

5. What are the three main UFH pipe classifications?

6. Name the three main constituent parts of composite pipe?

# Module 5

# Requirements of

# Design and Installation

# Module 5

## Design

When underfloor heating is being considered, it is imperative that a comprehensive feasibility study be carried out at the very first instance. To install UFH into a building with excessive heat loss or if existing heating plant is not suited, it will prove costly to remedy regardless of the quality of the actual installation.

There is a non-exhaustive list of points to look out for at the onset of any UFH project, two main points which are;

### Insulation Levels of the building.

As is key in ensuring energy efficiency of any heating system, insulation must at very least meet if not exceed the relevant building regulations for the specific region e.g. England and Wales, Part L (Conservation of fuel and power) and Part E (Resistance to the passage of sound).

It may not be practical to check wall cavities or underneath floors etc, in existing buildings, but architecture gives a good indication of the buildings age and indeed the level of insulation as indicated below.

The image above on the left shows a 1940's prefab which will almost certainly have colossal heat loss whatever the heating system installed. In fact, due to their high energy shortfalls, many of these properties have been demolished in favour of more modern and efficient homes as seen on the right.

The normal heat requirement for a modern, well designed and insulated property is around 50W/m² while an older, poorly designed and insulated property can be anywhere between 70 and 100W/m².

Heat requirement makes a huge difference in the design/specification of a system. Heat pumps tend to work best with the lower heat demands and some UFH floor products have a lower maximum heat output for example spreader plates at 52W/m². These would struggle to emit the heat energy required to heat the space due to requiring a flow temperature of 60ºC.

### Building structure

Some UFH floor systems can be rather weighty when installed and with older buildings a structural survey may be required to ensure that building regulation part A (structure) is complied with. In some instances, a more appropriate product may be required or worst-case scenario, the building may be deemed unsuitable for UFH.

## UFH System Design Methods

A perfect heating system will produce maximum output for minimum input and to achieve this, a full, and accurate design must be carried out which when complete must be adhered to throughout the installation.

Design support is available from ready reckoners to comprehensive and complete computer aided design (CAD). Many carry out this service free of charge but will need a minimum amount of information to return an accurate and completed design in a timely fashion.

Quite simply put, the more information collated at the start, the more data available to process, resulting in a clear, precise design which will not only be energy efficient, but will also be cost effective and will make installation much easier and faster.

### Ready Reckoners

The ready reckoner enables the installer to provide the customer with an approximate price and is calculated by square meterage of the room to be heated and usually quotes list price. This is the quickest method.

### Online Quote Tools

These are normally a piece of software or app designed to assist the registered user to produce a professional looking estimate. It requires the user to input more information to ensure its accuracy and has many features such as product quantities, trade discounts and labour rates with some also allowing the installers to add or remove products. It can also produce technical data for accurate balancing and commissioning.

## Technical Design

For a technical design to be possible, a scale drawing would normally be required. Ideally, this would be in either PDF, DWG, or DXF file format. This will allow the design engineer to make additions to the drawing. For example, pipe runs serving the heated zones and manifold locations.

The technical design has much more information for the engineer, such as a pipe optimisation chart as previously mentioned, for this reason, a minimum amount of information is required to ensure a timely return of a complete and accurate design.

It cannot be stressed enough, that the amount of information gathered at the beginning, will determine the quality of the design having an impact on the installation in terms of system output and efficiency. This early attention to detail, should promise a problem-free project from start to finish.

Below is a non-exhaustive list of basic items required as a minimum.

### Customer Details

- Customer contact details and address in full.
- Installer contact details and address in full.

### Room Details

- Room dimensions
- Which level the floor is e.g. basement.
- Subfloor construction e.g. timber or concrete.
- Which rooms require designing e.g. lounge.
- Manifold Locations.

### System Choice

- Type of system required e.g. between joists.
- Floor product e.g. double heat spreader plates.

### Schematics

- Are schematics (drawings) to be submitted.

As can be seen above, it isn't difficult to provide the minimum information the designer requires. Obviously, any extra information will only help the design process. Member, '*Too much is better than too little!* '

## CAD Design

CAD or computer aided design utilises a very high-tech design program which has the highest detail.

A CAD contains all the above, plus it can also add all individual floor circuits to the drawing. The CAD takes longer to produce due to the amount of work that is involved.

This type of design is usually requested by developers although there are manufacturers who will design for smaller projects. The beauty of a CAD design is that it helps to create a very professional handover pack which also helps justify the extra cost compared with radiator systems.

There are certain items of information regarding CAD designs which are;

- Project reference number.

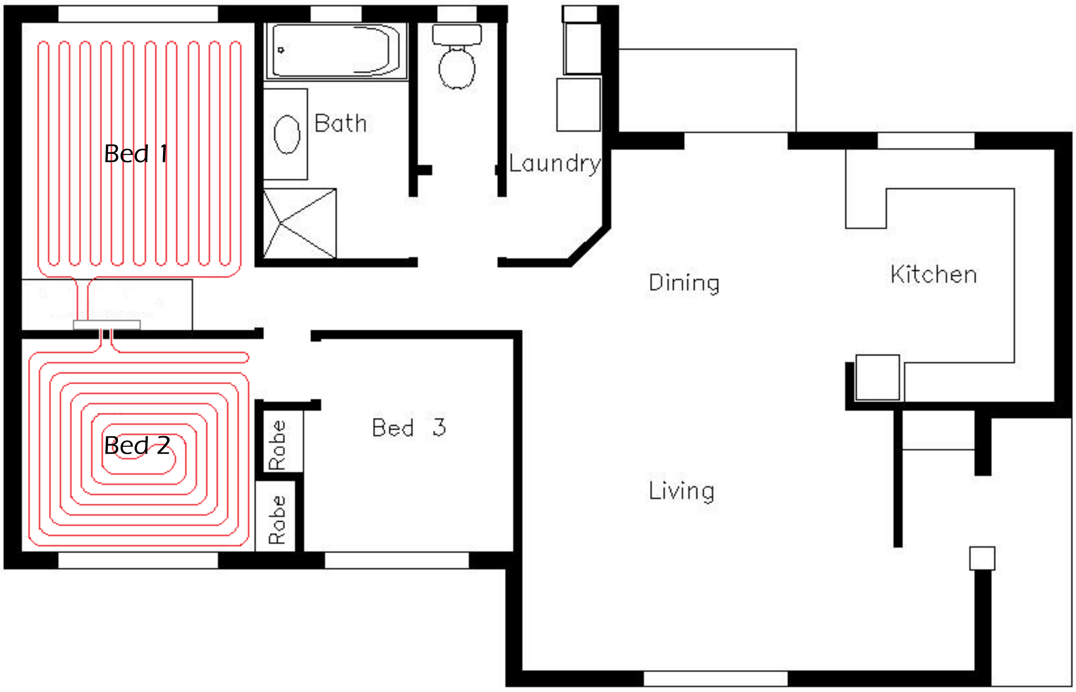
Confirmation that the following criteria are all met;

- Correct manifold positions
- Correct areas to be heated
- Correct floor constructions
- The design meets all requirements in full

The above four points are to confirm that no changes to the submitted design will be necessary which can slow down the process.

Confirmation of order

- Merchant name
- Branch
- Contact name
- Order number – most manufacturers provide this comprehensive design service but almost all will require confirmation that they will be supplying product prior to releasing any design




*An example of a CAD design showing pipe circuits and manifold location*

## Project Preparation

Always be present at delivery time to check that everything is as ordered and safely off-loaded. It is also important that there is a suitable area for storing the components. A simple way to check pipe quantities against the design is to use the formula below;

**Room area ÷ pipe spacing (in metres) e.g. 20m² ÷ 0.2 = 100 linear metres.**

The most important element of any project from beginning to end is cleanliness and site preparation. Cleanliness always gives a good impression and bolsters the engineers' reputation.

On new build thoroughly sweep the work area and remove any possible blemishes from the floor for example, plaster splats which can hinder some overlay systems.

The corresponding work area must be checked against the plan before starting as this is the final opportunity to make rectifications to the installations. This is especially important with screeded systems as when the screed is laid, it is a point of no return and alterations after this time will be very costly.

Sole plates in all timber framed buildings are load-bearing and therefore form an important part of the buildings integrity. Any UFH pipework must not penetrate the soleplate as this will weaken the whole structure. This means that the height of the chosen floor system must be such that the pipes will pass over any soleplates and not through them.

### Insulation

Any Insulation to be laid must comply with all applicable standards and regulations and be laid to the correct thickness for two main reasons. *(see page 21)*

- To maintain a maximum downward heat loss of no more than 7 to 10 W/m².
- To reduce deflection to a minimum. If the insulation is too thick, especially EPS, compressibility is reduced which compromises the weight loading of the finished screed floor.

Where any services are laid beneath the insulation, these must be laid first with special consideration to electric cables as insulating them can lower their current carrying capacity for example;

A 2.5mm² twin and earth cable can carry up to 27 amps but thermal insulation can reduce this down to as little as 13.5 amps so professional help must be sought.

### Pipe

The pipe coils should remain sealed until required, this will ensure it will be protected from potential damage such as extreme weather and UV, and mechanical/chemical damage for example, blowtorches or solvents.

With most good designs, a pipe optimisation chart will be included which will indicate the most economical pipe usage *(see page 65).* Check off the coil sizes on the chart and place the appropriately sized coils in each respective area before starting.

Where there is a potential for sub-zero temperatures, especially in screeded floors, precautions <u>must</u> be taken to prevent freezing. Water expands by 9% when it freezes which will certainly cause irreversible damage to the pipework.

A simple method is protecting the building by sealing all openings and/or using heaters. Another option is the addition of a compatible antifreeze which must be fully flushed out afterwards and disposed of safely.

Given the work and cost in rectifying faults after installation, before commencing work, it is good practice to make one final check of the design and feasibility of the system such as heat loading calculations, and that the pipework and ancillaries leading up to the UFH system are all suitable where applicable.

All flow and return pipework serving the manifold must not be of excessive length. If the pipes are too long, by the time the water reaches the blending valve, the water temperature will be too low to reach the blended temperature. If long distances cannot be avoided, at very least check the primary pump which may require uprating. In any case these pipes must be insulated. The pipes must also be insulated to satisfy building regulation part L.

During installation the system is exposed and at its most delicate, so it is wise to make all other tradespersons and operatives aware of this for its protection. It also makes good sense to work closely with electricians who will need to know positions of all ancillaries for routing and fixing cables.

Remember that when laying the pipe to be careful not to twist or kink it, especially in cold weather when its flexibility will be reduced. In colder temperatures, it will help if the pipe can be stored in a warmer environment prior to laying.

### Specialist Equipment

If the manufacturers design and directions are adhered to, then underfloor heating is relatively straight forward to install without any specialist tools, however these tools can make the installation easier and quicker and are normally a single purchase.

### Pipe Decoiler

The pipe decoiler is normally used with the larger coil lengths which normally would be too heavy to handle. One added benefit of using the decoiler is that the pipe is withdrawn much straighter reducing the risk of kinking.

*Pipe Decoiler*

### Infra-red Thermometer

A domestic hot water and heating system through normal running can produce high temperatures in the region of 60°C for domestic hot water, 70 to 80°C for radiator and even higher temperatures around the boiler. With these temperatures there is a risk of burning so contact needs to be kept to a minimum. When there is a need to take temperature of the pipework for example, an infra-red thermometer is ideal as it requires no physical contact with any hot surfaces.

The IR thermometer works by focusing light that is coming from the object in the form of IR rays and funneling that light into a detector. It is there that the IR radiation is turned into heat which is then turned into electricity, which is then measured. The amount of electricity generated by the rays emitted by the surface will provide a reading that is displayed on the thermometer. The reading will be generated in a manner of seconds, meaning an infrared thermometer is a quick and safe way to gather a temperature reading in several different scenarios.

*Infra-red Thermometer*

### Thermal Imaging Camera

Thermal imaging cameras are an excellent fault tracing tool. They can Identify leaks, cold spots and even pipe blockages. They can be expensive with some costing thousands, but a very effective low-cost option is the FLIR thermal imaging camera.

This attaches to a mobile device such as tablet or phone. It allows the user to record images for later work, and temperature reading is another of its many features.


*Thermal imaging camera attachment*

### Staple Gun

The staples used to secure the pipe to the insulation can be fixed by hand, but this would prove time consuming, so using a staple gun will save will save time and effort.

*Staple gun*

## Installation

This sequence of events is generic, and engineers may have their own methods which for them will still produce a satisfactory end result.

The first job normally is to mount the manifold and pump pack as this is the central part of the system and a good datum to work from. Most manifolds are supplied with their own fixings. With warranties in mind, it is best to use these where possible.

Once the insulation has been laid, the pipe is fixed using one of the methods as shown in module two. The pipe must be cut cleanly either using pipe shears or a rotary pipe cutter. Never force the pipe into shape or position at any time as this can kink the pipe which will have to be removed and re-laid.

Where any connections are made, a pipe insert of the correct type must always be used

To reduce puncture and heat damage to the pipes, it is recommended to keep a sensible distance away from where skirting boards and gripper rods are to be fixed and from any areas of high heat such as fireplaces.

**BS1264-4.1.2.6.2 states;**

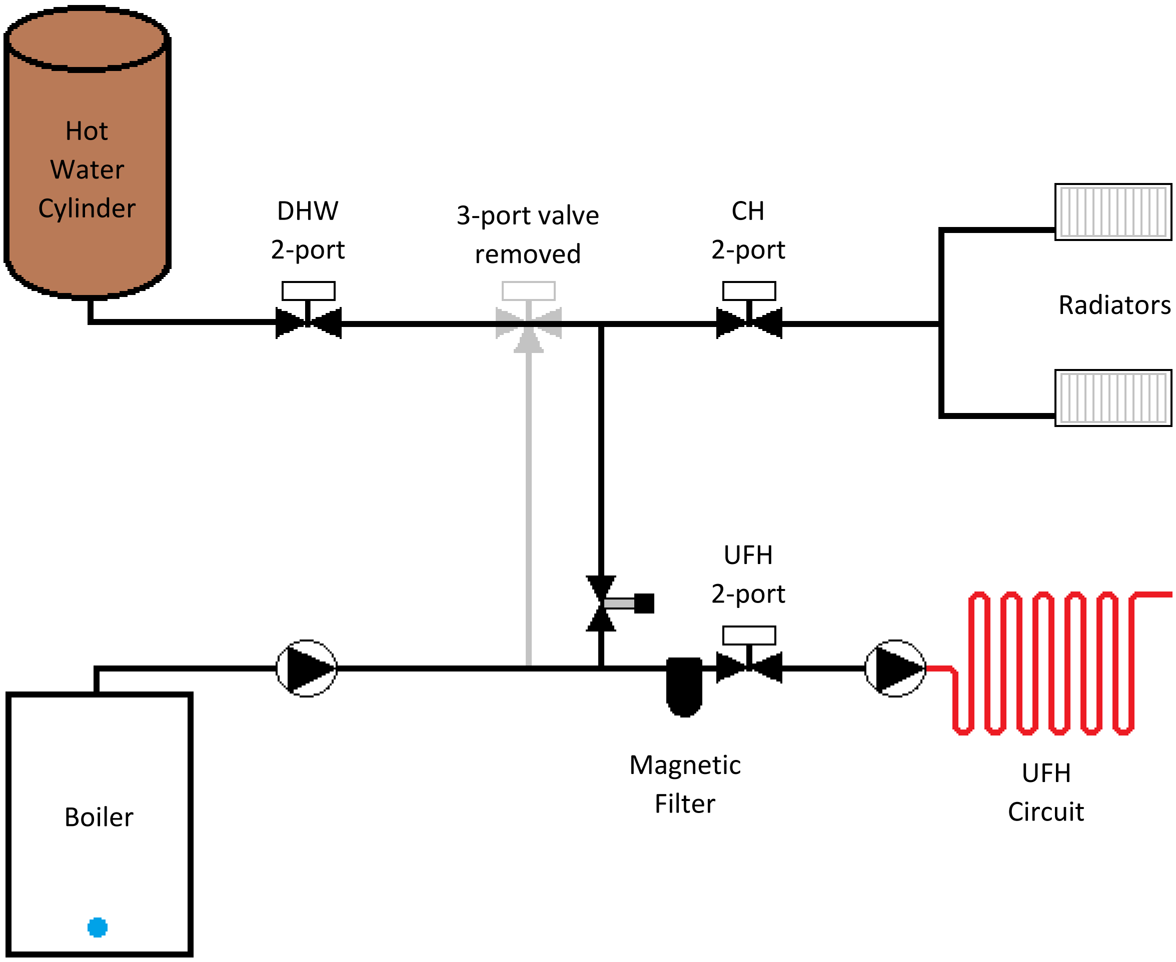
### Clearance areas

The pipes are placed more than:
a) 50 mm distance from vertical structures;
b) 200 mm distance from smoke ducts and open fireplaces, open or walled shafts, lift wells.

Any existing system pipework must be flushed clear of all sludge or debris before connecting the UFH system.

Next task is to connect primary flow and returns from the existing heating system or heat source up to the manifold, ensuring the pipes are fitted with the all necessary ancillaries such as filters and/or valves then insulated afterwards to comply with the relevant building regulations/standards.

When connecting into an existing system, A two port valve will be required to allow independent control of the UFH system. It is good practice to fit a bypass before the zone valve and is a necessity if converting from Y-plan to S-plan as below.




UFH being less crude than radiator systems, on a dual system especially, it is a good idea to fit a magnetic filter on the primary flow supplying the UFH manifold even if one is fitted at the boiler. This will ensure reliability and that the UFH system is kept clean.

Once the system is all connected, visually check all joints prior to carrying out a pressure test as below.

**BS 1264-4.1.3 states;**

**Leak test**

The leak test may be performed using water or compressed air.
Prior to the laying of the screed, the heating circuits shall be checked for leaks by means of a pressure test.
The test pressure must be not less than 4 bar, or not greater than 6 bar for standard systems.
In the case of gush asphalt, during the asphalt laying process, the pipes have to be depressurized.
The absence of leaks and the test pressure shall be specified in a test record.
When there is a danger of freezing, suitable measures such as the use of frost protection or the conditioning of the building shall be taken.
Being less susceptible to expansion on freezing, air works perfectly well as a testing medium, but water tends to be preferred as it gives a more visible indication of any leakage.

The system is pumped up to a pressure of 6bar and left for 30 minutes initially, and any slight pressure drop can be topped back up and then monitored for another 30 minutes. If there is no significant pressure drop then the system is deemed to be sound and test results should then be recorded.

Especially with screeded systems where pipe is left under pressure, a gauge may be fitted to allow checking during commissioning once the pressure tester has been removed.

*Pressure gauge*


*Pressure tester*

Gush asphalts sometimes known as tanking, consist of a course aggregate and molten tar with a temperature of approximately 200ºC and so the pipes must be depressurised as this heat can soften the pipe walls compromising integrity and strength.

When normal system operation begins, any frost protection fluids may be drained and disposed of in compliance with National Health & Safety Regulations, then flushed 3 times with clean water. Once the system has been hydraulically tested, and all electrical work is completed and certificated, the system is ready for commissioning.

## Commissioning

Commissioning is a vital part of any installation and is essential to comply with Building Regulation Part L. It also helps the installer to identify and rectify any faults which would show up at a later time.

Commissioning also sets a professional impression to the customer who will be able to rest assured that the system will remain reliable and economical. Manufacturers usually include a commissioning sheet as part of their handover packs which make the process straight forward. An example of a commissioning sheet is shown overleaf.

Polypipe Underfloor Heating

# Underfloor Heating

# Commissioning Checklist

| | | | |
|---|---|---|---|
| Commissioning Date: | | | |
| Project Reference Number: | | | |
| Project Address: | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| Commissioning Engineer Name: | | Signature: | |

| **System Operation** | **Yes** | **No** |
|---|---|---|
| Confirm heat source is in safe working order (service record present) | | |
| Confirm system is clear of air | | |
| Time clock/programmer switching | | |
| All room thermostats calling for heat | | |
| Check all actuators are operating correctly | | |
| Blending valve set to the correct design temperature of °C * | | |
| Pump adjusted to correct speed | | |
| Manifold flow valve open | | |
| Manifold return valve open | | |
| Zone valve open | | |
| Thermostat settings satisfied | | |

| **Actuator No.** | **Circuit Controlled** | **Thermostat Location** | **Paired ✓** | **Flow Regulator** | **l/m** |
|---|---|---|---|---|---|
| 1 | | | | 1 | |
| 2 | | | | 2 | |
| 3 | | | | 3 | |
| 4 | | | | 4 | |
| 5 | | | | 5 | |
| 6 | | | | 6 | |
| 7 | | | | 7 | |
| 8 | | | | 8 | |
| 9 | | | | 9 | |
| 10 | | | | 10 | |
| 11 | | | | 11 | |
| 12 | | | | 12 | |
| 13 | | | | 13 | |
| 14 | | | | 14 | |

* *With screeded systems, set valve to 25ºC and increase by 5ºC per day until design temp is met.*

# Remedial Work.

| Work Required | Action Taken | Completed✓ |
|---|---|---|
| **1.** | | |
| | | |
| | | |
| **2.** | | |
| | | |
| | | |
| **3.** | | |
| | | |
| | | |
| **4.** | | |
| | | |
| | | |
| **5.** | | |
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| **6.** | | |
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| **7.** | | |
| | | |
| | | |
| **8.** | | |
| | | |
| | | |
| **9.** | | |
| | | |
| | | |
| **10.** | | |
| | | |
| | | |

As can be seen, the check boxes on the commissioning sheet enable the engineer to very easily perform a comprehensive commissioning procedure by working systematically through the form ensuring when every box is checked, the system will maintain comfort levels at the correct temperature and at the right time.

The commissioning form is also a good tool for fault finding as it provides a logical path to fault identification.

The main form requirements are as follows.

- *Date of commissioning* – this also gives an indication of when the first service is due.
- *Project reference number* – the project reference number provides a link between the manufacturer, installer and end user and makes any technical queries easier to resolve.
- *Project address*
- *Commissioning engineer name* – the commissioning engineer can be a valuable contact in the event of any fault-finding queries.

The system operation section enables simple setting up of the UFH, and the completion of each task in order should result in a perfectly working system.

Checks to be made are;

- *Confirm heat source is in safe working order (service record present).* – There is no point whatsoever in installing a heating system with a highly efficient output section if the input section or heat source is not working at its most economical. Ensure that service record is up to date.
- *Check that the system is clear of air* – In most cases especially on commissioning, UFH faults are a result of air-locks through poor setting-up procedure. No matter how good an install is, if it is not thoroughly bled then it simply will not work.
- *Time clock/programmer switching* – Ensure the heating periods are set correctly and that the relevant areas are energised.
- *All room thermostats are calling for heat* – Ensure that the system starts when the thermostats are set to call for heat.
- *Check that actuators are operating correctly* – When the thermostats call for heat, the corresponding actuator should open. Don’t forget this can take up to 4 minutes to fully open.
- *Check that the blending valve is at the correct temperature* – check with design info-this is usually 50ºC but with screeded systems it is normally set to 25ºC, run at this temperature for three days then the valve is adjusted up to the design temperature in daily increments of 5ºC. Some boilers have a UFH setting where the blending valve is set to the design temperature and the boiler makes the daily adjustments.
- *Pump adjusted to the correct speed* – When setting up the system for the first time, adjust the pump to its lowest speed setting, then balance up the manifold. If extra power from the pump is required, then turn up the pump to its next setting. Many reports of a noisy system are because the engineer has set the pump to maximum then ‘gagged down’ the flow regulators. Not only does this waste energy, but it also causes premature wearing of the system components.
- *Manifold flow valve open – A simple error to make when first setting up.*
- *Manifold return valve open – As above.*
- *Zone valve open* – It is not uncommon for a new zone valve to be faulty but if the valve is open the manual lever should be free.
- *Thermostat settings are satisfied* – Having checked that the thermostats call for heat, make sure they also shut off once temperature is reached.

Labels can fall off actuators which can make it difficult to identify the respective circuits. A good idea is to compile an actuator chart as previously seen and number each actuator using an indelible marker. Thermostat status and location can be added as well as the design flow rates of each circuit.

It is advantageous to store all this data along with warranty information and user guides etc. electronically on a database, so it can be recalled for reference at any time.

## Handover

When commissioning is complete, where applicable, a handover must be carried out. This is to ensure that the end user is comfortable using the system in a safe, efficient manner. It goes without saying that *'a little knowledge is worse than none at all'.* Safety is first and foremost so discretion is required as knowledge levels will vary from person to person.

As previously seen with the commissioning sheet, a handover sheet can easily be compiled to ensure that all points outlined below are covered.

- Explain system layout including position of any key components. Indicate where isolation valves, switches or fuses are located for emergency purposes.
- Explain the purpose of any gauges that are fitted and what their readings and higher or lower limits should be.
- Explain thermostat operation especially setback – underfloor heating systems should never be compared to radiators as they are a totally different concept to the more conventional heating system so this must be appreciated at the very beginning.
- Explain that UFH solid floor systems in general respond differently to temperature change requests – again, different characteristics that have to be understood.
- At your own discretion, explain troubleshooting, but only that which is within the scope of the client – best is to leave your full company details for contact in the first instance.
- Leave layout and wiring diagrams safe – these can easily me mislaid so a good way is to put all information relevant to the system into a self-sealing freezer bag and either tuck the pack behind or tie it to the manifold. The pack could also be saved electronically.

Carrying out a full handover procedure will benefit everyone. The customer will understand and appreciate more the benefits of underfloor heating and should be well enough advised to seek professional advice prior to making alterations to any settings. The installer will be confident of maintaining a professional image and reputation.

# Module 5

## Phase Test Questions

1. In England and Wales, which two regulations must insulation comply with?

2. Which building regulation pertains to structure?

3. List three vital pieces of information required for an estimate.

4. What is the maximum downward heat loss for insulation in a UFH system.

5. State the two minimum perimeter distances according to BS 1264-4?

6. Outline the stages for a pressure test.

7. List 3 important elements of a handover procedure.

# Module 6

# System Maintenance

# and Repair.

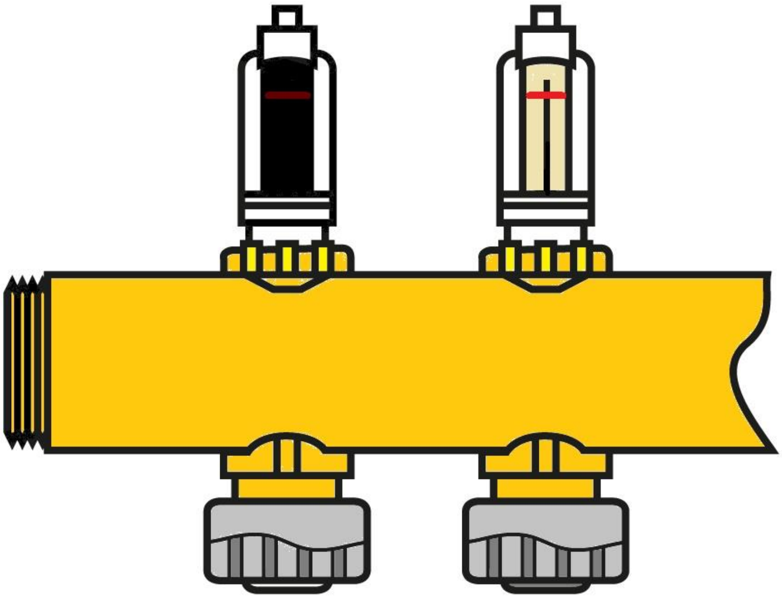
# Module 6

## System Maintenance and Repair

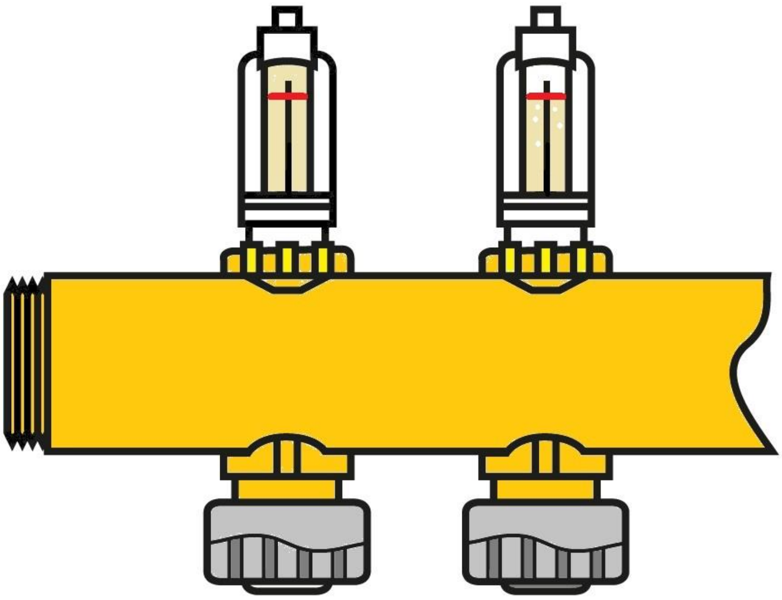
### Hydraulic section

Underfloor systems are much more reliable than radiator systems owing mainly to most if not all of the system components being concealed. And as a result, will require less maintenance other than a periodic service which would normally be tied in with the service schedule of the heat source.

Flow regulators can give a great deal of information just by looking at them. The diagram below indicates the left-hand port is badly silted while the right-hand port is clear.



As can be seen below, is air in the right-hand port. The regulator capsule should be full of water.



The most obvious information the flow regulators will tell is the flow rate. This can sometimes change itself over time but is usually due to user interference which is why many have tamperproof collars on them.

It is often perceived that the faster the flow rate, the faster the heat-up but this is most definitely not the case. Too fast, and the heat won't have time to dissipate up into the room which would be signified by a flow and return differential of less than 5ºC.

Too little flow, and much of the heat energy will be emitted at the beginning of the circuit resulting in a wider differential of above 10ºC.

The correct flow rate should be stated in the design but if this cannot be obtained then the flow rate may be set as follows.

- Adjust the flow rate to 1.5 l/minute which is a good average.
- Run the system upto temperature
- Check specific loop differential (Δt)
- If Δt is 5ºC or less, then reduce the flow rate.
- If Δt is 10ºC or above, then increase the flow rate.

There are several symptoms that can cause a reduction in flow rate.

- Air-lock. The most common reason for under performance of UFH.
- Blockage. More prevalent in mixed systems. Check colour of water in flow regulator and check any filters that are fitted. Also check blending valve strainer if fitted.
- Kinked pipework. Flow can be reduced greatly if the pipe has been kinked.
- UFH pump incorrectly sized, set or not working at all.
- Incorrectly adjusted flow regulator.
- Actuator not opening fully.

### Blending Valve

The blending valve is a very reliable system component however, the valve must be supplied with the correct water temperature which should either be 60ºC or 15ºC above the blending valve design setting.

## Fault Finding

It would be impossible to list every UFH fault that an engineer may encounter but the following should provide a solution to most scenarios.

Many complaints are due to incorrectly set or adjusted controls, so these should be checked first.

### Blending Valve

If on checking, the temperature at the blending valve is inadequate then the following should be established.

- The boiler is firing
- The primary pump is fitted, working, and the correct size
- The boiler is adequately sized
- The primary pipework is correctly sized and not too long

**If a circuit or part of a room is cold with the remainder of the zone working perfectly then check the following.**

- Check that the corresponding manifold valves are opening
- Check operation of actuator/s
- Check thermostat is calling for heat
- Check that the loop is free of airlocks
- Ensure that the flow regulator/s are correctly set and working

*Actuators*

It needs to be understood that actuators having a wax capsule inside need two to four minutes to open. If an actuator is suspected, there is a simple check that can be made with the system running.

- While looking at the flow regulator, remove the actuator. If flow begins or increases, it can be fair to say that the actuator is faulty.
- If there is still no flow-rate, then check the pin on the balancing valve is not stuck down. Sometimes a light tap will release it.

**If the entire room is cold, then this is most likely a control fault, so the following checks should be carried out.**

- Check room thermostat is calling for heat
- Check room thermostat is connected/paired and communicating with the correct actuators
- Check room thermostats are not in set-back mode
- Check correct flow temperature entering the loops
- Ensure the boiler is firing
- Check the primary pump is fitted, working, and the correct size
- Make sure the boiler is adequately sized
- Check the primary pipework is correctly sized

**If the system is producing excessive noise, then check for;**

- Airlocks
- All pipes and manifold brackets firmly fixed
- Pump not set too high
- Interference from another circulator in the system (hence fitting the bypass.

**If the system is not running at its most efficient**

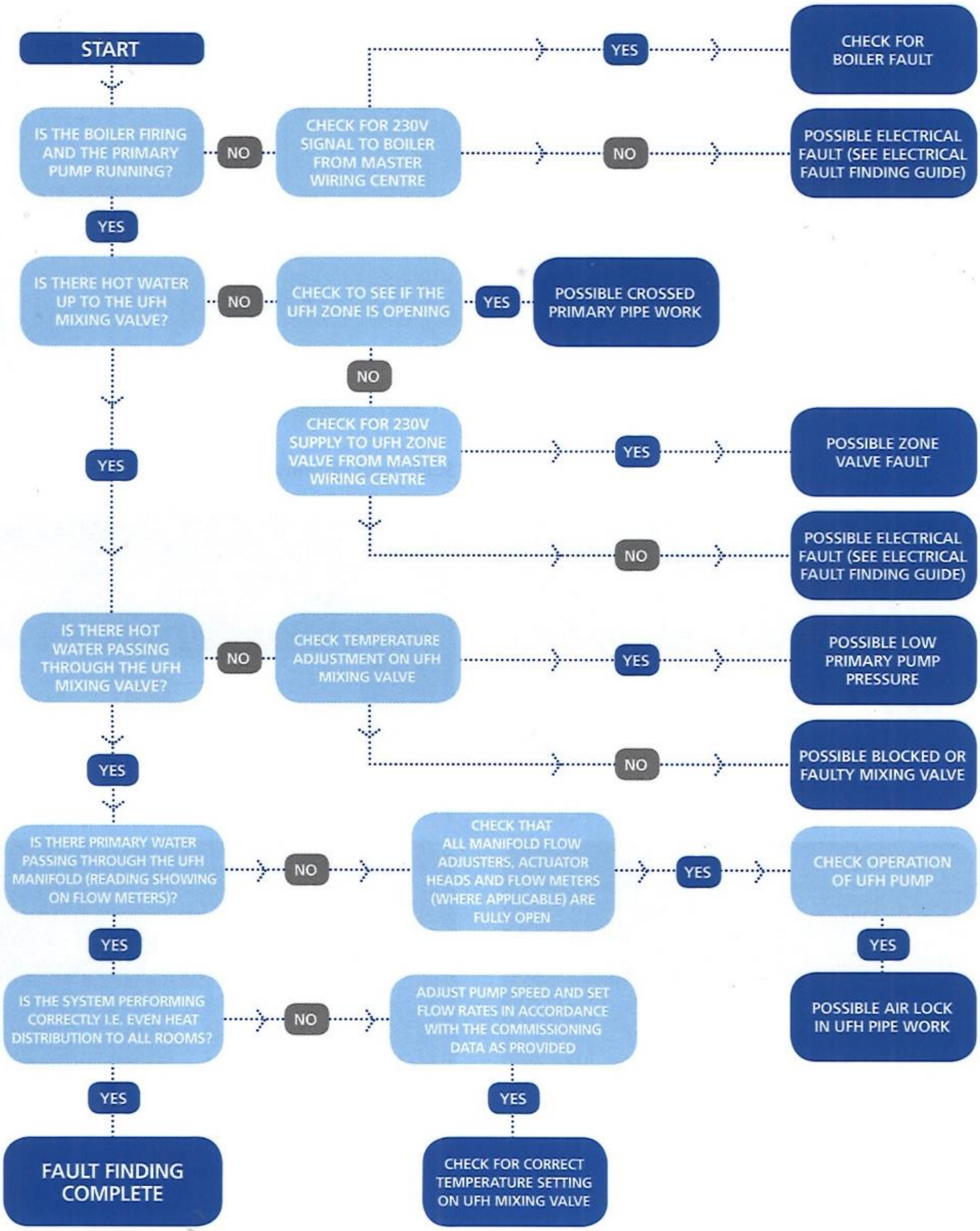
- Ensure that the boiler is not running when not required so check interlocks are working
- Thermostats not set too high
- Boiler has been correctly serviced
- Inadequate floor insulation

**System losing pressure**

- If the system is losing pressure either during or after testing before the floor is laid, visually check the loop and manifolds for any obvious leaks
- Carry out a pressure test
- If the floor has been laid, check for any wet patches
- Thermal imaging can also be used

Many manufacturers provide easy to follow trouble shooting flowcharts offering a systematic procedure for fault identification an example is shown overleaf.

## Hydraulic Fault-Finding Chart



# Electrical Fault-Finding Chart.

# Electrical Trouble Shooting

Due to regulations and health and safety constraints, electrical work should be left to a suitably qualified electrotechnical engineer.

This does not mean that basic fault-finding and testing is beyond the scope of a competent heating engineer.

Most electrical fault-finding associated with underfloor heating can be straight forward and can easily be traced and rectified safely with the simplest of equipment as listed below.

## Multi-meter

Multimeters can be easily sourced for only a few pounds with testing features such as Volts, Amps, and Ohms. Nearly all meters have an in-built continuity testing facility which is handy for tracing blown lamps. It is best to select a meter with a moulded rubber case for protection.

*Multimeter*

## Voltage indicators

Voltage indicators provide a quick confirmation that a voltage is present. They can either be of the probed variety *(left),* or non-contact *(right)*


*Voltage Indicators*

## Proving unit

While not compulsory to have, a proving unit is a device used to make certain that the test equipment is working before and after it is used to test a circuit. It consists of a 9V battery and a step-up transformer which provides a safe method of testing the equipment.


*Proving unit*

## Insulated hand tools

An electrical system must first be properly and safely isolated before commencing any work but for extra safety, insulated hand-tools such as screwdrivers and pliers should be used.

*Insulated hand tools*

As with all tools especially electrical tools, before every use, a visual check must be carried out to ensure that the tools are in safe, useable condition. Check that any insulated grips or handles are secure and intact. Make sure any blades are sharp and free of damage.

On test equipment, check the overall condition of the unit and any leads, is the equipment calibrated where necessary.

Select only the correct tool for the job.

# Electrical Fault-finding

As with all fault-finding situations, always look for the most obvious first.

### Is there an electrical supply?

The correct procedure for this is outlined as below.

- Carry out visual check of all equipment to be used.
- Prove test equipment by connecting to a proving unit or known live source to make sure a voltage is indicated. *(shown below)*

*Proving.*

- Test the circuit in question. If the tester fails to indicate a voltage, this does not mean that the circuit is dead or safe because with many types having intricate internal components, the tester itself could have failed. So, the next stage is to prove again. If the tester indicates a voltage, then it can be assumed that the circuit is dead.

### Is it switched on?

It is highly possible that a switch may have been turned off by accident especially if the switch is in a cupboard and something has fallen on it.

### Have any fuses/breakers operated?

If this has occurred, then it has done so for a reason. So before reinstating the circuit, the initial fault must first be investigated and remedied

### Are any components overloaded?

The central heating system should have its own dedicated supply from the fuse board. This is sometimes not the case, and professional help should be sought.

### Is everything wired correctly

Check wiring against diagram for correct polarity and that wires are not tightened down by their insulation.

### Never replace a fuse with one of a higher rating

The purpose of a fuse or breaker is to protect the wiring against short circuit or overcurrent and must not be uprated. Check manufacturer's instructions for correct ratings.

# Module 6

## Phase Test Questions

1. For optimum efficiency, what should the flow and return differential be at the manifold?

2. Give two possible reasons for pressure loss.

3. How can excessive noise be caused? (give two reasons)

4. Give three examples of why a circuit or part of a room is cold with the remainder of the zone working perfectly.

5. What is the purpose of a fuse or breaker?