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WIRSBO®
Systems

Wirsbo Underfloor Heating System

Basic Manual

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Introduction

As early as 80 B.C. the Romans discovered that the best way to heat an enclosed space was to introduce heat below the surface and let it radiate upward through the structure. The concept remains just as true today. This excellent heating method is called underfloor heating. The Romans used a type of airborne underfloor heating, the hypocaust, a system where smoke from a furnace chamber (the fuel was either charcoal or wood) was led through chimneys under the building to heat the structure.

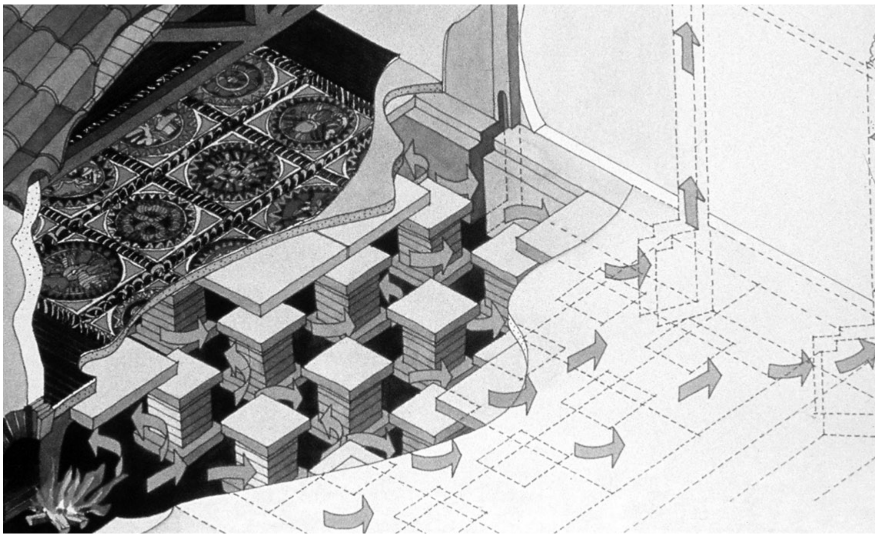

Figure 1 Hypocaust around 80 B.C.

Nowadays, of course, the hypocaust is no longer used. Underfloor heating systems have gradually become more and more advanced. In the 1930's systems were constructed using steel piping. Later still, in the 1960's and 1970's, they were made of copper. These performed reasonably well but proved unreliable in the long-term. It was found that metal pipes were simply not designed to withstand the stress forces imposed by a concrete slab. Therefore systems using plastic piping were developed.

Today Wirsbo-PEX piping, made from cross-linked polyethylene makes underfloor heating the perfect long-term solution for heating requirements. Unlike its predecessors and some of its current competitors, Wirsbo-PEX pipe products are designed to withstand the stresses placed upon underfloor heating applications. So much so that the Wirsbo Underfloor Heating System is proving its effectiveness worldwide in residential, commercial and industrial applications.

This manual provides the basic information required for the design of underfloor heating systems using Wirsbo-pePEX pipes. The purpose is to familiarise technicians, engineers and other professionals with the specific advantages of the Wirsbo Underfloor Heating System.

The material presented in this manual is sufficient for the complete design of underfloor heating systems in individual apartments or normal-size houses. Additional information for the selection of equipment used in larger installations can be supplied by Wirsbo.

Designing and installing the Wirsbo Underfloor Heating System is relatively simple. However, for the best results work should be carried out by professionals.

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Chapter 1

Wirsbo Underfloor Heating

General

Demographic studies indicate that nowadays people are spending more time than ever before in the home environment, whether because of increased leisure time, or because of the greater scope for working from home offered by technological development. Home comfort is more important than ever to both homeowner and building constructor alike and heating the home in the best possible way is given top priority. This is where underfloor heating, specifically the Wirsbo Underfloor Heating System, comes in.

Comfortable

Investigations show that the ideal vertical room temperature distribution allowing for the greatest comfort varies as shown in figure 2.

The most acceptable indoor climate is one in which the floor temperature ranges between 22-25°C and the head height temperature varies from 19-20°C. In other words people feel most comfortable with their feet a little warmer than their heads. Underfloor heating is the heating method that comes closest to producing an ideal room temperature distribution (See fig. 3).

The entire floor surface area becomes a low temperature radiator, which warms up the surfaces in a room, gives a horizontal even temperature distribution and surrounds the body with warmth. Heat loss, one of the primary causes of physical discomfort, is reduced to a minimum. In particular, there is no loss of heat owing to a cold floor surface. Moreover air movement, without the need for air circulation, is also at a low level, which helps prevent heat escape.

Other forms of heating cannot match this performance.

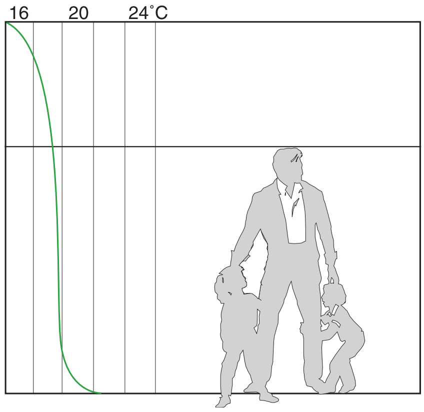


Figure 2 Ideal heating temperature curve

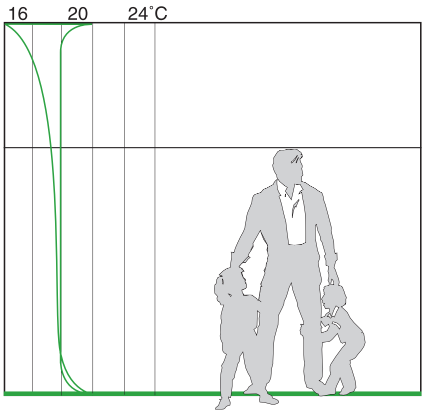
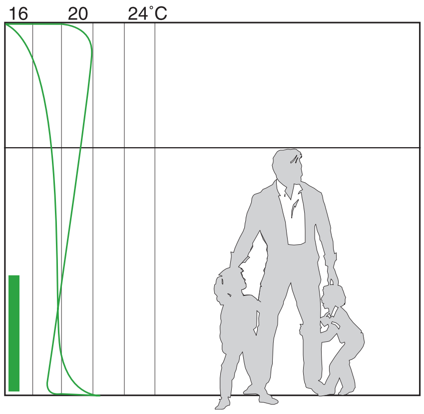


Figure 3 Underfloor heating temperature curve

Figs. 4-7 below show that radiator, convection, forced air and ceiling heating systems do not deliver sufficient warmth at or near floor level, whilst in the case of forced air systems, excess warmth at head height is produced. In addition, both radiator and convector heating systems create uneven pools of warmth, which may cause discomfort, whilst forced air heating often leads to an uneven temperature distribution.



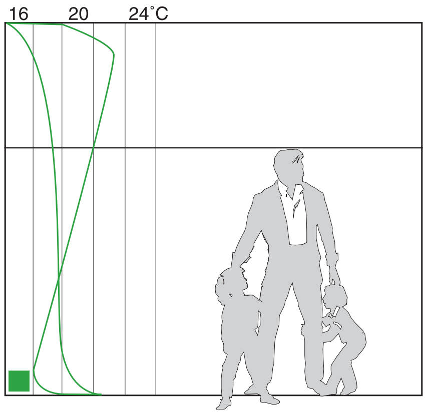
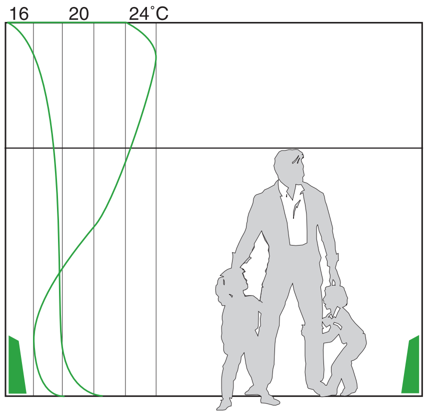


Figure 4 Radiator heating temperature curve (left) and figure 5 Convector heating temperature curve (right)



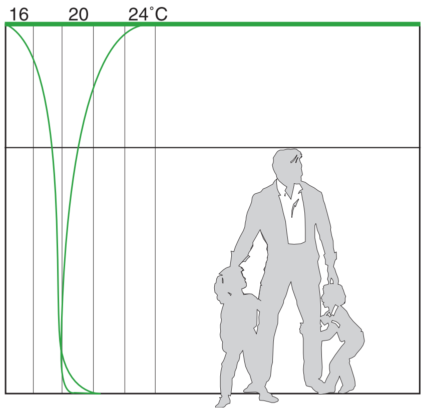


Figure 6 Forced air temperature curve (left) and figure 7 Ceiling heating temperature curve (right)

Energy efficient with low maintenance costs

Underfloor heating is the most efficient mode of heat delivery. It is designed to give comfort at temperatures lower than those used in radiator and convector systems because people and objects are warmed directly through the floor (floor surface temperatures are generally designed to remain at or below 29°C). Temperatures can be precisely controlled on a room-by-room basis. In addition, because there are few moving parts, the only items that will ever need service are simple and inexpensive to repair or replace.

Adaptable and easy to install

The Wirsbo Underfloor Heating System is adaptable to a variety of energy sources: geothermal, wood, gas, oil, electricity, or solar power. As such it can be converted to more cost-effective fuel sources as circumstances dictate. Furthermore it adapts to practically all kinds of flooring and can also be combined with other types of heating systems should the need arise. It is also easy to install.

Clean and healthy environment

Convector and forced air heating systems rely on air circulation for effect. The Wirsbo Underfloor Heating System, meanwhile, allows for natural air movement. Thus dust and other airborne particles such as pollen are not spread so quickly through the home, making the house a healthier and cleaner place to live in. Meanwhile there are no radiators to gather dirt or cause injury, from scalding for example, and because the Wirsbo Underfloor Heating System runs quietly there are no irritating or disturbing background noises. Furthermore because the floor surface is warm, cleaning and drying is made quick and easy, quick-drying floors being of particular benefit in bathrooms and hallways.

Complete design freedom

With the heating system out of sight under the floor (and thus protected from external damage), a room may be designed, decorated and furnished to the architect or homeowner's preference. There is more usable floor and wall space, and there are no ugly heating grilles or bulky radiators to detract from the appearance of the room. The Wirsbo Underfloor Heating System is ideal for advanced interior design.

Chapter 2
Wirsbo-PEX pipes

The Wirsbo Underfloor Heating System

The first Wirsbo-PEX pipe was produced in 1972. Since then both Wirsbo-pePEX and Wirsbo-evalPEX have been specially designed and developed for use in underfloor heating systems. Wirsbo can now offer a complete system for underfloor heating, a system which includes a full range of pipes and accessories carefully selected for optimum performance.

PE-X material

Wirsbo-PEX pipes are made of cross-linked high-density polyethylene in accordance with the Engel process. Cross-linking is defined as a chemical process where the two-dimensional structure of the polyethylene CH -chains is changed into a three-dimensional structure in which chemical bonds connect the CH-chains to each other. The new structure makes it impossible to melt or dissolve the PE-X material without first destroying its structure.

Wirsbo-PEX material has features common to most plastics and some, which are unique:

- It is not affected by corrosion or erosion
- It is not affected by additives in concrete
- Weak thermal expansion forces will not cause cracks either in the PE-X material or in the concrete in which it is laid.
- It is crack-resistant in the case of scratches of up to a depth of 20% of the wall thickness
- It has very low frictional forces
- It has a low weight
- It is flexible enough to allow small bending radii
- It is flexible at temperatures down to –40°C
- It has a flexibility, which will immediately absorb water hammer by 70%
- It has a flexibility, which will absorb noise generated at any given point within the pipe.

Marking and identification

Pipe manufacture, material properties and installation technique are approved in accordance with various international standards.

In most cases it is possible to see the manufacturing standard used by examining the pipe marking. In addition to the relevant standard, Wirsbo pipes are marked with a type approval label and, depending on the type of pipe, with the relevant production monitoring authority. They are also in some cases marked with an indication of the maximum levels of pressure and temperature permitted during use, and are always marked with the product name, outer diameter, wall thickness, date of manufacture, and continuous metre marks.

Oxygen barriers

Wirsbo-pePEX and Wirsbo-evalPEX pipes are coated with an extra plastic layer, which serves as an oxygen diffusion barrier. The “pe” and “eval” stand for two different oxygen diffusion techniques. In the case of Wirsbo-pePEX, the product mainly used for underfloor heating, the layer consists of a special low-temperature material with good elasticity. Wirsbo-pePEX pipes have been specifically developed for use in installations which operate from low temperatures up to a maximum temperature of 60°C. Wirsbo-evalPEX pipes, meanwhile, in common with Wirsbo-PEX pipes, are designed for use up to a maximum operating temperature of 80°C.

Regardless of the type of oxygen barrier being chosen, pipes are always tested in accordance with the DIN 4726/4729 standards, which deal solely with PEX pipes with oxygen diffusion barriers.

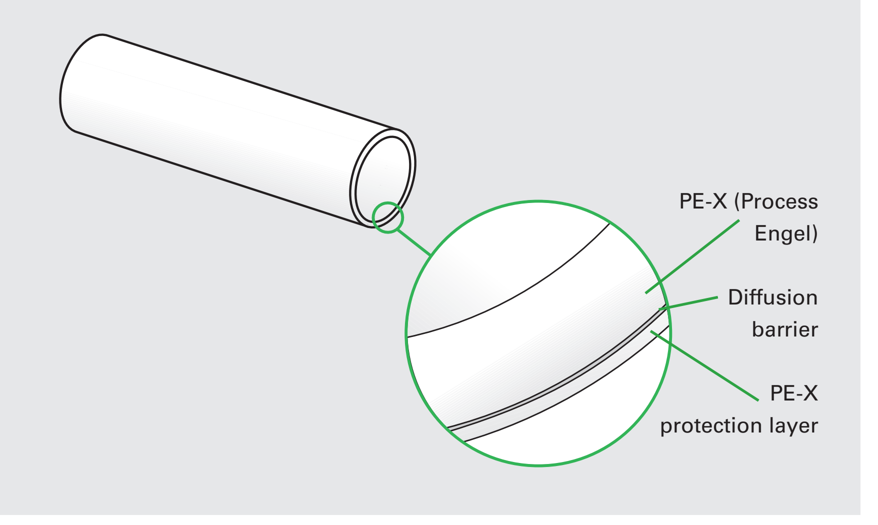


Figure 8 Oxygen barrier on a Wirsbo-pePEX pipe

Contraction in length

Note that the pipes can contract as much as 1.5% of their length owing to temperature and pressure decrease after use. (See also next chapter). However this should present no problem if one of Wirsbo's approved fittings, correctly mounted in accordance with manufacturers instructions, is used. This will ensure that the pipe's grip on the fitting remains stronger than the contraction force.

Storage

Wirsbo-pePEX pipes are supplied from the factory in coils whilst Wirsbo-evalPEX pipes are delivered in either coils or six metre lengths. The pipes are packed in boxes or sheet-wrapped in black plastic. Installation instructions and product information are included.

A set of special end plugs, which should be retained as long as possible during installation to prevent dirt from accumulating in the pipes, is also supplied.

Storing the pipe in the original packaging for as long as possible is recommended.

Pipes should not be exposed to UV-radiation (sunlight). Oil-based products, solvents, paints and tape should be prevented from coming into contact with the surface of the pipe as the composition in these products may have an adverse effect on the material.

Chapter 3
Design aspects

Concrete screeded floors

In concrete screeded floors or ”wet installations”, the screed spreads the heat out across the surface and thereby provides an even floor surface temperature. When laying the concrete, any air pockets, especially around the pipes, must be avoided because air is a poor thermal conductor. It is therefore important to vibrate the concrete. Alternatively, to help prevent this problem, there are concrete additives available on the market, which do not affect Wirsbo-pePEX or Wirsbo-evalPEX pipes.

There are a number of ways of laying underfloor heating pipes in concrete structures, ways which vary according to building construction standards and practices. The methods below apply generally for installations in concrete although it should be noted that other methods, which employ different types of accessories for fixing the pipe before concreting, are to be found.

In general

- Pipes are laid according to a desired layout plan
- The minimum thickness of concrete covering over the pipes should be 30 mm
- The maximum advisable thickness of covering over the pipes is 70 mm
- In larger installations, where there is a risk of external damage caused by other construction workers or even vehicles, loops should be immediately covered with concrete.

Embedded pipe loops tied to a reinforcement mesh

A steel reinforcement mesh strengthening the floor structure offers an easy and economic way of fixing the pipes according to the required layout pattern.

- Lay the reinforcement mesh on the whole floor area.
- The maximum distance between fixing points to the mesh should be 750 mm. At bends this should be 300 mm.

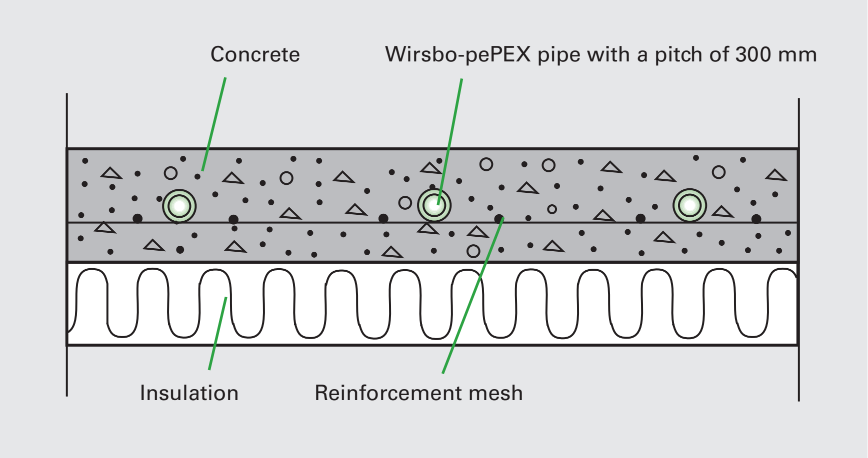


Figure 9 Concrete floor with insulation underneath. The pipe loops are laid on a mesh and fixed with tying wires before concreting.

Note: Ensure that the mesh is not laid directly on the insulation. The mesh is normally intended to reinforce the concrete structure.

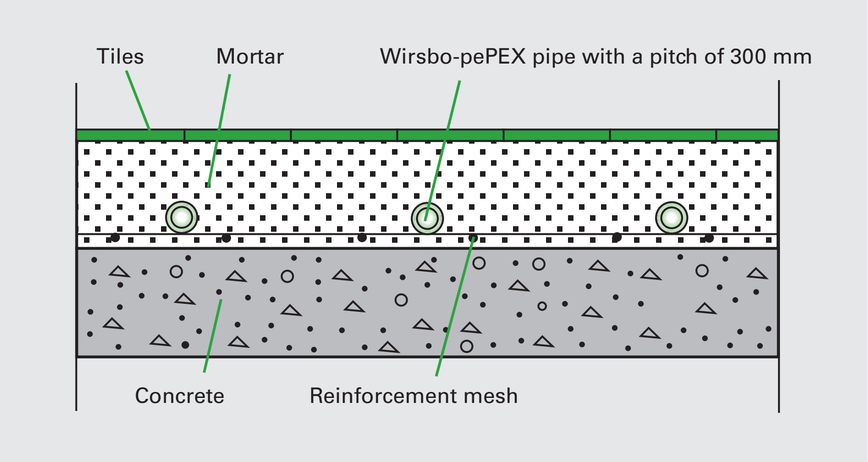


Figure 10 Mortar screed on concrete. Pipe loops laid on a mesh, fixed with tying wires before concreting.

Here the pipe loops are set in mortar screed above concrete.

Embedded pipe loops fixed with plastic holder bands or clips

The plastic holder band is an accessory that can be supplied with or without barbs. Holder bands with barbs or clips are suitable when the material beneath is for example polystyrene panels. If the material beneath is concrete, use holder bands without barbs and nail them to the concrete.

- Lay the plastic holder bands across the pipe pattern. Snap the band to the desired length.
- The first holder band is laid approx. 300 mm from the wall in order to allow room for the pipe to loop around.
- The remaining holder bands are laid up to a maximum distance of 750 mm from each other. Lay the last holder band 300 mm from the wall.

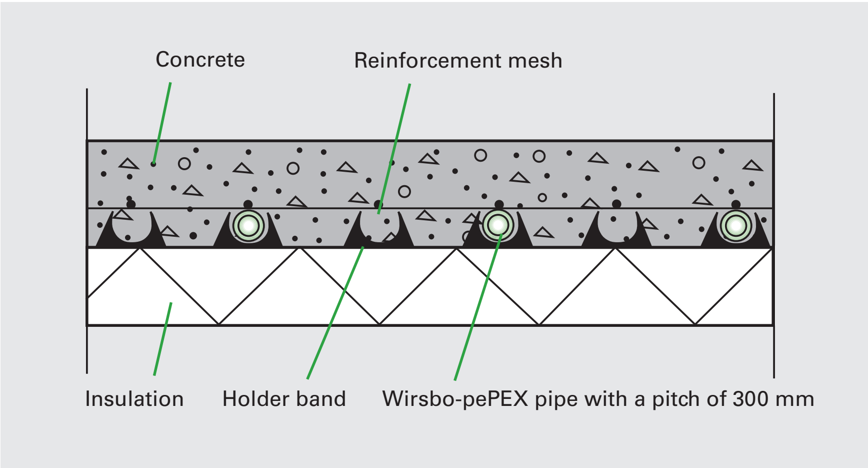


Fig 11 Concrete floor on polystyrene panel insulation. Pipe loops laid on plastic holder bands with barbs or fixed with clips.

- Press the barbs into the polystyrene panel.
- Snap the pipes into position.
- The reinforcement mesh is then laid on top of the pipe loop.

If plastic clips are used:

- Fix the pipes to the polystyrene panel with the clips.
- The maximum distance between fixing points should be 750 mm. At bends the maximum should be 300 mm.

Often clips are combined with plastic bands in order to make the installation quick and easy.

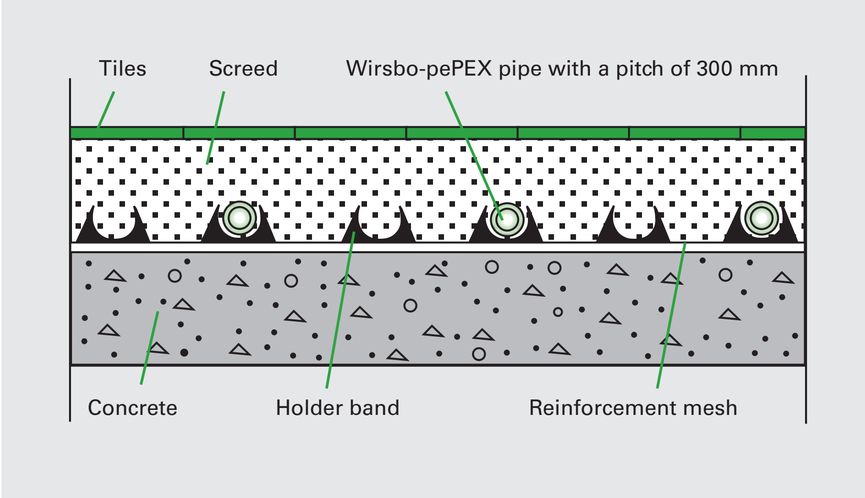


Figure 12 Pipe loops in screed. Loops laid on plastic holder bands without barbs.

- Fix the plastic holder band without barbs to the concrete with steel nails.
- Snap the pipes into position.

Wooden suspended floors

Wooden suspended floors do not conduct heat as efficiently as concrete. Therefore in this type of installation heat diffusion plates are required in order to achieve an even floor temperature.

Ensure that the wood is properly dried (maximum humidity content 10%).

The following guidelines are general and are based on a centre distance between joists of 600 mm (they are also applicable to centre distances of less than 600 mm).

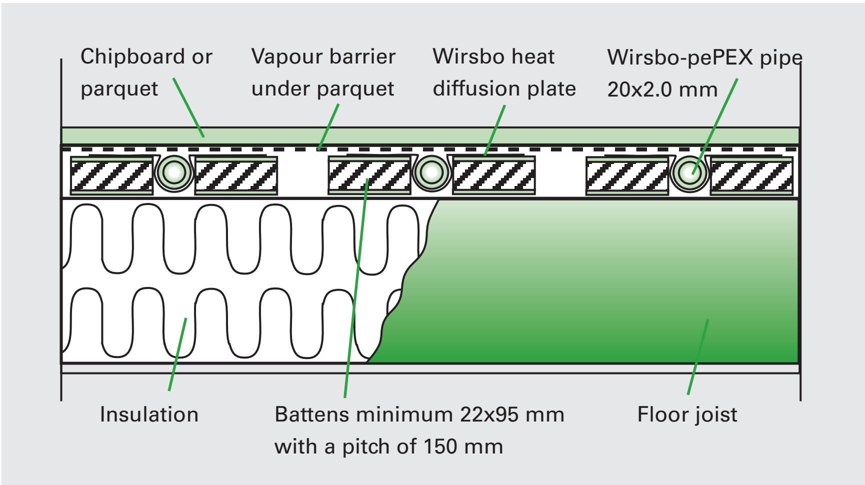


Figure 13 Cross section of pipe loops with heat diffusion plates.

- Nail battens measuring at least 22x95 mm using two nails to each joist (use hot zinc coated nails preferably). The first batten should be nailed approx. 50 mm from the outer wall so that the aluminium plate can be positioned correctly.
- Leave half the distance between the two last joists free of battens. Another batten is then laid along the last joist by the cross wall. Ensure that there is enough room left to allow for the positioning of the pipe loops .
- Lay the heat diffusion plates starting from the outer wall. Leave 300 mm free from the cross wall in order to allow the pipe to loop around. Cover as much as possible of the area with the diffusion plates (70-90%). The diffusion plates can be divided and adapted to room length. The gap between the plates should be at least 10 mm but not more than 100 mm.

- Pin the plates onto the battens ensuring that the pipe grooves are in alignment.
- Position the pipes according to the layout pattern.
- Lay a vapour barrier as required.
- Mark the routing of the pipes in order to prevent accidental perforation with screws.
- The chipboard (minimum thickness of 22 mm) is then laid across the battens in 600 mm sections and fixed with screws. Tongues and grooves are glued.

When laminated parquet is laid directly without chipboard beneath, the following should be observed:

- The structure must be reinforced. The battens must be at least 28x70 mm. They should be laid allowing for a gap of 25-30 mm to the wall and should be nailed to all the joists except for the last one. Then the ends of the battens should be lifted whilst the pipe loops are slotted round and underneath them before the nailing process is completed, the laminated parquet is laid across the battened area.
- Note that the battens should be nailed with hot zinc coated nails and that every fourth batten only need be nailed.

Floating floors

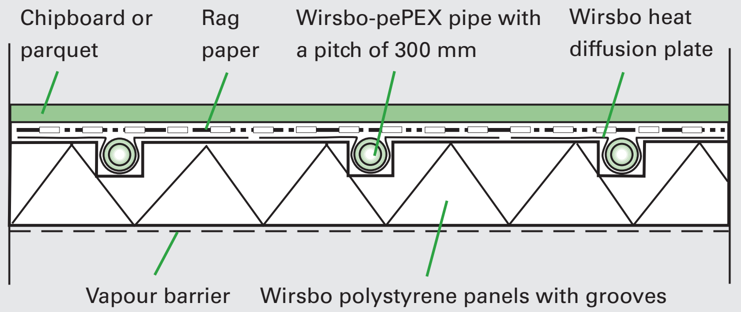


Figure 14 Cross section of a floating floor

On concrete floors it is possible to install underfloor heating using polystyrene panels provided with grooves for the heat diffusion plates and the pipes. This alternative can be used on all types of planed floors.

- Prepare the floor (grind, fill etc.) according to the existing norms or regulations regarding tolerance. Remove dust and dirt from the surface by, for example, vaccum cleaning.
- Concrete floors at ground level should be covered with an age-resistant polyethylene sheet of 0.2 mm (vapour barrier).
- Lay the polystyrene panels with regard to the relevant pipe pattern. The positioning of the panels should be staggered in order to minimise material waste and to prevent joins running in line across the floor.
- Lay the diffusion plates in the grooves.
- The plates can be divided and adapted to any length of room. The gap between the plates should be at least 10 mm but not more than 100 mm.
- Lay the pipes in the grooves in the diffusion plates.

Floor covering can be constructed in different ways:

- When laying chipboard, board of at least 16 mm thickness should be used. But note that with 30 mm thick polystyrene panels, the chipboard should be at least 22 mm thick. All joints should be glued.
- With parquet flooring either 22 mm floating laminated parquet or 14-15 mm laminated parquet may be used. But note that with 30 mm thick polystyrene panels, 22 mm parquet should be used. Again all joints should be glued.

Floor covering materials

The surface structure of the floor affects the heat radiation, whilst the floor covering material and its thickness influence heat transmission. A thick wall-to-wall carpet acts as an insulator, and thus a higher water temperature is required to reach the same surface temperature as for a floor with a thinner covering. On the other hand insulating covering materials provide a more even floor temperature. Other covering materials, such as tiles, are good heat conductors and require lower water temperatures.

Please note the following:

Floor cladding materials such as timber should have a moisture content suitable for underfloor heating applications.

With parquet floors Wirsbo recommends a maximum floor temperature of 27°C.

To discover the extent of the effect which the covering material has on heat transfer, the following formula can be used. A higher 1/R-value of the floor material means that the heat transfer is more efficient.

Floor material coefficient

$$\frac{1}{R} = \frac{\lambda}{d} \quad W/m^2K$$

λ = Heat conductivity, W/mK
d = Thickness, m

Example:
What is the material coefficient of a floor covered with 14 mm (0.014 m) thick parquet?

Parquet = 0.13 W/mK

$$\frac{1}{R} = \frac{0.13}{0.014} \approx \mathbf{10\ W/m^2K}$$

Note that if tiles are included in the 30 mm pipe covering, calculate with 1/R =100. Otherwise proceed as in the above calculations.

Insulation requirements

There are a number of aspects to be considered when it comes to the insulation of a building. General aspects related to heating systems but also those specifically applying to underfloor heating systems are as follows:

Figure 15 Insulation of a building

Floor structure insulation

Floor structure insulation is recommended in order to reduce unwanted heat loss downwards. On the ground floor, such heat loss may cause problems with the temperature control of the building. Insulation of a good quality (lamda-value <0,04 W/m²,K) should be used.

Reduction of downward heat loss

In order to neutralise the downward heat loss from an underfloor heating installation set in a concrete slab at ground level, the insulation thickness has to be increased by 80 mm. This figure is the result of calculations based on a household dimensioning heating demand of 50 W/m² of floor area. Calculations set out to reduce downward heat loss to a level of 10% of the total dimensioning heating demand, the normal ratio of downward heat loss in a well-insulated Scandinavian single-family house with no underfloor heating (see appendix for further details). Where specific demands for downward heat economy in other regions of the world differ, other targets for heat reduction can be set.

Moisture preventing insulation

In order to ensure an acceptable moisture level in the concrete (<85%), the temperature difference through the insulation beneath the concrete slab must be roughly 40°C. When calculated for a house with a dimensioning heating demand of 50W/m² of floor area, the thickness of the insulation under the concrete slab should be 100 mm (calculations have been made for a house with a width of 10 m).

Not exceeding a certain maximum moisture level in the concrete is essential if the concrete is to be ”coated”. This ”coating” could be a carpet or a parquet floor. If the relative moisture level reaches above 85%, this could result in an unhealthy indoor climate.

A bigger house will preserve some of the heat as a ”hot spot” under its centre. In order to secure the temperature drop of 4°C through the insulation, the thickness of the insulation must be increased. If the width of the house is 20 m the insulation thickness must be 120 mm.

A bigger house will be difficult to insulate against higher moisture levels. Here keeping the bare concrete floor or using floor tiles made of some natural stone material is recommended.

Compatibility with air conditioning and other heating systems

Figure 16 Wirsbo Underfloor Heating can be used with all energy sources

Underfloor heating can be combined with other systems such as air-conditioning, radiators or floor convectors. These additional systems should be set so that they do not interfere with the temperature control of the underfloor heating. This means that, for instance air-conditioning should operate at temperatures 2-3°C lower than the room setting of the underfloor heating. The floor temperature control of the underfloor heating system must override the other systems in order to operate effectively.

Floor temperature

The human foot could be considered to be the body's thermostat. In areas with cold winters, human beings have been concerned about floor temperature for many hundreds of years. This can be deduced from the use of early rudimentary underfloor heating or from the use of covering materials with high specific heat, such as wooden floors or carpets. One might say that the design factor determining the surface temperature of a floor is the sensitivity of the human foot. A basic temperature of 21°C on the floor's surface produces a feeling of comfort.

According to the International Standards Association ISO 7730, the most comfortable floor temperatures should range between 19-26°C. However systems may be designed to give a floor temperature of 29°C where a specific need arises, for example in the case of bathrooms or limited areas adjacent to walls.

It is important that an underfloor heating system is designed to ensure that the floor surface temperature does not exceed 29°C. A higher temperature will cause discomfort. Higher temperatures are a rare occurence in underfloor heating systems and could well be considered a waste of energy.

It is also important to ensure that the heating effect is dimensioned so that the temperature drop across the floor is no higher than 5°C. A higher temperature drop giving an uneven floor temperature could be perceived by the human foot as uncomfortable.

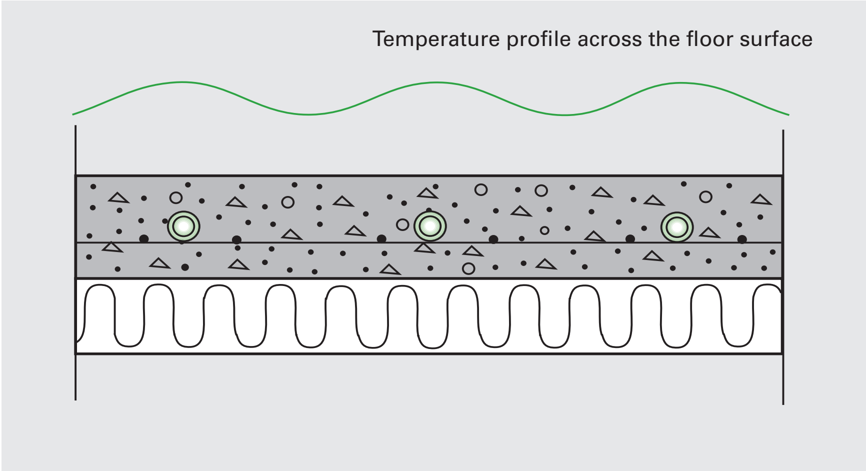


Figure 17 Illustration of floor surface temperature

Note

- Different floor covering materials have different temperature limitations. For example, for parquet a maximum temperature of 27°C is recommended. See the section on floor covering materials above for further detail.

Water temperature control

There are different principles for controlling the water temperature in underfloor heating.

Constant supply water temperature at constant flow

This technique is to be used only if the heated floor is used as a secondary heating source. It will satisfy only the minimum basic heating demand. Another heating system will have to control the room temperature. Under these conditions a constant supply temperature will give a near constant floor surface temperature. If the room is designed for a certain temperature the supply water temperature must be set 2-3°C below this level. Otherwise the floor temperature can, in some situations, override the room temperature control system.

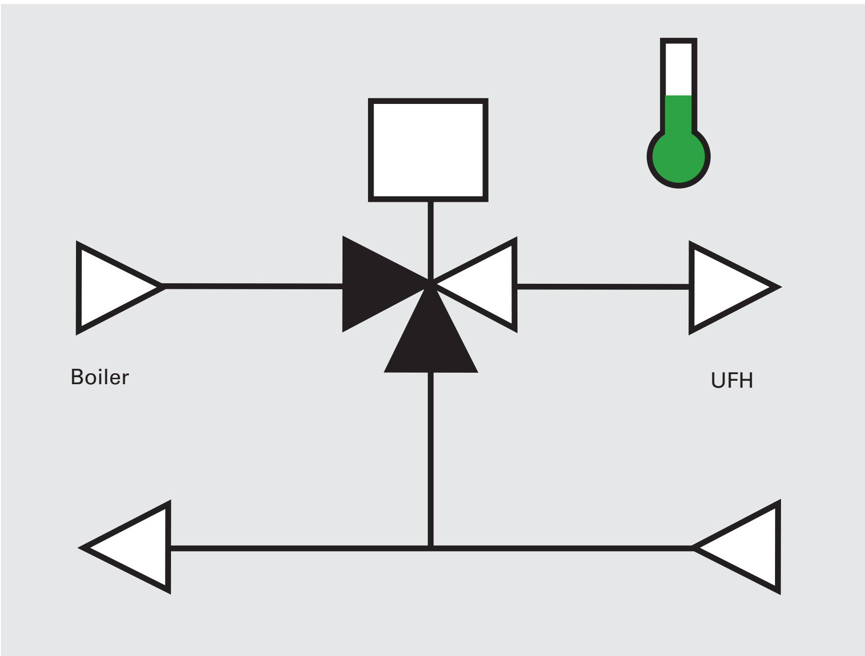


Figure 18 Principle diagram for constant supply water temperature

Constant return water temperature at constant flow

To be used as above. If the room is designed for a certain temperature the return water temperature must be set 8-10°C below this.

Indoor temperature compensation of supply water temperature at constant flow

Some experts on indoor climate control are of the opinion that an indoor temperature control technique is the best technique to use. The reason for this is the fact that most buildings have a very high thermal inertia. This means that a quick change in the outdoor temperature will start only a very slow change in the indoor temperature. It may take several days before the indoor temperature changes. In other words an indoor temperature control will harmonize with the thermal inertia of the house. In using this control technique, the risks for above and below temperature peaks in the indoor climate are minimized.

Outdoor temperature compensation of supply water temperature at constant flow

Contrary to the above an outdoor temperature control is regarded by some experts as the best technique. The reason for this is that it is possible then to work with a pre-set supply water temperature curve as a function of the outdoor temperature. The major advantage here is that when an increase in the outdoor temperature occurs the control system will immediately lower the supply water temperature, thus minimizing unwanted heat loss. On the other hand a decrease in the outdoor temperature will always create an above temperature peak in the indoor climate.

Variable flow at constant supply water temperature

Some experts consider that the techniques of indoor climate control using a variable supply water flow at a constant temperature, are the first modern temperature control techniques. Generally the heat output can be estimated by measuring the difference between the supply and return temperatures of the heating installation. A large temperature difference would then mean a low heating output and a small temperature difference consequently would mean a high heating output.

Constant floor surface temperature

The technique using a constant floor temperature is often used in places where floor temperature is essential, such as in swimming baths, shower rooms etc. The use of a constant floor temperature is to be seen only as part of an indoor climate control system. Room temperature control will be regulated by another heating system. Whatever the case, if the floor surface temperature is higher than the pre-set room temperature, the heated floor will in some instances override the indoor temperature control system.

Engineering principles and philosophies

As indicated in these differing examples of water temperature control techniques, methods, in most cases have to be combined in order to give good indoor climate control. Therefore it is of the utmost importance to ensure that the correct unit is in control. There must be no surfaces producing heat through radiation or convection, and thereby generating temperature levels that will override the controlling unit. A classical mistake is to set the temperature levels on the heating and cooling systems too close to each other and to use them as two individually-working, not internally-connected, control systems. In some cases the two systems can, like racehorses at the finishing line, work against each other at full power. One way to avoid this is to use an outdoor temperature control which, at a certain temperature level, switches on one system whilst switching off the other.

Room temperature control

Room temperature control is required to achieve the best indoor climate comfort. Different heat requirements exist within a building depending on external factors (orientation of the building, wind etc.) or internal factors (lights, open fire, time of occupancy etc.). Underfloor heating can cope with all these requirements. Every room can be controlled accurately by means of a room thermostat. However, in open-plan design, the different ”rooms” can be considered as one. Here Wirsbo recommends the use of only one room thermostat to control the whole open space, the thermostat being installed in the ”room” with the highest heating demand. Normally this is the room with the highest number of outer walls or windows.

On-off regulation

Wirsbo temperature controls normally work in accordance with an on-off regulation philosophy. Assume for example that the room temperature is somewhat lower than the thermostat setting. This will cause the thermostat to call for heat. Using the on-off principle the thermostat will open and call for heat for 5 minutes. After that it will close irrespective of the current room temperature (within some limits). If the room temperature is still lower than the pre-set level, the thermostat will open again after 5 minutes calling for heat for a further five minutes. And so on. The idea behind this control principle is to create as even a floor surface temperature as possible, an even floor temperature giving a higher degree of comfort than an uneven one. During the 5 minutes that the thermostat is open the water circulates at high speed and fills the underfloor heating circuit completely with fresh water at an even temperature.

Flow control

An underfloor heating installation can of course operate with a flow control. A high flow will give a high heat output from the floor and a low flow will do the opposite. However, this will give an uneven floor surface temperature.

Response time

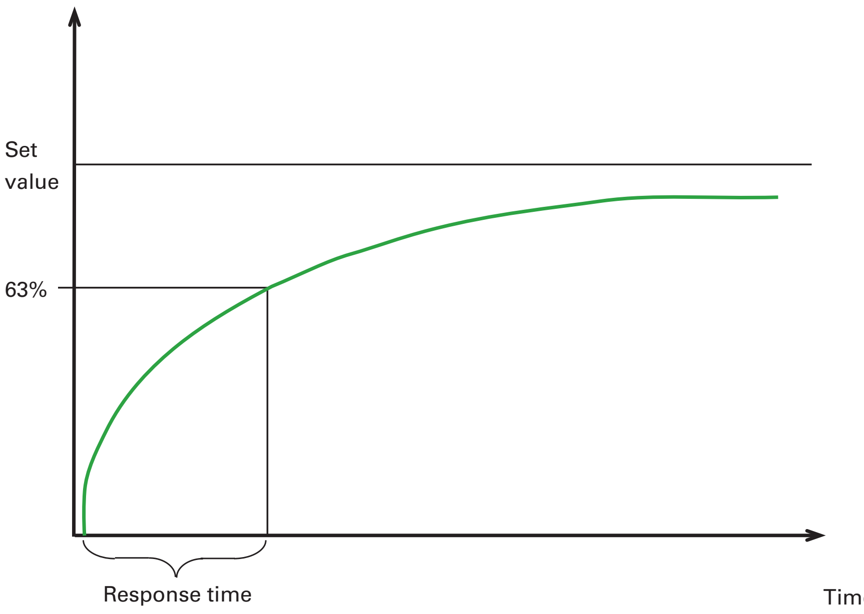


Figure 19 Typical response time diagram.

Different interrelated factors to do with climatic conditions and building design, affect the response time of an underfloor heating installation.

Climatic conditions

Response times vary in accordance with the outside temperature. Heating systems are designed to cope with temperatures during the coldest months of the year. However, they are not designed to work properly only during that period, because in the months before and after the cold season, there is a capacity reserve which will speed up the response time.

Building design

The insulation in a building, the U-value, will complement the performance of the underfloor heating system. If the structure is poorly insulated, resulting in energy wastage, the response time will be affected by the heat loss.

The floor structure will also affect the response time. In houses with concrete screeded floors, the screed will store energy, initially slowing response time. In public buildings this storage effect can be used to save energy at night or at weekends, a temperature drop being acceptable when the buildings are not occupied. The system can, for example, be controlled by a seven-day timer programmed to allow for system response. Houses with wooden suspended floors or floating floors will, conversely, have a faster response time, since wood has low thermal mass.

Design and installation of the underfloor heating system

Correct design and installation are crucial to the satisfactory operation of the system. Design features such as loop configuration, pipe size, pitch and depth are fundamental, whilst other important aspects which affect the system's performance are the calculated values, such as water temperature and required flow rate. Finally a correct installation and a balancing of the pipe loops will ensure an efficient performance.

Loop configuration

There are three main types of loop configuration for underfloor heating. The choice of configuration depends on the construction techniques and practices in different countries.

In general when pipe layout plans are being formulated, attention should be paid to first routing the supply flow to the external walls or other potentially cold areas.

Note that at this stage also, consideration should be given to ensuring that the pipes do not run through the expansion joints incorporated in the slab design.

The temperature drop in the pipe loops should be kept low, at approximately 5°C, in order to avoid uneven floor temperature.

Configuration A

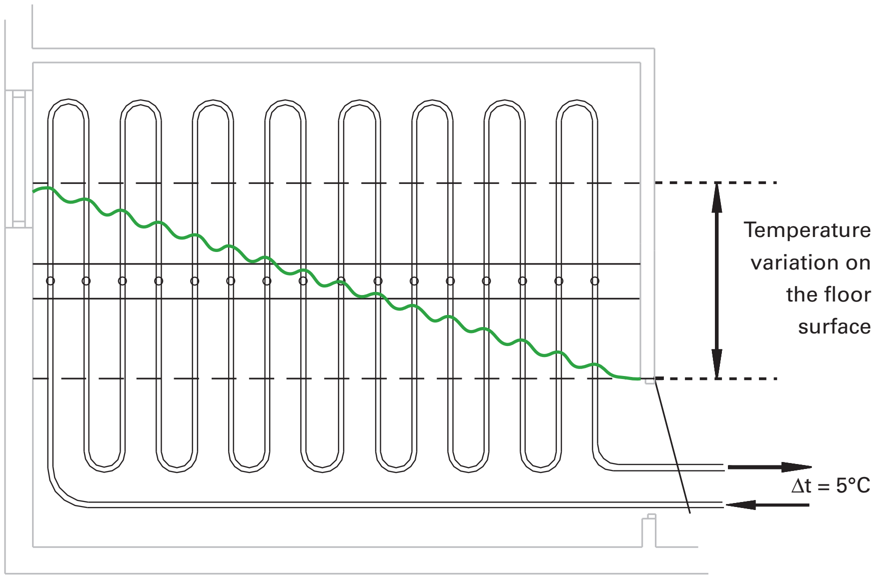


Figure 20 Configuration A, single serpentine run

Configuration A is easy to install and gives a more even distribution of heat over the floor surface. Temperature variations within small areas are kept to a minimum.

The main advantage of configuration A is that it adapts to all kinds of floor structures. It can also be easily modified for different energy requirements by altering the pipe pitch.

Configuration A is suitable for most underfloor heating installations in the home. In view of the relatively narrow bend radii, the use of a very flexible pipe, such as Wirsbo-pePEX, is recommended.

Configuration B

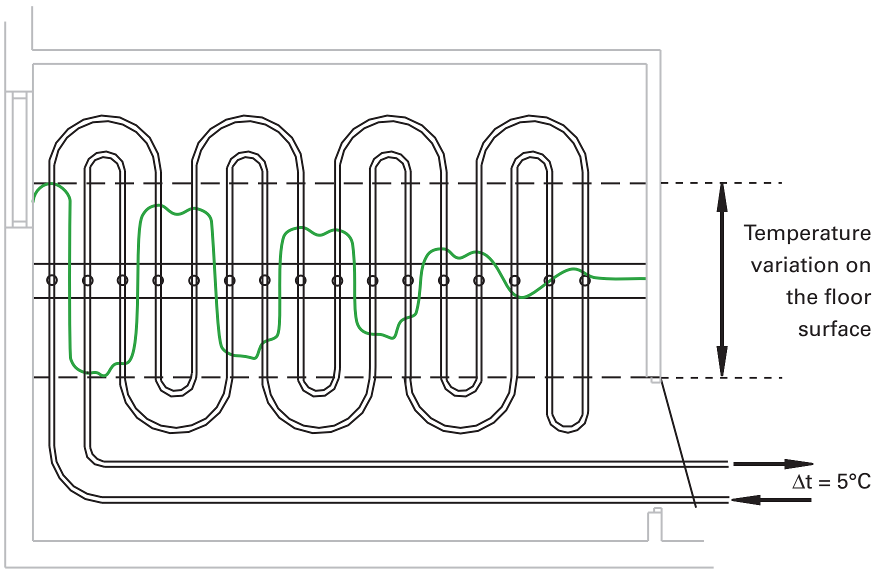


Figure 21 Configuration B, supply and return pipes in a parallel run

Characteristic for this configuration is that the supply and return pipes in the loop layout run parallel to each other.

Configuration B provides an even mean temperature but higher temperature variation within small areas. It is suitable for heating larger areas with a higher heat demand, such as churches and hangars, or outdoor areas where snow melting is required.

Configuration C

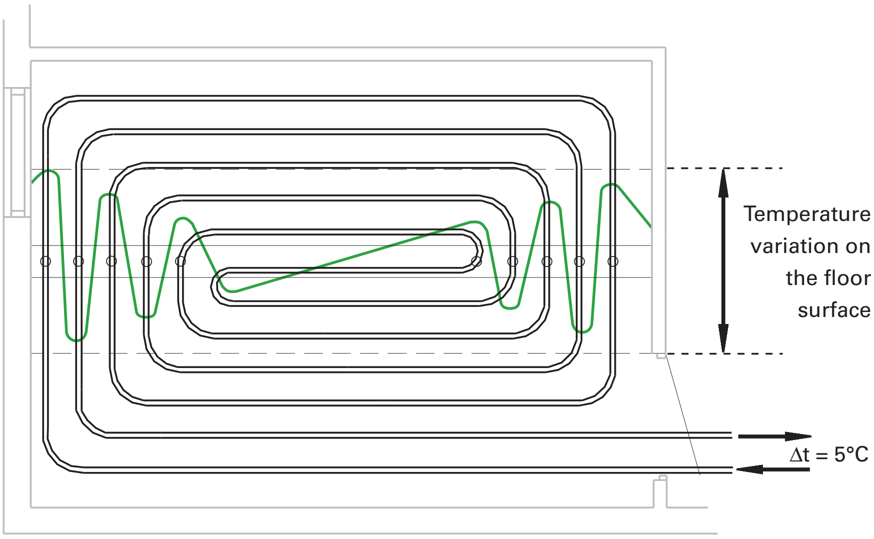


Figure 22 Configuration C, supply and return pipes in a parallel run: helical arrangement

This configuration is basically a variation of configuration B, but is shaped as a spiral.

Configuration C is suitable for housing with a higher heat demand. It is less suitable for installation in wooden floor structures.

This configuration overcomes the rigidity problem encountered in some pipes since there are no sharp bends. It also allows the pipe to be laid at a small pitch.

Pipe size

In this manual Wirsbo recommends the use of Wirsbo-pePEX 20x2.0 mm pipe, which fulfils the requirements for most of the installations. However, using other pipe dimensions might be considered, for example where there are specific requirements for heat output and pressure drop. Practical aspects such as how flexible the pipe is, can also determine the size.

Different pipe sizes require compensatory adjustment to the water temperature. Diagram 1 across shows this relationship by means of a factor.

For example if a 15 mm pipe is to be used instead of a 20 mm pipe, the water temperature has to be increased by a factor of 1.02, i.e. by 2%. It should be borne in mind that in order to keep the water flow constant, the water velocity must also be increased, and that this in turn will cause a substantial increase in the pressure drop.

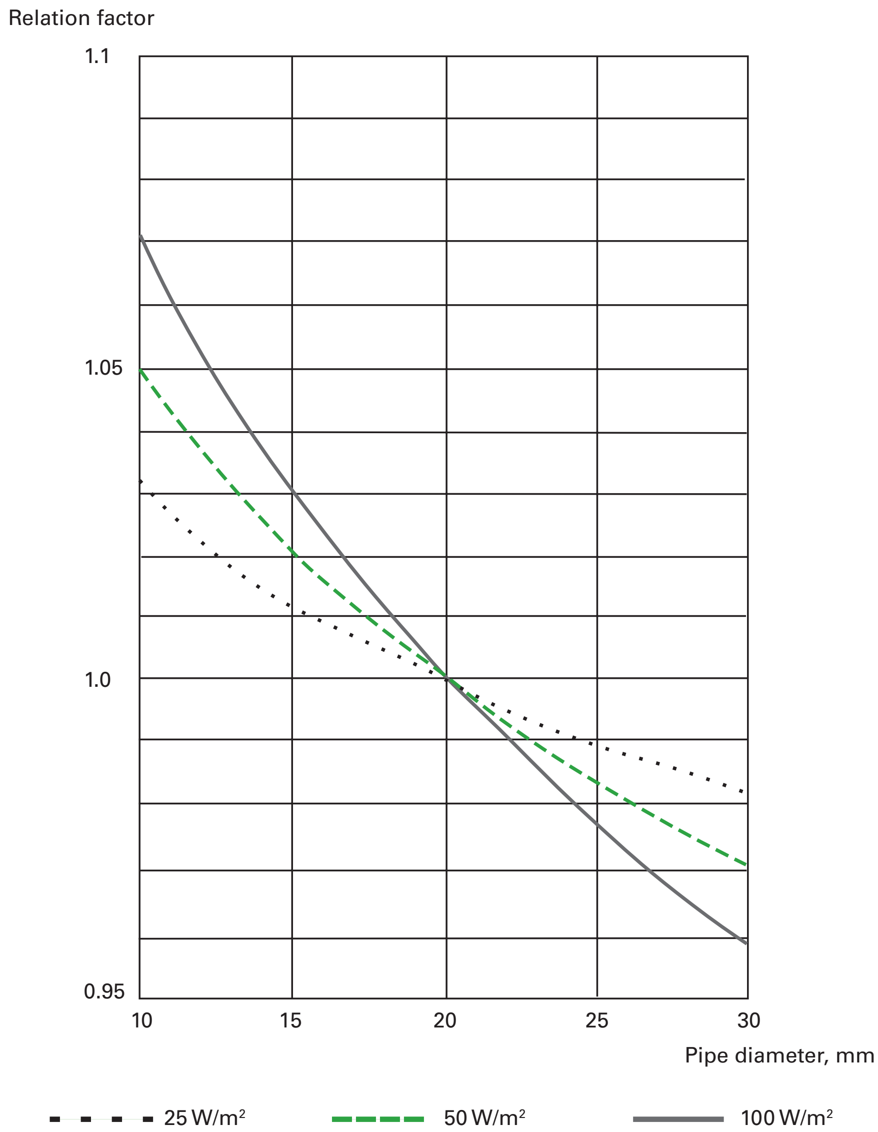


Diagram 1 Water temperature as a function of pipe diameter

Pipe depth

The depth of the pipe is directly related to the water temperature. Diagram 2 below shows this relationship. In a system where the pipe is installed deeper the water temperature must be set higher. However, in a deeper installation the floor temperature will be more even.

In concrete, a depth of 30-70 mm is recommended. If the pipe is installed too close to the surface of the concrete slab the floor temperature may vary too much. On the other hand, if the pipe is installed deep within the concrete slab, part of the heat energy will be stored. This situation will then increase the response time.

Note

- In installations where the material above the pipe has lower thermal conductivity (wood), the pipe can be positioned closer to the surface.
- When setting pipes in concrete it is important to prevent air pockets, which can impair the transfer of heat to the concrete, from forming around the pipes.

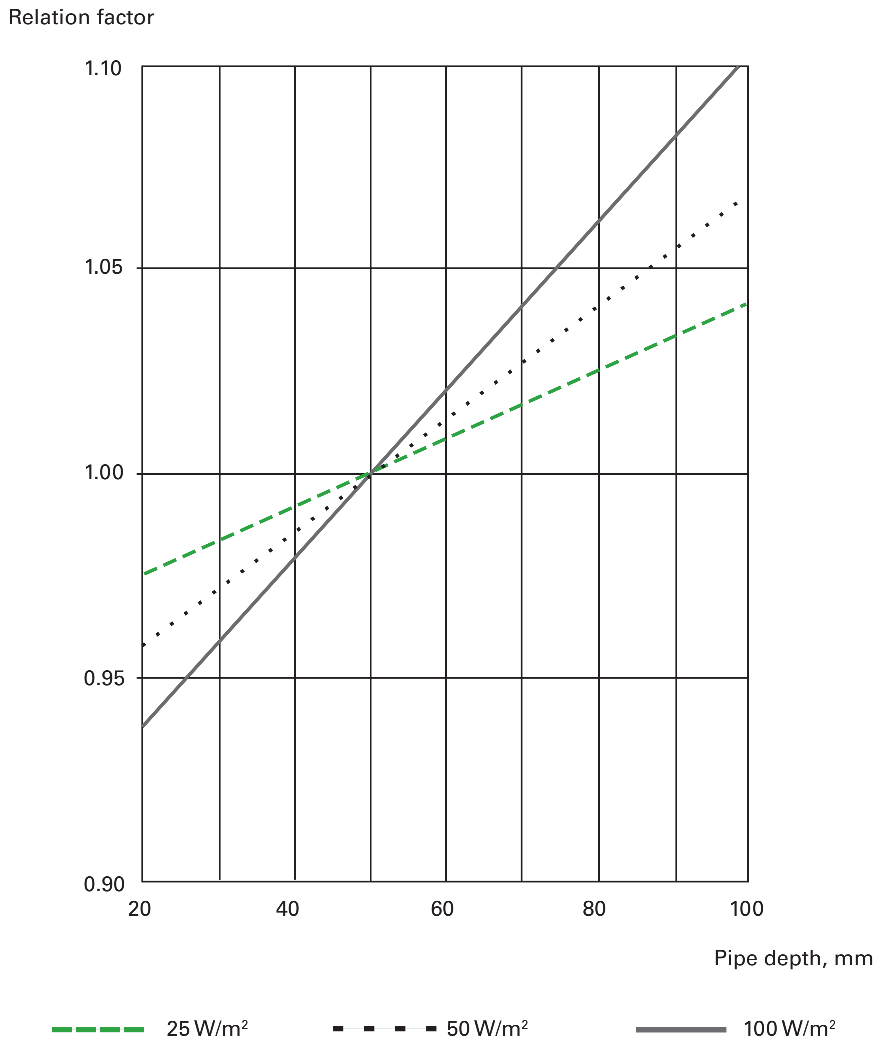


Diagram 2 Water temperature as a function of pipe depth

Pipe pitch

From both an economic and a technical standpoint, a pipe pitch (the centre distance between the respective pipe lengths in the loops) of 300 mm is the most suitable for the best underfloor heating system design and installation. This pipe pitch is common in Scandinavian underfloor heating installations.

One important factor determining the pipe pitch is the temperature variation on the surface of the floor. Studies on human beings show that a naked human foot cannot detect a temperature variation of less than 2°C. A pipe pitch of 300 mm for configuration A above, set in concrete at a pipe depth of a minimum of 30 mm, keeps the temperature within the range where the human foot cannot detect any variation in the floor temperature.

There are three main variables for the design of underfloor heating; heat demand, water temperature and pipe pitch. Heat demand is of course the determining variable. In order to simplify the design calculations, either water temperature or pipe pitch can be kept constant.

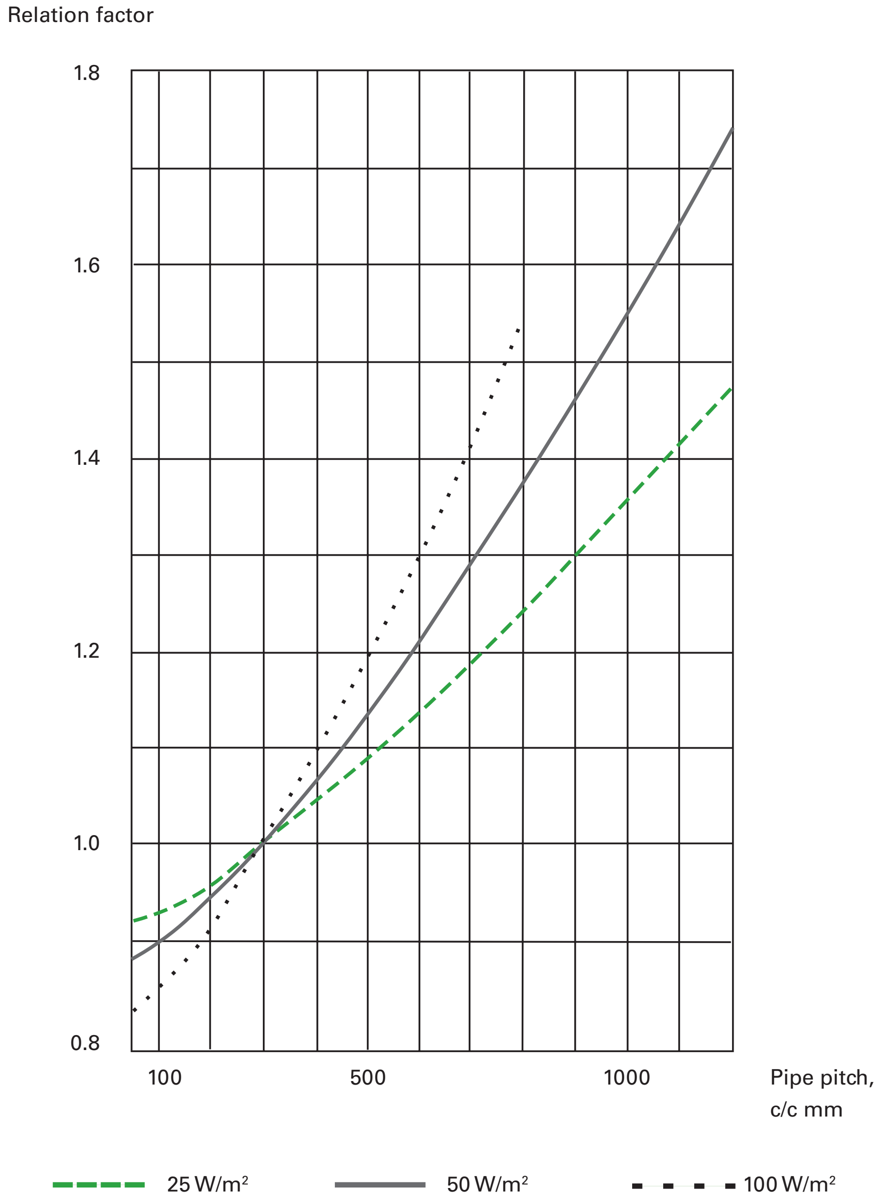


Diagram 3 Water temperature as a function of pipe pitch

a) Constant water temperature

If the supply water temperature is kept constant, there is a theoretical implication that different pipe pitches will balance the temperature inequalities. However, pitch modification will only succeed in altering temperatures to a certain extent. Thus in houses with different floor structures, for example with a concrete ground floor and a wooden suspended first floor, where the difference in the water temperature required for each floor may be over 15°C, it is difficult to compensate for the difference solely by altering the pipe pitch.Therefore systems with a water source at a constant temperature are mainly used where a heated floor functions as a secondary system and/or where supply water is only available at one temperature: for example when waste heat sources or heat pumps are used for underfloor heating.

Not only is this principle limited in application, but also the technician is greatly disadvantaged by having to deal with different pipe pitches during installation. Another drawback meanwhile becomes obvious when a floor covering is replaced by a different one, for instance with a change from tiles to wall-to-wall carpet: the pipe pitch cannot be easily changed to compensate the alteration in heat transfer.

b) Constant pipe pitch

Keeping the pipe pitch constant will necessitate different water supply temperatures. However, the design work (drawings etc.) and the installation will be easier. The installing technician has only one pipe pitch to work with and the water temperature can be easily adjusted afterwards.

It should however be kept in mind that there are limitations on the water temperature (see ”Floor temperature” above and ”Water temperature” chapter 4). In the cases where a higher temperature system might be installed, a different pipe pitch and loop configuration must be considered.

When the circuit is designed with a pipe pitch other than 300 mm, the water temperature must be altered in order to achieve the same heat output. See diagram 3 above. For example if the pipe pitch is 400 mm instead of 300 mm, a water temperature increase of 10% would be required. A pipe pitch of 100 mm on the other hand would require a reduction of the water temperature by just 10%. However, note that more pipes would then be required to cover the same area, making the installation more costly.

Forces of expansion and contraction

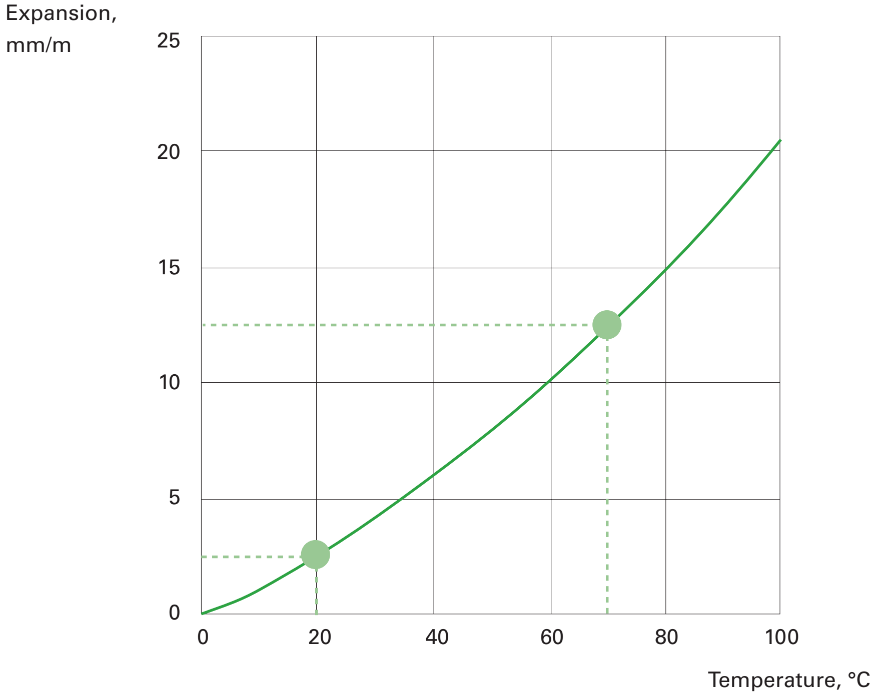


Diagram 4 Thermal expansion, longitudinal

Thermal expansion

In underfloor heating installations where Wirsbo-pePEX 20x2.0 mm and Wirsbo-evalPEX ≤ 25x2.3mm are used, the thermal expansion forces are negligible. Longitudinal expansion cannot take place when Wirsbo pipes are embedded in concrete although transversal expansion will result in a slight increase in wall thickness. This means that the pipes will not damage concrete, causing cracks for example, as in the case of metal pipe systems.

In general

The maximum force of expansion will occur when a fixed pipe is heated to its maximum operating temperature of 95°C. The maximum force of contraction, on the other hand, will be the sum of the thermal contraction and the longitudinal shrinkage of the pipe, when it has been installed in a fixed position at the maximum operating temperature. The remaining force of contraction in the pipe at installation temperature is caused by longitudinal shrinkage when a fixed pipe has been under maximum operating pressure and temperature for some time. For further information see table 10 in chapter 8.

Location of the manifolds

Careful consideration should be given to the location of the manifolds at the initial stage of the project. Manifolds should be located as near to the centre of the building as circumstances allow, so that the length of the pipe running between the manifolds and the individual heating zones is kept to a minimum. This will help to balance the system and improve the temperature control of the individual rooms. They should also be positioned so that maintenance can be easily carried out thus helping to minimize any water damage during maintenance. The aesthetics are a minor issue since the manifolds should be concealed, for example within walls.

Chapter 4

Calculation methods

Practical issues

A complete underfloor heating installation design includes:

- Specification of the material required
- A pipe layout drawing
- Technical information regarding pressure drop, water temperature and settings for balancing the pipe loops.

The design can be done manually (see calculation example in chapter 5).

The first step before beginning on the design and calculations is to check that all necessary information is at hand. There should be:

- A legible, simplified plan of the building, indicating the scale.
- Details of the heat demand (W/m^2).
- An indication as to where the boiler is placed in the building and of the location of risers or branches within the construction.
- Practical items such as a measuring wheel, a device to measure distances in drawings, and a template to draw the pipe loops.

The location of the manifolds should be given first priority, (see previous chapter). Manifolds can be located in a wardrobe or a box-room, below a sink or recessed in a wall with a cupboard cover. In public buildings a lockable steel plate cabinet can be used. The principle is to assign one pipe loop to each room. Larger rooms might require 2 or more loops. One thermostat can control up to 5 loops and manifolds can serve as many as 10-12 loops. However, in normal-size houses it is more practical to limit this figure to 6-8 loops.

With regard to the floor structure, applicable national regulations and standards regarding drainage, vapour barriers etc. must be observed. In houses built on a concrete slab the insulation should be increased by 80 mm in order to reduce the downward heat loss. The thickness of the insulation must be homogeneous over the whole area. Suspended floor structures should also be insulated (for further details regarding insulation requirements, see previous chapter).

In all cases instructions supplied by the manufacturer of the floor covering material should be followed.

Design criteria

This manual assumes the following design criteria :

- An inside air temperature of 20°C
- A heat requirement for the house <100 W/m^2, excluding downward loss (to limit the floor temperature to 29°C)
- A temperature drop across the pipe loop of approx. 5°C
- A loop configuration of type A (see previous chapter)
- A pipe pitch of 300 mm
- Pipe loops consisting of Wirsbo-pePEX pipes (20x2.0 mm)
- Wirsbo-evalPEX pipes as supply pipes.

Energy requirement (q-value)

Climatic conditions and construction techniques in Scandinavia normally require a maximum q-value of 50 W/m^2 (heat flow density) in order to obtain an indoor temperature of 20°C. The low energy requirement is a result of the excellent thermal insulation of Scandinavian buildings (triple-glazed windows etc.). This can often be used in calculations in countries where milder climates exist. However, it is nonetheless practical to calculate for a q-value of 100 W/m^2, which covers the energy requirement of most applications and gives a floor temperature of 29°C, the maximum comfortable floor temperature.

Note that the relationship between q-value and floor temperature is independent of any underfloor heating design variables such as water flow, water temperature, pipe pitch, pipe depth, pipe size and loop configuration (see section below entitled "Heat exchange coefficient, floors").

Calculating for a q-value of 100 W/m^2 as opposed to a q-value of 50 W/m^2 does not influence the amount of material (the number of pipe loops) required for the installation. This means that design work is made somewhat easier because the list of materials required will be the same regardless of the q-value. Rather the parameters that will vary according to the size of the q-value are the water flow, which in turn determines the size of the supply pipes, the pump size or the setting of the pump, and the water temperature, which determines the supply water temperature setting.

The q-value is the result of the following calculation:

$$q\text{-value} = \frac{P}{A_{floor}} \; W/m^2$$

P = Heat requirement, W

A_{floor} = Floor area, m^2

In general P, the heat requirement, depends on the design of the building itself and is required in calculations whatever the type of heating system to be selected. As such it is a standard consideration in the design process. However when discussing heating systems, it is useful to understand some of the factors involved.

The general formula for calculating P is:

$$P = \Delta T \times (U_c \times A_c + U_f \times A_f + ... + U_w \times A_w + V \times C_p \times \rho \times n \times \frac{1000}{3600})\; W$$

(c = ceiling, f = floor,....., w = wall)

ΔT = $T_i - T_o$, °C
T_i = Dimensioning indoor temperature , °C
T_o = Dimensioning outdoor temperature, °C
U_c = Overall heat transfer coefficient for surface c, W/m^2 K
A_c = Area of surface c, m^2
V = Volume of the air in the building/room, m^3
C_p = Specific heat of air at constant pressure for 1 m^3, kJ/ kg K approx 1.0 kJ/ kg K (1 J = 1 Ws)
ρ = 1.20 kg/m^3 for air at 20°C
n = Air exchange rate, times/hour

Example:

Calculate the q-value of the following house:

Given data:
Design criteria as above plus the following

Length	=	10 m	U_c	=	0.2 W/m²K
Width	=	10 m	U_f	=	0.3 W/m²K
Height	=	2.5 m	U_w	=	0.3 W/m²K
A_{floor}	=	10 x 10 = 100 m²	U_{window}	=	2.0 W/m²K
V	=	100 x 2.5 = 250 m³	U_{door}	=	1.0 W/m²K
n	=	0.5 times/hour	$A_{windows}$	=	25 m²
T_i	=	20°C indoor	A_{doors}	=	4 m²
T_o	=	-20°C outdoor			

Calculation:

P = (20 + 30 + 21.3 + 50 + 4 + 41.7) x 40 = 167 x 40 = 6680 W
(ceiling + floor + wall + windows + doors + ventilation) x temperature difference

$U_c \times A_c$	= 0.2 x 100	=	20	12.0%
$U_f \times A_f$	= 0.3 x 100	=	30	18.0%
$U_w \times A_w$	= 0.3 x ((10+10+10+10) · 2.5 - 25 - 4)	=	21.3	13.0%
$U_{windows} \times A_{windows}$	= 2.0 x 25	=	50	30.0%
$U_{door} \times A_{door}$	= 1.0 x 4	=	4	2.3%
$\frac{V \times C_p \times \rho \times 1000 \times n}{3600}$	$= \frac{250 \times 1.2 \times 1000 \times 0.5}{3600}$	=	41.7	24.7%
		=	167	100.0%

$$\text{q-value} = \frac{P}{A_{floor}} = \frac{6680}{100} = 67\ \text{W/m}^2$$

Comment:

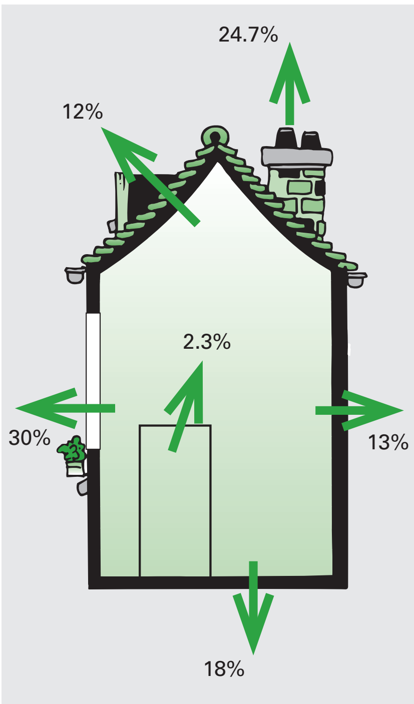


Figure 23 Heat loss distribution

It is interesting to note the percentage of heat loss in the house. The windows account for only 8% of the total area but are responsible for 30% of the total heat loss.

Heat loss distribution may vary depending on the type of heating system used. For example radiator and convection based systems have the highest room temperature close to the ceiling (see figure 4) thus causing higher ventilation heat loss. This is sometimes corrected by employing an additional heat pump or heat exchanger to extract heat from the outgoing air.

Underfloor heating systems have a greater heat loss in the floor structure (see figure 3). This can be corrected with additional insulation underneath the floor (see section on insulation requirements in previous chapter and also section on downward heat loss later in this chapter).

Heat exchange coefficient, floors

The heat exchange coefficient of a floor, α_{floor}, is 10 - 12 W/m²K. α_{floor} has two elements, radiation and convection, each one accounting for approximately 50% of the total α_{floor}.

The following formula can be used to calculate the mean floor surface temperature:

$$\Delta T_\alpha = t_{floor} - t_i = \frac{q\text{ - value}}{\alpha_{floor}}$$

Example:

Calculate the floor temperature of a house with a q-value of 63 W/m².

Given data:
Design criteria as above plus the following:

q-value	=	63 W/m²
α_{floor}	=	11 W/m²K
t_i	=	20°C

Calculation:

$$t_{floor} = 20 + \frac{63}{11} = \mathbf{25.7°C}$$

(Note that this figure should not exceed the maximum floor temperature, see section ”Floor temperature” in previous chapter.)

$\Delta T_\alpha = (t_{floor} - t_i)$ can be read in diagram 5 below. This diagram takes into consideration the nature of the floor surface i.e. whether the surface is smooth (tiles) or not (wall-to-wall carpet). The diagram for smooth surfaces is in line with the standard DIN 4725. The temperature drop, ΔT_α, is approximately **5.7°C**, which can be added to t_i = 20°C. Thus the floor temperature would be 20 + 5.7 = **25.7°C**.

Example

$\Delta T_\alpha \approx 5.7°C$

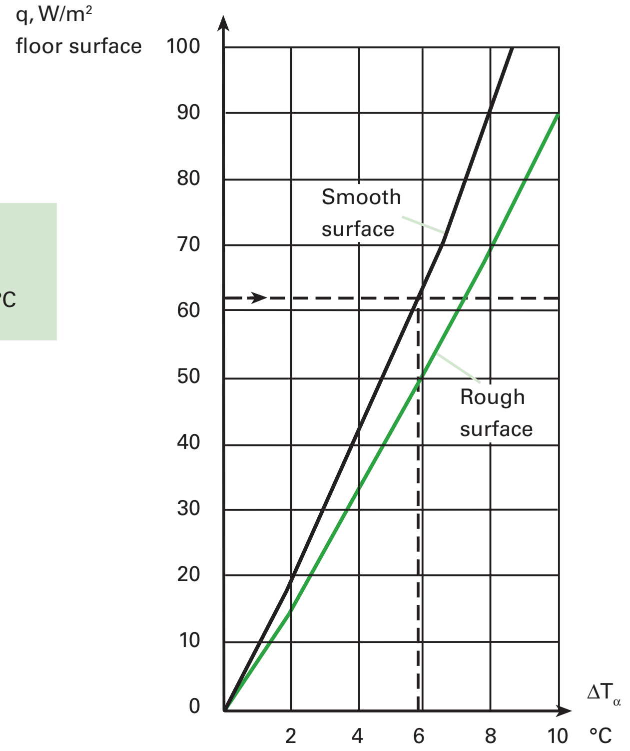


Diagram 5 Heat exchange, floor surface

Heat transfer value, floor covering

The type of floor covering material as well as its thickness will have an effect on the temperature drop through this layer. The heat transfer value can be calculated according to following formula:

$$\frac{1}{R} = \frac{\lambda}{d}$$

R = heat conduction resistance, m^2K/W
λ = thermal conductivity, W/mK
d = thickness, m

Example 1:
Calculate the heat transfer value 1/R for a parquet floor.

Given data:
Design criteria as above plus the following:

λ = 0.13 W/m K
d = 13 mm

Calculation:

$$\frac{1}{R} = \frac{0.13}{0.013} = \mathbf{10\ W/m^2K}$$

Temperature drop through floor covering
The temperature drop through the floor covering can be read from diagram 6 below.

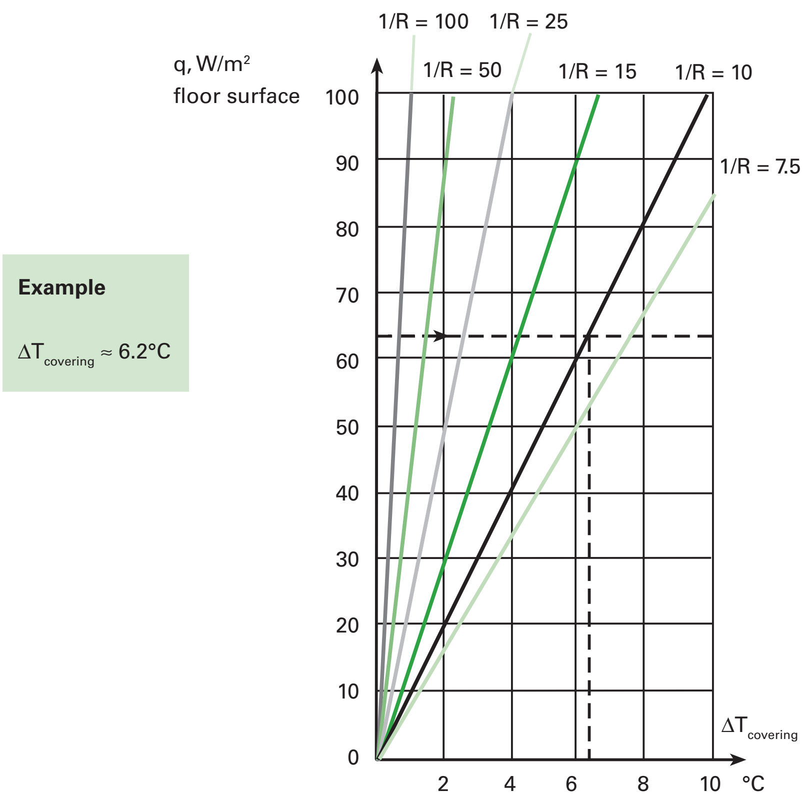


Diagram 6 Temperature drop through floor covering material

Example 2:
Calculate the temperature drop through a floor covering.

Given data:
Design criteria as above plus the folllowing:

$\frac{1}{R}$ = 10 W/m²K

q-value = 63 W/m²

Calculation:
The temperature drop through the floor covering at q-value = 63 W/m² and 1/R = 10 W/m²K can be read from diagram 6 above. The temperature drop is approximately **6.2°C**.

Floor structure

Underfloor heating pipes can be installed in different types of floor structures as described in the sections at the beginning of the previous chapter.

The temperature drop through these floor structures can be read in diagram 7 below, where:

Curve A applies for concrete screeded floors*
Curve B applies for floating floors with 16 mm chipboard **
Curve C applies for wooden suspended floors with 22 mm chipboard **

*) Concrete covering over the pipe 30 to 70 mm
**) 80 % of the floor area covered by aluminium heat diffusion plates

Example:
Determine the temperature drop through a concrete screeded floor.

Given data:
Design criteria as above plus the following:

Concrete floor covering = 40 mm
q-value = 63 W/m²

Solution:
From diagram 7, curve A, a temperature drop, $\Delta T_{structure}$, of approximately 3.2°C can be read.

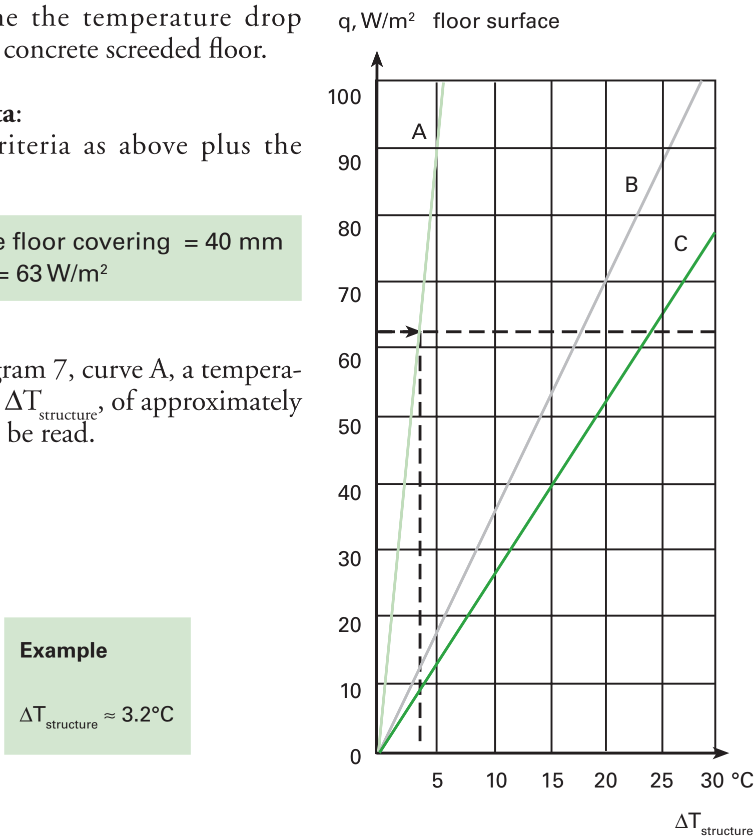


Diagram 7 Temperature drop in different types of floor structure

Water temperature

The temperature of the water in the underfloor heating pipes is determined by the room temperature that must be obtained at a certain q-value. This temperature is the mean water temperature.

Underfloor heating systems are normally designed for a temperature drop across the pipe loop of 5°C. This can be expressed as $\Delta T_{loop} = t_{supply} - t_{return} =$ 5°C. A low temperature drop through the pipe loop provides an even floor temperature.

ΔT_{loop} = 5°C means that the supply water temperature is calculated by adding 2.5°C to the mean water temperature and the return water temperature is calculated by subtracting 2.5°C from the mean water temperature.

Example:
Calculate the mean, supply and return water temperature of a house.

Given data:
Design criteria as above plus the following:

ΔT_{loop} = 5°C
q-value = 63 W/m^2
t_i = 20°C
Type of floor covering = parquet, 13 mm thick
Type of floor structure = concrete screeded floor (covering over the pipe, 40 mm)

Calculation:

Mean water temperature, $t_{mean} = t_i + \Delta T_a + \Delta T_{covering} + \Delta T_{structure}$
ΔT_α = 5.7°C, see diagram 5
$\Delta T_{covering}$ = 6.2°C, see diagram 6
$\Delta T_{structure}$ = 3.2°C, see diagram 7

t_{mean} = 20 + 5.7 + 6.2 + 3.2 = **35.1°C**
Supply water temperature, $t_{supply} = t_{mean}$ + 2.5 = 35.1 + 2.5 = **37.6°C**
Return water temperature, $t_{return} = t_{mean}$ - 2.5 = 35.1 - 2.5 = **32.6°C**

Water flow

The water in the underfloor heating system must flow in order to convey heat to the floor. The size of the water flow is determined by the amount of heat to be conveyed and the designed water temperature drop.

The water flow for an installation can be calculated with the following formula:

$$Q = \frac{P \times 0.86}{\Delta T_{water} \times 3600}$$

Q = Water flow, l/s
P = Heat requirement, W
ΔT_{water} = $t_{supply} - t_{return}$, °C

Example 1:
Calculate the water flow for the pump of the underfloor heating system in a house.

Given data:
Design criteria as above plus the following:

Heat requirement = 6304 W
ΔT_{water} = 5°C

Calculation:

$$Q = \frac{6304 \times 0.86}{5 \times 3600} = 0.30 \text{ l/s}$$

Rooms will vary in size according to the interior design of a house. Heat requirement will be proportional to the area of each room and pipe loops will vary in length accordingly. Normally the room which is the largest will have the highest flow. Heat requirement may also vary depending on the location of the room and the number of outer doors and windows.

Example 2:
Calculate the water flow of the different rooms in a house.

Given data:
Design criteria as above plus the following:

P = 6304 W
ΔT_{water} = 5°C
A_{house} = 100 m²
$A_{room1 ...8}$ = 20, 15, 12, 10, 15, 7, 8, 13 m² (100 m²)
$P_{room1.....8}$ = 1260, 946, 756, 630, 946, 442, 504, 820 W (= 6304 W)

Calculation:

$$Q_{room1} = \frac{P_{room\ 1} \times 0.86}{\Delta T_{water} \times 3600} = \frac{1260 \times 0.86}{5 \times 3600} = \mathbf{0.06\ l/s}$$

$Q_{room2.....8}$ = **0.045, 0.036, 0.03, 0.045, 0.021, 0.024, 0.039 l/s** (= 0.24 l/s)

Note:
The minimum water velocity required in order to drive air bubbles varies with the pipe size. In an underfloor heating system using a Wirsbo-pePEX pipe of 20x2.0 mm, the water velocity must exceed **0.2 m/s**. However, in a house where there are small rooms requiring a low water flow, which results in a low water velocity, special consideration should be given to the filling instructions in chapter 6.

The water velocity can be calculated in the following way:

$$v = \frac{Q}{V_{pipe}}$$

v = Water velocity, m/s
Q = Water flow, l/s
V_{pipe} = Water volume per metre, l/m (0.197 l/m for Wirsbo-pePEX 20x2.0 mm; for other dimensions please see the Wirsbo-PEX brochure)

Pressure drop

In order to dimension the pump capacity for the underfloor heating system, information on total pressure drop and flow must be available. The water flow can be obtained as shown in the section above.

The total pressure drop can be obtained by adding the pressure drop across:

1. The underfloor heating pipe loop(s)
2. The manifold(s)
3. The supply and return pipes
4. The boiler, valves etc.

Example:
Calculate the required pump capacity for an underfloor heating installation in a house.

Note:
The valve chart (diagram 8) used in calculation examples in this manual has been invented purely to illustrate and simplify calculations. Thus it should **not** be used for practical application.

For actual calculations it is essential to use the relevant diagrams for the particular manifolds in use.

Given data:
Design criteria as above plus the following:

Total water flow, Q = 0.3 l/s
Length of supply and return pipes, L = 10 m
Suitable pressure drop in supply and return pipes = 0.2 kPa/m
Water flow in the longest pipe loop = 0.06 l/s
Longest pipe loop length = 70 m

Calculation:

Pressure drop in the longest pipe loop can be read from diagram 9, selecting parameters 0.06 l/s and 70 m = 0.085 x 70 = **5.95 kPa**
Pressure drop in the valves (manifolds) can be read from diagram 8, selecting parameter 0.06 l/s, valves fully open = **3.0 kPa** (see note)
Pressure drop in the supply and return pipes is obtained by multiplying 10 m by 0.2 kPa/m = **2 kPa**
The total pressure drop = 5.95 + 3.0 + 2.0 = **10.95 kPa**
The required pump capacity data for this installation is: **Q = 0.3 l/s**
p = 10.95 kPa

Note that pressure drop in the boiler, valves etc is not included in this calculation.

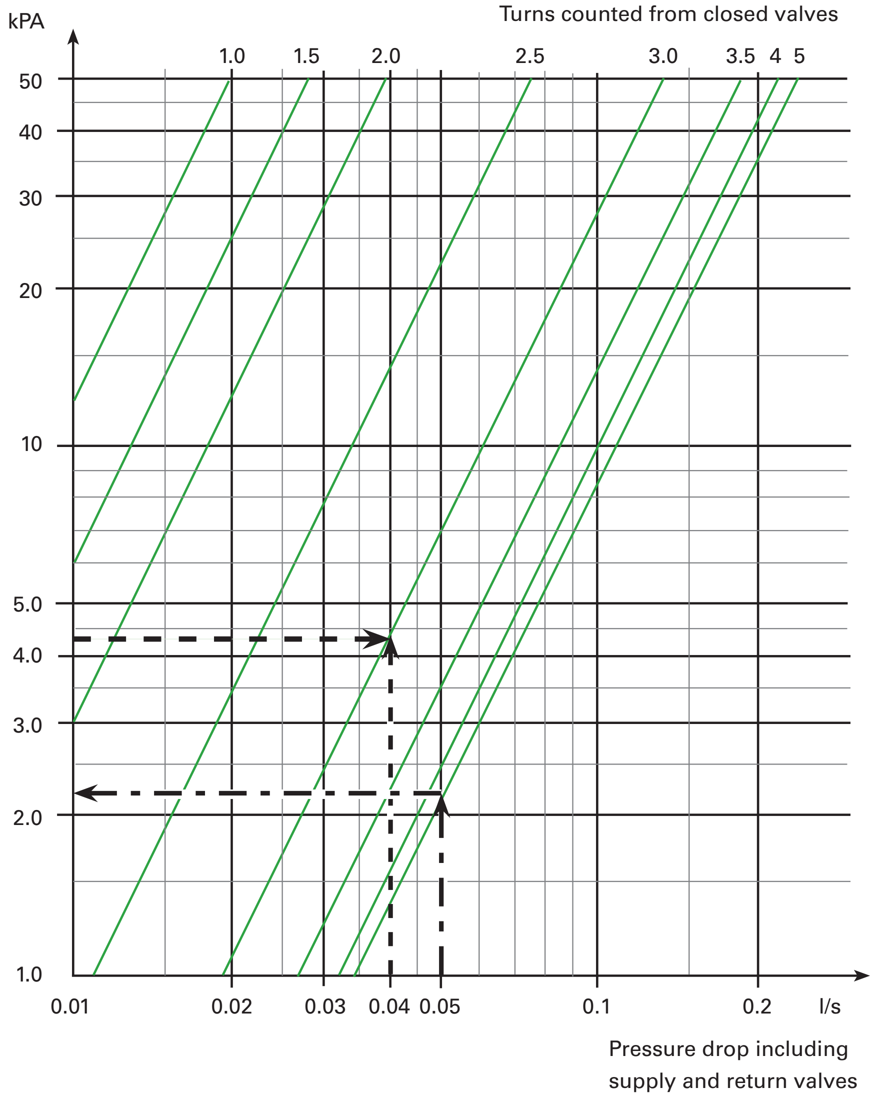


Diagram 8 Manifold valve chart

Balancing of loops

An installation with different pipe loop lengths and water flow requirements will have different pressure drops for the different loops. In order to achieve an even heat distribution between the rooms at the installation stage the pressure drop in the different loops must be balanced (equalised).

In the Wirsbo Underfloor Heating System this can be done by means of the lockshield valves in the return manifold.

Example:
Calculate the setting of the lockshield valves in the return manifold of a Wirsbo Underfloor Heating System installation.

Given data:
Design criteria as above plus the following:

Loop length in room 1....8	=	70,	53,	42,	35,	53,	26,	30,	46	m
$Q_{room1.....8}$	=	0.060,	0.045,	0.036,	0.030,	0.045,	0.021,	0.024,	0.039	l/s
Pressure drop loop 1.....8	=	5.25,	2.39,	1.30,	0.77,	2.39,	0.29 ,	0.45,	1.61	kPa

Calculation:
The longest loop (room 1) has a flow rate of 0.06 l/s. The pressure drop across the manifold can be read from diagram 8. This is 3.0 kPa including the pressure drop across the supply and return manifold with fully open valves. The total pressure drop over the longest loop and the valves in the manifold is then 5.25 + 3.0 = 8.25 kPa.

Room no	Length loop m	Flow loop l/s	Pressure drop loop kPa	Pressure drop valve kPa	Sum kPa	Diff*	Valve** setting
1	70	0.06	5.25	3.0	8.25	3.0	5.0
2	53	0.045	2.39	1.75	4.14	5.86	3.0
3	42	0.036	1.30	1.1	4.40	6.95	2.7
4	35	0.03	0.77	<1.0	<1.77	7.48	2.5
5	53	0.045	2.39	1.75	4.14	5.86	3.0
6	26	0.021	0.29	<1.0	<1.29	7.96	2.2
7	30	0.024	0.45	<1.0	<1.45	7.80	2.3
8	46	0.039	1.61	1.3	2.91	6.64	2.8

Table 1 Valve settings

*) Read off the highest value in the sum column. This is 8.25 kPa. Subtract the relevant figures in the column ”Pressure drop loop” from 8.25 kPa. This gives the pressure difference.

) The valve setting can be read in diagram 8. For room 1 the valve is completely open i.e. 5 turns. For the other rooms the valve settings are obtained by using the values in columns ”Flow loop” and ”Diff”. For instance for room 5 the loop flow is 0.045 l/s and the pressure difference is 5.86 kPa and gives 3.0 turns from the **closed valve.

Downward heat loss

The downward heat loss in a house will increase when an underfloor heating system is installed because the floor itself is warmer, unless extra insulation in the floor structure is added.

The type of floor structure material and its thickness have an effect on the heat loss. Another factor is the temperature difference (water temperature minus underneath temperature) through the floor structure.

Normally, an additional floor insulation of 80 mm is sufficient to correct the downward loss (see chapter 3 above). Further details can be found in Chapter 9, Appendix.

Expansion volumes

In underfloor heating systems, the demands on expansion vessels do not differ from other systems.

The water volume in the Wirsbo Underfloor Heating System can be calculated as follows:

$V = V_{pipe} \times L$
V = water volume in the underfloor heating pipe, l
V_{pipe} = approximately 0.2 l/m in Wirsbo-pePEX 20x2.0 mm
L = total pipe length, m = approx. 3.5 m/m^2 at c/c 300 mm

The water volume per m^2 according to the above figures will be approximately 0.7 l/m^2. The water volume in supply pipes and boiler must be included when selecting the expansion vessel.

The expansion coefficient of water is 1.8×10^{-4}/K at 20°C.

Pump group

Pump and shunt groups are normally required to provide the correct water temperature and pressure in the underfloor heating system. Underfloor heating systems operate with a low temperature drop and need to be adapted to different heat sources.

The Wirsbo Underfloor Heating System can be provided with pump and shunt groups.

List of materials

An accurate list of materials required for the Wirsbo Underfloor Heating system should be made when designing the installation. The length and dimension of supply pipes (Wirsbo-evalPEX) depend on the specific design of the building. However the rest of the system can be estimated as follows:

Pipe loops	Wirsbo-pePEX 20x2.0 mm. Theoretical length 3.33 m/m² (pitch 300 mm). Generally however 3.8 m/m² are required, but including the supply pipe from the manifold as well as wastage, approximately 4,2 m/m² are needed
Tying wire	2 lengths/pipe metre (a pack contains 250 lengths)
Pipe bend supports	2 supports/loop
Plastic pipe holder band	2.2 bands/m²
Pipe clips	2 clips/pipe metre (7 clips/m² at c/c 300 mm)
Insulation band	For screeded floors. Should be fixed around all walls and pillars before the screed is poured
Heat diffusion plates	Approx. 2.5 lengths/m². The plates are 1.15 m long and can be halved or sectioned in 3 or 6 equal-size pieces as appropriate. (One way of estimating the number of plate lengths required is to calculate how many 1/6 plates are needed per pipe length.)
Wirsbo polystyrene panels	With grooves for the heat diffusion plates and pipes. Size (where available) 1200x1200 mm = 1.44 m² i e 0.7 panels/m². Calculate for 10-20% wastage Thickness 30 mm, 10 panels/package Thickness 50 mm, 6 panels/package Thickness 70 mm, 4 panels/package
Manifolds	A maximum of 10-12 loops/manifold. Manifolds with two, three or four outlets should be combined as required. When using more than one manifold, it may prove more cost-effective to wire between the manifolds rather than using extra transformers. For every manifold there should be: - A pair of manifold brackets - A pair of shut-off valves - A pair of end caps
Room temperature control	1 room thermostat/actuator, or in large rooms with several loops a maximum of 5 actuators/room thermostat 1 actuator/loop 1 connection box/manifold (maximum 12 loops) 1 transformer/maximum 15 loops (actuators)

Table 2 Estimation values for accessories

Chapter 5
Calculation example

An object of study

In the following example an underfloor heating installation will be installed in the house shown below.

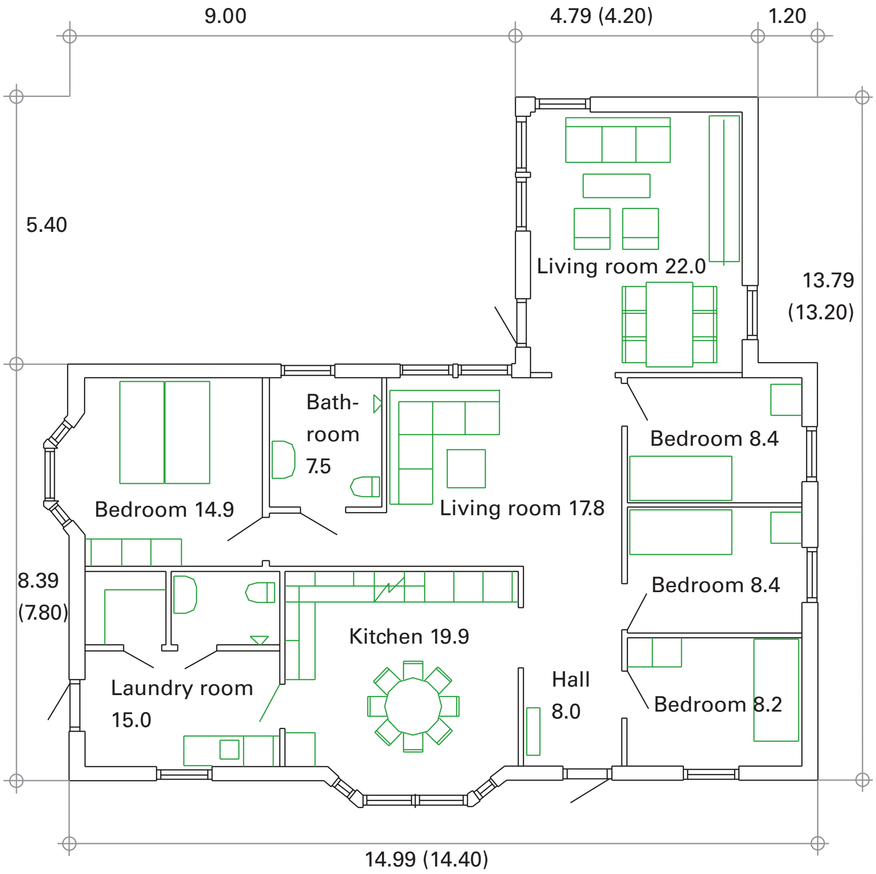


Figure 24 House: architect's drawing

The material needed for the installation will be specified and the mean water temperature, the set values for balancing the pipe loops and the pump capacity will be calculated.

Note
It is **important** that the drawings of the house indicate the measurements, especially if the drawings are to be photocopied or sent by telefax since this type of equipment distorts the scale of the drawing.
The drawing should show the room layout of the house, preferably on each floor level.

Given data:
Design criteria as in chapter 4 above plus the following:

Table 3 Design criteria

Heat requirement :	9950 W
Area of the house:	133 m² (habitable area)
Floor structure:	Concrete
Method of fixing the pipes:	See chapter 3, "Embedded pipe..."

Room	Type	Area, m²	Floor covering material
L 11	Living room	22.0	Parquet
L 12	Bedroom	8.4	Wall-to-wall carpet
L 13	Bedroom	8.4	Wall-to-wall carpet
L 14	Bedroom	8.2	Wall-to-wall carpet
L 15	Kitchen	19.9	Tiles
L 16	Hall	8.0	Tiles
L 17	Living room	17.8+2.5	Tiles
L 21	Laundry room	15.0	Tiles
L 22	Bedroom	14.9	Wall-to-wall carpet
L 23	Bathroom	7.5	Tiles
		≈ **133**	

Table 4 Summary

Calculation:

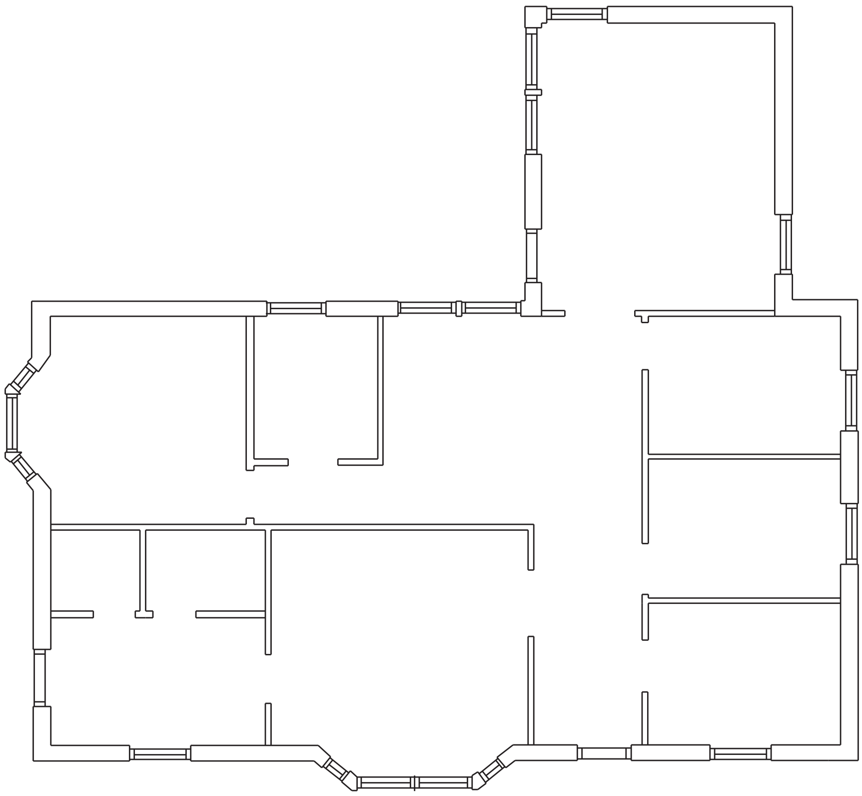


Figure 25 Simplified house drawing

Step 1 - Complete the drawings according to figures 25 and 26

In figure 25 the plan of the house has been cleared of unnecessary detail. The basic structure of the heating installation is determined by the location of the manifolds, which should be placed as centrally as possible, (see chapter 3). Note that the supply piping can be located in the floor as well as in the ceiling.

In figure 26 below the pipe loops have been drawn in. Note that the supply flow is routed along the external walls of the house and that the pipe loops run parallel to the longest side of the rooms in order to reduce the number of bends. When drawing the pipe loops begin first in the areas farthest from the manifolds, the better to avoid pipes crossing each other.

Routing the pipes through inner walls should be carefully considered with regard to the construction of the house; where the pipes cannot pass through load-bearing walls, the door opening offers an alternative.

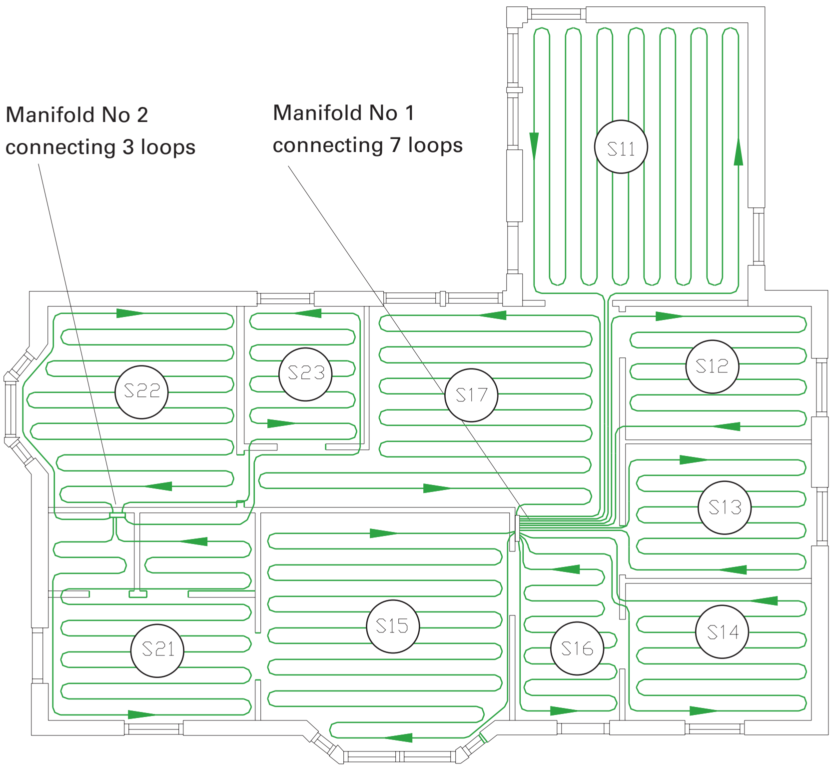


Figure 26 House drawing with pipe loops and manifolds

Very large rooms require more than one pipe loop in order to limit the dimensioning pressure drop of the installation. On the other hand, it might be convenient to combine the pipe loop of a very small room (<5 m²), with low occupancy, with the pipe loop of an adjacent room. However bathrooms, although of small size, should have a separate pipe loop.

Step 2 - Calculate the maximum mean water temperature, max t_{mean}

The q-value for the house will be as follows:

$$\text{q-value} = \frac{P}{A_{floor}} = \frac{9950}{133} = 75\ \text{W/m}^2$$

In order to find the room with the highest mean water temperature, each room must be taken in turn. Reference in each case should be made to diagram 10 in chapter 8.

Beginning with for example room L11, the living room with the parquet floor, and referring to the left of the diagram, first find the required floor surface temperature. Reading off the temperature drop for the q-value of 75 W/m² for a smooth surface (parquet), which is 7°C, and then adding this to the designed room temperature of 20°C, results in a mean floor surface temperature of 27°C.

Next, read off the temperature drop through the parquet in the centre of the diagram. Parquet has an 1/R value of 10 m K/W (see previous chapter "Heat transfer value, floor covering"). At q-value = 75 W/m², the temperature drop is 7.5°C.

Next read off the temperature drop through the floor structure, which is concrete (curve A) on the right of the diagram. At q-value = 75 W/m², the temperature drop is 4°C.

Now calculate the mean water temperature for room L11. This will be:

$$t_{mean} = 27+7.5+4 = \mathbf{38.5°C}$$

Now the values for each room in turn must be calculated. The results in this example are as follows:

Room No	t_{mean} °C
L11	38.5
L12	43.3
L13	43.3
L14	43.3
L15	32.8
L16	32.8
L17	32.8
L21	32.8
L22	43.3
L23	32.8

Table 5 Mean temperature for each room

From the table above the maximum mean water temperature of 43.3°C becomes apparent.

Step 3 Allow for the dimensioning water supply temperature

A figure of 2.5°C must be added to the maximum mean water temperature in order to obtain the dimensioning water supply for the pump (See previous chapter “Water temperature”). Thus this temperature will be:

t_{mean} + 2.5°C = **45.8°C**

Step 4 - Calculate the total water flow

Using the formula in chapter 4, ”Water flow”:

$$Q = \frac{P \times 0.86}{\Delta T \times 3600} = \frac{9950 \times 0.86}{5 \times 3600} = \mathbf{0.47\ l/s}$$

The total water flow is 0.471 l/s.

Step 5 - Calculate the loop length for each room

Room No	Area, m²	Loop length, m		Remarks/length from manifold
L11	22.0	75+13 =	88	2 x 6.5m
L12	8.4	29+10 =	39	2 x 5 m
L13	8.4	29+7 =	36	2 x 3.5 m
L14	8.2	28+10 =	38	2 x 5 m
L15	19.9	68+1 =	69	2 x 0.5 m
L16	8.0	27-2 =	25	Partially covered by another loop
L17	17.8+2.5	69+1 =	70	2 x 0.5 m
L21	15.0	51+1 =	52	2 x 0.5 m
L22	14.9	51+4 =	55	2 x 2 m
L23	7.5	26+9 =	35	2 x 4.5 m
	133		507	

Table 6 Loop length for each room

The lengths of each loop are given above. Note that the total length of each loop includes the length of pipe to and from the manifold. In room L11 for example, this is 75 m + (2x6.5 m) = 88 m. This is in fact the longest loop. However in this case, where the q-value is only 75 W/m², the long loop length should present no problem. Nonetheless it is **most important** to note that when designing with 100 W/m² and with Wirsbo-pePEX 20x2.0 mm, the maximum loop length **should not** be greater than 80 m (approx. 23 m²).

Step 6 - Calculate the pressure drop in the longest pipe loop

The longest pipe loop is 88 m in room L11. The flow in this loop is :

$$Flow_{L11} = \frac{P_{L11} \text{ x } 086}{\Delta T \text{ x } 3600} = \frac{22 \text{ x } 75 \text{ x } 0.86}{5 \text{ x } 3600} = 0.078 \text{ l/s}$$

The pressure drop/m can be read in diagram 9 (chapter 8) for Wirsbo-pePEX 20x2.0 mm. This is 0.14 kPa/m. The pressure drop over the loop will thus be 0.14 x 88 = **12.3 kPa**.

Step 7 - Calculate the pressure drop in the manifold

The highest flow through the manifold is 0.078 l/s. Looking at diagram 8 (chapter 4), the valve chart, with fully open valves the pressure drop will be **5.2 kPa**.

Step 8 - Calculate the pressure drop in the supply pipes

The length of the supply pipe to the manifold from the boiler is 8 m, (supply + return = 8 x 2 = 16 m). The pressure drop/m is 0.2 kPa/m. The pressure drop in the supply pipes will therefore be 16 x 0.2 = **3.2 kPa**

Note

Select the supply pipes (Wirsbo-evalPEX) so that the pressure drop **does not** exceed 0.2 kPa/m.

Compared to metal pipes, Wirsbo-evalPEX can be used at a higher pressure drop/m since higher water velocity does not result in erosion or noticeable noise.

Step 9 - Calculate the total pressure drop in the underfloor heating installation

Using figures obtained in steps 6-8 above:

Pressure drop in the loop	12.3 kPa
Pressure drop in the manifold	5.2 kPa
Pressure drop in the supply pipes	3.2 kPa
	20.7 kPa

The total pressure drop is 20.7 kPa.

Note that we are now in a position to summarise the data required for the selection of the pump in this installation as follows:

Flow	=	0.47 l/s
Head pressure	=	20.7 kPa
Required water temperature	=	45.8 °C

Step 10 - Balance the pressure drop of the pipe loops

When the balancing set values are calculated forms 1 and 2 should be used (for copies see chapter 10).

a) Begin by filling the columns ”**Loop No/Name**”, ”**Loop length**”, ”**Heat requirement**”, ”**Loop flow**”, ”**Pressure drop: Pipe loop, Manifold and Total (D=L+M)**” in form 1. Now ”**Total flow**” and ”**Max D**” can be filled in. Fill in one form for each manifold.

b) Then calculate the value of the pressure drop (S) in the supply pipes from the boiler to the manifolds for each manifold on form 2. The routing of the supply pipes can be divided in sections as shown in the example. Note that it is not necessarily the longest section of piping that has the highest pressure drop.

c) Now fill in the calculated **S-values** in form 1 and calculate **S + Max D**. Compare the value of S + Max D for each manifold, the highest value is the ”**Dimensioning Pressure Drop (A)**”, in this example 18.80 kPa.
d) Next fill in this value in form 2. ”**A**” is the minimum pressure available for the selection of the pump. The flow available for the pump in this example is 0.47 l/s.
e) Then calculate ”**Diff A-S-L**” for each manifold in form 1. The ”**Diff A-S-L**” column provides the required pressure drop values for every loop in order to balance the whole underfloor heating installation.

In order to obtain the correct pressure drop for every loop, the valves of the return manifold must be set. The number of turns from closed position can be read in diagram 8. In this example loop no L11 has the highest pressure drop in the whole installation, thus the valve must be fully open: i e 5 turns. The other loops are then adjusted and throttled, accordingly. For instance, in loop no L14 the pressure drop must be 15.29 kPa. Insert this value and the loop flow of 0.03 l/s in diagram 8. The setting 2.2 turns can then be read off.

Repeat this procedure for all the loops in the installation.

Bringing comfort to life — Uponor — WIRSBO Systems

Manual calculation, balancing set values — Form 1

Project: Basic — Project No: 6
Location: — Date: 1994-02-04
Designed by: MH — Page: 1

Manifold: M1

Loop No/Name	Loop length m	Heat requirement W	Loop flow l/s	Pressure drop kPa: Pipe loop (L)	Manifold (M) (5 turns)	(D) = L + M	Diff A–S–L	Turns
L11	88	1650	0.08	10.56	5.6	16.16	5.60	5.00
L12	39	630	0.03	0.90	0.9	1.80	15.26	2.20
L13	36	630	0.03	0.83	0.9	1.73	15.33	2.20
L14	38	620	0.03	0.87	0.9	1.77	15.29	2.20
L15	69	1490	0.07	6.90	4.2	11.10	9.26	3.30
L16	25	600	0.03	0.58	0.9	1.48	15.59	2.20
L17	70	1520	0.07	7.00	4.2	11.20	9.16	3.30

Total flow l/s: 0.34 l/s — max D: 16.16
Supply pipes, kPa (S): 2.64 — S + Max D: 18.80

Figure 27 Form 1, filled according to the calculation example

Bringing comfort to life — Uponor — WIRSBO Systems

Manual calculation, balancing set values — Form 1

Project: Basic — Project No: 6
Location: — Date: 1994-02-04
Designed by: MH — Page: 2

Manifold: M1

Loop No/Name	Loop length m	Heat requirement W	Loop flow l/s	Pressure drop kPa: Pipe loop (L)	Manifold (M) (5 turns)	(D) = L + M	Diff A–S–L	Turns
L21	52	1125	0.05	2.86	2.2	5.06	14.96	2.65
L22	55	1125	0.05	3.03	2.2	5.23	14.80	2.65
L23	35	570	0.03	0.81	0.9	1.71	17.02	2.20

Total flow l/s: 0.13 l/s — max D: 5.23
Supply pipes, kPa (S): 0.98 — S + Max D: 6.21

Figure 28 Form 1 (continued), filled according to the calculation example

Manual calculation, balancing set values

Form 2

Project: BASIC Project No: 6
Location: Date: 1994-02-04
Designed by: MH Page: 3

Supply piping

From – To	Valve kPa	Flow l/s	Length m (x2)	Dimension	Pressure drop kPa/m	Pressure drop kPa	Pressure drop Sum kPa
M1–T1		0.34	12	32x3.0	0.18	2.16	2.16
M2–T1		0.13	5	25x2.3	0.10	0.50	0.50
T1–B		**0.47**	4	40x3.7	0.12	0.48	0.48
M1–B							**2.64**
M2–B							0.98

Pump data:
Dimensioning Pressure drop **18.80** kPa
Dimensioning Flow **0.47** l/s

Figure 29 Form 2, filled according to the calculation example

Step 11 - List the material for the installation

See Chapter 4 ”List of materials”. In this case the following are required:

Pipes:
Wirsbo-pePEX 20x2.0 mm 540 m

507 m is the nominal pipe length according to the calculation. The standard lengths are 60, 120, 240 and 480 m. A coil of 480 m and a coil of 60 m cover installation requirements.

Table 7 Component list, total

Accessories:

Tying wires	5	packs (507 x 2 / 250 = 4,056 packs)
Pipe bends supports	20	
Insulation band (50 m/roll)	3	rolls
Manifolds 3RWG	2	pairs
Manifolds 2RWG	2	pairs
Manifold brackets	2	pairs
Shut-off valves	2	pairs
End caps	2	pairs
Room thermostats	10	
Actuators	10	
Connection box	2	
Transformer	1	

Chapter 6
Installation

Installation and filling

Manifolds, pipes and fittings
Fix the manifold wall bracket on to the wall. Concealment in a cupboard within a recess in the wall is possible, the installation depth required being about 85mm.

Assemble the manifold and clamp it into position.

Mount a bend support on the supply pipe at the base of the wall beneath the manifold leaving sufficient pipe length for connection to the manifold. Connect the pipe to the manifold and set out the pipe loop in accordance with the layout drawing. Pipe loops should be laid in an orderly manner for neat installation. Mount a bend support on the return pipe in the same way as for the supply pipe. Cut the pipe and connect it to the manifold.

Mark the loop number for identification purposes.

Note the precise length of each loop using the metre markings on the pipe and compare with the layout drawing. A major deviation in length may require an adjustment of the loop balance settings.

Filling
Fill the installation according to the following instructions:

1. Close all valves on the manifolds, both supply and return, as well as shut-off valves.
2. Connect hoses to the two end caps on the manifolds. Connect one of the hoses to the water mains. Run the other hose to a suitable drain.
3. Turn on the water from the mains. Open the end cap valves for the filling and draining of the system.
4. Open the supply and return valves for one loop. Let the water flow through the loop until all the air has been expelled. If the water does not flow through the loop check to see that the pipe is not buckled.
5. Close both valves and repeat the cycle for the other loops, one by one, until all the loops have been filled and bled of air.
6. Open all the valves and carry out pressure testing (3-4 bar). The pressure will drop during the first hours but will then remain steady, as long as there are no leaks and provided that the ambient temperature has been constant.
7. The floor can be finished (concreting, covering with chipboard, parquet etc.) after a final inspection has been carried out to ensure that the system is watertight.

Note:
There is a risk of frost damage to the system when temperatures are below freezing.

Commissioning

Follow these instructions when starting up the system:

1. Once all the pipe loops have been filled, deaerated and pressure tested, close all the loop valves and open the shut-off valves instead.
2. Fill the supply pipes and boiler with water and deaerate.Deaeration can be carried out at the end caps of the manifolds (supply and return). In houses with several storeys begin by deaerating the manifolds located in the basement.

3. Open all the loops and check once more to ensure that they are bled of air as described above. If there is still air in the loops repeat the filling operation.
4. The system is normally put under a pressure of 0.5-1.5 bar. Start up the pump and boiler. Open one loop in the manifold. The temperature should now increase slowly. In a while you should be able to feel the hot water reentering the manifold. Repeat the procedure with all the loops.
   In large installations it is convenient to open **one manifold** and then **one loop in the manifold** at a time. Normally every manifold should be equipped with a shut-off valve.
5. Set the calculated throttling values on the lockshield valves (return valves) for each loop. Count the number of turns from a closed valve (see also chapter 4, ”Balancing of the loops”). This operation is done by means of a 4 mm Allen key. If this procedure is not done thoroughly, the entire heat demand of the house may be covered by just one or two loops.
6. In the case of manual control valves, the water temperature from the boiler must be controlled in order to avoid excessive temperatures. This can be done by an outdoor temperature sensor or by a centrally-located indoor sensor and the relevant control equipment.
   Since underfloor heating is a low-temperature system, the maximum water temperature in wooden suspended floor structures need not be more than about 55°C. This should be even lower in concrete.
   Where the supply water temperature is controlled by a central unit, sensing for instance the outdoor temperature, set a flat response curve on the panel in order to let the system operate within the required range of the heating system.
7. When controlling room temperatures with room thermostats and actuators, the supply water temperature can be kept at a constant level all year round. The heat is sent out in pulses of 5-6 minutes only until the room temperature setting has been reached.
8. It is important that the control equipment at the heat source and the room thermostats work properly and are correctly set, particularly so when the floor covering material is parquet.

Comments

A. Concrete slab

When the underfloor heating installation has been completed and provided that the heat source is already installed, it is possible to run the whole system at the time the concrete slab is poured. However note that until the concrete has cured (this takes about 17 days in a one-family house), the maximum water temperature should be 25°C. After this period the underfloor heating system can be run at the designed temperature.

B. Wooden suspended floor structure

In timber-built houses, local regulations or recommendations regarding the moisture content of the timber should be observed. Manufacturer’s instructions on moisture content in parquet flooring should also be followed. An underfloor heating installation will help maintain the prescribed moisture level.

According to SS-27 23 44 (Swedish Standard) the moisture content should not exceed 10% either in the floor structure as a whole or in the parquet. See chapter 3, ”Wooden suspended floors” and ”Floor covering materials”. (This requirement is not just specific to underfloor heating installations.)

Maintenance

The Wirsbo Underfloor Heating System is in principle maintenance-free and designed to work for many years.

There are however some aspects to consider:

1. The pressure in the heating system should be checked now and again. If the pressure in the system is incorrect, check by means of the deaeration valves that the system has been bled of air. A large air bubble can disturb the circulation.
2. If the system still malfunctions, check for leakage. It may be necessary to tighten couplings.
3. If necessary, the system may need refilling. If the pressure cannot be maintained despite these measures, you must carry out more careful fault tracing and if necessary call in experts to go through the entire system.
   When tracing a fault follow the procedures indicated below.

Fault tracing

1. Check that the installation has been carried out in accordance with Wirsbo's instructions. In particular the loops should have been laid according to the drawing. The heat demand and the type of flooring should also correspond to the drawing specifications.

2. Make sure that the installation has been properly marked. The loops should have been clearly marked and should indicate which room they serve, the better to prevent loops from becoming cross-connected to the manifolds. Ensure that all loops are correctly connected.

3. Check that the hot water temperature to the manifold is correct.
   If not, check the following:
   • The boiler has sufficient capacity
   • All valves are opened
   • The correct circulation pump has been selected and has been set for the right curve
   • The control equipment for the supply water temperature is correctly adjusted.

   Note 1: In the event of long supply pipes running from the boiler to the manifolds, it may be necessary to bypass the manifold so that water circulates in the supply pipes.
   Note 2: Concrete floors and walls consume a considerable amount of heat whilst drying. Concrete floors should be allowed to cure before heat is applied. Alternatively, the procedure outlined in the section on commissioning above can be followed.
   Note 3: When checking large installations, it is easier to deal with one section at the time.

4. Ensure that the installation has been filled with water and deaerated according to Wirsbo's instructions.
   Air in the loops is the most common cause of poor performance in a system. That is why the filling instructions should be closely observed.

   Note: It is almost impossible to deaerate the loops without shut-off valves on the manifolds.

5. Make sure that the installation is correctly balanced.
   Check once more that the heat demand, the loop length, the dimensions and the layout of the supply pipes correspond with the drawing. If this is not the case, new calculations should be made with corresponding balancing adjustments.

Troubleshooting: the most common problems

1: One of the rooms is cold

All the loops work satisfactorily. However one of the rooms is cold and the return water temperature drop is too high.

If this is the case, the heat demand for this room is higher than calculated. Check to see if the ventilation supply temperature is too high and if the insulation of the room is sufficient. If neither is the case, and yet the problem remains, open the return valve approx. 1/2 turn at a time.

If necessary increase the supply water temperature and rebalance the loops. Also close the return valves for the rooms that are too warm, approx. 1/2 turn at a time.

2: The floors are cold

The floors are cold although the room temperature is correct. This means that there is another source of heating in the house. If for example, the heating system is a combination of underfloor heating and ventilation, check the temperature of the air inflow. It should be 2-3°C lower than the desired room temperature.

If the room is heated by other heat sources (for example office machines, lamps etc.) the room thermostat and actuator should be replaced by a manual valve handle on the manifold, to give a constant flow through the loop.

3: The floor temperature in the room is too high

When the floor temperature in a room is too high, it means that the water temperature in the loop is too high. One probable reason is that the valve spindle on the supply manifold is not watertight.

Shut off the flow through the loop at the manifold. This can be done by means of the manual valve handle or if the manifold is provided with an actuator by disconnecting the auxiliary voltage to the actuator. Shut off the return valve as well.

Disconnect the return pipe of the loop. If the supply valve is watertight no water should come out of the pipe.

Note: When valve spindle failure occurs the whole supply manifold should be replaced.

Chapter 7
Technical data

Wirsbo-pePEX

Special properties

The term Wirsbo-pePEX denotes Wirsbo-PEX pipes manufactured with additional oxygen diffusion barriers of PVOH (polyvinyl alcohol).

In heating systems, oxygen molecules can penetrate the wall of the pipe and oxygenate the water. Wirsbo-pePEX pipes are therefore provided with diffusion barriers. The barrier, which is applied to the outside of the Wirsbo-PEX pipe, consists of a PVOH layer with additional coatings of polyethylene on either side. Between the layers is a very thin application of glue. The polyethylene allows for a strong bond between the Wirsbo-PEX pipe and a final protective layer of PEX material,which is applied to the outside of the diffusion barrier. The combined thickness of the layers is 0.3 mm.

Wirsbo-pePEX pipe is oxygen-diffusion proof in accordance with DIN 4726.

Wirsbo-evalPEX

Special properties

The term Wirsbo-evalPEX denotes Wirsbo-PEX pipes supplied with an additional diffusion barrier of EVOH, ethylvinyl alcohol plastic.

Here, a thin layer of modified polyethylene followed by an equally thin layer of EVOH plastic is applied to the surface of Wirsbo-PEX pipes. The EVOH plastic acts as the oxygen diffusion barrier, and the polyethylene improves the adhesion of the pipe to the diffusion barrier. Wirsbo-evalPEX pipes are also oxygen-diffusion proof in accordance with DIN 4726.

Chapter 8

Diagrams and tables

Water temperature: 40°C

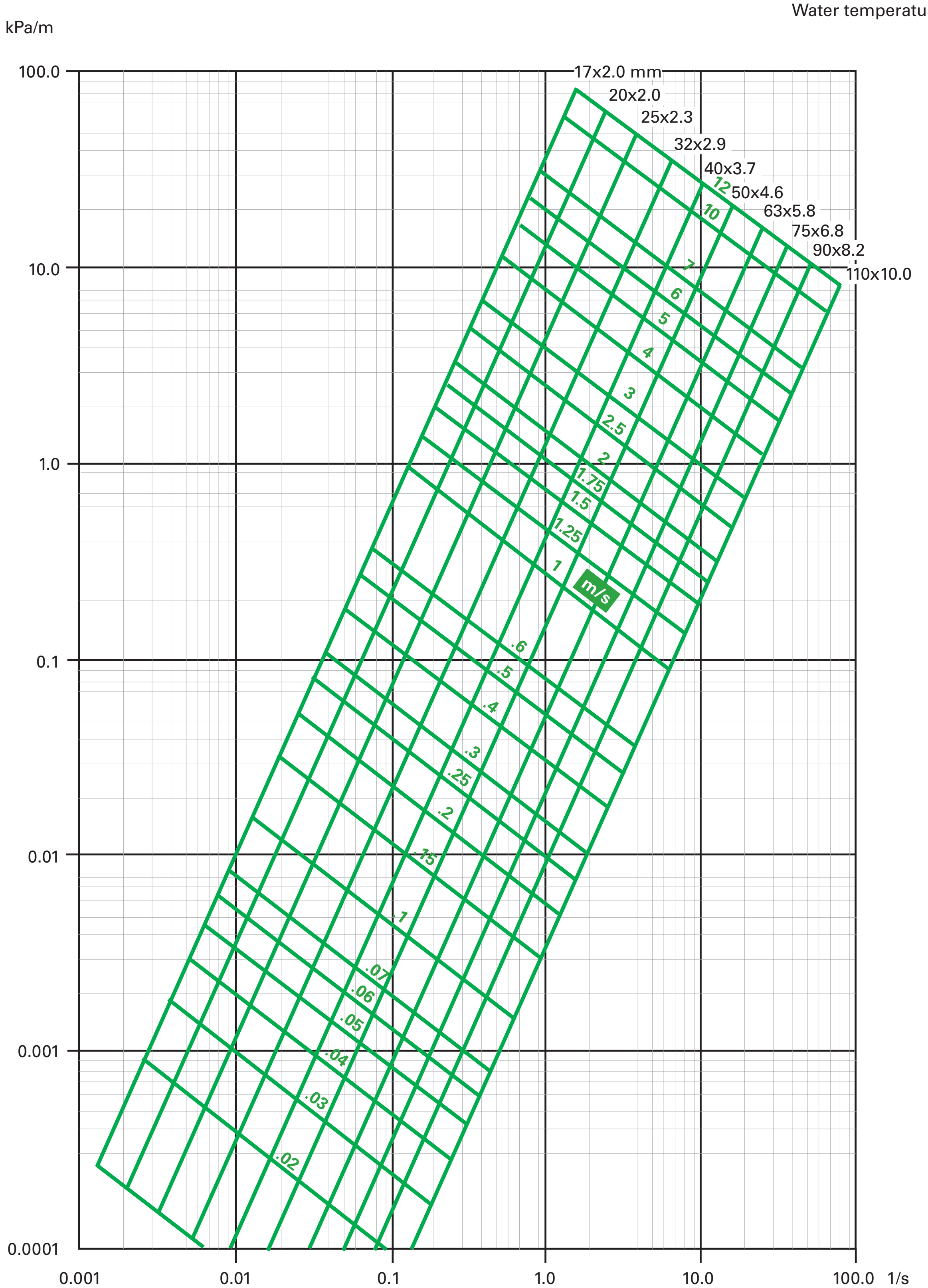


Diagram 9 Pressure drop nomogram Wirsbo-pePEX and Wirsbo-evalPEX

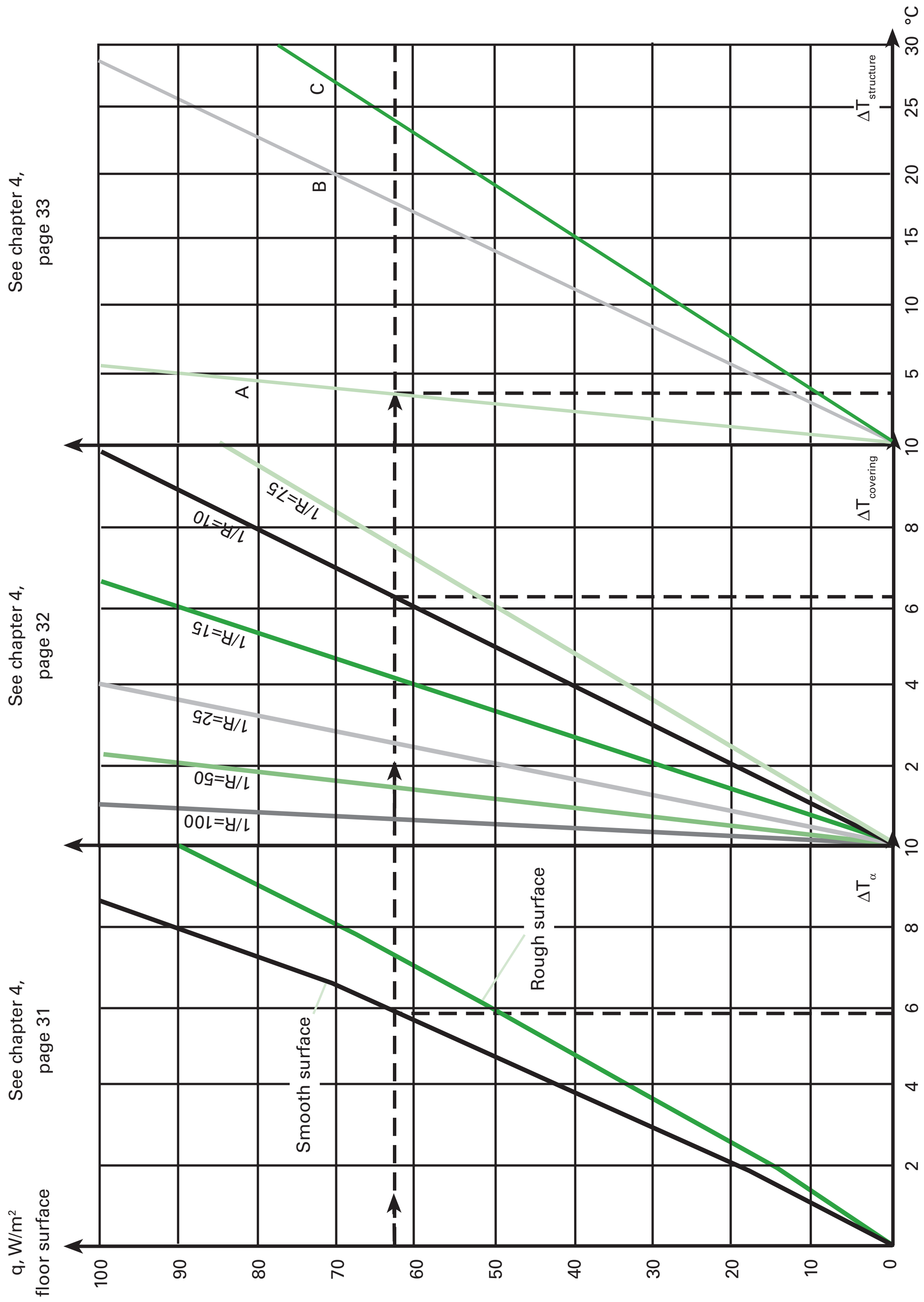


Diagram 10 Mean water temperature/heat loss

Material data

Material		Thermal conductivity W/mK λ	Density kg/m³ ρ	Specific Heat kJ/kgK at 20°C c_p
Mortar/Concrete				
Cement Mortar		1.2	2,000	1.0
Compo Mortar		1.0	1,800	1.0
Lime Mortar		0.9	1,700	1.0
Screed		1.9	2,500	—
Concrete		0.9	2,300	1.7
Bricks/Blocks				
Stock Brick		—	—	—
Clinker Brick		—	—	—
Perforated Brick		0.60	1,700	—
Face Brick		0.50	1,500	—
Concrete Block		0.70	2,000	—
Hollow Block		0.60	1,500	—
Light-weight Building slab		0.48	800	~1.5
-"-		0.57	1,000	—
-"-		0.66	1,200	~1.9
Aerated concrete block		0.47	800	—
Floor Tiles				
Cement Screed		—	—	0.8
Terrazzo Tile		1.05	—	—
Quarry Tile		—	—	—
Slate		—	—	—
Marble		2.1..3.5	2,500..2,800	0.8
PVC		0.2	1,350	1.0
Floor Finishes				
Timber Boarding		0.12	500	~2.4
Parquet Blocks		0.276	—	—
Vinyl Tiles		—	—	—
Marble		3.37	—	0.9
Carpet		—	—	—
Wall-to-wall Carpet		0.094	0.04	—
Insulation				
Glass Wool		0.035	—	—
Mineral Wool		0.040	400	—
Rock Wool		0.045	50..200	—
Polystyrene		0.040	20-40	—
Fibreglass		0.035	—	—
Boards				
Particle Board,	hard	0.13	1,000	—
	soft	0.05	300	—
Chipboard		0.14	600	2.3
Plywood		0.13	540	—
Plasterboard		0.22	840	~1.0
Wood,	Pine	0.14	500	—
	Oak	0.16	700	—

Table 8 Material data

Continuation

Material	Thermal conductivity W/mK λ	Density kg/m³ ρ	Specific Heat kJ/kgK at 20°C c_π
Other			
Snow	0.05	100	—
	0.64	500	—
Ice	2.22	910	2.1
Water	0.60	999	4.18
Freon, R12	—	—	1.05
Amonia	—	—	4.73
Glycol	—	1160	2.40
Glass	0.93	2500	0.84
Sand, (dry)	0.41	1500	0.8
Metal			
Aluminium	218	2700	0.89
Steel, 0.85% C	59	7800	0.46
Copper	395	8920	0.39

Building units

Windows		U-value W/m²K
Wood	Single glazing	5
	Double glazing	2.5
	Triple glazing	1.9
Aluminium	Single glazing	5.8
	Double glazing	3.4..4.3
	Triple glazing	2.7..3.5

Doors	U-value W/m²K	
External, Single	1.3	without window
	3.4	with window
External, Double	0.7	without window
	1.7	with window

Air gap	Thickness, mm	Unventilated, R-value, m²K/W
	5	0.11
	10	0.14
	20	0.16
	50-100	0.17

Table 9 Material data

Table 10 Forces of expansion and contraction

Dimen-sion mm	Max force of expans. N	Max force of contrac. N	Force of contrac. N
22x3.0	400	650	250
25x2.3	350	550	200
25x3.5	500	800	300
28x4.0	700	1,100	400
32x2.9	600	1,000	400
32x4.4	800	1,300	500
40x3.7	900	1,500	600
40x5.5	1,300	2,100	800
50x4.6	1,400	2,300	900
50x6.9	2,100	3,400	1,300
63x5.7	2,300	3,800	1,500
63x8.7	3,300	5,400	2,100
75x6.8	3,200	5,300	2,100
90x8.2	4,600	7,500	2,900
110x10.0	6,900	11,300	4,400

Chapter 9
Appendix

Downward heat loss calculations

Calculation description
The main purpose of this chapter is to demonstrate the technique of calculating the thickness of insulation necessary to limit the downward heat loss through a concrete slab on the ground to a certain level. Calculations will start with a house with no underfloor heating and will then show how much insulation thickness must be added in order to keep the temperature under the insulation at the same level but with underfloor heating. Calculations will be made using the theory of heat transmission through parallel layers.

General assumptions
In order to perform the calculations certain general assumptions must be made as follows:

- The dimensioning heat demand is 50 W/m^2 of heated floor area (Scandinavian standard).
- The insulation thermal conductivity is 0.035 W/m,K.
- The concrete thermal conductivity is 1.2 W/m,K.
- The underfloor heating loops are laid within the concrete at a depth of 50 mm from the surface of the concrete.
- The thickness of the concrete is 100 mm.
- When no underfloor heating system is installed, the thickness of the insulation under the concrete slab is 70 mm (Swedish Building Norms 1980, SBN 80).
- The dimensioning heat loss is 10% or 5 W/m^2 (Scandinavian standard values).
- The room temperature is 21°C
- The room has a parquet floor, which has a thickness of 14 mm.

Calculation 1
A concrete slab where no underfloor heating is installed.

Calculation of the temperature on the bottom surface of the insulation.

In this case we calculate the heat transmission from the floor surface inside the house down to the bottom surface of the insulation layer under the concrete slab. From the list of figures assumed in the list above we have the following:

$$R_T = \frac{1}{10} + \frac{0.04}{0.13} + \frac{0.1}{1.2} + \frac{0.07}{0.035} = \mathbf{2.40}$$

However

$$U = \frac{1}{R}$$

thus U = 0.417

next, since q = 5W/m^2, U = 0.417 W/m,K and T_1=21°C are now given, the temperature on the bottom surface of the insulation can be calculated. Using the equation q = U x (T_1-T_2) it could be calculated that T_2 is roughly 10°C.

Result: The temperature on the bottom surface of the insulation under the concrete slab is 10°C.

Calculation 2

A concrete slab where underfloor heating is installed.

Calculation of the mean underfloor heating temperature.

When performing calculations on the heat transmission through the concrete slab when underfloor heating is installed the calculation must be made for either above or below the underfloor heating layer. In this calculation we are searching for the mean water temperature in the underfloor heating circuits. To be able to do this we will calculate as if there was a certain heat generating layer within the concrete itself. The distance between this layer and the top concrete surface is assumed to be 40 mm. This is the distance between the centre line of the underfloor heating pipes and the top concrete surface. Using the same technique as in Calculation 1 we get

$$R_T = \frac{1}{11} + \frac{0.014}{0.13} + \frac{0.04}{1.2} = \mathbf{0.23193}$$

Thus U = 4.312. Using the equation $q = U \times (T_1 - T_2)$ where $q = 50\ W/m^2$, U = 4.312 W/m,K and $T_2 = 21°C$ we get $T_1 = 33°$.

Result: The mean water temperature in the underfloor heating circuits is roughly 33°C.

Calculation 3

A concrete slab where underfloor heating is installed

Calculation of the necessary thickness of the insulation under the concrete slab.

In Calculation 1 we calculated the target temperature on the bottom surface of the insulation under the concrete slab.

In Calculation 2 we calculated the temperature of the heat-generating layer within the concrete slab.

In Calculation 3 we will calculate the thickness of the insulation under the concrete slab necessary in order to achieve the target temperature on the bottom surface of the insulation under the concrete slab. The distance between the heat generating layer and the bottom surface of the concrete slab is assumed to be 60 mm.

Using the equation $q = U \times (T_1 - T_2)$, where $q = 5\ W/m^2$, $T_1 = 33°C$ and $T_2 = 10°C$ we get

$$U = \mathbf{0.21739}$$

Using the equation

$$U = \frac{1}{R_T}$$

we get the equation

$$\frac{1}{U} = 4.6 = \frac{0.06}{1.2} + \frac{X}{0.035}$$

Result: The result of equation 3, is that the necessary insulation thickness is 160 mm, an increase in the insulation thickness of 90 mm when compared to the case where no underfloor heating is installed.

These calculations are made for a well insulated house where the downward heat loss may not be more than 10% of the total heating demand of the house.

Conclusions

With a parquet floor of a thickness of 14 mm and with underfloor heating installed in the concrete slab, the insulation thickness must be increased from 70 mm to 165 mm. The increase in insulation thickness depends on the temperature of the underfloor heating, which in turn depends on the floor material. Installing a tiled floor for example, where the tiles have a thermal conductivity of λ = 1.2 W/m,K, will result in a necessary increase in the insulation thickness from 70 mm to 130 mm.

In conclusion, with regard to the above calculation examples, one can generally say that if the aim is to limit the downward heat loss to a level of 10%, the installation of an underfloor heating system in a concrete slab will necessitate an increase of approximately 80 mm in the thickness of the insulation.

Note that any acceptance of a higher downward heat loss will reduce the amount of additional insulation required.

Diagram 10 below shows the insulation thickness as a function of the ratio of the downward heat loss to the total heat deamand of the house.

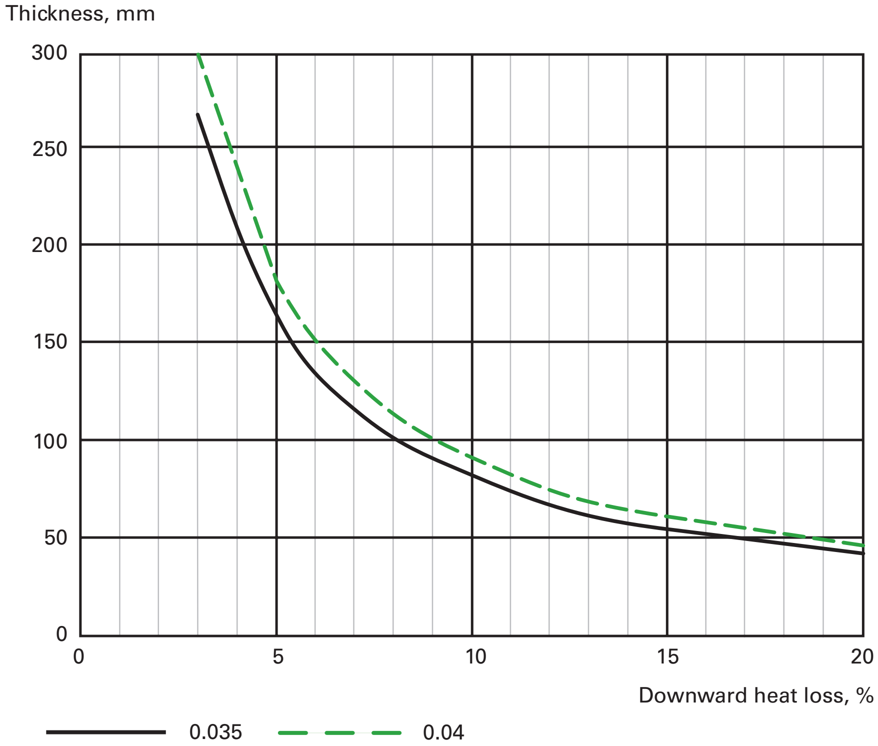


Diagram 10 Insulation thickness

Passive self-regulation

Although underfloor heating systems are used with temperature controls of differing degrees of sophistication, the system will nonetheless provide its own passive regulation.

Floor temperatures are set at levels slightly higher than those of air temperatures. However a rise in the temperature of the air through the sun's warmth or an increase in the number of people in a room means that the air will soon become as warm as the floor. As soon as this point is reached the laws of physics dictate that there can be no further heat emission from the floor. The effect is as if the system were to be shut down. The process is rapid and precise. Heat emission from the floor will begin to decrease as soon as the air temperature rises. Given an air temperature of 20°C and a floor temperature of 23°C, heat emission from the floor will decrease by one third for every degree of air temperature gain.

Chapter 10
Forms

Manual calculation, balancing set values/Manifold

Manual calculation, balancing set values/Supply piping

Bringing comfort to life

Form 1

Manual calculation, balancing set values

Project ______________________ Project No ______________________

Location ______________________ Date ______________________

Designed by ______________________ Page ______________________

Manifold

Loop No/Name	Loop length m	Heat requirement W	Loop flow l/s	Pressure drop			kPa	
				Pipe loop (L)	Manifold (M) (5 turns)	(D) = L + M	Diff A–S–L	Turns

Total flow l/s [ ] l/s max D [ ]

Supply pipes, kPa (S) [ ] S + Max D [ ]

Bringing comfort to life

Form 2

Manual calculation, balancing set values

Project ______________________ Project No ______________________

Location ______________________ Date ______________________

Designed by ______________________ Page ______________________

Supply piping

From – To	Valve kPa	Flow l/s	Length m (x2)	Dimension	Pressure drop kPa/m	Pressure drop kPa	Pressure drop Sum kPa

Pump data:

Dimensioning Pressure drop ______________ kPa

Dimensioning Flow ______________ l/s

Chapter 11
Symbol Definitions

Symbol	Unit	Description
P	W	Heat requirement
$P_{room\ 1}$	W	Heat requirement for room 1
$P_{room\ 1....8}$	W	Heat requirement for room 1....8
P_{L11}	W	Heat requirement for loop L11
Q	l/s	Water flow
$Q_{room\ 1}$	l/s	Water flow for room 1
$Q_{room\ 1....8}$	l/s	Water flow for room 1....8
Q_{L11}	l/s	Water flow in loop L11
q-value	W/m^2	Energy requirement
q	W/m^2	Heat exchange (load)
A_{floor}	m^2	Floor area
A_c	m^2	Area of surface "c"
A_{house}	m^2	Floor area of the house
$A_{room\ 1}$	m^2	Floor area of room 1
$A_{room\ 1....8}$	m^2	Floor area of room 1....8
U_c	W/m^2K	Overall heat-transfer coefficient for surface "c"
U_f	W/m^2K	Overall heat-transfer coefficient for surface "f"
V	m^3	Volume
V_{pipe}	l/m	Water volume per metre of the pipe
V	l	Water volume
C_p	kJ/kg K	Specific heat of air at constant pressure, approx. 1.0 kJ/kg K
ρ	kg/m^3	Air density, 1.2 kg/m^3 at 20°C
n	times/hour	Air exchange rate
T_i	°C	Indoor temperature
T_o	°C	Outdoor temperature
ΔT	°C	Temperature difference (T_i -T_o)
ΔT_{water}	°C	Water temperature difference (supply – return)
ΔT_{α}	°C	Temperature difference (surface – air)
$\Delta T_{covering}$	°C	Temperature difference over the floor covering material
$\Delta T_{structure}$	°C	Temperature difference in the floor structure
ΔT_{loop}	°C	Temperature difference in the loop (water temperature)
ΔT_{down}	°C	Temperature difference, downward, through the floor construction

Table 11 Symbol definitions

Symbol	Unit	Description
t	°C	Temperature difference
t_{floor}	°C	Floor temperature
t_{supply}	°C	Supply water temperature
t_{return}	°C	Return water temperature
t_{mean}	°C	Mean water temperature
t_{under}	°C	Temperature underneath
T_{vent}	°C	Air temperature difference in ventilation
t_i	°C	Air temperature indoors
R	$m^2 \cdot K/W$	Heat conduction resistance
1/R	W/m^2K	Heat transfer value
λ	W/mK	Thermal conductivity
d	m	Thickness
α_{floor}	$W/m^2 K$	Heat exchange (emission) coefficient from floor
v	m/s	Water velocity
p	kPa	Pressure drop
L	m	Pipe length
Kv	–	Kv-value, Flow through a valve at pressure drop of 1 bar.

Table 11 Continuing symbol definitions

Chapter 12

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