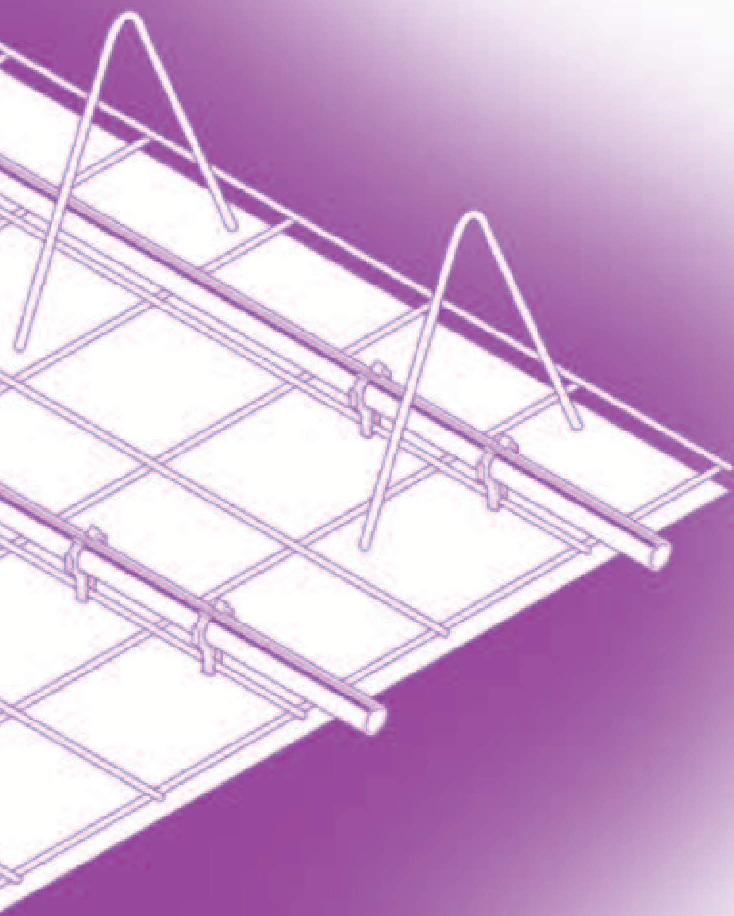
INDOOR CLIMATE
SOLUTIONS

TECHNICAL GUIDELINE

Industrial Underfloor Heating



Contents

Industrial Underfloor Heating

Benefits of the system

A sound investment

Hall space is too cost-sensitive to give over valuable space to a heating system. Because Uponor industrial underfloor heating systems are integrated into the hall's floor, they allow scope for architectural freedom. This also means that there need be no compromises with the way in which heat is distributed through the workplace. Moreover, there are no more static constraints regarding the roof construction due to the heating system. In other words, the ideal conditions for making optimal use of the interior hall space.

Conventional, visible heating surfaces incorporating pipework, ducting, and fans must be regularly cleaned, replaced, painted, and maintained. Quite the opposite with the Uponor industrial underfloor heating system. These do not require any effort in terms of individual maintenance. This reduces operating costs drastically, leading to a rapid return on investment. One economic factor that really ought to significantly influence the investors fundamental decision making.

Better indoor climate, better performance

Every machine has an optimal operating temperature. But what about people? Not a lot of people know it, but a pleasant temperature in the workplace also motivates staff to perform at their best. Workplace health and safety regulations prescribe that employees must not be exposed to unfavourable temperature conditions as a result of heating equipment. Unfavourable in this sense means that there is a major difference in temperature between the feet and head regions, due to forced hot air for example.

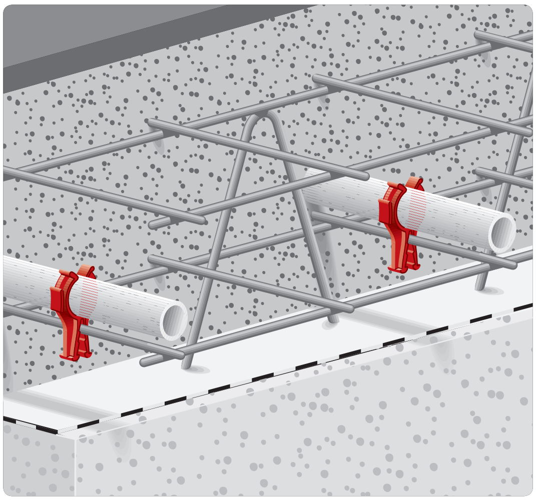
In general, the temperature of the floor plays an important role here, alongside the room air temperature. In this respect, sufficient protection against heat dissipation can be provided if the floor is kept at a temperature of at least 18 °C. Uponor industrial underfloor heating creates this ideal working atmosphere. It provides a large-area, mild radiation heat without dust circulation that would be caused by radiators.

10 good reasons to choose Uponor industrial underfloor heating

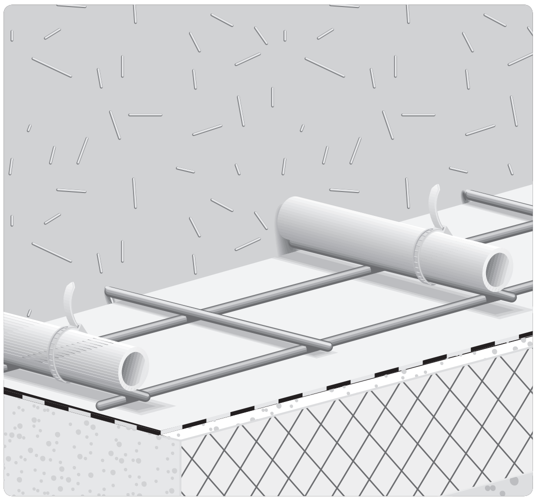
1. Rapid return on investment
2. Total design space freedom
3. Optimal building space utilisation
4. Uniform temperature profile
5. Low air speeds
6. No dust circulation
7. Stimulating working environment
8. No maintenance costs
9. Proven technology
10. Extensive declaration of liability

20,000 m² Uponor industrial underfloor heating in a high rack warehouse in Hückelhoven, Germany

Uponor Industrial underfloor heating: A safe foundation



Fixation with wire mesh reinforcement



Fast and easy fixation of the pipe on the steel mesh

Without any influence for static calculation

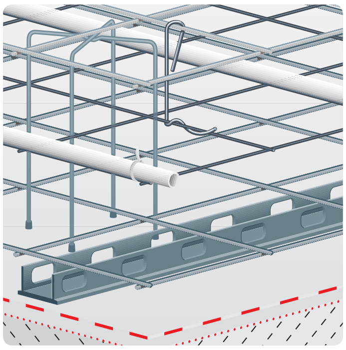
The construction and composition of industrial floors strongly depends on the effects of static and dynamic loads, such as wheel loads of vehicles, static loads of shelves and machines. But also mechanical and chemical impact on the floor surfaces have to be considered, before a structural engineer defines the appropriate floor construction.

The great advantage of Uponor industrial underfloor heating: It does not influence the static calculation. This is a fact that makes our solution so flexible and universally applicable.

Solid pipe construction meets highest demands

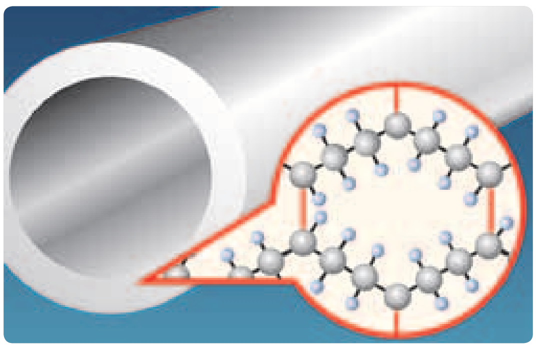
A proper pipe material is one of the essentials for a reliable underfloor heating in industrial settings. Only highly robust and durable pipes are able to cope with the rough environment of a floor construction.

For concrete mounting, our Uponor PE-Xa, manufactured from peroxide cross-linked polyethylene, has proved its superior material properties a million times



Hook-shaped mounting support for pipe fixation

Protection through cross-linked polyethylene structures



Favourable floor at reasonable costs

Profit from low temperature heating

Another feature of Uponor industrial underfloor heating is as trend-setting as it is cost-efficient: Its low energy consumption.

Because the entire system is operating on a low temperature level, heat losses at the point of heat generation and distribution are minimised. And the entire floor area turns itself to a heating surface. By using existing thermal energy, e. g. from production processes, you can additionally decrease your energy expenses – to almost zero in the best case.

Using the Uponor industrial underfloor heating means building the foundation for a cost-efficient way of doing business. An advantage that does not only save you money, but also puts you ahead of competition

Hack Heavy Duty Vehicles Maintenance Facility, Windhagen, Germany. Equipped with Uponor industrial underfloor heating.

BMW Dynamic Center, Dingolfing, Germany. Equipped with Uponor industrial underfloor heating.

Uponor industrial underfloor heating – universially applicable

- **Factories**
- **Shops**
- **DIY-markets**
- **Aircraft hangars**
- **High speed train depots**
- **Warehouses**
- **Spare part depots**
- **Logistic centres**
- **Gas stations**
- **Car wash**
- **Call centres**
- **Distribution centres**

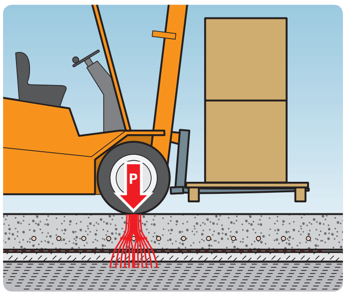
Field of application

Uponor industrial underfloor heating is a low-temperature heat distribution system for heating industrial spaces. Applications range from workshops, through production halls with light and heavy machinery, to warehouses where forklift trucks are used, and even airport maintenance hangers. The system is built directly into the concrete floor slab. It is even possible to make use of the standard steel reinforcement for the concrete slab as a support structure for the heating pipes. Heat can be supplied by any conventional warm water heating system designed for use in the type of building being in question.

Load capacity

The Uponor industrial underfloor heating system is, by its very nature, unaffected by the load exerted by vehicles, since it does not utilise any components that would limit the vehicle load, such as insulation. The Uponor industrial underfloor heating system can be incorporated into practically every type of concrete slab construction, including steel-reinforced concrete, prestressed concrete, vacuum concrete, roller compacted concrete and more.

The basic criteria for choosing a construction type are the requirements determining the type of use to which the floor will be subjected. Both point loads from racking and dynamic loads from forklift operations need to be considered here.



Because the heating pipes are embedded in the concrete, the lines of force run around the pipes as if they were bridges.

Important information for planning:

- **Unlimited vehicle load kN/m²**
- **Dimensioning of concrete slab by structural engineer**

Insulation of industrial floor slabs

The heat insulation of industrial type buildings has to be calculated according to actual valid standards for the thermal performance of buildings like e.g. ISO 13790, ISO 13789 or ISO 13370 "Thermal performance of buildings - Heat transfer via the ground".

If the groundwater level is less than 2 m below the concrete base, the use of thermal insulation should be considered in accordance with requirements.

Important information for planning:

- **Check if insulation required**
- **Groundwater level < 2 m, consider need for insulation**

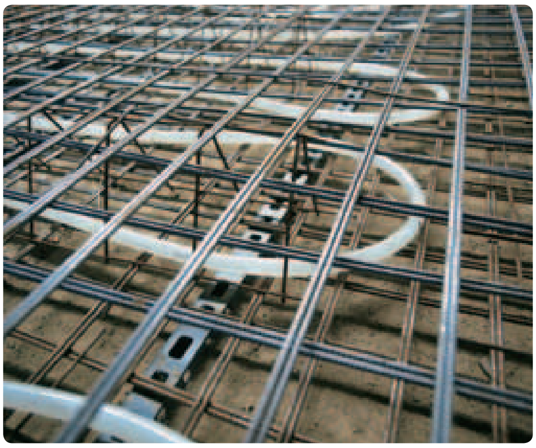
Calculation table from DIN 1055 Sheet 3 (based on European pre-norm DIN V ENV 1991-1-1) for forklifts and standard vehicles

Permitted Total weight [t]	Nominal load-bearing capacity [t]	Static axle load (standard load) P [Mp (kN)]	Average track width a [m]	Total width b [m]	Total length l [m]	Uniformly distributed vehicle loads (standard load) [kp/m² (kN/m²)]
2.5	0.6	2 (20)	0.8	1	2.4	1000 (10)
3.5	1	3 (30)	0.8	1	2.8	1250 (12,5)
7	2.5	6.5 (65)	1	1.2	3.4	1500 (15)
13	5	12 (120)	1.2	1.5	3.6	2500 (25)

Types of concrete

Reinforced concrete

Reinforced concrete is the most common concrete used for industrial floor heating systems. Concrete elements are strengthened by a reinforcement mesh of iron or steel bars. This reinforcement consists mostly of two reinforcement layers - an upper and lower one, both mounted into the concrete layer. They are mounted to the load bearing layer and raised by using spacers for upper reinforcement.



Reinforced concrete with mesh reinforcement.

Pre-stressed concrete

Pre-stressed concrete is done with a pre-stressed steel reinforcement which is mostly combined with a mesh reinforcement. This type of reinforcement consists of crosswise arranged stress-links which are being pre-stressed and equipped with a corrosion protection (PE-protection layer or metal cladding tube). The concrete slab is exposed to compressive strain which prevents cracks in the surface. The pre-stressed steel reinforcement is usually being mounted in the centre of the concrete slab secured by spacers for upper reinforcement.

Pre-stressed concrete with steel reinforcement.

Roller compacted concrete

Roller compacted concrete is much drier than conventional concrete and can be spread by dump trucks or bulldozers and compacted by vibratory rollers. The equipment does not undergo the risk of sinking into the concrete. As the driveways of the construction vehicles do cross already mounted heating pipes, this concrete type can be used in combination with surface heating only when applying special construction methods.

Using roller compacted concrete.

Steel fibre concrete

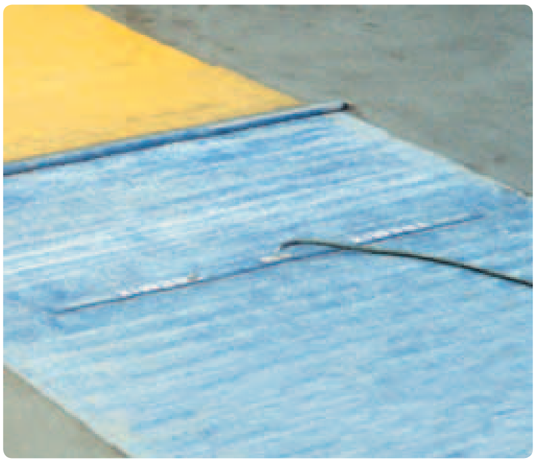
Steel fibre concrete consist of concrete under addition of steel fibres. This kind of concrete does completely without a mesh reinforcement so that a carrier element for the attachment of the heating pipes has to take into account.

The even mixed fibres secure a three dimensional anchoring of the concrete und improve the pressure-, bending- and tensile strength of an unreinforced concrete. Depending upon manufacturer the fibres are different profiled and the added amount varies in dependence of the requested concrete quality in the range of 40 - 80 kg/m³. The fibres are added to the mixer or to a screed pump and the placing of reinforcement is therefore simultaneous be done by placing of the concrete.

Three dimensional anchoring of the concrete by steel fibres.

Vacuum concrete

The expression "vacuum concrete" derives from the final vacuum treatment of the already compacted and levelled concrete. During this procedure, a mayor amount of the mixing water is being extracted from the concrete. Thus, the upper concrete features a better consistency in from the very beginning. The final consistency improves as well. The vacuum treatment requires filter mats and suction formworks which are put on the concrete surface. By generating a low pressure over the concrete surface with a vacuum pump the mixing water will be sucked off. Depending on the type of reinforcement the vacuum concrete consist of reinforced concrete, pre-stressed concrete or steel fibre concrete or similar.

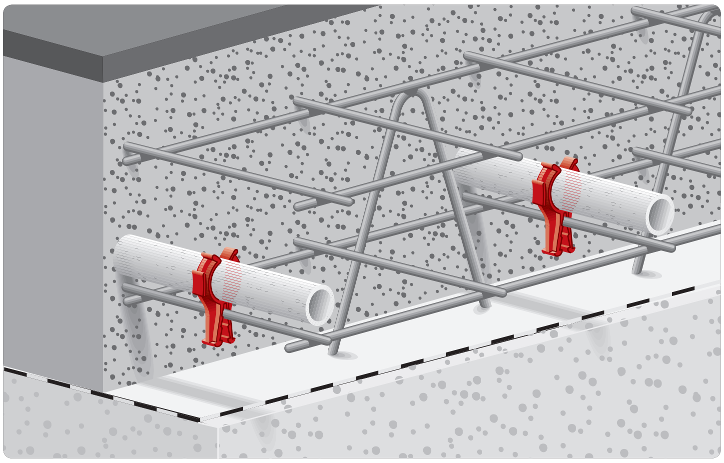


Vacuum-carpet for draining of the concrete surface.

Types of construction

With mesh reinforcement

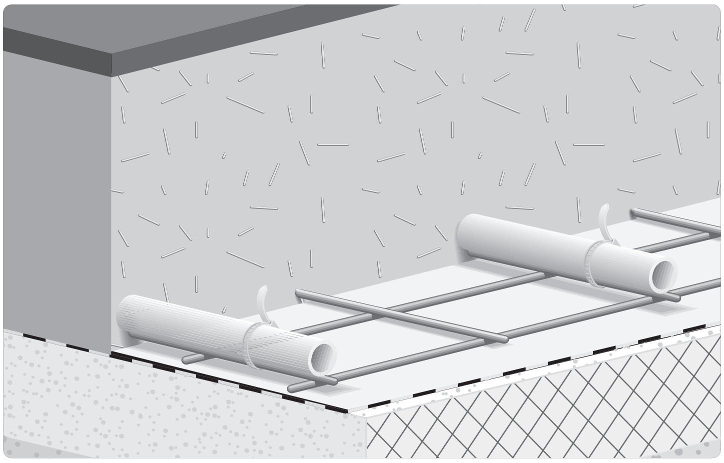
When concrete is laid with mesh reinforcement (steel-reinforced concrete, prestressed concrete with mesh reinforcement), the heating pipes are attached to the lowest level of the mesh.



Mesh reinforced construction

Without mesh reinforcement

When concrete is laid without mesh reinforcement (steel-fibre reinforced concrete, prestressed concrete without mesh reinforcement, non-reinforced concrete), the heating pipes must be attached to a support structure that is laid onto the concrete base (e.g. Q131).

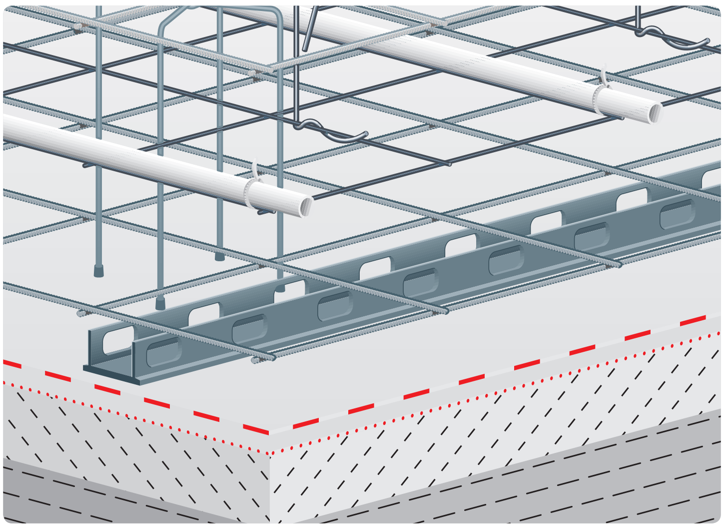


Non-reinforced construction

Raised support structure method

The raised support structure method is a patented Uponor system that allows the heating plane to be positioned in the centre of the concrete slab, between the lower and upper levels of the mesh reinforcement. The raised pipe supports are attached using special spacers, which are attached to the upper reinforcement.

This type of design is particularly beneficial when cooling operation is also required.



Raised support structure method of construction

Information for planning the floor construction

General

When planning the floor construction to include an industrial underfloor heating system, all relevant laws, directives, guidelines, construction contract procedures, and standards must be complied with.

Installation requirements

Stage of construction

If the floor slab is laid before the building framework/walls and roof are built, then measures to protect against the effects of the weather may be required as the construction will take place outdoors. It is essential when installing an Uponor industrial underfloor heating system to obtain approval for the proposed substructure from construction site management.

The industrial underfloor heating system is built into the concrete slab. A range of different designs of floor construction can be used. To give a general understanding of floor design, the various layers of the floor are described below.

An overview of the basic structure of the floor in an industrial building is shown in the diagram below. It is composed of a concrete slab, a load-bearing layer, and a substrate.

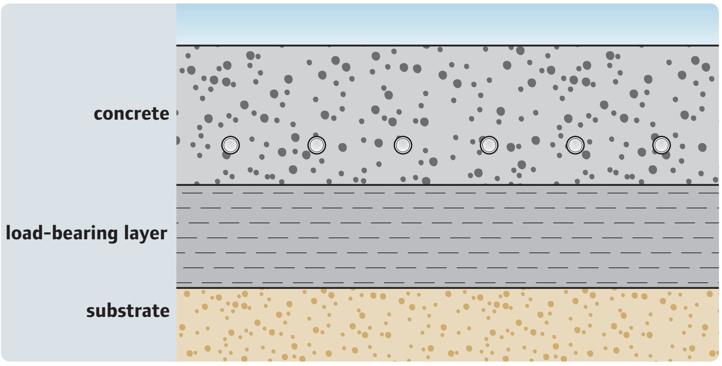
Substrate and load-bearing layer

The substrate must be suitable for the installation of a concrete floor, otherwise a load-bearing layer will be required. The ideal prerequisites are uniform composition across the entire surface, good compressibility, sufficient load bearing capacity and good drainage.

If the compressed substrate does not have sufficient load-bearing capacity, then a load-bearing layer must be installed on top of the substrate. The load-bearing layer absorbs loads transferred from the concrete slab and dissipates these into the substrate. It should have an uniform thickness across the entire area and must be sealed. Load-bearing layers are generally created using gravel or loose chippings. In order to increase its load-bearing capacity , a hydraulic binder (e.g. cement) can be added to the layer of gravel or chippings.

Blinding layer

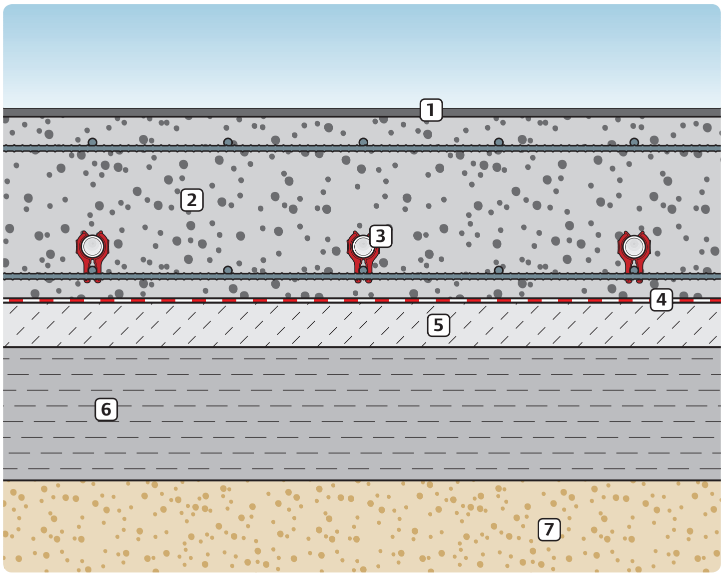
As a rule, a blinding layer is applied on top of the load-bearing layer or, if no load-bearing layer is present, above the substrate. The blinding layer may consist of a thin layer of concrete or cement screed, and ensures that the load-bearing layer, which is constructed of coarser material, has an even surface. Alternatives include, for example, spreading a course of fine sand (sand levelling).



Basic construction of a floor for an industrial building

Information:

Local standards for "waterproofing of buildings" to be followed.



Example configuration for waterproofing of building floors against ground moisture, with moderate requirements on the dryness of the room air.

1 Wearing layer

2 Concrete

3 Uponor PE-Xa pipe

4 Barrier layer/ glide layer

5 Blinding layer

6 Anti-capillary load-bearing layer acts as waterproofing for buildings

7 Substrate

Waterproofing of buildings

Depending on the degree of exposure of the substrate to ground moisture, non-pressing and pressing water, appropriate waterproofing measures must be provided in accordance with local standards (e.g. DIN 18195 in Germany). Usually, waterproofing takes the form of rolls of material (e.g. bitumen sheets, PVC sheets).

In case of buildings that have only moderate requirements for the dryness (e.g. warehouses for goods that are not sensitive to moisture), the waterproofing can be achieved using an anti-capillary layer of at least 15 cm depth ($k > 10^{-4}$ m/s). The responsibility for assessment of the substrate and the resultant decision on the type of waterproofing required lies with the building engineer.

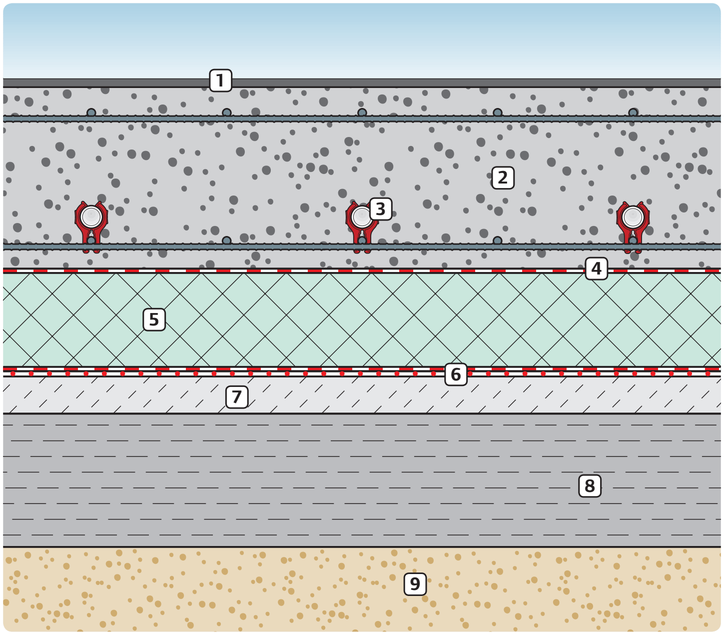
Insulation layer

If necessary, a thermal insulation layer must be installed below the concrete slab – i.e. next to the ground. This can be made from abutting extruded foam sheets or foamed glass panels laid either in hot bitumen or using a butt joint technique.

For multi-level industrial buildings with the same type of use, a thermal insulation layer must be provided below the concrete ceiling in accordance with EN 1264, Part 2, if the industrial underfloor heating is installed in the concrete ceiling. This insulation must be rated at $R_{\lambda, Ins} = 0.75$ m²K/W. In most cases, the insulation is installed by the construction contractor.

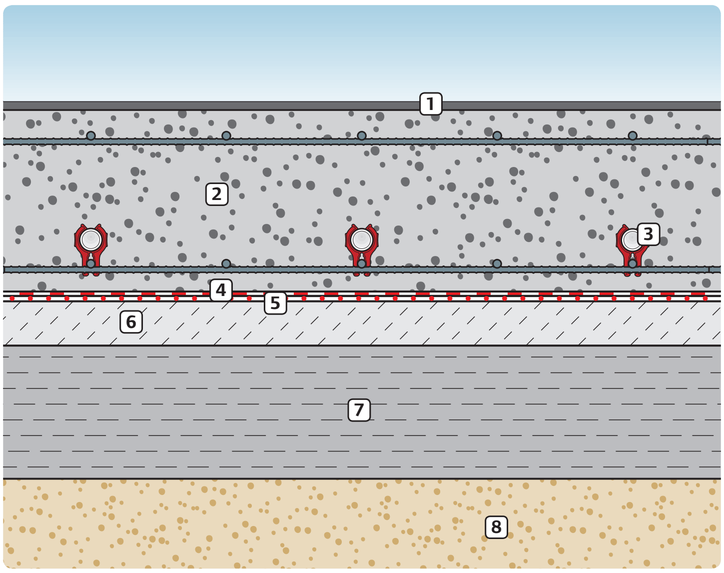
Barrier and glide layers

Insulating layers and load-bearing layers made of loose material must always be covered with a layer of polyethylene foil. This prevents any mass transfer between the load-bearing layer and the concrete slab while the concrete is curing, as well as preventing the concrete from penetrating between the joints in the insulation layer, which would create thermal bridges to the ground. Glide layers are used in situations where the concrete slab is subject to high loads and are created by laying a double-layer of polyethylene foil. This reduces the amount of friction between the concrete slab and the load-bearing layer, thereby reducing the loadings on the slab due to friction. Barrier and glide layers are normally laid by the construction contractor.



Example configuration for waterproofing of building floors using materials in roll form below the thermal insulation.

1 Wearing layer
2 Concrete
3 Uponor PE-Xa pipe
4 Barrier layer/glide layer
5 Insulation, e.g. extruded foam sheets
6 Waterproofing in roll form, possibly with intermediate foil
7 Blinding layer
8 Load-bearing layer
9 Substrate

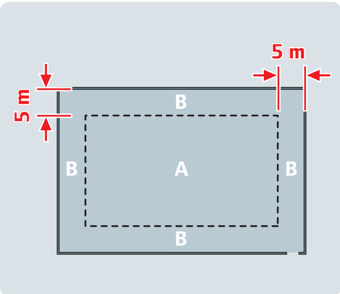


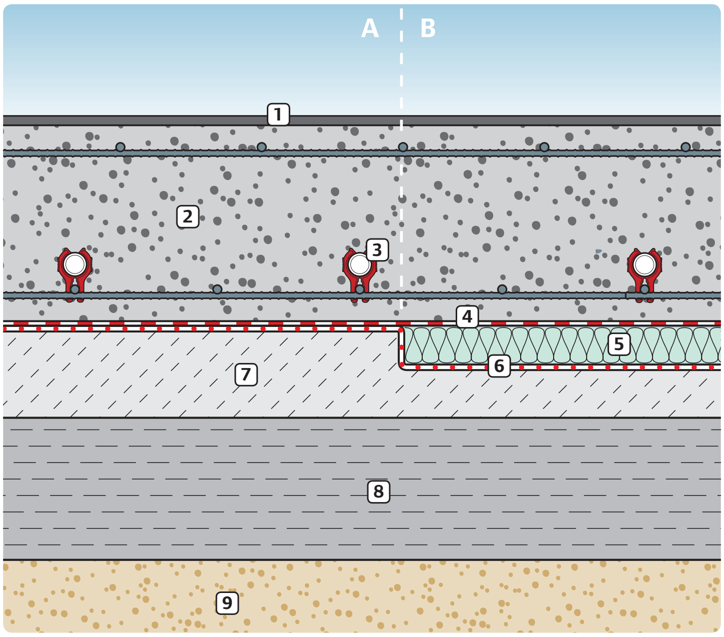
Example configuration for waterproofing of building floors using waterproofing material in roll form, without insulation.

1 Wearing layer
2 Concrete
3 Uponor PE-Xa pipe
4 Barrier layer/glide layer
5 Waterproofing in roll form
6 Blinding layer
7 Load-bearing layer
8 Substrate

Important information for planning:

Local regulation may require edge insulation to be used. For example in Germany, EnEV and DIN 4108-Part 2 generally require that edge insulation be installed to a room depth of up to 5 m.





Example configuration for water-proofing of building floors using material in roll form at the transition between the insulated and non-insulated areas.

1. Wearing layer
2. Concrete
3. Uponor PE-Xa pipe
4. Barrier layer/glide layer
5. Insulation, e.g. extruded foam sheets
6. Waterproofing in sheet form, possibly with intermediate foil
7. Blinding layer
8. Load-bearing layer
9. Substrate

German Energy Saving Ordinance: regulations/exceptions

Regulations

In Germany, buildings that consume energy for heating or cooling rooms are subject to the EnEV Energy Saving Ordinance. This requires that new buildings be constructed in accordance with a minimum level of thermal insulation in line with the state-of-the-art. The insulation fitted to industrial type buildings must comply with the minimum levels defined in DIN 4108, Part 2, July 2003, Table 3, as follows:

The minimum required thermal resistance R = 0.9 m² K/W corresponds to 40 mm thick insulation of thermal conductivity group WLG 040.

Indoors temperature	Minimum thermal resistance of the floor at the ground
< 12 °C	No requirements
12 °C to < 19 °C, heated for more than 4 months per year	R = 0.9 m² K/W to a room depth of up to 5 m
> 19 °C, heated for more than 4 months per year	R = 0.9 m² K/W to a room depth of up to 5 m

Insulation layers

General

Check if thermal insulation is required to comply with local energy saving regulations. Where the groundwater level lies at a depth of less than 2 m, plans must allow for insulation below the concrete slab. Consideration must always be given to the fact that an insulation layer represents the weakest part of the floor construction in terms of load capacity. The type of insulation used must have high compressive strength and be unaffected by moisture. A few common terms relating to thermal insulation are clarified below.

Perimeter insulation

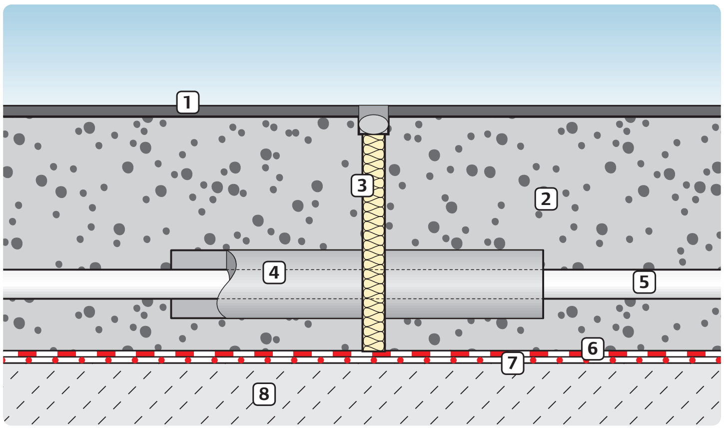
Thermal insulation that is located underneath the concrete slab, is moisture resistant, and is in direct contact with the ground is generally referred to as perimeter insulation. This must be suitable for the type of loads that occur in industrial applications. Usually, only those layers of a floor construction up to the waterproofing can be included in the calculation of the U-value. If the perimeter insulation is below the waterproofing and not constantly exposed to groundwater, then clarification must be sought from the insulation manufacturer, as to whether or not the insulation sheets may be included in the calculation of the U-value for the purpose of obtaining approval for use by the construction supervising authority. Please check with local standards how the U-value calculation of the floor construction is to be done.

Extruded foam sheets are the most commonly used type of perimeter insulation. These are manufactured from polystyrene in accordance with EN 13163, are available in thicknesses up to approximately 120 mm, and are predominately classified in thermal conductivity group 035. Extruded foam sheets normally correspond to Class PB as defined in EN 13163, meaning that they possess a high gross density (up to 30 kg/m^2) and are therefore intended for use under increased load. They are usually classified in Materials Class B/C (highly flammable) as per EN 13501-1. A special rebate edge simplifies the process of creating the loose butt joints between sheets on the blinding layer.

Foam glass panels are manufactured with gross densities between 100 and 150 kg/m^3 and are used in applications that are subject to particularly high-loads, where extruded foam sheets are no longer suitable (e.g. insulation beneath the foundation). Foam glass insulating panels can be coated with paper, board, roofing membrane, geomembrane, plastic film, or metal foil. They can either be laid onto loose blinding layers using butt joints or onto concrete blinding layers using hot bitumen.

Illustration of an expansion joint

1 Wearing layer
2 Concrete
3 Expansion joint
4 Protective pipe sleeve
5 Uponor PE-Xa pipe
6 Barrier layer/glide layer
7 Waterproofing
8 Blinding layer



Important information for planning:

- **Expansion joints must only be crossed by connecting pipes.**
- **Always protect connecting pipes that cross expansion joints using Uponor protective pipe sleeves.**

Concrete jointing techniques

Expansion joints

Joints that allow movement are generally known in the concrete construction trade as expansion joints. These provide continuous separation of the concrete slabs with a distance of approx. 20 mm and are filled with a soft jointing material (e.g. foam sheet or fibreboard), which is fixed in place before the concrete is poured. Expansion joints are not designed to break up the floor, but rather to provide separation from other objects (e.g. ducts, conduits, supports, walls). The underfloor heating system does not affect the planning of the expansion joints. Connecting pipes that cross over expansion joints must be protected against the anticipated mechanical stresses in the area around the joint using Uponor protective pipe sleeves of 1 m in length.

Construction joints (day joints)
Neighbouring areas of the slab are connected to each other by construction joints. These are not movement joints, but rather occur simply as a result of adjoining bays being poured at different times. In order to ensure proper transmission of force form one slab to the next, these sections are combined by using tongue and groove joints or creating a positive connection with dowelled joints.

Heating pipes that cross a construction joint must be sheathed for a distance of 1 m using Uponor protective pipe sleeves in cases where the heating pipe is subject to mechanical stress before pouring the concrete, for example due to the positioning of formwork over the heating pipe.

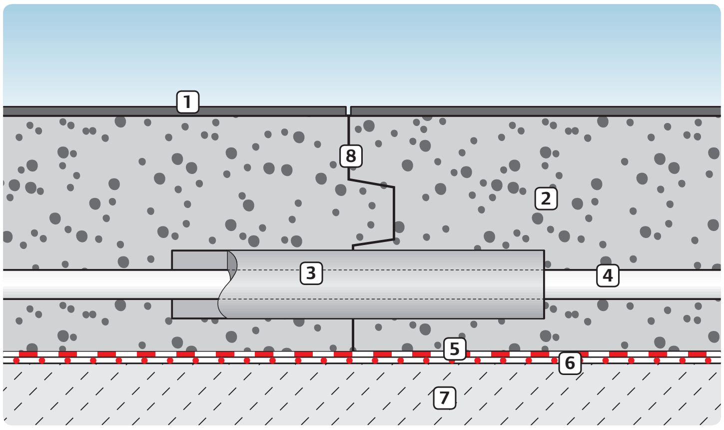


Illustration of a construction joint

1 Wearing layer
2 Concrete
3 Protective pipe sleeve
4 Uponor PE-Xa pipe
5 Barrier layer/glide layer
6 Waterproofing
7 Blinding layer
8 Dummy joints

Important information for planning:

Heating pipes that are subject to mechanical stress during installation where they cross construction joints must be sheathed with Uponor protective pipe sleeves.

Dummy joints
Dummy joints are cut into the concrete slab after it is formed and serve as predetermined breaking points. These cuts are approximately 3–4 mm wide and cut to a depth of around 25–30% of the slab thickness. The intentional crack that occurs below the cut has a certain amount of denticulation that allows transverse forces to be transferred from one concrete slab to the next. Dummy joints do not require the use of Uponor protective pipe sleeves. Dummy joints can also be of a "closed" type, created by cutting a post-casting groove approximately 25 mm deep, then using a special sealing compound and partially filling with foam rubber.

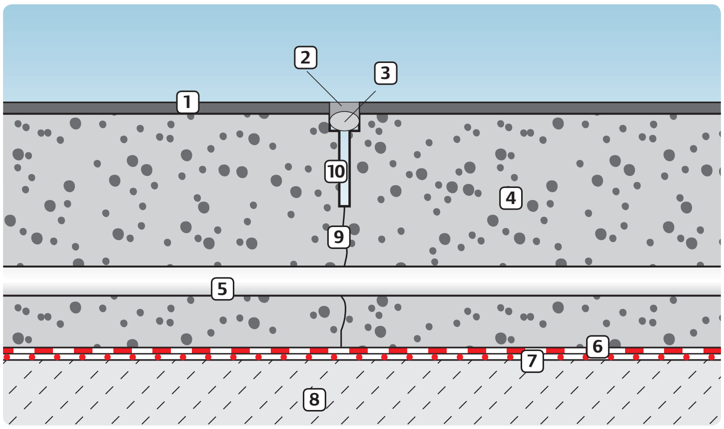


Illustration of a dummy joint

1 Wearing layer
2 Joint sealing compound
3 Foam rubber
4 Concrete
5 Uponor PE-Xa pipe
6 Barrier layer/glide layer
7 Waterproofing
8 Blinding layer
9 Fine crack
10 Dummy joint

Important information for planning:

Agree the maximum possible depth of cut with the building engineer

Joint layout

Joint planning is the responsibility of the structural engineer and, due to the low temperature of the heating surface, is unaffected by the industrial underfloor heating. The specialist heating engineer must request a joint plan, which will be used to agree the layout of the heating circuits and connecting pipes.

The type and positioning of a joint depends on numerous factors, for example:

- Slab thickness
- Other objects in vicinity (supports, walls, ducts)
- Long-term loadings
- Type of concrete placement

The bay size is dependent on various factors, for example the quality and load capacity of the substructure, and can therefore only be determined by a structural engineer. Edge joints around the concrete slab or fixtures in the concrete slab must be implemented as expansion joints and also shown on the joint plan. Below are some examples of possible joint arrangements for different methods of concrete placement.

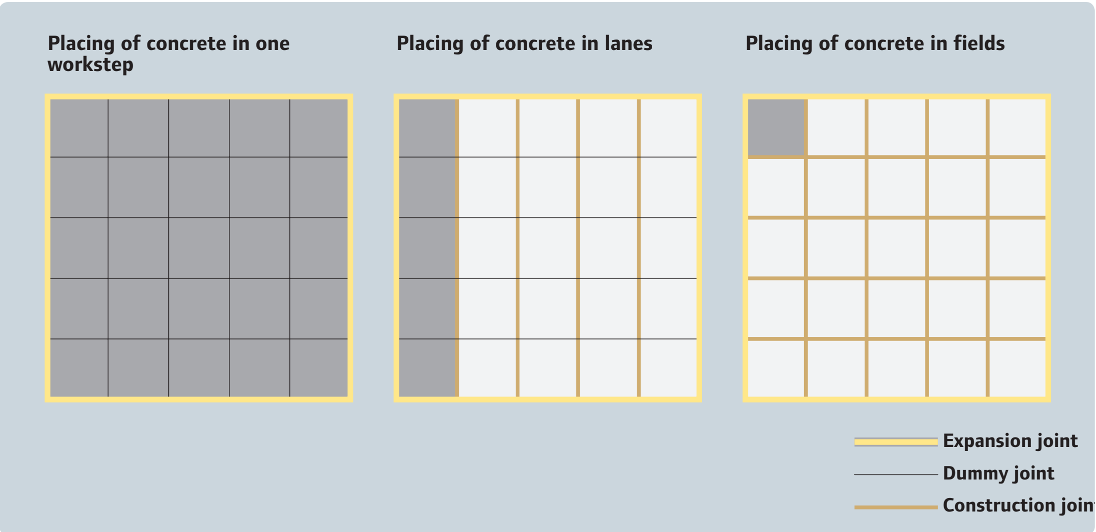
Note:

Base slabs with low-shrinkage rolled concrete can generally be designed without joints as far as possible.

Important information for planning:

- **Give consideration to the structural engineer's joint plan**
- **Agree placement of heating loops and connecting pipes on the joint plan.**

Examples of possible joint arrangements for different methods of concrete placement.



Wearing layer

Floors that are subject to heavy wear due to, for example, being driven on by forklifts and heavy industrial trucks, are exposed to a lot of abrasion and therefore need a stable surface layer, a wearing layer, as otherwise the surface of the concrete slab may suffer excessive wear. Which type of wear layer is best suited for a specific situation must be decided by the responsible building engineer. For example, the following may be applied to the surface of the concrete: mastic asphalt screed, magnesite screed, and cementitious hard-aggregate screed. The plasticity of the wearing layer and the concrete slab must be matched to each other. Joints in the concrete slab must therefore also be considered in the surface layer. Floors that are subject to less heavy wear do not necessarily require a separate surface layer. In many cases the concrete surface will be roughened by brushing or, in the case of floors that need to be extremely level, sanded down.

Important information for planning:

- **Take into account the thermal resistance, $R_{\lambda, B}$, of the wearing layer.**

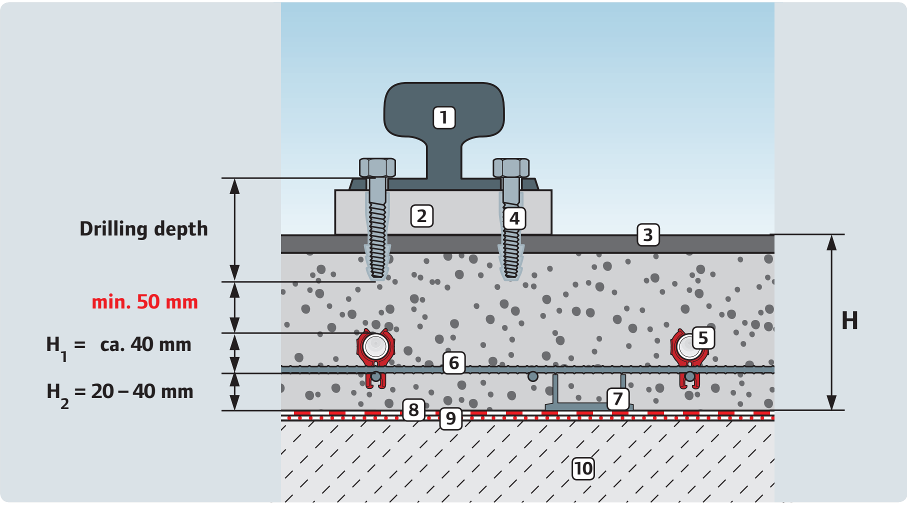
Rotor-type power trowel for smoothing of concrete surfaces

Equipment in the halls

Commercial buildings often have footings for various equipment, for example high rack storage and machine foundations, anchored into the concrete floor. The specialist heating engineer must remain informed about how deeply these foundations and anchor points penetrate into the concrete slab. Occasionally there is a risk that they penetrate far enough into the concrete slab to reach the level of the heating pipes. Should this be the case due to the concrete slab being insufficiently thick, then the heating pipes must be left out of this area, creating a so-called blind area.

Important information for planning:

- **Determine the maximum depth of penetration into the concrete slab of all anchor points and foundations for all equipment to be installed in the building.**
- **A minimum safety distance of 50 mm to the pipe should be observed.**



Penetration depth of equipment

1. Rails for industrial trucks
2. Equalisation base
3. Wearing layer
4. Anchors
5. Uponor PE-Xa pipe
6. Reinforcement
7. Spacer
8. Barrier layer/glide layer
9. Waterproofing
10. Blinding layer

Transporting concrete

Depending on the location at which it is mixed, concrete may be referred to as transit-mixed or job-mixed concrete. Transit-mixed concrete is pre-mixed at the concrete factory and then transported to the building site in concrete mixing trucks, whereas job-mixed concrete is prepared directly on site. The ready-mixed concrete is then moved to the installation site using concrete pumps, carrying containers, conveyors, or similar. Delivery of concrete directly to the actual installation site using the mixing truck is only possible if this would not involve driving over or damaging the exposed heating register.

Concrete compaction using vibrating cylinders

Concrete compaction

Concrete compaction is usually carried out using high-frequency internal vibrators. In most cases, the vibrators are drawn slowly through the freshly poured concrete at the same time it is levelled. The use of vibrators for compacting the concrete does not have any negative effect on the underfloor heating system integrated into the concrete.

Functional heating test

Concrete slabs with integrated underfloor heating must be heated up after the concrete and wearing layers have been laid.

The earliest point in time at which heating can be started is dependent on the quality and thickness of the concrete, so the functional test must be carried out in consultation with the relevant concreting contractor/ structural engineer and take into account their specifications.

The following procedure for the functional heating tests is usually acceptable for standard concrete thicknesses of 10–30 cm:

1. Start functional heating test once concrete floor has been signed-off by construction management (approx. 28 days after concrete placed)
2. Set flow temperature to 5 K above the concrete temperature and maintain for at least 1 week
3. Increase the flow temperature by 5 K each day until the design temperature is reached
4. Maintain design temperature for 1 day
5. Decrease the flow temperature by 10 K each day until the operating temperature is reached
6. Set the operating temperature

The functional heating procedure is designed to meet the requirements of local standards and not for drying out the concrete.

The operational status must be documented during and after the functional heating test procedure. Please request a copy of the Uponor Functional Heating Test Report for Uponor industrial underfloor heating systems. If the first time the industrial building is heated coincides with the heating season, then the building should be enclosed before the heating season starts. This allows the energy absorbed by the concrete slab from its surroundings to be used for heating.

The system must not be switched off during winter if there is a risk of frost, unless other precautionary measures have been implemented.

Important information for planning:

- **Agree the functional heating test procedure with the concrete contractor/ structural engineer**
- **Plan-in the heating-up time**
- **Consider precautionary measures to prevent frost damage**

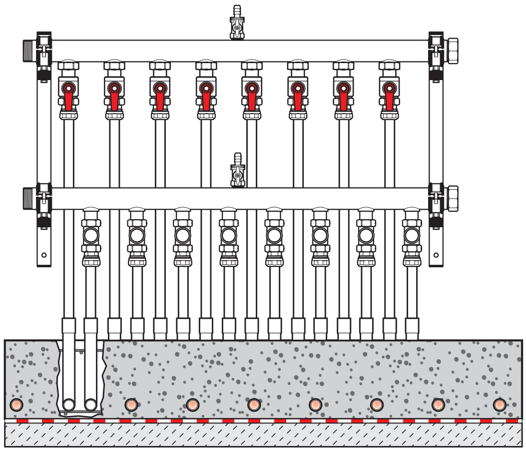
Information for planning the heating plant

Connection types

There are numerous options available for connecting the individual heating circuits to the heating system. The most suitable alternatives in any given case will be determined by the nature of the construction and the control concept to be used. Some common alternatives are described below.

Connection to the Uponor Industrial manifold

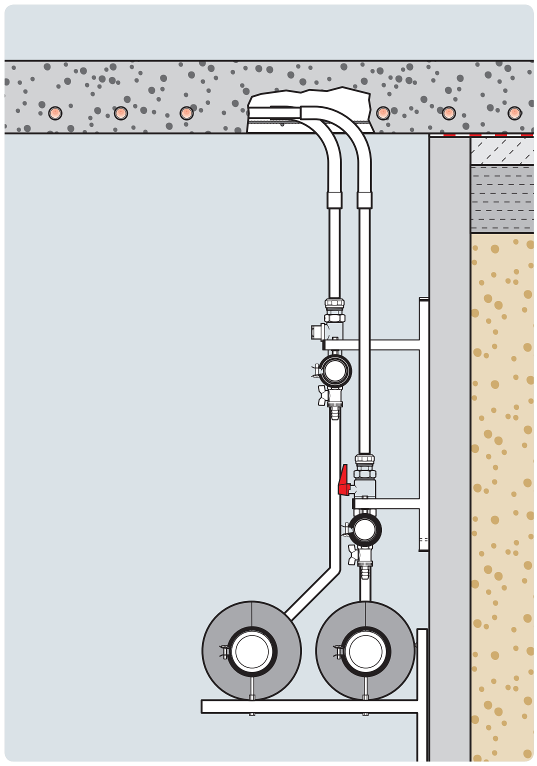
The Uponor Industrial Manifold is designed for use in industrial buildings. Depending on the on-site situation, the Uponor Industrial Manifold should be installed before the concrete is placed, either to an existing wall or, if no walls are (as yet) present, to an auxiliary structure constructed in-situ. The Uponor PE-Xa heating pipes must then be fed out of the heating plane below the manifold using Uponor pipe bend supports and connected to the manifold. The manifold feed pipes can be connected either alternately on the left and right, or to a single side.



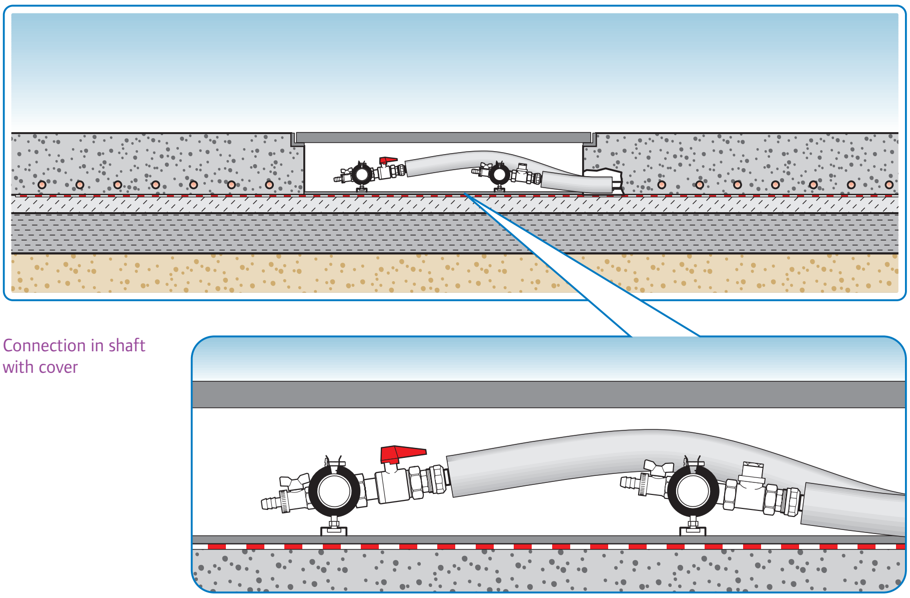
Manifold connections with Uponor pipe bend supports

Connection in supply corridor

Sometimes a supply corridor is provided for gas, water, electricity, and other installations either in the ground below the concrete slab or directly in the concrete itself . If this is the case, then it is also possible to install the Industrial Manifold in this supply corridor. It must, however, be rotated by 180° compared to the standard orientation before fitting to the wall of the supply corridor so that the heating loop connecting pipes lead upwards. The heating pipes must be routed through 90° towards the heating level using Uponor pipe bend supports. Since the industrial manifold may be mounted up to 1 m below the heating level, air separators must be included in the design to prevent formation of air bubbles. Stray residual air can also be transported out of the heating level and into the overall network at water speeds of 0.4 m/s and higher.



Connection of the Industrial Manifold in a supply corridor

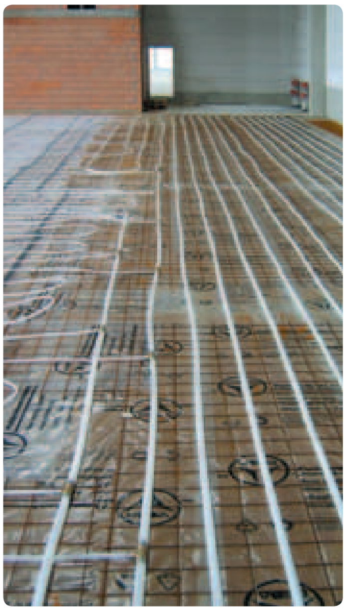


Connection in shaft
with cover

Connection in a shaft in the heating level
A space-saving solution, which is practically invisible, is to connect the heating loops in a purpose-built shaft within the heating level. If the connection shaft is located centrally in the heating level, then the heating loops can be connected from both sides, meaning that the connecting pipes to the heating loop can be kept short or even dispensed with altogether.

Feed and return valves allow the heating loops to be closed off and hydraulically adjusted, meaning that the heating loops can be of different lengths.

Connection to a Tichelmann ring
It can be beneficial to use a distribution/collection pipe system for connections, particularly where the area covered is large and uses zone control. Both the heating pipes and the distribution and collection pipes are made from the same PE-Xa material and can, for example, be connected directly to the integral structural steel mesh in the concrete surface. This connection option also means that the longitudinal expansion due to heating of the pipes does not need to be considered. Provided that the heating loops are all approximately the same length, the hydraulic equalisation valves are not necessary; access panels and inspection shafts are also rendered redundant.



Connection to a Uponor Tichelmann
distribution/collection pipe

Note:

Uponor also offers a range of other interesting, project-specific design variants, particularly for medium and large commercial spaces (> 2,500 m²). These can, for example, help save on additional installation effort (manifold connection pipes). Please contact us for more details.

Regulations applicable to the control system

Automatic control

Every heating system must be operated at the output level needed to meet the instantaneous demand for heat. An automatic control systems must therefore always be used. An underfloor heating system is always operated using a heating water control system that is dependent on the outside temperature.

The use of a room-temperature sensor is not usually advisable in large industrial buildings because of the relationship between the height/width/depth and the difficulty of selecting a suitable installation position. If room-temperature activation is to be used, then this can be connected directly to the outdoor-temperature controlled control system, provided that it only controls one section of the building (or sections of the same type and usage).

Control scheme

Temperature control

A centralised temperature control system for the heating water supply to the underfloor heating is essential in order to realise a truly "floating" heating water temperature control system that corresponds to the outside temperature. Mixers and three-way valves are suitable types of actuator here. Sections of an industrial building that are separated by walls and are of a different type and usage must correspondingly be fitted with their own central temperature control system. If a room-temperature activated system is to be incorporated, then the remote control unit can added on directly if, for example, the Uponor 3D heating system controller is used. In order to exclude the possibility of hydraulic problems caused by the temperature control system, we recommend that a controllable circulation pump or overflow device be installed.

Excess temperature protection

A limiting thermostat must be used to safeguard the flow temperature against excessive operating temperatures. The target value that is selected must be matched to the maximum permissible system temperature for the underfloor heating system.

Hydraulic requirements

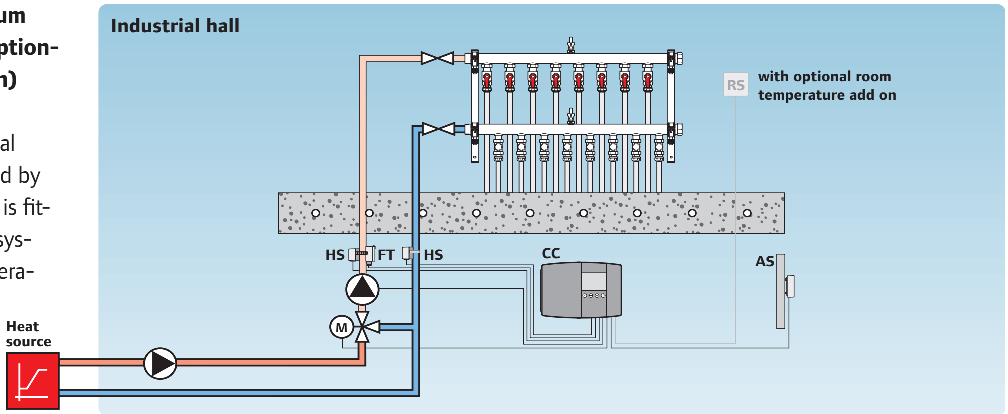
In order to ensure that the control system operates satisfactorily, the pipes connecting the underfloor heating system to the central energy plant must be well laid out from a hydraulic perspective. When considering the connection between the underfloor heating system and the heat source, attention should be paid as to whether the supply temperature from the heating generator is considerably higher than the supply temperature actually required by the underfloor heating system, and to whether the heating generator requires a minimum return temperature. In addition to this, it should also be established whether the heat generator requires forced water circulation, which is generally provided by a circulation pump in the boiler circuit. Safety devices must be included in accordance with all applicable regulations. The hydraulic zero point must be located at the inlet to the heat generator. Shut off devices must be provided as necessary to meet technical operating requirements.

Example systems

The following illustrations show various control schemes for industrial underfloor heating systems. The examples here are common concepts used for temperature control in industrial buildings. As will be seen, it is also possible to combine industrial underfloor heating systems with standard underfloor heating systems. The standard underfloor heating system must always be fitted with a single-room control system.

Heat generator with minimum return temperature (with optional room temperature add-on)

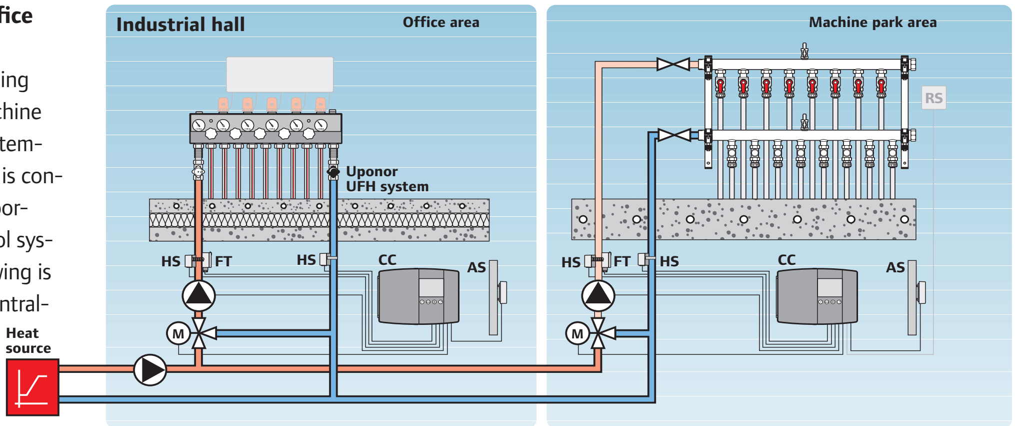
Control scheme for an industrial building that is not sub-divided by walls into sections/rooms and is fitted with a centralised control system, with optional room temperature add-on.



Connection to a heat source with outdoor temperature-dependent heating water control (with optional room temperature add on).

Industrial building with office area

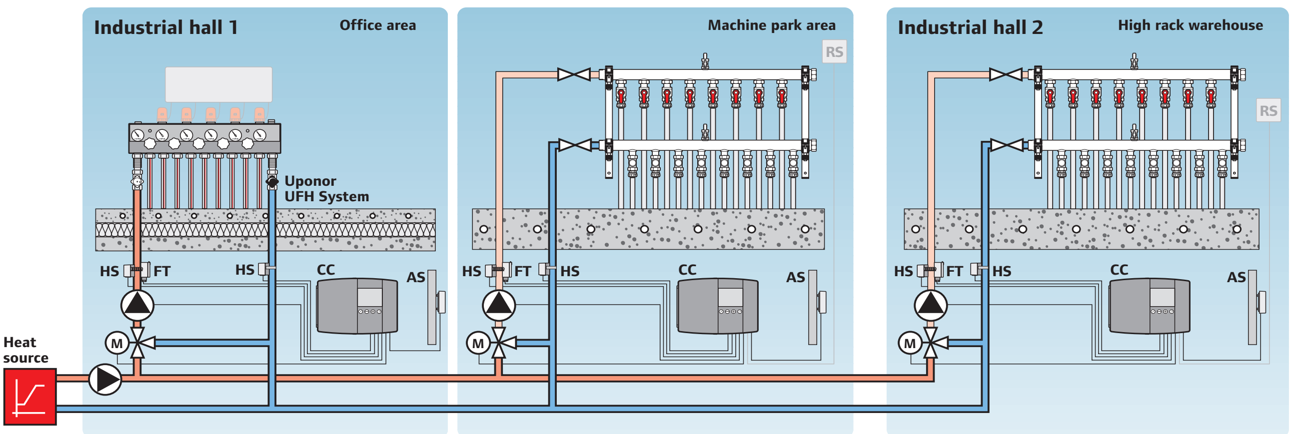
An industrial building comprising two separate sections – a machine shop and an office wing. The temperature in the machine shop is controlled by a centralised, outdoor-temperature-controlled control system, while that in the office wing is controlled by an additional centralised, outdoor-temperature-controlled control system combined with a Uponor single-room controller .



Connection to a heat source for an industrial hall with office wing.

Industrial building with office and warehouse

The industrial building consists of two separate sections: a machine shop and an office wing. The warehouse consists of a single section of the building that has a significantly lower room temperature. Each section has its own outdoor-temperature-controlled control system because the significantly different heating demand levels and room temperatures necessitate different heating curves. The office wing also features an additional single-room controller.



Connection to a heat source for an industrial hall with office and warehouse.

Information on designing the system/design specifications

Temperatures

Floor surface temperature
Particular attention should be paid to the temperature of the floor surface, whereby the medical and physiological limits on reasonable floor surface temperature must be taken into account.

The difference between the average surface temperature, $\theta_{F,m}$, of the floor and the standard interior temperature, θ_i, together with the basic characteristic curve, form the basis of the performance parameters of the heated floor surface. The maximum surface temperatures, $\theta_{F,max}$, are evaluated in accordance with the "heat flux density threshold" specified in EN 1264, which is taken as the theoretical design limit in the design diagram.

Max. surface temperatures as per EN 1264:

- **29 °C in the occupied zone**
- **35 °C in the peripheral zone**

Room temperature, perceived temperature, and average radiation temperature
Radiated heat systems like the Uponor underfloor heating system can generate considerable energy savings when compared to other less efficient heating systems.

The energy saving effect is mainly due to the favourable room air temperature and the vertical temperature profile. For human beings, not only is the room air temperature, θ_L, important, but also the average radiation temperature, θ_S, of the surfaces enclosing the room. This results in very positive perceived temperatures.

In larger spaces (industrial halls), a person is subject to a significant degree of radiation exchange with the floor. This can be clarified by calculating the angle factors. A cold floor therefore has a greater effect than under normal circumstances. An industrial underfloor heating system is needed in order to guarantee a comfortable thermal environment and sufficient protection against heat removal in industrial halls.

The "perceived temperature" is equivalent to the standard indoor temperature, θ_i, as specified in EN 12831 and is derived from the average radiation temperature and the room air temperature.

Mean radiation temperature:

$$\theta_S = \Phi_1 \cdot \theta_1 + \Phi_2 \cdot \theta_2 + ... + \Phi_n \cdot \theta_n$$

Φ_n: **Angle factor of the n-th component**
θ_n: **Surface temperature of the n-th component**

Heating medium excess temperature $\Delta\theta_H$
The heating medium excess temperature, $\Delta\theta_H$, is calculated as a logarithmic average based on the flow temperature, θ_V, the return temperature, θ_R, and the standard indoor temperature, θ_i, as specified in EN 1264. This determines the heat flux density for a fixed system structure.

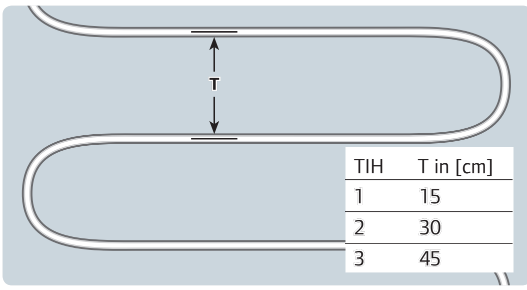
Equation (3)

As per EN 1264, Part 3:

$$\Delta\theta_H = \frac{\theta_V - \theta_R}{\ln \dfrac{\theta_V - \theta_i}{\theta_R - \theta_i}}$$

TIH loading

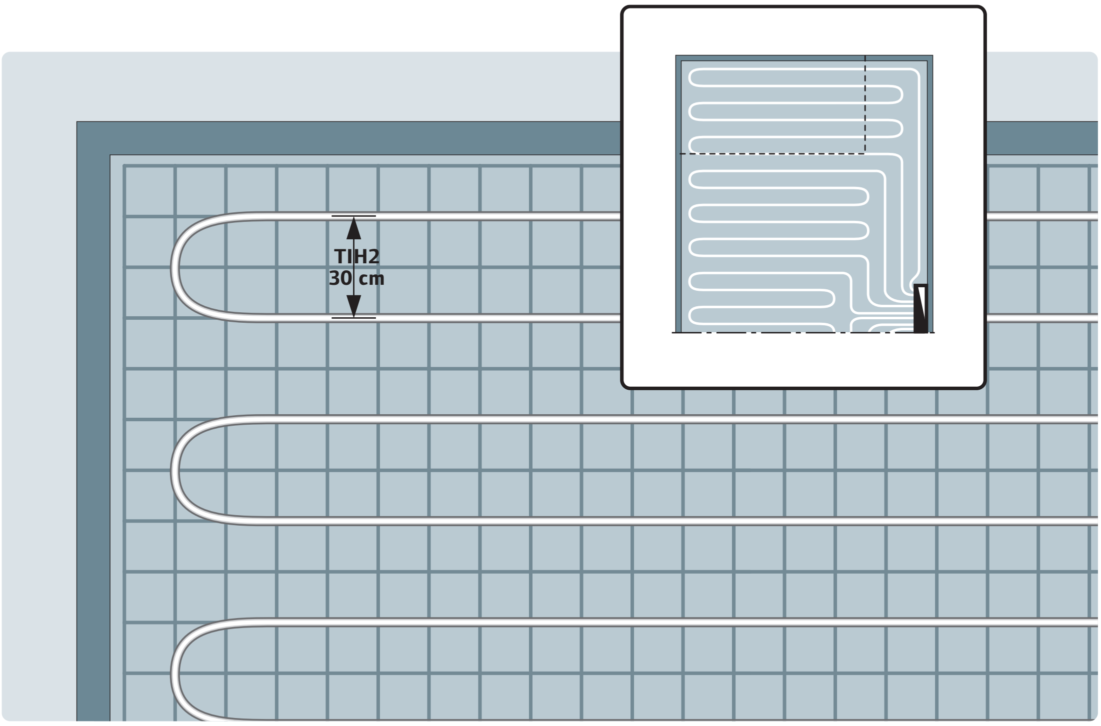
A specific pipe spacing T, should be selected according to the planning requirements. The Uponor industrial underfloor heating system covers three load cases, TIH 1, TIH 2 and TIH 3. Taken together, pipe spacing, T, and heating medium excess temperature, $\Delta\theta_H$, give the thermal output of the industrial underfloor heating system for a given combination of concrete covering, s_u, and thermal resistance of the wearing layer, $R_{\lambda,B}$. The heating loops are laid in a meandering pattern. Load cases can be combined when laying the pipes, for example with TIH 1 used in peripheral zones (e.g. in front of the main building doors), and TIH 2 used for the occupied areas of the inside of the building.



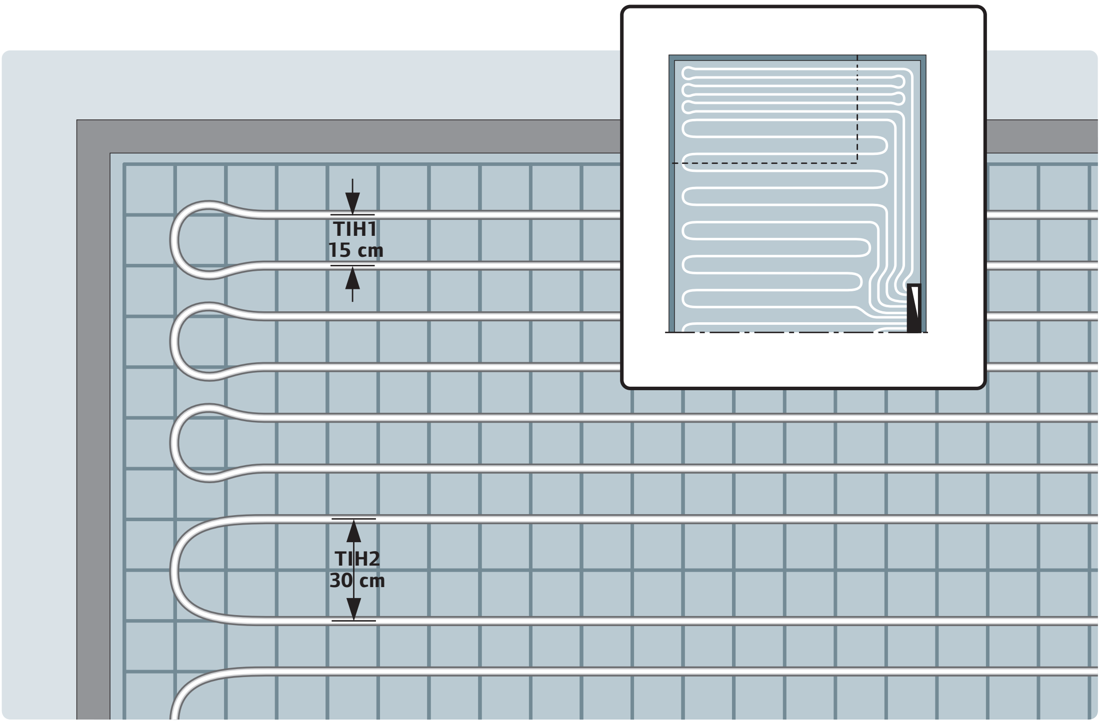
TIH	T in [cm]
1	15
2	30
3	45

Load cases for Uponor industrial undfloor heating systems

TIH loading for occupied zones



TIH loading for occupied zones with peripheral zones



Basis of calculations

Design

This sub-section provides the information necessary to determine all the relevant design data for an underfloor heating system. The design of a Uponor industrial underfloor heating system is carried out in accordance with EN 1264, Part 3:

Heating load as per EN 12831

The required thermal output of the individual sections of the building is determined according to EN 12831, with particular reference to Appendix B.1.

Depending on the height of the hall, the standard heat losses with a convective heating system or radiant ceiling heating are between 15 and 60% higher, since room temperature increases significantly with height, meaning that a lot of heat goes unused and is lost through the roof. Underfloor heating systems transfers heat mainly as radiant heat. The temperature gradient is practically constant across all room heights. It is therefore not usually necessary to apply a loading factor to the heating load calculation.

Peripheral zones

The TIH load cases allow the peripheral zones to be created at the rarely used edges of the floor. These zones have less distance between the pipes and therefore have a higher floor surface temperature. Using these peripheral zones compensates for the higher heat losses around the edges, and therefore increase comfort levels. The layout in the peripheral zone always uses TIH 15. The width of the peripheral zone should not be more than 1.0 m.

Information for planning:

- **Max. floor surface temperature in the peripheral zone, $q_{F, max}$ = 35 °C**

Using the design diagram

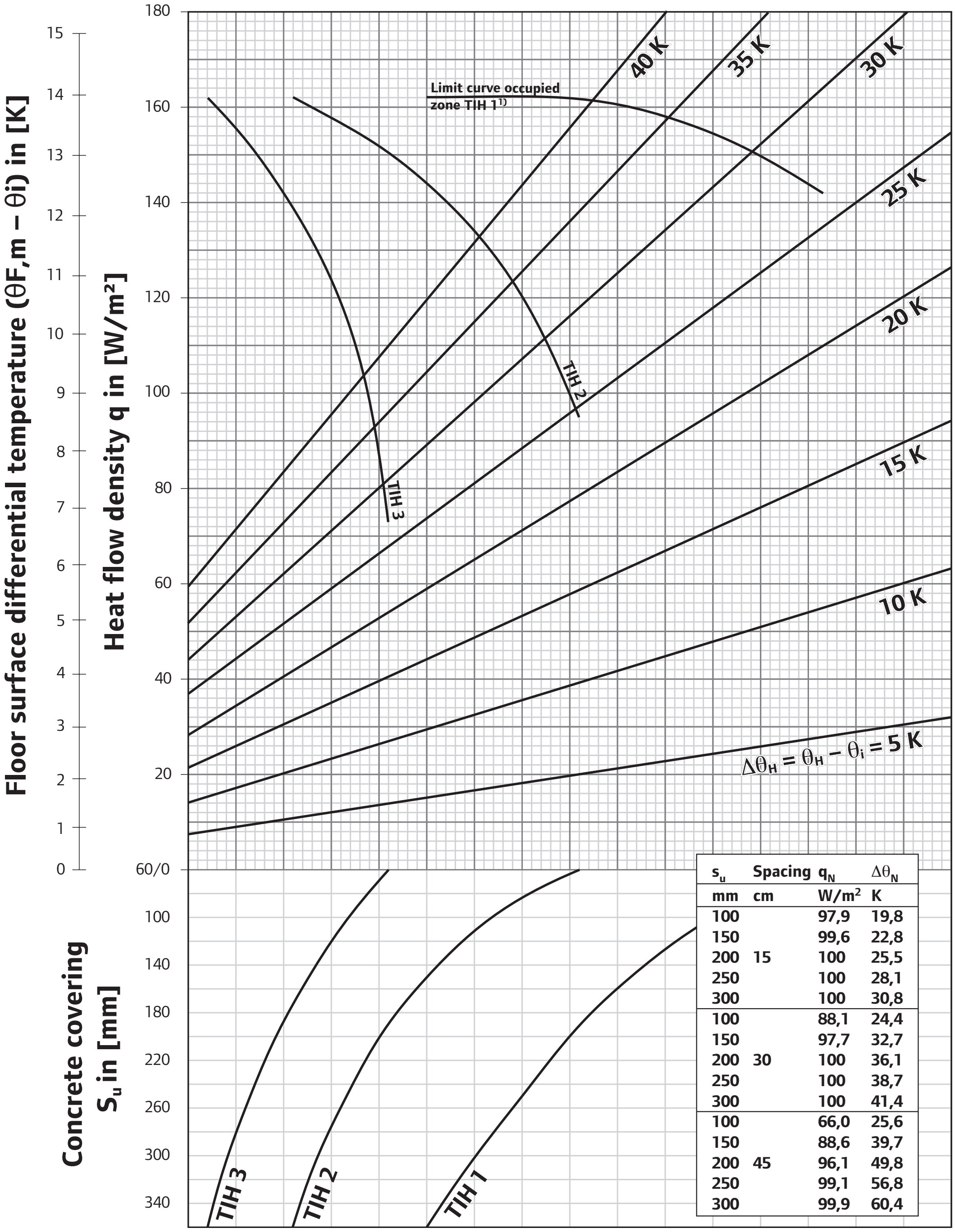
The thermodynamic design diagram provides a complete overview of the following influencing variables and their relationship to each other:

1. Heat flux density of the underfloor heating system, q, in [W/m^2]
2. Concrete covering s_u in [cm]
3. Pipe laying distances, TIH, in [cm]
4. Heating medium excess temperature $\Delta\theta_H = \theta_H - \theta_i$ in [K]
5. Floor excess temperature $\theta_{F, m} - \theta_i$ in [K]

Provided that three of the influencing variables are known, all the others can be calculated using this diagram. The presence of a wearing layer with properties $R_{\lambda, B}$ = 0.02 m^{2}K/W was assumed when creating this diagram. This thermal resistance corresponds to the average of the values for the most common wearing layers.

Design diagram

Design diagram for Uponor industrial underfloor heating integrated into a concrete slab with $\lambda = 2.1$ W/mK, wearing layer $R_{\lambda, B} = 0.02$ m² K/W, heating pipe 25 x 2.3 mm

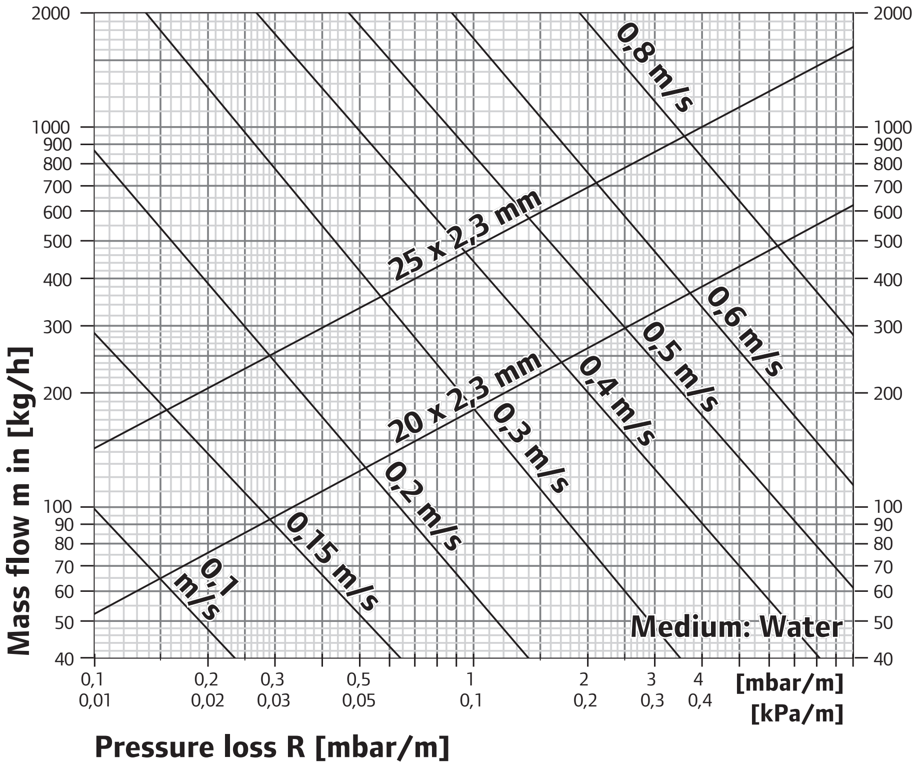


s_u	Spacing	q_N	$\Delta\theta_N$
mm	cm	W/m²	K
100		97,9	19,8
150		99,6	22,8
200	15	100	25,5
250		100	28,1
300		100	30,8
100		88,1	24,4
150		97,7	32,7
200	30	100	36,1
250		100	38,7
300		100	41,4
100		66,0	25,6
150		88,6	39,7
200	45	96,1	49,8
250		99,1	56,8
300		99,9	60,4

[1)] Threshold curve applies with $\theta_i = 15$ °C and $\theta_{F,\,max} = 29$ °C

Note:
The threshold curves must not be exceeded. The designed flow temperature can take a maximum value of:
$\theta_{V,\,des} = \Delta\theta_{H,\,g} + \theta_i + 2{,}5$ K.
The value $\Delta\theta_{H,\,g}$ is given by the threshold curve for the occupied zone at the smallest planned pipe separation.

Pressure loss diagram



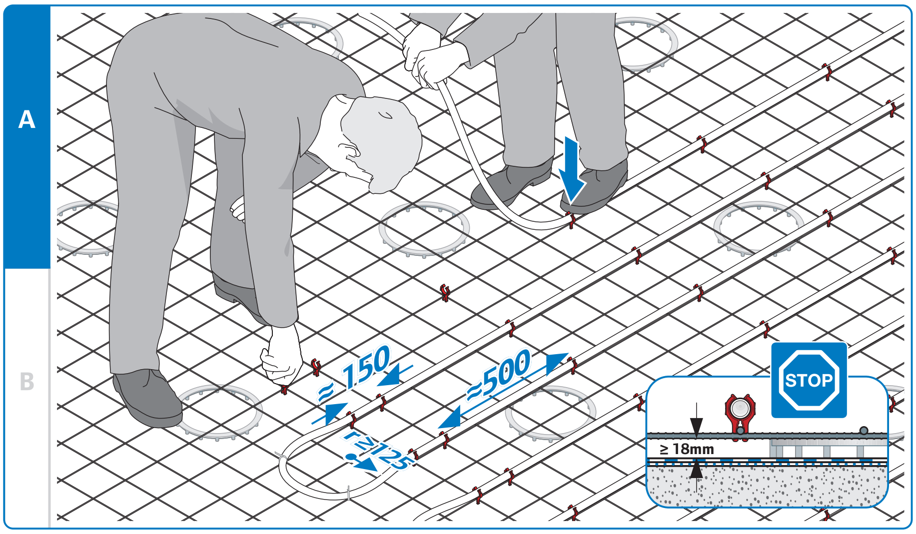
The pressure gradient in Uponor PE-Xa pipes can be determined using this diagram.

Installation

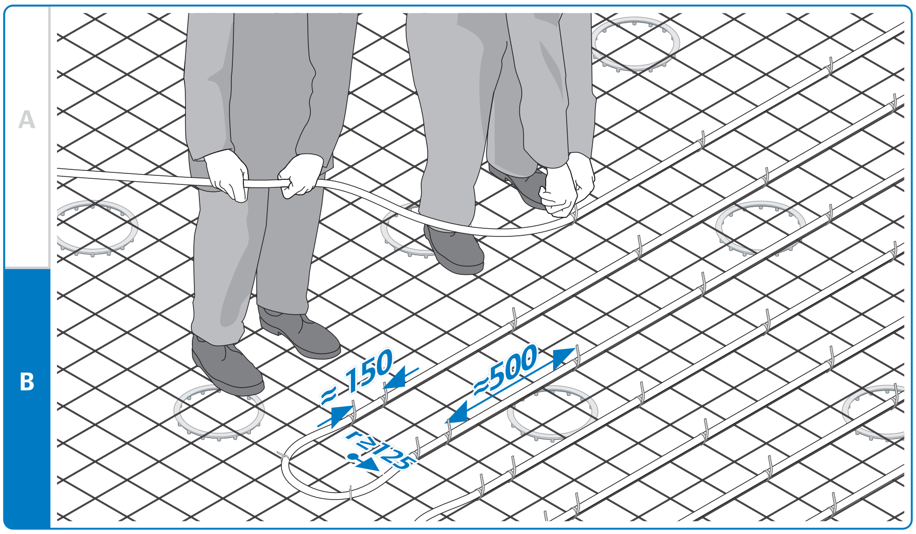
General

The brief guide below describes only some aspects of the process of installing Uponor industrial underfloor heating. Please read and follow the additional installation instructions supplied with the product.

Overview of installation steps

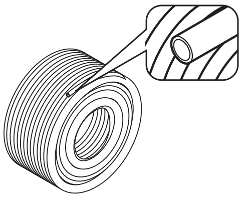


Fixing of pipe clips and installation of heating pipes.



Installation of heating pipes with cable ties.

Technical specifications



Uponor PE-Xa pipe, 25 x 2.3 mm	
Pipe dimensions	25 x 2.3 mm
Material	PE-Xa
Manufacture	As per EN ISO 15875
Oxygen impermeability	As per DIN 4726
Density	0.938 g/cm^3
Thermal conductivity	0.35 W/mK
Lin. expansion coefficient	At 20 °C, 1.4 x 10-4 1/K
	At 100 °C, 2.05 x 10-4 1/K
Crystalline melting temperature	133 °C
Materials class	E
Min. bending radius	125 mm
Surface roughness of pipe	0.007 mm
Water content	0.33 l/m
Range of heating application	70 °C/7.2 bar
Max. cont. operating pressure (water at 20 °C)	15.4 bar (safety factor ≥ 1.25)
Max. cont. operating pressure (water at 70 °C)	7.2 bar (safety factor ≥ 1.5)
DIN-CERTCO registration no.	3V209 PE-X
Pipe connections	Connector couplings and clamp ring screw connections, Q&E joints, type Uponor 25 x 2.3
Preferred installation temperature	≥ 0 °C
Approved water additive	Uponor GNF antifreeze
UV protection	Optically opaque cardboard (unused portion must be stored in the box)

Notes

Notes

Uponor – partnering with professionals

Uponor is a leading supplier of plumbing and heating systems for the residential and commercial building markets across Europe and North America, and a market leader in municipal infrastructure pipe systems in the Nordic countries. Uponor's key applications include indoor climate and plumbing systems. The Group employs 3,800 persons in 27 countries.

Uponor International Sales takes care of all business activities in the Balkans, Western, Central and East Asia, Africa and Latin America.

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Uponor Europe – East and International

International Sales
P.O. Box 1641
97433 Hassfurt
Germany
T +49-(0)9521 690 0
F +49-(0)9521 690 750
E export@uponor-europe.com
W www.uponor.com/international

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