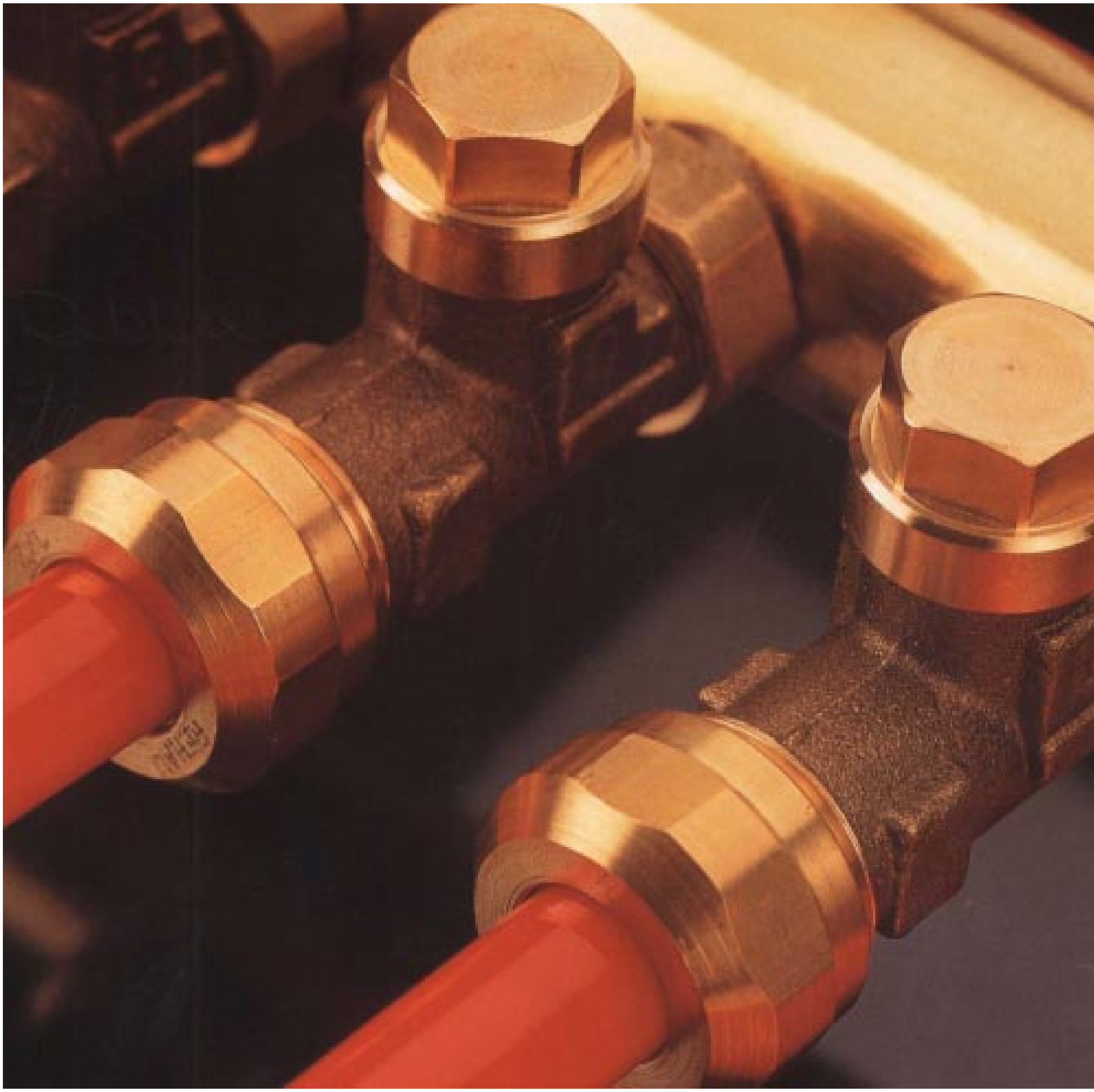
RAUPEX ™
Radiant Floor Heating Systems
Technical Manual



1. Introduction

This technical manual provides a thorough understanding of the design and installation of radiant floor heating systems using cross-linked polyethylene tubing produced by REHAU. It is intended to help experienced hydronic heating professionals achieve the best results with REHAU's RAUPEX heating systems.

Please also refer to "RAUPEX Radiant Floor Heating Systems Catalog/Price List" which provides a detailed description of each system component and includes information on weight, packaging and price.

REHAU also offers hydronic heating systems for special applications such as snow melting, material storage heating, stair de-icing and many others.

REHAU has over 20 years of experience in the field of hydronic heating, and has produced over 500 million feet (150 million meters) of cross-linked polyethylene tubing for heating systems.

Over 200,000 building projects, with a total area exceeding 250 million square feet (23 million square meters) are in successful operation.

Fig. 1.1:
REHAU radiant floor heating in an industrial project.

Fig. 1.3:
High ceiling areas are ideal for radiant floor heating.

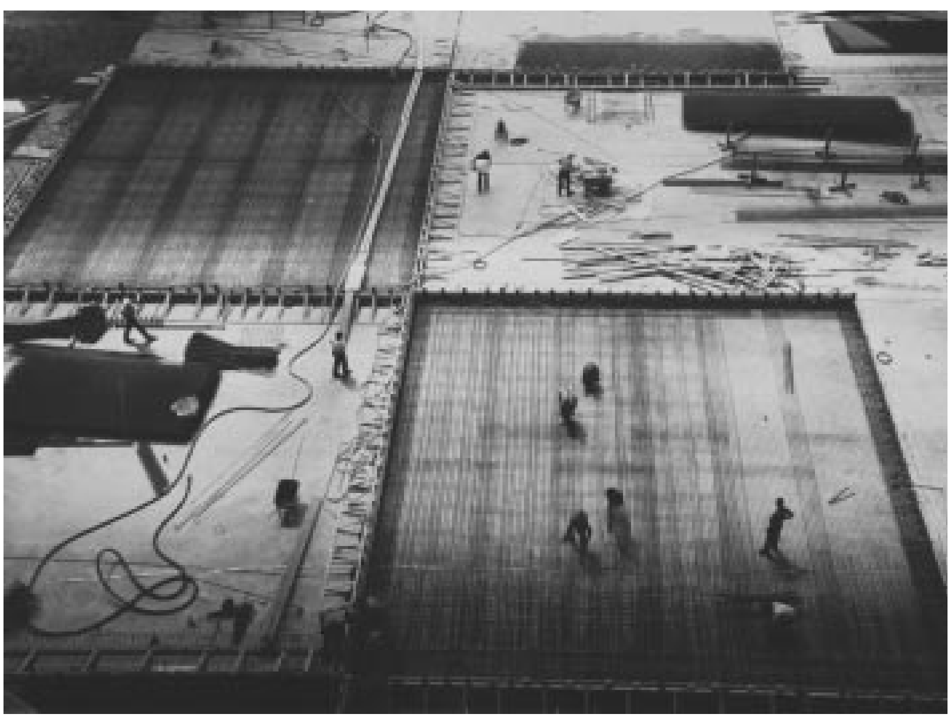


Fig. 1.2:
Floor of aircraft hangar incorporating RFH system.

1.1 Description

RAUPEX is REHAU's tradename for a specially formulated cross-linked polyethylene (PEX). RAUPEX is an unusually strong and stable polymer that stands up well to strenuous use which makes it ideally suited for hydronic heating systems.

RAUPEX heating tube, either with oxygen diffusion barrier (RAUPEX B) or without barrier (RAUPEX), is fully embedded in floor thermal mass or placed under wood subflooring. When used in conjunction with manually or thermostatically controlled supply- and return-flow valves that distribute water through the tube and back to a boiler, the system transforms the entire floor into a warm-water, low temperature heater.

1.2 Application

The REHAU radiant floor heating system can heat a whole room or it may serve in combination with other auxiliary heating systems. This offers you great flexibility in selecting heat output. For example, 60% of an area's heat might be supplied by the floor heating system, with the remaining 40% coming from a secondary system such as radiators or fan coil units.

Our system can be used in a wide variety of building types and uses including residences, schools, auditoriums, churches, convalescent homes, supermarkets, hospitals, warehouses, and factories. While well-insulated buildings offer ideal environments for floor heating, weather-exposed projects - parking garage entrance ramps, outdoor stairways, stadiums, parking decks, aircraft runways, and bridges - which must be kept free from ice and snow are also intelligent locations for floor heating systems.

1.3 Room temperature

Most people relate their comfort to ambient room temperature. However, many factors beside thermal temperature influence thermal comfort, making it impossible to specify "ideal room temperature". Instead, target temperatures must always be related to specific ambient conditions, including such things as the clothes we wear for particular activities. Calculated heat requirements for room temperatures must, therefore, always be regarded as mean temperatures and must allow for ambient influences.

1.4 Mean radiant temperature

The mean radiant temperature (MRT) of a room is most simply defined as the average temperature of its surfaces. Fig. 1.5 illustrates the combined effect of ambient room temperature and MRT on human comfort. The effect of MRT on the occupants in a room depends on the size and temperature of the room surfaces and the occupant's distance from these surfaces. RFH directly affects mean radiant temperature by heating the room's surfaces. The floor is directly heated to the design floor surface temperature, and the walls and ceiling are heated by radiant energy (heat) from the floor. Therefore, occupants benefit not only from the increase in ambient room temperature created by RFH systems but also from the increase in the MRT.

1.5 Temperature distribution

Uniform temperature distribution through the room is an important factor in human comfort. A room temperature profile, determined by measuring room temperatures along specified vertical and horizontal planes in the room, gives a clear picture of the uniformity of temperature distribution throughout the room, and can help you identify areas of significant heat loss.

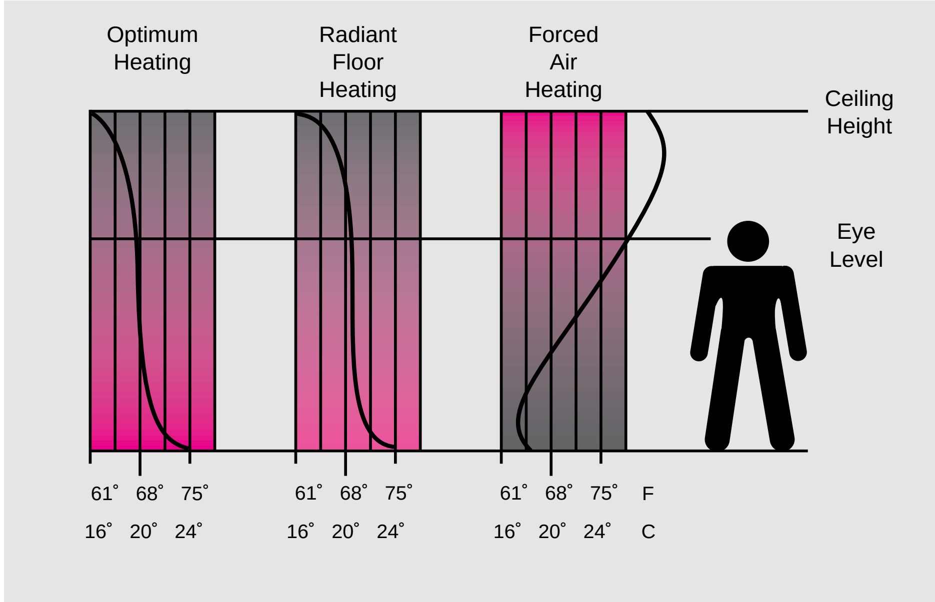
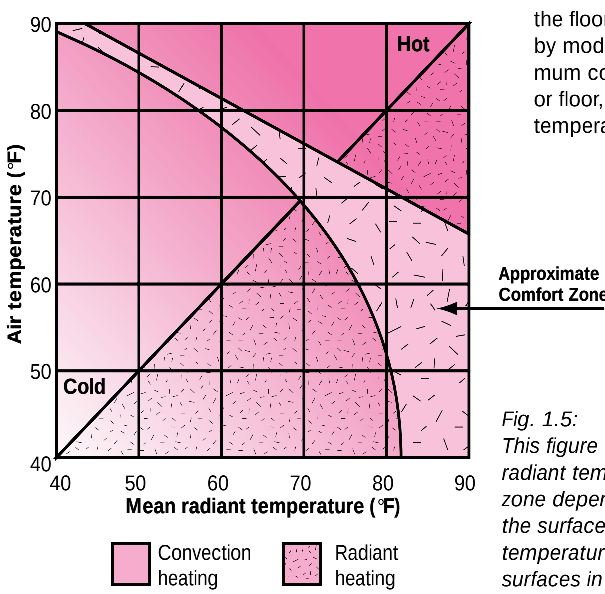


Fig. 1.4:
This figure compares temperature profiles for RFH, forced air and optimum heating distribution. You'll note that radiant floor heating's temperature profile very closely approximates an ideal temperature distribution.

The shape of these room temperature profiles depends on the type of heating system in use; the position, size and temperature of the area dissipating heat; the outside temperature; the arrangement of windows; and the position of the temperature sensor.

1.6 Floor temperature

A cold floor can literally draw the warmth energy from your body using your feet as the transfer point. As a result, floors are an excellent heating source. Floor temperature limitations do exist to protect certain types of floor finishes while still providing enough heat to meet the room requirement.



1.7 Heat sources

There are few restrictions, in principle, to the heat source you choose to use in conjunction with a REHAU radiant floor heating system. Two conditions, however, must be kept in mind for any heat source:

- First, the heat source must be sufficient to supply the heat required, including auxiliary requirements such as domestic hot water. Typical heat sources are low and high temperature boilers, designated hot water tanks, heat pumps, solar and, in certain regions, geothermal.
- Second, the maximum flow temperature in the floor heating circuit must be regulated by modern control systems to assure optimum comfort, to avoid damage to the tube or floor, and to prevent excessive floor temperatures.

Fig. 1.5:
This figure compares air temperature and mean radiant temperature showing that the comfort zone depends on the average temperature of the surface within the room as well as the air temperature. RFH raises the temperature of the surfaces in the room allowing inhabitants to be comfortable at lower air temperatures.
(Adapted from I=B=R Guide #400)

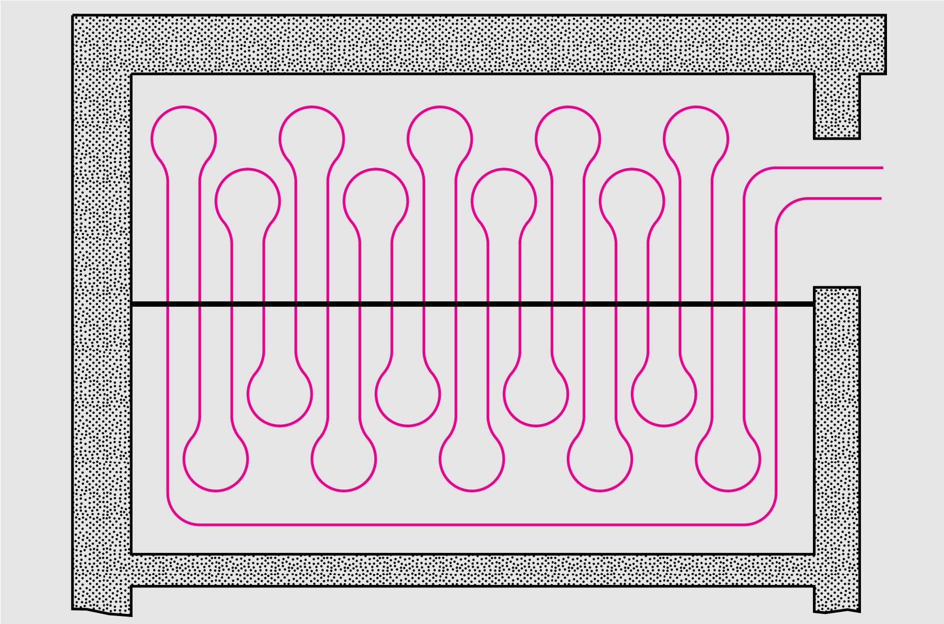


Fig. 1.6:
Serpentine pipe-layout pattern.

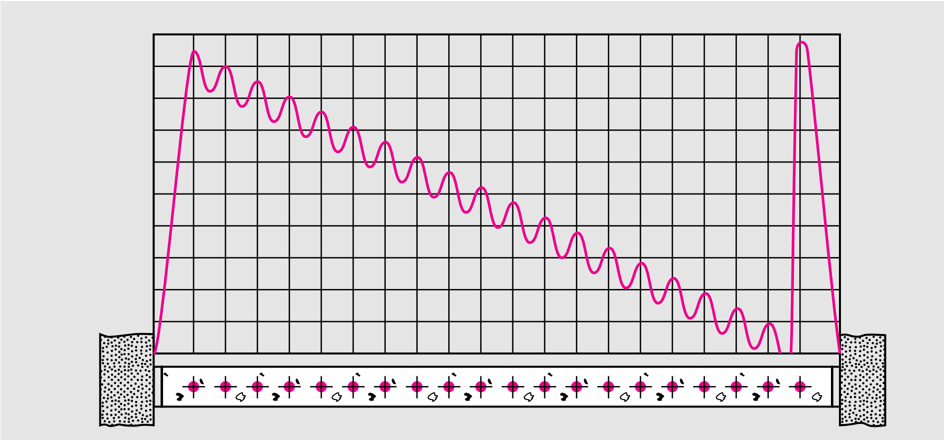


Fig. 1.7:
Surface temperature profile for serpentine pipe-layout pattern.

1.8 Tube circuit laying patterns

1.8.1 Serpentine

A serpentine pattern allows for warmer floors along the perimeter areas of a room or zone, where it is needed. Floor surface temperatures along perimeter walls will be greater than floor surface temperatures in the interior of the room, where occupants are more likely to gather. For residences, floor surface temperatures can be as high as 95°F (35°C) along the perimeter.

1.8.2 Counterflow spiral

This method allows closer tube spacing than the serpentine patterns, since there are fewer bend radius constraints. In addition, surface temperatures are distributed more evenly by laying tube in counterflow spiral form.

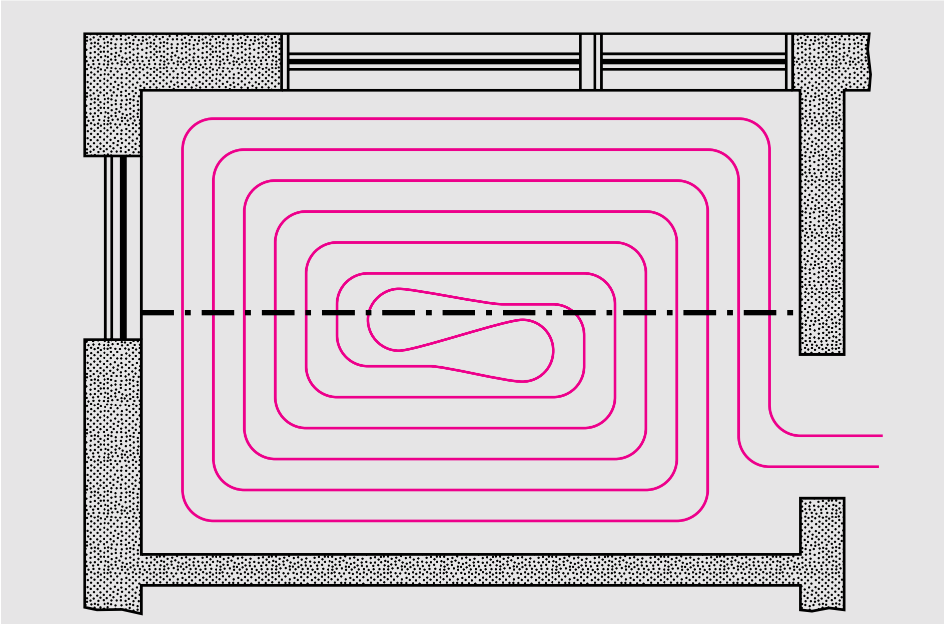


Fig. 1.8:
Counterflow spiral pipe-layout pattern.

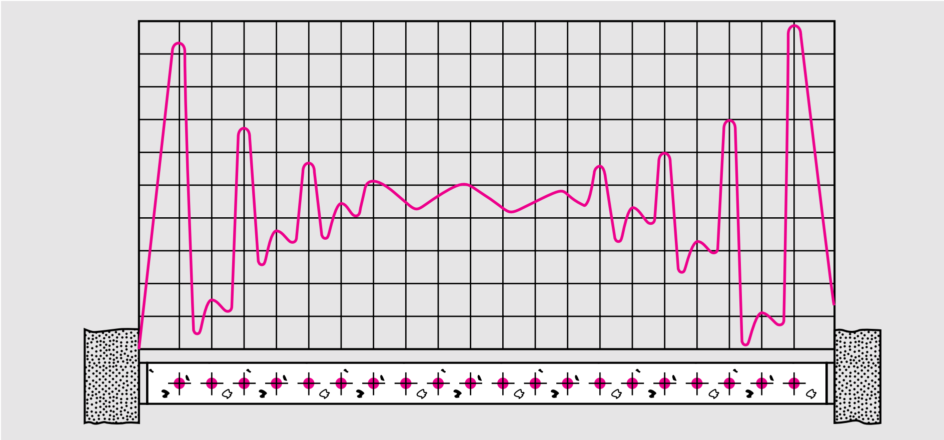


Fig. 1.9:
Surface temperature profile for counterflow spiral pipe-layout pattern.

1.8.3 Combination

Often the most effective way to heat a room is to use a serpentine pattern at the edges and a counterflow spiral pattern in the middle. There are many ways these basic patterns can be varied to meet the unique requirements of any application. Figures 1.10 and 1.11 show variations which allow for greater heat along perimeter areas in a zone.

1.8.4 Tube spacing and depth

REHAU radiant floor heating circuits may be laid in a variety of patterns. The tube spacing and depth in the thermal mass affect the uniformity of the floor surface temperature. There is a direct correlation between tube spacing and supply water temperature. The closer the tube spacing the lower the supply water temperature which corresponds to a design with greater efficiency.

In principle, the heat requirement of a room may be covered regardless of the laying pattern. However, the heating system must not only fulfill the task of covering the heat requirement but also create a sense of comfort. Keep in mind that the heat requirement of a room is higher near exterior wall (perimeter areas) and diminishes toward the center of the room (occupied area). The higher heat requirement at exterior walls and windows can usually be met by decreasing the tube spacing in comparison to the occupied area.

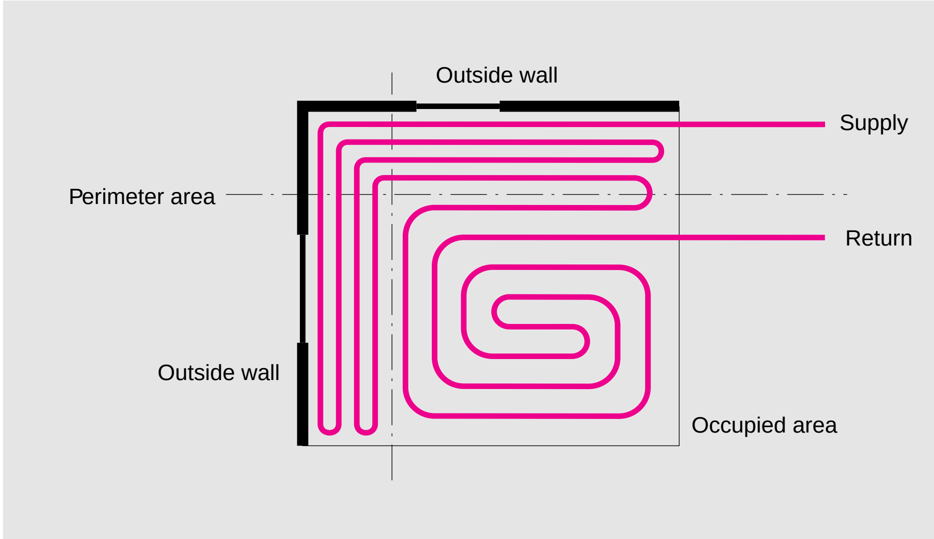


Fig. 1.10:
Perimeter and occupied areas using one circuit.

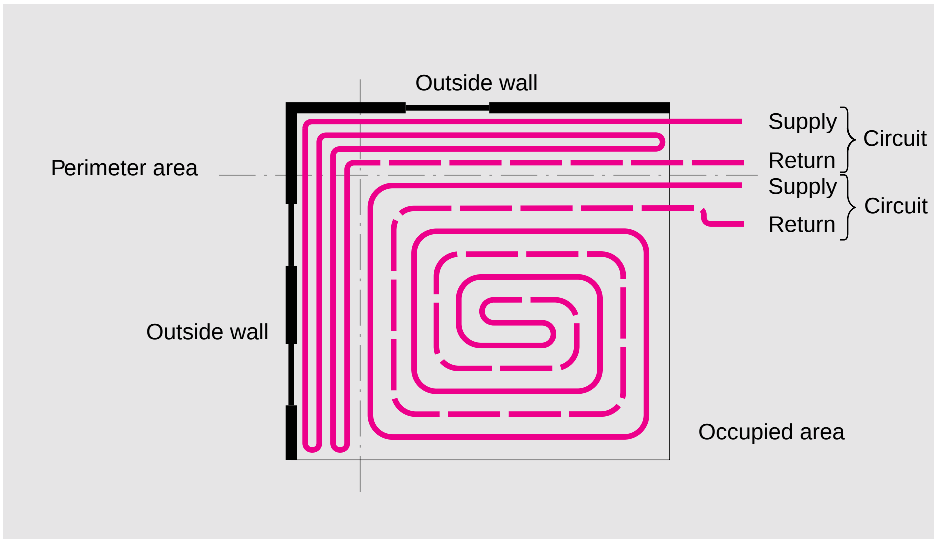


Fig. 1.11:
Perimeter and occupied areas requiring two circuits.

1.9 Control systems

The amount of energy consumed by a heating system is largely determined by the way in which it is operated. Avoidable energy loss resulting from poor system control design, improper heat source operation or failure to provide system service may account for up to 20% of the annual consumption of heating energy. Proper design of a floor heating control system can help to enhance system performance, efficiency and comfort.

Properly designed radiant floor heating systems require a much lower supply water temperature than conventional hydronic heating systems. Effective design of a floor heating system requires careful attention to control of the system. REHAU offers a variety of components for controlling radiant floor systems using RAUPEX tubing. Please refer to our "RAUPEX Radiant Floor Heating Systems Design Supplement" for detailed diagrams of suggested control schemes. Generally, these systems have the task of adjusting the supply water temperature according to the many variables that affect floor output, and ultimately human comfort. These controls should act in such a way that:

- rooms are not overheated.
- rooms are heated when and as required.
- compensates for free energy, such as sunshine.
- heat input is switched on or off at the proper time.

Heat output of radiant floor systems can be regulated by adjusting water flow rate or by adjusting supply water temperature. Adjusting supply water temperature has a much more linear effect on heat output. Therefore, most control systems vary the supply water temperature to control radiant floor heating systems. REHAU offers both weather-compensating and thermostatic methods to accomplish this control.

Weather-compensating control

Weather-compensating controls generally compare electrical resistance inputs from an outdoor temperature sensor and a supply water temperature sensor. With these inputs, a voltage output signal is generated based on an adjustable “heating curve” (ratio). The resulting output signal is used to control a heat source or a motorized mixing valve. Some controls have additional output signals for controlling system circulators or zone valves and may be used to control both low temperature and high temperature demands.

Weather-compensating controls can be very effective at matching heating system output to existing heat load throughout the heating season. Because of these fine tuning adjustments, room temperature can remain very stable with very little fluctuation. The disadvantages associated with these controls are the comparatively higher component costs and somewhat higher level of skill required for planning and installation.

Thermostatic control

Another method to control radiant floor heating systems is with thermostatic devices. These controls sense floor supply water temperature and mix boiler primary loop water with floor return water to maintain a preset temperature. Because thermostatic controls are set to maintain a specific supply water temperature they may require manual adjustment during the heating season. Overshooting the thermostat set point may be more noticeable with thermostatic control than with weather-compensating control. However, thermostatic control is typically much less expensive than weather-compensating control and is easier for installers to understand. Many homes have been heated successfully with this type of control.

Room control

In many buildings, it may be necessary to control individual rooms separately from other rooms without adjusting the thermostatic or weather-compensating control. One way to accomplish this is with valve actuators attached to individual manifold loops that service the rooms where control is desired. These low voltage actuators close individual manifold loops when the associated room thermostat is satisfied. Installers must plan for room thermostat wiring to the manifold locations during system rough-in.

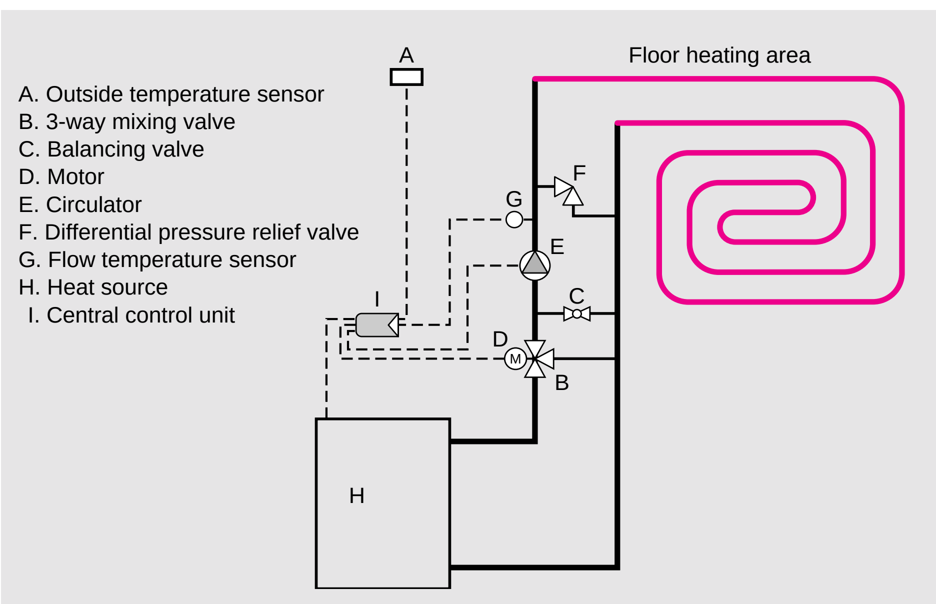


Fig. 1.12:
Constant temperature heat source with radiant floor heating circuit. Flow temperature is regulated in relation to outside temperature.

2. System components

A radiant floor heating system comprises REHAU products installed within the structure of the building floor using various methods to secure the tubing. REHAU offers the tube, manifolds, controls and several types of devices to install the tube.

Fig. 2.1:
REHAU system using 25 x 2.3 RFH tube and cable binder method of installation.

2.1 RAUPEX heating tube

The tube used in hydronic heating systems must be easy and efficient to install, must disperse heat well and must be durable.

Fig. 2.2:
RAUPEX coil.

RAUPEX hydronic heating tube with and without EVAL oxygen diffusion barrier conforms to CSA B137.5 and to ASTM F876/F877 for up to 100 psi (6.9 bar) water service and to a maximum working temperature of 180°F (82°C). RAUPEX tubing is independently certified by the Plastic Pipe Institute (PPI), the Canadian Standards Association (CSA), and the International Congress of Building Officials (ICBO).

2.1.1 Tube material

RAUPEX tube is extruded in cross-linked, high-density polyethylene. The base material is a high-density polyethylene (HDPE) with a molecular weight considerably higher than that of normal HDPE types. This material is notable for its particularly high endurance limit, impact resistance and thermal stability.

These properties provide the ideal basis for optimum tube behavior when exposed to high temperatures and pressure. Processing under extreme pressure and simultaneously cross-linking with the aid of organic peroxides eliminate the otherwise normal steep fall in long-term stress rupture found in conventional polyethylenes. This is because during the cross-linking process the polymer chains are linked to form a three-dimensional structure. In addition to creating outstanding long-term stress rupture resistance, cross-linking also produces maximum environmental stress cracking resistance.

Resistance to aging is also a decisive factor in determining the service life of tubes made of RAUPEX. Aging is a material change caused by temperature and oxidization and may negatively influence the long-term tube behavior.

To counteract these influences, special heat-stabilizing agents are added during the manufacturing process to enhance the innately stable properties of RAUPEX tube. This increases resistance to aging.

2.1.2 Flammability

RAUPEX is a hydrocarbon and, therefore, burns in a similar way to wax. Cross-linking increases the temperature at which the material begins to liquefy to above the decomposition temperature of 752°F (400°C). In contrast, polymers that have not been cross-linked drip as soon as they are heated beyond 392°F (200°C).

2.1.3 UV resistance

Once removed from their original packaging, RAUPEX tubes must be protected from direct sunlight when exposure time will exceed 3 months. Permanently surface-mounted tubes must be sheathed to protect them from direct sunlight.

Properties	Standard	Unit	Value
Density	ASTM D 1505	g/cm^3	0.93
Thermal Conductivity	DIN 52612	W/mK	0.41
O_2 Permeability with EVAL Barrier	DIN 4726	mg/l d	<0.025
Coefficient of Linear Thermal Expansion 68°F (20°C) 212°F (100°C)	DIN 42328	F^{-1}	7.8×10^{-5} 1.1×10^{-4}
		K^{-1}	1.4×10^{-4} 2.0×10^{-4}

Table 2.1:
Physical properties of RAUPEX tube.

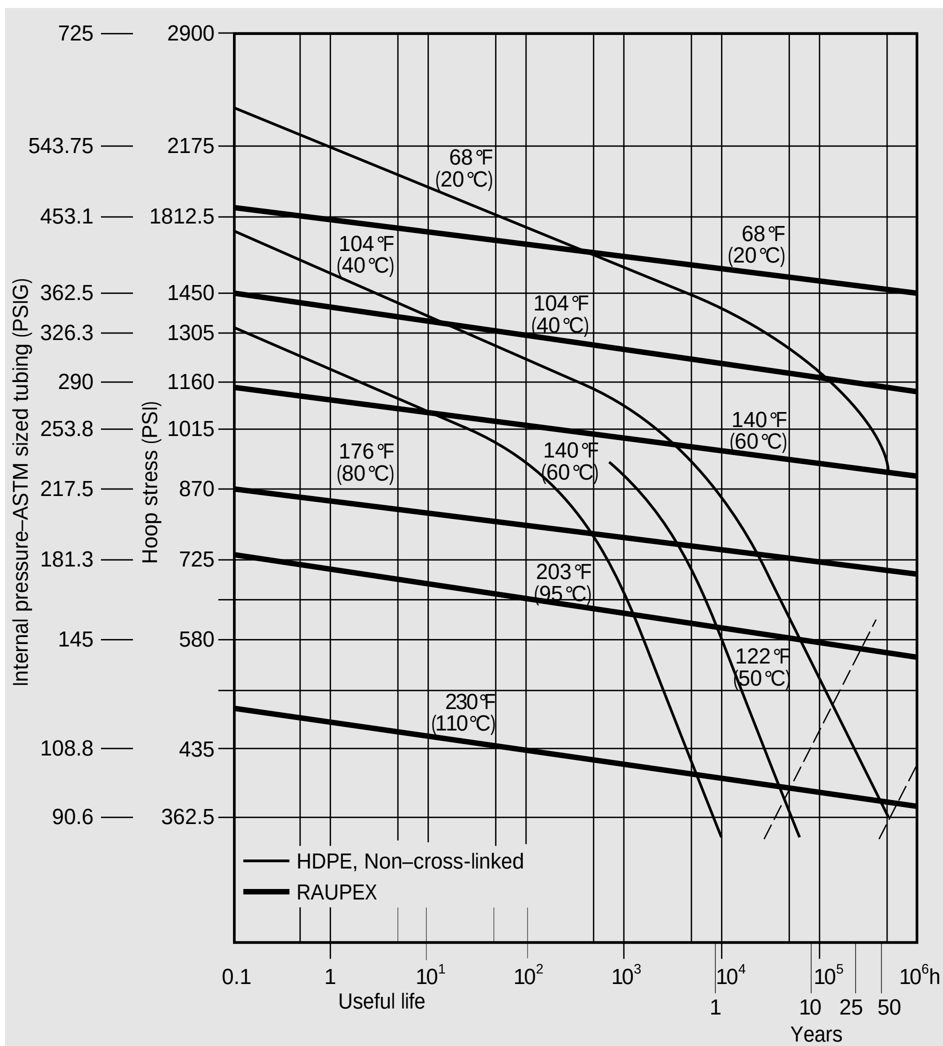


Fig. 2.3:
Useful life of RAUPEX tube.

2.1.4 Long term performance

Tests on internal pressure endurance over many years show that RAUPEX tube performs significantly better than tube made of other, similar polymers. RAUPEX has been subjected to more than 100,000 hours of continuous testing at 203°F (95°C) with no deviations in the endurance graphs.

On the basis of these tests the International Standardization Organization (ISO) permits extrapolation of the RAUPEX endurance characteristics for permanent operating temperatures of up to 158°F (70°C) and for a minimum service period of 50 years.

2.1.5 RAUPEX advantages

RAUPEX is distinguished by the following characteristic properties:

Gas and water vapor permeability

The uncontrolled diffusion of gas and vapor into closed hydronic systems has long been a cause of concern among engineers. RAUPEX tube features very low water and oxygen permeability and meets the DIN 4726 standard.

Our RAUPEX B tube with oxygen diffusion barrier eliminates the risk of corrosion damage that oxygen diffusion causes to ferrous components. It is protected against the admission of oxygen by its extruded EVAL barrier which surrounds the tube.

Thermal properties

The high density cross-linking molecular bridges allow it to maintain its elastic properties at temperatures above the crystalline melting point (approx. 266°F (130°C)). In its viscous-elastic range (-248°F to +248°F (-120°C to +120°C)), RAUPEX is softer and more malleable than non-cross-linked base material.

Mechanical properties

RAUPEX is tough and flexible, even under repeated bending. REHAU's method of cross-linking, which occurs at the molten state of tube processing, makes RAUPEX more elastic, and easier to bend than most other cross-linked polyethylene tubes.

Chemical resistance

RAUPEX resists conventional solvents, detergents, anti-freeze agents and corrosion inhibitors. Even at high temperatures, RAUPEX resists hydrous solutions of salts, acids and alkalies.

2.1.6 Tube dimensions

REHAU PEX tube is available in nominal sizes 17mm, 20mm, 25mm and 32mm (RAUTHERM); 1/2", 3/4" and 1" (RAUPEX). Table 2.2 provides dimensional data for REHAU heating tube.

2.1.7 Tube labeling

RAUPEX tube is marked with all information required by ASTM F876/F877 and CSA B137.5.

RAUPEX B - Tube is red and has the DIN 4726 EVAL oxygen diffusion barrier.

RAUPEX - Tube is white and is without oxygen diffusion barrier.

Length is marked at 1 meter or 3 foot intervals along coiled tube spools and straight sections as an aid to installers.

2.1.8 Quality assurance standards

REHAU PEX (cross-linked polyethylene) tube and fitting system are manufactured to meet ASTM F876 and F877 as tested by the NSF and CSA. RAUPEX tube production qualifies and has been independently certified to be in conformance to International Standard 9001.

RAUPEX (ASTM Tube) Sizes					RAUTHERM (Metric Tube) Sizes			
Nominal Diameter in	Wall in* (mm)	O.D. in* (mm)	I.D. in* (mm)		Nominal Diameter mm	Wall mm (in*)	O.D. mm (in*)	I.D. mm (in*)
1/2"	.07 (1.8)	.63 (16)	.49 (12)		17	2 (.079)	17 (.67)	13 (.51)
3/4"	.10 (2.5)	.88 (22)	.68 (17)		20	2 (.079)	20 (.79)	16 (.63)
1"	.13 (3.2)	1.13 (29)	.88 (22)		25	2.3 (0.091)	25 (.98)	20 (.80)
–	–	–	–		32	28 (.110)	32 (1.25)	26 (1.04)

* dimensions converted from metric

Table 2.2:
Tube dimensions.

2.2 RAUPEX fittings

REHAU offers two fitting systems for RAUPEX tube.

2.2.1 Compression sleeve fitting

The REHAU compression sleeve fitting is ideal for tube joints which are inaccessible after installation, such as in thermal mass or behind sheet rock.

This joining system employs the "memory" inherent in RAUPEX tubing. The tube is cold-expanded and pushed onto the supporting liner. As a result of its "memory", the RAUPEX tube shrinks securely onto the liner within seconds. The tube is then compressed onto the supporting liner by the compression sleeve.

The compression sleeve provides the following benefits:

- Permanent connection.
- The joint can be visually checked for leakage and final installation condition.
- The cross section is larger than more common clamping ring screw unions. Therefore, there is no appreciable pressure loss through the fitting.
- Cut lengths of tubing can be connected using compression sleeve couplings, thereby minimizing tube waste.

Fig. 2.4:
REHAU compression sleeve.

Fig. 2.5:
REHAU compression sleeve coupling.

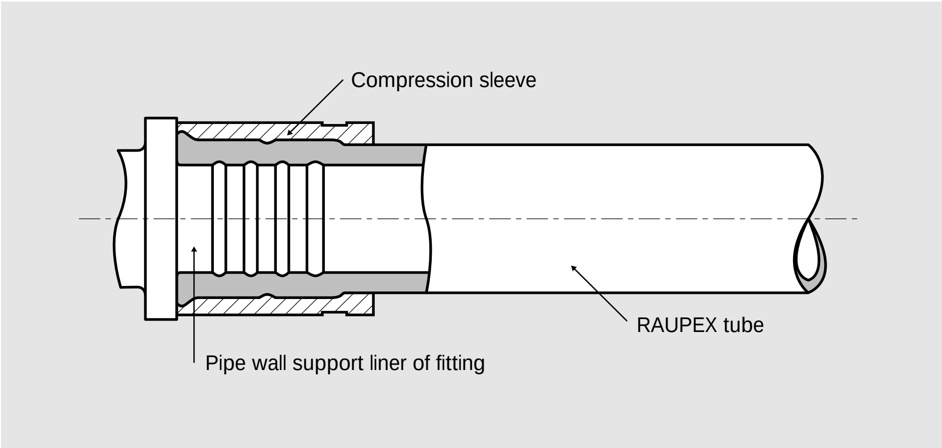


Fig. 2.6:
Cross section of the compression sleeve joint. The RAUPEX tube is tightly gripped between the compression sleeve and the ribbed support liner forming a pressure-tight seal. The end of the RAUPEX tube has been forced up against the shoulder of the fitting and the internal chamber of the compression sleeve.

2.2.2 REHAU compression union nut fitting

The REHAU compression union nut fitting is used where tube remains accessible after installation.

The compression union nut fitting allows easy disassembly of the tube from the connected device such as a manifold, another fitting or a piece of equipment.

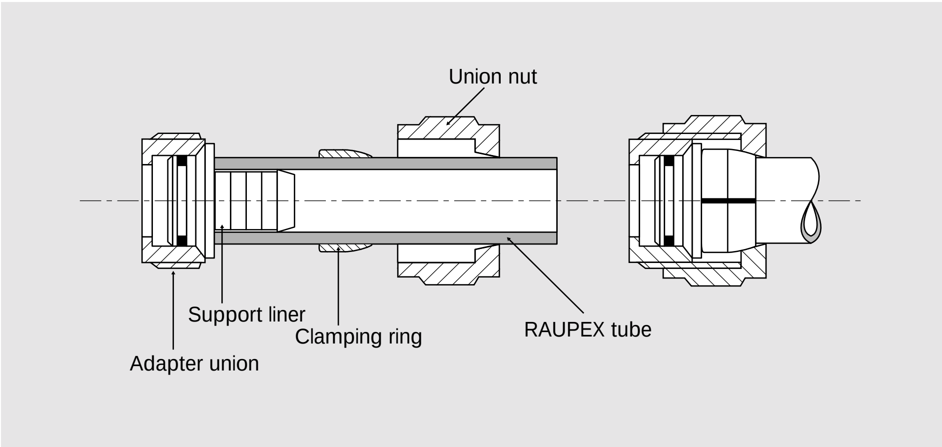


Fig. 2.7:
Tube connection with support liner, clamping ring and union nut.
-Fit clamping ring over the end of the tube.
-Push heating tube onto support liner as far as it will go.
-Tighten union nut 1/2 turn from hand tight.
-Retighten (check tightness) after 12 hours of operation.

2.2.3 Compression sleeve joining tools

To install the REHAU compression sleeve fittings a special tool is required. This “fitting tool” performs the cold expansion of the tube and joint compression.

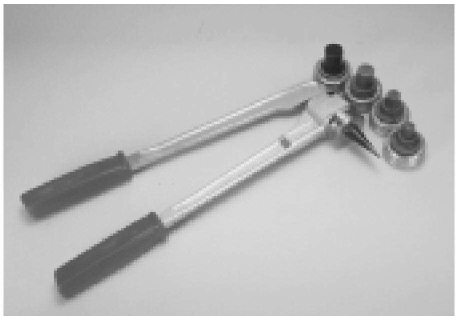
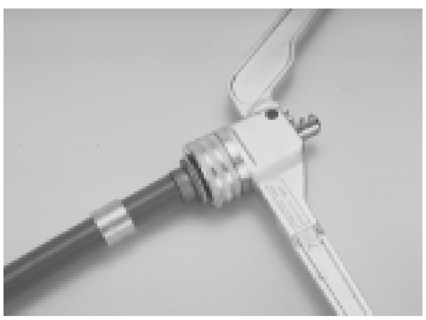


Fig. 2.8:
REHAU fitting tools are built to last.

Fig 2.9:
Compression sleeve installation steps.

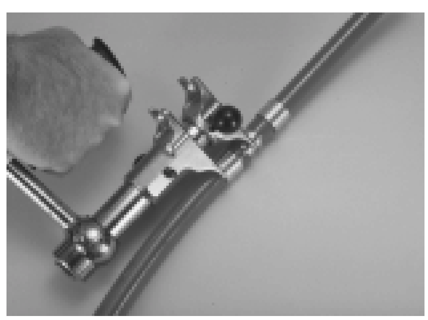


Step 1:
Slide compression sleeve onto the tube end, inside taper facing the fitting. Insert expander.

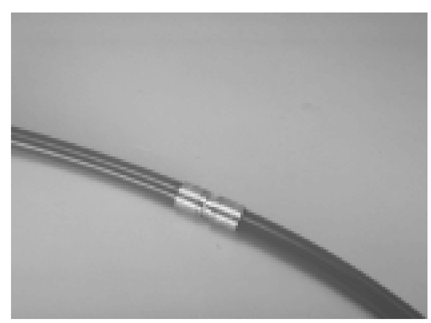
Step 2:
Expand end of PEX tube (no need for heat).

Step 3:
Insert fitting and then expand other mating tube end.

Step 4:
Joint before compression.



Step 5:
Compress sleeve up to shoulder fitting on both sides of coupling.



Step 6:
Final joint.

2.3 Heat distribution manifold

REHAU's heat distribution manifold can be used for 2 to 12 separate circuits. REHAU manifolds come as complete assemblies.

The manifold consists of brass supply and return headers, each with 1" female threaded isolation ball valves.

The distribution header mounts are fastened to rails at the rear of the REHAU distribution cabinet or directly to a support structure (wall). The distribution header can be properly aligned by vertically adjusting the fastening bolts.

A description of the manifold illustrated on this page follows:
- Material: Brass MS 63
- Distribution header/collector: Comprising separate 1-1/4" nominal width connection for flow distribution header and return collector.
- Heating circuits: for 2 to 12 heating circuits (groups).
- Fine regulator: One per heating circuit in return pipe.
- Thermostat valve: Thermostat valve positioner (individual room control); designed for connection to thermostat valve receptacle in flow pipe.
- Bleed valve: 3/8".
- Distance between valves on distribution header pipe: 2.2" (55 mm).

Fig. 2.10
Heating circuit distribution header HKV-D1.

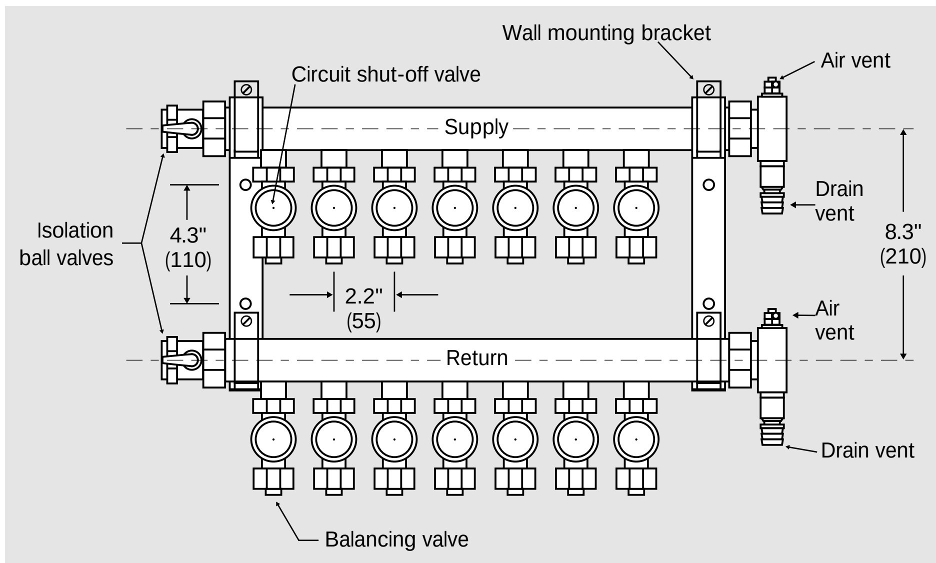


Fig. 2.11:
Dimensions of the heating circuit distribution header.

Groups	Length in*	w/ ball valves in*	Length mm	w/ ball valves mm
2	8.7	10.6	220	270
3	10.8	12.8	275	325
4	13.0	15.0	330	380
5	15.2	17.1	385	435
6	17.3	19.3	440	490
7	19.5	21.5	495	545
8	21.7	19.7	550	500
9	23.8	25.8	605	655
10	26.0	28.0	660	710
11	28.1	30.1	715	765
12	30.3	32.2	770	820

* dimensions converted from metric

Table 2.3
Dimensions of the heating circuit distribution header for sizes 2 - 12 stations.

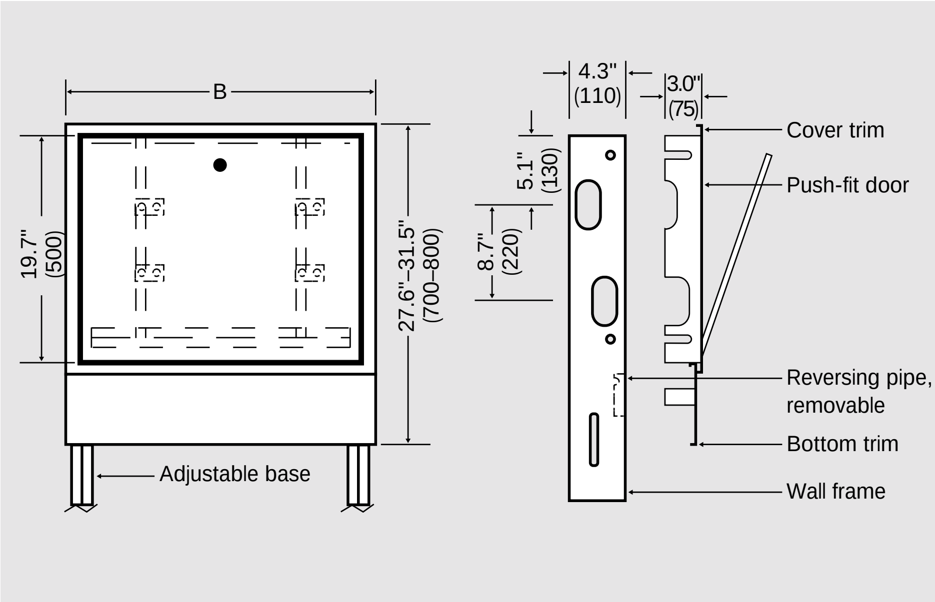


Fig. 2.12:
Distribution cabinet dimensions.

Table 2.4:
Concealed cabinet size and dimensions (designed for in-wall installation/flush mounting).

Cabinet Size	I	II	III	IV	V
No. of heating circuits	2-3	4-6	7-9	10-12	12
Cabinet height[1] in* mm	27.6 - 31.5 700 - 800	27.6 - 31.5 700 - 800	27.6 - 31.5 700 - 800	27.6 - 31.5 700 - 800	27.6 - 31.5 700 - 800
Total cabinet width outside "B" in* mm	15.7 400	21.7 550	29.5 750	37.4 950	45.3 1150
Total cabinet depth outside [2] in* mm	4.3 - 6.3 110 - 160	4.3 - 6.3 110 - 160	4.3 - 6.3 110 - 160	4.3 - 6.3 110 - 160	4.3 - 6.3 110 - 160
Necessary recess width in* mm	17.7 450	23.6 600	31.5 800	39.4 1000	47.5 1200
Necessary recess height in* mm	31.5 800	31.5 800	31.5 800	31.5 800	31.5 800
Necessary recess depth in* mm	4.9 - 6.9 125 - 175	4.9 - 6.9 125 - 175	4.9 - 6.9 125 - 175	4.9 - 6.9 125 - 175	4.9 - 6.9 125 - 175

* dimensions converted from metric
[1] Height is infinitely adjustable between 27.6" (700 mm) and 31.5" (800 mm) by means of adjustable enclosure base.
[2] The flush-mounted cabinet can be adapted to varying recess depths by means of the cover trim which can be infinitely adjusted between 4.3" (110 mm) and 6.3" (160 mm).

2.4 Installation accessories

2.4.1 Stapled
The use of a specially modified wide crown roofing stapler with a tube guide is the best method to install tube on top of wooden subfloors.

2.4.2 Star clips
REHAU star clips are of simple design, are easy to use, and have proved to be extremely successful in practice.

These star clips feature a clasp at the top to hold the RAUPEX tube, and a recess at the bottom for engagement onto the steel grid wire. Once the tube has been placed in the mesh clip it cannot be detached from the wire mesh.

The star clips can be spaced apart at any distance. On straight tube runs, REHAU recommends using a mesh clip every 2 to 3' (.8 to 1 m). In tight bend radii, two star clips should be spaced approximately 4" (10 cm) apart in order to ensure that the tube is held securely in place.

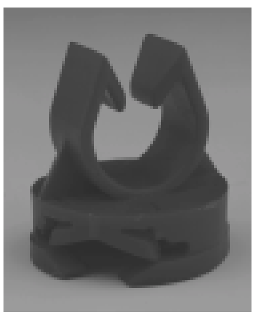


Fig. 2.13:
Star clip.

2.4.3 Cable binder/tie wraps
Nylon cable binders or plastic covered tie wraps are used to hold tube to rebar or wire mesh. This installation method is most common in commercial applications.

2.4.4 Screw clips
The insulation screw clip is designed to anchor the tube directly to board insulation. The screw clip is inserted easily into the insulation with the aid of the screw clip tool.

At the 180° turns, anchor the tube at the top of the arc and again on each side of the turn to prevent the tube from dislodging or floating up to the surface.

Board insulation should be a minimum of 1" (2.5 cm) thick.

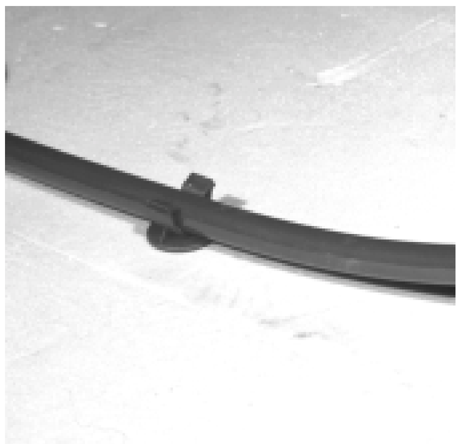


Fig. 2.14:
Screw clip secures RAUPEX to insulation.

2.4.5 RailFix
These plastic channels allow for easy installation with fixed tube spacing slots every 2" (5 cm). Channels are held down with a plastic staple on insulation board and wood screws on wood subfloors.

2.4.6 Joist space
The installation of tube under subfloor between joists is accomplished with tube talons. Heat transmission plates can be added to improve heat transfer performance.

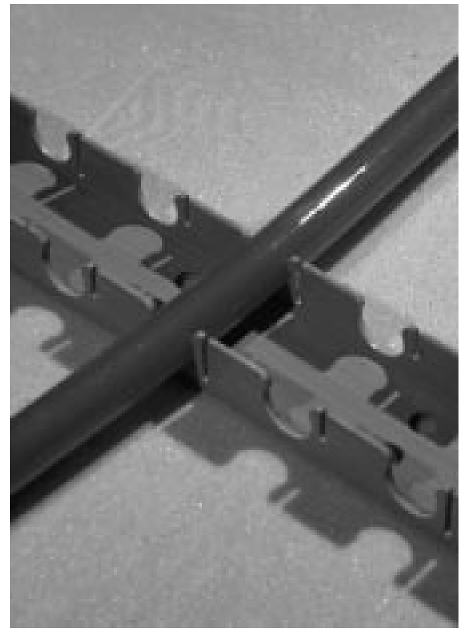


Fig. 2.15:
RailFix.

Fig. 2.16:
Plastic staple.

Fig. 2.17:
Heat Transmission plate.

2.4.7 Control components

REHAU offers control components for two basic types of control systems. When integrated with existing heating systems or in a new system, these controls allow limitless possibilities and opportunities for the heating system designer. These systems use constant water temperature supply and/or electronically modulated water temperature supply.

Fig. 2.20:
Residential and commercial 4-way mixing valves.

Fig. 2.18:
Thermostatic mixing control with built-in sensor.

Fig. 2.21:
HKV manifold circuit actuator for individual circuit control (on/off).

Fig. 2.22:
REHAU room thermostat with interchangeable °F & °C dial.

Fig. 2.19:
Remote bulb sensing injection control with injection valve.

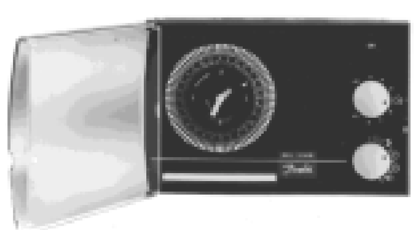


Fig. 2.23:
Weather-compensating controller.

Fig. 2.24:
Mixing valve control motor.

3. Floor construction

Floor construction plays an important role in the performance of the radiant floor heating system. The floor should allow for the heat from the tubes to dissipate readily and evenly upward to the heated space. Downward heat flow should be minimized through the use of adequate insulation.

Radiant floor heating performs ideally when tubes are embedded in a "thermal mass" which completely surrounds the tubes. This thermal mass could be concrete, gypsum-based products or other thickset thermal mass materials used in floor finishing. This is the poured method of installation in which a poured thermal mass is applied over the tubes.

However, radiant floor heating also can work very well in suspended wood frame floors without a poured thermal mass. This subfloor method of installation places tubes next to the underside of the subfloor. This method is ideal for retrofit or remodeling applications.

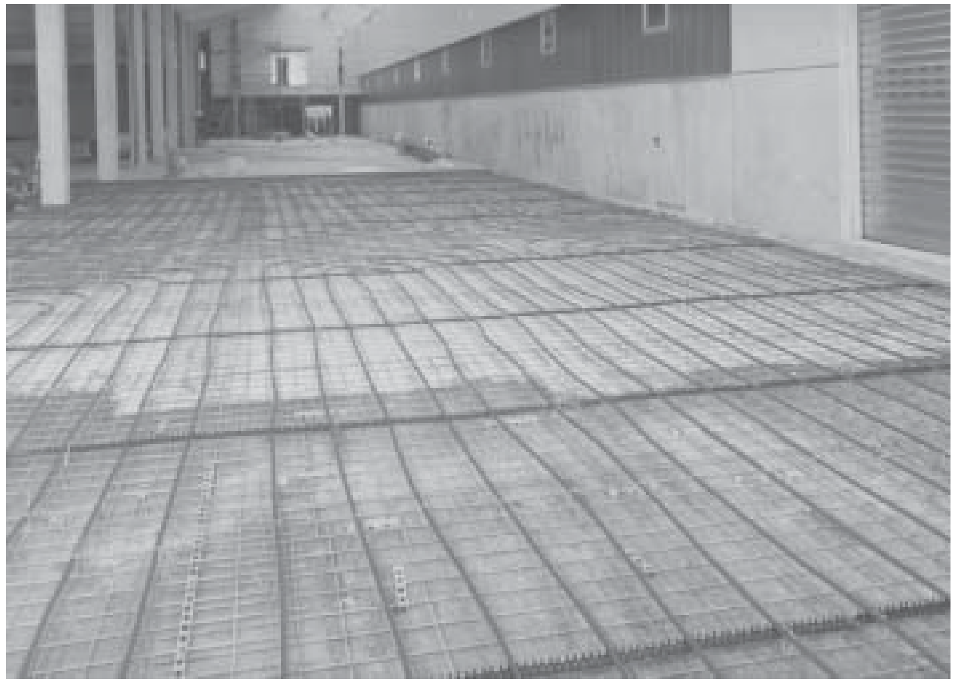


Fig. 3.1:
REHAU underfloor heating.

3.1 Applicable codes

Certain radiant floor installation methods involve penetrations through floor joists or other details which may be governed by local codes. Check with applicable code authorities before installation to determine specific requirements.

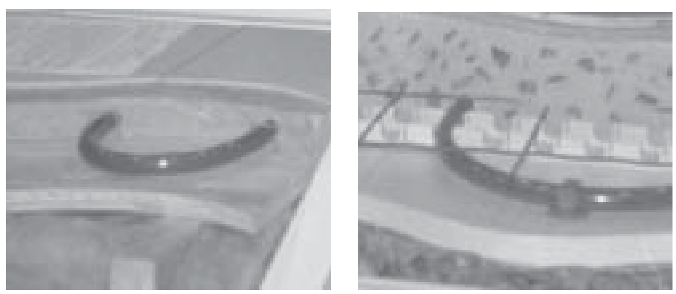


Fig. 3.2:
Two poured methods.

3.2 Floor materials and components

3.2.1 Thermal mass material

Unlike most heating equipment where performance can be measured in specific terms, the performance of RFH is related directly to the structure in which it is located. The heat output and responsiveness of a radiant floor has more to do with the thickness and the density of the concrete, or other "thermal mass", than almost any other part of the floor.

Gypsum-based thermal mass materials are commonly used for radiant floor heating, as are various lightweight, portland-cement-based toppings. Most ready-mix concrete plants will supply lightweight topping mixes if given a specific "recipe". Gypsum-based products are typically obtained through licensed applicators.

Thermal mass which will be poured on a suspended wood floor must be poured so that the top of tubes are at least 3/4" (19 mm) below the top finished surface of the thermal mass. This results in at least 1-1/2" (38 mm) thickness of thermal mass on most projects, and possibly more. The wood subfloor should be treated with a sealant to prevent moisture penetration from the thermal mass. Thermal mass materials that lose moisture too quickly during the curing process lose composition strength. Depending on the particular floor, this may require deeper joists than would normally be used to keep deflection within acceptable limits. Deflection limits vary with the thermal mass; ask the supplier for the actual values.

Thermal conductivity of the thermal mass is greatly affected by the amount of air entrained in the mix, which acts as an insulator (Figure 4.3). All normal concrete contains some air, usually between 3% and 6%. By the addition of various chemical agents, the amount of air entrained in the concrete can be increased or decreased to obtain desired qualities such as density, workability, strength and durability.

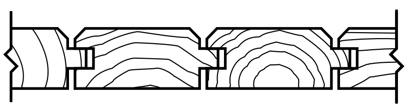
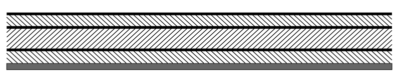
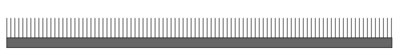
3.2.2 Moisture barriers

Polyethylene sheeting should be laid to prevent upward migration of ground water in slab-on-grade applications. Consult flooring suppliers for proper application of moisture barriers beneath floor covering.

3.2.3 Floor finishes

Ideally, all floor goods used with radiant floor heating systems should have relatively high heat transmission values (low R values). Floor finishes should also be as thin and dense as possible and unaffected by the heat output of the thermal mass system.

Table 3.1:
Floor covering system types.

This table shows the most common types of floor coverings, their thickness and resistance to thermal conductivity.			Thickness of the overall floor finish	Max. subfloor surface temp.	Resistance R-value
Des.	Type	Cross section	in (mm)	°F (°C)	$\frac{h \bullet ft^2 \bullet °F}{BTU}$ $\left(\frac{M^2 \bullet K}{W}\right)$
B1	Bare floor		-	-	0
B2	Solid hardwood		3/4" (19)	85° (27°)	0.68 (.12)
B3	Laminated hardwood with adhesive*		11/16" (17)	90° (32°)	0.87 (.15)
B4	PVC/linoleum with adhesive*		3/16" (4)	100° (38°)	0.26 (.05)
B5	Ceramic floor tile Mortar bed (elastometric bonding agent)		1/4" (6)	100° (38°)	0.23 (.04)
B6	Carpet (polyester) Rubber pad*		3/8" (9)	88° (31°)	1.17 (.21)
B7	Natural stone Mortar bed		1 1/2" (38)	100° (38°)	0.21 (.03)

*Verify suitability with manufacturer.

3.2.4 Ceramic tile and natural stone

Ceramic tile, pavers, marble and other stone finishes are ideal for radiant floor surfaces. An elastomeric adhesive between thermal mass and tile/stone helps reduce movement and isolates cracks. Tile cement with high heat resistance should be used. Check with manufacturers for recommendations when applying over mortar beds, floor leveling compounds or other thermal mass.

3.2.5 Hardwoods

Many successful RFH installations have been performed using both solid strip hardwood and laminated flooring as well as wood flooring which has been press dried for dimensional stability. Because wood readily absorbs and releases moisture, special precautions should be taken.

REHAU recommends consulting the National Oak Flooring Manufacturers Association at (901)526-5016 or National Wood Flooring Association at (314)391-5161, as appropriate, for wood flooring over RFH systems. A few issues to consider are:

- Boards with beveled edges and darker stain colors conceal shrinkage cracks between boards better.
- Quartersawn boards will shrink less than plane sawn.
- The wider the floorboards are, the wider the gaps. Using narrower boards spreads the shrinkage over more gaps, resulting in less noticeable gaps.
- Laminated wood floors are less likely to “cup” or “crown”.
- Laminated wood floors designed to “float” on the thermal mass (not directly glued) are also available and work well over radiant floor thermal mass.

No matter what type of wood flooring is used, proper RFH design, jobsite preparation and handling of floor materials are essential.

If wood flooring is allowed to acclimate to the jobsite conditions for several weeks prior to installation, and is installed when humidity conditions are average for the area, dimensional changes will be minimized.

Installers should ensure that the RFH thermal mass is thoroughly cured before applying the hardwood boards.

3.2.6 Vinyl and linoleum goods

Vinyl tiles are most affected by floor temperature. Consult with the vendor for the maximum subfloor surface temperature for both the adhesive and the covering.

Fig. 3.3:
Natural stone floors are ideal.

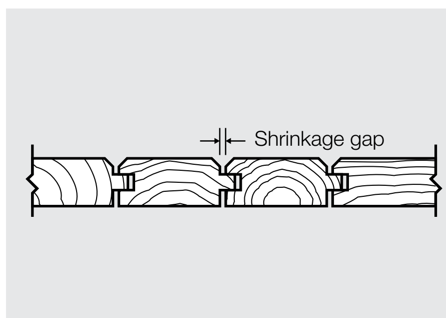


Fig. 3.4:
Beveled edges conceal shrinkage gaps.

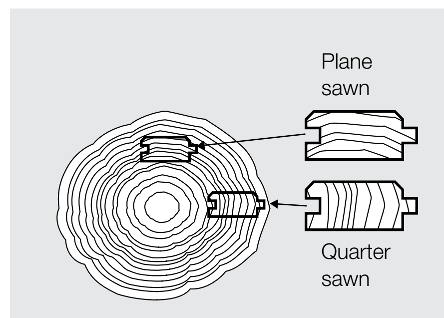


Fig. 3.5:
Quartersawn and plane sawn wood boards.

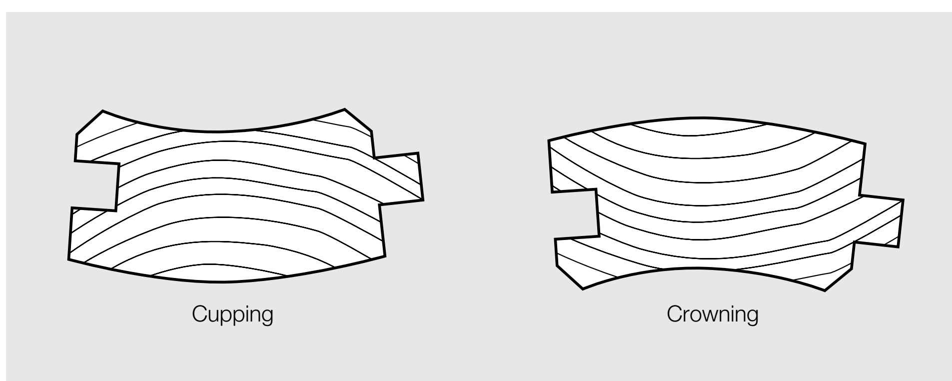


Fig. 3.6:
Cupping and crowning due to moisture.

3.2.7 Carpeting and padding

When selecting carpets for a radiant floor surface, consider the following:

- Watch R-values, especially of the pad. The use of bonded or prime urethane carpet pad may seriously impair the performance of radiant floor heating. Urethane carpets have a relatively high R-value and are designed to insulate occupants from a cold floor typically found with forced air systems.

- Consult with the vendor for the maximum subfloor surface temperature for the carpet covering system including adhesive limitations.

- There are various low R-value carpet pads available which are suitable for radiant floor use.

3.3 Radiant floor assembly methods

There are applications which call for the use of either a poured method or a subfloor method of RFH installation. The decision for which installation method is applicable is based on the building's structure and floor finish installation detail. Figures 3.7 -3.11 detail various RFH installation techniques.

3.3.1 Poured methods

Poured RFH systems have several advantages. During the pour, the mix fills the joint between the wall sole plate and the floor, reducing air infiltration along exterior walls. Poured systems have excellent heat transfer because the tubing is in complete contact with the thermal mass. This allows water temperatures 15°F (8°C) to 20°F (11°C) cooler than the typical temperature needed in a typical dry system. The thermal mass tends to even out temperature fluctuations caused by on/off cycling of the heat source. The thermal mass also dampens sound transmission through the floor system and can improve the fire resistance rating of the floor assembly.

Note that the minimum thickness for a poured floor above the top of the tubing is 3/4" (19 mm). Consult the poured floor applicator for recommended pour depth.

3.3.2 Subfloor methods

The subfloor method of installing RFH systems uses direct contact with the underside of the wood subfloor to transfer heat. The joist space method of RFH heating is an example of this technique. Tubing is attached directly to the underside of the subfloor in between the floor joists. The use of reflective panels partially surrounding the tubing will increase the efficiency of heat transfer from RAUPEX tube to the bottom of the subfloor.

	Poured					Subfloor
Installation Method	Stapled	Star Clip	Cable Binders Tie Wraps	RailFix Insulation Screw Clip	RailFix	Joist Space
Figure	3.9	3.7	3.7	3.8	3.10	3.11
Base	Subfloor	Grade	Grade	Grade	Subfloor	Subfloor
Insulation	Blanket	Rigid	Rigid	Rigid	Blanket	Blanket
Moisture Barrier	Wood Sealer	Sheet	Sheet	Sheet	Wood Sealer	None
Edge Insulation	x	x	x	x	x	
Manifold Cabinet	x	x	x	x	x	x
Manifold	x	x	x	x	x	x
Tools	Staple Gun			Rachet Tool	Screw Gun	Hammer
Mounting Devices	Staples	Star Clip	Cable Binder/ Tie Wraps	RailFix Screw Clips Plastic Staples	Railfix	Tube Hangers
Protection Sleeve	x	x	x	x	x	x
Tube Cutter	x	x	x	x	x	x
RAUPEX Tubing	x x	x	x	x	x	x
Expansion/ Compression Tools	x	x	x	x	x	x
Fittings	x	x	x	x	x	x
Manifold Wrench	x	x	x	x	x	x
Purge and Test Kit	x	x	x	x	x	x
Thermal Mass	x	x	x	x	x	
Thermostats	x	x	x	x	x	x
Contol Transformer	x	x	x	x	x	x
Zone Controls	x	x	x	x	x	x
Pumps	x	x	x	x	x	x

Table 3.2:
Overview of radiant floor heating system installation methods.

(shaded)	Indicates products supplied by REHAU
x	Indicates products required

Slab - on - grade application (poured system)

3.4 Installation applications

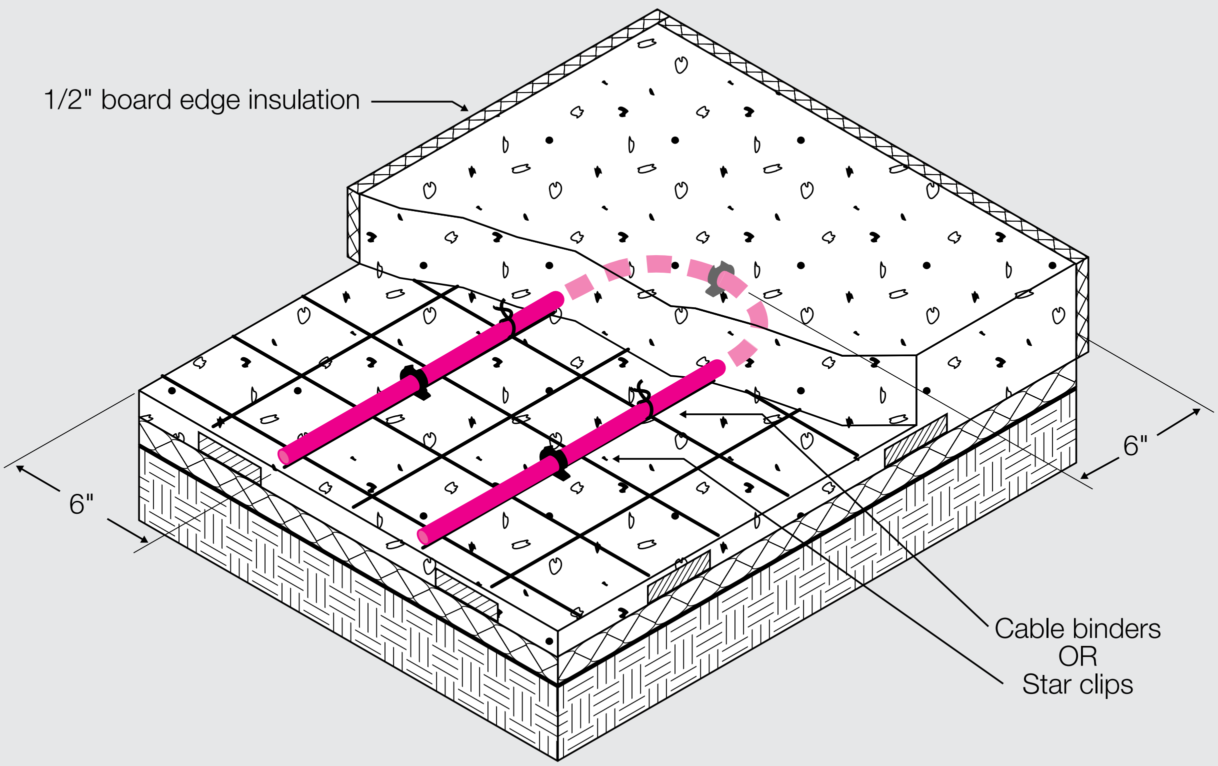
3.4.1 Star clip and cable binder method
Place wire mesh or rebar over the base material. If the base material is gravel, lay polyethylene sheeting over gravel to prevent any abrasion of the tube.

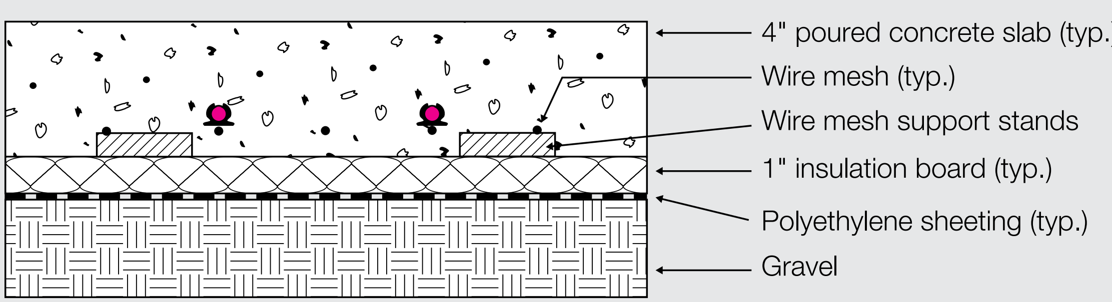
A better practice is to install a layer of 1" (25 mm) polystyrene insulation board on top of the polyethylene sheeting to minimize heat losses downward. When installing wire mesh on top of board insulation or flat substrate, use mesh support stands to raise the mesh so that it is completely encased in the poured slab. Support rebar in the same manner.

RAUPEX tube is permanently attached to the mesh with REHAU star clips according to the spacing required by the design. At the 180° turns, anchor the tubing at the top of the arc and again on each side of the turn to prevent the tubing from dislodging or floating up into the pour.

Tubes are secured to rebar with plastic cable binders which will not cause abrasion to the tube. Do not use wire ties without plastic coating.

Fig. 3.7





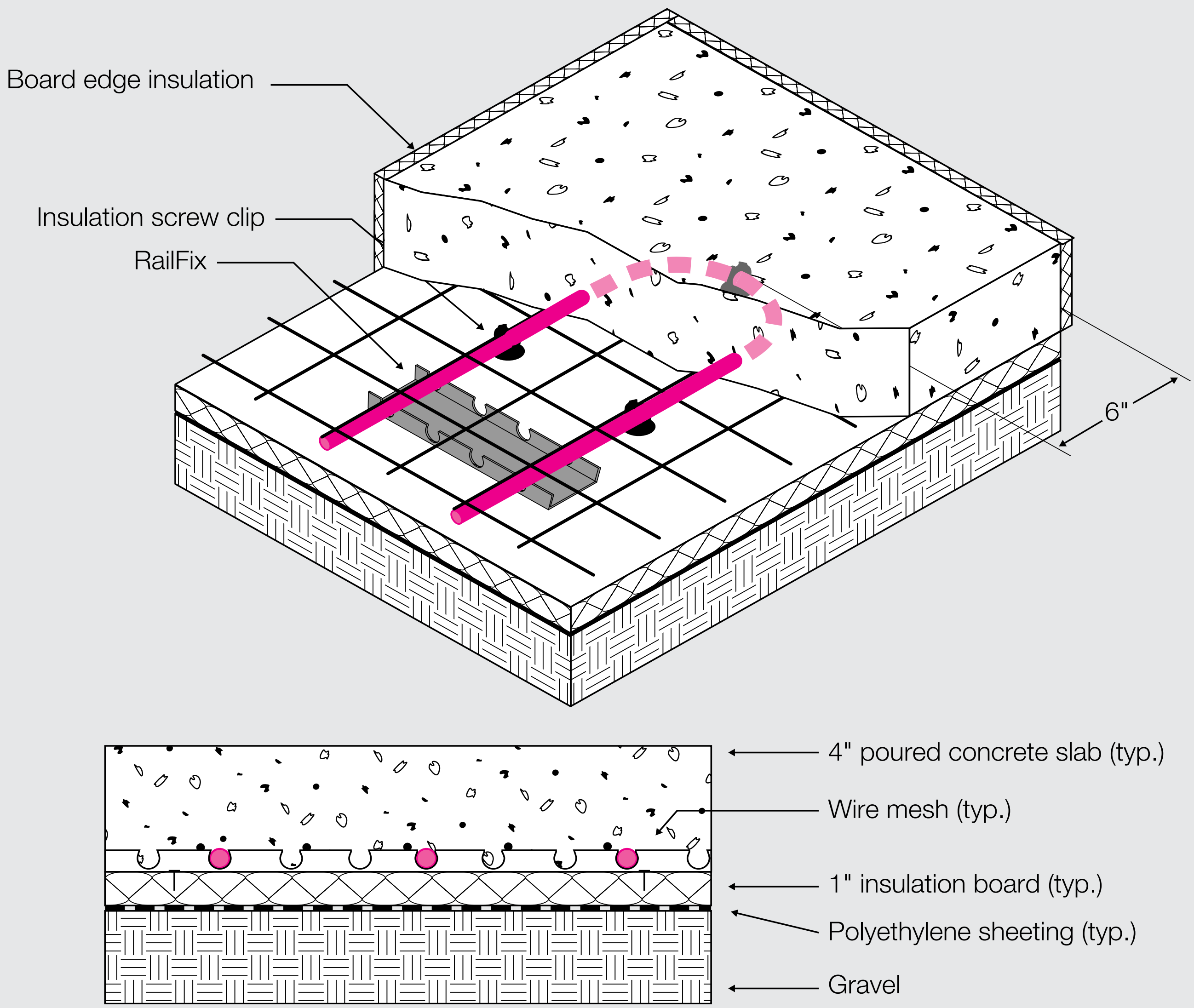
Slab - on - grade application (poured system)

3.4.2 RailFix/insulation screw clip method
Install a layer of 1" (25 mm) polystyrene insulation board on top of the base material to minimize heat loss downward.

Install RailFix channels in a pattern to suit the intended tube layout, spacing the channels so that the tube is anchored every 2 to 3' (0.5 to 1 m). At the 180° turns, anchor the tube at the top of the arc and again on each side of the turn with insulation screw clips where RailFix is difficult to run. This prevents the tube from dislodging or floating up into the pour. RailFix provides tube spacing every 2" (5 cm).

Anchor the RailFix channels to the board insulation using plastic staples.

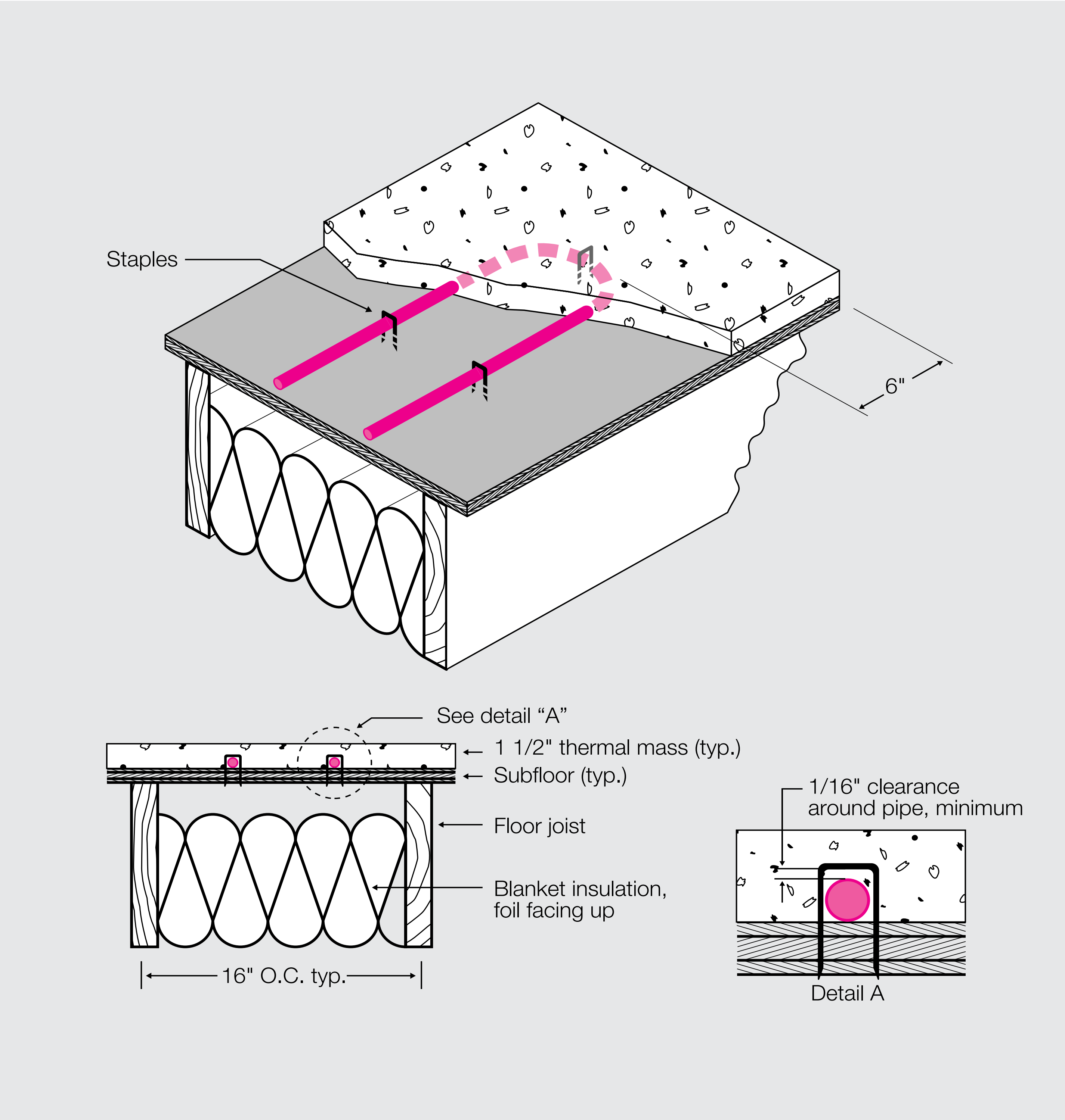
Fig. 3.8



Suspended wood floor application (poured system)

3.4.3 Stapled method
The REHAU tube stapler system is designed to fasten RAUPEX to wooden subfloor. Included are a stapler and guide plate. The tube is stapled securely to the subfloor. At the 180° turns, anchor the tubing at the top of the arc and again on each side of the turn to prevent the tubing from dislodging or floating up into the pour.

Fig. 3.9

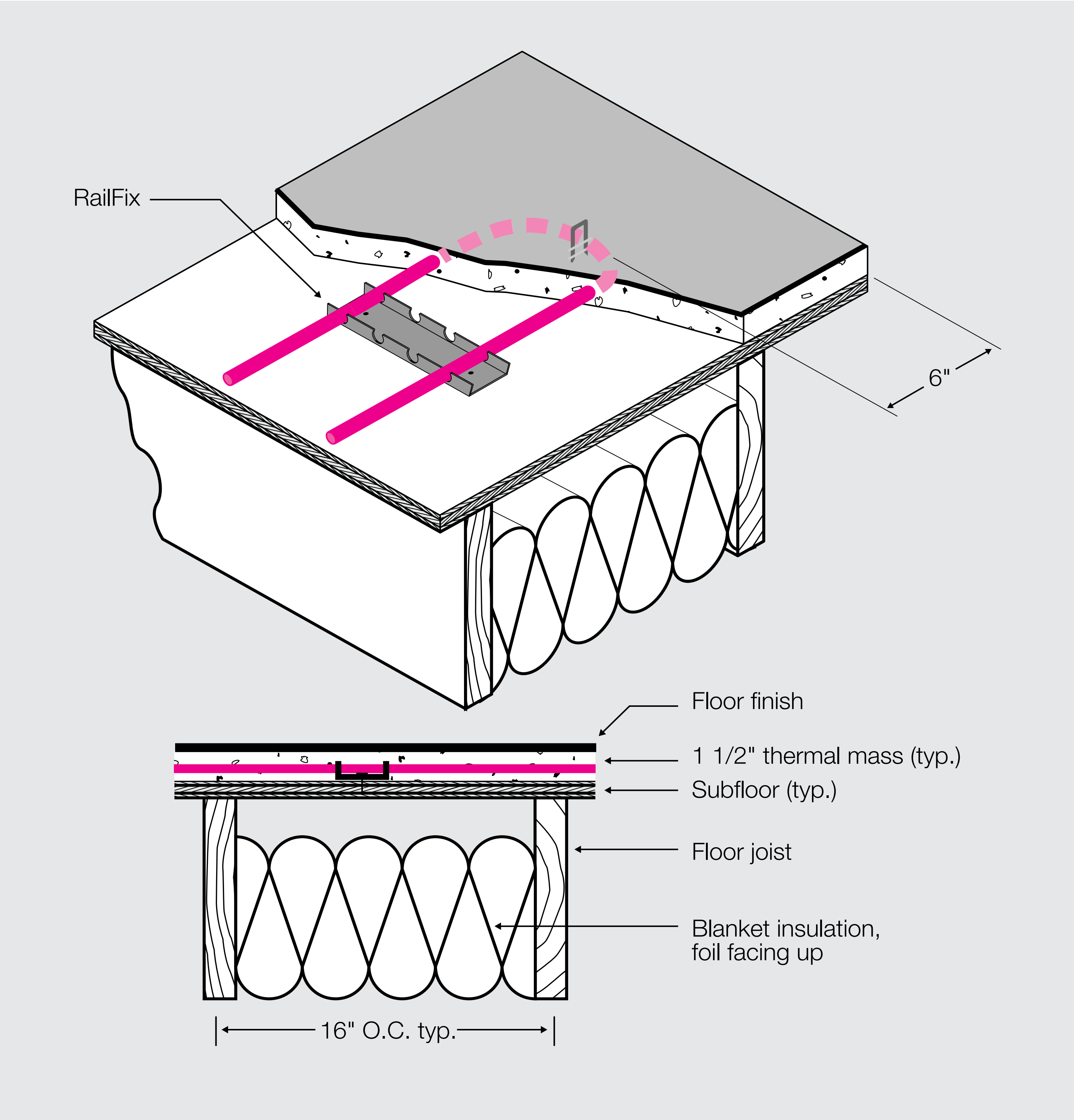


Suspended wood floor application (poured system)

3.4.4 RailFix method
Install RailFix channels in a pattern to suit the intended tube layout, spacing the channels so that the tube is anchored every 3' (1 m).

Anchor the RailFix channels to the subfloor using suitable screws. At the 180° turns, anchor the tube at the top of the arc and again on each side of the turn with tube talons to prevent the tube from dislodging or floating up into the pour.

Fig. 3.10



Joist space application (subfloor system)

3.4.5 Joist space
Following the tube layout plan, secure the RAUPEX tube to the underside of the floor using hangers, such as tube talons, or with heat transmission plates. When using plates, secure each plate to subfloor with screws (three on each side). Do not cut plates.

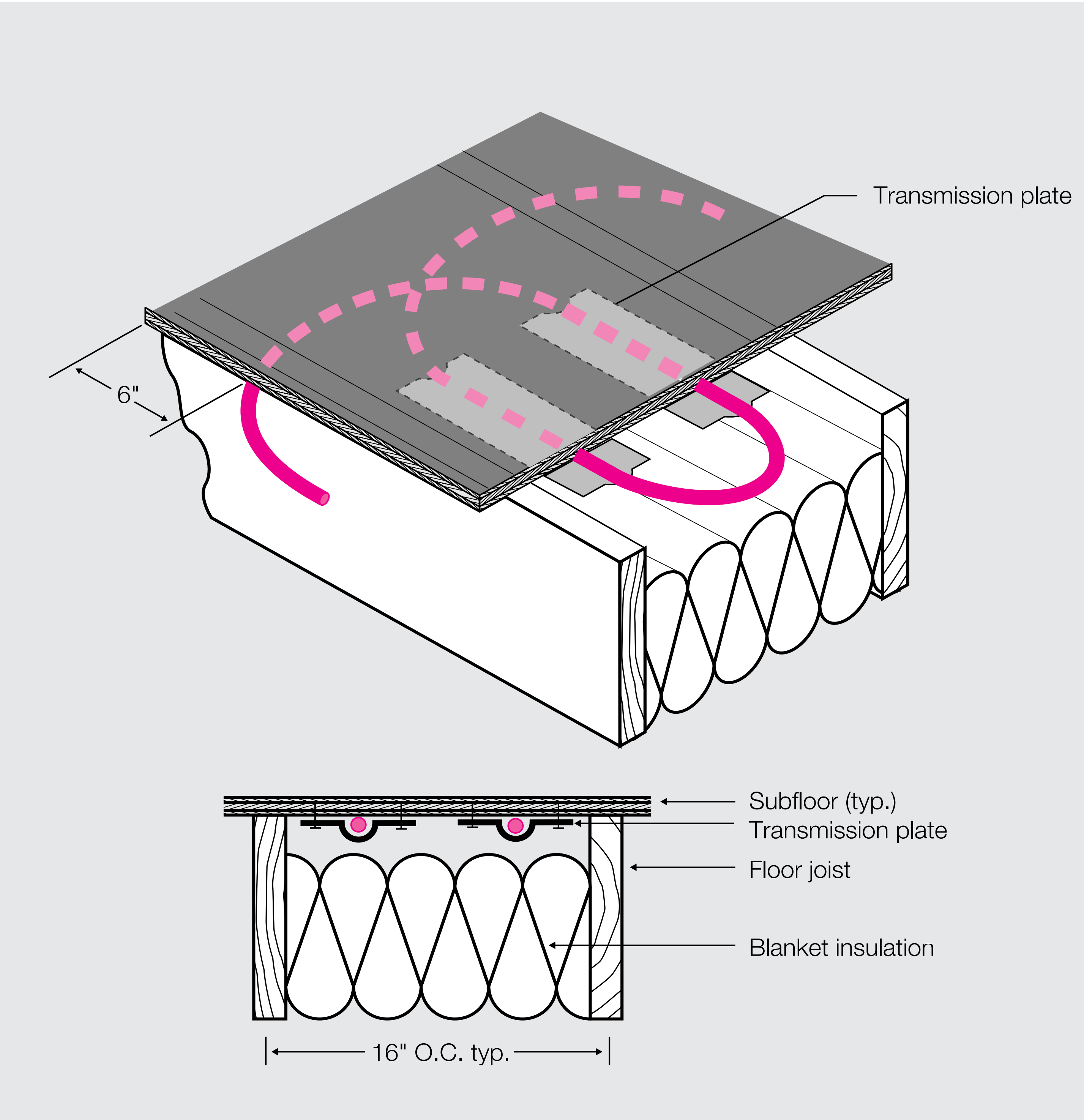
During installation it will be necessary to loop the tube from one joist cavity to another through holes cut into the joist.

Check local building codes before drilling or notching through joists.

Connect the tube to the manifold and perform test.

Use of conductive panels will increase the efficiency of heat transfer from RAUPEX tube to the bottom of subfloor.

Fig. 3.11



3.5 Thermal mass joints

3.5.1 Thermal mass movements

Floating thermal mass is always subject to movement. This can be caused by shrinkage as a result of drying or expansion as a result of temperature differences.

These movements mainly occur in the width and length of floor surface. However, vertical movement (bowing) may also be caused by differences in expansion at the surface and base of the thermal mass layer.

Movements resulting from shrinkage occur only once (when the thermal mass dries). Uncontrolled cracking is avoided by limiting the size of individual thermal mass bays and by employing an appropriate arrangement of joints.

Movement resulting from temperature differences can be estimated as follows:

$\Delta l = l_o \times \propto \times \Delta t$

Δl = longitudinal expansion - in (mm)

l_o = thermal mass length - ft (m)

$\propto$ = coefficient of longitudinal expansion 1/°F (1/°K) (value changes with thermal mass type)

Δt = temperature difference °F (°K)

Example:
Given: l_o = 25 ft
$\propto = 6.1 \times 10^{-6}$ 1/°F
Δt = 55°F

Longitudinal expansion of the thermal mass layer is Δl = .0084' or .10"

Planning and design must allow for absorption of these movements.

3.5.2 Joint plan

The location of joints is defined in the joint plan. This is generally specified by the architect and influences the planning of the tube layout of the radiant floor heating.

3.5.3 Arrangement of joints

Where are joints necessary?
- at the edge of the thermal mass to allow for thermal mass movement.
- around thermal mass bays.
- areas = 430 ft² (40 m²) (maximum).
- side length = 26' (8 m) (maximum).
- ratio of sides is less than 1:2.
- along movement joints in the building structure.
- in doorways.
- for bays in L-shaped rooms.

Incorrect arrangement and design of joints are the most common causes of thermal mass damage in floor structures.

3.5.4 Joint design

Heating tube circuits and thermal mass bays must be coordinated:
- Tube circuits should be planned and installed in such a way that they do not cross movement joints.
- These joints should only be crossed by connection tubes.
- In these areas, the heating tubes must be protected from shearing forces (at least 15" (40 cm) on either side of the joint) with protective sleeve, such as REHAU corrugated tube or other insulating channel (as shown in Figure 3.14).
- In the case of hard coverings (ceramic tiles), the joints must continue as far as the upper surface of the floor finish.

Important: Consult floor finish installer for coordination of thermal mass joint locations.

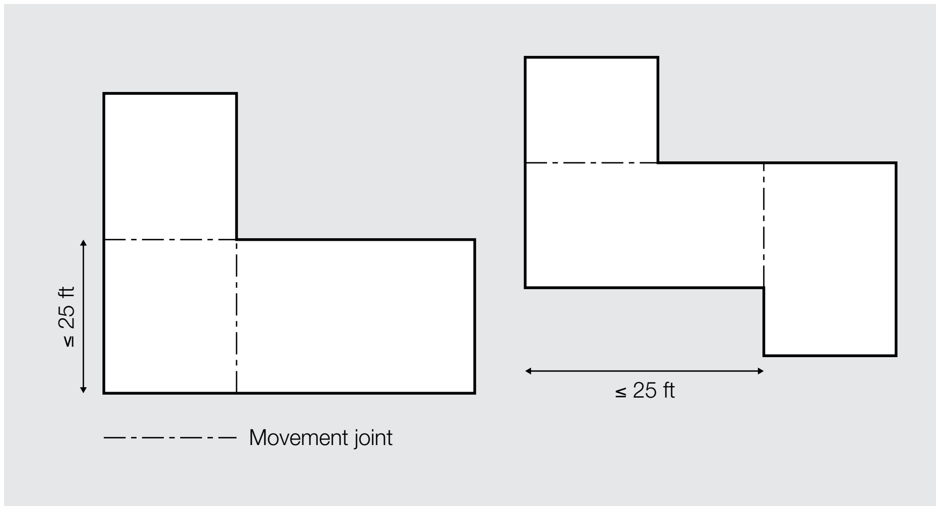


Fig. 3.12:
Arrangement of expansion joints.

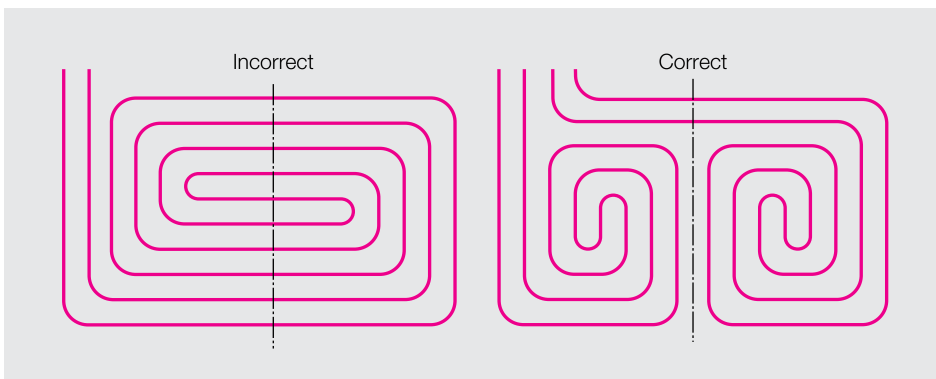


Fig. 3.13:
Arrangement of joints for heating circuits.

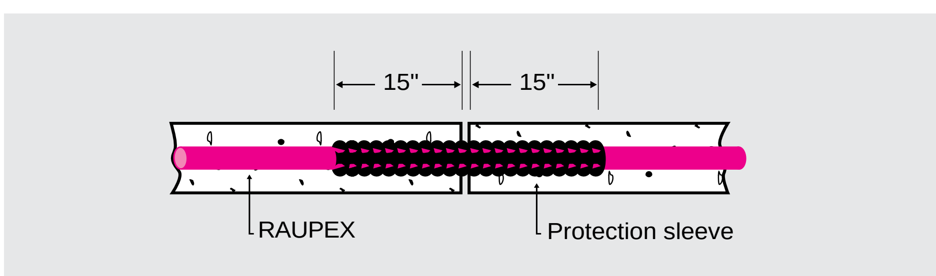


Fig. 3.14:
Protective sleeving thru joint.

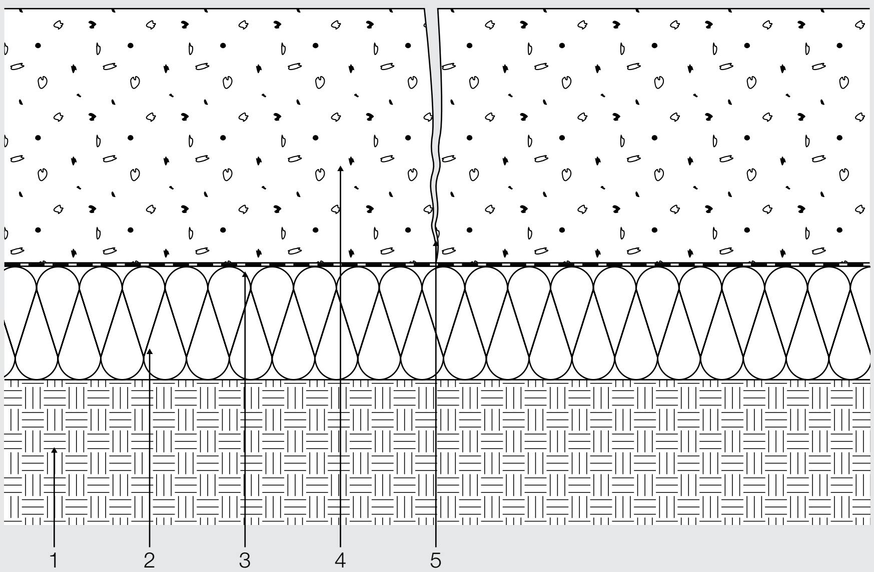


Fig. 3.15:
Contraction joint (joint cut into thermal mass).

3.5.5 Joint types

Contraction joints
Contraction joints are cut with a trowel into the wet thermal mass down to about 1/3 to 1/2 of the thermal mass depth. Their purpose is to prevent uncontrolled cracking. They are only capable of absorbing movements resulting from thermal mass shrinkage and are filled with synthetic resin mortar or similar material after contraction has taken place.

Contraction joints frequently have a temporary function only. They are used to further divide areas separated by movement joints. However, they are only suitable for use in heated thermal masses to a limited extent:
- for bay sizes up to 16' x 16' = 256 ft^2 *(5 x 5 m = 25 m^2).*
- only in cases where soft floor finishes are used - not in doorways.

1) Sub-floor
2) Insulation layer
3) Polyethylene membrane
4) Heated thermal mass
5) Contraction joint

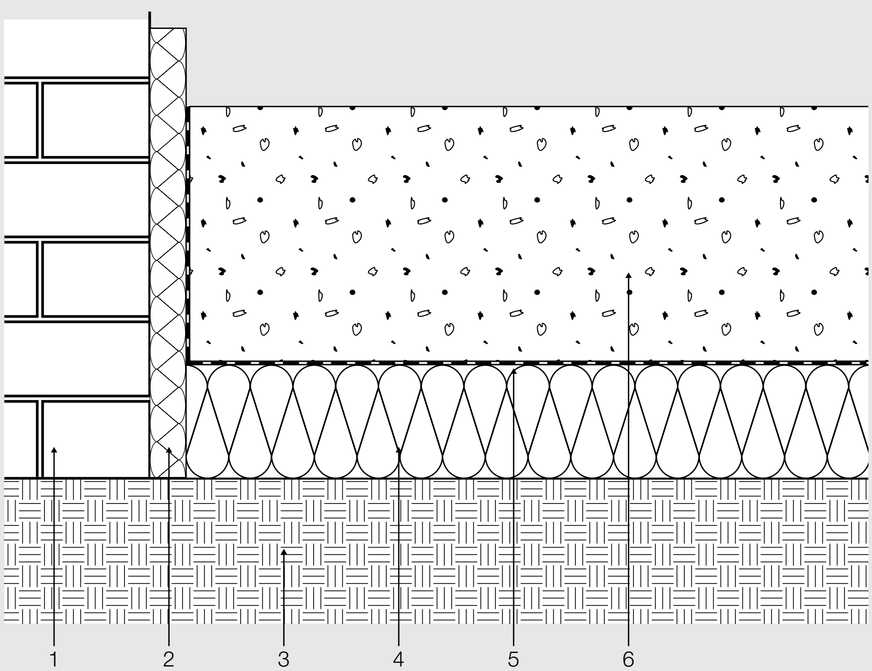


Fig. 3.16:
Edge joint.

Edge joints
This type of joint is also a movement joint. In the REHAU radiant floor heating system, they are formed by the edge insulating strip.

It is important that edge insulating strips are rigid enough to withstand compression from the wet thermal mass and soft enough to absorb movements.

1) Brickwork
2) Edge joint
3) Sub-floor
4) Insulation layer
5) Polyethylene membrane
6) Heated thermal mass

Movement joints
Movement can be absorbed by special joint structures. The following factors must be considered during joint design:
-Frequency of movement.
-The degree of thermal mass expansion caused by temperature.
-The requirements placed on sound and thermal insulation.

Movement joints are capable of absorbing major movement. They must be routed around the thermal mass bays, used to separate different thermal mass bays/floor finishes in doorways and must always be incorporated above joints in the building structure.

As a result of their construction, they are capable of absorbing major horizontal and vertical (structural) movement.

Movement joints are positioned in accordance with the joint plan and should have a width of at least 3/8" (8 mm).

Whenever heating tubes cross movement joints, a protective sleeve must encase the tube as shown in Figure 3.14.

1) Sub-floor
2) Insulation layer
3) Polyethylene membrane
4) Heated thermal mass
5) Movement joint

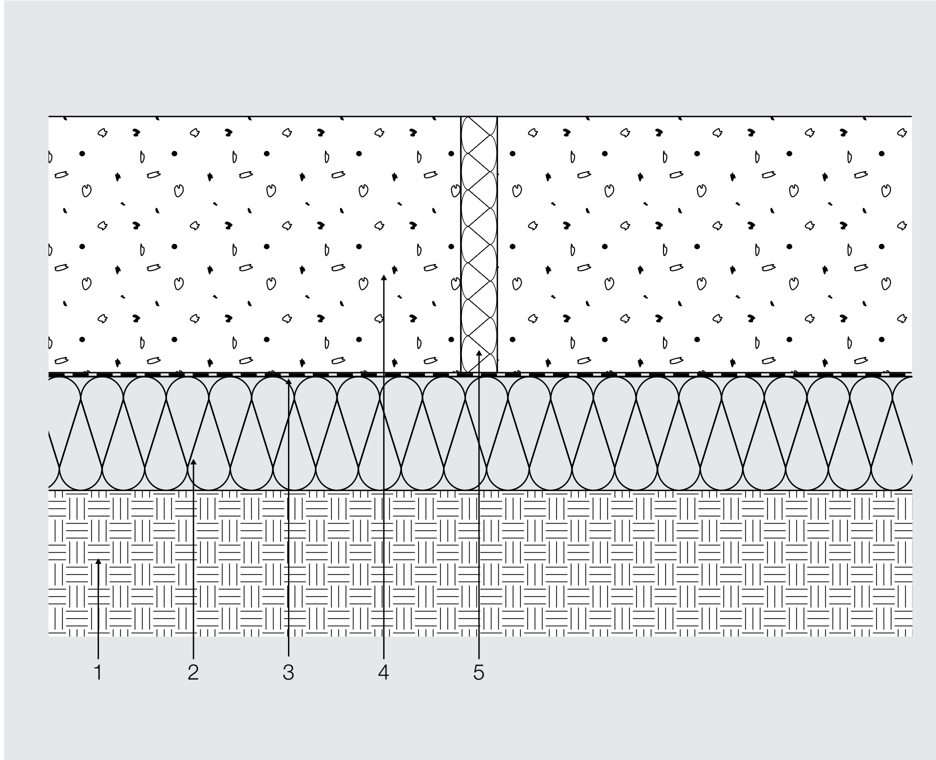


Fig. 3.17:
Movement joint.

Influence of joints on the floor finishes
To avoid cracking, each type of floor finish has different joint requirements.

Soft coverings
(PVC, linoleum, carpet)
Joint type and position, with the exception of structural joints, have minimal influence on these floor finishes since they are generally capable of absorbing movement.

1) Sub-floor
2) Insulation layer
3) Polyethylene membrane
4) Heated thermal mass
5) Movement joint
6) Carpet

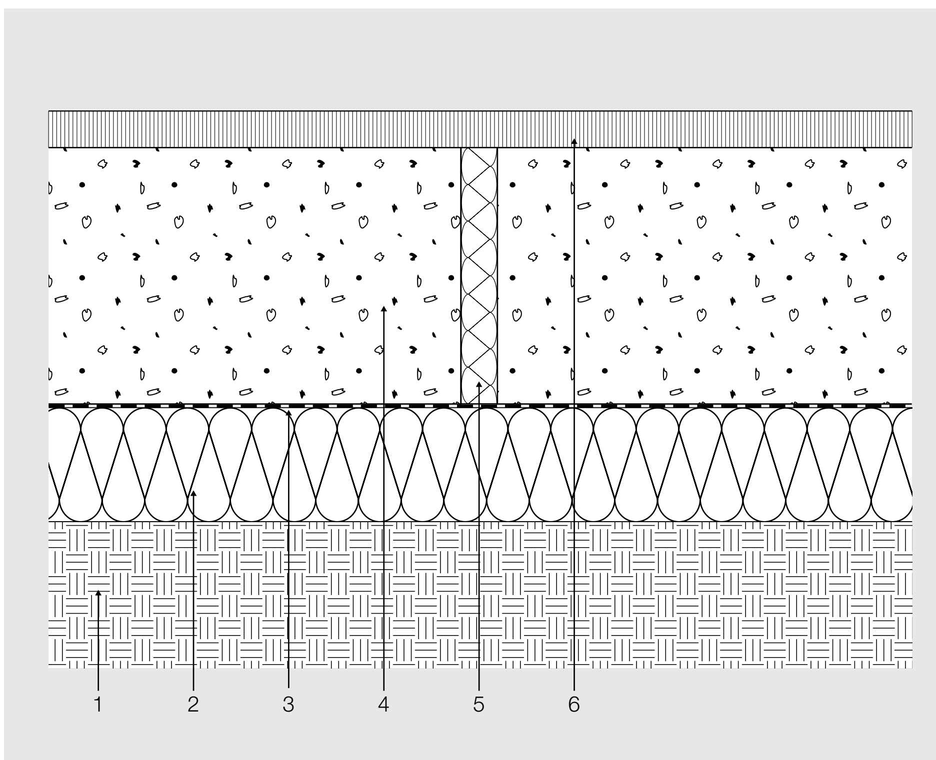


Fig. 3.18:
Joint design for soft floor finishes.

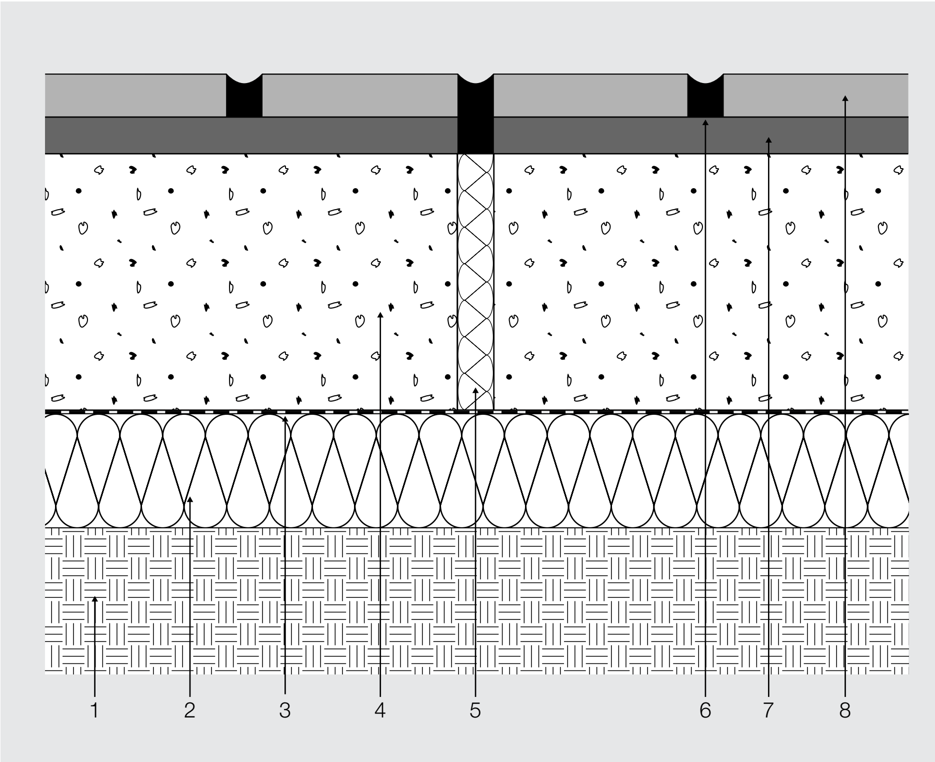


Fig. 3.19:
Joints for hard floor finishes.

Hard coverings
(tiles, stone floors)
When laying tiles with mortar, you must allow for the position of joints. Since the joint plan only indicates the approximate position of joints, the exact position of joints and corresponding tube laying pattern must be defined with the floor layer before the thermal mass is laid.

1) Sub-floor
2) Insulation layer
3) Polyethylene membrane
4) Heated thermal mass
5) Movement joint
6) Elastic joint compound
7) Mortar bed
8) Tiles

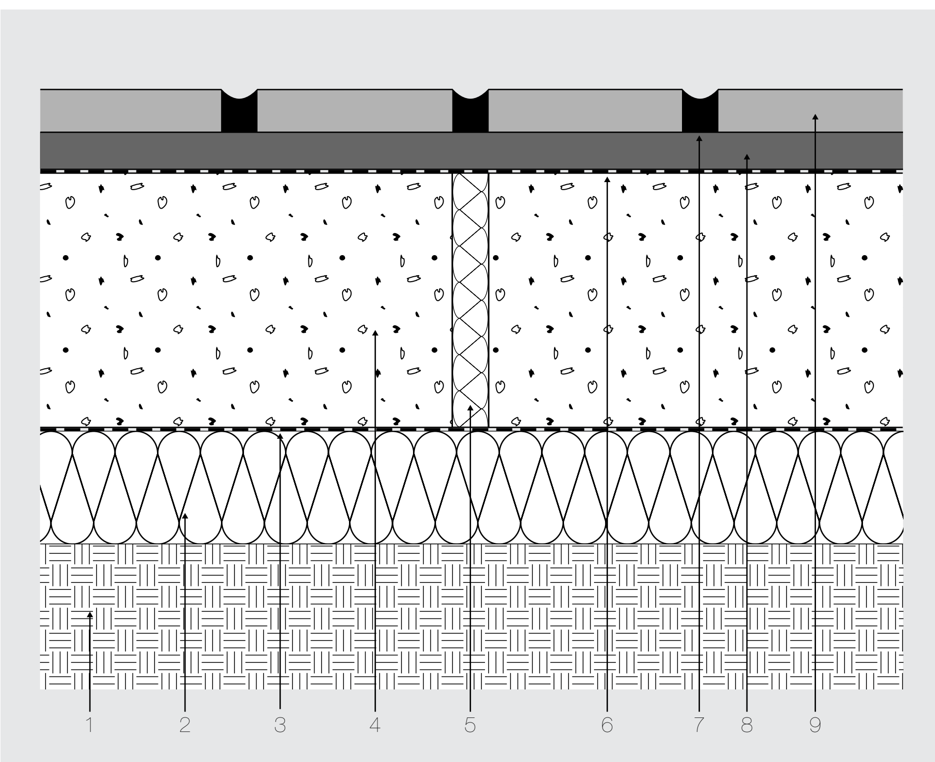


Fig. 3.20:
Joints for hard floor finishes laid on separation layer.

Hard coverings with separation layer
All joints can be arranged in the heated thermal mass as indicated in the joint plan, without having to allow for joints in the floor covering.

1) Sub-floor
2) Insulation layer
3) Polyethylene membrane
4) Heated thermal mass
5) Movement joint
6) Separation membrane
7) Elastic joint compound
8) Mortar bed
9) Tiles

Structural expansion joints

Irrespective of the type of floor finish, structural expansion joints must extend throughout the floor structure as far as the surface of the floor finish.

1) Sub-floor
2) Insulation layer
3) Polyethylene sheeting
4) Heated thermal mass
5) Structural expansion joint
6) Movement joint
7) Carpet

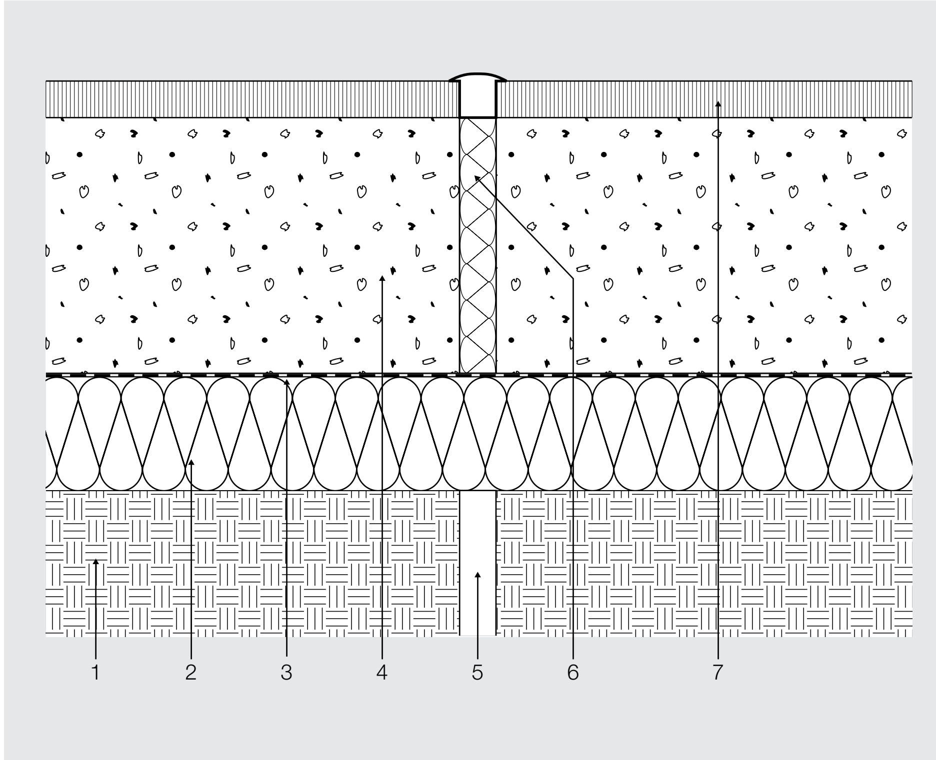


Fig. 3.21:
Structural expansion joints.

4. Planning and design

The planning and designing of a heating system involves many objectives: economy, comfort, use of space and noise. Tougher laws require stricter insulation regulations for structures, infiltration testing and heat loss design methods. All new structures, along with their heating systems, are to have an energy efficient design. RFH systems have little trouble meeting these new guidelines.

For a designer with a hydronic heating systems background, the planning and designing of RFH systems is relatively simple. This chapter will enable such a designer to specify RFH systems for a pre-existing hydronically heated building or a new construction. If you do not have prior experience with hydronic heating systems, please contact your local sales office listed on the back of this manual.

4.1 Planning

In order to do an accurate and complete job, the designer needs to start with a current set of drawings and specifications for the building, a clear understanding of any additional heating systems to be used, and the ability to discuss certain design issues with the owner and/or the owner's agent.

Because the RFH system is a permanent fixture within the building, the installation should be carefully coordinated with all interfacing trades in order to assure proper function.

4.2 Design

4.2.1 RFH WarmSource™ Design

REHAU RFH WarmSource software provides a means of estimating radiant floor heating systems constructed with RAUPEX tubing. It assists experienced hydronic heating professionals in completing efficient, thorough designs and estimates. The system is capable of performing all required design functions including:

1. Project Data - Storage of customer and project information, and project specific design defaults.

2. Heat Loss - Performs heat loss calculations for each building panel and room of the project. Provides a number of standard building panels and allows for custom assembly of building panels to meet your specifications. Geographical weather data is included in the "Help" section for easy reference.

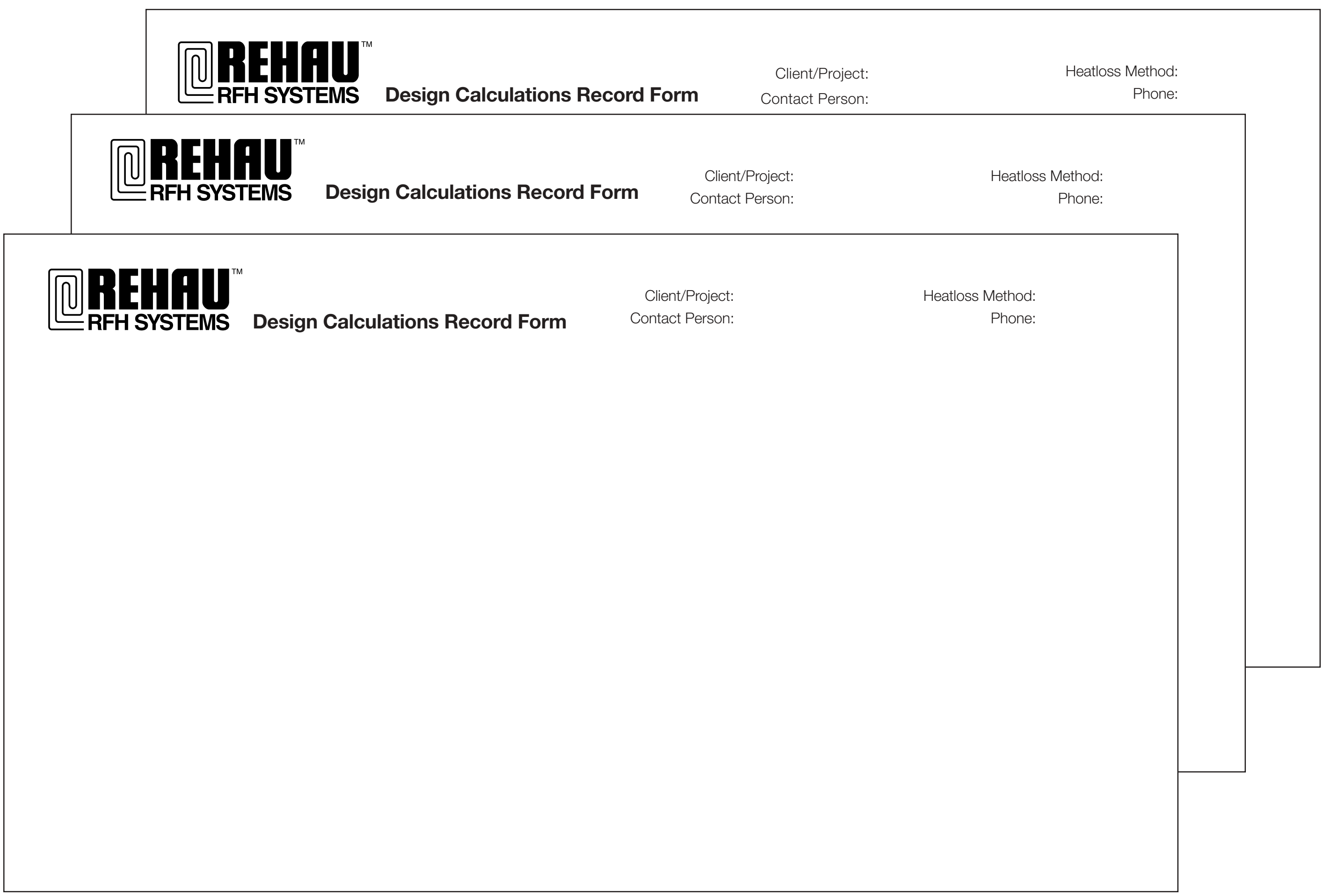
3. RFH Design - Allows definition of panel types and floor temperatures for sub-areas within each room. Sub-areas can then be combined in any combination and assigned to manifold circuits to optimize circuit layout patterns and tubing lengths. Calculates required water temperature, flow rate, and pressure drop across each circuit. Summarizes tubing length requirements, flow rates and pressure drop figures.

4. Electronic Catalog - Allows for complete and accurate estimates using current catalog data. System components displayed pictorially along with article numbers, descriptions, and list prices. List price multiplier can be specified and applied to all selected materials. Labor rate and time estimates can be included for complete quotations.

5. On-Line Help System - Allows designers to access technical and RFH WarmSource information at any time during the design process. The complete REHAU RFH Technical Manual is included within the "Help" system. RFH WarmSource system operating instructions and sequences are also included.

6. Printed Output - The designer has the option of printing the heat loss calculation, the RFH design, or the cost/material estimate separately or in combination.

Fig. 4.1:
Design Calculation Record Forms.



4.2.2 Design Calculation Record Forms
REHAU "Design Calculation Record Forms" (DCRFs) have been developed to lead the designer through the RFH design process. These three-page forms are offered on 11" x 17" pads. Individual sheets may be detached for photocopying.

The DCRFs provide the following information:
Page 1:
Room Data
RFH Panel Heat Requirement Data
RFH Panel Design

Page 2:
RFH Panel Performance Data
RFH Panel Tube Requirements

Page 3:
Pump Sizing Data
Balance Valve Setting Data

The Design Supplement to this manual provides REHAU RFH panel performance tables and graphs for common North American building construction methods.

4.3 Design Calculation Record Forms column definitions

4.3.1 Room data
Room data is obtained from the plans and the owner and/or owner's agent. It is very important to organize the rooms by floor level and/or common manifold location.

1. Floor level - The floor level will be identified as 1st, 2nd, 3rd, etc. It is important to know the floor level when organizing manifolds, common floor structures and controls.

2. Room no. - Each room should be identified with a room number. Reference the plan for preassigned room numbers or assign room numbers as required.

3. Room function - Reference the room's purpose: Dining, Kitchen, Living, Bath, etc. Note special conditions.

4. Room area - Total gross area within the perimeters of the room's walls.

5. Floor area type - Typical Floor Area Types:
RFH Perimeter Area - P
RFH Occupied Area - O
RFH Distribution - D
NO RFH - X

When RFH is used in a typical floor area, the most efficient designs separate the perimeter zone along the outside walls and occupied area(s) in the center of the room. The non-heated areas need to be identified to correct the total RFH panel heat capacity requirement for the room. Where distribution pipes run through one room to another or to another floor area type within a room, this space must be allocated as "distribution" (heated space with un-insulated tubes). When using insulated tubes, this floor area type is considered the same as a NO-RFH (X) floor area type.

Tube location rules and recommendations

- Note that areas under cabinets, window seats, large appliances, raised hearths, stairs, etc. will typically not require heat.

- Start at outside walls. Keep tube a minimum of 6" (15 cm) away from the edge of the slab and all walls and other locations where plates, fixtures or built-ins might be fastened into the thermal mass floor.

- If flow through different circuits will be balanced by keeping all the circuits the same length, circuit lengths should be kept within 10% of each other.

- Keep circuits separate for different rooms for better room temperature control.

- Keep area types reasonably sized. Areas over 450 ft^2 (42 m^2) are usually divided into two circuits for 17 x 2 mm and 1/2" RAUPEX tube (reference maximum allowable circuit length on the RFH panel performance table in the Design Supplement). For instance, when using 17 x 2 mm or 1/2" RAUPEX tube an occupied area measuring 750 ft^2 should be divided into two 375 ft^2 occupied areas. Larger diameter RAUPEX tubes allow for larger area types (coverage). RAUPEX tube sizes 1" or 25 x 2.3 mm are used for aircraft hangars and large industrial buildings allowing for 600' (183 m) circuit lengths for most designs.

- Keep circuits for high heat loss areas and low heat loss areas separate (exterior edges of rooms separate from center and interior edges).

- When carpet and tile, for example, are in the same zone with one circuit, the RFH design should select the appropriate tube spacing and run the tube first through carpeted (or highest R-value floor finish) areas.

6. Floor area per type - Measure the gross area for each floor area type.

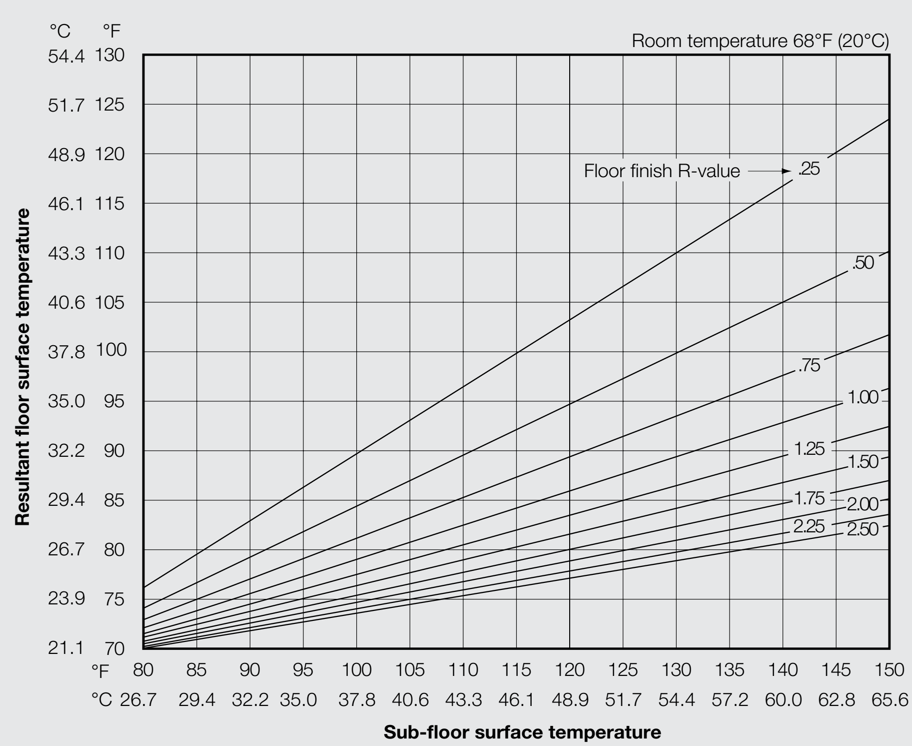
4.3.2 RFH panel heat requirement data

7. Required room temperature - Temperature values required for RFH heated rooms provide comfort at levels up to 3°F (1.7°C) lower than convection type heating systems. The owner of the building will have a specific temperature level to maintain. Make sure to determine this requirement. Most bathrooms are designed at 5°F (3°C) over the required room temperature for the rest of the building.

8. Total heat required - The required heat capacity for a building project is determined by performing a heat loss calculation. Various heat loss calculation standards are used throughout North America.

Examples of heat loss calculation methods:
- ASHRAE Fundamentals Handbook (Manual "J" Method)
- Hydronics Institute IBR H-22 Guide
- R-2000 Canadian Home Builders Association
- HOT2000 Program
- CSA Standard F280-M1986

Fig. 4.2:
Resultant floor surface temperature.



Energy conservation laws related to heat loss evaluation have been adopted by a few North American states and provinces. These new laws require the use of specific heat loss programs. Determine the applicable laws by checking with the local municipality and/or building inspection department. In most commercial and industrial applications, the required heat capacity will be calculated by a registered architect or engineer.

Detailed heat loss calculations must be done as accurately as possible. Oversized boilers will short cycle and create large temperature swings in the system supply water temperature, reducing efficiency. Oversized pumps are prone to cavitation, creating excess noise and wear in the system.

RFH systems may be combined with other hydronic heating systems such as fan coils or radiators. Such "integrated" systems may also be required to meet special building requirements, such as forced ventilation or pressurization in hospitals, while also providing comfort heating. The designer for such combined systems should carefully evaluate the interaction of each of the systems with respect to control and load diversity.

The DCRF provides a split column (col. 8) to record these values. The top of the column is the total heat required (btuh) and the bottom of the column is for the unit/area value for the total heat required (btuh/ft^2). When the unit/area value for the room seems excessive based on the heat loss calculation standard, it is important that the designer evaluate infiltration losses, glass area and type of windows and the need for heating the air space above a certain level in the room. RFH output typically results in very little air stratification and infiltration heat loss. As a result, RFH has proven to be the preferred method to heat large structures such as aircraft hangars.

9. Floor finish - Reference the type of floor finish: Tile, Oak, Marble, Slate, Thin Carpet, etc. Identify complimentary components like carpet pads, mastics and vapor barriers that will contribute to the heat resistance.

10. Floor finish thickness - Identify total thicknesses for the floor finish components.

11. Floor finish total resistence (R-value) - Check with the vendor of the floor finish for R-values of all additional components of the floor finish - adhesive, grout, carpet pad, etc.

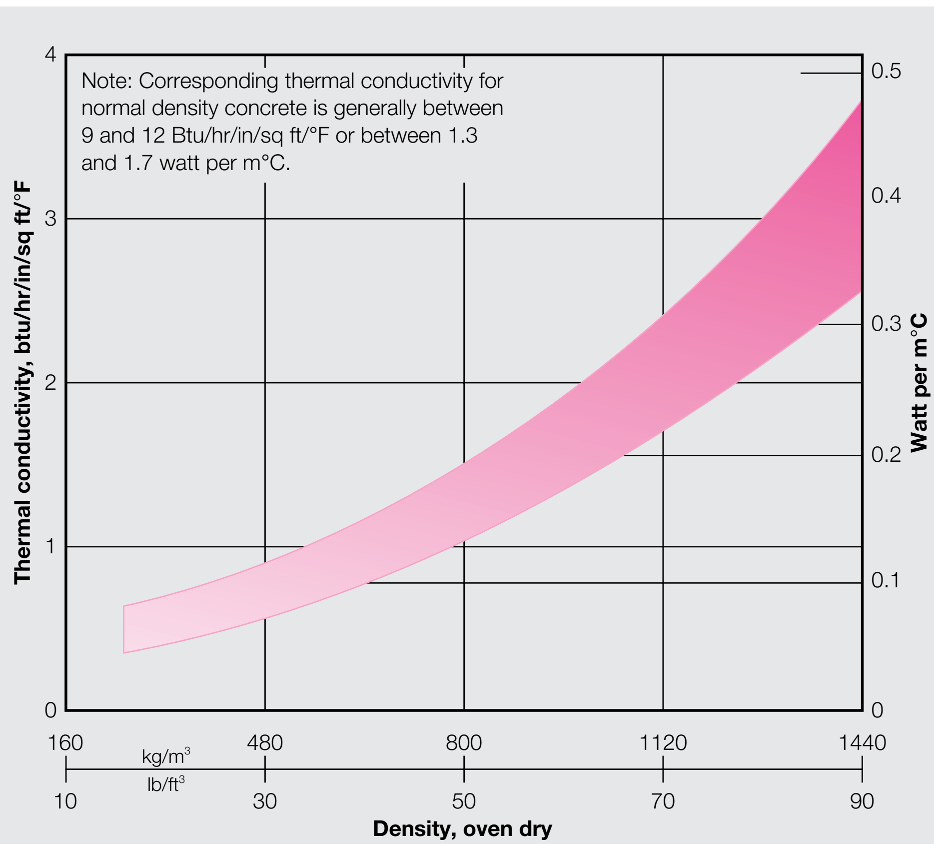


Fig. 4.3:
R - value for light weight thermal mass materials.

12. Thermal mass maximum allowable surface temperature - The maximum allowable surface temperature for a thermal mass is directly related to the maximum allowable exposure temperature for the planned floor finish. Floor finishes each have their own temperature limits. Wood floors are the most sensitive to thermal mass surface temperatures. Verify acceptable temperature limits with the vendor of the planned floor finish and installation system (adhesive/grout). See Table 3.1 for acceptable limits.

13. Resulting or allowable floor surface temperature - Floor surface temperatures are directly the result of the maximum allowable thermal mass surface temperature (col. 12) and the advisable temperature exposure limitations for human comfort. The floor surface temperature should never exceed 85°F (29°C) in the occupied areas, 91°F (33°C) for bathrooms and 95°F (35°C) for perimeter zones. When maximum allowable thermal mass surface temperatures fall below the acceptable temperatures for human comfort for different panel types, the resulting surface temperature for the floor finish can be found by using the "Floor Surface Temperature" column of the appropriate design table found in the Design Supplement. Figure 4.2 is a graph of resultant floor surface temperature for various sub-floor temperatures and floor finish R-values at a room temperature of 68°F (20°C).

14. Available RFH panel unit/area heat - The amount of heat available from an RFH panel is directly related to the maximum allowable floor surface temperature, required room temperature and the film coefficient of the air across the surface of the RFH panel. The maximum available panel unit/area heat is calculated by multiplying the temperature difference between the ambient air and the maximum allowable floor surface temperature by panel area for each panel by 1.9 btuh/ft^2 °F. If the result of this step is below the heat required, plan on either adding supplemental heat or reducing the heat load through energy conservation measures for the building.

15. Total available RFH panel area heat - This value is used to show the heat capacity of each area type with the maximum allowable floor surface temperature.

16. Total available RFH panel heat - To calculate total RFH heat available for the room, add all total available RFH panel area heats (col. 15) for each total available RFH panel area for the room. The final design most likely will not run the floor temperatures to the maximum levels. This value will show the designer very quickly if RFH will provide the heat output required when compared to the total heat required for the room.

17. Residual heat (+ or -) - Subtract the difference between the total heat required (col. 8) and the total available RFH panel heat (col. 16).

4.3.3 RFH panel design

18. RFH panel type - RFH panels are either designed around the poured or subfloor method. The poured method is based on the use of a cementitious type thermal mass. The subfloor method is based on the use of the tube mounted to the underside of the sub-floor with insulation 2" (5 cm) below the tube to reflect the heat upward.

19. Thermal mass type - The thermal mass is generally made from cementitious materials (Portland/Gypsum). The thermal mass will have both structural and weight requirements. RFH panels depend on the thermal mass to transfer the heat travelling through the heating water in the tubes to the room requiring heat. Thermal mass system types are typically available from concrete and floor leveling suppliers or licensed applicators of Gypsum products. Typical abbreviations used to identify thermal mass types are: LW for light weight, AG for aggregate, GYP for Gypsum, or JS for joist space method.

20. Thermal mass thickness - The thickness of the thermal mass is decided by the structural requirements, building floor height, variance requirements of the RFH panel design and thermal mass manufacturers' requirements. Conductive floor finishes over a thin thermal mass (1.5" or 38 mm) will require tube with a close spacing to prevent uneven heat along the surface. The thickness of the thermal mass also affects the time period required to bring the RFH panel to heating capacity.

21. Depth of thermal mass over tube - The depth of the tube in the thermal mass is required to determine the heat resistance upward with regard to the heat loss downward. REHAU RFH panel performance tables/graphs in the Design Supplement are provided for specified tube depths. The depth is measured from the top of the thermal mass to the top of the tube.

22. Insulation type - Insulation systems are very important for maximizing RFH panel performance. Roughly 15% of the RFH panel heat output can be taken as a basis for calculation of downward heat loss with insulation rated at R-5.

Polystyrene, styrofoam and fiberglass are the most common building insulation products. Polystyrene and styrofoam come in board form, from 1/2" to 4" (12 mm - 102 mm). Board form insulation is used with poured RFH panel installations. Fiberglass insulation comes rolled up in blanket form. The most common use for "batt" insulation is between floor joists, wall studs and ceiling/roof joists (attic space). When the fiberglass insulation has a reflective barrier, the reflective barrier will be closest to the tube for subfloor RFH panel construction.

23. Insulation thickness - Most R-values for insulation systems are given for the blanket or per inch for boards. The thickness of the insulation is required to calculate the total R-value for the insulation. If the insulation system being used has specific R-values for each thickness, skip this column.

24. Insulation total resistence (R-value) - This R-value is either given by the manufacturer of the insulation system or calculated knowing the total thickness and the R-value per inch.

4.3.4 RFH panel performance data

25. Room no. - Corresponding number for room from page one.

26. RAUPEX tube size selected - Size of tube being used in the RFH panel. Generally tube size is determined by average circuit lengths required for the building/zone. 17 mm and 1/2" tubing are used for residential radiant floor heating applications. 20 mm, 25 mm, 3/4" and 1" are used for commercial and industrial applications and snow melting.

27. REHAU RFH panel performance table/graph - The Design Supplement provides RFH performance tables and graphs for common RFH panel designs for North America. Page one of the Design Supplement provides an index for these tables/graphs. The performance tables and graphs assume 15% downward loss for poured installations and 25% downward loss for subfloor installations.

The following naming convention is used to catalog the performance tables and graphs:

P\LW\1.50\1.00\5.00\0.25\1

Col	Category
26	RAUPEX tube size selected
11	Floor finish total resistance (R-value)
24	Insulation total resistance (R-value)
21	Depth of thermal mass over tube
20	Thermal mass thickness
19	Thermal mass type LW - Light weight, AG - Aggregate, GYP - Gypsum, JS - Joist space
18	RFH panel type pour =P subfloor = S

By column numbers: 18\19\20\21\24\11\26

In cases where the DCRF form specifies information for an RFH panel performance table/graph that REHAU has not published, order one using the RFH Systems "Special Request" form in the Design Supplement. Write "SPECIAL" in column 27.

Example:
Identify the REHAU RFH panel performance table for a 4" concrete slab-on-grade with 2" of stryrofoam insulation with 17 x 2 mm RAUPEX tube installed 3.50" deep in the thermal mass with all the following R - values:

R-Value for Insulation = 10
R-Value for Floor Finish = 0.00
(No Floor Finish)

W\AG\4.00\3.5\10\0.00\17

In cases where the DCRF form specifies information for an RFH panel performance table/graph that REHAU has not published, order one using the RFH Systems "Special Request" form in the Design Supplement. Write "SPECIAL" in column 27.

Table: P\AG\4.00\3.5\10\0.00\17

Average temperature of water in tube - supply temperature and return temperature divided by 2
Tube spacing - center line to center line
Tube required per square foot of floor
Heat output per square foot of floor
Floor surface temperature
Maximum square feet covered based on tube length and spacing
Maximum circuit length for capacity and tube spacing requirement
Ambient room temperature

			Room Setpoint = 68° F				Room Setpoint = 72° F			
1	2	3	4	5	6	7	8	9	10	11
Mean Heating Water Temp.	**Distance Between Tubes**	**Specific Tube Require.**	**Capacity**	**Floor Surface Temp.**	**Max. Heating Circuit Area**	**Max. Heating Circuit Length**	**Capacity**	**Floor Surface Temp.**	**Max. Heating Circuit Area**	**Max. Heating Circuit Length**
°F	in	ft/ft²	btuh/ft²	°F	ft²	ft	btuh/ft²	°F	ft²	ft
80	2	6.0	14	75	131	787	9	77	131	787
	4	3.0	12	74	262	787	8	76	262	787
	6	2.0	10	73	393	787	7	75	393	787
	8	1.5	9	72	525	787	6	75	525	787
	10	1.2	8	72	656	787	5	75	656	787
	12	1.0	7	727	787	787	5	74	787	787
90										
100										
110										

Before beginning your calculations, you must already have
KNOWNS:

1. Heat requirement for room
2. Floor area of room (available)
3. Desired room temperature
4. Type of floor construction and floor covering

Find correct corresponding table depending on
T***ype of floor construction and floor covering***

Use the following steps to supply your **UNKNOWNS**.

1. Calculate Capacity (from knowns)
   Heat requirement divided by floor area
2. Select Mean Heating Water Temperature

Note: There are varying options available depending on your choice of *Mean Heating Water Temperature.*

All other variables are a result of table specifications.

Example:

12,000 btuh
1,200 ft²
68° F
Concrete over subbase floor construction,
Thin carpet floor covering

$\frac{12{,}000\ \text{btuh}}{1{,}200\ \text{ft}^2}$ **= 10 btuh/ft²**
Selected 80°F **Mean Heating Water Temp**.
Find 10 btuh/ft² (capacity) and read left on table to
Required Spacing - 6" and
Specific Tube Require. - 2.0 ft/ft²
Select **Ambient Room Temperature** - 68°F (known)
Read across table to find:
Floor Temperature - 73°F
Max. Heating Circuit Area - 393 ft²
Max. Heating Circuit Length - 787 ft²

Fig. 4.4:
REHAU RFH performance table method -
Once the correct table has been selected, use the MHWT, the room temperature and the maximum allowable surface temperature to find the RFH panel heat capacity. The designer, through experience, will select the tube spacing which provides evenly heated surfaces and optimized circuit lengths.

28. Heating water temperature spread - This is the temperature difference between the supply and return heating water to the RFH panel. Most typical hydronic designs are based on a temperature spread of 20°F (11°C) or 10°F (6°C). REHAU RFH panel performance tables/graphs are based on 20°F (11°C).

29. Required mean heating water temperature per room (MHWT) - The definition of mean heating water temperature (MHWT)is: the average temperature for the supply and return heating water to the RFH panel. The temperature selection should be based on economy and efficiency of design. Temperature selection, however, will also be constrained by the maximum allowable thermal mass surface temperature, maximum allowable floor surface temperature and heat output required for the room. In certain instances the maximum supply water temperature is limited (lower) due to the heat output of the heat source. In this case, the temperature limit of the heating source establishes the parameters for selecting the MHWT. Use of the lowest heating water temperature that will provide the required floor surface temperature will also minimize thermal stress on slabs and floor coverings, and minimize overshooting of desired room temperatures. Proper heating water control design will provide the correct MHWT for zone or building requirements. Providing specific MHWT for designated manifolds is the way to correct for heat capacity which varies due to floor covering or heat loss requirements of specific rooms.

The first step in selecting MHWT is to evaluate the MHWT requirements for each room based on the total unit/area heat required (col. 8) and available RFH panel unit/area heat (col. 14). Using the RFH panel performance table or graph selected in column 27, select "reasonable" tube spacings and MHWTs. MHWTs ranging from 80° to 130°F (27° to 60°C) are available with the corresponding RFH panel heat output values and tube spacings.

30. Selected mean heating water temperature per bldg/zone - Determining the MHWT for a building or a zone in a building is done by either the "Highest MHWT" method or the "Average MHWT" method in conjunction with the available heat from the heat source. Always verify that floor surface temperatures remain below maximum values for each floor area type.

Highest MHWT Method: Select the highest MHWT value from column 29 and use this MHWT for all the rooms in the building or zone.

Averaging method: The averaging method is based on evaluating the MHWT values for the entire building or zone simultaneously. If a majority of the rooms will work with the MHWT selected, then the designer can look at providing the remaining rooms with the additional heat required through supplemental heat or reorganizing the heating distribution system to provide specified MHWT groupings through zoning. The averaging method provides the lowest MHWT.

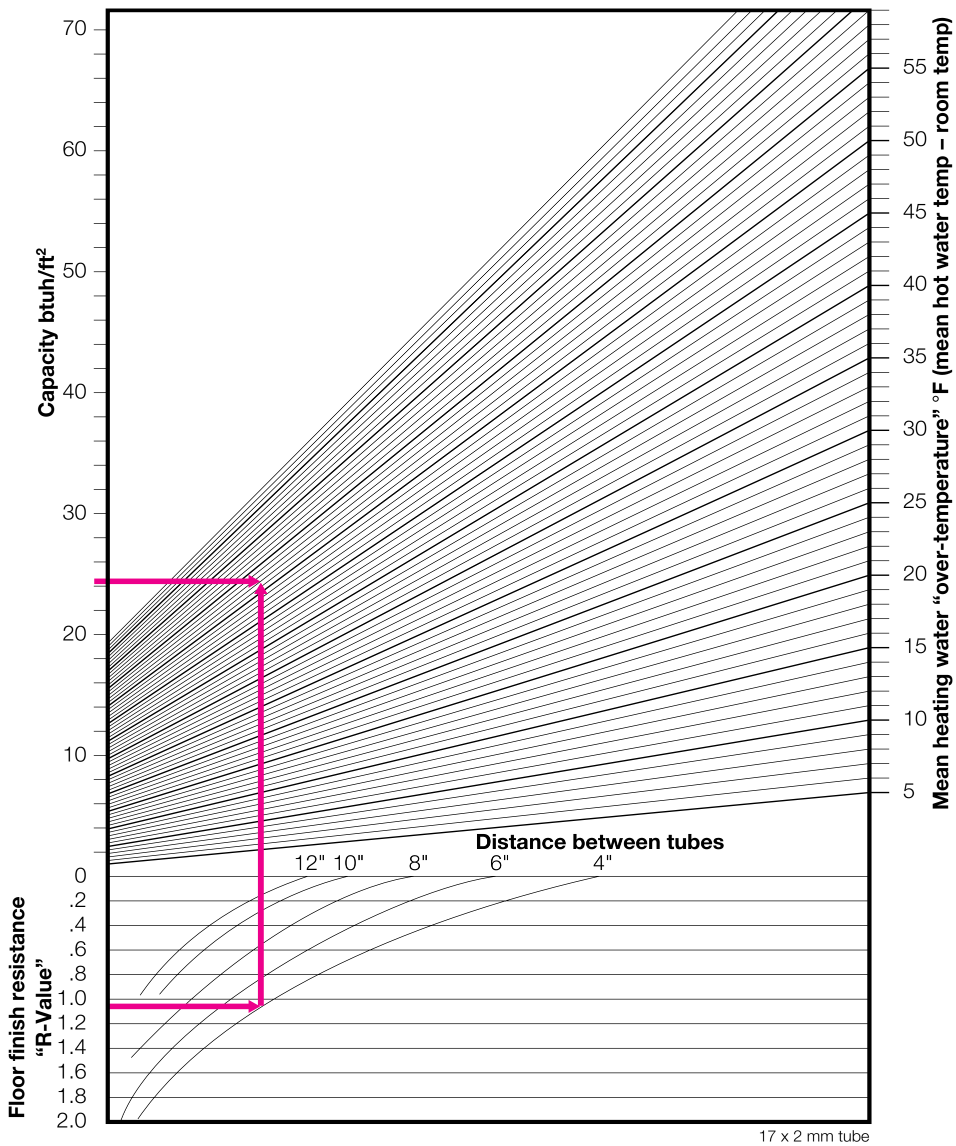


Fig. 4.5:
REHAU RFH performance graph.

Example:
(A) Determine the Mean Heating Water Temperature (MHWT) from the performance graph, given the following DCRF values;

col. 7 (Required Room Temp.):	68°F
col. 8 (Total Heat Required Per Area):	24 btuh/ft²
col. 11(Floor Finish Total Resistance):	R=1.05
col. 26(RAUPEX Tube Size Selected):	17 mm

(**B)** Using the performance graph shown in Figure 4.5 (or performance graph appropriate for your design) perform the following:

Step 1: Draw a horizontal line starting at R=1.05 (lower left side vertical axis) over to the 4" tube spacing curve (see note 1).
Step 2: Draw a horizontal line starting at 24 btuh/ft² (upper left side vertical axis) over to the right side vertical axis.
Step 3: Draw a vertical line perpendicular to the 4" spacing intersection point, found in Step 1, up to the horizontal line found in Step 2. At the intersection of these two lines, locate the nearest sloped (MHWT) line. Follow along this sloped line over to the right side vertical axis. FOR THIS EXAMPLE, we find that the value is 52°F. This value of 52°F is the MHWT over-temperature.
Step 4: Calculate MHWT from the following;
MHWT= 52°F (over-temperature) + 68°F (room temperature)
MHWT= 120°F
Step 5: Enter this MHWT into DCRF column 29.

note 1: If necessary, repeat steps 1-4 with various tube spacings to optimize MHWT.

31. RAUPEX tube spacing - The required tube spacing is determined by the available and remaining RFH panel unit/area heat capacity, maximum floor surface temperature allowed and the MHWT.

The following considerations affect tube spacing:

- Closer tube spacing allows for a lower MHWT
- Tiles are often selected as the floor covering with underfloor radiant heating systems. Closer tube spacing will prevent noticeable differences in floor surface temperature. For normal comfort applications, spacing should be no greater than 12" (30 cm) on center to avoid cold spots.
- The closer the tube spacing, the smaller the area which can be served by one heating circuit.
- Tubing should be at least 6" (15 cm) from the finished wall surface and nailing surfaces.

REHAU recommends that tube spacing be selected to provide the most efficient system, i.e., the lowest hot water temperature, considering the tube layout and tube length constraints noted above.

32. Resultant floor surface temperature - Resulting surface temperatures as referenced from RFH panel performance table/graph.

33. Available RFH panel unit/area heat capacity - This is the first iteration to determine the RFH panel capabilities for a room. If the room has a perimeter area, it is best to maximize the allowable floor surface temperature to meet as much of the heat load requirement for the room as possible.

34. Resulting RFH panel area heat output - Determined by multiplying the available RFH panel heat capacity (col. 33) by the available RFH floor area (col. 6).

35. Room heat capacity balance (+ or -) - Subtract the resulting area heat output from the total heat required. This value represents the remaining heat required for this room.

36. Total remaining RFH panel area - Available RFH panel area with heat capacity.

37. Remaining RFH panel unit/area heat capacity required - Knowing the remaining available RFH panel area and the heat capacity, this value provides the required unit/area heat capacity. This value is important to the designer to understand the remaining distribution of the RFH panel areas for the room.

38. Remaining RFH panel unit/area heat capacity available - Using the performance table/graph, determine the available unit/area heat capacity.

Tube spacing	Tube requirement factor (Tube required per square foot)
2"	6 feet
4"	3 feet
6"	2 feet
8"	1.5 feet
10"	1.2 feet
12"	1 foot

Fig. 4.6:
Tube requirement factor chart.

39. Resulting RFH panel area heat output - This value represents the total output of each of the remaining RFH panel area types.

40. Total RFH panel heat output - The total output of all the RFH panel area types for the room.

41. Supplemental heat capacity required (remainder) - The RFH panel output compared to the total heat required for the room.

4.3.5 RFH panel tube requirements

42. RAUPEX tube requirement factor - Circuit tube length required per unit RFH panel area. (See Fig. 4.6)

43. Maximum allowable RAUPEX tube circuit length - The maximum allowable circuit length is based on design conditions for temperature and heat capacity with a maximum pressure loss of 10 feet of head.

44. Length of RAUPEX tube circuit tails - The host RFH distribution manifold and the RFH heating panels are usually located in different areas of a building. The tubes to and from the RFH distribution manifold to the RFH panel are called circuit tails. The length of these circuit tails must be added to the RFH panel tube circuit length to calculate the total pressure requirement for the tube circuit.

45. RFH panel RAUPEX tube circuit length - Calculate total length of tubing required by the RFH panel by multiplying the tube requirment factor by the panel area.

46. Combined RAUPEX tube circuit length - The total length of tube required to make up the circuit effective length and circuit tails. The total allowable circuit length is based on the maximum allowable tube circuit length. REHAU offers a full range of tube diameters to allow the designer, with the proper thermal mass thickness, to change tube sizes for tube circuit length requirements.

47. Number of heating circuits - Total number of tube circuits required to supply RFH panels for this room.

Select zones. A zone is an area served by one or more tube circuits, and which will be controlled separately. Areas which will have dissimilar heat loss rates should be zoned separately. Areas with similar floor construction and finishes and with similar heat loss rates should be combined into the same zones.

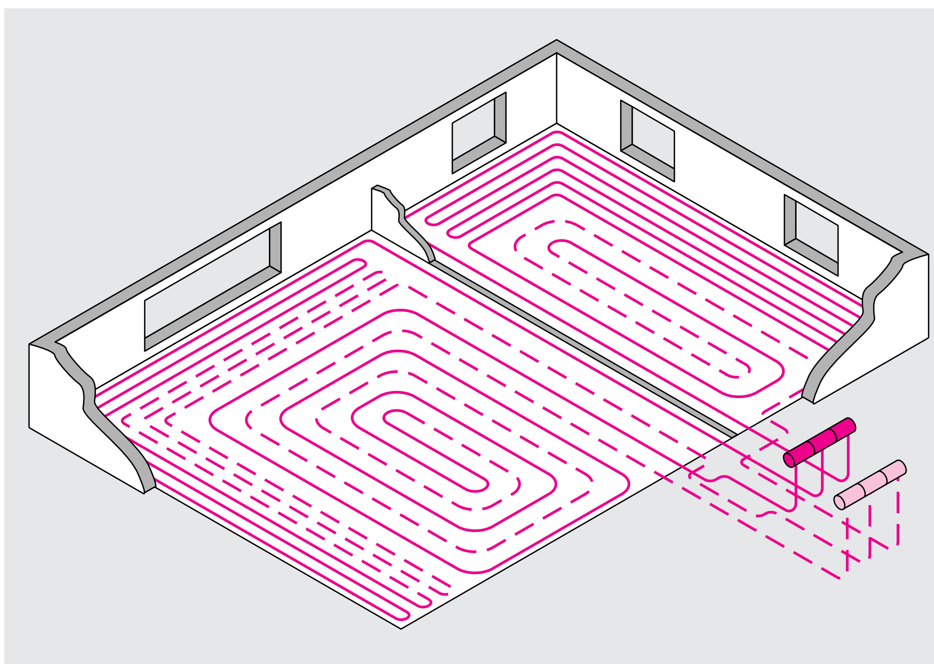


Fig. 4.7:
Distribution for RFH.

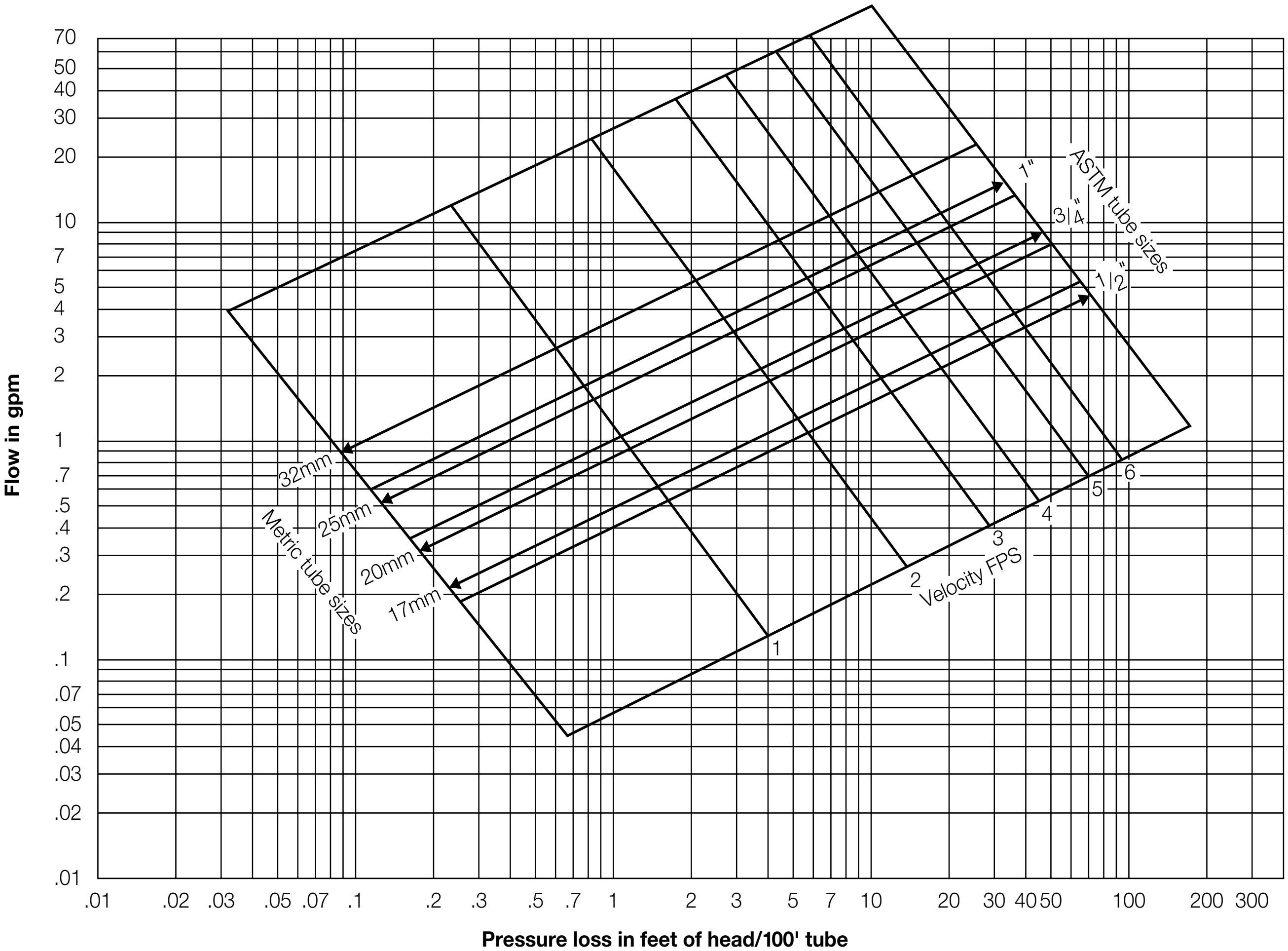


Fig. 4.8:
Pressure drop table for REHAU heating tubes.

The use of the building can also affect the zoning of the radiant floor heating.

- Residential. Residents will typically use different rooms within a home at different times of the day, such as bedrooms versus kitchens. Rooms that are used together should be zoned together. Rooms that are not used for substantial periods of time, such as formal dining areas, should be zoned separately, so that they may be set back to conserve energy and reduce operating costs.
- Commercial. Use of commercial buildings usually includes one or two types of activities, such as eating or shopping, and may change depending on the turnover. Zoning should be versatile enough to accommodate changes in these use patterns.
- Industrial. The industrial process usually determines the zoning, and may also contain large pieces of machinery which may add to the heat in the room. Zoning for industrial applications should be determined by the design engineer according to the considerations which apply.

48. Manifold station label - Identification of tube circuit. Suggested naming convention: A1 - "A" stands for the 1st manifold and "1" stands for the 1st tube circuit. Tube circuits should be labeled from left to right on the manifold. Another example: The 6th tube circuit from the left on the third manifold would be called C6.

4.3.6 Required water flow rate - Quantity of heating water required to support an RFH panel area type.

Water flow rate is calculated for each circuit using RFH panel heat output for the zones served by the circuit and the spreads between supply and return water temperatures. The equation is as follows:

$$\text{Flow} = \frac{\text{RFH Panel Unit/Area Heat Output (btuh)}}{.85 \times 500^{1} \times \text{Heating Water Temperature Spread}}$$

where:

Flow - gpm

Temperature - °F

Heating Water Temperature Spread: (t_s - t_r)

t_s - supply water temperature

t_r - return water temperature

.85 - compensation for downward RFH panel heat loss (for 15% downward panel heat loss)

Notes:

[1] 500 = (8.34 lb/gal of water) (60 min/hr)(1)
(a) (b)

(a) 8.34 = approximate density of water at RFH water temperatures.
(b) 1 = heat capacity of water. Values (a) and (b) will change when adding antifreeze.

4.3.7 Pump sizing data - Using the flow rates for each circuit from DCRF Page 3, enter the pressure loss chart (Figure 4.8) until you intersect the tube size line. Then follow the line vertically down to the pressure loss.

The result is a pressure loss in feet of head per 100 feet of tube. Measure the lengths of tube in the circuit, divide by 100, and multiply by the friction drop values from the chart to arrive at the total circuit pressure loss. The total energy requirement of a system comprising several branch circuits is determined by the circuit having the greatest pressure drop, i.e., the "worst case circuit".

If pressure drop for any circuit is excessive (greater than 10 feet of head per circuit), revise either the zoning, the number of circuits, the tube size or the flow rate. If the tube size or tube lengths change, recalculate the pressure loss and corresponding water temperatures.

When all circuit pressure drops are within acceptable ranges, estimate the pressure losses through balancing and shut-off valves, and find total pressure drops. Use Figures 4.9 and 4.10 to estimate valve losses.

For each manifold, add the flow rates for all circuits served from the manifold. Size the circulating pump using the sum of the flows, and the greatest of the pressure requirements served by that circuit.

Pump manufactures provide pump performance curves. The designer can compare the RFH requirements with the pump characteristics to optimize selection. Selection of pumps for closed circuit heating systems should be done through careful matching of the pump operating characteristics to the system operating requirements.

Pumps used for RFH systems are generally small, in-line circulator, (centrifugal) type. Circulating pumps should have a flat pressure head characteristic and should be selected to operate slightly to the left of the mid point of their performance curve. Pumps with steep performance curves should not be used since they tend to limit system flow rates.

4.3.8 Adjusting manifold balancing valves - With the pressure loss data for each circuit on a manifold, the designer can determine the difference between the greatest pressure loss and the remaining. Then use Fig. 4.10 to determine the appropriate number of turns for each balancing valve. Follow specific instructions supplied with the manifold.

4.3.9 Thermal mass quantities - The amount of thermal mass required for the project is easily calculated by knowing the thickness of the thermal mass, the volume of space the RFH components will consume in the thickness of the thermal mass, and the amount of additional thermal mass that will be required to fill in low points and pockets. Thermal mass quantities are normally specified in cubic yards or cubic meters.

4.3.10 Control quantities - A typical room with RFH will have a thermostat to control the comfort and valve actuator at the manifold to open and close the circuit isolation valve. In addition, the circuit may have specialized controls such as a separate water temperature regulator. One room with three circuits may have one thermostat with three circuit heads.

Usually, supply and return water temperatures are limited by the heat source. A condensing type boiler, electric boiler or heat pump can be operated at very low supply water temperatures. In contrast, conventional oil- or gas-fired boilers usually require a minimum return water temperature of 130°F (54°C) in order to prevent condensation of the flue gases and subsequent corrosion and blockage of the boiler heat exchanger and chimney. However, radiant floor heating systems require water temperatures lower than 130°F (54°C).

The best way to protect both the boiler and the tube is to mix the cooler radiant floor system return water with the boiler supply water. This mixing process can be controlled by the following generally accepted methods:
- 3- or 4-way mixing valve with or without outdoor reset control.
- Hot water injection system using a fixed speed pump.
- Hot water injection system using variable speed pump.

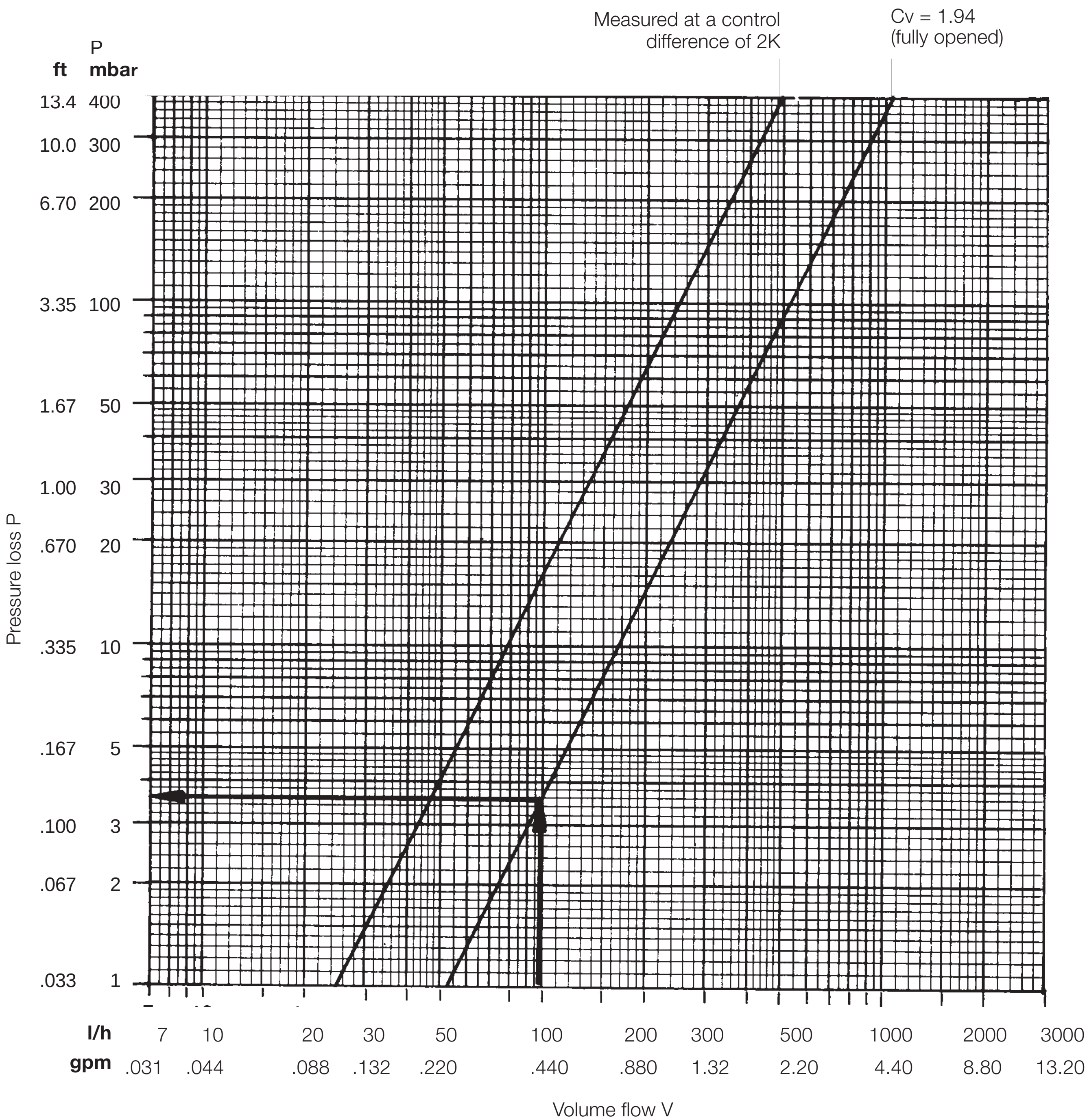


Fig. 4.9:
Pressure loss table for flow valves in the heating circuit distribution manifold. The flow valves in the heating circuit distribution manifold should be fully open to accommodate the flow through individual heating circuits and still generate a pressure loss. However, their pressure loss must be included in determining the total pressure loss of a heating circuit. This table can also be used to determine pressure loss for a specific volume flow.

Example:
A heating circuit has a flow rate of .44 gpm (100 l/h). The pressure loss that will occur in the flow valve amounts to .05 psi (3.55 mbar) determined from the fully open curve. This value is then added to the pressure loss derived from Figure 4.9.

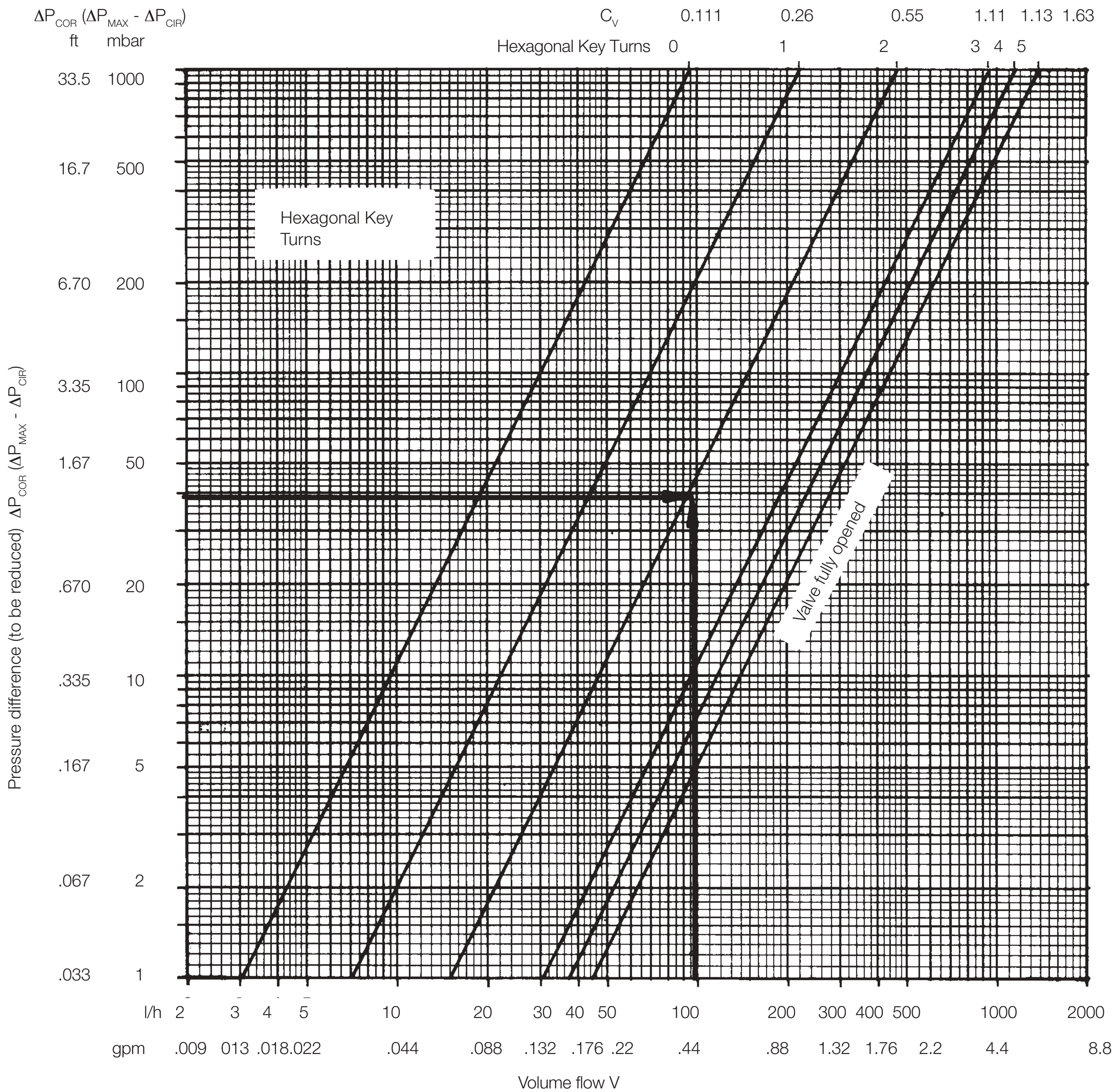


Fig. 4.10:
This table is used to determine the settings for the fine regulation valve in the heating circuit distribution manifold. Pressure losses computed for individual circuits from Figure 4.8 are the basis for determining these valve settings.

Example:
Balancing a 5-station manifold with circuits A1,A2,A3,A4,A5.

The circuit with the greatest pressure loss is A5

$\Delta P_{A5} = \Delta P_{MAX}$ = 5.02 ft of head

The circuit to be balanced against A5 is A3. Circuit A3 has a ΔP_{A3}= 3.68 ft of head at a volume of .44 GPM

The difference in pressure between the two heating circuits requiring correction is: ΔP_{Cor} (Cor = Correction)

$\Delta P_{Cor3} = \Delta P_{MAX} - \Delta P_{A3}$

ΔP_{Cor3} = 5.02 ft head - 3.68 ft head

ΔP_{Cor3} = 1.34 ft head

At ΔP_{Cor3} = 1.34 ft head and a volume flow of V = .44 GPM, the design table for fine regulation valves for REHAU manifolds with Heimier valves shows a setting of 2 turns open from the closed position.

4.4 Sample residential project design

This sample residential project (Figures 4.11-4.13) illustrates the design of a REHAU radiant floor heating system using the DCRF process.

Every design problem begins with "knowns". Below is a list of the knowns for the sample project.

Knowns:

1) Insulated (5-1/2" batt) crawl space construction.
2) Lightweight thermal mass, 1-1/2" thick.
3) Tubing will be stapled down.
4) RFH manifold to be located rear of vestibule closet.
5) Floor finish by room as follows:
   Living - Polyester Plush carpet, no pad, 1/4" thick
   Vestibule - Slate, 1/4" thick
   Dining - Hardwood, 3/8" thick
   Family - Acrylic Plush carpet, 3/4"
   Kitchen - Ceramic tile, 1/4"
   Half Bath - Ceramic tile, 1/4"

6) Heat loss as provided by owner:
   Living - 3168 btuh
   Vestibule - 2500 btuh
   Dining - 2880 btuh
   Family - 6720 btuh
   Kitchen - 3696 btuh
   Half Bath - 125 btuh

7) Required room temperatures will be 68°F.

8) Source of heat for water will be a boiler with normal minimum return temperature of 140°F.

9) Mixing water controls will be used to provide the supply heating water temperatures required to meet the design of the RFH system.

10) The following spaces will have thermostats:
   Living
   Dining
   Family
   Kitchen

.

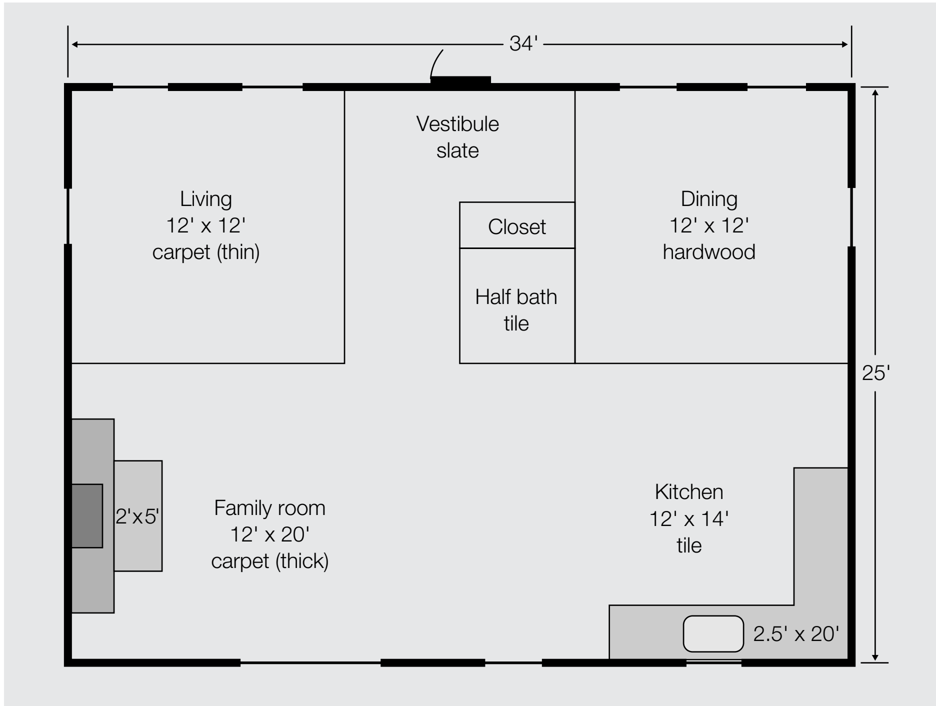


Fig. 4.11:
Project plan.

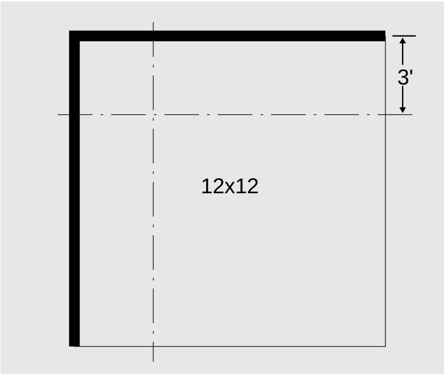


Fig. 4.12:
Perimeter zone and occupied area for project plan living room.

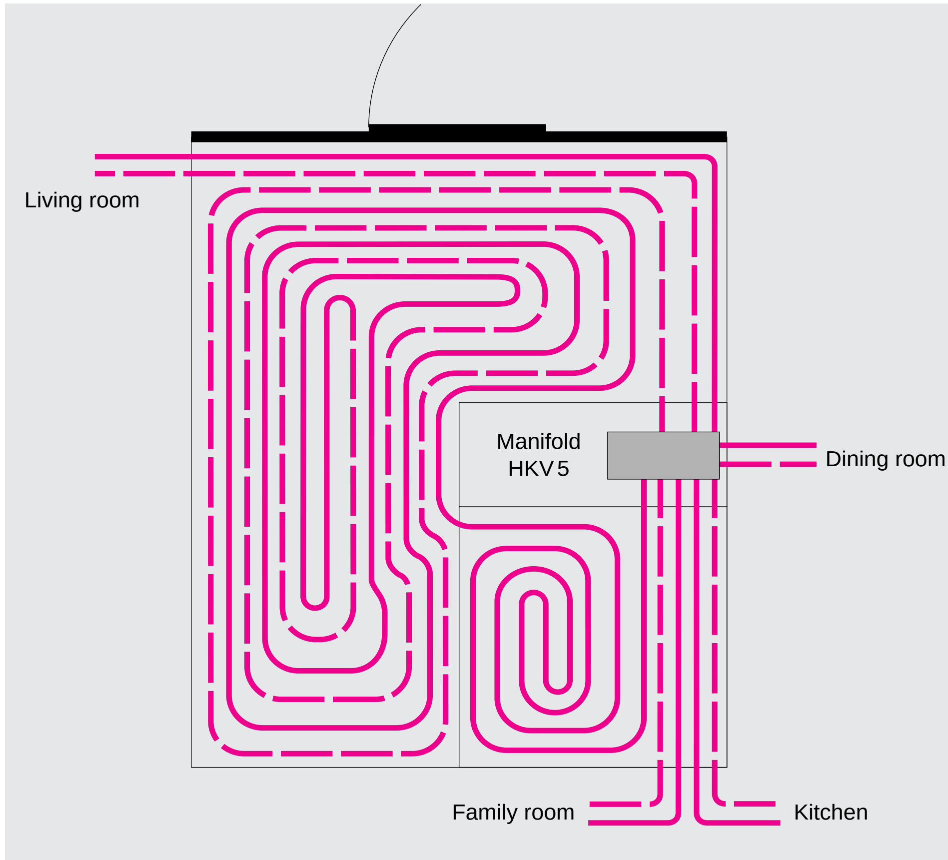


Fig. 4.13:
Distribution pipe, manifold location and guest bath vestibule heating circuit layout for project plan.

4.5 Completed DCRF's

The following 6 pages are completed DCRF's for our sample residential project.

5. Installation of RFH

The installation of an RFH system is very dependent upon the type of project. New construction, and renovation for residential, commercial and industrial projects present different site conditions as challenges to the installer. REHAU offers complete systems to meet these challenges. The site condition for tube installation will require either a poured or subfloor RFH system installation.

5.1 Poured tube installation
Poured tube installation can be accomplished with one or a combination of five different REHAU approved tube installation techniques.

5.1.1 Stapled method
REHAU provides an approved stapler to hold tube to wooden subfloors using wide crown roofing staples. The most common use of the stapled method is with tube sizes 17 x 2 mm and 1/2" in residential applications. Typically, a light-weight or fiber-reinforced concrete or gypsum-based material is poured over the tube in a thickness as little as 1.5" (3.8 cm). Insulation for the RFH installation is provided by installing fiberglass insulation between the floor joists below the wooden subfloor. Staples are placed every 3' (1 m) except for tube turns where the spacing shall be as required to hold the tube flat against the subfloor. Care should be taken to insure that no sharp staple edges gouge the tube wall.

Fig. 5.1:
Stapled method.

5.1.2 Star clip method
The majority of concrete slabs which are placed on grade or used in structural concrete floors include either wire mesh or rebar. The use of star clips with wire mesh reduces tube installation time and provides for a professional looking project. The star clips are designed for ease of installation for 17 x 2 mm, 20 x 2 mm, 1/2" and 3/4" tube. Insulation for the RFH installation is typically foam board insulation placed under the wire mesh. Star clips offer the tube hold down strength which is very important to prevent tubes from being kicked out of place by the thermal mass installer. Star clips should be placed every 3' (1 m) except for tube turns where the spacing shall be as required to hold the tube flat against the wire mesh.

Depths for the tube must be maintained as specified by the design. Care should be taken to ensure that no sharp edges from the wire mesh or tie wire used to connect the wire mesh gouge the tube wall.

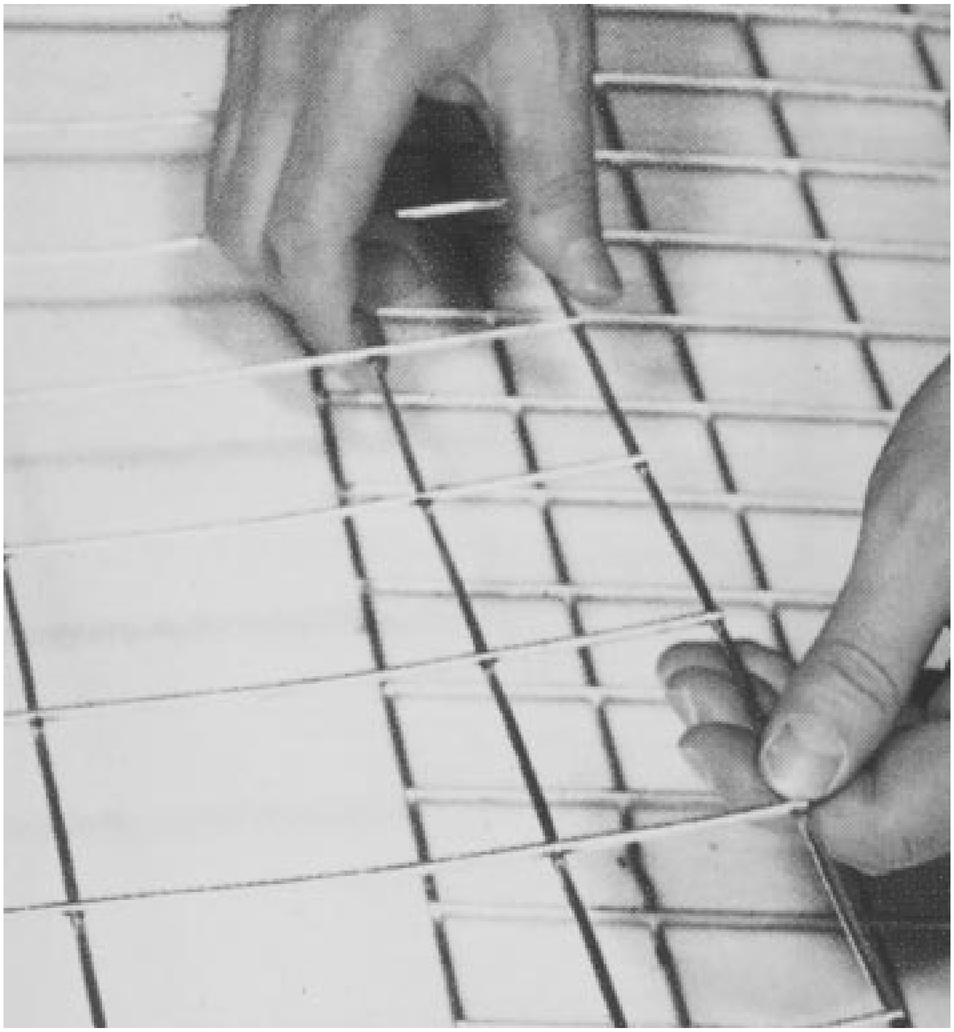


Fig. 5.2:
Using wire mesh.

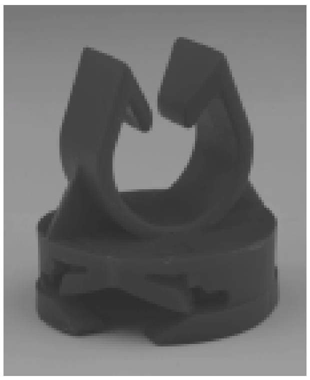


Fig. 5.3:
Star clip.

5.1.3 Cable binders and tie wraps

Cable binders and tie wraps are used to install tube with rebar designed slabs. These slabs can either be on grade or suspended. Binders and wraps are designed for ease of installation for all sizes of PEX tube. Insulation for the RFH installation is typically foam board insulation placed under the rebar. Binders and wraps should be placed every 3' (1 m) except for tube turns where the spacing shall be as required to hold the tube flat against the rebar. It is imperative to use REHAU approved cable binders and tie wraps to ensure that the tube is installed without installation defects. Tie wraps must be covered with plastic. Specified depths for the tube must be maintained as specified by the design. Care should be taken that no sharp edges from the rebar or the rebar tie wire gouge the tube wall.

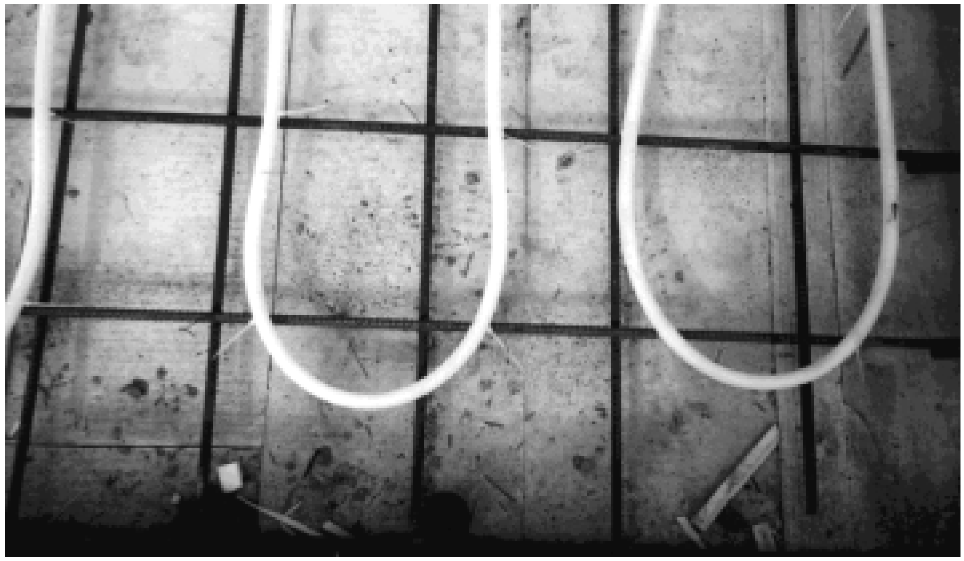


Fig. 5.4:
Cable binder method with rebar.

5.1.4 Insulation screw clip

The insulation screw clip requires the installation of 1" minimum thickness foam board insulation at the bottom of the thermal mass. Tube sizes 17 x 2 mm, 20 x 2 mm, 1/2" and 3/4" will work with the screw clip. A special ratchet tool is available to assist with rapid installation of the screw clip into the insulation. Screw clips should be installed every 3' (1 m) except for tube turns where the spacing shall be as required to hold the tube flat against the insulation. To reinforce the thermal mass if required, either wire mesh is placed carefully over the tubes or a fiber reinforcement is included in the mix. Care should be taken to ensure that no sharp edges from the wire mesh or tie wire used to connect the wire mesh gouge the tube wall.

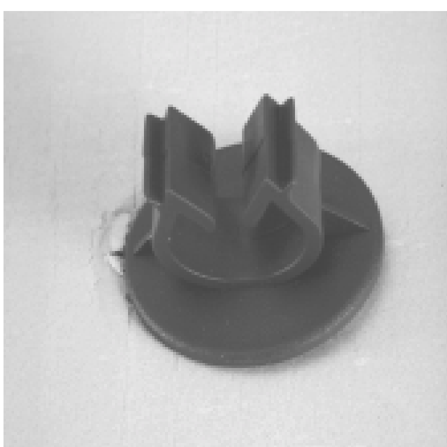


Fig. 5.5:
Insulation screw clip method.

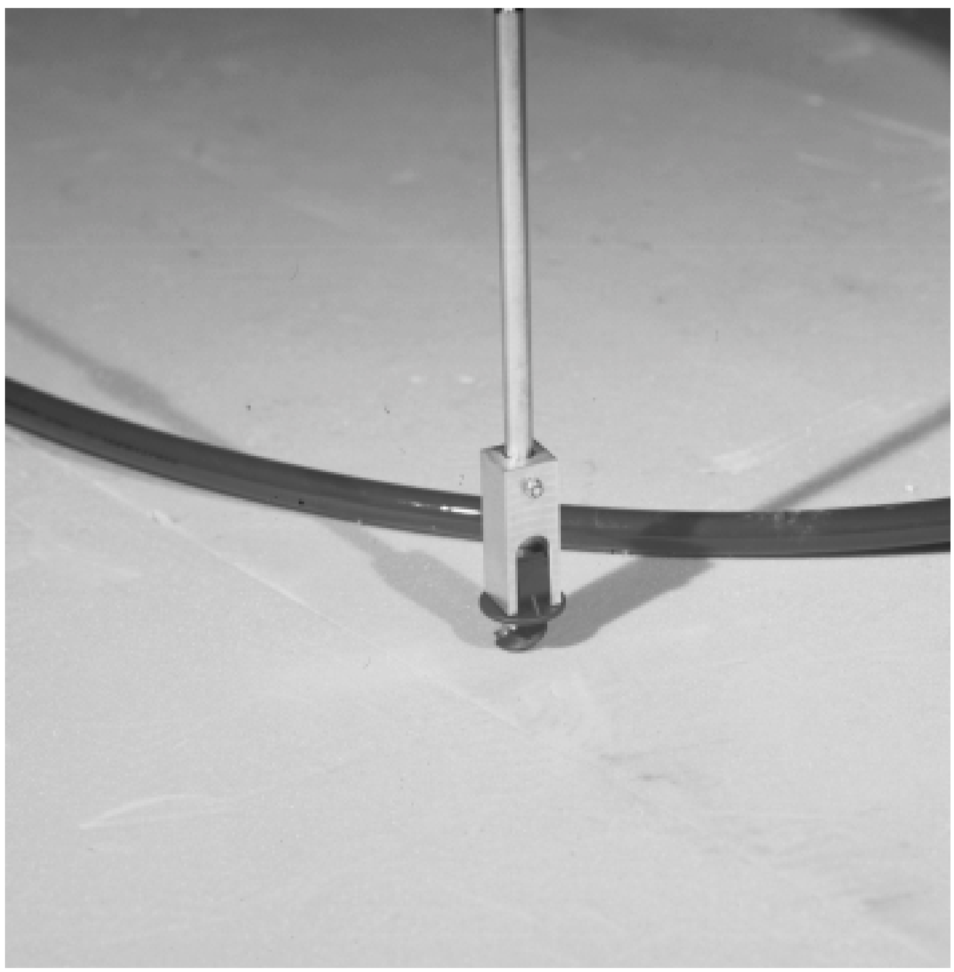


Fig. 5.6:
The screw clip is inserted easily into the insulation with the aid of the ratchet tool.

5.1.5 RailFix

RailFix is secured directly to the top of 1" minimum thickness foam board with plastic staples, or screwed to wooden subfloors, or attached to rebar or wire mesh with tie wire. RailFix is available for all tube sizes in stock lengths of 13' (4 m) with tube spacing every 2" (5 cm). Tube installation is very fast by simply “walking” the tube into the RailFix for a secure installation. Tube spacing is easy with the preset spacing built into the RailFix. RailFix should be installed every 3' (1m). It may be necessary to use insulation screw clips or cable binders for tube bends to aid with holding the tube flat. To reinforce the thermal mass, if required, either wire mesh is placed carefully over the tubes or a fiber reinforcement is included in the thermal mass mix. Care should be taken to ensure that no sharp edges from the wire mesh or tie wire used to connect the wire mesh gouge the tube wall.

Fig. 5.7:
Raw site.

Fig. 5.8:
Insulation.

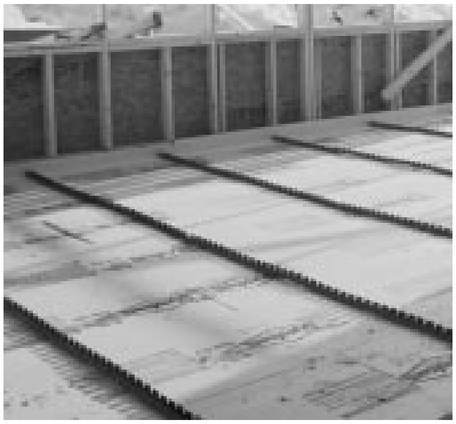


Fig. 5.9:
RailFix with 3' (1 m) spacing ready for tube.

Fig. 5.10:
Layout tube in accordance with design plans.

5.2 Subfloor tube installation

Subfloor tube installation can be accomplished with the use of tube talons or reflective heat transmission plates.

5.2.1 Joist space

The joist space method requires the tube to be installed below the subfloor and is only recommended for a tube size of 1/2". Wood subfloors are the predominate application for this installation method. Where no reflective heat transmission plates will be used, tube talons are the prescribed tube hangers. PEX tube will move with temperature change of the heating water. Plastic tube talons will prevent wear to the tube's outer wall. Tube talons should be placed every 3' (1 m) or as required to secure the tube below the subfloor. Use of heat transmission plates in lieu of tube talons is encouraged. Heat transmission plates are available in 2' (.6 m) lengths and are installed with a 2" gap between adjacent plates. Secure plates to subfloor using screws (three per side). Care should be taken to avoid sharp edges gouging the tube wall. Any structural fouls must be cleared with structural designer prior to placing holes to run tube. Insulation should be placed below the tube with a 2" (5 cm) minimum air space below the tube. Typical insulation for the joist space method is fiberglass blanket insulation.

Fig. 5.11:
Tube talon.

Fig. 5.12:
Blanket insulation for joist space method.

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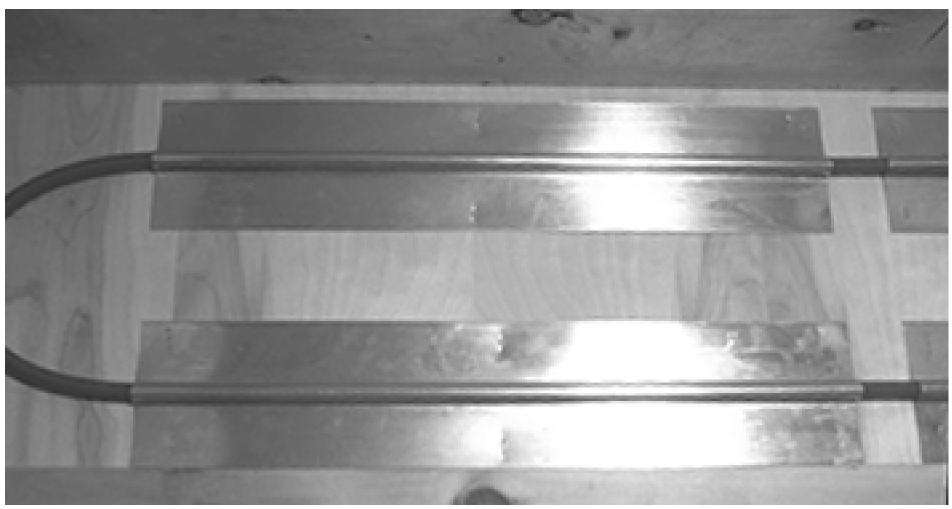
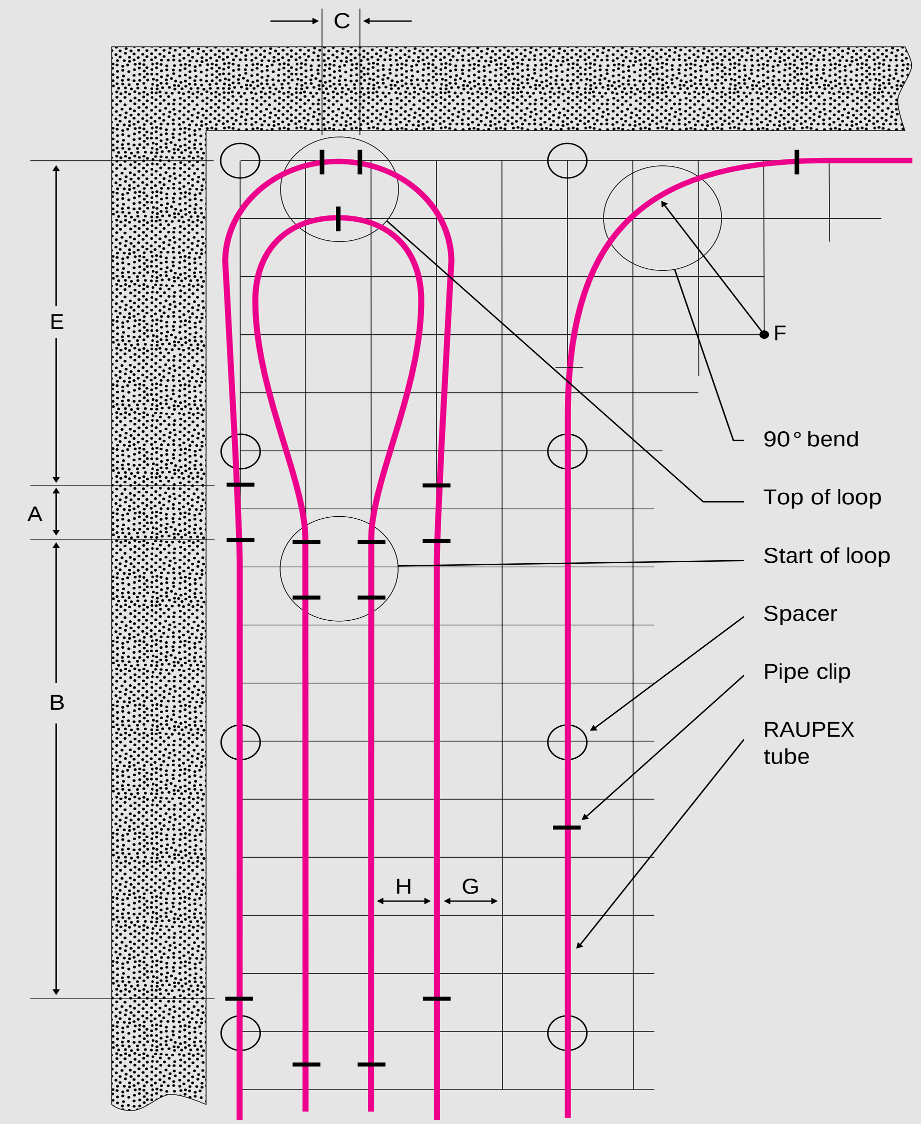


Fig. 5.13:
Tube installation with heat transmission plate.



A. Pipe clip spacing at start of loop (approx. 2 clips per mesh)
B. Pipe clip spacing on straights (approx. 3', 1 m)
C. Pipe clip spacing at the top of the loop (approx. 1 mesh)
D. Diameter of loop (> minimum bending radius)
E. Length of loop (> 20", 50.8 cm)
F. Bending radius (> 3", 7.6 cm)
G. Size of mesh
H. Distance between RAUPEX tube

Fig. 5.14:
Different tube bends meet tube spacing requirements.

5.2.2 Tube cutting, bending, insulation and identification
Use REHAU tube cutter or equal to provide clean square cuts. All open ends of tube shall be capped with tape to prevent contaminant from entering. Be sure to allow extra tube at manifold connections to provide proper fit up.

Tubes which are used to distribute hot water to manifolds or remote RFH zones shall be insulated to prevent energy loss.

Fig. 5.15:
RAUPEX can be insulated against heat loss where tubes pass through unheated areas.

Cold bending allows tubing to be bent to a radius equal to 5 times the tube outside diameter. Tubing can be bent to a radius equal to 3 times the tubing outside diameter by heating gently with a fan heater. It is best to store tube in a warm area 65°F (18°C) to 100°F (38°C) prior to installation for ease of bending. A REHAU uncoiler greatly aids in laying the tube. The tube should be uncoiled in a manner which avoids twisting.

Tube ends shall be labeled to designate supply and return and circuit location. Record the actual tube lengths for each circuit if they differ from those shown in the design. Verify with designer for adequate output.

Fig. 5.16:
Supports are available to hold tube at 90° bend.

5.3 Installation of manifolds

REHAU provides both surface-mounted and wall cavity cabinets for its distribution manifolds.

The location of the manifold is especially important where walls are to be erected which enclose the cabinet. The location of the cabinet should be verified from construction plans and any conflicts should be reported to the owner. Once the manifold cabinet has been located, it is best to pre-plan temporary supports which will not alter the original construction plans.

Fig. 5.18:
Tube and manifold installation.

Fig. 5.17:
Wall cavity manifold cabinet.

The cabinet must be located at the proper height for the pour. If walls have been placed or exist, use them to support the manifolds.

The manifold to tube connection, if done step by step, will save valuable time in the installation and pressure testing process.

a) Connect each supply and return circuit to the designated supply and return valve on the manifold.
b) Shut both the supply and the return valves. The supply valves are closed by turning the red manual activator knobs clockwise. The return valves are closed by removing the brass cap and turning the valve stem clockwise. See specific instructions included with the manifold.
c) Be sure to use a back-up wrench when tightening the compression joints. The valve union at the manifold may also require tightening.
d) Record the actual tube lengths for each circuit.

Fig. 5.19:
Manifold to tube connection.

5.4 Pressure tests

An initial pressure test is always performed on the system to find if the tubing is leak free. This initial test is always done prior to covering the tube.

5.4.1 Air test

An air test is done when there is danger of freezing the tube. The air test is done by opening all the supply and return valves and isolating the manifold from the primary and secondary piping.

The air pressure shall not exceed 100 psig (7 bar) under normal weather temperatures up to 100°F (38°C). Normal pressure tests are accomplished at 1-1/2 times the normal working pressure for a duration of two hours. The gauge pressure should not fluctuate more than 5 psig (.35 bar) over this period except for cases of 10-20°F (6-11°C) temperature change. Always check the manifold for air leaks with gas detection fluid or soapy water.

Isolate test connection leaks from the system during the hold period. Once the test is complete, fill out the initial pressure test report. This report is part of the warranty report. Leave all the test equipment attached for the thermal mass installation. Make a note that the system will require a water purge prior to fill.

Always isolate the RFH system pressure test from the boiler plant or any other complimentary system.

Fig. 5.20:
Pressure tests.

5.4.2 Water test

The water purge and fill procedure must take place prior to a water test of the RFH system. Take the following steps to purge the system.

a) Verify that all supply and return valves for each circuit are shut.

b) Verify that isolation valves for manifold supply and return headers are shut.

c) Connect water source to lowest manifold component and purge from the highest.

d) Working from one side of the manifold to the other, open one circuit supply and return isolation valve until the circuit is filled with water and all air is removed. Close the supply and return isolation valve and proceed to the next circuit. Do this procedure in turn until all circuits have been filled and purged.

To perform the initial pressure test for the manifold and circuits with water, the following steps shall be taken:

a) Keep the header isolation valves for the supply and return shut.

b) Connect the test pump or use standard municipal water pressure (if sufficient pressure is available) at the manifold through an isolation valve to pressurize the system.

c) Open all circuit supply and return valves.

d) Purge any remaining air.

e) Pressurize to 1-1/2 times working pressure and hold for 2 hours.

f) Inspect for pressure change at gauge. Any pressure change over 5 psig (.35 bar) will require hand-over-hand inspection of circuits for leakage. Changes in ambient temperature or test connection leakage should also be noted. Always remember to check for fitting leaks.

g) Complete the test report for the warranty report.

The water test can also be performed with antifreeze mixed into the water. Be sure to check with the designer of the system.

5.5 Thermal mass installation

The potential always exists during the installation of the thermal mass that the tube could be cut or pinholed by the installer of the thermal mass.

Maintain test pressure on the tube and look for pressure drop on the gauge. REHAU considers this step the responsibility of the tube installer, not the thermal mass installer (unless of course they are the same). After the thermal mass is installed, complete the inspection report. This report is part of the warranty.

Fig. 5.21:
Tube is pressurized during thermal mass installation.

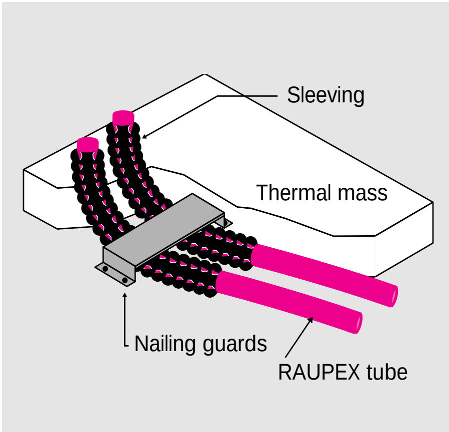


Fig. 5.22:
Install nail guard plates where nailing is likely.

Fig. 5.23:
Protection sleeves at slab penetrations.

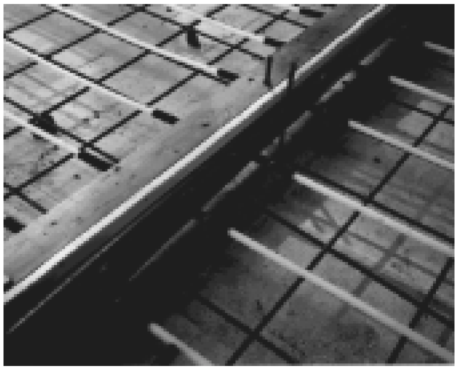


Fig. 5.24:
Protection sleeves at construction joints.

Fig. 5.25:
The design will have specified how many turns each valve will require to balance each circuit.

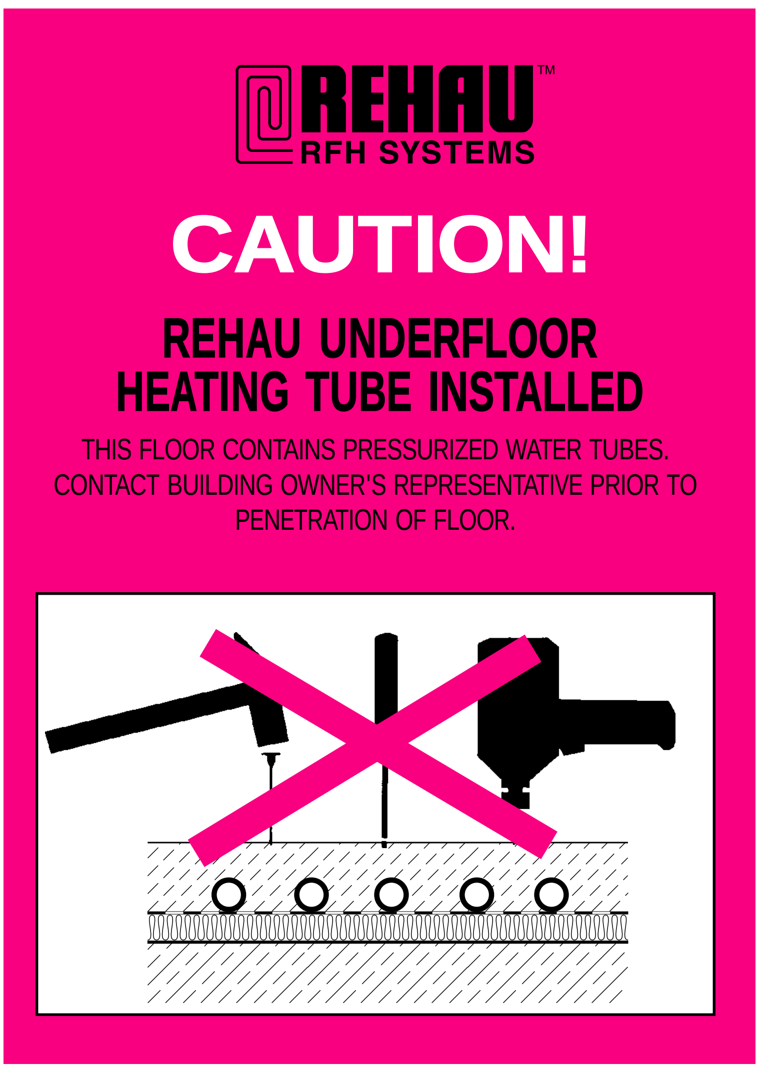


Fig. 5.26:
Mount this notice where it will be seen.

5.6 Start-up, balance and close-out
Thermal masses composed of concrete materials shall be cured for 28 days prior to system start-up. Gypsum-based thermal masses have different requirements. Consult the supplier to verify cure time.

Starting up the heat source and then distributing hot water to each zone and subsequently each circuit brings the entire floor heating system on-line. It is best to warm the thermal mass up slowly during start-up to help prevent possible shock to the slab. Warm-up periods could take as many as 10 days.

Once the system is on-line, all the balancing valves are to be adjusted as directed by the design plan.

It is always best to set the balancing valves from data derived from engineering tables. Finding the correct balance by trial and error is very difficult.

Provide the building owner or maintenance staff with training on their radiant floor heating system to minimize callbacks. Complete the RFH Systems "Project Start-up & Site Inspection Report" form and the warranty.

REHAU provides a label to be mounted at each manifold location and electrical circuit box as notification that floor heating tube is installed.

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