RATHE ASSOCIATES

EXPECT MORE & GET IT.

RADIANT HEATING SYSTEMS

COMPLETE DESIGN & INSTALLATION GUIDE

Advantages & Description of Radiant Heat

Introduction

Various forms of radiant heat have been enjoyed for centuries; it is the oldest form of central heating known to mankind. From ancient Roman baths to modern environmentally compliant buildings, radiant heating delivers flexibility and comfort. Radiant heating systems can vary from floor warming to space heating to snow melting - and from residences and classrooms to hospitals and convention centers. Despite differences in their size and complexity, radiant systems all share the same basic principles and provide the same unique benefits.

What is Radiant Heat?

Radiant heat is a form of energy that travels through space (air for instance) from a warmer object to a cooler one. Radiant heat is easy to recognize if one considers how the sun heats the earth. The sun (3,000,000˚ F avg.), being warmer than the earth (61˚ F avg.), radiates its energy towards the earth and yet the temperature of the interplanetary space between them averages -454˚ F. Why? The energy wave that radiates from sun to earth "heats" objects only, the earth in this instance. The radiant waves are absorbed by the earth and released as heat. Need an example?

Remember the last time you walked outside on a cool fall day? As you passed from an area of shade to one of sunshine, did you feel the warmth of the sun's radiant heat?

Think about it. There was no change in the air temperature from shade to sunshine; however you felt many degrees warmer because you were a direct recipient of the sun's radiant energy.

How to use it:

Radiant heating systems provide the same unseen comfort as the sun. By installing flexible Comfort-PEX® tubing just below or behind the surface of a floor, wall or ceiling and circulating heated water through the tube (typically 100-120˚ F), warmed surfaces heat the objects in the room - including the occupants.

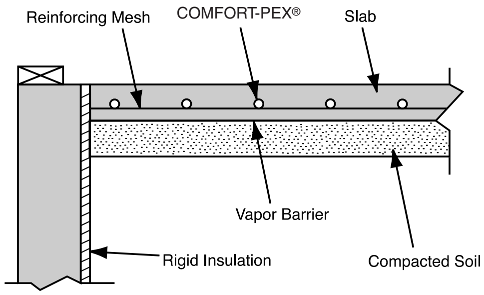
As you learn more about radiant heat design and installation in this workbook, industry developed standards and best practices will be explained. You will learn appropriate calculations, component selection and overall system design. The knowledge gained will translate to a comfortable and efficient system - leading to years of trouble free operation.

Key advantages of Radiant Heat:

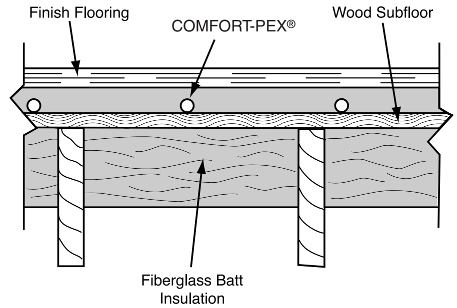
To better understand radiant heat, it is useful to recognize the differences between a radiant system and other forms of heating. The distinct advantages radiant heat offers to designers, owners and occupants can be more easily explained and valued by comparison to traditional space heating methods, such as hydronic fin-tube and forced hot-air systems.

- Radiant systems heat objects not air. As a result, little temperature stratification occurs in a room regardless of ceiling height.
- Your body feels comfortable at lower air temperatures. Comfort with radiant heat is achieved at a 67-68˚ F thermostat setting.
- A radiant system mimics your body's comfort profile, warm at your feet and cool at your head.
- Natural humidity levels are maintained using radiant heat, eliminating the dryness associated with heated air currents.
- Reduced air movement minimizes dust circulation and drafts, resulting in a cleaner and more healthful environment.
- Lower ceiling temperatures, reduced drafts and lower thermostat settings allow radiant heating systems to operate with savings as high as 50% over forced hot air and 30% over fin-tube baseboard systems.
- With no visible source of heat - there is nothing to distract from a rooms appearance.
- And with no fin-tube baseboard or forced air registers to consider, radiant heat provides complete freedom of interior design.

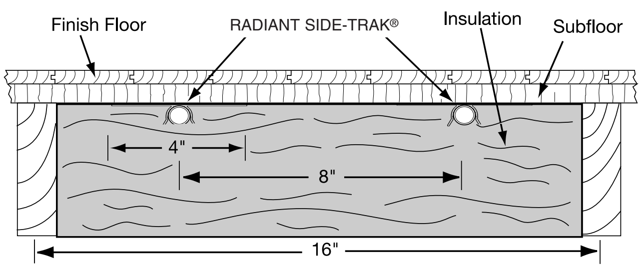
CUT-AWAY OF TYPICAL FLOOR CONSTRUCTION



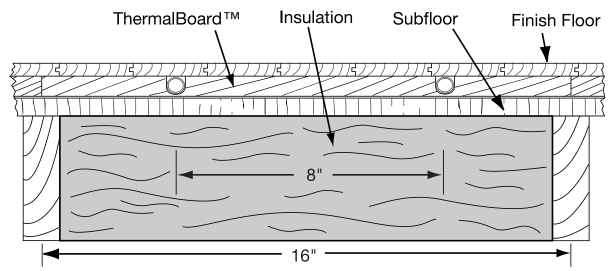
Radiant Floor Heating (slab-on-grade)



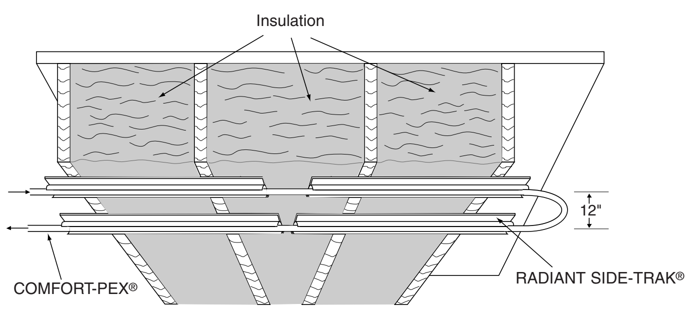
Radiant Floor Heating (suspended slab)



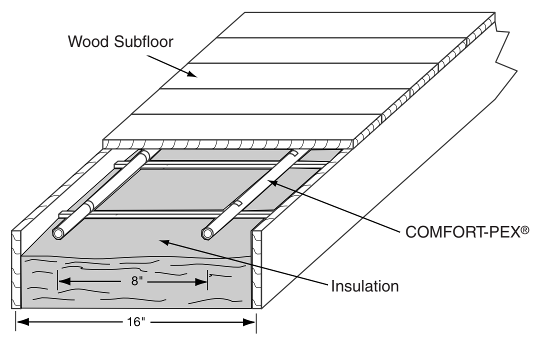
Radiant Side-Trak® Floor Heating (below subfloor)



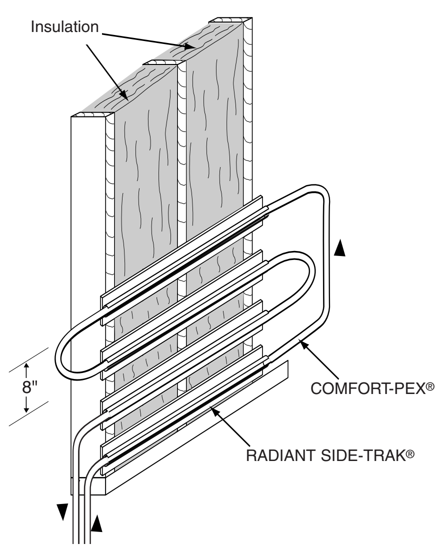
ThermalBoard™ Floor Heating (above subfloor)



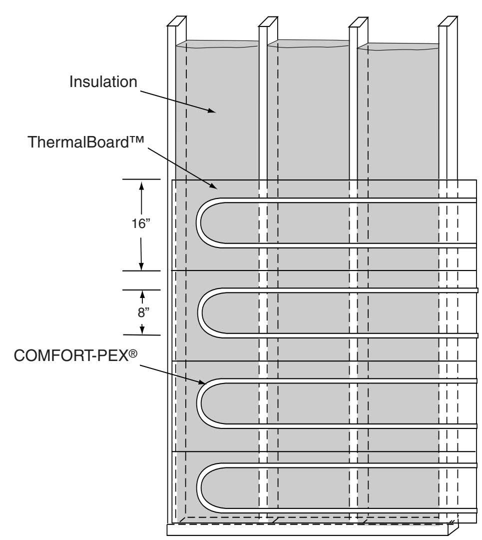
Radiant Side-Trak® Ceiling Heating



Joist Heating (floors/walls/ceilings)



Radiant Side-Trak® Wall Heating



ThermalBoard™ Wall Heating

General Guidelines

The purpose of this manual is to familiarize contractors, architects and engineers with Rathe Associates' recommended methods for the design and installation of our heating products.

Regulatory Codes

Comfort-PEX® systems should be installed by a hydronic heating technician after reviewing all applicable building codes. Any conflicts with the codes must be resolved before installation begins. Comfort-PEX® tubing is manufactured to ASTM F876 / F877 • CSA b137.5 • DIN 4726 / 4729 - Standard Specification for Cross-Linked Polyethylene (PEX) Tubing and is NSF 61 listed.

About Comfort-PEX® Tubing

Comfort-PEX® is cross-linked polyethylene tubing with an oxygen diffusion barrier. PEX is an acronym for cross-linked polyethylene. Molecular chains are linked into a three dimensional network that makes PEX remarkably durable within a wide range of temperatures and pressures.

Comfort-PEX® pressure/temperature ratings are issued by the Hydrostatic Stress Board of the Plastic Pipe Institute (PPI):

80 psi @ 200° F.
100 psi @ 180° F.
160 psi @ 73.4° F.

Oxygen Diffusion Barrier

Comfort-PEX® is sealed with a special polymer barrier (EVOH coating) to prevent oxygen diffusion and to protect the corrodible components of a closed loop hydronic heating system. This barrier meets the requirements of DIN 4726 / 4729 for oxygen diffusion prevention, as endorsed by the Hydronics Institute. Comfort-PEX® barrier is not affected by water temperatures up to 200° F.

Comfort-PEX® is available in the following dimensions and lengths:

3/8" nominal inside diameter (1/2" O.D.)
Standard coil lengths: 300', 1000'

1/2" nominal inside diameter (5/8" O.D.)
Standard coil lengths: 300', 600', 1000'
Standard straight lengths: 20'

5/8" nominal inside diameter (3/4" O.D.)
Standard coil lengths: 400', 1000'

3/4" nominal inside diameter (7/8" O.D.)
Standard coil lengths: 300', 500'
Standard straight lengths: 20'

1" nominal inside diameter (1-1/8" O.D.)
Standard coil lengths: 100', 500'
Standard straight lengths: 20'

Working With Comfort-PEX®

The following methods are recommended to simplify installation and help the installer avoid mistakes that might damage the product or compromise the installation.

Storage

Comfort-PEX® must be stored minimizing extended exposure to direct sunlight (diffused light is not harmful). Ultraviolet light can cause accelerated aging. Never install Comfort-PEX® if it has been exposed to direct sunlight for more than 30 days. Exposure to sunlight during normal installation is not harmful.

Bending Comfort-PEX®

Comfort-PEX® is a flexible and easily installed tubing product. However, bends less than 9" should be made slowly and carefully to avoid kinking. Bend supports are available and should be used when a 90° bend is required. For example, when the tubing leaves the floor and makes a 90° bend into a wall.

Minimum Bend Radius	
3/8" tubing	3"
1/2" tubing	4"
5/8" tubing	5"
3/4" tubing	6"
1" tubing	7"

Comfort-PEX® can be installed with closer center on center spacing by allowing for wider turn widths to accommodate the minimum bending radius.

Cutting Comfort-PEX®

It is important that when the tubing is cut, damage does not occur that would adversely affect the fitting connection. A Comfort-PEX® tubing cutter should be used for this purpose. Comfort-PEX® should be square cut perpendicular to the length of the tubing. No excess material should remain that might affect the fitting connection.

Fastening Comfort-PEX®

The following methods can be used for fastening:

1) Hand held stapler kit: Designed to fasten tubing to wood surfaces. Includes the hand held manual or the hand held pneumatic type stapler along with 3/8", 1/2", 5/8" or 3/4" tubing size plastic "U" shaped staples (packaged 100 per box).
   * Spacing of staples is every 2 to 2-1/2 feet. To calculate the quantity of boxes required take the total length of pipe and divide by 2, then divide that number by 100 (round to the nearest box).
2) Plastic U-nails: 3/8" through 1" for Comfort-PEX®. Spacing of U-nails is every 2 to 2-1/2 feet. To calculate the quantity of bags (packaged 50 per bag) required take the total length of pipe and divide by 2, then divide that number by 50 (round to the nearest bag).
   EXAMPLE: 2000 feet of tubing divided by 2 feet = 1000 of u-nails divided by 50 = 20 bags of U-nails.
3) Plastic Ties: For attaching tubing to reinforcing wire. To calculate the quantity of bags (packaged 100 per bag) required take the total length of tubing and divide by 250. Round up to the nearest whole bag.
   EXAMPLE: 3400 feet of tubing divided by 250 = 13.6 = 14 bags.
4) Pipe-Trak: 4 feet in length and secures 3/8", 1/2" & 5/8" Comfort-PEX® tubing to level surfaces such as existing concrete floors, walls, ceilings, etc. Pipe-Traks are spaced every 3 to 4 feet. To calculate the quantity of Pipe-Trak required divide the net square footage by 3 and then divide that number by 4. Round up to a whole Pipe-Trak.
   EXAMPLE: 1000 square feet floor area divided by 3 = 333 divided by 4 = 84 pcs. of Pipe-Trak.
5) Wire Mesh Clips: Can be attached directly onto wire mesh. Tubing can then be snapped into the clip, spaced every 2 to 2-1/2 feet.
6) Screw Clip: Can be screwed into rigid foam products. Tubing can then be snapped into the screw clip. Wire Mesh clips and Screw clips are calculated identically to plastic U-nails and should be spaced every 2 to 2-1/2 feet.

Comfort-PEX® Fittings

We recommend compression type fittings made of brass. A wide variety of fittings and adapters are available for the coupling of PEX tubing, manifold connection, or transitions to copper or NPT pipe.

Protect Comfort-PEX® from Freezing

Comfort-PEX® not buried in concrete is highly tolerant to freeze conditions. However, precautions must be taken to avoid freezing the tubing when embedded in concrete. If pressure testing with water, do not allow the water to freeze.

Comfort-PEX® Handling Precautions

Do not:

- use adhesive tapes on tubing
- apply an open flame to the tubing
- solder within 18" of tubing connection
- install tubing where it will come in direct contact with petroleum products such as fuels or solvents
- weld or glue tubing
- install within 12" of any recessed light fixture

Heat Loss Calculations

Introduction

The initial step in any heating system design is to determine the heating requirements (heat loss) of each individual room or area. An accurate heat loss calculation is required to assure that the maximum energy efficiency and comfort level of a specific system are achieved.

Conventional heat loss calculation (e.g. I=B=R) may be used for radiant heating design; however they will typically result in system "oversizing". Radiant heating systems provide for increased comfort while requiring on average 30% less energy than conventional systems.

This is a result of the basic principals and advantages of radiant heat discussed earlier. Conservatively, at least a 15% reduction may be taken when using conventional heat loss calculation methods.

The following BTU calculation form may also be used to determine room by room heating requirements.

BTU CALCULATION FORM
(SHORT FORM)

The following short form calculation may be used to compute the room by room heating requirements of an average home. The factors used in these calculations assume certain general construction practices, site conditions and a 70°F. desired indoor temperature. Choose the factors which best correspond to your construction conditions and average seasonal low temperature.

	FACTOR @ °F. (Average Seasonal Low Temperature)					
	-20°	-10°	0°	10°	20°	
CEILING*						
A. R-11 Insulation	9	8	7	6	5	
B. R-19 Insulation	6	5	4	3	2.6	______ FACTOR X ______ SQ. FT. = ______ BTU/HR
C. R-30 Insulation	3.5	3	2.5	2	1.8	
D. R-38 Insulation	3	2.5	2	1.8	1.5	
E. Heated Space Above	0	0	0	0	0	
WALLS*						
A. R-11 Insulation	9	8	7	6	5	______ FACTOR X ______SQ. FT. = ______BTU/HR
B. R-19 Insulation	6	5	4	3	2.6	
C. Interior	0	0	0	0	0	
FLOOR						
A. Uninsulated Wood Frame Over Crawl Space	21	18	15	12	10	
B. R-11 Insulation Over Crawl Space	9	8	7	6	5	
C. R-19 Insulation Over Crawl Space	6	5	4	3	2.6	
D. R-30 Insulation Over Crawl Space	3.5	3	2.5	2	1.8	
E. Uninsulated Wood Frame Over Unheated Cellar	9	8	7	6	5	
F. R-11 Insulation Over Cellar	5	4	3	2.5	2.3	______ FACTOR X ______ SQ. FT. = ______ BTU/HR
G. R-19 Insulation Over Cellar	3	2.5	2	1.5	1.3	
H. R-30 Insulation Over Cellar	2	1.5	1	.88	.83	
I. Uninsulated Slab on Grade	15	13	11.5	10	8.5	
J. R-10 Insulated Slab on Grade	4.5	4	3.5	3	2.5	
K. Heated Space Below	0	0	0	0	0	
WINDOWS/SKYLIGHTS						
A. Single Glazed	90	80	70	60	50	
B. Single Glazed With Storm	45	40	35	30	25	______ FACTOR X ______ SQ. FT. = ______ BTU/HR
C. Double Glazed	45	40	35	30	25	
D. Double Glazed (Low-E)	36	32	28	24	20	
EXTERIOR DOORS						
A. 2" Wood	40	35	30	26	22	
B. 1.75" Steel With Insulated Core	40	35	30	26	22	______ FACTOR X ______SQ. FT. = ______BTU/HR
INFILTRATION						
(Note: Cubic Footage is Used For This Calculation)						
A. Room With One Exterior Wall	.74	.66	.57	.49	.41	
B. Room With Two Exterior Walls	1.1	1	.88	.75	.63	
C. Room With Three Exterior Walls	1.6	1.4	1.2	1.05	.86	______ FACTOR X ____ CUBIC FT. = ______ BTU/HR
D. Bathroom	1.6	1.4	1.2	1.05	.8	
						Total Heat Loss ______ BTU/HR

*The square footage used for wall and ceiling calculations is minus all windows, doors and skylights.
Due to the many variables involved in calculating a heat loss this form should be used as a guide and does not guarantee that an accurate heat loss calculation will result.

Hydronic Design
(Slab-on-Grade/Suspended Slab Applications)

Introduction

Hydronic radiant floor heating uses the large surface area of a floor as a low temperature radiator. By circulating heated water through Comfort-PEX® tubing, which is installed below the floor surface, a uniform level of heat is provided to the room or building. With the gentle warming of the floor, the system creates a near perfect heat profile, warm at the feet where body temperature is lowest and temperate at head level where body heat is highest.

The following guidelines provide an overview of the important steps in the proper design and layout of a radiant heating system. A well designed system will not only simplify installation, but will also assure maximum energy savings and comfort levels. Our support staff is available to assist you with any aspect of your system design or installation.

Step 1 Determining Your Heating Requirements

The area heating requirements must be determined using a radiant design calculation or adjusted conventional heat loss calculation. Rathe Associates' support staff can assist you in determining your heating requirements.

Step 2 Required Heat Output

The heat loss of any given area must be replaced with the heat output provided by the radiant source (floor). It is important that only "open" floor area (Net Area) be utilized in determining the Required Heat Output. The Net Area is established by subtracting from the total square footage all cabinets, fixtures, etc.

$$\text{Required Heat Output} = \frac{\text{Heat Loss}}{\text{Net Area}}$$

Step 3 Comfort-PEX® Selection and Spacing

Most residential and light commercial systems are designed with 1/2" Comfort-PEX®. However, certain applications may warrant the use of 3/8" or 5/8" tubing. Likewise, large commercial and snow melting applications may warrant the use of 3/4" or 1" tubing. In general, design applications or considerations not specifically covered in this manual should be discussed with our support staff for proper tube sizing.

Tube spacing in a radiant floor heating installation directly affects the heat output, required supply water temperature and occupant comfort in the area. *Table A* shows the recommended pipe spacing for a variety of residential and commercial applications.

TABLE A Pipe Spacing

	Recommended Spacing		
Area	**3/8"**	**1/2"**	**5/8"**
Baths/Kitchens/Foyers	6"	6"- 9"	NR
Living/Dining/Bedrooms	6"- 9"	9"-12"	NR
Offices/Showrooms/Classrooms	NR	9"-12"	12'
Basements/Garages/Warehouses	NR	12"-15"	12"-15"

Increasing the tube spacing beyond these recommendations will in most cases still produce the required heat output with the use of a higher supply water temperature. While this can provide the benefit of reduced material requirements and system cost, occupant comfort may suffer as floor surface temperatures become uneven.

Step 4 Supply Water and Surface Temperatures

Using the *Radiant Heat Output Chart* the system Supply Water Temperature and Surface Temperature can now be determined.

1. Find the Required Heat Output (heat loss/net area) on the left side of the chart and read across to the right to determine the Surface Temperature.
2. Calculate the Total R-Value of your floor (*See R-Value Chart on page 40*) and extend a line up from this to a point at which it intersects your first line. Read the required Supply Water Temperature at the point of intersection.
3. If the Supply Water Temperature is above 160° F. or the Surface Temperature is above 85° F.:
   a. Check the heat loss calculations for accuracy. Have they been determined for radiant heat?
   b. Choose a flooring with a lower R-Value. (*See R-Value Chart on page 40*)
   c. Reduce the heat loss of the area (i.e. increased insulation, new windows).
   d. Add supplemental heating for area.

SLAB-ON-GRADE/SUSPENDED SLAB/SLAB BELOW GRADE

RADIANT HEAT OUTPUT CHART @ 20°F. △T

Supply Water Temperature (degrees F.)

REQUIRED HEAT OUTPUT (BTUs/Sq. Ft.)	Spacing (in.)	.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	SURFACE TEMPERATURE (degrees F.)
	15	138	165							
45	12	131	154							90
	9	125	146							
	6	120	140	160						
	15	132	155	179						
40	12	125	145	168						87
	9	119	136	159						
	6	114	131	152						
	15	125	143	164						
35	12	118	135	155						85
	9	112	129	148	165					
	6	108	123	141	158					
	15	117	131	149	166					
30	12	110	125	142	157					83
	9	105	120	136	151	167				
	6	102	115	130	145	160				
	15	109	121	136	149	163				
25	12	103	116	130	142	156				81
	9	99	112	125	137	150	163			
	6	95	108	120	133	145	157			
	15	101	110	121	132	143	155	168		
20	12	95	105	115	126	137	149	160		78
	9	92	102	112	123	134	144	154	164	
	6	90	100	110	120	130	140	149	159	
	15	93	100	108	116	125	134	145	156	
15	12	88	95	103	111	120	128	136	146	76
	9	86	93	101	109	117	125	132	141	
	6	85	92	100	107	115	123	128	137	
	15	87	91	95	101	109	116	125	134	
10	12	83	87	91	97	104	111	119	125	73
	9	81	85	89	95	102	108	114	120	
	6	80	83	87	93	100	105	108	114	
	15	82	84	88	91	95	99	105	110	
	12	78	80	84	87	90	94	99	103	70
5	9	76	78	82	85	88	91	94	97	
	6	75	77	80	83	85	87	89	91	

TOTAL R-VALUE

Step 5 Comfort-PEX® Tubing and Loop Requirements

Table C provides the maximum recommended individual radiant floor loop lengths for Comfort-PEX® tubing.

Table C Maximum Loop Lengths

Comfort-PEX®	Maximum Length
3/8"	200 ft.
1/2"	300 ft.
5/8"	400 ft.
3/4"	500 ft.
1"	800 ft.

Loop lengths in excess of those recommended may result in uneven or improper heat outputs and return water temperatures below acceptable design parameters.

1/2" Comfort-PEX® is available in 300, 600 and 1000 ft. coil lengths and 20 ft. straight lengths. For installations that will require more than one loop, the use of longer coils will offer greater design versatility. Commonly, a 600 ft. coil will be cut in half for two 300 ft. loops.

To determine the Comfort-PEX® requirements multiply the Net Area by the spacing factor shown in *Table D* for your planned tubing spacing. Next, measure or estimate the distance from this room to the manifold or boiler location. This distance should be multiplied by two, to account for both the supply and return run, and added to the room requirements. In general, if the distance to

Table D Spacing Factors

Tubing Spacing	Spacing Factor
6"	2
9"	1.33
12"	1
15"	0.80

the boiler location is greater than 50 ft. a remote manifold location should be established in order to minimize the tubing and loop requirements.

Example:

A 10 ft. x 10 ft. kitchen with 35 sq. ft. of cabinets would have a Net Area of 65 sq. ft. With 9" tubing spacing 87 ft. of tubing would be necessary in the room (65 x 1.33 = 86.5). The kitchen is 25 ft. from the boiler bringing the total Comfort-PEX® tubing requirements to 137 ft. (25 ft. x 2 + 87 ft. = 137 ft.).

For larger areas that require more than one loop calculate the combined supply and return run distance to the area and subtract this from the desired loop lengths. Divide this number into the room tubing requirements to determine the total number of loops. Unless the exact manifold location is known plan on including a 5-10 ft. tail on both the supply and return piping to the general manifold area. Finally, using the available coil lengths (for 1/2" tubing - 300', 600' or 1000') choose a combination of loops that will best fulfill your total tubing requirements. To simplify system balancing all loops in a multi-loop area should be kept as close in length as possible.

Step 6 Flow Rate and Pressure Drops

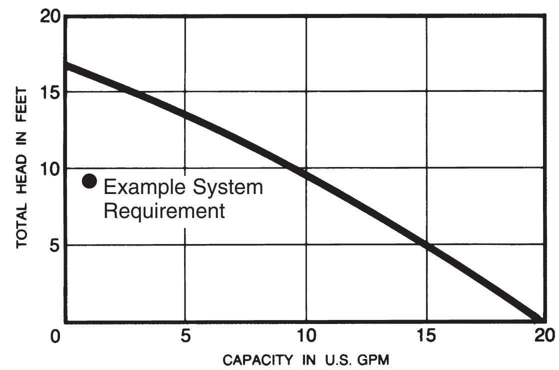
Typically, a 1/2" Comfort-PEX® radiant floor heating loop design which adheres to the pipe spacing, water temperature and loop limitations outlined in the previous steps will require approximately 8 feet of head at a 0.7 GPM flow. An Armstrong ASTRO 30-3 circulator or equivalent will handle many typically sized projects.

For systems requiring high heat outputs, numerous long loops or unconventional design the flow rate and feet of head requirements should be calculated as follows:

First, calculate the system flow rate by dividing the total BTU/hr output by 500 times the design ΔT (supply/return differential temp.), of the system. A design ΔT of 20° F. is considered optimum.

$$\text{Flow Rate} = \frac{\text{BTU/hr output}}{(500) \times (20)} \text{ GPM}$$

Next, with the same formula as above calculate the flow rate of the longest (highest heat output) single radiant loop. The pressure drop, in feet of head (FOH), can now be determined using Appendix B.



In order to properly size the circulator choose one that can produce the total system flow (GPM) while maintaining the highest single loop head pressure (FOH).

Design Example:

The calculated radiant heat loss for a given room is 7,500 Btuh. The room size is 220 square foot with an insulated plywood subfloor, 1-1/2" concrete and natural stone finish flooring.

The radiant floor design will utilize 1/2" Comfort-PEX® tubing (recommended residential pipe size) installed with 9" c-c (center to center) pipe spacing (recommended living area spacing).

Step 1

The total amount of 1/2" Comfort-PEX® tubing required for this room can be determined by multiplying square footage x the pipe spacing factor found in *Table D*. (220 x 1.33 = 292.6 ft. of pipe)

In this example the boiler connection is immediately below the room and will require only a minimal amount of piping for supply and return to the room above. A 300 ft. loop is determined to be sufficient.

*Note: it is extremely important to correctly estimate and include the required supply and return lengths to the boiler or manifold location to assure sufficient pipe.

Step 2

Dividing 7,500 by 220 will provide the btuh/sq. ft. output required to satisfactorily compensate for the calculated heat loss. btuh/sq. ft. = 34.

$$\frac{\text{heat loss}}{\text{net area}} = \text{required heat output (btuh/sq. ft.)}$$

Step 3

Using the R-Value table found in *Appendix-A* determine the R-Value of 3/4" natural stone. R = 0.9

Step 4

Now, knowing the required btuh/sq. ft. output and the R-Value of the floor covering we can use the Radiant Heat Output Chart (pg. 9) to determine the necessary water temperature and resulting floor surface temperature. Follow the 1.0 R-Value column up until it intersects with 34 (use 35) btuh/sq. ft. the necessary water temperature can be read for 9" c-c spacing (129° F.). Follow the row across to the right to establish the resulting floor surface temperature of this system (85° F.). At this point we can determine if the required water temperature and surface temperature are acceptable. In this example the answer is, yes.

Step 5

To determine the Pressure Drop (FOH) and Flow Rate (GPM) we use the formula:

$$FR = \frac{\text{BTUH/hr output}}{(500) \times \triangle T} \text{ GPM}$$

$$FR = \frac{7500}{500 \times 20} = .75 \text{ GPM}$$

Appendix B can be used to determine the Pressure Drop of this loop. Find the approximate point of intersection of .75 GPM and 1/2" Comfort-PEX® @ 129° F. The resulting Pressure Drop is 0.0201 FOH/ft. (determined by taking the average Pressure Drop shown for 120° F. and 140° F.) Since our loop is 300 ft. in length we must multiply .0201 x 300 to get the Pressure Drop for a 300 ft. loop (6.03 FOH). The circulator choice must be capable of compensating for 6.03 FOH @ .75 GPM. The Armstrong ASTRO 30-3 satisfactorily handles these requirements.

Design Determinations:

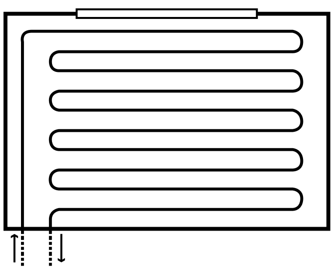
Loop length = 300 ft.
Tubing Spacing = 9" center to center
Btuh/sq. ft. req. = 34
Water Temp. = 129° F.
Surface Temp. = 85° F.
Loop Pressure Drop = 6.03 FOH
Loop Flow Req. = .75 GPM
Flow Rate = .75 GPM

TUBING LAYOUTS

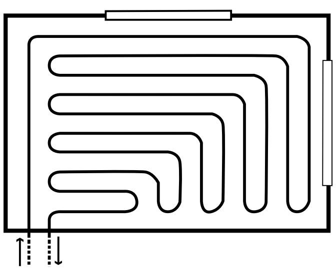
Radiant floor tubing layouts are based on two operational considerations that must be effectively balanced. These are the desire to maintain a relatively even surface temperature throughout the area while also providing for the increased output required along exterior surfaces. Layout patterns may be either single, double or triple serpentine or counter-flow spiral. Serpentine patterns allow for the hottest water to border the exterior perimeter (highest heat loss areas). Counter-flow patterns differ from serpentine in that the supply and return pipes are laid out next to each other creating an average temperature between them. Counter-flow is best suited when there is no specific area of highest heat loss or where an even floor surface temperature is critical. In general, if an area requires more than one loop it is common to utilize more than one layout pattern.

In areas of specific high heat loss, such as a patio door, perimeter bands of more closely spaced tubing are frequently used. Perimeter bands should be spaced 3" closer than that planned and continue for a width equal to 50% of the height of the heat loss exposure (patio door).

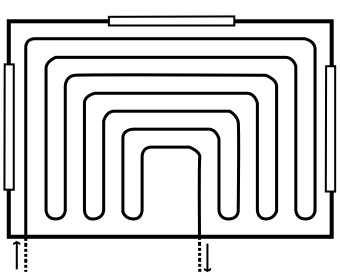
Single Serpentine



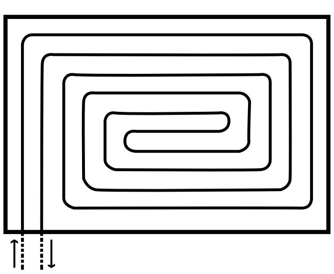
Double Serpentine



Triple Serpentine



Counterflow



INSTALLING THE TUBING

Tubing Depth

The absolute minimum concrete thickness for a radiant floor heating system is as follows:

Tubing Size	Slab Thickness (min.)
3/8" Comfort-PEX®	1-1/4"
1/2" Comfort-PEX®	1-1/4"
5/8" Comfort-PEX®	1-1/2"
3/4" Comfort-PEX®	2"

As most slabs on grade will be considerably thicker, these minimums generally concern suspended floor applications.

For thicker slabs the optimum depth of bury is usually 2" - 3" in order to provide effective thermal dispersion and response while maintaining the slab integrity. Deeper placement will in most instances still provide a highly successful system. However, an increased supply water temperature and decreased response time can be expected. The use of both perimeter and below slab insulation is recommended when deeper pipe placement is utilized. Structurally permitting, a slab may also be split into two pours with an inch or two of rigid insulation placed between. In split slab applications, and ideally in all slabs, fiberglass strands should be added to the concrete to provide additional crack resistance.

Tubing depth in a slab on grade application is maintained by securing the tubing to wire reinforcing mesh or rebar. The mesh may then be supported at the desired height with chairs, bricks or pulled in place at the time of the pour by the masonry contractor. Care should be taken to assure that a uniform tubing depth is maintained, as variations in depth can result in uneven surface temperatures.

Securing The Tubing

For slab on grade applications Comfort-PEX® tubing should be secured to wire reinforcing mesh/rebar with plastic installation ties. Tubing installation for a suspended slab, over a wooden subfloor, should be with plastic u-nail fasteners or a Comfort-PEX® hand-held stapler. For applications using wire-mesh, Wire-Ties and u-nails should be placed every 24" - 30" with additional placement at bends or where the tubing is visibly raised.

Another method is to use Pipe-Trak plastic mounting tracks secured to wood sub-floor. Pipe-Trak should be placed every 3-4 ft.

Also, if a radiant floor installation requires a secondary slab to be installed over an existing one, Pipe-Trak plastic mounting tracks may be utilized. Again, Pipe-Trak should be spaced every 3-4 ft. allowing for 3/8", 1/2" & 5/8" Comfort-PEX® to be snapped in and secured.

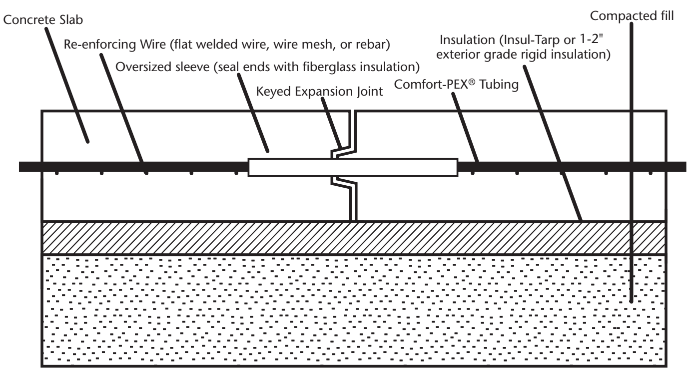
*NOTE: an **absolute** minimum of 1-1/4" slab is required when using Pipe-Trak in a "slab on slab" application.*

Expansion Joints and Slab Penetrations

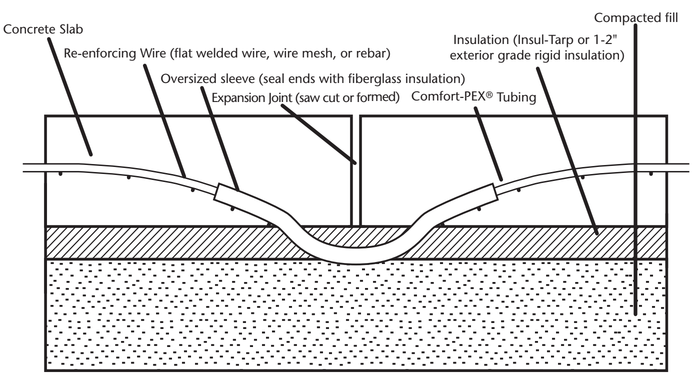
Concrete pours will often require "control" or "expansion joints" to compensate for settling, shifting and thermal expansion and contraction of the slab over time. Control joints are typically cut into the concrete to a specified depth which will allow the slab to relieve internal stress that would otherwise show through random cracks. Expansion joints are installed prior to a pour and provide a complete physical separation of individual slabs. If possible, a Comfort-PEX® tubing layout should be established that will minimize repeated tubing passes through joints.

Whenever Comfort-PEX® tubing does pass through a control joint, care must be taken to protect both. With either type of joint a sleeve of rigid pipe material (PVC) or foam insulation must be used. The sleeve can be spaced deep within the slab to ensure it is below the cut depth of the control joint or dipped below the joint and buried in the subsoil. Sleeves should be a minimum of 12" long and be equally spaced in or below the joint.

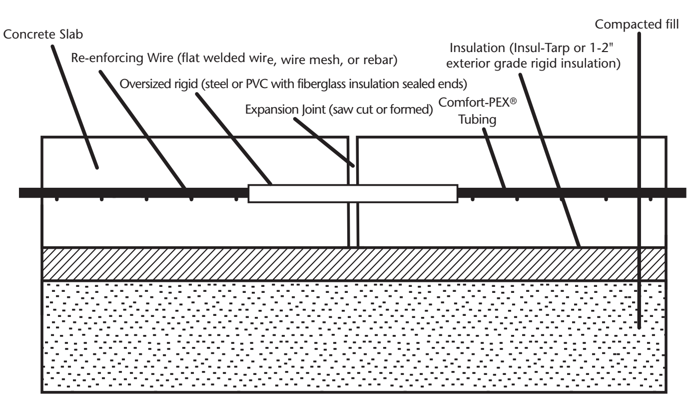
Comfort-PEX® tubing must also be sleeved for protection at all other slab penetrations such as initial entry and exit of the radiant loops.



Tubing sleeved through keyed expansion joint.



Tubing sleeved below slab. In slab on grade.



Tubing sleeved with steel, PVC, or foam for additional protection.

Bend Supports

Bend supports are available for all Comfort-PEX® tubing sizes and allow for a 90° bend to be maintained without fear of kinking. These supports will commonly be used for entering or leaving a slab when the continuation of the tubing either up or down a wall is desired. Bend supports are not necessary for the actual tubing layout within the floor area.

Manifold Connections

After the completion of all radiant loop installations the manifold connections may be made. If it is not practical to permanently mount the manifold at this time it is recommended that the radiant tubing still be at least temporarily connected. This will allow for simplified pressure testing of the radiant loops and prevent any construction debris from inadvertently making its way into the tubing.

The compression fittings for Comfort-PEX® connection to the manifold headers are a three piece assembly consisting of tubing insert, split ring ferrule and compression nut. The compression nut is slid over the tubing first followed by the ferrule, the tubing insert is then pushed into the tubing end. When connecting the fitting assembly to the manifold header, be sure that the tubing is fully seated on the insert and that the insert is fully seated into the header. The ferrule and compression nut may now be slid down over the insert and the nut tightened onto the manifold.

SYSTEM TESTING AND START UP

Pressure Testing

All radiant loops should be air tested at 50 - 100 psi for a period of 24 hours before and after the slab is to be poured. Connecting all loops to a manifold enables the entire system to be easily pressurized at once. The supply and return piping from each loop may also be inter-connected using compression couplings creating a single loop for testing.

If the system fails to maintain pressure or if the tubing is punctured during the pour, the leak must be located and repaired. Repairs should be made with Comfort-PEX® compression couplings only and sleeved as to prevent the concrete from coming in direct contact with the fitting.

System Purging

A purge valve is located on the return header of the manifold. Each loop should be purged individually upon completion of the system installation. This may be accomplished by closing either all supply header balancing valves or all return header manual shut-offs and opening one zone at a time. After all visible air has been removed, close the loop and proceed to the next. If the optional thermostatic zone valves are to be used they should not be installed until after complete system purging.

NOTE: For system purging when a thermostatic mixing valve is being utilized, the boiler temperature should be dropped below 100° F. to assure sufficient flow through the valve and allow proper purging.

System Balancing

Balancing valves are provided on both Caleffi Brass and Hydro-Lock manifolds. The valves allow for individual loop flow to be adjusted in systems where loop lengths differ by more than 10%. Correct system balancing is achieved when all loop return temperatures are maintained at the highest equal level during full system operation.

The following steps should be followed to correctly balance a Hydro-Lock or Caleffi manifold.

Balancing of loops is accomplished through the built-in flow indicator valves in the return module.

1. Make sure manifold pump is operating.
2. Ensure all supply shut-off knobs are fully open.
3. The flow indicator is a red piston that moves up and down in response to water flowing through the individual loops.
4. Initially, the pistons will be at different levels while operating. This is okay and is a function of the different loop lengths. The shortest loops will receive the greatest flow and the longer loops less flow.
5. Begin by adjusting the highest pistons (greatest flow) until all pistons are at the same level. At this point all the loops are receiving the same flow rates.

Temperature Adjustment

A “well mounted” or “clamp-on” temperature gauge should be located on the supply piping adjacent to the manifold. Boiler or mixing valve output temperature may now be confirmed and adjusted to meet the design requirements. An additional (highly recommended) gauge may also be used on the return piping to monitor system temperature drop.

System Operation

With the completion of system purging, balancing and temperature adjustment, the thermostatic or reset control of the system can be initiated and normal operation established.

Installation Guide

SITE PREPARATION: SLAB ON GRADE

General

Soil must be compacted and leveled with special care taken to assure for proper drainage. A high soil moisture content can rapidly extract heat out of a radiant slab affecting the system output, efficiency and response time. As such, a plastic vapor barrier should be utilized below all radiant slab areas. In addition crushed stone placed on top of the compacted soil is an excellent drainage aid and is recommended for any below grade (basement) areas or those susceptible to water accumulation.

Insulation

Type: Insul-Tarp – 1/2" Thickness, R-10 Value, composite closed-cell foam, woven poly, 97% reflectivity, vapor & radon barrier
OR
Rigid Foam polystyrene/polyurethane (Minimum 1", recommended 2").

The proper insulation of a radiant slab will greatly increase the efficiency and responsiveness of the system. The how and where of performing this step should be based upon the required system design and the cost/benefit relationship of the insulation.

Perimeter Insulation

The perimeter of a radiant slab accounts for the majority of the slab heat loss. In fact, an un-insulated radiant slab operating at 80° F. with an outside temperature of 10° F. can lose as much as 150 BTU's/hr for each lineal foot of slab perimeter. It is recommended that with the relatively low cost and tremendous benefit of perimeter insulation that it be installed for all radiant slab applications.

Under Slab Insulation

As a radiant slab heats up it must also heat the soil beneath it. In many applications this will result in only a small decrease of efficiency and responsiveness. However, in colder climates or where ground water is a concern, complete under slab insulation is recommended. In addition, for applications installed over bedrock, clay or other high heat sink materials, a layer of crushed stone as well as under slab insulation may be critical for the proper operation of the system.

SITE PREPARATION: SUSPENDED SLAB

General

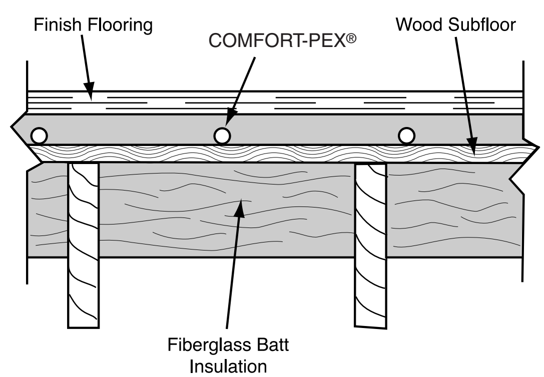
Suspended slabs will most commonly occur over wooden sub floors in upper level wood frame constructions. The sub floor should be structurally sound. A 1-1/2" thin slab with ceramic tile can weigh as much as 20 lbs. per sq. ft. This weight may exceed the recommended dead load of a given frame floor construction. A possible consequence of this is cracked tile or grout lines due to flexing of the floor joists. If this is a concern an architect or engineer should be consulted to determine acceptable floor loads.

A suitable vapor barrier (minimum 6 mil.) is required on top of the sub floor to prevent moisture from the concrete being absorbed into the wood. Expanded metal lath should be placed on top of the vapor barrier. Care should then be taken to not apply direct pressure (standing or kneeling) to the tubing.

Insulation

Type: Fiberglass Batt-kraft (paper) faced (minimum 5x the combined R-value above, recommended: fill entire joist cavity with insulation)

Suspended Slab with Fiberglass Batt Insulation

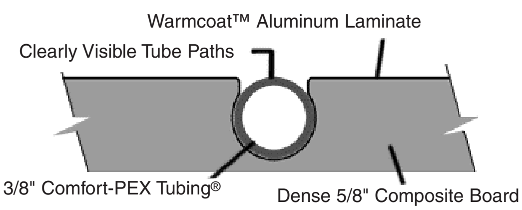


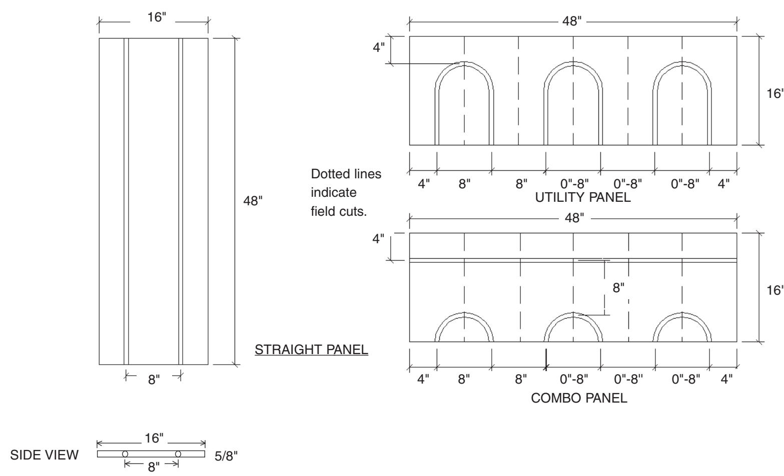
Suspended floor construction over an unheated basement or crawl space should always be insulated in order to minimize the heating requirements of the room above and maximize the efficiency of the radiant system. When installing over a heated area it is still recommended to insulate between floors to prevent downward heat transmission. In the absence of insulation, a radiant ceiling effect can occur causing overheating of the first floor while sacrificing the heat output to the second floor. Using a "foil-faced" insulation such as INSUL-Tarp Brand Double-Bubble, will greatly increase the upward reflected radiant heat and dramatically reduce the possibility of over-heating the area below.

ThermalBoard™

Above Sub-Floor

ThermalBoard™ is available in three modular Panel configurations: straight, utility and combo end piece. Once installed, ThermalBoard™ provides a continuous channel for 3/8" Comfort-PEX® tubing.





Material:	Engineered Wood	Weight:	13.3 lbs. per panel
Width (in.):	16"	Coating:	WarmCoat™ Aluminum Laminate
Length (in.):	48"	Packaging:	5 Panels per carton
Overall Height (in.):	5/8"	Pex Tubing Req.:	3/8" Comfort-PEX®

Storage: Store in a temperate, dry place (40° F - 90° F). Avoid prolonged exposure to sunlight. Do not store in a damp location.

Introduction

Hydronic radiant heating is the most comfortable and efficient way to heat your home or building with numerous construction benefits and unsurpassed flexibility in zoning. For many years, typical applications for radiant systems involved embedding tubing in concrete slabs or pouring “lightweight concrete” over tubing stapled to sub-floors. The ThermalBoard™ radiant floor heating system provides an attractive alternative to concrete with numerous advantages:

* 8" on center pipe spacing-perfect for most applications
* Only 5/8" thick
* Standard 3/8" Comfort-PEX® tubing
* Standard circulators
* Superior performing, high density thermal mass
* Excellent response time to heat up
* Even distribution of heat
* Easy layout and installation
* Lightweight - 5 times lighter than concrete
* Reduces need for structural upgrades
* Superb design and zoning flexibility
* Excellent compatibility with floor coverings

ThermalBoard™ is designed for fast, efficient installation over a variety of construction types. Although ThermalBoard™ is ideal in new construction; it is particularly advantageous in the retrofit market. Adding 5/8" to the existing floor height, and utilizing standard 3/8" Comfort-PEX® tubing, ThermalBoard™ provides a superior performing radiant heating system.

ThermalBoard™, How It Works

ThermalBoard™ is a dense engineered wood which is grooved to receive 3/8" Comfort-PEX® tubing and then laminated with a top layer of highly conductive aluminum called WarmCoat™. WarmCoat functions to efficiently transfer heat away from the groove to the surface of the board.

Traditional radiant heating systems in concrete work well but they must first warm a large thermal mass before heating the space. These systems accelerate slowly and can be difficult to control. ThermalBoard™, being thin but relatively dense and aided by its conductive aluminum layer, responds very rapidly. This results in greatly improved response time with almost no overheating since there is minimal "thermal lag" to overcome. ThermalBoard™ can be economically controlled with standard set back thermostats.

ThermalBoard™ System Design

ThermalBoard™ heating system design requires many of the same calculations and parameters of traditional radiant floor heating. The following Design and Installation information should be reviewed prior, to and referenced during, all ThermalBoard™ designs and installation.

Step 1 Determining Heating Requirements

As with all heating projects, a detailed and accurate heat loss calculation is critical and must be determined to establish proper design conditions. If the heat loss is too high, the insulation may be upgraded or supplemental heat added. In a high heat loss room ThermalBoard™ may be added to the walls or ceilings for extra heat.

NOTE: See *Heat Loss Calculations* or contact Rathe Associates support staff for assistance.

R-Value of Floor Coverings

Floor covering choices are also very important since they impact the system design and performance. While ThermalBoard™ will work with a wide variety of floor coverings, it is important to realize that all floor coverings offer a resistance to heat transfer as measured by their R-Value. The higher the R-Value of the floor covering the higher the water temperature it takes to overcome this resistance for a given heat output requirement. If the R-Value of the floor covering is greater than R3.0, heating system performance will be compromised due to lack of heat transfer and excessively high water temperatures (typically not to exceed 150° F).

NOTE: *R-Value Chart* (page 40) *and Appendix A: Floor Covering Material* (page 44) should be carefully reviewed.

Step 2 Required Heat Output

The heat loss established must be replaced by the output of the designed ThermalBoard™ heating system. Required Heat Output is stated in BtuH/ft². To calculate, use the net (open) floor area of the ThermalBoard system and the following formula.

$$\text{Required Heat Output} = \frac{\text{Heat Loss}}{\text{Net Area}}$$

Step 3 Comfort-PEX® Selection and Spacing

ThermalBoard™ has been designed to utilize efficient and cost effective 3/8" Comfort-PEX® tubing. All Panels provide a consistent 8" on center tube spacing.

Step 4 Supply Water and Surface Temperatures

Using the ThermalBoard™ Output Chart, the system Supply Water Temperature and Surface Temperature can now be determined.

1. Find the Required Output on the left side of the chart and read across to the right to determine the Surface Temperature.
2. Calculate the total R-Value of the covering material and extend a line up from this point at which it intersects the Required Output. The Supply Water Temperature can be read at the point of intersection.
3. If the Water Temperature is above 150° F. or the Surface Temperature is above 85° F.:
   a. Check the heat loss for accuracy. Has it been determined for radiant heat?
   b. Choose a floor covering with a lower R-Value.
   c. Reduce the heat loss of the area (ie. increased insulation, new windows)
   d. Include supplemental ThermalBoard™ heating for the area in ceiling or walls.

ThermalBoard™ Floor/Wall Output Chart

(8" on center spacing 20° F. △T)

Required Water Temperature (degrees F.)

Required Output (Btu/SQ.FT.)	0.5	1	1.5	2	2.5	3	Surface Temperature (Degrees F)
45	145	158					90
40	137	150	167				87
35	130	141	156				85
30	123	133	145	160			83
25	116	124	135	146	162		81
20	108	115	124	133	146	167	78
15	102	106	113	120	129	145	76
10	94	97	102	106	113	124	73
5	88	89	92	94	97	103	70

R-Value of Covering Material

Step 5 Comfort-PEX® Tubing and ThermalBoard™ Panel Requirements

A. Tubing Requirements: ThermalBoard™ utilizes 3/8" Comfort-PEX® tubing. Where required heat outputs are 25BtuH/ft² or greater, loop lengths should be designed around 200' including supply/return leaders. For heat outputs less than 25BtuH/ft², loop lengths should be designed around 200' including supply/return leaders.

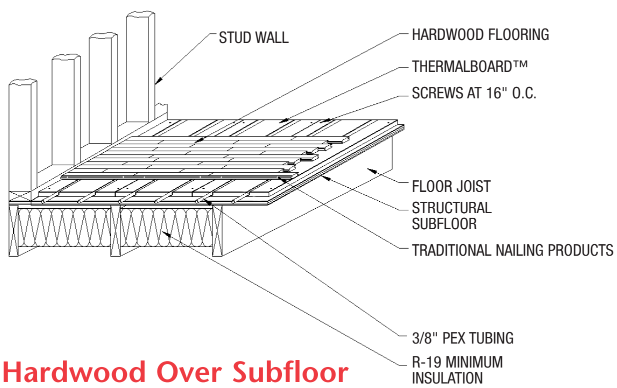
Because ThermalBoard™ is based on 8" on center spacing a tubing factor of 1.5 is used. To determine the required amount of pipe multiply the net square footage of the room by 1.5. The result is the total amount of pipe for ThermalBoard™ only. Supply/return leader lengths must also be included.

B. Number of loops/manifold size: To determine the total number of loops required, subtract the supply/return leader length from the desired total loop length (200 ft.). Divide the resulting loop length into the calculated total tubing requirement to determine the number of loops/manifold size for the area. Example: 200 ft. loops minus 25 ft. supply and 25 ft. return leader (50 ft.) = 150 ft. If the total tubing requirement is 1000 ft., 1000 ft. divided by 200 ft. = 5 loops.

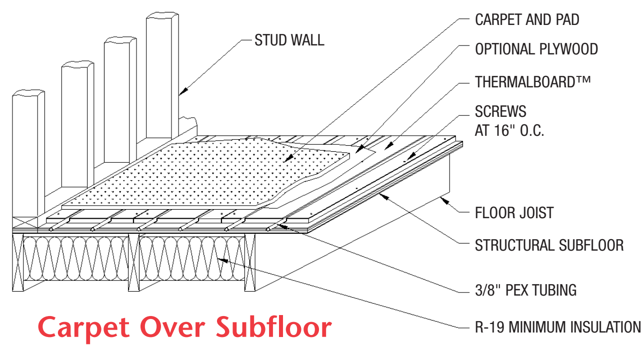
C. ThermalBoard™ Requirements: To estimate the number of panels needed, multiply the square footage of each room by the following (10% allowance for waste included):

Straight Panels = Sq. Ft. x 0.133
Combo Panels = Sq. Ft. x 0.028
Utility Panels = Sq. Ft. x 0.028

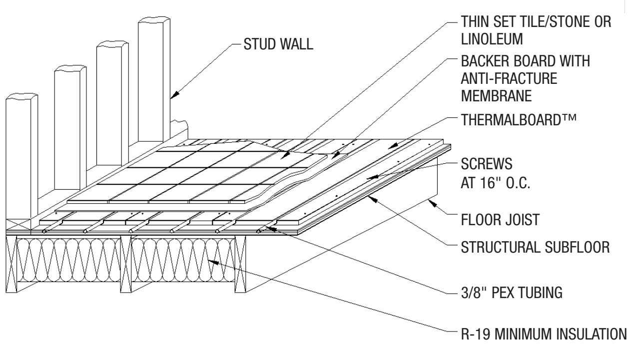
TYPICAL INSTALLATIONS



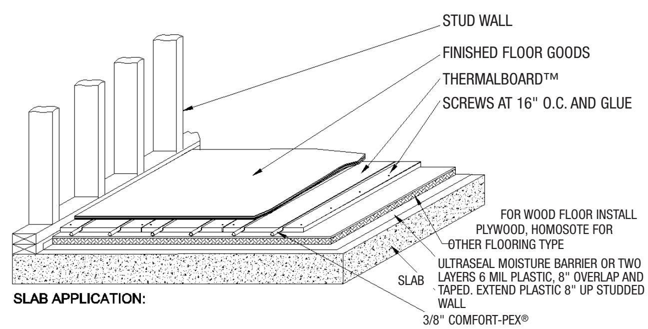
Hardwood Over Subfloor



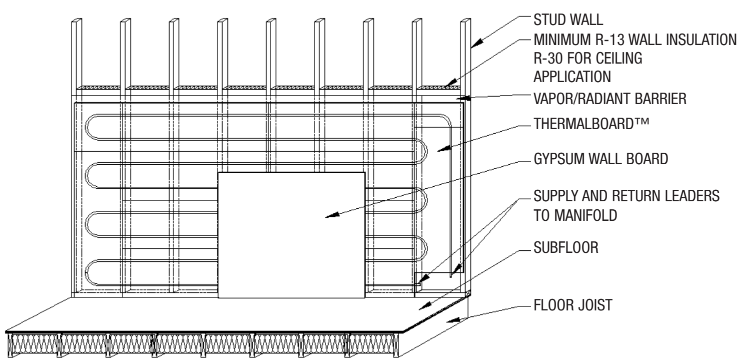
Carpet Over Subfloor



Tile/Stone/Vinyl Over Subfloor



Finish Floor Over Slab



Wall Heating

ThermalBoard™ Installation

Equipment Required

The following are recommended for the installation of ThermalBoard™:

* Table or circular saw (carbide blade recommended)
* Electric or cordless drill gun
* No. 2 Phillips bit
* 5/8" drill bit
* Drill extension (allows operator to remain standing)
* Screws
* Rubber or hard-hide mallet
* Chalk line
* Carpenter Square
* Waterproofing membrane or sealant (over concrete)
* Rollers and trowels for leveling compounds and mastic
* 6" pieces of 3/8" Comfort-PEX® for panel grooves alignment.

Subfloor Preparation

All subfloors must be structurally sound, level and free of voids or defects.

Wood:

Creaking subfloors must be repaired prior to installation. If the subfloor sags, inspect the joists below for twists or weakness. If the subfloor is cupped or uneven at the joints, check the moisture content of the subfloor. Wood subfloors must have a stable moisture content between 6-10%. Check for excessive moisture in the crawl space or basement and look for other signs of a potential water problem.

High areas should be sanded or planed, while low areas patched or filled with an appropriate leveling compound, or covered with a rigid underlayment. When using a leveling compound, be sure to follow the manufacturer's recommendations, and allow the compound to dry completely before installing ThermalBoard.

Concrete:

Since all concrete slabs give off supplementary moisture whether above, on or below grade, it is required that all slabs be sealed against moisture penetration before installing ThermalBoard™. Remember that while a slab may appear to be dry during one time of year, this may change as environmental conditions change. A concrete sealer product or an impermeable vapor barrier such as 6-mil plastic must be used.

To check for moisture, tape a 2' x 2' piece of 6-mil polyethylene in each 10 sq.ft. of floor area. Allow 48 to 72 hours for the test. Indications of high moisture content include darker or discolored concrete, cloudy polyethylene or condensation on the underside of the polyethylene.

When using a 6-mil polyethylene vapor barrier, the moisture content of the slab must not exceed 2.5% on a dry weight basis. New concrete slabs and basements must be cured for a minimum of 60 days prior to installation. After determining that the new or existing slab is sufficiently dry and sealed, you may proceed with the ThermalBoard™ installation.

There are two recommended underlayments for ThermalBoard™ when installed over a concrete slab:

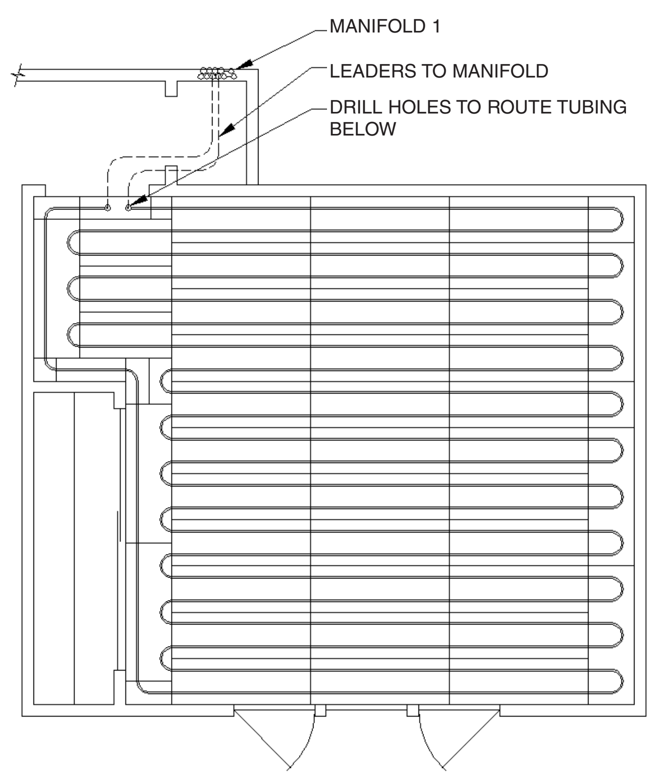
1. Plywood (recommended for hardwood and tile applications): 3/4" tongue and groove.
2. Homosote® (recommended for carpet/pad and floating wood floor applications): Homosote is a compressed 3/4" fiberboard that provides additional insulating value and sound deadening.

Install over a suitable vapor barrier. Glue and screw ThermalBoard™ perpendicular to the plywood/Homosote with special care to overlap all seams.

ThermalBoard™ Layout

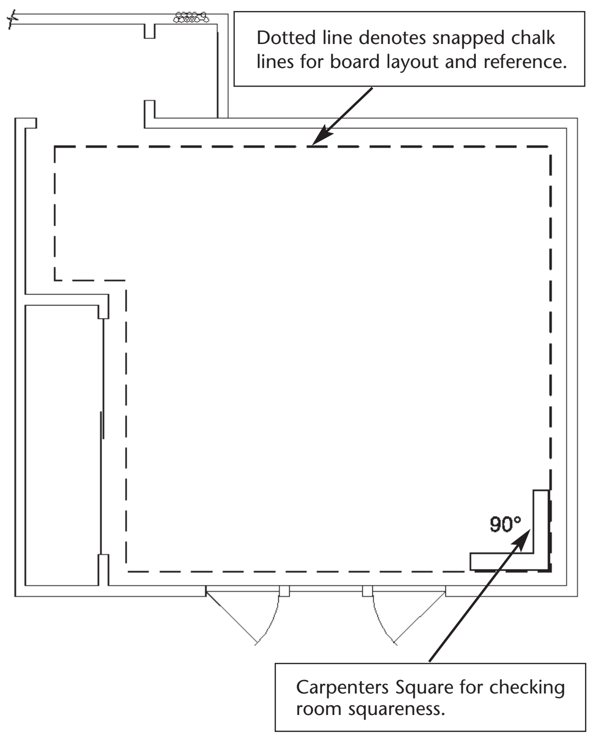
Utilizing a floor plan determine the best panel layout.

Review the following floor plan for the proper method of panel placement.



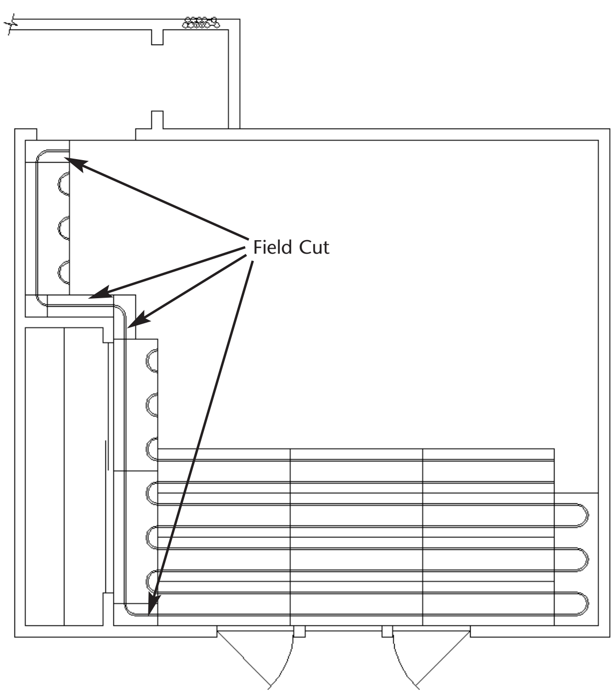
Establish Reference Lines

Using a carpenters square (a minimum 2 ft. square is recommended) determine if the room is out of square. This step is crucial to keeping the panels oriented and spaced correctly. Snap chalk lines 1/4" in from the room perimeter adjusting for any out of square condition. The chalk lines will be used as an installation reference and the 1/4" will allow for natural panel expansion and contraction.



Setting ThermalBoard™ Panels in Place:

Begin the ThermalBoard™ Panel installation at the start of the supply run and laying boards along the perimeter of the exterior wall where the highest heat loss occurs. Continue by adding end panels and straight panels to complete the floor. Secure the first panel only, Do Not Screw any other panels at this point of the installation, as adjustment may be required. Use 6" long pieces of 3/8" Comfort-PEX® tubing between boards to aid in panel groove alignment.

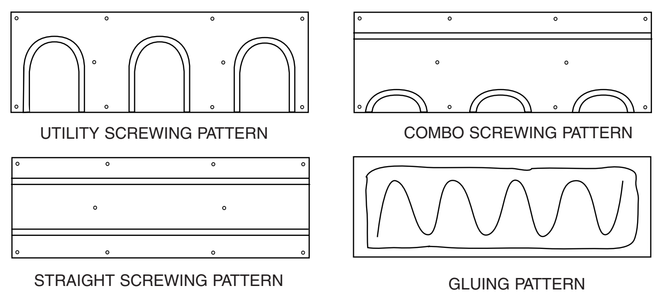


Note: Groove alignment will result in a slight gap between panels. This is provided to allow for natural panel expansion and contraction.

INSTALLERS NOTE: *ThermalBoard™ cuts easily with a quality circular saw blade. Panels will need to be cut to provide an accurate fit for each room. It is important that they be cut squarely to keep the alignment of grooves accurate in the installation.*

Securing ThermalBoard™ Panels

For full panels (16" x 48"), ten screws should be used, 8 on the perimeter and 2 in the middle. In general, maintain 16" c-c for the perimeter and 24" c-c for the interior of all panels. Construction adhesive using a minimum 1/8" bead should be applied to all boards.



Install Comfort-PEX®:

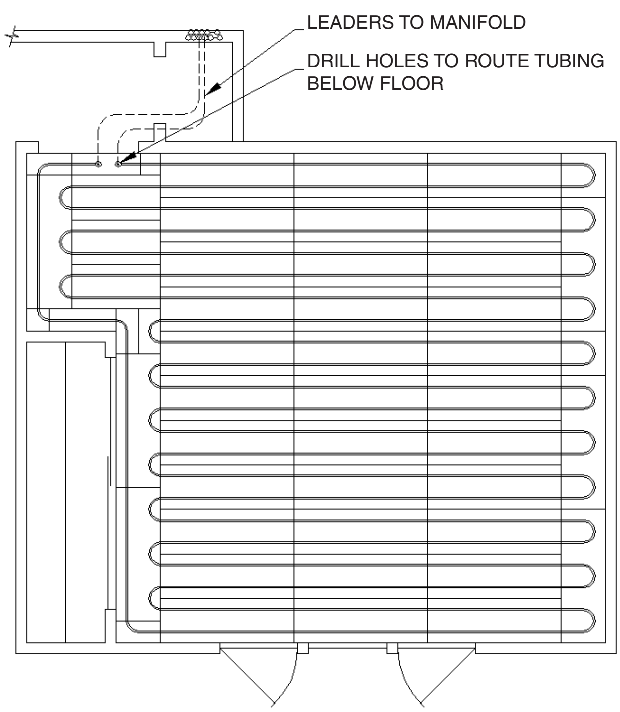
Vacuum the surface and grooves of all Panels. Note: Since there are manufacturing tolerances that make for slight variations in tubing dimension and in the depth of the ThermalBoard™ groove, it may be required to adjust the depth of the ThermalBoard™ groove so that the Comfort-PEX® tubing does not project above the surface of the Panels.

Leaving sufficient excess to connect to manifold, roll out tubing from coil and "snap" into panel groove. A rubber or hard hide mallet is recommended to assist with this step. To return tubing to the manifold location drill holes in floor if applicable, and run supply and returns leaders below the subfloor to manifold location.

In situations where there are several loops from a single area and it is not possible to route tubing below subfloor, two methods may be used to run tubing to the manifold.

1. A solid MDF sheet may be placed next to the manifold in which supply and return lines are custom routed to the manifold.
2. Tubing may be installed without ThermalBoard™, stapled to the subfloor, and run directly to the manifold. A leveling compound should then be used to cover the tubing to the level of the

ThermalBoard™. If needed, sleepers may be placed between the tubing to provide a nailing/screwing base for floor coverings.



ThermalBoard™ Wall Heating:

ThermalBoard™ Panels may also be installed vertically to a stud wall to provide efficient and effective radiant wall heating. The same design and installation parameters as floor heating will apply with the following additional requirements.

1. After Panels are installed add 5/8" thick furring strips to studs as necessary to provide an even base for wallboard installation.
2. Add steel plate protectors where tubing crosses studs.
3. Plan accordingly for any current and future wall "penetrations" (ie. nails/screws for molding, paneling, etc.). Surface mount only when possible.

Insulation:

Insulation must be installed below sub-floor for all ThermalBoard™ installations. Failure to provide suitable insulation will decrease system efficiency and may not allow for sufficient heat output. For radiant floor heating applications a minimum R-19 insulation is recommended. For radiant wall heating applications a minimum R-13 insulation is recommended.

Pressure Testing:

All radiant loops should be air tested at 50-100psi for a period of 24 hrs. prior to the finish floor covering installation. If the system fails to maintain pressure or a pipe is punctured during installation, the leak must be located and repaired. Repair couplings are available.

System Purging:

Each radiant loop must be purged of air individually upon completion of system installation and pressure testing. If a Caleffi Brass or Hydro-Lock Plastic Manifold has not been utilized, individual loop shut-off valves should be installed.

System Start Up:

System start up is dependent upon the mechanical and control strategy utilized with the individual system.

Mechanical Piping/Control Strategy:

Mechanical piping design and component selection should be performed by an experienced heating professional. Water temperature and room temperature control can be achieved through a wide variety of devices, these include:

* Thermostatic Mixing Valves
* Motorized Mixing Valves
* Injection Pumping
* Outdoor Reset Control
* Indoor Reset Control
* Room Thermostats

Finish Floor Coverings:

Carpet

It is advised that 1/4" Luan plywood be applied over ThermalBoard™ prior to carpet and pad installation. As with all radiant heating installations, a thin high-density rubber pad and short, high-density carpet should be used. If carpet pad is glued, a backer board is required and a high temperature latex adhesive must be applied. Glue to the backer board; do not allow glue to come in contact with the Comfort-PEX® tubing. If carpet tack strips are to be used, maintain adequate clearance from tubing.

Hardwood

Conventional nail and hardwood type systems may be used directly over ThermalBoard™ with nails long enough to penetrate the sub-floor and arranged to miss the tubing (pressurized tubing is a must). Glued down hardwood systems must employ latex high temperature adhesives only. Clip style floating systems must be installed such that clips never come in contact with tubing. ThermalBoard™ should be installed such that the hardwood runs perpendicular to the majority of the tubing runs.

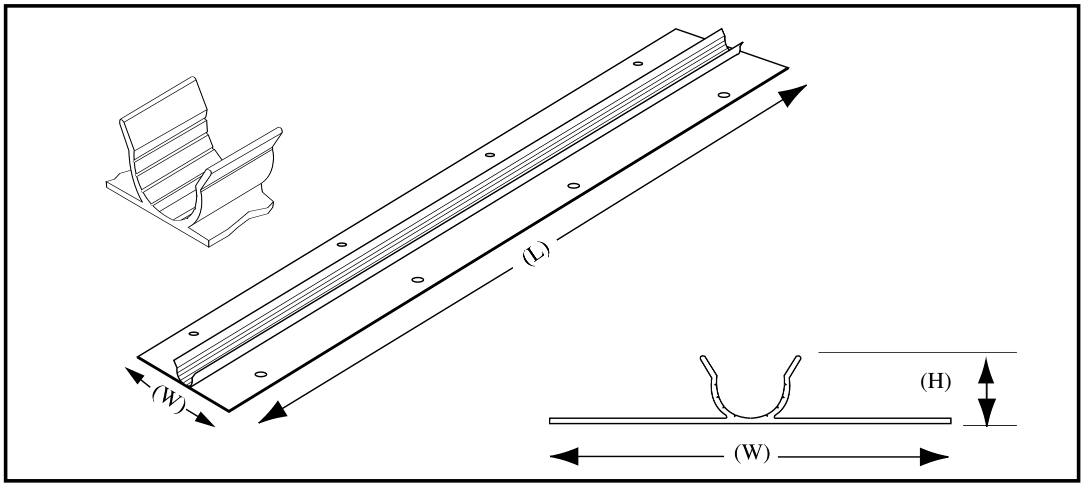
Tile/Stone/Vinyl

For masonry tile, stone and vinyl flooring, it is recommended that backer board be used over ThermalBoard™.

A conventional mortar bed or thin set installation may then be used. Use of vinyl floors and associated adhesives and materials should be checked for temperature limitations. In kitchen, bath, laundry or any other area where water may be present, water sealant or 6-mil plastic should be used.

Radiant Side-Trak®

Below Sub-Floor



RADIANT-SIDE TRAK® is available for the following Comfort-PEX® tubing sizes:			3/8"	1/2"
Application: Hot water, floor, wall and ceiling heating		Overall Height (in.):	.550	.675
Material: aluminum		Internal Channel Dia. (in.):	.515	.640
Width (in.):	4	Wall Thickness (in.):	.050	.050
Length (in.):	48	Weight Per Trak	1.20	1.28

Introduction

Radiant Side-Trak® Heating Panels allow for the fast, effective installation of radiant heat in virtually every application (Floors, Walls and Ceilings). The rigid channel construction enables flexible Comfort-PEX® to be easily "snapped" into place, tight and secure. No longer does one have to deal with expensive or impractical lightweight concrete pours and time consuming reflecting tray installations.

Radiant Side-Trak® benefits:

- Outstanding for both new construction and retrofit.
- The excellent thermal conductivity of aluminum (120 times greater than concrete) makes it the ideal material for today's radiant heating systems.
- Provides for increased heat output and more uniform floor temperatures and at lower water temperatures than "staple-up" installations.
- Easily installed from below the subfloor with no alteration to existing or planned wood frame floor construction.
- Adaptable for wall and ceiling applications.
- Self-supporting with no need for additional straps or fasteners with which to secure Comfort-PEX® tubing.
- Open channel design leaves tubing runs fully visible and accessible during installation.
- Convenient 4 foot lengths to simplify ordering and installation. (if necessary, Radiant Side-Trak® may be easily cut to length on the job.)
- "Dry" system installation greatly increases the response time to room temperature changes. "Wet" (concrete) installations are associated with slow response due to the large mass of the floor.

Design Notes

Radiant Side-Trak® heating system design incorporates many of the same required calculations and parameters discussed previously in Radiant Floor Design. The same steps must be followed. However, Radiant Side-Trak® design utilizes a separate Output Chart and requires the additional material calculation of the Radiant Side-Traks themselves.

Step 1 Determining Your Heating Requirements

(see Heat Loss Calculations)

Step 2 Required Heat Output

(see Radiant Floor Design)

$$\text{Required Heat Output} = \frac{\text{Heat Loss}}{\text{Net Area}}$$

Step 3 Comfort-PEX® Selection and Spacing

Radiant Side-Trak® system design differs from conventional radiant floor design in that spacing is generally based on 8" c-c. This is a direct result of the typical 16" on center floor joist construction found in most modern wood frame structures. It is possible that in older homes 24" on center spacing may be found. As this spacing is still a multiple of eight, 8" c-c Radiant Side-Trak® spacing remains applicable. Construction practices and joist spacing that differ from the above, as well as structures with low heating requirements, should be discussed with an experienced design engineer to determine acceptable Trak spacing and system alternatives.

Radiant Side-Trak® is available to receive 3/8" or 1/2" Comfort-PEX®. Larger dimensioned Comfort-PEX® tubing is not generally utilized in these circumstances due to space constraints when working within joist bays. 3/8" Radiant Side-Traks® are the recommended choice for below subfloor and other space constrained applications. Wall and ceiling applications should utilize 3/8" Radiant Side-Traks® also.

Step 4 Supply Water and Surface Temperatures

Using the *Radiant Side-Trak® Output Chart* the system Supply Water Temperature and Surface Temperature can now be determined.

1. Find the Required Trak Output on the left side of the chart and read across to the right to determine the Surface Temperature.

2. Calculate the Total R-Value of the covering material (*see R-Value Chart on page 40*) and extend a line up from this to a point at which it intersects the Required Heat Output. The Supply Water Temperature can be read at the point of intersection.

3. If the Supply Water Temperature is above 160° F. or the Surface Temperature is above 85° F.:

a. Check the heat loss calculations for accuracy. Have they been determined for radiant heat?

b. Choose a floor covering with a lower R-Value.

c. Reduce the heat loss of the area (i.e. increased insulation, new windows).

d. Include supplemental heating for area: Radiant Side-Trak®, or ThermalBoard™ wall/ceiling heating.

Step 5 Comfort-PEX® tubing and Radiant Side-Trak® Panel Requirements

A. Comfort-PEX® tubing: The Comfort-PEX® required, for 8" on center spacing, can be determined by multiplying the net area by 1.5. Be sure to also include the supply and return runs to the boiler/manifold location (see step C).

B. Radiant Side-Trak®: Multiply the total length of Comfort-PEX® by .85, this will take into account the turns at the end of each run that will not be utilized by Radiant Side-Trak®. (Do not include the supply and return runs to the boiler/manifold for this calculation.) Dividing this number by 4 (4 ft. Radiant Side-Trak® lengths) will give you the estimated number of Radiant Side-Trak® panels required for the area.

Radiant Side-Trak® Floor/Wall Output Chart
(8" on center spacing/20° F △T)

Required Water Temperature (degrees F.)

Required Output BTU/SQ. FT.	.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
45	112	135	157							
40	108	129	148							
35	104	122	139	156						
30	100	115	130	145	160					
25	95	108	120	133	145	157				
20	90	100	110	120	130	140	148	159	168	
15	85	93	100	108	115	123	128	137	144	153
10	80	85	90	95	100	105	108	114	119	125
5	75	77	80	83	85	87	89	91	94	98

Surface Temp. *(degrees F.)*: 90, 87, 85, 83, 81, 78, 76, 73, 70

R-Value of Covering Material

Radiant Side-Trak® Ceiling Output Chart
(12" on center spacing/20° F △T)

Required Water Temperature (degrees F.)

Required Output BTU/SQ. FT.	.5	1.0	1.5	2.0	2.5	3.0
45	120	140	160			
40	117	134	153			
35	114	130	145	160		
30	111	123	136	149	162	
25	108	118	128	139	149	159
20	105	112	120	128	136	143
15	101	107	112	117	122	127
10	98	101	104	106	109	111
5	97	98	100	101	102	104

Surface Temp. *(degrees F.)*: 90, 87, 85, 83, 81, 78, 76, 73, 70

R-Value of Covering Material

Water temperature not to exceed 120° F when sheetrock covering is used.

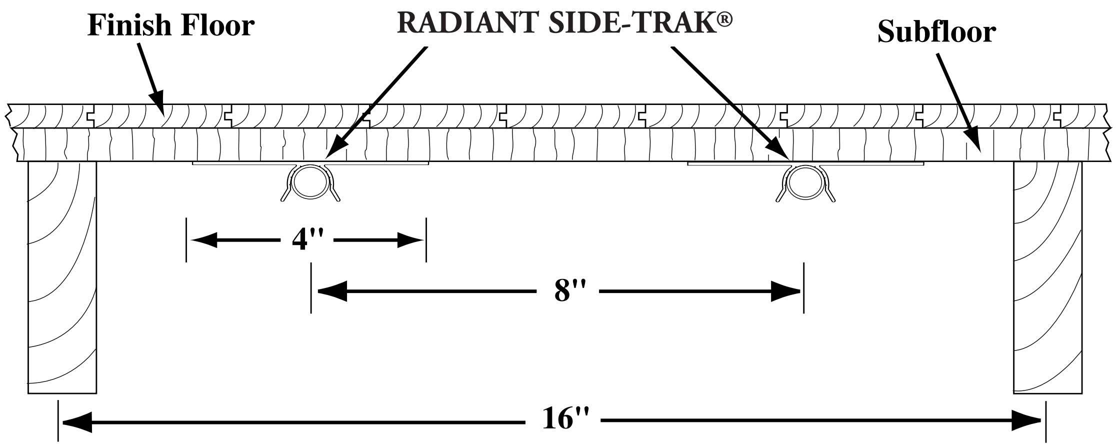
C. Number of loops/manifold size: The maximum circuit length for a Radiant Side-Trak® loop is *200 ft.* for 3/8" Comfort-PEX® and *300 ft.* for 1/2" Comfort-PEX®. The maximum areas that can be covered per loop, utilizing 8" c-c Radiant Side-Trak® spacing, is 125 sq. ft. with 10' supply and return leaders for 3/8" and 155 sq. ft. for 1/2" with 10' supply and return leaders. Taking into account the supply and return runs to the boiler/manifold location you can now determine the number of loops. If the boiler location is a great distance from the area to be heated a remote manifold location should be established.

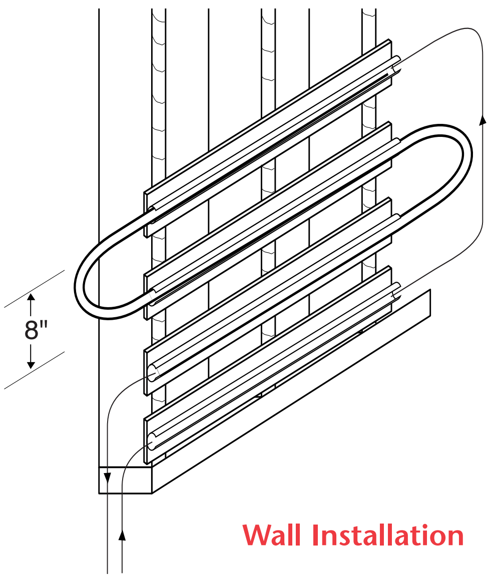
Step 6 Flow Rate and Pressure Drop

(see Hydronic Design - Page 10)

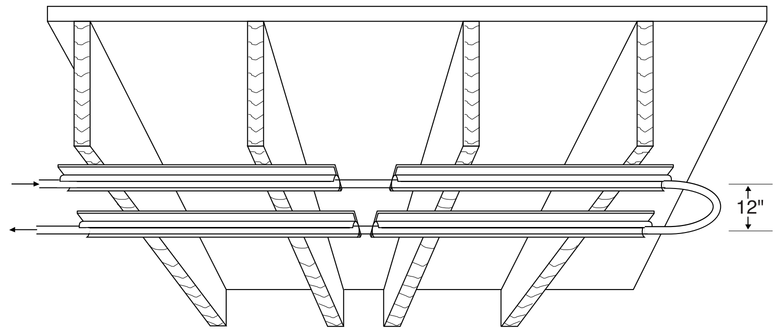
Typical Installations

Below SubFloor Installation





Wall Installation



Ceiling Installation

Radiant Side-Trak® Panel Installation

Trak Installation

Using the pre-punched mounting holes in the Radiant Side-Trak® panels speeds installation and a power nailer or screw gun may be used.

The Radiant Side-Traks® should be installed with a minimum of 1/4" gap between to allow for expansion and contraction. This gap can also be as wide as 5" to help maximize Trak coverage area and minimize the amount of Traks that have to be cut to fit into the end of joist bays. A minimum of 12" and maximum of 18" is required at the ends of all joist bays to allow for the Comfort-PEX® tubing piping being looped from Trak to Trak and bay to bay.

*If required, Radiant Side-Traks® can be easily cut on a standard miter saw (carbide blade) or with a hand hacksaw. Any burrs left from cutting should be cleaned off prior to installation.

Installing the Tubing

The Comfort-PEX® tubing may now be snapped into the channel of the Radiant Side-Trak® panels. A rubber mallet may be used to tap the pipe securely into place. When working overhead a suitable length of construction lumber (2" x 4") can be used to push the tubing into place as you walk along.

*In applications where the supply water temperature will exceed 140° F, it is recommended that an expansion loop be placed at the start of a joist bay approximately every 25 ft. of tubing.

Expansion loops counter the linear expansion of the Comfort-PEX® tubing in higher temperature systems. As the water warms and the tubing expands, the loop grows; as the water cools and the tubing contracts, the loop shrinks. See Appendix C.

When drilling holes in the joists for the Comfort-PEX® tubing to pass from bay to bay, care should be taken to allow sufficient clearance, or to "sleeve" the tubing. Under no circumstances should the Comfort-PEX® minimum bending radius be exceeded or the tubing installed in such a way as to be binding against the joist hole.

*See Page 29 "Joist Bay Tubing Installation Detail" for more information.

Insulation

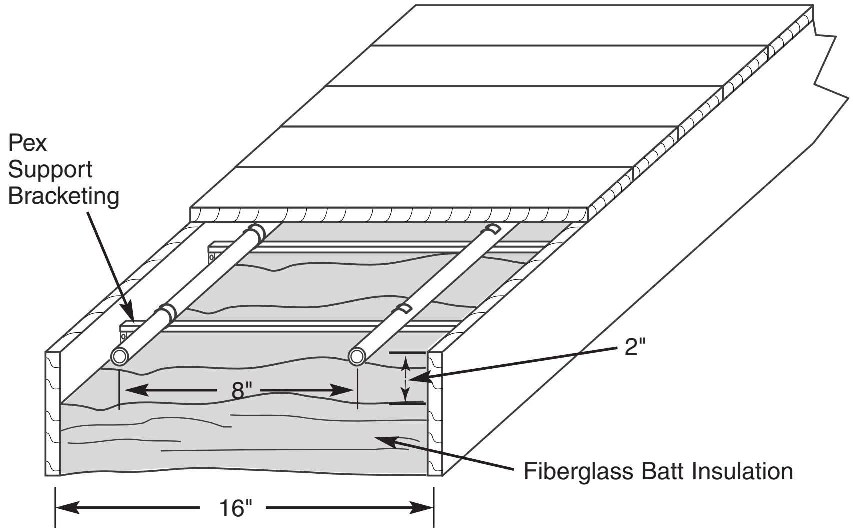
Fiberglass batt insulation or InsulTarp Double-Bubble Foil insulation must be installed below all Radiant Side-Trak® installations. Failure to provide suitable insulation will decrease system efficiency and may reduce heat output. Insulation should be installed tight against the Trak panels in order to minimize air gaps between sub-floor and the insulation.

Filler Boards

When installing 3/8" Radiant Side-Trak® panels to the face of a wall or ceiling it will be necessary to provide 5/8" thick filler boards between the channels of the Trak panels (5/8" sheetrock). 8" c-c wall spacing will require 7" wide filler boards. 12" on center ceiling spacing will require 11" wide filler boards.

The filler boards will provide an even surface for finish material to be applied. 3/8" or 1/2" Sheetrock may be installed directly over the filler boards.

Joist Heating



Introduction

Joist heating can be an alternative to Radiant Side-Trak Panels in those applications where the heating requirements and R-value of the covering materials are low. In the absence of a direct heat transfer material (Radiant Side-Trak® or concrete) a suspended pipe system is designed and installed utilizing a sealed air pocket below the subfloor. By circulating heated water through the Comfort-PEX® tubing, the surrounding air becomes warmed to a point where it can transfer the btu's (heat) to and through the subfloor and surface material above. In general, **joist heating systems are limited to a maximum of 20 btu's/sq. ft. and a total floor covering R-Value of 2.0 or less.**

Step 1 Determining Heating Requirements

Of all the radiant heat system designs, the joist application requires the most accurate heat loss calculation. If the heat loss is off by as little as 5 btu's/sq. ft. the system may be unable to satisfy the heating requirements. Those individuals not experienced with radiant heat loss calculations and joist heating specifically should consult with a Rathe Associates support staff member.

Step 2 Required Heat Output:

(see Radiant Floor Design)

$$\text{Required Heat Output} = \frac{\text{Heat Loss}}{\text{Net Area}}$$

Step 3 Comfort-PEX® Selection and Spacing:

3/8" Comfort-PEX® is the recommended tubing for joist heating system applications. Similar in design to Radiant Side-Trak® systems the tubing spacing is generally based on 8" c-c to accommodate uniform distribution between 16" on center floor joists.

Step 4 Supply Water and Surface Temperatures:

Using the *Joist Heating Output Chart* the system Supply Water Temperature and Surface Temperature can now be determined.

1. Find the Required Heat Output on the left side of the chart and read across to the right to determine the Surface Temperature.

Joist Heating Output Chart
(8" on center spacing/15° FsT)

Required Output BTU/SQ. FT.	0.5	1.0	1.5	2.0	2.5	3.0	Surface Temp. (degrees F.)
26	179						81
24	170	183					80
22	162	174	188				79
20	154	164	178	184			78
18	147	155	167	174	185		77
16	137	146	156	162	172	181	76
14	129	136	146	151	159	168	75
12	120	127	135	129	147	154	74
10	112	117	124	128	134	140	73
5	91	94	98	99	102	106	71

R-Value of Covering Material

2. Calculate the Total R-Value of the covering material (*use R-Value Chart on page 40*) and extend a line up from this to the point at which it intersects the Required Heat Output. The Supply Water Temperature can be read at the point of intersection.

3. If the Supply Water Temperature is above 160° F or the Surface Temperature is above 85° F:

a. Check the heat loss calculations for accuracy. Have they been determined for radiant heat?

b. Choose a floor covering with a lower R-Value.

c. Reduce the heat loss of the area (i.e. increased insulation, new windows).

d. Include supplemental heating for area: Radiant Side-Trak® or ThermalBoard™ wall/ceiling heating.

Step 5 Comfort-PEX® Tubing Requirements

A. Comfort-PEX® tubing: The Comfort-PEX® required, for 8" on center spacing, can be determined by multiplying the net area by 1.5. Be sure to include the supply and return runs to the boiler/manifold location.

B. Pex Support Brackets: Pex support bracketing quantity, such as excess wood, metal etc… cut to length between joists can be calculated by dividing square footage by (4). This will equate to one support bracket every 3 ft.

B.2 Plastic U-nails: 3/8" through 1" for Comfort-PEX®. Spacing of U-nails is every 2 to 2-1/2 feet. To calculate the quantity of bags (packaged 50 per bag) required take the total length of pipe and divide by 2, then divide that number by 50 (round to the nearest bag).

B.3 Hand Held Stapler Kit: 3/8" to 3/4" for Comfort-PEX®. Spacing of staples is every 2 to 2-1/2 feet. To calculate the quantity of bags (packaged 100 per box) required take the total length of pipe and divide by 2, then divide that number by 100 (round to the nearest box).

C. Number of loops/manifold size: The maximum circuit length for 3/8" Comfort-PEX® is 200 ft. The maximum area that can be covered per loop is 125 sq. ft. with 10' supply and return leaders for 3/8". Taking into account the supply/return runs to the boiler/manifold location you can now determine the number of loops required. If the boiler location is a great distance from the area to be heated a remote manifold location should be considered.

Step 6 Flow Rate and Pressure Drop

(see Hydronic Design - Page 10)

Joist Heating Output Chart
(8" on center spacing/15° FsT)

Required Output BTU/SQ. FT.	0.5	1.0	1.5	2.0	2.5	3.0	Surface Temp. (degrees F.)
26	179						81
24	170	183					80
22	162	174	188				79
20	154	164	178	184			78
18	147	155	167	174	185		77
16	137	146	156	162	172	181	76
14	129	136	146	151	159	168	75
12	120	127	135	129	147	154	74
10	112	117	124	128	134	140	73
5	91	94	98	99	102	106	71

R-Value of Covering Material

Joist Heating Installation

Installing the Tubing

Following the Joist Bay Installation Detail (Page 29), 3/8" Comfort-PEX® tubing should first be pulled into each joist bay and attached at the return bend with a plastic u-nail. Pex support brackets or plastic U-nails should then be tacked into place at approximate 2 to 2-1/2 ft. intervals. By clamping the Comfort-PEX® into / onto the support clips, U-nails etc… will allow the tubing to hang uniformly in the joist bay and provide even joist bay heating.

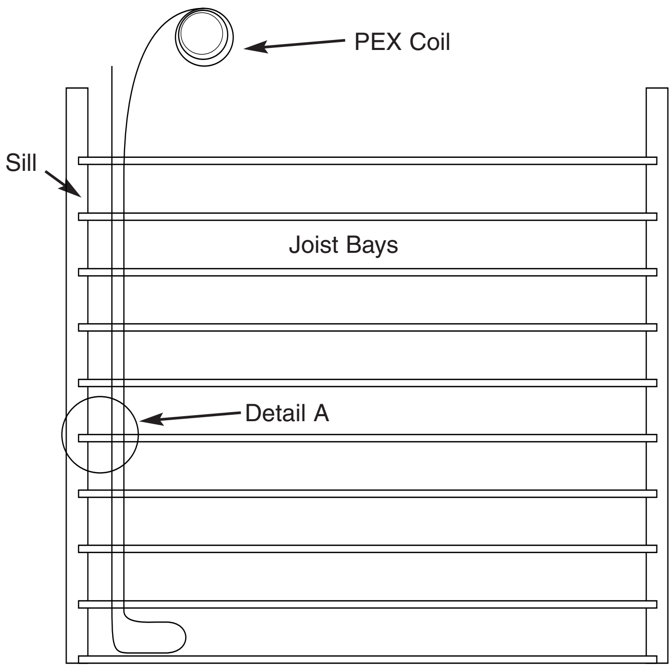
Due to the higher water temperatures associated with joist heating applications it is recommended that an expansion loop be placed at the start of a joist bay approximately every 25 ft. of pipe.

Expansion loops counter the linear expansion of the Comfort-PEX® tubing in higher temperature systems. As the water warms and the tubing expands, the loop grows; as the water cools and the tubing contracts, the loop shrinks.

Insulation

Fiberglass "batt" insulation (foil faced preferred) or InsulTarp Foil insulation must be installed below all joist heating installations. The insulation should be installed 2" below the subfloor creating an air gap between the two. The bay ends should be closed with additional insulation to assure as tight an enclosure as possible. The minimum insulation value is R-11. However, in colder climates or where the space below is entirely unconditioned, the maximum insulation should be installed. Failure to provide suitable insulation and an enclosed 2" air pocket will directly affect system output and efficiency.

Joist Bay Tubing Installation Detail



Step 1

Drill required holes in joists (*Detail A*). Allow sufficient clearance for tubing to be able to make gentle bends.

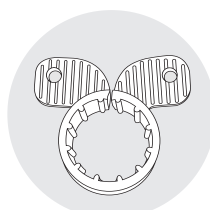
Step 2

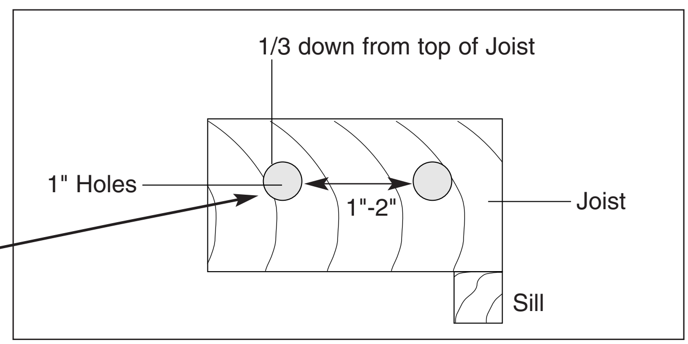
Feed piping down and back through holes in joists.

Step 3

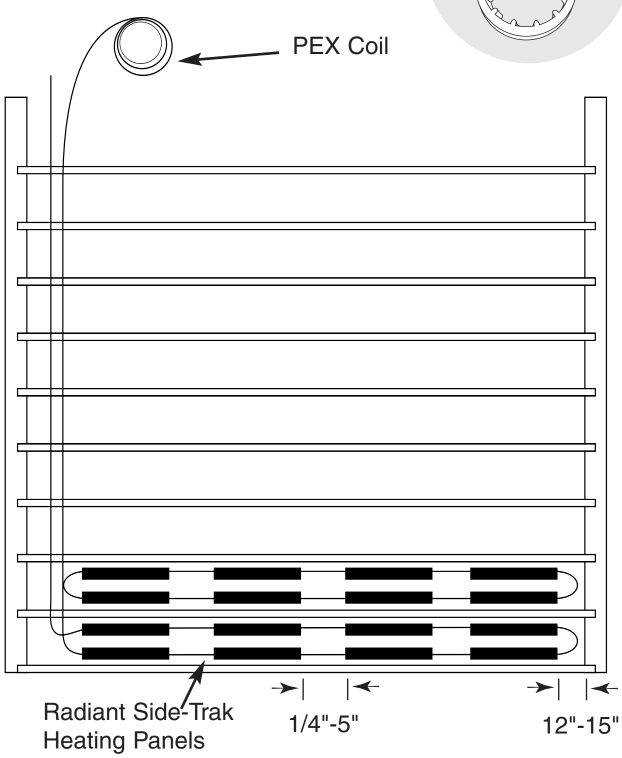
Pull tube from coil as needed to run down the length of the farthest joist bay. Secure at end of bay with plastic u-nail. Continue process for each joist bay as you work back towards PEX coil.

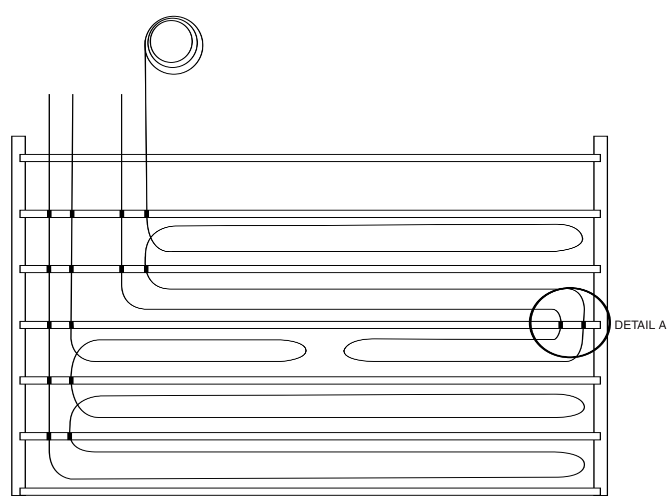
Suspension clamps reduce friction and noise from expansion of Comfort-PEX®





Detail A-Side View of Joist





Piping & Control Strategies

System Manifolds

System manifolds provide the flexibility necessary to design and tailor the optimum system for any given project. Manifolds allow for centralized piping of the many loops/zones typically associated with radiant heat systems. Mechanical design and control can be greatly simplified with the use of system manifolds.

Caleffi brass manifolds are manufactured of heavy wall extruded brass and can be supplied completely assembled (3-10 circuits) for labor saving installation. Pre-assembled manifolds include the following; Valved Supply Header (for balancing, and shut-off), Valved Return Header (for zone valves and positive shut-off), 1" and 1-1/4" threaded female adapters, mounting bracket(s), coin style air vents, and purge valves and flow meter. Zone valves and PEX manifold adapters are ordered separately.

Hydro-Lock Modular Plastic Manifold:

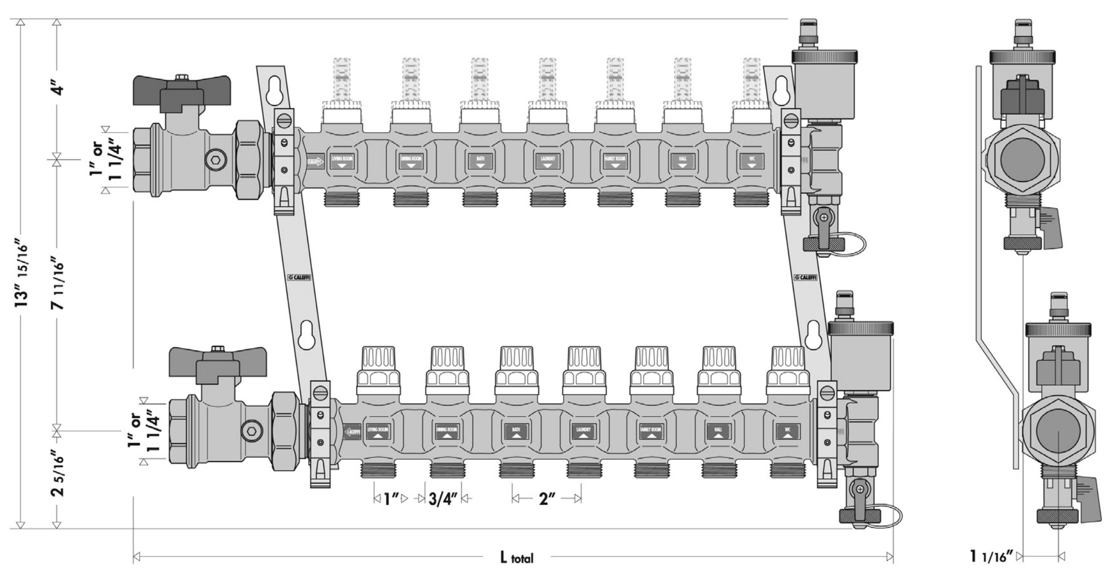
Offered as a completely modular system, the Hydro-Lock modules are simple to assemble with no tools required. The starter kit includes 1-1/4" Male threaded fittings with thermometer on the supply and return modules, end modules with coin air vents, purge valve and manifold brackets. Individual supply and return modules allow manifold combinations from 1-20 circuits. The unique nature of the locking manifold is that any module can be oriented up, down, or front and back. The supply modules have built in flow meters that also serve as positive shut-off valves. The return modules have threaded end caps that provide positive shut-off and can be removed for adding zone valves.

Copper Manifolds:

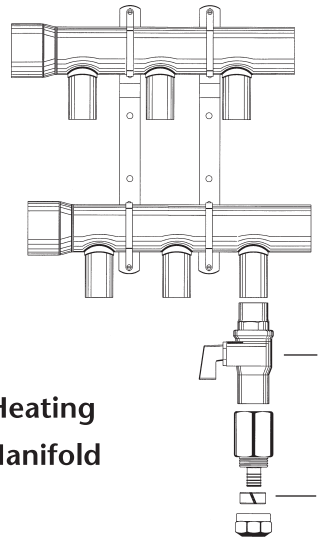
Copper manifolds are also available. Constructed of 1" type "L" copper with 1/2" branch outlets on 2-1/2" centers. These manifolds are fully modular, available in 2, 3 and 4 branch configurations which can be joined together to satisfy any design need.

*For radiant and snow melt applications larger copper headers are available. Offered in 1", 1-1/4", 1-1/2" & 2" diameter, up to 6 ft. in length, with 12, 18 or 24 sweat outlets of 1/2", 3/4" or 1". These headers can be field-cut to length for exact project requirements. Isolation and balancing valves, sweat to PEX adapter fittings, air vents and temperature gauges are available as needed to fulfill various installation requirements.

Brass Manifold Dimensions



Code (1 1/4")	**6637**7C5A	**6637**7D5A	**6637**7E5A	**6637**7F5A	**6637**7G5A	**6637**7H5A	**6637**7I5A	**6637**7L5A	**6637**7M5A	**6637**7N5A	**6637**7O5A
Code (1")	**6686**6C5S1A	**6686**6D5S1A	**6686**6E5S1A	**6686**6F5S1A	**6686**6G5S1A	**6686**6H5S1A	**6686**6I5S1A	**6686**6L5S1A	**6686**6M5S1A	**6686**6N5S1A	**6686**6O5S1A
Code (1 1/4")	**6687**7C5S1A	**6687**7D5S1A	**6687**7E5S1A	**6687**7F5S1A	**6687**7G5S1A	**6687**7H5S1A	**6687**7I5S1A	**6687**7L5S1A	**6687**7M5S1A	**6687**7N5S1A	**6687**7O5S1A
No. outlets	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Total length	15 3/16"	17 1/8"	19"	21"	23"	25	28 1/8"	30 1/8"	32 1/16"	34 1/16"	36"
Weight (lb)	16.1	17.3	18.5	20.9	22.5	23.6	25.4	27.1	28.9	30.4	32.2



Copper Heating System Manifold

Supply Water Temperature Control

Mixing Valves:

The relatively low supply water temperatures of radiant heating systems require the use of a tempering or mixing valve to lower the output of a conventional boiler. Exceptions to this are certain high temperature design suspended pipe heating applications. Rathe Associates offers Cash Acme three way mixing valves and tekmar® three and four way manual mixing (and control actuated) valves to provide precise temperature control. Thermostatic valves are ideal for small to medium size radiant applications requiring a set water temperature (below 150° F). Manual mixing (and control actuated) valves are suitable for larger installations, higher temperature operation or where motorized weather responsive control is desired (outdoor reset).

Thermostatic Mixing Valves:

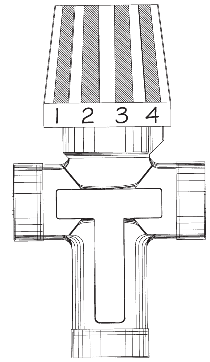
Cash Acme offers a self regulating valve available in 3/4" and 1" used to control the water temperature in small to medium sized radiant heating systems. Water temperature is maintained by a special wax/copper sensing element which controls the flow of hot (boiler supply water) and cold (system return water) to rapidly stabilize temperature at the desired level.

Note: If piped directly from the boiler supply a thermostatic mixing valve will return cool water back to the boiler. This lowering of the boiler return water temperature can result in thermal shock to the boiler and lead to flue gas condensation. Typically, the Btuh capacity of a 3/4" thermostatic temperature valve will not result in thermal shock or condensation. However, a 1" thermostatic valve installation should utilize primary/secondary or boiler bypass piping (see Piping Diagrams).

Valve settings @ 180° F Boiler Supply

Setting #	Temp output (F)
1	110
2	116
3	122
4	128
5	134
6	140

Temperature may vary - field verify



Technical Data

[Cash Acme Model: 110-H 3/4" or 1"]

Maximum Input (hot) Temperature: 194° F.
Maximum Working Pressure: 145 PSI
Regulated Temperature Range: 95°-140° F.
Material: Bronze Body, Brass Internal,
Stainless Springs, Brass fittings
Flow Rate: 1 gpm to 20 gpm (Cash Acme Model:
115-H 1" = 2.5 gpm to 50 gpm)
Capacity: 20,000 BTU's (Cash Acme Model:
115-H 1" = 50,000 BTU's)

Manual Mixing (Floating Action) Valves

Designed for use where temperature control of circulating water is desired. Proper system water temperature is achieved by the mixing of the cooler return water from the heating zone with some of the heated boiler water. This is achieved by manually setting the valve, or with the use of a mixing valve motor. These valves are either 3 or 4 way, and are available in sizes from 3/4" to 2".

Note: *3-way manual mixing valves are subject to the same boiler return water concerns as do thermostatic mixing valves. 3-way valves should be utilized with primary/secondary or boiler bypass piping.*

Technical Data [tekmar® 700 Series Valves]

Operating Temperature Range: -20 to 248° F.
Maximum Operating Pressure: 146 PSI
Material: CW 617N – EN 12165 Brass

Not for use with fluids that contain mineral oil or chlorinated pool water.

Manual Mixing Valves	Temperature Range°F	Maximum btuH
3/4" manual	70-180	70,000
1" manual	70-180	140,000
1-1/4" manual	70-180	210,000
1-1/2" manual	70-180	350,000
2" manual	70-180	500,000

System Controls:

Radiant heat system can be controlled through a variety of techniques. System requirements, planned usage, and comfort/efficiency expectations should all be considered when selecting controls. Technical data on all tekmar® controls can be found by visiting our web site and following the links to the tekmar® home page for downloadable literature or by contacting our support staff at Rathe Associates.

Thermostats:

Thermostats provide on/off operation of the system circulator and/or zone valve based on room air temperature. Wall mounted within the room to be controlled a thermostat signals a relay control to provide or cut power to the system circulator/zone valve. The full range of tekmar® thermostats available through Rathe Associates provide accurate, reliable, programmable or "set-and-forget" temperature control.

tekmar® thermostats are designed for radiant heat applications when air temperature is not necessarily the primary or sole desired control medium. "Surface-Stats" are ideally suited for floor warming applications. The "Surface-Stat" works in the same way as a room thermostat, by controlling the operation of the system circulator/zone valve. A sensor, embedded in the floor, provides temperature input in addition to an air temperature sensor located within the controller. For floor temperature control only, with no air temperature input, you can simply turn off the built-in sensor by programming the thermostat.

Reset Controls:

Reset Control maintains a buildings indoor temperature by continually adjusting the temperature of the heated system water. Water temperature adjustment is a response to an outdoor air temperature sensor and achieved by Mixing Valve or Injection Pump. Outdoor or Indoor Reset controls provide maximum comfort and efficiency by adjusting the supply water temperature in concert with outdoor temperature.

Outdoor reset control will increase the system water temperature as the outdoor temperature decreases and decrease the system water temperature as the outdoor temperature increases. Indoor reset control increases or decreases system water temperature based on indoor room air temperature rather than outdoor air temperature. Indoor reset is capable of adjusting in rapidly changing heat loss conditions more quickly than outdoor reset control.

Sequence of operation:

All heating systems have a control sequence. Radiant heating systems follow the same control sequence as baseboard and fan coils. Typically, there is a thermostat that senses room air temperature and acts as an on/off device. The thermostat switch closes a circuit, signaling to a circulator relay control that will start the system circulator. The circulator control also closes a switch that signals the heat source to start. When the thermostat is satisfied (room temperature has reached the thermostat "set-point"), the thermostat contacts open, which signals the circulator control to stop the heat source (boiler, heat exchanger, etc…) and then the circulator.

4-wire zone valve sequence:

The thermostat tells the zone valve control to open the zone valve; the zone valve end switch closes and tells the pump to start; the pump control tells the heat source control to make hot water.

2-wire zone valve sequence:

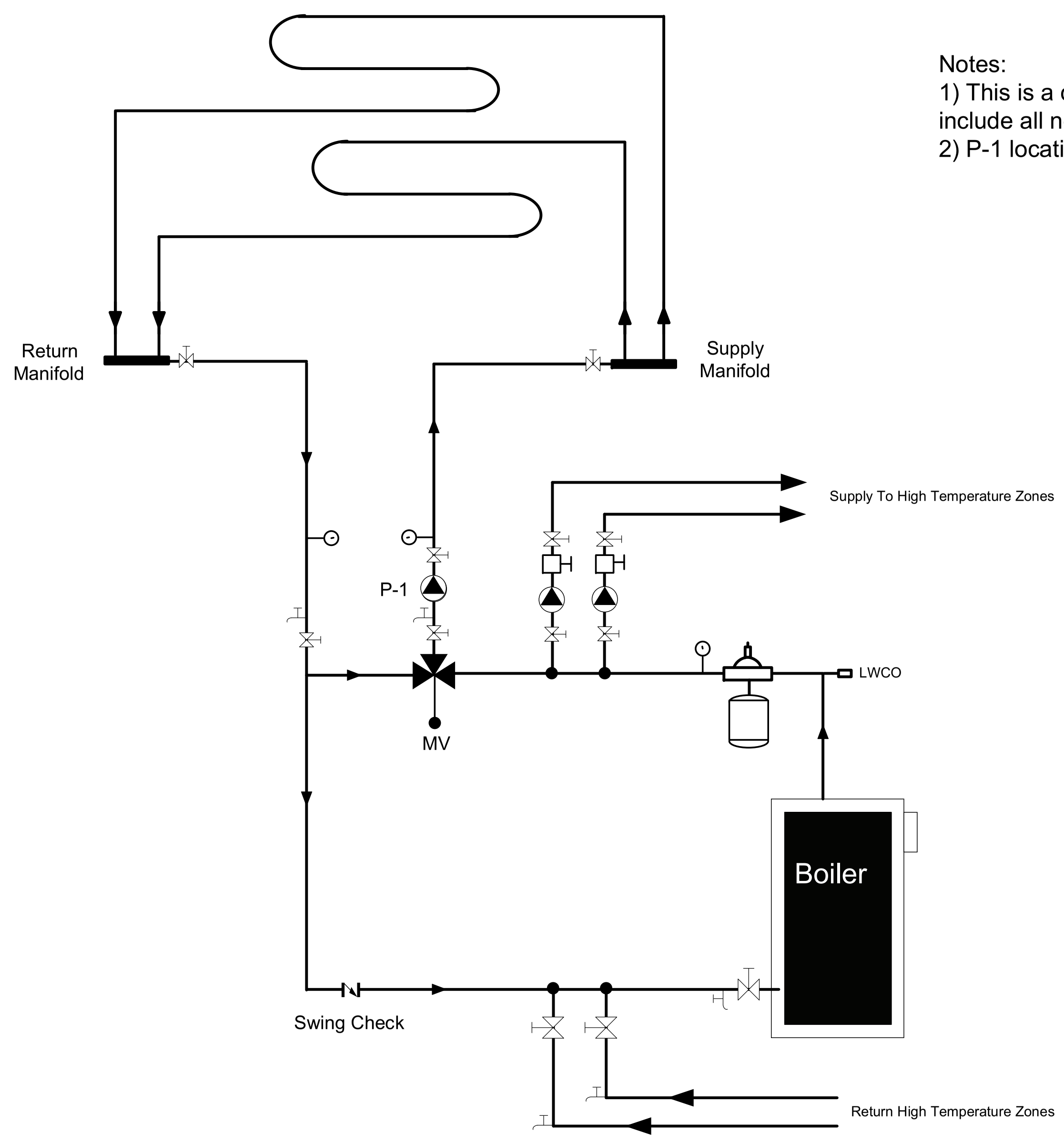
The thermostat tells the zone valve control to open the zone valve and tells the pump to start; the pump control tells the heat source control to make hot water.

Caleffi offers 2 and 4-wire zone valves. 2-wire zone valves offer slightly faster installation time but the pump starts as soon as the thermostat starts. This may cause the pump to push against the valve and create some noise. Zone valves are well controlled via a "Zone Valve Relay Control". The 4-wire zone valves have a built-in switch that signals the pump to start only after the zone valve has opened a minimum of 50%. This is the recommended zone valve because the pump is only "on" after the valve has opened. This prevents the pump from pushing against the valve while it's closed (called deadheading).

Reset control Sequence:

Rathe Associates designs heating systems so that individual controls can be isolated without affecting the entire system operation. With this in mind, outdoor reset controls and indoor reset are typically installed so the controller monitors and adjusts water temperature only. The outdoor reset control senses outdoor temperature and then changes the supply water temperature by means of a motorized mixing valve. Indoor reset control utilizes a wall-mounted thermostat with electronic logic that communicates directly with the mixing valve. Changes in room temperature are corrected quickly with constant room temperature monitoring through the tekmar® controller. Room thermostats are utilized for high temperature limits to prevent over heating.

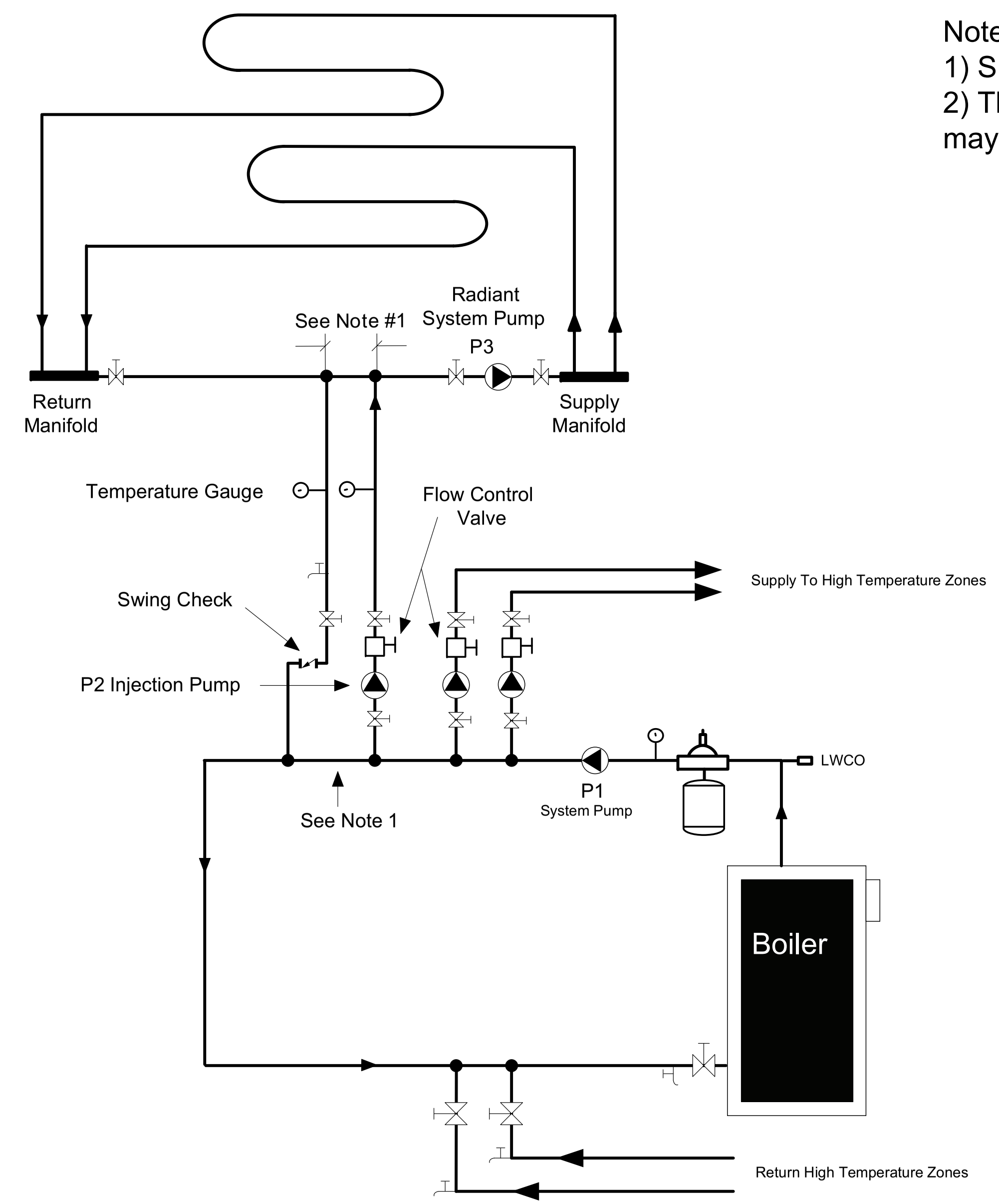
A variable speed pump reset control is another option that changes the supply water temperature based on outdoor air temperature and boiler return temperature. This control is activated by a call of heat from a zone; the variable speed control then tells the heat source to make hot water. With variable speed control of the injection pump, the water supply temperature can be adjusted up, down, or held at a constant temperature. The injection control has the added function of protecting the heat source from cold return temperatures that can occur during start-up or during routine operation (slab on grade or snow melt systems).



Notes:
1) This is a conceptual diagram and may not include all necessary details.
2) P-1 location must be after mixing valve.

RATHE ASSOCIATES	Project:	Manual Thermostatic Mixing Valve	Date: Drawing No: RHB-1022
	Location:		

Notes:
1) Spacing 4-pipe diameters maximum
2) This is a conceptual diagram and may not include all necessary details



RATHE ASSOCIATES	Project:	Injection Mixing	Date: Drawing No: RHB-1020
	Location:		

Snow & Ice Melting Systems

Introduction

Radiant snow and ice melting systems share many characteristics with radiant space heating systems, especially slab-on-grade installations. However, due to generally increased heat loads, loop lengths, drainage considerations, freeze protection and customer expectations, there are some notable differences. This section focuses on these distinctions.

Snow melting systems yield abundant benefits when properly designed and installed, such as:

- Safety: handicap access ramps, pedestrian walks, driveways and steps remain free of snow and ice.
- Reduced maintenance: eliminates plowing, shoveling, sanding or salting.
- Convenience: No delays waiting for a snow removal service.
- Economical: Weather dependent payback period, reduced insurance premiums.

Because snow melting system performance is dependent on the four following variable climatic conditions, it is difficult to guarantee results:

1) Rate of snow fall
2) Air temperature
3) Wind velocity
4) Humidity

Generally the designer must determine customer expectations and then discuss the cost-to-benefit relationship of various scenarios.

Most importantly, the designer must determine if and where the client need is critical or non-critical. ASHRAE defines three snow melting “Free Area Ratios” with specific guidelines for each.

Climatic data and desired outcome determines the acceptable free area ratio.

1) Free area ratio = 0 - permits 100 percent snow accumulation over entire surface. After snowfall the system is expected to melt the accumulated snow and prevent icing.
2) Free Area ratio= 0.5 - permits 50 percent accumulation snow after snowfall, the system is expected to melt the accumulated snow and prevent icing.
3) Free area ratio = 1.0 - no snow is allowed to accumulate and an extended evaporation period may be required to dry the slab completely before the melted snow freezes due to heavy loads, poor drainage or extreme drops in temperatures.

Refer to ASHRAE Applications Handbook, Chapter 50, page 4 for chart.

General Design Guidelines

HEAT OUTPUT AND SUPPLY WATER TEMPERATURE CHART

		O.A. 0F Slab Output/ Water Temp.	O.A. 10F Slab Output/ Water Temp.	O.A. 20F Slab Output/ Water Temp.	O.A. 30F Slab Output/ Water Temp.
Snowfall/hr: 0.5" Wind Speed (mph)	5	112/100	98/88	77/80	65/70
	10	150/120	126/115	96/85	75/75
	15	187/150	150/120	115/102	84/79
Snowfall/hr: 1.0" Wind Speed (mph)	5	184/125	**150/113**	133/125	105/85
	10	235/152	200/133	160/113	114/90
	15	242/179	237/152	185/126	124/94
Snowfall/hr: 1.5" Wind Speed (mph)	5	218/142	193/129	165/117	135/100
	10	270/170	233/149	191/129	144/105
	15	325/198	274/170	217/142	154/109
Snowfall/hr: 2.0" Wind Speed (mph)	5	255/161	229/147	200/134	169/117
	10	308/185	269/167	226/146	178/122
	15	363/214	310/187	252/159	264/126

O.A. = outdoor air temperature
Water Temp = supply water temperature deg. F (40% glycol)
Slab Output = BtuH/ft²

- BtuH/ft² are based on a 4" insulated concrete slab with a 2" pipe depth at 12" O.C. spacing.
- BtuH/ft² do not include allowance for back or edge losses. These typically can account for an additional 5-50%.
- In general, an un-insulated 4" concrete slab with a 40° F ground temperature (@ 24" depth) will result in approximately 25% higher losses.
- For asphalt or brick paver applications, raise water temperatures 5° F higher than shown and decrease pipe spacing to no more than 9" on center.

Concrete slabs:

Exterior concrete slab installations are similar to interior building slabs: i.e. expansion joints, control joints and keyed or rebar reinforced techniques may be encountered, follow the guidelines previously established.

It is recommended that the tubing be installed approximately 2" below the surface of the slab to minimize start-up time and prevent ice-damming.

INSUL-TARP insulation or 1" rigid insulation (exterior grade urethane insulation with 900 lb/sq.ft. compressive strength) below the slab is adequate for most systems.

Asphalt and paving stones:

To counter the reduced heat transfer of a sand/stone bed underlayment, center to center spacing should be reduced and water temperatures increased.

Asphalt and brick paver installations with sand/crushed stone underlayment should not include under-slab insulation if heavy machinery or heavy vehicle traffic is anticipated.

Asphalt driveways require special attention: during the surfacing operation constant water flow through the tubing circuits is mandatory. Water pressure should be maintained at a minimum of 20 PSI and adequate flow through the tubing should result in no more than a 20˚ F temperature rise between inlet and outlet.

Stairs, walkways and ramps:

For stairways, walkways and ramps 1/2" Comfort-PEX set 4-6" on center spacing is recommended. Also, piping must be placed carefully, within 2" of the tread nosing on every stair tread. If the tubing is installed too far inside the tread a dangerous ice dam may form on the edge of the nosing. INSUL-TARP or 1" rigid insulation is recommended under treads (and risers if tubing is installed).

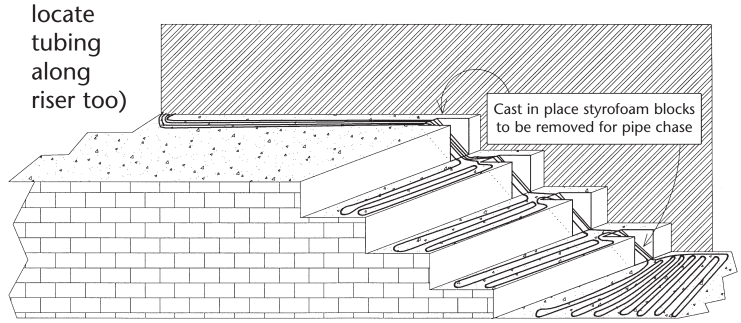
General guidelines:

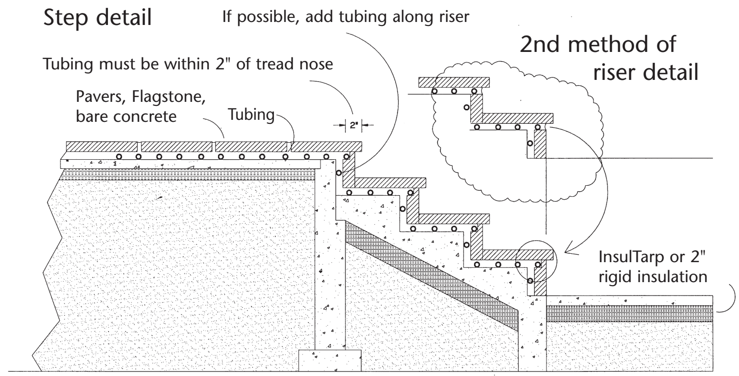
- Supply water temperature should never exceed 140˚ F in any snow melt system.
- Because the exposed perimeter to slab surface ratio is large, fully insulating under the slab is highly recommended; as is complete perimeter insulation.
- INSUL-TARP insulation or 1" rigid insulation (exterior grade urethane insulation with 900 lb/sq.ft. compressive strength) below the slab is adequate for most systems.

Design temperature drop:

With few exceptions snow melt systems are designed with a 25° F ΔT between supply and return piping circuits. In larger installations and under circumstances well known to the designer, the design temperature drop can be increased to 30° F.

Residential steps to receive stone risers and treads (if possible, locate tubing along riser too)





Example:

3/4" Comfort-PEX® tubing circuit 400 feet long.

- 20,000 Btuh heat load @ 10° F ΔT (plain water) = 4gpm flow rate = pressure drop of 26.31 FOH (Feet of Head)
- 20,000 Btuh heat load @ 20° F ΔT (plain water) = 2gpm flow rate = pressure drop of 7.59 FOH
- 20,000 Btuh heat load @ 30° F ΔT (plain water) = 1.3gpm flow rate = pressure drop of 3.51FOH

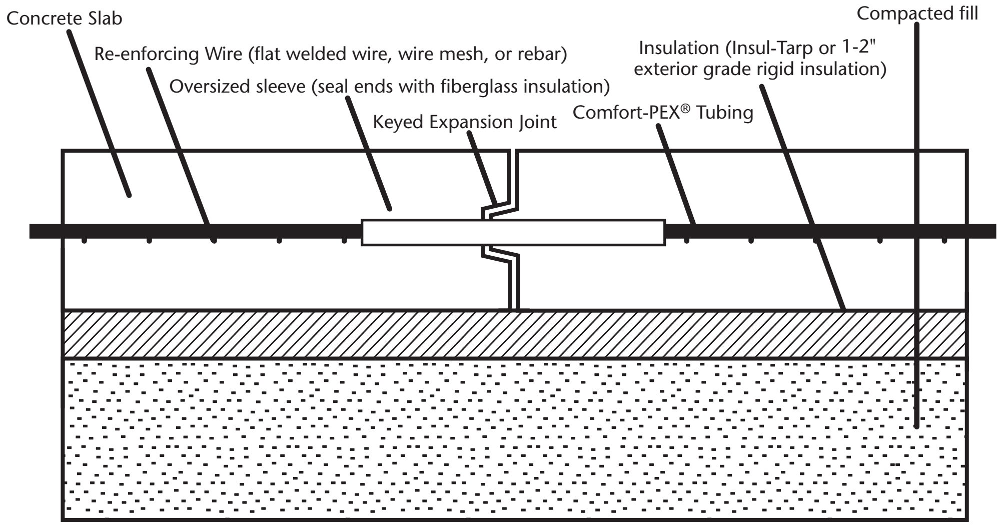
Notice that increasing the design temperature decreases the required flow rate and substantially lowers the head loss that the pump must overcome. Overall cost is thus reduced because smaller diameter tubing can be used as well as less expensive circulators.

Anti-freeze guidelines:

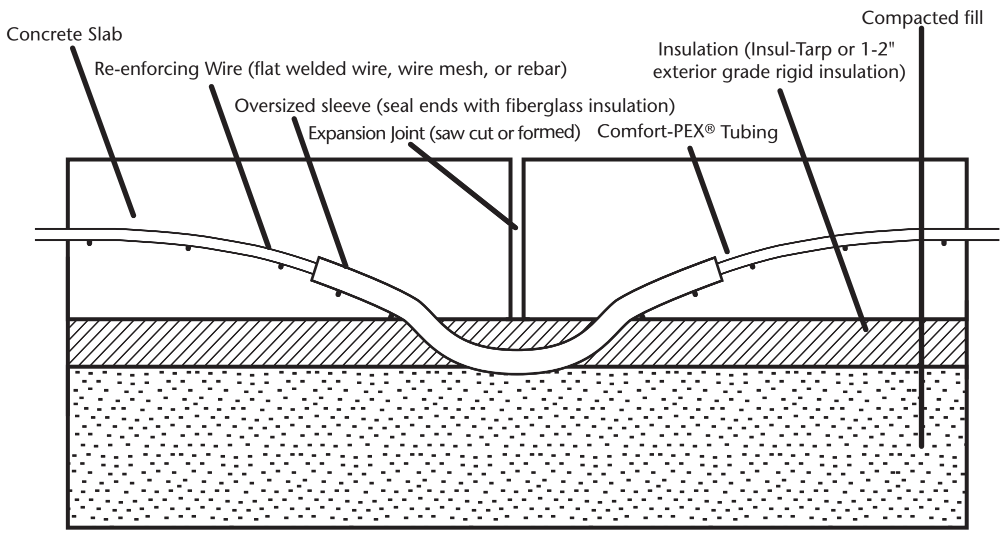
All snow melt systems require anti-freeze to protect the heating circuits. The correct anti-freeze is **INHIBITED PROPYLENE GLYCOL**. Ethylene glycol (automotive anti-freeze) contains silicates that will damage pump seals and should not be used. Glycol should be tested annually for freeze protection.

Automatic Glycol Feeders are a good alternative to maintaining and monitoring pressure. AXIOM Automatic Glycol Feeder Systems are composed of a self contained make-up pump, switch, gauge and check valve. Glycol feeders provide worry-free protection by maintaining system pressure with on-board glycol storage.

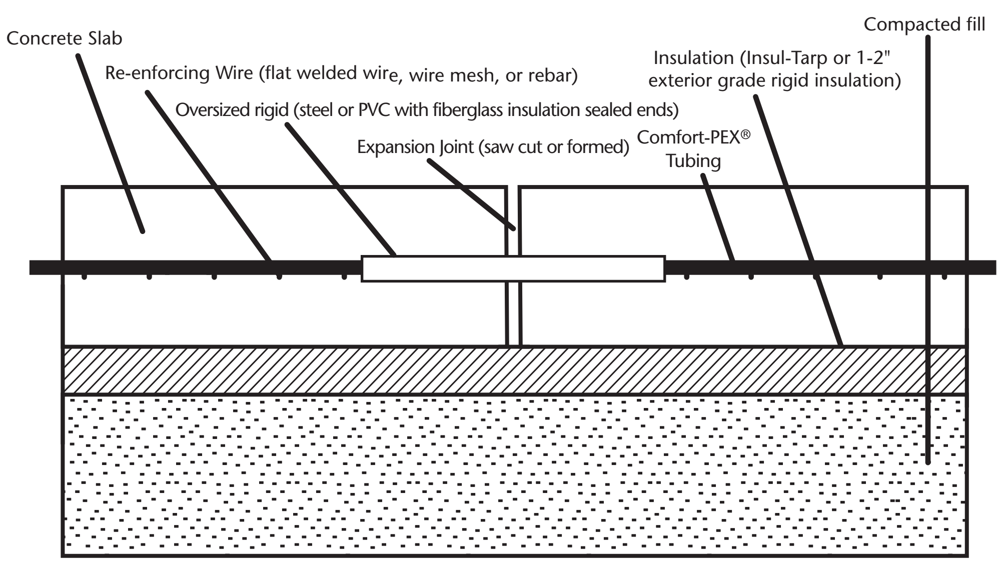
The addition of glycol increases the system pressure drop and requires a higher flow rate to transfer the same amount of heat (compared to water) to the snow melt system.



Tubing sleeved through keyed expansion joint.



Tubing sleeved below slab. In slab on grade.



Tubing sleeved with steel, PVC, or foam for additional protection.

The flow rate equation corrects for the increased flow required to deliver the same heat load as untreated water (water has a higher heat capacity). An increased flow rate increases the pressure drop through the tubing and will impact pump selection.

Also, glycol has a higher specific gravity than water and is therefore more viscous (thicker) than water. At typical water supply temperatures between 80-140˚ F, a correction of 10% (multiply by 1.10) is adequate.

50% glycol and 50% water -28˚ F
40% glycol and 60% water -13˚ F
30% glycol and 70% water +4˚ F

Expansion tank sizing:

Glycol protected systems require larger expansion tanks than do typical hydronic systems. It is imperative that the expansion tank be compatible with propylene glycol, the diaphragm bladder material must be made of EPDM rubber.

Heat Sources, Piping and Controls:

For residential and commercial snowmelt systems there are several options:

1) Dedicated boiler (cast iron or copper fin tube)
2) Dedicated water heater (if code allows)
3) Existing boiler with plate-type heat exchanger

To determine boiler size:

Multiply the square footage of the area by 150 for the net BTU's required, either add this amount to the boiler load or use this amount to size a dedicated boiler for the area. Unless it is a small area, a dedicated boiler is preferred. Cast iron boilers will require a temperature reduction method while copper fin tube boilers can operate at lower supply temperatures.

Example: (For BTU value refer to chart on page 35)
1000 sq. ft. area X 150 btu/sq.ft. = 150,000 BTU
Net Snow Melt Load

Next, the total amount of 3/4 Comfort-PEX® tubing needed can be calculated by multiplying:

sq. ft. area X pipe spacing factor (page 10 Table D)

1000 sq ft X 1.33 [9" spacing factor] = 1330 ft. 3/4 Comfort-PEX® tubing.

Over time, the ability of glycol to transfer heat diminishes. We recommend a 15-18% increase in BTU load to off-set.

With a minimally short supply and return, 4 equal loops of 333' each with a 3 loop manifold is indicated.

Note: Remember to allow for supply and return footage from the boiler to the manifold location.

Snowmelt controls

For small area and residential snow melt systems, tekmar® Snow Melt Control in conjunction with an optional Snow-Cup Switch is a good choice for simple automatic or manual on/off control.

For large area and commercial applications the commercial snow melt control with pavement sensor should be used. These intelligent controls provide adjustable set points and will maintain a minimum idle temperature in the slab (typically 32˚ F). When precipitation is detected the system ramps up to the snow melt design surface temperature (adjustable).

Drainage and slope guidelines:

Snow melting systems require good drainage to prevent re-freeze of run-off when it leaves the heated area. A thorough analysis and plan should be undertaken for any size installation. Piping to heated drains or creating sufficient slope can limit re-freeze.

Microclimates:

Sheltered, shaded or elevated locations and wind tunnel effects in particular locations should be analyzed and accounted for in system design.

Testing:

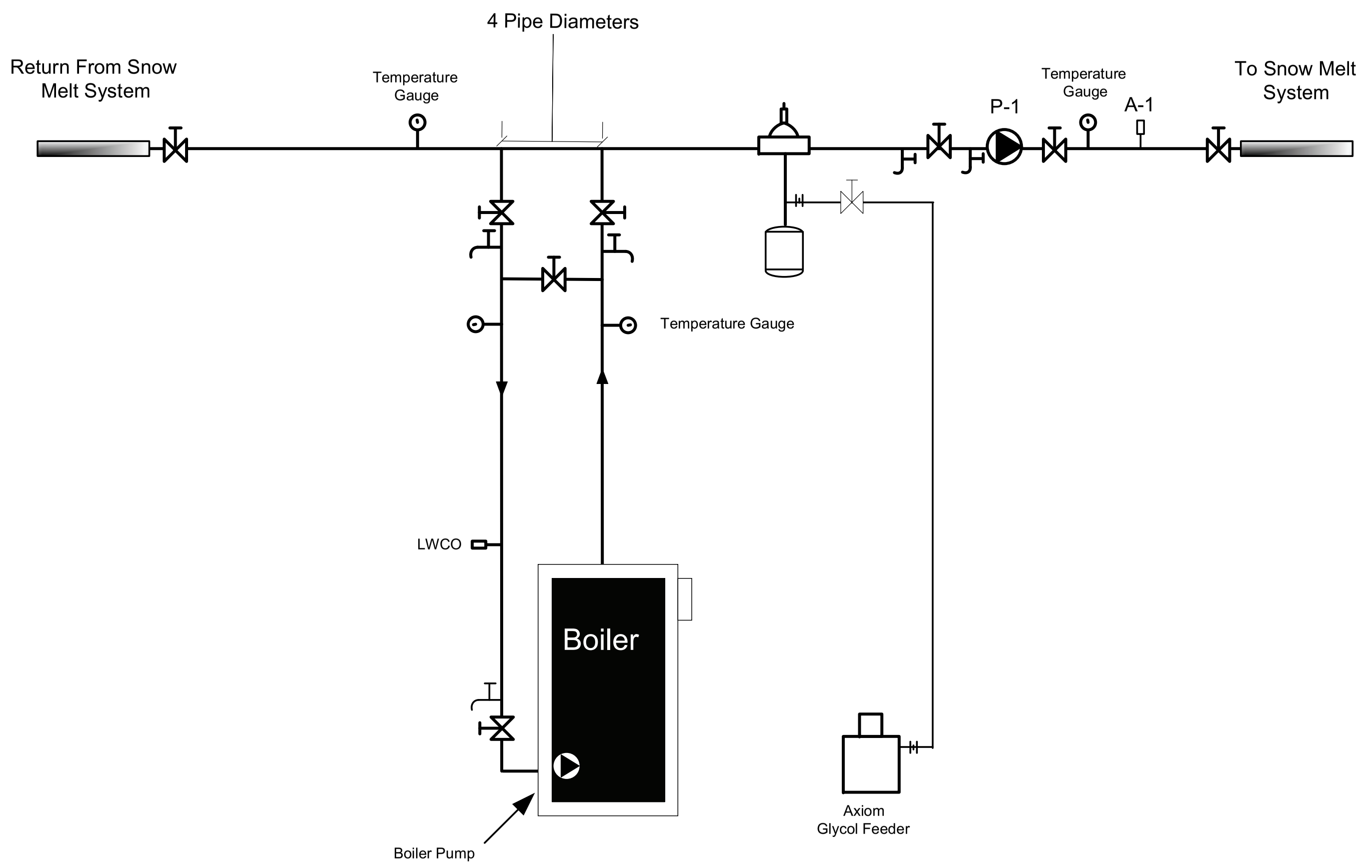
After completing the tubing installation and prior to concrete, asphalt or paver installation, the tubing should be air (not water) tested to 50-100 PSI. Air pressure should be maintained throughout the surfacing operation.

NOTE: These guidelines are provided as an aid for estimating snow melt system requirements. They are not intended to replace a complete system design by a licensed professional engineer.

Maximum Loop Lengths - Snow Melt

Comfort-PEX®	Maximum Length
1/2"	200 ft.
5/8"	300 ft.
3/4"	400 ft.
1"	600 ft.

Notes:
1) This is a conceptual diagram and may not include all necessary details.
2) A-1 Hi-Limit Aquastat. Turns off boiler when main gets above 130F.



RATHE ASSOCIATES	Project:	Snow Melt System	Date: Drawing No: RHB-1023
	Location:		

R-Value Chart

	1/8"	1/4"	3/8"	1/2"	5/8"	3/4"	7/8"	R-Value Per inch
Linoleum/Vinyl	0.21							
Ceramic tile			0.11	0.22				
Natural stone				0.2	0.44	0.9	1.2	1.4
CARPET								
Acrylic level loop			1.56	2.08	2.6	3.12		
Acrylic level loop with foam back			1.53	2.04	2.55	3.06		
Acrylic plush			1.29	1.72	2.15	2.58		
Polyester plush			1.44	1.92	2.4	2.88		
Nylon level loop			2.04	2.72	3.4	4.08		
Nylon plush			0.78	1.04	1.3	1.56		
Wool plush			1.65	2.2	2.75	3.3		
CARPET PAD								
Waffled sponge rubber			0.66	0.88				
Hair and Jute			1.47	1.96				
Bonded urethane 4 lb.			1.56	2.08				
Bonded urethane 8 lb.			1.65	2.2				
Virgin urethane 2 lb.			1.62	2.16				
HARDWOOD								
Ash			0.45	0.6		1		
Birch			0.36	0.48		0.9		
Cherry			0.45	0.6		0.72		
Hickory			0.33	0.44		0.9		
Maple			0.45	0.6		0.66		
Oak			0.39	0.52		0.78		
Poplar			0.48	0.64		0.96		
Fir-Douglas			0.57	0.76		1.14		
Fir			0.45	0.6		0.9		
Pine			0.6	0.8		1.2		
Spruce			0.6	0.8		1.2		
PLYWOOD								
1/4" luan		0.29						
Fir plywood			0.46	0.62	0.77	0.93		
BUILDING BOARD								
Gypsum or plaster board			0.32	0.45	0.56			
INSULATING MATERIALS								
Fiberglass batt insulation	Thickness listed under materials							
3-4 inches	11							
3.5 inches	13							
5.5-6.5 inches	19							
6-7.5 inches	22							
9-10 inches	30							
12-13 inches	38							
Expanded polystyrene								
extruded				2.5				5
Expanded polystyrene								
Molded beads				2				4
MASONRY								
Common brick								0.3
8" Concrete blocks								
Stone, sand, or lime								0.08
MASONRY MATERIALS								
Gypsum fiber concrete								0.6
lightweight concrete								
density - 120 lb/ft3								0.15
100 lb/ft3								0.2
80 lb/ft3								0.35
60 lb/ft3								0.6
40 lb/ft3								1.1

Pressure Loss Charts

100% Water

Comfort-PEX® Pressure Loss In Feet Of Water Per (1) One Foot Of Tube

80F°	FEET OF HEAD PER FOOT				
FLOW GPM	3/8"	1/2"	5/8"	3/4"	1"
.1	.0029	.0006	.0002		
.2	.0091	.0021	.0008		
.3	.0191	.0044	.0017		
.4	.0362	.0073	.0028		
.5	.0472	.0109	.0041	.0021	.0007
.6	.0659	.0151	.0057	.0029	.0009
.7	.0879	.0199	.0075	.0039	.0012
.8	.1097	.0253	.0095	.0049	.0015
.9	.1360	.0316	.0118	.0061	.0019
1.0	.1657	.0381	.0142	.0073	.0023
1.1	.1942	.0451	.0168	.0087	.0028
1.2	.2277	.0526	.0197	.0102	.0032
1.3	.2646	.0607	.0227	.0117	.0037
1.4	.2993	.0693	.0259	.0134	.0042
1.5	.3396	.0784	.0293	.0151	.0048
1.6	.3834	.0879	.0329	.0170	.0054
1.7	.4242	.0980	.0367	.0189	.0060
1.8	.4710	.1091	.0407	.0210	.0067
1.9	.5214	.1201	.0448	.0231	.0074
2.0	.5699	.1317	.0491	.0253	.0081
2.1		.1436	.0534	.0276	.0088
2.2		.1561	.0580	.0300	.0095
2.3		.1691	.0628	.0325	.0104
2.4		.1825	.0678	.0351	.0112
2.5		.1963	.0729	.0378	.0121
2.6			.0782	.0405	.0129
2.7			.0837	.0433	.0138
2.8			.0894	.0463	.0148
2.9			.0952	.0493	.0158
3.0			.1011	.0524	.0167
3.2				.0604	.0193
3.5				.0690	.0221
3.7				.0781	.0250
4.0				.0877	.0281
4.2					.0313
4.5					.0347
4.7					.0382
5.0					.0419

100F°	FEET OF HEAD PER FOOT				
FLOW GPM	3/8"	1/2"	5/8"	3/4"	1"
.1	.0028	.0006	.0002		
.2	.0080	.0020	.0008		
.3	.0181	.0042	.0016		
.4	.0309	.0069	.0026		
.5	.0457	.0103	.0039	.0020	.0006
.6	.0624	.0143	.0054	.0028	.0008
.7	.0832	.0189	.0071	.0037	.0012
.8	.1053	.0239	.0090	.0047	.0015
.9	.1289	.0299	.0111	.0057	.0018
1.0	.1570	.0360	.0135	.0069	.0022
1.1	.1858	.0427	.0160	.0082	.0025
1.2	.2158	.0499	.0186	.0096	.0030
1.3	.2508	.0575	.0215	.0111	.0035
1.4	.2860	.0657	.0246	.0127	.0039
1.5	.3220	.0743	.0278	.0143	.0045
1.6	.3635	.0833	.0312	.0161	.0050
1.7	.4048	.0929	.0348	.0179	.0055
1.8	.4466	.1034	.0385	.0199	.0062
1.9	.4945	.1139	.0425	.0219	.0068
2.0	.5387	.1248	.0462	.0240	.0075
2.1		.1361	.0505	.0262	.0082
2.2		.1479	.0549	.0284	.0088
2.3		.1602	.0595	.0308	.0096
2.4		.1729	.0642	.0332	.0104
2.5		.1861	.0691	.0358	.0112
2.6			.0741	.0384	.0120
2.7			.0793	.0411	.0128
2.8			.0847	.0438	.0137
2.9			.0902	.0467	.0145
3.0			.0959	.0496	.0155
3.2				.0573	.0179
3.5				.0654	.0205
3.7				.0741	.0232
4.0				.0832	.0260
4.2					.0290
4.5					.0322
4.7					.0354
5.0					.0388

120F°	FEET OF HEAD PER FOOT				
FLOW GPM	3/8"	1/2"	5/8"	3/4"	1"
.1	.0027	.0006	.0002		
.2	.0082	.0019	.0007		
.3	.0173	.0040	.0015		
.4	.0295	.0066	.0025		
.5	.0427	.0099	.0037	.0019	.0006
.6	.0596	.0137	.0052	.0027	.0008
.7	.0795	.0180	.0068	.0035	.0011
.8	.0993	.0229	.0086	.0044	.0013
.9	.1232	.0286	.0106	.0055	.0017
1.0	.1501	.0344	.0129	.0066	.0020
1.1	.1759	.0408	.0152	.0079	.0024
1.2	.2063	.0477	.0178	.0092	.0028
1.3	.2398	.0550	.0206	.0106	.0032
1.4	.2714	.0628	.0235	.0121	.0037
1.5	.3080	.0710	.0266	.0137	.0042
1.6	.3477	.0797	.0298	.0154	.0047
1.7	.3048	.0888	.0333	.0171	.0052
1.8	.4273	.0989	.0368	.0190	.0058
1.9	.4731	.1089	.0406	.0209	.0064
2.0	.5154	.1194	.0445	.0229	.0070
2.1		.1301	.0483	.0250	.0076
2.2		.1414	.0525	.0272	.0083
2.3		.1532	.0569	.0294	.0090
2.4		.1653	.0614	.0318	.0097
2.5		.1779	.0661	.0342	.0105
2.6			.0709	.0367	.0112
2.7			.0758	.0392	.0120
2.8			.0810	.0419	.0128
2.9			.0862	.0446	.0137
3.0			.0917	.0474	.0145
3.2				.0548	.0168
3.5				.0626	.0192
3.7				.0708	.0225
4.0				.0795	.0244
4.2					.0272
4.5					.0302
4.7					.0332
5.0					.0365

140°	FEET OF HEAD PER FOOT				
FLOW GPM	3/8"	1/2"	5/8"	3/4"	1"
.1	.0026	.0005	.0002		
.2	.0079	.0019	.0007		
.3	.0167	.0038	.0014		
.4	.0285	.0064	.0024		
.5	.0412	.0095	.0036	.0019	.0005
.6	.0576	.0132	.0050	.0026	.0008
.7	.0768	.0174	.0066	.0034	.0010
.8	.0959	.0221	.0083	.0043	.0013
.9	.1190	.0276	.0103	.0053	.0016
1.0	.1451	.0333	.0124	.0064	.0019
1.1	.1700	.0394	.0147	.0076	.0022
1.2	.1994	.0461	.0172	.0089	.0026
1.3	.2318	.0531	.0199	.0102	.0031
1.4	.2623	.0607	.0227	.0117	.0035
1.5	.2977	.0686	.0257	.0132	.0039
1.6	.3362	.0770	.0288	.0148	.0045
1.7	.3720	.0858	.0321	.0165	.0049
1.8	.4131	.0956	.0356	.0183	.0055
1.9	.4575	.1053	.0392	.0202	.0061
2.0	.4984	.1154	.0430	.0221	.0066
2.1		.1257	.0467	.0242	.0072
2.2		.1367	.0507	.0263	.0078
2.3		.1480	.0549	.0284	.0085
2.4		.1598	.0593	.0307	.0092
2.5		.1720	.0638	.0330	.0099
2.6			.0685	.0354	.0106
2.7			.0733	.0379	.0114
2.8			.0782	.0405	.0122
2.9			.0833	.0431	.0129
3.0			.0886	.0458	.0138
3.2				.0529	.0159
3.5				.0605	.0182
3.7				.0684	.0206
4.0				.0769	.0232
4.2					.0258
4.5					.0285
4.7					.0315
5.0					.0345

160°	FEET OF HEAD PER FOOT				
FLOW GPM	3/8"	1/2"	5/8"	3/4"	1"
.1	.0025	.0005	.0002		
.2	.0077	.0018	.0007		
.3	.0162	.0037	.0014		
.4	.0278	.0062	.0024		
.5	.0402	.0093	.0035	.0018	.0005
.6	.0561	.0129	.0049	.0025	.0007
.7	.0749	.0170	.0064	.0033	.0009
.8	.0936	.0215	.0081	.0042	.0012
.9	.1161	.0269	.0100	.0052	.0015
1.0	.1415	.0325	.0121	.0062	.0018
1.1	.1659	.0385	.0144	.0074	.0022
1.2	.1946	.0449	.0168	.0086	.0025
1.3	.2062	.0518	.0194	.0100	.0029
1.4	.2560	.0592	.0221	.0114	.0033
1.5	.2905	.0669	.0250	.0129	.0038
1.6	.3281	.0751	.0281	.0145	.0042
1.7	.3630	.0837	.0314	.0161	.0048
1.8	.4032	.0933	.0347	.0179	.0052
1.9	.4464	.1027	.0383	.0197	.0058
2.0	.4864	.1126	.0420	.0216	.0064
2.1		.1226	.0455	.0236	.0069
2.2		.1333	.0495	.0256	.0075
2.3		.1444	.0536	.0277	.0082
2.4		.1559	.0579	.0299	.0088
2.5		.1677	.0623	.0322	.0095
2.6			.0668	.0346	.0102
2.7			.0715	.0370	.0109
2.8			.0763	.0395	.0116
2.9			.0813	.0421	.0124
3.0			.0864	.0447	.0132
3.2				.0516	.0152
3.5				.0590	.0174
3.7				.0668	.0197
4.0				.0750	.0221
4.2					.0246
4.5					.0273
4.7					.0301
5.0					.0330

180°	FEET OF HEAD PER FOOT				
FLOW GPM	3/8"	1/2"	5/8"	3/4"	1"
.1	.0024	.0005	.0002		
.2	.0076	.0018	.0007		
.3	.0159	.0037	.0014		
.4	.0272	.0061	.0023		
.5	.0394	.0091	.0034	.0018	.0005
.6	.0550	.0126	.0048	.0024	.0007
.7	.0734	.0166	.0063	.0032	.0009
.8	.0917	.0211	.0080	.0041	.0012
.9	.1138	.0264	.0098	.0051	.0015
1.0	.1387	.0318	.0119	.0061	.0018
1.1	.1625	.0377	.0141	.0072	.0021
1.2	.1906	.0440	.0164	.0085	.0025
1.3	.2217	.0508	.0190	.0098	.0028
1.4	.2508	.0580	.0217	.0111	.0032
1.5	.2847	.0656	.0245	.0126	.0036
1.6	.3215	.0736	.0276	.0142	.0041
1.7	.3558	.0821	.0307	.0158	.0045
1.8	.3951	.0914	.0340	.0175	.0051
1.9	.4375	.1007	.0375	.0193	.0056
2.0	.4767	.1103	.0411	.0211	.0062
2.1		.1201	.0446	.0231	.0067
2.2		.1306	.0485	.0251	.0072
2.3		.1415	.0525	.0272	.0078
2.4		.1527	.0567	.0293	.0085
2.5		.1644	.0610	.0316	.0092
2.6			.0654	.0339	.0098
2.7			.0700	.0362	.0105
2.8			.0748	.0387	.0112
2.9			.0796	.0412	.0119
3.0			.0847	.0438	.0127
3.2				.0506	.0147
3.5				.0578	.0168
3.7				.0654	.0190
4.0				.0735	.0213
4.2					.0238
4.5					.0263
4.7					.0290
5.0					.0318

Conversions. Head To PSI = Head x 0.473 = PSI (lb per in²)

Water content (gallons) per foot
3/8" - 0.005
1/2" - 0.009
5/8" - 0.014
3/4" - 0.019
1" - 0.031

Pressure Loss Charts   30% Glycol

Comfort-PEX® Pressure Loss In Feet Of Water Per (1) One Foot Of Tube

80F°	FEET OF HEAD PER FOOT				
FLOW GPM	3/8"	1/2"	5/8"	3/4"	1"
.1	.0034	.0008	.0003		
.2	.0116	.0027	.0010		
.3	.0238	.0055	.0021		
.4	.0397	.0092	.0034		
.5	.0591	.0137	.0051	.0027	.0004
.6	.0818	.0190	.0071	.0037	.0078
.7	.1077	.0250	.0093	.0048	.001
.8	.1367	.0317	.0118	.0061	.0013
.9	.1687	.0391	.0146	.0076	.0017
1.0	.2036	.0472	.0176	.0091	.0022
1.1	.2414	.0560	.0208	.0108	.0027
1.2	.0283	.0654	.0243	.0126	.0032
1.3	.3253	.0754	.0281	.0145	.0038
1.4	.3714	.0861	.0320	.0166	.0044
1.5	.4201	.0974	.0362	.0188	.005
1.6	.4715	.1093	.0407	.0211	.0048
1.7	.5255	.1218	.0453	.0235	.0055
1.8	.0582	.1349	.0502	.0260	.0052
1.9	.6411	.1486	.0553	.0286	.0060
2.0	.7027	.1628	.0606	.0314	.0069
2.1		.1777	.0661	.0342	.0077
2.2		.1931	.0718	.0372	.0086
2.3		.2091	.0778	.0403	.0095
2.4		.2256	.0839	.0435	.0104
2.5		.2427	.0902	.0468	.0114
2.6			.0968	.0501	.0132
2.7			.1036	.0536	.0144
2.8			.1105	.0573	.0156
2.9			.1177	.0610	.0169
3.0			.1250	.0648	.0166
3.2				.0747	.0190
3.5				.0853	.0220
3.7				.0965	.0256
4.0				.1083	.0292

100F°	FEET OF HEAD PER FOOT				
FLOW GPM	3/8"	1/2"	5/8"	3/4"	1"
.1	.0032	.0007	.0003		
.2	.0109	.0025	.0010		
.3	.0225	.0052	.0020		
.4	.0376	.0087	.0033		
.5	.0560	.0130	.0049	.0025	.0005
.6	.0775	.0180	.0067	.0035	.0079
.7	.1020	.0237	.0088	.0046	.0011
.8	.1295	.0300	.0112	.0058	.0014
.9	.1598	.0371	.0138	.0071	.0018
1.0	.1929	.0447	.0167	.0086	.0023
1.1	.2287	.0530	.0198	.0102	.0028
1.2	.2672	.0619	.0231	.0119	.0033
1.3	.3083	.0715	.0267	.0138	.0039
1.4	.3519	.0816	.0304	.0157	.0045
1.5	.3982	.0923	.0344	.0178	.0051
1.6	.4469	.1036	.0386	.0200	.0049
1.7	.4981	.1154	.0431	.0222	.0056
1.8	.5518	.1278	.0477	.0246	.0062
1.9	.6078	.1408	.0525	.0271	.007
2.0	.6663	.1543	.0576	.0297	.0079
2.1		.1684	.0628	.0324	.0087
2.2		.1830	.0683	.0353	.0096
2.3		.2139	.0739	.0382	.0105
2.4		.2301	.0797	.0412	.0114
2.5			.0858	.0443	.0124
2.6			.0920	.0475	.0142
2.7			.0985	.0508	.0154
2.8			.1151	.0543	.0166
2.9			.1119	.0578	.0179
3.0			.1189	.0614	.0176
3.2				.0708	.02
3.5				.0809	.023
3.7				.0915	.0266
4.0				.1027	.0302

120F°	FEET OF HEAD PER FOOT				
FLOW GPM	3/8"	1/2"	5/8"	3/4"	1"
.1	.0029	.0007	.0003		
.2	.0101	.0023	.0009		
.3	.0208	.0048	.0018		
.4	.0347	.0081	.0030		
.5	.0517	.0120	.0045	.0023	.0006
.6	.0716	.0166	.0062	.0032	.008
.7	.0942	.0219	.0081	.0042	.0012
.8	.1196	.0277	.0103	.0053	.0015
.9	.1477	.0342	.0127	.0066	.0019
1.0	.1783	.0413	.0154	.0080	.0024
1.1	.2144	.0490	.0182	.0094	.0029
1.2	.2470	.0572	.0213	.0110	.0034
1.3	.2851	.0660	.0246	.0127	.004
1.4	.3255	.0754	.0280	.0145	.0046
1.5	.3683	.0853	.0317	.0164	.0052
1.6	.4135	.0957	.0356	.0184	.0059
1.7	.4609	.1067	.0397	.0206	.0066
1.8	.5106	.1182	.0440	.0228	.0072
1.9	.5625	.1302	.0484	.0251	.008
2.0	.6167	.1428	.0531	.0275	.0089
2.1		.1558	.0579	.0300	.0097
2.2		.1693	.0629	.0326	.0106
2.3		.1834	.0682	.0353	.0115
2.4		.1979	.0735	.0381	.0124
2.5		.2129	.0791	.0410	.0134
2.6			.0849	.0440	.0152
2.7			.0908	.0470	.0164
2.8			.0969	.0502	.0176
2.9			.1032	.0534	.0189
3.0			.1097	.0568	.0186
3.2				.0655	.021
3.5				.0749	.024
3.7				.0847	.0276
4.0				.0951	.0312

140F°	FEET OF HEAD PER FOOT				
FLOW GPM	3/8"	1/2"	5/8"	3/4"	1"
.1	.0028	.0007	.0002		
.2	.0096	.0022	.0008		
.3	.0198	.0046	.0017		
.4	.0332	.0077	.0029		
.5	.0494	.0115	.0043	.0022	.0003
.6	.0684	.0159	.0059	.0031	.0007
.7	.0901	.0209	.0078	.0040	.0012
.8	.1144	.0265	.0099	.0051	.0017
.9	.1412	.0327	.0122	.0063	.0022
1.0	.1705	.0395	.0147	.0076	.0027
1.1	.2022	.0468	.0174	.0090	.0033
1.2	.2363	.0547	.0204	.0105	.0038
1.3	.2727	.0631	.0235	.0122	.0043
1.4	.3114	.0721	.0268	.0139	.0048
1.5	.3524	.0816	.0303	.0157	.0053
1.6	.3956	.0916	.0340	.0176	.0058
1.7	.4410	.1021	.0379	.0197	.0063
1.8	.4885	.1131	.0420	.0218	.0068
1.9	.5383	.1246	.0463	.0240	.0074
2.0	.5901	.1366	.0508	.0263	.0079
2.1		.1490	.0554	.0287	.0084
2.2		.1620	.0602	.0312	.0089
2.3		.1754	.0652	.0338	.0094
2.4		.1893	.0704	.0364	.0099
2.5		.2037	.0757	.0392	.0106
2.6			.0812	.0420	.0111
2.7			.0869	.0450	.0116
2.8			.0927	.0480	.0121
2.9			.0988	.0511	.0126
3.0			.1049	.0543	.0196
3.2				.0627	.0201
3.5				.0716	.0206
3.7				.0811	.0211
4.0				.0910	.0216

160F°	FEET OF HEAD PER FOOT				
FLOW GPM	3/8"	1/2"	5/8"	3/4"	1"
.1	.0025	.0006	.0002		
.2	.0087	.0020	.0008		
.3	.0180	.0042	.0016		
.4	.0301	.0070	.0026		
.5	.0448	.0104	.0039	.0021	.0003
.6	.0621	.0144	.0054	.0029	.0008
.7	.0818	.0189	.0071	.0038	.0013
.8	.1039	.0241	.0090	.0048	.0018
.9	.1283	.0297	.0111	.0060	.0023
1.0	.1549	.0359	.0134	.0072	.0028
1.1	.1838	.0425	.0159	.0086	.0034
1.2	.2148	.0497	.0186	.0100	.0039
1.3	.2479	.0574	.0215	.0115	.0044
1.4	.2832	.0655	.0245	.0132	.0049
1.5	.3205	.0743	.0277	.0149	.0055
1.6	.3599	.0832	.0311	.0167	.0060
1.7	.4012	.0928	.0347	.0186	.0065
1.8	.4446	.1028	.0385	.0207	.0070
1.9	.4899	.1133	.0424	.0228	.0076
2.0	.5372	.1242	.0465	.0249	.0084
2.1		.1356	.0507	.0272	.0089
2.2		.1474	.0551	.0296	.0094
2.3		.1596	.0597	.0320	.0099
2.4		.1723	.0644	.0346	.0108
2.5		.1854	.0693	.0372	.0113
2.6			.0744	.0399	.0118
2.7			.0796	.0427	.0123
2.8			.0850	.0456	.0134
2.9			.0905	.0485	.0186
3.0			.0962	.0516	.0191
3.2				.0596	.0197
3.5				.0680	.0202
3.7				.0770	.0207
4.0				.0864	.0212

180F°	FEET OF HEAD PER FOOT				
FLOW GPM	3/8"	1/2"	5/8"	3/4"	1"
.1	.0026	.0006	.0002		
.2	.0088	.0020	.0008		
.3	.0182	.0042	.0016		
.4	.0304	.0070	.0026		
.5	.0452	.0105	.0039	.0020	.0002
.6	.0627	.0145	.0054	.0028	.0007
.7	.0825	.0191	.0071	.0037	.0010
.8	.1048	.0243	.0090	.0047	.0013
.9	.1294	.0300	.0111	.0058	.0016
1.0	.1563	.0362	.0135	.0070	.0021
1.1	.1854	.0429	.0160	.0083	.0028
1.2	.2167	.0502	.0186	.0097	.0033
1.3	.2502	.0579	.0215	.0111	.0039
1.4	.2857	.0661	.0246	.0127	.0044
1.5	.3234	.0748	.0278	.0144	.0049
1.6	.3631	.0840	.0312	.0162	.0055
1.7	.4048	.0936	.0348	.0180	.0060
1.8	.4485	.1037	.0385	.0200	.0065
1.9	.4942	.1143	.0425	.0220	.0070
2.0	.5419	.1253	.0466	.0241	.0076
2.1		.1368	.0508	.0263	.0081
2.2		.1487	.0552	.0286	.0089
2.3		.1610	.0598	.0310	.0095
2.4		.1738	.0646	.0334	.0100
2.5		.1870	.0695	.0360	.0105
2.6			.0745	.0386	.0118
2.7			.0797	.0413	.0123
2.8			.0851	.0441	.0128
2.9			.0907	.0469	.0181
3.0			.0963	.0499	.0186
3.2				.0576	.0192
3.5				.0658	.0197
3.7				.0744	.0202
4.0				.0836	.0208

Conversions. Head To PSI = Head x 0.473 = PSI (lb per in^2)

Water content (gallons) per foot
3/8" - 0.005
1/2" - 0.009
5/8" - 0.014
3/4" - 0.019
1" - 0.031

Pressure Loss Charts 40% Glycol

Comfort-PEX® Pressure Loss In Feet Of Water Per (1) One Foot Of Tube

80F°	FEET OF HEAD PER FOOT				
FLOW GPM	3/8"	1/2"	5/8"	3/4"	1"
.1	.0037	.0009	.0003		
.2	.0127	.0030	.0011		
.3	.0261	.0061	.0023		
.4	.0436	.0101	.0038		
.5	.0649	.0151	.0056	.0029	.0009
.6	.0898	.0208	.0078	.0040	.0012
.7	.1182	.0274	.0102	.0053	.0016
.8	.1499	.0348	.0130	.0067	.0020
.9	.1849	.0429	.0160	.0083	.0025
1.0	.2232	.0518	.0193	.0100	.0030
1.1	.2645	.0614	.0229	.0118	.0036
1.2	.3089	.0717	.0267	.0138	.0042
1.3	.3564	.0827	.0308	.0160	.0048
1.4	.4068	.0944	.0351	.0182	.0055
1.5	.4601	.1067	.0397	.0206	.0062
1.6	.5163	.1198	.0446	.0231	.0070
1.7	.5754	.1334	.0497	.0257	.0078
1.8	.6372	.1478	.0550	.0285	.0087
1.9	.7019	.1627	.0606	.0314	.0096
2.0	.7692	.1784	.0664	.0344	.0105
2.1		.1946	.0724	.0375	.0114
2.2		.2114	.0787	.0408	.0124
2.3		.2289	.0852	.0441	.0135
2.4		.2470	.0919	.0476	.0145
2.5		.2657	.0988	.0512	.0157
2.6			.1060	.0549	.0168
2.7			.1134	.0588	.0180
2.8			.1210	.0627	.0192
2.9			.1288	.0668	.0205
3.0			.1369	.0709	.0217
3.2				.0818	.0251
3.5				.0934	.0287
3.7				.1057	.0325
4.0				.1186	.0365
4.2					.0407
4.5					.0451
4.7					.0497
5.0					.0545

100F°	FEET OF HEAD PER FOOT				
FLOW GPM	3/8"	1/2"	5/8"	3/4"	1"
.1	.0035	.0008	.0003		
.2	.0119	.0028	.0010		
.3	.0244	.0057	.0021		
.4	.0407	.0095	.0035		
.5	.0606	.0141	.0052	.0027	.0008
.6	.0839	.0195	.0073	.0038	.0011
.7	.1104	.0256	.0095	.0049	.0015
.8	.1401	.0325	.0121	.0063	.0019
.9	.1729	.0401	.0149	.0077	.0023
1.0	.2086	.0484	.0180	.0093	.0028
1.1	.2473	.0574	.0214	.0111	.0033
1.2	.2889	.0670	.0249	.0129	.0039
1.3	.3333	.0773	.0288	.0149	.0045
1.4	.3805	.0882	.0328	.0170	.0051
1.5	.4304	.0998	.0371	.0192	.0058
1.6	.4830	.1120	.0417	.0216	.0065
1.7	.5383	.1248	.0464	.0241	.0072
1.8	.5962	.1382	.0514	.0266	.0080
1.9	.6567	.1522	.0566	.0293	.0088
2.0	.7198	.1668	.0621	.0322	.0097
2.1		.1820	.0677	.0351	.0106
2.2		.1978	.0736	.0381	.0115
2.3		.2142	.0797	.0413	.0125
2.4		.2311	.0860	.0445	.0135
2.5		.2486	.0925	.0479	.0145
2.6			.0992	.0514	.0156
2.7			.1061	.0550	.0167
2.8			.1132	.0587	.0178
2.9			.1205	.0624	.0189
3.0			.1281	.0663	.0201
3.2				.0766	.0233
3.5				.0874	.0266
3.7				.0989	.0301
4.0				.1110	.0328
4.2					.0337
4.5					.0418
4.7					.0460
5.0					.0505

120F°	FEET OF HEAD PER FOOT				
FLOW GPM	3/8"	1/2"	5/8"	3/4"	1"
.1	.0032	.0008	.0003		
.2	.0111	.0026	.0010		
.3	.0228	.0053	.0020		
.4	.0380	.0088	.0033		
.5	.0566	.0131	.0049	.0025	.0008
.6	.0784	.0182	.0068	.0035	.0010
.7	.1032	.0239	.0089	.0046	.0014
.8	.1310	.0304	.0113	.0059	.0017
.9	.1616	.0375	.0140	.0072	.0022
1.0	.1951	.0452	.0168	.0087	.0026
1.1	.2313	.0536	.0200	.0103	.0031
1.2	.2702	.0626	.0233	.0121	.0036
1.3	.3118	.0723	.0269	.0139	.0042
1.4	.3560	.0825	.0307	.0159	.0048
1.5	.4027	.0933	.0347	.0180	.0054
1.6	.4520	.1047	.0390	.0202	.0061
1.7	.5038	.1167	.0434	.0225	.0068
1.8	.5580	.1293	.0481	.0249	.0075
1.9	.6147	.1424	.0530	.0274	.0083
2.0	.6738	.1561	.0580	.0301	.0091
2.1		.1703	.0633	.0328	.0099
2.2		.1851	.0688	.0357	.0108
2.3		.2004	.0745	.0386	.0117
2.4		.2163	.0804	.0417	.0126
2.5		.2327	.0865	.0448	.0136
2.6			.0928	.0481	.0146
2.7			.0993	.0514	.0156
2.8			.1059	.0549	.0167
2.9			.1128	.0584	.0178
3.0			.1199	.0621	.0189
3.2				.0716	.0218
3.5				.0818	.0249
3.7				.0926	.0282
4.0				.1039	.0317
4.2					.0354
4.5					.0392
4.7					.0432
5.0					.0474

140°	FEET OF HEAD PER FOOT				
FLOW GPM	3/8"	1/2"	5/8"	3/4"	1"
.1	.0030	.0007	.0003		
.2	.0104	.0024	.0009		
.3	.0213	.0049	.0018		
.4	.0357	.0082	.0031		
.5	.0531	.0123	.0046	.0024	.0007
.6	.0735	.0170	.0063	.0033	.0010
.7	.0968	.0224	.0083	.0043	.0013
.8	.1229	.0284	.0106	.0055	.0017
.9	.1517	.0350	.0130	.0068	.0021
1.0	.1831	.0423	.0157	.0082	.0025
1.1	.2171	.0501	.0186	.0097	.0029
1.2	.2537	.0585	.0218	.0113	.0034
1.3	.2927	.0676	.0251	.0130	.0040
1.4	.3342	.0771	.0287	.0149	.0045
1.5	.3781	.0873	.0324	.0168	.0051
1.6	.4245	.0979	.0364	.0189	.0058
1.7	.4731	.1091	.0406	.0210	.0064
1.8	.5241	.1209	.0450	.0233	.0071
1.9	.5774	.1332	.0495	.0257	.0079
2.0	.6330	.1460	.0543	.0281	.0086
2.1		.1593	.0592	.0307	.0094
2.2		.1731	.0644	.0333	.0102
2.3		.1875	.0697	.0361	.0111
2.4		.2023	.0752	.0390	.0120
2.5		.2177	.0809	.0419	.0129
2.6			.0868	.0450	.0138
2.7			.0929	.0481	.0148
2.8			.0991	.0513	.0158
2.9			.1055	.0547	.0168
3.0			.1121	.0581	.0179
3.2				.0670	.0207
3.5				.0765	.0238
3.7				.0866	.0268
4.0				.0972	.0301
4.2					.0335
4.5					.0371
4.7					.0409
5.0					.0449

160°	FEET OF HEAD PER FOOT				
FLOW GPM	3/8"	1/2"	5/8"	3/4"	1"
.1	.0028	.0007	.0002		
.2	.0097	.0023	.0008		
.3	.0200	.0046	.0017		
.4	.0334	.0077	.0029		
.5	.0497	.0115	.0043	.0022	.0007
.6	.0689	.0160	.0059	.0031	.0009
.7	.0907	.0210	.0078	.0041	.0012
.8	.1152	.0267	.0099	.0051	.0016
.9	.1422	.0330	.0123	.0064	.0020
1.0	.1717	.0398	.0148	.0077	.0024
1.1	.2036	.0472	.0175	.0091	.0028
1.2	.2379	.0551	.0205	.0106	.0033
1.3	.2746	.0636	.0237	.0123	.0038
1.4	.3136	.0726	.0270	.0140	.0043
1.5	.3548	.0822	.0305	.0158	.0049
1.6	.3983	.0922	.0343	.0178	.0055
1.7	.4440	.1028	.0382	.0198	.0062
1.8	.4919	.1139	.0423	.0219	.0068
1.9	.5420	.1254	.0466	.0242	.0075
2.0	.5942	.1375	.0511	.0265	.0083
2.1		.1501	.0558	.0289	.0090
2.2		.1631	.0606	.0314	.0098
2.3		.1767	.0656	.0340	.0106
2.4		.1907	.0708	.0367	.0115
2.5		.2051	.0762	.0395	.0123
2.6			.0818	.0423	.0132
2.7			.0875	.0453	.0142
2.8			.0934	.0484	.0151
2.9			.0994	.0515	.0161
3.0			.1057	.0547	.0171
3.2				.0631	.0198
3.5				.0721	.0226
3.7				.0816	.0256
4.0				.0916	.0287
4.2					.0320
4.5					.0355
4.7					.0391
5.0					.0429

180°	FEET OF HEAD PER FOOT				
FLOW GPM	3/8"	1/2"	5/8"	3/4"	1"
.1	.0027	.0006	.0002		
.2	.0092	.0021	.0008		
.3	.0190	.0044	.0016		
.4	.0317	.0074	.0027		
.5	.0473	.0110	.0041	.0021	.0007
.6	.0655	.0152	.0056	.0029	.0009
.7	.0863	.0200	.0074	.0039	.0012
.8	.1096	.0254	.0094	.0049	.0015
.9	.1353	.0313	.0117	.0060	.0019
1.0	.1633	.0378	.0141	.0073	.0023
1.1	.1937	.0449	.0167	.0086	.0027
1.2	.2264	.0524	.0195	.0101	.0032
1.3	.2613	.0605	.0225	.0117	.0037
1.4	.2984	.0691	.0257	.0133	.0042
1.5	.3377	.0782	.0291	.0150	.0047
1.6	.3791	.0877	.0326	.0169	.0053
1.7	.4226	.0978	.0364	.0188	.0058
1.8	.4683	.1084	.0403	.0209	.0066
1.9	.5160	.1194	.0444	.0230	.0073
2.0	.5657	.1309	.0486	.0252	.0080
2.1		.1428	.0531	.0275	.0087
2.2		.1553	.0577	.0299	.0094
2.3		.1681	.0625	.0323	.0102
2.4		.1815	.0674	.0349	.0110
2.5		.1953	.0725	.0376	.0119
2.6			.0778	.0403	.0128
2.7			.0833	.0431	.0137
2.8			.0889	.0460	.0146
2.9			.0947	.0490	.0155
3.0			.1006	.0521	.0165
3.2				.0601	.0191
3.5				.0687	.0218
3.7				.0777	.0247
4.0				.0872	.0277
4.2					.0309
4.5					.0342
4.7					.0377
5.0					.0414

Conversions. Head To PSI = Head x 0.473 = PSI (lb per in^2)

Water content (gallons) per foot
3/8" - 0.005
1/2" - 0.009
5/8" - 0.014
3/4" - 0.019
1" - 0.031

Appendix A: Floor Covering Material

Floor Covering

The choice of floor coverings (tile, wood, carpet, etc.) over radiant floor heating is one of the most important decisions a customer must make and a heating system designer must understand. The choice of flooring should be well understood by the customer, installer and the heating system designer. Failure to communicate the flooring choice can result in a system that does not deliver the intended purpose…to provide a comfortable, efficient heating system. The following is a brief description of various materials, their advantages and disadvantages.

Tile (ceramic/natural stone)

Tile, whether ceramic or natural stone, is a highly desirable floor covering. These products are very stable and tolerate temperature extremes. They are highly resistant to moisture and have minimum expansion and contraction qualities. These products have a low resistance to heat flow; i.e., they allow heat to pass through with relatively warm water temperatures. Typical water temperatures range from 80° F to 140° F. Maximum heat transfer through tile is 35BtuH/ft^2 at a room set point of 70° F. At this heat transfer rate the floor temperature will be 85° F, the maximum floor temperature a typical person will feel comfortable at.

Wood Floors

Wood floors have been used successfully with radiant heat for the past 30 years. Although there have been stories of warped, cupped and split floors, this is more often than not the fault of the original installation and not the radiant heating system. Wood floors have challenging issues that are handled easily by properly calculating the heat load, applying design knowledge that is accepted by wood floor manufacturers (respecting maximum floor temperatures), and proper heating system installation; and most importantly, the actual installation of the wood floor system itself. The following information has been gathered from professional wood floor installers, wood floor manufacturers, and wood floor trade associations.

Wood floors are a natural product that contains natural moisture within the wood fibers. When wood fibers are exposed to water molecules the fibers swell. Likewise, when the fibers lose water molecules they shrink. Manufactured flooring (strip flooring, tongue and groove (T&G) for instance) is kiln dried to a specific moisture content as part of the manufacturing process. The moisture content of the flooring corresponds to a particular relative humidity. The amount of moisture present in today's flooring is about 7-8% at a corresponding humidity level of 40%. This is the approximate natural average.

The leading cause of problems with wood floors is rarely the heating system, cupping, gapping, and checking (cracking) are typically issues related to installation error. Moisture present at the job site is the most common cause of wood floor failure. If the delivered material is exposed to excessive moisture at the job site, it will swell throughout the installation. This can occur if the installation is rushed due to project scheduling. If the structure has a high moisture issue, it is the structure or job site that requires "drying out", not the wood flooring. Wood floors should never be installed unless the moisture content in the building resembles the anticipated moisture content of the occupied structure.

The easiest method to check for excessive moisture in either concrete or plywood is to completely tape a 1'x1' piece of polyethylene plastic on the floor. If moisture is present it will cloud or even form droplets on the underside of the plastic. The most accurate method for moisture detection is a probe type moisture meter. If flooring is installed with a high moisture content, as soon as the heat is turned on or the structure is sealed sufficiently to allow the humidity levels to drop significantly, the floors will begin to shrink, gap, and cup. This can occur with the heat off. This is another reason for proper site preparation. Wood floors should be installed in a heated space that is similar to the ultimate occupant temperatures. This heat should not be supplied by the floor system. A supplemental source of heat should be brought in if required.

Wood floors are typically nailed to a suitable sub floor material. This takes the form of 5/8" or 3/4" plywood. An alternate method is to lay 2 X 4 sleepers down on 12" spacing and nail to the sleepers that are partially filled with concrete. By partially filling (screeding a concave shape) the sleepers, thermal mass provides the Comfort-PEX® tubing the best heat transfer capacity. The shaped mass also provides the occupants with the natural feel wood floors exhibit when fastened to traditional sub floors.

Note: Glue down flooring systems should be discussed with the adhesive manufacturer for compatibility with heated floors. Issues have been raised concerning longevity of glued flooring and radiant heat and possible noise from expansion and contraction between wood floors and the adhesive.

Design Considerations

- Hardwoods (i.e. oak, maple) are a better choice over softwoods (i.e. pine).
- Prefinished floating wood floor systems are an excellent alternative to traditional wood flooring.
- Use boards narrower than 3". The narrower the board the less shrinkage that will occur. If wider boards are desired lower surface temperatures should be main-

with the system design.
- Quartersawn flooring should be used whenever possible in place of plainsawn. Quartersawn material expands and contracts only 30% that of plainsawn.

tained and the resulting lower heat outputs confirmed with the system design.

Laminated or floating floor systems

A recent addition to wood floor choice is an engineered flooring product. These products are constructed of multiple layers, which yield a very stable product. Laminated flooring is very compatible with radiant floor heating. For calculation purposes laminated floors are treated the same as tile, namely 35BtuH/ft^2 and 85° F surface temperature. These products are thin by nature and thus work well with radiant heating systems. The durability and resemblance to natural wood products have the laminated flooring products gaining wide acceptance in many applications.

Carpet and carpet/pad

Carpet is still the most widely used flooring product. It can work well with radiant floor heating, but there are significant factors that must be accounted for. Carpet and padding are by definition natural insulators. Many applications use carpet because it insulates the occupant from cold floors. These floors could be concrete or wood over a cold crawl space. Because carpet and padding are insulators the heat transfer is limited to about 25 BtuH/ft^2. The supply water temperatures are usually kept below 150° F to limit overheating of the padding. It is important to recognize the difference between good padding and good carpet. The best padding for radiant heat and typically the only padding recommended is called slab foam rubber.

The flatness of the product and relatively low resistance to heat transfer allows a broader range of carpet choices. The best thickness for radiant heating is 3/8" thick and an associated R-Value of 0.47. Compared to inexpensive bonded urethane (this type of padding is recognized by the different colored chunks glued together). 1/2" 4 lb. density has a heat resistive value of R-2.09. This means that to transfer the same amount of heat the water temperature will be approximately 30°F hotter under the bonded urethane padding. Depending on the carpet choice the radiant floor system may not be capable of delivering enough heat to the space.

The recommended carpet is the best quality the customer can afford. The “ounce weight” or “ounces per square yard” provides a reliable measure of the quality and density of the carpet construction. The heavier the ounce weight, the less resistive the carpet is to heat transfer. This seems contradictory but in reality the tighter the strands are packed, the fewer air cells exist between strands - air is an insulator.

The type of carpet is also important. Dense, cut pile is the favored choice. Loop carpet is generally avoided because the loops form tiny air cells, which creates a roadblock for heat transfer. Carpet height has the single greatest impact on heat transfer; thicker carpets have higher R-values and should be limited to 1/2" or less.

Mixing floor coverings (i.e. Carpet/pad over wood floor)

The contractor must make the customer aware that the floor covering will greatly affect the floor heating system. Under no circumstances should carpet and padding be placed on radiantly heated wood floors. To overcome the increased resistance to heat flow the water temperature would need to be raised approximately 30°F. At this temperature the wood floors will experience gapping and possible cupping. Thin area rugs without padding are an option if they are taken into account during the design phase. If the heat load is less than 20BtuH/ft^2 area rugs can be used without concern.

Carpet and padding can be installed over ceramic tile floors as long as the heat load is less than 25BtuH/ft^2 with no adverse effects to ceramic tile.

Carpet and padding over linoleum or vinyl tile should be avoided because the glue mastic may be not capable of tolerating the higher temperatures that will develop under the padding.

Additional information is available at the following sites:

1) www.woodfloors.org (National Wood Flooring Association)

2) www.hardwoodinfo.com (American Hardwood Information Center)

3) www.rugsandcarpets.com (Carpet and Rug Institute)

Appendix B: Comfort-PEX® Tubing and Conventional Heat Emitters

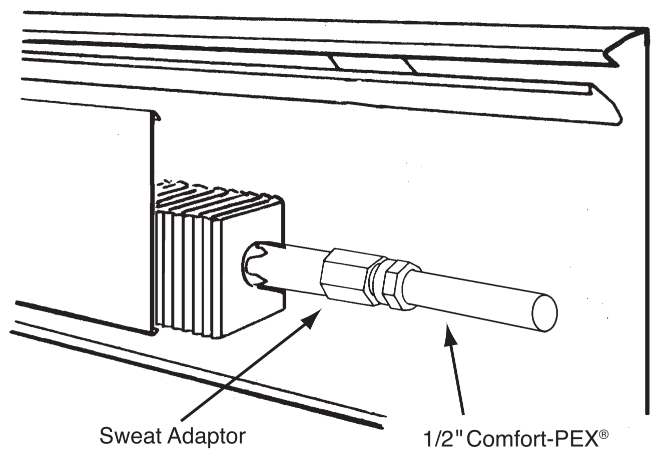
The unique flexibility in material and design of Comfort-PEX® tubing makes it the ideal choice for many conventional hydronic heating installations. Using Comfort-PEX® in these type applications is less expensive and easier to install than copper piping.

Comfort-PEX® is perfect for use with:

- Fin-tube Baseboard
- Panel Radiators
- Fan Coils
- Cast Iron Radiators

Comfort-PEX® allows for continuous pipe lengths to be run to each unit or zone, in much the same way an electrician would snake wires. Comfort-PEX® fittings easily allow connection to copper or other rigid piping.

Fin-Tube Baseboard



Maximum single loop of Comfort-PEX® to Baseboard lengths are based on 20˚ F temperature drop.

Baseboard output based on 180˚ F and 600 Btuh/ft (100% water)

(All calculations are based on an Armstrong circulator or equal)

			Armstrong Astro 30-3		Armstrong Astro 50-3	
BtuH	Baseboard Length (ft)	(gpm)	1/2" Comfort-PEX® Max length (ft)	5/8" Comfort-PEX® Max length (ft)	1/2" Comfort-PEX® Max length (ft)	5/8" Comfort-PEX® Max length (ft)
9000	15	0.90	400	1,000		
10,800	18	1.08	340	870		
12,600	21	1.26	240	650		
14,400	24	1.44	185	480		
16,200	27	1.62	150	400		
18,000	30	1.80	130	350		
19,800	33	1.98	100	290		
21,600	36	2.16	90	240		
23,400	39	2.34	75	200		
25,200	42	2.52	65	175		
27,000	45	2.70		160		
28,800	48	2.88		140		
30,600	51	3.06			90	242
32,400	54	3.24			86	230
34,200	57	3.42			80	210
36,000	60	3.60			73	180
37,800	63	3.78			64	164
39,600	66	3.96			58	140
41,400	69	4.14			50	125

Maximum Number of Baseboard Loops (multiple loop manifold system) As per Armstrong ASTRO 30-3 circulator (ASTRO 50-3 not recommended). Based on 15˚ F temperature drop to minimize reduced heat output of long baseboard lengths.

Note-Chart is a guide and represents an attempt to provide guidelines when determining how many loops an individual circulator can handle.

Example: If the longest baseboard length is 15 feet and the total length of 1/2" Comfort-PEX® tubing is 150' (75' supply and 75' return) the circulator is capable of handling a 7 loop manifold.

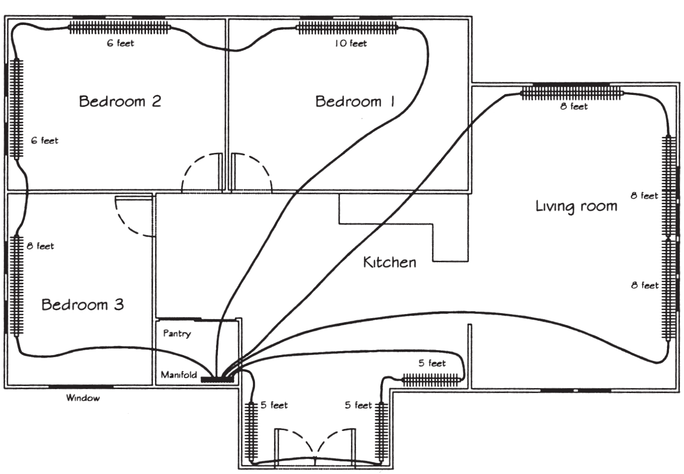
	Baseboard Length (ft)	150' total Comfort-PEX® Length	120' total Comfort-PEX® Length	100' total Comfort-PEX® Length	70' total Comfort-PEX® Length
1/2" Comfort-PEX®	12	13 loops	14 loops	15 loops	16 loops
1/2" Comfort-PEX®	15	7 loops	8 loops	10 loops	12 loops
1/2" Comfort-PEX®	18	4 loops	5 loops	7 loops	9 loops
1/2" Comfort-PEX®	21	2 loops	3 loops	5 loops	7 loops
5/8" Comfort-PEX®	24	6 loops	1 loop	2 loops	5 loops
5/8" Comfort-PEX®	27	5 loops	6 loops	1 loop	3 loops
5/8" Comfort-PEX®	30	3 loops	5 loops	5 loops	2 loops
5/8" Comfort-PEX®	33	3 loops	4 loops	4 loops	5 loops
5/8" Comfort-PEX®	36	2 loops	3 loops	3 loops	4 loops
5/8" Comfort-PEX®	39	1 loop	2 loops	2 loops	3 loops

Baseboard design:
Fin-tube and radiator design and installation

Decide on the number of zones. Within those zones, add the total length of baseboard and total length of Comfort-PEX® to satisfy the recommended maximum Comfort-PEX® per baseboard loop.

Remember – only copper and brass manifolds are applicable. The manifold can serve one zone with multiple loops or individual zone valves can be installed on the manifolds with multiple loops. Check the pressure drop of each baseboard loop. The circulator must meet the total flow rate of all loops and overcome the highest-pressure drop loop.

Example:



Heat loss was calculated on a room-by-room basis. The baseboard used delivers 600BtuH per foot at a 180˚ F supply temperature and 160˚ F outlet temperature.

Bed 1 – 6,000 BtuH = 6,000/600 = 10 feet baseboard and 30' total Comfort-PEX®

Bed 2 – 7,200 BtuH = 7,200/600 = 12 feet baseboard and 40' total Comfort-PEX®

Bed 3 – 4,800 BtuH = 4,800/600 = 8 feet baseboard and 60' total Comfort-PEX®

Living – 14,400 BtuH = 14,400/600 = 24 feet baseboard and 100' total Comfort-PEX®

Kitchen, Entrance – 9,000 BtuH = 9,000/600 = 15 feet baseboard 25' total Comfort-PEX®

The customer would like a 3-zone system and the manifold is located near the heat source below the pantry.

Zoning is as follows:
Zone 1: All Bedrooms
Zone 2: Living Room
Zone 3: Kitchen, Entrance

Add the baseboard lengths for each bedroom and calculate the BtuH

Zone 1: 10+12+8 = 30 feet of baseboard =
30 x 600 = 18,000 BtuH
Zone 2: 24 feet of baseboard = 14,400 BtuH
Zone 3: 14 feet of baseboard = 9,000 BtuH

Calculate the flow rate. The flow rate (gallons per minute, gpm) equation is; BtuH/(T x 500) Where T = 20

Zone 1: 18,000/10,000 = 1.8gpm
Zone 2: 1.44gpm
Zone 3: 0.90gpm

With the flow rate, determine the pressure drop for each loop of baseboard. The pressure drop through the baseboards is negligible.

see Pressure Loss Chart Page 41

	180F Flow-gpm	*Feet of Head per foot pipe* 1/2" Comfort-PEX®
Zone 3 ⑥	0.90	.0264
Zone 2 ⑥	1.44	.0656
Zone 1 ⑥	1.8	.0914

Multiply the *feet of head per foot of Comfort-PEX®* by the total Comfort-PEX® length calculated for each zone.

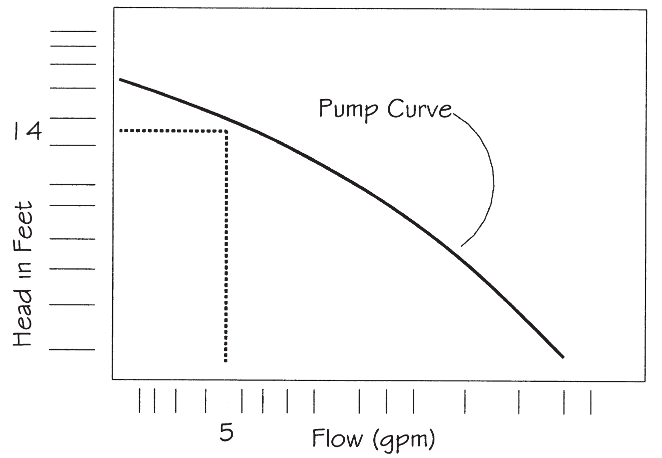
Zone 1:
Bed 1: 30' total Comfort-PEX®
Bed 2: 40' total Comfort-PEX®
Bed 3: 60' total Comfort-PEX®
\+ ______________________
= 130' total Comfort-PEX®
Zone 2: Living: 100' total Comfort-PEX®
Zone 3: Kitchen: 25' total Comfort-PEX®

Zone 1: .0914 feet of head Comfort-PEX® X 130' total Comfort-PEX® = 11.8 feet of head (FOH) = 12FOH
Zone 2: .0656 x 100 = 6.56FOH = 7FOH
Zone 3: .0265 x 25 = 0.7FOH = 1.0FOH

What is the highest-pressure drop loop?
Zone 1 at 12FOH. 12FOH x 1.15 = 14FOH

What is the total flow rate?
.9+1.44+1.8 = 4.14 = 5gpm

Check that the pump can handle the total flow and highest pressure drop. Rathe Associates typically designs systems with 15%-30% extra pump capacity (i.e. 12FOH x 1.15 = 13.8FOH = 14FOH) to take into consideration pressure losses from fittings, valves, etc.



If the FOH and total flow rate is under the curve, then the pump can handle the system requirements. If the intersection occurred on the other side of the pump curve, the result would be a larger temperature drop through the baseboards and lower heat output from the baseboard.

To learn more about
Rathe Associates
and view downloadable
Radiant CAD drawings go to
WWW.RATHEASSOC.COM

Notes:

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