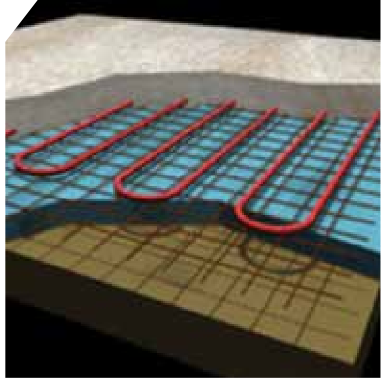
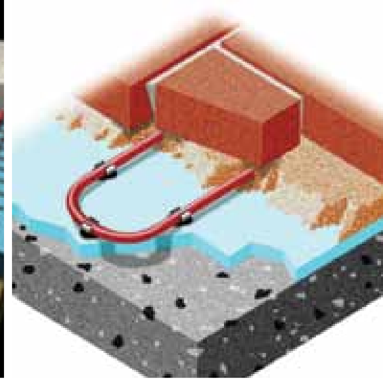
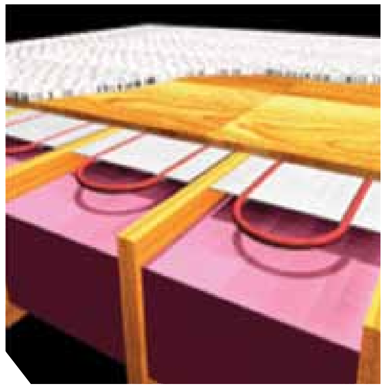
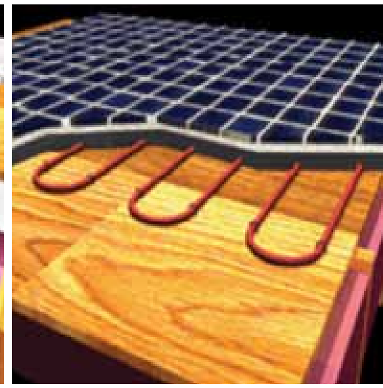
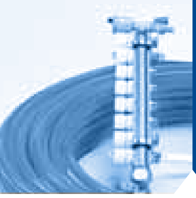






Hydronic Radiant Heating Systems

DESIGN AND INSTALLATION MANUAL

www.vanguard.ca

Vanguard Pipe & Fittings
A DIVISION OF CB SUPPLIES LTD



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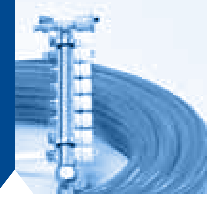


Family owned and Operated in western Canada since 1996, Vanguard Pipe and Fittings Ltd., is a second-generation business producing composite tubing primarily for potable water systems.

CANPEX Oxygen Barrier tubing is a superior quality PEX tubing with an oxygen barrier, designed for use in all types of hydronic heating systems and in particular, radiant panel heating systems. In addition, it has been approved for use in potable water applications, allowing installers to prevent waste by making use of any short pieces of tubing left over from hydronic installations. As with all of our PEX tubing, we use the Silane method of cross linking for superior burst pressure resistance and greater consistancy in manufacturing. We use state of the art measuring and testing equipment to ensure the best quality.

CANPEX Oxygen Barrier tubing is used in concrete slab-on-grade, thin-slab overpours of both concrete and lightweight gypsum, and staple-up or staple down jobs as well as radiant ceiling and wall applications. If you have any questions as to whether CANPEX Oxygen Barrier is suitable for your application, please call the Vanguard Canada Help Line at 1-888-PIPE-PEX (747-3739), or e-mail us at: technical@vanguard.ca, and we will be glad to assist you.

Easy to install and work with, CANPEX Oxygen Barrier uses proven Failsafe metallic insert fittings and crimp rings to join the tubing to distribution piping and other system components. Any ASTM approved compression fitting certified to CSA B137.5 for use with SDR-9 PEX pipe can also be used.

We at Vanguard Canada believe that the mystery and confusion associated with radiant floor heating design and installation is uneccessary. This Design and Installation guide is a part of our continued effort toward making high quality hydronic radiant heating systems easy. When sound design and installation practices are used, CANPEX Oxygen Barrier will provide the end user with a top quality, trouble free heating system at a reasonable cost.

PROFESSIONAL INSTALLATION

CANPEX Oxygen Barrier tubing is designed to be installed by, or under the direction of, professional plumbing & heating contractors who have received adequate training and are knowledgeable in the design and installation of radiant panel heating systems. This manual does not cover all of the design, installation and safety aspects of hydronic radiant heating; and is intended only as a guide for those already experienced in designing and installing these systems. It is the responsibility of the user to determine the applicability and safety of each individual installation, and ensure its compliance with local building codes. We strongly recommend that anyone lacking this knowledge should engage the services of a competent wholesale heating department, engineer, designer or qualified contractor.

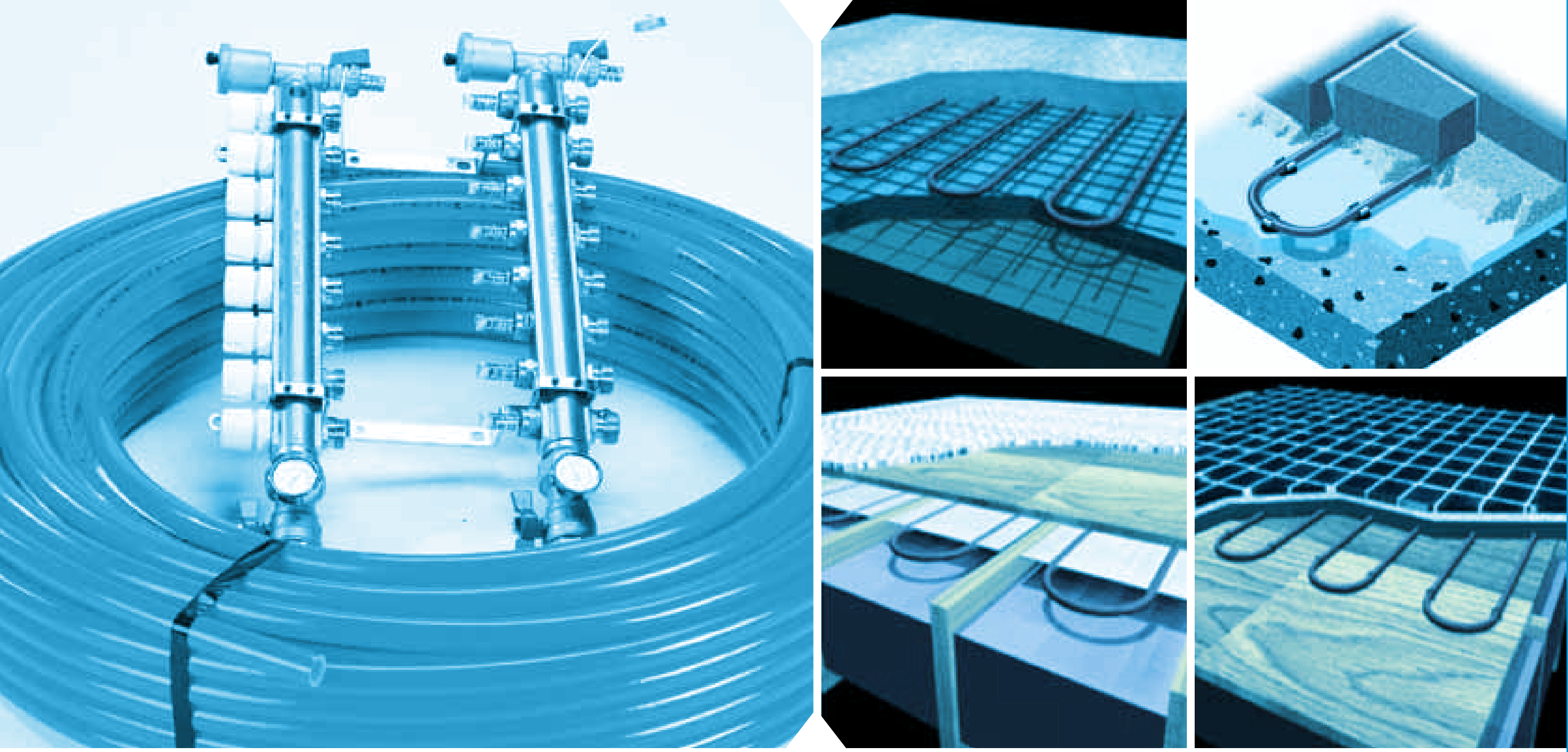
For those wishing to learn more about this technology, we refer you to:

Publications:

Ashrae	Systems Handbook
IBR	Radiant Floor Panel Design Manual
John Siegenthaler, P.E.	Modern Hydronic Heating - P & M Hydronics Toolbox
Dan Holohan	Numerous Publications About Hydronics

Organizations:

Canadian Hydronics Council	Fax: 416-695-0447
Radiant Panel Association	Fax: 801-245-0130
Residential Hot Water Heating Assoc. B.C.	Fax: 604-251-2122
Alberta Hydronics Advisory Council	Fax: 403-219-0686



Radiant System Design

DESIGN AND INSTALLATION MANUAL

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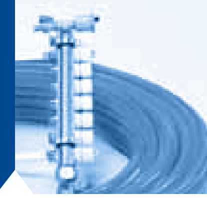
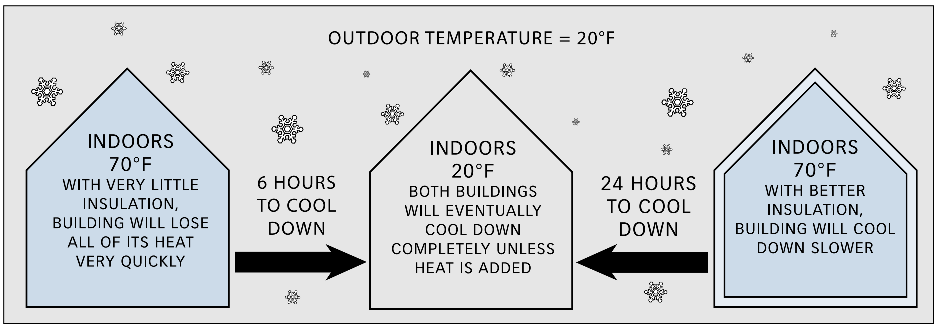


HOW IT WORKS

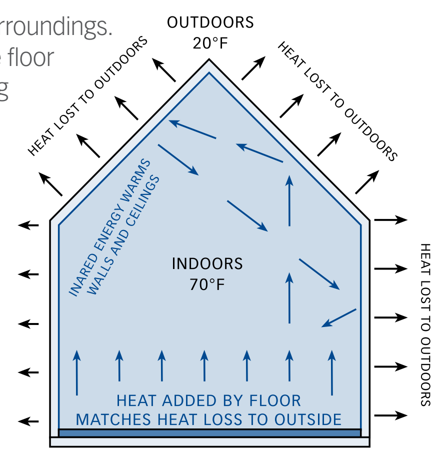
Low temperature radiant panel heating is the most comfortable way you can heat a space. This type of system offers more installation options than any other type and has been used in various designs for many years. Radiant heat gives the end user the ultimate in comfort and is the most economical way to warm a space, primarily because of the way it transfers energy. Here is how it works.

Heat travels to cold. If the outdoor air temperature is 20°F, and we have a house with an indoor temperature of 70°F; over time, the house will cool down to the same temperature as the outside. If we build the house using insulating materials that resist the transfer of heat (this resistance is often referred to as the “R” factor of a material), we can slow down the cooling, but we cannot stop it. Comfortable heating of a space is not so much about making it warm as it is about keeping it from getting cold.



It is clear that a house should have as much insulation as is practical in order to slow down the heat loss during cold weather. Good insulation to slow down heat loss is as important to comfort as is the heating system designed to fight the heat loss, but no matter how much insulation we use there are other big heat losses we can’t do much about. A house has to breathe or the air inside gets really nasty, and good ventilation is a major heat loss. Windows and doors also lose a large amount of heat, and to keep indoor temperatures at a comfortable level we have to add as much energy as we are losing. How we add that heat makes a huge difference between a comfortable space and an uncomfortable one.

When we warm a house with a radiant floor, we make the floor warmer than its surroundings. As the walls and ceiling of the house cool down by losing heat to the outdoors, the floor starts to radiate infrared heat towards the colder surfaces, replacing the heat being lost. If you stand in front of a campfire you can feel this happen yourself. Your body is colder than the fire, and even though the air around you may be cold, the side of your body that faces the fire feels warm because it is absorbing the infrared energy from the fire. If someone steps between you and the fire, you immediately feel cold again as the rays are blocked. Your back, facing away from the fire, will always feel cold as it radiates its heat away to the colder air. If you built a wall behind yourself, it would eventually warm up from the radiant heat of the fire, become a radiant surface itself, and keep your back from feeling so cold by preventing heat from leaving your body.

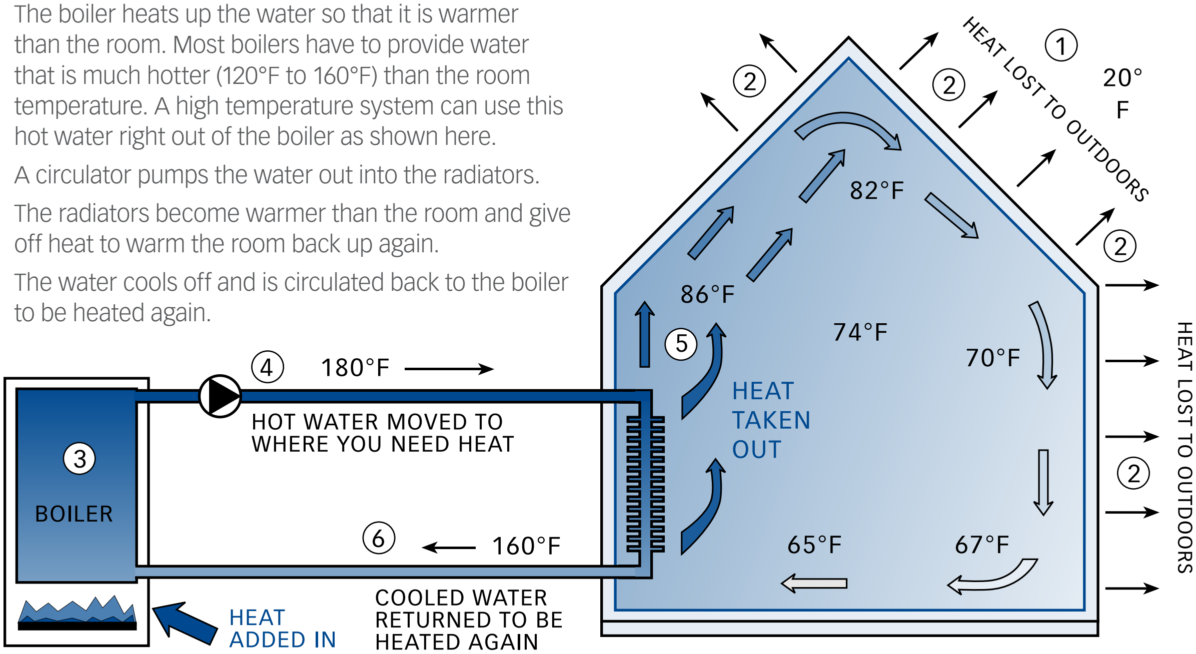


Keep in mind that in this example, the air temperature does not change. You feel more or less comfortable entirely as a result of infrared heat transfer. In the same way, the infrared rays from your warm floor bounce around in the house from floor to ceiling to wall as illustrated here, and all of the surfaces in the house will eventually be warmed by the floor heat. With warm floors, ceilings and walls, your body no longer loses heat and your comfort level increases dramatically. With a campfire, you can’t easily control how hot it is. The only way you can get comfortable is to constantly move forwards and backwards to balance the heat lost from your back with the heat gained from the fire. With modern hydronic heating we can control exactly the amount of heat to your house and make it the most comfortable place you have ever lived in.

THE BASIC HYDRONIC HEATING CYCLE - "CONVENTIONAL" SYSTEM

Illustrated below, is a conventional "high temperature" hydronic heating system. Using high temperature water (140°F plus), these systems are normally simpler than radiant systems and provide a good model for introducing hydronics basics. With minor variations, the basic hydronic heating cycle goes like this:

1. The outside air temperature drops lower than the desired room temperature.
2. The room gives off heat to the outdoors, cooling off to the point where a thermostat activates the system.
3. The boiler heats up the water so that it is warmer than the room. Most boilers have to provide water that is much hotter (120°F to 160°F) than the room temperature. A high temperature system can use this hot water right out of the boiler as shown here.
4. A circulator pumps the water out into the radiators.
5. The radiators become warmer than the room and give off heat to warm the room back up again.
6. The water cools off and is circulated back to the boiler to be heated again.

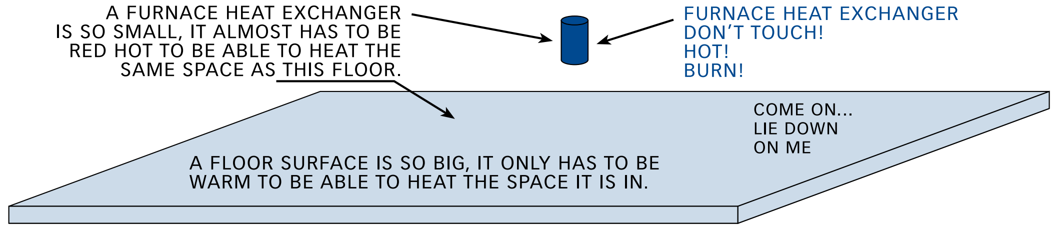


As long as it is colder outside than in the room, this cycle will continue. The illustration above shows that we will get air movement because we are heating air with a high temperature radiator and using convection (hot air rises, cold air falls) to transfer the heat to the rest of the room. Air is not a good way to move heat because it takes a lot of air to move just a little bit of heat. To heat a room with hot air results in variations in air temperature and air movement which people find uncomfortable. High temperature hydronic systems are still much more comfortable than full blown forced air systems; but the very best, most comfortable hydronic systems use a radiant floor to deliver the heat.

LOW AND SLOW – THE PERFECT HEATING SYSTEM

Why hydronic radiant systems are so comfortable and energy efficient

The beauty and magic of radiant floor heating lies in the fact that the heating cycle becomes a very gentle process. As far as radiators go, a floor is BIG. Because it is so big, it does not have to be very hot to comfortably warm the rest of the house and the heat loss is overcome in a quiet, elegant way. You heat your space low and slow. Radiant heating is calm and quiet, not in your face. The average floor surface temperature in a radiant system should normally never be more than 85°F in the coldest weather, and for most of the heating season the temperature will be much lower. It is very easy to control a radiant system to these low temperatures, whereas a smaller radiator or heater has to be much hotter to do the same job. A forced air furnace is the worst case of all. The heat exchanger is only about the size of a 45 gallon drum, and to get enough heat ofrom the heat exchanger you have to heat it up really, really hot then blow a whole lot of air over it. That's why furnaces always stink so much when they first start up in the Fall. They get hot enough to burn off all of the dust, plastic toys, etc. that fell down the registers during the Summer. When that monster fan kicks in and scorched air belches out of the ducts for the first time, its enough to knock you over. Ask an Asthma sufferer. On the other hand, when a radiant floor first kicks in come the Fall, you probably won't even know it is on. The floor isn't likely to get over 75°F for the first month - True comfort.



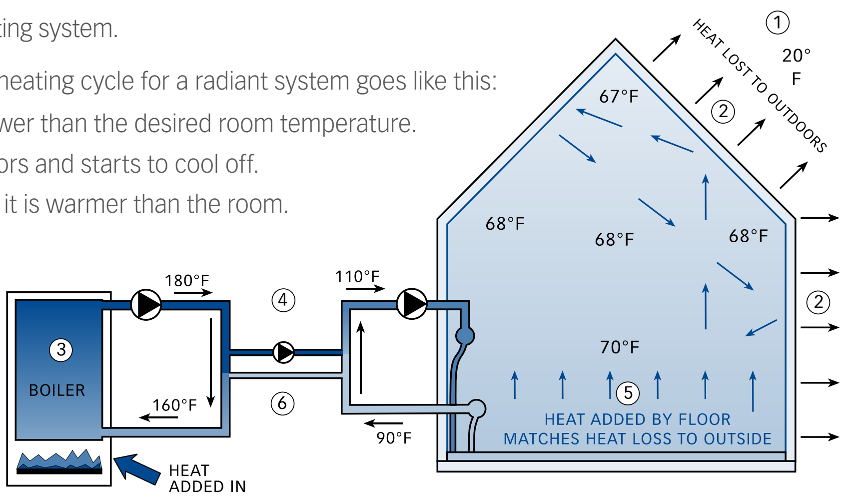
HOW RADIANT SYSTEMS SAVE ENERGY AND MONEY

1. You can put a whole lot of heat energy into a little bit of water and move it just about anywhere you want to without too much strain. That's why hydronic heating systems have such small pipes that are a snap to hide. You can move enough heat to warm a 2,000 Square foot house through a 1" pipe using a tiny little 1/25th H.P. circulator. To heat the same space with a forced air furnace usually requires a big, ugly duct at least 12" x 18" and a fan that will lift the cat right off the floor registers. It takes a lot more electricity just to deliver the heat in a forced air system.
2. Because we are not blowing a storm of air around, there is less heat loss from the building. Blowing air scrubs against the cold walls of the space and causes a faster transfer of your valuable heat to the outdoors. Walls and ceilings have a thin film of air that clings to the surface and actually increases their effective "R" value. Air movement disturbs this air film and results in higher energy usage.
3. A radiant system will have the most even surface and air temperatures everywhere. Other systems tend to develop hot spots at the ceilings and along the walls that have hot air registers (just where the largest heat losses happen to be).
4. Occupants are comfortable in radiant buildings where thermostats are typically set 4°F to 8°F lower than in other types of systems. You can get away with this because radiant heat makes your walls and ceilings warm. Warm surfaces don't try to suck all of the heat out of your body. Systems that use forced air rely on air movement to distribute heat around the room, but air blowing around the room (even if it is room temperature air) will make you feel cold. When we cover heat loss calculations later in this manual, we will cover in detail how, the bigger the difference there is between the outdoor temperature and the indoor temperature, the more heat loss there is. If we can use radiant floor heat to keep our thermostats lower and also prevent hot air in the room from hanging around at the ceiling, we can save a lot of energy and money.
5. Forced-air systems without balanced ventilation systems will pressurize a building causing too much warm air to squeeze out and through cracks, holes and building openings such as exhaust vents and flues.

Illustrated below, is a hydronic radiant heating system.

With minor variations, the basic hydronic heating cycle for a radiant system goes like this:

1. The outside air temperature drops lower than the desired room temperature.
2. The room gives off heat to the outdoors and starts to cool off.
3. The boiler heats up the water so that it is warmer than the room.
4. A circulator pumps the water out into the floor, or into a mixing device (here we show an injection pump) and then into the floor. A mixing device only lets a little bit of the hot water go into the floor. It mixes this hot water with the cool water coming back from heating the floor and brings the floor water up to just the right temperature.



5. The floor becomes warmer than the room and gives off heat to warm the room back up again.
6. The water cools off and is circulated back to the boiler to be heated again. If a mixing device is used, most of the water going back is hot boiler water that wasn't needed. This helps keep the boiler hot.

HOW RADIANT SYSTEMS GIVE YOU MORE COMFORT

The Heating, Refrigerating and Air Conditioning Institute (HRAI) in their 1986 Residential Heating & Cooling Load Calculation Manual described comfort as the "absence" of discomfort. They go on to say that "A comfortable environment might be one which is not offensive to any of the five senses; i.e. sight, sound, touch, smell and taste. Equipment that is installed to provide comfort should be designed with an acceptable appearance based on its intended use. Operating noise should be so low as to be indiscernible against the background or environmental sound and no undesirable contaminants should be added to the air by the equipment. The humidity, velocity and temperature of the air should be controlled so that there is neither a feeling of heat or cold." Let's look at how radiant floor heating stacks up to the test.

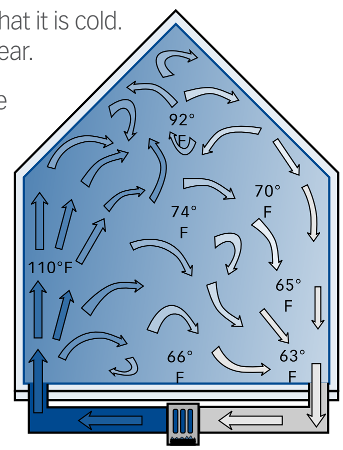
1. Sight. From a visual and decorating point of view, you simply cannot get a less intrusive heating system than radiant floor. The radiator is the floor. We can actually enhance the visual appeal of a space by making it possible to use natural stone, tile, even stained or painted concrete. Materials that people love, but often reject, simply because they are considered to be too cold to walk or stand on.

2. Sound. It is quiet. Silence is one of the great unsung benefits of radiant heating systems. No big noisy fan, just quiet comfort. You seldom ever know when a radiant system is running because you can't hear it. There is something extra special about the silence you experience when reading a good book, late on a cold winters' night in a house with radiant floors.

3. Touch. You feel warmer. Your normal body surface temperature is somewhere between 80°F and 90°F. Remember that heat always travels to cold. If the surfaces around you are much cooler than your body, your body becomes a radiator. Anytime your body radiates a lot of heat away, it makes you feel cold. Stand in front of a big picture window on a cold day and you will feel the effect. A radiant system warms up all of the surfaces around you, including the walls and ceilings. You feel warmer in a radiantly heated room, even if the air temperature in the room is lower than you are used to. If your body doesn't radiate heat away, it doesn't ever know that it is cold. With a hydronic radiant system, your feet are warm, your head is cool and your mind is clear.

   There are no drafts. Remember, we can lose that big noisy fan that most forced air people have to suffer with. We are not constantly turning the heat on and off, on and off, but are gently warming the room with just enough heat to make up for the outside heat loss. The room temperature remains constant and our body does not have to deal with those hot-cold-hot-cold cycles.

4. Taste & Smell. Because a forced air furnace has a heat exchanger with a surface temperature just on the cool side of red-hot, any combustible substance that can get into the ductwork can potentially come in contact with the heat exchanger and burn. A burning smell from a forced-air furnace is expected every fall for the first few weeks of the heating season. One can only hope that the smell comes from dust. Other common causes of the burning smell include toys, insects and small mammals. A radiant floor heating system will never cause problems as far as smell and taste are concerned.



Where would you want to sit, in this scorched-air heated house?

When a forced air house is subjected to temperatures close to design, especially in colder climates, the hot-cold-hot cycle effect gets really bad. At extreme outdoor temperatures the inside walls are always cold, the furnace fan is running almost constantly, the thermostat has to be set higher than required because at 70°F there just isn't enough heat contained in the air to overcome the heat loss, and you always feel cold.

When you turn the thermostat up to 78°F to compensate for the cold walls, you feel too hot for half the heating cycle and too cold for the other half as the thermostat bounces on and off six to ten times an hour depending on how oversized your furnace is. The cat crawls under the comforter and won't come out, and nobody wants to get out of bed in the morning. You find yourself staring mindlessly at all of the ads for sun and sand vacations and you have to call your banker to extend your line of credit before the utility bill comes in. Or you can live in a house with a hydronic radiant floor heating system. After a while you begin to accept the fact that you are always comfortable and expect it as the norm. It is usually quite a rude surprise when you have to endure a forced air system after getting used to radiant. It becomes difficult to believe that so many people live with such inferior ways of heating their living and working spaces. When you live with a radiant heating system for a winter, it is almost certain that you will become a True Believer in radiant heat and an avid Hydronics Crusader.

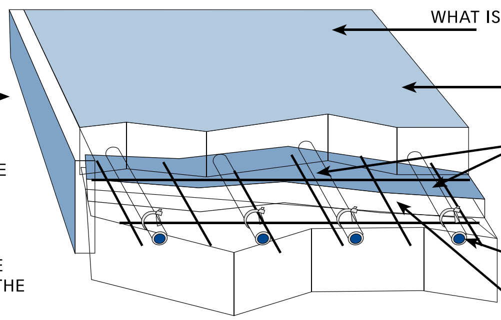
DESIGNING FOR COMFORT

The most important things you need to know to make comfortable radiant floor heating systems

In the past, most hydronic heating systems were designed using manufactured heat terminal units such as baseboard heaters or air handling units. These terminal units were factory built, coming complete with detailed heat output ratings which made it easy for a designer to pick something "off the shelf" and be guaranteed that it would deliver the heat required.

Hydronic radiant floor panels differ from these other types of terminal units in that the heat is delivered from a heating panel that has been custom designed for the building and constructed on site as an integral part of the structure itself. You are actually walking on the radiator surface. A typical panel cross section is illustrated below.

When designing a radiant floor panel, the following questions must be answered:



What are the general panel construction details?

Looking at the illustration above, it may seem as if designing a panel is extremely complicated, however it is surprisingly easy once you get the hang of it. There are often many choices made for you due to the nature of the job, and many "rules of thumb" and design practices and standards that narrow down your choices considerably. This manual will cover all of these aspects of panel design and point out handy rules of thumb as we go. With a bit of experience, radiant panel design becomes second nature and you will be able to lay out the most complicated jobs with ease.

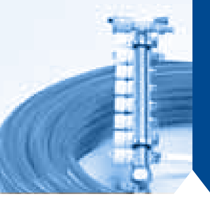
Radiant floor heating systems are the most comfortable and efficient heating systems ever devised. We must be careful in their design however as the user is in actual contact with the heating surface more so than with any other type of heating system. As radiant panel designers, we must be careful to ensure that the panels will not only deliver the required heat, but will also be comfortable to walk on and not cause any damage to the structure. Fortunately, if you stick to what we describe as the three golden rules of panel design as you work with these systems, you should never have a problem.

The most comfortable radiant systems follow these three golden rules:

1. They should operate with the lowest possible surface temperature
2. They should maintain the most **even** surface temperature possible
3. They should maintain the most **constant, unchanging** surface temperature possible
   (The surface temperature should only be changed when required by a change in the load conditions)

To conform to these rules a system should be designed so that:

4. The water temperature to the slab is kept as low as possible at all times.
5. The tubing is spaced as close together as is practical.
6. The tubing is spaced as evenly as is practical.
7. The tubing loops are kept as short as is practical.
8. The insulation below the panel is adequate to prevent excessive downward heat losses.
9. The floor coverings on top of the slab don't have a high "R" value.



Designing for Comfort

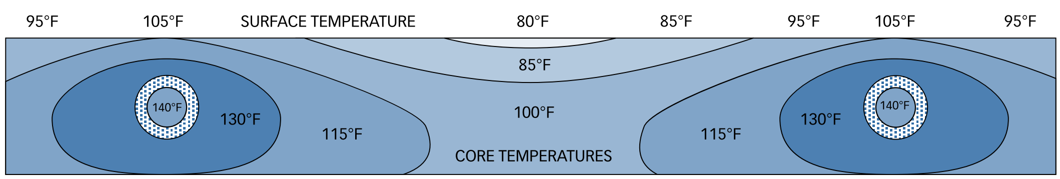
THE MOST IMPORTANT RELATIONSHIP IN RADIANT PANEL DESIGN

"R" values vs. water temperature vs. tube spacing = surface temperature.

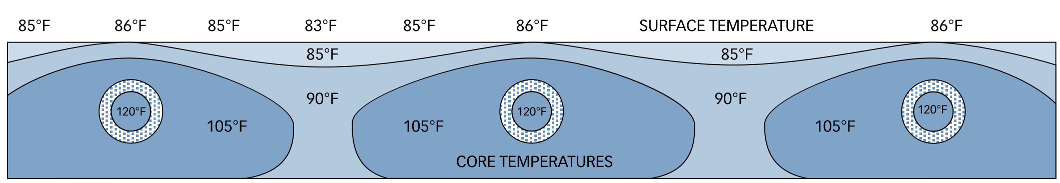
There are two basic types of radiant floor construction - the poured floor and the sub-floor. They both act a little differently when it comes to heat transfer and surface temperature. The poured system typically transfers heat away from the tubing and up to the surface more quickly than a sub-floor system and requires lower water temperatures (a good thing), but if there is no floor covering on the surface and if the tubing is too far apart, a poured system can be subject to hot and cold spotting (a bad thing)

As previously stated, designers should ensure that a radiant floor is constructed to maintain as even a floor surface temperature as possible with the lowest water temperature possible. The illustrations on this page, are floor cross sections that show how one of the most important factors in radiant floor construction, tube spacing, can affect the surface temperatures of the floor. In both cases, the average floor temperature is 84°F. One of the things most misunderstood about tube spacing is the relationship between BTU output and tube spacing. We do not normally require closer tube spacing to boost the heat output of a panel. In normal applications, this is an insignificant factor. Close tube spacing in a radiant panel is primarily a comfort issue and has less to do with required BTUH output than most people think.

An example of what not to do – This is a poured system with a bare, tiled or lino floor surface. The tubing is spaced far too wide, on 16" centers. The average floor surface temperature will be the required 84°F and will heat the space, but the wide (25°F) variation in floor surface temperature will result in uncomfortable hot and cold spots. This situation becomes worse the closer the tubing is to the surface. Some flooring materials may be discoloured or otherwise damaged by these temperature extremes.



A better floor panel design – This is a system like the one above but the tubing is more closely spaced, on 8" centers. The average floor surface temperature is also 84°F, but the variation in surface temperature is only 3°F and will not be noticed. Because the tubing is closer together, the water temperature can be lowered resulting in increased energy savings. Another way to even out the temperature of a slab surface is to space the tubing deeper in the slab. The further down the tubing is, the more the heat will have a chance to spread. The main problem with this approach, and the reason why it isn't recommended more often, is that the slab will then take much longer to respond whenever we want to change the temperature in the space. When we need to add heat to the slab, much of it will be absorbed by the thermal mass of the base material before it migrates to the surface where it can affect air temperature. If the space overheats, it takes an equally long time for the built-up heat under the slab to be released. If we insulate under the slab however, we can get the best of both worlds; more even floor temperatures with a fairly fast response to temperature changes.



How much more will this cost?

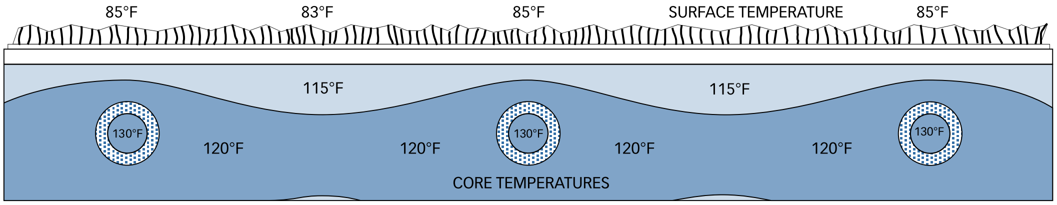
It doesn't cost as much as you would think to give your customer more comfort. The above example is extreme, and it is more likely that you would be deciding between say 12" and 8" centers. If we look at the chart to the right (you will see more of this chart later when we calculate loop lengths), you can see that tubing on 8" centers results in using approx. 50% more pipe than if you were on 12" centers. At 2011 prices, a home owner buying a 2,000 square foot house would only have to pay about $800.00 more to have a far more comfortable system. A small price to pay compared to the overall cost of the house.

Tube spacing factors

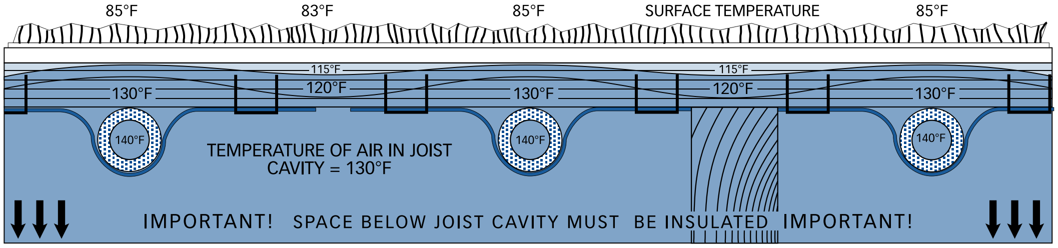
Spacing on center	ft. of pipe/sq.ft. floor
4"	3.0'
6"	2.0'
8"	1.5'
10"	1.2'
12"	1.0'
14"	0.86'
16"	0.75'

The examples shown on this page illustrate an even more important factor than tube spacing - the effect of the insulating materials between the tubing and the floor surface. To be able to get the same surface temperature as a bare floor, a floor with insulating materials must have a higher water temperature. We already know that a system will be more comfortable and efficient if the water temperature is lower, and it is clear that the preferred method of construction is a poured system with little or no floor covering. Systems with floor coverings do work very well however, but it is important that the designer explain the effect of the insulating factor to the end user so that poor decisions are avoided when picking floor coverings. There are many choices in low “R” value carpet and under-pad available.

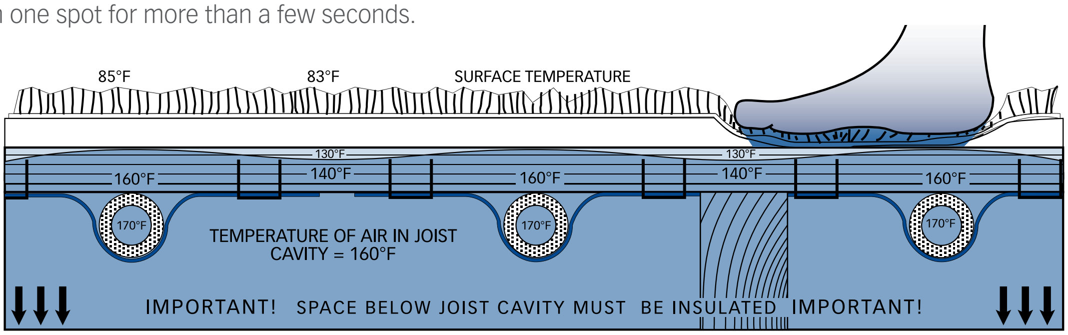
This is a good floor panel design – It is a poured system like the one on the last page with the tubing on 8” centers, but has a low “R” value carpet and under-pad finished surface. The average floor surface temperature is also 84°F, but the variation in surface temperature is now only 2°F. The water temperature and core temperature of the floor has to be higher in order to overcome the insulating effect of the carpet, and because of this it is good practice to keep the insulating value of floor coverings as low as possible for increased efficiency and comfort. When occupants stand in one place on thick carpet, the carpet will compress to the point where the insulation value is much lower than normal. Discomfort will result as feet come in contact with the much warmer core temperature of the floor.



This is a well designed sub-floor system – It is a staple-up system using heat transfer plates, and the tubing is installed on approximately 8” centers (approximate because most joist spacing seldom allows precise spacing). The installer must take care to ensure as even a spacing as practical to maintain even surface temperatures. Even with medium to low “R” value carpet and under-pad, the water temperature still has to be much hotter in order to overcome the additional insulating effect of the sub-floor materials. It is crucial to ensure adequate insulation levels below the sub-floor. Failing to do so will result in too much heat going down, and require even higher water temperatures.



This is another example of what not to do – By selecting high “R” value carpet and under-pad, the water temperature has to be cranked up far too high. This could damage the sub-floor and will definitely cause discomfort to anyone who stands in one spot for more than a few seconds.



Basic Tubing Layouts

The previous pages explained why we want to have our tubing spaced as close together as is practical to get the most even temperatures. Another basic rule for laying out tubing is just as simple; put the heat first, where it will be needed most. With very few exceptions, this will always be at an outside wall. It is also best to lay out the tubing so that the floor surface temperatures in areas where feet are in continuous contact with the floor are as low as possible and as even as possible.

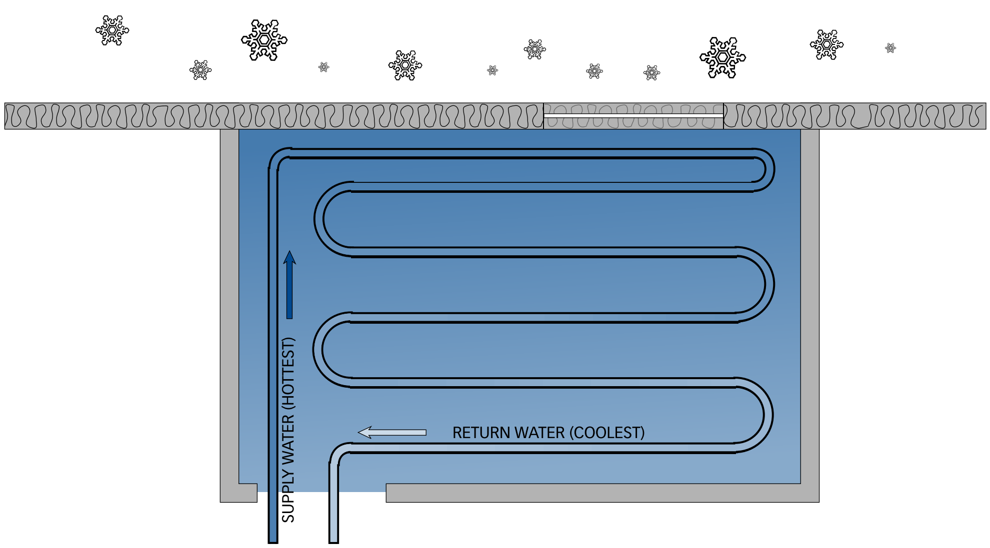
The basic layout patterns illustrated on the next three pages are designed to accomplish these goals. By laying the tubing so that the hottest water travels along the outside wall first, we can ensure that more heat goes to the highest heat loss areas. To enhance this effect, we can also space our tubing closer together in these areas, giving us a slightly higher surface temperature around the perimeter of the room, and a slightly lower temperature in the center of the room. This is most important in areas where there is a large amount of glass such as in front of a sliding patio door.

You can play around a bit with tube spacing within a room, but it is important to remember that the average tube spacing in the floor should be maintained. If you have designed the floor to have tubing on an average of 8" centers, you should calculate 1.5 linear feet of tubing per square foot of floor surface area (See chart on page A6).

A 200 square foot room would therefore require 300 feet of tubing. If you wanted to have 6" spacing near a cold outside wall, you would then increase the spacing slightly in the center of the room. This increase would normally be minor, perhaps going from 8" to 9" or 10". Care should be taken not to exceed the maximum tube spacing for your application. For more information on maximum tube spacing, see page A32.

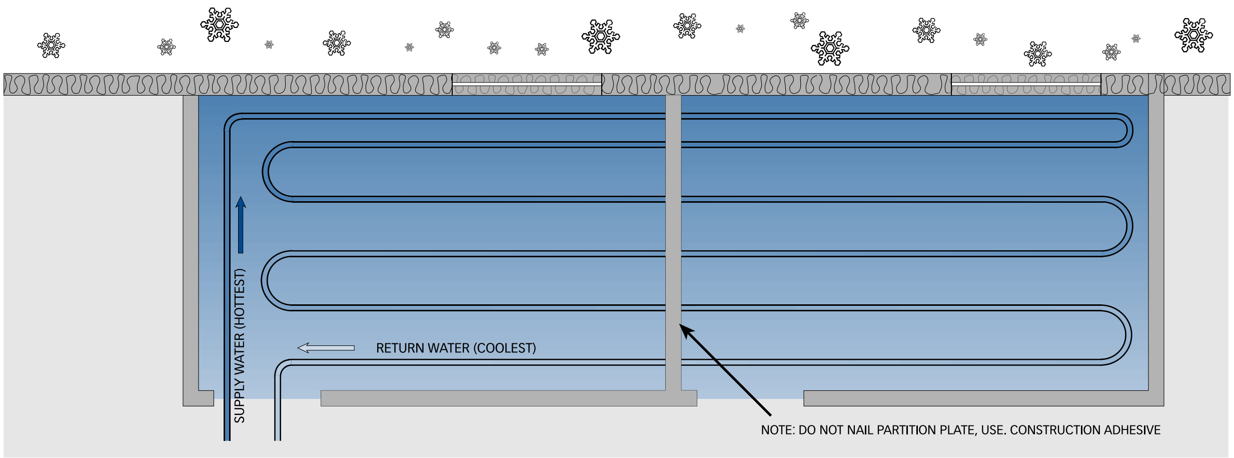
ONE WALL SERPENTINE LOOP

The easiest layout of all, this type of loop is used whenever you are heating a room with a single outside wall. Although this illustration shows tubing on tighter spacings next to the outside wall, this is usually only necessary where large windows create an extra heat loss in that area.



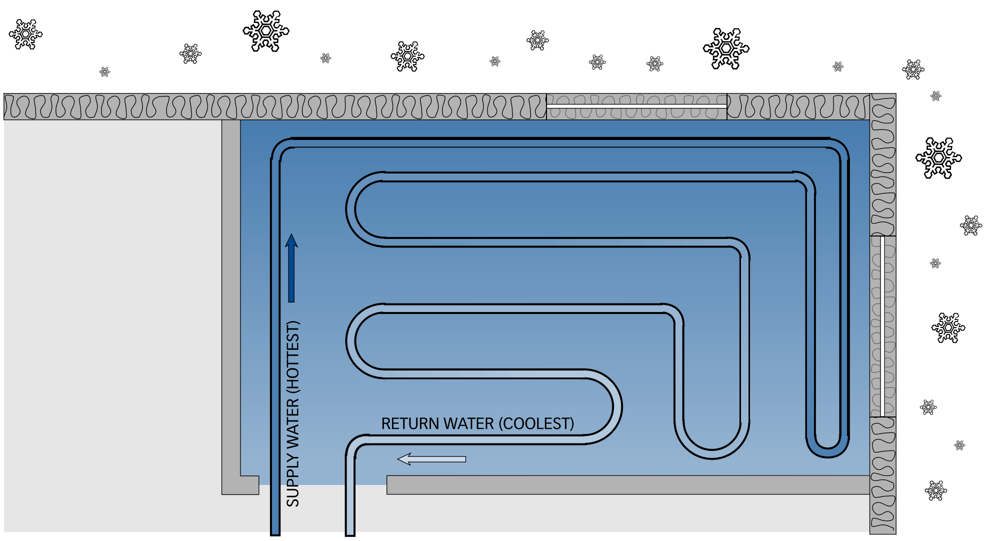
ONE WALL SERPENTINE LOOP – TWO ROOMS

It is common to see two smaller rooms side by side as illustrated. Usually it does not make sense to run an individual loop for each room, and unless there is a reason to zone them separately, it is usually easiest to run the loop through both rooms provided the loop doesn't get too long.



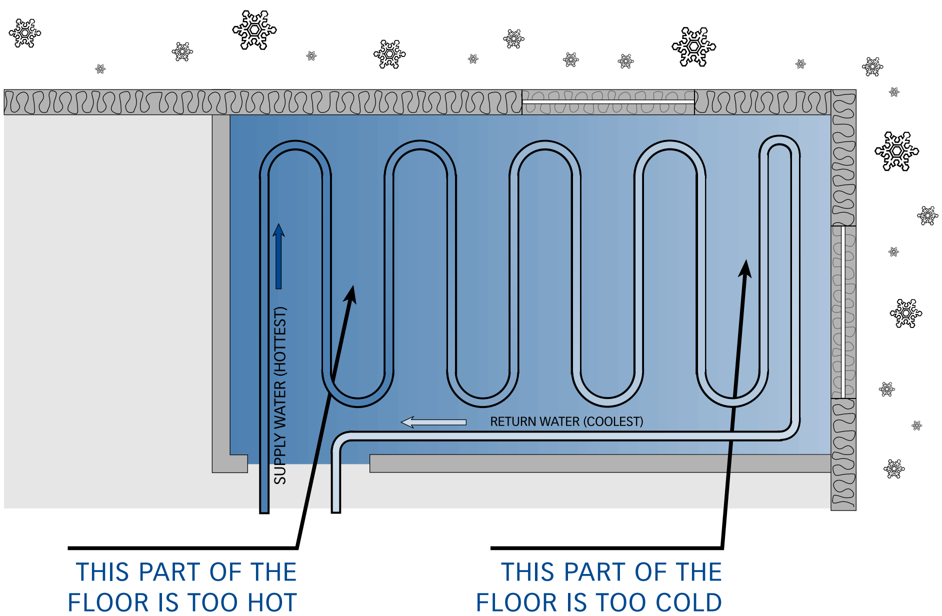
TWO WALL SERPENTINE LOOP

In this example, we have two outside walls in the room. Again, we are trying to put the heat in the areas where it is needed most by running the hottest part of the loop along the outside wall and spacing a bit tighter than in the rest of the room.

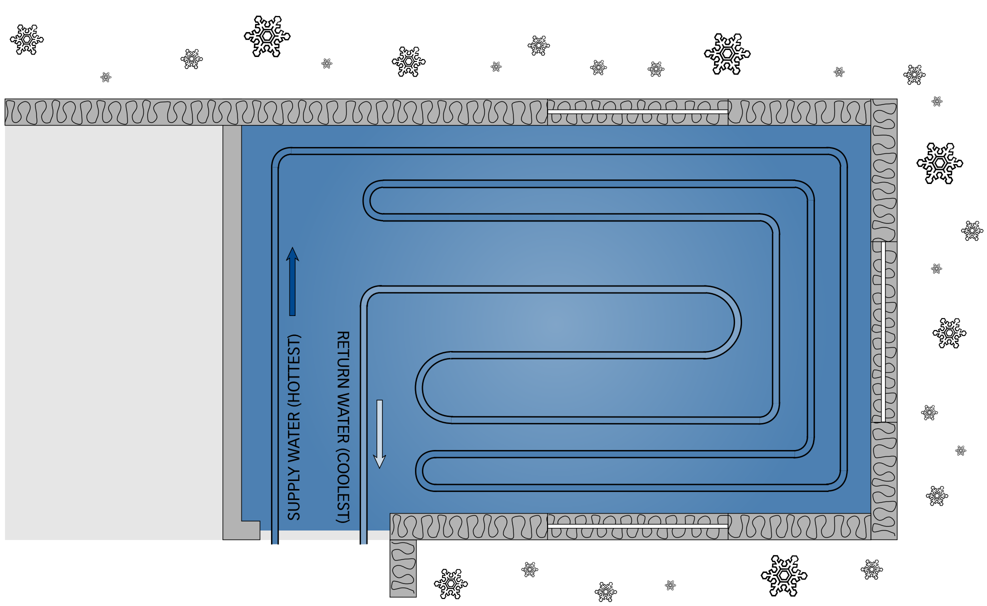


A POORLY DESIGNED LOOP – WHAT NOT TO DO

This is an example of what not to do – The lazy loop. There are two big problems with laying out a loop this way. The first problem is that there are far too many return bends in the tubing. Each one of these bends will slow down the water going through the loop and cause a higher pressure and temperature drop than we want from one end of the loop to the other. It is best to have as few bends as possible. The second problem is that the hottest water in the loop is concentrated on one side of the room. There could be a big difference in surface temperature from one side of the room to the other. The floor will be its coldest in the corner of the room with two outside walls where you need to put the most heat. Having said all of that, if you are laying tubing in a closet or other small, low heat loss area, it is unlikely that there will be any problems as a result. Just don't do it in a large area with significant heat loss.

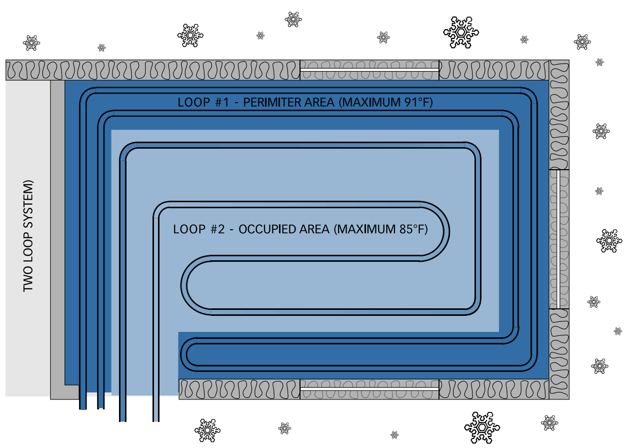


THREE WALL SERPENTINE LOOP



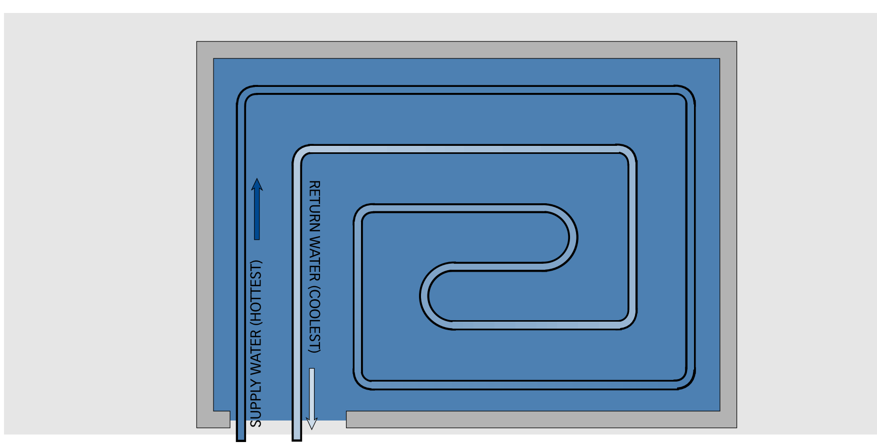
In this example, we have three outside walls in the room. We can run the hottest part of the loop along the outside wall with spacing a bit tighter than in the rest of the room, but in many rooms like this we run into a problem. As long as the insulation values in the outside walls are good enough and the windows aren't too large, we can probably heat the room without exceeding the maximum allowable floor temperature (see chart "A" on page A29). If we have to raise the floor surface temperature too high, we have to look at some alternative ways to make up the BTU required.

There are many ways to add supplemental heat to a room, but if we want to stay with just heat in the floor we have to get creative. The illustration below show how you can designate parts of the room as perimeter areas and raise the surface temperature higher than you would normally allow. Care must be taken to ensure that no one will be standing in the perimeter area for any length of time. It is almost impossible do this with a single loop/water temperature and tube spacing alone. If the room is large enough, two loops with different water temperatures can be employed. Both loops' water temperatures will have to be controlled individually using separate distribution piping.



COUNTERFLOW SPIRAL

Our last loop layout example is used in rooms that have no outside walls. This is common in smaller rooms like bathrooms and storage rooms. The whole concept of this layout is to place the hottest tubing next to the coolest so as to even out the surface temperature. It is a bit tricky to lay out if you have never done one before; a chalk line and tape measure are a great help.

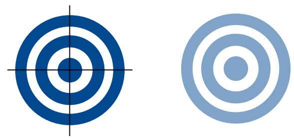


Designing a Radiant System

In this section of our manual, we are going to take you through the design process one step at a time. Computer programs can greatly speed up these procedures, but in order to fully understand all of the aspects of designing a proper system, it is best to learn by performing each step manually. After you are comfortable with these steps and procedures, we recommend using a good computer program to help you in the day-to-day designing of systems. Ask your CANPEX distributor about our design software.

Step 1 – Define The Heat Loss Conditions and Construction Details
Step 2 – Calculate the Square Footages and Volumes of Each Room
Step 3 – Calculate the Total Heat Loss from Each Room
Step 4 – Calculate the Square Footage of Floor Available as Heating Surface
Step 5 – Calculate How Hot the Heating Surface Must Be
Step 6 – Identify the Panel Construction Types and Materials & Calculate "R" Values
Step 7 – Determine Tube Spacing
Step 8 – Calculate Average Water Temperature Requirements
Step 9 – Determine Loop Layouts and Zoning Requirements
Step 10 – Determine Required Flow Rates Per Room
Step 11 – Determine the Best Manifold Placement
Step 12 – Determine Loop Lengths and Tubing Diameters
Step 13 – Determine the Type of Heat Source and Its Placement
Step 14 – Select a Control System
Step 15 – Calculate System Flow Rates and Pressure Drops
Step 16 – Select the Required Circulators
Step 17 – Select the Required Expansion Tank
Step 18 – Document the System

"IN THE RANGE"
During the different steps of your heating design, we will be showing you the most common and sensible ranges for a number of factors. Look to see these icons wherever there are many possible choices. They will help you make the right ones. The "IDEAL" icon on the left will point out the best possible solution. The "ACCEPTABLE" icon on the right will point to solutions that are less than ideal, but still good enough to result in a comfortable system.



IDEAL SOLUTION | ACCEPTABLE SOLUTION

On the next 4 pages you will find the following:

Floor plan for our practice house
We will use this house plan to base our first design on. All of the necessary room, window and door sizes are shown on this sheet. We recommend that you photocopy this page as you will probably be marking it up as you work along.

Designers, heat loss calculation worksheet
We will use this sheet to assist us in doing our heat loss calculations. When we have the totals we will enter them onto the System Design Worksheet. Photocopy this page to make a working copy.

System design worksheet
We will use this sheet to assist us in doing the necessary system desing calculations. Some of this information will be transferred to the Installers' worksheet. Photocopy this page to make a working copy.

Installers worksheet
Enter the applicable information on this sheet to give to the installing contractor to assist him in the installation of the system. Photocopy this page to make a working copy. You may also want to photocopy the finished sheet before giving it to the contractor so you have a record.

In addition to the above information, you should also include the following documentation with every job you design:

- Control and component wiring diagrams
- System piping schematics including floor loop layouts
- Manufacturers' literature for boilers, pumps, controls and other components
- Manufacturers' safety data sheets and labels for applicable chemicals to be used
- Any permit application forms required

PRACTICE HOUSE FLOOR PLAN AND SPECIFICATIONS

In many instances, a structure has insulation values rated as “R” (resistance) factors. To convert an “R” factor to a “U” (heat transmission) factor simply divide 1 by the “R” factor. Example: an R 20 wall would have a “U” factor of 1 divided by 20 = 0.05.

$$\text{“U”} = \frac{1}{\text{“R”}} \rightarrow \text{“U”} = \frac{1}{20} \rightarrow \text{“U”} = 0.05$$

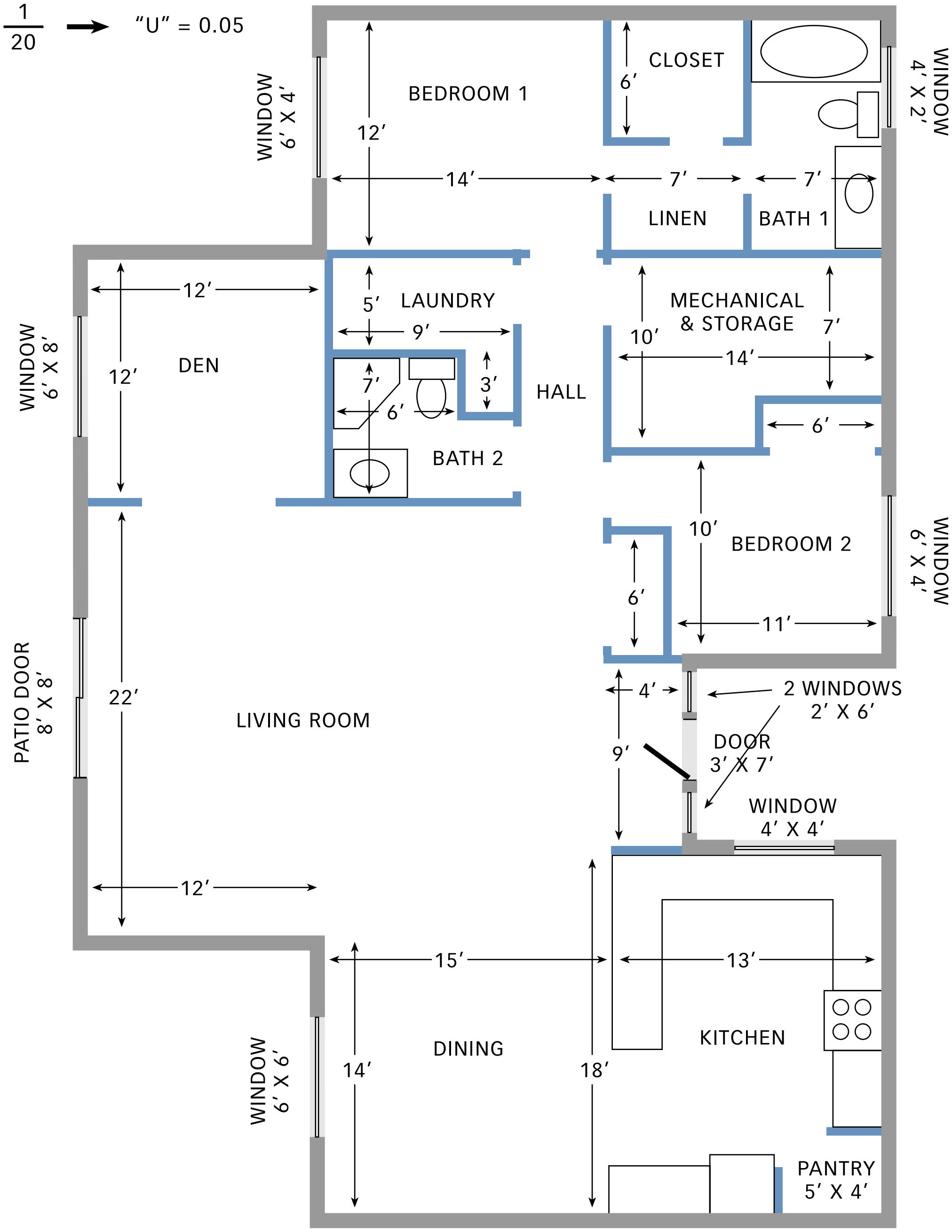
WINDOWS: DOUBLE GLAZED
“U” FACTOR = 0.65

DOORS: 1 1/2” STEEL/W FOAM INSULATION
“U” FACTOR = 0.15

WALLS: 2 X 6 STICKFRAME CONSTRUCTION WITH 5 1/2” FIBERGLASS BATT INSULATION, 1/2” OSB SHEATHING WITH VINYL SIDING, VAPOUR BARRIER AND 5/8” DRYWALL.
“U” FACTOR = 0.05

CEILINGS: 12” FIBERGLASS BATT INSULATION, 1/2” OSB ROOF DECK WITH ASPHALT SHINGLES, VAPOUR BARRIER AND 5/8” DRYWALL
“U” FACTOR 0.02

HOUSE IS SLAB-ON-GRADE, 2” EDGE INSULATION
FLOOR “U” FACTOR = 0.53 PER LINEAL FOOT OF EXPOSED EDGE



NEW HOUSE
LOCATION: CALGARY - OUTDOOR DESIGN TEMPERATURE = -27°F
INDOOR DESIGN TEMPERATURE = 72°F

CEILING HEIGHT = 10′ VENTILATION REQUIREMENT = 0.5 AIR CHANGES/HR. AIR CHANGE FACTOR = .009

HEAT LOSS CALCUATION - PROJECT WORKSHEET

PROJECT NAME		DESIGNER NAME		JOB #		DATE	
ADDRESS				INSPECTION BY			

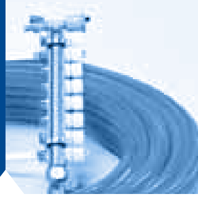
OUTDOOR DESIGN TEMP.		STRUCTURE	WINDOWS	DOORS	WALLS ABOVE GRADE	WALLS BELOW GRADE	CEILING	FLOOR	SLAB EDGE	AIR CHANGE (CHOOSE ONE)
INDOOR DESIGN TEMP.		"U" FACTOR								1/2 =.009 2/3 =.012 1 =.012
DESIGN TEMP. DIFF. (DTD)		"U" x DTD								
		= H. L. MULTI.								

ROOM IDENTIFICATION	HEAT LOSS IN BTU/H	CEILING	WINDOWS	DOORS	WALLS	FLOORS	AIR CHANGE
	→						
	→						
	→						
	→						
	→						
	→						
	→						
	→						
	→						
	→						
	→						
TOTAL BTU/H HEAT LOSS	→						

ADD UP THE TOTALS AND ENTER THE SUM HERE

BUILDING TOTAL BOILER LOAD CALCULATION	
	TOTAL HEAT LOSS BTU/H
+ PLUS +	
	TOTAL DOMESTIC HOT WATER LOAD IF FROM BOILER *
+ PLUS +	
	TOTAL AUXILIARY LOAD IF USED DURING HEATING SEASON
+ PLUS +	
	10% PICK-UP FACTOR IF NIGHT SETBACK IS USED
= EQUALS =	
	TOTAL BOILER LOAD BTU/H

* Check with the Authority having jurisdiction regarding acceptability of reducing load with DHW priority control.



HEAT LOSS CALCULATION WORKSHEET - SIZING THE ROOMS

Room Sketch

Room Data

ROOM -	L	W	H	**sq ft x H. L. Multiplier =**	**Btuh Heat Loss**
sq ft Ceiling - L x W				= x sq ft	
Windows - L x H			=	x	
sq ft Doors - L x H				= x	
sq ft Walls - L x H (minus window & door sq ft)				= x	
Lin. ft. Floor - L + W				= x	
Volume L x W x H			=	x	
"R" value above tubing =				Total Room Btuh Heat Loss =	

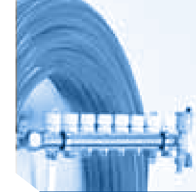
ROOM -	L	W	H	**sq ft x H. L. Multiplier =**	**Btuh Heat Loss**
sq ft Ceiling - L x W				= x sq ft	
Windows - L x H			=	x	
sq ft Doors - L x H				= x	
sq ft Walls - L x H (minus window & door sq ft)				= x	
Lin. ft. Floor - L + W				= x	
Volume L x W x H			=	x	
"R" value above tubing =				Total Room Btuh Heat Loss =	

ROOM -	L	W	H	**sq ft x H. L. Multiplier =**	**Btuh Heat Loss**
sq ft Ceiling - L x W				= x sq ft	
Windows - L x H			=	x	
sq ft Doors - L x H				= x	
sq ft Walls - L x H (minus window & door sq ft)				= x	
Lin. ft. Floor - L + W				= x	
Volume L x W x H			=	x	
"R" value above tubing =				Total Room Btuh Heat Loss =	

ROOM -	L	W	H	**sq ft x H. L. Multiplier =**	**Btuh Heat Loss**
sq ft Ceiling - L x W				= x sq ft	
Windows - L x H			=	x	
sq ft Doors - L x H				= x	
sq ft Walls - L x H (minus window & door sq ft)				= x	
Lin. ft. Floor - L + W				= x	
Volume L x W x H			=	x	
"R" value above tubing =				Total Room Btuh Heat Loss =	

Usable sq ft calculation. For sq ft TOTAL, use ceiling sq ft. If the room has a vaulted ceiling, calculate sq ft based on floor area. Refer to pages A22 and A27.

(A) sq ft TOTAL	minus (B) sq ft REDUCED	= (C) sq ft CLEAR	B x REDUCTION MULTIPLIER + C = USABLE sq ft – enter as (B) on worksheet, pg. D 14 –



RADIANT PANEL SYSTEM DESIGN WORKSHEET

PROJECT NAME		DESIGNER NAME		JOB #		DATE	
ADDRESS				INSPECTION BY			

INDOOR TEMPERATURE		DESIGN TEMPERATURE DROP (ΔT)		MAXIMUM RADIANT SUPPLY TEMPERATURE	
MAXIMUM PRESSURE DROP (ΔP)		(F) MAXIMUM LOOP LENGTH		MAXIMUM “R” VALUE ABOVE TUBING	

ROOM I.D.	HEAT LOSS Btuh	ZONE NO.	(A) FLOOR AREA sq ft	(B) USABLE FLOOR AREA sq ft	Btuh per sq ft REQUIRED	(C) SURFACE TEMP. REQUIRED	(D) MAX. SURFACE TEMP. ALLOWED	C minus D = SURF TEMP. SHORTFALL X 2 X B = SUPPLEM-ENTAL Btuh REQUIRED	“R” VALUE ABOVE TUBE	AVERAGE TUBE SPACING O.C.	(E) TUBE SPACING FACTOR	WATER TEMP. FROM CHART B, PG. A35 X E = MAXIMUM WATER TEMP. REQUIRED	(G) (A x E) = ft of TUBE IN FLOOR	LOOP I.D.#	(H) G FOR ZONE divided by NO. OF LOOPS = LOOP LENGTHS	LOOP TAIL LENGTH ft	(I) H + TAIL LENGTH = TOTAL LOOP LENGTH	(J) ROOM gpm -from page A43	(K) gpm per LOOP	LOOP PIPE SIZE	(L) LOOP PRESSURE DROP ft/head (Pg. A44)
TOTAL HEAT LOSS			TOTAL sq ft					TOTAL SUPPLEMENTAL				MAX. WATER TEMP.	TOTAL ft TUBE				LONGEST LOOP	TOTAL GPM			MAX. ΔP

RADIANT PANEL INSTALLERS' WORKSHEET

PROJECT NAME		DESIGNER NAME		JOB #		DATE	
ADDRESS				INSPECTION BY			

BOILER - MAKE, MODEL		BOILER PUMP - MAKE, MODEL		RADIANT PUMP - MAKE, MODEL			
EXPANSION TANK - MAKE, MODEL		TUBE DIA.		MAX. LOOP LENGTH		MAX. RADIANT SUPPLY TEMP.	
OTHER COMPONENTS & SPECIFICATIONS							
OTHER COMPONENTS & SPECIFICATIONS							

ROOM IDENTIFICATION	AVERAGE TUBE SPACING	LOOP LENGTHS INCL. TAILS				MANIFOLD NUMBER	ZONE VALVE NUMBER	BALANCING VALVE SETTING				"R" VALUE ABOVE TUBING	"R" VALUE BELOW TUBING	SPECIAL NOTES
		①	②	③	④			①	②	③	④			

STEP 1 - SIZING THE BUILDING & LISTING HEAT LOSS FACTORS

Why room-by-room heat loss?

The most important step in designing any heating system is to perform an accurate heat loss calculation for every room in the house. We need to do this because each room in a house can have wide variations in heat loss depending on such factors as window and door sizes as well as any variation in insulation levels in outside walls, ceilings and floors (over unheated spaces). Insulation levels in the actual exposed walls and ceilings are usually consistent, but larger windows are becoming more common and they can have a big effect on heat loss from room to room. There can also be a big difference in how much wall or ceiling is exposed to the outside. Some rooms may have three exposed walls while others may have none. The plans for a building must be examined in detail in order to find out how much heat we need to add to each room.

What are the design temperatures?

Two other pieces of information you must have are the required inside and outside temperature values for your design conditions. Design conditions occur on the coldest days of the year. Our indoor design temperature is really determined by comfort. In most areas, the indoor design temperature is legislated by building code to be between 68°F and 72°F, but your customer may want even warmer temperatures. We have given our practice house a design indoor temperature of 72°F for all rooms, but keep in mind that you could zone the house with different design indoor temperatures depending on customer needs. It is quite common to use an indoor design temperature of 72°F for living spaces and 60°F or lower for heated garages and storage rooms. However, if the heated garage is used quite often as a workshop, the customer may want a design indoor temperature that is higher.

The outdoor design temperature is not quite as low as the coldest temperature of the year, but close to it. The theory is that if we design our heating system to warm the space comfortably at design outdoor we should never run into a problem for the short periods of time that it may get colder. Design outdoor temperatures differ widely of course and if you don't know what it is for your area consult either the published ASHRAE charts or local building officials.

Some representative design outdoor temperatures, in degrees Fahrenheit, from the ASHRAE charts are:
VANCOUVER 19, WHITEHORSE -46, CALGARY -27, REGINA -33, WINNIPEG -30, TORONTO -5, OTTAWA -17, MONTREAL -16, QUEBEC -19, HALIFAX 1, BOSTON 6, WASHINGTON D.C. 14, ATLANTA 17, CHICAGO -8, WICHITA 3, MINNEAPOLIS -16, DENVER -5, SALT LAKE 3, LOS ANGELES 41.

Once we know both design temperatures we simply calculate the difference between the two to find out what the difference will be between the indoor and outdoor temperatures during the coldest weather. We call this factor the DESIGN TEMPERATURE DIFFERENCE (DTD).

EXAMPLE 1: Vancouver - Outdoor Design = 19°F Indoor Design 72°F. Subtract 19°F from 72°F = 53°F
So: in Vancouver, in the coldest weather, our DTD is 53°F
EXAMPLE 2: Calgary - Outdoor Design = -27°F Indoor Design 72°F. Subtract -27°F from 72°F = 99
So: in Calgary, in the coldest weather, our DTD is 99°F

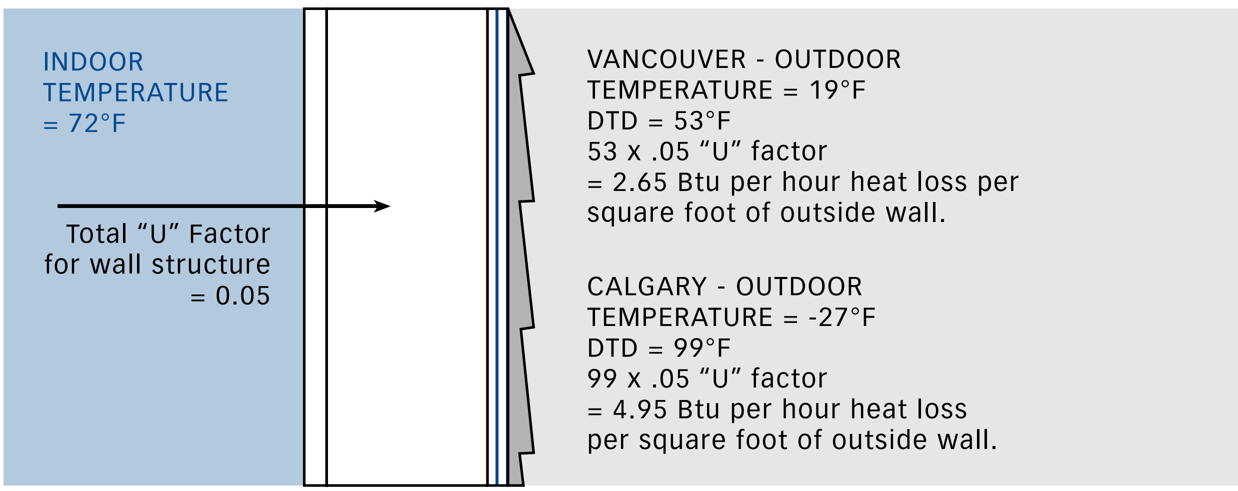
What is the structure made of?

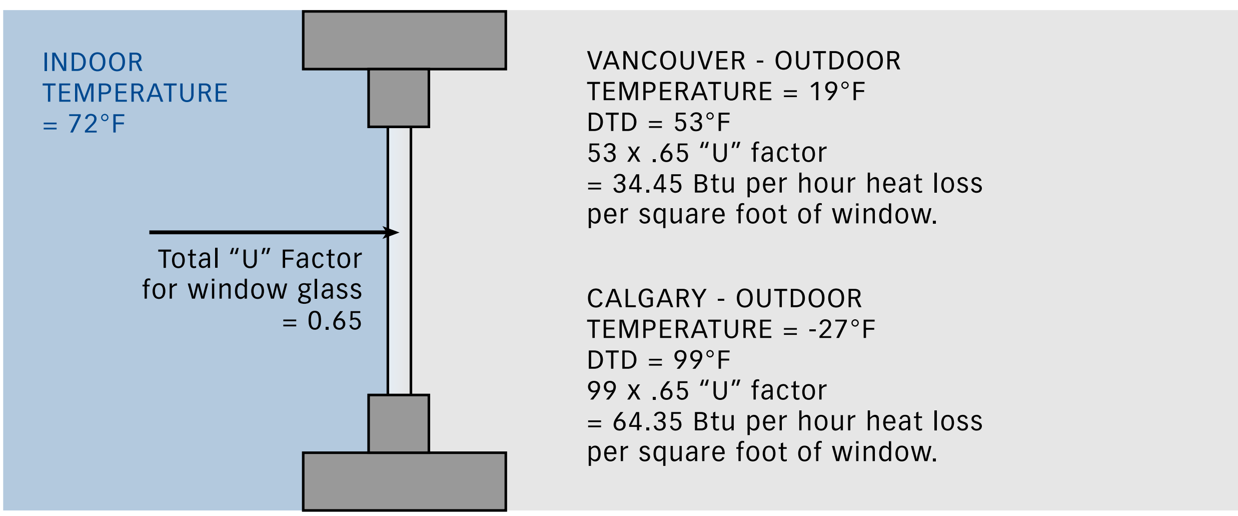
Different materials will allow heat to pass through them at different rates. All building materials that are used in constructing "cold" walls, ceilings or floors, are tested for conductivity and a thermal transfer resistance factor (called the "R" factor) has been assigned to them. Most materials are given an "R" factor per inch of thickness. Remember that heat travels to cold, and the more resistance we put between the warm air in your home and the cold outdoors, the longer it will take to draw the heat out. If it takes a long time to draw the heat through an insulated wall for instance, our heating system won't have to add as much heat as fast as it would if the heat was traveling quickly through an uninsulated wall. The second step in any heat loss calculation is to identify the different materials used in construction for each room and come up with "U" (rate of heat transmission) values for walls, ceilings, windows and doors. These values may be spelled out on the plans or can be calculated when the construction details are known.

Calculating "U" values is a Science in itself and there are many charts and formulas for determining them. This manual will not have the space to fully address the subject and is only going to cover the basics, so our practice house has the values already determined. We need to know the "U" factor so we can compare it to the DTD and see how much heat will be lost every hour through the different parts of the structure. The next page shows cross sections of the structure of our practice house and some examples of how we end up calculating a heat loss multiplier. Good information is available from HRAI, ASHRAE, I=B=R, etc. and we strongly recommend that you take an accredited heat loss calculation course to become good at it. Once you gain confidence and understand the Art and Science of heat loss calculation, you should get a good heat loss computer program to allow you to complete your calculations quickly and accurately. Contact your CANPEX distributor for information about the CANPEX design program.

Using the "U" value to calculate the heat loss multiplier

Once we have all of the heat loss multipliers calculated, we can enter them on our worksheets on page A14 and A15 and proceed to calculate heat loss. It is quite clear from the examples above, how much the local climate can influence the design of buildings and their heating systems. One would expect to see higher levels of insulation and smaller, more efficient windows in a climate like Calgary.





How much fresh air do you need?

The last piece of the heat loss puzzle is one of the most important. In the past, ventilation was accounted for as "infiltration" heat loss. Many complicated formulas took into account the age of the building, the types of windows and doors and a host of other factors including wind speed and building height. These formulas worked because houses were very leaky; until the mid 1970s when everything changed. Newer construction techniques, continuous vapour barriers, improved weather-stripping and caulking in combination with better windows mean that air no longer "infiltrates" a house the way it used to, it must be introduced through mechanical means. The best way to do this is through balanced ventilation. From an energy saving standpoint, a Heat Recovery Ventilation unit should be used. These packaged units have two fans. One fan brings in fresh air and another one exhausts the stale warm air, which gives off most of its heat to the cold air coming in saving 50% to 75% of the heat. With an HRV there is no more pressurizing the house and hoping the stale air sneaks out or sucking the stale air out and hoping the fresh air sneaks in; adequate ventilation is assured and the house isn't pressurized or brought down into a negative pressure condition. The use of HRV's in any new construction is strongly recommended. Many building codes require a minimum of 0.5 air changes per hour, which amounts to a "U" factor of .009 per cubic foot of air. It is up to the heating designer to ensure that the ventilation system can indeed exchange half of the air in the house in one hour. If an HRV is used, most of the heat from the warm air is recovered and the ventilation heat loss factor can be reduced accordingly. Check with local building officials regarding ventilation requirements, since they are changing almost daily in some jurisdictions. It is now generally accepted that poor indoor air quality is a major health problem and much more strict requirements for adequate ventilation will be introduced industry wide very soon.

STEP 2 - CALCULATING THE HEAT LOSS

Once we know our heat loss factors, we have to make decisions as to how far we want to break down the structure into rooms or groups of rooms. This is where heat loss calculations become less of a Science and more of an Art. When first starting to do heat loss calculations, it is best to break down the structure into the smallest units that are recognizable. This fine breakdown will make it easier to perform the heat loss calculations and will help us later on in the design process when we start to decide how to zone the spaces.

The illustration on the next page shows the complete floor plan with the corner bathroom broken out as a single room. In many cases, the linen closet and the bedroom closet could be lumped in as part of the bathroom for purposes of heat loss, but there are good reasons why you may want to include them with the bedroom heat loss. A common reason would be that you may want to treat the bathroom as a separate zone so that you can control it at a warmer temperature than the bedroom. By splitting up the bathroom, closets and bedroom, we leave our options open from a design standpoint and can easily configure the heating system to whatever the customer wants. Eventually, we will most likely include the closets with the bedroom heat loss.

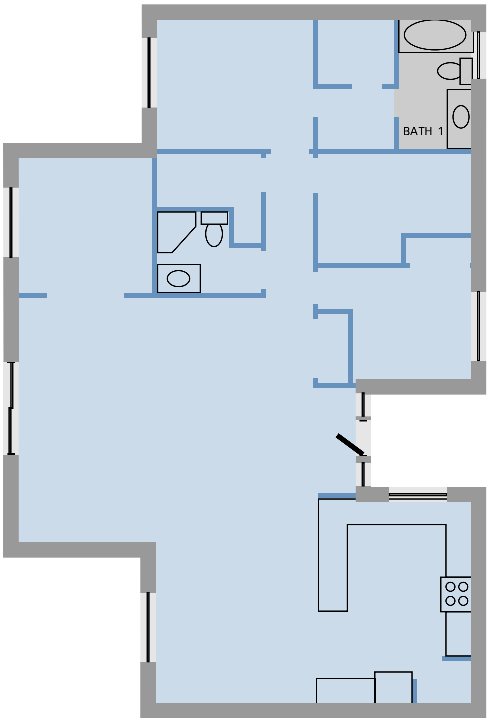
In this practice house plan, we were careful to make all of our dimensions come out to even, one foot measurements to make calculations easy. In real life, this is seldom the case and fractions of feet come into play. It is always better to be precise, but most heat loss calculations can be simplified by rounding the measurements up (that is, more heat loss than less) to the nearest six inches.

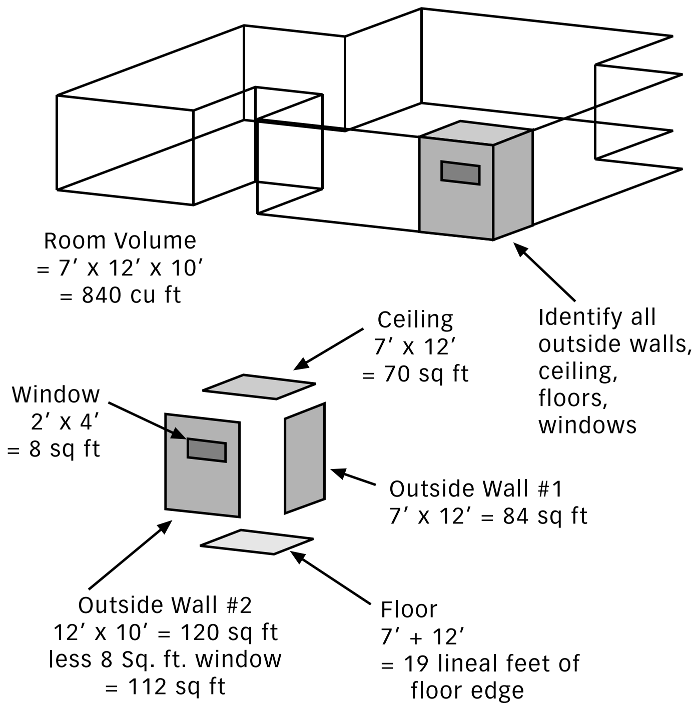
Once we pick a room, all of the dimensions are checked. If you have a scale plan, you can use a draftsman's scale to measure the dimensions. Needless to say it is important to check your scale against that of the plan to make sure it is accurate. Often, plans have been reduced or enlarged slightly causing no end of grief.

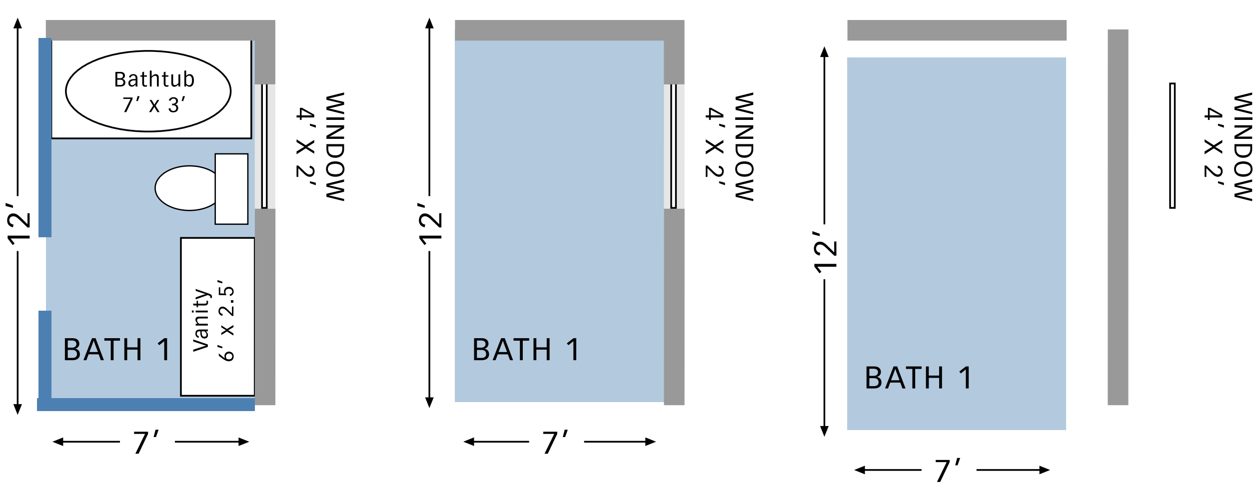
When first working with floor plans and heat loss calculations, it is useful to sketch out each room individually as we have on the next three pages; and enter in your calculations as you go. As you get better at it you can usually enter the information directly onto your worksheet, although even the experts find it useful on complex jobs to sketch out the individual zones. This house is designed with flat ceilings which makes calculations easier. Many houses today have cathedral ceilings where the area of the ceiling is much more than that of the floor, making area and volume calculations trickier.

Identify the wall, floor, ceiling, window and door elements of the room and calculate the square footage to be multiplied against each "U" Factor. In this example we have a total of 196 sq ft of outside wall - 70 sq ft of ceiling, 8 sq ft of window and 19 lineal feet of floor edge.

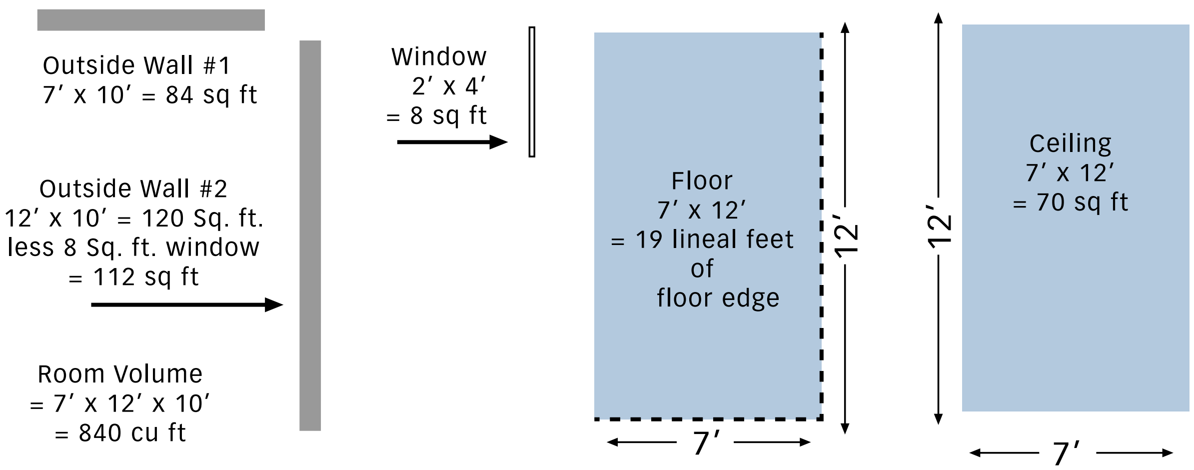
In addition to the transmission heat loss, we calculate a ventilation heat loss based on the room volume of 840 cubic feet. With 1/2 an air change per hour we will need to heat up 840 cubic feet divided by 0.5 = 420 cubic feet of air every hour. We will calculate the Btus required on the worksheet.







Identify all outside walls, ceilings, floors & windows/doors



ROOM - BATHROOM 1	L	W	H		sq ft x	H. L. Multiplier =	Btuh Heat Loss
sq ft Ceiling - L x W	12	7		=	84	x 1.98	166.32
sq ft Windows - L x H	2		4	=	8	x 64.35	514.8
sq ft Walls - L x H (minus window & door sq ft)	19		10	=	182	x 4.95	900.9
Lin. ft. Floor - L + W	7	12		=	19	x 52.47	996.93
Volume L x W x H	7	12	10	=	840	x .891	748.44
						TOTAL =	3327.39

(A) sq ft TOTAL	minus (B) sq ft REDUCED	= (C) sq ft CLEAR	B x REDUCTION MULTIPLIER + C = USABLE sq ft – enter as (B) on worksheet, pg. A16 –
84 sq ft	39.5 sq ft	44.5 sq ft	39.5 x .75 = 29.6 + 44.5 = 74.1
From sq ft Ceiling, above	Area of Bathtub and Vanity (Reduced Btuh output), see page D24	Uncovered clear floor area (Full Btuh output)	Bathtubs and vanities reduce heat output by 25%. The 39.5 sq ft under these items multiplied by .75 are equivalent to 29.6 sq ft. Adding this to the 44.5 sq ft clear area = a total usable sq ft of 74.1 sq ft.

On page A15 we have a layout sheet to help you fill in the square footages and calculate the heat losses. On page A23 is a layout of our test house with the individual heat loss areas identified. Note that the heat loss multipliers have been calculated already. These numbers should be entered on the worksheet Pg A14. With some experience, you should only need to use this one heat loss calculation worksheet, but when first learning to do heat losses, it is helpful to use the worksheet on page A15. Photocopy the worksheet and fill in the heat loss multipliers in the H.L. Multiplier column. You can then photocopy it again for the number of heat loss areas you require. Using these detailed worksheets allows you to sketch out the heat loss area being worked on and make notes and calculations. When you have the final numbers you can then enter them on the master heat loss calculation worksheet A14. In our example above, we have taken the room BATH 1 and broken it down to the component parts that are subject to heat losses, the outside walls, windows, ceiling and floor. The volume calculation allows us to calculate ventilation heat loss.

STEP 2 – CALCULATE THE SQUARE FOOTAGES AND VOLUMES OF EACH ROOM

In this example, we have divided the house up into 13 individual heat loss areas. Notice that the outside walls are shaded a grey colour for ease of identification. We can now proceed to calculate the square footages and volumes prior to calculating heat loss. To calculate our heat loss multipliers, we subtract our design outdoor temp from our design indoor to get our design temperature difference.

OUTDOOR DESIGN TEMPERATURE, -27°F, minus INDOOR DESIGN TEMPERATURE 72°F
equals DESIGN TEMPERATURE DIFFERENCE (DTD) OF 99. We will multiply each heat loss "U" factors by this DTD of 99 to come up with heat loss multipliers. ENTER THE DTD ON THE WORKSHEET PG. A14

0.5 AIR CHANGES/HR.
= AIR CHANGE "U" FACTOR OF .009
99 x .009 = .891 Btuh loss per cubic foot of interior space.
AIR CHANGE MULTIPLIER = .891

WINDOWS:
"U" FACTOR = 0.65
99 x .65 = 64.35 Btuh loss per square foot of glass surface.
WINDOW
MULTIPLIER = 64.35

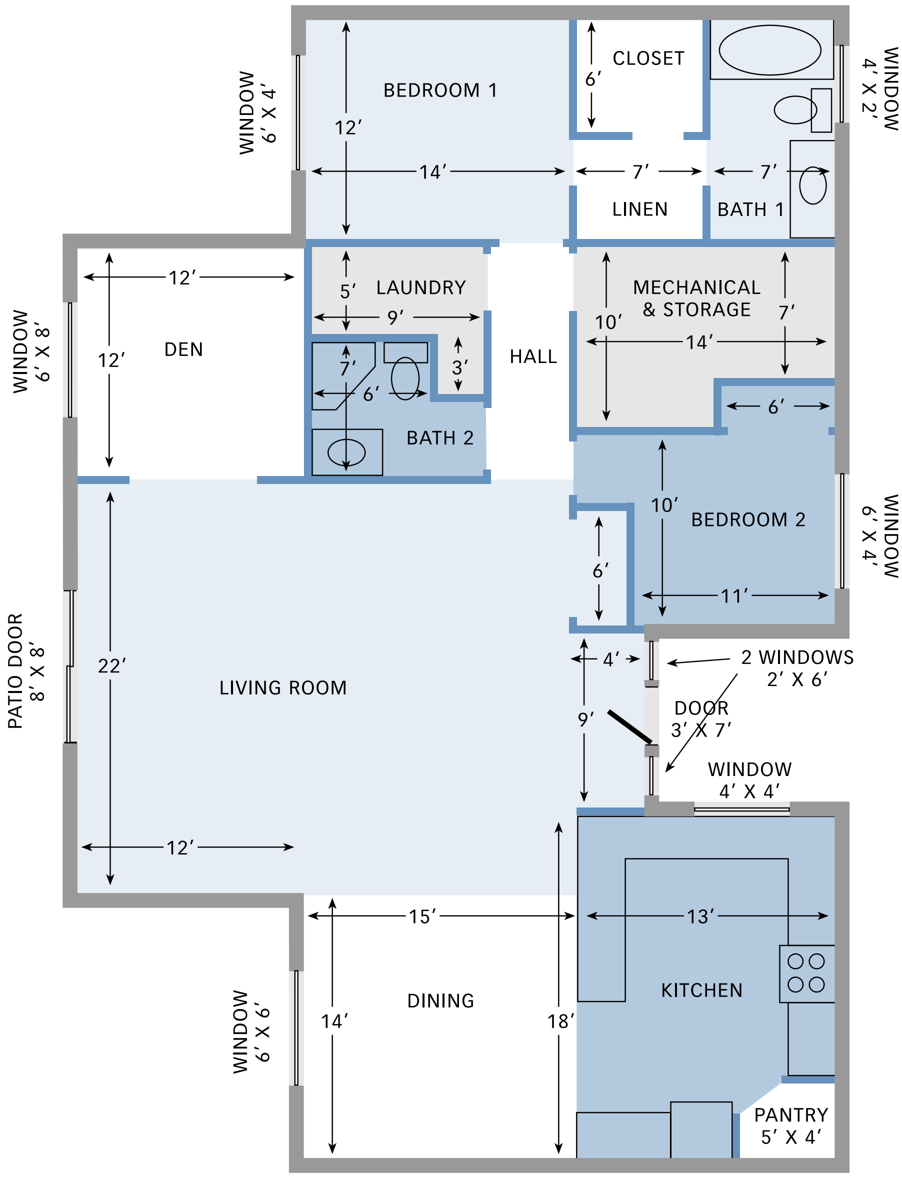
DOORS:
"U" FACTOR = 0.15
99 x .15 = 14.85 Btuh loss per square foot of door surface.
DOOR
MULTIPLIER = 14.85

WALLS:
"U" FACTOR = 0.05
99 x .05 = 4.95 Btuh loss per square foot of Wall surface.
WALL
MULTIPLIER = 4.95

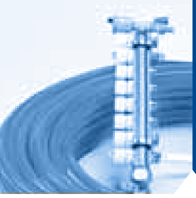
CEILINGS:
"U" FACTOR 0.02
99 x .02 = 1.98 Btuh loss per square foot of ceiling surface.
CEILING
MULTIPLIER = 1.98

FLOOR:
"U" FACTOR = 0.53 PER LINEAL FOOT OF OUTSIDE EDGE
99 x .53 = 52.47 Btuh loss per lineal foot of outside edge.
FLOOR MULTIPLIER = 52.47

ENTER ALL OF THE HEAT LOSS MULTIPLIERS ON THE WORKSHEETS PG. A14 AND A15

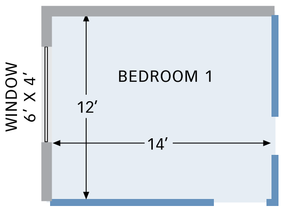


CEILING HEIGHT = 10′



Designing a Radiant System

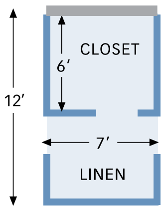
Step 2 – calculate the square Footages and volumes of each room
Step 3 – calculate the Btu/h heat loss of each room



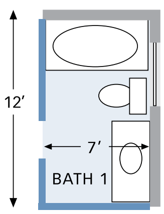
ROOM - BEDROOM 1	L	W	H		sq ft x H. L. Multiplier		=	Btuh Heat Loss
sq ft Ceiling - L x W	14	12		=	168	X	1.98	332.64
sq ft Windows - L x H	6		4	=	24	X	64.35	1544.4
sq ft Walls - L x H (minus window & door sq ft)	26		10	=	236	X	4.95	1168.2
Lin. ft. Floor - L + W	14	12		=	26	X	52.47	1364.22
Volume L x W x H	14	12	10	=	1680	X	.891	1496.88
"R" value above tubing = R 1.4							TOTAL =	5906.34

Bed = 8'x8'

(A) sq ft TOTAL	minus (B) sq ft REDUCED	= (C) sq ft CLEAR	B x REDUCTION MULTIPLIER + C = USABLE sq ft – enter as (B) on worksheet, pg. A15 –
168 sq ft	64 sq ft	104 sq ft	64 x .75 = 48 + 104 = 152



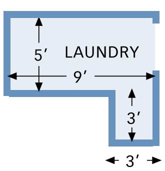
ROOM - CLOSETS	L	W	H		sq ft x H. L. Multiplier		=	Btuh Heat Loss
sq ft Ceiling - L x W	12	7		=	84	x	1.98	166.32
sq ft Windows - L x H	0		0	=	0	x	64.35	0
sq ft Walls - L x H (minus window & door sq ft)	7		10	=	70	x	4.95	346.5
Lin. ft. Floor - L + W	7	0		=	7	x	52.47	367.29
Volume L x W x H	12	7	10	=	840	x	.891	748.44
"R" value above tubing = R 1.4							TOTAL =	1628.55



ROOM - BATHROOM 1	L	W	H		sq ft x H. L. Multiplier		=	Btuh Heat Loss
sq ft Ceiling - L x W	7	12		=	84	x	1.98	166.32
sq ft Windows - L x H	2		4	=	8	x	64.35	514.8
sq ft Walls - L x H (minus window & door sq ft)	19		10	=	182	x	4.95	900.9
Lin. ft. Floor - L + W	7	12		=	19	x	52.47	996.93
Volume L x W x H	7	12	10	=	840	x	.891	748.44
"R" value above tubing = R 0.2							TOTAL =	3327.39

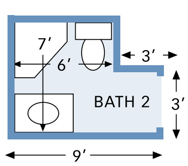
Tub = 3'x7'
Vanity = 2.5'x6'

(A) sq ft TOTAL	minus (B) sq ft REDUCED	= (C) sq ft CLEAR	B x REDUCTION MULTIPLIER + C = USABLE sq ft – enter as (B) on worksheet, pg. A15 –
84 sq ft	39.5 sq ft	44.5 sq ft	39.5 x .75 = 29.6 + 44.5 = 74.1



ROOM - LAUNDRY	L	W	H		sq ft x H. L. Multiplier		=	Btuh Heat Loss
sq ft Ceiling - L x W	6	9		=	54	x	1.98	106.92
sq ft Windows - L x H	0	0		=	0	x	64.35	0
sq ft Walls - L x H (minus window & door sq ft)	0	0		=	0	x	4.95	0
Lin. ft. Floor - L + W	0	0		=	0	x	52.47	0
Volume L x W x H	6	9	10	=	540	x	.891	481.14
"R" value above tubing = R 0.2							TOTAL =	588.06

NOTE: For easier calculation, the 3' x 3' nook = 9 sq ft was added to the 5' dimension to make room 6' x 9'.



ROOM - BATHROOM 2	L	W	H		sq ft x H. L. Multiplier		=	Btuh Heat Loss
sq ft Ceiling - L x W	7	7.5		=	52.5	x	1.98	103.95
sq ft Windows - L x H	0		0	=	0	x	64.35	0
sq ft Walls - L x H (minus window & door sq ft)	0		0	=	0	x	4.95	0
Lin. ft. Floor - L + W	0	0		=	0	x	52.47	0
Volume L x W x H	7	7.5	10	=	525	x	.891	467.77
"R" value above tubing = R 0.2							TOTAL =	571.72

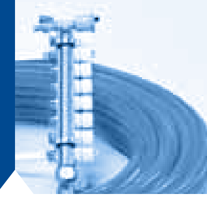
NOTE: For easier calculation, the 3' x 3' entrance = 9 sq ft was added to the 6' dimension to make room 7' x 7.5'.

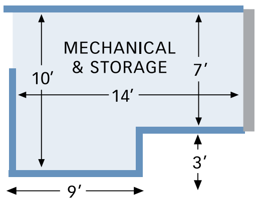
Shower = 3'x3'
Vanity = 2.5'x4'

(A) sq ft TOTAL	minus (B) sq ft REDUCED	= (C) sq ft CLEAR	B x REDUCTION MULTIPLIER + C = USABLE sq ft – enter as (B) on worksheet, pg. A15 –
52.5 sq ft	19 sq ft	33.5 sq ft	19 x .75 = 14.25 + 33.5 = 47.75

Designing a Radiant System

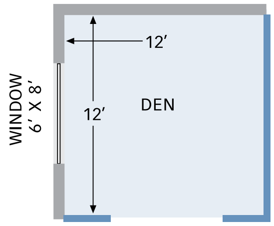
Step 2 – calculate the square Footages and volumes of each room
Step 3 – calculate the Btu/h heat loss of each room



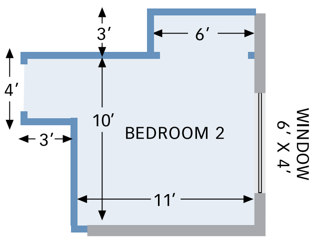


ROOM - MECHANICAL	L	W	H	sq ft x H. L. Multiplier =		Btuh Heat Loss
sq ft Ceiling - L x W	8.9	14		= 124.	x 1.98	246.708
sq ft Windows - L x H	0		0	= 0	x 64.35	0
sq ft Walls - L x H (minus window & door sq ft)	7		10	= 70	x 4.95	346.5
Lin. ft. Floor - L + W	7	0		= 7	x 52.47	367.29
Volume L x W x H	7	8.9	10	= 7	x .891	555.09
"R" value above tubing = R 0.2				623	TOTAL =	1515.59

NOTE: For easier calculation, the 3′ x 9′ nook = 27 sq ft was added to the 7′ dimension to make room 14′ x 8.9′.



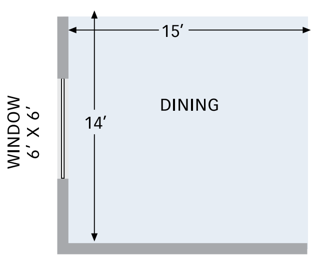
ROOM - DEN	L	W	H	sq ft x H. L. Multiplier =		Btuh Heat Loss
sq ft Ceiling - L x W	12	12		= 144	x 1.98	285.12
sq ft Windows - L x H	6		8	= 48	x 64.35	3088.8
sq ft Walls - L x H (minus window & door sq ft)	24		10	= 192	x 4.95	950.4
sq ft Floor - L + W	12	12		= 24	x 52.47	1259.28
Volume L x W x H	12	12	10	= 1440	x .891	1283.04
"R" value above tubing = R 1.4					TOTAL =	6866.64



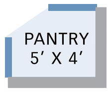
ROOM - BEDROOM 2	L	W	H	sq ft x H. L. Multiplier =		Btuh Heat Loss
sq ft Ceiling - L x W	10	14		= 140	x 1.98	277.2
sq ft Windows - L x H	6		4	= 24	x 64.35	1544.4
sq ft Walls - L x H (minus window & door sq ft)	24		10	= 216	x 4.95	1069.2
Lin. ft. Floor - L + W	13	11		= 24	x 52.47	1259.28
Volume L x W x H	10	14	10	= 1400	x .891	1247.4
"R" value above tubing = R 1.4					TOTAL =	5397.48

NOTE: For easier calculation, the 3′ x 4′ entrance = 12 sq ft and the 3′ x 6′ closet = 18 sq ft was added to the 11′ dimension to make room 10′ x 14′.

	(A) sq ft TOTAL	minus (B) sq ft REDUCED	= (C) sq ft CLEAR	B x REDUCTION MULTIPLIER + C = USABLE sq ft – enter as (B) on worksheet, pg. A15 –
Bed = 7′x6′	140 sq ft	42 sq ft	98 sq ft	42 x .75 = 31.5 + 98 = 129.5



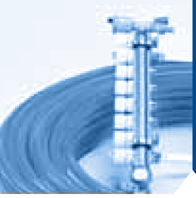
ROOM - DINING	L	W	H	sq ft x H. L. Multiplier =		Btuh Heat Loss
sq ft Ceiling - L x W	14	15		= 210	x 1.98	415.8
sq ft Windows - L x H	6		6	= 36	x 64.35	2316.6
sq ft Walls - L x H (minus window & door sq ft)	29		10	= 254	x 4.95	1257.3
Lin. ft. Floor - L + W	14	15		= 29	x 52.47	1521.63
Volume L x W x H	14	15	10	= 2100	x .891	1871.1
"R" value above tubing = R 0.2					TOTAL =	7382.43



Because the pantry is used for food storage, we will not heat it. The usable sq ft will be zero. * The 1135.53 Btuh heat loss from the pantry will be added to the kitchen heat loss.

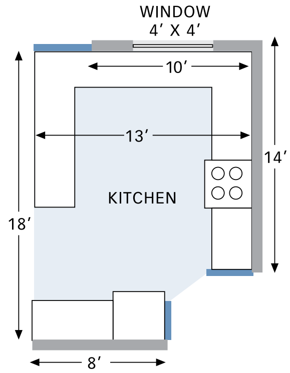
ROOM - PANTRY	L	W	H	sq ft x H. L. Multiplier =		Btuh Heat Loss
sq ft Ceiling - L x W	4	5		= 20	x 1.98	39.6
sq ft Windows - L x H	0		0	= 0	x 64.35	0
sq ft Walls - L x H (minus window & door sq ft)	9		10	= 90	x 4.95	445.5
Lin. ft. Floor - L + W	4	5		= 9	x 52.47	472.23
Volume L x W x H	4	5	10	= 200	x .891	178.2
					TOTAL =	1135.53 *

NOTE: For easier calculation, the approx. 2 sq ft lost by the angle of the door was ignored.



Designing a Radiant System

Step 2 – calculate the square Footages and volumes of each room
Step 3 – calculate the Btu/h heat loss of each room

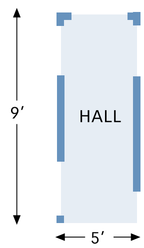


ROOM - KITCHEN	L	W	H		sq ft	x	H. L. Multiplier	= Btuh Heat Loss
sq ft Ceiling - L x W	18	12		=	216	x	1.98	427.68
sq ft Windows - L x H	4		4	=	16	x	64.35	1029.6
sq ft Walls - L x H (minus window & door sq ft)	32		10	=	304	x	4.95	1504.8
Lin. ft. Floor - L + W	32			=	32	x	52.47	1679.04
Volume L x W x H	18	12	10	=	2160	x	.891	1924.56
							TOTAL =	6565.68 *

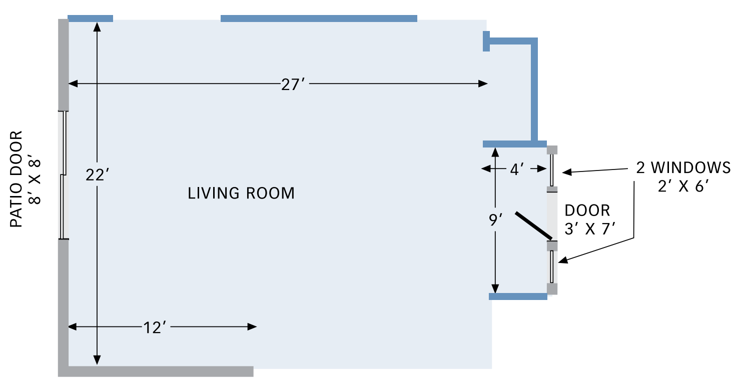
* The 1135.53 Btuh heat loss from the pantry will be added to the kitchen heat loss.
Total kitchen heat loss = 7,701.21

NOTE: For easier calculation, the 5' x 4' pantry = 20 sq ft was deducted from the 13' dimension to make room 18' x 12'.

	(A) sq ft TOTAL	minus (B) sq ft REDUCED	= (C) sq ft CLEAR	B x REDUCTION MULTIPLIER + C = USABLE sq ft – enter as (B) on worksheet, pg. A15 –
Cupboards = 31'x2.5'		77.5 sq ft		77.5 x .75 = 58.12
Cupboard = 5'x2.5'		12.5 sq ft		12.5 x 0 = 0
Stove = 3'x3'		9 sq ft		9 x .50 = 4.5
TOTALS	216 sq ft	99 sq ft	117 sq ft	Red. total = 62.6 + 117 = 179.6 sq ft



ROOM - HALL	L	W	H		sq ft	x	H. L. Multiplier	= Btuh Heat Loss
sq ft Ceiling - L x W	12	5		=	60	x	1.98	118.8
sq ft Windows - L x H	0		0	=	0	x	64.35	0
sq ft Walls - L x H (minus window & door sq ft)	0		0	=	0	x	4.95	0
Lin. ft. Floor - L + W	0	0		=	0	x	52.47	0
Volume L x W x H	12	5	10	=	600	x	.891	534.6
							TOTAL =	653.4

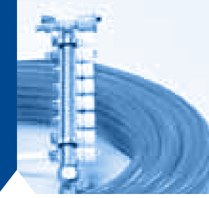


NOTES: For easier calculation, the 9' x 4' entrance = 36 sq ft and the 3' x 6' closet = 18 sq ft was added to the 22' dimension to make room 24' x 27'.

The heat loss multiplier for the patio door is the same as for the windows

ENTER THE APPLICABLE HEAT LOSS DATA ON THE WORKSHEET PG. A15

ROOM - LIVING, ENTRY	L	W	H		sq ft	x	H. L. Multiplier	= Btuh Heat Loss
sq ft Ceiling - L x W	24	27		=	648	x	1.98	1283.04
sq ft Windows - L x H	6		4	=	24	x	64.35	1544.4
sq ft Patio Door - L x H	8		8	=	64	x	64.35	4118.4
sq ft Doors - L x H	3		7	=	21	x	14.85	311.85
sq ft Walls - L x H (minus window & door sq ft)	34		10	=	231	x	4.95	1143.45
Lin. ft. Floor - L + W	14	12		=	26	x	52.47	1364.22
Volume L x W x H	24	27	10	=	6480	x	.891	5773.68
							TOTAL =	15539.04



STEP 4 - CALCULATING THE USABLE SURFACE AREA

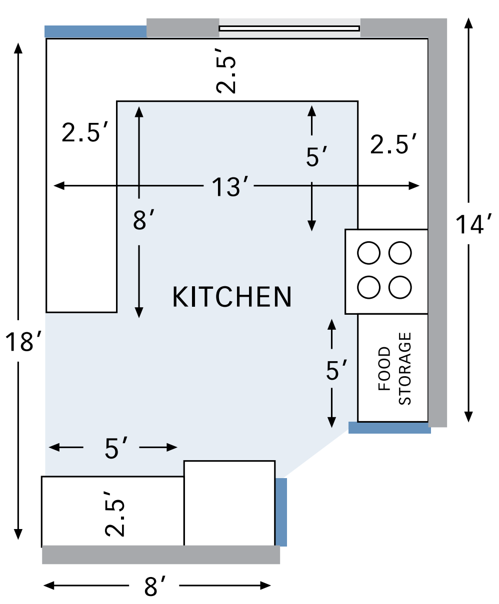
Once we have all of our square footages listed, the next step is to divide the available floor surface area by the total room heat loss in order to determine the required surface temperature. When calculating the floor surface area, keep in mind that it is not a good idea to run tubing underneath kitchen counters, since food and kitchen waste may be heated up and be spoiled. Another area where many people have found themselves in trouble is around the toilet. If higher temperature water is being used such as in a staple-up system the extra heat can melt the wax seal. In these cases stay at least 1 1/2′ away from the seal or have a rubber seal installed in its place. Although some designers subtract the floor area of such spaces as under stairways, closets that remain closed, under showers and tubs, these spaces do add heat to the space and shouldn't be ignored. On the other hand, there are times when you know that there will be heavy furniture, appliances, heavy area carpets and other objects brought into a space that could significantly decrease the amount of heat available. If you are aware of this type of situation, it is a good idea to make some attempt at estimating their effect. As you become better at system design, you will be able to readily identify those "borderline" situations where it becomes important to account for these factors.

Here are some factors to work with when trying to determine how much your heating system may be affected by things like closed doors (in the case of closets), heavy furniture and area rugs. These figures are based on rule-of thumb and experience, since it is impossible to know exactly how each item will effect heat transmission. Many designers ignore these factors, but they should be taken into account.

Percentage of heat available from floor:

Closets:	On outside walls	100%
	On inside walls	50% = .5 multiplier
Cupboards:	Bathroom Vanities	75% = .75 multiplier
	Kitchen (no food)	75% = .75 multiplier
	Kitchen (with food)	0%
Bathtubs and Showers:		75% = .75 multiplier (Insulated tubs, 25% = .25 multiplier)
Under heavy Furniture:		75% = .75 multiplier, if open underneath
Under heavy Furniture:		25 to 50% = .25 to .5 multiplier, if down to floor
Under heavy area rugs:		50 to 80% = .5 to .8 multiplier, depending on thickness
Under Refrigerators & Freezers:		100% (heat from appliance is usually more than from floor)
Under other appliances:		50% = .5 multiplier

Our test house kitchen has a total floor area of approx 18 x 12 = 216 Sq. ft. when we deduct the pantry area which we will not include with this rooms' heat loss. The cupboard next to the pantry (5 x 2.5 =12.5 Sq. ft.) will be used for food storage so we won't include it in our usable area. We will factor the other cupboards (31 x 2.5 = 77.5 Sq. ft.) at 75% available output or equivalent to 58 Sq. ft. (deduct 20 Sq. ft. from total). The refrigerator we will ignore and we will factor the stove (3 x 3 = 9 Sq. ft.) at 50% = 4.5 Sq ft.



So: Total Sq. ft. = 216, less 12.5, less 20, less 4.5 = 179 Sq. ft. usable floor area. See calculation, page A27.

Do we really need to go into this much detail? Normally not, but there are many times when the heat output to a room can be seriously impeded by these factors. With experience you will learn when these calculations are important and when they can be skipped. In particular, any room that is close to the maximum allowable Btuh should be examined in fine detail.

Go through each room in our test house and calculate the usable floor area. When you are done, enter the BTUH per square foot for each room on the System Design Worksheet on page D14. Remember that there are many judgement calls in this type of calculation and no right answers. We have filled out a sample of the System Design Worksheet on page D25 so you can compare your answers with ours.

RADIANT PANEL SYSTEM DESIGN PRACTICE WORKSHEET

PROJECT NAME	CANray Test House	DESIGNER NAME		JOB #		DATE	
ADDRESS		INSPECTION BY					

INDOOR TEMPERATURE		DESIGN TEMPERATURE DROP (ΔT)		MAXIMUM RADIANT SUPPLY TEMPERATURE	
MAXIMUM PRESSURE DROP (ΔP)		(F) MAXIMUM LOOP LENGTH		MAXIMUM "R" VALUE ABOVE TUBING	

ROOM I.D.	HEAT LOSS Btuh	ZONE NO.	(A) FLOOR AREA sq ft	(B) USABLE FLOOR AREA sq ft	Btuh per sq ft REQUIRED	(C) SURFACE TEMP. REQUIRED	(D) MAX. SURFACE TEMP. ALLOWED	C minus D = SURF TEMP. SHORTFALL X 2 X B = SUPPLEMENTAL Btuh REQUIRED	"R" VALUE ABOVE TUBE	AVERAGE TUBE SPACING O.C.	(E) TUBE SPACING FACTOR	WATER TEMP. FROM CHART B, PG. D31 X E = MAXIMUM WATER TEMP. REQUIRED	(G) (A x E) = ft of TUBE IN FLOOR	LOOP I.D.#	(H) G FOR ZONE divided by NO. OF LOOPS = LOOP LENGTHS	LOOP TAIL LENGTH ft	(I) H + TAIL LENGTH = TOTAL LOOP LENGTH	(J) ROOM gpm -from page D39	(K) gpm per LOOP	LOOP PIPE SIZE	(L) LOOP PRESSURE DROP ft/head (Pg. D40)
Bed 1	5907	1	168	152	39	90	92.5		1.4	8"	1.5	138°F	252	1	252	28	280	.59	.59	1/2"	3.9
clst/lin	1629	1	84	84	19	80	92.5		1.4	8"	1.5	104°F	126	2	252	28	280	.16	.49	1/2"	2.8
Bath 1	3328	1	84	74	45	92.5	92.5		0.2	8"	1.5	95°F	126	2				.33		1/2"	
Den	6867	2	144	144	48	95	85	2880	1.4	8"	1.5	118°F	216	3	216	30	246	.68	.68	1/2"	4.7
Laundry	589	3	54	54	11	77.5	85		0.2	8"	1.5	76°F	81	4	216	12	228	.06	.12	1/2"	0.5
Bath 2	572	3	53	47	12	77.5	92.5		0.2	8"	1.5	76°F	80	4				.06		1/2"	
Mec/stor	1516	3	125	125	12	77.5	92.5		0.2	8"	1.5	76°F	187	5	216	4	220	.15	.22	1/2"	0.9
Bed 2	5398	3	140	129	42	92.5	92.5		1.4	8"	1.5	139°F	210	6	216	4	220	.54	.54	1/2"	3.1
Hall	654	3	60	60	11	77.5	92.5		1.4	8"	1.5	89°F	90	5				.07		1/2"	
Living	15539	4	648	648	24	82.5	85		1.4	8"	1.5	102°F	972	7,8,9,10	243 X 4	14	257x4	1.55	.39 x 4	1/2"	1.8
Dining	7383	5	210	210	35	90	85	2100	0.2	8"	1.5	84°F	315	11,12	223 X 2	40	263x2	.74	.56 x 2	1/2"	3.7
Kitchen	7702	5	216	179	43	92.5	85	2685	0.2	8"	1.5	85°F	324	12 13	223	40	263	.77	.50	1/2"	2.7
Pantry	1136	5	20	0	0	0	0	0	0	0	0	0	30	13	0	0	0	.11	0	0	0
	58,220		2,006					7,665				139°F					280	5.81			4.7'

TOTAL HEAT LOSS	TOTAL sq ft	TOTAL SUPPLEMENTAL	MAX. WATER TEMP.	TOTAL ft TUBE	LONGEST LOOP	TOTAL GPM	MAX. ΔP
58,220	2,006	7,665	139°F	3,291'	280	5.81	4.7'

STEP 5 - CALCULATING THE REQUIRED SURFACE TEMPERATURE

As surface temperatures increase, the Btuh output of a radiant floor increases accordingly. A good rule of thumb that has stood the test of time is: One square foot of floor surface will deliver 2 Btuh for every degree that it is hotter than the air temperature. We can only get so much heat out of a floor before it becomes too hot to stand on, most people agreeing that 85°F is the highest we should go. If we use our rule of thumb, we see that an 85°F floor should deliver 30 Btuh to a 70°F room. The chart below is based on this rule of thumb and indicates the limits to how hot we can make a radiant floor before it becomes uncomfortable. To make sure we stay out of trouble and avoid future complaints, we normally do not want the floor to get hotter than the temperatures in the white area of the chart.

ROOM TEMP.	"CHART A" – AVERAGE FLOOR SURFACE TEMPERATURE VS. Btuh OUTPUT										
	10 Btuh	15 Btuh	20 Btuh	25 Btuh	30 Btuh	35 Btuh	40 Btuh	45 Btuh	50 Btuh	55 Btuh	60 Btuh
80°F	85°F	87.5°F	90°F	92.5°F	95°F	97.5°F	100°F	102.5°F	105°F	107.5°F	110°F
75°F	80°F	82.5°F	85°F	87.5°F	90°F	92.5°F	95°F	97.5°F	100°F	102.5°F	105°F
70°F	75°F	77.5°F	80°F	82.5°F	85°F	87.5°F	90°F	92.5°F	95°F	97.5°F	100°F
65°F	70°F	72.5°F	75°F	77.5°F	80°F	82.5°F	85°F	87.5°F	90°F	92.5°F	95°F
60°F	65°F	67.5°F	70°F	72.5°F	75°F	77.5°F	80°F	82.5°F	85°F	87.5°F	90°F

The following temperatures are recommended maximum floor surface temperatures:

General occupied areas – areas where feet are in continuous contact with the floor - 85°F – White area of chart. Most people will not even notice that the floor is heated.

Indoor swimming pools, bathrooms, change rooms, closets, most bedrooms – rooms where feet are not in continuous contact with the floor - 92.5°F – Light blue area of chart. Most people will notice the floor is warm and enjoy the feeling. Long term exposure is unusual and not normally a concern in these areas.

Panel perimeter areas or border zones at cold walls only (maximum distance from perimeter should extend no more than 3 ft. into the room) - 92.5°F – Lighter blue area of chart Most people will notice the floor is warm and may enjoy the feeling for a short period of time. The floor may start to feel too hot after standing on it for a long time.

Temperatures in the darker blue area of the chart are not recommended for any radiant floor surface Most people will immediately notice that the floor is hot and will not want to stand on it.

Using the chart with our test house, we will look at two different rooms. From our calculations on page A28, we see that the Living Room requires 24 Btuh/sq ft. With a room temperature of 70°F, we will need a surface temperature of 82.5°F to deliver the heat required. This is within the acceptable range of surface temperatures. If we look at the Den however, we see that we need 48 Btuh/sq ft. With a room temperature of 70°F, we will need a surface temperature of 95°F to deliver the heat required. This is an unacceptably high surface temperature for this room and we will have to add supplemental heat. If we installed a panel radiator below the window to deliver 3,000 Btuh, we can recalculate our floor temperature based on a new heat requirement of 6866 - 3000 = 3866 Btuh. This number divided by the room sq ft of 144 means we now only have to add 26 Btuh/sq ft to the room from the floor and our surface temperature will be down to 83°F. Because the Den has large windows and two outside walls, the average unheated surface temperature (AUST) is much colder than the room air temperature. We can use this factor to reduce our floor surface temperature requirement, since the floor will radiate more heat to the colder surfaces at lower temperatures. We will not cover AUST during these basic calculations, but AUST compensation factors and methods can be found elsewhere in this manual.

Hydronic systems offer many easy ways to add extra heat to a room. Remember that radiant tubing can be installed in walls and ceilings as well as floors. It is a good idea to run tubing under tubs and showers and even to run some tubing behind shower walls. Sometimes running a hotter perimeter loop around the outside of a room, as illustrated on page D10 can give you enough heat. Other common solutions include the addition of baseboard heaters or fan convectors. Your CANPEX distributor can help you with some creative solutions to supplemental heat.

Enter the surface temperature required for each room on the worksheet, Pg. A16.

STEP 6 - CALCULATING THE "R" VALUE ABOVE THE TUBING

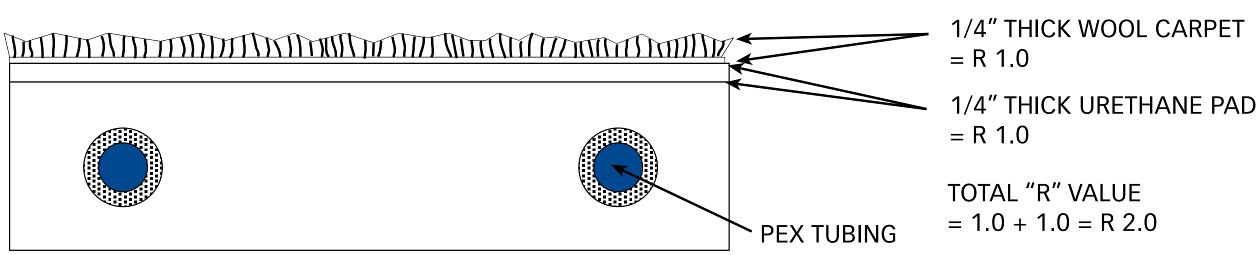
The next step is to determine what water temperatures are required in order to give us the correct surface temperatures. To do this we have to know what types and thicknesses of floor coverings are going to be used because floor coverings act as insulation against the heat coming to the surface of the floor. Different types of material insulate more than others and it is very important to know the type of material and the thickness being used. Some common floor coverings and their insulation, or "R" values, are listed in the next table. The values given are averages, it is best to check with the floor covering manufacturer to get exact "R" values for a particular product. Note that a bare concrete floor is considered to have a zero "R" value.

TYPE OF FLOORING	THICKNESS (in.)	"R" VALUE
CARPETING	1/8"	0.6
	1/4"	1.0
	1/2"	2.0
	3/4"	3.0
	1"	4.0
URETHANE PAD	1/4"	1.0
	1/2"	2.0

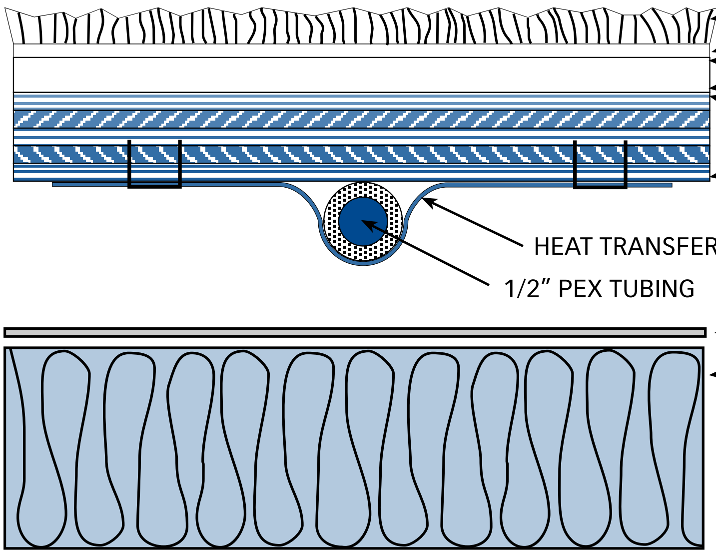
TYPE OF FLOORING	THICKNESS (in.)	"R" VALUE
RUBBER PAD	1/4"	0.4
	1/2"	0.8
VINYL OR LINO	1/8"	0.2
CERAMIC TILE OR STONE	1/8"	0.2
	1/4"	0.4
	1/2"	0.8

TYPE OF FLOORING	THICKNESS (in.)	"R" VALUE
HARDWOOD	1/4"	0.3
	1/2"	0.6
	3/4"	0.9
SOFTWOOD	1/4"	0.4
	1/2"	0.8
	3/4"	1.2
	1"	1.6

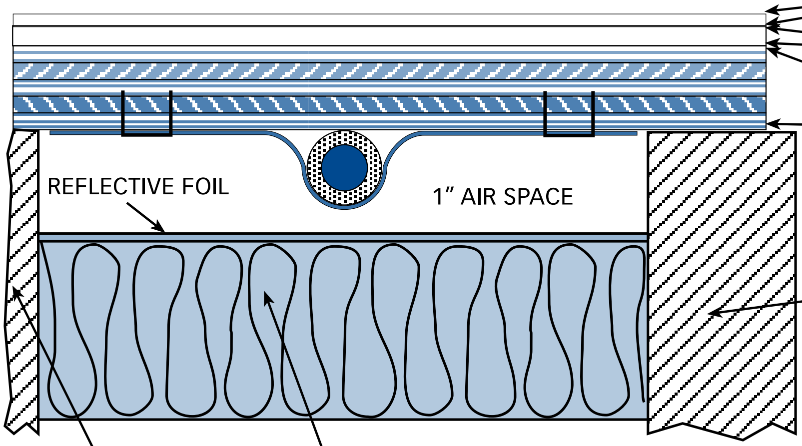
"R" VALUES OF COMMON FLOORING MATERIALS



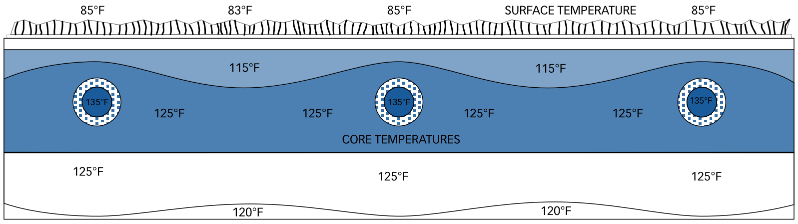
When designing a poured system, the surface of the pour is considered to be at an "R" value of zero.
Simply add up the "R" values of all of the materials on top of the poured surface to get the total insulating value of the finished floor.

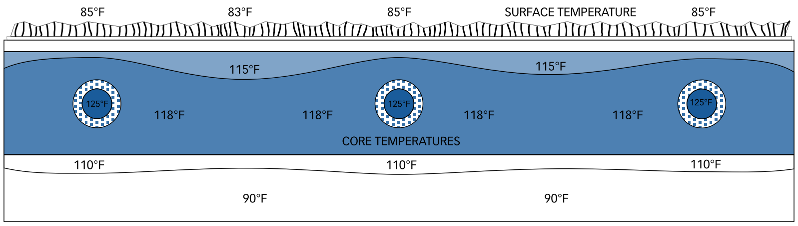


If you are designing a subfloor system, it is important to remember to also add in the "R" value of **all** flooring material (including the subfloor) above the tubing. The illustration above shows a typical subfloor system and the "R" values that might be associated with it. Most subfloor material such as plywood or OSB should be classified as a softwood. Note that although the value for 5/8" thick softwood is not in our chart, it can be obtained by taking a value halfway between the 1/2" and 3/4" material.



In this example we are showing a section of staple-up panel including the insulation below. The floor covering is a low "R" value linoleum so that all of the material above the tubing totals an "R" value of just 1.4. That is still enough however to drive the heat downwards if there is no insulation below the tubing. It is common practice to use a foil-backed friction fit insulation in the joist space below the tubing with a 1" air space between the sub-floor and the foil. In this example we only need "R" 6 insulation, but in the example on the previous page, the total insulation above the tubing was 3.4 meaning we would have to add insulation totalling "R" 13 beneath the tubing. Because we want our system to operate with the lowest water temperature possible, it is best to put as much insulation under the floor as is practical. When we calculate the water temperature required, we are assuming that adequate insulation levels have been provided. If they have not, the water temperature selected will be too low.





Without insulation under the slab, the soil beneath becomes a big heat-sink. The slab will be very slow to react to changes in temperature and if the water table is high, there could be serious downward heat losses.

Even a small amount of insulation under a slab will help. Insulation isolates the slab from the soil and allows it to heat up and cool down much more quickly. If the insulation under the slab is at least 10 times the insulation over, we calculate a zero downward heat loss. See Addendum DA1 for information regarding edge and downward heat losses from a slab-on-grade installation.

Our practice house is slab-on-grade. The owners want to have ceramic tile in the kitchen and dining room and linoleum in the bathrooms, laundry room and mechanical rooms. The rest of the house will be 1/4" carpet over 1/4" rubber pad. The "R" value for the ceramic tile is 0.2. The "R" value for the linoleum is 0.2. The "R" value for the carpet and underpad is 1.4.

Enter the "R" values for each room on the worksheet, Pg. A16.

STEP 7 - TUBE SPACING FOR COMFORT

Evenly and closely spaced tubing is important in order to provide a comfortable, even floor surface temperature. The charts below indicate the maximum tube spacing that a system should have. If in doubt, you can't go wrong by putting more tubing in the floor and reducing the spacing, provided it is done evenly and maximum loop lengths are not exceeded.

MAXIMUM SPACING FOR POURED SYSTEM TUBING		
Required Floor Output (Btu/sq ft/hr)	Tube Size	
	1/2 inch Tube	3/4 inch Tube
0 - 10 Btuh	12 inch o.c.	14 inch o.c.
10 - 20 Btuh	12 inch o.c.	14 inch o.c.
20 - 30 Btuh	10 inch o.c.	12 inch o.c.
30 - 40 Btuh	8 inch o.c.	10 inch o.c.

Note: These spacings may be too wide for some applications and heat output requirements should be used as maximum spacing guidelines only! It is recommended, for example, that in all areas where bare feet will be in contact with the floor surface – such as bathrooms, public showers, pool decks, etc. – the maximum pipe spacing not be more than 6".

For maximum comfort, we recommend tube spacing based on the chart below. Closer spacing means no hot or cold spotting and lower overall water temperatures. The designer should be careful to keep the spacing the same throughout the building in areas of similar floor covering.

RECOMMENDED TUBE SPACING (POURED SYSTEMS) FOR THE MOST COMFORT				
Required Floor Output (Btu/sq ft/hr)	FLOOR COVERING "R" VALUE			
	Less than R 0.5	R 0.5 to R 1.0	R 1.0 to R 1.5	R 1.5 to R 2.0
0 - 10 Btuh	8 inch o.c.	8 inch o.c.	10 inch o.c.	12 inch o.c.
10 - 20 Btuh	6 inch o.c.	8 inch o.c.	10 inch o.c.	10 inch o.c.
20 - 30 Btuh	6 inch o.c.	6 inch o.c.	8 inch o.c.	8 inch o.c.
30 - 40 Btuh	6 inch o.c.	6 inch o.c.	8 inch o.c.	8 inch o.c.

Staple up systems are different than poured systems because tube spacing is hard to control. You are restricted to the joist spaces available and cannot put the tube wherever you want. The good news is that because you are driving the heat through a sub-floor and finished floor, the heat has a chance to spread out and hot spots are not as much of a problem. The chart below gives the minimum number of tubes per joist for a comfortable system.

To use this chart for sub-floor (staple-up) systems:
1) Determine the combined "R" value of all materials above the tubing (sub-floor, carpet, tile, etc.)
2) Determine the joist spacing of the floor and select the correct column from the chart.
3) The required Btuh per square foot will determine the minimum number of tubes that must be installed in each joist space. Exact spacings per tube may vary due to construction details within the joist spaces but the installer should take care that the tubing is as evenly spaced as practicable.

Remember to make sure that foil-backed insulation is installed under the tubing. This insulation must be at least 4 times the "R" value of the materials above the tubing.

SUB-FLOOR SYSTEM TUBE DENSITY (MINIMUM tubes per joist)				
Required Floor Output (Btu/sq ft/hr)	JOIST SPACING AND FLOOR COVERING "R" VALUE			
	12 to 16 inch o.c. Less than R 0.5	12 to 16 inch o.c. More than R 0.5	16 to 24 inch o.c. Less than R 0.5	16 to 24 inch o.c. More than R 0.5
0 - 10 Btuh	2 Tubes per joist	2 Tubes per joist	2 Tubes per joist	3 Tubes per joist
10 - 20 Btuh	2 Tubes per joist	2 Tubes per joist	2 Tubes per joist	3 Tubes per joist
20 - 30 Btuh	2 Tubes per joist	3 Tubes per joist	3 Tubes per joist	3 Tubes per joist
30 - 40 Btuh	3 Tubes per joist	3 Tubes per joist	3 Tubes per joist	3 Tubes per joist

STEP 8 - CALCULATING THE AVERAGE WATER TEMPERATURE

We have now determined from the surface temperature chart how hot we have to make the floor surface and whether or not we need to add supplemental heat.

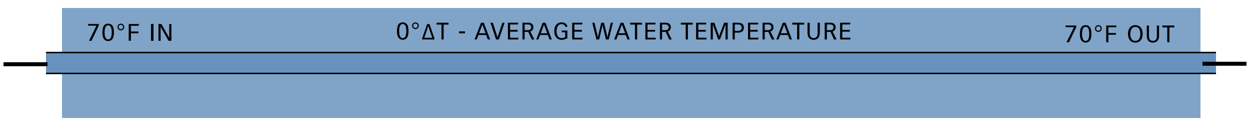
We know the insulation ("R") value of the flooring above the tubing, and have determined what our tube spacing will be. Now we just have to calculate how hot we have to make our water in order to get the floor surface up to the required temperature.

The chart on the next page will help us determine how hot to make the water so that the surface temperature gets to where it has to be. If it was a bare floor and the slab was well insulated below, the average water temperature could be kept close to what the surface temperature had to be. It is best to keep the water temperature as low as possible, so its important to understand what factors cause us to have to crank it up.

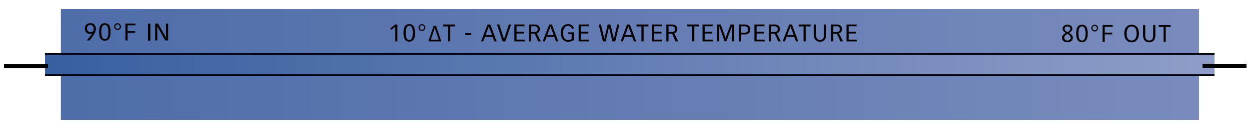
The factors that require a hotter average water temperature are:
Too much insulation above the tubing
A high BTUH load on the slab
Not enough insulation below the tubing
Very wide tube spacing

Anything we can do to reduce these effects will result in a better system.

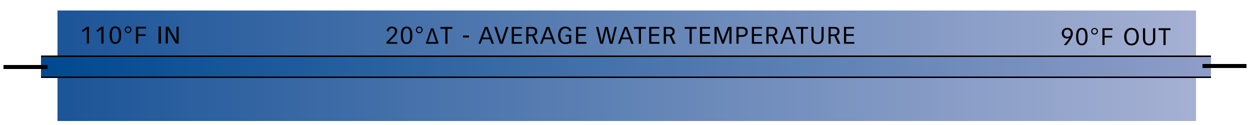
We are about to calculate "average water temperature". This is an important factor and one that is often misunderstood. When we say there is a "load" on the slab, we mean that the slab is warmer than its surroundings and is giving up heat to those surroundings. We replace the heat it gives up by pumping hot water through the tubing in the slab. The water goes in hot, gives up some of its heat and comes back cooler. The more heat the slab gives off, the more it takes heat from the water, and the cooler the water is when it comes back. If it comes back too cool, we have to; (a) make the water hotter going in at the front end, or (b) we have to push more water through the pipe in a given time so that it stays warmer (which means we have to make it go through much faster because you can only put so much water at a time in a given length of pipe). The effect of water going into the slab at one temperature and coming back at a cooler temperature is what we call ΔT (DELTA TEE). We will be talking more about ΔT later. The point we want to make here is that technically, it doesn't matter how big the ΔT is from one end of the tube to the other as long as the average water temperature is what we require. That doesn't mean we can use any ΔT we want though. The bigger it is, the more the temperature will vary on the floor surface (a bad thing). In fact, we want our ΔT to be as low as possible for the most comfort. We will show you how to do that later. The illustrations below show the same length of tubing reacting to three different temperature conditions affecting the same slab.



Warm outside - No load on the slab - water going in and leaving at the same temperature.

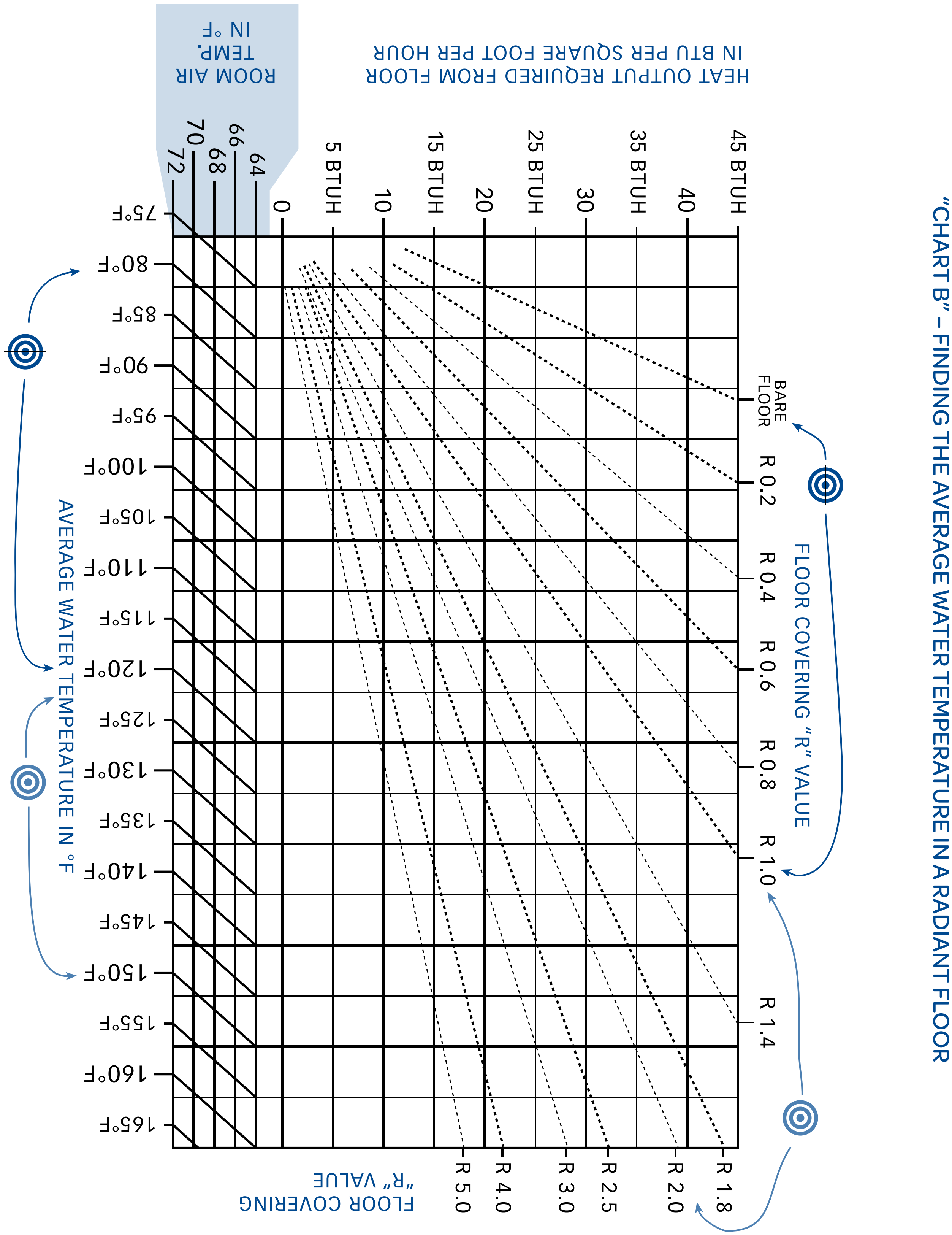


Getting colder - Small load on the slab - water going in warm and losing some (10°F) temperature.

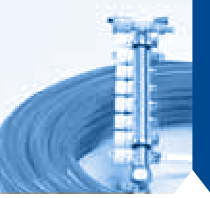


Cold outside - Big load on the slab - water going in hot and leaving 20°F cooler. This is what would happen during "design" conditions on the coldest day of the year with maximum load on the slab. We calculate our average water temperature to be hot enough to look after these conditions. We will show you how to design for a small ΔT later.

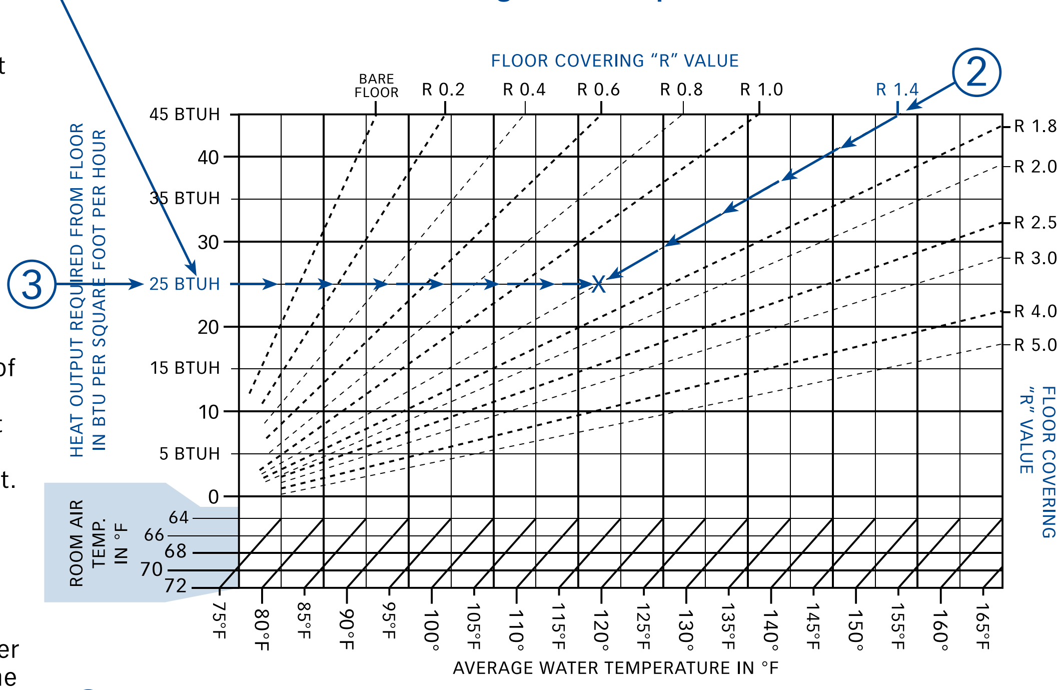
We have all of the information we need to calculate the average water temperature needed. You can see after using the chart for a while the factors that affect the average water temperature. Once you fully understand the relationships between BTUH output required and the "R" factors of the slab you will be able to design systems faster and better. Although the chart on the next page looks complicated, it is quite easy to use with a bit of practice.



"CHART B" – FINDING THE AVERAGE WATER TEMPERATURE IN A RADIANT FLOOR
HEAT OUTPUT REQUIRED FROM FLOOR IN BTU PER SQUARE FOOT PER HOUR
ROOM AIR TEMP. IN °F
64
66
68
70
72
0
5 BTUH
10
15 BTUH
20
25 BTUH
30
35 BTUH
40
45 BTUH
BARE FLOOR
R 0.2
R 0.4
R 0.6
R 0.8
R 1.0
R 1.4
FLOOR COVERING "R" VALUE
R 1.8
R 2.0
R 2.5
R 3.0
R 4.0
R 5.0
FLOOR COVERING "R" VALUE
75°F
80°F
85°F
90°F
95°F
100°F
105°F
110°F
115°F
120°F
125°F
130°F
135°F
140°F
145°F
150°F
155°F
160°F
165°F
AVERAGE WATER TEMPERATURE IN °F



Example: How to use this chart to calculate average water temperature.



① Look up the required BTH per square foot needed on the left hand side of the chart.

This example uses 25 BTH/SQ FT/HR

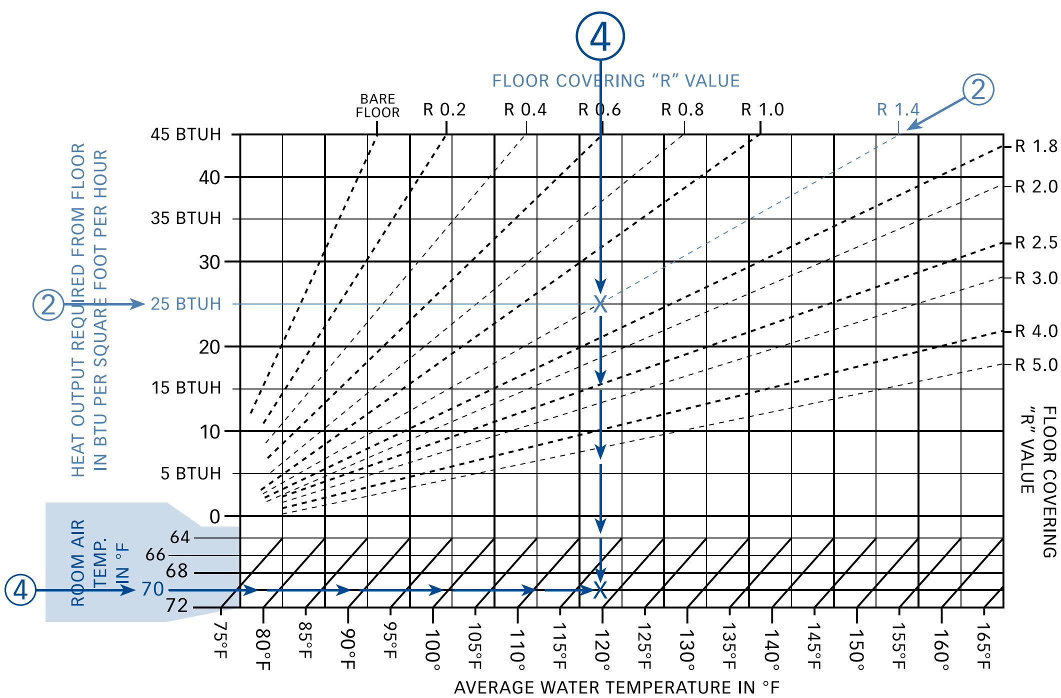
② Find out what the "R" factor of the flooring is and locate that number at the top of the chart.

This example uses an R 1.4 factor.

Trace the line from the number at the top of the chart down to the left.

③ Draw a line from the selected BTUH from left to right until it crosses the dotted line with the "R" factor of the flooring. Mark an "X" at this point.

Using the average water temperature chart - continued



④ Decide what room temperature you want and draw a line from left to right along the room temp. line. In this example we want a room air temperature of 70°F. From step 3; where the BTUH line and the "R" factor line crosses, draw a line straight down to the room temp. line.

Draw an "X" where the two lines in step 4 cross.

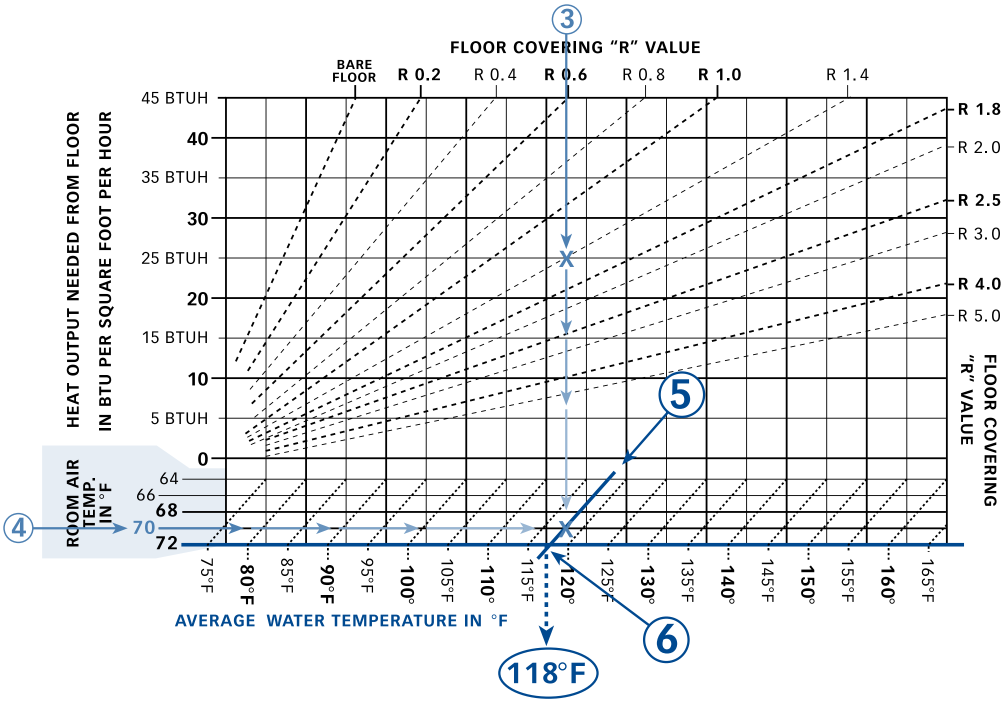
Using the average water temperature chart - continued

⑤

From the X where the two lines in step 4 cross, draw a line matching the same angle as the other diagonal lines down to the bottom line.

⑥

The average water temperature required is read where the diagonal crosses the bottom line. In this example we get 118°F.



As already mentioned, tube spacing is mostly a matter of comfort. Having your tubing closer together **will** allow you to lower your water temperature, but it is not usually the most significant factor in designing a normal system. For example, a bare concrete floor with an output requirement of 25 BTUH/sq. ft. needs an average water temperature of 88°F when the tubing is placed on 12" centres. How much can we lower the water temperature if we go to 6" centers? Only down to 84°F, just 4°F. The main reason we want closer spacings is for increased comfort, eliminating hot and cold spots. To account for tube spacing, use the multipliers listed below to come up with the adjusted water temperature required

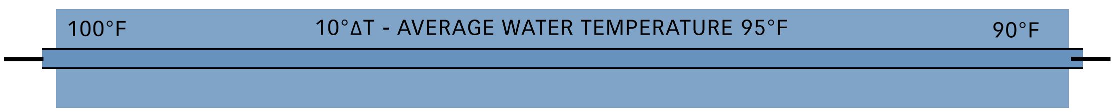
TUBE SPACING CORRECTION FACTORS FOR AVERAGE WATER TEMPERATURE				
Required Floor Output 25Btuh/sq ft	FLOOR COVERING "R" VALUE Less than R 0.5	R 0.5 to R 1.0	R 1.0 to R 1.5	R 1.5 to R 2.0
4" O.C.	subtract 5°F	subtract 8°F	subtract 10°F	subtract 12°F
6" O.C.	subtract 4°F	subtract 6°F	subtract 8°F	subtract 10°F
8" O.C.	subtract 2°F	subtract 4°F	subtract 5°F	subtract 6°F
10" O.C.	subtract 1°F	subtract 2°F	subtract 3°F	subtract 4°F
12" O.C.	– – –	– – –	– – –	– – –
14" O.C.	add 2°F	add 3°F	add 4°F	add 5°F
16" O.C.	add 5°F	add 6°F	add 8°F	add 10°F
Required Floor Output 40Btuh/sq ft	FLOOR COVERING "R" VALUE Less than R 0.5	R 0.5 to R 1.0	R 1.0 to R 1.5	R 1.5 to R 2.0
4" O.C.	subtract 15°F	subtract 20°F	subtract 25°F	subtract 30°F
6" O.C.	subtract 10°F	subtract 15°F	subtract 20°F	subtract 25°F
8" O.C.	subtract 7°F	subtract 10°F	subtract 15°F	subtract 20°F
10" O.C.	subtract 3°F	subtract 5°F	subtract 7°F	subtract 10°F
12" O.C.	– – –	– – –	– – –	– – –
14" O.C.	add 5°F	add 7°F	add 10°F	add 15°F
16" O.C.	add 10°F	add 15°F	add 20°F	add 30°F

Add the correct tube spacing correction factor to the average water temperature from chart B and enter this number on the worksheet, pg. A16.

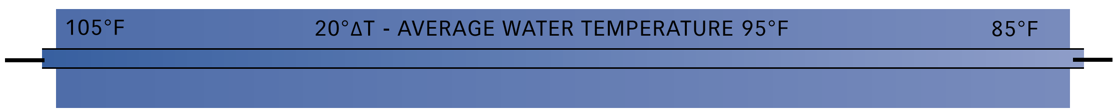
Loop lengths - the mysteries of Btuh, flow rates and ∆t

On page A33 and A34 we talked about average water temperature and then went about finding how to determine what it should be for a given floor construction and Btuh requirement. We talk about **average** water temperature because when we push warm water through a cooler slab, the water will always give up some of its heat to the slab, drop its temperature, and come out cooler. When we say there is a “load” on the slab, we mean that the slab is warmer than its surroundings and is giving up heat to those surroundings. We replace the heat it gives off by pumping more warm water through the tubing in the slab. The more heat the slab gives off, the more it takes heat from the water and the cooler the water is when it leaves. If it comes back too cool, we have two choices: 1) We can make the water hotter going in at the front end, which will result in a higher temperature difference (∆T) – something we really don’t want, or 2) We can push more water through the slab at a higher flow rate so that it stays warmer longer.

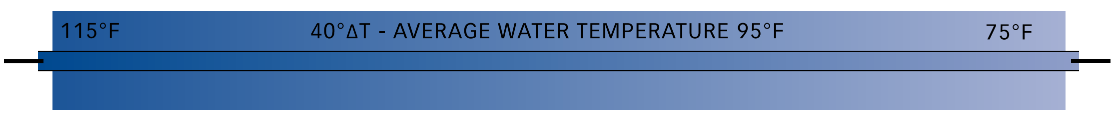
These illustrations are like the ones we looked at previously on page D30, but now we are going to leave the load conditions alone. The heat loss conditions are the same for all three examples but now we are going to change how fast we pump the water through. We end up with the same average water temperature and therefore the same Btuh output, but the ∆T changes dramatically with the change in flow rates.



2 gpm - Water going in really fast and leaving at the almost the same temperature



1 gpm - Water going in slower and leaving cooler, slab surface temperature starting to vary.



0.5 gpm - Water going in too slow and leaving cold, slab surface temperature varies too much.

Remember that in these three examples we are delivering the **same amount of heat**, but we are distributing it differently. When the water is flowing too slowly, we use up much of the heat before we get to the end of the loop and the floor is heated unevenly. Even though the **average** water temperature is the same, and the **average** floor surface temperature is the same, we can see big differences in surface temperature, some spots too hot, and some too cold. If we circulate the water quickly (more gallons per minute) through the loop, our ∆T is smaller and there are no cold or hot spots. In the top example, the water only loses 10°F on its journey through the floor, but there is four times as much water (thermal mass) going through as in the bottom example where the water loses 40°F.

So why don’t we always circulate the water through quickly? Because it can be expensive. If the pipe size and length does not change as you try to push more and more water through the pipe, the pipe will start to fight back by building up pressure (in heating we use the term head pressure). The pressure builds as a result of friction inside the pipe between the water and the pipe walls. The more gallons per minute you try to circulate, the harder it becomes to push and you start to need a big (high head pressure) pump. “High head” pumps cost more money than smaller pumps and use more electricity. Besides increasing pumping costs, higher head losses also mean that the fluid velocities in the pipe become too high. The extra friction created will wear out components more quickly and can be a cause of unwanted flow noises.

There are two things we can do to increase our gallons per minute without increasing the head pressure too much. One way is to use short tubing loops, the other is to use larger diameter tubing. Both solutions add cost to an installation and the designer has to find the right balance between a smaller ΔT, and the higher costs associated with shorter and therefore more numerous tubing loops. The other larger diameter pipe or higher head pumps. Don't fall into the trap of designing a system with long loops, just to save a few dollars, it never works. Fortunately, most residential and light commercial systems can be designed for fairly small ΔTs (10°F to 20°F) at reasonable pump heads without adding too much to the installed cost. When we start to calculate loop lengths, it will be clear that there is a reasonable range to work within for each tubing size.

Loop Lengths - The Mysteries of Btuh, Flow Rates and ΔT

It is really helpful to go through the Math involved in calculating Btuh outputs vs. flow rates and ΔTs because the relationships are so often misunderstood but so important. Most people in the heating industry have the basic knowledge, they just have to apply it, and complicated formulas are not required. Most people take on the old rule of thumb that if we have water flowing at 1 U.S. gallon per minute, and it drops in temperature by 20°F, it will deliver 10,000 Btu (British Thermal Units) in one hour. Where did that number come from, and how does it work with other flow rates or ΔTs? Let's work it through.

1 British Thermal Unit (Btu) = the amount of heat required to raise 1 pound of water by 1°F.
If a pound of water drops by 1 °F, then it has lost 1 Btu to its surroundings (in our case, into the floor)
1 U.S. gallon weighs 8.34 pounds
If 1 U.S. gallon (8.34 lb) loses 1°F to the floor, it will have delivered 8.34 Btus
If 1 U.S. gallon (8.34 lb) loses 20°F (20°F ΔT) to the floor, it will have delivered 8.34 x 20 = 166.8 Btus

NOW - If we circulate one gallon of water through the floor every minute (1 gpm), we will end up circulating 60 gallons (1 gpm x 60 minutes) through the floor in an hour. If each gallon loses 20°F going through, we will deliver 166.8 Btu x 60 gallons = you guessed it! 10,008 Btus

We can look at it another way:
60 gal x 8.34 lbs = 500.4 lbs of water going through the floor in one hour. Each pound loses loses 20°F, or in other words 20 Btu. Therefore 500.4 lb of water x 20 Btu = 10,008 Btu in one hour.

What about that extra 8 Btus? Well, when they came up with the rule of thumb, they tossed them out in order to make it easier to do simple flow rate calculations in your head for rapid horseback estimates. Not exactly precise, which is why Engineers dislike rules-of-thumb, but close enough for practical purposes.
Let's try this with a different temperature drop. We will use a 10° ΔT.

If 1 U.S. gallon loses 10°F (10°F ΔT) to the floor, it will have delivered 8.34 x 10 = 83.4 Btus
If we circulate 1 gallon of water through the floor every minute (1 gpm x 60 minutes), and each gallon loses 10°F on the way through, we will have delivered 83.4 Btu x 60 gallons = 5,004 Btus

So how can we use this information to help design our heating system? We know how many Btus we need for each room and we know what our average water temperature has to be. We just have to juggle these numbers so we can calculate how much flow we will need to deliver the Btus. The formula below is simple.

$$\frac{\text{Btuh REQUIRED}}{\Delta T \times 500} = \text{FLOW, in USgpm}$$

Makes perfect sense, doesn't it? The 500 is for 500 pounds of water. The ΔT is for how many degrees the 500 pounds loses every hour. Look at the examples again. If we need 10,000 Btuh in our room at design outdoor temperature and we want to have our water temperature drop by 20°F, then we need to keep 1 gallon of water per minute circulating through the floor. Here is how the formula would work it out:

$$\frac{10{,}000 \text{ Btuh needed}}{20°F\Delta T \times 500} = \text{FLOW, in USgpm} \quad \rightarrow \quad \frac{10{,}000}{10{,}000} = 1 \text{ USgpm}$$

Let's use the same example except with some different ΔTs; one with 10° ΔT and the other with 15°ΔT

$$\frac{10{,}000 \text{ Btuh needed}}{10°F\Delta T \times 500} = \text{FLOW, in USgpm} \quad \rightarrow \quad \frac{10{,}000}{5{,}000} = 2 \text{ USgpm}$$

$$\frac{10{,}000 \text{ Btuh needed}}{15°F\Delta T \times 500} = \text{FLOW, in USgpm} \quad \rightarrow \quad \frac{10{,}000}{7{,}500} = 1.5 \text{ USgpm}$$

As you can see, the ΔT makes a big difference on flow rates required to deliver the same amount of heat. Here again, we have to have a hard look at the cost factors vs. comfort when choosing the ΔT for your system. Many people use a 20°F ΔT, but there is nothing magical about that number. Some designers refuse to use higher than a 15° ΔT, but larger ΔTs can be succesfully used. As the ΔT becomes bigger, careful tubing layout becomes very important (see pages A8 to A11). At this point in the design procedure, we have to start making decisions about our loop layouts. We will come back to loop flow rates and lengths and calculate them after we decide how we are going to divide the house up as far as zoning is concerned. We need to know this so we can come up with a logical place to position our distrubution manifold, and so we can determine how many individual loops we will need.

STEP 9 - DETERMINE LOOP LAYOUTS AND ZONING REQUIREMENTS

Most hydronic radiant heating systems are split up into distinct, separately controlled heating zones. The three main reasons for creating separate zones are:

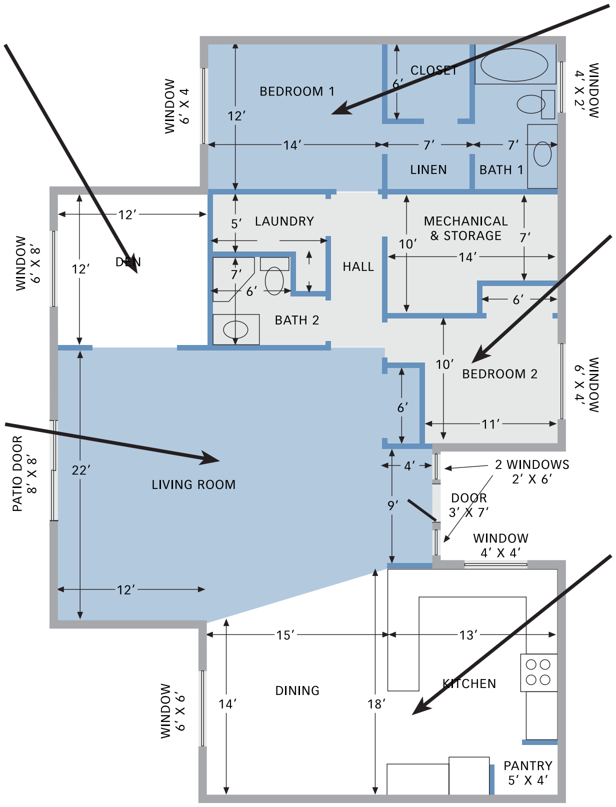
1) The end user wants to be able to control each zone at a different temperature at different times.
2) There are heat loss and heat gain factors that require separate control of areas. A good example is a room with large south facing windows. The sun shining in may heat up the room enough to require that the heat be turned down or even right off while the rest of the house still might need heat.
3) If a house has floor coverings with different "R" values, higher water temperatures will be required for the higher "R" value rooms. The lower "R" value rooms will overheat without some kind of separate control. It is not always necessary to have separate temperature controls for each zone in these situations, as they can often be corrected with proper flow balancing.

It is quite easy to zone with floor heat because of the flexibility we have when laying out loops. We only have to keep a few rules in mind regarding loop lengths and will go into greater detail later when we calculate pressure drops. For now, it is only important to keep within a certain range regarding loop lengths. The chart on the next page shows recommended maximums and minimums for all sizes of CANPEX.

If loops are too long, you will need to get special "high head" pumps to be able to circulate enough water through the tubing and if the loops are too short, it will be too difficult to throttle back the flow when balancing. If we find zones that need more than our recommended maximum loop lengths when we determine our zoning requirements and loop layouts, we will split those zones into two or more loops. There is no right way to zone a building, as so much depends on what the end user wants. We have divided up our house into 5 zones, but with careful selection of floor coverings, the house could be comfortably controlled as just one zone. Because each controlled zone adds cost and complexity to the system, most designers will try to use as few zones as possible.

ZONE 2
The den will be used as an office during the day and as a T.V. room at night. Because of the large window and the fact that the door will be closed most of the day it was decided to control the den on its own thermostat for increased temperature control flexibility.

ZONE 4
Because the floor covering has a high "R" value, the average water temp. will be different than the kitchen. It was decided to zone the living room with its loops, separate from the kitchen even though both rooms are one big space and will be on the same thermostat.



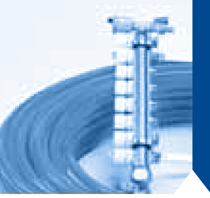
ZONE 1
The end user likes to have a cool bedroom to sleep in, but likes to turn up the heat on really cold nights. A separate thermostat for this area allows control of the master bedroom and bathroom.

ZONE 3
This bedroom is used as a guest room and is usually unoccupied. The end user wanted to be able to turn the heat down when not in use. Being centrally located in the house, they weren't too concerned that the laundry room or 2nd bathroom would get too cool when the bedroom was set back in temperature.

ZONE 5
The kitchen is a high heat loss area. Because the floor covering has a low "R" value, the average water temp. will be different than in the living room. It was decided to zone the kitchen with its loops separate from the living room even though they will both be on the same thermostat.

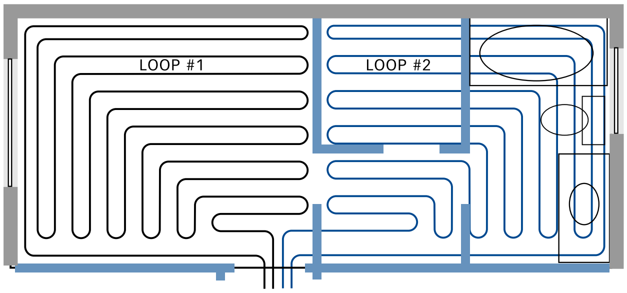
The recommended maximum loop lengths below, are based on reasonable flow rates and Btu deliveries vs. reasonable pressure drops (less than 8 feet of head with 100% water). Designers must weigh the cost between longer loops of larger diameter tubing vs. using smaller tubing with more manifold positions.

TUBING SIZE	3/8"	1/2"	3/4"	1"
MAXIMUM LENGTH	150'	300'	400'	600'



Designing a Radiant System

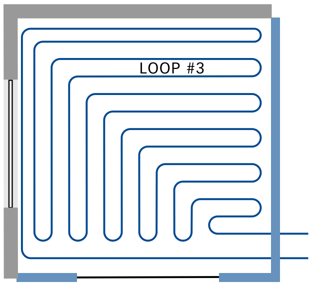
Step 9 - determine loop layouts and zoning requirements



ZONE 1
sq ft = 336 From (A) Pg A29
Tube spacing = 8" Pg A29
Tube spacing factor = 1.5 Pg A29
Total loop lengths = 336 sq ft x 1.5 = 504' or (H) x (G) Pg A29
Number of loops = 2 Pg A29
Loop length = 504/2 = 252
Manifold # = 1

ENTER NUMBERS ON WORKSHEET PG A16

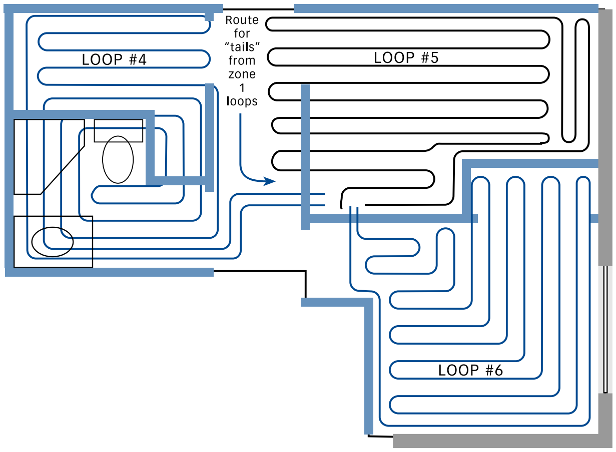
NOTES: This layout is perfect for the intended use of the space. Because there is carpet everywhere but the bathroom, the water temperature will be such that the bathroom floor and the room itself will be warmer than the rest of the zone. The end user can keep the bedroom cool and yet still have warm floors and tub in the bathroom. Both two wall serpentine loops cover the same amount of space without overlapping, so that flow balancing of either space will not affect the other. Note that most of the numbers used are from the practice worksheet on page D25. These numbers are normally chosen by the Designer for each project.



ZONE 2
sq ft = 144
Tube spacing = 8"
Tube spacing factor = 1.5
Total length of tubing = 144 sq ft x 1.5 = 216'
Number of loops = 1
Loop length = 216'
Manifold # = 1

ENTER NUMBERS ON WORKSHEET PG A16

NOTES: One simple two wall serpentine loop fits nicely into this zone so that a simple motorized zone valve head from the manifold with a thermostat will be all that is necessary to control the space.

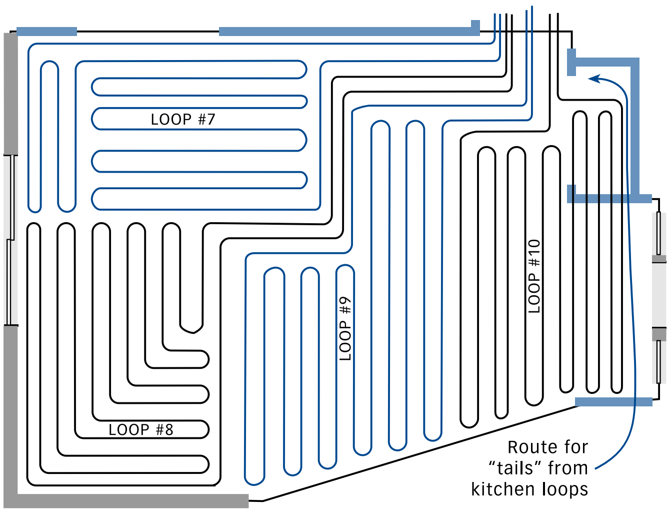


ZONE 3
sq ft = 432
Tube spacing = 8"
Tube spacing factor = 1.5
Total length of tubing = 432 sq ft x 1.5 = 648'
Number of loops = 3
Loop length = 648/3 = 216
Manifold # = 1

ENTER NUMBERS ON WORKSHEET PG A16

NOTES: Again, a nice breakdown of the space into three equal sized loops. Our main concern is control of the bedroom temperature, but because the laundry and bathroom have separate loops and low "R" value floors, much can be done with balancing to give those rooms more heat even when the unused bedroom is set back in temperature.

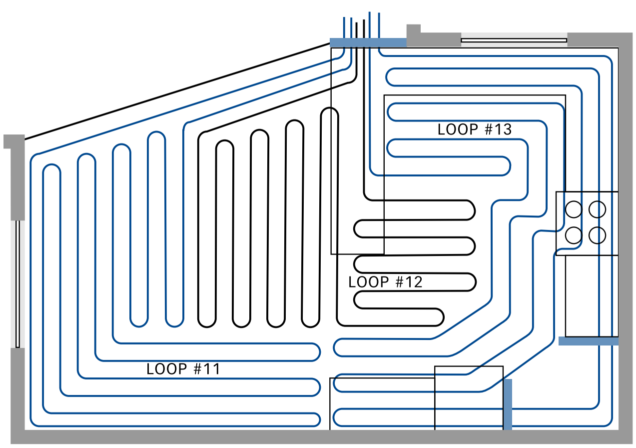
Note that in these examples we are showing the tubing passing under interior walls and some fixtures. This is for illustration purposes only. Most applications require running tubing around walls and avoiding fixtures. The installing contractor will have to make many such decisions during the installation of the tubing. In those slab-on-grade installations where tubing can be laid before interior walls are erected, it is extremely important to advise the framing contractor and the vanity and counter installers of the tubing locations and the need for caution when drilling or nailing into the floor.



ZONE 4
sq ft = 648
Tube spacing = 8"
Tube spacing factor = 1.5
Total length of tubing = 648 sq ft x 1.5 = 972'
Number of loops = 4
Loop length = 972/4 = 243
Manifold # = 1

ENTER NUMBERS ON WORKSHEET PG A16

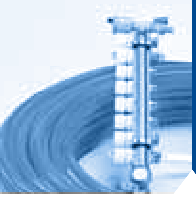
NOTES: Because this room is one big open space, loop layout is perhaps not as critical as in some other rooms however the heat loss is concentrated in the entrance area and along the opposite wall and care should be taken to ensure that our hottest water is circulated to those areas first. Note the higher tube densities near the entrance. This may not be necessary since the tails for our kitchen zones will have to also pass through this area. Note the space left open directly in front of the door for routing the kitchen loop tails. It is important to advise the installer to run the furthest loops first so they don't get "boxed in" by the loops closer to the manifold.



ZONE 5
sq ft = 446
Tube spacing = 8"
Tube spacing factor = 1.5
Total length of tubing = 446 sq ft x 1.5 = 669'
Number of loops = 3
Loop length = 669/3 = 223
Manifold # = 1

ENTER NUMBERS ON WORKSHEET PG A16

NOTES: The main concern we had with the kitchen was the routing of the tubing under food storage areas. Note that we only passed two tubes under the pantry and food storage cupboards. In colder climates you must have some heat in the perimeter area of the floor food storage or not, however in milder climates like Vancouver you may be able to eliminate tubing under the counters altogether.



STEP 10 - DETERMINE REQUIRED FLOW RATES PER LOOP

One of the easiest steps in the design process is to calculate flow rates for each loop. We can then complete our system design knowing how much water we have to circulate through the whole system during the coldest weather, and how to will split that flow into the different loops so that we get the right amount of heat to each room.
The calculations on page A38 showed us how to calculate flow rates for a given Btuh requirement. Now we will use the chart below to complete the calculations for our test house loop-by-loop.

We start by entering the design temperature drop (ΔT) at the top of the chart ① and completing the calculation to give us our value for "B". Most designers use the same ΔT for the whole system and will be able to fill in the whole column with the same multiplier. Zone-by-zone, identify each loop ② and the rooms that are on it and fill in the Btuh requirements per loop ③. In rooms that have more than one loop, divide the Btuh equally among them. The designer has a bit of leeway here to choose to put more heat in certain areas of a room by increasing flow in the loop for that area, but there should be no more than 25% difference in Btuh output between loops in a zone with the same floor covering. If you do decide to increase the Btuh output of a certain loop, make sure you go back to step 5 to make sure you don't exceed the maximum allowable floor temperature. Enter the flow information ④ from this worksheet on the worksheet on page A16. Individual loop balancing depends on the type of manifold you use.

Example, Zone 3, Test House

ZONE #	LOOP # ②	ROOMS ②	③ (A) Btuh REQUIRED	ΔT = 20 °F x 500 ① = (B)	A ÷ B = FLOW gpm ④	NO. OF TURNS ON BALANCING VALVE @ 1 psi PRESSURE DROP
3	1	BED 2/MECH	4,914 →	÷ 10,000	= 0.491 gpm	UNI-QUICK 9 turns
	2	BATH 2/LAUND	1,815 →	÷ 10,000	= 0.182 gpm	UNI-QUICK 5 turns
			→	÷	= gpm	
			→	÷	= gpm	

Flow Rate And Balancing Worksheet

ZONE #	LOOP #	ROOMS	(A) Btuh REQUIRED	ΔT = °F x 500 = (B)	A ÷ B = FLOW gpm	NO. OF TURNS ON BALANCING VALVE @ 1 psi PRESSURE DROP
			→	÷	= gpm	
			→	÷	= gpm	
			→	÷	= gpm	
			→	÷	= gpm	
			→	÷	= gpm	
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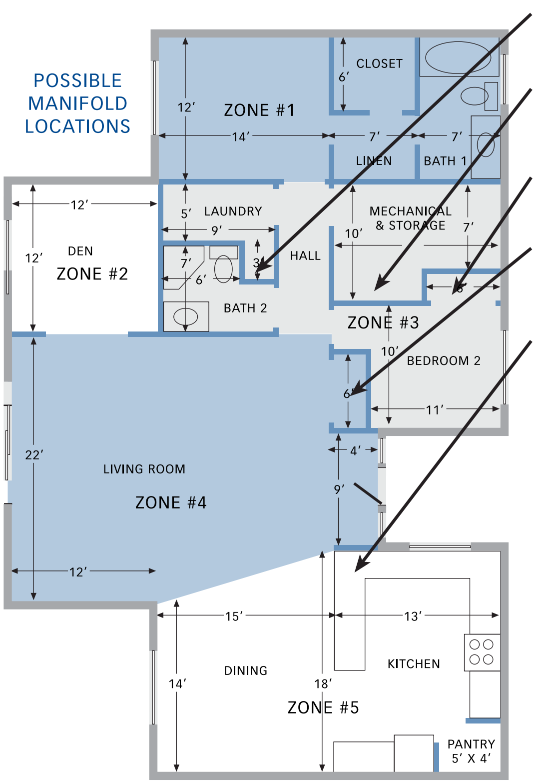
STEP 11 - LOCATING THE MANIFOLDS

There are 5 main points to consider when deciding where to put your loop distribution manifolds.

1. The most important consideration is in keeping the loop tail lengths as short as possible. For this reason, a central location in the building is the best.
2. The next consideration is to find a location that is as close to the heat source as possible. Ideally, the manifolds should be in the same room as the heat source, but often a compromise has to be made and the water from the heat source has to be piped to a remote manifold location. It is better to do this than to have tail lengths that are too long since we have to choose our circulator based on the highest pressure drop and all it takes is one extra long loop to force us into needing a high head pump.
3. Put the manifold in a place where we can separate the loop tails as quickly as possible so that we don't have them all running through a small common area like a hallway. This is a common mistake and can cause serious overheating in those areas because the tube spacing will be very close.
4. Look at your zoning and control options and see if it makes sense to split your zones into two or more manifolds. Our test house is a perfect example of this. Since we are going to control zone 4 (living room) and zone 5 (dining/ kitchen) with one thermostat, it makes sense to put the 5 loops of those two areas on one manifold and the other 5 loops of the house on a different one. If we do this, we can use a single zone valve for the living/dining/kitchen manifold, and separate zone valve heads for the three controlled zones of the other manifold. To keep things simple for our test house, we will use only one manifold, but many designers would use two in this case.
5. Find a location that is accessible for servicing and where fluid leakage will not cause damage. If the manifold is located other than in the mechanical room, it should be positioned where it can be easily concealed - closets are ideal.



At first glance, not a bad location. Across from the mechanical room and centrally located, but the washer & dryer will make it difficult to get to.

The ideal location. Close to the heat source and piping, centrally located for short loop tails, and in a room with a floor tdrain in case of leakage. We will choose this location for our test house.

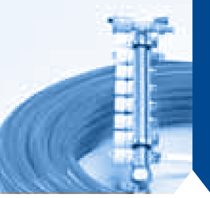
A good alternative location if the boiler room was too crowded. Sharing a wall with the boiler room is a bonus and it is easily concealed in the closet.

Probably the most central location in the house as far as keeping tail lengths short, but the 4 extra feet to the boiler room is not enough to justify running distribution piping.

An interesting under-counter location for a manifold if we were to use two. We could run distribution piping from the boiler room and have almost no tail lengths to speak of for the loops in zone 4 & 5.

ZONE #	LOOP #	LENGTH TO MANIFOLD x 2	PLUS 8 ft FOR RISERS
1	1	20	28
	2	20	28
2	3	34	42
3	4	8	16
	5	0	8
	6	0	8
4	7	10	22
	8	10	24
	9	10	40
	10	10	40
5	11	20	28
	12	20	28
	13	20	28

AFTER DECIDING ON THE MECHANICAL ROOM LOCATION WE MEASURE THE LOOP TAIL LENGTH (times 2), PLUS 8 EXTRA FEET PER LOOP FOR THE RISERS AND ENTER THE TOTAL ON THE WORKSHEETS REFER TO THE DRAWINGS ON PAGE A42 & A43. FROM WHERE THE LOOPS END, MEASURE THE LOOP TAILS TO THE MANIFOLD LOCATION



Designing a Radiant System
Step 11 - locating the manifolds

It takes energy to move fluid through a pipe, valve or fitting. As it moves through these restricted spaces, a fluid will rub against the sides and lose energy in the form of a pressure drop. To develop a specific fluid volume movement, we add mechanical energy to the fluid with a circulating pump. In hydronic systems, this energy is described as "pump head" and is measured in "feet" of head. There are four factors that determine how much energy is needed to maintain a constant fluid flow in a hydronic system.

1. How fast (fluid velocity) do we need to move the fluid? This really means how much fluid do we want to put through the pipe in a certain period of time. The more we want to push through, the harder it is to push. There are practical limits to how fast we can circulate a given volume of fluid through a certain size of pipe before problems start to occur. If there is too much friction, the pressure drop becomes so high that we have to select an overly large, "high head" pump to maintain our flow at the desired rate. The fluid itself can start to do damage to the system components as it creates more and more friction. In extreme cases, it can actually wear out the pipe. The chart below, and the one on page D42, give you practical limitations to work with. If you keep fluid velocities within the acceptable ranges shown, you will also automatically be putting together a system that will have reasonable pump head requirements.
2. How much resistance is the fluid going to encounter on its trip through the system? To get the most fluid through a hydronic loop, the pipe should be as large as is practical, as smooth as possible inside and there should be few turns in the pipe to cause turbulence. Every time you change the direction of the fluid flow, or add restrictions in the pipe such as valves and fittings, you create turbulence and friction which requires more energy to overcome. Good system design will minimize restrictions.
3. What is the viscosity (how "thick" is the fluid)? Thicker fluid creates more friction and pushes back harder. Many hydronic systems have chemicals such as Propylene Glycol added to the water for freeze protection. The addition of such chemicals thickens the fluid and adds to the pump head requirement. Make sure you account for chemical viscosity effects.
4. How hot is the fluid? Hotter fluid tends to be "thinner", which means it will flow more easily than cold fluid. Some chemicals add to this effect, creating an even greater thickening effect as temperatures get colder. When designing low temperature systems that use glycol, especially snow-melting systems, it is important to obtain viscosity/temperature information from the chemical manufacturer to properly size your circulators.

As we work on our system design, we must bear these factors in mind. The first main area of concern is to keep our pressure drops as low as are practical. On the one hand, high head pumps are expensive to buy and operate and on the other, larger piping and valves are expensive to install. We have to try and find the right balance between pump efficiency and cost, vs. piping and component sizing. The second main area of concern is to maintain reasonable fluid velocities. Good design keeps the fluid velocity (speed) within a narrow band - fast enough to establish turbulent flow in the tubing for good heat transfer, but slow enough to prevent erosion of system components and reduce noise. If we try to push too much fluid through piping components that are too small, flow velocities will become excessive. A good rule of thumb that has stood the test of time is to keep flow velocities below 4 ft/sec. If you follow the chart on the next page, staying out of the red area, you will not have a problem with flow velocities in your radiant panel tubing. For choosing the size of the rest of the piping in your system, the chart below is a good guide.

RECOMMENDED MAXIMUM FLOW RATES FOR SYSTEM DISTRIBUTION PIPING

TUBE SIZE TYPE M COPPER	FLOW RATE AT 4 ft/sec	PIPE SIZE NEW STEEL PIPE	FLOW RATE AT 4 ft/sec	TUBE SIZE CANPEX	FLOW RATE AT 4 ft/sec (THIS CHART FOR PEX SYSTEM DISTRIBUTION PIPING ONLY)
1/2"	3.2 gpm	1/2"	3.7 gpm		
3/4"	6.4 gpm	3/4"	6.8 gpm		
1"	10.9 gpm	1"	11.5 gpm	1/2"	2.8 gpm
1 1/4"	16.3 gpm	1 1/4"	19.8 gpm	3/4"	4.5 gpm
1 1/2"	22.8 gpm	1 1/2"	25.8 gpm	1"	7.6 gpm
2"	39.5 gpm	2"	43 gpm		

It is important not to confuse flow rate and velocity with pressure drop. As we can see from the chart above, we can push 2 gpm through 1/2" CANPEX pipe and remain below our 4 ft/sec velocity limit. If we look at the chart on page A46 & A47 however, we can see that it is unlikely that we would ever want to push that much through a "normal" 200 to 250' x 1/2" hydronic radiant floor loop. At 2 gpm, our head loss is 0.133 feet of head per 1 foot of tube. That would mean that by the time we got up to a 100' loop length, we would be looking at a head loss of 13.3 ft., already approaching the need for a high head pump. The main concern we have with pipe sizes and velocity, is in those shorter sections of boiler or system distribution piping, or in system components where we can develop excessive velocities without registering a significant pressure drop. These are the areas in a system where noise and velocity erosion of components can become a problem. We will cover this later when discussing system piping layout and design.

STEP 12 - DETERMINE FINAL LOOP LENGTHS AND TUBING DIAMETERS

From the charts below, it is clear that the amount of head pressure in a loop builds up very quickly once we reach a certain flow rate. We have already talked about keeping loop lengths below 250' for 1/2" CANPEX and below 400' for 3/4, but that is just a rule of thumb. Now we will look at why those numbers were chosen and at how we can calculate the exact pressure drop in a system.

Pressure drop and Btuh chart for 1/2" CANPEX tubing

PUMP SIZING IS BASED ON THE HIGHEST HEAD LOSS (LONGEST LOOP). IF ONE LOOP IS QUITE A BIT LONGER THAN THE REST, IT MAY BE BEST TO SPLIT THAT LOOP INTO TWO TO REDUCE OVERALL PUMP HEAD REQUIREMENTS

FLOW - GPM	1 FOOT OF TUBE HEAD LOSS/ft	250 FT OF TUBE HEAD LOSS	Btuh DELIVERY 20ΔT
0.2	0.002	0.5	2,000
0.3	0.004	1	3,000
0.4	0.007	1.75	4,000
0.5	0.01	2.5	5,000
0.6	0.014	3.5	6,000
0.7	0.019	4.75	7,000
0.8	0.024	6	8,000
0.9	0.03	7.5	9,000
1.0	0.037	9.25	10,000
1.5	0.078	19.5	15,000
2	0.133	33.25	20,000

Pressure Drop And Btuh Chart For 3/4" CANPEX Tubing

FLOW - GPM	1 FOOT OF TUBE HEAD LOSS/ft	350 FT OF TUBE HEAD LOSS	Btuh DELIVERY 20ΔT
0.6	0.03	0.9	6,000
0.7	0.004	1.2	7,000
0.8	0.005	1.5	8,000
0.9	0.006	1.8	9,000
1.0	0.007	2.1	10,000
1.5	0.015	4.5	15,000
2.0	0.025	7.5	20,000
2.5	0.037	11.1	25,000
3.0	0.052	15.6	30,000
3.5	0.07	21.0	35,000
4.0	0.089	26.7	40,000

3/4" tubing is generally used in larger residential and medium sized commercial radiant floor systems. The most common and economical circulators used in these systems develop between 15 and 25 feet of head at "normal" flow rates (being 15 to 30 gpm, which will allow us to deliver 150,000 to 300,000 btuh in a system designed with a 20°F ΔT). If we design our loops for no more than an 10 foot head loss, we have approx. 5 to 15 feet of head loss left over to play with.

GLYCOL MULTIPLICATION FACTORS
30% Glycol - multiply head loss from chart by 1.2
50% Glycol - multiply head loss from chart by 1.35

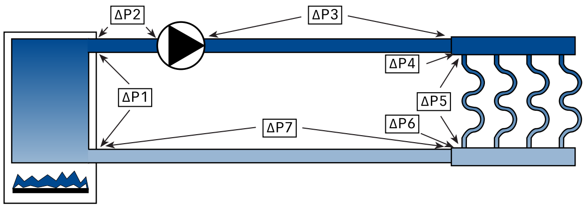
NOTE: Viscosities vary between types of glycol and manufacturer if your design is "close to the wire" obtain manufacturers' data and apply.

TEMPERATURE MULTIPLICATION FACTORS
Water becomes easier to circulate as it gets hotter, the charts above are for 80°F water.
For 100°F water - multiply head loss from chart by 0.95 - - For 120°F water - multiply head loss by 0.9
For 140°F water - multiply head loss by 0.86 - - For 160°F water - multiply head loss by 0.84

REFER TO ADDENDUM DA2 FOR 3/8" AND 1" PRESSURE DROP CHARTS, AND ADDITIONAL GLYCOL AND TEMPERATURE MULTIPLIERS.

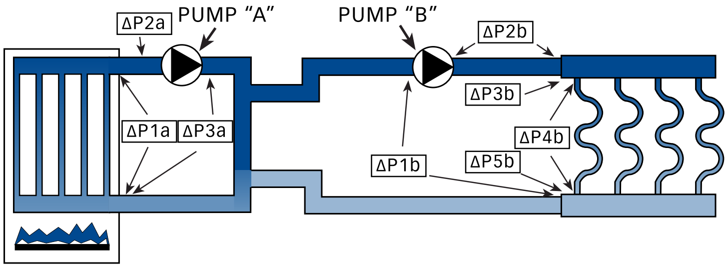
Before we can complete our system design, we have to account for all of the various components in the system that can cause restriction to fluid flow. Our immediate goal here is to get to the point where we can select the correct circulator for our system. Although many designers do not consider the boiler in these calculations, it can have a large effect on pressure drop depending on its type and placement. The selection criteria for specifying a boiler depend primarily on the size and variability of the load, the fuel availability, the efficiency required, the operating environment and the operating temperatures required. A whole book can be written on this topic, so we will narrow down the selection process to focus on those issues that will affect head loss - the type of boiler chosen, the placement of the boiler in the system and the piping of the boiler into the system.

1. When we talk about boiler type, we are interested in the developed pressure drop through its heat exchanger at the flow rates required by both the system and the boiler. Boiler manufacturers' requirements are critical here and must be considered above all else. When you consult their literature, they will supply you with the required minimum flow rates. In general, cast-iron and steel fire tube boilers have pressure drops that are very low, less than one foot of pressure drop. There are exceptions however, so don't make assumptions. Water tube boilers tend to have higher flow rate requirements, and therefore higher head losses. These boilers can be quite finicky when it comes to flow, but work beautifully when flow rates are within manufacturers' specifications. Be very careful with these boilers if flow rates in the system are to vary significantly. Primary/secondary piping and bypass arrangements must be employed if this is the case. There are a few boilers available that use a coil-type heat exchanger and have extremely high head losses through their heat exchangers. These boilers should always be piped in a primary/secondary arrangement to hydraulically isolate them from the system and give them assured flow.
2. The placement of the boiler in the system is primarily governed by the design of the structure and the boilers' venting requirements. Ideally, we want our boiler as close to our manifolds as possible to reduce the amount of distribution piping. In reality, the boiler room placement is often the lowest priority in the Architects' mind and will usually get tucked away into a far corner. In most residential applications this is not a serious factor, however in larger buildings, long runs of distribution piping can add significantly to pump head requirements. Try to keep your distribution piping as short as possible.
3. The way in which the boiler is piped into the system can make a big difference in the size of circulators required. In the first illustration below, we have shown a boiler piped into the heating system directly. When this is done, the circulator must provide enough head to overcome the resistance of all of the system piping and components as well as the resistance of the boiler. If the boiler has a very low pressure drop, this can work quite well, although you should only do this with an electric or condensing boiler unless some sort of mixing system is provided to protect the boiler from cold water or the floor system from overly hot water.



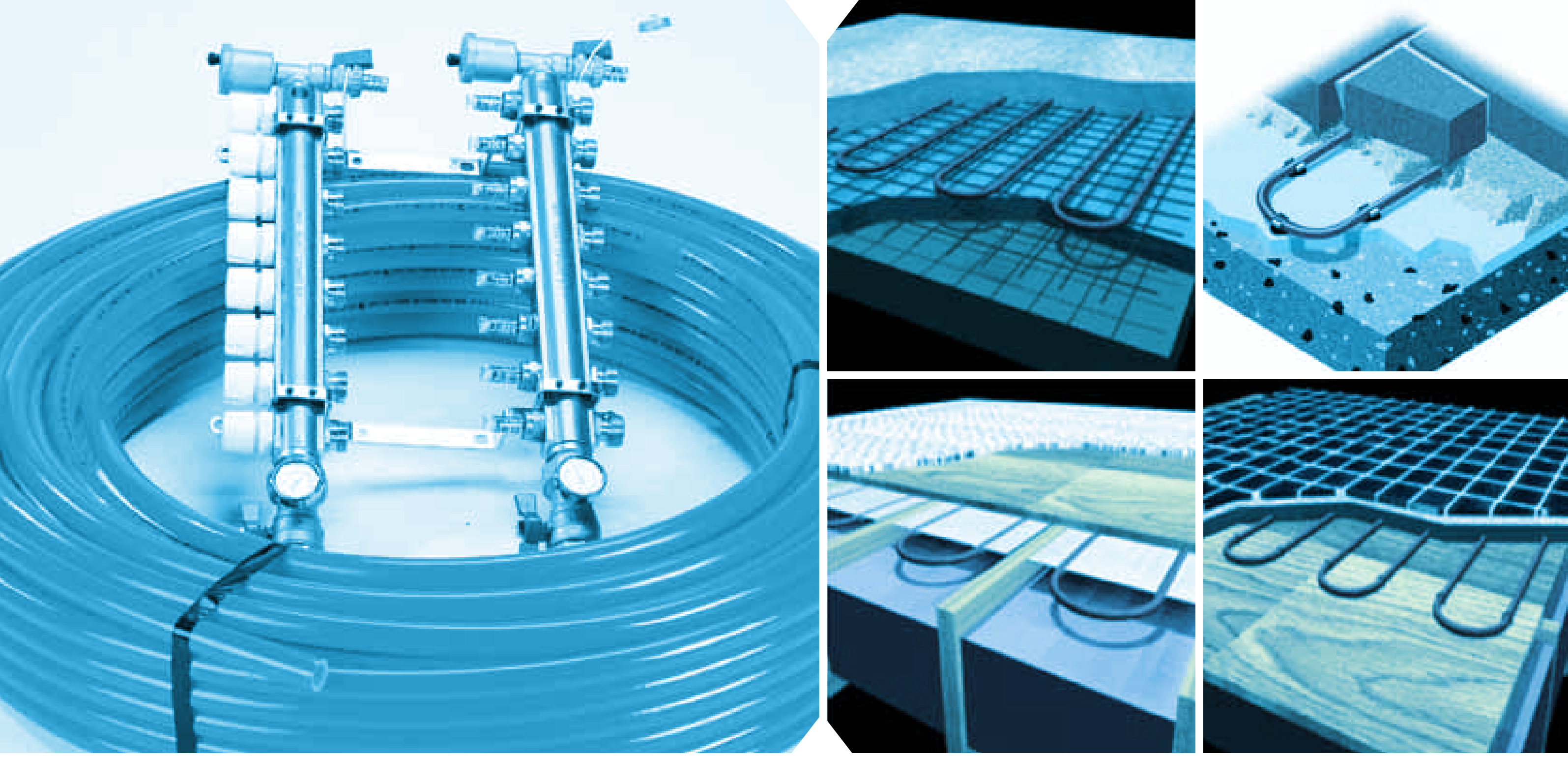
IN ORDER TO SIZE THE SYSTEM CIRCULATOR WE ADD UP THE PRESSURE LOSSES AT THE REQUIRED SYSTEM DESIGN FLOW RATE. IN THIS EXAMPLE, ΔP1 (PRESSURE DROP #1, THROUGH THE BOILER) + ΔP2 + ΔP3 + ΔP4 + ΔP5 + ΔP6 + ΔP7 = TOTAL SYSTEM PRESSURE DROP. THIS NUMBER IS USED TO SIZE THE CIRCULATOR.

The illustration below, shows a very basic primary/secondary piping arrangement that serves to hydraulically isolate the boiler from the system loop. This is done for a number of reasons, but the end result is that we do not have to include the pressure drop through the boiler when we are sizing the system pump (pump "B" in this example). We need only add up the pressure drops that directly affect each circulator. Although at first glance, this may seem to be adding unnecessary circulators to the system, close examination of pressure drops in a system will suggest that at times this type of piping arrangement can be less expensive. If there is a high head loss through the boiler, combined with a high head loss through the system, a designer may have to select an expensive high head circulator. Often, two smaller pumps are cheaper.



FOR BOILER PUMP (PUMP "A")
ΔP1a + ΔP2a + ΔP3a = TOTAL BOILER LOOP PRESSURE DROP.

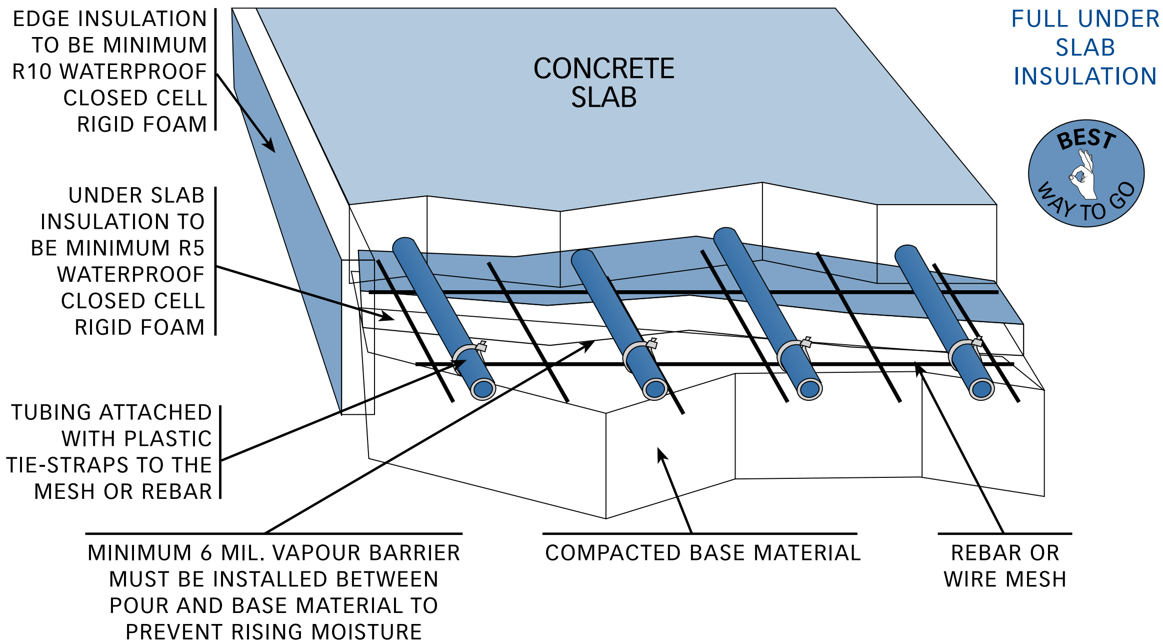
FOR SYSTEM PUMP (PUMP "B")
ΔP1b + ΔP2b + ΔP3b + ΔP4b + ΔP5b = TOTAL SYSTEM LOOP PRESSURE DROP.

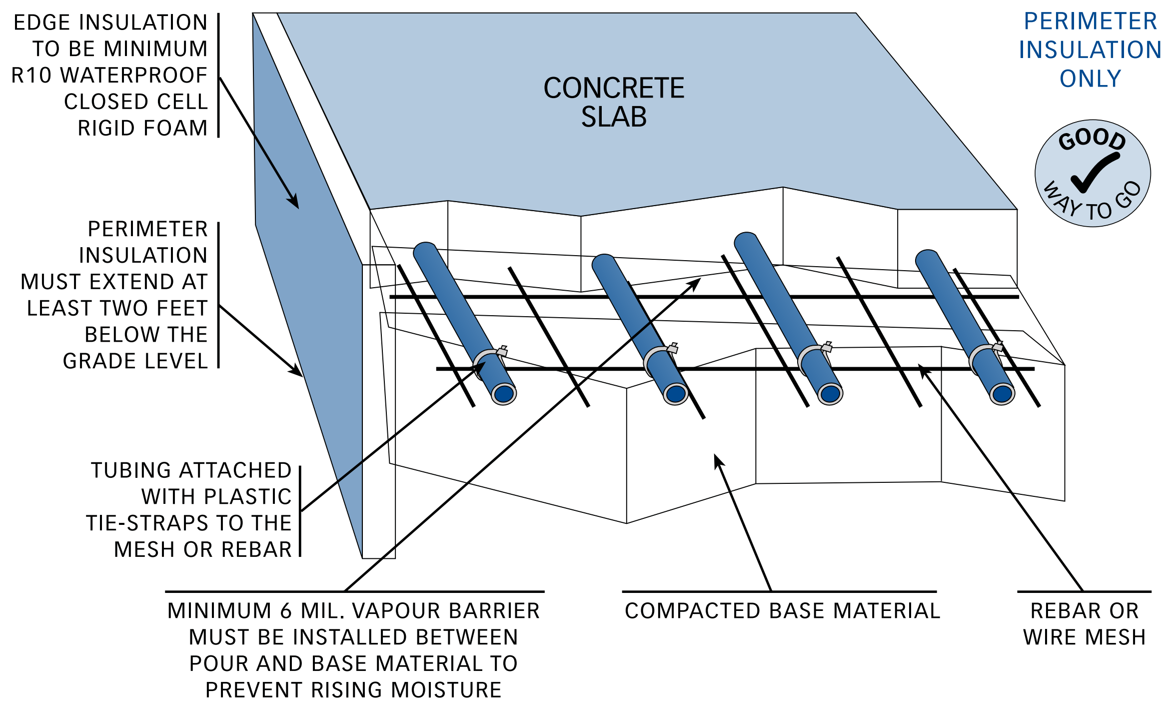


Installation & Start up

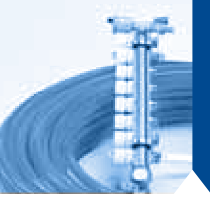
DESIGN AND INSTALLATION MANUAL

Vanguard Pipe & Fittings
A DIVISION OF CB SUPPLIES LTD



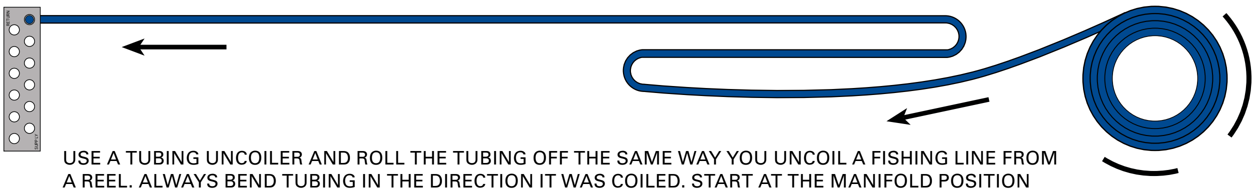


OF CRITICAL IMPORTANCE IN THIS APPLICATION IS THE INSTALLATION OF A MINIMUM 6 MIL. VAPOUR BARRIER AND THE EXTENSION OF THE PERIMETER INSULATION TO AT LEAST 2 FEET (MORE IS BETTER) BELOW GRADE LEVEL. IN AREAS THAT HAVE A HIGH WATER TABLE, ALWAYS USE THE FULL UNDER SLAB INSULATION METHOD ILLUSTRATED AT THE TOP OF THE PAGE. THIS METHOD SHOULD NOT BE USED.

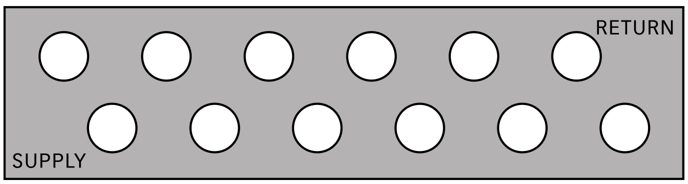


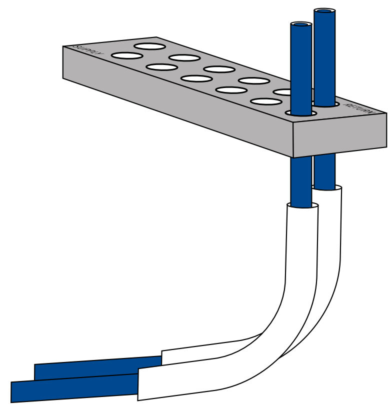
Construction Details

Slab-On-Grade, Poured Installations



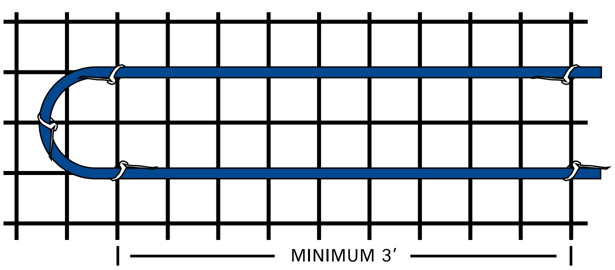
USE A TUBING UNCOILER AND ROLL THE TUBING OFF THE SAME WAY YOU UNCOIL A FISHING LINE FROM A REEL. ALWAYS BEND TUBING IN THE DIRECTION IT WAS COILED. START AT THE MANIFOLD POSITION AND TIE DOWN THE TUBING AS YOU LAY IT OUT.





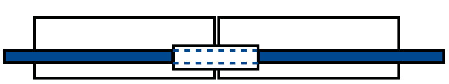
ONE OF THE BEST WAYS TO KEEP YOUR LOOPS FROM GETTING MIXED UP AND TO KEEP THE JOB LOOKING NEAT IS TO MAKE A MANIFOLD BLOCK TO RUN YOUR TUBING TO DURING ROUGH-IN. MADE OUT OF A PIECE OF 2 X 4 OR 2 X 6 LUMBER, IT CAN BE SECURED IN POSITION JUST BELOW WHERE THE MANIFOLD WILL BE. EACH LOOP IS RUN TO AND FROM IT WITH A FEW EXTRA FEET OF TUBING AND THE LOOPS LABELLED FOR FUTURE REFERENCE.

TUBING SHOULD BE SECURELY STRAPPED TO THE WIRE MESH OR REBAR AT LEAST EVERY 3 FEET AND AT THE ENDS OF TURNS.

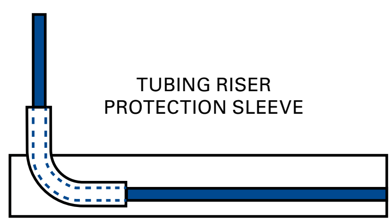


THE MESH AND REBAR SHOULD BE SECURED SO AS TO PREVENT THE TUBING FROM RISING UP IN THE CONCRETE DURING THE POUR. IDEALLY, THE MESH SHOULD BE SUPPORTED SO THAT THE TUBING IS HALF WAY BETWEEN THE SURFACE OF THE SLAB AND THE INSULATION, WITH A MINIMUM OF 1 1/2” ABOVE THE TUBING.

EXPANSION JOINT PROTECTION SLEEVE



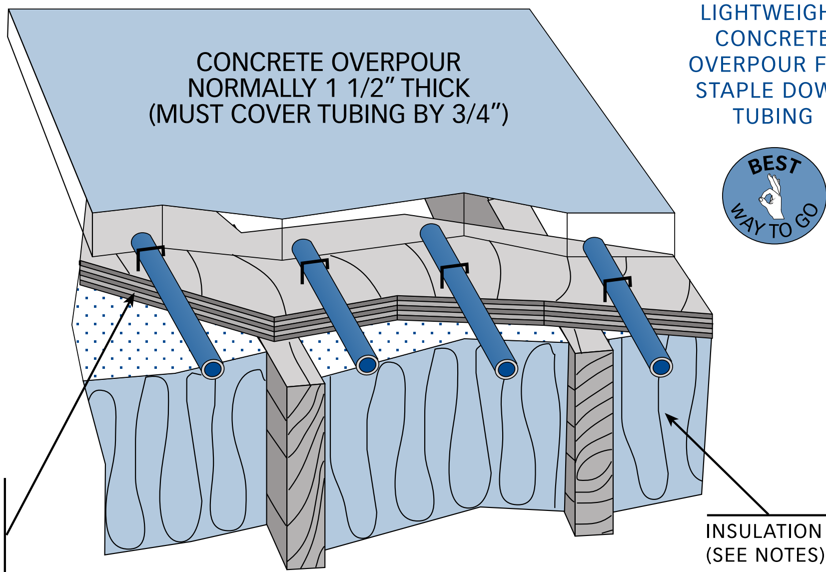
TUBING RISER PROTECTION SLEEVE

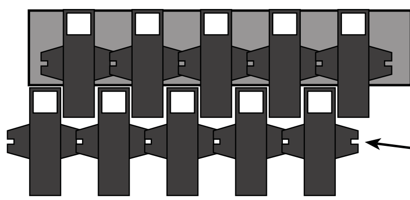


CROSSING AN EXPANSION JOINT OR RISING OUT OF CONCRETE, TUBING SHOULD BE PROTECTED

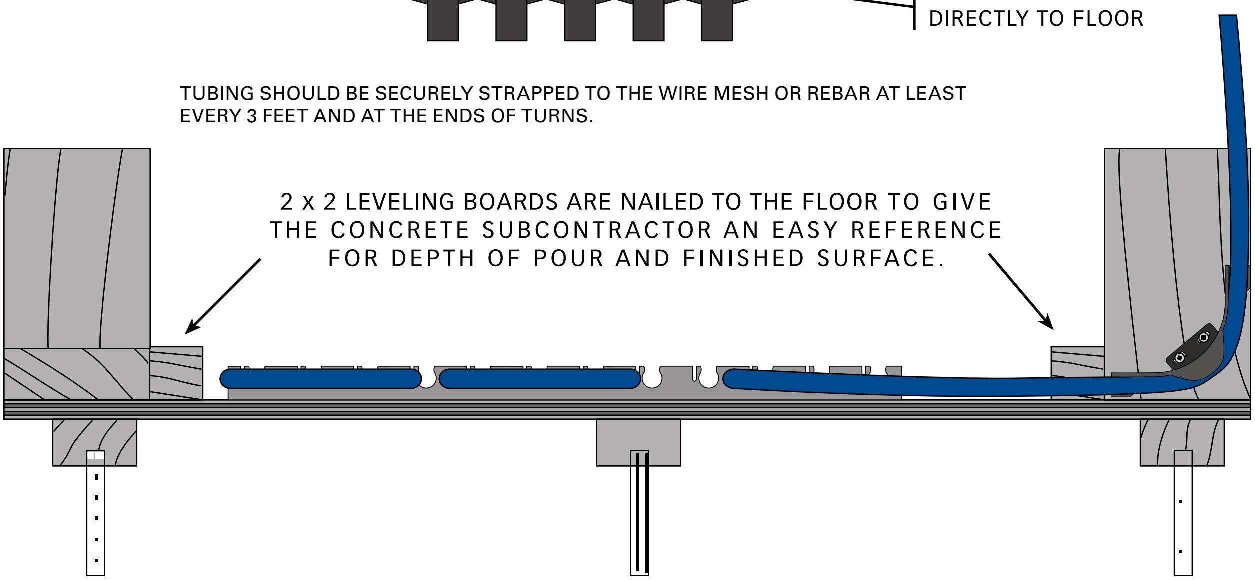
The heating system installer is responsible for informing the concrete subcontractor of any special requirements. The heating system installer should **always** be present during the concrete pour to monitor the pressure test on the tubing and watch for a sudden drop in pressure that would indicatedamage to the tube. Repair kits should be readily available on-site so that repairs can be accomplished quickly and properly should damage to the tubing occur. When it is known that expansion relief cuts will be made to the concrete after the pour, the heating system installer shall consult with the concrete contractor to find out where the cuts will be made and how deep they will be. Care shall be taken when laying out the tubing to avoid crossing expansion joints, but where it is unavoidable, protection sleeves shall be installed on the tubing at the location of the joint and the tubing shall be fastened down in such a way that it will remain below the depth of the saw cut. The heating system installer should **always** be present before the cutting of expansion joints to ensure that they are being made in the correct locations. The general contractor should instruct all sub-trades to avoid drilling, cutting or nailing into the slab without first consulting with the heating system installer.

IMPORTANT NOTES REGARDING INSULATION:
Poured, suspended floor systems must be insulated in the joist spaces below. Insulation, not less than twice the combined R value of the material above the radiant tubes shall be installed below the floor. The sub-floor material below the tubing can be added to the value of the insulation.

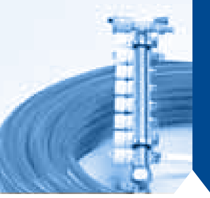




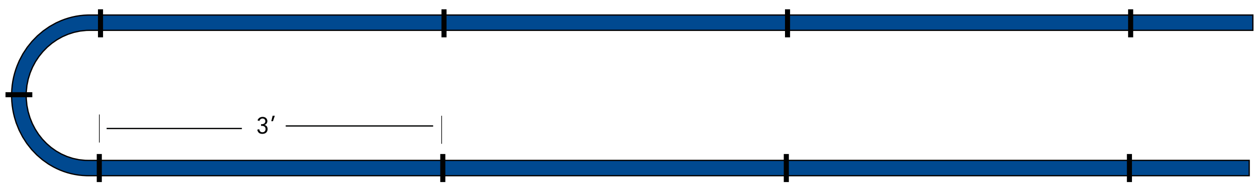
TUBING SHOULD BE SECURELY STRAPPED TO THE WIRE MESH OR REBAR AT LEAST EVERY 3 FEET AND AT THE ENDS OF TURNS.



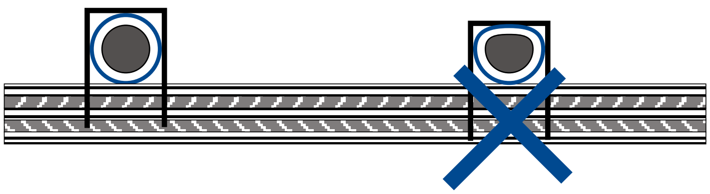
A staple-down concrete overpour on a suspended floor requires consultation with both the Architect or structural Engineer and the general contractor. The floor must be designed to handle the extra weight of the concrete, although there is not as much extra reinforcement required as most people think, and the pour must be coordinated with the other trades so that nothing is left out. The framing carpenter on the job must be aware of the slight differences in construction required in order to make the pour go smoothly.



Regardless of the type of poured system you use, a proper clip or attachment device shall be used to secure the tubing. Tubing shall be fastened in such a way as to ensure uniform depth and spacing within the slab. This is an easy thing to do with staple-down, overpour systems, as the tubing is attached directly to the sub-floor or to pipe tracking that is so attached. Vanguard has a number of items in the product line that will allow secure and precise fastening to the sub-floor.



TUBING SHOULD BE SECURELY FASTENED TO THE SUB-FLOOR AT LEAST EVERY 3 FEET AND AT THE ENDS OF TURNS.

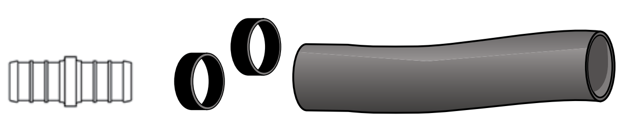


MAKE SURE AUTOMATIC STAPLERS HAVE A DEPTH STOP AND THAT IT IS PROPERLY SET IN ORDER TO PREVENT DISTORTION AND DAMAGE TO THE TUBING. IF TUBING IS NOTICABLY DAMAGED BY A STAPLER OR BY ANY OTHER DEVICE, IT SHOULD BE REPLACED BEFORE THE POUR.

The installation of fittings in a poured concrete slab or similar inaccessible area, should be avoided, however when necessary, the following steps should be taken:

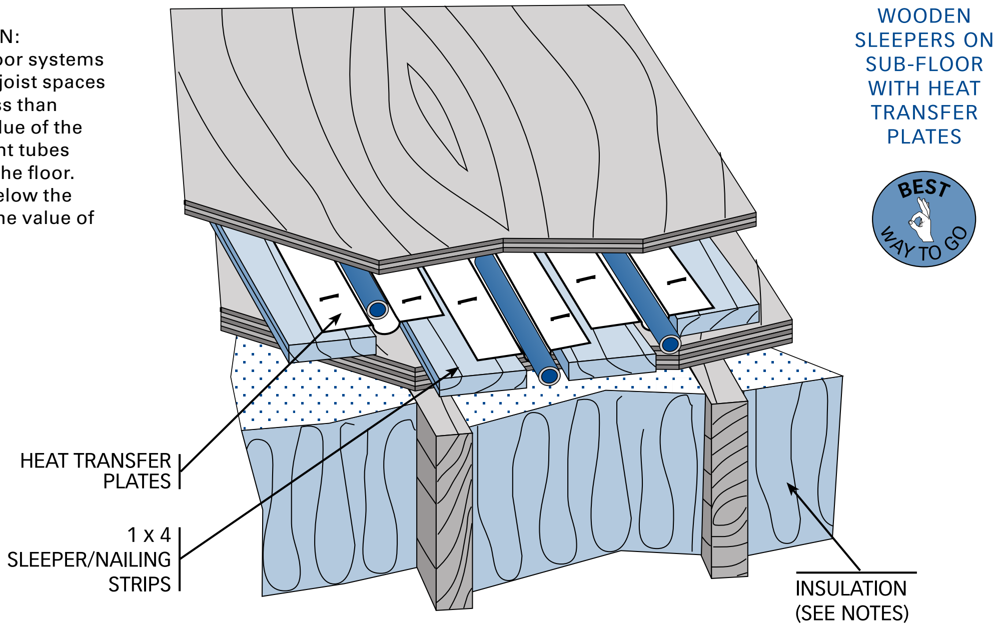
1. An access box of suitable size and depth must be placed around the fitting
2. Repair fittings must be installed according to manufacturers instructions.
3. A suitable protective covering must be installed over the fitting.
4. The installer must provide written authorization and repair verification prior to pour, start-up or commissioning.

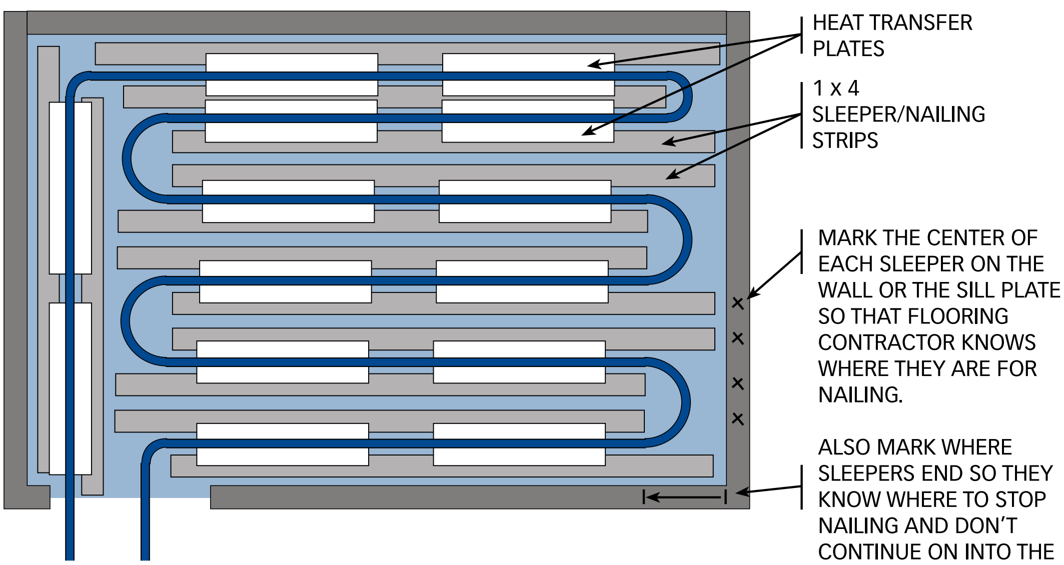
Installers should always be present during a pour to monitor their pressure test and check for any damage that may be caused during the pour. Repair kits should be available on-site during this time so that repairs can be made immediately upon discovery. Coordination with the concrete subcontractor is important, both to avoid damage being caused and to facilitate quick and proper repair when required. Repair kits for CANPEX tubing are available from your CANPEX distributor.



VANGUARD REPAIR KITS INCLUDE AN INSERT COUPLING, TWO BLACK COPPER PEX CRIMP RINGS AND A SHORT LENGTH OF HEAT-SHRINK TUBING. INSTALLERS SHOULD HAVE ON-SITE: THE CORRECT SIZE OF CRIMP TOOL FOR THE TUBING THEY ARE USING AND A HOT AIR GUN TO USE ON THE HEAT-SHRINK TUBING.

IMPORTANT NOTES REGARDING INSULATION:
Sandwich, suspended floor systems must be insulated in the joist spaces below. Insulation, not less than twice the combined R value of the material above the radiant tubes shall be installed below the floor. The sub-floor material below the tubing can be added to the value of the insulation.



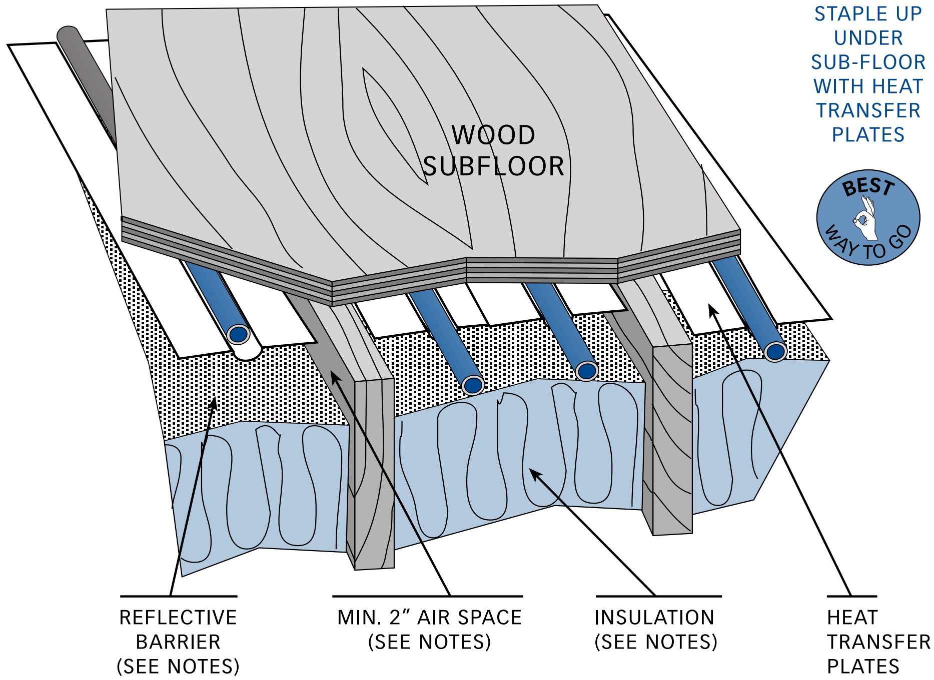


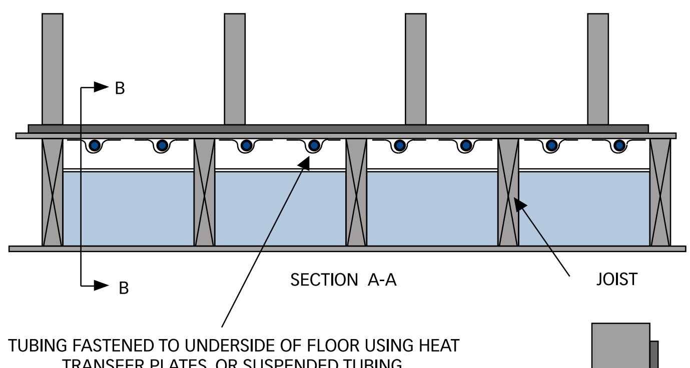
Typical layout of sub-floor sandwich. Heat transfer plates should be stapled down to the sleepers and should have at least a 2” gap between them. Ends of loop should be “bowed out” slightly so as to avoid expansion noise

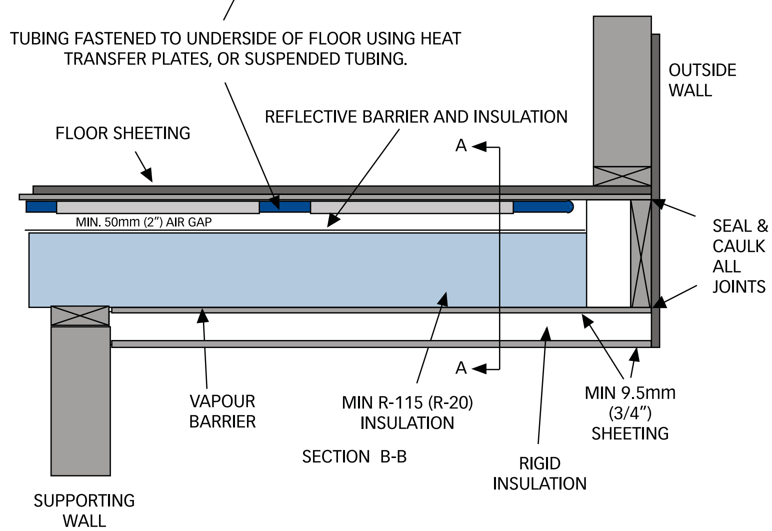
IMPORTANT NOTES REGARDING INSULATION:
More than any other type of system, staple-up, suspended floor systems must be insulated in the space below the tubing. A reflective barrier and insulation, not less than twice the combined R value of the material above the radiant tubes shall be installed below them. A 2 in. air space shall exist between the top of the reflective barrier and underside of radiant pipes. Reflective barrier and at least R-20 insulation with properly sealed air barrier must be installed at trimmer and header joists spaces (outside walls). Use rigid insulation cut to fit the joist end cavity then properly caulk. Reflective barrier and at least R-20 insulation with properly sealed air barrier must be installed between all cantilevered joists or other joists over unheated spaces. A layer of rigid insulation shall then be installed to the underside of these joists and be properly caulked.

STAPLE UP UNDER SUB-FLOOR WITH HEAT TRANSFER PLATES

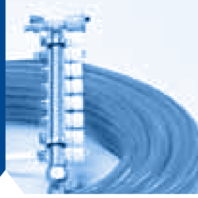
BEST WAY TO GO





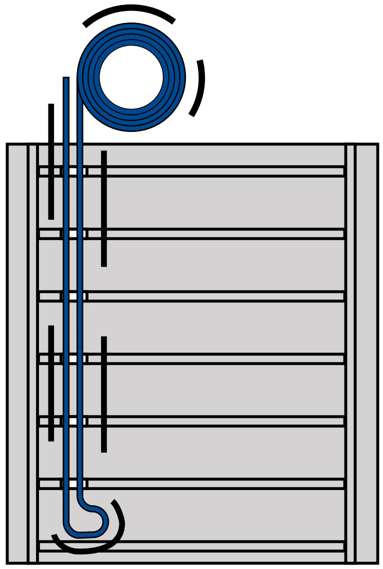


DETAIL OF INSULATION FOR CANTILEVERED FLOOR SECTION

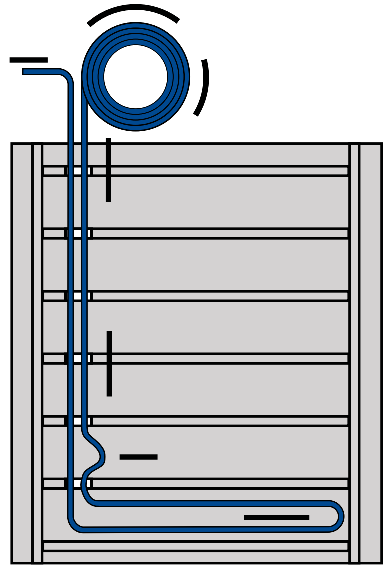


SUB-FLOOR SYSTEMS:
HOW TO PULL THE TUBING THROUGH THE JOIST SPACES

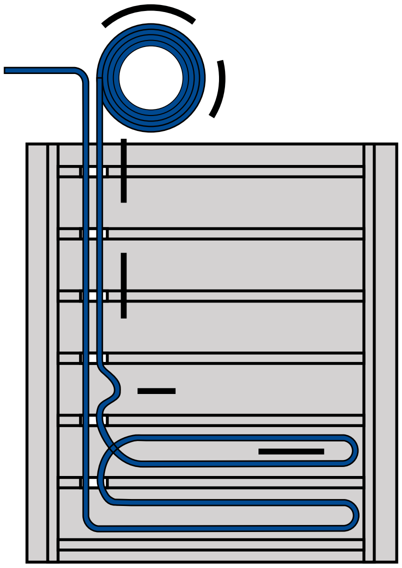
1 INSPECT THE JOIST SPACES FOR NAILS, STAPLES, ETC., AND REMOVE ANY THAT MAY DAMAGE THE TUBING. PULL TUBING ALL THE WAY DOWN TO THE LAST JOIST SPACE AND BACK



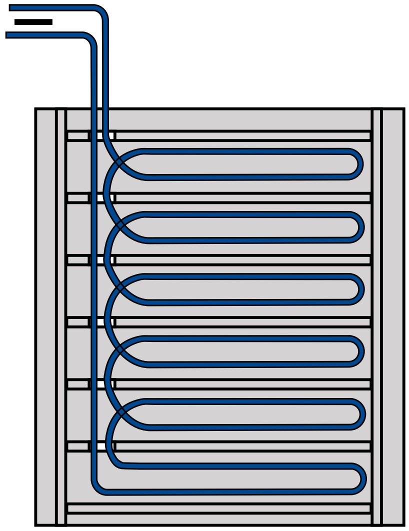
2 PULL TUBING LEADER OUT TO MANIFOLD POSITION AND SECURE. START PULLING TUBING INTO JOIST SPACES STARTING WITH THE FARTHEST ONE.



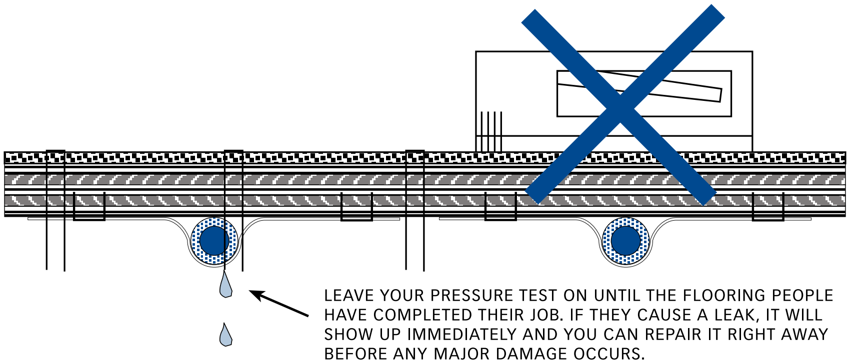
3 CONTINUE TO PULL TUBING INTO JOIST SPACES. NOTE THE CROSS OVER IN EACH LOOP TO KEEP BEND RADIUS LONGER.



4 FINISH PULLING JOIST LOOPS AND MEASURE TO MANIFOLD POSITION. CUT TUBING AND COMPLETE THE MANIFOLD CONNECTIONS. STAPLE THE TUBING UP AGAINST THE SUB-FLOOR, AVOIDING ANY SAGS.

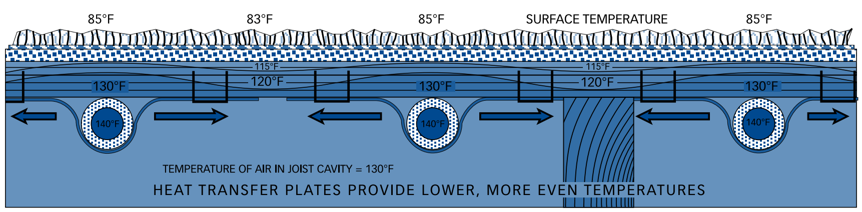


SPECIAL CONSIDERATIONS FOR STAPLE-UP SYSTEMS

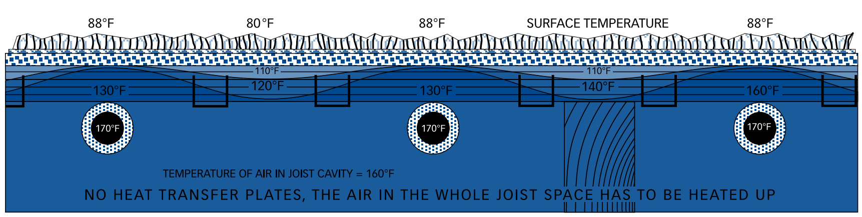


The importance of coordinating your installation with the other tradespeople on the job can't be stressed enough. Sometimes they have no idea there is anything under the floor that could be damaged. If stapling through the floor into the tubing is unavoidable, wait until the flooring people have completed their work and then cut out the offending sharp objects prior to installing the tubing. Some people have developed the technique of attaching tubing to the side of the joists 2" to 3" below the floor to avoid damage from staples. We do not recommend this practice as it requires system water temperatures to be very high and there is the possibility that long term exposure to high temperatures may damage structural materials, especially manufactured joists and sub-floor materials.

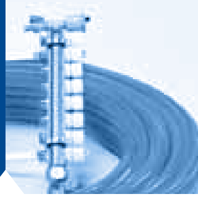
USING HEAT TRANSFER PLATES

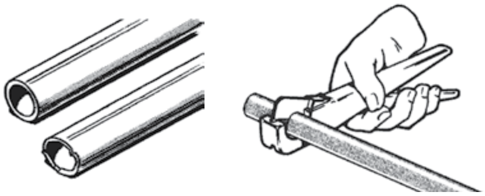


When heat transfer plates are used, the heat from the water spreads out from the tubing along the highly conductive metal plates. Because the heat moves faster through the metal than it does through the wood of the sub–floor or the air of the joist space, the floor surface heats up more quickly and more evenly, allowing us to heat with lower water temperatures. Another benefit is that the plates help to hold the tubing in contact with the bottom of the floor, further enhancing heat transfer through conduction.



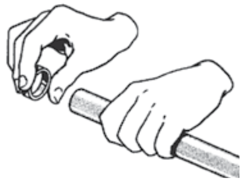
In this floor section without heat transfer plates, we see that the water temperature has to be much higher to be able to transfer heat into the floor as quickly as the floor with transfer plates. This raises two major concerns. If the floor has a low "R" value covering, it is quite likely that the user will notice hot spots on the floor. Perhaps a more serious concern is the fact that we would be subjecting the structural materials of the floor to extremely high temperatures on a continuous basis. The jury is still out on this point, but there is much concern in the Industry that long term exposure of some building materials (such as manufactured joists) to high temperatures might result in premature failure. Until the manufacturers of these components give them the all clear for extended exposure to high temperatures, the use of heat transfer plates to lower supply water temperatures would seem to be prudent.



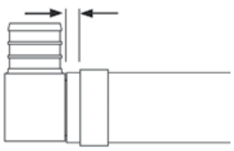


USE A PROPER TUBING CUTTER TO SQUARE OFF TUBING ENDS

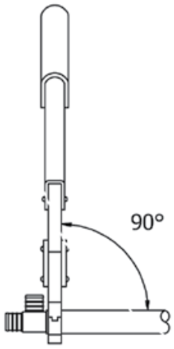
ENSURE THAT YOUR CRIMP TOOL IS PROPERLY CALIBRATED. CONSULT YOUR CANPEX DISTRIBUTOR FOR CORRECT CALIBRATION PROCEDURES



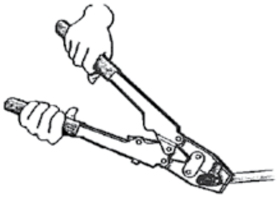
SLIDE THE CRIMP RING OVER THE TUBING AND SLIDE THE TUBING OVER THE FITTING THE INSERT FITTING SHOULD FIT SNUGLY INTO THE TUBING



THE CRIMP RING SHOULD BE POSITIONED BETWEEN 1/8″ AND 1/4″ FROM THE END OF THE TUBE OR FITTING SHOULDER

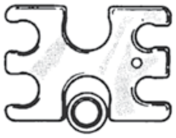


THE CRIMP RING MUST BE ATTACHED STRAIGHT. CENTER THE CRIMPING TOOL JAWS OVER THE RING AND KEEP THE TOOL AT 90° TO THE FITTING.



CLOSE THE JAWS OF THE CRIMP TOOL COMPLETELY. DO NOT CRIMP TWICE. IF THE CRIMP IS NOT SUCESSFUL, CUT OFF THE CRIMP RING AND TUBING, MAKING SURE TO NOT DAMAGE THE FITTING AND RE- CRIMP.

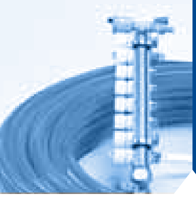
CLOSE THE JAWS OF THE CRIMP TOOL COMPLETELY. DO NOT CRIMP TWICE. IF THE CRIMP IS NOT SUCESSFUL, CUT OFF THE CRIMP RING AND TUBING, MAKING SURE TO NOT DAMAGE THE FITTING AND RE- CRIMP.



ALWAYS CHECK YOUR CRIMP CONNECTIONS WITH THE VANGUARD GO, NO-GO CRIMP CALIPER. A SIMPLE WAY TO INSURE THAT ALL OF YOUR CONNECTIONS WILL STAND THE TEST OF TIME.

IN MOST INSTALLATIONS THERE WILL BE ONLY TWO CRIMP CONNECTIONS PER LOOP AS EACH LOOP WILL RUN DIRECTLY FROM THE SUPPLY MANIFOLD TO THE RETURN MANIFOLD WITH NO FITTINGS REQUIRED BETWEEN THEM

FOR MORE DETAILED INSTRUCTIONS ON MAKING TROUBLE FREE CRIMP CONNECTIONS REFER TO THE VANGUARD BROCHURE “INSTALLATION GUIDELINES FOR THE VANEX AND VANEX PLUS PEX PLUMBING SYSTEM WITH INSERT FITTINGS - SDR9 PEX CROSS-LINKED POLYETHYLENE” AVAILABLE FREE OF CHARGE FROM YOUR CANPEX DISTRIBUTOR

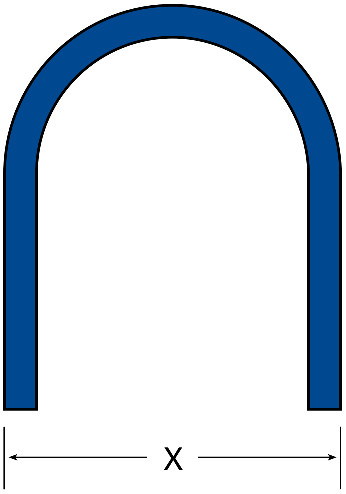


The Failsafe™ Fitting System

Components and Installation

Unwind the tubing in the reverse direction that it was coiled (the same way you would unwind a fishing line from a reel). This will prevent kinks and twisting during installation.

Bends should be made in the direction of the coil.

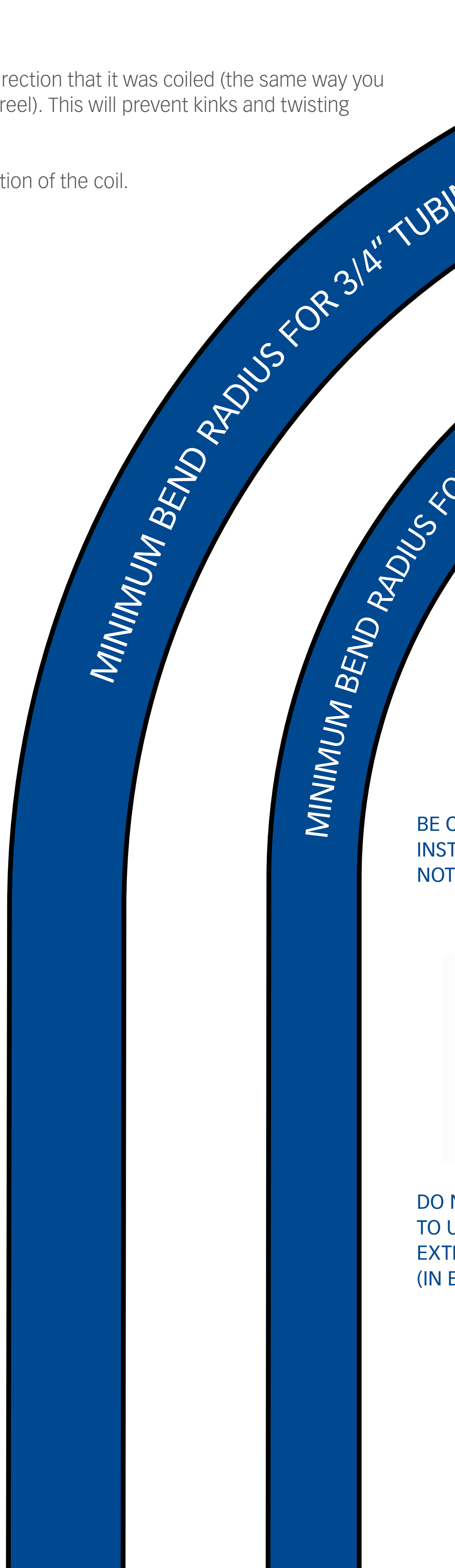


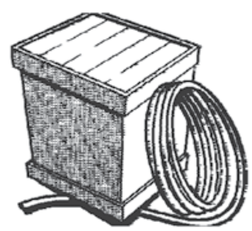
FOR 38″ TUBING
X = 8″

FOR 1/2″ TUBING
X = 10″

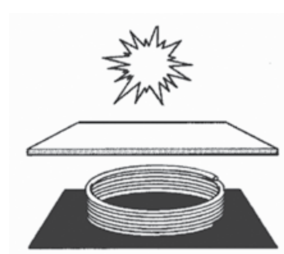
FOR 3/4″ TUBING
X = 14″

BEND “WITH” THE COIL DIRECTION

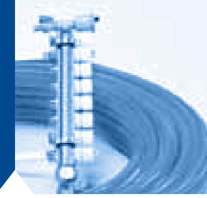


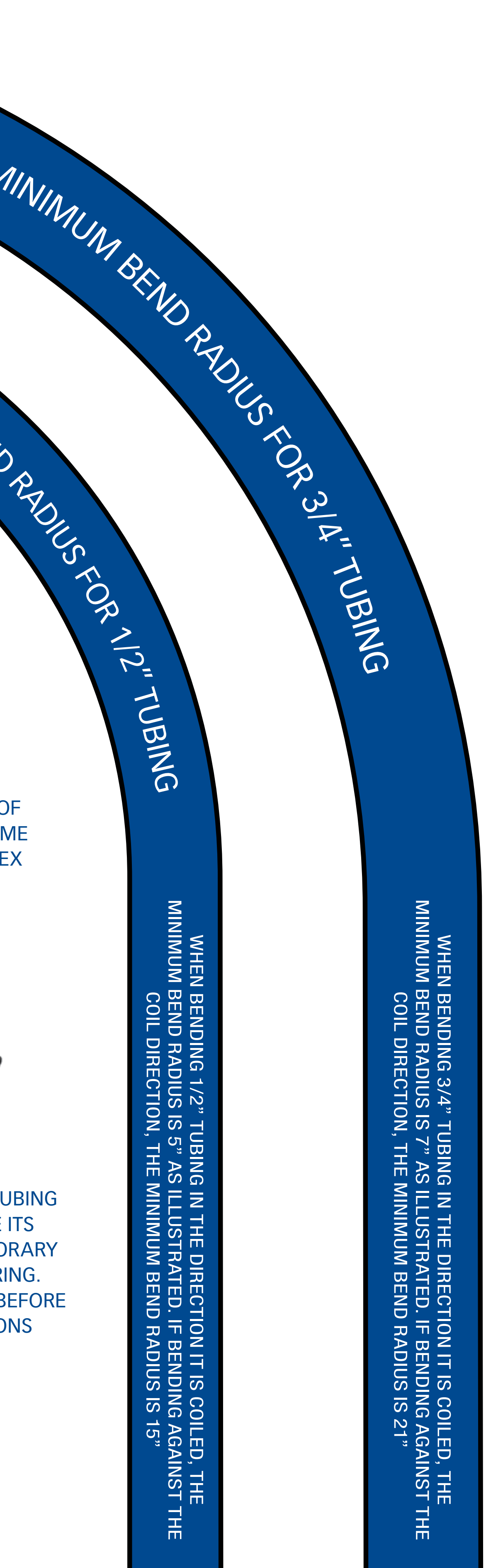


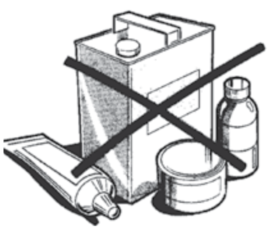
BE CAREFUL DURING INSTALLATION THAT THE PIPE IS NOT CUT OR DEEPLY SCRATCHED.



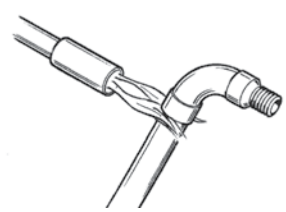
DO NOT EXPOSE CANPEX TUBING TO UNFILTERED SUNLIGHT FOR EXTENDED PERIODS OF TIME (IN EXCESS OF 30 DAYS)



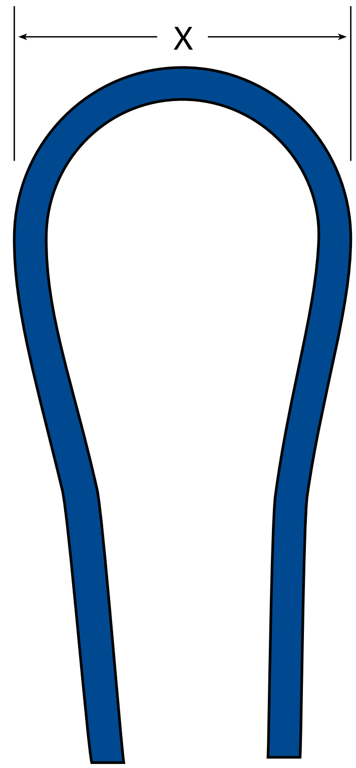




DO NOT ALLOW ANY TYPE OF ADHESIVES OR TAPE TO COME INTO CONTACT WITH CANPEX PEX TUBING



DO NOT EXPOSE CANPEX TUBING TO EXCESSIVE HEAT ABOVE ITS RATINGS INCLUDING TEMPORARY EXPOSURE DURING SOLDERING. ALWAYS SOLDER FITTINGS BEFORE MAKING CRIMP CONNECTIONS



FOR 38” TUBING, X = 8”

FOR 1/2” TUBING, X = 10”

FOR 3/4” TUBING, X = 14”

BEND “WITH” THE COIL DIRECTION

MAINTAIN MINIMUM BEND RADIUS AT END OF LOOPS WHEN O.C. DISTANCE IS LESS THAN “X”

Notes

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