

Manual of Modern Hydronics

WarmRiteFloor®
IPEX RADIANT SYSTEMS



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Committed to Excellence



SECOND EDITION

- Residential
- Industrial
- Commercial
- Snow and Ice Melt

Professional Radiant Heating Solutions

MANUAL OF MODERN HYDRONICS



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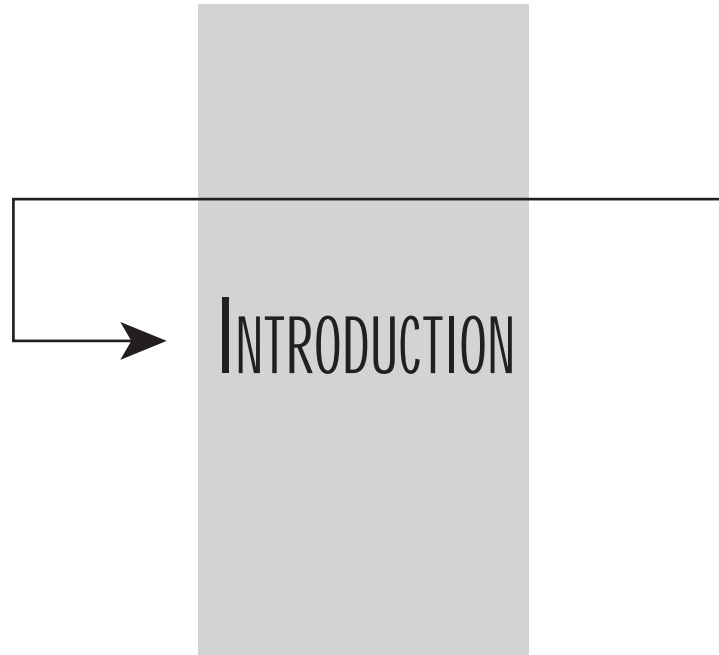
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MODERN HYDRONICS

Each year, construction begins on tens of thousands of new buildings all across North America. Thousands more undergo renovation. Whether new or remodeled, most of these buildings will require the installation or alteration of a comfort heating system. Along with hundreds of other decisions, the owners of these buildings must eventually select a heating system.

Unfortunately—and in most cases unintentionally—the choice is often based on factors that in the end, don't provide the comfort the owner or the occupants are expecting.

In many cases the heating system, which is often thought of as a necessary but uninspiring part of the building, is selected solely on the basis of installation cost. In other cases, the selection is based strictly on what the builder offers or recommends. Still other times, the choice is based on what's customary for the type of building being constructed or its location. Such decisions often lead to years of discomfort in thermally-challenged buildings. In retrospect, many people who have made such decisions—and lived with the consequences—would quickly change their mind if given the opportunity. Most would gladly spend more (if necessary) for a heating system that meets their expectations.

It doesn't have to be this way!

Few people don't appreciate a warm, comfortable interior environment on a cold winter day. A warm home or workplace lets them forget about the snow, ice, and wind outside. It's an environment that encourages a sense of well being, contentment, and productivity.

Hydronic heating can provide such an environment. It can enable almost any building to deliver unsurpassed thermal comfort year after year.

Hydronics technology is unmatched in its ability to transfer precise amounts of heat where and when it's needed. The warmth is delivered smoothly, quietly, and without objectionable drafts that cause discomfort, or carry dust

and airborne pollutants through the building. Properly designed hydronic systems are often significantly less expensive to operate than other forms of heating.

A wide variety of hydronic heating options exist for everything from a single room addition to huge industrial and commercial buildings. Knowledgeable designers can configure systems to the exact needs of each building and its occupants. The systems can then be installed without compromising the structure or aesthetics of the building.

In short, hydronic heating is for discriminating people who expect buildings to be as comfortable to live and work in as they are elegant to look at. Hydronic heating sets the standard of comfort, versatility and efficiency against which other forms of heating should be measured.

Now Is the Time

There has never been a better time for heating professionals to be involved with hydronics. New materials, design tools and installation techniques offer unprecedented and profitable opportunities to progressively-minded professionals.

IPEX produced this manual to assist you in deploying hydronic heating technology using the latest design and installation strategies. It is our goal to help you to meet the exact needs of your customer using the finest methods and materials available for modern hydronic heating. We want to inspire your thinking, and give you a "can do" attitude when faced with job requirements that often lead to compromise when undertaken without the versatility hydronics has to offer.

A Universal Piping System

Piping is obviously a crucial component in any hydronic system. Not only must it safely contain heated and pressurized water but it must also resist corrosion, withstand thermal cycling and be easy to install.

Kitec® XPA™ pipe was launched by IPEX in 1988 as a multipurpose pressure pipe with many potential uses in hydronic heating, including potable water distribution. Kitec's construction combines the best properties of both aluminum and cross-linked polyethylene (a.k.a. PEX) to create a unique composite tube that can be used in applications often beyond the limits of either metal or plastic alone.

The aluminum core of Kitec pipe provides strength, yet allows for easy bending. It results in a tube that expands and contracts far less than all plastic tubing when heated and cooled. It also provides an extremely effective barrier against oxygen penetration, which can lead to corrosion of other hydronic system components.

The outer PEX layer protects the integrity of the aluminum core, shielding it from abrasion or chemical reactions when embedded in materials such as concrete. The inner PEX layer provides a smooth surface for excellent flow characteristics as well as chemical resistance.

The unique construction of Kitec tubing also provides excellent flexibility for easy installation, especially in tight situations where rigid pipe is simply out of the question.

Unlike most plastic tubing, Kitec retains the desired shape when bent. It can also be easily straightened for a neat and professional appearance in exposed locations.

Kitec pipe is truly a "universal" product suitable for all types of service in hydronic heating systems. From heated floor slabs, to heated walls and ceilings or snowmelting systems to baseboard circuits, you'll find the qualities Kitec possesses will soon make it the tubing of choice for all your hydronic heating needs.

From piping to systems

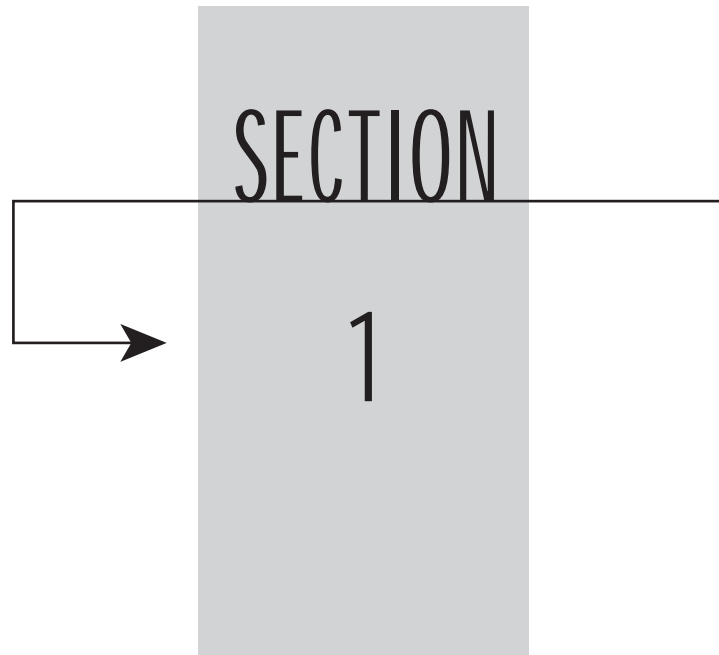
In addition to Kitec tubing, IPEX also offers a complete line of accessories such as tubing connectors, adapter fittings, manifolds and WarmRite Floor® Control Panels. These products are designed to allow fast and easy installation and can be used in a variety of applications.

In the sections that follow, we'll show you how to apply these products in new ways that let you design and install systems that epitomize the quality and comfort hydronics has long been known for. These are techniques that let you profitably take on the challenging jobs others stay away from while steadily building your reputation as a true comfort professional.

Together with IPEX, you can successfully harness the almost endless possibilities offered through modern hydronics technology.

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CONSIDER THE POSSIBILITIES!

Question:

What kinds of heating loads can be handled using modern hydronics technology?

Answer:

Almost any load you can think of!

For years the concept of hydronic heating evoked thoughts of cast-iron radiators or fin-tube baseboards in homes and commercial buildings—and not much else.

Early hydronic systems were usually classified as being “residential” or “commercial” in nature. Residential systems were the domain of plumbing / heating contractors. Rule of thumb design was usually good enough given the limited variety of systems installed. The piping and control methods used in these systems remained essentially unchanged between the 1950’s and the 1980’s in North America.

Commercial hydronic systems were a world apart from their residential counterparts. Techniques such as primary / secondary piping, multiple water temperature distribution systems, and outdoor reset control were successfully deployed in commercial systems, but almost never considered for residential applications.

A New Era for Hydronics

Times have changed considerably, hydronically speaking. Residential and commercial systems now share some common piping and control strategies. Successful installation strategies first developed decades ago are being “redeployed” using modern materials and control strategies that ensure decades of reliable and energy efficient operation.

The days when hydronic systems consisted solely of cast-iron radiators, copper or black iron pipe and fin-tube baseboard are gone. New hardware such as Kitec pipe and WarmRite Control Panels now make it possible to install quality systems that serve a multitude of heating loads. Modern systems can incorporate a variety of heat emitters. Each are selected to match the exact thermal, aesthetic and budget constraints of a project.

Today, hydronic heating contractors are being asked to furnish heating systems for everything from small apartments to large custom-built houses, as well as a variety of commercial buildings. Each job brings its own particular set of requirements.

Many modern systems contain several types of heat emitters operating at different water temperatures and divided up into a dozen or more independently controlled zones.

Some contractors hesitate to take on such challenging systems. Others recognize that with the right materials and design methods, these systems are not only possible, but also offer excellent profit potential as well as the likelihood of future referrals.

Contractors who recognize what modern hydronics technology has to offer, and who take the time to learn how to apply new design techniques and hardware, are enjoying unprecedented business growth. Discriminating clients seek out these hydronic specialists because they offer what their competition cannot—the ability to pull together modern materials and design methods to create heating systems specifically tailored to their client's needs.

To take advantage of such opportunities, you need to know how to use these modern piping and control techniques. That's what this manual is all about. It will show you how to use Kitec pipe, WarmRite Control Panels, and other hardware to assemble state-of-the-art hydronic systems that deliver comfort, economical and reliable operation and most importantly, satisfied customers. Armed with this knowledge you'll find modern hydronic heating to be among the most satisfying and profitable niches in the HVAC industry.

IPEX Incorporated is ready, willing, and able to help you achieve the many benefits offered to those who know how to apply modern hydronics technology.

One System that Does It All

The concept that best describes modern hydronic heating is:

One heat source serving multiple loads

Those loads include:

- Radiant heating of floors, walls and ceilings
- Baseboard heating
- Panel radiators
- Hydro-air subsystems
- Indirect domestic water heating
- Intermittent garage heating
- Pool and spa heating
- Snow melting
- "District heating" of several adjacent buildings
- Agricultural / horticultural loads such as animal enclosures, greenhouse heating, and turf warming

Many projects may have several of these loads, each requiring heat in different amounts, at different times and at different temperatures.

For example, the space heating loads of a given building might best be served by a combination of hydronic heat emitters. Some areas might be perfect for radiant floor heating while others are better suited to radiant ceiling heating. Still other areas might be ideal for baseboard or even ducted forced-air through an air handler equipped with a hot water coil.

Almost every house and commercial building also needs domestic hot water. In some cases, this load can be as large or larger than the space heating load.

Many facilities are also perfect candidates for hydronic snow melting - if those in charge are aware of the benefits it offers compared to traditional methods of snow removal.

Some designers approach situations like these by proposing a separate, isolated hydronic system for each load. One boiler to heat the building, another to melt the snow in the driveway, and perhaps still another to heat the pool. The same building might also use one or more direct-fired domestic water heaters.

Although such an approach is possible, it seldom takes advantage of the unique ability of hydronics to connect all the loads to a single heat source. The latter approach often reduces the size and cost of the overall system. It also makes for easier servicing and reduces fuel consumption. Such a synergistic system is made possible through modern hydronics technology.

From Simple to Sophisticated

Let's look at the versatility of modern hydronics technology in meeting the demands of both simple and sophisticated load requirements.

We'll start with something basic: a floor heating system for a small addition to a home. Because the load is small, a water heater will be used as the heat source. It, as well as the other system components, is shown in figure 1-1

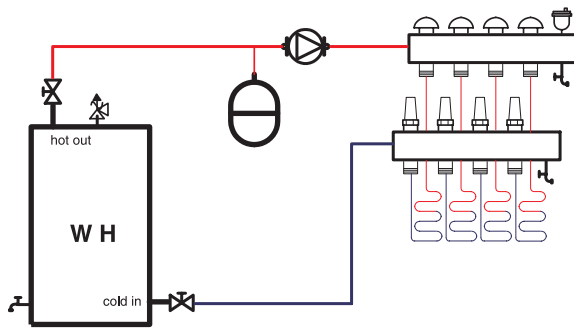


Figure 1-1

Although the installer could purchase components (such as the manifolds, a bronze circulator, expansion tank) and all the valving separately, using a WarmRite control panel can save much time and labor. All the needed components are preassembled into a compact

and easily mounted unit. All that's left to do is to pipe

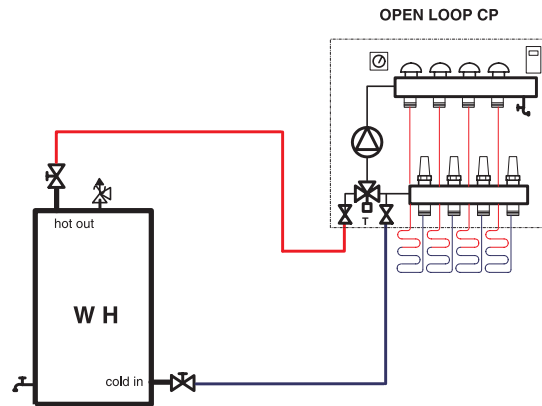


Figure 1-2

the WarmRite control panel to the water heater, connect the floor circuits, and then route power to it.

Although this system is very simple in concept and construction it's also capable of delivering comfort far superior to its alternatives, several of which may cost more to install as well as to operate.

A Slightly Larger Requirement

A typical home often has a design heating load greater than what can be supplied from a residential water heater, especially if the same unit also has to supply domestic hot water. In such cases a boiler is a more appropriate heat source.

Figure 1-3 is an example of a hydronic system that

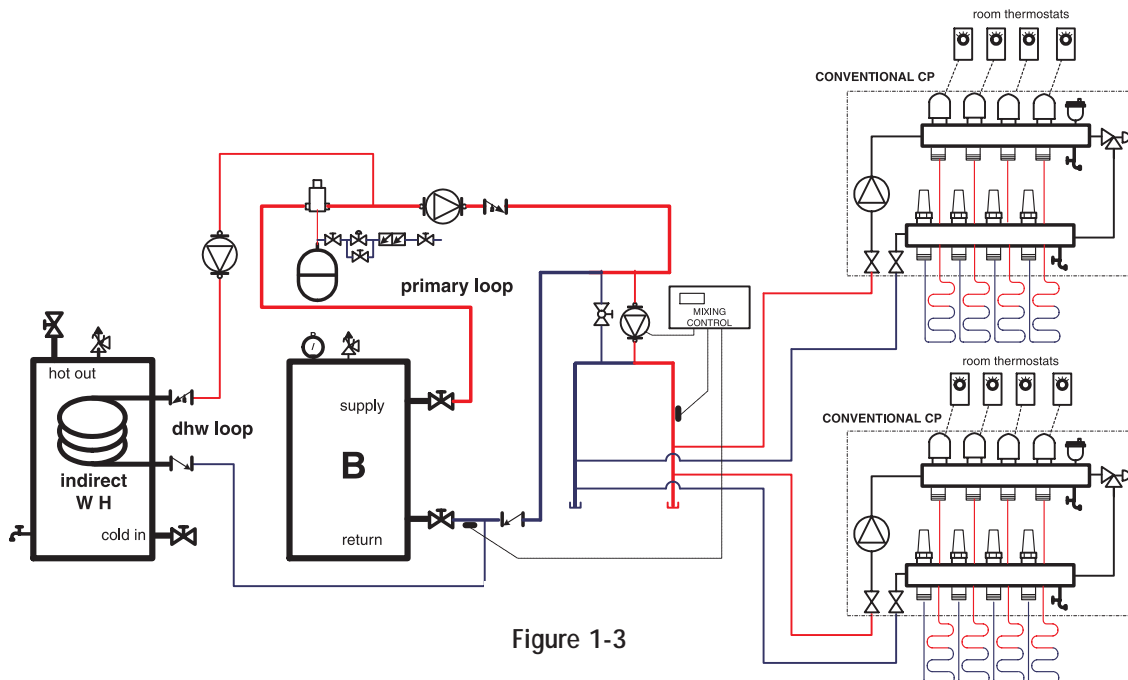


Figure 1-3

supplies space heating through a radiant floor subsystem as well as domestic hot water via an indirect water heater.

Two WarmRite control panels are used to provide the water and electrical control functions for the space heating portion of the system. In this case, electric valve actuators have been included in the WarmRite control panels to allow individual temperature control of several rooms. An external injection mixing system has been installed between the WarmRite control panels and the primary loop, to vary the water temperature supplied to the floor circuits based on outside temperature (e.g. outdoor reset control). This mixing system also protects the boiler from flue gas condensation that can be caused by low return water temperatures.

Multiple Water Temperatures...No Problem

Some buildings may require (or some customers may prefer) different types of hydronic heat emitters that operate at different water temperatures. For example, a portion of a building may use radiant floor heating. The tubing circuits in the heated floor slab might operate at 105 deg. F. water temperature at design conditions.

Another part of the building may be heated with fin-tube baseboard that needs 180 deg. F. water at the same time. Providing these multiple water temperatures is relatively straightforward using the piping/control scheme depicted in figure 1-4.

Notice that the manifold supplying the baseboard circuits is piped directly into the primary loop and thus receives hot (180 deg. F.) water. The floor heating circuits are supplied with reduced water temperature through use of an injection mixing system and the WarmRite control panel. Note that all components related to run the floor heating circuits are integrated into one preassembled WarmRite control panel. The boiler also supplies hot (180 deg. F.) water to the heat exchanger of the indirect water heater for fast recovery.

This system now serves three different heating loads using two water temperatures. But that's far from pushing the limits of modern hydronics technology.

A Sophisticated System

Suppose that after discussing the above system, your customer asks if you can also provide snow melting, occasional garage heating or pool heating. Maybe even all three at the same time. This is an opportunity where

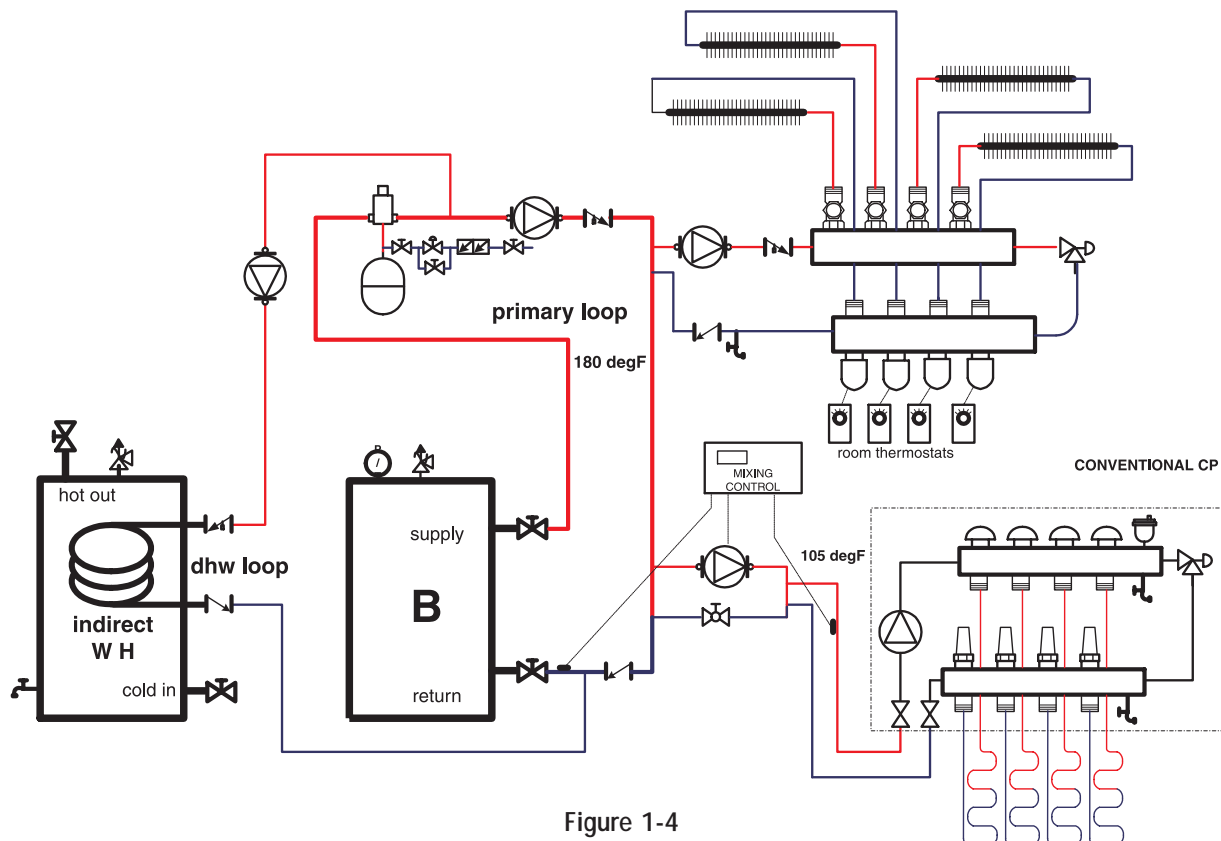


Figure 1-4

hydronics can really come through. It is a situation where you can provide an efficient customized system that's exactly right for your customers needs.

Figure 1-5 depicts one way such a system could be assembled.

Think of this system as a collection of subassemblies "plugged" into a common source of heated water: the primary loop. The floor heating subassembly appears the same as in figure 1-4 except now there are two of them. It's simply plugged into larger primary loop. Likewise, the manifold supplying the baseboard zones is plugged into the primary loop the same as in figure 1-4.

What's new are the subassemblies that supply the heat exchanger for the snow melting and pool heating systems. Think of the heat exchangers as the separating point between the hot water in the primary loop and the fluids that carry heat to the snow melting circuits and the pool. The heat gets passed from one fluid to the other, but the fluids themselves never mix.

The "power plant" for this sophisticated system is a

pair of boilers controlled by a staging control. This concept—called a multiple boiler system—is now common in larger residential as well as commercial systems. The multiple boiler system is sized to deliver the proper amount of heat when all the loads that are capable of running simultaneously are doing so. Such an approach yields higher seasonal efficiency compared to a single large boiler. It also adds to the system's reliability since one boiler can still operate should the other be down for service.

The system shown in figure 1-5 uses state-of-the-art piping and control techniques to serve all the heating loads of a large house with many amenities. It also makes use of Kitec and WarmRite hardware to speed installation and ensure top quality.

The sections to follow discuss many of the key concepts and available options for assembling both simple and sophisticated hydronic systems. Learn them, apply them, and then take pride in providing your customers with the comfort and efficiency that only modern hydronics technology can deliver.

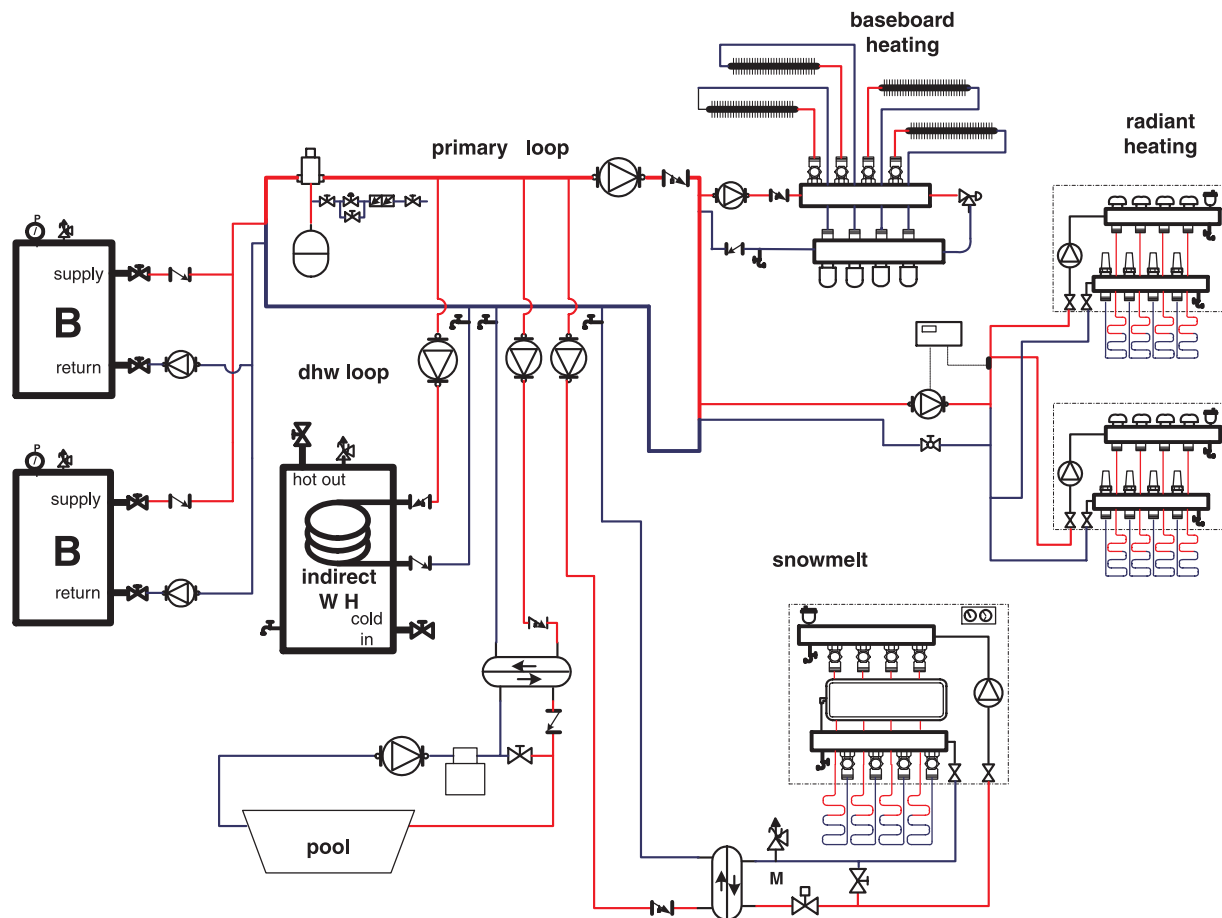
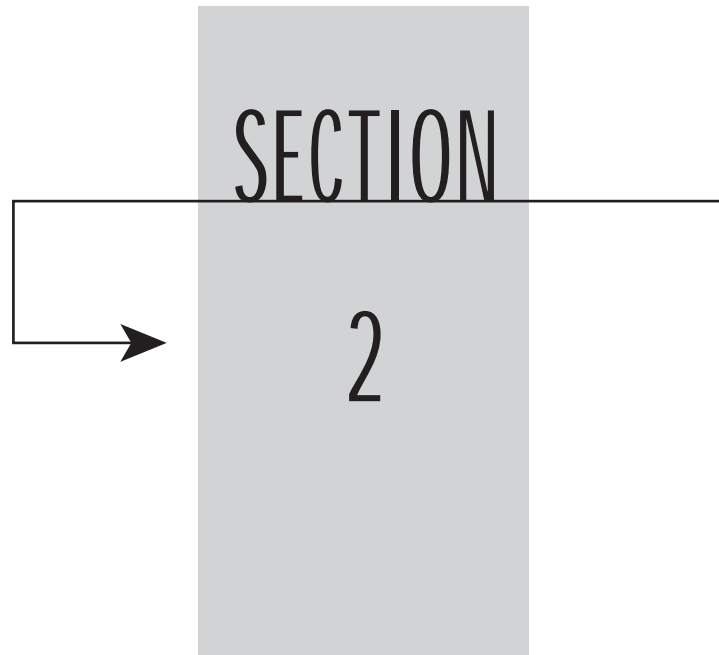


Figure 1-5



HEAT SOURCE OPTIONS

A wide variety of heat sources can be used with hydronic heating systems. They include gas- and oil-fired boilers, hydronic heat pumps and domestic water heaters to name a few. Some are better suited to higher temperature systems, while others are ideal for low temperature systems.

This section briefly describes the characteristics of several heat sources suitable for hydronic systems. More detailed information pertaining to their selection and installation is best found in manufacturer's literature and manuals. Relevant building / mechanical codes should also be consulted for specific installation requirement.

The information at the end of this section allows designers to compare the cost of energy provided by several common fuels based on their local cost and the efficiency at which they are converted to heat.

2-1 Conventional Boilers

The most common hydronic heat source is a "conventional" gas- or oil-fired boiler. They are available with heat exchangers made of cast-iron, steel and finned copper tubing.

Although designed to operate at relatively high water temperatures, conventional boilers can be adapted to lower temperature hydronic systems such as radiant floor heating by using a mixing device. Their ability to produce high temperature water makes them a good choice in systems where both low temperature and high temperature heat emitters are used.

The term "conventional" describes boilers that are intended to operate without sustained condensation of the flue gases produced during the combustion process inside the boiler. These flue gases are made up of water vapor, carbon dioxide, and trace amounts of other combustion products depending on the fuels used, and the tuning of the burner.

All boilers experience temporary flue gas condensation during cold starts. If the boiler is connected to a low mass

distribution system that is designed to operate at higher water temperatures—fin-tube baseboard for example—such flue gas condensation is short-lived. It rapidly evaporates as the boiler warms above the dew point of the exhaust gases.

However, when a conventional boiler serves as the heat source for a low temperature distribution system it is imperative to keep the inlet temperature to the boiler above the dew point of the exhaust gases. For gas-fired boilers, the inlet water temperature during sustained operation should not be less than 130 deg. F. For oil-fired boilers, it should not be less than 150 deg. F.

Failure to provide such boiler inlet temperature protection will cause the water vapor (and other compounds present in the exhaust gases) to continually condense on the internal heat exchanger surfaces. The acidic nature of such condensate can cause swift and severe corrosion along with scale formation inside the boiler. It can also rapidly corrode galvanized vent piping, as well as the deterioration of masonry chimneys

Hydronic distribution systems with high thermal mass can also cause prolonged flue gas condensation as the system warms up to normal operating temperature. A cool concrete slab with embedded tubing circuits is a good example. As the slab begins to warm, its thermal mass can extract heat from the circulating water stream 3 to 4 times faster than normal. Since the rate of heat release from the water is much higher than the rate of heat production, the water temperature (in an unprotected boiler) will quickly drop well below the dew point temperature of the exhaust gases. The boiler can operate for hours with sustained flue gas condensation. Such a situation must be avoided.

The key to avoiding low boiler inlet water temperature is preventing the distribution system—whatever type it happens to be—from extracting heat from the water faster than the boiler can produce heat.

Modern mixing devices can automatically monitor and

adjust boiler return temperature by limiting the rate of heat transfer allowed to pass through a mixing device and into the distribution system. The piping concept is shown in figure 2-1. The details involved in providing boiler return temperature protection will be discussed in section 3.

2-2 Condensing Boilers

In contrast to conventional boilers, gas-fired condensing boilers are specifically designed to promote condensation of the water vapor that is produced during combustion. They use large internal heat exchanger surfaces to coax as much heat as possible from the exhaust gases. The heat exchanger surfaces are made of high-grade stainless steel or other special alloys, and are not corroded by the acidic condensate that forms as the flue gases cool below the dew point. When properly applied in low temperature hydronic systems, such boilers can attain efficiency of 95+ %.

Although they are more complicated and more expensive than most conventional boilers, condensing boilers are well suited for low temperature hydronic systems such as slab-type floor heating, snow melting, pool heating and low- to medium- temperature domestic water heating. The lower the temperature of the water returning from the distribution system, the greater the rate of condensate formation, and the higher the boiler's efficiency.

Although condensing boilers can be used as heat sources for higher temperature hydronic systems, this is generally not advisable. The higher operating water temperatures prevent the boiler from operating with sustained flue gas condensation. Under such conditions their efficiency is comparable to that of a conventional boiler. Again, the key to attaining high efficiency from a condensing boiler is matching it with a low-temperature distribution system.

Systems with condensing boilers typically do NOT use mixing devices between the boiler and the distribution

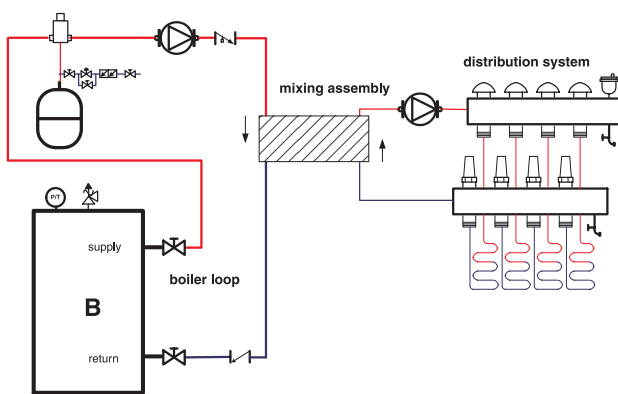


Figure 2-1

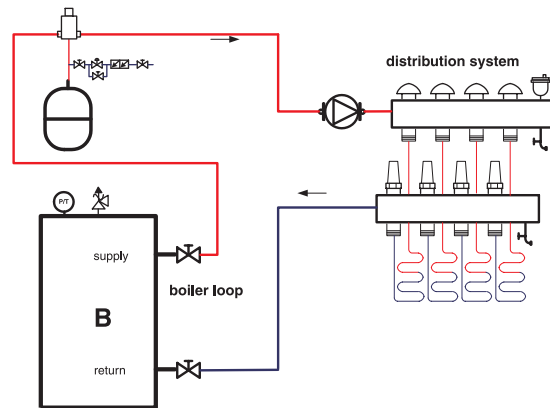


Figure 2-2

system. This helps offset a portion of the boiler's higher cost. Most condensing boilers can also be side wall vented through a 2" CPVC pipe. This too lowers installation cost relative to boilers vented through a chimney. Figure 2-2 shows how a condensing boiler would be piped in a typical floor heating system.

2-3 Tank-type Water Heaters

Some hydronic systems can use tank-type domestic water heaters as their heat source. Usually the size of such systems is limited by the heating capacity of the water heater. Residential water heaters have heat outputs in the range of 15,000 to 40,000 Btu/hr. This usually limits their application to small apartments or modest residential additions.

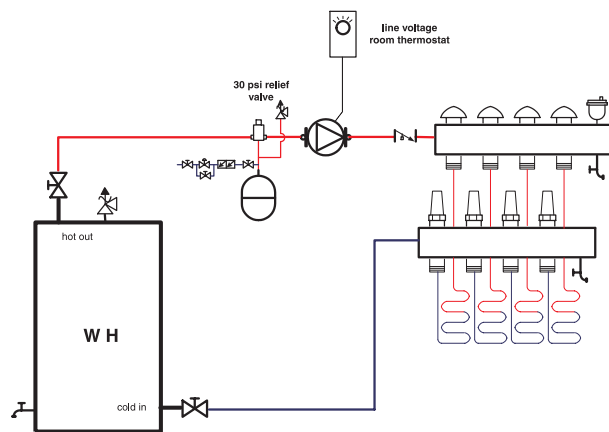


Figure 2-3

Because tank-type water heaters are designed to operate at lower water temperatures, mixing devices are not usually used between the tank and the distri-

bution system. The tank is directly piped to the distribution system as shown in figure 2-3. The tank's thermostat is set for the desired supply water temperature.

In some systems a water heater is expected to supply both domestic hot water and space heating. Although possible under some circumstances, the designer must ensure that the heating capacity of the water heater can handle both the space heating and domestic water heating loads. If these loads occur simultaneously, it is usually necessary to make the domestic water heating load a priority over the space heating load. Temperature controls can be used to temporarily suspend heat output to the space heating system until the domestic water heating load subsides and the tank temperature recovers.

Opinions vary on the suitability of circulating potable water through the space heating circuits. Under some circumstances, the potable water can remain stagnant in the space heating circuits for several months allowing for the possibility of microbe growth. Because potable water is used in the space heating circuits, all metal components must be bronze or stainless steel to resist corrosion from the oxygen-rich water. There is also the possibility of scale or sediment in the space heating system due to contaminants in the potable water.

The preferred approach to such "dual use" systems is to separate the space heating portions of the system from those containing domestic water using a small stainless steel heat exchanger as shown in figure 2-4. Because the heat exchanger isolates the space heating components the distribution system must have an expansion tank, pressure relief valve and air separator.

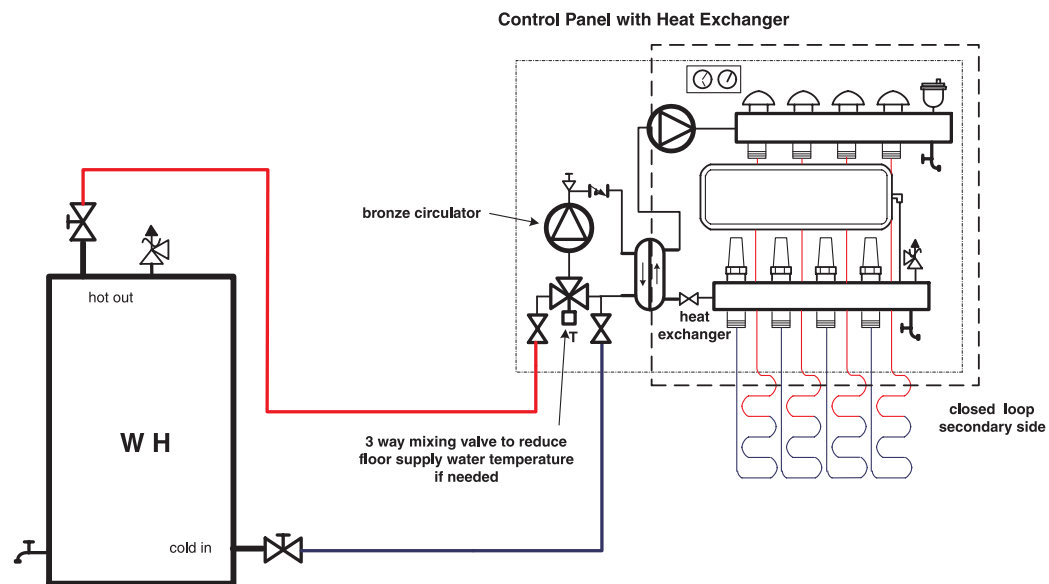


Figure 2-4

2-4 Geothermal Heat Pumps

Geothermal heat pumps are one of the newest heat sources suitable for some types of hydronic heating systems. They extract low temperature heat from a tubing circuit buried in the earth, or directly from water wells or other sources of water such as a large pond or lake. Using a refrigeration system similar to that in a central air conditioner, the heat captured from the earth is boosted in temperature and then transferred to a stream of water flowing to the distribution system.

As with condensing boilers, no mixing device is required between the heat pump and the distribution circuits. However, if the distribution system is divided into several independently controlled zones, an insulated buffer tank should be installed between the heat pump and the distribution system as shown in figure 2-5. This tank allows the heat output rate of the heat pump to be different than the heat extraction rate of the distribution system. It prevents the heat pump

from short cycling under low load conditions.

As with condensing boilers, geothermal heat pumps attain their highest efficiency when matched to low-temperature distribution systems. Slab type radiant floor heating systems operating at water temperatures in the range of 100 to 115 deg. F. at design conditions are ideal. The lower the water temperature, the higher the heat pump efficiency the system can operate at.

Avoid geothermal heat pumps in systems requiring design water temperatures above 130 deg. F.

In addition to heating, geothermal heat pumps can also supply chilled water for hydronic cooling applications. The most common approach uses an air handler equipped with a chilled water coil. Other terminal units such as radiant ceiling panels can be used for chilled water cooling, but such systems require accurate and reliable dew point control to avoid condensation on the chilled surfaces. A separate air handler is usually required to control humidity.

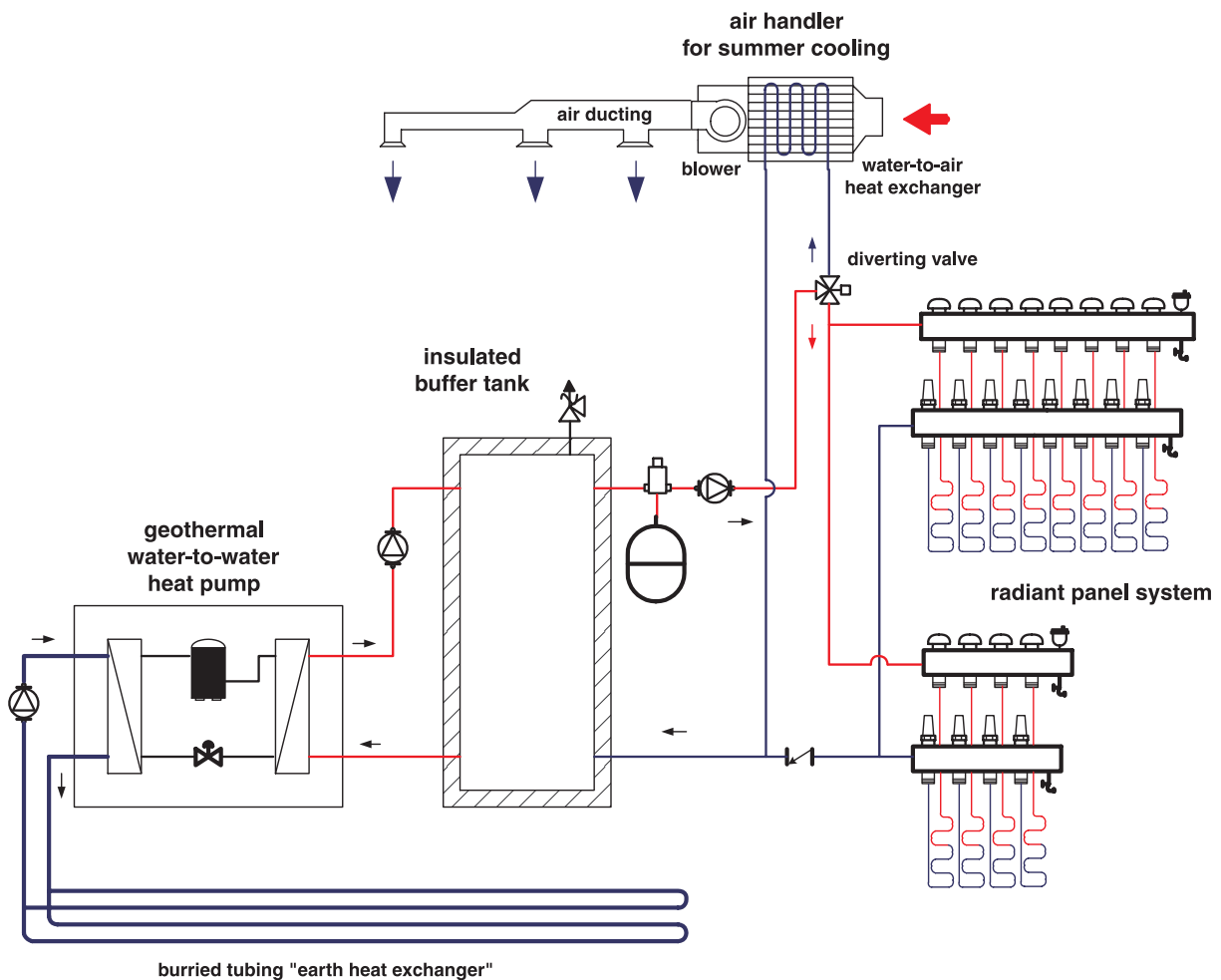


Figure 2-5

2-5 Thermal Energy Storage Systems

Many electric utilities offer “off-peak” electrical rates. Power that is purchased during off-peak hours is usually much less expensive than during periods of high demand.

A hydronic heating system is an excellent means of taking advantage of these rates. The idea is to purchase the electricity during the off-peak period and store the energy as heated water. This water is then used to heat the building during the “on-peaks” periods when electrical rates are higher. A schematic showing how this concept can be implemented is shown in figure 2-6.

The beginning of an off-peak charging cycle is initiated by a switch contact in the electric meter. At this point, one or more electrical heating elements are turned on to heat water in the large, well-insulated storage tank. Charging continues for several hours, and the tank become progressively hotter. If heat is needed by the

building during the charging cycle, some of the tank water is routed out through the distribution system the same as any other time of day. By the end of the charging cycle the water temperature in the tank may be as high as 200 deg. F. When the switch contact in the meter opens, the electrical elements are turned off. The hot water in the tank contains the heat needed for most if not all of the “on-peak” hours to follow.

Low temperature distribution systems such as radiant floor heating are ideally suited to such a heat source. Their low operating temperature allows the tank to be deeply discharged and thus maximizes its heat storage capability. The heat stored in a heated floor slab also allows the system to “coast” through the last 2 to 4 hours of the on-peak period should the energy in the tank be depleted.

A mixing device installed between the storage tank and the distribution system automatically reduces the water temperature supplied to the distribution system as necessary.

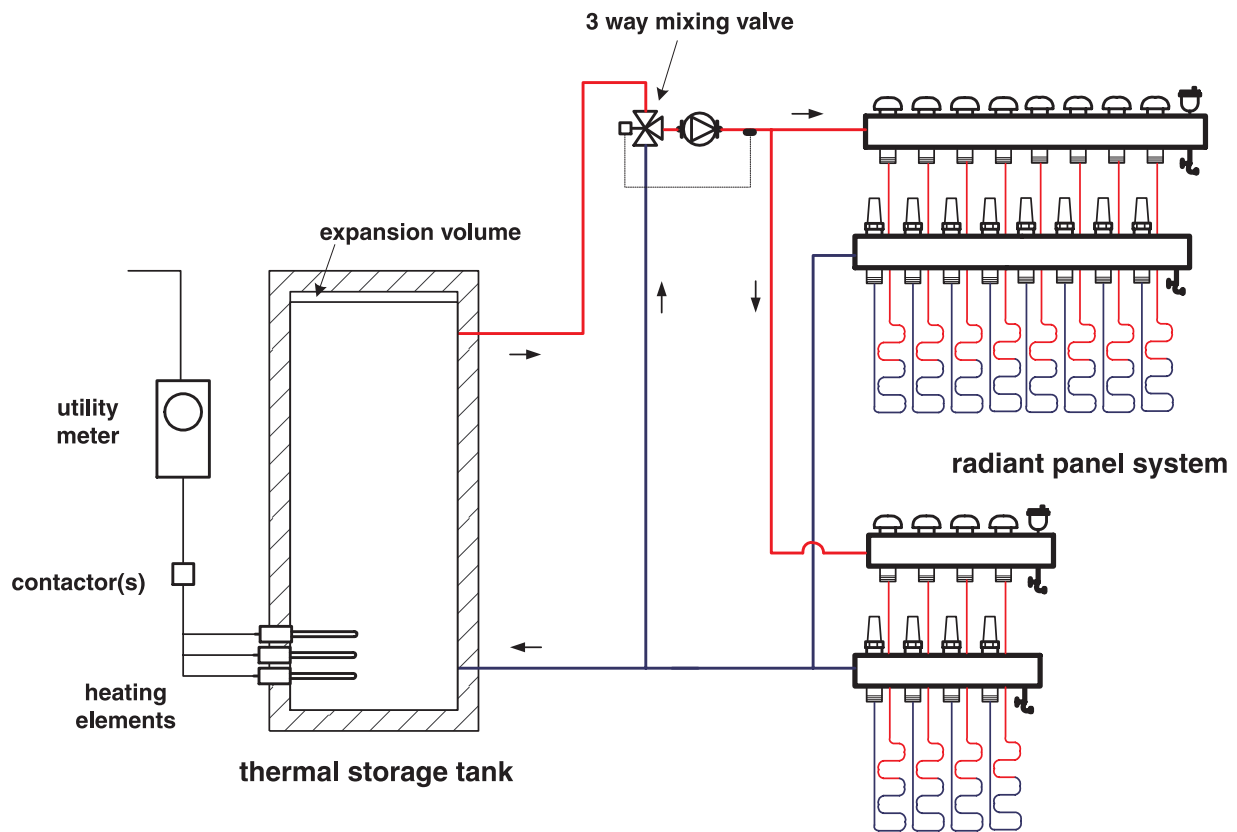


Figure 2-6

2-6 Wood-fired Boilers

When firewood is readily available and competitive in cost with conventional fuels, wood-fired boilers are another possible hydronic heat source.

In some systems, a wood-fired boiler is used in tandem with a conventional fuel boiler. The piping concept is shown in figure 2-7. Each boiler is piped as a secondary circuit into a common primary piping loop. This arrangement allows either boiler to operate without circulating hot water through the other (unfired) boiler, thus reducing heat loss. System controls are usually configured so the conventional fuel boiler automatically assumes the load as the fire dies down in the wood-fired boiler.

Heat output from a wood-fired boiler is harder to control than that from a conventional boiler. A large volume of water in the system adds to its stability. The

water volume may be contained in the wood-fired boiler itself or in a separate insulated thermal storage tank. Such a tank must be well insulated so that it can store heat for several hours with minimal losses. The concept is also shown in figure 2-7.

Some wood-fired boilers are not pressure rated. The water chambers inside the boiler are vented directly to the atmosphere. Although opinions vary on how best to connect such "open system" boilers to hydronic distribution systems the conservative approach is to install a stainless steel heat exchanger to isolate the boiler water from that in the pressurized distribution system. Not only does this allow the distribution system to be pressurized for quiet, air-free operation, but it also protects the cast iron and steel components in the distribution system from the possibility of corrosion through contact with boiler water that has a higher concentration of dissolved oxygen.

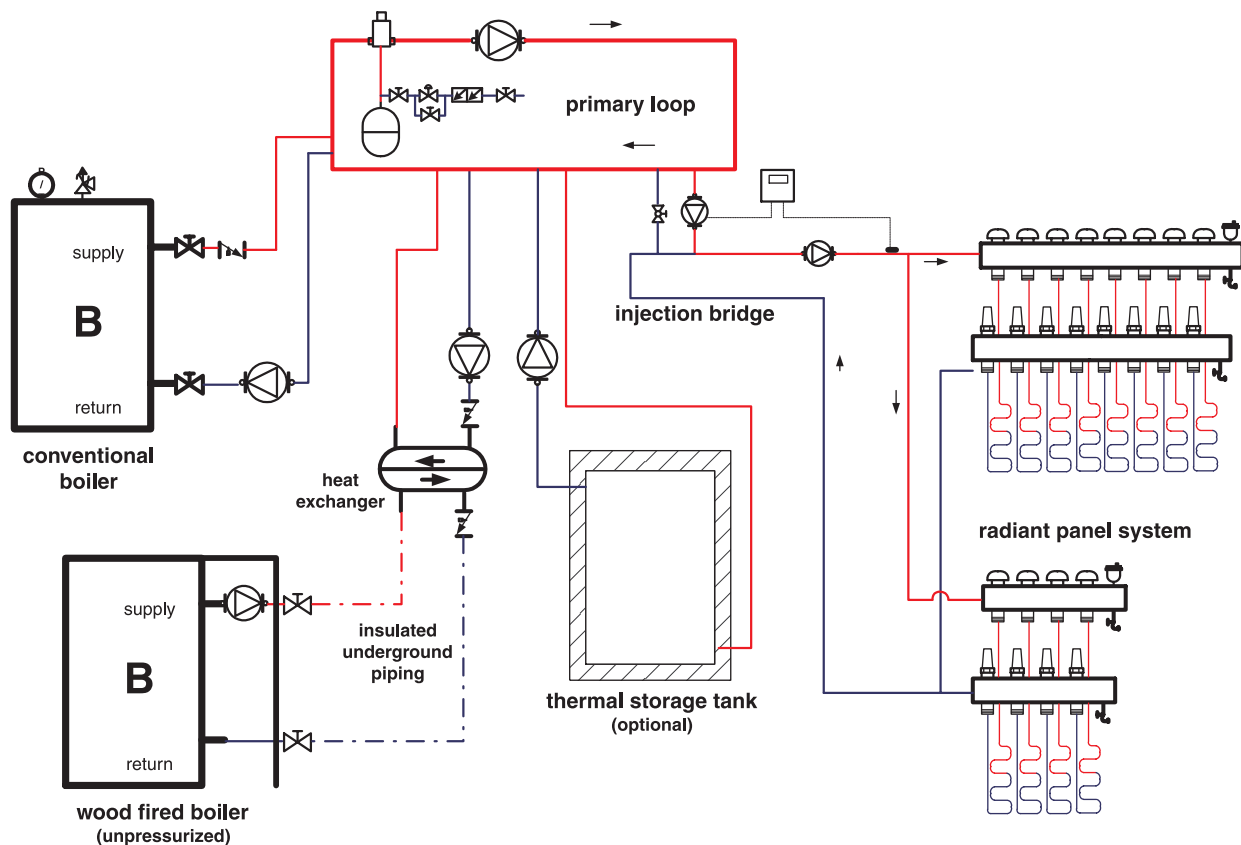


Figure 2-7

2-7 Comparing Fuel Costs

In many cases the heat source is selected based on the type of fuel that is available or determined to be most economical over the life of the system. The commonly used fuels are sold in different units such as kilowatt-hours for electricity, therms for natural gas, gallons for fuel oil and face cords for firewood. To perform an accurate comparison it is necessary to express the cost and energy content of each candidate fuel on a

common basis.

The formulas in figure 2-8 allow the cost of heating energy from each of several fuels to be expressed on the common basis of dollars per million Btu's of delivered heat. This is abbreviated as \$/MMBtu. These formulas take into account the cost, purchase units, as well as efficiency of the heat source in converting the fuel into useful heat.

Fuel Cost Comparison Worksheet

Electric Heat cents / KWhr x 2.93 = \$ / MMBtu
Heat Pump	$\frac{\text{..... cents / KWhr} \times 2.93}{\text{..... average COP}} = \text{..... } \$ / \text{MMBtu}$
#2 Fuel Oil	$\frac{\text{..... } \$ / \text{gallon} \times 7.14}{\text{..... AFUE (decimal)}} = \text{..... } \$ / \text{MMBtu}$
Propane	$\frac{\text{..... } \$ / \text{gallon} \times 10.9}{\text{..... AFUE (decimal)}} = \text{..... } \$ / \text{MMBtu}$
Natural Gas	$\frac{\text{..... cents / therm} \times 0.1}{\text{..... AFUE (decimal)}} = \text{..... } \$ / \text{MMBtu}$
Fire wood*	$\frac{\text{..... } \$ / \text{face cord} \times 0.149}{\text{..... avg. efficiency (decimal)}} = \text{..... } \$ / \text{MMBtu}$

Notes:

1. \$ / MMBtu = dollars per million Btu of heat delivered to building
2. KWhr = kilowatt hour = 3413 Btu
3. Average COP = average Coefficient Of Performance during heating season (for geothermal heat pump with low temperature distribution system generally 2.5 - 3.5)
4. AFUE = Annual Fuel Utilization Efficiency of appliance (for typical oil or gas boiler use 0.75 - 0.8)

* Assumes a 50/50 mix of maple and beech dried to 20% moisture content
Price is for 4 ft x 8 ft x 16" face cord split and delivered

Figure 2-8

SECTION

3

WATER TEMPERATURE CONTROL

All hydronic heating systems must control the water temperature supplied to their heat emitters. A simple system may only need to supply one water temperature to all the loads it serves. A more sophisticated system containing several types of heat emitters may need to simultaneously supply two or more water temperatures.

This section discusses several methods of water temperature control and the hardware necessary to accomplish it.

3-1 Setpoint control

The simplest method of water temperature control is called "setpoint control." As its name implies, a single (set) water temperature is supplied to the distribution system regardless of which loads are active, or how great the demand for heat is (as long as there is a demand).

To prevent short cycling of the heat source or other equipment in the system, setpoint controls require an operating differential. This refers to the variation in temperature between which control closes or opens its electrical contacts. A contact closure is the most common way to turn the heat source on and off. For example, a setpoint control with a setting of 180 deg. F. and a differential of 10 deg. F. would turn the heat source off at 180 deg. F. and back on when it the temperature drops to 170 deg. F.

Some setpoint controls "center" their differential on the setpoint. A device of this type, when set to 180 deg. F. and a 10 deg. F. differential, would open its electrical contacts to turn the heat

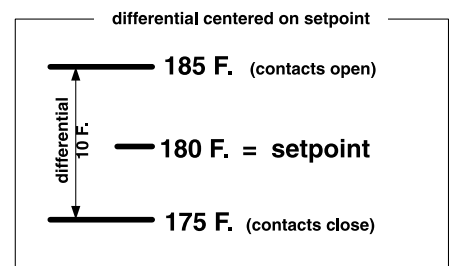
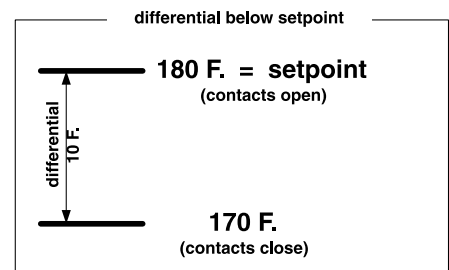


Figure 3-1

source off at 185 deg. F. and close them when the sensed temperature drops to 175 deg. F. Figure 3-1 compares these two types of setpoint control.

Some setpoint controls have fixed (non-adjustable) differentials, while others provide an adjustable differential. The narrower the differential, the closer the water temperature stays to the desired setpoint. However if the differential is too narrow, the heat source or other equipment in the system could experience excessively short operating cycles that reduce their efficiency and shorten their life. Heat source operating differentials in the range of 10 deg. F. are common in hydronic systems.

Systems using setpoint controls provide the same average water temperature to the loads whenever there is a call for heat, regardless of the rate of heat input required by the load. For example, a boiler operated by a setpoint control supplying a circuit of fin-tube baseboard would deliver hot water (perhaps averaging around 175 deg. F.) whether the outdoor temperature was -10 deg. F. on a cold January night, or 50 deg. F. on a mild October afternoon. To prevent overheating under all but design load conditions, flow must be periodically interrupted by turning off the circulator or closing the zone valves. To keep room temperature variations to a minimum, it's important to have a thermostat with a narrow differential of perhaps 1 or 2 deg. F. If the thermostat has an anticipator it should be carefully set for the electrical current flow through it during its on-cycle.

3-2 Outdoor reset control

Rather than deliver heat in "spurts," an ideal system would continually adjust its rate of heat delivery to match the heat loss of the building. The indoor air temperature would remain constant, and there would be no difference in comfort regardless of outside conditions.

Outdoor reset control (ORC) was developed for this purpose. It enables heat to flow from the heat emitters to the space being heated at just the right rate. ORC is increasingly recognized as the preferred method of water temperature control, especially for high thermal mass floor heating systems.

All outdoor reset controls use outside air temperature to determine the ideal "target" water temperature to be supplied to the system's heat emitters. The colder it is outside, the higher the water temperature. The goal is to match the rate of heat delivery to the rate of heat loss from the building.

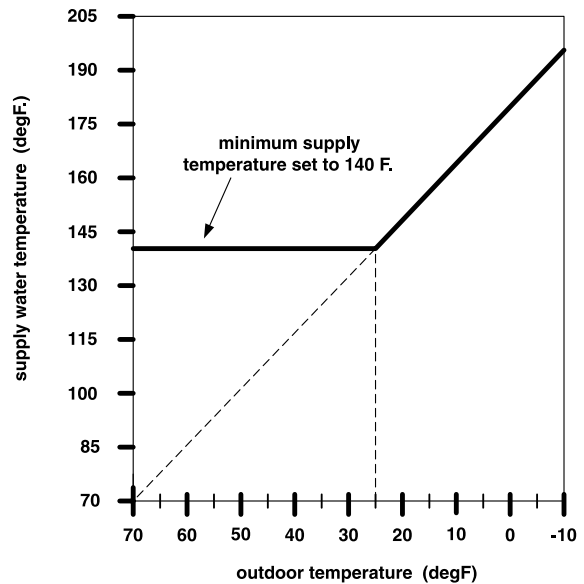
There are two methods of using reset control in a hydronic system. Each can be used by itself, or the two can be used in combination.

They are:

1. boiler reset control
2. mixing reset control

A boiler reset control takes over operation of the burner from the standard (fixed) high limit control supplied with most boilers. As the outside air temperature changes, the reset control continually recalculates how high the boiler water temperature will be allowed to climb and operates the burner accordingly.

Boiler reset is well suited for systems using relatively high temperature hydronic heat emitters, like baseboard or panel radiators. However, because conventional boilers should not operated for prolonged periods at temperatures below the dew point of their exhaust gases, boiler reset is limited when used in conjunction with low temperature heat emitters. In such cases, boiler water temperature can only "partially reset" down to a user-selected minimum temperature setting as shown in figure 3-2.



Note: at outside air temperatures above approximately 25 F., this configuration will supply 140 F. water to the distribution system whenever there is a call for heat.

Figure 3-2

For the case shown, the boiler outlet temperature would not be reduced below 140 deg. F. This water temperature happens to correspond to an outside air temperature of 25 deg. F. Air temperatures of 25 deg. F. and higher represent a large percentage of the heating season in many parts of North America. This implies the 140 deg. F. water temperature supplied to the heat emitters will be higher than necessary during much of the heating season. The room thermostat must turn the circulator (or zone valve) on and off to prevent overheating under these conditions.

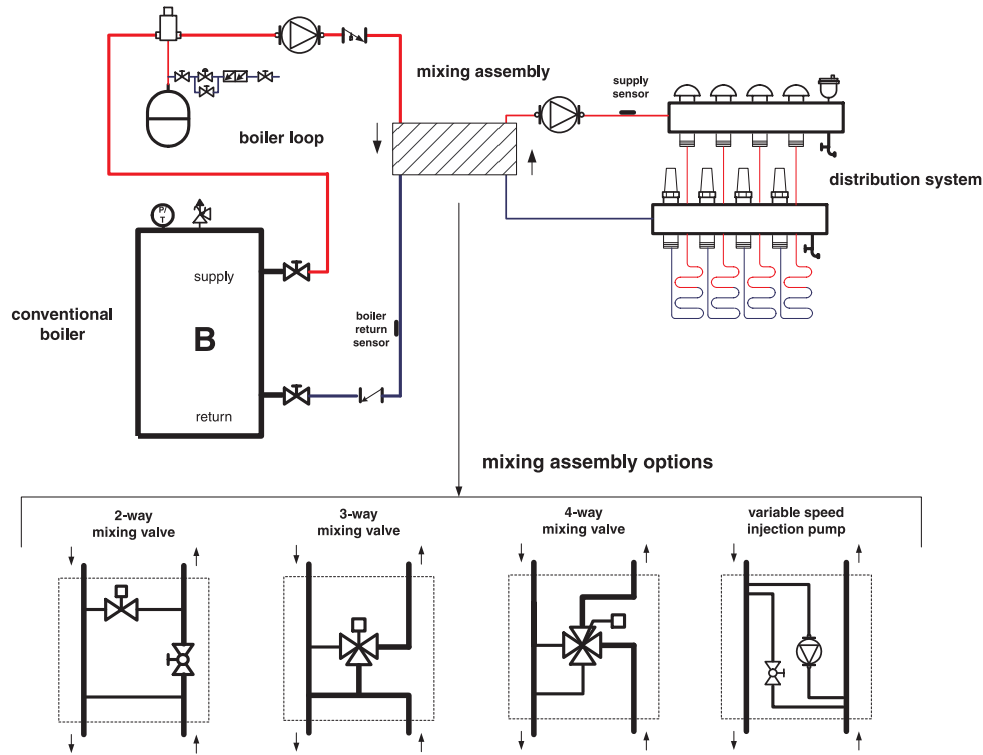


Figure 3-3

Mixing reset control requires a mixing assembly between the boiler loop and a separate distribution circuit. This assembly could contain a modulating 2-way, 3-way, or 4-way valve, or a variable speed injection pump as depicted in figure 3-3. These options are discussed in more detail later in this section.

The mixing assembly provides the proper supply water temperature to the distribution system. When necessary, it also acts as a “clutch” to prevent the cold thermal mass of a distribution system from extracting heat faster than the boiler can produce it. This latter function, commonly called “boiler protection,” is crucially important when a conventional boiler provides heat to a slab-type floor heating system.

Mixing reset control allows “deep” reduction in the water temperature supplied to the distribution system while simultaneously protecting the boiler from low inlet water temperatures.

Boiler reset can be used in combination with mixing reset in the same system. The concept is shown in figure 3-4.

The boiler reset control monitors and adjusts the water temperature in the primary loop by varying the firing cycles of the boiler(s). The primary loop temperature is often partially reset to prevent the boiler(s) from operating below dew point temperature. The mixing

reset control operates the mixing device to reduce the primary loop water temperature as appropriate for the loads they serve. Some systems may have two or more independent mixing devices supplied from a common primary loop.

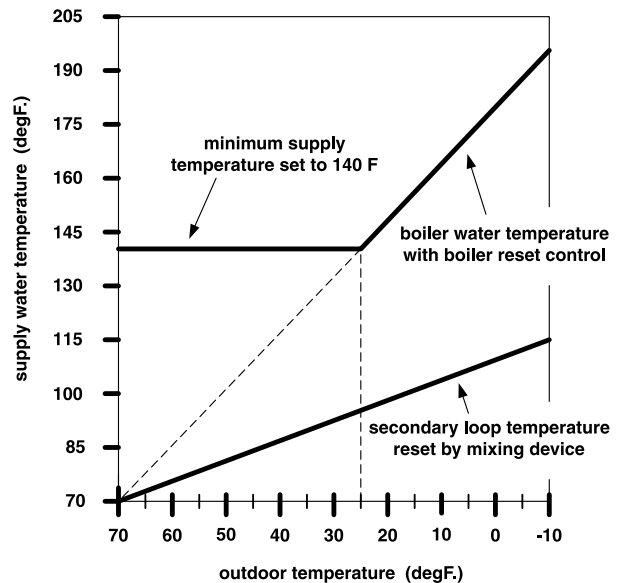


Figure 3-4

An example of the reset lines for a system using both boiler reset and mixing reset is given in figure 3-5. Notice that the primary loop has a minimum supply temperature of 140 to protect the boiler from sustained flue gas condensation. However, the mixing reset control can reduce the temperature of the water to the distribution system all the way down to room air temperature.

3-3 Mixing requirements

Several types of mixing devices can be used to reduce the water temperature supplied from the heat source to the distribution system. These include 2-way, 3-way, and 4-way valves as well as several forms of injection mixing.

Controlling the water temperature supplied to the distribution system is often not the only function of the mixing device. In systems using a conventional boiler as the heat source the mixing device must also prevent low inlet water temperatures that can cause sustained flue gas condensation within the boiler.

This second requirement applies when any type of fuel-burning boiler—that's not designed to operate with sustained flue gas condensation—is paired with a low temperature distribution system. Most "conventional"

gas- and oil-fired boilers fall into this category. Failure to provide this protection can result in severe corrosion and scaling within the boiler. This not only shortens boiler life, but it can also lead to failure of vent piping and spillage of combustion products into the building. Unfortunately, the need to protect the boiler inlet temperature is often viewed as secondary to providing the proper supply temperature to the distribution system. This is an oversight with potentially deadly consequences.

It is generally recognized that maintaining return temperatures of 130 deg. F. or higher for gas-fired boilers, and 150 deg. F. or higher for oil-fired boilers will eliminate the damaging effects of flue-gas condensation. There are exceptions, and boiler manufacturers should be consulted regarding the minimum operating temperature of their equipment.

Condensing boilers, discussed in section 5, are specifically designed to withstand sustained flue gas condensation and don't need return temperature protection. The cooler the return water temperature the higher their efficiency. In most cases a mixing device is not needed when a condensing boiler is used to supply heat to a low temperature hydronic distribution system as long as the supply temperature matches the design criteria.

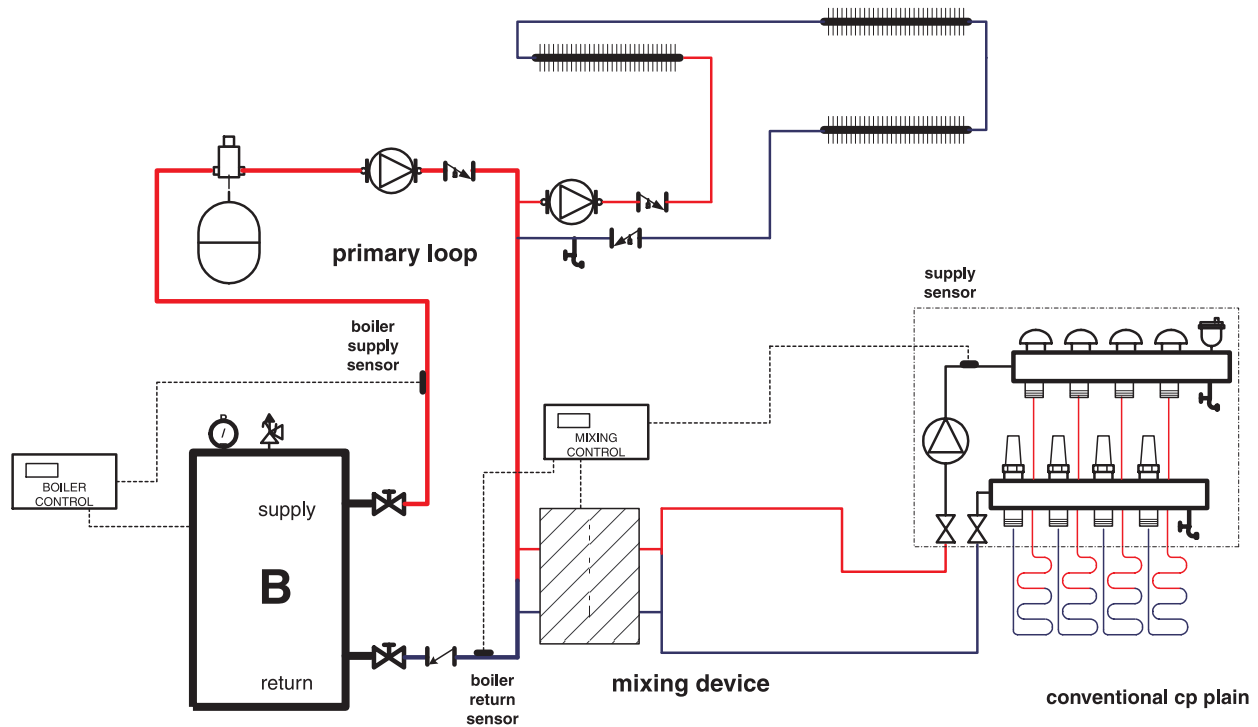


Figure 3-5

Hydronic heat sources that don't produce flue gases don't need to be protected against flue gas condensation. These include electric boilers, hydronic heat pumps, thermal storage tanks, and heat exchangers.

3-4 3-way thermostatic mixing valves

One of the most common mixing devices used in low temperature hydronic systems is a 3-way thermostatic valve. It has two inlet ports—one for hot water, the other for cold—and a single outlet port for the mixed stream. Inside the valve is a shuttle mechanism that determines the proportions of hot and cold water allowed into the valve. The shuttle is moved up and down inside the valve body by the expansion and contraction of a wax-filled actuator. The sealed wax assembly is heated by the mixed flow across it. If the mixing stream is slightly too hot, the wax assembly expands, forcing the shuttle to partially close the hot inlet port and simultaneously open the cold inlet port.

A knob on the valve sets the actuator to the desired outlet water temperature. As the temperatures of the incoming hot and cold streams change, the wax-filled actuator moves the shuttle to maintain the set outlet water temperature.

Some 3-way mixing valves are operated by a gas-filled

bellows actuator rather than an internal wax-filled actuator. Their sensing bulb contains a fluid that increases in pressure when heated. This increased pressure causes the valve to partially close the hot water port as it opens the cold water port. A knob on the valve is used to set the desired mixed water temperature.

The preferred location of the temperature-sensing bulb is downstream of the distribution loop circulator. This ensures thorough mixing by the time the flow passes by the sensing bulb. Improper placement of the sensing bulb can cause erratic operation. The most accurate temperature sensing takes place with the sensing bulb immersed in the flowing water. If this is not possible the bulb should be tightly strapped to the pipe and covered with pipe insulation.

The piping schematics in figure 3-6 show one piping arrangement for a 3-way valve. This piping arrangement is appropriate if (and only if) low inlet water temperatures or reduced flow rates under low load conditions do not adversely effect the heat source.

Reduced boiler flow rate is seldom a problem for high mass boilers or storage tanks. However, low mass boilers, heat pumps or electric boilers may require a minimum flow rate whenever they operate. In such

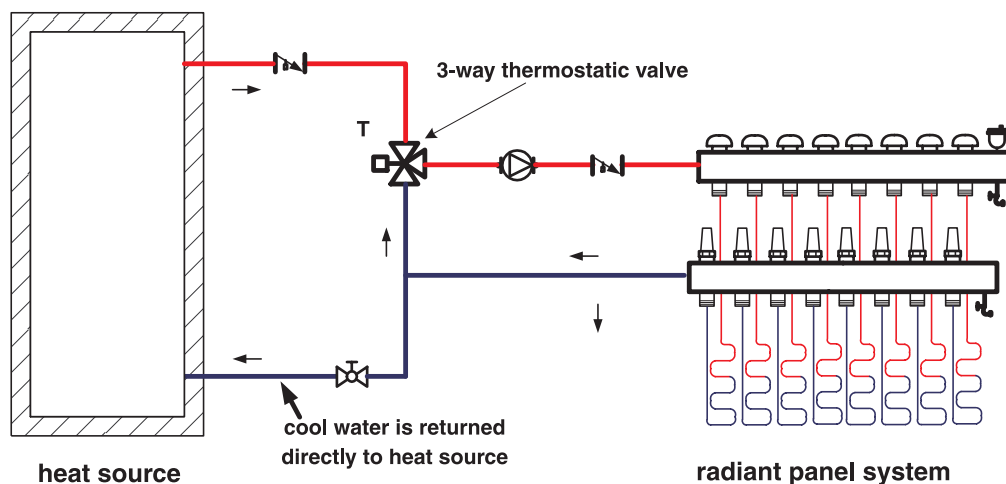


Figure 3-6

cases, the heat source should be equipped with its own pumped bypass circuit as shown in figure 3-7. With this arrangement, flow through the heat source does

will overheat the building unless flow through the heat emitters is interrupted when the desired room temperature is attained.

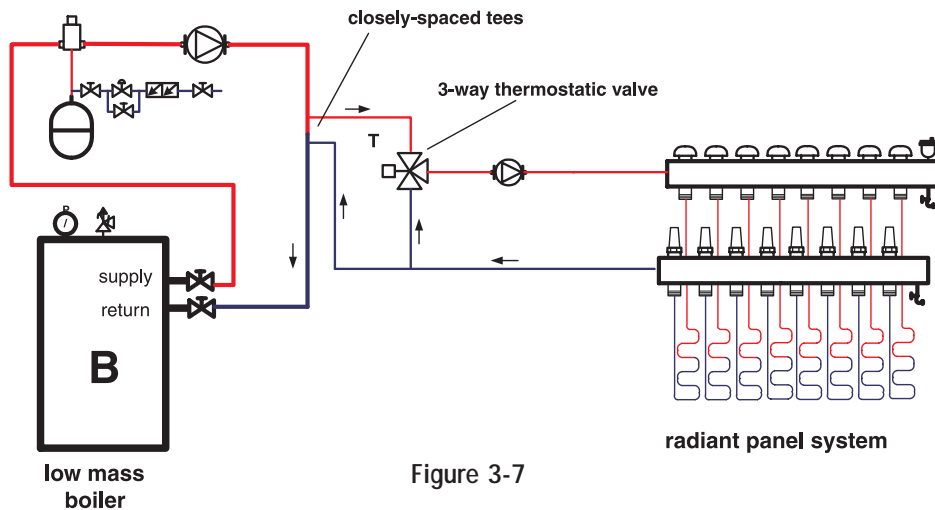


Figure 3-7

A single 3-way thermostatic mixing valve that controls water temperature to the distribution system does NOT protect a conventional boiler from flue gas condensation. Figure 3-7 shows that a portion of water returning from the distribution system goes directly back to the boiler. When the distribution system operates at low temperatures, this return water will cause sustained flue gas condensation in the boiler. This must be avoided.

not change regardless of the flow proportions through the 3-way valve. Connections from the bypass circuit to the remaining piping system are made using primary secondary tees to prevent interference between the two circulators.

One way to protect a conventional boiler from sustained flue gas condensation is to install a second 3-way thermostatic mixing valve as shown in figure 3-8. The additional valve monitors return temperature, and if necessary, mixes hot water from the boiler with cool return water from the return side of the primary loop to boost water temperature entering the boiler. Some manufacturers even build this thermostatic valve into their boilers.

3-way thermostatic valves supply the distribution system with a fixed water temperature regardless of the heating load. Under partial load conditions, the system

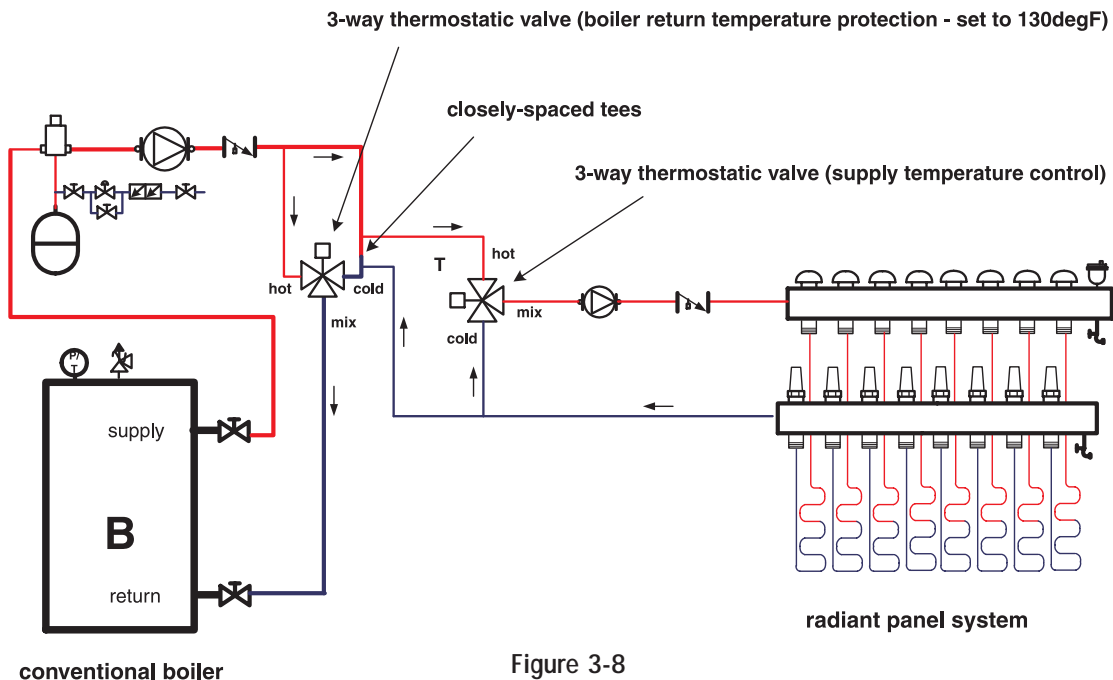


Figure 3-8

3-5 3-way motorized mixing valves

3-way valve bodies can also be paired with precision motorized actuators. An electronic controller regulates such actuators. The resulting motorized valve system can supply either fixed or variable water temperatures to a radiant panel.

The valve body used for this type of mixing system is often different from that used for a 3-way thermostatic valve. It has a rotating (as opposed to linear motion) shaft. As the shaft rotates through approximately 90 degrees of arc, the internal spool simultaneously opens one inlet port and closes the other. This regulates the proportions of hot and cold water entering the valve, and thus determines the mixed outlet temperature.

The actuating motor turns the valve shaft very slowly. Rotating the shaft through 90 degrees of arc may take 2 to 3 minutes. This slow rotation is not a problem given the slow response of many high mass distribution systems. It actually helps stabilize the system against overshooting or undershooting the target water temperature.

A temperature sensor attached to the piping leading to the distribution system measures the mixed water temperature leaving the valve. It provides feedback to an electronic controller that regulates the valve motor. If the temperature is exactly where it should be, the motor does not change the valve's stem position. If the supply temperature is slightly low, the motor very slowly rotates the valve stem to allow more hot water to

enter the mix and vice versa. Since the sensor is downstream of the valve's outlet port, it provides constant feedback to the controller allowing it to fine tune water temperature.

The piping for a 3-way motorized valve is shown in figure 3-9.

Note the use of a boiler loop with a pair of closely-spaced tees to interface to the distribution system. This accomplishes two important functions. First, it prevents the boiler loop circulator from interfering within the flow through the 3-way valve. Second, it provides another mixing point (shown as point B) allowing hot water in the boiler loop to mix with cool water returning from the distribution system before entering the boiler.

The controller operating the valve motor senses both system supply and boiler return temperature. When necessary, the controller can partially close the hot port of the 3-way valve to prevent the distribution system from extracting heat faster than the boiler can produce it. This allows a single 3-way motorized valve to control both the supply temperature, and protect the boiler from low inlet temperature.

Most controllers used for mixing valves are able to provide either setpoint or outdoor reset control. The latter cannot be accomplished (automatically) with 3-way thermostatic valves. A single 3-way motorized valve piped and controlled as described provides more versatility than does a pair of 3-way thermostatic valves.

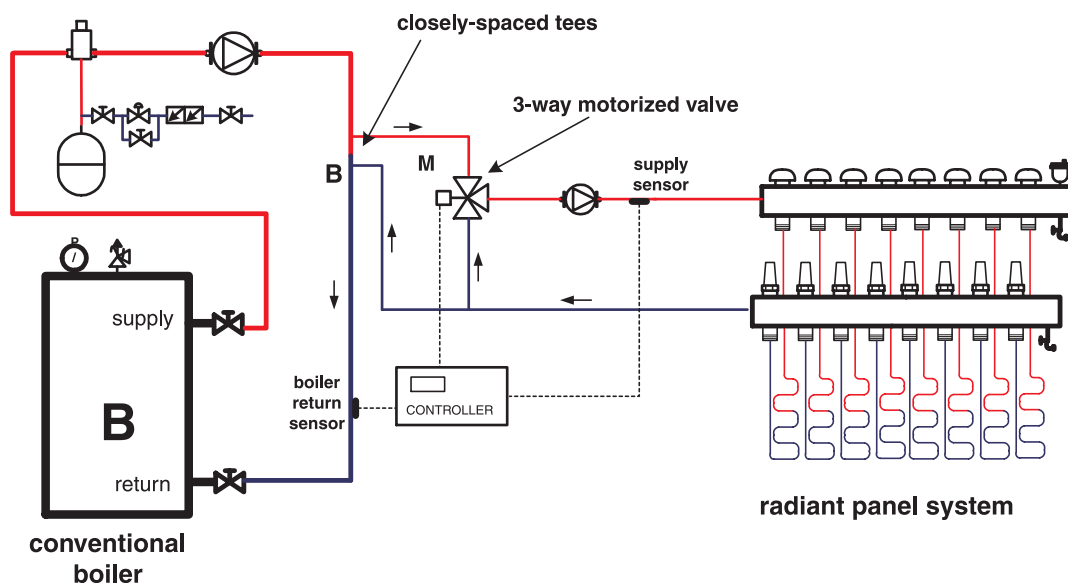


Figure 3-9

3-6 4-way motorized mixing valves

Another mixing device that has seen extensive usage in systems pairing a conventional boiler and low temperature distribution system is a 4-way motorized mixing valve. These valves were designed to provide both supply temperature control and boiler return temperature boosting. Figure 3-10 shows a cross section of a typical 4-way valve body.

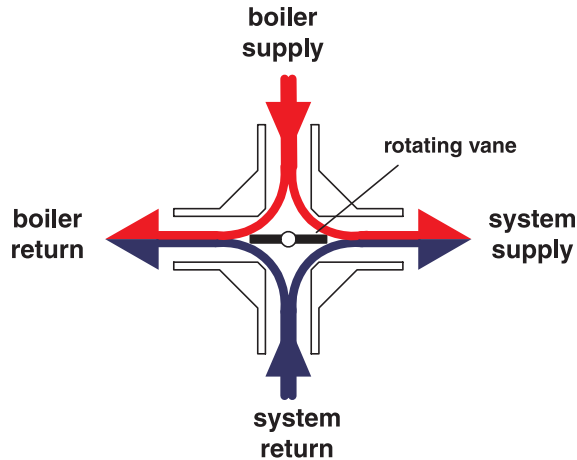


Figure 3-10

Hot water from the boiler is mixed with cool return water from the distribution system at two locations inside a 4-way valve. In the upper mixing chamber, the hot and cool water streams mix to form the stream supplied to the distribution system. At the same time, mixing also occurs in the lower valve chamber. Here the objective is to boost the temperature of the water returning to the boiler. As with motorized 3-way valve systems, a temperature sensor mounted on the supply pipe to the distribution system provides feedback to the valve controller. Another temperature sensor mounted near the boiler return allows the controller to monitor boiler inlet temperature. When necessary, the controller would partially close the hot inlet port to the valve to prevent the distribution system from extracting heat faster than the boiler can produce it.

The recommended piping for a 4-way mixing valve is shown in figure 3-11. Closely-spaced tees are used to connect the valve to the boiler loop. This prevents flow interference between the boiler circulator and distribution circulator. The valve draws hot water from the boiler loop using the momentum of the flow returning from the distribution system. The boiler loop also ensures adequate flow through the boiler under all conditions.

It's important to understand that merely using a 4-way mixing valve body in a system does NOT guarantee that the distribution system will receive the proper supply temperature. Neither does it guarantee the boiler is protected from low inlet water temperatures. For proper control, the valve must react to both the supply and boiler return temperatures. To do so, it must be

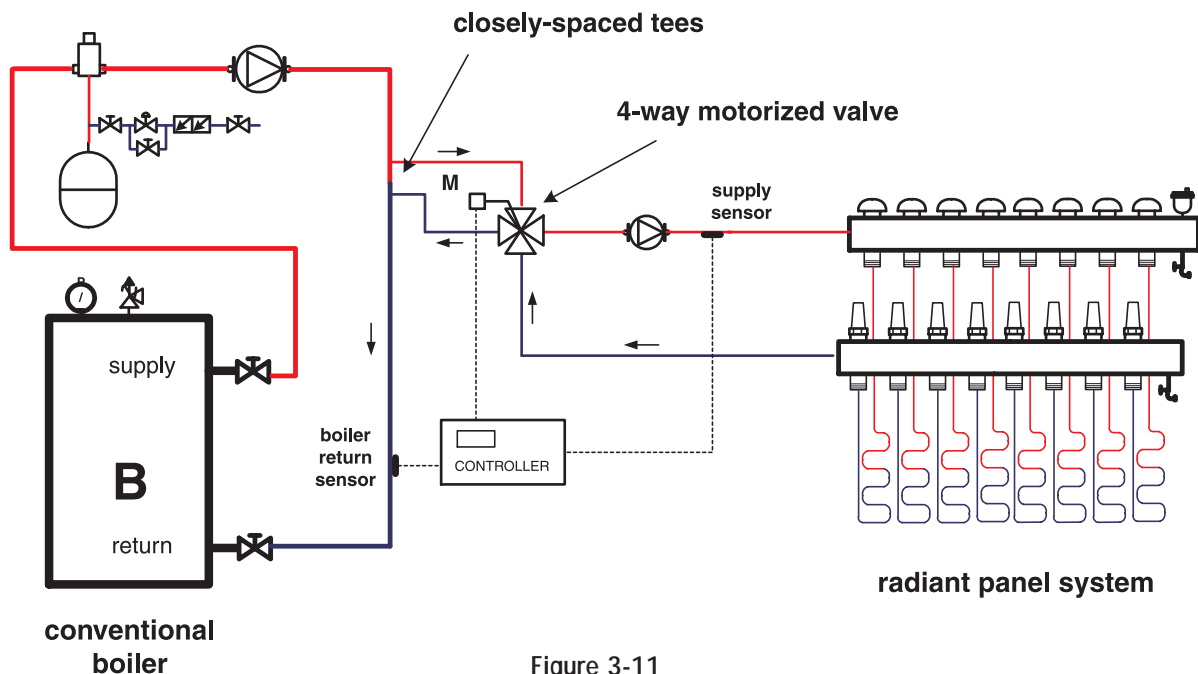


Figure 3-11

directed by a controller that senses both supply and return temperature. It's pointless to install a 4-way valve body while omitting the actuator / controller it needs for proper operation.

3-7 Injection Mixing (the concept)

Injection mixing is one of the simplest yet most versatile methods of controlling the water temperature in a hydronic distribution system. The concept is shown in figure 3-12.

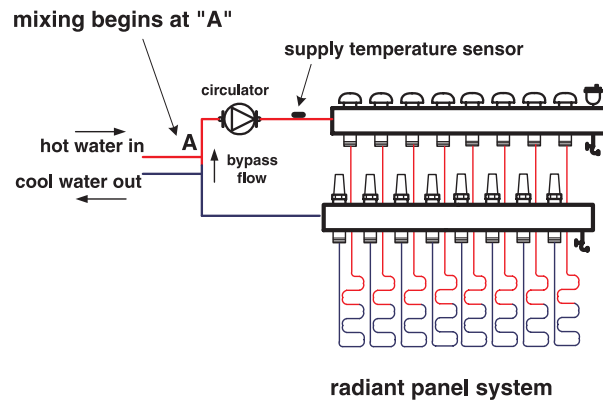


Figure 3-12

Hot water from the boiler loop is pushed through a pipe called an injection riser. It enters the side port of a tee at point (A) where it mixes with cool water returning from the distribution system. The blending of these two streams determines the supply temperature to the secondary circuit. The greater the flow rate of hot water entering the tee, the warmer the distribution system gets and the greater its heat output.

Injection mixing is ideal for systems pairing a conventional boiler to a low temperature distribution system. The large temperature difference (ΔT) between the incoming hot water and the outgoing return water allows a high rate of heat transfer using a minimal injection flow rate.

3-8 Injection mixing using a 2-way valve

One of the devices used for injection mixing control is a modulating 2-way valve. Either a non-electric thermostatic actuator or motorized actuator operates the valve. The piping concept is shown in figure 3-13.

Hot water from the boiler loop is drawn into the supply injection riser at point B. It passes through the injection control valve and enters the side port of a tee at point C where it mixes with cool return water from the distribution system. The flow rate through the injection risers depends on the stem position of the injection control valve, as well as the flow restrictor valve's setting. The greater the injection flow rate, the

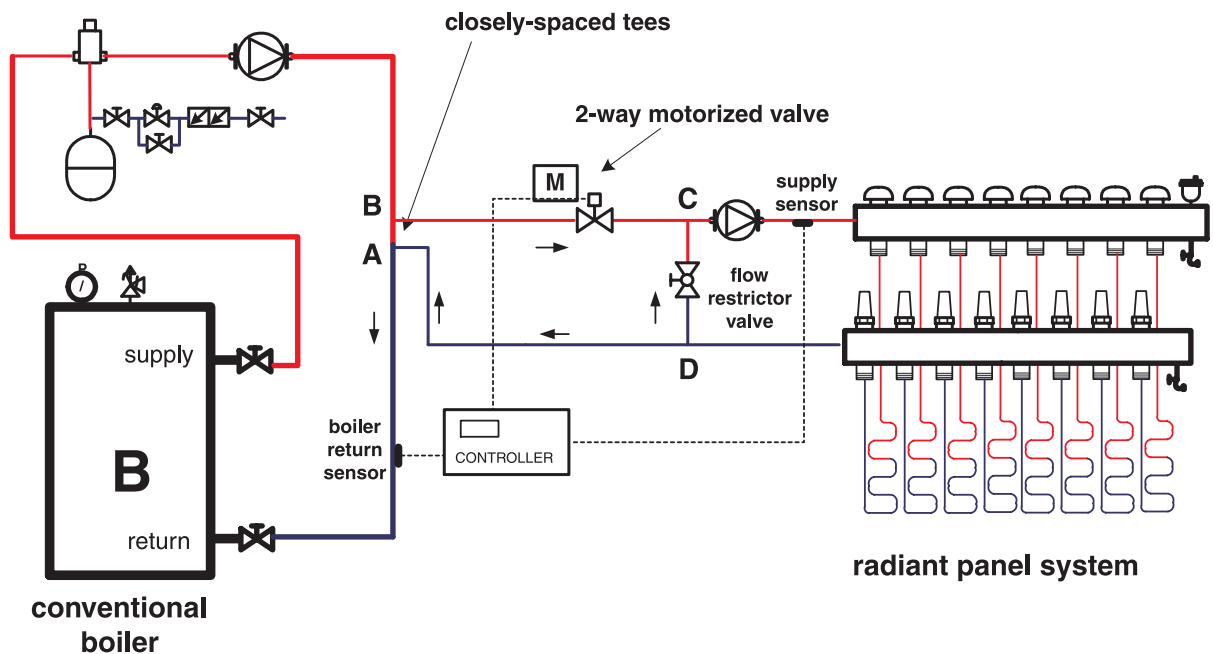


Figure 3-13

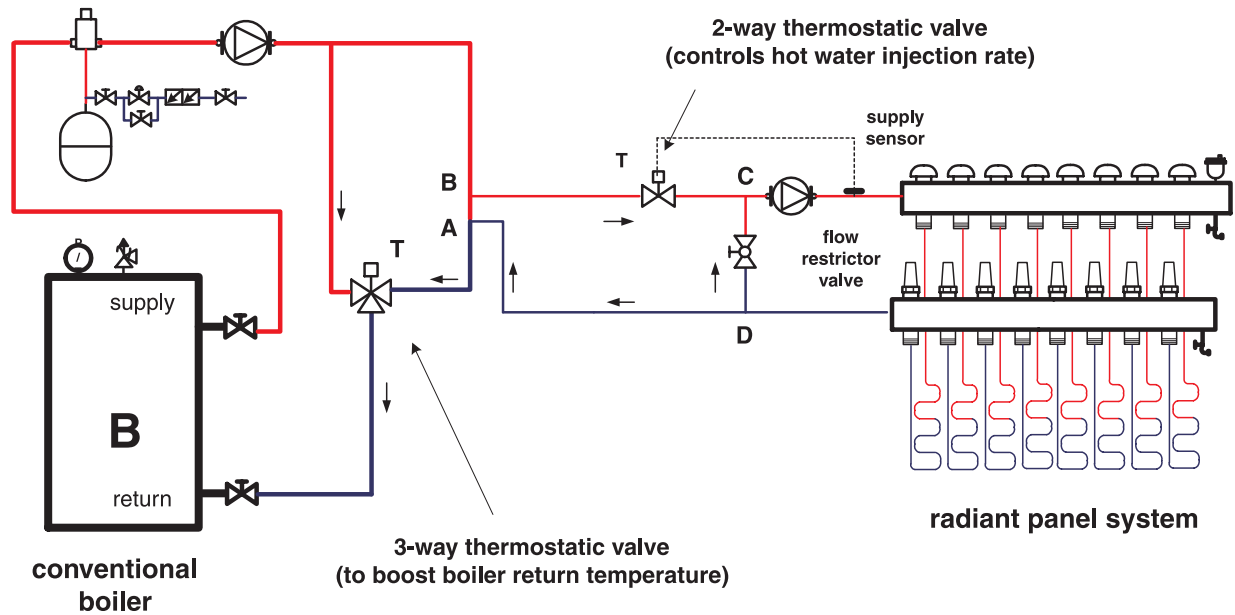


Figure 3-14

higher the water temperature supplied to the distribution system and the greater its heat output. In a typical low temperature floor heating system supplied by a conventional boiler, the flow rate through the injection control valve is about 15 to 20% of the flow rate in the distribution system. This allows a relatively small modulating injection valve to regulate a large rate of heat transfer.

When a motorized valve operated by an electronic controller is used, boiler protection is accomplished by monitoring the boiler inlet temperature and partially closing the injection valve when necessary to prevent the distribution system from absorbing heat faster than the boiler can produce it.

Unlike a motorized valve with a “smart” controller, a single thermostatic 2-way modulating valve cannot control both the supply temperature to the distribution system and the inlet temperature to the boiler. To protect the boiler, it is necessary to use another mixing device that can monitor and adjust the boiler inlet temperature when necessary. Figure 3-14 shows the use of a 3 way thermostatic valve for this purpose.

When using a 2-way valve for injection mixing, be sure the tees at points A and B in figure 3-13 are as close as possible. Also be sure there’s a vertical drop of at least 18 inches between where the return injection riser connects to the boiler loop and where it connects to the distribution system. This drop forms a thermal trap to reduce heat migration into the distribution system when no heat input is needed.

It is important to select the injection control valve based on its Cv rating, NOT the size of the injection riser piping. Oversized injection valves will not produce smooth heat input control under low load conditions. Undersized injection valves will cause excessive head loss and may not be able to deliver design load heat transfer rates.

Before selecting the injection control valve, calculate the necessary injection flow rate under design load conditions using the following formula:

Formula 3-1

$$f_i = \frac{Q}{500 \times (T_1 - T_2)}$$

Where:

- f_i = required design injection flow rate at design load (in gpm)
- Q = Heat input to distribution at design load conditions (in Btu/hr)
- T_1 = water temperature being injected (in deg. F.)
- T_2 = water temperature returning from distribution system (in deg. F.)
- 500 = a constant for water (use 479 for 30% glycol, 450 for 50% glycol)

Select an injection control valve with a Cv factor approximately equal to the injection flow rate just calculated.

Once the system is operational, set the flow restrictor valve so the injection control valve remains fully open at design load conditions. This allows the valve to operate over its full range of stem travel as heat input to the distribution system varies from zero to full design load.

3-9 Injection mixing using a variable speed pump

Another method of injection mixing uses a small wet rotor circulator operated at variable speeds as the injection device. The piping concept is shown in figure 3-15.

Hot water from the boiler loop is drawn into the supply injection riser at point B. It enters the side port of a tee at point C, where it mixes with cool water returning from the distribution system. An equal flow rate of cool return water flows back from the distribution system to the primary circuit through the other riser. The flow rate of hot water passing through the supply riser is controlled by the speed of the injection pump. The faster the pump runs, the faster hot water flows into the distribution system and the greater its heat output. In a typical low temperature floor heating system supplied by a conventional boiler, the flow rate through the injection pump is about 15 to 20% of the flow rate in the secondary circuit. This allows a relatively small injection pump to control a large rate of heat transfer.

The injection mixing control also protects the boiler by monitoring the inlet temperature and reducing the speed of the injection pump when necessary to prevent the distribution system from absorbing heat faster than the boiler can produce it.

When using variable speed injection mixing, be sure the tees at points A and B in figure 3-15 are as close together as possible. Also be sure there is a vertical drop of at least 18 inches between the (return) injection riser connection to the primary circuit and its connection to the secondary circuit. This drop forms a thermal trap to reduce heat migration into the distribution system when no heat input is needed.

In a properly balanced system, the injection pump should run at full speed when the system is operating at design load conditions. Achieving this balance requires adjustment of the balancing valve located in the return injection riser. There are several ways to set this valve. One of the easier ways is to use a valve that has built-in measuring capability. Many "circuit-setter" type valves are available for this purpose.

To properly set the circuit setter valve, it's necessary to calculate the required injection flow rate under design load conditions using formula 3-1. With the injection pump running at full speed, partially close the circuit setter valve until it indicates a flow equal to the value calculated.

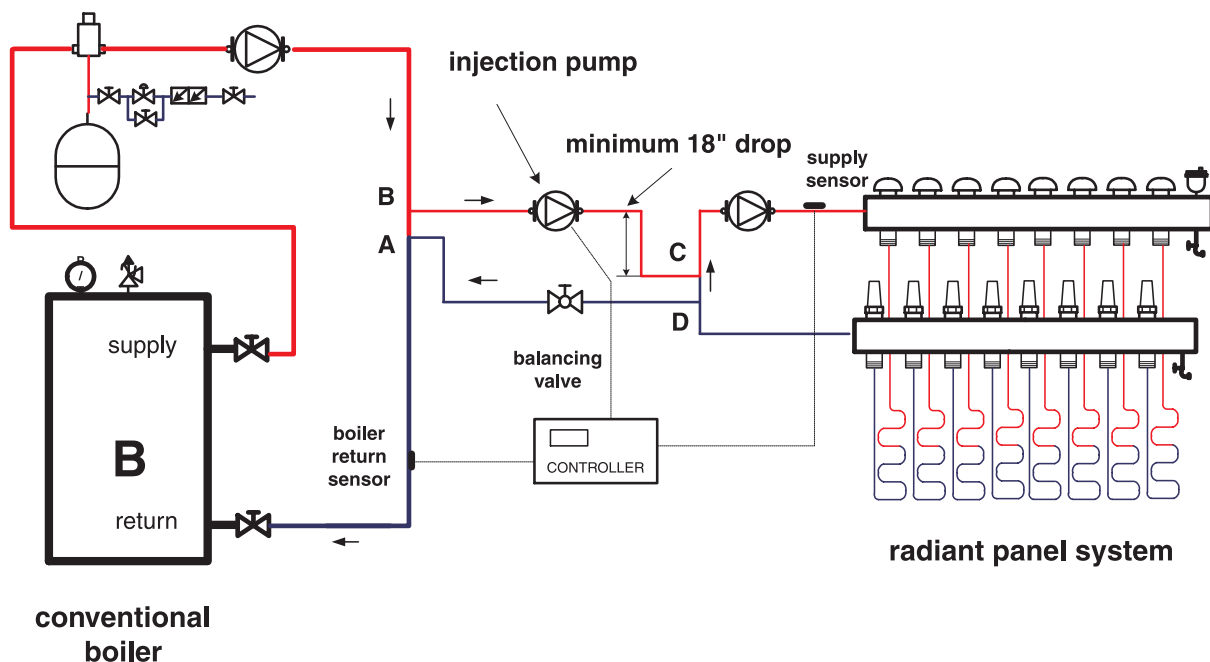


Figure 3-15

A diagram consisting of a horizontal black line that extends across the width of the page. From the left side of this line, a vertical black line descends, then a horizontal black line extends to the right, ending in an arrowhead pointing towards a vertical grey rectangle. The rectangle is labeled 'SECTION 4' in large, bold, black capital letters. The word 'SECTION' is positioned at the top of the rectangle, and the number '4' is centered below it.

RADIANT FLOOR HEATING METHODS

The availability of modern materials such as Kitec pipe has allowed the market for hydronic radiant floor heating to increase approximately ten fold over the last decade. Installation methods have been developed for many types of floor constructions in residential, commercial and industrial buildings. Each year these installation techniques allow thousands of buildings to be equipped with what many consider to be the ultimate comfort heating system.

4-1 What is radiant heating?

Before discussing the installation details of radiant floor heating, it's important to have a clear understanding of how radiant heating works as well as how it differs from other forms of heating.

Nature has three means of transferring heat from objects at a given temperature to objects at lower temperatures.

Conduction is how heat moves through solid materials, or from one solid material to another when the two are in contact. If you stand barefooted on a cool basement floor slab, heat transfers from your feet to the floor by conduction.

Convection is how heat moves between a solid surface and a fluid. The fluid may be either a liquid or a gas. Hot water flowing through a pipe transfers heat to the inside wall of the pipe by convection. Likewise, air flowing across the heat exchanger inside a furnace absorbs heat from the hot metal surfaces.

Radiant heat transfer occurs when infrared light leaves the surface of an object and travels to the surface(s) of other cooler objects. Unlike conduction and convection, radiant heat transfer does not require a fluid or solid material between the two objects transferring heating. It only requires a space between the two objects. Solar energy travels approximately 93 million miles from the sun to the earth, through the emptiness of space, solely as radiant energy. The radiant energy only becomes sensible heat when absorbed by a surface.

The radiant energy emitted by the relatively low temperature heat emitters used in hydronic heating is technically described as infrared electromagnetic radiation. It's simply light that the human eye can't see. However, other than the fact that it's invisible, infrared light behaves just like visible light. It travels in straight lines at the speed of light (186,000 miles per second), and can be partially reflected by polished metallic surfaces. Unlike warm air, radiant energy travels equally well in any direction. Up, down or sideways, direction simply doesn't matter. This characteristic allows a heated ceiling to deliver radiant heat to the room below.

The radiant energy emitted by a warm floor, wall or ceiling is a completely natural phenomenon that's literally as old as the universe itself. A surface warmed by sunlight gives off infrared radiation just like one warmed by embedded tubing. The latter simply uses a different heat source and transport system to deliver heat to the surface. Most low temperature radiant panels emit less than 1/10 the radiant flux of bright sunlight, and all of it is infrared as opposed to ultraviolet light. Even the human body gives off infrared radiation to cooler surrounding surfaces.

4-2 The Benefits of Hydronic Radiant Floor Heating

Radiant floor heating is considered by many as the ultimate form of comfort heating. In addition to the advantages of hydronic heating in general, warm floors provide benefits that virtually no other system can match. Any one of these benefits can become the "hot button" that convinces a discriminating customer to install a hydronic radiant floor heating system. Here's a summary of these key benefits.

Unsurpassed thermal comfort:

Buildings equipped with radiant flooring have interior environments that are highly favorable to human thermal comfort. Unlike many systems that directly heat the air, radiant floor heating gently warms the surfaces of objects in the room as well as the air itself. The warm surfaces significantly reduce the rate of heat loss from the occupants, allowing most to feel comfortable at room temperatures 3 to 5 deg. F. lower than with other methods of heating.

The air temperature at floor level is slightly higher than the average room temperature. This significantly reduces the rate of heat loss from the feet and legs. Several feet above the floor, the air temperature begins to decrease. Most people tend to feel more alert with slightly lower air temperatures at head level. The lowest air temperatures in the room typically occur just below the ceiling. The result is reduced heat loss through the

ceiling insulation and hence lower heating costs.

A system that's out of sight:

Most people realize that just about every occupied building in North America needs a heating system. However, few enjoy looking at the heat emitters that are a necessary part of that system. The fact that such heat emitters often restrict furniture placement further adds to their invasiveness.

With hydronic radiant floor heating, the floor surface is the heat emitter. There's no need to compromise the aesthetics of the space or restrict furniture placement. It's a system that gives your clients a building interior that's as thermally luxurious as it is aesthetically elegant.

A quiet system:

One of the strengths of hydronic heating is its ability to deliver heat without delivering noise. A properly designed radiant floor heating system is the epitome of silence. The gas or oil burner on the boiler is often the only component that makes any detectable noise, and it's usually located in the mechanical room away from the occupied spaces.

A clean system:

One of the biggest complaints associated with forced air heating is its tendency to distribute dust, odors and germs throughout a house. In contrast to whole house air movement, hydronic flooring heating creates very gentle (imperceptible) room air circulation. Many people who suffer from allergies have found that radiant floor heating doesn't aggravate the symptoms the way a forced air system often does.

A durable system:

A slab type floor heating system is nearly as indestructible as the slab itself. It's the ideal way to heat garage facilities, industrial buildings, recreation rooms or other buildings with high interior traffic.

A system that reduces fuel usage:

Hydronic floor heating systems have a proven record of reduced energy usage relative to other forms of heating, both in residential and commercial / industrial buildings. The savings result from several factors such as the ability to sustain comfort at lower indoor air temperatures, reduced air temperature stratification, non-pressurization of rooms (which leads to higher rates of air leakage), and the ability to operate with lower water temperatures.

Savings vary from one building to the next. Although some projects have shown savings in excess of 50%, a more conservative estimate is 10 to 20% in savings.

As energy costs continue to escalate, the ability to

reduce fuel consumption will play an increasingly important role in how heating systems are selected. Hydronic radiant floor heating can keep energy costs to a minimum while also delivering exceptional comfort. It's truly the benchmark system against which all other methods of heating will be compared.

4-3 The History of Hydronic Radiant Floor Heating

The origins of hydronic radiant floor heating date back to the early 1900s when systems were installed using wrought iron and steel piping. During the 1940s and 50's, many radiant floor heating systems were installed by embedding copper tubing in concrete slabs. Although the installations were somewhat crude in comparison to today, these early systems quickly proved they could deliver unsurpassed comfort.

Some of these early systems are still in operation. However, others have long since been abandoned due to fatigue or corrosion of the embedded metal tubing. Although the comfort they delivered was exceptional, too many of the early systems using embedded copper, steel or iron pipe eventually developed leaks. Consumer confidence in the thought that a hydronic floor heating system could provide both comfort as well as a long, trouble-free service life steadily declined. The debut of central air conditioning in the late 50's, along with strong promotion of forced air (ducted) systems as a "preferred" means of delivering both heating and cooling all but eliminated the use of hydronic floor heating. Or so it seemed.

Ironically, as the hydronic floor heating market was nearing extinction in North America, a new tubing material was being developed in Western Europe. That

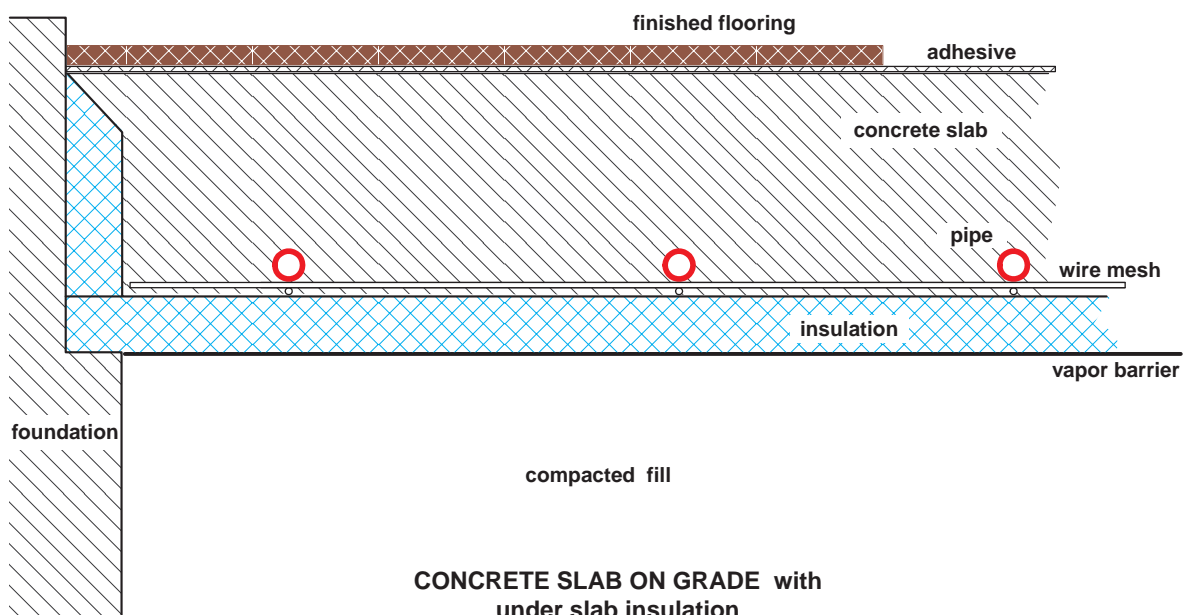
material was cross-linked polyethylene (or PEX). It would soon prove to be the single biggest factor underlying the reemergence of hydronic floor heating in North America.

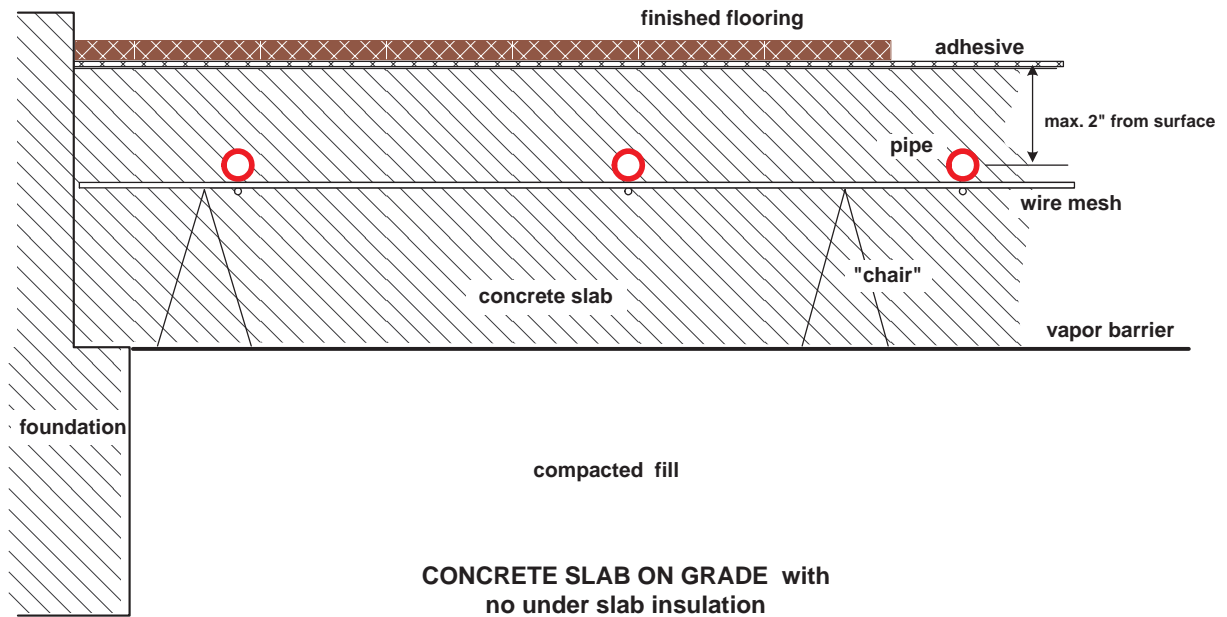
Europeans had amassed considerable experience with PEX and PEX-AL-PEX tubing in floor heating applications by the time these products made their first appearances on the North American market in the early 1980's. Slowly but surely these modern piping materials demonstrated they could deliver comfort, easy installation and long life. The rest—as they say—is history.

Today consumers are learning about new methods for installation of hydronic floor heating as never before. They are seeking qualified professional installers and quality products. Kitec pipe and WarmRite accessories let you give these discriminating consumers exactly what they're looking for. Read on to see all the different ways these systems can be installed.

4-4 Slab on Grade Systems

As the past has demonstrated, concrete slab-on-grade floors are ideal for hydronic floor heating. The number of buildings with this type of floor construction is huge. It includes a significant percentage of single family houses as well as a large percentage of commercial buildings. Some of the best floor heating opportunities are in "garage facilities" such as automotive service centers, town highway garages, fire stations and aircraft hangers. These buildings almost always have uncovered concrete floors, and benefit tremendously from the warm, dry floors that hydronic floor heating can provide.





Installation Procedure:

Figure 4-1 shows a cut-away view of a modern heated slab-on-grade floor.

The installation of a heated floor slab begins by verifying the subgrade has been properly leveled and compacted. Although the heating system installer is probably not responsible for this aspect of

CONCRETE SLAB ON GRADE

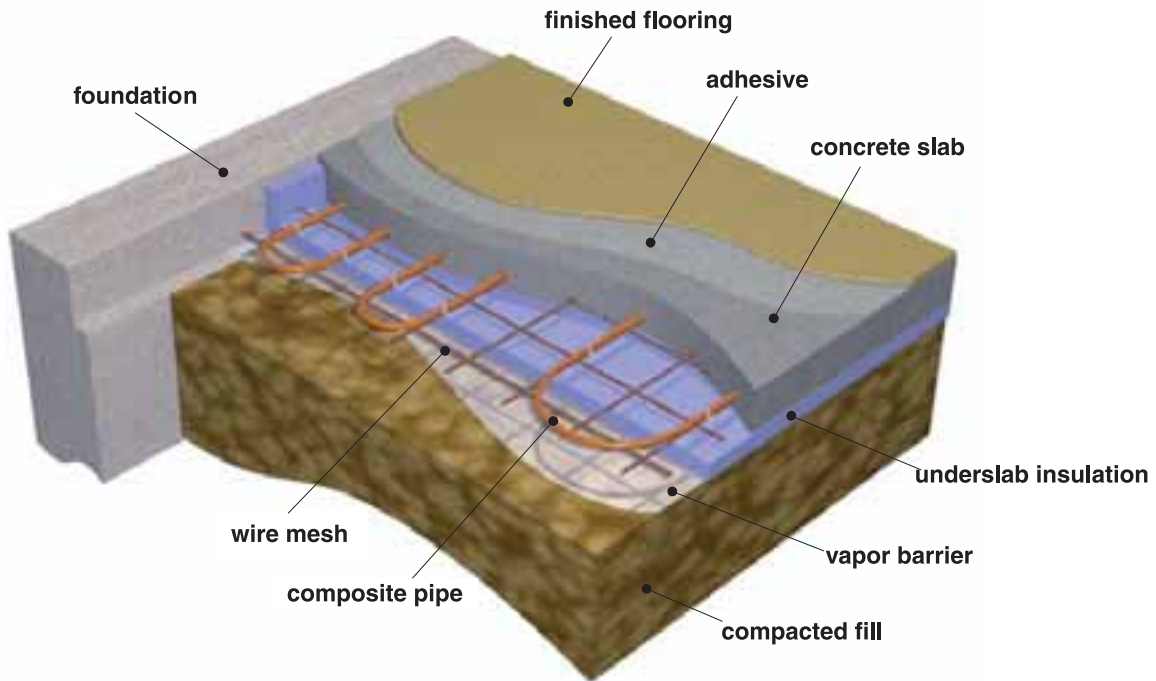


Figure 4-1

construction, failing to check for proper subgrade preparation could eventually compromise the embedded tubing circuits. It could also leave the installer having to defend why the floor heating system isn't at least partly responsible for cracks in the slab or other defects.

After the subgrade has been prepared, the soil vapor barrier and underslab insulation should be installed. Some building specifications may not call for an underslab vapor barrier. However, its ability to resist moisture migration from the underlying soils can be indispensable, especially when wood products are used as the finish flooring.

Heat loss from the edge and underside of a heated slab on grade can be substantial, especially in areas with high water tables or where the slab rests on bedrock. Edge and underslab insulation are essential in reducing these losses. They are a necessary part of any quality floor heating system. Not taking steps to mitigate such heat loss is like leaving the windows open throughout the winter.

Realistically there's only one opportunity to install underslab insulation—before the slab is poured. Discovering high downward heat loss after the system is in operation is a situation that's virtually impossible to correct. It makes little sense to attempt the installation of a high quality heating system while omitting crucial and relatively low cost details. Do it right the first time.

The most commonly used material for slab edge and underside insulation is extruded polystyrene. It's sold in 2 by 8 foot and 4 by 8 foot sheets in several thicknesses. It's also available in several densities to handle different floor loading. Extruded polystyrene panels are highly resistant to moisture absorption, and have a well-established record in ground contact insulation applications.

New insulating materials are developed to promote the use of under slab insulation. One of them is called radiant barrier foil. It is a composite of plastic and aluminum layers. The concrete Barrier Foils consists of an aluminum layer sandwiched between two layers of "bubble" insulation. The "insulating" effect of this new product is comparable with the rigid foam products, but its handling and resistance to mechanical damage is far superior.

The amount of underside insulation depends on several factors. Among them are:

- The severity of the climate: colder climates justify edge- and underside insulation of greater R-value.
- The cost of energy: higher energy costs justify

edge- and underside insulation of greater R-value.

- The thermal resistance (R-value) of the floor covering(s): high thermal resistance coverings justify edge- and underside insulation of greater R-value.
- The shape of the slab: slabs with high ratios of edge length to floor area justify edge- and underside insulation of greater R-value.

In most buildings the underslab insulation should have a minimum R-value of 5. In colder climates, it is often recommended that the outer 4 feet of the slab (referred to as the "outer band") have R-10 underside insulation. The insulation is generally omitted under structural bearing points such as beneath interior columns or bearing walls.

The edge of the slab is especially vulnerable to heat loss. It should be insulated to a minimum of R-5 in mild climates and R-10 in colder climates.

The next step on most installations is to locate and temporarily mount the manifold station(s). If one or more of the manifold stations will be located within a stud cavity, it's imperative to make accurate measurements when fixing the manifold's location.

The manifolds can be temporarily bracketed to a plywood panel supported on wooden or steel stakes driven into the subgrade (as shown in figure 4-2)

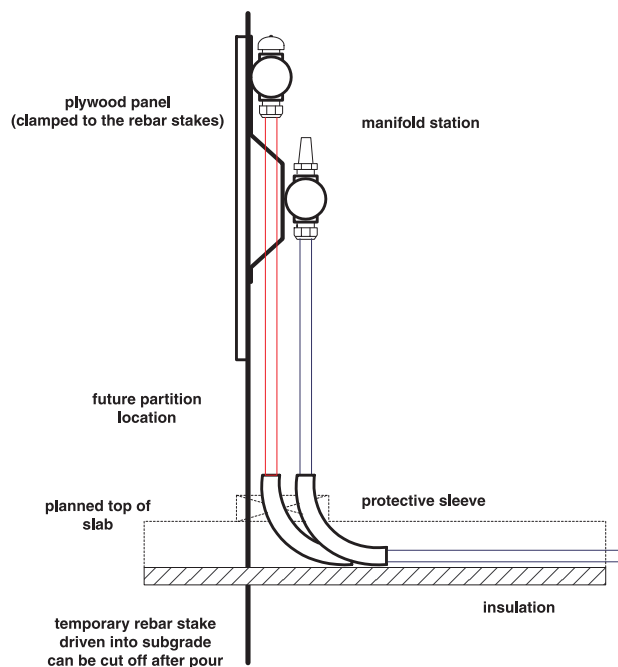


Figure 4-2

Once the insulation is in place, the steel reinforcement for the slab is installed. Most concrete slab on grade floors use welded wire fabric (WWF) for reinforcement and crack control. WWF comes in sheets or rolls. It should be placed directly on top of the underslab insulation. Edges should be overlapped approximately 6" and tied together.

Tubing installation takes place one circuit at a time. Begin by securing one end of the circuit to the supply manifold. Roll out the coil like rolling a "tire" following the layout pattern. The composite pipe, because of the metal content, allows laying the pipe roughly without tying down immediately. This allows it to run the full loop and get the end out to the manifold. Make sure the end reaches the manifold and then tie the piping to the wire mesh. The main difference to laying PEX tubing is that the pipe stays in place and does not want to go back to the coil shape.

This is why there is no need to use an uncoiler. If the uncoiler is available, it is also possible to lay the pipe using it. In this case place the tubing coil on an uncoiler and pull the tubing from the coil as needed. Keep plenty of slack ahead of you as the tubing is fastened in place.

Kitec tubing should be secured to the WWF using either twisted wire ties or nylon pull ties. The tubing should be tied to the WWF reinforcing every 60 to 72" on straight runs, and two ties at the bend on each side.

When all circuits have been installed, prepare the manifold(s) for pressure testing. Install a pressure gauge in one end of either the supply or return manifold and a schrader air valve in the other end. Plug the unused manifold ends.

Use an air compressor to increase the pressure in the circuits to about 100 psi. Use a soap bubble solution to check for leaks at the manifold connections. Leave the circuits pressurized for at least 24 hours. If the air pressure drops double check all manifold connections for possible leaks before inspecting the tubing. Aside from the possibility of extreme damage from other construction activity, it's very unlikely that the tubing is the source of the air leak. Still, a pressure test is mandatory on any radiant tubing installation.

If the WWF has to be positioned in the slab, be sure the concrete placement crew knows to lift the tubing and WWF prior to starting the pour. If the WWF has to be positioned within the slab, it has to be lifted or "chaired" up to the final position before the concrete is poured. The WWF and attached tubing should be lifted up so the pipe center is 2" below the slab surface. This allows the slab to respond faster when warm water circulates through the tubing.

From the heat output point of view, the position of the

piping in the slab is not so critical if full slab insulation is used. Appropriate thermal break will direct the heat flow towards the surface. If insulation is not used the pipe position is critical and in this case the piping has to be lifted to 2" below the surface.

As long as the pipe is kept 2" below the surface saw cut control joints will not affect the pipe. If deeper than 3/4" saw cuts are planned the pipe position has to be adjusted accordingly. Anywhere where full cut control joints are used (slabs are separated) a protective sleeve has to be used on the pipe passing through. The sleeve has to be 12" long centered on the joint and approximately 1" diameter. The sleeve reduces stress on the tubing should the slab move slightly at the control joint.

4-5 Thin Slab Systems

There are several methods of installing hydronic radiant heating over a conventional wood-framed floor. One of the most common is called a thin slab system. The concept is shown in figure 4-3.

Thin slabs consist of either a specially formulated concrete or poured gypsum underlayment. Both types of slabs have installation requirements that must be carefully coordinated with the building design process.

One requirement that must be accommodated is that thin-slabs typically add 1.25 to 1.5 inches to the floor height. This requires adjustments in the rough opening heights of windows and doors as well as the height of door thresholds. It will also affect the riser heights on stairs.

Another issue that must be addressed is the added weight of the thin-slab. Poured gypsum thin-slabs typically add 13 to 15 pounds per square foot to the "dead loading" of a floor structure. Standard weight concrete thin slabs add about 18 pounds per square foot (at 1.5" thickness). Never assume the proposed floor structure can simply support the added weight of either type of thin-slab. Have a competent designer or structural engineer verify what, if any, changes are necessary to support the added load.

The additional floor thickness and weight are easily managed if planned into the building as it is designed. However they can present obstacles in retrofit situations.

Poured Gypsum Thin-slab systems

Poured gypsum underlayments have been used for many years for floor leveling as well as to enhance the acoustic and fire resistance properties of wood-framed floors. They also function well as the slab material for thin-slab floor heating systems. In most cases, the slab is installed by a subcontractor trained and equipped to

THIN SLAB (GYPSUM SLAB)

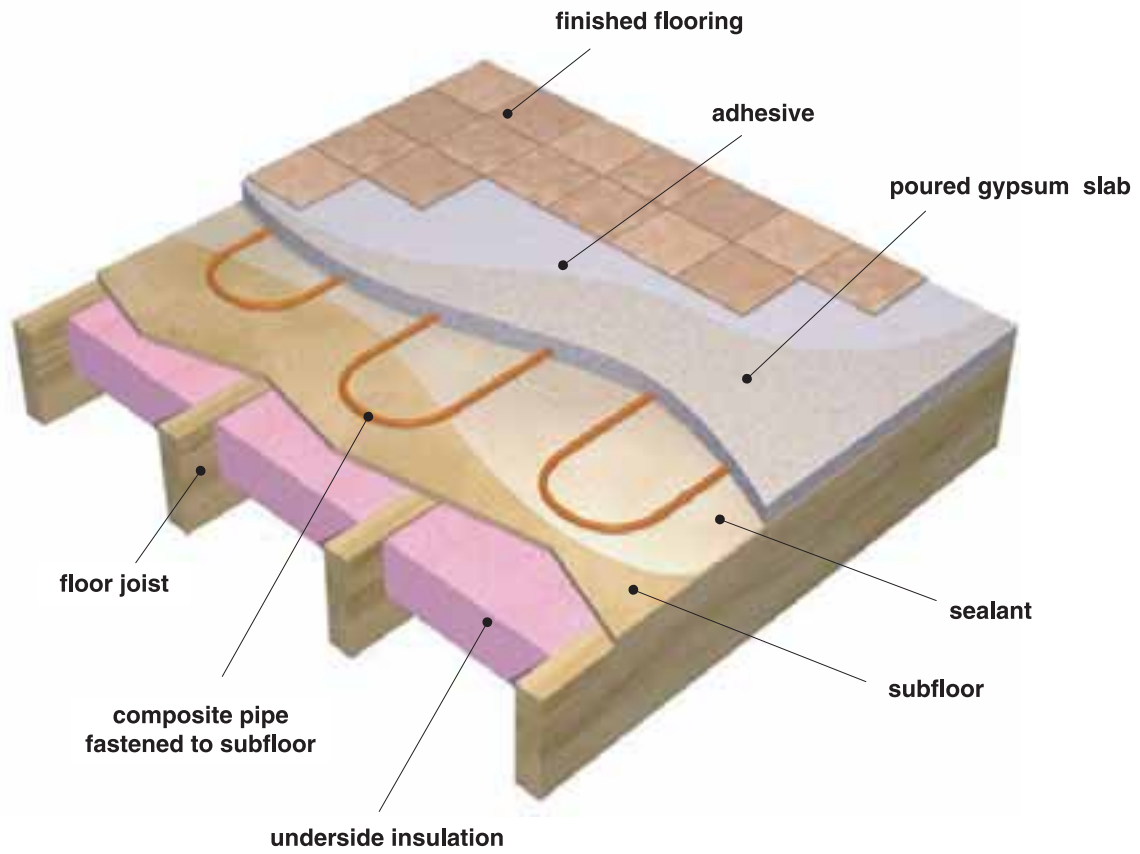
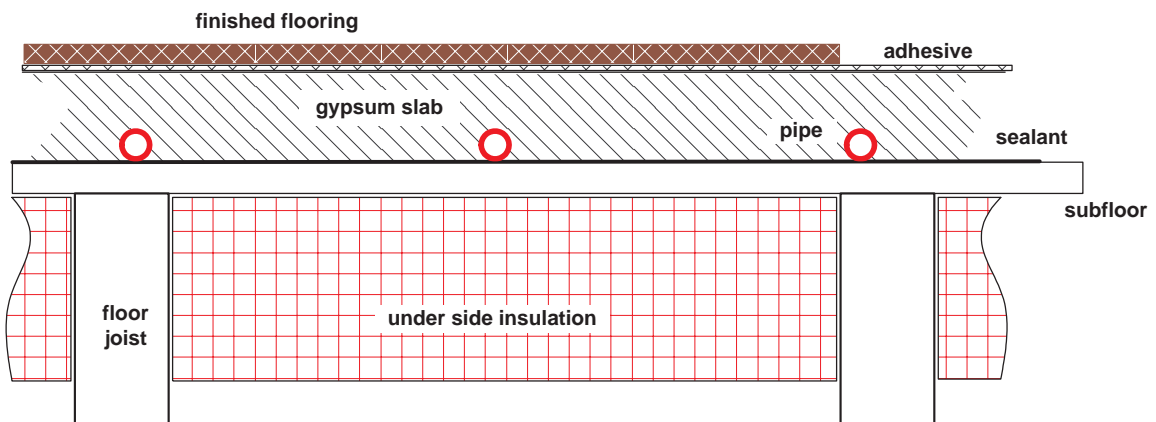


Figure 4-3



THIN SLAB (CONCRETE SLAB)

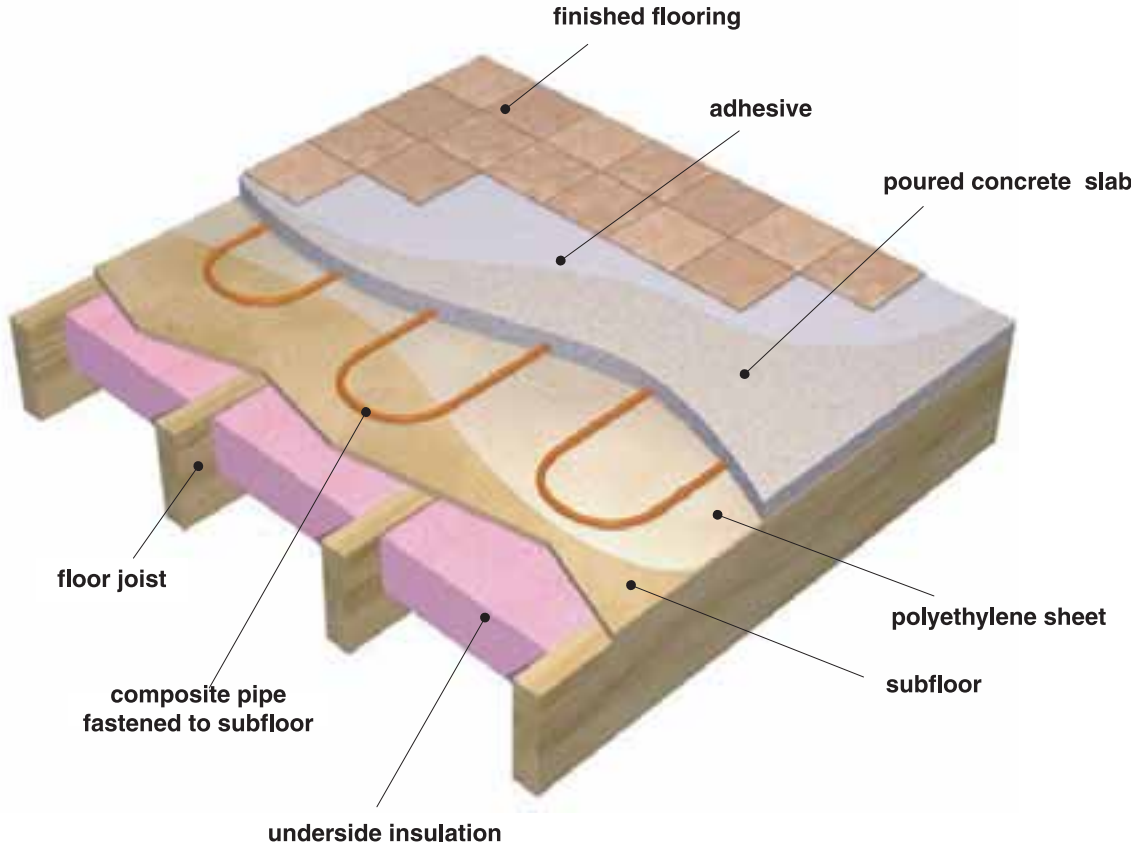
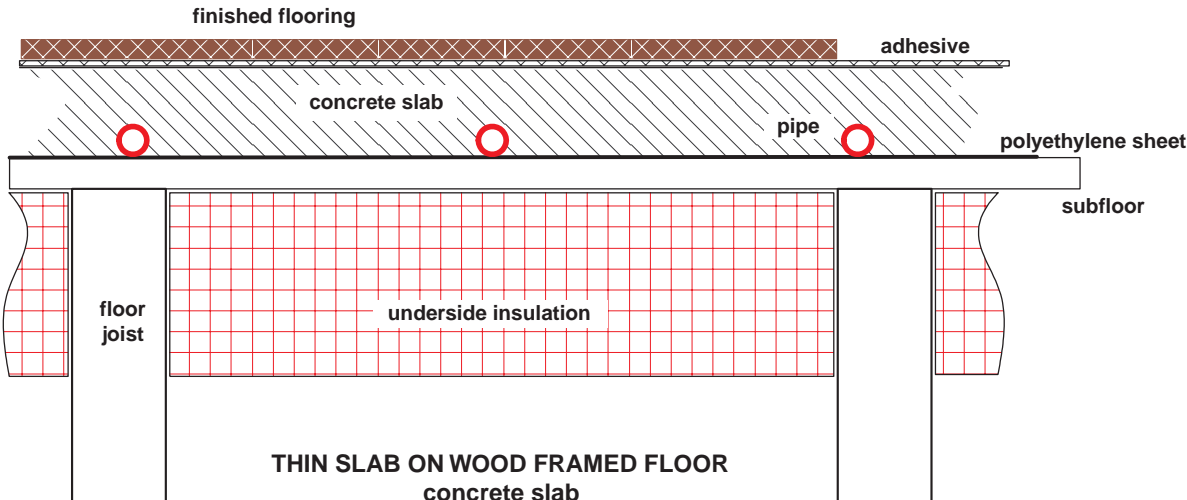


Figure 4-3A



mix and place the materials.

Installation Procedure

Installation begins by stapling the tubing to the subfloor. A pneumatic stapler with a special attachment allows the staples to be quickly placed without damage to the tubing. It's the preferred attachment method for all but very small thin-slab areas.

Once all tubing circuits have been installed they should be pressure tested as described earlier.

Next the floor is sprayed with a combination sealant/bond enhancement coating. This minimizes water absorption into the subfloor as well as strengthening the bond between the slab and subfloor.

The poured gypsum underlayment consists of gypsum cement, masonry sand, admixtures and water. The product is prepared in a special mixer usually placed outside the building, and is then pumped in through a hose. As the product is poured, it self-levels with minimum floating.

Some installers prefer to install the gypsum slab in two layers (or "lifts"). This minimizes any differential shrinkage in the slab, resulting in a very flat finish surface.

When poured gypsum underlayment cures, it resembles plaster and is almost as hard as standard concrete. However, unlike concrete it is NOT intended to serve as a permanent "wearing surface."

With the proper preparation, a poured gypsum slab can be covered with almost any finish flooring including carpet, sheet vinyl, ceramic tile and glue-down wood flooring. Always follow the gypsum underlayment manufacturer's procedures to verify that the slab is adequately cured and the surface is properly prepared before installing finish flooring.

Poured gypsum slabs are water-resistant not waterproof. The slab will eventually soften if exposed to water for prolonged periods. They should not be installed under conditions where rain or other sources of moisture can accumulate. They should also not be installed in areas that are likely to experience flooding.

Concrete Thin-Slab Systems

A specially formulated concrete mix can also be used to create a heated thin-slab floor. The mix proportions are given in figure 4-4

The installation of a concrete thin-slab differs considerably from that of a poured gypsum slab. Concrete is not self-leveling. It must be screeded flat when placed. To simplify screeding, the concrete thin-slab is best poured before walls are constructed.

MIX DESIGN for 1 cubic yard of 3000 psi @28 day concrete topping

Type 1 portland cement	517 lbs.
Concrete sand	1639 lbs.
#1A (1/4" maximum) peastone	1485 lbs.
Air entrainment agent	4.14 oz.
Hycol (water reducing agent)	15.5 oz.
Fibermesh	1.5 lbs.
Superplasticizer (WRDA-19)	51.7 oz.
Water	about 20 gal.

Figure 4-4

Unlike with gypsum underlayments, it's crucial to prevent the bottom of the slab from bonding to either the subfloor or any wall framing it may contact. The goal is to allow the wood floor deck and concrete thin-slab to move independently of each other during curing or seasonal moisture changes. This reduces tensile stresses that can crack the slab.

It's also important to divide large floor areas into a grid of smaller areas using plastic control joint strips. As the concrete cures, cracks will develop directly above these strips. These "controlled" cracks preempt random cracking of the slab.

The slab should be cured for a minimum of 3 weeks prior to being heated. This allows time for the concrete to develop strength before being exposed to thermal stresses. To drive off any residual moisture, the slab should also be operated (heated) for several days prior to installation of the finish floor.

With either type of thin-slab it's imperative to install underside insulation. When the space below the heated floor is also heated, use a minimum of R-11 underside insulation. If the space below the floor is partially heated, install a minimum of R-19 insulation. If the space below the heated floor is an unheated crawl space, install a minimum of R-30 underside insulation. Although these suggested underside R-values are conservative, the installer should verify they meet or exceed local energy code requirements.

The concept of thin slab installation can be used retrofitting radiant floor heating to existing concrete surfaces. A thin over pour or topping pour is created on the existing surface. Figure 4-4a shows the layers of the installation.

Ideally the new layer is separated with a thin layer of insulation. This will drive the heat upwards where we need it and provide quick reaction time. Generally 1/2"

to 1" rigid foam is used. Using a vapor barrier ensures that no moisture gets into the heated layer. A new type of insulation is also now available. Two layers of "bubble" insulation with aluminum foil in between has a comparable insulating effect to the rigid foam. It also acts as a vapor barrier. The most difficult part when laying pipe on existing concrete is how to fasten the pipe. Individual clips can be used, though it is very

TOPPING POUR on existing slab

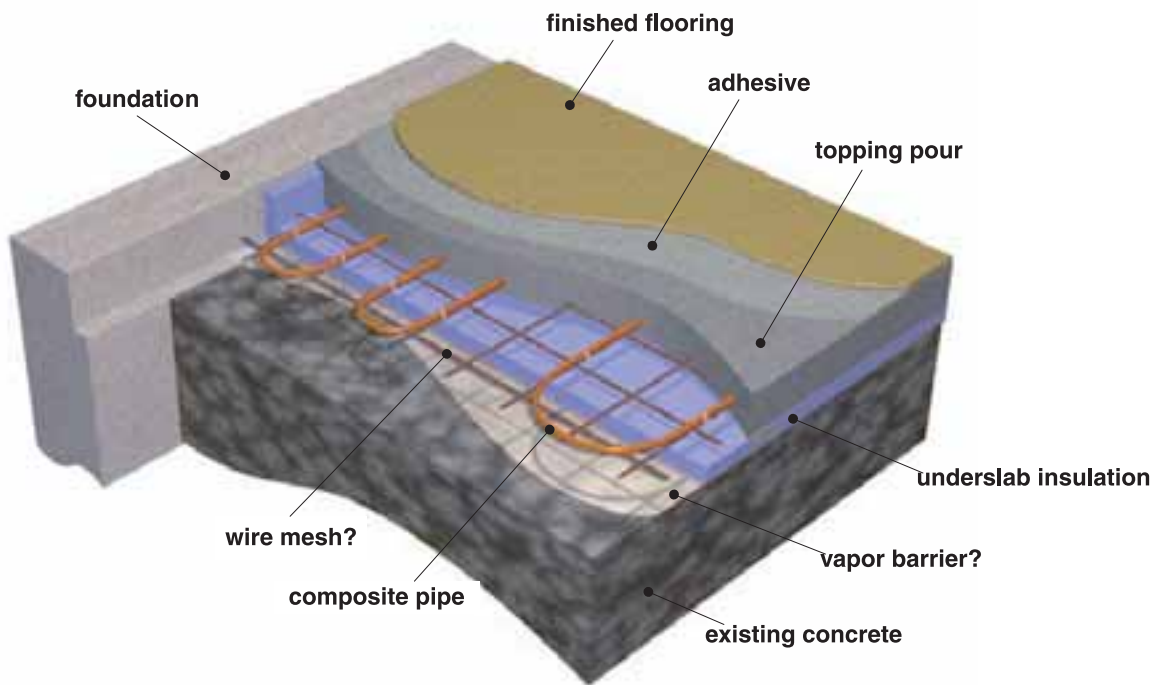
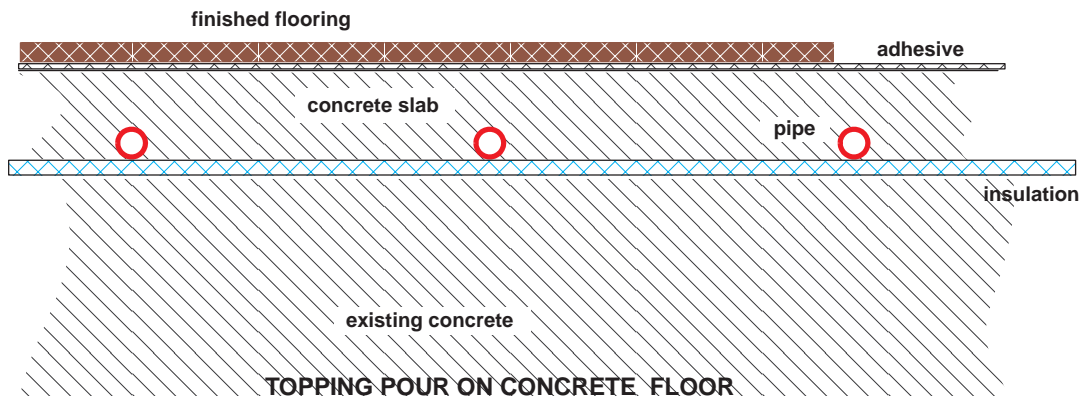


Figure 4-4a



time and labor consuming. Special plastic staples or clips can be used when 1" foam is used as insulation. Another effective way is to use pipe track, sometimes called rail fix, to hold the pipe in place. This 6.5 feet long plastic channel is mounted to the floor at 3 points. The pipe clips into the side cutouts perpendicular to the track.

1¼"-1½" thickness of smooth regular concrete is poured to cover the pipe and create a very effective thermal mass. There are no structural or strength issues—the original slab takes care of that. The doors have to be adjusted accordingly to accommodate the level increase.

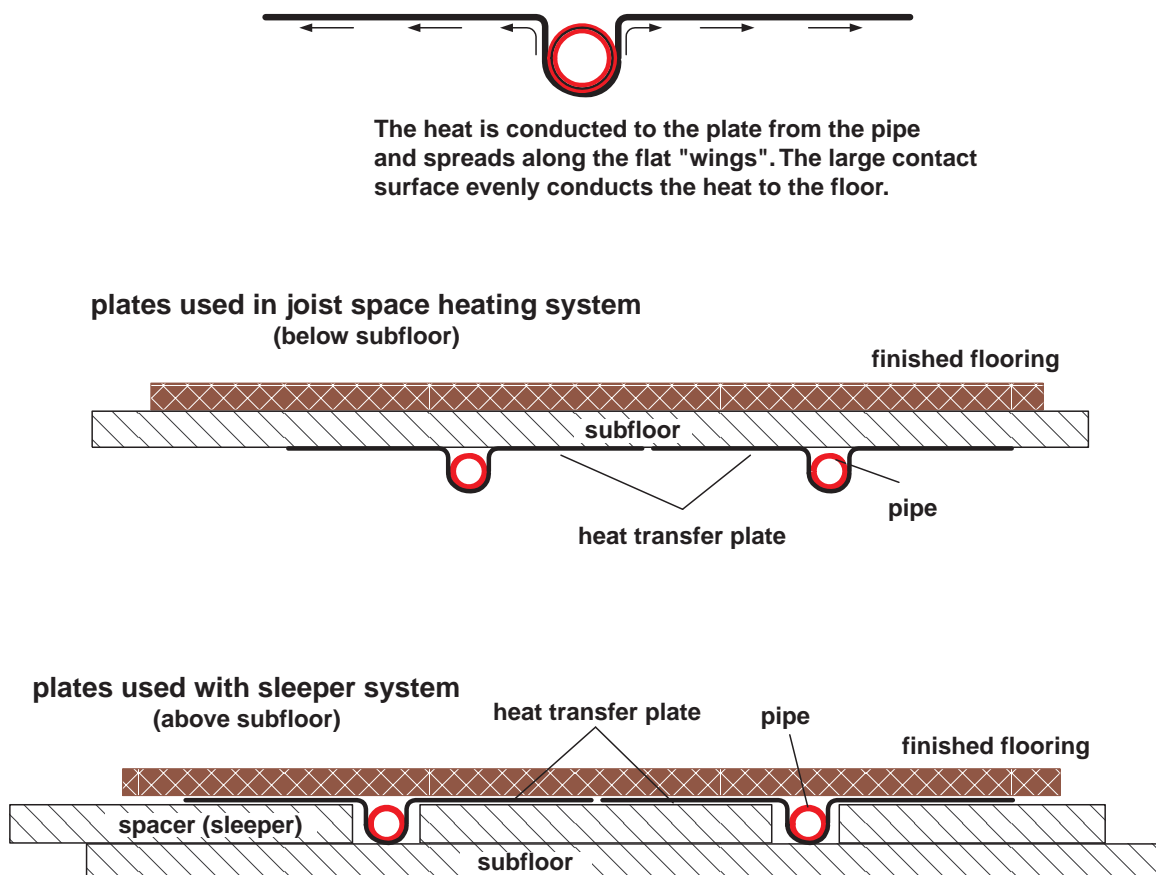
4-6 Tube & Plate Systems

A concrete or gypsum slab acts as a "thermal wick" to help spread the heat releases from the embedded tubing across the floor surface. However, there are

situations where slab installation is not an option. In such cases the heat dispersion can be provided by highly conductive aluminum plates.

Kitec PEX-AL-PEX pipe is ideal for tube and plate applications. Its rate of thermal expansion is very close to that of the aluminum heat dispersion plates. This greatly reduces the potential for expansion sounds as the system warms and cools.

Figure 4-5 shows the general concept of a tube and plate system. Notice how the aluminum plates are shaped to fit the perimeter of the tubing. Heat transferred from the tubing to the trough portion of the plate conducts out along the "wings" of the plate. Because aluminum is an excellent heat conductor, these relatively thin plates can disperse across the floor almost as well as a slab yet at a tiny fraction of the weight and only about 1/2 the added floor height of a thin-slab. They are a versatile component both for floor heating systems as well as radiant walls and ceilings.



THE CONCEPT OF TUBE & PLATE SYSTEMS

Figure 4-5

Above Floor Tube & Plate Systems

Figure 4-6 shows the installation of an "above floor" tube and plate system.

Here the tubing and plates are located on the top side of the floor deck. The tubing can be run in virtually any direction. The system can be adapted to several types of finish flooring, and is particularly well suited for nailed down wood floor installations.

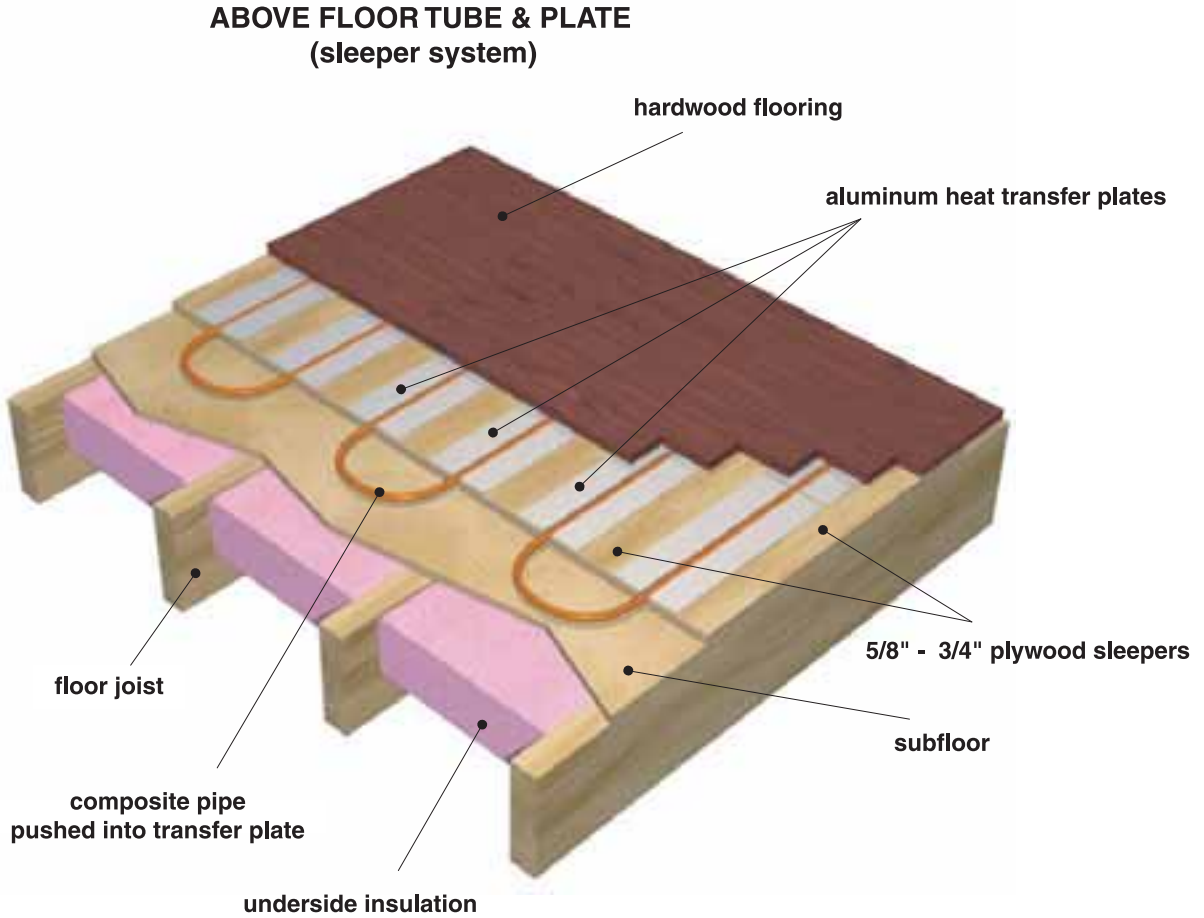
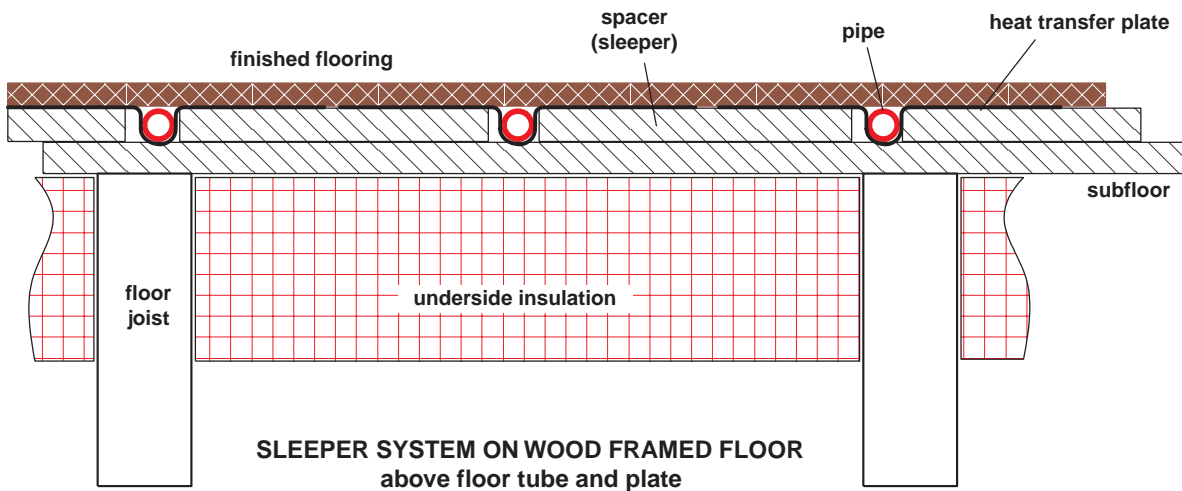


Figure 4-6



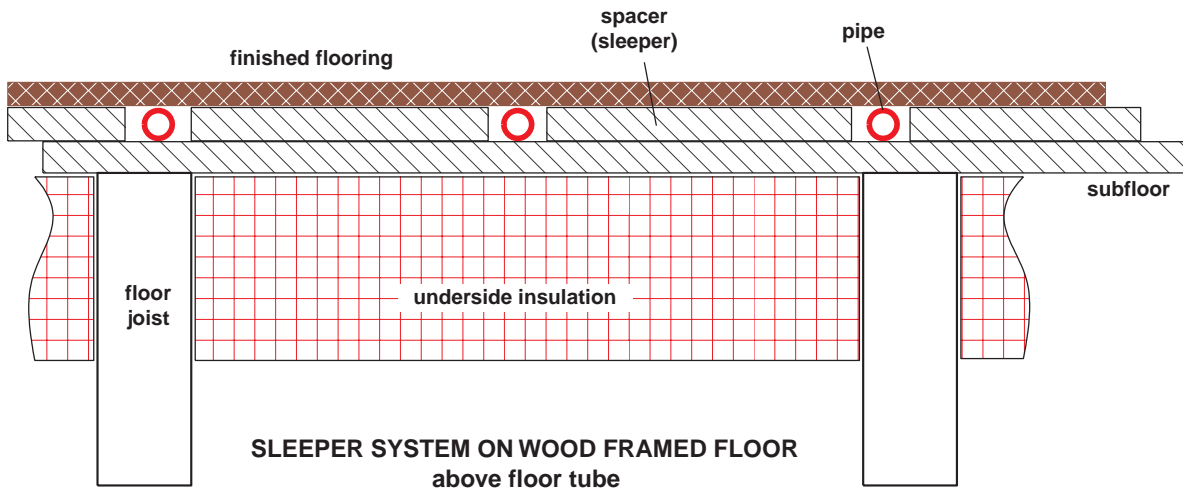
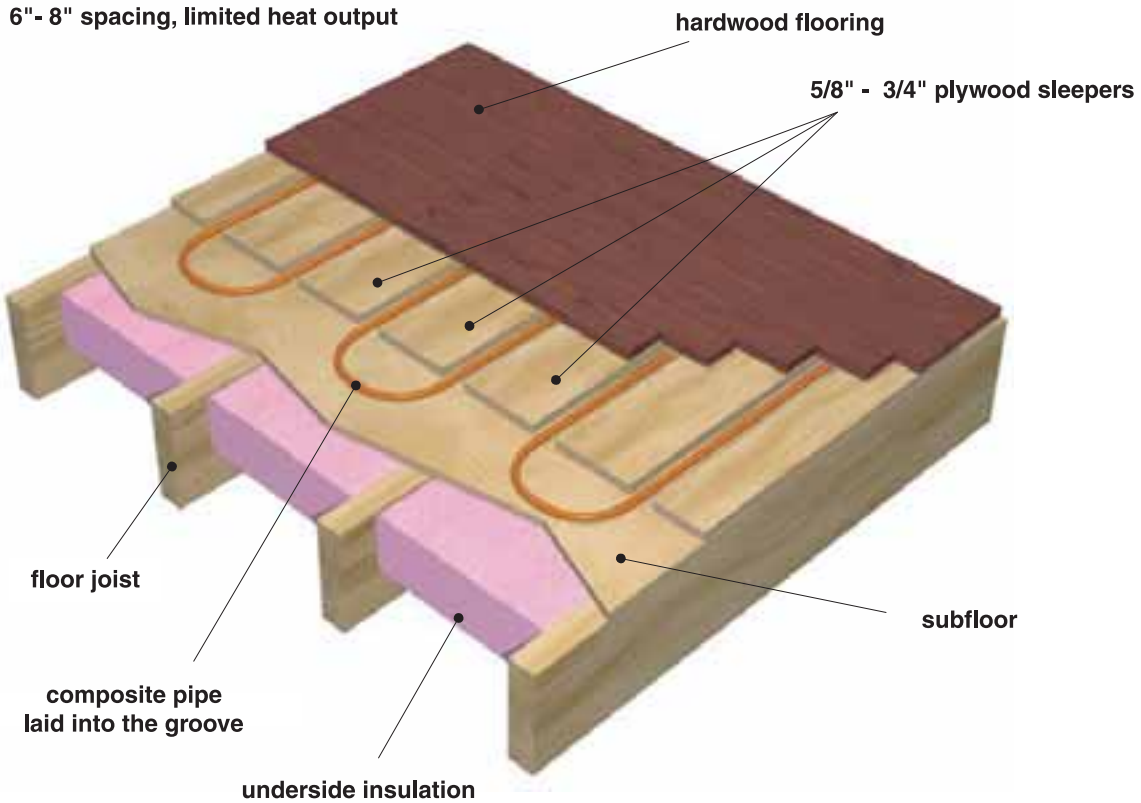
Installation Procedure:

Begin by fastening 5/8" - 3/4" plywood or oriented strand board (OSB) "sleepers" to the floor. The sleepers are placed to create 3/4" wide grooves into which the tubing and trough portion of the plates are recessed. To minimize any squeaks, the sleepers

should be glued as well as nailed (or screwed) to the subflooring.

Grooves for the return bends, as well as other curved tubing paths can be formed by routing out the 3/4" plywood or OSB. Another way is to place triangular shaped spacers to support the secondary floor layer at

**ABOVE FLOOR TUBE
(sleeper system)**



curved areas.

The plates are set into the grooves with ends spaced about 1" apart. Pull each plate against one edge of the sleeper and tack it in place with two or three light gauge staples on the same side (and only on this side). This allows the plate to expand as the tubing is pushed into it as well as when the plate heats and cools.

Then tubing is laid out and pushed into the grooves in the plates. Stepping on the tube as it aligns with the grooves ensures it is pushed all the way into the groove.

It is NOT necessary to install silicone caulking into the troughs of the plates when installing Kitec PEX-AL-PEX pipe.

Above floor tube and plate systems are ideal when nailed-down wood flooring will be installed. The flooring can be placed directly over the tube and plates without needing an additional cover sheet. The flooring should be installed with its long dimension perpendicular to the tubing. Nails can be driven through the heat transfer plates, through the sleepers and into the subfloor. Be careful not to drive nails through the tubing on return bends or other areas when the tubing is not visible as the flooring is laid. If the tubing needs to run parallel to the flooring at times, it is best to drill a shallow hole through the subfloor and route the tubing through the floor framing where it is protected against nail punctures. The tubing can also be "plunged" beneath the subfloor and then routed up through the bottom plate of a partition to connect to the manifolds.

For other types of flooring, it is necessary to install a thin 1/4" or 3/8" cover sheet over the tube and plates to serve as a smooth stable substrate. Plywood is often used as the cover sheet under vinyl flooring or carpet. Cement board has also been used under ceramic tile. All tubing circuits should be pressure tested prior to installing the cover sheet. The tubing should remain pressurized as the cover sheet is installed. Be careful not to drive fasteners through the tubing when securing the cover sheet.

The same concept of the sleeper system can be used in low heat load installations, but without the heat transfer plates—mostly for floor warming systems.

The wood structure is a poor conductor of heat so there is limited heat transfer sideways. The relatively thin layer directly above the pipe will allow a lot more heat through than sideways. This results in large local temperature differences depending on the position of the pipe. This effect limits the amount of heat that can be transferred without creating high temperature "lines" on the floor surface.

The spacing used should be 6"-8" and again only a

limited amount of heat output can be provided. To overcome this limitation, some manufacturers produce pre-routed plywood sheets with aluminum layer attached to it to improve sideways transfer.

Below floor tube & plate systems

It's also possible to fasten the tubing and aluminum heat dispersion plates against the bottom of the subfloor. Below floor tube and plate systems work well when raising the floor level is not an option. The concept is shown in figure 4-7.

The plate cradles the tubing against the subfloor as well as disperses the heat across the floor to avoid objectionable variations in floor surface temperatures.

The ideal installation conditions for this system would be completely unobstructed floor joist cavities. However this is often not what the installer has to deal with. In some cases, plumbing, electrical, ducting or other utilities may already be routed through the joist cavities. This could make access to the underside of the subfloor difficult or even impossible. Always inspect the underside of the floor deck before committing to a below floor tube & plate installation method.

BELOW FLOOR TUBE & PLATE

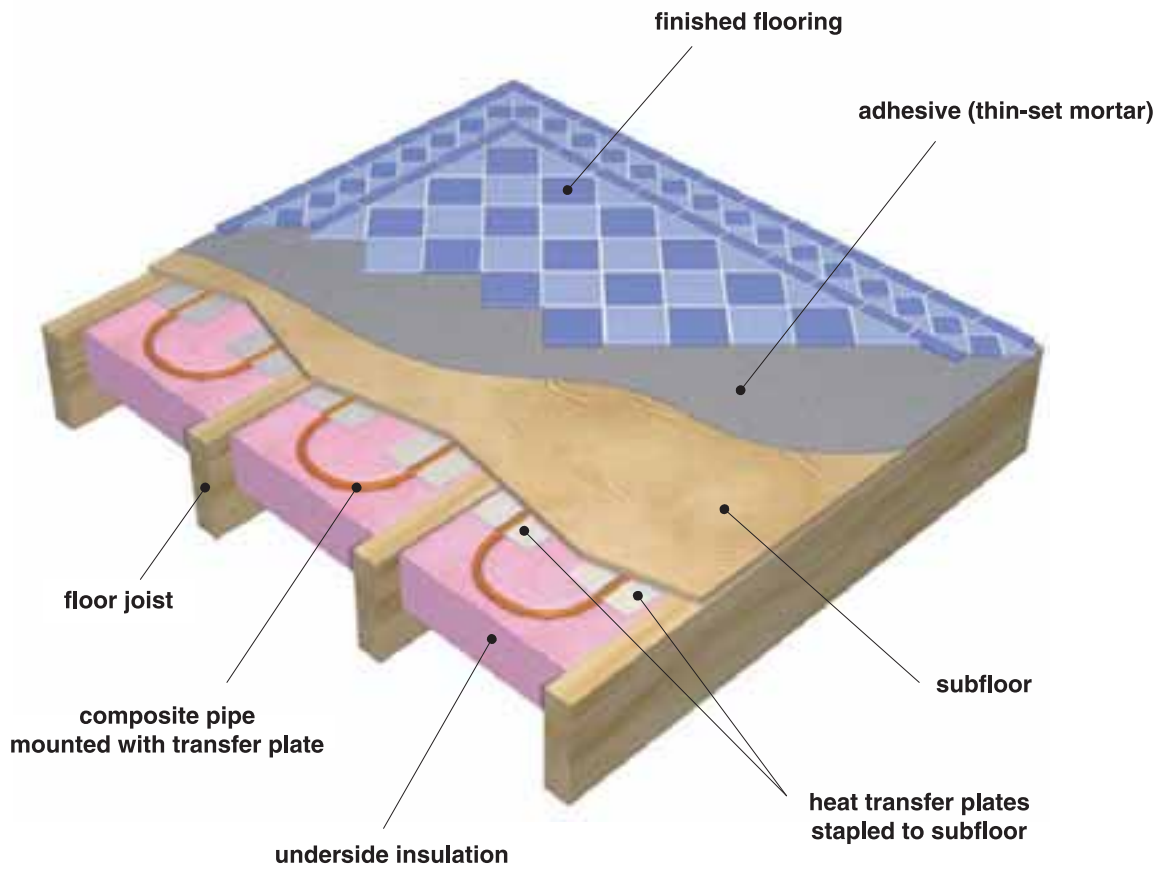
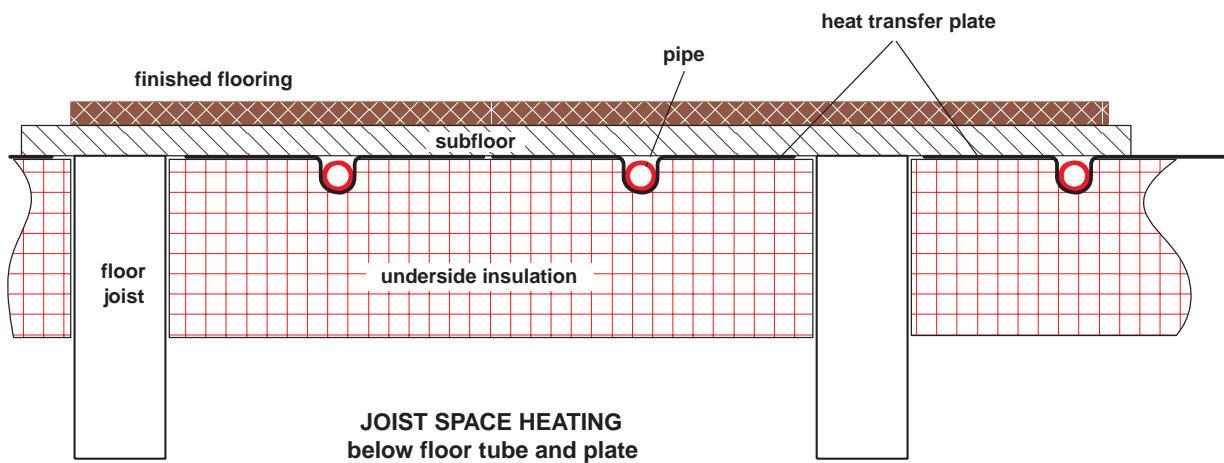


Figure 4-7



With a below floor installation, the tubing is pulled into one joist cavity at a time and fastened up along with the heat dispersion plates. The suggested installation sequence is depicted in figure 4-8.

The holes in the floor framing must be large enough for the tubing to be easily pulled through.

As with thin-slab systems, it's imperative to install underside insulation. When the space below the heated

floor is also heated, use a minimum of R-11 underside insulation. If the space below the floor is partially heated, install a minimum of R-19 insulation. If the space below the heated floor is an unheated crawl space, install a minimum of R-30 underside insulation. Although these suggested underside R-values are conservative, the installer should verify they meet or exceed local energy code requirements.

THREADING pipe IN for joist space heating systems

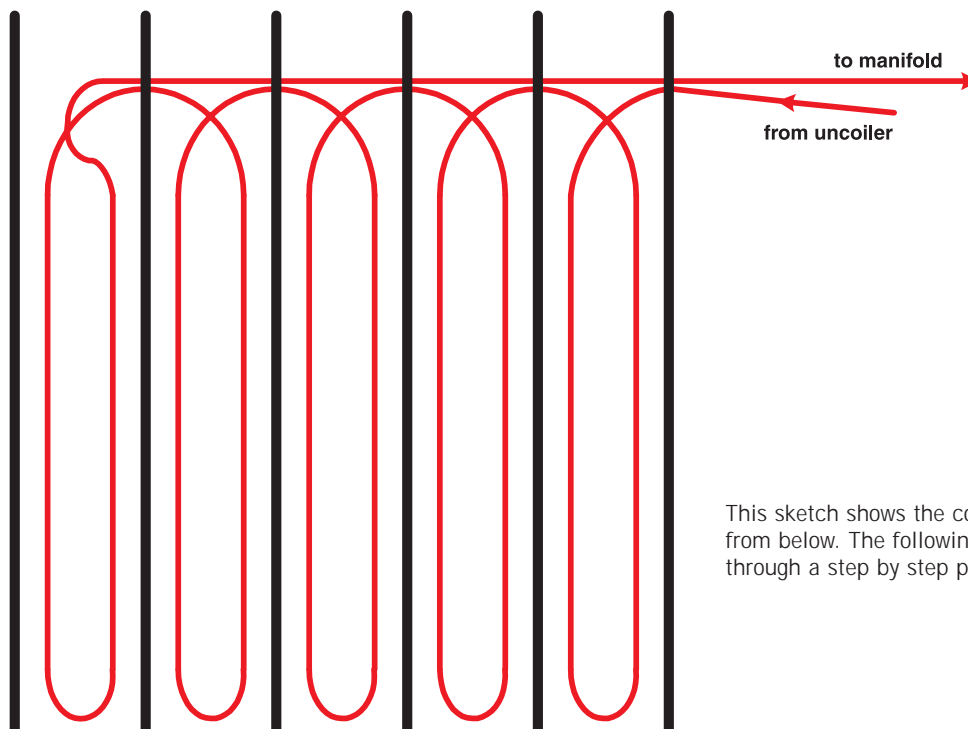
Preparation:

Make a sketch of the floor surface and joists through which piping will be threaded and installed. Identify the manifold location and route to the manifold for each pipe loop.

Measure the length of the floor joist and multiply the joist length by two. This defines the footage of pipe per joist cavity when floor joists are installed on 10" through 18" centers. When floor joists are on 10" through 18" centers, two runs of pipe are installed in each joist space. Three runs of pipe are installed in a joist space when joists are spaced greater than 18" apart.

Calculate the number of joist spaces you can cover with the pipe coil length you are using. For example, if the joist is installed on 18" centers and it is 20 feet long, multiply 20 x 2 to get 40 feet of pipe per cavity. Assuming a 300 foot coil length, 7 joists cavities could be covered. But, remember that you need to allow for the length of pipe running from the manifold and back again. In this example and depending on the manifold location perhaps only 6 cavities can be filled.

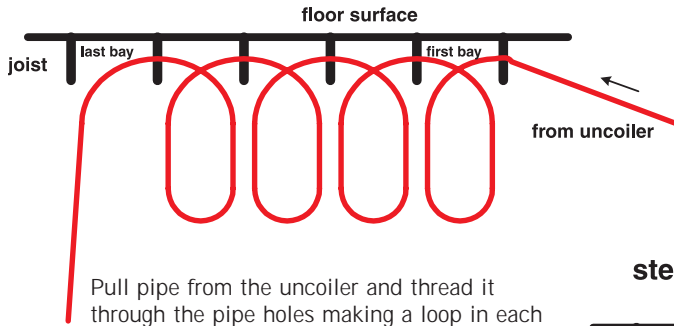
Pre-drill holes in the floor joists through which pipes will run. Two 1/2" pipes require a 1-1/2" diameter hole, while four 1/2" pipes require a 2" diameter hole. Holes should always be straight and aligned. Holes must be drilled in the center of the floor joist and at least one foot away from the end of the joist support point.



This sketch shows the completed installation from below. The following figures lead us through a step by step process.

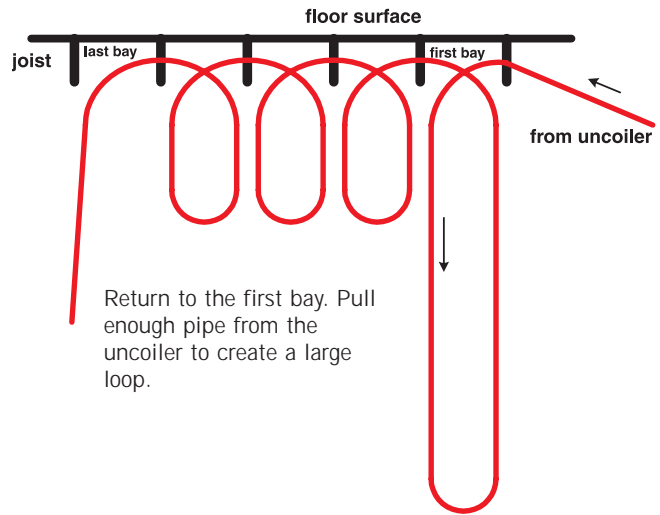
Figure 4-8

step 1



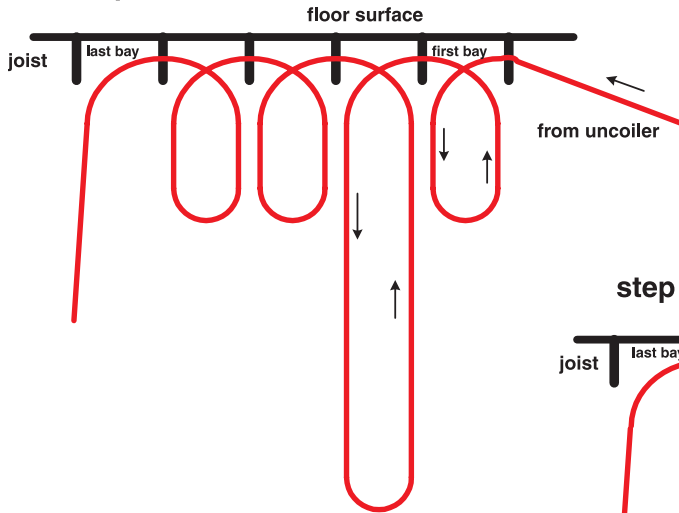
Pull pipe from the uncoiler and thread it through the pipe holes making a loop in each bay. The loops needn't be too long, leave just enough hanging from the joist that allows you to handle the pipe. Leave the pipe end hanging free in the last bay.

step 2



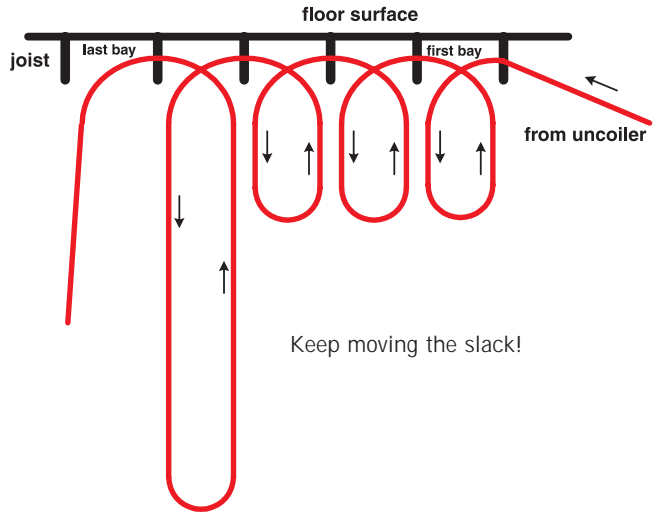
Return to the first bay. Pull enough pipe from the uncoiler to create a large loop.

step 3

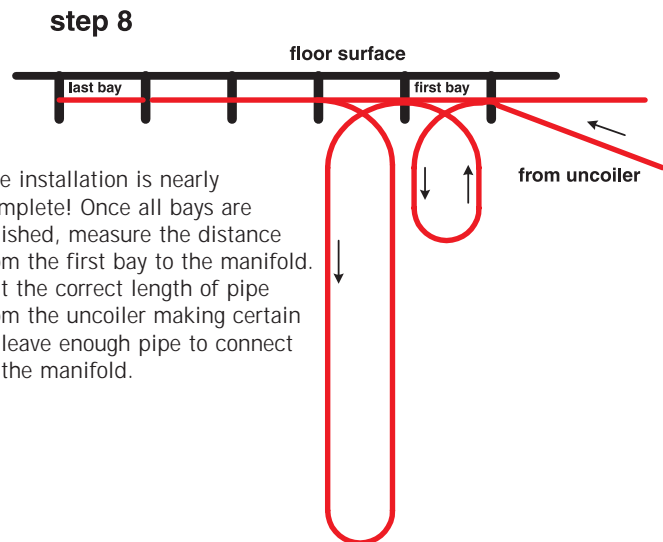
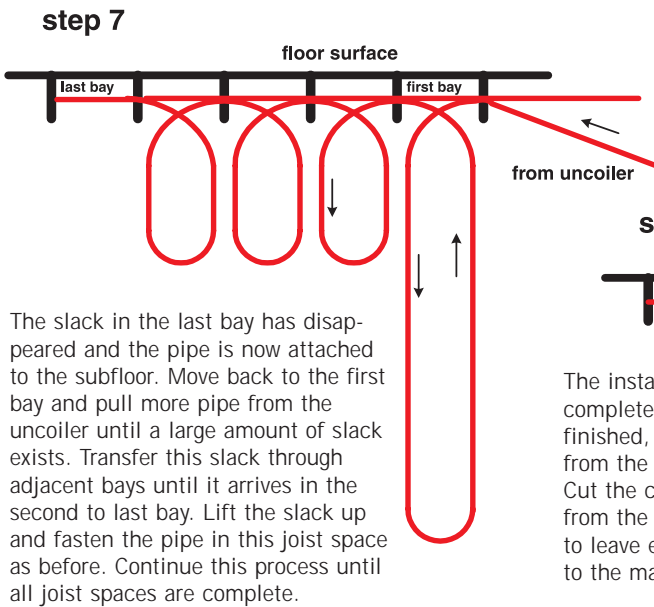
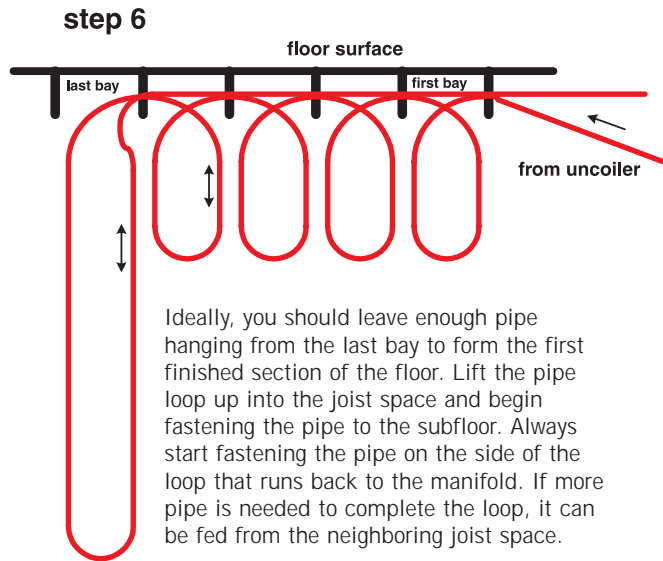
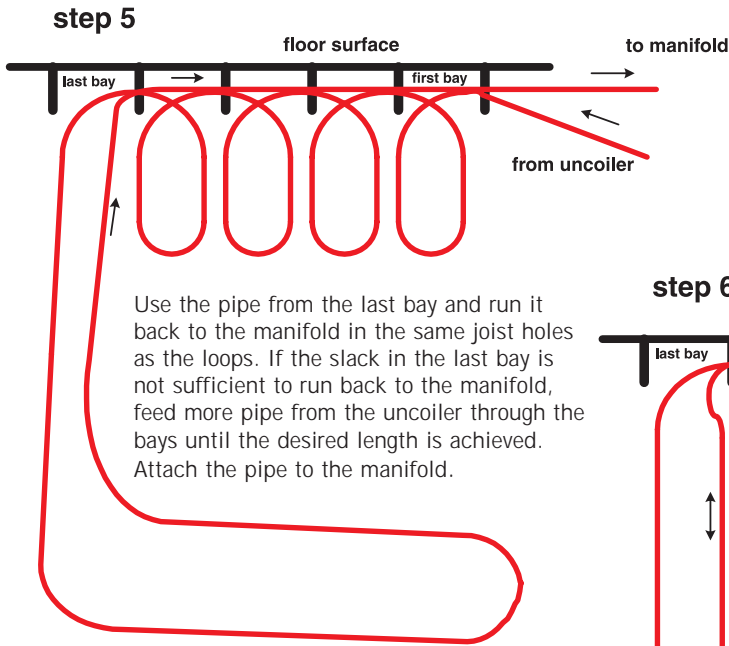


Move the slack from the first bay over to the second bay, then over to the third, fourth, etc., until the last bay has enough pipe to run back to the manifold and complete the pipe loop inside the bay itself.

step 4

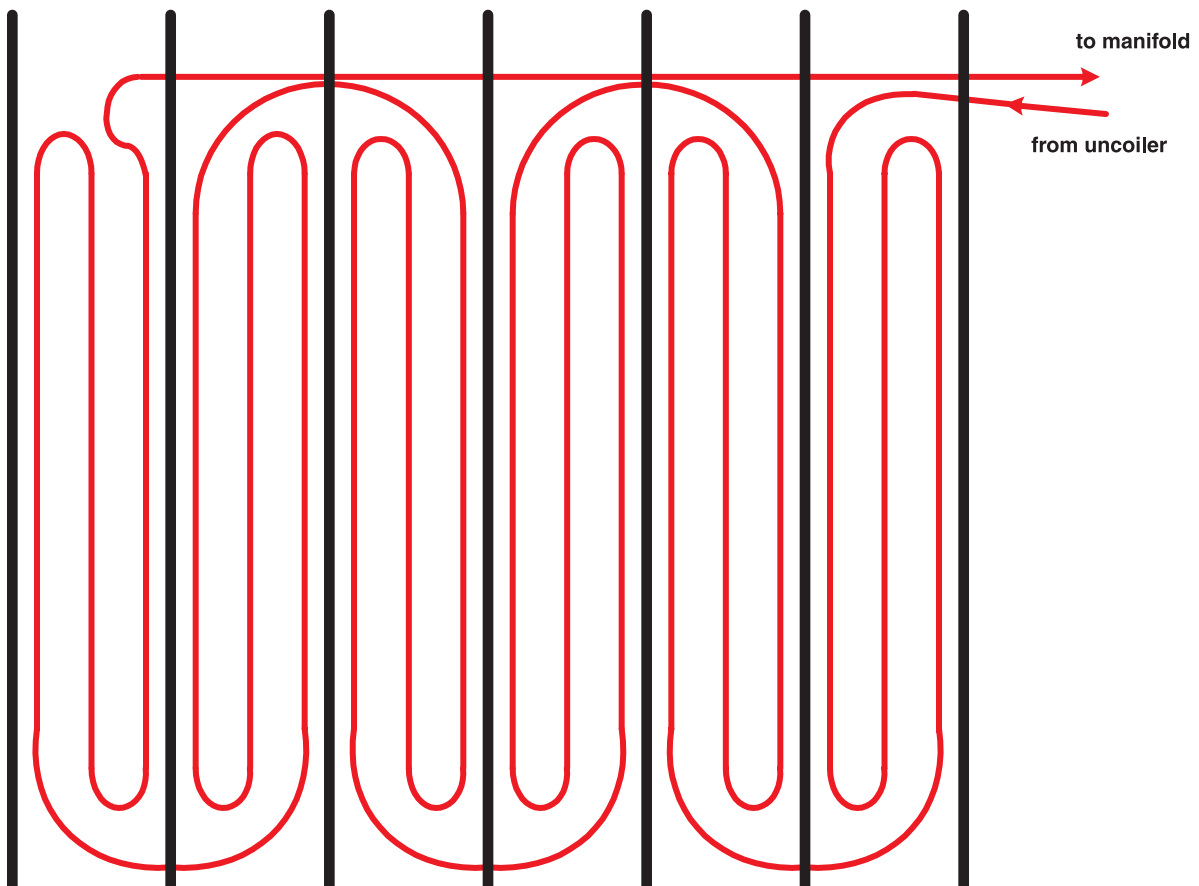


Keep moving the slack!



This process involves a good deal of pipe threading, but it eliminates pipe kinks and reduces stress on the pipe. Two people can work very effectively together with this installation method - one feeding pipe while the other fastens pipe in the joist space.

For joists installed on greater than 18" centers, three runs of pipe are required in each joist space. The pipe handling and installation technique is similar in concept to that described in steps 1 through 8. Create pipe slack and transfer the slack to adjacent bays as before. Note in the following sketch however, that pipe enters the bay at one end of the joist and exists at the opposite end in order to accommodate three runs of pipe.



4-7 Suspended tube systems

The ability of Kitec PEX-AL-PEX piping to handle relatively high water temperatures makes it possible to install a suspended tube system as depicted in figure 4-9.

The tubing is placed within the air cavity between the floor joists. The tubing gives off direct radiant energy to the surfaces within the joist cavity. The outside of the tubing also gives off heat to the surrounding air, establishing a gentle convective circulation within the joist cavities. The warm air flows across the underside of the subfloor transferring more heat to it.

Suspended tube systems have some unique benefits. They don't require heat dispersion plates and thus reduce installation cost. They operate at high water temperatures under design load conditions and thus can often be piped directly to a boiler without needing a mixing valve. When the tubing is suspended below the subfloor, it is not subject to puncture from the nail

points associated with installation of hardwood flooring.

Kitec PEX-AL-PEX piping is ideal for suspended tube systems. Its aluminum core provides the structure that prevents the tubing from sagging between supports when operated with high water temperatures.

As with all floor heating systems, it's imperative to install underside insulation.

This must be a reflective insulation system meaning that there is a shining reflective metal surface facing the pipe. There has to be an air gap between the pipe and the reflective layer minimum 2" or more.

Foil faced batting insulation or the aforementioned "bubble" insulation can be used. The "bubble" insulation is different from the one used with concrete. The aluminum layer is exposed on one side minimum and is always facing the piping. The insulating layer can be one or two layers of plastic "bubble" depending on the amount of insulation required.

JOIST SPACE HEATING BELOW FLOOR TUBE

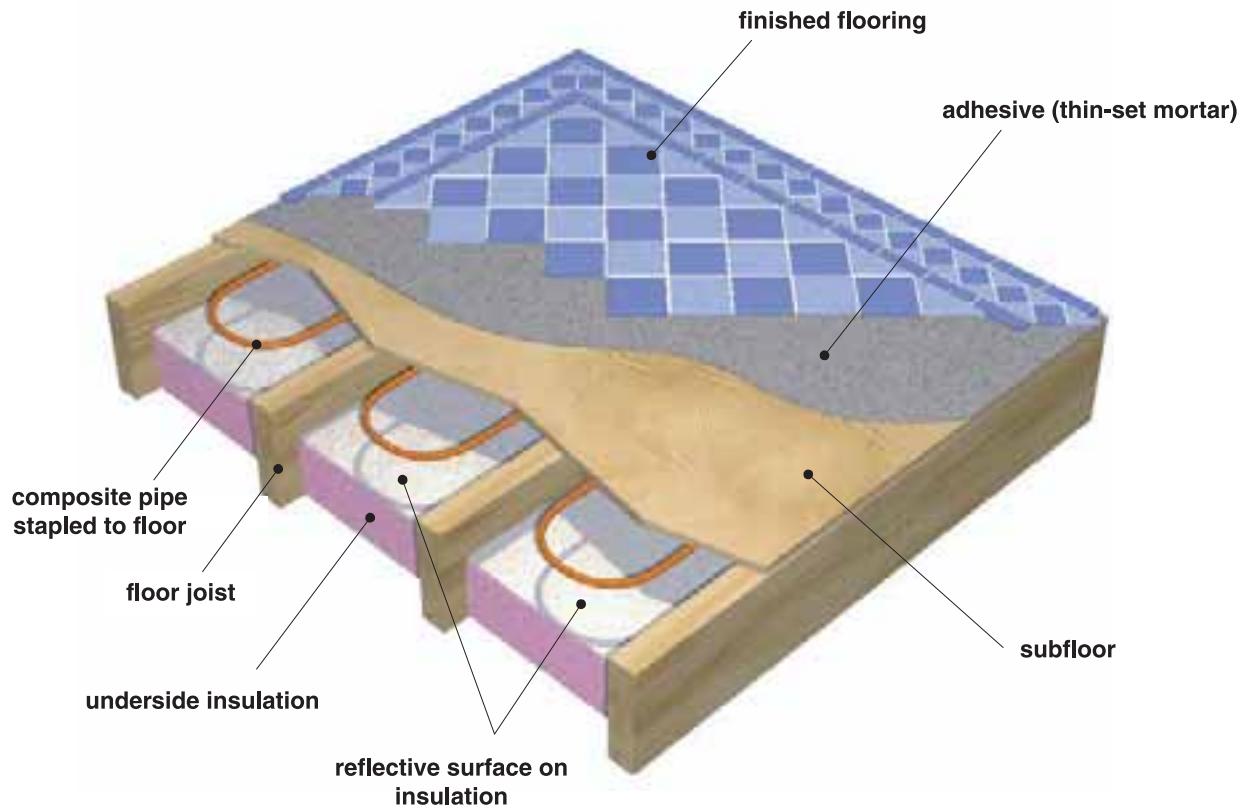


Figure 4-9

When the space below the heated floor is also heated, use a minimum of R-11 underside insulation. If the space below the floor is partially heated, install a minimum of R-19 insulation. If the space below the heated floor is an unheated crawl space, install a minimum of R-30 underside insulation. Although these suggested underside R-values are conservative, the installer should verify they meet or exceed local energy code requirements.

Threading the pipe into the joist space is identical to the method explained under the section discussing joist space heating with heat transfer plates.

The fastening of the pipe is different in this case. There are three main ways to secure the pipe; stapling to the underside of the subfloor; using a pipe hanger to suspend the pipe in the joist cavity; or use a nail clip to nail the pipe directly to the side of the joist.

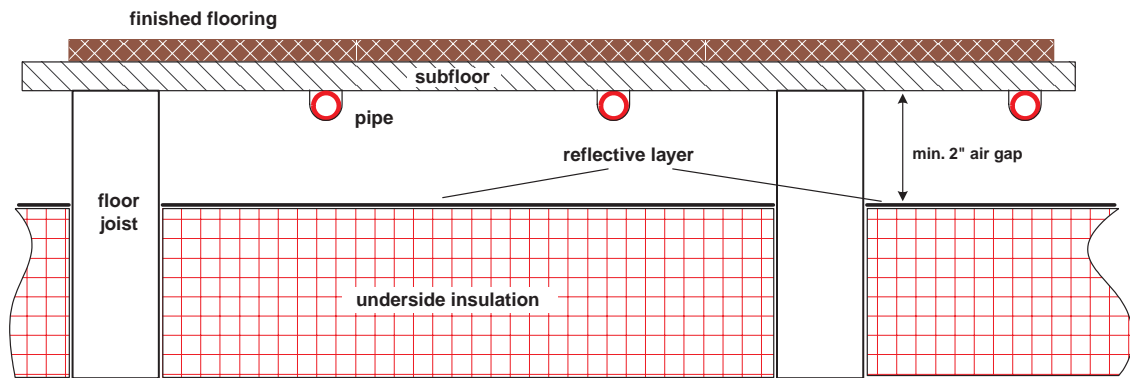
Stapling to the floor is very simple, however the pipe is close to the surface and can be punctured easily from above. The other two overcome this problem, but an

extra item pipe hanger or nail clip is used.

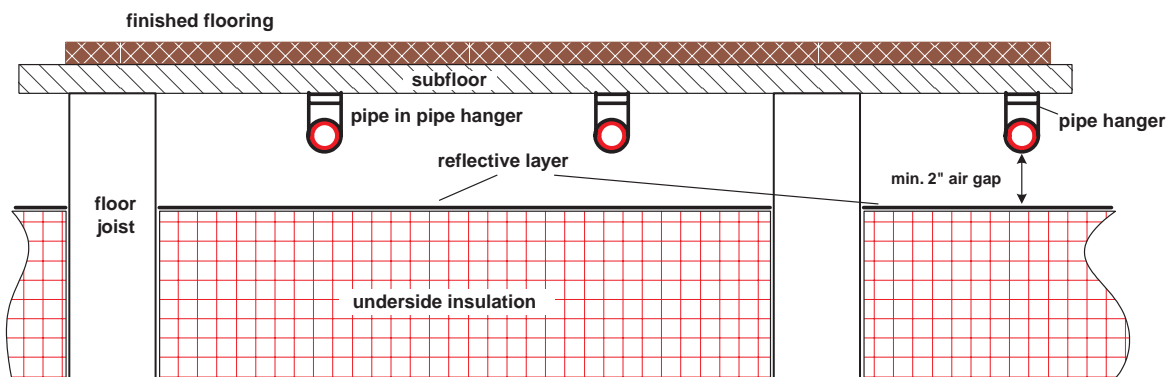
In high heat load installations, the direct stapling to the underside can result in high and low temperature "lines" on the floor.

The fastest and easiest to install is the nail clip method. They all have their advantages and disadvantages.

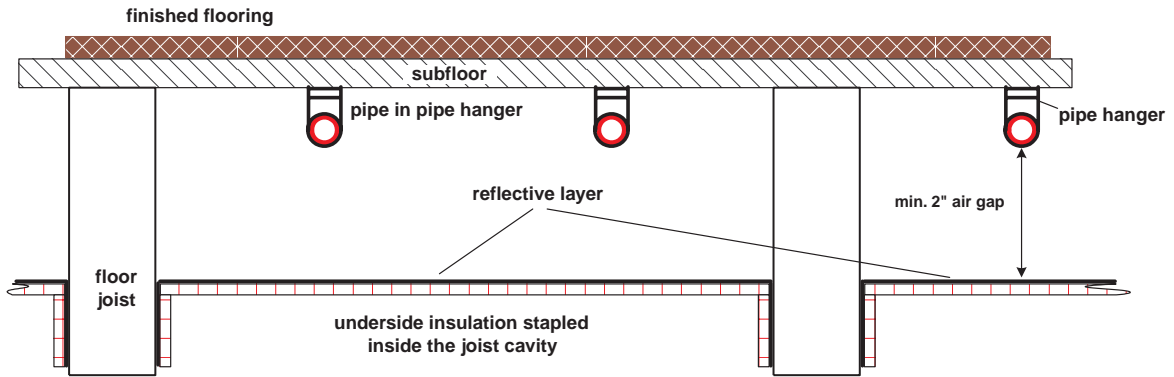
It's possible to staple Kitec pipe directly against the underside of the subflooring without using heat dispersion plates. As discussed above this approach is only suggested for low heating load situations such as rooms that have minimal if any exterior exposure. Without either a slab or aluminum heat dispersion plates, the floor's ability to spread the heat laterally away from the tubing is more limited. Still, when the design heat load of the space doesn't exceed 15 Btu/hr/sqft, this installation method can deliver adequate heat output at reasonable water temperatures.



**JOIST SPACE HEATING
below floor tube stapled**

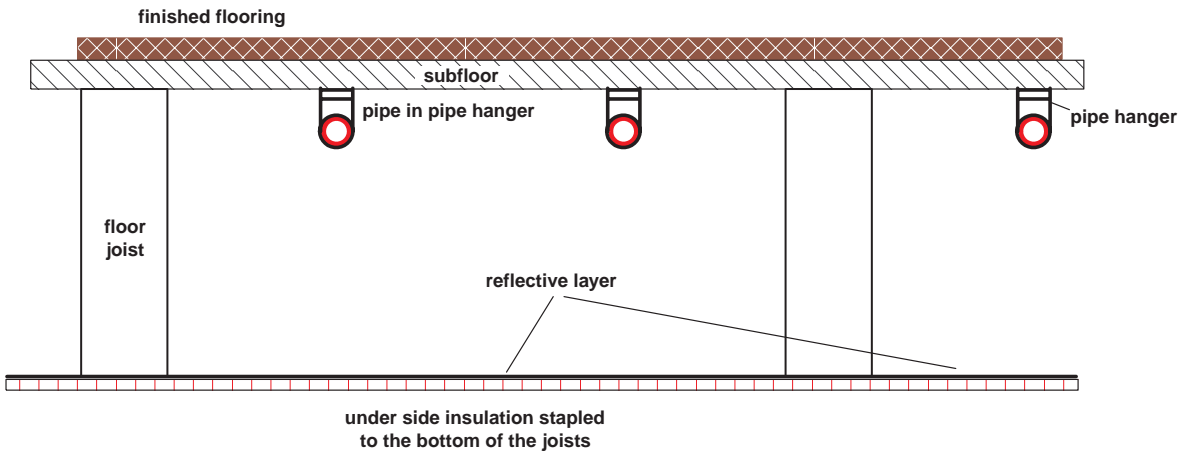


**JOIST SPACE HEATING
below floor tube suspended**



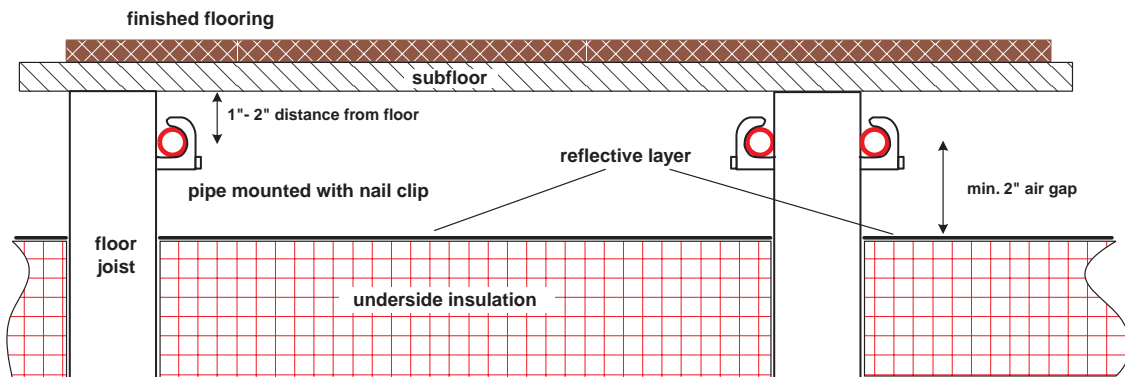
Reflective foil insulation (aluminum-bubble)

JOIST SPACE HEATING
below floor tube suspended



Reflective foil insulation (aluminum-bubble)

JOIST SPACE HEATING
below floor tube suspended



JOIST SPACE HEATING
below floor tube clipped to joist

In this chapter, we pointed out the effects of the floor construction method on the radiant floor heating system. As a summary, it is probably fair to say that piping can be fitted into any floor surface and there are numerous variations to fit the project circumstances. It should also be clear that there are important differences between these methods and some are better suited than the other for effective heat transfer.

The following image (figure 4-10) illustrates the heat transfer process during joist space installation using heat transfer plates or direct staple up.

The image speaks for itself and gives very good reasons to consider using the heat transfer plates wherever it is possible.

Comparison of floor surface temperatures with and without heat transfer plates for 1/2" tubing 8" o.c., operated at 100°F and 140°F water temperatures

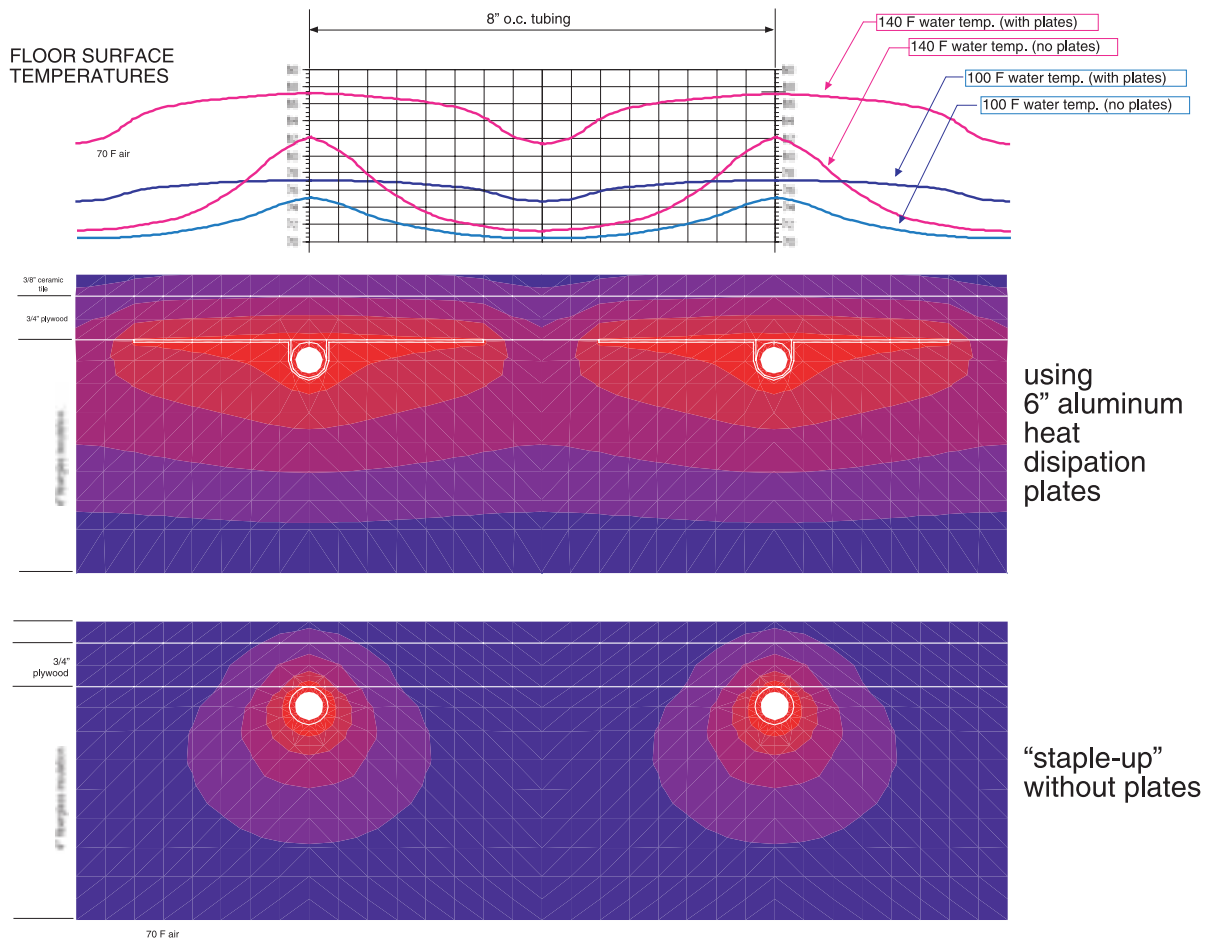


Figure 4-10