ZURN

Radiant Heating Design and Application Guide

PURPOSE AND LIMITATIONS OF USE

Zurn Radiant Heating Design and Application Guide

The purpose of this manual is to assist the radiant panel design professional by providing specific information regarding the Zurn Radiant Heating System. This manual constitutes the "Manufacturer's Recommendations" for design and installation of radiant floor, ceiling and wall systems. For the purpose of clarity in communication concepts, this manual is conceptual in nature. The designer and the installer must rely on his knowledge of radiant panel heating, regional climate conditions, and the local administrative requirements to determine suitability of any particular material or process. Any conflicts between this manual and the local administrative building, plumbing, or mechanical codes must be resolved prior to installing the system.

All radiant heating systems should be installed by qualified professionals who are familiar with building heat loss analysis, radiant hydronic installation techniques, and hydronic good practice.

Failure to follow the manufacturer's design and installation instructions, hydronic good practice, applicable codes, or failure to use common sense can give an unsatisfactory result.

The following is a registered trade name:

Qicktite®

The following are trade-marked names:

Qickport™

Thermal Track™

QickPak™

Add-A-Port™

Qickzone™

Qicksert™

THE DICTIONARY DESCRIBES COMMON SENSE AS HAVING AND EXHIBITING NATIVE GOOD JUDGEMENT.

Common sense is often described as something we should all have but as something many of us do not always utilize. All of us can improve our chances of exhibiting "native good judgement" with regards to radiant heating. If we have a well informed mind as a backdrop, native good judgement often comes naturally.

Enhanced common sense would be combining native good judement with a lot of knowledge, training and experience.

COMMON SENSE AND RADIANT HEATING

Knowledge Is Your Best Resource

We all know that common sense is a precious resource, but it is often hard to define. With radiant heating, common sense requires that the designer and installer arm themselves with as much information as possible. The following common sense steps are the responsibility of the designer and installer of Zurn radiant heating systems:

- Read and study this manual and other Zurn literature in detail.
- Familiarize yourself with the applicable codes in your area. This means get copies of the code documents, read the relevant sections, and put the code into practice.
- Seek out training from Zurn and participate.
- Purchase and read the "Standard Guidelines for the Design and Installation of Residential Radiant Heating Systems" published by the non profit Radiant Panel Association. This is a consensus document on minimum standards for how radiant heating systems should be designed and installed.
- If you are unfamiliar with radiant heating systems, make an effort to visit a job site where radiant heat is being installed and see the sequencing of the project.
- Understand all the components of the system, how they are used and where and when they are normally installed.
- Learn what is standard good practice for any hydronic system.
- Familiarize yourself with typical heat losses for your climate. Do enough practice radiant designs by hand that you have a feel for what results you should get before you use a computer.
- Notice the relationships between Panel Surface Temperature, panel covering R-Values, system type and the required water temperatures.
- Respect the limitations of radiant heat. Do not expect the physics of heat transfer to change for your job.
- Anticipate and visualize how a job is sequenced, what needs to be done when and where by which trades. Make sure to communicate this to the relevant parties.
- If you are doing radiant floor heating, pay close attention to the floor coverings and floor assemblies. These need to be integrated into the design process.
- When radiant heat cannot reasonably provide all the heat for a structure, make provisions for supplemental heat.
- Above all, when you are unsure, seek out the answer from an experienced, qualified, source.

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CHAPTER 1: UNDERSTANDING RADIANT HEAT

The world's most comfortable heating systems from Zurn

AN INTRODUCTION TO RADIANT PANELS

Radiant panels are modern forms of space heating using warm water circulated through tubing systems embedded within the floors, ceilings, or walls to distribute heat energy. Radiant panel heating systems provide superior comfort and efficiency when compared to other forms of heat distribution. This is due primarily to the relatively mild surface temperature of the panels. The radiant surfaces emit invisible rays of energy that are absorbed by cooler objects in the room. As the surfaces reach room temperature, they begin to re-radiate any additional energy they receive. The combination of radiation, re-radiation and any mild convection in the room provides comfort to every part of the structure.

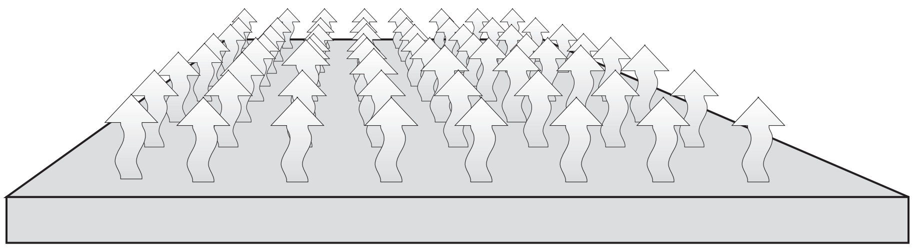


FIGURE 1: how a radiant panel gives off an even, gentle heat over a wide area

ADVANTAGES OF RADIANT PANEL HEATING

The primary advantages of radiant panel heating are comfort and efficiency. With hydronic radiant panels, heat energy follows the path of the tubing embedded within the panel. The designer is able to route the tubing precisely to the regions that require heat and, through various layout patterns, distribute the heat in a manner that addresses the particular heat loss features of the room. The architectural freedom of no soffits or floor registers for forced air heating means houses look better and have more usable floor space.

Each loop can be individually controlled, allowing the energy to be placed where and when it is needed. This control capability is the key to achieving both comfort and efficiency. No other heat distribution system is capable of this measure of control. No other form of heat distribution is capable of bringing warmth and comfort to massive concrete floors. Because of their mass, concrete floors require huge amounts of energy during acceleration phases, which can only be provided by an embedded system. Forced air and baseboard radiation systems lack the heat transfer ability to heat concrete floors to a comfortable surface temperature.

The heat capacity of water makes it a vastly more efficient medium than forced air for the delivery of heat. Water has 3000 times more heat capacity per cubic foot than air. This means that 3/4" tubing can carry heat that would normally require a duct measuring 8" x 14". Also small energy efficient pumps are used for water rather than large blowers. Pipes are small and easy to insulate, whereas ducts and duct losses are much larger.

A radiant panel turns a large area into a low temperature radiator. Since the area is large, the temperature of the panel usually only needs to be warm, not hot. The result is a broad expanse which gives off warm, even heat. Radiant panels are used to heat houses, for soil warming, and snow melting.

MEAN RADIANT TEMPERATURE

Mean Radiant Temperature (MRT) is defined as the average temperature of all the surfaces of a room. Because with radiant panels, there is a large warm surface, the average surface temperature (MRT) of all the surfaces in the room is high, thus less heat is lost to the colder surfaces. Therefore we are comfortable with radiant heat at a lower room temperature and save energy.

THE DEFINITION OF A RADIANT PANEL

(from the Radiant Panel Association): "A radiant panel is defined as a floor, wall or ceiling surface designed to heat and/or cool a space where the panel has a controlled surface temperature of under 300°F (floor surfaces typically operate at less than 90°F), and the heat transferred by radiation is 50% or greater of the total heat transferred between the panel and the space."

Hydronic radiant panel systems from Zurn typically operate in the range of 70°F-90°F for floors and in the range of 70°F-110°F for walls and ceilings.

This radiant floor heating profile shows how a radiant floor heating system does not generate high temperatures where it is not needed. The profile for radiant heat is near what scientists consider ideal for human comfort. Notice that it is warm on the feet then very even up to head heigh, then it cools down in the upper reaches of the room where the heat is not needed.

OTHER BENEFITS OF RADIANT HEAT:

• People are comfortable at lower air temperatures; lower heat stratification results in lower envelope heat losses.

• Radiant systems are quiet. There is no noise from big blowers coming on and off pushing intermittent blasts of hot air around a room.

• Since Zurn provides hydronic radiant heating systems, it is adaptable to any fuel source that will provide hot water.

• Radiant heat does not blow dust and pollen around a house and is better for people with allergies than typical forced air systems. It is also not as drying to the skin as “scorched air”.

• The biggest benefit of Zurn radiant heating systems is happy customers who appreciate the even, quiet warmth.

RADIATION

Color, texture, orientation, distance and temperature all have an effect on the output of a radiant panel. The colder it is, the more radiant energy is “pulled” out of the radiant panel.

Radiant panel heating increases our comfort in many ways. For example, radiant floor heat has more even floor-to-ceiling temperatures than other systems since the heat starts on the floor. The temperature profiles of a typical radiant floor heating system and a typical forced air heating system are compared below:

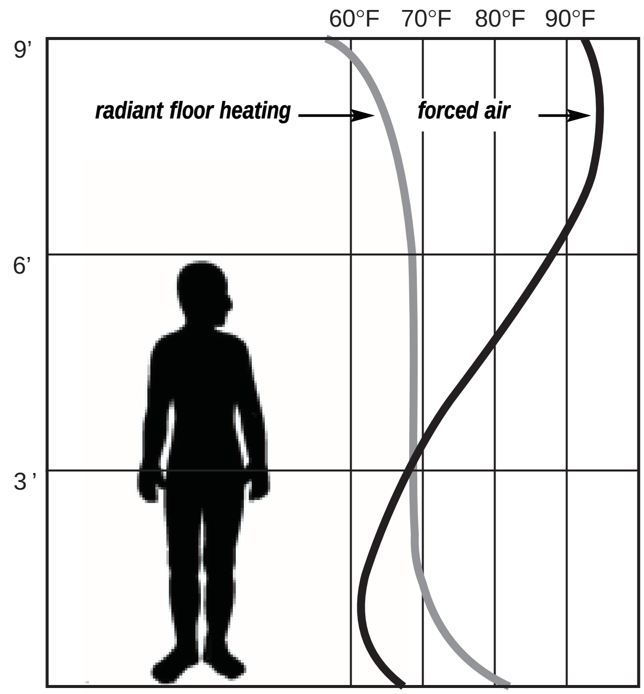


FIGURE 2:
Temperature Profiles For Radiant Floor Heating And Forced Air

THE BASICS OF HEAT TRANSFER

When studying heat transfer remember that heat transfers to cold by means of three heat transfer processes, radiation, conduction and convection. It is a misconception that heat rises. Heated air and fluids may rise particularly due to convection.

RADIANT PANEL HEAT TRANSFER

Radiant panel space heating systems transfer heat into the room through one or more of the three thermal transfer processes; radiation, convection, and conduction. It is helpful to understand how these processes work in conjunction with radiant panels in order to properly apply the technology.

Transfer Through Radiation

Radiant heat transfer occurs as energy is emitted from a warm object to a cooler object through invisible electromagnetic rays that move at the speed of light. These energy rays impact upon the cooler object where they are either absorbed or reflected. As the energy is absorbed, the temperature of the object rises.

The amount of energy absorbed depends upon several factors: the temperature of the object, the angle of radiant impact and surface characteristics. Cool objects absorb more energy than warm objects. Heat energy radiates from the warm object at an angle 90° to its surface.

A perpendicular (90°) angle of impact concentrates more energy on the heated object than lower angles of impact. Dark and opaque surfaces absorb more energy than light colored or reflective surfaces. Any radiant energy that impacts upon an object, but is not absorbed, will continue to re-radiate until it is absorbed. In this way, radiant heating is capable of providing excellent heat distribution.

In radiant heat transfer, objects are heated by electromagnetic rays, travelling at the speed of light and warmer surfaces heat cooler surfaces.

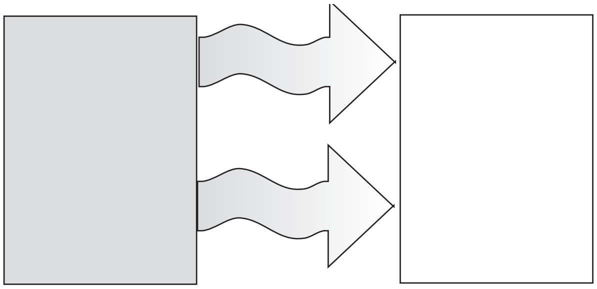


Figure 3: Radiant Heat Transfer

Heat Transfer Through Convection

When cool air comes into contact with a warmer surface, it absorbs energy and is heated. Temperature increases in the air are dependent upon velocity, surface area and surface characteristics. This transfer of heat is called convection.

Convection can occur naturally or can be developed mechanically. Natural convection results from the change in density of air as it is heated. Warm air has less mass than cool air and it will rise within the air mass. Cool air sinks to replace the warm air. In floor heating as the cool air sinks, it comes into contact with the heated surface and continues the natural convection process.

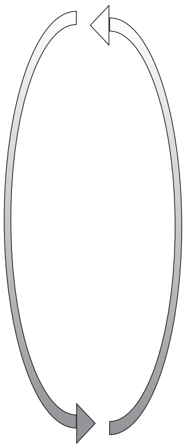


Figure 4: Convective Loop

Forced convection occurs from the mechanical movement of air across the surface, not as a result of the natural convection of the heated surface. Forced convection may be driven by many sources such as the operation of ventilation equipment or ceiling fans.

Heat Transfer Through Conduction

Conduction heat transfer occurs within objects and between objects that are in direct contact with one another. This powerful form of heat transfer occurs as objects of different energy levels tend to equalize their energy between them until thermal equilibrium is achieved.

CONDUCTION

"The process of heat transfer where heat moves through a material or between two materials that are in contact with each other."

In radiant floor heating, conduction occurs in the materials of the floor assembly itself as the heat passes through on its way to the surface where it begins to radiate, convect, and conduct to the objects in the room.

Conduction always transfers heat from the warm object to the cooler object. In some instances, objects placed directly on radiant floors will improve the performance of the system by acting as a "heat sink". The energy absorbed by the object can in turn be transferred to the room through convection and/or radiation.

Since Zurn radiant heating systems can be installed in floors, walls or ceilings, the designer has great flexibility in how to deliver heat to a project. Many projects utilize more than one way of installing radiant heat. The chapter on Installation and Construction Methods will provide much more detailed information on the installation and application of these different systems.

Many different systems will usually work on any given project.

PERFORMANCE OF RADIANT FLOORS, WALLS AND CEILINGS: Radiant floors, walls and ceilings operate somewhat differently from each other. The most important differences have to do with allowable surface panel temperatures, and in the amount of convective heat transfer that each type of system typically generates. The information on the following page summarizes this in graphic form.

TYPES OF RADIANT PANEL SYSTEMS FROM ZURN

Zurn supplies the materials for radiant floor, wall and ceiling systems. Radiant floor heating systems are the most popular, but wall and ceiling systems are useful and work well. Since we all know “warm air rises”, radiant walls and floors seem counter intuitive. However, they work very well since the majority of the heat is transferred by radiation, not by convection or conduction.

Radiant Floor Heating Systems

In radiant floor heating systems, PEX plastic tubing is embedded in the floor utilizing one of the many available methods. The most common form of radiant floor heating is with the tubing embedded in a cement slab or in a thin slab of cement or gypsum cement. The tubing can also be hung in a joist space, with or without the use of heat transfer plates or sandwiched between layers of flooring. With radiant floors, the floor goods become part of the heating system itself. Therefore radiant floor system design must take into account the ability of the flooring assembly to transfer heat.

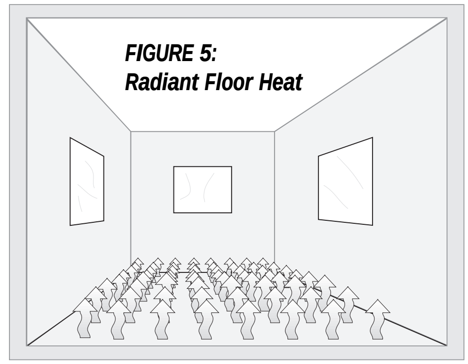


FIGURE 5: Radiant Floor Heat

Radiant Ceiling Heating Systems

In radiant ceiling heating systems, PEX plastic tubing is placed above the ceiling goods, either with or without the use of heat transfer plates. Radiant ceilings work very well but are often an overlooked choice due to the public’s lack of familiarity with their effectiveness. Radiant ceilings have an advantage in that they are usually covered only with a thin layer of sheetrock making heat transfer less restricted. Ceiling systems are very useful in remodeling. They can be installed in a soffit furred down from an existing ceiling.

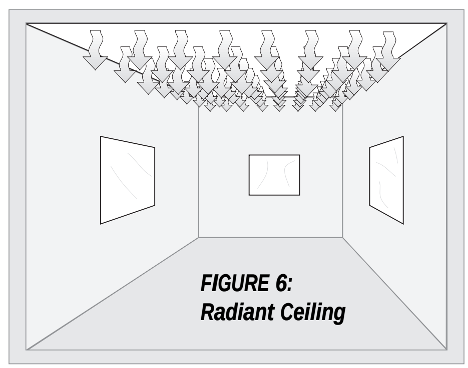


FIGURE 6: Radiant Ceiling

Radiant Wall Heating Systems

In radiant wall heating systems, PEX plastic tubing is placed behind the wall finish goods, either with or without the use of heat transfer plates. Radiant walls are often used to augment radiant floor heat or where the building configuration makes it advantageous.

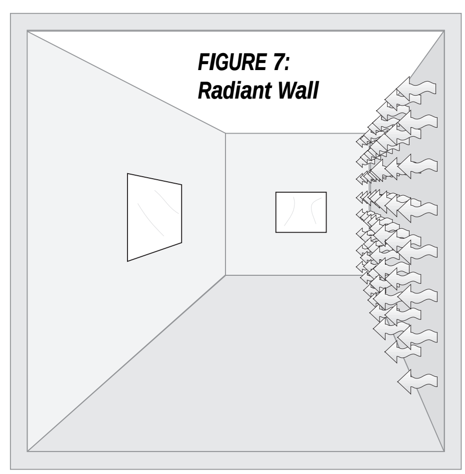


FIGURE 7: Radiant Wall

In the drawings below, the radiant surface is shown by the short arrows and the convective loop by the big looping arrows.

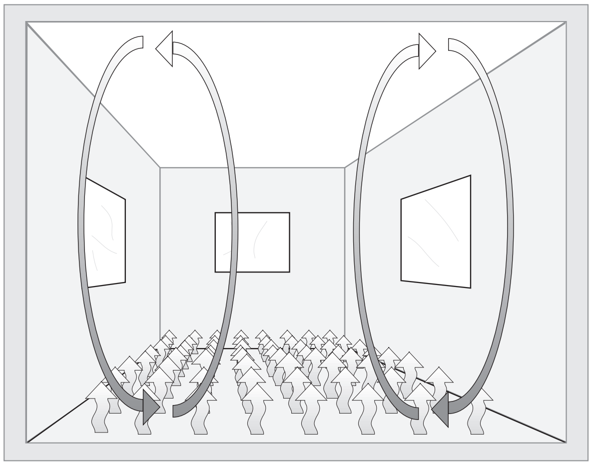


FIGURE 8: RADIANT FLOORS

Convective Component:
38% -45% of total output

Maximum Surface Temperature:
85°F in areas where people stand, 90°F in border areas

Maximum Output: Typically 45 BTU/HR/SQ FT at a surface temperature of 85°F

Notes: Output may be more limited by resistance of floor coverings

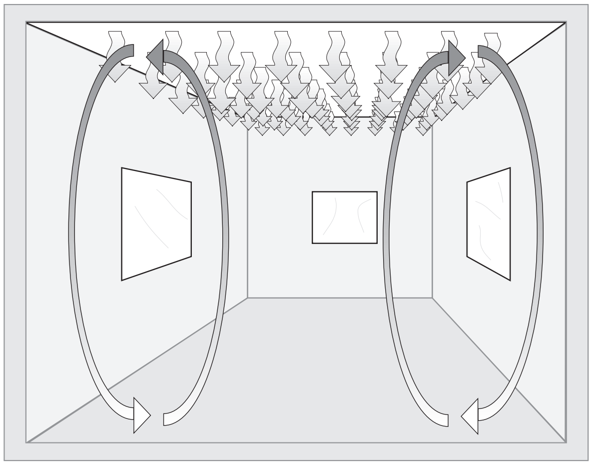


FIGURE 9: RADIANT CEILINGS

Convective Component:
4% -10% of total output

Maximum Surface Temperature:
100°F in areas with ceilings up to 10', 110°F in higher ceiling areas

Maximum Output: Typically 45-55 BTU/HR/SQ FT

Notes: Since surface temperatures are higher than with floors, radiant ceilings can have a higher output

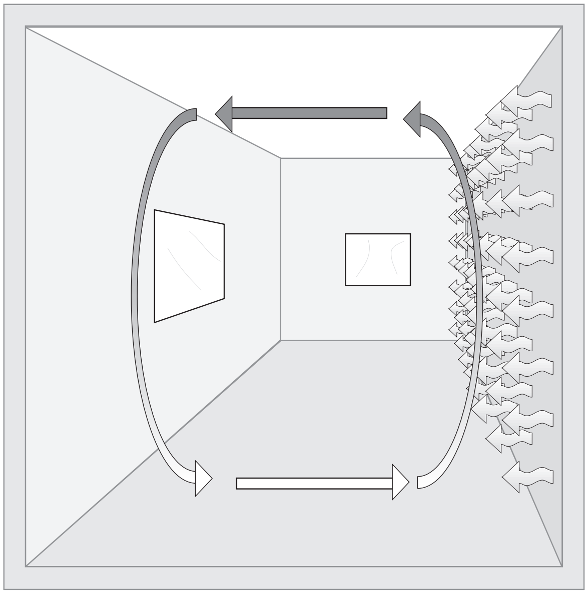


FIGURE 10: Radiant Walls

Convective Component:
10% -20% of total output

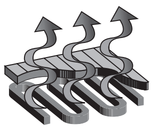
Maximum Surface Temperature:
100°F

Maximum Output: Typically 45-55 BTU/HR/SQ FT

Notes: Since surface temperatures are higher than with floors, radiant walls can have a higher output

While this manual contains a great deal of technical information about radiant heating, the basic principles are quite simple and quite forgiving.

Zurn has available software to make designing systems easy. It is very important that the user is also familiar with the information in this manual.



Right Radiant Software is a powerful tool for heat loss and design

THE IMPORTANCE OF THE DESIGN

Radiant panel heating systems are integrated within the structure. They are embedded in the floors, ceilings and walls in a manner that becomes a permanent part of the structure. Therefore, it is extremely important during the design process to perform a thorough assessment of the building. Particular attention must be paid to the structural heat loss, potential use patterns, and the thermodynamics of radiant panel performance to determine suitability of the design. Radiant panel heating systems have definite limits in terms of maximum output that must never be exceeded.

Analyzing heat loss, determining the radiant panel output, planning the tubing layouts and flow rates, and selecting the appropriate controls and heat source are the key elements of designing a complete radiant heating system. Following the design process described in this manual will help ensure that the radiant heating system will successfully meet the needs of each project.

ADVANCED PRODUCTS have now made radiant heating easy to control and very long lasting.

RADIANT HEATING IS NOW PERFECTED AND HAS A GREAT FUTURE

Radiant heating has always been a good idea but has now been perfected with modern materials and controls. The idea of radiant floors dates back at least as far as the Romans. The Romans heated the floors of their baths with vast underground fire boxes and long, efficient flues under the floors. The famous American architect Frank Lloyd Wright was a great believer in radiant heat for most of his career. In the 1950's many houses were built on the east and west coasts of the United States with radiant heat using primitive controls, copper, or steel pipe. These system showed the promise of radiant heat in delivering comfort, but had problems with control and longevity of materials. New controls and the use of PEX tubing for radiant heating have perfected radiant heating into a reliable, long lasting method for heating. This is demonstrated by the tremendous use of radiant heating in Europe and very fast growth rates for its application in the United States and Canada.

AUTHENTIC SELLING

Authentic selling can be defined as selling something you believe truly improves the life of the consumer. At Zurn we authentically believe in radiant heating and in the products and services that we provide.

RADIANT HEATING WITH ZURN IS GOOD BUSINESS

Many radiant heating contractors remark that radiant heating is a wonderful business to be in. They know that properly designed radiant systems generate good will and many happy customers. They know that providing real comfort improves the quality of life for their customers. The radiant installer can be in the enviable position of selling a product that he or she really believes in. The authenticity of selling quality comfort is a profitable business opportunity. Zurn provides the quality products and services you need to do this right.

This chapter provides an overview of the products and services available from Zurn Radiant Heating Systems.

CHAPTER 2: SYSTEM OVERVIEW

The Products And Services You Need From Zurn

The Zurn Radiant Heating System is a complete system of tubing, fittings, manifolds and controls that are matched for optimum performance and reliability, providing many years of relaible service. The product line is further enhanced by technical support staff, training programs, design software, knowledgeable dealers, and a nation wide network of sales representatives. When used together, the products of the Zurn Radiant Heating System provide trouble-free installation and long term reliability.

There are three primary commercial methods for producing PEX tubing: Silane method, Peroxide (or Engel) method and Radiation (or E-beam) method. Zurn makes Silane method PEX because we believe that it produces the highest quality product with the greatest flexibility and efficiency in manufacturing.

PEX, THE HEART OF THE SYSTEM

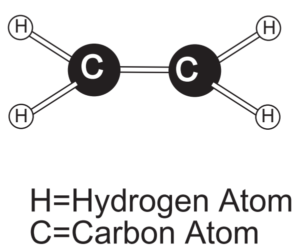
PEX was developed to replace rigid and non-corrosion resistant fluid distribution materials such as steel pipe, copper tubing and CPVC – among other products. PEX tubing has become the predominant tubing used for radiant heating world wide and has been in use for more than 25 years. The PEX system demonstrates these advantages over rigid piping systems:

- Long life expectancy and high temperature ratings
- Requires up to 90% less fittings – reducing installation time.
- Encrustation resistant – no mineral and lime build-up like other materials.
- Corrosion resistant – tubing can be installed directly in concrete.
- Resistant to electrolysis and poor water quality.
- Freeze damage resistant – able to expand and avoid costly ruptures.
- Water hammer resistant – absorbs water hammer in flexible pipe walls.
- Quieter than copper or CPVC systems – does not amplify noise.
- Pricing is very stable, unlike copper.
- Lightweight and flexible – easy to handle and install.
- Flexibility in installation techniques, PEX can be used in many parts of the system-supply and return lines as well as the tubing in a radiant panel.
- The materials can be easily shipped by truck or UPS.

The American Society for Testing and Measurements (ASTM) has developed minimum performance standards to determine PEX tubing's suitability for high temperature, pressure fluid distribution applications. In North America, PEX made by the various different methods are certified to the same standard by an independent third party when made by a quality manufacturer. That standard is ASTM F876.

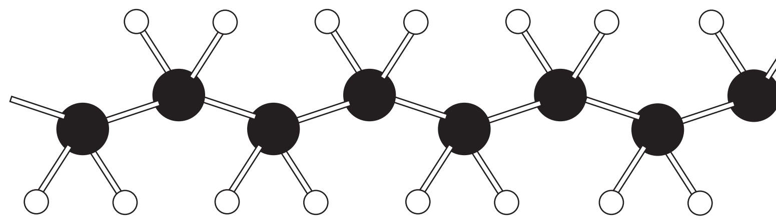
WHAT IS PEX?

PEX is an acronym: PE stands for Polyethylene and the X stand for a process called cross linking. Proper cross linking of polyethylene adds exceptional chemical and physical properties to the pipe making it specifically suited to hydronic heating systems and potable water plumbing systems. The basic building blocks of PEX are polyethylene molecular chains which are called polymers. These chains can be long and include up to 50,000 carbon atoms. Polyethylene is a hydrocarbon. Hydrocarbons are made from carbon and hydrogen atoms.



The Ethylene Molecule, a basic building block in PEX

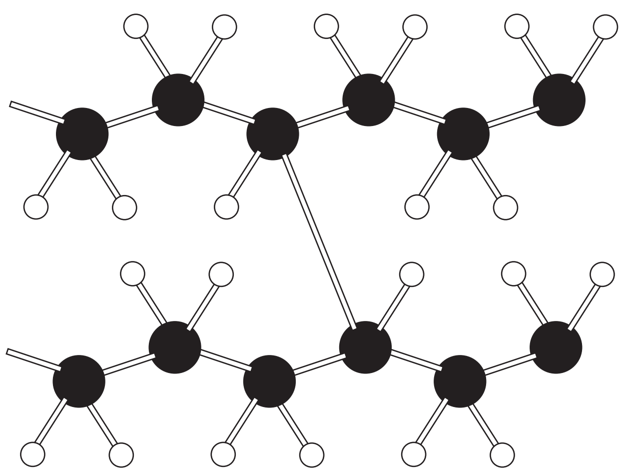
Polyethylene is made from chains of hydrogen and carbon atoms. Cross-linked polyethylene is a product in which those chains are linked together to make a much more advanced and stable product.



Polyethylene Molecular Chain

Cross-linked polyethylene is made of polyethylene chains linked together by carbon-to-carbon bonds or, in the case of PEX by a somewhat more complex Silane bridge bond. This cross-linking converts a product from one with linear chains to one that is bound strongly together in a three-dimensional matrix. When this occurs, the material properties of the tubing are greatly enhanced. For example, in non cross-linked polyethylene the molecular chains are not bound together and can under pressure and elevated temperature, deform by sliding past each other. Since cross-linked polyethylene is bound together three dimensionally, it requires breaking these bonds for it to deform comparably. Since these bonds have great strength, this is very hard to do. Cross linking also gives the pipe greater resistance to chemical attack, since it is a very stable polymer.

Zurn manufactures tubing that is 74% cross-linked to produce the highest strength and chemically resistant product possible.



Cross-linked Polyethylene

Zurn utilizes the Silane method of production, which was developed by DOW Corning in the late 1960s. It is initiated by grafting vinyl silane onto the backbone of the polyethylene. This material is then mixed with the optimal levels of antioxidant stabilizers, initiators, colorant dyes and a catalyst during extrusion.

PEX uses a Silane bridge bond that is somewhat more complex than shown. It has numerous advantages, but one of the most important is that it provides superior sites to also attach antioxidants which further protect the pipe from chemical, UV and thermal degradation.

TYPES OF PEX

There are three commercially common methods of cross-linking tubing. They are Silane, Engel and Electron Beam. All three methods can make tubing that when properly manufactured meet the ASTM F876 standard.

Zurn PEX is a superior product

PEX SILANE PIPE HAS HIGH TENSILE YIELD STRENGTH:

Testing Results

Material	73°F	180°F
PEX	**2922**	**1806**
Peroxide/Engel	2438	1647
Radiation/E-beam	2753	1501

Tensile Yield Strength (psi) testing performed at an independent laboratory. Yield strength is the stress point at which the material becomes permanently deformed.

PEX SILANE PIPE HAS HIGH BURST STRENGTH:

Quick Burst Testing Results

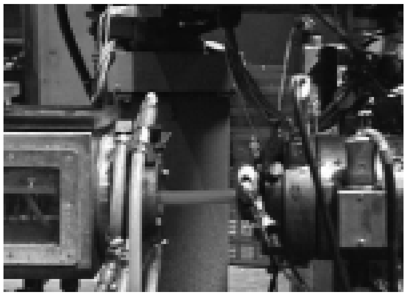
Material	180°F
PEX	**375**
Peroxide/Engel	305
Radiation/E-beam	315

Quick Burst (psi) testing performed at an independent laboratory. Average quick burst pressure at 180°F in accordance with ASTM requirements.

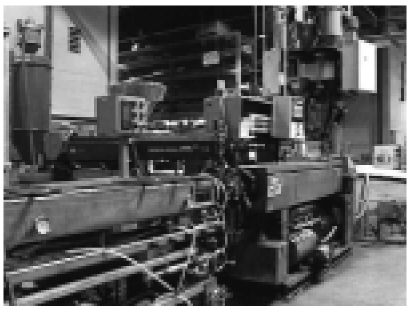
The Engel Method is a method whereby all the cross linking occurs in the extruder at high temperature and pressure. The Engel Method is slow, often more costly, and provides a more challenging environment for adding antioxidants. It also typically uses piston type extruders that pulse the material down a high pressure, long temperature-controlled extruder. Often this makes it more difficult to control the inner diameter of the pipe. The *Electron Beam Method* is a method in which the tubing is exposed to an electron beam after production, and this causes the pipe to cross-link. In this method, exposure, duration and orientation are all issues that need to be tightly controlled. Both Engel and Electron Beam Methods are more limited than Silane Methods in locations for protective additives to reduce chemical, Ultra Violet and thermal degradation

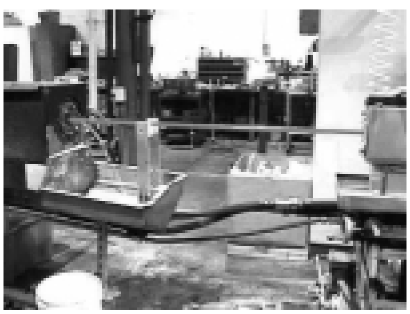
The *Zurn Silane Method* utilizes a standard screw type extruder that provides excellent mixing and dimensional tolerance. Dimensional tolerances is particularly important when utilizing crimp type insert fittings. In the Zurn Silane Method, the silane material is grafted onto a polyethylene backbone to provide the appropriate number of cross linking points. The tubing is extruded with an additional catalyst that initiates the cross linking reaction. Although the mixture would finish cross-linking on its own, the extruded tubing is then run through a water or steam bath to speed the curing time. The compound formulation is the determining factor in the degree of cross-linking, so precise control is achieved (71-74%). Higher degrees of cross-linking are achievable (up to 90%) by simply grafting more silane molecules onto the polyethylene. This is not necessary, though, because the starting density of the base polyethylene used in Zurn Silane production can be and is typically higher than in the other two methods. The starting density of PEX is 0.952 g/cm3 which gives PEX the highest burst pressure ratings and highest tensile strength in the industry. Unlike the Peroxide/Engel and Radiation/E-beam methods, PEX/Silane produced pipes will continue to cross-link to completion, if necessary, even after the extrusion process is completed. This ensures a perfectly cross-linked product every time. Every foot of PEX tubing is placed in high temperature steam chambers to drive the cross-linking of the tubing to completion before it ever leaves our production plants.

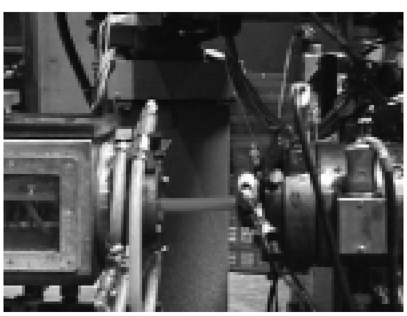
Zurn chose the Silane method of production for very significant reasons. Additives like dyes (for producing colored tubing), antioxidant stabilizers and ultraviolet (UV) stabilizers are critical to the benefits and overall quality of our tubing. During Silane production, these additives do not interfere with the material's ability to cross-link (as in other methods), so the optimal levels of each of these products are in every inch of PEX that is installed, ensuring long-term resistance to chemical and oxidative degradation and very good service life for our products. Because the Zurn Silane method relies on a chemical mixture and not high temperature and pressure to cause the material to cross-link, the dimensional stability is much more consistent as well.



Zurn PEX is extruded in a state-of-the-art factories with a commitment to quality control.







This consistency allows us to utilize our QICKSERT insert and crimp fitting for permanent, worry-free connections every time and we back it with a 25-year limited warranty (the best in the industry)! Special tools that stretch the tubing to a consistent diameter are not necessary. Silane Method PEX demonstrates superior performance in these areas:

High temperature and pressure resistance
Life expectancy at elevated temperatures and pressures
Resistance to UV degradation (up to 6 months of direct exposure)
Flexibility and impact resistance to stand up to tough job site conditions and allow for easy installations
Available in colors – red, white and blue
Backed by a 25 year limited warranty on the tubing and QICKSERT fittings (when installed as a system).

USING ZURN PEX

PEX tubing is cross linked polyethylene that is used in both potable water systems and radiant heating applications that do not contain ferrous metals. PEX Barrier Tubing is cross linked polyethylene with an "Oxygen Barrier" added to limit the amount of oxygen entering a system and causing oxidation of ferrous (cast iron or steel) components. PEX barrier tubing is listed for use in Radiant Heating Systems only, and maybe used in Potable Water.

Systems and Standards

PEX, PEX Barrier Tubing, and PEX insert fittings meet the performance requirements of the following standards:

American Society for Testing and Materials
ASTM F876 Cross linked Polyethylene (PEX) tubing
ASTM F877 Cross linked Polyethylene (PEX) tubing and Fitting Systems
ASTM F1807 Metal Insert Fittings for PEX Tubing
NSF International (National Sanitation Foundation)
ANSI/NSF Standard 14 Plastic Piping Components
ANSI/NSF Standard 61 Drinking Water System Components Health Effects

Certifications and Listings

PEX and PEX Barrier Tubing and fittings have the following certifications and listings from these independent evaluation services:

NSF International (National Sanitation Foundation)
PEX non-barrier tubing and insert fittings
PEX barrier tubing
National Evaluation Service (NES) – BOCA, ICBO, SBCCI
PEX non-barrier tubing and insert fittings
International Association of Plumbing and Mechanical Officials (IAPMO)
PEX non-barrier tubing, PEX barrier tubing, and insert fittings
Canadian Standards Association (CSA)
PEX non-barrier tubing and insert fittings

RATINGS: ZURN PEX TUBING CARRIES THE FOLLOWING MAXIMUM TEMPERATURE AND PRESSURE RATINGS:
200°F (93.3°C) at 80 psi
180°F (82.2°C) at 100 psi
73.4°F (23°C) at 160 psi

WARNING: Do not exceed temperature or pressure limitations. PEX, PEX Barrier Tubing and fittings are manufactured to meet the performance requirements of ASTM F876 and ASTM F877. The temperature and pressure ratings above have been developed by the Plastic Pipe Institute on the basis of long term testing. These ratings are given on the basis of actual test data in accordance with ASTM F876 and Test Method D2837.

Model Codes

The following Model Codes reference Cross linked Polyethylene (PEX) tubing or plastic tubing rated at 100 psi at 180 °F. PEX tubing and PEX Barrier Tubing are rated at 100 psi at 180 °F per ASTM F876 and F877 standards:

Plumbing
- International Plumbing Code – 2000 (BOCA, ICBO, SBCCI)
- Uniform Plumbing Code – 2000 (IAPMO)
- International Code For One And Two Family Dwellings -- 2000

Mechanical
- International Mechanical Code – 2000 (BOCA, ICBO, SBCCI)
- Uniform Mechanical Code – 2000 (IAPMO)

Dimensions

PEX and PEX Barrier Tubing are available in the following CTS sizes:
PEX Non-barrier tubing ASTM F876 Nominal Sizes:
3/8" 1/2" 5/8" 3/4" 1" 1.25" 1.5" 2"
PEX Barrier tubing ASTM F876 Nominal Sizes:
3/8" 1/2" 5/8" 3/4" 1"

Markings on Tubing

PEX tubing is marked according to the ASTM F876 and F877 standards and contains foot markings which are an assistance in installation.

Tubing Information

Zurn Designation	Nom. Size (in)	Avg OD (in)	Avg ID (in)	Min Wall (in)	Wt Per 100Ft (lbs)	Volume (gal/ft)
Q2P/QH2P	3/8	0.500	0.35	0.07	4.19	0.0050
Q3P/QH3P	1/2	0.627	0.475	0.07	5.4	0.0092
QJP/QHJP	5/8	0.750	0.574	0.083	7.8	0.0134
Q4P/QH4P	3/4	0.875	0.671	0.097	10.2	0.0184
Q5P/QH5P	1	1.125	0.862	0.125	16.62	0.0303
Q6P*	1-1/4	1.375	1.055	.153	25.6 lbs	0.0454
Q7P*	1-1/2	1.625	1.245	.181	35.9 lbs	0.0632
Q8P*	2	2.125	1.629	.236	61.1 lbs	0.1083

* Check For Availablity

Warranty

PEX Tubing, PEX Barrier Tubing and Qicksert fittings are warranted for 25 years for hydronic applications when properly installed according to our installation instructions. All other system components are warranted for two years from the date of installation. For complete warranty information see appendix C.

Chapter 2

***APPLICATIONS: PEX TUBING IS PERFECTLY SUITED FOR MANY HYDRONIC HEATING APPLICATIONS INCLUDING*:**

- residential, commercial and industrial radiant floor/wall/ceiling heating
- potable water systems
- snow and ice melt systems
- soil conditioning in greenhouse/ stadium applications
- hot water baseboard heating distribution
- water distribution piping to manifolds, hydronic coils in air handlers, etc.
- radiant cooling
- underground fluid distribution
- anywhere that hot or cold fluid distribution is needed (within the temperature and pressure limitations)
- many, many more …

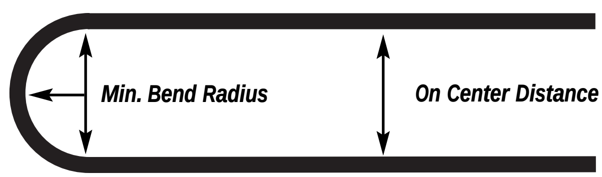
PEX TUBING EXPANDS SIGNIFICANTLY WITH TEMPERATURE CHANGE:
Approximately 1.0" per 100' per 10°F temperature rise. When the tubing is embedded in cement or gypsum cement slabs and thin slabs, it cannot expand in length or width. Since it is locked in place by the cement, it accommodates the expansion under these circumstances by thickening the pipe wall inward, slightly reducing the inner diameter of the tubing. PEX has been successfully embedded in slabs for over a quarter century. It is a proven and successful use of PEX.

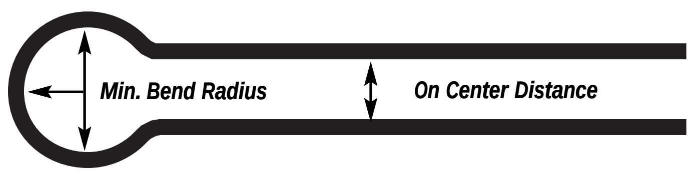
Flexibility

PEX Tubing and PEX Barrier Tubing are very flexible over a wide range of temperatures. For cold weather installation, bends should be made slowly to avoid kinking, or the tubing can be warmed prior to installation. PEX is very resistant to damage when exposed to freezing temperatures.

Bend radius

PEX is very workable and can be bent to a radius equal to 6 times the outside diameter of the tube without kinking. For 1/2" inch nominal tubing, this equates to a radius of 3.75 inches or a diameter of 7.5 inches. If the tubing must be bent against the natural curvature of the coil, multiply the normal bend radius by 3. Narrower on center distances can be achieved by making a keyhole loop on the ends. See figure below.





Linear Expansion

When free to expand, cross linked polyethylene (PEX) tubing will expand at an approximate rate of 1.0 inches for every 100 feet of pipe for each 10°F increase in temperature. Expansion occurs both linearly and radially. Free hanging PEX tubing will actually increase in volume with an increase in temperature. When filled with water, this free expansion can actually accommodate the corresponding expansion of water without an increase in pressure. If the tubing is installed in a manner that restricts expansion, as when it is embedded in a concrete floor, the expansion of tubing and outside diameter will be arrested. This means that the walls will get thicker as the tubing heats up. Thicker walls will reduce the volume of the tubing at the same time the water within it is expanding with temperature.

Chemical Resistance

PEX and PEX Barrier Tubing are highly resistant to chemical degradation from most chemicals present in construction projects, as well as chemicals commonly used in hydronic heating systems. Avoid long term exposure to any chemicals that are harmful to plastics, such as solvents or unusually high concentrations of chlorine.

An oxygen barrier is added as a layer to PEX Barrier Tubing to limit the amount of oxygen than can permeate the pipe wall. The barrier helps protect from corrosion your investment in ferrous components such as cast-iron boilers.

Oxygen Diffusion

Most plastic materials are permeable to oxygen. When plastic tubing is used in hydronic heating systems, the movement of oxygen through the tubing walls can have serious detrimental affects on ferrous (cast iron or steel) components within the system. High levels of oxygen along with high operating temperatures will cause the iron and steel components to oxidize (rust) at a rapid rate and become unserviceable. In order to protect the iron and steel corrodible components from excessive corrosion, PEX Barrier Tubing is available with a specialized Oxygen Diffusion Barrier. The Oxygen Barrier inhibits the passage of oxygen molecules through the tubing wall at a level that is safe for corrodible components and meets the requirements of the current German DIN Standard 4726. Non-Barrier PEX may be used in systems without corrodible components.

PEX pipe can best be described as freeze resistant. That is, it is suitably flexible that it can often freeze without damaging the pipe itself. However, even if the PEX does not burst, the expansion from freezing may damage concrete and other components in a system. Care should be taken to protect fluids in PEX pipe from freezing.

Freezing

Avoid freezing PEX and PEX Barrier tubing when filled with water. Pressure testing with a water and glycol mixture is recommended when installing PEX and PEX Barrier tubing that may be exposed to freezing temperatures prior to system activation. Air testing procedures are listed in Appendix C.

Brazing or Soldering Connections to PEX or PEX Barrier Tubing

Avoid brazing or soldering fittings within 18 inches of PEX or PEX Barrier Tubing connected to the same pipe. Brazed or soldered joints should be completed and allowed to cool before connecting with PEX or PEX Barrier Tubing.

Thawing Frozen PEX or PEX Barrier Tubing:

Do not apply an open flame to PEX or PEX Barrier Tubing. Instead, use an electric hair dryer or heat gun on the low setting to avoid surface temperatures that exceed 200°F.

All plastic pipe can break down when exposed to ultraviolet rays (sunlight) unless they contain certain pigments and stabilizers intended to prevent the damage. Exposure of unstabilized pipe to ultraviolet rays causes the pipe to become brittle and eventually rupture. PEX now has UV stabilizers that are designed to protect a pipe for up to 6 months in case a project is delayed. Even so, it is good practice to minimize the exposure of the pipe to UV rays to as low a level as possible.

Ultra Violet (UV) Light Limitations for PEX or PEX Barrier Tubing

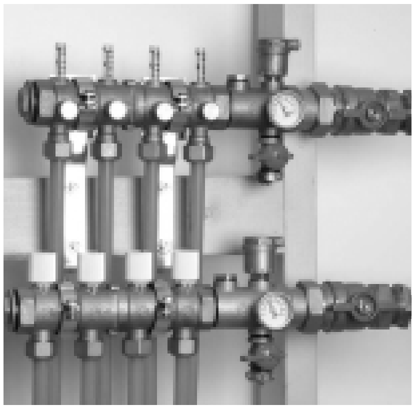
Like most plastic materials, cross-linked polyethylene is subject to ultraviolet (UV) deterioration and must not be exposed to sunlight, either direct or indirect. Outside storage is not recommended, but if necessary, the tubing must be covered with a material that will protect it from ultraviolet light. Failure to do so will void the warranty.

Pressure Testing

Pressure test the system at 80-100 psi hydrostatic pressure or 60-80 psi air pressure in accordance with local code requirements. Pressure testing is to be performed for a minimum of 12 hours prior to pouring slab materials. Pressure must be maintained during site preparation and pouring of slab materials in order to detect any leaks caused by damage to the tubing.

Protection With Glycol

When freezing conditions are likely to occur, a glycol and water solution is recommended to protect the hydronic fluid from freezing. When hydrostatic testing is not feasible, air testing in accordance with the guidelines found in Appendix C of this manual may be used.



QickZone Manifold

QickZone Supply Module

QickZone Return Module

QickZone™ Modular Brass Manifolds

The QickZone manifold is centered around its fully modular supply and return outlets. Constructed of brass, which greatly reduces expansion and contraction difficulties associated with non-brass heating manifolds, it features reliable and easy-to-connect bayonet style locking connectors and can be assembled from two to twelve outlets. It has a maximum working temperature of 230 °F and a maximum working pressure of 150 psi. The heating fluid enters through 1 1/4" full port isolation ball valves with color coded handles, and is directed through 1 1/4" headers designed to handle up to 16 gpm. The supply header features flow gauges, with a flow range from 0.13 gpm to 1.3 gpm, and is designed to take the guess-work out of system balancing. Balancing each circuit is achieved by simply turning the balancing valve until the desired flow rate is indicated on the flow gauge. Balancing valves also feature an integral lock point indicator so that the valve can be closed and reopened to the same position time and time again for circuit isolation. Return headers feature integral shut-off/zoning valves which can be easily fitted with our new zone drive actuators for individual circuit control. System air removal is simplified with two different choices of air vent assembly kits. Air Vent Assembly Kit 1 is installed between the isolation ball valve and first circuit modules. It features a purge valve with a positive seal shut-off valve and a 3/4" hose connection and cap plus a brass auto vent as well as supply and return temperature gauges. Air Vent Assembly 2 is installed on the end of each header and has the same features less the supply and return temperature gauges.

Zurn Copper Manifolds For Radiant Heating

Zurn offers economical copper manifolds for radiant heating in many configurations.

Zurn Fittings For Radiant Heating

Zurn offers three different fitting systems that are matched to the manifold system used – compression, eurostyle and crimp insert fittings.

Zurn Controls For Radiant Heating

Zurn offers a full line of hydronic controls to make your whole system work properly. See chapter on Controls.

Zurn People And Training Are Part Of The System

The network of Zurn technical support staff, representatives and distributors are committed to giving you the training and support that you need to install the system correctly.

This chapter shows many of the major ways Zurn PEX can be installed in radiant panel heating systems.

CHAPTER 3: ZURN PEX RADIANT PANELS

Installation And Construction Methods

General: The methods of constructing radiant panel heating systems are numerous. They can be separated into three main categories; radiant floors, ceilings and walls. Within these three main categories there are several sub categories. This section describes some common methods of constructing radiant panel heating systems. The information is general in nature and is intended to provide only the thermodynamic aspects of these designs. These drawings are not intended to provide any guidance regarding those aspects of the design that are governed by the local building and mechanical codes, such as, but not limited to structural loads, embedded tubing requirements, fire safety, etc.

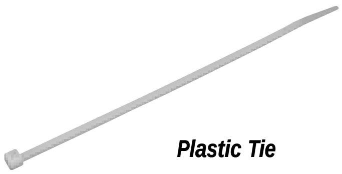
Radiant Floors: Radiant floors are separated into two main categories, those that are placed in concrete and those that are placed on or under suspended wood floors. Within these categories, the methods will vary significantly. The designer and contractor must be familiar with the proper construction methods to properly design a system and avoid any damage to the tubing as a result of improper installation.

Remember that there are many different ways to successfully install radiant panel heating systems with PEX. Many of them will work for your project. Often the most important consideration will be which system is a qualified installer most comfortable and experienced at installing? Other considerations are cost, acceleration, thermal mass or lack of it, and capacity for heat transfer.

Concrete Radiant Floors: Concrete radiant floors can either be placed directly on the grade of the soil or on upper levels of a building over support structures. Suspended Concrete Floors: PEX or PEX Barrier Tubing may be installed on suspended concrete floors. Depending on the type of floor, the construction techniques will vary considerably. If the suspended floor is made of pre-stressed concrete, then the method will be similar to the concrete double pour. If the suspended floor is poured in a corrugated metal pan, the method may be similar to a single pour in a slab on grade, where the 6 X 6 inch wire mesh is welded to the metal pan and the tubing is fastened to the mesh. In all cases, it is important not to undermine the structural integrity of the suspended slab. Therefore, consult with the structural engineer to approve all placement of tubing on suspended slabs.

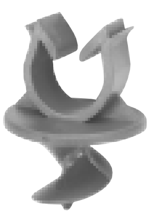
Suspended Wood Frame Radiant Floors: Suspended wood frame radiant floors are those constructed over unheated crawl spaces, or on intermediate floors within buildings. The actual construction and support structures for such floors can vary significantly, with a wide variety of joist, subfloor, under layment and finished floor products. There are three primary types of suspended radiant floors: those which use a poured floor under layment, those which use aluminum heat transfer plates, and those which are constructed within the joists in a free hanging system. The main objective in designing a suspended radiant floor is to achieve the required output without “hot spots” over the tubing.

Zurn provides many convenient ties and clips to secure the pipe to the steel reinforcement or to the insulation, as shown below.

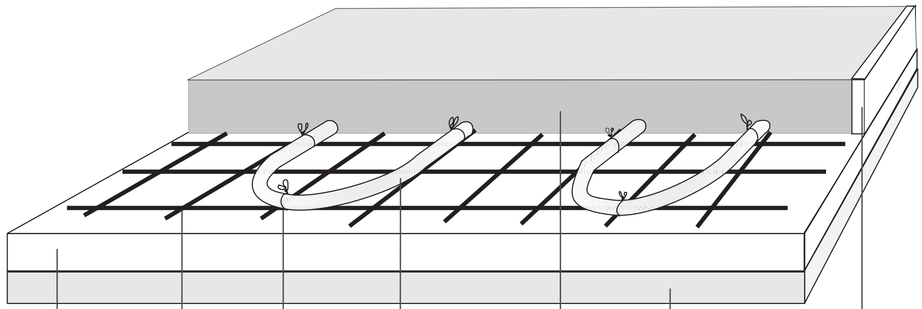


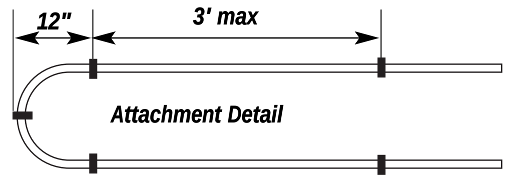
Plastic Tie

Clip For Attaching Tubing To Mesh

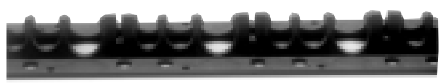


Screw In Clip For Attaching Tubing To Insulation





Track may be attached to the steel and then the pipe snapped in place



INSULATION UNDER SLABS

Industry recommendations for insulating under slabs on grade in residential construction suggest 3 minimum options. Insulate under the whole slab to at least R-5, insulate in or down at the perimeter at least 4' with R-10 insulation, or insulate down to the frost line on the perimeter with a minimum R-value calculated by multiplying 0.125 by the Inside Temperature (°F) - the Outside Design Temperature (°F).

Of these options, Zurn recommends full under slab insulation since it helps the slab respond faster and soil conditions can change. Moist conductive soil will cause a much greater back loss under an uninsulated slab than dry soil. Something as simple as new construction nearby can often change sub soil water movement and soil moisture conditions.

Radiant Floor Slab On Grade

General Comments: Placing a radiant floor panel within a concrete slab on grade is usually one of the simplest and least costly installations.

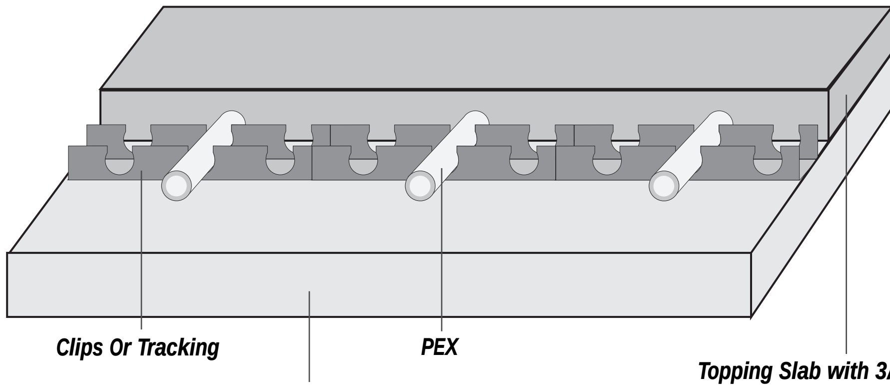
Where to use: Use any time a slab is being poured unless the high thermal mass is a disadvantage.

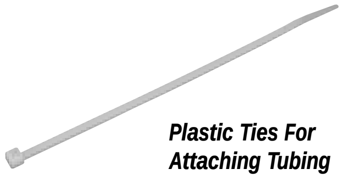
Site Preparation: There is no difference for a radiant slab than for any other slab except that the soil upon which the PEX or PEX Barrier Tubing is placed must be free of any sharp objects or debris that could damage the tubing. If a vapor barrier or insulation is placed beneath the slab, the soil must be smooth and compacted to avoid punctures in the vapor barrier and provide support for the insulation.

How It is Done: Typically, rigid closed cell insulation suitable for use under slabs is placed on well compacted fill. A vapor barrier is often installed either under or over the foam. PEX tubing is usually attached to the mesh or rebar using plastic ties or with clips. Tubing should be secured to the metal every 3 to 4 feet on the straight runs and at the middle of the corners and within 12" of the corner on either side, as shown above.

What To Be On The Look Out For: Pressure test the tubing to code and maintain pipe under test during pour. Try to place the tubing in the middle of the slab by lifting the wire mesh for faster response. Protect tubing where it exits the slab with Zurn sleeving.

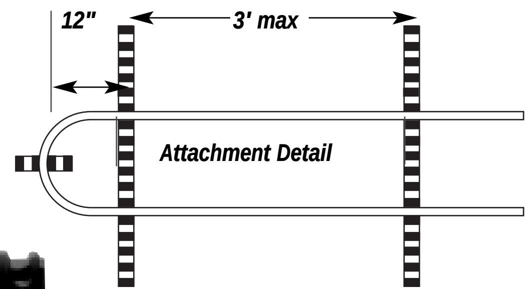
Zurn provides many convenient ties and clips to secure the pipe to the steel reinforcement or to the insulation, as shown below.

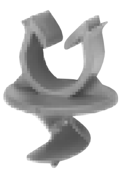




Plastic Ties For Attaching Tubing To Steel

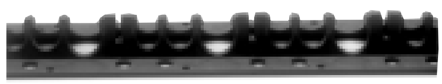
Clips may be glued to base slab or attached to mesh in topping slab





Screw In Clip For Attaching Tubing To Insulation

Tracking may be glued to base slab or attached to mesh in topping slab



TUBING ATTACHMENT OPTIONS

Option 1: Adhere tracking or clips to base slab with construction adhesive.
Option 2: Use flat sheets of 6" x 6" steel mesh in topping slab and attach tubing to it with tracking, clips, or plastic ties.
Option 3: If rigid insulation is used between slabs, use the screw-in type clips.

INSULATING TOPPING SLABS

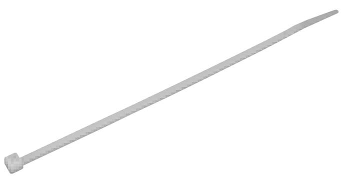
Rigid insulation suitable for use under slabs may be used between the two slabs. Insulation may also be placed under and on the perimeter of the base slab in new construction. In Retrofit applications, upgrading perimeter insulation becomes very important because it is often more easily accomplished.

Radiant Floor Topping Slab Or Double Pour

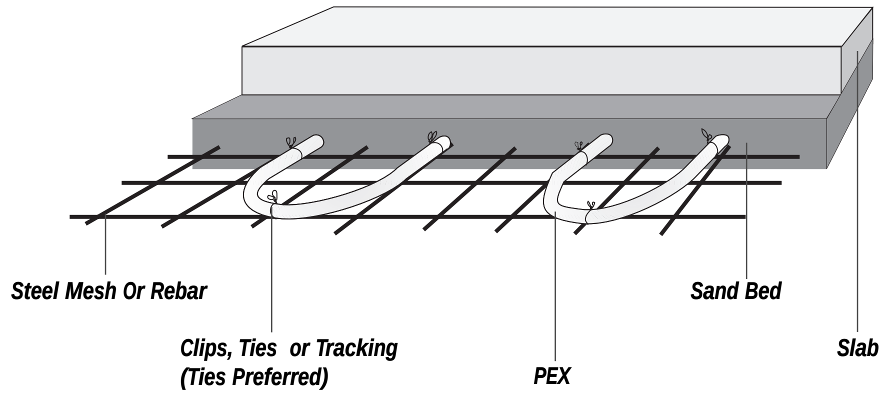
General Comments: In this method of construction, the tubing is embedded within a topping slab that is placed over an existing concrete slab. It may be used in a retrofit application when a slab already exists at the site, or when a secondary slab is poured over a structural slab. The topping slab may be concrete or a poured floor under-layment, depending on the structural and compressive loads the slab must meet.
Where to use: This is often done in retrofits and increasingly in new construction in seismic areas.
Site Preparation: Make sure existing slab is clean and structurally sound.
How It is Done: Typically, the PEX or PEX Barrier Tubing is attached to the structural slab by use of pipe tracking. The pipe tracking is either fastened directly to the concrete floor with adhesives or concrete fasteners, or to the insulation with pipe track insulation staples. Other methods of fastening the tubing to the floor will provide acceptable results as long as the fastener does not damage the pipe. Tubing should be installed at least 3/4" of an inch below the surface of the topping slab. Consult with the local codes and the structural engineer for specific requirements.
What To Be on the Lookout For: Pressure test the tubing to code and maintain pipe under test during pour. Protect tubing where it exits the slab using Zurn protective sleeving.

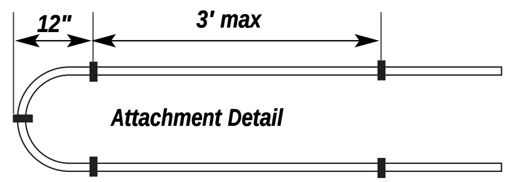
Zurn provides many convenient ties and clips to secure the pipe to the steel reinforcement.

Clips may be attached to mesh in sand bed

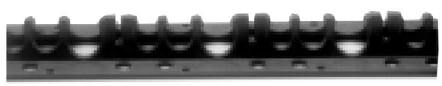


Plastic Ties for attaching tubing to steel in sand bed





Tracking may be attached to mesh in sand bed



TUBING IN SAND BEDS NEEDS TO BE WELL ATTACHED
Since plastic tubing expands and contracts with changes in temperature, it will "walk" in a sand bed unless well attached to steel. It is a good idea to stake the steel firmly to the ground. Adhere tubing with clips, plastic ties or tracking.

INSULATING SAND BEDS
Rigid insulation suitable for use under slabs may be used under the sand bed. In general follow code and industry recommendations as shown in sidebar on Radiant Floor, Slab On Grade.

Radiant Floor: Tubing In Sand Bed Under Slab

General Comments: Typically, the tubing is placed beneath the slab in a bed of sand or other acceptable soils. The purpose of this method is to obtain greater mass storage of energy. In order to meet the heating load at the surface of the slab, more physical material will need to be heated. The stored heat acts as a flywheel or heat sink and allows very little variation in surface temperature.

Where to use: The flywheel effect can be useful in projects where the heat energy is intermittent, such as solar or electric off-peak applications.

Site Preparation: After the insulation is in place and the site preparation is complete, 6 inch by 6 inch wire mesh is placed in the same horizontal plane as the tubing.

How It is Done: The wire mesh is used to support the tubing within the sand bed. The PEX or PEX Barrier Tubing is then attached to the wire mesh with wire ties, plastic tie wraps, or specially designed plastic clips. These fasteners should be placed at intervals of no more than 2 feet. The tubing is laid out onto the wire mesh according to the layout design. The 6-inch by 6-inch wire mesh provides a convenient measuring guide to assist in following the layout.

What To Be on the Look Out For: Once the tubing is installed and pressure tested, the sand bed is placed over the tubing and leveled to accept the concrete slab. Care must be taken not to damage the tubing while laying the sand bed or concrete. Maintain test pressure during these operations so that any loss of pressure can be observed.

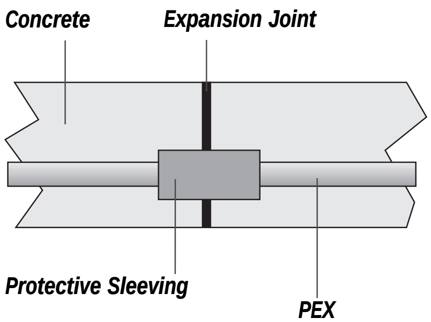
Details Of PEX In Concrete

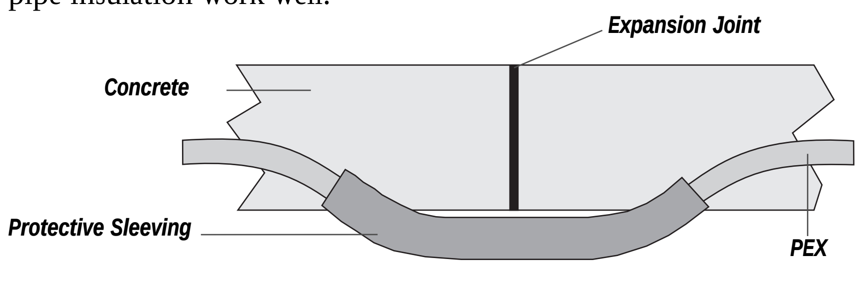
There are general considerations that should be observed when using PEX and Barrier PEX in cement.

Do not tie PEX to steel reinforcement with wire ties with sharp ends. The preferred method is to use plastic zip ties, clips or tracking.

Do check all steel reinforcing tie wires to make sure that no sharp wire ends that could puncture the tubing are protruding near where the pipe is installed.

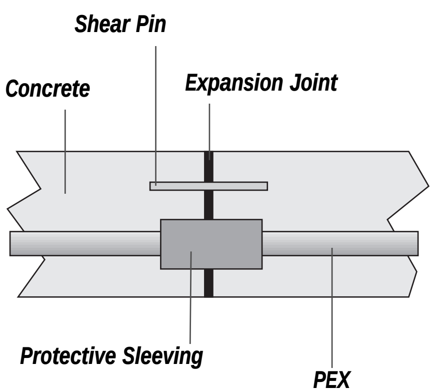
Do sleeve tubing where it goes through expansion joints in the cement, or alternatively go under and around the expansion joint. Pieces of foam pipe insulation work well.



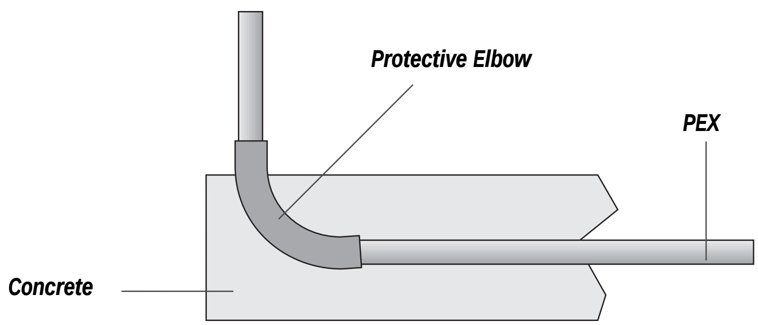


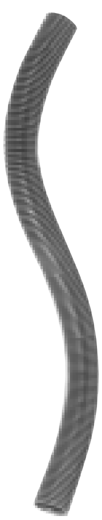
Do insist that normal expansion joints should be installed. A radiant slab may expand 1/20" over thirty feet due to temperature changes.

Consider using shear pins across an expansion joint in a seismic or areas prone to severe slab settling. These help prevent differential settling of sections of the slab, but must be carefully designed to still allow for horizontal expansion and contraction.



Do protect the tubing where it exits a slab. This is normally done with a long sweeping plastic elbow.






Zurn can supply material for use as a protective sleeve across expansion joints and conduit type protective elbows for use where the tubing exits the slab.

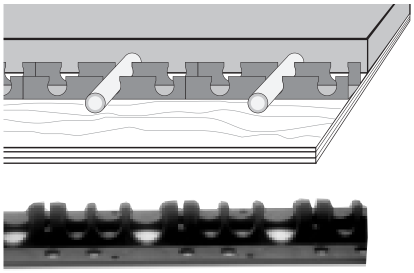
Do not use duct tape or other tape on the tubing without checking with Zurn. Many types of tapes use solvents in the adhesive that are aggressive to the pipe.

Keep the pipe ends capped while installing the tubing so that dirt and sand do not get in the tubing. It is very hard to get out later.

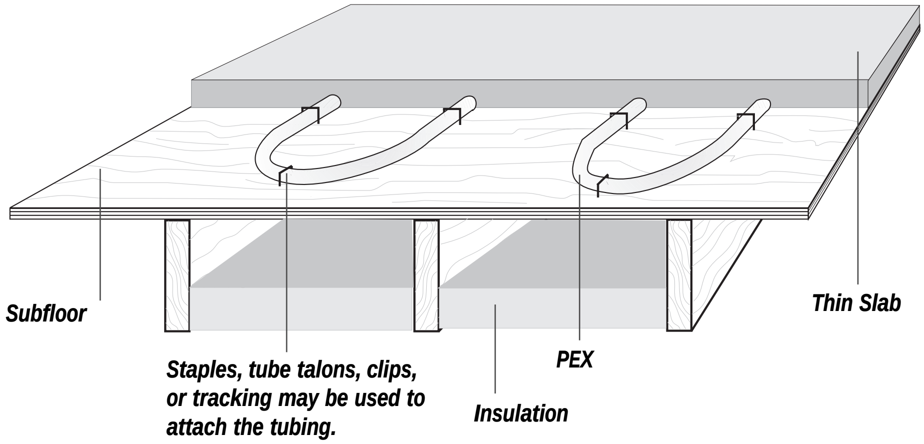
Replace any tubing that has been damaged during installation. Walk the tubing installation and check that the pipe is in sound condition.

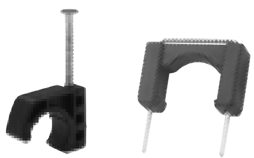
Chapter 3

Zurn provides many convenient ways to secure the pipe to a wooden subfloor.

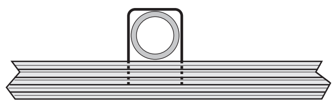


Tracking may be attached to subfloor and tubing snapped in place, as shown above.

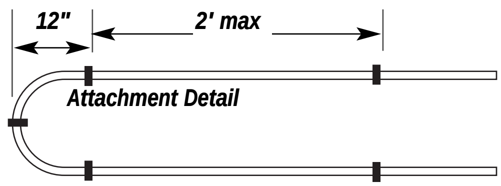




Staples and talons come in many shapes and sizes.



If staples are used they should not be so tight that there is an indentation made on the tube.



ATTACHMENT: The tubing needs to be well attached to the subfloor to maintain the recommended 3/4" minimum of cover.

THIN SLAB CEMENTS

Most thin slabs are poured using gypsum based cement or conventional cement. With conventional cement, often a 6-sack mix with pea gravel is pumped as stiff as will flow, and then the slab is dried slowly to prevent cracking. Gypsum based cements typically weigh 13.5 lbs. sq. ft. and regular cement 17.5 lbs. sq. ft. at a thickness of 1.5". Lightweight cements should be avoided because they are weaker and more likely to crack.

PLACEMENT OF TUBE: Do not install tubing closer than 6" from framing to allow for future carpet tack strips, etc. Protect tubing with metal plates where it exits the floor and where future door jambs and the like may be installed.

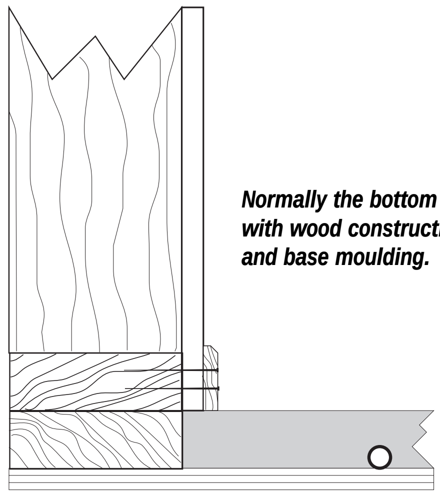
Floor Underlayment Suspended Radiant Floors:

General Comments: In this method the PEX or PEX Barrier Tubing is embedded within a thin, lightweight topping slab placed over a suspended wood subfloor. It is important to consult with the vendors to insure that the topping slab is of sufficient compressive strength to carry the loads without damage to the tubing and is capable of operating at elevated temperatures.
Where to use: It may be used in new construction or in a retrofit application over an existing floor.
Site Preparation: Make sure subfloor is clean, level and free of sharp objects. Seal all holes in floor with silicone or similar sealants.
How It is Done: Usually walls are framed with an extra bottom plate and a 1.5" thin slab is utilized. Typically the subfloor is sealed with PVA, then the tubing is fastened to the floor using pipe tracking, staples, tube talons, clips or alternative compatible fastening methods that do not chafe, nick or damage the tube. Fasteners will provide acceptable results as long as they do not damage the pipe. Tubing should be installed at least 3/4" of an inch below the surface of the slab. Consult with the local codes and the structural engineer for specific requirements.
What To Be on the Lookout For: Check the loads, span and likely deflection of the subfloor at the design stage. Plan for the extra thickness of the slab and how that effects stair construction, etc. Pressure test the tubing to code and maintain pipe under test during pour and construction phases that might damage the tube. Protect the tubing where it exits the slab with Zurn protective sleeving.

Specialty tools from Zurn make installing the pipe easier. Pictured above: air powered stapler with walking stick for large jobs, and hand powered unit that can be used for smaller jobs.

Notes on thin slabs with suspended floors:

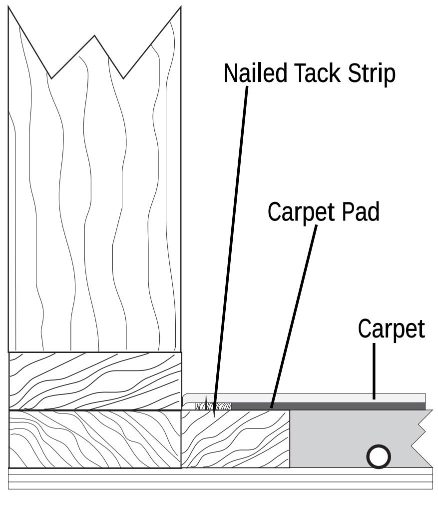
The most common thin slab applications use 1.5" of cement or gypsum based cement. Normally, in a wood framed building, the framing is modified to include a double bottom plate to accommodate the thickness of the cement and still allow for the nailing of the sheetrock and base molding. When carpet is to be installed over the thin slab, some contractors like to run an additional perimeter strip of wood around the outside to allow nailing of the carpet tack strips to wood. This avoids having to glue the tack strips down. Nailing tack strips to the outer edge of a thin slab often chips and damages the edge of the slab and should be avoided where possible.

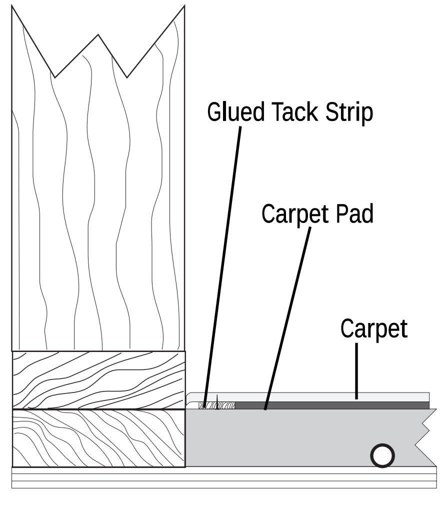


Normally the bottom plate is doubled when using a thin slab with wood construction to allow for the nailing of sheetrock and base moulding.

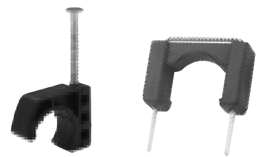
The preferred method of attaching carpet tack strips with a thin slab is to either nail carpet tack strips to an extra strip of wood which also functions as a screed when pouring the slab, or to glue them to the thin slab, as shown below.

NOTE: When PEX or PEX Barrier Tubing is installed in a poured floor underlayment, it is best to apply the underlayment in two pours. During the first pour, the under layment is placed up to the level of the top of the tubing and left to "set up". This process will encapsulate any debris and release any trapped air bubbles within the first pour. The second pour brings the floor up to its proper level. Applying two pours will result in a much better finish on the topping slab.

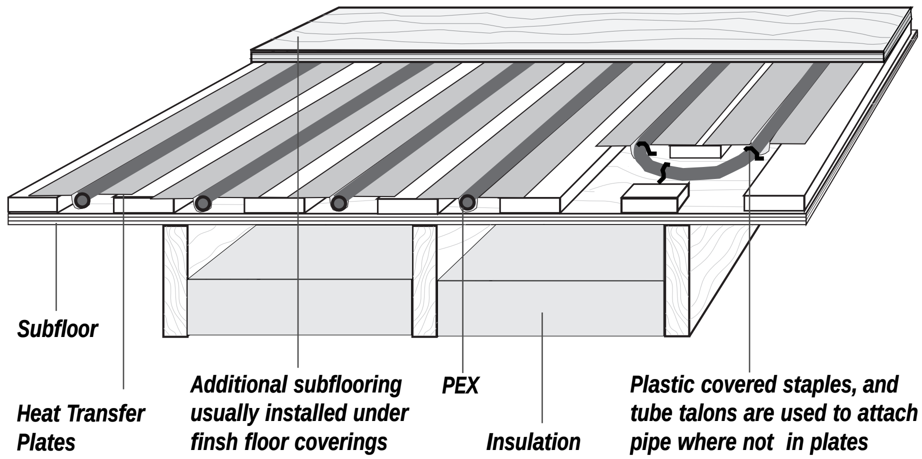


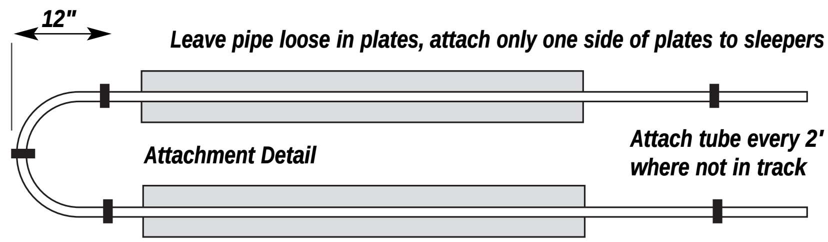


Zurn provides many convenient ways to secure the pipe to a wooden subfloor where it is not in the metal heat transfer plates:



Staples and talons come in many shapes and sizes.





Chapter 3

NOISE AND METAL PLATES

Plastic pipe expands significantly with temperature change, and this must be accounted for in the installation of metal plate systems to prevent noise. Barrier Pex pipe is tackier as it heats up and is more prone to creating noise as the pipe moves through the plates. Measures that will minimize the likelihood of noise are:

1) Secure on one side only, single groove plates, allowing the other wing to move to accommodate expansion.
2) Place a layer of 1 mil clear polyethylene between the pipe and the plate. Polyethylene stays slippery as it heats up and will move in the plate more freely.
3) Use a control strategy that modulates water temperatures to control room temperature. This way the temperature changes in the tubing and plates are gradual.

Radiant Floor Using Sandwich Method With Plates:

General Comments: In this method the PEX or PEX (normally 1/2") Barrier Tubing is placed between sleepers in heat transfer plates over a wood subfloor.

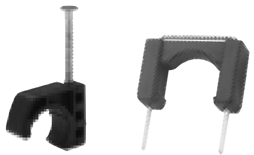
Where to use: It may be used in new construction or in a retrofit application over an existing floor.

Site Preparation: Make sure subfloor is clean, level and free of sharp objects.

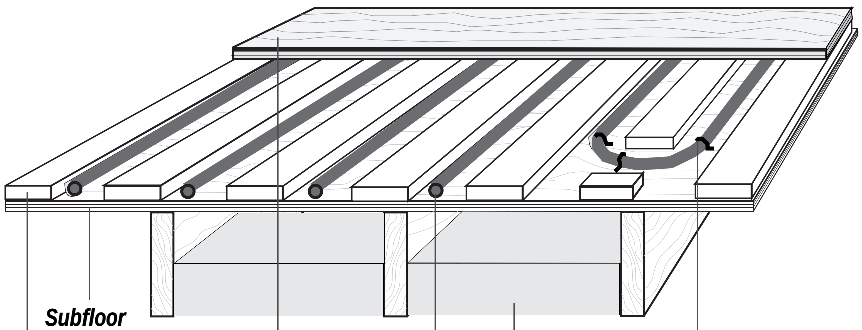
How It is Done: 3/4" x 4" sleepers are firmly attached to the wood subfloor 8" on center by gluing and nailing or screwing Notches are cut in sleepers to allow for tubing. Metal heat transfer plates are installed by attaching one side only to sleepers. Metal heat transfer plates should cover approximately 80% of sleeper area. Use tube talons to attach tubing on corners and staights where not in plates. Usually another layer of subflooring is installed over the sleepers before finished floor goods are applied.

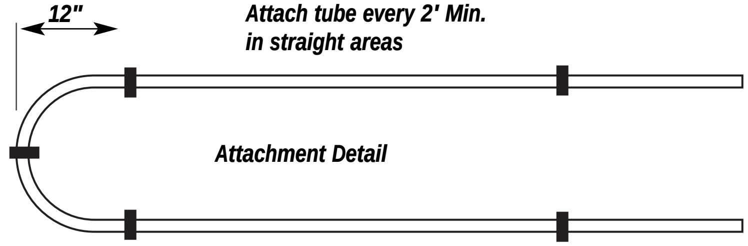
What To Be on the Lookout For: Do not attach plates on both sides. Where curving pipe between sleeper bays, firmly attch on both sides with tube talons. Allow adequate space in notches in sleepers so as not to pinch pipe against sleepers when curving pipe between sleeper bays.

Zurn provides many convenient ways to secure the pipe to a wooden subfloor where it is not in the metal heat transfer plates:



Staples and talons come in many shapes and sizes.

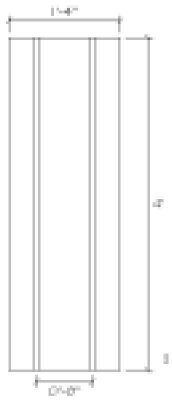




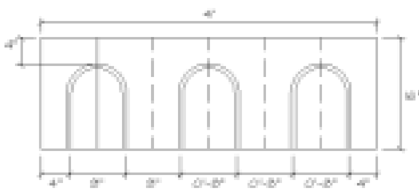
Radiant Floor Using Sandwich Method Without Plates:

General Comments: In this method the PEX or PEX (normally 1/2") Barrier Tubing is placed between sleepers over a wood subfloor.
Where to use: It may be used in new construction or in a retrofit application over an existing floor but should only be used where modest heat output is required and where floor coverings are of a modest R-value.
Site Preparation: Make sure subfloor is clean, level and free of sharp objects.
How It is Done: 3/4" x 4" sleepers are firmly attached to the wood subfloor 8" on centers by gluing and nailing or screwing Notches are cut in sleepers to allow for tubing. Tubing is attached at a minimum of every 2' on straight runs. Use tube talons to attach tubing on corners and staights. Usually another layer of subflooring is installed over the sleepers before finished floor goods are applied
What To Be on the Lookout For: Use only where the reduced output due to lack of plates is acceptable. Allow adequate space in notches in sleepers so as not to pinch pipe against sleepers when curving pipe between sleeper bays.

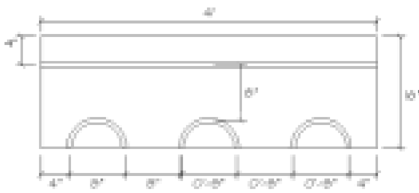
Zurn provides 3 shapes of Thermal Track:



Straight Panel

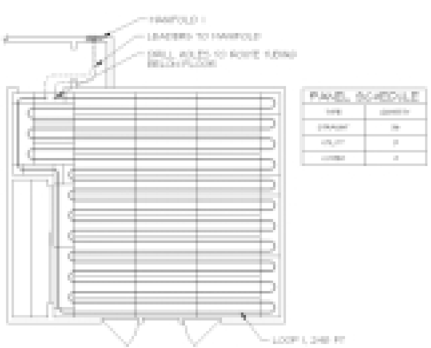


Utility Panel

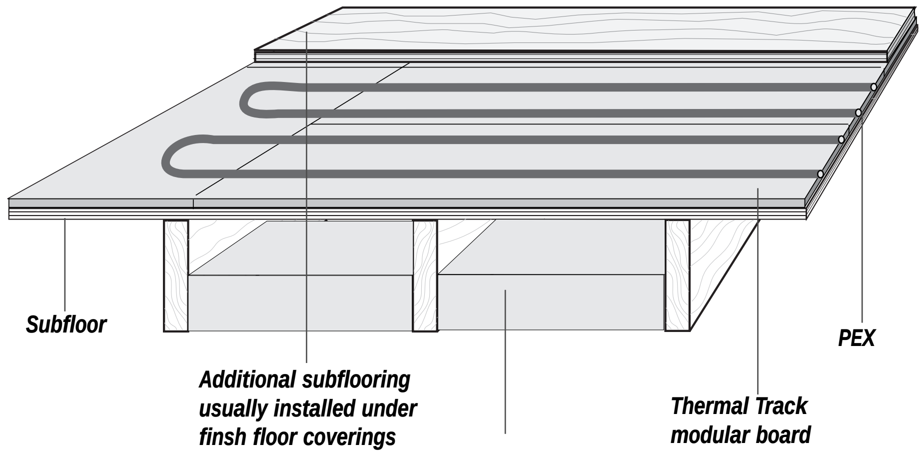


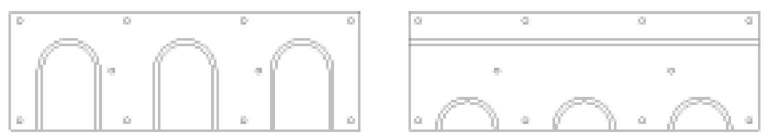
Combo Panel

Thermal Track is a thin dense board with an upper layer of aluminum to improve heat transfer.

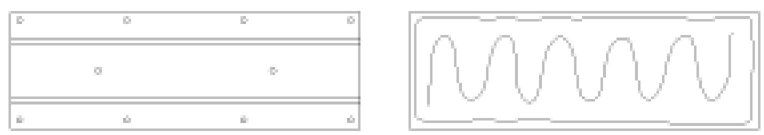


Thermal Track installations need a layout plan as shown above. A typical Thermal Track installation requires 70% Straight Panels, 15% Utility Panels and 15% Combo End Panels. A 10% overage factor is usually a reasonable allowance.





Be sure to follow Thermal Track gluing and attachment instructions.



Radiant Floor Using Thermal Track Modular Boards:

General Comments: In this method Thermal Track Modular Panels are attached to the subfloor forming a channel for 3/8" PEX or PEX Barrier Tubing.

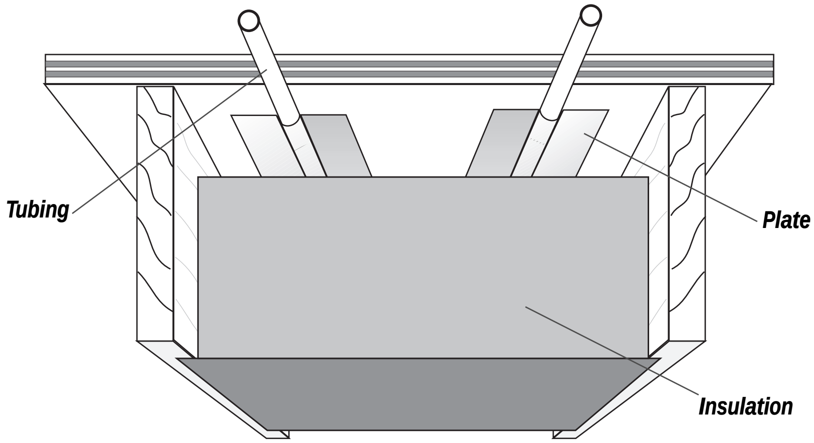
Where to use: It may be used in new construction or in a retrofit application over a subfloor.

Site Preparation: Make sure subfloor is clean, level and free of sharp objects and meets mositure and flatness requirements in the Thermal Track Installation Manual.

How It is Done: The 3 different panel shapes (straight, combo end piece, utility end piece) are glued and screwed or glued and cross stapled (as shown in the Thermal Track Installation Manual) to the subfloor according to a design. The tubing is then installed in the groove by being pressed in place. Depending on the type of floor covering, additional subflooring material is usually installed before application of finish flooring.

What To Be on the Lookout For: A layout plan for the installation of the Panels should be done in advance of the installation. First time installers may require a CAD layout drawing. Cut Panels square, allow expansion spaces between Panels. Use and follow the most current Thermal Track Installation Manual as a requirement of installation.

Formed aluminum heat transfer plate



NOTE: All systems installed from below the subfloor must overcome the added resistance of the extra layers of material. This needs to be carefully accounted for in the design. Systems installed from below the subfloor are more limited in output and are more limited in the R-Value of the floor coverings that may be placed over them.

NOISE AND METAL PLATES

Plastic pipe expands significantly with temperature change, and this must be accounted for in the installation of metal plate systems to prevent noise. Barrier Pex pipe is tackier as it heats up and is more prone to creating noise as the pipe moves through the plates. Measures that will minimize the likelihood of noise are:

1) Secure on one side only, single groove plates, allowing the other wing to move to accommodate expansion.
2) Place a layer of 1 mil clear polyethylene between the pipe and the plate. Polyethylene stays slippery as it heats up and will move in the plate more freely.
3) Use a control strategy that modulates water temperatures to control room temperature. This way the temperature changes in the tubing and plates are gradual.

Suspended Radiant Floors with Aluminum Heat Transfer Plates

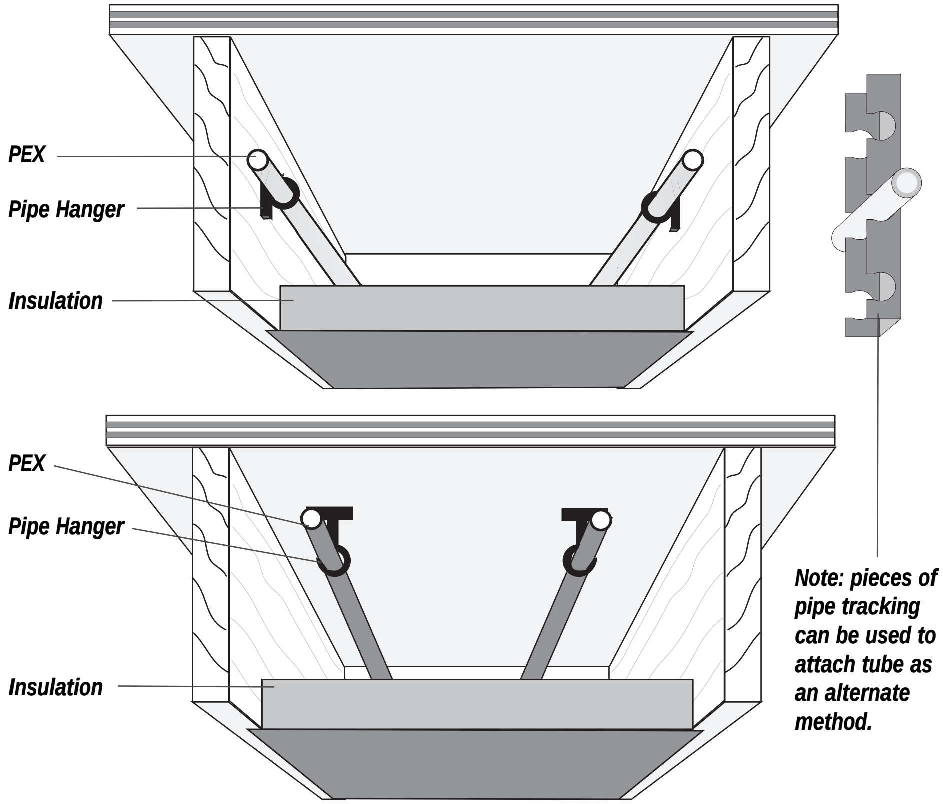
General Comments: In this method the PEX or PEX Barrier Tubing is installed with formed aluminum heat transfer plates which are fastened to the underside of the subfloor. The heat transfer plates conduct heat energy from the tubing and spread that energy out laterally across the plate. This lateral thermal transfer eliminates hot spots directly over the tubing, improves acceleration and provides more consistent temperatures at the floor surface. The plates offer a medium by which conductive heat transfer can occur, much like a concrete slab.

Where to use: This method may be used in new construction or retrofit applications, but care must be used to select floor coverings with a reasonable R-Value.

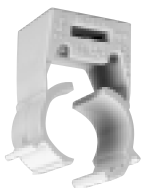
Site Preparation: Make sure there are no nails or sharp objects protruding through the subfloor that could damage the tubing.

How It is Done: The joists are drilled and the tubing is pulled in the joist space (See Tubing Layout). PEX or PEX Barrier Tubing is installed to the underside of a suspended floor with aluminum heat transfer plates. The tubing is looped through each cavity between the joists to provide two passes per cavity minimum. This provides an 8 inch on center distance for a typical 16 inch on center joist schedule. The heat transfer plates provide the support for attaching the tubing. Provide a 3 to 6-inch space between each aluminum heat transfer plate, and also at the beginning of the tubing bend radius. Plates are fastened to the underside of the subfloor by use of staples, nails or screws. Plates are placed from below, covering the tubing, and attached to the subfloor. 80% coverage is typical.

What To Be on the Lookout For: Insulation is required below the plates if the space below is unheated. If the space below is heated and no insulation is installed under the aluminum heat transfer plates, back losses will create a radiant ceiling effect to the space below. Unless accounted for in the design this can create a control problem.



When the tubing is hung from below the subfloor, there should be an airspace between the tubing and the insulation. This space allows a convective loop to develop around the tubing, which evens out the joist cavity temperature and thus provides more even temperatures on the flooring materials above. For this reason it is the preferred method for installing hanging systems.



LOCKING CLIC-HOLDERS are an excellent choice for hanging systems. They may be screwed to the underside of the subfloor or to the joist, and then the pipe is simply snapped into the holder which will then lock the tubing in place. Tubing should be fastened with clips at least every 3' on the straights and on both sides 12", from the end of the corners.

NOTE: All systems installed from below the subfloor must overcome the added resistance of the extra layers of material. This needs to be carefully accounted for in the design. Systems installed from below the subfloor are more limited in output and are more limited in the R-Value of the floor coverings that may be placed over them.

If the space below is heated and no insulation is installed under the tubing, back losses will create a radiant ceiling effect. If the heat load and resistance upward is high for the radiant floor and the heat load in the lower heated space is low, an overheating condition will occur in the space below.

Suspended Radiant Floors: Hanging Systems

General Comments: In this method the PEX or PEX Barrier Tubing is installed within the joist cavity using pipe hangers that are fastened to the sides of the joists or the bottom of the subfloor.

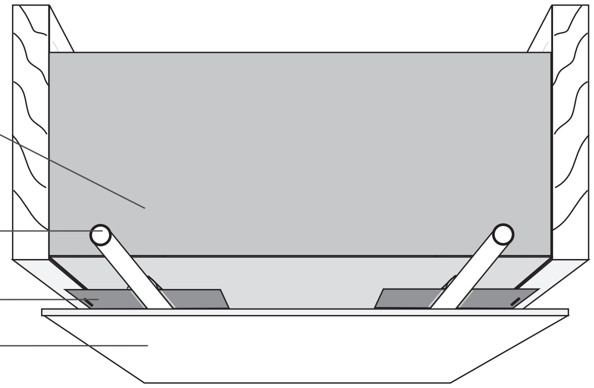
Where to use: This method may be used in new construction or in retrofit applications when the heating load is minimal and the resistance upward is low. Heat is transferred from the tubing to the floor through radiation and convection.

Site Preparation: Make sure there are no nails or sharp objects protruding through the subfloor that could damage the tubing.

How It is Done: The joists are drilled and the tubing is pulled in the joist space (See Tube Layout.) PEX or PEX Barrier Tubing is installed in clips under the subfloor or on the sides of thejoists. The tubing is looped through each cavity between the joists to provide two passes per cavity minimum. This provides an 8-inch on center distance for a typical 16-inch on center joist schedule.

What To Be on the Lookout For: Avoid placing the tubing in direct contact with the underside of the floor. These systems typically operate at high temperatures. Direct contact between the tubing and the floor can produce hot spots over the tubing, particularly when the floor covering has low resistance to thermal transfer. Insulation is required below the tubing if the space below is unheated. Allow space between tubing and the insulation for convection to even out the cavity temperature.

RADIANT CEILINGS are very versatile. They can be installed in nearly any situation to provide total comfort heating or to assist radiant floors in meeting very high heat loads. Radiant ceilings are separated into two main categories: those that use aluminum heat transfer plates and those that are installed freely within a joist space. Construction methods can vary significantly between these categories. The designer and contractor must be familiar with the proper methods to avoid any damage to the tubing as a result of improper installation.



Radiant Ceilings: With Metal Transfer Plates

General Comments: In this method, the PEX or PEX Barrier Tubing is installed in formed aluminum heat transfer plates which are fastened to the underside of the joists or rafters. The heat energy is then conducted to the topside of the gypsum "sheet rock" ceiling and to the space below. The heat transfer plates conduct heat energy from the tubing and spread that energy out laterally across the plate. This lateral thermal transfer eliminates hot spots directly under the tubing at high operating temperatures, improves acceleration, and provides more consistent and uniform temperatures at the ceiling surface.

Where to use: This method may be used in new construction or retrofit applications.

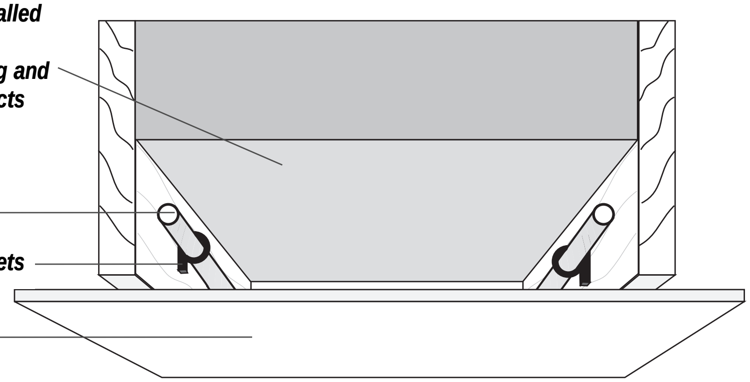
Site Preparation: Make sure the joist space is free of sharp objects.

How It is Done: The joists are drilled and the tubing is pulled in the joist space (See page 35). PEX or PEX Barrier Tubing is installed to the underside of joists or rafters with aluminum heat transfer plates. The tubing is looped through each cavity between the joists or rafters to provide two runs per cavity minimum. This provides a 8 inch on center distance for a typical 16-inch on center joist or rafter schedule. The heat transfer plates provide the support for attaching the tubing, and set the tubing away from the joist or rafter to permit the installation of sheetrock. Provide a 3 to 6-inch space between each heat transfer plate, and also at the beginning of the tubing bend radius. Plates may be fastened to the underside of the joists or rafters by use of staples, nails or screws. Silicone caulk applied between the tubing and transfer plates ensures quiet operation during acceleration.

What To Be on the Lookout For: These systems typically operate at temperatures of less than 120° F. Temperatures above 120 °F for extended periods of time may damage sheet rock and plaster joints. If using materials other than sheet rock, calculate the thermal transfer resistance to insure that adequate capacity is available. Insulation is required above the plates if the space above is unheated. If the space above is heated, generally no insulation is required because the resistance downward through the radiant ceiling is normally very low.

Heat Transfer Plate

Chapter 3



Radiant Ceilings: Hanging Method Without Plates

General Comments: In this method the PEX or PEX Barrier Tubing is installed directly within the joist or rafter cavity using pipe hangers that are fastened to the sides of the joists or rafters. Heat is transferred from the tubing to the ceiling through radiation and convection.

Where to use: This method may be used in new construction or retrofit applications.

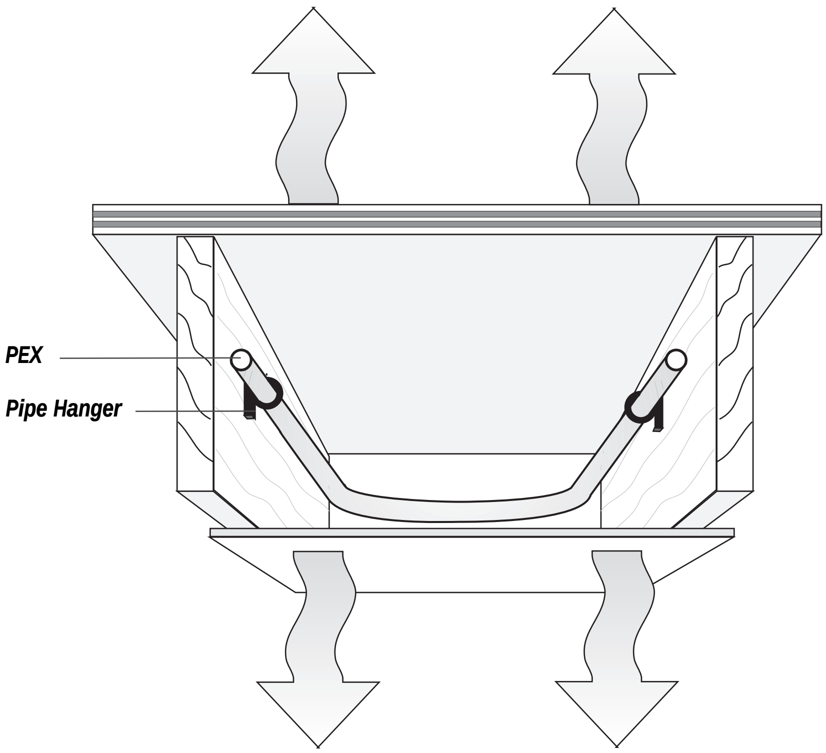
Site Preparation: Make sure the joist space is free of sharp objects.

How It is Done: The joists are drilled and the tubing is pulled in the joist space similar to suspended radiant floor installation (see section on Tube Layout). PEX or PEX Barrier Tubing is installed within the joist or rafter space of a suspended ceiling with pipe hangers fastened to the sides of the joist. Tubing must be supported a minimum of every 36 inches and 12" from the ends on bends. Provide an air gap between the tubing and the top side of the gypsum ceiling to eliminate hot spots on the ceiling surface. The tubing is looped through each cavity between the joists or rafters to provide two runs per joist cavity. If insulation is placed above the tubing, it must be placed in such a manner as to not interfere with the thermal transfer from the tubing to the top surface of the gypsum ceiling.

What To Be on the Lookout For: These systems typically operate at temperatures of less than 120° F. Temperatures above 120° F for extended periods of time may damage sheetrock and plaster joints. Insulation is required above the tubing if the space above is unheated. If the space above is heated, generally no insulation is required because the resistance downward through the radiant ceiling is normally very low. If insulation is installed above the tubing, care must be taken to insure that the insulation does not interfere with thermal transfer to the ceiling.

NOTE: Temperatures above 120 °F for extended periods of time may damage sheetrock and plaster joints. It is recommended that a device such as an aquastat be installed that will prevent the pump that supplies the radiant ceiling from operating when the temperatures are too hot. This gives an added level of assurance that high temperature water will not damage the sheetrock.

One practical method of using radiant heat panels is to combine both radiant floors and ceilings into the same room. By installing radiant ceilings without insulation above the tubing between the intermediate floors, back losses can contribute to the space above.



Combining radiant floor and radiant ceiling heat in a situation where the floor is dominant and is being regulated to heat the room is not recommended. If the floor is being relied upon for the majority of the heat source, the supply water will have to run at a higher temperature and/or capacity to overcome the greater thermal resistance. Also, since the heat created through the back losses from the radiant floor is controlled from the room above and can often exceed the heat energy being transferred from the radiant floor of the lower room, an overheating situation can arise. This type of configuration can lead to inefficiency, temperature and control problems, and should not be considered.

Combined Radiant Ceilings And Floors: Hanging Method

General Comments: The heat load analysis should be based upon the lower room, and the radiant ceiling should be regulated to control the temperature in that space. Since the thermal resistance in the subfloor and the floor covering is much greater than the thermal resistance of the gypsum ceiling, the majority of the heat will travel downward through the path of least resistance. The system becomes much more efficient since the back losses are not truly lost, but contributing to the upper room.

Where to use: Use only when a detailed calculation of how much heat is needed and how much heat will flow up and down can be done. Also, note that the top room must have a dedicated radiant ceiling with proper insulation since the back losses transmitted through the floor will most likely not satisfy the required heat load in the room.

Site Preparation: Make sure the joist space is free of sharp objects.

How It is Done: The joists are drilled and the tubing is pulled in the joist space similar to supended floor installation method (see Tube Layout section). PEX or PEX Barrier Tubing is installed in the joist space with pipe hangers similar to a hanging radiant floor system. Tubing must be supported a minimum of every 36 inches and 12" from the ends on bends.

What To Be on the Lookout For: Note that the insulation is eliminated between floors so that the heat may flow in both directions. Do not use this method when the two floors have very different heat loss and use patterns.

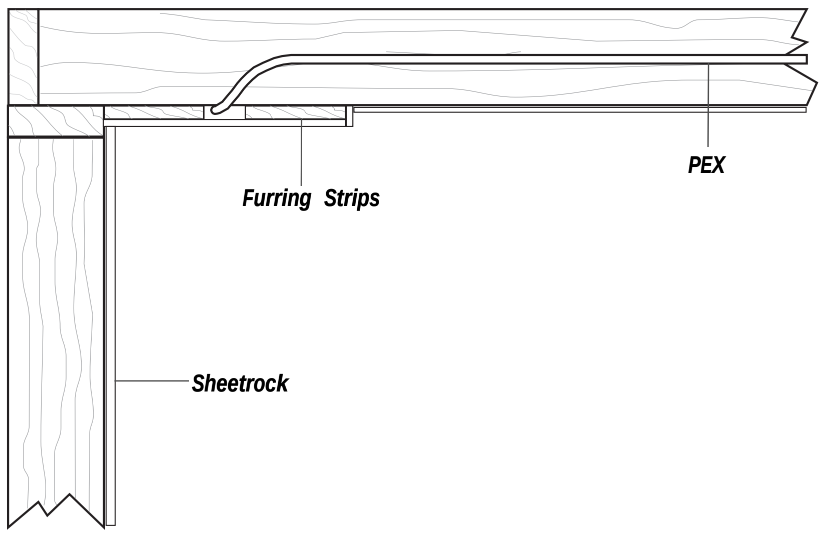
Chapter 3

Installing Tubing Between Joists or Rafters:

There are several methods of installing the PEX or PEX Barrier Tubing between joists or rafters. Drilling holes and pulling the tubing throughout the maze of joists or rafters can be frustrating and damaging to the structural integrity. Alternative methods can be considered to reduce the labor and subsequent costs.

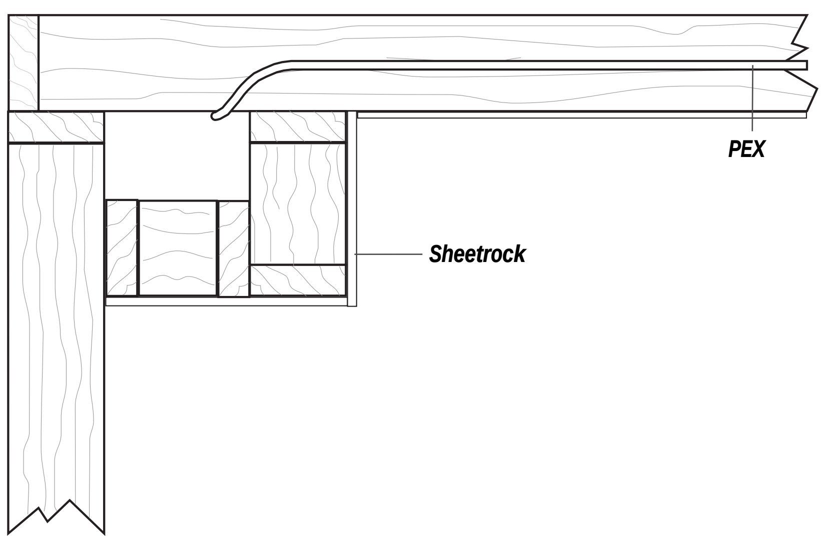
The furring strip method shown on the following page for use in wall systems may be used in a similar manner on the ceiling.

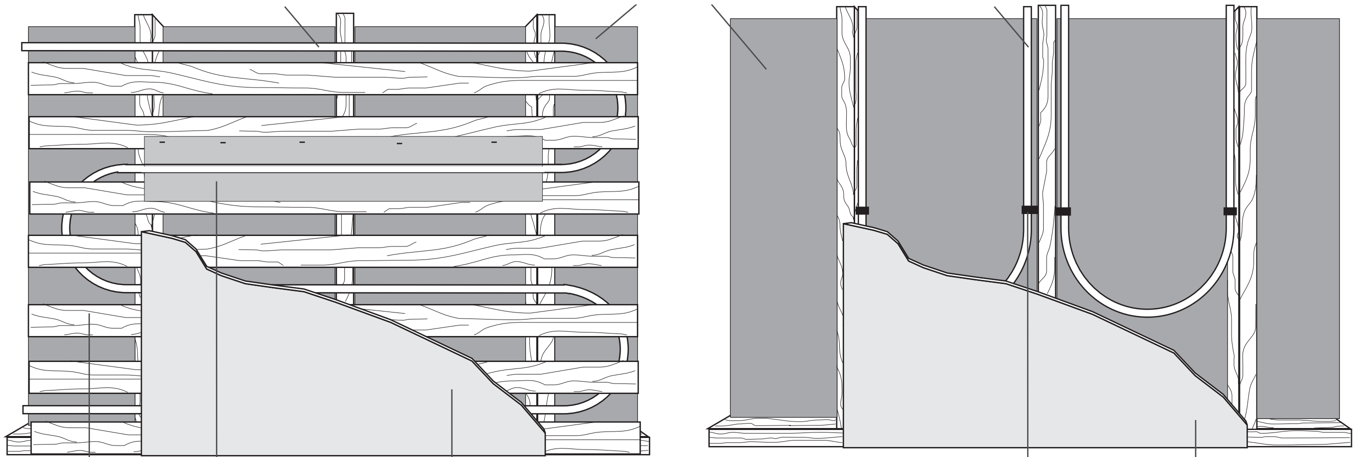
Using a Drop Down Method: In this method the tubing is dropped below the joist or rafter in an area provided between the bottom of the joist or rafter and the finished ceiling. Fasten furring strips under the joists or rafters in either a parallel or perpendicular fashion.



COVE CEILINGS AND SOFFITS HAVE BECOME DECORATIVE ELEMENTS IN MANY HOUSES. With a little imagination and communication with the owner and designer, these approaches can make installing pipe in the joists much easier. Also, with the high output of radiant ceiling systems, often it is only necessary to install the heating around the perimeter of the room. Coving the ceiling down with furring strips and installing the tubing between the furring strips can be an easy way to do this. It is very effective in retrofits.

Using Available Beams and Soffits: Often beams and soffits are "boxed" into the finished ceiling. These areas can be made slightly larger to accommodate PEX or PEX Barrier Tubing crossing under joists or rafters. In finished basements, the outside walls can provide excellent areas for dropping down and crossing rafters.





Radiant Walls: Hanging And Furring Strip Methods

In radiant walls, the furring strip method is easier to purge the air since the tubing runs horizontally and an air vent may be installed at a serviceable high point. The furring strip method can also be used for radiant ceilings and is very useful for retrofits.

Many contractors use radiant walls to augment the performance of floor and ceiling systems. Frequently, the radiant wall is installed only below the height at which future owners might hang pictures and be more likely to puncture the pipe.

General Comments: Radiant walls can be very useful in some projects. They can assist radiant floors or ceilings in meeting very high heat loads, particularly in those projects with a minimum amount of floor or ceiling space where radiant panels can be installed. Radiant walls can be constructed with aluminum heat transfer plates or installed freely within a stud wall space. Construction methods vary significantly. When constructing a radiant wall, be sure that the installation does not diminish the weight bearing capability of any structural wall. Also, since radiant walls are warmer than conventional unheated walls, an increased amount of insulation should be installed behind the tubing to minimize back losses.

Where to use: This method may be used in new construction or retrofit applications.

Site Preparation: Make sure the wall space is free of sharp objects.

How It is Done: The studs are drilled and the tubing is pulled in the wall space in an essentially similar manner to radiant ceilings (see and read the information on radiant ceilings). Tubing must be supported a minimum of every 36 inches and 12” from the ends on bends. If insulation is placed above the tubing, it must be placed in such a manner as to not interfere with the thermal transfer from the tubing to the gypsum wall.

What To Be on the Lookout For: These systems typically operate at temperatures of less than 120° F. Temperatures above 120° F for extended periods of time may damage sheet rock and plaster joints. Insulation is required behind the tubing. Care must be taken to insure that the insulation does not interfere with thermal transfer to the wall.

The tubing layout is a permanent part of the heating system and, when properly done, can enhance system performance and make it easier to control. The tubing layout can be thought of as an energy drawing. Visualize in your mind where the higher heat losses and needs are. Then think how the tubing can be installed to meet those needs and losses.

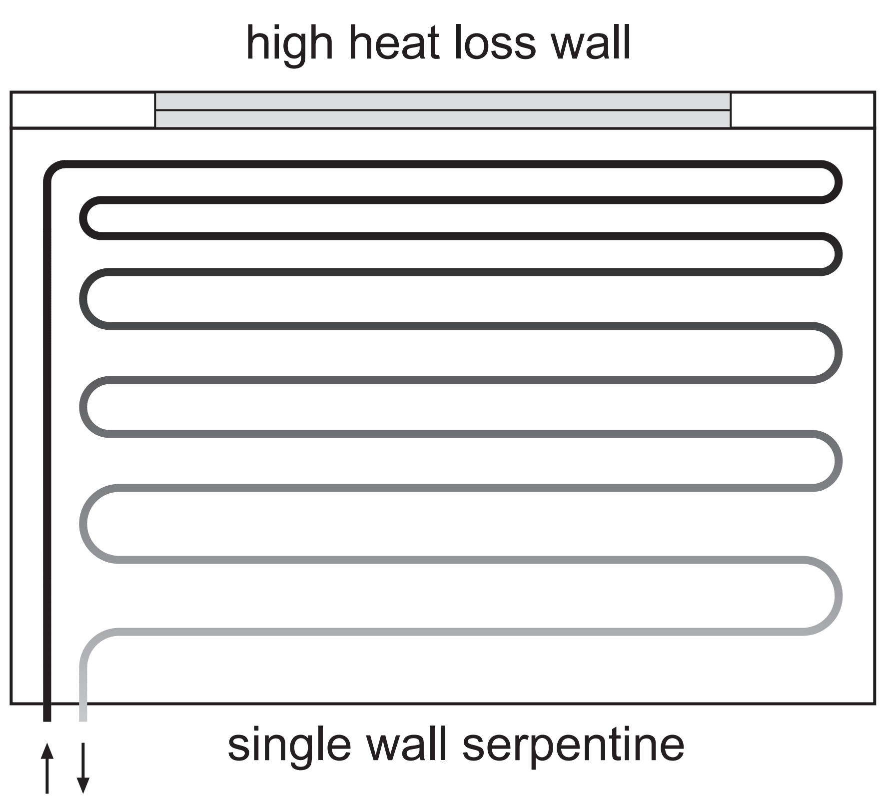
CHAPTER 4: TUBING LAYOUT FOR RADIANT PANELS

Patterns And Variations

The tubing layout patterns for a project require that the building plan be separated into individual loops before combining individual loops into heating zones. The radiant panels may be laid out in any number of patterns or variations of patterns to meet the heating load of the zone. The primary objective of the layout pattern is to provide ample heat energy to the area in which it is needed. The objective is NOT to try to obtain an even floor temperature. An even floor temperature can overheat interior regions while inadequately heating areas near the outside walls where the heat loss is much greater. It is important to understand the purpose behind the layout patterns in order to properly apply them to a project.

The Single Wall Serpentine Pattern: The single wall serpentine pattern is designed to distribute more heat energy along an outside, high heat loss wall, and then less energy as the pattern moves inwardly toward areas with little or no heat losses. This is done by placing the supply portion of the loop immediately along the high heat loss wall and paralleling the wall inwardly in a serpentine pattern.

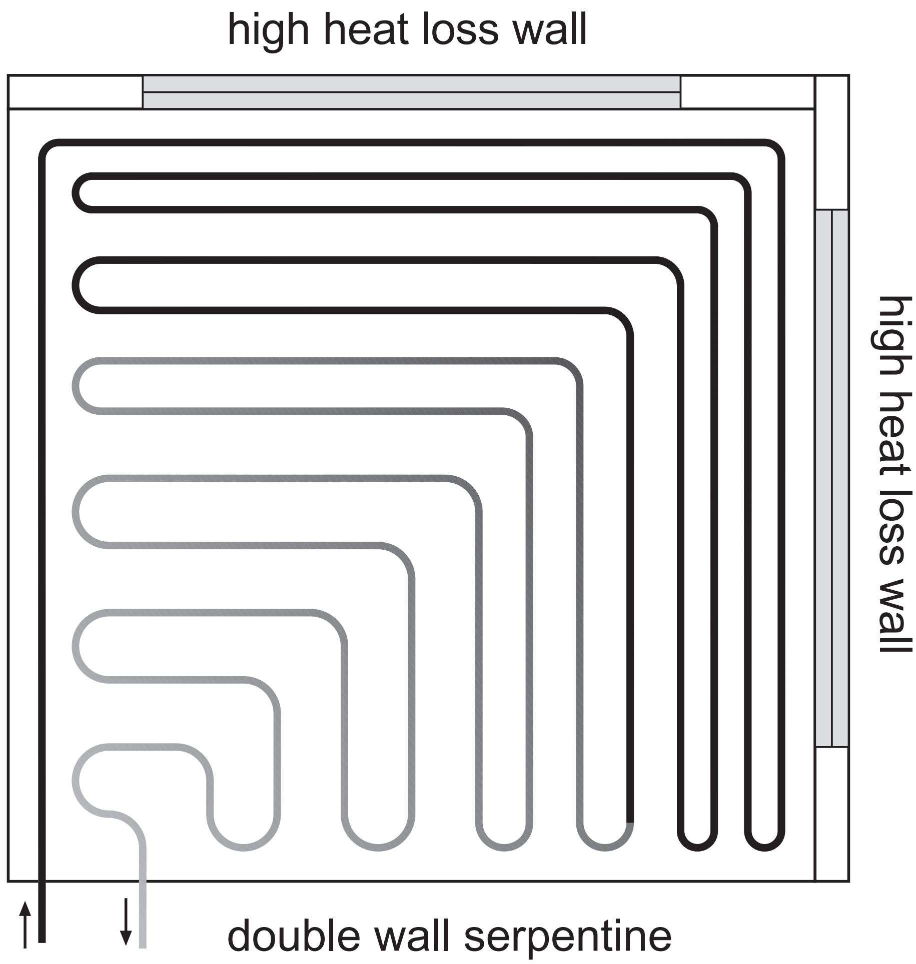
In this drawing the hottest water on the outside of the room is shown in black and as it cools it is shown in lighter shades. Most radiant designers design so the temperature drop between supply and return lines will be less than 20°F or less.



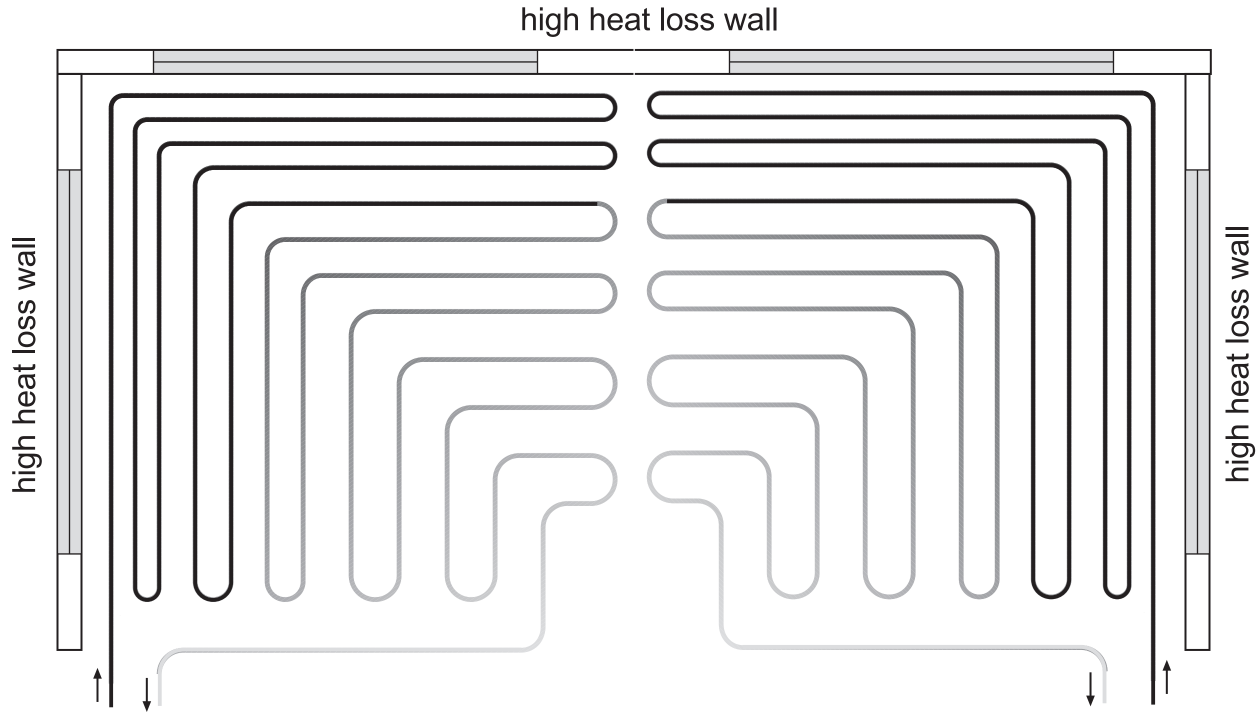
Chapter 4

The Double Wall Serpentine Pattern: The double wall serpentine pattern is designed to distribute more heat energy along two outside high heat loss walls, and then diminished energy as the pattern moves inwardly toward areas with little or no heat losses. This is done by placing the supply portion of the loop immediately along the high heat loss walls and paralleling the wall inwardly in a double serpentine pattern.

When you are running more than one loop in a larger room, consider running a loop along each wall and have the returns down the middle. Try your best to install the tubing in a manner that makes sense with the structure's heat loss. Since there is a strong convective loop in radiant heating, the tubing layout does not have to be perfect to achieve quite even results.



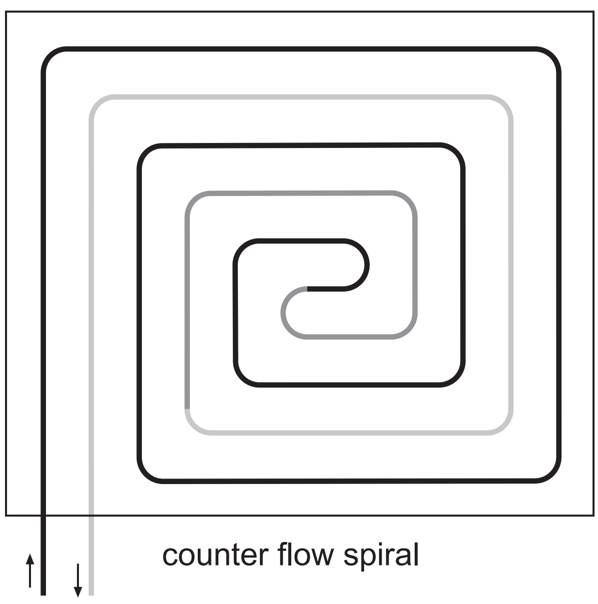
Reduced Perimeter Spacing: Reduced perimeter spacing is designed to offset high heat loss through exterior walls. Tube spacing is reduced to as much as 1/2 the regular distance (typically 6") in the first two tubing runs paralleling an outside wall or walls. This concentrates more heat energy in the area of the greatest heat loss. Reduced perimeter spacing of less than 4" on centers is not recommended. Tubing can also be installed on reduced centers in front of large windows and doors. Reduce the tube spacing to 1/2 the regular distance in the area directly in front of doors or windows and continue this pattern out into the room for a distance equal to 2/3 (66%) of the height of the door or window (typically 2'-3'). Reduced spacing increases the amount of tubing in the radiant panel and the total length of a loop, and it must be considered in flow and pressure loss calculations.



Combination Patterns: Many rooms or zones are too large for a single loop. When splitting these areas into two or more loops, be certain that heat losses and the total heat load are equally shared, as shown above.

Counter flow Spiral Pattern: The counter flow spiral pattern is designed for areas with evenly distributed heat losses. This is done by placing the supply and return portions of the loop immediately adjacent to one another. The tubing is laid along the perimeter of the room and spiraled inward at distances equal to twice the on center distance required in the plan. Once the loop reaches the center of the room, the direction is reversed so that the tubing follows a return path between the supply loops. This pattern then places a supply tube immediately alongside a corresponding return tube. The average temperature between the loops is approximately the same at any point between two corresponding loops, thus making the floor surface temperature approximately uniform.

The counterflow spiral pattern is best accomplished with two people installing, since it requires placing two parts of the loop similtaneously. Serpentine patterns may be installed by one person, but they too, are usually more efficiently installed with an assistant.



Chapter 4

Note: When installing PEX tubing through joist spaces, make the job easier by drilling adequately sized holes, typically 1-3/8" when using plastic pipe insulators.

Tubing Layout Patterns in Joist or Rafter Areas:

When installing PEX tubing within joists or rafter areas, the layout pattern is restricted by the direction of the joists or rafters. Placing the tubing near the high heat loss walls can still be accomplished with the following joist layout patterns.

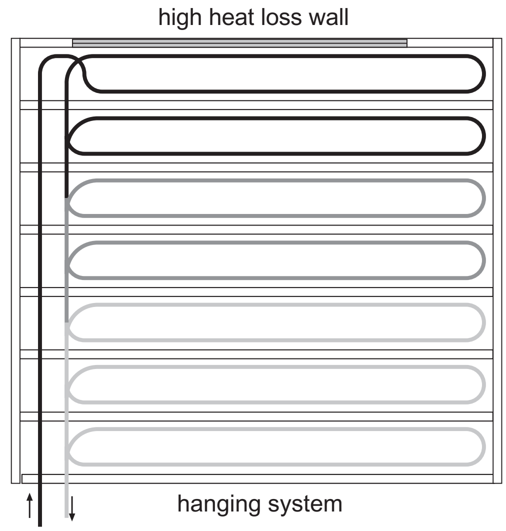
Single Wall Serpentine (Joist Pattern):

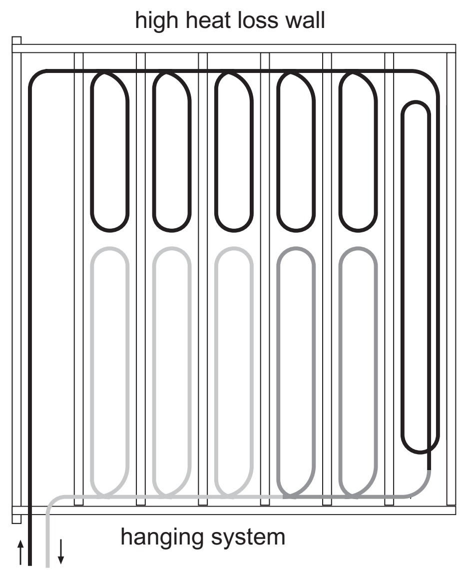
When the joists or rafters run parallel to the high heat loss wall, the single wall serpentine pattern is quite simple, as shown to the right.

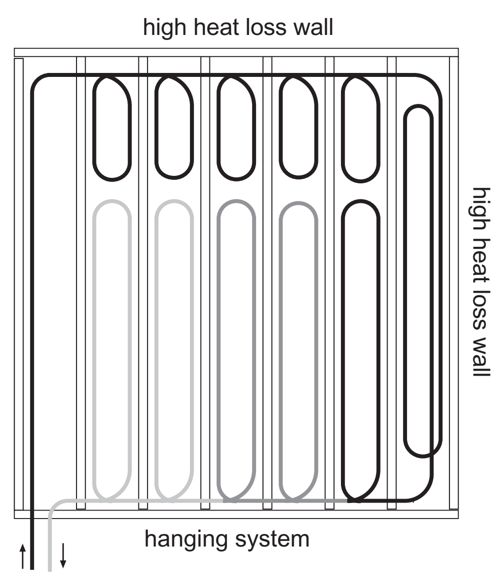
If the joists or rafters run perpendicular to the high heat loss wall, the single wall serpentine pattern can be modified, as shown to the right.

Double Wall Serpentine (Joist Pattern):

In the double wall serpentine joist pattern, the joists or rafters will run perpendicular to one wall and parallel to the other. Tubing can be installed as shown to the right.







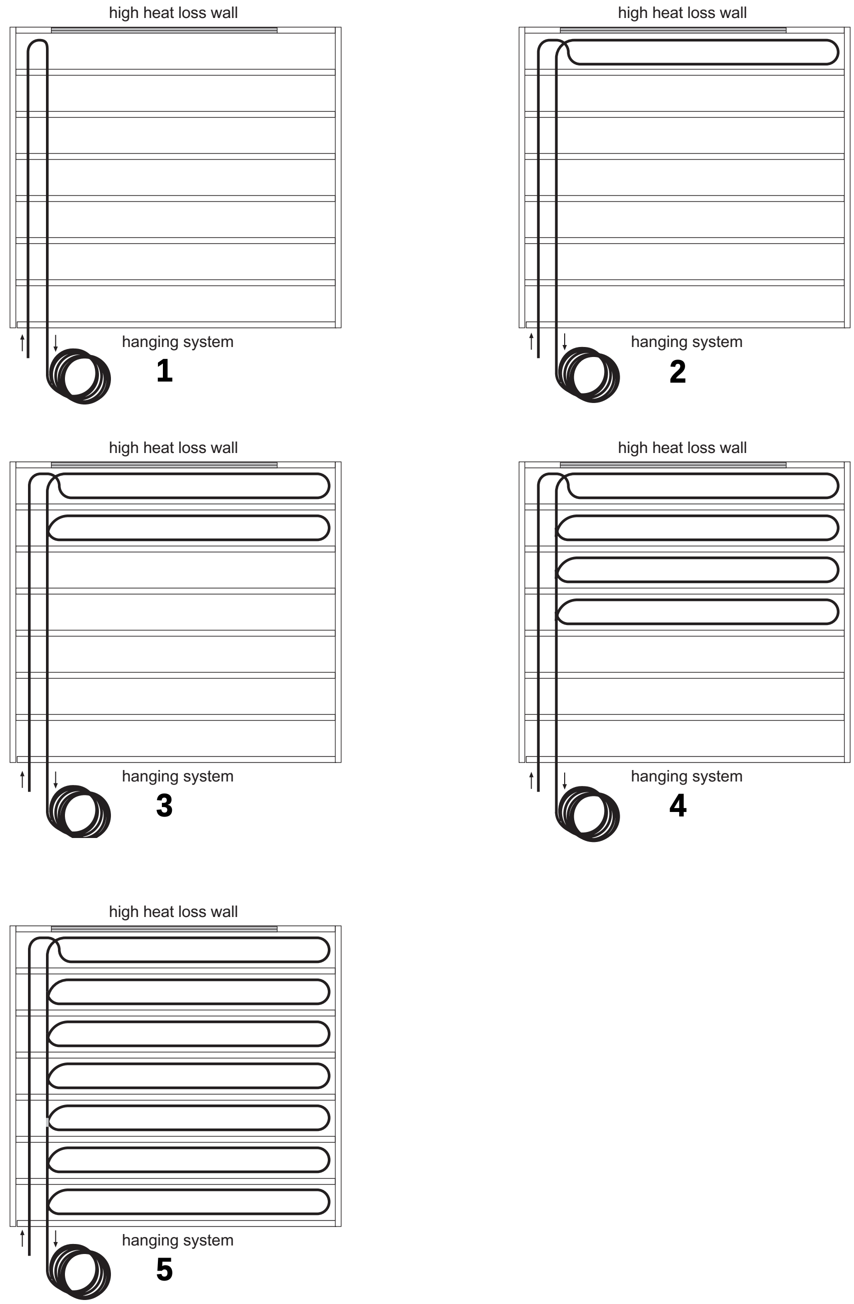
Chapter 4

HOW TO INSTALL TUBING IN JOISTS OR RAFTERS:

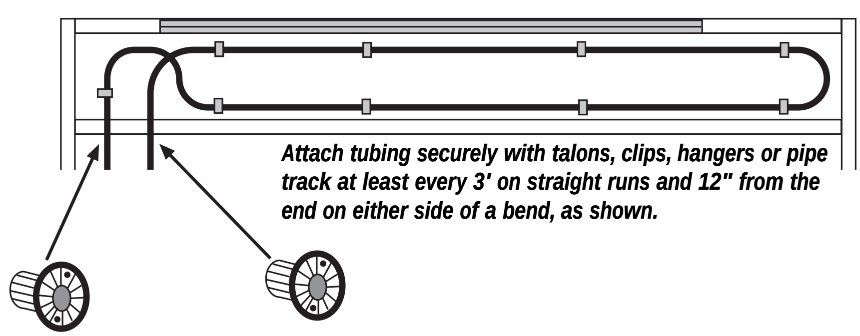
1. Drill the joists or rafters with a 1-3/8" drill bit for the supply and return. Be sure to follow drilling requirements in codes which specify acceptable drilling areas in joists and rafters. Locate a pipe unspooler in a convenient location and feed tubing, as shown in step 1.

2. Loop tubing in farthest joist/rafter bay as shown in step 2. Attach pipe as you go, as shown at the bottom of the page. If you are using plates, they will take the place of the clips or pipe holders in the areas that they are installed. Use 1-3/8" plastic pipe insulators to secure the pipe in the joists/rafters.

Continue adding loops as shown in steps 3, 4, and 5 by twisting a loop and feeding the tubing into the joist/ rafter bay. Notice how the tubing is routed to the far side of the joist . This eliminates a tight bend feeding into the bay, reducing the chance of a kink in the tubing and making it easier to accomplish. In a large room you may have more than one loop and will have to drill additional supply and return holes.



It is important to attach tubing securely in hanging systems because the plastic tubing expands and contracts with changes in temperature. If it is not well attached, it will "walk" due to this movement.



Use 1-3/8" plastic pipe insulators where the tube penetrates rafters or joists

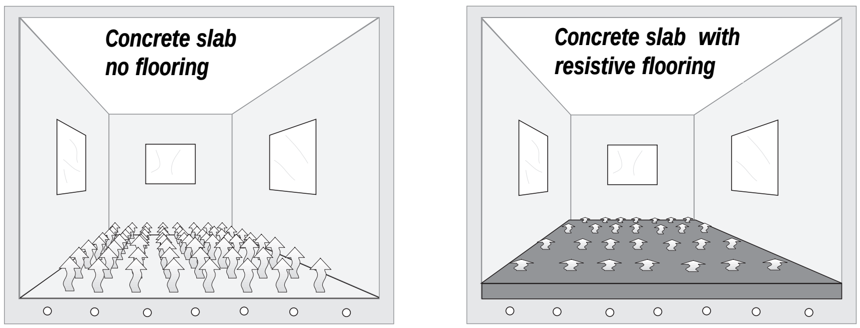
CHAPTER 5: FLOOR COVERINGS FOR RADIANT

With Radiant Floors, Flooring Is Part Of The System

It is important to understand the issues of pairing floor coverings with radiant floors. These issues can be divided into heat transfer, limitations and proper use of different flooring materials, and installation-specific issues of flooring assemblies.

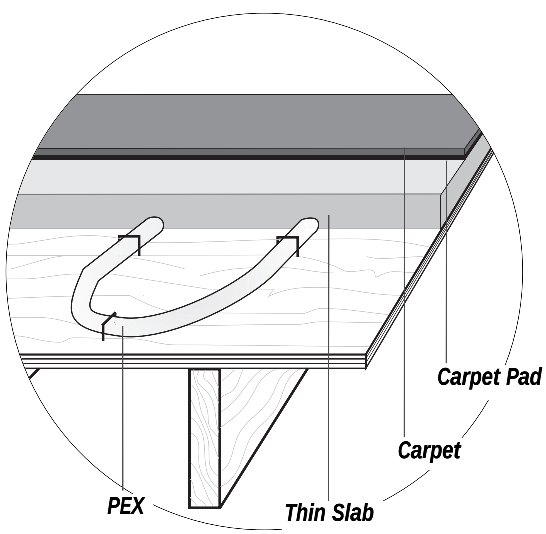
Heat Transfer Through Floors: Radiant floor heating must transfer the heat from the heated water in the tubing to the surface of the floor. When the materials between the tubing and the top of the floor are not sufficiently conductive, the system will not transfer heat at a rate sufficient to heat the space. An example would be a radiant system installed in

Floor coverings that significantly resist heat transfer can limit the output of a radiant floor heating system.



cement that works fine with no floor coverings, works well with moderately resistive floor coverings, but when a very resistive floor covering is installed the system no longer provides sufficient heat. Designing systems that perform to expectations requires that systems are designed to account for the resistance of floor coverings.

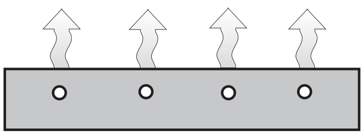
For the example to the right, to transfer heat to the surface, the temperature of the water in the tubing must be sufficient to overcome the resistance to heat transfer of the tubing, the thin slab of cement, the carpet pad, and lastly the carpet itself. As the resistance of the materials between the water and the surface becomes greater, higher water temperatures are required to overcome it. At a certain point, when the resistance becomes too high, water temperatures that are not practical or available would be required. The key to designing radiant systems that perform well is to accurately account for all these resistances in the design process and make sure they are within the performance capabilities of the system.



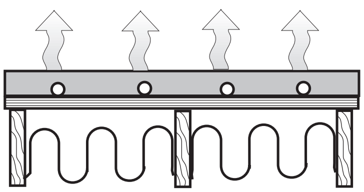
The heat from the tube must transfer through the thin slab and the carpet goods, effectively making the floor coverings part of the heat transfer system. Radiant floor heating contractors and designers must become very knowledgeable about flooring goods.

Chapter 5

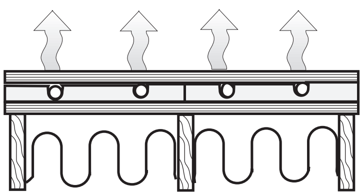
Both the radiant floor system and the floor coverings contribute to the overall resistance of the system. Tubing in conductive cement has less resistance, for example than a hanging system. The qualified radiant system designer takes both into account. The top three systems shown below have the least resistance, and the hanging system at the bottom the highest resistance to heat transfer since the tubing is under the subfloor in an airspace.



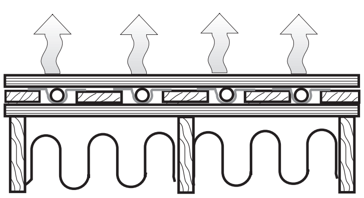
Slab



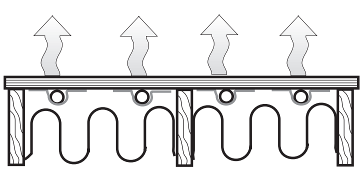
Thin Slab



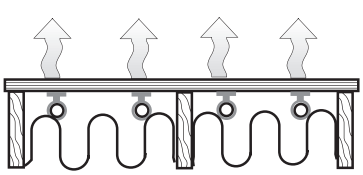
Thermal Track



Sandwich Method With Plates



With Plates From Below



Hanging

Most floor coverings are possible with radiant floor heat, but they must be selected knowledgeably with an eye towards the performance of the system. Floor coverings vary widely in R-value, as shown below. In the chapter on system design we will take both the R value of the floor coverings and the delivery system itself into account as we design a radiant heating system. Radiant installers and designers must become involved in the selection of flooring goods to assure that the system will perform correctly. For example, insist on a thin slab rubber pad and thin carpet. This will assure that the system puts out more heat. Make the customer understand that thick carpets are for cold floors, and that they will feel more comfortable with a carpet of modest thickness that is warmed by radiant heats than they ever would on a thick carpet over a cold floor.

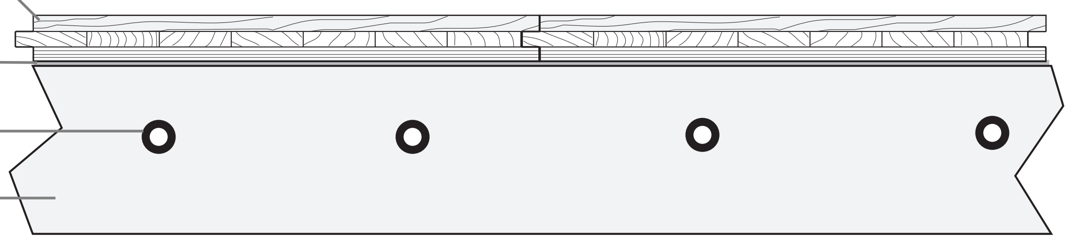
Floor Covering R-Value Chart:

Typical R-Value	R-Value Per Inch	Typical Thickness	Material
0.825	1.1	0.75	Plywood
1.05	1.4	0.75	OSB
0.825	1.1	0.75	Softwood
0.25	1.0	0.25	Ceramic Tile
0.05	0.4	0.125	Thinset Mortar
0.2	1.6	0.125	Vivyl
0.4	1.6	0.25	Linoleum
0.2	1.6	0.125	Linoleum
2.25	1.5	1.5	Brick
0.4	0.8	0.5	Marble
0.5	1.0	0.5	MDF/Plastic Laminate
0.625	1.0	0.625	Laminated Wood
0.2	1.6	0.125	Wood Flooring Pad
0.6375	0.85	0.75	Oak
0.75	1.0	0.75	Ash
0.75	1.0	0.75	Maple
0.975	1.3	0.75	Pine
0.9	1.2	0.75	Fir
0.32	1.28	0.25	Slab Rubber 33 lb.
0.48	1.28	0.375	Slab Rubber 33 lb.
0.64	1.28	0.5	Slab Rubber 33 lb.
0.62	2.48	0.25	Waffle Rubber 25 lb.
1.24	2.48	0.5	Waffle Rubber 25 lb.
1.94	3.88	0.5	Hair Jute
1.25	3.88	0.325	Hair Jute
1.4	4.3	0.325	Prime Urethane
2.15	4.3	0.5	Prime Urethane
1.35	4.2	0.3325	Bonded Urethane
2.1	4.2	0.5	Bonded Urethane
0.7	2.8	0.25	Carpet
0.91	2.8	0.325	Carpet
1.4	2.8	0.5	Carpet
2.1	2.8	0.75	Carpet
1.35	4.2	0.325	Wool Carpet
2.1	4.2	0.5	Wool Carpet

Understand that the flooring installer does not have all the same concerns as the radiant heat installer, but they must come to a meeting of the minds. For example, the wood flooring installer wants the most stable substrata for nailing wood floors, and the radiant heating installer wants the floor assembly with the least resistance to heat transfer. These interests can be knowledgeably reconciled with good communication.

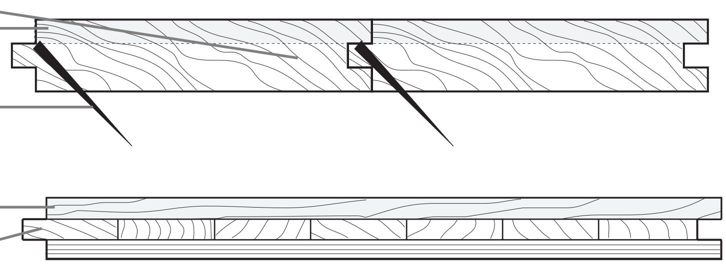
Wood Floors And Radiant Floor Heating: There are many successful ways to install wood floors over radiant heating, The National Wood Flooring Manufacturers Association (www.woodfloors.org) publishes useful guidelines with many optional ways of installing wood floors over radiant floor heating systems. Zurn recommends that designers and installers familiarize themselves with these guidelines. The options for installing wood floors with the least resistance to heat transfer are the most preferable for the performance of the heating system. Options that add multiple sub layers of wood add cost, limit heat transfer and should be avoided when possible.

Use Of Prefinished Laminated Floors Is Preferred: Prefinished laminated floors have many advantages for use with radiant floor heating. They may be edge glued and installed as a floating system that is free to expand and contract separately from the radiant floor heating system. Many have specific instructions and warranties for use over radiant heat. Being made of multiple layers of material that is laminated together, they are inherently dimensionally more stable than traditional wood flooring systems. At 5/8" thickness, most prefinished floors transfer heat well.



Prefinished laminated wood floors may be edge glued and "floated" over radiant floors. A thin polyethylene pad often goes in between the floor and the thermal mass, which puts some "give" in the floor.

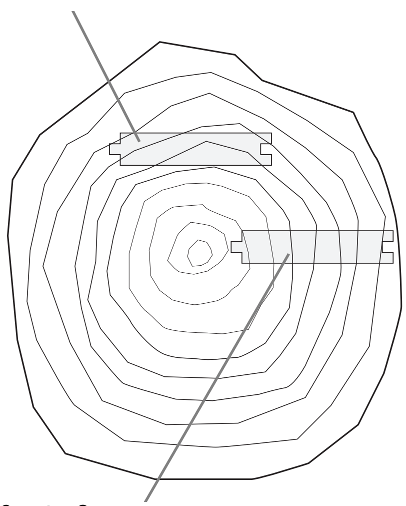
Many customers are resistant to giving up "traditional" wood floors since they are worried that prefinished laminated floors cannot be refinished as many times as a traditional wood floor. In actuality, the wear layer or resurfaceable top surface of a tradional wood floor is limited by the nails that are used to install it. The illustration below shows that the wear layer of prefinished floors is actually very similar in thickness.



Prefinished laminated wood floors solve many problems for the radiant heating installer. With good communication, most customers can be made to understand their advantages.

Chapter 5

Quarter sawn wood shrinks less and is less likely to cup or crown than plain sawn wood.

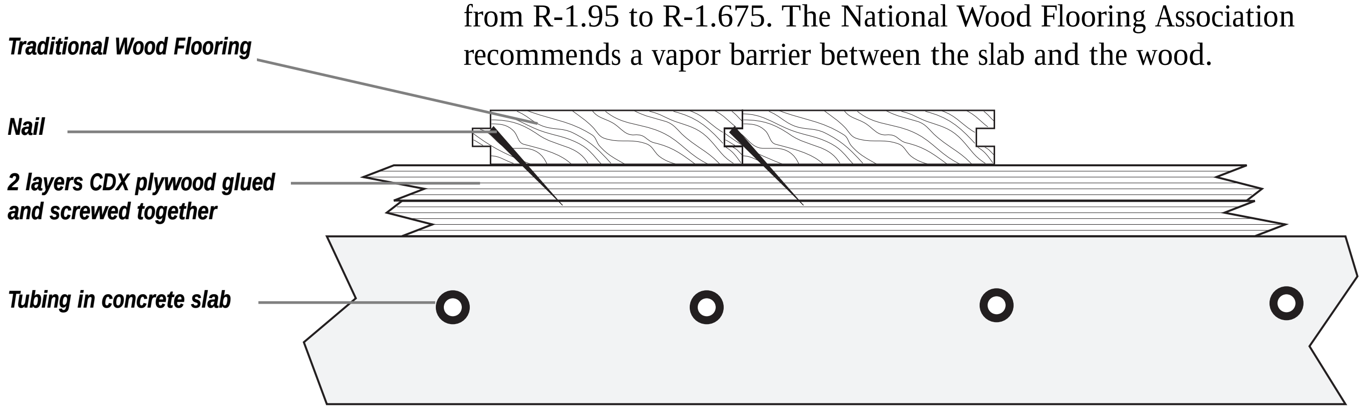


Most problems with wood flooring and radiant heating are related to humidity issues and would happen regardless of whether radiant heating is installed. These problems may be incorrectly attributed to the radiant heating system, but in fact are caused by lack of proper humidity control. Also always make sure wood flooring has had adequate time to stabilize to the environment of the structure prior to installation.

Traditional Wood Floors and Radiant Floor Heating: Traditional wood floors may be installed successfully over radiant floor heating. There are important considerations:

- Use species that are known to be more dimensionally stable. For example, American cherry and teak are known to be very stable, Bamboo while technically a grass is very stable, oak is reasonably stable. Maple and Brazilian cherry are known to be less stable.
- Use quartersawn or rift sawn wood. They are more dimensionally stable in width than plain sawn.
- Use narrow boards. Never use boards wider than 4". Narrow boards give more small gaps for expansion and contraction.
- Operate the radiant heating system and drive out the moisture from any radiant heated slab before any wood floors are installed. The National Wood Flooring Association recommends that the heat be on for a minimum of 5 days before installation to drive out any residual moisture. Most flooring contractors are familiar with methods to test a slab for moisture.
- Maximum surface temperature of the wood floor should be limited to 85°F.
- Operate the heating system until the humidity in the structure stabilizes to the average level expected for the area in which it will be installed. Allow the wood to acclimatize to this humidity level (usually several weeks) before installation. This way, dimensional changes due to moisture issues will be minimized.

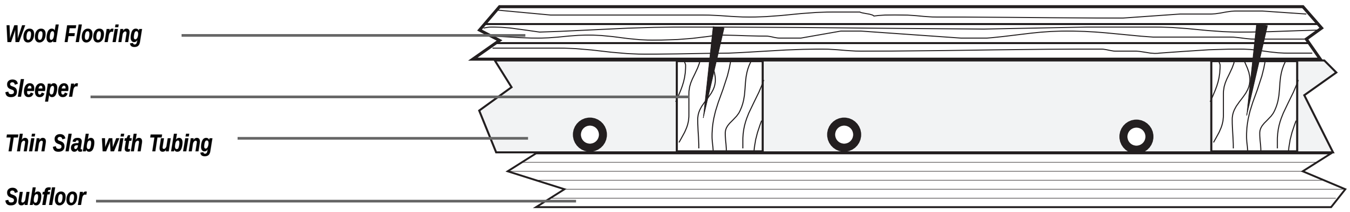
Traditional Wood Floors Over Slabs On Grade: The National Wood Flooring Association recommends installing traditional wood floors over slabs with two layers of 1/2" CDX plywood glued and screwed together Underneath. This method provides a stable nailing base for the floors, but the 2 layers of 1/2" plywood plus 3/4" of hardwood adds a resistance of R-1.95 to that of the heating system itself. As a result, many radiant contractors have installed wood floors over 2 layers of 3/8" CDX plywood glued and screwed together or over one layer of 3/4 T&G plywood that has been glued to the slab. This reduces the R-Value of all the wood from R-1.95 to R-1.675. The National Wood Flooring Association recommends a vapor barrier between the slab and the wood.



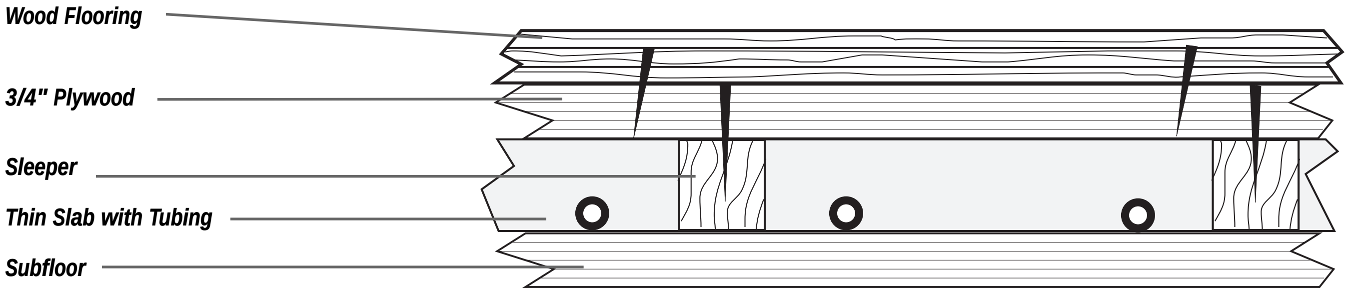
Detail showing National Wood Flooring Association method of installing wood floors over 2 plies of CDX that float on slab.

The illustrations below and to the right show three methods of installing traditional wood flooring over thin slabs. Note that more layers of wood make for more resistance to heat transfer and a higher installation cost. In the direct nail-to-sleeper method, if the hardwood is 3/4" it would add a resistance of R-0.85 to the system. Adding a layer of 3/4" plywood brings it to R-1.675 Adding 2 layers of 1/2" plywood brings it to R-1.95.

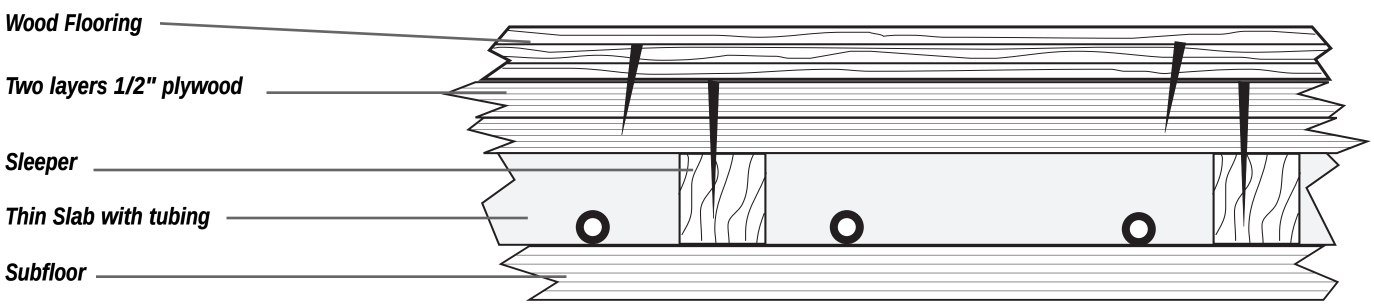
Traditional Wood Floors Over Thin Slabs: When using thin slabs, it is recommended that sleepers be installed to provide nailing for the wood. Three methods are recommended by the National Wood Flooring Association which vary significantly in their resistance to heat transfer. They are direct nail-to-sleepers (least resistance), adding one layer of 3/4" plywood in between the wood and sleepers, and adding 2 layers of 1/2" plywood in between the wood and the sleepers (most resistance to heat transfer). From the point of view of the radiant heating system, the first option, which has the least resistance to heat transfer, is the best. It is also the least costly.



Direct nail to sleepers



With plywood nailed to sleepers



With two layers of plywood nailed to sleepers

Traditional Wood Floors Over Hanging And Plate Systems From Below: Wood floors may be installed in normal manners over systems that are from below the subfloor. Take care that nails do not penetrate the subfloor and damage the tube.

A typical 1/8" vinyl floor has an R-Value of R-0.2

Resilient Flooring over Radiant Floor Heating Systems: Resilient flooring is typically thin and offers little resistance to heat transfer. Both the resilient floor industry ASTM standards (ASTM F 710 and ASTM F 1482) and the RPA "Standard Guidelines For The Design And Installation Of Residential Radiant Panel Heating Systems" recommend an 85° F temperature limitation for resilient flooring. Vinyl flooring undergoes a significant expansion under heat and should be adequately stretched when installed and or bonded with an adhesive rated for the temperatures it will be subject to.

A typical 1/2" laminate floor has an R-Value of R-0.5

MDF/HDF "Laminate" Flooring Over Radiant Floor Heating Systems: Properly constructed laminate flooring is a very good product for radiant heating since these products are dense and thin and can be floated over a radiant thermal mass. These products are made of a combination of layers. These layers are typically a clear wear layer, a view layer, 2 layers of MDF or HDF and a plastic bonding layer. Bonding all these layers is a complex process, and not all laminate flooring products are warranted or recommended for use with radiant heat. Most are. Check with the manufacturer before installing. These products have very specific requirements for the moisture content of slabs. These must be observed.

A typical 1/4" tile and thin set mortar has an R-Value of R-0.3

Installing Tile Over Radiant Floors: Tile is dense, conductive, usually thin, and a good choice for radiant heat. Tile contractors worry a great deal about the rigidity of the floor system they install on, as well as the quality of the bond between the tile and its substrata. A crack isolation membrane placed between the tile and the thermal mass is recommended. This allows the mass of the heating system to expand and move separately from the tile by allowing a layer of give in between. As tile industry guidelines for radiant floor heating are developed, they should be followed.

R-VALUES AND CARPET UNDER- LAYMENT:
A 1/4" slab rubber pad has an R-Value of R-0.31 but a 3/8" prime urethane pad has an R-Value of R-1.65. This difference is very important since the R-Value of the carpet must also be added.

SYNTHETIC CARPET R-VALUES
Can vary significantly, but the following are typical:
1/4" synthetic carpet = R-0.7
1/2" synthetic carpet = R-1.4

Carpet And Underlayments For Use With Radiant Floors: Carpet is routinely used successfully with radiant floor heating. The following recommendations should be followed:

- Use thin slab rubber pads. They cost more but conduct heat better and will actually prolong the life of the carpet due to their high quality, give, and long life expectancy. If necessary, convince the customer to spend a little less on the carpet and more on this type of pad. Avoid prime and bonded urethane pads because they have high R-values. Thin waffle rubber or thin fiber jute pads may be used if they do not compromise the heat transfer of the system.
- Use thin synthetic carpets preferably berber or commercial style carpets that conduct heat better. Avoid wool carpets which are very resistant to heat transfer.
- Install protective metal plates over the tubing where it may be subject to damage from carpet tack strips.

CHAPTER 6: WHICH RADIANT SYSTEM TO USE

Zurn Gives You Many Intelligent Choices

There are many possible ways of successfully installing a radiant system. The following information can be used to help make these decisions:

- Whenever a concrete slab is being poured, it is always very economical to put tubing in it for a radiant floor heating system. Examples are basements, garages and workshops that normally use concrete floors.
- Understand that some methods will produce more heat with lower water temperatures than others. This is the result of how much resistance the system itself has to heat transfer. For example, slab systems, thin slab systems, Thermal Track, radiant walls, and radiant ceilings put out more heat at lower water temperatures than do systems from below a subfloor such as hanging systems. Sandwich systems with plates fall somewhere in between. Systems that require modest water temperatures may be able to use a water heater as a heat source, depending on local codes.
- Hanging systems and other systems installed from below a subfloor require higher water temperatures (usually provided by a boiler) and are more limited in heat transfer by the extra layers the heat must penetrate. They are most suitable for mild climates and should be used in more demanding climates only with careful heat loss analysis and with floor coverings of modest resistance.
- Slab and thin slab systems contain a great deal of thermal mass and help stabilize temperature swings. They accelerate slowly and are more difficult to use with temperature setbacks. Ceiling systems accelerate rapidly and can be controlled to easily provide numerous temperature setbacks.
- Retrofit applications require looking at what surface is available for installing the radiant heat. Hanging systems and systems with plates from below can be installed where there is access to the underside of joists. Ceilings and walls can have furring strips placed to allow the installation of a radiant ceiling or wall system. Where floor goods are removed, Thermal Track, a thin slab, or sandwich system may be retrofitted.
- Use the knowledge of your contractor, supplier and Zurn Representative to help you decide what is best. Many systems will work. A quality system that your installer is familiar with, can install successfully, and will warrant and service, is of great importance.
- Integrated hydronic heating may cost-effectively provide many functions for your project, such as domestic hot water, snow and ice melt, pool, and spa heating.

Acceleration is a measure of how fast a system can accomplish a change in temperature. Systems with high thermal mass accelerate more slowly with a longer time lag.

Thermal mass is a measure of how many BTUs are stored within the system. Thermal mass can temper solar gains and helps stabilize temperatures. Mostly, this is an advantage. In climates where there are significant temperature changes in the course of a single day, generating a heating and a cooling load in the same day, this is a disadvantage since this mass can be slow to respond to rapid temperature changes. Considerations of thermal mass characteristics should be made when designing and choosing radiant systems.

CHAPTER 7: ZURN RADIANT SYSTEM DESIGN

Design Overview

General System Design Overview: The process of designing a radiant heating system is vitally important to both comfort and efficiency. Basic system design consists of a five-step process:

- Do an Accurate Heat Loss Analysis
- Design the Radiant Panel to have the Correct Output
- Tubing Layout and Flow Analysis
- Choose the Control System
- Select and List the Required Parts

Most designs are now done using computers and software. However, it is important that the designer can successfully do a design without one. Input errors or errors in understanding software can generate a very unsatisfactory result. It is important that the designer be able to double check the computer results by manual calculations. Zurn has an excellent radiant software package, *Design Pro*, by Wrightsoft that can be used to design a radiant heating system. In the following chapters a simple example will be used to demonstrate how a system would be designed with and without a computer. The overview on computer aided design ("Design Pro" software) will demonstrate the steps involved in utilizing the software. The following chapter will provide a reference of how floor, wall, and ceiling radiant systems are designed without a computer. They will yield very similar results, but *not identical* results. This is because the software takes into account more sophisticated information.

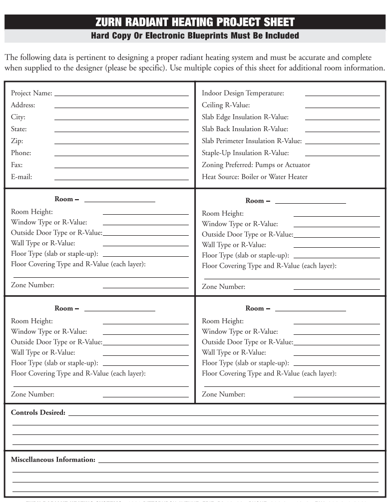
Whether you are utilizing computer assisted design or doing manual designs based on methods in this book, you need to be knowledgeable to be successful. Contact Zurn for training programs.

A thorough knowledge of each of the five design steps is necessary to optimize the system and ensure that it is capable of heating the space properly. Each of these steps will be discussed in detail in the chapters on manual design. This manual provides general insight into each of these areas and is intended as a supplement to the specific knowledge of a designer, contractor or engineer who is familiar with heating technology. A comprehensive design checklist is provided in Appendix A.

Organize The Correct Information

You will need to look at the plans for the project and gather the correct information. The Zurn Radiant Heating Project Sheet included in Appendix A is helpful in organizing information that is required by a radiant designer in addition to a set of plans. It is also helpful to tabulate the wall, floor, window, door and ceiling areas and R-Values as shown on the next page.

Both computer assisted design and manual designs require that you have organized, accurate input information. Most of the information required is the same for both methods. The computer generates the results faster and will select required Zurn materials automatically.


ZURN RADIANT HEATING PROJECT SHEET
Hard Copy Or Electronic Blueprints Must Be Included

The following data is pertinent to designing a proper radiant heating system and must be accurate and complete when supplied to the designer (please be specific). Use multiple copies of this sheet for additional room information.

Project Name:
Address:
City:
State:
Zip:
Phone:
Fax:
E-mail:

Indoor Design Temperature:
Ceiling R-Value:
Slab Edge Insulation R-Value:
Slab Back Insulation R-Value:
Slab Perimeter Insulation R-Value:
Staple-Up Insulation R-Value:
Zoning Preferred: Pumps or Actuator
Heat Source: Boiler or Water Heater

Room –
Room Height:
Window Type or R-Value:
Outside Door Type or R-Value:
Wall Type or R-Value:
Floor Type (slab or staple-up):
Floor Covering Type and R-Value (each layer):
Zone Number:

Room –
Room Height:
Window Type or R-Value:
Outside Door Type or R-Value:
Wall Type or R-Value:
Floor Type (slab or staple-up):
Floor Covering Type and R-Value (each layer):
Zone Number:

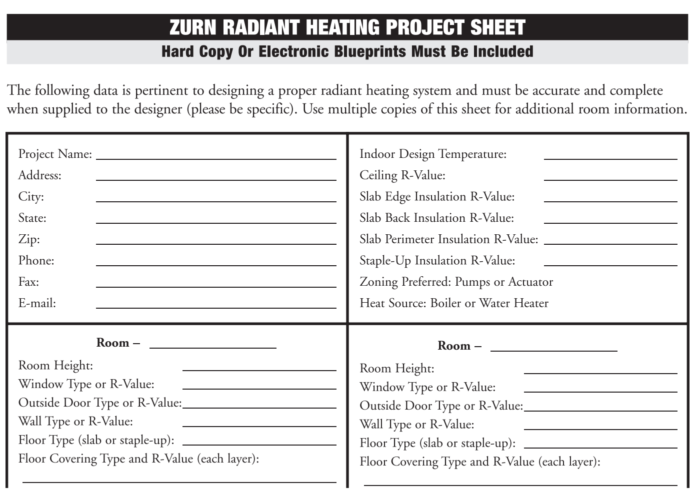
Room –
Room Height:
Window Type or R-Value:
Outside Door Type or R-Value:
Wall Type or R-Value:
Floor Type (slab or staple-up):
Floor Covering Type and R-Value (each layer):
Zone Number:

Room –
Room Height:
Window Type or R-Value:
Outside Door Type or R-Value:
Wall Type or R-Value:
Floor Type (slab or staple-up):
Floor Covering Type and R-Value (each layer):
Zone Number:

Controls Desired:

Miscellaneous Information:

ZURN RADIANT HEATING SYSTEMS · 1801 PITTSBURGH AVENUE, ERIE, PA 16502 · PHONE: 814-875-1358 · FAX: 814-871-6141


ZURN RADIANT HEATING PROJECT SHEET
Hard Copy Or Electronic Blueprints Must Be Included

The following data is pertinent to designing a proper radiant heating system and must be accurate and complete when supplied to the designer (please be specific). Use multiple copies of this sheet for additional room information.

Project Name:
Address:
City:
State:
Zip:
Phone:
Fax:
E-mail:

Indoor Design Temperature:
Ceiling R-Value:
Slab Edge Insulation R-Value:
Slab Back Insulation R-Value:
Slab Perimeter Insulation R-Value:
Staple-Up Insulation R-Value:
Zoning Preferred: Pumps or Actuator
Heat Source: Boiler or Water Heater

Room –
Room Height:
Window Type or R-Value:
Outside Door Type or R-Value:
Wall Type or R-Value:
Floor Type (slab or staple-up):
Floor Covering Type and R-Value (each layer):

Room –
Room Height:
Window Type or R-Value:
Outside Door Type or R-Value:
Wall Type or R-Value:
Floor Type (slab or staple-up):
Floor Covering Type and R-Value (each layer):

Zurn Radiant Heating Project Sheet is a starting point for a radiant design.

Chapter 7

The heat loss analysis either manually or by computer requires an accurate set of plans. Make sure to get them before you start. You will need information similar to what is shown below.

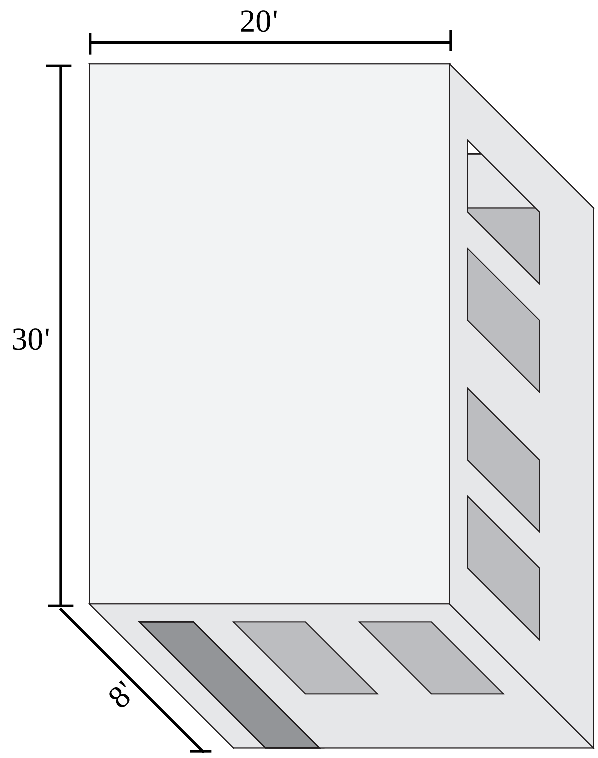
DESIGN SAMPLE

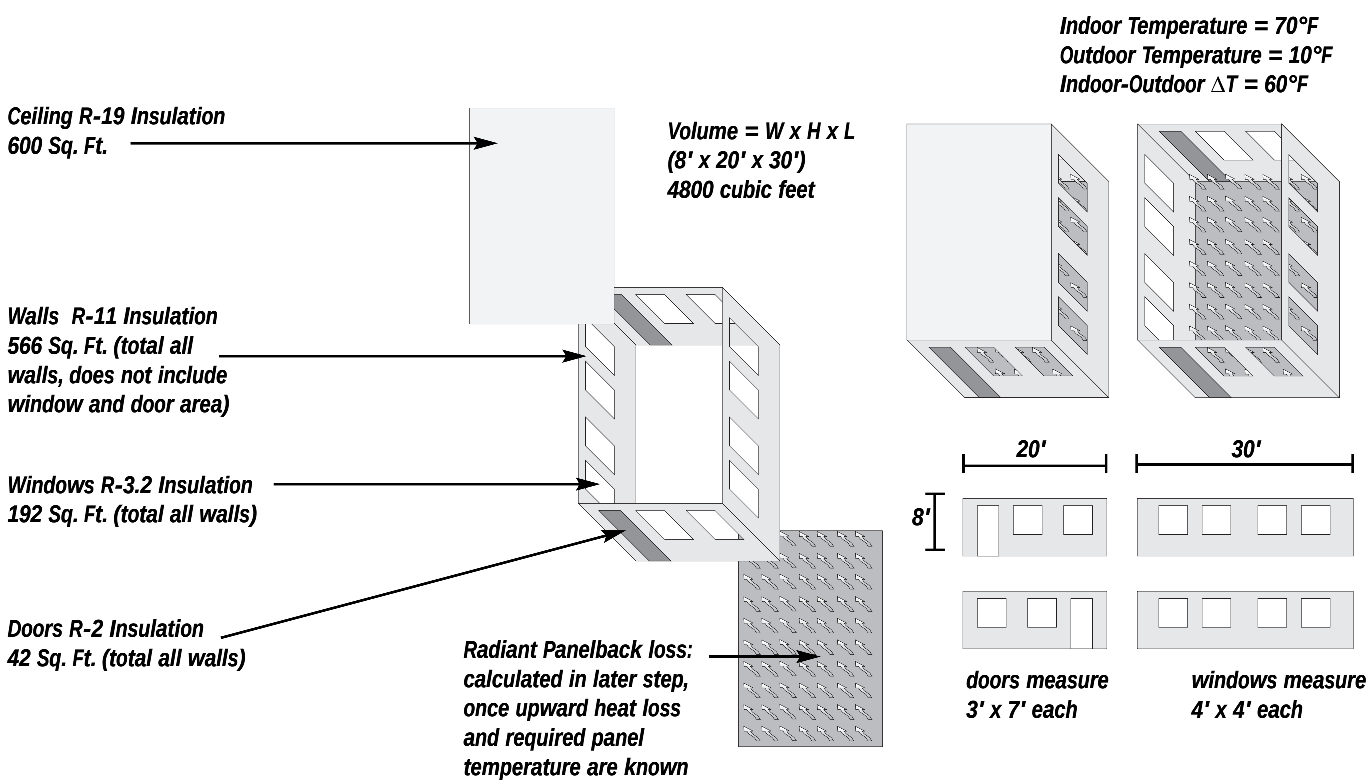
For both computer assisted and manual system design we will be using a simple 20' wide x 30' tall x 8' high single room cabin with a radiant slab and a flat ceiling as an example. For simplicity it has a flat roof.

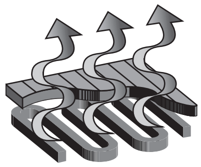
SAMPLE CABIN SUMMARY INFORMATION:
Before a heat loss can be accurately calculated, the needed information on the floor, wall, ceiling, doors and windows must be assembled in an orderly and useful manner. The indoor and outdoor design temperatures must be determined. It is helpful to put this in summary form:

Ceiling Area = 600 Sq. Ft.	R-19
Floor Area = 600 Sq. Ft.	R-19*
Wall Area = 566 Sq. Ft.	R-11
Door Area = 42 Sq. Ft.	R-2
Window Area = 192 Sq. Ft.	R3.2
Volume = 4800 cubic feet	
Indoor Temperature = 70°F	
Outdoor Temperature = 10°F	
Indoor-Outdoor ΔT = 60°F	

*Slab floor example uses outer area of R-10 and inner portions of R-5 insulation.







There is no substitute for reading the manual and going to a training class. In addition, do enough calculations by hand that you can double-check what sort of results are reasonable. For example, it would be useful to know that in a given climate, most well insulated new homes with a reasonable amount of glass average a heat loss of 25 BTUH per square foot, and that rooms with high ceilings and more glass often average 33 BTUH per square feet (example for your climate would be different). With this baseline knowledge, results that are significantly different would indicate a need to double-check your inputs. Similar knowledge of expected floor surface temperatures, flow rates, etc., is very useful for double-checking results.

CHAPTER 8: COMPUTERIZED DESIGN

Design Pro Software

Designing a radiant heating system without a computer is time consuming and cumbersome. Knowledge of how to do hand calculations is important in understanding the software and in double-checking results. Most radiant heating systems are now designed using software.

The Design Pro software simplifies the work, speeds the process and gives very professional outputs. Contact Zurn, your Zurn Representative or Zurn Wholesaler about training and software availability.

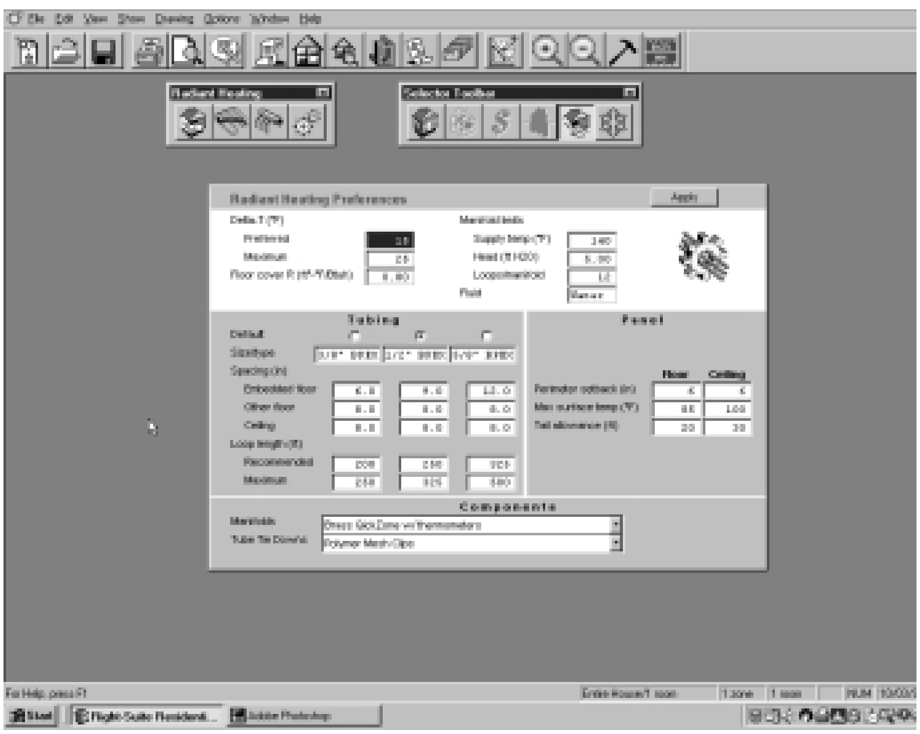
The software automates many aspects of radiant heating design but still requires accurate input and knowledgeable choices. The Zurn software requires that you have the following information available to facilitate an accurate room-by-room assessment of heat loss and design:

- Area and R-Value of doors, windows, and skylights
- Dimensions and R-Values of walls, floors, and ceilings
- Outdoor design temperature (many can be looked up in program)
- Indoor design temperature
- Radiant system or systems type (slab, hanging, ceiling, etc.)
- Subtractions from panel area (areas not containing tubing)

The following computerized design for our sample cabin is not designed to offer detailed operational instructions for the software, but rather to give an overview of the steps that go into utilizing the software. For detailed instructions refer to the Design Pro Users Manual.

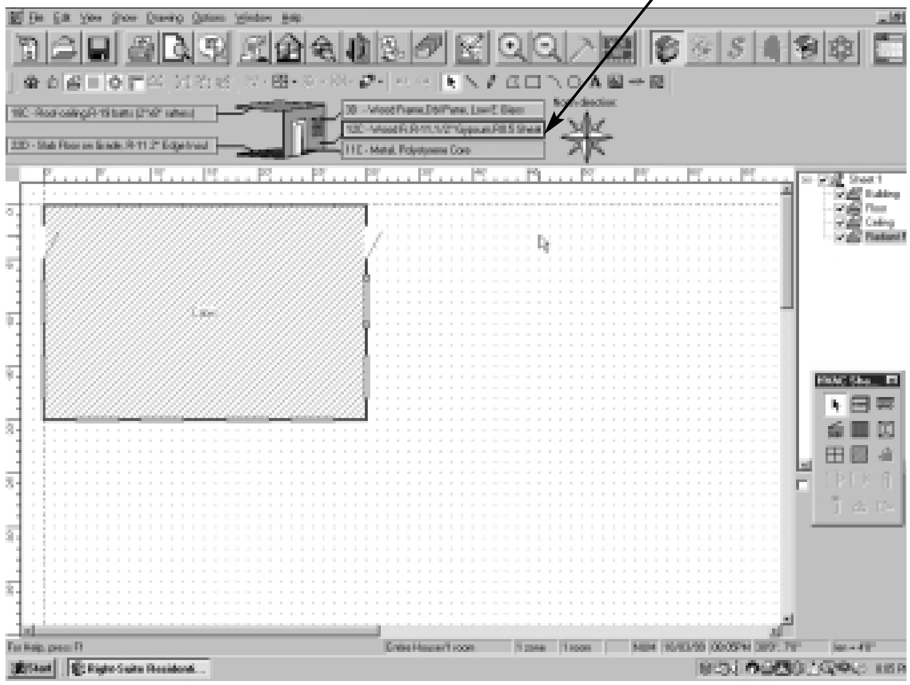
Chapter 8

The software contains screens where default preferences are entered. This saves re-entering data later. For our sample cabin, we have selected 1/2" barrier PEX on 9" centers with a 6" setback from the walls as a default. In other screens we will enter the default air change rate, and indoor and outdoor design temperatures.



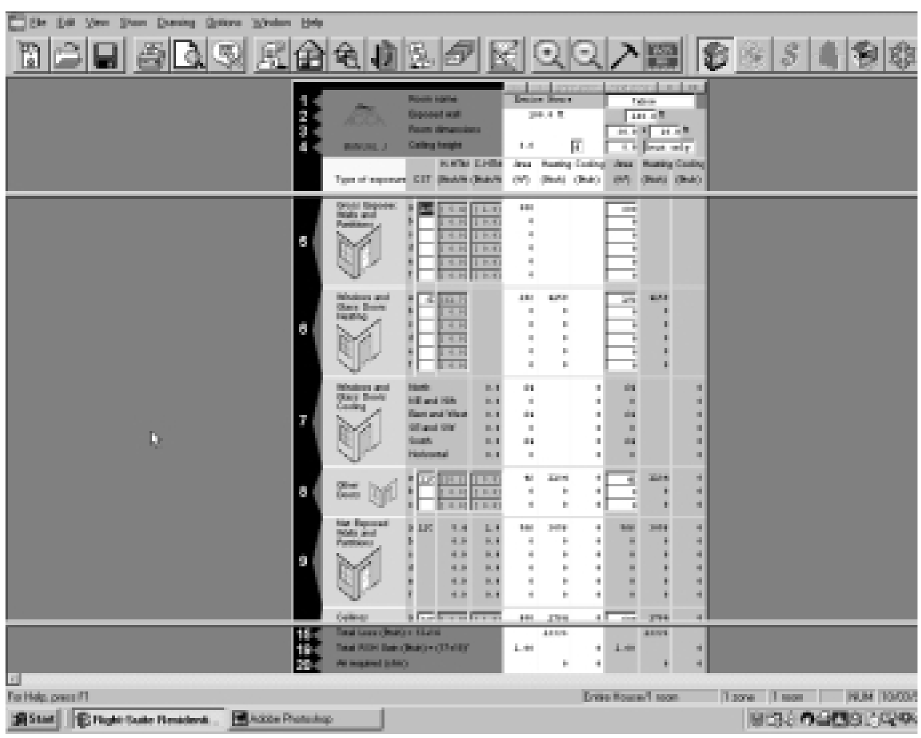
Notice how default settings can be utilized

Room-by-room data entry can be done in one of two ways. The first data entry method is through a drawing screen where the different surfaces are placed on the drawing screen. Property boxes may be double clicked on, for each item, to give more detail. For example, a window property box, when double clicked will allow entry of dimensional and R-Value information. The default settings again may be stored and retrieved from a library. Notice the default settings specified above the drawing screen in the small cutaway house.

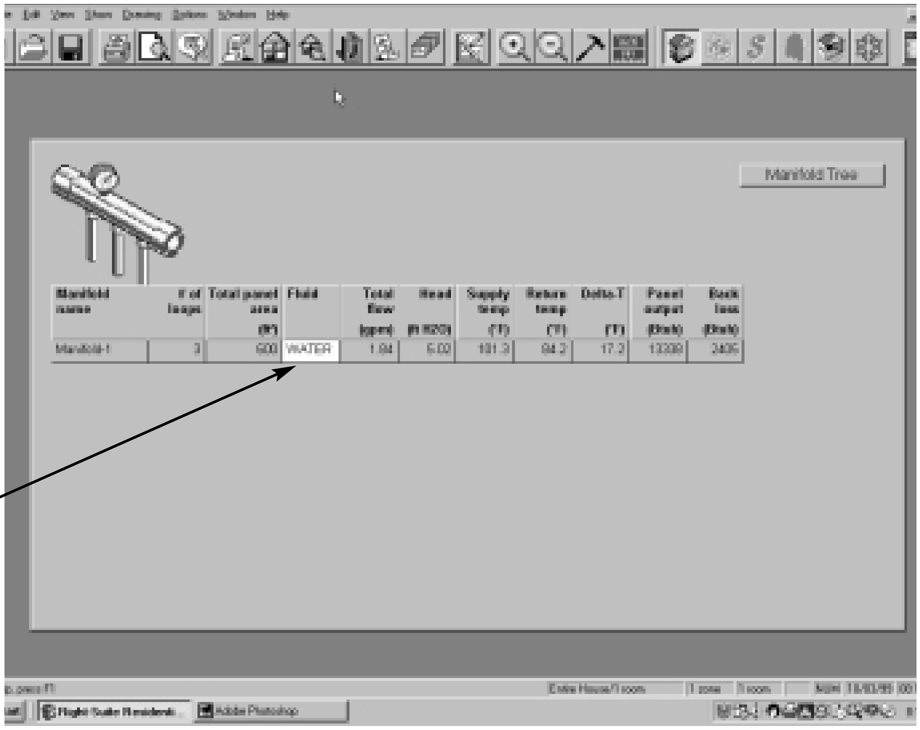


The second option, as shown to the right, is to enter into a worksheet the required information for each room. Each surface, (doors, walls, ceiling, etc.) is entered into the worksheet. Libraries of often used assemblies may be developed to save time. Many of the standard construction assemblies are already included in the library that comes with the software. For example, the wall assembly 12c, that is in the library is, described as "wood framing, R-11 insulation and 1/2" of sheetrock." This describes typical 2" x 4" construction. Typical settings may be saved as default templates for further use.

Warning: Use of this method severs connections to drawing screen.

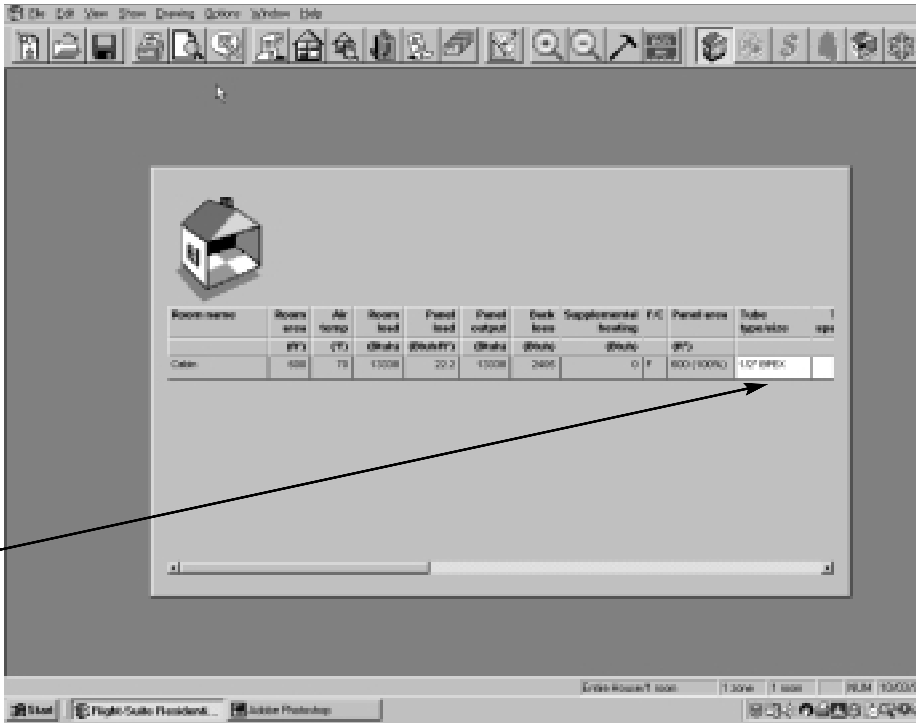


The software contains screens where detailed design parameters may be fine tuned. For example, on this manifold screen the highlighted fluid says water. It may be changed to various percentages of propylene glycol. The computer will then calculate the heat transfer and flow rates based on the fluid entered.



Highlighted fluid selection box

Pipe size, pipe spacing and other parameters may be set on a room-by-room basis.



Pipe size selection can be set for each room.

The software will output numerous useful and very professional reports. The attractive format, solid information, and ease of use make this program an essential tool for the design of hydronic heating systems. The software can also design cooling systems, as well as forced air, making it an invaluable aid in designing hybrid systems.

ZURN

RADIANT HEATING DESIGN SUMMARY

Sample Company **Job: s-1**

Your Company Address, Your City, ST

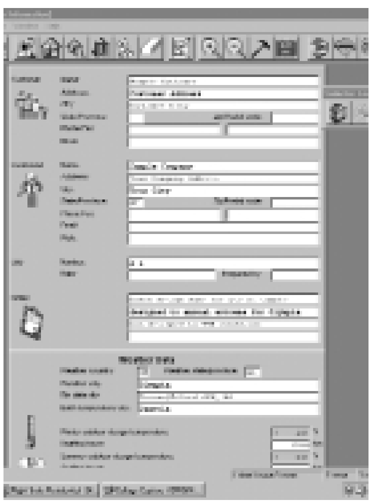
Project Information

For: Sample Customer

Design Information

Total floor area:	600	ft≤	Design temperature:	10	∞F
Radiantly heated area:	600	ft≤		101	∞F
Total panel area:	600	ft≤	Total flow rate:	1.84	gpm
Total tubing area:	600	ft≤	Maximum head loss:	5.02	ft H2O
Total room load:	13338	Btuh	Total tubing required:	860	ft
Total panel output:	13338	Btuh	Number of loops:	3	
Total supplemental heat:	0	Btuh	Number of zones:	1	
Total back loss:	2405	Btuh	Number of manifolds:	1	
Boiler output required:	15743	Btuh			

Room name	Room area (ft≤)	Air temp (∞F)	Room load (Btuh)	Supp. heat (Btuh)	F/C	Panel area (ft≤)	Tubing area (ft≤)	Surf. temp. (∞F)	Deliv. temp. (∞F)	Panel output (Btuh /ft≤)	Back loss (Btuh /ft≤)
Cabin	600	70	13338	0	F	600	600	83	101	22	4.0
Totals	600		13338	0		600	600				



ZURN

QUOTATION

Sample Company **Job: s-1**

Your Company Address, Your City, ST

For: Sample Customer

Description of work:

Src	Part #	Description	Qty	Unit price	Extension
		Radiant Heating Equipment			
QST	QHR3PC300X	1/2" x 300' Roll (Barrier)	3	279.00	837.00
QST	QHPMC	Polymer Mesh Clip	344	0.33	113.52
QST	QHCE3	1/2" Conduit Elbow	6	2.50	15.00
QST	QHMKIT		1	115.00	115.00
QST	QHMAVKIT1	QickZone Air Vent Assembly Kit 1 w/ Thermometers	1	94.00	94.00
QST	QHMCM		1	37.00	37.00
QST	QHMMC3	QickZone Manifold PEX Connectors - 1/2" (2 per bag)	3	8.41	25.23
		Subtotal, Radiant Heating Equipment			**1236.75**
		Overall total			**1236.75**

Notes:

DESIGN PRO VERSUS HAND CALCULATIONS

The software specified a total heat loss of 15,743 BTUH for our sample cabin. Our hand calculations in the chapters on designing a radiant system came out to 15,175 BTUH, or within about 3% the software result. The wall, door, window and ceiling assemblies used in the software were similar but not identical to those used in our hand calculations. The two methods, properly done, will always produce similar, but only rarely, identical results.

ZURN

RADIANT HEATING TUBING REQUIREMENTS

Sample Company **Job: s-1**

Your Company Address, Your City, ST

Project Information

For: Sample Customer

Tubing Requirements

Roll 1: 300 ft 1/2" BPEX (Part # QHR3PC300X) 1 length 13 ft waste
Cabin-A: 287 ft

Roll 2: 300 ft 1/2" BPEX (Part # QHR3PC300X) 1 length 13 ft waste
Cabin-B: 287 ft

Roll 3: 300 ft 1/2" BPEX (Part # QHR3PC300X) 1 length 13 ft waste
Cabin-C: 287 ft

Software Steps:

The correct use of the software includes the sequential entry and use of 27 steps that are summarized below. The software includes an extensive manual and examples. Remember, you need accurate information for data entry, the software manual for reference and training in the correct use of the software. When used correctly, the software will provide you a rapid accurate design and a quotation of required Zurn parts.

	Screen Location	Action
	First Time Defaults	
1	Project Information	Set Weather City and Weather State
2	Radiant Preferences	Preferred and Maximum Delta-T
3	"	Manifold Limits - (Supply Temperature, Head Pressure, & Loops/Manifold)
4	"	Tubing Size, Spacing, & Loop Length
5	"	Manifold Selection
6	"	Tube Tie Down Selection
7	Quote Summary	Type in List Price Disclaimer
8	Save As	C:\My Documents\Qest Hydronics\Template\default.rtr
	Per Job Defaults	
9	Project Information	Input Customer Information
10	"	Check (and change if needed) Weather City and Weather State
11	Zone Information	Check (and change if needed) Indoor Design Temperature
12	Infiltration Screen	Check (and change if needed) Infiltration
13	Right-J Keysaver	Check (and change if needed) Ceiling Height
14	Radiant Preferences	Check (and change if needed) Preferred and Maximum Delta-T
15	"	Check (and change if needed) Manifold Limits
16	"	Check (and change if needed) Tubing Size, Spacing, & Loop Length
17	"	Check (and change if needed) Manifold Selection
18		Check (and change if needed) Tube Tie Down Selection
19	Right Draw	Input Roof, Floor, Walls, Windows, & Door Information
	Structure and Quotes	
20	Right Draw	Draw Structure
21	"	Change any information different from defaults
22	"	Place Radiant Panel
23	"	Change radiant panels from heat transfer plates to the needed option
24	Quote Summary - Details	Click on section you want additional parts placed
25	Quote Cost Database	Select additional parts needed to finish quote
26	Quote Summary	Type in Description of Work
27	Print Preview	View & Print Quotation, Design Summary, Manifold Summary, & Tubing Requirements

	Sidenotes
ALL	Placing cursor arrow on each icon will pop up the icon's name for a screen location reference
1&8	Nearest City to job site
2&13	Preferred - 20, Max - 25
3&14	140 Deg F, 10 ft Head, 14 Loops - Plastic, 12 Loops Brass
4&15	1/2" is 90% of jobs, 3/8" for staple up, 5/8 or 3/4 Commercial and Snowmelt
6	NOTE: ALL PRICES QUOTED ARE LIST PRICES SUBJECT T ZURN PUBLISHED DISCOUNTS AND TERMS OF SALE. THESE PRICES ARE FOR THZURN MATERIALS AS LISTED AND DO NOT INCLUDE THE HEAT SOURCE, CIRCULATING PUMPS OR RELAYS, PIPE OR FITTINGS BETWEEN HEAT SOURCE AND MANIFOLDS, OR THE COST OF INSTALLATION. NO SALES TAX INCLUDED
7	Saves file that will be brought up when the software is accessed
18	Click and drag rooms, windows & doors
24	Zurn Radiant Floor Heating Equipment as listed. d. Includes: 1/2" PEX tubing with oxygen barrier, manifolds, and controls for one (1) heating zones. NO CIRCULATING PUMPS OR HEAT SOURCE INCLUDED.

CHAPTER 9: REFERENCE DESIGN METHODS

This chapter is intended to demonstrate how a radiant design may be done without the use of a computer. It also provides the reference methods to double-check results that are generated by computer assisted design. A qualified radiant designer needs to be proficient both with these manual calculations and with computerized design.

Heat Loss Analysis Heat loss analysis is the basis for any heating system design. It is the critical analysis upon which all subsequent calculations are dependent. Radiant panel heating systems are unique in the fact that they are integrated within the structure of the building. Once installed, they are difficult, if not impossible to change. The performance calculations that are developed from the heat loss calculations must be sufficiently accurate to ensure that the radiant panel heating system performs properly.

Room-by-Room Analysis Typically, each and every room of a structure behaves differently with regard to heat loss. Even in buildings with relatively mild heating loads, some rooms with large windows and small floors may have proportionately higher heating loads per square foot of floor. If a radiant panel heating system embedded in the floor can not provide enough capacity to provide sufficient heat to the individual high load area, wall or ceiling panels may need to be considered in addition to the floor panel. This is why it is so important that heat loss analysis be performed on a room-by-room basis, to identify areas that may be difficult to heat individually or require special considerations in order to heat properly.

Remember that a heat loss is done for a specific condition usually what is called a 99% winter condition. This means that 99% of the time in the winter it will actually be warmer outside than designed for. So most of the time the structure will be losing much less energy than the design condition.

Economy of Design A thorough heat loss analysis can be useful in making recommendations to reduce the heat loss of the structure, thus enhancing comfort and efficiency. Often, minor changes in insulation or floor coverings can have dramatic effects on the performance of the heating system. The designer should be very familiar with the principles of heat loss and able to apply those principles toward improving the design.

Input Data Heat loss analysis requires precise input data regarding dimensions and a variety of other thermal performance data. Dimensions should be as accurate as possible, and thermal efficiencies (R-Values) of components should be accurate within 5%. The thermal efficiencies (R-Values) of windows and doors should be obtained from the manufacturer, and based on industry recognized standards of testing.

Input Temperatures Heat loss analysis is based on the difference between indoor and outdoor temperatures at the lowest sustained temperature of the heating season. Higher indoor temperatures or lower outdoor temperatures will result in higher heat loss calculations. Lower indoor temperatures or high outdoor temperatures will result in lower heat loss calculations. If the heat loss calculations are too high, the system may be oversized for the building and operate inefficiently at lower demands. If the heat loss calculations are too low, the system will be undersized for the building and unable to satisfy peak demands for heat.

THE RADIANT SET POINT ADVANTAGE: Forced air systems provide a chilling effect (wind chill) to the body. In order to compensate for the chilling effect of forced air, the thermostat must be set higher than would be the case with radiant panel systems.

RESISTANCE VALUES (R-VALUES): The terms "resistance values" or "R-Values" refer to the resistance to heat transfer of components of a structure to the outside. Materials and components are tested for their ability to resist the transfer of heat and are assigned a numerical value. The higher the R-Value, the greater the resistance to heat transfer. Resistance values of various components in the wall may be added together, such as for insulation, sheathing, and siding in a wall. In other cases, the panel may be given a composite rating such as for a door or window that has both wood and glass components. General guides for R-values of building materials are available from several sources. Specific product information should be obtained from the manufacturer.

CONDUCTANCE VALUES (U-VALUES): This term refers to a material's ability to transfer and conduct heat. Simply stated, the U-Value is the inverse function of the R-Value ($U = 1/R$). The higher the U-Value of a material, the greater its ability to conduct heat.

Indoor Set Point Temperature Radiant panel heating systems provide more efficient heat distribution, which results in greater comfort at a lower set point temperature. Radiant heating systems have proven to be very comfortable for residential type applications when they are set at a room temperature between 65°F and 70°F, particularly when installed as a multi-zoned system. Single zone systems often place the thermostat in the center of the building where it is sheltered from the major heat loss. In order to be comfortable near the exterior walls, a higher set point is selected.

Outdoor Design Temperature Outdoor temperature is the driving force behind heat loss. For design purposes, select an outdoor design temperature that represents the lowest normal temperature that is likely to occur over a sustained period of time. Do not use the lowest recorded temperature for these calculations because it does not occur for a sustained period. Knowledge of the regional weather conditions is critical in determining outdoor design temperature. The ASHRAE 1997 Fundamentals Handbook provides a guide for outdoor design temperature, as well as the Design Pro Software.

Temperature Differential Indoor/Outdoor The difference between indoor and outdoor temperature is the thermodynamic force which draws heat from indoors to the outdoors. Normally this differential temperature (often called Delta T or ΔT) is easy to calculate as the difference between room set point temperature and the outdoor design temperature. In other cases, however, there may be losses of heat from one room to another room, such as a garage, which is heated, but to a lower temperature than the remainder of the home. Special cases require accurate estimating of the differential temperature.

Structural Heat Loss Structural heat loss results from heat energy that is conducted through the various walls, ceilings, floors, doors and windows that exist between the indoor heated space and the outdoors, or another unheated space. The amount of heat that is lost depends upon the indoor and outdoor differential temperature (ΔT), the amount of surface area exposed, and the specific resistance to heat transfer (R-Value) of the structural materials.

Calculating Heat Loss Through a Panel To calculate heat loss through a panel, divide the difference in temperature (ΔT) between the outside and the inside temperatures by the R-Value of the panel. The result will be the amount of heat loss (BTUH) transmitted through a single square foot of panel surface per hour. Multiply this number by the total area of the panel to determine the heat loss for that panel. Heat loss for panels with different R-Values such as doors, walls, and windows, are calculated separately.

$(T_I - T_O)$ is often also expressed as the indoor/outdoor ΔT (temperature difference).

Remember that the U-Value of a material is the reciprocal of the R-Value, therefore multiplying by 1/R-Value is the same as multiplying by the U-Value.

Formula for Heat Loss Through an Outside Structural Panel

$(T_I - T_O) / R_V = Q\text{-}_L{}'$

Where:

T_I is the inside temperature

T_O is the outside temperature

R_V is the resistance value of the structural panel

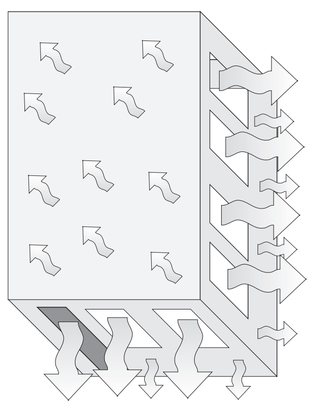
$Q_L{}'$ is the heat loss expressed in BTUH per sq. ft.

By multiplying $Q_L{}'$ by the area of the wall, we can find the total heat loss through the wall:

' x wall area = Q_L or expressed another way: wall Area/R_V x $(\Delta T) = Q_L$

Calculating the Total Room Losses Through the Envelope Analyze the heat loss of each room individually. When heat loss for each panel has been calculated, add the total heat losses from the various panels to obtain the total heating load for the room at the selected design temperature. Only exterior walls, doors, windows, skylights and ceiling panels are used to determine the heat load of each room. For rooms with no exterior walls, calculate the heat losses through the ceiling only. Do not consider any heat gains from adjoining rooms at this time. Do not consider the heat losses below a heated floor or above a heated ceiling at this time. These losses are calculated as back losses to the heated panel and are discussed later.

The heat loss through windows, doors walls and ceiling of our sample cabin would be calculated as shown below:



Cabin Q_L = 9842 BTU/HR

The graphic above shows how small areas like windows and doors lose more heat due to their lower low R-Value.

CABIN SURFACE HEAT LOSS CALCULATION (DOES NOT INCLUDE RADIANT PANEL)

	R-VALUE	U-VALUE	INDOOR-OUTDOOR ˜T	AREA	BTU/HR
CEILING	19	0.053	60	600	1895
WINDOWS	3.2	0.313	60	192	3600
DOORS	2	0.500	60	42	1260
WALL	11	0.091	60	566	3087
				TOTAL	**9842**

FORMULA: U-VALUE*INDOOR-OUTDOOR ˜T*AREA=BTU/HR or A/R x (˜T)=BTU/HR

The Effects of R-Value on Heat Loss Very low R-Values on even very small panels can create large heating loads. Windows with R-Values of 2 will lose half of the energy exposed to them. Using our cabin as an example, notice that a relatively small area of windows and doors contributes 4860 BTU/HR. This is due to the low R-Value of these materials. This heat loss could be modified by reducing the number of windows or upgrading the R-Value of the windows and doors.

Doing the heat loss analysis gives you an opportunity to see where improving insulation levels can reduce the heat loss and make the structure easier to heat.

The amount of infiltration depends on construction quality and environmental factors. Remember that environmental factors such as wind speed and location have a great deal of influence on the amount of infiltration in a structure.

The volume of air exchange is normally calculated in Air Changes Per Hour or ACH. The following values of ACH are often used:

Tight Construction	0.3 ACH
Average Construction	0.5 ACH
Poor Construction	0.7-1 ACH

THE HEAT CAPACITY OF AIR (HCA) DEFINED:

The constant of 0.0183 represents the amount of energy (BTU) needed to raise 1 cubic foot of air 1°F.

Remember that our cabin was 8' tall by 20' wide by 30' long. Volume is calculated by:

W x L x H which in this case equals 4800 cubic feet

Infiltration and Ventilation Heat Losses In addition to structural heat losses, a portion of the heat energy in the room will be lost to infiltration and ventilation. The air that exchanges between outdoors and indoors carries with it a certain amount of mass that must be heated to maintain room comfort. Air changes come about by opening and closing doors, leaks around windows and doors, natural and forced ventilation, and drawing combustion air for fuel burning heat appliances.

Calculating the Volume of Air Exchanged It is important to provide good data for the volume of air exchanged. In some cases, the amount of energy lost to air changes is critical. For normal new construction in residential buildings, air changes can be estimated at around 0.5 air changes per hour. Older buildings with poor fitting windows and poor seals around doors will have much higher infiltration rates. Sealed combustion burners and non-combustion heat plants reduce the amount of air drawn into the building and result in lower air exchange rates.

Calculating Air Exchange Heat Loss To calculate air exchange heat loss we must know the indoor temperature, the outdoor temperature, the volume of the room, and the rate of air exchange.

Formula for Heat Loss Due to Air Exchanges

$(T_I - T_o) \times (AC/HR \times Volume) \times 0.0183 = Q_i$

Where:

T_i is the inside temperature

T_o is the outside temperature

Volume is the room volume in cubic feet

AC/HR is the air changes per hour

0.0183 is the Heat Capacity of Air

Q_i is the heat loss expressed due to infiltration in BTUH

Referring to ACCA Manual J, residential air exchange values can range from 2.2 to 0.3. For the sake of this example, we used 0.6 AC/HR in our sample cabin design. Using our cabin as an example, an 8-foot tall, 600 square foot room has an air change of 0.6 per hour with an indoor temperature of 70°F and an outdoor temperature of 10°F. The equation above shows the heat loss due to air exchange to be 3110 BTUH.

(70 – 10) x (.6 x 4800) x 0.0183 = 3110 BTUH as shown below:

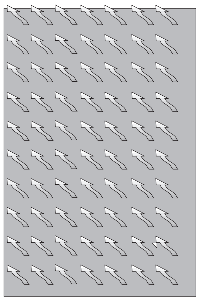
VOLUME	AIR CHANGES	INDOOR-OUTDOOR ˜T	HCA	BTU/HR
4800	0.6	60	0.018	**3110**

FORMULA: VOLUME*AIR CHANGES*INDOOR-OUTDOOR ˜T*HCA=BTU/HR
HCA=HEAT CAPACITY OF AIR

Chapter 9

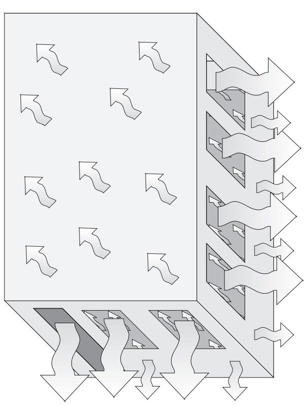
Air-to-Air Heat Recovery Exchangers When an air-to air-heat exchanger is used to recover some heat energy from the exhausted air and to heat the incoming air, the total effect of air change is reduced by the efficiency of the unit. If a unit is 40% efficient, then only 60% of the volume of air changed will need to be heated by the radiant panel system.

Special Air Change Requirements In certain commercial buildings ventilation requirements are increased because of industrial processes or high occupancy rates. Areas that are designated as “Smoking” require more ventilation than “Non-Smoking” areas. In all of these circumstances, the designer must determine if the additional ventilation will require more heat energy from the radiant panel. Some industrial processes actually contribute more heat than the additional ventilation will demand. Therefore, when the equipment is running and the ventilation is at its peak, no additional heat will be needed because of the additional heat contributed by the equipment. This is also true of high occupancy rates. The heat that is provided by additional bodies in the room more than offsets the additional heating load for the ventilation. In other cases, very little additional heat may be available from the industrial process. In those cases, supplemental heated make-up air may be required.



The upward output of a radiant panel is looked at separately from the back loss.

Heated Make-Up Air In those cases where the air change requirement is high, it may not be practical to overcome the additional heat losses with the radiant panel. The radiant panel may not respond quickly enough to maintain the comfort level, or may over-compensate when the ventilation rate is slowed. In such cases, it may be more practical to heat the make-up air. A typical system might involve a fan coil, placed within the ventilation system, to heat the discharge air.



The radiant floor panel in our cabin will provide the heat to counteract the upward heat losses and maintain a comfortable room temperature. The upward amount of energy required is called Q_{up}. Once this is calculated, we can calculate what floor temperature is required and from this calculate the slab back loss.

Q_{up}, The Total Upward Load The total upward heating load consists of the structural heat losses and ventilation losses that must be overcome by the radiant panel distribution system. Any supplemental heat, make-up air, or other heat sources must be subtracted from the total heating load. For our sample cabin, this is calculated as follows:

HEAT LOSS: CEILING, WALLS, DOORS, WINDOWS AND INFILTRATION

EXPRESSED AS TOTAL (9842+3110)	BTU/HR	**12952**
AS EXPRESSED IN BTU/SQ/FT OF FLOOR AREA	BTU/SQ/FT/HR	**22**

Chapter 9

CHAPTER 10: DESIGNING A RADIANT SYSTEM

Radiant Panel Output, Sizing And Calculations

Performance Planning Once we have determined the heating demands of a room through heat loss analysis, we must next ensure that the performance of the radiant panel will meet the heating demands of the room. Performance planning will determine the required energy output, surface temperature, supply water temperature, and tubing spacing for slab on grade, suspended floor, ceiling, and wall installations of radiant panels.

Energy Output Determining the BTUH Load Per Square Foot: Room-by-room heat loss analysis determines the amount of heat loss that each room will experience at the maximum heating load. The next step is to determine how much floor surface area will be available to distribute the energy required to heat each room.

The following equation is used to determine the BTUH load per square foot. Divide the Upward Load by the number of square feet in a room.

Total Upward Load/Total sq. ft. = Upward Load BTUH per sq. ft.

Using the room in our sample cabin the BTUH per sq. ft. is 22

12,952 / 600 = 22 BTUH per sq. ft.

Subtractions from panel area frequently occur from areas that are not practical to put tubing in. The areas under cabinets and stair landings are the examples given at right, but there are others such as under fireplaces, pantries where people want food or wine kept cool. Heat under a refrigerator just makes it work harder and could be eliminated. Bathroom fixtures also obstruct floor space.

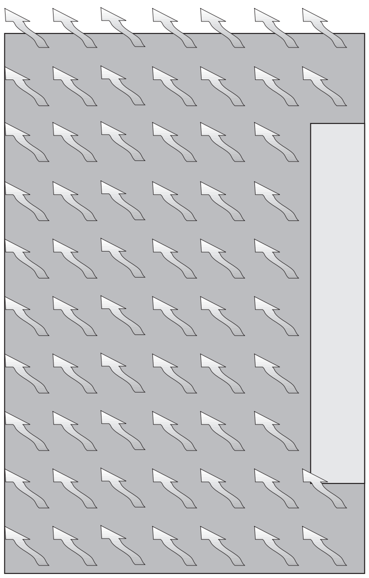
After these subtractions from the usable panel area, what's left is referred to as the Effective Floor Area or Usable Panel Area.

Unheated Floor Areas In a typical building there are areas where the floor surfaces may not be heated, or will be heated minimally. Areas under cabinets and stairs may not have tubing in them and should not be considered part of the radiant floor area. Any reduction in the heated floor area will increase the required heat load per square foot.

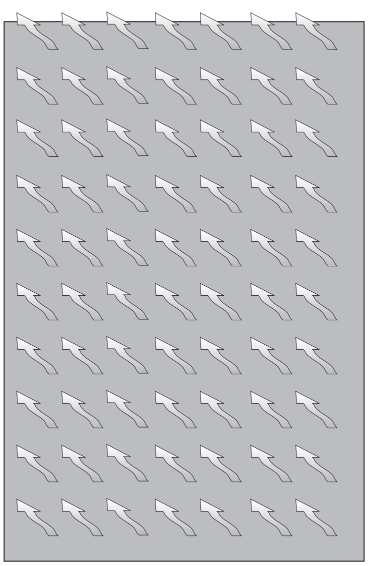
The designer must also take into consideration that although a bedroom or living room may have up to 50% of its floor space covered by furniture, furniture arrangements are not permanent and can change with time or different occupants. As discussed in Chapter 1, there is still some heating benefit when a large object is placed on the floor. The object can conduct heat from the floor then transmit this heat into the room via convection or radiation.

Effective Floor Area The designer must consider the patterns of a room when judging how much of the floor will be useful for distributing radiant heat. If the items placed on the floor inhibit thermal transfer, then they will effectively reduce the amount of heated surface and increase the required load per sq. ft. in heated areas.

The example at right, where cabinets are subtract from floor area is often encountered, but some contractors put tubing under counters and cabinets, arguing that the average American remodels every seven years and may put these items in totally different places during the remodel.



With an EFF of 90%, more heat per square foot of usable panel area must compensate for the smaller effective area. In the case of our cabin, the Total Usable Panel Upward Load = 24.44 BTUH per sq. ft.



With an EFF of 100% The Total Usable Panel Upward Load = 22 BTUH per sq. ft.

If, for example, our cabin had 60 sq. ft. of cabinets that inhibit heat transfer from the floor, then the effective floor area is 90% of the total square feet of the room. The designer should look at each room and estimate the amount of floor space that will adversely affect heat transfer. The “Effective Floor Factor” (EFF) is calculated using the following equation:

1 – (Total Room Area-Subtractions From Panel Area)/
Total Room Area = EFF

Using the above equation and the parameters for the cabinets in the above example, the Effective Floor Factor would be:

(600-60)/600 = .9 or 90% EFF

Dividing the upward load per sq. ft. by the EFF determines the total upward usable panel load per sq. ft. (BTUH per sq. ft.) needed to satisfy the heating requirements of the room. The usable panel upward load per sq. ft. is calculated using the equation below:

Upward Load per sq. ft./EFF = Total Usable Panel Upward Load per sq. ft.

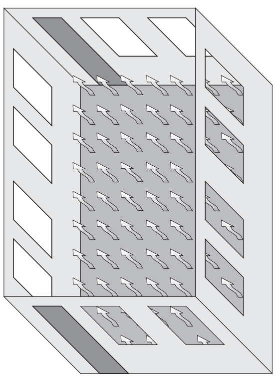
Using our cabin as an example, subtracting out the cabinet area would give us a Total Usable Panel Upward Load per sq. ft. of 24.44 BTUH per sq. ft. instead of the 22 BTUH per sq. ft. we would get with 100% EFF.

22/.9 = 24.44 BTUH per sq. ft. Total Usable Panel Upward Load

For simplicity in our sample cabin design, we will use a 100% EFF or 600 sq. ft. panel area with a 22 BTUH per sq. ft. Total Usable Panel Upward Load The following steps are done the same way using either.

Coefficient of Heat Transfer It is important for the designer and installer to understand the amount of energy that a radiant floor will transfer into a room at any given surface temperature. This factor is called the coefficient of heat transfer. The precise amount of energy transferred depends on many complex variables, and ranges from about 1.8 BTUH per square foot to 2.1 over the range of temperatures normally used in radiant heat panels. For the purpose of performance planning, it is practical to use a coefficient of heat transfer of 2.0, which represents the output over most of the critical range of temperature. A thermal transfer coefficient of 2.0 means that 2 BTU per hour will be transferred from one square foot of heated floor for every degree Fahrenheit the floor surface temperature exceeds room temperature.

AUST or Average Unheated Surface Temperature, of the non-radiant panels has an effect on the output of the panel. As the walls are colder the ΔT between the panel and the surfaces in the room goes up, and typically, also the convective loop of cooler air cascading down the walls and across the warm radiant panel increases. These facts mean a panel will transfer more heat at the same temperature if the AUST is lower. The computations to calculate AUST and its effects on the output of a radiant panel are somewhat complex, and best left to a computer. Typically, AUST is lower in cold climates with high heat losses.



Cabin Radiant Floor Surface Temperature is estimated to be 81°F to have an upward output of 22 BTUH per sq. ft

Radiant Floor Surface Temperature Total Usable Panel Upward Load (BTUH) per square foot determines the required floor surface temperature. The floor surface temperature can be calculated with the formula below, using the Table below, or from looking at the ASHRAE radiant heating nomograph.

The floor surface temperature is determined by dividing the Total Usable Panel Upward Load (BTUH) per square foot by the coefficient of heat transfer, then adding the room set point temperature. As previously mentioned, this coefficient can vary from 1.8 to 2.2 depending on some complex variables such as AUST, but a reasonable approximation for many conditions is 2.0. The formula, as shown below, is:

Inside temp. + (Upward Usable Panel Load per sq. ft. / h) = FSF

Where:

h is the coefficient of heat transfer Surface Temp.

FSF is floor surface temperature

The formula with our sample cabin:

FSF = 70 + (22/2) = 81°F

Where:

Upward Usable Panel Load per sq. ft. / h = 22

The coefficient of heat transfer Surface Temp. = 2

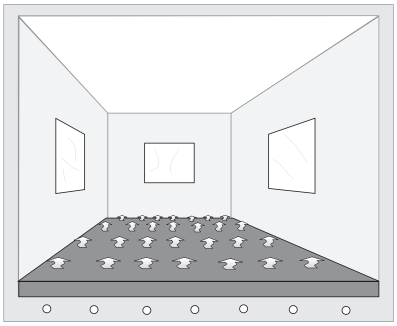
FSF is floor surface temperature

The floor surface temperature can also be estimated using the Table below. To determine the floor surface temperature, locate the room set point temperature on the left side of the chart and follow it across to the appropriate BTUH per sq. ft. column. In the case of our cabin with a room set point of 70°F and an Upward Usable Panel Load of 22 BTU, the chart gives an answer 0f 81.5°F.

Radiant Floor Surface Temperatures

Room Set Point Temperature °F	BTUH PER SQUARE FOOT										
	10	15	20	25	30	35	40	45	50	55	60
75	80.0	82.5	85.0	87.5	90.0	92.5	95.0	97.5	100.0	102.5	105.0
74	79.0	81.5	84.0	86.5	89.0	91.5	94.0	96.5	99.0	101.5	104.0
73	78.0	80.5	83.0	85.5	88.0	90.5	93.0	95.5	98.0	100.5	103.0
72	77.0	79.5	82.0	84.5	87.0	89.5	92.0	94.5	97.0	99.5	102.0
71	76.0	78.5	81.0	83.5	86.0	88.5	91.0	93.5	96.0	98.5	101.0
70	75.0	77.5	80.0	82.5	85.0	87.5	90.0	92.5	95.0	97.5	100.0
69	74.0	76.5	79.0	81.5	84.0	86.5	89.0	91.5	94.0	96.5	99.0
68	73.0	75.5	78.0	80.5	83.0	85.5	88.0	90.5	93.0	95.5	98.0
67	72.0	74.5	77.0	79.5	82.0	84.5	87.0	89.5	92.0	94.5	97.0
66	71.0	73.5	76.0	78.5	81.0	83.5	86.0	88.5	91.0	93.5	96.0
65	70.0	72.5	75.0	77.5	80.0	82.5	85.0	87.5	90.0	92.5	95.0
64	69.0	71.5	74.0	76.5	79.0	81.5	84.0	86.5	89.0	91.5	94.0
63	68.0	70.5	73.0	75.5	78.0	80.5	83.0	85.5	88.0	90.5	93.0
62	67.0	69.5	72.0	74.5	77.0	79.5	82.0	84.5	87.0	89.5	92.0
61	66.0	68.5	71.0	73.5	76.0	78.5	81.0	83.5	86.0	88.5	91.0
60	65.0	67.5	70.0	72.5	75.0	77.5	80.0	82.5	85.0	87.5	90.0
	SURFACE TEMPERATURES										

The ASHRAE nomograph in Appendix D can also be used to estimate floor surface temperature. See the appendix for how to use this chart.



As the resistance to heat transfer increases from floor coverings, the water temperature in the slab must be increased to overcome it. There are limitations to the R-Value of coverings that any radiant heating system can transfer through. These must be observed.

Take the time to familiarize yourself with floor covering R-Values by looking at the chart in Appendix C or the chapter on floor coverings. This knowledge is an indispensible part of designing radiant floor heating systems.

NOTE: Resistance (R-Values) for all flooring coverings and structural materials must be combined for determining the total resistance to the flow of heat energy to the floor surface. R-Values for specific floor covering materials should be obtained directly from the manufacturer.

Limitations of Radiant Floors There are limits to the amount of energy a radiant floor is capable of providing to a heated space. These limits are based on commonly accepted maximum floor surface temperatures of 87°F in areas that are occupied for extended periods of time, and 90°F in areas that are occupied for short periods of time. Exceeding these floor temperatures may result in physical discomfort of the occupant's feet. If the BTUH needed to heat a room requires a floor surface temperature higher than 87°F, the designer should consider decreasing the heating load by using insulating materials with higher R-Values, or by utilizing additional radiant panels in the ceiling or walls.

Resistance Upward in Radiant Floors In a radiant floor system, heat energy that is supplied must penetrate a number of structural materials before reaching the floor surface. Every material presents some form of resistance to the transfer of heat energy. In order to overcome the resistance and reach the required surface temperature, the water supply temperature is maintained at a higher level. The amount of energy that will penetrate the material at a given water temperature depends on the material's thermal resistance (R-Value) and the temperature differential across the structural material.

Structural Resistance Upward Each building material has its own thermal transfer characteristics. As a general rule, dense materials conduct heat better than lightweight materials. Heat transfer is indirectly proportional to the thickness of the material. It is best to design a system with minimal resistance upward through to the radiant floor. For example, when constructing a wooden suspended floor system, it is better to use a dense tongue and groove plywood subfloor that does not need an additional underlayment, than to use a less sophisticated subfloor, which requires additional layers of underlayment.

Floor Covering Resistance Upward Floor coverings vary in their resistance to heat transfer. Thick, lightweight materials like carpet pads present very high resistance to thermal transfer, while thin, dense materials such as ceramic tile offer minimal resistance. Both the chapter on floor coverings and Appendix C have charts on the R-Value of flooring goods.

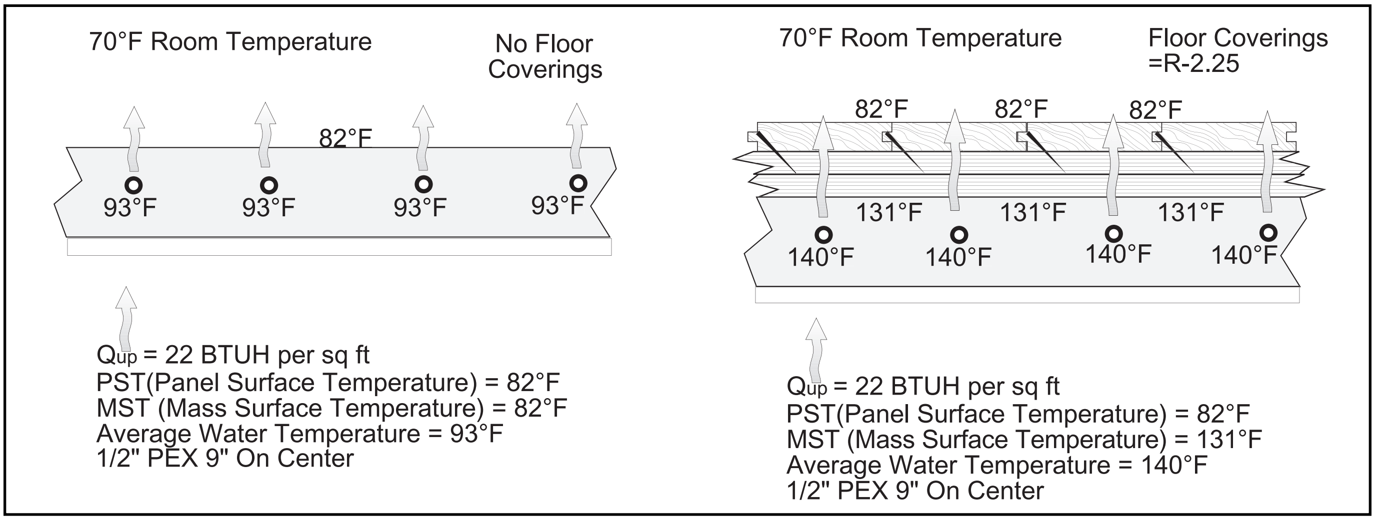
Radiant System Resistance and Floor Covering Resistance The radiant heating delivery system and the panel coverings each have a resistance to heat transfer. These are added together to calculate the overall system resistance. For your convenience, this manual contains charts in Appendix A that already have the delivery system resistance figured into them; all you have to do is add the R-Value of additional coverings to use these charts. To Use the ASHRAE nomograph in Appendix D, you must first have calculated the combined system and floor covering resistance.

The following examples should be useful in understanding how radiant heat transfer works and in understanding some of the limitations.

Radiant Heat Transfer, Illustrative Examples:

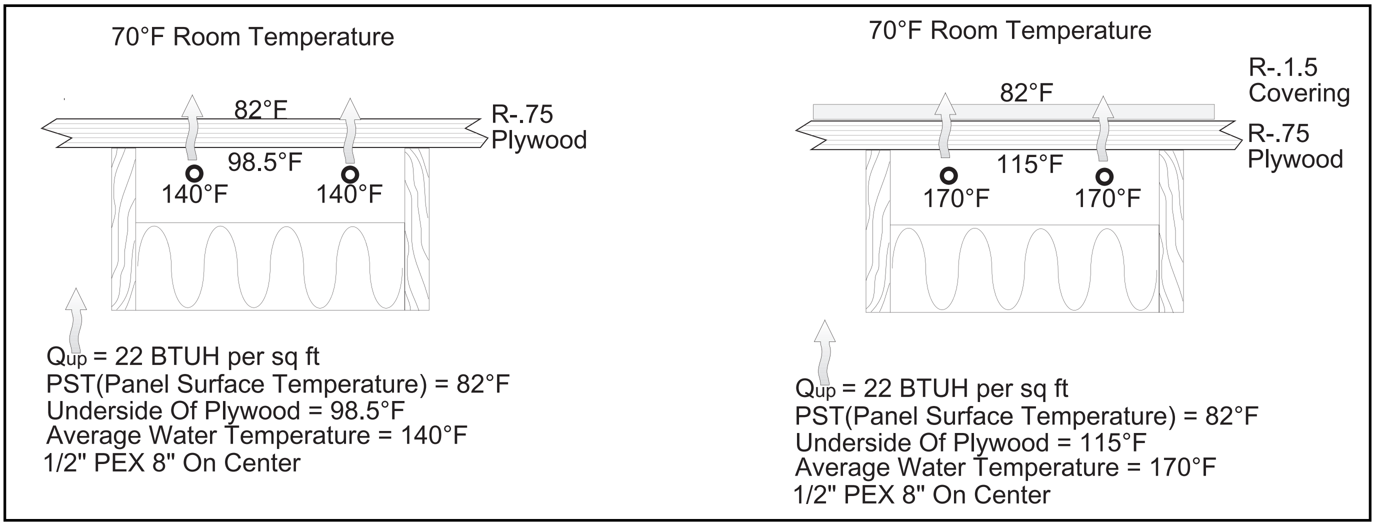
Example 1 gives a comparison of the necessary average water temperature, mass surface temperature and panel surface temperature for an output of 22 BTUH per square foot at a room temperature of 70°F utilizing a 4" slab radiant floor heating system with 1/2" PEX installed 9" on center. Version 1 has no floor coverings; version 2 has coverings that add up to R-2.25. Notice how both the average water temperature and mass surface temperature must increase to overcome the resistance of the floor coverings.

EXAMPLE 1 – SLAB ON GRADE: Version 1, no coverings; Version 2, R-2.25 floor coverings



Example 2 gives a comparison of a below-joist hanging type radiant floor heating system with 1/2" PEX installed 8" on center under a plywood subfloor. Version 1 has just the 3/4" plywood subfloor; version 2 has coverings of R-1.5. Notice how in version 2 the average water temperature required is 170°F. With a supply-return ΔT of 20°F, the required supply water is 180°F. Since 180°F is usually the maximum temperature used in these systems, this example shows us that a floor covering of R-1.5 is the maximum R-Value we could use on this system and still get 22 BTUH per square foot of output at customary water temperatures. The more general lesson is that hanging systems are limited in output and need to be designed carefully with regard to output and coverings.

EXAMPLE 2 – HANGING SYSTEM FROM BELOW JOISTS: Version 1, subfloor only; Version 2, subfloor + R-1.5 covering



Chapter 10

The equation

$TBC = (Q_{up} \times R_c) + PST$ is actually taking a standard equation for conduction and solving it for ΔT for an area of 1 square foot. That standard equation for conductance is

$Q = (A/R) \times \Delta T$

A is area in square feet

R is resistance

ΔT is temperature difference

This is essentially the same formula we used to do our heat loss.

Computing Temperature Below Coverings (TBC): On the previous page the PST (Panel Surface Temperature) and average water temperatures were computed from the charts in this manual. The Temperature Below Coverings,TBC, (mass surface temperature for a slab or for the hanging system, under plywood temperature) were computed from a simple equation. To compute TBC on a radiant panel we need to know the Panel Surface Temperature (PST), required heat transfer (Q_{up} for radiant floors) and the R-Value of the coverings. Knowing these things, the equation for computing the temperature required under the coverings in a radiant floor heating system is:

$$TBC = (Q_{up} \times R_c) + PST$$

Where:

TBC = Temperature Below Coverings

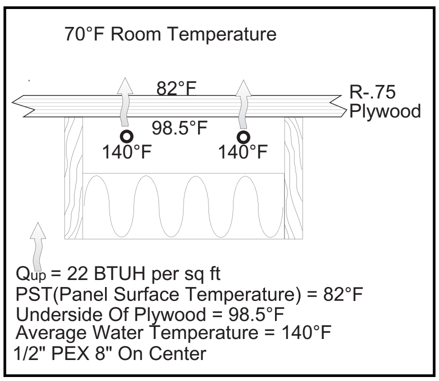
Q_{up} = Required Upward Output of Radiant Floor Heating System

PST = Panel Surface Temperature (the surface that faces to the room)

R_c = Resistance of coverings over the panel

Using the example to the left, where we know from our heat- loss that Q_{up}= 22 BTUH per square foot, we know from the charts in this manual that PST = 82°F and we know that the R-Value of the plywood is R.75. Therefore,

$$(Q_{up} \times R_c) + PST = (22 \times .75) + 82 = 98.5°F$$



Calculating Back Loss: It is reasonable to assume that the temperature on top of the insulation of a hanging system is the same as the temperature under the plywood. We can use this number to calculate the back loss of the hanging system over a crawl space, as shown in version 2 on the previous page, assuming a 10°F outside air temperature.

$$(T_c - T_o) / R_v = Q_{down}$$

Where:

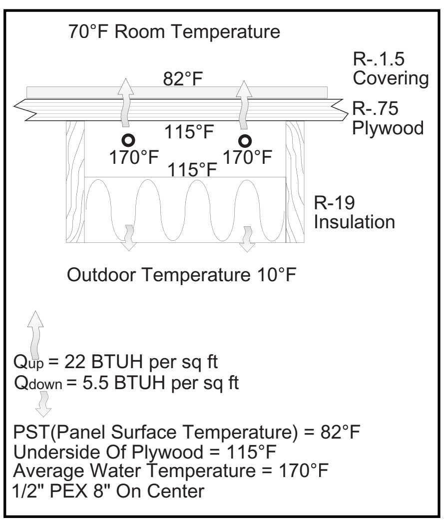
T_c is the cavity temperature above the insulation

T_o is the outside temperature

R_v is the resistance value of the structural panel

For the example to the left

$$Q_{down} = (115-10)/19 = 5.5 \text{ BTUH per square foot}$$



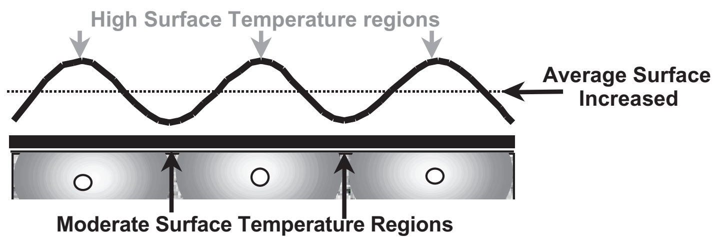
Notice below that putting tubing spacing closer together under resistive coverings helps acceleration, but has less effect on "banding" or uneven surface temperatures. This is because the resistance of the covering spreads the heat out more. "Banding" is more noticeable with low resistive floor coverings such as tile or vinyl. Therefore, closer spacing, such as 6" or 9" on center, is often used under these surfaces, particularly in high output cold climates where the banding would be most noticeable.

Note: To this point, the total upward load, surface temperature, and resistance upward through the floor has been calculated. These parameters are determined without regard to floor construction. The specific type of floor construction must be considered in determining the supply water temperature, back losses, tube spacing, and layout patterns.

Slab on Grade Performance Planning

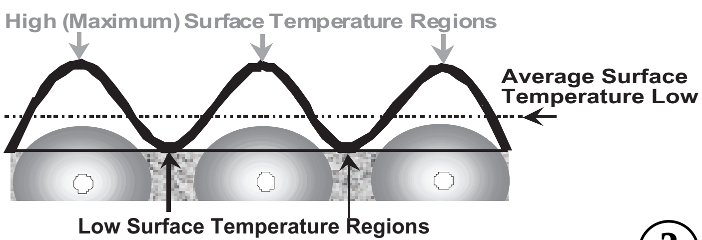
Selecting a Tube Spacing Interval Most residential applications with slab on grade construction utilize 1/2" tubing and spacing of 9 or12 inches on center, while most commercial projects use 5/8" or 3/4" tubing with spacing of 12 inches on center.

Tube Spacing (High resistance floor coverings)



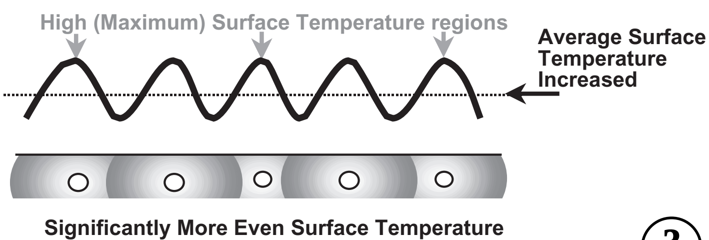
1

Tube Spacing (Low resistance floor coverings)



2

Increased Tube Spacing (Low resistance floor coverings)



3

Acceleration Placing the tubing at closer on center distances puts more tubing in the panel and will, therefore, increase the acceleration of the slab. This is useful in geographic regions with extreme heat loads, and in areas in a room with high heat loss, such as near windows and doors.

If the resistance upward is high, then placing the tubing close together will have a minimal affect on the total output, because the upward resistance will spread out the energy within the slab. See Example 1 to the left.

If the resistance upward is very low, wide tube spacing may cause variations in floor surface temperature. If the maximum floor temperature (87°F) is reached in a small area directly over the tubes, much of the surface between the loops is effectively unheated. This produces a lower average surface temperature and reduces the total heat output. See Example 2 to the left.

If the resistance upward is low, placing the tubing close together will raise the average surface temperature and increase the total radiant panel output. See Example 3 to the left.

TUBE SPACING EXTERIOR WALLS: Two passes on 6" centers and then two at 9" on center are normally used on exterior walls before going to any wider spacing.

Closer Tube Spacing on Outside Walls and Under Windows
Closer tube spacing is normally utilized on outside walls and under windows. This gives more output and faster acceleration where the majority of the heat loss usually occurs. A rule of thumb under high heat loss windows would be to put tubing on tighter spacing for a distance from the wall that is equivalent to the window height. See note on walls to the left.

DIFFERENTIAL TEMPERATURE*:* The differential temperature is the difference in temperature between the fluid going into the radiant panel (supply water) and the fluid coming out of the panel (return water). Differential temperature is often referred to as "Delta T," "DT" or symbolized as Δ T.

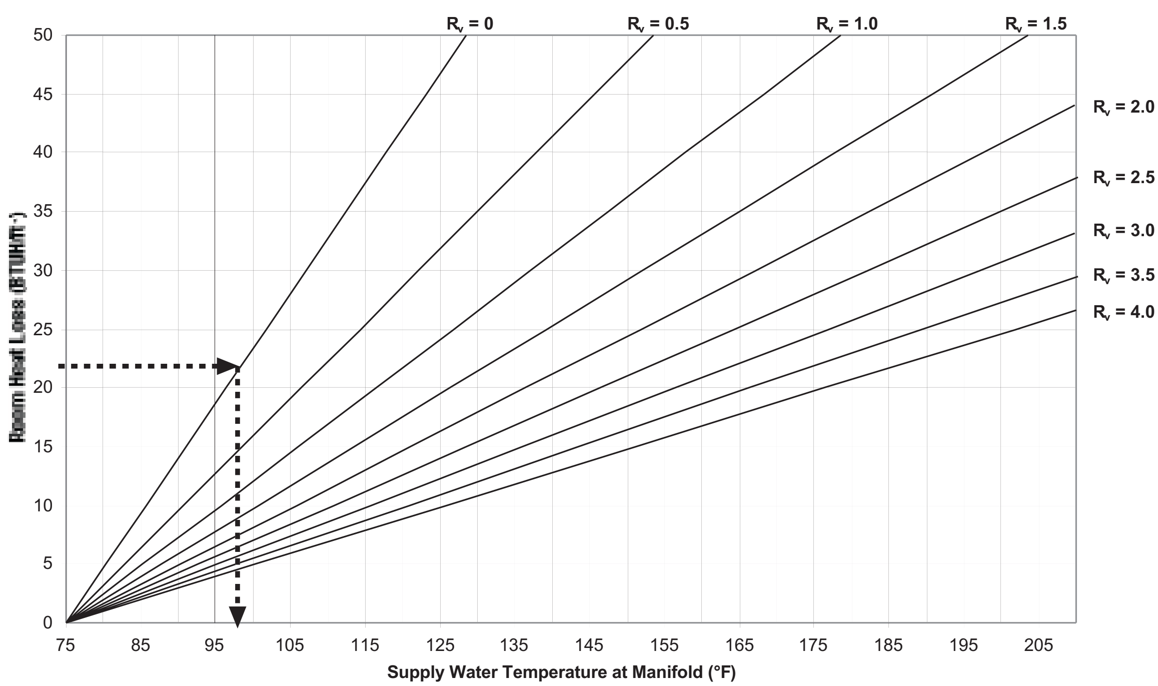
THREE METHODS FOR DETERMINING WATER SUPPLY TEMPERATURE: Water supply temperatures may be determined using the ASHRAE Nomograph as shown in Appendix D or by using the charts that are specific to certain construction methods in Appendix A. When using "Design Pro," the water temperature is calculated for you, provided all the information has been entered correctly.

The chart below shows the calculation of Water Supply Temperature for 22 BTU/h with no floor covering. At 65°F room temperature the Supply Water Temperature = 98°F. To calculate a 70° room temperature, one degree for every degree of room temperature over 65°F is added. In this example, 98°F + 5°F = 103°F. Notice how much water temperatures increase as floor coverings are added. For example, supply water temperatures are 30°F higher with floor coverings of R-2.

Water Supply Temperature Radiant floor heating systems are designed with either a 10°F or 20°F differential temperature. A 10°F differential temperature delivers more consistent temperatures through the entire length of the loop at a lower water supply temperature than a 20°F differential temperature, but has the drawback of requiring larger pumps that use more energy for the lifetime of the system.

Determining Supply Water Temperature From Appendix A: To determine the supply water temperature using the charts in Appendix A, the designer must select either a 10°F or 20°F differential temperature. Water supply temperature charts are provided in Appendix A for both 10°F and 20°F differential temperatures for a variety of radiant panel construction methods and tube spacing. Calculating the upward BTUH per sq. ft. requirements of each room provides the information needed to utilize the Water Supply Temperature charts in Appendix A. Select the appropriate supply water temperature chart from Appendix A for the method of construction, differential temperature, and the tube spacing of the radiant panel. The required upward load (BTUH/ft2) is listed on the left side of the chart. Locate the BTUH/ft2 and follow the chart across to the intersection of the total R-Value of the floor. Then move down the chart to find the water supply temperature required. If the room set point is above 65°F in the chart, add one degree for each degree above 65°F. For our example cabin, using tubing 9" on center in a 4" slab where Upward Usable Panel Load per sq. ft. / h = 22 BTU, the calculation is 98°F + 5°F, which equals 103°F.

Water Supply Temperatures for 4-inch Concrete Slab*
65 °F Room Temperature - 3/4", 5/8", 1/2" & 3/8" PEX Tubing - 9" On Center
20 degree supply / return temperature differential



Note: The Water Supply Temperature chart on the previous page is specific to a 65°F indoor design temperature. For indoor design temperatures above 65°F, add one degree to the water supply temperature for each degree above 65°F, subtract one degree to the water supply temperature for each degree below 65°F. Additional water supply temperature charts are listed in Appendix A.

Insulation: The resistance value (R-Value) of the specific insulation material is provided by the manufacturer. Most expanded or extruded polystyrene materials that are suitable for below grade applications have R-Values of R-5 per inch.

Radiant Panel Back Losses Some of the energy sent to a radiant panel will be transferred downward, in the case of radiant floors, or upward in the case of radiant ceilings. This transfer is considered a back loss in the sense that it does not go toward heating the room. If the back losses contribute toward heating adjacent rooms that are served by the same heat plant, then they do not count toward the heating load, for the purpose of sizing the heat plant. If the back losses leave the building or go toward an area that is not served by the heat plant, they must be added to the heating load for the purpose of sizing the heat plant. Normally, back losses do not affect the supply water temperature of the panel, but instead are considered in calculating the flow rate requirement.

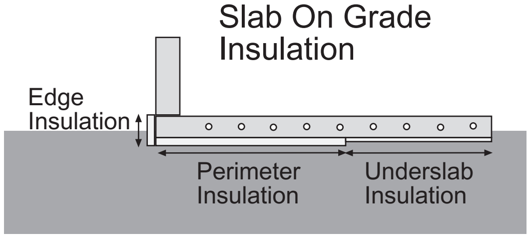
Insulation suitable for use under a slab should be a closed cell type that maintains its R-Value when wet, and should be of sufficient compressive strength. Dowboard and Foamular are two well known brand names. Both products come in different thicknesses and compressive strengths.

Control of Back Losses Back losses can adversely affect the performance and efficiency of a radiant system. Heated floors, ceilings, and walls are naturally much warmer than unheated panels in conventional construction. High panel temperatures will drive more thermal transfer through the insulation to the exterior of the building, unless higher levels of insulation are used. In a heated panel, the back losses must be calculated using the water supply temperature of the radiant panel, rather than the room set point temperature.

Edge, perimeter, and underslab insulation is much more critical with concrete radiant floors than with unheated floors. Radiant wall and ceiling insulation, although critical, is usually adequate when it meets local codes for unheated panels.

Insulating a Radiant Slab Insulation is more important with a heated slab than with an unheated slab because the difference in temperature between the slab and the outdoor temperature is much greater, making the potential for heat transfer much greater. All insulation materials must be suitable for burial and must be of sufficient compressive strength to support any structural loads.

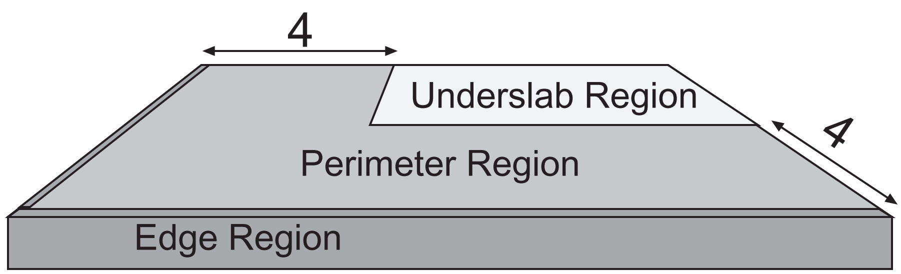
Edge Insulation Edge insulation is intended to resist heat transfer from the edge of the slab to the exterior of the building. The insulation may be installed separately or as part of the extended perimeter insulation. See the figure below. Edge insulation must be protected from any environmental degradation such as ultraviolet light, boring insects or rodents, or physical damage from lawn mowers or snow removal equipment.



Perimeter Insulation Perimeter insulation is intended to resist the transfer of heat from the underslab perimeter region of the slab to the exterior. Perimeter insulation should be placed at a minimum of the depth of the frost line either vertically or horizontally. See Figure 5.5. Local administrative building codes prescribe minimum requirements for frost depth protection.

Underslab Insulation Underslab insulation is intended to resist the transfer of heat from the underside of the slab to the earth below, increasing heating efficiency and decreasing response time.

Slab On Grade Back Losses Radiant slabs that are placed on the grade of the earth will tend to lose heat energy to the soil directly below and adjacent to the slab. The three regions of heat loss are the Edge, Perimeter, and Underslab. See the figure below.



The amount of energy lost will depend on the water supply temperature, the soil temperature, and the resistance value of insulation materials between the slab and soil.

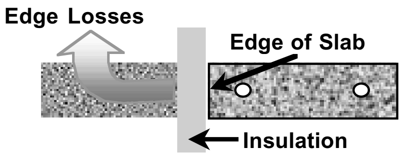
Slab Temperature as a Factor in Slab Back Loss Water supply temperature is determined from the total upward load and resistance of floor coverings. The higher the upward load and/or resistance of floor coverings, the higher the slab temperature. The higher the slab temperature, the greater the need for insulation to reduce back losses and improve response time.

SLAB BACK LOSS is greater in conductive soil. A dry, well-drained site and insulation are important design aspects for limiting back loss.

Soil Temperature Soil temperature will range from outdoor design temperature near the surface and along the edge, to about 32°F at the frost line. The temperature below the frost line will continue to rise with depth until it reaches the water table temperature. Most heat loss will occur along the edge of the slab and within four feet of the perimeter. Inside the 4-foot perimeter area, normally the heat losses become minimal. This is because the soil temperature under the slab will increase as the heating season progresses, until the soil temperature below reaches approximately room temperature.

Slab on Grade Back Loss Region Radiant slabs that are placed on the grade of the earth will tend to lose heat energy through the edges, perimeter and underslab regions. Each region must be considered to determine the heat loss potential and the amount of insulation necessary to properly control such losses.

Estimating Heat Loss At Edge Region



Edge Region Heat Loss The edge region of the slab is the vertical surface along the perimeter of a radiant slab that is exposed to heat loss. See the figure to the left. If the slab is poured on grade, the edge will be exposed to the outdoor design temperature. If the slab is below grade and below the frost line, it will be exposed to a temperature of at least 32°F.

Remember, our cabin measures 20' x 30'. To calculate the perimeter area of a 4" slab, multiply the total perimeter length in feet (in the case of our cabin, 100') by the height of the slab (4" or .33'):

100 x .33 = 33 square feet of perimeter area. This number is used in the calculation at right. Remember also, the U-Value is the inverse of the R-Value. In this case, .1 (U-Value) is the inverse of 10 (R-Value).

Estimating Edge Heat Loss The amount of heat loss through the edge of a slab can be calculated using the following equation:

Edge Losses (BTUH) = (MST – T_o.) x Area x Insulation U-Value

Where:

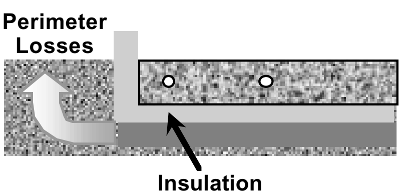
MST = Mass Surface Temperature

T_o = Outdoor Temperature

Utilizing our sample cabin, with an outside design temperature of 10°F, a Mass Surface Temperature of 81°F, a slab depth of 4", and 2" (R-10) insulation extending below the frost line, the edge heat loss for the cabin is calculated as follows:

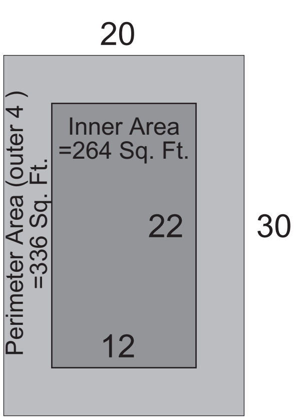
(81 – 10) x (33 x .1) = 234 BTUH

Estimating Perimeter Region Losses



Perimeter Region Heat Loss The perimeter region of the slab is the bottom horizontal surface of the slab along the outside wall that extends inward from the edge to a length of up to four feet. See the figure to the left. In this region, heat is lost as the heat energy migrates toward the exterior of the building. Perimeter losses occur only on slabs that are placed on or near grade. The perimeter region is generally exposed to an average of the outside design temperature and indoor design temperature.

Sample Cabin Heat Loss Areas



Estimating Perimeter Heat Losses The amount of heat loss through the perimeter area of a slab can be calculated using the following equation:

Perimeter Loss (BTUH) = {MST – [(T_i. + T_o.)/2]} x Area x U-Value

Where:

MST = Mass Surface Temperature

T_o = Outdoor Temperature

T_i = Indoor Temperature

Utilizing our sample cabin, with an outside design temperature of 10, a slab depth of 4" and 2" insulation underslab, the perimeter heat loss for the cabin is calculated as follows:

{81 – [(70 + 10) /2]} x 336 x .1 = 1378 BTUH

Chapter 10

NOTE ON METHODOLOGY:
Many people feel that the edge region, perimeter region inner underslab region method used here significantly overestimates back losses from a slab, since it does not take into account the R-Value of the soil itself. Energy must travel through the soil as it is lost. It is difficult to model soil R-Values which change significantly with moisture content. This method provides a very conservative calculation. It is likely that it overestimates the back loss significantly particularly in a dry well drained site. As presented, it assumes the tubing is in the middle of the slab and therefore that the bottom edge of the radiant panel would be approximately the same temperature as the Mass Surface Temperature.

In radiant floor heating with a slab, the Mass Surface Temperature, or MST, is the temperature of the top of the slab, and which is also a close estimation of the temperature at the bottom of the slab. Panel Surface Temperature, or PST, is the temperature on top of the floor coverings. If there are no floor coverings, MST and PST are the same. Otherwise, MST is a higher temperature.

The Total Heating Load for the sample cabin when it is slab on grade is shown below:

CABIN TOTAL HEAT LOAD

Walls	3087
Ceiling	1895
Windows	3600
Doors	1260
Infiltration	3110
Slab Back Loss	2193
Total Heat Load*	15145
*(BTUH)	
BTUH PER SQ/FT	25

Underslab Region Heat Loss The underslab region of a radiant slab is the horizontal surface under the heated slab which is not within the 4-foot perimeter region. The underslab region is exposed only to heat transfer to the soil below. As the soil warms up during the heating season, heat transfer downward minimizes. The length of time it will take to raise the underslab soil temperature depends on the type of soil and its moisture content. Typically, when the slab is up to maximum temperature during the highest heating loads, the underslab soil temperature will reach approximately room temperature. Therefore, using the room set point temperature in downward loss calculations is practical for performance at the maximum load. Placing insulation below the slab will increase acceleration and improve response time. Heat loss is generally the same across the surface of the underslab region of a radiant floor.

Estimating Underslab Heat Losses The amount of heat loss through the underslab area can be calculated using the following equation

$(MST - T_i)$ x Area x U-Value = Underslab Losses (BTUH)

Where:

MST = Mass Surface Temperature

T_i = Indoor Temperature

Utilizing our sample cabin with a slab depth of 4" and 1" insulation (R-5) under the slab, the underslab heat loss for Room #1 is calculated as follows:

(81 – 70) x 264 x .2 = 581 BTUH

Total Slab Back Losses Per Square Foot Add the back losses of the Edge Region, Perimeter Region, and Inner Under Slab Region for total back losses. Then divide the total by the square feet of the panel to determine the back losses per sq. ft.

In our sample cabin:

Edge Region Back Loss = 234 BTUH

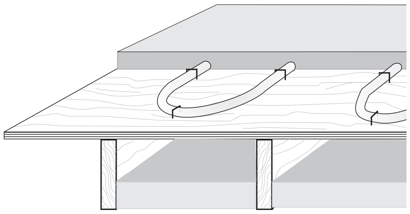
Perimeter Region Back Loss = 1378 BTUH

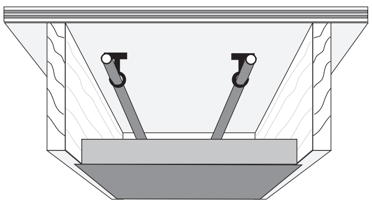
Inner Under Slab Region Back Loss = 581 BTUH

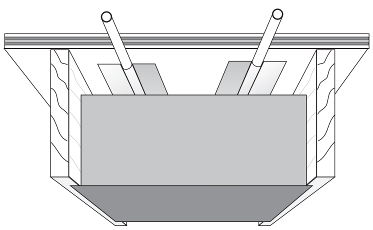
Total Slab Back Loss = 2193 BTUH

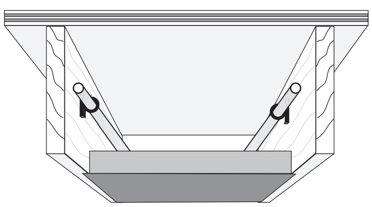
Utilizing the sample cabin with an area of 600 square feet, the back loss per sq. ft. is 3.65 BTUH per square foot.

The Total Heating Load This is simply the sum of all heat losses, including the slab back loss. The Total Heating Load for our sample cabin when utilizing a slab on grade construction method is summarized to the left. For our sample cabin, with a radiant slab, this total is 25 BTUH per square foot.









There are many ways to install radiant heat with suspended floors. Several of these methods are shown above.

As with slab-on-grade applications water supply temperatures may be estimated from the charts in Appendix A, from the ASHRAE Nomograph in Appendix D, or by computer using the "Design Pro software."

Suspended Floors Performance Planning

Suspended Wood Frame Radiant Floors: Suspended wood frame radiant floors are those constructed over unheated crawl spaces, or on intermediate floors within buildings. The actual construction and support structures for such floors can vary significantly with a wide variety of joist, subfloor, underlayment and finished floor products. There are three primary types of suspended radiant floors: those which use a poured floor underlayment, those which use aluminum heat transfer plates, and those which are constructed within the joists in a free hanging system.

Determining the BTUH Load Per Square Foot: Room-by-room heat loss analysis determines how much energy is needed to overcome the heat loss of each room. Calculating the Total Upward Load and the Floor Surface Temperature required to provide the necessary BTUH per square foot are the same for all methods of radiant floor construction. See the previous sections to determine the Total Upward Load and to determine Floor Surface Temperature.

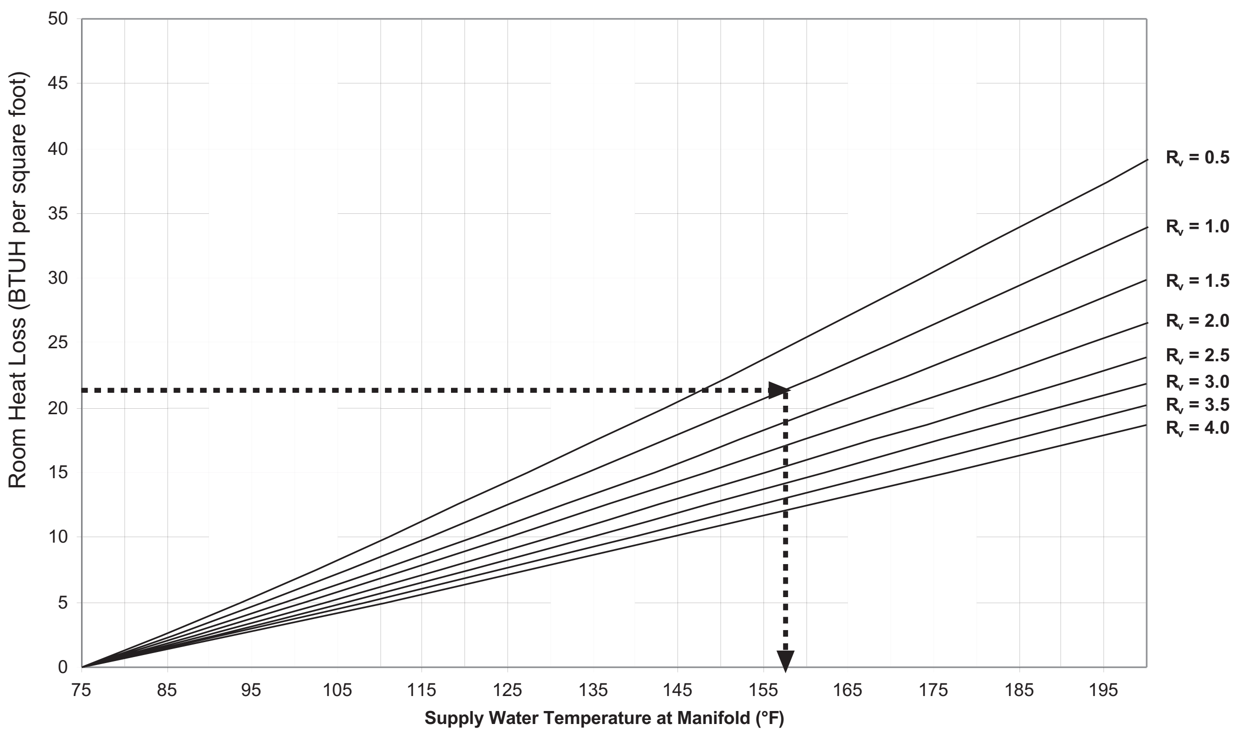
Resistance Upward in Suspended Floors: Structural resistance differs with the construction method used in a radiant floor. To determine the resistance of a suspended floor, all materials between the tubing and floor surface must be combined to establish the Total Resistance Upward. The R-Values of floor materials and floor coverings are listed in the Appendix C.

Selecting a Tube Spacing Interval: Most residential applications with a poured floor underlayment or "thin slabs" utilize 1/2" tubing and spacing of 12", 9", or 6" on center. See the previous discussion of tube spacing in slab-on-grade applications. Suspended floors with tubing mounted below the subfloor normally utilize heat transfer plates set at 8" on center or the tubing is attached to the sides of the floor joists. Most other hanging systems are also installed 8" on center. Water Supply Temperature charts are provided in Appendix A for a variety of tube spacing and installation options.

Determining Supply Water Temperature: Calculating the upward BTUH per sq. ft. requirements of each room provides the information needed to utilize the Water Supply Temperature charts. To determine the supply water temperature using the charts in Appendix A, the designer must select either a 10°F or 20°F differential temperature. Water supply temperature charts are provided in Appendix A for both 10°F and 20°F differential temperatures for a variety of radiant panel construction methods and tube spacing. Calculating the upward BTUH per sq. ft. requirements of each room provides the information needed to utilize the Water Supply Temperature charts in Appendix A. Select the appropriate supply water temperature chart from Appendix A for the method of construction, differential temperature, and the tube spacing of the radiant panel. The required upward load (BTUH/ft2) is listed on the left side of the chart.

Locate the BTUH/ft2 and follow across the chart to the intersection of the total R-Value of the floor. Then, move down the chart to find the water supply temperature required. If the room set point is above 65°F in the chart, add one degree for each degree above 65°F. For our example cabin using 1/2" tubing 8" on center and aluminum plates in a joist cavity where the Upward Usable Panel Load per sq. ft. / h = 22 BTU and with floor coverings of R-1, the calculation is 158°F + 5°F, (for a 70°F indoor temperature) which equals 162°F using chart A-9 from Appendix A, as shown below:

Water Supply Temperatures for Aluminum Plates in Joist Cavity with 3/4" Plywood Subfloor
65 °F Room Temperature - 3/4", 5/8" & 1/2" PEX Tubing - 8" On Center
20 degree supply / return temperature differential



Note: The Water Supply Temperature chart above is specific to a 65°F indoor design temperature. For indoor design temperatures above 65°F, add one degree to the water supply temperature for each degree above 65°F. For indoor design temperatures below 65°F, subtract one degree to the water supply temperature for each degree below 65°F. Additional water supply temperature charts are listed in Appendix A.

Back Losses with Suspended Floors: The back losses from suspended radiant floors result from thermal transfer downward through the ceilings below them into lower heated rooms or to the exterior of the building when the space below is unheated. The amount of energy transferred as a back loss will depend on the average supply water temperature, the resistance downward, and the temperature below. Average supply water temperature will depend on the heating load and the resistance upward and downward. If the heating load is high and the resistance upward through the floor is high, then the average supply water temperature will be high. If the resistance downward is low and the temperature below is low, then the thermal transfer of back losses will be high.

Insulating to R-11 between floors will help prevent control problems on a lower floor due to back losses from a radiant floor heating system on the floor above. Insulate between floors as a preventive measure unless a detailed design accounts for the effects of the back losses from a floor above. Minimum insulation requirements should be five times the resistance above the tubing.

Back Losses From a Suspended Floor to a Heated Room Below: When back losses occur from a suspended radiant floor through the ceiling of a heated room below, the back losses contribute to heating the room below and make heating the room above more difficult. Since radiant ceilings are powerful at low temperatures, this heat gain from above can present difficult control problems. Often the lower rooms of a building have less heat loss than the upper rooms. This, coupled with the relatively high performance of the radiant ceiling, will result in overheating the lower room. If the upper room has highly resistant floor coverings, such as carpeting, the need for higher supply water temperatures will increase the downward heat transfer. The resistance downward for poured floor underlayment systems includes the wood subfloor structure, as well as any finished ceiling materials. Aluminum heat transfer plate systems have very little downward resistance and can promote higher back losses. When high average water temperatures are required, place adequate insulation between the floors in order to maintain control and limit heat loss to the lower room.

Radiant Back Losses From a Suspended Floor to an Unheated Space: When radiant back losses occur from a suspended radiant floor to an unheated space below, the energy loss becomes part of the total heating load. The amount of energy lost will depend on the Mass Surface Temperature, in the case of a thin slab, and the cavity temperature in the case of plate and hanging systems, the resistance value of insulation and materials below the radiant floor, and the temperature of the unheated space. If the space is open to the outside, then the temperature below is the outdoor design temperature. Unlike slab radiant floors, suspended radiant floors have no perimeter region. Heat loss is generally the same across the entire bottom surface of the floor. Calculate downward heat loss per square foot for a suspended radiant floor over an unheated space using the following methods.

Estimating Back Losses to Suspended Floors over an Unheated Space: The amount of downward heat back loss per sq. ft. (Q_{down}) through suspended floors over an unheated space can be calculated using the following equation:

$$Q_{down} = (TBC - T_o)/.\ R_{down}$$

Where:

TBC = Temperature Below Coverings

T_o = Outdoor Design Temperature

R_{down} = The composite R-Value of all materials between the tubing and unheated space.

We previously learned to calculate TBC (the temperature below coverings). The formula was

$$TBC = (Q_{up} \times R_c) + PST$$

Where:

TBC = Temperature Below Coverings

Q_{up} = Required Upward Output Of Radiant Floor Heating System

PST = Panel Surface Temperature (the surface that faces to the room)

R_c = Resistance of coverings over the panel

Remember to add the R-Value of the subfloor to the floor coverings when computing TBC in hanging or plate systems that are installed from below the subfloor.

Chapter 10

The Total Heating Load for the sample cabin with a joist system under a 3/4" subfloor, with R-1 floor coverings and R-19 below the joists. The slight difference in the results to the right are due to how numbers were rounded up.

CABIN TOTAL HEAT LOAD

Walls	**3087**
Ceiling	**1895**
Windows	**3600**
Doors	**1260**
Infiltration	**3110**
Back Loss	**3420**
Total Heat Load*	**16372**
*(BTUH)	
BTUH PER SQ/FT	**27.3**

For example, let us assume our sample cabin utilizes tubing with plates from below a 3/4" plywood subfloor (R-.75), R-1 floor coverings with a 70°F indoor temperature, a 10°F outdoor temperature, 22 BTUH per square foot required upward output, a panel surface temperature of 81°F, and R-19 in the joist under the plates. The combined R-Value above the tubing and plates is the R-.75 of the subfloor plus the R-1 of the floor coverings which in total equals R-1.75

We would first calculates TBC (temperature below coverings) using the equation:

$$TBC = (Q_{up} \times R_c) + PST$$

$$(22 \times 1.75) + 81 = 119.5°F$$

Then we would calculate the downward heat loss with the equation

$$(TBC - T_o) / R_{down} = Q_{down}$$

$$(119.5 - 10)/19 = 5.7 \text{ BTUH per square foot}$$

The Total Upward Load per sq. ft. (Q_{up}) and Downward Heat Loss per sq. ft. (Q_{down}) are combined to determine the Total Heat Load per sq. ft. of each room. In the case of our cabin:

$$22 + 5.7 = 27.7 \text{ BTUH per square foot}$$

Radiant Ceiling Performance Planning

Radiant Ceilings: Radiant ceilings can be installed in nearly any situation to provide total comfort heating or to assist radiant floors in meeting very high heat loads. Radiant ceilings transfer heat energy to a room almost exclusively through radiation.

Determining the BTUH Load Per Square Foot: Room-by-room heat loss analysis determines how much energy is needed to overcome the heat loss of each room. The process is essentially the same as with radiant floors only the back loss from a ceiling, not the floor, is calculated separately and downward losses from a room are part of the initial calculation. The next step is to determine how much ceiling surface area will be available to distribute the energy.

Although ceilings are very powerful radiant panels, there are factors that may reduce the total surface area to critical levels. In particular, it is important to note the location, number, and type of recessed lighting fixtures in the room. Many recessed lighting fixtures require a clearance of at least 12 inches from the PEX or PEX Barrier Tubing. Several fixtures placed within three feet of one another can consume a significant amount of ceiling area. Skylight windows will also reduce the available radiant ceiling panel area. The designer should look at each room and estimate

Q_{up} and Q_{down} are reversed in radiant ceilings from radiant floors. That is, with ceilings, Q_{down} is the required panel output and Q_{up} is the back loss. With radiant floors, it is the other way around.

CABIN CEILING Q_{down}

Walls	3087
Floor	1895
Windows	3600
Doors	1260
Infiltration	3110
Total Heat Load*	12,952
*(BTUH)	
BTUH PER SQ/FT	21.6

EFFECTIVE CEILING FACTOR:
The ECF simply takes into account non-usable areas of the ceiling. It is logical that when areas are subtracted, the remaining area must put out more heat to make up for it.

Heat Transfer Coefficient:
The rate at which heat is transferred to the room varies by panel type. Typical heat transfer coefficients are:

Floor = 2 BTU per SQ. F. per °F
Wall = 1.9 BTU per SQ. F. per °F
Ceiling = 1.7 BTU per SQ. F. per °F

the amount of ceiling space that will adversely affect heat transfer. The "Effective Ceiling Factor" (ECF) is calculated using the following equation:

ECF = (Total Ceiling Area - Subtractions From Panel Area)/
Total Ceiling Area\

Heat loss calculations for non-heated panels in a radiant floor design are considered Upward Loads and are expressed as an Upward Load per square foot. In a radiant ceiling system, heat loss calculations of non-heated panels are referred to as a Downward Load per square foot (Q_{down}). The downward load for our sample cabin is summarized to the left. In this case, (Q_{down}) = 21.6 BTUH per square foot. Let us assume we can use 90% of the ceiling area for a radiant ceiling system (ECF = .9).

Dividing the Total Downward Load per sq. ft. by the ECF provides the required Total Usable Panel Downward Load per square foot.

(BTUH per sq. ft.) to satisfy the heating requirements of the room. The Total Usable Panel Downward Load is calculated using the following equation:

Q_{down}/ ECF = Total Usable Downward Panel Load sq. ft.

Using our cabin again as an example

Total Usable Panel Downward Load = 21.6 / .9 = 24 BTUH per sq. ft.

Where

Q_{down} = 21.6 BTUH per square foot
ECF = .9

If the ECF = 1 and 100% of the area is utilized, the Total Usable Panel Load per square foot would be the same as Q_{down}, 21.6 BTUH per square foot.

Coefficient of heat transfer: It is important for the designer and installer to understand the amount of energy that a radiant ceiling will transfer into a room at any given surface temperature. This factor is called the coefficient of heat transfer. The precise amount of energy transferred depends on many complex variables. For the purpose of performance planning, it is practical to use a coefficient of heat transfer of 1.7, for radiant ceilings, which represents the output over the most critical range of temperatures used in radiant heat panels. A thermal transfer coefficient of 1.7 means that 1.7 BTUH will be transferred from one square foot of heated ceiling, for every degree Fahrenheit the ceiling surface temperature exceeds the room temperature.

Radiant Ceiling Surface Temperature: The Total Usable Panel Downward Load (BTUH) per square foot dictates the surface temperature required in the remaining performance calculations. Surface temperature is determined by dividing the Total Downward Load (BTUH) per square foot by the coefficient of heat transfer and adding the room set point temperature.

The surface temperature can be calculated using the equation below, or using the Table. To determine the surface temperature using the table, locate the room set point temperature on the left side of the chart and follow across to the appropriate BTUH per sq. ft. column.

Radiant Ceiling Surface Temperatures

Room Set Point Temperature ¡F	BTUH PER SQUARE FOOT										
	10	15	20	25	30	35	40	45	50	55	60
75	80.9	83.8	86.8	89.7	92.6	95.6	98.5	101.5	104.4	107.4	110.3
74	79.9	82.8	85.8	88.7	91.6	94.6	97.5	100.5	103.4	106.4	109.3
73	78.9	81.8	84.8	87.7	90.6	93.6	96.5	99.5	102.4	105.4	108.3
72	77.9	80.8	83.8	86.7	89.6	92.6	95.5	98.5	101.4	104.4	107.3
71	76.9	79.8	82.8	85.7	88.6	91.6	94.5	97.5	100.4	103.4	106.3
70	75.9	78.8	81.8	84.7	87.6	90.6	93.5	96.5	99.4	102.4	105.3
69	74.9	77.8	80.8	83.7	86.6	89.6	92.5	95.5	98.4	101.4	104.3
68	73.9	76.8	79.8	82.7	85.6	88.6	91.5	94.5	97.4	100.4	103.3
67	72.9	75.8	78.8	81.7	84.6	87.6	90.5	93.5	96.4	99.4	102.3
66	71.9	74.8	77.8	80.7	83.6	86.6	89.5	92.5	95.4	98.4	101.3
65	70.9	73.8	76.8	79.7	82.6	85.6	88.5	91.5	94.4	97.4	100.3
64	69.9	72.8	75.8	78.7	81.6	84.6	87.5	90.5	93.4	96.4	99.3
63	68.9	71.8	74.8	77.7	80.6	83.6	86.5	89.5	92.4	95.4	98.3
62	67.9	70.8	73.8	76.7	79.6	82.6	85.5	88.5	91.4	94.4	97.3
61	66.9	69.8	72.8	75.7	78.6	81.6	84.5	87.5	90.4	93.4	96.3
60	65.9	68.8	71.8	74.7	77.6	80.6	83.5	86.5	89.4	92.4	95.3
	SURFACE TEMPERATURES										

You can estimate the Ceiling Surface Temperature using the following equation:

T_i + (Usable Panel Downward Load per sq. ft. / h) = CST

Where:

h = coefficient of heat transfer

T_i = the Indoor Design Temperature

CST = Ceiling Surface Temperature

Using our cabin with an inside design temperature of 70°F and the Downward Loss where EFT = 1 (22.6 BTUH per square foot), as calculated above, we can calculate the Ceiling Surface Temperature:

CST = 70 + (21.6 / 1.7) = 82.7°F

The Heat Transfer Coefficient is the rate at which heat energy is transferred to the room. Heat transfer coefficients vary by panel type. Typical Heat Transfer Coefficients are:

Floor = 2 BTU/Sq.Ft. per °F
Wall = 1.9 BTU/Sq.Ft. per °F
Floor = 1.7 BTU/Sq.Ft. per °F

Ceiling Material R-values	
Material	**R-value**
Sheetrock	
3/8"	0.32
1/2"	0.45
5/8"	0.56
Plywood	
3/8"	0.47
1/2"	0.63
5/8"	0.77
Particle Board	
3/8"	0.49
1/2"	0.66
5/8"	0.88

THERMAL RESISTANCE OF A CEILING STRUCTURES: Normally, radiant ceilings are constructed in a manner that presents very little resistance to heat transfer from the tubing to the ceiling surface. Gypsum (sheetrock) is commonly used as both the finished ceiling and the majority of the ceiling structure. This material is very good at conducting heat, having an R-Value of approximately 0.45 per 1/2 inch thickness. If other materials are used for ceiling panels, they may have greater resistance and require higher average water temperatures. Suspended acoustic ceiling tiles can present very high resistance to thermal transfer (R-2.5 per inch), and should not be used. See the chart above for typical R-Values.

Radiant Ceiling Heated Area: In some applications, radiant ceilings have the potential to be more powerful than radiant floors, despite the fact that the heat transfer coefficient is smaller. Radiant floors are limited to 87°F maximum surface temperature. However, radiant ceilings can easily operate up to 100°F surface temperature because ceiling materials typically offer very little resistance to thermal transfer.

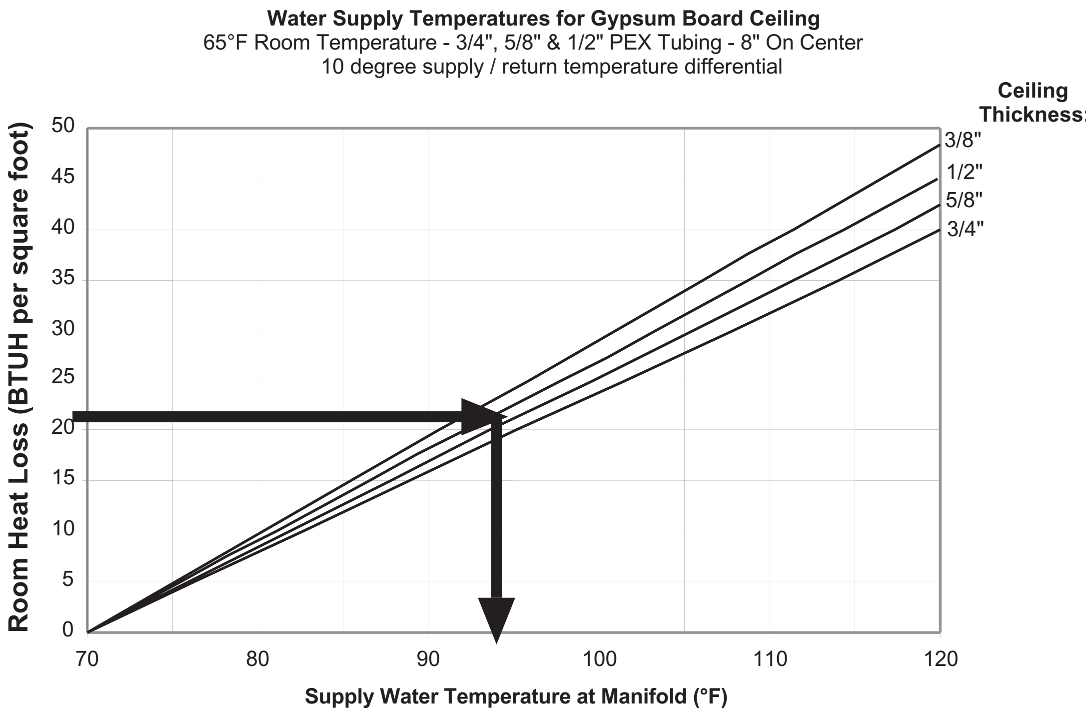
The Radiant Ceiling Height: Normal 8-12 foot ceiling heights work well as radiant ceilings. If the ceiling is less than 8 feet and the heating load is very high, the elevated surface temperatures may present some overheating and discomfort when occupants are standing. If the surface temperature is kept under 85°F, there will be no discomfort. If the ceiling is above 12 feet, and the heating load is high, the radiant distance may require a higher-than-practical surface temperature.

Radiant Ceiling Output Limitations: In order to protect the gypsum (sheetrock) against degradation, it is best to keep the supply water temperature below 120°F. Temperatures above 120°F will cause a "calcination" effect that will break down the gypsum materials, particularly in the areas of taped joints. Surface temperature should never exceed 100°F.

Selecting a Tube Spacing Interval: Most residential applications with radiant ceilings utilize 1/2" tubing attached to the joists providing two tubing runs per joist cavity. Water Supply Temperature charts are provided in Appendix A for a variety of tube spacing and installation options.

Determining Supply Water Temperature: Calculating the Total Usable Panel Area Output (BTUH per sq. ft.) requirements provides the information needed to utilize the Water Supply Temperature chart in the Table below. Select the appropriate supply water temperature chart from Appendix A for the method of construction, differential temperature, and the tube spacing of the radiant panel. The required Total Usable Panel Area Output (BTUH per sq. ft.) is listed on the left side of the chart. Locate the BTUH per sq. ft. and follow across the chart to the intersection of the gypsum ceiling thickness. Then, move down the chart to find the water supply temperature required.

Note: The Water Supply Temperature chart on the next page is specific to a 65°F indoor design temperature. For indoor design temperatures above 65°F, add one degree to the water supply temperature for each degree above 65°F. For indoor design temperatures below 65°F, subtract one degree from the water supply temperature for each degree below 65°F. Additional water supply temperature charts are listed in Appendix A.



The chart above is accurate for a 65°F room. Add 1°F to the results for every degree of room temperature over 65°F.

Note: Subtract 1/2 of the supply/return temperature differential from the supply water temperature to determine the average water temperature.

In the equation to the right :

TBC = (Usable Panel Area Q_{down} x R_c) +PST

(22.6 x .45) + 83.3 = 92.9°F

Where:

Usable Panel Area Q_{down} = 22.6

PST = 83.3°F

R_c = .45 (R-Value of 1/2" sheetrock)

Utilizing our sample cabin and a 1/2" gypsum ceiling, a 70°F room temperature, and a Usable Panel Area Output of 21.6 BTUH per square foot, the supply water temperature required for the cabin is 99°F (94°F + 5°F).

Back Losses From Radiant Ceilings: Back losses to unheated spaces from radiant ceilings can result in poor performance and high operating costs. Normally, the minimum requirements for unheated ceiling and wall insulation are adequate for heated ceilings. Poor insulation technique, however, can lead to excessive back losses. Care must be taken to avoid even small voids in the insulation. When radiant ceilings are installed on intermediate floors, the back losses upward to heated areas will be minimal because the resistance upward through the floor structure and coverings is normally quite high compared to the resistance downward through a sheetrock ceiling. Back losses that migrate upward are not objectionable in that they will serve to condition the temperature of the floor without overheating the room. Heat loss is generally the same across the surface of the ceiling. Calculate upward heat loss per square foot for a radiant ceiling to an unheated space using TBC (temperature below covering), as similarly to previous examples.

We would first calculate TBC (temperature below coverings) using the equation:

TBC = (Usable Panel Area Q_{down} x R_c) + PST

(22.6 x .45) + 82.7 = 92.9°F

Chapter 10

Note: R_{up} in the case of a ceiling under an unheated space is the composite R-Value of all materials between the tubing and unheated space.

RADIANT CEILING CABIN TOTAL HEAT LOAD

Walls	3087
Floor	1895
Windows	3600
Doors	1260
Infiltration	3110
Ceil. Back Loss	2637
Total Heat Load*	15589
*(BTUH)	
BTUH PER SQ/FT	26.0

Then, we would calculate the radiant ceiling upward heat loss with the equation:

$(TBC – T_o)/ R_{up} = Q_{up}$

(92.9 - 10)/19 = 4.4 BTUH per square foot

The Total Downward Load per sq. ft.(Q_{down}) and Upward Ceiling Back Loss per sq. ft. (Q_{up}) are combined to determine the Total Heat Load per sq. ft. of each room. In the case of our cabin:

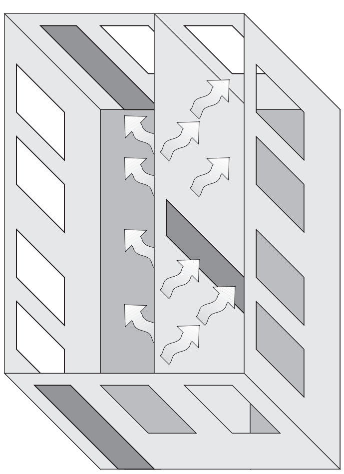
21.6 + 4.4 = 26 BTUH per square foot

Utilizing a radiant ceiling system in our sample cabin, the total heat load for the room is 26 BTUH per sq. ft.

Radiant Wall Performance Planning

Radiant Wall Performance Planning: Radiant walls transfer heat energy to the room through radiation and convection. The natural convective component of heat transfer falls between that of floors and ceilings. Air molecules in contact with the wall will warm and rise along its surface. Forced convection will also occur from the movement of persons and any mechanical ventilation equipment.

Exterior walls usually contain less insulation than floors or ceilings. Therefore, radiant walls are most frequently used on interior walls, narrow rooms and to add extra heat to a radiant floor or ceiling system. If our cabin had an interior partition, both sides could be used to give a broad area of radiant walls. About 460 square feet of wall area would be available using both sides of this interior partition once the door area is subtracted out.



Determining the BTUH Load Per Square Foot: Heat loss calculations for non-heated panels in a radiant floor design are considered Upward Loads and are expressed as an Upward Load per square foot (Q_{up}). In a radiant wall system, back loss calculations of heated exterior wall panels are calculated similarly to ceilings under unheated space, only the heated wall back loss is calculated as the later step. The wall panel output is called Q_{in} and the back loss of an exterior wall Q_{out}.

The amount of wall space that will be used as a radiant panel must be determined. Divide the Total Inward Load (heat loss) by the square footage of the panel to determine the Total Inward Load per square foot. We will assume our cabin has a partition, as shown to the left, with 460 square feet of available area.

Coefficient of Heat Transfer: It is important for the designer and installer to understand the amount of energy that a radiant wall will transfer into a room at any given surface temperature. This factor is called the coefficient of heat transfer. The precise amount of energy transferred depends on many complex variables. For the purpose of performance planning, it is practical to use a coefficient of heat transfer of 1.9 for radiant walls, which represents the output over the most critical range of temperatures used in radiant panels. A coefficient of 1.9 means that 1.9 BTUH will be transferred from one square foot of heated wall for every degree Fahrenheit the wall surface temperature exceeds room temperature.

INTERIOR PARTITION RADIANT WALL CABIN TOTAL HEAT LOAD

Walls	3087
Floor	1895
Windows	3600
Doors	1260
Infiltration	3110
Ceiling	1895
Total Heat Load*	**14847**
*(BTUH)	
BTUH PER SQ/FT	**24.7**

In our sample cabin, the radiant wall is being installed on an interior partition, so there is no back loss from the radiant heating system and we get a lower overall heat loss. If exterior walls were utilized, the heat loss would be calculated first on all the non-radiant panel surfaces, the panel would be designed to this output, and then the back loss from the heated wall panels would be calculated in a similar manner to the back losses for radiant floors or ceilings adjacent to unconditioned spaces.

NOTE: The maximum surface temperature of a wall should not exceed 90°F.

Radiant Wall Surface Temperature: The Total Wall Load (Q_{in})in BTUH per square foot dictates the surface temperature required in the remaining performance calculations. Surface temperature is determined by dividing the Total Wall Load (BTUH) per square foot by the coefficient of heat transfer, and then adding the room set point temperature. In the case of our sample cabin, we have a Total Heat Load of 14,847 BTUH and 460 square feet of available wall area. Therefore,

Q_{in} = 14,847/460 = 32.3 BTUH per square foot

The wall surface temperature (WST) can be calculated with the following equation or using the Table below. Using the equation:

$T_i + (Q_{in}$ per sq. ft. / h) = WST

Where:

h is the Coefficient of Heat Transfer

WST is the Wall Surface Temperature

T_i is the Indoor Temperature

Q_{in} is the Total Wall Load

For our cabin :

WST = 70 + (32.3/1.9) = 87°F

To use the Table, locate the room set point temperature on the left side of the chart and follow across to the appropriate BTUH per sq. ft. column using the established inside design temperature of 70°F and the Inward Loss calculated above.

Radiant Wall Surface Temperatures

Room Set Point Temperature °F	BTUH PER SQUARE FOOT 10	15	20	25	30	35	40	45	50	55	60
75	80.3	82.9	85.5	88.2	90.8	93.4	96.1	98.7	101.3	103.9	106.6
74	79.3	81.9	84.5	87.2	89.8	92.4	95.1	97.7	100.3	102.9	105.6
73	78.3	80.9	83.5	86.2	88.8	91.4	94.1	96.7	99.3	101.9	104.6
72	77.3	79.9	82.5	85.2	87.8	90.4	93.1	95.7	98.3	100.9	103.6
71	76.3	78.9	81.5	84.2	86.8	89.4	92.1	94.7	97.3	99.9	102.6
70	75.3	77.9	80.5	83.2	85.8	88.4	91.1	93.7	96.3	98.9	101.6
69	74.3	76.9	79.5	82.2	84.8	87.4	90.1	92.7	95.3	97.9	100.6
68	73.3	75.9	78.5	81.2	83.8	86.4	89.1	91.7	94.3	96.9	99.6
67	72.3	74.9	77.5	80.2	82.8	85.4	88.1	90.7	93.3	95.9	98.6
66	71.3	73.9	76.5	79.2	81.8	84.4	87.1	89.7	92.3	94.9	97.6
65	70.3	72.9	75.5	78.2	80.8	83.4	86.1	88.7	91.3	93.9	96.6
64	69.3	71.9	74.5	77.2	79.8	82.4	85.1	87.7	90.3	92.9	95.6
63	68.3	70.9	73.5	76.2	78.8	81.4	84.1	86.7	89.3	91.9	94.6
62	67.3	69.9	72.5	75.2	77.8	80.4	83.1	85.7	88.3	90.9	93.6
61	66.3	68.9	71.5	74.2	76.8	79.4	82.1	84.7	87.3	89.9	92.6
60	65.3	67.9	70.5	73.2	75.8	78.4	81.1	83.7	86.3	88.9	91.6
	SURFACE TEMPERATURES										

Radiant Wall Heated Area: Radiant walls can be as powerful as radiant ceilings or floors, but usually the amount of area available is limited. Rooms that require a lot of heat usually do so because of large windows that limit the available wall surface area. Placing radiant panels on interior walls is not effective unless located within 10 feet of an outside wall. Radiant wall surface temperatures above 90°F are not recommended.

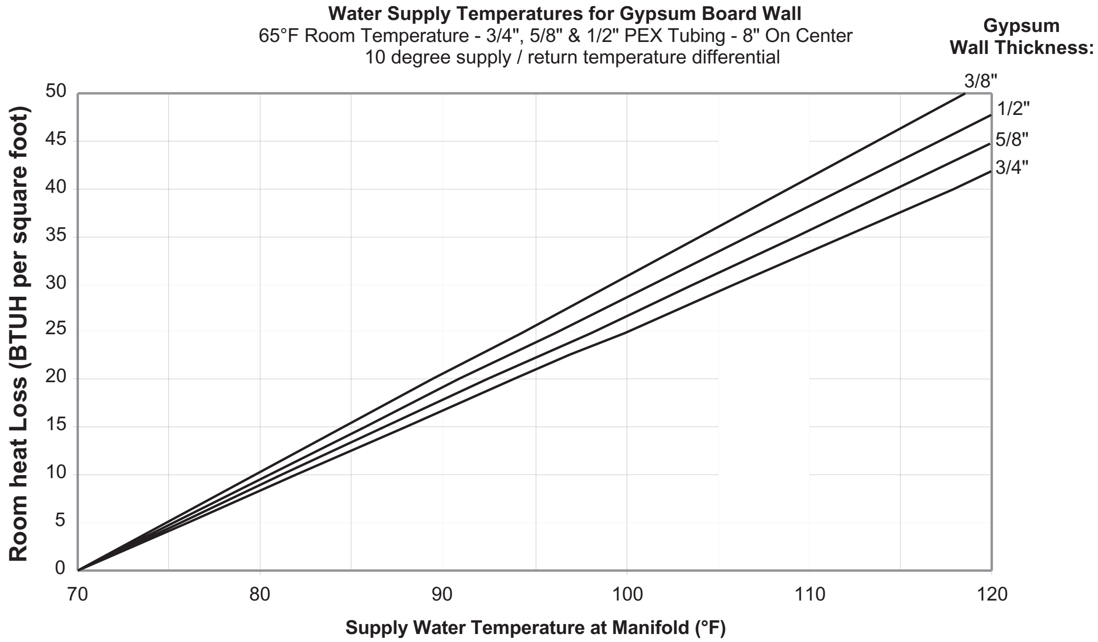
NOTE: The Water Supply Temperature chart below is specific to a 65°F indoor design temperature. For indoor design temperatures above 65°F, add one degree to the water supply temperature for each degree above 65°F. The Table below shows a required supply temperature of 91°F, a 70°F indoor design temperature will require a water supply temperature of 96°F. For indoor design temperatures below 65°F, subtract one degree from the water supply temperature for each degree below 65°F. Additional water supply temperature charts are listed in Appendix A.

Thermal Resistance of a Wall Structure: Radiant walls are constructed in a manner that presents very little resistance to heat transfer from the tubing to the wall surface. Gypsum (sheetrock) is the most common material used as finished walls. This material is very good at conducting heat, having an R-Value of approximately 0.45 per 1/2 inch thickness. Other materials used for wall panels may have greater resistance and require higher average water temperatures.

Selecting a Tube Spacing Interval: Most applications for radiant walls utilize 1/2" tubing attached directly to the studs, providing two tubing runs per stud cavity.

Determining Supply Water Temperature: Calculating the outward BTUH per sq. ft. requirements of each room provides the information needed to utilize the Water Supply Temperature chart shown below. Select the appropriate supply water temperature chart from Appendix A for the method of construction, differential temperature, and the tube spacing of the radiant panel. The required upward load (BTUH/per sq.ft.) is listed on the left side of the chart. Locate the BTUH/ per sq. ft. and follow across the chart to the intersection of the gypsum wall thickness. Then, move down the chart to find the water supply temperature required. Add or subtract 1°F for every degree the room temperature is above or below 65°F.

In our cabin example, the room temperature is 70°F, so we would add 5°F to the 96°F water we would get using the chart at 65°F. Therefore, our supply water temperature would be 101°F.



Utilizing the cabin with a 1/2" gypsum wall, the supply water temperature required for the cabin radiant walls is 101°F degrees.

Back Losses From Radiant Walls: Back losses to unheated spaces from radiant walls can result in poor performance and high operating costs. Normally, the minimum requirements for unheated wall insulation are adequate for heated walls to transfer heat energy into a room. Poor insulation technique, however, can lead to excessive back losses. Care must be taken to avoid even small voids or crushing the insulation. When utilizing interior walls, place insulation behind the tubing in order to maintain controllability and limit heat loss to other interior rooms. Water supply temperatures over 120°F will cause a “calcination” effect that will break down the gypsum materials commonly used in ceiling construction. Calculate outward heat loss per square foot for a radiant wall to an unheated space using the average supply water temperature.

Combination Radiant Panel Systems: In order to optimize heat distribution within a building, it may be most effective to use a combination radiant panel heating system that provides the most optimal distribution for each room. Combining radiant floors, ceilings, and walls within the structure permits the designer to meet the heating load in even the most critical rooms. Radiant floors can warm otherwise cold concrete slabs and tile areas, whereas radiant ceilings can meet the high loads in window areas and still permit the use of plush carpets or rich wood floors. Using both radiant floors and ceilings in the same room can provide the best of both technologies.

Combination with Radiators and Fin Tube Convectors: High output radiators and fin tube convectors can be used in combination with radiant floors and ceilings. Most of these units are placed near windows and can easily provide up to 400 BTUH per linear foot or more. Radiators and fin tube convectors, however, operate at much higher supply water temperatures than radiant panels. In most cases, a split tempering system will be required to provide the dual supply water temperatures to each distribution system.

Calculating Performance of Radiant Convectors: In order to calculate the performance of any radiator or fin tube convector, you will need to know the performance ratings in BTUH per linear foot at any given supply water temperature for the indoor set point temperature of the room. These values typically run about 4.5 BTUH per degree Fahrenheit difference in temperature between the average supply water and the room. The variations between products are very important, check the manufacturer’s performance calculations and recommendations when designing a radiant convector system.

Other Forms of Supplemental Heat Distribution: It may be useful to combine radiant panel heating systems with fan coils or other forms of forced air heating. This is particularly true when it becomes necessary to use heated make up air. If the ventilation air is not heated, it can cause an uncomfortable draft in some areas.

CHAPTER 11: FLOW ANALYSIS IN RADIANT DESIGN

In Hydronics, Fluids Transfer The Heat

MANIFOLD DEFINED: A manifold is a chamber with attachments for conveniently connecting the loops of tubing used in radiant floor heating systems. They may be made of plastic, copper or brass.

Manifold Location

Distribution Manifolds: The location of the distribution manifold is important. Long runs between the manifolds and the radiant panels can reduce the amount of tubing available for the radiant panel and increase the pump capacity requirements. Poor accessibility to the manifold can complicate the installation and servicing of the system. Complicated distribution piping can add cost and complexity to the system. The following design criteria should be considered when selecting a manifold location.

Manifolds should be placed in an accessible location above the tubing that is connected to them. It is good practice to provide air vents at all high points in a hydronic system. With up to a mile of tubing in an average residence, air vents on the supply and return manifolds will help purge the air out of the system and reduce start up labor time and cost. Manifolds are often placed in the back of a closet near the zone they serve, in an enclosure that has been framed into the wall.

Accessibility: The manifold must be accessible during installation and when service is required. It should be in a position that allows the runs to be made to the individual zones without excess leader lengths. Normally, it is best to locate the manifold on an inside wall where the tubing can be routed from both sides of the wall to the manifold. It should be mounted high enough to permit easy connections from below, particularly in concrete or poured floor underlayment applications where the tubing is embedded and cannot easily be moved while connecting or reconnecting the fittings. Do not place the manifold in an area that could be damaged by minor water spillage during purging or servicing.

Heat Loss: Do not install the manifold in a location that could experience excessive heat loss to the exterior of the building, freezing conditions, or exposure to sunlight.

Determining Flow Rates

Radiant Floor Design Temperature: Radiant floors are unique in that they are the only heat system that comes into direct contact with the occupants on a regular basis. For this reason, the floor temperature must be accurately controlled to ensure the comfort of the occupants.

Designing with a 20°F Δ T instead of a 10°F Δ T means that smaller pumps can be used, since only half as much water is being pumped. The smaller pump will save energy for the life of the system and will cost less to install.

Differential Temperature: The differential temperature is the difference in temperature between the fluid going into the radiant panel (supply water) and the fluid coming out of the panel (return water). Differential temperature is often referred to as "Delta T" or "ΔT." Radiant floor heating systems are commonly designed with either a 10°F or 20°F differential temperature. A 10°F differential temperature delivers more consistent temperatures through the entire length of the loop and requires a higher flow rate than a 20°F differential temperature. A 20°F differential temperature will produce more BTUH per square foot than a 10°F differential temperature at the same flow rate.

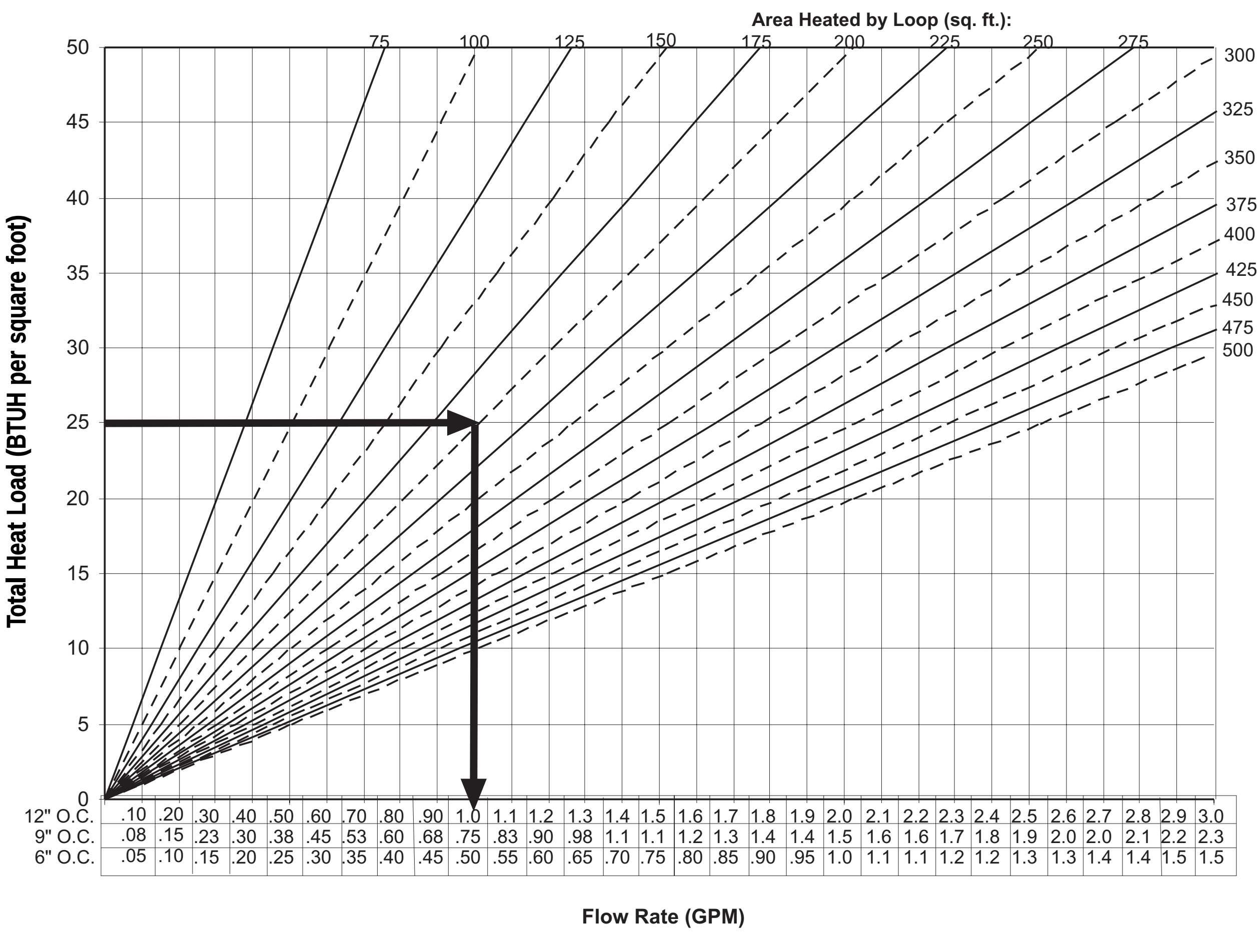
FLOW: Flow in a radiant panel heating system is the amount of fluid passing through the panel in a given amount of time. The amount of flow is referred to as the flow rate and is usually expressed in "gallons per minute" (GPM).

The area served by a loop, the spacing of the tubing, temperature differential, and the type of fluid used in the radiant panel all have an effect on the flow rate required to meet the heating requirement.

Flow Requirement Chart: The chart below can be used to determine the flow requirement for radiant panels of PEX tubing up to 500 square feet in area at a differential temperature of 10°F using 100% water. Enter the chart on the left at the total heating load per square foot. Then move right until intersecting the slope of the line that represents the area heated by the loop. Move downward to find the flow requirement at 12", 9", or 6" on center tube spacing. Additional flow rate charts for water and glycol mixtures with 10°F and 20°F Differential Temperatures are shown in Appendix B.

Example: If the heating load is 25 BTUH per square foot and the area served by the loop is 200 sq. ft., the minimum flow will be 1.0 GPM when using 12" on center tube spacing.

Flow Rate Chart - 100% Water - 10¡F Supply/ Return Temperature Differential



The Relationships Between Differential Temperature and Flow: In a radiant panel heating system, differential temperature (DT)and flow rate are inversely related. The larger the differential temperature, the lower the flow rate. Inversely, the smaller the differential temperature, the higher the flow rate required to reach the same BTUH output. Total heat output can be calculated by the following equation:

Note: The factor of 500 represents the nominal weight of water per gallon (8.34 lbs.) multiplied by 60 minutes. Remember that a BTU is a unit of measure of the amount of heat that it takes to raise the temperature of a pound of water one degree Fahrenheit.

Heat Output in BTUH = (DT) x (GPM) x 500

Examples: If the DT is 10°F and the Flow is 1 GPM, the Heat Output is 5000 Btu/hr.

If the DT is 20°F and the Flow is .5 GPM, the Heat Output is 5000 Btu/hr.

If you know the BTU requirements and the system water Δ T, you can calculate the GPM requirement using the following formula:

GPM = BTUH/(500 x Δ T)

An increase in either DT or flow will increase output as long as the other factors remain constant.

An increase in flow will reduce the DT, increase the average supply water temperature and increase the thermal output.

A decrease in flow will increase the DT, decrease the average supply water temperature and decrease the thermal output.

Pressure loss can be defined as the loss of fluid pressure caused by friction between any two points in a flowing system. It is often expressed in PSI or in feet of head.

1 PSI = 2.0366 feet of head

Pressure Loss: Fluid passing through PEX tubing experiences pressure loss due to friction between the moving fluid and the tubing wall. This pressure loss can be expressed in either pounds per square inch (psi) or in feet of head (ft H20). It is very important that the circulator has enough power to deliver the minimum flow requirement to each and every loop. The designer should be familiar with the factors that influence pressure loss and the relationships between them:

- At any given flow rate, the longer the tubing, the more pressure loss there will be because the fluid contacts more tubing wall surface.
- At any given flow rate, the smaller the tubing diameter, the more pressure loss there will be because the ratio of fluid to tubing wall surface is high.
- At any given length, the faster the fluid flows, the greater the pressure loss will be because the turbulence is greater.
- The denser the fluid, the greater pressure loss.
- Pressure loss decreases as fluid temperature increases.

When hydronic fluids pass through reduced size orifices, such as manifolds and small diameter fittings, and then into larger diameter tubing, a regain in pressure occurs such that the small diameter orifice has a minimal effect on the flow.

Propylene glycol should be used rather than ethylene glycol wherever possible since it is environmentally much more benign. Very small amounts of ethylene glycol can be lethal and are flammable. Propylene glycol, on the other hand, is available as a food grade material and is in fact used as a binder in many manufactured foods.

Heat Transfer of Hydronic Fluids: Several types of fluids may be circulated within the radiant panel system. Plain water has the least amount of friction because its density is the lowest. Water mixed with various forms of glycol increases the friction as the percentage of glycol increases. Freeze protection is accomplished with either ethylene glycol or propylene glycol. Ethylene glycol presents less flow restriction and transfers heat better than propylene glycol, but is very toxic, and thus dangerous to humans and the environment. Propylene glycol should be preferred because of its low toxicity or local code requirements.

Tubing Size: PEX tubing is available in five sizes for heating applications: 3/8", 1/2", 5/8" 3/4", and one inch nominal. The chart below shows the specifications for each size. The outside diameter corresponds to copper tube sizes (CTS), but due to the wall thickness, the inside diameters are somewhat smaller than copper pipe. You should also note that a 1/2-inch tube provides nearly twice the volume per cubic inch as the 3/8-inch pipe, and 1-inch pipe carries over three times the volume per cubic inch of a 1/2 inch-pipe.

Tubing Information

Zurn Designation	Nom. Size (in)	Avg OD (in)	Avg ID (in)	Min Wall (in)	Wt Per 100Ft (lbs)	Volume (gal/ft)
Q2P/QH2P	3/8	0.500	0.35	0.07	4.19	0.0050
Q3P/QH3P	1/2	0.627	0.475	0.07	5.4	0.0092
QJP/QHJP	5/8	0.750	0.574	0.083	7.8	0.0134
Q4P/QH4P	3/4	0.875	0.671	0.097	10.2	0.0184
Q5P/QH5P	1	1.125	0.862	0.125	16.62	0.0303
Q6P*	1-1/4	1.375	1.055	.153	25.6 lbs	0.0454
Q7P*	1-1/2	1.625	1.245	.181	35.9 lbs	0.0632
Q8P*	2	2.125	1.629	.236	61.1 lbs	0.1083

* Check For Availablity

Determining the amount of tubing in a room using tube spacing factors:

Multiply heated area by tube spacing factor (TSF).

12" O.C. = 1
10" O.C. = 1.2
9" O.C. = 1.33
8" O.C. = 1.5
6" O.C. = 2
18" O.C. = 0.67
24" O.C. = 0.5

Recommended Loop Lengths: The length of a loop includes the tubing in the radiant panel and connections to the manifold. The Table below provides recommended loop lengths and maximum flow rates for PEX and PEX Barrier Tubing using 100% water at 120°F.

Loop Lengths

PEX Tubing

Tube Size	Recommended Loop Lengths	Max. Flow Rate @ Max. Loop Length
3/8"	200 to 250 ft.	.5 GPM
1/2"	250 to 325 ft.	1.0 GPM
5/8"	325 to 500 ft.	1.3 GPM
3/4"	500 to 600 ft.	1.7 GPM
1"	600 to 750 ft.	3.0 GPM

Pressure Loss Charts: In order to make it easy for the designer to obtain pressure loss information, a complete series of pressure loss charts are provided in Appendix B of this manual. These charts are prepared for each dimension of tubing at six temperatures (from 80°F to 180°F), at 100% water, and at 30, 40 and 50% glycol mixtures. The charts provide pressure loss values in both pounds per square inch (psi) and head loss in feet of head (ft H20) for each temperature. An additional column provides the corresponding velocity in feet per second. The chart gives pressure loss for one foot of PEX tubing.

Note: Glycol mixture percentages refer to the amount of glycol relative to total volume.

Using the Pressure Loss Chart: First, select the correct chart for the size of PEX tubing used and the fluid medium. (See the Table below.) If using a glycol fluid mixture that is between those charted, use the next highest percentage or interpolate. Enter the chart on the left margin at the minimum flow rate and read across to determine pressure losses (in psi or feet of water) per foot of pipe. Multiply the value by total feet of pipe in the loop to determine total pressure loss for the loop. Velocity in feet per second is listed in the second column and is not affected by temperature or loop length.

		Pressure Loss per Linear Foot – 1/2" PEX – 100% Water											
		80 °F		100 °F		120 °F		140 °F		160 °F		180 °F	
Flow (GPM)	Velocity (FPS)	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot
0.1	0.18	0.0003	0.0008	0.0003	0.0007	0.0003	0.0007	0.0003	0.0006	0.0003	0.0006	0.0003	0.0006
0.2	0.36	0.0011	0.0025	0.0010	0.0024	0.0010	0.0023	0.0009	0.0022	0.0009	0.0021	0.0009	0.0020
0.3	0.54	0.0022	0.0051	0.0021	0.0049	0.0020	0.0047	0.0019	0.0044	0.0018	0.0043	0.0017	0.0042
0.4	0.72	0.0037	0.0085	0.0035	0.0081	0.0033	0.0077	0.0031	0.0073	0.0030	0.0071	0.0029	0.0069
0.5	0.90	0.0054	0.0126	0.0051	0.0119	0.0049	0.0114	0.0046	0.0109	0.0044	0.0105	0.0043	0.0102
0.6	1.08	0.0075	0.0173	0.0071	0.0164	0.0067	0.0157	0.0064	0.0149	0.0061	0.0144	0.0059	0.0140
0.7	1.26	0.0098	0.0227	0.0093	0.0215	0.0088	0.0205	0.0083	0.0196	0.0080	0.0189	0.0077	0.0183
0.8	1.44	0.0124	0.0287	0.0117	0.0272	0.0111	0.0259	0.0105	0.0247	0.0101	0.0239	0.0097	0.0231
0.9	1.62	0.0152	0.0352	0.0144	0.0334	0.0137	0.0319	0.0129	0.0304	0.0124	0.0293	0.0119	0.0284
1.0	1.80	0.0183	0.0423	0.0173	0.0402	0.0164	0.0383	0.0156	0.0365	0.0149	0.0353	0.0144	0.0342
1.1	1.97	0.0216	0.0500	0.0204	0.0475	0.0194	0.0453	0.0184	0.0431	0.0177	0.0417	0.0170	0.0404
1.2	2.15	0.0252	0.0583	0.0238	0.0553	0.0226	0.0527	0.0214	0.0502	0.0206	0.0486	0.0198	0.0470
1.3	2.33	0.0290	0.0670	0.0274	0.0636	0.0260	0.0606	0.0246	0.0578	0.0237	0.0559	0.0227	0.0541
1.4	2.51	0.0330	0.0763	0.0312	0.0724	0.0296	0.0690	0.0280	0.0658	0.0269	0.0636	0.0259	0.0616
1.5	2.69	0.0372	0.0861	0.0352	0.0817	0.0334	0.0779	0.0316	0.0742	0.0304	0.0717	0.0292	0.0695
1.6	2.87	0.0416	0.0964	0.0394	0.0915	0.0374	0.0872	0.0354	0.0831	0.0340	0.0803	0.0327	0.0778
1.7	3.05	0.0463	0.1072	0.0438	0.1017	0.0416	0.0970	0.0394	0.0924	0.0378	0.0893	0.0364	0.0865
1.8	3.23	0.0512	0.1185	0.0484	0.1124	0.0459	0.1072	0.0435	0.1021	0.0418	0.0987	0.0402	0.0956
1.9	3.41	0.0563	0.1302	0.0532	0.1236	0.0505	0.1178	0.0479	0.1123	0.0460	0.1085	0.0442	0.1050
2.0	3.59	0.0615	0.1424	0.0582	0.1352	0.0552	0.1289	0.0524	0.1228	0.0503	0.1187	0.0483	0.1149
2.1	3.77	0.0670	0.1551	0.0634	0.1472	0.0602	0.1404	0.0570	0.1338	0.0548	0.1293	0.0526	0.1251
2.2	3.95	0.0727	0.1683	0.0688	0.1597	0.0653	0.1523	0.0619	0.1451	0.0594	0.1402	0.0571	0.1358
2.3	4.13	0.0786	0.1819	0.0743	0.1727	0.0705	0.1646	0.0669	0.1569	0.0642	0.1516	0.0617	0.1467
2.4	4.31	0.0847	0.1960	0.0801	0.1860	0.0760	0.1773	0.0720	0.1690	0.0692	0.1633	0.0665	0.1581
2.5	4.49	0.0909	0.2105	0.0860	0.1998	0.0816	0.1905	0.0774	0.1815	0.0743	0.1754	0.0714	0.1698
2.6	4.67	0.0974	0.2254	0.0921	0.2140	0.0874	0.2040	0.0829	0.1944	0.0796	0.1879	0.0765	0.1819
2.7	4.85	0.1041	0.2408	0.0984	0.2286	0.0934	0.2179	0.0885	0.2077	0.0850	0.2007	0.0817	0.1943
2.8	5.03	0.1109	0.2566	0.1049	0.2436	0.0995	0.2322	0.0943	0.2213	0.0906	0.2139	0.0871	0.2070
2.9	5.21	0.1179	0.2729	0.1115	0.2590	0.1058	0.2470	0.1003	0.2353	0.0963	0.2274	0.0926	0.2202
3.0	5.39	0.1251	0.2896	0.1183	0.2749	0.1123	0.2621	0.1064	0.2497	0.1022	0.2413	0.0983	0.2336

0.0164 PSI = 0.0383 feet of head

4.1 PSI = 9.57 feet of head

Example: A 250-foot length of 1/2" PEX tubing with a 1.0 gallon per minute flow, at 120°F, and 100% water, will generate a pressure loss of 0.0164 psi per linear foot of pipe.

250 x .0164 = 4.1 psi (pressure loss of the loop)

To find the pressure loss in feet of head, multiply 250 feet of tubing by the factor of 0.0383 to get a pressure loss of 9.57 feet of head. The water velocity is 1.80 feet per second at this flow rate.

NOTE:
The use of the Qickzone modular brass heating manifold with flow gauges eliminates the need to calculate individual circuit pressure loss for balancing, but the pressure loss need to be calculated to establish the pressure loss associated with the manifold assembly. See calculating manifold pressure loss below.

Balancing Flow at the Manifold: Flow balancing at the supply manifold compensates for variations in the loop length and flow rates required for each individual loop. Use of the Qickzone modular brass heating manifold with flow gauges eliminates the need to calculate individual circuit pressure los for balancing. To balance the system the installer simply adjusts the balancing valve until the required flow is indicated on the gauge. Since fluid flow follows the path of least resistance (lowest pressure drop), shorter loop lengths will tend to receive a higher flow rate. This is problematic because short runs tend to require less flow than longer runs. Thus, the areas being served by short runs will likely overheat and the areas served by the longer runs will be short of the required heat output.

Calculating Manifold Pressure Loss: The pressure loss associated with a manifold assembly is established by determining which loop has the greatest pressure drop.

The following exercise will step through the process necessary to determine the proper balancing flow valve settings for a given manifold system with unique loops.

Pressure losses were calculated for a modular manifold system using 100% water at 120°F with four loops of the following sizes, lengths, and flow rates.

Loop Number (n)	Tube Size	Loop Length (ft)	Flow Rate (GPM)	Tube Pressure Loss (FT-H2O)
1	1/2	150	0.85	4.34
2	1/2	250	0.9	7.98
3	1/2	350	0.6	5.50
4	1/2	300	0.4	2.31

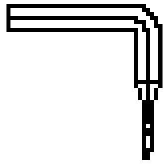
The modular manifold balancing valves have settings that are in relation to the valve being fully closed. Fully closed has no flow, and four turns from closed (fully open) has full flow. Pressure loss for each section of manifold has a unique characteristic based upon flow rates and turns from closed. A chart showing this relationship is found in Appendix C.

Using the flow rates from the previous table, the following valve openings were determined. Loop #1 - 1-1/2 turns from closed, Loop #2 - 1-1/2 turns from closed, Loop #3 - 1-1/4 turns from closed, and Loop #4 - 1 turn from closed.

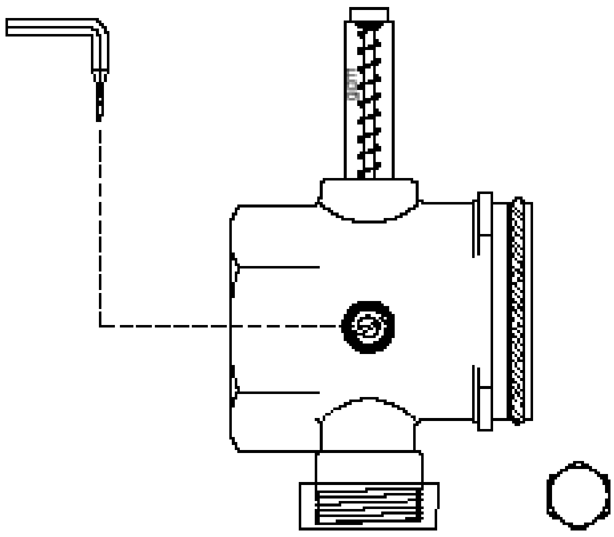
To calculate the total system pressure loss, the manifold pressure loss for each loop must first be determined. Using the chart in Appendix C, the pressure loss for each loop was calculated. These values are then added to the loop pressure loss to determine the maximum pressure loss for all of the loops. The maximum pressure loss of all the loops that is the highest is then used as the total system pressure loss. As seen in the table below, Loop #2 will be used as the total system pressure loss because it was the highest out of all the maximum pressure losses.

Loop Number (n)	Tube Pressure Loss (FT-H2O)	Manifold Pressure Loss (FT-H2O)	Maximum Pressure Losses (FT-H2O)
1	4.34	2.00	6.34
2	7.98	2.50	10.48
3	5.50	1.50	7.00
4	2.31	2.50	4.81

Qickzone Balancing Method: Determine the flow rate needed for each loop either with computer software or by manual calculation. Fully open (counterclockwise) all isolating valves on the Return Modules, remove the Lock Shield Caps (counterclockwise) on each of the Supply Modules. Then using the Adjustment Key, completely unscrew (counterclockwise) the mechanical memories on all Supply Modules and then using the Adjustment Key completely open (counterclockwise the Lock Shield Valves on all Supply Modules. Slowly close the Lock Shield Valve of each circuit until the desired flow rate is obtained on the flow meters. Repeat the balancing procedure, if necessary, when the initial balancing is completed on all Supply Modules. Using the Adjustment Key, tighten the mechanical memories on all Supply Modules and reinstall Lock Shield Caps.



Adjustment Key has hex end for Flow Adjustment and straight end for Mechanical Memory Adjustment



Below are Cv values of different settings:

1/4 turn	Cv = 0.15	1/2 turn	Cv = 0.20		
1 turn	Cv = 0.25	1-1/4 turns	Cv = 0.48	1-1/2 turns	Cv= 0.60
2 turns	Cv = 0.72	2-1/2 turns	Cv = 1.01		
3 turns	Cv = 1.25	3-1/2 turns	Cv = 1.58		
Full Open	Cv = 1.84				

Use PEX tubing for distribution piping where possible. It is easier to use and will lose less heat. Pressure loss charts for the various sizes are included in Appendix B.

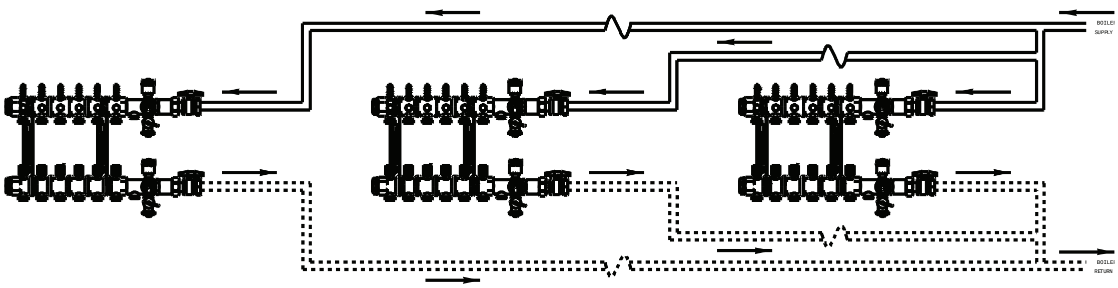
Flow Restriction in Copper and PEX Distribution Piping: Copper and PEX pipe are often used for piping hydronic fluids from the heat source to the manifold. Pressure losses for PEX are shown in Appendix B. Pressure losses for copper are different than in plastic pipe and must be included in pressure loss calculations for the complete system. Fittings used with rigid pipe present an additional restriction, normally amounting to the equivalent of less than two additional feet of pipe. The Table below illustrates typical flow restriction in nominal copper Type L copper tubing. The ASHRAE pocket guide also provides detailed information about pressure losses in other types of pipe and fittings.

	Typical Copper Tubing Type L				
	Pressure loss in ft Head per foot of tubing				
GPM	1/2" Nom	3/4" Nom	1" Nom	1 1/4" Nom	1 1/2" Nom
0.5	0.007				
1.0	0.025	0.004			
1.5	0.045	0.009			
2.0	0.205	0.015			
2.5		0.02	0.006		
3.0		0.03	0.008		
3.5		3.8	0.012		
4.0		0.05	0.014	0.006	
5.0		0.07	0.02	0.007	
6.0		0.1	0.027	0.01	0.005
7.0		0.13	0.037	0.013	0.006
8.0		0.16	0.044	1.7	0.0075
9.0		0.2	0.059	0.02	0.009
10.0			0.07	0.025	0.11
15.0			0.15	0.05	0.02
20.0				0.075	0.039
30.0				0.18	0.08
40.0					0.17

Remote Distribution Manifolds: Radiant panel systems can involve multiple remote manifold locations throughout the building. Distribution from the heat plant to the manifolds must be adequate to deliver ample flow to each loop. The distribution system includes circulators, mixing valves, and distribution piping. Circulators must be powerful enough to provide ample flow and ample pressure. Distribution piping must be large enough to carry the fluid at the required flow rates without presenting flow restrictions that the circulator cannot overcome. Each circulating loop has its own flow restriction which is determined by flow rate, size, length of tubing, and viscosity of the circulating fluid. When grouped on a manifold with other circuits, the loop with the maximum flow restriction determines the pressure loss for the entire manifold. Do not add pressure losses together.

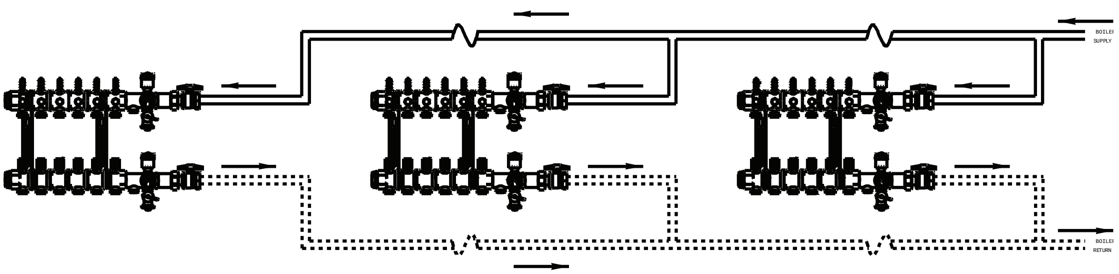
It is assumed that all pressure loss will be balanced, either by installing similar lengths of tubing or by balancing valves. The maximum flow for the manifold, however, is the sum of the required flow for all of the circuits served. If, for example, there are four loops on a manifold and the maximum loop has a pressure loss of 3 feet of head, and each loop requires 1 gallon per minute, the fluid distribution requirement at the manifold is 4 GPM at 3 feet of head. Flow restriction for distribution piping must be added to the manifold restriction to determine total flow restriction in order to properly size the distribution piping and the circulator.

Home Run Distribution To Manifolds: When the manifolds are supplied by a home run distribution pipe system there is a dedicated run of supply and return pipe from the mechanical room to each manifold. With larger systems, individual circulators can be used for each manifold run. In smaller systems, it may be necessary to balance flow between manifolds to ensure adequate flow.



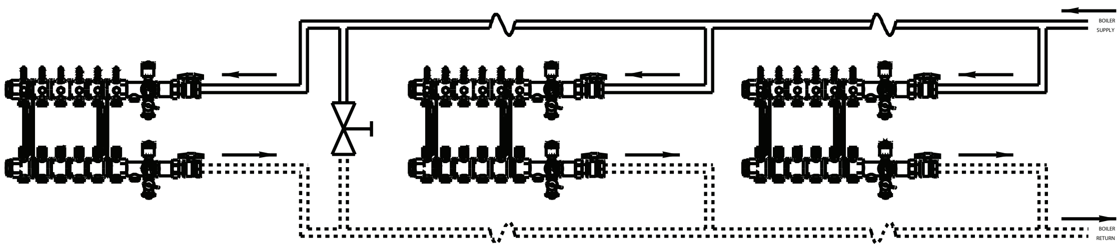
Home Run Manifolds

Branch Distribution To Manifolds: When the manifolds are supplied by a branch distribution pipe system, there is a main supply line with individual branches to each manifold. A single circulator provides all of the flow. This method requires larger distribution pipe to provide adequate flow as well as some degree of balancing between manifolds. If runs are very long, a pressure bypass system may be necessary.



Branch Manifolds

Pressure Bypass: It may be necessary to install a pressure bypass on branch distribution piping systems when there are long runs to the manifolds. In such situations, if a single small zone is calling for heat at the furthest reach of the distribution system, it will take an unacceptably long time for the heated fluid to reach the manifold. Also, since large systems will have large circulators, the single small zone or other zone valves may be overpowered by the circulator, causing excessive noise, or the circulator will overheat as a result of dead heading its discharge.

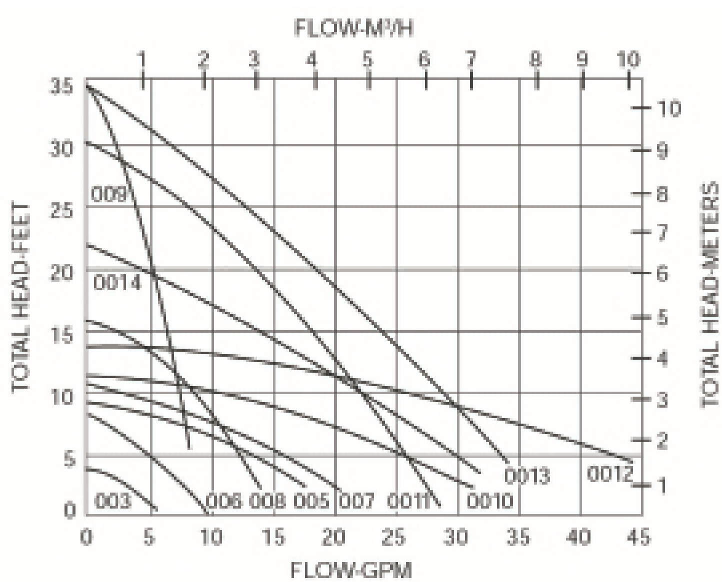


Use of Pressure Bypass

NOTE: Heat appliances are often sold with package circulators. These circulators are sized to the pressure loss within the unit and the anticipated flow restrictions of a typical baseboard convector loop. Often these circulators are too small for hydronic radiant panel systems with very long runs of tubing. Do not assume that these package circulators will provide sufficient flow in a radiant panel system.

Hydronic Circulators: Circulators (pumps) are important components in the radiant panel heating system. There are a number of types and brands of hydronic circulators that can be used, and they are available in a variety of sizes and capacities. Most manufacturers have circulators that are available in cast iron, or in stainless steel and bronze for those applications that require non-corrodible components. The circulator(s) must be powerful enough to provide the flow needed to distribute the heat energy. Manufacturers provide performance data (pump curves) on their circulators which show the capacity in gallons per minute at various pressure losses. Pressure losses are normally expressed in feet of head or pounds per square inch.

An example of a pump curve:



Sizing the Circulator: A circulator serves a loop or series of loops. After determining the maximum flow requirement and the maximum pressure loss for each loop, a circulator must be selected that meets these minimum delivery requirements. In doing so, add all of the minimum flow rates that the circulator will be providing to determine the total flow required of the circulator. Then, find the loop with the highest pressure loss. Add this pressure loss to the pressure losses of the heat plant, heat exchangers and all other components in the distribution system up to the manifold to obtain maximum pressure loss. Do not add pressure losses of any other loops served by the circulator. Select a circulator that is able to deliver the total flow at the maximum pressure loss (head loss). Multiple speed pumps should be sized based on the performance at the middle speed.

EXPANSION IN RADIANT PANEL HEATING SYSTEMS: When the hydronic fluid is heated within the radiant system, it will tend to expand based on the particular characteristics of the hydronic fluid. For example, water that is heated from 50°F to 120°F will expand at a rate of 1%, or one gallon for every 100 gallons. Heating fluids cannot be compressed. Therefore, in a sealed system they can develop very powerful expansion forces that can cause explosive rupture of even the strongest metal vessels. In order to compensate for the expansion of the heating fluids, a properly sized expansion system must be installed. The expansion system consists of a properly sized expansion tank and pressure relief valve. Additional components, such as an automatic makeup water fill device and back flow preventer, may also be required.

Start Up Loads: When the heating fluids are cold, they are denser and require more energy to get moving. As they warm up, they become less dense and require less energy to circulate. For most systems, the difference is immaterial. During start up, the flow might be sluggish until the fluid gets up to temperature. If, however, a system is glycol protected and turned off for a period of time that results in the fluid temperature becoming very low, the start up load may be too great for the circulator to overcome. In such systems, it may be necessary to oversize the circulator or start only one zone at a time until all zones are sufficiently close to operating temperatures.

Temperature Rise: When calculating temperature rise, it is important to understand that different areas within the system will contain different temperatures of water. Boiler vessels may operate at 180°F +, whereas the areas that are served by tempering devices may operate at much lower temperatures. It may be necessary to calculate expansion separately for each area.

Pressure Relief Valve: The pressure relief valve is designed to vent excess system pressure in the event of a control system failure in the heat plant. A pressure relief valve must be selected that has a relief pressure that is higher than the system fill pressure and lower than the maximum rated pressure of any component in the hydronic system. In order to protect the system, the pressure relief valve must not be isolated from the heat plant by any valve or flow restrictive mechanism. The difference between fill pressure and the vent pressure of the relief valve has a big effect on the required size of expansion tank. When the difference between fill pressure and relief pressure is small, the expansion tank will need to be large. When the difference is large the tank will need to be smaller.

Typical automatic fill valve.

A properly sized expansion tank is an important part of the system.

EXPANSION TANKS DEFINED:
The expansion tank is a vessel in which captive air (or other suitable gas) is available to the hydronic circulating loop. As the heating fluid expands, the force of expansion compresses the air within the tank to absorb the expansion without exceeding pressure limitations. The air or gas may be free within the tank or contained behind an elastomeric membrane. The amount of air required will depend on: the type and amount of fluid heated, the minimum and maximum temperatures of the fluid, the fill pressure, and the maximum pressure allowed by the pressure relief valve. Expansion tank sizing and application is specific to the acceptance volume of their particular products. It is important not to undersize an expansion tank.

PSIG is PSI Gauge Pressure

Automatic Fill Valves: Automatic fill valves (or makeup valves) may be used to keep the system filled in the event of minor water losses or to add water as the air is vented from the system after initial start up. The fill pressure setting of such valves will determine the lowest operating pressure. In some systems, it may be advisable to ensure that the automatic fill valve does not dilute any antifreeze mixture or cause excessive water damage in the event of a leak.

Expansion Tank Sizing: Five parameters must be known in order to properly calculate the minimum expansion tank size for a radiant panel heating system.

1. Volume of water in the system
2. Fill pressure
3. Relief valve pressure
4. Fill temperature
5. Maximum water temperature

The expansion volume is the amount of water in the system which will expand during periods of maximum water temperature. In order to calculate this value, the total system volume (Vs) must first be calculated. This is done by totaling the volume of the various water holding components of the system, such as the boiler and the piping. The gallon per 100 linear foot capacities of PEX tubing and copper tubing are shown in the table below:

Zurn PEX Size	AVG. OD (inches)	AVG. ID (inches)	VOLUME (Gallons Per 100’)
3/8"	0.5	0.352	0.5056
1/2"	0.625	0.477	0.9284
5/8"	0.75	0.574	1.3443
3/4"	0.825	0.673	1.8481
1"	1.125	0.865	3.0529
TYPE M Copper			
Nom. Diameter	AVG. OD (inches)	AVG. ID (inches)	VOLUME (Gallons Per 10’)
1"	1.25"	1.055	0.4541
1.125"	1.375	1.291	0.68
1.5"	1.625	1.527	0.9514

Once the total system volume of water is calculated, the Net Expansion Factor (E) must be determined. Net Expansion Factors (E) for various fill temperatures and maximum system operating temperatures are shown in the table on page 13.

Fill Temp. (F)	Maximum System Operating Temperature (F)												
	80	90	100	110	120	130	140	150	160	170	180	190	200
40	0.003	0.004	0.006	0.008	0.01	0.012	0.015	0.018	0.021	0.024	0.028	0.031	0.035
50	0.003	0.004	0.006	0.008	0.01	0.012	0.015	0.018	0.021	0.024	0.028	0.031	0.035
60	0.002	0.004	0.005	0.007	0.01	0.012	0.015	0.017	0.02	0.024	0.027	0.031	0.035
70	0.001	0.003	0.004	0.006	0.009	0.011	0.014	0.016	0.019	0.023	0.026	0.03	0.034
80	-	0.001	0.003	0.005	0.007	0.01	0.012	0.015	0.018	0.022	0.025	0.029	0.033
90	-	-	0.002	0.004	0.006	0.008	0.011	0.013	0.017	0.02	0.024	0.027	0.031
	Net Expansion Factors for 100% Water (E)												

Additional data required for proper expansion tank determination include the fill pressure and the relief valve pressure. A pressure reducing valve installed within the system will regulate the fill pressure. Pressure reducing valves typically operate at 20 PSIG in these systems. Boiler relief valves usually are set for 30 PSIG. The value of the pressure relief valve setting is multiplied by 0.90, thus allowing for a 10% margin of safety in the system.

The following formula has been derived from Boyle's Law as it pertains to captive air tanks.

Tank Volume = Expansion Volume / Acceptance Factor

Tank Volume = (Vs x E) / [((Pr + Pa) – (Pf + Pa)) / (Pr + Pa)]

Where:

- Vs = Volume of water in the system (gallons)
- E = Net Expansion Factor of water (see Table 6.7)
- Pr = Pressure relief setting x 0.9 (PSIG)
- Pf = Fill pressure (PSIG)
- Pa = Atmospheric Pressure (14.7 PSI)

For example, a radiant panel heating system is to be installed using 3000' of 1/2" PEX tubing, 20' of 1" copper tubing and an 80-gallon boiler/storage tank. The boiler will operate at 140°F and the fill water temperature is 50°F. A pressure reducing valve with a setting of 20 PSIG will be used to fill the system and the relief valve has a rating of 30 PSIG. What size expansion tank should be used in the system?

First, the volume of water in the system must be calculated:

Volume of PEX tubing = 3000 x (0.9284 / 100) = 27.85 gallons

Volume of copper tubing = 20 x (0.4541 / 10) = 0.908 gallons

Volume of boiler = 80 gallons

Total = 108.80 gallons

Next, the Net Expansion Factor (E) must be found from Table 6.7. With a fill water temperature of 50°F and a maximum operating temperature of 140°F, the value for E is 0.0149. Plugging these values into the following equation yields:

Tank Volume = (108.8 x 0.0149) / [((27* + 14.7) – (20 + 14.7)) / (27* + 14.7)]* relief valve setting multiplied by 0.90

Tank Volume = 9.6 gallons (This is the minimum expansion tank size for this system.)

A comprehensive design checklist is provided in Appendix A.

CHAPTER 12: FLUID MANAGEMENT

Controlling Radiant Panel Heating Systems:

Radiant panel heating systems utilize relatively simple controls to provide the proper amount of energy to the space during fluctuations in heat demand. In order to be effective, the control system must be capable of recognizing these fluctuations in heat losses or gains and "sensing" a call for heat. Once the call for heat is initiated, the control must be capable of reacting with an appropriate increase or decrease in energy supplied to the circulating loops. The control must have authority over the devices that change the energy level of the circulating fluid. A good control system is judged by the precision with which it is capable of recognizing changes in heat demand, as well as the precision and appropriateness of the response.

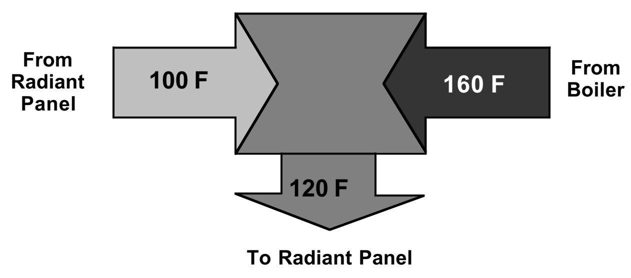
There are two stages of control that must be considered with radiant systems. The first stage of control is "Tempering." Tempering reduces excessive temperatures of the outlet water from a boiler to the proper maximum temperature needed to supply the radiant panels. The second stage is the "call for heat." In this stage, the heat plant output is varied to respond to changes in heating load.

Tempering: There is a maximum supply water temperature that each radiant panel will need in order to provide adequate heat energy under the most severe conditions of heat loss. That temperature is determined at the maximum heating load, taking into consideration the method of panel construction, resistance of panel materials, and flow rates.

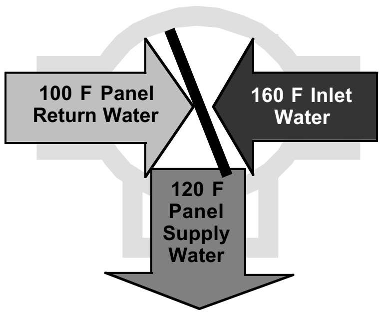
Types of Tempering Devices: There are many types of tempering devices available to the designer. Their operation may be described as manual, mechanical, electro-mechanical, electronic or pneumatic. They are divided into two general categories: non-reactive and reactive devices. Reactive tempering devices are capable of maintaining the desired outlet temperature regardless of fluctuations in water temperatures, whereas non-reactive tempering devices cannot.

If a radiant panel is supplied a water temperature that is much higher than required, proper control may be difficult. Several types of "tempering" devices are available that blend the high temperature boiler output with the cooler return water from the radiant panel to achieve the proper supply water temperature to the panel. These tempered supply water temperatures may be significantly lower than the minimum outlet temperatures of some heat plants.

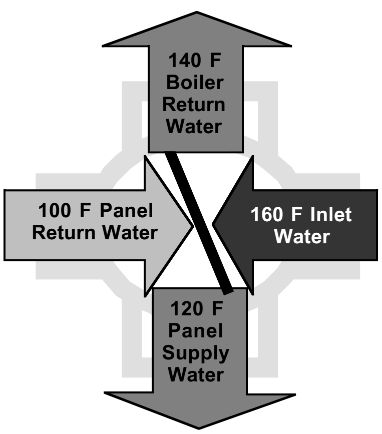
Non-Reactive Tempering Devices: Non-reactive tempering devices (valves) simply mix the boiler water with the radiant panel return water. With these devices, the outlet temperature to the radiant panel is fully dependent upon the temperature of the boiler outlet water and the return water as a function of the proportional rate of mixture. See the figure below. If the boiler outlet water temperature remains constant, the temperature of the water sent to the radiant panel will vary directly with the temperature of the return water. If the return water temperature is low, the supply water temperature will also be low. When the return water temperature is high, the supply water temperature will be high.



Non-Reactive Tempering Valve (Three-Way Mixing Valve)



Non-Reactive Tempering Valve (Four-Way Mixing Valve)



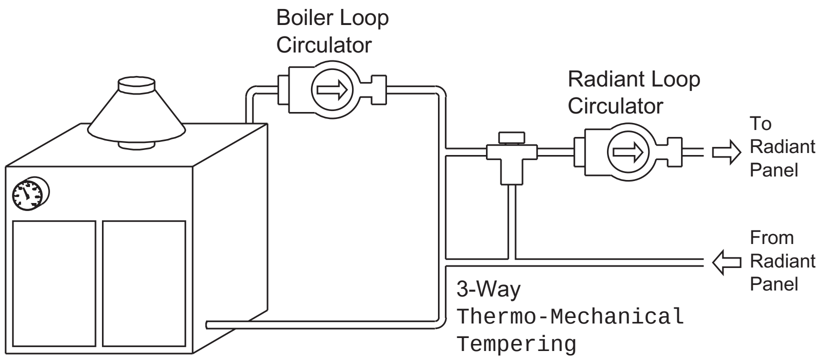
Note: Return water temperatures vary significantly during acceleration phases, thus the use of non-reactive tempering devices can result in very erratic control. Concrete slabs require significant amounts of energy to accelerate their very large mass. With non-reactive tempering (mixing) valves, the outlet temperature during acceleration will be its lowest because the return water from the cool slab will be low. When the slab overcomes acceleration and reaches the necessary operating temperature to meet the heating load, it will require far less energy and the return water will be at its highest. When the acceleration is complete, the supply water to the slab also reaches its highest temperature.

Three-Way Mixing Valve (Non-Reactive): The three-way, non-reactive mixing valve blends the supply water with return water from the radiant panel to produce supply water to the radiant panel that is somewhere between the two temperatures. A manually adjustable vane within the valve sets the proportion of the mix. Since this device does not react to changes in either temperature, the panel supply temperature can vary significantly.

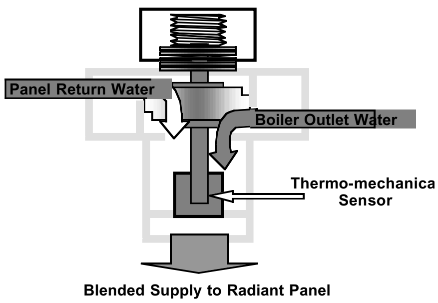
Four-Way Mixing Valve (Non-Reactive): The four-way, non-reactive mixing valve blends the supply water from the heat plant with return water from the radiant panel to provide a supply water temperature to the radiant panel that is somewhere between the two temperatures. A manually adjustable vane within the valve sets the proportion of the mix. The fourth port on this valve blends the boiler inlet water with the panel return water for return to the boiler. This additional function may increase the boiler inlet temperature, reducing the possibility of condensation at the boiler caused by low return water temperature. Since this device does not react to changes in boiler or return water temperature, the panel supply temperature and boiler return temperature can vary significantly.

Reactive Tempering Devices: Reactive tempering devices (valves) are capable of mixing the boiler water with the radiant panel return water to produce a specific supply water temperature to the radiant panel. The mixing action within these devices reacts to changes in boiler and radiant return water temperatures. These devices may be either electronic or thermo-mechanical. Since these devices react to changing temperatures, they are very effective in maintaining the proper supply water temperature to the radiant panel.

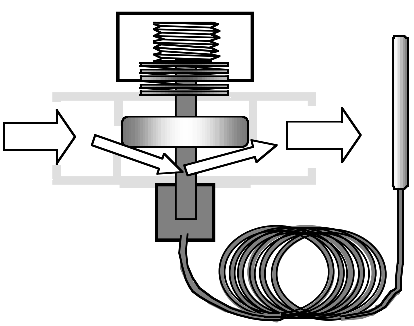
Electrically Operated Reactive Tempering Valves: Electrically operated reactive tempering valves are simply motorized versions of the non-reactive three-way and four-way mixing valves. Normally, a sensor is placed at the outlet of the valve and provides feedback to a controller, which opens and closes the vane in order to maintain the desired outlet temperature.



Thermo-Mechanically Operated Tempering Valves: Thermo-mechanically operated tempering valves use either an internal or external temperature sensor, which operates a proportioning valve to regulate the water temperature supplied to the radiant panel.



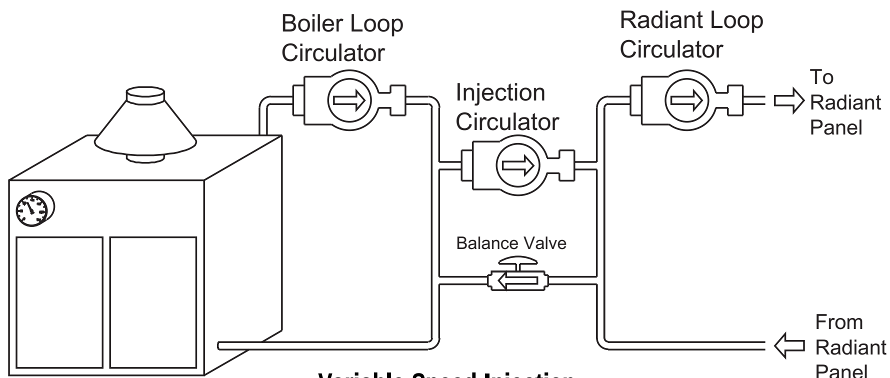
Self-Contained Thermo-Mechanical Tempering Valves: The self-contained thermo-mechanical tempering valve uses a sensor in the mix port of the valve. As the temperature rises in the mix port, the sensor heats up. Expansion within the sensor moves a shuttle valve in the main body of the unit, which proportionally changes the mixture between the hot and cold inlets. A hand wheel adjuster on the top of the unit sets the spring tension against the sensor, which limits the outlet temperature. Thermo-mechanical tempering valves are very effective and can maintain outlet temperatures within one or two degrees of the selected outlet temperature.



Thermo-Mechanical Two-Way Valve with Remote Sensor: This device uses a remote bulb sensor that is installed downstream of the valve location. As the temperature rises at the sensor, expansion within the sensor moves a shuttle valve in the main body of the unit, which proportionally changes the mixture between the hot and cold inlets. See the figure to the left. A hand wheel adjuster on the top of the unit sets the spring tension against the sensor, which limits the outlet temperature. Thermo-mechanical tempering valves are very effective and can maintain outlet temperatures within one or two degrees of the selected outlet temperature.

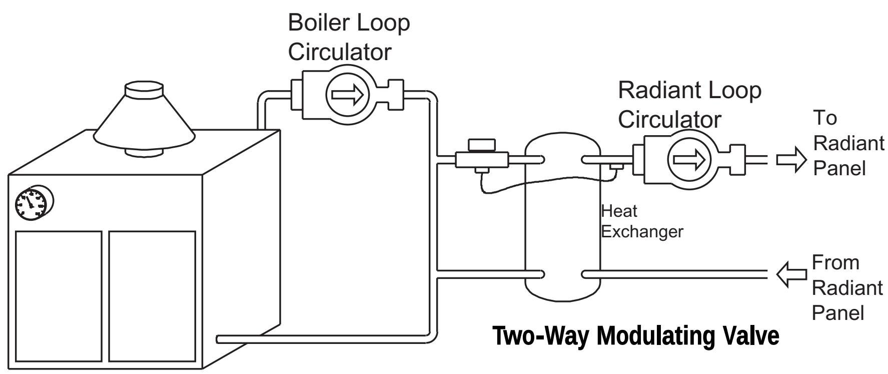
Reset Controls: Reset controls manipulate the temperature of the supply water by directly controlling the heat source output temperature. The temperature of the supply water is determined by monitoring the indoor and/or outdoor temperatures to anticipate changes in the heating load, and then providing a water supply temperature to meet requirements. Non-reactive tempering devices used in a system with a reset control can make effective control difficult during periods of acceleration.

Injection Pump Tempering Systems: Injection pump systems use variable speed circulators to inject water from a boiler circulating loop to the radiant panel circulating loop. See figure below. Electronic controls regulate the speed of the circulator to maintain the radiant panel circulating loop temperature. These systems require a bypass valve on the return line to balance the flow between the boiler circulating loop and the radiant panel.



Variable Speed Injection

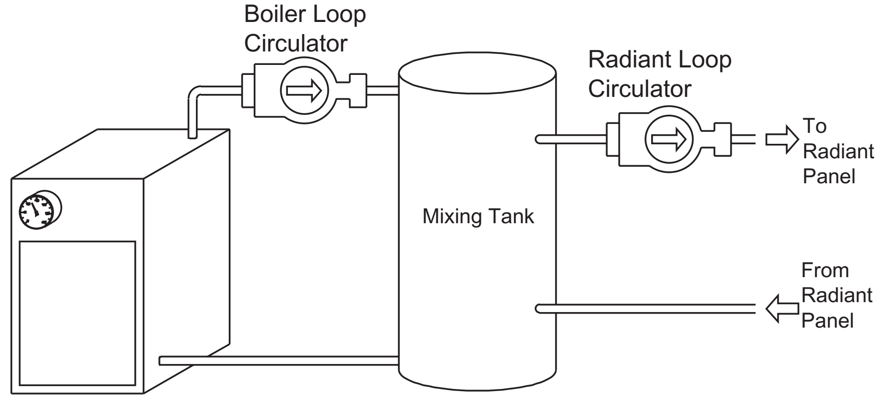
Heat Exchanger Tempering Systems: Water-to-water heat exchangers can be used as tempering devices in hydronic heating systems. The boiler loop is placed on the primary side of the heat exchanger and the radiant panel is placed on the secondary side. See figure below. Varying temperature or flow on the primary side will change the temperature of the radiant panel.



Two-Way Modulating Valve

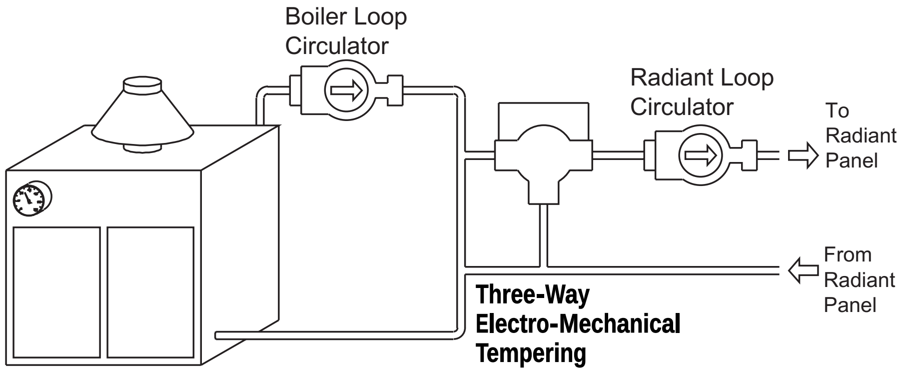
Side Arm Mixing Tanks: Side arm mixing tanks may be used in the tempering system in hydronic heating systems. See next figure on page 5. Controlling the storage temperature will regulate the outlet temperature to the radiant panel. The storage temperature within the mixing tank can be controlled by cycling the heat supply on and off in response to a temperature sensing aquastat placed either within or on the surface of the mixing tank.

Side arm mixing tanks are very useful where high efficiency, low-mass condensing type boilers or geothermal water-to-water heat exchangers are used. The relatively large amount of storage water eliminates short run times in systems with small zones, allowing these devices to operate more efficiently. Side arm mixing tanks can be open systems where the boiler water mixes directly with the radiant panel water, or they can be closed systems with internal heat exchangers within the tanks. When external heat exchangers are used, the boiler loop and the radiant loop must each have an expansion tank.



Side Arm
Mixing Tank

Electro-Mechanical Tempering Valve Systems: A manual three- or four-way mixing valve may be installed with an electro-mechanical operator that changes the mixture proportion between the hot and cold ports. See figure below. The electro-mechanical operator is controlled by an electronic controller that maintains the outlet temperature at the desired set point temperature or according to a reset schedule. Four-way mixing valves have an additional port that feeds blended water back into the boiler return water in order to reduce the adverse results of low return water temperature.



**Three-Way
Electro-Mechanical
Tempering**

Call for Heat: The heat demands of a room or structure continuously change. Heat demand varies with daily fluctuations of outdoor temperature, solar gains, and any variety of internal losses and gains. In order to compensate for these changes in heat demand, several control devices are available to react to a "call for heat" and cause the energy to be distributed appropriately.

Radiant Panel Zones: A "Zone" is an area within a building that is controlled from a single thermostat. One major advantage of radiant panel heating is the ability to separate a building into zones that can be controlled individually. This feature allows the system to distribute heat where and when it is needed to achieve superior comfort and efficiency. Typically, each room of a building behaves differently from the other rooms in terms of heat requirements. With zone heating, the system can recognize these differences and adjust the heat distribution to accommodate them.

Selecting Zones: There are several factors that influence the heat load of a room. In selecting which rooms should be grouped together as a zone, the designer should look at these factors and decide which rooms will have similar heat requirements.

Factors Influencing Zone Selection:

Floor Construction: Zone concrete floors separately from suspended wood floors. Concrete slabs on grade will require more acceleration time than suspended floors.

- *Floor Coverings:* When the resistance value of floor coverings among areas of the building vary significantly, they may require significantly different supply water temperatures and should be placed on separate zones. Also, consider individual zones for areas that are likely to experience changes in floor coverings over time.
- *Use Patterns:* Individual rooms can have internal gains and losses that require them to be zoned separately. Kitchens and baths produce internal heat gains during cooking or bathing. Industrial machinery in production facilities may produce additional heat, whereas the warehouse may be receiving cold shipments of products with doors open and require much more energy to maintain the desired room temperature.
- *Type of Radiant Panel:* Radiant ceilings operate at low supply water temperatures and accelerate quickly. Rooms heated exclusively by radiant ceiling panels should not be zoned with other rooms heated exclusively by radiant floor panels. Rooms utilizing a combination of floor and ceiling panels in the same room should be zoned together.
- *Individual Room Controls:* The single most important function of any heating system control is to place the proper amount of energy where it is needed and when it is needed. The amount of energy needed in a room or zone at any given time depends on factors such as heat loss through windows, walls, and ceilings, as well as heat gains from solar effects, the number of occupants, and other internal heat sources. Rarely will two rooms in a building behave exactly the same in terms of heat losses and gains, or require exactly the same amount of energy to operate at its highest efficiency. Individual room thermostat systems recognize variations in heat demand and activate individual zone valves in response to a call for heat.

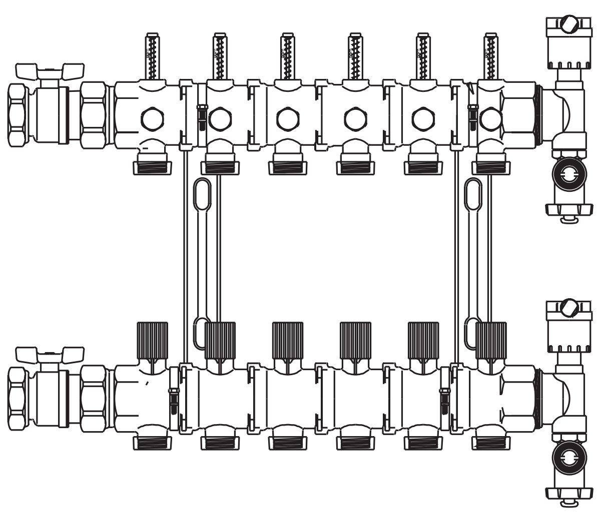
Adjusting Flow for Variations in Heat Load: Flow balancing valves can be adjusted to compensate for a certain amount of variation in heat requirements between zones. Adjusting the flow balancing valves in a manifold can limit the amount of flow to individual loops relative to other loops on the same manifold. This indirect control cannot react to changes in activity levels or other internal gains that may happen on a daily basis.

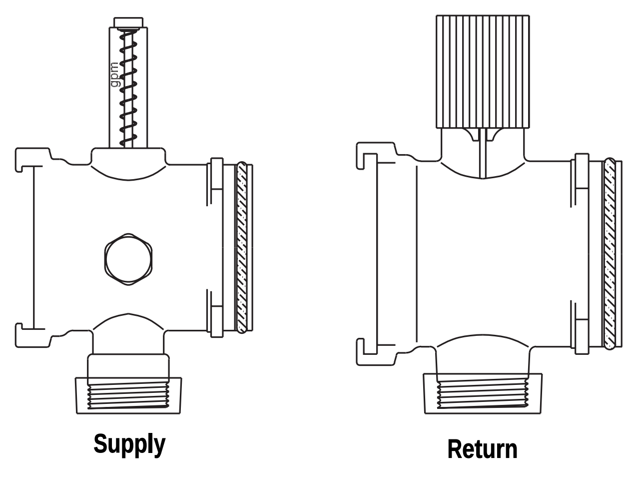
On/Off Zone Control Effects on Panel Surface Temperature: A zone control that uses a single supply water temperature and cycles the flow on and off in response to a call for heat will distribute more heat energy at the beginning of the tubing run than toward the end. Tubing routed along the high heat loss walls first will provide more heat energy to the area of greatest heat loss. As much as 65% of most room heating loads can exist within 10 feet of an outside wall. Initially, during start up when the run cycles are short or the panel is accelerating, only a small area of the panel surface transfers heat. When the heating load reaches its maximum requirements, the run cycles are longer and more of the panel surface transfers heat.

The Acceleration Factor: Massive radiant panels, such as concrete slabs, require a great deal of energy to accelerate in temperature to meet the heating load. The greatest amount of acceleration occurs during start up, when outdoor temperatures are relatively mild. On and off controls with sufficient supply water temperature for the coldest conditions also have sufficient temperature for acceleration during mild changes in heat demand. Reset controls that reduce supply water temperature during mild start up conditions also reduce the systems ability to accelerate.

Outdoor Reset Control vs. Indoor Temperature Sensing Controls: Indoor temperature sensing controls monitor actual conditions inside the building. If the room temperature is too cold, the indoor control will provide a call for heat. When the indoor control is satisfied, it will discontinue the call for heat. Outdoor reset controls respond to a theoretical relationship between outdoor temperature and heat requirements. The relationship is not always accurate. Where some rooms may demand heat because of low outdoor temperatures, others may not need any heat because of solar gains or high occupancy levels. Each room or zone behaves differently from the others. Outdoor reset controls are not a substitute for good indoor temperature sensing controls.

Brass Modular Manifold System: The Zurn brass modular manifold system consists of modular 1-1/4" cast brass modules. Manifolds are sold with a two loop starter kit that has threaded ends for attachment to supply and return lines. The interior loops are sold separately and snap lock together without any threads. End pieces are sold separately for either side, and could include air vents or shut off valves. These manifolds can be assembled up to 12 loops with a flow rate up to 15 gpm. See figure below.





Brass Supply Modules:
These individual loop modules normally include flow gauges and flow setters.

Brass Return Modules:
These individual loop modules normally include shut off valve caps. These may be removed and replaced with zone valve actuators to allow for the individual thermostatic control of each loop.

Fittings for Qickzone Manifold

Brass Modular Manifold Assembly and Fittings: Be sure to get a copy and follow the Qickzone Brass Manifold Installation Instructions. The following is an overview of considerations when installing these manifolds. The interior brass modules are assembled by rotating the two sections 90° apart, pushing them together, and then while still pushing, turn them back to the original upright alignment. That is all that is required. The manifolds use "Eurostyle fittings with an "O" ring that seats up inside the manifolds. To assemble, place the large nut over the end of the tubing with the threads toward the manifold, then put the split nut on between the the large nut and the end of the pipe. Next push the insert inside the pipe. Holding the tubing firmly, push the whole assembly up inside the connection for the loop until the insert seats, then pull up on the nut and tighten. As with all compression fittings, retighten once after the fitting has been in service with heated water for at least an hour.

Zone Control Module

Integrated Zone Control Modules: A Zurn Zone Control Module offers a convenient centralized way to control a hydronic heating system. These modules are self contained units that provide a 24VAC internal transformer, boiler control relay, thermostat connections, pump relay, and in the appropriate models, power for zone valves. These units allow for domestic water priority, and can be equipped with additional add in features such as injection mixing control with outdoor reset. The current offering includes 4 and 6 zone control models and 1, 4, and 6 pump control models. The zone control modules can be ganged together to create larger multi zone or control units. Similarly the pump control modules can be ganged together to create larger multi pump control units. Pump control modules are typically used where each radiant heating zone has a pump, often referred to as pump zoning. In this method when a thermostat calls for heat the pump to that zone is activated. This method has the advantage that if one pump fails heat is still delivered to all other zones. It does, however, require a good understanding of piping layout since flows caused by thermosiphoning can occur since there is not the positive shut off of water that a zone control system offers. "Drop loops" are usually plumbed into a pump control system to prevent this. Zone control modules typically control a centralized pump that provides flow for multiple zones. In this method when a thermostat calls for heat a zone valve opens and then the heating pump is activated. Zone control provides the advantage of positive shut off of flow to unheated loops, simplifying piping layout, but has the disadvantage that failure of the pump can mean multiple zones are without heat. The use of these systems seems to vary by regional practice. They both provide proven ways of controlling hydronic heating systems. Control with pumps is more common in the eastern United States and zone control with zone valves is more common in the western United States. See Zurn control literature for more information.

Standard Zurn Thermostat

Thermostats: Thermostats monitor the temperature and initiate a call for heat when needed. Zurn offers three thermostats specifically designed for radiant heating systems.

The standard model thermostat provides precise control over the heating system. Setback and programmable models offer multiple temperature settings to maximize efficiency and reduce energy consumption during periods of limited use or vacancy. A multi-zone system utilizes multiple thermostats to accurately control an area served by one or more manifolds. Multi-zone systems provide the ultimate in comfort and energy conservation, controlling several areas independently and directing energy to those areas of a building as needed.

Effective System Controls: There are several methods and devices to control a radiant heating system. The designer must determine the amount of control needed based on varying indoor design temperatures, heat losses, floor coverings, and overall system efficiencies. The best control system is the one that meets the objectives of the designer without adding unnecessary cost to the project.

Zurn provides many different controls.

Piping and Electric Schematics: Illustrations of several common system configurations are shown in Chapter 11 and in Appendix C.

A design checklist is provided in Appendix A to review the critical steps in designing a radiant heating system, as outlined in the chapters on system design.

CHAPTER 13: HEAT SOURCES

Additional System Components:

This section provides an overview of several different heat sources as an aid to installers and designers. Specific information about any heat source must be obtained from the manufacturer.

Heat Plants: The heat plant is a key component in any heating system. The most important factors in selecting a heat plant are:
1. Availability of fuel
2. Heating capacity
3. Corrosion (in non-barrier tubing systems)
4. Code compliance.

HEATING CAPACITY: The heating capacity of an appliance is its ability to maintain the required supply water temperature at the maximum heating load. The maximum heating load is determined by room-by-room heat loss analysis.

Note: Additional capacity may be necessary when the radiant panels consist of large amounts of concrete which must be accelerated to meet the heating load. This is often called the pick up requirement.

PRODUCT ACCEPTABILITY: The heat plant must meet the code requirements of the local administrative authority. Check with the local code officials prior to installing the heat plant to ensure that the installation meets code requirements.

Availability of Fuel Sources: The availability and cost of energy is a major consideration in the selection of a heat source. Fossil fuels generally cost less than electricity and can vary on a regional basis as to the most popular or most economical fuel.

Corrosion: In a non-barrier tubing system, all components in contact with the heating water should be constructed of non-corrodible materials, such as brass, stainless steel, copper, plastic or rubber. Corrodible components can also be isolated from the non-barrier tubing by using a heat exchanger. Using corrodible iron or steel in such systems requires a corrosion inhibitor management program that can be complex and costly to maintain.

Traditional Fossil Fuel Burning Boilers: Traditional fuel burning boilers are pressurized vessels that are capable of very high output temperatures. They burn fossil fuels and require adequate venting of flue gases. Fossil fuels include fuel oil, natural gas, propane, and any other petroleum based fuel that can be atomized into a burner. These appliances are available in two broad categories, condensing and non-condensing.

Fossil Fuel Condensing Boilers: Condensing fossil fuel boilers are designed to operate at a wide range of temperatures from 80°F to 200°F. These boilers are referred to as “condensing boilers” because low return water temperatures can cause condensation to occur on the fire side heat exchanger. For this reason, the exchangers are constructed of non-corrodible materials such as copper or stainless steel. Condensing boilers are very efficient, with an AFUE rating in the 80% to 90% range. Condensing boilers are capable of extracting more heat from the burned fuel while creating exhaust flue gases which are generally quite cool and can be conveyed through non-metallic flue pipe.

Flow rates through the heat exchangers are critical with condensing boilers. To connect a condensing boiler directly to a multi-zone radiant panel heating system, a single zone must be capable of handling the minimum flow requirements. A condensing boiler can also be connected to a multi-zone system by using a side arm tank with the radiant heating system drawing from the tank, and the boiler maintaining the proper flow and tank temperature.

Non-condensing boilers are available in a wide range of outputs and usually perform at average to high efficiencies, with AFUE ratings in the low to mid 80% ranges. They also produce high temperature flue gases, which require a metallic flue pipe.

Fossil Fuel Boilers: (Non-condensing): Non-condensing fossil fuel boilers are designed to operate at temperatures from 160°F to over 200°F. Non-condensing boilers require return water temperatures above 140°F because the fireside heat exchangers are constructed of iron or steel and are not designed to accept condensation. A tempering device may be required to ensure that the return water does not fall below 140°F. The heat exchangers are durable and capable of accepting most flow conditions. Some non-condensing boilers are constructed entirely of non-corrodible materials in the circulating loop and can be used with non-barrier pipe. Others have cast iron headers and require PEX Barrier tubing.

Electric Boilers: Electric boilers can be either condensing or non-condensing. These units are often used as spa or pool heaters and are designed to operate at a wide range of temperatures from 70°F to over 200°F. They are usually capable of being adjusted directly to the radiant panel supply water temperatures. Since electric boilers create heat energy through non-combustible methods, AFUE efficiency ratings do not really apply to them. Instead, their efficiency is measured in the cost of the electric power to the unit. Normally, electric energy is quite expensive and not suitable for large radiant panel projects. Since electric boilers do not require a flue or ventilation, they can be very attractive for some retrofit installations in inaccessible areas.

Note: Storage type water heaters have been used successfully in radiant panel heating systems for years. Their low cost, durability and simplicity of design has proven very effective in these applications. Some jurisdictions restrict or prohibit the use of domestic water heaters as space heating appliances. Consult local code authorities to determine the acceptability of using storage- type water heaters in space heating applications. Electric storage water heaters are very limited in their heat output. A 4500 watt element puts out 15,345 BTUH. Therefore they can only heat very small spaces. Gas, propane and oil water heaters have a much higher output.

Storage-Type Water Heaters: Storage-type water heaters heat water within a storage tank. They are normally used for domestic hot water applications. They can be either fossil fuel fired or electric. Storage-type water heaters are designed to operate at a wide range of temperatures, from ambient (70°F) to 180°F. Because of their wide range, they can be adjusted directly to radiant temperatures. Storage type water heaters operate at medium to high efficiency and are available in sizes up to 75,000 BTUH. Unless the water heater is specifically rated for a heating application, the AFUE efficiency rating does not apply to space heating applications. Water heaters are often used as stand alone heat appliances and are installed as a closed heating system in the same manner as a boiler. Some combination appliances have internal heat exchangers that provide heat for both the radiant system and domestic hot water while isolating the heating fluid from the potable water. Storage type water heaters are normally designed and operate with non-corrodible components contacting with water.

Note: Storage type water heaters have been used successfully in radiant panel heating systems for years. Their low cost, durability and simplicity of design has proven very effective in these applications. Some jurisdictions restrict or prohibit the use of domestic water heaters as space heating appliances. Consult local code authorities to determine acceptability of using of storage type water heaters in space heating applications.

Combination Space Heating and Potable Water Appliances: Combination space heating and potable water appliances use a single burner to provide both domestic hot water and radiant heating fluids. Some units are directly fired with two separate internal heat exchangers, while others are indirectly fired units, which circulate hot water from the heat plant of one application to a separate external heat exchanger. The combination space heating and potable water appliances are very efficient because they eliminate the standby losses of one additional heat plant.

Geothermal Heating Units: Geothermal heat extractors or "heat pumps" are specialized units that use fluids to extract heat from the earth, much the same as air conditioners extract heat from a building. The geothermal unit uses a refrigerant-to-water heat exchanger to heat the water used in the radiant panel heating systems. Since much of the heat energy generated by geothermal heat extractors comes from the earth, they can be very efficient units. Their efficiency is expressed as a coefficient of performance (C-O-P), which refers to the ratio of energy provided to energy consumed. Geothermal heat extractors perform best at low supply water temperatures such as those necessary for radiant panel heating systems. They normally cannot provide temperatures in excess of 120°F.

Active Solar Energy: Active solar collectors provide heat energy for storage and distribution and are capable of providing large amounts of low temperature heat. They operate most efficiently at the temperatures that are typical of radiant panel heating. There are several configurations of solar collectors: flat plate solar panels, concentrating solar panels, and some more exotic "evacuated tube" systems. Flat plate solar collectors are the most versatile units, producing heat energy from both direct and diffuse light. Concentrating solar collectors must have direct light. Concentrating solar panels provide less energy than flat plate collectors, but usually do so at a higher temperature. Active solar panel systems require positive supply water temperature controls to prevent damage to the system components. In order to prevent over-temperature stagnation, solar collector systems may require a tempering tank with sufficient volume to accept large amounts of energy at one time.

Water-to-Water Heat Exchangers: Water-to-water heat exchangers provide for the transfer of heat energy between two liquid mediums without mixing of the fluids. They may be used to isolate glycol treated loops from non treated loops, potable from non-potable water, corrodible materials from non-barrier tubing loops, or to reduce pressure in tall buildings. Heat exchangers are categorized by method of construction: plate, tube, bundle, tank or coil. Special double-walled heat exchangers offer additional protection against cross contamination potable water supplies by providing a leak path to the exterior of the heat exchanger in the event of a rupture.

Zurn supplies useful heat exchangers (plate type pictured).

Chapter 13

When using indirect water heaters with a heat exchange, consider the use of additional timers that limit domestic hot water production during hours when there will be no demand. This saves energy. In mild climates heating domestic water can consume as much energy as space heating.

NOTE: When using a storage tank type heat exchanger as an indirect fired water heater, check the local codes for any requirements regarding single or double-walled heat exchangers when connecting to potable water. supplies.

Sizing Heat Exchangers: Thermal transfer within heat exchangers can be very complex. The amount of energy transferred depends on the difference in temperature between the fluids, the resistance to heat transfer of the walls between them, and the movement (forced convection) of the fluids. Heat exchanger performance will change dramatically with any change in these conditions. It is important to size the heat exchanger to the exact and most critical conditions that will occur within the system

Plate Type Heat Exchangers: Plate type heat exchangers use a series of flat stamped metal plates that are either brazed together or bolted together into a frame. Spaces between the plates provide small passageways for the water to pass. The water paths of each fluid alternate between one another so that heat can pass through the plates from one fluid to the next. Small passages in plate type heat exchangers can become fouled with foreign materials and require a strainer device on the inlets to prevent clogging of the small passageways.

Shell and Tube Type Heat exchangers: Shell and tube type heat exchangers typically consist of metal tubing within an outer shell. Heat is transferred from the fluid circulating through the tubing to the fluid surrounding the tubing. Shell and tube type heat exchangers can be very large and designed to be serviced and cleaned in place.

Storage Tank Type Heat Exchangers: Storage tank type heat exchangers consist of a storage tank with an internal heat transfer coil. The internal loop is typically made of large diameter copper, stainless steel, aluminum, or a composite plastic and metal tubing. In radiant systems, these units can be used as a side arm tank for tempering or increasing the run cycle on appliances. They may also be used as indirectly fired water heaters.

CHAPTER 14: COMMERCIAL RADIANT HEATING

Design of Commercial Projects:

What is different between a commercial project and a residential radiant project? The answer is many things. The heat gain and loss patterns can be dramatically different. So can the need for make-up air. The crew sizes needed to reasonably install these systems, as well as the controls needed often differ. Pipe and pump sizing are often very different. What follows to the right is a list of many considerations unique to commercial radiant projects.

The design process of a commercial radiant panel heating project is similar to a residential project. Both begin with an accurate heat loss analysis, followed by determining the output of the radiant panel, tubing layout and flow analysis, and developing a control system. However commercial projects present some unusual heat losses, use patterns, and structural elements that must be considered during the design process.

Commercial Heat loss Analysis:

Heat Loss Analysis: A comprehensive room by room heat loss analysis provides the details needed to design an effective commercial radiant heating system. Commercial projects may have extremely high heating loads per square foot due to large display windows, doors, and high infiltration rates. There may also be areas or rooms in a commercial building that have very little heat loss, such as the interior rooms in a middle story room with heated areas on all sides. Very large buildings can sometimes compensate for all of the heat loss at the perimeter areas, leaving the internal spaces neutral in terms of heat loss. A room-by-room analysis will identify those areas that need special consideration, as well as those areas that do not need heat.

The human occupants give off heat and can be a significant factor in internal heat gains.

Internal Heat Losses and Gains: The designer should examine the commercial activity for potential heat losses or gains that will affect the need for more or less heating capacity.

Internal Gains and Losses from Manufacturing Use Patterns: A building used primarily for manufacturing may have some manufacturing processes that present significant internal heat gains or losses. If cooling towers or chillers are used to eliminate excess heat from the manufacturing process, the designer should examine the possibility of recovering that heat and redistributing it throughout the building during the heating season. Internal heat losses may occur as a result of receiving shipments of cold materials into the building. For example, a 40,000 pound shipment of iron at 40 degrees below room temperature would present an additional 192,000 BTU loss that the heating system will need to replace.

Remember 1 Watt = 3.41 BTUs

Internal Gains and Losses from Retail Sales Use Patterns: A building used primarily for retail sales may experience additional heat gains from the lighting and other electrical consumption, as well as from the occupants of the building. Unusual heat losses may occur as a result of repeated opening and closing of entrance doors or doors to shipping and receiving areas.

Internal Gains and Losses from Warehouse Use Patterns: A building used primarily for warehouse activities may experience internal heat gains from the lighting and from the operation of material handling equipment. Internal heat losses may occur as a result of receiving shipments of cold materials into the building. Other unusual losses may occur as a result of repeated opening and closing of doors in shipping and receiving areas. Warehouse activity may also result in materials impeding the transfer of energy from the surface of a radiant floor to the room because of the storage of materials on the floor surface.

Internal Gains and Losses from Institutional Use Patterns: A building used for institutional activities such as schools, hospitals, and churches, will experience internal heat gains from the occupants. The amount of heat contributed will depend on the number of occupants and their activity level. Additional heat gains will come from lighting, computers, and other equipment. Additional losses may occur as a result of the additional ventilation required when occupancy is high, or from running ventilation equipment during periods of low occupancy.

Internal Gains and Losses from Restaurant and Entertainment Use Patterns: A building used for restaurant or entertainment activities may experience internal heat gains from the food preparation equipment and from the occupants. Food preparation areas are usually very well ventilated and are isolated from other areas of the building. Additional heat gains may come from lighting and other food service equipment. Additional losses may occur as a result of ventilation equipment that is running at high levels during periods of time when the occupancy or food preparation activity is low.

Internal Gains and Losses from Commercial Residential Use Patterns: If the building is primarily used as a hotel, condominium, or apartment, internal heat gains may come from pools, spas, food preparation equipment, laundry equipment, and elevators. Lobby entrances and underground garages may cause additional heat losses.

Air changes can be very project specific. For example, an automotive service facility may have a paint spray booth area that moves a great deal of air. This large amount of make-up air often requires that this air is preheated with duct heaters.

Air Change Requirements for Commercial Projects: The air change requirements in commercial projects can be very high compared to residential projects. Commercial buildings have specific ventilation requirements based on the occupancy level and the various activities they contain. If the heat losses due to air changes are extreme, an-air to-air heat exchanger or heated make-up air may be required to compensate for the heat loss.

Air change Requirements for Manufacturing Facilities: Manufacturing facilities may require additional air changes to remove by products from the manufacturing process, painting, or chemical treatments. In manufacturing facilities with substantial air changes, the best method of replacing heat energy lost to ventilation is with heated make-up air.

Air Change Requirements for Retail Facilities: Retail sales facilities experience additional air changes through the opening and closing of doors as the occupants and clients enter and exit.

Air Change Requirements for Warehouse Facilities: Warehouse facilities experience air changes from opening and closing of loading dock doors for shipping and receiving. There may be additional air changes as a result of ventilation equipment used to remove odors from materials that are kept in the facility or to ventilate exhaust from material handling equipment.

Air Change Requirements for Institutional Facilities: Air change requirements for institutional facilities are normally based on the occupancy level. The ventilation requirement is to ensure that adequate equipment is installed in the building to replace stale air. When the occupancy is very low, such as when schools are not in session, the ventilation equipment normally operates at a reduced capacity.

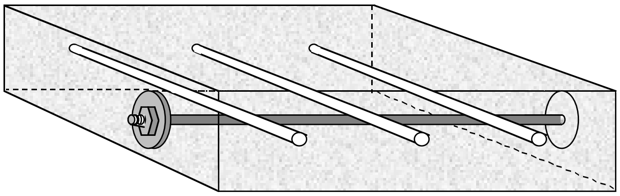
Ventilation Requirements for Food and Entertainment Facilities: The ventilation requirements for food and entertainment facilities are based on the occupancy level, the size of food preparation equipment, and whether or not smoking is permitted in the building. Changes in the smoking laws of many code jurisdictions have had a significant effect on the air change requirements of many facilities.

Ventilation Requirements for Commercial Residence Facilities: The ventilation requirements for commercial residence facilities are normally provided through the use of individual unit ventilation equipment. There may be an additional requirement for common areas such as pools, gymnasiums and other community areas with potentially high occupancy rates.

Structural Considerations for Commercial Facilities: Because of their size, commercial buildings must use different construction techniques than single family residential buildings. They must support much greater weight and are made primarily of steel and concrete. The installation of tubing within the structure requires approval by the structural engineer or other competent authorities capable of assessing the structural effects of such placement.

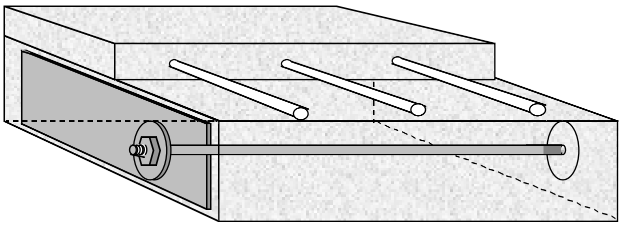
Commercial Installations in Concrete Slabs on Grade: Normally with commercial projects where the concrete floor is poured on grade, radiant tubing can be installed within the concrete floor in the same manner as residential buildings. Commercial slabs may need to support heavy loads, such as fork lifts, so the density and type of under slab insulation, reinforcing rods and placement of tubing may need to be adjusted accordingly.

Commercial Installations on Structurally Reinforced Concrete Slabs: Structurally reinforced concrete slabs are intended to take very heavy loads. In order to do so, they are placed under a constant compressive load by the use of tension rods. These rods are installed within the concrete slab at precise intervals. The ends of the rods are threaded and fitted with large nuts. After the concrete cures, the rods are "post-tensioned" by tightening the nuts. Concrete is capable of holding very high compressive loads, but comparably small tensile loads. By keeping the concrete under compressive load, its strength is preserved even when subjected to high rolling loads. Tubing placed within a post-tensioned slab can severely degrade the structural capabilities especially when running parallel to the tension rods.



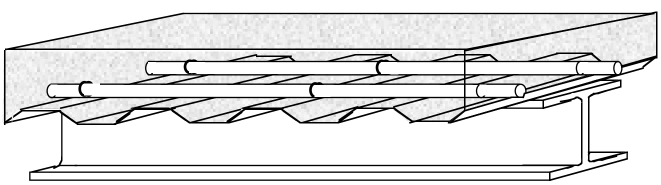
Post Tensioned Slab

Therefore, it is critical that the designer obtain approval from the structural engineer before installing the tubing. The tubing can be also installed in a secondary pour (or topping slab) over the structurally reinforced slab. See illustration below.



Post Tensioned Slab With Tubing In Topping

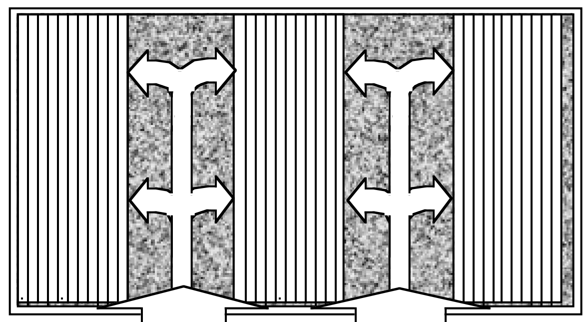
Commercial Installations of Concrete Slabs Poured in a Metal Pan: Many commercial buildings use concrete floors that are poured over a metal sheeting that is supported by various post and beams in the superstructure. Most pans are made of a corrugated sheet metal product that gives varying depths of concrete. The radiant tubing must have a minimum concrete cover as prescribed in the codes for embedded tubing, or 3/4 inch, whichever is greater. The tubing may be fastened to the pan with pipe clamps, ties, or pipe tracking that can be fastened to the metal pan with self tapping sheet metal screws.



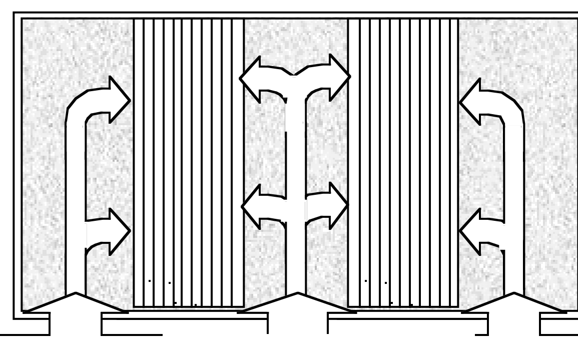
Suspended Concrete Slab Poured On Metal Pan

Joints in Concrete Construction: There are a number of different joints used in concrete construction. They are commonly referred to as construction joints, control joints, and expansion joints, depending on their purpose. The designer must understand the purpose of the joint, their placement within the project, and how they affect the placement of tubing. Tubing layouts should be planned in a way that minimizes the crossing of joints.

Concrete Construction Joints: Construction joints are those that are placed within the slab to end one section or pour of concrete and begin another. Depending on the size of the crew, and their type of equipment, the manageable size of a pour can vary significantly. In very large projects, the construction joints can also be placed to provide convenient phases of installing the radiant tubing. To avoid moving heavy equipment over unprotected radiant tubing, a large slab can be segmented into separate sections with avenues between them that can provide access to the adjacent slabs. Tubing can be alternately installed in the separate sections, as shown below:



In very large projects the tubing can be installed in alternating sections so that the spaces between the sections can serve as an access to placing concrete.



Once the concrete has been placed in the first set of sections, the tubing can be installed in the other section. The new concrete becomes the access for placing remaining concrete.

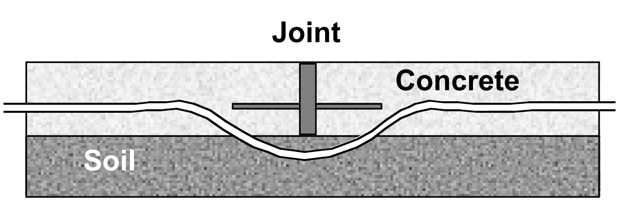
Concrete Control Joints: As concrete begins to cure it experiences slight shrinkage. The shrinkage, in turn, produces tensile stress in the concrete. Over large concrete slabs, the tensile stress can produce shrinkage cracks. Control joints are placed in the concrete to induce the cracking in a controlled manner. Concrete control joints can either be troweled into the wet concrete during the pour, or cut into the concrete after it has set.

Normally the depth of a concrete control joint is less than one inch. The radiant panel contractor should know the location and depth of any control joint and provide adequate clearance between the embedded pipe and any such joint.

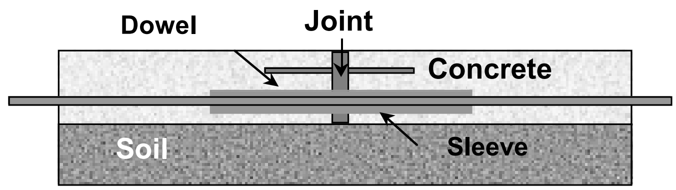
Concrete Expansion Joints: When concrete is heated, it expands at a rate of approximately 0.08 inches for every 100 linear feet that is raised 10°F. In order to accommodate this thermal expansion, concrete expansion joints are placed within the slab or around the perimeter. These joints are made of a material that will compress as the concrete expands against it and rebound to fill the joint as the concrete cools and contracts to its original size.

Traversing Concrete Joints with Radiant Tubing: It is important to coordinate the tubing layout with the schedule of concrete joints and minimize such crossings by designing a tubing layout pattern that crosses only where necessary. There are several methods of traversing a concrete joint. The main concern is to traverse the joint and avoid any damage to the tubing from tools that cut the joint, or from stresses due to movement of the concrete.

Crossing a Joint by Running Tubing Under the Joint: When crossing an expansion joint, the tubing can be buried in the subsoil area. This is probably the safest method of crossing a joint because it completely avoids any cutting, shearing, or tensile stresses.



Crossing a Joint by Running Tubing Through the Joint: When running the tubing through the joint, it is important to protect the tubing from any damage due to shearing if the slabs move independently of one another. Place shear rods between the slabs to restrict movement up and down. Then place the tubing in a sleeve to allow movement of the slabs without stressing the tubing Secure the sleeve to prevent it from floating up in the slab during the pour.



Radiant Tubing in Fire-Rated Structures: Many of the walls, ceilings, and floors in commercial buildings must meet fire-rating standards. Specific tests have been developed and standards set for various structures. Any time a penetration is made through these structures, the penetration must also be tested to meet minimum standards. A number of firestop penetration products have been developed for use with plastic pipe. Typically, these products are made of non-flammable intumescent materials. The designer should consult with the firestop contractor to insure that the penetrations will meet the minimum requirements for the rated structure.

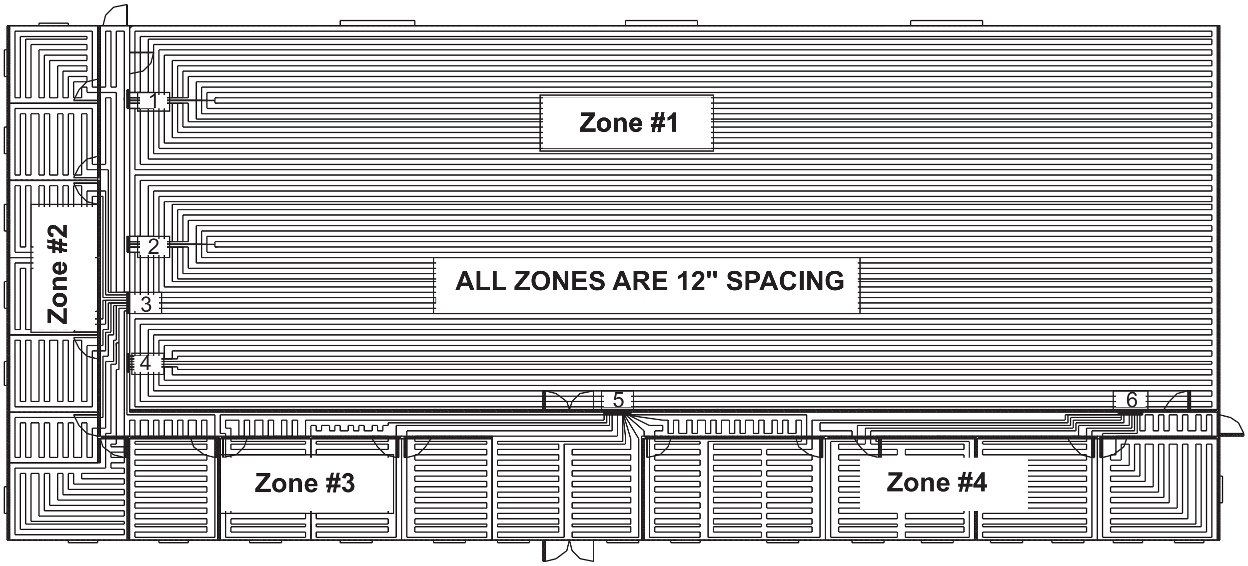
Control of Radiant Panels in Commercial Buildings: Many of the system controls that are used in residential projects can also be used in commercial projects. Controlling a radiant system in a commercial building may also require integration with a ventilation system or computerized energy management equipment. Zurn offers a wide variety of products specifically designed to meet the control requirements of a commercial installation.

Tubing Layout in Commercial Buildings: The tubing layout plan for a commercial building must meet the same general requirements of residential buildings, except that large areas may only need to be heated along the perimeter in order to meet the heating load. This is fortunate because many large commercial buildings have restrictions as to where the tubing can be installed because of heavy equipment, footings, or stressed concrete areas.

The following commercial examples address a 20,000 square foot building's heating requirements with radiant floor heating systems designed for three different uses for the same size building. Each scenario provides a different level of comfort, control and energy management. They demonstrate the flexibility that radiant panel systems offer the designer and owner to achieve a cost-effective design. It is important to note that all three designs meet the total heat loss requirement of 403,582 BTUH. A list of the key system components, project specifications, and a cost analysis is provided for each example.

The base commercial building is a 100' by 200' rectangle with an area of 20,000 square feet. For the purpose of heat loss analysis, the building is located in the upper Midwest. Referencing the 2001 ASHRAE Fundamentals Handbook, the outdoor design temperature is found to be –10°F. The indoor design temperature will be 70°F, yielding a Delta T of 80°F. The building has a 4" concrete slab that is covered by a low level loop carpet with an integral foam backing in the office areas. The shop floor and warehouse areas have bare concrete floors. 1" insulation with an R-value of 5 is used for the foundation edge and the first 4 feet of the under slab perimeter. The walls and ceilings have 6" fiberglass insulation with an R-value of 24. The ceilings are 8 feet high in the offices and 20 feet high in the shop and warehouse areas. Each window is 4 feet by 3 feet and the insulated garage doors are each 12-feet by 12-feet. A thorough heat loss analysis yields a total heat loss of 403,582 BTUH (254,119 BTUH upward and 149,463 BTUH downward). All three designs are based upon using 5/8" PEX barrier tubing embedded in the slab.

Example 1-Full Coverage



In this example, the building is used as an office building with a large open shop area with 3 large overhead garage doors. The shop area is designed to serve as a vehicle maintenance area that is continuously occupied and is subject to frequent overhead door openings and closings. Each perimeter office has its own loop (or loops) which allow for flexibility in zoning and flow balancing. The building is divided into 4 separate zones with the tubing laid out on 12" centers across the entire building. Below is a cost analysis for this tubing layout using 2002 Zurn list prices.

Material List

Total of PEX tubing:	20,000 feet
QickZone Mod. Man. Kits(2 port):	6
QickZone Air Vent Ass, Kit1 (with thermometers)	6
QickZone Central Supply/Return Module Kits:	57 pairs
QickZone Manifold Pex Connectors	57
Conduit Elbows:	114
Thermostats:	4
Zone Valves:	6
Zone Valve Motors:	6
Other Materials	

Total List Price of Zurn Materials (2002): $25,804.17

Project Specifications

Supply Water temperatures:

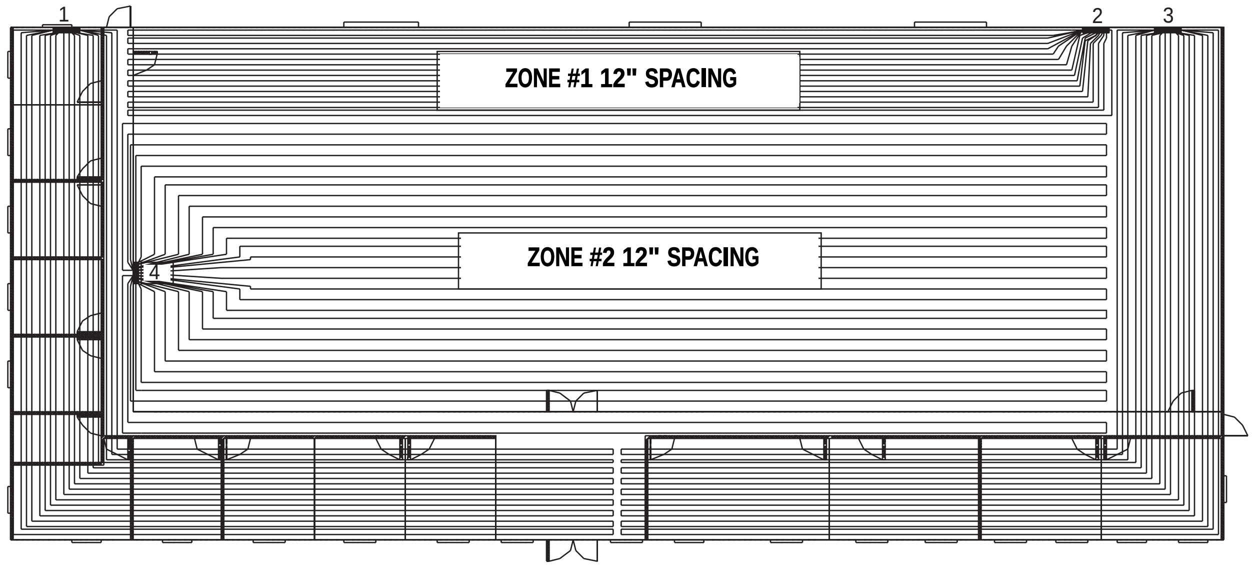
Manifolds 1, 2, 4:	92°F
Manifolds 3, 5, 6:	107°F
Tube spacing:	12"
Office loop lengths:	231' to 453' @ 0.63 GPM
Shop loop lengths:	331' to 381' @ 0.76 GPM
Number of zones:	4
No. of manifold locations:	6
Total GPM:	41

Pump requirements:
#1 (shop): 28 GPM @ 12 ft-H2O
#2 (offices): 13 GPM @ 11 ft-H2O

Or $1.29 per sq. ft.

These prices are only for the Zurn materials and do not include heat sources, circulating pumps, pipe or fittings between heat source and manifolds, or cost of installation.

Example 2 Mixed Coverage



In this example the building combines office space and manufacturing processes in one facility. The tubing layout offers adequate temperature control, and a reduced capital cost; however, there is no individual flow control in each office. The perimeter is covered by a 12-inch on center layout while the interior is based upon a wider spacing of 24 inches. This design satisfies the total heat loss of 403,582 BTUH for the entire building with two separate heating zones. One zone serves the outside perimeter and office areas, the other serves the interior area used for manufacturing. Below is a cost analysis for this tubing layout using 2002 Zurn list prices.

Material List

Length of PEX tubing:	15,000 feet
QickZone Mod. Man. Kits(2 port)::	4
QickZone Air Vent Ass, Kit1 (with thermometers):	4
QickZone Central Supply/Return Module Kits:	34
QickZone Manifold Pex Connectors:	42
Conduit Elbows:	84
Thermostats:	2
Zone Valves:	4
Zone Valve Motors:	4
Other Materials	

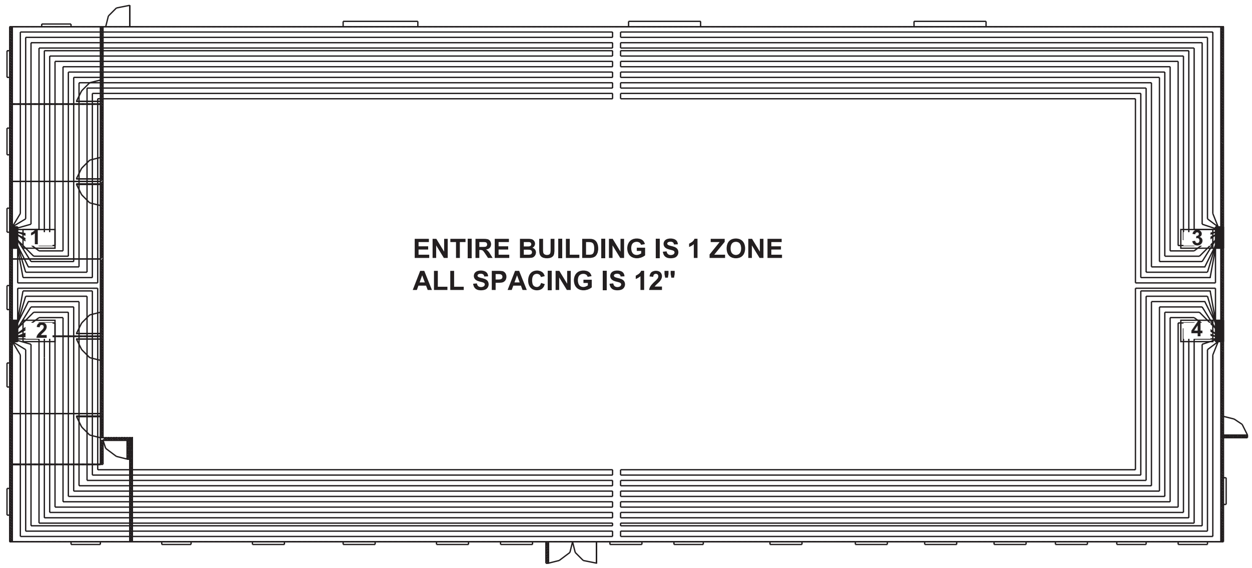
Project Specifications

Supply Water temperatures:	
Manifolds 1, 3, 4:	107°F
Manifold 2:	92°F
Tube spacing:	12" & 24"
Office loop lengths:	341’ to 406’ @ 0.78 GPM
Shop loop lengths:	322’ to 383’ @ 1.45 GPM
Number of zones:	2
No. of manifold locations:	4
Total GPM:	42
Pump requirements:	
#1 (shop):	21 GPM @ 20 ft-H2O
#2 (offices):	21 GPM @ 12 ft-H2O

Total List Price of Zurn Materials: (2002 $19,106.52 Or $1.00 per sq. ft.

These prices are only for the Zurn materials and do not include heat sources, circulating pumps, pipe or fittings between heat source and manifolds, or cost of installation.

Example 3 Perimeter Coverage



In this example, office space is limited to one row of offices along the west wall with the rest of the building being used for storage and essentially unoccupied. In this situation, the storage area requires only perimeter heating in order to satisfy the 70°F indoor design temperature. The carpeting has been removed where the south offices were previously. Although the floor coverings have changed, the decrease in heat loss has been offset by an increase in heat loss due to the higher ceiling height in the new storage area. The entire heat loss for the building remains essentially unchanged at 403,582 BTUH, although the upward heat loss has increased to 280,117 BTUH and the downward heat loss has decreased to 123,465 BTUH. The maximum floor surface temperature for the office area is 87°F.

Using a water supply temperature of 135°F, the maximum upward heat output from the radiant floor in the offices and the storage area is 20 BTUH/ft2 and 44 BTUH/ft2, respectively. First, calculate the amount of heat energy which will be generated by the radiant floor in the offices by multiplying the office floor surface area (about 1,600 square ft) by the maximum upward heat output of the radiant floor. The amount of upward heat energy provided by the radiant floor under the office is 32,000 BTUH (20 BTUH/ft2 x 1600 ft2 = 32,000 BTUH).

The radiant floors in the storage area must supply the remainder of the heat in the building. To calculate the remaining required heat energy, subtract the upward heat supplied by the office floors from the upward heat loss for the entire building (280,117 BTUH – 32,000 BTUH = 248,117 BTUH). The minimum coverage necessary in the storage area can be calculated by dividing the remaining heat loss by the output of the radiant panel (248,117 BTUH / 44 BTUH/ft2 = 5,639 square feet). The storage area of the building will be heated by tubing placed on 12" centers and covering 5,639 square feet of floor surface around the perimeter of the building. This design reduces the number of loops, manifolds, zone valves, and tubing, etc. while meeting the heating requirements of the building. Zoning has been simplified to one single zone for the entire building. Below is a cost analysis for this tubing using 2002 Zurn list prices.

Chapter 14

Material List

Total of PEX tubing:	8,000 feet
QickZone Mod. Man. Kits(2 port):	4
QickZone Air Vent Ass, Kit1 (with thermometers):	4
QickZone Central Supply/Return Module Kits:	20
QickZone Manifold Pex Connectors:	28
Conduit Elbows:	56
Thermostats:	1
Zone Valves:	4
Zone Valve Motors:	4
Other Materials	

Project Specifications

Supply Water temperatures:

Manifolds 1, 2, 3, 4:	135°F
Tube spacing:	12"
Loop lengths:	269’ to 272’ @ 1.7 GPM
Number of zones:	1
No. of manifold locations:	4
Total GPM:	48

Pump requirements:

#1: 48 GPM @ 21 ft-H_2O

Total List Price of Zurn Materials (2002): $11,045.93 Or $0.55 per sq. ft.per sq. ft.

These prices are only for the Zurn materials and do not include heat sources, circulating pumps, pipe or fittings between heat source and manifolds, or cost of installation.

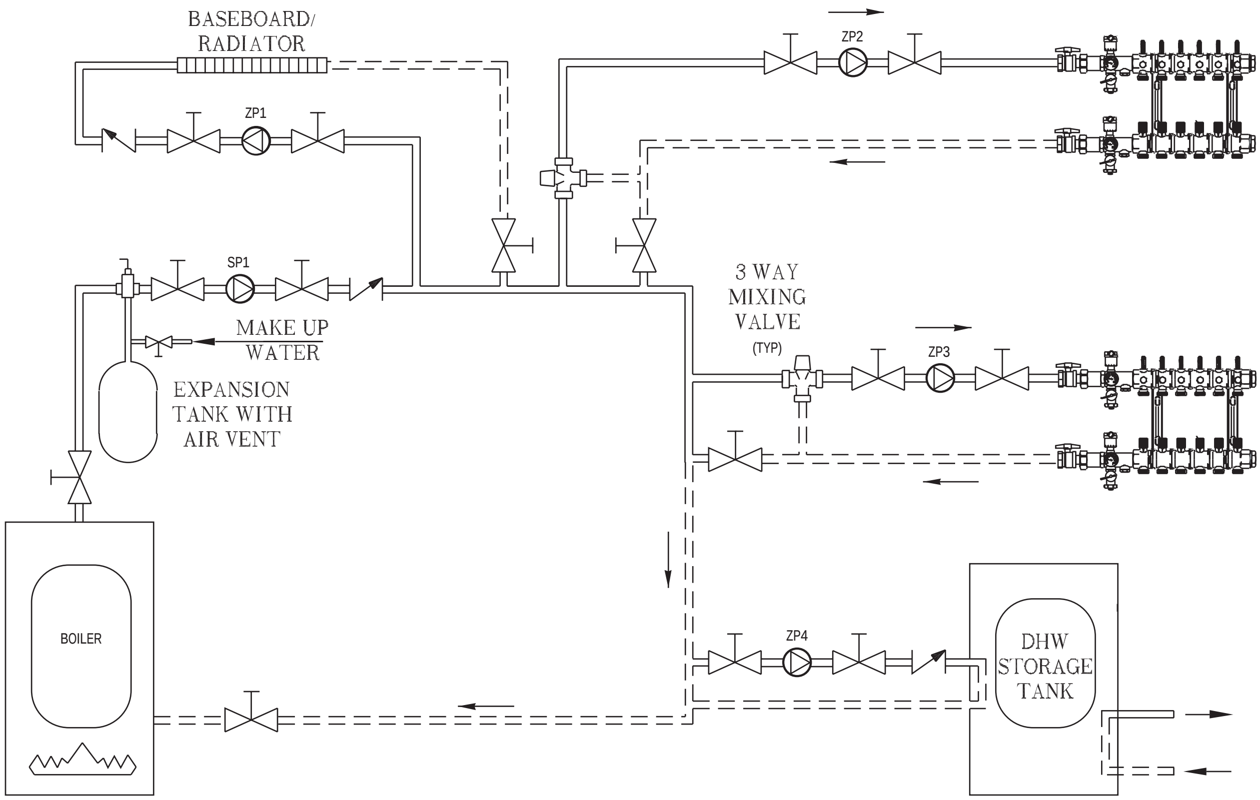
CHAPTER 15: APPLICATIONS AND WIRING

Piping and Electrical Schematics

PIPING SCHEMATIC 1

Closed Loop, Non-Condensing Boiler System

Two Temperature Radiant, Two Manifolds plus Baseboard and Domestic Hot Water



Notes:

1. The piping schematic is conceptual. Some components have been removed for clarity. Layout should be approved by a designer prior to installation.
2. Additional controls and equipment may be necessary to meet specific heat loads and other jobsite conditions.
3. Boiler and other system components must be installed to the manufacturers' instructions. All system components must be installed to all local codes. Isolation valves are recommended on all system components to allow easy service.
4. System should be installed by a licensed professional.

Where Used

Radiant Panel where the supply temperature is different for each manifold, a baseboard/radiator is used and domestic hot water is also used.

Description

The piping layout shows a non-condensing boiler supplying water to a domestic hot water (DHW) storage tank, two radiant manifolds with different supply temperatures, and a baseboard/radiator. A separate zone pump (ZP4) and a check valve are required on the supply side of the DHW loop. A 3-way thermostatic mixing valve and zone pump (ZP4 and ZP3) are required on each radiant manifold loop. The mixing valve will mix the hot boiler supply water with the cool radiant return water to give the required radiant panel supply water temperature. Zone pump (ZP1) is used to control the supply water for the baseboard/ radiator loop. Boiler manufacturers' installation instructions should be followed for boiler piping and return water limits.

System Equipment

Ball Valves: Ball valves are used as isolation valves. Ball valves are recommended on the supply and return lines of the non-condensing boiler, DHW tank and manifolds to ease service. It is also recommended that isolation valves be installed on all zone pumps or install flanged zone pumps to allow easy service.

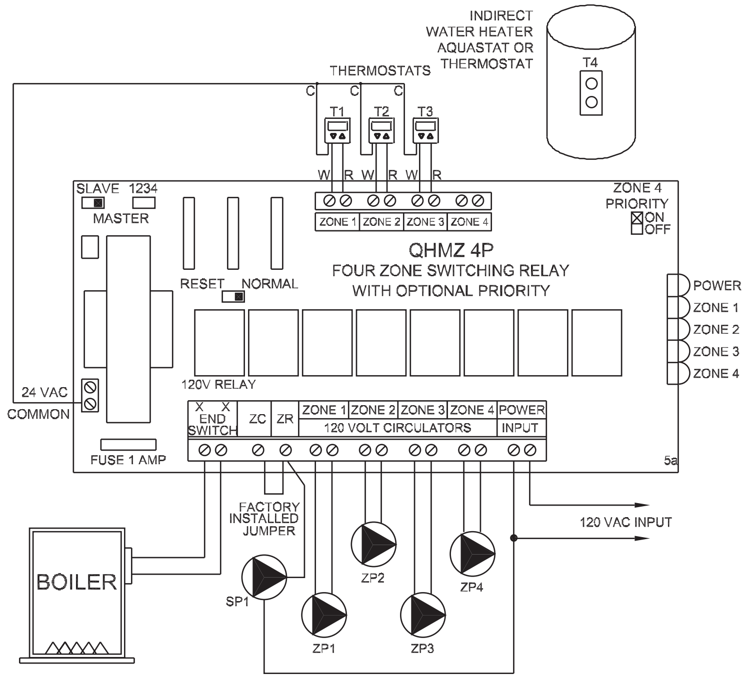
Bypass Loop: An additional bypass loop is not needed on the boiler in this application. The primary loop will also act as the bypass loop for the boiler.

Zone Pumps: A zone pump is required for each radiant manifold to circulate the water through the radiant system. The radiant zone pumps (ZP2 and ZP3) must be installed on the mixed side of the thermostatic mixing valve. Without the zone pump on the mixed side, when the mixing valve closes the boiler supply side of the valve, circulation of the radiant system would stop. Individual zone pumps are also used to circulate the water through the radiator/baseboard loop and the DHW loop.

DETAILED ELECTRICAL SCHEMATIC 1

Closed Loop, Non-Condensing Boiler System

Two Temperature Radiant, Two Manifolds plus Baseboard and Domestic Hot Water



Operation: When any thermostat calls for heat, the appropriate circulator (ZP1 - ZP4) is energized and the isolated end switch (X and X) will start the boiler.

Priority Operation: When zone 4 is switched to the priority setting and is actuated, all other zones will stop operation until zone 4 is satisfied. When zone 4 is not switched to priority, all zones will operate independently.

Mode Operation: With the mode switch set to NORMAL, the end switch relay will be energized if any zone is in operation.

Jumper Placement: The jumper should be placed between terminals ZC and ZR. Connect the isolated end switch to the aquastat control on the boiler.

Power Input: Connect 120VAC power input to terminals N and H. Neutral wire to terminal N. Hot wire to terminal H.

Expansion Connections: If future expansion is necessary, set the expansion switch to MASTER on the switching relay that has the designated priority zone. Set all other daisy chained controls to SLAVE. Connect thermostat wire (18-22 gauge) between terminals 1, 2, 3, 4 on the master control to the corresponding 1, 2, 3, 4 on the SLAVE control(s). Controls may be daisy chained up to 20 zones using any combination of zone controls (QHMZ4A or QHMZ6A) or pump relay controls (QHMZ4P or QHMZ6P).

External Diagnostics: Externally visible lights show full functionality of the switching relay. The green light should always be on, indicating that power is connected. When a thermostat calls for heat, both the appropriate circulator and red indicating light are energized.

Warning: Wiring connections must be made in accordance with all applicable electrical codes. Use copper wire only. Failure to follow this instruction can result in personal injury or death and/or property damage. 10-18 gauge wire is recommended for 120VAC connections with 9 in.-lbs. max. torque, 12-22 gauge wire for thermostat connections with 9 in.-lbs. max. torque, and 12-22 gauge wire for 24VAC source with 5 in.-lbs. max. torque.

Switch Settings: Master/Slave: Master
Reset/Normal: Normal
Priority Zone: Off

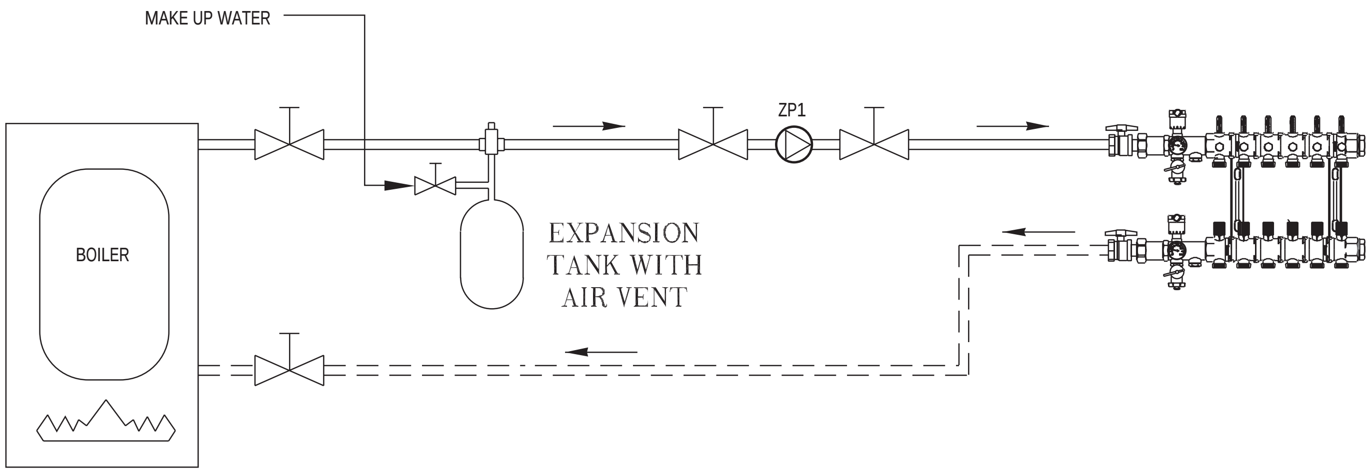
Notes:

1. Additional controls and equipment may be necessary to meet specific heat loads and other jobsite conditions.
2. Boiler and other system components must be installed to the manufacturers' instructions and to all local codes.
3. All electrical components should be installed by a licensed professional.

PIPING SCHEMATIC 2

Closed Loop, Condensing Boiler System

Single Temperature Radiant Panel



Where Used

Radiant Panel or Snow Melt where the supply water temperature is constant.

Description

The piping layout shows a condensing boiler supplying water to a single radiant floor or snow melt system. Condensing boilers are designed to operate on low return water temperatures. This allows the system to operate without the use of a mixing valve or bypass loop. The boiler limit is set to supply the required water temperature for the radiant panel. Boiler manufacturers' installation instructions should be followed for boiler piping and return water limits.

System Equipment

Ball Valves: Ball valves are used as isolation valves. Ball valves are recommended on the supply and return lines of the boiler and manifolds to ease service. It is also recommended that isolation valves be installed on all zone pumps or install flanged zone pumps to allow easy service.

Bypass Loop: A bypass loop is not used with a condensing boiler.

Zone Pump: Most boilers are equipped with an internal circulator pump. This pump may not meet the flow requirements needed to circulate water through the radiant panel. An additional zone pump (ZP1) is then required to circulate the water through the radiant system.

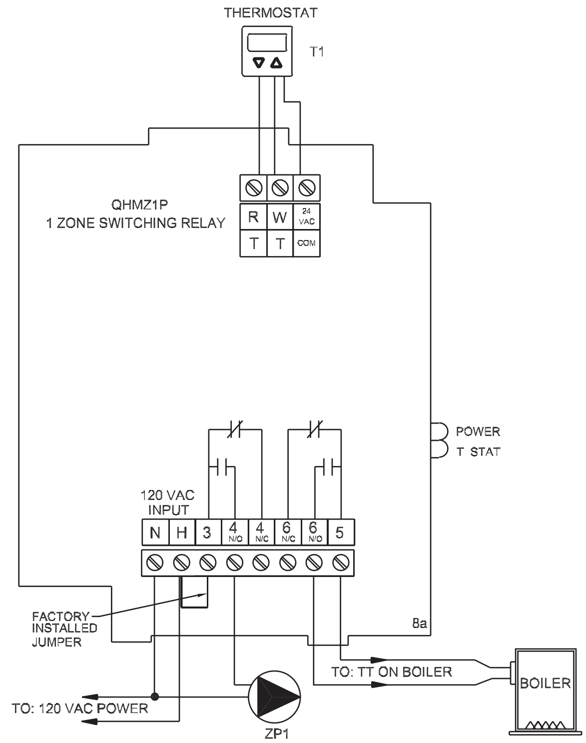
Notes:

1. The piping schematic is conceptual. Some components have been removed for clarity. Layout should be approved by a designer prior to installation.
2. Additional controls and equipment may be necessary to meet specific heat loads and other jobsite conditions.
3. Boiler and other system components must be installed to the manufacturers' instructions. All system components must be installed to all local codes. Isolation valves are recommended on all system components to allow easy service.
4. System should be installed by a licensed professional.

DETAILED ELECTRICAL SCHEMATIC 2

Closed Loop, Condensing Boiler System

Single Temperature Radiant Panel



Operation: Connect a thermostat to the "TT" terminals on the switching relay. When the thermostat calls for heat, the relay is energized and power is supplied to the zone pump (ZP1).

Power Input: Connect 120VAC power to terminals N and H.

Jumper Placement: The jumper is factory installed between terminals H and 3 to switch power on terminals 4 N/O and 4 N/C.

External Diagnostics: The External lights show full functionality of the switching relay. The green light should always be on, indicating that power is connected. When the thermostat calls for heat, both the zone pump (ZP1) and the red indicating light are energized.

Terminal Description:

T & T	Thermostat Connection
COM	Common side of transformer, to power some setback thermostats
N	Neutral wire of power input
H	Hot wire of power input
3	Common terminal for 4 N/O and 4 N/C
4 N/O	Normally open position
4 N/C	Normally closed position
6 N/C	Normally closed position
6 N/O	Normally open position
5	Common terminal for 6 N/O and 6 N/C

Warning: Wiring connections must be made in accordance with all applicable electrical codes. Use copper wire only. Failure to follow this instruction can result in personal injury or death and/or property damage. 10-18 gauge wire recommended for 120VAC connections with 9 in.-lbs. max. torque, 12-22 gauge wire for thermostat connections with 9 in.-lbs. max. torque, and 12-22 gauge wire for 24VAC source with 5 in.-lbs. max. torque.

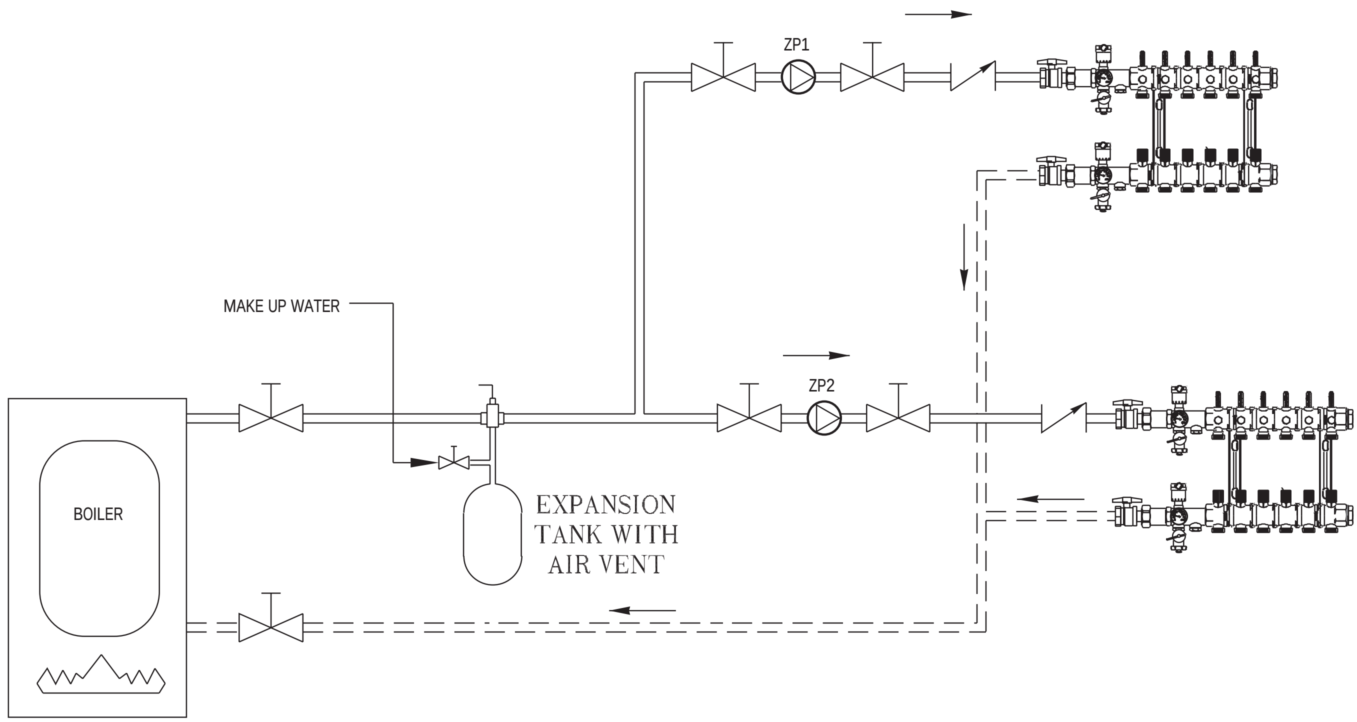
Notes:

1. Additional controls and equipment may be necessary to meet specific heat loads and other jobsite conditions.
2. Boiler and other system components must be installed to the manufacturers' instructions and to all local codes.
3. All electrical components should be installed by a licensed professional.

PIPING SCHEMATIC 3

Closed Loop, Condensing Boiler System

Single Temperature Radiant with Two Manifolds



Where Used

Radiant Panel or Snow Melt where the supply water temperature is constant. Snow melt systems with glycol may require a boiler rated to circulate glycol.

Description

The piping layout shows a condensing boiler supplying water to two manifolds requiring the same supply water temperature. Condensing boilers are designed to operate on low return water temperatures. This allows the system to operate without the use of a mixing valve or bypass loop. The boiler limit is set to supply the required water temperature for the radiant panel. Boiler manufactures installation instructions should be followed for boiler piping and return water limits.

System Equipment

Ball Valves: Ball valves are used as isolation valves. Ball valves are recommended on the supply and return lines of the boiler and manifolds to ease service. It is also recommended that isolation valves be installed on all zone pumps or install flanged zone pumps to allow easy service.

Bypass Loop: A bypass loop is not used with a condensing boiler.

Zone Pump: Most boilers are equipped with an internal circulator pump. This pump may not meet the flow requirements needed to circulate water through the radiant panels. An additional zone pump (ZP1 and ZP2) is then required to circulate the water through the radiant system.

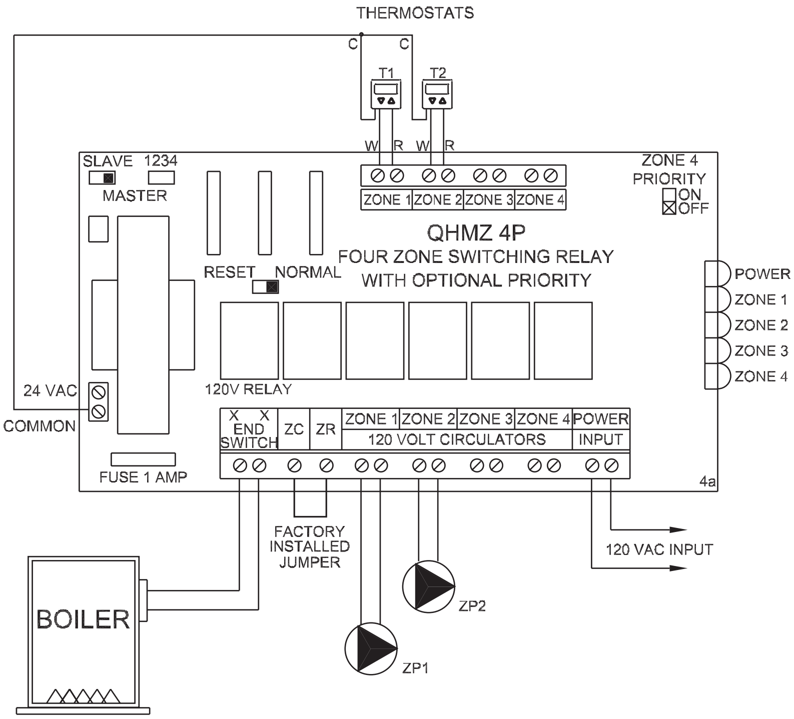
Notes:

1. The piping schematic is conceptual. Some components have been removed for clarity. Layout should be approved by a designer prior to installation.
2. Additional controls and equipment may be necessary to meet specific heat loads and other jobsite conditions.
3. Boiler and other system components must be installed to the manufacturers' instructions. All system components must be installed to all local codes. Isolation valves are recommended on all system components to allow easy service.
4. System should be installed by a licensed professional.

DETAILED ELECTRICAL SCHEMATIC 3

Closed Loop, Condensing Boiler System

Single Temperature Radiant with Two Manifolds



Operation: When any thermostat calls for heat, the appropriate circulator is energized and the isolated end switch (X and X) will start the boiler.

Priority Operation: This system does not require Domestic Hot Water Priority.

Mode Operation: With the mode switch set to NORMAL, the end switch relay will be energized if any zone is in operation.

Jumper Placement: The jumper should be placed between terminals ZC and ZR. Connect the isolated end switch to the aquastat control on the boiler.

Power Input: Connect 120VAC power input to terminals N and H. Neutral wire to terminal N. Hot wire to terminal H.

Expansion Connections: If future expansion is necessary, set the expansion switch to MASTER on the switching relay that has the designated priority zone. Set all other daisy chained controls to SLAVE. Connect thermostat wire (18-22 gauge) between terminals 1, 2, 3, 4 on the master control to the corresponding 1, 2, 3, 4 on the SLAVE control(s). Controls may be daisy chained up to 20 zones using any combination of zone controls (QHMZ4A or QHMZ6A) or pump relay controls (QHMZ4P or QHMZ6P).

External Diagnostics: Externally visible lights show full functionality of the switching relay. The green light should always be on, indicating that power is connected. When a thermostat calls for heat, both the appropriate circulator and red indicating light are energized.

Warning: Wiring connections must be made in accordance with all applicable electrical codes. Use copper wire only. Failure to follow this instruction can result in personal injury or death and/or property damage. 10-18 gauge wire recommended for 120VAC connections with 9 in.-lbs. max. torque, 12-22 gauge wire for thermostat connections with 9 in.-lbs. max. torque, and 12-22 gauge wire for 24VAC source with 5 in.-lbs. max. torque.

Switch Settings: Master/Slave: Master
Reset/Normal: Normal
Priority Zone: Off

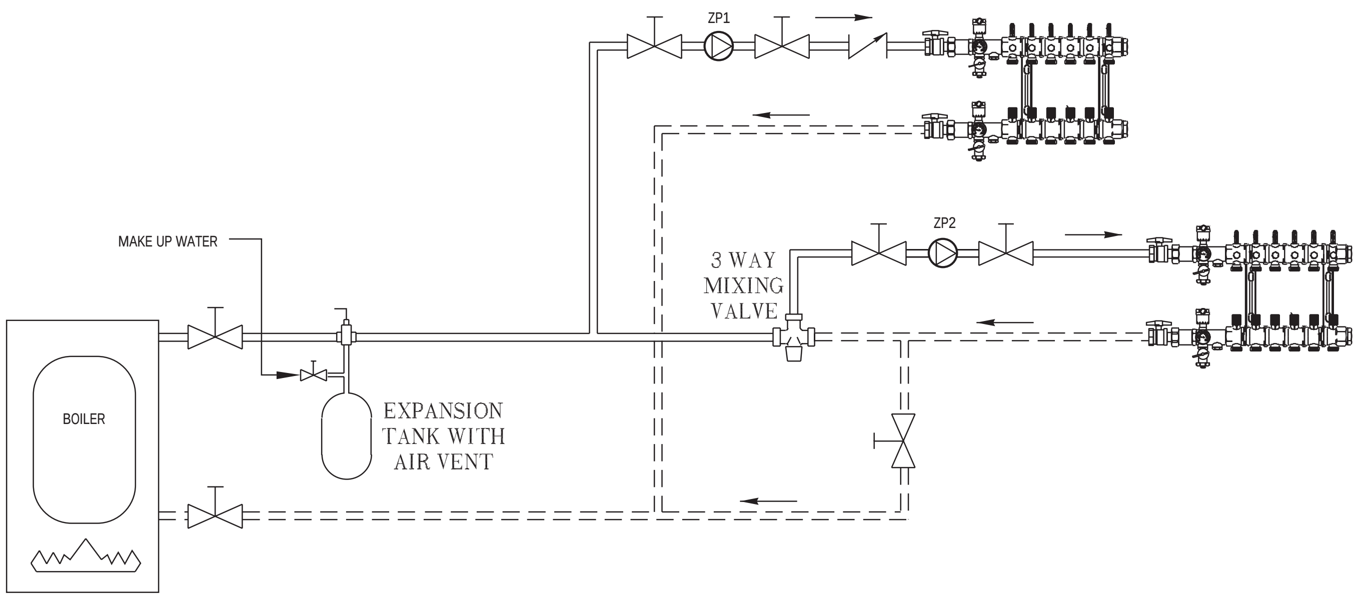
Notes:

1. Additional controls and equipment may be necessary to meet specific heat loads and other jobsite conditions.
2. Boiler and other system components must be installed to the manufacturers' instructions and to all local codes.
3. All electrical components should be installed by a licensed professional.

PIPING SCHEMATIC 4

Closed Loop, Condensing Boiler System

One Zone, Two Temperature Radiant with Two Manifolds



Where Used

Radiant Panel where the supply water temperature is different for each manifold.

Description

The piping layout shows a condensing boiler supplying water to two manifolds requiring different supply water temperatures. Condensing boilers are designed to operate on low return water temperatures. This allows the system to operate without using a mixing valve on the higher temperature radiant panel.
The boiler limit is set to supply the required higher water temperature for the radiant panel. A 3-way thermostatic mixing valve is required on the lower temperature radiant system. The mixing valve will mix the hotter boiler supply water with the cooler radiant return water to give the required radiant panel supply water temperature. Boiler manufacturers' installation instructions should be followed for boiler piping and return water limits.

System Equipment

Ball Valves: Ball valves are used as isolation valves. Ball valves are recommended on the supply and return lines of the condensing boiler and manifolds to ease service. It is also recommended that isolation valves be installed on all zone pumps or install flanged zone pumps to allow easy service.

Bypass Loop: A bypass loop is not used with a condensing boiler.

Low Temperature Zone Pump: A zone pump (ZP2) is required to circulate the water through the radiant system. The zone pump must be installed on the mixed side of the thermostatic mixing valve. Without the zone pump on the mixed side, when the mixing valve closes the boiler supply side of the valve, circulation of the radiant system would stop.

High Temperature Zone Pump: Most boilers are equipped with an internal circulator pump. This pump may not meet the flow requirements needed to circulate water through the radiant panel. An additional zone pump (ZP1) is then required to circulate the water through the radiant system.

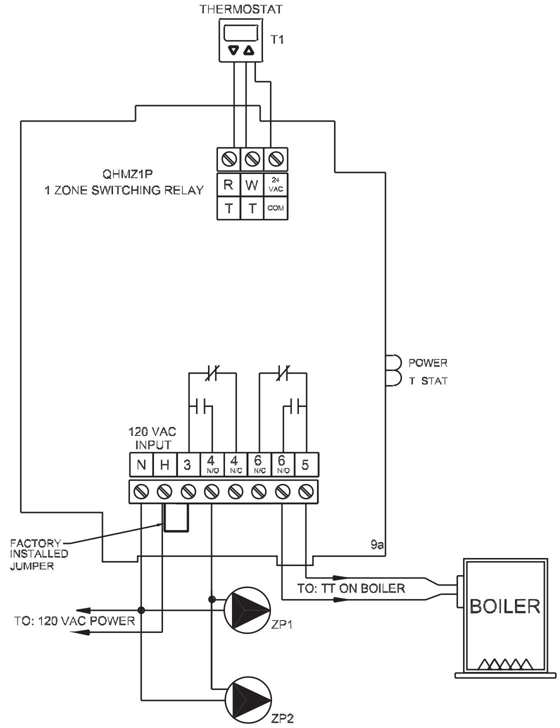
Notes:

1. The piping schematic is conceptual. Some components have been removed for clarity. Layout should be approved by a designer prior to installation.
2. Additional controls and equipment may be necessary to meet specific heat loads and other jobsite conditions.
3. Boiler and other system components must be installed to the manufacturers' instructions. All system components must be installed to all local codes. Isolation valves are recommended on all system components to allow easy service.
4. System should be installed by a licensed professional.

DETAILED ELECTRICAL SCHEMATIC 4

Closed Loop, Condensing Boiler System

One Zone, Two Temperature Radiant with Two Manifolds



Operation: Connect a thermostat to the "TT" terminals on the switching relay. When the thermostat calls for heat, the relay is energized and power is supplied to the zone pumps (ZP1 and ZP2).

Power Input: Connect 120VAC power to terminals N and H.

Jumper Placement: The jumper is factory installed between terminals H and 3 to switch power on terminals 4 N/O and 4 N/C.

External Diagnostics: The External lights show full functionality of the switching relay. The green light should always be on, indicating that power is connected. When the thermostat calls for heat, both the zone pumps and the red indicating light are energized.

Terminal Description:

T & T	Thermostat Connection
COM	Common side of transformer, to power some setback thermostats
N	Neutral wire of power input
H	Hot wire of power input
3	Common terminal for 4 N/O and 4 N/C
4 N/O	Normally open position
4 N/C	Normally closed position
6 N/C	Normally closed position
6 N/O	Normally open position
5	Common terminal for 6 N/O and 6 N/C

Warning: Wiring connections must be made in accordance with all applicable electrical codes. Use copper wire only. Failure to follow this instruction can result in personal injury or death and/or property damage. 10-18 gauge wire recommended for 120VAC connections with 9 in.-lbs. max. torque, 12-22 gauge wire for thermostat connections with 9 in.-lbs. max. torque, and 12-22 gauge wire for 24VAC source with 5 in.-lbs. max. torque.

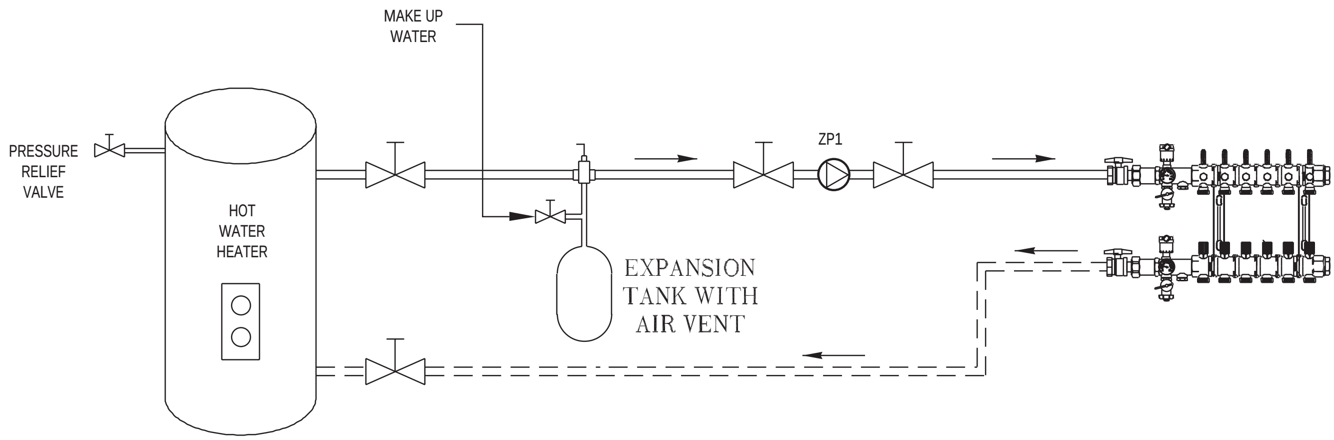
Notes:

1. Additional controls and equipment may be necessary to meet specific heat loads and other jobsite conditions.
2. Boiler and other system components must be installed to the manufacturers' instructions and to all local codes.
3. All electrical components should be installed by a licensed professional.

PIPING SCHEMATIC 5

Closed Loop, Hot Water System

Temperature of 145°F or Less



Where Used

Radiant application where supply water temperature is less than 145°F.

Description

The piping layout illustrates a hot water heater dedicated to the radiant panel. The water temperature is controlled by the hot water heaters' internal thermostat. This allows the system to be run without a mixing valve to control return water temperature.

System Equipment

Ball Valves: Ball valves are used as isolation valves. Ball valves are recommended on the supply and return lines of the hot water heater and manifolds to ease service. It is also recommended that isolation valves be installed on all zone pumps or install flanged zone pumps to allow easy service.

Bypass Loop: A bypass loop is not used with a hot water heater.

Pressure Relief Valve: An additional pressure relief valve should be installed in the supply line close to the hot water heater. The additional relief valve can not be installed downstream of the hot water heater isolation ball valve. Do not remove the factory installed temperature and pressure valve from the hot water heater.

Zone Pump: A zone pump (ZP1) is required to circulate the water through the radiant system.

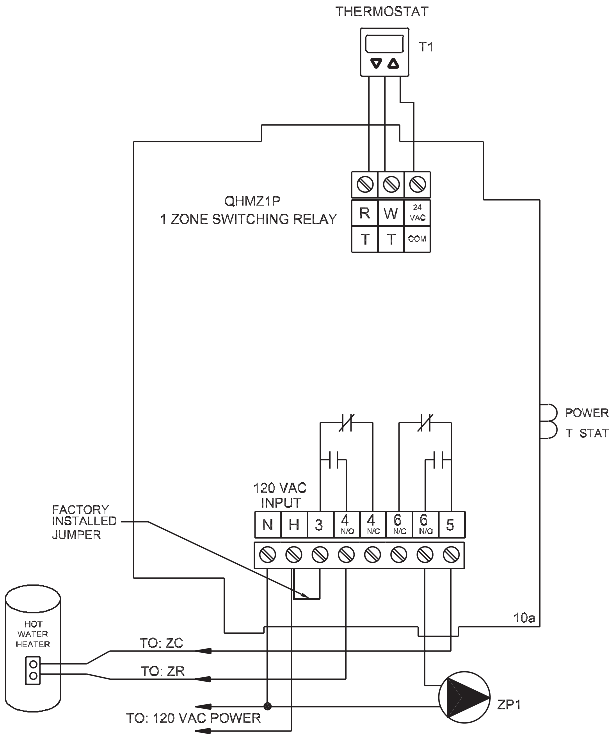
Notes:

1. The piping schematic is conceptual. Some components have been removed for clarity. Layout should be approved by a designer prior to installation.
2. Additional controls and equipment may be necessary to meet specific heat loads and other jobsite conditions.
3. Boiler and other system components must be installed to the manufacturers' instructions. All system components must be installed to all local codes. Isolation valves are recommended on all system components to allow easy service.
4. System should be installed by a licensed professional.

DETAILED ELECTRICAL SCHEMATIC 5

Closed Loop, Hot Water System

Temperature of 145°F or Less



Operation: Connect a thermostat to the "TT" terminals on the switching relay. When the thermostat calls for heat, the relay is energized and power is supplied to the zone pump (ZP1).

Power Input: Connect 120VAC power to terminals N and H.

Jumper Placement: The jumper is factory installed between terminals H and 3 to switch power on terminals 4 N/O and 4 N/C.

External Diagnostics: The External lights show full functionality of the switching relay. The green light should always be on, indicating that power is connected. When the thermostat calls for heat, both the zone pump (ZP1) and the red indicating light are energized.

Terminal Description:

T & T	Thermostat Connection
COM	Common side of transformer, to power some setback thermostats
N	Neutral wire of power input
H	Hot wire of power input
3	Common terminal for 4 N/O and 4 N/C
4 N/O	Normally open position
4 N/C	Normally closed position
6 N/C	Normally closed position
6 N/O	Normally open position
5	Common terminal for 6 N/O and 6 N/C

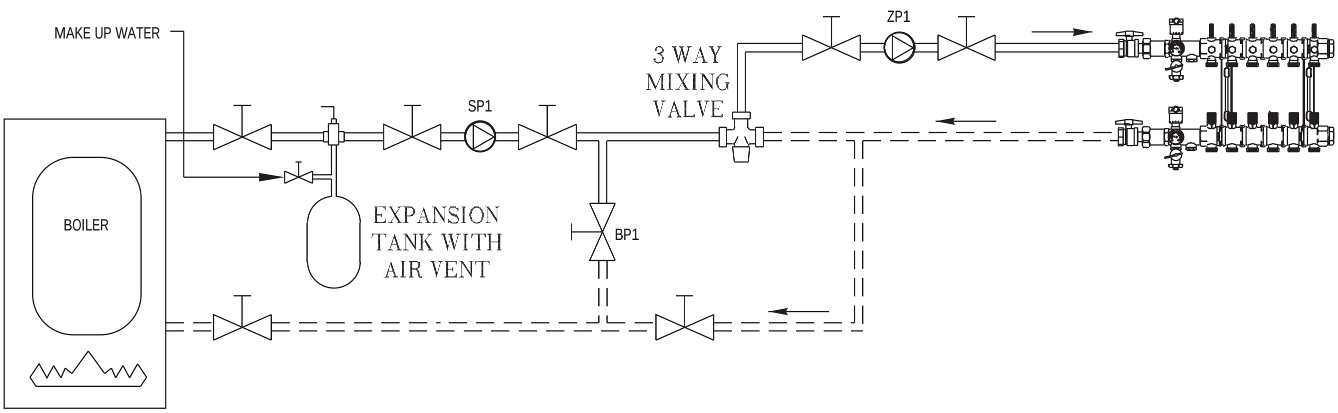
Warning: Wiring connections must be made in accordance with all applicable electrical codes. Use copper wire only. Failure to follow this instruction can result in personal injury or death and/or property damage. 10-18 gauge wire recommended for 120VAC connections with 9 in.-lbs. max. torque, 12-22 gauge wire for thermostat connections with 9 in.-lbs. max. torque, and 12-22 gauge wire for 24VAC source with 5 in.-lbs. max. torque.

Notes:
1. Additional controls and equipment may be necessary to meet specific heat loads and other jobsite conditions.
2. Boiler and other system components must be installed to the manufacturers' instructions and to all local codes.
3. All electrical components should be installed by a licensed professional.
4. Local building codes must be checked before using a hot water heater as a heat source.

PIPING SCHEMATIC 6

Closed Loop, Non-Condensing Boiler System

Single Temperature Radiant



Where Used

Radiant Panel or Snow Melt where the supply water temperature is less than 160°F.

Description

The piping layout illustrates a non-condensing boiler supplying water to a single radiant panel. A 3-way thermostatic mixing valve is used to mix boiler supply water and radiant panel return water to supply the radiant panel with a tempered water.

System Equipment

Ball Valves: Ball valves are used as isolation valves. Ball valves are recommended on the supply and return lines of the non-condensing boiler and manifolds to ease service. It is also recommended that isolation valves be installed on all zone pumps or install flanged zone pumps to allow easy service.

Bypass Loop: A bypass loop is used at the boiler. Non-condensing boilers require a minimum return water temperature of 140°F to prevent flue gas condensation. The bypass loop allows some boiler supply water to be mixed with cooler return water to maintain the 140°F boiler return water. The bypass loop utilizes a bypass valve (BP1) to maintain the correct return water temperature.

Bypass Valve: The bypass valve (BP1) should be set approximately in the half open position at system startup to regulate the boiler return water. The bypass valve can be closed slowly if the radiant panel supply temperature is too low, until the desired temperature is achieved.

Zone Pump: A zone pump is required to circulate the water through the radiant system. The zone pump (ZP1) must be installed on the mixed side of the thermostatic mixing valve. Without the zone pump on the mixed side, when the mixing valve closes the boiler supply side of the valve, circulation of the radiant system would stop.

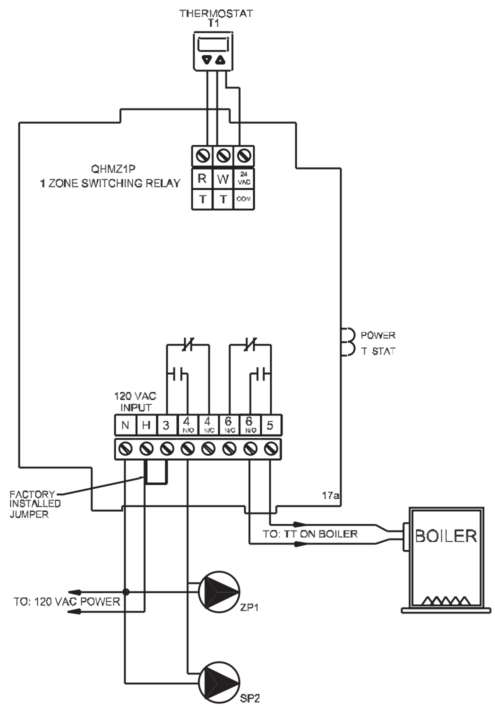
Notes:

1. The piping schematic is conceptual. Some components have been removed for clarity. Layout should be approved by a designer prior to installation.
2. Additional controls and equipment may be necessary to meet specific heat loads and other jobsite conditions.
3. Boiler and other system components must be installed to the manufacturers' instructions. All system components must be installed to all local codes. Isolation valves are recommended on all system components to allow easy service.
4. System should be installed by a licensed professional.

DETAILED ELECTRICAL SCHEMATIC 6

Closed Loop, Non-Condensing Boiler System

Single Temperature Radiant



Operation: Connect a thermostat to the "TT" terminals on the switching relay. When the thermostat calls for heat, the relay is energized and power is supplied to the zone pump (ZP1) and system pump (SP1).

Power Input: Connect 120VAC power to terminals N and H.

Jumper Placement: The jumper is factory installed between terminals H and 3 to switch power on terminals 4 N/O and 4 N/C.

External Diagnostics: The External lights show full functionality of the switching relay. The green light should always be on, indicating that power is connected. When the thermostat calls for heat, the zone pump (ZP1), system pump (SP1) and the red indicating light are energized.

Terminal Description:

T & T	Thermostat Connection
COM	Common side of transformer, to power some setback thermostats
N	Neutral wire of power input
H	Hot wire of power input
3	Common terminal for 4 N/O and 4 N/C
4 N/O	Normally open position
4 N/C	Normally closed position
6 N/C	Normally closed position
6 N/O	Normally open position
5	Common terminal for 6 N/O and 6 N/C

Warning: Wiring connections must be made in accordance with all applicable electrical codes. Use copper wire only. Failure to follow this instruction can result in personal injury or death and/or property damage. 10-18 gauge wire recommended for 120VAC connections with 9 in.-lbs. max. torque, 12-22 gauge wire for thermostat connections with 9 in.-lbs. max. torque, and 12-22 gauge wire for 24VAC source with 5 in.-lbs. max. torque.

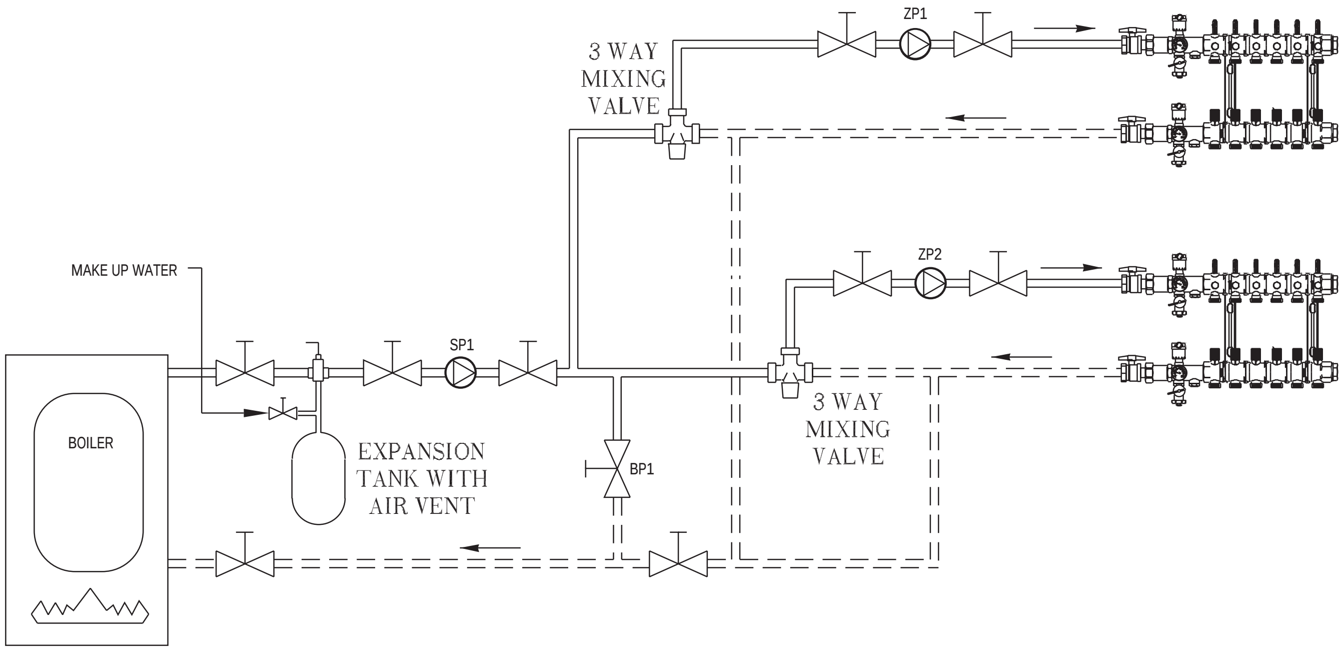
Notes:

1. Additional controls and equipment may be necessary to meet specific heat loads and other jobsite conditions.
2. Boiler and other system components must be installed to the manufacturers' instructions and to all local codes.
3. All electrical components should be installed by a licensed professional.

PIPING SCHEMATIC 7

Closed Loop, Non-Condensing Boiler System

Two Temperature Radiant and Two Manifolds



Where Used

Radiant Panel where the supply water temperature is different for each manifold.

Description

The piping layout shows a non-condensing boiler supplying water to two manifolds requiring different supply water temperatures. A 3-way thermostatic mixing valve is required on both radiant systems. The mixing valves will mix the hotter boiler supply water with the cooler radiant return water to give the required radiant panel supply water temperature. Boiler manufacturers' installation instructions should be followed for boiler piping and return water limits.

System Equipment

Ball Valves: Ball valves are used as isolation valves. Ball valves are recommended on the supply and return lines of the non-condensing boiler and manifolds to ease service. It is also recommended that isolation valves be installed on all zone pumps or install flanged zone pumps to allow for easy service.

Bypass Loop: A bypass loop is used at the boiler. Non-condensing boilers require a minimum return water temperature of 140°F to prevent flue gas condensation. The bypass loop allows some boiler supply water to be mixed with cooler return water to maintain the 140°F boiler return water. The bypass loop utilizes a bypass valve (BP1) to maintain the correct return water temperature.

Bypass Valve: The bypass valve (BP1) should be set approximately in the half open position at system startup to regulate the boiler return water. The bypass valve can be closed slowly if the radiant panel supply temperature is too low, until the desired temperature is achieved.

Zone Pump: A zone pump is required for each manifold to circulate the water through the radiant system. The zone pumps (ZP1 and ZP2) must be installed on the mixed side of the thermostatic mixing valves. Without the zone pump on the mixed side, when the mixing valve closes the boiler supply side of the valve, circulation of the radiant system would stop.

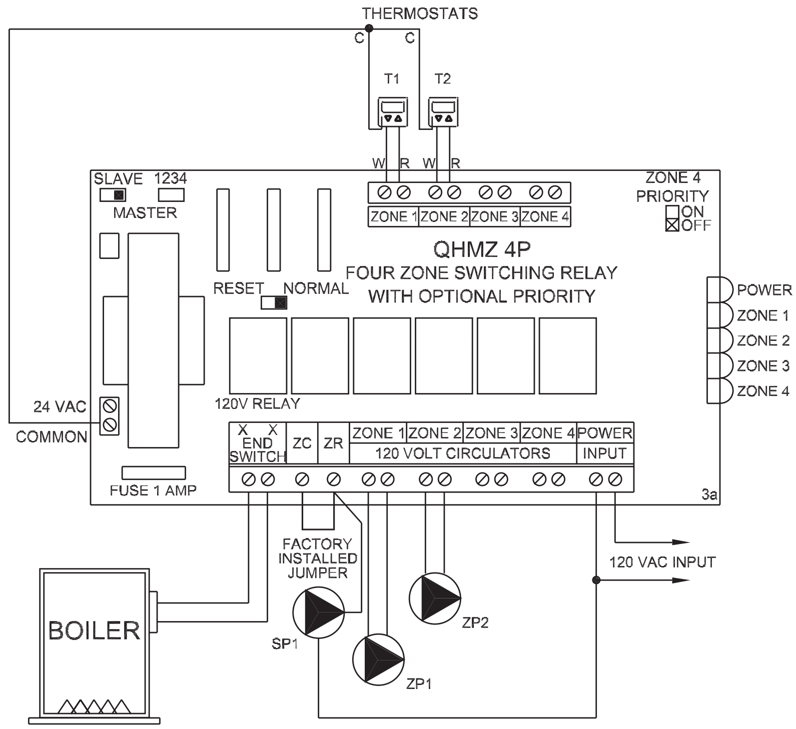
Notes:

1. The piping schematic is conceptual. Some components have been removed for clarity. Layout should be approved by a designer prior to installation.
2. Additional controls and equipment may be necessary to meet specific heat loads and other jobsite conditions.
3. Boiler and other system components must be installed to the manufacturers' instructions. All system components must be installed to all local codes. Isolation valves are recommended on all system components to allow easy service.
4. System should be installed by a licensed professional.

DETAILED ELECTRICAL SCHEMATIC 7

Closed Loop, Non-Condensing Boiler System

Two Temperature Radiant and Two Manifolds



Operation: When any thermostat calls for heat, the appropriate circulator is energized and the isolated end switch (X and X) will start the boiler.

Priority Operation: This system does not require Domestic Hot Water Priority.

Mode Operation: With the mode switch set to NORMAL, the end switch relay will be energized if any zone is in operation.

Jumper Placement: The jumper should be placed between terminals ZC and ZR. Connect the isolated end switch to the aquastat control on the boiler.

Power Input: Connect 120VAC power input to terminals N and H. Neutral wire to terminal N. Hot wire to terminal H.

Expansion Connections: If future expansion is necessary, set the expansion switch to MASTER on the switching relay that has the designated priority zone. Set all other daisy chained controls to SLAVE. Connect thermostat wire (18-22 gauge) between terminals 1, 2, 3, 4 on the master control to the corresponding 1, 2, 3, 4 on the SLAVE control(s). Controls may be daisy chained up to 20 zones using any combination of zone controls (QHMZ4A or QHMZ6A) or pump relay controls (QHMZ4P or QHMZ6P).

External Diagnostics: Externally visible lights show full functionality of the switching relay. The green light should always be on, indicating that power is connected. When a thermostat calls for heat, both the appropriate circulator and red indicating light are energized.

Warning: Wiring connections must be made in accordance with all applicable electrical codes. Use copper wire only. Failure to follow this instruction can result in personal injury or death and/or property damage. 10-18 gauge wire recommended for 120VAC connections with 9 in.-lbs. max. torque, 12-22 gauge wire for thermostat connections with 9 in.-lbs. max. torque, and 12-22 gauge wire for 24VAC source with 5 in.-lbs. max. torque.

Switch Settings: Master/Slave: Master
Reset/Normal: Normal
Priority Zone: Off

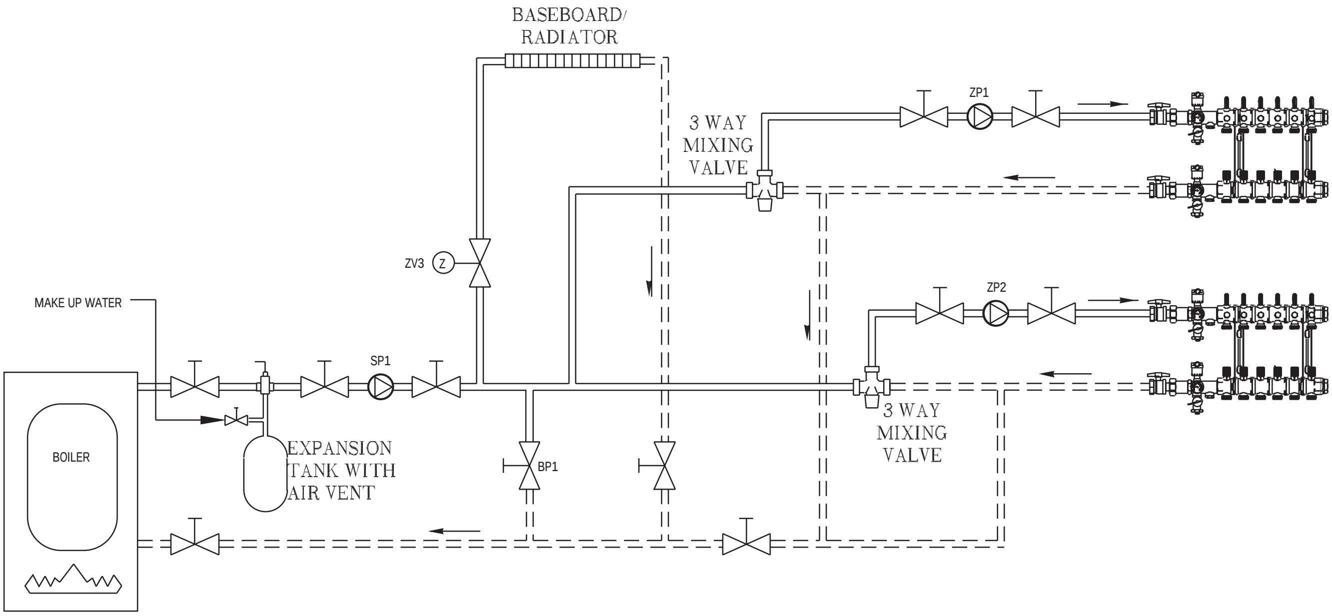
Notes:

1. Additional controls and equipment may be necessary to meet specific heat loads and other jobsite conditions.
2. Boiler and other system components must be installed to the manufacturers' instructions and to all local codes.
3. All electrical components should be installed by a licensed professional.

PIPING SCHEMATIC 8

Closed Loop, Non-Condensing Boiler System

Two Temperature Radiant, Two Manifolds, and Baseboard



Where Used

Radiant Panel where the supply water temperature is different for each manifold and a baseboard/radiator is also used.

Description

The piping layout shows a non-condensing boiler supplying water to two manifolds requiring different supply water temperatures and a baseboard. A 3-way thermostatic mixing valve is required on each radiant system. The mixing valve will mix the hotter boiler supply water with the cooler radiant return water to give the required radiant panel supply water. A zone valve (ZV3) is used to control the supply water for the baseboard/radiator. Boiler manufacturers' installation instructions should be followed for boiler piping and return water limits.

System Equipment

Ball Valves: Ball valves are used as isolation valves. Ball valves are recommended on the supply and return lines of the non-condensing boiler and manifolds to ease service. It is also recommended that isolation valves be installed on all zone pumps or install flanged zone pumps to allow easy service.

Bypass Loop: A bypass loop is used at the boiler. Non-condensing boilers require a minimum return water temperature of 140°F to prevent flue gas condensation. The bypass loop allows some boiler supply water to be mixed with cooler return water to maintain the 140°F boiler return water. The bypass loop utilizes a bypass valve (BP1) to maintain the correct return water temperature.

Bypass Valve: The bypass valve (BP1) should be set approximately in the half open position at system startup to regulate the boiler return water. The bypass valve can be closed slowly if the radiant panel supply temperature is too low, until the desired temperature is achieved.

Zone Pump: A zone pump is required for each manifold to circulate the water through the radiant system. The zone pumps (ZP1 and ZP2) must be installed on the mixed side of the thermostatic mixing valves. Without the zone pump on the mixed side, when the mixing valve closes the boiler supply side of the valve, circulation of the radiant system would stop.

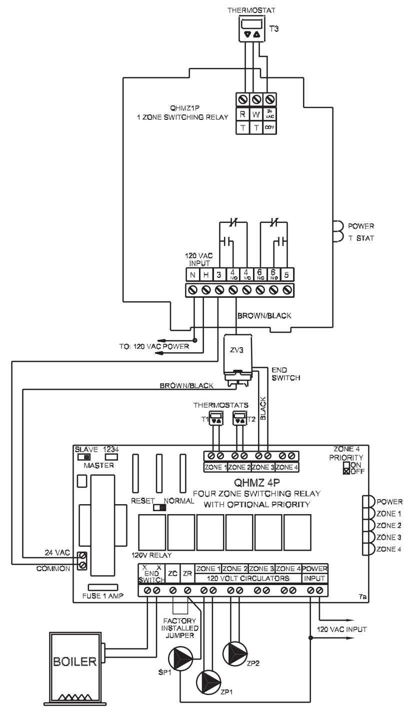
Notes:

1. The piping schematic is conceptual. Some components have been removed for clarity. Layout should be approved by a designer prior to installation.
2. Additional controls and equipment may be necessary to meet specific heat loads and other jobsite conditions.
3. Boiler and other system components must be installed to the manufacturers' instructions. All system components must be installed to all local codes. Isolation valves are recommended on all system components to allow easy service.
4. System should be installed by a licensed professional.

DETAILED ELECTRICAL SCHEMATIC 8

Closed Loop, Non-Condensing Boiler System

Two Temperature Radiant, Two Manifolds, and Baseboard



Operation: When any thermostat calls for heat, the appropriate circulator is energized and the isolated end switch (X and X) will start the boiler.

Priority Operation: This system does not require Domestic Hot Water Priority.

Mode Operation: With the mode switch set to NORMAL, the end switch relay will be energized if any zone is in operation.

Jumper Placement: The jumper should be placed between terminals ZC and ZR. Connect the isolated end switch to the aquastat control on the boiler.

Power Input: Connect 120VAC power input to terminals N and H. Neutral wire to terminal N. Hot wire to terminal H.

Expansion Connections: If future expansion is necessary, set the expansion switch to MASTER on the switching relay that has the designated priority zone. Set all other daisy chained controls to SLAVE. Connect thermostat wire (18-22 gauge) between terminals 1, 2, 3, 4 on the master control to the corresponding 1, 2, 3, 4 on the SLAVE control(s). Controls may be daisy chained up to 20 zones using any combination of zone controls (QHMZ4A or QHMZ6A) or pump relay controls (QHMZ4P or QHMZ6P).

External Diagnostics: Externally visible lights show full functionality of the switching relay. The green light should always be on, indicating that power is connected. When a thermostat calls for heat, both the appropriate circulator and red indicating light are energized.

Warning: Wiring connections must be made in accordance with all applicable electrical codes. Use copper wire only. Failure to follow this instruction can result in personal injury or death and/or property damage. 10-18 gauge wire recommended for 120VAC connections with 9 in.-lbs. max. torque, 12-22 gauge wire for thermostat connections with 9 in.-lbs. max. torque, and 12-22 gauge wire for 24VAC source with 5 in.-lbs. max. torque.

Switch Settings: Master/Slave: Master
Reset/Normal: Normal
Priority Zone: Off

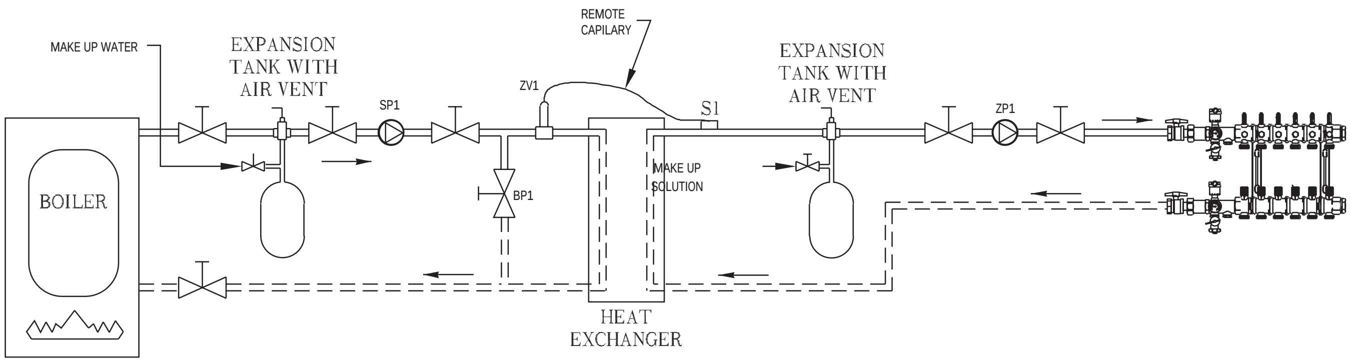
Notes:

1. Additional controls and equipment may be necessary to meet specific heat loads and other jobsite conditions.
2. Boiler and other system components must be installed to the manufacturers' instructions and to all local codes.
3. All electrical components should be installed by a licensed professional.

PIPING SCHEMATIC 9

Closed Loop, Non-Condensing Boiler System

With Heat Exchanger



Notes:

1. The piping schematic is conceptual. Some components have been removed for clarity. Layout should be approved by a designer prior to installation.
2. Additional controls and equipment may be necessary to meet specific heat loads and other jobsite conditions.
3. Boiler and other system components must be installed to the manufacturers' instructions. All system components must be installed to all local codes. Isolation valves are recommended on all system components to allow easy service.
4. System should be installed by a licensed professional.

Where Used

Radiant Panel or Snow Melt where the supply temperature is constant.

Description

The piping layout shows a non-condensing boiler supplying water to a plate heat exchanger. The heat exchanger provides water temperature control and isolation when necessary. Water temperature control for the radiant panel is maintained by using a remote capillary sensor (S1) on the outlet supply of the heat exchanger. The sensor (S1) is wired to a thermostatic head which is set for the desired radiant panel water temperature. The thermostatic head opens a zone valve (ZV1) to maintain the set temperature in the radiant panel loop. A heat exchanger will also allow the radiant panel to be isolated from the boiler. The heat exchanger will also allow the use of glycol for snow melt applications.

System Equipment

Ball Valves: Ball valves are used as isolation valves. Ball valves are recommended on the supply and return lines of the non-condensing boiler and manifolds to ease service. It is also recommended that isolation valves be installed on all zone pumps or flanged zone pumps be installed to allow easy service.

Bypass Loop: A bypass loop is used at the boiler. Non-condensing boilers require a minimum return water temperature of 140°F to prevent flue gas condensation. The bypass loop allows some boiler supply water to be mixed with cooler return water to maintain the 140°F boiler return water. The bypass loop utilizes a bypass valve (BP1) to maintain the correct return water temperature.

Bypass Valve: The bypass valve (BP1) should be set approximately in the half open position at system startup to regulate the boiler return water. The bypass valve can be closed slowly if the radiant panel supply temperature is too low, until the desired temperature is achieved.

Expansion Tank: A second expansion tank is added to the radiant side of the heat exchanger. This will allow for proper air elimination and expansion because the panel is isolated from the boiler side expansion tank.

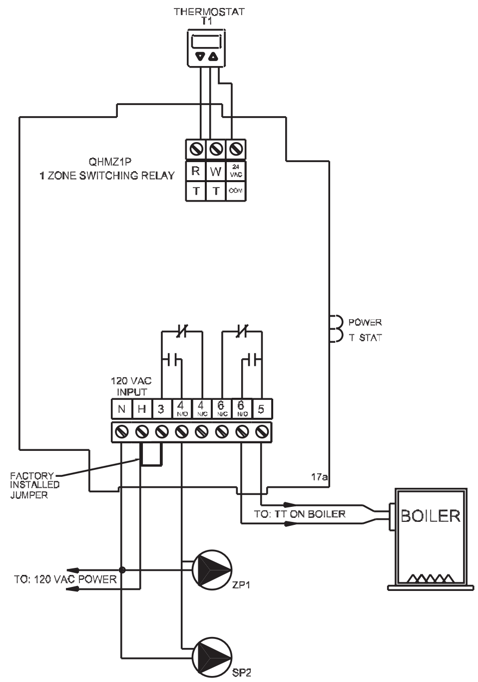
Zone Valve: An on/off zone valve (ZV1) located on the boiler side of the heat exchanger controls the set temperature of the radiant panel when connected to sensor (S1).

Zone Pump: A zone pump (ZP1) located on the radiant side of the heat exchanger is required to circulate the water through the radiant system.

DETAILED ELECTRICAL SCHEMATIC 9

Closed Loop, Non-Condensing Boiler System

With Heat Exchanger



Operation: Connect a thermostat to the "TT" terminals on the switching relay. When the thermostat calls for heat, the relay is energized and power is supplied to the zone pump (ZP1) and system pump (SP1).

Power Input: Connect 120VAC power to terminals N and H.

Jumper Placement: The jumper is factory installed between terminals H and 3 to switch power on terminals 4 N/O and 4 N/C.

External Diagnostics: The External lights show full functionality of the switching relay. The green light should always be on, indicating that power is connected. When the thermostat calls for heat, the zone pump (ZP1), system pump (SP1) and the red indicating light are energized.

Terminal Description:

T & T	Thermostat Connection
COM	Common side of transformer, to power some setback thermostats
N	Neutral wire of power input
H	Hot wire of power input
3	Common terminal for 4 N/O and 4 N/C
4 N/O	Normally open position
4 N/C	Normally closed position
6 N/C	Normally closed position
6 N/O	Normally open position
5	Common terminal for 6 N/O and 6 N/C

Warning: Wiring connections must be made in accordance with all applicable electrical codes. Use copper wire only. Failure to follow this instruction can result in personal injury or death and/or property damage. 10-18 gauge wire recommended for 120VAC connections with 9 in.-lbs. max. torque, 12-22 gauge wire for thermostat connections with 9 in.-lbs. max. torque, and 12-22 gauge wire for 24VAC source with 5 in.-lbs. max. torque.

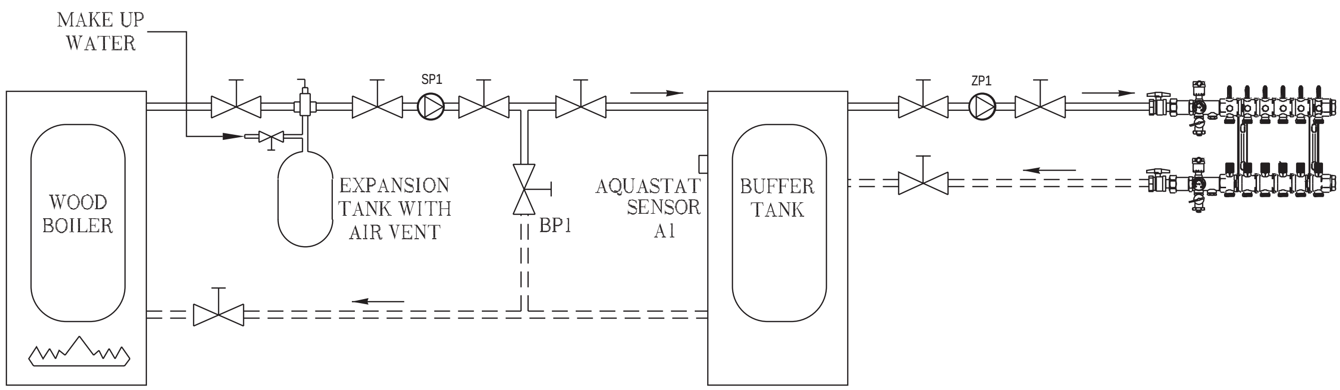
Notes:

1. Additional controls and equipment may be necessary to meet specific heat loads and other jobsite conditions.
2. Boiler and other system components must be installed to the manufacturers' instructions and to all local codes.
3. All electrical components should be installed by a licensed professional.

PIPING SCHEMATIC 10

Closed Loop, Wood Boiler System

Single Temperature Radiant



Where Used

Radiant Panel or Snow Melt where the supply temperature is constant.

Description

The piping layout shows a wood boiler supplying water to a buffering tank. The buffering tank allows hot boiler supply water to mix with cooler radiant return water to give the desired radiant supply water. Water temperature control for the radiant panel is maintained by using the aquastat (A1) on the buffering tank. The sensor monitors the water temperature in the tank and tells the system pump (SP1) when to circulate hot water.

System Equipment

Ball Valves: Ball valves are used as isolation valves. Ball valves are recommended on the supply and return lines of the wood boiler and manifolds to ease service. It is also recommended that isolation valves be installed on all zone pumps or install flanged zone pumps to allow easy service.

Bypass Loop: A bypass loop is used at the boiler to maintain the temperature of the boiler return water. The bypass loop utilizes a bypass valve (BP1) to maintain the correct return water temperature.

Bypass Valve: The bypass valve (BP1) should be set approximately in the half open position at system startup to regulate the boiler return water. The bypass valve can be closed slowly if the radiant panel supply temperature is too low, until the desired temperature is achieved.

Zone Pump: A zone pump (ZP1) located on the radiant side of the buffer tank is required to circulate the water through the radiant system.

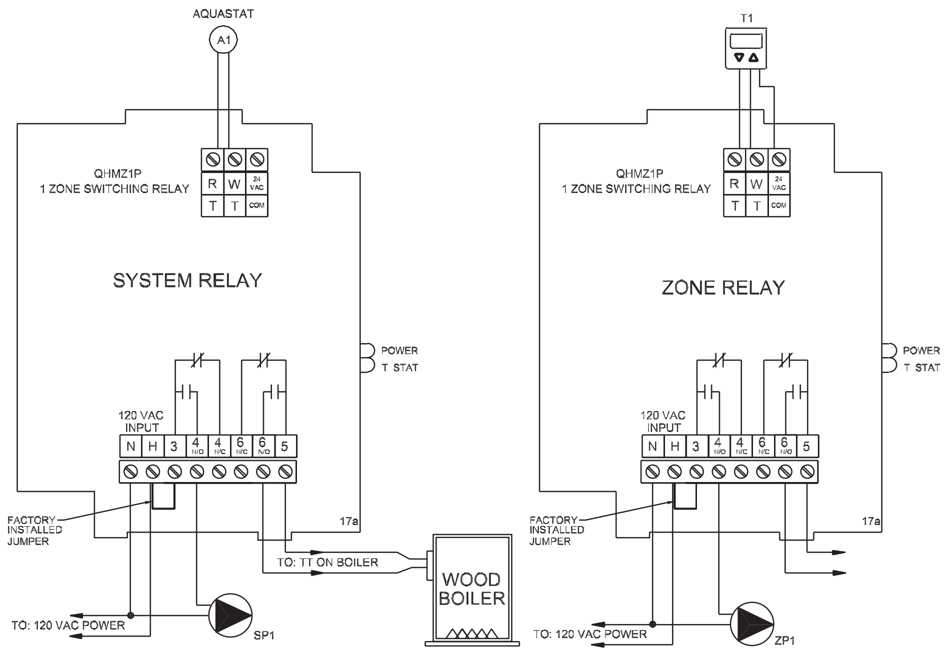
Notes:

1. The piping schematic is conceptual. Some components have been removed for clarity. Layout should be approved by a designer prior to installation.
2. Additional controls and equipment may be necessary to meet specific heat loads and other jobsite conditions.
3. Boiler and other system components must be installed to the manufacturers' instructions. All system components must be installed to all local codes. Isolation valves are recommended on all system components to allow easy service.
4. System should be installed by a licensed professional.

DETAILED ELECTRICAL SCHEMATIC 10

Closed Loop, Wood Boiler System

Single Temperature Radiant



Operation: Connect the aquastat sensor (A1) to the "TT" terminals on the system switching relay. When the aquastat calls for heat, the relay is energized and power is supplied to the system pump (SP1). Connect the thermostat (T1) to the "TT" terminals on the zone switching relay. When the thermostat calls for heat, the relay is energized and power is supplied to the zone pump (ZP1).

Power Input: Connect 120VAC power to terminals N and H on both switching relays.

Jumper Placement: The jumper is factory installed between terminals H and 3 to switch power on terminals 4 N/O and 4 N/C.

External Diagnostics: The External lights show full functionality of the switching relay. The green light should always be on, indicating that power is connected. When the thermostat calls for heat, the zone pump (ZP1) and the red indicating light are energized. When the aquastat calls for heat, the system pump (SP1) and the red indicating light are energized.

Warning: Wiring connections must be made in accordance with all applicable electrical codes. Use copper wire only. Failure to follow this instruction can result in personal injury or death and/or property damage. 10-18 gauge wire recommended for 120VAC connections with 9 in.-lbs. max. torque, 12-22 gauge wire for thermostat connections with 9 in.-lbs. max. torque, and 12-22 gauge wire for 24VAC source with 5 in.-lbs. max. torque.

Terminal Description:

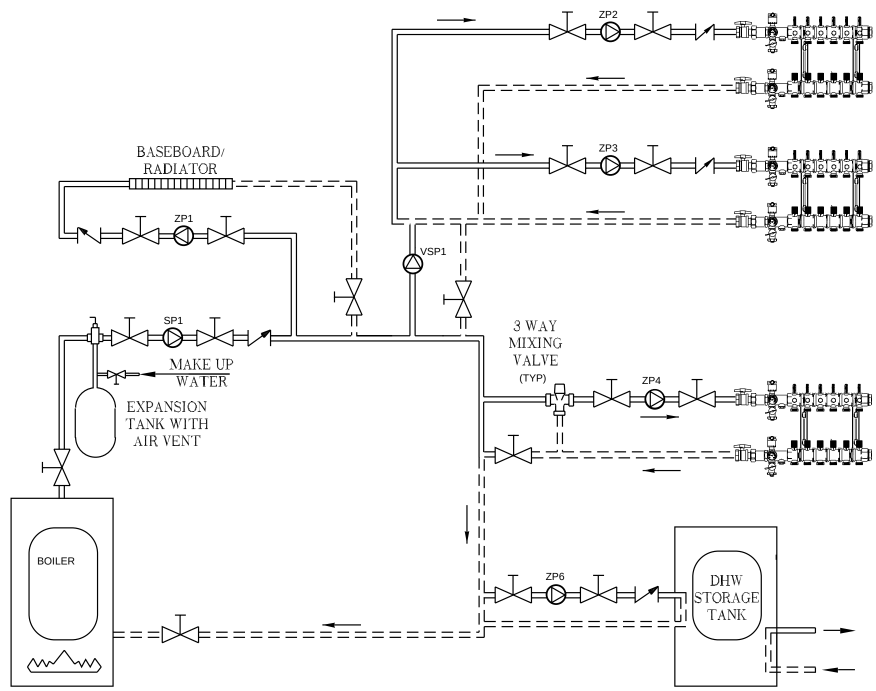
T & T	Thermostat Connection
COM	Common side of transformer, to power some setback thermostats
N	Neutral wire of power input
H	Hot wire of power input
3	Common terminal for 4 N/O and 4 N/C
4 N/O	Normally open position
4 N/C	Normally closed position
6 N/C	Normally closed position
6 N/O	Normally open position
5	Common terminal for 6 N/O and 6 N/C

Notes:
1. Additional controls and equipment may be necessary to meet specific heat loads and other jobsite conditions.
2. Boiler and other system components must be installed to the manufacturers' instructions and to all local codes.
3. All electrical components should be installed by a licensed professional.
4. For more information, see **One Zone Switching Relay Installation Instructions (QFN122).**

PIPING SCHEMATIC 11

Closed Loop, Non-Condensing Boiler System

Two Temperature Radiant, Three Manifolds, Baseboard, and Domestic Hot Water



Where Used

Radiant Panel where the supply temperature is different for one manifold and the other two manifolds have the same supply temperature and domestic hot water is used.

Description

The piping layout shows a non-condensing boiler supplying water to a domestic hot water (DHW) storage tank, one radiant manifold with a lower supply temperature than the other two manifolds and a baseboard/ radiator. A separate zone pump (ZP1 and ZP6) and a check valve are required on the supply side of the DHW loop and baseboard loop. A 3-way mixing thermostatic mixing valve and zone pump (ZP4) are required on the manifold with the lower supply water temperature. The mixing valve will mix the hot boiler supply water with the cool radiant return water to give the required radiant panel supply water temperature. A variable speed injection pump (VSP1) will supply the mixed water to the two manifolds with the same supply water temperature. Zone pumps (ZP2 and ZP3) are used to circulate the supply water for each radiant manifold. Boiler manufacturers' instructions should be followed for boiler piping and return water limits.

System Equipment

Ball Valves: Ball valves are used as isolation valves. Ball valves are recommended on the supply and return lines of the non-condensing boiler, DHW tank and manifolds to ease service. It is also recommended that isolation valves be installed on all zone pumps or install flanged zone pumps to allow easy service.

Bypass Loop: An additional bypass loop is not needed on the boiler in this application. The primary loop will also act as the bypass loop for the boiler.

Zone Pumps: A zone pump (ZP2, ZP3 and ZP4) is required for each radiant manifold to circulate the water through the radiant system. The radiant zone pump must be installed on the mixed side of the thermostatic mixing valve. Without the zone pump on the mixed side, when the mixing valve closes the boiler supply side of the valve, circulation of the radiant system would stop. Individual zone pumps (ZP1 and ZP6) are also used to circulate the water through the DHW loop and the baseboard/radiator loop.

Variable Speed Injection Pump: A variable speed injection pump (VSP1) is required to supply hot boiler water to the secondary loop (radiant manifolds).

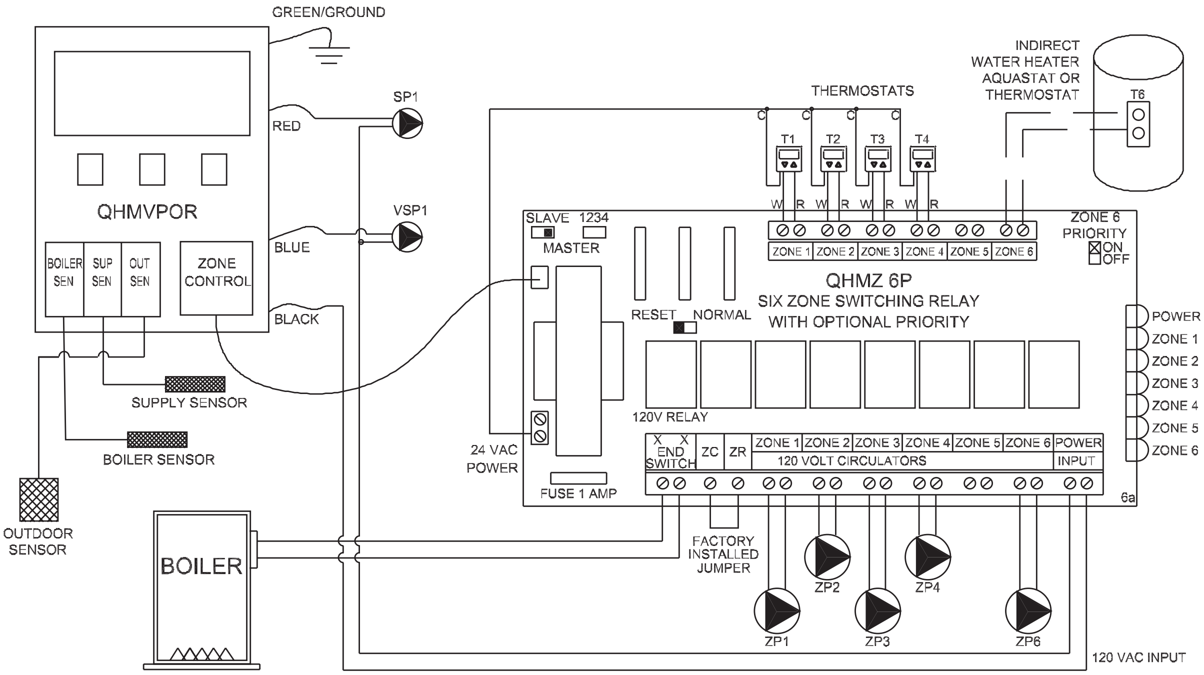
Notes:

1. The piping schematic is conceptual. Some components have been removed for clarity. Layout should be approved by a designer prior to installation.
2. Additional controls and equipment may be necessary to meet specific heat loads and other jobsite conditions.
3. Boiler and other system components must be installed to the manufacturers' instructions. All system components must be installed to all local codes. Isolation valves are recommended on all system components to allow easy service.
4. System should be installed by a licensed professional.

DETAILED ELECTRICAL SCHEMATIC 11

Closed Loop, Non-Condensing Boiler System

Two Temperature Radiant, Three Manifolds, Baseboard, and Domestic Hot Water



Operation: When any thermostat calls for heat, the appropriate circulator is energized and the isolated end switch (X and X) will start the boiler.

Priority Operation: When zone 6 is switched to the priority setting and is actuated, all other zones will stop operation until zone 6 is satisfied. When zone 6 is not switched to priority, all zones will operate independently.

Mode Operation: With the mode switch set to NORMAL, the end switch relay will be energized if any zone is in operation.

Jumper Placement: The jumper should be placed between terminals ZC and ZR. Connect the isolated end switch to the aquastat control on the boiler.

Power Input: Connect 120VAC power input to terminals N and H. Neutral wire to terminal N. Hot wire to terminal H.

Expansion Connections: If future expansion is necessary, set the expansion switch to MASTER on the switching relay that has the designated priority zone. Set all other daisy chained controls to SLAVE. Connect thermostat wire (18-22 gauge) between terminals 1, 2, 3, 4 on the master control to the corresponding 1, 2, 3, 4 on the SLAVE control(s). Controls may be daisy chained up to 20 zones using any combination of zone controls (QHMZ4A or QHMZ6A) or pump relay controls (QHMZ4P or QHMZ6P).

External Diagnostics: Externally visible lights show full functionality of the switching relay. The green light should always be on, indicating that power is connected. When a thermostat calls for heat, both the appropriate circulator and red indicating light are energized.

Warning: Wiring connections must be made in accordance with all applicable electrical codes. Use copper wire only. Failure to follow this instruction can result in personal injury or death and/or property damage. 10-18 gauge wire recommended for 120VAC connections with 9 in.-lbs. max. torque, 12-22 gauge wire for thermostat connections with 9 in.-lbs. max. torque, and 12-22 gauge wire for 24VAC source with 5 in.-lbs. max. torque.

Switch Settings: Master/Slave: Master
Reset/Normal: Reset
Priority Zone: On

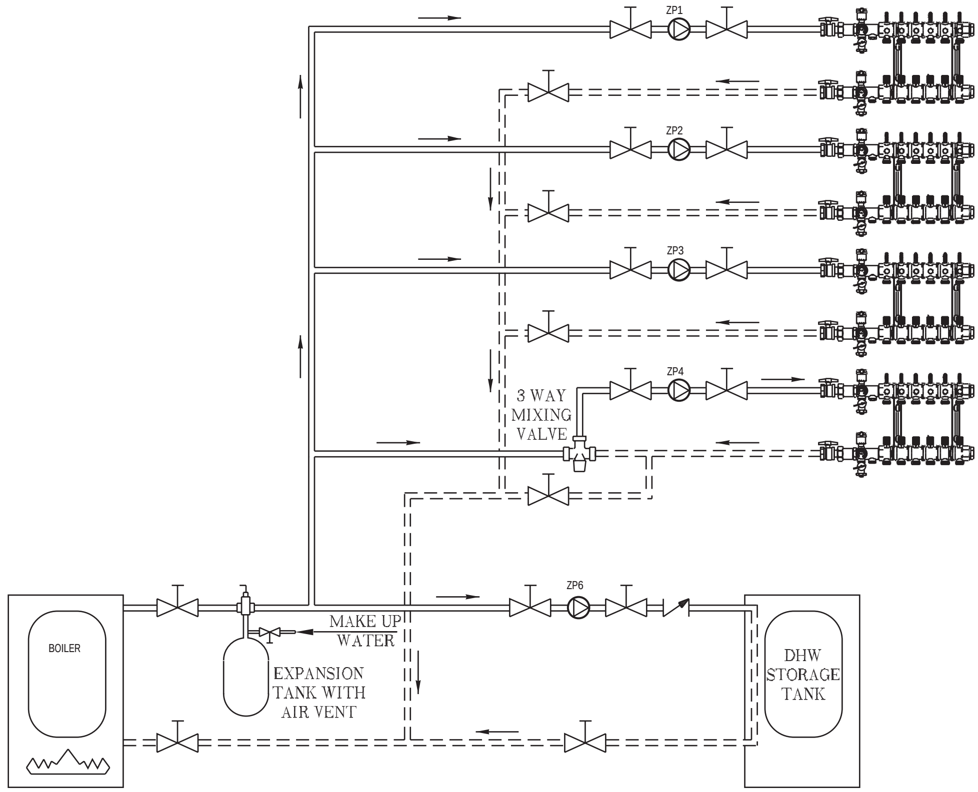
Notes:

1. Additional controls and equipment may be necessary to meet specific heat loads and other jobsite conditions.
2. Boiler and other system components must be installed to the manufacturers' instructions and to all local codes.
3. All electrical components should be installed by a licensed professional.

PIPING SCHEMATIC 12

Closed Loop, Condensing Boiler System

Two Temperature Radiant, Four Manifolds, and Domestic Hot Water



Notes:

1. The piping schematic is conceptual. Some components have been removed for clarity. Layout should be approved by a designer prior to installation.
2. Additional controls and equipment may be necessary to meet specific heat loads and other jobsite conditions.
3. Boiler and other system components must be installed to the manufacturers' instructions. All system components must be installed to all local codes. Isolation valves are recommended on all system components to allow easy service.
4. System should be installed by a licensed professional.

Where Used

Radiant Panel where the supply temperature is different for one manifold and the other three manifolds have the same supply temperature and domestic hot water is used.

Description

The piping layout shows a condensing boiler supplying water to a domestic hot water (DHW) storage tank, one radiant manifold with a lower supply temperature than the other three manifolds. A separate zone pump (ZP6) and a check valve are required on the supply side of the DHW loop. A 3-way mixing thermostatic mixing valve and zone pump (ZP4) are required on the manifold with the lower supply water temperature. The mixing valve will mix the hot boiler supply water with the cool radiant return water to give the required radiant panel supply water temperature. A zone pump (ZP1 - ZP3) is used to circulate the supply water for each radiant manifold. Boiler manufacturers' instructions should be followed for boiler piping and return water limits.

System Equipment

Ball Valves: Ball valves are used as isolation valves. Ball valves are recommended on the supply and return lines of the non-condensing boiler, DHW tank and manifolds to ease service. It is also recommended that isolation valves be installed on all zone pumps or install flanged zone pumps to allow easy service.

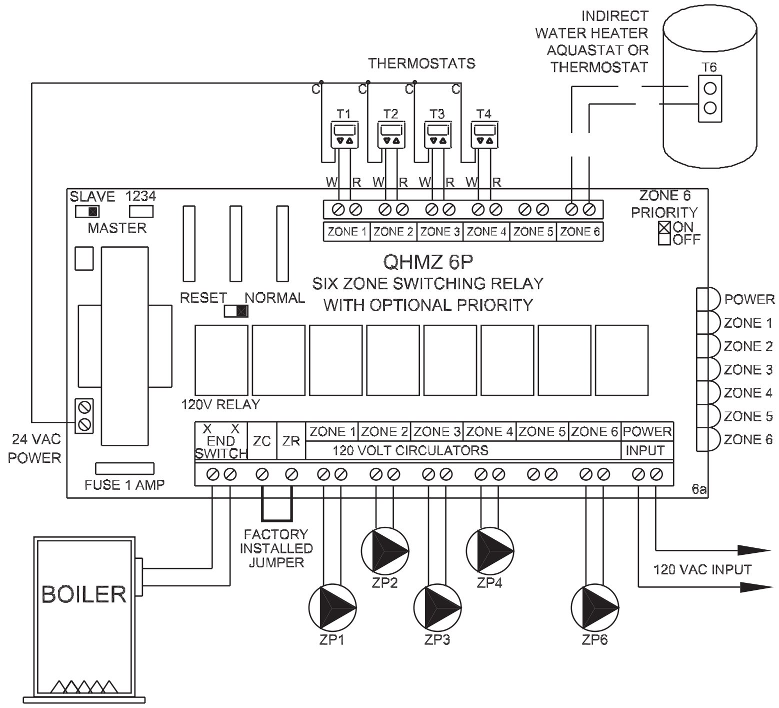
Bypass Loop: An additional bypass loop is not used with a condensing boiler.

Zone Pump: A zone pump (ZP1 - ZP4) is required for each radiant manifold to circulate the water through the radiant system. The radiant zone pump (ZP4) must be installed on the mixed side of the thermostatic mixing valve. Without the zone pump on the mixed side, when the mixing valve closes the boiler supply side of the valve, circulation of the radiant system would stop. Individual zone pump are also used to circulate the water through the DHW loop and for each radiant manifold.

DETAILED ELECTRICAL SCHEMATIC 12

Closed Loop, Condensing Boiler System

Two Temperature Radiant, Four Manifolds, and Domestic Hot Water



Operation: When any thermostat calls for heat, the appropriate circulator is energized and the isolated end switch (X and X) will start the boiler.

Priority Operation: When zone 6 is switched to the priority setting and is actuated, all other zones will stop operation until zone 6 is satisfied. When zone 6 is not switched to priority, all zones will operate independently.

Mode Operation: With the mode switch set to NORMAL, the end switch relay will be energized if any zone is in operation.

Jumper Placement: The jumper should be placed between terminals ZC and ZR. Connect the isolated end switch to the aquastat control on the boiler.

Power Input: Connect 120VAC power input to terminals N and H. Neutral wire to terminal N. Hot wire to terminal H.

Expansion Connections: If future expansion is necessary, set the expansion switch to MASTER on the switching relay that has the designated priority zone. Set all other daisy chained controls to SLAVE. Connect thermostat wire (18-22 gauge) between terminals 1, 2, 3, 4 on the master control to the corresponding 1, 2, 3, 4 on the SLAVE control(s). Controls may be daisy chained up to 20 zones using any combination of zone controls (QHMZ4A or QHMZ6A) or pump relay controls (QHMZ4P or QHMZ6P).

External Diagnostics: Externally visible lights show full functionality of the switching relay. The green light should always be on, indicating that power is connected. When a thermostat calls for heat, both the appropriate circulator and red indicating light are energized.

Warning: Wiring connections must be made in accordance with all applicable electrical codes. Use copper wire only. Failure to follow this instruction can result in personal injury or death and/or property damage. 10-18 gauge wire recommended for 120VAC connections with 9 in.-lbs. max. torque, 12-22 gauge wire for thermostat connections with 9 in.-lbs. max. torque, and 12-22 gauge wire for 24VAC source with 5 in.-lbs. max. torque.

Switch Settings: Master/Slave: Master
Reset/Normal: Normal
Priority Zone: On

Notes:

1. Additional controls and equipment may be necessary to meet specific heat loads and other jobsite conditions.
2. Boiler and other system components must be installed to the manufacturers' instructions and to all local codes.
3. All electrical components should be installed by a licensed professional.

APPENDIX A

DESIGN CHECK LIST

RADIANT HEAT PROJECT SHEET

WATER SUPPLY TEMPERATURE CHARTS

Design Checklist

1. Complete Room-By-Room Heat Loss Analysis
2. Calculate Room-By-Room Upward Load.
   If Floor Heating, Downward Load, If Ceiling Heating,
   Inward Load, If Wall Heating.
3. Determine Surface Temperature
4. Select Tube Spacing
5. Select Temperature Differential
6. Determine Water Supply Temperature
7. Complete Back Losses Analysis
8. Select Tubing Layout And Pattern
9. Determine Manifold(s) Location(s)
10. Determine Flow Rate Requirements
11. Determine Loop Lengths And Number Of Loops Required
12. Calculate Pressure Drop For Individual Loops
13. Determine Pressure Drop For Entire System
14. Size And Select Circulating Pump(s)
15. Determine Expansion Tank Requirements
16. Select Heat Source
17. Select System Controls
18. Develop Material List

ZURN RADIANT HEATING PROJECT SHEET

Hard Copy Or Electronic Blueprints Must Be Included

The following data is pertinent to designing a proper radiant heating system and must be accurate and complete when supplied to the designer (please be specific). Use multiple copies of this sheet for additional room information.

Project Name: ____________________
Address: ____________________
City: ____________________
State: ____________________
Zip: ____________________
Phone: ____________________
Fax: ____________________
E-mail: ____________________

Indoor Design Temperature: ____________
Ceiling R-Value: ____________
Slab Edge Insulation R-Value: ____________
Slab Back Insulation R-Value: ____________
Slab Perimeter Insulation R-Value: ____________
Staple-Up Insulation R-Value: ____________
Zoning Preferred: Pumps or Actuator
Heat Source: Boiler or Water Heater

Room – ____________
Room Height: ____________
Window Type or R-Value: ____________
Outside Door Type or R-Value: ____________
Wall Type or R-Value: ____________
Floor Type (slab or staple-up): ____________
Floor Covering Type and R-Value (each layer):
____
Zone Number: ____________

Room – ____________
Room Height: ____________
Window Type or R-Value: ____________
Outside Door Type or R-Value: ____________
Wall Type or R-Value: ____________
Floor Type (slab or staple-up): ____________
Floor Covering Type and R-Value (each layer):
____
Zone Number: ____________

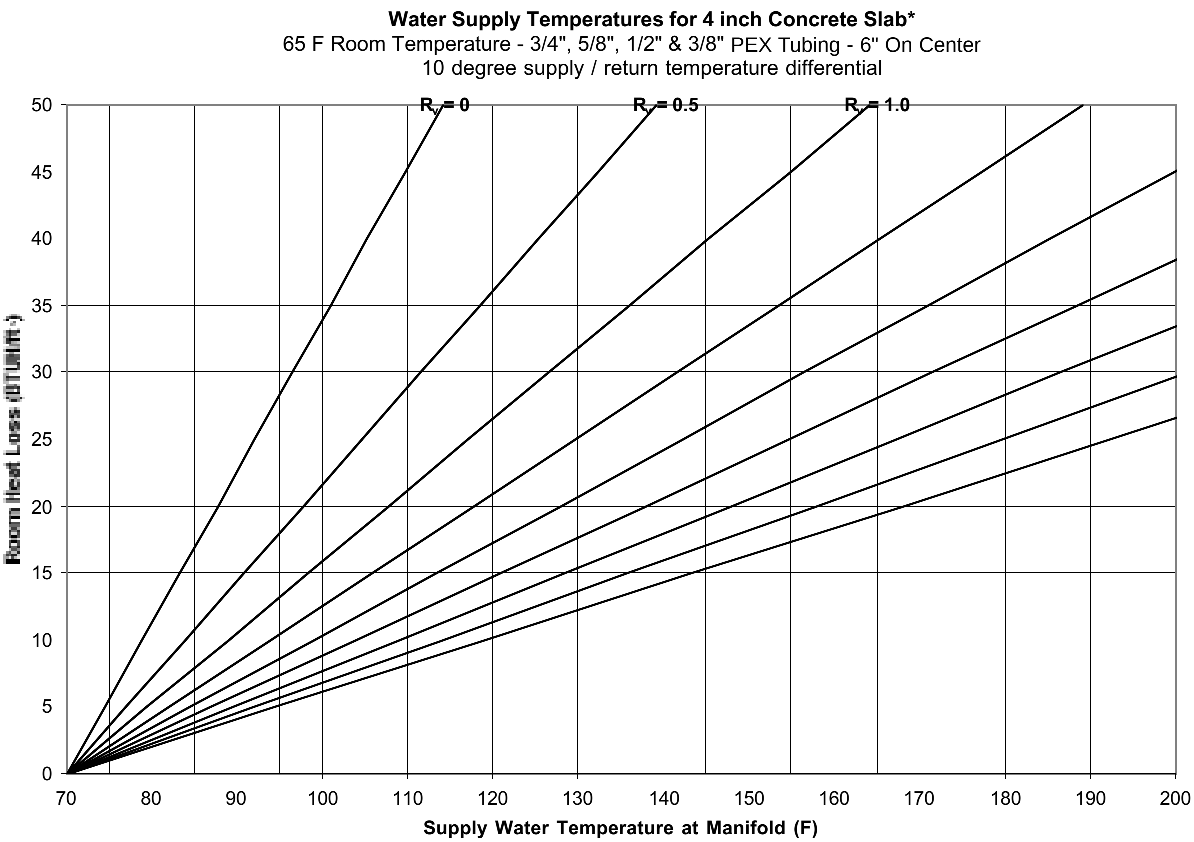
Room – ____________
Room Height: ____________
Window Type or R-Value: ____________
Outside Door Type or R-Value: ____________
Wall Type or R-Value: ____________
Floor Type (slab or staple-up): ____________
Floor Covering Type and R-Value (each layer):
____
Zone Number: ____________

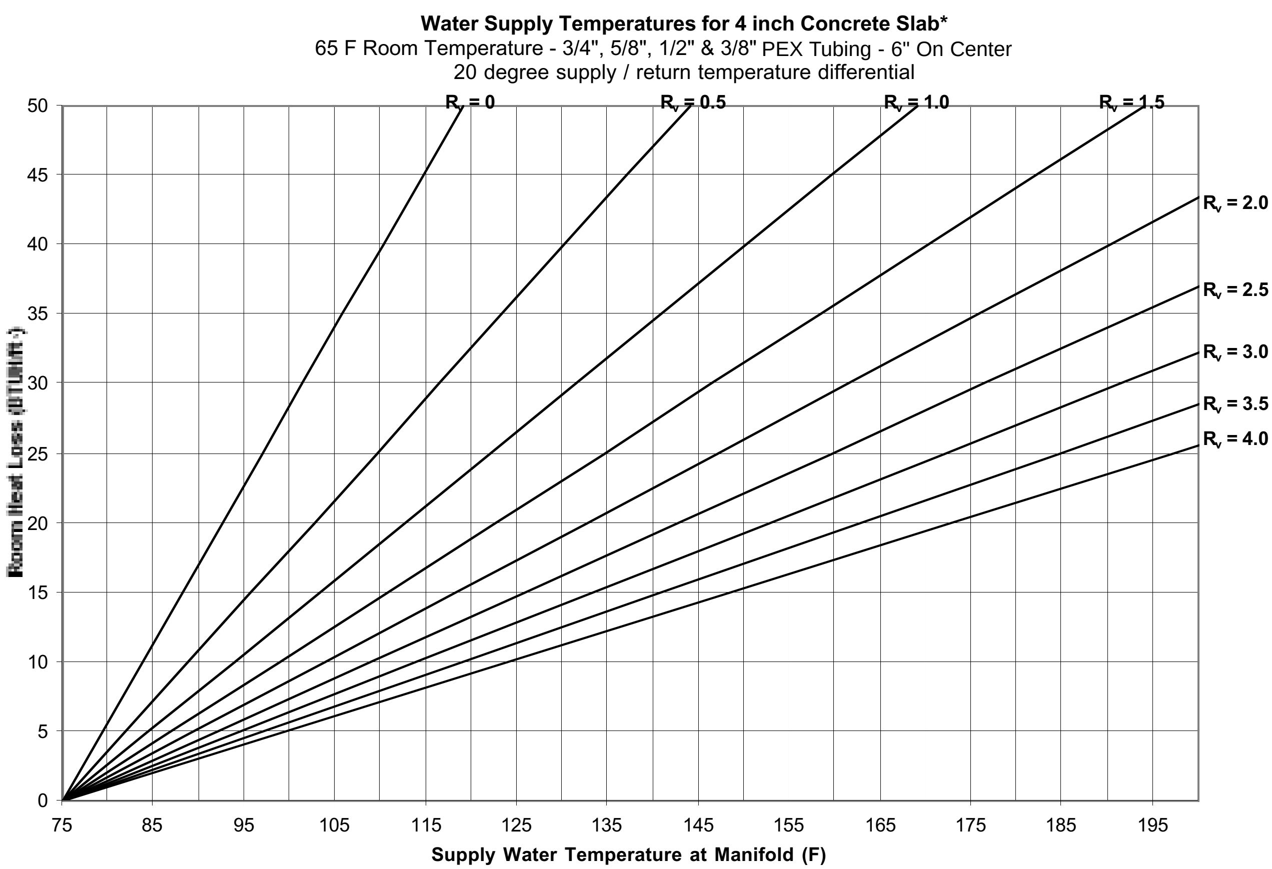
Room – ____________
Room Height: ____________
Window Type or R-Value: ____________
Outside Door Type or R-Value: ____________
Wall Type or R-Value: ____________
Floor Type (slab or staple-up): ____________
Floor Covering Type and R-Value (each layer):
____
Zone Number: ____________

Controls Desired: ____
____
____
____

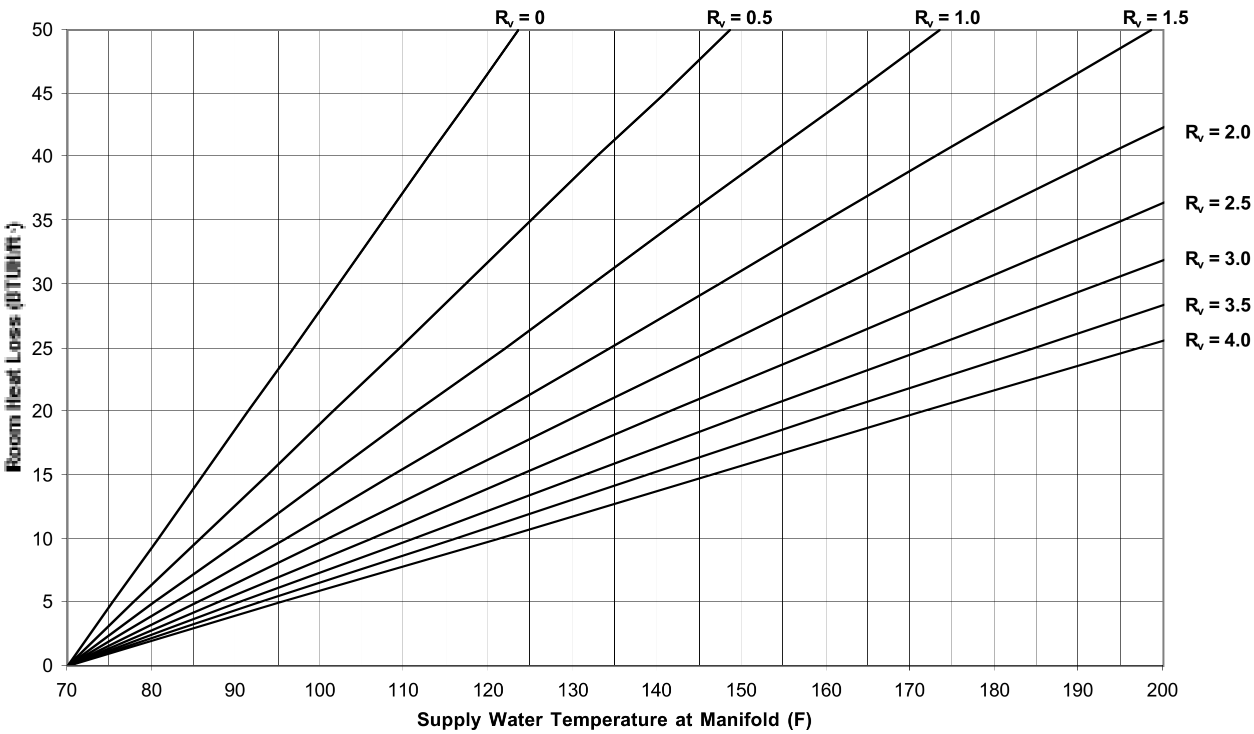
Miscellaneous Information: ____
____
____
____

ZURN RADIANT HEATING SYSTEMS · 1801 PITTSBURGH AVENUE, ERIE, PA 16502 · PHONE: 814-875-1358 · FAX: 814-871-6141

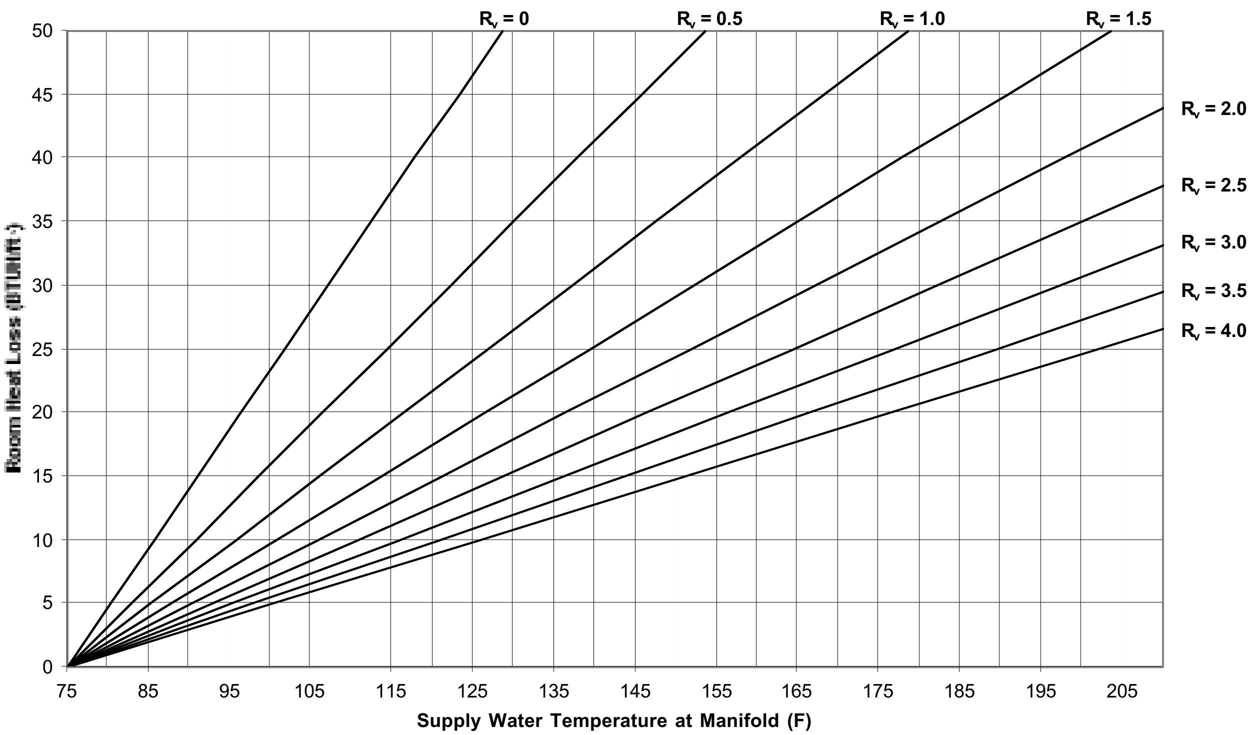

Water Supply Temperatures for 4 inch Concrete Slab*
65 F Room Temperature - 3/4", 5/8", 1/2" & 3/8" PEX Tubing - 6" On Center
10 degree supply / return temperature differential
R_v = 0
R_v = 0.5
R_v = 1.0
Room Heat Loss (BTUH/ft²)
0
5
10
15
20
25
30
35
40
45
50
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Supply Water Temperature at Manifold (F)


Water Supply Temperatures for 4 inch Concrete Slab*
65 F Room Temperature - 3/4", 5/8", 1/2" & 3/8" PEX Tubing - 6" On Center
20 degree supply / return temperature differential
R_v = 0
R_v = 0.5
R_v = 1.0
R_v = 1.5
R_v = 2.0
R_v = 2.5
R_v = 3.0
R_v = 3.5
R_v = 4.0
Room Heat Loss (BTUH/ft²)
0
5
10
15
20
25
30
35
40
45
50
75
85
95
105
115
125
135
145
155
165
175
185
195
Supply Water Temperature at Manifold (F)

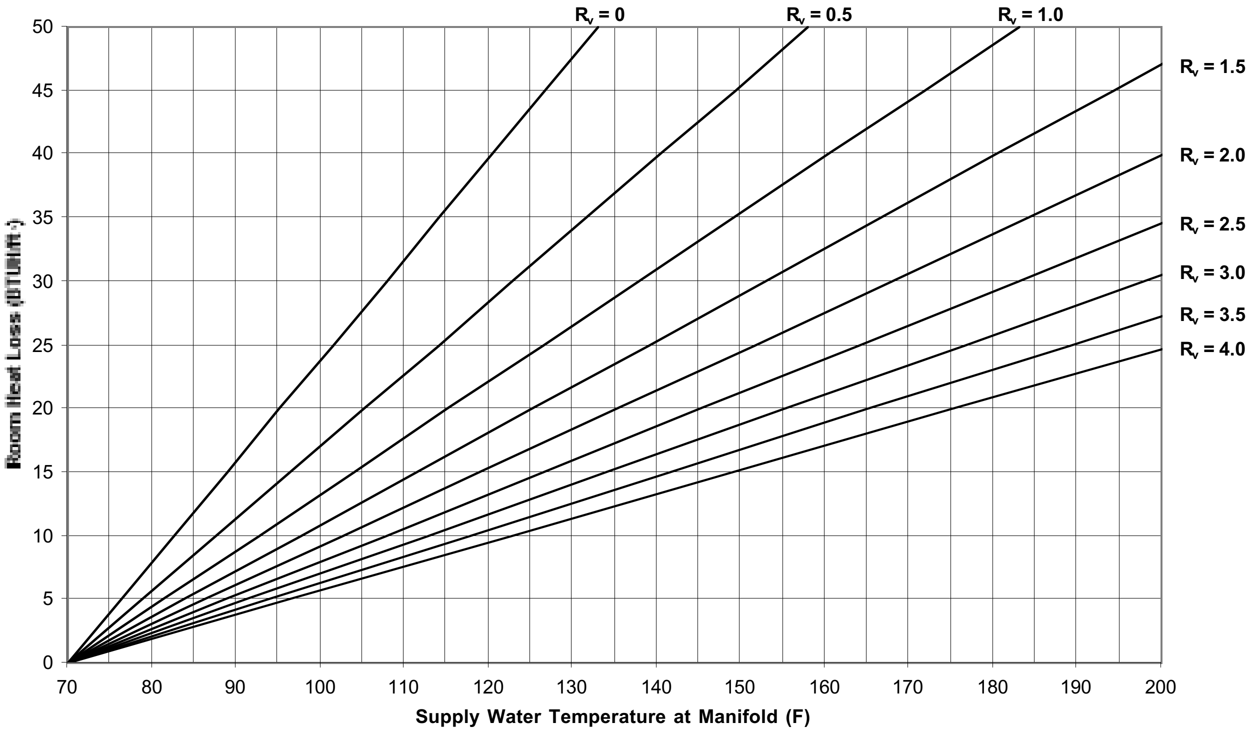
Water Supply Temperatures for 4 inch Concrete Slab*
65 F Room Temperature - 3/4", 5/8", 1/2" & 3/8" PEX Tubing - 9" On Center
10 degree supply / return temperature differential



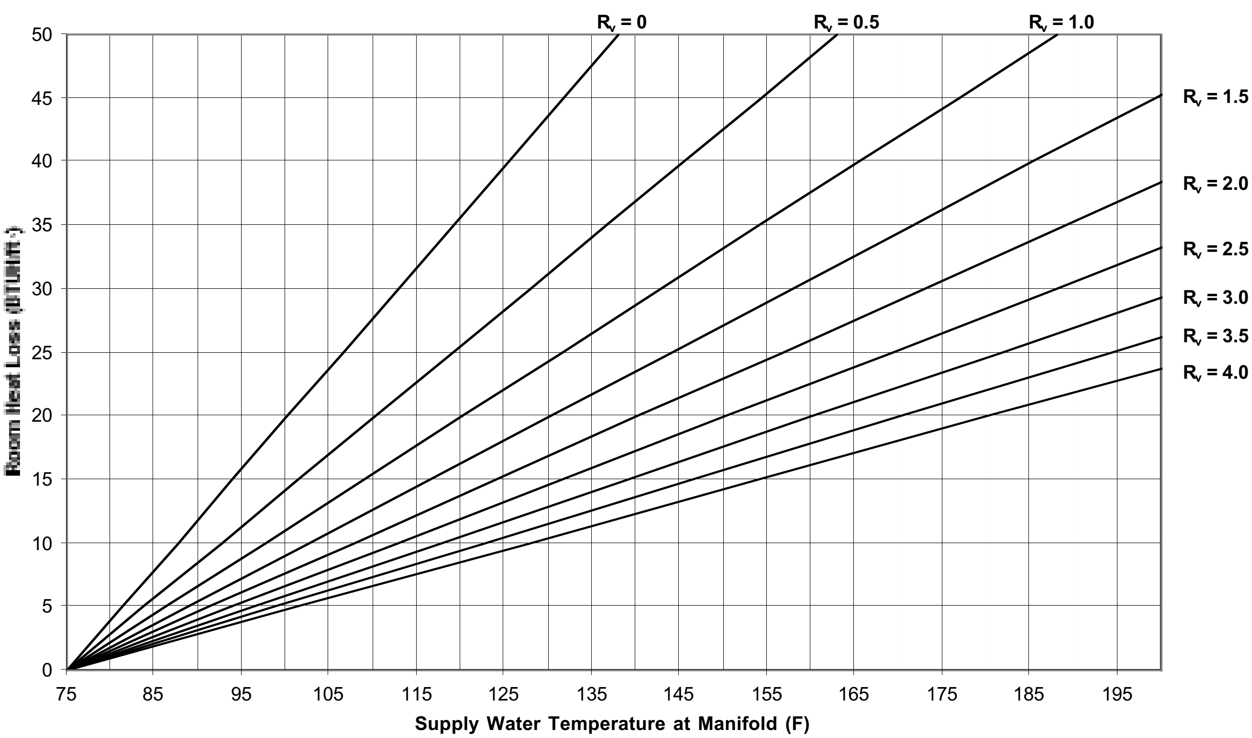
Water Supply Temperatures for 4 inch Concrete Slab*
65 F Room Temperature - 3/4", 5/8", 1/2" & 3/8" PEX Tubing - 9" On Center
20 degree supply / return temperature differential



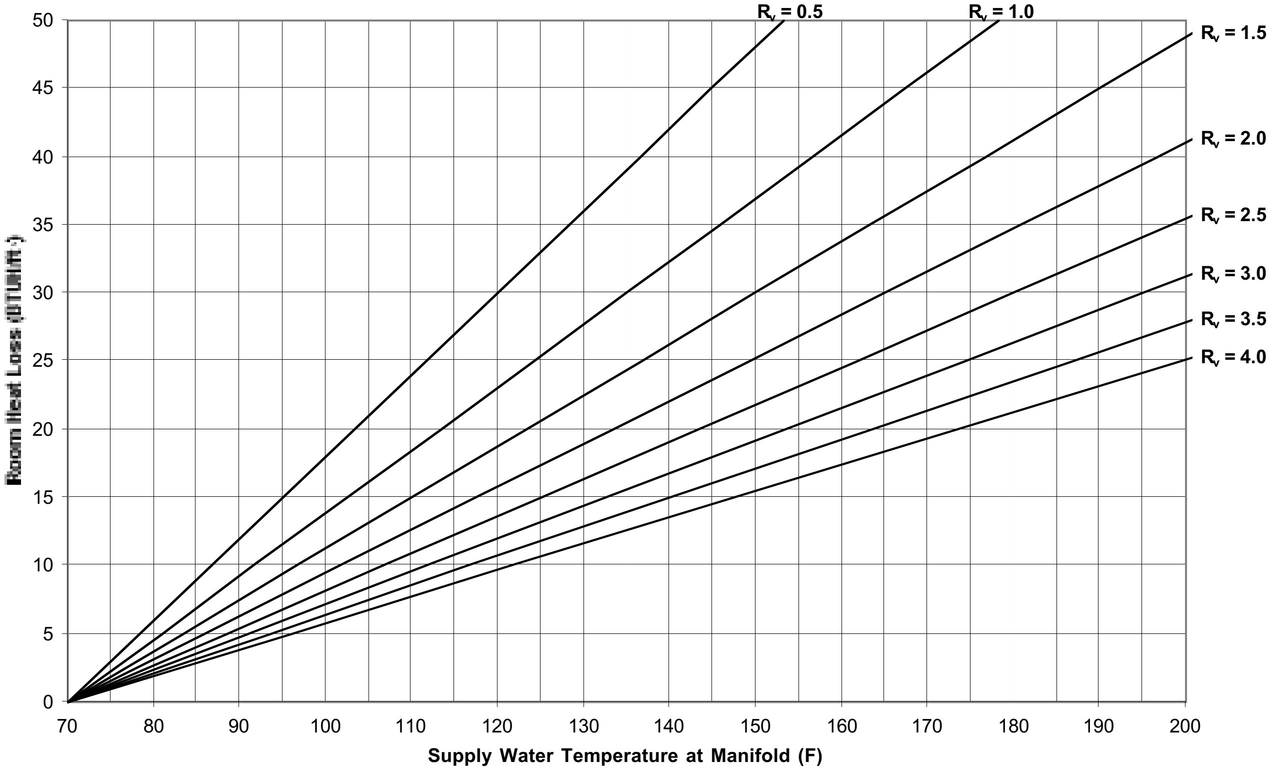
Water Supply Temperatures for 4 inch Concrete Slab*
65 F Room Temperature - 3/4", 5/8" & 1/2" PEX Tubing - 12" On Center
10 degree supply / return temperature differential



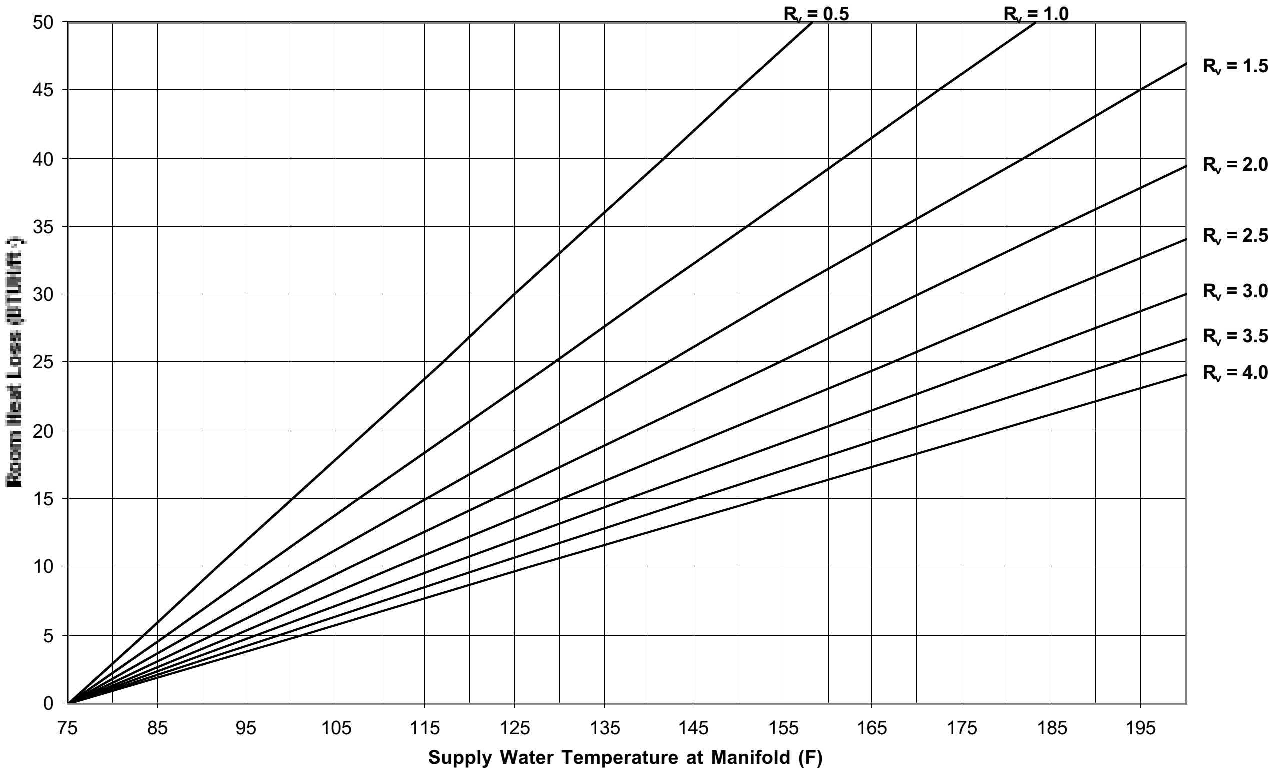
Water Supply Temperatures for 4 inch Concrete Slab*
65 F Room Temperature - 3/4", 5/8" & 1/2" PEX Tubing - 12" On Center
20 degree supply / return temperature differential



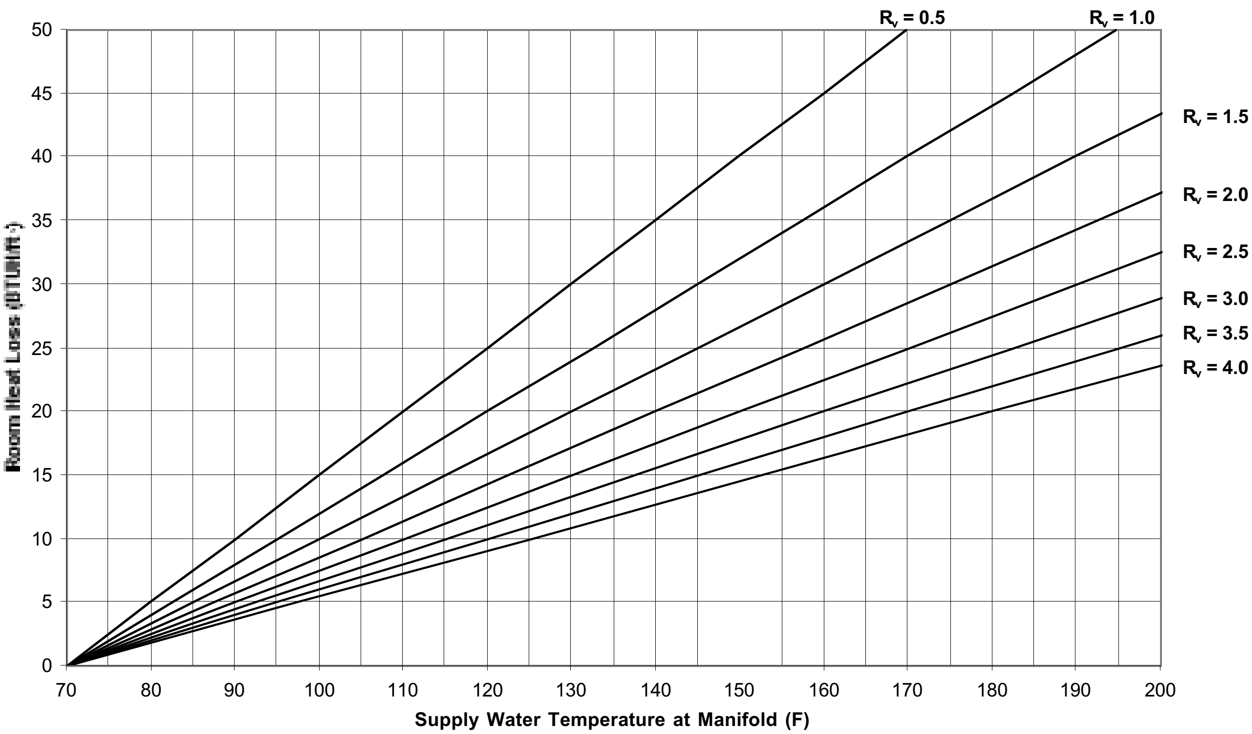
Water Supply Temperatures for 2 inch Poured Floor Underlayment*
65 F Room Temperature - 3/4", 5/8", 1/2" & 3/8" PEX Tubing - 6" On Center
10 degree supply / return temperature differential



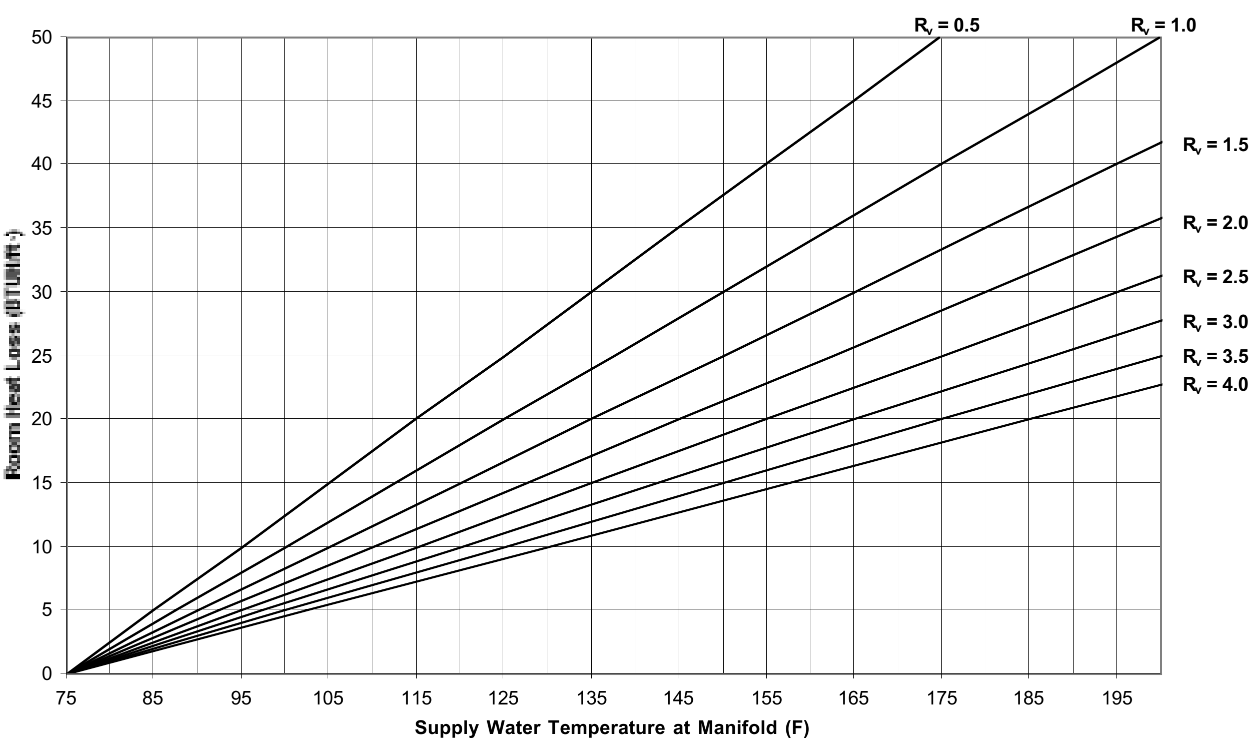
Water Supply Temperatures for 2 inch Poured Floor Underlayment*
65 F Room Temperature - 3/4", 5/8", 1/2" & 3/8" PEX Tubing - 6" On Center
20 degree supply / return temperature differential



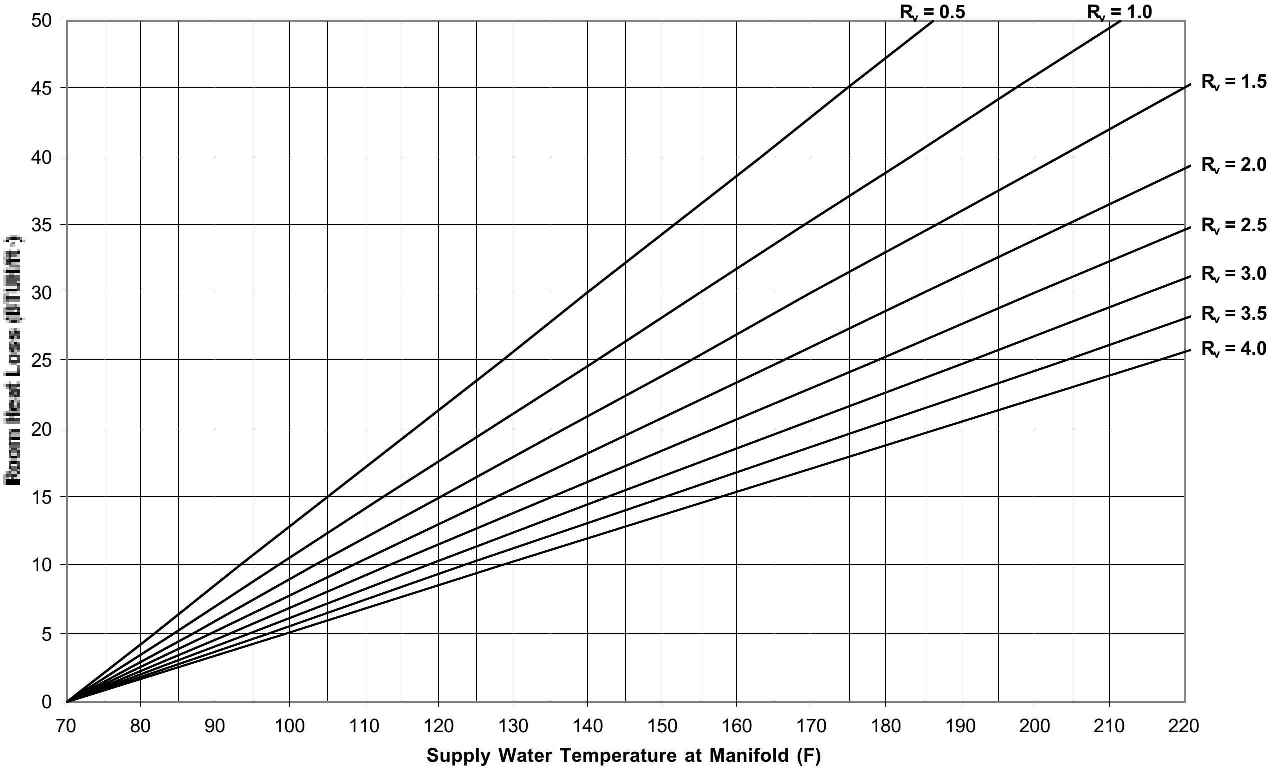
Water Supply Temperatures for 2 inch Poured Floor Underlayment*
65 F Room Temperature - 3/4", 5/8", 1/2" & 3/8" PEX Tubing - 9" On Center
10 degree supply / return temperature differential



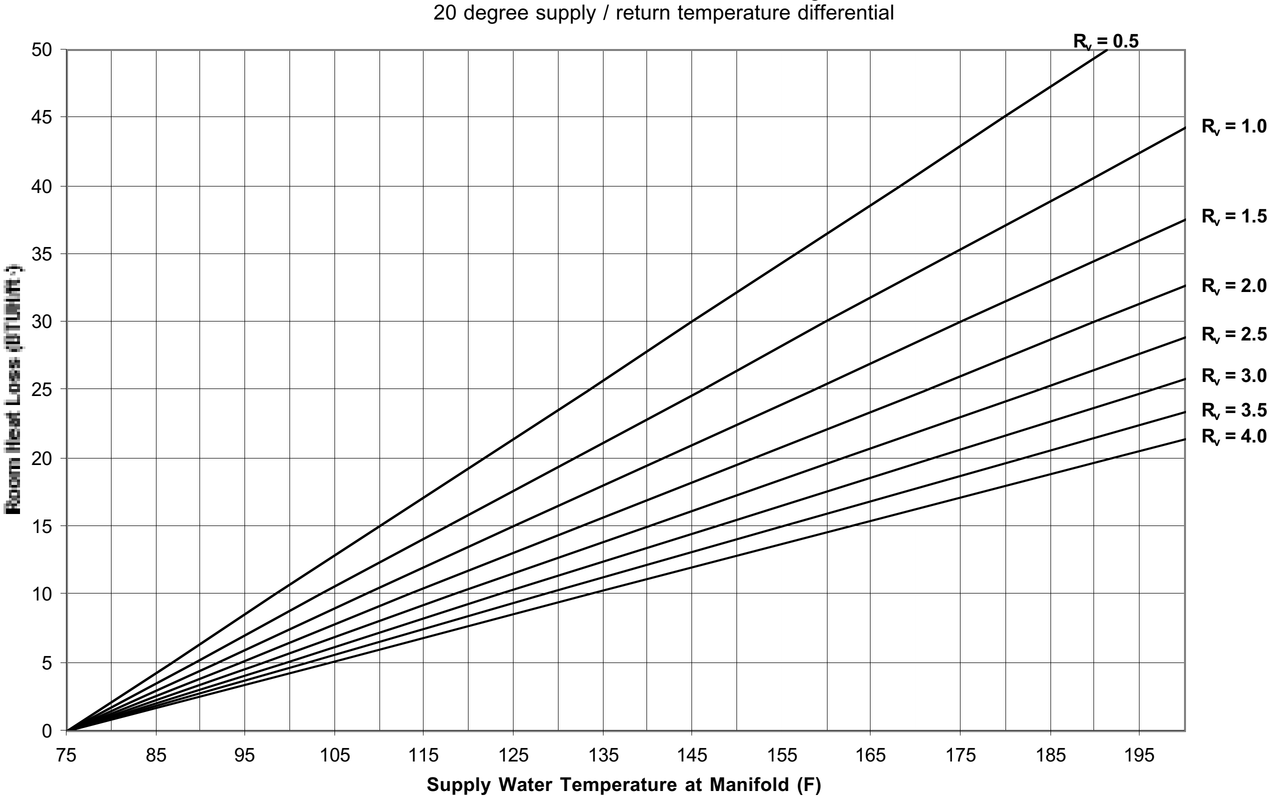
Water Supply Temperatures for 2 inch Poured Floor Underlayment*
65 F Room Temperature - 3/4", 5/8", 1/2" & 3/8" PEX Tubing - 9" On Center
20 degree supply / return temperature differential



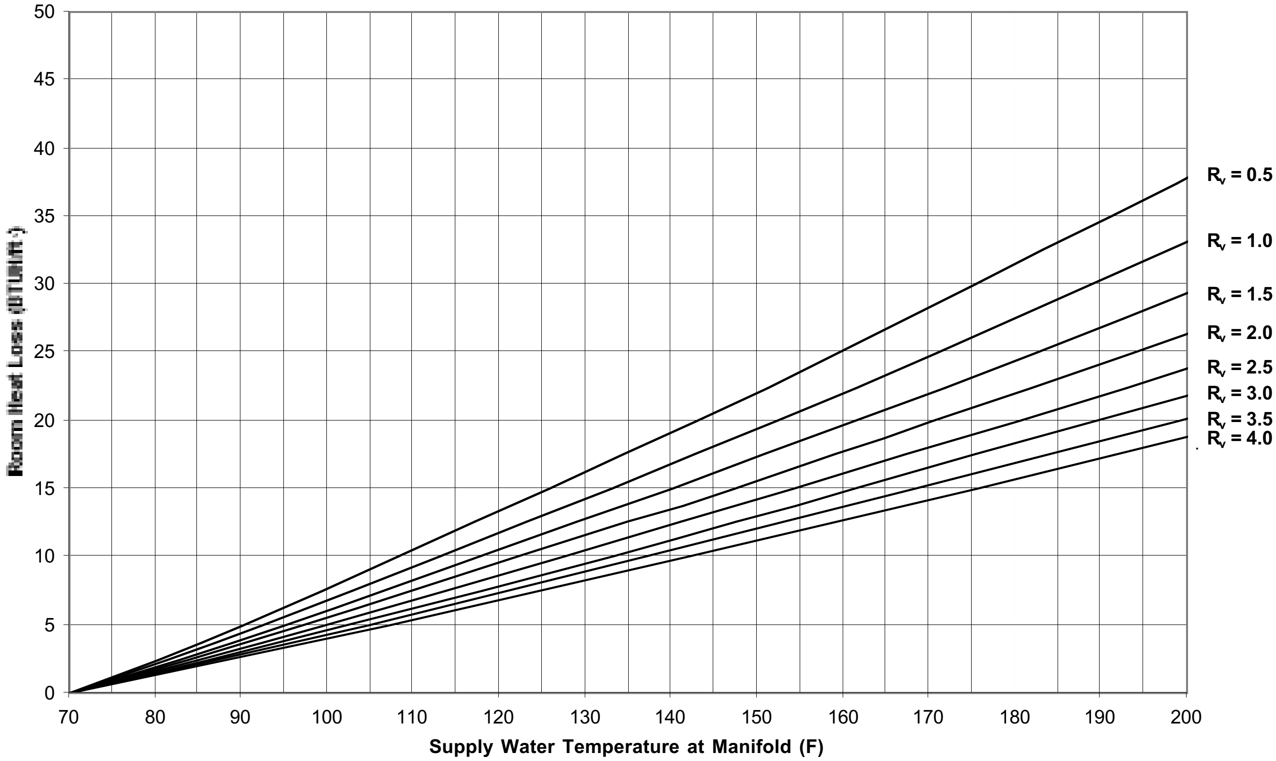
Water Supply Temperatures for 2 inch Poured Floor Underlayment*
65 F Room Temperature - 3/4", 5/8" & 1/2" PEX Tubing - 12" On Center
10 degree supply / return temperature differential



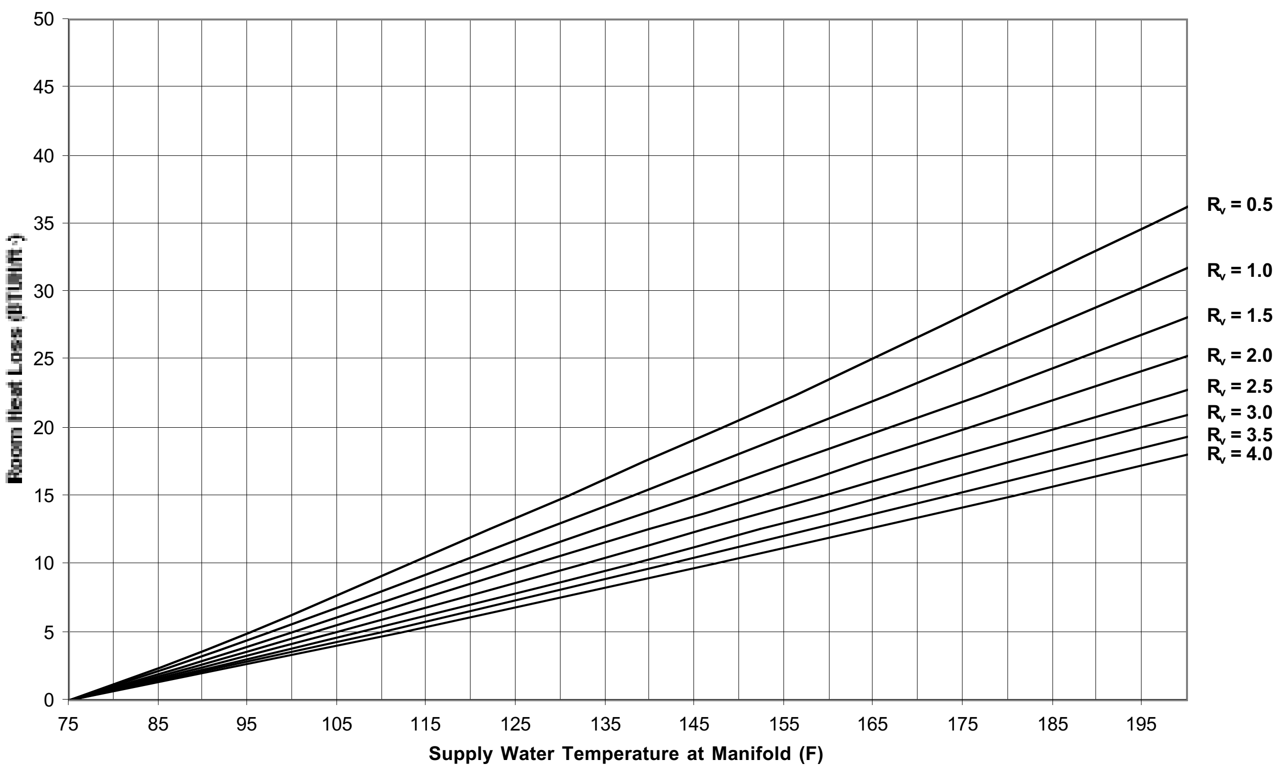
Water Supply Temperatures for 2 inch Poured Floor Underlayment*
65 F Room Temperature - 3/4", 5/8" & 1/2" PEX Tubing - 12" On Center
20 degree supply / return temperature differential



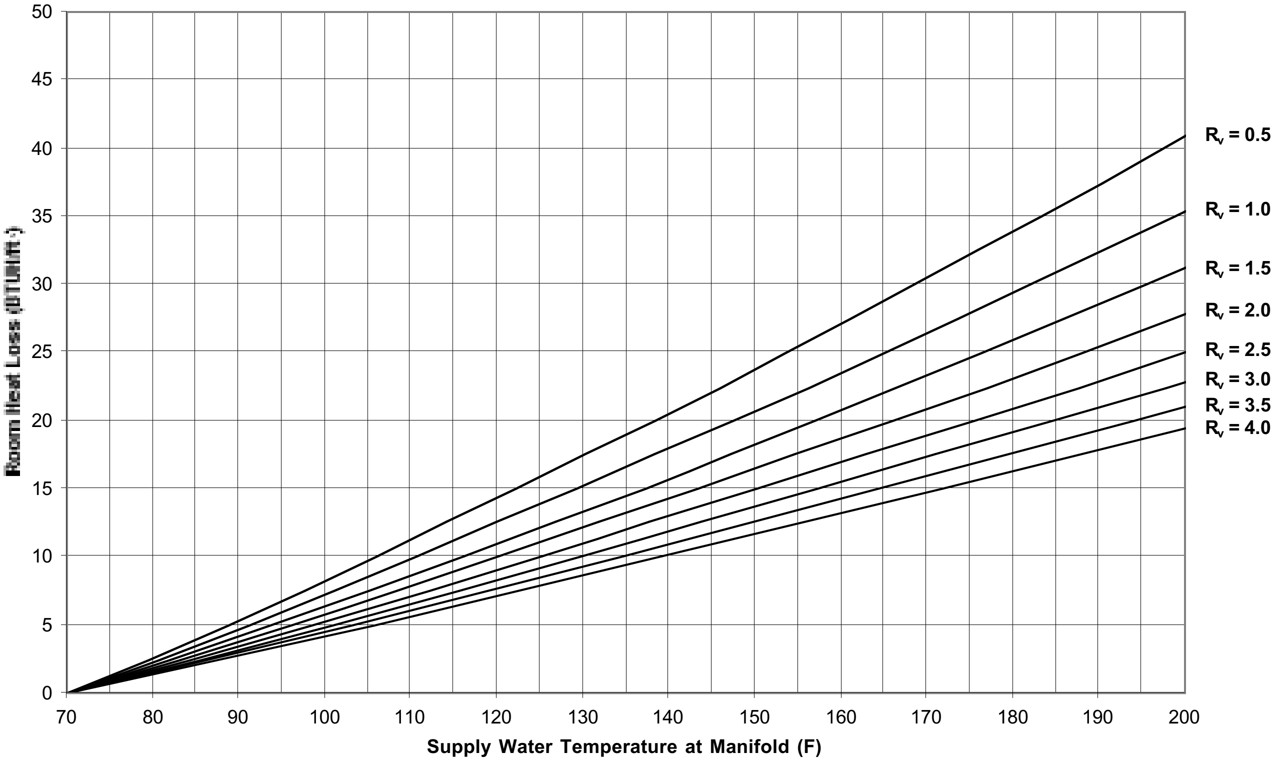
Water Supply Temperatures for 3/4" Plywood Subfloor
65 F Room Temperature - 3/4", 5/8" & 1/2" PEX Tubing - 8" On Center
10 degree supply / return temperature differential



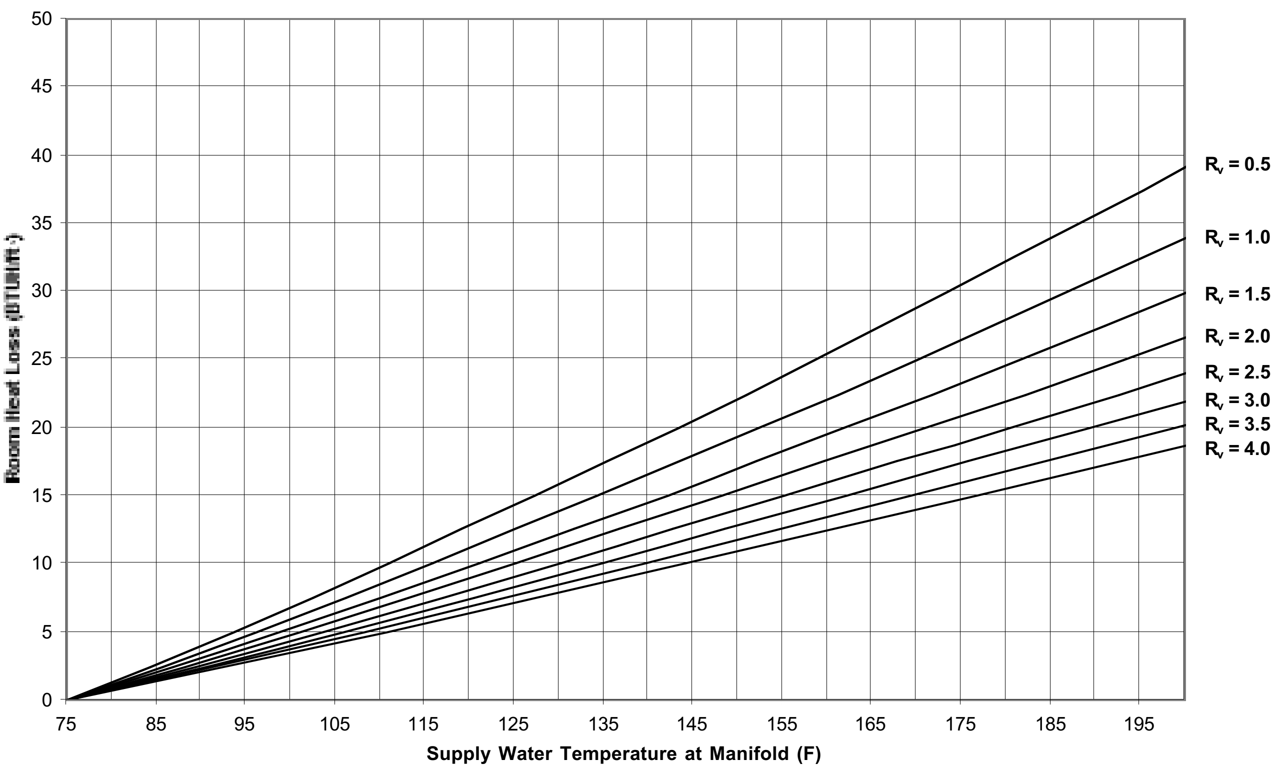
Water Supply Temperatures for 3/4" Plywood Subfloor
65 F Room Temperature - 3/4", 5/8" & 1/2" PEX Tubing - 8" On Center
20 degree supply / return temperature differential



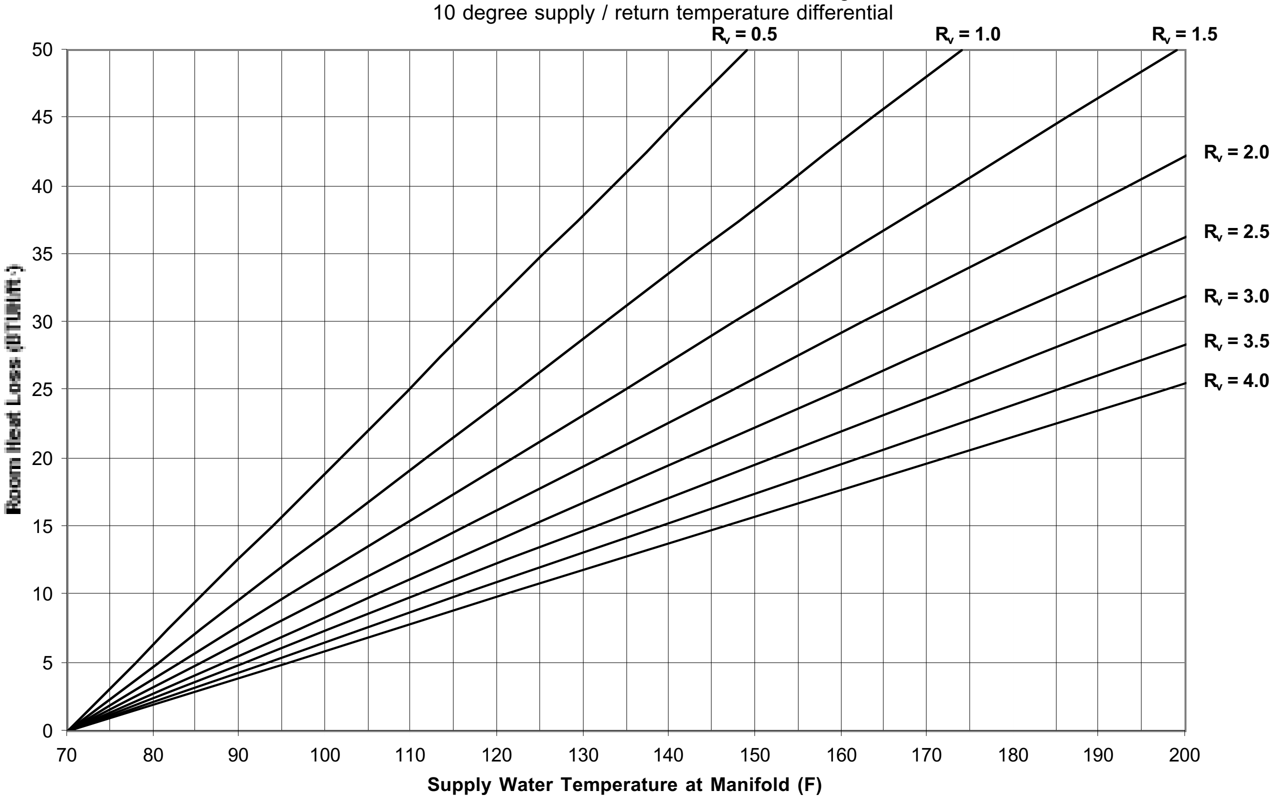
Water Supply Temperatures for Aluminum Plates in Joist Cavity with 3/4" Plywood Subfloor
65 F Room Temperature - 3/4", 5/8" & 1/2" PEX Tubing - 8" On Center
10 degree supply / return temperature differential



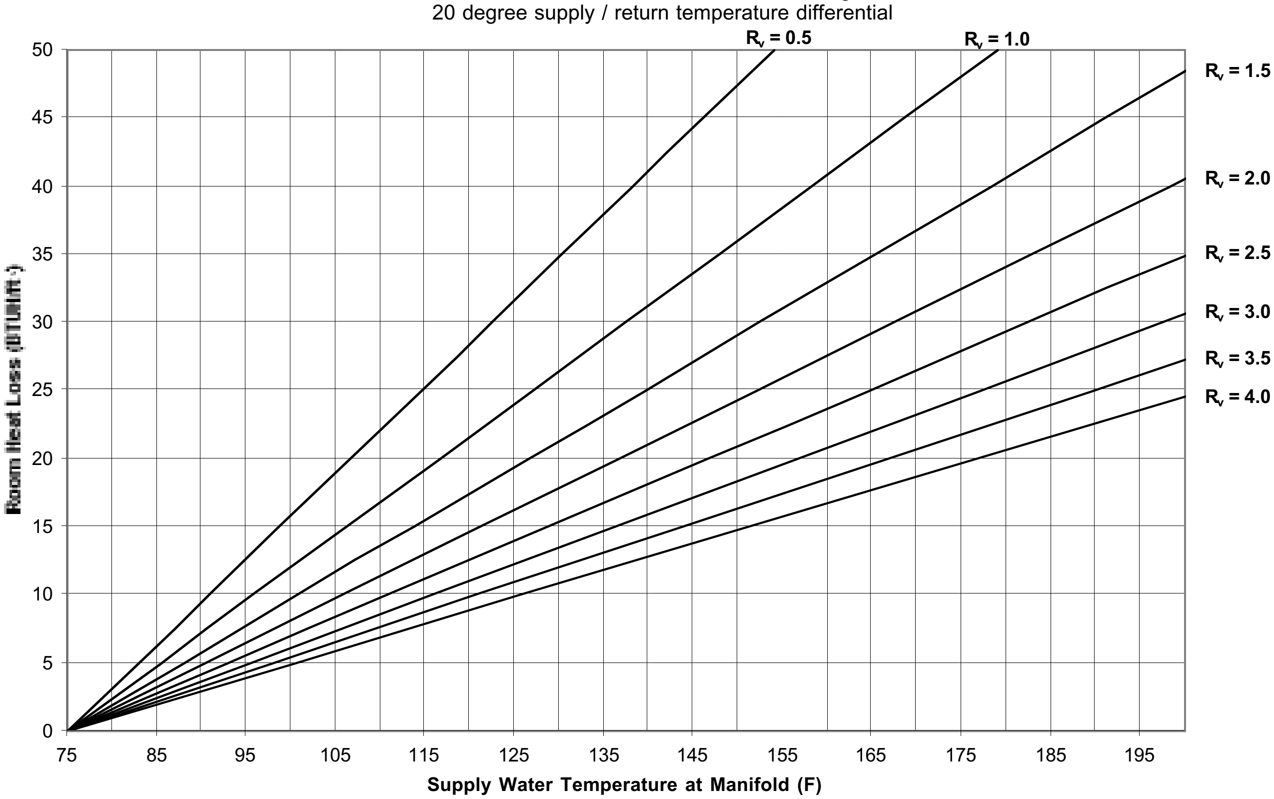
Water Supply Temperatures for Aluminum Plates in Joist Caivity with 3/4" Plywood Subfloor
65 F Room Temperature - 3/4", 5/8" & 1/2" PEX Tubing - 8" On Center
20 degree supply / return temperature differential



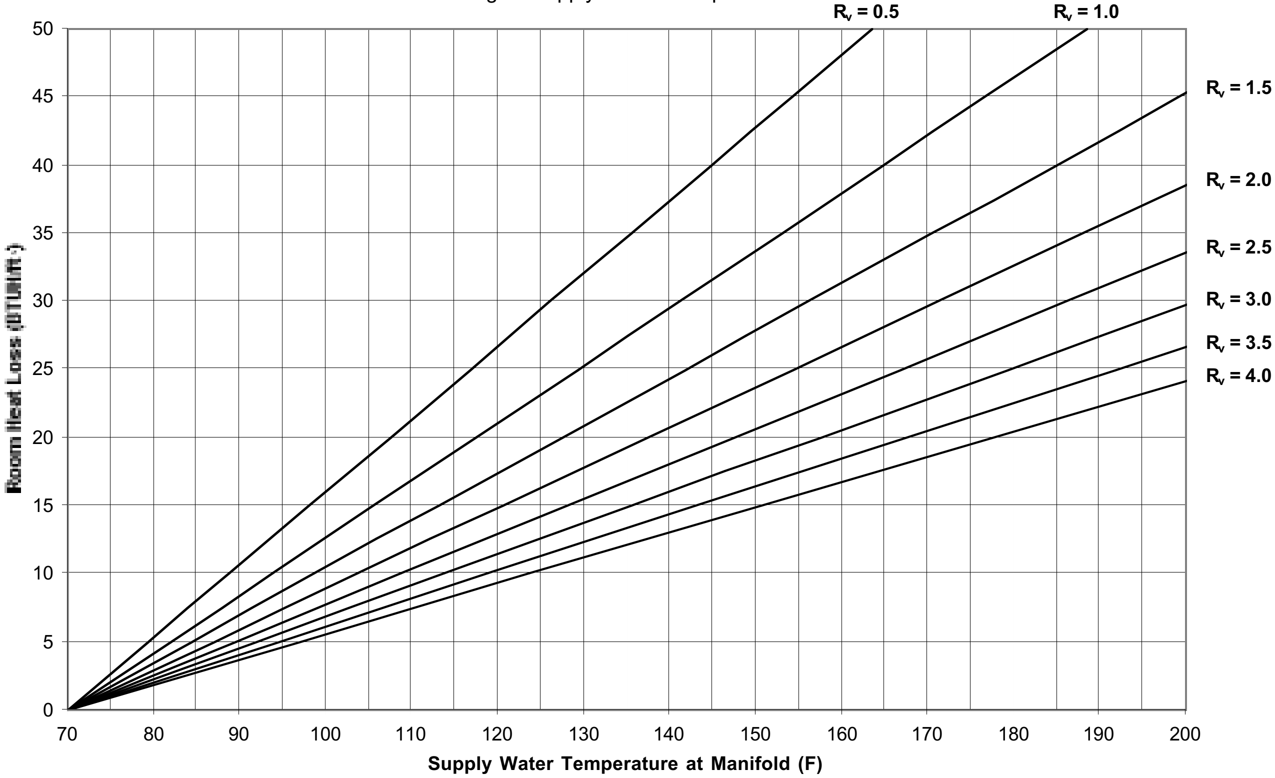
Water Supply Temperatures for Aluminum Plates above Joists with 3/4" Plywood Subfloor
65 F Room Temperature - 3/4", 5/8", 1/2" & 3/8" PEX Tubing - 6" On Center
10 degree supply / return temperature differential



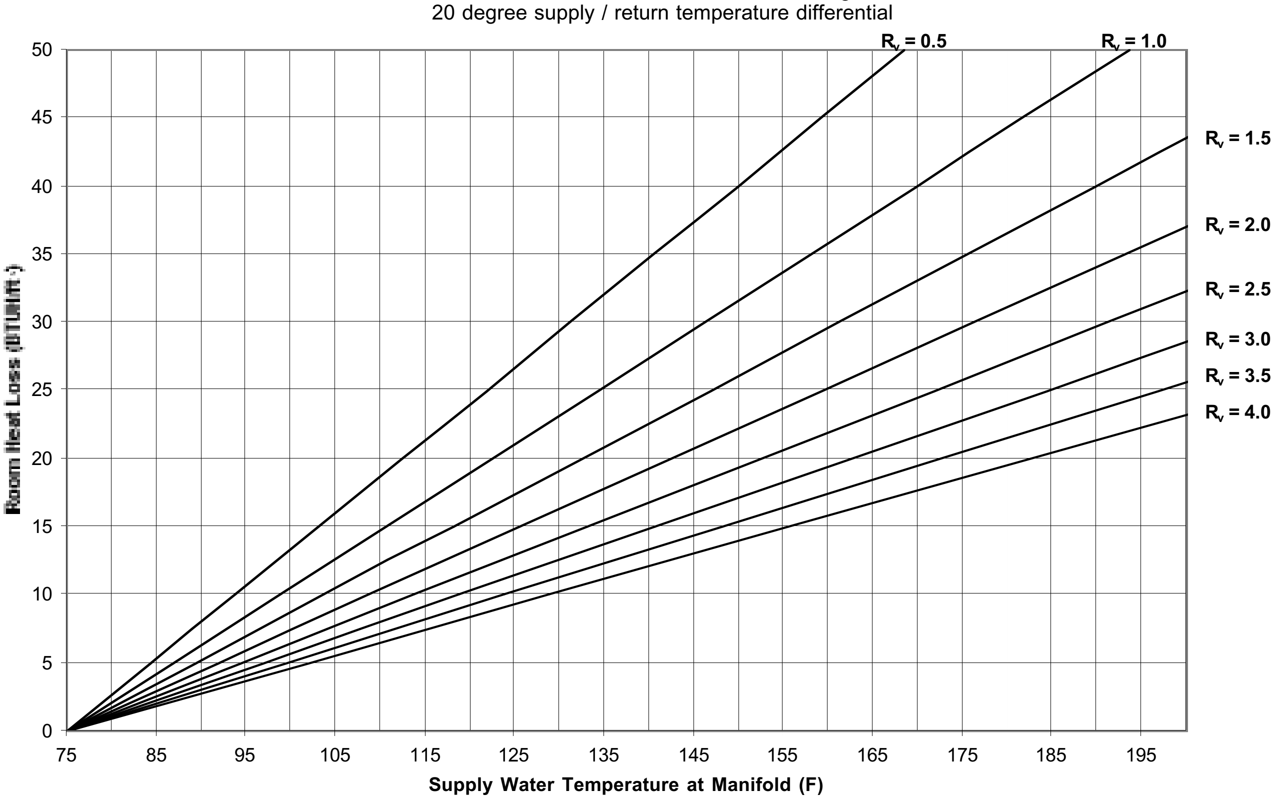
Water Supply Temperatures for Aluminum Plates above Joists with 3/4" Plywood Subfloor
65 F Room Temperature - 3/4", 5/8", 1/2" & 3/8" PEX Tubing - 6" On Center
20 degree supply / return temperature differential



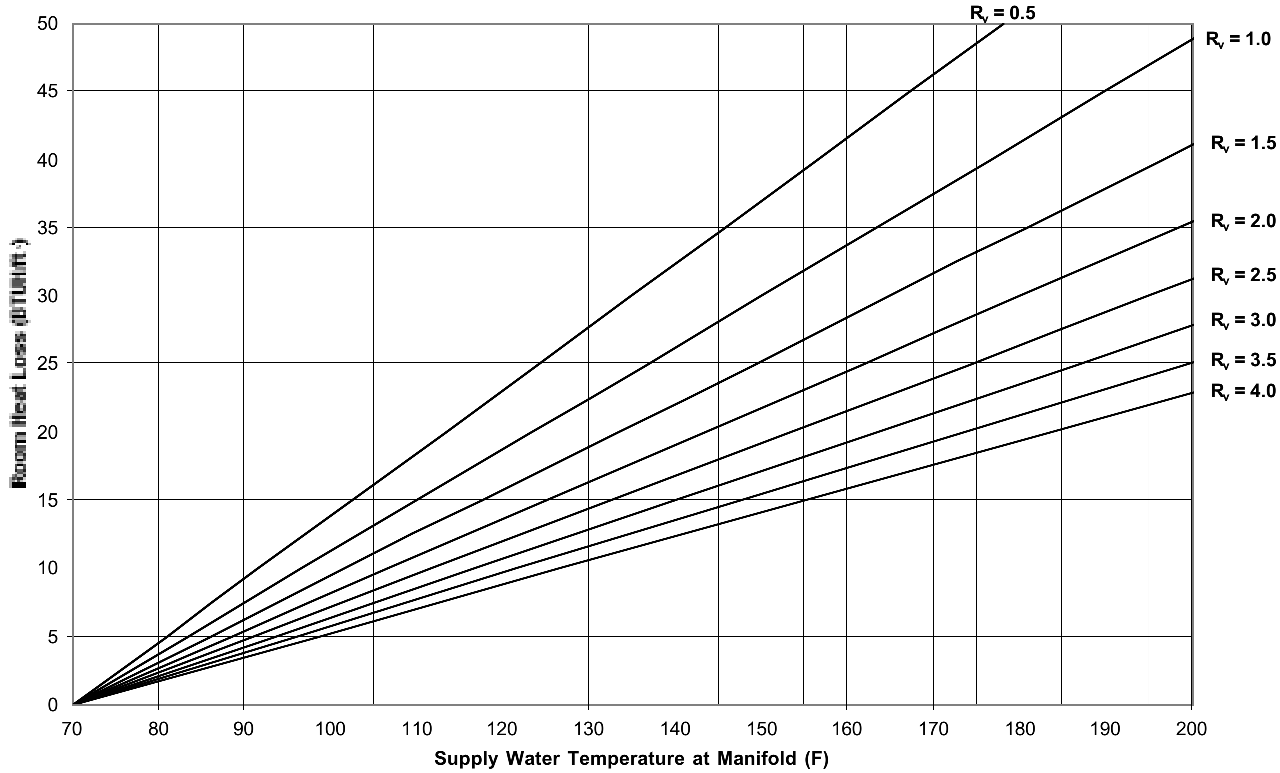
Water Supply Temperatures for Aluminum Plates above Joists with 3/4" Plywood Subfloor
65 F Room Temperature - 3/4", 5/8", 1/2" & 3/8" PEX Tubing - 9" On Center
10 degree supply / return temperature differential



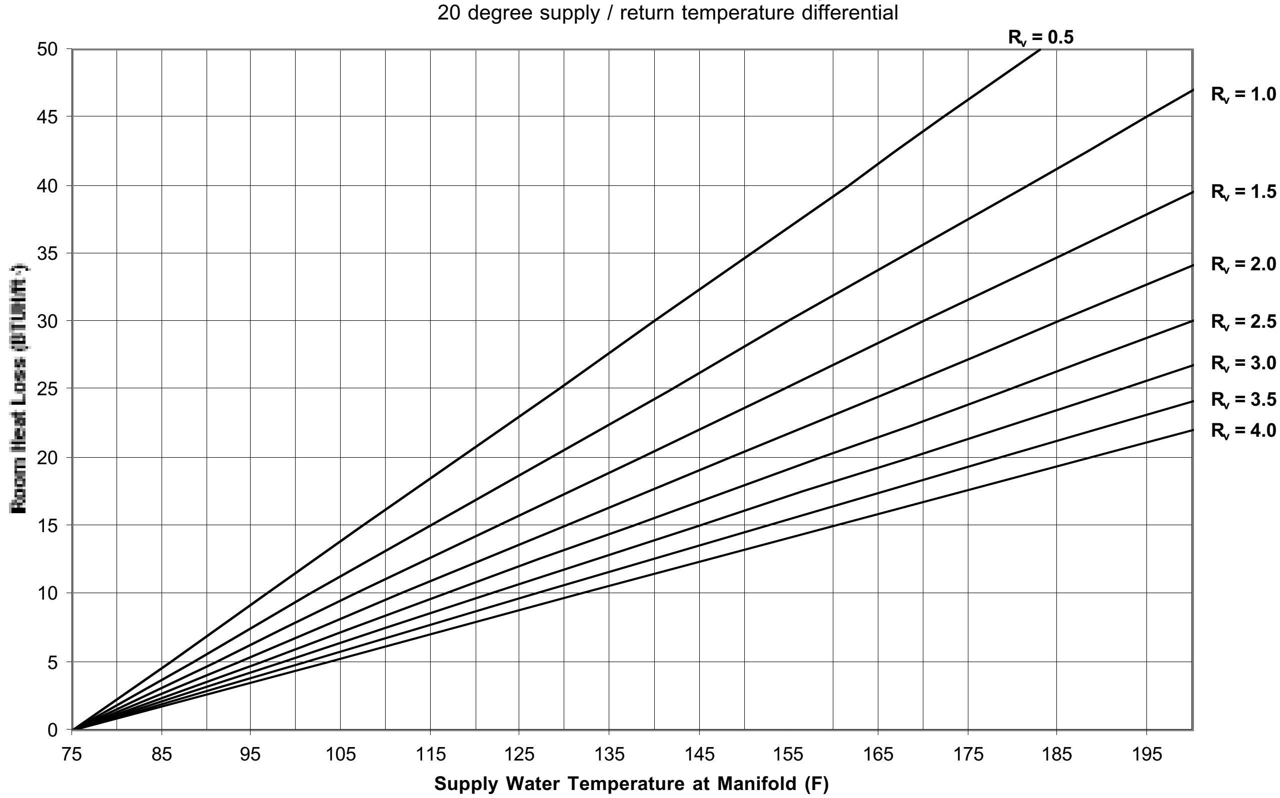
Water Supply Temperatures for Aluminum Plates above Joists with 3/4" Plywood Subfloor
65 F Room Temperature - 3/4", 5/8", 1/2" & 3/8" PEX Tubing - 9" On Center
20 degree supply / return temperature differential



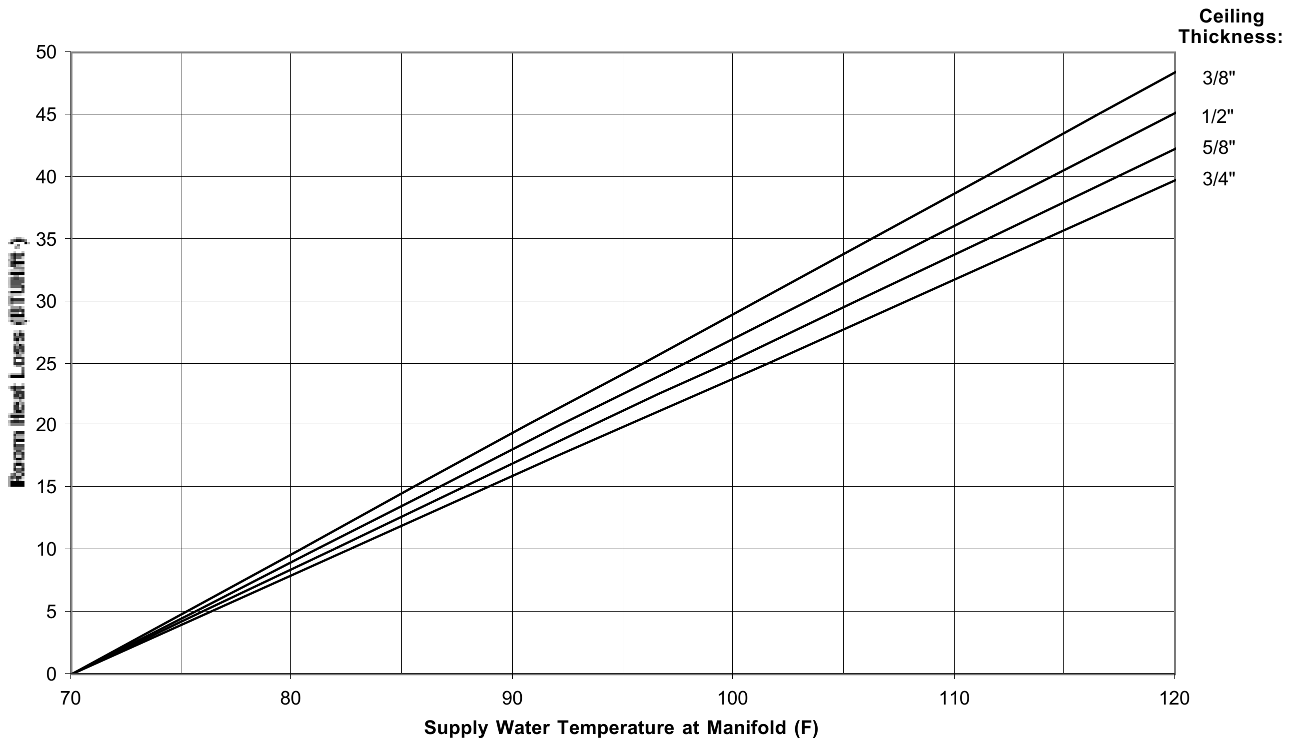
Water Supply Temperatures for Aluminum Plates above Joists with 3/4" Plywood Subfloor
65 F Room Temperature - 3/4", 5/8" & 1/2" PEX Tubing - 12" On Center
10 degree supply / return temperature differential



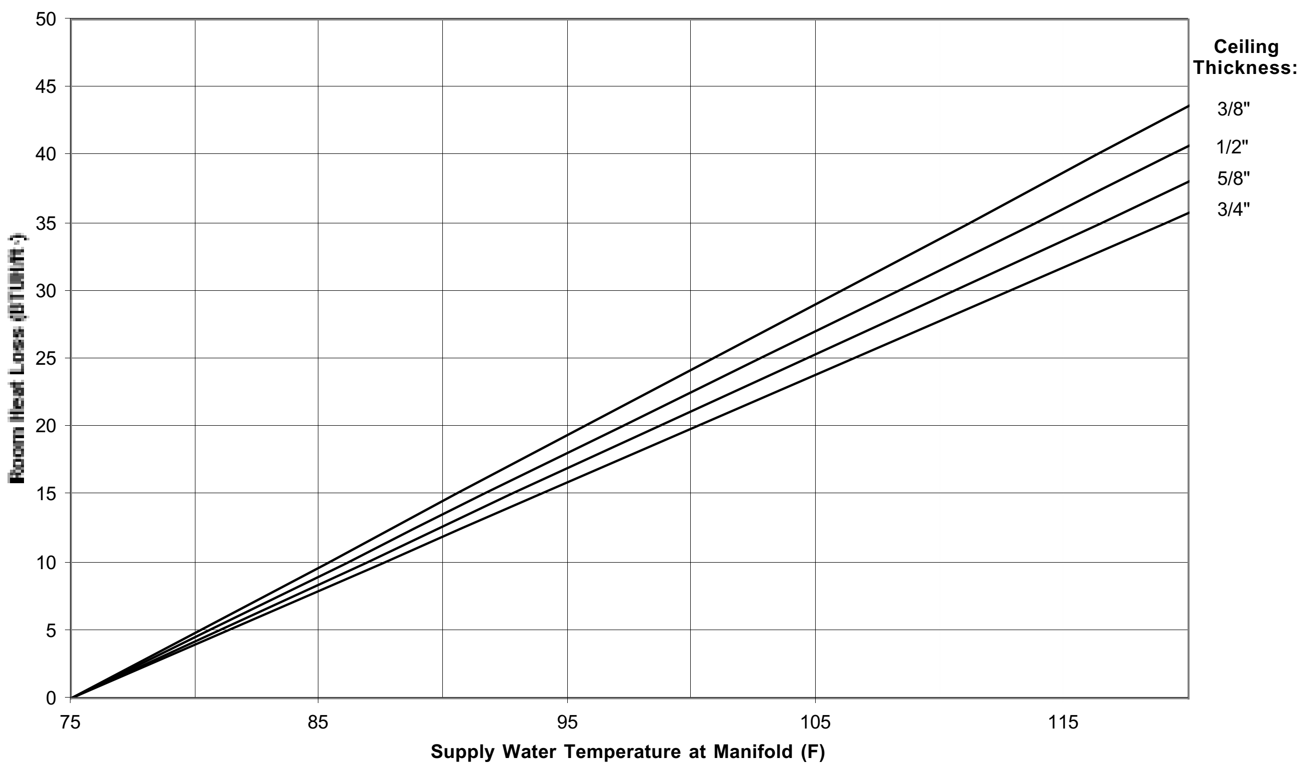
Water Supply Temperatures for Aluminum Plates above Joists with 3/4" Plywood Subfloor
65 F Room Temperature - 3/4", 5/8" & 1/2" PEX Tubing - 12" On Center
20 degree supply / return temperature differential



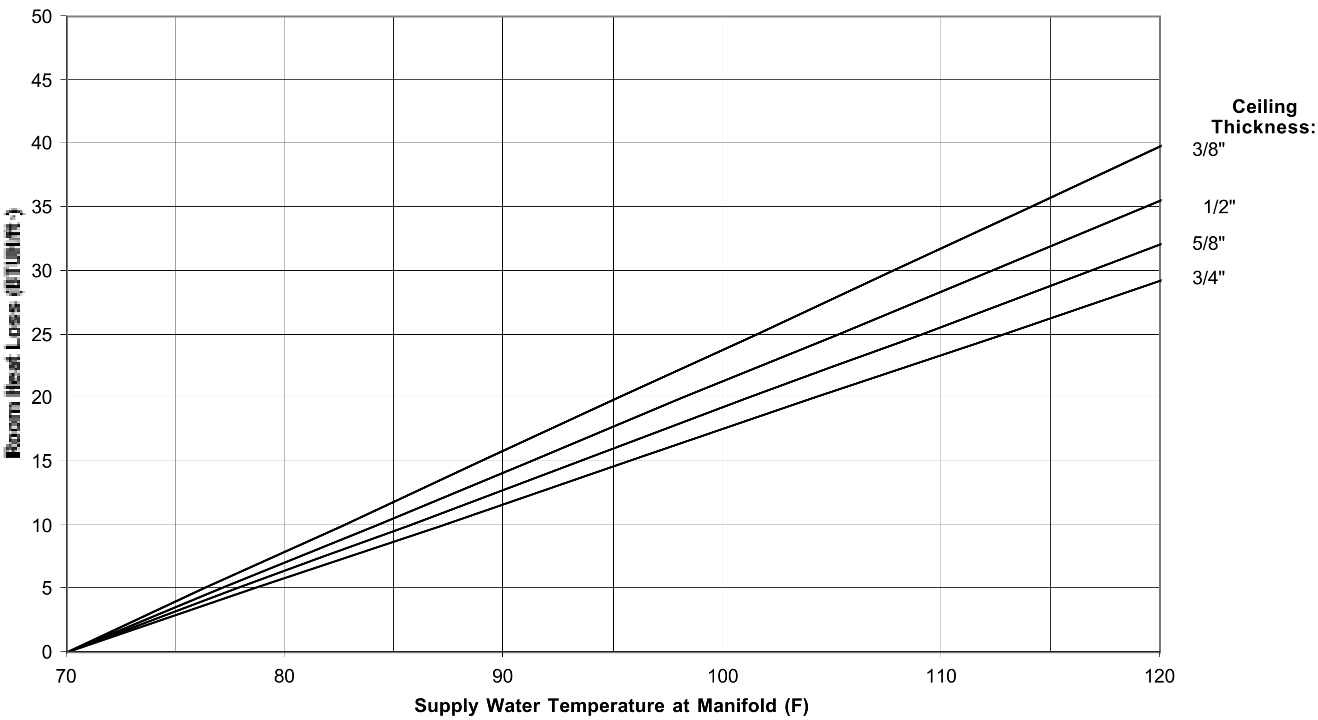
Water Supply Temperatures for Gypsum Board Ceiling
65 F Room Temperature - 3/4", 5/8" & 1/2" PEX Tubing - 8" On Center
10 degree supply / return temperature differential



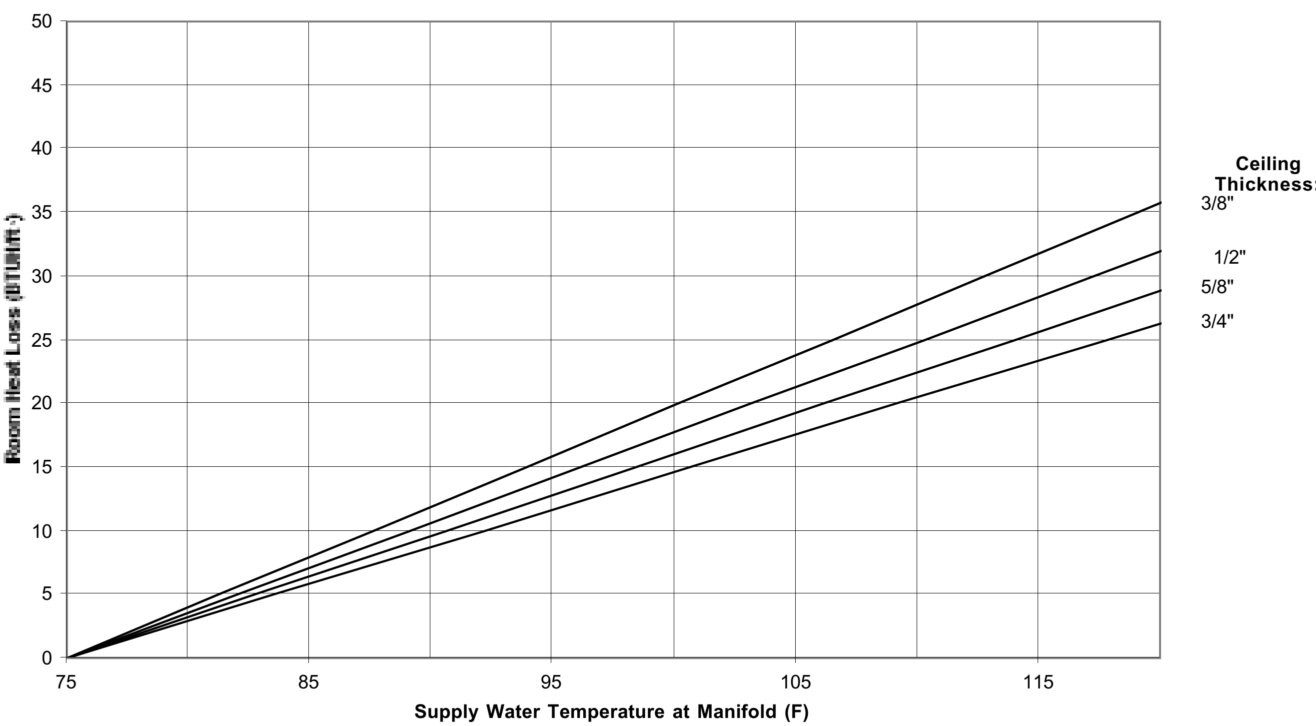
Water Supply Temperatures for Gypsum Board Ceiling
65 F Room Temperature - 3/4", 5/8" & 1/2" PEX Tubing - 8" On Center
20 degree supply / return temperature differential



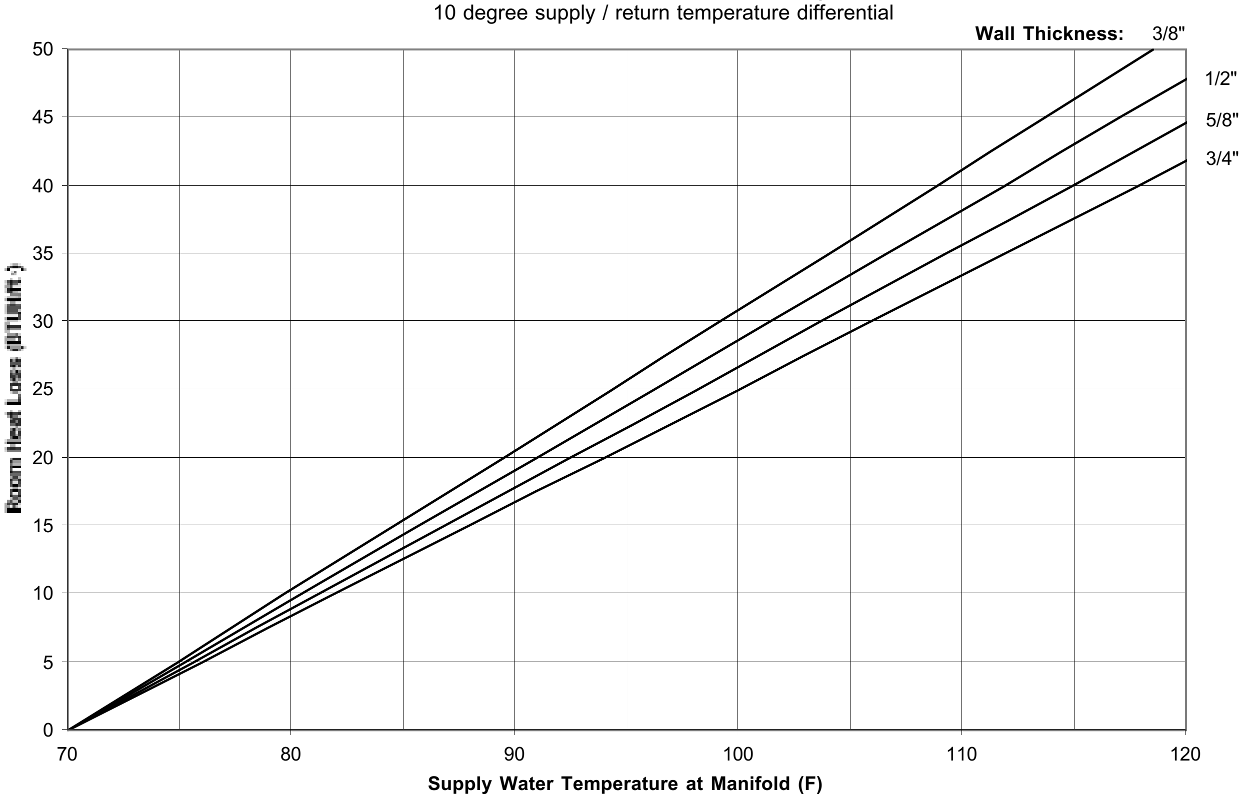
Water Supply Temperatures for Gypsum Board Ceiling
65 F Room Temperature - 3/4", 5/8" & 1/2" PEX Tubing - 16" On Center
10 degree supply / return temperature differential



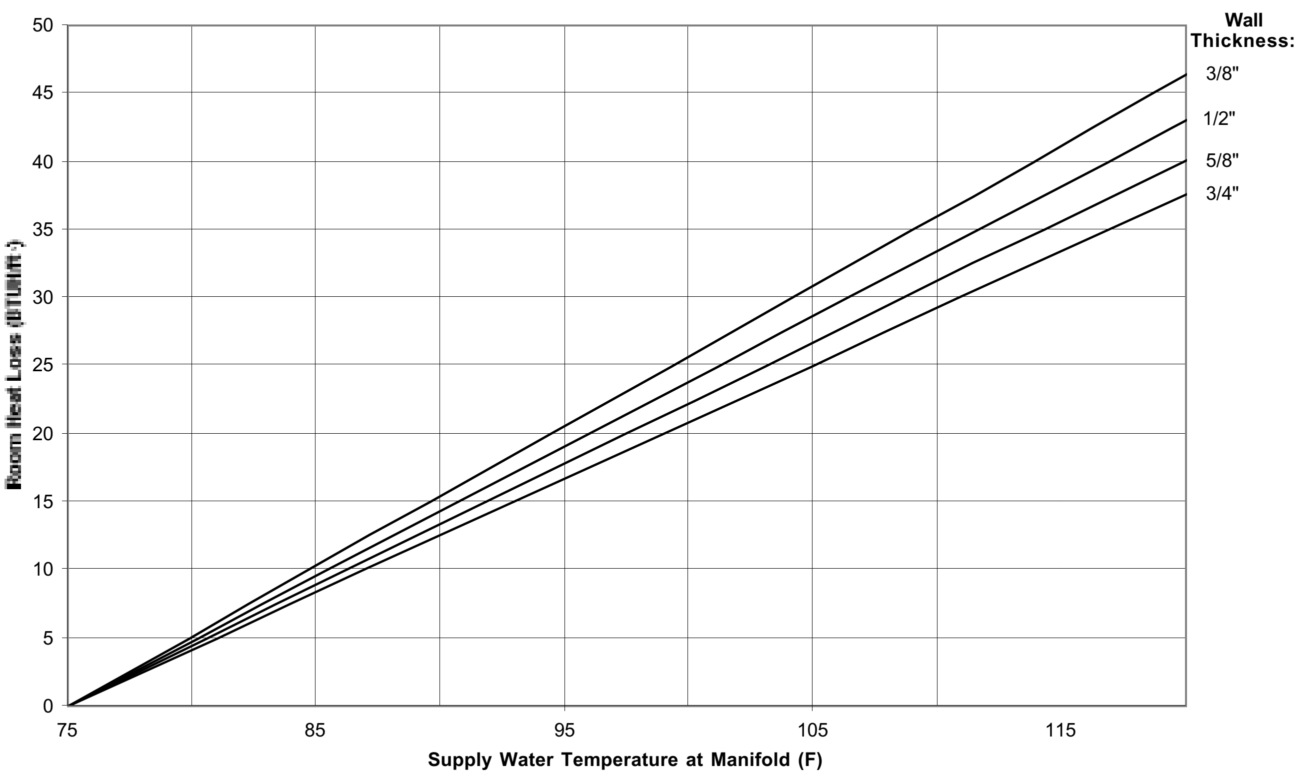
Water Supply Temperatures for Gypsum Board Ceiling
65 F Room Temperature - 3/4", 5/8" & 1/2" PEX Tubing - 16" On Center
20 degree supply / return temperature differential



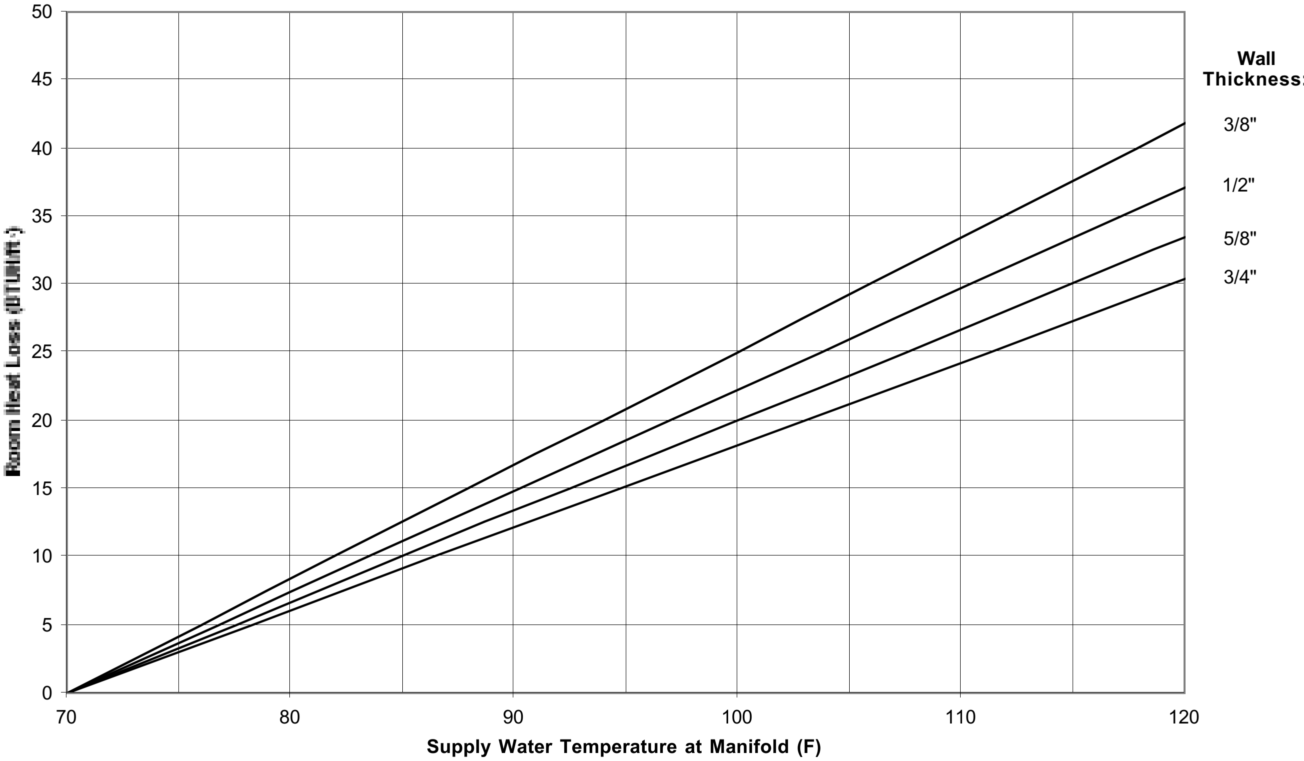
Water Supply Temperatures for Gypsum Board Wall
65 F Room Temperature - 3/4", 5/8" & 1/2" PEX Tubing - 8" On Center
10 degree supply / return temperature differential



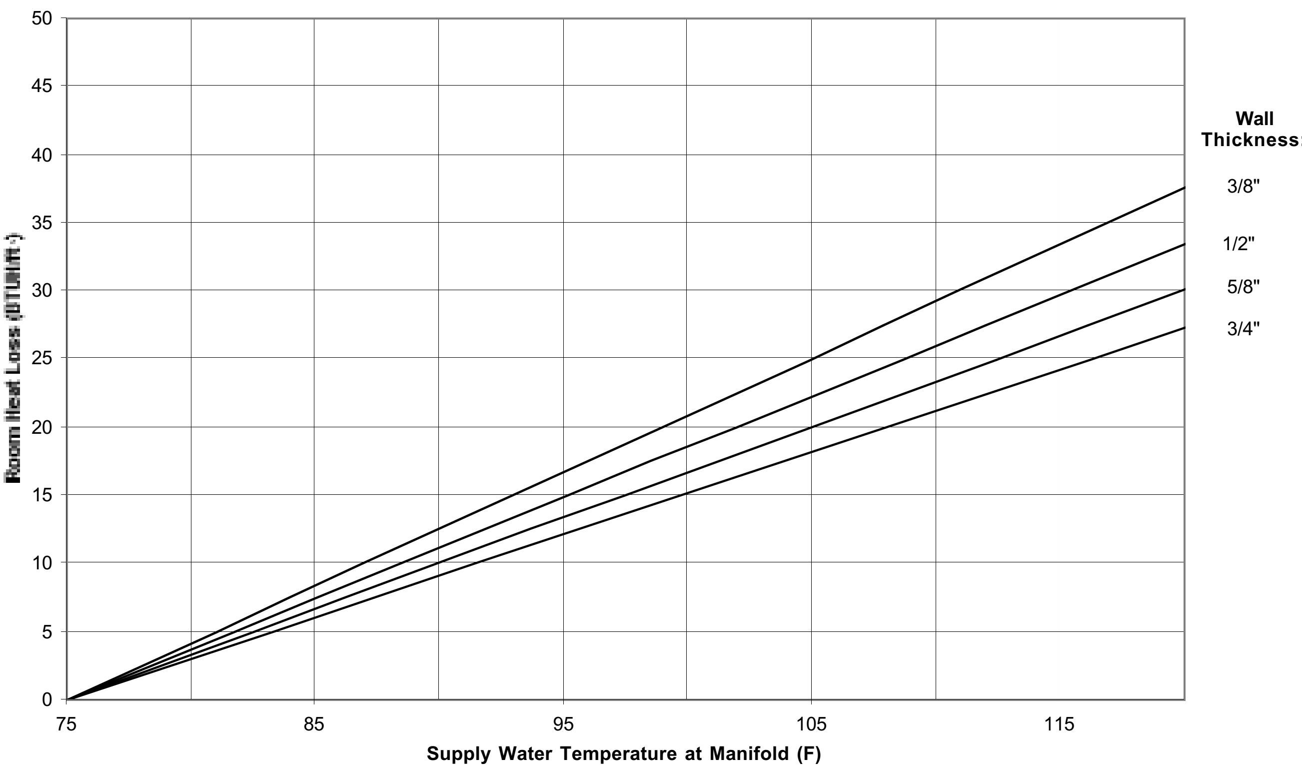
Water Supply Temperatures for Gypsum Board Wall
65 F Room Temperature - 3/4", 5/8" & 1/2" PEX Tubing - 8" On Center
20 degree supply / return temperature differential



Water Supply Temperatures for Gypsum Board Wall
65 F Room Temperature - 3/4", 5/8" & 1/2" PEX Tubing - 16" On Center
10 degree supply / return temperature differential



Water Supply Temperatures for Gypsum Board Wall
65 F Room Temperature - 3/4", 5/8" & 1/2" PEX Tubing - 16" On Center
20 degree supply / return temperature differential

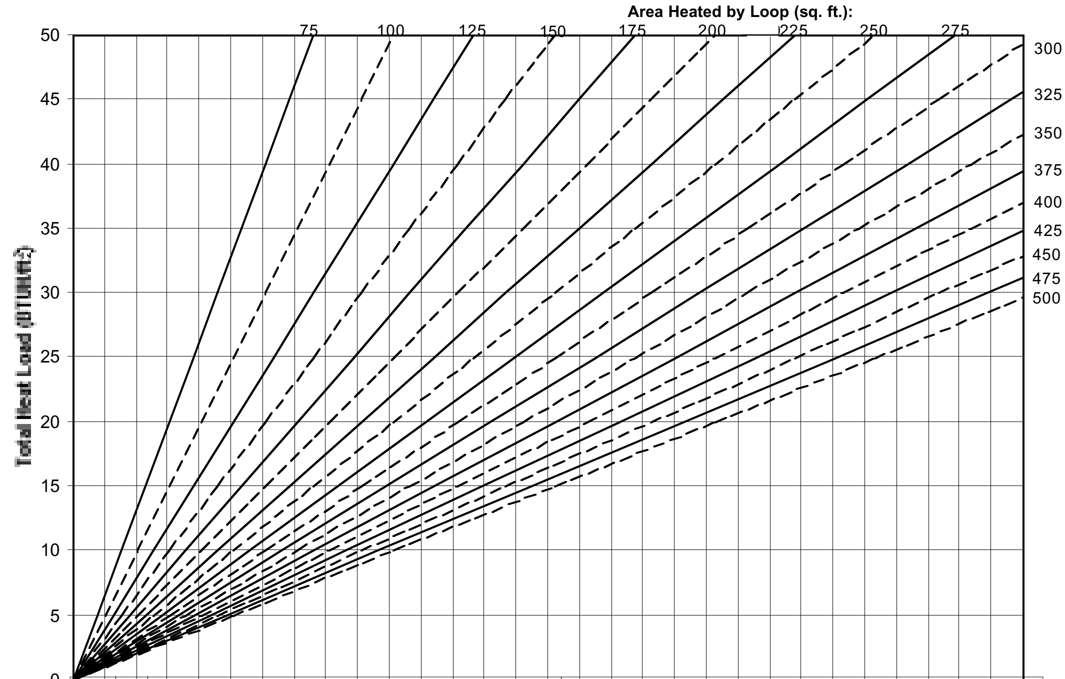


APPENDIX B

FLOW RATE CHARTS

PRESSURE LOSS CHARTS

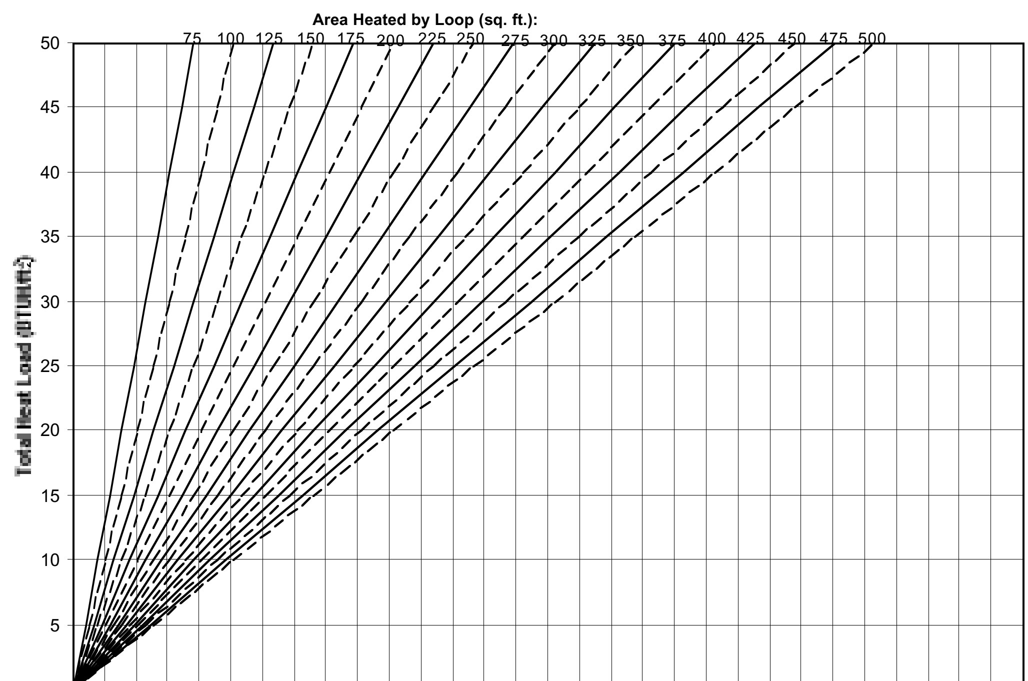
Flow Rate Chart - 100% Water - 10°F Supply/ Return Temperature Differential



12" O.C.	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0
9" O.C.	.08	.15	.23	.30	.38	.45	.53	.60	.68	.75	.83	.90	.98	1.1	1.1	1.2	1.3	1.4	1.4	1.5	1.6	1.6	1.7	1.8	1.9	2.0	2.0	2.1	2.2	2.3
6" O.C.	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	.55	.60	.65	.70	.75	.80	.85	.90	.95	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.5

Flow Rate (GPM)

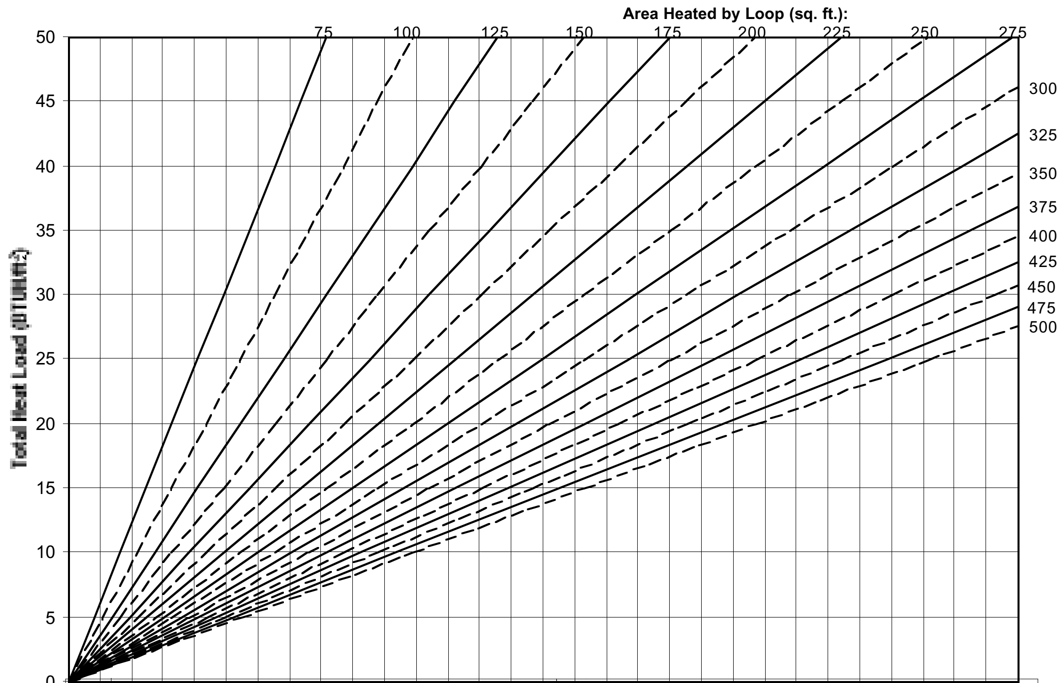
Flow Rate Chart - 100% Water - 20°F Supply/ Return Temperature Differential



12" O.C.	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0
9" O.C.	.08	.15	.23	.30	.38	.45	.53	.60	.68	.75	.83	.90	.98	1.1	1.1	1.2	1.3	1.4	1.4	1.5	1.6	1.6	1.7	1.8	1.9	2.0	2.0	2.1	2.2	2.3
6" O.C.	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	.55	.60	.65	.70	.75	.80	.85	.90	.95	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.5

Flow Rate (GPM)

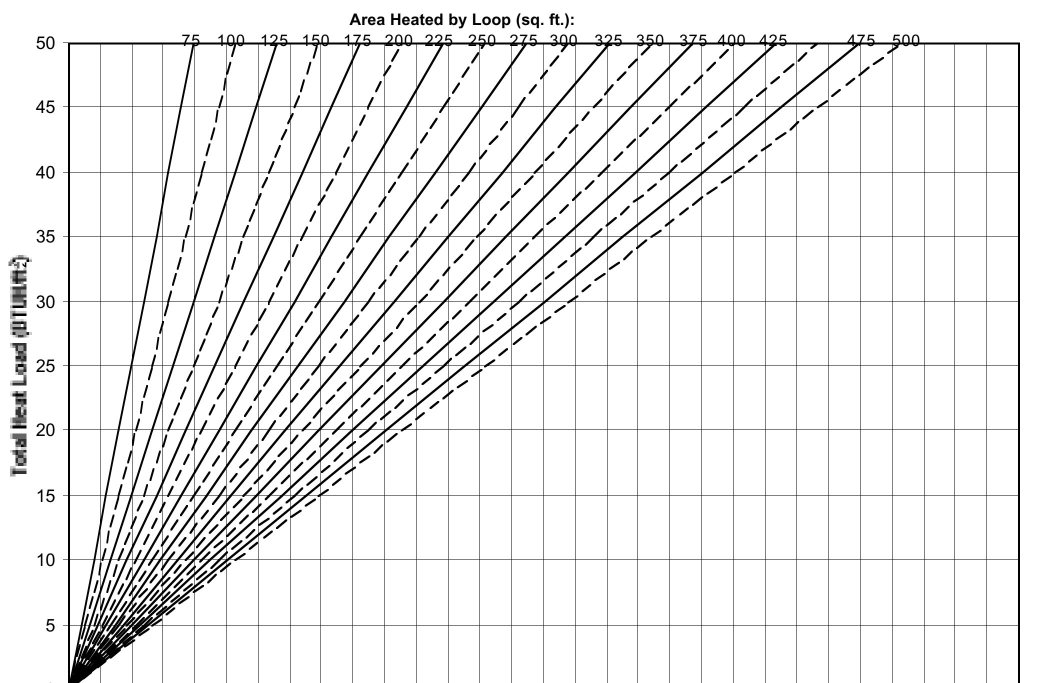
Flow Rate Chart - 30% Ethlylene Glycol / 70% Water - 10°F Supply/ Return Temperature Differential



12" O.C.	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0
9" O.C.	.08	.15	.23	.30	.38	.45	.53	.60	.68	.75	.83	.90	.98	1.1	1.1	1.2	1.3	1.4	1.4	1.5	1.6	1.6	1.7	1.8	1.9	2.0	2.0	2.1	2.2	2.3
6" O.C.	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	.55	.60	.65	.70	.75	.80	.85	.90	.95	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.5

Flow Rate (GPM)

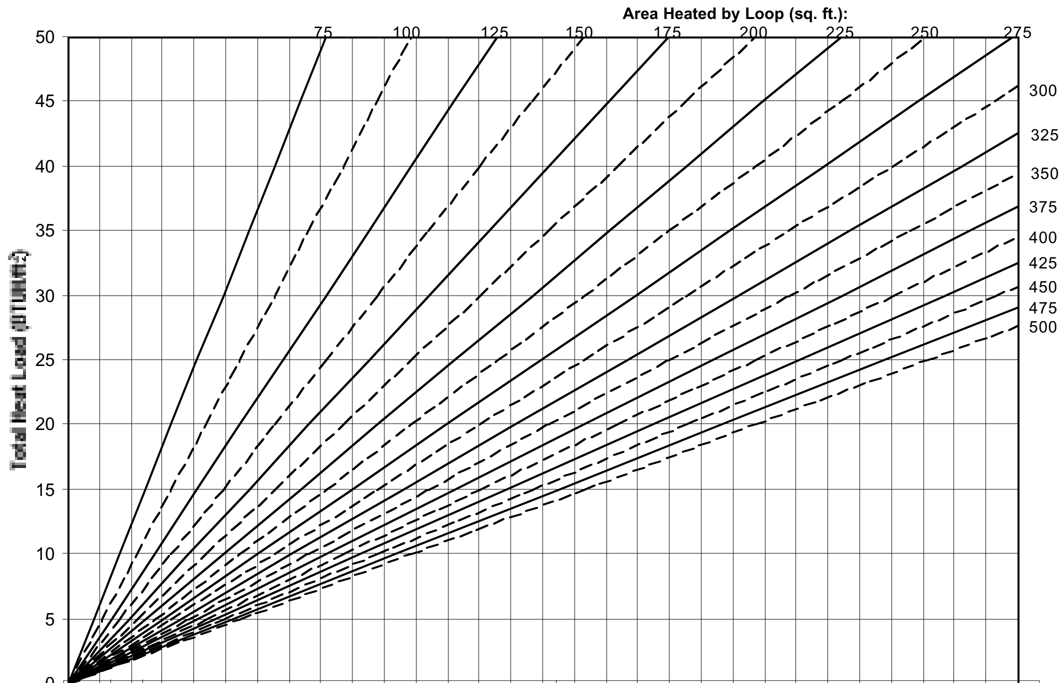
Flow Rate Chart - 30% Propylene Glycol / 70% Water - 20°F Supply/ Return Temperature Differential



12" O.C.	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0
9" O.C.	.08	.15	.23	.30	.38	.45	.53	.60	.68	.75	.83	.90	.98	1.1	1.1	1.2	1.3	1.4	1.4	1.5	1.6	1.6	1.7	1.8	1.9	2.0	2.0	2.1	2.2	2.3
6" O.C.	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	.55	.60	.65	.70	.75	.80	.85	.90	.95	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.5

Flow Rate (GPM)

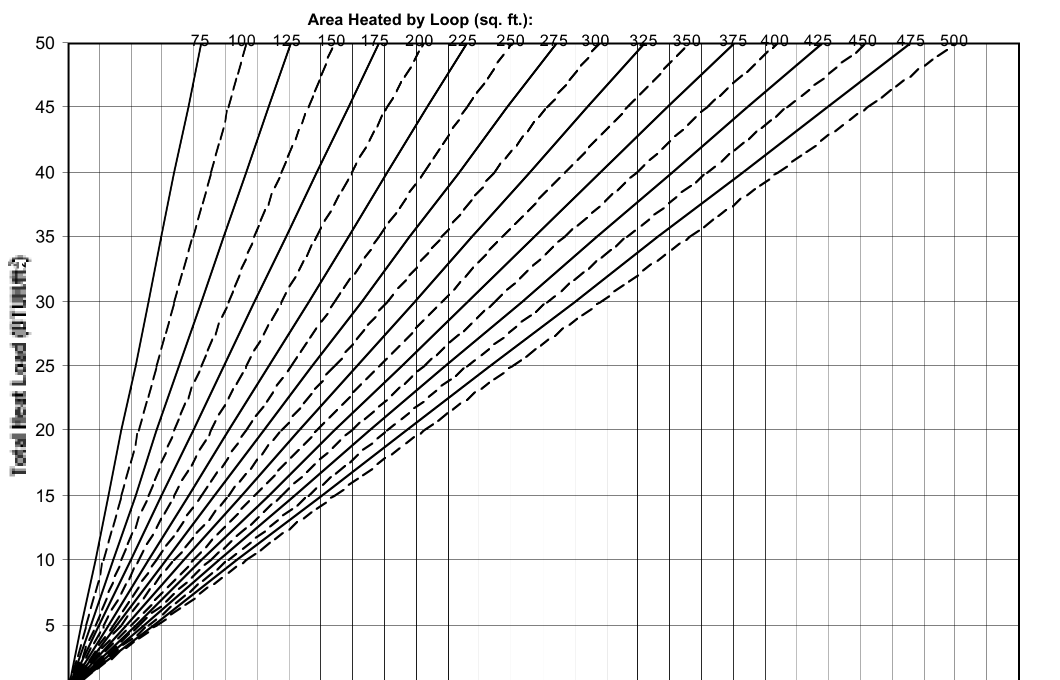
Flow Rate Chart - 40% Propylene Glycol / 60% Water - 10°F Supply/ Return Temperature Differential



12" O.C.	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0
9" O.C.	.08	.15	.23	.30	.38	.45	.53	.60	.68	.75	.83	.90	.98	1.1	1.1	1.2	1.3	1.4	1.4	1.5	1.6	1.6	1.7	1.8	1.9	2.0	2.0	2.1	2.2	2.3
6" O.C.	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	.55	.60	.65	.70	.75	.80	.85	.90	.95	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.5

Flow Rate (GPM)

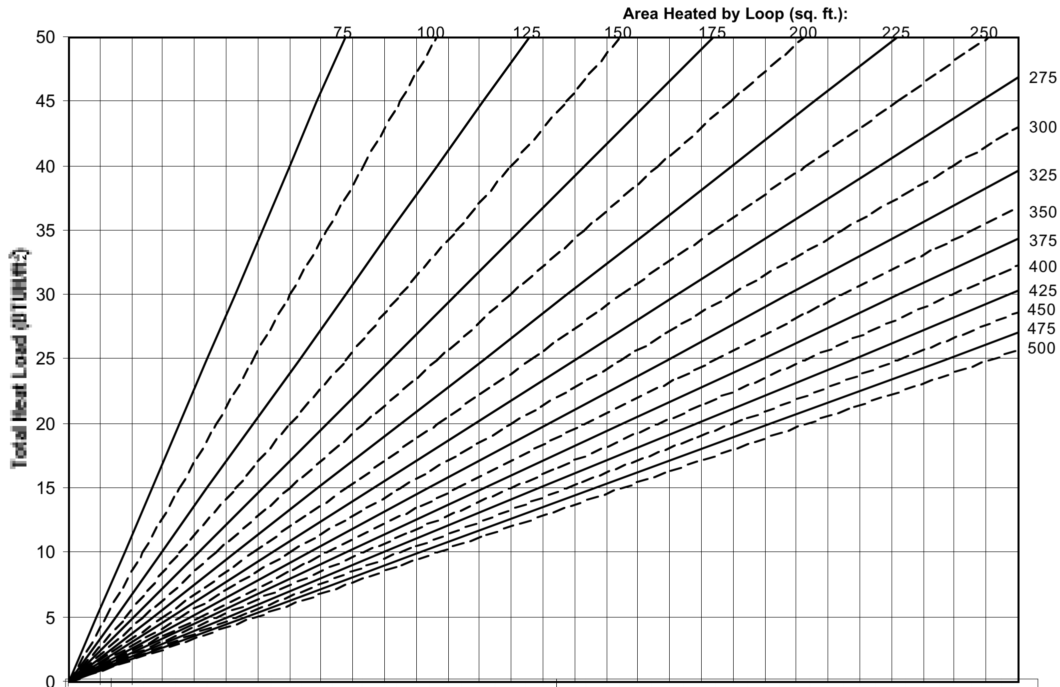
Flow Rate Chart - 40% Ethylene Glycol / 60% Water - 20°F Supply/ Return Temperature Differential



12" O.C.	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0
9" O.C.	.08	.15	.23	.30	.38	.45	.53	.60	.68	.75	.83	.90	.98	1.1	1.1	1.2	1.3	1.4	1.4	1.5	1.6	1.6	1.7	1.8	1.9	2.0	2.0	2.1	2.2	2.3
6" O.C.	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	.55	.60	.65	.70	.75	.80	.85	.90	.95	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.5

Flow Rate (GPM)

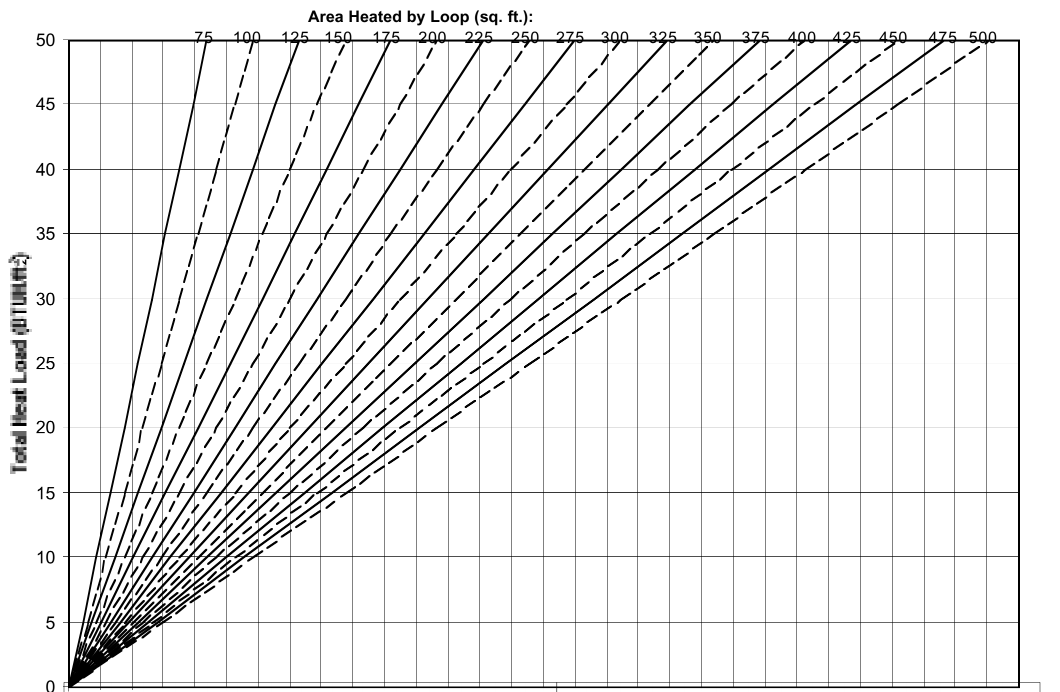
Flow Rate Chart - 50% Ethlylene Glycol / 50% Water - 10°F Supply/ Return Temperature Differential



12" O.C.	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0
9" O.C.	.08	.15	.23	.30	.38	.45	.53	.60	.68	.75	.83	.90	.98	1.1	1.1	1.2	1.3	1.4	1.4	1.5	1.6	1.6	1.7	1.8	1.9	2.0	2.0	2.1	2.2	2.3
6" O.C.	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	.55	.60	.65	.70	.75	.80	.85	.90	.95	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.5

Flow Rate (GPM)

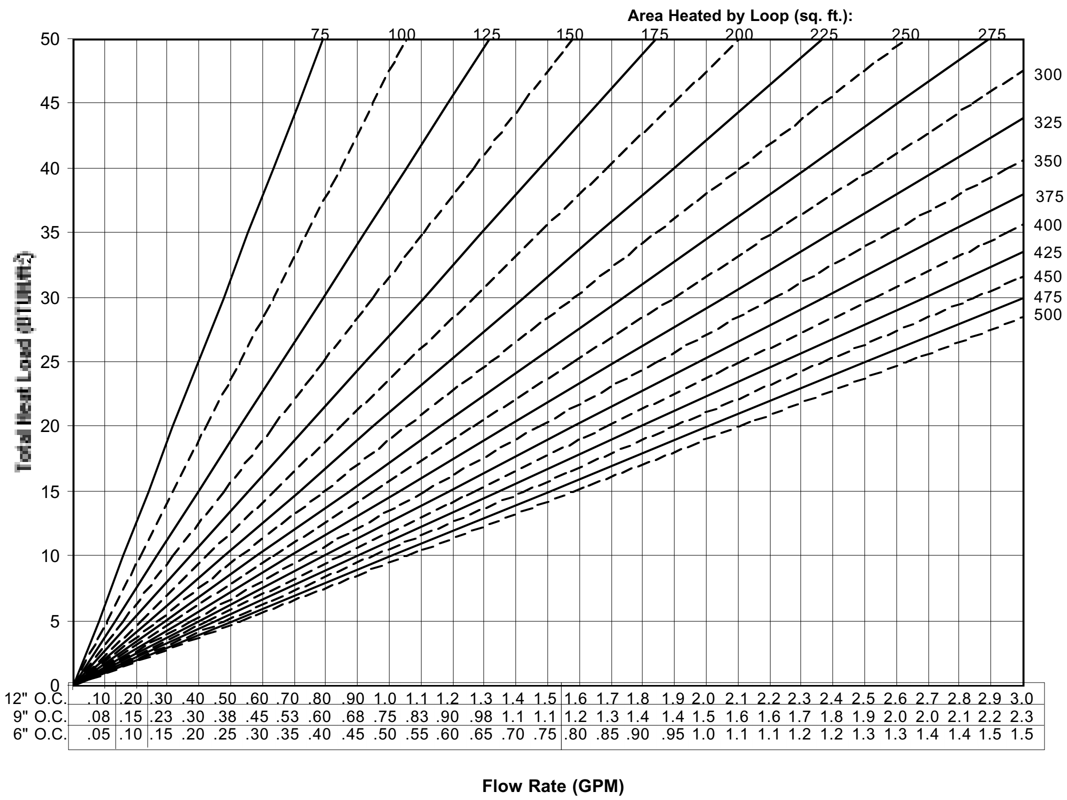
Flow Rate Chart - 50% Ethylene Glycol / 50% Water - 20°F Supply/ Return Temperature Differential



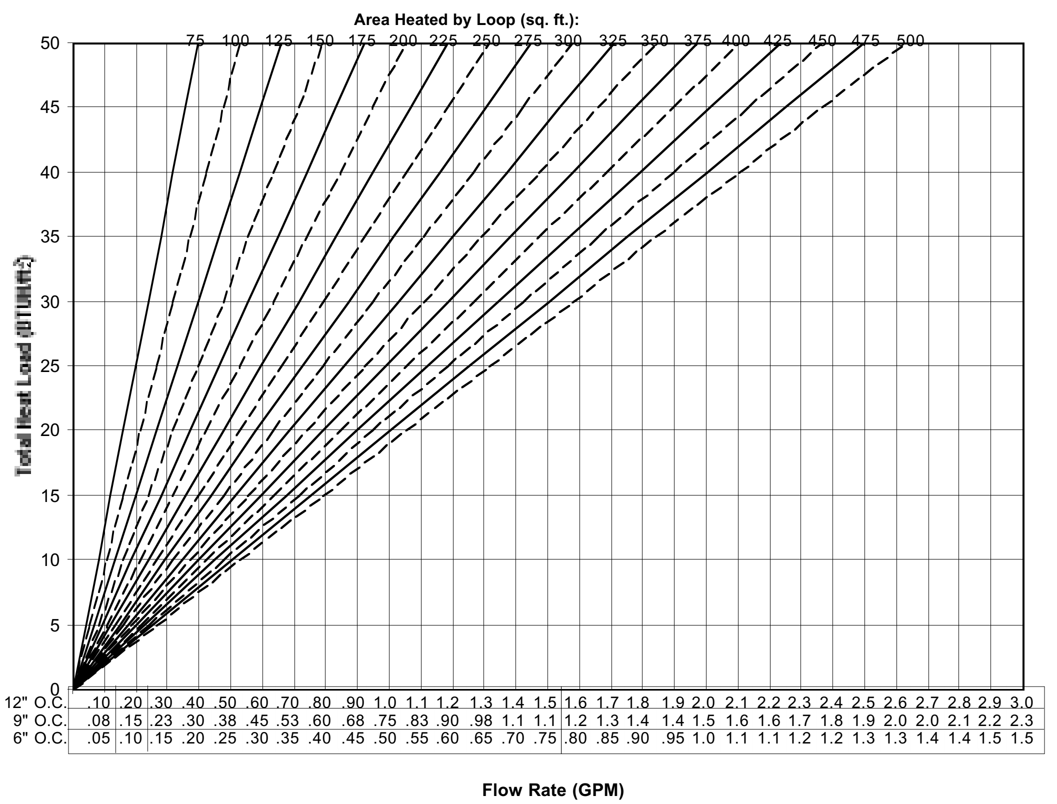
12" O.C.	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0
9" O.C.	.08	.15	.23	.30	.38	.45	.53	.60	.68	.75	.83	.90	.98	1.1	1.1	1.2	1.3	1.4	1.4	1.5	1.6	1.6	1.7	1.8	1.9	2.0	2.0	2.1	2.2	2.3
6" O.C.	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	.55	.60	.65	.70	.75	.80	.85	.90	.95	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.5

Flow Rate (GPM)

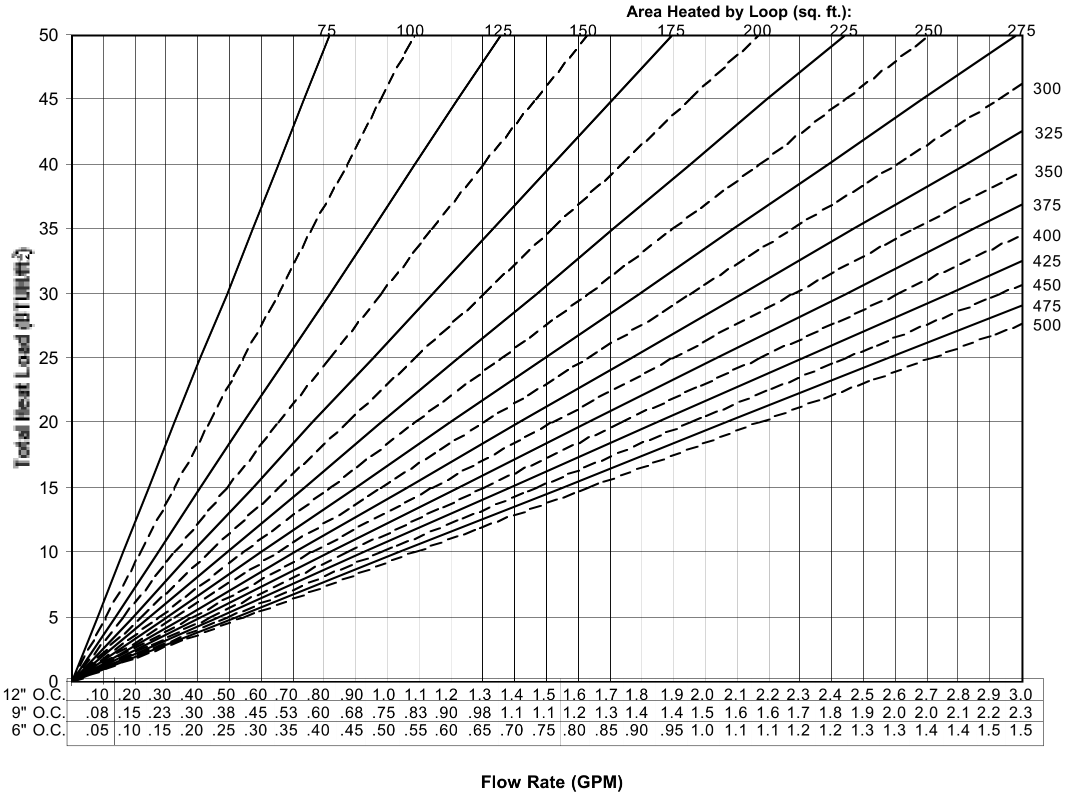
Flow Rate Chart - 30% Propylene Glycol / 70% Water - 10°F Supply/ Return Temperature Differential



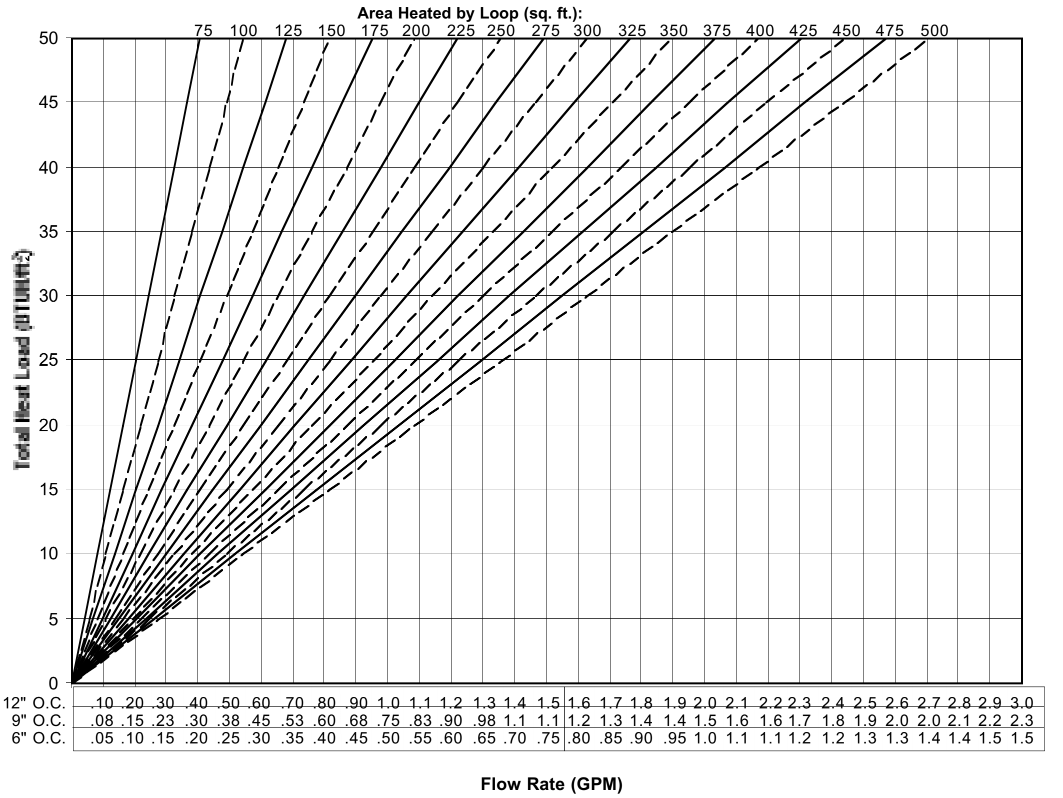
Flow Rate Chart - 30% Propylene Glycol / 70% Water - 20°F Supply/ Return Temperature Differential



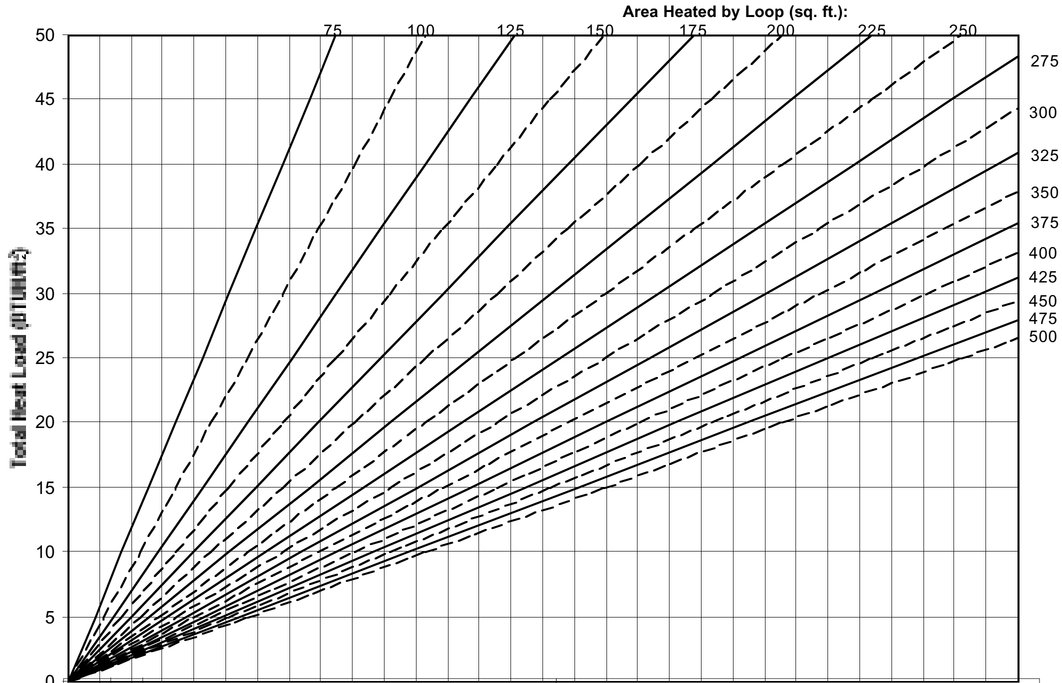
Flow Rate Chart - 40% Propylene Glycol / 60% Water - 10ºF Supply/ Return Temperature Differential



Flow Rate Chart - 40% Propylene Glycol / 60% Water - 20ºF Supply/ Return Temperature Differential



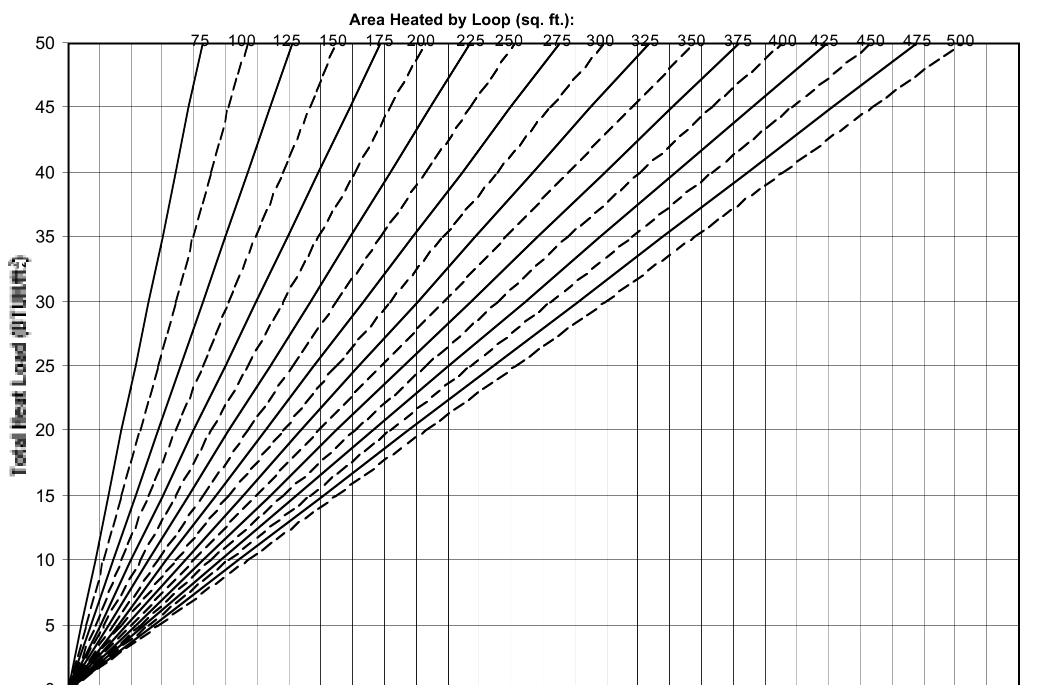
Flow Rate Chart - 50% Propylene Glycol / 50% Water - 10ºF Supply/ Return Temperature Differential



12" O.C.	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0
9" O.C.	.08	.15	.23	.30	.38	.45	.53	.60	.68	.75	.83	.90	.98	1.1	1.1	1.2	1.3	1.4	1.4	1.5	1.6	1.6	1.7	1.8	1.9	2.0	2.0	2.1	2.2	2.3
6" O.C.	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	.55	.60	.65	.70	.75	.80	.85	.90	.95	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.5

Flow Rate (GPM)

Flow Rate Chart - 50% Propylene Glycol / 50% Water - 20ºF Supply/ Return Temperature Differential



12" O.C.	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0
9" O.C.	.08	.15	.23	.30	.38	.45	.53	.60	.68	.75	.83	.90	.98	1.1	1.1	1.2	1.3	1.4	1.4	1.5	1.6	1.6	1.7	1.8	1.9	2.0	2.0	2.1	2.2	2.3
6" O.C.	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	.55	.60	.65	.70	.75	.80	.85	.90	.95	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.5

Flow Rate (GPM)

Pressure Loss per Linear Foot - 1" PEX - 100% Water

		80 °F		100 °F		120 °F		140 °F		160 °F		180 °F	
Flow (GPM)	Velocity (FPS)	Pressure Loss (PSI) per foot	Head Loss (FT-H_2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H_2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H_2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H_2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H_2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H_2O) per foot
0.1	0.05	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.2	0.11	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
0.3	0.16	0.0001	0.0003	0.0001	0.0003	0.0001	0.0003	0.0001	0.0003	0.0001	0.0003	0.0001	0.0002
0.4	0.22	0.0002	0.0005	0.0002	0.0005	0.0002	0.0005	0.0002	0.0004	0.0002	0.0004	0.0002	0.0004
0.5	0.27	0.0003	0.0007	0.0003	0.0007	0.0003	0.0007	0.0003	0.0006	0.0003	0.0006	0.0003	0.0006
0.6	0.33	0.0004	0.0010	0.0004	0.0010	0.0004	0.0009	0.0004	0.0009	0.0004	0.0009	0.0003	0.0008
0.7	0.38	0.0006	0.0013	0.0005	0.0013	0.0005	0.0012	0.0005	0.0012	0.0005	0.0011	0.0005	0.0011
0.8	0.44	0.0007	0.0017	0.0007	0.0016	0.0007	0.0015	0.0006	0.0015	0.0006	0.0014	0.0006	0.0014
0.9	0.49	0.0009	0.0021	0.0009	0.0020	0.0008	0.0019	0.0008	0.0018	0.0007	0.0017	0.0007	0.0017
1.0	0.55	0.0011	0.0025	0.0010	0.0024	0.0010	0.0023	0.0009	0.0022	0.0009	0.0021	0.0009	0.0020
1.1	0.60	0.0013	0.0030	0.0012	0.0028	0.0011	0.0027	0.0011	0.0026	0.0010	0.0025	0.0010	0.0024
1.2	0.66	0.0015	0.0034	0.0014	0.0033	0.0013	0.0031	0.0013	0.0030	0.0012	0.0029	0.0012	0.0028
1.3	0.71	0.0017	0.0040	0.0016	0.0038	0.0015	0.0036	0.0015	0.0034	0.0014	0.0033	0.0013	0.0032
1.4	0.76	0.0020	0.0045	0.0018	0.0043	0.0018	0.0041	0.0017	0.0039	0.0016	0.0038	0.0015	0.0036
1.5	0.82	0.0022	0.0051	0.0021	0.0048	0.0020	0.0046	0.0019	0.0044	0.0018	0.0042	0.0017	0.0041
1.6	0.87	0.0025	0.0057	0.0023	0.0054	0.0022	0.0052	0.0021	0.0049	0.0020	0.0048	0.0019	0.0046
1.7	0.93	0.0027	0.0063	0.0026	0.0060	0.0025	0.0057	0.0023	0.0055	0.0022	0.0053	0.0022	0.0051
1.8	0.98	0.0030	0.0070	0.0029	0.0067	0.0027	0.0063	0.0026	0.0060	0.0025	0.0058	0.0024	0.0057
1.9	1.04	0.0033	0.0077	0.0031	0.0073	0.0030	0.0070	0.0028	0.0066	0.0027	0.0064	0.0026	0.0062
2.0	1.09	0.0036	0.0084	0.0034	0.0080	0.0033	0.0076	0.0031	0.0073	0.0030	0.0070	0.0029	0.0068
2.1	1.15	0.0040	0.0092	0.0038	0.0087	0.0036	0.0083	0.0034	0.0079	0.0032	0.0077	0.0031	0.0074
2.2	1.20	0.0043	0.0100	0.0041	0.0095	0.0039	0.0090	0.0037	0.0086	0.0035	0.0083	0.0034	0.0080
2.3	1.26	0.0047	0.0108	0.0044	0.0102	0.0042	0.0097	0.0040	0.0093	0.0038	0.0090	0.0037	0.0087
2.4	1.31	0.0050	0.0116	0.0047	0.0110	0.0045	0.0105	0.0043	0.0100	0.0041	0.0097	0.0039	0.0094
2.5	1.36	0.0054	0.0125	0.0051	0.0118	0.0048	0.0113	0.0046	0.0107	0.0044	0.0104	0.0042	0.0100
2.6	1.42	0.0058	0.0133	0.0055	0.0127	0.0052	0.0121	0.0049	0.0115	0.0047	0.0111	0.0045	0.0108
2.7	1.47	0.0062	0.0143	0.0058	0.0135	0.0055	0.0129	0.0052	0.0123	0.0050	0.0119	0.0048	0.0115
2.8	1.53	0.0066	0.0152	0.0062	0.0144	0.0059	0.0137	0.0056	0.0131	0.0054	0.0127	0.0052	0.0123
2.9	1.58	0.0070	0.0161	0.0066	0.0153	0.0063	0.0146	0.0059	0.0139	0.0057	0.0135	0.0055	0.0130
3.0	1.64	0.0074	0.0171	0.0070	0.0163	0.0066	0.0155	0.0063	0.0148	0.0060	0.0143	0.0058	0.0138

Pressure Loss per Linear Foot - 3/4" PEX - 100% Water

		80 °F		100 °F		120 °F		140 °F		160 °F		180 °F	
Flow (GPM)	Velocity (FPS)	Pressure Loss (PSI) per foot	Head Loss (FT-H_2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H_2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H_2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H_2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H_2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H_2O) per foot
0.1	0.09	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0001
0.2	0.18	0.0002	0.0005	0.0002	0.0005	0.0002	0.0004	0.0002	0.0004	0.0002	0.0004	0.0002	0.0004
0.3	0.27	0.0004	0.0010	0.0004	0.0010	0.0004	0.0009	0.0004	0.0009	0.0004	0.0008	0.0003	0.0008
0.4	0.36	0.0007	0.0017	0.0007	0.0016	0.0006	0.0015	0.0006	0.0014	0.0006	0.0014	0.0006	0.0013
0.5	0.45	0.0011	0.0025	0.0010	0.0023	0.0010	0.0022	0.0009	0.0021	0.0009	0.0020	0.0008	0.0020
0.6	0.54	0.0015	0.0034	0.0014	0.0032	0.0013	0.0031	0.0012	0.0029	0.0012	0.0028	0.0011	0.0027
0.7	0.63	0.0019	0.0044	0.0018	0.0042	0.0017	0.0040	0.0016	0.0038	0.0016	0.0037	0.0015	0.0036
0.8	0.72	0.0024	0.0056	0.0023	0.0053	0.0022	0.0051	0.0021	0.0048	0.0020	0.0047	0.0019	0.0045
0.9	0.81	0.0030	0.0069	0.0028	0.0065	0.0027	0.0062	0.0025	0.0059	0.0024	0.0057	0.0023	0.0055
1.0	0.90	0.0036	0.0083	0.0034	0.0078	0.0032	0.0075	0.0030	0.0071	0.0029	0.0069	0.0028	0.0067
1.1	0.99	0.0042	0.0098	0.0040	0.0093	0.0038	0.0088	0.0036	0.0084	0.0034	0.0081	0.0033	0.0079
1.2	1.08	0.0049	0.0114	0.0046	0.0108	0.0044	0.0103	0.0042	0.0098	0.0040	0.0095	0.0039	0.0092
1.3	1.17	0.0056	0.0131	0.0053	0.0124	0.0051	0.0118	0.0048	0.0113	0.0046	0.0109	0.0044	0.0105
1.4	1.26	0.0064	0.0149	0.0061	0.0141	0.0058	0.0135	0.0055	0.0128	0.0053	0.0124	0.0050	0.0120
1.5	1.35	0.0073	0.0168	0.0069	0.0159	0.0065	0.0152	0.0062	0.0145	0.0059	0.0140	0.0057	0.0135
1.6	1.44	0.0081	0.0188	0.0077	0.0178	0.0073	0.0170	0.0069	0.0162	0.0066	0.0157	0.0064	0.0152
1.7	1.53	0.0090	0.0209	0.0085	0.0198	0.0081	0.0189	0.0077	0.0180	0.0074	0.0174	0.0071	0.0169
1.8	1.62	0.0100	0.0231	0.0094	0.0219	0.0090	0.0209	0.0085	0.0199	0.0082	0.0192	0.0078	0.0186
1.9	1.71	0.0110	0.0254	0.0104	0.0241	0.0098	0.0230	0.0093	0.0219	0.0090	0.0212	0.0086	0.0205
2.0	1.80	0.0120	0.0278	0.0113	0.0264	0.0108	0.0251	0.0102	0.0239	0.0098	0.0231	0.0094	0.0224
2.1	1.89	0.0131	0.0302	0.0124	0.0287	0.0117	0.0274	0.0111	0.0261	0.0107	0.0252	0.0103	0.0244
2.2	1.98	0.0142	0.0328	0.0134	0.0311	0.0127	0.0297	0.0121	0.0283	0.0116	0.0273	0.0111	0.0265
2.3	2.07	0.0153	0.0355	0.0145	0.0337	0.0138	0.0321	0.0130	0.0306	0.0125	0.0296	0.0120	0.0286
2.4	2.16	0.0165	0.0382	0.0156	0.0363	0.0148	0.0346	0.0140	0.0329	0.0135	0.0318	0.0130	0.0308
2.5	2.25	0.0177	0.0410	0.0168	0.0389	0.0159	0.0371	0.0151	0.0354	0.0145	0.0342	0.0139	0.0331
2.6	2.34	0.0190	0.0439	0.0180	0.0417	0.0170	0.0398	0.0162	0.0379	0.0155	0.0366	0.0149	0.0355
2.7	2.43	0.0203	0.0469	0.0192	0.0446	0.0182	0.0425	0.0173	0.0405	0.0166	0.0391	0.0159	0.0379
2.8	2.53	0.0216	0.0500	0.0204	0.0475	0.0194	0.0453	0.0184	0.0431	0.0177	0.0417	0.0170	0.0404
2.9	2.62	0.0230	0.0532	0.0217	0.0505	0.0206	0.0481	0.0196	0.0459	0.0188	0.0443	0.0181	0.0429
3.0	2.71	0.0244	0.0565	0.0231	0.0536	0.0219	0.0511	0.0207	0.0487	0.0199	0.0470	0.0192	0.0455

Pressure Loss per Linear Foot - 5/8" PEX - 100% Water

		80 ºF		100 ºF		120 ºF		140 ºF		160 ºF		180 ºF	
Flow (GPM)	Velocity (FPS)	Pressure Loss (PSI) per foot	Head Loss (FT-H_2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H_2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H_2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H_2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H_2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H_2O) per foot
0.1	0.12	0.0001	0.0003	0.0001	0.0003	0.0001	0.0003	0.0001	0.0003	0.0001	0.0003	0.0001	0.0003
0.2	0.25	0.0005	0.0011	0.0004	0.0010	0.0004	0.0010	0.0004	0.0009	0.0004	0.0009	0.0004	0.0008
0.3	0.37	0.0009	0.0021	0.0009	0.0020	0.0008	0.0019	0.0008	0.0018	0.0008	0.0018	0.0007	0.0017
0.4	0.50	0.0015	0.0035	0.0014	0.0034	0.0014	0.0032	0.0013	0.0030	0.0012	0.0029	0.0012	0.0029
0.5	0.62	0.0023	0.0052	0.0021	0.0050	0.0020	0.0047	0.0019	0.0045	0.0018	0.0044	0.0018	0.0042
0.6	0.74	0.0031	0.0072	0.0029	0.0068	0.0028	0.0065	0.0026	0.0062	0.0025	0.0060	0.0024	0.0058
0.7	0.87	0.0041	0.0094	0.0038	0.0089	0.0037	0.0085	0.0035	0.0081	0.0033	0.0078	0.0032	0.0076
0.8	0.99	0.0051	0.0119	0.0049	0.0113	0.0046	0.0108	0.0044	0.0103	0.0042	0.0099	0.0040	0.0096
0.9	1.12	0.0063	0.0146	0.0060	0.0139	0.0057	0.0132	0.0054	0.0126	0.0052	0.0122	0.0050	0.0118
1.0	1.24	0.0076	0.0176	0.0072	0.0167	0.0068	0.0159	0.0065	0.0152	0.0062	0.0146	0.0060	0.0142
1.1	1.36	0.0090	0.0208	0.0085	0.0197	0.0081	0.0188	0.0076	0.0179	0.0073	0.0173	0.0070	0.0168
1.2	1.49	0.0104	0.0242	0.0099	0.0230	0.0094	0.0219	0.0089	0.0209	0.0085	0.0202	0.0082	0.0195
1.3	1.61	0.0120	0.0278	0.0114	0.0264	0.0108	0.0252	0.0102	0.0240	0.0098	0.0232	0.0094	0.0224
1.4	1.74	0.0137	0.0317	0.0129	0.0301	0.0123	0.0287	0.0116	0.0273	0.0112	0.0264	0.0107	0.0255
1.5	1.86	0.0154	0.0357	0.0146	0.0339	0.0139	0.0323	0.0131	0.0308	0.0126	0.0298	0.0121	0.0288
1.6	1.98	0.0173	0.0400	0.0164	0.0380	0.0155	0.0362	0.0147	0.0345	0.0141	0.0333	0.0136	0.0323
1.7	2.11	0.0192	0.0445	0.0182	0.0422	0.0173	0.0403	0.0164	0.0384	0.0157	0.0371	0.0151	0.0359
1.8	2.23	0.0212	0.0492	0.0201	0.0467	0.0191	0.0445	0.0181	0.0424	0.0174	0.0410	0.0167	0.0397
1.9	2.36	0.0234	0.0540	0.0221	0.0513	0.0210	0.0489	0.0199	0.0466	0.0191	0.0450	0.0183	0.0436
2.0	2.48	0.0255	0.0591	0.0242	0.0561	0.0229	0.0535	0.0217	0.0510	0.0209	0.0493	0.0201	0.0477
2.1	2.60	0.0278	0.0644	0.0263	0.0611	0.0250	0.0583	0.0237	0.0555	0.0227	0.0537	0.0218	0.0519
2.2	2.73	0.0302	0.0699	0.0285	0.0663	0.0271	0.0632	0.0257	0.0602	0.0247	0.0582	0.0237	0.0564
2.3	2.85	0.0326	0.0755	0.0309	0.0717	0.0293	0.0683	0.0278	0.0651	0.0267	0.0629	0.0256	0.0609
2.4	2.98	0.0351	0.0813	0.0332	0.0772	0.0315	0.0736	0.0299	0.0701	0.0287	0.0678	0.0276	0.0656
2.5	3.10	0.0377	0.0874	0.0357	0.0829	0.0339	0.0791	0.0321	0.0753	0.0308	0.0728	0.0296	0.0705
2.6	3.22	0.0404	0.0936	0.0382	0.0888	0.0363	0.0847	0.0344	0.0807	0.0330	0.0780	0.0318	0.0755
2.7	3.35	0.0432	0.1000	0.0409	0.0949	0.0388	0.0905	0.0367	0.0862	0.0353	0.0833	0.0339	0.0806
2.8	3.47	0.0460	0.1065	0.0435	0.1011	0.0413	0.0964	0.0392	0.0919	0.0376	0.0888	0.0361	0.0859
2.9	3.60	0.0489	0.1133	0.0463	0.1075	0.0439	0.1025	0.0416	0.0977	0.0400	0.0944	0.0384	0.0914
3.0	3.72	0.0519	0.1202	0.0491	0.1141	0.0466	0.1088	0.0442	0.1037	0.0424	0.1002	0.0408	0.0970

Pressure Loss per Linear Foot - 1/2" PEX - 100% Water

		80 ºF		100 ºF		120 ºF		140 ºF		160 ºF		180 ºF	
Flow (GPM)	Velocity (FPS)	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot
0.1	0.18	0.0003	0.0008	0.0003	0.0007	0.0003	0.0007	0.0003	0.0006	0.0003	0.0006	0.0003	0.0006
0.2	0.36	0.0011	0.0025	0.0010	0.0024	0.0010	0.0023	0.0009	0.0022	0.0009	0.0021	0.0009	0.0020
0.3	0.54	0.0022	0.0051	0.0021	0.0049	0.0020	0.0047	0.0019	0.0044	0.0018	0.0043	0.0017	0.0042
0.4	0.72	0.0037	0.0085	0.0035	0.0081	0.0033	0.0077	0.0031	0.0073	0.0030	0.0071	0.0029	0.0069
0.5	0.90	0.0054	0.0126	0.0051	0.0119	0.0049	0.0114	0.0046	0.0109	0.0044	0.0105	0.0043	0.0102
0.6	1.08	0.0075	0.0173	0.0071	0.0164	0.0067	0.0157	0.0064	0.0149	0.0061	0.0144	0.0059	0.0140
0.7	1.26	0.0098	0.0227	0.0093	0.0215	0.0088	0.0205	0.0083	0.0196	0.0080	0.0189	0.0077	0.0183
0.8	1.44	0.0124	0.0287	0.0117	0.0272	0.0111	0.0259	0.0105	0.0247	0.0101	0.0239	0.0097	0.0231
0.9	1.62	0.0152	0.0352	0.0144	0.0334	0.0137	0.0319	0.0129	0.0304	0.0124	0.0293	0.0119	0.0284
1.0	1.80	0.0183	0.0423	0.0173	0.0402	0.0164	0.0383	0.0156	0.0365	0.0149	0.0353	0.0144	0.0342
1.1	1.97	0.0216	0.0500	0.0204	0.0475	0.0194	0.0453	0.0184	0.0431	0.0177	0.0417	0.0170	0.0404
1.2	2.15	0.0252	0.0583	0.0238	0.0553	0.0226	0.0527	0.0214	0.0502	0.0206	0.0486	0.0198	0.0470
1.3	2.33	0.0290	0.0670	0.0274	0.0636	0.0260	0.0606	0.0246	0.0578	0.0237	0.0559	0.0227	0.0541
1.4	2.51	0.0330	0.0763	0.0312	0.0724	0.0296	0.0690	0.0280	0.0658	0.0269	0.0636	0.0259	0.0616
1.5	2.69	0.0372	0.0861	0.0352	0.0817	0.0334	0.0779	0.0316	0.0742	0.0304	0.0717	0.0292	0.0695
1.6	2.87	0.0416	0.0964	0.0394	0.0915	0.0374	0.0872	0.0354	0.0831	0.0340	0.0803	0.0327	0.0778
1.7	3.05	0.0463	0.1072	0.0438	0.1017	0.0416	0.0970	0.0394	0.0924	0.0378	0.0893	0.0364	0.0865
1.8	3.23	0.0512	0.1185	0.0484	0.1124	0.0459	0.1072	0.0435	0.1021	0.0418	0.0987	0.0402	0.0956
1.9	3.41	0.0563	0.1302	0.0532	0.1236	0.0505	0.1178	0.0479	0.1123	0.0460	0.1085	0.0442	0.1050
2.0	3.59	0.0615	0.1424	0.0582	0.1352	0.0552	0.1289	0.0524	0.1228	0.0503	0.1187	0.0483	0.1149
2.1	3.77	0.0670	0.1551	0.0634	0.1472	0.0602	0.1404	0.0570	0.1338	0.0548	0.1293	0.0526	0.1251
2.2	3.95	0.0727	0.1683	0.0688	0.1597	0.0653	0.1523	0.0619	0.1451	0.0594	0.1402	0.0571	0.1358
2.3	4.13	0.0786	0.1819	0.0743	0.1727	0.0705	0.1646	0.0669	0.1569	0.0642	0.1516	0.0617	0.1467
2.4	4.31	0.0847	0.1960	0.0801	0.1860	0.0760	0.1773	0.0720	0.1690	0.0692	0.1633	0.0665	0.1581
2.5	4.49	0.0909	0.2105	0.0860	0.1998	0.0816	0.1905	0.0774	0.1815	0.0743	0.1754	0.0714	0.1698
2.6	4.67	0.0974	0.2254	0.0921	0.2140	0.0874	0.2040	0.0829	0.1944	0.0796	0.1879	0.0765	0.1819
2.7	4.85	0.1041	0.2408	0.0984	0.2286	0.0934	0.2179	0.0885	0.2077	0.0850	0.2007	0.0817	0.1943
2.8	5.03	0.1109	0.2566	0.1049	0.2436	0.0995	0.2322	0.0943	0.2213	0.0906	0.2139	0.0871	0.2070
2.9	5.21	0.1179	0.2729	0.1115	0.2590	0.1058	0.2470	0.1003	0.2353	0.0963	0.2274	0.0926	0.2202
3.0	5.39	0.1251	0.2896	0.1183	0.2749	0.1123	0.2621	0.1064	0.2497	0.1022	0.2413	0.0983	0.2336

		Pressure Loss per Linear Foot - 3/8" PEX - 100% Water											
		80 °F		100 °F		120 °F		140 °F		160 °F		180 °F	
Flow (GPM)	Velocity (FPS)	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot
0.1	0.33	0.0014	0.0032	0.0013	0.0030	0.0012	0.0029	0.0012	0.0028	0.0011	0.0027	0.0011	0.0026
0.2	0.66	0.0046	0.0107	0.0044	0.0102	0.0042	0.0097	0.0039	0.0093	0.0038	0.0089	0.0036	0.0087
0.3	0.99	0.0094	0.0218	0.0089	0.0207	0.0085	0.0197	0.0080	0.0188	0.0077	0.0182	0.0074	0.0176
0.4	1.32	0.0156	0.0361	0.0147	0.0342	0.0140	0.0327	0.0133	0.0311	0.0127	0.0301	0.0122	0.0291
0.5	1.65	0.0230	0.0533	0.0218	0.0506	0.0207	0.0483	0.0196	0.0460	0.0188	0.0444	0.0181	0.0430
0.6	1.98	0.0317	0.0734	0.0300	0.0696	0.0284	0.0664	0.0270	0.0633	0.0259	0.0611	0.0249	0.0592
0.7	2.31	0.0415	0.0961	0.0393	0.0912	0.0373	0.0869	0.0353	0.0828	0.0339	0.0801	0.0326	0.0775
0.8	2.64	0.0524	0.1214	0.0496	0.1152	0.0471	0.1098	0.0446	0.1047	0.0428	0.1011	0.0412	0.0979
0.9	2.97	0.0644	0.1491	0.0610	0.1416	0.0578	0.1350	0.0548	0.1286	0.0526	0.1243	0.0506	0.1203
1.0	3.30	0.0775	0.1793	0.0733	0.1702	0.0696	0.1623	0.0659	0.1547	0.0633	0.1495	0.0609	0.1447
1.1	3.63	0.0916	0.2119	0.0866	0.2011	0.0822	0.1918	0.0779	0.1827	0.0748	0.1766	0.0719	0.1709
1.2	3.96	0.1066	0.2468	0.1008	0.2342	0.0957	0.2233	0.0907	0.2128	0.0871	0.2056	0.0837	0.1991
1.3	4.29	0.1226	0.2839	0.1160	0.2694	0.1101	0.2569	0.1043	0.2448	0.1002	0.2366	0.0963	0.2290
1.4	4.62	0.1396	0.3232	0.1321	0.3067	0.1253	0.2924	0.1188	0.2787	0.1141	0.2693	0.1097	0.2607
1.5	4.95	0.1576	0.3646	0.1490	0.3461	0.1414	0.3300	0.1340	0.3144	0.1287	0.3039	0.1237	0.2942
1.6	5.27	0.1764	0.4082	0.1668	0.3875	0.1583	0.3694	0.1501	0.3520	0.1441	0.3402	0.1385	0.3293
1.7	5.60	0.1961	0.4539	0.1855	0.4309	0.1760	0.4108	0.1668	0.3914	0.1602	0.3783	0.1540	0.3662
1.8	5.93	0.2168	0.5017	0.2050	0.4762	0.1945	0.4540	0.1844	0.4326	0.1771	0.4181	0.1702	0.4047
1.9	6.26	0.2383	0.5515	0.2254	0.5234	0.2139	0.4990	0.2027	0.4755	0.1946	0.4596	0.1871	0.4449
2.0	6.59	0.2607	0.6033	0.2465	0.5726	0.2339	0.5459	0.2217	0.5202	0.2129	0.5027	0.2047	0.4867
2.1	6.92	0.2839	0.6570	0.2685	0.6236	0.2548	0.5946	0.2415	0.5666	0.2319	0.5475	0.2229	0.5300
2.2	7.25	0.3080	0.7127	0.2913	0.6765	0.2764	0.6450	0.2620	0.6146	0.2516	0.5940	0.2419	0.5750
2.3	7.58	0.3329	0.7704	0.3149	0.7313	0.2988	0.6972	0.2832	0.6643	0.2719	0.6420	0.2614	0.6215
2.4	7.91	0.3586	0.8300	0.3392	0.7878	0.3219	0.7511	0.3051	0.7157	0.2930	0.6917	0.2816	0.6696
2.5	8.24	0.3852	0.8914	0.3643	0.8462	0.3457	0.8067	0.3277	0.7687	0.3147	0.7429	0.3025	0.7191
2.6	8.57	0.4125	0.9548	0.3902	0.9063	0.3703	0.8640	0.3509	0.8233	0.3370	0.7957	0.3240	0.7702
2.7	8.90	0.4407	1.0200	0.4168	0.9681	0.3955	0.9230	0.3749	0.8795	0.3600	0.8500	0.3461	0.8228
2.8	9.23	0.4697	1.0870	0.4442	1.0318	0.4215	0.9836	0.3995	0.9373	0.3837	0.9059	0.3688	0.8769
2.9	9.56	0.4994	1.1558	0.4724	1.0971	0.4482	1.0459	0.4248	0.9967	0.4080	0.9632	0.3922	0.9324
3.0	9.89	0.5299	1.2265	0.5012	1.1642	0.4756	1.1099	0.4508	1.0576	0.4329	1.0221	0.4162	0.9894

		Pressure Loss per Linear Foot - 1" PEX - 30% Ethylene Glycol / 70% Water											
		80 ºF		100 ºF		120 ºF		140 ºF		160 ºF		180 ºF	
Flow (GPM)	Velocity (FPS)	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot
0.1	0.05	0.0000	0.0001	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.2	0.11	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001
0.3	0.16	0.0002	0.0004	0.0002	0.0003	0.0001	0.0003	0.0001	0.0003	0.0001	0.0003	0.0001	0.0003
0.4	0.22	0.0003	0.0006	0.0003	0.0006	0.0002	0.0005	0.0002	0.0005	0.0002	0.0005	0.0002	0.0005
0.5	0.27	0.0004	0.0009	0.0004	0.0008	0.0004	0.0008	0.0003	0.0007	0.0003	0.0007	0.0003	0.0007
0.6	0.33	0.0006	0.0012	0.0005	0.0012	0.0005	0.0011	0.0005	0.0010	0.0004	0.0010	0.0004	0.0009
0.7	0.38	0.0007	0.0016	0.0007	0.0015	0.0006	0.0014	0.0006	0.0014	0.0006	0.0013	0.0005	0.0012
0.8	0.44	0.0009	0.0020	0.0009	0.0019	0.0008	0.0018	0.0008	0.0017	0.0007	0.0016	0.0007	0.0016
0.9	0.49	0.0011	0.0025	0.0011	0.0023	0.0010	0.0022	0.0009	0.0021	0.0009	0.0020	0.0009	0.0019
1.0	0.55	0.0014	0.0030	0.0013	0.0028	0.0012	0.0027	0.0011	0.0025	0.0011	0.0024	0.0010	0.0023
1.1	0.60	0.0016	0.0035	0.0015	0.0033	0.0014	0.0031	0.0013	0.0030	0.0013	0.0029	0.0012	0.0027
1.2	0.66	0.0019	0.0041	0.0018	0.0039	0.0016	0.0037	0.0016	0.0035	0.0015	0.0033	0.0014	0.0032
1.3	0.71	0.0022	0.0048	0.0020	0.0045	0.0019	0.0042	0.0018	0.0040	0.0017	0.0038	0.0016	0.0037
1.4	0.76	0.0025	0.0054	0.0023	0.0051	0.0022	0.0048	0.0020	0.0045	0.0019	0.0043	0.0018	0.0042
1.5	0.82	0.0028	0.0061	0.0026	0.0057	0.0024	0.0054	0.0023	0.0051	0.0022	0.0049	0.0021	0.0047
1.6	0.87	0.0031	0.0068	0.0029	0.0064	0.0027	0.0060	0.0026	0.0057	0.0024	0.0055	0.0023	0.0053
1.7	0.93	0.0035	0.0076	0.0032	0.0071	0.0030	0.0067	0.0029	0.0064	0.0027	0.0061	0.0026	0.0059
1.8	0.98	0.0038	0.0084	0.0036	0.0079	0.0033	0.0074	0.0032	0.0071	0.0030	0.0067	0.0029	0.0065
1.9	1.04	0.0042	0.0092	0.0039	0.0086	0.0037	0.0082	0.0035	0.0078	0.0033	0.0074	0.0031	0.0071
2.0	1.09	0.0046	0.0101	0.0043	0.0095	0.0040	0.0089	0.0038	0.0085	0.0036	0.0081	0.0034	0.0078
2.1	1.15	0.0050	0.0110	0.0047	0.0103	0.0044	0.0097	0.0041	0.0092	0.0039	0.0088	0.0037	0.0085
2.2	1.20	0.0054	0.0119	0.0051	0.0112	0.0048	0.0105	0.0045	0.0100	0.0043	0.0096	0.0041	0.0092
2.3	1.26	0.0059	0.0129	0.0055	0.0121	0.0051	0.0114	0.0049	0.0108	0.0046	0.0104	0.0044	0.0099
2.4	1.31	0.0063	0.0139	0.0059	0.0130	0.0055	0.0123	0.0052	0.0117	0.0050	0.0112	0.0047	0.0107
2.5	1.36	0.0068	0.0149	0.0063	0.0140	0.0059	0.0132	0.0056	0.0125	0.0053	0.0120	0.0051	0.0115
2.6	1.42	0.0073	0.0160	0.0068	0.0150	0.0064	0.0141	0.0060	0.0134	0.0057	0.0128	0.0054	0.0123
2.7	1.47	0.0078	0.0171	0.0073	0.0160	0.0068	0.0151	0.0064	0.0143	0.0061	0.0137	0.0058	0.0132
2.8	1.53	0.0083	0.0182	0.0077	0.0170	0.0072	0.0161	0.0068	0.0153	0.0065	0.0146	0.0062	0.0140
2.9	1.58	0.0088	0.0193	0.0082	0.0181	0.0077	0.0171	0.0073	0.0162	0.0069	0.0156	0.0066	0.0149
3.0	1.64	0.0094	0.0205	0.0087	0.0192	0.0082	0.0181	0.0077	0.0172	0.0073	0.0165	0.0070	0.0158

		Pressure Loss per Linear Foot - 3/4" PEX - 30% Ethylene Glycol / 70% Water											
		80 ºF		100 ºF		120 ºF		140 ºF		160 ºF		180 ºF	
Flow (GPM)	Velocity (FPS)	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot
0.1	0.09	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
0.2	0.18	0.0003	0.0006	0.0003	0.0006	0.0002	0.0005	0.0002	0.0005	0.0002	0.0005	0.0002	0.0005
0.3	0.27	0.0005	0.0012	0.0005	0.0011	0.0005	0.0011	0.0005	0.0010	0.0004	0.0010	0.0004	0.0009
0.4	0.36	0.0009	0.0020	0.0008	0.0019	0.0008	0.0018	0.0007	0.0017	0.0007	0.0016	0.0007	0.0015
0.5	0.45	0.0013	0.0029	0.0012	0.0028	0.0012	0.0026	0.0011	0.0025	0.0011	0.0024	0.0010	0.0023
0.6	0.54	0.0018	0.0040	0.0017	0.0038	0.0016	0.0036	0.0015	0.0034	0.0014	0.0033	0.0014	0.0031
0.7	0.63	0.0024	0.0053	0.0022	0.0050	0.0021	0.0047	0.0020	0.0044	0.0019	0.0043	0.0018	0.0041
0.8	0.72	0.0030	0.0067	0.0028	0.0063	0.0027	0.0059	0.0025	0.0056	0.0024	0.0054	0.0023	0.0052
0.9	0.81	0.0037	0.0082	0.0035	0.0077	0.0033	0.0073	0.0031	0.0069	0.0029	0.0066	0.0028	0.0063
1.0	0.90	0.0045	0.0099	0.0042	0.0093	0.0039	0.0087	0.0037	0.0083	0.0035	0.0079	0.0034	0.0076
1.1	0.99	0.0053	0.0117	0.0050	0.0109	0.0047	0.0103	0.0044	0.0098	0.0042	0.0094	0.0040	0.0090
1.2	1.08	0.0062	0.0136	0.0058	0.0127	0.0054	0.0120	0.0051	0.0114	0.0049	0.0109	0.0046	0.0105
1.3	1.17	0.0071	0.0157	0.0066	0.0147	0.0062	0.0138	0.0059	0.0131	0.0056	0.0126	0.0053	0.0121
1.4	1.26	0.0081	0.0178	0.0076	0.0167	0.0071	0.0157	0.0067	0.0150	0.0064	0.0143	0.0061	0.0137
1.5	1.35	0.0092	0.0201	0.0085	0.0188	0.0080	0.0178	0.0076	0.0169	0.0072	0.0162	0.0068	0.0155
1.6	1.44	0.0103	0.0225	0.0096	0.0211	0.0090	0.0199	0.0085	0.0189	0.0080	0.0181	0.0077	0.0174
1.7	1.53	0.0114	0.0250	0.0106	0.0234	0.0100	0.0221	0.0094	0.0210	0.0089	0.0201	0.0085	0.0193
1.8	1.62	0.0126	0.0277	0.0117	0.0259	0.0110	0.0244	0.0104	0.0232	0.0099	0.0222	0.0094	0.0213
1.9	1.71	0.0139	0.0304	0.0129	0.0285	0.0121	0.0269	0.0114	0.0255	0.0109	0.0244	0.0104	0.0234
2.0	1.80	0.0152	0.0333	0.0141	0.0312	0.0132	0.0294	0.0125	0.0279	0.0119	0.0267	0.0113	0.0256
2.1	1.89	0.0165	0.0362	0.0154	0.0339	0.0144	0.0320	0.0136	0.0304	0.0130	0.0291	0.0123	0.0279
2.2	1.98	0.0179	0.0393	0.0167	0.0368	0.0157	0.0347	0.0148	0.0330	0.0141	0.0316	0.0134	0.0303
2.3	2.07	0.0194	0.0425	0.0180	0.0398	0.0169	0.0375	0.0160	0.0357	0.0152	0.0341	0.0145	0.0327
2.4	2.16	0.0209	0.0458	0.0194	0.0429	0.0182	0.0404	0.0172	0.0384	0.0164	0.0368	0.0156	0.0353
2.5	2.25	0.0224	0.0492	0.0209	0.0460	0.0196	0.0434	0.0185	0.0413	0.0176	0.0395	0.0167	0.0379
2.6	2.34	0.0240	0.0526	0.0224	0.0493	0.0210	0.0465	0.0198	0.0442	0.0188	0.0423	0.0179	0.0406
2.7	2.43	0.0256	0.0562	0.0239	0.0527	0.0224	0.0497	0.0212	0.0472	0.0201	0.0452	0.0191	0.0434
2.8	2.53	0.0273	0.0599	0.0255	0.0561	0.0239	0.0530	0.0225	0.0503	0.0214	0.0482	0.0204	0.0462
2.9	2.62	0.0290	0.0637	0.0271	0.0597	0.0254	0.0563	0.0240	0.0535	0.0228	0.0512	0.0217	0.0491
3.0	2.71	0.0308	0.0676	0.0287	0.0634	0.0269	0.0598	0.0254	0.0568	0.0242	0.0544	0.0230	0.0521

Pressure Loss per Linear Foot - 5/8" PEX - 30% Ethylene Glycol / 70% Water

Flow (GPM)	Velocity (FPS)	80 ºF Pressure Loss (PSI) per foot	80 ºF Head Loss (FT-H2O) per foot	100 ºF Pressure Loss (PSI) per foot	100 ºF Head Loss (FT-H2O) per foot	120 ºF Pressure Loss (PSI) per foot	120 ºF Head Loss (FT-H2O) per foot	140 ºF Pressure Loss (PSI) per foot	140 ºF Head Loss (FT-H2O) per foot	160 ºF Pressure Loss (PSI) per foot	160 ºF Head Loss (FT-H2O) per foot	180 ºF Pressure Loss (PSI) per foot	180 ºF Head Loss (FT-H2O) per foot
0.1	0.12	0.0002	0.0004	0.0002	0.0004	0.0001	0.0003	0.0001	0.0003	0.0001	0.0003	0.0001	0.0003
0.2	0.25	0.0006	0.0013	0.0005	0.0012	0.0005	0.0011	0.0005	0.0011	0.0005	0.0010	0.0004	0.0010
0.3	0.37	0.0012	0.0026	0.0011	0.0024	0.0010	0.0023	0.0010	0.0022	0.0009	0.0021	0.0009	0.0020
0.4	0.50	0.0019	0.0042	0.0018	0.0040	0.0017	0.0037	0.0016	0.0036	0.0015	0.0034	0.0014	0.0033
0.5	0.62	0.0029	0.0063	0.0027	0.0059	0.0025	0.0055	0.0024	0.0053	0.0022	0.0050	0.0021	0.0048
0.6	0.74	0.0039	0.0086	0.0037	0.0081	0.0034	0.0076	0.0032	0.0072	0.0031	0.0069	0.0029	0.0066
0.7	0.87	0.0051	0.0113	0.0048	0.0106	0.0045	0.0100	0.0042	0.0095	0.0040	0.0091	0.0038	0.0087
0.8	0.99	0.0065	0.0142	0.0061	0.0133	0.0057	0.0126	0.0054	0.0120	0.0051	0.0115	0.0049	0.0110
0.9	1.12	0.0080	0.0175	0.0074	0.0164	0.0070	0.0155	0.0066	0.0147	0.0063	0.0141	0.0060	0.0135
1.0	1.24	0.0096	0.0211	0.0089	0.0197	0.0084	0.0186	0.0079	0.0177	0.0075	0.0169	0.0072	0.0162
1.1	1.36	0.0113	0.0249	0.0106	0.0233	0.0099	0.0220	0.0094	0.0209	0.0089	0.0200	0.0085	0.0192
1.2	1.49	0.0132	0.0290	0.0123	0.0271	0.0115	0.0256	0.0109	0.0243	0.0104	0.0233	0.0099	0.0223
1.3	1.61	0.0152	0.0333	0.0142	0.0312	0.0133	0.0295	0.0125	0.0280	0.0119	0.0268	0.0113	0.0257
1.4	1.74	0.0173	0.0379	0.0161	0.0355	0.0151	0.0335	0.0143	0.0319	0.0136	0.0305	0.0129	0.0293
1.5	1.86	0.0195	0.0428	0.0182	0.0401	0.0170	0.0378	0.0161	0.0360	0.0153	0.0344	0.0146	0.0330
1.6	1.98	0.0218	0.0479	0.0204	0.0449	0.0191	0.0424	0.0180	0.0403	0.0171	0.0385	0.0163	0.0370
1.7	2.11	0.0243	0.0533	0.0226	0.0499	0.0212	0.0471	0.0200	0.0448	0.0191	0.0428	0.0181	0.0411
1.8	2.23	0.0268	0.0589	0.0250	0.0552	0.0235	0.0521	0.0222	0.0495	0.0211	0.0473	0.0201	0.0454
1.9	2.36	0.0295	0.0647	0.0275	0.0607	0.0258	0.0572	0.0244	0.0544	0.0232	0.0520	0.0220	0.0499
2.0	2.48	0.0323	0.0708	0.0301	0.0664	0.0282	0.0626	0.0266	0.0595	0.0253	0.0569	0.0241	0.0546
2.1	2.60	0.0352	0.0771	0.0328	0.0723	0.0307	0.0682	0.0290	0.0648	0.0276	0.0620	0.0263	0.0595
2.2	2.73	0.0381	0.0837	0.0355	0.0784	0.0333	0.0740	0.0315	0.0703	0.0299	0.0673	0.0285	0.0645
2.3	2.85	0.0412	0.0904	0.0384	0.0847	0.0360	0.0799	0.0340	0.0760	0.0323	0.0727	0.0308	0.0697
2.4	2.98	0.0444	0.0974	0.0414	0.0913	0.0388	0.0861	0.0367	0.0818	0.0348	0.0783	0.0332	0.0751
2.5	3.10	0.0477	0.1047	0.0444	0.0980	0.0417	0.0925	0.0394	0.0879	0.0374	0.0841	0.0356	0.0807
2.6	3.22	0.0511	0.1121	0.0476	0.1050	0.0446	0.0991	0.0422	0.0942	0.0401	0.0901	0.0382	0.0864
2.7	3.35	0.0546	0.1197	0.0509	0.1122	0.0477	0.1058	0.0450	0.1006	0.0428	0.0963	0.0408	0.0923
2.8	3.47	0.0582	0.1276	0.0542	0.1196	0.0508	0.1128	0.0480	0.1072	0.0456	0.1026	0.0435	0.0984
2.9	3.60	0.0618	0.1357	0.0576	0.1271	0.0540	0.1199	0.0510	0.1140	0.0485	0.1091	0.0462	0.1046
3.0	3.72	0.0656	0.1440	0.0612	0.1349	0.0573	0.1273	0.0542	0.1209	0.0515	0.1158	0.0490	0.1110

Pressure Loss per Linear Foot - 1/2" PEX - 30% Ethylene Glycol / 70% Water

Flow (GPM)	Velocity (FPS)	80 ºF Pressure Loss (PSI) per foot	80 ºF Head Loss (FT-H2O) per foot	100 ºF Pressure Loss (PSI) per foot	100 ºF Head Loss (FT-H2O) per foot	120 ºF Pressure Loss (PSI) per foot	120 ºF Head Loss (FT-H2O) per foot	140 ºF Pressure Loss (PSI) per foot	140 ºF Head Loss (FT-H2O) per foot	160 ºF Pressure Loss (PSI) per foot	160 ºF Head Loss (FT-H2O) per foot	180 ºF Pressure Loss (PSI) per foot	180 ºF Head Loss (FT-H2O) per foot
0.1	0.18	0.0004	0.0009	0.0004	0.0008	0.0004	0.0008	0.0003	0.0008	0.0003	0.0007	0.0003	0.0007
0.2	0.36	0.0014	0.0030	0.0013	0.0028	0.0012	0.0027	0.0011	0.0025	0.0011	0.0024	0.0010	0.0023
0.3	0.54	0.0028	0.0062	0.0026	0.0058	0.0025	0.0055	0.0023	0.0052	0.0022	0.0050	0.0021	0.0048
0.4	0.72	0.0047	0.0102	0.0043	0.0096	0.0041	0.0090	0.0038	0.0086	0.0036	0.0082	0.0035	0.0079
0.5	0.90	0.0069	0.0151	0.0064	0.0141	0.0060	0.0133	0.0057	0.0127	0.0054	0.0121	0.0051	0.0116
0.6	1.08	0.0095	0.0207	0.0088	0.0194	0.0083	0.0183	0.0078	0.0174	0.0074	0.0167	0.0071	0.0160
0.7	1.26	0.0124	0.0272	0.0115	0.0255	0.0108	0.0240	0.0102	0.0228	0.0097	0.0218	0.0093	0.0210
0.8	1.44	0.0156	0.0343	0.0146	0.0322	0.0137	0.0303	0.0129	0.0288	0.0123	0.0276	0.0117	0.0265
0.9	1.62	0.0192	0.0422	0.0179	0.0395	0.0168	0.0373	0.0159	0.0354	0.0151	0.0339	0.0144	0.0325
1.0	1.80	0.0231	0.0507	0.0215	0.0475	0.0202	0.0448	0.0191	0.0426	0.0181	0.0408	0.0173	0.0391
1.1	1.97	0.0273	0.0599	0.0255	0.0562	0.0239	0.0530	0.0225	0.0503	0.0214	0.0482	0.0204	0.0462
1.2	2.15	0.0318	0.0698	0.0296	0.0654	0.0278	0.0617	0.0263	0.0586	0.0250	0.0561	0.0238	0.0538
1.3	2.33	0.0366	0.0803	0.0341	0.0752	0.0320	0.0710	0.0302	0.0674	0.0287	0.0645	0.0273	0.0619
1.4	2.51	0.0417	0.0914	0.0388	0.0856	0.0364	0.0808	0.0344	0.0768	0.0327	0.0735	0.0311	0.0705
1.5	2.69	0.0470	0.1031	0.0438	0.0966	0.0411	0.0911	0.0388	0.0866	0.0369	0.0829	0.0351	0.0795
1.6	2.87	0.0526	0.1155	0.0490	0.1082	0.0460	0.1020	0.0434	0.0970	0.0413	0.0928	0.0393	0.0890
1.7	3.05	0.0585	0.1284	0.0545	0.1203	0.0511	0.1135	0.0483	0.1078	0.0459	0.1032	0.0437	0.0990
1.8	3.23	0.0647	0.1419	0.0603	0.1329	0.0565	0.1254	0.0534	0.1192	0.0507	0.1141	0.0483	0.1094
1.9	3.41	0.0711	0.1560	0.0662	0.1461	0.0621	0.1379	0.0587	0.1310	0.0558	0.1254	0.0531	0.1203
2.0	3.59	0.0778	0.1706	0.0725	0.1599	0.0680	0.1508	0.0642	0.1433	0.0610	0.1372	0.0581	0.1315
2.1	3.77	0.0847	0.1858	0.0789	0.1741	0.0740	0.1642	0.0699	0.1561	0.0665	0.1494	0.0633	0.1433
2.2	3.95	0.0919	0.2016	0.0856	0.1889	0.0803	0.1782	0.0758	0.1693	0.0721	0.1621	0.0686	0.1554
2.3	4.13	0.0993	0.2179	0.0925	0.2041	0.0868	0.1926	0.0820	0.1830	0.0779	0.1752	0.0742	0.1680
2.4	4.31	0.1070	0.2348	0.0997	0.2199	0.0935	0.2075	0.0883	0.1972	0.0839	0.1887	0.0799	0.1810
2.5	4.49	0.1149	0.2521	0.1071	0.2362	0.1004	0.2228	0.0948	0.2118	0.0902	0.2027	0.0859	0.1944
2.6	4.67	0.1231	0.2700	0.1147	0.2530	0.1075	0.2387	0.1016	0.2268	0.0966	0.2171	0.0920	0.2082
2.7	4.85	0.1315	0.2885	0.1225	0.2703	0.1149	0.2550	0.1085	0.2423	0.1032	0.2319	0.0982	0.2224
2.8	5.03	0.1401	0.3074	0.1306	0.2880	0.1224	0.2717	0.1156	0.2582	0.1099	0.2471	0.1047	0.2370
2.9	5.21	0.1490	0.3269	0.1388	0.3063	0.1302	0.2889	0.1230	0.2746	0.1169	0.2628	0.1113	0.2520
3.0	5.39	0.1581	0.3469	0.1473	0.3250	0.1382	0.3066	0.1305	0.2914	0.1241	0.2789	0.1181	0.2675

Pressure Loss per Linear Foot - 3/8" PEX - 30% Ethylene Glycol / 70% Water

		80 ºF		100 ºF		120 ºF		140 ºF		160 ºF		180 ºF	
Flow (GPM)	Velocity (FPS)	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot
0.1	0.33	0.0017	0.0038	0.0016	0.0036	0.0015	0.0034	0.0014	0.0032	0.0014	0.0031	0.0013	0.0029
0.2	0.66	0.0059	0.0129	0.0055	0.0120	0.0051	0.0114	0.0048	0.0108	0.0046	0.0103	0.0044	0.0099
0.3	0.99	0.0119	0.0261	0.0111	0.0245	0.0104	0.0231	0.0098	0.0219	0.0093	0.0210	0.0089	0.0201
0.4	1.32	0.0197	0.0432	0.0184	0.0405	0.0172	0.0382	0.0163	0.0363	0.0155	0.0347	0.0147	0.0333
0.5	1.65	0.0291	0.0639	0.0271	0.0598	0.0254	0.0565	0.0240	0.0537	0.0228	0.0513	0.0217	0.0492
0.6	1.98	0.0401	0.0879	0.0373	0.0823	0.0350	0.0777	0.0331	0.0738	0.0314	0.0706	0.0299	0.0678
0.7	2.31	0.0525	0.1151	0.0489	0.1078	0.0458	0.1017	0.0433	0.0967	0.0412	0.0925	0.0392	0.0887
0.8	2.64	0.0663	0.1454	0.0617	0.1362	0.0579	0.1285	0.0547	0.1221	0.0520	0.1169	0.0495	0.1121
0.9	2.97	0.0814	0.1787	0.0759	0.1674	0.0712	0.1579	0.0672	0.1501	0.0639	0.1436	0.0608	0.1377
1.0	3.30	0.0979	0.2148	0.0912	0.2013	0.0856	0.1899	0.0808	0.1805	0.0768	0.1727	0.0732	0.1656
1.1	3.63	0.1157	0.2538	0.1078	0.2378	0.1011	0.2243	0.0955	0.2132	0.0908	0.2041	0.0864	0.1957
1.2	3.96	0.1347	0.2956	0.1255	0.2769	0.1177	0.2612	0.1112	0.2483	0.1057	0.2376	0.1006	0.2279
1.3	4.29	0.1550	0.3400	0.1444	0.3186	0.1354	0.3005	0.1279	0.2856	0.1216	0.2733	0.1158	0.2622
1.4	4.62	0.1764	0.3871	0.1644	0.3627	0.1542	0.3421	0.1456	0.3252	0.1384	0.3112	0.1318	0.2985
1.5	4.95	0.1991	0.4368	0.1855	0.4092	0.1740	0.3860	0.1643	0.3669	0.1562	0.3511	0.1487	0.3368
1.6	5.27	0.2229	0.4890	0.2077	0.4582	0.1948	0.4322	0.1840	0.4108	0.1749	0.3931	0.1665	0.3770
1.7	5.60	0.2478	0.5438	0.2309	0.5094	0.2166	0.4806	0.2045	0.4567	0.1945	0.4371	0.1852	0.4192
1.8	5.93	0.2739	0.6010	0.2552	0.5630	0.2393	0.5311	0.2261	0.5048	0.2149	0.4831	0.2046	0.4633
1.9	6.26	0.3011	0.6606	0.2806	0.6189	0.2631	0.5838	0.2485	0.5549	0.2362	0.5310	0.2249	0.5093
2.0	6.59	0.3293	0.7226	0.3069	0.6770	0.2878	0.6387	0.2718	0.6070	0.2584	0.5809	0.2461	0.5571
2.1	6.92	0.3587	0.7871	0.3343	0.7374	0.3134	0.6956	0.2961	0.6611	0.2815	0.6327	0.2680	0.6068
2.2	7.25	0.3891	0.8538	0.3626	0.7999	0.3400	0.7546	0.3212	0.7172	0.3053	0.6864	0.2907	0.6583
2.3	7.58	0.4206	0.9229	0.3920	0.8646	0.3675	0.8157	0.3472	0.7752	0.3300	0.7419	0.3142	0.7115
2.4	7.91	0.4531	0.9942	0.4223	0.9315	0.3960	0.8787	0.3740	0.8351	0.3555	0.7993	0.3385	0.7665
2.5	8.24	0.4867	1.0679	0.4535	1.0005	0.4253	0.9438	0.4017	0.8970	0.3819	0.8584	0.3636	0.8233
2.6	8.57	0.5213	1.1437	0.4857	1.0715	0.4555	1.0108	0.4302	0.9607	0.4090	0.9194	0.3894	0.8818
2.7	8.90	0.5568	1.2218	0.5189	1.1447	0.4866	1.0799	0.4596	1.0263	0.4369	0.9822	0.4160	0.9420
2.8	9.23	0.5934	1.3021	0.5530	1.2199	0.5186	1.1508	0.4898	1.0937	0.4656	1.0467	0.4434	1.0039
2.9	9.56	0.6310	1.3846	0.5880	1.2972	0.5514	1.2237	0.5208	1.1630	0.4951	1.1130	0.4715	1.0675
3.0	9.89	0.6696	1.4692	0.6240	1.3765	0.5851	1.2985	0.5527	1.2341	0.5254	1.1811	0.5003	1.1327

Pressure Loss per Linear Foot - 1" PEX - 40% Ethylene Glycol / 60% Water

		80 ºF		100 ºF		120 ºF		140 ºF		160 ºF		180 ºF	
Flow (GPM)	Velocity (FPS)	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot
0.1	0.05	0.0000	0.0001	0.0000	0.0001	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.2	0.11	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002	0.0001	0.0001
0.3	0.16	0.0002	0.0004	0.0002	0.0004	0.0002	0.0003	0.0001	0.0003	0.0001	0.0003	0.0001	0.0003
0.4	0.22	0.0003	0.0006	0.0003	0.0006	0.0003	0.0006	0.0002	0.0005	0.0002	0.0005	0.0002	0.0005
0.5	0.27	0.0004	0.0010	0.0004	0.0009	0.0004	0.0008	0.0004	0.0008	0.0003	0.0008	0.0003	0.0007
0.6	0.33	0.0006	0.0013	0.0006	0.0012	0.0005	0.0012	0.0005	0.0011	0.0005	0.0010	0.0004	0.0010
0.7	0.38	0.0008	0.0017	0.0007	0.0016	0.0007	0.0015	0.0006	0.0014	0.0006	0.0014	0.0006	0.0013
0.8	0.44	0.0010	0.0022	0.0009	0.0020	0.0009	0.0019	0.0008	0.0018	0.0008	0.0017	0.0007	0.0017
0.9	0.49	0.0012	0.0027	0.0011	0.0025	0.0011	0.0024	0.0010	0.0022	0.0010	0.0021	0.0009	0.0020
1.0	0.55	0.0015	0.0032	0.0014	0.0030	0.0013	0.0028	0.0012	0.0027	0.0011	0.0026	0.0011	0.0024
1.1	0.60	0.0017	0.0038	0.0016	0.0036	0.0015	0.0034	0.0014	0.0032	0.0014	0.0030	0.0013	0.0029
1.2	0.66	0.0020	0.0044	0.0019	0.0041	0.0018	0.0039	0.0017	0.0037	0.0016	0.0035	0.0015	0.0034
1.3	0.71	0.0023	0.0051	0.0022	0.0048	0.0020	0.0045	0.0019	0.0043	0.0018	0.0040	0.0017	0.0039
1.4	0.76	0.0027	0.0058	0.0025	0.0054	0.0023	0.0051	0.0022	0.0048	0.0021	0.0046	0.0020	0.0044
1.5	0.82	0.0030	0.0066	0.0028	0.0061	0.0026	0.0058	0.0025	0.0055	0.0023	0.0052	0.0022	0.0050
1.6	0.87	0.0034	0.0073	0.0031	0.0069	0.0029	0.0065	0.0028	0.0061	0.0026	0.0058	0.0025	0.0056
1.7	0.93	0.0037	0.0082	0.0035	0.0076	0.0033	0.0072	0.0031	0.0068	0.0029	0.0065	0.0028	0.0062
1.8	0.98	0.0041	0.0090	0.0038	0.0084	0.0036	0.0079	0.0034	0.0075	0.0032	0.0071	0.0030	0.0068
1.9	1.04	0.0045	0.0099	0.0042	0.0093	0.0040	0.0087	0.0037	0.0083	0.0035	0.0079	0.0033	0.0075
2.0	1.09	0.0050	0.0108	0.0046	0.0101	0.0043	0.0095	0.0041	0.0090	0.0039	0.0086	0.0037	0.0082
2.1	1.15	0.0054	0.0118	0.0050	0.0110	0.0047	0.0104	0.0044	0.0098	0.0042	0.0094	0.0040	0.0090
2.2	1.20	0.0059	0.0128	0.0055	0.0120	0.0051	0.0113	0.0048	0.0107	0.0046	0.0102	0.0043	0.0097
2.3	1.26	0.0064	0.0138	0.0059	0.0129	0.0055	0.0122	0.0052	0.0115	0.0049	0.0110	0.0047	0.0105
2.4	1.31	0.0068	0.0149	0.0064	0.0139	0.0060	0.0131	0.0056	0.0124	0.0053	0.0118	0.0050	0.0113
2.5	1.36	0.0073	0.0160	0.0068	0.0150	0.0064	0.0141	0.0060	0.0134	0.0057	0.0127	0.0054	0.0121
2.6	1.42	0.0079	0.0172	0.0073	0.0160	0.0069	0.0151	0.0065	0.0143	0.0061	0.0136	0.0058	0.0130
2.7	1.47	0.0084	0.0183	0.0078	0.0171	0.0073	0.0161	0.0069	0.0153	0.0065	0.0145	0.0062	0.0139
2.8	1.53	0.0090	0.0195	0.0083	0.0183	0.0078	0.0172	0.0073	0.0163	0.0069	0.0155	0.0066	0.0148
2.9	1.58	0.0095	0.0208	0.0089	0.0194	0.0083	0.0183	0.0078	0.0173	0.0074	0.0165	0.0070	0.0158
3.0	1.64	0.0101	0.0220	0.0094	0.0206	0.0088	0.0194	0.0083	0.0184	0.0078	0.0175	0.0074	0.0167

Pressure Loss per Linear Foot - 3/4" PEX - 40% Ethylene Glycol / 60% Water

		80 ºF		100 ºF		120 ºF		140 ºF		160 ºF		180 ºF	
Flow (GPM)	Velocity (FPS)	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot
0.1	0.09	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001
0.2	0.18	0.0003	0.0006	0.0003	0.0006	0.0003	0.0006	0.0002	0.0005	0.0002	0.0005	0.0002	0.0005
0.3	0.27	0.0006	0.0013	0.0006	0.0012	0.0005	0.0011	0.0005	0.0011	0.0005	0.0010	0.0004	0.0010
0.4	0.36	0.0010	0.0021	0.0009	0.0020	0.0009	0.0019	0.0008	0.0018	0.0008	0.0017	0.0007	0.0016
0.5	0.45	0.0014	0.0032	0.0013	0.0030	0.0013	0.0028	0.0012	0.0026	0.0011	0.0025	0.0011	0.0024
0.6	0.54	0.0020	0.0043	0.0019	0.0041	0.0017	0.0038	0.0016	0.0036	0.0015	0.0034	0.0015	0.0033
0.7	0.63	0.0026	0.0057	0.0024	0.0053	0.0023	0.0050	0.0021	0.0047	0.0020	0.0045	0.0019	0.0043
0.8	0.72	0.0033	0.0072	0.0031	0.0067	0.0029	0.0063	0.0027	0.0060	0.0026	0.0057	0.0024	0.0054
0.9	0.81	0.0040	0.0088	0.0038	0.0083	0.0035	0.0078	0.0033	0.0074	0.0031	0.0070	0.0030	0.0067
1.0	0.90	0.0049	0.0106	0.0045	0.0099	0.0042	0.0093	0.0040	0.0089	0.0038	0.0084	0.0036	0.0081
1.1	0.99	0.0058	0.0125	0.0054	0.0117	0.0050	0.0110	0.0047	0.0105	0.0045	0.0099	0.0042	0.0095
1.2	1.08	0.0067	0.0146	0.0062	0.0137	0.0058	0.0129	0.0055	0.0122	0.0052	0.0116	0.0049	0.0111
1.3	1.17	0.0077	0.0168	0.0072	0.0157	0.0067	0.0148	0.0063	0.0140	0.0060	0.0133	0.0057	0.0127
1.4	1.26	0.0088	0.0191	0.0082	0.0179	0.0076	0.0168	0.0072	0.0159	0.0068	0.0152	0.0065	0.0145
1.5	1.35	0.0099	0.0216	0.0092	0.0202	0.0086	0.0190	0.0081	0.0180	0.0077	0.0171	0.0073	0.0164
1.6	1.44	0.0111	0.0242	0.0103	0.0226	0.0097	0.0213	0.0091	0.0201	0.0086	0.0192	0.0082	0.0183
1.7	1.53	0.0123	0.0269	0.0115	0.0251	0.0107	0.0236	0.0101	0.0224	0.0095	0.0213	0.0091	0.0204
1.8	1.62	0.0136	0.0297	0.0127	0.0278	0.0119	0.0261	0.0112	0.0248	0.0106	0.0235	0.0100	0.0225
1.9	1.71	0.0150	0.0326	0.0139	0.0305	0.0130	0.0287	0.0123	0.0272	0.0116	0.0259	0.0110	0.0248
2.0	1.80	0.0164	0.0357	0.0152	0.0334	0.0143	0.0314	0.0134	0.0298	0.0127	0.0283	0.0121	0.0271
2.1	1.89	0.0178	0.0389	0.0166	0.0364	0.0155	0.0342	0.0146	0.0324	0.0138	0.0308	0.0131	0.0295
2.2	1.98	0.0194	0.0422	0.0180	0.0394	0.0169	0.0371	0.0159	0.0352	0.0150	0.0335	0.0142	0.0320
2.3	2.07	0.0209	0.0456	0.0195	0.0426	0.0182	0.0401	0.0172	0.0380	0.0162	0.0362	0.0154	0.0346
2.4	2.16	0.0225	0.0491	0.0210	0.0459	0.0196	0.0432	0.0185	0.0410	0.0175	0.0390	0.0166	0.0373
2.5	2.25	0.0242	0.0528	0.0225	0.0493	0.0211	0.0464	0.0199	0.0440	0.0188	0.0418	0.0178	0.0400
2.6	2.34	0.0259	0.0565	0.0241	0.0528	0.0226	0.0497	0.0213	0.0471	0.0201	0.0448	0.0191	0.0429
2.7	2.43	0.0277	0.0604	0.0258	0.0564	0.0241	0.0531	0.0227	0.0503	0.0215	0.0479	0.0204	0.0458
2.8	2.53	0.0295	0.0643	0.0275	0.0601	0.0257	0.0566	0.0242	0.0536	0.0229	0.0510	0.0217	0.0488
2.9	2.62	0.0314	0.0684	0.0292	0.0640	0.0273	0.0602	0.0257	0.0570	0.0243	0.0542	0.0231	0.0519
3.0	2.71	0.0333	0.0726	0.0310	0.0679	0.0290	0.0639	0.0273	0.0605	0.0258	0.0576	0.0245	0.0551

Pressure Loss per Linear Foot - 5/8" PEX - 40% Ethylene Glycol / 60% Water

		80 ºF		100 ºF		120 ºF		140 ºF		160 ºF		180 ºF	
Flow (GPM)	Velocity (FPS)	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot
0.1	0.12	0.0002	0.0004	0.0002	0.0004	0.0002	0.0004	0.0002	0.0003	0.0001	0.0003	0.0001	0.0003
0.2	0.25	0.0006	0.0014	0.0006	0.0013	0.0005	0.0012	0.0005	0.0011	0.0005	0.0011	0.0005	0.0010
0.3	0.37	0.0013	0.0027	0.0012	0.0026	0.0011	0.0024	0.0010	0.0023	0.0010	0.0022	0.0009	0.0021
0.4	0.50	0.0021	0.0045	0.0019	0.0043	0.0018	0.0040	0.0017	0.0038	0.0016	0.0036	0.0015	0.0034
0.5	0.62	0.0031	0.0067	0.0029	0.0063	0.0027	0.0059	0.0025	0.0056	0.0024	0.0053	0.0023	0.0051
0.6	0.74	0.0042	0.0092	0.0039	0.0086	0.0037	0.0081	0.0035	0.0077	0.0033	0.0073	0.0031	0.0070
0.7	0.87	0.0056	0.0121	0.0052	0.0113	0.0048	0.0107	0.0046	0.0101	0.0043	0.0096	0.0041	0.0092
0.8	0.99	0.0070	0.0153	0.0065	0.0143	0.0061	0.0135	0.0058	0.0128	0.0054	0.0121	0.0052	0.0116
0.9	1.12	0.0086	0.0188	0.0080	0.0176	0.0075	0.0165	0.0071	0.0157	0.0067	0.0149	0.0063	0.0143
1.0	1.24	0.0104	0.0226	0.0096	0.0211	0.0090	0.0199	0.0085	0.0188	0.0080	0.0179	0.0076	0.0171
1.1	1.36	0.0123	0.0267	0.0114	0.0250	0.0107	0.0235	0.0101	0.0223	0.0095	0.0212	0.0090	0.0203
1.2	1.49	0.0143	0.0311	0.0133	0.0291	0.0124	0.0274	0.0117	0.0259	0.0111	0.0247	0.0105	0.0236
1.3	1.61	0.0164	0.0358	0.0153	0.0334	0.0143	0.0315	0.0135	0.0298	0.0127	0.0284	0.0121	0.0271
1.4	1.74	0.0187	0.0407	0.0174	0.0381	0.0163	0.0358	0.0153	0.0340	0.0145	0.0323	0.0137	0.0309
1.5	1.86	0.0211	0.0460	0.0196	0.0430	0.0184	0.0404	0.0173	0.0383	0.0163	0.0364	0.0155	0.0349
1.6	1.98	0.0236	0.0515	0.0220	0.0481	0.0206	0.0453	0.0194	0.0429	0.0183	0.0408	0.0174	0.0390
1.7	2.11	0.0262	0.0572	0.0244	0.0535	0.0229	0.0503	0.0215	0.0477	0.0203	0.0454	0.0193	0.0434
1.8	2.23	0.0290	0.0632	0.0270	0.0591	0.0253	0.0556	0.0238	0.0527	0.0225	0.0501	0.0213	0.0480
1.9	2.36	0.0319	0.0695	0.0297	0.0650	0.0278	0.0612	0.0262	0.0580	0.0247	0.0551	0.0235	0.0527
2.0	2.48	0.0349	0.0760	0.0324	0.0711	0.0304	0.0669	0.0286	0.0634	0.0270	0.0603	0.0257	0.0577
2.1	2.60	0.0380	0.0828	0.0353	0.0774	0.0331	0.0729	0.0312	0.0690	0.0294	0.0657	0.0280	0.0628
2.2	2.73	0.0412	0.0898	0.0383	0.0840	0.0359	0.0791	0.0338	0.0749	0.0319	0.0712	0.0303	0.0681
2.3	2.85	0.0445	0.0971	0.0414	0.0908	0.0388	0.0854	0.0365	0.0810	0.0345	0.0770	0.0328	0.0737
2.4	2.98	0.0480	0.1046	0.0446	0.0978	0.0418	0.0921	0.0394	0.0872	0.0372	0.0829	0.0353	0.0793
2.5	3.10	0.0515	0.1124	0.0480	0.1050	0.0449	0.0989	0.0423	0.0937	0.0399	0.0891	0.0379	0.0852
2.6	3.22	0.0552	0.1203	0.0514	0.1125	0.0481	0.1059	0.0453	0.1003	0.0428	0.0954	0.0406	0.0913
2.7	3.35	0.0590	0.1286	0.0549	0.1202	0.0514	0.1131	0.0484	0.1072	0.0457	0.1019	0.0434	0.0975
2.8	3.47	0.0628	0.1370	0.0585	0.1281	0.0547	0.1206	0.0516	0.1142	0.0487	0.1086	0.0462	0.1039
2.9	3.60	0.0668	0.1457	0.0622	0.1362	0.0582	0.1282	0.0548	0.1215	0.0518	0.1155	0.0492	0.1105
3.0	3.72	0.0709	0.1546	0.0660	0.1445	0.0618	0.1360	0.0582	0.1289	0.0549	0.1226	0.0522	0.1173

Pressure Loss per Linear Foot - 1/2" PEX - 40% Ethylene Glycol / 60% Water

		80 ºF		100 ºF		120 ºF		140 ºF		160 ºF		180 ºF	
Flow (GPM)	Velocity (FPS)	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot
0.1	0.18	0.0004	0.0010	0.0004	0.0009	0.0004	0.0009	0.0004	0.0008	0.0003	0.0008	0.0003	0.0007
0.2	0.36	0.0015	0.0033	0.0014	0.0030	0.0013	0.0029	0.0012	0.0027	0.0012	0.0026	0.0011	0.0025
0.3	0.54	0.0030	0.0066	0.0028	0.0062	0.0026	0.0058	0.0025	0.0055	0.0024	0.0053	0.0022	0.0050
0.4	0.72	0.0050	0.0110	0.0047	0.0102	0.0044	0.0096	0.0041	0.0091	0.0039	0.0087	0.0037	0.0083
0.5	0.90	0.0074	0.0162	0.0069	0.0151	0.0065	0.0142	0.0061	0.0135	0.0058	0.0128	0.0055	0.0123
0.6	1.08	0.0102	0.0223	0.0095	0.0208	0.0089	0.0196	0.0084	0.0186	0.0079	0.0177	0.0075	0.0169
0.7	1.26	0.0134	0.0292	0.0125	0.0273	0.0117	0.0257	0.0110	0.0243	0.0104	0.0231	0.0098	0.0221
0.8	1.44	0.0169	0.0369	0.0157	0.0345	0.0147	0.0324	0.0139	0.0307	0.0131	0.0292	0.0124	0.0280
0.9	1.62	0.0208	0.0453	0.0193	0.0423	0.0181	0.0399	0.0170	0.0378	0.0161	0.0359	0.0153	0.0344
1.0	1.80	0.0250	0.0545	0.0232	0.0509	0.0218	0.0479	0.0205	0.0454	0.0194	0.0432	0.0184	0.0413
1.1	1.97	0.0295	0.0643	0.0275	0.0602	0.0257	0.0566	0.0242	0.0537	0.0229	0.0510	0.0217	0.0488
1.2	2.15	0.0344	0.0749	0.0320	0.0700	0.0299	0.0659	0.0282	0.0625	0.0266	0.0594	0.0253	0.0568
1.3	2.33	0.0395	0.0862	0.0368	0.0806	0.0344	0.0758	0.0324	0.0719	0.0306	0.0683	0.0291	0.0654
1.4	2.51	0.0450	0.0981	0.0419	0.0917	0.0392	0.0863	0.0369	0.0818	0.0349	0.0778	0.0331	0.0744
1.5	2.69	0.0508	0.1107	0.0473	0.1035	0.0442	0.0974	0.0417	0.0923	0.0394	0.0878	0.0374	0.0840
1.6	2.87	0.0569	0.1240	0.0529	0.1159	0.0495	0.1091	0.0466	0.1034	0.0441	0.0983	0.0418	0.0940
1.7	3.05	0.0632	0.1378	0.0588	0.1289	0.0551	0.1213	0.0519	0.1149	0.0490	0.1093	0.0465	0.1045
1.8	3.23	0.0699	0.1523	0.0650	0.1424	0.0609	0.1340	0.0573	0.1270	0.0541	0.1208	0.0514	0.1155
1.9	3.41	0.0768	0.1674	0.0715	0.1565	0.0669	0.1474	0.0630	0.1396	0.0595	0.1328	0.0565	0.1270
2.0	3.59	0.0840	0.1832	0.0782	0.1712	0.0732	0.1612	0.0689	0.1527	0.0651	0.1452	0.0618	0.1389
2.1	3.77	0.0915	0.1995	0.0851	0.1865	0.0797	0.1756	0.0751	0.1664	0.0709	0.1582	0.0673	0.1513
2.2	3.95	0.0993	0.2164	0.0924	0.2023	0.0865	0.1904	0.0814	0.1805	0.0769	0.1716	0.0731	0.1642
2.3	4.13	0.1073	0.2339	0.0998	0.2187	0.0935	0.2059	0.0880	0.1951	0.0831	0.1855	0.0790	0.1774
2.4	4.31	0.1156	0.2520	0.1076	0.2356	0.1007	0.2218	0.0948	0.2101	0.0896	0.1998	0.0851	0.1912
2.5	4.49	0.1242	0.2707	0.1155	0.2531	0.1081	0.2382	0.1019	0.2257	0.0962	0.2146	0.0914	0.2053
2.6	4.67	0.1330	0.2899	0.1237	0.2710	0.1158	0.2551	0.1091	0.2417	0.1030	0.2299	0.0979	0.2199
2.7	4.85	0.1421	0.3097	0.1322	0.2895	0.1237	0.2725	0.1165	0.2582	0.1101	0.2456	0.1045	0.2349
2.8	5.03	0.1514	0.3301	0.1409	0.3086	0.1319	0.2904	0.1242	0.2752	0.1173	0.2617	0.1114	0.2504
2.9	5.21	0.1610	0.3510	0.1498	0.3281	0.1402	0.3088	0.1321	0.2926	0.1247	0.2783	0.1185	0.2662
3.0	9.89	0.7236	1.5773	0.6732	1.4745	0.6302	1.3880	0.5936	1.3152	0.5606	1.2506	0.5324	1.1964

		Pressure Loss per Linear Foot - 3/8" PEX - 40% Ethylene Glycol / 60% Water											
		80 °F		100 °F		120 °F		140 °F		160 °F		180 °F	
Flow (GPM)	Velocity (FPS)	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot
0.1	0.33	0.0019	0.0041	0.0018	0.0038	0.0016	0.0036	0.0015	0.0034	0.0015	0.0033	0.0014	0.0031
0.2	0.66	0.0063	0.0138	0.0059	0.0129	0.0055	0.0121	0.0052	0.0115	0.0049	0.0109	0.0047	0.0105
0.3	0.99	0.0129	0.0280	0.0120	0.0262	0.0112	0.0247	0.0106	0.0234	0.0100	0.0222	0.0095	0.0213
0.4	1.32	0.0213	0.0464	0.0198	0.0434	0.0185	0.0408	0.0175	0.0387	0.0165	0.0368	0.0157	0.0352
0.5	1.65	0.0315	0.0686	0.0293	0.0641	0.0274	0.0603	0.0258	0.0572	0.0244	0.0544	0.0231	0.0520
0.6	1.98	0.0433	0.0943	0.0403	0.0882	0.0377	0.0830	0.0355	0.0787	0.0335	0.0748	0.0318	0.0716
0.7	2.31	0.0567	0.1236	0.0527	0.1155	0.0494	0.1087	0.0465	0.1030	0.0439	0.0980	0.0417	0.0937
0.8	2.64	0.0716	0.1561	0.0666	0.1459	0.0624	0.1374	0.0587	0.1301	0.0555	0.1238	0.0527	0.1184
0.9	2.97	0.0880	0.1918	0.0819	0.1793	0.0766	0.1688	0.0722	0.1599	0.0682	0.1521	0.0647	0.1455
1.0	3.30	0.1058	0.2306	0.0984	0.2156	0.0921	0.2030	0.0868	0.1923	0.0820	0.1829	0.0779	0.1750
1.1	3.63	0.1250	0.2725	0.1163	0.2548	0.1089	0.2398	0.1026	0.2272	0.0969	0.2161	0.0920	0.2067
1.2	3.96	0.1456	0.3173	0.1354	0.2967	0.1268	0.2792	0.1194	0.2646	0.1128	0.2516	0.1071	0.2407
1.3	4.29	0.1675	0.3650	0.1558	0.3413	0.1458	0.3212	0.1374	0.3044	0.1297	0.2894	0.1232	0.2769
1.4	4.62	0.1906	0.4156	0.1774	0.3885	0.1660	0.3657	0.1564	0.3465	0.1477	0.3295	0.1403	0.3152
1.5	4.95	0.2151	0.4689	0.2001	0.4384	0.1873	0.4126	0.1765	0.3910	0.1667	0.3718	0.1583	0.3557
1.6	5.27	0.2408	0.5250	0.2241	0.4908	0.2097	0.4620	0.1976	0.4378	0.1866	0.4163	0.1772	0.3982
1.7	5.60	0.2678	0.5838	0.2491	0.5457	0.2332	0.5137	0.2197	0.4868	0.2075	0.4628	0.1970	0.4428
1.8	5.93	0.2960	0.6452	0.2753	0.6031	0.2578	0.5677	0.2428	0.5380	0.2293	0.5115	0.2178	0.4894
1.9	6.26	0.3253	0.7092	0.3027	0.6630	0.2833	0.6241	0.2669	0.5914	0.2521	0.5623	0.2394	0.5379
2.0	6.59	0.3559	0.7758	0.3311	0.7253	0.3100	0.6827	0.2919	0.6469	0.2757	0.6151	0.2619	0.5885
2.1	6.92	0.3876	0.8449	0.3606	0.7899	0.3376	0.7435	0.3180	0.7046	0.3003	0.6699	0.2852	0.6409
2.2	7.25	0.4205	0.9166	0.3912	0.8569	0.3662	0.8066	0.3449	0.7643	0.3258	0.7268	0.3094	0.6953
2.3	7.58	0.4545	0.9908	0.4228	0.9262	0.3958	0.8719	0.3728	0.8261	0.3521	0.7856	0.3344	0.7515
2.4	7.91	0.4896	1.0674	0.4555	0.9979	0.4264	0.9393	0.4017	0.8900	0.3794	0.8463	0.3603	0.8096
2.5	8.24	0.5259	1.1464	0.4893	1.0717	0.4580	1.0088	0.4314	0.9559	0.4074	0.9090	0.3870	0.8696
2.6	8.57	0.5633	1.2279	0.5240	1.1479	0.4906	1.0805	0.4621	1.0238	0.4364	0.9735	0.4144	0.9314
2.7	8.90	0.6017	1.3117	0.5598	1.2263	0.5241	1.1543	0.4936	1.0937	0.4662	1.0400	0.4427	0.9950
2.8	9.23	0.6413	1.3979	0.5966	1.3068	0.5585	1.2301	0.5261	1.1656	0.4968	1.1084	0.4718	1.0603
2.9	9.56	0.6819	1.4864	0.6344	1.3896	0.5939	1.3080	0.5594	1.2394	0.5283	1.1785	0.5017	1.1275
3.0	9.89	0.7236	1.5773	0.6732	1.4745	0.6302	1.3880	0.5936	1.3152	0.5606	1.2506	0.5324	1.1964

Pressure Loss per Linear Foot - 1" PEX - 50% Ethylene Glycol / 50% Water

		80 °F		100 °F		120 °F		140 °F		160 °F		180 °F	
Flow (GPM)	Velocity (FPS)	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot
0.1	0.05	0.0000	0.0001	0.0000	0.0001	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.2	0.11	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002
0.3	0.16	0.0002	0.0004	0.0002	0.0004	0.0002	0.0004	0.0002	0.0003	0.0001	0.0003	0.0001	0.0003
0.4	0.22	0.0003	0.0007	0.0003	0.0006	0.0003	0.0006	0.0003	0.0006	0.0002	0.0005	0.0002	0.0005
0.5	0.27	0.0005	0.0010	0.0004	0.0009	0.0004	0.0009	0.0004	0.0008	0.0004	0.0008	0.0003	0.0008
0.6	0.33	0.0007	0.0014	0.0006	0.0013	0.0006	0.0012	0.0005	0.0011	0.0005	0.0011	0.0005	0.0010
0.7	0.38	0.0009	0.0018	0.0008	0.0017	0.0007	0.0016	0.0007	0.0015	0.0007	0.0014	0.0006	0.0014
0.8	0.44	0.0011	0.0023	0.0010	0.0022	0.0009	0.0020	0.0009	0.0019	0.0008	0.0018	0.0008	0.0017
0.9	0.49	0.0013	0.0029	0.0012	0.0026	0.0011	0.0025	0.0011	0.0023	0.0010	0.0022	0.0010	0.0021
1.0	0.55	0.0016	0.0034	0.0015	0.0032	0.0014	0.0030	0.0013	0.0028	0.0012	0.0027	0.0012	0.0025
1.1	0.60	0.0019	0.0041	0.0018	0.0038	0.0016	0.0035	0.0015	0.0033	0.0014	0.0032	0.0014	0.0030
1.2	0.66	0.0022	0.0047	0.0020	0.0044	0.0019	0.0041	0.0018	0.0039	0.0017	0.0037	0.0016	0.0035
1.3	0.71	0.0025	0.0054	0.0024	0.0050	0.0022	0.0047	0.0020	0.0044	0.0019	0.0042	0.0018	0.0040
1.4	0.76	0.0029	0.0062	0.0027	0.0057	0.0025	0.0054	0.0023	0.0051	0.0022	0.0048	0.0021	0.0046
1.5	0.82	0.0033	0.0070	0.0030	0.0065	0.0028	0.0061	0.0026	0.0057	0.0025	0.0054	0.0023	0.0052
1.6	0.87	0.0037	0.0078	0.0034	0.0073	0.0031	0.0068	0.0029	0.0064	0.0028	0.0061	0.0026	0.0058
1.7	0.93	0.0041	0.0087	0.0038	0.0081	0.0035	0.0075	0.0033	0.0071	0.0031	0.0068	0.0029	0.0064
1.8	0.98	0.0045	0.0096	0.0042	0.0089	0.0039	0.0083	0.0036	0.0079	0.0034	0.0075	0.0032	0.0071
1.9	1.04	0.0049	0.0105	0.0046	0.0098	0.0042	0.0092	0.0040	0.0086	0.0037	0.0082	0.0035	0.0078
2.0	1.09	0.0054	0.0115	0.0050	0.0107	0.0046	0.0100	0.0044	0.0095	0.0041	0.0090	0.0039	0.0085
2.1	1.15	0.0059	0.0126	0.0054	0.0117	0.0051	0.0109	0.0047	0.0103	0.0045	0.0098	0.0042	0.0093
2.2	1.20	0.0064	0.0136	0.0059	0.0127	0.0055	0.0118	0.0051	0.0112	0.0048	0.0106	0.0046	0.0101
2.3	1.26	0.0069	0.0147	0.0064	0.0137	0.0059	0.0128	0.0056	0.0121	0.0052	0.0115	0.0050	0.0109
2.4	1.31	0.0074	0.0159	0.0069	0.0147	0.0064	0.0138	0.0060	0.0130	0.0056	0.0123	0.0053	0.0118
2.5	1.36	0.0080	0.0170	0.0074	0.0158	0.0069	0.0148	0.0064	0.0140	0.0061	0.0133	0.0057	0.0126
2.6	1.42	0.0086	0.0183	0.0079	0.0170	0.0074	0.0159	0.0069	0.0150	0.0065	0.0142	0.0061	0.0135
2.7	1.47	0.0092	0.0195	0.0085	0.0181	0.0079	0.0170	0.0074	0.0160	0.0069	0.0152	0.0066	0.0145
2.8	1.53	0.0098	0.0208	0.0090	0.0193	0.0084	0.0181	0.0078	0.0170	0.0074	0.0162	0.0070	0.0154
2.9	1.58	0.0104	0.0221	0.0096	0.0205	0.0089	0.0192	0.0083	0.0181	0.0079	0.0172	0.0074	0.0164
3.0	1.64	0.0110	0.0235	0.0102	0.0218	0.0094	0.0204	0.0089	0.0192	0.0083	0.0182	0.0079	0.0174

Pressure Loss per Linear Foot - 3/4" PEX - 50% Ethylene Glycol / 50% Water

		80 °F		100 °F		120 °F		140 °F		160 °F		180 °F	
Flow (GPM)	Velocity (FPS)	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot
0.1	0.09	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002	0.0001	0.0001
0.2	0.18	0.0003	0.0007	0.0003	0.0006	0.0003	0.0006	0.0003	0.0006	0.0002	0.0005	0.0002	0.0005
0.3	0.27	0.0006	0.0014	0.0006	0.0013	0.0006	0.0012	0.0005	0.0011	0.0005	0.0011	0.0005	0.0010
0.4	0.36	0.0011	0.0023	0.0010	0.0021	0.0009	0.0020	0.0009	0.0019	0.0008	0.0018	0.0008	0.0017
0.5	0.45	0.0016	0.0034	0.0015	0.0031	0.0014	0.0029	0.0013	0.0028	0.0012	0.0026	0.0011	0.0025
0.6	0.54	0.0022	0.0046	0.0020	0.0043	0.0019	0.0040	0.0017	0.0038	0.0016	0.0036	0.0016	0.0034
0.7	0.63	0.0028	0.0061	0.0026	0.0056	0.0024	0.0053	0.0023	0.0050	0.0022	0.0047	0.0020	0.0045
0.8	0.72	0.0036	0.0076	0.0033	0.0071	0.0031	0.0066	0.0029	0.0063	0.0027	0.0059	0.0026	0.0057
0.9	0.81	0.0044	0.0094	0.0041	0.0087	0.0038	0.0082	0.0035	0.0077	0.0033	0.0073	0.0032	0.0070
1.0	0.90	0.0053	0.0113	0.0049	0.0105	0.0046	0.0098	0.0043	0.0093	0.0040	0.0088	0.0038	0.0084
1.1	0.99	0.0063	0.0133	0.0058	0.0124	0.0054	0.0116	0.0050	0.0109	0.0047	0.0104	0.0045	0.0099
1.2	1.08	0.0073	0.0155	0.0067	0.0144	0.0063	0.0135	0.0059	0.0127	0.0055	0.0121	0.0052	0.0115
1.3	1.17	0.0084	0.0179	0.0077	0.0166	0.0072	0.0155	0.0067	0.0147	0.0064	0.0139	0.0060	0.0132
1.4	1.26	0.0096	0.0204	0.0088	0.0189	0.0082	0.0177	0.0077	0.0167	0.0072	0.0158	0.0068	0.0151
1.5	1.35	0.0108	0.0230	0.0100	0.0213	0.0093	0.0200	0.0087	0.0188	0.0082	0.0179	0.0077	0.0170
1.6	1.44	0.0121	0.0257	0.0111	0.0239	0.0104	0.0224	0.0097	0.0211	0.0091	0.0200	0.0086	0.0191
1.7	1.53	0.0134	0.0286	0.0124	0.0266	0.0115	0.0249	0.0108	0.0234	0.0102	0.0222	0.0096	0.0212
1.8	1.62	0.0148	0.0316	0.0137	0.0294	0.0127	0.0275	0.0119	0.0259	0.0112	0.0246	0.0106	0.0234
1.9	1.71	0.0163	0.0347	0.0151	0.0323	0.0140	0.0302	0.0131	0.0285	0.0123	0.0270	0.0117	0.0257
2.0	1.80	0.0178	0.0380	0.0165	0.0353	0.0153	0.0330	0.0143	0.0312	0.0135	0.0296	0.0128	0.0282
2.1	1.89	0.0194	0.0414	0.0179	0.0384	0.0167	0.0360	0.0156	0.0339	0.0147	0.0322	0.0139	0.0307
2.2	1.98	0.0211	0.0449	0.0195	0.0417	0.0181	0.0390	0.0169	0.0368	0.0160	0.0349	0.0151	0.0333
2.3	2.07	0.0228	0.0485	0.0210	0.0451	0.0196	0.0422	0.0183	0.0398	0.0172	0.0377	0.0163	0.0360
2.4	2.16	0.0245	0.0523	0.0227	0.0486	0.0211	0.0454	0.0197	0.0429	0.0186	0.0407	0.0176	0.0387
2.5	2.25	0.0264	0.0562	0.0243	0.0522	0.0226	0.0488	0.0212	0.0460	0.0200	0.0437	0.0189	0.0416
2.6	2.34	0.0282	0.0601	0.0261	0.0559	0.0242	0.0523	0.0227	0.0493	0.0214	0.0468	0.0202	0.0446
2.7	2.43	0.0302	0.0643	0.0278	0.0597	0.0259	0.0558	0.0242	0.0527	0.0228	0.0500	0.0216	0.0476
2.8	2.53	0.0321	0.0685	0.0297	0.0636	0.0276	0.0595	0.0258	0.0561	0.0243	0.0533	0.0230	0.0507
2.9	2.62	0.0342	0.0728	0.0316	0.0676	0.0293	0.0633	0.0275	0.0597	0.0259	0.0566	0.0245	0.0539
3.0	2.71	0.0363	0.0773	0.0335	0.0718	0.0311	0.0672	0.0292	0.0633	0.0275	0.0601	0.0260	0.0572

Pressure Loss per Linear Foot - 5/8" PEX - 50% Ethylene Glycol / 50% Water

		80 °F		100 °F		120 °F		140 °F		160 °F		180 °F	
Flow (GPM)	Velocity (FPS)	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot
0.1	0.12	0.0002	0.0004	0.0002	0.0004	0.0002	0.0004	0.0002	0.0004	0.0002	0.0003	0.0001	0.0003
0.2	0.25	0.0007	0.0014	0.0006	0.0013	0.0006	0.0013	0.0005	0.0012	0.0005	0.0011	0.0005	0.0011
0.3	0.37	0.0014	0.0029	0.0013	0.0027	0.0012	0.0025	0.0011	0.0024	0.0010	0.0023	0.0010	0.0022
0.4	0.50	0.0023	0.0048	0.0021	0.0045	0.0019	0.0042	0.0018	0.0040	0.0017	0.0038	0.0016	0.0036
0.5	0.62	0.0034	0.0072	0.0031	0.0066	0.0029	0.0062	0.0027	0.0059	0.0025	0.0056	0.0024	0.0053
0.6	0.74	0.0046	0.0098	0.0043	0.0091	0.0040	0.0086	0.0037	0.0081	0.0035	0.0077	0.0033	0.0073
0.7	0.87	0.0060	0.0129	0.0056	0.0120	0.0052	0.0112	0.0049	0.0106	0.0046	0.0100	0.0043	0.0095
0.8	0.99	0.0076	0.0163	0.0071	0.0151	0.0066	0.0141	0.0061	0.0133	0.0058	0.0127	0.0055	0.0121
0.9	1.12	0.0094	0.0200	0.0087	0.0186	0.0081	0.0174	0.0075	0.0164	0.0071	0.0156	0.0067	0.0148
1.0	1.24	0.0113	0.0241	0.0104	0.0223	0.0097	0.0209	0.0091	0.0197	0.0085	0.0187	0.0081	0.0178
1.1	1.36	0.0133	0.0284	0.0123	0.0264	0.0115	0.0247	0.0107	0.0233	0.0101	0.0221	0.0096	0.0211
1.2	1.49	0.0155	0.0331	0.0143	0.0307	0.0133	0.0288	0.0125	0.0271	0.0118	0.0257	0.0111	0.0245
1.3	1.61	0.0179	0.0381	0.0165	0.0354	0.0153	0.0331	0.0144	0.0312	0.0135	0.0296	0.0128	0.0282
1.4	1.74	0.0203	0.0434	0.0188	0.0403	0.0175	0.0377	0.0164	0.0355	0.0154	0.0337	0.0146	0.0321
1.5	1.86	0.0230	0.0489	0.0212	0.0454	0.0197	0.0425	0.0185	0.0401	0.0174	0.0380	0.0164	0.0362
1.6	1.98	0.0257	0.0548	0.0237	0.0509	0.0221	0.0476	0.0207	0.0449	0.0195	0.0426	0.0184	0.0406
1.7	2.11	0.0286	0.0609	0.0264	0.0566	0.0245	0.0529	0.0230	0.0499	0.0216	0.0474	0.0205	0.0451
1.8	2.23	0.0316	0.0673	0.0292	0.0625	0.0271	0.0585	0.0254	0.0552	0.0239	0.0523	0.0226	0.0499
1.9	2.36	0.0347	0.0740	0.0321	0.0687	0.0298	0.0643	0.0279	0.0606	0.0263	0.0575	0.0249	0.0548
2.0	2.48	0.0380	0.0809	0.0351	0.0752	0.0326	0.0703	0.0305	0.0663	0.0288	0.0629	0.0272	0.0599
2.1	2.60	0.0414	0.0881	0.0382	0.0819	0.0355	0.0766	0.0333	0.0722	0.0313	0.0685	0.0296	0.0653
2.2	2.73	0.0449	0.0956	0.0414	0.0888	0.0385	0.0831	0.0361	0.0784	0.0340	0.0744	0.0321	0.0708
2.3	2.85	0.0485	0.1033	0.0448	0.0960	0.0416	0.0898	0.0390	0.0847	0.0367	0.0804	0.0347	0.0766
2.4	2.98	0.0523	0.1113	0.0482	0.1034	0.0449	0.0968	0.0420	0.0913	0.0396	0.0866	0.0374	0.0825
2.5	3.10	0.0561	0.1196	0.0518	0.1111	0.0482	0.1039	0.0451	0.0980	0.0425	0.0930	0.0402	0.0886
2.6	3.22	0.0601	0.1281	0.0555	0.1190	0.0516	0.1113	0.0483	0.1050	0.0455	0.0996	0.0430	0.0949
2.7	3.35	0.0642	0.1368	0.0593	0.1271	0.0551	0.1189	0.0516	0.1121	0.0486	0.1064	0.0460	0.1014
2.8	3.47	0.0684	0.1458	0.0632	0.1354	0.0587	0.1267	0.0550	0.1195	0.0518	0.1134	0.0490	0.1080
2.9	3.60	0.0728	0.1550	0.0672	0.1440	0.0625	0.1348	0.0585	0.1271	0.0551	0.1206	0.0521	0.1149
3.0	3.72	0.0772	0.1645	0.0713	0.1528	0.0663	0.1430	0.0621	0.1349	0.0585	0.1279	0.0553	0.1219

Pressure Loss per Linear Foot - 1/2" PEX - 50% Ethylene Glycol / 50% Water

		80 °F		100 °F		120 °F		140 °F		160 °F		180 °F	
Flow (GPM)	Velocity (FPS)	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot
0.1	0.18	0.0005	0.0010	0.0004	0.0010	0.0004	0.0009	0.0004	0.0008	0.0004	0.0008	0.0003	0.0008
0.2	0.36	0.0016	0.0035	0.0015	0.0032	0.0014	0.0030	0.0013	0.0028	0.0012	0.0027	0.0012	0.0026
0.3	0.54	0.0033	0.0070	0.0031	0.0065	0.0028	0.0061	0.0027	0.0058	0.0025	0.0055	0.0024	0.0052
0.4	0.72	0.0055	0.0117	0.0051	0.0108	0.0047	0.0101	0.0044	0.0096	0.0041	0.0091	0.0039	0.0086
0.5	0.90	0.0081	0.0172	0.0075	0.0160	0.0069	0.0150	0.0065	0.0141	0.0061	0.0134	0.0058	0.0128
0.6	1.08	0.0111	0.0237	0.0103	0.0220	0.0096	0.0206	0.0089	0.0194	0.0084	0.0184	0.0080	0.0176
0.7	1.26	0.0146	0.0310	0.0135	0.0288	0.0125	0.0270	0.0117	0.0255	0.0110	0.0241	0.0104	0.0230
0.8	1.44	0.0184	0.0392	0.0170	0.0364	0.0158	0.0341	0.0148	0.0322	0.0139	0.0305	0.0132	0.0291
0.9	1.62	0.0226	0.0482	0.0209	0.0448	0.0194	0.0419	0.0182	0.0395	0.0171	0.0375	0.0162	0.0357
1.0	1.80	0.0272	0.0580	0.0251	0.0538	0.0234	0.0504	0.0219	0.0475	0.0206	0.0451	0.0195	0.0429
1.1	1.97	0.0321	0.0685	0.0297	0.0636	0.0276	0.0595	0.0258	0.0561	0.0243	0.0533	0.0230	0.0507
1.2	2.15	0.0374	0.0797	0.0346	0.0741	0.0321	0.0693	0.0301	0.0654	0.0283	0.0620	0.0268	0.0591
1.3	2.33	0.0431	0.0917	0.0398	0.0852	0.0370	0.0797	0.0346	0.0752	0.0326	0.0713	0.0308	0.0680
1.4	2.51	0.0490	0.1044	0.0453	0.0970	0.0421	0.0908	0.0394	0.0856	0.0371	0.0812	0.0351	0.0774
1.5	2.69	0.0553	0.1178	0.0511	0.1095	0.0475	0.1024	0.0445	0.0966	0.0419	0.0916	0.0396	0.0873
1.6	2.87	0.0619	0.1319	0.0572	0.1225	0.0531	0.1147	0.0498	0.1081	0.0469	0.1026	0.0443	0.0977
1.7	3.05	0.0689	0.1467	0.0636	0.1363	0.0591	0.1275	0.0554	0.1202	0.0521	0.1141	0.0493	0.1087
1.8	3.23	0.0761	0.1621	0.0703	0.1506	0.0653	0.1409	0.0612	0.1329	0.0576	0.1261	0.0545	0.1201
1.9	3.41	0.0837	0.1782	0.0772	0.1655	0.0718	0.1549	0.0672	0.1461	0.0633	0.1386	0.0599	0.1320
2.0	3.59	0.0915	0.1950	0.0845	0.1811	0.0785	0.1694	0.0736	0.1598	0.0693	0.1516	0.0655	0.1444
2.1	3.77	0.0997	0.2123	0.0920	0.1972	0.0855	0.1845	0.0801	0.1740	0.0755	0.1651	0.0713	0.1573
2.2	3.95	0.1081	0.2303	0.0998	0.2140	0.0928	0.2002	0.0869	0.1888	0.0819	0.1791	0.0774	0.1706
2.3	4.13	0.1169	0.2490	0.1079	0.2313	0.1003	0.2164	0.0939	0.2041	0.0885	0.1936	0.0837	0.1844
2.4	4.31	0.1259	0.2682	0.1162	0.2492	0.1081	0.2331	0.1012	0.2199	0.0953	0.2086	0.0901	0.1987
2.5	4.49	0.1352	0.2881	0.1248	0.2676	0.1161	0.2504	0.1087	0.2361	0.1024	0.2240	0.0968	0.2134
2.6	4.67	0.1448	0.3086	0.1337	0.2866	0.1243	0.2682	0.1164	0.2529	0.1097	0.2399	0.1037	0.2286
2.7	4.85	0.1547	0.3296	0.1428	0.3062	0.1328	0.2865	0.1244	0.2702	0.1171	0.2563	0.1107	0.2442
2.8	5.03	0.1649	0.3513	0.1522	0.3263	0.1415	0.3053	0.1326	0.2879	0.1248	0.2732	0.1180	0.2602
2.9	5.21	0.1753	0.3735	0.1619	0.3470	0.1505	0.3246	0.1409	0.3062	0.1327	0.2905	0.1255	0.2767
3.0	5.39	0.1860	0.3964	0.1718	0.3682	0.1597	0.3445	0.1496	0.3249	0.1409	0.3082	0.1332	0.2936

		Pressure Loss per Linear Foot - 3/8" PEX - 50% Ethylene Glycol / 50% Water											
		80 °F		100 °F		120 °F		140 °F		160 °F		180 °F	
Flow (GPM)	Velocity (FPS)	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot
0.1	0.33	0.0020	0.0044	0.0019	0.0041	0.0018	0.0038	0.0016	0.0036	0.0016	0.0034	0.0015	0.0032
0.2	0.66	0.0069	0.0147	0.0064	0.0136	0.0059	0.0128	0.0055	0.0120	0.0052	0.0114	0.0049	0.0109
0.3	0.99	0.0140	0.0299	0.0129	0.0277	0.0120	0.0259	0.0113	0.0245	0.0106	0.0232	0.0100	0.0221
0.4	1.32	0.0232	0.0494	0.0214	0.0459	0.0199	0.0429	0.0186	0.0405	0.0176	0.0384	0.0166	0.0366
0.5	1.65	0.0343	0.0730	0.0316	0.0678	0.0294	0.0634	0.0275	0.0598	0.0259	0.0568	0.0245	0.0541
0.6	1.98	0.0471	0.1004	0.0435	0.0933	0.0405	0.0873	0.0379	0.0823	0.0357	0.0781	0.0337	0.0744
0.7	2.31	0.0617	0.1315	0.0570	0.1222	0.0530	0.1143	0.0496	0.1078	0.0467	0.1023	0.0442	0.0974
0.8	2.64	0.0780	0.1661	0.0720	0.1543	0.0669	0.1444	0.0627	0.1362	0.0590	0.1292	0.0558	0.1231
0.9	2.97	0.0958	0.2041	0.0885	0.1896	0.0822	0.1774	0.0770	0.1673	0.0726	0.1588	0.0686	0.1512
1.0	3.30	0.1152	0.2455	0.1064	0.2280	0.0989	0.2134	0.0926	0.2012	0.0872	0.1909	0.0825	0.1819
1.1	3.63	0.1361	0.2900	0.1257	0.2694	0.1168	0.2521	0.1094	0.2377	0.1031	0.2255	0.0974	0.2149
1.2	3.96	0.1585	0.3377	0.1464	0.3137	0.1361	0.2935	0.1274	0.2768	0.1200	0.2626	0.1135	0.2502
1.3	4.29	0.1824	0.3885	0.1684	0.3609	0.1565	0.3377	0.1466	0.3185	0.1381	0.3021	0.1305	0.2878
1.4	4.62	0.2076	0.4423	0.1917	0.4109	0.1782	0.3844	0.1669	0.3626	0.1572	0.3440	0.1486	0.3277
1.5	4.95	0.2343	0.4991	0.2163	0.4636	0.2011	0.4338	0.1883	0.4091	0.1774	0.3881	0.1677	0.3697
1.6	5.27	0.2623	0.5588	0.2421	0.5190	0.2251	0.4856	0.2108	0.4580	0.1986	0.4345	0.1877	0.4139
1.7	5.60	0.2916	0.6213	0.2692	0.5771	0.2503	0.5400	0.2344	0.5093	0.2208	0.4831	0.2087	0.4603
1.8	5.93	0.3223	0.6867	0.2976	0.6378	0.2766	0.5968	0.2591	0.5629	0.2440	0.5340	0.2307	0.5087
1.9	6.26	0.3543	0.7548	0.3271	0.7011	0.3041	0.6560	0.2848	0.6187	0.2682	0.5870	0.2536	0.5592
2.0	6.59	0.3876	0.8257	0.3578	0.7670	0.3326	0.7176	0.3116	0.6768	0.2934	0.6421	0.2774	0.6117
2.1	6.92	0.4221	0.8993	0.3897	0.8353	0.3623	0.7816	0.3393	0.7371	0.3196	0.6993	0.3021	0.6662
2.2	7.25	0.4579	0.9756	0.4228	0.9062	0.3930	0.8479	0.3681	0.7997	0.3467	0.7586	0.3278	0.7227
2.3	7.58	0.4949	1.0545	0.4570	0.9795	0.4248	0.9165	0.3979	0.8644	0.3747	0.8200	0.3543	0.7812
2.4	7.91	0.5332	1.1360	0.4923	1.0552	0.4577	0.9873	0.4287	0.9312	0.4037	0.8834	0.3817	0.8416
2.5	8.24	0.5727	1.2202	0.5287	1.1334	0.4916	1.0605	0.4604	1.0001	0.4336	0.9488	0.4100	0.9039
2.6	8.57	0.6134	1.3069	0.5663	1.2139	0.5265	1.1358	0.4931	1.0712	0.4644	1.0162	0.4391	0.9681
2.7	8.90	0.6553	1.3961	0.6050	1.2968	0.5624	1.2133	0.5268	1.1443	0.4961	1.0856	0.4691	1.0342
2.8	9.23	0.6983	1.4878	0.6447	1.3820	0.5994	1.2931	0.5614	1.2195	0.5287	1.1570	0.4999	1.1022
2.9	9.56	0.7426	1.5821	0.6856	1.4695	0.6373	1.3750	0.5969	1.2968	0.5622	1.2302	0.5315	1.1720
3.0	9.89	0.7879	1.6788	0.7275	1.5594	0.6763	1.4590	0.6334	1.3760	0.5966	1.3054	0.5640	1.2436

Pressure Loss per Linear Foot - 1" PEX - 30% Propylene Glycol / 70% Water

		80 ºF		100 ºF		120 ºF		140 ºF		160 ºF		180 ºF	
Flow (GPM)	Velocity (FPS)	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot
0.1	0.05	0.0000	0.0001	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.2	0.11	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001
0.3	0.16	0.0002	0.0004	0.0002	0.0004	0.0001	0.0003	0.0001	0.0003	0.0001	0.0003	0.0001	0.0003
0.4	0.22	0.0003	0.0007	0.0003	0.0006	0.0002	0.0006	0.0002	0.0005	0.0002	0.0005	0.0002	0.0005
0.5	0.27	0.0004	0.0010	0.0004	0.0009	0.0004	0.0008	0.0003	0.0008	0.0003	0.0007	0.0003	0.0007
0.6	0.33	0.0006	0.0013	0.0005	0.0012	0.0005	0.0011	0.0005	0.0011	0.0004	0.0010	0.0004	0.0010
0.7	0.38	0.0008	0.0017	0.0007	0.0016	0.0007	0.0015	0.0006	0.0014	0.0006	0.0013	0.0005	0.0013
0.8	0.44	0.0010	0.0022	0.0009	0.0020	0.0008	0.0019	0.0008	0.0018	0.0007	0.0017	0.0007	0.0016
0.9	0.49	0.0012	0.0027	0.0011	0.0025	0.0010	0.0023	0.0009	0.0022	0.0009	0.0021	0.0008	0.0020
1.0	0.55	0.0014	0.0032	0.0013	0.0030	0.0012	0.0028	0.0011	0.0026	0.0011	0.0025	0.0010	0.0024
1.1	0.60	0.0017	0.0038	0.0016	0.0035	0.0014	0.0033	0.0013	0.0031	0.0013	0.0029	0.0012	0.0028
1.2	0.66	0.0020	0.0045	0.0018	0.0041	0.0017	0.0038	0.0016	0.0036	0.0015	0.0034	0.0014	0.0033
1.3	0.71	0.0023	0.0051	0.0021	0.0047	0.0019	0.0044	0.0018	0.0041	0.0017	0.0039	0.0016	0.0038
1.4	0.76	0.0026	0.0058	0.0024	0.0054	0.0022	0.0050	0.0021	0.0047	0.0019	0.0045	0.0018	0.0043
1.5	0.82	0.0029	0.0066	0.0027	0.0061	0.0025	0.0056	0.0023	0.0053	0.0022	0.0050	0.0021	0.0048
1.6	0.87	0.0033	0.0074	0.0030	0.0068	0.0028	0.0063	0.0026	0.0059	0.0025	0.0057	0.0023	0.0054
1.7	0.93	0.0036	0.0082	0.0033	0.0075	0.0031	0.0070	0.0029	0.0066	0.0027	0.0063	0.0026	0.0060
1.8	0.98	0.0040	0.0091	0.0037	0.0083	0.0034	0.0078	0.0032	0.0073	0.0030	0.0069	0.0029	0.0066
1.9	1.04	0.0044	0.0100	0.0041	0.0092	0.0038	0.0085	0.0035	0.0080	0.0033	0.0076	0.0031	0.0073
2.0	1.09	0.0048	0.0109	0.0044	0.0100	0.0041	0.0093	0.0038	0.0088	0.0036	0.0084	0.0034	0.0080
2.1	1.15	0.0053	0.0119	0.0048	0.0109	0.0045	0.0102	0.0042	0.0096	0.0039	0.0091	0.0037	0.0087
2.2	1.20	0.0057	0.0129	0.0052	0.0118	0.0049	0.0110	0.0045	0.0104	0.0043	0.0099	0.0041	0.0094
2.3	1.26	0.0062	0.0139	0.0057	0.0128	0.0052	0.0119	0.0049	0.0112	0.0046	0.0107	0.0044	0.0102
2.4	1.31	0.0067	0.0150	0.0061	0.0138	0.0057	0.0128	0.0053	0.0121	0.0050	0.0115	0.0047	0.0110
2.5	1.36	0.0072	0.0161	0.0066	0.0148	0.0061	0.0138	0.0057	0.0130	0.0054	0.0123	0.0051	0.0118
2.6	1.42	0.0077	0.0172	0.0070	0.0159	0.0065	0.0148	0.0061	0.0139	0.0057	0.0132	0.0054	0.0126
2.7	1.47	0.0082	0.0184	0.0075	0.0169	0.0069	0.0158	0.0065	0.0149	0.0061	0.0141	0.0058	0.0135
2.8	1.53	0.0087	0.0196	0.0080	0.0180	0.0074	0.0168	0.0069	0.0158	0.0065	0.0151	0.0062	0.0144
2.9	1.58	0.0093	0.0209	0.0085	0.0192	0.0079	0.0179	0.0074	0.0168	0.0069	0.0160	0.0066	0.0153
3.0	1.64	0.0099	0.0221	0.0090	0.0204	0.0084	0.0190	0.0078	0.0179	0.0074	0.0170	0.0070	0.0162

Pressure Loss per Linear Foot - 3/4" PEX - 30% Propylene Glycol / 70% Water

		80 ºF		100 ºF		120 ºF		140 ºF		160 ºF		180 ºF	
Flow (GPM)	Velocity (FPS)	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot
0.1	0.09	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001
0.2	0.18	0.0003	0.0006	0.0003	0.0006	0.0002	0.0005	0.0002	0.0005	0.0002	0.0005	0.0002	0.0005
0.3	0.27	0.0006	0.0013	0.0005	0.0012	0.0005	0.0011	0.0005	0.0010	0.0004	0.0010	0.0004	0.0010
0.4	0.36	0.0010	0.0021	0.0009	0.0020	0.0008	0.0018	0.0008	0.0017	0.0007	0.0016	0.0007	0.0016
0.5	0.45	0.0014	0.0032	0.0013	0.0029	0.0012	0.0027	0.0011	0.0026	0.0011	0.0024	0.0010	0.0023
0.6	0.54	0.0019	0.0044	0.0018	0.0040	0.0016	0.0037	0.0015	0.0035	0.0015	0.0033	0.0014	0.0032
0.7	0.63	0.0025	0.0057	0.0023	0.0053	0.0022	0.0049	0.0020	0.0046	0.0019	0.0044	0.0018	0.0042
0.8	0.72	0.0032	0.0072	0.0029	0.0066	0.0027	0.0062	0.0025	0.0058	0.0024	0.0055	0.0023	0.0053
0.9	0.81	0.0039	0.0089	0.0036	0.0082	0.0033	0.0076	0.0031	0.0072	0.0029	0.0068	0.0028	0.0065
1.0	0.90	0.0047	0.0107	0.0043	0.0098	0.0040	0.0091	0.0038	0.0086	0.0035	0.0082	0.0034	0.0078
1.1	0.99	0.0056	0.0126	0.0051	0.0116	0.0048	0.0108	0.0044	0.0102	0.0042	0.0097	0.0040	0.0092
1.2	1.08	0.0065	0.0147	0.0060	0.0135	0.0055	0.0126	0.0052	0.0118	0.0049	0.0113	0.0046	0.0108
1.3	1.17	0.0075	0.0169	0.0069	0.0155	0.0064	0.0145	0.0059	0.0136	0.0056	0.0129	0.0053	0.0124
1.4	1.26	0.0086	0.0192	0.0078	0.0177	0.0072	0.0165	0.0068	0.0155	0.0064	0.0147	0.0061	0.0141
1.5	1.35	0.0096	0.0217	0.0088	0.0199	0.0082	0.0186	0.0076	0.0175	0.0072	0.0166	0.0068	0.0159
1.6	1.44	0.0108	0.0243	0.0099	0.0223	0.0092	0.0208	0.0086	0.0196	0.0081	0.0186	0.0077	0.0178
1.7	1.53	0.0120	0.0270	0.0110	0.0248	0.0102	0.0232	0.0095	0.0218	0.0090	0.0207	0.0085	0.0198
1.8	1.62	0.0133	0.0298	0.0121	0.0274	0.0113	0.0256	0.0105	0.0241	0.0099	0.0229	0.0094	0.0219
1.9	1.71	0.0146	0.0328	0.0133	0.0302	0.0124	0.0281	0.0116	0.0264	0.0109	0.0252	0.0103	0.0241
2.0	1.80	0.0160	0.0359	0.0146	0.0330	0.0135	0.0308	0.0126	0.0289	0.0119	0.0275	0.0113	0.0263
2.1	1.89	0.0174	0.0391	0.0159	0.0359	0.0147	0.0335	0.0138	0.0315	0.0130	0.0300	0.0123	0.0287
2.2	1.98	0.0189	0.0424	0.0173	0.0390	0.0160	0.0364	0.0149	0.0342	0.0141	0.0325	0.0134	0.0311
2.3	2.07	0.0204	0.0458	0.0186	0.0421	0.0173	0.0393	0.0161	0.0370	0.0152	0.0351	0.0145	0.0336
2.4	2.16	0.0220	0.0493	0.0201	0.0454	0.0186	0.0423	0.0174	0.0398	0.0164	0.0379	0.0156	0.0362
2.5	2.25	0.0236	0.0530	0.0216	0.0488	0.0200	0.0455	0.0187	0.0428	0.0176	0.0407	0.0167	0.0389
2.6	2.34	0.0253	0.0568	0.0231	0.0522	0.0214	0.0487	0.0200	0.0458	0.0189	0.0436	0.0179	0.0416
2.7	2.43	0.0270	0.0606	0.0247	0.0558	0.0229	0.0520	0.0214	0.0489	0.0202	0.0465	0.0191	0.0445
2.8	2.53	0.0288	0.0646	0.0263	0.0594	0.0244	0.0554	0.0228	0.0521	0.0215	0.0496	0.0204	0.0474
2.9	2.62	0.0306	0.0687	0.0280	0.0632	0.0259	0.0589	0.0242	0.0554	0.0229	0.0527	0.0217	0.0504
3.0	2.71	0.0325	0.0729	0.0297	0.0671	0.0275	0.0626	0.0257	0.0588	0.0243	0.0559	0.0230	0.0535

Pressure Loss per Linear Foot - 5/8" PEX - 30% Propylene Glycol / 70% Water

		80 °F		100 °F		120 °F		140 °F		160 °F		180 °F	
Flow (GPM)	Velocity (FPS)	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot
0.1	0.12	0.0002	0.0004	0.0002	0.0004	0.0002	0.0003	0.0001	0.0003	0.0001	0.0003	0.0001	0.0003
0.2	0.25	0.0006	0.0014	0.0006	0.0012	0.0005	0.0012	0.0005	0.0011	0.0005	0.0010	0.0004	0.0010
0.3	0.37	0.0012	0.0028	0.0011	0.0025	0.0010	0.0024	0.0010	0.0022	0.0009	0.0021	0.0009	0.0020
0.4	0.50	0.0020	0.0046	0.0019	0.0042	0.0017	0.0039	0.0016	0.0037	0.0015	0.0035	0.0014	0.0034
0.5	0.62	0.0030	0.0068	0.0027	0.0062	0.0025	0.0058	0.0024	0.0054	0.0022	0.0052	0.0021	0.0050
0.6	0.74	0.0041	0.0093	0.0038	0.0085	0.0035	0.0080	0.0033	0.0075	0.0031	0.0071	0.0029	0.0068
0.7	0.87	0.0054	0.0122	0.0050	0.0112	0.0046	0.0104	0.0043	0.0098	0.0040	0.0093	0.0038	0.0089
0.8	0.99	0.0068	0.0154	0.0063	0.0141	0.0058	0.0132	0.0054	0.0124	0.0051	0.0118	0.0048	0.0113
0.9	1.12	0.0084	0.0189	0.0077	0.0174	0.0071	0.0162	0.0067	0.0152	0.0063	0.0145	0.0060	0.0139
1.0	1.24	0.0101	0.0227	0.0092	0.0209	0.0086	0.0195	0.0080	0.0183	0.0076	0.0174	0.0072	0.0167
1.1	1.36	0.0119	0.0268	0.0109	0.0247	0.0101	0.0230	0.0095	0.0216	0.0089	0.0206	0.0085	0.0197
1.2	1.49	0.0139	0.0312	0.0127	0.0287	0.0118	0.0268	0.0110	0.0252	0.0104	0.0240	0.0099	0.0229
1.3	1.61	0.0160	0.0359	0.0146	0.0331	0.0136	0.0308	0.0127	0.0290	0.0120	0.0276	0.0113	0.0264
1.4	1.74	0.0182	0.0409	0.0167	0.0376	0.0154	0.0351	0.0144	0.0330	0.0136	0.0314	0.0129	0.0300
1.5	1.86	0.0205	0.0462	0.0188	0.0425	0.0174	0.0396	0.0163	0.0372	0.0154	0.0354	0.0146	0.0339
1.6	1.98	0.0230	0.0517	0.0210	0.0475	0.0195	0.0443	0.0182	0.0417	0.0172	0.0396	0.0163	0.0379
1.7	2.11	0.0256	0.0575	0.0234	0.0529	0.0217	0.0493	0.0203	0.0464	0.0191	0.0441	0.0181	0.0422
1.8	2.23	0.0283	0.0635	0.0259	0.0584	0.0240	0.0545	0.0224	0.0512	0.0211	0.0487	0.0200	0.0466
1.9	2.36	0.0311	0.0698	0.0284	0.0642	0.0263	0.0599	0.0246	0.0563	0.0232	0.0536	0.0220	0.0512
2.0	2.48	0.0340	0.0764	0.0311	0.0703	0.0288	0.0655	0.0269	0.0616	0.0254	0.0586	0.0241	0.0560
2.1	2.60	0.0370	0.0832	0.0339	0.0765	0.0314	0.0713	0.0293	0.0671	0.0277	0.0638	0.0262	0.0610
2.2	2.73	0.0402	0.0902	0.0367	0.0830	0.0340	0.0774	0.0318	0.0728	0.0300	0.0692	0.0285	0.0662
2.3	2.85	0.0434	0.0975	0.0397	0.0897	0.0368	0.0837	0.0344	0.0787	0.0324	0.0748	0.0308	0.0716
2.4	2.98	0.0468	0.1051	0.0428	0.0967	0.0396	0.0901	0.0370	0.0848	0.0350	0.0806	0.0332	0.0771
2.5	3.10	0.0502	0.1129	0.0459	0.1038	0.0426	0.0968	0.0398	0.0910	0.0375	0.0866	0.0356	0.0828
2.6	3.22	0.0538	0.1209	0.0492	0.1112	0.0456	0.1037	0.0426	0.0975	0.0402	0.0927	0.0381	0.0887
2.7	3.35	0.0575	0.1291	0.0526	0.1188	0.0487	0.1108	0.0455	0.1042	0.0430	0.0991	0.0407	0.0947
2.8	3.47	0.0612	0.1376	0.0560	0.1266	0.0519	0.1180	0.0485	0.1110	0.0458	0.1056	0.0434	0.1010
2.9	3.60	0.0651	0.1463	0.0596	0.1346	0.0552	0.1255	0.0516	0.1180	0.0487	0.1123	0.0462	0.1073
3.0	3.72	0.0691	0.1553	0.0632	0.1428	0.0586	0.1332	0.0547	0.1253	0.0517	0.1191	0.0490	0.1139

Pressure Loss per Linear Foot - 1/2" PEX - 30% Propylene Glycol / 70% Water

		80 °F		100 °F		120 °F		140 °F		160 °F		180 °F	
Flow (GPM)	Velocity (FPS)	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot
0.1	0.18	0.0004	0.0010	0.0004	0.0009	0.0004	0.0008	0.0003	0.0008	0.0003	0.0007	0.0003	0.0007
0.2	0.36	0.0015	0.0033	0.0013	0.0030	0.0012	0.0028	0.0012	0.0026	0.0011	0.0025	0.0010	0.0024
0.3	0.54	0.0030	0.0067	0.0027	0.0061	0.0025	0.0057	0.0023	0.0054	0.0022	0.0051	0.0021	0.0049
0.4	0.72	0.0049	0.0110	0.0045	0.0101	0.0042	0.0094	0.0039	0.0089	0.0037	0.0084	0.0035	0.0081
0.5	0.90	0.0072	0.0163	0.0066	0.0150	0.0061	0.0139	0.0057	0.0131	0.0054	0.0125	0.0051	0.0119
0.6	1.08	0.0100	0.0224	0.0091	0.0206	0.0084	0.0192	0.0079	0.0180	0.0074	0.0172	0.0071	0.0164
0.7	1.26	0.0130	0.0293	0.0119	0.0270	0.0111	0.0251	0.0103	0.0236	0.0097	0.0225	0.0092	0.0215
0.8	1.44	0.0165	0.0370	0.0151	0.0341	0.0140	0.0318	0.0130	0.0299	0.0123	0.0284	0.0117	0.0272
0.9	1.62	0.0202	0.0455	0.0185	0.0418	0.0172	0.0390	0.0160	0.0367	0.0151	0.0349	0.0144	0.0334
1.0	1.80	0.0243	0.0547	0.0223	0.0503	0.0206	0.0469	0.0193	0.0441	0.0182	0.0420	0.0173	0.0401
1.1	1.97	0.0288	0.0646	0.0263	0.0595	0.0244	0.0554	0.0228	0.0521	0.0215	0.0496	0.0204	0.0474
1.2	2.15	0.0335	0.0753	0.0306	0.0692	0.0284	0.0646	0.0265	0.0607	0.0250	0.0577	0.0237	0.0552
1.3	2.33	0.0385	0.0866	0.0352	0.0796	0.0327	0.0743	0.0305	0.0698	0.0288	0.0664	0.0273	0.0635
1.4	2.51	0.0439	0.0986	0.0401	0.0907	0.0372	0.0845	0.0347	0.0795	0.0328	0.0756	0.0311	0.0723
1.5	2.69	0.0495	0.1112	0.0453	0.1023	0.0420	0.0954	0.0392	0.0897	0.0370	0.0853	0.0351	0.0816
1.6	2.87	0.0554	0.1245	0.0507	0.1145	0.0470	0.1068	0.0439	0.1004	0.0414	0.0955	0.0393	0.0913
1.7	3.05	0.0616	0.1385	0.0564	0.1274	0.0522	0.1188	0.0488	0.1117	0.0461	0.1062	0.0437	0.1016
1.8	3.23	0.0681	0.1530	0.0623	0.1407	0.0577	0.1313	0.0539	0.1234	0.0509	0.1174	0.0483	0.1123
1.9	3.41	0.0749	0.1682	0.0685	0.1547	0.0635	0.1443	0.0593	0.1357	0.0560	0.1290	0.0531	0.1234
2.0	3.59	0.0819	0.1840	0.0749	0.1692	0.0694	0.1578	0.0648	0.1484	0.0612	0.1412	0.0580	0.1350
2.1	3.77	0.0892	0.2004	0.0816	0.1843	0.0756	0.1719	0.0706	0.1617	0.0667	0.1537	0.0632	0.1470
2.2	3.95	0.0968	0.2174	0.0885	0.2000	0.0820	0.1865	0.0766	0.1754	0.0723	0.1668	0.0686	0.1595
2.3	4.13	0.1046	0.2350	0.0957	0.2161	0.0887	0.2016	0.0828	0.1896	0.0782	0.1803	0.0741	0.1724
2.4	4.31	0.1127	0.2532	0.1031	0.2329	0.0955	0.2171	0.0892	0.2042	0.0842	0.1942	0.0799	0.1857
2.5	4.49	0.1210	0.2719	0.1107	0.2501	0.1026	0.2332	0.0958	0.2193	0.0904	0.2086	0.0858	0.1995
2.6	4.67	0.1296	0.2912	0.1186	0.2679	0.1099	0.2498	0.1026	0.2349	0.0969	0.2234	0.0919	0.2136
2.7	4.85	0.1385	0.3111	0.1267	0.2862	0.1174	0.2668	0.1096	0.2510	0.1035	0.2387	0.0981	0.2282
2.8	5.03	0.1476	0.3315	0.1350	0.3050	0.1251	0.2844	0.1168	0.2674	0.1103	0.2543	0.1046	0.2432
2.9	5.21	0.1569	0.3525	0.1435	0.3243	0.1330	0.3024	0.1242	0.2844	0.1173	0.2705	0.1112	0.2586
3.0	5.39	0.1665	0.3741	0.1523	0.3441	0.1411	0.3209	0.1318	0.3018	0.1244	0.2870	0.1180	0.2744

		Pressure Loss per Linear Foot - 3/8" PEX - 30% Propylene Glycol / 70% Water											
		80 ºF		100 ºF		120 ºF		140 ºF		160 ºF		180 ºF	
Flow (GPM)	Velocity (FPS)	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot
0.1	0.33	0.0018	0.0041	0.0017	0.0038	0.0016	0.0035	0.0015	0.0033	0.0014	0.0032	0.0013	0.0030
0.2	0.66	0.0062	0.0139	0.0056	0.0127	0.0052	0.0119	0.0049	0.0112	0.0046	0.0106	0.0044	0.0102
0.3	0.99	0.0125	0.0282	0.0115	0.0259	0.0106	0.0242	0.0099	0.0227	0.0094	0.0216	0.0089	0.0207
0.4	1.32	0.0207	0.0466	0.0190	0.0429	0.0176	0.0400	0.0164	0.0376	0.0155	0.0358	0.0147	0.0342
0.5	1.65	0.0307	0.0689	0.0280	0.0634	0.0260	0.0591	0.0243	0.0556	0.0229	0.0528	0.0217	0.0505
0.6	1.98	0.0422	0.0948	0.0386	0.0872	0.0358	0.0813	0.0334	0.0764	0.0315	0.0727	0.0299	0.0695
0.7	2.31	0.0552	0.1241	0.0505	0.1142	0.0468	0.1065	0.0437	0.1001	0.0413	0.0952	0.0392	0.0910
0.8	2.64	0.0698	0.1568	0.0638	0.1442	0.0592	0.1345	0.0553	0.1265	0.0522	0.1203	0.0495	0.1150
0.9	2.97	0.0858	0.1927	0.0784	0.1772	0.0727	0.1653	0.0679	0.1554	0.0641	0.1478	0.0608	0.1413
1.0	3.30	0.1031	0.2317	0.0943	0.2131	0.0874	0.1987	0.0816	0.1869	0.0771	0.1777	0.0731	0.1700
1.1	3.63	0.1218	0.2737	0.1114	0.2518	0.1033	0.2348	0.0965	0.2208	0.0911	0.2100	0.0864	0.2008
1.2	3.96	0.1419	0.3188	0.1298	0.2932	0.1203	0.2734	0.1123	0.2571	0.1060	0.2445	0.1006	0.2338
1.3	4.29	0.1632	0.3667	0.1493	0.3373	0.1383	0.3145	0.1292	0.2958	0.1220	0.2813	0.1157	0.2690
1.4	4.62	0.1858	0.4175	0.1700	0.3840	0.1575	0.3581	0.1471	0.3368	0.1389	0.3203	0.1317	0.3062
1.5	4.95	0.2096	0.4710	0.1918	0.4333	0.1777	0.4040	0.1660	0.3800	0.1567	0.3614	0.1486	0.3455
1.6	5.27	0.2347	0.5274	0.2147	0.4851	0.1990	0.4523	0.1858	0.4254	0.1754	0.4046	0.1664	0.3869
1.7	5.60	0.2610	0.5864	0.2387	0.5394	0.2212	0.5030	0.2066	0.4730	0.1951	0.4499	0.1850	0.4302
1.8	5.93	0.2884	0.6481	0.2639	0.5961	0.2445	0.5559	0.2284	0.5228	0.2156	0.4972	0.2045	0.4754
1.9	6.26	0.3171	0.7124	0.2900	0.6553	0.2688	0.6111	0.2510	0.5747	0.2370	0.5465	0.2247	0.5226
2.0	6.59	0.3468	0.7793	0.3173	0.7168	0.2940	0.6684	0.2746	0.6286	0.2592	0.5978	0.2459	0.5717
2.1	6.92	0.3777	0.8488	0.3456	0.7807	0.3202	0.7280	0.2991	0.6847	0.2823	0.6511	0.2678	0.6226
2.2	7.25	0.4098	0.9207	0.3749	0.8469	0.3474	0.7898	0.3245	0.7427	0.3063	0.7064	0.2905	0.6754
2.3	7.58	0.4429	0.9952	0.4052	0.9154	0.3755	0.8537	0.3507	0.8028	0.3310	0.7635	0.3140	0.7301
2.4	7.91	0.4772	1.0722	0.4365	0.9862	0.4045	0.9197	0.3778	0.8649	0.3566	0.8225	0.3383	0.7865
2.5	8.24	0.5125	1.1516	0.4688	1.0592	0.4345	0.9878	0.4058	0.9289	0.3831	0.8834	0.3633	0.8448
2.6	8.57	0.5489	1.2334	0.5022	1.1345	0.4653	1.0579	0.4347	0.9949	0.4103	0.9462	0.3891	0.9048
2.7	8.90	0.5864	1.3176	0.5364	1.2120	0.4971	1.1302	0.4643	1.0629	0.4383	1.0108	0.4157	0.9666
2.8	9.23	0.6249	1.4042	0.5717	1.2916	0.5298	1.2044	0.4948	1.1327	0.4671	1.0772	0.4430	1.0301
2.9	9.56	0.6645	1.4931	0.6079	1.3734	0.5633	1.2807	0.5262	1.2045	0.4967	1.1455	0.4710	1.0953
3.0	9.89	0.7051	1.5844	0.6451	1.4574	0.5978	1.3590	0.5583	1.2781	0.5270	1.2155	0.4998	1.1623

Pressure Loss per Linear Foot - 1" PEX - 40% Propylene Glycol / 60% Water

		80 ºF		100 ºF		120 ºF		140 ºF		160 ºF		180 ºF	
Flow (GPM)	Velocity (FPS)	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot
0.1	0.05	0.0000	0.0001	0.0000	0.0001	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.2	0.11	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002
0.3	0.16	0.0002	0.0004	0.0002	0.0004	0.0002	0.0004	0.0001	0.0003	0.0001	0.0003	0.0001	0.0003
0.4	0.22	0.0003	0.0007	0.0003	0.0006	0.0003	0.0006	0.0002	0.0006	0.0002	0.0005	0.0002	0.0005
0.5	0.27	0.0005	0.0011	0.0004	0.0010	0.0004	0.0009	0.0004	0.0008	0.0003	0.0008	0.0003	0.0007
0.6	0.33	0.0007	0.0014	0.0006	0.0013	0.0005	0.0012	0.0005	0.0011	0.0005	0.0011	0.0004	0.0010
0.7	0.38	0.0009	0.0019	0.0008	0.0017	0.0007	0.0016	0.0007	0.0015	0.0006	0.0014	0.0006	0.0013
0.8	0.44	0.0011	0.0024	0.0010	0.0022	0.0009	0.0020	0.0008	0.0019	0.0008	0.0018	0.0007	0.0017
0.9	0.49	0.0013	0.0029	0.0012	0.0027	0.0011	0.0025	0.0010	0.0023	0.0010	0.0022	0.0009	0.0021
1.0	0.55	0.0016	0.0035	0.0014	0.0032	0.0013	0.0030	0.0012	0.0028	0.0011	0.0026	0.0011	0.0025
1.1	0.60	0.0019	0.0042	0.0017	0.0038	0.0016	0.0035	0.0014	0.0033	0.0014	0.0031	0.0013	0.0030
1.2	0.66	0.0022	0.0049	0.0020	0.0044	0.0018	0.0041	0.0017	0.0038	0.0016	0.0036	0.0015	0.0035
1.3	0.71	0.0025	0.0056	0.0023	0.0051	0.0021	0.0047	0.0019	0.0044	0.0018	0.0042	0.0017	0.0040
1.4	0.76	0.0029	0.0064	0.0026	0.0058	0.0024	0.0054	0.0022	0.0050	0.0021	0.0047	0.0020	0.0045
1.5	0.82	0.0032	0.0072	0.0029	0.0066	0.0027	0.0061	0.0025	0.0057	0.0023	0.0054	0.0022	0.0051
1.6	0.87	0.0036	0.0081	0.0033	0.0073	0.0030	0.0068	0.0028	0.0063	0.0026	0.0060	0.0025	0.0057
1.7	0.93	0.0040	0.0090	0.0036	0.0082	0.0033	0.0075	0.0031	0.0070	0.0029	0.0067	0.0027	0.0063
1.8	0.98	0.0044	0.0099	0.0040	0.0090	0.0037	0.0083	0.0034	0.0078	0.0032	0.0074	0.0030	0.0070
1.9	1.04	0.0049	0.0109	0.0044	0.0099	0.0041	0.0092	0.0038	0.0086	0.0035	0.0081	0.0033	0.0077
2.0	1.09	0.0053	0.0119	0.0048	0.0109	0.0044	0.0100	0.0041	0.0094	0.0039	0.0089	0.0036	0.0084
2.1	1.15	0.0058	0.0130	0.0053	0.0118	0.0048	0.0109	0.0045	0.0102	0.0042	0.0096	0.0040	0.0092
2.2	1.20	0.0063	0.0141	0.0057	0.0128	0.0052	0.0118	0.0049	0.0111	0.0046	0.0105	0.0043	0.0100
2.3	1.26	0.0068	0.0152	0.0062	0.0139	0.0057	0.0128	0.0053	0.0120	0.0049	0.0113	0.0047	0.0108
2.4	1.31	0.0074	0.0164	0.0067	0.0149	0.0061	0.0138	0.0057	0.0129	0.0053	0.0122	0.0050	0.0116
2.5	1.36	0.0079	0.0176	0.0071	0.0160	0.0066	0.0148	0.0061	0.0138	0.0057	0.0131	0.0054	0.0125
2.6	1.42	0.0085	0.0189	0.0077	0.0172	0.0070	0.0159	0.0065	0.0148	0.0061	0.0140	0.0058	0.0134
2.7	1.47	0.0090	0.0202	0.0082	0.0183	0.0075	0.0169	0.0070	0.0158	0.0065	0.0150	0.0062	0.0143
2.8	1.53	0.0096	0.0215	0.0087	0.0196	0.0080	0.0180	0.0074	0.0169	0.0070	0.0160	0.0066	0.0152
2.9	1.58	0.0102	0.0228	0.0093	0.0208	0.0085	0.0192	0.0079	0.0179	0.0074	0.0170	0.0070	0.0162
3.0	1.64	0.0109	0.0242	0.0098	0.0221	0.0090	0.0204	0.0084	0.0190	0.0078	0.0180	0.0074	0.0171

Pressure Loss per Linear Foot - 3/4" PEX - 40% Propylene Glycol / 60% Water

		80 ºF		100 ºF		120 ºF		140 ºF		160 ºF		180 ºF	
Flow (GPM)	Velocity (FPS)	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot
0.1	0.09	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002	0.0001	0.0001
0.2	0.18	0.0003	0.0007	0.0003	0.0006	0.0003	0.0006	0.0002	0.0005	0.0002	0.0005	0.0002	0.0005
0.3	0.27	0.0006	0.0014	0.0006	0.0013	0.0005	0.0012	0.0005	0.0011	0.0005	0.0011	0.0004	0.0010
0.4	0.36	0.0011	0.0023	0.0010	0.0021	0.0009	0.0020	0.0008	0.0018	0.0008	0.0017	0.0007	0.0017
0.5	0.45	0.0016	0.0035	0.0014	0.0032	0.0013	0.0029	0.0012	0.0027	0.0011	0.0026	0.0011	0.0025
0.6	0.54	0.0021	0.0048	0.0019	0.0043	0.0018	0.0040	0.0016	0.0037	0.0015	0.0035	0.0015	0.0034
0.7	0.63	0.0028	0.0063	0.0025	0.0057	0.0023	0.0053	0.0022	0.0049	0.0020	0.0046	0.0019	0.0044
0.8	0.72	0.0035	0.0079	0.0032	0.0072	0.0029	0.0066	0.0027	0.0062	0.0026	0.0059	0.0024	0.0056
0.9	0.81	0.0044	0.0097	0.0039	0.0088	0.0036	0.0082	0.0033	0.0076	0.0031	0.0072	0.0030	0.0069
1.0	0.90	0.0052	0.0117	0.0047	0.0106	0.0043	0.0098	0.0040	0.0092	0.0038	0.0087	0.0036	0.0083
1.1	0.99	0.0062	0.0138	0.0056	0.0126	0.0051	0.0116	0.0048	0.0108	0.0045	0.0102	0.0042	0.0098
1.2	1.08	0.0072	0.0161	0.0065	0.0146	0.0060	0.0135	0.0055	0.0126	0.0052	0.0119	0.0049	0.0114
1.3	1.17	0.0083	0.0185	0.0075	0.0168	0.0069	0.0155	0.0064	0.0145	0.0060	0.0137	0.0057	0.0131
1.4	1.26	0.0094	0.0210	0.0085	0.0191	0.0078	0.0177	0.0073	0.0165	0.0068	0.0156	0.0064	0.0149
1.5	1.35	0.0106	0.0237	0.0096	0.0216	0.0088	0.0199	0.0082	0.0186	0.0077	0.0176	0.0073	0.0168
1.6	1.44	0.0119	0.0266	0.0108	0.0242	0.0099	0.0223	0.0092	0.0209	0.0086	0.0197	0.0081	0.0188
1.7	1.53	0.0133	0.0296	0.0120	0.0269	0.0110	0.0248	0.0102	0.0232	0.0096	0.0219	0.0090	0.0209
1.8	1.62	0.0146	0.0327	0.0132	0.0297	0.0121	0.0274	0.0113	0.0256	0.0106	0.0243	0.0100	0.0231
1.9	1.71	0.0161	0.0359	0.0146	0.0327	0.0134	0.0302	0.0124	0.0282	0.0116	0.0267	0.0110	0.0254
2.0	1.80	0.0176	0.0393	0.0159	0.0357	0.0146	0.0330	0.0135	0.0308	0.0127	0.0292	0.0120	0.0278
2.1	1.89	0.0192	0.0428	0.0173	0.0389	0.0159	0.0359	0.0148	0.0336	0.0138	0.0318	0.0131	0.0303
2.2	1.98	0.0208	0.0464	0.0188	0.0422	0.0173	0.0390	0.0160	0.0364	0.0150	0.0345	0.0142	0.0328
2.3	2.07	0.0225	0.0502	0.0203	0.0457	0.0187	0.0421	0.0173	0.0394	0.0162	0.0372	0.0153	0.0355
2.4	2.16	0.0242	0.0540	0.0219	0.0492	0.0201	0.0454	0.0186	0.0424	0.0175	0.0401	0.0165	0.0382
2.5	2.25	0.0260	0.0580	0.0235	0.0528	0.0216	0.0488	0.0200	0.0456	0.0188	0.0431	0.0177	0.0411
2.6	2.34	0.0279	0.0622	0.0252	0.0566	0.0231	0.0522	0.0214	0.0488	0.0201	0.0462	0.0190	0.0440
2.7	2.43	0.0298	0.0664	0.0269	0.0604	0.0247	0.0558	0.0229	0.0521	0.0215	0.0493	0.0203	0.0470
2.8	2.53	0.0317	0.0708	0.0287	0.0644	0.0263	0.0594	0.0244	0.0556	0.0229	0.0525	0.0216	0.0501
2.9	2.62	0.0337	0.0753	0.0305	0.0685	0.0280	0.0632	0.0260	0.0591	0.0244	0.0559	0.0230	0.0532
3.0	2.71	0.0358	0.0799	0.0324	0.0727	0.0297	0.0671	0.0275	0.0627	0.0258	0.0593	0.0244	0.0565

		Pressure Loss per Linear Foot - 5/8" PEX - 40% Propylene Glycol / 60% Water											
		80 ºF		100 ºF		120 ºF		140 ºF		160 ºF		180 ºF	
Flow (GPM)	Velocity (FPS)	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot
0.1	0.12	0.0002	0.0004	0.0002	0.0004	0.0002	0.0004	0.0002	0.0003	0.0001	0.0003	0.0001	0.0003
0.2	0.25	0.0007	0.0015	0.0006	0.0014	0.0006	0.0012	0.0005	0.0012	0.0005	0.0011	0.0005	0.0011
0.3	0.37	0.0014	0.0030	0.0012	0.0028	0.0011	0.0025	0.0010	0.0024	0.0010	0.0022	0.0009	0.0021
0.4	0.50	0.0022	0.0050	0.0020	0.0046	0.0019	0.0042	0.0017	0.0039	0.0016	0.0037	0.0015	0.0035
0.5	0.62	0.0033	0.0074	0.0030	0.0067	0.0027	0.0062	0.0025	0.0058	0.0024	0.0055	0.0023	0.0052
0.6	0.74	0.0046	0.0102	0.0041	0.0093	0.0038	0.0085	0.0035	0.0080	0.0033	0.0076	0.0031	0.0072
0.7	0.87	0.0060	0.0133	0.0054	0.0121	0.0050	0.0112	0.0046	0.0105	0.0043	0.0099	0.0041	0.0094
0.8	0.99	0.0075	0.0168	0.0068	0.0153	0.0063	0.0141	0.0058	0.0132	0.0054	0.0125	0.0051	0.0119
0.9	1.12	0.0093	0.0207	0.0084	0.0188	0.0077	0.0174	0.0071	0.0162	0.0067	0.0154	0.0063	0.0146
1.0	1.24	0.0111	0.0249	0.0101	0.0226	0.0092	0.0209	0.0086	0.0195	0.0080	0.0185	0.0076	0.0176
1.1	1.36	0.0132	0.0294	0.0119	0.0267	0.0109	0.0247	0.0101	0.0231	0.0095	0.0218	0.0090	0.0208
1.2	1.49	0.0153	0.0342	0.0139	0.0311	0.0127	0.0287	0.0118	0.0269	0.0111	0.0254	0.0105	0.0242
1.3	1.61	0.0176	0.0394	0.0160	0.0358	0.0146	0.0331	0.0136	0.0309	0.0127	0.0292	0.0120	0.0278
1.4	1.74	0.0201	0.0448	0.0182	0.0408	0.0167	0.0376	0.0155	0.0352	0.0145	0.0333	0.0137	0.0317
1.5	1.86	0.0227	0.0506	0.0205	0.0460	0.0188	0.0425	0.0174	0.0397	0.0164	0.0375	0.0155	0.0358
1.6	1.98	0.0254	0.0566	0.0230	0.0515	0.0210	0.0475	0.0195	0.0444	0.0183	0.0420	0.0173	0.0400
1.7	2.11	0.0282	0.0629	0.0255	0.0573	0.0234	0.0529	0.0217	0.0494	0.0204	0.0467	0.0192	0.0445
1.8	2.23	0.0312	0.0696	0.0282	0.0633	0.0259	0.0584	0.0240	0.0546	0.0225	0.0516	0.0213	0.0492
1.9	2.36	0.0343	0.0765	0.0310	0.0696	0.0284	0.0642	0.0264	0.0600	0.0247	0.0568	0.0234	0.0541
2.0	2.48	0.0375	0.0836	0.0339	0.0761	0.0311	0.0702	0.0288	0.0657	0.0271	0.0621	0.0256	0.0592
2.1	2.60	0.0408	0.0911	0.0369	0.0829	0.0339	0.0765	0.0314	0.0715	0.0295	0.0676	0.0278	0.0644
2.2	2.73	0.0443	0.0988	0.0401	0.0899	0.0367	0.0830	0.0341	0.0776	0.0320	0.0734	0.0302	0.0699
2.3	2.85	0.0479	0.1068	0.0433	0.0972	0.0397	0.0897	0.0368	0.0838	0.0346	0.0793	0.0327	0.0756
2.4	2.98	0.0516	0.1151	0.0467	0.1047	0.0428	0.0967	0.0397	0.0903	0.0372	0.0854	0.0352	0.0814
2.5	3.10	0.0554	0.1236	0.0501	0.1125	0.0460	0.1038	0.0426	0.0970	0.0400	0.0918	0.0378	0.0874
2.6	3.22	0.0593	0.1324	0.0537	0.1205	0.0492	0.1112	0.0457	0.1039	0.0428	0.0983	0.0405	0.0936
2.7	3.35	0.0634	0.1414	0.0573	0.1287	0.0526	0.1188	0.0488	0.1110	0.0458	0.1050	0.0432	0.1000
2.8	3.47	0.0676	0.1507	0.0611	0.1371	0.0560	0.1266	0.0520	0.1183	0.0488	0.1119	0.0461	0.1066
2.9	3.60	0.0718	0.1602	0.0650	0.1458	0.0596	0.1346	0.0553	0.1258	0.0519	0.1190	0.0490	0.1134
3.0	3.72	0.0762	0.1700	0.0690	0.1547	0.0632	0.1428	0.0587	0.1335	0.0550	0.1262	0.0520	0.1203

		Pressure Loss per Linear Foot - 1/2" PEX - 40% Propylene Glycol / 60% Water											
		80 ºF		100 ºF		120 ºF		140 ºF		160 ºF		180 ºF	
Flow (GPM)	Velocity (FPS)	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot
0.1	0.18	0.0005	0.0011	0.0004	0.0010	0.0004	0.0009	0.0004	0.0008	0.0003	0.0008	0.0003	0.0008
0.2	0.36	0.0016	0.0036	0.0015	0.0033	0.0013	0.0030	0.0012	0.0028	0.0012	0.0027	0.0011	0.0025
0.3	0.54	0.0033	0.0073	0.0030	0.0066	0.0027	0.0061	0.0025	0.0057	0.0024	0.0054	0.0022	0.0052
0.4	0.72	0.0054	0.0121	0.0049	0.0110	0.0045	0.0101	0.0042	0.0095	0.0039	0.0089	0.0037	0.0085
0.5	0.90	0.0080	0.0178	0.0072	0.0162	0.0066	0.0150	0.0061	0.0140	0.0058	0.0132	0.0054	0.0126
0.6	1.08	0.0110	0.0245	0.0099	0.0223	0.0091	0.0206	0.0085	0.0192	0.0079	0.0182	0.0075	0.0173
0.7	1.26	0.0144	0.0321	0.0130	0.0292	0.0119	0.0270	0.0111	0.0252	0.0104	0.0238	0.0098	0.0227
0.8	1.44	0.0182	0.0405	0.0164	0.0369	0.0151	0.0340	0.0140	0.0318	0.0131	0.0301	0.0124	0.0287
0.9	1.62	0.0223	0.0498	0.0202	0.0453	0.0185	0.0418	0.0172	0.0391	0.0161	0.0370	0.0152	0.0352
1.0	1.80	0.0269	0.0599	0.0243	0.0545	0.0223	0.0503	0.0207	0.0470	0.0194	0.0445	0.0183	0.0424
1.1	1.97	0.0317	0.0708	0.0287	0.0644	0.0263	0.0594	0.0244	0.0556	0.0229	0.0525	0.0216	0.0501
1.2	2.15	0.0369	0.0824	0.0334	0.0750	0.0306	0.0692	0.0284	0.0647	0.0267	0.0612	0.0252	0.0583
1.3	2.33	0.0425	0.0948	0.0384	0.0863	0.0353	0.0796	0.0327	0.0744	0.0307	0.0704	0.0290	0.0671
1.4	2.51	0.0484	0.1079	0.0438	0.0982	0.0401	0.0907	0.0372	0.0847	0.0349	0.0801	0.0330	0.0764
1.5	2.69	0.0546	0.1218	0.0494	0.1108	0.0453	0.1023	0.0420	0.0956	0.0394	0.0904	0.0372	0.0862
1.6	2.87	0.0611	0.1364	0.0553	0.1241	0.0507	0.1145	0.0470	0.1070	0.0441	0.1012	0.0417	0.0965
1.7	3.05	0.0680	0.1516	0.0615	0.1380	0.0564	0.1273	0.0523	0.1190	0.0491	0.1126	0.0464	0.1073
1.8	3.23	0.0751	0.1676	0.0680	0.1525	0.0623	0.1407	0.0578	0.1315	0.0542	0.1244	0.0512	0.1185
1.9	3.41	0.0826	0.1842	0.0747	0.1676	0.0685	0.1547	0.0635	0.1446	0.0596	0.1368	0.0563	0.1303
2.0	3.59	0.0903	0.2015	0.0817	0.1834	0.0749	0.1692	0.0695	0.1582	0.0652	0.1496	0.0616	0.1426
2.1	3.77	0.0984	0.2195	0.0890	0.1997	0.0816	0.1843	0.0757	0.1723	0.0710	0.1629	0.0671	0.1553
2.2	3.95	0.1067	0.2381	0.0965	0.2167	0.0885	0.2000	0.0821	0.1869	0.0770	0.1768	0.0728	0.1684
2.3	4.13	0.1154	0.2573	0.1044	0.2342	0.0957	0.2161	0.0888	0.2020	0.0833	0.1911	0.0787	0.1820
2.4	4.31	0.1243	0.2772	0.1124	0.2523	0.1031	0.2328	0.0956	0.2176	0.0897	0.2058	0.0848	0.1961
2.5	4.49	0.1335	0.2977	0.1207	0.2710	0.1107	0.2501	0.1027	0.2337	0.0964	0.2211	0.0910	0.2106
2.6	4.67	0.1430	0.3189	0.1293	0.2902	0.1186	0.2679	0.1100	0.2503	0.1032	0.2368	0.0975	0.2256
2.7	4.85	0.1527	0.3407	0.1382	0.3100	0.1267	0.2861	0.1175	0.2674	0.1103	0.2529	0.1042	0.2410
2.8	5.03	0.1628	0.3631	0.1472	0.3304	0.1350	0.3049	0.1252	0.2850	0.1175	0.2696	0.1110	0.2569
2.9	5.21	0.1731	0.3861	0.1566	0.3513	0.1435	0.3243	0.1332	0.3030	0.1249	0.2866	0.1180	0.2731
3.0	5.39	0.1837	0.4097	0.1661	0.3728	0.1523	0.3441	0.1413	0.3216	0.1326	0.3042	0.1252	0.2898

		Pressure Loss per Linear Foot - 3/8" PEX - 40% Propylene Glycol / 60% Water											
		80 ºF		100 ºF		120 ºF		140 ºF		160 ºF		180 ºF	
Flow (GPM)	Velocity (FPS)	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot
0.1	0.33	0.0020	0.0045	0.0018	0.0041	0.0017	0.0038	0.0016	0.0035	0.0015	0.0033	0.0014	0.0032
0.2	0.66	0.0068	0.0152	0.0062	0.0138	0.0056	0.0127	0.0052	0.0119	0.0049	0.0113	0.0046	0.0107
0.3	0.99	0.0138	0.0309	0.0125	0.0281	0.0115	0.0259	0.0106	0.0242	0.0100	0.0229	0.0094	0.0218
0.4	1.32	0.0229	0.0510	0.0207	0.0465	0.0190	0.0429	0.0176	0.0401	0.0165	0.0379	0.0156	0.0361
0.5	1.65	0.0338	0.0754	0.0306	0.0686	0.0280	0.0634	0.0260	0.0592	0.0244	0.0560	0.0231	0.0534
0.6	1.98	0.0465	0.1038	0.0421	0.0944	0.0386	0.0872	0.0358	0.0815	0.0336	0.0771	0.0317	0.0734
0.7	2.31	0.0609	0.1359	0.0551	0.1237	0.0505	0.1142	0.0469	0.1067	0.0440	0.1009	0.0416	0.0962
0.8	2.64	0.0770	0.1717	0.0696	0.1563	0.0638	0.1442	0.0592	0.1348	0.0556	0.1275	0.0525	0.1215
0.9	2.97	0.0946	0.2110	0.0856	0.1920	0.0785	0.1772	0.0728	0.1656	0.0683	0.1567	0.0645	0.1493
1.0	3.30	0.1137	0.2537	0.1029	0.2309	0.0943	0.2131	0.0875	0.1992	0.0821	0.1884	0.0776	0.1795
1.1	3.63	0.1344	0.2998	0.1216	0.2728	0.1115	0.2518	0.1034	0.2353	0.0970	0.2226	0.0916	0.2121
1.2	3.96	0.1565	0.3491	0.1416	0.3177	0.1298	0.2932	0.1204	0.2740	0.1130	0.2592	0.1067	0.2470
1.3	4.29	0.1800	0.4016	0.1628	0.3654	0.1493	0.3373	0.1385	0.3152	0.1300	0.2981	0.1228	0.2841
1.4	4.62	0.2050	0.4572	0.1854	0.4160	0.1700	0.3840	0.1577	0.3589	0.1479	0.3394	0.1398	0.3234
1.5	4.95	0.2313	0.5158	0.2092	0.4694	0.1918	0.4333	0.1779	0.4049	0.1669	0.3830	0.1577	0.3649
1.6	5.27	0.2589	0.5775	0.2342	0.5256	0.2147	0.4851	0.1992	0.4533	0.1869	0.4288	0.1766	0.4086
1.7	5.60	0.2879	0.6421	0.2604	0.5844	0.2388	0.5394	0.2215	0.5041	0.2078	0.4768	0.1963	0.4543
1.8	5.93	0.3182	0.7097	0.2878	0.6459	0.2639	0.5961	0.2448	0.5571	0.2297	0.5269	0.2170	0.5021
1.9	6.26	0.3497	0.7801	0.3164	0.7100	0.2901	0.6552	0.2691	0.6124	0.2525	0.5792	0.2385	0.5519
2.0	6.59	0.3826	0.8534	0.3461	0.7766	0.3173	0.7168	0.2944	0.6699	0.2762	0.6336	0.2609	0.6037
2.1	6.92	0.4167	0.9294	0.3769	0.8459	0.3456	0.7807	0.3206	0.7296	0.3008	0.6901	0.2842	0.6576
2.2	7.25	0.4520	1.0083	0.4089	0.9176	0.3749	0.8469	0.3478	0.7915	0.3263	0.7486	0.3083	0.7133
2.3	7.58	0.4886	1.0898	0.4420	0.9918	0.4052	0.9154	0.3759	0.8555	0.3527	0.8092	0.3332	0.7710
2.4	7.91	0.5264	1.1741	0.4761	1.0685	0.4366	0.9862	0.4050	0.9216	0.3800	0.8717	0.3590	0.8307
2.5	8.24	0.5654	1.2611	0.5114	1.1477	0.4689	1.0592	0.4350	0.9899	0.4081	0.9363	0.3855	0.8922
2.6	8.57	0.6055	1.3506	0.5477	1.2292	0.5022	1.1345	0.4659	1.0602	0.4371	1.0028	0.4129	0.9555
2.7	8.90	0.6469	1.4429	0.5851	1.3131	0.5365	1.2119	0.4977	1.1326	0.4670	1.0713	0.4411	1.0208
2.8	9.23	0.6894	1.5377	0.6236	1.3994	0.5718	1.2916	0.5304	1.2070	0.4976	1.1417	0.4701	1.0879
2.9	9.56	0.7330	1.6351	0.6631	1.4880	0.6080	1.3734	0.5640	1.2835	0.5292	1.2140	0.4999	1.1568
3.0	9.89	0.7778	1.7350	0.7036	1.5790	0.6451	1.4573	0.5985	1.3619	0.5615	1.2882	0.5304	1.2275

		Pressure Loss per Linear Foot - 1" PEX - 50% Propylene Glycol / 50% Water											
		80 ºF		100 ºF		120 ºF		140 ºF		160 ºF		180 ºF	
Flow (GPM)	Velocity (FPS)	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot
0.1	0.05	0.0000	0.0001	0.0000	0.0001	0.0000	0.0001	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000
0.2	0.11	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002
0.3	0.16	0.0002	0.0005	0.0002	0.0004	0.0002	0.0004	0.0002	0.0004	0.0001	0.0003	0.0001	0.0003
0.4	0.22	0.0004	0.0008	0.0003	0.0007	0.0003	0.0006	0.0003	0.0006	0.0002	0.0006	0.0002	0.0005
0.5	0.27	0.0005	0.0012	0.0005	0.0010	0.0004	0.0010	0.0004	0.0009	0.0004	0.0008	0.0003	0.0008
0.6	0.33	0.0007	0.0016	0.0006	0.0014	0.0006	0.0013	0.0005	0.0012	0.0005	0.0011	0.0005	0.0011
0.7	0.38	0.0009	0.0021	0.0008	0.0019	0.0008	0.0017	0.0007	0.0016	0.0007	0.0015	0.0006	0.0014
0.8	0.44	0.0012	0.0026	0.0011	0.0024	0.0010	0.0022	0.0009	0.0020	0.0008	0.0019	0.0008	0.0018
0.9	0.49	0.0015	0.0032	0.0013	0.0029	0.0012	0.0027	0.0011	0.0025	0.0010	0.0023	0.0010	0.0022
1.0	0.55	0.0017	0.0039	0.0016	0.0035	0.0014	0.0032	0.0013	0.0030	0.0012	0.0028	0.0012	0.0027
1.1	0.60	0.0021	0.0046	0.0019	0.0041	0.0017	0.0038	0.0016	0.0035	0.0015	0.0033	0.0014	0.0031
1.2	0.66	0.0024	0.0053	0.0022	0.0048	0.0020	0.0044	0.0018	0.0041	0.0017	0.0039	0.0016	0.0037
1.3	0.71	0.0028	0.0061	0.0025	0.0055	0.0023	0.0051	0.0021	0.0047	0.0019	0.0044	0.0018	0.0042
1.4	0.76	0.0031	0.0070	0.0028	0.0063	0.0026	0.0058	0.0024	0.0054	0.0022	0.0051	0.0021	0.0048
1.5	0.82	0.0036	0.0079	0.0032	0.0071	0.0029	0.0065	0.0027	0.0061	0.0025	0.0057	0.0023	0.0054
1.6	0.87	0.0040	0.0088	0.0036	0.0080	0.0033	0.0073	0.0030	0.0068	0.0028	0.0064	0.0026	0.0061
1.7	0.93	0.0044	0.0098	0.0040	0.0089	0.0036	0.0081	0.0033	0.0076	0.0031	0.0071	0.0029	0.0067
1.8	0.98	0.0049	0.0108	0.0044	0.0098	0.0040	0.0090	0.0037	0.0084	0.0034	0.0078	0.0032	0.0074
1.9	1.04	0.0054	0.0119	0.0048	0.0108	0.0044	0.0099	0.0041	0.0092	0.0038	0.0086	0.0035	0.0082
2.0	1.09	0.0059	0.0130	0.0053	0.0118	0.0048	0.0108	0.0044	0.0101	0.0041	0.0094	0.0039	0.0089
2.1	1.15	0.0064	0.0142	0.0057	0.0128	0.0052	0.0118	0.0048	0.0109	0.0045	0.0103	0.0042	0.0097
2.2	1.20	0.0069	0.0154	0.0062	0.0139	0.0057	0.0128	0.0052	0.0119	0.0049	0.0112	0.0046	0.0106
2.3	1.26	0.0075	0.0166	0.0067	0.0150	0.0061	0.0138	0.0057	0.0128	0.0053	0.0121	0.0050	0.0114
2.4	1.31	0.0081	0.0179	0.0073	0.0162	0.0066	0.0149	0.0061	0.0138	0.0057	0.0130	0.0053	0.0123
2.5	1.36	0.0087	0.0192	0.0078	0.0174	0.0071	0.0160	0.0066	0.0149	0.0061	0.0139	0.0057	0.0132
2.6	1.42	0.0093	0.0206	0.0084	0.0186	0.0076	0.0171	0.0070	0.0159	0.0065	0.0149	0.0061	0.0142
2.7	1.47	0.0099	0.0220	0.0089	0.0199	0.0081	0.0183	0.0075	0.0170	0.0070	0.0160	0.0066	0.0151
2.8	1.53	0.0106	0.0235	0.0095	0.0212	0.0087	0.0195	0.0080	0.0181	0.0074	0.0170	0.0070	0.0161
2.9	1.58	0.0113	0.0250	0.0101	0.0226	0.0092	0.0207	0.0085	0.0193	0.0079	0.0181	0.0074	0.0171
3.0	1.64	0.0119	0.0265	0.0107	0.0239	0.0098	0.0220	0.0090	0.0204	0.0084	0.0192	0.0079	0.0182

		Pressure Loss per Linear Foot - 3/4" PEX - 50% Propylene Glycol / 50% Water											
		80 ºF		100 ºF		120 ºF		140 ºF		160 ºF		180 ºF	
Flow (GPM)	Velocity (FPS)	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot
0.1	0.09	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002	0.0001	0.0002
0.2	0.18	0.0003	0.0008	0.0003	0.0007	0.0003	0.0006	0.0003	0.0006	0.0002	0.0006	0.0002	0.0005
0.3	0.27	0.0007	0.0016	0.0006	0.0014	0.0006	0.0013	0.0005	0.0012	0.0005	0.0011	0.0005	0.0011
0.4	0.36	0.0012	0.0026	0.0010	0.0023	0.0009	0.0021	0.0009	0.0020	0.0008	0.0019	0.0008	0.0018
0.5	0.45	0.0017	0.0038	0.0015	0.0034	0.0014	0.0031	0.0013	0.0029	0.0012	0.0027	0.0011	0.0026
0.6	0.54	0.0024	0.0052	0.0021	0.0047	0.0019	0.0043	0.0018	0.0040	0.0017	0.0038	0.0016	0.0036
0.7	0.63	0.0031	0.0068	0.0028	0.0062	0.0025	0.0057	0.0023	0.0053	0.0022	0.0050	0.0020	0.0047
0.8	0.72	0.0039	0.0086	0.0035	0.0078	0.0032	0.0072	0.0029	0.0067	0.0027	0.0063	0.0026	0.0059
0.9	0.81	0.0048	0.0106	0.0043	0.0096	0.0039	0.0088	0.0036	0.0082	0.0034	0.0077	0.0032	0.0073
1.0	0.90	0.0058	0.0128	0.0052	0.0115	0.0047	0.0106	0.0043	0.0098	0.0040	0.0092	0.0038	0.0088
1.1	0.99	0.0068	0.0151	0.0061	0.0136	0.0056	0.0125	0.0051	0.0116	0.0048	0.0109	0.0045	0.0104
1.2	1.08	0.0079	0.0175	0.0071	0.0159	0.0065	0.0146	0.0060	0.0135	0.0056	0.0127	0.0052	0.0121
1.3	1.17	0.0091	0.0202	0.0082	0.0183	0.0075	0.0168	0.0069	0.0156	0.0064	0.0146	0.0060	0.0139
1.4	1.26	0.0104	0.0230	0.0093	0.0208	0.0085	0.0191	0.0078	0.0177	0.0073	0.0167	0.0068	0.0158
1.5	1.35	0.0117	0.0259	0.0105	0.0235	0.0096	0.0215	0.0088	0.0200	0.0082	0.0188	0.0077	0.0178
1.6	1.44	0.0131	0.0290	0.0118	0.0263	0.0107	0.0241	0.0099	0.0224	0.0092	0.0210	0.0087	0.0199
1.7	1.53	0.0146	0.0323	0.0131	0.0292	0.0119	0.0268	0.0110	0.0249	0.0102	0.0234	0.0096	0.0222
1.8	1.62	0.0161	0.0357	0.0145	0.0323	0.0132	0.0296	0.0122	0.0275	0.0113	0.0259	0.0106	0.0245
1.9	1.71	0.0177	0.0392	0.0159	0.0355	0.0145	0.0326	0.0134	0.0303	0.0124	0.0284	0.0117	0.0269
2.0	1.80	0.0194	0.0429	0.0174	0.0388	0.0158	0.0356	0.0146	0.0331	0.0136	0.0311	0.0128	0.0295
2.1	1.89	0.0211	0.0467	0.0189	0.0423	0.0173	0.0388	0.0159	0.0361	0.0148	0.0339	0.0139	0.0321
2.2	1.98	0.0229	0.0507	0.0205	0.0458	0.0187	0.0421	0.0173	0.0391	0.0161	0.0367	0.0151	0.0348
2.3	2.07	0.0247	0.0548	0.0222	0.0495	0.0202	0.0455	0.0187	0.0423	0.0174	0.0397	0.0163	0.0376
2.4	2.16	0.0266	0.0590	0.0239	0.0534	0.0218	0.0490	0.0201	0.0456	0.0187	0.0428	0.0176	0.0406
2.5	2.25	0.0286	0.0634	0.0257	0.0573	0.0234	0.0526	0.0216	0.0489	0.0201	0.0459	0.0189	0.0436
2.6	2.34	0.0306	0.0679	0.0275	0.0614	0.0251	0.0564	0.0231	0.0524	0.0215	0.0492	0.0202	0.0467
2.7	2.43	0.0327	0.0725	0.0294	0.0656	0.0268	0.0602	0.0247	0.0560	0.0230	0.0526	0.0216	0.0498
2.8	2.53	0.0349	0.0773	0.0313	0.0699	0.0285	0.0642	0.0263	0.0597	0.0245	0.0560	0.0230	0.0531
2.9	2.62	0.0371	0.0822	0.0333	0.0743	0.0304	0.0682	0.0280	0.0634	0.0261	0.0596	0.0245	0.0565
3.0	2.71	0.0393	0.0872	0.0354	0.0789	0.0322	0.0724	0.0297	0.0673	0.0277	0.0632	0.0260	0.0599

Pressure Loss per Linear Foot - 5/8" PEX - 50% Propylene Glycol / 50% Water

Flow (GPM)	Velocity (FPS)	80 ºF Pressure Loss (PSI) per foot	80 ºF Head Loss (FT-H2O) per foot	100 ºF Pressure Loss (PSI) per foot	100 ºF Head Loss (FT-H2O) per foot	120 ºF Pressure Loss (PSI) per foot	120 ºF Head Loss (FT-H2O) per foot	140 ºF Pressure Loss (PSI) per foot	140 ºF Head Loss (FT-H2O) per foot	160 ºF Pressure Loss (PSI) per foot	160 ºF Head Loss (FT-H2O) per foot	180 ºF Pressure Loss (PSI) per foot	180 ºF Head Loss (FT-H2O) per foot
0.1	0.12	0.0002	0.0005	0.0002	0.0004	0.0002	0.0004	0.0002	0.0004	0.0002	0.0004	0.0001	0.0003
0.2	0.25	0.0007	0.0016	0.0007	0.0015	0.0006	0.0013	0.0006	0.0013	0.0005	0.0012	0.0005	0.0011
0.3	0.37	0.0015	0.0033	0.0013	0.0030	0.0012	0.0027	0.0011	0.0025	0.0010	0.0024	0.0010	0.0023
0.4	0.50	0.0025	0.0055	0.0022	0.0049	0.0020	0.0045	0.0019	0.0042	0.0017	0.0040	0.0016	0.0038
0.5	0.62	0.0036	0.0081	0.0033	0.0073	0.0030	0.0067	0.0028	0.0062	0.0026	0.0059	0.0024	0.0055
0.6	0.74	0.0050	0.0111	0.0045	0.0100	0.0041	0.0092	0.0038	0.0086	0.0035	0.0081	0.0033	0.0076
0.7	0.87	0.0066	0.0145	0.0059	0.0132	0.0054	0.0121	0.0050	0.0112	0.0046	0.0105	0.0043	0.0100
0.8	0.99	0.0083	0.0184	0.0074	0.0166	0.0068	0.0153	0.0063	0.0142	0.0058	0.0133	0.0055	0.0126
0.9	1.12	0.0102	0.0226	0.0092	0.0204	0.0083	0.0187	0.0077	0.0174	0.0072	0.0164	0.0067	0.0155
1.0	1.24	0.0123	0.0272	0.0110	0.0246	0.0100	0.0225	0.0093	0.0210	0.0086	0.0197	0.0081	0.0187
1.1	1.36	0.0145	0.0321	0.0130	0.0290	0.0119	0.0266	0.0109	0.0248	0.0102	0.0233	0.0096	0.0220
1.2	1.49	0.0169	0.0374	0.0151	0.0338	0.0138	0.0310	0.0127	0.0288	0.0119	0.0271	0.0111	0.0257
1.3	1.61	0.0194	0.0430	0.0174	0.0389	0.0159	0.0357	0.0146	0.0332	0.0136	0.0312	0.0128	0.0295
1.4	1.74	0.0221	0.0489	0.0198	0.0443	0.0181	0.0406	0.0167	0.0378	0.0155	0.0355	0.0146	0.0336
1.5	1.86	0.0249	0.0552	0.0224	0.0499	0.0204	0.0458	0.0188	0.0426	0.0175	0.0400	0.0165	0.0379
1.6	1.98	0.0279	0.0618	0.0251	0.0559	0.0228	0.0513	0.0211	0.0477	0.0196	0.0448	0.0184	0.0425
1.7	2.11	0.0310	0.0687	0.0279	0.0622	0.0254	0.0571	0.0234	0.0530	0.0218	0.0498	0.0205	0.0472
1.8	2.23	0.0343	0.0760	0.0308	0.0687	0.0281	0.0631	0.0259	0.0586	0.0241	0.0551	0.0226	0.0522
1.9	2.36	0.0377	0.0835	0.0338	0.0755	0.0308	0.0693	0.0285	0.0644	0.0265	0.0605	0.0249	0.0574
2.0	2.48	0.0412	0.0913	0.0370	0.0826	0.0337	0.0758	0.0311	0.0705	0.0290	0.0662	0.0272	0.0628
2.1	2.60	0.0449	0.0995	0.0403	0.0900	0.0367	0.0826	0.0339	0.0768	0.0316	0.0721	0.0296	0.0684
2.2	2.73	0.0487	0.1079	0.0437	0.0976	0.0399	0.0896	0.0368	0.0833	0.0342	0.0782	0.0322	0.0742
2.3	2.85	0.0526	0.1167	0.0473	0.1055	0.0431	0.0968	0.0398	0.0900	0.0370	0.0846	0.0348	0.0802
2.4	2.98	0.0567	0.1257	0.0509	0.1137	0.0464	0.1043	0.0428	0.0970	0.0399	0.0911	0.0375	0.0864
2.5	3.10	0.0609	0.1350	0.0547	0.1221	0.0499	0.1120	0.0460	0.1042	0.0428	0.0978	0.0402	0.0927
2.6	3.22	0.0652	0.1446	0.0586	0.1308	0.0534	0.1200	0.0493	0.1116	0.0459	0.1048	0.0431	0.0993
2.7	3.35	0.0697	0.1544	0.0626	0.1397	0.0570	0.1282	0.0526	0.1192	0.0490	0.1119	0.0460	0.1061
2.8	3.47	0.0742	0.1646	0.0667	0.1489	0.0608	0.1366	0.0561	0.1270	0.0522	0.1193	0.0491	0.1131
2.9	3.60	0.0790	0.1750	0.0709	0.1583	0.0646	0.1453	0.0596	0.1351	0.0555	0.1269	0.0522	0.1203
3.0	3.72	0.0838	0.1857	0.0753	0.1680	0.0686	0.1542	0.0633	0.1433	0.0589	0.1346	0.0553	0.1276

Pressure Loss per Linear Foot - 1/2" PEX - 50% Propylene Glycol / 50% Water

Flow (GPM)	Velocity (FPS)	80 ºF Pressure Loss (PSI) per foot	80 ºF Head Loss (FT-H2O) per foot	100 ºF Pressure Loss (PSI) per foot	100 ºF Head Loss (FT-H2O) per foot	120 ºF Pressure Loss (PSI) per foot	120 ºF Head Loss (FT-H2O) per foot	140 ºF Pressure Loss (PSI) per foot	140 ºF Head Loss (FT-H2O) per foot	160 ºF Pressure Loss (PSI) per foot	160 ºF Head Loss (FT-H2O) per foot	180 ºF Pressure Loss (PSI) per foot	180 ºF Head Loss (FT-H2O) per foot
0.1	0.18	0.0005	0.0012	0.0005	0.0011	0.0004	0.0010	0.0004	0.0009	0.0004	0.0008	0.0003	0.0008
0.2	0.36	0.0018	0.0039	0.0016	0.0035	0.0014	0.0032	0.0013	0.0030	0.0012	0.0028	0.0012	0.0027
0.3	0.54	0.0036	0.0080	0.0032	0.0072	0.0029	0.0066	0.0027	0.0061	0.0025	0.0058	0.0024	0.0055
0.4	0.72	0.0059	0.0132	0.0053	0.0119	0.0049	0.0109	0.0045	0.0102	0.0042	0.0095	0.0039	0.0090
0.5	0.90	0.0088	0.0195	0.0079	0.0176	0.0072	0.0161	0.0066	0.0150	0.0062	0.0141	0.0058	0.0134
0.6	1.08	0.0121	0.0268	0.0108	0.0242	0.0099	0.0222	0.0091	0.0207	0.0085	0.0194	0.0080	0.0184
0.7	1.26	0.0158	0.0350	0.0142	0.0317	0.0129	0.0291	0.0119	0.0270	0.0111	0.0254	0.0104	0.0241
0.8	1.44	0.0200	0.0443	0.0179	0.0400	0.0164	0.0368	0.0151	0.0342	0.0140	0.0321	0.0132	0.0304
0.9	1.62	0.0245	0.0544	0.0221	0.0492	0.0201	0.0452	0.0185	0.0420	0.0173	0.0394	0.0162	0.0374
1.0	1.80	0.0295	0.0654	0.0265	0.0592	0.0242	0.0543	0.0223	0.0505	0.0208	0.0474	0.0195	0.0450
1.1	1.97	0.0349	0.0773	0.0313	0.0699	0.0285	0.0642	0.0263	0.0597	0.0245	0.0560	0.0230	0.0531
1.2	2.15	0.0406	0.0900	0.0365	0.0814	0.0332	0.0747	0.0307	0.0695	0.0286	0.0652	0.0268	0.0618
1.3	2.33	0.0467	0.1036	0.0420	0.0937	0.0382	0.0860	0.0353	0.0799	0.0329	0.0751	0.0309	0.0711
1.4	2.51	0.0532	0.1179	0.0478	0.1066	0.0435	0.0979	0.0402	0.0910	0.0374	0.0855	0.0351	0.0810
1.5	2.69	0.0600	0.1330	0.0539	0.1203	0.0491	0.1104	0.0453	0.1027	0.0422	0.0964	0.0396	0.0914
1.6	2.87	0.0672	0.1489	0.0604	0.1347	0.0550	0.1236	0.0507	0.1149	0.0473	0.1079	0.0444	0.1023
1.7	3.05	0.0747	0.1656	0.0671	0.1498	0.0612	0.1375	0.0564	0.1278	0.0525	0.1200	0.0493	0.1138
1.8	3.23	0.0826	0.1830	0.0742	0.1655	0.0676	0.1519	0.0624	0.1412	0.0581	0.1327	0.0545	0.1257
1.9	3.41	0.0907	0.2012	0.0815	0.1819	0.0743	0.1670	0.0685	0.1553	0.0638	0.1458	0.0600	0.1382
2.0	3.59	0.0993	0.2201	0.0892	0.1990	0.0813	0.1827	0.0750	0.1698	0.0698	0.1595	0.0656	0.1512
2.1	3.77	0.1081	0.2397	0.0972	0.2168	0.0885	0.1990	0.0817	0.1850	0.0761	0.1737	0.0714	0.1647
2.2	3.95	0.1173	0.2600	0.1054	0.2352	0.0960	0.2158	0.0886	0.2007	0.0825	0.1885	0.0775	0.1787
2.3	4.13	0.1268	0.2810	0.1139	0.2542	0.1038	0.2333	0.0958	0.2169	0.0892	0.2037	0.0838	0.1931
2.4	4.31	0.1366	0.3028	0.1227	0.2738	0.1118	0.2513	0.1032	0.2337	0.0961	0.2195	0.0902	0.2080
2.5	4.49	0.1467	0.3252	0.1318	0.2941	0.1201	0.2699	0.1108	0.2510	0.1032	0.2357	0.0969	0.2234
2.6	4.67	0.1571	0.3483	0.1412	0.3150	0.1286	0.2891	0.1187	0.2688	0.1105	0.2525	0.1038	0.2393
2.7	4.85	0.1678	0.3721	0.1508	0.3365	0.1374	0.3089	0.1268	0.2872	0.1181	0.2697	0.1109	0.2557
2.8	5.03	0.1789	0.3965	0.1607	0.3586	0.1464	0.3292	0.1351	0.3060	0.1258	0.2874	0.1182	0.2725
2.9	5.21	0.1902	0.4217	0.1709	0.3813	0.1557	0.3500	0.1437	0.3254	0.1338	0.3056	0.1257	0.2897
3.0	5.39	0.2018	0.4474	0.1814	0.4046	0.1652	0.3714	0.1525	0.3453	0.1420	0.3243	0.1333	0.3074

		Pressure Loss per Linear Foot - 3/8" PEX - 50% Propylene Glycol / 50% Water											
		80 ºF		100 ºF		120 ºF		140 ºF		160 ºF		180 ºF	
Flow (GPM)	Velocity (FPS)	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot	Pressure Loss (PSI) per foot	Head Loss (FT-H2O) per foot
0.1	0.08	0.0022	0.0049	0.0020	0.0045	0.0018	0.0041	0.0017	0.0038	0.0016	0.0036	0.0015	0.0034
0.2	0.16	0.0075	0.0166	0.0067	0.0150	0.0061	0.0138	0.0056	0.0128	0.0053	0.0120	0.0049	0.0114
0.3	0.25	0.0152	0.0337	0.0137	0.0305	0.0124	0.0280	0.0115	0.0260	0.0107	0.0244	0.0100	0.0232
0.4	0.33	0.0251	0.0558	0.0226	0.0504	0.0206	0.0463	0.0190	0.0430	0.0177	0.0404	0.0166	0.0383
0.5	0.41	0.0372	0.0824	0.0334	0.0745	0.0304	0.0684	0.0281	0.0636	0.0261	0.0597	0.0246	0.0566
0.6	0.49	0.0511	0.1133	0.0459	0.1025	0.0419	0.0941	0.0386	0.0875	0.0360	0.0822	0.0338	0.0779
0.7	0.58	0.0670	0.1484	0.0602	0.1343	0.0548	0.1232	0.0506	0.1146	0.0471	0.1076	0.0442	0.1020
0.8	0.66	0.0846	0.1875	0.0760	0.1696	0.0693	0.1557	0.0639	0.1447	0.0595	0.1359	0.0559	0.1288
0.9	0.74	0.1040	0.2304	0.0934	0.2084	0.0851	0.1913	0.0785	0.1778	0.0731	0.1670	0.0687	0.1583
1.0	0.82	0.1250	0.2771	0.1123	0.2506	0.1023	0.2300	0.0944	0.2139	0.0879	0.2009	0.0826	0.1904
1.1	0.91	0.1477	0.3274	0.1327	0.2961	0.1209	0.2718	0.1116	0.2527	0.1039	0.2373	0.0976	0.2250
1.2	0.99	0.1720	0.3812	0.1545	0.3448	0.1408	0.3165	0.1299	0.2942	0.1210	0.2763	0.1136	0.2619
1.3	1.07	0.1978	0.4386	0.1778	0.3966	0.1620	0.3640	0.1494	0.3385	0.1392	0.3179	0.1307	0.3013
1.4	1.15	0.2252	0.4993	0.2024	0.4516	0.1844	0.4145	0.1701	0.3853	0.1584	0.3619	0.1488	0.3431
1.5	1.24	0.2541	0.5634	0.2284	0.5095	0.2081	0.4676	0.1920	0.4348	0.1788	0.4084	0.1679	0.3871
1.6	1.32	0.2845	0.6307	0.2557	0.5704	0.2329	0.5236	0.2149	0.4868	0.2001	0.4572	0.1880	0.4334
1.7	1.40	0.3164	0.7013	0.2843	0.6343	0.2590	0.5822	0.2390	0.5413	0.2225	0.5083	0.2090	0.4819
1.8	1.48	0.3497	0.7751	0.3142	0.7010	0.2863	0.6434	0.2641	0.5982	0.2459	0.5618	0.2310	0.5326
1.9	1.57	0.3844	0.8520	0.3454	0.7706	0.3147	0.7073	0.2903	0.6576	0.2704	0.6176	0.2539	0.5854
2.0	1.65	0.4204	0.9321	0.3778	0.8429	0.3442	0.7737	0.3176	0.7193	0.2957	0.6756	0.2778	0.6404
2.1	1.73	0.4579	1.0151	0.4115	0.9181	0.3749	0.8426	0.3459	0.7834	0.3221	0.7358	0.3025	0.6975
2.2	1.81	0.4968	1.1012	0.4464	0.9960	0.4067	0.9141	0.3752	0.8499	0.3494	0.7982	0.3282	0.7566
2.3	1.90	0.5370	1.1903	0.4825	1.0765	0.4396	0.9881	0.4056	0.9186	0.3777	0.8628	0.3547	0.8179
2.4	1.98	0.5785	1.2824	0.5198	1.1598	0.4736	1.0645	0.4370	0.9897	0.4069	0.9295	0.3822	0.8811
2.5	2.06	0.6213	1.3773	0.5583	1.2456	0.5087	1.1433	0.4693	1.0630	0.4370	0.9983	0.4105	0.9463
2.6	2.14	0.6654	1.4752	0.5979	1.3341	0.5448	1.2245	0.5027	1.1385	0.4681	1.0692	0.4396	1.0136
2.7	2.23	0.7109	1.5759	0.6388	1.4252	0.5820	1.3081	0.5370	1.2162	0.5000	1.1422	0.4696	1.0828
2.8	2.31	0.7576	1.6795	0.6807	1.5189	0.6202	1.3941	0.5723	1.2961	0.5329	1.2173	0.5005	1.1539
2.9	2.39	0.8056	1.7858	0.7238	1.6151	0.6595	1.4824	0.6085	1.3782	0.5666	1.2944	0.5322	1.2270
3.0	2.47	0.8548	1.8950	0.7681	1.7138	0.6998	1.5730	0.6457	1.4625	0.6013	1.3735	0.5647	1.3020

APPENDIX C

WARRANTY

SURFACE TEMPERATURE CHARTS

HEAT OUTPUT CHART

FLOOR COVERING R-VALUES

ZONE VALVE PRESSURE LOSS CHART

BRASS MANIFOLD BALANCING CHART

AIR TESTING PROCEDURE

CONVERSION TABLE

MINIMUM INSULATION

ZURN PEX PLUMBING AND RADIANT HEATING SYSTEMS PROFESSIONAL INSTALLATION LIMITED WARRANTY

Subject to the terms and conditions of this Limited Warranty, Zurn PEX Plumbing and Radiant Heating Systems warrants only to the owner of the real property when installed by licensed professional contractors or authorized distributors who purchase and properly install in a potable plumbing system and/or radiant heating system its:

(I) Zurn PEX Non-Barrier and Barrier cross-linked polyethylene tubing (PEX) and QICK/SERT® insert fittings, when installed as a system with our Zurn PEX Non-Barrier and Barrier cross-linked polyethylene tubing (PEX), for a period of twenty-five (25) years and

(II) QickPort Plumbing manifolds, under normal conditions of use, for a period of ten(10) years and

(III) Qick/Sert® insert fitting when not installed with Zurn PEX Non-Barrier and Barrier cross-linked polyethylene tubing (PEX) and installed with PEX tubing that meets the ASTM F876 requirements for a period of five (5) years and

(IV) the associated hardware and accessories, including manifolds, distribution headers, valves, electrical controls, tools, and miscellaneous fittings for a period of two (2) years from the date of installation.

In order for this Limited Warranty to apply, the above referenced products must be installed by a licensed professional contractor in accordance with Zurn installation instructions as outlined in the Zurn PEX Plumbing and Radiant Heating Systems Installation Guide, meeting all applicable code requirements and good plumbing practices. FAILURE TO INSTALL ZURN PRODUCTS ACCORDING TO MANUFACTURER'S INSTRUCTIONS WILL VOID ALL APPLICABLE WARRANTIES AND MAY RESULT IN SEVERE WATER DAMAGE. See our free Zurn PEX Installation Guide for instructions. For your copy, call toll-free 1-800-872-7277. Under this warranty, you only have a right to reimbursement if the failure or leak is a direct result of a manufacturing defect in the products covered by this warranty and occurred during the warranty period. This warranty does not apply and you do not have a right of reimbursement if the failure or resulting damage is caused by:

(I) freezing during or after the installation or inadequate freeze protection,

(II) damage due to tear, breaks or other external damages before, during or after installation,

(III) components not manufactured or sold by Zurn,

(IV) exposure to temperatures and pressures beyond the specified range for Zurn products as specified on the product or in the Zurn PEX Installation Manual or Zurn Design Manual,

(V) exposure to harmful, unauthorized or unanticipated chemicals or substances or corrosive water conditions,

(VI) exposure to ultraviolet light,

(VII) damage or wear from abnormal operating conditions, accident, abuse, misuse or unauthorized alterations or repair.

THIS WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES OR OBLIGATIONS, EXPRESS OR IMPLIED, INCLUDING ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. ZURN DOES NOT GUARANTEE OR IN ANY WAY WARRANT THE INSTALLATION OF ZURN PEX PRODUCTS DUE TO THE WIDE VARIANCE IN INSTALLATION PRACTICES AND OTHER CONDITIONS BEYOND OUR CONTROL.

If you believe that a product fails to meet the above Limited Warranty, you should notify us in writing within 30 days following the failure and prior to expiration of the applicable warranty period set forth above, at the following address:

Zurn Industries, Inc.
PEX Plumbing and Radiant Heating Systems
1801 Pittsburgh Avenue
Erie, PA 16502
ATTENTION: CLAIMS DEPARTMENT.

Notification should include a description of the product, the failed part, model number (if available), date of purchase and/or date of installation, and how the product fails to meet the above warranty. Upon receipt of a written claim under this Limited Warranty and evidence/identification of the date of manufacture of product, and after inspection by an authorized Zurn representative and determination of a manufacturing defect, Zurn will reimburse the property owner for reasonable repair or replacement charges, to include drywall and painting as well as damages to real property and the premises within which the product is installed, resulting from the failure or leak. At our option, and in our sole discretion, we will either repair or replace the product with a Zurn product of the same or similar type, size and like quantity. Except as specified above, we will not pay any costs (labor or otherwise) associated with removing previously installed product(s), installing replacement product(s), or transportation or return of a product. If, as determined by Zurn, repair or replacement of the product is not commercially practicable, or cannot be completed in a timely manner, we may refund the ultimate purchase price paid for the product upon verification by providing a copy of your purchase order, invoice, receipt or bill of sale.

ZURN WILL NOT BE LIABLE FOR ANY OTHER LOSS OR EXPENSE(S) NOT SPECIFICALLY DESCRIBED ABOVE, AND DISCLAIMS ANY LIABILITY FOR CONSEQUENTIAL OR INCIDENTAL DAMAGES.

For more information, call Zurn toll free at 1-800-872-7277.

Form No. QTW12-00, Rev. 11/02

Radiant Floor Surface Temperatures

Room Set Point Temperature F	BTUH PER SQUARE FOOT										
	10	15	20	25	30	35	40	45	50	55	60
75	80.0	82.5	85.0	87.5	90.0	92.5	95.0	97.5	100.0	102.5	105.0
74	79.0	81.5	84.0	86.5	89.0	91.5	94.0	96.5	99.0	101.5	104.0
73	78.0	80.5	83.0	85.5	88.0	90.5	93.0	95.5	98.0	100.5	103.0
72	77.0	79.5	82.0	84.5	87.0	89.5	92.0	94.5	97.0	99.5	102.0
71	76.0	78.5	81.0	83.5	86.0	88.5	91.0	93.5	96.0	98.5	101.0
70	75.0	77.5	80.0	82.5	85.0	87.5	90.0	92.5	95.0	97.5	100.0
69	74.0	76.5	79.0	81.5	84.0	86.5	89.0	91.5	94.0	96.5	99.0
68	73.0	75.5	78.0	80.5	83.0	85.5	88.0	90.5	93.0	95.5	98.0
67	72.0	74.5	77.0	79.5	82.0	84.5	87.0	89.5	92.0	94.5	97.0
66	71.0	73.5	76.0	78.5	81.0	83.5	86.0	88.5	91.0	93.5	96.0
65	70.0	72.5	75.0	77.5	80.0	82.5	85.0	87.5	90.0	92.5	95.0
64	69.0	71.5	74.0	76.5	79.0	81.5	84.0	86.5	89.0	91.5	94.0
63	68.0	70.5	73.0	75.5	78.0	80.5	83.0	85.5	88.0	90.5	93.0
62	67.0	69.5	72.0	74.5	77.0	79.5	82.0	84.5	87.0	89.5	92.0
61	66.0	68.5	71.0	73.5	76.0	78.5	81.0	83.5	86.0	88.5	91.0
60	65.0	67.5	70.0	72.5	75.0	77.5	80.0	82.5	85.0	87.5	90.0

SURFACE TEMPERATURES

Radiant Ceiling Surface Temperatures

Room Set Point Temperature F	BTUH PER SQUARE FOOT										
	10	15	20	25	30	35	40	45	50	55	60
75	80.9	83.8	86.8	89.7	92.6	95.6	98.5	101.5	104.4	107.4	110.3
74	79.9	82.8	85.8	88.7	91.6	94.6	97.5	100.5	103.4	106.4	109.3
73	78.9	81.8	84.8	87.7	90.6	93.6	96.5	99.5	102.4	105.4	108.3
72	77.9	80.8	83.8	86.7	89.6	92.6	95.5	98.5	101.4	104.4	107.3
71	76.9	79.8	82.8	85.7	88.6	91.6	94.5	97.5	100.4	103.4	106.3
70	75.9	78.8	81.8	84.7	87.6	90.6	93.5	96.5	99.4	102.4	105.3
69	74.9	77.8	80.8	83.7	86.6	89.6	92.5	95.5	98.4	101.4	104.3
68	73.9	76.8	79.8	82.7	85.6	88.6	91.5	94.5	97.4	100.4	103.3
67	72.9	75.8	78.8	81.7	84.6	87.6	90.5	93.5	96.4	99.4	102.3
66	71.9	74.8	77.8	80.7	83.6	86.6	89.5	92.5	95.4	98.4	101.3
65	70.9	73.8	76.8	79.7	82.6	85.6	88.5	91.5	94.4	97.4	100.3
64	69.9	72.8	75.8	78.7	81.6	84.6	87.5	90.5	93.4	96.4	99.3
63	68.9	71.8	74.8	77.7	80.6	83.6	86.5	89.5	92.4	95.4	98.3
62	67.9	70.8	73.8	76.7	79.6	82.6	85.5	88.5	91.4	94.4	97.3
61	66.9	69.8	72.8	75.7	78.6	81.6	84.5	87.5	90.4	93.4	96.3
60	65.9	68.8	71.8	74.7	77.6	80.6	83.5	86.5	89.4	92.4	95.3

SURFACE TEMPERATURES

Radiant Wall Surface Temperatures

Room Set Point Temperature F	BTUH PER SQUARE FOOT										
	10	15	20	25	30	35	40	45	50	55	60
75	80.3	82.9	85.5	88.2	90.8	93.4	96.1	98.7	101.3	103.9	106.6
74	79.3	81.9	84.5	87.2	89.8	92.4	95.1	97.7	100.3	102.9	105.6
73	78.3	80.9	83.5	86.2	88.8	91.4	94.1	96.7	99.3	101.9	104.6
72	77.3	79.9	82.5	85.2	87.8	90.4	93.1	95.7	98.3	100.9	103.6
71	76.3	78.9	81.5	84.2	86.8	89.4	92.1	94.7	97.3	99.9	102.6
70	75.3	77.9	80.5	83.2	85.8	88.4	91.1	93.7	96.3	98.9	101.6
69	74.3	76.9	79.5	82.2	84.8	87.4	90.1	92.7	95.3	97.9	100.6
68	73.3	75.9	78.5	81.2	83.8	86.4	89.1	91.7	94.3	96.9	99.6
67	72.3	74.9	77.5	80.2	82.8	85.4	88.1	90.7	93.3	95.9	98.6
66	71.3	73.9	76.5	79.2	81.8	84.4	87.1	89.7	92.3	94.9	97.6
65	70.3	72.9	75.5	78.2	80.8	83.4	86.1	88.7	91.3	93.9	96.6
64	69.3	71.9	74.5	77.2	79.8	82.4	85.1	87.7	90.3	92.9	95.6
63	68.3	70.9	73.5	76.2	78.8	81.4	84.1	86.7	89.3	91.9	94.6
62	67.3	69.9	72.5	75.2	77.8	80.4	83.1	85.7	88.3	90.9	93.6
61	66.3	68.9	71.5	74.2	76.8	79.4	82.1	84.7	87.3	89.9	92.6
60	65.3	67.9	70.5	73.2	75.8	78.4	81.1	83.7	86.3	88.9	91.6

SURFACE TEMPERATURES

HEAT OUTPUT CHART

Flow Rate (Gallons per Minute)	TEMPERATURE DIFFERENTIAL (¡F)									
	1	2	3	4	5	6	7	8	9	10
1.0	494	988	1482	1976	2471	2965	3459	3953	4447	4941
1.5	741	1482	2223	2965	3706	4447	5188	5929	6670	7412
2.0	988	1976	2965	3953	4941	5929	6917	7906	8894	9882
2.5	1235	2471	3706	4941	6176	7412	8647	9882	11117	12353
3.0	1482	2965	4447	5929	7412	8894	10376	11858	13341	14823
3.5	1729	3459	5188	6917	8647	10376	12106	13835	15564	17294
4.0	1976	3953	5929	7906	9882	11858	13835	15811	17788	19764
4.5	2223	4447	6670	8894	11117	13341	15564	17788	20011	22235
5.0	2471	4941	7412	9882	12353	14823	17294	19764	22235	24705
5.5	2718	5435	8153	10870	13588	16305	19023	21741	24458	27176
6.0	2965	5929	8894	11858	14823	17788	20752	23717	26682	29646
6.5	3212	6423	9635	12847	16058	19270	22482	25693	28905	32117
7.0	3459	6917	10376	13835	17294	20752	24211	27670	31129	34587
7.5	3706	7412	11117	14823	18529	22235	25940	29646	33352	37058
8.0	3953	7906	11858	15811	19764	23717	27670	31623	35575	39528
8.5	4200	8400	12600	16800	20999	25199	29399	33599	37799	41999
9.0	4447	8894	13341	17788	22235	26682	31129	35575	40022	44469
9.5	4694	9388	14082	18776	23470	28164	32858	37552	42246	46940
10.0	4941	9882	14823	19764	24705	29646	34587	39528	44469	49410

HEAT OUTPUT (BTUH)*

***Output based upon properties for 100% water, assuming a mean temperature of 120 ¡F**

FLOW RATE (Gallons Per Minute)	TEMPERATURE DIFFERENTIAL (¡F)									
	11	12	13	14	15	16	17	18	19	20
1.0	5435	5929	6423	6917	7412	7906	8400	8894	9388	9882
1.5	8153	8894	9635	10376	11117	11858	12600	13341	14082	14823
2.0	10870	11858	12847	13835	14823	15811	16800	17788	18776	19764
2.5	13588	14823	16058	17294	18529	19764	20999	22235	23470	24705
3.0	16305	17788	19270	20752	22235	23717	25199	26682	28164	29646
3.5	19023	20752	22482	24211	25940	27670	29399	31129	32858	34587
4.0	21741	23717	25693	27670	29646	31623	33599	35575	37552	39528
4.5	24458	26682	28905	31129	33352	35575	37799	40022	42246	44469
5.0	27176	29646	32117	34587	37058	39528	41999	44469	46940	49410
5.5	29893	32611	35328	38046	40764	43481	46199	48916	51634	54351
6.0	32611	35575	38540	41505	44469	47434	50399	53363	56328	59292
6.5	35328	38540	41752	44963	48175	51387	54598	57810	61022	64234
7.0	38046	41505	44963	48422	51881	55340	58798	62257	65716	69175
7.5	40764	44469	48175	51881	55587	59292	62998	66704	70410	74116
8.0	43481	47434	51387	55340	59292	63245	67198	71151	75104	79057
8.5	46199	50399	54598	58798	62998	67198	71398	75598	79798	83998
9.0	48916	53363	57810	62257	66704	71151	75598	80045	84492	88939
9.5	51634	56328	61022	65716	70410	75104	79798	84492	89186	93880
10.0	54351	59292	64234	69175	74116	79057	83998	88939	93880	98821

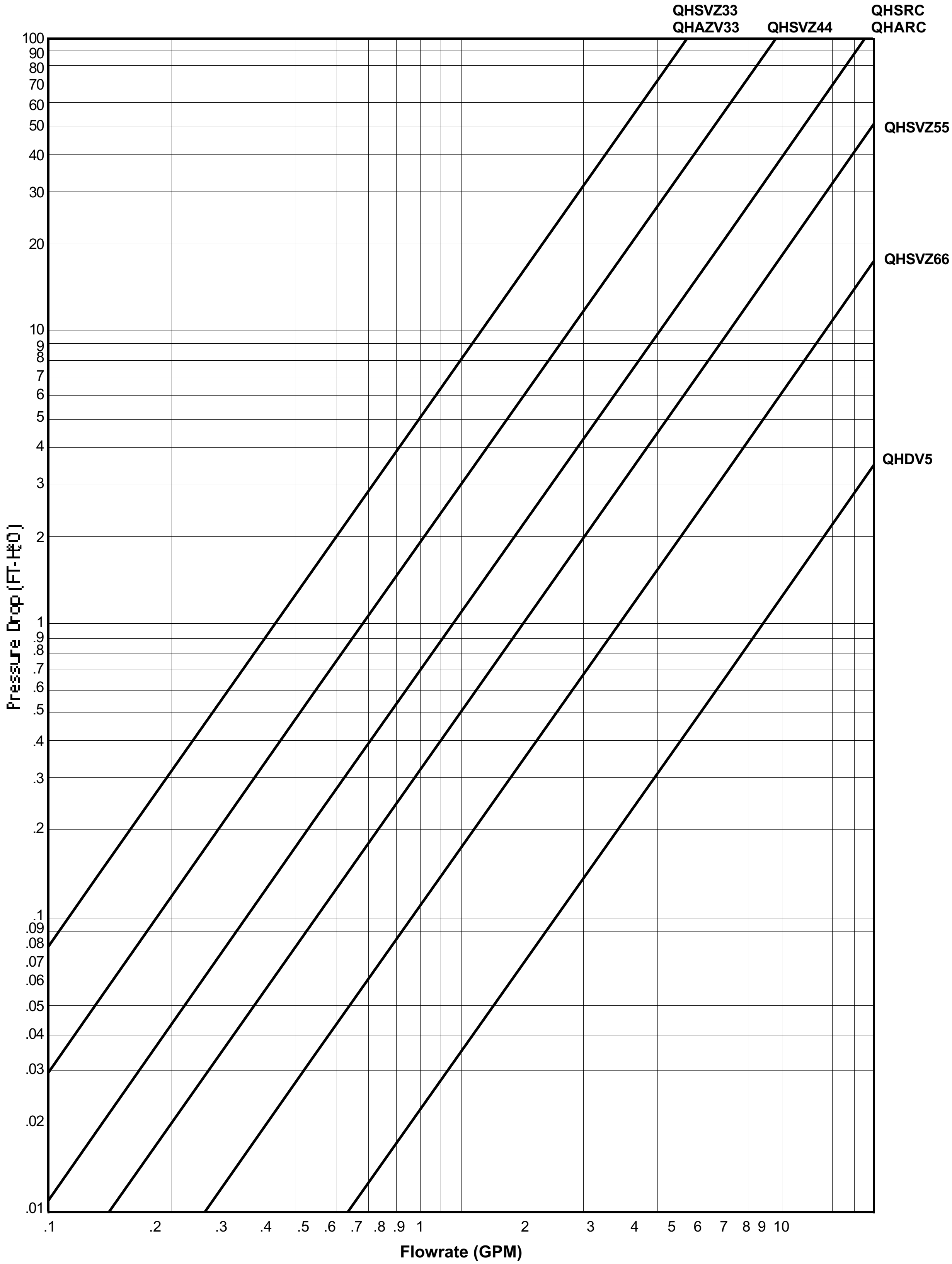
HEAT OUTPUT (BTUH)*

***Output based upon properties for 100% water, assuming a mean temperature of 120 ¡F**

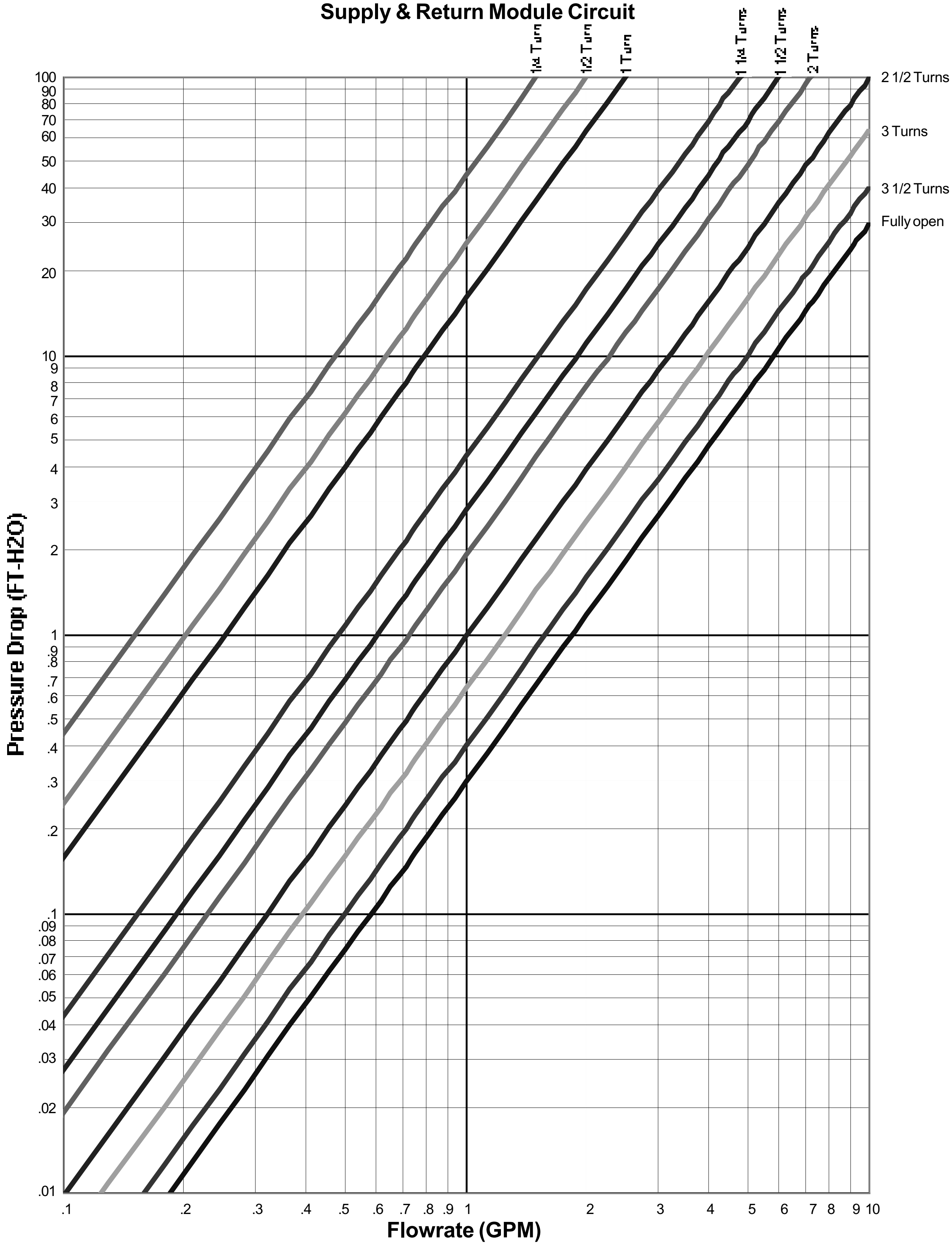
FLOOR COVERING R-VALUES

Typical R-Value	R-Value Per Inch	Typical Thickness	Material
0.825	1.1	0.75	Plywood
1.05	1.4	0.75	OSB
0.825	1.1	0.75	Softwood
0.25	1	0.25	Ceramic Tile
0.05	0.4	0.125	Thinset Mortar
0.2	1.6	0.125	Vinyl
0.4	1.6	0.25	Linoleum
0.2	1.6	0.125	Linoleum
2.25	1.5	1.5	Brick
0.4	0.8	0.5	Marble
0.5	1	0.5	MDF/Plastc Laminate
0.625	1	0.625	Laminated Wood
0.2	1.6	0.125	Wood Flooring Pad
0.6375	0.85	0.75	Oak
0.75	1	0.75	Ash
0.75	1	0.75	Maple
0.975	1.3	0.75	Pine
0.9	1.2	0.75	Fir
0.32	1.28	0.25	Slab Rubber 33lb
0.48	1.28	0.375	Slab Rubber 33lb
0.64	1.28	0.5	Slab Rubber 33lb
0.62	2.48	0.25	Waffle Rubber 25 lb
1.24	2.48	0.5	Waffle Rubber 25 lb
1.94	3.88	0.5	Hair Jute
1.25	3.88	0.325	Hair Jute
1.4	4.3	0.325	Prime Urethane
2.15	4.3	0.5	Prime Urethane
1.35	4.2	0.325	Bonded Urethane
2.1	4.2	0.5	Bonded Urethane
0.7	2.8	0.25	Carpet
0.91	2.8	0.325	Carpet
1.4	2.8	0.5	Carpet
2.1	2.8	0.75	Carpet
1.35	4.2	0.325	Wool Carpet
2.1	4.2	0.5	Wool Carpet

Zone Valve Pressure Loss



QickZone 1-1/4 Modular Brass Manifold Supply & Return Module Circuit



METHOD FOR TESTING ZURN SYSTEMS WITH AIR

Zurn recommends leak testing radiant heating systems with water or water/glycol solutions. If this is not practical and an Installer chooses to use an air test, the following points must be considered.

1. Air tests can be hazardous. Incorrectly joined fittings may be blown out with some significant force. The Installer is responsible for the safety of the people at the job site while the test is being conducted.

2. DO NOT TEST with air pressure greater than 100 psi. Test tubing as required by local code then lower pressure to 50 psi when pouring concrete or gypsum cement around the tubing.

3. Zurn recommends using an ultrasonic leak detector because it is quicker and doesn't require the use of any chemical solutions.

4. If the Installer chooses to use a liquid leak detector, the following is the ONLY SOLUTION permitted for Zurn Radiant Heating Systems.

   Dilute no more than two ounces of green Ultra Palmolive Original Scent concentrated dishwashing liquid in one gallon of potable water. DO NOT use full strength green Palmolive dishwashing detergent on Zurn Radiant Heating System Components. DO NOT use this solution on Zurn Qicktite plastic fittings or other manufacturer's plastic fittings or components. It could cause failure of these parts.

5. This test method applies only to systems with Zurn manifolds (modular plastic or brass), PEX tube and brass compression or brass insert and crimp fittings.

6. Zurn is not responsible for damage caused by the effects of other leak detectors or chemicals applied to Zurn Radiant Heating System components.

7. Maintain and monitor system pressure test throughout concrete pour and system installation to ensure the system is not damaged during construction. Note: Air pressure test kits are available from Zurn.

WARNING: Some components may have lower pressure ratings than the tubing and need to be isolated from tubing tests and tested at lower pressures.

Conversion Factors

Convert from	Into	Multiply by
	Velocity	
Feet per sec.	meters per sec.	0.3048
Meters per sec.	feet per sec.	3.281
	Length	
Inches	feet	0.0833
Inches	centimeters	2.54
Inches	meters	0.0254
Feet	inches	12
Feet	centimeters	30.48
Feet	meters	0.3048
Centimeters	inches	0.3937
Centimeters	feet	0.0328
Centimeters	meters	0.01
Meters	inches	39.37
Meters	feet	3.281
Meters	centimeters	100
	Area	
Square inches	sq. feet	0.0069
Square inches	sq. centimeters	6.452
Square inches	sq. meters	0.00065
Square feet	sq. inches	144
Square feet	sq. centimeters	929.03
Square feet	sq. meters	0.0929
Sq. centimeters	sq. inches	0.155
Sq. centimeters	sq. feet	0.0011
Sq. centimeters	sq. meters	0.0001
Square meters	sq. inches	1550
Square meters	sq. feet	10.764
Square meters	sq. centimeters	10000
	Volume Flow Rate	
Gallons/minute	cubic ft./sec.	0.0022
Gallons/minute	liter/sec.	3.786
Cubic ft./sec.	gallons/min.	448.86
Cubic ft./sec.	liter/sec.	28.32
Liter/sec.	gallons/min.	0.264
Liter/sec.	cubic ft./sec.	0.0353
	Weight	
Pounds	kilograms	0.4536
Pounds	grams	453.6
Kilograms	pounds	2.205
Kilograms	grams	1000
Gallons of water	pounds*	8.25
Gallons of water	kilograms*	3.743
Liters of water	kilograms*	0.988
Liters of water	pounds*	2.18
	Energy	
Calorie	BTU	0.00397
Calorie	kWh	0.000001163
BTU	calorie	252
BTU	kWh	0.000293
kWh	calorie	860100000
kWh	BTU	341.3

*** at 120 degrees F**

Convert from	Into	Multiply by
	Volume	
Cubic inches	cubic feet	0.00058
Cubic inches	cubic meters	0.00002
Cubic inches	U.S. gallons	0.0043
Cubic inches	liters	0.0164
Cubic feet	cubic inches	1728
Cubic feet	cubic meters	0.0283
Cubic feet	U.S. gallons	7.481
Cubic feet	liters	28.33
Cubic meters	cubic inches	61024
Cubic meters	cubic feet	35.31
Cubic meters	U.S. gallons	264.13
Cubic meters	liters	1000
U.S. gallons	cubic inches	231
U.S. gallons	cubic feet	0.1337
U.S. gallons	cubic meters	0.0038
U.S. gallons	liters	3.786
Liters	cubic inches	61.01
Liters	cubic feet	0.0353
Liters	cubic meters	0.001
Liters	U.S. gallons	0.264
	Power	
Horsepower	kilowatt	0.746
Horsepower	BTUH	2546
Kilowatt (kW)	horsepower	1.34
Kilowatt (kW)	BTUH	3413
BTUH	kilowatt	0.000293
BTUH	horsepower	0.00039
	Pressure	
Atmospheres	feet of water*	34.28
Atmospheres	mm of mercury	760
Atmospheres	pounds/sq. inch	14.7
Atmospheres	pascals	101300
Feet of water	atmospheres*	0.0292
Feet of water	mm of mercury*	22.17
Feet of water	pounds/sq. inch*	0.4287
Feet of water	pascals*	2956
mm of mercury	atmospheres	0.00132
mm of mercury	feet of water*	0.04511
mm of mercury	pounds/sq. inch	0.01934
mm of mercury	pascals	133.32
Pounds/sq. inch	atmospheres	0.06805
Pounds/sq. inch	feet of water*	2.333
Pounds/sq. inch	mm of mercury	51.71
Pounds/sq. inch	pascals	6895
Pascals	atmospheres	0.00000987
Pascals	feet of water*	0.000338
Pascals	mm of mercury	0.007501
Pascals	pounds/sq. inch	0.000145
	Temperature	
	Fahrenheit = (Centigrade x 1.8) + 32	
	Centigrade = (Fahrenheit x .555) - 17.8	

*** at 120 degrees F**

Appendix C

INSULATION AND RADIANT HEAT

Insulation Helps Assure System Performance:

The following is a summary of industry consensus on the minimum use of insulation with radiant heating systems and is adapted from a table in the "Standard Guidelines For The Design And Installation Of Residential Radiant Heating Systems" Revision III published by The Radiant Panel Association.

INSULATION TABLE

Floor Type	Application	Min. R-Value	Coverage
Slab			
Slab On Grade	Alternate # 1	* (Ti-To) x 0.125	perimeter to below frost line
Slab On Grade	Alternate # 2	R-5	4' horizontal or vertical at perimeter
Slab On Grade	Alternate # 3	R-5	under entire slab
Slab Below Grade		** R-5	
Suspended Floor			
Over Heated Space	Hard Surface	R-5	under entire floor with 2" air gap
Over Heated Space	Carpeted Surface	R-11	under entire floor with 2" air gap
Over Unheated Space	Hard Surface	R-13	under entire floor with 2" air gap
Over Unheated Space	Carpeted Surface	R-19	under entire floor with 2" air gap

* R-Value = Inside Temperature (ϒF) - Outside Temperature (ϒF) x 0.125
** For slabs above Frost Line

Remember the above are recommended minimums. Zurn recommends the following:

Radiant Slab With Insulation In contact With Soil:

- Full underslab insulation in residential applications if possible and anywhere sub soil and groundwater conditions warrant. This means anywhere there is moist soil or the possibility of changes in future soil conditions. A site that is dry in one season may not be dry in another. Future construction nearby can change soil moisture conditions as well.

GLOSSARY

Terms and Definitions

Actuator – A device that promotes mechanical operation of a valve assembly.

ASTM – American Society for Testing and Materials. Publishes standard specifications for terminology, labeling, testing and production.

Air vent – A device that removes air that accumulated within a piping system.

Automatic air vent – Air vents that automatically eject air that accumulates under a float style valve.

Bend support – Preformed devices that hold flexible tubing at predetermined radiuses without kinking.

Boiler feed water valve – A pressure reducing valve used to reduce the water main pressure while providing makeup water need by a hydronic system.

BTU (British Thermal Unit) – A unit of measure equal to the amount of heat necessary to raise the temperature of one pound of water one degree Fahrenheit.

Bypass loop – A piping arrangement that directs the flow of fluid around rather than through a piece of mechanical equipment.

Cavitation – The formation of vapor pockets when the pressure on a liquid drops below its vapor pressure. Can pose problems in circulators.

Chase – A passageway within a building that contains mechanical equipment and piping systems.

Closed loop – A piping arrangement not exposed to atmospheric conditions.

Closed system – Any closed loop hydronic piping system which prevents atmospheric oxygen from entering the system to a degree which effectively protects components from excessive oxidative corrosion. (See *DIN 4726*.)

Conduction – A process of heat transfer whereby heat moves through a material or between two materials that are in direct contact with each other.

Convection – Transfer of heat by movement of a liquid or a gas.

- *Natural convection* is a result of movement caused by changes in density as temperature changes within a fluid medium such as a liquid or a gas.
- *Forced convection* is the result of mechanical force moving a fluid or gas.

Cross-linking – A chemical process that changes the molecular structure of a plastic material by linking otherwise independent hydrocarbon chains. Cross-linking creates a three dimensional network of hydrocarbons. The end product is incapable of being melted and is insoluble.

Differential temperature (T) – The difference in temperature between two opposing masses used to describe the potential that exists for heat transfer.

Diffusion – A penetration process that describes the tendency of gas or liquid molecules to spread out into the entire space available (including the spaces that exist within solids, like concrete). Diffusion is expressed as a function of the volume of space that is available. A related process, permeation, describes the movement of such substances through solid membrane and is expressed in terms of the area of membrane penetrated.

DIN – The abbreviation for the German Institute of Standards.

DIN 4726 – An internationally recognized standard that prescribes the maximum rate of oxygen diffusion allowed for non-metallic pipes used in closed loop hydronic heating systems.

Downward loss – The amount of heat energy in BTUH transferring downward from a radiant heated floor.

Edge area – The exposed surface of a radiant heated slab equal to the thickness of the slab multiplied by the exposed perimeter length.

Edge insulation – The amount of insulation (expressed in R-Value) directly covering the thickness of the slab along the exposed perimeter (perimeter less than four feet below grade).

Effective floor area (EFA) – The approximate square footage of a radiant floor that effectively radiates heat to satisfy the heat load of a zone. EFA is the result of multiplying the net floor area by the effective floor factor.

Effective floor factor (EFF) – An approximation (expressed in percentage) used to describe the amount of net floor area that will effectively radiate heat. This factor is used by the designer to take into consideration intangibles (such as abnormally large furniture that covers a large percentage of floor space) that might interfere with heat transfer from the floor.

Efficiency rating (ER) – A ratio of energy output to energy input expressed as a percentage. It is used to describe the amount of energy available for the intended purpose of the appliance and is independent of cost.

Emission – A measure of propensity of a surface to radiate heat energy to its surroundings in the form of longwave radiation.

Exposed perimeter length – Equal to the linear feet of perimeter less than four feet below grade along an outside wall.

Exposed perimeter insulation – The amount of insulation (expressed in R-Value) placed either horizontally or vertically to a distance or depth of four feet along an exposed perimeter of a radiant slab less than four feet below grade.

Extrusion – A method used for the continuous formation of tubing from plastic materials.

Floor insulation – The amount of insulation (expressed in R-Value) placed directly below a radiant floor to prevent downward heat loss.

Gross floor area – The entire floor surface area of a room or zone whether heated or not.

HDPE – Abbreviation for high-density polyethylene.

Head pressure – The pressure available at the outlet side of a pump or inlet side of a flow conducting system. It is expressed in feet of head. Feet of head is the height of a column of water that can be supported by a pump against standard atmospheric pressure.

Heating load – The amount of energy (in BTUH) required for space heating.

Heating capacity – The rate of heat output of a heat source. Typically expressed in Btu/hr.

Heat loss – The transfer of heat from a contained space to the atmosphere surrounding it. Heat loss is the result of thermal conductivity through walls, windows, roofs, and other building envelope components, as well as infiltration losses due to the exchange of inside air with outside air.

Infiltration – The exchange of warm air inside a building with the cold air outside. Natural infiltration takes place as a result of air leakage through minute openings in walls, windows, doors, and ceilings. Controlled infiltration occurs due to the forced exchange of a mechanical system. Infiltration is expressed in air changes per hour or fractions thereof. For natural infiltration in newly constructed homes, the recommended calculation is a rate of 0.35 air changes per hour for new construction. Compensate accordingly for older homes.

Infiltration losses – The loss of heat energy due to infiltration which is expressed in BTUH. Infiltration losses are calculated from the air changes per hour, differential indoor/outdoor temperature and the heat carrying capability of the lost air.

Laminar flow – A classification of fluid flow where streamlines remain parallel as the fluid moves throughout a piping system.

Latent heat – Heat that is added or removed to a substance that does not affect the substances temperature. Latent energy is commonly discussed during a materials phase change between solid, liquid, and gas.

Mean radiant temperature – The average temperature of all the surfaces in a room.

Mixing valve – A valve that blends multiple streamlines of fluid to achieve a desired outlet temperature.

Injection mixing – A method of raising radiant system water by injecting hot boiler water into a lower temperature distribution loop in order to maintain proper radiant system supply water temperature.

Net floor area (NFA) – The gross floor area minus the unheated floor area. This is the area of the radiant floor measured in square feet which will have PEX tubing installed.

Olefins – Unsaturated hydrocarbon substances (double bond). The most important building blocks (monomers) of the olefins are ethylene, propylene, and butylene.

Open system – A circulating hydronic system exposed to atmospheric conditions. Open systems require components resistant to oxidative corrosion. Open systems are the result of continual introduction of fresh water, open vessels or oxygen diffusion through non-metallic components.

Outdoor design temperature – A standard design temperature somewhat warmer than the seasonable low or record low temperature for the area. The ASHRAE 90A-1980 energy conservation standards recommend selecting a residential design temperature for a region to permit the outdoor temperature to be lower than the outdoor design temperature for 2.5 percent of the heating season. Adjustments may be made to reflect local climates which differ from the tabulated temperatures, altitude differences or local weather experiences. Outdoor design temperature is used to calculate anticipated load under the most severe conditions expected to occur without over-sizing the heat appliance.

Partially exposed basement slab – A concrete slab in which a portion of the slab is more than four feet below grade and a portion less than four feet below grade.

PE – Abbreviation for polyethylene.

Perimeter area – The first four feet around the exposed perimeter of the slab.

Perimeter length – The length of perimeter of the slab for a room exposed to outside conditions. Used to calculate perimeter and edge area.

Perimeter insulation – The amount of insulation (expressed in R-Value) placed either horizontally or vertically for the first four feet along the exposed perimeter of the slab.

PEX – Abbreviation for cross-linked polyethylene.

Polyolefin – A general term for a polymer built from olefins. For example, polypropylene and polyethylene.

Poured floor underlayment – A thin (typically 1-1/2") underlayment of either gypsum-based concrete or lightweight aggregate concrete. The material is poured over tubing that is directly fastened to a plywood subfloor. Depending on the material, these thin slabs generally add 12 to 14 pounds per square foot to the floor load.

Pressure loss – The loss of fluid pressure between any two points in a flow conducting system, expressed in pounds per square inch (psi). The loss of pressure is caused by friction against the tubing walls and is further influenced by the tubing size, length and texture of the inside wall of the tube, fittings, valves and other components. Pressure loss is also influenced by the temperature and viscosity of the fluid.

Primary/secondary pumping – A piping arrangement in which high temperature water is circulated through a primary circuit off the boiler, with separate secondary loops piped off of that primary circuit. Same temperature secondary loops, or lower temperature secondary loops may be piped directly off the primary loop.

R-Value – A measure of material's ability to resist the flow of heat. R-Value is expressed in BTU/hr/ft^2.

Radiation – The process in which energy in the form of rays of light or heat is transferred from body to body without heating the intermediate air acting as the transfer medium.

Room setpoint temperature – The desired thermostat setting for the room, typically 65°F for radiant floor heating.

Slab below grade floor – A concrete slab with the entire slab a minimum of four feet below grade.

Slab depth – The thickness of the slab at the perimeter.

Slab on grade floor – A concrete slab that rests on the surface of the earth with a perimeter that is less than four feet below the surface of the earth surrounding it.

Supplemental heat – Additional heat provided by some distribution means other than the primary radiant floor or ceiling system to satisfy the heat loss requirement.

Surface temperature – The required temperature at the floor surface needed to transfer the calculated amount of BTUH's into a room for a given setpoint temperature to satisfy the current load. Radiant floor surface temperature should not exceed 87.5°F. Radiant ceiling surface temperature should not exceed 100°F for 8' ceilings, and 110°F for 8' - 12' ceilings.

Suspended floors – Any floor which does not rest directly on the surface of the earth. Suspended floors may be constructed of any material and may be over heated or non-heated spaces.

Three-way tempering valve – A three-way, non-electric valve that, when used in radiant heating applications, will maintain a constant radiant supply water temperature despite variations in boiler supply water temperature. A tempering valve will mix hot boiler water with cooler radiant system return water to produce a specific radiant supply water temperature.

Unheated floor area – The amount of floor included in the gross floor area that will not have tubing installed.

Upward load – The amount of BTUH required to overcome the envelope losses of the room.

Under slab area – The interior portion of the slab to include all but the first four feet around perimeter.

Under slab insulation – The amount of insulation (expressed in R-Value) under the interior area of the slab, excluding the perimeter area.

Water table temperature – Equal to the estimated temperature of the water table for the area and should used when the presence of a water table will effect the performance of the radiant panel heating system. Typically, insulation should be added below a radiant slab if there is a water table within 6 feet of the slab.

Weather responsive reset control – A method of controlling a radiant system by changing the system water temperature based on changing weather conditions.

Thermal conductivity (K) – A property of materials that indicates the amount of heat (BTU) that penetrates 1 square foot of a uniform material, 1" thick, in 1 hour for each degree Fahrenheit difference in temperature between the surfaces. It is expressed in BTU/(hour/ft^2/°F). The thermal conductivity of PEX = 0.22 BTU/(hour/ft^2/°F).

Thermal (linear) expansion – Refers to the physical material characteristic of a body which causes it to expand in the presence of heat. It is known as heat expansion. The linear expansion rate for PEX is approximately 1.1 inches per 10°F temperature change for each 100 feet of tubing. Linear expansion creates a force within the product which, if held back by huge compressive strengths such as concrete, will transmit itself as an internal stress. Unlike other tubing products, PEX is highly resistant to stresses caused by linear expansion.

Thermal mass – Any material used to store heat energy or the affinity for heat energy.

Turbulent flow – The flow of a fluid within a piping system that allows streamlines to repeatedly cross over each other.

U-Value – The capability of a substance to transfer heat. Used to describe the conductance of a material or composite of materials, in construction. U-Value is expressed in BTU/hr/ft^2 and is the inverse function of R-Value.

Wet rotor circulator – a circulator that has the motor's armature and its impeller surrounded by and cooled by the fluid it circulates.

Velocity – The speed of fluid at a specific flow expressed in feet per second (FPS).

Zone – An area of radiant panel served by one or more loops and individually controlled.

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