Uponor complete design assistance manual (CDAM)

Hydronic radiant systems

Uponor complete design assistance manual
is published by

Uponor Inc.
5925 148th Street West
Apple Valley, MN 55124 USA
T 800.321.4739
F 952.891.2008
uponor.com

Uponor Ltd.
6510 Kennedy Road
Mississauga, ON L5T 2X4 CANADA
T 888.594.7726
F 800.638.9517

© 2023 Uponor
All rights reserved.

Eighth edition
First printing March 1994
Printed in the United States of America

Uponor has used reasonable efforts in collecting, preparing and providing quality information and material in this manual. However, system enhancements may result in modification of features or specifications without notice.

Uponor is not liable for installation practices that deviate from this manual or are not acceptable practices within the mechanical trades.

Table of contents

Table of contents

Foreword

Uponor, formerly Wirsbo, is dedicated to partnering with professionals to create better human environments. As the North American leading manufacturer of Engel-method crosslinked polyethylene (PEX-a) piping, Uponor provides system solutions that include both the quality products and technical support required to design, install and operate radiant heating and cooling systems.

As part of this technical support, Uponor publishes the Complete Design Assistance Manual (CDAM) for heating and cooling contractors; heating, ventilation and air conditioning (HVAC) engineers; architects; building officials; building managers; and other individuals interested in hydronic radiant heating and cooling. The CDAM describes Uponor hydronic radiant systems and assists in specification, design, installation and inspection of radiant floor, ceiling and wall applications.

Please direct any questions about the suitability of an application to Uponor Technical Services at 888.594.7726 or technical.services@uponor.com.

In addition to the CDAM, Uponor provides:

- Other technical literature
- Warranties
- Videos
- Training
- Construction services
- Technical support

For information about these support services and tools, please contact your Uponor sales representative or visit uponor.com.

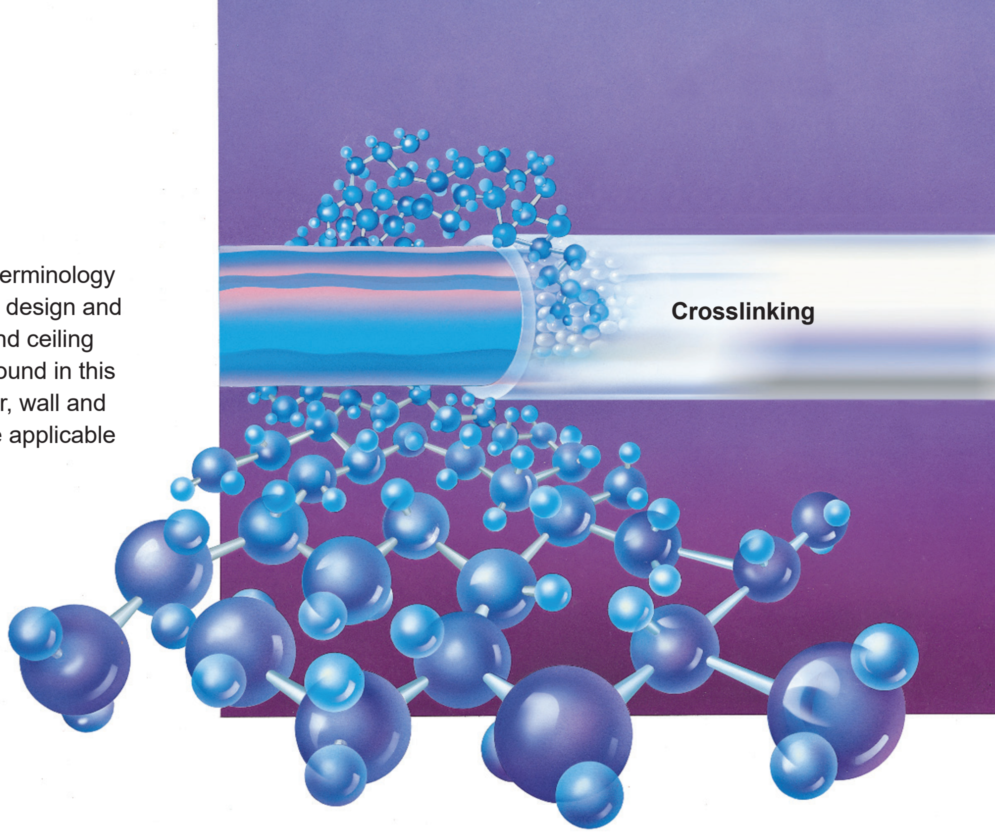
Important safety information

To reduce the risk of injury, read and understand this design manual before beginning work. Read all product safety warnings and operator's manuals for the Milwaukee® ProPEX® expansion tools, PEX pipe cutters and other installation tools to operate those tools safely and correctly. Always wear safety goggles or safety glasses with side shields when performing work.

WARNING: Cancer and Reproductive Harm
P65Warnings.ca.gov

Chapter 1:

Glossary



It is important to become familiar with the terminology used in this manual to fully understand the design and installation of hydronic radiant floor, wall and ceiling heating systems. Some of the definitions found in this chapter are unique to hydronic radiant floor, wall and ceiling heating systems, and some may be applicable only to Uponor systems.

Active loop length — The length of piping within the total loop length that is physically installed within the room to be heated.

Below-grade edge insulation — The amount of insulation (expressed in R-value) placed against the vertical edge of a radiant slab that is more than 4 feet below grade.

Below-grade perimeter insulation — The amount of insulation (expressed in R-value) placed horizontally under the first 4 feet from the perimeter of a radiant slab that is more than 4 feet below grade.

BTU (British Thermal Unit) — A unit of measure equal to the amount of energy necessary to raise the temperature of one pound of water one degree Fahrenheit.

- BTU/h — The amount of BTU expended per hour.
- BTU/h/ft^2 — The amount of BTU expended per hour per square foot of panel. BTU/h/ft^2 is derived by dividing the BTU/h by the amount of available square footage in the room to be heated.

Bypass loop — A piping arrangement that directs the flow of a heat-absorbing medium (water) around, rather than through, a piece of mechanical equipment.

Closed loop — Any piping arrangement in a circulating system that protects the circulating medium (water) against exposure to atmospheric pressure.

Closed system — Any closed-loop hydronic piping system that 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.

Crosslinking — A chemical process that changes the molecular structure of a polymer material by linking otherwise independent hydrocarbon chains. Crosslinking creates a three-dimensional network of hydrocarbons. The end product is incapable of being melted and is insoluble.

Degree day — A unit of measurement used to describe potential heat load (Heating Degree Day or HDD). It is equal to one degree variation from a standard temperature to the average temperature of one day. For example, if the standard is 65°F and the average outside temperature is 50°F for one day, then the number of degree days equals 15 (65 - 50 = 15).

Differential temperature (Δt) — 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 that is available (including spaces that exist within solids). Diffusion is expressed as a function of the volume of space available. A related process, permeation, describes the movement of such substances through a solid membrane and is expressed in terms of the area of membrane penetrated.

DIN — DIN is an abbreviation for the German Institute of Standards (Deutsches Institut fur Normung).

DIN 4726 — An internationally recognized standard that prescribes, among other things, 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 BTU/h/ft^2 transferring downward from a radiant heated floor.

Dry-bulb temperature — The temperature of air recorded by a thermometer that is freely exposed to the air, but does not take into account effects from moisture or radiation. The dry-bulb temperature is the temperature that is generally referred to as the air temperature.

Edge area — The exposed surface of a radiant heated slab equal to the thickness of the slab multiplied by the exposed linear perimeter length.

Edge insulation — The amount of insulation (expressed in R-value) placed vertically along the exposed perimeter of the slab.

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.

Engel method — A peroxide-based method of manufacturing crosslinked polyethylene (PEX) piping. Engel-method PEX is crosslinked during the extrusion process while the raw polyethylene is above its crystal melting temperature, creating an even, consistent, three-dimensional network of joined hydrocarbons.

Exposed perimeter insulation — The amount of insulation (expressed in R-value) placed either horizontally or vertically to a distance or depth of 4 feet along an exposed perimeter of a radiant slab less than 4 feet below grade.

Exposed perimeter length — Equal to the linear feet of perimeter less than 4 feet below grade along an outside wall.

Floating action — Output used to modulate the position of an actuator motor and mixing valve. Power is applied to drive the valve further open or closed. If no power is supplied, the valve will remain at its present position.

Floor insulation — The amount of insulation (expressed in R-value) placed directly below a radiant floor to reduce 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 loss — 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 is supported by a pump against standard atmospheric pressure.

Heat loss — The transfer of heat from a contained space to the atmosphere surrounding it. Heat loss is the result of heat transfer through walls, windows, roofs and other building-envelope components, as well as infiltration losses due to the exchange of heated inside air with unheated outside air.

Heating load — The amount of energy (in BTU/h) required for space heating.

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, Uponor recommends calculation at 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 BTU/h. Infiltration losses are calculated from the air changes per hour, differential indoor/outdoor temperature and the heat-carrying capability of the lost air.

Injection mixing — A method of resetting radiant system water by injecting hot boiler water into a lower-temperature distribution loop in order to maintain proper radiant system supply water temperature. In addition, injection mixing can allow for changes in radiant system supply water temperatures based on changes in outside weather conditions. Injection mixing can be controlled through either an on/off valve or variable-speed injection pumping using a simple wet rotor type circulator. Refer to the variable-speed injection essay in **Appendix I** for more information.

Leader loop length — The horizontal and vertical distance from the heated room to the manifold in which the loop originated. This distance is multiplied by two (supply and return) and added to the active loop length to obtain the total loop length.

Lightweight concrete — Thinly poured concrete (typically 1½ inches) with small aggregate that can be used in some poured-floor applications. The concrete is poured over the piping that is directly fastened to a plywood subfloor. The lightweight concrete needs to be leveled and is prone to cracking due to structural movement if reinforcing material is not used in the concrete. Do not confuse with gypsum-based concrete underlayment. (See definition for **poured-floor underlayment**.)

Linear expansion (thermal) — 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. 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 piping products, PEX is highly resistant to stresses caused by linear expansion.

Mean radiant temperature (MRT) — The area-weighted average temperature of all the surfaces in a room.

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, that has PEX piping 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.

Operative temperature — The uniform temperature where an occupant would exchange the same amount of heat via radiation and convection as the surrounding controlled environment. Simply, the operative temperature combines the effects of radiation and convection. The operative temperature equals the sum of the air temperature and mean radiant temperature, divided by two. Operative temperature may also be referred to as the equivalent temperature or operative temperature.

Outdoor design temperature — A standard design temperature somewhat warmer than the seasonal lowest temperature for the area. In the 2017 ASHRAE Handbook, Chapter 14 Climatic Design Information, Appendix: Design Conditions for Selected Locations recommends selecting a residential design temperature at 99% of the seasonal lowest temperature. Adjustments may be made to reflect local climates which differ from the tabulated temperatures due to altitude differences or local weather experiences. Outdoor design temperature is used to calculate anticipated load under the most common low-temperature 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 4 feet below grade and a portion is less than 4 feet below grade. This is commonly featured in homes with walk-out lower levels.

PE — Abbreviation for polyethylene.

Perimeter area — The first 4 horizontal feet in from the exposed perimeter of the slab (applicable to under-slab insulation).

Perimeter insulation — The amount of insulation (expressed in R-value) placed horizontally for the first 4 feet along the exposed perimeter of the slab.

Perimeter length — The linear length of the slab perimeter for a room exposed to outside conditions (used to calculate edge area).

PEX — Abbreviation for crosslinked polyethylene.

PEX-a — PEX-a is produced using the peroxide (Engel) method of extrusion. The peroxide method is a result of the crosslinking taking place above the crystal-melting point during extrusion. This method is also called hot crosslinking. Hot crosslinking produces crosslinking all the way through the piping wall. PEX-a piping is approximately 85% crosslinked, making it the most uniformly crosslinked type of PEX.

PEX-b — PEX-b is made via two separate processes. Crosslinking is performed in a secondary, post-extrusion process that produces about 65% to 70% crosslinking. As crosslinking occurs below the crystal-melting point, there is not uniform crosslinking throughout the piping wall.

PEX-c — PEX-c is produced by using an electron beam to change the molecular structure of the piping, which generates crosslinking after the extrusion process. Multiple passes of the beam are required to create crosslinking of 70% to 75%. This process may discolor the piping as well as result in a slightly stiffer product.

Polymer extrusion — A method used for the continuous formation of piping from polymer materials.

Polyolefin — A general term for a polymer built from olefins (e.g., polypropylene, polybutylene and polyethylene).

Poured-floor underlayment — A thin (typically 1½ inches) underlayment of gypsum-based concrete. The material is poured over the piping that is directly fastened to a plywood subfloor. The material is self-leveling and requires minimal finishing by the installer. The poured underlayment must be sealed for moisture after the concrete has cured. Do not confuse with lightweight concrete.

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 piping walls and is further influenced by the piping size, length and texture of the inside wall of the piping, fittings, valves and other components. Pressure loss is also influenced by the temperature and viscosity of the fluid.

Primary/secondary pumping — The boiler loop with its own circulator is referred to as the primary loop. Secondary loop is any feed from the primary (boiler loop) that is the same or lower temperature with its own circulator for flow control. Often in radiant floor systems, the secondary flow is first tempered to a lower temperature before entering the secondary loop.

R-value — A measure of a material's ability to resist the flow of heat. R-value is expressed in BTU/h/ft^2 (1/U = R).

Radiant emission — A measure of the propensity of a surface to radiate heat energy to its surroundings in the form of long-wave radiation.

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.

Reactive tempering valve — A three-way, nonelectric valve that, when used in radiant heating applications, maintains a constant supply water temperature despite variations in boiler supply water temperatures. A reactive tempering valve mixes hot boiler water with cooler radiant system return water to produce a specific supply water temperature (setpoint).

Room setpoint temperature — The desired thermostat setting for the room, typically 65°F to 68°F for radiant floor heating. Radiant ceiling systems are designed with a 70°F setpoint temperature. Radiant ceiling systems use a higher setpoint due to the lack of conductive transfer from the system.

Slab below grade — A concrete slab with the entire slab at a minimum of 4 feet below grade.

Slab depth — The thickness of the slab at the perimeter.

Slab on grade — A concrete slab with a perimeter that is less than 4 feet below the surface.

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 required to transfer the calculated amount of BTU/h into a room for a given setpoint temperature to satisfy the current load. Radiant floor surface temperatures should not exceed 87.5°F for constant habitation. The surface temperatures should not exceed 80°F for hardwood floors. Radiant ceiling surface temperature should not exceed 100°F for 8-foot ceilings and 110°F for 9-foot to 12-foot ceilings.

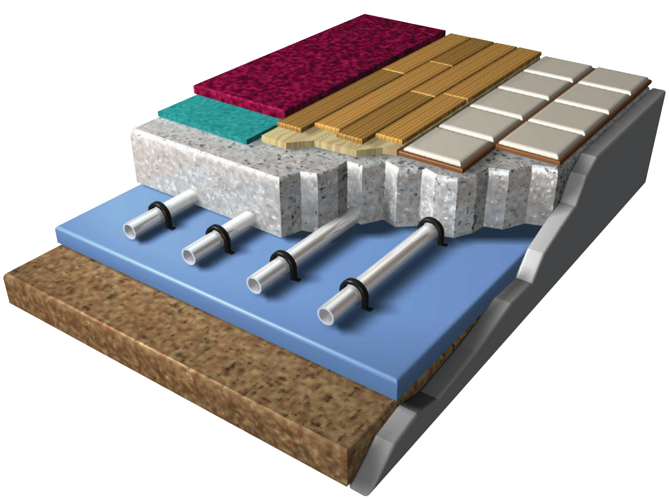


Figure 1-1: Slab-on or below-grade with underslab and edge insulation

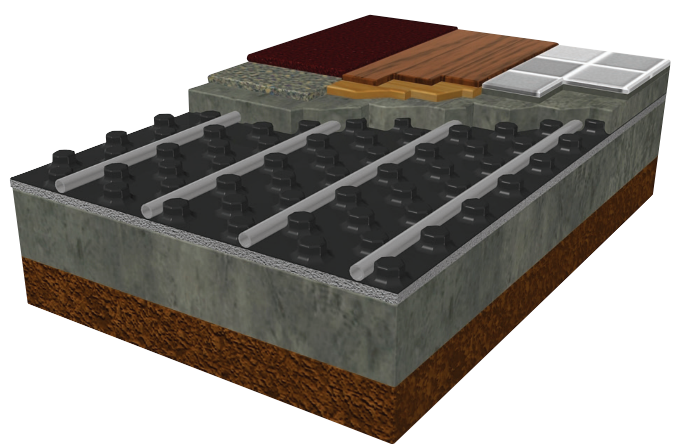


Figure 1-2: Poured-floor underlayment with Uponor Fast Trak™ 1.3i on finished floors

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 installed over heated or unheated spaces.

Temperature below — The temperature of the soil or air below the center of the radiant slab or suspended floor. For slab-on-grade or slab-below-grade floors not exposed to very high water tables, Uponor recommends using a temperature below or equal to the room setpoint temperature. This temperature is likely to occur for the longest portion of the heating season and under design conditions.

Thermal conductivity — Thermal conductivity is a metric for the ability of a material to conduct heat. For a given material, the thermal conductivity is the rate of heat transfer through a unit thickness per unit area per degree of temperature difference. In English units, thermal conductivity is measured in BTU/hr/ft/°F.

The thermal conductivity of PEX-a piping is 0.202 BTU/hr/ft/°F.

Thermal mass — Any material used to store heat energy or the affinity for heat energy.

Total heat transfer coefficient — Describes the transfer of heat from a bordering surface expressed in BTU/h/ft^2/°F. Thermal transfer coefficient is comprised of radiation, convection and conduction properties, as well as the orientation of the radiant surface (floor, ceiling or wall).

- Radiant floor thermal transfer coefficient = 2.0 BTU/h/ft^2/°F
- Radiant wall thermal transfer coefficient = 1.4 BTU/h/ft^2/°F
- Radiant ceiling thermal transfer coefficient = 1.1 BTU/h/ft^2/°F

Total loop length — The active loop length added to the leader loop length equals the total loop length.

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/h/ft^2 and is the inverse function of R-value (1/R = U)

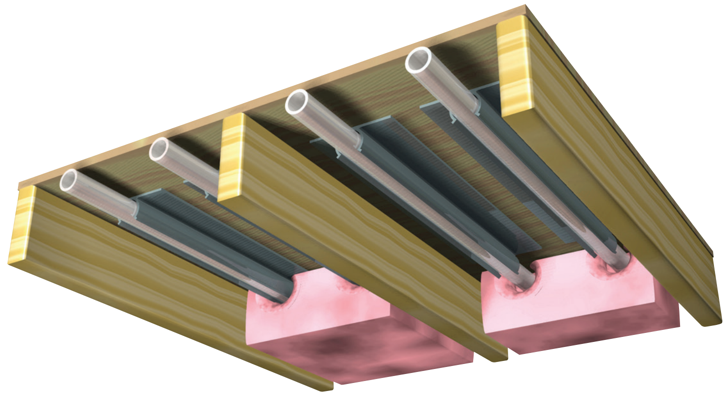


Figure 1-3: Suspended floors heating with Uponor Joist Trak™ heat emission plates

Under-slab area — The interior portion of the slab to include all but the first 4 feet around the perimeter.

Under-slab insulation — The amount of insulation (expressed in R-value) under the interior area of the slab, excluding the perimeter area.

Unheated floor area — The amount of floor included in the gross floor area that does not have piping installed.

Upward load — The amount of heat energy expressed in BTU/h/ft^2 required to overcome the envelope losses of the room.

Velocity — The speed of fluid at a specific flow expressed in feet per second (fps).

Volumetric flow rate — The volume of a fluid that passes through a given cross-sectional area per unit of time. Volumetric flow rate is commonly expressed in terms of cubic feet per minute (cfm) or gallons per minute (gpm).

Water table temperature — Equal to the estimated temperature of the water table for the area and is used when the presence of a water table will affect 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 — A method of fine-tuning a radiant system by changing the system supply water temperature based on changing weather conditions. As the outside temperature decreases, the supply water increases. Likewise, as the outside temperature increases, the supply water temperature decreases.

Zone — An area of a radiant panel served by one or more loops, and individually controlled through a thermostat.

Notes

Chapter 2:
Radiant advantages

History of radiant

There's nothing quite like radiant floor heating. Over the past several years, radiant heating has been the fastest-growing segment of the heating industry, offering numerous advantages over more traditional alternatives.

While some people may think of radiant floor heating as new technology, it actually dates back thousands of years. Archaeological finds date early radiant systems in China and Korea to approximately 5,000 B.C. Heated floors and walls are seen in Greek and Roman cultures around 500 B.C. While sophisticated, hydronic systems using crosslinked polyethylene (PEX) piping have replaced simple, wood and charcoal-fired systems, the end results are similar — a comfortable and economical way to heat homes and buildings.

Radiant and PEX today

With more than 35 years of service — longer than any other PEX manufacturer in North America — Uponor is the leader in PEX piping for radiant heating, plumbing and fire safety systems. More than two billion feet of Uponor PEX piping is in service in North America alone, and more than 12 billion feet of piping is installed worldwide.

Many demographic studies indicate that people are spending more time at home. As a result, home comfort has become a priority for many families. Homeowners are paying closer attention to benefits provided by the heating system. Greater comfort combined with unmatched fuel efficiency explains why residential radiant floor heating is becoming a popular alternative to forced-air heating.

Radiant floor heating also offers increased comfort and fuel economy for office buildings and other commercial applications, such as stores, schools, airport hangars, greenhouses and more. Aware of the benefits, a greater number of building designers and owners now provide their clients with comfortable, healthy buildings with lower fuel bills.

Radiant floor heating benefits

Radiant heating offers many advantages over other heating systems — primarily forced air.

Comfort — Radiant floor heating warms people, furniture and other things in a room. Since the objects and surfaces are warmed, people don't lose body heat to things in the room. Uponor's radiant heating system turns floors into radiators that can be zoned to provide comfortable and even heat throughout homes — even in difficult-to-heat areas such as bathrooms, entryways and garages. Warm radiant floors are ideal for today's homes and rooms with vaulted ceilings and expansive windows. The comfort system concentrates the heat near the floor — where people are located.

Efficiency — Radiant floor heating is an extremely efficient mode of heat delivery. Floor heating is a low-temperature system and can be precisely controlled in each room. Because floor heating warms people and objects directly (as opposed to heating air), comfort may be achieved at lower thermostat settings. Radiant floor heating systems can provide energy savings up to 30% over forced-air systems.

Buildings with high ceilings, large windows, high infiltration or a combination of these and other factors typically experience greater savings. Energy savings vary depending on building use, occupancy, design and construction.

Clean and healthy — Because radiant floor heating does not rely on circulating air (as forced air or convective baseboard do), dust particles do not readily spread throughout a home. Radiant also greatly reduces the spread of other airborne particles, such as pollen.

Quiet — Radiant floor heating is virtually silent when it operates. There are no noisy fans, clunky ductwork or pinging pipes.

Complete design freedom — Because the heating system is in the floor, radiant heating allows greater freedom for furniture placement – without having to worry about blocking vents or radiators.

More usable space — With no bulky radiators or baseboards, homes with radiant floor heating tend to have more usable floor space.

Aesthetically pleasing — Since the heating system is virtually invisible, radiant heating does not detract from the appearance of a room. There are no messy heating grills or bulky radiators to look at or to collect dirt.

Low maintenance — Floor-heating systems require very few moving parts. There are no fans, belts or blowers that need replacing, and no ducts to clean.

Increased property values — In many parts of the country, homes with radiant heating have enhanced property values compared to similar homes with other types of heating systems. In nearly all cases, homes with radiant heating systems tend to attract buyers.

Perfect for concrete slabs — Radiant floor heating is the only solution for basement slabs. Turning a cold slab into a cozy, warm floor can convert these traditionally difficult-to-heat areas into comfortable, livable spaces. This can also increase property values.

Clean, dry, safe floors — Because the floor surface is warm, cleaning and drying are quick and easy. Quick-drying floors help prevent slick spots, especially in bathrooms, where people can slip and fall.

Choice of heat sources — Uponor hydronic radiant floors can be heated by any source of energy, such as gas, oil, electricity, geothermal, solar or wood. All the system needs is warm water.

This list is not all-inclusive. There are a myriad of benefits and advantages that make radiant floor heating the best choice to heat a structure.

What makes radiant floors so comfortable?

When considering the issue of personal comfort, it's important to fully examine the question, "Just what is comfort, and what are the elements that make a person comfortable?" It's more than simply feeling warm or not feeling cold. Most people think that comfort is a matter of supplying heat to the body. Rather, comfort is controlling the rate at which a body loses heat.

Think of a body as a heat source. Science has known for years that a human body generates more heat than it needs. In order to be truly comfortable, the body needs to lose the excess heat. A typical person at normal or light activity loses heat at a rate of about 400 BTU/h. That heat energy is lost in three specific ways. First, the body loses heat through convection, or air currents passing over the body surface. Second, the body loses heat through evaporation, by breathing and sweating. Third, the body loses heat through radiation, or the transfer of energy from a warm surface to a cooler surface.

A person feels most comfortable if the body loses its 400 BTU/h in a certain ratio: approximately 50% through radiation, 30% through convection and 20% through evaporation.

A common misconception, even among heating professionals, is that heat rises. In reality, hot air rises and cold air falls due to differences in density.

Heat goes to cold. Energy always travels from a hot surface or mass to a colder one. Think of how a stove heats water to a boil. A relatively cold pot filled with water is placed on a hot burner. The burner transfers its heat to the pot, which, in turn, transfers its heat to the water. This is why people feel uncomfortable when standing on a cold tile floor or next to a cold wall, even though the thermostat reads an air temperature of 70°F to 72°F. What is happening is that the colder floor or wall surface is drawing heat out of that person's body faster than it can be replaced.

A common response to this type of situation would be to simply turn up the thermostat and increase the air temperature. This response may offset the radiation heat loss to a small degree, but other comfort issues may decline. For instance, higher air temperatures generally result in stuffiness and dryness, both of which detract from overall comfort. In addition, since hot air rises, the air temperature at or near the ceiling is considerably warmer than the air temperature at the thermostat level. Consequently, people feel warmer near their head and colder at their feet, which also negatively impacts personal comfort.

Radiant floor heating delivers personal comfort by controlling the radiation heat loss of a body. When surrounded by surfaces that are roughly the same temperature as the body surface, natural heat loss via radiation is controlled.

Another way to help control natural heat loss is to reduce or eliminate unwanted air movement. Radiant floor heating virtually eliminates unwanted air movement because it doesn't use fans to circulate the heat. The only air movement in the room heated by radiant floor is natural air.

By combining these two factors — similar surface and body temperature and the elimination of unwanted air movement — a radiant system can control about 80% of the human body's natural heat loss.

In many rooms that are common in modern construction, this phenomenon can be dramatic. For example, in rooms with cathedral ceilings, large amounts of glass, hardwood, tile or vinyl floors, or anything built on a concrete slab, radiant floor heating is the only solution when it comes to delivering even, consistent, effective and efficient comfort.

Radiant floor heating generally also provides greater comfort levels at lower thermostat settings compared to baseboard or forced air. Experience shows that perfect thermal comfort may be achieved at thermostat settings of 65°F to 68°F. Review the ideal heating curve, illustrated in **Figure 2-1**.

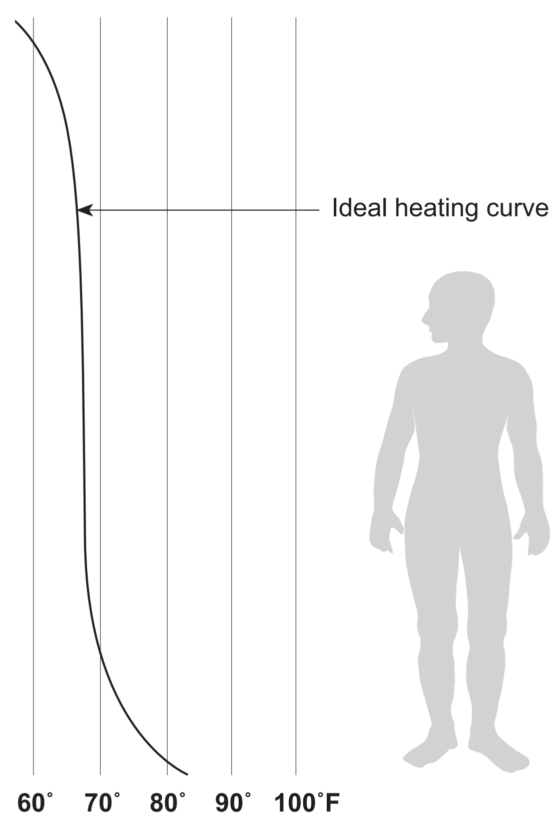


Figure 2-1: Ideal heating curve

Think of the body as a hydronic heating system with a priority-zoning package. Priority number one is the central torso and its critical organs. Priority two is the head, and priority three is the extremities. When placed in a cold environment, the body takes care of the central torso and head first, while restricting blood flow to the hands and feet. This is why people feel cold in those areas first. The head, however, is filled with blood vessels that provide plenty of body warmth. As a result, the air temperature needed at head level to create comfort does not need to be very high. Science and experience both indicate that most people are more comfortable and more alert with head-level air temperatures around 65°F to 68°F.

The goal of the ideal heating curve is to achieve a temperature just below skin temperature at the floor. Moving toward the ceiling from the floor, the air temperature lowers to about 65°F right at and slightly above head level. Closer to the ceiling, the air temperature decreases slightly.

Forced air — The common forced-air system heats air to the temperature necessary to overcome the heat loss of the structure. Hot air is then forced into the occupied space by blowers through ductwork. The heat loss of the structure determines both the temperature and speed of the air the occupants must endure.

If the heat loss is high, the air temperature must be uncomfortably high to maintain the thermostat setting (typically 70°F to 72°F). If the heat loss is low, the thermostat can be satisfied by blowing short blasts of excessively high-temperature air or by blowing low-temperature air more steadily. Either approach leaves people feeling uncomfortable.

In **Figure 2-2**, notice how a forced-air heating curve differs greatly from the ideal heating curve. Since hot air rises, the air temperature at head level and above is higher than ideal, and the closer to the ceiling you go, the warmer the air. Hot-air systems do not distribute heat to the extremities, where the body needs it most. In order to meet those needs, the air must be heated to a level that is much too hot and uncomfortable for the upper body. The choice is either cold feet or hot heads.

The temperature at floor level never reaches the desired level, and the temperature of the ceiling is too hot. Add to this equation unnatural convection, or air movement, that can alter the delicate heat-loss balance of the human body. Also note that the area between the forced-air curve and the ideal curve represents wasted energy and, as a result, higher energy bills.

Convective baseboard — Hot water and electric baseboard systems provide virtually all their heat through convection, although a relatively small amount is delivered via radiant means. Baseboard has very little surface area and operates at high temperatures. Air passes over the heated element of the baseboard and creates a convective warm-air current.

Since baseboards are generally placed on outside walls, the warm air then flows along the outside wall and collects at the ceiling. This air movement is the result of natural convection, compared to the forced convection from forced hot air. The actual air movement with a baseboard system is less objectionable than that created by a forced-air system. However, this air movement tends to create uneven pools of warmth and can adversely affect the ideal convective heat loss of the body.

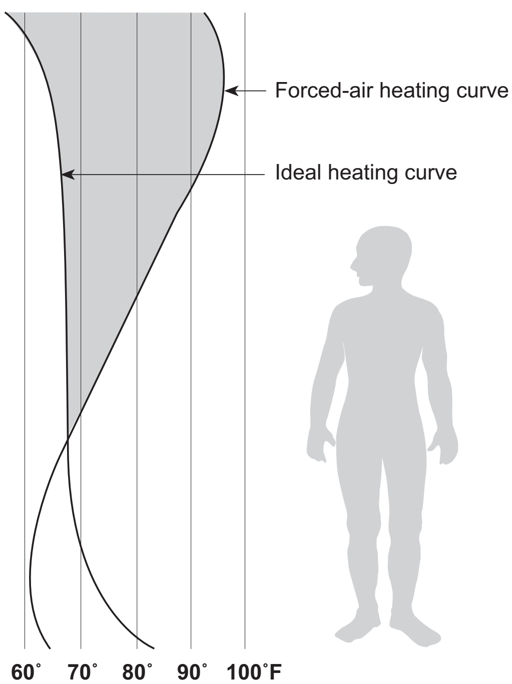


Figure 2-2: Comparison of ideal and forced-air heating curves

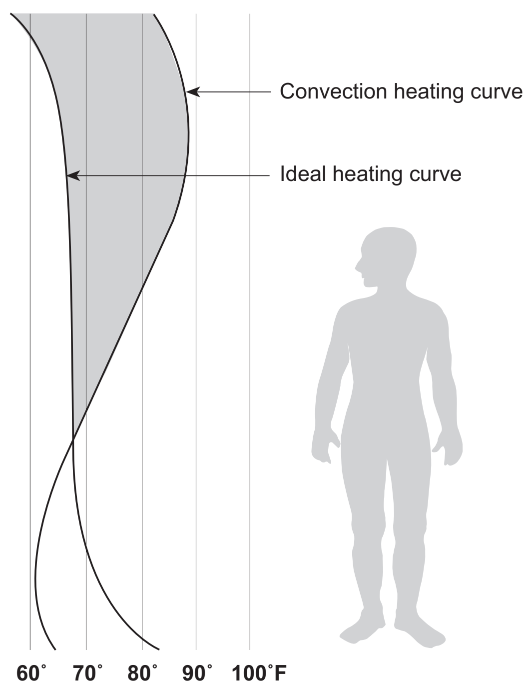


Figure 2-3: Comparison of ideal and convection heating curves

Although closer to the ideal curve than forced air, baseboard heating is unable to distribute heat where the body needs it. As with forced air, the temperature at the floor is too cool for true comfort, and the temperature at head level and the ceiling is too warm. Note the area between the baseboard convection heating curve and the ideal heating curve in **Figure 2-3**, representing wasted energy.

Radiators — Radiators, made of either cast iron or decorative aluminum, have more mass than either baseboard or forced-air delivery systems. Accordingly, they are able to provide a higher degree of radiant heat. As a result, radiators are much more comfortable than baseboard or forced-air heating systems. However, most of the heat delivered by radiators is still through convection because the surface area is relatively small. Radiators also require higher water temperatures. As with baseboards, air passes over and through the radiators, creating convective warm air currents. Radiators tend to create uneven pools of warmth, with the warm air currents affecting the ideal convective heat loss of the body.

The heating curve for radiators is closer to the ideal heating curve than either forced air or baseboard. However, radiators, like the others, cannot deliver needed warmth at or near floor level. In **Figure 2-4**, as with other non-radiant heating methods, the area between the two heating curves represents wasted energy.

Radiant floor — Radiant floor heating is the only heating system that comes close to matching the ideal heating curve. The entire floor surface area becomes, in effect, a low-temperature radiator. Since a person in that room is always in contact with the floor, or in contact with something that's in contact with the floor (e.g., furniture), that person is warmed directly by the floor, rather than chilled by losing heat to a cold surface. In addition, the floor acts as a radiator by warming surfaces in that room, which helps keep about 80% of a person's heat loss in balance.

Radiant floor heating can be designed around water temperatures lower than those used in baseboard or radiator systems. Floor surface temperatures are generally designed to remain at or below 87.5°F for all types of finished floors except hardwood, which has a maximum floor surface temperature of 80°F. See **Chapter 16** for more information about hardwood floors.

As shown in **Figure 2-5**, the radiant floor heating curve very closely mirrors the ideal heating curve. There's plenty of warmth at floor level, 65°F at head level and temperatures dropping off from there. There's very little difference between the two curves, clearly demonstrating radiant floor's superior energy efficiency.

Since there is a maximum floor surface temperature (87.5°F) with radiant floors, there is a maximum BTU/h/ft^2 output the floor can provide. The thermal transfer coefficient for radiant floor is 2 BTU/h/ft^2/°F. Therefore, when the room setpoint temperature is 65°F, the radiant floor can deliver a maximum of 45 BTU/h/ft^2, with the floor surface temperature being the limiting factor. Requirements beyond 45 BTU/h/ft^2 can be satisfied with the second best form of heating available — radiant ceiling (addressed later in this chapter).

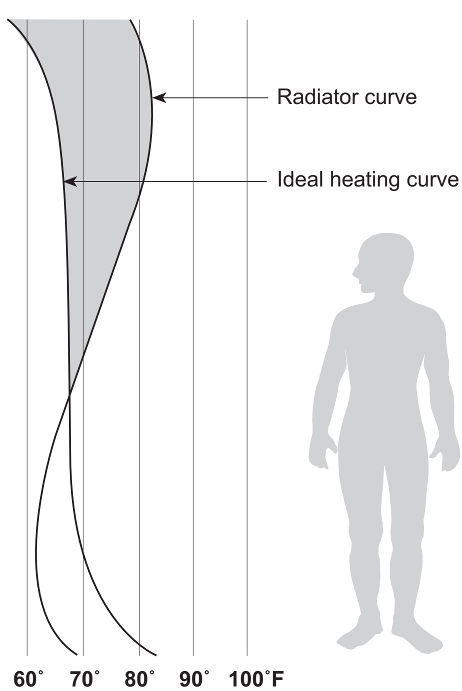


Figure 2-4: Comparison of ideal and radiator heating curves

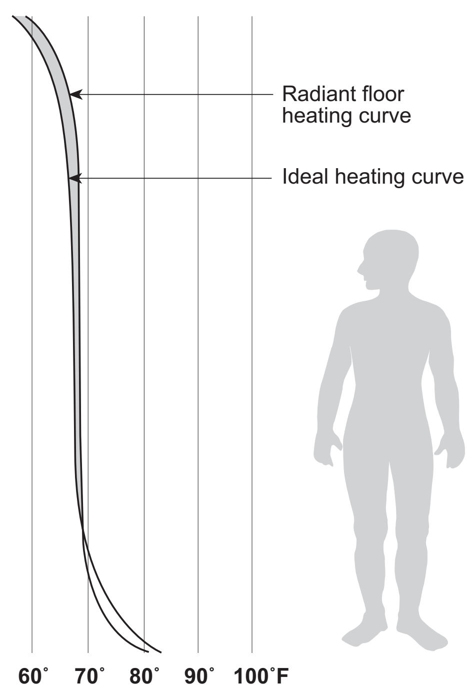


Figure 2-5: Comparison of ideal and radiant floor heating curves

A few words about efficiency — The true seasonal efficiency of a heating system is often misunderstood. True efficiency depends on several factors, including the actual and rated efficiency of the heating appliance and how effectively the heat-delivery system uses what the appliance creates. For example, an extremely efficient heating appliance connected to an inefficient delivery system does not produce an efficient system.

Radiant heating makes maximum use of the energy produced by the heating plant and provides comfort that other delivery systems cannot. Efficiency ratings on boilers and other hot-water heating plants, as well as those on hot-air furnaces, only reflect laboratory estimates of how efficiently that unit turns fuel into energy compared to other similar appliances. These ratings do not reflect the true seasonal efficiency of the entire heating system.

Uponor radiant ceiling heat

Radiant ceiling acts as a supplemental heat source. See **Figure 2-6** for the radiant ceiling curve. Like radiant floor heating, radiant ceiling uses the same three types of heat transfer: conduction, radiation and convection.

Radiation heat transfer — Radiant ceiling panels radiate heat to furnishings, floors and occupants the same way the sun radiates heat to the earth. The space between the sun and earth is cold, but the surfaces that heat radiation strikes are warm.

Conduction heat transfer — Heat radiation warms room surfaces, furnishings and floors. Those surfaces then provide secondary transfer through conduction (direct contact) and re-radiation. When people walk across the floor or touch a table that is warm as a result of heat radiation, some of that heat is transferred to them. That's conduction. Note that the effect of conduction with radiant ceiling is less than that of radiant floor.

Convection heat transfer — Radiant ceilings heat the objects in a room. Heat from the ceiling and objects in the room then warms the air, driving natural convective air currents. Convective currents (warm air) come into contact with other objects and again transfer heat. Convective heat transfer becomes pronounced when surface temperatures reach approximately 7°F above the room setpoint temperature.

The thermal transfer coefficient of radiant ceiling heat takes into account the transfer of heat energy due to convection and radiation. The coefficient of radiant ceiling heat is about 1.1 BTU/h/ft^2/°F difference between the ceiling surface temperature and room setpoint temperature (with radiant floor, the heat transfer coefficient is 2.0). For example, a room setpoint temperature of 70°F, with a ceiling surface temperature of 100°F would yield a maximum of 33 BTU/h/ft^2.

Uponor radiant ceiling heat advantages

Radiant ceiling heat, like radiant floor heating, offers many advantages.

Responsive — Radiant ceiling heat is very responsive because it's a low-mass system, using highly conductive gypsum sheetrock.

Effective — Radiant ceiling heating systems are effective because they are suitable for surface temperatures as high as 100°F with normal 8-foot ceilings and 110°F for ceilings higher than 8 feet, but lower than 12 feet. Radiant ceilings produce 33 BTU/h/ft^2 at a 70°F room setpoint temperature.

Adaptable — Radiant ceiling heating systems adapt easily to retrofit installations. Radiant ceilings are typically lowered less than 1½ inches.

Accessible — Radiant ceiling panels have clear access to heated space. They're not subject to changes in floor coverings or use patterns.

Economical — As a supplemental heat source, radiant ceiling offers the opportunity to concentrate additional heat in the area with the greatest heat loss. They also require low-water temperatures, typically no higher than 120°F.

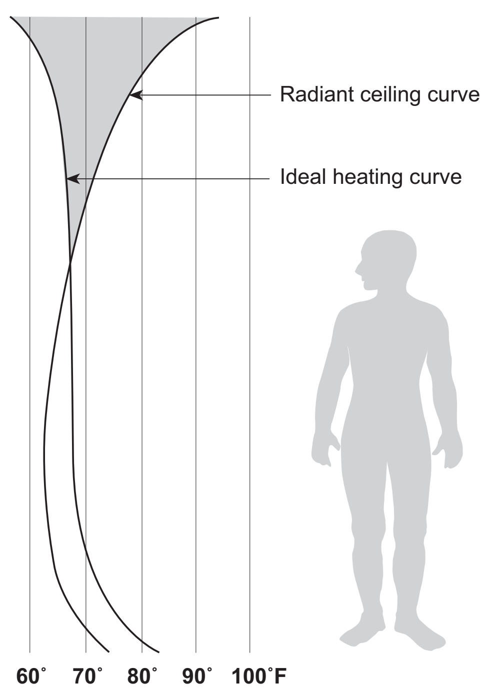


Figure 2-6: Comparison of ideal and radiant ceiling heating curves

Chapter 3:

Uponor piping products

PEX is an acronym for crosslinked polyethylene. The "PE" refers to the raw material used to make polyethylene, and the "X" refers to the crosslinking of the polyethylene across its molecular chains. The molecular chains are linked into a three-dimensional network that makes PEX remarkably durable within a wide range of temperatures and pressures.

Currently, three methods for producing PEX exist:

- Engel or peroxide method (PEX-a)
- Silane method (PEX-b)
- Electron beam (e-beam) or radiation method (PEX-c)

All three processes generate piping that is crosslinked to various degrees and that is acceptable for potable water-distribution applications according to ASTM F876 and F877 standards.

Engel method (PEX-a) — Uponor manufactures Engel-method PEX-a piping. The PEX piping industry considers this piping superior because the crosslinking is done during the manufacturing process when the polyethylene is in its amorphic state (above the crystalline melting point). Accordingly, the degree of crosslinking reaches approximately 85%, resulting in a more uniform product with no weak links in the molecular chain.

Silane method (PEX-b) — PEX-b piping is crosslinked after the extrusion process by placing the piping in a hot water bath or steam sauna. The degree of crosslinking for PEX-b is typically about 65% to 70%. This method produces PEX that is not as evenly crosslinked as that produced by the PEX-a method. In addition, PEX-b lacks the same degree of thermal memory, which allows kinked piping to be reshaped with the use of a heat gun.

Electron beam method (PEX-c) — PEX-c uses an e-beam to change the molecular structure of the piping (i.e., crosslink) after the extrusion process. The PEX-c method requires multiple passes of the piping under the beam to reach a 70% to 75% degree of crosslinking. This method produces PEX that is not as evenly crosslinked as that produced by the PEX-a method. Side effects of this process are discoloration due to oxidation (from natural white to yellow, unless other pigment is added), and a slightly stiffer product.

PEX-a distinctions

The properties of PEX-a piping make it the most flexible PEX on the market. This flexibility allows the tightest bend radius available — 6 times the outside diameter of the piping. Its flexibility also greatly reduces instances of kinked piping.

However, in the rare instance of a kink, that's okay, because PEX-a piping has thermal memory. Thermal memory allows kink repairs by applying heat from a heat gun. The shape memory of PEX-a piping offers the unique opportunity for ProPEX® fitting connections. Shape memory allows PEX-a to expand and then shrink back to normal size — creating strong, durable and reliable fitting connections.

Finally, PEX-a piping offers more resistance to crack propagation (how a crack grows) than PEX-b or PEX-c piping. A crack that occurs in PEX-a piping is the least likely to grow over time and cause leaks or damage.

Stress resistance

Piping installed in radiant floor, wall and ceiling applications must be capable of withstanding the extreme stresses that result from installation within a concrete slab or a structural wood floor. Typical stresses include:

- Expansion and contraction that result from repeated heating and subsequent cooling of the heat-transfer fluid
- Mechanical abrasion, shearing, and stretching that occurs as a result of installation, normal structural movement, and heating and cooling from seasonal weather changes

Uponor PEX provides the durability and reliability that's needed for these applications and currently holds the unofficial world record for long-term testing at elevated temperature and pressure. From 1973 to 2009, the piping was subjected to ongoing testing at 203°F/175 psi by Studvik in Sweden and BASF in Germany. The resulting data indicates a life expectancy of well over 100 years.

Chemical resistance

Crosslinked polyethylene has greatly enhanced resistance to chemical-dissolving agents. The unique molecular structure is stable, inert and unaffected by chemicals commonly found in plumbing and heating systems. PEX is also resistant to many other chemical-dissolving agents, making it suitable for many applications. Please contact Uponor Technical Services at technical.services@uponor.com or 888.594.7726 regarding questions about chemical compatibility.

Oxygen diffusion

Oxygen diffusion can cause corrosion problems in a heating system. All non-metallic (plastic or rubber) piping is permeable to the passage of dissolved oxygen molecules through its walls. Permeability allows these dissolved oxygen molecules to enter an otherwise closed hydronic heating system.

In any new hydronic heating installation, dissolved oxygen molecules exist in the new, fresh water. The large bubbles are purged from the system prior to initial start-up. The dissolved oxygen, however, remains. This dissolved oxygen is not visible in the form of bubbles, and cannot be eliminated by the use of an air vent or scoop.

As the heating system brings the water up to temperature, these dissolved oxygen molecules increasingly bond with ferrous components in the system. The result is corrosion or rust. After a few years of operation, a layer of rust on all ferrous components becomes apparent.

In a typical hydronic system using metallic pipe, almost all dissolved oxygen molecules are used up and cause a non-aggressive rust called "ferrous oxide" usually within the first 72 hours. That's the end of the corrosion process.

However, in a non-metallic system using plastic or rubber piping, oxygen continues to enter the system through the permeable piping. Accordingly, the corrosion process continues. Left unchecked, this corrosion will cause considerable damage to the ferrous components of the radiant heating system.

Damage may include:

- Circulator failures
- Pinhole leaks at expansion tanks
- A red, sludgy build-up inside the system piping (reducing flow)
- Eventual boiler failure (if a cast-iron or steel boiler is used)

Here are four ways to manage oxygen-diffusion corrosion.

Option 1 — Use piping that limits the oxygen diffusion into the heat-transfer fluid to a level consistent with established standards. Use Wirsbo hePEX™ for these applications.

Option 2 — Isolate the heat-transfer fluid from components likely to corrode (e.g., cast-iron pumps, boilers, expansion tanks, etc.) with a non-ferrous heat exchanger. Uponor AquaPEX® piping, without the oxygen-diffusion barrier, is available for those systems that isolate the heating loops from the heat plant and circulator components. All other components (e.g., expansion tanks, circulators and piping) on the floor heating side of the heat exchanger must be made of a non-ferrous material as well.

Option 3 — Eliminate all corrosive ferrous components from the system. Uponor AquaPEX is available for those systems that use non-ferrous components (e.g., bronze pumps, copper tube boilers with bronze headers, etc.).

Option 4 — Treat all heat-transfer fluid with corrosion inhibitors. Corrosion inhibitors require regular maintenance from the heat plant manager to maintain the correct inhibitor level. In the event the system mixture is allowed to lapse, corrosion damage may occur. For these reasons, Uponor does not recommend the use of corrosion inhibitors to counter the effects of oxygen diffusion.

Handling guidelines for PEX piping

The following list highlights the most common guidelines when handling Uponor PEX-a piping.

- Always install Uponor systems according to the installation instructions.
- Do not use PEX-a piping where temperatures and pressures exceed ratings.
- Do not use or store PEX-a piping where it will be exposed to direct sunlight for more than 30 days.
- Do not weld, glue or use adhesives with PEX-a piping.
- Do not apply open flame to PEX-a piping.
- Do not install PEX-a piping within 6 inches of any gas appliance vents, with the exception of double-wall B-vents, which have a minimum clearance of 1 inch.
- Do not install PEX-a piping within 12 inches (over or under) of any recessed light fixture unless the piping line is protected with suitable insulation.
- Do not solder within 18 inches of any PEX-a piping in the same water line. Sweat connections must be made prior to making a ProPEX connection.
- Do not spray on or allow organic chemicals, pesticides, strong acids or strong bases to come into contact with PEX-a piping without checking chemical compatibility.
- Do not use petroleum or solvent-based paints, greases or sealants on PEX-a piping.
- During remodeling or ceiling repair, implement appropriate precautions to protect the piping from damage.
- Do not install PEX-a piping in soil environments contaminated with solvents, fuels, organic compounds, pesticides or other detrimental materials that may cause permeation, corrosion, degradation or structural failure of the piping. Where such conditions are suspected, perform a chemical analysis of the soil or groundwater to ascertain the acceptability of PEX-a piping for the specific installation. Check local codes for additional requirements.

Reforming kinked piping

If the piping is kinked and hinders flow, repairs can be made easily.

1. Make sure the system is not pressurized.
2. Straighten the kinked portion of the piping.
3. Heat the kinked area to approximately 265ºF with an electric heat gun (approximately 450 watts of power). Apply the heat evenly until the piping returns to its original size and shape. Do not use an open flame.
4. Let the repaired piping cool undisturbed to room temperature. When the piping returns to its opaque appearance, the repair is complete.

Caution: Temperature of the piping surface must not exceed 338ºF. Do not apply direct flame to the piping. Uponor PEX-a piping repaired according to these recommendations will return to its original shape and strength. If the piping is sliced, punctured or otherwise damaged beyond the capacity of the crosslinked memory, install a ProPEX coupling. PEX piping cannot be welded or repaired with adhesives.

Thawing frozen piping

Uponor PEX-a piping can withstand extreme freeze/thaw cycles better than other piping or pipe. The crosslinking of the piping allows it to expand and absorb much of the expansion energy from the freezing process. No piping product is freeze-proof, but Uponor PEX-a piping is extremely resistant to freeze damage.

If freezing occurs, the contractor should advise the end user to correct the lack of insulation or heat to eliminate the problem from reoccurring. Should Uponor PEX-a piping experience an ice blockage, thaw the piping using these methods:

1. Pour hot water over the piping's affected area.
2. Wrap hot towels around the piping's affected area.

Kinks in Uponor PEX are easily repaired with a heat gun.

3. Place a small portable heating unit in the area to heat the space and thaw the ice blockage from the piping.
4. Slowly heat the affected area with a heat gun. Rub a hand over the area while heating to ensure the piping does not get too hot.

Note: Use Wirsbo hePEX when an oxygen-diffusion barrier piping is required.

Uponor piping

With more than 35 years of service — longer than any other PEX manufacturer in North America — Uponor is the leader in PEX piping for radiant heating, plumbing and fire-protection systems. More than two billion feet of Uponor PEX piping is in service in North America alone, and more than 17 billion feet of piping is installed worldwide. With that kind of history, you can count on Uponor PEX to offer the highest-quality piping for all your application needs.

The Uponor ProPEX fitting system (ASTM F1960) was tested with various components provided by Uponor, including the PEX-a pipe, PEX-a ring and ProPEX fitting, and the assembly was listed by CSA. The testing program included sustained pressure testing, bent-tube pressure testing, excessive temperature and pressure capability testing as well as several other tests with weekly and yearly follow-up procedures. Uponor's unique cold-expansion fitting system is highly reliant on the elastic memory of the product and the unique material properties in its formulation. CSA will only provide a system certification if warranted; properties of each component are proven to be required to form a fully functional system.

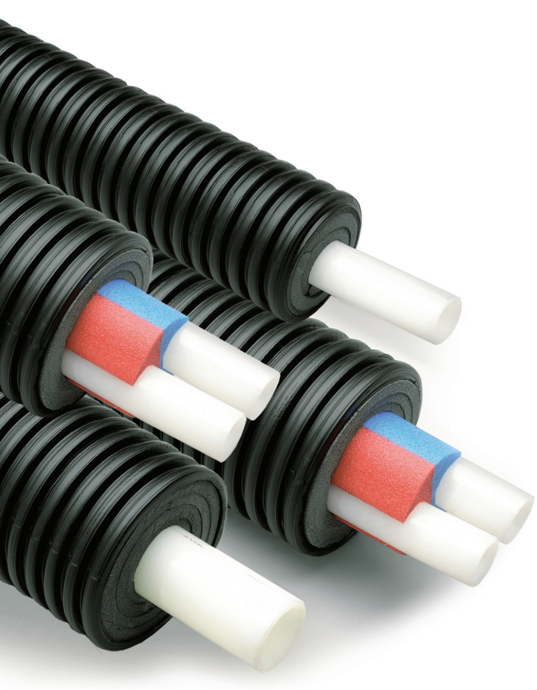
Selecting an Uponor piping product

Uponor offers Wirsbo hePEX, Uponor AquaPEX and Ecoflex® for distribution piping in radiant applications.

Refer to the following pages for details about each piping product.

Uponor piping	Application and design considerations	Standards, listings and ratings	
Wirsbo hePEX Wirsbo hePEX is Engel-method PEX-a piping with an oxygen-diffusion barrier. 	**Application** — Wirsbo hePEX is designed for use in closed-loop hydronic radiant heating systems operating at sustained temperatures up to 200°F. Corrodible or ferrous components may be used in hot- water heating systems designed with Wirsbo hePEX piping.	Wirsbo hePEX is manufactured to meet ASTM F876 and ASTM F877 standards. Wirsbo hePEX has a Standard Grade Hydrostatic Design Stresses and Pressure Rating in accordance with all three temperatures and pressures listed in Table 1 of ASTM F876. Wirsbo hePEX piping is tested in accordance with PPI TR-3 and listed in PPI TR-4. **The Standard Grade hydrostatic ratings are:** • 200°F at 80 psi • 180°F at 100 psi • 73°F at 160 psi The Hydrostatic Design Stress Board of the Plastics Pipe Institute (PPI) issues these pressure and temperature ratings. These values listed are ratings, not limitations. If the designer stays within these parameters during design, there should not be a problem with the product. Burst pressures are values used only in manufacturing the product, not for the system specification or design. For the complete codes, standards and listings for Wirsbo hePEX, refer to the submittal on uponor.com.	
Uponor AquaPEX Uponor AquaPEX is a registered trade name for the company's hot and cold potable-water piping. It is essentially the same product as Wirsbo hePEX, but without the oxygen-diffusion barrier. 	**Application** — Uponor AquaPEX can be used in closed-loop hydronic heating systems operating at sustained temperatures up to 200°F, provided any issues concerning oxygen diffusion are properly addressed. Corrodible or ferrous components may not be used in a system designed with Uponor AquaPEX unless these components are isolated from the piping. **Design considerations** — Uponor AquaPEX is permeable to oxygen at a rate up to 13.6 grams per cubic meter per day at 158°F. Radiant floor systems using Uponor AquaPEX piping must be designed to accept oxygen permeation.	Uponor AquaPEX is manufactured to meet: ASTM F876, ASTM F877 and CAN/CSA B137.5. Uponor AquaPEX has a Standard Grade Hydrostatic Design Stresses and Pressure Rating in accordance with all three temperatures and pressures listed in **Table 1** of ASTM F876. Uponor AquaPEX piping is tested in accordance with PPI TR-3 and listed in PPI TR-4. **The Standard Grade hydrostatic ratings are:** • 200°F at 80 psi • 180°F at 100 psi • 73°F at 160 psi The Hydrostatic Design Stress Board of PPI issues these pressure and temperature ratings. Burst pressures are values used only in manufacturing of the product, not for the system specification or design. For the complete codes, standards and listings for Uponor AquaPEX, refer to the submittal on uponor.com.	

	Barrier information	Linear expansion rate	Dimensions	Coil lengths
	Wirsbo hePEX is sealed with a special polymer barrier to prevent the diffusion of oxygen through the piping wall and to protect the ferrous components of a closed-loop hydronic heating system from corrosion damage. The barrier consists of an ethylene vinyl alcohol (EVOH) layer co-extruded onto the piping during the manufacturing process. Uponor applies another thin polyethylene layer over the EVOH barrier on the piping to reduce possible onsite damage to the oxygen-diffusion barrier. This polyethylene layer also provides protection for the EVOH barrier if the piping is immersed in high-moisture applications. The Wirsbo hePEX barrier meets the requirements of the German DIN Standard 4726 for oxygen-diffusion prevention. The amount of oxygen that enters the system must be less than 0.10 grams per cubic meter per day at 104°F.	The unrestrained linear (thermal) expansion rate for Wirsbo hePEX piping is approximately 1.1 inches per 10°F temperature change per 100 feet of piping.	• 5⁄16" nominal inside diameter (contains 0.35 gallons/100' of piping) • 3⁄8" nominal inside diameter (contains 0.50 gallons/100' of piping) • ½" nominal inside diameter (contains 0.92 gallons/100' of piping) • 5⁄8" nominal inside diameter (contains 1.34 gallons/100' of piping) • ¾" nominal inside diameter (contains 1.84 gallons/100' of piping) • 1" nominal inside diameter (contains 3.03 gallons/100' of piping) • 1¾" nominal inside diameter (contains 4.54 gallons/100' of piping) • 1½" nominal inside diameter (contains 6.33 gallons/100' of piping) • 2"nominal inside diameter (contains 10.85 gallons/100' of piping) • 2½" nominal inside diameter (contains 16.53 gallons/100' of piping) • 3" nominal inside diameter (contains 23.51 gallons/100' of piping) • 4" nominal inside diameter (contains 41.05 gallons/100' of piping)	Refer to the Uponor Product Catalog for available coil lengths. Custom coil lengths are also available for qualifying orders. Allow six weeks for delivery. Call Uponor Customer Service at 888.594.7726 for availability and pricing.
	Uponor AquaPEX is a non-barrier product.	The unrestrained linear expansion (thermal) rate for Uponor AquaPEX piping is approximately 1.1 inches per 10°F temperature change per 100 feet of piping.	• ¼" nominal inside diameter (contains 0.24 gallons/100' of piping) • 3⁄8" nominal inside diameter (contains 0.50 gallons/100' of piping) • ½" nominal inside diameter (contains 0.92 gallons/100' of piping) • 5⁄8" nominal inside diameter (contains 1.34 gallons/100' of piping) • ¾" nominal inside diameter (contains 1.84 gallons/100' of piping) • 1" nominal inside diameter (contains 3.03 gallons/100' of piping) • 1¼" nominal inside diameter (contains 4.53 gallons/100' of piping) • 1½" nominal inside diameter (contains 6.32 gallons/100' of piping) • 2"nominal inside diameter (contains 10.85 gallons/100' of piping) • 2½" nominal inside diameter (contains 16.53 gallons/100' of piping) • 3" nominal inside diameter (contains 23.51 gallons/100' of piping)	Refer to the Uponor Product Catalog for available coil lengths. Custom coil lengths are also available for qualifying orders. Allow six weeks for delivery. Call Uponor Customer Service at 888.594.7726 for availability and pricing.



Ecoflex pre-insulated pipe systems

Designed for fluid transfer in a variety of hydronic heating, cooling and potable-water applications, Ecoflex pre-insulated pipes are easy to install, dependable, cost-effective and energy-saving.

Lightweight and flexible, Ecoflex installs easily and quickly in commercial and residential applications — even over obstacles and around corners.

Recognized for its ability to stand up to harsh environments, Ecoflex is virtually maintenance-free. This feature is especially important since Ecoflex usually involves an underground installation. With coil lengths available up to 1,000 feet, Ecoflex practically eliminates the need for underground joints — resulting in seamless runs of piping.

Ecoflex thermal

ASTM Ecoflex Thermal is a pre-insulated pipe for buried or above-ground commercial and residential hydronic radiant heating and cooling applications with single or twin pipe options. Service pipes are made from PEX-a Wirsbo hePEX (oxygen-diffusion barrier) piping, protected by multi-layer, PEX-foam insulation and covered by a corrugated, watertight, HDPE jacket. Use with ProPEX fittings (up to 3") or WIPEX dezincification-resistant (DZR) brass compression fittings.

Ecoflex potable PEX

Ideal for hot and cold potable-water applications, ASTM Ecoflex Potable PEX features Uponor AquaPEX (PEX-a) service pipe protected by multi-layer, PEX-foam insulation and covered by a corrugated, watertight HDPE jacket. Ecoflex Potable PEX uses ProPEX fittings (up to 3").

Ecoflex potable PEX plus

Ideal for direct-burial applications in freezing conditions, Ecoflex Potable PEX plus features a self-regulating heat-trace wire with a maximum output of 5 W/ft. to keep water inside the pipes from freezing.

Fire-resistant standards

National building codes, such as the IBC and UBC, require that products used in commercial construction meet specific standards. In addition to recognized product standards, PEX piping systems must meet fire-resistant construction standards. To ensure compliance with all national standards, Uponor commissioned Intertek Testing Services (formerly known as Warnock Hersey) to test and list Uponor AquaPEX and Wirsbo hePEX piping and systems. Uponor PEX achieved the following fire-resistant construction ratings when tested in accordance with the applicable standards:

- ANSI/UL 263 (ASTM E119, NFPA No. 251) "Standard for safety for fire tests of building construction and materials"
  - UL Design No. L557 rating applies to ½" to 2" Uponor AquaPEX and Wirsbo hePEX piping, fittings and manifolds installed in one-hour wood frame floor and ceiling assemblies.
  - UL Design No. K913 rating applies to ½" to 2" Uponor AquaPEX and Wirsbo hePEX piping, fittings and manifolds installed in one and two-hour concrete floor/ceiling unrestrained (and restrained) assemblies.
  - UL Design No. V444 rating applies to ½" to 2" AquaPEX and Wirsbo hePEX piping, fittings and manifolds installed in one-hour steel stud/gypsum wallboard wall assemblies.
- ASTM E84 "Standard test method for surface burning characteristics of building materials"
  - Certification of flame spread/smoke development rating of 25/50 in accordance with ASTM E84 for the following Uponor AquaPEX and Wirsbo hePEX piping sizes: 5⁄16", ⅜", ½", ⅝" and ¾".

Firestop listings

Numerous firestop systems are listed with PEX piping in one- and two-hour through penetration assemblies. Several firestop manufacturers listed their products for use with PEX piping when installed in accordance with the listed construction assembly. Acceptable firestop systems are tested in accordance with the standard below.

- ASTM E814 (UL 1479) "Standard test method for fire tests of through-penetration fire stops"
  - 3M fire protection products
  - HILTI, Inc.
  - RectorSeal, Metacaulk

Notes

Chapter 4:
Uponor distribution components

This section outlines the manifold sets available for use with radiant floor heating and cooling systems in residential and commercial applications.

Figure 4-1: Uponor stainless-steel manifold

Figure 4-2: Uponor TruFLOW™ manifold

Figure 4-3: Uponor engineered polymer (EP) manifold

Uponor stainless-steel manifold

The Uponor stainless-steel manifold is targeted for commercial and residential radiant heating and cooling applications, the Uponor stainless-steel manifold is available in 1" and 1¼" sizes and comes pre-assembled right out of the box for faster installs and greater material cost savings.

Features

- 1" and 1¼" manifold offering
- Competitively priced metal alternative
- Corrosion-resistant, stainless-steel barrel
- NPT-threaded ball valve for easy, cost-effective transition
- Balancing and isolation valves for complete loop isolation
- Compatible with all glycols used in radiant heating and cooling systems
- Integrated, full-port ball valves with temperature gauges
- Integrated flow meters for simple system balancing
  – 1" manifold features 1.5 gpm flow meters
  – 1¼" manifold features 2 gpm flow meters
- Temperature/pressure ratings:
  – 68°F (20°C) at 145 psi
  – 158°F (70°C) at 87.4 psi
  – 194°F (90°C) a t 43.8 psi
- Pre-assembled and ready to install right out of the box

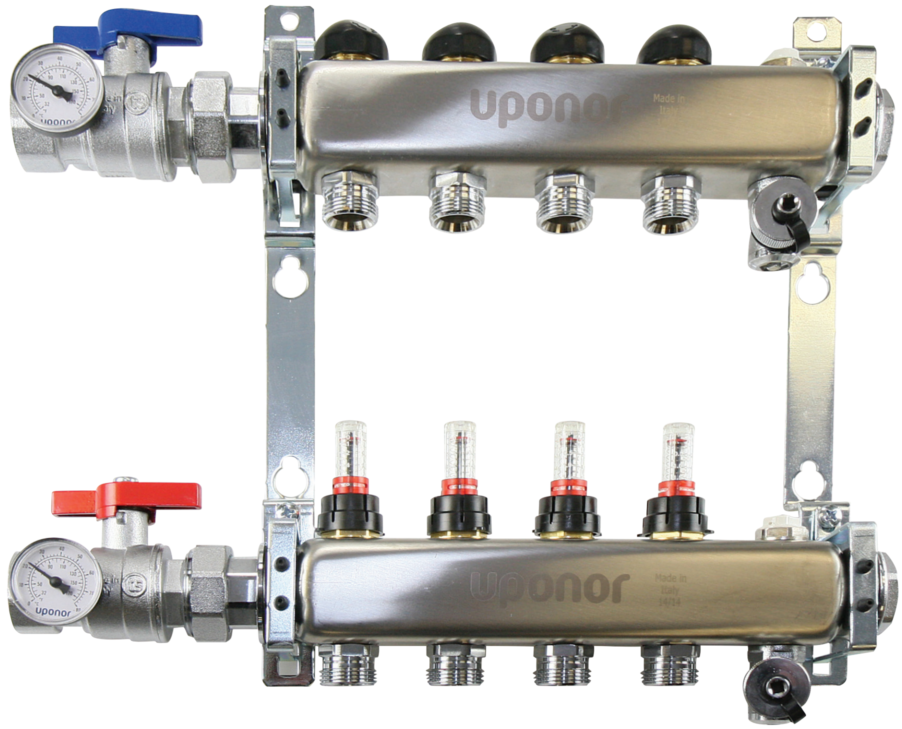


Figure 4-4: Uponor stainless-steel manifold

Stainless-steel manifolds exploded view

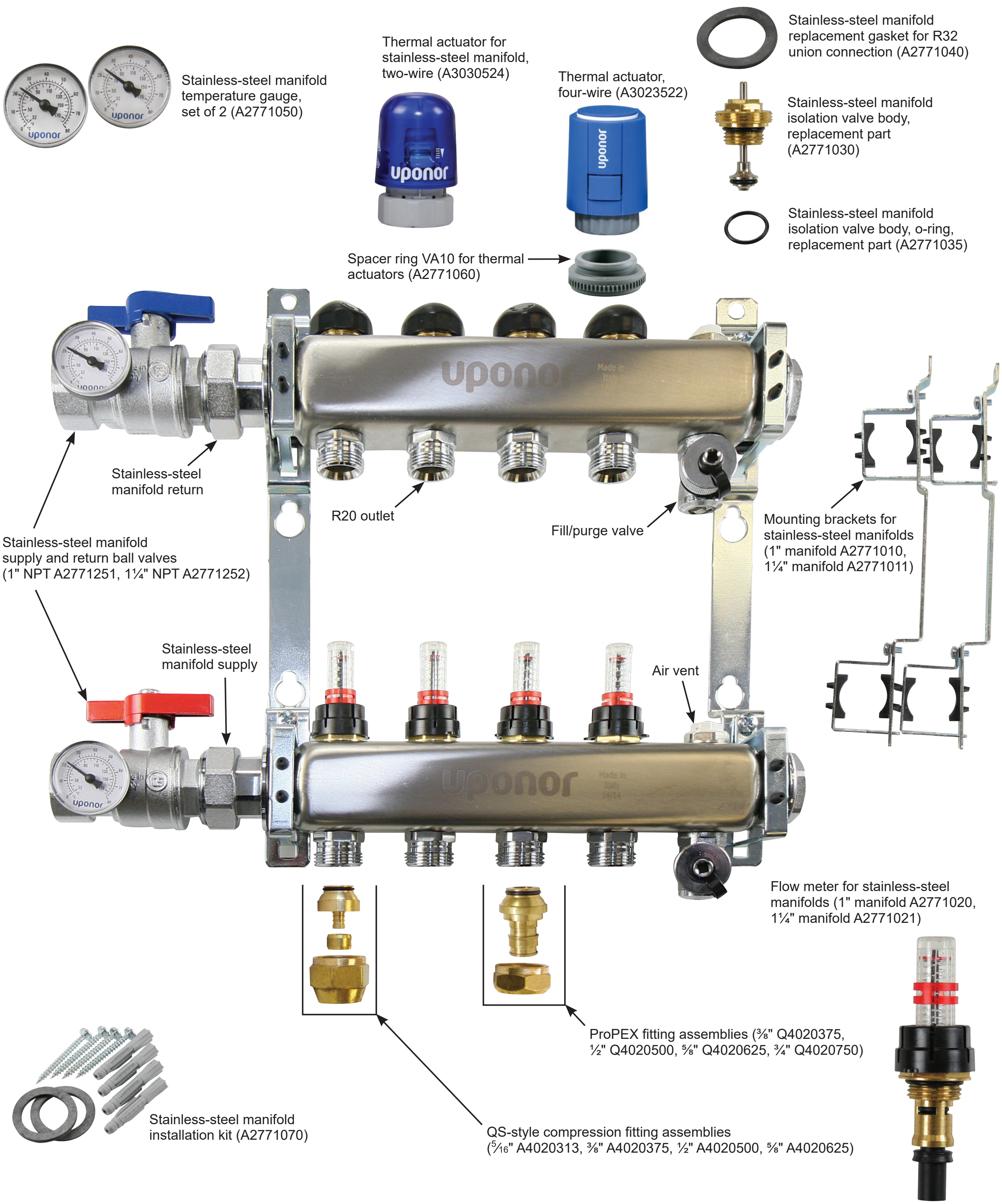


Figure 4-5: Exploded view of Uponor stainless-steel manifold

Uponor engineered polymer (EP) heating manifold

The Uponor engineered polymer (EP) heating manifold is constructed of thermoplastic, high-performance, advanced materials suitable for use under conditions of high impact, heat and moisture. They are a lightweight, economically priced and a sustainable choice for both residential and commercial radiant applications.

The EP heating manifold is rated with the following capabilities:

- 140°F at 87 psi
- 158°F at 72 psi
- 176°F at 58 psi
- 194°F at 44 psi

The manifold comes with a mounting bracket for fast and easy installation on a wall. Simply snap the manifold into the mounting bracket, and installation is complete.

The EP heating manifold is available in two through eight loops, and it accommodates 15.4 gallons per minute (gpm). Uponor also offers single loops to extend service up to 12 loops total. Refer to **page 25** for the exploded EP heating manifold view.

Balancing — Balance an EP heating manifold with the included visual flow meter.

Applicable piping — EP heating manifolds use Wirsbo hePEX and Uponor AquaPEX piping with ProPEX or QS-style fitting assemblies.

Figure 4-6: Uponor EP heating manifold

EP heating manifolds exploded view

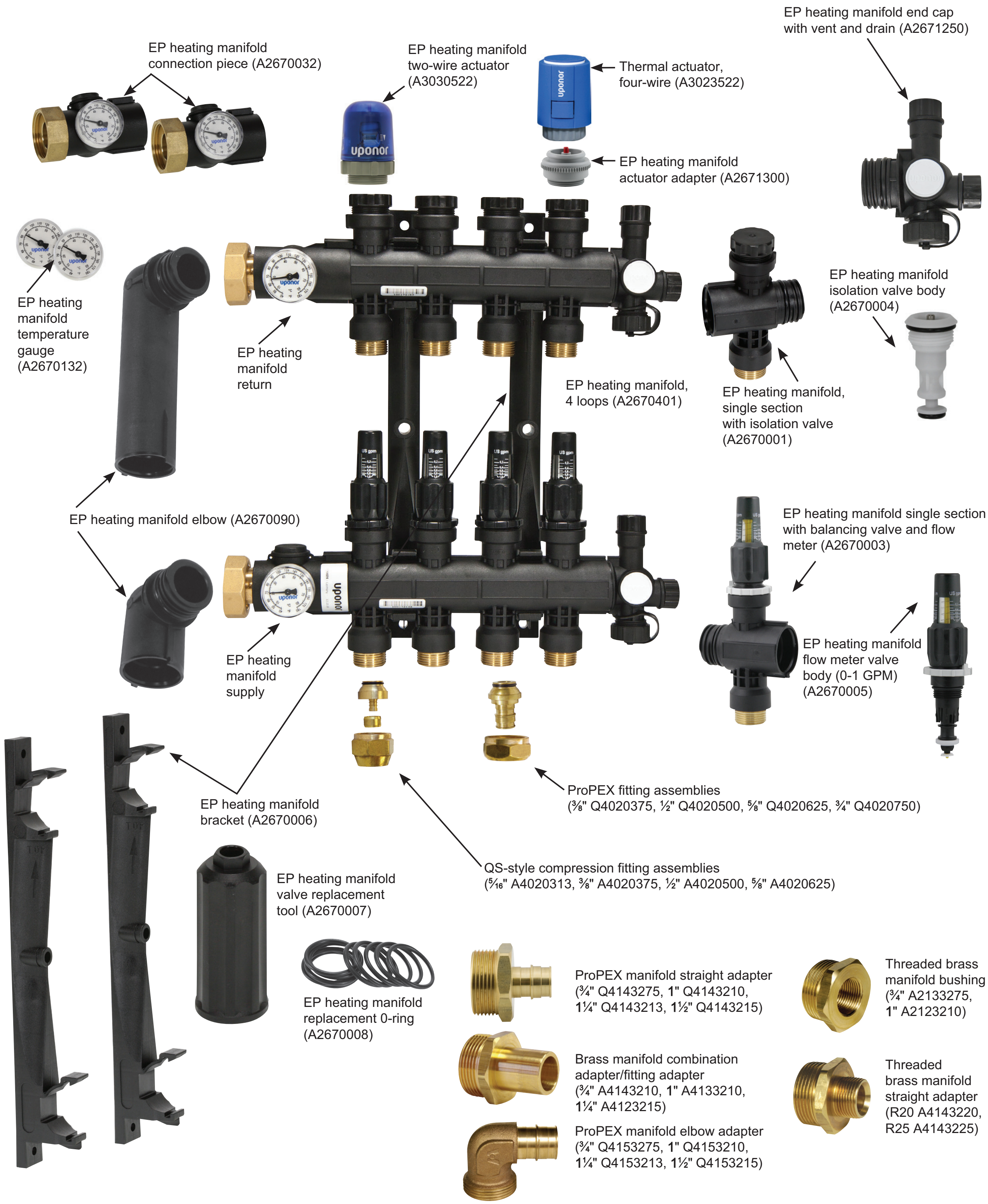


Figure 4-7: Exploded view of Uponor EP heating manifold

TruFLOW manifolds

TruFLOW manifolds are made of highly reliable extruded brass and come preassembled for easy installation. The manifold mounts on a durable metal bracket and features a basic end cap on the supply and an end cap with vent and drain on the return. The inlet side of the manifold is equipped with R32 unions to fit any manifold adapter currently offered. The supply manifold body features calibrated balancing valves. The return manifold comes with on/off valves to mount thermal actuators. Its high-flow capacity can handle up to 12-loop configurations.

Balancing — TruFLOW manifolds traditionally use balancing valves for ease in situations where loop lengths vary across the manifold body. To balance manifolds that do not have visual flow meters, refer to Performing Initial Flow Balance Calculations on **page 96**.

The TruFLOW manifold is also available in a valveless configuration for situations that do not require balancing on the loops. For example, a manifold that has only one zone, equal loop lengths and is configured in a reverse-return orientation would be a great application for the TruFLOW valveless manifold.

The maximum operating temperature and pressure for the TruFLOW manifolds and flow/temperature meters is 220°F at 145 psi. Refer to **page 27** for the exploded TruFLOW manifold view.

Applicable piping — TruFLOW manifolds support the following piping.

- ½", ⅝" and ¾" Wirsbo hePEX and Uponor AquaPEX piping with ProPEX fitting assemblies
- ⁵⁄₁₆", ⅜", ½", ⅝" Wirsbo hePEX and Uponor AquaPEX piping with QS-style compression fitting assemblies

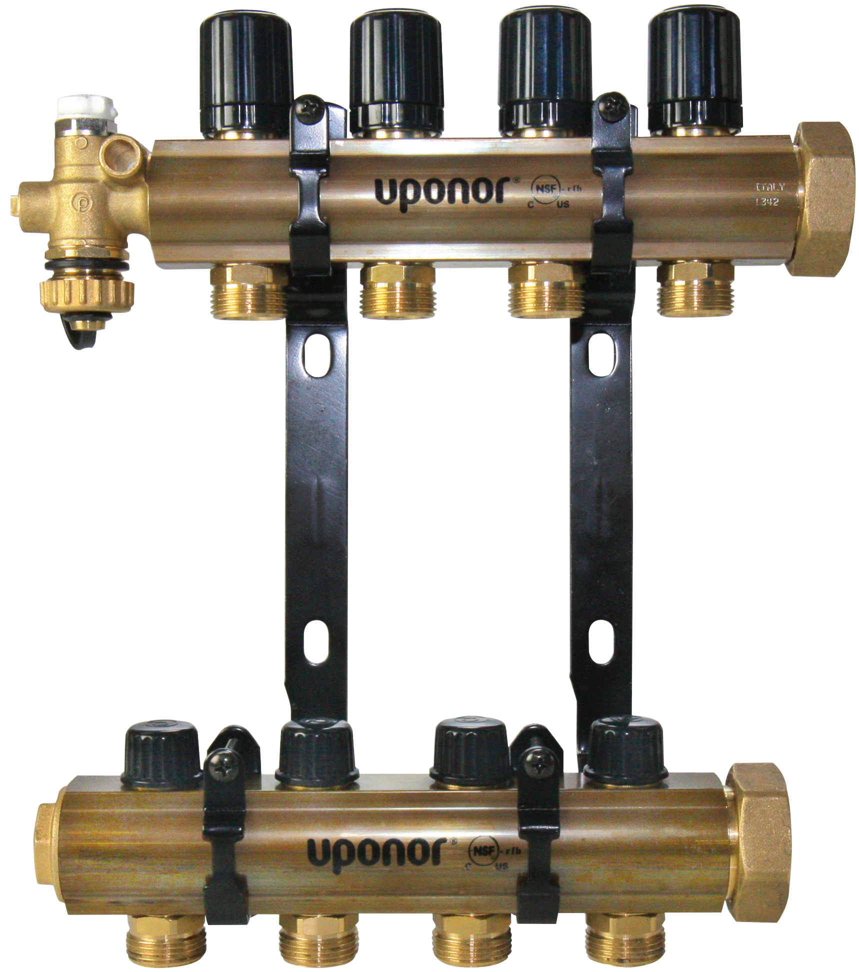


Figure 4-8: Uponor TruFLOW manifold

TruFLOW Classic and Jr. manifolds exploded view

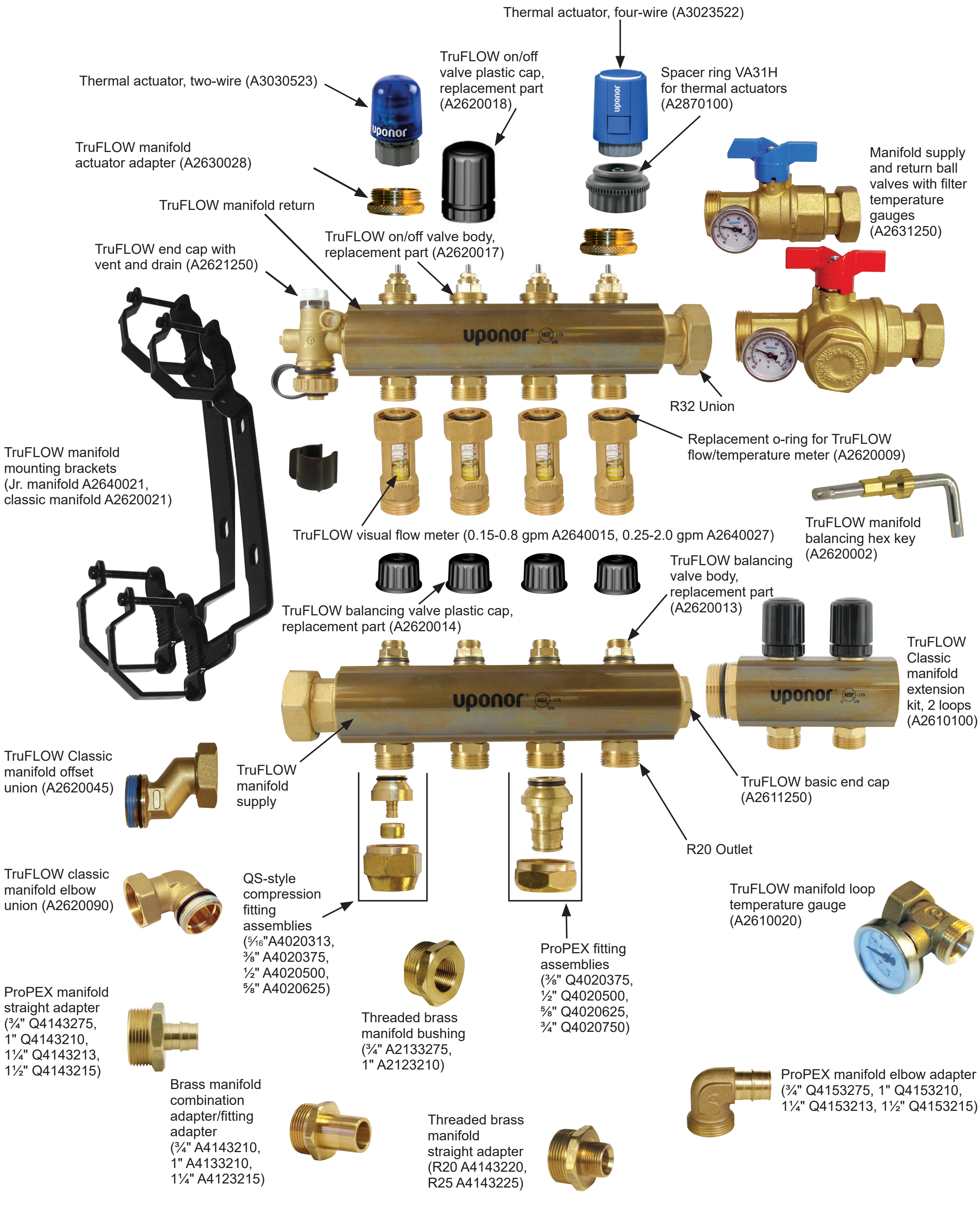


Figure 4-9: Exploded view of Uponor TruFLOW manifold

HDPE valveless manifolds

The HDPE manifolds are available in 3 and 4-inch dimensions. The manifolds feature 300-series stainless steel ProPEX fitting adapters preformed on the HDPE outlets. The manifold is designed to only support ¾" and 1" PEX piping. The HDPE manifolds do not offer an oxygen-diffusion barrier. Primary application is for direct burial in systems isolated with a heat exchanger.

Balancing — HDPE manifolds are not designed to balance across the manifold. All loop lengths must be within 3% of each other in length on the manifold.

Example

If the design calls for 267-foot loops on the manifold, then the range of loop lengths must fall within 263 and 271 feet. Three percent of 267 feet is 8 feet — 4 feet on either side of your target length.

Supply and return piping to the manifold should be installed in a reverse-return configuration to allow self-balancing across the manifold.

Applicable piping — HDPE manifolds support the following piping.

- ¾" and 1" Wirsbo hePEX and Uponor AquaPEX piping with ProPEX fitting assemblies

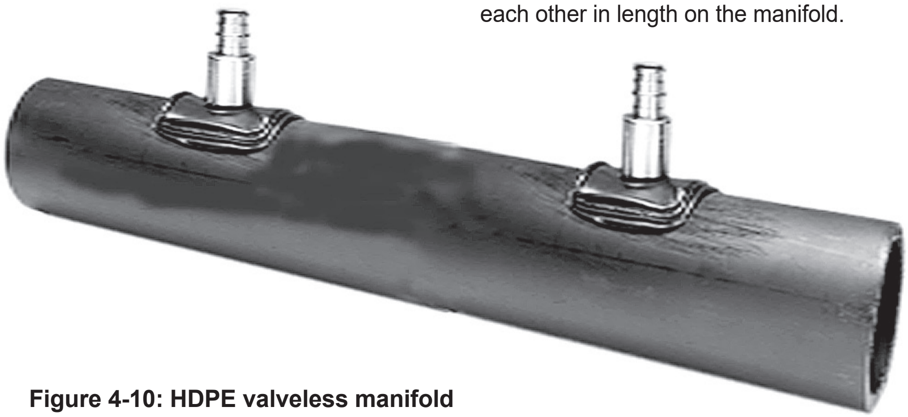


Figure 4-10: HDPE valveless manifold

Copper valved manifolds

These 2-inch copper valved manifolds are 48 inches long with 12 valved outlets. The outlets come in several configurations of ProPEX or male threaded connections. The outlets are valved with either a ball valve (isolation) or a ball valve/balancing valve combination (isolation with balancing).

Balancing — Remove the knurled safety cap from the valve. Using an Allen or hex key, turn the memory spindle clockwise until closed. To balance, turn the hex key (counterclockwise) the number of required turns from close. Replace the safety cap.

The longest loop on the manifold will be left full open. From closed to full open is 10 full turns of the memory spindle. Balance the other loops using this formula:

Loop to be balanced/longest loop on the manifold x 10 = number of turns from closed

Example

Loop to be balanced: 250 feet

Longest loop on the manifold: 300 feet

x = 250 / 300 x 10
x = 0.83 x 10
x = 8.3

The memory spindle for that 250-foot loop would be turned open 8.3 turns from closed.

Applicable piping — These copper valved manifolds support the following piping.

- ⅝" and ¾" Wirsbo hePEX and Uponor AquaPEX piping with ProPEX or QS-style fitting assemblies

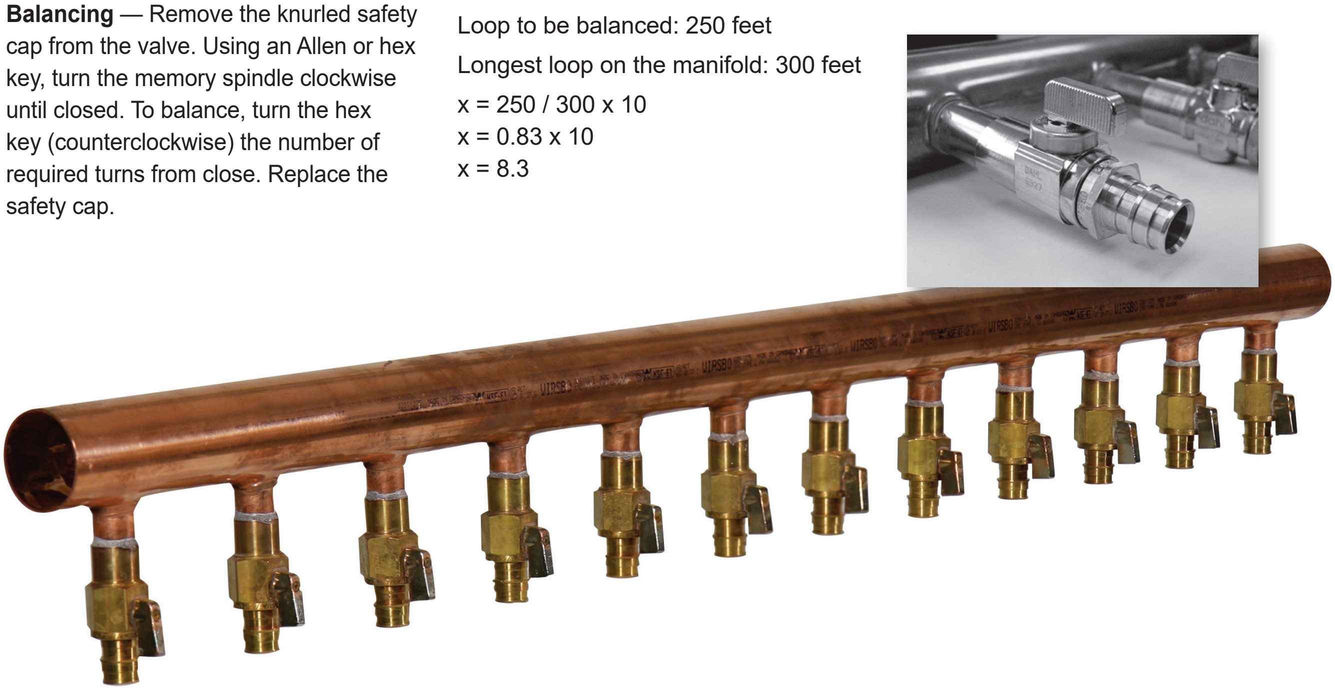


Figure 4-11: Copper valved manifolds

Chapter 5:
Economy of design

Technology is constantly evolving. What was once considered innovative, or even far-fetched, becomes the norm. For example, the earliest pioneers of computers did not anticipate that people would want or even need a computer in their homes. Now, they're as common as television sets, mobile phones and iPads.

So, too, have things evolved in the heating industry. Just two decades ago, few people were aware of radiant floor heating, and even fewer seriously considered installing it in their homes. Now, radiant floor heating is the fastest growing segment of the heating industry in North America.

In today's world, if contractors are not accessible by e-mail or at least a cell phone, customers wonder about the contractor's ability to provide current technologies for their home. As technology evolves, so must heating and cooling solutions. The days of manual mixing valves and single thermostats in a radiant floor system are almost obsolete. Contractors must continually train and become educated about newer technologies.

This chapter highlights some of the newer technologies in radiant floor heating that are available to heating professionals from Uponor.

Figure 5-1: Uponor EP heating manifold

Manifolds

A contractor no longer needs to consider zoning by manifold throughout the structure. It is more economical to install multiple zones per manifold location than to install multiple manifold locations. Consider the amount of time it takes to install several manifold locations compared to just a few.

Another factor to consider is the lack of zoning in a structure. For example, forced-air systems typically only use one thermostat for the entire building. Radiant floors, however, allow customized zoning for different rooms. Remember, a radiant floor heats only the space above it and does not migrate to other rooms. Too often, large homes are installed with minimal zoning, so the customer is forced to compromise on comfort.

Manufacturers are responding to the market's desire for speed and simplicity. Earlier versions of manifolds left the contractor assembling the manifold sections. Now, the contractor simply pulls an assembled manifold set out of the box and mounts it in the proper location. The only requirement for the contractor is to install the different options ordered with the manifold.

Figure 5-2: Uponor wireless digital thermostat (left) and heat-only thermostat with touchscreen (right)

Thermostats

The customer's point of interface with the heating system is the thermostat. Some contractors feel that a thermostat is a thermostat — any one will work as well as another. That's like saying a car is just a car. Along with other hydronic controls, thermostats have also evolved to provide a sophisticated control interface.

In the past, the only function of a thermostat was activating one appliance on a call for heat. That simplicity required a basic design. Lifestyles have changed, and heating equipment offers greater diversity. Using an old thermostat designed in the 1950s is like putting a single-barrel carburetor on a Ferrari®. It will run, but it will come nowhere near providing the performance the customer expects.

Uponor thermostats are specifically designed to support radiant floor applications. Anticipation of radiant mass is different than that of air mass. Also, radiant floor systems have a number of voltage load changes across the circuit due to the opening and closing of zone valves or actuators. Most forced-air thermostats do not consider these options in their design. Do not limit the customer's control of their system by using thermostats not designed for radiant applications.

Reset controls

Reset controls, used in baseboard systems for years, have a proven track record for saving money by reducing fuel utilization. Using reset with radiant system also makes sense. Reset allows the supply water temperature to adjust as the outdoor temperature fluctuates. In turn, this helps eliminate short cycling of the boiler.

Note that modulating-condensing (mod-con) boilers can provide reset to a radiant system. Accordingly, it isn't necessary to include additional mixing controls in the radiant system when a mod-con boiler is providing that control.

Design software

Design software provides three primary advantages: speed, accuracy and documentation. The computer printout provides documentation of the design at the time of design. Should the customer change any of the structural design, the heating system designer can document the requirement for a change order. The documentation protects both the designer and the customer. The designer documents the system, and the customer receives documentation of their project. See **Chapter 7** for more information about Uponor design software.

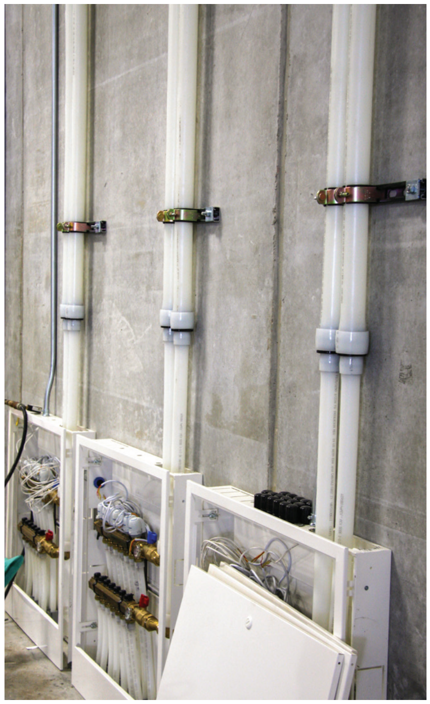


Figure 5-3: Wirsbo hePEX distribution piping

Distribution piping

Consider the speed of installation using PEX piping for distribution piping between manifolds and the mechanical room. The piping is woven through the truss or joist at a fraction of the time needed to install copper piping. And no joints means a straight, seamless run.

Optimal spacing

Typical piping spacing for radiant systems in concrete slabs is 12 inches on center when used to heat living spaces (unless the design dictates otherwise). In areas — such as storage areas and garages — that are not considered living spaces, piping spacing may be increased to 18 or 24 inches on center. The key is meeting the heat loss, which determines the appropriate piping spacing along with other design elements. Use the Uponor radiant design software to gauge the impact on water temperatures.

Do not install piping where it is not required. An area that will be used for cold storage would not require piping as the contents of the room do not require a conditioned space. Interior rooms with no exposed walls or ceiling loss are also areas where piping may not be needed. An exception may be an interior bathroom with tile flooring. Installing piping will provide comfort where the floor might otherwise be unpleasantly cool.

Figure 5-4: Uponor LoopCAD® radiant design software

Figure 5-5: Uponor Radiant Rollout Mat

Radiant Rollout™ Mat

Uponor has introduced several products that can significantly lower total installed cost for a radiant heating system. The Radiant Rollout™ Mat is a custom-designed, prefabricated network of Uponor PEX-a piping (Wirsbo hePEX barrier piping or Uponor AquaPEX non-barrier piping) connected with ProPEX engineered plastic (EP) fittings, which are safe for direct burial in a slab. The product comes from the factory pre-pressurized to protect against damage during shipping. The mats are constructed with an in-slab, reverse-return header assembly so each mat only has one supply-and-return line. This construction significantly reduces the required number of wall-mounted manifolds. As the mats are custom-designed for each project, the installer simply anchors the header in place and rolls the mat out into its designed location — providing a fast, efficient, and consistent method for installing radiant piping in large areas. The faster installation time reduces installation labor costs and helps contractors stay on schedule — so projects are completed and building open on time.

Fast Trak™

Fast Trak™ is a product line offered by Uponor that removes complexity from radiant installations, yielding reductions in installation time and system cost.

Fast Trak 0.5 is offered as a solution for applications where ceiling height is at a premium. Fast Trak 0.5 requires a total flooring height increase of less than 1 inch, which is unprecedented for poured underlayment applications. This minimal total flooring height minimizes adjustments needed to stairs and door frames, reducing extra work after the radiant installation is complete. Fast Trak 0.5 is very easy to install because it comes with an adhesive backing that sticks to the existing slab — eliminating any sliding that might otherwise occur.

Fast Trak 1.3i is offered for applications where a thermal break is recommended — for example, with an uninsulated slab over a high water table. Fast Trak 1.3i comes with a layer of expanded polystyrene directly below the knobbed area, providing a layer of insulation and a method to fasten the piping in one package. This product not only reduces installation time for the contractor, but also saves the property owner money through reduced monthly energy bills.

Both Fast Trak panels are easy to cut and fit into any floor geometry; simply snap the panels together to make a continuous mat. Also, since the piping snaps between the knobs on the panel, it is easy to achieve a variation of on-center tube spacing as well as a multitude of layout options.

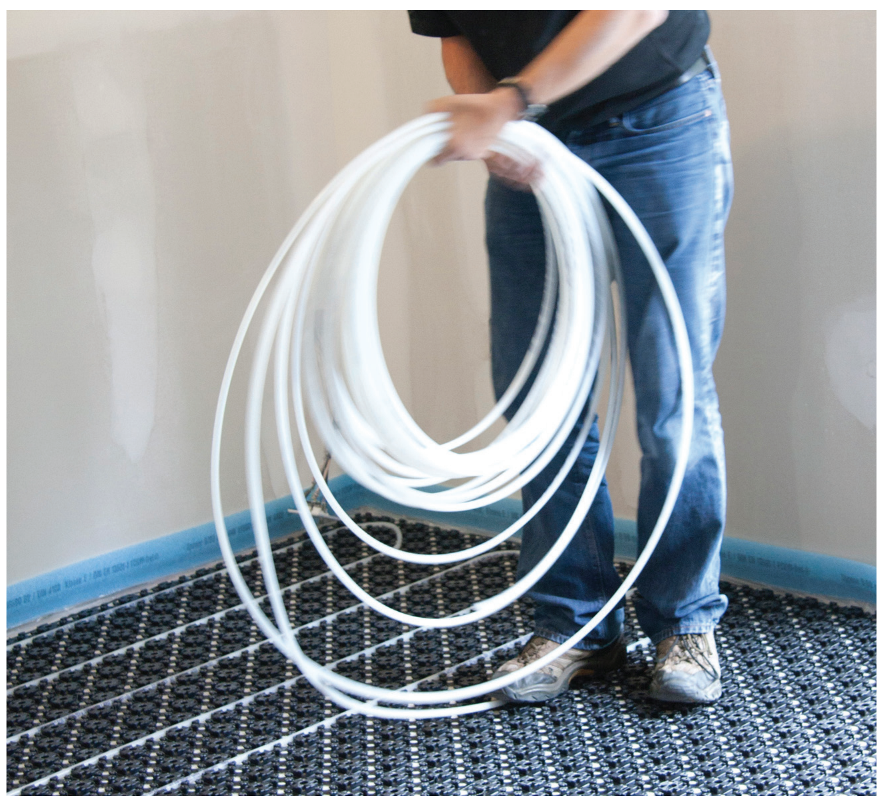


Figure 5-6: Uponor Fast Trak knobbed mats

Ecoflex

Ecoflex is yet another Uponor product that reduces total installation time and delivers cost savings. Ecoflex is a flexible, pre-insulated and jacketed PEX-a product that is typically buried underground. Ecoflex can be buried in unlevel and serpentine trenches — making it a viable solution for potable, hydronic or chilled-water distribution applications. It offers significant advantages over rigid piping: eliminates expansion joints, reduces trenching time, is available in continuous lengths up to 600 feet, uses high-flow ProPEX fitting technology and offers more than 25 years of success. Ecoflex can reduce installation time by up to 70% while reducing risk to the contractor and property owner by removing unnecessary fittings and connection points in the ground.

Figure 5-7: Uponor Ecoflex pre-insulated pipe

Figure 5-8: Ecoflex connection vault

Chapter 6:
Installation methods

This chapter profiles a number of radiant floor and ceiling installation techniques and some helpful hints. Each page includes a detailed illustration, as well as how, where and what to look for when installing radiant heating. Listed below are several general categories of installation methods with several approaches detailed within these categories.

- Slab on or below grade
- Poured-floor underlayment
  - Fast Trak™
  - Staple down
- Dry above
  - Quik Trak® for floors
- Staple up
  - Joist Trak™ panels
  - Joist heating
- Radiant wall
  - Quik Trak for walls
- Radiant ceiling
  - Joist Trak panels

Site preparations

The key to any successful installation is coordination and preparation of the project site. A professional, cooperative approach will make the installation a positive experience for all involved. Respect the work of others. There are phases to the construction schedule. A little planning and coordination will streamline project installation.

Phase 1: Preparatory — Ensure the latest changes to the design are incorporated to avoid work stoppage or distractions during the installation phases. Coordination between other trade personnel on the site is crucial for an effective and efficient installation. Normally, the general contractor is responsible for this coordination. If needed, coordinate between the other heating, cooling and electrical trades yourself to eliminate any possible conflicts.

Phase 2: Initial — Take the time to assign the loop lengths used from each piping coil. This effort will minimize waste piping. Use a piping uncoiler. A good uncoiler eliminates needing another person for the job.

If the preparatory phase is executed correctly, the installer can quickly run the supply and return piping and low-voltage wiring for the manifold locations with minimal conflict. Coordinate with the carpenters for each manifold location rough-in. Remember to let the electrician know your requirements throughout the structure as well as in the mechanical room.

Be sure to keep the jobsite clear of debris and tools. The general contractor should coordinate a debris collection on the jobsite to facilitate cleanup. Plan for each day's scheduled work to ensure the availability of materials and labor.

Phase 3: In progress — Coordinate the piping installation to minimize other trade traffic over the exposed piping. Pressure test from each manifold location. Install isolation ball valves on the supply and return piping to the manifold at the manifold location. This isolates the manifold and distribution piping from the supply and return piping for air testing. The sequence for air testing begins at the manifolds, then the supply and return piping and finally within the mechanical room.

When running low-voltage wiring, always run more wire in the bundle than needed. For example, if the thermostat requires two wires for proper operation, run at least three-wire thermostat wire. The additional wire comes in handy should one of the wires break within the bundle. If only two wires are installed, a lot of time and money is spent trying to find the location of the break. The cost difference is insignificant between two-wire and three-wire thermostat wire, but it can save profit on a job.

It is a good practice to draw the mechanical layout before construction begins. The drawing helps identify any potential problems, which can be corrected prior to installation. The drawing also helps identify products for the final mechanical material list.

Phase 4: Completion — Once the piping installation is complete with connections to the manifold, pressure test it to a minimum of 60 psi for at least 24 hours (or to local code requirement) to ensure system integrity. Also, keep the system under pressure during the concrete pour or when other trades are working in the area of the piping. Pressurize the system with air. If water is used, you must drain and blow out the system after the pour to prevent freezing. Water is not recommended when weather is close to freezing since it is nearly impossible to completely drain the system.

Assemble a binder for the end user that contains all the heat loss, design and performance information for the radiant floor system. Add other component information, including warranty documentation. If involved with service support, offer a service contract for the system.

Phase 5: Testing and start up — Review the mechanical drawings in **Chapter 13** for placement of the initial fill stations. Proper placement will save time when filling and bleeding the system. Using an air eliminator in the boiler room helps eliminate micro air bubbles from the system. The air eliminator is usually installed with the expansion tank piped in from below. If an automatic fill station is used, it is normally installed between the expansion tank and the air eliminator.

Follow the manufacturer's instructions when testing all electrical components. Ensure all thermostats function properly, and activate the corresponding thermal actuator, zone valve or circulator. After the system is filled and bled of air, fire the boiler and pumps to ensure proper operation.

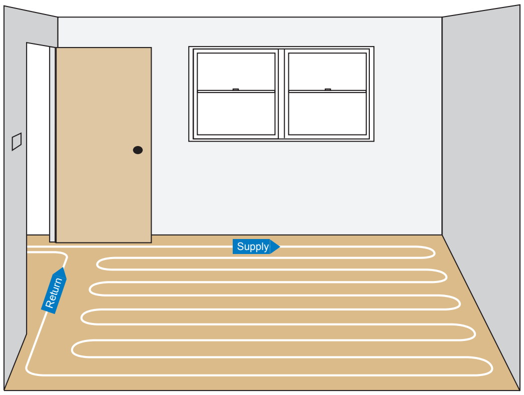


Figure 6-1: Single-wall serpentine piping layout

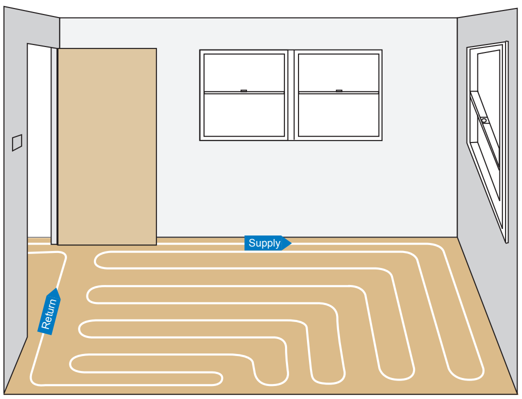


Figure 6-2: Double-wall serpentine piping layout

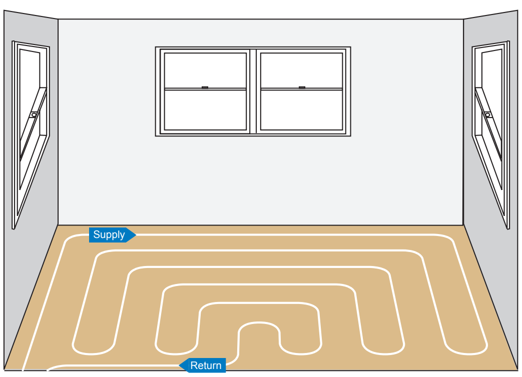


Figure 6-3: Triple-wall serpentine piping layout

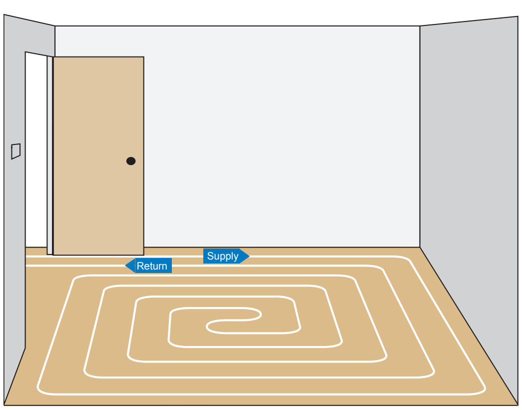


Figure 6-4: Counter flow piping layout

Installation

The following section addresses some common installation procedures and material use.

Review and understand material capabilities and limitations, and ensure compliance with local and state code requirements. Establish good communication with the code inspectors in your area to avoid any surprises. Challenges may arise when different installation practices or components are not clearly addressed in the codes. If you have questions concerning the codes, contact your local inspector. Most inspectors appreciate working with proactive contractors.

Piping layout patterns

The four most common piping layout patterns are single-wall serpentine, double-wall serpentine, triple-wall serpentine and counter flow. The object of each method is to replace the heat loss of the zone where it occurs as precisely as possible. This is accomplished by supplying the warmest water to the areas of the zone with the highest heat loss. As the heat loss diminishes, so does the heat requirement. More than one pattern may be used within a single loop or when an area requires multiple loops.

Single-wall serpentine — Use this pattern when a single wall represents the major heat loss of the zone. Feed the supply directly to the high heat-loss wall and then serpentine toward the lower heat-loss area. Piping runs start 6 inches from walls or nailing surfaces. Six-inch on-center piping runs are often installed 12 to 18 inches from the exterior wall to improve response time (see **Figure 6-1**).

Double-wall serpentine — Use this pattern when two adjacent walls represent the major heat loss of the room. Feed the supply directly to either of the heat-loss walls and then serpentine toward the lower heat-loss area in an alternating pattern against the two heat-loss walls. Piping runs start 6 inches from walls or nailing surfaces. Six-inch on-center piping runs are often installed 12 to 18 inches from the exterior wall to improve response time (see **Figure 6-2**).

Triple-wall serpentine — Use this pattern when three walls represent the major heat loss of the room. Feed the supply along the heat-loss walls in an alternating pattern and serpentine toward the lower heat-loss area of the room. Piping runs start 6 inches from walls or nailing surfaces. Six-inch on-center piping runs are often installed 12 to 18 inches from the exterior wall to improve response time (see **Figure 6-3**).

Counter flow — Use this pattern when the heat loss for the room is evenly distributed throughout the entire room or when the major heat loss is the floor. Feed the supply along the exterior of the room, spiraling inward. Once the piping reaches the center of the room, the return spirals outward, parallel to the supply. Piping runs start 6 inches from walls or nailing surfaces. Six-inch on-center piping runs are often installed 12 to 18 inches from the exterior wall to improve response time (see **Figure 6-4**).

Insulation

Insulation is crucial for proper and efficient operation of radiant heating systems. Heat energy flows in the line of least resistance. Proper use of insulation directs the flow of heat toward the intended space. Good insulation practices also improve response time of the system.

Under-slab insulation

Under-slab insulation must be rated for use in that application. Insulation below heated concrete slabs must withstand the weight of the slab along with any additional dead or live loads. When concrete is applied over the insulation, the weight of the concrete causes the insulation to compress slightly. The amount of compression depends on the weight of the concrete, the thickness of the insulation and the compressibility of the insulation. Although compression reduces the insulating effect of the foam, it presents little structural effect because it remains relatively constant over the life of the structure.

A more important structural factor is the long-term compressive creep that occurs within the insulation. Creep should be accommodated in the ability of the slab to move relative to the plane of its surface. Foam insulation manufacturers provide specific recommendations regarding the limits of live and dead loads, compressive creep and the proper application of their products. Check with the foam insulation manufacturer for more information.

Use under-slab insulation when high water tables and/or moist soil conditions are present. If a known moist soil condition exists, ensure an effective drainage system is installed beneath the intended radiant floor slab. After proper compaction, install a vapor barrier over the soil, and then install the high-density insulation. The drainage system is crucial to the success of the radiant floor system. Without correcting the moist soil condition beneath the slab, downward losses can exceed heat loss of the room above.

When in doubt, insulate. The situation cannot be corrected after the structure is complete. Additionally, proper insulation means better and more efficient operation for the life of the system.

Between-floor insulation

Insulation is normally considered for areas in contact with the exterior of the structure. With radiant floors, often the need arises for insulation between the heated floors to direct the flow of heat upward. The accepted rate of insulation between floors is a ratio of 5 to 1. For every value of resistance upward, install five times that resistance beneath the heating system. For example, if the total resistance value above the heating system (floor coverings, etc.) is R-2, then install at least R-10 beneath the heating system. In this situation, 3½ inch batt insulation (R-11) would be sufficient.

Vertical or edge

This area denotes the vertical edge of the slab or profile. Edge insulation keeps the heat contained within the area for which it is designed and minimizes lateral heat loss.

Construction, expansion and control joints

Construction, expansion and control joints are required for every slab application of any size. Coordination between the engineer, concrete installer and the radiant floor contractor is essential to avoid confusion and delays on the project.

Construction joints

Construction joints separate individual pours of a slab completed at different times. Because it is difficult to construct a large slab in one pour, a bulkhead is installed to contain sections of the slab until the next phase is poured. A phased approach makes it easier to move concrete equipment and reduces the chances that the piping will be damaged during installation.

To avoid the construction joint during installation, dip the piping below the slab into the subsoil or sleeve the piping with pipe insulation or plastic piping 6 inches on each side of the joint (see **Figures 6-5 and 6-6**).

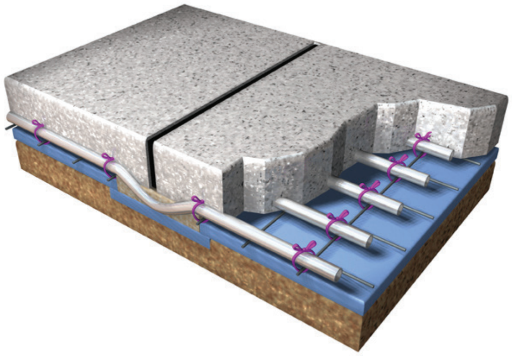


Figure 6-5: Piping dipped below construction joint

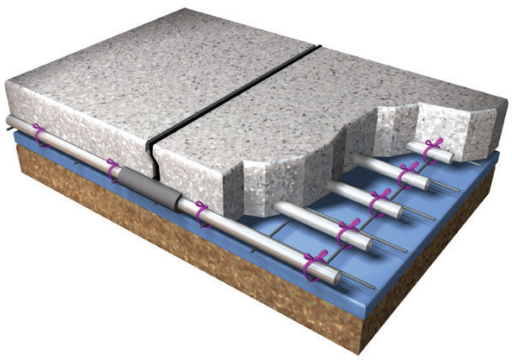


Figure 6-6: Piping wrapped with pipe insulation near construction joint

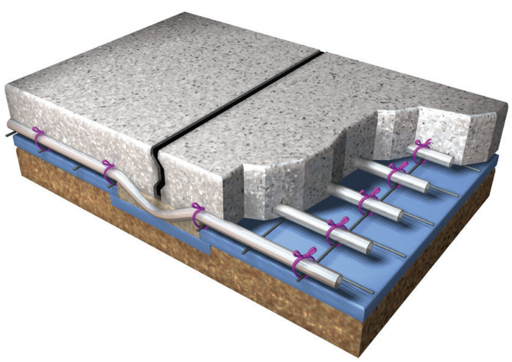


Figure 6-7: Piping dippped below expansion joint

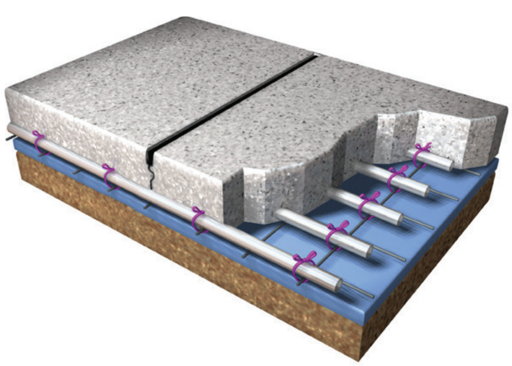


Figure 6-8: Piping secured on each side of control joint

Expansion joints

Expansion joints (also called isolation joints), absorb horizontal movement caused by the thermal expansion and contraction of the slab. Radiant floor heating systems can reduce the range of expansion the slab experiences by maintaining a fairly consistent temperature across the slab area.

If the piping must penetrate the fibrous expansion joint, wrap it with pipe insulation for 6 inches on both sides of the expansion joint (see **Figure 6-6**).

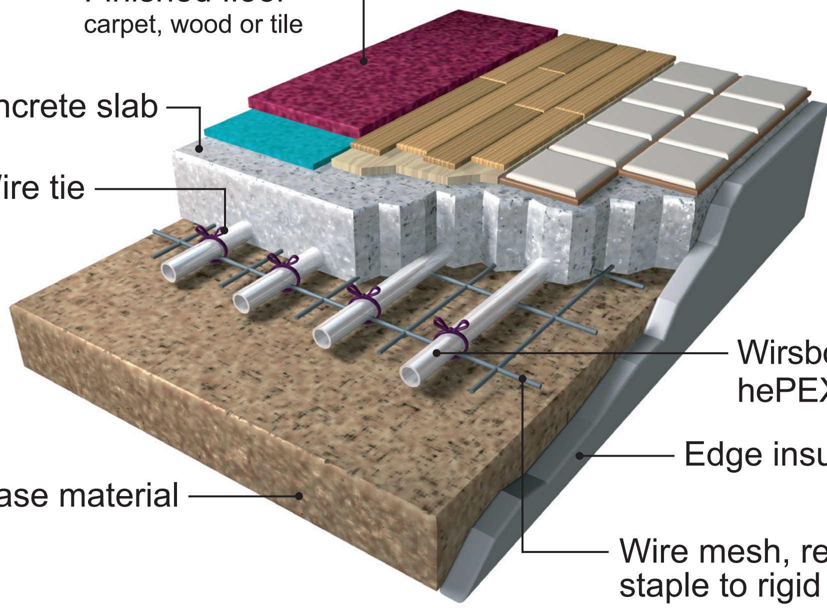
Another option is to dip the piping below the slab into the subsoil (see **Figure 6-7**). When foam insulation is used to sleeve the PEX piping running through an expansion joint and/or to accommodate minor shear action, minimum cover should be determined by the wall thickness of the insulation. For example, if the insulation used is to accommodate ⅜ inch of vertical shear, select pipe insulation with a minimum wall thickness of ⅜ inch.

Control joints

Control joints allow the concrete to fracture along a controlled line. There is no concern for the piping penetrating beneath a cut joint during the cracking phase of the concrete. The concern for the piping is during the phase in which the concrete is initially cut. Depending on the depth of the concrete, the control joint may penetrate from ½ inch to depths greater than 1 inch.

Ensure that the piping is secured from the reach of the saw blade and cannot be harmed. It is recommended to secure the piping 6 inches on each side of the control joint. It is important to mark where the joint can be made after the pour (see **Figure 6-8**).

Note: When designing a radiant floor system, avoid passing the piping through or below construction, expansion and control joints whenever possible. Coordinate the placement of these joints prior to designing the piping layout.



Slab on or below grade with edge insulation only

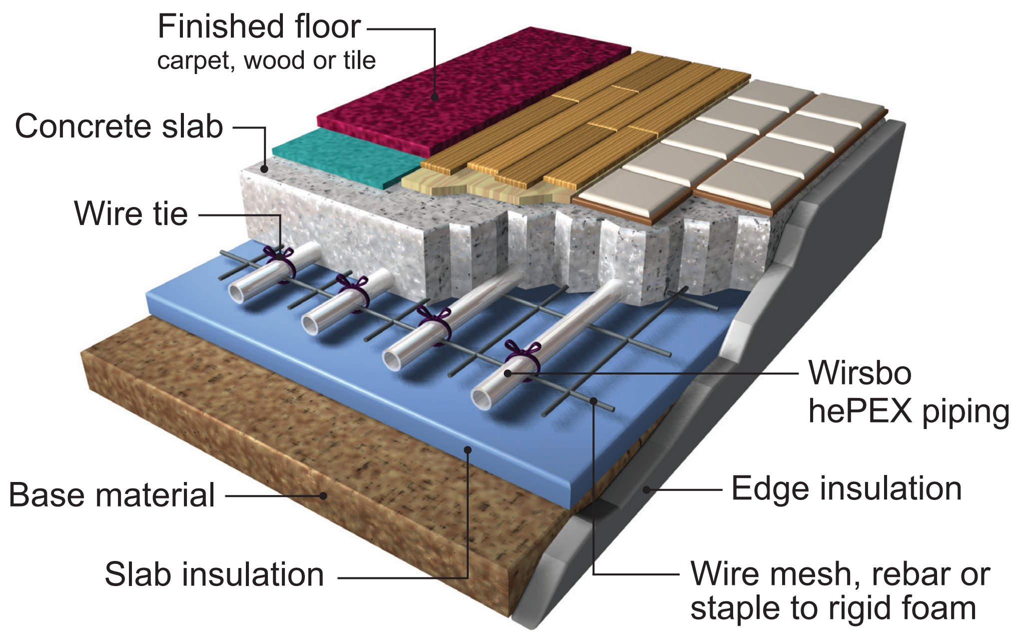
How — Place wire mesh or rebar over the compacted base material. Using Uponor Fixing Wire, secure the piping to the wire mesh or rebar. Space the wire ties a minimum of every 3 feet along straight runs. At the 180-degree turns, tie the piping at the top of the arc and once on each side, 12 inches from the top of the arc. This prevents the piping from dislodging and/or floating up into the pour.

Connect the piping to the manifold, and pressure test to a minimum of 60 psi at least overnight to ensure system integrity. Keep the piping under pressure until after the concrete is poured.

Where — This application is used primarily in commercial and light commercial construction, where room setpoint temperatures and space activities remain fairly constant. This method has several advantages including lower material costs and greater thermal storage ability. Some of the drawbacks include greater initial heat demand, longer ramp-up periods and slower response times to room setpoint changes.

What to look for — under-slab heat loss may be critical to the performance of this radiant slab design. Complete under-slab insulation is required when:

- High water table or moist soil conditions are present
- Bedrock or ledge is present
- The upper envelope heat load is greater than 25 BTU/h
- Floor covering R-value is greater than 2.0
- The linear feet of perimeter is high in comparison to the gross floor area, as in most residential applications



Slab on or below grade with under-slab and edge insulation

How — Place suitable, high-density rigid foam insulation over the compacted base material. Using Uponor Foam Staples with the Uponor Manual Stapler, secure the piping to the high-density insulation. Place the staples a minimum of every 3 feet along the straight runs. At the 180-degree turns, staple the piping at the top of the arc and once on each side, 12 inches from the top of the arc. This prevents the piping from dislodging and/or floating up into the pour.

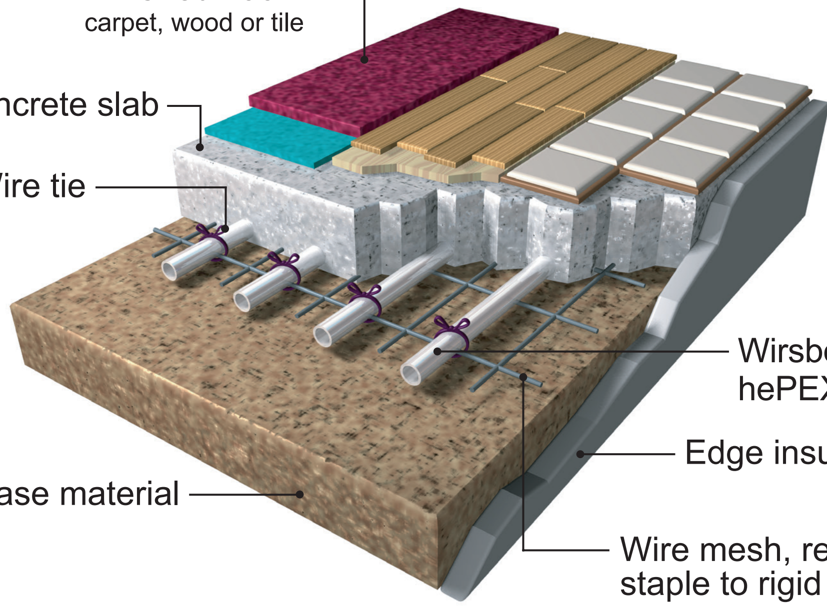
Connect the piping to the manifold, and pressure test to a minimum of 60 psi at least overnight to ensure system integrity. Keep the piping under pressure until after the concrete is poured.

Note: The wire mesh or rebar is used only as a grid system to secure the piping. Mesh or rebar has no reinforcing value when installed at the bottom of the concrete slab.

Where — This method is primarily used in residential slab on or below grade installations or where downward losses are great. Some of the advantages of this method include quicker response time, lower initial heat load and lower operational costs through the life of the system. The primary drawback is higher costs up front for the initial materials due to the high-density insulation.

What to look for — Under-slab heat loss may be critical to the performance of this radiant slab design. A minimum of 1 inch of insulation is used. When one or more of the items listed below are involved with the application, a minimum of 2 inches of insulation is required.

- High water table or moist soil conditions are present
- Bedrock or ledge is present
- The upper envelope heat load is high
- High R-value floor coverings are used
- The linear feet of perimeter is high in relationship to the gross floor area, as in most residential applications



Slab on or below grade over a compacted soil/sand bed

How — Place the wire mesh or rebar over the compacted base material. Using Uponor Fixing Wire, secure the piping to the wire mesh or rebar. Place the wire ties a minimum of every 3 feet along straight runs. At the 180-degree turns, tie the piping at the top of the arc and once on each side, 12 inches from the top of the arc. This prevents the piping from dislodging and/or floating up into the pour.

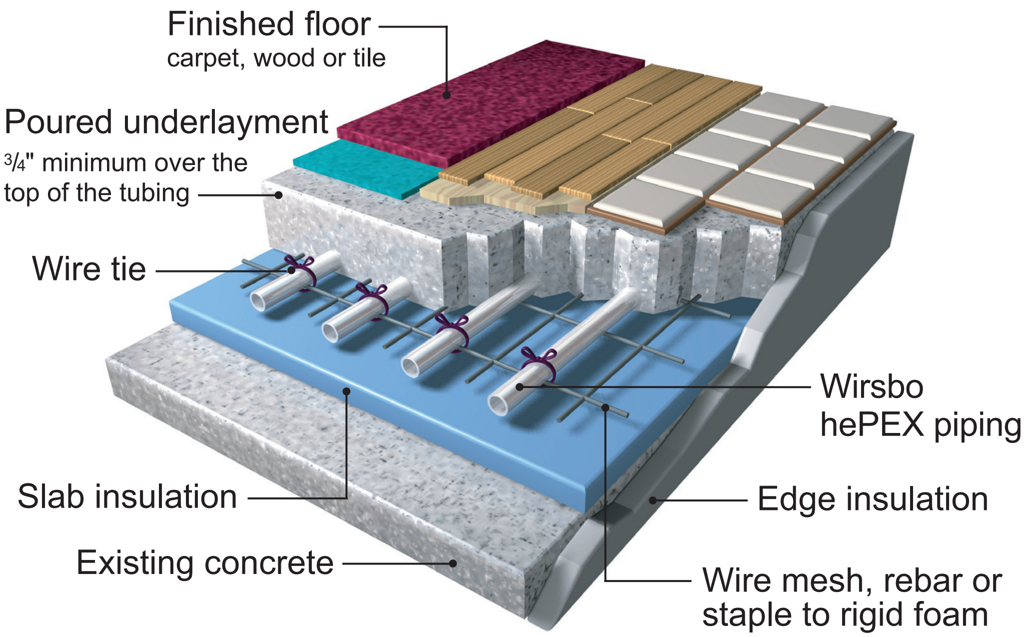
Connect the piping to the manifold, and pressure test to a minimum of 60 psi at least overnight to ensure system integrity. Keep the piping under pressure until after the concrete is poured.

Lay and level a 2-inch layer of medium-grade, compacted soil/sand fill over the piping. Ensure the fill over the piping does not contain sharp aggregate. Pour concrete over the soil/sand bed.

Where — This method is used primarily in commercial and industrial applications. The purpose of the soil/sand bed is to protect the piping in case the structural slab is drilled. The advantage of this method is that the piping is unlikely to be damaged due to drilling for anchoring equipment or machinery. The disadvantages include greater material and labor costs. The slower response time due to the greater mass will have little effect within the commercial or industrial workspace.

What to look for — Under-slab heat loss may be critical to the performance of this radiant slab design. Complete under-slab insulation is recommended and essential when:

- High water table or moist soil conditions are present
- Bedrock or ledge is present
- The upper envelope heat load is high
- High R-value floor coverings are used
- The linear feet of perimeter is high in relationship to the gross floor area, as in most residential applications



Cap pour over existing slab with under-slab insulation

How — Secure high-density insulation (minimum thickness of 1 inch) to the lower concrete slab by suitable construction adhesive and concrete screws fitted with fender washers. Secure non-structural flat wire mesh to the insulation. Using Uponor Fixing Wire, secure the piping to the wire mesh. Place the wire ties a minimum of every 3 feet along straight runs. At the 180-degree turns, tie the piping at the top of the arc and once on each side, 6 inches from the top of the arc. This prevents the piping from dislodging and/or floating up into the pour.

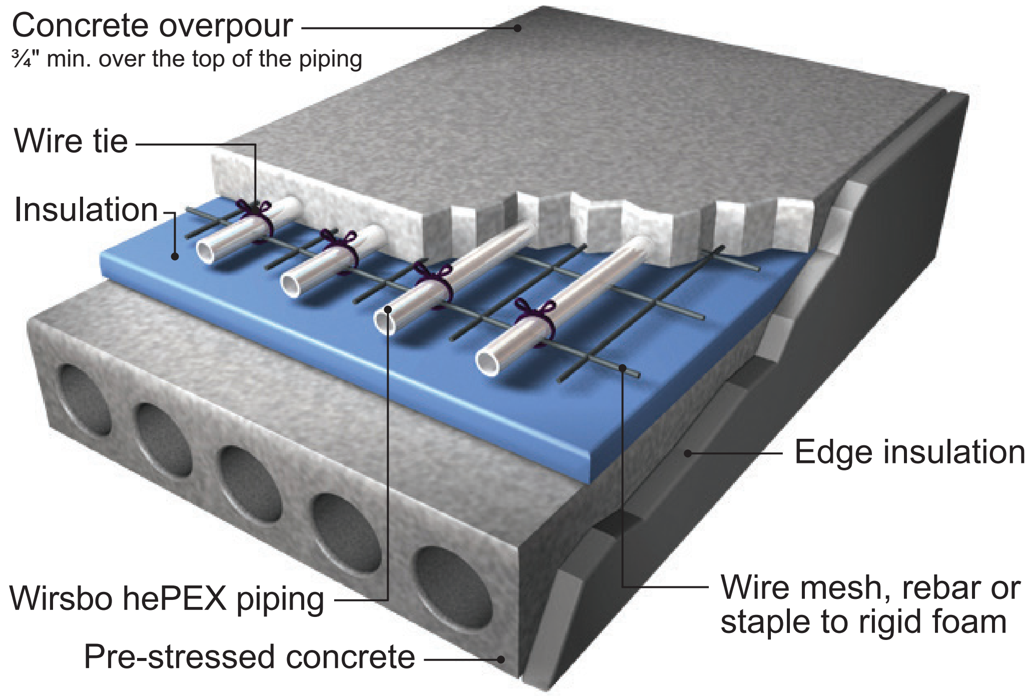
Connect the piping to the manifold, and pressure test to a minimum of 60 psi at least overnight to ensure system integrity. Keep the piping under pressure until after the concrete is poured.

An alternate installation method uses the Uponor Manual Stapler designed for foam insulation applications and omits the non-structural wire mesh. Using 1½" Plastic Foam Staples, secure the piping to the insulation. Staple the piping every 2 feet. At the 180-degree turns, secure two staples 6 inches below the top of the arc and two more staples on each side of the arc.

Where — This installation method is used in both commercial and residential applications. Commercially, this method is used in retrofit situations over existing concrete slabs or in new construction when piping is laid over pre-stressed concrete panels. Residentially, this method is used in retrofit situations over an existing slab, such as finishing an existing basement.

What to look for — In this type of application, the minimum pour thickness must be at least 1½ inches. The depth of the pour over the top of the piping must be at least ¾ inch. This will prevent cracking and promote good lateral and vertical heat transfer. Consult applicator for further details.

Note: The project engineer must determine the vertical compressive strength of the high-density insulation. Consult the insulation manufacturer for further information.



Cap pour over precast plank

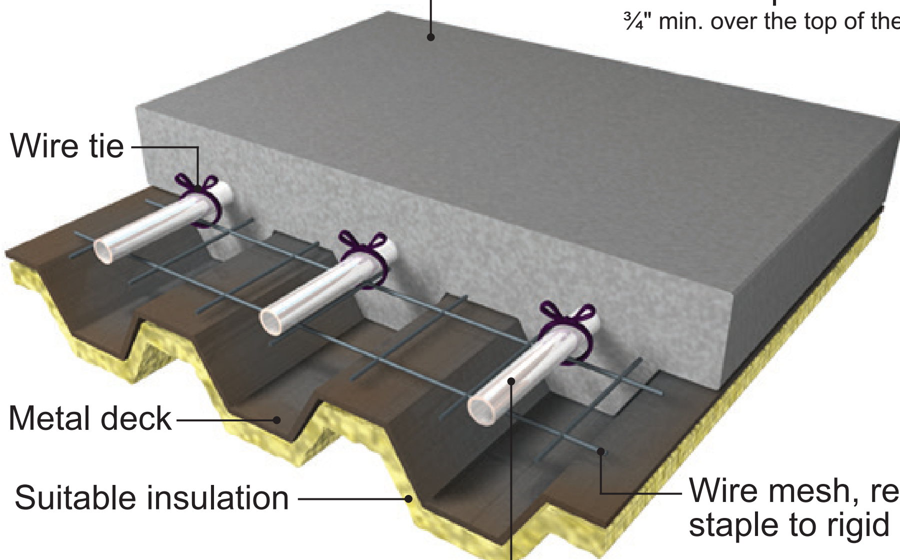
How — Secure high-density insulation (minimum thickness of 1 inch) to the precast concrete plank with suitable construction adhesive and concrete screws fitted with fender washers. Secure nonstructural flat wire mesh to the insulation. Using Uponor Fixing Wire, secure the piping to the wire mesh. Place the wire ties a minimum of every 3 feet along straight runs. At the 180-degree turns, tie the piping at the top of the arc and once on each side, 6 inches from the top of the arc. This prevents the piping from dislodging and/or floating up into the pour.

Connect the piping to the manifold, and pressure test to a minimum of 60 psi at least overnight to ensure system integrity. Keep the piping under pressure until after the concrete is poured.

Where — Use this installation method primarily in commercial applications. This method may be used in retrofit situations or new construction.

What to look for — Ensure the minimum pour thickness is at least 1½ inches and the depth of the cap pour over the top of the piping is at least ¾ inch. The project engineer must determine the depth of the cap pour.

Note: The project engineer must determine the vertical compressive strength of the high-density insulation. Consult the insulation manufacturer for further information. The resistance value of the high-density insulation is determined by the radiant floor design.



Poured-in-place slab over steel decking

How — Place wire mesh or rebar over the steel deck. In some situations, secure the piping to rebar that is chaired above the deck. Using Uponor Fixing Wire, secure the piping to the wire mesh or rebar. Place wire ties a minimum of every 3 feet along straight runs. At the 180-degree turns, tie the piping at the top of the arc and once on each side, 12 inches from the top of the arc. This prevents the piping from dislodging and/or floating up into the pour.

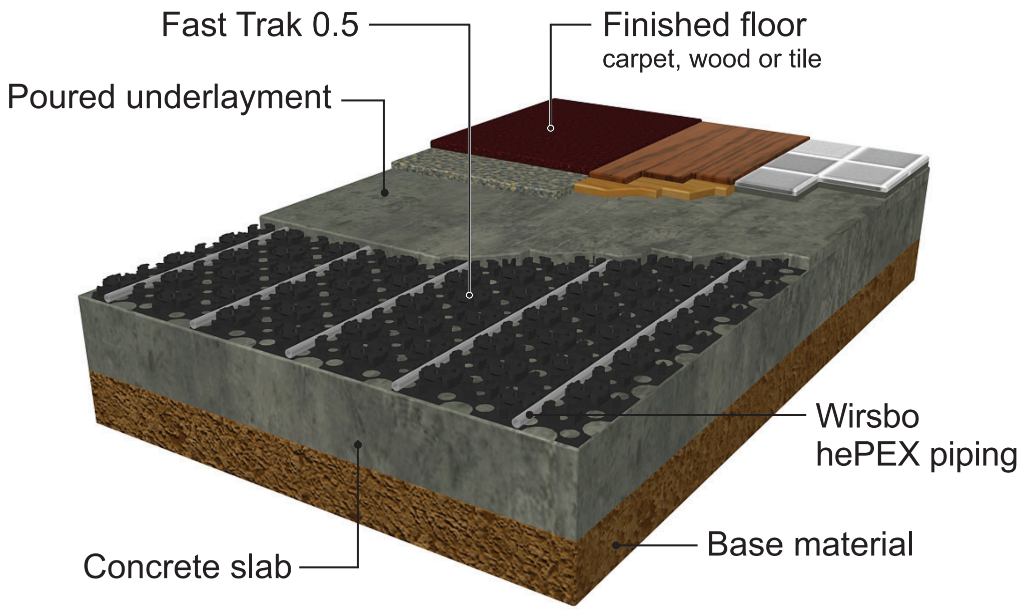
Connect the piping to the manifold, and pressure test to a minimum of 60 psi at least overnight to ensure system integrity. Keep the piping under pressure until after the concrete is poured.

Pour concrete over the piping and decking. The illustration above shows spray-on insulation installed beneath the decking. The radiant floor heating design determines the amount of insulation that is required for proper operation.

Where — Use this method primarily in commercial and industrial applications. With this method, the piping is installed within the concrete pour, eliminating the need for a second or cap pour.

What to look for — Under-slab heat loss may be crucial to the performance of this radiant slab design. Complete under-slab insulation is recommended and essential when:

- The upper envelope heat load is high
- High R-value floor coverings are used
- The linear feet of perimeter is high in relationship to the gross floor area
- Ambient temperature below the decking is unconditioned



Fast Trak 0.5

How — Make sure that the subsurface is free from dust and debris before laying out the panels. Attach Fast Trak Edge Strips to the wall; be sure to cover all walls that will be exposed to the overpour. Remove the plastic foil to expose the adhesive backing before placing the panels on the floor.

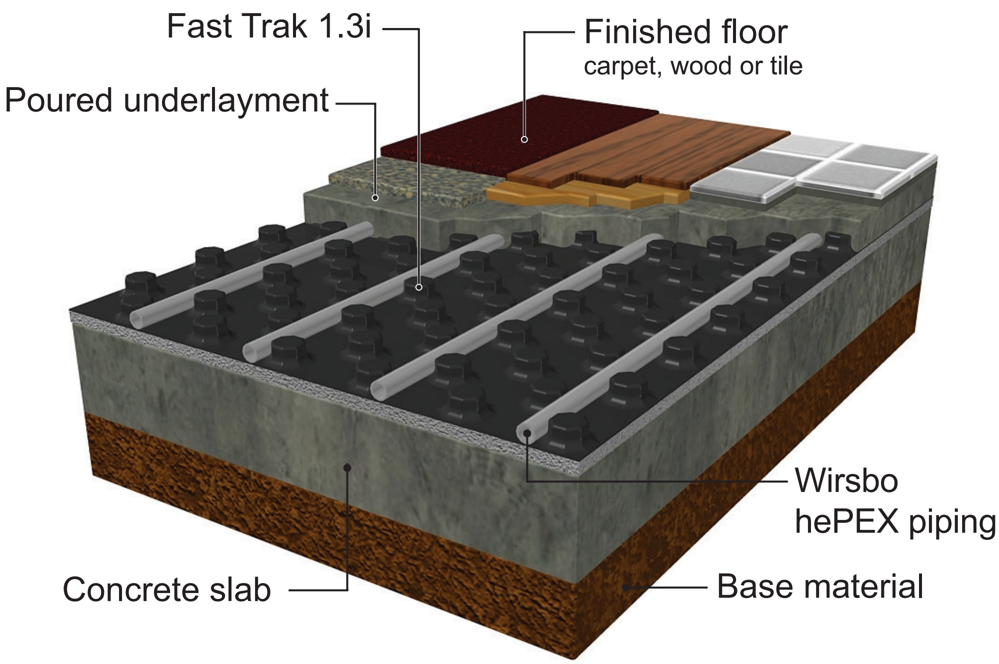
Keep a 2-inch spacing to the wall when laying down the panels. Install the piping by walking or stepping the piping into the knobs on the panel. Piping spacing can be as little as 2 inches, but the turns must have a minimum radius of 3 inches.

Connect the piping to the manifold and pressure test to a minimum of 60 psi at least overnight to ensure system integrity. Keep the piping under pressure until after the overpour is poured. The overpour may be as thin as ¼ inch above the piping and still promote lateral heat transfer; however, local code may require thicker pours due to structural requirements and to avoid cracking.

Where — Uponor Fast Trak is the ideal overpour installation method for remodel and retrofit applications. The preformed, knobbed panels make it easy to install ⁵⁄₁₆" Wirsbo hePEX piping for radiant floor heating systems. The Fast Trak 0.5 system requires a structural subsurface of some kind.

What to look for — A structural subsurface is required for this system, and the added weight of the overpour must be considered when determining if the finished installation can be supported by the structure.

Always check the local code for overpours to verify the pour thickness required.



Fast Trak 1.3i

How — Make sure that the subsurface is level (see installation manual for details). If necessary, the subsurface can be leveled by using a self-leveling primer.

Ensure that the subsurface is free from dust and debris. Attach Fast Trak Edge Strips to the wall; be sure to cover all walls that will be exposed to the overpour.

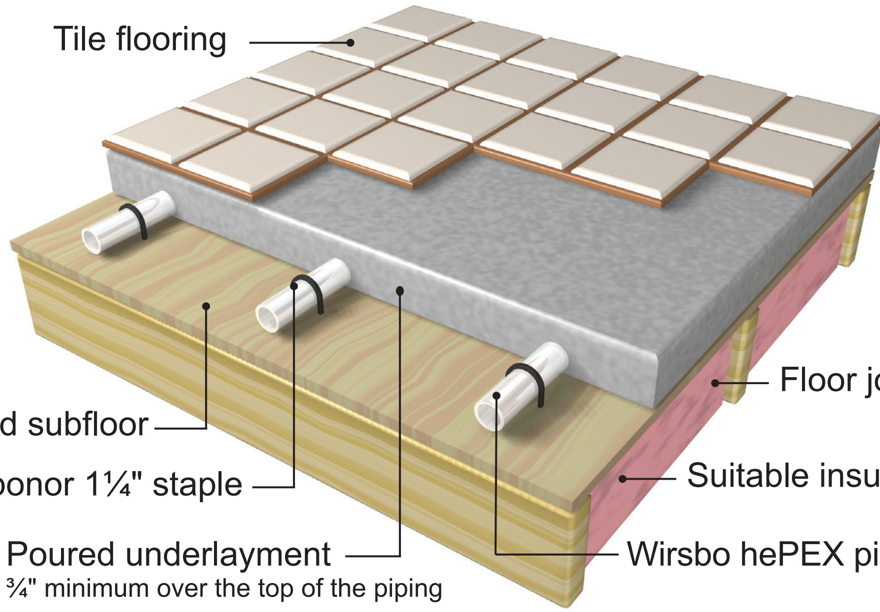
Place the panels on the floor. The panels have an interlocking feature that ensures the overpour will not seep under the panels. After panels are laid out, apply the polyethylene self-adhesive strip of the Edge Strip to the Fast Trak panels to ensure the overpour cannot seep under the edges of the panel surface.

Install the piping by walking or stepping the piping into the knobs on the panel. Piping spacing can be as little as 2 inches. Turns must have a minimum radius of 3 inches for ⅜" piping and 3½ inches for ½" piping.

Connect the piping to the manifold and pressure test to a minimum of 60 psi at least overnight to ensure system integrity. Keep the piping under pressure until after the overpour is poured.

Where — Uponor Fast Trak is the ideal overpour installation method for remodel and retrofit applications. The preformed, knobbed panels make it easy to install ⅜" or ½" Wirsbo hePEX piping for radiant floor heating systems.

What to look for — In this type of application, the pour must be at least 1½ inches. The depth of the pour over the top of the piping must be at least ¾ inch. This will prevent cracking and promote good lateral and vertical heat transfer. Consult applicator for further details.



Poured underlayment on a suspended wood subfloor

How — Staple Uponor PEX directly to the subfloor using the Uponor Pneumatic Stapler. Staple the piping every 2 to 3 feet on the straight runs to prevent it from floating during the pour. At the 180-degree turns, secure one staple at the top of the arc and one staple on each side, 12 inches below the top of the arc.

Connect the piping to the manifold, and pressure test to a minimum of 60 psi at least overnight to ensure system integrity. Keep the piping under pressure until after the underlayment is poured.

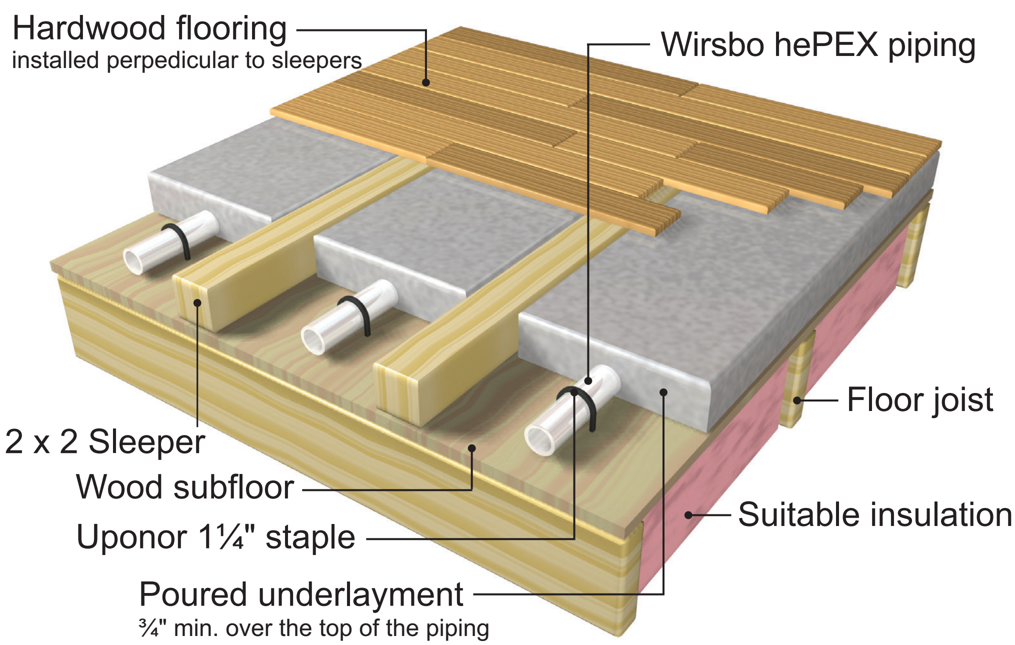
Install suitable batt insulation tightly against the subfloor between the floor joists.

Where — This common residential and light commercial installation method is used when the piping is installed in a poured-floor underlayment. Pours are typically 1½ inches thick and are used as an underlayment for a hardwood, tile or carpeted finished floor.

What to look for — Take special care when installing hardwood flooring over radiant slabs. Please consult **Chapter 16** for detailed wood floor information.

The minimum depth for a concrete pour in this application should be at least ¾ inch over the top of the piping. Consult the underlayment applicator for recommended pour depths.

If a lightweight, non-gypsum based concrete is used instead of the underlayment, take care to install proper expansion joints around the perimeter of the room and on all framed walls. Additionally, use suitable wire or plastic mesh in the lightweight concrete to add structural strength to the pour. Consult the lightweight concrete installer for installation recommendations.



Poured underlayment with sleepers over a suspended wood subfloor

How — Staple Uponor PEX piping directly to the subfloor using the Uponor Pneumatic Stapler. Staple the piping every 2 to 3 feet on the straight runs to prevent it from floating during the pour. At the 180-degree turns, secure one staple at the top of the arc and one staple on each side, 12 inches below the top of the arc.

Install 2x2 (actual dimensions are 1½" by 1½") wood sleepers between the runs of piping, 9 to 12 inches on center. These sleepers serve as a nailing surface for hardwood floors or carpet tack strips. Install additional sleepers around the perimeter of the room.

Connect the piping to the manifold, and pressure test to a minimum of 60 psi at least overnight to ensure system integrity. Keep the piping under pressure until after the underlayment is poured.

The poured underlayment floats to the top of the sleepers resulting in a smooth, finished pour. Install suitable batt insulation tightly against the subfloor between the floor joists.

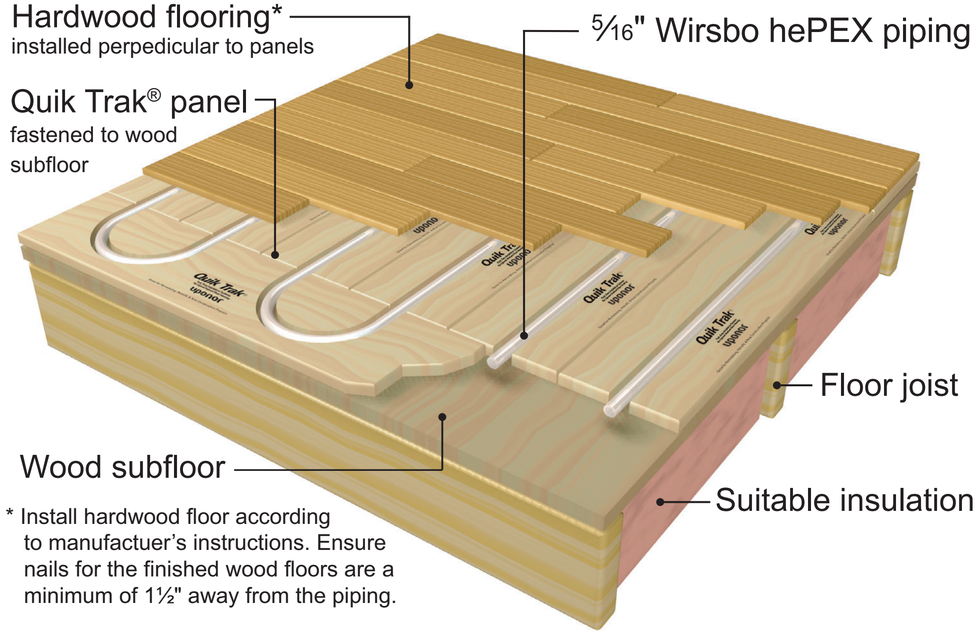
Where — This common residential and light commercial installation method is used when the piping is installed in a poured-floor underlayment. Pours are typically 1½ inches thick and are used as an underlayment for a hardwood, tile or carpeted finished floor.

Note: Uponor recommends floor surface temperatures not exceed 80°F unless the wood flooring manufacturer provides a higher temperature rating.

What to look for — Take special care when installing hardwood flooring over radiant floors. Please consult **Chapter 16** for detailed wood floor information.

The minimum depth for a concrete pour in this application should be at least ¾ inch over the top of the piping. Consult the underlayment applicator for recommended pour depths.

If a lightweight, non-gypsum based concrete is used instead of the underlayment, take care to install proper expansion joints around the perimeter of the room and on all framed walls. Additionally, use suitable wire or plastic mesh in the lightweight concrete to add structural strength to the pour. Consult the lightweight concrete installer for installation recommendations.



* Install hardwood floor according to manufactuer's instructions. Ensure nails for the finished wood floors are a minimum of 1½" away from the piping.

Quik Trak over a wood subfloor with hardwood floor covering

How — Lay Quik Trak panels over a plywood subfloor perpendicular to the finished wood floor. Make sure to stagger the seams of the Quik Trak.

After laying the panels, vacuum the debris from the panel grooves. Next, apply a thin (⅛-inch) bead of Uponor Quik Trak Sealant throughout the entire length of the groove. The sealant is 100% silicone. It acts as an adhesive agent and promotes good heat transfer from the piping to the panel.

Install the piping by walking or stepping the piping into the panel grooves. If you're not wearing hard-sole shoes, you may need to use a rubber hammer to snap the piping into the groove.

Secure panels to the subfloor with 1¼" Quik Trak Screws or 1" staples. To start, secure the middle of the panel with a screw or staple. Work from the middle to the ends, alternating from side to side.

Where — This application is used in residential construction as an alternative to joist heating and poured-floor underlayment installations. Quik Trak is also beneficial when the finished floor material is hardwood. Installers can actually see the piping when installing the hardwood floor. This method offers several advantages, including minimal increase in floor height, no moisture from concrete and increased BTU/h/ft^2 output potential over joist heating.

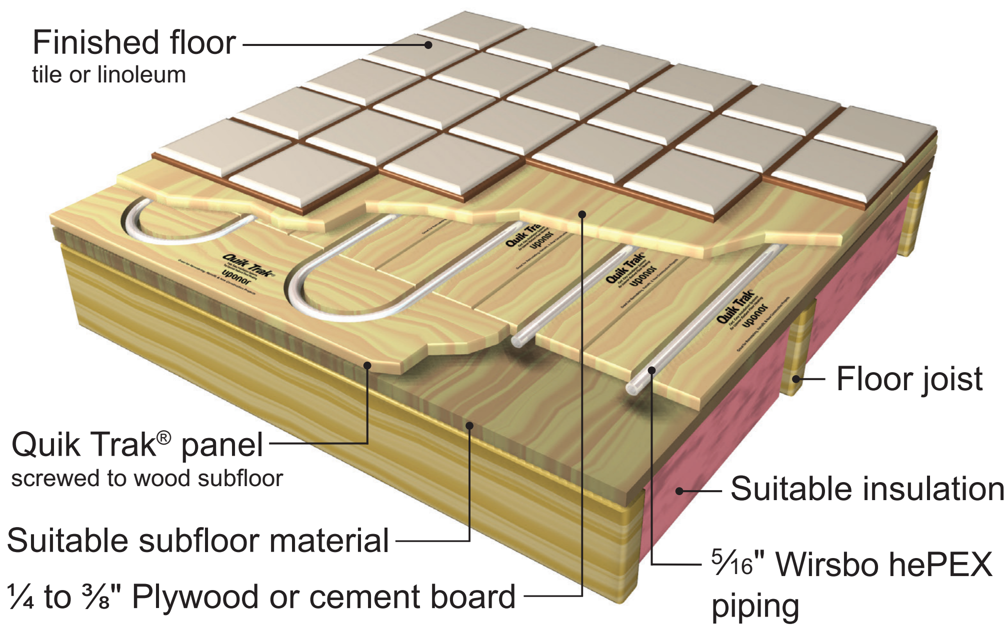
What to look for — Take special care when installing hardwood flooring over radiant floors. Please consult **Chapter 16** for detailed wood floor information.

Always install hardwood floors in accordance with the flooring manufacturer's instructions. Ensure nails for the finished wood floor are a minimum of 1½ inches away from the piping.

Note: Uponor recommends floor surface temperatures not exceed 80°F unless the wood flooring manufacturer provides a higher temperature rating.

Proper insulation is critical to the performance of Quik Trak. A minimum of R-19 is recommended in between the floor joists beneath the floor.

In all Quik Trak applications, the maximum loop length for 5⁄16" Wirsbo hePEX piping is 250 feet, including leader lengths. Flow rates for all Quik Trak installations are calculated to a 20°F temperature differential.



Quik Trak over a wood subfloor with tile/linoleum floor covering

How — Lay Quik Trak panels over a plywood subfloor perpendicular to the floor joists. Make sure to stagger the seams of the Quik Trak.

After laying the panels, vacuum the debris from the panel grooves. Next, apply a thin (⅛-inch) bead of Uponor Quik Trak Sealant throughout the entire length of the groove. The sealant is 100% silicone. It acts as an adhesive agent and promotes good heat transfer from the piping to the panel.

Install the piping by walking or stepping the piping into the panel grooves. If you're not wearing hard-sole shoes, you may need to use a rubber hammer to snap the piping into the groove.

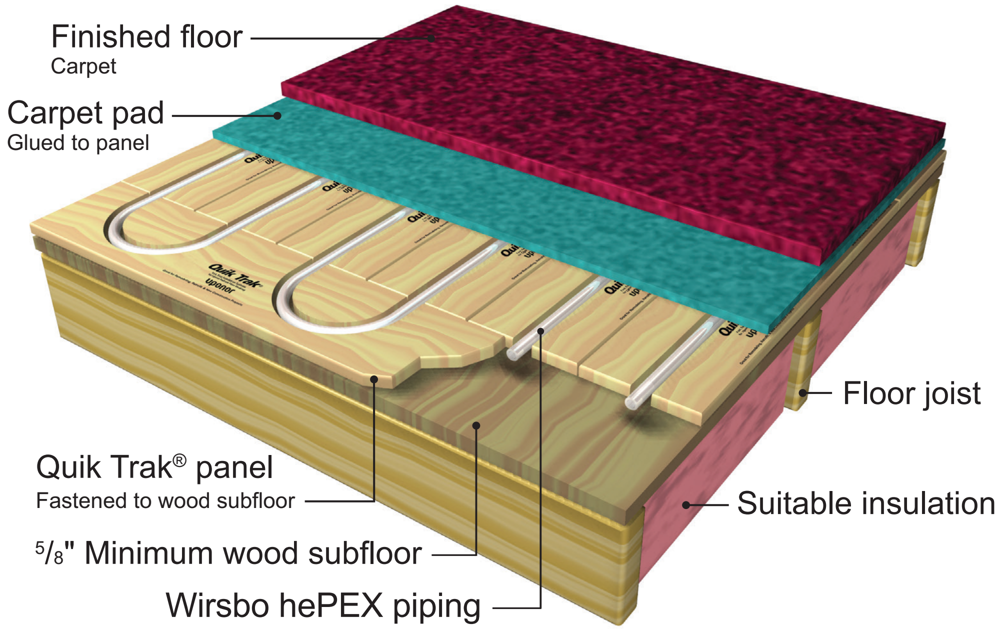
Secure panels to the subfloor with 1¼" Quik Trak Screws or 1" staples. To start, secure the middle of the panel with a screw or staple. Work from the middle to the ends, alternating from side to side.

Where — This application is used in residential construction as an alternative to joist heating and poured-floor underlayment installations.
Quik Trak is also beneficial when the finished floor material is hardwood. Installers can actually see the piping when installing the hardwood floor. This method offers several advantages, including minimal increase in floor height, no moisture from concrete and increased BTU/h/ft^2 output potential over joist heating.

What to look for — Proper insulation is critical to the performance of Quik Trak. A minimum of R-19 is recommended in between the floor joists beneath the floor.

Note: Do not exceed 87.5ºF for tile and linoleum floor surface temperatures.

In all Quik Trak applications, the maximum loop length for 5/16" Wirsbo hePEX piping is 250 feet, including leader lengths. Flow rates for all Quik Trak installations are calculated to a 20°F temperature differential.



Quik Trak over a wood subfloor with carpet floor covering

How — Lay Quik Trak panels over a plywood subfloor perpendicular to the floor joists. Make sure to stagger the seams of the Quik Trak.

After laying the panels, vacuum the debris from the panel grooves. Next, apply a thin (⅛-inch) bead of Uponor Quik Trak Sealant throughout the entire length of the groove. The sealant is 100% silicone. It acts as an adhesive agent and promotes good heat transfer from the piping to the panel.

Install the piping by walking or stepping the piping into the panel grooves. If you're not wearing hard-sole shoes, you may need to use a rubber hammer to snap the piping into the groove.

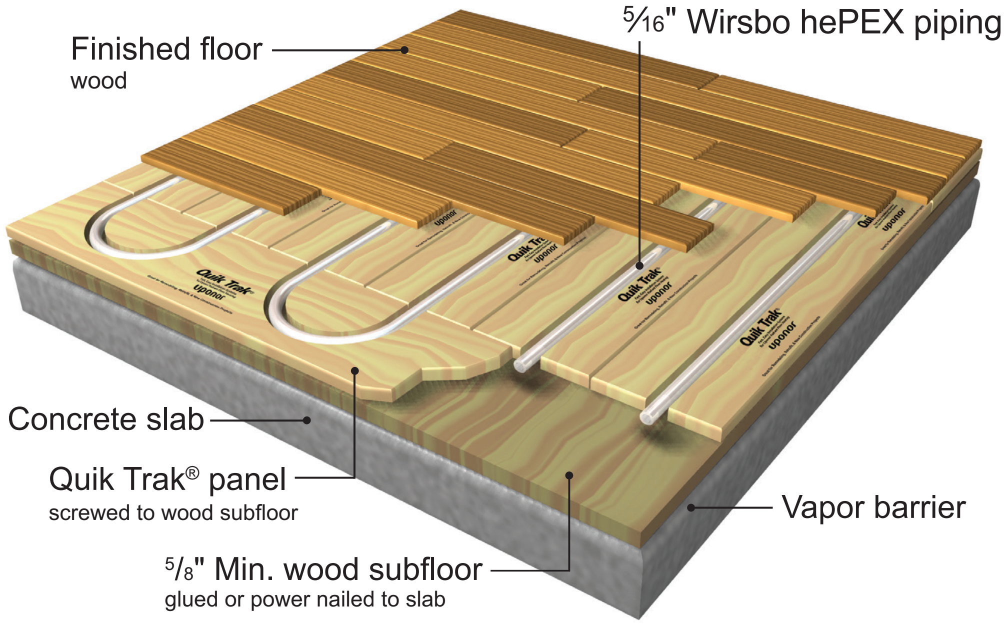
Secure panels to the subfloor with 1¼" Quik Trak Screws or 1" staples. To start, secure the middle of the panel with a screw or staple. Work from the middle to the ends, alternating from side to side.

Where — This application is used in residential construction as an alternative to joist heating and poured-floor underlayment installations. Quik Trak is also beneficial when the finished floor material is hardwood. Installers can actually see the piping when installing the hardwood floor. This method offers several advantages, including minimal increase in floor height, no moisture from concrete and increased BTU/h/ft^2 output potential over joist heating.

What to look for — Proper insulation is critical to the performance of Quik Trak. A minimum of R-19 is recommended in between the floor joists beneath the floor.

Note: Do not exceed 87.5ºF for carpeted floor surface temperatures.

In all Quik Trak applications, the maximum loop length for ⁵⁄₁₆" Wirsbo hePEX piping is 250 feet, including leader lengths. Flow rates for all Quik Trak installations are calculated to a 20°F temperature differential.



Quik Trak over an existing concrete slab

How — First, install a layer of ⅝-inch or ¾-inch plywood subfloor over the concrete slab. Glue or power-nail the plywood directly to the concrete if a vapor barrier is not required. If a vapor barrier is required, then you must power-nail the plywood to the concrete slab.

Lay Quik Trak panels over a plywood subfloor perpendicular to the floor joists. Make sure to stagger the seams of the Quik Trak.

After laying the panels, vacuum the debris from the panel grooves. Next, apply a thin (⅛-inch) bead of Uponor Quik Trak Sealant throughout the entire length of the groove. The sealant is 100% silicone. It acts as an adhesive agent and promotes good heat transfer from the piping to the panel.

Install the piping by walking or stepping the piping into the panel grooves. If you're not wearing hard-sole shoes, you may need to use a rubber hammer to snap the piping into the groove.

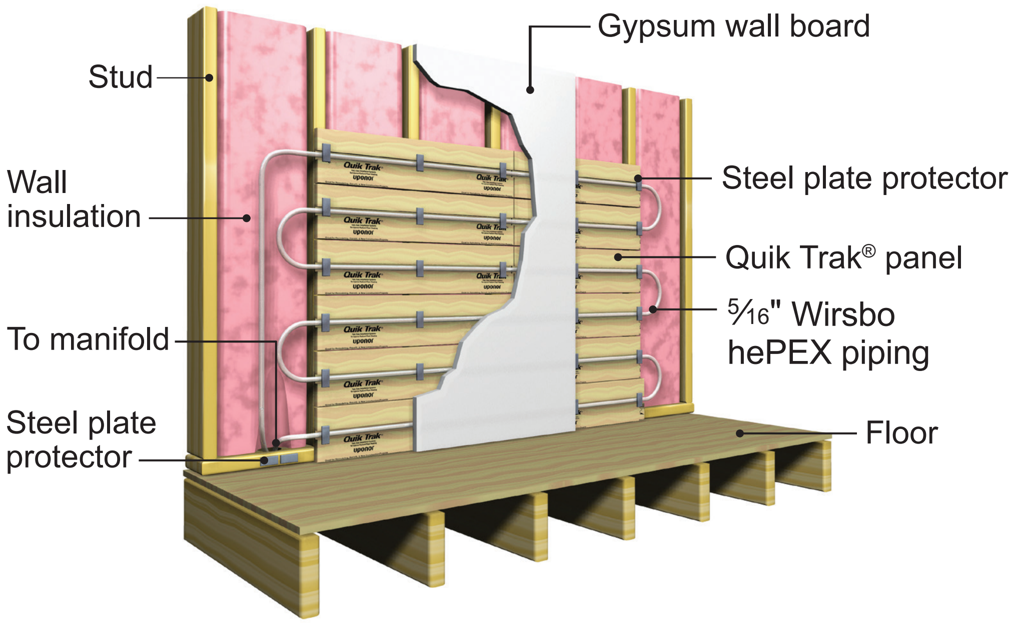
Secure the panels to the subfloor with 1" screws or 1" staples. To start, secure the middle of the panel with a screw or staple. Work from the middle to the ends, alternating from side to side.

Where — This application is used in residential construction over existing concrete slabs. The plywood base together with the Quik Trak panel only adds 1⅛ to 1¼ inches in floor height. It is the ideal solution when retrofitting or remodeling a basement.

What to look for — A high water table will adversely affect the performance of this application. If there is moisture present that cannot be eliminated from the area, do not use this application.

Note: In a basement or walkout application, it is very important to install perimeter and edge insulation for proper design performance.

In all Quik Trak applications, the maximum loop length for 5⁄16" Wirsbo hePEX piping is 250 feet, including leader lengths. Flow rates for all Quik Trak installations are calculated to a 20°F temperature differential.



Quik Trak radiant wall installation

How — Starting at the floor level on the outside wall, install Quik Trak panels parallel to the floor at a maximum of six rows high (42 inches) to avoid interference with window and picture placement. Screw panels to the studs on both sides of the groove with 1-inch drywall screws. After the panels are installed, attach ½-inch furring strips to the remainder of the stud wall, to provide an even base for the sheetrock.

To install the piping, drill two ⅝-inch holes in the footer plate opposite the Quik Trak Return Panel. Feed the supply through the ⅝-inch hole and attach to the supply manifold. Vacuum the grooves. Apply a thin (⅛-inch) bead of Quik Trak Sealant in to the grooves. Firmly press piping into the groove. Feed return to the second ⅝-inch hole and attach to the return manifold. Lastly, attach protector plates (strike plates) where the piping crosses the studs to protect the piping from puncture.

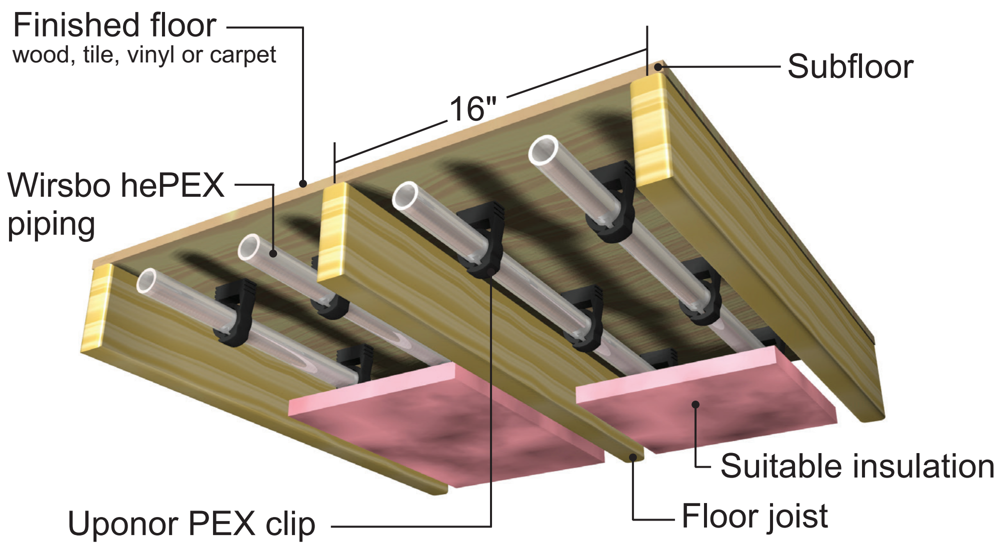
Where — Radiant wall installations are a low-cost alternative to radiant floor heating and are often installed when radiant floor is not viable. This method is routinely used in retrofit applications. In addition, radiant wall installations are most often used in supplemental heat situations when the radiant floor cannot satisfy the heat loss of a room under design conditions.

What to look for — Do not install piping in an area where pictures may be hung.

Ensure the supply loop feeds from the top of the panel and works its way to the bottom. This will help eliminate the possibility of air lock in the loop.

Install a minimum of R-19 insulation in the exterior wall behind the Quik Trak panels.

In all Quik Trak applications, the maximum loop length for 5⁄16" Wirsbo hePEX piping is 250 feet, including leader lengths. Flow rates for all Quik Trak installations are calculated to a 20°F temperature differential.



Joist heating using PEX clips

How — Drill two holes (1¼-inches minimum) side by side at the end of each joist cavity. Thread Uponor PEX piping in between the floor joists from below, looping from one joist cavity to the next as necessary. After installing piping in the last joist bay, run the PEX straight back through the joist holes behind the first set of holes. Return this end of the PEX to the manifold and connect.

Next, fasten Uponor PEX Clips to the bottom of the subfloor in each joist bay. The clips are 8 inches on center in 16-inch joist bays, 6 inches on center in 12-inch joist bays and 3 feet apart. Attach the PEX Clips with screws no larger than ¾ inch.

Install the loop farthest from the manifold by pulling the loop the length of that bay. Borrow slack from the loop hanging from the next joist bay. Snap the piping into the PEX Clips, which suspends the piping about an inch below the subfloor. Continue the process until all loops are neatly installed in the joist bays.

Install suitable insulation in the bay, an inch below the piping, leaving about a 2-inch to 3-inch air gap under the subfloor. Connect the piping to the manifold, and pressure test to a minimum of 60 psi at least overnight to ensure system integrity.

Where — This method is commonly used in both new and retrofit work where poured underlayment applications are impractical. This installation is also used for floor conditioning — the warming of floors without providing heat into the space.

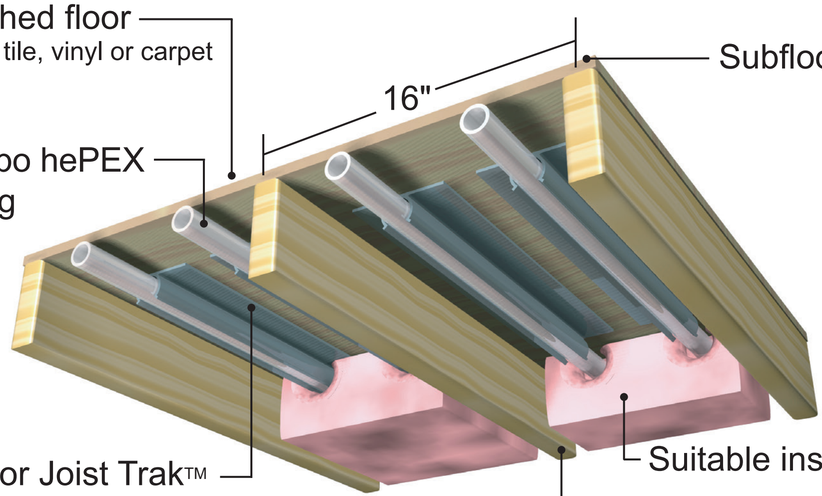
Note: This installation method is not recommended for open-web truss construction. Joist heating applications using only the PEX piping suspended in the plenum must have sufficient insulation R-value, and the insulation must be installed to limit air movement from the plenum. Joist heating applications with open-web truss construction should use the Joist Trak Panels as shown on **page 53** of this manual.

What to look for — A minimum R-11 fiberglass insulation is required even if the piping is installed over a heated space. A minimum R-19 is recommended when the piping is installed in a crawlspace. Standard unfaced insulation is adequate; foil-faced insulation is not necessary.

Install piping to align with the zone areas. Install insulation vertically to block the joist cavity beneath the zone wall.

Note: Check with local building codes before drilling through floor joists.

Use either ⅜" or ½" PEX piping in joist heating applications. It is not recommended to exceed maximum individual loop lengths.



Joist heating using Joist Trak panel

How — Install the Joist Trak panels beneath the wood subfloor with ¾-inch drywall screws. In a 16-inch, on-center joist bay, install the panels equal distance between the joists. Leave about a foot at the end of the joist bay without panels to allow piping turns. Leave about an inch between panel ends.

Drill two holes (1¼-inches minimum) side by side at the end of each joist cavity. Thread PEX piping in between the floor joists from below, looping from one joist cavity to the next as necessary. After piping is installed in the last joist bay, run the PEX straight back through the joist holes behind the first set of holes. Return this end of the PEX to the manifold and connect.

Install the loop farthest from the manifold by pulling the loop the length of that bay. Borrow slack from the loop hanging from the next joist bay. Next, snap the Uponor PEX piping into the grooves of the Joist Trak panels. Continue this process until all loops are neatly installed in the joist bays.

Install suitable installation in the joist bay, snug against the panels. Connect the piping to the manifold, and pressure test to a minimum of 60 psi at least overnight to ensure system integrity.

Where — This method is commonly used in both new and retrofit work where poured underlayment applications are impractical. Installing Joist Trak panels provides the same amount of heat load support using lower supply water temperatures than joist heating without panels.

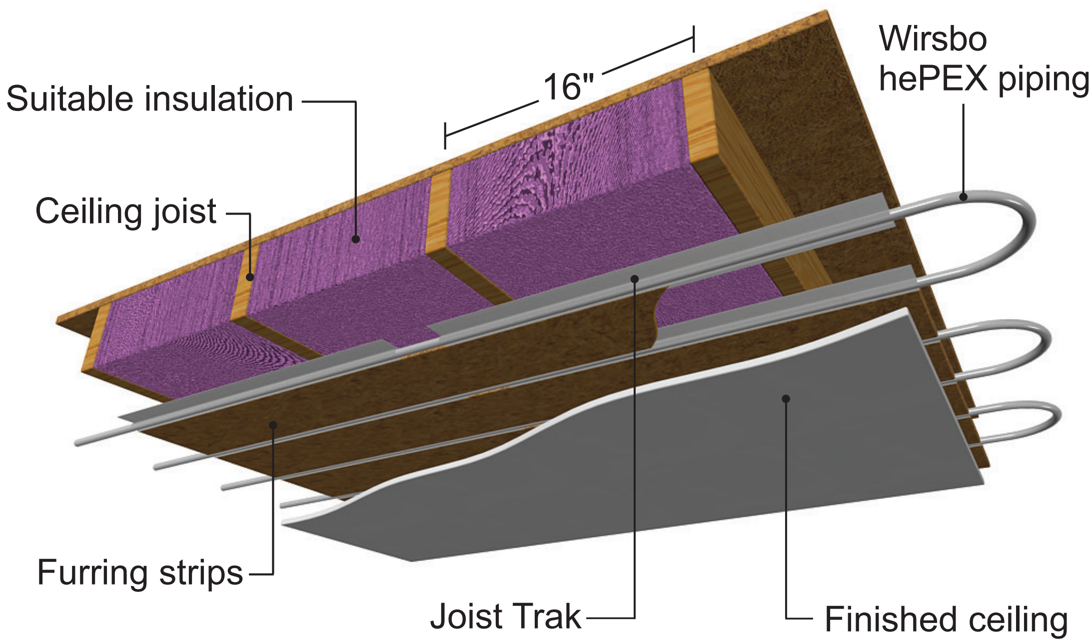
Note: Check with local building codes before drilling through floor joists.

What to look for — Allow the bends of the piping at either end of the joist bay to straighten prior to installing in the panel. This ensures the piping enters t he panels in a straight line so that it does not cause noise by rubbing against the sides of the groove during operation.

A minimum R-11 fiberglass insulation is required even if the piping is installed over a heated space. A minimum R-19 is recommended when the piping is installed in a crawlspace. Standard unfaced insulation is adequate; foil-faced insulation is not necessary.

Install piping to align with the zone areas. Install insulation vertically to block the joist cavity beneath the zone wall.

Use either ⅜" or ½" PEX piping in joist heating applications. It is not recommended to exceed maximum individual loop lengths.



Radiant ceiling using Joist Trak panel

How — Starting at the outside wall (area of highest heat loss), secure a row of 1x6 furring strips to the bottom of the ceiling joists, perpendicular to the joists. Next, using an aluminum plate as a guide, install more rows of furring strips parallel to the first row. Staple the plates to the furring strips on one side only, allowing the plates to expand during operation. Leave about an inch gap between each plate in a row. Be sure to leave space where the wall and ceiling meet to allow for 180-degree turns in the piping. Next, following the layout pattern, snap the piping into the Joist Trak groove to complete the room.

Connect the piping to a manifold, and pressure test to a minimum of 60 psi at least overnight.

Where — Radiant ceiling is a low-cost alternative to radiant floor, and it is often installed when radiant floor is not practical or viable (e.g., common retrofit applications). Radiant ceiling is often used in bedrooms where its relative low cost and quick response time are valued. In addition, radiant ceiling is a common method of providing auxiliary or extra heat in rare situations when a radiant floor cannot satisfy the heat loss of a room under design conditions.

What to look for — While radiant ceiling can be a powerful and versatile option, it is not as comfortable as a radiant floor.

Do not exceed 120ºF water temperatures with radiant ceiling. Otherwise, flash from the ceiling, streaking and hot-head/cold-feet syndrome may develop. Because of its powerful output, it is not always necessary to install radiant ceiling over the entire ceiling area.

The amount of radiant panel area installed should equal the heat load of the room. Concentrate this panel area on the outside wall where the heat loss is the greatest.

Be sure there is adequate insulation installed above the piping and plates. Insulation required by code is generally adequate, but additional insulation is required in ceilings that aren’t usually insulated.

Avoid puncturing the piping while installing the sheetrock. Mark safe areas for nailing or screwing on the walls and adjacent sheetrock panels prior to installing the sheetrock.

Do not use the system to accelerate the drying time of joint compound or sprayed ceilings.

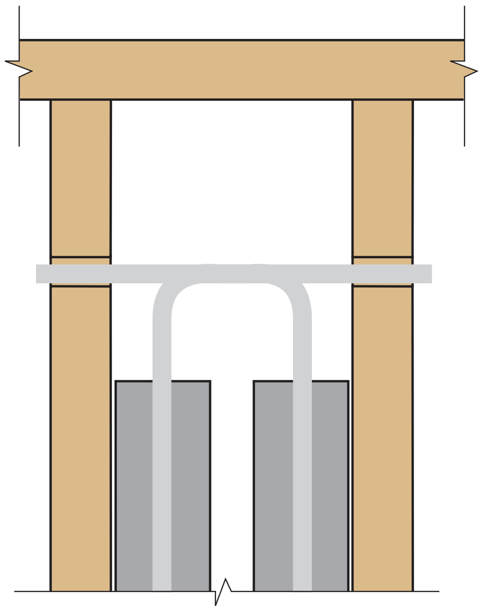


Figure 6-9: Double-run expansion loop

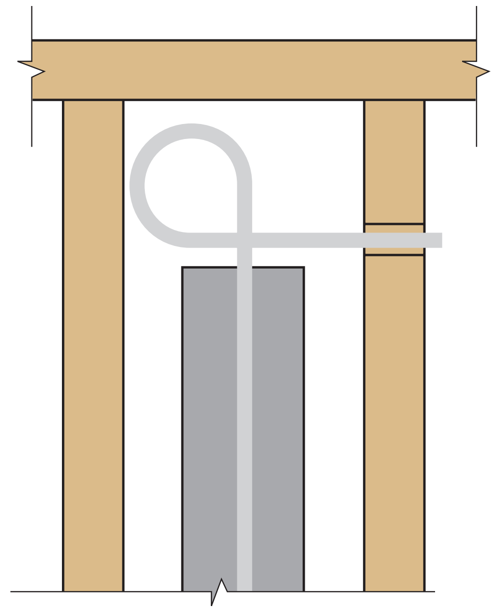


Figure 6-10: Single-plate expansion loop

Avoid expansion/contraction noise in Joist Trak installations

When using aluminum plates in radiant floor heating systems, a ticking sound can occur during operation. The sound is a result of the thermal expansion of PEX piping and the stresses placed on the aluminum plates from thermal expansion.

Uponor PEX piping products expand at a rate of 1.1 inch per 100 feet of piping per 10°F temperature rise. Aluminum plate radiant floor systems often operate around 160°F; the total temperature rise from the time of installation is around 100°F. Expansion will occur because of the significant temperature rise. If the expansion is not accommodated, some noise in the system is possible.

PEX contains a very low friction coefficient, so the piping does not make noise when it moves in the aluminum plates. The noise is caused when the piping expands and the 90-degree turns at the end of the runs move until they meet the far side of the hole drilled in the joist. If the piping continues to expand after it has hit the far end of the hole, the stress of the expansion will transmit to the joist and back to the plate, resulting in noise.

There are several easy ways to reduce or eliminate noise.

1. Drill the holes through the joists large enough so the piping does not hit the back side of the hole when it expands. Check local building codes for information about drilling through floor joists.
2. Use open-truss span joists to avoid drilling holes in the joists.
3. Install shorter runs so more loops are available to accommodate expansion.
4. The higher the water temperature, the more the piping expands. A weather-responsive reset control will ensure the lowest required water temperature is used to provide adequate heat.
5. Install expansion loops for longer runs.

Notes

Chapter 7:

Heat-loss considerations and calculations

The most critical step in a properly designed radiant system is an accurate room-by-room heat-loss analysis. All decisions and calculations are based, to some extent, on the building heat-loss requirements.

This section explains how to calculate heat loss manually as well as electronically using the Uponor design program. These programs analyze analyzes how a building will perform under design conditions (worst-case scenario) by determining the heat loss and heat gain.

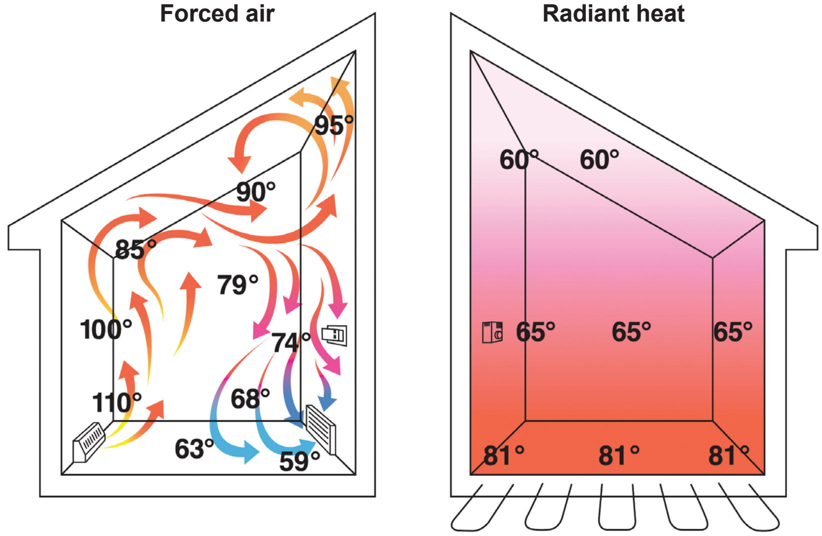


Figure 7-1: Forced air versus radiant heat comparison

Downward loss

Downward loss is the amount of heat energy in BTU/h transferred downward from the radiant floor at any given load. Whether calculating heat loss manually or with a design program, downward loss is a critical factor. Downward loss is significant with a radiant floor heating system and must be properly analyzed.

The importance of insulating below the floor to counteract the downward loss depends on the project. The importance increases specifically when the following are present in a design:

- An increase in the thickness of the slab
- An increase in floor covering R-value
- An increase in the differential temperature between the slab and the soil below
- The presence of a water table below the slab
- An increase in the ratio of slab perimeter area to total slab area
- Suspended floors

Slab thickness

Thicker slabs mean longer response times. Adding insulation prevents the downward transfer of energy, allowing for a greater amount of heat to transfer into the conditioned space.

Floor covering

Heat follows the line of least resistance. High R-value floor coverings force heat to travel downward or laterally. Insulation will help prevent heat from traveling downward and force it into the conditioned space.

Differential temperature

Uponor's design software will automatically calculate the correct ground temperature and differential based on the setting or checkbox for a water table being present within 6 feet of the slab. Always insulate the slab when lower-temperature conditions are present beneath the heating slab.

High water table

A water table lowers the ground temperature. The lower ground temperature increases downward loss, and higher supply water temperature is needed to overcome that loss. Properly designing and installing insulation beneath the slab in this condition will greatly minimize the downward loss.

If a high water table exists, check the box marked Water Table Present in the a design program. The program will change the water temperature below to 40°F. This value cannot be changed with the presence of a water table.

Slab areas

Three distinct areas of slab exist, each with a different potential for downward loss.

- The under-slab area is the interior portion of the slab including all but the first 4 feet around the exposed perimeter.
- The perimeter area is the first 4 feet around the exposed perimeter of the slab.
- The edge area is the exposed surface of a radiant slab, equal to the thickness of the slab multiplied by the exposed perimeter length.

Downward loss increases as the ratio of perimeter area to the total area increases. This means the perimeter is especially crucial to downward loss in residential and similarly sized applications. A perimeter without insulation will allow excessive BTU/h movement away from the concrete slab due to the temperature differential between the slab perimeter and the ground, thus affecting the system performance and the heat loss.

Slab insulation — The three slab-area insulation values are defined as follows.

- The under-slab R-value is the amount of insulation under the interior area of the slab, excluding the perimeter area.
- The perimeter R-value is the amount of insulation placed either horizontally or vertically for the first 4 feet along the perimeter of the slab.
- The edge R-value is the amount of insulation directly covering the thickness of the slab around the exposed perimeter (less than 4 feet below grade).

Uponor recommends total under-slab insulation for residential applications.

Suspended floors

Downward loss also exists for suspended floors. A suspended floor is defined as any floor that does not rest directly on the earth's surface. Suspended floors may be constructed of any material and may be constructed over heated or unheated spaces.

Downward loss exists in areas with a heated space below. If the heated area below uses the same heat plant as the area above, the loss does not increase the total load/heat plant load because the heat is not lost out of the structure. If downward loss to the heated space below exceeds either the upward load or 10 BTU/h/ft^2, insulate the suspended floor. Without insulation, the room temperature below is impossible to control.

Excessive downward loss is likely to occur with the use of high R-value floor coverings. The suspended floor must be insulated if the space below is not heated (e.g., crawl spaces). Unheated spaces below have the greatest potential for downward losses. These areas should always be insulated.

Summary

Calculating an accurate heat loss is the most critical step in radiant system design. Regardless of the heating system, it is good practice to insulate the area below the floor to minimize the downward loss. This is especially true with concrete slab installations. Once the concrete is poured, it's too late to add insulation. Also, an insulated slab will perform better if a finished floor with a higher R-value is added in the future.

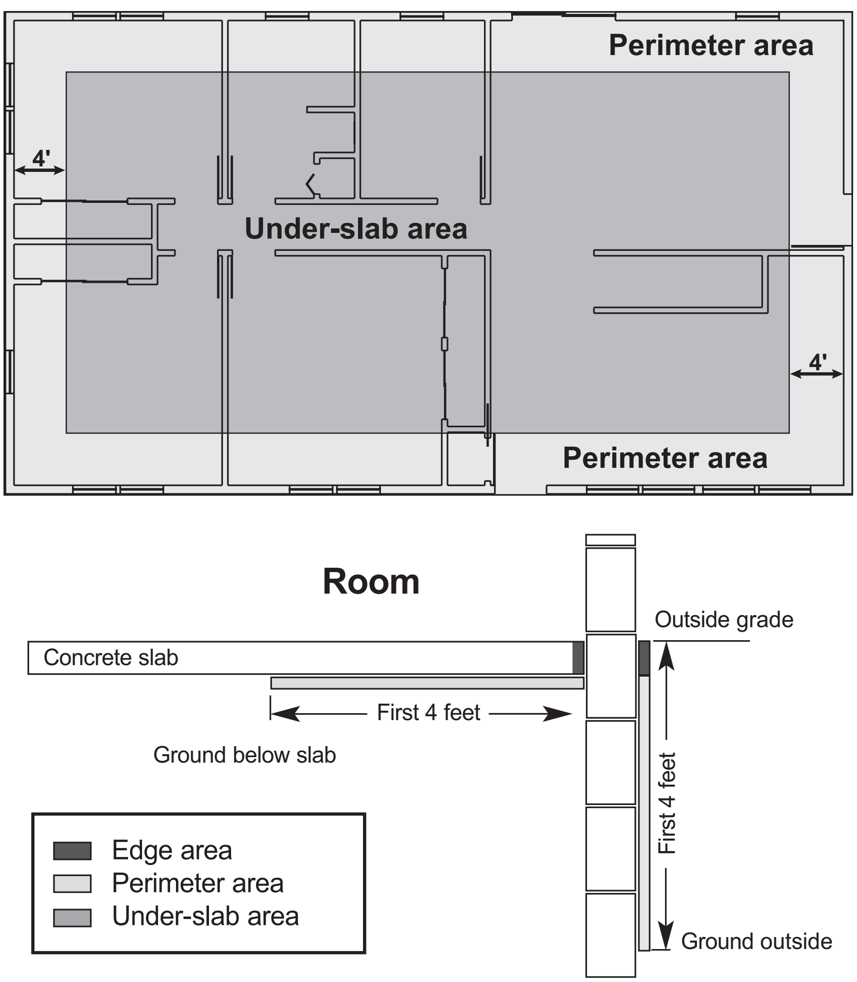


Figure 7-2: Slab areas

Manual heat-loss calculations

Understanding the variables

- **Design Temperature Difference (DTD):** This value is the difference between the outdoor design temperature and the indoor design temperature. For this example, the indoor design temperature is 65°F, and the outdoor design temperature is 40°F — yielding a DTD of 25°F.
- **Infiltration:** Infiltration is the exchange of warm air inside a building with the cold air outside. Infiltration is generally very low with radiant systems. The infiltration value used in calculating heat loss will vary based on local codes and conditions. For Minnesota, 0.33 air change per hour (ACH) is adequate; 0.33 ACH is equal to an infiltration factor of 0.006.
- **Calculation area:** This value represents the area to be analyzed. This example uses the room shown in **Figure 7-3**.
- **Test room construction:** It is important to understand the different types of construction methods used in the analysis as well as the thermal properties of key components such windows, exterior walls, interior walls, floors and ceilings. This heat loss example considers the exterior walls, ceiling and windows:
  - Five exterior windows: 3' x 5' each; R-value = 0.91
  - Exterior walls; R-19 insulation
  - 8' ceiling; R-30 insulation

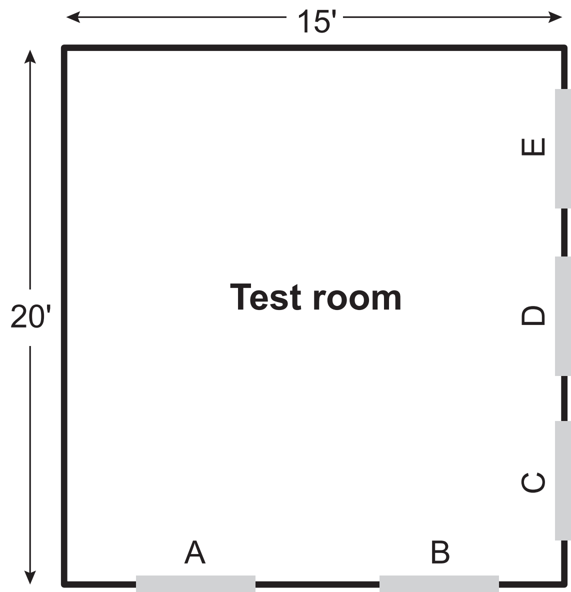


Figure 7-3: Test room

Doing the math

Heat-loss	Formula
Infiltration loss = 360 BTU/h =	Room volume x DTD x infiltration factor 20 x 15 x 8 x 25 x 0.00 6
Ceiling loss = 247.5 BTU/h =	Ceiling area x DTD x ceiling U-value 20 x 15 x 25 x 0.033 • Ceiling U-value = 1/R-value • Ceiling U-value = 1/30 = 0.033
Exposed wall loss = 256.25 BTU/h =	(Exposed wall area - window area) x DTD x wall U-value (280 - 75) x 25 x 0.05 • Exposed wall U-value = 1/R-value • Exposed wall U-value = 1/19 = 0.05
Window loss = 2,062.5 BTU/h =	Window area x DTD x window U-value 75 x 25 x 1.1 • Window U-value = 1/R-value • Window U-value = 1/0.91 = 1.1
Total heat loss = 2,926.25 BTU/h =	Infiltration loss + ceiling loss + exposed wall loss + window Loss 360 + 247.5 + 256.25 + 2,062.5
Heat Loss per Square Foot = 9.75 BTU/h/ft^2 =	Total Heat Loss/Total Floor Area 2,962.25/300

Table 7-1: Heat-loss formulas

Computer program design calculations

Along with heat-loss calculations, the program guides the system designer through the radiant panel design, system requirements and material list generation. This powerful design tool also provides the contractor with a host of business tools for a variety of job-management functions.

The calculation portion of prompts the user to input the type of piping product to be used, the design differential temperature and the specifics of floor construction. The program design analyzes the information and calculates a supply water temperature and the piping on-center distance for each room. The program allows the user to make adjustments to the design (e.g., on-center distance, unheated area, etc.) for each room. The user assigns each room or area to a manifold. The program then calculates loop lengths, flow and feet of head.

Program functions

The design software performs several functions.

- Calculates accurate room-by-room heat loss
- Calculates system performance requirements
- Calculates total flow and pressure loss for accurate circulator sizing
- Provides mechanical specifications
- Generates an Uponor material list
- Provides current list pricing
- Creates a customer database
- Provides a job follow-up reminder
- Creates management reports for jobs won, lost and pending
- Generates job quotations for presentation to customers

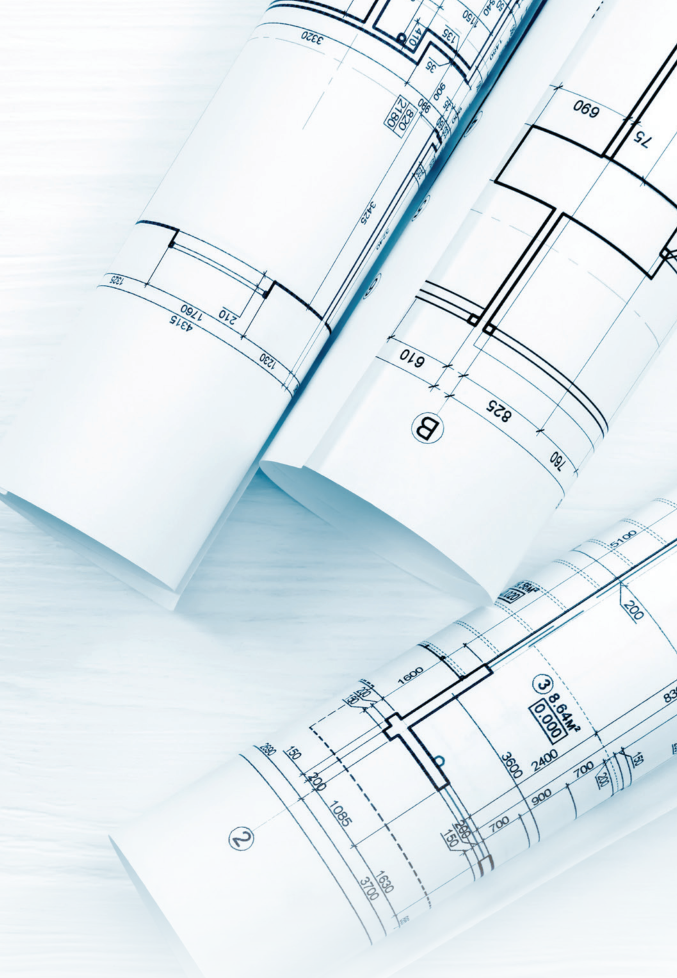


Figure 7-4: Joist Trak aluminum heat transfer plates

Features and benefits

Templates —- The radiant floor heating module offers the ability to create and save templates based on typical building types.

Updates — Periodically, Uponor enhances the software. Users can easily download the updates by clicking the Help menu.

Easy navigation — The program is designed like a web page for fast, easy, intuitive navigation.

Visual interface — The visual interface immediately shows when design thresholds and limits are met.

Drag-and-drop flexibility — Add or delete zones, move manifolds between water temperatures and move loops easily with the drag-and-drop feature.

Advanced settings — Settings are available to allow either the program to determine the correct number of water temperatures for the system or the user to set the maximum number to be designed around. These settings also allow the user to set a maximum water temperature based on the heat source.

Control auto selection — Easily customize projects with the Climate Cŏntrol Zoning System II.

Snow and ice melting module — This module allows users to easily design a snow and ice melting system, either as a standalone system or as part of a radiant heating design. This module also provides expanded design parameters.

Supply and return piping — Users can select the type of material connected to the manifolds and specify the distance and the connector type in the design steps. The programs will automatically calculate the materials and report the resulting pressure drops for pump sizing.

Cooling module — This module allows the user to calculate the cooling load. No additional programs are needed.

ASHRAE data — A drop-down list provides complete climatic design data for areas in the U.S. and Canada. Additionally, users can add climatic information for areas not listed in the ASHRAE data.

Pressure loss calculator — This feature eliminates the need to look up pressure losses in tables or charts. Simply select the piping size, flow rate, distance, etc., and the program generates the resulting loss. PEX and copper are available as selections in the supply-and-return portion of the design to calculate pressure loss accurately.

Parts catalog — The program includes heating and plumbing components with expanded detail.

Loop mapping wizard — The Loop Mapping Wizard automatically maps the loops to a specific coil to minimize the amount of waste or scrap in the project.

Loop adjustment — The programs allow allows for simple adjustment of the final loop length.

Supplemental heat — The supplemental heat components of the heat loss are shown in the heat-loss data, making them easier to track.

Global changes — Users can apply changes in construction, insulation values, floor coverings, etc., on a floor-plan basis, rather than room by room.

C_v values — The associated pressure drops with three-way floating action and tempering valves are automatically calculated and reported.

Manifold mapping — Any or all changes that are made to the manifold mapping are saved. The programs do no does not re-map the manifolds and the associated loops (as in earlier software versions) when other data is changed in the program.

Manifold configuration — Manifolds automatically configure with 10 loops. Users can add loops up to the maximum flow limit of the manifolds.

Exporting — Material lists can export to Microsoft® Excel® files. Project files are stored in a file or folder locations (versus a database) to make the project data more portable.

Fastener preferences — Users can edit the number of fasteners the programs automatically calculate to better reflect the habits of the installer.

Tool and part preferences — Users can specify the tools and parts they want to include with every job.

Quantity values — When parts are manually added to a material list, a pop-up box is displayed to prompt the user to enter the quantity.

Help manual — A comprehensive help manual is available in the program, complete with content index and search.

Notes

Chapter 8:

Radiant floor system design

Although it is easiest to quickly and accurately create a radiant design with a software program, it's essential to understand how to design a system manually to help make decisions and alterations to optimize system performance.

To design a radiant floor system, one must determine the:

- BTU/h/ft^2 heat loss for each room
- Floor surface temperature
- Project installation method
- Piping type and size
- Finished floor material R-value
- Piping on-center distance
- Supply water temperature
- Loop length, including leader distance
- Fluid flow in gpm
- Pressure loss or head

Radiant floor design tutorial

To demonstrate radiant floor design, this tutorial moves step by step through the design of a single room (Bedroom 1) in the Uponor Training House. The complete Training House radiant floor heat loss and design information is provided on **pages 72-85**.

Figure 8-1 shows a partial floor plan for the Uponor Training House including Bedroom 1.

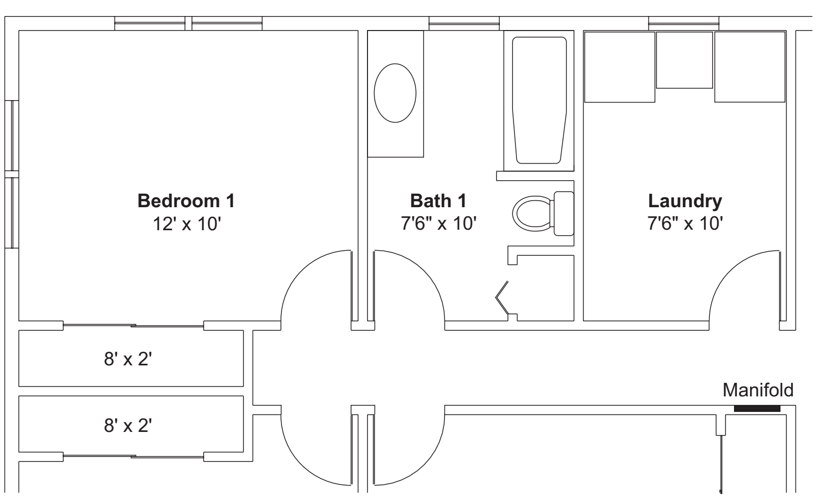


Figure 8-1: Uponor training house (partial)

Step 1: Heat-loss analysis

The radiant floor design worksheet provides a format to organize the building's raw heat-loss information. A copy of this worksheet is available in **Appendix A**. Copy as necessary. Fill out the worksheet for the project, and then enter the information into the computer heat-loss program. Entering the data into the computer will go much faster if you complete the worksheet first. Take special note of the input for floor covering R-values and the different floor insulation types and values.

Figure 8-2 shows heat-loss data from the design program for Bedroom 1.

> **Note:** When determining system performance data, note which load to use: upward, downward or total. All load-related entries require the upward load value. The total load value is only used when calculating flow information.

Bedroom 1 (floor plan 1)	
Total area	136 ft^2
Average height	8 ft
Volume	1,088 ft^2
Air changes	0.35/hr
Room temperature	65°F
Components	1,841 BTU/hr
Infiltration	348 BTU/hr
Ceiling upward	236 BTU/hr
Floor downward	1,020 BTU/hr
Total heat loss	3,279 BTU/hr
Supplemental	0 BTU/hr
Total room loss	3,279
Radiant to room load	2,607 BTU/hr
Unit load	19.8 BTU/ft^2/hr
Total radiant load	3,279 BTU/hr
Unit load	24.8 BTU/ft^2/hr

Figure 8-2: Heat-loss data for bedroom 1

Radiant floor design worksheet

Project name: Training House main level

			Loop 1
	A	**Room name**	**Bedroom 1**
Step 1	B	**Room setpoint temp. (°F)**	**65°F**
	C	**Zone number**	**1**
	D	**Upward load (BTU/h/ft^2)**	**19.8**
	E	**Total load (BTU/h/ft^2)**	**24.8**
	F	Floor surface temp. (°F)	
	G	Installation method	
	H	Piping size	
	I	Floor covering R-value	
	J	Differential temp. (°F)	
	K	Piping o.c. distance (in)	
	L	Supply water temp. (°F)	
	M	Active loop length	
	N	Leader loop length	
	O	Total loop length	
	P	Loop flow in gpm	
	Q	Loop head pressure (ft)	
	R	Loop balancing turns	

Manifold totals

S	Supply water temp. (°F)	
T	Manifold flow in gpm	
U	Highest pressure head (ft)	

Figure 8-3: Radiant floor design worksheet

Use the radiant floor worksheet (**Appendix B**) when manually designing a system. Note that this appendix also contains worksheets for radiant ceiling and Quik Trak® designs. Make a copy of the worksheet prior to beginning this tutorial.

From the selected heat-loss information given for Bedroom 1, enter the following information into the appropriate cell on the worksheet:

- Room name
- Room setpoint temperature
- Upward BTU/h/ft² load
- Total BTU/h/ft² load (upward and downward added together)

> **Note:** Obtain BTU/h/ft² values either from the design printout or calculate manually by dividing the BTU/h by the floor area (in square feet) where piping can be installed. Remember to subtract areas where piping will not be installed. All load values in this tutorial are BTU/h/ft².

Step 2: Floor surface temperature

The floor surface temperature is the temperature at the top of the floor needed to transfer the calculated BTU/h into the room at the maximum designed heat load. This surface temperature is based solely on the floor area. Floor covering, construction or piping on-center distances do not influence the required surface temperature. If conditions are milder than design, the floor surface temperature will be lower. Surface temperature is based on a simple relationship between the room setpoint temperature and the required upward BTU/h/ft² load. Do not include downward BTU/h/ft² loss when calculating floor surface temperature. Areas with differing BTU/h/ft² requirements or setpoint requirements have different surface temperatures.

The coefficient of radiant floor thermal transfer is 2.0 BTU/h/ft²/°F. This transfer coefficient changes as the position of the radiant panel changes in the room. Radiant wall has a transfer coefficient of 1.8, and radiant ceiling has a transfer coefficient of 1.6. Simply put, the floor surface temperature is equal to the room setpoint temperature plus half the required upward BTU/h/ft² load.

For bedroom 1: (19.8 BTU/h/ft² ÷ 2 BTU/h/ft²) + 65°F = 74.9°F floor surface temperature.

The formula used to calculate the floor surface temperature is precise and is supplied by the design program. If manually designing the system, use the formula or the floor surface temperature chart found in **Appendix C**. This chart is also shown in **Figure 8-4**. This chart quickly brackets the floor surface temperature to determine if the temperature is within requirements.

Floor surface temperature limitations — Hardwood floors have a maximum floor surface temperature of 80°F. Please consult the wood flooring manufacturer for their recommendations. All other flooring types have a maximum floor surface temperature of 87.5°F.

Using the floor surface temperature chart:

Find: The required floor surface temperature.

Procedure:

1. Find the desired room setpoint temperature in the first column of the table; for this example, use 65°F.
2. Move right until you reach the correct upward BTU/h/ft² requirement (19.8). The chart is divided into five BTU/h/ft² increments. If between values, round to the next higher value. For this example of 19.8 BTU/h/ft², use the 20 BTU/h/ft² entry.
3. The temperature found at the intersection of the two values is the bracketed floor surface temperature.

Keep in mind this chart is used to quickly assess whether the floor surface temperature is within limitations. At 75°F floor surface temperature, the room floor surface temperature is well within all limitations. Actual floor surface temperature is 74.9°F.

If the design does not use wood flooring, and the required surface temperature exceeds 87.5°F, reduce the heat loss of the room or add

Radiant floor surface temperatures

Room setpoint										
75°F	80.0	82.5	85.0	87.5	90.0	92.5	95.0	97.5	100.0	102.5
72°F	77.0	79.5	82.0	84.5	87.0	89.5	92.0	94.5	97.0	99.5
70°F	75.0	77.5	80.0	82.5	85.0	87.5	90.0	92.5	95.0	97.5
68°F	73.0	75.5	78.0	80.5	83.0	85.5	88.0	90.5	93.0	95.5
65°F	70.0	72.5	75.0	77.5	80.0	82.5	85.0	87.5	90.0	92.5
60°F	65.0	67.5	70.0	72.5	75.0	77.5	80.0	82.5	85.0	87.5
	10.0	**15.0**	**20.0**	**25.0**	**30.0**	**35.0**	**40.0**	**45.0**	**50.0**	**55.0**

BTU/h/ft²

Exceeds the maximum recommended surface temperature for all floors.

Exceeds the maximum recommended surface temperature for hardwood floors.

Figure 8-4: Excerpt from radiant floor surface temperatures chart

supplemental heat. Take the same action for wood flooring applications when the floor surface temperature exceeds 80°F.

Reversing the floor surface temperature formula determines the maximum load in BTU/h/ft² for a room. To calculate the maximum upward BTU/h/ft² at a given room setpoint temperature, use this equation:

(87.5°F - room setpoint) x 2 = maximum BTU/h/ft²

Using this formula, a room with a setpoint temperature of 65°F will support 45 BTU/h/ft² for a maximum upward BTU/h/ft² load. Conversely, if the room setpoint temperature is 70°F, then 35 BTU/h/ft² is the maximum upward load. Obviously, if wood flooring is used, the BTU/h/ft² capability is less. Remember, these loads are maximum capabilities and may be reduced by floor construction and floor covering selections.

Enter 74.9°F in the floor surface temperature cell on the worksheet.

Step 3: Installation method

Next, determine which installation method to use for the particular job. Of all the options outlined in **Chapter 6**, the most common are:

- Slab on or below grade
- Poured-floor underlayment
- Quik Trak
- Joist Trak
- Joist heating

Sometimes the decision is obvious, but other times the designer may help influence the decision. For instance, does the actual heat source have a fixed water temperature that must be designed around? Has the building already been framed, making poured-floor underlayment impractical? What is the project budget? Consider all these factors when determining an installation method.

One final note: there really is no best or preferred installation method. All have their applications, advantages and limitations. In addition, the superior efficiency of radiant floor heating in general makes any installation method preferable over other heat-delivery options.

For this tutorial, use the poured-floor underlayment for the type of installation method. In the floor construction cell on the worksheet, enter "Poured Floor."

Step 4: Piping size

People often ask, "Do you get more heat out of ½" piping than ⅜" piping?" The surprising answer is no, not really. The most common piping sizes used in radiant floor heating are ⅜" and ½". Both are fairly equal in terms of heat output per square foot when installed in a radiant mass. Remember, the floor — not the piping — is the heat emitter. The piping merely carries water to the heat emitter.

Larger piping sizes do allow for longer loop lengths due to lower friction losses at the same flow rates, but do not increase the actual per square foot heat output of a radiant system to any extent. Other factors, such as installation method, piping spacing, water temperature, finished floor materials and flow are more important factors in determining performance capabilities.

The biggest difference between piping sizes is pressure loss. Smaller piping produces much greater pressure loss than larger piping. Therefore, shorter loop lengths are suggested for smaller-diameter piping. This pressure loss, rather than heat output, is the determining factor when it comes to selecting a piping size.

Enter ½" Wirsbo hePEX in the piping size cell on the worksheet.

Radiant floor design worksheet

Project name: Training House main level

			Loop 1
	A	**Room name**	**Bedroom 1**
	B	Room setpoint temp. (°F)	65°F
	C	Zone number	1
	D	Upward load (BTU/h/ft²)	19.8
	E	Total load (BTU/h/ft²)	24.8
Step 2	F	**Floor surface temp. (°F)**	**74.9°F**
Step 3	G	**Installation method**	**Poured floor**
Step 4	H	**Piping size**	**½" Wirsbo hePEX**
	I	Floor covering R-value	
	J	Differential temp. (°F)	
	K	Piping o.c. distance (in)	
	L	Supply water temp. (°F)	
	M	Active loop length	
	N	Leader loop length	
	O	Total loop length	
	P	Loop flow in gpm	
	Q	Loop head pressure (ft)	
	R	Loop balancing turns	

Manifold totals

S	Supply water temp. (°F)	
T	Manifold flow in gpm	
U	Highest pressure head (ft)	

Figure 8-5: Radiant floor design worksheet

Step 5: Finished floor covering R-value

The next step is to determine the type of finished flooring material and its corresponding R-value. This information is needed to determine the appropriate supply water temperature. **Appendix D** includes a chart listing a variety of common floor coverings and their R-values; an excerpt of the chart is shown in **Figure 8-7**.

Use the chart to select the floor covering closest to the proposed floor covering.

Many times the finished floor material is unknown at the time of design. People will question, "Shouldn't I simply design for the worst possible case?" This approach may prevent a potential under-design problem. However, it frequently leads to over-design issues, where more piping or excessive supply water temperatures may be needlessly factored into a job, adding to the overall design cost. Designers must carefully weigh the overall results of their design decisions, especially with floor coverings.

Find: The R-value of ¼-inch nylon saxony carpet with ¼-inch bonded urethane padding (4-lb. density).

Procedure:

1. In the R-value table, find the type of carpeting to be installed.
2. Move to the right and read the value for the appropriate thickness.
3. In this example, the R-value of ¼-inch nylon saxony is 0.88.
4. In the R-value table, find the type of carpet pad to be installed.
5. Move to the right and read the value for the appropriate thickness.
6. In this example, the R-value of ¼-inch bonded urethane is 1.04.
7. Add the two values together to obtain the total R-value: 0.88 + 1.04 = 1.92
8. Enter 1.92 in the floor covering R-value cell on the worksheet.

Step 6: Determining differential temperature

The supply and return differential temperature is the temperature drop from the supply manifold to the return manifold. A supply and return differential temperature of 10°F is ideal for residential radiant floors. A 20°F differential temperature is common for commercial projects. For the exercise, use a supply and return differential temperature of 10°F.

Enter 10°F in the differential temperature cell on the worksheet.

Step 7: On-center distance

Piping on-center distance is a function of flow, temperature and comfort. You must deliver the required flow through the piping at the selected piping on-center distance and be within the operational temperature range of the floor construction medium (e.g., concrete, underlayment, etc.).

Decreasing the piping spacing (bringing the piping closer together) will lower the required supply water temperature and produce a more even surface temperature, but increases the amount of piping used in the project.

For poured-floor underlayments, the maximum on-center distance is

Radiant floor design worksheet

Project name: Training House main level

			Loop 1
	A	Room name	Bedroom 1
	B	Room setpoint temp. (°F)	65°F
	C	Zone number	1
	D	Upward load (BTU/h/ft²)	19.8
	E	Total load (BTU/h/ft²)	24.8
	F	Floor surface temp. (°F)	74.9°F
	G	Installation method	Poured floor
	H	Piping size	½" Wirsbo hePEX
Step 5	I	**Floor covering R-value**	**1.92**
Step 6	J	**Differential temp. (°F)**	**10°F**
Step 7	K	**Piping o.c. distance (in)**	**9"**
Step 8	L	**Supply water temp. (°F)**	**132°F**
	M	Active loop length	
	N	Leader loop length	
	O	Total loop length	
	P	Loop flow in gpm	
	Q	Loop head pressure (ft)	
	R	Loop balancing turns	

Manifold totals

S	Supply water temp. (°F)	
T	Manifold flow in gpm	
U	Highest pressure head (ft)	

Figure 8-6: Radiant floor design worksheet

Carpeting	⅛"	¼"	⅜"	½"	⅝"	¾"
Commercial glue down		0.60	0.90			
Acrylic level loop		1.04	1.56	2.08	2.60	3.12
Acrylic plush		0.83	1.25	1.66	2.08	2.49
Polyester plush		0.96	1.44	1.92	2.40	2.88
Nylon saxony		0.88	1.32	1.76	2.20	2.64
Nylon shag		0.54	0.81	1.08	1.35	1.62
Wool plush		1.10	1.65	2.20	2.75	3.30
Carpet pads						
Rubber (solid)		0.31	0.47	0.62	0.78	0.93
Rubber (waffled)		0.62	0.93	1.24	1.55	1.86
Hair and jute		0.98	1.47	1.96	2.45	2.94
Prime urethane (2-lb. density)		1.08	1.62	2.16	2.70	3.24
Bonded urethane (4-lb. density)		1.04	1.56	2.08	2.60	3.12
Bonded urethane (8-lb. density)		1.10	1.65	2.20	2.75	3.30

Figure 8-7: Excerpt from floor covering R-value chart

9 inches. Due to the shallow depth of the pour, install the piping closer together to avoid possible striping, which creates warm and cool spots across the floor. If the supply water temperature is found to be too high later in the design process, reduce the on-center distances.

Enter 9 inches in the on-center distance cell on the worksheet.

Step 8: Supply water temperature

The required supply water temperature is the temperature necessary to provide the amount of energy required to create the floor surface temperature as it relates to the upward resistance of floor coverings. Supply water temperature is based on a complex relationship between the conditions above and below the radiant mass and several other characteristics of the installation.

The factors required to calculate supply water temperature are:

- Installation method
- Required upward BTU/h/ft² load
- Room setpoint temperature
- Floor covering R-value
- Supply and return differential temperature

The required information to determine the supply water temperature is known. Use the appropriate chart in **Appendix E** (see **Figure 8-8**).

Find: The required supply water temperature for a load of 19.8 BTU/h/ft² using poured-floor underlayment construction with piping at 9 inches on center with a floor covering R-value of 1.92.

Procedure:

1. Find the appropriate supply water temperature chart (poured-floor underlayment with piping 9 inches on center).
2. Enter the chart in the BTU/h/ft² column for the given load (19.8 BTU/h/ft²).
3. Move to the right until intersecting the approximate R-value slope line. The slope line for this R-value (1.92) falls between the published lines in the chart.
4. Move straight down from the intersecting point of the 1.92 R-value line and the 19.8 BTU/h/ft² line.
5. Read the required supply water temperature at the appropriate differential temperature. The required water temperature for Bedroom 1 is 132°F.

Enter 132°F in the supply water temperature cell on the worksheet.

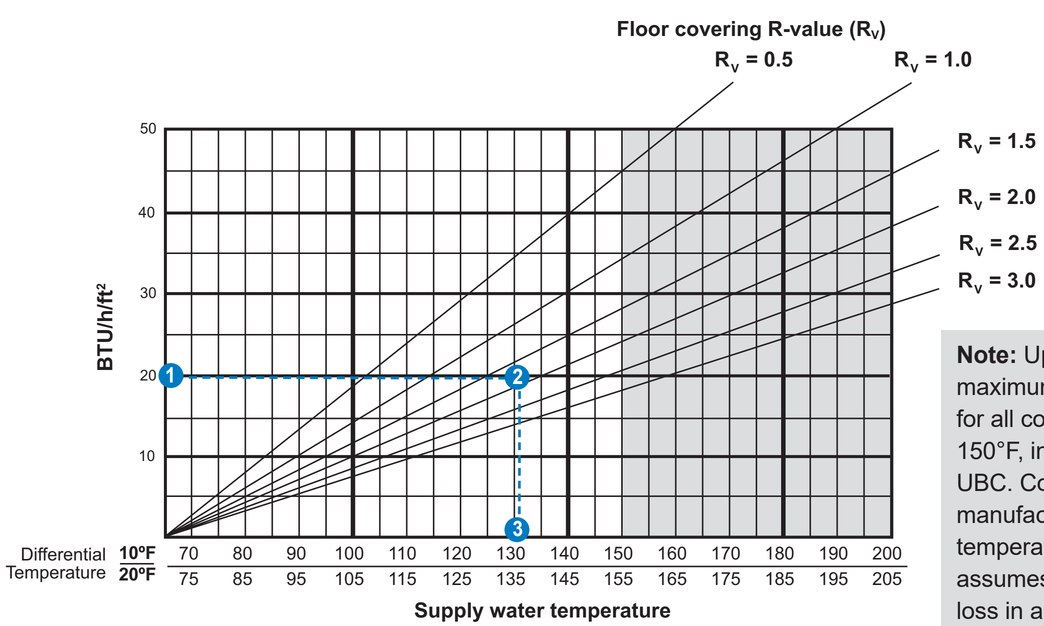
Note: If the calculated downward loss in BTU/h/ft² exceeds the upward load requirement, use the greater of the two values when calculating the supply water temperature.

Concrete slabs and poured-floor underlayments thicker than the depth shown on the charts in **Appendix E** require slightly higher supply water temperatures.

If the supply water temperature exceeds the piping's sustained operating temperature or the floor construction limitation, the best ways to decrease the water temperature are to:

- Reduce the piping on-center distance
- Reduce the floor covering R-value
- Reduce the upward heat loss through improved insulation
- Provide supplemental heat

The maximum operating water temperature for concrete is 150°F and 140°F for poured-floor underlayment (verify with the product manufacturer). When installing piping between floor joists, with or without heat emission plates, limit the supply water design temperature to 165°F.



Note: Uponor's recommended maximum fluid temperature for all concrete applications is 150°F, in accordance with the UBC. Consult underlayment manufacturer's recommended temperature limitations. This data assumes negligible downward loss in accordance with good insulation practices.

Figure 8-8: Excerpt from supply water temperature chart

Step 9: Determine loop length

Loop length is a function of room size, piping on-center distance and the length of the piping that runs to and from the manifold (leader distance).

Active loop length — To determine the amount of piping to be installed in a room, use the following multipliers:

12" o.c.	Multiply the square footage of the room by 1.0
10" o.c.	Multiply the square footage of the room by 1.2
9" o.c.	Multiply the square footage of the room by 1.33
8" o.c.	Multiply the square footage of the room by 1.5
7" o.c.	Multiply the square footage of the room by 1.7
6" o.c.	Multiply the square footage of the room by 2.0

These factors determine the amount of active piping to install in the room.

Find: The active loop length for Bedroom 1 with the piping installed at 9 inches on center.

Procedure:

1. Multiply the square footage of the room by the appropriate multiplier: 132 ft^2 x 1.33 = 176 feet
2. The active loop length for Bedroom 1 is 176 feet.

Enter 176 feet in the active loop length cell on the worksheet.

Leader length — To determine the leader length for the loop, add the horizontal distance from the room to the manifold to include any vertical distance. Multiply this value by two (supply and return) to obtain the leader length for the loop. To determine the total loop length, add the active loop length to the leader length.

Find: The leader length for Bedroom 1.

Procedure:

1. Add the horizontal distance from the room to the manifold location and back to the amount of vertical distance at the manifold location.
2. The manifold location is approximately 20 feet from Bedroom 1. Multiply this distance by 2 (to account for supply and return piping) to obtain the amount of horizontal piping in the leader length: 20 x 2 = 40 feet
3. At the manifold location, this example will require approximately 5 feet of piping to run from the floor to the manifold and back to the floor (roughly 2 feet on one side with 3 feet on the other). Add the horizontal and vertical piping amounts together: 40 + 5 = 45 feet
4. The total leader length for Bedroom 1 is 45 feet.

Enter 45 feet in the leader length cell on the worksheet.

Find: The total loop length for Bedroom 1.

Procedure:

1. Add the active loop length to the leader length to obtain the total loop length: 176 + 45 = 221
2. The total loop length for Bedroom 1 is 221 feet.

Enter 221 feet in the total loop length cell on the worksheet.

Radiant floor design worksheet

Project name: Training House main level

			Loop 1
	A	**Room name**	**Bedroom 1**
	B	Room setpoint temp. (°F)	65°F
	C	Zone number	1
	D	Upward load (BTU/h/ft^2)	19.8
	E	Total load (BTU/h/ft^2)	24.8
	F	Floor surface temp. (°F)	74.9°F
	G	Installation method	Poured floor
	H	Piping size	½" Wirsbo hePEX
	I	Floor covering R-value	1.92
	J	Differential temp. (°F)	10°F
	K	Piping o.c. distance (in)	9"
	L	Supply water temp. (°F)	132°F
Step 9	M	**Active loop length**	**176'**
	N	**Leader loop length**	**45'**
	O	**Total loop length**	**221'**
Step 10	P	**Loop flow in gpm**	**0.67**
Step 11	Q	**Loop head pressure (ft)**	**4.6'**
	R	Loop balancing turns	

Manifold totals

S	Supply water temp. (°F)	
T	Manifold flow in gpm	
U	Highest pressure head (ft)	

Figure 8-9: Radiant floor design worksheet

Step 10: Calculating fluid flow

To satisfy the calculated heat load, the system must provide adequate fluid flow through each loop of the hydronic radiant floor system. Fluid flow is based on a relationship between the heat load, active loop length and the supply and return differential temperature. The information required to calculate fluid flow includes:

- Required total BTU/h/ft^2 load (upward and downward combined)
- Piping on-center distance
- Active loop length

For Bedroom 1 of the Training House, the total load from the heat loss is 24.8 BTU/h/ft^2. The active loop length, based on 9 inches on-center spacing, is 176 feet.

Use the charts in **Appendix F** to calculate flow for each loop in the system. Select the appropriate chart for the water or water-and-glycol mixture when calculating flow.

Find: The required flow per loop.

Procedure:

1. Find the appropriate chart based on the type of fluid used. In this tutorial, use the 100% water chart (see **Figure 8-10**).
2. Enter the chart at the total BTU/h/ft² load (24.8) in the BTU/h/ft² column. In small applications, round to the nearest BTU/h/ft² value (25 BTU/h/ft²) or use the formula in **Step 3** to determine the flow per foot value for the actual BTU/h/ft².
3. For actual flow value, move to the right until you intersect the column for 9 inches on center for 25 BTU/h/ft².
4. The flow value is 0.00380 gpm per foot of piping.
5. Using the actual flow, multiply it by the active loop length: 0.00380 x 176 = 0.67 gpm

Enter 0.67 gpm in the flow per loop cell in the worksheet.

Step 11: Pressure loss

To calculate the feet of pressure head drop (ft hd) for the loop, use the following information: flow per loop, total loop length, size of piping, type of piping, supply water temperature and fluid concentration.

The flow for this loop is 0.67 gallons per minute. The total loop length is 221 feet. The type and size of piping is ½" Wirsbo hePEX. The supply water temperature is 132°F. The fluid concentration is 100% water.

Find: Feet of head drop.

Procedure:

1. Find the appropriate chart in **Appendix G** (100% water using ½" Wirsbo hePEX).
2. Enter the gpm column and round to the nearest flow for the loop (0.72 gpm).
3. Move right to the closest supply water column for the manifold (130ºF).

> **Note:** If the system water temperature is between two columns, round up or down to the nearest temperature. If the temperature falls exactly between two columns (110°F for example), use the lower temperature column (100°F). For this example, use the 130°F column.

4. Read the feet of head drop per foot (0.02094).
5. Multiply the feet of head value per foot by the total loop length to determine total feet of head for the loop. (0.02094 x 221 = 4.6')

Normally, the feet of head calculations are completed only after the manifold supply water temperature is known (after the project design is completed). The feet of head loss is completed now for training purposes.

If the head loss is higher than desired after completing the pressure-loss calculation, you may need to decrease loop length(s), add loops or increase the PEX piping size.

If the piping size or total loop length change, recalculate pressure loss using the new loop length or piping size (and corresponding water temperature).

Enter 4.6 feet of head in the loop head pressure cell in the worksheet.

This completes the design of Bedroom 1. Once all rooms are designed and calculated for the Training House tutorial, perform the initial flow balancing and determine the system totals. The answers for the tutorial are on **page 88**.

100% Water | 10º Supply/return differential flow in GPM per foot of piping.

	Piping on-center distances					
BTU/h/ft²	6" o.c.	7" o.c.	8" o.c.	9" o.c.	10" o.c.	12
50	0.00507	0.00591	0.00676	0.00760	0.00845	0.
49	0.00497	0.00579	0.00662	0.00745	0.00828	0.
48	0.00487	0.00568	0.00649	0.00730	0.00811	0.
47	0.00476	0.00556	0.00635	0.00715	0.00476	0.
46	0.00466	0.00544	0.00622	0.00699	0.00777	0.
45	0.00456	0.00532	0.00608	0.00684	0.00760	0.
44	0.00446	0.00520	0.00595	0.00669	0.00743	0.
43	0.00436	0.00508	0.00581	0.00654	0.00726	0.
42	0.00426	0.00497	0.00568	0.00639	0.00709	0.
41	0.00416	0.00485	0.00554	0.00623	0.00693	0.
40	0.00405	0.00473	0.00541	0.00608	0.00676	0.
39	0.00395	0.00461	0.00527	0.00593	0.00659	0.
38	0.00385	0.00449	0.00513	0.00578	0.00642	0.
37	0.00375	0.00437	0.00500	0.00563	0.00625	0.
36	0.00365	0.00426	0.00486	0.00547	0.00608	0.
35	0.00355	0.00414	0.00473	0.00532	0.00591	0.
34	0.00345	0.00402	0.00459	0.00517	0.00574	0.
33	0.00334	0.00390	0.00446	0.00502	0.00557	0.
32	0.00324	0.00378	0.00432	0.00487	0.00541	0.
31	0.00314	0.00367	0.00419	0.00471	0.00524	0.
30	0.00304	0.00355	0.00405	0.00456	0.00507	0.
29	0.00294	0.00343	0.00392	0.00441	0.00490	0.
28	0.00284	0.00331	0.00378	0.00426	0.00473	0.
27	0.00274	0.00319	0.00365	0.00410	0.00456	0.
26	0.00264	0.00307	0.00351	0.00395	0.00439	0.
25	0.00253	0.00296	0.00338	0.00380	0.00422	0.
24	0.00243	0.00284	0.00324	0.00365	0.00405	0.
23	0.00233	0.00272	0.00311	0.00350	0.00389	0.
22	0.00223	0.00260	0.00297	0.00334	0.00372	0.
21	0.00213	0.00248	0.00284	0.00319	0.00355	0.
20	0.00203	0.00236	0.00270	0.00304	0.00338	0.

Figure 8-10: Excerpt from 100% water flow chart on page 194

System reminders

Water temperature

When designing a radiant system, a situation may arise where different loops serving different rooms on the same manifold have different required water temperatures. Typically, if this difference is no greater than 20°F to 25°F, it will not impact the system. This, of course, will vary depending on room traffic patterns and floor coverings.

However, if the difference is greater than 25°F, consider some design changes to reduce the temperature differential.

First, in wet applications (poured-floor underlayment), decrease the piping spacing of the loops requiring higher water temperatures. This will lower the required water temperature in those loops while maintaining the same output and floor surface temperature. However, loop length and pressure loss will increase, which may necessitate adding a second loop to that area.

Second, in dry installations (between the joists), you may choose to add aluminum heat emission plates to lower the water temperature.

Third, decreasing the finished floor R-value will lead to lower required water temperatures.

Last, move the higher supply water temperature loops to another manifold and run appropriate water temperature to that manifold.

Head and GPM

When calculating the flow and head total for a system, gpm (or total flow) is cumulative. The flow of all loops served by a single circulator should be added together. Head (or pressure loss) is not cumulative. Simply select the highest pressure drop of all the loops per manifold served by that circulator. Remember to add in the supply and return mechanical piping and any other appliances the circulator will push flow through.

When selecting a circulator, consult the manufacturer's published performance curves, and select the circulator that best fits the specific gpm and head requirements for the project.

The complete design

The following is the entire room schedule for the Uponor Training House. The floor plans and heat-loss information appear on **pages 72 to 85**. Finish the design with the worksheet started by Bedroom 1. See **page 88** for the completed tutorial design calculations.

Room schedule		
Bedroom 1	136 ft^2	¼" nylon saxony with ¼" bonded urethane
Bedroom 2	160 ft^2	¼" nylon saxony with ¼" bonded urethane
Bedroom 3	183 ft^2	¼" nylon saxony with ¼" bonded urethane
Living room	260 ft^2	¾" oak
Kitchen/dining	260 ft^2	¾" oak
Bath/laundry	150 ft^2	¼" ceramic tile with ¼" underlayment
Bedroom 4	209 ft^2	¼" nylon saxony with ¼" bonded urethane
Bath 2	75 ft^2	¼" ceramic tile with ¼" underlayment
Family room	270 ft^2	¼" nylon saxony with ¼" bonded urethane
Recreation room	270 ft^2	¼" nylon saxony with ¼" bonded urethane
Storage	383 ft^2	No floor covering
Window schedule		
Window 1 — 2'6" x 4'0"	Double pane, wood frame	R-1.81
Window 2 — 5'0" x 4'0"	Double pane, wood frame	R-1.81
Door schedule		
Door 1 — 6'0" x 7'0"	Sliding, double pane, wood frame	R-1.82
Door 2 — 3'0" x 7'0"	Metal with urethane core	R-5.29

Figure 8-11: Room, window and door schedules

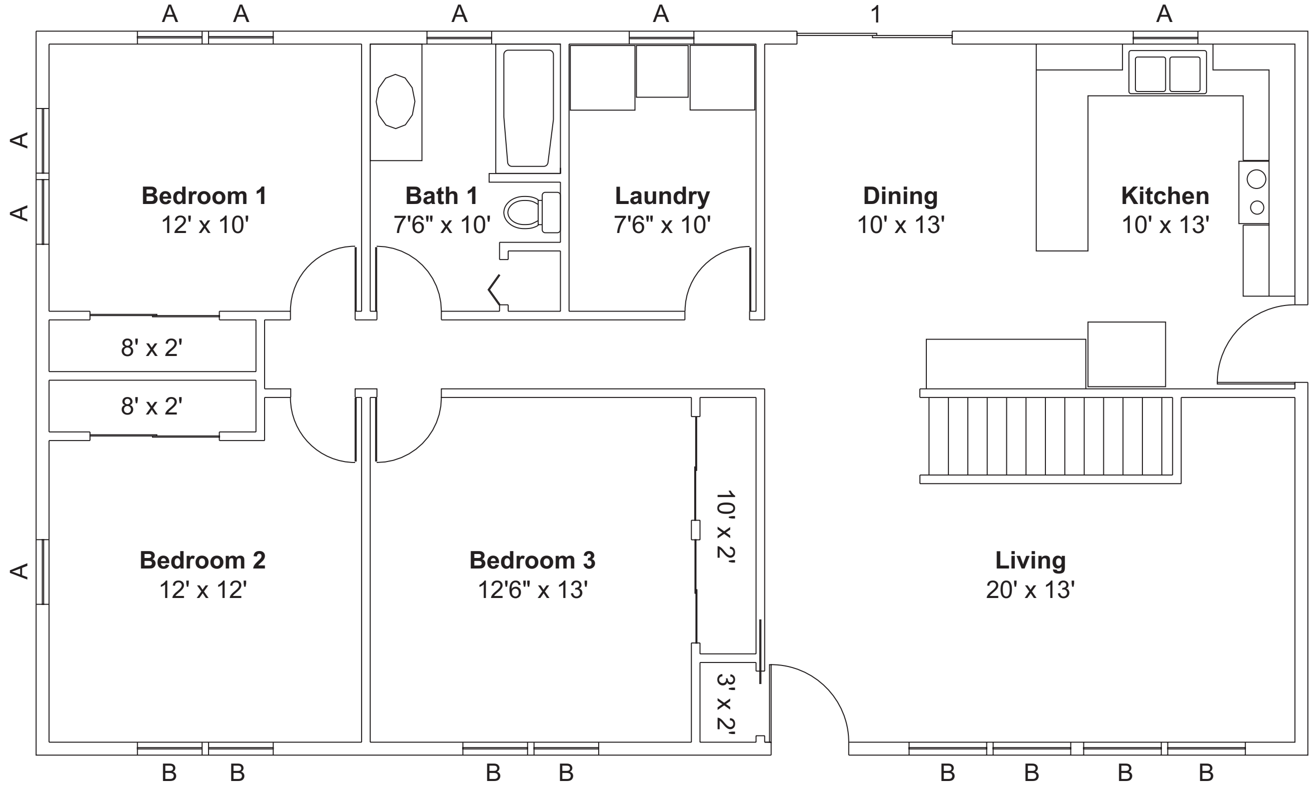


Figure 8-12: Main-level floor plan (no scale)

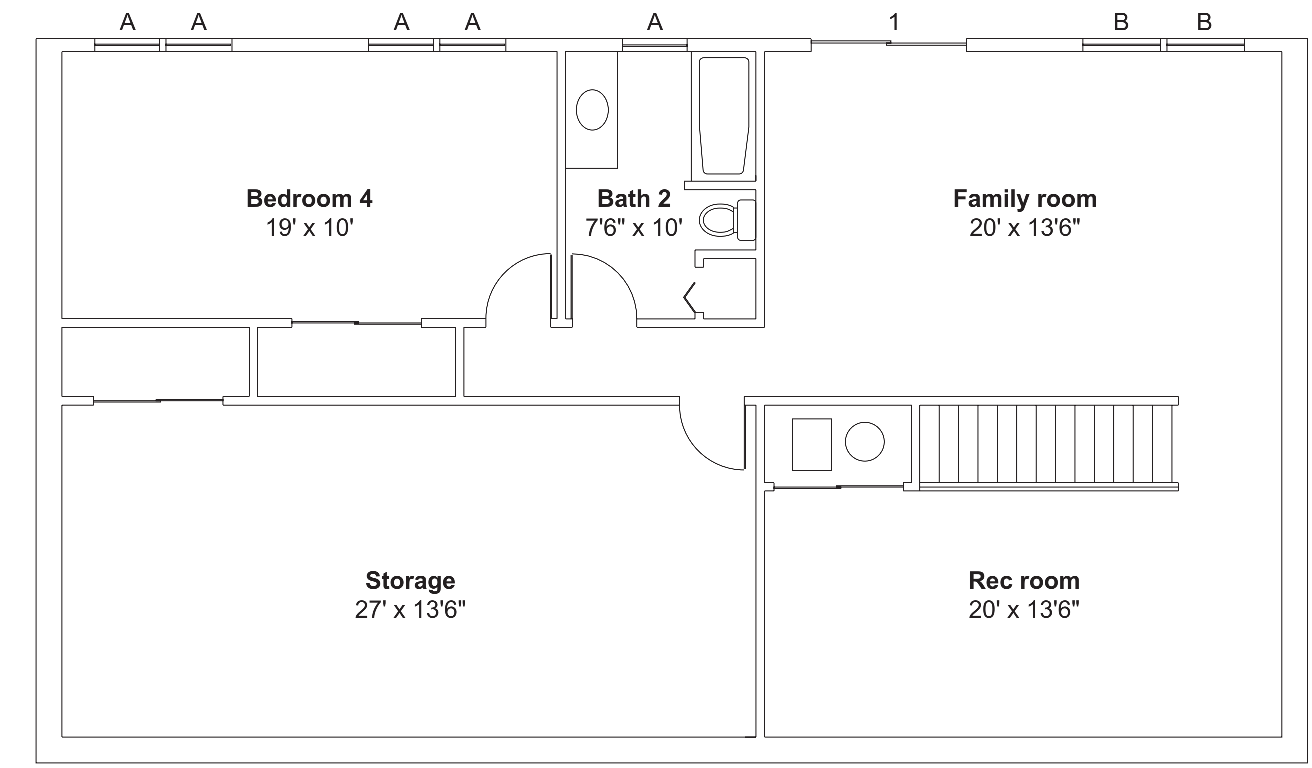


Figure 8-13: Lower-level floor plan (no scale)

uponor

Heat Loss Detail

ASHRAE Load Calculation

Project #:A- Z Heating Supply

July 08, 2020

Project Information

Project #: A- Z Heating Supply

Name: Training House

Location:

Notes:

Load Calculation Summary

Design Location:	CHICAGO O'HARE INTL, Illinois	Component Losses:	19,866 Btu/hr
Load Calculation Method:	ASHRAE	Infiltration/Ventilation:	5,451 Btu/hr
Outdoor Temperature:	4.5 °F	Radiant Back Losses:	3,331 Btu/hr
Floorplans / Levels:		Total Heating Load:	28,649 Btu/hr
Basement	1,246 ft²		
Main Floor1	1,259 ft²	Radiant Heating:	25,317 Btu/hr
Total Area:	2,505 ft²	Radiant Back Losses:	3,331 Btu/hr
		Other:	0 Btu/hr
		Total Heating Load:	28,649 Btu/hr
		Surface Temperature:	71 - 82 °F

Load Calculation Data

Project Summary

Room	Area	Heating Type	Room Temp	Walls	Windows	Doors	Skylights	Floor	Ceiling	Infiltration	Additional	Recovered Panel Loss	Design Load	Unit Loss
Basement	1,246	RH	65.0	2,460	2,416	3,026	0	3,164	0	2,531	0	0	13,596	11.6
Main Floor1	1,259	RH	65.0	4,051	5,521	412	0	4,248	1,981	2,921	0	-4,081	15,053	13.2
Total For Project	2,505	RH	65.0	6,511	7,937	3,437	0	7,413	1,981	5,451	0	-4,081	28,649	12.4

Length = ft Area = ft² Temperature = °F Flowrate = USGPM Air Flow = cfm Heat Loss = Btu/hr Unit Heat Loss = Btu/(hr·ft²) Rv = hr·ft²·°F/btu
Head Loss = ft water RH = Radiant Floor Heating BB = Baseboard FA = Forced Air OTH = Other Heating SM = Snowmelt N = Not Heated

Created Using LoopCAD 2020 Uponor(US) (7/14/2020)
Version:20.0.0094 R

See end of report for important Notes and Disclaimers.

Page 1 of 14

Basement

Bath 2

Total Area:	97 ft²	Infiltration/Ventilation Load:	198 Btu/hr
Ceiling Height:	8' ft	Component Losses:	625 Btu/hr
Volume:	681 ft³	Additional Losses:	0 Btu/hr
Exposed Perimeter:	8' ft	Total Room Loss:	823 Btu/hr
		Recovered Floor Loss:	0 Btu/hr
Room Temperature:	65 °F	Net Room Load:	823 Btu/hr
Space Above:	Main Floor1		

Heating System

Heating Type:	Radiant	Surface Temp:	69 °F
Floor Area:	89 ft²	Net Room Load:	823 Btu/hr
Unheated Area:	0 ft²	Floor Back Loss:	173 Btu/hr
Net Heated Area:	89 ft²	Recovered Floor Loss:	0 Btu/hr
Floor Cover Rv:	0.6 hr·ft²·°F/btu	Gross Upward Load:	650 Btu/hr
Panel Type:	Embedded Slab		
		Supplemental Heat Supply:	0 Btu/hr
Supplemental Heating Type:	Other	Net Upward Load:	650 Btu/hr
Required Supply Temp:	80 °F	Total Radiant Load:	823 Btu/hr

Component Losses

Component	Length	Width/Height	Area	Construction	Rv	Heat Loss	Unit Loss
Window	2'-6"	4'	10	C2	1.8	345	3.9
Exposed Walls Above Grade	8'	0'	11	-	-	0	0.0
Basement with Walls	-	-	97	C1	Exterior Wall Insulation: 10.0 hr·ft²·°F/btu Slab Insulation: 10.0 hr·ft²·°F/btu	280	3.1
Exposed Ceiling	-	-	0	-	38.5	0	0.0
Total	-	-	-	-	-	625	7.0

Length = ft Area = ft² Temperature = °F Flowrate = USGPM Air Flow = cfm Heat Loss = Btu/hr Unit Heat Loss = Btu/(hr·ft²) Rv = hr·ft²·°F/btu
Head Loss = ft water RH = Radiant Floor Heating BB = Baseboard FA = Forced Air OTH = Other Heating SM = Snowmelt N = Not Heated

Created Using LoopCAD 2020 Uponor(US) (7/14/2020)
Version:20.0.0094 R

See end of report for important Notes and Disclaimers.

Bedroom 4

Total Area:	233 ft^2	Infiltration/Ventilation Load:	473 Btu/hr
Ceiling Height:	8' ft	Component Losses:	2,644 Btu/hr
Volume:	1,632 ft^3	Additional Losses:	0 Btu/hr
Exposed Perimeter:	31'-4" ft	Total Room Loss:	3,117 Btu/hr
		Recovered Floor Loss:	0 Btu/hr
Room Temperature:	65 °F	Net Room Load:	3,117 Btu/hr
Space Above:	Main Floor1		

Heating System

Heating Type:	Radiant	Surface Temp:	71 °F
Floor Area:	218 ft^2	Net Room Load:	3,117 Btu/hr
Unheated Area:	0 ft^2	Floor Back Loss:	709 Btu/hr
Net Heated Area:	218 ft^2	Recovered Floor Loss:	0 Btu/hr
Floor Cover Rv:	1.9 hr·ft^2·°F/btu	Gross Upward Load:	2,408 Btu/hr
Panel Type:	Embedded Slab		
		Supplemental Heat Supply:	0 Btu/hr
Supplemental Heating Type:	Other	Net Upward Load:	2,408 Btu/hr
Required Supply Temp:	98 °F	Total Radiant Load:	3,117 Btu/hr

Component Losses

Component	Length	Width/Height	Area	Construction	Rv	Heat Loss	Unit Loss
Window	2'-6"	4'	10	C2	1.8	345	1.6
Window	2'-6"	4'	10	C2	1.8	345	1.6
Window	2'-6"	4'	10	C2	1.8	345	1.6
Window	2'-6"	4'	10	C2	1.8	345	1.6
Exposed Walls Above Grade	31'-4"	0'	43	-	-	0	0.0
Basement with Walls	-	-	233	C1	Exterior Wall Insulation: 10.0 hr·ft^2·°F/btu Slab Insulation: 10.0 hr·ft^2·°F/btu	1,263	5.8
Exposed Ceiling	-	-	0	-	38.5	0	0.0
Total	-	-	-	-	-	2,644	12.1

See end of report for important Notes and Disclaimers.

Family Room

Total Area:	286 ft²	Infiltration/Ventilation Load:	580 Btu/hr
Ceiling Height:	8' ft	Component Losses:	3,444 Btu/hr
Volume:	2,000 ft³	Additional Losses:	0 Btu/hr
Exposed Perimeter:	34'-4" ft	Total Room Loss:	4,024 Btu/hr
		Recovered Floor Loss:	0 Btu/hr
Room Temperature:	65 °F	Net Room Load:	4,024 Btu/hr
Space Above:	Main Floor1		

Heating System

Heating Type:	Radiant	Surface Temp:	71 °F
Floor Area:	269 ft²	Net Room Load:	4,024 Btu/hr
Unheated Area:	0 ft²	Floor Back Loss:	847 Btu/hr
Net Heated Area:	269 ft²	Recovered Floor Loss:	0 Btu/hr
Floor Cover Rv:	1.9 hr·ft²·°F/btu	Gross Upward Load:	3,177 Btu/hr
Panel Type:	Embedded Slab		
		Supplemental Heat Supply:	0 Btu/hr
Supplemental Heating Type:	Other	Net Upward Load:	3,177 Btu/hr
Required Supply Temp:	100 °F	Total Radiant Load:	4,024 Btu/hr

Component Losses

Component	Length	Width/Height	Area	Construction	Rv	Heat Loss	Unit Loss
Window	5'	4'	20	C2	1.8	690	2.6
Door	6'	6'-8"	40	C5	1.8	1,331	5.0
Exposed Walls Above Grade	34'-4"	0'	49	-	-	0	0.0
Basement with Walls	-	-	286	C1	Exterior Wall Insulation: 10.0 hr·ft²·°F/btu Slab Insulation: 10.0 hr·ft²·°F/btu	1,423	5.3
Exposed Ceiling	-	-	0	-	38.5	0	0.0
Total	-	-	-	-	-	3,444	12.8

Length = ft Area = ft² Temperature = °F Flowrate = USGPM Air Flow = cfm Heat Loss = Btu/hr Unit Heat Loss = Btu/(hr·ft²) Rv = hr·ft²·°F/btu
Head Loss = ft water RH = Radiant Floor Heating BB = Baseboard FA = Forced Air OTH = Other Heating SM = Snowmelt N = Not Heated

See end of report for important Notes and Disclaimers.

Rec Room

Total Area:	245 ft²	Infiltration/Ventilation Load:	498 Btu/hr
Ceiling Height:	8' ft	Component Losses:	1,189 Btu/hr
Volume:	1,718 ft³	Additional Losses:	0 Btu/hr
Exposed Perimeter:	32'-4" ft	Total Room Loss:	1,688 Btu/hr
		Recovered Floor Loss:	0 Btu/hr
Room Temperature:	65 °F	Net Room Load:	1,688 Btu/hr
Space Above:	Main Floor1		

Heating System

Heating Type:	Radiant	Surface Temp:	67 °F
Floor Area:	229 ft²	Net Room Load:	1,688 Btu/hr
Unheated Area:	0 ft²	Floor Back Loss:	623 Btu/hr
Net Heated Area:	229 ft²	Recovered Floor Loss:	0 Btu/hr
Floor Cover Rv:	1.9 hr·ft²·°F/btu	Gross Upward Load:	1,065 Btu/hr
Panel Type:	Embedded Slab		
		Supplemental Heat Supply:	0 Btu/hr
Supplemental Heating Type:	Other	Net Upward Load:	1,065 Btu/hr
Required Supply Temp:	80 °F	Total Radiant Load:	1,688 Btu/hr

Component Losses

Component	Length	Width/Height	Area	Construction	Rv	Heat Loss	Unit Loss
Exposed Walls Above Grade	32'-4"	0'	65	-	-	0	0.0
Basement with Walls	-	-	245	C1	Exterior Wall Insulation: 10.0 hr·ft²·°F/btu Slab Insulation: 10.0 hr·ft²·°F/btu	1,189	5.2
Exposed Ceiling	-	-	0	-	38.5	0	0.0
Total	-	-	-	-	-	1,189	5.2

Length = ft Area = ft² Temperature = °F Flowrate = USGPM Air Flow = cfm Heat Loss = Btu/hr Unit Heat Loss = Btu/(hr·ft²) Rv = hr·ft²·°F/btu
Head Loss = ft water RH = Radiant Floor Heating BB = Baseboard FA = Forced Air OTH = Other Heating SM = Snowmelt N = Not Heated

See end of report for important Notes and Disclaimers.

Storage

Total Area:	385 ft²	Infiltration/Ventilation Load:	781 Btu/hr
Ceiling Height:	8' ft	Component Losses:	3,164 Btu/hr
Volume:	2,694 ft³	Additional Losses:	0 Btu/hr
Exposed Perimeter:	41'-4" ft	Total Room Loss:	3,945 Btu/hr
		Recovered Floor Loss:	0 Btu/hr
Room Temperature:	65 °F	Net Room Load:	3,945 Btu/hr
Space Above:	Main Floor1		

Heating System

Heating Type:	Radiant	Surface Temp:	69 °F
Floor Area:	364 ft²	Net Room Load:	3,945 Btu/hr
Unheated Area:	0 ft²	Floor Back Loss:	812 Btu/hr
Net Heated Area:	364 ft²	Recovered Floor Loss:	0 Btu/hr
Floor Cover Rv:	0.0 hr·ft²·°F/btu	Gross Upward Load:	3,133 Btu/hr
Panel Type:	Embedded Slab		
		Supplemental Heat Supply:	0 Btu/hr
Supplemental Heating Type:	Other	Net Upward Load:	3,133 Btu/hr
Required Supply Temp:	80 °F	Total Radiant Load:	3,945 Btu/hr

Component Losses

Component	Length	Width/Height	Area	Construction	Rv	Heat Loss	Unit Loss
Door	7'	6'-8"	47	C4	1.7	1,695	4.7
Exposed Walls Above Grade	41'-4"	0'	71	-	-	0	0.0
Basement with Walls	-	-	385	C1	Exterior Wall Insulation: 10.0 hr·ft²·°F/btu Slab Insulation: 10.0 hr·ft²·°F/btu	1,468	4.0
Exposed Ceiling	-	-	0	-	38.5	0	0.0
Total	-	-	-	-	-	3,164	8.7

Main Floor1

Bath Laundry

Total Area:	184 ft²	Infiltration/Ventilation Load:	426 Btu/hr
Ceiling Height:	8' ft	Component Losses:	1,720 Btu/hr
Volume:	1,470 ft³	Additional Losses:	0 Btu/hr
Exposed Perimeter:	15' ft	Total Room Loss:	2,146 Btu/hr
		Recovered Floor Loss:	-315 Btu/hr
Room Temperature:	65 °F	Net Room Load:	1,832 Btu/hr
Space Above:	Not Heated		
Space Below:	Basement/Open or Vented Crawlspace		

Heating System

Heating Type:	Radiant	Surface Temp:	70 °F
Floor Area:	167 ft²	Net Room Load:	1,832 Btu/hr
Unheated Area:	0 ft²	Floor Back Loss:	329 Btu/hr
Net Heated Area:	167 ft²	Recovered Floor Loss:	-315 Btu/hr
Floor Cover Rv:	0.6 hr·ft²·°F/btu	Gross Upward Load:	1,817 Btu/hr
Panel Type:	Lightweight Over-pour		
		Supplemental Heat Supply:	0 Btu/hr
Supplemental Heating Type:	Other	Net Upward Load:	1,817 Btu/hr
Required Supply Temp:	93 °F	Total Radiant Load:	2,146 Btu/hr

Component Losses

Component	Length	Width/Height	Area	Construction	Rv	Heat Loss	Unit Loss
Window	2'-6"	4'	10	C2	1.8	345	2.1
Window	2'-6"	4'	10	C2	1.8	345	2.1
Exposed Walls Above Grade	15'	8'	100	C6	14.7	412	2.5
Floor	-	-	184	C7	5.0 (panel Insulation)	329	2.0
Exposed Ceiling	-	-	184	C3	38.5	289	1.7
Total	-	-	-	-	-	1,720	10.3

Length = ft Area = ft² Temperature = °F Flowrate = USGPM Air Flow = cfm Heat Loss = Btu/hr Unit Heat Loss = Btu/(hr·ft²) Rv = hr·ft²·°F/btu
Head Loss = ft water RH = Radiant Floor Heating BB = Baseboard FA = Forced Air OTH = Other Heating SM = Snowmelt N = Not Heated

See end of report for important Notes and Disclaimers.

Bedroom 1

Total Area:	150 ft^2	Infiltration/Ventilation Load:	348 Btu/hr
Ceiling Height:	8' ft	Component Losses:	3,279 Btu/hr
Volume:	1,200 ft^3	Additional Losses:	0 Btu/hr
Exposed Perimeter:	24'-6" ft	Total Room Loss:	3,627 Btu/hr
		Recovered Floor Loss:	-985 Btu/hr
Room Temperature:	65 °F	Net Room Load:	2,642 Btu/hr
Space Above:	Not Heated		
Space Below:	Basement/Open or Vented Crawlspace		

Heating System

Heating Type:	Radiant	Surface Temp:	75 °F
Floor Area:	132 ft^2	Net Room Load:	2,642 Btu/hr
Unheated Area:	0 ft^2	Floor Back Loss:	1,020 Btu/hr
Net Heated Area:	132 ft^2	Recovered Floor Loss:	-985 Btu/hr
Floor Cover Rv:	1.9 hr·ft^2·°F/btu	Gross Upward Load:	2,607 Btu/hr
Panel Type:	Lightweight Over-pour		
		Supplemental Heat Supply:	0 Btu/hr
Supplemental Heating Type:	Other	Net Upward Load:	2,607 Btu/hr
Required Supply Temp:	132 °F	Total Radiant Load:	3,627 Btu/hr

Component Losses

Component	Length	Width/Height	Area	Construction	Rv	Heat Loss	Unit Loss
Window	2'-6"	4'	10	C2	1.8	345	2.6
Window	2'-6"	4'	10	C2	1.8	345	2.6
Window	2'-6"	4'	10	C2	1.8	345	2.6
Window	2'-6"	4'	10	C2	1.8	345	2.6
Exposed Walls Above Grade	24'-6"	8'	156	C6	14.7	642	4.9
Floor	-	-	150	C7	5.0 (panel Insulation)	1,020	7.7
Exposed Ceiling	-	-	150	C3	38.5	236	1.8
Total	-	-	-	-	-	3,279	24.8

Length = ft Area = ft^2 Temperature = °F Flowrate = USGPM Air Flow = cfm Heat Loss = Btu/hr Unit Heat Loss = Btu/(hr·ft^2) Rv = hr·ft^2·°F/btu
Head Loss = ft water RH = Radiant Floor Heating BB = Baseboard FA = Forced Air OTH = Other Heating SM = Snowmelt N = Not Heated

Created Using LoopCAD 2020 Uponor(US) (7/14/2020)
Version:20.0.0094 R

See end of report for important Notes and Disclaimers.

Bedroom 2

Total Area:	175 ft²	Infiltration/Ventilation Load:	405 Btu/hr
Ceiling Height:	8' ft	Component Losses:	3,026 Btu/hr
Volume:	1,397 ft³	Additional Losses:	0 Btu/hr
Exposed Perimeter:	26'-6" ft	Total Room Loss:	3,431 Btu/hr
		Recovered Floor Loss:	-932 Btu/hr
Room Temperature:	65 °F	Net Room Load:	2,499 Btu/hr
Space Above:	Not Heated		
Space Below:	Basement/Open or Vented Crawlspace		

Heating System

Heating Type:	Radiant	Surface Temp:	73 °F
Floor Area:	155 ft²	Net Room Load:	2,499 Btu/hr
Unheated Area:	0 ft²	Floor Back Loss:	967 Btu/hr
Net Heated Area:	155 ft²	Recovered Floor Loss:	-932 Btu/hr
Floor Cover Rv:	1.9 hr·ft²·°F/btu	Gross Upward Load:	2,464 Btu/hr
Panel Type:	Lightweight Over-pour		
		Supplemental Heat Supply:	0 Btu/hr
Supplemental Heating Type:	Other	Net Upward Load:	2,464 Btu/hr
Required Supply Temp:	127 °F	Total Radiant Load:	3,431 Btu/hr

Component Losses

Component	Length	Width/Height	Area	Construction	Rv	Heat Loss	Unit Loss
Window	5'	4'	20	C2	1.8	690	4.4
Window	2'-6"	4'	10	C2	1.8	345	2.2
Exposed Walls Above Grade	26'-6"	8'	182	C6	14.7	749	4.8
Floor	-	-	175	C7	5.0 (panel Insulation)	967	6.2
Exposed Ceiling	-	-	175	C3	38.5	275	1.8
Total	-	-	-	-	-	3,026	19.5

Length = ft Area = ft² Temperature = °F Flowrate = USGPM Air Flow = cfm Heat Loss = Btu/hr Unit Heat Loss = Btu/(hr·ft²) Rv = hr·ft²·°F/btu
Head Loss = ft water RH = Radiant Floor Heating BB = Baseboard FA = Forced Air OTH = Other Heating SM = Snowmelt N = Not Heated

Created Using LoopCAD 2020 Uponor(US) (7/14/2020)
Version:20.0.0094 R

See end of report for important Notes and Disclaimers.

Bedroom 2

Total Area:	175 ft²	Infiltration/Ventilation Load:	405 Btu/hr
Ceiling Height:	8' ft	Component Losses:	3,026 Btu/hr
Volume:	1,397 ft³	Additional Losses:	0 Btu/hr
Exposed Perimeter:	26'-6" ft	Total Room Loss:	3,431 Btu/hr
		Recovered Floor Loss:	-932 Btu/hr
Room Temperature:	65 °F	Net Room Load:	2,499 Btu/hr
Space Above:	Not Heated		
Space Below:	Basement/Open or Vented Crawlspace		

Heating System

Heating Type:	Radiant	Surface Temp:	73 °F
Floor Area:	155 ft²	Net Room Load:	2,499 Btu/hr
Unheated Area:	0 ft²	Floor Back Loss:	967 Btu/hr
Net Heated Area:	155 ft²	Recovered Floor Loss:	-932 Btu/hr
Floor Cover Rv:	1.9 hr·ft²·°F/btu	Gross Upward Load:	2,464 Btu/hr
Panel Type:	Lightweight Over-pour		
		Supplemental Heat Supply:	0 Btu/hr
Supplemental Heating Type:	Other	Net Upward Load:	2,464 Btu/hr
Required Supply Temp:	127 °F	Total Radiant Load:	3,431 Btu/hr

Component Losses

Component	Length	Width/Height	Area	Construction	Rv	Heat Loss	Unit Loss
Window	5'	4'	20	C2	1.8	690	4.4
Window	2'-6"	4'	10	C2	1.8	345	2.2
Exposed Walls Above Grade	26'-6"	8'	182	C6	14.7	749	4.8
Floor	-	-	175	C7	5.0 (panel Insulation)	967	6.2
Exposed Ceiling	-	-	175	C3	38.5	275	1.8
Total	-	-	-	-	-	3,026	19.5

Dining / Kitchen

Total Area:	289 ft²	Infiltration/Ventilation Load:	670 Btu/hr
Ceiling Height:	8' ft	Component Losses:	2,544 Btu/hr
Volume:	2,308 ft³	Additional Losses:	0 Btu/hr
Exposed Perimeter:	34'-6" ft	Total Room Loss:	3,213 Btu/hr
		Recovered Floor Loss:	-493 Btu/hr
Room Temperature:	65 °F	Net Room Load:	2,720 Btu/hr
Space Above:	Not Heated		
Space Below:	Basement/Open or Vented Crawlspace		

Heating System

Heating Type:	Radiant	Surface Temp:	70 °F
Floor Area:	263 ft²	Net Room Load:	2,720 Btu/hr
Unheated Area:	0 ft²	Floor Back Loss:	526 Btu/hr
Net Heated Area:	263 ft²	Recovered Floor Loss:	-493 Btu/hr
Floor Cover Rv:	0.7 hr·ft²·°F/btu	Gross Upward Load:	2,687 Btu/hr
Panel Type:	Lightweight Over-pour		
		Supplemental Heat Supply:	0 Btu/hr
Supplemental Heating Type:	Other	Net Upward Load:	2,687 Btu/hr
Required Supply Temp:	92 °F	Total Radiant Load:	3,213 Btu/hr

Component Losses

Component	Length	Width/Height	Area	Construction	Rv	Heat Loss	Unit Loss
Door	3'	6'-8"	20	C8	5.9	206	0.8
Window	2'-6"	4'	10	C2	1.8	345	1.3
Exposed Walls Above Grade	34'-6"	8'	246	C6	14.7	1,013	3.8
Floor	-	-	289	C7	5.0 (panel Insulation)	526	2.0
Exposed Ceiling	-	-	289	C3	38.5	454	1.7
Total	-	-	-	-	-	2,544	9.7

Length = ft Area = ft² Temperature = °F Flowrate = USGPM Air Flow = cfm Heat Loss = Btu/hr Unit Heat Loss = Btu/(hr·ft²) Rv = hr·ft²·°F/btu
Head Loss = ft water RH = Radiant Floor Heating BB = Baseboard FA = Forced Air OTH = Other Heating SM = Snowmelt N = Not Heated

Created Using LoopCAD 2020 Uponor(US) (7/14/2020)
Version:20.0.0094 R

See end of report for important Notes and Disclaimers.

Living Room

Total Area:	248 ft²	Infiltration/Ventilation Load:	576 Btu/hr
Ceiling Height:	8' ft	Component Losses:	3,452 Btu/hr
Volume:	1,984 ft³	Additional Losses:	0 Btu/hr
Exposed Perimeter:	32'-6" ft	Total Room Loss:	4,028 Btu/hr
		Recovered Floor Loss:	-619 Btu/hr
Room Temperature:	65 °F	Net Room Load:	3,409 Btu/hr
Space Above:	Not Heated		
Space Below:	Basement/Open or Vented Crawlspace		

Heating System

Heating Type:	Radiant	Surface Temp:	73 °F
Floor Area:	224 ft²	Net Room Load:	3,409 Btu/hr
Unheated Area:	0 ft²	Floor Back Loss:	652 Btu/hr
Net Heated Area:	224 ft²	Recovered Floor Loss:	-619 Btu/hr
Floor Cover Rv:	0.7 hr·ft²·°F/btu	Gross Upward Load:	3,376 Btu/hr
Panel Type:	Lightweight Over-pour		
		Supplemental Heat Supply:	0 Btu/hr
Supplemental Heating Type:	Other	Net Upward Load:	3,376 Btu/hr
Required Supply Temp:	105 °F	Total Radiant Load:	4,028 Btu/hr

Component Losses

Component	Length	Width/Height	Area	Construction	Rv	Heat Loss	Unit Loss
Window	5'	4'	20	C2	1.8	690	3.1
Window	5'	4'	20	C2	1.8	690	3.1
Door	3'	6'-8"	20	C8	5.9	206	0.9
Exposed Walls Above Grade	32'-6"	8'	200	C6	14.7	823	3.7
Floor	-	-	248	C7	5.0 (panel Insulation)	652	2.9
Exposed Ceiling	-	-	248	C3	38.5	390	1.7
Total	-	-	-	-	-	3,452	15.4

Length = ft Area = ft² Temperature = °F Flowrate = USGPM Air Flow = cfm Heat Loss = Btu/hr Unit Heat Loss = Btu/(hr·ft²) Rv = hr·ft²·°F/btu
Head Loss = ft water RH = Radiant Floor Heating BB = Baseboard FA = Forced Air OTH = Other Heating SM = Snowmelt N = Not Heated

Created Using LoopCAD 2020 Uponor(US) (7/14/2020)
Version:20.0.0094 R

See end of report for important Notes and Disclaimers.

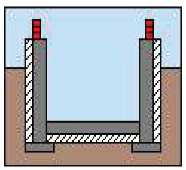
Name:Training House
Project #:A- Z Heating Supply

Heat Loss Detail
July 08, 2020

Construction Legend

Construction Code	Component	R-Value	Source	Description
C2	Window	1.8	Manual J 8th Edition V2	Double pane operable window or sliding glass door, with Clear Glass - Wood, Wood with Metal Clad or Vinyl Framing
C3	Ceiling	38.5	Manual J 8th Edition V2	No radiant barrier over ceiling or same type of air space behind an attic knee wall; R-38 Insulation; Materials: Asphalt Shingles(a), Metal(m), Wood Shakes(w), Tar / Gravel(x), Membrane(z), Tile, Slate or Concrete; Colors: Dark(d), Light(l), White(w);
C4	Door	1.7	Manual J 8th Edition V2	Metal Door with Fiberglass Core
C5	Door	1.8	User Specified	Sliding Wood Frame
C6	Wall	14.7	Manual J 8th Edition V2	Frame Wall or Partition; Wood Framing; R-19 Insulation in 2 x 6 Stud Cavity; Stucco or Wood Siding; Plus Interior Finish
C7	Heated Floor	5.0 (panel Insulation)	User Specified	Lightweight Over-pour
C8	Door	5.9	Manual J 8th Edition V2	Metal Door with Polyurethane Core with Storm

CSA Construction Legend



C1

Description

BCEB_1
- concrete walls and floor
- exterior surface of wall insulated over full-height
- sub-surface of floor slab fully insulated but no insulation under footings
- first storey brick veneer placed directly on basement's concrete walls

Options

Exterior Wall Insulation: 10.0 hr·ft²·°F/btu
Slab Insulation: 10.0 hr·ft²·°F/btu

Length = ft Area = ft² Temperature = °F Flowrate = USGPM Air Flow = cfm Heat Loss = Btu/hr Unit Heat Loss = Btu/(hr·ft²) Rv = hr·ft²·°F/btu
Head Loss = ft water RH = Radiant Floor Heating BB = Baseboard FA = Forced Air OTH = Other Heating SM = Snowmelt N = Not Heated

See end of report for important Notes and Disclaimers.

Disclaimers

With the permission of ASHRAE, portions of the 2017 ASHRAE Handbook – Fundamentals are reproduced in this software, including the Climatic Design Conditions data. The program and data are provided "as is" without warranty of any kind either expressed or implied. The entire risk as the quality and performance of the program and data is with you. In no event will ASHRAE be liable to you for any damages, including without limitation any lost profits, lost savings, or other incidental or consequential damages arising out of the use or inability to use this program or the data . © 2017 ASHRAE, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

Cold weather humidification, or some lifestyles that produce excessive moisture, may cause condensation to occur if the absolute humidity of the indoor air is too high for the momentary circumstances. Condensation can occur on surfaces or concealed within the structure, and can lead to mold, mildew, frost damage, and moisture damage. The software does not perform calculations for the estimation or detection of possible condensation problems, and it is the designers (i.e. software users) responsibility to do so independently if required.

The calculated values shown in this report are based on the data input by the user of the software. Inaccurate or erroneous data input will result in inaccurate or erroneous results. You are strongly advised to review all input data carefully, and to have the calculated results reviewed by an experienced heating professional to ensure reasonableness and suitability for your application.

IN NO EVENT WILL AVENIR SOFTWARE INC. (“AVENIR”) OR ITS AFFILIATES BE LIABLE UNDER ANY CONTRACT, NEGLIGENCE, STRICT LIABILITY OR OTHER LEGAL OR EQUITABLE THEORY FOR ANY CONSEQUENTIAL, INCIDENTAL, INDIRECT OR SPECIAL OR PUNITIVE DAMAGES WHATSOEVER (INCLUDING, BUT NOT LIMITED TO, DAMAGES FOR LOSS OF BUSINESS PROFITS, BUSINESS INTERRUPTION, LOSS OF BUSINESS INFORMATION OR DATA AND THE LIKE), EVEN IF SUCH PARTY HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. AVENIR'S CUMULATIVE LIABILITY FROM ANY CAUSE RELATED TO OR ARISING FROM THE USE THIS REPORT, AND REGARDLESS OF THE FORM OF THE ACTION, SHALL BE LIMITED TO NO GREATER THAN THE AMOUNT OF FEES PAID TO AVENIR UNDER THE SOFTWARE LICENSE AGREEMENT.

Radiant floor design worksheet

Project name: Training House lower level **Manifold number:** 1

		Loop 1	Loop 2	Loop 3	Loop 4	Loop 5	Loop 6	Loop 7	Loop 8	Loop 9	Loop 10
A	Room name	Bedroom 4	Bath 2	Family	Rec room	Storage					
B	Room setpoint temp. (°F)	65°F	65°F	65°F	65°F	65°F					
C	Zone number	1	7	8	9	10					
D	Upward load (BTU/h/ft²)	18.2	8.7	13.6	6.6	5.6					
E	Total load (BTU/h/ft²)	21.9	11.1	17.8	10.1	8.6					
F	Floor surface temp. (°F)	74.1	69	71	67	67					
G	Installation method	Poured floor	Poured floor	Poured floor	Poured floor	Poured floor					
H	Piping size	½"	½"	½"	½"	½"					
I	Floor covering R-value	1.92	0.56	1.92	1.92	0.0					
J	Differential temp. (°F)	10°F	10°F	10°F	10°F	10°F					
K	Piping o.c. distance (in)	9"	12"	12"	12"	12"					
L	Supply water temp. (°F)	125ºF	80	105	84	80					
M	Active loop length (ft)	181'	90	269	230	183					
N	Leader loop length (ft)	35'	3	8	9	3					
O	Total loop length (ft)	216'	96	285	248	189					
P	Loop flow in gpm	0.60	0.43	0.81	0.67	0.4					
Q	Loop head pressure (ft)	2.76'	0.9	7.8	4.9	1.7					

Manifold totals

R	Supply water temp. (°F)	133°F
S	Manifold flow in gpm	2.97
T	Highest pressure head (ft)	13.2

A Enter the name of the room. The room may have more than one loop.

B Room setpoint temperature is normally 65°F for radiant floor.

C Zone is equal to thermostat.

D Enter the "Floor unit load to room" value from design software printout (upward load).

E Enter the "Floor unit load" value from design software printout (total load).

F (**Row D**/2) + **Row B** = floor surface temperature. Do not exceed 87.5°F for all floors (exception: wood floor limit is 80°F).

G Enter the installation method.

H Enter the size of PEX piping for project.

I Refer to **Appendix D** for floor covering information.

J Indicate differential temperature (10°F for residential; 15°F for light commercial; 20°F for commercial).

K Maximum piping o.c. distance is 12" for residential. Do not exceed 9" o.c. under tile or linoleum.

L Use information from **Rows D, G, I, K** with **Appendix E** to obtain the supply water temperature.

M Enter the length of piping installed within the room (i.e., active loop).

N Enter the length of the piping from the room being heated to the respective manifold and multiply by 2 to account for both the supply and return.

O Use formula: (**Row M** + **Row N**) = total loop length.

x

P Use the values in **Rows E** and **M** with **Appendix F** to obtain the flow per loop.

Q Use the values in **Rows H** and **P** with **Appendix G** to obtain the head pressure per loop. Choose the appropriate solution (water or water/glycol solution).

R Enter highest temperature from **Row L**.

S Add and enter all values from **Row P**.

T Enter highest value from **Row Q**.

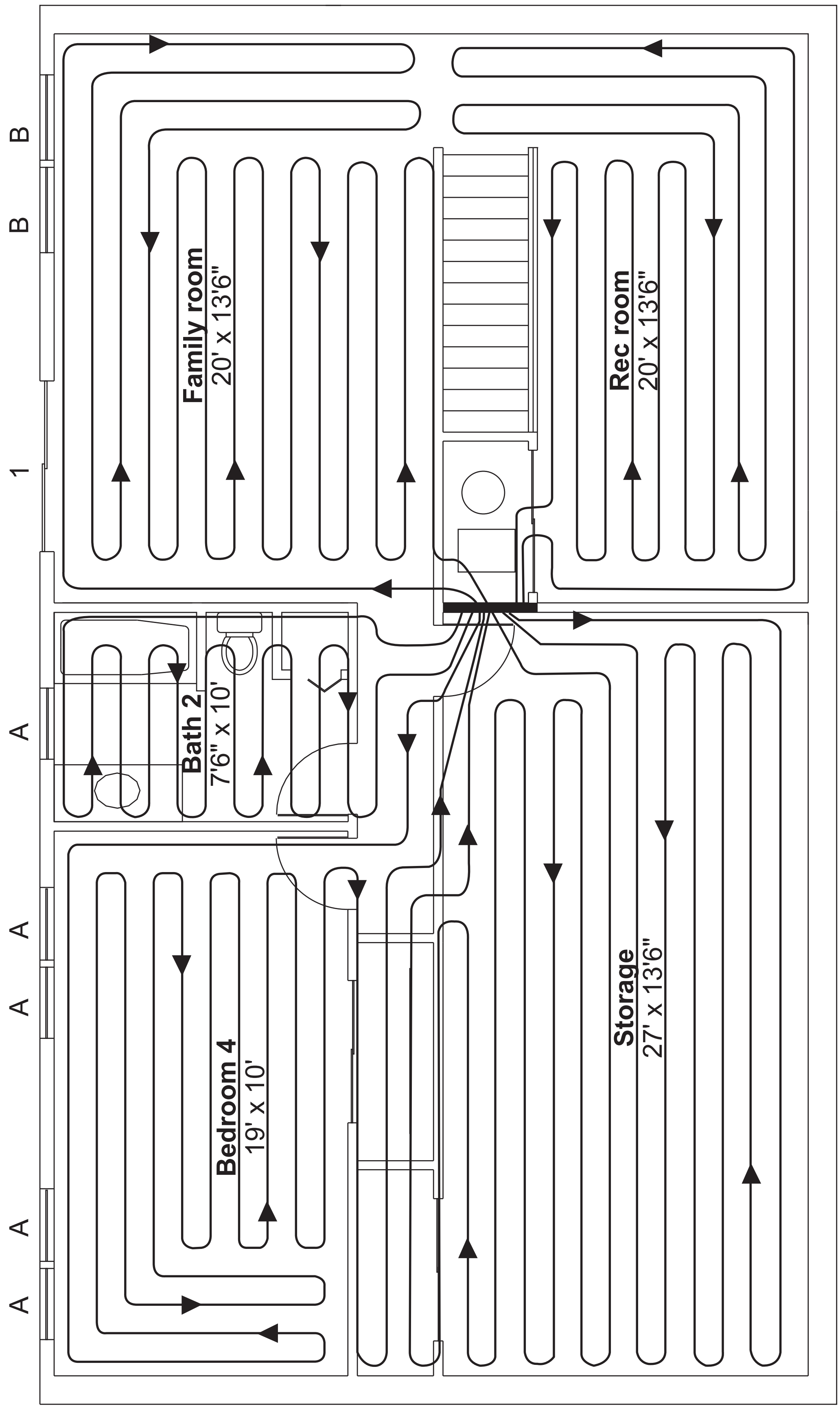


Figure 8-14: Lower-level floor plan (no scale)

Radiant floor design worksheet

Project name: Training house main level **Manifold number:** 2

		Loop 1	Loop 2	Loop 3	Loop 4	Loop 5	Loop 6	Loop 7	Loop 8	Loop 9	Loop 10
A	**Room name**	**Bedroom 1**	**Bath/Ldry**	**Din/Kit**	**Living Room**	**Bedroom 3**	**Bedroom 2**				
B	Room setpoint temp. (°F)	65°F	65°F	65°F	65°F	65°F	65°F				
C	Zone number	1	2	3	4	6	7				
D	Upward load (BTU/h/ft²)	18.2	10.9	10.4	15.2	10.0	16.0				
E	Total load (BTU/h/ft²)	21.9	13.0	12.4	18.2	13.9	22.3				
F	Floor surface temp. (°F)	74.1	70	70	73	70	73				
G	Installation method	Poured Floor	Poured Floor	Poured Floor	Poured Floor	Poured Floor	Poured Floor				
H	Piping size	½"	½"	½"	½"	½"	½"				
I	Floor covering R-value	1.92	0.56	0.67	0.67	1.92	1.92				
J	Differential temp. (°F)	10°F	10°F	10°F	10°F	10°F	10°F				
K	Piping o.c. distance (in)	9"	12"	12"	12"	12"	12"				
L	Supply water temp. (°F)	132ºF	93	92	105	104	127				
M	Active loop length (ft)	176'	167	263	224	196	175				
N	Leader loop length (ft)	45'	6	12	12	6	24				
O	Total loop length (ft)	221'	173	275	236	202	199				
P	Loop flow in gpm	0.67	0.94	1.45	1.28	0.83	0.74				
Q	Loop head pressure (ft)	4.6'	5.6	18.9	13.0	5.3	4.2				

Manifold totals

R	Supply water temp. (°F)	132°F
S	Manifold flow in gpm	5.97
T	Highest pressure head (ft)	18.9

A Enter the name of the room. The room may have more than one loop.

B Room setpoint temperature is normally 65°F for radiant floor.

C Zone is equal to thermostat.

D Enter the "Floor Unit Load to Room" value from design program printout (upward load).

E Enter the "Floor Unit Load" value from design program printout (total load).

F (**Row D**/2) + **Row B** = floor surface temperature. Do not exceed 87.5°F for all floors (exception: wood floor limit is 80°F).

G Enter the installation method.

H Enter the size of PEX piping for project.

I Refer to **Appendix D** for floor covering information.

J Indicate differential temperature (10°F for residential; 15°F for light commercial; 20°F for commercial).

K Maximum piping o.c. distance is 12" for residential. Do not exceed 9" o.c. under tile or linoleum.

L Use information from **Rows D, G, I, K** with **Appendix E** to obtain the supply water temperature.

M Enter the length of piping installed within the room (i.e., active loop).

N Enter the length of the piping from the room being heated to the respective manifold and multiply by 2 to account for both the supply and return.

O Use formula: (**Row M** + **Row N**) = total loop length.

P Use the values in **Rows E** and **M** with **Appendix F** to obtain the flow per loop.

Q Use the values in **Rows H** and **P** with **Appendix G** to obtain the head pressure per loop. Choose the appropriate solution (water or water/glycol solution).

R Enter highest temperature from **Row L**.

S Add and enter all values from **Row P**.

T Enter highest value from **Row Q**.

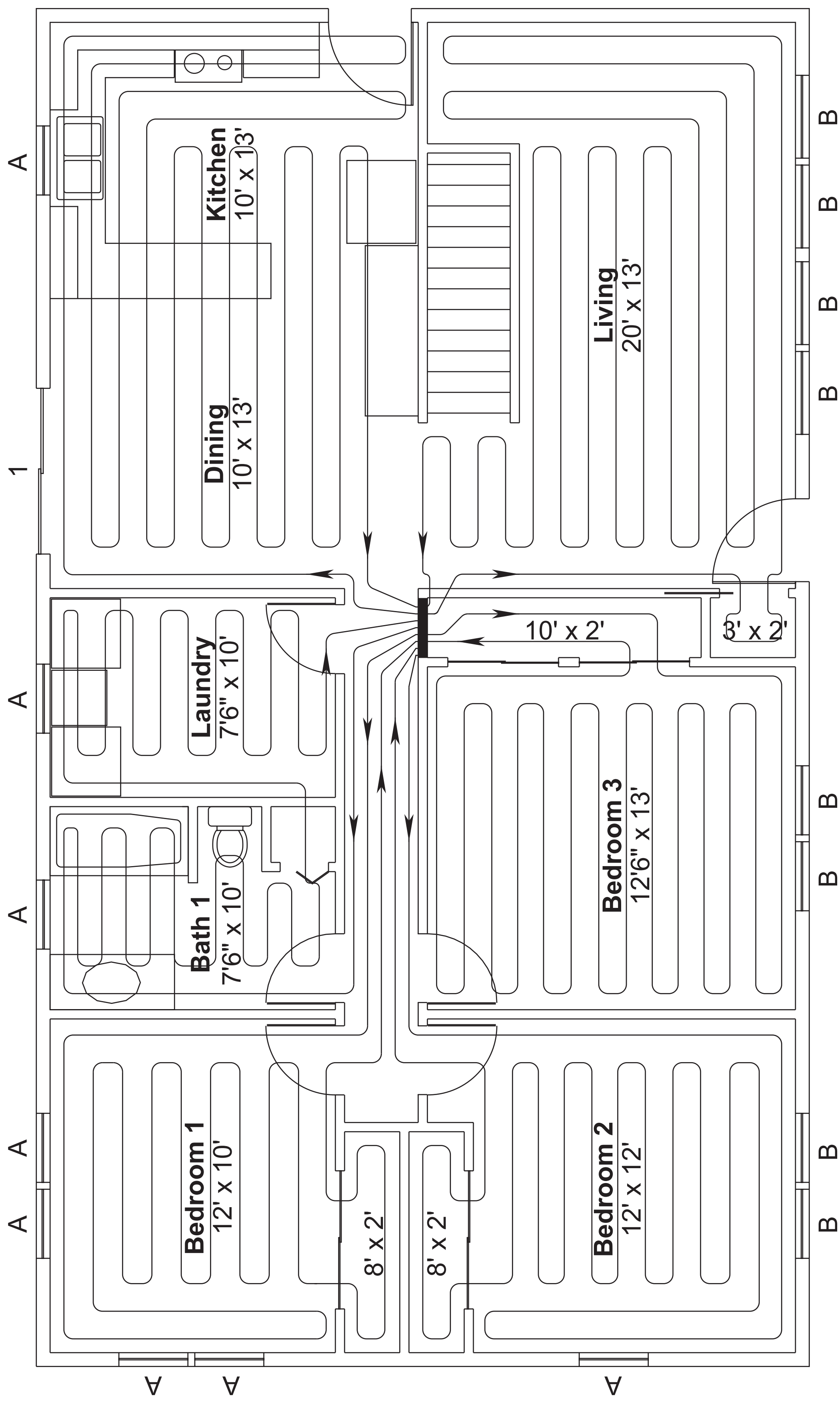


Figure 8-15: Main-level floor plan (no scale)

Radiant floor design worksheet

Project name: ______________________ **Manifold number:** ________

		Loop 1	Loop 2	Loop 3	Loop 4	Loop 5	Loop 6	Loop 7	Loop 8	Loop 9	Loop 10
A	**Room name**										
B	Room setpoint temp. (°F)										
C	Zone number										
D	Upward load (BTU/h/ft²)										
E	Total load (BTU/h/ft²)										
F	Floor surface temp. (°F)										
G	Installation method										
H	Piping size										
I	Floor covering R-value										
J	Differential temp. (°F)										
K	Piping o.c. distance (in)										
L	Supply water temp. (°F)										
M	Active loop length (ft)										
N	Leader loop length (ft)										
O	Total loop length (ft)										
P	Loop flow in gpm										
Q	Loop head pressure (ft)										

Manifold totals

R	Supply water temp. (°F)	
S	Manifold flow in gpm	
T	Highest pressure head (ft)	

A Enter the name of the room. The room may have more than one loop.

B Room setpoint temperature is normally 65°F for radiant floor.

C Zone is equal to thermostat.

D Enter the “Floor Unit Load to Room” value from design program printout (upward load).

E Enter the “Floor Unit Load” value from design program printout (total load).

F (**Row D**/2) + **Row B** = floor surface temperature. Do not exceed 87.5°F for all floors (exception: wood floor limit is 80°F).

G Enter the installation method.

H Enter the size of PEX piping for project.

I Refer to **Appendix D** for floor covering information.

J Indicate differential temperature (10°F for residential; 15°F for light commercial; 20°F for commercial).

K Maximum piping o.c. distance is 12" for residential. Do not exceed 9" o.c. under tile or linoleum.

L Use information from **Rows D, G, I, K** with **Appendix E** to obtain the supply water temperature.

M Enter the length of piping installed within the room (i.e., active loop).

N Enter the length of the piping from the room being heated to the respective manifold and multiply by 2 to account for both the supply and return.

O Use formula: (**Row M** + **Row N**) = total loop length.

P Use the values in **Rows E** and **M** with **Appendix F** to obtain the flow per loop.

Q Use the values in **Rows H** and **P** with **Appendix G** to obtain the head pressure per loop. Choose the appropriate solution (water or water/glycol solution).

R Enter highest temperature from **Row L**.

S Add and enter all values from **Row P**.

T Enter highest value from **Row Q**.

Chapter 9:

Radiant ceiling system design

Designing a radiant ceiling heating system is fairly simple. Unlike radiant floor heating, floor coverings are not a concern and the surface temperature limitations are higher. The exception is when radiant ceiling is installed over an un-insulated concrete slab. In this case, using a high R-value floor covering may be beneficial.

Uponor radiant ceiling systems are designed for residential applications over suspended wood floors. The system can be used as a sole source of heat or as a supplemental heat. Radiant ceiling is not recommended over un-insulated, bare concrete floors.

It is important to perform an accurate room-by-room heat-loss analysis using an appropriate indoor design temperature. Uponor recommends a 70°F room setpoint temperature for radiant ceiling systems.

With radiant ceiling, it is not always necessary to install piping over the entire ceiling area. If the BTU/h/ft^2 requirement is low, increasing the load per square foot and concentrating the piping and plates in the high heat-loss areas of the room reduce the amount of material required and lower the installed price.

At the most basic level, five performance factors must be calculated when designing a hydronic radiant ceiling heating system.

1. Accurate room-by-room heat-loss analysis
2. Surface temperature requirements
3. Supply water temperature requirements
4. Fluid flow requirements
5. Pressure loss

Note: This tutorial is designed with Joist Trak™ aluminum plates. Joist Trak aluminum plates produce approximately 26 BTU/h/ft^2 with 120°F supply water. Joist Trak plates provide a higher output than Quik Trak® panels in the ceiling. On average, Quik Trak panels provide 20 BTU/h/ft^2 output using 120°F supply water. Quik Trak panels are recommended for supplemental use in radiant ceiling applications.

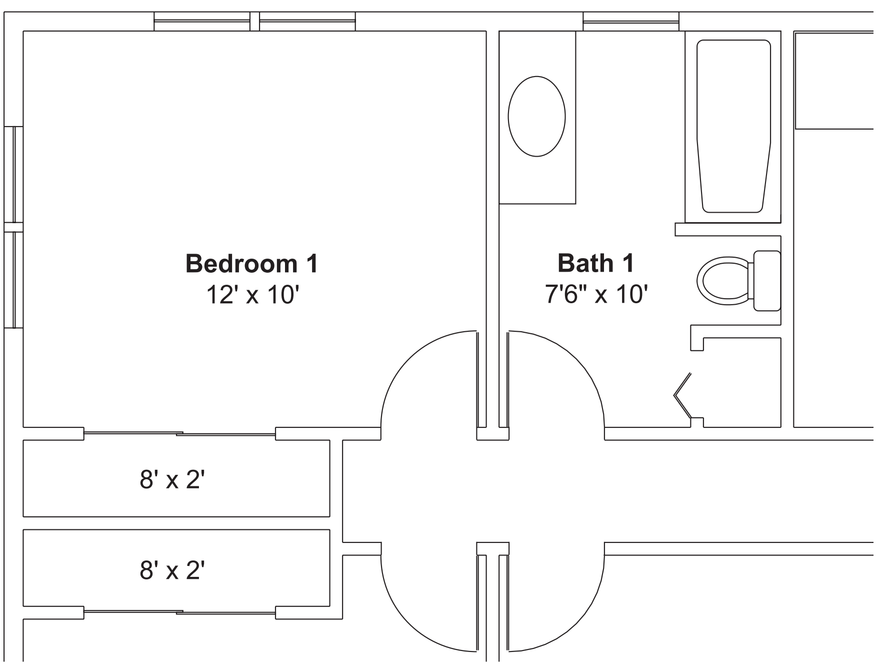


Figure 9-1: Uponor training house (partial)

Bedroom 1 (floor plan 1)	
Total area	136 ft^2
Average height	8 ft
Volume	1,088 ft^2
Air changes	0.35/hr
Room temperature	70°F
Components	1,990 BTU/hr
Infiltration	454 BTU/hr
Ceiling upward	1,089 BTU/hr
Floor downward	0 BTU/hr
Total heat loss	3,533 BTU/hr
Supplemental	0 BTU/hr
Total room loss	3,533
Radiant to room load	2,444 BTU/hr
Unit load	18 BTU/ft^2/hr
Total radiant load	3,533 BTU/hr
Unit load	26 BTU/ft^2/hr

Figure 9-2: Heat-loss data for bedroom 1

Radiant ceiling design tutorial

To demonstrate the radiant ceiling design process, this exercise walks step by step through the design of a single room (Bedroom 1) of the Uponor Training House.

Step 1: Heat-loss analysis

The radiant heating design worksheet provides a format to organize the building's raw heat-loss information. A copy of this worksheet is available in **Appendix A**. Copy as necessary. Fill out the worksheet for the project, and then enter the information into the computer heat-loss program. Entering the data into the computer will go much faster if you complete the worksheet first.

The heat loss for this tutorial has already been completed. **Figure 9-1** shows a partial floor plan for the Uponor Training House. **Figure 9-2** shows heat-loss data from the radiant design program for Bedroom 1.

The radiant ceiling design worksheet template in **Appendix B** is provided for recording the radiant ceiling design information. Note that this appendix also contains worksheets for radiant floor and Quik Trak designs. Copy the template and fill in the information during the tutorial. Enter the following information from the Bedroom 1 heat loss into the design worksheet: room name, setpoint temperature, zone number (thermostat) and BTU/h load.

Step 2: Calculating the BTU/h/ft^2 requirements

1. Determine the heat loss. For Bedroom 1, the total load is 3,533 BTU/h. It is slightly different from the radiant floor heat loss from **Chapter 8** because the setpoint temperature increases from 65°F to 70°F.
2. Calculate the total ceiling area available for radiant ceiling panel. Remember to subtract areas that must be avoided. For example, allow a 6-inch clearance for any flues and 12 inches for light fixtures. This example uses 130 ft^2, which will become the active square footage.
3. Divide the heat load by active ceiling area available to find the BTU/h/ft^2 (3,533 BTU/h ÷ 130 = 27.2 BTU/h/ft^2).

Step 3: Ceiling surface temperature

The ceiling surface temperature is the temperature at the bottom of the sheetrock needed to transfer the calculated BTU/h into a single area at design heat load. If the conditions are milder than design, the ceiling surface temperature will be lower. Surface temperature is based on a simple relationship between the room setpoint temperature and the required BTU/h/ft^2 load. Areas with differing BTU/h/ft^2 requirements or setpoints require different surface temperatures.

The coefficient of radiant ceiling thermal transfer is 1.1 BTU/h/ft^2/°F. This transfer coefficient changes as the position of the radiant panel changes in the room.

For Bedroom 1:

Example
(27.2 BTU/h/ft^2 ÷ 1.1 BTU/h/ft^2) + 70°F = 95°F ceiling surface temperature

The formula used to calculate the ceiling surface temperature is precise and is supplied by the radiant design software. If manually designing the system, use the formula or the ceiling surface temperature chart found in **Appendix C**. An excerpt of this chart is shown in **Figure 9-3**. This chart quickly brackets the ceiling surface temperature to determine if the temperature is within limitations.

Ceiling surface temperature limitations

Ceilings up to 8 feet = maximum of 100°F surface temperature

If the surface temperature exceeds a limitation, reduce the heat loss or the load per square feet (if it was artificially increased), or add supplemental heat.

Note: The Uponor radiant ceiling system is designed for residential applications with ceilings up to 12 feet.

Using the ceiling surface temperature chart:

Find: The ceiling surface temperature.

Procedure:

1. Find the desired room setpoint temperature in the room setpoint column (70°F).
2. On the BTU/h/ft^2 column, move right until you reach the correct BTU/h/ft^2 requirement (27.5).
3. The temperature at the intersection of the two is the required ceiling surface temperature (95.0°F).

Enter the calculated surface temperature (95ºF) into the design worksheet.

Radiant ceiling surface temperatures

Ceiling surface temperature = (BTU/h/ft^2 ÷ 1.1) + room setpoint

Room setpoint	10.0	15.0	20.0	25.0	27.5	30.0	35.0	40.0
75°F	84.1	88.6	93.2	97.7	100.0	102.3	106.8	111.4
72°F	81.1	85.6	90.2	94.7	97.0	99.3	103.8	108.4
70°F	79.1	83.6	88.2	92.7	95.0	97.3	101.8	106.4
68°F	77.1	81.6	86.2	90.7	93.0	95.3	99.8	104.4
65°F	74.1	78.6	83.2	87.7	90.0	92.3	96.8	101.4
60°F	69.1	73.6	78.2	82.7	85.0	87.3	91.8	96.4

BTU/h/ft^2

Exceeds maximum recommended surface temperature for 8-foot ceilings.

Figure 9-3: Radiant ceiling surface temperatures

Step 4: Piping size

Because Uponor radiant ceilings use Joist Trak aluminum heat emission plates, piping size is limited to ⅜" or ½". It is important to note that increasing the piping size does NOT increase the heat delivered.

The following example uses ½" Wirsbo hePEX to minimize head loss per loop. If using ⅜" Wirsbo hePEX, the resulting head loss on this loop would be 16 feet. For residential systems, maximum recommended head loss per loop is 12 feet to keep pumping costs down.

In this example, using ½" Wirsbo hePEX will ensure the pump can be purchased off-the-shelf and is cost-effective.

Enter the piping size (½") into the design worksheet.

Step 5: Differential temperature

The supply and return differential temperature is the temperature drop from the supply manifold to the return manifold. A supply and return differential temperature of 10°F is ideal for residential radiant ceilings.
For the exercise, use a supply and return differential temperature of 10°F.

Enter the differential temperature (10ºF) into the design worksheet.

Step 6: On-center distance

Piping spacing is 8 inches on center.

Enter the piping on-center distance (8") into the design worksheet.

Step 7: Supply water temperature

The required supply water temperature is the temperature necessary to achieve the required ceiling surface temperature. The information required to calculate supply water temperature for a radiant ceiling is:

- Required BTU/h/ft² load
- Room setpoint temperature
- Piping on-center distance
- Supply and return differential temperature

All the information needed to calculate the supply water temperature is available. See **Appendix E** and **Figure 9-4**.

Find: Required supply water temperature.

Procedure:

1. Enter the chart at the required BTU/h/ft² (26) in the BTU/h/ft² column.
2. Move to the right until you intersect the diagonal line. Move straight down and read the required supply water temperature. This chart is based off a 10°F temperature differential.

   Example The required water temperature is 120°F.

   The chart calculates the correct supply water temperature at 70°F room setpoint temperature and a supply and return differential temperature of 10°F.

   Enter the supply water temperature (120°F) into the design worksheet.

Radiant ceiling with Joist Trak plates (8" on center)

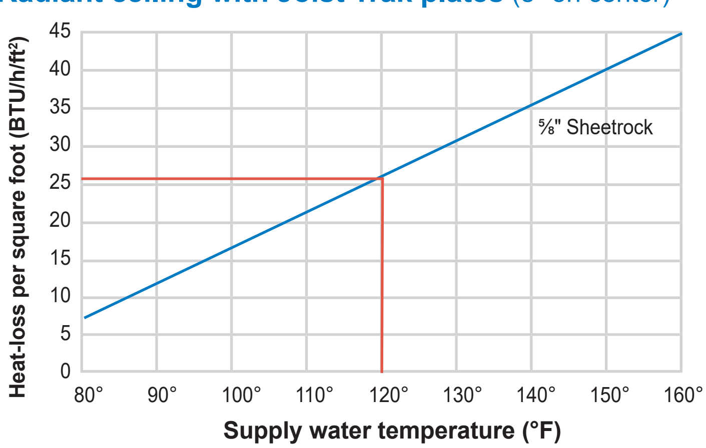


Figure 9-4: Radiant ceiling with Joist Trak plates (8" on center)

Radiant ceiling design worksheet

Project name: Training House main level

			Loop 1
	A	Room name	Bedroom 1
Step 2	B	Room setpoint temp. (°F)	70°F
	C	Zone number	1
	D	BTU/h	3,533
Step 3	E	Ceiling square footage	136
	F	BTU/h/ft²	26
	G	Active square footage	130
	H	Ceiling surface temp. (°F)	95°F
Step 4	I	Piping size	½"
Step 5	J	Differential temp. (°F)	10°F
Step 6	K	Piping o.c. distance (in)	8"
Step 7	L	Supply water temp. (°F)	122°F
	M	Active loop length	
	N	Leader loop length	
	O	Total loop length	
	P	Loop flow in gpm	
	Q	Loop head pressure (ft)	
	R	Loop balancing turns	

Manifold totals

S	Supply water temp. (°F)	
T	Manifold flow in gpm	
U	Highest pressure head (ft)	

Figure 9-5: Radiant ceiling design worksheet

Radiant ceiling design worksheet

Project name: Training House main level

			Loop 1
	A	**Room name**	**Bedroom 1**
	B	Room setpoint temp. (°F)	70°F
	C	Zone number	1
	D	BTU/h	3,533
	E	Ceiling square footage	136
	F	BTU/h/ft²	26
	G	Active square footage	130
	H	Ceiling surface temp. (°F)	95°F
	I	Piping size	½"
	J	Differential temp. (°F)	10°F
	K	Piping o.c. distance (in)	8"
	L	Supply water temp. (°F)	120°F
Step 8	M	**Active loop length**	**195**
	N	**Leader loop length**	**66**
	O	**Total loop length**	**261**
Step 9	P	**Loop flow in gpm**	**0.69**
Step 10	Q	**Loop head pressure (ft)**	**5.6'**
	R	Loop balancing turns	

Manifold totals

S	Supply water temp. (°F)	
T	Manifold flow in gpm	
U	Highest pressure head (ft)	

Figure 9-6: Radiant ceiling design worksheet

100% Water | 10º Supply/return differential flow in GPM per foot of piping.

	Piping on-center distances					
BTU/h/ft²	**6" o.c.**	**7" o.c.**	**8" o.c.**	**9" o.c.**	**10" o.c.**	**12**
50	0.00507	0.00591	0.00676	0.00760	0.00845	0.
49	0.00497	0.00579	0.00662	0.00745	0.00828	0.
48	0.00487	0.00568	0.00649	0.00730	0.00811	0.
47	0.00476	0.00556	0.00635	0.00715	0.00476	0.
46	0.00466	0.00544	0.00622	0.00699	0.00777	0.
45	0.00456	0.00532	0.00608	0.00684	0.00760	0.
44	0.00446	0.00520	0.00595	0.00669	0.00743	0.
43	0.00436	0.00508	0.00581	0.00654	0.00726	0.
42	0.00426	0.00497	0.00568	0.00639	0.00709	0.
41	0.00416	0.00485	0.00554	0.00623	0.00693	0.
40	0.00405	0.00473	0.00541	0.00608	0.00676	0.
39	0.00395	0.00461	0.00527	0.00593	0.00659	0.
38	0.00385	0.00449	0.00513	0.00578	0.00642	0.
37	0.00375	0.00437	0.00500	0.00563	0.00625	0.
36	0.00365	0.00426	0.00486	0.00547	0.00608	0.
35	0.00355	0.00414	0.00473	0.00532	0.00591	0.
34	0.00345	0.00402	0.00459	0.00517	0.00574	0.
33	0.00334	0.00390	0.00446	0.00502	0.00557	0.
32	0.00324	0.00378	0.00432	0.00487	0.00541	0.
31	0.00314	0.00367	0.00419	0.00471	0.00524	0.
30	0.00304	0.00355	0.00405	0.00456	0.00507	0.
29	0.00294	0.00343	0.00392	0.00441	0.00490	0.
28	0.00284	0.00331	0.00378	0.00426	0.00473	0.
27	0.00274	0.00319	0.00365	0.00410	0.00456	0.
26	0.00264	0.00307	0.00351	0.00395	0.00439	0.

Figure 9-7: Excerpt from 100% water flow chart on page 194

Step 8: Determining loop length

Loop length is a function of room size (or coverage area), piping on-center, distance to and from the manifold, and the ability to supply a pump to circulate the required flow through the loop(s).

The amount of piping per loop equals the square footage of ceiling coverage by the loop (installed 8 inches on center), the leader length and an additional length of about 10 feet to get up and down the wall to the manifold (as required).

The net ceiling area for Bedroom 1 is 136 square feet. The adjusted ceiling area when calculated to the ideal load of 26 BTU/h/ft² is 130 square feet. Distance from the room to the manifold location is 10 feet. Additional distance within the room is 7 feet. Add 6 feet for the distance from the ceiling to the manifold.

Find: The active loop length for Bedroom 1.

Procedure: Convert the active square footage into length of piping: 130 x 1.5 = 195 feet

Example Active loop length for Bedroom 1 is 195 feet.

Enter the active loop length (195 feet) into the design worksheet.

Find: The leader length for Bedroom 1.

Procedure:

1. Determine the distance from the heated panel in the room to the exit location from the room. In this example, the distance is approximately 7 feet. Multiply this value by 2 to account for the supply and return piping (7 x 2 = 14 feet).
2. Determine the distance from the room exit location to the appropriate manifold location. In this example, the distance is approximately 20 feet. Multiply this value by 2 to account for the supply and return piping (20 x 2 = 40 feet).
3. Determine the distance above the manifold location to the manifold itself. In this example, the distance is approximately 6 feet. Multiply this value by 2 to account for the supply and return piping (6 x 2 = 12 feet).

4. Add all the piping lengths from the three steps above to obtain the amount of leader length for this loop (14 + 40 + 12 = 66 feet).

Example The leader length for Bedroom 1 is 66 feet.

Enter the leader length (66 feet) into the design worksheet.

Find: Total loop length for Bedroom 1.

Procedure: Add the active loop length with the leader length to obtain the total loop length (195 + 66 = 261 feet).

The total loop length for Bedroom 1 is 261 feet.

Enter the total loop length (261 feet) into the design worksheet.

Step 9: Fluid flow

To satisfy the calculated heat load, the system must provide adequate fluid flow through each loop of the hydronic radiant ceiling system. Fluid flow is based on a relationship between the heat load, active loop length and the supply and return differential temperature. The information required to calculate fluid flow is:

- BTU/h/ft² load
- Piping on-center distance
- Active loop length

All the information required to calculate the required flow for Bedroom 1 has been determined. Use the charts in **Appendix F** to calculate flow for each loop of the system. Select the appropriate chart for either water or water/glycol solution when calculating flow.

Find: The required flow for the loop in Bedroom 1.

Procedure:

1. Find the appropriate chart based on the type of fluid used. In this tutorial, use the 100% water chart.
2. Enter the chart at the total BTU/h/ft² load (26) in the BTU/h/ft² column.
3. To obtain the flow value per foot of active piping, move to the right until you intersect the column for 8 inches on center (0.00351).
4. Multiply the flow per foot by the amount of active loop length 0.00351 x 195 = 0.69 gpm).

   Example The flow for the loop servicing Bedroom 1 is 0.69 gpm.

   Enter 0.69 gpm in the flow per loop cell in the worksheet.

Step 10: Pressure loss

To correctly size a circulator for a radiant ceiling heating system, you must know two things.

1. Total gpm required
2. Feet of head pressure drop across the system the pump services

The flow requirement for the loop was determined in **Step 9** (0.69 gpm). Next, determine the feet of head pressure drop for the loop. For this exercise, use the charts in **Appendix G** to calculate feet of head drop per foot of piping. Select the chart for the correct type and size piping, water temperature and water or water/glycol mixture.

Find: Feet of head drop.

Procedure:

1. Identify the appropriate pressure loss chart (½" Wirsbo hePEX piping using 100% water).
2. Enter the chart at the calculated flow value (0.69 gpm). For smaller applications such as this, round to the next value (0.72).
3. Move right until you intersect the appropriate supply water temperature column (for 122°F, use 120°F column).
4. Find the feet of head drop per foot of piping at the intersection of the flow row and water temperature column (0.02144).
5. Multiply the feet of head value per foot by the total loop length to determine total feet of head for the loop.

   Example 0.02144 feet of head per foot x 261 feet of total loop length = 5.6 feet of head.

> **Note:** If the system water temperature is between two columns, round up or down to the nearest temperature. If the temperature falls exactly between two columns (110°F for example), use the lower temperature column (100°F column).

If the feet of head is too great, you may need to decrease loop length(s), add additional loops or increase piping diameter. If the total loop length or piping diameter changes, recalculate pressure loss.

Enter the feet of head drop per loop (4.8) into the design worksheet.

This completes the design of Bedroom 1. Once all rooms are designed and calculated for the Training House tutorial, check your answers on **page 98**. Then, perform the initial flow balancing and determine the system totals.

½" Uponor PEX — 100% Water — feet of head per foot of piping

Velocity (ft./sec.)	GPM	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C
0.9	0.50	0.01334	0.01284	0.01241	0.01202	0.01168	0.01137	0.01109
1.0	0.55	0.01596	0.01537	0.01486	0.01440	0.01399	0.01363	0.01330
1.1	0.61	0.01878	0.01809	0.01749	0.01696	0.01649	0.01606	0.01568
1.2	0.66	0.02179	0.02100	0.02031	0.01970	0.01916	0.01867	0.01823
1.3	0.72	0.02498	0.02409	0.02331	0.02262	0.02200	0.02144	0.02094
1.4	0.77	0.02837	0.02736	0.02648	0.02570	0.02501	0.02438	0.02381
1.5	0.83	0.03193	0.03081	0.02983	0.02896	0.02818	0.02748	0.02684

Figure 9-8: ½" Uponor PEX pressure loss chart (100% water)

Performing initial flow balance calculations

In order to ensure adequate flow among the varying loop lengths of 1¼" brass manifolds, they must be balanced. The balance valve on an Uponor manifold is located on the return manifold under the protective plastic cap.

Note: This only applies to TruFLOW manifolds without flow indicators. Manifolds with flow indictors should be balanced to the specified gpm.

To calculate the setting, use the formula below.

$$\frac{\text{Length of loop to be balanced x 4}}{\text{Length of longest loop/manifold}} = \text{Number of half turns from closed position (balance setting)}$$

Example
Calculate the balance for a 200-foot loop with the longest loop in the manifold being 300 feet.
(200' x 4) ÷ 300 = half turns from closed 800 ÷ 300 = half turns from closed 2.67 = half turns from closed

To adjust the valve setting for an individual loop, follow the steps listed below.

1. Remove the protective plastic cap and turn it upside down.
2. Place the cap over the operating pin and insert the notch in its slot.
3. Close the valve by turning it clockwise until it stops.
4. Turn the valve counterclockwise the calculated number of half turns from the closed position.
5. Perform this adjustment for each loop on the manifold.
6. Replace the balancing cap on the manifold and tighten a maximum of a half turn or the valve may begin to close.

Selecting the system water temperature

The supply water temperature used in a single-temperature system is the highest required water temperature of any individual room or area. In some instances, the highest water temperature required may be too high for other areas of the building. If the highest water temperature exceeds all other water temperatures by more than 20°F to 25°F, take steps to decrease the supply water temperature for that room. The other option is to provide two water temperatures. Careful manifold planning is required for systems requiring multiple water temperatures.

Compare the various required supply water temperatures and select the highest for the project. Because radiant ceilings are generally designed to an ideal load of 40 BTU/h/ft^2, supply water temperatures are generally very similar.

Enter the system supply water temperature (120°F) into the design worksheet.

System flow requirement

Calculate total flow (for the system or the portion of the system that an individual circulator will serve) for circulator sizing. Add all the individual loop requirements together to determine total flow.

Enter the system flow (3.64 gpm) into the design worksheet.

Determining feet of head for system

The feet of head for circulator sizing is the sum of the feet of head for the heat plant components, supply piping, manifolds and the loop in the system with the highest feet of head loss (generally the longest loop). For the Training House, the loop with the highest feet of head is the dining/kitchen loop with 4.1 feet of head.

Do not calculate pressure loss for each loop and add them together. Find the loop with the highest feet of head and add that to the feet of head of the system components. Make your calculations using the correct supply water temperature.

Enter the system feet of head drop (4.1 ft hd) into the design worksheet.

In order to size the circulator for this level of the training house, all the head pressure drops before and after the manifold location must be added together to determine the total head drop. To properly size the circulator, identify the total system flow and head.

The final step is to follow the manufacturer's circulator performance curves to determine which circulator provides the correct flow and feet of head capacity. When designing a system with multiple circulators, determine the flow and feet of head separately for each circulator.

The complete design

To complete the design, use the radiant ceiling worksheet found in **Appendix B**. See **page 98** for the completed tutorial design calculations.

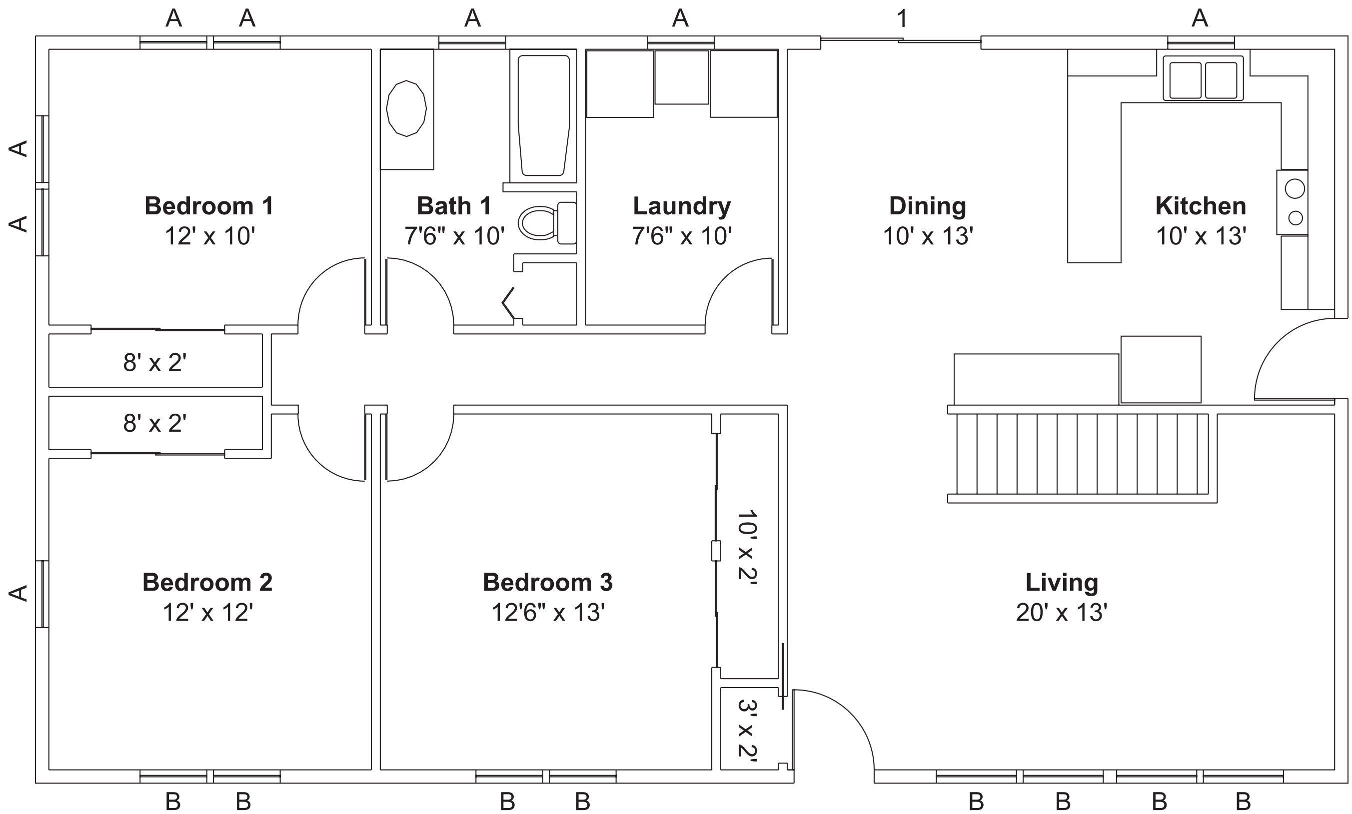


Figure 9-9: Main-level floor plan (no scale)

Room schedule		
Bedroom 1	136 ft²	¼" nylon saxony with ¼" bonded urethane
Bedroom 2	160 ft²	¼" nylon saxony with ¼" bonded urethane
Bedroom 3	183 ft²	¼" nylon saxony with ¼" bonded urethane
Living room	260 ft²	¾" oak
Kitchen/dining	260 ft²	¾" oak
Bath/laundry	150 ft²	¼" ceramic tile with ¼" underlayment
Bedroom 4	209 ft²	¼" nylon saxony with ¼" bonded urethane
Bath 2	75 ft²	¼" ceramic tile with ¼" underlayment
Family room	270 ft²	¼" nylon saxony with ¼" bonded urethane
Recreation room	270 ft²	¼" nylon saxony with ¼" bonded urethane
Storage	383 ft²	No floor covering

Window schedule		
Window 1 — 2'6" x 4'0"	Double pane, wood frame	R-1.81
Window 2 — 5'0" x 4'0"	Double pane, wood frame	R-1.81

Door schedule		
Door 1 — 6'0" x 7'0"	Sliding, double pane, wood frame	R-1.82
Door 2 — 3'0" x 7'0"	Metal with urethane core	R-5.29

Figure 9-10: Room, window and door schedules

Radiant ceiling design worksheet

Project name: Training House **Manifold number:** 1

Note: Ensure insulation between floors is at least R-19. Ensure ceiling exposed to the attic is at least R-38 (higher if required by code).

		Loop 1	Loop 2	Loop 3	Loop 4	Loop 5	Loop 6	Loop 7	Loop 8	Loop 9	Loop 10
A	Room name	Bedroom 1	Laun/Bath	Din/Kit	Living room	Bedroom 3	Bedroom 2				
B	Room setpoint temp. (°F)	70°F	70°F	70°F	70°F	70°F	70°F				
C	Zone number	1	2	3	4	6	6				
D	BTU/h	3,533	1,822	4,252	4,177	2,122	3,506				
E	Ceiling square footage	136	150	260	266	183	165				
F	BTU/h/ft²	26	40	40	40	40	22				
G	Active square footage	130	47	106	105	53	155				
H	Ceiling surface temp. (°F)	95°F	95°F	95°F	95°F	95°F	84°F				
I	Piping size	½"	½"	½"	½"	½"	½"				
J	Differential temp. (°F)	10°F	10°F	10°F	10°F	10°F	10°F				
K	Piping o.c. distance (in)	8"	8"	8"	8"	8"	8"				
L	Supply water temp. (°F)	120°F	117°F	117°F	117°F	117°F	113°F				
M	Active loop length	195	47	106	105	53	232				
N	Leader loop length	66	30	38	25	25	50				
O	Total loop length	261	77	144	130	78	282				
P	Loop flow in gpm	0.69	0.38	0.86	0.85	0.43	0.72				
Q	Feet of head drop per loop	5.6	0.5	4.1	3.7	0.7	5.2				
R	Loop balancing turns* (TruFLOW)	3.8	2.1	4.0	3.6	2.2	3.8				

Manifold totals

S	Supply water temp. (°F)	122°F									
T	Manifold flow in gpm	3.64									
U	Highest pressure head (ft)	5.6'									

A Enter the name of the room. The room may have more than one loop.

B Room setpoint temperature is normally 70°F for radiant ceiling.

C Zone is equal to thermostat. First zone is 1.

D Enter the "Total Unit Load" value from radiant design printout in BTU/h.

E Enter the ceiling square footage.

F Divide Row D by **Row E**. If value is less than 40 BTU/h/ft², divide **Row D** by 40.

*When using TruFLOW manifolds

G If **Row F** was obtained through dividing by 40, then divide **Row E** by 40. If Row F was greater than 40 BTU/h/ft², then enter the value from **Row E**.

H Row F divided by 1.6 plus the value in **Row B** equals the ceiling surface temperature. Do not exceed 100°F for ceilings at 8 feet or less. Do not exceed 110°F for ceilings greater than 8 feet.

I Enter the size of PEX piping for project (½" Wirsbo hePEX piping).

J Use 10°F differential temperature for all radiant ceiling applications.

K Maximum piping o.c. distance is 12" for all radiant ceiling applications.

L Use information from Rows F and J with **Appendix E** to obtain the supply water temperature.

M Multiply **Row G** by the on-center factor of 1.5.

N Enter the length of the piping from the room being heated to the respective manifold and multiply by 2 to account for supply and return.

O Use formula: (**Row M** + **Row N**) = total loop length.

P Use the values in **Rows F** and **L** with **Appendix F** to obtain the flow per loop.

Q Use the values in **Rows I, L** and **P** with **Appendix G** to obtain the feet of head pressure drop per foot. Next, multiply this value by **Row O** to obtain the feet of head drop per loop.

R These cells are calculated after the design is completed. Use the formula: (current loop value in Row O x 4) / longest loop length on the manifold.

S Enter highest temperature from **Row L**.

T Add all values in **Row P**.

U Enter highest value from **Row Q**.

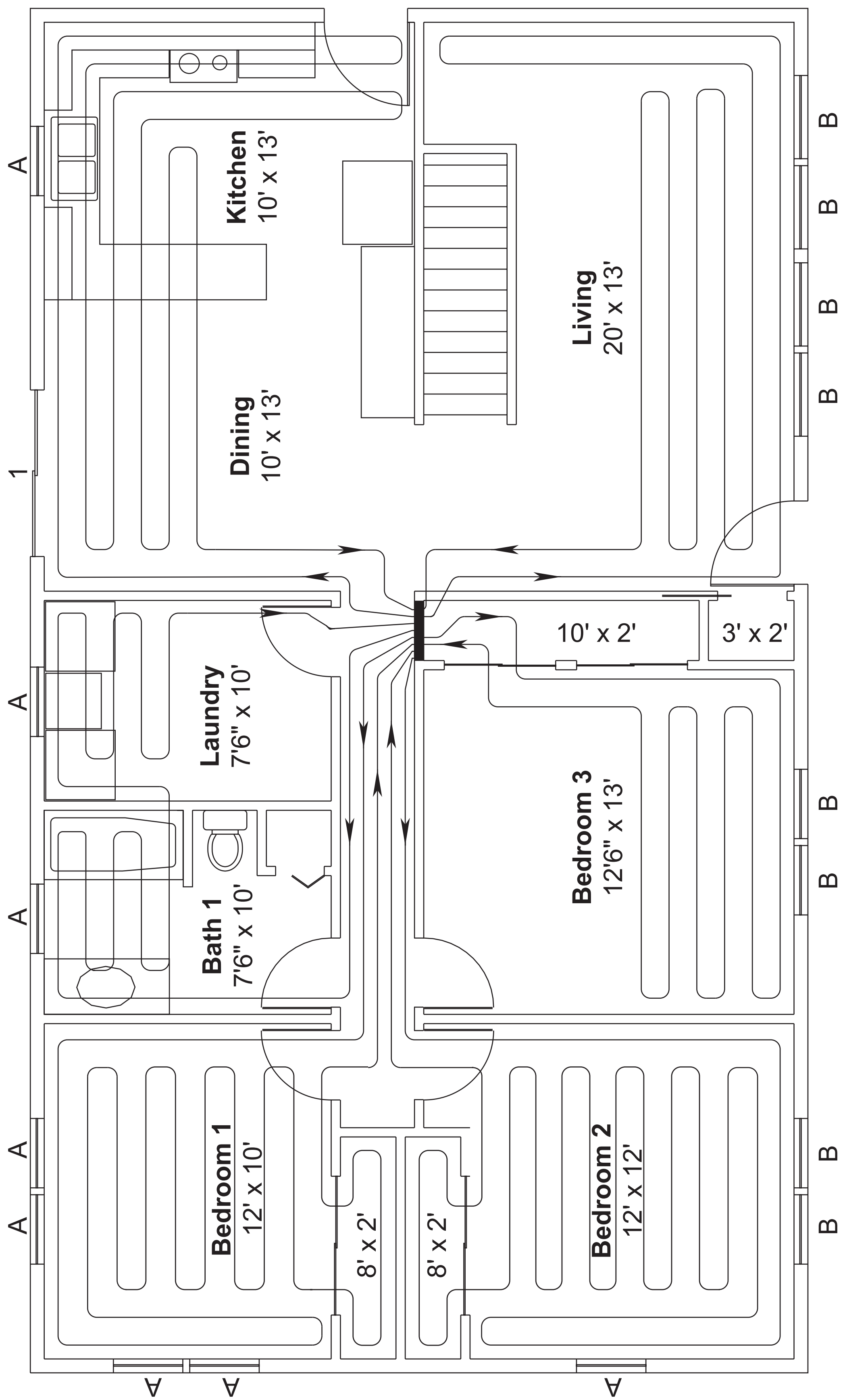


Figure 9-11: Main-level floor plan (no scale)

Radiant ceiling design worksheet

Project name: ______________________ **Manifold number:** _____

Note: Ensure insulation between floors is at least R-19. Ensure ceiling exposed to the attic is at least R-38 (higher if required by code).

		Loop 1	Loop 2	Loop 3	Loop 4	Loop 5	Loop 6	Loop 7	Loop 8	Loop 9	Loop 10
A	**Room name**										
B	Room setpoint temp. (°F)										
C	Zone number										
D	BTU/h										
E	Ceiling square footage										
F	BTU/h/ft²										
G	Active square footage										
H	Ceiling surface temp. (°F)										
I	Piping size										
J	Differential temp. (°F)										
K	Piping o.c. distance (in)										
L	Supply water temp. (°F)										
M	Active loop length										
N	Leader loop length										
O	Total loop length										
P	Loop flow in gpm										
Q	Feet of head drop per loop										
R	Loop balancing turns* (TruFLOW)										

Manifold totals

S	Supply water temp. (°F)										
T	Manifold flow in gpm										
U	Highest pressure head (ft)										

A Enter the name of the room. The room may have more than one loop.

B Room setpoint temperature is normally 70°F for radiant ceiling.

C Zone is equal to thermostat. First zone is 1.

D Enter the "Total Unit Load" value from radiant design printout in BTU/h.

E Enter the ceiling square footage.

F Divide Row D by **Row E**. If value is less than 40 BTU/h/ft², divide **Row D** by 40.

*When using TruFLOW manifolds

G If **Row F** was obtained through dividing by 40, then divide **Row E** by 40. If Row F was greater than 40 BTU/h/ft², then enter the value from **Row E**.

H **Row F** divided by 1.6 plus the value in **Row B** equals the ceiling surface temperature. Do not exceed 100°F for ceilings at 8 feet or less. Do not exceed 110°F for ceilings greater than 8 feet.

I Enter the size of PEX piping for project (½" Wirsbo hePEX piping).

J Use 10°F differential temperature for all radiant ceiling applications.

K Maximum piping o.c. distance is 12" for all radiant ceiling applications.

L Use information from Rows F and J with **Appendix E** to obtain the supply water temperature.

M Multiply **Row G** by the on-center factor of 1.5.

N Enter the length of the piping from the room being heated to the respective manifold and multiply by 2 to account for supply and return.

O Use formula: (**Row M** + **Row N**) = total loop length.

P Use the values in **Rows F** and **L** with **Appendix F** to obtain the flow per loop.

Q Use the values in **Rows I, L** and **P** with **Appendix G** to obtain the feet of head pressure drop per foot. Next, multiply this value by **Row O** to obtain the feet of head drop per loop.

R These cells are calculated after the design is completed. Use the formula: (current loop value in Row O x 4) / longest loop length on the manifold.

S Enter highest temperature from **Row L**.

T Add all values in **Row P**.

U Enter highest value from **Row Q**.

Chapter 10:

Commercial radiant heating and cooling applications

This chapter summarizes aspects of radiant floor design that are specific to commercial projects. Before reading this chapter, study **Chapters 7 and 8** to obtain more detailed information about heat loss and radiant floor design. **Chapter 8** provides step-by-step instructions for the design process and explains how to correctly calculate surface temperature, water temperature, fluid flow and head pressure. The design process is essentially the same for commercial as for residential. Take note to use the correct charts as necessary.

Commercial radiant cooling

Hydronic radiant cooling has significant potential for reducing space-conditioning energy use while improving indoor environmental quality (IEQ). Radiant cooling uses active surfaces to absorb thermal energy and remove it from a space — more or less the inverse of radiant heating systems. In the case of radiant cooling, thermal energy flows from the occupants, equipment, lights and other interior surfaces to the actively cooled surface.

Since there are typically internal latent loads (humidity) from occupants and infiltration, plus sensible and latent loads associated with outside ventilation air, radiant cooling is often part of a hybrid system that includes conditioning of ventilation air to address these loads.

Commercial design considerations

A commercial building design is the art of balancing heat losses with heat gains in a manner that provides a consistent temperature.

Heat-loss

Commercial buildings experience the same envelope losses as residential buildings. The thermodynamics of commercial buildings are easily calculated with the radiant design program. However, commercial buildings differ from residential buildings in the magnitude of heat-loss.

The ratio of floor surface area to exterior surface area is generally larger in commercial buildings than in residential ones. The result is lower overall heat load per square foot. Lower heat loads offer some opportunity to reduce the heated floor area in the building. Less heated area reduces the overall cost of a project. A room-by-room heat-loss analysis identifies those areas with little or no heat-loss. Some internal rooms may not require heat.

Envelope losses are not the only losses to consider in commercial buildings. In general, the greatest single heat-loss results from air exchanges.

Air exchange

Air exchange requirements are high for buildings in which fumes from automotive exhaust, paint, adhesives, etc. are present. Buildings that house industrial processes often need a high number of air exchanges because of chemical use. These types of commercial buildings require heated make-up air to counter the loss from fresh air intake.

Air exchange requirements are also affected by the occupancy of commercial buildings. Many buildings are designed to accommodate a large number of people. These buildings

must provide adequate air exchanges to keep the air fresh. Air exchanges remove both the heat and moisture produced by occupants.

Most air exchange requirements are stated as “must be capable of providing at least X number of air changes per hour.” This statement does not mean the air exchange system must continually operate at these exchange rates. Some buildings have high air exchange requirements even though they rarely meet the maximum occupancy rates. Gymnasiums, churches, stadiums and other similar buildings should only operate at maximum air exchange rates when they are filled to capacity. When the building is not filled to maximum occupancy, the air exchange rate should be proportionately reduced to reduce the heating load and increase operating efficiency.

When designing a commercial radiant floor heating system, it is helpful to understand the proper method of computing air exchanges. Since the air handling system is not used in combination with forced-air heating, it is much smaller and less costly. Air exchange requirements, expressed in cubic feet per minute (CFM) of outside air, are stated in any locally accepted mechanical code. The actual requirements are based on the maximum number of occupants multiplied by the minimum CFM of fresh air for the particular type of structure, and the activity levels, of the occupants.

For example, a particular mechanical code requires a minimum of 10 CFM per student in a classroom. If the projected maximum number of persons in the classroom is 30, the minimum requirement is 300 CFM. Therefore, the air handling system must provide 300 CFM of fresh air. This is much smaller than a similar system using forced-air heat distribution, where the air handling system must also move sufficient air to heat the structure.

Note: Smoke-free designated buildings require fewer air exchanges than buildings where smoking is permitted. The requirement for buildings where smoking is permitted may be five times higher than in a building designated as a smoke-free environment. Many state and local building governments are legislating smoke-free environments in public buildings.

Additional heat requirements for air exchanges

The introduction of fresh air from outside the building results in an additional heating load. In the previous example, 300 CFM is equal to 18,000 cubic feet per hour, and the heat ability of air is 0.0182 BTU per cubic foot per degree Fahrenheit. Therefore, the air exchange requires 327.6 BTU for every degree Fahrenheit that the incoming air is below room setpoint. If the incoming air is 50°F below setpoint, then about 16,380 BTU/h is needed to offset the load. Each student adds about 400 BTU/h from normal body heat, accounting for approximately 12,000 BTU/h for 30 occupants. Therefore, an additional 4,380 BTU/h is required to offset the load from the introduction of fresh air into the classroom.

The best way to provide the additional heat is through the use of a hydronic fan coil in the air exchange ductwork. The fan coil is controlled from an air discharge sensor. This control strategy adjusts to changes in the outside temperature, as well as intermittent operation of the ventilation system.

Other significant losses may exist in commercial buildings as a result of the activity that takes place within the building.

Heat requirements for additional internal loads

Fresh air infiltration rates are very high when large doors are opened. Shipping and receiving areas are a perfect example. When loading dock doors are open, the heating load increases greatly. Receiving large quantities of cold, raw materials also places a large internal heating load on the building. The heating load from cold objects is calculated by multiplying the weight of the object by its specific heat and again by the differential temperature.

Example: A 40,000-pound delivery of iron with a specific heat of 0.12 BTU/h/lb and a differential temperature of 60°F results in an approximate load of 288,000 BTU/h.

(40,000 lb x 0.12 BTU/h/lb) x 60°F = 288,000 BTU/h

Airplane hangars and vehicle repair facilities contain similar loads. Cold, heavy machinery adds internal loads that the heating system must overcome. Some of these loads are offset by engines and other components that may add heat during operation.

Radiant floor heating systems are uniquely capable of recovering setpoint temperature after an influx of cold air. The concrete mass takes a considerable time to cool off. As a result, when the doors of an airplane hangar close, the temperature quickly returns to setpoint because the heat is retained in the concrete.

Internal gains in commercial buildings also result from activities within the building. For example, fleet parking facilities that bring in warm vehicles may experience an overall heat gain from their operations. Often these same gains exist in residential buildings, but the levels of activity within the commercial building make the factors much more significant.

Another example of an internal gain is lighting and electrical appliances. Every kilowatt of electrical energy use not vented to the exterior results in 3,412 BTU/h of heat. The constant use of tools, machinery, lighting, hot water and even refrigeration produces considerable heat energy.

Fossil-fuel burning tools and appliances such as ovens, ranges, torches and dryers also produce large amounts of heat energy. Consider subtracting that amount from the heat load.

Heat gains, such as fireplaces, are also considered supplemental heat. Subtract these gains from the total heat loss. Information on adding supplemental heat (subtracting from the total heat load) is available in the heat-loss section of the radiant design program.

Structural factors in commercial buildings

Commercial buildings are generally constructed with concrete floors and concrete or steel structures. The stresses in this type of construction are carefully calculated. An engineer's involvement is essential to ensure the integrity of the structure.

Concrete floor construction in commercial buildings

Typical concrete commercial floors include pour-in-place slabs, composite beam construction, precast concrete planking with an overpour and post-tensioned slabs.

Pour-in-place slabs — Pour-in-place slabs are placed on compacted earth or on planking above grade. Radiant floor heating is easily integrated into pour-in-place slabs and is generally reinforced with steel bars or 6x6 wire mesh. The reinforcement provides a convenient fastening system to support the piping prior to the pour. Minimum cover for piping is detailed in the local building codes. Generally, pour a minimum of 1½ inches of concrete over the top of the piping when the slab is exposed to the soil or weather (1997 UBC Sec. 1906.3.10.). When the slab is not exposed to the soil or weather, a ¾-inch concrete pour over the piping is generally acceptable (1997 UBC Sec. 1906.3.10.).

Composite beam construction — In composite beam construction, slabs are poured over decking and supported by planking on concrete or steel beams. In composite beam construction, place the piping on the steel decking prior to the pour, and secure to wire mesh. Typically, weld the wire to the decking. Avoid diminishing the structural integrity by:

- Placing the radiant piping parallel to the beams (perpendicular to the deck)
- Keeping sufficient distance outside the effective design width which is (2 x span)/8
- Placing the piping in a concrete slab with a minimum 1½-inch cover over the top

Insulate the decking to prevent excessive downward heat transfer. Ensure the insulation R-value is at least equivalent to the composite R-value above. Be alert for situations in the structure where heat may conduct through the steel structure to the outside without an adequate thermal break.

Precast concrete planks — Precast concrete construction consists of pre-formed concrete planks delivered to the construction site and put in place. Two ways to install a radiant floor system over precast concrete include:

1. Lay wire mesh over the concrete and pour over the top.
2. Place high-density foam insulation over the precast concrete and staple the piping to the insulation. Insulation placed between the precast planks and the overpour reduces the thermal transfer to the concrete planks and increases the response capability of the heated overpour. Generally, the concrete pour over precast with radiant floor piping is ¾ inch over the top of the piping.

Post-tensioned concrete slabs — Post-tensioned concrete slabs are those in which tendons are placed within the slab prior to the pour. After the pour is sufficiently cured, the tendons are tightened to very high stresses, placing the entire slab under a compressive load. Do not place the piping near the tendons without the approval of the structural engineer. Radiant floor piping is often installed within a second pour over the top of the post-tensioned slab.

See **Chapter 6** for more information on the various installation methods for Uponor radiant floor heating systems.

Under-slab insulation

Insulation below heated concrete slabs must withstand the weight of the slab along with any additional dead or live loads. When concrete is applied over the insulation, the weight of the concrete causes the insulation to compress. The amount of compression depends on the weight of the concrete, the thickness of the insulation and the compressibility of the insulation.

Although compression reduces the insulating effect of the foam, it presents little structural effect because it remains relatively constant over the life of the structure. A more important structural factor is the long-term compressive creep that occurs within the insulation. Creep should be accommodated in the ability of the slab to move relative to the plane of its surface. Foam insulation manufacturers provide specific recommendations regarding the limits of live and dead loads, compressive creep and the proper application of their products. Check with the foam insulation manufacturer for more information.

Fire-rated structures

Many commercial buildings are fire rated according to the activity within or the occupancy of the building. Fire-rated structures require firewalls that do not allow fire or smoke to spread past them for a period of time. Firewall penetrations must be rated so they do not reduce the overall rating of the wall. Install fire penetration devices in accordance with the manufacturers' recommendations. Note that fire-stop materials designed for metal pipe penetrations are not necessarily suitable for PEX piping. See **Chapter 3** for a list of firestop materials.

Controls for commercial radiant floor systems

Control of a commercial building is similar to that of a residential building except that the controls are integrated with air handling systems designed to provide air exchanges. Many commercial buildings feature computer interfacing input/output devices used for that purpose. It is important that such systems do not work against each other, causing excess energy use.

See **Chapter 12** for more information about controls for radiant floor heating systems.

Acceleration

Large-mass radiant slabs respond at a predictable rate when heat energy is applied to them. Consider the acceleration rate in the control strategy. Because concrete weighs approximately 120 pounds per cubic foot and has a specific heat amount of about 0.21 BTU/h/lb, the amount of energy necessary to accelerate radiant slabs of various thickness can be calculated (assuming there is adequate insulation below to prevent downward loss).

- A 4-inch slab requires about 8.4 BTU/h/ft^2 to accelerate 1°F
- A 5-inch slab requires about 10.5 BTU/h/ft^2 to accelerate 1°F
- A 6-inch slab requires about 12.6 BTU/h/ft^2 to accelerate 1°F
- A 7-inch slab requires about 14.7 BTU/h/ft^2 to accelerate 1°F
- An 8-inch slab requires about 16.8 BTU/h/ft^2 to accelerate 1°F
- A 9-inch slab requires about 18.9 BTU/h/ft^2 to accelerate 1°F

Average water temperature has the greatest effect on acceleration. Average water temperature is increased by increasing the supply water temperature and/or decreasing the return differential temperature (increasing flow). It is best to provide the maximum supply water temperature during acceleration phases. The graph in **Figure 10-1** shows acceleration times at various increases in heating load for various average water temperatures. The higher the average water temperature, the shorter time required to accelerate. As the building reaches maximum design load, the acceleration requirements are negligible.

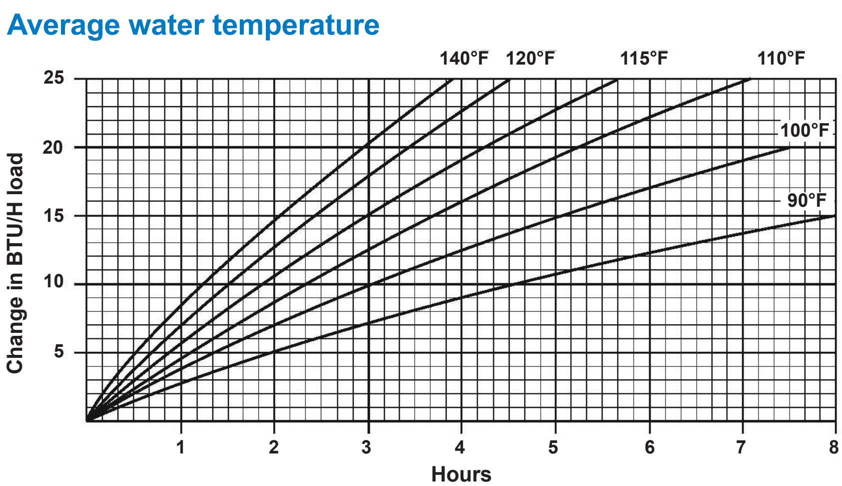


Figure 10-1: Acceleration times (Data accurate for 4" slab acceleration)

Piping installation options

Several factors determine how much piping is needed for installation. The following sections provide some general guidelines. Refer to the Uponor radiant design program to determine the amount of required piping.

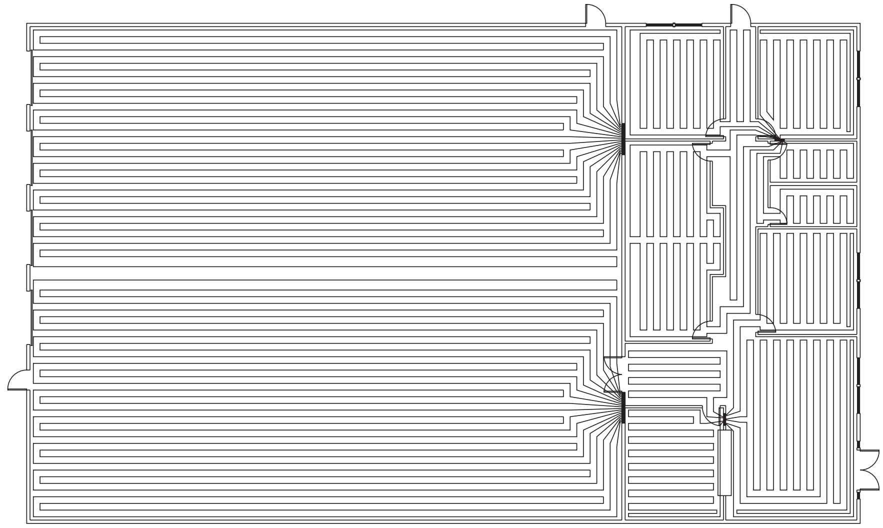
Full coverage — Use full coverage when the major heat load is evenly distributed, such as when internal heat loads and/or unheated air exchanges are excessively high or when high-resistance floor coverings are used. The full coverage option features piping installed 12 inches on center throughout the entire floor.

Perimeter-only coverage — To determine the suitability of a perimeter-only design, use the heat-loss section of the Uponor radiant design program. The goal is to increase the heated floor surface area of the room without exceeding the floor temperature or supply water temperature limitations. For perimeter-only coverage, install piping inside and along the perimeter walls of the building. Do not install piping in the interior areas of the room.

Commercial and industrial projects usually install minimal floor coverings, resulting in diminished upward resistance to heat transfer. This improves the effectiveness of the radiant floor system so that perimeter-only designs are both effective and efficient.

Varied coverage — Use this method when the major heat load is at the perimeter, but a small load is anticipated in the interior of the building. Small loads may come from air changes or heat losses through the ceiling. Install the piping 12 inches on center near the perimeter and at increased distances (18 to 24 inches on center) in the interior areas.

Reduced coverage — Use this method when the heat loss is minimal and evenly distributed throughout the building. Install the piping throughout the floor at distances greater than 12 inches on center.



1. Building square footage: 9,375
2. Piping installed on center: 12"
3. Feet of piping installed: 9,016
4. Number of loops: 28
5. Number of manifold locations: 4
6. Number of zones: 3

Figure 10-2: Full coverage piping installation

1. Building square footage: 9,375
2. Piping installed on center: 12"
3. Feet of piping installed: 4,860
4. Number of loops: 18
5. Number of manifold locations: 2
6. Number of zones: 1

Figure 10-3: Perimeter-only coverage piping linstallation

Piping layout patterns

The designer determines the piping layout pattern for a specific project. Although the pattern is influenced by a number of factors, some general guidelines are helpful.

The most significant envelope heat losses occur near the exterior walls, especially near exterior windows and doors. Begin the piping run in these areas. Additionally, shorter piping runs in high heat-loss areas result in higher average water temperatures. Higher average water temperatures satisfy the heat load faster.

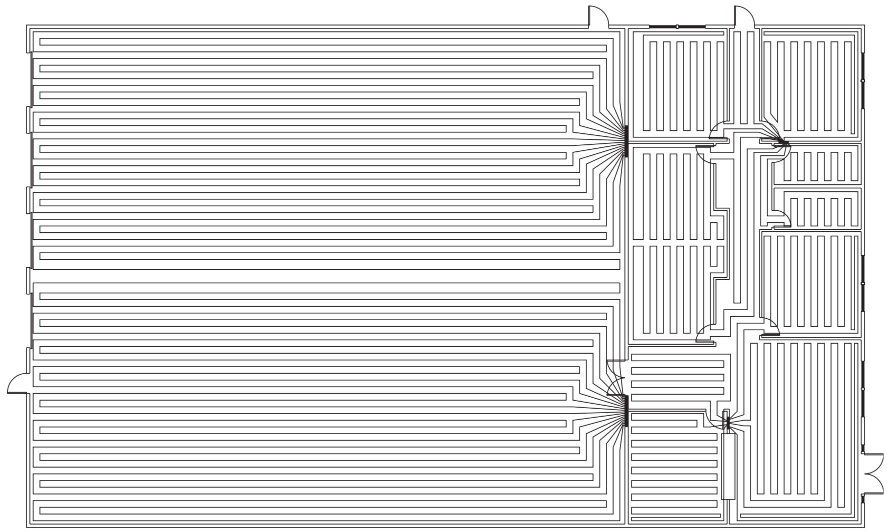
When the primary heat loss of the structure is from the building envelope, areas without exterior walls or ceilings have little or no heat loss and do not need to be heated. The only exception is to counter the effects of unheated make-up air. Again, the radiant design program identifies areas that do not require heat.

Tall buildings typically produce diminishing heat loads at the upper levels due to the buoyancy of heated air.

Uponor recommends full piping coverage for shipping and receiving areas. Infiltration from open doors, additional heat loss from cold materials entering the building, and the loss of effective floor area due to materials placed on the floor that reduce heat transfer all contribute to the heat load of shipping and receiving areas.

Full piping coverage is also recommended for restrooms, showers and locker rooms because of the high air exchange rates and because people often wear little or no clothing in these areas.

Never overlook the possibility that the original intended use of a building may change in the future. Design the system so that adequate heat is provided regardless of the intended use.



1. Building square footage: 9,375
2. Piping installed on center: 12" and 18"
3. Feet of piping installed: 7,624
4. Number of loops: 32
5. Number of manifold locations: 4
6. Number of zones: 1

Figure 10-4: Varied coverage piping installation

1. Building square footage: 9,375
2. Piping installed on center: 18"
3. Feet of piping installed: 6,075
4. Number of loops: 26
5. Number of manifold locations: 4
6. Number of zones: 1

Figure 10-5: Reduced coverage piping installation

Distribution flow options

Reverse-return header system with Radiant Rollout™ Mat — Commercial buildings are a prime candidate for value engineering the water distribution system that supplies radiant piping and panels. A self-balancing reverse-return header system can be specified to reduce the number of wall manifolds and wall-manifold loops that are needed to balance and distribute water to piping loops. This type of system can save money by simplifying and reducing the amount of distribution piping from the heating and cooling sources in the mechanical room. In those commercial buildings, or zones within buildings, that lack adequate space to install wall manifolds, the self-balancing reverse-return header system can increase available space and eliminate difficult decisions on how and where to place wall manifolds.

The reverse-return header system:

- Is self-balancing
- Prevents long leader lengths and crowding near wall-mounted manifolds
- Economizes design by requiring fewer wall manifolds
- Offers space savings as wall manifolds can be eliminated
- Reduces length of distribution piping (less branch distribution piping to wall manifolds)

The reverse-return header is a feature of the Uponor Radiant Rollout mat, which is shown in **Figure 10-6**.

The reverse-return header in the mat uses ¾" piping and can connect to either ½" or ⅝" piping using Uponor engineered polymer (EP) reducing tee fittings. Each mat is equipped with one supply-and-return line and SpaceGuard support strips that allow piping in the mat to be accurately spaced and fastened. Mats are pre-pressurized at the factory. **Figure 10-7** shows a two-dimensional drawing of a reverse-return header system. The system uses one central wall manifold, which serves as an origination for the distribution flow system. There are four mats with the reverse-return header connected to the central wall manifold; each mat contains 10 single-pass loops.

The mat is available in the following construction options:

- Length: Customizable from 40 to 225 feet
- Width: From 5 to 10 feet
- Piping: Wirsbo hePEX (oxygen barrier) or Uponor AquaPEX (barrier free), ½" or ⅝" piping
- Distribution flow options:
  1) In-slab with ¾" reverse-return header option or
  2) Wall manifold featuring the Uponor TruFLOW Classic
- Supports: Acetal polymer support braces with pre-drilled holes for stake and anchor points

Figure 10-7: Reverse-return header system

Figure 10-6: Uponor Radiant Rollout Mat

Figure 10-8: Radiant Rollout Mat featuring reverse-return header with piping module

The Uponor Radiant Rollout Mat offers the following advantages in commercial installations:

- Reduces installation time by up to 85% versus conventional installation methods
- Reduces installation errors, promotes worker safety and offers fast commissioning and start up through pre-fabrication and pre-pressurized testing
- Features durable Uponor ProPEX fittings, which are approved for direct burial. The EP fittings used in the reverse-return header assembly are approved with listings from the International Association of Plumbing and Mechanical Officials (IAMPO) [International Mechanical Code (IMC) compliant] and NSF International [Uniform Mechanical Code (UMC) compliant]
- Helps projects stay on schedule
- Reduces and eliminates piping waste
- Comes with Uponor design and technical support assistance

For any questions about Uponor Radiant Rollout mats or for design assistance to quote a project, contact Uponor Technical Services toll free at 888.594.7726.

Reverse-return header system with piping modules — A self-balancing reverse-return header system can also be customized using a piping module. The piping is laid out in a "module" pattern, as shown in **Figures 10-8** and **10-9**.

The advantages of a reverse-return distribution system are the same as those listed for the reverse-return header.

- Self-balancing
- Prevents long leader lengths and crowding near wall-mounted manifolds
- Economizes design by requiring fewer wall manifolds
- Offers space savings as wall manifolds can be eliminated
- Reduces length of distribution piping (less branch distribution piping to wall manifolds)

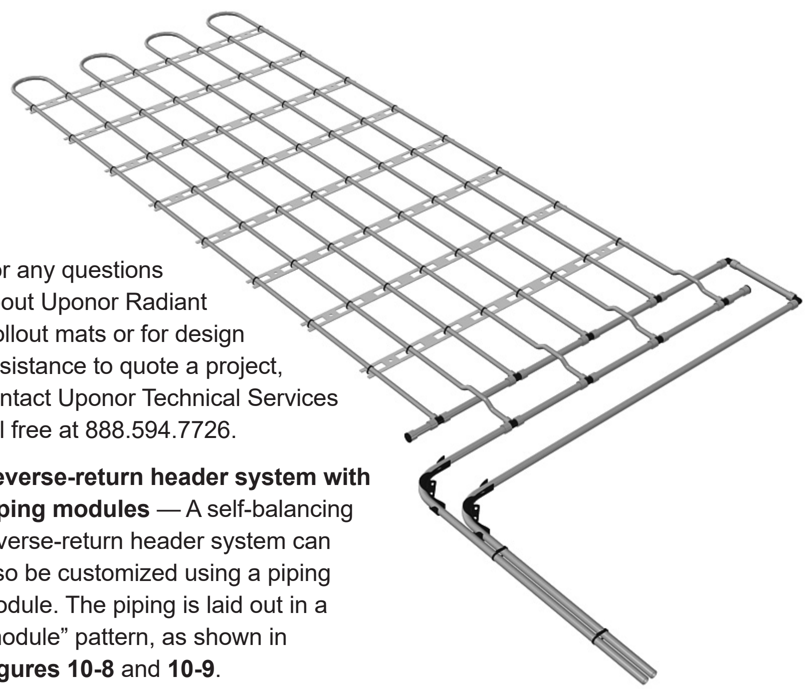


Figure 10-9: Reverse-return header with piping module

Conventional wall manifolds — Commercial distribution flow systems have traditionally been designed with wall manifolds. Uponor offers the following types of wall manifolds:

- TruFLOW Classic (21 gpm)
- TruFLOW Jr. (14 gpm)
- Engineered polymer (EP) heating manifolds (14 gpm)
- 1¼" stainless-steel manifolds (21 gpm)
- 1" stainless-steel manifolds (14 gpm)

Refer to **Chapter 4** for more information about Uponor wall manifolds.

HDPE manifolds — Uponor offers high-density polyethylene (HDPE) manifolds, which are effective distribution flow products for large snow-melt and turf-conditioning projects. The HDPE manifolds are valve-less manifolds manufactured with ¾" or 1" stainless steel ProPEX fittings. The HDPE manifolds are typically buried and can be designed with HDPE leader piping to provide a reverse-return type of system.

Refer to **Chapter 4** for more information about Uponor HDPE manifolds.

Copper manifolds — Uponor offers 2" copper manifolds that are effective distribution flow products for large commercial and snow-melt projects, handling flows up to 45 gpm. The copper manifold offers economic advantages when combined with a reverse-return Radiant Rollout mat or piping module system. Significant flow can be balanced, controlled and distributed through a copper manifold and then routed to a self-balancing piping layout. Copper manifolds come with the following accessories: ball valves, balancing valves, and end caps with vent and drain.

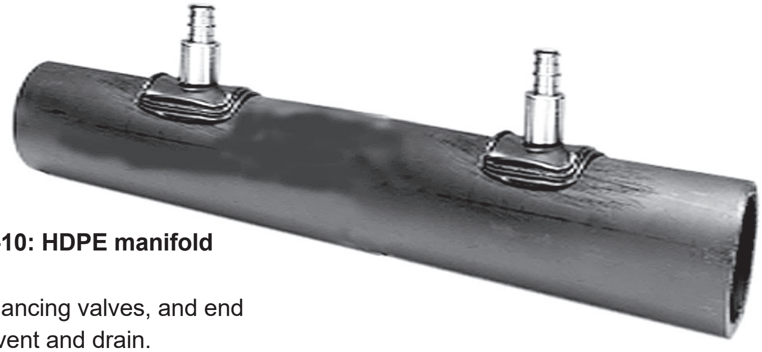


Figure 10-10: HDPE manifold

Copper manifolds are available in ⅝", ¾", R20 and R25 sizes.

Refer to **Chapter 4** for more information about Uponor copper manifolds.

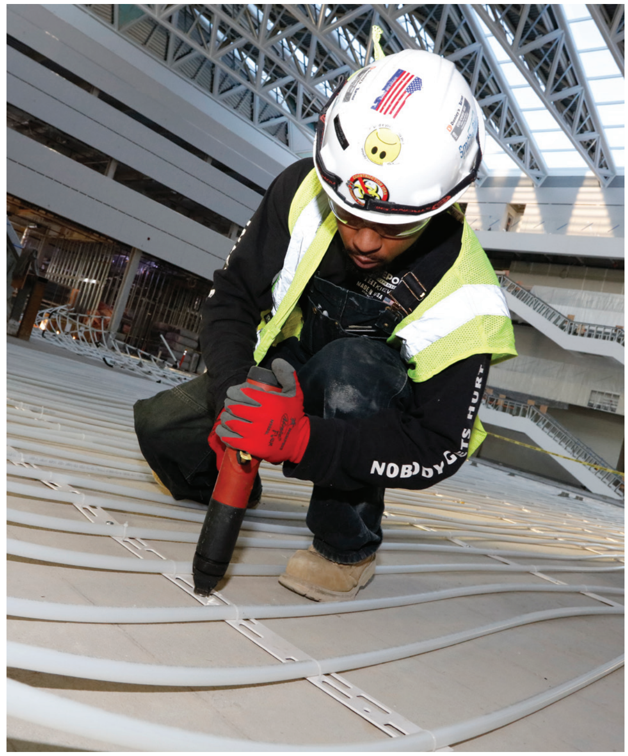
Commercial building zones

Zone selection – Those areas similar in terms of heat loss and heat gain that can be controlled from the same thermostat. For more detailed information on zone selection, see **Chapter 11**.

Zone control – Commercial projects typically involve large panel areas, so the use of actuators on individual loops is usually impractical. The alternative is to zone by manifold using zone valves or zone circulators. Small independent areas on the same manifold, such as restrooms and conference rooms, can be sub-zoned with individual thermostats and actuators to meet their requirements. In any case, the Uponor manifold system is extremely versatile and able to accommodate virtually any control strategy.

Manifold pressure bypass – Large commercial projects often require large circulator pumps. When a small zone calls for heat, release the excess pressure from the pump through a pressure bypass. In systems with short distribution piping to the manifold, install a bypass in the mechanical room near the circulator. In systems with long or large distribution piping to the manifolds, install a bypass near the manifold. A bypass at the manifold allows heat energy to reach the zone more rapidly than if the flow for a single zone was used to fill a large distribution pipe.

Figure 10-11: Copper manifold



Chapter 11:
Design considerations

When planning and designing a hydronic radiant heating system, it is important to consider design options that support the intended need of the customer and the type of heat source available to the system. Radiant systems are significantly different from other hydronic or forced-air heating systems.

Differences include:

- A relatively large size of the heat transfer surface
- The panel's ability to absorb and disperse surges or fluctuations in supply water temperature (capacitor effect)
- A relative composition of the heat transfer (i.e., conduction, radiation and convection) as it relates to how the human body perceives thermal comfort

It is important to realize that the strategies used in forced-air systems are not necessarily applicable for radiant systems. The way in which energy is evaluated and managed is on a more finite level with radiant systems. The temperature in one room will not impact the temperature in the next room. This is why it is easier and less inexpensive to zone a radiant system than a forced-air system. Since most people like to sleep in a cooler room, bedrooms can be set to a lower setpoint temperature than common-use areas (e.g., kitchen, family room).

The air exchange in a structure does not affect radiant systems in the same way it affects forced-air systems. Forced-air systems use heated air circulating within the structure to heat objects. If a door is opened in a forced-air system, the heated air (the medium for heating) is lost to the outside. In contrast, radiant systems heat objects, not air. As a result it is not necessary to overdesign systems.

Surface area

The surface area of a radiant panel system is relatively large compared to other methods of radiant heating, such as baseboards and radiators. Therefore, the heat required per square foot of heated surface and the corresponding surface temperature is much lower.

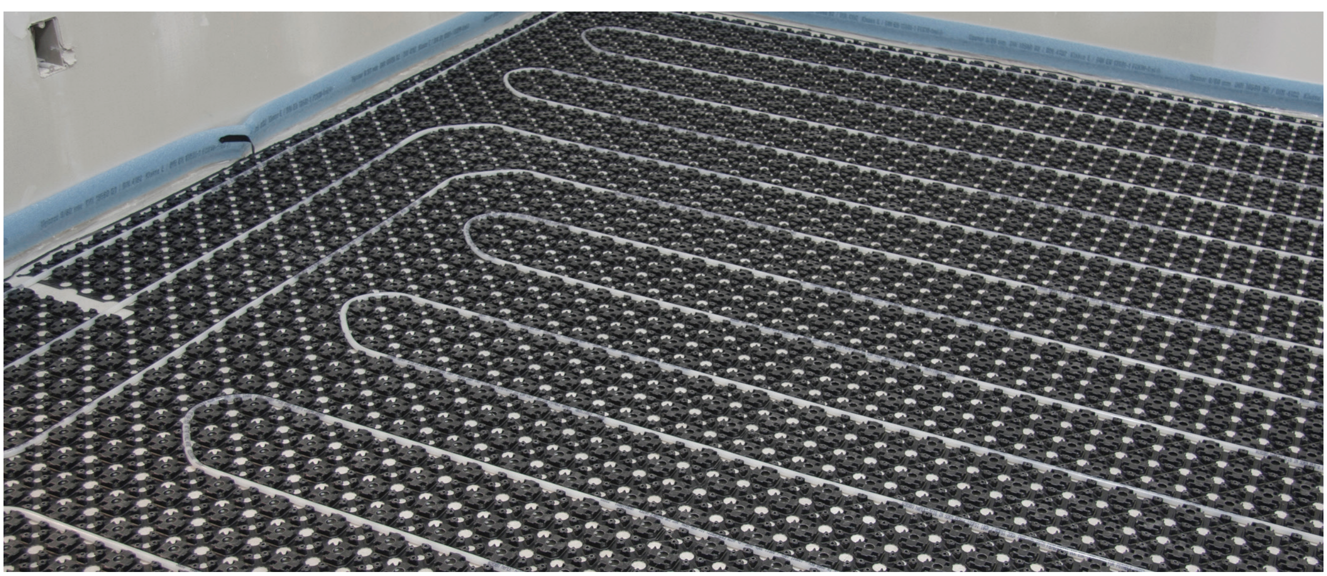
Capacitor effect

Because the radiant panel is massive, its surface temperature does not change instantly when heat is introduced. Instead, the mass of the system (as well as normal resistance) spreads the heat. Internally, heat disperses until the mass reaches capacity while gradually transferring heat to the space. Because of this natural capacitor effect, a radiant panel is not as sensitive to supply water temperature fluctuations as baseboard convectors or radiators.

Composition

Radiant panels effectively use all three forms of heat transfer: radiation, conduction and convection. The unique composition of radiant panel heat transfer results in a comfortable environment at lower room air temperatures because a radiant panel produces more consistent mean radiant temperatures than other types of heating systems.

Remember also that hot air — not heat — rises. Radiant systems are successful because the heat transfers primarily through conduction and radiation. The amount of convective transfer is minimal from radiant systems. Consider the fact that the majority of radiant systems operate with surface temperatures between 75°F to 80°F. Very little convective action is moving from a panel at that temperature.



Zone selection

A zone is an area of a radiant floor or ceiling served by one or more piping loops and controlled by a dedicated thermostat. Consider the following issues when determining zones.

Heat-loss

Place areas with different heat losses in separate zones. For example, a room with a 10 BTU/h/ft^2 heat-loss and one with a 25 BTU/h/ft^2 heat-loss should be in different zones.

Floor construction

Place areas with different floor constructions in separate zones. For example, do not zone rooms constructed over a concrete slab (heavy-floor construction) with rooms constructed over suspended wood floors (light-floor construction) with aluminum plates.

Heavy construction contains a great mass and uses large or thick concrete slabs. More energy is required to accelerate the mass and increase the temperature; similarly, more time is required to decelerate the slab or reduce the temperature.

Light construction contains less mass and uses suspended wood floors with heat emission plates or a poured-floor underlayment and radiant ceiling. Less energy is required to increase temperature and less time is required to decrease temperature. Low-mass construction provides a quick response, but may be subject to hot spots when supplied with sudden increases in water temperature. Radiant ceiling is especially sensitive to excessive supply water temperature as are radiant floors with low R-value floor coverings.

Use patterns

The use of a building can affect the desired setpoint temperature and the heat load. Analyze the intended use of each area before selecting zones. In many situations, use patterns will change over the life of the building. Design the zones with some flexibility to accommodate potential changes.

Residential – The use patterns of homes cover a wide range of possibilities. The age of residents as well as the types of activities in the home can vary greatly. For example, high-energy use patterns, such as cleaning, exercise, children's play, etc., may require cooler temperatures. Low-energy activities, such as reading and watching television may require higher temperatures. Additionally, clothing is also something to consider. Some rooms may need to be warmer or cooler (e.g., bathrooms versus living rooms). Rooms unused for extended periods of time are often zoned separately, so the temperatures can be set lower to conserve energy and reduce operating costs.

Commercial – A commercial building usually centers on one or two activities, such as shopping, eating or entertainment. Consider the activities when determining zones. Also consider that the commercial buildings house a variety of businesses or enterprises over time, and use patterns may significantly change with each new occupant. Zones should be versatile enough to accommodate changes in the use patterns.

Industrial – Industrial buildings usually house a process that dictates zone requirements. The process may necessitate temperature and air changes that make proper zoning critical. An industrial plant may house equipment that significantly contributes to the heat in the building or the heat load of the building. Industrial processes often produce heat that can be recovered in heat exchangers and used to supply warm water to the radiant panel.

Internal gains and losses

Take into account additional heat gains and losses when determining zones.

In residential structures, additional gains may result from cooking, bathing or mechanical equipment. Additional losses may result from frequently used doors.

In commercial and industrial structures, additional gains may result from industrial processes, mechanical equipment or lighting. Additional losses may result from introducing cold vehicles or materials.

Consider zoning areas exposed to different solar conditions separately. Solar gain is influenced by the orientation of the building, length of the eaves and the amount of window area. Windows that provide a heat gain when it is sunny become a significant heat loss when there is no solar gain. The presence of large windows or significant window area increases the need for precise local zone control. Window coverings are useful for controlling solar exposure and window heat-loss.

Chapter 12:
Control strategies

This chapter discusses control strategies for hydronic radiant systems. Uponor offers a comprehensive line of controls from thermostats for local zone control to supply water temperature control as well as a network-based system that can control a wide range of HVAC functions. Understanding the available options and selecting the appropriate approach for a given project are key to a properly controlled radiant heating system.

Local zone control

Good control logic requires accurate information to respond with a logical control action. Control action should be based on information (e.g., a call for heat) that has a direct relationship to the item controlled (e.g., the application of heat). No logic is more appropriate for hydronic radiant panel systems than local zone control. Local control is defined as a thermostat in a room that determines when the room is not within an acceptable margin of the setpoint and sends a signal that heating or cooling is needed.

The local thermostat monitors the climate of the room. It recognizes a reduction in the heat requirement due to solar gain, high occupancy or internal gains, and responds by not calling for heat. The local zone thermostat also recognizes the need for additional heat when the outdoor temperature drops, curtains are opened or cold materials are introduced into an area. A local zone thermostat also provides the homeowner with the means to easily change the room setpoint temperature according to personal preference.

Two conditions must be met to achieve good local zone control.

- First, supply water temperature must be limited to no more than the maximum required for the highest heat load served. Using the highest required water temperature for a given area brings the system to within the "control authority" of the thermostat. Large projects with multiple heat plants and/or tempering devices very often use several supply water temperatures for different areas of the building. The correct supply water temperature should be maintained by using mixing devices, such as tempering valves, modulating valves, injection pumps or modulating-condensing boilers. All of these components have the ability to maintain a desired water temperature at a specific condition.
- Second, the control input and output logic must be equipped with appropriate and synchronized mechanisms for anticipating and distributing heat. These devices should be precisely engineered to work together. Because radiant panel systems can be either high mass or low mass, and because the resistance of potential floor coverings varies widely, anticipation is more critical with radiant floor than other forms of heating and cooling.

Refer to **Chapter 11** for information on determining zones.

Figure 12-1: Uponor Climate Control Zoning System II

Thermostats

Uponor offers several types of thermostats that vary in both operation and appearance. Regardless of the hardware set used, pay close attention to using the correct thermostats for properly sensing and accurately controlling a radiant heating system. This is because, due to the mass, radiant system dynamics are different than conventional air systems. All Uponor thermostats are designed for use in a radiant system to provide the highest level of comfort and efficiency.

Heat-only thermostats with touchscreen

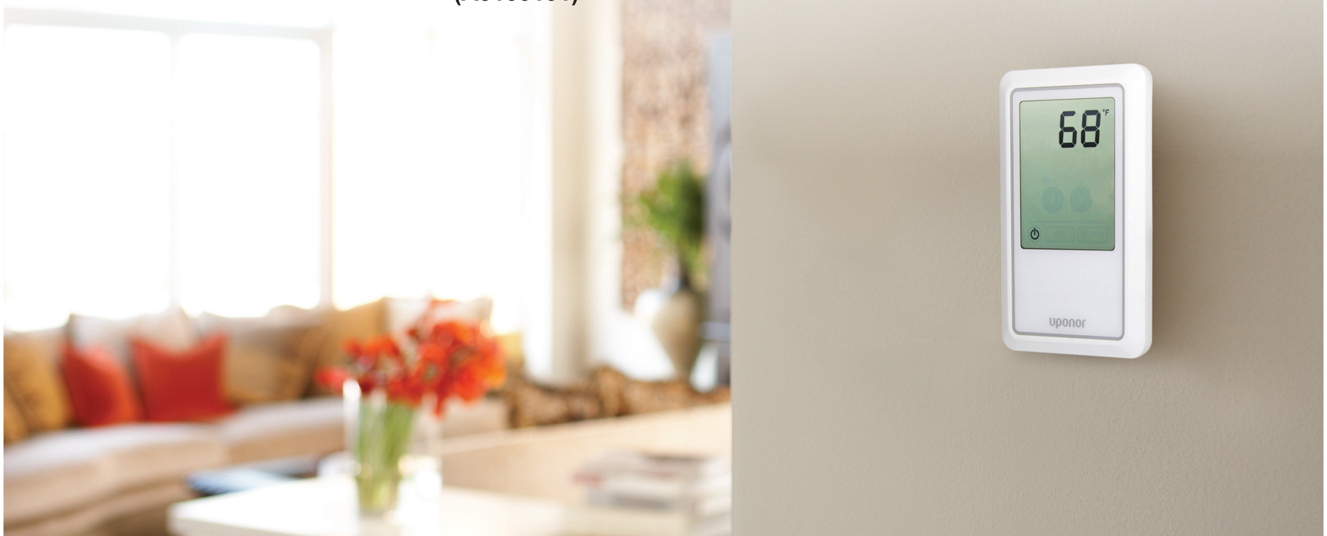
Heat-only thermostats with touchscreen are designed specifically for radiant floor heating. They use fully automatic differential and pulse width modulation (PWM) to ensure each zone or area is comfortable and energy efficient. The touchscreen provides a simple, intuitive display with large, easy-to-read numbers. The thermostat can control room temperature through operative temperature sensing, an optional floor sensor or a combination of both. The floor sensor can be used to maintain warm floors throughout the heating season as well as provide temperature limit protection. The thermostat is designed to operate using two wires, making it simple to install and service.

Figure 12-2: Uponor Heat-only Thermostat with Touchscreen (A3100101)

SetPoint 521 programmable thermostats

SetPoint 521 programmable thermostats are designed to provide three different modes of operation: single-stage heating, two stages of heating with a fan, or one stage of heating and one stage of cooling with a fan. Auxiliary sensors may be added to measure floor, outdoor or room temperature. The thermostat includes an Uponor Floor Sensor (A3040079) to measure floor temperature for protecting the floor from overheating and enhancing comfort. Programmable schedules support either a 7-day or 24-hour schedule with two or four events per day.

Figure 12-3: SetPoint 521 Programmable Thermostat (A3040521)



Piping and control options

The following pages show piping and control arrangements for various radiant floor and radiant ceiling zoning options that support local zone control.

Option 1:

Multiple zones on a single manifold with actuators

- Single manifold with multiple zones, serviced by a single circulator (P1)
- Each circuit or group of circuits is an individual zone, controlled by an Uponor thermostat. Uponor Four-wire Actuator(s) and thermostats are wired into the Uponor Zone Control Module (ZCM).
- Uponor ZCM is wired into a hydronic relay (single or multiple).

Advantages:

- Allows for zoning flexibility within a single manifold
- Makes room-by-room zoning simple and cost effective

Refer to **pages 145-168** for the specific wiring schematic.

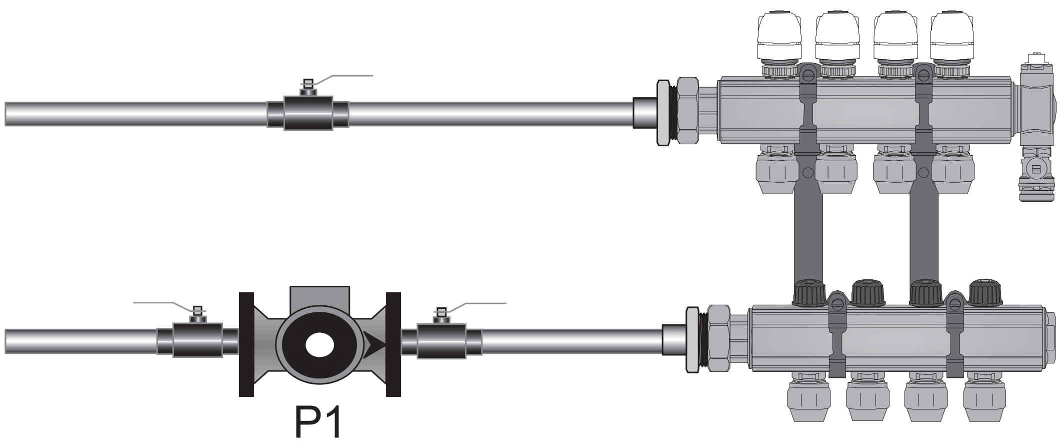


Figure 12-4: Multiple zones on a single manifold with actuators

Option 2:

Multiple zones on multiple manifolds with zone valves

- Each manifold is a single zone, all serviced by one circulator (P1).
- Each manifold (zone) is controlled by an Uponor thermostat and an Uponor four-wire zone valve.
- Thermostats and zone valves are wired into the Uponor Zone Control Module (ZCM).
- Uponor ZCM is wired into a hydronic relay (single or multiple).

Refer to **pages 145-168** for the specific wiring schematic.

Advantages:

- Simplified zoning — single-zone valve instead of multiple actuators
- Possible reduced costs
- Easiest way to zone a manifold with a single zone

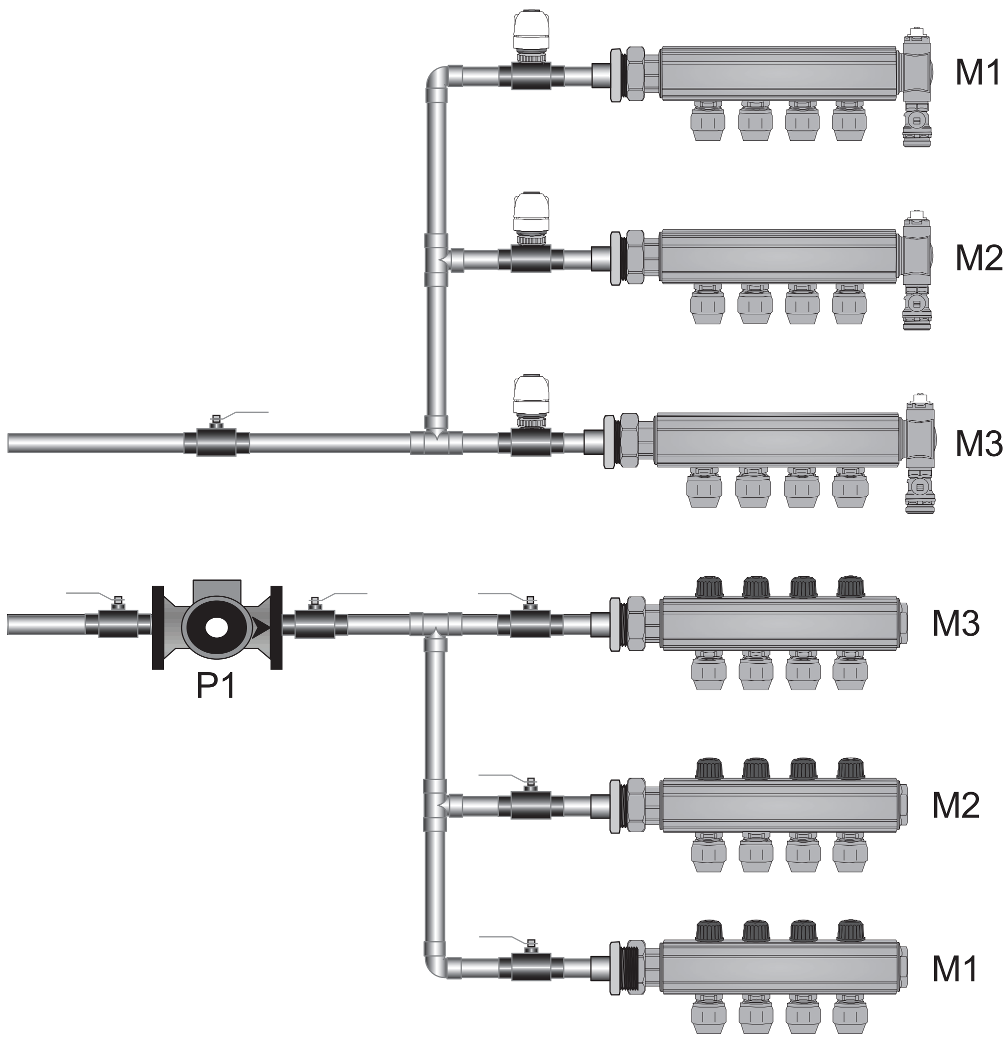


Figure 12-5: Multiple zones on multiple manifolds with zone valves

Option 3:

Multiple zones on multiple manifolds with actuators and zone valves

- Mixture of options 1 and 2
- Some manifolds are single zones, controlled by Uponor thermostats and Uponor Four-wire Zones Valves.
- Other manifolds are multiple zones, controlled by Uponor thermostats and Uponor four-wire actuators.
- Thermostats, actuators and zone valves are wired into the Uponor Zone Control Module (ZCM).
- Uponor ZCM is wired into a hydronic relay (single or multiple).

Advantages:

- Simplified zoning where applicable
- Room-by-room zoning where applicable
- Can add actuators later to single-zone manifolds for multiple zoning

Refer to **pages 145-168** for the specific wiring schematic.

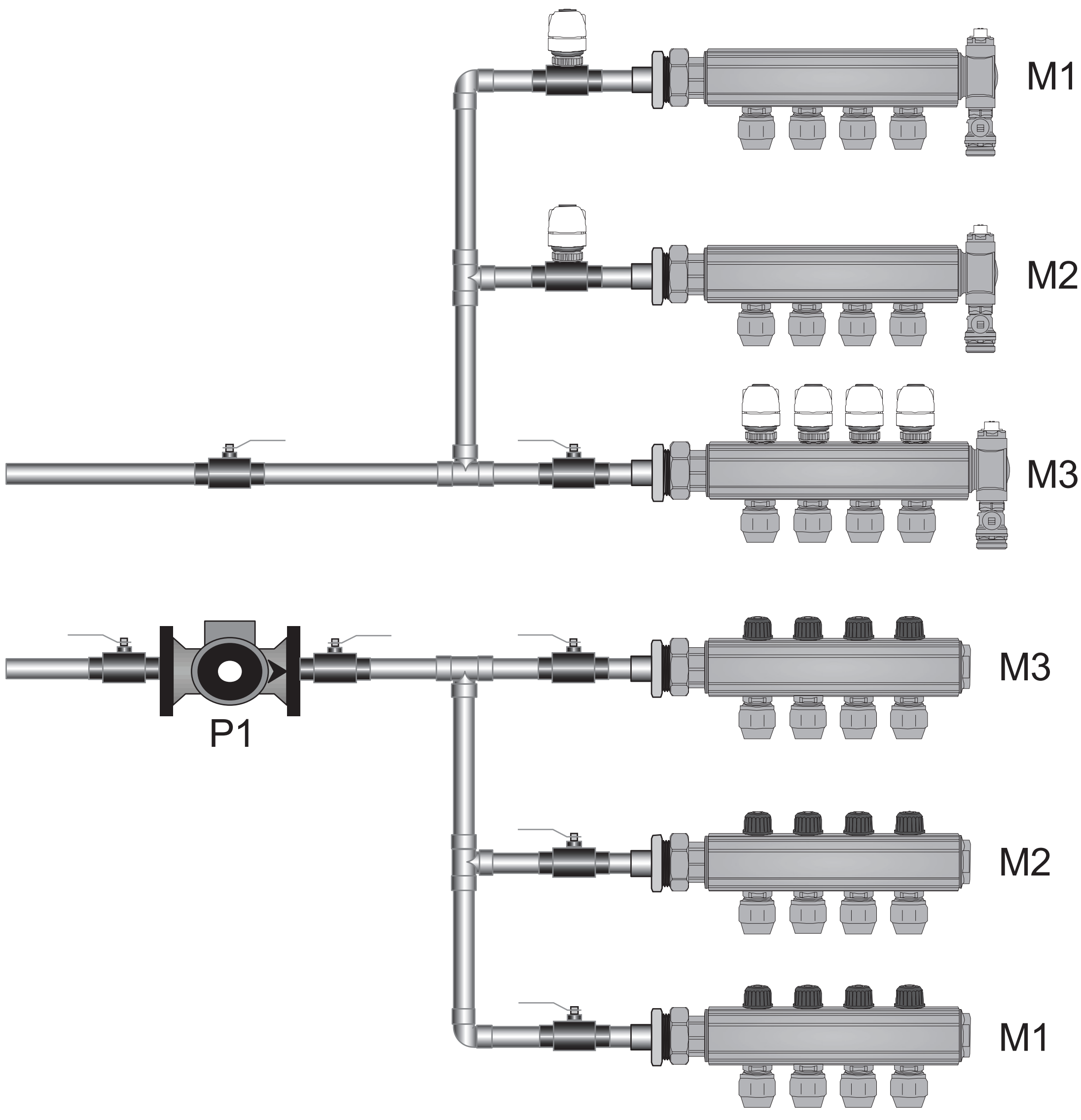


Figure 12-6: Multiple zones on multiple manifolds with actuators and zone valves

Option 4:

Single zones on multiple manifolds with circulators

- Each manifold is a single zone, each serviced by its own circulator.
- Each manifold (zone) is controlled by an Uponor thermostat and a hydronic relay (single or multiple).

Note: Add flow control valves as needed if circulators do not come with internal check valves to prevent flow when zone is not calling.

Refer to **pages 145-168** for the specific wiring schematic.

Advantages:

- Each zone controlled with its own circulator
- Circulator only needs sizing for its particular zone

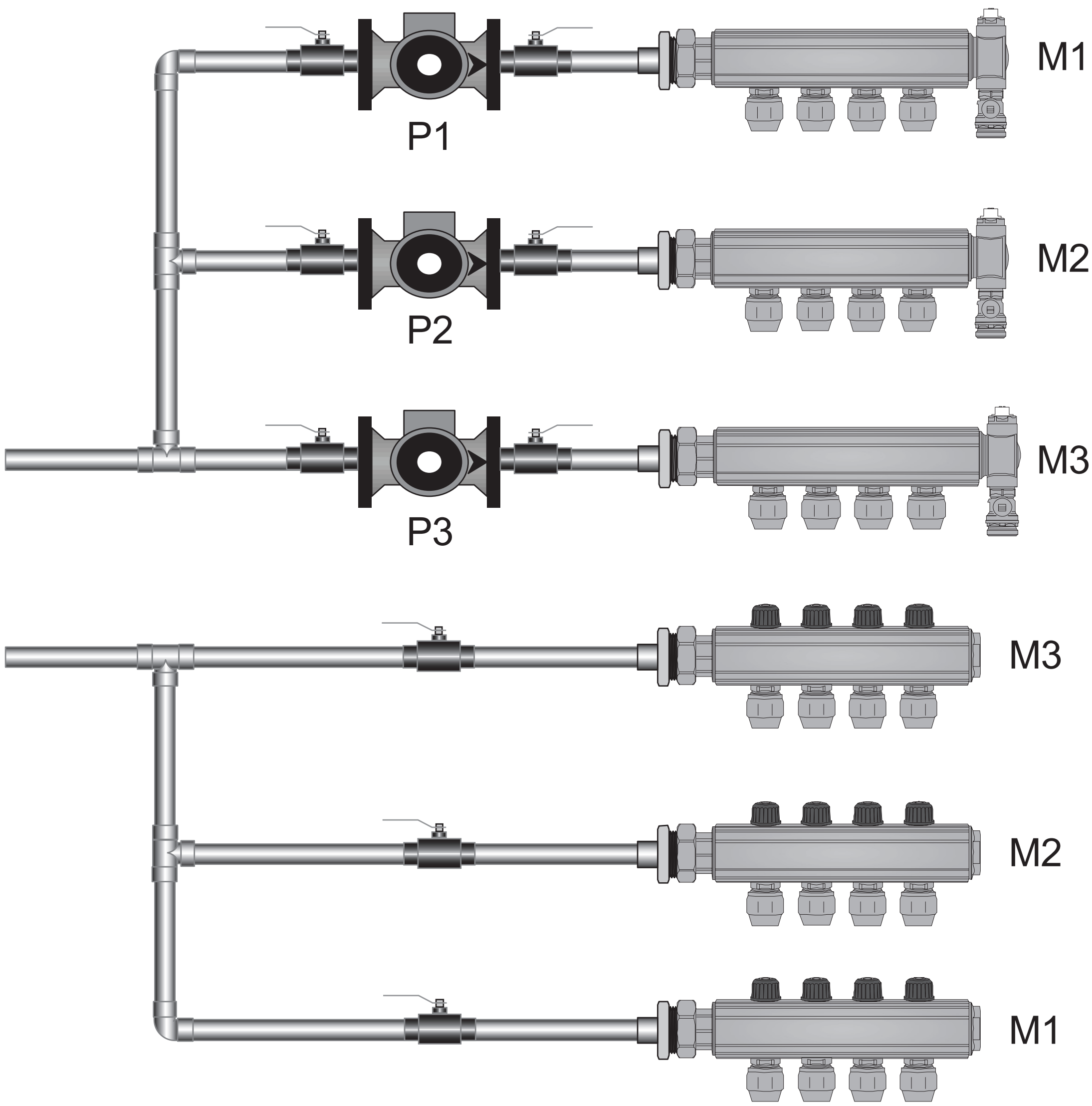


Figure 12-7: Single zones on multiple manifolds with circulators

Option 5:

Combination zoning with circulators

- Some manifolds are single zones, serviced by their own circulators and controlled by Uponor thermostats and a hydronic relay (single or multiple).
- Other manifolds are multiple zones, serviced by their own circulators, and controlled by Uponor thermostats and Uponor Four-wire Actuators.
- Actuators and thermostats are wired into the Uponor Zone Control Module (ZCM).
- Uponor ZCM, plus the other thermostats and circulators, are wired into hydronic relays (single or multiple).

Note: Add flow control valves as needed if circulators do not come with internal check valves to prevent flow when zone is not calling.

Refer to **pages 145-168** for the specific wiring schematic.

Advantages:

- Simplified zoning where applicable
- Room-by-room zoning where applicable
- Can add actuators later to single-zone manifolds for multiple zoning

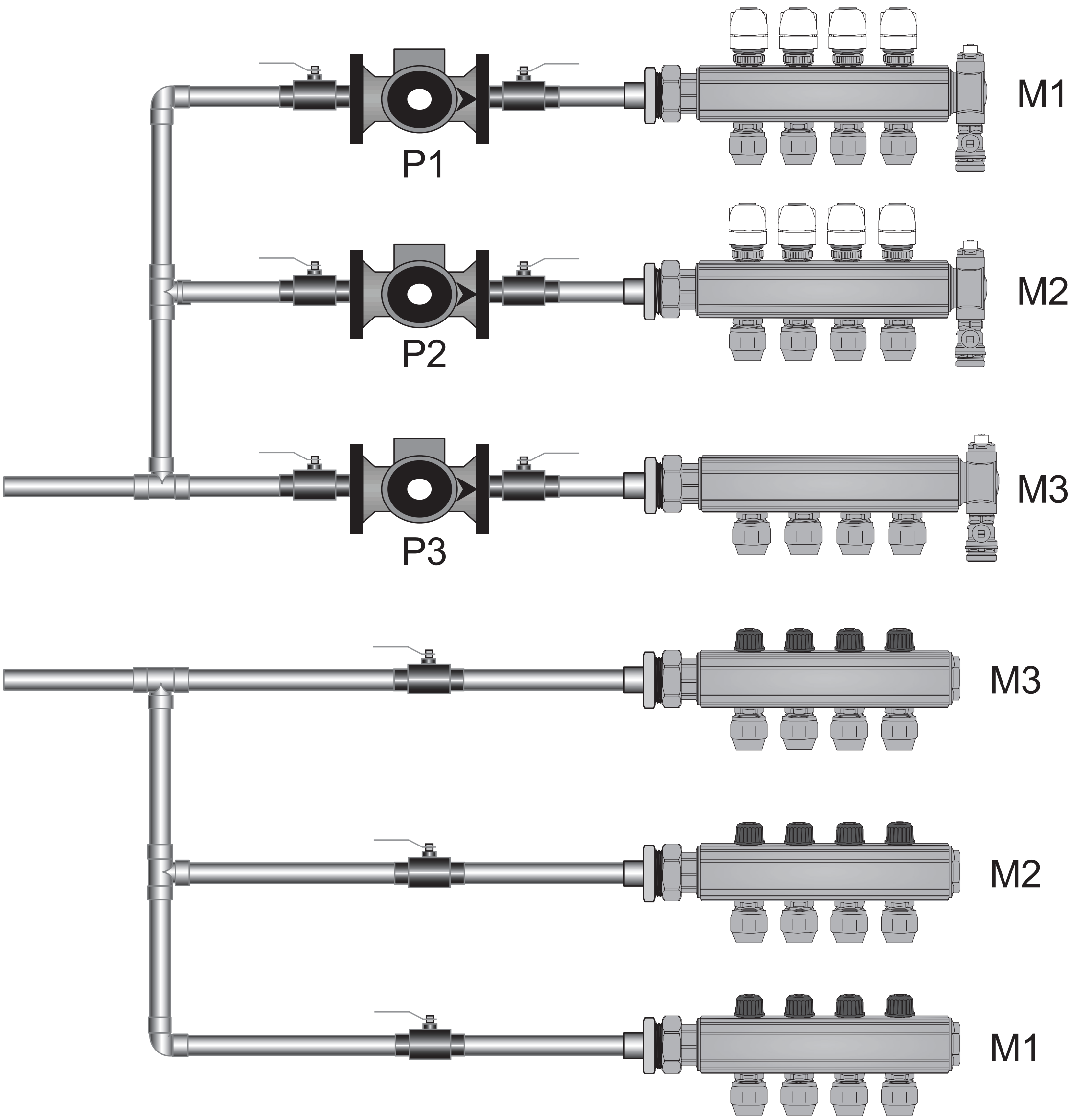


Figure 12-8: Combination zoning with circulators

Water temperature control

When considering radiant floor heating control, it is important to distinguish between zone control and water temperature control. For the most part, zone control may be achieved through the use of thermostats plus actuators, zone valves or circulators. This section discusses water temperature control for radiant floor heating.

Radiant floor heating is, in general, a relatively low water temperature system. There is no ideal or preferred water temperature for radiant. As discussed in **Chapter 8**, a variety of factors determine system water temperature. These factors include installation method, tube spacing, finished floor material and heat load. Once the system water temperature is determined, the question becomes how best to achieve and control that water temperature.

Radiant system water temperature control is categorized into three levels:

Level 1 — No additional temperature control

Level 2 — Single-temperature tempering

Level 3 — Weather-responsive reset control

Level 1 control is by far the simplest in terms of installation and operation.

Level 1 — No Additional Temperature

"No additional control" means using the water temperature control that comes with the heat source to control the radiant system water temperature. For example, if a simple gas-fired or electric water heater is used as a heat source, the desired system water temperature can be dialed into the water heater's control. If 110°F water is needed, simply set the water heater to provide 110°F water.

Condensing boilers are ideal for Level 1 control. These boilers are designed to operate at extremely low return water temperatures. In fact, the lower the return water temperature to a condensing boiler, the more efficiently it operates. Condensing boilers use low return water temperatures to condense the flue gasses. The boiler then uses the latent heat in the condensed flue gasses to help heat the system water. This extra energy can increase the overall efficiency of a condensing boiler by 10% when compared to a non-condensing boiler.

Other heat sources are also suitable for Level 1 control. Electric boilers, like water heaters, may be controlled to provide a specific water temperature. Since there is no flue and no combustion gasses, electric boilers can operate at very low water temperatures with no fear of condensation.

Since a radiant system often requires relatively low water temperatures, a traditional cast iron non-condensing boiler (oil or gas fired), is not usually advisable for Level 1 control. Non-condensing boilers typically require return water temperatures of 125°F to 145°F to prevent flue gas condensation. If a system with return water temperatures lower than 125°F to 145°F is connected to such a boiler, the flue gasses within the boiler will condense. This condensation is highly acidic, and it can damage the flue pipe and the boiler itself. Only use non-condensing boilers for Level 1 control if return water temperatures are above the manufacturer's minimum return limit. Refer to boiler manufacturer's installation guidelines for model-specific information.

Level 2 — Simple mixing control

In its most basic form, single-temperature tempering mixes hot boiler supply water with cooler radiant system return water to achieve the desired radiant supply water temperature. Single-temperature tempering is used in cases where a standard non-condensing boiler is the heat source. Since these boilers are limited to no less than 125°F to 145°F return water temperatures, a tempering device is needed between the boiler and the radiant system for two reasons:

1. To achieve the desired radiant supply water temperature
2. To protect the boiler against return water temperatures below 125°F to 145°F, thereby preventing flue gas condensation

Three-way mixing valves — Uponor three-way mixing valves are microprocessor-controlled valves designed to regulate the supply water temperature to a radiant heating system by modulating the position of the valve. Configure mixed supply setpoint to reset from the outdoor air temperature or a fixed setpoint. Use an optional boiler sensor to provide boiler protection in non-condensing boiler applications.

Thermal mixing valves — A thermal mixing valve is the simplest and most effective way to achieve Level 2 control. The Uponor thermal mixing valves (A5402112) provide a constant, fixed water temperature for radiant floor heating, without affecting boiler operation.

The valve has three ports, labeled + (plus), - (minus) and MIX. Hot boiler water is supplied to the + port. Inside, the valve contains an element that expands and contracts to control the temperature of the radiant system supply water coming out of the MIX

Figure 12-9: Uponor three-way mixing valve (A3040075)

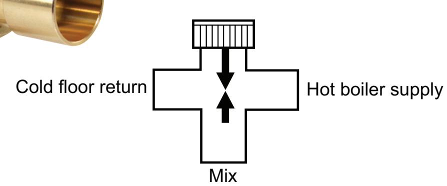


Figure 12-10: Thermal mixing valve (A5402112)

port. The port is for radiant system return water, piped into the – (minus) port as part of a bypass that also goes back to the boiler.

The valve has a dial for setting a fixed system water temperature. The internal element then expands and contracts as it senses the water temperature leaving the MIX port. If the MIX temperature is too hot, the element expands, pushing a shuttle valve to restrict the flow of hot boiler water from the + (plus) port. If the water temperature in the MIX port is too low, the element contracts, relaxing tension on the shuttle valve and allowing more flow of hot boiler water into the system through the + (plus) port. In effect, the valve will temper the hot boiler water with cooler radiant return water that is recirculated through the bypass and into the - (minus) port.

The valve is considered a reactive valve in that it supplies a constant water temperature to the radiant heating system, despite potential drops in boiler supply water temperature. A reactive valve works well with intermittent, or on-off, zone control.

There are several advantages to this valve, including:

• Low cost
• Non-electric — no additional wiring required
• Reactive — automatically adjusts to maintain proper supply water temperature
• Easy installation — only three piping connections
• Operating temperature range from 80ºF to 160°F

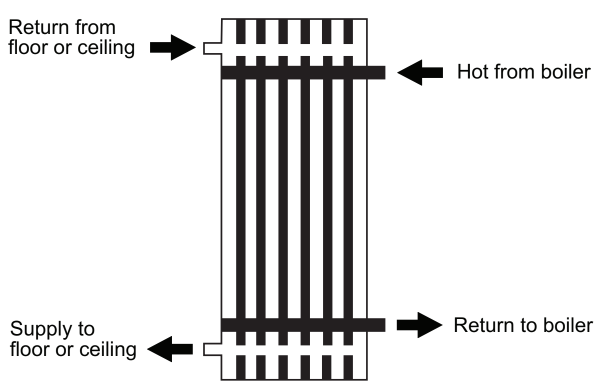


Figure 12-11: Heat exchanger

The valve can be installed in any position. The valve must have a circulator installed on the radiant side to insure proper flow through the radiant system. The best location for this circulator is between the MIX port and the supply manifold. In addition, a temperature gauge should be installed downstream of the MIX port to monitor supply water temperature. Refer to **Chapter 13** for a piping schematic.

Other level 2 options — There are several other methods of achieving Level 2 control, including mixing tanks, heat exchangers, four-way motorized mixing valves and injection mixing. Motorized mixing valves and injection mixing controls can also be made weather responsive; see the Level 3 section on **page 123** for more information.

Heat exchangers —Stainless steel brazed-plate heat exchangers provide fixed water temperatures for radiant floor heating and, more commonly, snow melting. Heat exchangers have two separate chambers, or sides. One side contains boiler water, and the other contains radiant heating system water. The hot boiler water is pumped through the heat exchanger, warming the walls of the exchanger itself. Radiant system water is pumped through the other side of the exchanger, and the water is warmed as it comes in contact with the hot wall of the exchanger. The boiler water and the radiant system water never mix.

Heat exchangers are most commonly used to deal with the issue of oxygen-diffusion corrosion when non-barrier Uponor AquaPEX® piping is used for radiant heating or snow melting. Non-ferrous components are used with the non-barrier piping on the radiant or snow-melting side of the heat exchanger. This means using a bronze or stainless steel circulator with non-ferrous flanges, a potable water-type expansion tank, a brass or bronze air separator, and all non-ferrous hard piping. No steel or cast iron piping or other ferrous materials may be used with non-barrier piping.

On the boiler side of the heat exchanger, traditional piping materials may be used. The heat exchanger prevents oxygen-diffusion corrosion by separating the “open” system (using the non-barrier piping on non-ferrous components) from the boiler system.

Heat exchangers are also used in conjunction with domestic water heaters for small heating or floor conditioning jobs. The heat exchanger keeps the radiant system water separate from the potable water system. In all cases in which a heat exchanger is used for radiant heating, a circulator and expansion tank are required on the radiant side of the exchanger.

Water temperature on the radiant side of the heat exchanger is controlled by an aquastat, which is set to maintain a fixed supply temperature. When the aquastat remote sensor detects the supply water temperature dropping below that fixed temperature, the aquastat will fire a circulator on the boiler side of the heat exchanger (and the boiler, if necessary). Hot boiler water will pass through the heat exchanger, heating the radiant system water on the radiant side of the exchanger.

Advantages of heat exchangers include:

• Universally acceptable
• Provides protection from oxygen-diffusion corrosion when using non-barrier piping
• Perfect for snow-melt applications — protects heat plant from cold return temperatures
• Allows for isolation of systems using high glycol mixes

Heat exchangers can add expense to some systems, since an additional circulator, expansion tank, air separator and hard piping will be necessary. However, in snow-melting applications and installations using a domestic water heater, heat exchangers can be the ideal solution. Refer to **Chapter 13** for a piping schematic.

Mixing tanks — Mixing tanks are often referred to as buffer tanks. Water from the heat plant is mixed with return water from the radiant panel. A boiler loop circulator and a radiant panel loop circulator are required. A fixed water temperature is maintained in the mixing tank with an aquastat (either immersion or strap-on) that senses supply water temperature for the radiant panel. When that water temperature drops below the desired temperature, the aquastat fires the boiler loop circulator (and the boiler, if necessary), to pump more hot water into the mixing tank.

A mixing tank is often used with extremely low mass, or “flash” type, boilers. The mixing tank adds water to the system and can prevent the boiler from short cycling. Any insulated tank is suitable for use as a mixing tank.

Mixing tank advantages include:

- Medium to low cost
- Provides water mass to reduce potential boiler short-cycling
- Provides energy storage
- Excellent for wood boilers
- Simple piping

Refer to **Chapter 13** for a piping schematic.

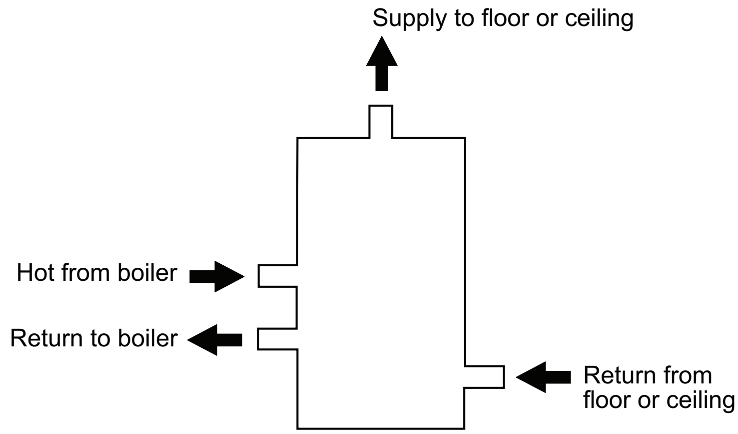


Figure 12-12: Mixing tank

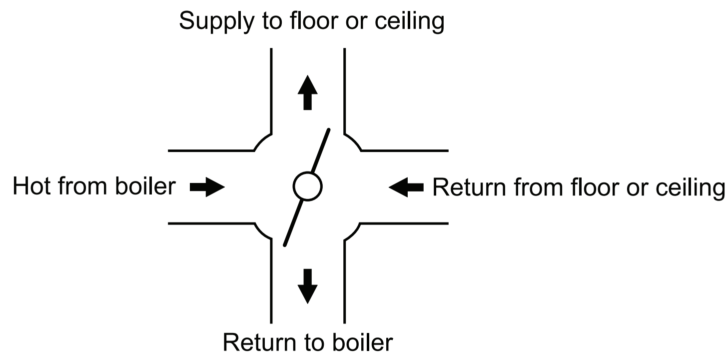


Figure 12-13: Four-way motorized mixing valve

Four-way motorized mixing valves — Four-way motorized valves are automatic and respond to control input from electronic sensors to maintain a fixed water temperature within a radiant system. They perform essentially the same function as a three-way tempering valve, performing those functions electronically and mechanically.

A sensor (either strap-on or immersion-type) senses radiant supply water temperature. When that temperature falls below the desired temperature, a control fires a circulator on the boiler side of the valve and tells the motor on the mixing valve to adjust the valve setting. The control and valve will regulate the amount of hot boiler water and of radiant return water that mix together to produce the desired water temperature.

In order to be “reactive,” four-way mixing valves must be equipped with a motor. The motor adjusts the position of an internal diverting flapper, which regulates the amount of hot boiler water and cool radiant return water mixed together to create the desired radiant supply water temperature. This is important since the boiler supply water temperature and/or the radiant return water temperature may not be fixed. If either of those temperatures is not fixed, a non-motorized valve will not be able to maintain a constant supply water temperature.

A non-motorized mixing valve merely provides a “fixed ratio” mixture of hot boiler water with cooler radiant return water. A motor on the mixing valve will allow the valve to alter the mix to provide a constant radiant supply water temperature, regardless of changes in the other two water temperatures.

Advantages of motorized four-way mixing valves:

- Universally acceptable
- Can be made weather responsive with additional control

Four-way mixing valves can add expense to a system, since a valve, motor and separate control is required. Additional wiring may also be required.

Injection mixing with constant temperature — Injection mixing achieves Level 2 control in a manner very similar to the three-way tempering valve. A constant radiant supply water temperature is maintained by mixing short blasts of hot water boiler water with relatively cool radiant return water. Injection mixing is often piped in a primary/secondary configuration. Hot boiler water flows through the primary loop, with the relatively cooler radiant supply water flowing through the secondary loop. Supply and return injection legs connect the two loops, with a two-position zone valve on the supply injection leg.

A setpoint control or aquastat is used to measure the radiant supply water temperature. Whenever the sensor reads that radiant supply water temperature drops below the desired level, the zone valve on the injection leg opens and fires the primary circulator. Hot boiler water will then be injected into the radiant loop, bringing the radiant supply water temperature up to the desired level. A suitable balancing valve is required on the radiant loop, between the supply and return injection legs, to create the pressure drop required for injection to take place.

Advantages of injection mixing:

- Universally acceptable
- Can be made weather responsive with additional controls
- Protects boiler from low return water temperatures
- Relatively low cost

Level 3 control — weather-responsive reset

Weather-responsive reset is used to maximize both system efficiency and comfort. At its most basic level, weather-responsive reset control adjusts the radiant system supply water temperature to match the exact heat demand of a building on a given day. Heating systems are designed to maintain a certain indoor temperature under design conditions, or the coldest day of the year in that specific geographic region.

Figure 12-14: An appropriate analogy for weather responsive reset control is cruise control on a car.

The radiant system supply water temperature is the water temperature required to heat a room or building under design conditions. However, the heat load changes as weather conditions outside change. As the outdoor temperature increases, the heat load of a building decreases. By the same token, the radiant supply water temperature required to satisfy that heat load decreases. Weather-responsive reset control monitors outdoor temperatures and then adjusts, or modulates, the system supply water temperature to satisfy the specific heat load at that given time. As the outdoor temperature decreases, the radiant supply water temperature will increase, and vice versa.

An appropriate analogy for weather responsive reset control is cruise control on a car. Cruise control is set for maintaining a specific speed, and it will adjust the amount of gas going to the engine based on road conditions: more gas if the car is going uphill, ess gas if the car is going downhill. As cruise control maximizes the comfort of the ride and the fuel economy of the vehicle, weather responsive reset maximizes both the comfort and fuel economy of the heating system. Indoor comfort is maximized by closely matching system output to the heating load, while system efficiency is maximized by providing the lowest possible supply water temperature at a given load, while minimizing distribution losses.

Weather-responsive reset controls may be applied to the heat source or to the radiant distribution system. Condensing boilers are most often reset, given their capacity to 1) reduce the firing rate (which effectively lowers the heat output and water temperature) and 2) accept very low return water temperatures without causing flue gas condensation. This is known as “full reset.” Non-condensing boilers may also be reset, but they require a minimum return water temperature of 125°F to 145°F to prevent condensation. This is known as “partial reset.”

When full reset is applied to the radiant heat distribution system only, the boiler must be protected from low return water temperatures, flue gas condensation and possible thermal shock.

Notes

Chapter 13:

Piping schematics

Piping schematic level 1 control

- Water heater
- Closed system
- Single-temperature radiant floor heating

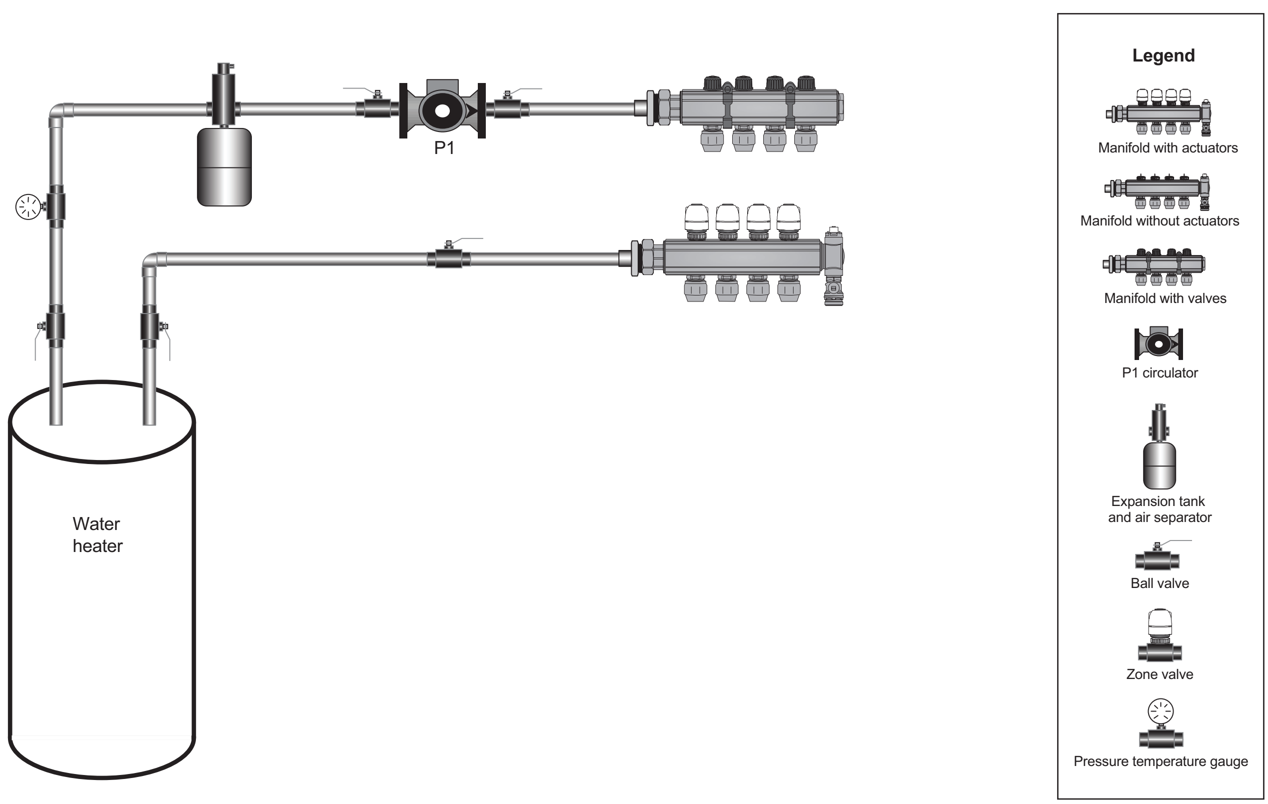
Where: All low-temperature radiant applications (< 145˚F)

Why: This illustration shows a dedicated water heater supplying water for a single radiant manifold. The water heater provides the required supply water temperature directly to the radiant panel, with the water temperature controlled by the water heater's internal aquastat. As a result, no additional water temperature control device is needed.

Important: Consult local building codes prior to installing a water heater as a heat source for radiant heating.

What to look for:

- **Bypass loop** – A bypass loop is not required when using a water heater with radiant heat.
- **Radiant loop circulator** – A circulator (P1) has been added in the radiant loop. This circulator is necessary to insure flow through the radiant panel.
- **Isolation valves** – Isolation valves are recommended at the supply and return radiant manifolds to facilitate purging and service. Isolation valves or flanges are recommended at all circulators for easy service.
- **Pressure-relief valve** – When using a water heater as a heat source, install a 30-pound relief valve in the near heat source piping. Ensure there is NO isolation between the relief valve and the water heater. Most water heaters come equipped with a Temperature and Pressure (T&P) Valve. Do not remove this valve from the water heater, as it provides additional temperature safety.
- **Pressure-reducing valve** – Uponor recommends installing a pressure-reducing valve in the fresh water makeup line to the water heater. This is necessary to properly set the system fill pressure for additional safety.
- **Zoning options 1-5** – See **pages 115-119**.
- **Specific wiring schematic 10** – See **pages 159-160**.



Piping schematic level I control

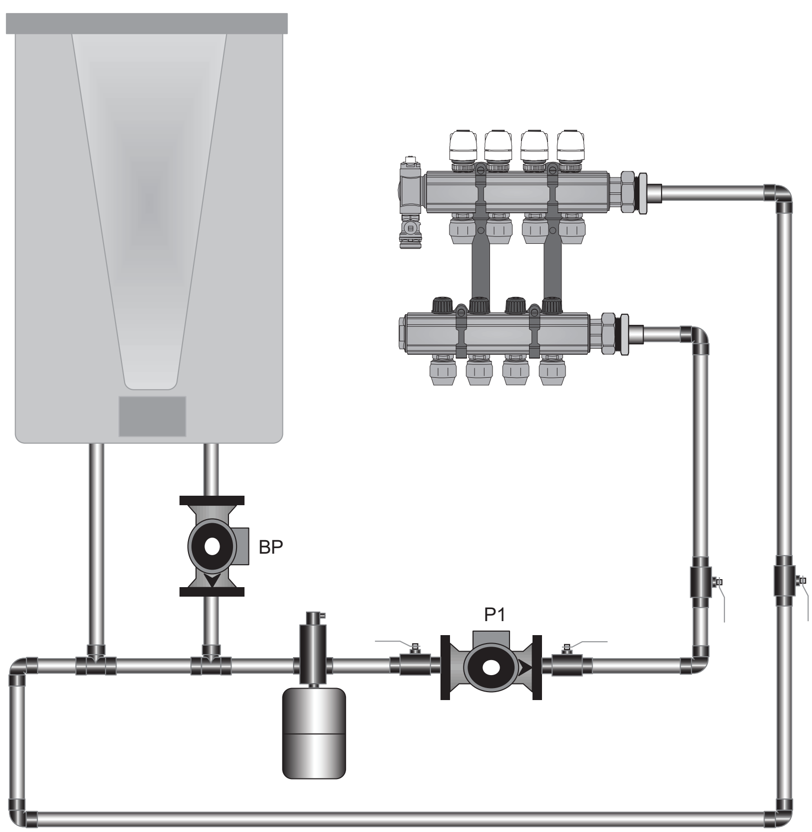
- Modulating-condensing boiler
- Single-temperature radiant floor heating

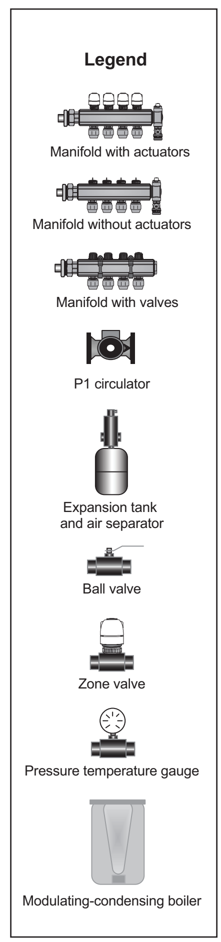
Where: All radiant and snow melt applications

Why: This illustration shows a condensing boiler supplying water to a single radiant manifold for space heat or snow melting. Condensing boilers are designed to operate safely and efficiently at low return water temperatures. As a result, no additional water temperature control device is required. The boiler operating control is set up to provide the correct supply water temperature to the radiant panel. When using a condensing boiler in radiant and snow melt applications, consult the boiler manufacturer's installation and operation instructions for specific near-boiler piping information and return water temperature limitations.

What to look for:

- **Bypass loop** – A bypass loop is not required when using a condensing boiler with radiant heat.
- **Boiler circulator** – Many condensing boilers are packaged with an internal circulator (BP), but require an additional system circulator (P1). Consult the boiler manufacturer's installation and operation instructions for specific requirements. If the boiler is equipped with a system circulator, flow (gpm) and head requirements for the radiant panels may exceed the capacity of that circulator. Review radiant flow requirements and size the system circulator appropriately.
- **Isolation valves** – Isolation valves are recommended at the supply and return radiant manifolds to facilitate purging and service. Isolation valves or flanges are recommended at all circulators for easy service.
- **Zoning option 1-5** – See **pages 115-119**.
- **Specific wiring schematic 1** – See **page 145**.





Piping schematic level I control

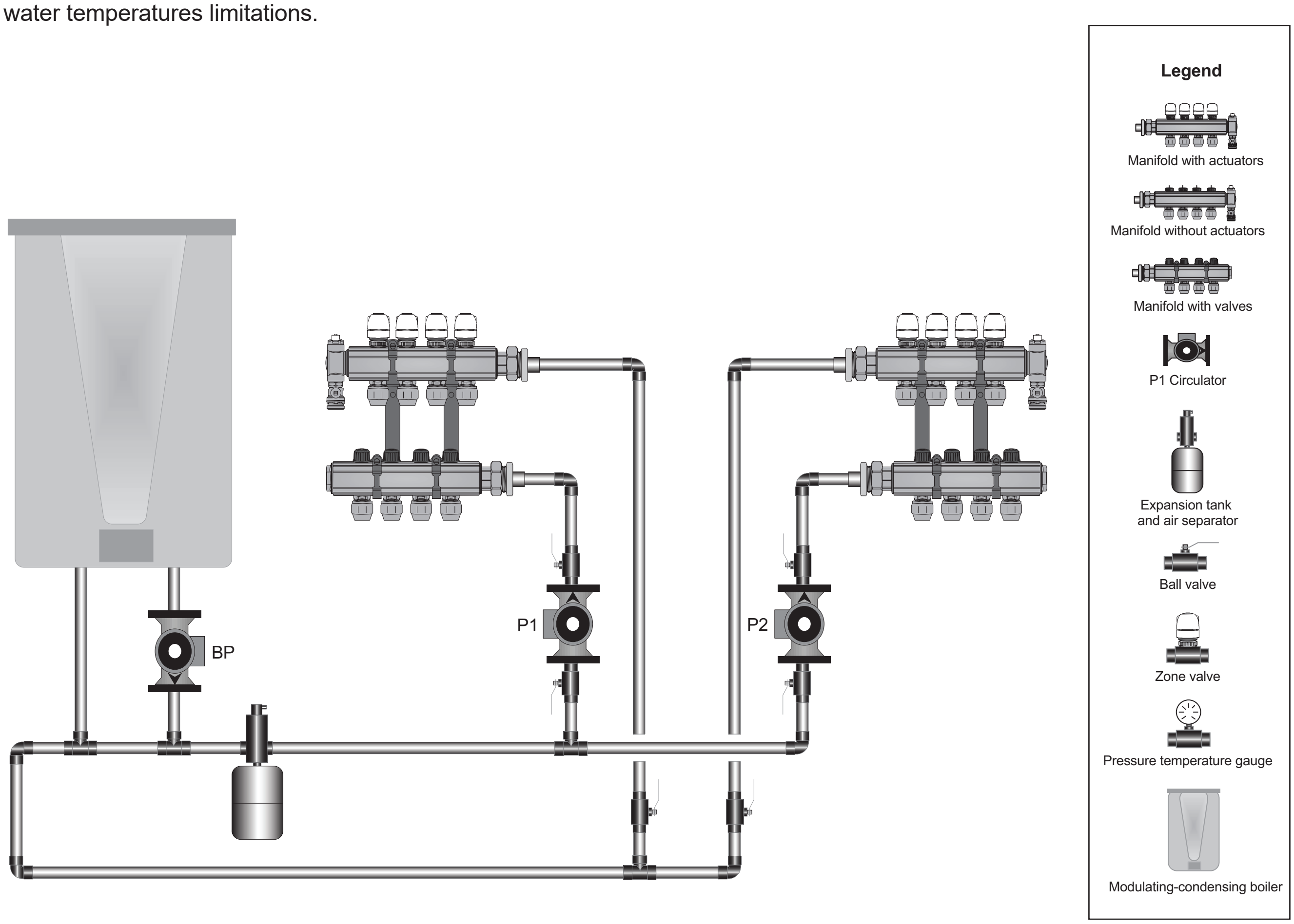
- Modulating-condensing boiler
- Single-temperature radiant floor heating
- Multiple manifolds

Where: All radiant and snow melt applications

Why: This illustration shows a condensing boiler supplying water to multiple radiant manifolds operating at the same supply water temperature. Condensing boilers are designed to operate safely and efficiently at low return water temperatures. As a result, no additional water temperature control device is required. The boiler operating control is set up to provide the correct supply water temperature to the radiant panel. When using a condensing boiler in radiant and snow melt applications, consult the boiler manufacturer's installation and operation instructions for specific near-boiler piping information and return water temperatures limitations.

What to look for:

- **Bypass loop** — A bypass loop is not required when using a condensing boiler with radiant heat.
- **Boiler circulator** — Many condensing boilers are packaged with an internal circulator (BP), but require additional system circulators (P1). Consult the boiler manufacturer's installation and operation instructions for specific requirements. If the boiler is equipped with a system circulator, flow (gpm) and head requirements for the radiant panels may exceed the capacity of that circulator. Review radiant flow requirements and size the system circulator appropriately.
- **Isolation valves** — Isolation valves are recommended at the supply and return radiant manifolds to facilitate purging and service. Isolation valves or flanges are recommended at all circulators for easy service.
- **Zoning options 1-5** — See **pages 115-119**.
- **Specific wiring schematic 8** — See **pages 155-156**.



Piping schematic level I control

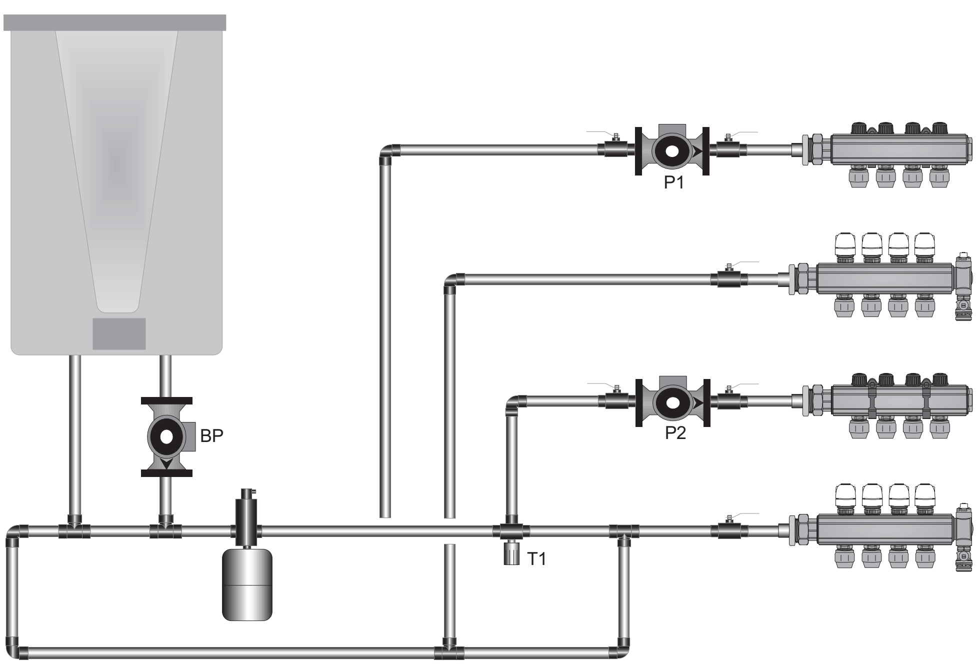
- Modulating-condensing boiler
- Dual-temperature radiant floor heating
- Three-way tempering valve

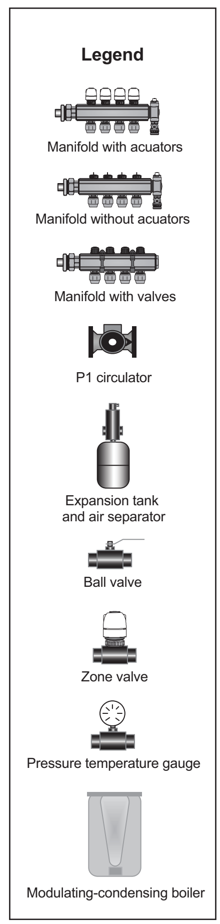
Where: Multiple temperature radiant applications

Why: This illustration shows a condensing boiler supplying water to multiple radiant panels requiring dramatically different supply water temperature, or having different installation methods (i.e. concrete vs. Joist Trak™). Condensing boilers are designed to operate safely and efficiently at low return water temperatures. As a result, no additional water temperature control device is required for the higher temperature radiant. The boiler operating control is set up to provide the correct supply water temperature to the high temperature radiant panel. For the low-temperature radiant panel, an Uponor Three-way Tempering Valve (T1) will mix hotter boiler water with cooler radiant return water to achieve the selected radiant supply water temperature per the valve setting (See **Chapter 12** for details on Three-way Tempering Valve operation). A Three-way Tempering Valve allows the radiant supply water temperature to be adjusted from 80°F to 160°F. When using a condensing boiler in radiant applications, consult the boiler manufacturer's installation and operation instructions for specific near boiler piping information and return water temperature limitations.

What to look for:

- **Bypass loop** — A bypass loop is not required when using a condensing boiler with radiant heat.
- **Low-temperature radiant loop circulator** — Circulators (P1) have been added on the radiant loop side of the Three-way Tempering Valve. This circulator is necessary to insure flow through the radiant panel. Without this circulator, flow through the radiant panel would stop once the tempering valve senses the supply water has reached the desired temperature, closing the hot (+) port of the valve.
- **High-temperature radiant loop circulator** — Many condensing boilers are packaged with an internal circulator (BP), but require an additional system circulator (P2). Consult the boiler manufacturer's installation and operation instructions for specific requirements. If the boiler is equipped with a system circulator, flow (gpm) and head requirements for the radiant panel may exceed the capacity of that circulator. Review radiant flow requirements and sized the system circulator appropriately.
- **Isolation valves** — Isolation valves are recommended at the supply and return radiant manifolds to facilitate purging and service. Isolation valves or flanges are recommended at all circulators for easy service.
- **Zoning options 1-5** — See **pages 115-119**.
- **Specific wiring schematic 8** — See **pages 155-156**.





Piping schematic level I control

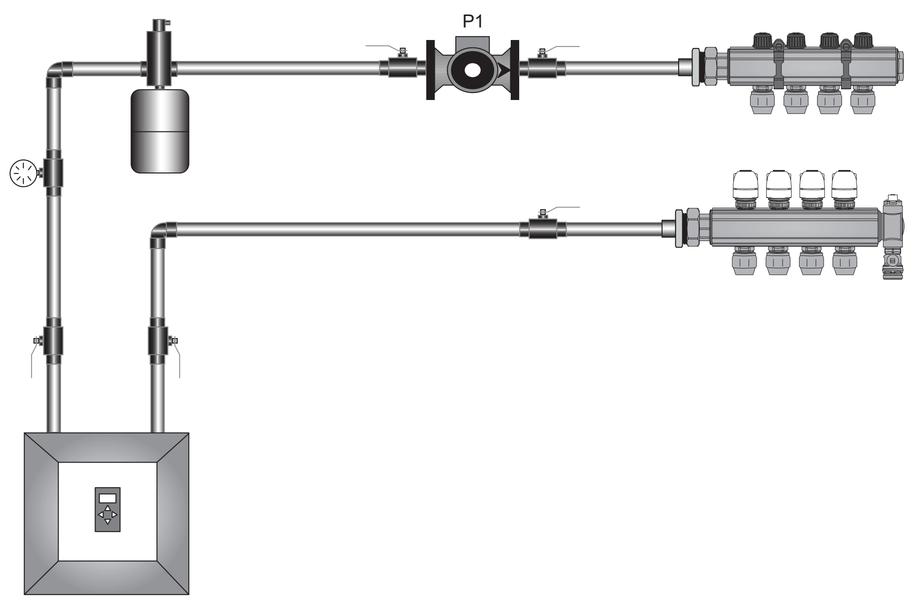
- Electric boiler
- Single-temperature radiant floor heating

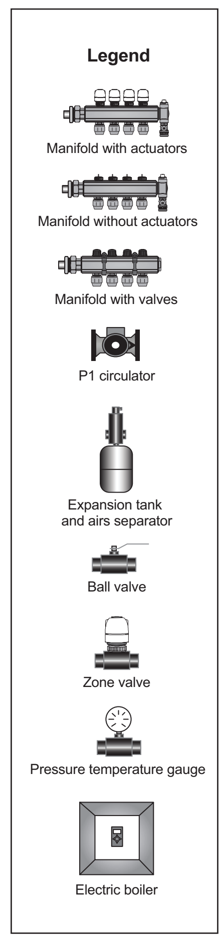
Where: All radiant applications

Why: This illustration shows an electric boiler supplying water to a single radiant panel. Electric boilers are designed to operate safely and efficiently at low return water temperatures. As a result, no additional water temperature control device is required. The boiler high limit is set to provide the maximum supply water temperature to the radiant panel. When using an electric boiler in radiant applications, consult the boiler manufacturer's installation and operation instructions for specific near-boiler piping information and return water temperature limitations.

What to look for:

- **Bypass loop** — A bypass loop is not required when using an electric boiler with radiant heat.
- **Boiler circulator** — Electric boilers are not typically packaged with a circulator, and therefore require the installation of a system circulator (P1). Review radiant flow requirements (gpm and head) and size the system circulator appropriately.
- **Isolation valves** — Isolation valves are recommended at the supply and return radiant manifolds to facilitate purging and service. Isolation valves or flanges are recommended at all circulators for easy service.
- **Zoning options 1-5** — See **pages 115-119**.
- **Specific wiring schematic 1** — See **page 145**.





Piping schematic level I control

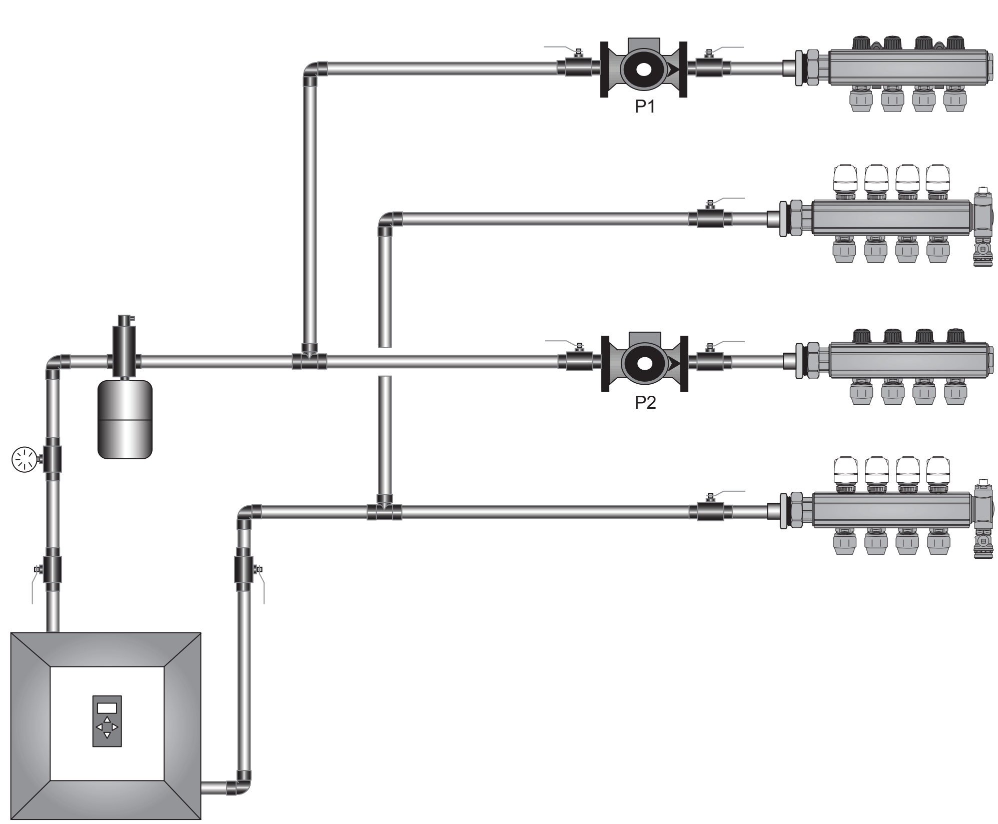
- Electric boiler
- Single-temperature radiant floor heating
- Multiple manifolds

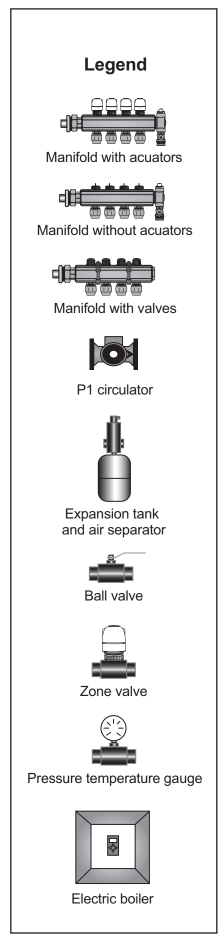
Where: All radiant applications

Why: This illustration shows an electric boiler supplying water to multiple radiant panels operating at the same supply water temperature. Electric boilers are designed to operate safely and efficiently at low return water temperatures. As a result, no additional water temperature control device is required. The boiler high limit is set to provide the maximum supply water temperature to the radiant panel. When using an electric boiler in radiant applications, consult the boiler manufacturer's installation and operation instructions for specific near-boiler piping information.

What to look for:

- **Bypass loop** — A bypass loop is not required when using an electric boiler with radiant heat.
- **Boiler circulator** — Electric boilers are not packaged with a circulator, and therefore require the installation of additional system circulators (P1 and P2). Review radiant flow requirements (gpm and head) and size the system circulators appropriately.
- **Isolation valves** — Isolation valves are recommended at the supply and return radiant manifolds to facilitate purging and service. Isolation valves or flanges are recommended at all circulators for easy service.
- **Zoning options 1-5** — See **pages 115-119**.
- **Specific wiring schematic 8** — See **pages 155-156**.





Piping schematic level I control

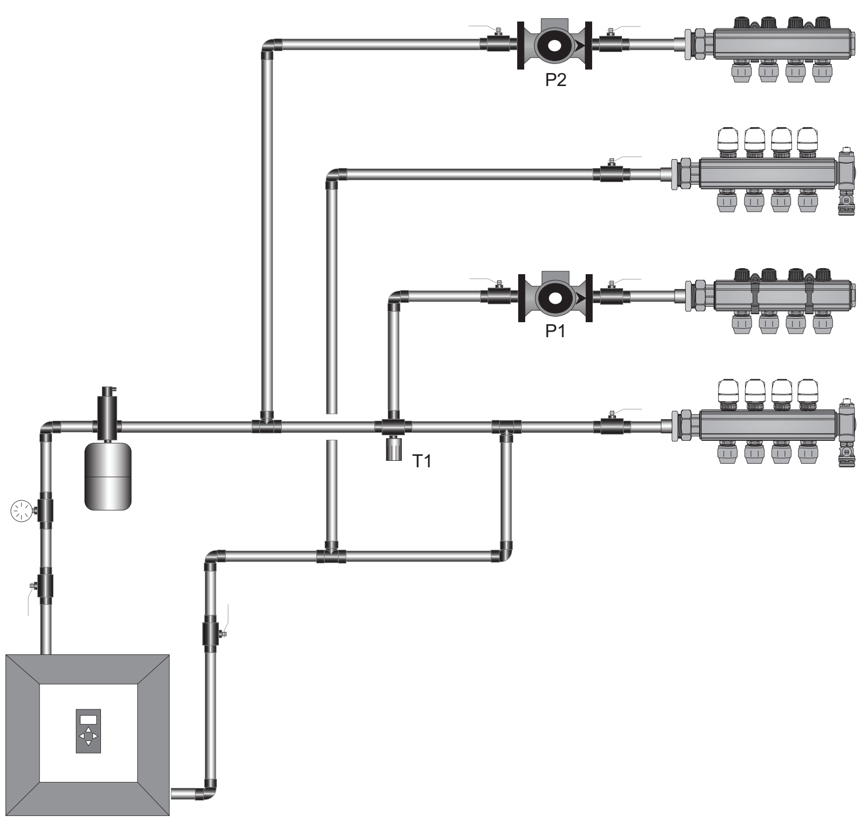
- Electric boiler
- Multiple-temperature radiant floor heating
- Three-way tempering valve

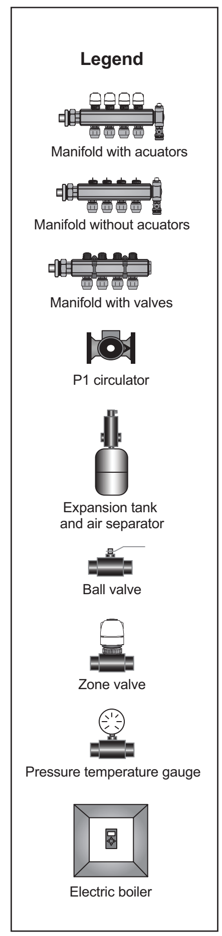
Where: Multiple temperature radiant applications

Why: This illustration shows an electric boiler supplying water to multiple radiant panels requiring dramatically different supply water temperatures, or having different installation methods (i.e. concrete vs. Joist Trak). Electric boilers are designed to operate safely and efficiently at low return water temperatures. As a result, no additional water temperature control device is required for the higher temperature radiant. The boiler high limit is set to provide the maximum supply water temperature to the high temperature radiant panel. For the low temperature radiant panel, an Uponor Three-way Tempering Valve is used to mix hot boiler water with cooler radiant return water to achieve the selected radiant supply water temperature per the valve setting (see **Chapter 12** for details on Three-way Tempering Valve operation). A Three-way Tempering Valve allows the radiant supply water temperature to be adjusted from 80°F to 160°F. When using an electric boiler in radiant applications, consult the boiler manufacturer's installation and operation instructions for specific near boiler piping information and return water temperature limitations.

What to look for:

- **Bypass loop** — A bypass loop is not required when using an electric boiler with radiant heat.
- **Low-temperature radiant loop circulator** — A circulator (P1) has been added on the radiant loop side of the Three-way Tempering Valve. This circulator is necessary to insure flow through the radiant panel. Without this circulator, flow through the radiant panel would stop once the Three-way Tempering Valve senses the supply water has reached the desired temperature, closing the hot (+) port of the valve.
- **High-temperature radiant loop circulator** — Electric boilers are not packaged with circulators, and therefore require an additional system circulator (P2). Consult the boiler manufacturer's installation and operation instructions for specific requirements. Review radiant flow requirements and size the system circulator appropriately.
- **Isolation valves** — Isolation valves are recommended at the supply and return radiant manifolds to facilitate purging and service. Isolation valves or flanges are recommended at all circulators for easy service.
- **Zoning options 1-5** — See **pages 115-119**.
- **Specific wiring schematic 8** — See **pages 155-156**.





Piping schematic level II control

• Non-condensing boiler

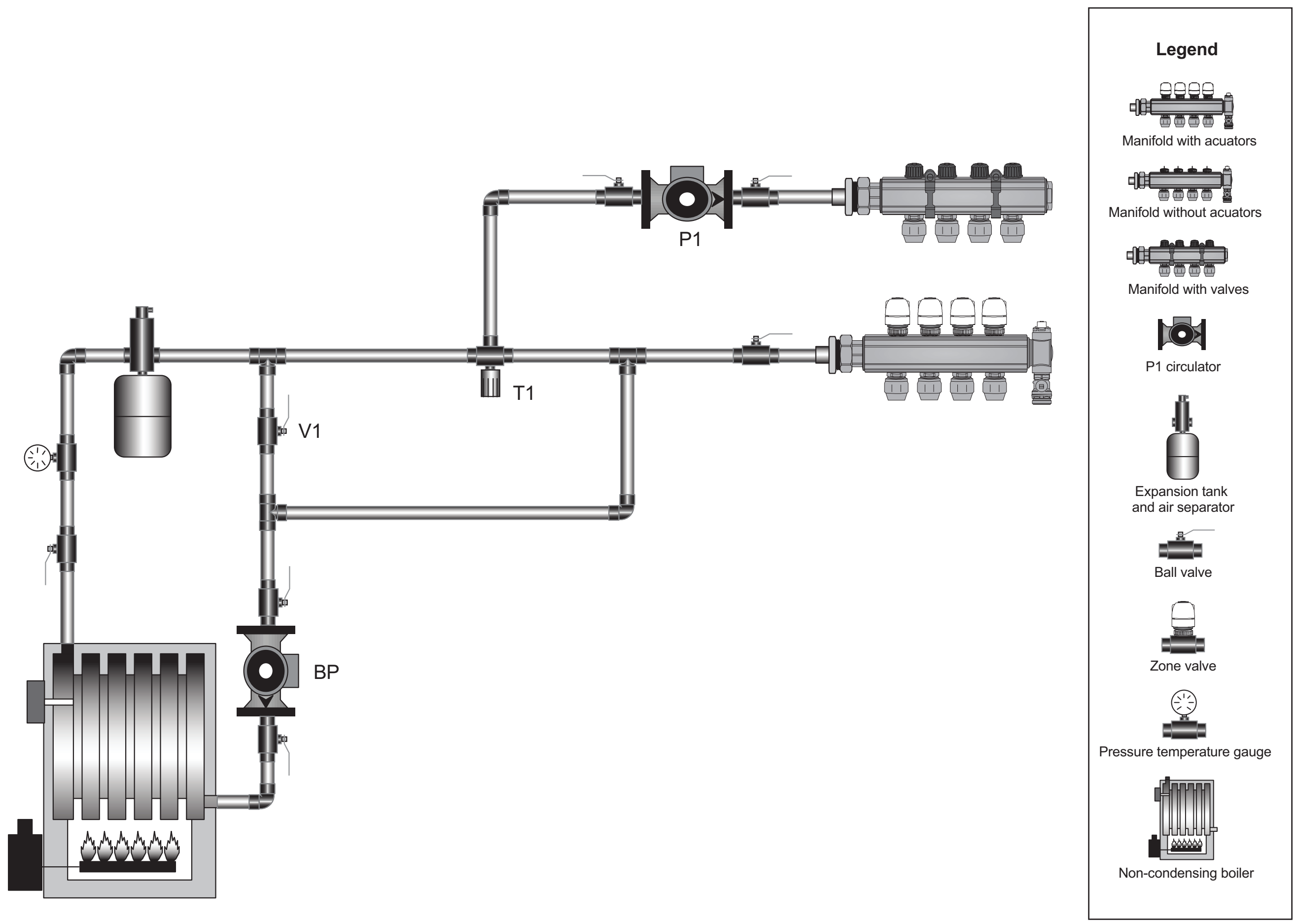
• Three-way tempering valve

Where: All low-temperature radiant applications (< 160°F)

Why: This illustration shows a non-condensing boiler supplying water to a single radiant panel. The Uponor Three-way Tempering Valve (T1) is used to mix hot boiler water with cooler radiant return water to achieve the selected radiant supply water temperature per the valve setting (see **Chapter 12** for details on Three-way Tempering Valve operation). In low-temperature (< 160°F) radiant heating applications using a non-condensing boiler, the boiler supply water temperature must be reduced to the proper radiant supply water temperature. A Three-way Tempering Valve allows the radiant supply water temperature to be adjusted from 80°F to 160°F.

What to look for:

- **Bypass loop** — This piping schematic includes a "bypass" loop at the boiler. Non-condensing boilers require minimum return water temperatures of 140°F or higher (see boiler manufacturer's installation instructions for specific requirements) to prevent flue gas condensation, potential internal corrosion, and potential thermal shock. The bypass loop allows an amount of hot boiler water (depending on bypass valve position) to circulate through the boiler to maintain return water temperatures above the minimum, preventing the boiler's flue gasses from condensing. Condensed flue gasses are highly corrosive and will shorten the boiler's life and may void the boiler's warranty. The bypass valve (V1) should never be left in the full open position during normal operation.
- **Bypass valve setting** — At system startup, position a suitable valve (V1) in the half-open position. If the radiant supply water does not reach the desired temperature, continue to close the valve in small increments until that temperature is reached.
- **Radiant loop circulator** — A circulator (P1) has been added on the radiant loop side of the Three-way Tempering Valve. This circulator is necessary to insure flow through the radiant panel. Without this circulator, flow through the radiant panel would stop once the Three-way Tempering Valve senses the supply water has reached the desired temperature, closing the hot (+) port of the valve.
- **Isolation valves** — Isolation valves are recommended at the supply and return radiant manifolds to facilitate purging and service. Isolation valves or flanges are recommended at all circulators for easy service.
- **Zoning options 1-5** — See **pages 115-119**.
- **Specific wiring schematic 1** — See **page 145**.



Piping schematic level II control

- Non-condensing boiler
- Three-way tempering valve
- Dual-temperature radiant floor heating

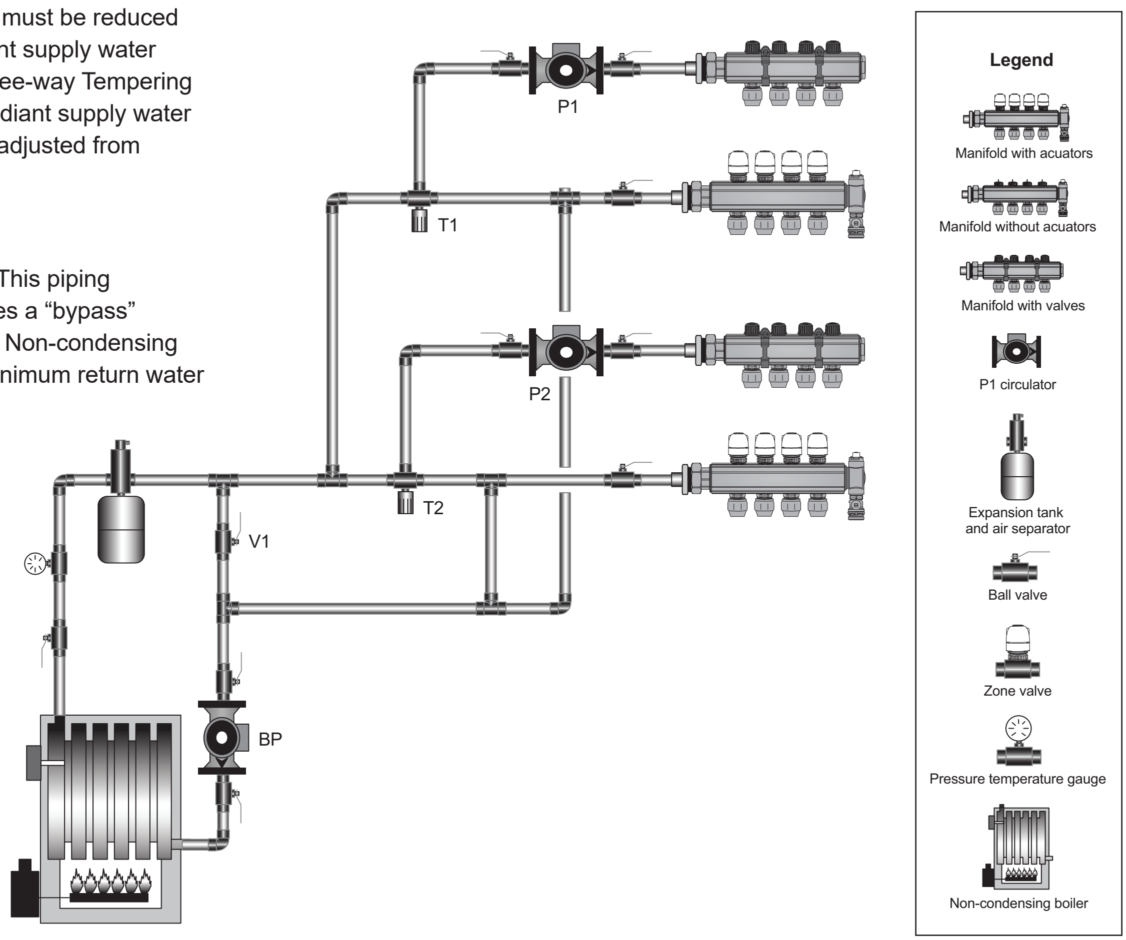
Where: All low-temperature radiant applications (< 160°F)

Why: This illustration shows a non-condensing boiler supplying water to a multiple radiant panels requiring dramatically different supply water temperatures, or having different installation methods (i.e. concrete vs. Joist Trak). The Uponor Three-way Tempering Valves (T1 and T2) will mix hot boiler water with cooler radiant return water to achieve the selected radiant supply water temperatures per the valve settings (see **Chapter 12** for details on Three-way Tempering Valve operation).

In low-temperature (< 160°F) radiant heating applications using a non-condensing boiler, the boiler supply water temperature must be reduced to the proper radiant supply water temperature. A Three-way Tempering Valve allows the radiant supply water temperature to be adjusted from 80°F to 160°F.

What to look for:

- **Bypass loop** — This piping schematic includes a "bypass" loop at the boiler. Non-condensing boilers require minimum return water temperatures of 140°F or higher (see boiler manufacturer's installation instructions for specific requirements) to prevent flue gas condensation, potential internal corrosion, and potential thermal shock. The bypass loop allows an amount of hot boiler water (depending on bypass valve position) to circulate through the boiler to maintain return water temperatures above the minimum, preventing the boiler's flue gasses from condensing. Condensed flue gasses are highly corrosive and will shorten the boiler's life and may void the boiler's warranty. The bypass valve (V1) should never be left in the full open position during normal operation.
- **Bypass valve setting** — At system startup, position a suitable valve (V1) in the half-open position. If the radiant supply water does not reach the desired temperature, continue to close the valve in small increments until that temperature is reached.
- **Radiant loop circulator** — Circulators (P1 and P2) have been added on the radiant loop sides of each Three-way Tempering Valve. These circulators are necessary to insure flow through the radiant panels. Without these circulators, flow through the radiant panels would stop once the Three-way Tempering Valves sense the supply water has reached the desired temperature, closing the hot (+) port of the valve.
- **Isolation valves** — Isolation valves are recommended at the supply and return radiant manifolds to facilitate purging and service. Isolation valves or flanges are recommended at all circulators for easy service.
- **Zoning options 1-5** — See **pages 115-119**.
- **Specific wiring schematic 8** — See **pages 155-156**.



Piping schematic level II control

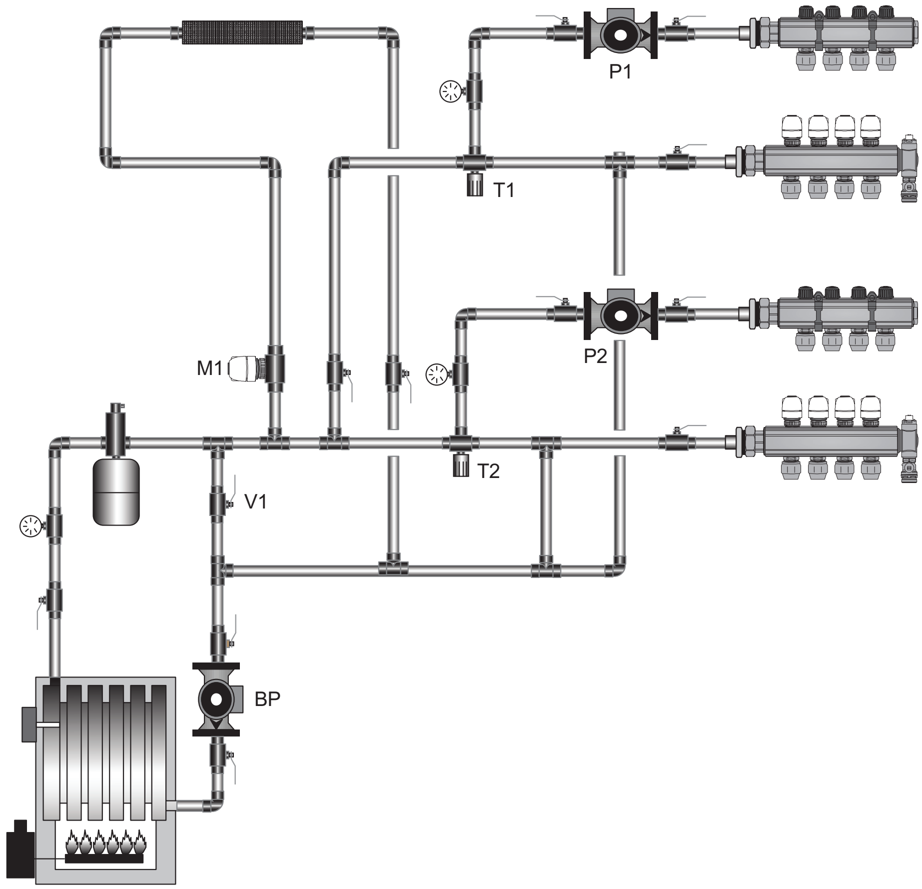
- Non-condensing boiler
- Three-way tempering valve
- Dual-temperature radiant floor heating
- High-temperature radiation

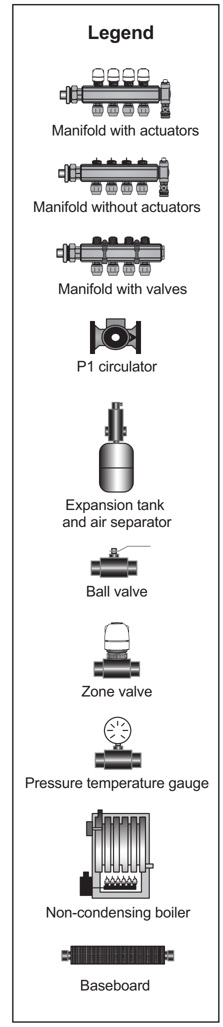
Where: All low-temperature radiant applications (< 160°F), with high-temperature radiation

Why: This illustration shows a non-condensing boiler supplying water to multiple radiant panels requiring dramatically different supply water temperatures or having different installation methods (i.e. concrete vs. Joist Trak) plus high-temperature radiation (baseboard, panel radiators, fan coils, etc.). The Uponor Three-way Tempering Valves (T1 and T2) are used to mix hot boiler water with cooler radiant return water to achieve the selected radiant supply water temperature per the valve settings (see **Chapter 12** for details on Three-way Tempering Valve operation). In low-temperature (< 160°F) radiant heating applications using a non-condensing boiler, the boiler supply water temperature must be reduced to the proper radiant supply water temperature. A Three-way Tempering Valve allows the radiant supply water temperature to be adjusted from 80°F to 160°F. The high-temperature radiation is supplied directly with boiler water.

What to look for:

- **Bypass loop** — This piping schematic includes a “bypass” loop at the boiler. Non-condensing boilers require minimum return water temperatures of 140°F or higher (see boiler manufacturer’s installation instructions for requirements) to prevent flue gas condensation, potential internal corrosion, and potential thermal shock. The bypass loop allows an amount of hot boiler water (depending on bypass valve position) to circulate through the boiler to maintain return water temperatures above the minimum, preventing the boiler’s flue gasses from condensing. Condensed flue gasses are highly corrosive and will shorten the boiler’s life and may void the boiler’s warranty. The bypass valve (V1) should never be left in the full open position during normal operation.
- **Bypass valve setting** — At system startup, position a suitable valve (V1) in the half-open position. If the radiant supply water does not reach the desired temperature, continue to close the valve in small increments until that temperature is reached.
- **Radiant loop circulator** — Circulators (P1 and P2) have been added on the radiant loop sides of the Three-way Tempering Valves (T1 and T2). These circulators are necessary to insure flow through the radiant panels. Without these circulators, flow through the radiant panels would stop once the Three-way Tempering Valves sense the supply water has reached the desired temperatures, closing the hot (+) port of the valves.
- **Isolation valves** — Isolation valves are recommended at the supply and return radiant manifolds to facilitate purging and service. Isolation valves or flanges are recommended at all circulators for easy service.
- **Baseboard zone control** — In this schematic, the baseboard loop(s) are controlled with a zone valve (M1), which operates independently of the radiant heat.
- **Zoning options 1-5** — See **pages 115-119**.
- **Specific wiring schematic 7** — See **pages 153-154**.


P1
T1
P2
M1
T2
V1
BP


Legend
Manifold with actuators
Manifold without actuators
Manifold with valves
P1 circulator
Expansion tank
and air separator
Ball valve
Zone valve
Pressure temperature gauge
Non-condensing boiler
Baseboard

Piping schematic level II control

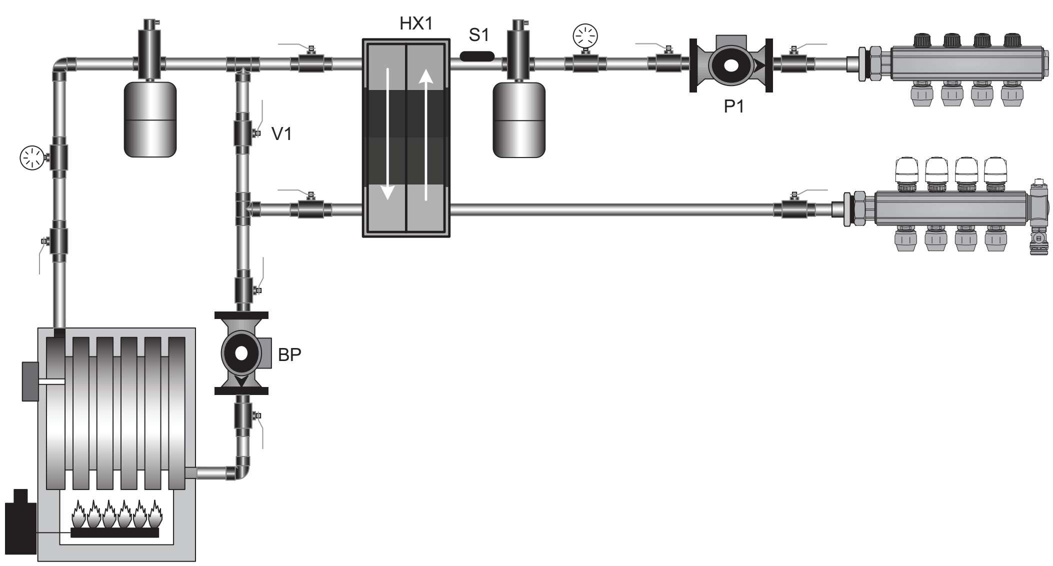
- Non-condensing boiler
- Heat exchanger

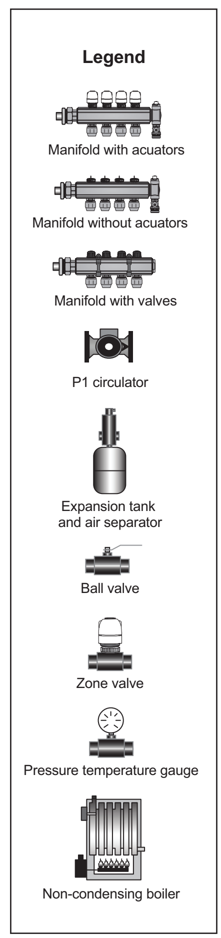
Where: All radiant and snow melt applications

Why: This illustration shows a non-condensing boiler supplying water to a heat exchanger (HX1) to provide water temperature control and isolation where necessary. Water temperature for the radiant panel or snow melt system is controlled by a sensor (S1), either immersion type or strap-on type, placed on the supply outlet of the heat exchanger. The sensor is wired to a set-point controller or aquastat, which is set for the desired supply water temperature. When the supply water temperature drops below the desired level, the set-point controller or aquastat will fire the boiler circulator and/or boiler to send hot water through the boiler side of the heat exchanger. The radiant supply water temperature will increase until the desired level is reached, shutting off the boiler circulator and/or boiler. Besides controlling water temperature, a heat exchanger can be used for isolating the boiler and its ferrous (corrodible) components when Uponor AquaPEX (non-barrier) piping is used on the radiant or snow melt side of the heat exchanger. A heat exchanger will also protect non-condensing boilers from thermal shock and low return water temperatures, and allows for glycol to be added to the radiant/snow melt portion of the system only.

What to look for:

- **Bypass loop** — This piping schematic includes a "bypass" loop at the boiler. Non-condensing boilers require minimum return water temperatures of 140°F or higher (see boiler manufacturer's installation instructions for specific requirements) to prevent flue gas condensation,, and potential thermal shock potential internal corrosion. The bypass loop allows an amount of hot boiler water (depending on bypass valve position) to circulate through the boiler to maintain return water temperatures above the minimum, preventing the boiler's flue gasses from condensing. Condensed flue gasses are highly corrosive and will shorten the boiler's life and may void the boiler's warranty. The bypass valve (V1) should never be left in the full open position during normal operation.
- **Bypass valve setting** — At system startup, position a suitable valve (V1) in the half-open position. If the radiant supply water does not reach the desired temperature, continue to close the valve in small increments until that temperature is reached.
- **Radiant loop circulator** — A circulator (P1) has been added on the radiant loop side of the heat exchanger (HX1). This circulator is necessary to insure flow through the radiant panel.
- **Expansion tank** — An expansion tank and air separator are added to the radiant/snow melt side of the heat exchanger. This is required for proper air elimination and thermal expansion due to isolation from the boiler loop by the heat exchanger.
- **Isolation valves** — Isolation valves are recommended at the supply and return radiant manifolds to facilitate purging and service. Isolation valves or flanges are recommended at all circulators for easy service.
- **Zoning options 1-5** — See **pages 115-119**.
- **Specific wiring schematic 12** — See **page 162**.





Piping schematic Level II Control

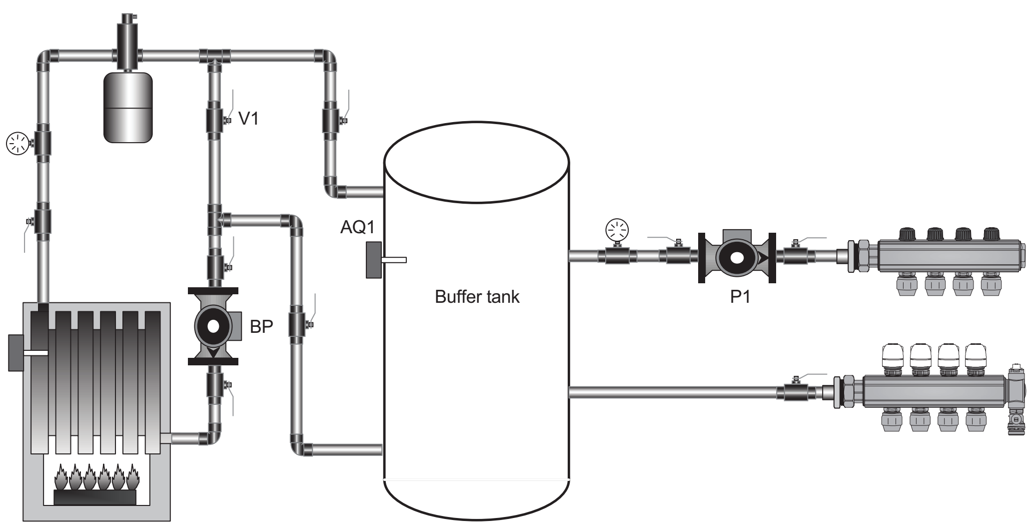
- Wood boiler
- Mixing tank
- Single-temperature radiant floor heating

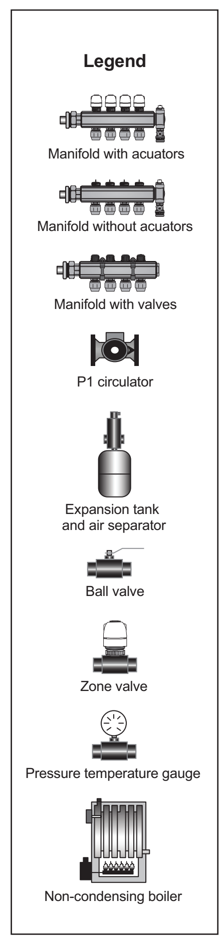
Where: All radiant applications

Why: This illustration shows a wood boiler supply water for a single radiant panel, using a mixing, or "buffer", tank as a tempering device. The wood boiler supplies hot boiler water to the tank that will mix with the cooler radiant return water to deliver the proper radiant supply water temperature. An aquastat (AQ1), either an immersion type or strap-on type, controls the tank temperature. When the aquastat senses the radiant supply water temperature has dropped below the desired level, it starts the boiler pump (P1), mixing hot boiler water into the tank until the desired temperature has been reached. In all radiant applications using a wood boiler, a buffer tank must be used to control the radiant supply water temperature, and to protect the radiant panel from excessive boiler water temperatures.

What to look for:

- **Bypass loop** — This piping schematic includes a "bypass" loop at the boiler. The installation of a bypass will allow an amount of hot boiler supply water (depending on bypass valve position) to circulate through the boiler to prevent low boiler return water temperatures, preventing the boiler's flue gasses from condensing. Condensed flue gasses are highly corrosive and will shorten the boiler's life and may void the boiler's warranty. The bypass valve (V1) should never be left in the full open position during normal operation.
- **Bypass valve setting** — At system startup, position a suitable valve (V1) in the half-open position. If the radiant supply water does not reach the desired temperature, continue to close the valve in small increments until that temperature is reached.
- **Radiant loop circulator** — A circulator (P1) has been added on the radiant loop side of the buffer tank. This circulator is necessary to insure flow through the radiant panel.
- **Aquastat** — An aquastat (AQ1) is used to sense and control water temperature inside the buffer tank. The aquastat is set to the desired radiant supply water temperature, and is wired to a relay that controls the boiler circulator (P1).
- **Isolation valves** — Isolation valves are recommended at the supply and return radiant manifolds to facilitate purging and service. Isolation valves or flanges are recommended at all circulators for easy service.
- **Zoning options 1-5** — See **pages 115-119**.
- **Specific wiring schematic 9** — See **pages 157-158**.





Piping schematic level II control

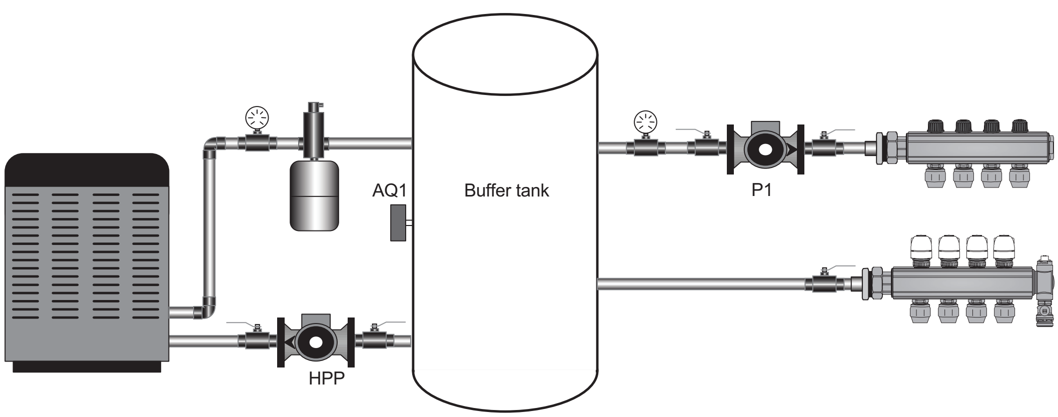
- Heat pump
- Mixing tank
- Single-temperature radiant floor heating

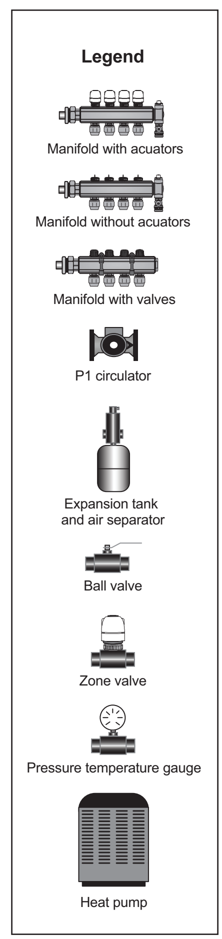
Where: All low-temperature radiant applications (< 120°F)

Why: This illustration shows a geo-thermal heat pump supplying water for a single radiant panel, using a mixing, or “buffer”, tank as a tempering device. The geo-thermal heat pump supplies warm water to the tank that will mix will cooler radiant return water to deliver the proper radiant supply water temperature. An aquastat (AQ1), either an immersion type or strap-on type, controls the tank temperature. When the aquastat senses the radiant supply water temperature has dropped below the desired level, it starts the heat pump circulator (P1), mixing warmer heat pump water into the tank until the desired temperature has been reached. Some geothermal manufacturers make buffer tanks and controls available for their equipment in radiant applications. Refer to the manufacturer’s installation and operation instructions for specifics.

What to look for:

- **Radiant loop circulator** — A circulator (P1) has been added on the radiant loop side of the buffer tank. This circulator is necessary to insure flow through the radiant panel.
- **Aquastat** — An aquastat (AQ1) is used to sense and control water temperature inside the buffer tank. The aquastat is set to the desired radiant supply water temperature, and is wired to a relay that controls the system circulator (P1).
- **Isolation valves** — Isolation valves are recommended at the supply and return radiant manifolds to facilitate purging and service. Isolation valves or flanges are recommended at all circulators for easy service.
- **Zoning options 1-5** — See **pages 115-119**.
- **Specific wiring schematic 9** — See **pages 157-158**.





Piping schematic level III control

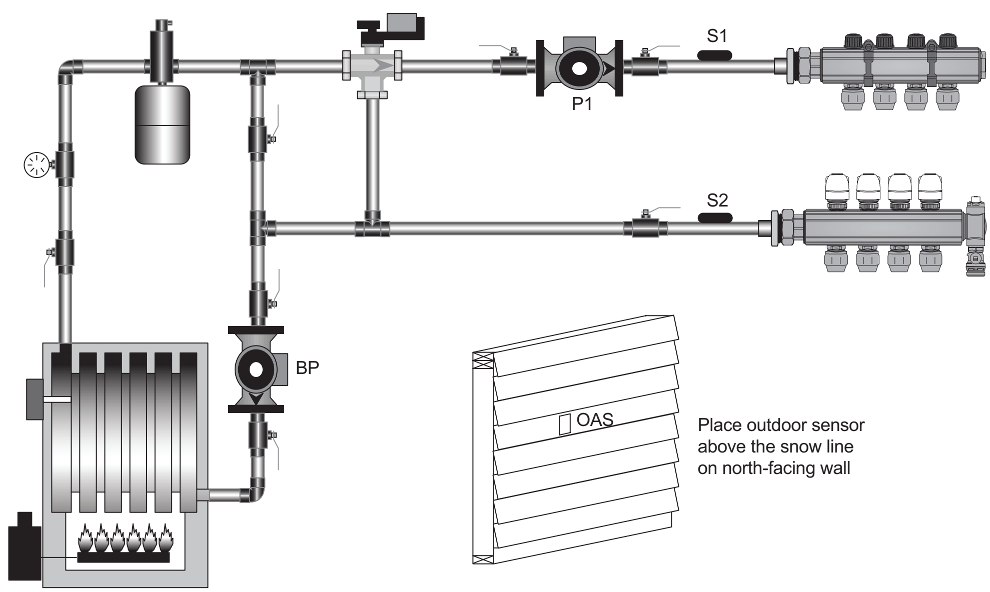
- Non-condensing boiler
- Three-way modulating valve
- Single-temperature radiant floor heating

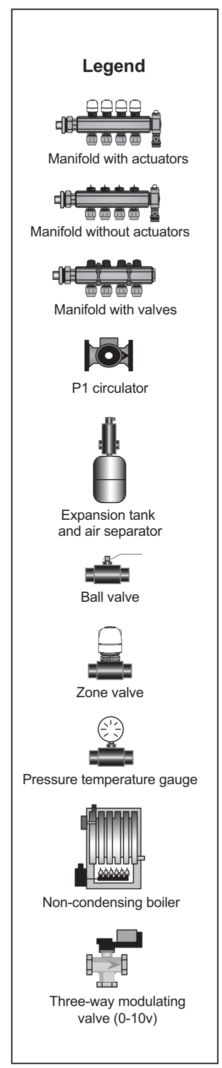
Where: All radiant and hydronic applications where full outdoor reset with a weather-responsive reset control is desirable

Why: This illustration shows a non-condensing boiler supplying water to a single radiant panel.

What to look for:

- **Bypass loop** — This piping schematic includes a “bypass” loop at the boiler. Non-condensing boilers require minimum return water temperatures of 140°F or higher (see boiler manufacturer’s installation instructions for specific requirements) to prevent flue gas condensation and potential internal corrosion. The bypass loop allows an amount of hot boiler water (depending on bypass valve position and Three-way Modulating Valve position) to circulate through the boiler to maintain return water temperatures above the minimum, preventing the boiler’s flue gasses from condensing. Condensed flue gasses are highly corrosive and will shorten the boiler’s life and may void the boiler’s warranty. The bypass valve (V1) should never be left in the full open position during normal operation.
- **Bypass valve setting** — At system startup, position a suitable valve (V1) in the half-open position. If the radiant supply water does not reach the desired temperature, continue to close the valve in small increments until that temperature is reached.
- **Radiant loop circulator** — A circulator (P2) has been added on the radiant side of the Three-way Modulating Valve (MV1). This circulator is necessary to insure adequate flow through the radiant panel. Without this circulator, flow through the radiant panel would vary based on the position of the Three-way Modulating Valve.
- **Sensors** — Strap-on sensors (S1 and S2) are placed on the piping between the MIX port of the Three-way Modulating Valve and the radiant manifolds, on the boiler return piping (S3) near the boiler return inlet, and outdoors (OAS) on the north side of the structure, preferably out of direct sunlight.
- **Isolation valves** — Isolation valves are recommended at the supply and return radiant manifolds to facilitate purging and service. Isolation valves or flanges are recommended at all circulators for easy service.
- **Zoning options 1-5** — See **pages 115-119**.
- **Specific wiring schematic 13** — See **pages 163-164.**





Piping schematic level III control

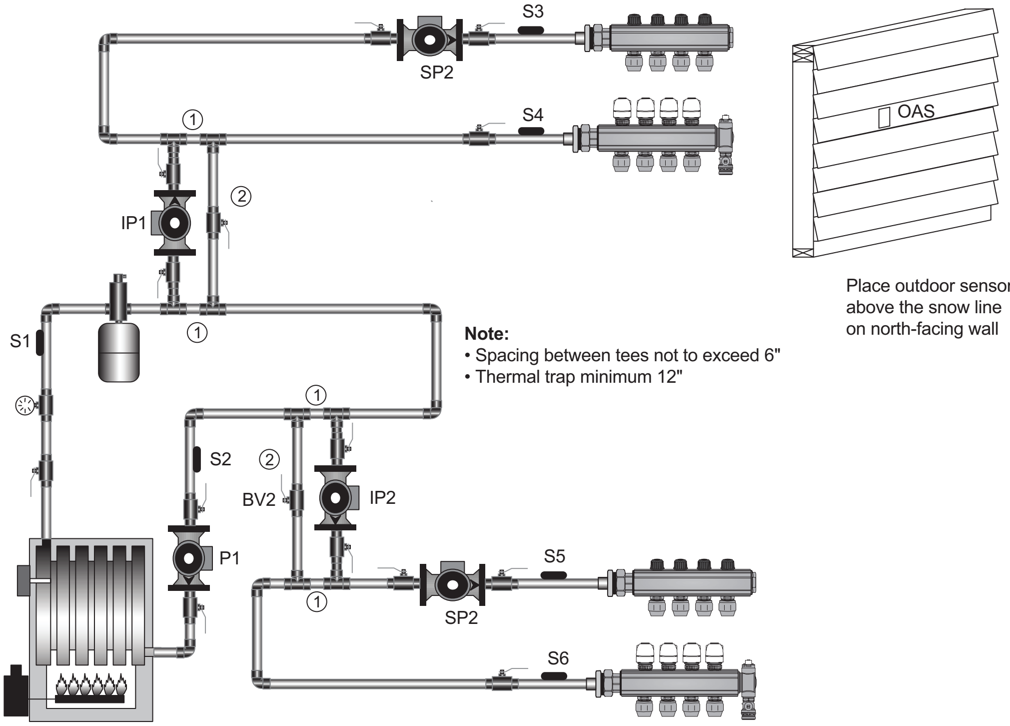
- Non-condensing boiler
- Multiple-temperature radiant floor heating and snow melting
- Variable-speed injection mixing

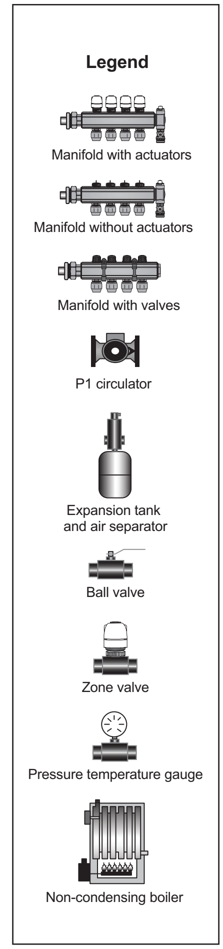
Where: All single-temperature radiant floor heating or other hydronic applications, plus integrated snow melting where full outdoor reset with a weather- responsive control is desirable, using primary/ secondary piping.

Why: This illustration shows a non-condensing boiler supplying water to a single radiant panel.

What to look for:

- **Bypass loop** — Even though a non-condensing boiler is used in this application, an additional bypass loop is not required. The primary loop will suffice as a bypass loop.
- **Primary loop circulator** — The primary circulator (BP) should be sized to meet the flow (gpm) demands of the entire heating system. The primary pump head should be sized to the pressure drop of the primary loop only, plus associated valves and fittings.
- **Radiant and snow melt loop circulators** — Circulators (SP1 and SP2) have been added to the secondary loops. These circulators are necessary to insure flow through the radiant panels. These are considered secondary circulators and should be sized to the flow (gpm) and head loss of the secondary loops only.
- **Injection circulators** — These circulators (IP1 and IP2) are used to inject hot water from the primary boiler loop into the secondary radiant loops. This variable-speed injection mixing will change the radiant and snow melt supply water temperatures based on outdoor weather conditions (see **Appendix I** for injection pump sizing).
- **Thermal traps** — Thermal traps are required in the injection piping to prevent thermal migration of hot water from the primary loop into the secondary loops, possibly affecting radiant supply water temperature control (see **Appendix I** for variable-speed injection mixing piping detail).
- **Balancing valves** — Balancing valves (BV1 and BV2) are required on the return legs of the injection piping to balance flow through the injection legs and to maximize circulator operation.
- **Tee spacing** — Spacing between supply and return tees off the boiler primary loop and off the secondary loops should not exceed 6 inches. This will eliminate pressure drop between the tees. As a result, flow will only occur in the secondary loop when the secondary circulator is in operation.
- **Sensors** — Strap-on sensors (S1 and S2) are placed on the boiler piping near the boiler, on the secondary radiant/snow melt loops (S3 through S6) between the secondary loop circulators and the radiant manifolds, and outdoors (OAS) on the north side of the structure, preferably out of direct sunlight.
- **Isolation valves** — Isolation valves are recommended at the supply and return radiant manifolds to facilitate purging and service. Isolation valves or flanges are recommended at all circulators for easy service.
- **Expansion tank** — An expansion tank and air separator are added to the snow melt side of the heat exchanger. This allows for proper air elimination and thermal expansion, as the snow melt loop is isolated from the boiler loop by the heat exchanger.
- **Zoning options 1-5** — See **pages 115-119**.
- **Specific wiring schematic 14** — See **pages 165-166.**


S3
SP2
S4
①
②
IP1
OAS
Place outdoor sensor above the snow line on north-facing wall
S1
Note:
• Spacing between tees not to exceed 6"
• Thermal trap minimum 12"
S2
BV2
IP2
P1
S5
SP2
S6


Legend
Manifold with actuators
Manifold without actuators
Manifold with valves
P1 circulator
Expansion tank and air separator
Ball valve
Zone valve
Pressure temperature gauge
Non-condensing boiler

Piping schematic level III control

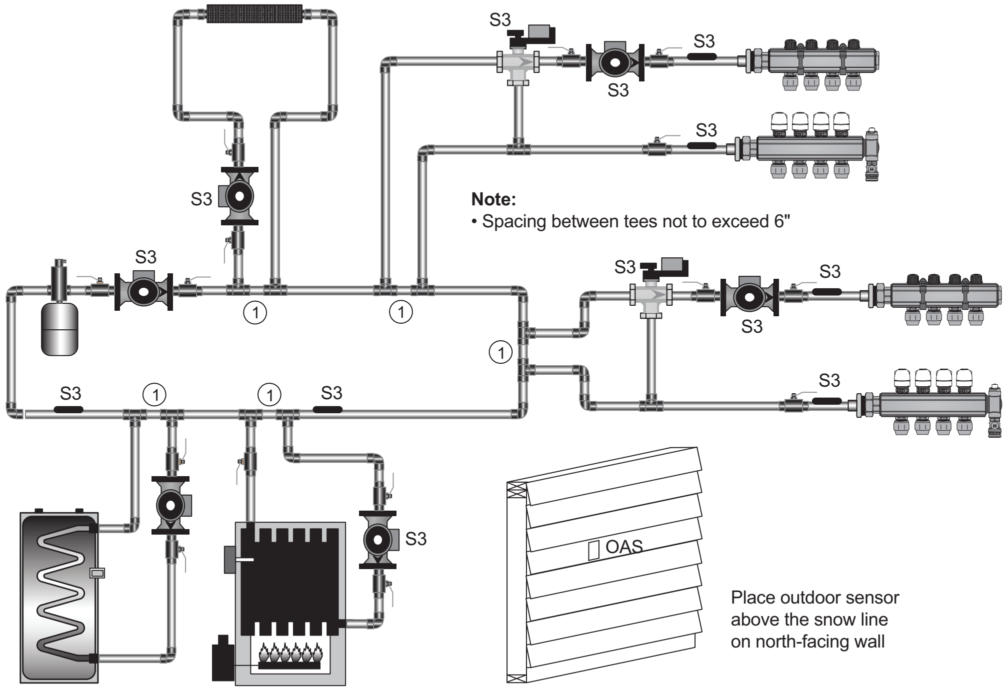
- Non-condensing boiler
- Three-way modulating valve
- Dual-temperature radiant floor heating
- High-temperature radiation
- Domestic hot water
- Primary/secondary piping

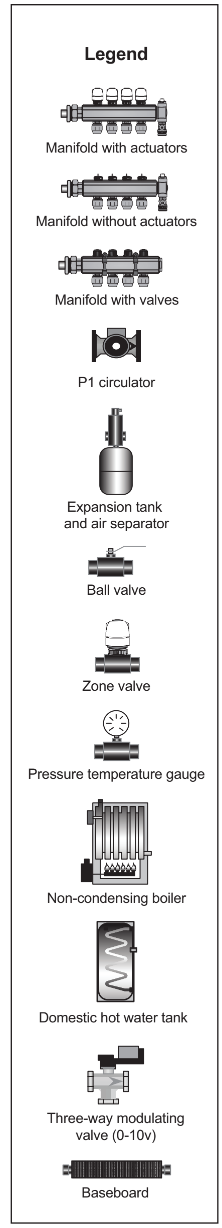
Where: All low-temperature radiant applications (< 160°F), with high-temperature radiation and indirect domestic hot water using primary/secondary piping

Why: This illustration shows a non-condensing boiler supplying water to multiple radiant panels requiring dramatically different supply water temperatures or having different installation methods (i.e. concrete vs. Joist Trak) plus high temperature radiation (base board, panel radiators, fan coils, etc.) and an indirect hot water tank using a single pipe primary/secondary boiler piping arrangement. The Three-way Modulating Valves (MV1 and MV2) are used to mix hot boiler water from the primary loop with cooler radiant return water from the secondary loop to achieve the selected radiant supply water temperature per the valve settings. The radiant panel loop(s) become the secondary piping. Hot boiler water off the primary boiler loop will feed the Secondary loops for both the high- temperature radiation and the domestic hot water tank. Primary/secondary boiler piping allows for simplified piping in multiple temperature applications, protects the boiler against low return water temperature, possible flue gas condensation and possible short cycling. In low-temperature (< 160°F) radiant heating applications using a non-condensing boiler, the boiler supply water temperature must be reduced to the proper radiant supply water temperature. A Three-way Modulating Valve allows the radiant supply water temperature to be mixed from 80°F to 160°F. The high-temperature radiation is supplied directly with boiler water.

What to look for:

- **Bypass loop** — Even though a non-condensing boiler is used in this application, an additional bypass loop is not required. The primary loop will suffice as the bypass loop and will protect the boiler.
- **Primary loop circulator** — The primary circulator (PP) should be sized to meet the flow (gpm) demands of the entire heating system. The primary pump head should be sized to the pressure drop of the primary loop only, plus associated valves and fittings.
- **Radiant loop circulator** — Circulators (SP1 and SP2) have been added on the radiant loop side of the Three-way Modulating Valves (MV1 and MV2). These circulators are necessary to insure flow through the radiant panels. Without these circulators, flow through each radiant panel would stop once the Three-way Modulating Valves sense the supply water has reached the desired temperatures, closing the hot (+) port of the valves. These are considered secondary circulators, and should be sized to the flow (gpm) and head loss of the secondary loops only.
- **Baseboard control** — In this schematic, the baseboard loop(s) is controlled with a circulator (ZP1), which will provide flow through the high-temperature radiation during a call for heat. Multiple high-temperature zones may be controlled by multiple circulators or zone valves.
- **Tee spacing** — Spacing between tees off the boiler Primary loop and off the secondary loop should not exceed 6 inches. This will eliminate pressure drop between the tees. As a result, flow will only occur in the secondary loop when the secondary circulator is in operation.
- **Sensors** — Strap-on sensors (S1 and S2) are placed on the boiler piping near the boiler, on the secondary radiant/snow melt loops (S3 through S6) between the secondary loop circulators and the radiant manifolds, and outdoors (OAS) on the north side of the structure, preferably out of direct sunlight.
- **Isolation valves** — Isolation valves are recommended at the supply and return radiant manifolds to facilitate purging and service. Isolation valves or flanges are recommended at all circulators for easy service.
- **Zoning options 1-5** — See **pages 115-119**.
- **Specific wiring schematic 15** — See **pages 167-168**.


S3
S3
S3
S3
S3
S3
S3
S3
S3
S3
S3
S3
1
1
1
1
1
Note:
• Spacing between tees not to exceed 6"
OAS
Place outdoor sensor
above the snow line
on north-facing wall


Legend
Manifold with actuators
Manifold without actuators
Manifold with valves
P1 circulator
Expansion tank
and air separator
Ball valve
Zone valve
Pressure temperature gauge
Non-condensing boiler
Domestic hot water tank
Three-way modulating
valve (0-10v)
Baseboard

Chapter 14:
Electrical schematics

Wiring schematic 1

- A3100101 Uponor Thermostats
- A3023522 Thermal Actuators
- A3031003/A3031004 Zone Control Module (ZCM)
- A3010100 Single-zone Pump Relay
- A3050050 50 VA Transformer

Overview: Multiple zone control and boiler enable using Uponor Thermostats, Uponor Thermal Actuators, the Uponor Zone Control Module (ZCM) and the Uponor Single-zone Pump Relay.

Sequence of operation: On a call for heat, the Uponor Thermostat sends a signal to the Uponor ZCM, illuminating the yellow light on the ZCM. This call for heat sends power to the actuator(s) for that zone, energizing the Y1-Y2 terminals on the ZCM. This activates or opens the actuator(s), allowing flow through these loops on the manifold. Once the actuator(s) have opened to a minimal position, an end switch inside of the actuator(s) will close, illuminating the red light on the ZCM. When end switch closure is detected, a contact will close between the ES-ES terminals on the ZCM, energizing the Uponor Single-zone Pump Relay. Following this control procedure will eliminate any "dead-head" circulator conditions for radiant circulator (P1). The actuators must be open before the circulator will operate.

The ES terminals are considered "dry contacts." This means any wiring connected to these terminals is unpowered and will require an auxiliary power source. In this schematic, power is applied to the ES terminals by the R/T, G/T terminals on the Uponor Single-zone Pump Relay from an internal transformer. When the circuit is completed between the relay and the ZCM, a coil in the relay is energized, closing the contacts to start the circulator and, in this illustration, fire the boiler. Again, the contact 5 and 6NO on the Uponor Single-zone Pump Relay are dry contacts and require an additional power supply. In most instances, power is supplied to these contacts from a transformer within the boiler control off the T-T or R-G terminals. Consult the heating equipment manufacturer's wiring schematics for the proper terminals to energize the boiler.

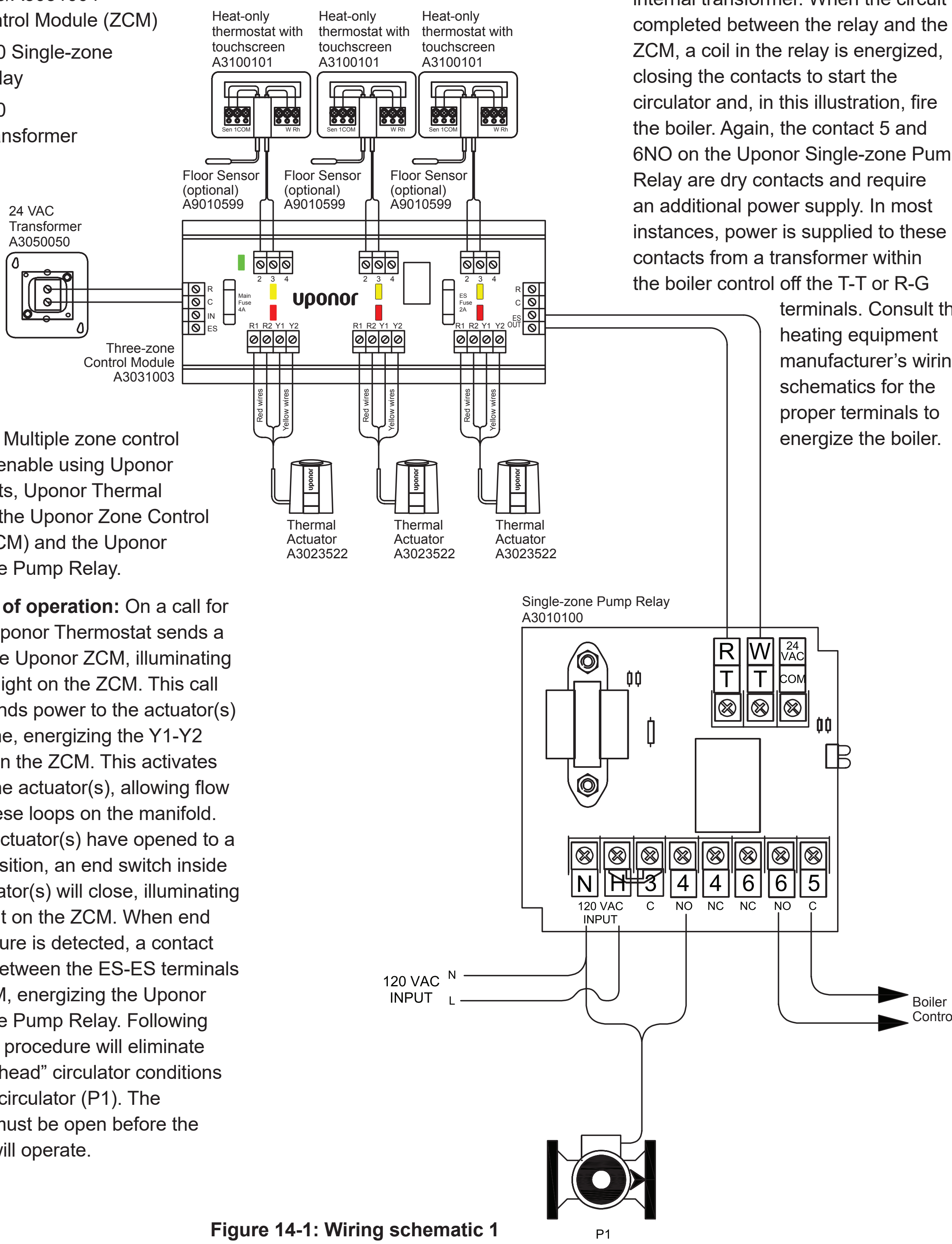


Figure 14-1: Wiring schematic 1

Wiring schematic 2

- A3100101 Uponor Thermostats
- A3011075 Uponor Zone Valve
- A3031003/A3031004 Zone Control Module (ZCM)
- A3010100 Single-zone Pump Relay
- A3050050 50 VA Transformer

Overview: Multiple zone control and boiler enable using Uponor Thermostats, Uponor Zone Valves, the Uponor Zone Control Module (ZCM) and the Uponor Single-zone Pump Relay.

Sequence of operation: On a call for heat, the Uponor Thermostat sends a signal to the Uponor ZCM, illuminating the yellow light on the ZCM. This call for heat sends power to the Zone Valve for that zone, energizing the Y1-Y2 terminals on the ZCM. This activates or opens the actuator, allowing flow through these loops on the manifold. Once the actuator has opened to a minimal position, an end switch inside the actuator will close, illuminating the red light on the ZCM. When end switch closure is detected, a contact will close between the ES-ES terminals on the ZCM, energizing the Uponor Single-zone Pump Relay. Following this control procedure will eliminate any “dead-head” circulator conditions for radiant circulator (P1). The actuators must be open before the circulator will operate.

The ES terminals are considered “dry contacts.” This means any wiring connected to these terminals is unpowered and will require an auxiliary power source. In this schematic, power is applied to the ES terminals by the R/T, G/T terminals on the Uponor Single-zone Pump Relay from an internal transformer. When the circuit is completed between the relay and the ZCM, a coil in the relay is energized, closing the contacts to start the circulator and, in this illustration, fire the boiler. Again, the contact 5 and 6NO on the Uponor Single-zone Pump Relay are dry contacts and require an additional power supply. In most instances, power is supplied to these contacts from a transformer within the boiler control off the T-T or R-G terminals. Consult the heating equipment manufacturer’s wiring schematics for the proper terminals to energize the boiler.

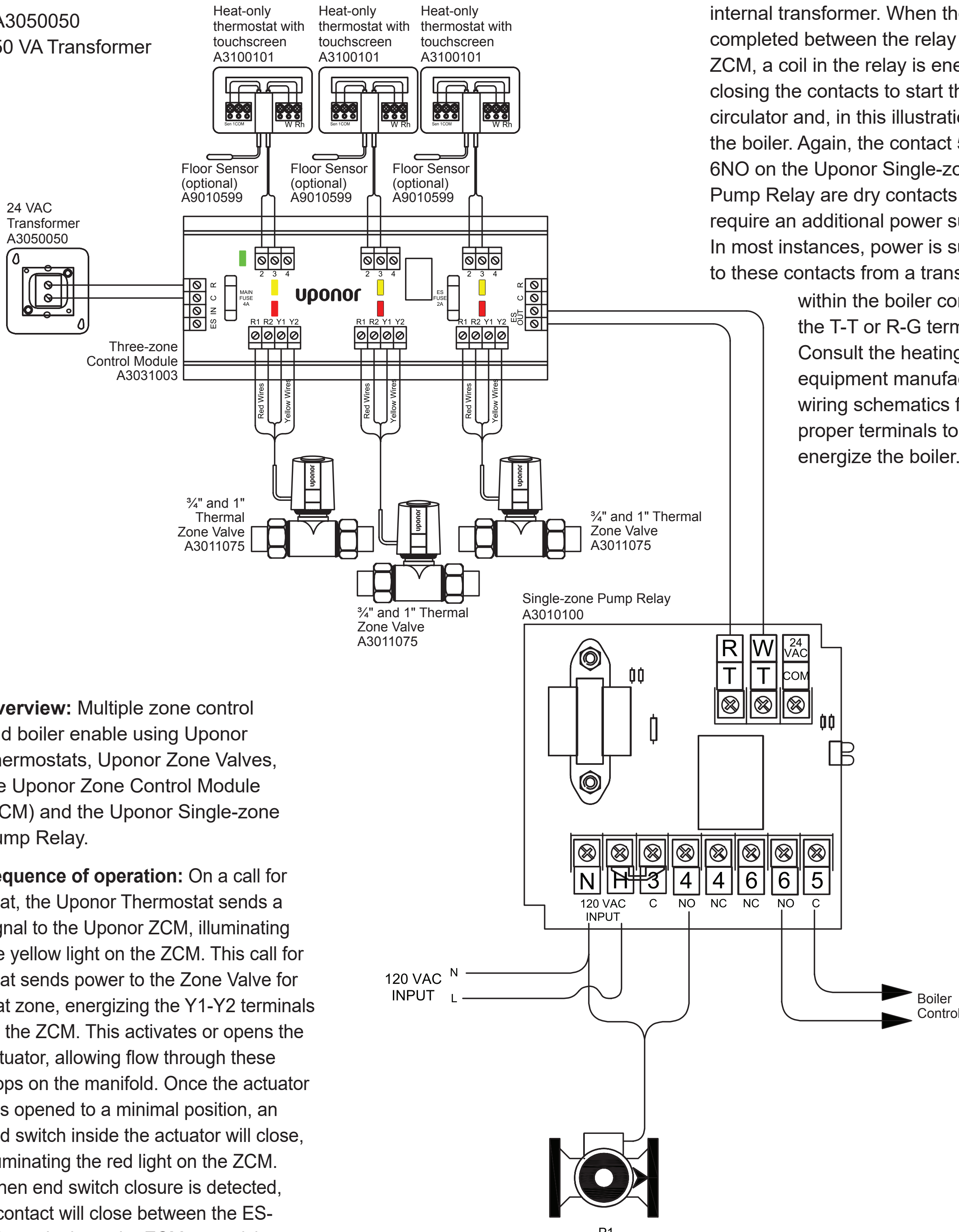


Figure 14-2: Wiring schematic 2

Wiring schematic 3

- A3100101 Uponor Thermostats
- A3023522 Thermal Actuators
- A3023522 Uponor Zone Valve
- A3031003/A3031004 Zone Control Module (ZCM)
- A3010100 Single-zone Pump Relay
- A3050050 50 VA Transformer

Overview: Multiple zone control and boiler enable using Uponor Thermostats, Uponor Actuators, Zone Valves, the Uponor Zone Control Module (ZCM) and the Uponor Single Pump Relay.

Sequence of operation: On a call for heat, the Uponor Thermostat sends a signal to the Uponor Zone Control Module (ZCM), illuminating the yellow light on the ZCM. This call for heat sends power to the actuator(s) or Zone Valve for that zone, energizing the Y1-Y2 terminals on the ZCM. This activates or opens the actuator, allowing flow through these loops on the manifold. Once the actuator has opened to a minimal position, an end switch inside of the actuator will close, illuminating the red light on the ZCM. When end switch closure is detected, a contact will close between the ES-ES terminals on the ZCM, energizing the Uponor Single-zone Pump Relay. Following this control procedure will eliminate any “deadhead” circulator conditions for radiant circulator (P1). The actuator(s) must be open before the circulator will operate.

The ES terminals are considered “dry contacts.” This means any wiring connected to these terminals is unpowered and will require an auxiliary power source. In this schematic, power is applied to the ES terminals by the R/T, G/T terminals on the Uponor Single-zone Pump Relay from an internal transformer. When the circuit is completed between the relay and the ZCM, a coil in the relay is energized, closing the contacts to start the circulator and, in this illustration, fire the boiler. Again, the contact 5 and 6NO on the Uponor Single-zone Pump Relay are dry contacts and require an additional power supply. In most instances, power is supplied to these contacts from a transformer within the boiler control off the T-T or R-G terminals. Consult the heating equipment manufacturer’s wiring schematics for the proper terminals to energize the boiler.

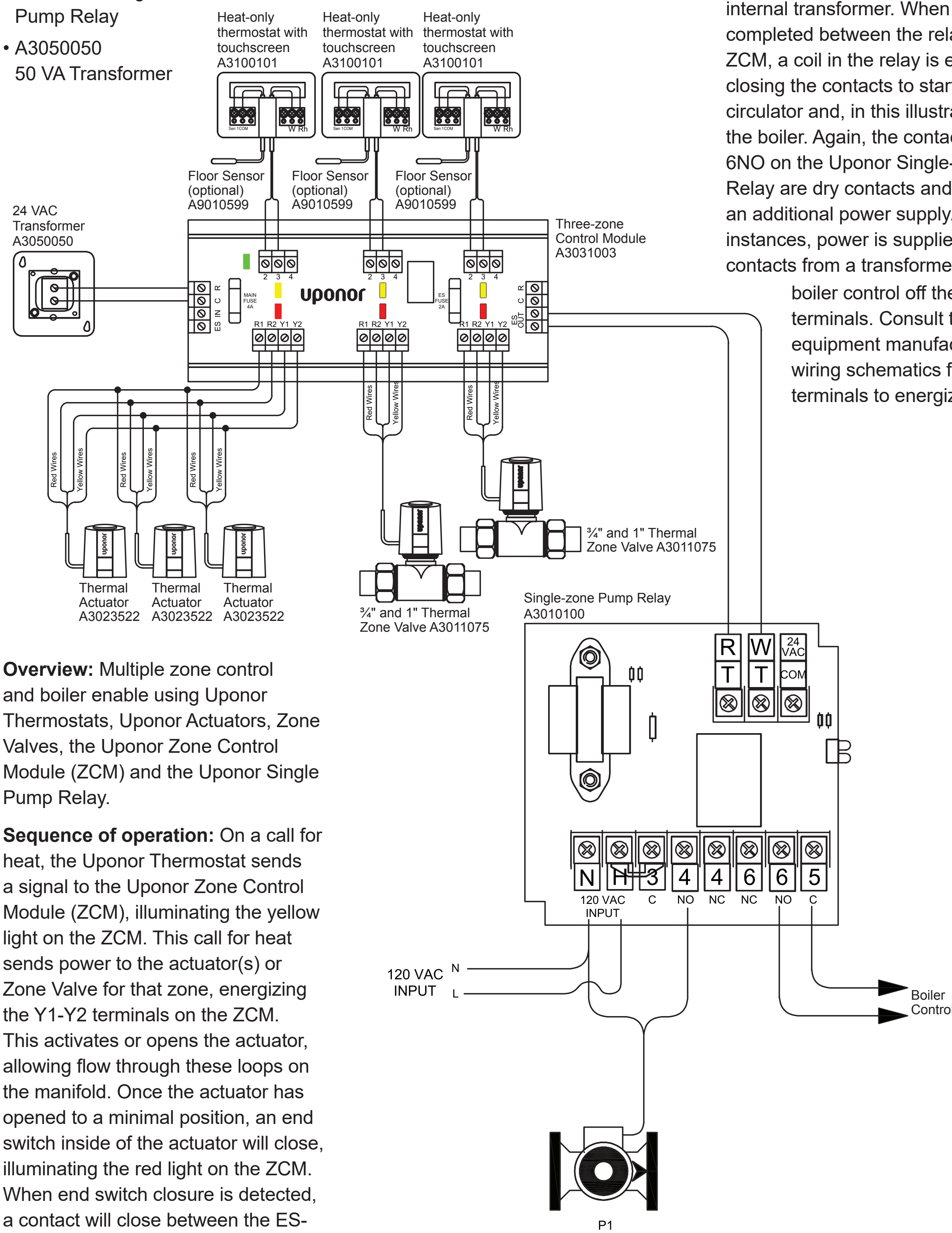


Figure 14-3: Wiring schematic 3

Wiring schematic 4

- A3100101 Uponor Thermostats
- A3080301 Three-zone Multi-pump Relay

Overview: Multiple zone control and boiler enable using Uponor Thermostats operating multiple radiant circulators (P1 and P2), using the Uponor Three-zone Multi-pump Relay.

Sequence of operation: On a call for heat, the Uponor Thermostat sends a signal to the Uponor Three-zone Multi-pump Relay. In this schematic, power is applied to the DT10 Thermostats by the T1 and T2 terminals on the Uponor Three-zone Multi-pump Relay from an internal transformer. When the circuit is completed between the thermostat and the circulator panel, a coil in the relay is energized, closing the contacts to start the circulator and, in this illustration, fire the boiler. Contacts X1/X2 are considered "dry contacts." This means any wiring connected to these terminals is unpowered and will require an auxiliary power source. In most instances, power is supplied to these contacts from a transformer within the boiler controls off the T-T or R-G terminals. Consult the heating equipment manufacturer's wiring schematics for the proper terminals to energize the boiler.

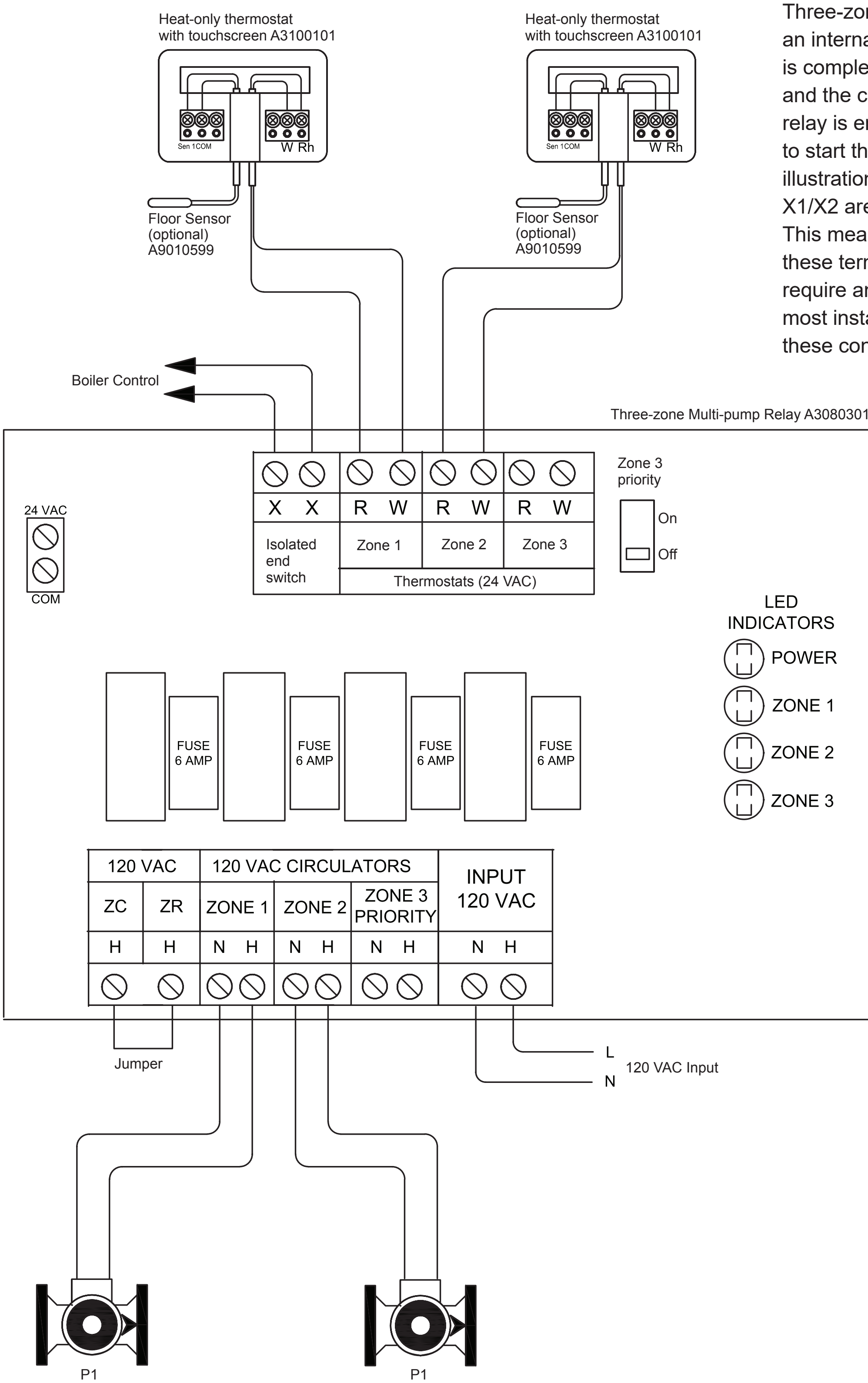


Figure 14-4: Wiring schematic 4

Wiring schematic 5

- A3030101 Uponor Thermostats
- A3010522 Thermal Actuators
- A3030003/A3030004 Zone Control Module (ZCM)
- A3080301 Three-zone Multi-pump Relay
- A3050050 50 VA Transformer

Overview: Multiple zone control and boiler enable using Uponor Thermostats, Uponor Actuators, the Uponor Zone Control Module (ZCM) operating multiple radiant circulators (P1, P2, P3), using the Uponor Three-zone Multi-pump Relay.

Sequence of operation: On a call for heat, the Uponor Thermostat sends a signal to the Uponor ZCM, illuminating the yellow light on the ZCM. This call for heat sends power to the actuator(s) for that zone, energizing the Y1-Y2 terminals on the ZCM. This activates or opens the actuator(s), allowing flow through these loops on the manifold. Once the actuator(s) have opened to a minimal position, an end switch inside of the actuator(s) will close, illuminating the red light on the ZCM. When end switch closure is detected, a contact will close between the ES-ES terminals on the ZCM, energizing the Uponor Three-zone Multi-pump Relay. Following this control procedure will eliminate any “dead-head” circulator conditions for the radiant circulator (P1). The actuator(s) must be open before the circulator will operate.

The ES terminals are considered “dry contacts.” This means any wiring connected to these terminals are unpowered and will require an auxiliary power source. In this schematic, power is applied to the ES terminals by the T1/T1 terminals on the Uponor Three-zone Multi-pump Relay from an internal transformer. When the circuit is completed between the relay and the ZCM, a coil in the relay is energized, closing the contacts to start the circulator and, in this illustration, fire the boiler. Again, the contacts X1/X2 are dry contacts and require an additional power supply. In most instances, power is supplied to these contacts from a transformer within the boiler controls off the T-T or R-G terminals. Consult the heating equipment manufacturer’s wiring schematics for the proper terminals to energize the boiler.

Also shown in this schematic is a separate thermostat used to control a second radiant circulator (P2). In this example, the thermostat is directly wired to the relay to operate that second circulator. This scenario exists when a manifold is treated as a single zone, controlled by a circulator instead of a zone valve. Power is supplied to the thermostat from the T2/T2 terminals. When the thermostat calls for heat, the circuit between the T2 terminals is closed and a coil is energized in the relay, starting the radiant circulator (P2) and closing the contacts between X1/X2, starting the boiler.

See wiring schematic 5 on page 150.

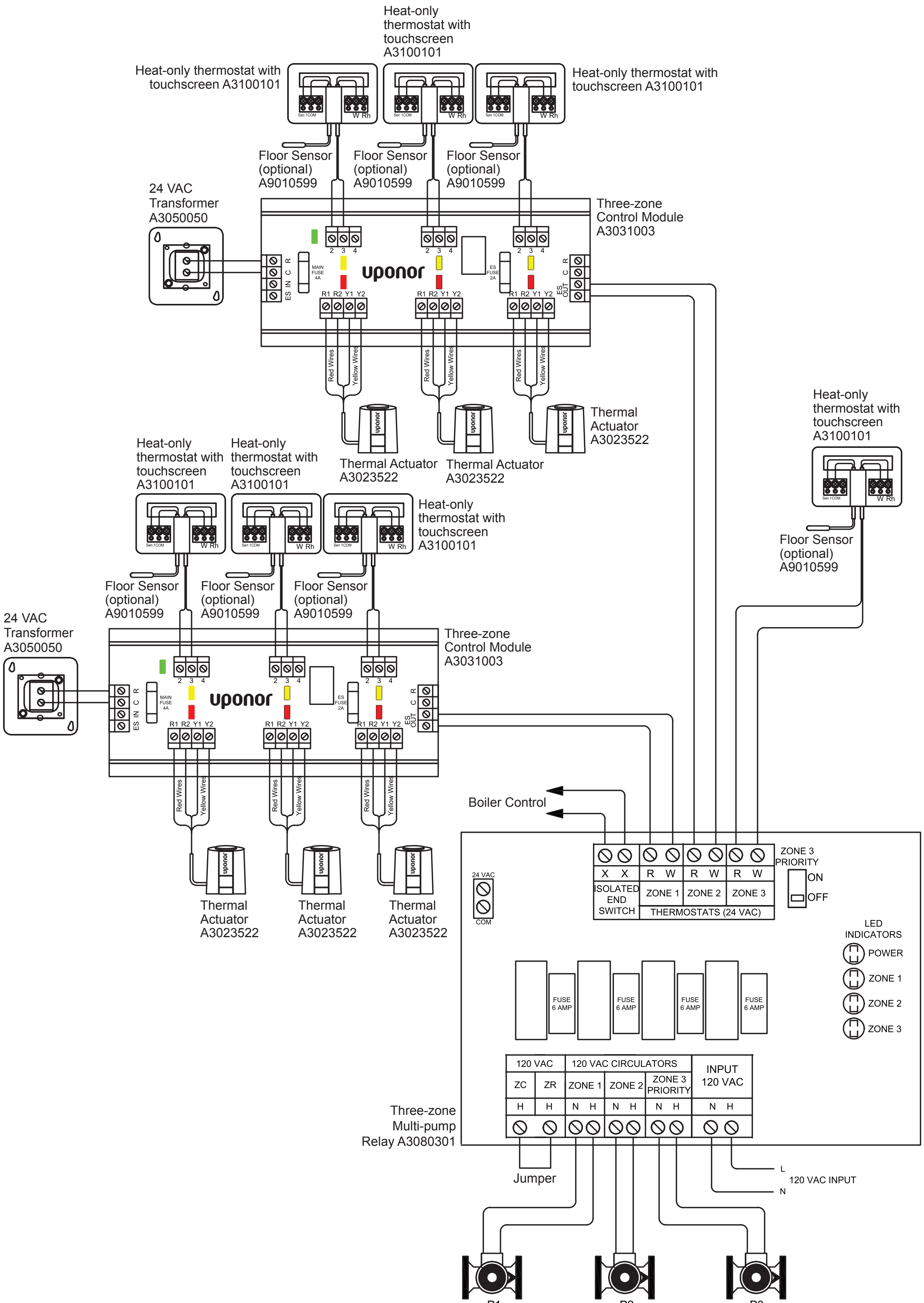


Figure 14-5: Wiring schematic 5

Wiring schematic 6

- A3030101 Uponor Thermostats
- A3010522 Thermal Actuators
- A3030003/A3030004 Zone Control Module (ZCM)
- A3080301 Three-zone Multi-pump Relay
- A3050050 50 VA Transformer

Overview: Multiple zone control and boiler enable using Uponor Thermostats, Uponor Actuators, the Uponor Zone Control Module (ZCM) operating one radiant circulator (P1), along with a single Uponor Thermostat operating a second radiant circulator (P2), using the Uponor Three-zone Multi-pump Relay.

Sequence of Operation: On a call for heat, the Uponor Thermostat sends a signal to the Uponor ZCM, illuminating the yellow light on the ZCM. This call for heat sends power to the actuator(s) for that zone, energizing the Y1-Y2 terminals on the ZCM. This activates or opens the actuator(s), allowing flow through these loops on the manifold. Once the actuator(s) have opened to a minimal position, an end switch inside of the actuator(s) will close, illuminating the red light on the ZCM. When end switch closure is detected, a contact will close between the ES-ES terminals on the ZCM, energizing the Uponor Three-zone Multi-pump Relay. Following this control procedure will eliminate any "dead-head" circulator conditions for radiant circulator (P1). The actuator(s) must be open before the circulator will operate.

The ES terminals are considered "dry contacts." This means any wiring connected to these terminals are unpowered and will require an auxiliary power source. In this schematic, power is applied to the ES terminals by the T1/T1 terminals on the Uponor Three-zone Multi-pump Relay from an internal transformer. When the circuit is completed between the relay and the ZCM, a coil in the relay is energized, closing the contacts to start the circulator and, in this illustration, fire the boiler. Again, the contacts X1/X2 are dry contacts and require an additional power supply. In most instances, power is supplied to these contacts from a transformer within the boiler controls off the T-T or R-G terminals. Consult the heating equipment manufacturer's wiring schematics for the proper terminals to energize the boiler.

Also shown in this schematic is a separate thermostat used to control a second radiant circulator (P2). In this example, the thermostat is directly wired to the relay to operate that second circulator. This scenario exists when a manifold is treated as a single zone, controlled by a circulator instead of a zone valve. Power is supplied to the thermostat from the T2/T2 terminals. When the thermostat calls for heat, the circuit between the T2 terminals is closed and a coil is energized in the relay, starting the radiant circulator (P2) and closing the contacts between X1/X2, starting the boiler.

See wiring schematic 6 on page 152.

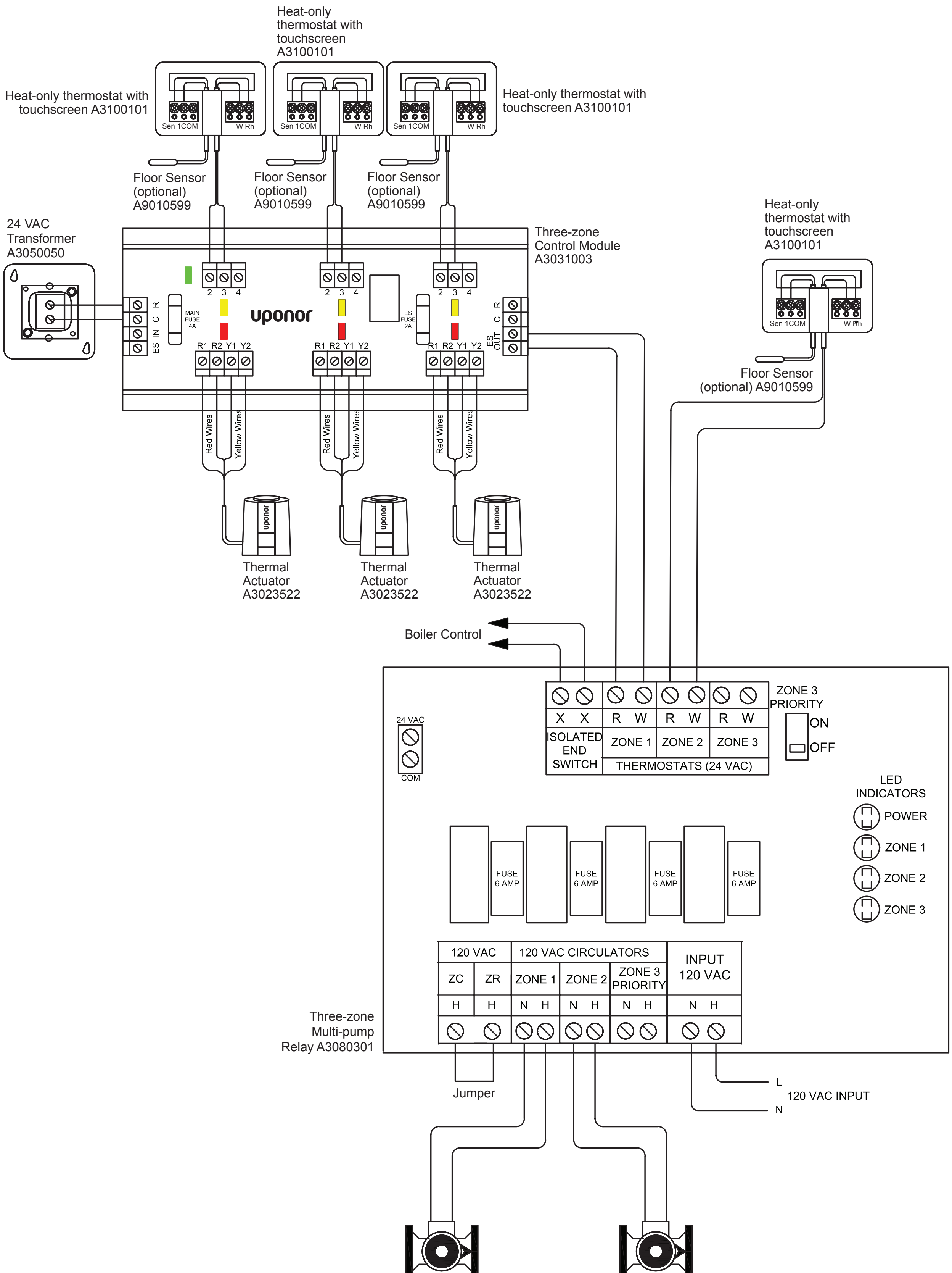


Figure 14-6: Wiring schematic 6

Wiring schematic 7

- A3100101 Uponor Thermostats
- A3023522 Thermal Actuators
- A3031003/A3031004 Zone Control Module (ZCM)
- A3080301 Three-zone Multi-pump Relay
- A3050050 50 VA Transformer
- A3070526 Uponor 1" Zone Valve

Overview: Multiple zone control, multiple circulator control (P1 and P2) and boiler enable using Uponor Thermostats, Uponor Actuators, the Uponor Zone Control Module (ZCM) and the Uponor Three-zone Multi-pump Relay, along with a single Uponor Thermostat operating a zone valve (M1), also wired through the Uponor ZCM.

Sequence of operation:
On a call for heat, the Uponor Thermostat sends a signal to the Uponor ZCM, illuminating the yellow light on the ZCM. This call for heat sends power to the actuator(s) for that zone, energizing the Y1-Y2 terminals on the ZCM. This activates or opens the actuator(s), allowing flow through these loops on the manifold. Once the actuator(s) have opened to a minimal position, an end switch inside of the actuator(s) will close, illuminating the red light on the ZCM. When end switch closure is detected, a contact will close between the ES-ES terminals on the ZCM, energizing the Uponor Three-zone Multi-pump Relay. Following this control procedure will eliminate any “dead-head” circulator conditions for radiant circulator (P1). The actuator(s) must be open before the circulator will operate.

The ES terminals are considered “dry contacts.” This means any wiring connected to these terminals is unpowered and will require an auxiliary power source. In this schematic, power is applied to the ZCM ES terminals by the T1-T1 and T2-T2 terminals on the Uponor Three-zone Multi-pump Relay from an internal transformer. When the circuit is completed between the relay and the ZCM, a coil in the relay is energized, closing the contacts to start the circulator and, in this illustration, fire the boiler. Again, the contacts X1/X2 on the Uponor Three-zone Multi-pump Relay are dry contacts and require an additional power supply. In most instances, power is supplied to these contacts from a transformer within the boiler control off the T-T or R-G terminals. Consult the heating equipment manufacturer’s wiring schematics for the proper terminals to energize the boiler.

Also shown in this schematic is a separate thermostat wired to a ZCM to control a zone valve (M1). The zone valve can be wired to the thermostat using the ZCM. Following the same sequence of operation as above, the red wires from the internal end switch are wired in parallel to the wiring from the multiple circulator relay panel. This wiring configuration will allow a call for heat from either the relay panel or the zone valve to activate the boiler.

See wiring schematic 7 on page 154.

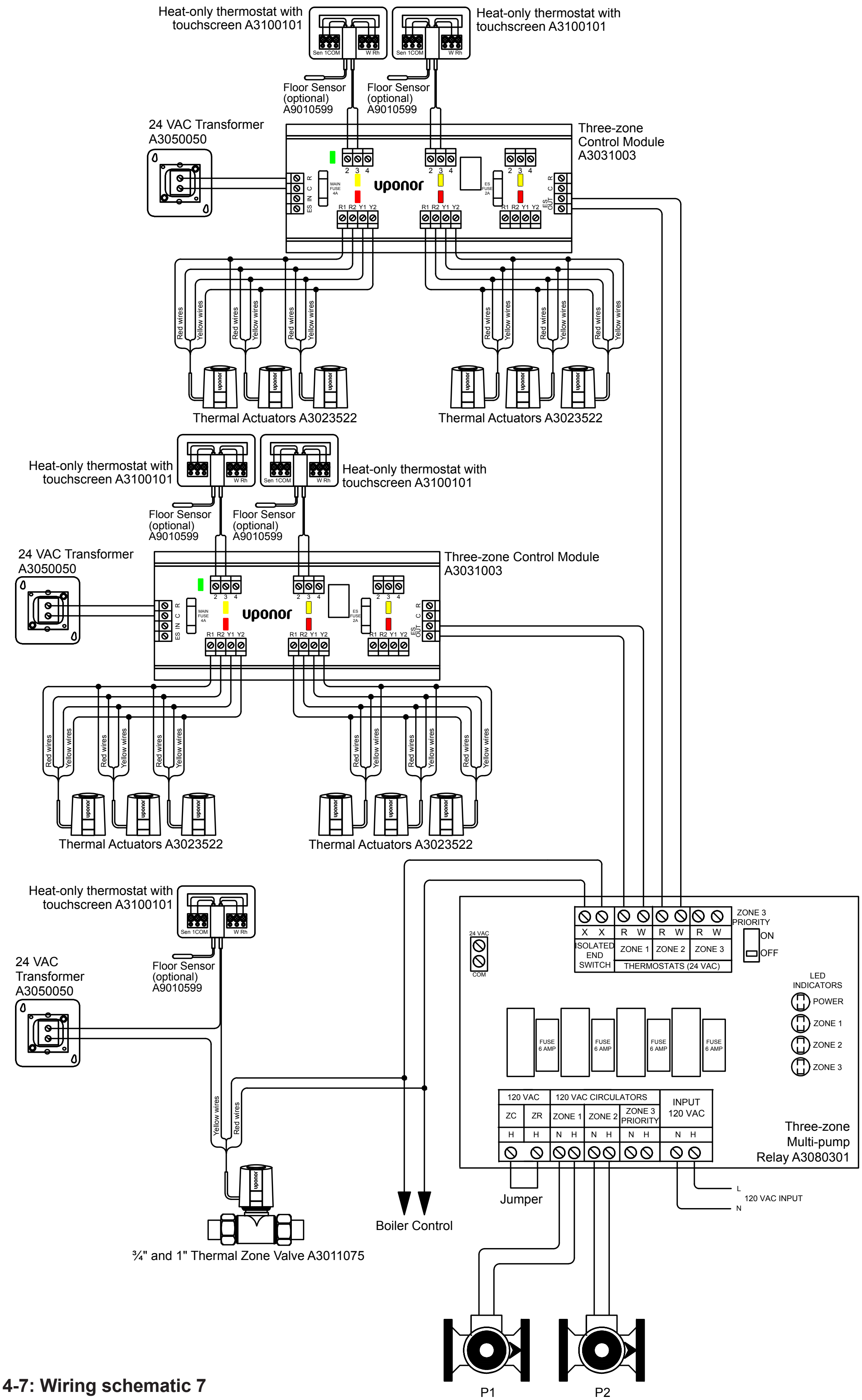


Figure 14-7: Wiring schematic 7

Wiring schematic 8

- A3100101 Uponor Thermostats
- A3023522 Thermal Actuators
- A3031003/A3031004 Zone Control Module (ZCM)
- A3010100 Single-zone Pump Relay
- A3050050 50 VA Transformer

Overview: Multiple zone control and circulator control (P1) using Uponor Thermostats, Uponor Actuators, the Uponor Zone Control Module (ZCM) and the Uponor Single-zone Pump Relay. Radiant supply water temperature and boiler enable is controlled by the Uponor SetPoint 150 Controller (SPC).

Sequence of operation: On a call for heat, the Uponor Thermostat sends a signal to the Uponor ZCM, illuminating the yellow light on the ZCM. This call for heat sends power to the actuator(s) for that zone, energizing the Y1-Y2 terminals on the ZCM. This activates or opens the actuator(s), allowing flow through these loops on the manifold. Once the actuator(s) have opened to a minimal position, an end switch inside of the actuator(s) will close, illuminating the red light on the ZCM. When end switch closure is detected, a contact will close between the ES-ES terminals on the ZCM, energizing the Uponor Single-zone Pump Relay. Following this control procedure will eliminate any “dead-head” circulator conditions for the radiant circulator (P1). The actuators must be open before the circulator will operate.

The ES terminals are considered “dry contacts.” This means any wiring connected to these terminals is unpowered and will require an auxiliary power source. In this schematic, power is applied to the ES terminals by the R/T, G/T terminals on the Uponor Single-zone Pump Relay from an internal transformer. When the circuit is completed between the relay and the ZCM, a coil in the relay is energized, closing the contacts to start the circulator and, in this illustration, fire the boiler. Again, the contact 5 and 6NO on the Uponor Single-zone Pump Relay are dry contacts and require an additional power supply. In most instances, power is supplied to these contacts from a transformer within the boiler control off the T-T or R-G terminals. Consult the heating equipment manufacturer’s wiring schematics for the proper terminals to energize the boiler.

The Uponor SetPoint 150 Controller is added in series to the wiring between the Uponor Single-zone Pump Relay and the boiler control. The SPC is used to control the radiant supply water temperature, possibly through a heat exchanger. For example, if the SPC is set for 120°F and the sensor (S1) is reading a temperature below the setpoint, the contacts 3 and 4 are closed and the boiler is allowed to fire. If the temperature being read on sensor S1 is higher the than the desired temperature, the contacts between 3 and 4 are open and the boiler does not fire. The zones open, and the radiant circulator (P1) operates, but it is not necessary to fire the boiler and add heat when the proper supply water temperature is being delivered. Consult the boiler manufacturer’s wiring schematics for the proper terminals to energize the boiler.

See wiring schematic 8 on page 156.

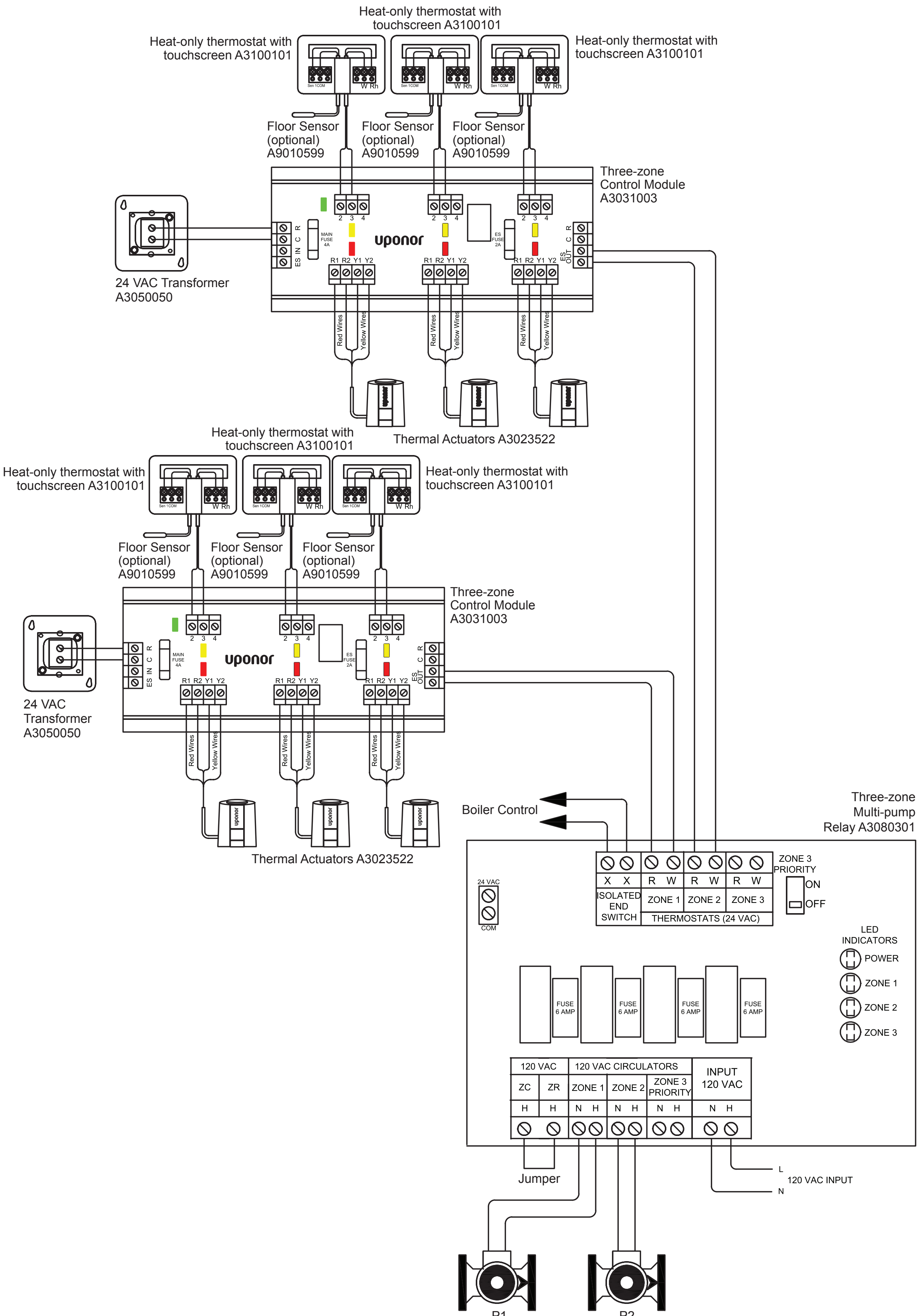


Figure 14-8: Wiring schematic 8

Wiring schematic 9

- A3100101 Uponor Thermostats
- A3023522 Thermal Actuators)
- A3031003/A3031004 Zone Control Module (ZCM)
- A3080301 Three-zone Multi-pump Relay
- A3050050 50 VA Transformer

Overview: Multiple zone control and boiler enable using Uponor Thermostats, Uponor Actuators, the Uponor Zone Control Module (ZCM) operating two radiant circulators (P1 and P2) using the Uponor Three-zone Multi-pump Relay.

Sequence of operation: On a call for heat, the Uponor Thermostat sends a signal to the Uponor ZCM, illuminating the yellow light on the ZCM. This call for heat sends power to the actuator(s) for that zone, energizing the Y1-Y2 terminals on the ZCM. This activates or opens the actuator(s), allowing flow through these loops on the manifold. Once the actuator(s) have opened to a minimal position, an end switch inside of the actuator will close, illuminating the red light on the ZCM. When end switch closure is detected, a contact will close between the ES-ES terminals on the ZCM, energizing the corresponding circulator through the Uponor Three-zone Multi-pump Relay. Following this control procedure will eliminate any "dead-head" circulator condition for the radiant circulators (P1 and P2). The actuators must be open before the circulator will operate.

The ES terminals are considered "dry contacts." This means any wiring connected to these terminals are unpowered and will require an auxiliary power source. In this schematic, power is applied to the ES terminals on either ZCM by the T1/T1 and T2/T2 terminals on the Uponor Three-zone Multi-pump Relay from an internal transformer. When the circuit is completed between the relay and the ZCM, a coil in the relay is energized, closing the contacts to start the circulator and, in this illustration, fire the boiler. Again, the contacts X1/X2 are dry contacts and require an additional power supply.

In most instances, power is supplied to these contacts from a transformer within the boiler controls off the T-T or R-G terminals. Consult the heating equipment manufacturer's wiring schematics for the proper terminals to energize the boiler.

See wiring schematic 9 on page 158.

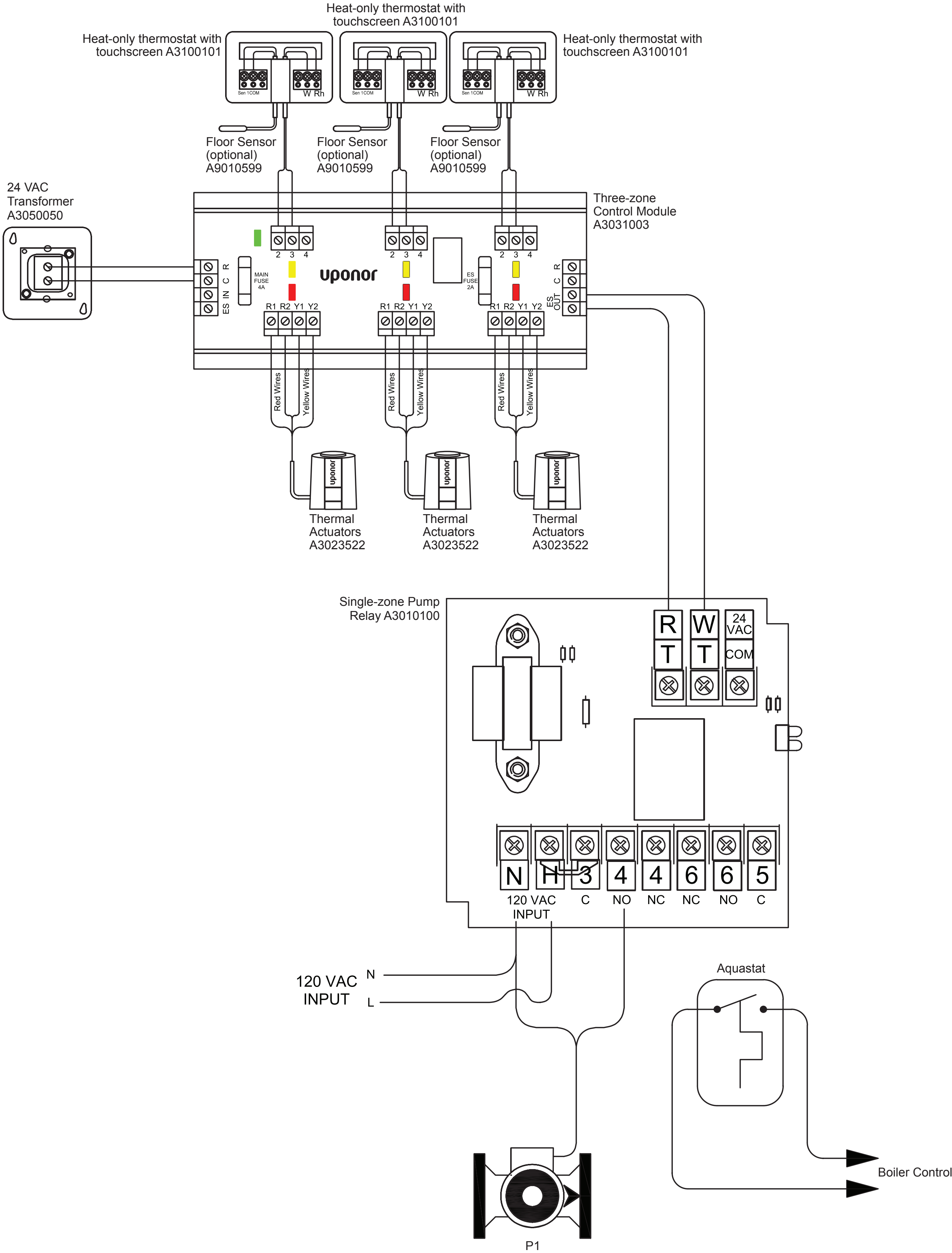


Figure 14-9: Wiring schematic 9

Wiring schematic 10

- A3100101 Uponor Thermostats
- A3023522 Thermal Actuators
- A3031003/A3031004 Zone Control Module (ZCM)
- A3010100 Single-zone Pump Relay
- A3050050 50 VA Transformer

Overview: Multiple zone control and boiler enable using Uponor Thermostats, Uponor Actuators, the Uponor Zone Control Module (ZCM) and the Uponor Single-zone Pump Relay.

Sequence of operation: On a call for heat, the Uponor Thermostat sends a signal to the Uponor ZCM, illuminating the yellow light on the ZCM. This call for heat sends power to the actuator(s) for that zone, energizing the Y1-Y2 terminals on the ZCM. This activates or opens the actuator(s), allowing flow through these loops on the manifold. Once the actuator(s) have opened to a minimal position, an end switch inside of the actuator(s) will close, illuminating the red light on the ZCM. When end switch closure is detected, a contact will close between the ES-ES terminals on the ZCM, energizing the Uponor Single-zone Pump Relay. Following this control procedure will eliminate any “dead-head” circulator conditions for radiant circulator (P1). The actuator(s) must be open before the circulator will operate.

This wiring schematic is typical of piping arrangements using a mixing tank to add mass to the system and control water temperature. In this schematic, there is no wiring between the single circulator relay panel and the heat plant. This heat plant could be a non-condensing boiler, condensing boiler, heat circulator, etc. A call for heat from any of the zones will start the radiant circulator (P2) and begin to circulator the heat away from the buffer tank. An aquastat (AQ1) is added to the tank to control the heat plant. Depending on the differential setting on the aquastat, once the tank temperature has dropped below the desired temperature setting, the contact will close and fire the heating equipment. The terminals inside of the aquastat are considered “dry contacts.” This means any wiring connected to these terminals is unpowered and will require an auxiliary power source. In most instances, power is supplied to these contacts from a transformer within the boiler control off the TT or R-G terminals. Consult the heating equipment manufacturer’s wiring schematics for the proper terminals to energize the boiler.

It is also important to understand how this type of wiring scheme de-energizes. Once the call from the thermostat is ended, signifying a satisfied space temperature, the radiant circulator (P1) is shut off. However, depending on the water temperature inside the tank, the aquastat contacts will remain closed, continuing to fire the heat plant, until the required water temperature is achieved by the buffer tank. After the set temperature is sensed in the tank by the aquastat, the contacts open and interrupt the signal to the heat plant.

See wiring schematic 10 on page 160.

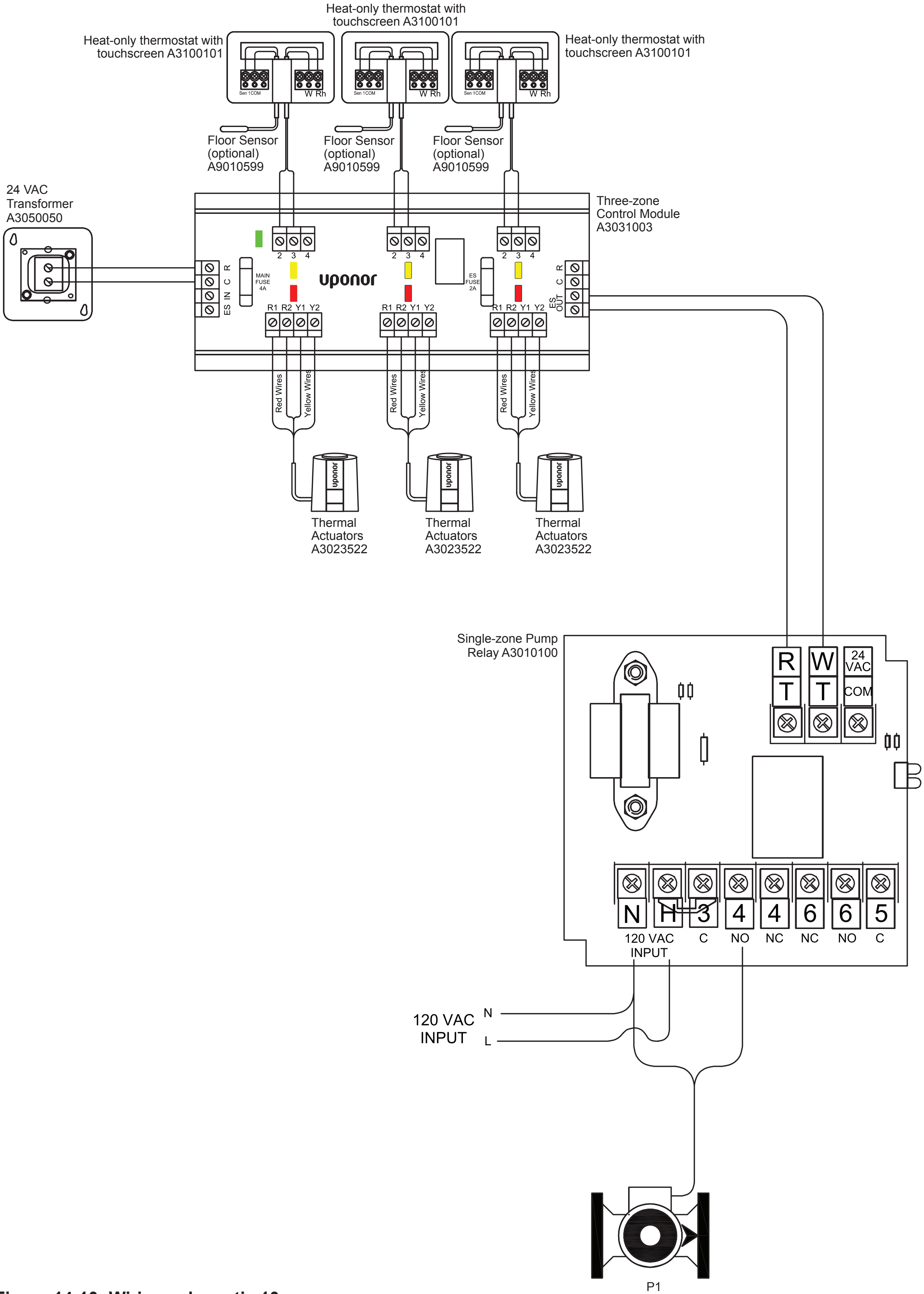


Figure 14-10: Wiring schematic 10

Wiring schematic 11

- A3100101 Uponor Thermostats
- A3023522 Thermal Actuators
- A3031003/A3031004 Zone Control Module (ZCM)
- A3050050 50 VA Transformer

Overview: Multiple zone control and boiler enable using Uponor Thermostats, Uponor Actuators and the Uponor Zone Control Module (ZCM).

Sequence of operation: On a call for heat, the Uponor Thermostat sends a signal to the Uponor ZCM, illuminating the yellow light on the ZCM. This call for heat sends power to the actuator(s) for that zone, energizing the Y1-Y2 terminals on the ZCM. This activates or opens the actuator(s), allowing flow through these loops on the manifold. Once the actuator(s) have opened to a minimal position, an end switch inside of the actuator(s) will close, illuminating the red light on the ZCM. When end switch closure is detected, a contact will close between the ES-ES terminals on the ZCM, completing the boiler circuit. The actuator(s) must be open before the boiler will operate.

The ES terminals are considered "dry contacts." This means any wiring connected to these terminals is unpowered and will require an auxiliary power source. In this schematic, power is supplied to these contacts from a transformer within the boiler control off the T-T or R-G terminals. Consult the heating equipment manufacturer's wiring schematics for the proper terminals to energize the boiler.

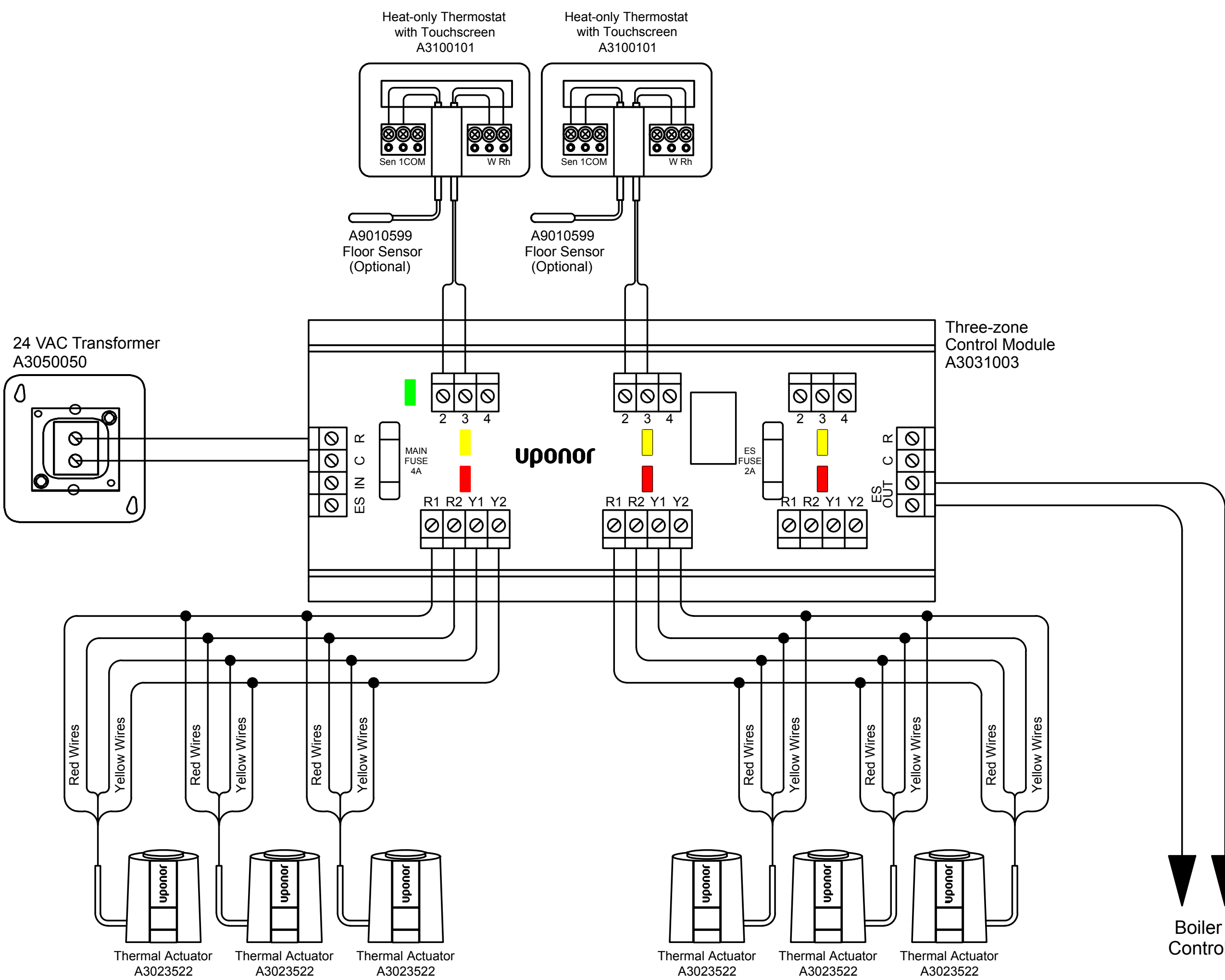


Figure 14-11: Wiring schematic 11

Wiring schematic 12

- A3030101 Uponor Thermostats
- A3010522 Thermal Actuators
- A3030003/A3030004 Zone Control Module (ZCM)
- A3010100 Single-zone Pump Relay
- A3050050 50 VA Transformer
- Setpoint controller

Overview: Multiple zone control and circulator control (P1) using Uponor Thermostats, Uponor Actuators, the Uponor Zone Control Module (ZCM) and the Uponor Single-zone Pump Relay. Radiant supply water temperature and boiler enable is controlled by a setpoint controller.

Sequence of operation: On a call for heat, the Uponor Thermostat sends a signal to the Uponor ZCM, illuminating the yellow light on the ZCM. This call for heat sends power to the actuator(s) for that zone, energizing the Y1-Y2 terminals on the ZCM. This activates or opens the actuator(s), allowing flow through these loops on the manifold. Once the actuator(s) have opened to a minimal position, an end switch inside of the actuator(s) will close, illuminating the red light on the ZCM. When end switch closure is detected, a contact will close between the ES-ES terminals on the ZCM, energizing the Uponor Single-zone Pump Relay. Following this control procedure will eliminate any “dead-head” circulator conditions for the radiant circulator (P1). The actuators must be open before the circulator will operate.

The ES terminals are considered “dry contacts.” This means any wiring connected to these terminals is unpowered and will require an auxiliary power source. In this schematic, power is applied to the ES terminals by the R/T, G/T terminals on the Uponor Single-zone Pump Relay from an internal transformer. When the circuit is completed between the relay and the ZCM, a coil in the relay is energized, closing the contacts to start the circulator and, in this illustration, fire the

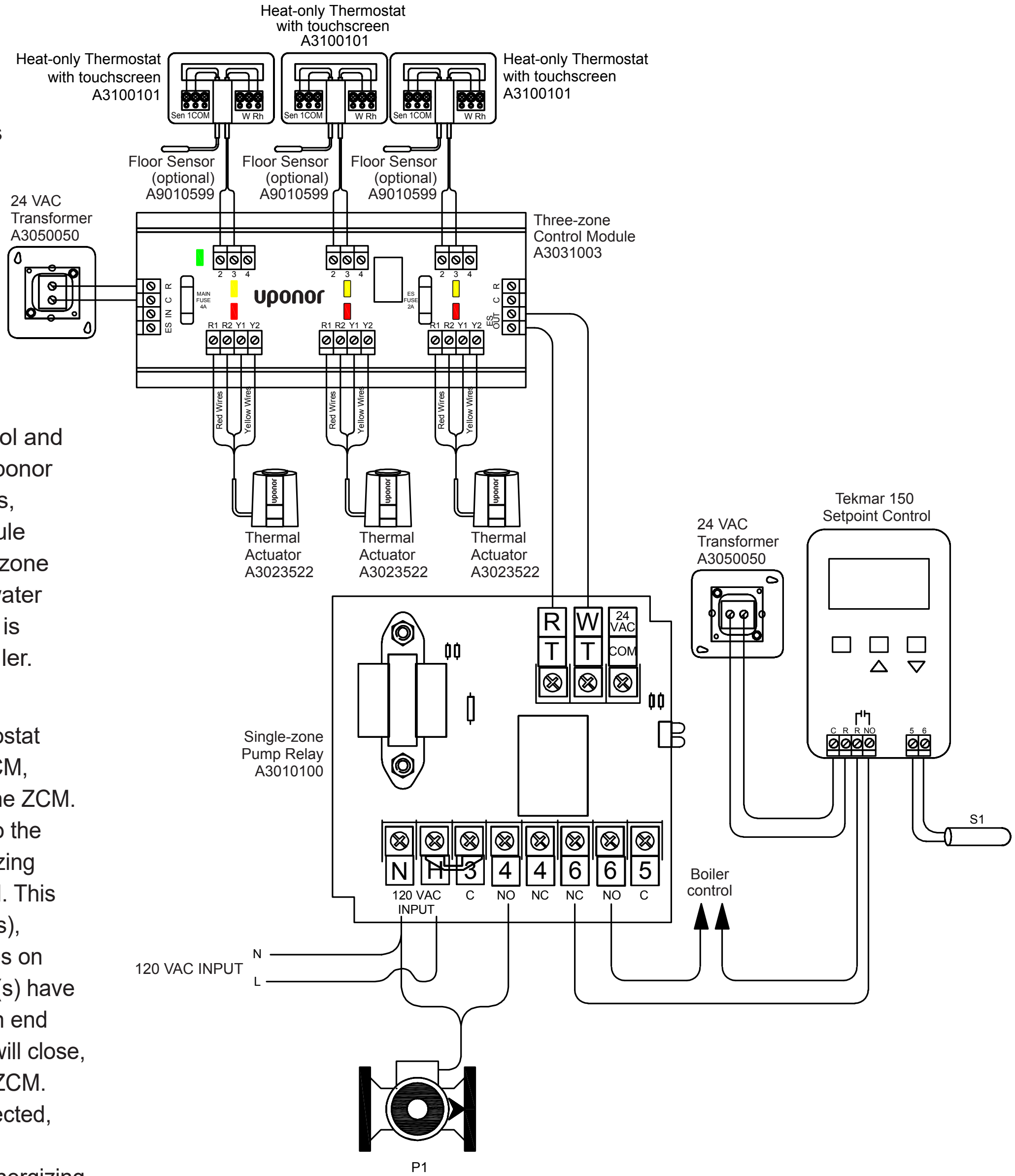


Figure 14-12: Wiring schematic 12

boiler. Again, the contact 5 and 6NO on the Uponor Single-zone Pump Relay are dry contacts and require an additional power supply. In most instances, power is supplied to these contacts from a transformer within the boiler control off the T-T or R-G terminals. Consult the heating equipment manufacturer’s wiring schematics for the proper terminals to energize the boiler.

The setpoint controller is added in series to the wiring between the Uponor Single-zone Pump Relay and the boiler control. The setpoint controller is used to control the radiant supply water temperature, possibly through a heat exchanger.

For example, if the setpoint controller is set for 120°F and the sensor (S1) is reading a temperature below the setpoint, the contacts 3 and 4 are closed and the boiler is allowed to fire. If the temperature being read on sensor S1 is higher the than the desired temperature, the contacts between 3 and 4 are open and the boiler does not fire. The zones open, and the radiant circulator (P1) operates, but it is not necessary to fire the boiler and add heat when the proper supply water temperature is being delivered. Consult the boiler manufacturer’s wiring schematics for the proper terminals to energize the boiler.

Wiring schematic 13

- A310101 Uponor Thermostats
- A3023522 Thermal Actuators
- A3031003/A3031004 Zone Control Modules (ZCM)
- A3050050 50VA Transformer
- A3040075 / A3040100 Three-way Mixing Valve

Overview: Multiple zone control and boiler enable using Uponor Thermostats, Uponor Actuators, the Uponor Zone Control Module (ZCM), the Uponor Transformer and the Uponor Three-way Mixing Valve to control the radiant supply water temperature.

Sequence of operation: On a call for heat, the Uponor Thermostat sends a signal to the ZCM, illuminating the yellow light for that specific zone. This call for heat sends power to the actuator(s) for that zone, energizing the Y1-Y2 terminals on the ZCM. This activates or opens the actuators(s), allowing flow through these loops on the manifold. Once the actuator(s) have opened to a minimal position, an end switch inside the actuator(s) will close, illuminating the red light on the ZCM. When the end switch closure is detected, the contacts between ES-ES terminals will close, energizing the Uponor Single-zone Pump Relay. Following this control procedure will eliminate any "dead-head" circulator conditions for the radiant circulator (P1). The actuators must be open before the circulator will operate.

Power is supplied to the Three-way Mixing Valve from the power supply on the Uponor Single-zone Pump Relay, using the R and COM terminals. Note that the Three-way Mixing Valve does not require wiring for a call for heat, only power. This valve will automatically adjust itself to deliver the correct water temperature based on the user set-up information and the current outdoor and supply water temperature. This valve will open and close, mixing the return water from the radiant loops along with the boiler supply water to achieve the correct temperature based on the supply sensor.

The ES terminals are considered "dry" contacts". This means any wiring connected to these terminals will require an auxiliary power source. In this schematic, power is applied to the ES terminals by the R and W terminals on the Uponor Single-zone Pump Relay from an internal transformer. Then, the circuit is completed between the relay and the ZCM, energizing a coil in the relay and closing the contacts to start the circulator (P1) and the boiler. Again, contacts 5 and 6NO on the Uponor Single-zone Pump Relay are dry contacts and require an additional power supply. In most instances, power is supplied to these contacts from a transformer within the boiler control. Consult the heating equipment manufacturer's wiring schematic for the proper terminals to energize the boiler.

See wiring schematic 13 on page 164.

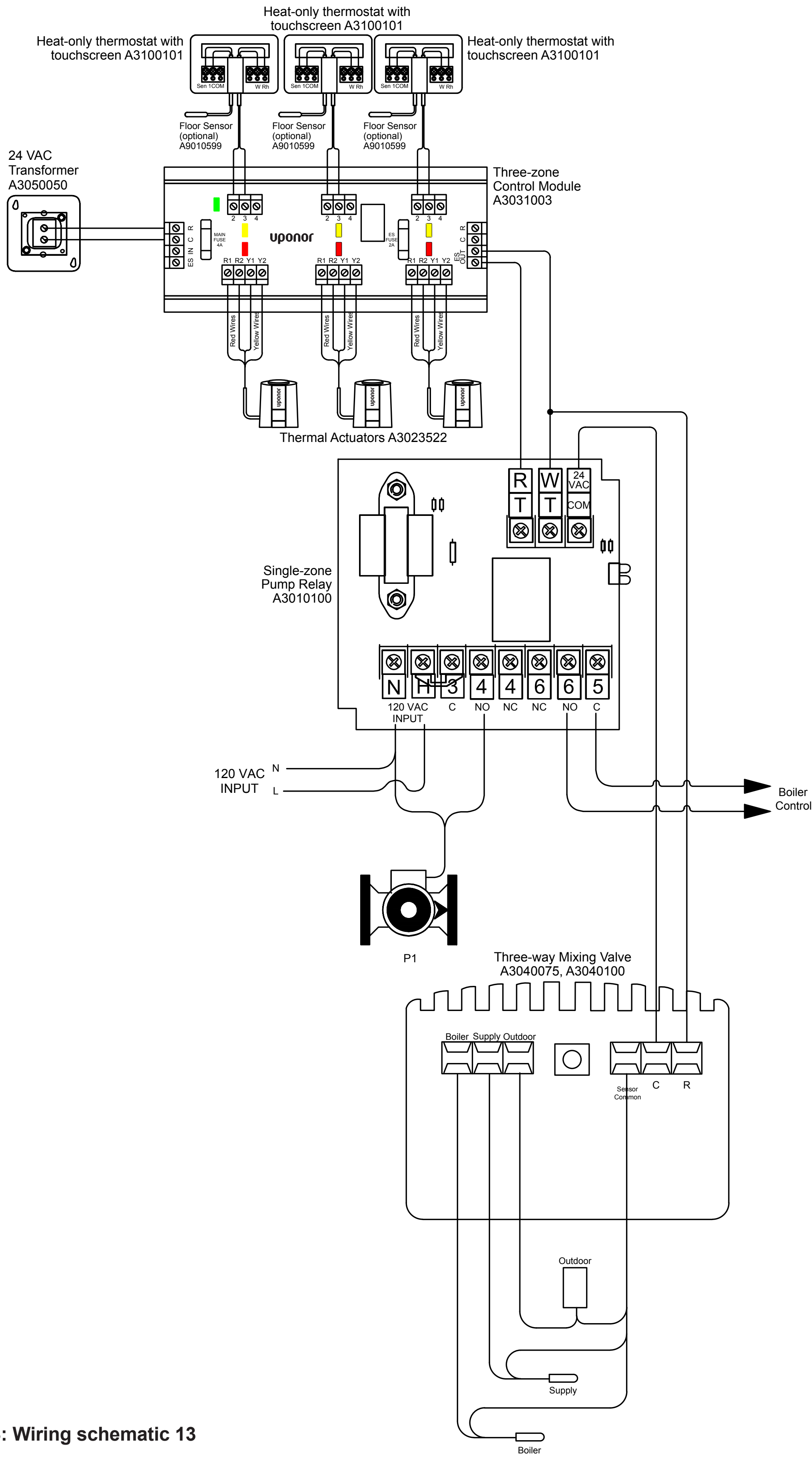


Figure 14-13: Wiring schematic 13

Wiring schematic 14

- A310101 Uponor Thermostats
- A3023522 Thermal Actuators
- A3031003/A3031004 Zone Control Modules (ZCM)
- A3050050 50VA Transformer
- Third-party mixing controls

Overview: Multiple zone control and boiler enable using Uponor Thermostats, Uponor Actuators, the Uponor Zone Control Module (ZCM), the Uponor Transformer and third-party mixing controls to control multiple radiant supply water temperatures using injection pumps.

Sequence of operation: On a call for heat, the Uponor Thermostat sends a signal to the ZCM, illuminating the yellow light for that specific zone. This call for heat sends power to the actuator(s) for that zone, energizing the Y1-Y2 terminals on the ZCM. This activates or opens the actuators(s), allowing flow through these loops on the manifold. Once the actuator(s) have opened to a minimal position, an end switch inside the actuator(s) will close, illuminating the red light on the ZCM. When the end switch closure is detected, the contacts between ES-ES terminals will close, energizing the appropriate third-party mixing control. Following this control procedure will eliminate any "dead-head" circulator conditions for the radiant circulators (SP1/SP2). The actuators must be open before the circulator will operate.

The ES terminals are considered "dry" contacts. This means any wiring connected to these terminals will require an auxiliary power source. In this schematic, there is a generic reference to a third-party mixing control.

Important: Consult the manufacturer's wiring schematic for that control to verify if an external transformer will be required. When a heat demand occurs on either control, the secondary pumps (SP1/SP2) will run continuously until the heat demand has ended. At the same time, the injection pumps (IP1/IP2) will become active. These will automatically adjust to deliver the correct water temperature based on the user set-up information and the current outdoor and supply water temperature.

Typically, the boiler connection on these controls are considered "dry" contacts. This means any wiring connected to these terminals is unpowered and will require an auxiliary power source. In most instances, power is supplied to these contacts from a transformer within the boiler control. Consult the heating equipment manufacturer's wiring schematic for the proper terminals to energize the boiler.

See wiring schematic 14 on page 166.

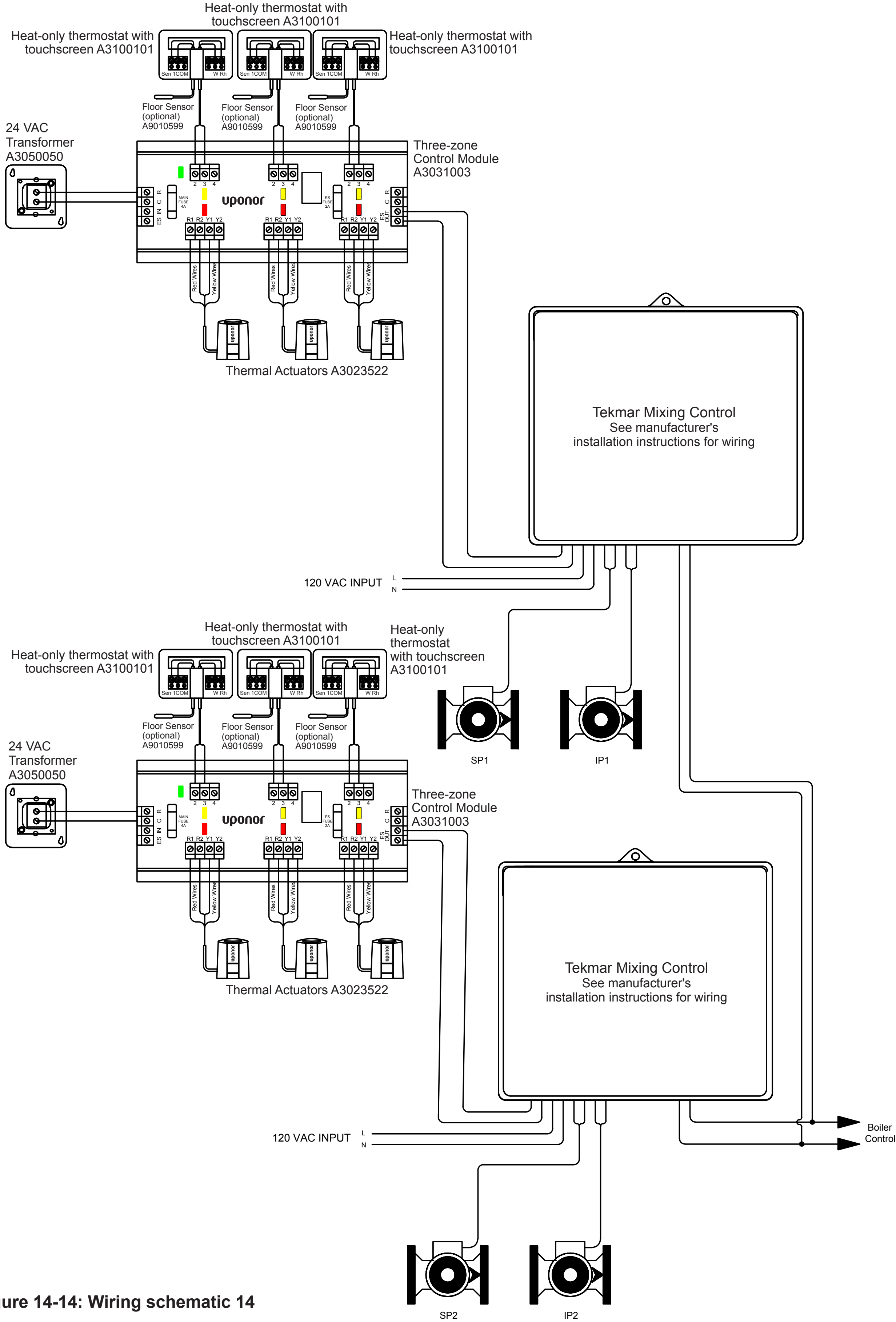


Figure 14-14: Wiring schematic 14

Wiring schematic 15

- A310101 Uponor Thermostats
- A3023522 Thermal Actuators
- A3031003/A3031004 Zone Control Modules (ZCM)
- A3050050 50VA Transformer
- A3040075 / A3040100 Three-way Mixing Valve
- A3010100 Single-pump Relay
- Taco SR-504 Multiple-pump Relay

Overview: Multiple zone control and boiler enable using Uponor Thermostats, Uponor Actuators, the Uponor Zone Control Module (ZCM), the Uponor Transformer, the Uponor Transformer, the Uponor Three-way Mixing Valve and relays to control multiple radiant supply water temperatures, high temperature baseboard and domestic hot water (DHW).

Sequence of operation: On a call for heat, the Uponor Thermostat sends a signal to the ZCM, illuminating the yellow light for that specific zone. This call for heat sends power to the actuator(s) for that zone, energizing the Y1-Y2 terminals on the ZCM. This activates or opens the actuators(s), allowing flow through these loops on the manifold. Once the actuator(s) have opened to a minimal position, an end switch inside the actuator(s) will close illuminating the red light on the ZCM. When the end switch closure is detected, the contacts between ES-ES terminals will close, energizing the pump wired to the Taco relay panel. Following this control procedure will eliminate any "dead-head" circulator conditions for the radiant circulators (P2/P3). The actuators must be open before the circulator will operate.

The single thermostat for the high temperature baseboard is directly connected to the pump relay panel. A call for heat will activate P4 and circulate continuously until the need for heating has ended. Heating calls from ZCMs or the single thermostat will all activate the primary pump (P1) and will run continuously until all heating calls have ended, unless there is a heating need for the domestic hot-water tank. There is an aquastat that measures the tank temperature. Once that falls below the differential, the aquastat will close and energize the DHW pump and turn the other pumps (P1, P2, P3) off to "prioritize" the hot-water demand. The primary pump (P1) will continue to run. Once the domestic hot water call is satisfied, the other pumps will return to normal operation, providing the heating demand still exists.

Power is supplied to the Three-way Mixing Valve from an external transformer. Note that the Three-way Mixing Valve does not require wiring for a call for heat, only power. This valve will automatically adjust itself to deliver the correct water temperature based on the user set-up information and the current outdoor and supply water temperature. This valve will open and close, mixing the return water from the radiant along with the boiler supply water to achieve the correct temperature based on the supply sensor.

Typically, the boiler connection on these controls are considered dry contacts. This means any wiring connected to these terminals is unpowered and will require an auxiliary power source. In most instances, power is supplied to these contacts from a transformer within the boiler control. Consult the heating equipment manufacturer's wiring schematic for the proper terminals to energize the boiler.

See wiring schematic 15 on page 168.

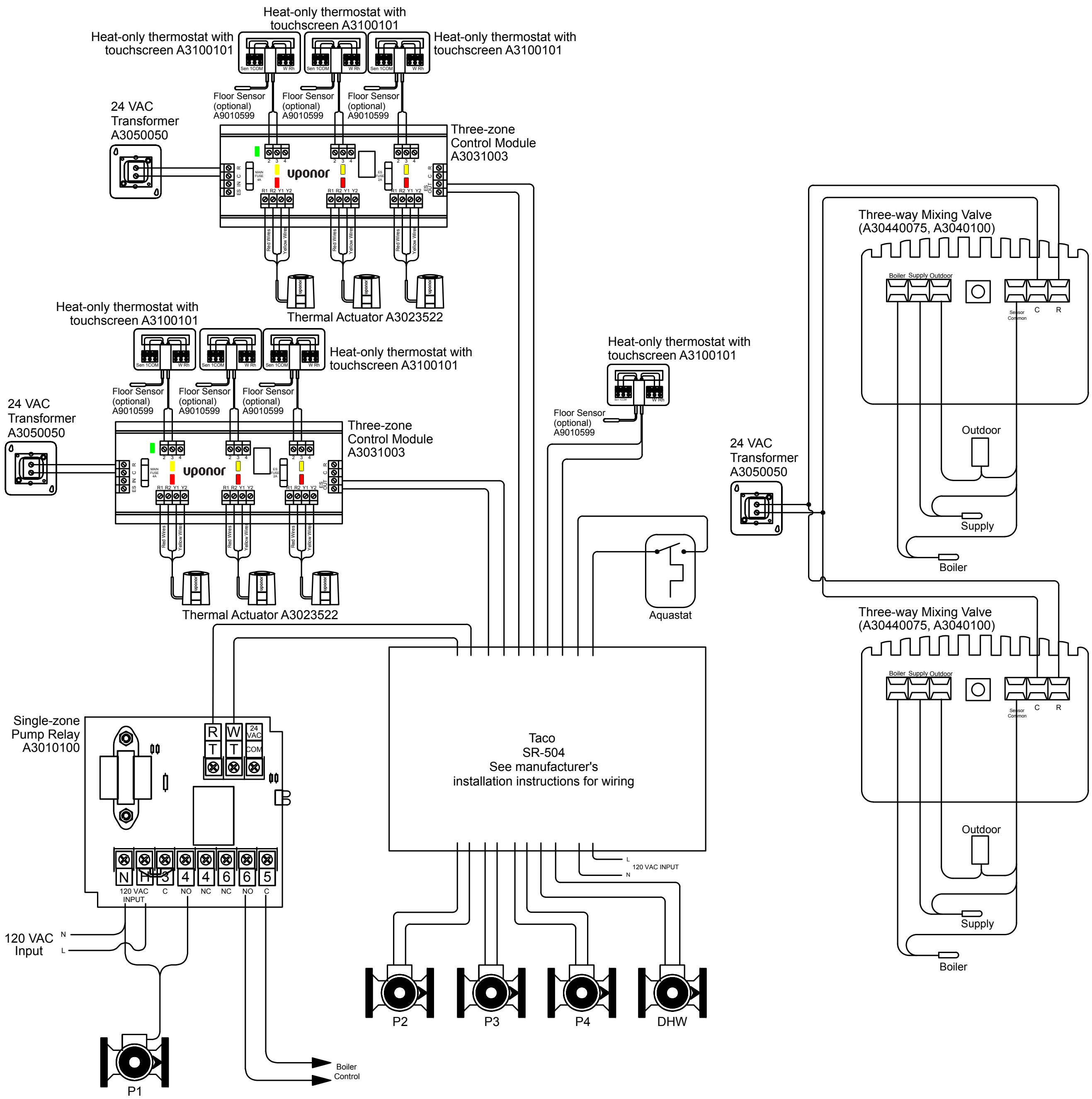


Figure 14-15: Wiring schematic 15

Chapter 15:

Uponor distribution piping

Uponor distribution piping uses Wirsbo hePEX or Ecoflex in lieu of copper or steel piping in traditional hydronic distribution systems. Uponor distribution piping systems can be installed overhead, in a traditional manner, or below-grade — providing design flexibility to the contractor, designer and/or engineer.

Uponor distribution piping is ideal in new construction, and it also has tremendous benefits in both retrofit and remodel applications where piping may be installed without having to cut into walls and ceilings, or without necessitating soldering in potentially dangerous areas.

Distribution solution for any application

Uponor PEX-a straight lengths are available in 20-foot sections up to 3" diameters, enabling contractors to provide an ideal solution for any hydronic distribution heating and/or cooling application. Uponor PEX-a straight lengths offer the finished appearance of rigid piping with all the benefits of PEX-a piping.

For longer continuous runs or other applications in which piping is embedded in a slab, Uponor offers a wide variety of coil lengths in various diameters. See the Uponor Product Catalog for more information.

Ecoflex is a pre-insulated, jacketed product that uses Wirsbo hePEX or Uponor AquaPEX designed for direct burial. Ecoflex is ideal for applications where traditional overhung pipe is expensive or space is at a premium.

PEX piping operating limits

The following tables detail the upper and lower limits for PEX piping of various diameters.

Precise pipe sizing information

For precise sizing data, please refer to the steps below for gpm, velocity and feet of head loss per foot.

1. Determine the BTU/h for the desired zone.
2. Determine the gpm flow rate required to supply the BTU/h to that zone by using the following equation where Delta T (ΔT) is the supply/return temperature differential.

   gpm = BTU/h ÷ (ΔT x 500)

PEX piping operating limits

The following tables detail the upper and lower limits for PEX piping of various diameters.

Piping size	Operating limit	BTU/h	Gallons per minute (gpm)	Velocity (feet per second)	Head-loss (per 100 ft)
5/16"	Lower Limit	4,000	0.4	1.86	6.185
	Upper Limit	15,000	1.5	7.44	71.30
3/8"	Lower Limit	6,000	0.6	1.81	2.08
	Upper Limit	20,000	2.0"	7.71	30.19
½"	Lower Limit	10,000	1.0	1.92	1.73
	Upper Limit	40,000	4.0	7.70	22.46
5/8"	Lower Limit	15,000	1.5	1.86	2.61
	Upper Limit	60,000	6.0	7.44	33.88
¾"	Lower Limit	20,000	2.0	1.81	2.08
	Upper Limit	85,000	8.5	7.71	30.19
1"	Lower Limit	35,000	3.5	1.92	1.73
	Upper Limit	140,000	14.0	7.70	22.46
1¼"	Lower Limit	50,000	5.0	1.84	1.26
	Upper Limit	210,000	21.0	7.72	17.88
1½"	Lower Limit	70,000	7.0	1.85	1.05
	Upper Limit	300,000	30.0	7.92	15.44
2"	Lower Limit	120,000	12.0	1.85	0.76
	Upper Limit	520,000	52.0	8.00	11.50
2½"	Lower Limit	180,000	18.0	1.82	0.58
	Upper Limit	780,000	78.0	7.88	8.74
3"	Lower Limit	260,000	26.0	1.85	0.49
	Upper Limit	1,120,000	112.0	7.96	7.25
3½"	Lower Limit	350,000	35.0	1.84	0.41
	Upper Limit	1,500,000	150.0	7.91	6.02
4"	Lower Limit	450,000	45.0	1.83	0.35
	Upper Limit	1,950,000	195.0	7.93	5.21

Note: The values above assume a 160°F supply water temperature, a 20°F supply/return temperature difference, and velocity between 1.75 and 8.0 ft/sec.

Table 15-1: Recommended PEX-a piping size limits

3. Determine the velocity of the fluid in the piping using the calculated gpm and the pipe interior diameter (i.d.) in inches by using the following equation.

   $V = 0.408496 \times (gpm \div i.d.^2)$

   Note: In most applications, keep velocity between 1.75 and 8.0 ft/sec.

4. Determine the feet of head loss per foot, with 160°F supply water temperature, using the gpm and the piping i.d., by using the following equation.

   $\text{Feet of Head Loss/Foot} = 0.0008436 \times (gpm^{1.85} \div i.d.^{4.8655})$

5. For a supply water temperature not equal to 160°F, multiply the head loss (from step 4) by the appropriate temperature correction factor from **Table 15-3** to yield the correct head loss per foot for systems using 100% water.

6. For systems that use a glycol mixture, multiply the head loss (from step 5) by the appropriate glycol correction factor from the table below to yield the correct result.

100% Water	30% Glycol	40% Glycol	50% Glycol
1.00	1.24	1.33	1.40

Table 15-2: Glycol correction factors

See **Appendix G** for pressure loss and velocity tables.

Distribution pipe heat loss

Heat loss in distribution systems is also a very important parameter. For example, a zone may need 40,000 BTU/h to be satisfied, but that does not include the heat loss that occurs when transporting the energy to the zone. **Figure 15-1** illustrates the heat loss per foot when using PEX-a as a distribution system.

200°F	180°F	160°F	140°F	120°F	100°F	80°F	60°F	40°F
0.96	0.98	1	1.02	1.05	1.1	1.14	1.2	1.3

Table 15-3: Temperature correction factor

Figure 15-1: Pre-insulated Uponor PEX piping

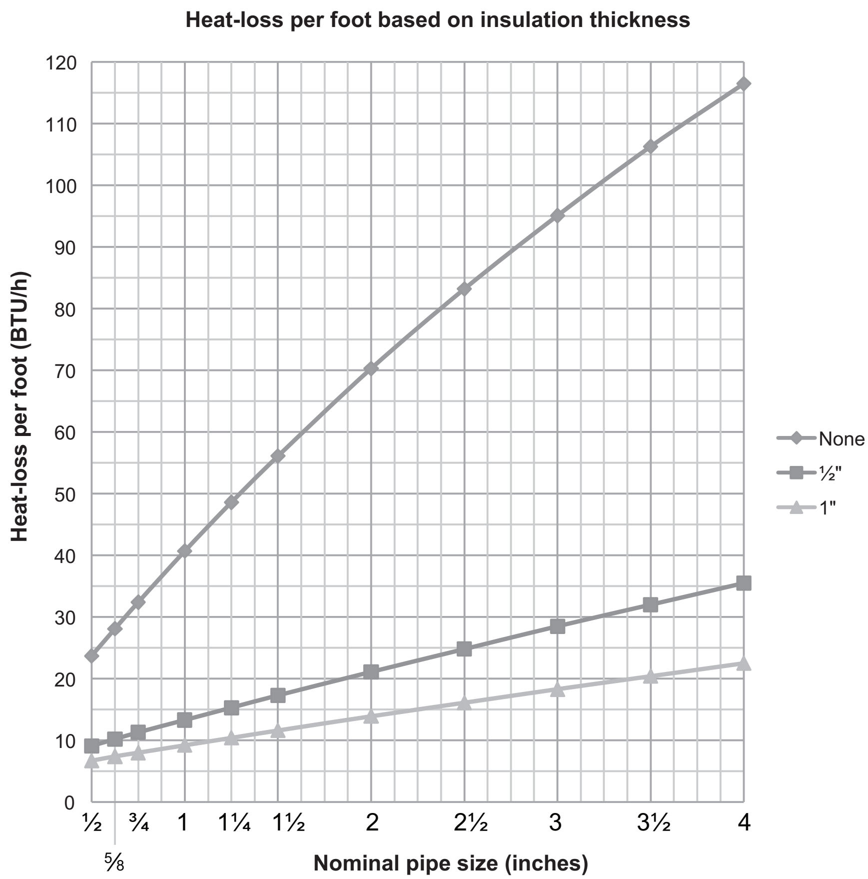


Figure 15-2: Distribution pipe heat-loss per foot

Figure 15-2 is based on the following set of parameters: a temperature differential between the ambient air and the water flowing in the pipe of 90°F, turbulent flow at 8 ft/sec, insulation conductivity is constant at 0.021 BTU/hr/ft/°F heat transfer coefficient off the outer surface of 2.2 BTU/hr/ft²/°F.

Chapter 16:
Wood floors

Uponor radiant floor heating systems can be successfully installed in a variety of floor constructions under a variety of floor coverings. Among the various floor coverings, wood floors present some unique design challenges. The designer and contractor should understand the boundaries of wood floor coverings and the methods used to maximize effectiveness. Communication between the heating contractor and the wood floor installer is key to a successful installation.

Wood flooring materials are fairly resistant to heat transfer (approximate R-value = 1 per inch). Nonetheless, wood floors can work effectively in conjunction with radiant floor heating systems when designed appropriately. Resistance to heat transfer is a significant factor in the design of a well-functioning radiant floor heating system — for all floor coverings, including wood. Pay close attention to the supply water temperature and the resulting effective floor surface temperature. Wide temperature differentials (greater than 60°F) from the bottom of the wood flooring to the surface can potentially damage the floor. Please contact the wood flooring manufacturer for safe limitations, as they can vary from product to product.

Design with wood floors

When designing any radiant panel heating system, it is important to first verify the heating load. In particular, it is essential to be precise in determining the amount of energy necessary to heat the space served by a wood-covered radiant floor. The Uponor radiant design program can help with this task. To assist with the heat-loss analysis, the R-values of various wood-flooring materials are listed in **Appendix D**.

After the heat-loss analysis is complete, consult the appropriate chart to determine the floor surface temperature and supply water temperature necessary to meet the calculated heating load. The surface temperature of a wood floor should not exceed 80°F. Surface temperatures above 80°F may, over time, cause the wood floor to become excessively dry. Such drying may cause shrinkage and exaggerate joint separation. If the design requires higher surface temperatures, consult the wood flooring manufacturer for maximum temperature limits.

Uponor's recommended wood floor maximum heating loads at 65°F room setpoint temperature and 80°F floor surface temperature is 30 BTU/h/ft^2. The recommended wood floor maximum heating load at 70°F room setpoint temperature is 20 BTU/h/ft^2.

Moisture and wood floors

When wood absorbs moisture, it swells. When wood loses moisture, it shrinks.

Sources of moisture from below include inadequate moisture barrier, ground water wicking through the slab or an unsealed subfloor. Moisture from above is generally the result of high relative humidity. If moisture negatively affects a wood floor, the source of the moisture affects the changes that one will see in the floor.

If the moisture content of the wood is relatively high near the bottom of the plank, the plank will cup upward on the edges. Cupping due to moisture below exaggerates cracks in the wood (see **Figure 16-1**).

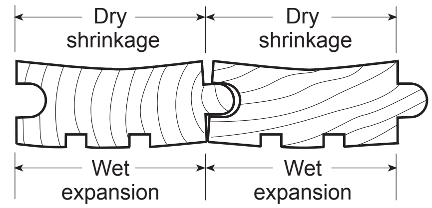


Figure 16-1: Cupping of wood floor

If the moisture content is relatively high near the top surface of the plank, it will crown downward on the edges (see **Figure 16-2**).

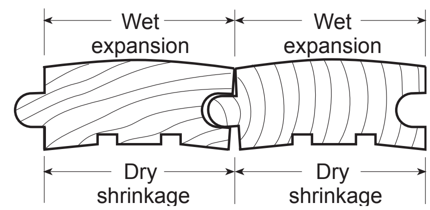


Figure 16-2: Crowning of wood floor

Cupping and crowning also occur because of moisture loss in wood floors. If the installed wood floor has high moisture content, the eventual drying can cause cupping or crowning regardless of the type of heating system used.

The wood flooring installer should follow the flooring manufacturer's installation manual or National Wood Flooring Association (NWFA) manual for acclimation and installation of the wood.

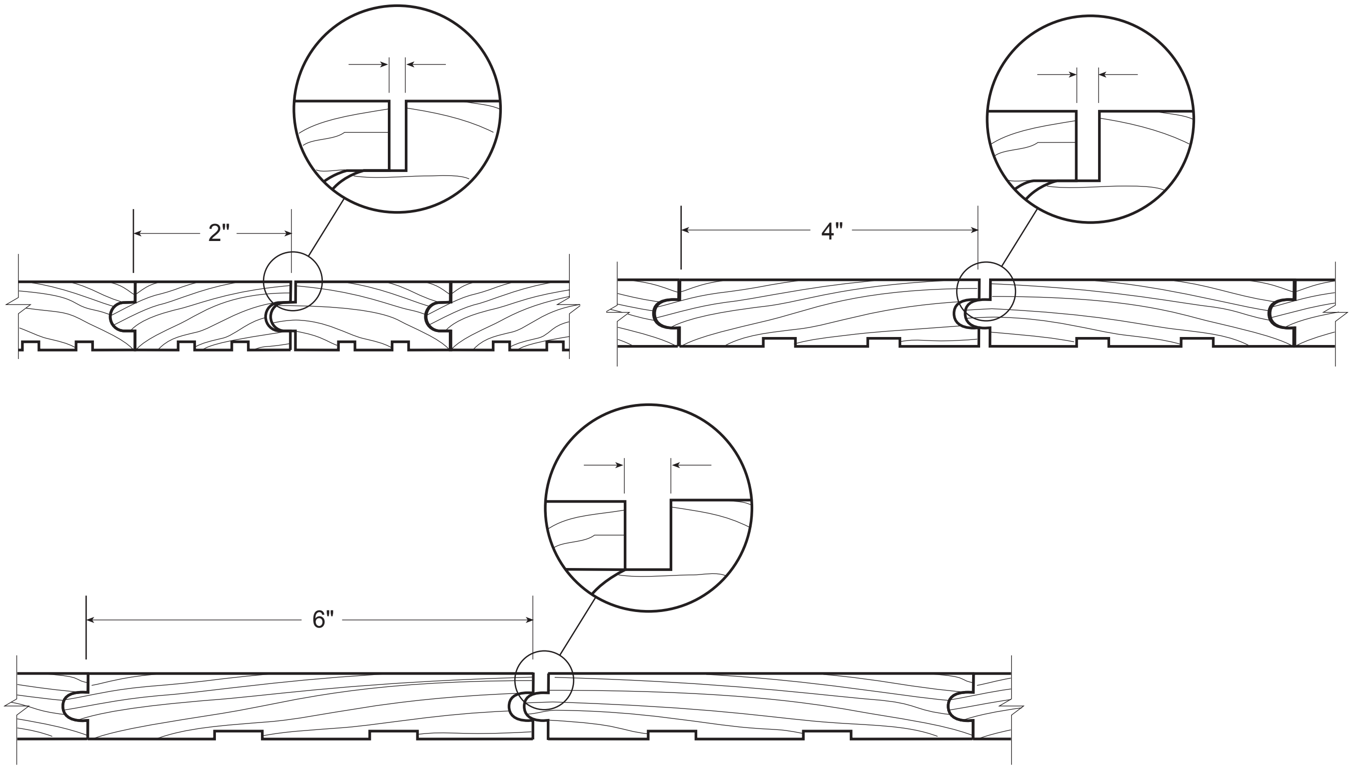


Figure 16-3: Board shrinkage and separation

Note: Never use the radiant system to speed up the acclimation.

Moisture changes will affect the width of boards proportionately. Wider-cut boards will shrink more than narrow boards. Separations between boards may be cumulative (see **Figure 16-3**).

Cumulative separation can be limited by installing the boards parallel to the longer dimension of the room (see **Figure 16-4**).

Selecting a wood floor with beveled edges helps reduce the appearance of shrinkage cracks (see **Figure 16-5**).

Panelization — Panelization is a phenomenon that occurs as a result of the wood planks bonding to adjacent planks within the floor. Bonding results from the adhesive or surface finish hardening between the planks. When shrinkage occurs, the bonding causes larger than normal cracks because the combined shrinkage of several planks is concentrated in fewer separations or cracks (see **Figure 16-6**).

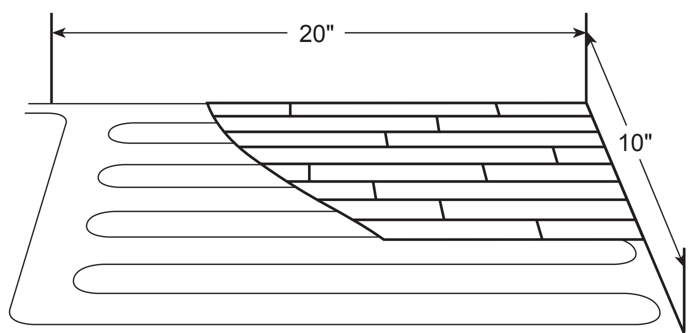


Figure 16-4: Wood floor installation to minimize cumulative separation

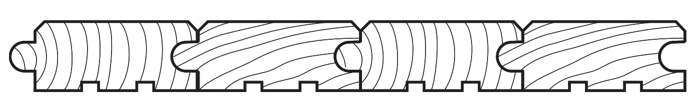


Figure 16-5: Wood floor with beveled edge

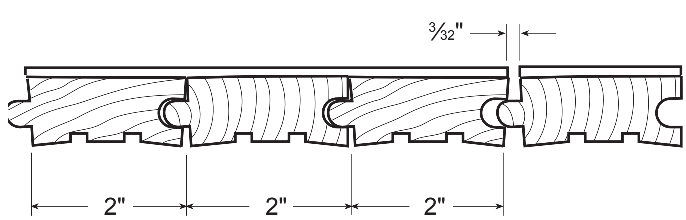


Figure 16-6: Panelization of wood floor

Laminate floors

Laminate wood-floor systems provide solutions to the potential problems associated with ¾-inch solid wood floors. The most significant advantage of laminate floors is their ability to resist shrinkage. The shrinkage, cupping or crowning that occurs with solid wood floors is not likely to occur with laminate wood floors because they are biaxially oriented (similar to plywood). Also, laminate wood floors are typically thinner than ¾-inch solid wood floors, and they have less resistance to the radiant heat (see **Figure 16-7**).

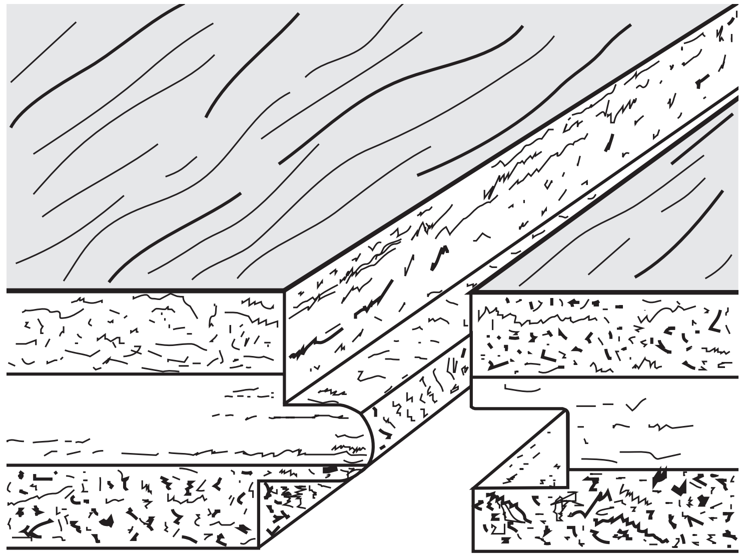


Figure 16-7: Laminate wood floor

Installation

Wood floors can be installed over many types of radiant floor constructions.

Wood floor over poured floor — The wood flooring is nailed to 2x2 sleepers placed between the PEX piping loops. The underlayment is poured to the top of the sleepers, leaving an exposed nailing surface to secure the wood floor. Follow the underlayment or wood manufacturer's recommendations on sealing their product prior to the installation of the wood product (see **Figure 16-8**).

Wood floor glued to underlayment — Underlayment must be dry and sealed prior to the attachment of the adhesive. Follow the wood floor manufacturer's installation manual for specifics on vapor barrier or sealer prior to the installation of their product (see **Figure 16-9**).

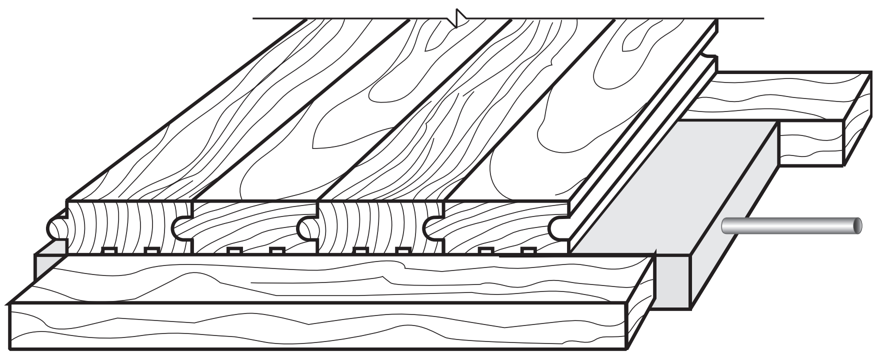


Figure 16-8: Wood floor nailed to sleepers in poured floor

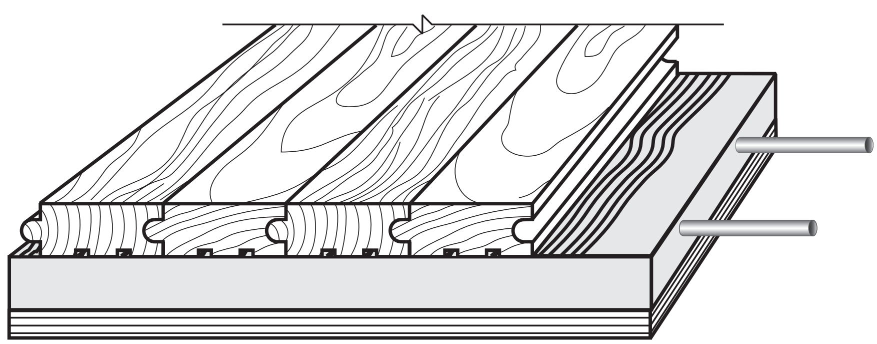


Figure 16-9: Wood floor glued to underlayment

Wood floor nailed to subfloor — Wood must be acclimated to the subfloor. Check the wood floor manufacturer's installation manual for requirements on vapor barriers or sealers. If the piping is mounted to the subfloor, the contractor must mark the piping location so the wood floor installer does not puncture the piping with nails (see **Figure 16-10**).

Wood floor over Quik Trak® — Please refer to the Quik Trak Design and Installation Manual for information.

Wood floor over concrete — Wood floors installed directly on concrete slabs above grade typically require a vapor barrier and/or adhesives resistant to heat. Check with the adhesive manufacturer for specific instructions regarding the application of heat during the curing process (see **Figure 16-11**).

Floating wood floors and engineered hardwoods over concrete or underlayment — Check the wood floor manufacturer's installation manual for requirements on vapor barriers, sealers and/or temperature restrictions (see **Figure 16-12**).

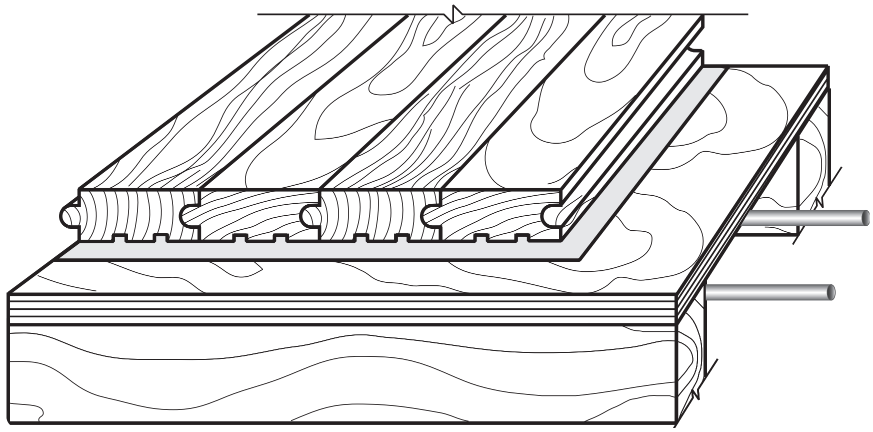


Figure 16-10: Wood floor nailed to subfloor

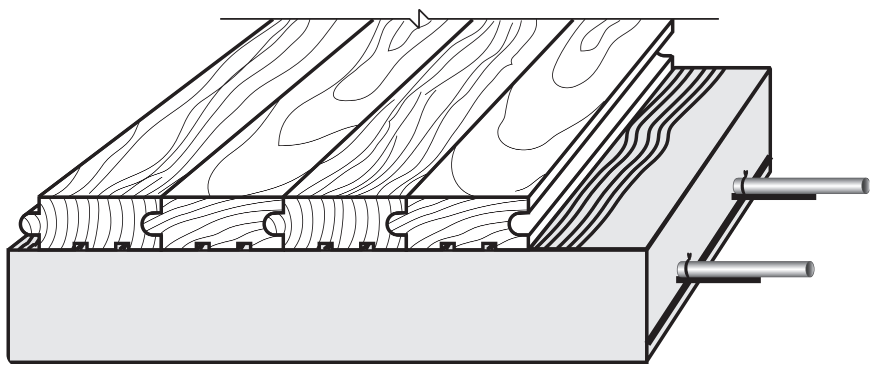


Figure 16-11: Wood floor over concrete

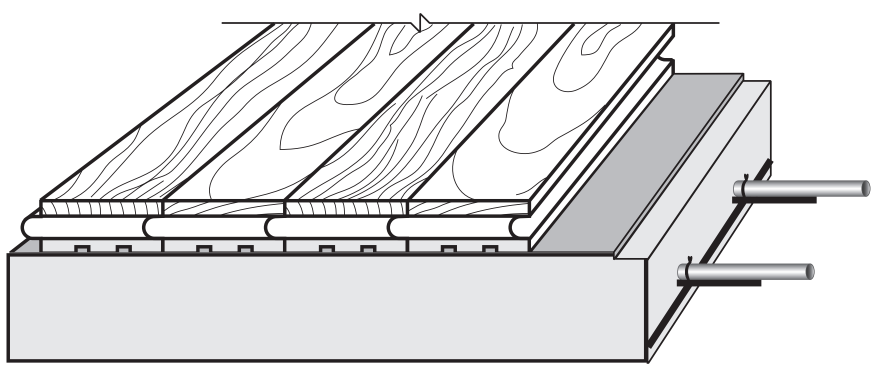


Figure 16-12: Floating wood floor

Appendix A:

Uponor LoopCAD® or Radiant Express worksheet

Project information

Project name ______________________ Date received ______________

Project location ______________________ Date design due ______________

Contact person ______________________ Contact number ______________

Design information

Outdoor design temp.	

Default settings/components***	
Wall R-value	
Ceiling R-value	
Window R-value	
Skylight R-value	
Door R-value	
Air change/hour	

Suspended floors	
Under-floor insulation R-value	

Slab-on-grade floors	
Water table present	
Under-slab R-value	
Water table temperature	
Edge R-value	
Slab depth	
Perimeter R-value	

Notes

Plan information

Floor level ______________

Room name								
Room temp.								
Zone number								
Gross floor area								
Unheated floor area								
Net ceiling area								
Average wall height								
Floor construction*								
Floor type**								
Floor covering***								
Distance to manifold								
Assigned to manifold #								
Wall 1 (L x H)	x	x	x	x	x	x	x	x
Wall 2 (L x H)	x	x	x	x	x	x	x	x
Wall 3 (L x H)	x	x	x	x	x	x	x	x
Door 1 (L x W)	x	x	x	x	x	x	x	x
Door 2 (L x W)	x	x	x	x	x	x	x	x
Window 1 (L x W)	x	x	x	x	x	x	x	x
Window 2 (L x W)	x	x	x	x	x	x	x	x
Skylight (L x W)	x	x	x	x	x	x	x	x

*Floor construction
- Slab on grade = SO
- Slab below grade = SB
- Suspended over heated = SH
- Suspended over unheated = SU

**Floor type
- Concrete slab = C
- Poured underlayment = U
- Single plates = S
- Double plates = D
- Joist (piping alone) = J
- Joist Trak™ = JT
- Quik Trak® = QT

***R-values are in **Appendix D**.

Notes

Appendix B: Radiant design worksheet (Radiant floor)

Radiant floor design worksheet

Project name: ______________________ **Manifold number:** __________

		Loop 1	Loop 2	Loop 3	Loop 4	Loop 5	Loop 6	Loop 7	Loop 8	Loop 9	Loop 10
A	**Room name**										
B	Room setpoint temp. (°F)										
C	Zone number										
D	Upward load (BTU/h/ft²)										
E	Total load (BTU/h/ft²)										
F	Floor surface temp. (°F)										
G	Installation method										
H	Piping size										
I	Floor covering R-value										
J	Differential temp. (°F)										
K	Piping o.c. distance (in)										
L	Supply water temp. (°F)										
M	Active loop length (ft)										
N	Leader loop length (ft)										
O	Total loop length (ft)										
P	Loop flow in gpm										
Q	Loop head pressure (ft)										
R	Loop balancing turns* (TruFLOW)										

Manifold totals

S	Supply water temp. (°F)										
T	Manifold flow in gpm										
U	Highest pressure head (ft)										

A Enter the name of the room. The room may have more than one loop.

B Room setpoint temperature is normally 65°F for radiant floor.

C Zone is equal to thermostat.

D Enter the "Floor Unit Load to Room" value from design program printout (upward load).

E Enter the "Floor Unit Load" value from design program printout (total load).

F (**Row D**/2) + **Row B** = floor surface temperature. Do not exceed 87.5°F for all floors (exception: wood floor limit is 80°F).

*When using TruFLOW manifolds

G Enter the installation method.

H Enter the size of PEX piping for project.

I Refer to **Appendix D** for floor covering information.

J Indicate differential temperature (10°F for residential; 15°F for light commercial; 20°F for commercial).

K Maximum piping o.c. distance is 12" for residential. Do not exceed 9" o.c. under tile or linoleum.

L Use information from **Rows D, G, I, K** with **Appendix E** to obtain the supply water temperature.

M Enter the length of piping installed within the room (i.e., active loop).

N Enter the length of the piping from the room being heated to the respective manifold and multiply by 2 to account for both the supply and return.

O Use formula: (**Row M** + **Row N**) = total loop length.

P Use the values in **Rows E** and **M** with **Appendix F** to obtain the flow per loop.

Q Use the values in **Rows H** and **P** with **Appendix G** to obtain the head pressure per loop. Choose the appropriate solution (water or water/glycol solution).

R These cells are calculated after the design is completed. Use the formula: (current loop value in **Row O** x 4) / longest loop length on the manifold when using TruFLOW manifolds.

S Enter highest temperature from **Row L**.

T Add and enter all values from **Row P**.

U Enter highest value from **Row Q**.

Appendix B: Radiant design worksheet (Quik Trak®)

Quik Trak® design worksheet

Project name: ____________________ **Manifold number:** _____

		Loop 1	Loop 2	Loop 3	Loop 4	Loop 5	Loop 6	Loop 7	Loop 8	Loop 9	Loop 10
A	Room name										
B	Room setpoint temp. (°F)										
C	Zone number										
D	Net floor area (ft^2)										
E	Upward load ($BTU/h/ft^2$)										
F	Total load ($BTU/h/ft^2$)										
G	Floor surface temp. (°F)										
H	Piping size										
I	Floor covering R-value										
J	Differential temp. (°F)										
K	Piping o.c. distance (in)										
L	Supply water temp. (°F)										
M	Active loop length										
N	Leader loop length										
O	Total loop length										
P	Loop flow in gpm										
Q	Loop head pressure (ft)										
R	Loop balancing turns										
S	Quik Trak panels										
T	Quik Trak returns										

Manifold totals

U	Supply water temp. (°F)	
V	Manifold flow in gpm	
W	Highest pressure head (ft)	

A Enter the name of the room. The room may have more than one loop.

B Room setpoint temperature is normally 65°F for radiant floor.

C Zone is equal to thermostat.

D Enter the amount of square footage used in the room.

E Enter the "Floor Unit Load to Room" value from design program printout (upward load).

F Enter the "Floor Unit Load" value from design program printout (total load).

G (**Row E**/2) + **Row B** = floor surface temperature. Do not exceed 87.5°F for all floors (exception: wood floor limit is 80°F).

H The only piping size available for Quik Trak is 5⁄16" Wirsbo hePEX.

I Refer to **Appendix D** for floor covering information.

J Indicate differential temperature (20°F for Quik Trak).

K Piping o.c. distance is 7" for Quik Trak.

L Use information from **Rows E, I, K** with **Appendix E** to obtain the supply water temperature.

M Enter the length of piping installed within the room (i.e., active loop).

N Enter the length of the piping from the room being heated to the respective manifold and multiply by 2 to account for both the supply and return.

O Use formula: (**Row M** + **Row N**) = total loop length.

P Use the values in **Rows F** and **M** with **Appendix F** to obtain the flow per loop.

Q Use the values in **Rows O** and **P** with **Appendix G** to obtain the head pressure per loop. Choose the appropriate solution (water or water/glycol solution).

R These cells are calculated after the design is completed. Use the formula: (current loop value in **Row O** x 4) / longest loop length on the manifold when using TruFLOW manifolds.

S Enter the number of panels. (For 7" o.c., multiply **Row D** by 0.386.)

T Enter the number of returns. (For 7" o.c., multiply **Row D** by 0.043.)

U Enter highest temperature from **Row L**.

V Add and enter all values from **Row P**.

W Enter highest value from **Row Q**.

Radiant ceiling design worksheet

Project name: ______________________ **Manifold number:** _____

Note: Ensure insulation between floors is at least R-19. Ensure ceiling exposed to the attic is at least R-38 (higher if required by code).

		Loop 1	Loop 2	Loop 3	Loop 4	Loop 5	Loop 6	Loop 7	Loop 8	Loop 9	Loop 10
A	**Room name**										
B	Room setpoint temp. (°F)										
C	Zone number										
D	BTU/h										
E	Ceiling square footage										
F	BTU/h/ft²										
G	Active square footage										
H	Ceiling surface temp. (°F)										
I	Piping size										
J	Differential temp. (°F)										
K	Piping o.c. distance (in)										
L	Supply water temp. (°F)										
M	Active loop length										
N	Leader loop length										
O	Total loop length										
P	Loop flow in gpm										
Q	Feet of head drop per loop										
R	Loop balancing turns* (TruFLOW)										

Manifold totals

S	Supply water temp. (°F)										
T	Manifold flow in gpm										
U	Highest pressure head (ft)										

A Enter the name of the room. The room may have more than one loop.

B Room setpoint temperature is normally 70°F for radiant ceiling.

C Zone is equal to thermostat. First zone is 1.

D Enter the "Total Unit Load" value from radiant design printout in BTU/h.

E Enter the ceiling square footage.

F Divide Row D by **Row E**. If value is less than 40 BTU/h/ft², divide **Row D** by 40.

*When using TruFLOW manifolds

G If **Row F** was obtained through dividing by 40, then divide **Row E** by 40. If Row F was greater than 40 BTU/h/ft², then enter the value from **Row E**.

H **Row F** divided by 1.6 plus the value in **Row B** equals the ceiling surface temperature. Do not exceed 100°F for ceilings at 8 feet or less. Do not exceed 110°F for ceilings greater than 8 feet.

I Enter the size of PEX piping for project (½" Wirsbo hePEX piping).

J Use 10°F differential temperature for all radiant ceiling applications.

K Maximum piping o.c. distance is 12" for all radiant ceiling applications.

L Use information from Rows F and J with **Appendix E** to obtain the supply water temperature.

M Multiply **Row G** by the on-center factor of 1.5.

N Enter the length of the piping from the room being heated to the respective manifold and multiply by 2 to account for both the supply and return.

O Use formula: (**Row M** + **Row N**) = total loop length.

P Use the values in **Rows F** and **L** with **Appendix F** to obtain the flow per loop.

Q Use the values in **Rows I, L** and **P** with **Appendix G** to obtain the feet of head pressure drop per foot. Next, multiply this value by **Row O** to obtain the feet of head drop per loop.

R These cells are calculated after the design is completed. Use the formula: (current loop value in Row O x 4) / longest loop length on the manifold when using TruFLOW manifolds.

S Enter highest temperature from **Row L**.

T Add all values in **Row P**.

U Enter highest value from **Row Q**.

Appendix B: Radiant design worksheet (radiant floor)

Radiant floor design worksheet

Project name: ______________________ **Manifold number:** __________

		Loop 1	Loop 2	Loop 3	Loop 4	Loop 5	Loop 6	Loop 7	Loop 8	Loop 9	Loop 10
A	**Room name**										
B	Room setpoint temp. (°F)										
C	Zone number										
D	Upward load (BTU/h/ft²)										
E	Total load (BTU/h/ft²)										
F	Floor surface temp. (°F)										
G	Installation method										
H	Piping size										
I	Floor covering R-value										
J	Differential temp. (°F)										
K	Piping o.c. distance (in)										
L	Supply water temp. (°F)										
M	Active loop length (ft)										
N	Leader loop length (ft)										
O	Total loop length (ft)										
P	Loop flow in gpm										
Q	Loop head pressure (ft)										
R	Loop balancing turns* (TruFLOW)										

Manifold totals

S	Supply water temp. (°F)										
T	Manifold flow in gpm										
U	Highest pressure head (ft)										

A Enter the name of the room. The room may have more than one loop.

B Room setpoint temperature is normally 65°F for radiant floor.

C Zone is equal to thermostat.

D Enter the “Floor Unit Load to Room” value from design program printout (upward load).

E Enter the “Floor Unit Load” value from design program printout (total load).

F (**Row D**/2) + **Row B** = floor surface temperature. Do not exceed 87.5°F for all floors (exception: wood floor limit is 80°F).

*When using TruFLOW manifolds

G Enter the installation method.

H Enter the size of PEX piping for project.

I Refer to **Appendix D** for floor covering information.

J Indicate differential temperature (10°F for residential; 15°F for light commercial; 20°F for commercial).

K Maximum piping o.c. distance is 12" for residential. Do not exceed 9" o.c. under tile or linoleum.

L Use information from **Rows D, G, I, K** with **Appendix E** to obtain the supply water temperature.

M Enter the length of piping installed within the room (i.e., active loop).

N Enter the length of the piping from the room being heated to the respective manifold and multiply by 2 to account for both the supply and return.

O Use formula: (**Row M** + **Row N**) = total loop length.

P Use the values in **Rows E** and **M** with **Appendix F** to obtain the flow per loop.

Q Use the values in **Rows H** and **P** with **Appendix G** to obtain the head pressure per loop. Choose the appropriate solution (water or water/glycol solution).

R These cells are calculated after the design is completed. Use the formula: (current loop value in **Row O** x 4) / longest loop length on the manifold when using TruFLOW manifolds.

S Enter highest temperature from **Row L**.

T Add and enter all values from **Row P**.

U Enter highest value from **Row Q**.

Appendix C:
Radiant surface temperature charts

Radiant floor

Surface temperatures

Floor surface temperature = (BTU/h/ft² ÷ 2) + room setpoint

Room setpoint											
	75°F	80.0	82.5	85.0	87.5	90.0	92.5	95.0	97.5	100.0	102.5
	72°F	77.0	79.5	82.0	84.5	87.0	89.5	92.0	94.5	97.0	99.5
	70°F	75.0	77.5	80.0	82.5	85.0	87.5	90.0	92.5	95.0	97.5
	68°F	73.0	75.5	78.0	80.5	83.0	85.5	88.0	90.5	93.0	95.5
	65°F	70.0	72.5	75.0	77.5	80.0	82.5	85.0	87.5	90.0	92.5
	60°F	65.0	67.5	70.0	72.5	75.0	77.5	80.0	82.5	85.0	87.5
		10.0	**15.0**	**20.0**	**25.0**	**30.0**	**35.0**	**40.0**	**45.0**	**50.0**	**55.0**
		BTU/h/ft²									

Exceeds the maximum recommended surface temperature for hardwood floors

Exceeds the maximum recommended surface temperature for all floors

Figure C-1: Radiant floor surface temperature chart

Radiant ceiling

Surface temperatures

Ceiling surface temperature = (BTU/h/ft² ÷ 1.1) + room setpoint

Room setpoint									
	75°F	84.1	88.6	93.2	97.7	100.0	102.3	106.8	114.4
	72°F	81.1	85.6	90.2	94.7	97.0	99.3	103.8	108.4
	70°F	79.1	83.6	88.2	92.7	95.0	97.3	101.8	106.4
	68°F	77.1	81.6	86.2	90.7	93.0	95.3	99.8	104.4
	65°F	74.1	78.6	83.2	87.7	90.0	92.3	96.8	101.4
	60°F	69.1	73.6	78.2	82.7	85.0	87.3	91.8	96.4
		10.0	**15.0**	**20.0**	**25.0**	**27.5**	**30.0**	**35.0**	**40.0**
		BTU/h/ft²							

Exceeds the maximum recommended surface temperature for 8-foot ceilings
Maximum is 110°F for ceilings higher than 8 feet, but lower than 12 feet.

Figure C-2: Radiant ceiling surface temperature chart

Notes

Appendix D:

R-value charts

Construction materials	⅛"	¼"	⅜"	½"	⅝"	¾"
Plywood (Douglas fir)		0.31	0.47	0.62	0.77	0.93
Oriented strand board (OSB)		0.31	0.47	0.62	0.78	0.94
Asbestos-cement board	0.03	0.06	0.09			
Particle board (underlayment)	0.17	0.33	0.49	0.66	0.82	

Sheet goods

Vinyl	0.20					
Linoleum (uninsulated)	0.20					
Linoleum (insulated)		0.40				

Tiles and stone

Ceramic tile		0.23	0.34	0.45	0.57	0.68
Cork tile	0.28	0.56	0.84			
Limestone			0.38	0.50	0.63	0.76
Quarried stone			0.30	0.40	0.50	0.60
Marble		0.20	0.30	0.40	0.50	0.60
Brick			0.38	0.50	0.63	0.76

Carpeting

Commercial glue down		0.60	0.90			
Acrylic level loop		1.04	1.56	2.08	2.60	3.12
Acrylic plush		0.83	1.25	1.66	2.08	2.49
Polyester plush		0.96	1.44	1.92	2.40	2.88
Nylon saxony		0.88	1.32	1.76	2.20	2.64
Nylon shag		0.54	0.81	1.08	1.35	1.62
Wool plush		1.10	1.65	2.20	2.75	3.30

Carpet pads

Rubber (solid)		0.31	0.47	0.62	0.78	0.93
Rubber (waffled)		0.62	0.93	1.24	1.55	1.86
Hair and jute		0.98	1.47	1.96	2.45	2.94
Prime urethane (2-lb. density)		1.08	1.62	2.16	2.70	3.24
Bonded urethane (4-lb. density)		1.04	1.56	2.08	2.60	3.12
Bonded urethane (8-lb. density)		1.10	1.65	2.20	2.75	3.30

Wood flooring	⅛"	¼"	⅜"	½"	⅝"	¾"
Ash			0.35	0.47	0.59	0.71
Cherry			0.35	0.46	0.58	0.69
Elm			0.33	0.45	0.56	0.67
Redwood			0.51	0.68	0.84	1.01
Maple			0.35	0.46	0.58	0.69
Oak			0.33	0.45	0.56	0.67
Walnut			0.34	0.45	0.57	0.68
Douglas fir			0.40	0.53	0.66	0.80
Southern pine			0.38	0.50	0.62	0.75
Spruce			0.51	0.68	0.84	1.01
Floating wood floor pad	0.20	0.40				

Windows

Single glass	0.91
Single glass with storm	2.00
Double glazed – 3/16" air space	1.61
Double glazed – ¼" air space	1.69
Double glazed – ½" air space	2.04
Double glazed – ¾" air space	2.38
Double glazed – with suspended film	2.77
Double glazed – with 2 suspended films	3.85
Low-E	3.13
Low-E – with suspended film	4.05
Low-E – with 2 suspended films	5.05

Note: The R-values depicted in this chart are representative and may vary by manufacturer. For specific R-values, check with the appropriate floor covering manufacturer.

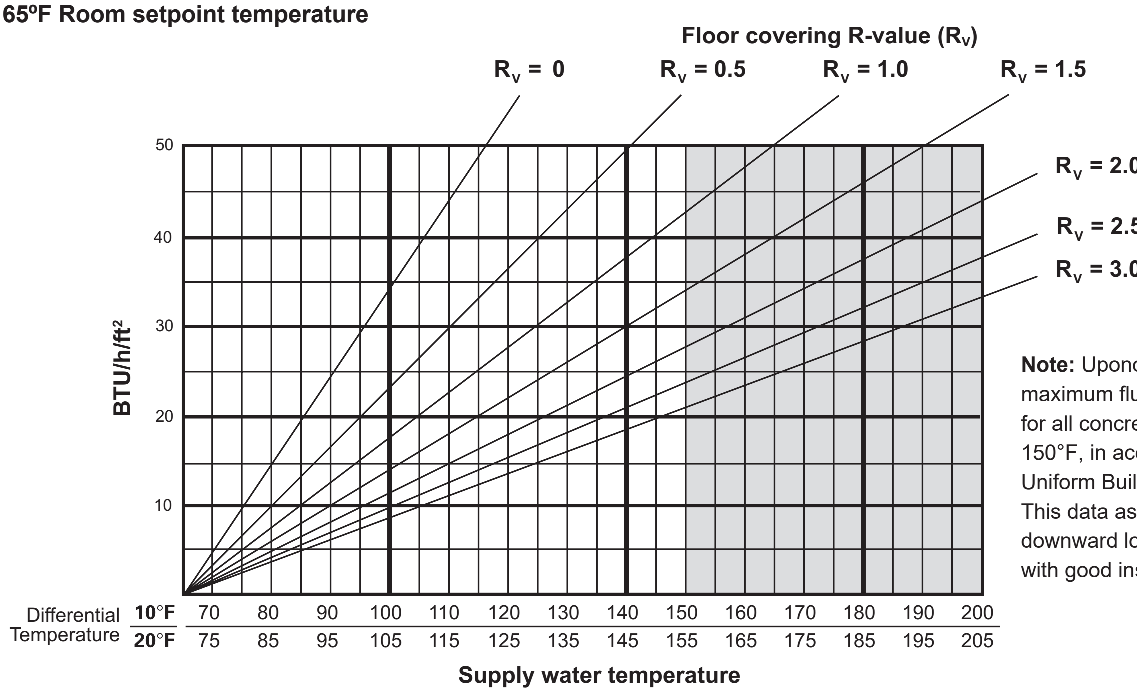
Notes

Appendix E:

Supply water temperature charts

Concrete — 4" slab (12" on center)

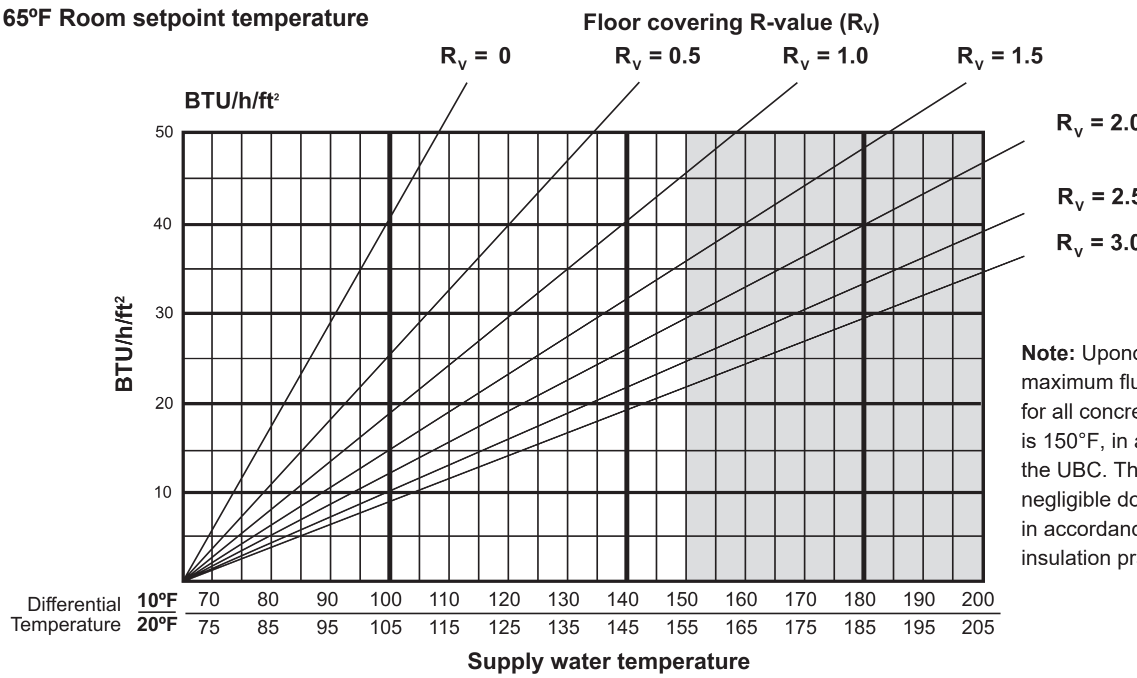
65ºF Room setpoint temperature



Note: Uponor's recommended maximum fluid temperature for all concrete applications is 150°F, in accordance with the Uniform Building Code (UBC). This data assumes negligible downward loss in accordance with good insulation practices.

Concrete — 4" slab (9" on center)

65ºF Room setpoint temperature



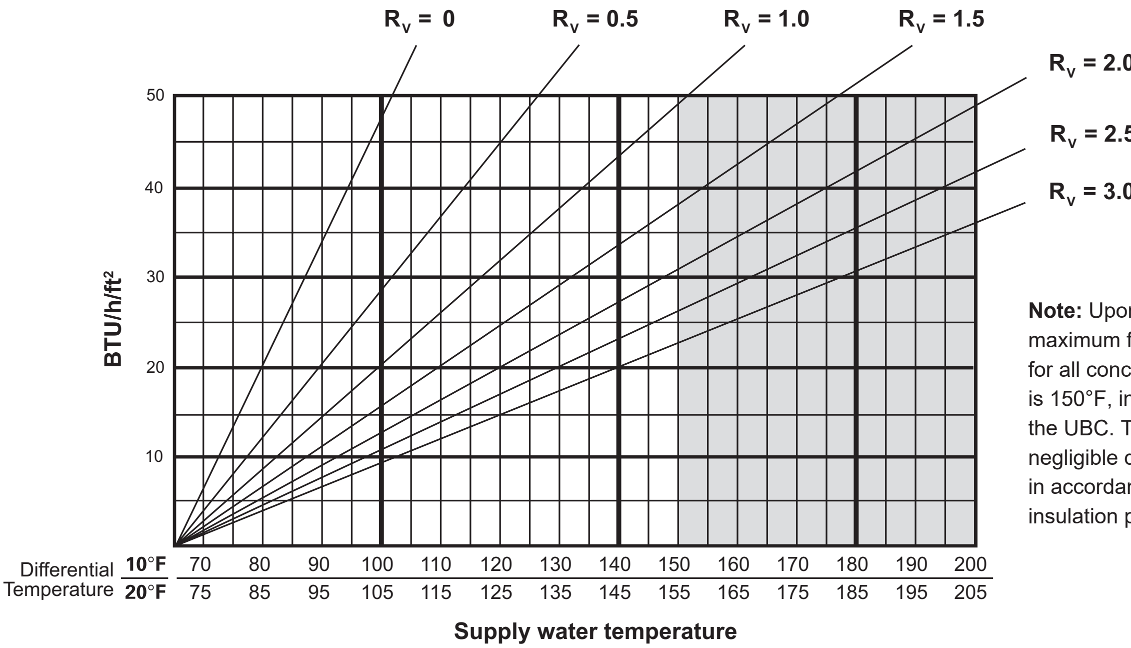
Note: Uponor's recommended maximum fluid temperature for all concrete applications is 150°F, in accordance with the UBC. This data assumes negligible downward loss in accordance with good insulation practices.

Appendix E:

Supply water temperature charts

Concrete — 4" slab (6" on center)

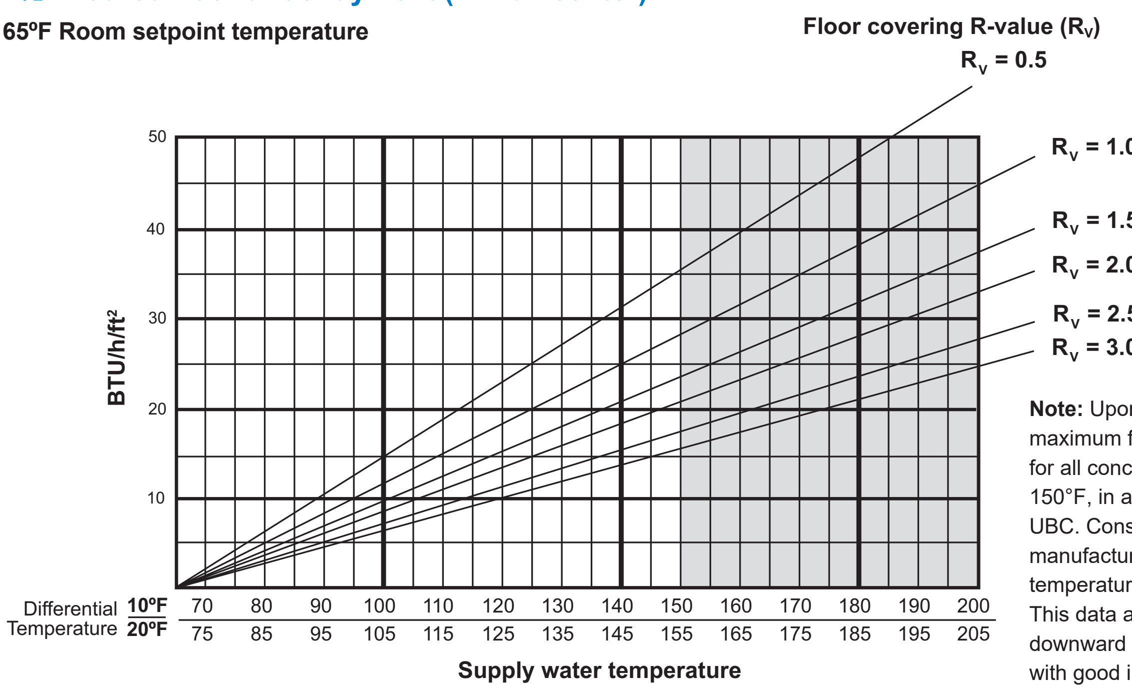
65ºF Room setpoint temperature



Note: Uponor's recommended maximum fluid temperature for all concrete applications is 150°F, in accordance with the UBC. This data assumes negligible downward loss in accordance with good insulation practices.

1½" Poured floor underlayment (12" on center)

65ºF Room setpoint temperature



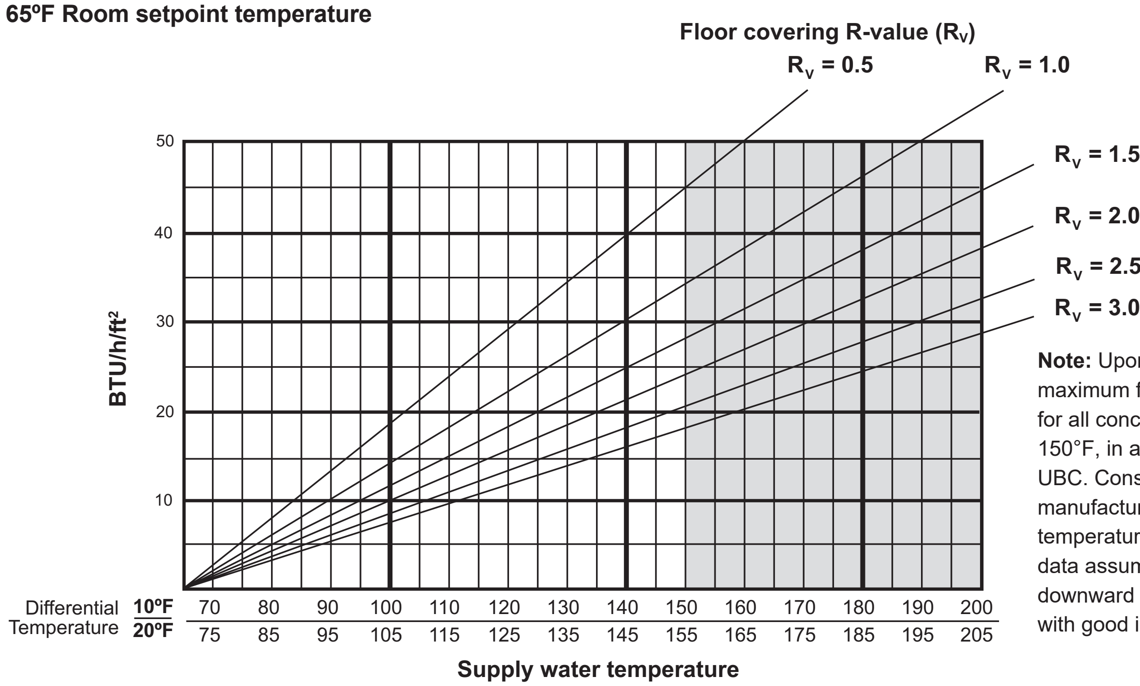
Note: Uponor's recommended maximum fluid temperature for all concrete applications is 150°F, in accordance with the UBC. Consult underlayment manufacturer's recommended temperature limitations.
This data assumes negligible downward loss in accordance with good insulation practices.

Appendix E:

Supply water temperature charts

1½" Poured floor underlayment (9" on center)

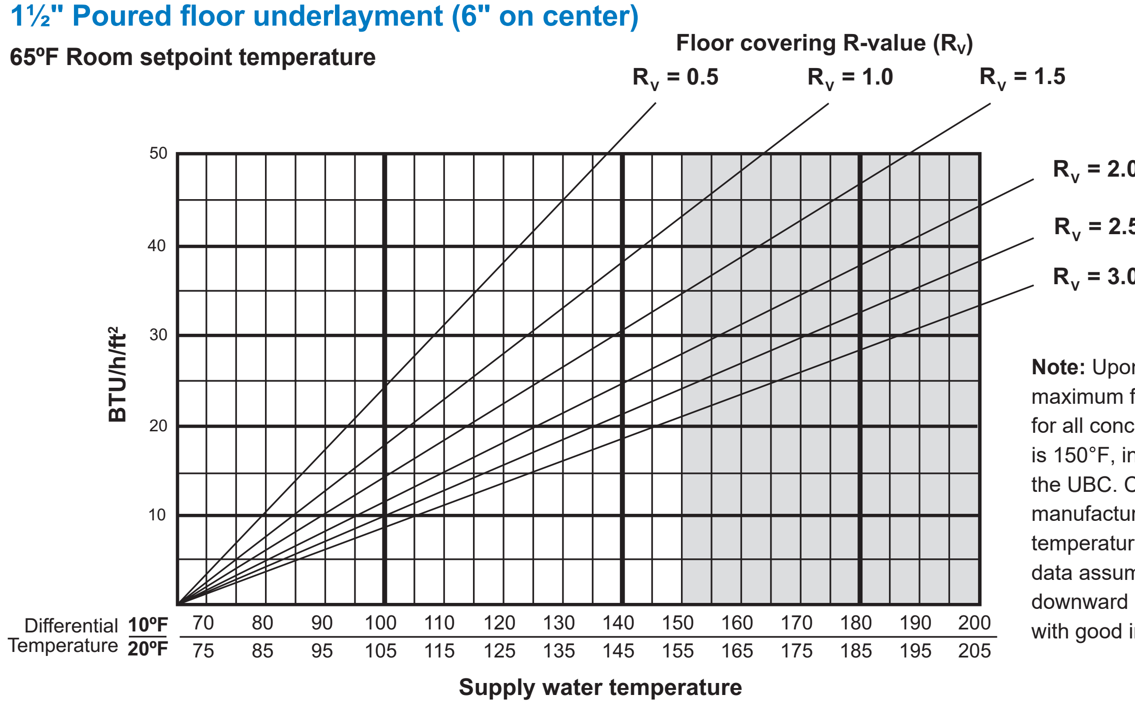
65ºF Room setpoint temperature



Note: Uponor's recommended maximum fluid temperature for all concrete applications is 150°F, in accordance with the UBC. Consult underlayment manufacturer's recommended temperature limitations. This data assumes negligible downward loss in accordance with good insulation practices.

1½" Poured floor underlayment (6" on center)

65ºF Room setpoint temperature



Note: Uponor's recommended maximum fluid temperature for all concrete applications is 150°F, in accordance with the UBC. Consult underlayment manufacturer's recommended temperature limitations. This data assumes negligible downward loss in accordance with good insulation practices.

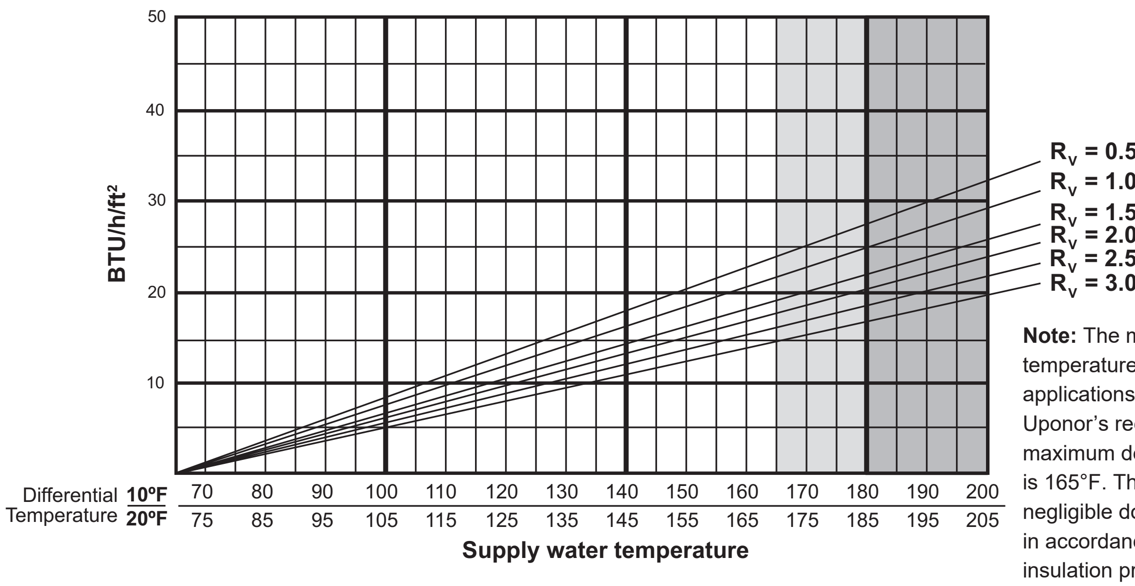
Appendix E:
Supply water temperature charts

Joist heating — no plates (8" on center)

65ºF Room setpoint temperature

Floor covering R-value (R_V)

This temperature chart has already factored in the R-value for a ¾-inch plywood subfloor.



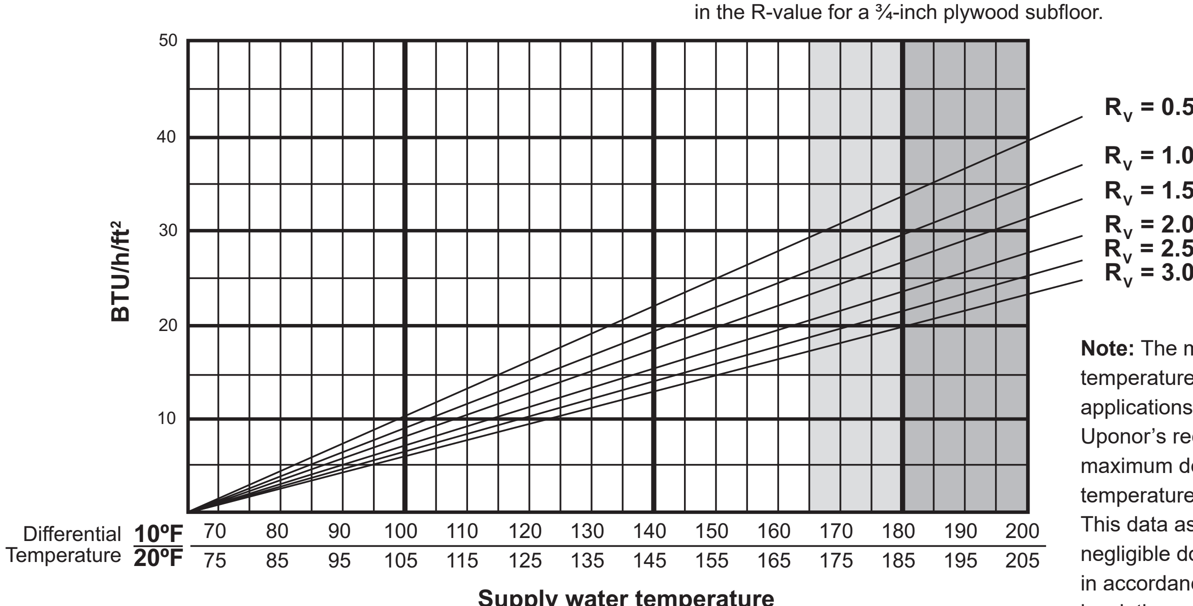
Note: The maximum fluid temperature for all joist applications is 180°F. Uponor's recommended maximum design temperature is 165°F. This data assumes negligible downward loss in accordance with good insulation practices.

Joist heating — double-groove aluminum plates (8" on center)

65ºF Room setpoint temperature

Floor covering R-value (R_V)

This temperature chart has already factored in the R-value for a ¾-inch plywood subfloor.



Note: The maximum fluid temperature for all joist applications is 180°F. Uponor's recommended maximum design temperature is 165°F. This data assumes negligible downward loss in accordance with good insulation practices.

Appendix E:

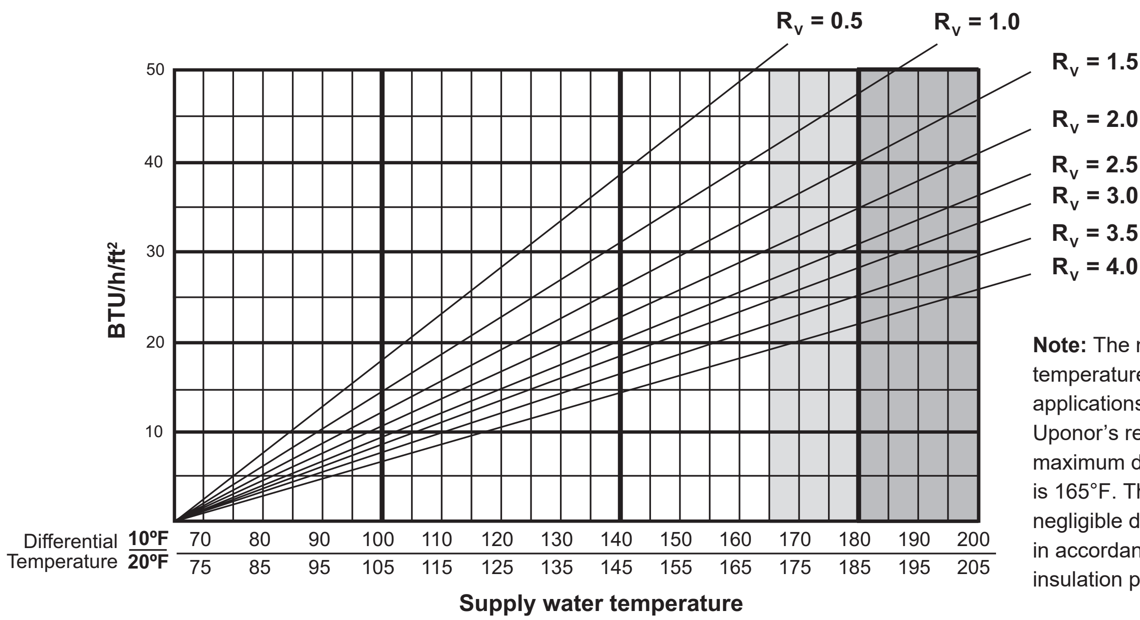
Supply water temperature charts

Joist heating — Joist Trak™ (8" on center)

65ºF Room setpoint temperature

Floor covering R-value (R_v)

This temperature chart has already factored in the R-value for a ¾-inch plywood subfloor.



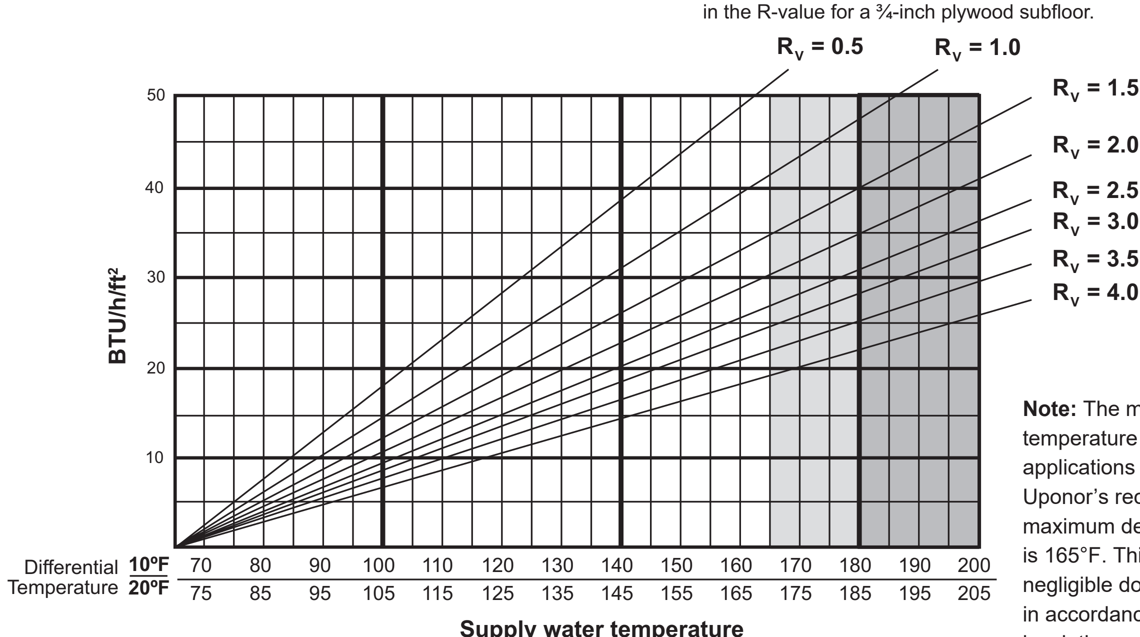
Note: The maximum fluid temperature for all joist applications is 180°F. Uponor's recommended maximum design temperature is 165°F. This data assumes negligible downward loss in accordance with good insulation practices.

Radiant ceiling — Joist Trak (8" on center)

65ºF Room setpoint temperature

Floor covering R-value (R_v)

This temperature chart has already factored in the R-value for a ¾-inch plywood subfloor.



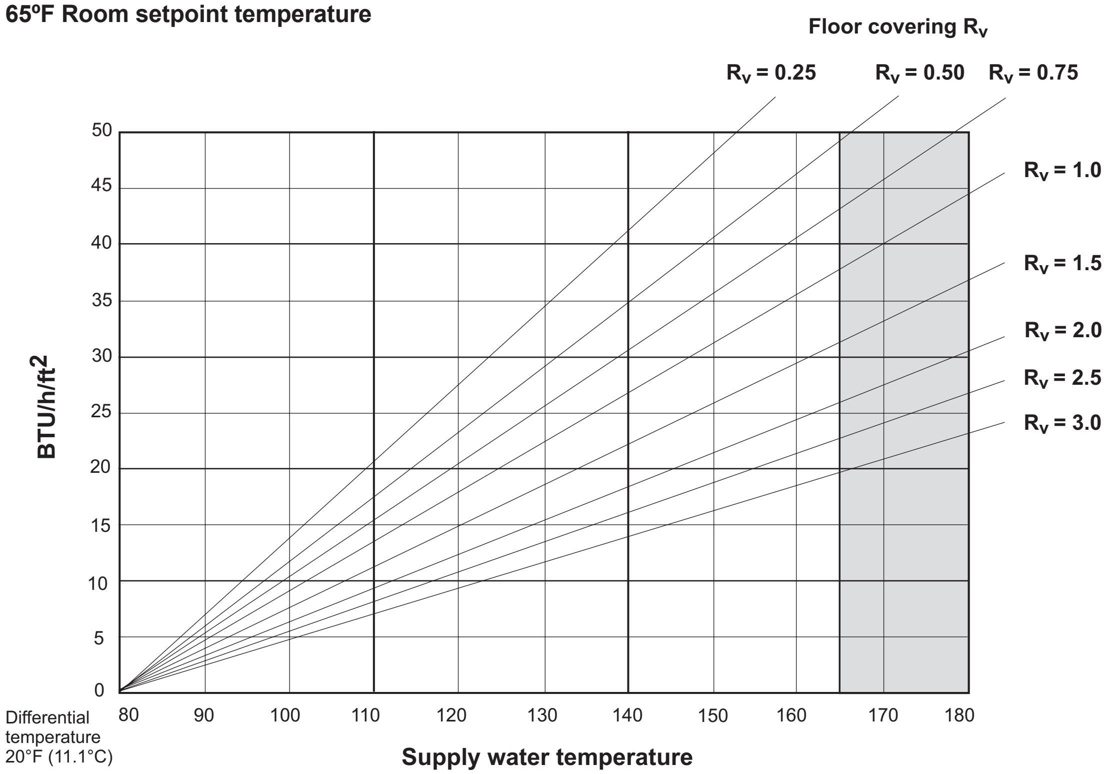
Note: The maximum fluid temperature for all joist applications is 180°F. Uponor's recommended maximum design temperature is 165°F. This data assumes negligible downward loss in accordance with good insulation practices.

Appendix E:

Supply water temperature charts

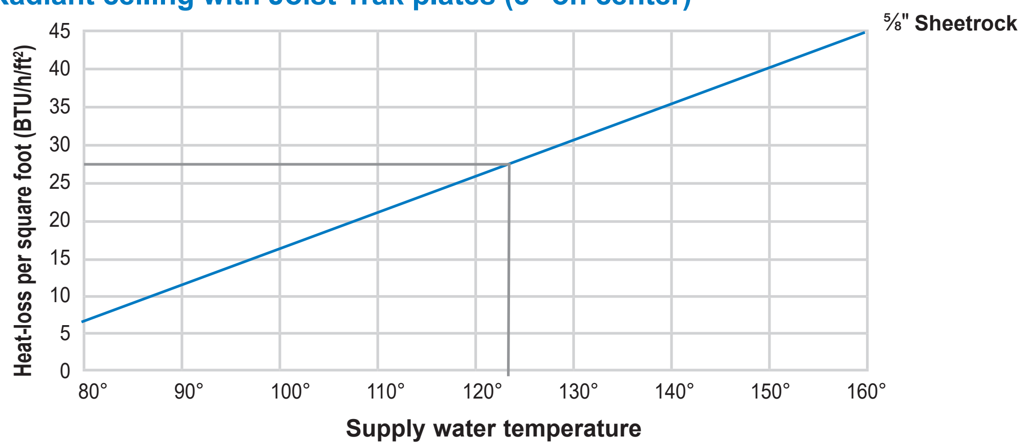
Quik Trak® radiant floor (7" on center)

65ºF Room setpoint temperature



Note: Uponor's recommended maximum design temperature is 165ºF.

Radiant ceiling with Joist Trak plates (8" on center)

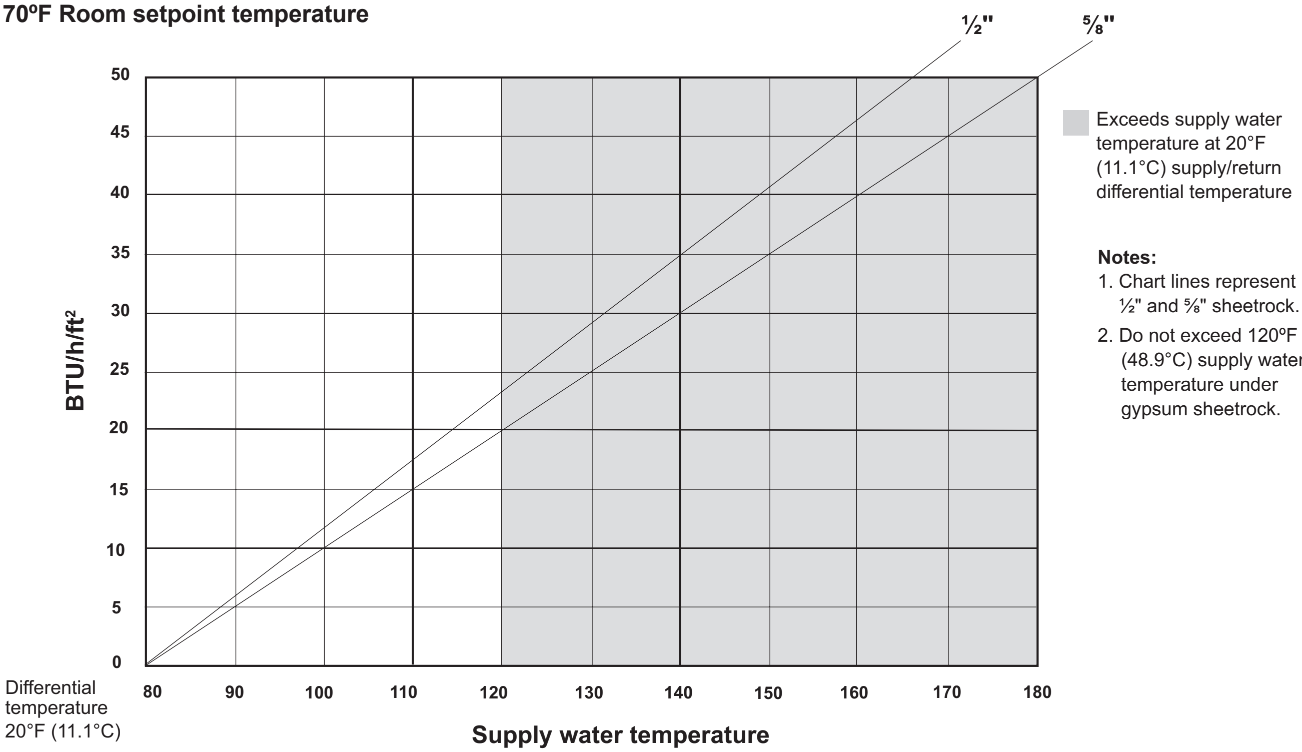


Appendix E:

Supply water temperature charts

Quik Trak radiant wall (7" on center)

70ºF Room setpoint temperature



Notes:

1. Chart lines represent ½" and ⅝" sheetrock.
2. Do not exceed 120ºF (48.9°C) supply water temperature under gypsum sheetrock.

Notes

Appendix F:

Flow charts

The charts in this appendix are arranged by fluid type and differential temperatures. The charts are further broken down into columns of flow by the on-center (o.c.) distance of the piping. On the left side of each chart is the BTU/h/ft² column. See **Figure F-1**.

Note: The shaded area on the charts should not be used for residential applications. Never exceed 12 inches on center for residential applications.

Example

Determine the flow per loop for the room.

- The room is 12 foot by 12 foot with the piping installed at 9 inches on center. The load for the room is 40 BTU/h/ft².The room is 15 feet from the manifold location.
- First determine the amount of piping in the room.

  12 x 12 = 144 square feet
  144 x 1.333 = 192 feet
  There is 192 feet of active loop in the room.
- Next determine the amount of leader length from the room to the manifold location. The distance from the room to the manifold location is 15 feet. The distance is doubled to account for the supply and return piping.

  15 x 2 = 30 feet
  Vertical distance of piping at the manifold = 3 feet

  30 + 6 = 36 feet
  There is 36 feet of leader length for this loop.
- Total loop length is the active and leader length added together.
  192 + 36 = 228 total loop length
- To determine the flow for the loop, select the appropriate chart. In this example, use the 100% water at 10ºF differential chart.

1. Enter the chart at the BTU/h/ft² for the room (40).
2. Move to the right to the 9" o.c. column.
3. Where the two lines intersect is the value in gallons per minute (gpm) per foot of piping (0.00608).

4. Multiply the active loop length by the value found in line 3 above.

192 x 0.00608 = 1.17 gpm

5. Flow for the loop in the example room is 1.17 gpm.

Note: Flow is based on the active loop length in the room. Head pressure drop is computed from the flow for the loop and the total loop length. Do not use the total loop length to determine the flow for the loop. See **Appendix G** for pressure loss charts.

100% Water | 10º Supply/return differential flow in GPM per foot of piping.

	Piping on-center distances						
BTU/h/ft²	6" o.c.	7" o.c.	8" o.c.	9" o.c.	10" o.c.	12" o.c.	15" o.c.
50	0.00507	0.00591	0.00676	0.00760	0.00845	0.01014	0.01267
49	0.00497	0.00579	0.00662	0.00745	0.00828	0.00993	0.01242
48	0.00487	0.00568	0.00649	0.00730	0.00811	0.00973	0.01216
47	0.00476	0.00556	0.00635	0.00715	0.00476	0.00556	0.00635
46	0.00466	0.00544	0.00622	0.00699	0.00777	0.00932	0.01166
45	0.00456	0.00532	0.00608	0.00684	0.00760	0.00912	0.01140
44	0.00446	0.00520	0.00595	0.00669	0.00743	0.00892	0.01115
43	0.00436	0.00508	0.00581	0.00654	0.00726	0.00872	0.01090
42	0.00426	0.00497	0.00568	0.00639	0.00709	0.00851	0.01064
41	0.00416	0.00485	0.00554	0.00623	0.00693	0.00831	0.01039
40	0.00405	0.00473	0.00541	0.00608	0.00676	0.00811	0.01014
39	0.00395	0.00461	0.00527	0.00593	0.00659	0.00791	0.00988
38	0.00385	0.00449	0.00513	0.00578	0.00642	0.00770	0.00963
37	0.00375	0.00437	0.00500	0.00563	0.00625	0.00750	0.00938
36	0.00365	0.00426	0.00486	0.00547	0.00608	0.00730	0.00912

Figure F-1: Excerpt from 100% water flow chart

Appendix F:

Flow charts

100% Water | 10º Supply/return differential flow in GPM per foot of piping.

	Piping on-center distances						
BTU/h/ft²	6" o.c.	7" o.c.	8" o.c.	9" o.c.	10" o.c.	12" o.c.	15" o.c.
50	0.00507	0.00591	0.00676	0.00760	0.00845	0.01014	0.01267
49	0.00497	0.00579	0.00662	0.00745	0.00828	0.00993	0.01242
48	0.00487	0.00568	0.00649	0.00730	0.00811	0.00973	0.01216
47	0.00476	0.00556	0.00635	0.00715	0.00476	0.00556	0.00635
46	0.00466	0.00544	0.00622	0.00699	0.00777	0.00932	0.01166
45	0.00456	0.00532	0.00608	0.00684	0.00760	0.00912	0.01140
44	0.00446	0.00520	0.00595	0.00669	0.00743	0.00892	0.01115
43	0.00436	0.00508	0.00581	0.00654	0.00726	0.00872	0.01090
42	0.00426	0.00497	0.00568	0.00639	0.00709	0.00851	0.01064
41	0.00416	0.00485	0.00554	0.00623	0.00693	0.00831	0.01039
40	0.00405	0.00473	0.00541	0.00608	0.00676	0.00811	0.01014
39	0.00395	0.00461	0.00527	0.00593	0.00659	0.00791	0.00988
38	0.00385	0.00449	0.00513	0.00578	0.00642	0.00770	0.00963
37	0.00375	0.00437	0.00500	0.00563	0.00625	0.00750	0.00938
36	0.00365	0.00426	0.00486	0.00547	0.00608	0.00730	0.00912
35	0.00355	0.00414	0.00473	0.00532	0.00591	0.00709	0.00887
34	0.00345	0.00402	0.00459	0.00517	0.00574	0.00689	0.00862
33	0.00334	0.00390	0.00446	0.00502	0.00557	0.00669	0.00836
32	0.00324	0.00378	0.00432	0.00487	0.00541	0.00649	0.00811
31	0.00314	0.00367	0.00419	0.00471	0.00524	0.00628	0.00786
30	0.00304	0.00355	0.00405	0.00456	0.00507	0.00608	0.00760
29	0.00294	0.00343	0.00392	0.00441	0.00490	0.00588	0.00735
28	0.00284	0.00331	0.00378	0.00426	0.00473	0.00568	0.00709
27	0.00274	0.00319	0.00365	0.00410	0.00456	0.00547	0.00684
26	0.00264	0.00307	0.00351	0.00395	0.00439	0.00527	0.00659
25	0.00253	0.00296	0.00338	0.00380	0.00422	0.00507	0.00633
24	0.00243	0.00284	0.00324	0.00365	0.00405	0.00487	0.00608
23	0.00233	0.00272	0.00311	0.00350	0.00389	0.00466	0.00583
22	0.00223	0.00260	0.00297	0.00334	0.00372	0.00446	0.00557
21	0.00213	0.00248	0.00284	0.00319	0.00355	0.00426	0.00532
20	0.00203	0.00236	0.00270	0.00304	0.00338	0.00405	0.00507
19	0.00193	0.00225	0.00257	0.00289	0.00321	0.00385	0.00481
18	0.00182	0.00213	0.00243	0.00274	0.00304	0.00365	0.00456
17	0.00172	0.00201	0.00230	0.00258	0.00287	0.00345	0.00431
16	0.00162	0.00189	0.00216	0.00243	0.00270	0.00324	0.00405
15	0.00152	0.00177	0.00203	0.00228	0.00253	0.00304	0.00380
14	0.00142	0.00166	0.00189	0.00213	0.00236	0.00284	0.00355
13	0.00132	0.00154	0.00176	0.00198	0.00220	0.00264	0.00329
12	0.00122	0.00142	0.00162	0.00182	0.00203	0.00243	0.00304
11	0.00111	0.00130	0.00149	0.00167	0.00186	0.00223	0.00279
10	0.00101	0.00118	0.00135	0.00152	0.00169	0.00203	0.00253
9	0.00091	0.00106	0.00122	0.00137	0.00152	0.00182	0.00228
8	0.00081	0.00095	0.00108	0.00122	0.00135	0.00162	0.00203
7	0.00071	0.00083	0.00095	0.00106	0.00118	0.00142	0.00177
6	0.00061	0.00071	0.00081	0.00091	0.00101	0.00122	0.00152
5	0.00051	0.00059	0.00068	0.00076	0.00084	0.00101	0.00127

Note: Flow is based on 100% water at 120ºF. 15" O.C. is NOT FOR USE with residential applications.

Table F-1

Appendix F:

Flow charts

100% Water | 20º Supply/return differential flow in GPM per foot of piping.

	Piping on-center distances						
BTU/h/ft²	6" o.c.	7" o.c.	8" o.c.	9" o.c.	10" o.c.	12" o.c.	15" o.c.
50	0.00253	0.00296	0.00338	0.00380	0.00422	0.00507	0.00633
49	0.00248	0.00290	0.00331	0.00372	0.00414	0.00497	0.00621
48	0.00243	0.00284	0.00324	0.00365	0.00405	0.00487	0.00608
47	0.00238	0.00278	0.00318	0.00357	0.00397	0.00476	0.00595
46	0.00233	0.00272	0.00311	0.00350	0.00389	0.00466	0.00583
45	0.00228	0.00266	0.00304	0.00342	0.00380	0.00456	0.00570
44	0.00223	0.00260	0.00297	0.00334	0.00372	0.00446	0.00557
43	0.00218	0.00254	0.00291	0.00327	0.00363	0.00436	0.00545
42	0.00213	0.00248	0.00284	0.00319	0.00355	0.00426	0.00532
41	0.00208	0.00242	0.00277	0.00312	0.00346	0.00416	0.00519
40	0.00203	0.00236	0.00270	0.00304	0.00338	0.00405	0.00507
39	0.00198	0.00231	0.00263	0.00296	0.00329	0.00395	0.00494
38	0.00193	0.00225	0.00257	0.00289	0.00321	0.00385	0.00481
37	0.00188	0.00219	0.00250	0.00281	0.00313	0.00375	0.00469
36	0.00182	0.00213	0.00243	0.00274	0.00304	0.00365	0.00456
35	0.00177	0.00207	0.00236	0.00266	0.00296	0.00355	0.00443
34	0.00172	0.00201	0.00230	0.00258	0.00287	0.00345	0.00431
33	0.00167	0.00195	0.00223	0.00251	0.00279	0.00334	0.00418
32	0.00162	0.00189	0.00216	0.00243	0.00270	0.00324	0.00405
31	0.00157	0.00183	0.00209	0.00236	0.00262	0.00314	0.00393
30	0.00152	0.00177	0.00203	0.00228	0.00253	0.00304	0.00380
29	0.00147	0.00171	0.00196	0.00220	0.00245	0.00294	0.00367
28	0.00142	0.00166	0.00189	0.00213	0.00236	0.00284	0.00355
27	0.00137	0.00160	0.00182	0.00205	0.00228	0.00274	0.00342
26	0.00132	0.00154	0.00176	0.00198	0.00220	0.00264	0.00329
25	0.00127	0.00148	0.00169	0.00190	0.00211	0.00253	0.00317
24	0.00122	0.00142	0.00162	0.00182	0.00203	0.00243	0.00304
23	0.00117	0.00136	0.00155	0.00175	0.00194	0.00233	0.00291
22	0.00111	0.00130	0.00149	0.00167	0.00186	0.00223	0.00279
21	0.00106	0.00124	0.00142	0.00160	0.00177	0.00213	0.00266
20	0.00101	0.00118	0.00135	0.00152	0.00169	0.00203	0.00253
19	0.00096	0.00112	0.00128	0.00144	0.00160	0.00193	0.00241
18	0.00091	0.00106	0.00122	0.00137	0.00152	0.00182	0.00228
17	0.00086	0.00101	0.00115	0.00129	0.00144	0.00172	0.00215
16	0.00081	0.00095	0.00108	0.00122	0.00135	0.00162	0.00203
15	0.00076	0.00089	0.00101	0.00114	0.00127	0.00152	0.00190
14	0.00071	0.00083	0.00095	0.00106	0.00118	0.00142	0.00177
13	0.00066	0.00077	0.00088	0.00099	0.00110	0.00132	0.00165
12	0.00061	0.00071	0.00081	0.00091	0.00101	0.00122	0.00152
11	0.00056	0.00065	0.00074	0.00084	0.00093	0.00111	0.00139
10	0.00051	0.00059	0.00068	0.00076	0.00084	0.00101	0.00127
9	0.00046	0.00053	0.00061	0.00068	0.00076	0.00091	0.00114
8	0.00041	0.00047	0.00054	0.00061	0.00068	0.00081	0.00101
7	0.00035	0.00041	0.00047	0.00053	0.00059	0.00071	0.00089
6	0.00030	0.00035	0.00041	0.00046	0.00051	0.00061	0.00076
5	0.00025	0.00030	0.00034	0.00038	0.00042	0.00051	0.00063

Note: Flow is based on 100% water at 120ºF. 15" O.C. is NOT FOR USE with residential applications.

Table F-2

30% Glycol | 10º Supply/return differential flow in GPM per foot of piping.

	Piping on-center distances						
BTU/h/ft²	6" o.c.	7" o.c.	8" o.c.	9" o.c.	10" o.c.	12" o.c.	15" o.c.
50	0.00528	0.00616	0.00704	0.00792	0.00880	0.01056	0.01320
49	0.00517	0.00603	0.00690	0.00776	0.00862	0.01035	0.01293
48	0.00507	0.00591	0.00676	0.00760	0.00844	0.01013	0.01267
47	0.00496	0.00579	0.00661	0.00744	0.00827	0.00992	0.01240
46	0.00486	0.00566	0.00647	0.00728	0.00809	0.00971	0.01214
45	0.00475	0.00554	0.00633	0.00713	0.00792	0.00950	0.01188
44	0.00464	0.00542	0.00619	0.00697	0.00774	0.00929	0.01161
43	0.00454	0.00530	0.00605	0.00681	0.00757	0.00908	0.01135
42	0.00443	0.00517	0.00591	0.00665	0.00739	0.00887	0.01108
41	0.00433	0.00505	0.00577	0.00649	0.00721	0.00866	0.01082
40	0.00422	0.00493	0.00563	0.00633	0.00704	0.00845	0.01056
39	0.00412	0.00480	0.00549	0.00618	0.00686	0.00823	0.01029
38	0.00401	0.00468	0.00535	0.00602	0.00669	0.00802	0.01003
37	0.00391	0.00456	0.00521	0.00586	0.00651	0.00781	0.00976
36	0.00380	0.00443	0.00507	0.00570	0.00633	0.00760	0.00950
35	0.00369	0.00431	0.00493	0.00554	0.00616	0.00739	0.00924
34	0.00359	0.00419	0.00479	0.00538	0.00598	0.00718	0.00897
33	0.00348	0.00406	0.00464	0.00523	0.00581	0.00697	0.00871
32	0.00338	0.00394	0.00450	0.00507	0.00563	0.00676	0.00845
31	0.00327	0.00382	0.00436	0.00491	0.00545	0.00654	0.00818
30	0.00317	0.00369	0.00422	0.00475	0.00528	0.00633	0.00792
29	0.00306	0.00357	0.00408	0.00459	0.00510	0.00612	0.00765
28	0.00296	0.00345	0.00394	0.00443	0.00493	0.00591	0.00739
27	0.00285	0.00333	0.00380	0.00428	0.00475	0.00570	0.00713
26	0.00274	0.00320	0.00366	0.00412	0.00457	0.00549	0.00686
25	0.00264	0.00308	0.00352	0.00396	0.00440	0.00528	0.00660
24	0.00253	0.00296	0.00338	0.00380	0.00422	0.00507	0.00633
23	0.00243	0.00283	0.00324	0.00364	0.00405	0.00486	0.00607
22	0.00232	0.00271	0.00310	0.00348	0.00387	0.00464	0.00581
21	0.00222	0.00259	0.00296	0.00333	0.00369	0.00443	0.00554
20	0.00211	0.00246	0.00281	0.00317	0.00352	0.00422	0.00528
19	0.00201	0.00234	0.00267	0.00301	0.00334	0.00401	0.00501
18	0.00190	0.00222	0.00253	0.00285	0.00317	0.00380	0.00475
17	0.00179	0.00209	0.00239	0.00269	0.00299	0.00359	0.00449
16	0.00169	0.00197	0.00225	0.00253	0.00281	0.00338	0.00422
15	0.00158	0.00185	0.00211	0.00238	0.00264	0.00317	0.00396
14	0.00148	0.00172	0.00197	0.00222	0.00246	0.00296	0.00369
13	0.00137	0.00160	0.00183	0.00206	0.00229	0.00274	0.00343
12	0.00127	0.00148	0.00169	0.00190	0.00211	0.00253	0.00317
11	0.00116	0.00135	0.00155	0.00174	0.00194	0.00232	0.00290
10	0.00106	0.00123	0.00141	0.00158	0.00176	0.00211	0.00264
9	0.00095	0.00111	0.00127	0.00143	0.00158	0.00190	0.00238
8	0.00084	0.00099	0.00113	0.00127	0.00141	0.00169	0.00211
7	0.00074	0.00086	0.00099	0.00111	0.00123	0.00148	0.00185
6	0.00063	0.00074	0.00084	0.00095	0.00106	0.00127	0.00158
5	0.00053	0.00062	0.00070	0.00079	0.00088	0.00106	0.00132

Note: Flow is based on 30% water at 120ºF. 15" O.C. is NOT FOR USE with residential applications.

Table F-3

30% Glycol | 20º Supply/return differential flow in GPM per foot of piping.

	Piping on-center distances						
BTU/h/ft²	6" o.c.	7" o.c.	8" o.c.	9" o.c.	10" o.c.	12" o.c.	15" o.c.
50	0.00264	0.00308	0.00352	0.00396	0.00440	0.00528	0.00660
49	0.00259	0.00302	0.00345	0.00388	0.00431	0.00517	0.00647
48	0.00253	0.00296	0.00338	0.00380	0.00422	0.00507	0.00633
47	0.00248	0.00289	0.00331	0.00372	0.00413	0.00496	0.00620
46	0.00243	0.00283	0.00324	0.00364	0.00405	0.00486	0.00607
45	0.00238	0.00277	0.00317	0.00356	0.00396	0.00475	0.00594
44	0.00232	0.00271	0.00310	0.00348	0.00387	0.00464	0.00581
43	0.00227	0.00265	0.00303	0.00340	0.00378	0.00454	0.00567
42	0.00222	0.00259	0.00296	0.00333	0.00369	0.00443	0.00554
41	0.00216	0.00252	0.00289	0.00325	0.00361	0.00433	0.00541
40	0.00211	0.00246	0.00281	0.00317	0.00352	0.00422	0.00528
39	0.00206	0.00240	0.00274	0.00309	0.00343	0.00412	0.00515
38	0.00201	0.00234	0.00267	0.00301	0.00334	0.00401	0.00501
37	0.00195	0.00228	0.00260	0.00293	0.00325	0.00391	0.00488
36	0.00190	0.00222	0.00253	0.00285	0.00317	0.00380	0.00475
35	0.00185	0.00216	0.00246	0.00277	0.00308	0.00369	0.00462
34	0.00179	0.00209	0.00239	0.00269	0.00299	0.00359	0.00449
33	0.00203	0.00232	0.00261	0.00290	0.00348	0.00348	0.00435
32	0.00169	0.00197	0.00225	0.00253	0.00281	0.00338	0.00422
31	0.00164	0.00191	0.00218	0.00245	0.00273	0.00327	0.00409
30	0.00158	0.00185	0.00211	0.00238	0.00264	0.00317	0.00396
29	0.00153	0.00179	0.00204	0.00230	0.00255	0.00306	0.00383
28	0.00148	0.00172	0.00197	0.00222	0.00246	0.00296	0.00369
27	0.00143	0.00166	0.00190	0.00214	0.00238	0.00285	0.00356
26	0.00137	0.00160	0.00183	0.00206	0.00229	0.00274	0.00343
25	0.00132	0.00154	0.00176	0.00198	0.00220	0.00264	0.00330
24	0.00127	0.00148	0.00169	0.00190	0.00211	0.00253	0.00317
23	0.00121	0.00142	0.00162	0.00182	0.00202	0.00243	0.00303
22	0.00116	0.00135	0.00155	0.00174	0.00194	0.00232	0.00290
21	0.00111	0.00129	0.00148	0.00166	0.00185	0.00222	0.00277
20	0.00106	0.00123	0.00141	0.00158	0.00176	0.00211	0.00264
19	0.00100	0.00117	0.00134	0.00150	0.00167	0.00201	0.00251
18	0.00095	0.00111	0.00127	0.00143	0.00158	0.00190	0.00238
17	0.00090	0.00105	0.00120	0.00135	0.00150	0.00179	0.00224
16	0.00084	0.00099	0.00113	0.00127	0.00141	0.00169	0.00211
15	0.00079	0.00092	0.00106	0.00119	0.00132	0.00158	0.00198
14	0.00074	0.00086	0.00099	0.00111	0.00123	0.00148	0.00185
13	0.00069	0.00080	0.00091	0.00103	0.00114	0.00137	0.00172
12	0.00063	0.00074	0.00084	0.00095	0.00106	0.00127	0.00158
11	0.00058	0.00068	0.00077	0.00087	0.00097	0.00116	0.00145
10	0.00053	0.00062	0.00070	0.00079	0.00088	0.00106	0.00132
9	0.00048	0.00055	0.00063	0.00071	0.00079	0.00095	0.00119
8	0.00042	0.00049	0.00056	0.00063	0.00070	0.00084	0.00106
7	0.00037	0.00043	0.00049	0.00055	0.00062	0.00074	0.00092
6	0.00032	0.00037	0.00042	0.00048	0.00053	0.00063	0.00079
5	0.00026	0.00031	0.00035	0.00040	0.00044	0.00053	0.00066

Note: Flow is based on 30% water at 120ºF. 15" O.C. is NOT FOR USE with residential applications.

Table F-4

Appendix F:

Flow charts

40% Glycol | 10º Supply/return differential flow in GPM per foot of piping.

	Piping on-center distances						
BTU/h/ft²	6" o.c.	7" o.c.	8" o.c.	9" o.c.	10" o.c.	12" o.c.	15" o.c.
50	0.00542	0.00632	0.00722	0.00813	0.00903	0.01084	0.01354
49	0.00531	0.00619	0.00708	0.00796	0.00885	0.01062	0.01327
48	0.00520	0.00607	0.00693	0.00780	0.00867	0.01040	0.01300
47	0.00509	0.00594	0.00679	0.00764	0.00849	0.01019	0.01273
46	0.00498	0.00581	0.00665	0.00748	0.00831	0.00997	0.01246
45	0.00488	0.00569	0.00650	0.00731	0.00813	0.00975	0.01219
44	0.00477	0.00556	0.00636	0.00715	0.00795	0.00954	0.01192
43	0.00466	0.00544	0.00621	0.00699	0.00777	0.00932	0.01165
42	0.00455	0.00531	0.00607	0.00683	0.00758	0.00910	0.01138
41	0.00444	0.00518	0.00592	0.00666	0.00740	0.00888	0.01111
40	0.00433	0.00506	0.00578	0.00650	0.00722	0.00867	0.01084
39	0.00423	0.00493	0.00563	0.00634	0.00704	0.00845	0.01056
38	0.00412	0.00480	0.00549	0.00618	0.00686	0.00823	0.01029
37	0.00401	0.00468	0.00534	0.00601	0.00668	0.00802	0.01002
36	0.00390	0.00455	0.00520	0.00585	0.00650	0.00780	0.00975
35	0.00379	0.00442	0.00506	0.00569	0.00632	0.00758	0.00948
34	0.00368	0.00430	0.00491	0.00553	0.00614	0.00737	0.00921
33	0.00358	0.00417	0.00477	0.00536	0.00596	0.00715	0.00894
32	0.00347	0.00404	0.00462	0.00520	0.00578	0.00693	0.00867
31	0.00336	0.00392	0.00448	0.00504	0.00560	0.00672	0.00840
30	0.00325	0.00379	0.00433	0.00488	0.00542	0.00650	0.00813
29	0.00314	0.00367	0.00419	0.00471	0.00524	0.00628	0.00786
28	0.00303	0.00354	0.00404	0.00455	0.00506	0.00607	0.00758
27	0.00293	0.00341	0.00390	0.00439	0.00488	0.00585	0.00731
26	0.00282	0.00329	0.00376	0.00423	0.00470	0.00563	0.00704
25	0.00271	0.00316	0.00361	0.00406	0.00451	0.00542	0.00677
24	0.00260	0.00303	0.00347	0.00390	0.00433	0.00520	0.00650
23	0.00249	0.00291	0.00332	0.00374	0.00415	0.00498	0.00623
22	0.00238	0.00278	0.00318	0.00358	0.00397	0.00477	0.00596
21	0.00228	0.00265	0.00303	0.00341	0.00379	0.00455	0.00569
20	0.00217	0.00253	0.00289	0.00325	0.00361	0.00433	0.00542
19	0.00206	0.00240	0.00274	0.00309	0.00343	0.00412	0.00515
18	0.00195	0.00228	0.00260	0.00293	0.00325	0.00390	0.00488
17	0.00184	0.00215	0.00246	0.00276	0.00307	0.00368	0.00461
16	0.00173	0.00202	0.00231	0.00260	0.00289	0.00347	0.00433
15	0.00163	0.00190	0.00217	0.00244	0.00271	0.00325	0.00406
14	0.00152	0.00177	0.00202	0.00228	0.00253	0.00303	0.00379
13	0.00141	0.00164	0.00188	0.00211	0.00235	0.00282	0.00352
12	0.00130	0.00152	0.00173	0.00195	0.00217	0.00260	0.00325
11	0.00119	0.00139	0.00159	0.00179	0.00199	0.00238	0.00298
10	0.00108	0.00126	0.00144	0.00163	0.00181	0.00217	0.00271
9	0.00098	0.00114	0.00130	0.00146	0.00163	0.00195	0.00244
8	0.00087	0.00101	0.00116	0.00130	0.00144	0.00173	0.00217
7	0.00076	0.00088	0.00101	0.00114	0.00126	0.00152	0.00190
6	0.00065	0.00076	0.00087	0.00098	0.00108	0.00130	0.00163
5	0.00054	0.00063	0.00072	0.00081	0.00090	0.00108	0.00135

Note: Flow is based on 40% water at 120ºF. 15" O.C. is NOT FOR USE with residential applications.

Table F-5

Appendix F:
Flow charts

40% Glycol | 20º Supply/return differential flow in GPM per foot of piping.

	Piping on-center distances						
BTU/h/ft²	6" o.c.	7" o.c.	8" o.c.	9" o.c.	10" o.c.	12" o.c.	15" o.c.
50	0.00271	0.00316	0.00361	0.00406	0.00451	0.00542	0.00677
49	0.00265	0.00310	0.00354	0.00398	0.00442	0.00531	0.00664
48	0.00260	0.00303	0.00347	0.00390	0.00433	0.00520	0.00650
47	0.00255	0.00297	0.00339	0.00382	0.00424	0.00509	0.00637
46	0.00249	0.00291	0.00332	0.00374	0.00415	0.00498	0.00623
45	0.00244	0.00284	0.00325	0.00366	0.00406	0.00488	0.00609
44	0.00238	0.00278	0.00318	0.00358	0.00397	0.00477	0.00596
43	0.00233	0.00272	0.00311	0.00349	0.00388	0.00466	0.00582
42	0.00228	0.00265	0.00303	0.00341	0.00379	0.00455	0.00569
41	0.00222	0.00259	0.00296	0.00333	0.00370	0.00444	0.00555
40	0.00217	0.00253	0.00289	0.00325	0.00361	0.00433	0.00542
39	0.00211	0.00246	0.00282	0.00317	0.00352	0.00423	0.00528
38	0.00206	0.00240	0.00274	0.00309	0.00343	0.00412	0.00515
37	0.00200	0.00234	0.00267	0.00301	0.00334	0.00401	0.00501
36	0.00195	0.00228	0.00260	0.00293	0.00325	0.00390	0.00488
35	0.00190	0.00221	0.00253	0.00284	0.00316	0.00379	0.00474
34	0.00184	0.00215	0.00246	0.00276	0.00307	0.00368	0.00461
33	0.00179	0.00209	0.00238	0.00268	0.00298	0.00358	0.00447
32	0.00173	0.00202	0.00231	0.00260	0.00289	0.00347	0.00433
31	0.00168	0.00196	0.00224	0.00252	0.00280	0.00336	0.00420
30	0.00163	0.00190	0.00217	0.00244	0.00271	0.00325	0.00406
29	0.00157	0.00183	0.00209	0.00236	0.00262	0.00314	0.00393
28	0.00152	0.00177	0.00202	0.00228	0.00253	0.00303	0.00379
27	0.00146	0.00171	0.00195	0.00219	0.00244	0.00293	0.00366
26	0.00141	0.00164	0.00188	0.00211	0.00235	0.00282	0.00352
25	0.00135	0.00158	0.00181	0.00203	0.00226	0.00271	0.00339
24	0.00130	0.00152	0.00173	0.00195	0.00217	0.00260	0.00325
23	0.00125	0.00145	0.00166	0.00187	0.00208	0.00249	0.00312
22	0.00119	0.00139	0.00159	0.00179	0.00199	0.00238	0.00298
21	0.00114	0.00133	0.00152	0.00171	0.00190	0.00228	0.00284
20	0.00108	0.00126	0.00144	0.00163	0.00181	0.00217	0.00271
19	0.00103	0.00120	0.00137	0.00154	0.00172	0.00206	0.00257
18	0.00098	0.00114	0.00130	0.00146	0.00163	0.00195	0.00244
17	0.00092	0.00107	0.00123	0.00138	0.00153	0.00184	0.00230
16	0.00087	0.00101	0.00116	0.00130	0.00144	0.00173	0.00217
15	0.00081	0.00095	0.00108	0.00122	0.00135	0.00163	0.00203
14	0.00076	0.00088	0.00101	0.00114	0.00126	0.00152	0.00190
13	0.00070	0.00082	0.00094	0.00106	0.00117	0.00141	0.00176
12	0.00065	0.00076	0.00087	0.00098	0.00108	0.00130	0.00163
11	0.00060	0.00070	0.00079	0.00089	0.00099	0.00119	0.00149
10	0.00054	0.00063	0.00072	0.00081	0.00090	0.00108	0.00135
9	0.00049	0.00057	0.00065	0.00073	0.00081	0.00098	0.00122
8	0.00043	0.00051	0.00058	0.00065	0.00072	0.00087	0.00108
7	0.00038	0.00044	0.00051	0.00057	0.00063	0.00076	0.00095
6	0.00033	0.00038	0.00043	0.00049	0.00054	0.00065	0.00081
5	0.00027	0.00032	0.00036	0.00041	0.00045	0.00054	0.00068

Note: Flow is based on 40% water at 120ºF. 15" O.C. is NOT FOR USE with residential applications.

Table F-6

50% Glycol | 10º Supply/return differential flow in GPM per foot of piping.

	Piping on-center distances						
BTU/h/ft²	6" o.c.	7" o.c.	8" o.c.	9" o.c.	10" o.c.	12" o.c.	15" o.c.
50	0.00568	0.00663	0.00758	0.00852	0.00947	0.01136	0.01421
49	0.00557	0.00650	0.00742	0.00835	0.00928	0.01114	0.01392
48	0.00546	0.00636	0.00727	0.00818	0.00909	0.01091	0.01364
47	0.00534	0.00623	0.00712	0.00801	0.00890	0.01068	0.01335
46	0.00523	0.00610	0.00697	0.00784	0.00871	0.01046	0.01307
45	0.00511	0.00597	0.00682	0.00767	0.00852	0.01023	0.01279
44	0.00500	0.00583	0.00667	0.00750	0.00833	0.01000	0.01250
43	0.00489	0.00570	0.00652	0.00733	0.00814	0.00977	0.01222
42	0.00477	0.00557	0.00636	0.00716	0.00796	0.00955	0.01193
41	0.00466	0.00544	0.00621	0.00699	0.00777	0.00932	0.01165
40	0.00455	0.00530	0.00606	0.00682	0.00758	0.00909	0.01136
39	0.00443	0.00517	0.00591	0.00665	0.00739	0.00886	0.01108
38	0.00432	0.00504	0.00576	0.00648	0.00720	0.00864	0.01080
37	0.00421	0.00491	0.00561	0.00631	0.00701	0.00841	0.01051
36	0.00409	0.00477	0.00545	0.00614	0.00682	0.00818	0.01023
35	0.00398	0.00464	0.00530	0.00597	0.00663	0.00796	0.00994
34	0.00386	0.00451	0.00515	0.00580	0.00644	0.00773	0.00966
33	0.00375	0.00438	0.00500	0.00563	0.00625	0.00750	0.00938
32	0.00364	0.00424	0.00485	0.00546	0.00606	0.00727	0.00909
31	0.00352	0.00411	0.00470	0.00528	0.00587	0.00705	0.00881
30	0.00341	0.00398	0.00455	0.00511	0.00568	0.00682	0.00852
29	0.00330	0.00384	0.00439	0.00494	0.00549	0.00659	0.00824
28	0.00318	0.00371	0.00424	0.00477	0.00530	0.00636	0.00796
27	0.00307	0.00358	0.00409	0.00460	0.00511	0.00614	0.00767
26	0.00295	0.00345	0.00394	0.00443	0.00492	0.00591	0.00739
25	0.00284	0.00331	0.00379	0.00426	0.00474	0.00568	0.00710
24	0.00273	0.00318	0.00364	0.00409	0.00455	0.00546	0.00682
23	0.00261	0.00305	0.00348	0.00392	0.00436	0.00523	0.00653
22	0.00250	0.00292	0.00333	0.00375	0.00417	0.00500	0.00625
21	0.00239	0.00278	0.00318	0.00358	0.00398	0.00477	0.00597
20	0.00227	0.00265	0.00303	0.00341	0.00379	0.00455	0.00568
19	0.00216	0.00252	0.00288	0.00324	0.00360	0.00432	0.00540
18	0.00205	0.00239	0.00273	0.00307	0.00341	0.00409	0.00511
17	0.00193	0.00225	0.00258	0.00290	0.00322	0.00386	0.00483
16	0.00182	0.00212	0.00242	0.00273	0.00303	0.00364	0.00455
15	0.00170	0.00199	0.00227	0.00256	0.00284	0.00341	0.00426
14	0.00159	0.00186	0.00212	0.00239	0.00265	0.00318	0.00398
13	0.00148	0.00172	0.00197	0.00222	0.00246	0.00295	0.00369
12	0.00136	0.00159	0.00182	0.00205	0.00227	0.00273	0.00341
11	0.00125	0.00146	0.00167	0.00188	0.00208	0.00250	0.00313
10	0.00114	0.00133	0.00152	0.00170	0.00189	0.00227	0.00284
9	0.00102	0.00119	0.00136	0.00153	0.00170	0.00205	0.00256
8	0.00091	0.00106	0.00121	0.00136	0.00152	0.00182	0.00227
7	0.00080	0.00093	0.00106	0.00119	0.00133	0.00159	0.00199
6	0.00068	0.00080	0.00091	0.00102	0.00114	0.00136	0.00170
5	0.00057	0.00066	0.00076	0.00085	0.00095	0.00114	0.00142

Note: Flow is based on 50% water at 120ºF. 15" O.C. is NOT FOR USE with residential applications.

Table F-7

Appendix F:
Flow charts

50% Glycol | 20º Supply/return differential flow in GPM per foot of piping.

	Piping on-center distances						
BTU/h/ft²	6" o.c.	7" o.c.	8" o.c.	9" o.c.	10" o.c.	12" o.c.	15" o.c.
50	0.00507	0.00591	0.00676	0.00760	0.00845	0.01014	0.01267
49	0.00497	0.00579	0.00662	0.00745	0.00828	0.00993	0.01242
48	0.00487	0.00568	0.00649	0.00730	0.00811	0.00973	0.01216
47	0.00476	0.00556	0.00635	0.00715	0.00794	0.00953	0.01191
46	0.00466	0.00544	0.00622	0.00699	0.00777	0.00932	0.01166
45	0.00456	0.00532	0.00608	0.00684	0.00760	0.00912	0.01140
44	0.00446	0.00520	0.00595	0.00669	0.00743	0.00892	0.01115
43	0.00436	0.00508	0.00581	0.00654	0.00726	0.00872	0.01090
42	0.00426	0.00497	0.00568	0.00639	0.00709	0.00851	0.01064
41	0.00416	0.00485	0.00554	0.00623	0.00693	0.00831	0.01039
40	0.00405	0.00473	0.00541	0.00608	0.00676	0.00811	0.01014
39	0.00395	0.00461	0.00527	0.00593	0.00659	0.00791	0.00988
38	0.00385	0.00449	0.00513	0.00578	0.00642	0.00770	0.00963
37	0.00375	0.00437	0.00500	0.00563	0.00625	0.00750	0.00938
36	0.00365	0.00426	0.00486	0.00547	0.00608	0.00730	0.00912
35	0.00355	0.00414	0.00473	0.00532	0.00591	0.00709	0.00887
34	0.00345	0.00402	0.00459	0.00517	0.00574	0.00689	0.00862
33	0.00334	0.00390	0.00446	0.00502	0.00557	0.00669	0.00836
32	0.00324	0.00378	0.00432	0.00487	0.00541	0.00649	0.00811
31	0.00314	0.00367	0.00419	0.00471	0.00524	0.00628	0.00786
30	0.00304	0.00355	0.00405	0.00456	0.00507	0.00608	0.00760
29	0.00294	0.00343	0.00392	0.00441	0.00490	0.00588	0.00735
28	0.00284	0.00331	0.00378	0.00426	0.00473	0.00568	0.00709
27	0.00274	0.00319	0.00365	0.00410	0.00456	0.00547	0.00684
26	0.00264	0.00307	0.00351	0.00395	0.00439	0.00527	0.00659
25	0.00253	0.00296	0.00338	0.00380	0.00422	0.00507	0.00633
24	0.00243	0.00284	0.00324	0.00365	0.00405	0.00487	0.00608
23	0.00233	0.00272	0.00311	0.00350	0.00389	0.00466	0.00583
22	0.00223	0.00260	0.00297	0.00334	0.00372	0.00446	0.00557
21	0.00213	0.00248	0.00284	0.00319	0.00355	0.00426	0.00532
20	0.00203	0.00236	0.00270	0.00304	0.00338	0.00405	0.00507
19	0.00193	0.00225	0.00257	0.00289	0.00321	0.00385	0.00481
18	0.00182	0.00213	0.00243	0.00274	0.00304	0.00365	0.00456
17	0.00172	0.00201	0.00230	0.00258	0.00287	0.00345	0.00431
16	0.00162	0.00189	0.00216	0.00243	0.00270	0.00324	0.00405
15	0.00152	0.00177	0.00203	0.00228	0.00253	0.00304	0.00380
14	0.00142	0.00166	0.00189	0.00213	0.00236	0.00284	0.00355
13	0.00132	0.00154	0.00176	0.00198	0.00220	0.00264	0.00329
12	0.00122	0.00142	0.00162	0.00182	0.00203	0.00243	0.00304
11	0.00111	0.00130	0.00149	0.00167	0.00186	0.00223	0.00279
10	0.00101	0.00118	0.00135	0.00152	0.00169	0.00203	0.00253
9	0.00091	0.00106	0.00122	0.00137	0.00152	0.00182	0.00228
8	0.00081	0.00095	0.00108	0.00122	0.00135	0.00162	0.00203
7	0.00071	0.00083	0.00095	0.00106	0.00118	0.00142	0.00177
6	0.00061	0.00071	0.00081	0.00091	0.00101	0.00122	0.00152
5	0.00051	0.00059	0.00068	0.00076	0.00084	0.00101	0.00127

Note: Flow is based on 50% water at 120ºF. 15" O.C. is NOT FOR USE with residential applications.

Table F-8

Notes

Appendix G:

Hydronic friction loss tables

5⁄16" Uponor PEX-a — 100% Water — feet of head per foot of piping

Velocity (ft./sec.)	GPM	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
0.5	0.10	0.00908	0.00873	0.00841	0.00814	0.00789	0.00767	0.00747	0.00729	0.00712	0.00697	0.00683	0.00670	0.00659
0.6	0.13	0.01230	0.01183	0.01141	0.01105	0.01072	0.01043	0.01016	0.00992	0.00970	0.00950	0.00931	0.00914	0.00899
0.7	0.15	0.01591	0.01531	0.01479	0.01433	0.01391	0.01354	0.01320	0.01289	0.01261	0.01235	0.01212	0.01190	0.01170
0.8	0.17	0.01990	0.01917	0.01852	0.01795	0.01744	0.01698	0.01657	0.01619	0.01584	0.01552	0.01523	0.01496	0.01471
0.9	0.19	0.02426	0.02338	0.02261	0.02192	0.02131	0.02075	0.02025	0.01979	0.01938	0.01899	0.01864	0.01832	0.01802
1.0	0.21	0.02898	0.02795	0.02703	0.02622	0.02550	0.02484	0.02425	0.02371	0.02322	0.02276	0.02235	0.02197	0.02161
1.1	0.23	0.03405	0.03285	0.03179	0.03085	0.03000	0.02924	0.02856	0.02793	0.02735	0.02682	0.02634	0.02589	0.02548
1.2	0.25	0.03946	0.03808	0.03687	0.03579	0.03482	0.03395	0.03316	0.03243	0.03178	0.03116	0.03061	0.03010	0.02962
1.3	0.27	0.04520	0.04364	0.04226	0.04104	0.03994	0.03895	0.03805	0.03723	0.03648	0.03579	0.03516	0.03458	0.03404
1.4	0.29	0.05127	0.04952	0.04797	0.04660	0.04536	0.04424	0.04324	0.04231	0.04147	0.04068	0.03998	0.03932	0.03871
1.5	0.31	0.05767	0.05572	0.05399	0.05246	0.05107	0.04983	0.04870	0.04767	0.04673	0.04585	0.04506	0.04433	0.04365
1.6	0.33	0.06438	0.06222	0.06031	0.05861	0.05707	0.05569	0.05445	0.05330	0.05226	0.05128	0.05041	0.04959	0.04884
1.7	0.35	0.07141	0.06903	0.06692	0.06505	0.06336	0.06184	0.06047	0.05920	0.05805	0.05698	0.05601	0.05512	0.05428
1.8	0.38	0.07874	0.07614	0.07383	0.07178	0.06993	0.06826	0.06676	0.06537	0.06411	0.06293	0.06187	0.06089	0.05997
1.9	0.40	0.08638	0.08355	0.08103	0.07880	0.07678	0.07496	0.07332	0.07180	0.07043	0.06914	0.06799	0.06692	0.06592
2.0	0.42	0.09433	0.09125	0.08852	0.08609	0.08390	0.08193	0.08014	0.07850	0.07701	0.07561	0.07435	0.07319	0.07210
2.1	0.44	0.10257	0.09924	0.09629	0.09367	0.09130	0.08916	0.08723	0.08545	0.08384	0.08233	0.08097	0.07970	0.07853
2.2	0.46	0.11110	0.10752	0.10434	0.10152	0.09896	0.09666	0.09458	0.09266	0.09092	0.08929	0.08782	0.08646	0.08519
2.3	0.48	0.11993	0.11609	0.11267	0.10964	0.10689	0.10442	0.10219	0.10013	0.09826	0.09650	0.09493	0.09346	0.09210
2.4	0.50	0.12905	0.12494	0.12128	0.11803	0.11509	0.11244	0.11005	0.10784	0.10584	0.10396	0.10227	0.10070	0.09924
2.5	0.52	0.13845	0.13406	0.13015	0.12669	0.12355	0.12072	0.11816	0.11580	0.11367	0.11165	0.10985	0.10817	0.10661
2.6	0.54	0.14814	0.14346	0.13930	0.13561	0.13226	0.12925	0.12653	0.12401	0.12174	0.11959	0.11767	0.11588	0.11422
2.7	0.56	0.15811	0.15314	0.14872	0.14480	0.14124	0.13804	0.13514	0.13247	0.13005	0.12777	0.12572	0.12382	0.12205
2.8	0.58	0.16836	0.16309	0.15841	0.15424	0.15047	0.14708	0.14400	0.14117	0.13860	0.13618	0.13401	0.13199	0.13011
2.9	0.61	0.17888	0.17331	0.16835	0.16395	0.15996	0.15636	0.15311	0.15011	0.14739	0.14483	0.14253	0.14039	0.13840
3.0	0.63	0.18968	0.18380	0.17856	0.17391	0.16970	0.16590	0.16246	0.15929	0.15641	0.15371	0.15128	0.14902	0.14692
3.1	0.65	0.20076	0.19456	0.18904	0.18413	0.17968	0.17568	0.17205	0.16871	0.16568	0.16282	0.16026	0.15788	0.15566
3.2	0.67	0.21210	0.20558	0.19977	0.19460	0.18992	0.18571	0.18189	0.17837	0.17517	0.17217	0.16947	0.16696	0.16462
3.3	0.69	0.22372	0.21686	0.21075	0.20533	0.20041	0.19597	0.19196	0.18826	0.18490	0.18174	0.17890	0.17626	0.17380
3.4	0.71	0.23560	0.22841	0.22200	0.21630	0.21114	0.20648	0.20227	0.19838	0.19486	0.19154	0.18856	0.18579	0.18320

Recommended head loss design range

Sizing in this region will lead to excessive head loss conditions.

⁵⁄₁₆" Uponor PEX-a — 30% Propylene glycol — feet of head per foot of piping

Velocity (ft./sec.)	GPM	80ºF 27ºC	90ºF 32ºC	100ºF 38ºC	110ºF 43ºC	120ºF 49ºC	130ºF 54ºC	140ºF 60ºC	150ºF 66ºC	160ºF 71ºC	170ºF 77ºC	180ºF 82ºC	190ºF 88ºC	200ºF 93ºC
0.5	0.10	0.01318	0.01231	0.01159	0.01096	0.01044	0.00998	0.00957	0.00924	0.00893	0.00864	0.00840	0.00817	0.00800
0.6	0.13	0.01767	0.01654	0.01559	0.01477	0.01409	0.01348	0.01294	0.01251	0.01209	0.01171	0.01140	0.01109	0.01087
0.7	0.15	0.02268	0.02126	0.02007	0.01903	0.01817	0.01741	0.01672	0.01618	0.01565	0.01517	0.01477	0.01438	0.01410
0.8	0.17	0.02819	0.02646	0.02499	0.02373	0.02267	0.02174	0.02090	0.02023	0.01958	0.01899	0.01850	0.01803	0.01767
0.9	0.19	0.03417	0.03211	0.03036	0.02885	0.02759	0.02647	0.02546	0.02466	0.02388	0.02317	0.02258	0.02201	0.02159
1.0	0.21	0.04061	0.03820	0.03615	0.03438	0.03289	0.03157	0.03039	0.02945	0.02853	0.02769	0.02700	0.02632	0.02583
1.1	0.23	0.04750	0.04472	0.04235	0.04030	0.03858	0.03706	0.03568	0.03459	0.03353	0.03256	0.03175	0.03096	0.03038
1.2	0.25	0.05483	0.05165	0.04895	0.04661	0.04465	0.04290	0.04133	0.04008	0.03886	0.03775	0.03683	0.03592	0.03526
1.3	0.27	0.06259	0.05900	0.05595	0.05330	0.05108	0.04910	0.04732	0.04590	0.04452	0.04326	0.04222	0.04119	0.04044
1.4	0.29	0.07077	0.06675	0.06333	0.06037	0.05787	0.05566	0.05365	0.05206	0.05051	0.04910	0.04792	0.04677	0.04592
1.5	0.31	0.07936	0.07490	0.07110	0.06780	0.06502	0.06255	0.06032	0.05855	0.05682	0.05524	0.05393	0.05264	0.05170
1.6	0.33	0.08836	0.08343	0.07923	0.07559	0.07252	0.06979	0.06732	0.06536	0.06344	0.06169	0.06024	0.05882	0.05777
1.7	0.35	0.09776	0.09235	0.08773	0.08373	0.08036	0.07735	0.07464	0.07248	0.07038	0.06845	0.06685	0.06528	0.06412
1.8	0.38	0.10754	0.10164	0.09660	0.09222	0.08853	0.08525	0.08228	0.07992	0.07761	0.07551	0.07376	0.07204	0.07077
1.9	0.40	0.11772	0.11130	0.10582	0.10106	0.09705	0.09347	0.09024	0.08766	0.08515	0.08286	0.08095	0.07907	0.07769
2.0	0.42	0.12827	0.12133	0.11539	0.11024	0.10589	0.10201	0.09851	0.09572	0.09299	0.09050	0.08843	0.08639	0.08489
2.1	0.44	0.13921	0.13172	0.12532	0.11975	0.11506	0.11087	0.10709	0.10407	0.10113	0.09843	0.09619	0.09399	0.09237
2.2	0.46	0.15051	0.14246	0.13558	0.12960	0.12455	0.12004	0.11597	0.11272	0.10955	0.10665	0.10424	0.10187	0.10012
2.3	0.48	0.16219	0.15356	0.14619	0.13977	0.13435	0.12952	0.12515	0.12167	0.11826	0.11515	0.11256	0.11001	0.10813
2.4	0.50	0.17423	0.16501	0.15713	0.15027	0.14448	0.13931	0.13463	0.13090	0.12726	0.12393	0.12116	0.11843	0.11642
2.5	0.52	0.18663	0.17681	0.16841	0.16109	0.15492	0.14940	0.14441	0.14043	0.13655	0.13299	0.13003	0.12711	0.12497
2.6	0.54	0.19938	0.18895	0.18002	0.17223	0.16566	0.15980	0.15449	0.15025	0.14611	0.14232	0.13917	0.13607	0.13378
2.7	0.56	0.21249	0.20143	0.19195	0.18369	0.17672	0.17049	0.16485	0.16035	0.15595	0.15192	0.14858	0.14528	0.14285
2.8	0.58	0.22596	0.21424	0.20421	0.19547	0.18808	0.18148	0.17550	0.17073	0.16607	0.16180	0.15825	0.15476	0.15218
2.9	0.61	0.23977	0.22739	0.21679	0.20755	0.19974	0.19276	0.18644	0.18139	0.17647	0.17195	0.16819	0.16449	0.16176

Recommended head loss design range

Sizing in this region will lead to excessive head loss conditions.

Appendix G:

Hydronic friction loss tables

⁵⁄₁₆" Uponor PEX-a — 40% Propylene glycol — feet of head per foot of piping

Velocity (ft./sec.)	GPM	80ºF 27ºC	90ºF 32ºC	100ºF 38ºC	110ºF 43ºC	120ºF 49ºC	130ºF 54ºC	140ºF 60ºC	150ºF 66ºC	160ºF 71ºC	170ºF 77ºC	180ºF 82ºC	190ºF 88ºC	200ºF 93ºC
0.5	0.10	0.01528	0.01408	0.01311	0.01229	0.01158	0.01100	0.01048	0.01005	0.00968	0.00932	0.00906	0.00876	0.00855
0.6	0.13	0.02041	0.01885	0.01758	0.01651	0.01559	0.01482	0.01414	0.01357	0.01309	0.01262	0.01227	0.01188	0.01160
0.7	0.15	0.02611	0.02416	0.02257	0.02123	0.02006	0.01909	0.01824	0.01752	0.01691	0.01631	0.01587	0.01538	0.01502
0.8	0.17	0.03235	0.02999	0.02805	0.02641	0.02499	0.02380	0.02276	0.02188	0.02113	0.02040	0.01985	0.01925	0.01881
0.9	0.19	0.03913	0.03631	0.03400	0.03205	0.03036	0.02894	0.02768	0.02663	0.02574	0.02486	0.02420	0.02348	0.02295
1.0	0.21	0.04641	0.04312	0.04042	0.03813	0.03614	0.03448	0.03300	0.03177	0.03072	0.02968	0.02891	0.02806	0.02743
1.1	0.23	0.05419	0.05040	0.04728	0.04464	0.04235	0.04042	0.03871	0.03729	0.03607	0.03486	0.03397	0.03298	0.03225
1.2	0.25	0.06245	0.05813	0.05458	0.05157	0.04895	0.04674	0.04480	0.04317	0.04177	0.04039	0.03937	0.03823	0.03740
1.3	0.27	0.07118	0.06632	0.06231	0.05891	0.05595	0.05345	0.05125	0.04940	0.04782	0.04626	0.04510	0.04381	0.04287
1.4	0.29	0.08037	0.07494	0.07046	0.06665	0.06333	0.06054	0.05806	0.05599	0.05422	0.05246	0.05116	0.04971	0.04865
1.5	0.31	0.09002	0.08399	0.07901	0.07478	0.07109	0.06798	0.06523	0.06293	0.06095	0.05899	0.05754	0.05592	0.05475
1.6	0.33	0.10011	0.09346	0.08797	0.08330	0.07923	0.07579	0.07275	0.07020	0.06802	0.06585	0.06424	0.06245	0.06115
1.7	0.35	0.11064	0.10335	0.09733	0.09221	0.08773	0.08396	0.08061	0.07781	0.07541	0.07302	0.07126	0.06928	0.06785
1.8	0.38	0.12159	0.11365	0.10708	0.10148	0.09659	0.09247	0.08882	0.08575	0.08312	0.08051	0.07858	0.07642	0.07485
1.9	0.40	0.13297	0.12435	0.11721	0.11113	0.10582	0.10133	0.09735	0.09401	0.09115	0.08831	0.08620	0.08385	0.08214
2.0	0.42	0.14477	0.13545	0.12773	0.12115	0.11539	0.11053	0.10622	0.10260	0.09950	0.09641	0.09413	0.09158	0.08972
2.1	0.44	0.15699	0.14694	0.13862	0.13152	0.12531	0.12007	0.11541	0.11151	0.10816	0.10482	0.10236	0.09960	0.09759
2.2	0.46	0.16961	0.15882	0.14988	0.14225	0.13558	0.12994	0.12493	0.12073	0.11712	0.11353	0.11088	0.10790	0.10574
2.3	0.48	0.18263	0.17108	0.16151	0.15334	0.14618	0.14014	0.13477	0.13026	0.12639	0.12254	0.11969	0.11650	0.11417
2.4	0.50	0.19605	0.18372	0.17350	0.16477	0.15712	0.15066	0.14492	0.14010	0.13596	0.13184	0.12879	0.12537	0.12289
2.5	0.52	0.20987	0.19674	0.18585	0.17655	0.16840	0.16151	0.15539	0.15024	0.14583	0.14143	0.13817	0.13453	0.13187
2.6	0.54	0.22407	0.21013	0.19856	0.18868	0.18001	0.17268	0.16617	0.16069	0.15599	0.15131	0.14784	0.14396	0.14113
2.7	0.56	0.23867	0.22389	0.21162	0.20114	0.19194	0.18417	0.17725	0.17144	0.16645	0.16147	0.15779	0.15367	0.15067
2.8	0.58	0.25364	0.23801	0.22503	0.21394	0.20420	0.19597	0.18864	0.18248	0.17719	0.17192	0.16802	0.16365	0.16047

Recommended head loss design range

Sizing in this region will lead to excessive head loss conditions.

Appendix G:

Hydronic friction loss tables

5⁄16" Uponor PEX-a — 50% Propylene glycol — feet of head per foot of piping

Velocity (ft./sec.)	GPM	80ºF 27ºC	90ºF 32ºC	100ºF 38ºC	110ºF 43ºC	120ºF 49ºC	130ºF 54ºC	140ºF 60ºC	150ºF 66ºC	160ºF 71ºC	170ºF 77ºC	180ºF 82ºC	190ºF 88ºC	200ºF 93ºC
0.5	0.10	0.01774	0.01620	0.01495	0.01391	0.01303	0.01228	0.01164	0.01109	0.01061	0.01018	0.00980	0.00948	0.00918
0.6	0.13	0.02360	0.02161	0.01997	0.01862	0.01748	0.01650	0.01566	0.01494	0.01431	0.01374	0.01324	0.01283	0.01243
0.7	0.15	0.03009	0.02761	0.02557	0.02387	0.02244	0.02121	0.02015	0.01924	0.01846	0.01774	0.01710	0.01658	0.01608
0.8	0.17	0.03718	0.03417	0.03170	0.02964	0.02789	0.02639	0.02510	0.02399	0.02303	0.02215	0.02136	0.02072	0.02011
0.9	0.19	0.04486	0.04129	0.03835	0.03589	0.03381	0.03203	0.03049	0.02916	0.02801	0.02695	0.02601	0.02525	0.02451
1.0	0.21	0.05309	0.04893	0.04550	0.04263	0.04019	0.03811	0.03630	0.03474	0.03339	0.03215	0.03104	0.03014	0.02927
1.1	0.23	0.06187	0.05709	0.05314	0.04983	0.04702	0.04461	0.04252	0.04072	0.03915	0.03772	0.03644	0.03540	0.03439
1.2	0.25	0.07119	0.06575	0.06125	0.05749	0.05428	0.05154	0.04915	0.04709	0.04530	0.04366	0.04219	0.04100	0.03985
1.3	0.27	0.08102	0.07490	0.06984	0.06559	0.06197	0.05887	0.05617	0.05384	0.05182	0.04996	0.04830	0.04695	0.04564
1.4	0.29	0.09135	0.08453	0.07887	0.07413	0.07008	0.06660	0.06358	0.06097	0.05870	0.05662	0.05476	0.05324	0.05177
1.5	0.31	0.10219	0.09463	0.08835	0.08309	0.07859	0.07473	0.07137	0.06847	0.06594	0.06363	0.06155	0.05986	0.05822
1.6	0.33	0.11351	0.10518	0.09827	0.09247	0.08751	0.08325	0.07954	0.07633	0.07354	0.07097	0.06868	0.06681	0.06500
1.7	0.35	0.12531	0.11620	0.10862	0.10226	0.09682	0.09215	0.08807	0.08455	0.08148	0.07866	0.07614	0.07408	0.07208
1.8	0.38	0.13758	0.12765	0.11940	0.11246	0.10652	0.10142	0.09697	0.09312	0.08976	0.08668	0.08392	0.08167	0.07948
1.9	0.40	0.15032	0.13955	0.13060	0.12306	0.11661	0.11106	0.10622	0.10203	0.09838	0.09503	0.09202	0.08957	0.08719
2.0	0.42	0.16351	0.15188	0.14220	0.13406	0.12707	0.12107	0.11583	0.11129	0.10734	0.10370	0.10044	0.09779	0.09520
2.1	0.44	0.17715	0.16464	0.15422	0.14544	0.13791	0.13144	0.12578	0.12089	0.11662	0.11269	0.10918	0.10631	0.10351
2.2	0.46	0.19124	0.17782	0.16663	0.15721	0.14912	0.14216	0.13608	0.13082	0.12623	0.12200	0.11822	0.11513	0.11212
2.3	0.48	0.20578	0.19142	0.17945	0.16936	0.16070	0.15324	0.14673	0.14108	0.13616	0.13163	0.12757	0.12425	0.12102
2.4	0.50	0.22074	0.20543	0.19266	0.18188	0.17264	0.16467	0.15771	0.15167	0.14641	0.14156	0.13722	0.13367	0.13022
2.5	0.52	0.23614	0.21985	0.20625	0.19478	0.18493	0.17644	0.16902	0.16259	0.15698	0.15180	0.14717	0.14338	0.13970
2.6	0.54	0.25196	0.23467	0.22023	0.20805	0.19758	0.18856	0.18067	0.17383	0.16785	0.16235	0.15742	0.15339	0.14947
2.7	0.56	0.26821	0.24989	0.23460	0.22168	0.21058	0.20101	0.19264	0.18538	0.17904	0.17320	0.16796	0.16369	0.15952

Recommended head loss design range

Sizing in this region will lead to excessive head loss conditions.

Appendix G:

Hydronic friction loss tables

⅜" Uponor PEX-a — 100% Water — feet of head per foot of piping

Velocity (ft./sec.)	GPM	80ºF 27ºC	90ºF 32ºC	100ºF 38ºC	110ºF 43ºC	120ºF 49ºC	130ºF 54ºC	140ºF 60ºC	150ºF 66ºC	160ºF 71ºC	170ºF 77ºC	180ºF 82ºC	190ºF 88ºC	200ºF 93ºC
0.6	0.18	0.00713	0.00685	0.00661	0.00640	0.00621	0.00604	0.00589	0.00575	0.00562	0.00550	0.00540	0.00530	0.00521
0.7	0.21	0.00966	0.00930	0.00899	0.00871	0.00845	0.00823	0.00802	0.00784	0.00767	0.00751	0.00737	0.00724	0.00711
0.8	0.24	0.01252	0.01206	0.01166	0.01130	0.01098	0.01069	0.01043	0.01019	0.00998	0.00977	0.00959	0.00943	0.00927
0.9	0.27	0.01567	0.01511	0.01461	0.01417	0.01378	0.01342	0.01310	0.01281	0.01254	0.01229	0.01207	0.01186	0.01167
1.0	0.30	0.01912	0.01845	0.01785	0.01732	0.01685	0.01642	0.01603	0.01568	0.01535	0.01505	0.01478	0.01453	0.01430
1.1	0.33	0.02286	0.02207	0.02136	0.02074	0.02017	0.01967	0.01921	0.01879	0.01841	0.01805	0.01773	0.01744	0.01716
1.2	0.36	0.02688	0.02595	0.02513	0.02441	0.02375	0.02316	0.02263	0.02214	0.02170	0.02128	0.02091	0.02056	0.02024
1.3	0.39	0.03117	0.03011	0.02917	0.02833	0.02758	0.02690	0.02629	0.02573	0.02522	0.02474	0.02431	0.02392	0.02355
1.4	0.42	0.03572	0.03452	0.03345	0.03251	0.03165	0.03088	0.03019	0.02955	0.02897	0.02843	0.02794	0.02749	0.02706
1.5	0.45	0.04054	0.03919	0.03799	0.03692	0.03596	0.03510	0.03431	0.03359	0.03294	0.03233	0.03178	0.03127	0.03079
1.6	0.48	0.04562	0.04411	0.04277	0.04158	0.04051	0.03954	0.03867	0.03786	0.03713	0.03645	0.03583	0.03526	0.03473
1.7	0.51	0.05095	0.04928	0.04780	0.04648	0.04529	0.04421	0.04324	0.04235	0.04154	0.04078	0.04010	0.03947	0.03888
1.8	0.54	0.05653	0.05469	0.05306	0.05161	0.05029	0.04911	0.04804	0.04706	0.04616	0.04533	0.04457	0.04387	0.04322
1.9	0.57	0.06237	0.06035	0.05856	0.05697	0.05553	0.05423	0.05306	0.05198	0.05100	0.05008	0.04925	0.04848	0.04777
2.0	0.60	0.06844	0.06624	0.06429	0.06255	0.06098	0.05957	0.05829	0.05711	0.05604	0.05504	0.05413	0.05330	0.05252
2.1	0.63	0.07476	0.07237	0.07025	0.06836	0.06666	0.06512	0.06373	0.06245	0.06129	0.06020	0.05922	0.05831	0.05746
2.2	0.66	0.08131	0.07873	0.07644	0.07440	0.07255	0.07089	0.06939	0.06800	0.06674	0.06556	0.06450	0.06351	0.06259
2.3	0.69	0.08810	0.08532	0.08285	0.08065	0.07866	0.07687	0.07525	0.07376	0.07240	0.07112	0.06998	0.06892	0.06792
2.4	0.72	0.09513	0.09214	0.08949	0.08713	0.08499	0.08306	0.08132	0.07971	0.07826	0.07689	0.07565	0.07451	0.07344
2.5	0.75	0.10239	0.09919	0.09635	0.09382	0.09153	0.08946	0.08760	0.08588	0.08431	0.08284	0.08152	0.08030	0.07915
2.6	0.78	0.10987	0.10646	0.10342	0.10072	0.09827	0.09607	0.09408	0.09224	0.09057	0.08899	0.08758	0.08627	0.08505
2.7	0.81	0.11759	0.11395	0.11072	0.10784	0.10523	0.10288	0.10076	0.09879	0.09701	0.09534	0.09384	0.09244	0.09113
2.8	0.84	0.12553	0.12167	0.11823	0.11517	0.11240	0.10990	0.10764	0.10555	0.10366	0.10188	0.10028	0.09879	0.09740
2.9	0.87	0.13369	0.12960	0.12595	0.12270	0.11976	0.11712	0.11472	0.11250	0.11049	0.10860	0.10690	0.10533	0.10385
3.0	0.90	0.14208	0.13775	0.13388	0.13045	0.12734	0.12453	0.12199	0.11965	0.11752	0.11552	0.11372	0.11205	0.11049
3.1	0.93	0.15069	0.14611	0.14203	0.13840	0.13511	0.13215	0.12946	0.12699	0.12474	0.12262	0.12072	0.11895	0.11730
3.2	0.96	0.15951	0.15469	0.15038	0.14656	0.14309	0.13996	0.13713	0.13452	0.13214	0.12991	0.12790	0.12604	0.12430
3.3	0.99	0.16856	0.16348	0.15895	0.15492	0.15127	0.14797	0.14499	0.14224	0.13974	0.13739	0.13527	0.13331	0.13147
3.4	1.02	0.17782	0.17248	0.16772	0.16348	0.15964	0.15618	0.15304	0.15015	0.14752	0.14504	0.14282	0.14075	0.13883
3.5	1.05	0.18729	0.18169	0.17669	0.17225	0.16821	0.16458	0.16129	0.15825	0.15549	0.15289	0.15055	0.14838	0.14636
3.6	1.08	0.19698	0.19111	0.18587	0.18121	0.17698	0.17317	0.16972	0.16653	0.16364	0.16091	0.15846	0.15619	0.15406
3.7	1.11	0.20688	0.20074	0.19525	0.19037	0.18595	0.18196	0.17834	0.17500	0.17197	0.16912	0.16655	0.16417	0.16194
3.8	1.14	0.21700	0.21057	0.20484	0.19974	0.19511	0.19093	0.18715	0.18366	0.18049	0.17750	0.17482	0.17233	0.17000
3.8	1.14	0.22732	0.22061	0.21462	0.20929	0.20446	0.20010	0.19615	0.19250	0.18919	0.18607	0.18327	0.18066	0.17823

Recommended head loss design range

Sizing in this region will lead to excessive head loss conditions.

Appendix G:

Hydronic friction loss tables

⅜" Uponor PEX-a — 30% Propylene glycol — feet of head per foot of piping

Velocity (ft./sec.)	GPM	80ºF 27ºC	90ºF 32ºC	100ºF 38ºC	110ºF 43ºC	120ºF 49ºC	130ºF 54ºC	140ºF 60ºC	150ºF 66ºC	160ºF 71ºC	170ºF 77ºC	180ºF 82ºC	190ºF 88ºC	200ºF 93ºC
0.5	0.15	0.01025	0.00960	0.00904	0.00857	0.00817	0.00782	0.00751	0.00726	0.00702	0.00680	0.00662	0.00644	0.00631
0.6	0.18	0.01377	0.01292	0.01219	0.01157	0.01105	0.01059	0.01017	0.00984	0.00952	0.00923	0.00899	0.00876	0.00859
0.7	0.21	0.01771	0.01663	0.01572	0.01493	0.01427	0.01369	0.01316	0.01275	0.01234	0.01197	0.01167	0.01137	0.01115
0.8	0.24	0.02203	0.02072	0.01960	0.01864	0.01783	0.01712	0.01647	0.01596	0.01546	0.01501	0.01464	0.01427	0.01400
0.9	0.27	0.02674	0.02517	0.02384	0.02269	0.02172	0.02086	0.02009	0.01947	0.01888	0.01833	0.01788	0.01744	0.01711
1.0	0.30	0.03182	0.02998	0.02841	0.02706	0.02592	0.02491	0.02400	0.02328	0.02257	0.02193	0.02140	0.02088	0.02049
1.1	0.33	0.03725	0.03513	0.03332	0.03175	0.03043	0.02926	0.02820	0.02737	0.02655	0.02580	0.02519	0.02458	0.02413
1.2	0.36	0.04304	0.04061	0.03854	0.03675	0.03524	0.03390	0.03269	0.03173	0.03080	0.02994	0.02923	0.02854	0.02802
1.3	0.39	0.04917	0.04642	0.04408	0.04206	0.04035	0.03883	0.03746	0.03637	0.03531	0.03434	0.03354	0.03275	0.03216
1.4	0.42	0.05563	0.05256	0.04994	0.04766	0.04575	0.04404	0.04250	0.04128	0.04009	0.03900	0.03809	0.03720	0.03655
1.5	0.45	0.06242	0.05901	0.05609	0.05356	0.05143	0.04953	0.04782	0.04645	0.04512	0.04390	0.04290	0.04190	0.04117
1.6	0.48	0.06954	0.06577	0.06255	0.05975	0.05739	0.05529	0.05339	0.05188	0.05041	0.04906	0.04794	0.04685	0.04604
1.7	0.51	0.07698	0.07284	0.06930	0.06622	0.06363	0.06132	0.05923	0.05757	0.05595	0.05446	0.05323	0.05202	0.05113
1.8	0.54	0.08473	0.08020	0.07634	0.07298	0.07014	0.06761	0.06533	0.06351	0.06173	0.06011	0.05876	0.05744	0.05646
1.9	0.57	0.09279	0.08787	0.08367	0.08001	0.07692	0.07417	0.07168	0.06970	0.06776	0.06599	0.06452	0.06308	0.06201
2.0	0.60	0.10116	0.09583	0.09128	0.08731	0.08397	0.08098	0.07829	0.07613	0.07404	0.07211	0.07052	0.06895	0.06779
2.1	0.63	0.10983	0.10408	0.09917	0.09489	0.09128	0.08805	0.08514	0.08281	0.08055	0.07847	0.07675	0.07505	0.07380
2.2	0.66	0.11880	0.11262	0.10734	0.10273	0.09885	0.09538	0.09224	0.08974	0.08730	0.08506	0.08320	0.08137	0.08003
2.3	0.69	0.12807	0.12145	0.11578	0.11084	0.10667	0.10295	0.09958	0.09690	0.09428	0.09188	0.08988	0.08792	0.08647
2.4	0.72	0.13763	0.13055	0.12449	0.11921	0.11475	0.11078	0.10717	0.10430	0.10149	0.09892	0.09679	0.09468	0.09313
2.5	0.75	0.14748	0.13993	0.13347	0.12785	0.12309	0.11884	0.11500	0.11193	0.10894	0.10619	0.10391	0.10167	0.10001
2.6	0.78	0.15761	0.14959	0.14272	0.13674	0.13167	0.12716	0.12306	0.11980	0.11661	0.11369	0.11126	0.10887	0.10711
2.7	0.81	0.16803	0.15953	0.15224	0.14588	0.14051	0.13571	0.13136	0.12790	0.12451	0.12140	0.11883	0.11629	0.11441
2.8	0.84	0.17873	0.16973	0.16201	0.15528	0.14959	0.14451	0.13990	0.13622	0.13263	0.12934	0.12661	0.12392	0.12193
2.9	0.87	0.18972	0.18020	0.17205	0.16493	0.15891	0.15354	0.14867	0.14478	0.14098	0.13750	0.13461	0.13176	0.12966
3.0	0.90	0.20098	0.19094	0.18234	0.17483	0.16848	0.16281	0.15767	0.15356	0.14955	0.14588	0.14282	0.13981	0.13759
3.1	0.93	0.21251	0.20195	0.19289	0.18498	0.17829	0.17231	0.16689	0.16257	0.15834	0.15447	0.15125	0.14807	0.14573
3.2	0.96	0.22432	0.21322	0.20369	0.19537	0.18834	0.18205	0.17635	0.17180	0.16735	0.16327	0.15988	0.15655	0.15408
3.3	0.99	0.23640	0.22475	0.21475	0.20601	0.19863	0.19202	0.18603	0.18125	0.17658	0.17229	0.16873	0.16522	0.16264

Recommended head loss design range

Sizing in this region will lead to excessive head loss conditions.

Appendix G:

Hydronic friction loss tables

⅜" Uponor PEX-a — 40% Propylene glycol — feet of head per foot of piping

Velocity (ft./sec.)	GPM	80ºF 27ºC	90ºF 32ºC	100ºF 38ºC	110ºF 43ºC	120ºF 49ºC	130ºF 54ºC	140ºF 60ºC	150ºF 66ºC	160ºF 71ºC	170ºF 77ºC	180ºF 82ºC	190ºF 88ºC	200ºF 93ºC
0.5	0.15	0.01183	0.01093	0.01019	0.00957	0.00903	0.00859	0.00819	0.00787	0.00759	0.00731	0.00711	0.00688	0.00672
0.6	0.18	0.01583	0.01465	0.01369	0.01288	0.01218	0.01159	0.01107	0.01064	0.01027	0.00991	0.00964	0.00934	0.00913
0.7	0.21	0.02028	0.01881	0.01760	0.01658	0.01570	0.01496	0.01430	0.01375	0.01329	0.01283	0.01249	0.01211	0.01183
0.8	0.24	0.02517	0.02338	0.02191	0.02066	0.01958	0.01867	0.01786	0.01719	0.01662	0.01605	0.01564	0.01517	0.01483
0.9	0.27	0.03048	0.02834	0.02659	0.02510	0.02380	0.02271	0.02175	0.02095	0.02026	0.01958	0.01908	0.01852	0.01811
1.0	0.30	0.03619	0.03369	0.03163	0.02989	0.02837	0.02709	0.02596	0.02501	0.02420	0.02340	0.02281	0.02215	0.02167
1.1	0.33	0.04229	0.03941	0.03703	0.03502	0.03326	0.03178	0.03047	0.02937	0.02844	0.02750	0.02682	0.02605	0.02549
1.2	0.36	0.04878	0.04549	0.04278	0.04048	0.03847	0.03678	0.03528	0.03403	0.03295	0.03189	0.03110	0.03022	0.02958
1.3	0.39	0.05565	0.05194	0.04887	0.04627	0.04400	0.04208	0.04039	0.03897	0.03775	0.03654	0.03565	0.03465	0.03392
1.4	0.42	0.06287	0.05873	0.05530	0.05238	0.04983	0.04769	0.04578	0.04419	0.04282	0.04146	0.04046	0.03933	0.03852
1.5	0.45	0.07046	0.06586	0.06205	0.05881	0.05597	0.05358	0.05146	0.04968	0.04816	0.04664	0.04552	0.04427	0.04336
1.6	0.48	0.07841	0.07333	0.06912	0.06554	0.06241	0.05976	0.05742	0.05545	0.05376	0.05209	0.05085	0.04946	0.04845
1.7	0.51	0.08670	0.08113	0.07651	0.07258	0.06913	0.06623	0.06365	0.06149	0.05963	0.05778	0.05642	0.05489	0.05378
1.8	0.54	0.09533	0.08925	0.08421	0.07992	0.07615	0.07298	0.07015	0.06779	0.06575	0.06373	0.06224	0.06056	0.05934
1.9	0.57	0.10430	0.09770	0.09222	0.08755	0.08346	0.08000	0.07693	0.07435	0.07213	0.06993	0.06830	0.06648	0.06515
2.0	0.60	0.11361	0.10646	0.10053	0.09547	0.09104	0.08729	0.08396	0.08117	0.07876	0.07637	0.07461	0.07262	0.07118
2.1	0.63	0.12324	0.11554	0.10915	0.10369	0.09890	0.09486	0.09126	0.08824	0.08564	0.08306	0.08115	0.07901	0.07745
2.2	0.66	0.13320	0.12492	0.11806	0.11219	0.10704	0.10269	0.09882	0.09556	0.09277	0.08999	0.08793	0.08562	0.08394
2.3	0.69	0.14348	0.13462	0.12726	0.12097	0.11545	0.11078	0.10663	0.10314	0.10014	0.09715	0.09494	0.09246	0.09066
2.4	0.72	0.15408	0.14461	0.13675	0.13003	0.12413	0.11913	0.11469	0.11096	0.10775	0.10455	0.10218	0.09953	0.09760
2.5	0.75	0.16499	0.15491	0.14653	0.13936	0.13307	0.12775	0.12301	0.11902	0.11560	0.11218	0.10966	0.10682	0.10476
2.6	0.78	0.17621	0.16550	0.15659	0.14897	0.14228	0.13661	0.13157	0.12733	0.12368	0.12005	0.11736	0.11434	0.11214
2.7	0.81	0.18774	0.17639	0.16694	0.15886	0.15175	0.14574	0.14038	0.13588	0.13200	0.12814	0.12528	0.12208	0.11974
2.8	0.84	0.19958	0.18756	0.17757	0.16901	0.16148	0.15511	0.14944	0.14466	0.14056	0.13647	0.13343	0.13003	0.12755
2.9	0.87	0.21172	0.19903	0.18847	0.17942	0.17147	0.16473	0.15874	0.15369	0.14934	0.14501	0.14180	0.13821	0.13558
3.0	0.90	0.22416	0.21078	0.19964	0.19010	0.18171	0.17461	0.16827	0.16294	0.15836	0.15379	0.15040	0.14660	0.14383
3.1	0.93	0.23690	0.22282	0.21109	0.20105	0.19221	0.18472	0.17805	0.17243	0.16760	0.16278	0.15921	0.15520	0.15228
3.2	0.96	0.24993	0.23514	0.22282	0.21225	0.20296	0.19508	0.18807	0.18215	0.17707	0.17200	0.16824	0.16402	0.16094

Recommended head loss design range

Sizing in this region will lead to excessive head loss conditions.

Appendix G:

Hydronic friction loss tables

3/8" Uponor PEX-a — 50% Propylene glycol — feet of head per foot of piping

Velocity (ft./sec.)	GPM	80ºF 27ºC	90ºF 32ºC	100ºF 38ºC	110ºF 43ºC	120ºF 49ºC	130ºF 54ºC	140ºF 60ºC	150ºF 66ºC	160ºF 71ºC	170ºF 77ºC	180ºF 82ºC	190ºF 88ºC	200ºF 93ºC
0.5	0.15	0.01368	0.01252	0.01158	0.01079	0.01013	0.00956	0.00908	0.00866	0.00830	0.00796	0.00767	0.00743	0.00720
0.6	0.18	0.01823	0.01674	0.01550	0.01448	0.01361	0.01287	0.01223	0.01168	0.01121	0.01077	0.01038	0.01007	0.00977
0.7	0.21	0.02329	0.02142	0.01988	0.01859	0.01750	0.01657	0.01576	0.01507	0.01447	0.01392	0.01343	0.01303	0.01265
0.8	0.24	0.02882	0.02655	0.02468	0.02311	0.02178	0.02064	0.01966	0.01881	0.01807	0.01740	0.01680	0.01631	0.01583
0.9	0.27	0.03482	0.03212	0.02989	0.02802	0.02644	0.02508	0.02390	0.02288	0.02200	0.02119	0.02047	0.01989	0.01932
1.0	0.30	0.04126	0.03811	0.03550	0.03332	0.03146	0.02987	0.02848	0.02729	0.02625	0.02530	0.02445	0.02376	0.02309
1.1	0.33	0.04813	0.04450	0.04150	0.03898	0.03683	0.03499	0.03339	0.03201	0.03081	0.02971	0.02872	0.02792	0.02714
1.2	0.36	0.05542	0.05130	0.04788	0.04501	0.04256	0.04045	0.03862	0.03704	0.03567	0.03441	0.03328	0.03236	0.03147
1.3	0.39	0.06313	0.05848	0.05462	0.05138	0.04862	0.04624	0.04417	0.04238	0.04083	0.03940	0.03812	0.03708	0.03606
1.4	0.42	0.07123	0.06604	0.06173	0.05811	0.05501	0.05235	0.05003	0.04802	0.04628	0.04467	0.04323	0.04206	0.04093
1.5	0.45	0.07973	0.07398	0.06919	0.06517	0.06173	0.05877	0.05619	0.05395	0.05201	0.05022	0.04862	0.04732	0.04605
1.6	0.48	0.08862	0.08228	0.07701	0.07257	0.06877	0.06550	0.06264	0.06018	0.05803	0.05605	0.05428	0.05283	0.05143
1.7	0.51	0.09789	0.09095	0.08516	0.08029	0.07612	0.07253	0.06940	0.06668	0.06432	0.06214	0.06019	0.05861	0.05706
1.8	0.54	0.10753	0.09996	0.09366	0.08834	0.08379	0.07986	0.07644	0.07347	0.07089	0.06851	0.06637	0.06463	0.06294
1.9	0.57	0.11755	0.10933	0.10248	0.09671	0.09176	0.08749	0.08377	0.08054	0.07772	0.07513	0.07281	0.07091	0.06907
2.0	0.60	0.12792	0.11905	0.11164	0.10539	0.10003	0.09541	0.09138	0.08788	0.08483	0.08201	0.07949	0.07744	0.07543
2.1	0.63	0.13866	0.12910	0.12112	0.11439	0.10861	0.10362	0.09926	0.09549	0.09219	0.08916	0.08643	0.08421	0.08204
2.2	0.66	0.14975	0.13949	0.13092	0.12369	0.11747	0.11212	0.10743	0.10337	0.09982	0.09655	0.09362	0.09122	0.08889
2.3	0.69	0.16119	0.15021	0.14104	0.13329	0.12664	0.12089	0.11587	0.11151	0.10770	0.10420	0.10105	0.09848	0.09598
2.4	0.72	0.17298	0.16127	0.15147	0.14320	0.13609	0.12995	0.12457	0.11991	0.11584	0.11209	0.10872	0.10597	0.10329
2.5	0.75	0.18511	0.17264	0.16222	0.15340	0.14582	0.13928	0.13355	0.12858	0.12424	0.12023	0.11664	0.11370	0.11084
2.6	0.78	0.19758	0.18434	0.17326	0.16390	0.15584	0.14888	0.14279	0.13750	0.13288	0.12862	0.12479	0.12167	0.11862
2.7	0.81	0.21039	0.19636	0.18462	0.17469	0.16614	0.15876	0.15229	0.14668	0.14177	0.13725	0.13318	0.12986	0.12663
2.8	0.84	0.22352	0.20869	0.19627	0.18577	0.17672	0.16890	0.16205	0.15611	0.15091	0.14611	0.14181	0.13829	0.13486
2.9	0.87	0.23699	0.22134	0.20823	0.19713	0.18757	0.17931	0.17207	0.16579	0.16029	0.15522	0.15066	0.14694	0.14331
3.0	0.90	0.25079	0.23430	0.22048	0.20878	0.19870	0.18999	0.18235	0.17572	0.16992	0.16456	0.15975	0.15582	0.15199

Recommended head loss design range

Sizing in this region will lead to excessive head loss conditions.

Appendix G:

Hydronic friction loss tables

½" Uponor PEX-a — 100% Water — feet of head per foot of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
0.5	0.28	0.00626	0.00588	0.00545	0.00532	0.00518	0.00507	0.00495	0.00475	0.00458	0.00442	0.00429	0.00416	0.00405	0.00396	0.00386	0.00378	0.00371	0.00364	0.00357	0.00351
0.6	0.33	0.00846	0.00795	0.00739	0.00721	0.00703	0.00688	0.00672	0.00646	0.00623	0.00602	0.00584	0.00568	0.00553	0.00540	0.00528	0.00517	0.00507	0.00497	0.00489	0.00481
0.7	0.39	0.01091	0.01027	0.00956	0.00934	0.00910	0.00891	0.00872	0.00838	0.00809	0.00783	0.00760	0.00739	0.00720	0.00703	0.00688	0.00674	0.00661	0.00649	0.00638	0.00628
0.8	0.44	0.01362	0.01284	0.01196	0.01169	0.01140	0.01117	0.01093	0.01051	0.01015	0.00983	0.00954	0.00929	0.00906	0.00885	0.00866	0.00848	0.00832	0.00817	0.00804	0.00791
0.9	0.50	0.01658	0.01564	0.01459	0.01426	0.01392	0.01364	0.01334	0.01284	0.01241	0.01202	0.01168	0.01137	0.01109	0.01084	0.01061	0.01040	0.01020	0.01002	0.00986	0.00971
1.0	0.55	0.01977	0.01867	0.01743	0.01704	0.01664	0.01631	0.01596	0.01537	0.01486	0.01440	0.01399	0.01363	0.01330	0.01300	0.01273	0.01248	0.01224	0.01203	0.01184	0.01166
1.1	0.61	0.02320	0.02192	0.02048	0.02003	0.01956	0.01918	0.01878	0.01809	0.01749	0.01696	0.01649	0.01606	0.01568	0.01533	0.01501	0.01472	0.01445	0.01420	0.01398	0.01377
1.2	0.66	0.02685	0.02538	0.02374	0.02323	0.02269	0.02225	0.02179	0.02100	0.02031	0.01970	0.01916	0.01867	0.01823	0.01783	0.01746	0.01712	0.01681	0.01653	0.01627	0.01602
1.3	0.72	0.03073	0.02906	0.02720	0.02662	0.02601	0.02551	0.02498	0.02409	0.02331	0.02262	0.02200	0.02144	0.02094	0.02048	0.02006	0.01968	0.01933	0.01901	0.01871	0.01843
1.4	0.77	0.03482	0.03295	0.03086	0.03020	0.02952	0.02895	0.02837	0.02736	0.02648	0.02570	0.02501	0.02438	0.02381	0.02330	0.02283	0.02240	0.02200	0.02163	0.02130	0.02098
1.5	0.83	0.03913	0.03705	0.03472	0.03398	0.03322	0.03259	0.03193	0.03081	0.02983	0.02896	0.02818	0.02748	0.02684	0.02627	0.02574	0.02526	0.02481	0.02441	0.02403	0.02368
1.6	0.88	0.04365	0.04134	0.03876	0.03795	0.03710	0.03641	0.03568	0.03444	0.03335	0.03238	0.03152	0.03074	0.03003	0.02940	0.02881	0.02828	0.02778	0.02733	0.02691	0.02652
1.7	0.94	0.04837	0.04584	0.04300	0.04211	0.04117	0.04040	0.03960	0.03824	0.03704	0.03597	0.03502	0.03415	0.03338	0.03268	0.03203	0.03144	0.03089	0.03039	0.02993	0.02950
1.8	0.99	0.05330	0.05053	0.04742	0.04644	0.04542	0.04458	0.04370	0.04220	0.04089	0.03971	0.03867	0.03773	0.03688	0.03611	0.03540	0.03475	0.03415	0.03360	0.03309	0.03262
1.9	1.05	0.05843	0.05541	0.05203	0.05096	0.04985	0.04893	0.04798	0.04634	0.04490	0.04362	0.04249	0.04146	0.04053	0.03969	0.03891	0.03821	0.03754	0.03695	0.03639	0.03588
2.0	1.10	0.06376	0.06049	0.05682	0.05566	0.05445	0.05346	0.05242	0.05064	0.04908	0.04769	0.04646	0.04534	0.04433	0.04341	0.04257	0.04180	0.04108	0.04043	0.03983	0.03927
2.1	1.16	0.06929	0.06576	0.06179	0.06054	0.05923	0.05815	0.05703	0.05511	0.05342	0.05192	0.05058	0.04937	0.04827	0.04728	0.04637	0.04554	0.04476	0.04406	0.04341	0.04280
2.2	1.22	0.07501	0.07121	0.06693	0.06559	0.06418	0.06302	0.06181	0.05974	0.05792	0.05630	0.05485	0.05355	0.05237	0.05130	0.05031	0.04942	0.04858	0.04782	0.04711	0.04646
2.3	1.27	0.08093	0.07685	0.07226	0.07081	0.06930	0.06805	0.06675	0.06453	0.06258	0.06083	0.05928	0.05787	0.05661	0.05546	0.05440	0.05343	0.05253	0.05171	0.05096	0.05025
2.4	1.33	0.08703	0.08267	0.07775	0.07621	0.07459	0.07325	0.07186	0.06948	0.06739	0.06552	0.06386	0.06235	0.06099	0.05976	0.05862	0.05759	0.05662	0.05574	0.05493	0.05417
2.5	1.38	0.09333	0.08867	0.08343	0.08177	0.08004	0.07862	0.07713	0.07459	0.07235	0.07036	0.06858	0.06697	0.06552	0.06420	0.06298	0.06188	0.06084	0.05991	0.05904	0.05823
2.6	1.44	0.09981	0.09485	0.08927	0.08751	0.08566	0.08415	0.08257	0.07986	0.07747	0.07534	0.07345	0.07173	0.07019	0.06878	0.06748	0.06631	0.06520	0.06420	0.06328	0.06241
2.7	1.49	0.10648	0.10121	0.09528	0.09341	0.09145	0.08984	0.08816	0.08528	0.08274	0.08048	0.07847	0.07664	0.07499	0.07350	0.07212	0.07087	0.06969	0.06863	0.06764	0.06672
2.8	1.55	0.11333	0.10775	0.10146	0.09948	0.09740	0.09570	0.09391	0.09086	0.08817	0.08577	0.08363	0.08169	0.07994	0.07836	0.07689	0.07556	0.07431	0.07319	0.07214	0.07116
2.9	1.60	0.12036	0.11446	0.10781	0.10571	0.10352	0.10171	0.09982	0.09659	0.09374	0.09120	0.08894	0.08688	0.08503	0.08335	0.08180	0.08039	0.07906	0.07787	0.07676	0.07573
3.0	1.66	0.12758	0.12135	0.11433	0.11211	0.10979	0.10788	0.10589	0.10247	0.09946	0.09677	0.09438	0.09221	0.09025	0.08848	0.08684	0.08535	0.08395	0.08269	0.08151	0.08042
3.1	1.71	0.13497	0.12841	0.12101	0.11867	0.11622	0.11421	0.11211	0.10850	0.10533	0.10250	0.09997	0.09768	0.09562	0.09374	0.09201	0.09044	0.08896	0.08763	0.08639	0.08523
3.2	1.77	0.14255	0.13564	0.12785	0.12539	0.12282	0.12070	0.11848	0.11469	0.11135	0.10836	0.10570	0.10329	0.10111	0.09914	0.09732	0.09566	0.09410	0.09270	0.09139	0.09017
3.3	1.82	0.15030	0.14304	0.13486	0.13228	0.12957	0.12734	0.12501	0.12102	0.11751	0.11437	0.11157	0.10904	0.10675	0.10467	0.10275	0.10101	0.09937	0.09789	0.09652	0.09524
3.4	1.88	0.15823	0.15061	0.14203	0.13932	0.13647	0.13414	0.13169	0.12750	0.12381	0.12052	0.11758	0.11492	0.11252	0.11033	0.10832	0.10649	0.10476	0.10321	0.10177	0.10042
3.5	1.93	0.16633	0.15835	0.14936	0.14652	0.14354	0.14109	0.13853	0.13413	0.13027	0.12681	0.12373	0.12094	0.11842	0.11613	0.11402	0.11210	0.11029	0.10866	0.10714	0.10573
3.6	1.99	0.17460	0.16626	0.15684	0.15387	0.15075	0.14819	0.14551	0.14091	0.13686	0.13324	0.13002	0.12709	0.12445	0.12205	0.11984	0.11783	0.11593	0.11423	0.11264	0.11116
3.7	2.04	0.18305	0.17433	0.16449	0.16138	0.15812	0.15544	0.15264	0.14783	0.14360	0.13981	0.13644	0.13338	0.13062	0.12811	0.12579	0.12369	0.12171	0.11992	0.11826	0.11671
3.8	2.10	0.19167	0.18257	0.17230	0.16905	0.16565	0.16285	0.15992	0.15490	0.15048	0.14652	0.14300	0.13980	0.13692	0.13430	0.13188	0.12968	0.12760	0.12574	0.12400	0.12238

Continued on next page

Recommended head loss design range

Sizing in this region will lead to excessive head loss conditions.

½" Uponor PEX-a — 100% Water — feet of head per foot of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
3.9	2.15	0.20046	0.19097	0.18026	0.17688	0.17333	0.17040	0.16735	0.16211	0.15750	0.15337	0.14970	0.14636	0.14335	0.14061	0.13808	0.13579	0.13362	0.13168	0.12987	0.12818
4.0	2.21	0.20942	0.19954	0.18838	0.18485	0.18115	0.17811	0.17493	0.16947	0.16466	0.16036	0.15653	0.15305	0.14990	0.14705	0.14442	0.14203	0.13977	0.13774	0.13585	0.13409
4.1	2.26	0.21855	0.20827	0.19665	0.19298	0.18913	0.18596	0.18265	0.17697	0.17196	0.16748	0.16349	0.15987	0.15659	0.15362	0.15088	0.14839	0.14604	0.14392	0.14195	0.14012
4.2	2.32	0.22785	0.21716	0.20508	0.20127	0.19726	0.19397	0.19052	0.18461	0.17940	0.17474	0.17059	0.16682	0.16341	0.16032	0.15747	0.15487	0.15243	0.15022	0.14818	0.14627
4.3	2.38	0.23732	0.22621	0.21367	0.20970	0.20554	0.20212	0.19854	0.19239	0.18698	0.18213	0.17782	0.17390	0.17036	0.16715	0.16418	0.16148	0.15894	0.15665	0.15452	0.15253
4.4	2.43	0.24695	0.23542	0.22240	0.21829	0.21397	0.21041	0.20669	0.20031	0.19469	0.18966	0.18518	0.18111	0.17743	0.17410	0.17101	0.16821	0.16557	0.16319	0.16098	0.15891
4.5	2.49	0.25674	0.24480	0.23129	0.22702	0.22254	0.21885	0.21500	0.20838	0.20254	0.19733	0.19268	0.18845	0.18464	0.18117	0.17797	0.17506	0.17232	0.16985	0.16756	0.16542
4.6	2.54	0.26670	0.25433	0.24033	0.23591	0.23126	0.22744	0.22344	0.21658	0.21053	0.20512	0.20030	0.19592	0.19197	0.18838	0.18506	0.18204	0.17919	0.17664	0.17426	0.17203

Recommended head loss design range

Sizing in this region will lead to excessive head loss conditions.

½" Uponor PEX-a — 30% Propylene glycol — feet of head per foot of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
0.5	0.28	0.00940	0.00897	0.00852	0.00817	0.00781	0.00752	0.00721	0.00673	0.00631	0.00597	0.00566	0.00541	0.00519	0.00499	0.00483	0.00468	0.00453	0.00442	0.00430	0.00422
0.6	0.33	0.01255	0.01200	0.01141	0.01096	0.01048	0.01010	0.00970	0.00906	0.00852	0.00806	0.00767	0.00733	0.00704	0.00677	0.00656	0.00636	0.00617	0.00602	0.00586	0.00575
0.7	0.39	0.01606	0.01536	0.01463	0.01406	0.01346	0.01299	0.01248	0.01168	0.01100	0.01042	0.00991	0.00949	0.00912	0.00878	0.00851	0.00825	0.00802	0.00782	0.00762	0.00748
0.8	0.44	0.01990	0.01905	0.01816	0.01747	0.01674	0.01616	0.01555	0.01456	0.01373	0.01301	0.01240	0.01188	0.01142	0.01101	0.01068	0.01035	0.01006	0.00982	0.00958	0.00940
0.9	0.50	0.02406	0.02306	0.02199	0.02117	0.02031	0.01961	0.01888	0.01770	0.01670	0.01585	0.01511	0.01449	0.01394	0.01344	0.01304	0.01266	0.01230	0.01201	0.01172	0.01151
1.0	0.55	0.02854	0.02737	0.02612	0.02516	0.02415	0.02333	0.02247	0.02109	0.01992	0.01892	0.01805	0.01731	0.01666	0.01607	0.01561	0.01515	0.01473	0.01439	0.01404	0.01379
1.1	0.61	0.03332	0.03197	0.03054	0.02943	0.02826	0.02732	0.02633	0.02473	0.02337	0.02221	0.02120	0.02035	0.01959	0.01891	0.01836	0.01783	0.01735	0.01694	0.01655	0.01626
1.2	0.66	0.03840	0.03687	0.03523	0.03397	0.03263	0.03156	0.03043	0.02860	0.02704	0.02572	0.02456	0.02359	0.02272	0.02194	0.02131	0.02070	0.02014	0.01968	0.01923	0.01889
1.3	0.72	0.04377	0.04204	0.04019	0.03877	0.03726	0.03605	0.03477	0.03271	0.03095	0.02944	0.02813	0.02703	0.02605	0.02516	0.02445	0.02375	0.02312	0.02259	0.02207	0.02169
1.4	0.77	0.04943	0.04749	0.04543	0.04383	0.04215	0.04079	0.03935	0.03704	0.03506	0.03338	0.03191	0.03067	0.02956	0.02856	0.02776	0.02698	0.02627	0.02568	0.02509	0.02466
1.5	0.83	0.05536	0.05321	0.05092	0.04915	0.04727	0.04577	0.04417	0.04160	0.03940	0.03752	0.03588	0.03450	0.03327	0.03215	0.03126	0.03039	0.02959	0.02893	0.02828	0.02780
1.6	0.88	0.06156	0.05919	0.05667	0.05472	0.05265	0.05098	0.04922	0.04638	0.04395	0.04187	0.04005	0.03852	0.03716	0.03592	0.03493	0.03397	0.03308	0.03235	0.03162	0.03109
1.7	0.94	0.06803	0.06544	0.06267	0.06053	0.05826	0.05643	0.05450	0.05137	0.04870	0.04641	0.04442	0.04273	0.04123	0.03987	0.03878	0.03772	0.03674	0.03593	0.03513	0.03454
1.8	0.99	0.07477	0.07194	0.06892	0.06659	0.06411	0.06211	0.06000	0.05658	0.05366	0.05116	0.04898	0.04713	0.04548	0.04399	0.04280	0.04163	0.04056	0.03968	0.03880	0.03816
1.9	1.05	0.08177	0.07869	0.07542	0.07288	0.07019	0.06802	0.06572	0.06200	0.05883	0.05610	0.05372	0.05171	0.04992	0.04829	0.04699	0.04572	0.04455	0.04358	0.04263	0.04192
2.0	1.10	0.08902	0.08570	0.08215	0.07941	0.07649	0.07415	0.07166	0.06763	0.06419	0.06123	0.05866	0.05648	0.05453	0.05276	0.05135	0.04997	0.04870	0.04765	0.04661	0.04584
2.1	1.16	0.09653	0.09295	0.08913	0.08617	0.08303	0.08050	0.07781	0.07347	0.06975	0.06656	0.06377	0.06142	0.05931	0.05740	0.05587	0.05438	0.05301	0.05187	0.05074	0.04992
2.2	1.22	0.10429	0.10044	0.09634	0.09317	0.08979	0.08707	0.08418	0.07951	0.07551	0.07207	0.06907	0.06654	0.06427	0.06221	0.06056	0.05895	0.05747	0.05624	0.05503	0.05414
2.3	1.27	0.11229	0.10818	0.10379	0.10039	0.09677	0.09385	0.09076	0.08575	0.08146	0.07777	0.07455	0.07183	0.06939	0.06718	0.06541	0.06368	0.06210	0.06078	0.05947	0.05851
2.4	1.33	0.12054	0.11615	0.11146	0.10783	0.10397	0.10085	0.09754	0.09219	0.08760	0.08366	0.08021	0.07730	0.07469	0.07232	0.07043	0.06857	0.06687	0.06546	0.06406	0.06303
2.5	1.38	0.12904	0.12436	0.11937	0.11550	0.11138	0.10806	0.10454	0.09883	0.09393	0.08973	0.08605	0.08294	0.08015	0.07762	0.07560	0.07362	0.07180	0.07029	0.06880	0.06770
2.6	1.44	0.13777	0.13281	0.12750	0.12339	0.11901	0.11548	0.11173	0.10566	0.10045	0.09598	0.09206	0.08875	0.08578	0.08309	0.08093	0.07882	0.07689	0.07528	0.07369	0.07251
2.7	1.49	0.14674	0.14148	0.13586	0.13150	0.12685	0.12311	0.11913	0.11269	0.10716	0.10241	0.09825	0.09473	0.09158	0.08871	0.08642	0.08418	0.08212	0.08041	0.07872	0.07747
2.8	1.55	0.15594	0.15038	0.14443	0.13982	0.13491	0.13094	0.12673	0.11991	0.11405	0.10902	0.10461	0.10088	0.09753	0.09450	0.09207	0.08969	0.08751	0.08569	0.08389	0.08257
2.9	1.60	0.16538	0.15951	0.15323	0.14836	0.14317	0.13898	0.13453	0.12732	0.12113	0.11580	0.11114	0.10719	0.10366	0.10044	0.09787	0.09535	0.09304	0.09112	0.08922	0.08781
3.0	1.66	0.17505	0.16886	0.16224	0.15711	0.15164	0.14722	0.14253	0.13492	0.12839	0.12276	0.11785	0.11367	0.10994	0.10654	0.10382	0.10117	0.09872	0.09669	0.09468	0.09320
3.1	1.71	0.18495	0.17844	0.17148	0.16607	0.16031	0.15566	0.15072	0.14271	0.13583	0.12990	0.12472	0.12032	0.11638	0.11280	0.10993	0.10713	0.10455	0.10240	0.10029	0.09872
3.2	1.77	0.19508	0.18824	0.18092	0.17524	0.16919	0.16430	0.15911	0.15068	0.14344	0.13721	0.13175	0.12713	0.12298	0.11921	0.11619	0.11324	0.11052	0.10826	0.10603	0.10438
3.3	1.82	0.20543	0.19826	0.19058	0.18462	0.17827	0.17314	0.16769	0.15884	0.15124	0.14469	0.13896	0.13410	0.12974	0.12578	0.12260	0.11950	0.11664	0.11427	0.11192	0.11019
3.4	1.88	0.21601	0.20849	0.20045	0.19421	0.18755	0.18218	0.17646	0.16719	0.15921	0.15234	0.14633	0.14123	0.13665	0.13249	0.12917	0.12591	0.12291	0.12041	0.11795	0.11613
3.5	1.93	0.22680	0.21895	0.21053	0.20400	0.19703	0.19141	0.18542	0.17571	0.16736	0.16017	0.15387	0.14852	0.14372	0.13936	0.13588	0.13246	0.12932	0.12670	0.12411	0.12220
3.6	1.99	0.23782	0.22961	0.22082	0.21399	0.20671	0.20083	0.19458	0.18442	0.17568	0.16816	0.16156	0.15597	0.15095	0.14639	0.14273	0.13916	0.13586	0.13313	0.13042	0.12842
3.7	2.04	0.24906	0.24050	0.23132	0.22419	0.21659	0.21045	0.20392	0.19331	0.18418	0.17632	0.16943	0.16358	0.15833	0.15356	0.14974	0.14600	0.14256	0.13969	0.13686	0.13477
3.8	2.10	0.26052	0.25159	0.24202	0.23459	0.22666	0.22026	0.21344	0.20237	0.19285	0.18464	0.17745	0.17134	0.16586	0.16088	0.15689	0.15298	0.14939	0.14640	0.14344	0.14125

Continued on next page

Recommended head loss design range

Sizing in this region will lead to excessive head loss conditions.

½" Uponor PEX-a — 30% Propylene glycol — feet of head per foot of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
3.9	2.15	0.27219	0.26289	0.25293	0.24519	0.23693	0.23026	0.22315	0.21162	0.20169	0.19313	0.18563	0.17926	0.17355	0.16835	0.16419	0.16011	0.15636	0.15324	0.15015	0.14787
4.0	2.21	0.28408	0.27441	0.26404	0.25598	0.24739	0.24044	0.23305	0.22104	0.21070	0.20179	0.19398	0.18734	0.18139	0.17597	0.17163	0.16739	0.16347	0.16022	0.15700	0.15462
4.1	2.26	0.29618	0.28613	0.27535	0.26698	0.25804	0.25082	0.24313	0.23064	0.21988	0.21061	0.20248	0.19557	0.18938	0.18374	0.17922	0.17480	0.17073	0.16734	0.16398	0.16151

Recommended head loss design range

Sizing in this region will lead to excessive head loss conditions.

Appendix G:

Hydronic friction loss tables

½" Uponor PEX-a — 40% Propylene glycol — feet of head per foot of piping

Velocity (ft./sec.)	GPM	40ºF 4ºC	45ºF 7ºC	50ºF 10ºC	55ºF 13ºC	60ºF 16ºC	65ºF 18ºC	70ºF 21ºC	80ºF 27ºC	90ºF 32ºC	100ºF 38ºC	110ºF 43ºC	120ºF 49ºC	130ºF 54ºC	140ºF 60ºC	150ºF 66ºC	160ºF 71ºC	170ºF 77ºC	180ºF 82ºC	190ºF 88ºC	200ºF 93ºC
0.5	0.28	0.01170	0.01103	0.01032	0.00980	0.00925	0.00884	0.00840	0.00772	0.00715	0.00669	0.00630	0.00596	0.00568	0.00543	0.00522	0.00505	0.00487	0.00474	0.00460	0.00449
0.6	0.33	0.01553	0.01467	0.01375	0.01308	0.01236	0.01183	0.01126	0.01036	0.00963	0.00902	0.00851	0.00806	0.00769	0.00736	0.00708	0.00685	0.00662	0.00644	0.00625	0.00611
0.7	0.39	0.01977	0.01870	0.01755	0.01671	0.01582	0.01515	0.01444	0.01331	0.01239	0.01162	0.01098	0.01042	0.00994	0.00953	0.00918	0.00888	0.00858	0.00836	0.00812	0.00794
0.8	0.44	0.02440	0.02310	0.02171	0.02069	0.01961	0.01880	0.01793	0.01656	0.01543	0.01450	0.01370	0.01301	0.01243	0.01192	0.01149	0.01112	0.01076	0.01049	0.01019	0.00997
0.9	0.50	0.02941	0.02786	0.02622	0.02501	0.02372	0.02275	0.02172	0.02009	0.01874	0.01762	0.01668	0.01585	0.01515	0.01454	0.01402	0.01358	0.01314	0.01282	0.01245	0.01219
1.0	0.55	0.03477	0.03297	0.03105	0.02965	0.02815	0.02701	0.02580	0.02389	0.02231	0.02100	0.01989	0.01892	0.01810	0.01737	0.01676	0.01624	0.01572	0.01534	0.01491	0.01460
1.1	0.61	0.04048	0.03842	0.03622	0.03460	0.03287	0.03156	0.03017	0.02796	0.02613	0.02462	0.02333	0.02221	0.02126	0.02041	0.01971	0.01910	0.01850	0.01806	0.01756	0.01720
1.2	0.66	0.04654	0.04420	0.04169	0.03985	0.03788	0.03639	0.03481	0.03229	0.03021	0.02848	0.02700	0.02572	0.02463	0.02366	0.02285	0.02216	0.02147	0.02096	0.02039	0.01997
1.3	0.72	0.05293	0.05029	0.04748	0.04540	0.04319	0.04151	0.03972	0.03688	0.03452	0.03257	0.03090	0.02944	0.02821	0.02711	0.02620	0.02541	0.02462	0.02404	0.02339	0.02292
1.4	0.77	0.05964	0.05671	0.05356	0.05124	0.04877	0.04689	0.04490	0.04172	0.03907	0.03688	0.03501	0.03338	0.03199	0.03076	0.02973	0.02884	0.02796	0.02731	0.02658	0.02605
1.5	0.83	0.06667	0.06342	0.05994	0.05737	0.05463	0.05255	0.05033	0.04680	0.04386	0.04142	0.03934	0.03752	0.03598	0.03461	0.03345	0.03247	0.03148	0.03075	0.02994	0.02934
1.6	0.88	0.07401	0.07044	0.06661	0.06378	0.06076	0.05847	0.05602	0.05212	0.04888	0.04618	0.04388	0.04186	0.04016	0.03864	0.03736	0.03627	0.03518	0.03437	0.03346	0.03281
1.7	0.94	0.08167	0.07776	0.07356	0.07047	0.06716	0.06464	0.06196	0.05769	0.05412	0.05116	0.04863	0.04641	0.04453	0.04286	0.04146	0.04025	0.03905	0.03816	0.03716	0.03644
1.8	0.99	0.08962	0.08537	0.08080	0.07742	0.07381	0.07107	0.06815	0.06348	0.05959	0.05635	0.05359	0.05116	0.04910	0.04727	0.04574	0.04441	0.04310	0.04212	0.04103	0.04023
1.9	1.05	0.09787	0.09326	0.08830	0.08465	0.08073	0.07775	0.07457	0.06950	0.06527	0.06175	0.05874	0.05610	0.05386	0.05187	0.05019	0.04875	0.04731	0.04625	0.04506	0.04419
2.0	1.10	0.10641	0.10144	0.09609	0.09213	0.08790	0.08468	0.08124	0.07576	0.07117	0.06736	0.06410	0.06123	0.05880	0.05664	0.05482	0.05326	0.05170	0.05054	0.04925	0.04830
2.1	1.16	0.11525	0.10989	0.10414	0.09988	0.09532	0.09185	0.08815	0.08223	0.07729	0.07318	0.06965	0.06656	0.06393	0.06160	0.05963	0.05794	0.05625	0.05500	0.05360	0.05258
2.2	1.22	0.12436	0.11863	0.11245	0.10788	0.10299	0.09927	0.09529	0.08893	0.08362	0.07919	0.07540	0.07207	0.06925	0.06673	0.06461	0.06279	0.06097	0.05962	0.05811	0.05701
2.3	1.27	0.13376	0.12763	0.12103	0.11614	0.11091	0.10692	0.10266	0.09585	0.09016	0.08541	0.08135	0.07777	0.07474	0.07204	0.06976	0.06781	0.06585	0.06441	0.06278	0.06160
2.4	1.33	0.14344	0.13690	0.12986	0.12465	0.11906	0.11481	0.11026	0.10299	0.09690	0.09183	0.08748	0.08366	0.08041	0.07752	0.07509	0.07299	0.07090	0.06935	0.06761	0.06634
2.5	1.38	0.15340	0.14644	0.13895	0.13341	0.12746	0.12293	0.11809	0.11034	0.10385	0.09844	0.09381	0.08972	0.08626	0.08318	0.08058	0.07834	0.07611	0.07445	0.07259	0.07124
2.6	1.44	0.16363	0.15625	0.14830	0.14241	0.13610	0.13128	0.12614	0.11790	0.11100	0.10525	0.10032	0.09597	0.09229	0.08900	0.08623	0.08385	0.08147	0.07971	0.07773	0.07628
2.7	1.49	0.17412	0.16631	0.15789	0.15166	0.14497	0.13986	0.13441	0.12568	0.11836	0.11226	0.10702	0.10240	0.09849	0.09500	0.09206	0.08952	0.08699	0.08512	0.08301	0.08148
2.8	1.55	0.18489	0.17664	0.16774	0.16115	0.15407	0.14867	0.14290	0.13366	0.12591	0.11945	0.11390	0.10901	0.10486	0.10116	0.09804	0.09536	0.09268	0.09069	0.08845	0.08682
2.9	1.60	0.19592	0.18721	0.17783	0.17087	0.16340	0.15771	0.15162	0.14185	0.13367	0.12683	0.12097	0.11580	0.11141	0.10750	0.10419	0.10135	0.09851	0.09641	0.09404	0.09232
3.0	1.66	0.20721	0.19805	0.18816	0.18084	0.17297	0.16696	0.16054	0.15025	0.14162	0.13441	0.12822	0.12276	0.11813	0.11399	0.11051	0.10750	0.10450	0.10228	0.09978	0.09796
3.1	1.71	0.21876	0.20913	0.19874	0.19103	0.18276	0.17644	0.16969	0.15885	0.14976	0.14217	0.13565	0.12990	0.12501	0.12065	0.11698	0.11381	0.11065	0.10830	0.10567	0.10374
3.2	1.77	0.23057	0.22046	0.20955	0.20147	0.19277	0.18614	0.17904	0.16765	0.15810	0.15011	0.14325	0.13720	0.13207	0.12748	0.12361	0.12028	0.11695	0.11448	0.11170	0.10968
3.3	1.82	0.24263	0.23204	0.22061	0.21213	0.20301	0.19605	0.18861	0.17666	0.16663	0.15824	0.15104	0.14469	0.13929	0.13447	0.13040	0.12690	0.12340	0.12080	0.11788	0.11575
3.4	1.88	0.25495	0.24387	0.23190	0.22302	0.21348	0.20619	0.19838	0.18586	0.17535	0.16656	0.15900	0.15234	0.14668	0.14162	0.13735	0.13367	0.13000	0.12727	0.12421	0.12197
3.5	1.93	0.26752	0.25594	0.24343	0.23414	0.22416	0.21653	0.20837	0.19527	0.18426	0.17505	0.16714	0.16016	0.15423	0.14893	0.14445	0.14060	0.13675	0.13389	0.13068	0.12833
3.6	1.99	0.28034	0.26825	0.25518	0.24549	0.23506	0.22709	0.21856	0.20487	0.19336	0.18373	0.17546	0.16815	0.16194	0.15640	0.15172	0.14768	0.14365	0.14065	0.13729	0.13484
3.7	2.04	0.29341	0.28080	0.26717	0.25706	0.24618	0.23786	0.22896	0.21466	0.20264	0.19259	0.18394	0.17631	0.16982	0.16402	0.15913	0.15491	0.15070	0.14757	0.14405	0.14148
3.8	2.10	0.30673	0.29359	0.27939	0.26885	0.25751	0.24884	0.23956	0.22465	0.21211	0.20162	0.19260	0.18463	0.17786	0.17181	0.16670	0.16229	0.15789	0.15462	0.15095	0.14826
3.9	2.15	0.32029	0.30662	0.29184	0.28087	0.26906	0.26003	0.25037	0.23483	0.22177	0.21084	0.20143	0.19312	0.18606	0.17975	0.17442	0.16983	0.16523	0.16182	0.15799	0.15519
4.0	2.21	0.33409	0.31988	0.30452	0.29310	0.28082	0.27143	0.26137	0.24521	0.23161	0.22023	0.21043	0.20178	0.19442	0.18785	0.18230	0.17751	0.17272	0.16916	0.16517	0.16225

Recommended head loss design range

Sizing in this region will lead to excessive head loss conditions.

Appendix G:

Hydronic friction loss tables

½" Uponor PEX-a — 50% Propylene glycol — feet of head per foot of piping

Velocity (ft./sec.)	GPM	40ºF 4ºC	45ºF 7ºC	50ºF 10ºC	55ºF 13ºC	60ºF 16ºC	65ºF 18ºC	70ºF 21ºC	80ºF 27ºC	90ºF 32ºC	100ºF 38ºC	110ºF 43ºC	120ºF 49ºC	130ºF 54ºC	140ºF 60ºC	150ºF 66ºC	160ºF 71ºC	170ºF 77ºC	180ºF 82ºC	190ºF 88ºC	200ºF 93ºC
0.5	0.28	0.01398	0.01312	0.01221	0.01154	0.01083	0.01030	0.00974	0.00887	0.00815	0.00756	0.00707	0.00665	0.00630	0.00599	0.00573	0.00550	0.00529	0.00510	0.00495	0.00480
0.6	0.33	0.01848	0.01737	0.01619	0.01533	0.01441	0.01372	0.01300	0.01186	0.01093	0.01016	0.00952	0.00897	0.00850	0.00810	0.00775	0.00744	0.00717	0.00692	0.00672	0.00652
0.7	0.39	0.02343	0.02205	0.02059	0.01952	0.01838	0.01752	0.01661	0.01519	0.01402	0.01306	0.01225	0.01156	0.01097	0.01046	0.01002	0.00963	0.00928	0.00897	0.00871	0.00846
0.8	0.44	0.02881	0.02716	0.02539	0.02409	0.02271	0.02168	0.02058	0.01885	0.01743	0.01625	0.01526	0.01442	0.01369	0.01307	0.01252	0.01205	0.01162	0.01123	0.01092	0.01062
0.9	0.50	0.03462	0.03266	0.03058	0.02904	0.02740	0.02617	0.02487	0.02282	0.02112	0.01972	0.01854	0.01753	0.01666	0.01591	0.01526	0.01470	0.01418	0.01371	0.01334	0.01297
1.0	0.55	0.04083	0.03856	0.03613	0.03434	0.03244	0.03100	0.02948	0.02708	0.02510	0.02346	0.02207	0.02089	0.01987	0.01899	0.01822	0.01756	0.01695	0.01640	0.01595	0.01552
1.1	0.61	0.04743	0.04483	0.04205	0.03999	0.03781	0.03616	0.03441	0.03165	0.02936	0.02746	0.02586	0.02449	0.02332	0.02229	0.02140	0.02063	0.01992	0.01929	0.01877	0.01826
1.2	0.66	0.05441	0.05146	0.04831	0.04598	0.04350	0.04163	0.03963	0.03649	0.03389	0.03172	0.02989	0.02833	0.02699	0.02581	0.02480	0.02391	0.02310	0.02237	0.02178	0.02120
1.3	0.72	0.06177	0.05846	0.05492	0.05230	0.04951	0.04740	0.04516	0.04162	0.03868	0.03623	0.03417	0.03240	0.03088	0.02955	0.02840	0.02740	0.02647	0.02565	0.02497	0.02431
1.4	0.77	0.06948	0.06580	0.06186	0.05894	0.05583	0.05348	0.05097	0.04702	0.04373	0.04099	0.03868	0.03670	0.03499	0.03350	0.03221	0.03108	0.03004	0.02911	0.02835	0.02761
1.5	0.83	0.07755	0.07348	0.06913	0.06590	0.06246	0.05985	0.05707	0.05268	0.04904	0.04599	0.04342	0.04122	0.03932	0.03766	0.03622	0.03496	0.03380	0.03277	0.03192	0.03109
1.6	0.88	0.08597	0.08150	0.07672	0.07317	0.06938	0.06651	0.06345	0.05862	0.05459	0.05123	0.04839	0.04596	0.04386	0.04202	0.04042	0.03903	0.03775	0.03660	0.03566	0.03475
1.7	0.94	0.09473	0.08985	0.08462	0.08074	0.07659	0.07345	0.07011	0.06481	0.06039	0.05670	0.05359	0.05091	0.04860	0.04658	0.04483	0.04330	0.04189	0.04062	0.03959	0.03858
1.8	0.99	0.10383	0.09852	0.09283	0.08861	0.08410	0.08068	0.07703	0.07125	0.06643	0.06241	0.05900	0.05608	0.05355	0.05134	0.04942	0.04775	0.04620	0.04482	0.04368	0.04258
1.9	1.05	0.11325	0.10751	0.10135	0.09678	0.09188	0.08818	0.08422	0.07795	0.07272	0.06834	0.06464	0.06146	0.05871	0.05630	0.05421	0.05238	0.05070	0.04919	0.04795	0.04675
2.0	1.10	0.12301	0.11682	0.11017	0.10523	0.09995	0.09595	0.09167	0.08489	0.07923	0.07450	0.07049	0.06704	0.06406	0.06145	0.05918	0.05720	0.05537	0.05373	0.05239	0.05109
2.1	1.16	0.13308	0.12643	0.11929	0.11398	0.10830	0.10399	0.09938	0.09208	0.08598	0.08087	0.07655	0.07283	0.06961	0.06679	0.06434	0.06220	0.06023	0.05845	0.05700	0.05559
2.2	1.22	0.14347	0.13635	0.12869	0.12301	0.11691	0.11229	0.10735	0.09951	0.09296	0.08747	0.08282	0.07882	0.07536	0.07232	0.06969	0.06738	0.06525	0.06334	0.06178	0.06026
2.3	1.27	0.15417	0.14657	0.13839	0.13231	0.12580	0.12085	0.11557	0.10718	0.10017	0.09429	0.08930	0.08501	0.08130	0.07804	0.07521	0.07274	0.07045	0.06840	0.06672	0.06509
2.4	1.33	0.16518	0.15708	0.14837	0.14190	0.13495	0.12968	0.12404	0.11509	0.10760	0.10131	0.09599	0.09140	0.08743	0.08395	0.08092	0.07827	0.07583	0.07363	0.07183	0.07008
2.5	1.38	0.17650	0.16790	0.15864	0.15175	0.14437	0.13876	0.13276	0.12323	0.11525	0.10855	0.10288	0.09799	0.09375	0.09003	0.08680	0.08398	0.08137	0.07902	0.07710	0.07523
2.6	1.44	0.18812	0.17900	0.16919	0.16188	0.15404	0.14809	0.14172	0.13160	0.12312	0.11601	0.10997	0.10477	0.10026	0.09630	0.09287	0.08986	0.08707	0.08458	0.08253	0.08053
2.7	1.49	0.20004	0.19039	0.18001	0.17227	0.16398	0.15767	0.15093	0.14020	0.13121	0.12367	0.11726	0.11174	0.10695	0.10276	0.09910	0.09591	0.09295	0.09029	0.08812	0.08600
2.8	1.55	0.21225	0.20207	0.19110	0.18293	0.17417	0.16750	0.16037	0.14903	0.13952	0.13153	0.12475	0.11890	0.11383	0.10938	0.10551	0.10212	0.09899	0.09618	0.09387	0.09162
2.9	1.60	0.22476	0.21403	0.20247	0.19386	0.18461	0.17758	0.17006	0.15808	0.14804	0.13960	0.13244	0.12625	0.12090	0.11619	0.11210	0.10851	0.10520	0.10222	0.09978	0.09739
3.0	1.66	0.23755	0.22627	0.21410	0.20504	0.19531	0.18790	0.17998	0.16736	0.15678	0.14788	0.14032	0.13380	0.12814	0.12318	0.11885	0.11507	0.11157	0.10842	0.10584	0.10332
3.1	1.71	0.25064	0.23878	0.22601	0.21648	0.20625	0.19847	0.19013	0.17686	0.16572	0.15635	0.14840	0.14152	0.13557	0.13033	0.12578	0.12179	0.11810	0.11478	0.11206	0.10940
3.2	1.77	0.26400	0.25157	0.23817	0.22818	0.21744	0.20927	0.20052	0.18658	0.17487	0.16503	0.15667	0.14944	0.14317	0.13767	0.13287	0.12867	0.12479	0.12129	0.11843	0.11564
3.3	1.82	0.27766	0.26464	0.25060	0.24013	0.22888	0.22031	0.21114	0.19651	0.18424	0.17390	0.16512	0.15753	0.15095	0.14517	0.14013	0.13572	0.13164	0.12797	0.12496	0.12202
3.4	1.88	0.29159	0.27797	0.26329	0.25233	0.24055	0.23159	0.22198	0.20666	0.19380	0.18298	0.17377	0.16581	0.15891	0.15285	0.14756	0.14293	0.13865	0.13479	0.13163	0.12855
3.5	1.93	0.30580	0.29158	0.27623	0.26478	0.25247	0.24310	0.23305	0.21703	0.20358	0.19224	0.18261	0.17427	0.16705	0.16069	0.15516	0.15030	0.14581	0.14177	0.13846	0.13523
3.6	1.99	0.32028	0.30545	0.28944	0.27748	0.26463	0.25484	0.24435	0.22761	0.21355	0.20171	0.19163	0.18292	0.17536	0.16871	0.16291	0.15784	0.15314	0.14891	0.14544	0.14206
3.7	2.04	0.33504	0.31958	0.30289	0.29043	0.27703	0.26682	0.25587	0.23841	0.22373	0.21136	0.20084	0.19174	0.18384	0.17689	0.17084	0.16553	0.16062	0.15620	0.15257	0.14903
3.8	2.10	0.35007	0.33398	0.31660	0.30362	0.28966	0.27902	0.26762	0.24941	0.23411	0.22121	0.21023	0.20073	0.19249	0.18524	0.17892	0.17338	0.16825	0.16364	0.15985	0.15616
3.9	2.15	0.36538	0.34864	0.33056	0.31706	0.30253	0.29146	0.27958	0.26063	0.24469	0.23125	0.21981	0.20991	0.20132	0.19376	0.18717	0.18139	0.17604	0.17123	0.16728	0.16342

Recommended head loss design range

Sizing in this region will lead to excessive head loss conditions.

⅝" Uponor PEX-a — 100% Water — feet of head per foot of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
0.5	0.40	0.00485	0.00456	0.00423	0.00413	0.00403	0.00394	0.00385	0.00370	0.00357	0.00345	0.00335	0.00326	0.00317	0.00310	0.00303	0.00296	0.00290	0.00285	0.00280	0.00276
0.6	0.48	0.00655	0.00617	0.00575	0.00561	0.00547	0.00536	0.00524	0.00504	0.00486	0.00471	0.00457	0.00445	0.00433	0.00423	0.00414	0.00406	0.00398	0.00391	0.00384	0.00378
0.7	0.56	0.00847	0.00799	0.00745	0.00728	0.00710	0.00696	0.00680	0.00655	0.00632	0.00613	0.00595	0.00579	0.00565	0.00552	0.00540	0.00529	0.00519	0.00510	0.00501	0.00494
0.8	0.65	0.01059	0.00999	0.00933	0.00912	0.00890	0.00872	0.00854	0.00822	0.00794	0.00770	0.00748	0.00728	0.00711	0.00695	0.00680	0.00667	0.00654	0.00643	0.00632	0.00623
0.9	0.73	0.01290	0.01218	0.01138	0.01113	0.01087	0.01066	0.01043	0.01005	0.00972	0.00942	0.00916	0.00892	0.00871	0.00852	0.00834	0.00818	0.00802	0.00789	0.00776	0.00764
1.0	0.81	0.01540	0.01455	0.01361	0.01332	0.01301	0.01276	0.01249	0.01204	0.01165	0.01130	0.01099	0.01070	0.01045	0.01022	0.01001	0.00982	0.00964	0.00948	0.00933	0.00919
1.1	0.89	0.01808	0.01710	0.01601	0.01566	0.01531	0.01501	0.01471	0.01418	0.01372	0.01331	0.01295	0.01262	0.01233	0.01206	0.01181	0.01159	0.01138	0.01119	0.01102	0.01085
1.2	0.97	0.02094	0.01982	0.01857	0.01817	0.01776	0.01742	0.01707	0.01647	0.01594	0.01547	0.01506	0.01468	0.01434	0.01403	0.01375	0.01349	0.01325	0.01303	0.01283	0.01264
1.3	1.05	0.02397	0.02271	0.02128	0.02084	0.02037	0.01999	0.01959	0.01890	0.01830	0.01777	0.01730	0.01687	0.01648	0.01613	0.01581	0.01551	0.01524	0.01499	0.01476	0.01454
1.4	1.13	0.02718	0.02576	0.02416	0.02366	0.02313	0.02270	0.02225	0.02148	0.02081	0.02020	0.01967	0.01918	0.01875	0.01835	0.01799	0.01766	0.01735	0.01707	0.01681	0.01657
1.5	1.21	0.03056	0.02897	0.02719	0.02663	0.02604	0.02556	0.02506	0.02420	0.02344	0.02277	0.02217	0.02163	0.02114	0.02070	0.02029	0.01992	0.01958	0.01926	0.01897	0.01870
1.6	1.29	0.03411	0.03235	0.03037	0.02975	0.02910	0.02857	0.02801	0.02706	0.02622	0.02547	0.02481	0.02421	0.02367	0.02317	0.02272	0.02231	0.02192	0.02158	0.02125	0.02095
1.7	1.37	0.03781	0.03588	0.03371	0.03302	0.03230	0.03172	0.03110	0.03005	0.02913	0.02830	0.02757	0.02691	0.02631	0.02577	0.02527	0.02481	0.02439	0.02400	0.02365	0.02331
1.8	1.45	0.04169	0.03957	0.03719	0.03644	0.03565	0.03501	0.03433	0.03318	0.03217	0.03126	0.03046	0.02973	0.02908	0.02848	0.02793	0.02743	0.02696	0.02654	0.02615	0.02578
1.9	1.53	0.04572	0.04341	0.04081	0.04000	0.03914	0.03844	0.03770	0.03644	0.03534	0.03435	0.03348	0.03268	0.03196	0.03131	0.03071	0.03017	0.02966	0.02919	0.02877	0.02837
2.0	1.61	0.04990	0.04740	0.04458	0.04370	0.04277	0.04200	0.04121	0.03984	0.03864	0.03757	0.03661	0.03575	0.03497	0.03426	0.03361	0.03302	0.03246	0.03196	0.03149	0.03106
2.1	1.69	0.05425	0.05154	0.04850	0.04754	0.04653	0.04571	0.04484	0.04337	0.04207	0.04091	0.03987	0.03894	0.03809	0.03733	0.03662	0.03598	0.03537	0.03483	0.03432	0.03385
2.2	1.77	0.05875	0.05583	0.05255	0.05152	0.05044	0.04955	0.04862	0.04702	0.04562	0.04437	0.04325	0.04224	0.04133	0.04051	0.03974	0.03905	0.03840	0.03781	0.03726	0.03675
2.3	1.86	0.06340	0.06027	0.05675	0.05564	0.05447	0.05352	0.05252	0.05081	0.04930	0.04795	0.04676	0.04567	0.04469	0.04380	0.04298	0.04223	0.04153	0.04090	0.04031	0.03976
2.4	1.94	0.06820	0.06485	0.06108	0.05989	0.05865	0.05762	0.05655	0.05472	0.05310	0.05166	0.05038	0.04921	0.04816	0.04721	0.04633	0.04553	0.04477	0.04409	0.04346	0.04288
2.5	2.02	0.07315	0.06958	0.06555	0.06428	0.06295	0.06186	0.06071	0.05875	0.05703	0.05549	0.05411	0.05287	0.05174	0.05072	0.04978	0.04893	0.04812	0.04740	0.04672	0.04609
2.6	2.10	0.07825	0.07445	0.07016	0.06881	0.06739	0.06622	0.06500	0.06291	0.06107	0.05943	0.05797	0.05664	0.05544	0.05435	0.05335	0.05244	0.05158	0.05080	0.05008	0.04941
2.7	2.18	0.08350	0.07946	0.07490	0.07347	0.07196	0.07072	0.06942	0.06720	0.06524	0.06350	0.06194	0.06053	0.05925	0.05809	0.05702	0.05605	0.05514	0.05432	0.05355	0.05284
2.8	2.26	0.08889	0.08461	0.07978	0.07826	0.07666	0.07534	0.07397	0.07161	0.06953	0.06768	0.06603	0.06453	0.06317	0.06194	0.06081	0.05978	0.05881	0.05793	0.05712	0.05636
2.9	2.34	0.09443	0.08990	0.08479	0.08318	0.08148	0.08009	0.07864	0.07614	0.07394	0.07198	0.07023	0.06864	0.06720	0.06590	0.06470	0.06361	0.06258	0.06165	0.06079	0.05998
3.0	2.42	0.10012	0.09533	0.08993	0.08823	0.08644	0.08497	0.08343	0.08079	0.07847	0.07639	0.07454	0.07286	0.07134	0.06997	0.06870	0.06754	0.06645	0.06547	0.06456	0.06371
3.1	2.50	0.10594	0.10090	0.09521	0.09341	0.09152	0.08997	0.08835	0.08556	0.08311	0.08092	0.07897	0.07720	0.07559	0.07414	0.07280	0.07158	0.07043	0.06939	0.06843	0.06753
3.2	2.58	0.11191	0.10660	0.10061	0.09872	0.09673	0.09509	0.09339	0.09046	0.08787	0.08556	0.08351	0.08164	0.07995	0.07842	0.07701	0.07572	0.07451	0.07342	0.07240	0.07146
3.3	2.66	0.11801	0.11244	0.10614	0.10415	0.10206	0.10034	0.09855	0.09547	0.09275	0.09032	0.08816	0.08619	0.08442	0.08281	0.08132	0.07997	0.07869	0.07754	0.07648	0.07548
3.4	2.74	0.12426	0.11841	0.11180	0.10971	0.10752	0.10572	0.10383	0.10060	0.09774	0.09519	0.09292	0.09086	0.08899	0.08730	0.08574	0.08431	0.08297	0.08177	0.08065	0.07960
3.5	2.82	0.13065	0.12452	0.11759	0.11540	0.11310	0.11121	0.10924	0.10584	0.10285	0.10018	0.09779	0.09563	0.09367	0.09190	0.09026	0.08877	0.08736	0.08609	0.08492	0.08382
3.6	2.90	0.13717	0.13076	0.12351	0.12121	0.11881	0.11683	0.11476	0.11121	0.10807	0.10527	0.10278	0.10051	0.09846	0.09660	0.09488	0.09332	0.09184	0.09052	0.08928	0.08813
3.7	2.98	0.14383	0.13713	0.12955	0.12715	0.12464	0.12257	0.12040	0.11669	0.11341	0.11048	0.10787	0.10549	0.10335	0.10140	0.09961	0.09797	0.09643	0.09504	0.09375	0.09254
3.8	3.07	0.15063	0.14363	0.13571	0.13321	0.13059	0.12842	0.12616	0.12228	0.11886	0.11580	0.11307	0.11059	0.10835	0.10631	0.10443	0.10272	0.10111	0.09966	0.09831	0.09705

Continued on next page

Recommended head loss design range

Sizing in this region will lead to excessive head loss conditions.

⅝" Uponor PEX-a — 100% Water — feet of head per foot of piping

Velocity (ft./sec.)	GPM	40ºF 4ºC	45ºF 7ºC	50ºF 10ºC	55ºF 13ºC	60ºF 16ºC	65ºF 18ºC	70ºF 21ºC	80ºF 27ºC	90ºF 32ºC	100ºF 38ºC	110ºF 43ºC	120ºF 49ºC	130ºF 54ºC	140ºF 60ºC	150ºF 66ºC	160ºF 71ºC	170ºF 77ºC	180ºF 82ºC	190ºF 88ºC	200ºF 93ºC
3.9	3.15	0.15756	0.15026	0.14201	0.13940	0.13666	0.13440	0.13204	0.12799	0.12442	0.12122	0.11837	0.11579	0.11345	0.11132	0.10936	0.10758	0.10589	0.10438	0.10297	0.10165
4.0	3.23	0.16463	0.15703	0.14842	0.14570	0.14285	0.14050	0.13804	0.13381	0.13009	0.12676	0.12379	0.12109	0.11865	0.11644	0.11439	0.11253	0.11078	0.10920	0.10773	0.10635
4.1	3.31	0.17183	0.16392	0.15496	0.15213	0.14916	0.14671	0.14415	0.13975	0.13587	0.13241	0.12931	0.12650	0.12396	0.12165	0.11952	0.11758	0.11575	0.11411	0.11258	0.11115
4.2	3.39	0.17917	0.17094	0.16163	0.15868	0.15559	0.15304	0.15038	0.14580	0.14177	0.13816	0.13494	0.13202	0.12937	0.12697	0.12475	0.12273	0.12083	0.11912	0.11752	0.11604
4.3	3.47	0.18664	0.17809	0.16841	0.16535	0.16214	0.15949	0.15672	0.15197	0.14777	0.14402	0.14068	0.13763	0.13489	0.13239	0.13008	0.12798	0.12600	0.12422	0.12257	0.12102
4.4	3.55	0.19424	0.18536	0.17532	0.17214	0.16880	0.16606	0.16318	0.15824	0.15389	0.14999	0.14652	0.14336	0.14050	0.13791	0.13551	0.13333	0.13127	0.12942	0.12770	0.12609
4.5	3.63	0.20197	0.19277	0.18235	0.17905	0.17559	0.17274	0.16976	0.16463	0.16011	0.15607	0.15246	0.14918	0.14622	0.14353	0.14104	0.13878	0.13664	0.13472	0.13293	0.13126
4.6	3.71	0.20983	0.20030	0.18950	0.18608	0.18249	0.17954	0.17644	0.17113	0.16645	0.16225	0.15851	0.15511	0.15204	0.14925	0.14667	0.14432	0.14210	0.14011	0.13826	0.13652
4.7	3.79	0.21782	0.20795	0.19677	0.19323	0.18951	0.18645	0.18325	0.17774	0.17289	0.16854	0.16467	0.16114	0.15796	0.15506	0.15239	0.14996	0.14766	0.14560	0.14368	0.14188
4.8	3.87	0.22595	0.21573	0.20416	0.20049	0.19664	0.19348	0.19016	0.18446	0.17944	0.17494	0.17092	0.16728	0.16398	0.16098	0.15821	0.15569	0.15332	0.15118	0.14919	0.14733
4.9	3.95	0.23420	0.22363	0.21166	0.20787	0.20389	0.20062	0.19719	0.19129	0.18609	0.18144	0.17729	0.17351	0.17010	0.16700	0.16413	0.16152	0.15907	0.15685	0.15479	0.15287
5.0	4.03	0.24258	0.23166	0.21929	0.21537	0.21126	0.20787	0.20433	0.19823	0.19286	0.18805	0.18375	0.17985	0.17632	0.17311	0.17015	0.16745	0.16491	0.16262	0.16049	0.15850
5.1	4.11	0.25109	0.23981	0.22704	0.22299	0.21874	0.21524	0.21158	0.20528	0.19973	0.19476	0.19032	0.18628	0.18264	0.17932	0.17626	0.17347	0.17085	0.16848	0.16628	0.16422
5.2	4.19	0.25973	0.24809	0.23490	0.23072	0.22634	0.22272	0.21894	0.21244	0.20671	0.20157	0.19699	0.19282	0.18906	0.18563	0.18247	0.17959	0.17688	0.17443	0.17216	0.17003

Recommended head loss design range

Sizing in this region will lead to excessive head loss conditions.

Appendix G:

Hydronic friction loss tables

⅝" Uponor PEX-a — 30% Propylene glycol — feet of head per foot of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
0.5	0.40	0.00719	0.00687	0.00654	0.00628	0.00601	0.00579	0.00556	0.00519	0.00489	0.00462	0.00440	0.00420	0.00404	0.00388	0.00376	0.00365	0.00354	0.00345	0.00336	0.00330
0.6	0.48	0.00963	0.00921	0.00877	0.00844	0.00808	0.00779	0.00749	0.00701	0.00661	0.00626	0.00596	0.00571	0.00548	0.00528	0.00512	0.00496	0.00482	0.00470	0.00459	0.00450
0.7	0.56	0.01234	0.01182	0.01127	0.01084	0.01039	0.01004	0.00966	0.00905	0.00853	0.00810	0.00772	0.00740	0.00711	0.00685	0.00665	0.00645	0.00627	0.00612	0.00597	0.00586
0.8	0.65	0.01531	0.01468	0.01401	0.01349	0.01294	0.01250	0.01204	0.01130	0.01067	0.01013	0.00966	0.00926	0.00891	0.00860	0.00835	0.00810	0.00788	0.00769	0.00751	0.00737
0.9	0.73	0.01854	0.01778	0.01698	0.01637	0.01572	0.01519	0.01464	0.01375	0.01299	0.01234	0.01178	0.01131	0.01089	0.01051	0.01020	0.00991	0.00964	0.00941	0.00919	0.00903
1.0	0.81	0.02201	0.02113	0.02019	0.01947	0.01871	0.01809	0.01744	0.01640	0.01551	0.01474	0.01408	0.01352	0.01303	0.01258	0.01222	0.01187	0.01155	0.01128	0.01102	0.01083
1.1	0.89	0.02572	0.02471	0.02363	0.02279	0.02191	0.02120	0.02045	0.01924	0.01820	0.01732	0.01655	0.01591	0.01533	0.01481	0.01439	0.01398	0.01361	0.01330	0.01300	0.01277
1.2	0.97	0.02967	0.02851	0.02728	0.02633	0.02532	0.02451	0.02365	0.02227	0.02108	0.02007	0.01919	0.01845	0.01779	0.01719	0.01671	0.01624	0.01581	0.01546	0.01511	0.01485
1.3	1.05	0.03385	0.03254	0.03115	0.03007	0.02893	0.02802	0.02704	0.02548	0.02414	0.02299	0.02200	0.02115	0.02040	0.01972	0.01917	0.01864	0.01816	0.01775	0.01735	0.01706
1.4	1.13	0.03824	0.03678	0.03523	0.03402	0.03274	0.03172	0.03063	0.02887	0.02737	0.02608	0.02496	0.02401	0.02317	0.02240	0.02179	0.02119	0.02064	0.02018	0.01973	0.01940
1.5	1.21	0.04286	0.04124	0.03951	0.03817	0.03675	0.03561	0.03440	0.03244	0.03077	0.02933	0.02808	0.02702	0.02608	0.02522	0.02454	0.02387	0.02326	0.02275	0.02225	0.02188
1.6	1.29	0.04769	0.04590	0.04400	0.04252	0.04095	0.03969	0.03835	0.03619	0.03433	0.03275	0.03136	0.03019	0.02914	0.02819	0.02743	0.02669	0.02601	0.02545	0.02489	0.02448
1.7	1.37	0.05274	0.05077	0.04868	0.04706	0.04534	0.04395	0.04248	0.04010	0.03807	0.03632	0.03479	0.03350	0.03235	0.03130	0.03047	0.02965	0.02890	0.02828	0.02766	0.02721
1.8	1.45	0.05799	0.05585	0.05356	0.05179	0.04991	0.04840	0.04679	0.04419	0.04196	0.04005	0.03838	0.03696	0.03570	0.03455	0.03364	0.03274	0.03192	0.03124	0.03056	0.03006
1.9	1.53	0.06344	0.06112	0.05864	0.05671	0.05467	0.05302	0.05127	0.04844	0.04601	0.04393	0.04211	0.04057	0.03919	0.03794	0.03694	0.03596	0.03507	0.03432	0.03358	0.03304
2.0	1.61	0.06910	0.06659	0.06390	0.06182	0.05961	0.05782	0.05593	0.05286	0.05023	0.04797	0.04599	0.04432	0.04283	0.04147	0.04038	0.03932	0.03834	0.03753	0.03673	0.03614
2.1	1.69	0.07496	0.07225	0.06936	0.06711	0.06472	0.06280	0.06075	0.05744	0.05460	0.05216	0.05002	0.04821	0.04660	0.04513	0.04395	0.04280	0.04175	0.04087	0.04000	0.03936
2.2	1.77	0.08102	0.07811	0.07500	0.07259	0.07002	0.06795	0.06575	0.06218	0.05912	0.05650	0.05420	0.05225	0.05050	0.04892	0.04765	0.04641	0.04527	0.04433	0.04339	0.04270
2.3	1.86	0.08727	0.08416	0.08082	0.07824	0.07549	0.07327	0.07091	0.06708	0.06380	0.06098	0.05851	0.05642	0.05455	0.05285	0.05148	0.05015	0.04893	0.04791	0.04690	0.04616
2.4	1.94	0.09372	0.09039	0.08683	0.08407	0.08113	0.07876	0.07623	0.07214	0.06863	0.06561	0.06297	0.06073	0.05873	0.05690	0.05544	0.05402	0.05270	0.05161	0.05053	0.04974
2.5	2.02	0.10036	0.09681	0.09302	0.09008	0.08694	0.08441	0.08172	0.07736	0.07362	0.07039	0.06757	0.06518	0.06304	0.06109	0.05953	0.05801	0.05660	0.05544	0.05428	0.05343
2.6	2.10	0.10718	0.10342	0.09939	0.09626	0.09292	0.09023	0.08737	0.08273	0.07875	0.07531	0.07231	0.06976	0.06748	0.06540	0.06374	0.06212	0.06062	0.05938	0.05815	0.05724
2.7	2.18	0.11420	0.11021	0.10593	0.10261	0.09907	0.09622	0.09318	0.08826	0.08402	0.08038	0.07719	0.07448	0.07205	0.06985	0.06808	0.06635	0.06476	0.06344	0.06213	0.06117
2.8	2.26	0.12140	0.11717	0.11265	0.10914	0.10539	0.10237	0.09915	0.09394	0.08945	0.08559	0.08220	0.07933	0.07676	0.07442	0.07254	0.07071	0.06902	0.06762	0.06623	0.06520
2.9	2.34	0.12878	0.12432	0.11954	0.11583	0.11187	0.10868	0.10528	0.09976	0.09502	0.09093	0.08735	0.08431	0.08159	0.07911	0.07713	0.07519	0.07340	0.07191	0.07044	0.06936
3.0	2.42	0.13635	0.13165	0.12661	0.12269	0.11852	0.11515	0.11157	0.10574	0.10073	0.09642	0.09264	0.08943	0.08655	0.08393	0.08184	0.07978	0.07790	0.07632	0.07477	0.07362
3.1	2.50	0.14410	0.13915	0.13384	0.12973	0.12533	0.12178	0.11800	0.11187	0.10659	0.10205	0.09806	0.09468	0.09164	0.08888	0.08667	0.08450	0.08251	0.08085	0.07921	0.07800
3.2	2.58	0.15203	0.14682	0.14125	0.13692	0.13230	0.12857	0.12460	0.11815	0.11259	0.10781	0.10361	0.10005	0.09685	0.09395	0.09162	0.08934	0.08724	0.08549	0.08376	0.08249
3.3	2.66	0.16013	0.15467	0.14883	0.14428	0.13943	0.13552	0.13134	0.12457	0.11874	0.11371	0.10930	0.10555	0.10219	0.09914	0.09669	0.09429	0.09208	0.09024	0.08843	0.08708
3.4	2.74	0.16841	0.16270	0.15657	0.15181	0.14672	0.14262	0.13824	0.13114	0.12502	0.11974	0.11512	0.11119	0.10766	0.10445	0.10188	0.09936	0.09704	0.09511	0.09320	0.09179
3.5	2.82	0.17687	0.17089	0.16448	0.15949	0.15417	0.14987	0.14529	0.13785	0.13144	0.12591	0.12106	0.11694	0.11325	0.10988	0.10719	0.10455	0.10212	0.10009	0.09809	0.09661
3.6	2.90	0.18551	0.17926	0.17255	0.16734	0.16178	0.15728	0.15249	0.14471	0.13800	0.13222	0.12714	0.12283	0.11896	0.11544	0.11262	0.10985	0.10730	0.10518	0.10309	0.10153
3.7	2.98	0.19431	0.18779	0.18079	0.17535	0.16954	0.16484	0.15984	0.15171	0.14470	0.13865	0.13335	0.12884	0.12480	0.12111	0.11816	0.11527	0.11260	0.11038	0.10819	0.10657
3.8	3.07	0.20329	0.19649	0.18919	0.18352	0.17746	0.17256	0.16734	0.15885	0.15153	0.14522	0.13968	0.13498	0.13075	0.12690	0.12382	0.12080	0.11802	0.11570	0.11340	0.11171

Continued on next page

Recommended head loss design range

Sizing in this region will lead to excessive head loss conditions.

Appendix G:
Hydronic friction loss tables

⅝" Uponor PEX-a — 30% Propylene glycol — feet of head per foot of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
3.9	3.15	0.21244	0.20536	0.19775	0.19184	0.18553	0.18042	0.17498	0.16613	0.15851	0.15192	0.14615	0.14124	0.13683	0.13281	0.12960	0.12644	0.12354	0.12112	0.11873	0.11696
4.0	3.23	0.22176	0.21439	0.20648	0.20032	0.19375	0.18843	0.18277	0.17356	0.16561	0.15876	0.15274	0.14762	0.14303	0.13884	0.13549	0.13220	0.12917	0.12665	0.12416	0.12231
4.1	3.31	0.23125	0.22359	0.21536	0.20896	0.20213	0.19660	0.19071	0.18112	0.17286	0.16572	0.15946	0.15413	0.14935	0.14499	0.14150	0.13807	0.13492	0.13229	0.12970	0.12777
4.2	3.39	0.24091	0.23295	0.22441	0.21776	0.21066	0.20491	0.19879	0.18882	0.18023	0.17281	0.16630	0.16076	0.15578	0.15125	0.14762	0.14406	0.14078	0.13804	0.13534	0.13334
4.3	3.47	0.25074	0.24248	0.23361	0.22671	0.21933	0.21337	0.20701	0.19667	0.18774	0.18003	0.17327	0.16751	0.16234	0.15763	0.15385	0.15015	0.14674	0.14390	0.14109	0.13901
4.4	3.55	0.26073	0.25216	0.24297	0.23581	0.22816	0.22198	0.21538	0.20465	0.19538	0.18738	0.18036	0.17438	0.16902	0.16412	0.16020	0.15636	0.15282	0.14987	0.14695	0.14479
4.5	3.63	0.27089	0.26201	0.25248	0.24507	0.23714	0.23073	0.22389	0.21276	0.20316	0.19486	0.18758	0.18138	0.17581	0.17073	0.16667	0.16268	0.15900	0.15594	0.15291	0.15067
4.6	3.71	0.28121	0.27202	0.26216	0.25448	0.24627	0.23963	0.23254	0.22101	0.21106	0.20247	0.19492	0.18849	0.18272	0.17746	0.17324	0.16910	0.16529	0.16212	0.15898	0.15665
4.7	3.79	0.29169	0.28219	0.27198	0.26404	0.25554	0.24867	0.24134	0.22940	0.21910	0.21020	0.20238	0.19572	0.18975	0.18430	0.17993	0.17564	0.17169	0.16840	0.16515	0.16274

Recommended head loss design range

Sizing in this region will lead to excessive head loss conditions.

Appendix G:

Hydronic friction loss tables

⅝" Uponor PEX-a — 40% Propylene glycol — feet of head per foot of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
0.5	0.40	0.00890	0.00840	0.00788	0.00749	0.00708	0.00678	0.00645	0.00594	0.00552	0.00517	0.00488	0.00462	0.00441	0.00422	0.00406	0.00393	0.00379	0.00369	0.00358	0.00350
0.6	0.48	0.01184	0.01120	0.01052	0.01002	0.00949	0.00909	0.00866	0.00799	0.00744	0.00698	0.00659	0.00626	0.00598	0.00573	0.00552	0.00534	0.00516	0.00503	0.00488	0.00478
0.7	0.56	0.01510	0.01430	0.01345	0.01283	0.01216	0.01166	0.01113	0.01028	0.00958	0.00901	0.00852	0.00810	0.00774	0.00742	0.00715	0.00693	0.00670	0.00653	0.00635	0.00621
0.8	0.65	0.01867	0.01770	0.01666	0.01591	0.01510	0.01448	0.01383	0.01280	0.01195	0.01125	0.01065	0.01013	0.00969	0.00929	0.00897	0.00869	0.00841	0.00820	0.00797	0.00781
0.9	0.73	0.02253	0.02138	0.02015	0.01925	0.01828	0.01755	0.01678	0.01555	0.01453	0.01369	0.01297	0.01234	0.01181	0.01135	0.01095	0.01062	0.01028	0.01003	0.00976	0.00955
1.0	0.81	0.02667	0.02533	0.02389	0.02284	0.02171	0.02086	0.01995	0.01851	0.01732	0.01633	0.01548	0.01474	0.01412	0.01357	0.01310	0.01271	0.01231	0.01202	0.01169	0.01145
1.1	0.89	0.03109	0.02954	0.02789	0.02668	0.02538	0.02440	0.02335	0.02169	0.02030	0.01916	0.01818	0.01732	0.01660	0.01596	0.01542	0.01495	0.01449	0.01415	0.01377	0.01349
1.2	0.97	0.03577	0.03402	0.03214	0.03076	0.02928	0.02816	0.02697	0.02506	0.02348	0.02217	0.02105	0.02007	0.01924	0.01851	0.01789	0.01736	0.01683	0.01644	0.01600	0.01568
1.3	1.05	0.04071	0.03874	0.03663	0.03507	0.03340	0.03214	0.03079	0.02864	0.02686	0.02537	0.02410	0.02299	0.02205	0.02122	0.02051	0.01991	0.01931	0.01887	0.01837	0.01800
1.4	1.13	0.04591	0.04371	0.04135	0.03961	0.03775	0.03633	0.03483	0.03242	0.03042	0.02875	0.02733	0.02608	0.02502	0.02408	0.02329	0.02262	0.02194	0.02144	0.02088	0.02047
1.5	1.21	0.05136	0.04893	0.04631	0.04438	0.04231	0.04074	0.03907	0.03639	0.03416	0.03231	0.03072	0.02933	0.02815	0.02711	0.02622	0.02547	0.02471	0.02415	0.02352	0.02307
1.6	1.29	0.05706	0.05438	0.05150	0.04937	0.04709	0.04535	0.04351	0.04055	0.03809	0.03604	0.03429	0.03274	0.03144	0.03028	0.02930	0.02846	0.02762	0.02700	0.02631	0.02580
1.7	1.37	0.06300	0.06006	0.05690	0.05457	0.05207	0.05017	0.04814	0.04490	0.04219	0.03994	0.03801	0.03632	0.03488	0.03360	0.03253	0.03160	0.03068	0.02999	0.02923	0.02867
1.8	1.45	0.06917	0.06597	0.06253	0.05999	0.05727	0.05519	0.05298	0.04944	0.04648	0.04401	0.04190	0.04005	0.03847	0.03707	0.03589	0.03488	0.03387	0.03312	0.03228	0.03166
1.9	1.53	0.07558	0.07211	0.06838	0.06562	0.06266	0.06041	0.05800	0.05415	0.05093	0.04825	0.04595	0.04393	0.04222	0.04069	0.03940	0.03830	0.03719	0.03637	0.03546	0.03479
2.0	1.61	0.08222	0.07848	0.07444	0.07146	0.06826	0.06582	0.06321	0.05905	0.05556	0.05265	0.05016	0.04797	0.04611	0.04445	0.04305	0.04185	0.04065	0.03976	0.03877	0.03804
2.1	1.69	0.08909	0.08506	0.08071	0.07750	0.07405	0.07142	0.06861	0.06412	0.06035	0.05722	0.05452	0.05215	0.05015	0.04835	0.04684	0.04554	0.04425	0.04328	0.04220	0.04142
2.2	1.77	0.09618	0.09186	0.08719	0.08374	0.08004	0.07722	0.07420	0.06937	0.06532	0.06194	0.05904	0.05649	0.05433	0.05240	0.05077	0.04937	0.04797	0.04693	0.04577	0.04492
2.3	1.86	0.10349	0.09887	0.09388	0.09019	0.08622	0.08320	0.07997	0.07479	0.07045	0.06683	0.06372	0.06098	0.05865	0.05658	0.05483	0.05333	0.05182	0.05071	0.04946	0.04854
2.4	1.94	0.11103	0.10609	0.10077	0.09683	0.09260	0.08937	0.08592	0.08038	0.07574	0.07187	0.06854	0.06561	0.06312	0.06090	0.05903	0.05742	0.05581	0.05461	0.05327	0.05229
2.5	2.02	0.11878	0.11353	0.10787	0.10367	0.09916	0.09572	0.09204	0.08615	0.08120	0.07707	0.07352	0.07039	0.06773	0.06536	0.06336	0.06164	0.05992	0.05864	0.05721	0.05616
2.6	2.10	0.12674	0.12117	0.11516	0.11070	0.10592	0.10226	0.09835	0.09208	0.08682	0.08242	0.07864	0.07531	0.07248	0.06996	0.06783	0.06599	0.06416	0.06280	0.06127	0.06015
2.7	2.18	0.13492	0.12902	0.12265	0.11793	0.11285	0.10898	0.10483	0.09818	0.09259	0.08792	0.08391	0.08038	0.07737	0.07469	0.07242	0.07047	0.06852	0.06708	0.06545	0.06427
2.8	2.26	0.14331	0.13707	0.13034	0.12534	0.11998	0.11587	0.11149	0.10444	0.09853	0.09358	0.08933	0.08558	0.08240	0.07955	0.07715	0.07508	0.07301	0.07148	0.06975	0.06849
2.9	2.34	0.15191	0.14533	0.13822	0.13295	0.12728	0.12295	0.11831	0.11087	0.10462	0.09939	0.09490	0.09093	0.08756	0.08455	0.08201	0.07982	0.07763	0.07600	0.07417	0.07284
3.0	2.42	0.16071	0.15378	0.14630	0.14074	0.13477	0.13020	0.12531	0.11746	0.11087	0.10535	0.10060	0.09642	0.09286	0.08968	0.08699	0.08468	0.08236	0.08064	0.07871	0.07731
3.1	2.50	0.16972	0.16244	0.15456	0.14872	0.14243	0.13763	0.13248	0.12422	0.11727	0.11146	0.10646	0.10204	0.09829	0.09493	0.09210	0.08966	0.08722	0.08541	0.08337	0.08189
3.2	2.58	0.17893	0.17128	0.16302	0.15688	0.15027	0.14523	0.13982	0.13113	0.12382	0.11771	0.11245	0.10780	0.10385	0.10032	0.09734	0.09477	0.09220	0.09029	0.08815	0.08658
3.3	2.66	0.18834	0.18033	0.17166	0.16522	0.15829	0.15300	0.14732	0.13820	0.13053	0.12411	0.11858	0.11370	0.10955	0.10584	0.10271	0.10000	0.09730	0.09530	0.09304	0.09139
3.4	2.74	0.19796	0.18957	0.18049	0.17375	0.16649	0.16094	0.15499	0.14543	0.13739	0.13066	0.12486	0.11974	0.11538	0.11149	0.10820	0.10536	0.10252	0.10042	0.09805	0.09632
3.5	2.82	0.20777	0.19900	0.18951	0.18245	0.17486	0.16905	0.16283	0.15282	0.14440	0.13735	0.13127	0.12591	0.12134	0.11726	0.11381	0.11084	0.10786	0.10565	0.10317	0.10136
3.6	2.90	0.21778	0.20862	0.19870	0.19134	0.18340	0.17733	0.17083	0.16037	0.15156	0.14418	0.13783	0.13221	0.12743	0.12316	0.11955	0.11644	0.11332	0.11101	0.10841	0.10651
3.7	2.98	0.22799	0.21843	0.20809	0.20040	0.19212	0.18578	0.17899	0.16806	0.15886	0.15116	0.14452	0.13865	0.13365	0.12919	0.12541	0.12216	0.11890	0.11648	0.11376	0.11177
3.8	3.07	0.23839	0.22843	0.21765	0.20963	0.20100	0.19440	0.18731	0.17592	0.16632	0.15827	0.15134	0.14522	0.14000	0.13534	0.13140	0.12799	0.12459	0.12206	0.11922	0.11714

Continued on next page

Recommended head loss design range

Sizing in this region will lead to excessive head loss conditions.

Appendix G:
Hydronic friction loss tables

⅝" Uponor PEX-a — 40% Propylene glycol — feet of head per foot of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
3.9	3.15	0.24898	0.23862	0.22739	0.21905	0.21006	0.20318	0.19580	0.18392	0.17392	0.16553	0.15831	0.15192	0.14648	0.14161	0.13750	0.13395	0.13040	0.12776	0.12480	0.12263
4.0	3.23	0.25977	0.24899	0.23732	0.22864	0.21928	0.21212	0.20444	0.19208	0.18167	0.17293	0.16541	0.15875	0.15308	0.14801	0.14373	0.14003	0.13633	0.13358	0.13049	0.12823
4.1	3.31	0.27074	0.25955	0.24742	0.23840	0.22867	0.22123	0.21324	0.20039	0.18956	0.18047	0.17264	0.16571	0.15982	0.15454	0.15008	0.14622	0.14237	0.13951	0.13629	0.13393
4.2	3.39	0.28191	0.27029	0.25770	0.24833	0.23823	0.23050	0.22221	0.20885	0.19759	0.18815	0.18001	0.17281	0.16667	0.16118	0.15654	0.15254	0.14853	0.14555	0.14220	0.13975
4.3	3.47	0.29327	0.28121	0.26815	0.25843	0.24796	0.23993	0.23132	0.21746	0.20577	0.19596	0.18751	0.18003	0.17365	0.16795	0.16313	0.15897	0.15480	0.15170	0.14822	0.14568
4.4	3.55	0.30481	0.29232	0.27878	0.26871	0.25785	0.24953	0.24060	0.22622	0.21409	0.20392	0.19514	0.18738	0.18076	0.17484	0.16983	0.16551	0.16119	0.15797	0.15435	0.15171
4.5	3.63	0.31654	0.30361	0.28959	0.27915	0.26790	0.25928	0.25003	0.23513	0.22256	0.21201	0.20291	0.19485	0.18799	0.18185	0.17666	0.17217	0.16768	0.16435	0.16059	0.15785
4.6	3.71	0.32845	0.31507	0.30056	0.28976	0.27812	0.26919	0.25961	0.24418	0.23116	0.22023	0.21080	0.20246	0.19535	0.18898	0.18360	0.17895	0.17430	0.17084	0.16694	0.16410
4.7	3.79	0.29169	0.28219	0.27198	0.26404	0.25554	0.24867	0.24134	0.22940	0.21910	0.21020	0.20238	0.19572	0.18975	0.18430	0.17993	0.17564	0.17169	0.16840	0.16515	0.16274

Recommended head loss design range

Sizing in this region will lead to excessive head loss conditions.

Appendix G:

Hydronic friction loss tables

⅝" Uponor PEX-a — 50% Propylene glycol — feet of head per foot of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
0.5	0.40	0.01058	0.00995	0.00928	0.00878	0.00826	0.00786	0.00745	0.00680	0.00626	0.00582	0.00545	0.00514	0.00487	0.00464	0.00444	0.00427	0.00411	0.00397	0.00385	0.00374
0.6	0.48	0.01402	0.01320	0.01233	0.01169	0.01101	0.01050	0.00996	0.00911	0.00841	0.00784	0.00735	0.00694	0.00659	0.00628	0.00602	0.00579	0.00558	0.00539	0.00524	0.00509
0.7	0.56	0.01781	0.01679	0.01571	0.01491	0.01407	0.01343	0.01275	0.01169	0.01081	0.01009	0.00948	0.00896	0.00852	0.00813	0.00779	0.00750	0.00723	0.00700	0.00680	0.00661
0.8	0.65	0.02194	0.02071	0.01940	0.01844	0.01741	0.01664	0.01582	0.01452	0.01346	0.01257	0.01182	0.01119	0.01064	0.01017	0.00975	0.00940	0.00907	0.00877	0.00853	0.00830
0.9	0.73	0.02640	0.02495	0.02340	0.02225	0.02104	0.02012	0.01914	0.01760	0.01633	0.01527	0.01438	0.01362	0.01296	0.01239	0.01190	0.01147	0.01107	0.01072	0.01043	0.01015
1.0	0.81	0.03118	0.02949	0.02768	0.02635	0.02493	0.02386	0.02272	0.02092	0.01942	0.01818	0.01714	0.01624	0.01547	0.01480	0.01422	0.01371	0.01324	0.01283	0.01249	0.01215
1.1	0.89	0.03626	0.03432	0.03225	0.03072	0.02909	0.02785	0.02654	0.02446	0.02274	0.02130	0.02010	0.01906	0.01817	0.01739	0.01671	0.01612	0.01558	0.01509	0.01470	0.01431
1.2	0.97	0.04164	0.03944	0.03709	0.03535	0.03350	0.03209	0.03060	0.02823	0.02627	0.02463	0.02325	0.02206	0.02104	0.02015	0.01937	0.01870	0.01808	0.01752	0.01706	0.01662
1.3	1.05	0.04731	0.04484	0.04220	0.04025	0.03816	0.03657	0.03489	0.03222	0.03000	0.02815	0.02659	0.02525	0.02409	0.02308	0.02220	0.02143	0.02073	0.02009	0.01958	0.01907
1.4	1.13	0.05327	0.05052	0.04758	0.04539	0.04306	0.04129	0.03941	0.03643	0.03394	0.03187	0.03012	0.02861	0.02731	0.02617	0.02519	0.02433	0.02353	0.02282	0.02224	0.02167
1.5	1.21	0.05950	0.05646	0.05320	0.05079	0.04820	0.04624	0.04415	0.04084	0.03809	0.03578	0.03383	0.03215	0.03070	0.02944	0.02834	0.02738	0.02649	0.02570	0.02505	0.02441
1.6	1.29	0.06601	0.06267	0.05908	0.05642	0.05358	0.05142	0.04912	0.04547	0.04242	0.03988	0.03772	0.03587	0.03426	0.03286	0.03164	0.03058	0.02960	0.02872	0.02800	0.02729
1.7	1.37	0.07278	0.06913	0.06521	0.06230	0.05919	0.05682	0.05430	0.05030	0.04696	0.04416	0.04179	0.03975	0.03799	0.03645	0.03511	0.03393	0.03285	0.03188	0.03109	0.03031
1.8	1.45	0.07982	0.07585	0.07158	0.06842	0.06502	0.06244	0.05969	0.05533	0.05168	0.04862	0.04603	0.04380	0.04188	0.04019	0.03872	0.03744	0.03625	0.03519	0.03432	0.03347
1.9	1.53	0.08712	0.08282	0.07820	0.07476	0.07108	0.06828	0.06530	0.06055	0.05659	0.05327	0.05045	0.04802	0.04592	0.04408	0.04248	0.04109	0.03979	0.03863	0.03768	0.03676
2.0	1.61	0.09467	0.09003	0.08504	0.08133	0.07736	0.07434	0.07111	0.06598	0.06169	0.05809	0.05504	0.05241	0.05013	0.04813	0.04640	0.04488	0.04348	0.04222	0.04119	0.04018
2.1	1.69	0.10248	0.09749	0.09213	0.08813	0.08385	0.08060	0.07712	0.07159	0.06697	0.06308	0.05979	0.05695	0.05449	0.05234	0.05046	0.04882	0.04730	0.04594	0.04482	0.04373
2.2	1.77	0.11053	0.10519	0.09944	0.09516	0.09056	0.08707	0.08334	0.07740	0.07243	0.06825	0.06471	0.06166	0.05901	0.05669	0.05467	0.05290	0.05126	0.04980	0.04859	0.04742
2.3	1.86	0.11883	0.11312	0.10698	0.10240	0.09749	0.09375	0.08976	0.08340	0.07807	0.07360	0.06980	0.06652	0.06368	0.06119	0.05902	0.05712	0.05536	0.05379	0.05249	0.05123
2.4	1.94	0.12737	0.12129	0.11474	0.10986	0.10462	0.10064	0.09637	0.08958	0.08389	0.07911	0.07505	0.07154	0.06850	0.06583	0.06351	0.06148	0.05960	0.05791	0.05653	0.05517
2.5	2.02	0.13616	0.12969	0.12273	0.11754	0.11196	0.10772	0.10318	0.09595	0.08989	0.08479	0.08046	0.07672	0.07348	0.07063	0.06815	0.06598	0.06397	0.06217	0.06069	0.05924
2.6	2.10	0.14518	0.13832	0.13093	0.12543	0.11951	0.11500	0.11018	0.10250	0.09605	0.09063	0.08603	0.08205	0.07860	0.07556	0.07293	0.07061	0.06847	0.06655	0.06498	0.06344
2.7	2.18	0.15443	0.14718	0.13936	0.13353	0.12726	0.12249	0.11738	0.10923	0.10240	0.09664	0.09175	0.08753	0.08387	0.08065	0.07784	0.07538	0.07311	0.07107	0.06939	0.06776
2.8	2.26	0.16392	0.15626	0.14800	0.14183	0.13521	0.13016	0.12476	0.11614	0.10891	0.10282	0.09764	0.09316	0.08928	0.08587	0.08290	0.08029	0.07788	0.07571	0.07393	0.07220
2.9	2.34	0.17364	0.16556	0.15685	0.15035	0.14336	0.13804	0.13233	0.12323	0.11559	0.10915	0.10368	0.09895	0.09484	0.09123	0.08809	0.08533	0.08278	0.08048	0.07860	0.07676
3.0	2.42	0.18358	0.17509	0.16592	0.15907	0.15171	0.14610	0.14009	0.13050	0.12244	0.11565	0.10988	0.10488	0.10055	0.09673	0.09341	0.09050	0.08781	0.08538	0.08339	0.08145
3.1	2.50	0.19376	0.18483	0.17519	0.16800	0.16025	0.15436	0.14803	0.13794	0.12946	0.12231	0.11623	0.11096	0.10640	0.10238	0.09888	0.09581	0.09296	0.09040	0.08831	0.08626
3.2	2.58	0.20416	0.19479	0.18468	0.17712	0.16899	0.16280	0.15616	0.14556	0.13664	0.12912	0.12273	0.11719	0.11239	0.10816	0.10447	0.10124	0.09825	0.09555	0.09335	0.09119
3.3	2.66	0.21478	0.20496	0.19437	0.18645	0.17793	0.17143	0.16447	0.15334	0.14399	0.13610	0.12938	0.12357	0.11852	0.11407	0.11020	0.10680	0.10366	0.10083	0.09851	0.09624
3.4	2.74	0.22562	0.21535	0.20426	0.19597	0.18705	0.18025	0.17296	0.16130	0.15150	0.14323	0.13618	0.13008	0.12479	0.12013	0.11606	0.11250	0.10920	0.10622	0.10379	0.10140
3.5	2.82	0.23668	0.22595	0.21436	0.20570	0.19637	0.18926	0.18163	0.16943	0.15917	0.15051	0.14314	0.13675	0.13120	0.12632	0.12206	0.11832	0.11486	0.11174	0.10919	0.10669
3.6	2.90	0.24795	0.23676	0.22466	0.21562	0.20587	0.19845	0.19047	0.17773	0.16700	0.15795	0.15024	0.14355	0.13775	0.13264	0.12818	0.12427	0.12065	0.11738	0.11471	0.11209
3.7	2.98	0.25945	0.24778	0.23516	0.22573	0.21557	0.20782	0.19950	0.18620	0.17500	0.16554	0.15748	0.15050	0.14444	0.13909	0.13444	0.13035	0.12656	0.12315	0.12035	0.11761

Continued on next page

Recommended head loss design range

Sizing in this region will lead to excessive head loss conditions.

⅝" Uponor PEX-a — 50% Propylene glycol — feet of head per foot of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
3.8	3.07	0.27115	0.25900	0.24586	0.23603	0.22545	0.21737	0.20870	0.19483	0.18315	0.17328	0.16488	0.15759	0.15126	0.14568	0.14082	0.13655	0.13259	0.12903	0.12611	0.12325
3.9	3.15	0.28307	0.27043	0.25676	0.24653	0.23551	0.22710	0.21807	0.20363	0.19146	0.18118	0.17242	0.16482	0.15822	0.15241	0.14733	0.14288	0.13875	0.13503	0.13198	0.12900
4.0	3.23	0.29520	0.28207	0.26786	0.25722	0.24576	0.23701	0.22762	0.21259	0.19992	0.18922	0.18010	0.17219	0.16532	0.15926	0.15397	0.14933	0.14503	0.14116	0.13798	0.13487
4.1	3.31	0.30755	0.29391	0.27915	0.26810	0.25619	0.24710	0.23734	0.22172	0.20855	0.19742	0.18793	0.17970	0.17255	0.16624	0.16074	0.15591	0.15143	0.14740	0.14409	0.14085
4.2	3.39	0.32010	0.30595	0.29063	0.27917	0.26680	0.25737	0.24723	0.23101	0.21733	0.20576	0.19590	0.18735	0.17991	0.17335	0.16763	0.16261	0.15795	0.15376	0.15031	0.14695
4.3	3.47	0.33285	0.31819	0.30231	0.29042	0.27760	0.26781	0.25729	0.24046	0.22626	0.21426	0.20401	0.19513	0.18741	0.18060	0.17465	0.16943	0.16460	0.16023	0.15666	0.15316
4.4	3.55	0.34582	0.33063	0.31418	0.30186	0.28857	0.27843	0.26753	0.25007	0.23535	0.22290	0.21227	0.20305	0.19504	0.18797	0.18180	0.17638	0.17136	0.16683	0.16311	0.15948

Recommended head loss design range

Sizing in this region will lead to excessive head loss conditions.

Appendix G:

Hydronic friction loss tables

¾" Uponor PEX-a — 100% Water — feet of head per foot of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
0.5	0.55	0.00393	0.00370	0.00344	0.00336	0.00328	0.00321	0.00314	0.00302	0.00291	0.00282	0.00274	0.00266	0.00259	0.00253	0.00248	0.00243	0.00238	0.00234	0.00230	0.00226
0.6	0.66	0.00532	0.00502	0.00468	0.00457	0.00446	0.00437	0.00427	0.00411	0.00397	0.00385	0.00374	0.00364	0.00355	0.00347	0.00339	0.00332	0.00326	0.00320	0.00315	0.00310
0.7	0.77	0.00688	0.00650	0.00606	0.00593	0.00579	0.00567	0.00555	0.00535	0.00517	0.00501	0.00487	0.00474	0.00462	0.00452	0.00442	0.00434	0.00426	0.00418	0.00412	0.00405
0.8	0.88	0.00861	0.00813	0.00760	0.00744	0.00726	0.00712	0.00697	0.00672	0.00650	0.00630	0.00612	0.00597	0.00582	0.00570	0.00558	0.00547	0.00537	0.00528	0.00519	0.00511
0.9	0.99	0.01050	0.00993	0.00929	0.00909	0.00888	0.00871	0.00853	0.00822	0.00795	0.00772	0.00750	0.00731	0.00714	0.00699	0.00684	0.00671	0.00659	0.00648	0.00638	0.00628
1.0	1.10	0.01254	0.01187	0.01111	0.01088	0.01063	0.01043	0.01022	0.00985	0.00954	0.00925	0.00900	0.00878	0.00857	0.00839	0.00822	0.00806	0.00792	0.00779	0.00767	0.00755
1.1	1.21	0.01473	0.01395	0.01308	0.01280	0.01251	0.01228	0.01203	0.01161	0.01124	0.01091	0.01062	0.01036	0.01012	0.00990	0.00970	0.00952	0.00935	0.00920	0.00906	0.00893
1.2	1.32	0.01707	0.01618	0.01517	0.01486	0.01453	0.01426	0.01397	0.01349	0.01307	0.01269	0.01235	0.01205	0.01177	0.01152	0.01130	0.01109	0.01089	0.01072	0.01055	0.01040
1.3	1.43	0.01956	0.01854	0.01740	0.01704	0.01667	0.01636	0.01604	0.01549	0.01501	0.01458	0.01419	0.01385	0.01354	0.01325	0.01299	0.01276	0.01253	0.01233	0.01215	0.01197
1.4	1.54	0.02218	0.02104	0.01976	0.01936	0.01894	0.01859	0.01823	0.01761	0.01706	0.01658	0.01615	0.01576	0.01541	0.01509	0.01479	0.01452	0.01427	0.01405	0.01384	0.01364
1.5	1.65	0.02495	0.02368	0.02225	0.02180	0.02133	0.02094	0.02054	0.01984	0.01924	0.01869	0.01821	0.01777	0.01738	0.01702	0.01669	0.01639	0.01611	0.01586	0.01562	0.01540
1.6	1.76	0.02786	0.02645	0.02486	0.02436	0.02384	0.02341	0.02296	0.02219	0.02152	0.02092	0.02038	0.01990	0.01946	0.01906	0.01869	0.01836	0.01805	0.01777	0.01751	0.01726
1.7	1.87	0.03090	0.02934	0.02760	0.02705	0.02647	0.02600	0.02550	0.02466	0.02391	0.02325	0.02266	0.02212	0.02164	0.02120	0.02079	0.02043	0.02008	0.01977	0.01948	0.01921
1.8	1.98	0.03407	0.03237	0.03046	0.02985	0.02922	0.02870	0.02816	0.02723	0.02642	0.02569	0.02504	0.02445	0.02392	0.02344	0.02299	0.02259	0.02221	0.02187	0.02155	0.02125
1.9	2.09	0.03737	0.03552	0.03344	0.03278	0.03209	0.03152	0.03093	0.02992	0.02903	0.02823	0.02752	0.02688	0.02630	0.02577	0.02529	0.02485	0.02443	0.02406	0.02371	0.02338
2.0	2.20	0.04081	0.03880	0.03654	0.03582	0.03507	0.03446	0.03382	0.03271	0.03174	0.03088	0.03011	0.02941	0.02878	0.02821	0.02768	0.02720	0.02674	0.02634	0.02596	0.02561
2.1	2.31	0.04437	0.04220	0.03975	0.03898	0.03817	0.03751	0.03681	0.03562	0.03457	0.03363	0.03280	0.03204	0.03135	0.03073	0.03016	0.02964	0.02915	0.02871	0.02830	0.02792
2.2	2.43	0.04807	0.04573	0.04309	0.04225	0.04138	0.04066	0.03991	0.03863	0.03750	0.03648	0.03558	0.03477	0.03403	0.03336	0.03274	0.03218	0.03165	0.03117	0.03073	0.03032
2.3	2.54	0.05188	0.04937	0.04654	0.04564	0.04470	0.04393	0.04313	0.04174	0.04053	0.03944	0.03847	0.03759	0.03680	0.03608	0.03541	0.03481	0.03424	0.03373	0.03325	0.03280
2.4	2.65	0.05583	0.05314	0.05010	0.04914	0.04814	0.04731	0.04645	0.04497	0.04366	0.04250	0.04146	0.04051	0.03966	0.03889	0.03818	0.03753	0.03692	0.03637	0.03586	0.03538
2.5	2.76	0.05989	0.05702	0.05378	0.05276	0.05168	0.05080	0.04988	0.04829	0.04690	0.04565	0.04454	0.04353	0.04262	0.04180	0.04103	0.04034	0.03968	0.03910	0.03855	0.03804
2.6	2.87	0.06408	0.06102	0.05757	0.05648	0.05534	0.05439	0.05341	0.05172	0.05023	0.04891	0.04772	0.04665	0.04567	0.04479	0.04398	0.04324	0.04254	0.04191	0.04133	0.04078
2.7	2.98	0.06839	0.06514	0.06147	0.06031	0.05910	0.05810	0.05705	0.05525	0.05367	0.05226	0.05100	0.04985	0.04882	0.04788	0.04702	0.04623	0.04548	0.04482	0.04419	0.04361
2.8	3.09	0.07283	0.06938	0.06549	0.06426	0.06297	0.06190	0.06079	0.05889	0.05721	0.05571	0.05437	0.05316	0.05206	0.05106	0.05014	0.04930	0.04852	0.04781	0.04714	0.04653
2.9	3.20	0.07738	0.07373	0.06961	0.06831	0.06694	0.06582	0.06464	0.06262	0.06085	0.05926	0.05784	0.05655	0.05539	0.05433	0.05336	0.05247	0.05163	0.05088	0.05018	0.04953
3.0	3.31	0.08205	0.07820	0.07384	0.07247	0.07102	0.06983	0.06859	0.06646	0.06458	0.06290	0.06140	0.06004	0.05881	0.05769	0.05666	0.05572	0.05484	0.05404	0.05330	0.05261
3.1	3.42	0.08683	0.08277	0.07818	0.07673	0.07521	0.07396	0.07265	0.07040	0.06841	0.06664	0.06506	0.06362	0.06232	0.06114	0.06005	0.05906	0.05813	0.05729	0.05650	0.05577
3.2	3.53	0.09174	0.08747	0.08263	0.08110	0.07950	0.07818	0.07680	0.07443	0.07234	0.07047	0.06880	0.06729	0.06592	0.06468	0.06353	0.06248	0.06150	0.06061	0.05979	0.05902
3.3	3.64	0.09676	0.09227	0.08719	0.08558	0.08390	0.08251	0.08106	0.07856	0.07636	0.07440	0.07264	0.07105	0.06961	0.06830	0.06709	0.06600	0.06496	0.06403	0.06316	0.06235
3.4	3.75	0.10190	0.09718	0.09185	0.09016	0.08839	0.08694	0.08541	0.08279	0.08048	0.07842	0.07658	0.07490	0.07339	0.07202	0.07075	0.06959	0.06850	0.06752	0.06661	0.06576
3.5	3.86	0.10715	0.10221	0.09662	0.09485	0.09299	0.09147	0.08987	0.08712	0.08470	0.08253	0.08060	0.07884	0.07726	0.07582	0.07448	0.07327	0.07213	0.07110	0.07014	0.06925
3.6	3.97	0.11252	0.10734	0.10149	0.09964	0.09770	0.09610	0.09442	0.09155	0.08901	0.08674	0.08472	0.08288	0.08121	0.07970	0.07831	0.07704	0.07584	0.07476	0.07376	0.07282
3.7	4.08	0.11799	0.11259	0.10647	0.10453	0.10250	0.10083	0.09908	0.09607	0.09341	0.09104	0.08892	0.08700	0.08526	0.08368	0.08221	0.08089	0.07963	0.07850	0.07745	0.07647

Continued on next page

Recommended head loss design range

Sizing in this region will lead to excessive head loss conditions.

¾" Uponor PEX-a — 100% Water — feet of head per foot of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
3.8	4.19	0.12359	0.11794	0.11155	0.10953	0.10741	0.10566	0.10383	0.10069	0.09791	0.09543	0.09322	0.09121	0.08939	0.08773	0.08621	0.08482	0.08351	0.08233	0.08123	0.08020
3.9	4.30	0.12929	0.12340	0.11674	0.11463	0.11241	0.11059	0.10868	0.10540	0.10250	0.09991	0.09760	0.09550	0.09360	0.09188	0.09028	0.08883	0.08746	0.08623	0.08509	0.08401
4.0	4.41	0.13511	0.12897	0.12203	0.11983	0.11752	0.11562	0.11363	0.11021	0.10719	0.10449	0.10208	0.09989	0.09791	0.09611	0.09444	0.09293	0.09150	0.09022	0.08902	0.08790
4.1	4.52	0.14103	0.13465	0.12742	0.12513	0.12272	0.12074	0.11867	0.11511	0.11196	0.10915	0.10664	0.10436	0.10230	0.10042	0.09869	0.09711	0.09562	0.09429	0.09304	0.09187
4.2	4.63	0.14707	0.14043	0.13291	0.13053	0.12803	0.12596	0.12381	0.12010	0.11683	0.11391	0.11129	0.10892	0.10677	0.10482	0.10302	0.10137	0.09983	0.09843	0.09713	0.09592
4.3	4.74	0.15322	0.14632	0.13850	0.13603	0.13343	0.13129	0.12904	0.12519	0.12179	0.11875	0.11603	0.11356	0.11133	0.10930	0.10743	0.10572	0.10411	0.10266	0.10131	0.10005
4.4	4.85	0.15947	0.15231	0.14420	0.14163	0.13893	0.13670	0.13438	0.13038	0.12684	0.12368	0.12086	0.11829	0.11597	0.11387	0.11192	0.11014	0.10847	0.10696	0.10556	0.10425
4.5	4.96	0.16584	0.15841	0.14999	0.14733	0.14452	0.14222	0.13980	0.13565	0.13198	0.12870	0.12578	0.12311	0.12070	0.11852	0.11649	0.11465	0.11291	0.11135	0.10989	0.10853
4.6	5.07	0.17231	0.16462	0.15589	0.15312	0.15022	0.14783	0.14532	0.14102	0.13722	0.13381	0.13078	0.12801	0.12552	0.12325	0.12115	0.11924	0.11744	0.11581	0.11430	0.11289
4.7	5.18	0.17890	0.17092	0.16188	0.15902	0.15601	0.15353	0.15094	0.14648	0.14254	0.13901	0.13587	0.13300	0.13041	0.12806	0.12589	0.12391	0.12204	0.12036	0.11879	0.11733
4.8	5.29	0.18558	0.17733	0.16798	0.16501	0.16190	0.15933	0.15664	0.15203	0.14795	0.14430	0.14104	0.13807	0.13539	0.13296	0.13070	0.12865	0.12672	0.12498	0.12336	0.12184
4.9	5.40	0.19238	0.18385	0.17417	0.17110	0.16788	0.16523	0.16245	0.15767	0.15345	0.14967	0.14630	0.14323	0.14046	0.13794	0.13560	0.13348	0.13148	0.12968	0.12800	0.12643
5.0	5.51	0.19928	0.19046	0.18046	0.17729	0.17396	0.17121	0.16834	0.16340	0.15904	0.15513	0.15165	0.14847	0.14560	0.14300	0.14058	0.13839	0.13632	0.13445	0.13272	0.13109
5.1	5.62	0.20629	0.19718	0.18685	0.18357	0.18013	0.17730	0.17433	0.16923	0.16472	0.16068	0.15708	0.15380	0.15083	0.14814	0.14564	0.14337	0.14123	0.13931	0.13751	0.13584
5.2	5.73	0.21340	0.20400	0.19334	0.18995	0.18640	0.18347	0.18041	0.17514	0.17048	0.16631	0.16259	0.15921	0.15614	0.15336	0.15078	0.14844	0.14623	0.14424	0.14239	0.14065
5.3	5.84	0.22062	0.21092	0.19992	0.19643	0.19276	0.18974	0.18658	0.18114	0.17634	0.17203	0.16819	0.16470	0.16154	0.15866	0.15600	0.15358	0.15130	0.14925	0.14733	0.14555
5.4	5.95	0.22795	0.21795	0.20660	0.20300	0.19922	0.19611	0.19284	0.18723	0.18228	0.17784	0.17388	0.17027	0.16701	0.16405	0.16130	0.15881	0.15645	0.15433	0.15236	0.15051
5.5	6.06	0.23538	0.22507	0.21338	0.20967	0.20577	0.20256	0.19920	0.19342	0.18831	0.18373	0.17965	0.17593	0.17257	0.16951	0.16668	0.16411	0.16168	0.15949	0.15746	0.15556
5.6	6.17	0.24291	0.23230	0.22025	0.21643	0.21242	0.20911	0.20564	0.19969	0.19442	0.18971	0.18550	0.18167	0.17820	0.17505	0.17214	0.16949	0.16699	0.16473	0.16263	0.16067
5.7	6.28	0.25054	0.23962	0.22722	0.22329	0.21915	0.21575	0.21218	0.20605	0.20063	0.19577	0.19144	0.18749	0.18392	0.18068	0.17768	0.17495	0.17237	0.17005	0.16789	0.16587
5.8	6.39	0.25828	0.24704	0.23428	0.23024	0.22598	0.22248	0.21881	0.21250	0.20692	0.20192	0.19746	0.19339	0.18972	0.18638	0.18329	0.18048	0.17783	0.17544	0.17321	0.17113
5.9	6.50	0.26613	0.25457	0.24144	0.23728	0.23291	0.22930	0.22553	0.21903	0.21329	0.20815	0.20356	0.19938	0.19560	0.19216	0.18899	0.18609	0.18336	0.18090	0.17861	0.17647

Recommended head loss design range

Sizing in this region will lead to excessive head loss conditions.

Appendix G:

Hydronic friction loss tables

¾" Uponor PEX-a — 30% Propylene glycol — feet of head per foot of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
0.5	0.55	0.00578	0.00553	0.00526	0.00506	0.00485	0.00467	0.00449	0.00420	0.00396	0.00375	0.00357	0.00342	0.00328	0.00316	0.00307	0.00297	0.00289	0.00282	0.00275	0.00269
0.6	0.66	0.00775	0.00742	0.00707	0.00681	0.00653	0.00630	0.00606	0.00568	0.00536	0.00508	0.00485	0.00464	0.00447	0.00430	0.00418	0.00405	0.00394	0.00384	0.00375	0.00368
0.7	0.77	0.00994	0.00953	0.00910	0.00876	0.00841	0.00812	0.00782	0.00734	0.00693	0.00658	0.00628	0.00603	0.00580	0.00559	0.00543	0.00527	0.00512	0.00500	0.00488	0.00480
0.8	0.88	0.01235	0.01185	0.01132	0.01091	0.01048	0.01013	0.00977	0.00917	0.00867	0.00824	0.00787	0.00755	0.00727	0.00702	0.00682	0.00662	0.00644	0.00629	0.00615	0.00604
0.9	0.99	0.01497	0.01438	0.01374	0.01325	0.01274	0.01232	0.01188	0.01117	0.01057	0.01006	0.00961	0.00923	0.00889	0.00859	0.00834	0.00811	0.00789	0.00771	0.00753	0.00740
1.0	1.10	0.01779	0.01709	0.01635	0.01578	0.01517	0.01469	0.01417	0.01334	0.01263	0.01202	0.01149	0.01104	0.01064	0.01028	0.01000	0.00972	0.00946	0.00925	0.00904	0.00888
1.1	1.21	0.02081	0.02000	0.01915	0.01849	0.01778	0.01722	0.01662	0.01566	0.01483	0.01413	0.01351	0.01299	0.01253	0.01211	0.01178	0.01145	0.01115	0.01090	0.01066	0.01048
1.2	1.32	0.02402	0.02310	0.02212	0.02137	0.02056	0.01992	0.01924	0.01813	0.01719	0.01638	0.01568	0.01508	0.01455	0.01407	0.01368	0.01331	0.01296	0.01268	0.01239	0.01219
1.3	1.43	0.02741	0.02638	0.02527	0.02442	0.02351	0.02278	0.02201	0.02076	0.01969	0.01877	0.01797	0.01730	0.01669	0.01615	0.01571	0.01528	0.01489	0.01456	0.01424	0.01401
1.4	1.54	0.03099	0.02983	0.02860	0.02764	0.02662	0.02581	0.02494	0.02353	0.02233	0.02130	0.02040	0.01964	0.01896	0.01835	0.01785	0.01737	0.01693	0.01656	0.01620	0.01593
1.5	1.65	0.03475	0.03346	0.03209	0.03103	0.02990	0.02898	0.02802	0.02646	0.02512	0.02397	0.02296	0.02212	0.02136	0.02067	0.02012	0.01958	0.01909	0.01868	0.01827	0.01797
1.6	1.76	0.03869	0.03727	0.03575	0.03457	0.03333	0.03232	0.03125	0.02952	0.02804	0.02677	0.02566	0.02471	0.02387	0.02311	0.02250	0.02190	0.02135	0.02090	0.02045	0.02012
1.7	1.87	0.04280	0.04124	0.03957	0.03828	0.03691	0.03580	0.03463	0.03273	0.03110	0.02970	0.02847	0.02744	0.02651	0.02567	0.02499	0.02433	0.02373	0.02323	0.02273	0.02236
1.8	1.98	0.04708	0.04538	0.04356	0.04215	0.04065	0.03944	0.03815	0.03607	0.03429	0.03276	0.03142	0.03028	0.02926	0.02834	0.02760	0.02688	0.02621	0.02566	0.02512	0.02472
1.9	2.09	0.05153	0.04968	0.04770	0.04617	0.04454	0.04322	0.04182	0.03956	0.03761	0.03594	0.03448	0.03324	0.03213	0.03113	0.03032	0.02953	0.02881	0.02820	0.02761	0.02717
2.0	2.20	0.05615	0.05415	0.05200	0.05034	0.04858	0.04715	0.04564	0.04318	0.04107	0.03926	0.03767	0.03633	0.03512	0.03403	0.03315	0.03229	0.03151	0.03085	0.03020	0.02973
2.1	2.31	0.06093	0.05877	0.05646	0.05467	0.05276	0.05122	0.04959	0.04693	0.04466	0.04270	0.04098	0.03953	0.03822	0.03704	0.03609	0.03516	0.03431	0.03360	0.03290	0.03238
2.2	2.43	0.06587	0.06355	0.06107	0.05915	0.05709	0.05544	0.05368	0.05082	0.04837	0.04626	0.04441	0.04284	0.04144	0.04016	0.03914	0.03814	0.03722	0.03645	0.03570	0.03514
2.3	2.54	0.07098	0.06849	0.06583	0.06377	0.06157	0.05980	0.05791	0.05484	0.05221	0.04994	0.04796	0.04627	0.04476	0.04339	0.04229	0.04122	0.04023	0.03940	0.03859	0.03799
2.4	2.65	0.07624	0.07359	0.07075	0.06854	0.06619	0.06429	0.06227	0.05899	0.05618	0.05375	0.05162	0.04982	0.04820	0.04673	0.04555	0.04440	0.04334	0.04246	0.04159	0.04094
2.5	2.76	0.08166	0.07884	0.07581	0.07346	0.07095	0.06892	0.06677	0.06327	0.06027	0.05767	0.05540	0.05348	0.05175	0.05018	0.04892	0.04769	0.04655	0.04561	0.04468	0.04399
2.6	2.87	0.08724	0.08424	0.08102	0.07852	0.07585	0.07370	0.07140	0.06768	0.06448	0.06172	0.05930	0.05725	0.05541	0.05373	0.05239	0.05108	0.04987	0.04886	0.04787	0.04713
2.7	2.98	0.09297	0.08979	0.08637	0.08372	0.08089	0.07860	0.07617	0.07222	0.06881	0.06588	0.06331	0.06113	0.05917	0.05739	0.05597	0.05457	0.05328	0.05221	0.05115	0.05037
2.8	3.09	0.09886	0.09548	0.09187	0.08906	0.08606	0.08364	0.08106	0.07688	0.07327	0.07016	0.06744	0.06512	0.06305	0.06116	0.05964	0.05816	0.05680	0.05566	0.05454	0.05371
2.9	3.20	0.10489	0.10133	0.09751	0.09454	0.09138	0.08882	0.08609	0.08166	0.07785	0.07456	0.07168	0.06923	0.06703	0.06503	0.06342	0.06185	0.06041	0.05920	0.05801	0.05713
3.0	3.31	0.11108	0.10732	0.10330	0.10017	0.09682	0.09412	0.09125	0.08657	0.08254	0.07907	0.07603	0.07344	0.07111	0.06900	0.06731	0.06565	0.06412	0.06284	0.06159	0.06065
3.1	3.42	0.11742	0.11346	0.10922	0.10593	0.10241	0.09956	0.09653	0.09160	0.08736	0.08370	0.08049	0.07776	0.07531	0.07308	0.07129	0.06954	0.06792	0.06658	0.06525	0.06427
3.2	3.53	0.12390	0.11975	0.11529	0.11182	0.10812	0.10513	0.10194	0.09676	0.09229	0.08844	0.08506	0.08218	0.07960	0.07725	0.07537	0.07352	0.07183	0.07041	0.06901	0.06797
3.3	3.64	0.13053	0.12617	0.12149	0.11785	0.11397	0.11083	0.10748	0.10203	0.09734	0.09329	0.08974	0.08672	0.08400	0.08153	0.07955	0.07761	0.07582	0.07433	0.07286	0.07177
3.4	3.75	0.13731	0.13274	0.12784	0.12402	0.11995	0.11665	0.11314	0.10743	0.10251	0.09826	0.09453	0.09135	0.08851	0.08591	0.08383	0.08179	0.07992	0.07835	0.07681	0.07566
3.5	3.86	0.14423	0.13945	0.13432	0.13032	0.12606	0.12261	0.11893	0.11295	0.10779	0.10333	0.09942	0.09610	0.09311	0.09039	0.08821	0.08607	0.08410	0.08246	0.08084	0.07964
3.6	3.97	0.15130	0.14630	0.14093	0.13676	0.13230	0.12869	0.12484	0.11858	0.11318	0.10852	0.10443	0.10095	0.09782	0.09497	0.09269	0.09045	0.08839	0.08667	0.08497	0.08371
3.7	4.08	0.15851	0.15329	0.14768	0.14332	0.13866	0.13489	0.13088	0.12434	0.11869	0.11382	0.10954	0.10590	0.10263	0.09965	0.09726	0.09492	0.09276	0.09096	0.08918	0.08787
3.8	4.19	0.16586	0.16042	0.15457	0.15002	0.14516	0.14123	0.13703	0.13021	0.12432	0.11923	0.11476	0.11096	0.10754	0.10443	0.10193	0.09949	0.09723	0.09535	0.09349	0.09212

Continued on next page

Recommended head loss design range

Sizing in this region will lead to excessive head loss conditions.

¾" Uponor PEX-a — 30% Propylene glycol — feet of head per foot of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
3.9	4.30	0.17335	0.16768	0.16159	0.15685	0.15178	0.14768	0.14331	0.13619	0.13005	0.12474	0.12008	0.11612	0.11255	0.10930	0.10670	0.10415	0.10179	0.09983	0.09789	0.09645
4.0	4.41	0.18099	0.17508	0.16874	0.16381	0.15853	0.15426	0.14971	0.14230	0.13590	0.13037	0.12551	0.12138	0.11766	0.11428	0.11156	0.10890	0.10645	0.10440	0.10238	0.10088
4.1	4.52	0.18876	0.18262	0.17603	0.17090	0.16541	0.16097	0.15623	0.14852	0.14186	0.13610	0.13105	0.12674	0.12287	0.11935	0.11652	0.11375	0.11119	0.10906	0.10695	0.10539
4.2	4.63	0.19667	0.19029	0.18345	0.17811	0.17241	0.16779	0.16287	0.15485	0.14793	0.14194	0.13668	0.13221	0.12818	0.12452	0.12157	0.11869	0.11603	0.11381	0.11162	0.10999
4.3	4.74	0.20472	0.19810	0.19099	0.18546	0.17954	0.17474	0.16963	0.16130	0.15411	0.14789	0.14243	0.13777	0.13359	0.12978	0.12672	0.12372	0.12096	0.11865	0.11637	0.11468
4.4	4.85	0.21291	0.20604	0.19867	0.19293	0.18679	0.18181	0.17651	0.16787	0.16040	0.15394	0.14827	0.14344	0.13910	0.13514	0.13196	0.12885	0.12597	0.12358	0.12121	0.11946
4.5	4.96	0.22123	0.21412	0.20648	0.20053	0.19416	0.18900	0.18350	0.17454	0.16680	0.16010	0.15422	0.14921	0.14470	0.14059	0.13730	0.13406	0.13108	0.12860	0.12614	0.12432
4.6	5.07	0.22969	0.22233	0.21441	0.20825	0.20165	0.19631	0.19062	0.18133	0.17331	0.16637	0.16027	0.15507	0.15040	0.14614	0.14273	0.13937	0.13628	0.13370	0.13115	0.12927
4.7	5.18	0.23828	0.23066	0.22248	0.21610	0.20927	0.20374	0.19785	0.18823	0.17992	0.17274	0.16642	0.16104	0.15620	0.15179	0.14825	0.14477	0.14157	0.13890	0.13625	0.13430
4.8	5.29	0.24701	0.23913	0.23067	0.22407	0.21701	0.21129	0.20519	0.19525	0.18665	0.17921	0.17267	0.16710	0.16209	0.15753	0.15386	0.15026	0.14695	0.14418	0.14144	0.13942
4.9	5.40	0.25587	0.24774	0.23899	0.23217	0.22487	0.21896	0.21265	0.20237	0.19348	0.18579	0.17903	0.17327	0.16808	0.16336	0.15957	0.15584	0.15241	0.14955	0.14672	0.14462
5.0	5.51	0.26487	0.25647	0.24743	0.24039	0.23285	0.22675	0.22023	0.20961	0.20042	0.19247	0.18548	0.17953	0.17417	0.16928	0.16536	0.16151	0.15797	0.15501	0.15208	0.14991
5.1	5.62	0.27400	0.26533	0.25600	0.24873	0.24095	0.23465	0.22792	0.21695	0.20747	0.19926	0.19204	0.18588	0.18035	0.17530	0.17125	0.16727	0.16361	0.16055	0.15752	0.15528
5.2	5.73	0.28326	0.27431	0.26470	0.25720	0.24917	0.24267	0.23573	0.22441	0.21462	0.20615	0.19869	0.19234	0.18663	0.18141	0.17723	0.17312	0.16934	0.16618	0.16305	0.16074
5.3	5.84	0.29265	0.28343	0.27352	0.26579	0.25751	0.25081	0.24365	0.23197	0.22188	0.21314	0.20544	0.19889	0.19300	0.18762	0.18330	0.17906	0.17515	0.17189	0.16867	0.16628

Recommended head loss design range

Sizing in this region will lead to excessive head loss conditions.

¾" Uponor PEX-a — 40% Propylene glycol — feet of head per foot of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
0.5	0.55	0.00711	0.00673	0.00632	0.00601	0.00569	0.00545	0.00520	0.00479	0.00446	0.00418	0.00395	0.00375	0.00358	0.00343	0.00330	0.00320	0.00309	0.00301	0.00292	0.00286
0.6	0.66	0.00948	0.00898	0.00845	0.00805	0.00764	0.00732	0.00699	0.00646	0.00602	0.00566	0.00535	0.00508	0.00486	0.00466	0.00449	0.00435	0.00421	0.00410	0.00399	0.00390
0.7	0.77	0.01211	0.01149	0.01082	0.01033	0.00980	0.00941	0.00899	0.00832	0.00777	0.00731	0.00692	0.00658	0.00630	0.00604	0.00583	0.00565	0.00547	0.00534	0.00519	0.00508
0.8	0.88	0.01499	0.01423	0.01342	0.01282	0.01218	0.01170	0.01119	0.01037	0.00969	0.00914	0.00866	0.00824	0.00789	0.00758	0.00732	0.00709	0.00687	0.00671	0.00652	0.00639
0.9	0.99	0.01811	0.01721	0.01624	0.01553	0.01477	0.01419	0.01358	0.01261	0.01180	0.01113	0.01056	0.01005	0.00963	0.00926	0.00894	0.00867	0.00840	0.00821	0.00798	0.00782
1.0	1.10	0.02146	0.02041	0.01928	0.01845	0.01756	0.01688	0.01616	0.01502	0.01407	0.01328	0.01261	0.01202	0.01152	0.01108	0.01071	0.01039	0.01007	0.00983	0.00957	0.00938
1.1	1.21	0.02504	0.02382	0.02252	0.02156	0.02054	0.01976	0.01893	0.01761	0.01651	0.01559	0.01481	0.01413	0.01355	0.01303	0.01260	0.01223	0.01186	0.01159	0.01128	0.01106
1.2	1.32	0.02883	0.02745	0.02597	0.02488	0.02371	0.02282	0.02187	0.02036	0.01910	0.01806	0.01716	0.01638	0.01572	0.01513	0.01463	0.01420	0.01378	0.01346	0.01311	0.01285
1.3	1.43	0.03284	0.03129	0.02962	0.02838	0.02706	0.02606	0.02499	0.02328	0.02186	0.02067	0.01966	0.01877	0.01802	0.01735	0.01678	0.01630	0.01582	0.01546	0.01506	0.01477
1.4	1.54	0.03706	0.03532	0.03346	0.03208	0.03060	0.02948	0.02828	0.02637	0.02477	0.02344	0.02230	0.02130	0.02045	0.01970	0.01907	0.01852	0.01798	0.01757	0.01712	0.01679
1.5	1.65	0.04148	0.03956	0.03749	0.03596	0.03432	0.03307	0.03174	0.02961	0.02783	0.02635	0.02508	0.02397	0.02302	0.02218	0.02147	0.02086	0.02026	0.01981	0.01930	0.01893
1.6	1.76	0.04611	0.04399	0.04171	0.04002	0.03821	0.03683	0.03536	0.03301	0.03104	0.02940	0.02800	0.02677	0.02572	0.02479	0.02400	0.02333	0.02265	0.02215	0.02159	0.02118
1.7	1.87	0.05093	0.04861	0.04611	0.04426	0.04227	0.04076	0.03915	0.03656	0.03440	0.03260	0.03105	0.02969	0.02854	0.02752	0.02665	0.02590	0.02516	0.02461	0.02399	0.02354
1.8	1.98	0.05595	0.05342	0.05069	0.04867	0.04651	0.04486	0.04309	0.04027	0.03790	0.03593	0.03424	0.03275	0.03149	0.03037	0.02942	0.02860	0.02779	0.02718	0.02650	0.02601
1.9	2.09	0.06116	0.05841	0.05545	0.05326	0.05091	0.04911	0.04720	0.04412	0.04155	0.03941	0.03756	0.03594	0.03457	0.03334	0.03230	0.03141	0.03052	0.02986	0.02912	0.02858
2.0	2.20	0.06656	0.06359	0.06039	0.05802	0.05547	0.05353	0.05145	0.04813	0.04534	0.04301	0.04102	0.03926	0.03776	0.03643	0.03530	0.03434	0.03337	0.03265	0.03185	0.03126
2.1	2.31	0.07214	0.06895	0.06550	0.06295	0.06020	0.05811	0.05587	0.05228	0.04927	0.04676	0.04460	0.04269	0.04108	0.03964	0.03842	0.03737	0.03633	0.03555	0.03468	0.03404
2.2	2.43	0.07791	0.07448	0.07078	0.06804	0.06509	0.06284	0.06043	0.05657	0.05334	0.05063	0.04831	0.04626	0.04452	0.04296	0.04165	0.04052	0.03939	0.03856	0.03762	0.03693
2.3	2.54	0.08387	0.08020	0.07624	0.07330	0.07014	0.06773	0.06515	0.06101	0.05754	0.05464	0.05214	0.04994	0.04807	0.04640	0.04499	0.04378	0.04257	0.04167	0.04066	0.03992
2.4	2.65	0.09000	0.08609	0.08186	0.07872	0.07535	0.07277	0.07002	0.06559	0.06188	0.05877	0.05610	0.05375	0.05174	0.04996	0.04845	0.04715	0.04585	0.04488	0.04380	0.04301
2.5	2.76	0.09631	0.09215	0.08764	0.08430	0.08071	0.07797	0.07503	0.07031	0.06635	0.06304	0.06019	0.05767	0.05553	0.05363	0.05201	0.05062	0.04924	0.04820	0.04705	0.04620
2.6	2.87	0.10280	0.09838	0.09359	0.09005	0.08623	0.08331	0.08019	0.07517	0.07096	0.06743	0.06440	0.06172	0.05944	0.05741	0.05569	0.05421	0.05273	0.05163	0.05039	0.04949
2.7	2.98	0.10946	0.10478	0.09971	0.09595	0.09190	0.08881	0.08549	0.08017	0.07569	0.07195	0.06873	0.06588	0.06346	0.06130	0.05947	0.05790	0.05632	0.05515	0.05384	0.05288
2.8	3.09	0.11630	0.11134	0.10598	0.10200	0.09772	0.09445	0.09094	0.08530	0.08056	0.07659	0.07318	0.07016	0.06759	0.06530	0.06336	0.06169	0.06002	0.05878	0.05739	0.05637
2.9	3.20	0.12331	0.11808	0.11242	0.10822	0.10369	0.10024	0.09653	0.09057	0.08556	0.08136	0.07775	0.07456	0.07184	0.06941	0.06736	0.06559	0.06383	0.06251	0.06103	0.05996
3.0	3.31	0.13048	0.12498	0.11901	0.11459	0.10982	0.10617	0.10226	0.09598	0.09069	0.08626	0.08244	0.07907	0.07620	0.07364	0.07147	0.06960	0.06773	0.06634	0.06478	0.06364
3.1	3.42	0.13783	0.13204	0.12577	0.12111	0.11609	0.11225	0.10813	0.10151	0.09594	0.09127	0.08725	0.08369	0.08067	0.07797	0.07568	0.07371	0.07174	0.07027	0.06862	0.06742
3.2	3.53	0.14535	0.13926	0.13267	0.12778	0.12250	0.11847	0.11414	0.10718	0.10132	0.09641	0.09218	0.08843	0.08525	0.08240	0.08000	0.07792	0.07584	0.07430	0.07256	0.07129
3.3	3.64	0.15302	0.14665	0.13974	0.13460	0.12907	0.12483	0.12029	0.11298	0.10683	0.10167	0.09722	0.09329	0.08994	0.08695	0.08442	0.08223	0.08005	0.07842	0.07660	0.07526
3.4	3.75	0.16087	0.15419	0.14695	0.14157	0.13577	0.13133	0.12657	0.11891	0.11246	0.10704	0.10238	0.09825	0.09474	0.09160	0.08894	0.08665	0.08435	0.08265	0.08073	0.07933
3.5	3.86	0.16888	0.16189	0.15432	0.14869	0.14262	0.13798	0.13300	0.12497	0.11821	0.11254	0.10765	0.10333	0.09965	0.09635	0.09357	0.09116	0.08876	0.08697	0.08496	0.08349
3.6	3.97	0.17705	0.16975	0.16184	0.15596	0.14962	0.14476	0.13955	0.13116	0.12409	0.11816	0.11304	0.10852	0.10466	0.10121	0.09830	0.09578	0.09326	0.09139	0.08928	0.08774
3.7	4.08	0.18538	0.17777	0.16951	0.16337	0.15675	0.15168	0.14624	0.13748	0.13009	0.12389	0.11855	0.11382	0.10979	0.10618	0.10313	0.10050	0.09786	0.09590	0.09370	0.09209
3.8	4.19	0.19387	0.18594	0.17733	0.17093	0.16403	0.15874	0.15307	0.14393	0.13621	0.12974	0.12416	0.11922	0.11502	0.11125	0.10806	0.10531	0.10256	0.10051	0.09821	0.09652

Continued on next page

Recommended head loss design range

Sizing in this region will lead to excessive head loss conditions.

¾" Uponor PEX-a — 40% Propylene glycol — feet of head per foot of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
3.9	4.30	0.20252	0.19426	0.18530	0.17863	0.17144	0.16594	0.16002	0.15050	0.14246	0.13571	0.12989	0.12474	0.12035	0.11642	0.11310	0.11023	0.10735	0.10522	0.10281	0.10106
4.0	4.41	0.21133	0.20274	0.19342	0.18648	0.17900	0.17327	0.16711	0.15719	0.14882	0.14180	0.13573	0.13036	0.12579	0.12169	0.11823	0.11524	0.11224	0.11002	0.10751	0.10568
4.1	4.52	0.22030	0.21137	0.20168	0.19447	0.18669	0.18073	0.17433	0.16402	0.15531	0.14799	0.14168	0.13610	0.13134	0.12707	0.12346	0.12035	0.11723	0.11491	0.11230	0.11039
4.2	4.63	0.22942	0.22015	0.21009	0.20260	0.19452	0.18833	0.18168	0.17096	0.16191	0.15431	0.14775	0.14194	0.13699	0.13255	0.12880	0.12556	0.12231	0.11990	0.11718	0.11520
4.3	4.74	0.23870	0.22908	0.21865	0.21088	0.20249	0.19606	0.18916	0.17803	0.16863	0.16074	0.15392	0.14789	0.14274	0.13813	0.13423	0.13086	0.12749	0.12498	0.12215	0.12009
4.4	4.85	0.24813	0.23816	0.22735	0.21929	0.21060	0.20393	0.19677	0.18523	0.17547	0.16728	0.16020	0.15394	0.14860	0.14381	0.13976	0.13626	0.13276	0.13015	0.12722	0.12508
4.5	4.96	0.25771	0.24739	0.23619	0.22785	0.21884	0.21193	0.20451	0.19254	0.18243	0.17393	0.16660	0.16010	0.15456	0.14959	0.14539	0.14176	0.13812	0.13542	0.13237	0.13015
4.6	5.07	0.26745	0.25677	0.24518	0.23654	0.22721	0.22006	0.21237	0.19998	0.18950	0.18070	0.17310	0.16636	0.16062	0.15547	0.15112	0.14735	0.14358	0.14078	0.13762	0.13531
4.7	5.18	0.27734	0.26630	0.25431	0.24537	0.23572	0.22832	0.22037	0.20754	0.19669	0.18758	0.17971	0.17273	0.16678	0.16145	0.15694	0.15304	0.14913	0.14623	0.14296	0.14057
4.8	5.29	0.28739	0.27597	0.26358	0.25434	0.24436	0.23671	0.22849	0.21522	0.20400	0.19457	0.18642	0.17921	0.17305	0.16753	0.16286	0.15882	0.15478	0.15177	0.14838	0.14591
4.9	5.40	0.29758	0.28579	0.27299	0.26344	0.25313	0.24523	0.23673	0.22302	0.21142	0.20167	0.19325	0.18578	0.17942	0.17371	0.16887	0.16470	0.16052	0.15740	0.15390	0.15134
5.0	5.51	0.30792	0.29575	0.28254	0.27268	0.26204	0.25388	0.24510	0.23094	0.21896	0.20889	0.20018	0.19247	0.18588	0.17998	0.17499	0.17067	0.16634	0.16313	0.15950	0.15685
5.1	5.62	0.31841	0.30586	0.29223	0.28206	0.27108	0.26265	0.25360	0.23898	0.22661	0.21621	0.20722	0.19925	0.19245	0.18636	0.18120	0.17673	0.17227	0.16894	0.16520	0.16246

Recommended head loss design range

Sizing in this region will lead to excessive head loss conditions.

Appendix G:

Hydronic friction loss tables

¾" Uponor PEX-a — 50% Propylene glycol — feet of head per foot of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
0.5	0.55	0.00843	0.00793	0.00741	0.00702	0.00661	0.00630	0.00598	0.00547	0.00505	0.00470	0.00441	0.00416	0.00395	0.00377	0.00361	0.00347	0.00334	0.00323	0.00314	0.00305
0.6	0.66	0.01118	0.01054	0.00987	0.00936	0.00883	0.00843	0.00801	0.00734	0.00679	0.00634	0.00595	0.00563	0.00535	0.00510	0.00489	0.00471	0.00454	0.00439	0.00427	0.00415
0.7	0.77	0.01423	0.01344	0.01259	0.01197	0.01130	0.01080	0.01027	0.00943	0.00874	0.00817	0.00768	0.00727	0.00692	0.00661	0.00634	0.00611	0.00590	0.00571	0.00555	0.00540
0.8	0.88	0.01756	0.01660	0.01557	0.01481	0.01401	0.01340	0.01275	0.01173	0.01089	0.01018	0.00959	0.00909	0.00865	0.00827	0.00795	0.00766	0.00740	0.00716	0.00697	0.00678
0.9	0.99	0.02115	0.02001	0.01880	0.01790	0.01694	0.01622	0.01545	0.01423	0.01322	0.01238	0.01168	0.01107	0.01055	0.01009	0.00970	0.00935	0.00904	0.00875	0.00852	0.00830
1.0	1.10	0.02500	0.02368	0.02226	0.02121	0.02009	0.01925	0.01835	0.01693	0.01574	0.01476	0.01393	0.01321	0.01260	0.01206	0.01160	0.01119	0.01082	0.01048	0.01021	0.00994
1.1	1.21	0.02910	0.02758	0.02596	0.02475	0.02346	0.02249	0.02145	0.01981	0.01844	0.01730	0.01634	0.01551	0.01480	0.01418	0.01364	0.01317	0.01273	0.01234	0.01203	0.01172
1.2	1.32	0.03345	0.03172	0.02988	0.02851	0.02704	0.02593	0.02475	0.02288	0.02132	0.02002	0.01891	0.01797	0.01715	0.01644	0.01582	0.01528	0.01478	0.01433	0.01397	0.01361
1.3	1.43	0.03803	0.03609	0.03402	0.03247	0.03082	0.02957	0.02824	0.02613	0.02436	0.02289	0.02165	0.02057	0.01965	0.01884	0.01814	0.01752	0.01696	0.01645	0.01603	0.01563
1.4	1.54	0.04285	0.04069	0.03837	0.03665	0.03481	0.03341	0.03192	0.02955	0.02758	0.02593	0.02453	0.02333	0.02229	0.02138	0.02059	0.01990	0.01926	0.01869	0.01822	0.01776
1.5	1.65	0.04789	0.04550	0.04294	0.04103	0.03898	0.03743	0.03578	0.03315	0.03096	0.02912	0.02756	0.02622	0.02507	0.02405	0.02317	0.02240	0.02169	0.02105	0.02053	0.02002
1.6	1.76	0.05316	0.05053	0.04771	0.04561	0.04335	0.04165	0.03982	0.03692	0.03450	0.03247	0.03075	0.02926	0.02798	0.02686	0.02588	0.02503	0.02424	0.02353	0.02295	0.02239
1.7	1.87	0.05865	0.05577	0.05268	0.05038	0.04791	0.04604	0.04404	0.04086	0.03820	0.03597	0.03408	0.03245	0.03104	0.02980	0.02872	0.02778	0.02691	0.02613	0.02549	0.02487
1.8	1.98	0.06435	0.06122	0.05786	0.05535	0.05266	0.05062	0.04844	0.04496	0.04206	0.03962	0.03755	0.03577	0.03422	0.03287	0.03169	0.03066	0.02971	0.02885	0.02815	0.02746
1.9	2.09	0.07027	0.06688	0.06323	0.06051	0.05759	0.05537	0.05300	0.04923	0.04607	0.04342	0.04117	0.03922	0.03754	0.03606	0.03478	0.03366	0.03262	0.03168	0.03092	0.03017
2.0	2.20	0.07640	0.07274	0.06879	0.06585	0.06270	0.06031	0.05774	0.05366	0.05024	0.04736	0.04492	0.04282	0.04099	0.03939	0.03800	0.03677	0.03565	0.03463	0.03380	0.03299
2.1	2.31	0.08273	0.07879	0.07455	0.07139	0.06799	0.06541	0.06265	0.05825	0.05455	0.05145	0.04882	0.04654	0.04457	0.04284	0.04133	0.04001	0.03879	0.03769	0.03679	0.03592
2.2	2.43	0.08927	0.08504	0.08049	0.07710	0.07346	0.07069	0.06772	0.06299	0.05902	0.05568	0.05285	0.05040	0.04828	0.04641	0.04479	0.04337	0.04205	0.04087	0.03990	0.03895
2.3	2.54	0.09600	0.09149	0.08663	0.08300	0.07910	0.07613	0.07295	0.06789	0.06364	0.06006	0.05702	0.05439	0.05211	0.05011	0.04836	0.04684	0.04542	0.04415	0.04311	0.04209
2.4	2.65	0.10294	0.09813	0.09295	0.08907	0.08491	0.08175	0.07835	0.07294	0.06840	0.06457	0.06132	0.05851	0.05607	0.05393	0.05206	0.05042	0.04891	0.04754	0.04643	0.04534
2.5	2.76	0.11008	0.10496	0.09945	0.09533	0.09090	0.08753	0.08391	0.07815	0.07330	0.06923	0.06576	0.06276	0.06015	0.05786	0.05587	0.05412	0.05250	0.05105	0.04985	0.04869
2.6	2.87	0.11741	0.11198	0.10613	0.10175	0.09705	0.09347	0.08963	0.08350	0.07835	0.07402	0.07032	0.06713	0.06436	0.06192	0.05980	0.05793	0.05621	0.05466	0.05339	0.05214
2.7	2.98	0.12493	0.11919	0.11299	0.10836	0.10337	0.09958	0.09551	0.08901	0.08355	0.07894	0.07502	0.07163	0.06869	0.06610	0.06384	0.06186	0.06003	0.05838	0.05702	0.05570
2.8	3.09	0.13264	0.12658	0.12002	0.11513	0.10986	0.10584	0.10154	0.09466	0.08888	0.08400	0.07985	0.07626	0.07314	0.07039	0.06800	0.06590	0.06395	0.06220	0.06077	0.05936
2.9	3.20	0.14054	0.13415	0.12724	0.12207	0.11651	0.11227	0.10773	0.10046	0.09435	0.08920	0.08481	0.08101	0.07771	0.07480	0.07227	0.07004	0.06799	0.06613	0.06461	0.06313
3.0	3.31	0.14863	0.14190	0.13462	0.12918	0.12333	0.11886	0.11407	0.10641	0.09996	0.09452	0.08989	0.08588	0.08239	0.07933	0.07665	0.07430	0.07213	0.07017	0.06856	0.06699
3.1	3.42	0.15691	0.14983	0.14218	0.13646	0.13030	0.12560	0.12056	0.11250	0.10571	0.09998	0.09510	0.09087	0.08720	0.08397	0.08114	0.07867	0.07637	0.07431	0.07261	0.07096
3.2	3.53	0.16537	0.15794	0.14991	0.14391	0.13744	0.13250	0.12720	0.11873	0.11160	0.10557	0.10044	0.09599	0.09212	0.08872	0.08575	0.08314	0.08073	0.07855	0.07677	0.07502
3.3	3.64	0.17401	0.16623	0.15781	0.15152	0.14473	0.13956	0.13400	0.12511	0.11762	0.11129	0.10590	0.10123	0.09717	0.09359	0.09047	0.08772	0.08519	0.08290	0.08102	0.07919
3.4	3.75	0.18284	0.17469	0.16588	0.15929	0.15219	0.14676	0.14094	0.13163	0.12377	0.11714	0.11149	0.10658	0.10232	0.09857	0.09529	0.09241	0.08975	0.08735	0.08538	0.08345
3.5	3.86	0.19184	0.18333	0.17412	0.16723	0.15980	0.15412	0.14803	0.13828	0.13006	0.12312	0.11720	0.11206	0.10759	0.10366	0.10023	0.09721	0.09441	0.09190	0.08983	0.08781
3.6	3.97	0.20103	0.19214	0.18252	0.17532	0.16756	0.16163	0.15527	0.14508	0.13649	0.12922	0.12303	0.11765	0.11298	0.10886	0.10527	0.10211	0.09918	0.09655	0.09438	0.09227
3.7	4.08	0.21039	0.20112	0.19109	0.18358	0.17548	0.16930	0.16265	0.15202	0.14304	0.13545	0.12898	0.12337	0.11848	0.11418	0.11042	0.10712	0.10406	0.10130	0.09903	0.09682
3.8	4.19	0.21992	0.21027	0.19982	0.19200	0.18356	0.17711	0.17018	0.15909	0.14973	0.14181	0.13506	0.12919	0.12410	0.11960	0.11568	0.11223	0.10903	0.10615	0.10378	0.10147

Continued on next page

Recommended head loss design range

Sizing in this region will lead to excessive head loss conditions.

¾" Uponor PEX-a — 50% Propylene glycol — feet of head per foot of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
3.9	4.30	0.22963	0.21959	0.20872	0.20057	0.19178	0.18507	0.17785	0.16630	0.15654	0.14829	0.14125	0.13514	0.12982	0.12513	0.12104	0.11744	0.11411	0.11110	0.10863	0.10622
4.0	4.41	0.23952	0.22908	0.21777	0.20930	0.20016	0.19318	0.18567	0.17364	0.16349	0.15490	0.14756	0.14120	0.13566	0.13077	0.12651	0.12276	0.11928	0.11615	0.11358	0.11106
4.1	4.52	0.24958	0.23874	0.22699	0.21819	0.20869	0.20143	0.19363	0.18112	0.17056	0.16163	0.15400	0.14737	0.14161	0.13652	0.13208	0.12818	0.12456	0.12130	0.11862	0.11600
4.2	4.63	0.25981	0.24856	0.23637	0.22723	0.21737	0.20983	0.20173	0.18874	0.17777	0.16848	0.16055	0.15366	0.14767	0.14238	0.13776	0.13370	0.12994	0.12654	0.12376	0.12103
4.3	4.74	0.27021	0.25855	0.24590	0.23643	0.22620	0.21838	0.20997	0.19649	0.18510	0.17546	0.16722	0.16007	0.15384	0.14835	0.14355	0.13933	0.13542	0.13189	0.12899	0.12616
4.4	4.85	0.28078	0.26870	0.25560	0.24578	0.23517	0.22707	0.21835	0.20437	0.19255	0.18255	0.17401	0.16658	0.16012	0.15442	0.14943	0.14505	0.14099	0.13733	0.13432	0.13138
4.5	4.96	0.29152	0.27901	0.26545	0.25528	0.24430	0.23590	0.22687	0.21238	0.20014	0.18977	0.18091	0.17321	0.16651	0.16059	0.15543	0.15088	0.14667	0.14287	0.13974	0.13669
4.6	5.07	0.30242	0.28949	0.27545	0.26493	0.25357	0.24488	0.23553	0.22053	0.20785	0.19711	0.18793	0.17995	0.17301	0.16688	0.16152	0.15681	0.15244	0.14850	0.14526	0.14209
4.7	5.18	0.31350	0.30012	0.28562	0.27474	0.26298	0.25399	0.24432	0.22880	0.21568	0.20457	0.19506	0.18680	0.17961	0.17326	0.16772	0.16284	0.15831	0.15423	0.15087	0.14759
4.8	5.29	0.32474	0.31092	0.29593	0.28469	0.27254	0.26325	0.25325	0.23721	0.22364	0.21214	0.20231	0.19377	0.18633	0.17976	0.17401	0.16897	0.16428	0.16005	0.15658	0.15318
4.9	5.40	0.33614	0.32188	0.30641	0.29480	0.28225	0.27265	0.26232	0.24575	0.23172	0.21984	0.20968	0.20084	0.19315	0.18635	0.18041	0.17519	0.17034	0.16597	0.16238	0.15886

Recommended head loss design range

Sizing in this region will lead to excessive head loss conditions.

1" Uponor PEX-a — 100% Water — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
1.5	2.73	1.81	1.72	1.62	1.58	1.55	1.52	1.49	1.45	1.40	1.36	1.33	1.30	1.27	1.25	1.22	1.20	1.18	1.16	1.15	1.13
1.6	2.91	2.02	1.92	1.81	1.77	1.73	1.70	1.67	1.62	1.57	1.53	1.49	1.45	1.42	1.40	1.37	1.35	1.32	1.30	1.28	1.27
1.7	3.09	2.24	2.13	2.01	1.97	1.93	1.89	1.86	1.80	1.75	1.70	1.66	1.62	1.58	1.55	1.52	1.50	1.47	1.45	1.43	1.41
1.8	3.27	2.47	2.35	2.21	2.17	2.13	2.09	2.05	1.99	1.93	1.88	1.83	1.79	1.75	1.72	1.68	1.66	1.63	1.60	1.58	1.56
1.9	3.46	2.71	2.58	2.43	2.39	2.34	2.30	2.26	2.18	2.12	2.06	2.01	1.97	1.93	1.89	1.85	1.82	1.79	1.77	1.74	1.72
2.0	3.64	2.96	2.82	2.66	2.61	2.56	2.51	2.47	2.39	2.32	2.26	2.20	2.15	2.11	2.07	2.03	2.00	1.96	1.93	1.91	1.88
2.1	3.82	3.22	3.07	2.89	2.84	2.78	2.74	2.69	2.60	2.53	2.46	2.40	2.35	2.30	2.25	2.21	2.18	2.14	2.11	2.08	2.05
2.2	4.00	3.49	3.32	3.14	3.08	3.02	2.97	2.91	2.82	2.74	2.67	2.61	2.55	2.49	2.45	2.40	2.36	2.32	2.29	2.26	2.23
2.3	4.18	3.77	3.59	3.39	3.33	3.26	3.21	3.15	3.05	2.96	2.89	2.82	2.75	2.70	2.65	2.60	2.56	2.51	2.48	2.44	2.41
2.4	4.37	4.06	3.87	3.65	3.58	3.51	3.45	3.39	3.29	3.19	3.11	3.04	2.97	2.91	2.85	2.80	2.76	2.71	2.67	2.64	2.60
2.5	4.55	4.35	4.15	3.92	3.85	3.77	3.71	3.64	3.53	3.43	3.34	3.26	3.19	3.13	3.07	3.01	2.96	2.92	2.87	2.83	2.80
2.6	4.73	4.66	4.44	4.20	4.12	4.04	3.97	3.90	3.78	3.68	3.58	3.50	3.42	3.35	3.29	3.23	3.18	3.13	3.08	3.04	3.00
2.7	4.91	4.97	4.74	4.48	4.40	4.32	4.24	4.17	4.04	3.93	3.83	3.74	3.66	3.58	3.52	3.45	3.40	3.34	3.30	3.25	3.21
2.8	5.09	5.30	5.05	4.78	4.69	4.60	4.52	4.44	4.31	4.19	4.08	3.99	3.90	3.82	3.75	3.68	3.62	3.57	3.52	3.47	3.42
2.9	5.28	5.63	5.37	5.08	4.99	4.89	4.81	4.73	4.58	4.46	4.34	4.24	4.15	4.07	3.99	3.92	3.86	3.80	3.74	3.69	3.65
3.0	5.46	5.97	5.70	5.39	5.29	5.19	5.11	5.02	4.87	4.73	4.61	4.50	4.41	4.32	4.24	4.16	4.10	4.03	3.98	3.92	3.87
3.1	5.64	6.32	6.03	5.71	5.61	5.50	5.41	5.31	5.15	5.01	4.89	4.77	4.67	4.58	4.49	4.41	4.34	4.28	4.22	4.16	4.11
3.2	5.82	6.68	6.38	6.03	5.93	5.81	5.72	5.62	5.45	5.30	5.17	5.05	4.94	4.84	4.75	4.67	4.60	4.53	4.46	4.40	4.35
3.3	6.00	7.05	6.73	6.37	6.25	6.13	6.04	5.93	5.75	5.60	5.46	5.33	5.22	5.11	5.02	4.93	4.86	4.78	4.71	4.65	4.59
3.4	6.19	7.42	7.09	6.71	6.59	6.46	6.36	6.25	6.07	5.90	5.75	5.62	5.50	5.39	5.29	5.20	5.12	5.04	4.97	4.91	4.85
3.5	6.37	7.81	7.46	7.06	6.93	6.80	6.69	6.58	6.38	6.21	6.06	5.92	5.79	5.68	5.58	5.48	5.39	5.31	5.24	5.17	5.10
3.6	6.55	8.20	7.83	7.42	7.29	7.15	7.03	6.91	6.71	6.53	6.37	6.22	6.09	5.97	5.86	5.76	5.67	5.58	5.51	5.43	5.37
3.7	6.73	8.60	8.22	7.78	7.65	7.50	7.38	7.26	7.04	6.85	6.68	6.53	6.39	6.27	6.16	6.05	5.95	5.86	5.78	5.71	5.64
3.8	6.91	9.01	8.61	8.16	8.01	7.86	7.74	7.61	7.38	7.18	7.01	6.85	6.70	6.57	6.45	6.34	6.25	6.15	6.07	5.99	5.91
3.9	7.09	9.43	9.01	8.54	8.39	8.23	8.10	7.96	7.73	7.52	7.34	7.17	7.02	6.88	6.76	6.65	6.54	6.44	6.35	6.27	6.19
4.0	7.28	9.85	9.42	8.93	8.77	8.60	8.47	8.33	8.08	7.87	7.67	7.50	7.34	7.20	7.07	6.95	6.84	6.74	6.65	6.56	6.48
4.1	7.46	10.29	9.84	9.32	9.16	8.99	8.85	8.70	8.44	8.22	8.02	7.84	7.67	7.53	7.39	7.27	7.15	7.05	6.95	6.86	6.78
4.2	7.64	10.73	10.26	9.72	9.55	9.38	9.23	9.08	8.81	8.58	8.37	8.18	8.01	7.86	7.72	7.59	7.47	7.36	7.26	7.16	7.08
4.3	7.82	11.18	10.69	10.14	9.96	9.77	9.62	9.46	9.19	8.94	8.72	8.53	8.35	8.19	8.05	7.91	7.79	7.67	7.57	7.47	7.38
4.4	8.00	11.64	11.13	10.55	10.37	10.18	10.02	9.85	9.57	9.31	9.09	8.89	8.70	8.54	8.38	8.24	8.12	8.00	7.89	7.79	7.69
4.5	8.19	12.11	11.58	10.98	10.79	10.59	10.42	10.25	9.96	9.69	9.46	9.25	9.06	8.88	8.73	8.58	8.45	8.32	8.21	8.11	8.01
4.6	8.37	12.58	12.03	11.41	11.22	11.01	10.84	10.66	10.35	10.08	9.83	9.62	9.42	9.24	9.08	8.93	8.79	8.66	8.54	8.43	8.33
4.7	8.55	13.06	12.50	11.85	11.65	11.43	11.26	11.07	10.75	10.47	10.22	9.99	9.79	9.60	9.43	9.28	9.13	9.00	8.88	8.76	8.66

Continued on next page

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

Appendix G:

Hydronic friction loss tables

1" Uponor PEX-a — 100% Water — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
4.8	8.73	13.55	12.97	12.30	12.09	11.87	11.68	11.49	11.16	10.87	10.61	10.37	10.16	9.97	9.79	9.63	9.48	9.34	9.22	9.10	8.99
4.9	8.91	14.05	13.45	12.76	12.54	12.31	12.12	11.92	11.58	11.28	11.00	10.76	10.54	10.34	10.16	9.99	9.84	9.70	9.57	9.45	9.33
5.0	9.10	14.56	13.93	13.22	12.99	12.75	12.56	12.35	12.00	11.69	11.41	11.16	10.93	10.72	10.54	10.36	10.20	10.05	9.92	9.80	9.68
5.1	9.28	15.07	14.42	13.69	13.45	13.21	13.01	12.79	12.43	12.11	11.82	11.56	11.32	11.11	10.92	10.74	10.57	10.42	10.28	10.15	10.03
5.2	9.46	15.59	14.93	14.17	13.92	13.67	13.46	13.24	12.86	12.53	12.23	11.96	11.72	11.50	11.30	11.12	10.95	10.79	10.64	10.51	10.39
5.3	9.64	16.12	15.43	14.65	14.40	14.14	13.92	13.70	13.31	12.96	12.65	12.38	12.13	11.90	11.69	11.50	11.33	11.16	11.01	10.88	10.75
5.4	9.82	16.66	15.95	15.14	14.88	14.61	14.39	14.16	13.76	13.40	13.08	12.80	12.54	12.30	12.09	11.89	11.71	11.54	11.39	11.25	11.12
5.5	10.01	17.21	16.47	15.64	15.37	15.10	14.87	14.63	14.21	13.85	13.52	13.22	12.96	12.71	12.49	12.29	12.11	11.93	11.77	11.63	11.49
5.6	10.19	17.76	17.00	16.14	15.87	15.59	15.35	15.10	14.67	14.30	13.96	13.66	13.38	13.13	12.90	12.69	12.50	12.32	12.16	12.01	11.87
5.7	10.37	18.32	17.54	16.66	16.38	16.08	15.84	15.58	15.14	14.75	14.41	14.09	13.81	13.55	13.32	13.10	12.91	12.72	12.55	12.40	12.25
5.8	10.55	18.89	18.09	17.18	16.89	16.58	16.33	16.07	15.62	15.22	14.86	14.54	14.25	13.98	13.74	13.52	13.32	13.13	12.95	12.79	12.64
5.9	10.73	19.46	18.64	17.70	17.41	17.09	16.84	16.57	16.10	15.69	15.32	14.99	14.69	14.42	14.17	13.94	13.73	13.54	13.36	13.19	13.04
6.0	10.92	20.05	19.20	18.24	17.93	17.61	17.35	17.07	16.59	16.17	15.79	15.45	15.14	14.86	14.60	14.37	14.15	13.95	13.77	13.60	13.44
6.1	11.10	20.64	19.77	18.78	18.46	18.13	17.86	17.58	17.08	16.65	16.26	15.91	15.59	15.30	15.04	14.80	14.58	14.37	14.18	14.01	13.85
6.2	11.28	21.24	20.34	19.33	19.00	18.66	18.38	18.09	17.58	17.14	16.74	16.38	16.05	15.76	15.49	15.24	15.01	14.80	14.61	14.43	14.26
6.3	11.46	21.84	20.93	19.88	19.55	19.20	18.91	18.61	18.09	17.63	17.22	16.85	16.52	16.21	15.94	15.68	15.45	15.23	15.03	14.85	14.68
6.4	11.64	22.46	21.51	20.44	20.10	19.74	19.45	19.14	18.61	18.14	17.71	17.34	16.99	16.68	16.40	16.13	15.89	15.67	15.47	15.28	15.10
6.5	11.82	23.08	22.11	21.01	20.66	20.30	19.99	19.67	19.13	18.64	18.21	17.82	17.47	17.15	16.86	16.59	16.34	16.11	15.90	15.71	15.53
6.6	12.01	23.71	22.71	21.59	21.23	20.85	20.54	20.22	19.66	19.16	18.71	18.32	17.95	17.63	17.33	17.05	16.80	16.56	16.35	16.15	15.96
6.7	12.19	24.34	23.33	22.17	21.80	21.42	21.10	20.76	20.19	19.68	19.22	18.82	18.44	18.11	17.80	17.52	17.26	17.02	16.80	16.59	16.40
6.8	12.37	24.98	23.94	22.76	22.38	21.99	21.66	21.32	20.73	20.21	19.74	19.32	18.94	18.59	18.28	17.99	17.73	17.48	17.25	17.04	16.84
6.9	12.55	25.63	24.57	23.36	22.97	22.56	22.23	21.88	21.27	20.74	20.26	19.83	19.44	19.09	18.77	18.47	18.20	17.94	17.71	17.50	17.29
7.0	12.73	26.29	25.20	23.96	23.56	23.15	22.81	22.45	21.83	21.28	20.79	20.35	19.95	19.59	19.26	18.95	18.68	18.41	18.18	17.96	17.75
7.1	12.92	26.96	25.84	24.57	24.16	23.74	23.39	23.02	22.39	21.83	21.32	20.87	20.46	20.09	19.76	19.44	19.16	18.89	18.65	18.42	18.21
7.2	13.10	27.63	26.49	25.18	24.77	24.34	23.98	23.60	22.95	22.38	21.86	21.40	20.98	20.60	20.26	19.94	19.65	19.37	19.12	18.89	18.68
7.3	13.28	28.31	27.14	25.81	25.38	24.94	24.57	24.19	23.52	22.94	22.41	21.94	21.51	21.12	20.77	20.44	20.14	19.86	19.61	19.37	19.15
7.4	13.46	29.00	27.80	26.44	26.01	25.55	25.17	24.78	24.10	23.50	22.96	22.48	22.04	21.64	21.28	20.95	20.64	20.35	20.09	19.85	19.63
7.5	13.64	29.69	28.47	27.08	26.63	26.17	25.78	25.38	24.68	24.07	23.52	23.03	22.58	22.17	21.80	21.46	21.15	20.85	20.59	20.34	20.11
7.6	13.83	30.39	29.14	27.72	27.27	26.79	26.40	25.98	25.28	24.65	24.08	23.58	23.12	22.70	22.33	21.98	21.66	21.36	21.08	20.83	20.60
7.7	14.01	31.10	29.82	28.37	27.91	27.42	27.02	26.60	25.87	25.23	24.65	24.14	23.67	23.24	22.86	22.50	22.17	21.87	21.59	21.33	21.09
7.8	14.19	31.82	30.51	29.03	28.55	28.06	27.65	27.22	26.47	25.82	25.23	24.70	24.22	23.79	23.39	23.03	22.70	22.38	22.10	21.83	21.59
7.9	14.37	32.54	31.21	29.69	29.21	28.70	28.28	27.84	27.08	26.41	25.81	25.27	24.78	24.34	23.94	23.56	23.22	22.90	22.61	22.34	22.09
8.0	14.55	33.27	31.91	30.36	29.87	29.35	28.92	28.47	27.70	27.01	26.40	25.85	25.35	24.90	24.49	24.10	23.76	23.43	23.13	22.86	22.60

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

1" Uponor PEX-a — 30% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
1.5	2.73	2.49	2.40	2.30	2.23	2.15	2.09	2.02	1.91	1.82	1.74	1.67	1.61	1.55	1.50	1.47	1.43	1.39	1.36	1.33	1.31
1.6	2.91	2.77	2.67	2.57	2.49	2.40	2.33	2.25	2.13	2.03	1.94	1.86	1.80	1.74	1.68	1.64	1.60	1.56	1.53	1.49	1.47
1.7	3.09	3.07	2.96	2.84	2.75	2.66	2.58	2.50	2.37	2.25	2.15	2.07	1.99	1.93	1.87	1.82	1.78	1.73	1.70	1.66	1.64
1.8	3.27	3.38	3.26	3.13	3.03	2.93	2.85	2.76	2.61	2.48	2.38	2.28	2.20	2.13	2.07	2.01	1.96	1.91	1.88	1.84	1.81
1.9	3.46	3.70	3.57	3.43	3.33	3.21	3.12	3.02	2.86	2.73	2.61	2.51	2.42	2.34	2.27	2.21	2.16	2.10	2.06	2.02	1.99
2.0	3.64	4.03	3.89	3.74	3.63	3.51	3.41	3.30	3.13	2.98	2.85	2.74	2.64	2.56	2.48	2.42	2.36	2.30	2.26	2.21	2.18
2.1	3.82	4.38	4.23	4.07	3.94	3.81	3.70	3.59	3.40	3.24	3.10	2.98	2.88	2.79	2.70	2.63	2.57	2.51	2.46	2.41	2.37
2.2	4.00	4.74	4.57	4.40	4.27	4.12	4.01	3.88	3.68	3.51	3.36	3.23	3.12	3.02	2.93	2.86	2.79	2.72	2.67	2.61	2.57
2.3	4.18	5.11	4.93	4.75	4.60	4.45	4.32	4.19	3.98	3.79	3.63	3.49	3.37	3.26	3.17	3.09	3.01	2.94	2.88	2.83	2.78
2.4	4.37	5.49	5.30	5.10	4.95	4.78	4.65	4.51	4.28	4.08	3.91	3.76	3.63	3.52	3.41	3.33	3.25	3.17	3.11	3.05	3.00
2.5	4.55	5.88	5.68	5.47	5.31	5.13	4.99	4.84	4.59	4.38	4.20	4.04	3.90	3.78	3.67	3.58	3.49	3.41	3.34	3.27	3.22
2.6	4.73	6.28	6.07	5.85	5.67	5.49	5.34	5.17	4.91	4.69	4.49	4.32	4.18	4.04	3.93	3.83	3.74	3.65	3.58	3.51	3.46
2.7	4.91	6.70	6.48	6.24	6.05	5.85	5.69	5.52	5.24	5.00	4.80	4.61	4.46	4.32	4.19	4.09	3.99	3.90	3.83	3.75	3.69
2.8	5.09	7.13	6.89	6.64	6.44	6.23	6.06	5.88	5.58	5.33	5.11	4.92	4.75	4.60	4.47	4.36	4.26	4.16	4.08	4.00	3.94
2.9	5.28	7.56	7.31	7.05	6.84	6.62	6.44	6.24	5.93	5.66	5.43	5.23	5.05	4.90	4.75	4.64	4.53	4.43	4.34	4.25	4.19
3.0	5.46	8.01	7.75	7.47	7.25	7.01	6.82	6.62	6.29	6.01	5.76	5.55	5.36	5.20	5.05	4.93	4.81	4.70	4.61	4.52	4.45
3.1	5.64	8.47	8.19	7.90	7.67	7.42	7.22	7.01	6.66	6.36	6.10	5.87	5.68	5.50	5.35	5.22	5.09	4.98	4.88	4.79	4.72
3.2	5.82	8.94	8.65	8.34	8.10	7.84	7.63	7.40	7.04	6.72	6.45	6.21	6.00	5.82	5.65	5.52	5.39	5.27	5.16	5.06	4.99
3.3	6.00	9.42	9.12	8.79	8.53	8.26	8.04	7.80	7.42	7.09	6.80	6.55	6.34	6.14	5.97	5.83	5.69	5.56	5.45	5.35	5.27
3.4	6.19	9.92	9.60	9.25	8.98	8.70	8.47	8.22	7.81	7.47	7.17	6.90	6.68	6.47	6.29	6.14	5.99	5.86	5.75	5.64	5.56
3.5	6.37	10.42	10.08	9.72	9.44	9.14	8.90	8.64	8.22	7.85	7.54	7.26	7.02	6.81	6.62	6.46	6.31	6.17	6.05	5.94	5.85
3.6	6.55	10.93	10.58	10.20	9.91	9.60	9.34	9.07	8.63	8.25	7.92	7.63	7.38	7.16	6.95	6.79	6.63	6.48	6.36	6.24	6.15
3.7	6.73	11.46	11.09	10.70	10.39	10.06	9.80	9.51	9.05	8.65	8.31	8.00	7.74	7.51	7.30	7.13	6.96	6.81	6.68	6.55	6.46
3.8	6.91	11.99	11.61	11.20	10.88	10.54	10.26	9.96	9.48	9.06	8.70	8.38	8.11	7.87	7.65	7.47	7.30	7.13	7.00	6.87	6.77
3.9	7.09	12.53	12.14	11.71	11.38	11.02	10.73	10.42	9.92	9.48	9.11	8.78	8.49	8.24	8.01	7.82	7.64	7.47	7.33	7.19	7.09
4.0	7.28	13.09	12.67	12.23	11.88	11.51	11.21	10.89	10.36	9.91	9.52	9.17	8.88	8.61	8.37	8.18	7.99	7.81	7.67	7.52	7.41
4.1	7.46	13.65	13.22	12.76	12.40	12.01	11.70	11.36	10.82	10.35	9.94	9.58	9.27	9.00	8.75	8.54	8.35	8.16	8.01	7.86	7.75
4.2	7.64	14.23	13.78	13.30	12.93	12.52	12.20	11.85	11.28	10.79	10.37	9.99	9.67	9.39	9.13	8.92	8.71	8.52	8.36	8.20	8.09
4.3	7.82	14.81	14.35	13.85	13.46	13.04	12.71	12.34	11.75	11.24	10.80	10.41	10.08	9.79	9.51	9.29	9.08	8.88	8.72	8.55	8.43
4.4	8.00	15.41	14.93	14.41	14.01	13.57	13.22	12.85	12.24	11.71	11.25	10.84	10.50	10.19	9.91	9.68	9.46	9.25	9.08	8.91	8.79
4.5	8.19	16.02	15.52	14.98	14.56	14.11	13.75	13.36	12.72	12.17	11.70	11.28	10.92	10.60	10.31	10.07	9.84	9.63	9.45	9.27	9.14
4.6	8.37	16.63	16.11	15.56	15.12	14.66	14.28	13.88	13.22	12.65	12.16	11.72	11.35	11.02	10.72	10.47	10.23	10.01	9.83	9.64	9.51
4.7	8.55	17.26	16.72	16.15	15.70	15.21	14.82	14.41	13.73	13.14	12.63	12.18	11.79	11.45	11.13	10.88	10.63	10.40	10.21	10.02	9.88

Continued on next page

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

1" Uponor PEX-a — 30% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
4.8	8.73	17.89	17.34	16.74	16.28	15.78	15.38	14.94	14.24	13.63	13.10	12.64	12.24	11.88	11.55	11.29	11.04	10.80	10.60	10.40	10.26
4.9	8.91	18.54	17.97	17.35	16.87	16.35	15.94	15.49	14.76	14.13	13.58	13.10	12.69	12.32	11.98	11.71	11.45	11.20	11.00	10.79	10.64
5.0	9.10	19.19	18.60	17.97	17.47	16.94	16.51	16.04	15.29	14.64	14.07	13.58	13.15	12.77	12.42	12.14	11.86	11.61	11.40	11.19	11.03
5.1	9.28	19.86	19.25	18.59	18.08	17.53	17.08	16.61	15.83	15.16	14.57	14.06	13.62	13.22	12.86	12.57	12.29	12.03	11.81	11.59	11.43
5.2	9.46	20.53	19.90	19.23	18.70	18.13	17.67	17.18	16.38	15.68	15.08	14.55	14.09	13.69	13.31	13.01	12.72	12.45	12.22	12.00	11.83
5.3	9.64	21.22	20.57	19.87	19.32	18.74	18.27	17.76	16.93	16.21	15.59	15.04	14.58	14.16	13.77	13.46	13.16	12.88	12.64	12.41	12.24
5.4	9.82	21.91	21.24	20.52	19.96	19.36	18.87	18.35	17.49	16.75	16.11	15.55	15.07	14.63	14.23	13.92	13.60	13.31	13.07	12.83	12.66
5.5	10.01	22.61	21.93	21.18	20.61	19.98	19.48	18.94	18.06	17.30	16.64	16.06	15.56	15.11	14.70	14.38	14.05	13.76	13.51	13.26	13.08
5.6	10.19	23.33	22.62	21.86	21.26	20.62	20.10	19.55	18.64	17.86	17.18	16.58	16.06	15.60	15.18	14.84	14.51	14.20	13.95	13.69	13.51
5.7	10.37	24.05	23.32	22.54	21.92	21.26	20.73	20.16	19.23	18.42	17.72	17.10	16.57	16.10	15.67	15.32	14.97	14.66	14.39	14.13	13.94
5.8	10.55	24.78	24.03	23.22	22.59	21.92	21.37	20.78	19.82	18.99	18.27	17.63	17.09	16.60	16.16	15.80	15.45	15.12	14.85	14.58	14.38
5.9	10.73	25.52	24.75	23.92	23.27	22.58	22.01	21.41	20.43	19.57	18.83	18.17	17.62	17.11	16.65	16.28	15.92	15.59	15.31	15.03	14.83
6.0	10.92	26.27	25.48	24.63	23.96	23.25	22.67	22.05	21.04	20.16	19.39	18.72	18.15	17.63	17.16	16.78	16.41	16.06	15.77	15.49	15.28
6.1	11.10	27.04	26.22	25.35	24.66	23.93	23.33	22.69	21.65	20.75	19.97	19.28	18.69	18.15	17.67	17.28	16.90	16.54	16.25	15.95	15.74
6.2	11.28	27.80	26.97	26.07	25.37	24.61	24.00	23.35	22.28	21.35	20.55	19.84	19.23	18.69	18.19	17.79	17.39	17.03	16.72	16.42	16.20
6.3	11.46	28.58	27.73	26.80	26.08	25.31	24.68	24.01	22.91	21.96	21.13	20.41	19.78	19.22	18.71	18.30	17.89	17.52	17.21	16.90	16.67
6.4	11.64	29.37	28.49	27.55	26.81	26.01	25.37	24.68	23.55	22.58	21.73	20.98	20.34	19.77	19.24	18.82	18.40	18.02	17.70	17.38	17.15
6.5	11.82	30.17	29.27	28.30	27.54	26.73	26.07	25.36	24.20	23.20	22.33	21.56	20.91	20.32	19.78	19.35	18.92	18.52	18.20	17.87	17.63
6.6	12.01	30.98	30.05	29.06	28.28	27.45	26.77	26.04	24.86	23.83	22.94	22.15	21.48	20.88	20.32	19.88	19.44	19.04	18.70	18.37	18.12
6.7	12.19	31.79	30.85	29.83	29.03	28.18	27.48	26.74	25.53	24.47	23.56	22.75	22.06	21.44	20.87	20.42	19.97	19.55	19.21	18.87	18.61
6.8	12.37	32.62	31.65	30.60	29.79	28.91	28.20	27.44	26.20	25.12	24.18	23.35	22.65	22.01	21.43	20.96	20.50	20.08	19.72	19.37	19.11
6.9	12.55	33.45	32.46	31.39	30.56	29.66	28.93	28.15	26.88	25.77	24.81	23.97	23.24	22.59	21.99	21.51	21.04	20.61	20.25	19.89	19.62
7.0	12.73	34.29	33.28	32.19	31.33	30.41	29.67	28.87	27.57	26.43	25.45	24.58	23.84	23.17	22.56	22.07	21.59	21.14	20.77	20.40	20.13
7.1	12.92	35.15	34.11	32.99	32.11	31.17	30.41	29.60	28.26	27.10	26.10	25.21	24.45	23.77	23.14	22.64	22.14	21.69	21.31	20.93	20.65
7.2	13.10	36.01	34.95	33.80	32.91	31.94	31.16	30.33	28.96	27.78	26.75	25.84	25.06	24.36	23.72	23.21	22.70	22.24	21.85	21.46	21.17
7.3	13.28	36.88	35.79	34.62	33.71	32.72	31.93	31.07	29.67	28.46	27.41	26.48	25.68	24.97	24.31	23.79	23.27	22.79	22.39	22.00	21.70
7.4	13.46	37.76	36.65	35.45	34.51	33.51	32.69	31.82	30.39	29.15	28.07	27.12	26.31	25.58	24.91	24.37	23.84	23.35	22.94	22.54	22.24
7.5	13.64	38.65	37.51	36.29	35.33	34.30	33.47	32.58	31.12	29.85	28.75	27.78	26.94	26.20	25.51	24.96	24.42	23.92	23.50	23.09	22.78
7.6	13.83	39.54	38.39	37.13	36.16	35.11	34.26	33.34	31.85	30.55	29.43	28.43	27.59	26.82	26.12	25.56	25.00	24.49	24.07	23.64	23.33
7.7	14.01	40.45	39.27	37.99	36.99	35.92	35.05	34.12	32.59	31.27	30.12	29.10	28.23	27.45	26.74	26.16	25.59	25.07	24.63	24.20	23.88
7.8	14.19	41.37	40.16	38.85	37.83	36.74	35.85	34.90	33.34	31.99	30.81	29.77	28.89	28.09	27.36	26.77	26.19	25.66	25.21	24.77	24.44
7.9	14.37	42.29	41.06	39.72	38.68	37.57	36.66	35.69	34.09	32.71	31.51	30.45	29.55	28.73	27.98	27.38	26.79	26.25	25.79	25.34	25.01
8.0	14.55	43.22	41.96	40.60	39.54	38.40	37.47	36.48	34.86	33.45	32.22	31.14	30.22	29.38	28.62	28.01	27.40	26.85	26.38	25.92	25.58

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

1" Uponor PEX-a — 40% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40ºF 4ºC	45ºF 7ºC	50ºF 10ºC	55ºF 13ºC	60ºF 16ºC	65ºF 18ºC	70ºF 21ºC	80ºF 27ºC	90ºF 32ºC	100ºF 38ºC	110ºF 43ºC	120ºF 49ºC	130ºF 54ºC	140ºF 60ºC	150ºF 66ºC	160ºF 71ºC	170ºF 77ºC	180ºF 82ºC	190ºF 88ºC	200ºF 93ºC
1.5	2.73	2.95	2.82	2.68	2.57	2.46	2.37	2.28	2.13	2.01	1.90	1.81	1.74	1.67	1.61	1.56	1.52	1.47	1.44	1.41	1.38
1.6	2.91	3.28	3.14	2.98	2.86	2.74	2.64	2.54	2.38	2.24	2.13	2.03	1.94	1.87	1.80	1.75	1.70	1.65	1.61	1.57	1.55
1.7	3.09	3.63	3.47	3.30	3.17	3.03	2.93	2.82	2.63	2.48	2.36	2.25	2.15	2.07	2.00	1.94	1.89	1.83	1.79	1.75	1.72
1.8	3.27	3.99	3.82	3.63	3.49	3.34	3.22	3.10	2.90	2.74	2.60	2.48	2.38	2.29	2.21	2.14	2.08	2.03	1.98	1.93	1.90
1.9	3.46	4.37	4.18	3.97	3.82	3.66	3.53	3.40	3.18	3.00	2.85	2.72	2.61	2.51	2.43	2.35	2.29	2.23	2.18	2.13	2.09
2.0	3.64	4.75	4.55	4.33	4.16	3.99	3.85	3.71	3.47	3.28	3.12	2.98	2.85	2.75	2.65	2.57	2.50	2.43	2.38	2.33	2.28
2.1	3.82	5.16	4.93	4.70	4.52	4.33	4.18	4.03	3.78	3.56	3.39	3.24	3.10	2.99	2.89	2.80	2.73	2.65	2.60	2.53	2.49
2.2	4.00	5.57	5.33	5.08	4.89	4.68	4.53	4.36	4.09	3.86	3.67	3.51	3.36	3.24	3.13	3.04	2.96	2.88	2.82	2.75	2.70
2.3	4.18	6.00	5.75	5.47	5.27	5.05	4.88	4.70	4.41	4.17	3.96	3.79	3.63	3.50	3.38	3.28	3.20	3.11	3.05	2.97	2.92
2.4	4.37	6.44	6.17	5.88	5.66	5.42	5.24	5.05	4.74	4.48	4.26	4.08	3.91	3.77	3.64	3.53	3.44	3.35	3.28	3.20	3.15
2.5	4.55	6.90	6.61	6.30	6.06	5.81	5.62	5.42	5.09	4.81	4.57	4.37	4.20	4.04	3.91	3.80	3.70	3.60	3.52	3.44	3.38
2.6	4.73	7.36	7.06	6.73	6.48	6.21	6.01	5.79	5.44	5.14	4.89	4.68	4.49	4.33	4.19	4.06	3.96	3.85	3.78	3.69	3.62
2.7	4.91	7.85	7.52	7.17	6.91	6.62	6.41	6.18	5.80	5.49	5.22	5.00	4.80	4.62	4.47	4.34	4.23	4.12	4.04	3.94	3.87
2.8	5.09	8.34	7.99	7.62	7.34	7.05	6.82	6.57	6.18	5.84	5.56	5.32	5.11	4.93	4.76	4.63	4.51	4.39	4.30	4.20	4.13
2.9	5.28	8.84	8.48	8.09	7.79	7.48	7.24	6.98	6.56	6.21	5.91	5.66	5.43	5.24	5.07	4.92	4.79	4.67	4.58	4.47	4.39
3.0	5.46	9.36	8.98	8.57	8.26	7.92	7.67	7.39	6.95	6.58	6.27	6.00	5.76	5.56	5.38	5.22	5.09	4.96	4.86	4.75	4.66
3.1	5.64	9.89	9.49	9.05	8.73	8.38	8.11	7.82	7.36	6.96	6.64	6.35	6.10	5.89	5.69	5.53	5.39	5.25	5.15	5.03	4.94
3.2	5.82	10.44	10.01	9.55	9.21	8.84	8.56	8.26	7.77	7.36	7.01	6.71	6.45	6.22	6.02	5.85	5.70	5.55	5.44	5.32	5.23
3.3	6.00	10.99	10.55	10.07	9.71	9.32	9.02	8.71	8.19	7.76	7.39	7.08	6.80	6.56	6.35	6.17	6.02	5.86	5.74	5.61	5.52
3.4	6.19	11.56	11.09	10.59	10.21	9.81	9.50	9.16	8.62	8.17	7.79	7.46	7.17	6.92	6.69	6.50	6.34	6.18	6.06	5.92	5.82
3.5	6.37	12.14	11.65	11.12	10.73	10.31	9.98	9.63	9.07	8.59	8.19	7.84	7.54	7.28	7.04	6.84	6.67	6.50	6.37	6.23	6.12
3.6	6.55	12.73	12.22	11.67	11.26	10.81	10.47	10.11	9.52	9.02	8.60	8.24	7.92	7.64	7.40	7.19	7.01	6.83	6.70	6.55	6.44
3.7	6.73	13.33	12.80	12.22	11.80	11.33	10.98	10.59	9.98	9.46	9.02	8.64	8.31	8.02	7.76	7.55	7.36	7.17	7.03	6.87	6.76
3.8	6.91	13.95	13.39	12.79	12.34	11.86	11.49	11.09	10.45	9.90	9.45	9.05	8.70	8.40	8.13	7.91	7.71	7.52	7.37	7.20	7.08
3.9	7.09	14.57	14.00	13.37	12.90	12.40	12.01	11.60	10.93	10.36	9.88	9.47	9.11	8.79	8.51	8.28	8.07	7.87	7.72	7.54	7.42
4.0	7.28	15.21	14.61	13.96	13.47	12.95	12.55	12.11	11.42	10.83	10.33	9.90	9.52	9.19	8.90	8.65	8.44	8.23	8.07	7.89	7.76
4.1	7.46	15.86	15.24	14.56	14.05	13.51	13.09	12.64	11.91	11.30	10.78	10.34	9.94	9.60	9.30	9.04	8.82	8.59	8.43	8.24	8.11
4.2	7.64	16.52	15.87	15.17	14.65	14.08	13.64	13.18	12.42	11.78	11.24	10.78	10.37	10.01	9.70	9.43	9.20	8.97	8.80	8.60	8.46
4.3	7.82	17.19	16.52	15.79	15.25	14.66	14.21	13.72	12.94	12.27	11.71	11.23	10.80	10.44	10.11	9.83	9.59	9.35	9.17	8.97	8.82
4.4	8.00	17.87	17.18	16.42	15.86	15.25	14.78	14.28	13.46	12.77	12.19	11.69	11.25	10.87	10.53	10.24	9.99	9.74	9.55	9.34	9.19
4.5	8.19	18.57	17.85	17.07	16.48	15.85	15.36	14.84	14.00	13.28	12.68	12.16	11.70	11.30	10.95	10.65	10.39	10.13	9.94	9.72	9.56
4.6	8.37	19.28	18.53	17.72	17.11	16.46	15.96	15.41	14.54	13.80	13.18	12.64	12.16	11.75	11.38	11.07	10.80	10.53	10.33	10.11	9.94
4.7	8.55	19.99	19.22	18.38	17.75	17.08	16.56	16.00	15.09	14.33	13.68	13.12	12.63	12.20	11.82	11.50	11.22	10.94	10.74	10.50	10.33

Continued on next page

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

Appendix G:

Hydronic friction loss tables

1" Uponor PEX-a — 40% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40ºF 4ºC	45ºF 7ºC	50ºF 10ºC	55ºF 13ºC	60ºF 16ºC	65ºF 18ºC	70ºF 21ºC	80ºF 27ºC	90ºF 32ºC	100ºF 38ºC	110ºF 43ºC	120ºF 49ºC	130ºF 54ºC	140ºF 60ºC	150ºF 66ºC	160ºF 71ºC	170ºF 77ºC	180ºF 82ºC	190ºF 88ºC	200ºF 93ºC
4.8	8.73	20.72	19.92	19.06	18.41	17.71	17.17	16.59	15.65	14.86	14.19	13.61	13.10	12.66	12.27	11.94	11.65	11.36	11.14	10.90	10.72
4.9	8.91	21.46	20.64	19.74	19.07	18.35	17.79	17.19	16.22	15.40	14.71	14.11	13.58	13.13	12.72	12.38	12.08	11.78	11.56	11.31	11.12
5.0	9.10	22.21	21.36	20.43	19.74	18.99	18.42	17.80	16.80	15.95	15.24	14.62	14.07	13.61	13.18	12.83	12.52	12.21	11.98	11.72	11.53
5.1	9.28	22.97	22.09	21.14	20.42	19.65	19.06	18.42	17.39	16.51	15.78	15.14	14.57	14.09	13.65	13.28	12.97	12.65	12.41	12.14	11.94
5.2	9.46	23.74	22.84	21.85	21.12	20.32	19.71	19.05	17.99	17.08	16.32	15.66	15.08	14.58	14.13	13.75	13.42	13.09	12.84	12.57	12.36
5.3	9.64	24.53	23.59	22.58	21.82	21.00	20.37	19.69	18.59	17.66	16.87	16.19	15.59	15.08	14.61	14.22	13.88	13.54	13.29	13.00	12.79
5.4	9.82	25.32	24.36	23.31	22.53	21.69	21.04	20.34	19.20	18.24	17.44	16.73	16.11	15.58	15.10	14.70	14.35	14.00	13.73	13.44	13.22
5.5	10.01	26.12	25.14	24.06	23.25	22.38	21.71	20.99	19.83	18.84	18.00	17.28	16.64	16.09	15.60	15.18	14.82	14.46	14.19	13.88	13.66
5.6	10.19	26.94	25.92	24.81	23.99	23.09	22.40	21.66	20.46	19.44	18.58	17.84	17.18	16.61	16.10	15.67	15.30	14.93	14.65	14.34	14.11
5.7	10.37	27.76	26.72	25.58	24.73	23.81	23.10	22.33	21.10	20.05	19.17	18.40	17.72	17.14	16.62	16.17	15.79	15.40	15.12	14.80	14.56
5.8	10.55	28.60	27.53	26.35	25.48	24.53	23.80	23.02	21.75	20.67	19.76	18.97	18.27	17.67	17.13	16.68	16.28	15.89	15.59	15.26	15.02
5.9	10.73	29.45	28.34	27.14	26.24	25.26	24.52	23.71	22.40	21.29	20.36	19.55	18.83	18.21	17.66	17.19	16.78	16.38	16.07	15.73	15.48
6.0	10.92	30.31	29.17	27.93	27.01	26.01	25.24	24.41	23.07	21.93	20.97	20.13	19.39	18.76	18.19	17.71	17.29	16.87	16.56	16.21	15.95
6.1	11.10	31.17	30.01	28.74	27.79	26.76	25.97	25.12	23.74	22.57	21.58	20.73	19.97	19.32	18.73	18.24	17.81	17.38	17.06	16.69	16.43
6.2	11.28	32.05	30.86	29.55	28.58	27.52	26.71	25.84	24.42	23.22	22.21	21.33	20.55	19.88	19.28	18.77	18.33	17.89	17.56	17.19	16.91
6.3	11.46	32.94	31.71	30.38	29.38	28.30	27.46	26.57	25.11	23.88	22.84	21.94	21.13	20.45	19.83	19.31	18.86	18.40	18.06	17.68	17.40
6.4	11.64	33.84	32.58	31.21	30.19	29.08	28.22	27.30	25.81	24.55	23.48	22.55	21.73	21.02	20.39	19.86	19.39	18.92	18.58	18.19	17.90
6.5	11.82	34.75	33.46	32.06	31.01	29.87	28.99	28.05	26.52	25.22	24.12	23.17	22.33	21.61	20.96	20.41	19.93	19.45	19.10	18.70	18.40
6.6	12.01	35.67	34.35	32.91	31.83	30.67	29.77	28.80	27.23	25.90	24.78	23.81	22.94	22.20	21.53	20.97	20.48	19.99	19.62	19.21	18.91
6.7	12.19	36.60	35.25	33.77	32.67	31.47	30.55	29.56	27.96	26.59	25.44	24.44	23.56	22.80	22.11	21.54	21.03	20.53	20.16	19.73	19.42
6.8	12.37	37.54	36.15	34.65	33.52	32.29	31.35	30.33	28.69	27.29	26.11	25.09	24.18	23.40	22.70	22.11	21.60	21.08	20.70	20.26	19.95
6.9	12.55	38.49	37.07	35.53	34.37	33.12	32.15	31.11	29.43	28.00	26.79	25.74	24.81	24.01	23.30	22.69	22.16	21.63	21.24	20.80	20.47
7.0	12.73	39.45	38.00	36.42	35.24	33.95	32.97	31.90	30.18	28.71	27.48	26.40	25.45	24.63	23.90	23.28	22.74	22.20	21.79	21.34	21.01
7.1	12.92	40.42	38.94	37.32	36.11	34.80	33.79	32.70	30.94	29.44	28.17	27.07	26.09	25.26	24.51	23.87	23.32	22.76	22.35	21.89	21.54
7.2	13.10	41.40	39.89	38.23	36.99	35.65	34.62	33.51	31.70	30.17	28.87	27.75	26.75	25.89	25.12	24.47	23.91	23.34	22.92	22.44	22.09
7.3	13.28	42.39	40.84	39.15	37.89	36.51	35.46	34.32	32.47	30.90	29.58	28.43	27.41	26.53	25.74	25.08	24.50	23.92	23.49	23.00	22.64
7.4	13.46	43.39	41.81	40.08	38.79	37.39	36.31	35.14	33.25	31.65	30.29	29.12	28.07	27.18	26.37	25.69	25.10	24.51	24.06	23.56	23.20
7.5	13.64	44.40	42.79	41.02	39.70	38.27	37.16	35.97	34.04	32.40	31.02	29.82	28.75	27.83	27.01	26.31	25.71	25.10	24.65	24.14	23.76
7.6	13.83	45.43	43.77	41.97	40.62	39.15	38.03	36.81	34.84	33.16	31.75	30.52	29.43	28.49	27.65	26.94	26.32	25.70	25.24	24.71	24.33
7.7	14.01	46.46	44.77	42.93	41.55	40.05	38.90	37.66	35.65	33.93	32.49	31.23	30.12	29.16	28.30	27.57	26.94	26.30	25.83	25.30	24.91
7.8	14.19	47.50	45.77	43.89	42.49	40.96	39.78	38.52	36.46	34.71	33.23	31.95	30.81	29.83	28.96	28.21	27.56	26.92	26.43	25.89	25.49
7.9	14.37	48.55	46.79	44.87	43.43	41.87	40.67	39.38	37.28	35.50	33.99	32.68	31.51	30.51	29.62	28.86	28.20	27.53	27.04	26.48	26.08
8.0	14.55	49.61	47.81	45.86	44.39	42.80	41.57	40.25	38.11	36.29	34.75	33.41	32.22	31.20	30.29	29.51	28.84	28.16	27.66	27.09	26.67

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

Appendix G:

Hydronic friction loss tables

1" Uponor PEX-a — 50% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40ºF 4ºC	45ºF 7ºC	50ºF 10ºC	55ºF 13ºC	60ºF 16ºC	65ºF 18ºC	70ºF 21ºC	80ºF 27ºC	90ºF 32ºC	100ºF 38ºC	110ºF 43ºC	120ºF 49ºC	130ºF 54ºC	140ºF 60ºC	150ºF 66ºC	160ºF 71ºC	170ºF 77ºC	180ºF 82ºC	190ºF 88ºC	200ºF 93ºC
1.5	2.73	2.95	2.82	2.68	2.57	2.46	2.37	2.28	2.13	2.01	1.90	1.81	1.74	1.67	1.61	1.56	1.52	1.47	1.44	1.41	1.38
1.6	2.91	3.28	3.14	2.98	2.86	2.74	2.64	2.54	2.38	2.24	2.13	2.03	1.94	1.87	1.80	1.75	1.70	1.65	1.61	1.57	1.55
1.7	3.09	3.63	3.47	3.30	3.17	3.03	2.93	2.82	2.63	2.48	2.36	2.25	2.15	2.07	2.00	1.94	1.89	1.83	1.79	1.75	1.72
1.8	3.27	3.99	3.82	3.63	3.49	3.34	3.22	3.10	2.90	2.74	2.60	2.48	2.38	2.29	2.21	2.14	2.08	2.03	1.98	1.93	1.90
1.9	3.46	4.37	4.18	3.97	3.82	3.66	3.53	3.40	3.18	3.00	2.85	2.72	2.61	2.51	2.43	2.35	2.29	2.23	2.18	2.13	2.09
2.0	3.64	4.75	4.55	4.33	4.16	3.99	3.85	3.71	3.47	3.28	3.12	2.98	2.85	2.75	2.65	2.57	2.50	2.43	2.38	2.33	2.28
2.1	3.82	5.16	4.93	4.70	4.52	4.33	4.18	4.03	3.78	3.56	3.39	3.24	3.10	2.99	2.89	2.80	2.73	2.65	2.60	2.53	2.49
2.2	4.00	5.57	5.33	5.08	4.89	4.68	4.53	4.36	4.09	3.86	3.67	3.51	3.36	3.24	3.13	3.04	2.96	2.88	2.82	2.75	2.70
2.3	4.18	6.00	5.75	5.47	5.27	5.05	4.88	4.70	4.41	4.17	3.96	3.79	3.63	3.50	3.38	3.28	3.20	3.11	3.05	2.97	2.92
2.4	4.37	6.44	6.17	5.88	5.66	5.42	5.24	5.05	4.74	4.48	4.26	4.08	3.91	3.77	3.64	3.53	3.44	3.35	3.28	3.20	3.15
2.5	4.55	6.90	6.61	6.30	6.06	5.81	5.62	5.42	5.09	4.81	4.57	4.37	4.20	4.04	3.91	3.80	3.70	3.60	3.52	3.44	3.38
2.6	4.73	7.36	7.06	6.73	6.48	6.21	6.01	5.79	5.44	5.14	4.89	4.68	4.49	4.33	4.19	4.06	3.96	3.85	3.78	3.69	3.62
2.7	4.91	7.85	7.52	7.17	6.91	6.62	6.41	6.18	5.80	5.49	5.22	5.00	4.80	4.62	4.47	4.34	4.23	4.12	4.04	3.94	3.87
2.8	5.09	8.34	7.99	7.62	7.34	7.05	6.82	6.57	6.18	5.84	5.56	5.32	5.11	4.93	4.76	4.63	4.51	4.39	4.30	4.20	4.13
2.9	5.28	8.84	8.48	8.09	7.79	7.48	7.24	6.98	6.56	6.21	5.91	5.66	5.43	5.24	5.07	4.92	4.79	4.67	4.58	4.47	4.39
3.0	5.46	9.36	8.98	8.57	8.26	7.92	7.67	7.39	6.95	6.58	6.27	6.00	5.76	5.56	5.38	5.22	5.09	4.96	4.86	4.75	4.66
3.1	5.64	9.89	9.49	9.05	8.73	8.38	8.11	7.82	7.36	6.96	6.64	6.35	6.10	5.89	5.69	5.53	5.39	5.25	5.15	5.03	4.94
3.2	5.82	10.44	10.01	9.55	9.21	8.84	8.56	8.26	7.77	7.36	7.01	6.71	6.45	6.22	6.02	5.85	5.70	5.55	5.44	5.32	5.23
3.3	6.00	10.99	10.55	10.07	9.71	9.32	9.02	8.71	8.19	7.76	7.39	7.08	6.80	6.56	6.35	6.17	6.02	5.86	5.74	5.61	5.52
3.4	6.19	11.56	11.09	10.59	10.21	9.81	9.50	9.16	8.62	8.17	7.79	7.46	7.17	6.92	6.69	6.50	6.34	6.18	6.06	5.92	5.82
3.5	6.37	12.14	11.65	11.12	10.73	10.31	9.98	9.63	9.07	8.59	8.19	7.84	7.54	7.28	7.04	6.84	6.67	6.50	6.37	6.23	6.12
3.6	6.55	12.73	12.22	11.67	11.26	10.81	10.47	10.11	9.52	9.02	8.60	8.24	7.92	7.64	7.40	7.19	7.01	6.83	6.70	6.55	6.44
3.7	6.73	13.33	12.80	12.22	11.80	11.33	10.98	10.59	9.98	9.46	9.02	8.64	8.31	8.02	7.76	7.55	7.36	7.17	7.03	6.87	6.76
3.8	6.91	13.95	13.39	12.79	12.34	11.86	11.49	11.09	10.45	9.90	9.45	9.05	8.70	8.40	8.13	7.91	7.71	7.52	7.37	7.20	7.08
3.9	7.09	14.57	14.00	13.37	12.90	12.40	12.01	11.60	10.93	10.36	9.88	9.47	9.11	8.79	8.51	8.28	8.07	7.87	7.72	7.54	7.42
4.0	7.28	15.21	14.61	13.96	13.47	12.95	12.55	12.11	11.42	10.83	10.33	9.90	9.52	9.19	8.90	8.65	8.44	8.23	8.07	7.89	7.76
4.1	7.46	15.86	15.24	14.56	14.05	13.51	13.09	12.64	11.91	11.30	10.78	10.34	9.94	9.60	9.30	9.04	8.82	8.59	8.43	8.24	8.11
4.2	7.64	16.52	15.87	15.17	14.65	14.08	13.64	13.18	12.42	11.78	11.24	10.78	10.37	10.01	9.70	9.43	9.20	8.97	8.80	8.60	8.46
4.3	7.82	17.19	16.52	15.79	15.25	14.66	14.21	13.72	12.94	12.27	11.71	11.23	10.80	10.44	10.11	9.83	9.59	9.35	9.17	8.97	8.82
4.4	8.00	17.87	17.18	16.42	15.86	15.25	14.78	14.28	13.46	12.77	12.19	11.69	11.25	10.87	10.53	10.24	9.99	9.74	9.55	9.34	9.19
4.5	8.19	18.57	17.85	17.07	16.48	15.85	15.36	14.84	14.00	13.28	12.68	12.16	11.70	11.30	10.95	10.65	10.39	10.13	9.94	9.72	9.56
4.6	8.37	19.28	18.53	17.72	17.11	16.46	15.96	15.41	14.54	13.80	13.18	12.64	12.16	11.75	11.38	11.07	10.80	10.53	10.33	10.11	9.94
4.7	8.55	19.99	19.22	18.38	17.75	17.08	16.56	16.00	15.09	14.33	13.68	13.12	12.63	12.20	11.82	11.50	11.22	10.94	10.74	10.50	10.33

Continued on next page

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

Appendix G:

Hydronic friction loss tables

1" Uponor PEX-a — 50% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
4.8	8.73	20.72	19.92	19.06	18.41	17.71	17.17	16.59	15.65	14.86	14.19	13.61	13.10	12.66	12.27	11.94	11.65	11.36	11.14	10.90	10.72
4.9	8.91	21.46	20.64	19.74	19.07	18.35	17.79	17.19	16.22	15.40	14.71	14.11	13.58	13.13	12.72	12.38	12.08	11.78	11.56	11.31	11.12
5.0	9.10	22.21	21.36	20.43	19.74	18.99	18.42	17.80	16.80	15.95	15.24	14.62	14.07	13.61	13.18	12.83	12.52	12.21	11.98	11.72	11.53
5.1	9.28	22.97	22.09	21.14	20.42	19.65	19.06	18.42	17.39	16.51	15.78	15.14	14.57	14.09	13.65	13.28	12.97	12.65	12.41	12.14	11.94
5.2	9.46	23.74	22.84	21.85	21.12	20.32	19.71	19.05	17.99	17.08	16.32	15.66	15.08	14.58	14.13	13.75	13.42	13.09	12.84	12.57	12.36
5.3	9.64	24.53	23.59	22.58	21.82	21.00	20.37	19.69	18.59	17.66	16.87	16.19	15.59	15.08	14.61	14.22	13.88	13.54	13.29	13.00	12.79
5.4	9.82	25.32	24.36	23.31	22.53	21.69	21.04	20.34	19.20	18.24	17.44	16.73	16.11	15.58	15.10	14.70	14.35	14.00	13.73	13.44	13.22
5.5	10.01	26.12	25.14	24.06	23.25	22.38	21.71	20.99	19.83	18.84	18.00	17.28	16.64	16.09	15.60	15.18	14.82	14.46	14.19	13.88	13.66
5.6	10.19	26.94	25.92	24.81	23.99	23.09	22.40	21.66	20.46	19.44	18.58	17.84	17.18	16.61	16.10	15.67	15.30	14.93	14.65	14.34	14.11
5.7	10.37	27.76	26.72	25.58	24.73	23.81	23.10	22.33	21.10	20.05	19.17	18.40	17.72	17.14	16.62	16.17	15.79	15.40	15.12	14.80	14.56
5.8	10.55	28.60	27.53	26.35	25.48	24.53	23.80	23.02	21.75	20.67	19.76	18.97	18.27	17.67	17.13	16.68	16.28	15.89	15.59	15.26	15.02
5.9	10.73	29.45	28.34	27.14	26.24	25.26	24.52	23.71	22.40	21.29	20.36	19.55	18.83	18.21	17.66	17.19	16.78	16.38	16.07	15.73	15.48
6.0	10.92	30.31	29.17	27.93	27.01	26.01	25.24	24.41	23.07	21.93	20.97	20.13	19.39	18.76	18.19	17.71	17.29	16.87	16.56	16.21	15.95
6.1	11.10	31.17	30.01	28.74	27.79	26.76	25.97	25.12	23.74	22.57	21.58	20.73	19.97	19.32	18.73	18.24	17.81	17.38	17.06	16.69	16.43
6.2	11.28	32.05	30.86	29.55	28.58	27.52	26.71	25.84	24.42	23.22	22.21	21.33	20.55	19.88	19.28	18.77	18.33	17.89	17.56	17.19	16.91
6.3	11.46	32.94	31.71	30.38	29.38	28.30	27.46	26.57	25.11	23.88	22.84	21.94	21.13	20.45	19.83	19.31	18.86	18.40	18.06	17.68	17.40
6.4	11.64	33.84	32.58	31.21	30.19	29.08	28.22	27.30	25.81	24.55	23.48	22.55	21.73	21.02	20.39	19.86	19.39	18.92	18.58	18.19	17.90
6.5	11.82	34.75	33.46	32.06	31.01	29.87	28.99	28.05	26.52	25.22	24.12	23.17	22.33	21.61	20.96	20.41	19.93	19.45	19.10	18.70	18.40
6.6	12.01	35.67	34.35	32.91	31.83	30.67	29.77	28.80	27.23	25.90	24.78	23.81	22.94	22.20	21.53	20.97	20.48	19.99	19.62	19.21	18.91
6.7	12.19	36.60	35.25	33.77	32.67	31.47	30.55	29.56	27.96	26.59	25.44	24.44	23.56	22.80	22.11	21.54	21.03	20.53	20.16	19.73	19.42
6.8	12.37	37.54	36.15	34.65	33.52	32.29	31.35	30.33	28.69	27.29	26.11	25.09	24.18	23.40	22.70	22.11	21.60	21.08	20.70	20.26	19.95
6.9	12.55	38.49	37.07	35.53	34.37	33.12	32.15	31.11	29.43	28.00	26.79	25.74	24.81	24.01	23.30	22.69	22.16	21.63	21.24	20.80	20.47
7.0	12.73	39.45	38.00	36.42	35.24	33.95	32.97	31.90	30.18	28.71	27.48	26.40	25.45	24.63	23.90	23.28	22.74	22.20	21.79	21.34	21.01
7.1	12.92	40.42	38.94	37.32	36.11	34.80	33.79	32.70	30.94	29.44	28.17	27.07	26.09	25.26	24.51	23.87	23.32	22.76	22.35	21.89	21.54
7.2	13.10	41.40	39.89	38.23	36.99	35.65	34.62	33.51	31.70	30.17	28.87	27.75	26.75	25.89	25.12	24.47	23.91	23.34	22.92	22.44	22.09
7.3	13.28	42.39	40.84	39.15	37.89	36.51	35.46	34.32	32.47	30.90	29.58	28.43	27.41	26.53	25.74	25.08	24.50	23.92	23.49	23.00	22.64
7.4	13.46	43.39	41.81	40.08	38.79	37.39	36.31	35.14	33.25	31.65	30.29	29.12	28.07	27.18	26.37	25.69	25.10	24.51	24.06	23.56	23.20
7.5	13.64	44.40	42.79	41.02	39.70	38.27	37.16	35.97	34.04	32.40	31.02	29.82	28.75	27.83	27.01	26.31	25.71	25.10	24.65	24.14	23.76
7.6	13.83	45.43	43.77	41.97	40.62	39.15	38.03	36.81	34.84	33.16	31.75	30.52	29.43	28.49	27.65	26.94	26.32	25.70	25.24	24.71	24.33
7.7	14.01	46.46	44.77	42.93	41.55	40.05	38.90	37.66	35.65	33.93	32.49	31.23	30.12	29.16	28.30	27.57	26.94	26.30	25.83	25.30	24.91
7.8	14.19	47.50	45.77	43.89	42.49	40.96	39.78	38.52	36.46	34.71	33.23	31.95	30.81	29.83	28.96	28.21	27.56	26.92	26.43	25.89	25.49
7.9	14.37	48.55	46.79	44.87	43.43	41.87	40.67	39.38	37.28	35.50	33.99	32.68	31.51	30.51	29.62	28.86	28.20	27.53	27.04	26.48	26.08
8.0	14.55	49.61	47.81	45.86	44.39	42.80	41.57	40.25	38.11	36.29	34.75	33.41	32.22	31.20	30.29	29.51	28.84	28.16	27.66	27.09	26.67
8.1	14.74	56.61	54.43	52.05	50.25	48.30	46.81	45.19	42.57	40.35	38.45	36.82	35.39	34.15	33.04	32.08	31.22	30.43	29.71	29.12	28.54

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

1¼" Uponor PEX-a — 100% Water — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40ºF 4ºC	45ºF 7ºC	50ºF 10ºC	55ºF 13ºC	60ºF 16ºC	65ºF 18ºC	70ºF 21ºC	80ºF 27ºC	90ºF 32ºC	100ºF 38ºC	110ºF 43ºC	120ºF 49ºC	130ºF 54ºC	140ºF 60ºC	150ºF 66ºC	160ºF 71ºC	170ºF 77ºC	180ºF 82ºC	190ºF 88ºC	200ºF 93ºC
1.5	4.08	1.39	1.33	1.25	1.23	1.20	1.18	1.16	1.12	1.09	1.06	1.03	1.01	0.99	0.97	0.95	0.94	0.92	0.91	0.89	0.88
1.6	4.35	1.56	1.48	1.40	1.37	1.34	1.32	1.30	1.26	1.22	1.19	1.16	1.13	1.11	1.09	1.07	1.05	1.03	1.02	1.00	0.99
1.7	4.62	1.73	1.65	1.55	1.53	1.49	1.47	1.44	1.40	1.36	1.32	1.29	1.26	1.23	1.21	1.19	1.17	1.15	1.13	1.12	1.10
1.8	4.90	1.91	1.82	1.72	1.69	1.65	1.62	1.59	1.54	1.50	1.46	1.43	1.39	1.36	1.34	1.31	1.29	1.27	1.25	1.24	1.22
1.9	5.17	2.10	2.00	1.89	1.85	1.81	1.78	1.75	1.70	1.65	1.61	1.57	1.53	1.50	1.47	1.45	1.42	1.40	1.38	1.36	1.34
2.0	5.44	2.29	2.18	2.06	2.02	1.98	1.95	1.92	1.86	1.81	1.76	1.72	1.68	1.64	1.61	1.58	1.56	1.53	1.51	1.49	1.47
2.1	5.71	2.49	2.38	2.25	2.20	2.16	2.13	2.09	2.02	1.97	1.92	1.87	1.83	1.79	1.76	1.73	1.70	1.67	1.65	1.63	1.60
2.2	5.98	2.70	2.58	2.44	2.39	2.34	2.31	2.27	2.20	2.13	2.08	2.03	1.99	1.95	1.91	1.88	1.84	1.82	1.79	1.77	1.74
2.3	6.26	2.92	2.79	2.63	2.58	2.53	2.49	2.45	2.37	2.31	2.25	2.20	2.15	2.11	2.07	2.03	2.00	1.97	1.94	1.91	1.89
2.4	6.53	3.14	3.00	2.84	2.78	2.73	2.69	2.64	2.56	2.49	2.42	2.37	2.32	2.27	2.23	2.19	2.15	2.12	2.09	2.06	2.04
2.5	6.80	3.37	3.22	3.05	2.99	2.93	2.89	2.84	2.75	2.67	2.61	2.55	2.49	2.44	2.40	2.35	2.32	2.28	2.25	2.22	2.19
2.6	7.07	3.61	3.45	3.26	3.20	3.14	3.09	3.04	2.95	2.87	2.79	2.73	2.67	2.62	2.57	2.52	2.48	2.44	2.41	2.38	2.35
2.7	7.34	3.86	3.68	3.49	3.42	3.36	3.30	3.25	3.15	3.06	2.99	2.92	2.85	2.80	2.75	2.70	2.66	2.62	2.58	2.54	2.51
2.8	7.62	4.11	3.92	3.71	3.65	3.58	3.52	3.46	3.36	3.27	3.18	3.11	3.04	2.98	2.93	2.88	2.83	2.79	2.75	2.71	2.68
2.9	7.89	4.37	4.17	3.95	3.88	3.81	3.75	3.68	3.57	3.47	3.39	3.31	3.24	3.18	3.12	3.07	3.02	2.97	2.93	2.89	2.85
3.0	8.16	4.63	4.43	4.19	4.12	4.04	3.98	3.91	3.79	3.69	3.60	3.52	3.44	3.37	3.31	3.26	3.20	3.16	3.11	3.07	3.03
3.1	8.43	4.91	4.69	4.44	4.36	4.28	4.21	4.14	4.02	3.91	3.81	3.73	3.65	3.58	3.51	3.45	3.40	3.35	3.30	3.26	3.22
3.2	8.70	5.19	4.96	4.69	4.61	4.53	4.45	4.38	4.25	4.14	4.03	3.94	3.86	3.78	3.72	3.65	3.60	3.54	3.49	3.45	3.40
3.3	8.98	5.47	5.23	4.96	4.87	4.78	4.70	4.62	4.49	4.37	4.26	4.16	4.08	4.00	3.93	3.86	3.80	3.74	3.69	3.64	3.60
3.4	9.25	5.76	5.51	5.22	5.13	5.04	4.96	4.87	4.73	4.60	4.49	4.39	4.30	4.22	4.14	4.07	4.01	3.95	3.89	3.84	3.80
3.5	9.52	6.06	5.80	5.50	5.40	5.30	5.22	5.13	4.98	4.85	4.73	4.62	4.53	4.44	4.36	4.29	4.22	4.16	4.10	4.05	4.00
3.6	9.79	6.37	6.09	5.77	5.67	5.57	5.48	5.39	5.23	5.10	4.97	4.86	4.76	4.67	4.59	4.51	4.44	4.37	4.31	4.26	4.21
3.7	10.06	6.68	6.39	6.06	5.96	5.84	5.75	5.66	5.49	5.35	5.22	5.10	5.00	4.90	4.82	4.73	4.66	4.59	4.53	4.47	4.42
3.8	10.34	7.00	6.70	6.35	6.24	6.13	6.03	5.93	5.76	5.61	5.47	5.35	5.24	5.14	5.05	4.97	4.89	4.82	4.75	4.69	4.63
3.9	10.61	7.33	7.01	6.65	6.53	6.41	6.31	6.21	6.03	5.87	5.73	5.60	5.49	5.38	5.29	5.20	5.12	5.05	4.98	4.91	4.86
4.0	10.88	7.66	7.33	6.95	6.83	6.71	6.60	6.49	6.31	6.14	6.00	5.86	5.74	5.63	5.53	5.44	5.36	5.28	5.21	5.14	5.08
4.1	11.15	8.00	7.65	7.26	7.14	7.01	6.90	6.79	6.59	6.42	6.26	6.13	6.00	5.89	5.78	5.69	5.60	5.52	5.45	5.38	5.31
4.2	11.42	8.34	7.98	7.58	7.45	7.31	7.20	7.08	6.88	6.70	6.54	6.40	6.26	6.15	6.04	5.94	5.85	5.76	5.69	5.61	5.55
4.3	11.70	8.69	8.32	7.90	7.76	7.62	7.50	7.38	7.17	6.99	6.82	6.67	6.53	6.41	6.30	6.20	6.10	6.01	5.93	5.86	5.79
4.4	11.97	9.05	8.66	8.22	8.08	7.94	7.82	7.69	7.47	7.28	7.10	6.95	6.81	6.68	6.56	6.46	6.36	6.27	6.18	6.10	6.03
4.5	12.24	9.42	9.01	8.56	8.41	8.26	8.13	8.00	7.77	7.57	7.39	7.23	7.09	6.95	6.83	6.72	6.62	6.52	6.44	6.36	6.28
4.6	12.51	9.79	9.37	8.90	8.75	8.59	8.46	8.32	8.08	7.88	7.69	7.52	7.37	7.23	7.11	6.99	6.89	6.79	6.70	6.61	6.53
4.7	12.78	10.16	9.73	9.24	9.08	8.92	8.78	8.64	8.40	8.18	7.99	7.82	7.66	7.52	7.39	7.27	7.16	7.05	6.96	6.87	6.79

Continued on next page

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

Appendix G:

Hydronic friction loss tables

1¼" Uponor PEX-a — 100% Water — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40ºF 4ºC	45ºF 7ºC	50ºF 10ºC	55ºF 13ºC	60ºF 16ºC	65ºF 18ºC	70ºF 21ºC	80ºF 27ºC	90ºF 32ºC	100ºF 38ºC	110ºF 43ºC	120ºF 49ºC	130ºF 54ºC	140ºF 60ºC	150ºF 66ºC	160ºF 71ºC	170ºF 77ºC	180ºF 82ºC	190ºF 88ºC	200ºF 93ºC
4.8	13.06	10.55	10.10	9.59	9.43	9.26	9.12	8.97	8.72	8.50	8.29	8.12	7.95	7.80	7.67	7.55	7.43	7.32	7.23	7.14	7.05
4.9	13.33	10.93	10.47	9.95	9.78	9.60	9.46	9.31	9.04	8.81	8.61	8.42	8.25	8.10	7.96	7.83	7.71	7.60	7.50	7.41	7.32
5.0	13.60	11.33	10.85	10.31	10.13	9.95	9.80	9.65	9.38	9.14	8.92	8.73	8.55	8.40	8.25	8.12	8.00	7.88	7.78	7.68	7.59
5.1	13.87	11.73	11.24	10.67	10.50	10.31	10.15	9.99	9.71	9.46	9.24	9.04	8.86	8.70	8.55	8.41	8.29	8.17	8.06	7.96	7.87
5.2	14.14	12.14	11.63	11.05	10.86	10.67	10.51	10.34	10.05	9.80	9.57	9.36	9.18	9.01	8.85	8.71	8.58	8.46	8.35	8.24	8.15
5.3	14.42	12.55	12.03	11.43	11.24	11.04	10.87	10.70	10.40	10.14	9.90	9.69	9.49	9.32	9.16	9.01	8.88	8.75	8.64	8.53	8.43
5.4	14.69	12.97	12.43	11.81	11.61	11.41	11.24	11.06	10.75	10.48	10.23	10.02	9.82	9.64	9.47	9.32	9.18	9.05	8.93	8.83	8.72
5.5	14.96	13.40	12.84	12.20	12.00	11.79	11.61	11.43	11.11	10.83	10.58	10.35	10.15	9.96	9.79	9.63	9.49	9.36	9.24	9.12	9.02
5.6	15.23	13.83	13.25	12.60	12.39	12.17	11.99	11.80	11.47	11.18	10.92	10.69	10.48	10.29	10.11	9.95	9.80	9.67	9.54	9.42	9.31
5.7	15.50	14.27	13.67	13.00	12.78	12.56	12.37	12.17	11.84	11.54	11.27	11.03	10.82	10.62	10.44	10.27	10.12	9.98	9.85	9.73	9.62
5.8	15.78	14.71	14.10	13.40	13.18	12.95	12.76	12.56	12.21	11.90	11.63	11.38	11.16	10.95	10.77	10.60	10.44	10.30	10.16	10.04	9.92
5.9	16.05	15.16	14.53	13.82	13.59	13.35	13.15	12.94	12.59	12.27	11.99	11.74	11.51	11.30	11.11	10.93	10.77	10.62	10.48	10.35	10.23
6.0	16.32	15.62	14.97	14.23	14.00	13.75	13.55	13.34	12.97	12.65	12.36	12.09	11.86	11.64	11.45	11.27	11.10	10.94	10.80	10.67	10.55
6.1	16.59	16.08	15.41	14.66	14.42	14.16	13.95	13.74	13.36	13.03	12.73	12.46	12.21	11.99	11.79	11.61	11.44	11.27	11.13	11.00	10.87
6.2	16.86	16.54	15.86	15.09	14.84	14.58	14.36	14.14	13.75	13.41	13.10	12.83	12.58	12.35	12.14	11.95	11.78	11.61	11.46	11.32	11.19
6.3	17.13	17.02	16.32	15.52	15.27	15.00	14.78	14.55	14.15	13.80	13.48	13.20	12.94	12.71	12.50	12.30	12.12	11.95	11.80	11.66	11.52
6.4	17.41	17.50	16.78	15.96	15.70	15.43	15.20	14.96	14.55	14.19	13.87	13.58	13.31	13.07	12.85	12.65	12.47	12.29	12.14	11.99	11.85
6.5	17.68	17.98	17.25	16.40	16.14	15.86	15.62	15.38	14.96	14.59	14.26	13.96	13.69	13.44	13.22	13.01	12.82	12.64	12.48	12.33	12.19
6.6	17.95	18.47	17.72	16.86	16.58	16.29	16.05	15.81	15.38	14.99	14.65	14.35	14.07	13.82	13.59	13.37	13.18	13.00	12.83	12.68	12.53
6.7	18.22	18.97	18.20	17.31	17.03	16.73	16.49	16.23	15.79	15.40	15.05	14.74	14.45	14.19	13.96	13.74	13.54	13.35	13.18	13.03	12.88
6.8	18.49	19.47	18.68	17.77	17.48	17.18	16.93	16.67	16.22	15.82	15.46	15.14	14.84	14.58	14.34	14.11	13.91	13.72	13.54	13.38	13.23
6.9	18.77	19.98	19.17	18.24	17.94	17.63	17.38	17.11	16.65	16.24	15.87	15.54	15.24	14.97	14.72	14.49	14.28	14.08	13.90	13.74	13.58
7.0	19.04	20.50	19.66	18.71	18.41	18.09	17.83	17.55	17.08	16.66	16.28	15.94	15.64	15.36	15.10	14.87	14.65	14.45	14.27	14.10	13.94
7.1	19.31	21.02	20.16	19.19	18.88	18.55	18.28	18.00	17.52	17.09	16.70	16.35	16.04	15.75	15.49	15.25	15.03	14.83	14.64	14.47	14.30
7.2	19.58	21.54	20.67	19.67	19.36	19.02	18.75	18.46	17.96	17.52	17.12	16.77	16.45	16.16	15.89	15.64	15.42	15.21	15.02	14.84	14.67
7.3	19.85	22.07	21.18	20.16	19.84	19.49	19.21	18.92	18.41	17.96	17.55	17.19	16.86	16.56	16.29	16.04	15.81	15.59	15.39	15.21	15.04
7.4	20.13	22.61	21.70	20.65	20.32	19.97	19.68	19.38	18.86	18.40	17.99	17.62	17.28	16.97	16.69	16.44	16.20	15.98	15.78	15.59	15.42
7.5	20.40	23.15	22.22	21.15	20.81	20.46	20.16	19.85	19.32	18.85	18.42	18.05	17.70	17.39	17.10	16.84	16.60	16.37	16.17	15.97	15.80
7.6	20.67	23.70	22.75	21.66	21.31	20.95	20.64	20.33	19.78	19.30	18.87	18.48	18.13	17.81	17.52	17.25	17.00	16.77	16.56	16.36	16.18
7.7	20.94	24.26	23.28	22.17	21.81	21.44	21.13	20.81	20.25	19.76	19.32	18.92	18.56	18.23	17.93	17.66	17.41	17.17	16.95	16.75	16.57
7.8	21.21	24.82	23.82	22.68	22.32	21.94	21.62	21.29	20.72	20.22	19.77	19.36	18.99	18.66	18.36	18.07	17.82	17.57	17.35	17.15	16.96
7.9	21.49	25.38	24.36	23.20	22.83	22.44	22.12	21.78	21.20	20.69	20.22	19.81	19.43	19.09	18.78	18.49	18.23	17.98	17.76	17.55	17.36
8.0	21.76	25.95	24.91	23.73	23.35	22.95	22.62	22.28	21.68	21.16	20.69	20.26	19.88	19.53	19.21	18.92	18.65	18.40	18.17	17.96	17.76

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

1¼" Uponor PEX-a — 30% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
1.5	4.08	1.91	1.84	1.77	1.71	1.65	1.61	1.56	1.47	1.40	1.34	1.29	1.24	1.20	1.17	1.14	1.11	1.08	1.06	1.04	1.02
1.6	4.35	2.13	2.05	1.97	1.91	1.85	1.79	1.74	1.65	1.57	1.50	1.44	1.39	1.35	1.31	1.27	1.24	1.21	1.19	1.16	1.14
1.7	4.62	2.35	2.27	2.19	2.12	2.05	1.99	1.93	1.83	1.74	1.67	1.60	1.55	1.50	1.45	1.42	1.38	1.35	1.32	1.29	1.27
1.8	4.90	2.59	2.50	2.41	2.34	2.26	2.19	2.13	2.02	1.92	1.84	1.77	1.71	1.65	1.60	1.56	1.53	1.49	1.46	1.43	1.41
1.9	5.17	2.84	2.74	2.64	2.56	2.48	2.41	2.33	2.21	2.11	2.02	1.94	1.88	1.82	1.76	1.72	1.68	1.64	1.61	1.57	1.55
2.0	5.44	3.10	2.99	2.88	2.80	2.70	2.63	2.55	2.42	2.31	2.21	2.12	2.05	1.99	1.93	1.88	1.83	1.79	1.76	1.72	1.70
2.1	5.71	3.36	3.25	3.13	3.04	2.94	2.86	2.77	2.63	2.51	2.40	2.31	2.23	2.16	2.10	2.05	2.00	1.95	1.91	1.88	1.85
2.2	5.98	3.64	3.52	3.39	3.29	3.18	3.09	3.00	2.85	2.72	2.61	2.51	2.42	2.35	2.28	2.22	2.17	2.12	2.08	2.04	2.01
2.3	6.26	3.93	3.80	3.66	3.55	3.43	3.34	3.24	3.08	2.94	2.82	2.71	2.62	2.54	2.46	2.40	2.35	2.29	2.25	2.20	2.17
2.4	6.53	4.22	4.08	3.93	3.82	3.69	3.59	3.49	3.31	3.16	3.03	2.92	2.82	2.73	2.65	2.59	2.53	2.47	2.42	2.38	2.34
2.5	6.80	4.52	4.38	4.22	4.09	3.96	3.85	3.74	3.55	3.39	3.26	3.13	3.03	2.94	2.85	2.78	2.72	2.66	2.60	2.55	2.52
2.6	7.07	4.84	4.68	4.51	4.38	4.24	4.12	4.00	3.80	3.63	3.49	3.36	3.25	3.15	3.06	2.98	2.91	2.85	2.79	2.74	2.70
2.7	7.34	5.16	4.99	4.81	4.67	4.52	4.40	4.27	4.06	3.88	3.72	3.58	3.47	3.36	3.26	3.19	3.11	3.04	2.98	2.93	2.88
2.8	7.62	5.49	5.31	5.12	4.97	4.81	4.69	4.55	4.33	4.13	3.97	3.82	3.69	3.58	3.48	3.40	3.32	3.24	3.18	3.12	3.07
2.9	7.89	5.83	5.64	5.44	5.28	5.11	4.98	4.83	4.60	4.39	4.22	4.06	3.93	3.81	3.70	3.62	3.53	3.45	3.39	3.32	3.27
3.0	8.16	6.17	5.98	5.76	5.60	5.42	5.28	5.13	4.88	4.66	4.47	4.31	4.17	4.04	3.93	3.84	3.75	3.66	3.59	3.53	3.48
3.1	8.43	6.53	6.32	6.10	5.92	5.74	5.59	5.42	5.16	4.93	4.74	4.56	4.42	4.28	4.16	4.07	3.97	3.88	3.81	3.74	3.68
3.2	8.70	6.89	6.68	6.44	6.26	6.06	5.90	5.73	5.45	5.22	5.01	4.83	4.67	4.53	4.40	4.30	4.20	4.11	4.03	3.95	3.90
3.3	8.98	7.27	7.04	6.79	6.60	6.39	6.22	6.05	5.75	5.50	5.29	5.09	4.93	4.78	4.65	4.54	4.44	4.34	4.26	4.18	4.12
3.4	9.25	7.65	7.41	7.15	6.95	6.73	6.55	6.37	6.06	5.80	5.57	5.37	5.20	5.04	4.90	4.79	4.68	4.57	4.49	4.40	4.34
3.5	9.52	8.04	7.78	7.51	7.30	7.08	6.89	6.70	6.38	6.10	5.86	5.65	5.47	5.31	5.16	5.04	4.92	4.81	4.73	4.64	4.57
3.6	9.79	8.43	8.17	7.89	7.67	7.43	7.24	7.03	6.70	6.41	6.15	5.93	5.75	5.58	5.42	5.30	5.17	5.06	4.97	4.87	4.81
3.7	10.06	8.84	8.56	8.27	8.04	7.79	7.59	7.37	7.02	6.72	6.46	6.23	6.03	5.85	5.69	5.56	5.43	5.31	5.22	5.12	5.05
3.8	10.34	9.25	8.97	8.66	8.42	8.16	7.95	7.72	7.36	7.04	6.77	6.53	6.32	6.13	5.96	5.83	5.69	5.57	5.47	5.37	5.29
3.9	10.61	9.68	9.38	9.05	8.80	8.53	8.31	8.08	7.70	7.37	7.08	6.83	6.61	6.42	6.24	6.10	5.96	5.83	5.73	5.62	5.54
4.0	10.88	10.11	9.79	9.46	9.20	8.92	8.69	8.44	8.05	7.70	7.40	7.14	6.92	6.71	6.53	6.38	6.24	6.10	5.99	5.88	5.80
4.1	11.15	10.55	10.22	9.87	9.60	9.31	9.07	8.81	8.40	8.04	7.73	7.46	7.22	7.01	6.82	6.67	6.52	6.38	6.26	6.14	6.06
4.2	11.42	10.99	10.65	10.29	10.01	9.70	9.46	9.19	8.76	8.39	8.07	7.78	7.54	7.32	7.12	6.96	6.80	6.66	6.53	6.41	6.32
4.3	11.70	11.45	11.10	10.72	10.42	10.11	9.85	9.58	9.13	8.74	8.41	8.11	7.86	7.63	7.42	7.26	7.09	6.94	6.81	6.69	6.60
4.4	11.97	11.91	11.54	11.15	10.85	10.52	10.25	9.97	9.50	9.10	8.75	8.45	8.18	7.95	7.73	7.56	7.39	7.23	7.10	6.97	6.87
4.5	12.24	12.38	12.00	11.59	11.28	10.94	10.66	10.37	9.89	9.47	9.11	8.79	8.51	8.27	8.04	7.86	7.69	7.52	7.39	7.25	7.15
4.6	12.51	12.86	12.46	12.04	11.72	11.36	11.08	10.77	10.27	9.84	9.46	9.13	8.85	8.60	8.36	8.18	7.99	7.82	7.68	7.54	7.44
4.7	12.78	13.34	12.94	12.50	12.16	11.80	11.50	11.18	10.67	10.22	9.83	9.49	9.19	8.93	8.69	8.50	8.31	8.13	7.98	7.84	7.73

Continued on next page

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

1¼" Uponor PEX-a — 30% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40ºF 4ºC	45ºF 7ºC	50ºF 10ºC	55ºF 13ºC	60ºF 16ºC	65ºF 18ºC	70ºF 21ºC	80ºF 27ºC	90ºF 32ºC	100ºF 38ºC	110ºF 43ºC	120ºF 49ºC	130ºF 54ºC	140ºF 60ºC	150ºF 66ºC	160ºF 71ºC	170ºF 77ºC	180ºF 82ºC	190ºF 88ºC	200ºF 93ºC
4.8	13.06	13.83	13.42	12.97	12.61	12.24	11.93	11.60	11.07	10.60	10.20	9.85	9.54	9.27	9.02	8.82	8.62	8.44	8.29	8.14	8.03
4.9	13.33	14.33	13.90	13.44	13.07	12.68	12.37	12.03	11.47	10.99	10.58	10.21	9.90	9.61	9.36	9.15	8.94	8.76	8.60	8.44	8.33
5.0	13.60	14.84	14.40	13.92	13.54	13.14	12.81	12.46	11.89	11.39	10.96	10.58	10.26	9.96	9.70	9.48	9.27	9.08	8.91	8.75	8.63
5.1	13.87	15.36	14.90	14.40	14.01	13.60	13.26	12.90	12.31	11.79	11.35	10.96	10.62	10.32	10.04	9.82	9.60	9.40	9.23	9.07	8.94
5.2	14.14	15.88	15.41	14.89	14.49	14.06	13.72	13.34	12.73	12.20	11.74	11.34	10.99	10.68	10.40	10.17	9.94	9.73	9.56	9.39	9.26
5.3	14.42	16.41	15.92	15.40	14.98	14.54	14.18	13.79	13.17	12.62	12.15	11.73	11.37	11.05	10.75	10.52	10.29	10.07	9.89	9.71	9.58
5.4	14.69	16.95	16.45	15.90	15.48	15.02	14.65	14.25	13.60	13.04	12.55	12.12	11.75	11.42	11.12	10.87	10.63	10.41	10.23	10.04	9.91
5.5	14.96	17.50	16.98	16.42	15.98	15.51	15.13	14.72	14.05	13.47	12.97	12.52	12.14	11.80	11.49	11.23	10.99	10.76	10.57	10.38	10.24
5.6	15.23	18.05	17.52	16.94	16.49	16.00	15.61	15.19	14.50	13.90	13.38	12.93	12.53	12.18	11.86	11.60	11.35	11.11	10.91	10.72	10.57
5.7	15.50	18.62	18.06	17.47	17.00	16.51	16.10	15.67	14.96	14.34	13.81	13.34	12.93	12.57	12.24	11.97	11.71	11.47	11.26	11.06	10.91
5.8	15.78	19.18	18.62	18.01	17.53	17.01	16.60	16.15	15.42	14.79	14.24	13.75	13.34	12.96	12.62	12.35	12.08	11.83	11.62	11.41	11.26
5.9	16.05	19.76	19.18	18.55	18.06	17.53	17.10	16.64	15.89	15.24	14.67	14.18	13.75	13.36	13.01	12.73	12.45	12.19	11.98	11.77	11.61
6.0	16.32	20.34	19.74	19.10	18.59	18.05	17.61	17.14	16.37	15.70	15.12	14.60	14.16	13.77	13.41	13.12	12.83	12.57	12.35	12.13	11.96
6.1	16.59	20.93	20.32	19.66	19.14	18.58	18.13	17.64	16.85	16.16	15.56	15.04	14.59	14.18	13.81	13.51	13.21	12.94	12.72	12.49	12.32
6.2	16.86	21.53	20.90	20.22	19.69	19.11	18.65	18.15	17.34	16.63	16.02	15.48	15.01	14.60	14.21	13.91	13.60	13.32	13.09	12.86	12.69
6.3	17.13	22.14	21.49	20.79	20.24	19.66	19.18	18.67	17.83	17.11	16.48	15.92	15.45	15.02	14.62	14.31	14.00	13.71	13.47	13.23	13.06
6.4	17.41	22.75	22.09	21.37	20.81	20.21	19.72	19.19	18.33	17.59	16.94	16.37	15.88	15.44	15.04	14.72	14.40	14.10	13.86	13.61	13.43
6.5	17.68	23.37	22.69	21.95	21.38	20.76	20.26	19.72	18.84	18.08	17.41	16.83	16.33	15.87	15.46	15.13	14.80	14.50	14.25	14.00	13.81
6.6	17.95	24.00	23.30	22.55	21.96	21.32	20.81	20.26	19.35	18.57	17.89	17.29	16.77	16.31	15.89	15.55	15.21	14.90	14.64	14.38	14.19
6.7	18.22	24.63	23.92	23.14	22.54	21.89	21.36	20.80	19.87	19.07	18.37	17.76	17.23	16.75	16.32	15.97	15.62	15.31	15.04	14.78	14.58
6.8	18.49	25.27	24.54	23.75	23.13	22.46	21.92	21.35	20.40	19.58	18.86	18.23	17.69	17.20	16.76	16.40	16.04	15.72	15.45	15.18	14.98
6.9	18.77	25.92	25.17	24.36	23.73	23.05	22.49	21.90	20.93	20.09	19.35	18.71	18.15	17.65	17.20	16.83	16.47	16.13	15.85	15.58	15.37
7.0	19.04	26.58	25.81	24.98	24.33	23.63	23.07	22.46	21.47	20.60	19.85	19.19	18.62	18.11	17.64	17.27	16.90	16.55	16.27	15.99	15.78
7.1	19.31	27.24	26.46	25.61	24.94	24.23	23.65	23.03	22.01	21.13	20.36	19.68	19.10	18.57	18.10	17.71	17.33	16.98	16.69	16.40	16.18
7.2	19.58	27.91	27.11	26.24	25.56	24.83	24.24	23.60	22.56	21.65	20.87	20.17	19.58	19.04	18.55	18.16	17.77	17.41	17.11	16.81	16.59
7.3	19.85	28.59	27.77	26.88	26.18	25.44	24.83	24.18	23.11	22.19	21.38	20.67	20.06	19.52	19.01	18.61	18.21	17.85	17.54	17.24	17.01
7.4	20.13	29.27	28.43	27.52	26.81	26.05	25.43	24.76	23.67	22.73	21.91	21.18	20.56	20.00	19.48	19.07	18.66	18.29	17.97	17.66	17.43
7.5	20.40	29.96	29.10	28.18	27.45	26.67	26.03	25.35	24.24	23.27	22.43	21.69	21.05	20.48	19.95	19.53	19.12	18.73	18.41	18.09	17.86
7.6	20.67	30.66	29.78	28.84	28.09	27.30	26.65	25.95	24.81	23.83	22.96	22.20	21.55	20.97	20.43	20.00	19.57	19.18	18.85	18.53	18.29
7.7	20.94	31.37	30.47	29.50	28.74	27.93	27.27	26.56	25.39	24.38	23.50	22.73	22.06	21.46	20.91	20.47	20.04	19.64	19.30	18.97	18.72
7.8	21.21	32.08	31.16	30.17	29.40	28.57	27.89	27.17	25.98	24.94	24.05	23.25	22.57	21.96	21.40	20.95	20.51	20.10	19.75	19.41	19.16
7.9	21.49	32.80	31.86	30.85	30.06	29.21	28.52	27.78	26.57	25.51	24.60	23.79	23.09	22.47	21.89	21.43	20.98	20.56	20.21	19.86	19.60
8.0	21.76	33.53	32.57	31.54	30.73	29.86	29.16	28.40	27.16	26.09	25.15	24.32	23.61	22.98	22.39	21.92	21.46	21.03	20.67	20.32	20.05

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

1¼" Uponor PEX-a — 40% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
1.5	4.08	2.25	2.15	2.05	1.97	1.88	1.82	1.75	1.64	1.55	1.47	1.40	1.34	1.29	1.25	1.21	1.18	1.14	1.12	1.09	1.07
1.6	4.35	2.51	2.40	2.28	2.19	2.10	2.03	1.95	1.83	1.73	1.64	1.57	1.50	1.45	1.40	1.35	1.32	1.28	1.25	1.22	1.20
1.7	4.62	2.77	2.65	2.52	2.43	2.33	2.25	2.16	2.03	1.92	1.82	1.74	1.67	1.61	1.55	1.50	1.46	1.42	1.39	1.36	1.34
1.8	4.90	3.05	2.92	2.78	2.67	2.56	2.48	2.38	2.24	2.11	2.01	1.92	1.84	1.77	1.71	1.66	1.62	1.57	1.54	1.50	1.48
1.9	5.17	3.34	3.20	3.04	2.93	2.81	2.71	2.61	2.45	2.32	2.20	2.11	2.02	1.95	1.88	1.83	1.78	1.73	1.69	1.65	1.63
2.0	5.44	3.64	3.48	3.32	3.20	3.06	2.96	2.85	2.68	2.53	2.41	2.30	2.21	2.13	2.06	2.00	1.95	1.89	1.85	1.81	1.78
2.1	5.71	3.94	3.78	3.60	3.47	3.33	3.22	3.10	2.91	2.75	2.62	2.51	2.40	2.32	2.24	2.17	2.12	2.06	2.02	1.97	1.94
2.2	5.98	4.26	4.09	3.90	3.75	3.60	3.48	3.36	3.15	2.98	2.84	2.72	2.61	2.51	2.43	2.36	2.30	2.24	2.19	2.14	2.10
2.3	6.26	4.59	4.41	4.20	4.05	3.88	3.76	3.62	3.40	3.22	3.07	2.93	2.82	2.72	2.63	2.55	2.48	2.42	2.37	2.32	2.28
2.4	6.53	4.93	4.73	4.51	4.35	4.17	4.04	3.89	3.66	3.47	3.30	3.16	3.03	2.92	2.83	2.75	2.68	2.61	2.55	2.50	2.45
2.5	6.80	5.29	5.07	4.84	4.66	4.47	4.33	4.18	3.93	3.72	3.54	3.39	3.26	3.14	3.04	2.95	2.88	2.80	2.74	2.68	2.64
2.6	7.07	5.65	5.42	5.17	4.98	4.78	4.63	4.47	4.20	3.98	3.79	3.63	3.49	3.36	3.25	3.16	3.08	3.00	2.94	2.87	2.82
2.7	7.34	6.02	5.77	5.51	5.31	5.10	4.94	4.76	4.48	4.25	4.05	3.87	3.72	3.59	3.48	3.38	3.29	3.21	3.14	3.07	3.02
2.8	7.62	6.40	6.14	5.86	5.65	5.43	5.26	5.07	4.77	4.52	4.31	4.13	3.97	3.83	3.70	3.60	3.51	3.42	3.35	3.28	3.22
2.9	7.89	6.79	6.51	6.22	6.00	5.76	5.58	5.39	5.07	4.80	4.58	4.39	4.22	4.07	3.94	3.83	3.73	3.64	3.57	3.49	3.43
3.0	8.16	7.19	6.90	6.59	6.36	6.11	5.92	5.71	5.38	5.10	4.86	4.65	4.47	4.32	4.18	4.06	3.96	3.86	3.79	3.70	3.64
3.1	8.43	7.60	7.29	6.97	6.72	6.46	6.26	6.04	5.69	5.39	5.14	4.93	4.74	4.57	4.43	4.30	4.20	4.09	4.01	3.92	3.86
3.2	8.70	8.01	7.70	7.35	7.10	6.82	6.61	6.38	6.01	5.70	5.44	5.21	5.01	4.84	4.68	4.55	4.44	4.33	4.24	4.15	4.08
3.3	8.98	8.44	8.11	7.75	7.48	7.19	6.97	6.73	6.34	6.01	5.73	5.50	5.28	5.10	4.94	4.81	4.69	4.57	4.48	4.38	4.31
3.4	9.25	8.88	8.53	8.15	7.87	7.57	7.33	7.08	6.67	6.33	6.04	5.79	5.57	5.38	5.21	5.06	4.94	4.82	4.72	4.62	4.54
3.5	9.52	9.33	8.96	8.57	8.27	7.95	7.71	7.44	7.02	6.66	6.35	6.09	5.86	5.66	5.48	5.33	5.20	5.07	4.97	4.86	4.78
3.6	9.79	9.78	9.40	8.99	8.68	8.35	8.09	7.81	7.37	6.99	6.67	6.40	6.15	5.95	5.76	5.60	5.46	5.33	5.23	5.11	5.03
3.7	10.06	10.25	9.85	9.42	9.10	8.75	8.48	8.19	7.73	7.33	7.00	6.71	6.46	6.24	6.04	5.88	5.74	5.59	5.49	5.36	5.28
3.8	10.34	10.72	10.31	9.86	9.52	9.16	8.88	8.58	8.09	7.68	7.33	7.03	6.77	6.54	6.33	6.16	6.01	5.86	5.75	5.62	5.53
3.9	10.61	11.21	10.78	10.31	9.96	9.58	9.28	8.97	8.46	8.03	7.67	7.36	7.08	6.84	6.63	6.45	6.29	6.14	6.02	5.89	5.79
4.0	10.88	11.70	11.25	10.76	10.40	10.00	9.70	9.37	8.84	8.40	8.02	7.69	7.40	7.16	6.93	6.75	6.58	6.42	6.30	6.16	6.06
4.1	11.15	12.20	11.74	11.23	10.85	10.44	10.12	9.78	9.23	8.77	8.37	8.03	7.73	7.47	7.24	7.05	6.88	6.71	6.58	6.44	6.33
4.2	11.42	12.71	12.23	11.70	11.30	10.88	10.55	10.20	9.63	9.14	8.73	8.38	8.07	7.80	7.56	7.35	7.18	7.00	6.87	6.72	6.61
4.3	11.70	13.23	12.73	12.18	11.77	11.33	10.99	10.62	10.03	9.52	9.10	8.73	8.41	8.13	7.88	7.66	7.48	7.30	7.16	7.01	6.89
4.4	11.97	13.76	13.24	12.67	12.25	11.79	11.43	11.05	10.44	9.91	9.47	9.09	8.75	8.46	8.20	7.98	7.79	7.60	7.46	7.30	7.18
4.5	12.24	14.30	13.76	13.17	12.73	12.25	11.88	11.49	10.85	10.31	9.85	9.46	9.11	8.80	8.54	8.31	8.11	7.91	7.76	7.60	7.47
4.6	12.51	14.84	14.28	13.67	13.22	12.72	12.34	11.94	11.27	10.71	10.24	9.83	9.46	9.15	8.87	8.64	8.43	8.22	8.07	7.90	7.77
4.7	12.78	15.40	14.82	14.19	13.72	13.20	12.81	12.39	11.70	11.12	10.63	10.21	9.83	9.51	9.22	8.97	8.76	8.54	8.39	8.21	8.07

Continued on next page

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

Appendix G:

Hydronic friction loss tables

1¼" Uponor PEX-a — 40% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
4.8	13.06	15.96	15.36	14.71	14.22	13.69	13.29	12.85	12.14	11.54	11.03	10.59	10.20	9.87	9.57	9.31	9.09	8.87	8.70	8.52	8.38
4.9	13.33	16.53	15.92	15.24	14.74	14.19	13.77	13.32	12.58	11.96	11.44	10.98	10.58	10.23	9.92	9.66	9.43	9.20	9.03	8.84	8.70
5.0	13.60	17.12	16.48	15.78	15.26	14.69	14.26	13.79	13.03	12.39	11.85	11.38	10.96	10.60	10.28	10.01	9.77	9.54	9.36	9.16	9.02
5.1	13.87	17.70	17.04	16.33	15.79	15.20	14.76	14.27	13.49	12.83	12.27	11.78	11.35	10.98	10.65	10.37	10.12	9.88	9.70	9.49	9.34
5.2	14.14	18.30	17.62	16.88	16.32	15.72	15.26	14.76	13.96	13.27	12.69	12.19	11.74	11.36	11.02	10.73	10.48	10.22	10.04	9.82	9.67
5.3	14.42	18.91	18.21	17.44	16.87	16.25	15.77	15.26	14.43	13.72	13.12	12.61	12.15	11.75	11.40	11.10	10.84	10.58	10.38	10.16	10.00
5.4	14.69	19.52	18.80	18.01	17.42	16.78	16.29	15.76	14.90	14.18	13.56	13.03	12.55	12.15	11.78	11.47	11.20	10.93	10.73	10.51	10.34
5.5	14.96	20.15	19.40	18.59	17.98	17.32	16.82	16.27	15.39	14.64	14.00	13.45	12.96	12.55	12.17	11.85	11.57	11.30	11.09	10.86	10.69
5.6	15.23	20.78	20.01	19.18	18.55	17.87	17.35	16.79	15.88	15.11	14.45	13.89	13.38	12.95	12.56	12.24	11.95	11.67	11.45	11.21	11.04
5.7	15.50	21.42	20.63	19.77	19.13	18.43	17.89	17.32	16.38	15.58	14.91	14.33	13.81	13.36	12.96	12.63	12.33	12.04	11.82	11.57	11.39
5.8	15.78	22.06	21.25	20.37	19.71	18.99	18.44	17.85	16.88	16.06	15.37	14.77	14.24	13.78	13.37	13.02	12.72	12.42	12.19	11.94	11.75
5.9	16.05	22.72	21.89	20.98	20.30	19.56	19.00	18.39	17.39	16.55	15.84	15.22	14.67	14.20	13.78	13.42	13.11	12.80	12.57	12.31	12.11
6.0	16.32	23.38	22.53	21.60	20.90	20.14	19.56	18.93	17.91	17.05	16.32	15.68	15.12	14.63	14.20	13.83	13.51	13.19	12.95	12.68	12.48
6.1	16.59	24.06	23.18	22.22	21.51	20.73	20.13	19.48	18.44	17.55	16.80	16.14	15.56	15.07	14.62	14.24	13.91	13.58	13.34	13.06	12.86
6.2	16.86	24.74	23.84	22.85	22.12	21.32	20.71	20.04	18.97	18.06	17.28	16.61	16.02	15.51	15.05	14.66	14.32	13.98	13.73	13.45	13.24
6.3	17.13	25.43	24.50	23.49	22.74	21.92	21.29	20.61	19.51	18.57	17.78	17.09	16.48	15.95	15.48	15.08	14.74	14.39	14.13	13.84	13.62
6.4	17.41	26.12	25.18	24.14	23.37	22.53	21.88	21.18	20.05	19.09	18.28	17.57	16.94	16.40	15.92	15.51	15.15	14.80	14.53	14.23	14.01
6.5	17.68	26.83	25.86	24.80	24.00	23.14	22.48	21.76	20.60	19.62	18.78	18.06	17.41	16.86	16.36	15.94	15.58	15.21	14.94	14.63	14.40
6.6	17.95	27.54	26.55	25.46	24.65	23.76	23.08	22.35	21.16	20.15	19.29	18.55	17.89	17.32	16.81	16.38	16.01	15.63	15.35	15.03	14.80
6.7	18.22	28.26	27.24	26.13	25.30	24.39	23.70	22.94	21.72	20.69	19.81	19.05	18.37	17.79	17.27	16.83	16.44	16.06	15.77	15.44	15.21
6.8	18.49	28.99	27.95	26.81	25.95	25.03	24.31	23.54	22.30	21.23	20.33	19.55	18.86	18.26	17.73	17.28	16.88	16.49	16.19	15.86	15.62
6.9	18.77	29.73	28.66	27.49	26.62	25.67	24.94	24.15	22.87	21.78	20.86	20.06	19.35	18.74	18.20	17.73	17.33	16.92	16.62	16.28	16.03
7.0	19.04	30.47	29.38	28.19	27.29	26.32	25.57	24.77	23.46	22.34	21.40	20.58	19.85	19.23	18.67	18.19	17.78	17.36	17.05	16.70	16.45
7.1	19.31	31.23	30.11	28.89	27.97	26.98	26.21	25.39	24.05	22.91	21.94	21.10	20.36	19.72	19.14	18.65	18.23	17.81	17.49	17.13	16.87
7.2	19.58	31.99	30.84	29.59	28.66	27.64	26.86	26.01	24.64	23.48	22.49	21.63	20.87	20.21	19.62	19.12	18.69	18.26	17.93	17.57	17.30
7.3	19.85	32.76	31.59	30.31	29.35	28.31	27.51	26.65	25.25	24.05	23.04	22.16	21.38	20.71	20.11	19.60	19.16	18.71	18.38	18.01	17.73
7.4	20.13	33.53	32.34	31.03	30.05	28.99	28.17	27.29	25.85	24.63	23.60	22.70	21.90	21.22	20.60	20.08	19.63	19.17	18.83	18.45	18.17
7.5	20.40	34.32	33.10	31.76	30.76	29.68	28.84	27.94	26.47	25.22	24.17	23.25	22.43	21.73	21.10	20.57	20.10	19.64	19.29	18.90	18.61
7.6	20.67	35.11	33.86	32.50	31.48	30.37	29.51	28.59	27.09	25.82	24.74	23.80	22.96	22.25	21.60	21.06	20.58	20.11	19.75	19.35	19.06
7.7	20.94	35.91	34.64	33.24	32.20	31.07	30.19	29.25	27.72	26.42	25.31	24.36	23.50	22.77	22.11	21.55	21.07	20.58	20.22	19.81	19.51
7.8	21.21	36.72	35.42	33.99	32.93	31.77	30.88	29.92	28.35	27.02	25.90	24.92	24.05	23.30	22.63	22.06	21.56	21.06	20.69	20.27	19.97
7.9	21.49	37.53	36.20	34.75	33.67	32.48	31.57	30.59	29.00	27.64	26.49	25.49	24.60	23.83	23.15	22.56	22.06	21.55	21.17	20.74	20.43
8.0	21.76	38.36	37.00	35.52	34.41	33.20	32.28	31.27	29.64	28.25	27.08	26.06	25.15	24.37	23.67	23.07	22.56	22.04	21.65	21.21	20.89

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

Appendix G:

Hydronic friction loss tables

1¼" Uponor PEX-a — 50% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40ºF 4ºC	45ºF 7ºC	50ºF 10ºC	55ºF 13ºC	60ºF 16ºC	65ºF 18ºC	70ºF 21ºC	80ºF 27ºC	90ºF 32ºC	100ºF 38ºC	110ºF 43ºC	120ºF 49ºC	130ºF 54ºC	140ºF 60ºC	150ºF 66ºC	160ºF 71ºC	170ºF 77ºC	180ºF 82ºC	190ºF 88ºC	200ºF 93ºC
1.5	4.08	2.58	2.46	2.33	2.23	2.12	2.04	1.96	1.82	1.71	1.61	1.53	1.46	1.40	1.35	1.30	1.26	1.22	1.19	1.16	1.13
1.6	4.35	2.86	2.73	2.59	2.48	2.37	2.28	2.18	2.03	1.91	1.80	1.71	1.63	1.57	1.51	1.45	1.41	1.37	1.33	1.30	1.27
1.7	4.62	3.16	3.02	2.86	2.74	2.62	2.52	2.42	2.25	2.11	2.00	1.90	1.81	1.74	1.67	1.62	1.56	1.52	1.48	1.44	1.41
1.8	4.90	3.48	3.32	3.15	3.02	2.88	2.78	2.66	2.48	2.33	2.20	2.09	2.00	1.92	1.85	1.78	1.73	1.68	1.63	1.59	1.56
1.9	5.17	3.80	3.63	3.44	3.30	3.15	3.04	2.92	2.72	2.56	2.42	2.30	2.20	2.11	2.03	1.96	1.90	1.84	1.79	1.75	1.71
2.0	5.44	4.14	3.95	3.75	3.60	3.44	3.31	3.18	2.97	2.79	2.64	2.51	2.40	2.30	2.22	2.14	2.08	2.02	1.96	1.92	1.87
2.1	5.71	4.49	4.29	4.07	3.91	3.73	3.60	3.45	3.22	3.03	2.87	2.73	2.61	2.50	2.41	2.33	2.26	2.19	2.14	2.09	2.04
2.2	5.98	4.85	4.63	4.40	4.22	4.03	3.89	3.74	3.49	3.28	3.11	2.96	2.83	2.71	2.61	2.53	2.45	2.38	2.32	2.26	2.21
2.3	6.26	5.22	4.99	4.74	4.55	4.35	4.19	4.03	3.76	3.54	3.35	3.19	3.05	2.93	2.82	2.73	2.65	2.57	2.50	2.45	2.39
2.4	6.53	5.60	5.35	5.09	4.89	4.67	4.51	4.33	4.05	3.81	3.61	3.44	3.29	3.16	3.04	2.94	2.85	2.77	2.70	2.64	2.58
2.5	6.80	5.99	5.73	5.45	5.23	5.01	4.83	4.64	4.34	4.09	3.87	3.69	3.53	3.39	3.27	3.16	3.06	2.98	2.90	2.83	2.77
2.6	7.07	6.40	6.12	5.82	5.59	5.35	5.16	4.96	4.64	4.37	4.14	3.94	3.77	3.63	3.50	3.38	3.28	3.19	3.11	3.04	2.97
2.7	7.34	6.81	6.52	6.20	5.96	5.70	5.50	5.29	4.95	4.66	4.42	4.21	4.03	3.87	3.73	3.61	3.51	3.41	3.32	3.24	3.17
2.8	7.62	7.24	6.93	6.59	6.34	6.06	5.85	5.63	5.27	4.96	4.70	4.48	4.29	4.13	3.98	3.85	3.74	3.63	3.54	3.46	3.38
2.9	7.89	7.68	7.35	6.99	6.72	6.43	6.21	5.97	5.59	5.27	5.00	4.76	4.56	4.39	4.23	4.09	3.97	3.86	3.76	3.68	3.60
3.0	8.16	8.12	7.78	7.40	7.12	6.81	6.58	6.33	5.93	5.59	5.30	5.05	4.84	4.65	4.49	4.34	4.22	4.10	3.99	3.91	3.82
3.1	8.43	8.58	8.22	7.82	7.52	7.20	6.96	6.69	6.27	5.91	5.61	5.35	5.12	4.93	4.75	4.60	4.47	4.34	4.23	4.14	4.05
3.2	8.70	9.05	8.67	8.25	7.94	7.60	7.34	7.07	6.62	6.24	5.92	5.65	5.41	5.21	5.02	4.86	4.72	4.59	4.47	4.38	4.28
3.3	8.98	9.53	9.13	8.69	8.36	8.01	7.74	7.45	6.98	6.58	6.25	5.96	5.71	5.49	5.30	5.13	4.98	4.85	4.72	4.62	4.52
3.4	9.25	10.02	9.60	9.14	8.80	8.43	8.14	7.84	7.35	6.93	6.58	6.28	6.02	5.79	5.59	5.41	5.25	5.11	4.98	4.87	4.77
3.5	9.52	10.52	10.08	9.60	9.24	8.85	8.56	8.24	7.72	7.29	6.92	6.60	6.33	6.09	5.88	5.69	5.53	5.38	5.24	5.13	5.02
3.6	9.79	11.03	10.57	10.07	9.69	9.29	8.98	8.64	8.11	7.65	7.26	6.93	6.65	6.40	6.17	5.98	5.81	5.65	5.51	5.39	5.27
3.7	10.06	11.55	11.07	10.55	10.16	9.73	9.41	9.06	8.50	8.02	7.62	7.27	6.97	6.71	6.48	6.27	6.10	5.93	5.78	5.66	5.54
3.8	10.34	12.08	11.58	11.03	10.63	10.18	9.85	9.48	8.90	8.40	7.98	7.62	7.30	7.03	6.79	6.57	6.39	6.21	6.06	5.93	5.80
3.9	10.61	12.62	12.10	11.53	11.11	10.65	10.29	9.91	9.30	8.79	8.35	7.97	7.64	7.36	7.10	6.88	6.69	6.51	6.34	6.21	6.08
4.0	10.88	13.17	12.63	12.04	11.59	11.12	10.75	10.35	9.72	9.18	8.72	8.33	7.99	7.69	7.43	7.19	6.99	6.80	6.63	6.49	6.36
4.1	11.15	13.73	13.16	12.55	12.09	11.59	11.21	10.80	10.14	9.58	9.10	8.70	8.34	8.03	7.75	7.51	7.30	7.11	6.93	6.78	6.64
4.2	11.42	14.30	13.71	13.08	12.60	12.08	11.69	11.26	10.57	9.99	9.49	9.07	8.70	8.38	8.09	7.84	7.62	7.41	7.23	7.08	6.93
4.3	11.70	14.87	14.27	13.61	13.11	12.58	12.17	11.72	11.01	10.40	9.89	9.45	9.06	8.73	8.43	8.17	7.94	7.73	7.54	7.38	7.22
4.4	11.97	15.46	14.84	14.15	13.64	13.08	12.66	12.20	11.46	10.83	10.29	9.83	9.44	9.09	8.78	8.51	8.27	8.05	7.85	7.69	7.53
4.5	12.24	16.06	15.41	14.70	14.17	13.59	13.15	12.68	11.91	11.26	10.70	10.23	9.81	9.45	9.13	8.85	8.61	8.38	8.17	8.00	7.83
4.6	12.51	16.67	16.00	15.26	14.71	14.12	13.66	13.16	12.37	11.69	11.12	10.63	10.20	9.82	9.49	9.20	8.95	8.71	8.49	8.32	8.14
4.7	12.78	17.29	16.59	15.83	15.26	14.65	14.17	13.66	12.84	12.14	11.54	11.03	10.59	10.20	9.86	9.56	9.29	9.05	8.82	8.64	8.46

Continued on next page

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

Appendix G:

Hydronic friction loss tables

1¼" Uponor PEX-a — 50% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
4.8	13.06	17.91	17.19	16.41	15.82	15.18	14.69	14.16	13.31	12.59	11.98	11.45	10.99	10.59	10.23	9.92	9.64	9.39	9.16	8.97	8.78
4.9	13.33	18.55	17.81	17.00	16.39	15.73	15.22	14.68	13.80	13.05	12.41	11.87	11.39	10.98	10.61	10.29	10.00	9.74	9.50	9.30	9.11
5.0	13.60	19.20	18.43	17.59	16.96	16.28	15.76	15.20	14.29	13.52	12.86	12.29	11.80	11.37	10.99	10.66	10.37	10.09	9.85	9.64	9.44
5.1	13.87	19.85	19.06	18.20	17.55	16.85	16.31	15.72	14.79	13.99	13.31	12.73	12.22	11.78	11.38	11.04	10.73	10.45	10.20	9.99	9.78
5.2	14.14	20.51	19.70	18.81	18.14	17.42	16.86	16.26	15.29	14.47	13.77	13.17	12.64	12.18	11.78	11.42	11.11	10.82	10.55	10.34	10.13
5.3	14.42	21.19	20.35	19.43	18.74	18.00	17.42	16.80	15.80	14.96	14.23	13.61	13.07	12.60	12.18	11.81	11.49	11.19	10.92	10.69	10.47
5.4	14.69	21.87	21.01	20.06	19.35	18.58	17.99	17.35	16.32	15.45	14.70	14.07	13.51	13.02	12.59	12.21	11.88	11.57	11.29	11.05	10.83
5.5	14.96	22.56	21.67	20.70	19.97	19.18	18.57	17.91	16.85	15.95	15.18	14.52	13.95	13.45	13.00	12.61	12.27	11.95	11.66	11.42	11.19
5.6	15.23	23.26	22.35	21.35	20.60	19.78	19.15	18.48	17.39	16.46	15.67	14.99	14.40	13.88	13.42	13.02	12.67	12.34	12.04	11.79	11.55
5.7	15.50	23.97	23.03	22.00	21.23	20.39	19.75	19.05	17.93	16.97	16.16	15.46	14.85	14.32	13.85	13.43	13.07	12.73	12.42	12.17	11.92
5.8	15.78	24.69	23.72	22.67	21.87	21.01	20.35	19.63	18.48	17.50	16.66	15.94	15.31	14.76	14.28	13.85	13.48	13.13	12.81	12.55	12.30
5.9	16.05	25.42	24.43	23.34	22.52	21.64	20.96	20.22	19.03	18.02	17.16	16.43	15.78	15.22	14.72	14.28	13.89	13.53	13.21	12.94	12.68
6.0	16.32	26.16	25.14	24.02	23.18	22.27	21.57	20.82	19.60	18.56	17.68	16.92	16.25	15.67	15.16	14.71	14.31	13.94	13.61	13.33	13.06
6.1	16.59	26.90	25.86	24.71	23.85	22.92	22.20	21.42	20.17	19.10	18.19	17.41	16.73	16.14	15.61	15.15	14.74	14.36	14.01	13.73	13.45
6.2	16.86	27.66	26.58	25.41	24.53	23.57	22.83	22.03	20.75	19.65	18.72	17.92	17.22	16.61	16.06	15.59	15.17	14.78	14.42	14.13	13.85
6.3	17.13	28.42	27.32	26.12	25.21	24.22	23.47	22.65	21.33	20.21	19.25	18.43	17.71	17.08	16.52	16.04	15.60	15.20	14.84	14.54	14.25
6.4	17.41	29.20	28.06	26.83	25.90	24.89	24.11	23.28	21.92	20.77	19.79	18.94	18.21	17.56	16.99	16.49	16.05	15.63	15.26	14.96	14.66
6.5	17.68	29.98	28.82	27.55	26.60	25.56	24.77	23.91	22.52	21.34	20.33	19.47	18.71	18.05	17.46	16.95	16.49	16.07	15.69	15.38	15.07
6.6	17.95	30.77	29.58	28.28	27.31	26.25	25.43	24.55	23.13	21.92	20.88	20.00	19.22	18.54	17.94	17.41	16.95	16.51	16.12	15.80	15.48
6.7	18.22	31.57	30.35	29.02	28.02	26.94	26.10	25.20	23.74	22.50	21.44	20.53	19.74	19.04	18.42	17.88	17.41	16.96	16.56	16.23	15.90
6.8	18.49	32.37	31.13	29.77	28.75	27.63	26.78	25.85	24.36	23.09	22.00	21.07	20.26	19.54	18.91	18.36	17.87	17.41	17.00	16.66	16.33
6.9	18.77	33.19	31.92	30.53	29.48	28.34	27.46	26.52	24.99	23.69	22.57	21.62	20.78	20.05	19.41	18.84	18.34	17.87	17.45	17.10	16.76
7.0	19.04	34.02	32.71	31.29	30.22	29.05	28.15	27.19	25.62	24.29	23.15	22.17	21.32	20.57	19.91	19.33	18.81	18.33	17.90	17.55	17.20
7.1	19.31	34.85	33.52	32.06	30.96	29.77	28.85	27.86	26.26	24.90	23.73	22.73	21.86	21.09	20.41	19.82	19.29	18.80	18.36	18.00	17.64
7.2	19.58	35.69	34.33	32.84	31.72	30.50	29.56	28.55	26.91	25.51	24.32	23.30	22.40	21.62	20.93	20.32	19.78	19.28	18.82	18.45	18.08
7.3	19.85	36.54	35.15	33.63	32.48	31.23	30.28	29.24	27.56	26.14	24.92	23.87	22.96	22.15	21.44	20.82	20.27	19.76	19.29	18.91	18.54
7.4	20.13	37.40	35.98	34.42	33.25	31.98	31.00	29.94	28.23	26.77	25.52	24.45	23.51	22.69	21.97	21.33	20.76	20.24	19.77	19.38	18.99
7.5	20.40	38.27	36.82	35.23	34.03	32.73	31.73	30.64	28.89	27.40	26.13	25.03	24.08	23.24	22.49	21.84	21.27	20.73	20.24	19.85	19.45
7.6	20.67	39.15	37.66	36.04	34.82	33.49	32.46	31.36	29.57	28.04	26.74	25.62	24.64	23.79	23.03	22.36	21.77	21.22	20.73	20.32	19.92
7.7	20.94	40.03	38.52	36.86	35.61	34.25	33.21	32.08	30.25	28.69	27.36	26.22	25.22	24.34	23.57	22.89	22.28	21.72	21.22	20.80	20.39
7.8	21.21	40.92	39.38	37.69	36.41	35.02	33.96	32.80	30.94	29.35	27.99	26.82	25.80	24.91	24.11	23.42	22.80	22.23	21.71	21.28	20.87
7.9	21.49	41.83	40.25	38.52	37.22	35.80	34.72	33.54	31.63	30.01	28.62	27.43	26.39	25.47	24.66	23.95	23.32	22.74	22.21	21.77	21.35
8.0	21.76	42.74	41.13	39.37	38.04	36.59	35.48	34.28	32.34	30.68	29.26	28.04	26.98	26.05	25.22	24.49	23.85	23.25	22.71	22.27	21.83

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

1½" Uponor PEX-a — 100% Water — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
1.5	5.68	1.13	1.08	1.01	1.00	0.98	0.96	0.94	0.91	0.89	0.86	0.84	0.82	0.81	0.79	0.78	0.76	0.75	0.74	0.73	0.72
1.6	6.06	1.26	1.20	1.14	1.11	1.09	1.07	1.05	1.02	0.99	0.97	0.94	0.92	0.90	0.89	0.87	0.86	0.84	0.83	0.82	0.81
1.7	6.44	1.40	1.34	1.26	1.24	1.21	1.19	1.17	1.14	1.10	1.08	1.05	1.03	1.01	0.99	0.97	0.95	0.94	0.92	0.91	0.90
1.8	6.82	1.55	1.48	1.39	1.37	1.34	1.32	1.30	1.26	1.22	1.19	1.16	1.14	1.11	1.09	1.07	1.05	1.04	1.02	1.01	1.00
1.9	7.20	1.70	1.62	1.53	1.50	1.47	1.45	1.42	1.38	1.34	1.31	1.28	1.25	1.22	1.20	1.18	1.16	1.14	1.13	1.11	1.10
2.0	7.58	1.86	1.77	1.68	1.64	1.61	1.59	1.56	1.51	1.47	1.43	1.40	1.37	1.34	1.32	1.29	1.27	1.25	1.23	1.22	1.20
2.1	7.96	2.02	1.93	1.82	1.79	1.76	1.73	1.70	1.65	1.60	1.56	1.52	1.49	1.46	1.43	1.41	1.39	1.36	1.35	1.33	1.31
2.2	8.34	2.19	2.09	1.98	1.94	1.91	1.88	1.84	1.79	1.74	1.69	1.66	1.62	1.59	1.56	1.53	1.51	1.48	1.46	1.44	1.42
2.3	8.71	2.37	2.26	2.14	2.10	2.06	2.03	1.99	1.93	1.88	1.83	1.79	1.75	1.72	1.69	1.66	1.63	1.60	1.58	1.56	1.54
2.4	9.09	2.55	2.44	2.31	2.26	2.22	2.18	2.15	2.08	2.03	1.98	1.93	1.89	1.85	1.82	1.79	1.76	1.73	1.71	1.68	1.66
2.5	9.47	2.74	2.62	2.48	2.43	2.39	2.35	2.31	2.24	2.18	2.12	2.08	2.03	1.99	1.96	1.92	1.89	1.86	1.84	1.81	1.79
2.6	9.85	2.93	2.80	2.65	2.61	2.56	2.52	2.47	2.40	2.33	2.28	2.23	2.18	2.14	2.10	2.06	2.03	2.00	1.97	1.94	1.92
2.7	10.23	3.13	2.99	2.83	2.78	2.73	2.69	2.64	2.57	2.50	2.43	2.38	2.33	2.28	2.24	2.20	2.17	2.14	2.11	2.08	2.05
2.8	10.61	3.34	3.19	3.02	2.97	2.91	2.87	2.82	2.74	2.66	2.60	2.54	2.48	2.44	2.39	2.35	2.32	2.28	2.25	2.22	2.19
2.9	10.99	3.55	3.39	3.21	3.16	3.10	3.05	3.00	2.91	2.83	2.76	2.70	2.64	2.59	2.55	2.50	2.46	2.43	2.39	2.36	2.33
3.0	11.37	3.76	3.60	3.41	3.35	3.29	3.24	3.18	3.09	3.01	2.93	2.87	2.81	2.76	2.71	2.66	2.62	2.58	2.54	2.51	2.48
3.1	11.75	3.98	3.81	3.61	3.55	3.48	3.43	3.37	3.27	3.19	3.11	3.04	2.98	2.92	2.87	2.82	2.78	2.74	2.70	2.66	2.63
3.2	12.12	4.21	4.03	3.82	3.75	3.68	3.63	3.57	3.46	3.37	3.29	3.22	3.15	3.09	3.04	2.99	2.94	2.90	2.86	2.82	2.79
3.3	12.50	4.45	4.25	4.03	3.96	3.89	3.83	3.77	3.66	3.56	3.48	3.40	3.33	3.27	3.21	3.15	3.11	3.06	3.02	2.98	2.94
3.4	12.88	4.68	4.48	4.25	4.18	4.10	4.04	3.97	3.86	3.76	3.67	3.58	3.51	3.44	3.38	3.33	3.28	3.23	3.18	3.14	3.11
3.5	13.26	4.93	4.72	4.47	4.40	4.32	4.25	4.18	4.06	3.95	3.86	3.77	3.70	3.63	3.56	3.50	3.45	3.40	3.35	3.31	3.27
3.6	13.64	5.18	4.95	4.70	4.62	4.54	4.47	4.39	4.27	4.16	4.06	3.97	3.89	3.81	3.75	3.69	3.63	3.58	3.53	3.48	3.44
3.7	14.02	5.43	5.20	4.93	4.85	4.76	4.69	4.61	4.48	4.36	4.26	4.17	4.08	4.01	3.94	3.87	3.81	3.76	3.71	3.66	3.62
3.8	14.40	5.69	5.45	5.17	5.08	4.99	4.92	4.84	4.70	4.58	4.47	4.37	4.28	4.20	4.13	4.06	4.00	3.94	3.89	3.84	3.79
3.9	14.78	5.96	5.70	5.41	5.32	5.23	5.15	5.06	4.92	4.79	4.68	4.58	4.48	4.40	4.32	4.25	4.19	4.13	4.07	4.02	3.97
4.0	15.16	6.23	5.96	5.66	5.57	5.47	5.38	5.30	5.15	5.01	4.90	4.79	4.69	4.60	4.52	4.45	4.38	4.32	4.26	4.21	4.16
4.1	15.53	6.50	6.23	5.91	5.82	5.71	5.62	5.53	5.38	5.24	5.12	5.00	4.90	4.81	4.73	4.65	4.58	4.52	4.46	4.40	4.35
4.2	15.91	6.79	6.50	6.17	6.07	5.96	5.87	5.78	5.61	5.47	5.34	5.22	5.12	5.02	4.94	4.86	4.78	4.72	4.65	4.60	4.54
4.3	16.29	7.07	6.77	6.43	6.33	6.21	6.12	6.02	5.85	5.70	5.57	5.45	5.34	5.24	5.15	5.07	4.99	4.92	4.86	4.79	4.74
4.4	16.67	7.36	7.05	6.70	6.59	6.47	6.37	6.27	6.10	5.94	5.80	5.68	5.56	5.46	5.37	5.28	5.20	5.13	5.06	5.00	4.94
4.5	17.05	7.66	7.34	6.97	6.86	6.73	6.63	6.53	6.35	6.18	6.04	5.91	5.79	5.69	5.59	5.50	5.42	5.34	5.27	5.20	5.14
4.6	17.43	7.96	7.63	7.25	7.13	7.00	6.90	6.79	6.60	6.43	6.28	6.15	6.02	5.91	5.81	5.72	5.63	5.55	5.48	5.41	5.35
4.7	17.81	8.27	7.92	7.53	7.41	7.27	7.17	7.05	6.86	6.68	6.53	6.39	6.26	6.15	6.04	5.94	5.86	5.77	5.70	5.63	5.56

Continued on next page

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

Appendix G:

Hydronic friction loss tables

1½" Uponor PEX-a — 100% Water — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
4.8	18.19	8.58	8.22	7.82	7.69	7.55	7.44	7.32	7.12	6.94	6.78	6.63	6.50	6.38	6.27	6.17	6.08	6.00	5.92	5.85	5.78
4.9	18.57	8.90	8.53	8.11	7.97	7.83	7.72	7.59	7.38	7.20	7.03	6.88	6.75	6.62	6.51	6.41	6.31	6.22	6.14	6.07	6.00
5.0	18.94	9.22	8.84	8.40	8.26	8.12	8.00	7.87	7.66	7.46	7.29	7.14	6.99	6.87	6.75	6.64	6.55	6.45	6.37	6.29	6.22
5.1	19.32	9.55	9.15	8.70	8.56	8.41	8.28	8.15	7.93	7.73	7.55	7.39	7.25	7.12	7.00	6.88	6.78	6.69	6.60	6.52	6.45
5.2	19.70	9.88	9.47	9.01	8.86	8.70	8.58	8.44	8.21	8.00	7.82	7.65	7.50	7.37	7.24	7.13	7.02	6.93	6.84	6.75	6.68
5.3	20.08	10.22	9.80	9.32	9.16	9.00	8.87	8.73	8.49	8.28	8.09	7.92	7.77	7.62	7.50	7.38	7.27	7.17	7.08	6.99	6.91
5.4	20.46	10.56	10.13	9.63	9.47	9.31	9.17	9.03	8.78	8.56	8.37	8.19	8.03	7.88	7.75	7.63	7.52	7.41	7.32	7.23	7.15
5.5	20.84	10.91	10.46	9.95	9.79	9.62	9.48	9.33	9.07	8.85	8.64	8.46	8.30	8.15	8.01	7.89	7.77	7.66	7.56	7.47	7.39
5.6	21.22	11.26	10.80	10.27	10.11	9.93	9.78	9.63	9.37	9.14	8.93	8.74	8.57	8.42	8.28	8.15	8.03	7.92	7.81	7.72	7.63
5.7	21.60	11.62	11.14	10.60	10.43	10.25	10.10	9.94	9.67	9.43	9.22	9.02	8.85	8.69	8.54	8.41	8.29	8.17	8.07	7.97	7.88
5.8	21.98	11.98	11.49	10.93	10.76	10.57	10.42	10.25	9.98	9.73	9.51	9.31	9.13	8.96	8.82	8.68	8.55	8.43	8.33	8.23	8.13
5.9	22.35	12.35	11.84	11.27	11.09	10.90	10.74	10.57	10.28	10.03	9.80	9.60	9.41	9.24	9.09	8.95	8.82	8.70	8.59	8.48	8.39
6.0	22.73	12.72	12.20	11.61	11.42	11.23	11.06	10.89	10.60	10.34	10.10	9.89	9.70	9.53	9.37	9.22	9.09	8.96	8.85	8.75	8.65
6.1	23.11	13.10	12.56	11.96	11.77	11.56	11.39	11.22	10.92	10.65	10.41	10.19	9.99	9.82	9.65	9.50	9.37	9.24	9.12	9.01	8.91
6.2	23.49	13.48	12.93	12.31	12.11	11.90	11.73	11.55	11.24	10.96	10.71	10.49	10.29	10.11	9.94	9.79	9.64	9.51	9.39	9.28	9.18
6.3	23.87	13.86	13.30	12.66	12.46	12.25	12.07	11.88	11.56	11.28	11.03	10.80	10.59	10.40	10.23	10.07	9.93	9.79	9.67	9.55	9.44
6.4	24.25	14.26	13.68	13.02	12.81	12.59	12.41	12.22	11.89	11.60	11.34	11.11	10.89	10.70	10.52	10.36	10.21	10.07	9.95	9.83	9.72
6.5	24.63	14.65	14.06	13.39	13.17	12.95	12.76	12.56	12.23	11.93	11.66	11.42	11.20	11.00	10.82	10.66	10.50	10.36	10.23	10.11	9.99
6.6	25.01	15.05	14.45	13.76	13.54	13.30	13.11	12.91	12.57	12.26	11.98	11.74	11.51	11.31	11.12	10.95	10.80	10.65	10.52	10.39	10.27
6.7	25.38	15.46	14.84	14.13	13.90	13.67	13.47	13.26	12.91	12.59	12.31	12.06	11.83	11.62	11.43	11.25	11.09	10.94	10.81	10.68	10.56
6.8	25.76	15.87	15.23	14.51	14.27	14.03	13.83	13.62	13.26	12.93	12.64	12.38	12.15	11.93	11.74	11.56	11.39	11.24	11.10	10.97	10.85
6.9	26.14	16.28	15.63	14.89	14.65	14.40	14.19	13.98	13.61	13.28	12.98	12.71	12.47	12.25	12.05	11.87	11.70	11.54	11.40	11.26	11.14
7.0	26.52	16.70	16.04	15.27	15.03	14.78	14.56	14.34	13.96	13.62	13.32	13.05	12.80	12.57	12.37	12.18	12.01	11.84	11.70	11.56	11.43
7.1	26.90	17.13	16.45	15.66	15.42	15.15	14.94	14.71	14.32	13.97	13.66	13.38	13.13	12.90	12.69	12.50	12.32	12.15	12.00	11.86	11.73
7.2	27.28	17.56	16.86	16.06	15.81	15.54	15.32	15.08	14.68	14.33	14.01	13.72	13.46	13.23	13.01	12.82	12.63	12.46	12.31	12.16	12.03
7.3	27.66	17.99	17.28	16.46	16.20	15.92	15.70	15.46	15.05	14.69	14.36	14.07	13.80	13.56	13.34	13.14	12.95	12.78	12.62	12.47	12.33
7.4	28.04	18.43	17.70	16.86	16.60	16.32	16.08	15.84	15.42	15.05	14.72	14.42	14.15	13.90	13.67	13.47	13.28	13.10	12.93	12.78	12.64
7.5	28.42	18.88	18.13	17.27	17.00	16.71	16.47	16.23	15.80	15.42	15.08	14.77	14.49	14.24	14.01	13.80	13.60	13.42	13.25	13.10	12.95
7.6	28.79	19.32	18.56	17.68	17.40	17.11	16.87	16.61	16.18	15.79	15.44	15.13	14.84	14.58	14.35	14.13	13.93	13.74	13.57	13.42	13.27
7.7	29.17	19.78	18.99	18.10	17.82	17.52	17.27	17.01	16.56	16.16	15.81	15.49	15.20	14.93	14.69	14.47	14.27	14.07	13.90	13.74	13.59
7.8	29.55	20.24	19.43	18.52	18.23	17.92	17.67	17.40	16.95	16.54	16.18	15.85	15.55	15.28	15.04	14.81	14.60	14.41	14.23	14.06	13.91
7.9	29.93	20.70	19.88	18.95	18.65	18.34	18.08	17.81	17.34	16.92	16.55	16.22	15.91	15.64	15.39	15.15	14.94	14.74	14.56	14.39	14.24
8.0	30.31	21.16	20.33	19.38	19.07	18.75	18.49	18.21	17.73	17.31	16.93	16.59	16.28	16.00	15.74	15.50	15.29	15.08	14.90	14.73	14.56

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

1½" Uponor PEX-a — 30% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
1.5	5.68	1.53	1.48	1.42	1.38	1.33	1.30	1.26	1.19	1.14	1.09	1.05	1.01	0.98	0.95	0.92	0.90	0.88	0.86	0.84	0.83
1.6	6.06	1.71	1.65	1.59	1.54	1.49	1.45	1.40	1.33	1.27	1.22	1.17	1.13	1.09	1.06	1.03	1.01	0.99	0.97	0.95	0.93
1.7	6.44	1.89	1.83	1.76	1.71	1.65	1.61	1.56	1.48	1.41	1.35	1.30	1.25	1.22	1.18	1.15	1.12	1.10	1.07	1.05	1.04
1.8	6.82	2.09	2.02	1.94	1.88	1.82	1.77	1.72	1.63	1.56	1.49	1.43	1.39	1.34	1.30	1.27	1.24	1.21	1.19	1.16	1.15
1.9	7.20	2.29	2.21	2.13	2.07	2.00	1.94	1.89	1.79	1.71	1.64	1.58	1.52	1.48	1.43	1.40	1.36	1.33	1.31	1.28	1.26
2.0	7.58	2.50	2.41	2.33	2.26	2.18	2.12	2.06	1.96	1.87	1.79	1.72	1.67	1.61	1.57	1.53	1.49	1.46	1.43	1.40	1.38
2.1	7.96	2.71	2.62	2.53	2.45	2.37	2.31	2.24	2.13	2.03	1.95	1.88	1.81	1.76	1.71	1.67	1.63	1.59	1.56	1.53	1.51
2.2	8.34	2.93	2.84	2.74	2.66	2.57	2.50	2.43	2.31	2.20	2.11	2.04	1.97	1.91	1.85	1.81	1.77	1.73	1.69	1.66	1.64
2.3	8.71	3.17	3.06	2.95	2.87	2.78	2.70	2.62	2.49	2.38	2.29	2.20	2.13	2.06	2.00	1.96	1.91	1.87	1.83	1.80	1.77
2.4	9.09	3.40	3.29	3.18	3.08	2.99	2.91	2.82	2.68	2.56	2.46	2.37	2.29	2.22	2.16	2.11	2.06	2.01	1.97	1.94	1.91
2.5	9.47	3.65	3.53	3.41	3.31	3.20	3.12	3.03	2.88	2.75	2.64	2.55	2.46	2.39	2.32	2.27	2.21	2.16	2.12	2.08	2.05
2.6	9.85	3.90	3.78	3.64	3.54	3.43	3.34	3.24	3.08	2.95	2.83	2.73	2.64	2.56	2.49	2.43	2.37	2.32	2.28	2.23	2.20
2.7	10.23	4.16	4.03	3.89	3.78	3.66	3.56	3.46	3.29	3.15	3.02	2.91	2.82	2.73	2.66	2.60	2.54	2.48	2.43	2.39	2.35
2.8	10.61	4.43	4.29	4.14	4.02	3.90	3.79	3.69	3.51	3.35	3.22	3.10	3.01	2.92	2.83	2.77	2.70	2.64	2.59	2.55	2.51
2.9	10.99	4.70	4.56	4.40	4.27	4.14	4.03	3.92	3.73	3.57	3.43	3.30	3.20	3.10	3.01	2.95	2.88	2.81	2.76	2.71	2.67
3.0	11.37	4.99	4.83	4.66	4.53	4.39	4.28	4.15	3.96	3.78	3.64	3.50	3.39	3.29	3.20	3.13	3.05	2.99	2.93	2.88	2.84
3.1	11.75	5.27	5.11	4.93	4.79	4.65	4.53	4.40	4.19	4.01	3.85	3.71	3.59	3.49	3.39	3.31	3.24	3.17	3.11	3.05	3.01
3.2	12.12	5.57	5.40	5.21	5.06	4.91	4.78	4.65	4.43	4.24	4.07	3.93	3.80	3.69	3.59	3.51	3.42	3.35	3.29	3.23	3.18
3.3	12.50	5.87	5.69	5.49	5.34	5.18	5.04	4.90	4.67	4.47	4.30	4.14	4.01	3.90	3.79	3.70	3.62	3.54	3.47	3.41	3.36
3.4	12.88	6.18	5.99	5.78	5.62	5.45	5.31	5.16	4.92	4.71	4.53	4.37	4.23	4.11	3.99	3.90	3.81	3.73	3.66	3.59	3.54
3.5	13.26	6.50	6.30	6.08	5.91	5.73	5.59	5.43	5.18	4.96	4.76	4.60	4.45	4.32	4.20	4.11	4.01	3.93	3.86	3.79	3.73
3.6	13.64	6.82	6.61	6.38	6.21	6.02	5.87	5.70	5.44	5.21	5.01	4.83	4.68	4.54	4.42	4.32	4.22	4.13	4.05	3.98	3.92
3.7	14.02	7.15	6.93	6.69	6.51	6.31	6.15	5.98	5.70	5.46	5.25	5.07	4.91	4.77	4.64	4.53	4.43	4.34	4.26	4.18	4.12
3.8	14.40	7.48	7.26	7.01	6.82	6.61	6.45	6.27	5.98	5.72	5.50	5.31	5.15	5.00	4.86	4.75	4.65	4.55	4.46	4.38	4.32
3.9	14.78	7.83	7.59	7.33	7.13	6.92	6.74	6.56	6.25	5.99	5.76	5.56	5.39	5.23	5.09	4.98	4.87	4.76	4.68	4.59	4.53
4.0	15.16	8.18	7.93	7.66	7.45	7.23	7.05	6.85	6.54	6.26	6.02	5.81	5.63	5.47	5.32	5.21	5.09	4.98	4.89	4.80	4.74
4.1	15.53	8.53	8.27	8.00	7.78	7.55	7.36	7.16	6.83	6.54	6.29	6.07	5.89	5.72	5.56	5.44	5.32	5.21	5.11	5.02	4.95
4.2	15.91	8.89	8.63	8.34	8.11	7.87	7.67	7.46	7.12	6.82	6.56	6.34	6.14	5.97	5.81	5.68	5.55	5.43	5.34	5.24	5.17
4.3	16.29	9.26	8.98	8.68	8.45	8.20	7.99	7.78	7.42	7.11	6.84	6.60	6.40	6.22	6.05	5.92	5.79	5.67	5.56	5.46	5.39
4.4	16.67	9.64	9.35	9.04	8.79	8.53	8.32	8.10	7.72	7.40	7.12	6.88	6.67	6.48	6.31	6.17	6.03	5.90	5.80	5.69	5.62
4.5	17.05	10.02	9.72	9.40	9.14	8.87	8.65	8.42	8.04	7.70	7.41	7.16	6.94	6.74	6.56	6.42	6.28	6.14	6.03	5.93	5.85
4.6	17.43	10.41	10.10	9.76	9.50	9.22	8.99	8.75	8.35	8.01	7.71	7.44	7.21	7.01	6.82	6.67	6.53	6.39	6.28	6.16	6.08
4.7	17.81	10.80	10.48	10.13	9.86	9.57	9.34	9.08	8.67	8.31	8.00	7.73	7.49	7.28	7.09	6.93	6.78	6.64	6.52	6.41	6.32

Continued on next page

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

1½" Uponor PEX-a — 30% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40ºF 4ºC	45ºF 7ºC	50ºF 10ºC	55ºF 13ºC	60ºF 16ºC	65ºF 18ºC	70ºF 21ºC	80ºF 27ºC	90ºF 32ºC	100ºF 38ºC	110ºF 43ºC	120ºF 49ºC	130ºF 54ºC	140ºF 60ºC	150ºF 66ºC	160ºF 71ºC	170ºF 77ºC	180ºF 82ºC	190ºF 88ºC	200ºF 93ºC
4.8	18.19	11.20	10.87	10.51	10.23	9.93	9.69	9.43	9.00	8.63	8.31	8.02	7.78	7.56	7.36	7.20	7.04	6.89	6.77	6.65	6.56
4.9	18.57	11.61	11.26	10.89	10.61	10.29	10.04	9.77	9.33	8.95	8.61	8.32	8.07	7.84	7.63	7.47	7.30	7.15	7.03	6.90	6.81
5.0	18.94	12.02	11.67	11.28	10.98	10.66	10.40	10.12	9.67	9.27	8.93	8.62	8.36	8.13	7.91	7.74	7.57	7.42	7.28	7.15	7.06
5.1	19.32	12.44	12.07	11.68	11.37	11.04	10.77	10.48	10.01	9.60	9.24	8.93	8.66	8.42	8.20	8.02	7.84	7.68	7.55	7.41	7.31
5.2	19.70	12.87	12.49	12.08	11.76	11.42	11.14	10.84	10.36	9.93	9.57	9.24	8.96	8.71	8.49	8.30	8.12	7.95	7.81	7.68	7.57
5.3	20.08	13.30	12.91	12.49	12.16	11.81	11.52	11.21	10.71	10.27	9.89	9.56	9.27	9.01	8.78	8.59	8.40	8.23	8.08	7.94	7.84
5.4	20.46	13.74	13.33	12.90	12.56	12.20	11.90	11.59	11.07	10.62	10.23	9.88	9.59	9.32	9.08	8.88	8.69	8.51	8.36	8.21	8.10
5.5	20.84	14.18	13.77	13.32	12.97	12.60	12.29	11.96	11.43	10.97	10.56	10.21	9.90	9.63	9.38	9.17	8.98	8.79	8.64	8.49	8.37
5.6	21.22	14.63	14.20	13.74	13.38	13.00	12.68	12.35	11.80	11.32	10.90	10.54	10.22	9.94	9.68	9.47	9.27	9.08	8.92	8.76	8.65
5.7	21.60	15.09	14.65	14.17	13.80	13.41	13.08	12.74	12.17	11.68	11.25	10.87	10.55	10.26	9.99	9.78	9.57	9.37	9.21	9.05	8.93
5.8	21.98	15.55	15.10	14.61	14.23	13.82	13.49	13.13	12.55	12.04	11.60	11.21	10.88	10.58	10.31	10.09	9.87	9.67	9.50	9.33	9.21
5.9	22.35	16.02	15.55	15.05	14.66	14.24	13.90	13.53	12.93	12.41	11.96	11.56	11.22	10.91	10.63	10.40	10.17	9.97	9.80	9.62	9.50
6.0	22.73	16.49	16.02	15.50	15.10	14.67	14.31	13.94	13.32	12.79	12.32	11.91	11.56	11.24	10.95	10.71	10.48	10.27	10.09	9.92	9.79
6.1	23.11	16.97	16.48	15.95	15.54	15.10	14.74	14.35	13.72	13.16	12.69	12.26	11.90	11.57	11.28	11.04	10.80	10.58	10.40	10.22	10.08
6.2	23.49	17.46	16.96	16.41	15.99	15.53	15.16	14.76	14.11	13.55	13.06	12.62	12.25	11.91	11.61	11.36	11.12	10.89	10.71	10.52	10.38
6.3	23.87	17.95	17.44	16.88	16.44	15.97	15.59	15.19	14.52	13.94	13.43	12.99	12.60	12.26	11.94	11.69	11.44	11.21	11.02	10.83	10.68
6.4	24.25	18.45	17.92	17.35	16.90	16.42	16.03	15.61	14.93	14.33	13.81	13.35	12.96	12.61	12.28	12.02	11.77	11.53	11.33	11.14	10.99
6.5	24.63	18.95	18.41	17.82	17.37	16.87	16.47	16.04	15.34	14.73	14.20	13.73	13.32	12.96	12.63	12.36	12.10	11.86	11.65	11.45	11.30
6.6	25.01	19.46	18.91	18.31	17.84	17.33	16.92	16.48	15.76	15.13	14.59	14.10	13.69	13.32	12.98	12.70	12.43	12.18	11.98	11.77	11.62
6.7	25.38	19.98	19.41	18.79	18.31	17.79	17.37	16.92	16.18	15.54	14.98	14.49	14.06	13.68	13.33	13.05	12.77	12.52	12.30	12.09	11.93
6.8	25.76	20.50	19.92	19.29	18.79	18.26	17.83	17.37	16.61	15.95	15.38	14.87	14.44	14.05	13.69	13.40	13.12	12.85	12.63	12.42	12.26
6.9	26.14	21.03	20.43	19.79	19.28	18.74	18.29	17.82	17.04	16.37	15.78	15.26	14.82	14.42	14.05	13.75	13.46	13.19	12.97	12.75	12.58
7.0	26.52	21.56	20.95	20.29	19.77	19.21	18.76	18.28	17.48	16.79	16.19	15.66	15.20	14.79	14.42	14.11	13.81	13.54	13.31	13.08	12.91
7.1	26.90	22.10	21.48	20.80	20.27	19.70	19.24	18.74	17.93	17.22	16.60	16.06	15.59	15.17	14.79	14.48	14.17	13.89	13.65	13.42	13.25
7.2	27.28	22.65	22.01	21.31	20.77	20.19	19.71	19.21	18.37	17.65	17.02	16.46	15.98	15.55	15.16	14.84	14.53	14.24	14.00	13.76	13.58
7.3	27.66	23.20	22.54	21.83	21.28	20.68	20.20	19.68	18.83	18.09	17.44	16.87	16.38	15.94	15.54	15.21	14.89	14.60	14.35	14.11	13.92
7.4	28.04	23.76	23.09	22.36	21.79	21.18	20.69	20.16	19.28	18.53	17.87	17.28	16.78	16.33	15.92	15.59	15.26	14.96	14.71	14.46	14.27
7.5	28.42	24.32	23.63	22.89	22.31	21.69	21.18	20.64	19.75	18.97	18.30	17.70	17.19	16.73	16.31	15.97	15.63	15.32	15.06	14.81	14.62
7.6	28.79	24.89	24.19	23.43	22.84	22.20	21.68	21.13	20.22	19.42	18.73	18.12	17.60	17.13	16.70	16.35	16.01	15.69	15.43	15.17	14.97
7.7	29.17	25.46	24.74	23.97	23.37	22.72	22.19	21.62	20.69	19.88	19.17	18.55	18.02	17.53	17.09	16.74	16.39	16.06	15.79	15.53	15.33
7.8	29.55	26.04	25.31	24.52	23.90	23.24	22.70	22.12	21.17	20.34	19.62	18.98	18.44	17.94	17.49	17.13	16.77	16.44	16.16	15.89	15.69
7.9	29.93	26.63	25.88	25.07	24.44	23.76	23.21	22.62	21.65	20.80	20.07	19.42	18.86	18.36	17.90	17.52	17.16	16.82	16.54	16.26	16.05
8.0	30.31	27.22	26.45	25.63	24.99	24.29	23.73	23.13	22.13	21.27	20.52	19.86	19.29	18.77	18.30	17.92	17.55	17.21	16.92	16.63	16.42

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

1½" Uponor PEX-a — 40% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
1.5	5.68	1.80	1.73	1.64	1.58	1.52	1.46	1.41	1.32	1.25	1.19	1.13	1.09	1.05	1.01	0.98	0.96	0.93	0.91	0.89	0.87
1.6	6.06	2.01	1.92	1.83	1.76	1.69	1.63	1.57	1.48	1.40	1.33	1.27	1.22	1.17	1.13	1.10	1.07	1.04	1.02	1.00	0.98
1.7	6.44	2.22	2.13	2.03	1.95	1.87	1.81	1.74	1.64	1.55	1.47	1.41	1.35	1.30	1.26	1.22	1.19	1.16	1.13	1.11	1.09
1.8	6.82	2.45	2.34	2.23	2.15	2.06	2.00	1.92	1.81	1.71	1.63	1.55	1.49	1.44	1.39	1.35	1.31	1.28	1.25	1.22	1.20
1.9	7.20	2.68	2.57	2.45	2.36	2.26	2.19	2.11	1.98	1.87	1.78	1.71	1.64	1.58	1.53	1.48	1.45	1.41	1.38	1.35	1.32
2.0	7.58	2.92	2.80	2.67	2.57	2.47	2.39	2.30	2.16	2.05	1.95	1.87	1.79	1.73	1.67	1.62	1.58	1.54	1.51	1.47	1.45
2.1	7.96	3.17	3.04	2.90	2.79	2.68	2.60	2.50	2.35	2.23	2.12	2.03	1.95	1.88	1.82	1.77	1.72	1.68	1.64	1.61	1.58
2.2	8.34	3.43	3.29	3.14	3.02	2.90	2.81	2.71	2.55	2.41	2.30	2.20	2.11	2.04	1.97	1.92	1.87	1.82	1.78	1.74	1.71
2.3	8.71	3.69	3.54	3.38	3.26	3.13	3.03	2.92	2.75	2.61	2.48	2.38	2.28	2.21	2.13	2.07	2.02	1.97	1.93	1.89	1.85
2.4	9.09	3.97	3.81	3.63	3.51	3.37	3.26	3.15	2.96	2.81	2.67	2.56	2.46	2.38	2.30	2.23	2.18	2.12	2.08	2.03	2.00
2.5	9.47	4.25	4.08	3.90	3.76	3.61	3.50	3.37	3.18	3.01	2.87	2.75	2.64	2.55	2.47	2.40	2.34	2.28	2.24	2.18	2.15
2.6	9.85	4.54	4.36	4.16	4.02	3.86	3.74	3.61	3.40	3.22	3.07	2.94	2.83	2.73	2.65	2.57	2.51	2.44	2.40	2.34	2.30
2.7	10.23	4.84	4.65	4.44	4.29	4.12	3.99	3.85	3.63	3.44	3.28	3.14	3.02	2.92	2.83	2.75	2.68	2.61	2.56	2.50	2.46
2.8	10.61	5.15	4.94	4.72	4.56	4.38	4.25	4.10	3.86	3.66	3.50	3.35	3.22	3.11	3.01	2.93	2.86	2.78	2.73	2.67	2.63
2.9	10.99	5.46	5.25	5.02	4.84	4.65	4.51	4.36	4.11	3.89	3.72	3.56	3.43	3.31	3.20	3.12	3.04	2.96	2.91	2.84	2.79
3.0	11.37	5.79	5.56	5.31	5.13	4.93	4.78	4.62	4.35	4.13	3.94	3.78	3.64	3.51	3.40	3.31	3.23	3.15	3.09	3.02	2.97
3.1	11.75	6.12	5.88	5.62	5.43	5.22	5.06	4.89	4.61	4.37	4.17	4.00	3.85	3.72	3.60	3.50	3.42	3.33	3.27	3.20	3.14
3.2	12.12	6.45	6.21	5.93	5.73	5.51	5.34	5.16	4.87	4.62	4.41	4.23	4.07	3.93	3.81	3.71	3.62	3.53	3.46	3.38	3.33
3.3	12.50	6.80	6.54	6.25	6.04	5.81	5.63	5.44	5.14	4.87	4.66	4.47	4.30	4.15	4.02	3.91	3.82	3.72	3.65	3.57	3.51
3.4	12.88	7.16	6.88	6.58	6.36	6.12	5.93	5.73	5.41	5.13	4.90	4.70	4.53	4.38	4.24	4.12	4.03	3.93	3.85	3.77	3.71
3.5	13.26	7.52	7.23	6.92	6.68	6.43	6.23	6.03	5.69	5.40	5.16	4.95	4.76	4.60	4.46	4.34	4.24	4.13	4.05	3.97	3.90
3.6	13.64	7.89	7.59	7.26	7.01	6.75	6.55	6.33	5.97	5.67	5.42	5.20	5.01	4.84	4.69	4.56	4.45	4.34	4.26	4.17	4.10
3.7	14.02	8.26	7.95	7.61	7.35	7.07	6.86	6.63	6.26	5.95	5.68	5.46	5.25	5.08	4.92	4.79	4.67	4.56	4.47	4.38	4.31
3.8	14.40	8.65	8.32	7.96	7.70	7.41	7.19	6.95	6.56	6.23	5.96	5.72	5.50	5.32	5.16	5.02	4.90	4.78	4.69	4.59	4.52
3.9	14.78	9.04	8.70	8.33	8.05	7.75	7.52	7.27	6.86	6.52	6.23	5.98	5.76	5.57	5.40	5.26	5.13	5.01	4.91	4.81	4.73
4.0	15.16	9.44	9.08	8.69	8.41	8.09	7.85	7.59	7.17	6.82	6.52	6.26	6.02	5.83	5.65	5.50	5.37	5.24	5.14	5.03	4.95
4.1	15.53	9.84	9.47	9.07	8.77	8.44	8.19	7.92	7.49	7.12	6.80	6.53	6.29	6.09	5.90	5.74	5.61	5.47	5.37	5.25	5.17
4.2	15.91	10.26	9.87	9.45	9.14	8.80	8.54	8.26	7.81	7.42	7.10	6.81	6.56	6.35	6.16	5.99	5.85	5.71	5.60	5.48	5.40
4.3	16.29	10.68	10.28	9.85	9.52	9.17	8.90	8.61	8.13	7.73	7.40	7.10	6.84	6.62	6.42	6.25	6.10	5.95	5.84	5.72	5.63
4.4	16.67	11.11	10.69	10.24	9.91	9.54	9.26	8.96	8.47	8.05	7.70	7.39	7.12	6.89	6.68	6.51	6.35	6.20	6.09	5.96	5.86
4.5	17.05	11.54	11.11	10.65	10.30	9.92	9.63	9.31	8.81	8.37	8.01	7.69	7.41	7.17	6.96	6.77	6.61	6.45	6.34	6.20	6.10
4.6	17.43	11.98	11.54	11.06	10.69	10.30	10.00	9.68	9.15	8.70	8.32	8.00	7.70	7.46	7.23	7.04	6.88	6.71	6.59	6.45	6.35
4.7	17.81	12.43	11.97	11.47	11.10	10.69	10.38	10.04	9.50	9.04	8.64	8.30	8.00	7.74	7.51	7.31	7.14	6.97	6.85	6.70	6.60

Continued on next page

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

1½" Uponor PEX-a — 40% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
4.8	18.19	12.89	12.41	11.90	11.51	11.09	10.77	10.42	9.85	9.37	8.97	8.62	8.31	8.04	7.80	7.59	7.42	7.24	7.11	6.96	6.85
4.9	18.57	13.35	12.86	12.33	11.93	11.49	11.16	10.80	10.22	9.72	9.30	8.94	8.61	8.34	8.09	7.88	7.69	7.51	7.37	7.22	7.11
5.0	18.94	13.82	13.32	12.76	12.35	11.90	11.56	11.19	10.58	10.07	9.64	9.26	8.93	8.64	8.38	8.16	7.97	7.78	7.64	7.48	7.37
5.1	19.32	14.30	13.78	13.21	12.78	12.32	11.96	11.58	10.95	10.42	9.98	9.59	9.24	8.95	8.68	8.46	8.26	8.06	7.92	7.75	7.63
5.2	19.70	14.78	14.25	13.66	13.22	12.74	12.37	11.98	11.33	10.79	10.32	9.92	9.57	9.26	8.99	8.75	8.55	8.35	8.20	8.03	7.90
5.3	20.08	15.28	14.72	14.11	13.66	13.17	12.79	12.38	11.72	11.15	10.68	10.26	9.89	9.58	9.29	9.05	8.85	8.64	8.48	8.30	8.17
5.4	20.46	15.77	15.20	14.58	14.11	13.60	13.21	12.79	12.10	11.52	11.03	10.61	10.23	9.90	9.61	9.36	9.14	8.93	8.77	8.59	8.45
5.5	20.84	16.28	15.69	15.05	14.56	14.04	13.64	13.20	12.50	11.90	11.39	10.95	10.56	10.23	9.93	9.67	9.45	9.22	9.06	8.87	8.73
5.6	21.22	16.79	16.18	15.52	15.03	14.49	14.07	13.63	12.90	12.28	11.76	11.31	10.90	10.56	10.25	9.98	9.76	9.53	9.35	9.16	9.02
5.7	21.60	17.31	16.69	16.00	15.49	14.94	14.51	14.05	13.31	12.67	12.13	11.67	11.25	10.90	10.58	10.30	10.07	9.83	9.66	9.46	9.31
5.8	21.98	17.84	17.19	16.49	15.97	15.40	14.96	14.49	13.72	13.06	12.51	12.03	11.60	11.24	10.91	10.63	10.38	10.14	9.96	9.75	9.60
5.9	22.35	18.37	17.71	16.99	16.45	15.86	15.41	14.92	14.13	13.46	12.89	12.40	11.96	11.58	11.24	10.96	10.71	10.46	10.27	10.06	9.90
6.0	22.73	18.91	18.23	17.49	16.93	16.33	15.87	15.37	14.56	13.86	13.28	12.77	12.32	11.93	11.58	11.29	11.03	10.77	10.58	10.36	10.21
6.1	23.11	19.45	18.76	18.00	17.43	16.81	16.33	15.82	14.98	14.27	13.67	13.15	12.69	12.29	11.93	11.62	11.36	11.10	10.90	10.68	10.51
6.2	23.49	20.00	19.29	18.51	17.92	17.29	16.80	16.27	15.42	14.69	14.07	13.53	13.06	12.65	12.28	11.97	11.70	11.42	11.22	10.99	10.82
6.3	23.87	20.56	19.83	19.03	18.43	17.78	17.28	16.73	15.85	15.11	14.47	13.92	13.43	13.01	12.63	12.31	12.03	11.75	11.55	11.31	11.14
6.4	24.25	21.13	20.38	19.56	18.94	18.27	17.76	17.20	16.30	15.53	14.88	14.31	13.81	13.38	12.99	12.66	12.38	12.09	11.88	11.63	11.46
6.5	24.63	21.70	20.93	20.09	19.46	18.77	18.24	17.67	16.75	15.96	15.29	14.71	14.20	13.75	13.35	13.02	12.72	12.43	12.21	11.96	11.78
6.6	25.01	22.28	21.49	20.63	19.98	19.28	18.74	18.15	17.20	16.39	15.71	15.11	14.58	14.13	13.72	13.38	13.07	12.77	12.55	12.29	12.11
6.7	25.38	22.86	22.06	21.17	20.51	19.79	19.23	18.63	17.66	16.83	16.13	15.52	14.98	14.51	14.09	13.74	13.43	13.12	12.89	12.63	12.44
6.8	25.76	23.46	22.63	21.72	21.04	20.31	19.74	19.12	18.13	17.28	16.56	15.93	15.38	14.90	14.47	14.11	13.79	13.47	13.24	12.97	12.77
6.9	26.14	24.05	23.21	22.28	21.58	20.83	20.25	19.62	18.60	17.73	16.99	16.35	15.78	15.29	14.85	14.48	14.15	13.83	13.59	13.31	13.11
7.0	26.52	24.66	23.79	22.84	22.13	21.36	20.76	20.12	19.07	18.18	17.43	16.77	16.19	15.69	15.24	14.85	14.52	14.19	13.94	13.66	13.45
7.1	26.90	25.27	24.38	23.41	22.68	21.89	21.28	20.62	19.55	18.64	17.87	17.20	16.60	16.09	15.63	15.23	14.89	14.55	14.30	14.01	13.80
7.2	27.28	25.89	24.98	23.99	23.24	22.43	21.81	21.13	20.04	19.11	18.32	17.63	17.02	16.49	16.02	15.62	15.27	14.92	14.66	14.37	14.15
7.3	27.66	26.51	25.58	24.57	23.81	22.98	22.34	21.65	20.53	19.58	18.77	18.07	17.44	16.90	16.42	16.01	15.65	15.29	15.03	14.73	14.51
7.4	28.04	27.14	26.19	25.15	24.38	23.53	22.88	22.17	21.03	20.05	19.23	18.51	17.87	17.32	16.82	16.40	16.04	15.67	15.40	15.09	14.86
7.5	28.42	27.78	26.81	25.75	24.95	24.09	23.42	22.70	21.53	20.53	19.69	18.95	18.30	17.74	17.23	16.80	16.43	16.05	15.77	15.46	15.23
7.6	28.79	28.42	27.43	26.35	25.53	24.65	23.97	23.23	22.04	21.02	20.15	19.40	18.73	18.16	17.64	17.20	16.82	16.44	16.15	15.83	15.59
7.7	29.17	29.07	28.06	26.95	26.12	25.22	24.52	23.77	22.55	21.51	20.62	19.86	19.17	18.59	18.06	17.61	17.22	16.83	16.53	16.20	15.96
7.8	29.55	29.73	28.69	27.56	26.72	25.79	25.08	24.32	23.07	22.00	21.10	20.32	19.62	19.02	18.48	18.02	17.62	17.22	16.92	16.58	16.34
7.9	29.93	30.39	29.34	28.18	27.32	26.37	25.65	24.86	23.59	22.50	21.58	20.78	20.07	19.45	18.90	18.43	18.03	17.62	17.31	16.97	16.72
8.0	30.31	31.06	29.98	28.80	27.92	26.96	26.22	25.42	24.12	23.01	22.07	21.25	20.52	19.89	19.33	18.85	18.44	18.02	17.71	17.36	17.10

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

Appendix G:
Hydronic friction loss tables

1½" Uponor PEX-a — 50% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
1.5	5.68	2.06	1.96	1.86	1.79	1.70	1.64	1.57	1.47	1.38	1.30	1.24	1.18	1.13	1.09	1.05	1.02	0.99	0.96	0.94	0.92
1.6	6.06	2.29	2.19	2.07	1.99	1.90	1.83	1.76	1.64	1.54	1.45	1.38	1.32	1.27	1.22	1.18	1.14	1.11	1.08	1.05	1.03
1.7	6.44	2.53	2.42	2.29	2.20	2.10	2.03	1.94	1.82	1.71	1.61	1.53	1.47	1.41	1.36	1.31	1.27	1.23	1.20	1.17	1.14
1.8	6.82	2.78	2.66	2.52	2.42	2.31	2.23	2.14	2.00	1.88	1.78	1.69	1.62	1.55	1.50	1.45	1.40	1.36	1.33	1.30	1.27
1.9	7.20	3.04	2.91	2.76	2.65	2.53	2.44	2.35	2.19	2.06	1.95	1.86	1.78	1.71	1.64	1.59	1.54	1.50	1.46	1.42	1.39
2.0	7.58	3.31	3.17	3.01	2.89	2.76	2.67	2.56	2.39	2.25	2.13	2.03	1.94	1.86	1.80	1.74	1.69	1.64	1.59	1.56	1.52
2.1	7.96	3.59	3.44	3.27	3.14	3.00	2.89	2.78	2.60	2.45	2.32	2.21	2.11	2.03	1.96	1.89	1.84	1.78	1.74	1.70	1.66
2.2	8.34	3.88	3.71	3.53	3.39	3.25	3.13	3.01	2.82	2.65	2.51	2.39	2.29	2.20	2.12	2.05	1.99	1.93	1.88	1.84	1.80
2.3	8.71	4.18	4.00	3.80	3.66	3.50	3.38	3.25	3.04	2.86	2.71	2.58	2.47	2.38	2.29	2.22	2.15	2.09	2.04	1.99	1.95
2.4	9.09	4.49	4.30	4.09	3.93	3.76	3.63	3.49	3.27	3.08	2.92	2.78	2.66	2.56	2.47	2.39	2.32	2.25	2.19	2.15	2.10
2.5	9.47	4.81	4.60	4.38	4.21	4.03	3.89	3.74	3.50	3.30	3.13	2.99	2.86	2.75	2.65	2.57	2.49	2.42	2.36	2.31	2.26
2.6	9.85	5.13	4.91	4.68	4.50	4.31	4.16	4.00	3.75	3.53	3.35	3.20	3.06	2.94	2.84	2.75	2.67	2.59	2.53	2.47	2.42
2.7	10.23	5.47	5.23	4.98	4.79	4.59	4.44	4.27	4.00	3.77	3.58	3.41	3.27	3.14	3.03	2.94	2.85	2.77	2.70	2.64	2.58
2.8	10.61	5.81	5.56	5.30	5.10	4.88	4.72	4.54	4.26	4.01	3.81	3.63	3.48	3.35	3.23	3.13	3.04	2.95	2.88	2.82	2.76
2.9	10.99	6.16	5.90	5.62	5.41	5.18	5.01	4.82	4.52	4.26	4.05	3.86	3.70	3.56	3.44	3.33	3.23	3.14	3.06	3.00	2.93
3.0	11.37	6.52	6.25	5.95	5.73	5.49	5.31	5.11	4.79	4.52	4.29	4.10	3.93	3.78	3.65	3.53	3.43	3.34	3.25	3.18	3.11
3.1	11.75	6.89	6.61	6.29	6.06	5.81	5.61	5.40	5.07	4.79	4.54	4.34	4.16	4.00	3.86	3.74	3.63	3.53	3.45	3.37	3.30
3.2	12.12	7.27	6.97	6.64	6.40	6.13	5.93	5.71	5.35	5.05	4.80	4.58	4.39	4.23	4.08	3.96	3.84	3.74	3.64	3.57	3.49
3.3	12.50	7.66	7.34	7.00	6.74	6.46	6.25	6.02	5.65	5.33	5.06	4.84	4.64	4.46	4.31	4.17	4.06	3.95	3.85	3.77	3.69
3.4	12.88	8.05	7.72	7.36	7.09	6.80	6.57	6.33	5.94	5.61	5.33	5.09	4.88	4.70	4.54	4.40	4.28	4.16	4.06	3.97	3.89
3.5	13.26	8.45	8.11	7.73	7.45	7.14	6.91	6.65	6.25	5.90	5.61	5.36	5.14	4.95	4.78	4.63	4.50	4.38	4.27	4.18	4.09
3.6	13.64	8.87	8.50	8.11	7.82	7.49	7.25	6.98	6.56	6.20	5.89	5.63	5.40	5.20	5.02	4.87	4.73	4.60	4.49	4.39	4.30
3.7	14.02	9.29	8.91	8.50	8.19	7.85	7.60	7.32	6.88	6.50	6.18	5.90	5.66	5.45	5.27	5.11	4.96	4.83	4.71	4.61	4.51
3.8	14.40	9.71	9.32	8.89	8.57	8.22	7.95	7.66	7.20	6.81	6.47	6.18	5.93	5.71	5.52	5.35	5.20	5.06	4.94	4.83	4.73
3.9	14.78	10.15	9.74	9.29	8.96	8.59	8.32	8.01	7.53	7.12	6.77	6.47	6.21	5.98	5.78	5.60	5.45	5.30	5.17	5.06	4.96
4.0	15.16	10.59	10.17	9.70	9.35	8.98	8.68	8.37	7.87	7.44	7.07	6.76	6.49	6.25	6.04	5.86	5.69	5.54	5.41	5.29	5.18
4.1	15.53	11.05	10.60	10.12	9.76	9.36	9.06	8.74	8.21	7.76	7.39	7.06	6.78	6.53	6.31	6.12	5.95	5.79	5.65	5.53	5.42
4.2	15.91	11.50	11.04	10.54	10.17	9.76	9.44	9.11	8.56	8.10	7.70	7.36	7.07	6.81	6.58	6.38	6.21	6.04	5.89	5.77	5.65
4.3	16.29	11.97	11.50	10.98	10.58	10.16	9.83	9.48	8.92	8.43	8.02	7.67	7.37	7.10	6.86	6.65	6.47	6.30	6.15	6.02	5.89
4.4	16.67	12.45	11.95	11.41	11.01	10.57	10.23	9.87	9.28	8.78	8.35	7.99	7.67	7.39	7.14	6.93	6.74	6.56	6.40	6.27	6.14
4.5	17.05	12.93	12.42	11.86	11.44	10.98	10.63	10.26	9.65	9.13	8.69	8.31	7.98	7.69	7.43	7.21	7.01	6.83	6.66	6.53	6.39
4.6	17.43	13.42	12.89	12.31	11.88	11.41	11.04	10.65	10.02	9.48	9.03	8.63	8.29	7.99	7.73	7.49	7.29	7.10	6.93	6.79	6.65
4.7	17.81	13.92	13.37	12.78	12.32	11.84	11.46	11.05	10.40	9.85	9.37	8.97	8.61	8.30	8.03	7.78	7.57	7.37	7.20	7.05	6.91

Continued on next page

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

Appendix G:

Hydronic friction loss tables

1½" Uponor PEX-a — 50% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40ºF 4ºC	45ºF 7ºC	50ºF 10ºC	55ºF 13ºC	60ºF 16ºC	65ºF 18ºC	70ºF 21ºC	80ºF 27ºC	90ºF 32ºC	100ºF 38ºC	110ºF 43ºC	120ºF 49ºC	130ºF 54ºC	140ºF 60ºC	150ºF 66ºC	160ºF 71ºC	170ºF 77ºC	180ºF 82ºC	190ºF 88ºC	200ºF 93ºC
4.8	18.19	14.43	13.86	13.24	12.78	12.27	11.88	11.46	10.79	10.21	9.72	9.30	8.93	8.61	8.33	8.08	7.86	7.66	7.47	7.32	7.17
4.9	18.57	14.94	14.36	13.72	13.24	12.71	12.31	11.88	11.18	10.59	10.08	9.64	9.26	8.93	8.64	8.38	8.15	7.94	7.75	7.59	7.44
5.0	18.94	15.47	14.86	14.20	13.70	13.16	12.75	12.30	11.58	10.97	10.44	9.99	9.60	9.26	8.95	8.68	8.45	8.23	8.03	7.87	7.71
5.1	19.32	16.00	15.37	14.69	14.18	13.62	13.19	12.73	11.98	11.35	10.81	10.34	9.94	9.58	9.27	8.99	8.75	8.52	8.32	8.15	7.99
5.2	19.70	16.53	15.89	15.19	14.66	14.08	13.64	13.17	12.40	11.74	11.18	10.70	10.28	9.92	9.59	9.31	9.06	8.82	8.61	8.44	8.27
5.3	20.08	17.08	16.41	15.69	15.15	14.55	14.10	13.61	12.81	12.14	11.56	11.07	10.63	10.26	9.92	9.63	9.37	9.13	8.91	8.73	8.55
5.4	20.46	17.63	16.95	16.20	15.64	15.03	14.56	14.05	13.24	12.54	11.95	11.44	10.99	10.60	10.25	9.95	9.68	9.43	9.21	9.02	8.84
5.5	20.84	18.19	17.49	16.72	16.14	15.51	15.03	14.51	13.67	12.95	12.34	11.81	11.35	10.95	10.59	10.28	10.00	9.75	9.52	9.32	9.14
5.6	21.22	18.76	18.03	17.24	16.65	16.00	15.50	14.97	14.10	13.36	12.73	12.19	11.72	11.30	10.94	10.61	10.33	10.06	9.83	9.63	9.44
5.7	21.60	19.33	18.59	17.78	17.16	16.50	15.99	15.43	14.54	13.78	13.13	12.57	12.09	11.66	11.28	10.95	10.66	10.39	10.14	9.94	9.74
5.8	21.98	19.91	19.15	18.31	17.68	17.00	16.47	15.91	14.99	14.21	13.54	12.96	12.46	12.02	11.64	11.29	10.99	10.71	10.46	10.25	10.05
5.9	22.35	20.50	19.72	18.86	18.21	17.51	16.97	16.38	15.44	14.64	13.95	13.36	12.84	12.39	11.99	11.64	11.33	11.04	10.78	10.57	10.36
6.0	22.73	21.10	20.29	19.41	18.75	18.02	17.47	16.87	15.90	15.07	14.37	13.76	13.23	12.77	12.35	11.99	11.67	11.38	11.11	10.89	10.67
6.1	23.11	21.70	20.88	19.97	19.29	18.55	17.98	17.36	16.36	15.51	14.79	14.17	13.62	13.14	12.72	12.35	12.02	11.72	11.44	11.21	10.99
6.2	23.49	22.32	21.47	20.54	19.84	19.07	18.49	17.86	16.83	15.96	15.22	14.58	14.02	13.53	13.09	12.71	12.37	12.06	11.78	11.54	11.32
6.3	23.87	22.93	22.06	21.11	20.39	19.61	19.01	18.36	17.31	16.41	15.65	14.99	14.42	13.91	13.47	13.08	12.73	12.41	12.12	11.88	11.64
6.4	24.25	23.56	22.67	21.69	20.95	20.15	19.53	18.87	17.79	16.87	16.09	15.41	14.82	14.31	13.85	13.45	13.09	12.76	12.46	12.22	11.98
6.5	24.63	24.19	23.28	22.27	21.52	20.70	20.07	19.38	18.28	17.34	16.53	15.84	15.23	14.71	14.24	13.82	13.46	13.12	12.81	12.56	12.31
6.6	25.01	24.83	23.89	22.87	22.09	21.25	20.60	19.90	18.77	17.81	16.98	16.27	15.65	15.11	14.63	14.20	13.83	13.48	13.17	12.91	12.65
6.7	25.38	25.48	24.52	23.47	22.67	21.81	21.15	20.43	19.27	18.28	17.44	16.71	16.07	15.51	15.02	14.59	14.20	13.85	13.52	13.26	13.00
6.8	25.76	26.13	25.15	24.07	23.26	22.38	21.70	20.96	19.77	18.76	17.89	17.15	16.50	15.93	15.42	14.98	14.58	14.22	13.89	13.61	13.35
6.9	26.14	26.80	25.79	24.69	23.85	22.95	22.25	21.50	20.28	19.25	18.36	17.60	16.93	16.34	15.82	15.37	14.97	14.59	14.25	13.97	13.70
7.0	26.52	27.46	26.43	25.31	24.45	23.53	22.82	22.05	20.80	19.74	18.83	18.05	17.36	16.76	16.23	15.77	15.35	14.97	14.62	14.34	14.06
7.1	26.90	28.14	27.08	25.93	25.06	24.11	23.39	22.60	21.32	20.23	19.30	18.50	17.80	17.19	16.65	16.17	15.75	15.35	15.00	14.71	14.42
7.2	27.28	28.82	27.74	26.56	25.67	24.71	23.96	23.15	21.85	20.74	19.79	18.97	18.25	17.62	17.07	16.58	16.14	15.74	15.38	15.08	14.78
7.3	27.66	29.51	28.41	27.20	26.29	25.30	24.54	23.72	22.38	21.24	20.27	19.43	18.70	18.06	17.49	16.99	16.55	16.13	15.76	15.45	15.15
7.4	28.04	30.21	29.08	27.85	26.92	25.91	25.13	24.28	22.92	21.76	20.76	19.90	19.16	18.50	17.92	17.40	16.95	16.53	16.15	15.83	15.53
7.5	28.42	30.91	29.76	28.50	27.55	26.52	25.72	24.86	23.47	22.27	21.26	20.38	19.61	18.94	18.35	17.82	17.36	16.93	16.54	16.22	15.90
7.6	28.79	31.62	30.45	29.16	28.19	27.13	26.32	25.44	24.01	22.80	21.76	20.86	20.08	19.39	18.78	18.25	17.78	17.34	16.94	16.61	16.29
7.7	29.17	32.34	31.14	29.83	28.83	27.75	26.92	26.02	24.57	23.33	22.26	21.35	20.55	19.85	19.22	18.68	18.19	17.74	17.34	17.00	16.67
7.8	29.55	33.06	31.84	30.50	29.48	28.38	27.53	26.62	25.13	23.86	22.78	21.84	21.02	20.31	19.67	19.11	18.62	18.16	17.74	17.40	17.06
7.9	29.93	33.79	32.54	31.18	30.14	29.02	28.15	27.21	25.70	24.40	23.29	22.34	21.50	20.77	20.12	19.55	19.05	18.58	18.15	17.80	17.46
8.0	30.31	34.53	33.26	31.86	30.81	29.66	28.77	27.82	26.27	24.95	23.81	22.84	21.99	21.24	20.58	19.99	19.48	19.00	18.56	18.21	17.85

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

Appendix G:

Hydronic friction loss tables

2" Uponor PEX-a — 100% Water — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
1.5	9.75	0.80	0.76	0.72	0.71	0.70	0.68	0.67	0.65	0.63	0.62	0.60	0.59	0.58	0.57	0.56	0.55	0.54	0.53	0.52	0.52
1.6	10.39	0.90	0.86	0.81	0.79	0.78	0.77	0.75	0.73	0.71	0.69	0.68	0.66	0.65	0.64	0.62	0.61	0.60	0.60	0.59	0.58
1.7	11.04	1.00	0.95	0.90	0.88	0.87	0.85	0.84	0.81	0.79	0.77	0.75	0.74	0.72	0.71	0.70	0.68	0.67	0.66	0.66	0.65
1.8	11.69	1.10	1.05	0.99	0.98	0.96	0.94	0.93	0.90	0.87	0.85	0.83	0.81	0.80	0.78	0.77	0.76	0.75	0.74	0.73	0.72
1.9	12.34	1.21	1.15	1.09	1.07	1.05	1.04	1.02	0.99	0.96	0.94	0.92	0.90	0.88	0.86	0.85	0.83	0.82	0.81	0.80	0.79
2.0	12.99	1.32	1.26	1.20	1.17	1.15	1.13	1.11	1.08	1.05	1.03	1.00	0.98	0.96	0.95	0.93	0.91	0.90	0.89	0.88	0.87
2.1	13.64	1.44	1.38	1.30	1.28	1.26	1.24	1.22	1.18	1.15	1.12	1.09	1.07	1.05	1.03	1.01	1.00	0.98	0.97	0.96	0.94
2.2	14.29	1.56	1.49	1.41	1.39	1.36	1.34	1.32	1.28	1.25	1.22	1.19	1.16	1.14	1.12	1.10	1.08	1.07	1.05	1.04	1.03
2.3	14.94	1.69	1.61	1.53	1.50	1.47	1.45	1.43	1.39	1.35	1.32	1.29	1.26	1.23	1.21	1.19	1.17	1.16	1.14	1.13	1.11
2.4	15.59	1.82	1.74	1.65	1.62	1.59	1.56	1.54	1.49	1.45	1.42	1.39	1.36	1.33	1.31	1.29	1.27	1.25	1.23	1.21	1.20
2.5	16.24	1.95	1.87	1.77	1.74	1.71	1.68	1.65	1.61	1.56	1.53	1.49	1.46	1.43	1.41	1.38	1.36	1.34	1.32	1.31	1.29
2.6	16.89	2.09	2.00	1.90	1.86	1.83	1.80	1.77	1.72	1.68	1.64	1.60	1.57	1.54	1.51	1.48	1.46	1.44	1.42	1.40	1.38
2.7	17.54	2.23	2.14	2.03	1.99	1.96	1.93	1.89	1.84	1.79	1.75	1.71	1.68	1.64	1.61	1.59	1.56	1.54	1.52	1.50	1.48
2.8	18.19	2.38	2.28	2.16	2.12	2.09	2.05	2.02	1.96	1.91	1.87	1.82	1.79	1.75	1.72	1.69	1.67	1.64	1.62	1.60	1.58
2.9	18.84	2.53	2.42	2.30	2.26	2.22	2.19	2.15	2.09	2.03	1.99	1.94	1.90	1.87	1.83	1.80	1.78	1.75	1.73	1.71	1.68
3.0	19.49	2.69	2.57	2.44	2.40	2.36	2.32	2.28	2.22	2.16	2.11	2.06	2.02	1.98	1.95	1.92	1.89	1.86	1.84	1.81	1.79
3.1	20.14	2.85	2.72	2.59	2.54	2.50	2.46	2.42	2.35	2.29	2.24	2.19	2.14	2.10	2.07	2.03	2.00	1.97	1.95	1.92	1.90
3.2	20.79	3.01	2.88	2.74	2.69	2.64	2.60	2.56	2.49	2.42	2.37	2.32	2.27	2.23	2.19	2.15	2.12	2.09	2.06	2.04	2.01
3.3	21.44	3.18	3.04	2.89	2.84	2.79	2.75	2.70	2.63	2.56	2.50	2.45	2.40	2.35	2.31	2.27	2.24	2.21	2.18	2.15	2.13
3.4	22.09	3.35	3.21	3.05	2.99	2.94	2.90	2.85	2.77	2.70	2.64	2.58	2.53	2.48	2.44	2.40	2.36	2.33	2.30	2.27	2.24
3.5	22.74	3.52	3.37	3.21	3.15	3.10	3.05	3.00	2.92	2.84	2.78	2.72	2.66	2.61	2.57	2.53	2.49	2.45	2.42	2.39	2.36
3.6	23.39	3.70	3.55	3.37	3.31	3.25	3.21	3.16	3.07	2.99	2.92	2.86	2.80	2.75	2.70	2.66	2.62	2.58	2.55	2.52	2.49
3.7	24.04	3.88	3.72	3.54	3.48	3.42	3.37	3.31	3.22	3.14	3.07	3.00	2.94	2.89	2.84	2.79	2.75	2.71	2.68	2.64	2.61
3.8	24.69	4.07	3.90	3.71	3.65	3.58	3.53	3.47	3.38	3.29	3.22	3.15	3.09	3.03	2.98	2.93	2.89	2.85	2.81	2.77	2.74
3.9	25.34	4.26	4.08	3.88	3.82	3.75	3.70	3.64	3.54	3.45	3.37	3.30	3.23	3.17	3.12	3.07	3.02	2.98	2.94	2.91	2.87
4.0	25.99	4.46	4.27	4.06	3.99	3.92	3.87	3.81	3.70	3.61	3.52	3.45	3.38	3.32	3.26	3.21	3.17	3.12	3.08	3.04	3.01
4.1	26.64	4.65	4.46	4.24	4.17	4.10	4.04	3.98	3.87	3.77	3.68	3.61	3.54	3.47	3.41	3.36	3.31	3.26	3.22	3.18	3.14
4.2	27.29	4.86	4.66	4.43	4.36	4.28	4.22	4.15	4.04	3.94	3.85	3.77	3.69	3.62	3.56	3.51	3.46	3.41	3.36	3.32	3.28
4.3	27.94	5.06	4.85	4.62	4.54	4.46	4.40	4.33	4.21	4.11	4.01	3.93	3.85	3.78	3.72	3.66	3.61	3.55	3.51	3.47	3.43
4.4	28.59	5.27	5.06	4.81	4.73	4.65	4.58	4.51	4.39	4.28	4.18	4.09	4.01	3.94	3.87	3.81	3.76	3.70	3.66	3.61	3.57
4.5	29.24	5.48	5.26	5.01	4.92	4.84	4.77	4.69	4.57	4.45	4.35	4.26	4.18	4.10	4.03	3.97	3.91	3.86	3.81	3.76	3.72
4.6	29.89	5.70	5.47	5.20	5.12	5.03	4.96	4.88	4.75	4.63	4.53	4.43	4.35	4.27	4.20	4.13	4.07	4.01	3.96	3.92	3.87
4.7	30.54	5.92	5.68	5.41	5.32	5.23	5.15	5.07	4.93	4.81	4.70	4.61	4.52	4.44	4.36	4.29	4.23	4.17	4.12	4.07	4.02

Continued on next page

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

2" Uponor PEX-a — 100% Water — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40ºF 4ºC	45ºF 7ºC	50ºF 10ºC	55ºF 13ºC	60ºF 16ºC	65ºF 18ºC	70ºF 21ºC	80ºF 27ºC	90ºF 32ºC	100ºF 38ºC	110ºF 43ºC	120ºF 49ºC	130ºF 54ºC	140ºF 60ºC	150ºF 66ºC	160ºF 71ºC	170ºF 77ºC	180ºF 82ºC	190ºF 88ºC	200ºF 93ºC
4.8	31.18	6.15	5.90	5.61	5.52	5.43	5.35	5.27	5.12	5.00	4.88	4.78	4.69	4.61	4.53	4.46	4.40	4.33	4.28	4.23	4.18
4.9	31.83	6.37	6.12	5.82	5.73	5.63	5.55	5.46	5.32	5.19	5.07	4.96	4.87	4.78	4.70	4.63	4.56	4.50	4.44	4.39	4.34
5.0	32.48	6.61	6.34	6.04	5.94	5.84	5.75	5.66	5.51	5.38	5.26	5.15	5.05	4.96	4.88	4.80	4.73	4.67	4.61	4.55	4.50
5.1	33.13	6.84	6.57	6.25	6.15	6.05	5.96	5.87	5.71	5.57	5.45	5.33	5.23	5.14	5.05	4.97	4.90	4.84	4.78	4.72	4.67
5.2	33.78	7.08	6.80	6.47	6.37	6.26	6.17	6.07	5.91	5.77	5.64	5.52	5.42	5.32	5.23	5.15	5.08	5.01	4.95	4.89	4.83
5.3	34.43	7.32	7.03	6.69	6.59	6.48	6.38	6.28	6.12	5.97	5.83	5.71	5.61	5.51	5.42	5.33	5.26	5.18	5.12	5.06	5.00
5.4	35.08	7.57	7.27	6.92	6.81	6.69	6.60	6.50	6.32	6.17	6.03	5.91	5.80	5.69	5.60	5.52	5.44	5.36	5.29	5.23	5.17
5.5	35.73	7.82	7.51	7.15	7.04	6.92	6.82	6.71	6.54	6.38	6.24	6.11	5.99	5.89	5.79	5.70	5.62	5.54	5.47	5.41	5.35
5.6	36.38	8.07	7.75	7.38	7.27	7.14	7.04	6.93	6.75	6.59	6.44	6.31	6.19	6.08	5.98	5.89	5.81	5.73	5.65	5.59	5.53
5.7	37.03	8.33	8.00	7.62	7.50	7.37	7.27	7.16	6.97	6.80	6.65	6.51	6.39	6.28	6.17	6.08	5.99	5.91	5.84	5.77	5.71
5.8	37.68	8.59	8.25	7.86	7.74	7.60	7.50	7.38	7.19	7.01	6.86	6.72	6.59	6.48	6.37	6.27	6.19	6.10	6.03	5.96	5.89
5.9	38.33	8.86	8.50	8.10	7.98	7.84	7.73	7.61	7.41	7.23	7.07	6.93	6.80	6.68	6.57	6.47	6.38	6.29	6.22	6.14	6.07
6.0	38.98	9.12	8.76	8.35	8.22	8.08	7.97	7.85	7.64	7.45	7.29	7.14	7.01	6.88	6.77	6.67	6.58	6.49	6.41	6.33	6.26
6.1	39.63	9.39	9.02	8.60	8.46	8.32	8.20	8.08	7.87	7.68	7.51	7.36	7.22	7.09	6.98	6.87	6.78	6.68	6.60	6.52	6.45
6.2	40.28	9.67	9.29	8.85	8.71	8.57	8.45	8.32	8.10	7.91	7.73	7.58	7.43	7.30	7.19	7.08	6.98	6.88	6.80	6.72	6.65
6.3	40.93	9.95	9.56	9.11	8.97	8.82	8.69	8.56	8.34	8.14	7.96	7.80	7.65	7.52	7.40	7.29	7.18	7.09	7.00	6.92	6.84
6.4	41.58	10.23	9.83	9.37	9.22	9.07	8.94	8.81	8.57	8.37	8.19	8.02	7.87	7.73	7.61	7.50	7.39	7.29	7.20	7.12	7.04
6.5	42.23	10.51	10.10	9.63	9.48	9.32	9.19	9.05	8.82	8.61	8.42	8.25	8.09	7.95	7.83	7.71	7.60	7.50	7.41	7.32	7.24
6.6	42.88	10.80	10.38	9.90	9.74	9.58	9.45	9.30	9.06	8.85	8.65	8.48	8.32	8.18	8.05	7.92	7.81	7.71	7.61	7.53	7.44
6.7	43.53	11.10	10.66	10.17	10.01	9.84	9.70	9.56	9.31	9.09	8.89	8.71	8.55	8.40	8.27	8.14	8.03	7.92	7.83	7.74	7.65
6.8	44.18	11.39	10.95	10.44	10.28	10.10	9.96	9.82	9.56	9.33	9.13	8.95	8.78	8.63	8.49	8.36	8.25	8.14	8.04	7.95	7.86
6.9	44.83	11.69	11.23	10.71	10.55	10.37	10.23	10.08	9.81	9.58	9.37	9.19	9.01	8.86	8.72	8.59	8.47	8.36	8.25	8.16	8.07
7.0	45.48	11.99	11.53	10.99	10.82	10.64	10.49	10.34	10.07	9.83	9.62	9.43	9.25	9.09	8.95	8.81	8.69	8.58	8.47	8.38	8.28
7.1	46.13	12.30	11.82	11.27	11.10	10.92	10.76	10.60	10.33	10.09	9.87	9.67	9.49	9.33	9.18	9.04	8.92	8.80	8.69	8.59	8.50
7.2	46.78	12.61	12.12	11.56	11.38	11.19	11.04	10.87	10.59	10.34	10.12	9.92	9.73	9.57	9.42	9.28	9.15	9.03	8.92	8.81	8.72
7.3	47.43	12.92	12.42	11.85	11.67	11.47	11.31	11.15	10.86	10.60	10.37	10.17	9.98	9.81	9.65	9.51	9.38	9.25	9.14	9.04	8.94
7.4	48.08	13.24	12.73	12.14	11.95	11.76	11.59	11.42	11.13	10.87	10.63	10.42	10.23	10.05	9.89	9.75	9.61	9.49	9.37	9.26	9.16
7.5	48.73	13.56	13.03	12.43	12.24	12.04	11.87	11.70	11.40	11.13	10.89	10.68	10.48	10.30	10.14	9.99	9.85	9.72	9.60	9.49	9.39
7.6	49.38	13.88	13.35	12.73	12.54	12.33	12.16	11.98	11.67	11.40	11.15	10.93	10.73	10.55	10.38	10.23	10.09	9.96	9.84	9.72	9.62
7.7	50.03	14.21	13.66	13.03	12.83	12.62	12.45	12.27	11.95	11.67	11.42	11.19	10.99	10.80	10.63	10.47	10.33	10.20	10.07	9.96	9.85
7.8	50.68	14.54	13.98	13.34	13.13	12.92	12.74	12.55	12.23	11.95	11.69	11.46	11.25	11.06	10.88	10.72	10.58	10.44	10.31	10.19	10.09
7.9	51.33	14.87	14.30	13.64	13.44	13.22	13.03	12.84	12.51	12.22	11.96	11.72	11.51	11.32	11.14	10.97	10.82	10.68	10.55	10.43	10.32
8.0	51.97	15.21	14.62	13.95	13.74	13.52	13.33	13.14	12.80	12.50	12.23	11.99	11.77	11.58	11.39	11.23	11.07	10.93	10.80	10.68	10.56

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

2" Uponor PEX-a — 30% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
1.5	9.75	1.08	1.04	1.00	0.97	0.94	0.92	0.89	0.84	0.81	0.77	0.74	0.72	0.70	0.68	0.66	0.64	0.63	0.62	0.60	0.60
1.6	10.39	1.20	1.16	1.12	1.09	1.05	1.02	0.99	0.94	0.90	0.86	0.83	0.80	0.78	0.76	0.74	0.72	0.70	0.69	0.68	0.67
1.7	11.04	1.33	1.29	1.24	1.21	1.17	1.14	1.10	1.05	1.00	0.96	0.93	0.89	0.87	0.84	0.82	0.80	0.78	0.77	0.75	0.74
1.8	11.69	1.47	1.42	1.37	1.33	1.29	1.25	1.22	1.16	1.11	1.06	1.02	0.99	0.96	0.93	0.91	0.89	0.87	0.85	0.83	0.82
1.9	12.34	1.61	1.56	1.50	1.46	1.41	1.38	1.34	1.27	1.22	1.17	1.12	1.09	1.05	1.02	1.00	0.98	0.95	0.94	0.92	0.91
2.0	12.99	1.76	1.70	1.64	1.60	1.55	1.51	1.46	1.39	1.33	1.28	1.23	1.19	1.15	1.12	1.10	1.07	1.05	1.03	1.01	0.99
2.1	13.64	1.91	1.85	1.79	1.74	1.68	1.64	1.59	1.51	1.45	1.39	1.34	1.30	1.26	1.22	1.19	1.17	1.14	1.12	1.10	1.08
2.2	14.29	2.07	2.01	1.94	1.88	1.82	1.77	1.72	1.64	1.57	1.51	1.45	1.41	1.36	1.33	1.30	1.27	1.24	1.21	1.19	1.17
2.3	14.94	2.24	2.17	2.09	2.03	1.97	1.92	1.86	1.77	1.70	1.63	1.57	1.52	1.48	1.43	1.40	1.37	1.34	1.31	1.29	1.27
2.4	15.59	2.40	2.33	2.25	2.19	2.12	2.06	2.01	1.91	1.83	1.76	1.69	1.64	1.59	1.55	1.51	1.48	1.44	1.42	1.39	1.37
2.5	16.24	2.58	2.50	2.41	2.35	2.27	2.22	2.15	2.05	1.96	1.89	1.82	1.76	1.71	1.66	1.62	1.59	1.55	1.52	1.50	1.47
2.6	16.89	2.76	2.67	2.58	2.51	2.43	2.37	2.30	2.20	2.10	2.02	1.95	1.89	1.83	1.78	1.74	1.70	1.66	1.63	1.60	1.58
2.7	17.54	2.94	2.85	2.76	2.68	2.60	2.53	2.46	2.35	2.25	2.16	2.08	2.02	1.96	1.90	1.86	1.82	1.78	1.75	1.72	1.69
2.8	18.19	3.13	3.04	2.93	2.85	2.77	2.70	2.62	2.50	2.39	2.30	2.22	2.15	2.09	2.03	1.99	1.94	1.90	1.86	1.83	1.80
2.9	18.84	3.33	3.23	3.12	3.03	2.94	2.87	2.79	2.66	2.55	2.45	2.36	2.29	2.22	2.16	2.11	2.07	2.02	1.98	1.95	1.92
3.0	19.49	3.53	3.42	3.31	3.22	3.12	3.04	2.96	2.82	2.70	2.60	2.51	2.43	2.36	2.30	2.24	2.19	2.15	2.11	2.07	2.04
3.1	20.14	3.73	3.62	3.50	3.40	3.30	3.22	3.13	2.99	2.86	2.75	2.66	2.57	2.50	2.43	2.38	2.33	2.28	2.23	2.19	2.16
3.2	20.79	3.94	3.83	3.70	3.60	3.49	3.40	3.31	3.16	3.03	2.91	2.81	2.72	2.64	2.57	2.52	2.46	2.41	2.36	2.32	2.29
3.3	21.44	4.16	4.03	3.90	3.79	3.68	3.59	3.49	3.33	3.19	3.07	2.97	2.87	2.79	2.72	2.66	2.60	2.54	2.50	2.45	2.42
3.4	22.09	4.38	4.25	4.11	4.00	3.88	3.78	3.68	3.51	3.36	3.24	3.13	3.03	2.94	2.87	2.80	2.74	2.68	2.63	2.59	2.55
3.5	22.74	4.60	4.47	4.32	4.20	4.08	3.98	3.87	3.69	3.54	3.41	3.29	3.19	3.10	3.02	2.95	2.89	2.83	2.77	2.72	2.69
3.6	23.39	4.83	4.69	4.54	4.41	4.28	4.18	4.07	3.88	3.72	3.58	3.46	3.35	3.26	3.17	3.10	3.03	2.97	2.92	2.87	2.83
3.7	24.04	5.07	4.92	4.76	4.63	4.49	4.38	4.27	4.07	3.90	3.76	3.63	3.52	3.42	3.33	3.26	3.19	3.12	3.06	3.01	2.97
3.8	24.69	5.31	5.15	4.98	4.85	4.71	4.59	4.47	4.27	4.09	3.94	3.81	3.69	3.59	3.49	3.42	3.34	3.27	3.21	3.16	3.11
3.9	25.34	5.55	5.39	5.21	5.07	4.93	4.81	4.68	4.47	4.28	4.12	3.98	3.86	3.76	3.66	3.58	3.50	3.43	3.37	3.31	3.26
4.0	25.99	5.80	5.63	5.45	5.30	5.15	5.02	4.89	4.67	4.48	4.31	4.17	4.04	3.93	3.83	3.74	3.66	3.59	3.52	3.46	3.41
4.1	26.64	6.06	5.88	5.69	5.54	5.38	5.25	5.11	4.88	4.68	4.51	4.35	4.22	4.10	4.00	3.91	3.83	3.75	3.68	3.62	3.57
4.2	27.29	6.31	6.13	5.93	5.77	5.61	5.47	5.33	5.09	4.88	4.70	4.54	4.41	4.28	4.17	4.08	3.99	3.91	3.84	3.78	3.72
4.3	27.94	6.58	6.38	6.18	6.02	5.84	5.70	5.55	5.30	5.09	4.90	4.74	4.59	4.47	4.35	4.26	4.16	4.08	4.01	3.94	3.89
4.4	28.59	6.84	6.65	6.43	6.26	6.08	5.94	5.78	5.52	5.30	5.10	4.93	4.79	4.65	4.53	4.44	4.34	4.25	4.18	4.10	4.05
4.5	29.24	7.12	6.91	6.69	6.51	6.33	6.17	6.01	5.74	5.51	5.31	5.13	4.98	4.84	4.72	4.62	4.52	4.43	4.35	4.27	4.22
4.6	29.89	7.39	7.18	6.95	6.77	6.57	6.42	6.25	5.97	5.73	5.52	5.34	5.18	5.04	4.91	4.80	4.70	4.60	4.52	4.44	4.38
4.7	30.54	7.67	7.45	7.21	7.03	6.83	6.66	6.49	6.20	5.95	5.74	5.54	5.38	5.23	5.10	4.99	4.88	4.78	4.70	4.62	4.56

Continued on next page

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

Appendix G:

Hydronic friction loss tables

2" Uponor PEX-a — 30% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40ºF 4ºC	45ºF 7ºC	50ºF 10ºC	55ºF 13ºC	60ºF 16ºC	65ºF 18ºC	70ºF 21ºC	80ºF 27ºC	90ºF 32ºC	100ºF 38ºC	110ºF 43ºC	120ºF 49ºC	130ºF 54ºC	140ºF 60ºC	150ºF 66ºC	160ºF 71ºC	170ºF 77ºC	180ºF 82ºC	190ºF 88ºC	200ºF 93ºC
4.8	31.18	7.96	7.73	7.48	7.29	7.08	6.91	6.73	6.44	6.18	5.95	5.76	5.59	5.43	5.29	5.18	5.07	4.97	4.88	4.80	4.73
4.9	31.83	8.25	8.01	7.76	7.56	7.34	7.17	6.98	6.67	6.41	6.18	5.97	5.79	5.64	5.49	5.37	5.26	5.15	5.06	4.98	4.91
5.0	32.48	8.55	8.30	8.04	7.83	7.61	7.43	7.23	6.92	6.64	6.40	6.19	6.01	5.84	5.69	5.57	5.45	5.34	5.25	5.16	5.09
5.1	33.13	8.85	8.59	8.32	8.11	7.88	7.69	7.49	7.16	6.88	6.63	6.41	6.22	6.05	5.90	5.77	5.65	5.54	5.44	5.35	5.28
5.2	33.78	9.15	8.89	8.61	8.39	8.15	7.96	7.75	7.41	7.12	6.86	6.63	6.44	6.27	6.11	5.98	5.85	5.73	5.63	5.54	5.46
5.3	34.43	9.46	9.19	8.90	8.67	8.43	8.23	8.01	7.67	7.36	7.10	6.86	6.66	6.48	6.32	6.18	6.05	5.93	5.83	5.73	5.65
5.4	35.08	9.77	9.49	9.19	8.96	8.71	8.50	8.28	7.92	7.61	7.34	7.09	6.89	6.70	6.53	6.39	6.26	6.13	6.03	5.92	5.85
5.5	35.73	10.09	9.80	9.49	9.25	8.99	8.78	8.55	8.18	7.86	7.58	7.33	7.12	6.92	6.75	6.61	6.47	6.34	6.23	6.12	6.04
5.6	36.38	10.41	10.12	9.80	9.55	9.28	9.06	8.83	8.45	8.11	7.83	7.57	7.35	7.15	6.97	6.82	6.68	6.55	6.44	6.32	6.24
5.7	37.03	10.74	10.43	10.11	9.85	9.57	9.35	9.11	8.72	8.37	8.07	7.81	7.58	7.38	7.19	7.04	6.89	6.76	6.64	6.53	6.45
5.8	37.68	11.07	10.76	10.42	10.16	9.87	9.64	9.39	8.99	8.64	8.33	8.06	7.82	7.61	7.42	7.27	7.11	6.97	6.85	6.74	6.65
5.9	38.33	11.40	11.08	10.74	10.46	10.17	9.94	9.68	9.26	8.90	8.58	8.30	8.07	7.85	7.65	7.49	7.33	7.19	7.07	6.95	6.86
6.0	38.98	11.74	11.41	11.06	10.78	10.48	10.23	9.97	9.54	9.17	8.84	8.56	8.31	8.09	7.88	7.72	7.56	7.41	7.28	7.16	7.07
6.1	39.63	12.09	11.75	11.38	11.09	10.79	10.54	10.27	9.83	9.44	9.11	8.81	8.56	8.33	8.12	7.95	7.79	7.63	7.50	7.38	7.28
6.2	40.28	12.43	12.09	11.71	11.42	11.10	10.84	10.57	10.11	9.72	9.38	9.07	8.81	8.58	8.36	8.19	8.02	7.86	7.73	7.60	7.50
6.3	40.93	12.79	12.43	12.04	11.74	11.42	11.15	10.87	10.40	10.00	9.65	9.33	9.07	8.82	8.60	8.43	8.25	8.09	7.95	7.82	7.72
6.4	41.58	13.14	12.78	12.38	12.07	11.74	11.47	11.17	10.70	10.28	9.92	9.60	9.32	9.08	8.85	8.67	8.49	8.32	8.18	8.04	7.94
6.5	42.23	13.50	13.13	12.72	12.40	12.06	11.78	11.48	10.99	10.57	10.20	9.87	9.59	9.33	9.10	8.91	8.73	8.55	8.41	8.27	8.16
6.6	42.88	13.87	13.48	13.07	12.74	12.39	12.10	11.80	11.30	10.86	10.48	10.14	9.85	9.59	9.35	9.16	8.97	8.79	8.65	8.50	8.39
6.7	43.53	14.24	13.84	13.42	13.08	12.72	12.43	12.12	11.60	11.15	10.76	10.42	10.12	9.85	9.61	9.41	9.21	9.03	8.88	8.73	8.62
6.8	44.18	14.61	14.21	13.77	13.43	13.06	12.76	12.44	11.91	11.45	11.05	10.69	10.39	10.12	9.86	9.66	9.46	9.28	9.12	8.97	8.86
6.9	44.83	14.99	14.57	14.13	13.78	13.40	13.09	12.76	12.22	11.75	11.34	10.98	10.66	10.38	10.13	9.92	9.71	9.52	9.37	9.21	9.09
7.0	45.48	15.37	14.95	14.49	14.13	13.74	13.43	13.09	12.54	12.05	11.63	11.26	10.94	10.65	10.39	10.18	9.97	9.77	9.61	9.45	9.33
7.1	46.13	15.76	15.32	14.85	14.49	14.09	13.77	13.42	12.86	12.36	11.93	11.55	11.22	10.93	10.66	10.44	10.22	10.03	9.86	9.70	9.57
7.2	46.78	16.15	15.70	15.22	14.85	14.44	14.11	13.76	13.18	12.67	12.23	11.84	11.51	11.20	10.93	10.70	10.48	10.28	10.11	9.94	9.82
7.3	47.43	16.54	16.09	15.60	15.21	14.80	14.46	14.10	13.50	12.99	12.54	12.14	11.79	11.48	11.20	10.97	10.75	10.54	10.37	10.19	10.06
7.4	48.08	16.94	16.48	15.97	15.58	15.16	14.81	14.44	13.83	13.30	12.84	12.43	12.08	11.77	11.48	11.24	11.01	10.80	10.62	10.45	10.31
7.5	48.73	17.34	16.87	16.36	15.95	15.52	15.17	14.79	14.17	13.63	13.15	12.74	12.38	12.05	11.76	11.52	11.28	11.07	10.88	10.70	10.57
7.6	49.38	17.75	17.27	16.74	16.33	15.89	15.53	15.14	14.50	13.95	13.47	13.04	12.67	12.34	12.04	11.80	11.55	11.33	11.15	10.96	10.82
7.7	50.03	18.16	17.67	17.13	16.71	16.26	15.89	15.49	14.84	14.28	13.79	13.35	12.97	12.64	12.33	12.08	11.83	11.60	11.41	11.22	11.08
7.8	50.68	18.58	18.07	17.52	17.09	16.63	16.25	15.85	15.19	14.61	14.11	13.66	13.28	12.93	12.61	12.36	12.11	11.87	11.68	11.49	11.34
7.9	51.33	19.00	18.48	17.92	17.48	17.01	16.62	16.21	15.54	14.94	14.43	13.97	13.58	13.23	12.91	12.65	12.39	12.15	11.95	11.75	11.61
8.0	51.97	19.42	18.89	18.32	17.87	17.39	17.00	16.58	15.89	15.28	14.76	14.29	13.89	13.53	13.20	12.93	12.67	12.43	12.23	12.02	11.87

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

2" Uponor PEX-a — 40% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40ºF 4ºC	45ºF 7.2ºC	50ºF 10ºC	55ºF 12.8ºC	60ºF 15.6ºC	65ºF 18.3ºC	70ºF 21.1ºC	80ºF 26.7ºC	90ºF 32.2ºC	100ºF 37.8ºC	110ºF 43.3ºC	120ºF 48.9ºC	130ºF 54.4ºC	140ºF 60ºC	150ºF 65.6ºC	160ºF 71.1ºC	170ºF 76.7ºC	180ºF 82.2ºC	190ºF 87.8ºC	200ºF 93.3ºC
1.5	9.75	1.26	1.21	1.15	1.11	1.07	1.03	0.99	0.93	0.88	0.84	0.81	0.77	0.75	0.72	0.70	0.68	0.66	0.65	0.64	0.62
1.6	10.39	1.41	1.35	1.29	1.24	1.19	1.15	1.11	1.04	0.99	0.94	0.90	0.86	0.83	0.81	0.78	0.76	0.74	0.73	0.71	0.70
1.7	11.04	1.56	1.49	1.42	1.37	1.32	1.28	1.23	1.16	1.10	1.05	1.00	0.96	0.93	0.90	0.87	0.85	0.83	0.81	0.79	0.78
1.8	11.69	1.71	1.64	1.57	1.51	1.45	1.41	1.36	1.28	1.21	1.15	1.11	1.06	1.02	0.99	0.96	0.94	0.91	0.90	0.88	0.86
1.9	12.34	1.88	1.80	1.72	1.66	1.59	1.54	1.49	1.40	1.33	1.27	1.21	1.17	1.13	1.09	1.06	1.03	1.01	0.99	0.96	0.95
2.0	12.99	2.05	1.97	1.88	1.81	1.74	1.69	1.63	1.53	1.45	1.39	1.33	1.28	1.23	1.19	1.16	1.13	1.10	1.08	1.06	1.04
2.1	13.64	2.22	2.14	2.04	1.97	1.89	1.83	1.77	1.67	1.58	1.51	1.45	1.39	1.34	1.30	1.26	1.23	1.20	1.18	1.15	1.13
2.2	14.29	2.41	2.31	2.21	2.13	2.05	1.99	1.92	1.81	1.71	1.64	1.57	1.51	1.46	1.41	1.37	1.34	1.30	1.28	1.25	1.23
2.3	14.94	2.59	2.49	2.38	2.30	2.21	2.14	2.07	1.95	1.85	1.77	1.69	1.63	1.57	1.52	1.48	1.45	1.41	1.38	1.35	1.33
2.4	15.59	2.79	2.68	2.56	2.47	2.38	2.31	2.23	2.10	1.99	1.90	1.83	1.76	1.70	1.64	1.60	1.56	1.52	1.49	1.46	1.43
2.5	16.24	2.99	2.87	2.75	2.65	2.55	2.47	2.39	2.26	2.14	2.04	1.96	1.89	1.82	1.77	1.72	1.68	1.63	1.60	1.57	1.54
2.6	16.89	3.19	3.07	2.94	2.84	2.73	2.65	2.56	2.41	2.29	2.19	2.10	2.02	1.95	1.89	1.84	1.80	1.75	1.72	1.68	1.65
2.7	17.54	3.41	3.28	3.13	3.03	2.91	2.83	2.73	2.58	2.45	2.34	2.24	2.16	2.09	2.02	1.97	1.92	1.87	1.84	1.80	1.77
2.8	18.19	3.62	3.48	3.33	3.22	3.10	3.01	2.91	2.75	2.61	2.49	2.39	2.30	2.22	2.16	2.10	2.05	2.00	1.96	1.92	1.89
2.9	18.84	3.85	3.70	3.54	3.42	3.29	3.20	3.09	2.92	2.77	2.65	2.54	2.45	2.37	2.29	2.23	2.18	2.13	2.09	2.04	2.01
3.0	19.49	4.07	3.92	3.75	3.63	3.49	3.39	3.28	3.09	2.94	2.81	2.70	2.60	2.51	2.44	2.37	2.31	2.26	2.21	2.17	2.13
3.1	20.14	4.31	4.15	3.97	3.84	3.70	3.59	3.47	3.28	3.11	2.98	2.86	2.75	2.66	2.58	2.51	2.45	2.39	2.35	2.30	2.26
3.2	20.79	4.55	4.38	4.19	4.05	3.90	3.79	3.66	3.46	3.29	3.15	3.02	2.91	2.81	2.73	2.66	2.59	2.53	2.48	2.43	2.39
3.3	21.44	4.80	4.62	4.42	4.28	4.12	4.00	3.87	3.65	3.47	3.32	3.19	3.07	2.97	2.88	2.81	2.74	2.67	2.62	2.57	2.53
3.4	22.09	5.05	4.86	4.65	4.50	4.34	4.21	4.07	3.85	3.66	3.50	3.36	3.24	3.13	3.04	2.96	2.89	2.82	2.77	2.71	2.66
3.5	22.74	5.30	5.11	4.89	4.73	4.56	4.42	4.28	4.05	3.85	3.68	3.54	3.41	3.30	3.20	3.11	3.04	2.97	2.91	2.85	2.81
3.6	23.39	5.56	5.36	5.14	4.97	4.79	4.65	4.50	4.25	4.04	3.87	3.72	3.58	3.47	3.36	3.27	3.20	3.12	3.06	3.00	2.95
3.7	24.04	5.83	5.62	5.38	5.21	5.02	4.87	4.71	4.46	4.24	4.06	3.90	3.76	3.64	3.53	3.44	3.36	3.28	3.22	3.15	3.10
3.8	24.69	6.10	5.88	5.64	5.45	5.26	5.10	4.94	4.67	4.45	4.25	4.09	3.94	3.81	3.70	3.60	3.52	3.43	3.37	3.30	3.25
3.9	25.34	6.38	6.15	5.89	5.70	5.50	5.34	5.17	4.89	4.65	4.45	4.28	4.12	3.99	3.87	3.77	3.69	3.60	3.53	3.46	3.40
4.0	25.99	6.67	6.42	6.16	5.96	5.74	5.58	5.40	5.11	4.86	4.65	4.47	4.31	4.18	4.05	3.95	3.85	3.76	3.69	3.62	3.56
4.1	26.64	6.95	6.70	6.43	6.22	6.00	5.82	5.64	5.34	5.08	4.86	4.67	4.51	4.36	4.23	4.12	4.03	3.93	3.86	3.78	3.72
4.2	27.29	7.25	6.99	6.70	6.48	6.25	6.07	5.88	5.56	5.30	5.07	4.88	4.70	4.55	4.42	4.30	4.20	4.10	4.03	3.95	3.89
4.3	27.94	7.55	7.27	6.98	6.75	6.51	6.33	6.12	5.80	5.52	5.29	5.08	4.90	4.75	4.61	4.49	4.38	4.28	4.20	4.12	4.05
4.4	28.59	7.85	7.57	7.26	7.03	6.78	6.58	6.38	6.04	5.75	5.50	5.29	5.10	4.94	4.80	4.67	4.57	4.46	4.38	4.29	4.22
4.5	29.24	8.16	7.87	7.55	7.31	7.05	6.85	6.63	6.28	5.98	5.73	5.51	5.31	5.14	4.99	4.86	4.75	4.64	4.56	4.47	4.40
4.6	29.89	8.48	8.17	7.84	7.59	7.32	7.11	6.89	6.53	6.21	5.95	5.72	5.52	5.35	5.19	5.06	4.94	4.83	4.74	4.64	4.57
4.7	30.54	8.80	8.48	8.14	7.88	7.60	7.39	7.15	6.78	6.45	6.18	5.95	5.74	5.56	5.39	5.26	5.14	5.02	4.93	4.83	4.75

Continued on next page

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

2" Uponor PEX-a — 40% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40ºF 4ºC	45ºF 7.2ºC	50ºF 10ºC	55ºF 12.8ºC	60ºF 15.6ºC	65ºF 18.3ºC	70ºF 21.1ºC	80ºF 26.7ºC	90ºF 32.2ºC	100ºF 37.8ºC	110ºF 43.3ºC	120ºF 48.9ºC	130ºF 54.4ºC	140ºF 60ºC	150ºF 65.6ºC	160ºF 71.1ºC	170ºF 76.7ºC	180ºF 82.2ºC	190ºF 87.8ºC	200ºF 93.3ºC
4.8	31.18	9.12	8.79	8.44	8.17	7.88	7.66	7.42	7.03	6.70	6.42	6.17	5.95	5.77	5.60	5.46	5.33	5.21	5.12	5.01	4.93
4.9	31.83	9.45	9.11	8.75	8.47	8.17	7.94	7.69	7.29	6.94	6.65	6.40	6.18	5.98	5.81	5.66	5.53	5.40	5.31	5.20	5.12
5.0	32.48	9.78	9.44	9.06	8.77	8.46	8.23	7.97	7.55	7.20	6.90	6.63	6.40	6.20	6.02	5.87	5.74	5.60	5.50	5.39	5.31
5.1	33.13	10.12	9.77	9.37	9.08	8.76	8.52	8.25	7.82	7.45	7.14	6.87	6.63	6.42	6.24	6.08	5.94	5.80	5.70	5.59	5.50
5.2	33.78	10.47	10.10	9.69	9.39	9.06	8.81	8.53	8.09	7.71	7.39	7.11	6.86	6.65	6.46	6.29	6.15	6.01	5.90	5.78	5.70
5.3	34.43	10.82	10.44	10.02	9.71	9.37	9.11	8.82	8.36	7.97	7.64	7.35	7.10	6.88	6.68	6.51	6.36	6.22	6.11	5.98	5.89
5.4	35.08	11.17	10.78	10.35	10.03	9.68	9.41	9.12	8.64	8.24	7.90	7.60	7.34	7.11	6.90	6.73	6.58	6.43	6.32	6.19	6.09
5.5	35.73	11.53	11.13	10.69	10.35	9.99	9.71	9.41	8.93	8.51	8.16	7.85	7.58	7.34	7.13	6.95	6.80	6.64	6.53	6.39	6.30
5.6	36.38	11.90	11.48	11.03	10.68	10.31	10.03	9.72	9.21	8.78	8.42	8.11	7.82	7.58	7.37	7.18	7.02	6.86	6.74	6.60	6.50
5.7	37.03	12.27	11.84	11.37	11.02	10.64	10.34	10.02	9.50	9.06	8.69	8.36	8.07	7.83	7.60	7.41	7.25	7.08	6.96	6.82	6.71
5.8	37.68	12.64	12.20	11.72	11.36	10.96	10.66	10.33	9.80	9.35	8.96	8.63	8.33	8.07	7.84	7.65	7.48	7.30	7.18	7.03	6.93
5.9	38.33	13.02	12.57	12.07	11.70	11.29	10.98	10.65	10.10	9.63	9.24	8.89	8.58	8.32	8.08	7.88	7.71	7.53	7.40	7.25	7.14
6.0	38.98	13.40	12.94	12.43	12.05	11.63	11.31	10.96	10.40	9.92	9.51	9.16	8.84	8.57	8.33	8.12	7.94	7.76	7.63	7.47	7.36
6.1	39.63	13.79	13.31	12.79	12.40	11.97	11.64	11.29	10.71	10.21	9.80	9.43	9.11	8.83	8.58	8.37	8.18	7.99	7.86	7.70	7.58
6.2	40.28	14.19	13.70	13.16	12.75	12.32	11.98	11.61	11.02	10.51	10.08	9.71	9.37	9.09	8.83	8.61	8.42	8.23	8.09	7.93	7.81
6.3	40.93	14.59	14.08	13.53	13.12	12.67	12.32	11.94	11.33	10.81	10.37	9.99	9.65	9.35	9.09	8.86	8.67	8.47	8.32	8.16	8.04
6.4	41.58	14.99	14.47	13.91	13.48	13.02	12.66	12.28	11.65	11.12	10.66	10.27	9.92	9.62	9.35	9.11	8.91	8.71	8.56	8.39	8.27
6.5	42.23	15.40	14.87	14.29	13.85	13.38	13.01	12.62	11.97	11.43	10.96	10.56	10.20	9.89	9.61	9.37	9.16	8.96	8.80	8.63	8.50
6.6	42.88	15.81	15.27	14.67	14.22	13.74	13.36	12.96	12.30	11.74	11.26	10.85	10.48	10.16	9.87	9.63	9.42	9.21	9.05	8.87	8.74
6.7	43.53	16.23	15.67	15.06	14.60	14.10	13.72	13.31	12.63	12.05	11.57	11.14	10.76	10.43	10.14	9.89	9.68	9.46	9.30	9.11	8.98
6.8	44.18	16.65	16.08	15.45	14.98	14.48	14.08	13.66	12.96	12.37	11.87	11.44	11.05	10.71	10.41	10.16	9.94	9.71	9.55	9.36	9.22
6.9	44.83	17.07	16.49	15.85	15.37	14.85	14.45	14.01	13.30	12.70	12.18	11.74	11.34	11.00	10.69	10.43	10.20	9.97	9.80	9.61	9.46
7.0	45.48	17.51	16.91	16.25	15.76	15.23	14.82	14.37	13.64	13.02	12.50	12.04	11.63	11.28	10.97	10.70	10.46	10.23	10.06	9.86	9.71
7.1	46.13	17.94	17.33	16.66	16.16	15.61	15.19	14.73	13.99	13.35	12.82	12.35	11.93	11.57	11.25	10.97	10.73	10.49	10.31	10.11	9.96
7.2	46.78	18.38	17.76	17.07	16.56	16.00	15.57	15.10	14.34	13.69	13.14	12.66	12.23	11.86	11.53	11.25	11.01	10.76	10.58	10.37	10.22
7.3	47.43	18.83	18.19	17.49	16.96	16.39	15.95	15.47	14.69	14.03	13.46	12.97	12.54	12.16	11.82	11.53	11.28	11.03	10.84	10.63	10.47
7.4	48.08	19.28	18.62	17.91	17.37	16.78	16.33	15.84	15.05	14.37	13.79	13.29	12.84	12.46	12.11	11.82	11.56	11.30	11.11	10.89	10.73
7.5	48.73	19.73	19.06	18.33	17.78	17.18	16.72	16.22	15.41	14.71	14.12	13.61	13.15	12.76	12.41	12.10	11.84	11.58	11.38	11.16	11.00
7.6	49.38	20.19	19.51	18.76	18.20	17.59	17.12	16.60	15.77	15.06	14.46	13.94	13.47	13.07	12.70	12.39	12.13	11.86	11.66	11.43	11.26
7.7	50.03	20.66	19.96	19.19	18.62	18.00	17.51	16.99	16.14	15.42	14.80	14.26	13.78	13.37	13.00	12.69	12.41	12.14	11.93	11.70	11.53
7.8	50.68	21.12	20.41	19.63	19.04	18.41	17.91	17.38	16.51	15.77	15.14	14.59	14.11	13.69	13.31	12.98	12.70	12.42	12.21	11.98	11.80
7.9	51.33	21.60	20.87	20.07	19.47	18.82	18.32	17.78	16.89	16.13	15.49	14.93	14.43	14.00	13.61	13.28	13.00	12.71	12.50	12.25	12.08
8.0	51.97	22.07	21.33	20.52	19.91	19.24	18.73	18.17	17.27	16.49	15.84	15.27	14.76	14.32	13.92	13.59	13.29	13.00	12.78	12.53	12.35

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

2" Uponor PEX-a — 50% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7.2°C	50°F 10°C	55°F 12.8°C	60°F 15.6°C	65°F 18.3°C	70°F 21.1°C	80°F 26.7°C	90°F 32.2°C	100°F 37.8°C	110°F 43.3°C	120°F 48.9°C	130°F 54.4°C	140°F 60°C	150°F 65.6°C	160°F 71.1°C	170°F 76.7°C	180°F 82.2°C	190°F 87.8°C	200°F 93.3°C
1.5	9.75	1.43	1.37	1.30	1.25	1.19	1.15	1.11	1.03	0.97	0.92	0.88	0.84	0.80	0.78	0.75	0.73	0.71	0.69	0.67	0.66
1.6	10.39	1.59	1.52	1.45	1.39	1.33	1.28	1.23	1.15	1.09	1.03	0.98	0.94	0.90	0.87	0.84	0.81	0.79	0.77	0.75	0.74
1.7	11.04	1.76	1.69	1.60	1.54	1.47	1.42	1.37	1.28	1.20	1.14	1.09	1.04	1.00	0.96	0.93	0.91	0.88	0.86	0.84	0.82
1.8	11.69	1.94	1.86	1.77	1.70	1.62	1.57	1.51	1.41	1.33	1.26	1.20	1.15	1.10	1.07	1.03	1.00	0.97	0.95	0.93	0.91
1.9	12.34	2.12	2.03	1.93	1.86	1.78	1.72	1.65	1.55	1.46	1.38	1.32	1.26	1.21	1.17	1.13	1.10	1.07	1.04	1.02	1.00
2.0	12.99	2.31	2.21	2.11	2.03	1.94	1.88	1.80	1.69	1.59	1.51	1.44	1.38	1.33	1.28	1.24	1.20	1.17	1.14	1.11	1.09
2.1	13.64	2.51	2.40	2.29	2.20	2.11	2.04	1.96	1.84	1.73	1.64	1.57	1.50	1.44	1.39	1.35	1.31	1.27	1.24	1.21	1.19
2.2	14.29	2.71	2.60	2.48	2.38	2.28	2.21	2.12	1.99	1.88	1.78	1.70	1.63	1.57	1.51	1.46	1.42	1.38	1.35	1.32	1.29
2.3	14.94	2.92	2.80	2.67	2.57	2.46	2.38	2.29	2.15	2.03	1.92	1.84	1.76	1.69	1.63	1.58	1.54	1.50	1.46	1.43	1.40
2.4	15.59	3.14	3.01	2.87	2.76	2.65	2.56	2.46	2.31	2.18	2.07	1.98	1.90	1.82	1.76	1.71	1.66	1.61	1.57	1.54	1.50
2.5	16.24	3.36	3.22	3.07	2.96	2.84	2.74	2.64	2.48	2.34	2.22	2.12	2.04	1.96	1.89	1.83	1.78	1.73	1.69	1.65	1.62
2.6	16.89	3.59	3.45	3.29	3.16	3.03	2.93	2.83	2.65	2.51	2.38	2.27	2.18	2.10	2.03	1.96	1.91	1.86	1.81	1.77	1.73
2.7	17.54	3.83	3.67	3.50	3.37	3.24	3.13	3.02	2.83	2.67	2.54	2.43	2.33	2.24	2.17	2.10	2.04	1.98	1.93	1.89	1.85
2.8	18.19	4.07	3.91	3.73	3.59	3.44	3.33	3.21	3.01	2.85	2.71	2.59	2.48	2.39	2.31	2.24	2.17	2.12	2.06	2.02	1.98
2.9	18.84	4.32	4.15	3.96	3.81	3.66	3.54	3.41	3.20	3.03	2.88	2.75	2.64	2.54	2.45	2.38	2.31	2.25	2.20	2.15	2.10
3.0	19.49	4.58	4.39	4.19	4.04	3.87	3.75	3.61	3.40	3.21	3.05	2.92	2.80	2.70	2.61	2.53	2.46	2.39	2.33	2.28	2.23
3.1	20.14	4.84	4.64	4.43	4.27	4.10	3.97	3.82	3.59	3.40	3.23	3.09	2.96	2.86	2.76	2.68	2.60	2.53	2.47	2.42	2.37
3.2	20.79	5.10	4.90	4.68	4.51	4.33	4.19	4.04	3.80	3.59	3.42	3.27	3.13	3.02	2.92	2.83	2.75	2.68	2.61	2.56	2.51
3.3	21.44	5.38	5.16	4.93	4.75	4.56	4.42	4.26	4.00	3.79	3.60	3.45	3.31	3.19	3.08	2.99	2.91	2.83	2.76	2.70	2.65
3.4	22.09	5.66	5.43	5.19	5.00	4.80	4.65	4.48	4.22	3.99	3.80	3.63	3.49	3.36	3.25	3.15	3.06	2.98	2.91	2.85	2.79
3.5	22.74	5.94	5.71	5.45	5.26	5.05	4.89	4.71	4.43	4.20	3.99	3.82	3.67	3.54	3.42	3.31	3.22	3.14	3.06	3.00	2.94
3.6	23.39	6.23	5.99	5.72	5.52	5.30	5.13	4.95	4.66	4.41	4.19	4.01	3.85	3.71	3.59	3.48	3.39	3.30	3.22	3.15	3.09
3.7	24.04	6.53	6.27	5.99	5.78	5.55	5.38	5.19	4.88	4.62	4.40	4.21	4.04	3.90	3.77	3.66	3.56	3.46	3.38	3.31	3.24
3.8	24.69	6.83	6.56	6.27	6.05	5.81	5.63	5.43	5.11	4.84	4.61	4.41	4.24	4.09	3.95	3.83	3.73	3.63	3.54	3.47	3.40
3.9	25.34	7.14	6.86	6.56	6.33	6.08	5.89	5.68	5.35	5.07	4.82	4.62	4.44	4.28	4.14	4.01	3.90	3.80	3.71	3.64	3.56
4.0	25.99	7.45	7.16	6.85	6.61	6.35	6.15	5.94	5.59	5.29	5.04	4.83	4.64	4.47	4.33	4.20	4.08	3.98	3.88	3.80	3.73
4.1	26.64	7.77	7.47	7.14	6.90	6.63	6.42	6.20	5.83	5.53	5.26	5.04	4.84	4.67	4.52	4.38	4.27	4.16	4.06	3.98	3.89
4.2	27.29	8.10	7.79	7.44	7.19	6.91	6.69	6.46	6.08	5.76	5.49	5.26	5.05	4.87	4.71	4.58	4.45	4.34	4.23	4.15	4.07
4.3	27.94	8.43	8.11	7.75	7.48	7.19	6.97	6.73	6.34	6.01	5.72	5.48	5.27	5.08	4.91	4.77	4.64	4.52	4.42	4.33	4.24
4.4	28.59	8.77	8.43	8.06	7.79	7.48	7.25	7.00	6.60	6.25	5.96	5.70	5.48	5.29	5.12	4.97	4.84	4.71	4.60	4.51	4.42
4.5	29.24	9.11	8.76	8.38	8.09	7.78	7.54	7.28	6.86	6.50	6.20	5.93	5.71	5.50	5.33	5.17	5.03	4.90	4.79	4.69	4.60
4.6	29.89	9.46	9.10	8.70	8.40	8.08	7.83	7.56	7.13	6.76	6.44	6.17	5.93	5.72	5.54	5.38	5.23	5.10	4.98	4.88	4.78
4.7	30.54	9.81	9.44	9.03	8.72	8.39	8.13	7.85	7.40	7.02	6.69	6.41	6.16	5.94	5.75	5.58	5.44	5.30	5.17	5.07	4.97

Continued on next page

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

2" Uponor PEX-a — 50% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7.2°C	50°F 10°C	55°F 12.8°C	60°F 15.6°C	65°F 18.3°C	70°F 21.1°C	80°F 26.7°C	90°F 32.2°C	100°F 37.8°C	110°F 43.3°C	120°F 48.9°C	130°F 54.4°C	140°F 60°C	150°F 65.6°C	160°F 71.1°C	170°F 76.7°C	180°F 82.2°C	190°F 87.8°C	200°F 93.3°C
4.8	31.18	10.17	9.79	9.36	9.04	8.70	8.43	8.14	7.68	7.28	6.94	6.65	6.39	6.17	5.97	5.80	5.64	5.50	5.37	5.26	5.16
4.9	31.83	10.54	10.14	9.70	9.37	9.01	8.74	8.44	7.96	7.55	7.19	6.89	6.63	6.40	6.19	6.01	5.85	5.71	5.57	5.46	5.35
5.0	32.48	10.91	10.49	10.04	9.70	9.33	9.05	8.74	8.24	7.82	7.45	7.14	6.87	6.63	6.42	6.23	6.07	5.91	5.78	5.66	5.55
5.1	33.13	11.28	10.86	10.39	10.04	9.66	9.36	9.05	8.53	8.09	7.72	7.40	7.11	6.87	6.65	6.45	6.29	6.13	5.98	5.87	5.75
5.2	33.78	11.66	11.23	10.74	10.38	9.99	9.68	9.36	8.83	8.37	7.99	7.65	7.36	7.11	6.88	6.68	6.51	6.34	6.19	6.07	5.95
5.3	34.43	12.05	11.60	11.10	10.73	10.32	10.01	9.67	9.12	8.66	8.26	7.91	7.61	7.35	7.12	6.91	6.73	6.56	6.41	6.28	6.16
5.4	35.08	12.44	11.98	11.47	11.08	10.66	10.34	9.99	9.43	8.94	8.53	8.18	7.87	7.60	7.36	7.14	6.96	6.78	6.63	6.50	6.37
5.5	35.73	12.84	12.36	11.83	11.44	11.01	10.67	10.31	9.73	9.24	8.81	8.45	8.13	7.85	7.60	7.38	7.19	7.01	6.85	6.71	6.58
5.6	36.38	13.24	12.75	12.21	11.80	11.36	11.01	10.64	10.04	9.53	9.10	8.72	8.39	8.10	7.85	7.62	7.42	7.24	7.07	6.93	6.80
5.7	37.03	13.65	13.14	12.59	12.17	11.71	11.36	10.98	10.36	9.83	9.38	9.00	8.66	8.36	8.10	7.86	7.66	7.47	7.30	7.15	7.02
5.8	37.68	14.07	13.54	12.97	12.54	12.07	11.71	11.31	10.68	10.14	9.68	9.28	8.93	8.62	8.35	8.11	7.90	7.71	7.53	7.38	7.24
5.9	38.33	14.48	13.95	13.36	12.91	12.43	12.06	11.66	11.00	10.45	9.97	9.56	9.20	8.89	8.61	8.36	8.15	7.94	7.76	7.61	7.46
6.0	38.98	14.91	14.36	13.75	13.29	12.80	12.42	12.00	11.33	10.76	10.27	9.85	9.48	9.16	8.87	8.62	8.39	8.19	8.00	7.84	7.69
6.1	39.63	15.34	14.77	14.15	13.68	13.17	12.78	12.35	11.66	11.08	10.57	10.14	9.76	9.43	9.13	8.87	8.64	8.43	8.24	8.08	7.92
6.2	40.28	15.77	15.19	14.55	14.07	13.55	13.14	12.71	12.00	11.40	10.88	10.43	10.05	9.70	9.40	9.13	8.90	8.68	8.48	8.32	8.16
6.3	40.93	16.21	15.61	14.96	14.47	13.93	13.52	13.07	12.34	11.72	11.19	10.73	10.33	9.98	9.67	9.40	9.16	8.93	8.73	8.56	8.39
6.4	41.58	16.66	16.04	15.37	14.87	14.32	13.89	13.43	12.69	12.05	11.51	11.04	10.63	10.27	9.95	9.66	9.42	9.18	8.98	8.80	8.63
6.5	42.23	17.11	16.48	15.79	15.27	14.71	14.27	13.80	13.04	12.38	11.82	11.34	10.92	10.55	10.22	9.94	9.68	9.44	9.23	9.05	8.88
6.6	42.88	17.56	16.92	16.21	15.68	15.10	14.66	14.17	13.39	12.72	12.15	11.65	11.22	10.84	10.50	10.21	9.95	9.70	9.48	9.30	9.12
6.7	43.53	18.02	17.36	16.64	16.09	15.50	15.04	14.55	13.75	13.06	12.47	11.97	11.52	11.13	10.79	10.49	10.22	9.97	9.74	9.55	9.37
6.8	44.18	18.49	17.81	17.07	16.51	15.91	15.44	14.93	14.11	13.40	12.80	12.28	11.83	11.43	11.08	10.77	10.49	10.24	10.00	9.81	9.62
6.9	44.83	18.96	18.27	17.51	16.94	16.31	15.83	15.32	14.47	13.75	13.14	12.61	12.14	11.73	11.37	11.05	10.77	10.51	10.27	10.07	9.88
7.0	45.48	19.43	18.72	17.95	17.37	16.73	16.24	15.70	14.84	14.11	13.47	12.93	12.45	12.04	11.66	11.34	11.05	10.78	10.54	10.33	10.14
7.1	46.13	19.91	19.19	18.40	17.80	17.15	16.64	16.10	15.22	14.46	13.82	13.26	12.77	12.34	11.96	11.63	11.33	11.06	10.81	10.60	10.40
7.2	46.78	20.40	19.66	18.85	18.24	17.57	17.05	16.50	15.59	14.82	14.16	13.59	13.09	12.65	12.26	11.92	11.62	11.34	11.08	10.87	10.66
7.3	47.43	20.89	20.13	19.30	18.68	18.00	17.47	16.90	15.98	15.19	14.51	13.93	13.42	12.97	12.57	12.22	11.91	11.62	11.36	11.14	10.93
7.4	48.08	21.38	20.61	19.76	19.12	18.43	17.89	17.31	16.36	15.55	14.86	14.27	13.74	13.28	12.88	12.52	12.20	11.91	11.64	11.42	11.20
7.5	48.73	21.88	21.10	20.23	19.58	18.86	18.31	17.72	16.75	15.93	15.22	14.61	14.07	13.61	13.19	12.82	12.50	12.20	11.92	11.70	11.47
7.6	49.38	22.39	21.58	20.70	20.03	19.30	18.74	18.13	17.15	16.30	15.58	14.96	14.41	13.93	13.50	13.13	12.80	12.49	12.21	11.98	11.75
7.7	50.03	22.90	22.08	21.17	20.49	19.75	19.17	18.55	17.54	16.68	15.94	15.31	14.75	14.26	13.82	13.44	13.10	12.78	12.50	12.26	12.03
7.8	50.68	23.42	22.58	21.65	20.96	20.20	19.61	18.98	17.95	17.07	16.31	15.66	15.09	14.59	14.14	13.75	13.41	13.08	12.79	12.55	12.31
7.9	51.33	23.94	23.08	22.14	21.43	20.65	20.05	19.40	18.35	17.45	16.68	16.02	15.43	14.92	14.47	14.07	13.71	13.38	13.09	12.84	12.60
8.0	51.97	24.46	23.59	22.63	21.90	21.11	20.50	19.84	18.76	17.84	17.06	16.38	15.78	15.26	14.80	14.39	14.03	13.69	13.38	13.13	12.88

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

2½" Uponor PEX-a — 100% Water — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7.2°C	50°F 10°C	55°F 12.8°C	60°F 15.6°C	65°F 18.3°C	70°F 21.1°C	80°F 26.7°C	90°F 32.2°C	100°F 37.8°C	110°F 43.3°C	120°F 48.9°C	130°F 54.4°C	140°F 60°C	150°F 65.6°C	160°F 71.1°C	170°F 76.7°C	180°F 82.2°C	190°F 87.8°C	200°F 93.3°C
1.5	14.85	0.61	0.59	0.56	0.55	0.53	0.53	0.52	0.50	0.49	0.48	0.47	0.46	0.45	0.44	0.43	0.42	0.42	0.41	0.41	0.40
1.6	15.84	0.69	0.66	0.62	0.61	0.60	0.59	0.58	0.56	0.55	0.53	0.52	0.51	0.50	0.49	0.48	0.48	0.47	0.46	0.46	0.45
1.7	16.83	0.76	0.73	0.69	0.68	0.67	0.66	0.64	0.63	0.61	0.59	0.58	0.57	0.56	0.55	0.54	0.53	0.52	0.51	0.51	0.50
1.8	17.82	0.84	0.81	0.76	0.75	0.74	0.73	0.71	0.69	0.67	0.66	0.64	0.63	0.62	0.61	0.60	0.59	0.58	0.57	0.56	0.55
1.9	18.81	0.93	0.89	0.84	0.83	0.81	0.80	0.78	0.76	0.74	0.72	0.71	0.69	0.68	0.67	0.66	0.65	0.64	0.63	0.62	0.61
2.0	19.80	1.01	0.97	0.92	0.90	0.89	0.87	0.86	0.83	0.81	0.79	0.77	0.76	0.74	0.73	0.72	0.71	0.70	0.69	0.68	0.67
2.1	20.79	1.11	1.06	1.00	0.99	0.97	0.95	0.94	0.91	0.89	0.86	0.85	0.83	0.81	0.80	0.78	0.77	0.76	0.75	0.74	0.73
2.2	21.78	1.20	1.15	1.09	1.07	1.05	1.03	1.02	0.99	0.96	0.94	0.92	0.90	0.88	0.87	0.85	0.84	0.83	0.82	0.81	0.80
2.3	22.77	1.30	1.24	1.18	1.16	1.14	1.12	1.10	1.07	1.04	1.02	0.99	0.97	0.96	0.94	0.92	0.91	0.90	0.88	0.87	0.86
2.4	23.76	1.40	1.34	1.27	1.25	1.22	1.21	1.19	1.15	1.12	1.10	1.07	1.05	1.03	1.01	1.00	0.98	0.97	0.95	0.94	0.93
2.5	24.75	1.50	1.44	1.36	1.34	1.32	1.30	1.28	1.24	1.21	1.18	1.15	1.13	1.11	1.09	1.07	1.06	1.04	1.03	1.01	1.00
2.6	25.74	1.61	1.54	1.46	1.44	1.41	1.39	1.37	1.33	1.29	1.26	1.24	1.21	1.19	1.17	1.15	1.13	1.12	1.10	1.09	1.07
2.7	26.73	1.72	1.65	1.56	1.54	1.51	1.49	1.46	1.42	1.38	1.35	1.32	1.30	1.27	1.25	1.23	1.21	1.19	1.18	1.16	1.15
2.8	27.72	1.83	1.75	1.67	1.64	1.61	1.59	1.56	1.52	1.48	1.44	1.41	1.38	1.36	1.33	1.31	1.29	1.27	1.26	1.24	1.23
2.9	28.71	1.95	1.87	1.77	1.74	1.71	1.69	1.66	1.61	1.57	1.54	1.50	1.47	1.45	1.42	1.40	1.38	1.36	1.34	1.32	1.31
3.0	29.70	2.07	1.98	1.88	1.85	1.82	1.79	1.76	1.71	1.67	1.63	1.60	1.57	1.54	1.51	1.49	1.46	1.44	1.42	1.41	1.39
3.1	30.69	2.19	2.10	2.00	1.96	1.93	1.90	1.87	1.82	1.77	1.73	1.69	1.66	1.63	1.60	1.58	1.55	1.53	1.51	1.49	1.47
3.2	31.68	2.32	2.22	2.11	2.08	2.04	2.01	1.98	1.92	1.87	1.83	1.79	1.76	1.72	1.70	1.67	1.64	1.62	1.60	1.58	1.56
3.3	32.67	2.45	2.34	2.23	2.19	2.15	2.12	2.09	2.03	1.98	1.93	1.89	1.86	1.82	1.79	1.76	1.74	1.71	1.69	1.67	1.65
3.4	33.66	2.58	2.47	2.35	2.31	2.27	2.24	2.20	2.14	2.09	2.04	2.00	1.96	1.92	1.89	1.86	1.83	1.81	1.78	1.76	1.74
3.5	34.65	2.71	2.60	2.47	2.43	2.39	2.36	2.32	2.26	2.20	2.15	2.10	2.06	2.03	1.99	1.96	1.93	1.90	1.88	1.86	1.84
3.6	35.64	2.85	2.73	2.60	2.56	2.51	2.48	2.44	2.37	2.31	2.26	2.21	2.17	2.13	2.09	2.06	2.03	2.00	1.98	1.95	1.93
3.7	36.63	2.99	2.87	2.73	2.69	2.64	2.60	2.56	2.49	2.43	2.37	2.32	2.28	2.24	2.20	2.17	2.13	2.10	2.08	2.05	2.03
3.8	37.62	3.14	3.01	2.86	2.82	2.77	2.73	2.69	2.61	2.55	2.49	2.44	2.39	2.35	2.31	2.27	2.24	2.21	2.18	2.15	2.13
3.9	38.61	3.28	3.15	3.00	2.95	2.90	2.86	2.81	2.74	2.67	2.61	2.55	2.50	2.46	2.42	2.38	2.35	2.31	2.28	2.26	2.23
4.0	39.60	3.43	3.29	3.14	3.09	3.03	2.99	2.94	2.86	2.79	2.73	2.67	2.62	2.57	2.53	2.49	2.46	2.42	2.39	2.36	2.34
4.1	40.59	3.59	3.44	3.28	3.22	3.17	3.12	3.08	2.99	2.92	2.85	2.79	2.74	2.69	2.65	2.61	2.57	2.53	2.50	2.47	2.44
4.2	41.58	3.74	3.59	3.42	3.37	3.31	3.26	3.21	3.12	3.05	2.98	2.92	2.86	2.81	2.76	2.72	2.68	2.65	2.61	2.58	2.55
4.3	42.57	3.90	3.75	3.57	3.51	3.45	3.40	3.35	3.26	3.18	3.11	3.04	2.99	2.93	2.88	2.84	2.80	2.76	2.73	2.69	2.66
4.4	43.57	4.06	3.90	3.72	3.66	3.59	3.54	3.49	3.40	3.31	3.24	3.17	3.11	3.06	3.01	2.96	2.92	2.88	2.84	2.81	2.78
4.5	44.56	4.23	4.06	3.87	3.81	3.74	3.69	3.63	3.53	3.45	3.37	3.30	3.24	3.18	3.13	3.08	3.04	3.00	2.96	2.92	2.89
4.6	45.55	4.40	4.22	4.02	3.96	3.89	3.84	3.78	3.68	3.59	3.51	3.44	3.37	3.31	3.26	3.21	3.16	3.12	3.08	3.04	3.01
4.7	46.54	4.57	4.39	4.18	4.11	4.04	3.99	3.92	3.82	3.73	3.65	3.57	3.50	3.44	3.39	3.33	3.29	3.24	3.20	3.16	3.13

Continued on next page

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

Appendix G:

Hydronic friction loss tables

2½" Uponor PEX-a — 100% Water — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40ºF 4ºC	45ºF 7.2ºC	50ºF 10ºC	55ºF 12.8ºC	60ºF 15.6ºC	65ºF 18.3ºC	70ºF 21.1ºC	80ºF 26.7ºC	90ºF 32.2ºC	100ºF 37.8ºC	110ºF 43.3ºC	120ºF 48.9ºC	130ºF 54.4ºC	140ºF 60ºC	150ºF 65.6ºC	160ºF 71.1ºC	170ºF 76.7ºC	180ºF 82.2ºC	190ºF 87.8ºC	200ºF 93.3ºC
4.8	47.53	4.74	4.55	4.34	4.27	4.20	4.14	4.08	3.97	3.87	3.79	3.71	3.64	3.57	3.52	3.46	3.41	3.37	3.33	3.29	3.25
4.9	48.52	4.92	4.72	4.50	4.43	4.35	4.29	4.23	4.12	4.02	3.93	3.85	3.78	3.71	3.65	3.59	3.54	3.49	3.45	3.41	3.37
5.0	49.51	5.10	4.90	4.67	4.59	4.51	4.45	4.38	4.27	4.17	4.07	3.99	3.92	3.85	3.79	3.73	3.67	3.63	3.58	3.54	3.50
5.1	50.50	5.28	5.07	4.83	4.76	4.68	4.61	4.54	4.42	4.32	4.22	4.14	4.06	3.99	3.92	3.86	3.81	3.76	3.71	3.67	3.63
5.2	51.49	5.46	5.25	5.00	4.93	4.84	4.77	4.70	4.58	4.47	4.37	4.28	4.20	4.13	4.06	4.00	3.94	3.89	3.84	3.80	3.76
5.3	52.48	5.65	5.43	5.18	5.10	5.01	4.94	4.87	4.74	4.63	4.52	4.43	4.35	4.27	4.21	4.14	4.08	4.03	3.98	3.93	3.89
5.4	53.47	5.84	5.61	5.35	5.27	5.18	5.11	5.03	4.90	4.78	4.68	4.58	4.50	4.42	4.35	4.28	4.22	4.17	4.12	4.07	4.02
5.5	54.46	6.04	5.80	5.53	5.44	5.35	5.28	5.20	5.06	4.94	4.84	4.74	4.65	4.57	4.50	4.43	4.37	4.31	4.25	4.21	4.16
5.6	55.45	6.23	5.99	5.71	5.62	5.53	5.45	5.37	5.23	5.11	4.99	4.89	4.80	4.72	4.64	4.57	4.51	4.45	4.40	4.35	4.30
5.7	56.44	6.43	6.18	5.89	5.80	5.71	5.63	5.54	5.40	5.27	5.16	5.05	4.96	4.87	4.80	4.72	4.66	4.60	4.54	4.49	4.44
5.8	57.43	6.63	6.38	6.08	5.99	5.89	5.80	5.72	5.57	5.44	5.32	5.21	5.12	5.03	4.95	4.87	4.81	4.74	4.68	4.63	4.58
5.9	58.42	6.84	6.57	6.27	6.17	6.07	5.99	5.90	5.74	5.61	5.49	5.38	5.28	5.19	5.10	5.03	4.96	4.89	4.83	4.78	4.72
6.0	59.41	7.05	6.77	6.46	6.36	6.25	6.17	6.08	5.92	5.78	5.65	5.54	5.44	5.35	5.26	5.18	5.11	5.04	4.98	4.92	4.87
6.1	60.40	7.26	6.97	6.65	6.55	6.44	6.35	6.26	6.10	5.95	5.83	5.71	5.60	5.51	5.42	5.34	5.27	5.20	5.13	5.07	5.02
6.2	61.39	7.47	7.18	6.85	6.74	6.63	6.54	6.45	6.28	6.13	6.00	5.88	5.77	5.67	5.58	5.50	5.42	5.35	5.29	5.23	5.17
6.3	62.38	7.68	7.39	7.05	6.94	6.83	6.73	6.63	6.46	6.31	6.17	6.05	5.94	5.84	5.75	5.66	5.58	5.51	5.44	5.38	5.32
6.4	63.37	7.90	7.60	7.25	7.14	7.02	6.92	6.82	6.65	6.49	6.35	6.23	6.11	6.01	5.91	5.83	5.75	5.67	5.60	5.54	5.48
6.5	64.36	8.12	7.81	7.45	7.34	7.22	7.12	7.02	6.84	6.68	6.53	6.40	6.29	6.18	6.08	5.99	5.91	5.83	5.76	5.70	5.63
6.6	65.35	8.35	8.03	7.66	7.54	7.42	7.32	7.21	7.03	6.86	6.71	6.58	6.46	6.35	6.25	6.16	6.07	6.00	5.92	5.86	5.79
6.7	66.34	8.57	8.24	7.87	7.75	7.62	7.52	7.41	7.22	7.05	6.90	6.76	6.64	6.53	6.42	6.33	6.24	6.16	6.09	6.02	5.95
6.8	67.33	8.80	8.47	8.08	7.96	7.83	7.72	7.61	7.41	7.24	7.09	6.95	6.82	6.70	6.60	6.50	6.41	6.33	6.25	6.18	6.12
6.9	68.32	9.03	8.69	8.29	8.17	8.03	7.92	7.81	7.61	7.43	7.27	7.13	7.00	6.88	6.78	6.68	6.59	6.50	6.42	6.35	6.28
7.0	69.31	9.27	8.92	8.51	8.38	8.24	8.13	8.01	7.81	7.63	7.47	7.32	7.19	7.07	6.95	6.85	6.76	6.67	6.59	6.52	6.45
7.1	70.30	9.51	9.14	8.73	8.60	8.46	8.34	8.22	8.01	7.83	7.66	7.51	7.37	7.25	7.14	7.03	6.94	6.85	6.76	6.69	6.62
7.2	71.29	9.75	9.37	8.95	8.81	8.67	8.55	8.43	8.22	8.03	7.85	7.70	7.56	7.43	7.32	7.21	7.11	7.02	6.94	6.86	6.79
7.3	72.28	9.99	9.61	9.17	9.04	8.89	8.77	8.64	8.42	8.23	8.05	7.90	7.75	7.62	7.50	7.39	7.29	7.20	7.11	7.03	6.96
7.4	73.27	10.23	9.85	9.40	9.26	9.11	8.99	8.86	8.63	8.43	8.25	8.09	7.95	7.81	7.69	7.58	7.48	7.38	7.29	7.21	7.13
7.5	74.26	10.48	10.08	9.63	9.48	9.33	9.20	9.07	8.84	8.64	8.46	8.29	8.14	8.01	7.88	7.77	7.66	7.56	7.47	7.39	7.31
7.6	75.25	10.73	10.33	9.86	9.71	9.56	9.43	9.29	9.06	8.85	8.66	8.49	8.34	8.20	8.07	7.96	7.85	7.75	7.65	7.57	7.49
7.7	76.24	10.98	10.57	10.09	9.94	9.78	9.65	9.51	9.27	9.06	8.87	8.70	8.54	8.40	8.27	8.15	8.04	7.93	7.84	7.75	7.67
7.8	77.23	11.24	10.82	10.33	10.17	10.01	9.88	9.73	9.49	9.27	9.08	8.90	8.74	8.59	8.46	8.34	8.23	8.12	8.03	7.94	7.85
7.9	78.22	11.50	11.07	10.57	10.41	10.24	10.10	9.96	9.71	9.49	9.29	9.11	8.94	8.80	8.66	8.53	8.42	8.31	8.21	8.12	8.04
8.0	79.21	11.76	11.32	10.81	10.65	10.48	10.34	10.19	9.93	9.70	9.50	9.32	9.15	9.00	8.86	8.73	8.61	8.50	8.40	8.31	8.22

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

2½" Uponor PEX-a — 30% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40ºF 4ºC	45ºF 7.2ºC	50ºF 10ºC	55ºF 12.8ºC	60ºF 15.6ºC	65ºF 18.3ºC	70ºF 21.1ºC	80ºF 26.7ºC	90ºF 32.2ºC	100ºF 37.8ºC	110ºF 43.3ºC	120ºF 48.9ºC	130ºF 54.4ºC	140ºF 60ºC	150ºF 65.6ºC	160ºF 71.1ºC	170ºF 76.7ºC	180ºF 82.2ºC	190ºF 87.8ºC	200ºF 93.3ºC
1.5	14.85	0.82	0.79	0.77	0.74	0.72	0.70	0.68	0.65	0.62	0.59	0.57	0.55	0.54	0.52	0.51	0.50	0.48	0.48	0.47	0.46
1.6	15.84	0.92	0.89	0.85	0.83	0.80	0.78	0.76	0.72	0.69	0.66	0.64	0.62	0.60	0.58	0.57	0.56	0.54	0.53	0.52	0.52
1.7	16.83	1.02	0.98	0.95	0.92	0.89	0.87	0.84	0.80	0.77	0.74	0.71	0.69	0.67	0.65	0.63	0.62	0.60	0.59	0.58	0.57
1.8	17.82	1.12	1.08	1.05	1.02	0.99	0.96	0.93	0.89	0.85	0.82	0.79	0.76	0.74	0.72	0.70	0.68	0.67	0.66	0.64	0.64
1.9	18.81	1.23	1.19	1.15	1.12	1.08	1.05	1.02	0.98	0.93	0.90	0.86	0.84	0.81	0.79	0.77	0.75	0.74	0.72	0.71	0.70
2.0	19.80	1.34	1.30	1.25	1.22	1.18	1.15	1.12	1.07	1.02	0.98	0.95	0.92	0.89	0.86	0.84	0.82	0.81	0.79	0.78	0.77
2.1	20.79	1.46	1.41	1.37	1.33	1.29	1.25	1.22	1.16	1.11	1.07	1.03	1.00	0.97	0.94	0.92	0.90	0.88	0.86	0.85	0.84
2.2	21.78	1.58	1.53	1.48	1.44	1.39	1.36	1.32	1.26	1.21	1.16	1.12	1.08	1.05	1.02	1.00	0.98	0.96	0.94	0.92	0.91
2.3	22.77	1.71	1.65	1.60	1.55	1.51	1.47	1.43	1.36	1.30	1.25	1.21	1.17	1.14	1.11	1.08	1.06	1.03	1.02	1.00	0.98
2.4	23.76	1.84	1.78	1.72	1.67	1.62	1.58	1.54	1.47	1.40	1.35	1.30	1.26	1.23	1.19	1.17	1.14	1.12	1.10	1.08	1.06
2.5	24.75	1.97	1.91	1.85	1.80	1.74	1.70	1.65	1.57	1.51	1.45	1.40	1.36	1.32	1.28	1.25	1.23	1.20	1.18	1.16	1.14
2.6	25.74	2.11	2.04	1.98	1.92	1.86	1.82	1.77	1.69	1.62	1.55	1.50	1.45	1.41	1.37	1.34	1.31	1.29	1.26	1.24	1.22
2.7	26.73	2.25	2.18	2.11	2.05	1.99	1.94	1.89	1.80	1.73	1.66	1.60	1.55	1.51	1.47	1.44	1.41	1.38	1.35	1.33	1.31
2.8	27.72	2.39	2.32	2.25	2.19	2.12	2.07	2.01	1.92	1.84	1.77	1.71	1.66	1.61	1.57	1.53	1.50	1.47	1.44	1.42	1.40
2.9	28.71	2.54	2.47	2.39	2.32	2.26	2.20	2.14	2.04	1.96	1.88	1.82	1.76	1.71	1.67	1.63	1.60	1.56	1.53	1.51	1.49
3.0	29.70	2.70	2.62	2.53	2.46	2.39	2.33	2.27	2.17	2.08	2.00	1.93	1.87	1.82	1.77	1.73	1.70	1.66	1.63	1.60	1.58
3.1	30.69	2.86	2.77	2.68	2.61	2.53	2.47	2.40	2.30	2.20	2.12	2.05	1.99	1.93	1.88	1.84	1.80	1.76	1.73	1.70	1.67
3.2	31.68	3.02	2.93	2.83	2.76	2.68	2.61	2.54	2.43	2.33	2.24	2.17	2.10	2.04	1.99	1.94	1.90	1.86	1.83	1.80	1.77
3.3	32.67	3.18	3.09	2.99	2.91	2.83	2.76	2.68	2.56	2.46	2.37	2.29	2.22	2.16	2.10	2.05	2.01	1.97	1.93	1.90	1.87
3.4	33.66	3.35	3.25	3.15	3.07	2.98	2.90	2.83	2.70	2.59	2.50	2.41	2.34	2.27	2.21	2.17	2.12	2.08	2.04	2.00	1.98
3.5	34.65	3.52	3.42	3.31	3.22	3.13	3.06	2.97	2.84	2.73	2.63	2.54	2.46	2.39	2.33	2.28	2.23	2.19	2.15	2.11	2.08
3.6	35.64	3.70	3.59	3.48	3.39	3.29	3.21	3.13	2.99	2.87	2.76	2.67	2.59	2.52	2.45	2.40	2.35	2.30	2.26	2.22	2.19
3.7	36.63	3.88	3.77	3.65	3.55	3.45	3.37	3.28	3.13	3.01	2.90	2.80	2.72	2.64	2.57	2.52	2.46	2.41	2.37	2.33	2.30
3.8	37.62	4.07	3.95	3.82	3.72	3.62	3.53	3.44	3.28	3.15	3.04	2.94	2.85	2.77	2.70	2.64	2.58	2.53	2.49	2.44	2.41
3.9	38.61	4.25	4.13	4.00	3.90	3.78	3.69	3.60	3.44	3.30	3.18	3.07	2.98	2.90	2.83	2.77	2.71	2.65	2.61	2.56	2.53
4.0	39.60	4.44	4.32	4.18	4.07	3.96	3.86	3.76	3.60	3.45	3.33	3.22	3.12	3.04	2.96	2.89	2.83	2.78	2.73	2.68	2.64
4.1	40.59	4.64	4.51	4.36	4.25	4.13	4.03	3.93	3.76	3.61	3.48	3.36	3.26	3.17	3.09	3.03	2.96	2.90	2.85	2.80	2.76
4.2	41.58	4.84	4.70	4.55	4.43	4.31	4.21	4.10	3.92	3.76	3.63	3.51	3.40	3.31	3.23	3.16	3.09	3.03	2.98	2.93	2.89
4.3	42.57	5.04	4.90	4.74	4.62	4.49	4.38	4.27	4.08	3.92	3.78	3.66	3.55	3.45	3.37	3.29	3.22	3.16	3.11	3.05	3.01
4.4	43.57	5.25	5.10	4.94	4.81	4.68	4.57	4.45	4.25	4.09	3.94	3.81	3.70	3.60	3.51	3.43	3.36	3.29	3.24	3.18	3.14
4.5	44.56	5.46	5.30	5.13	5.00	4.86	4.75	4.63	4.43	4.25	4.10	3.96	3.85	3.75	3.65	3.57	3.50	3.43	3.37	3.31	3.27
4.6	45.55	5.67	5.51	5.34	5.20	5.05	4.94	4.81	4.60	4.42	4.26	4.12	4.00	3.89	3.80	3.72	3.64	3.57	3.50	3.44	3.40
4.7	46.54	5.89	5.72	5.54	5.40	5.25	5.13	4.99	4.78	4.59	4.43	4.28	4.16	4.05	3.94	3.86	3.78	3.71	3.64	3.58	3.53

Continued on next page

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

2½" Uponor PEX-a — 30% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7.2°C	50°F 10°C	55°F 12.8°C	60°F 15.6°C	65°F 18.3°C	70°F 21.1°C	80°F 26.7°C	90°F 32.2°C	100°F 37.8°C	110°F 43.3°C	120°F 48.9°C	130°F 54.4°C	140°F 60°C	150°F 65.6°C	160°F 71.1°C	170°F 76.7°C	180°F 82.2°C	190°F 87.8°C	200°F 93.3°C
4.8	47.53	6.11	5.93	5.75	5.60	5.45	5.32	5.18	4.96	4.77	4.60	4.45	4.32	4.20	4.10	4.01	3.93	3.85	3.78	3.72	3.67
4.9	48.52	6.33	6.15	5.96	5.81	5.65	5.52	5.38	5.14	4.94	4.77	4.61	4.48	4.36	4.25	4.16	4.07	3.99	3.93	3.86	3.81
5.0	49.51	6.56	6.37	6.17	6.02	5.85	5.72	5.57	5.33	5.12	4.94	4.78	4.64	4.52	4.41	4.31	4.22	4.14	4.07	4.00	3.95
5.1	50.50	6.79	6.60	6.39	6.23	6.06	5.92	5.77	5.52	5.31	5.12	4.95	4.81	4.68	4.56	4.47	4.38	4.29	4.22	4.15	4.09
5.2	51.49	7.02	6.83	6.61	6.45	6.27	6.13	5.97	5.71	5.49	5.30	5.13	4.98	4.85	4.73	4.63	4.53	4.44	4.37	4.29	4.24
5.3	52.48	7.26	7.06	6.84	6.67	6.48	6.33	6.17	5.91	5.68	5.48	5.30	5.15	5.02	4.89	4.79	4.69	4.60	4.52	4.44	4.39
5.4	53.47	7.50	7.29	7.07	6.89	6.70	6.55	6.38	6.11	5.87	5.67	5.48	5.33	5.19	5.06	4.95	4.85	4.75	4.67	4.60	4.54
5.5	54.46	7.74	7.53	7.30	7.12	6.92	6.76	6.59	6.31	6.07	5.85	5.67	5.50	5.36	5.23	5.12	5.01	4.91	4.83	4.75	4.69
5.6	55.45	7.99	7.77	7.53	7.35	7.14	6.98	6.80	6.52	6.26	6.04	5.85	5.68	5.53	5.40	5.29	5.18	5.08	4.99	4.91	4.84
5.7	56.44	8.24	8.02	7.77	7.58	7.37	7.20	7.02	6.72	6.46	6.24	6.04	5.87	5.71	5.57	5.46	5.34	5.24	5.15	5.07	5.00
5.8	57.43	8.50	8.26	8.01	7.81	7.60	7.43	7.24	6.93	6.67	6.43	6.23	6.05	5.89	5.75	5.63	5.51	5.41	5.32	5.23	5.16
5.9	58.42	8.76	8.52	8.26	8.05	7.83	7.65	7.46	7.15	6.87	6.63	6.42	6.24	6.08	5.93	5.80	5.69	5.57	5.48	5.39	5.32
6.0	59.41	9.02	8.77	8.50	8.29	8.07	7.88	7.69	7.36	7.08	6.83	6.62	6.43	6.26	6.11	5.98	5.86	5.75	5.65	5.56	5.49
6.1	60.40	9.28	9.03	8.75	8.54	8.31	8.12	7.91	7.58	7.29	7.04	6.81	6.62	6.45	6.29	6.16	6.04	5.92	5.82	5.72	5.65
6.2	61.39	9.55	9.29	9.01	8.79	8.55	8.35	8.15	7.80	7.51	7.25	7.02	6.82	6.64	6.48	6.34	6.22	6.09	5.99	5.89	5.82
6.3	62.38	9.82	9.55	9.26	9.04	8.79	8.59	8.38	8.03	7.72	7.46	7.22	7.02	6.83	6.67	6.53	6.40	6.27	6.17	6.07	5.99
6.4	63.37	10.10	9.82	9.52	9.29	9.04	8.84	8.62	8.26	7.94	7.67	7.42	7.22	7.03	6.86	6.72	6.58	6.45	6.35	6.24	6.16
6.5	64.36	10.38	10.09	9.79	9.55	9.29	9.08	8.86	8.49	8.16	7.88	7.63	7.42	7.23	7.05	6.91	6.77	6.64	6.53	6.42	6.34
6.6	65.35	10.66	10.37	10.05	9.81	9.54	9.33	9.10	8.72	8.39	8.10	7.84	7.63	7.43	7.25	7.10	6.95	6.82	6.71	6.60	6.52
6.7	66.34	10.94	10.64	10.32	10.07	9.80	9.58	9.34	8.95	8.62	8.32	8.06	7.83	7.63	7.44	7.29	7.15	7.01	6.89	6.78	6.70
6.8	67.33	11.23	10.93	10.60	10.34	10.06	9.84	9.59	9.19	8.85	8.54	8.27	8.04	7.84	7.64	7.49	7.34	7.20	7.08	6.96	6.88
6.9	68.32	11.52	11.21	10.87	10.61	10.32	10.09	9.84	9.44	9.08	8.77	8.49	8.26	8.04	7.85	7.69	7.53	7.39	7.27	7.15	7.06
7.0	69.31	11.82	11.50	11.15	10.88	10.59	10.35	10.10	9.68	9.31	9.00	8.71	8.47	8.25	8.05	7.89	7.73	7.58	7.46	7.34	7.25
7.1	70.30	12.11	11.79	11.43	11.16	10.86	10.62	10.35	9.93	9.55	9.23	8.94	8.69	8.47	8.26	8.09	7.93	7.78	7.65	7.53	7.43
7.2	71.29	12.41	12.08	11.72	11.44	11.13	10.88	10.61	10.18	9.79	9.46	9.16	8.91	8.68	8.47	8.30	8.13	7.98	7.85	7.72	7.63
7.3	72.28	12.72	12.38	12.01	11.72	11.41	11.15	10.88	10.43	10.04	9.70	9.39	9.13	8.90	8.68	8.51	8.34	8.18	8.05	7.92	7.82
7.4	73.27	13.03	12.68	12.30	12.00	11.68	11.42	11.14	10.68	10.28	9.93	9.62	9.36	9.12	8.90	8.72	8.54	8.38	8.25	8.11	8.01
7.5	74.26	13.34	12.98	12.59	12.29	11.96	11.70	11.41	10.94	10.53	10.17	9.86	9.59	9.34	9.12	8.93	8.75	8.59	8.45	8.31	8.21
7.6	75.25	13.65	13.29	12.89	12.58	12.25	11.98	11.68	11.20	10.78	10.42	10.09	9.82	9.57	9.33	9.15	8.97	8.80	8.65	8.51	8.41
7.7	76.24	13.97	13.60	13.19	12.87	12.53	12.26	11.96	11.47	11.04	10.66	10.33	10.05	9.79	9.56	9.37	9.18	9.01	8.86	8.72	8.61
7.8	77.23	14.29	13.91	13.50	13.17	12.82	12.54	12.23	11.73	11.30	10.91	10.57	10.28	10.02	9.78	9.59	9.40	9.22	9.07	8.92	8.81
7.9	78.22	14.61	14.22	13.80	13.47	13.12	12.83	12.51	12.00	11.55	11.16	10.82	10.52	10.25	10.01	9.81	9.61	9.43	9.28	9.13	9.02
8.0	79.21	14.94	14.54	14.11	13.77	13.41	13.11	12.80	12.27	11.82	11.42	11.07	10.76	10.49	10.24	10.03	9.83	9.65	9.49	9.34	9.23

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

2½" Uponor PEX-a — 40% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7.2°C	50°F 10°C	55°F 12.8°C	60°F 15.6°C	65°F 18.3°C	70°F 21.1°C	80°F 26.7°C	90°F 32.2°C	100°F 37.8°C	110°F 43.3°C	120°F 48.9°C	130°F 54.4°C	140°F 60°C	150°F 65.6°C	160°F 71.1°C	170°F 76.7°C	180°F 82.2°C	190°F 87.8°C	200°F 93.3°C
1.5	14.85	0.96	0.92	0.88	0.84	0.81	0.79	0.76	0.71	0.68	0.64	0.62	0.59	0.57	0.55	0.54	0.52	0.51	0.50	0.49	0.48
1.6	15.84	1.07	1.02	0.98	0.94	0.91	0.88	0.85	0.80	0.76	0.72	0.69	0.66	0.64	0.62	0.60	0.59	0.57	0.56	0.55	0.54
1.7	16.83	1.18	1.13	1.08	1.05	1.00	0.97	0.94	0.89	0.84	0.80	0.77	0.74	0.71	0.69	0.67	0.65	0.64	0.62	0.61	0.60
1.8	17.82	1.30	1.25	1.19	1.15	1.11	1.07	1.04	0.98	0.93	0.88	0.85	0.82	0.79	0.76	0.74	0.72	0.70	0.69	0.68	0.66
1.9	18.81	1.43	1.37	1.31	1.26	1.22	1.18	1.14	1.07	1.02	0.97	0.93	0.90	0.87	0.84	0.82	0.80	0.78	0.76	0.74	0.73
2.0	19.80	1.55	1.49	1.43	1.38	1.33	1.29	1.24	1.17	1.11	1.06	1.02	0.98	0.95	0.92	0.89	0.87	0.85	0.83	0.81	0.80
2.1	20.79	1.69	1.62	1.55	1.50	1.44	1.40	1.35	1.28	1.21	1.16	1.11	1.07	1.03	1.00	0.97	0.95	0.93	0.91	0.89	0.87
2.2	21.78	1.83	1.76	1.68	1.63	1.56	1.52	1.47	1.38	1.31	1.26	1.20	1.16	1.12	1.09	1.06	1.03	1.01	0.99	0.96	0.95
2.3	22.77	1.97	1.90	1.82	1.75	1.69	1.64	1.58	1.49	1.42	1.36	1.30	1.25	1.21	1.17	1.14	1.12	1.09	1.07	1.04	1.03
2.4	23.76	2.12	2.04	1.95	1.89	1.82	1.76	1.70	1.61	1.53	1.46	1.40	1.35	1.31	1.27	1.23	1.20	1.17	1.15	1.13	1.11
2.5	24.75	2.27	2.19	2.09	2.02	1.95	1.89	1.83	1.73	1.64	1.57	1.51	1.45	1.40	1.36	1.32	1.29	1.26	1.24	1.21	1.19
2.6	25.74	2.43	2.34	2.24	2.17	2.09	2.02	1.96	1.85	1.76	1.68	1.61	1.55	1.50	1.46	1.42	1.39	1.35	1.33	1.30	1.28
2.7	26.73	2.59	2.50	2.39	2.31	2.23	2.16	2.09	1.98	1.88	1.80	1.72	1.66	1.61	1.56	1.52	1.48	1.45	1.42	1.39	1.37
2.8	27.72	2.76	2.66	2.54	2.46	2.37	2.30	2.23	2.10	2.00	1.91	1.84	1.77	1.71	1.66	1.62	1.58	1.54	1.51	1.48	1.46
2.9	28.71	2.93	2.82	2.70	2.61	2.52	2.45	2.37	2.24	2.13	2.04	1.96	1.88	1.82	1.77	1.72	1.68	1.64	1.61	1.58	1.55
3.0	29.70	3.10	2.99	2.87	2.77	2.67	2.59	2.51	2.37	2.26	2.16	2.08	2.00	1.94	1.88	1.83	1.79	1.74	1.71	1.68	1.65
3.1	30.69	3.28	3.16	3.03	2.93	2.83	2.75	2.66	2.51	2.39	2.29	2.20	2.12	2.05	1.99	1.94	1.89	1.85	1.81	1.78	1.75
3.2	31.68	3.47	3.34	3.20	3.10	2.99	2.90	2.81	2.66	2.53	2.42	2.33	2.24	2.17	2.11	2.05	2.00	1.96	1.92	1.88	1.85
3.3	32.67	3.66	3.52	3.38	3.27	3.15	3.06	2.96	2.80	2.67	2.55	2.46	2.37	2.29	2.22	2.17	2.12	2.07	2.03	1.99	1.95
3.4	33.66	3.85	3.71	3.56	3.44	3.32	3.22	3.12	2.95	2.81	2.69	2.59	2.50	2.42	2.34	2.28	2.23	2.18	2.14	2.09	2.06
3.5	34.65	4.04	3.90	3.74	3.62	3.49	3.39	3.28	3.11	2.96	2.83	2.72	2.63	2.54	2.47	2.40	2.35	2.29	2.25	2.21	2.17
3.6	35.64	4.25	4.09	3.93	3.80	3.66	3.56	3.45	3.26	3.11	2.98	2.86	2.76	2.67	2.59	2.53	2.47	2.41	2.37	2.32	2.28
3.7	36.63	4.45	4.29	4.12	3.99	3.84	3.73	3.62	3.43	3.26	3.12	3.00	2.90	2.81	2.72	2.65	2.59	2.53	2.49	2.44	2.40
3.8	37.62	4.66	4.49	4.31	4.17	4.03	3.91	3.79	3.59	3.42	3.27	3.15	3.04	2.94	2.86	2.78	2.72	2.66	2.61	2.55	2.52
3.9	38.61	4.87	4.70	4.51	4.37	4.21	4.09	3.96	3.76	3.58	3.43	3.30	3.18	3.08	2.99	2.91	2.85	2.78	2.73	2.68	2.64
4.0	39.60	5.09	4.91	4.71	4.56	4.40	4.28	4.14	3.93	3.74	3.58	3.45	3.33	3.22	3.13	3.05	2.98	2.91	2.86	2.80	2.76
4.1	40.59	5.31	5.12	4.92	4.76	4.59	4.47	4.33	4.10	3.91	3.74	3.60	3.48	3.37	3.27	3.19	3.11	3.04	2.99	2.93	2.88
4.2	41.58	5.54	5.34	5.13	4.97	4.79	4.66	4.51	4.28	4.08	3.91	3.76	3.63	3.51	3.41	3.33	3.25	3.18	3.12	3.06	3.01
4.3	42.57	5.77	5.56	5.34	5.17	4.99	4.85	4.70	4.46	4.25	4.07	3.92	3.78	3.66	3.56	3.47	3.39	3.31	3.25	3.19	3.14
4.4	43.57	6.00	5.79	5.56	5.38	5.20	5.05	4.90	4.64	4.42	4.24	4.08	3.94	3.82	3.71	3.61	3.53	3.45	3.39	3.32	3.27
4.5	44.56	6.24	6.02	5.78	5.60	5.40	5.25	5.09	4.83	4.60	4.41	4.25	4.10	3.97	3.86	3.76	3.68	3.59	3.53	3.46	3.41
4.6	45.55	6.48	6.25	6.00	5.82	5.62	5.46	5.29	5.02	4.78	4.59	4.41	4.26	4.13	4.01	3.91	3.82	3.74	3.67	3.60	3.54
4.7	46.54	6.72	6.49	6.23	6.04	5.83	5.67	5.49	5.21	4.97	4.76	4.59	4.43	4.29	4.17	4.06	3.97	3.88	3.81	3.74	3.68

Continued on next page

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

2½" Uponor PEX-a — 40% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40ºF 4ºC	45ºF 7.2ºC	50ºF 10ºC	55ºF 12.8ºC	60ºF 15.6ºC	65ºF 18.3ºC	70ºF 21.1ºC	80ºF 26.7ºC	90ºF 32.2ºC	100ºF 37.8ºC	110ºF 43.3ºC	120ºF 48.9ºC	130ºF 54.4ºC	140ºF 60ºC	150ºF 65.6ºC	160ºF 71.1ºC	170ºF 76.7ºC	180ºF 82.2ºC	190ºF 87.8ºC	200ºF 93.3ºC
4.8	47.53	6.97	6.73	6.46	6.26	6.05	5.88	5.70	5.41	5.16	4.95	4.76	4.60	4.46	4.33	4.22	4.13	4.03	3.96	3.88	3.82
4.9	48.52	7.23	6.97	6.70	6.49	6.27	6.10	5.91	5.61	5.35	5.13	4.94	4.77	4.62	4.49	4.38	4.28	4.18	4.11	4.03	3.97
5.0	49.51	7.48	7.22	6.94	6.73	6.49	6.32	6.12	5.81	5.54	5.32	5.12	4.94	4.79	4.65	4.54	4.44	4.34	4.26	4.18	4.11
5.1	50.50	7.74	7.48	7.18	6.96	6.72	6.54	6.34	6.02	5.74	5.50	5.30	5.12	4.96	4.82	4.70	4.60	4.49	4.42	4.33	4.26
5.2	51.49	8.01	7.73	7.43	7.20	6.96	6.77	6.56	6.22	5.94	5.70	5.49	5.30	5.14	4.99	4.87	4.76	4.65	4.57	4.48	4.41
5.3	52.48	8.28	7.99	7.68	7.45	7.19	6.99	6.78	6.44	6.14	5.89	5.67	5.48	5.31	5.16	5.04	4.93	4.81	4.73	4.64	4.57
5.4	53.47	8.55	8.25	7.93	7.69	7.43	7.23	7.01	6.65	6.35	6.09	5.87	5.67	5.49	5.34	5.21	5.09	4.98	4.89	4.80	4.72
5.5	54.46	8.82	8.52	8.19	7.94	7.67	7.46	7.24	6.87	6.56	6.29	6.06	5.85	5.68	5.52	5.38	5.26	5.14	5.06	4.96	4.88
5.6	55.45	9.10	8.79	8.45	8.20	7.92	7.70	7.47	7.09	6.77	6.50	6.26	6.04	5.86	5.70	5.56	5.44	5.31	5.22	5.12	5.04
5.7	56.44	9.39	9.07	8.72	8.45	8.17	7.95	7.71	7.32	6.98	6.70	6.46	6.24	6.05	5.88	5.74	5.61	5.48	5.39	5.28	5.21
5.8	57.43	9.68	9.35	8.99	8.71	8.42	8.19	7.95	7.55	7.20	6.91	6.66	6.43	6.24	6.07	5.92	5.79	5.66	5.56	5.45	5.37
5.9	58.42	9.97	9.63	9.26	8.98	8.68	8.44	8.19	7.78	7.42	7.13	6.87	6.63	6.43	6.25	6.10	5.97	5.83	5.74	5.62	5.54
6.0	59.41	10.26	9.91	9.53	9.25	8.93	8.69	8.43	8.01	7.65	7.34	7.07	6.83	6.63	6.44	6.29	6.15	6.01	5.91	5.80	5.71
6.1	60.40	10.56	10.20	9.81	9.52	9.20	8.95	8.68	8.25	7.87	7.56	7.28	7.04	6.83	6.64	6.48	6.34	6.19	6.09	5.97	5.88
6.2	61.39	10.86	10.50	10.09	9.79	9.46	9.21	8.93	8.49	8.10	7.78	7.50	7.25	7.03	6.83	6.67	6.52	6.38	6.27	6.15	6.06
6.3	62.38	11.17	10.79	10.38	10.07	9.73	9.47	9.19	8.73	8.34	8.00	7.71	7.45	7.23	7.03	6.86	6.71	6.56	6.45	6.33	6.23
6.4	63.37	11.48	11.09	10.67	10.35	10.00	9.74	9.45	8.98	8.57	8.23	7.93	7.67	7.44	7.23	7.06	6.91	6.75	6.64	6.51	6.41
6.5	64.36	11.79	11.40	10.96	10.64	10.28	10.01	9.71	9.23	8.81	8.46	8.16	7.88	7.65	7.44	7.26	7.10	6.94	6.83	6.69	6.60
6.6	65.35	12.11	11.70	11.26	10.92	10.56	10.28	9.97	9.48	9.05	8.69	8.38	8.10	7.86	7.64	7.46	7.30	7.14	7.02	6.88	6.78
6.7	66.34	12.43	12.01	11.56	11.22	10.84	10.55	10.24	9.73	9.30	8.93	8.61	8.32	8.07	7.85	7.66	7.50	7.33	7.21	7.07	6.97
6.8	67.33	12.76	12.33	11.86	11.51	11.13	10.83	10.51	9.99	9.54	9.17	8.84	8.54	8.29	8.06	7.87	7.70	7.53	7.40	7.26	7.15
6.9	68.32	13.08	12.65	12.17	11.81	11.42	11.11	10.79	10.25	9.79	9.41	9.07	8.77	8.51	8.27	8.08	7.90	7.73	7.60	7.45	7.34
7.0	69.31	13.42	12.97	12.48	12.11	11.71	11.40	11.06	10.52	10.05	9.65	9.30	9.00	8.73	8.49	8.29	8.11	7.93	7.80	7.65	7.54
7.1	70.30	13.75	13.29	12.79	12.41	12.00	11.69	11.34	10.78	10.30	9.90	9.54	9.23	8.95	8.71	8.50	8.32	8.14	8.00	7.85	7.73
7.2	71.29	14.09	13.62	13.11	12.72	12.30	11.98	11.63	11.05	10.56	10.15	9.78	9.46	9.18	8.93	8.72	8.53	8.34	8.20	8.05	7.93
7.3	72.28	14.43	13.95	13.43	13.03	12.60	12.27	11.91	11.33	10.82	10.40	10.03	9.70	9.41	9.15	8.93	8.74	8.55	8.41	8.25	8.13
7.4	73.27	14.78	14.29	13.75	13.35	12.91	12.57	12.20	11.60	11.09	10.65	10.27	9.93	9.64	9.38	9.15	8.96	8.76	8.62	8.45	8.33
7.5	74.26	15.13	14.63	14.08	13.67	13.22	12.87	12.49	11.88	11.36	10.91	10.52	10.17	9.88	9.61	9.38	9.18	8.98	8.83	8.66	8.54
7.6	75.25	15.48	14.97	14.41	13.99	13.53	13.17	12.79	12.16	11.63	11.17	10.77	10.42	10.11	9.84	9.60	9.40	9.20	9.04	8.87	8.74
7.7	76.24	15.84	15.32	14.74	14.31	13.84	13.48	13.09	12.45	11.90	11.43	11.03	10.66	10.35	10.07	9.83	9.62	9.41	9.26	9.08	8.95
7.8	77.23	16.20	15.67	15.08	14.64	14.16	13.79	13.39	12.73	12.17	11.70	11.28	10.91	10.59	10.31	10.06	9.85	9.64	9.48	9.29	9.16
7.9	78.22	16.56	16.02	15.42	14.97	14.48	14.10	13.69	13.02	12.45	11.97	11.54	11.16	10.84	10.54	10.29	10.08	9.86	9.70	9.51	9.38
8.0	79.21	16.93	16.37	15.76	15.31	14.81	14.42	14.00	13.32	12.73	12.24	11.80	11.42	11.09	10.79	10.53	10.31	10.08	9.92	9.73	9.59

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

2½" Uponor PEX-a — 50% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7.2°C	50°F 10°C	55°F 12.8°C	60°F 15.6°C	65°F 18.3°C	70°F 21.1°C	80°F 26.7°C	90°F 32.2°C	100°F 37.8°C	110°F 43.3°C	120°F 48.9°C	130°F 54.4°C	140°F 60°C	150°F 65.6°C	160°F 71.1°C	170°F 76.7°C	180°F 82.2°C	190°F 87.8°C	200°F 93.3°C
1.5	14.85	1.08	1.03	0.98	0.95	0.91	0.87	0.84	0.79	0.74	0.70	0.67	0.64	0.62	0.59	0.58	0.56	0.54	0.53	0.52	0.51
1.6	15.84	1.20	1.15	1.10	1.06	1.01	0.98	0.94	0.88	0.83	0.79	0.75	0.72	0.69	0.67	0.64	0.63	0.61	0.59	0.58	0.57
1.7	16.83	1.33	1.28	1.22	1.17	1.12	1.08	1.04	0.98	0.92	0.87	0.83	0.80	0.77	0.74	0.72	0.70	0.68	0.66	0.64	0.63
1.8	17.82	1.47	1.41	1.34	1.29	1.23	1.19	1.15	1.08	1.02	0.96	0.92	0.88	0.85	0.82	0.79	0.77	0.75	0.73	0.71	0.70
1.9	18.81	1.61	1.54	1.47	1.41	1.35	1.31	1.26	1.18	1.11	1.06	1.01	0.97	0.93	0.90	0.87	0.85	0.82	0.80	0.78	0.77
2.0	19.80	1.75	1.68	1.60	1.54	1.48	1.43	1.37	1.29	1.22	1.16	1.10	1.06	1.02	0.98	0.95	0.93	0.90	0.88	0.86	0.84
2.1	20.79	1.90	1.82	1.74	1.67	1.60	1.55	1.49	1.40	1.32	1.26	1.20	1.15	1.11	1.07	1.04	1.01	0.98	0.96	0.94	0.92
2.2	21.78	2.06	1.97	1.88	1.81	1.74	1.68	1.62	1.52	1.44	1.36	1.30	1.25	1.20	1.16	1.13	1.09	1.07	1.04	1.02	1.00
2.3	22.77	2.22	2.13	2.03	1.95	1.87	1.81	1.75	1.64	1.55	1.47	1.41	1.35	1.30	1.26	1.22	1.18	1.15	1.12	1.10	1.08
2.4	23.76	2.38	2.28	2.18	2.10	2.02	1.95	1.88	1.77	1.67	1.59	1.52	1.46	1.40	1.35	1.31	1.28	1.24	1.21	1.19	1.16
2.5	24.75	2.55	2.45	2.34	2.25	2.16	2.09	2.02	1.90	1.79	1.70	1.63	1.56	1.51	1.46	1.41	1.37	1.34	1.30	1.28	1.25
2.6	25.74	2.73	2.62	2.50	2.41	2.31	2.24	2.16	2.03	1.92	1.82	1.74	1.67	1.61	1.56	1.51	1.47	1.43	1.40	1.37	1.34
2.7	26.73	2.91	2.79	2.66	2.57	2.47	2.39	2.30	2.17	2.05	1.95	1.86	1.79	1.72	1.67	1.62	1.57	1.53	1.49	1.46	1.43
2.8	27.72	3.09	2.97	2.84	2.73	2.63	2.54	2.45	2.31	2.18	2.08	1.99	1.91	1.84	1.78	1.72	1.68	1.63	1.59	1.56	1.53
2.9	28.71	3.28	3.15	3.01	2.90	2.79	2.70	2.60	2.45	2.32	2.21	2.11	2.03	1.95	1.89	1.83	1.78	1.74	1.69	1.66	1.63
3.0	29.70	3.48	3.34	3.19	3.08	2.96	2.86	2.76	2.60	2.46	2.34	2.24	2.15	2.07	2.01	1.95	1.89	1.84	1.80	1.76	1.73
3.1	30.69	3.67	3.53	3.37	3.26	3.13	3.03	2.92	2.75	2.60	2.48	2.37	2.28	2.20	2.13	2.06	2.01	1.95	1.91	1.87	1.83
3.2	31.68	3.88	3.73	3.56	3.44	3.30	3.20	3.09	2.91	2.75	2.62	2.51	2.41	2.32	2.25	2.18	2.12	2.07	2.02	1.98	1.94
3.3	32.67	4.09	3.93	3.76	3.62	3.48	3.37	3.26	3.07	2.90	2.77	2.65	2.54	2.45	2.37	2.30	2.24	2.18	2.13	2.09	2.05
3.4	33.66	4.30	4.13	3.95	3.82	3.67	3.55	3.43	3.23	3.06	2.92	2.79	2.68	2.59	2.50	2.43	2.36	2.30	2.25	2.20	2.16
3.5	34.65	4.52	4.34	4.15	4.01	3.85	3.73	3.61	3.40	3.22	3.07	2.94	2.82	2.72	2.63	2.56	2.49	2.42	2.37	2.32	2.27
3.6	35.64	4.74	4.56	4.36	4.21	4.05	3.92	3.79	3.57	3.38	3.22	3.09	2.97	2.86	2.77	2.69	2.62	2.55	2.49	2.44	2.39
3.7	36.63	4.97	4.78	4.57	4.41	4.24	4.11	3.97	3.74	3.55	3.38	3.24	3.11	3.00	2.91	2.82	2.75	2.68	2.61	2.56	2.51
3.8	37.62	5.20	5.00	4.78	4.62	4.44	4.31	4.16	3.92	3.72	3.54	3.39	3.26	3.15	3.05	2.96	2.88	2.81	2.74	2.68	2.63
3.9	38.61	5.43	5.23	5.00	4.83	4.65	4.50	4.35	4.10	3.89	3.71	3.55	3.41	3.30	3.19	3.10	3.01	2.94	2.87	2.81	2.76
4.0	39.60	5.67	5.46	5.22	5.05	4.85	4.71	4.55	4.29	4.06	3.88	3.71	3.57	3.45	3.34	3.24	3.15	3.07	3.00	2.94	2.88
4.1	40.59	5.92	5.70	5.45	5.27	5.07	4.91	4.74	4.47	4.24	4.05	3.88	3.73	3.60	3.48	3.38	3.29	3.21	3.14	3.07	3.01
4.2	41.58	6.17	5.94	5.68	5.49	5.28	5.12	4.95	4.67	4.43	4.22	4.05	3.89	3.76	3.64	3.53	3.44	3.35	3.27	3.21	3.15
4.3	42.57	6.42	6.18	5.92	5.72	5.50	5.33	5.15	4.86	4.61	4.40	4.22	4.06	3.92	3.79	3.68	3.59	3.50	3.41	3.35	3.28
4.4	43.57	6.68	6.43	6.16	5.95	5.72	5.55	5.36	5.06	4.80	4.58	4.39	4.22	4.08	3.95	3.84	3.74	3.64	3.56	3.49	3.42
4.5	44.56	6.94	6.68	6.40	6.18	5.95	5.77	5.58	5.26	5.00	4.77	4.57	4.40	4.24	4.11	3.99	3.89	3.79	3.70	3.63	3.56
4.6	45.55	7.21	6.94	6.65	6.42	6.18	6.00	5.80	5.47	5.19	4.95	4.75	4.57	4.41	4.27	4.15	4.04	3.94	3.85	3.78	3.70
4.7	46.54	7.48	7.20	6.90	6.67	6.42	6.22	6.02	5.68	5.39	5.14	4.93	4.75	4.58	4.44	4.31	4.20	4.10	4.00	3.92	3.85

Continued on next page

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

2½" Uponor PEX-a — 50% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40ºF 4ºC	45ºF 7.2ºC	50ºF 10ºC	55ºF 12.8ºC	60ºF 15.6ºC	65ºF 18.3ºC	70ºF 21.1ºC	80ºF 26.7ºC	90ºF 32.2ºC	100ºF 37.8ºC	110ºF 43.3ºC	120ºF 48.9ºC	130ºF 54.4ºC	140ºF 60ºC	150ºF 65.6ºC	160ºF 71.1ºC	170ºF 76.7ºC	180ºF 82.2ºC	190ºF 87.8ºC	200ºF 93.3ºC
4.8	47.53	7.76	7.47	7.15	6.91	6.66	6.46	6.24	5.89	5.59	5.34	5.12	4.93	4.76	4.61	4.48	4.36	4.25	4.15	4.07	3.99
4.9	48.52	8.03	7.74	7.41	7.17	6.90	6.69	6.47	6.11	5.80	5.54	5.31	5.11	4.94	4.78	4.64	4.52	4.41	4.31	4.23	4.14
5.0	49.51	8.32	8.01	7.68	7.42	7.14	6.93	6.70	6.33	6.01	5.74	5.50	5.30	5.12	4.96	4.81	4.69	4.57	4.47	4.38	4.30
5.1	50.50	8.61	8.29	7.94	7.68	7.39	7.17	6.94	6.55	6.22	5.94	5.70	5.48	5.30	5.13	4.99	4.86	4.74	4.63	4.54	4.45
5.2	51.49	8.90	8.57	8.21	7.94	7.65	7.42	7.18	6.78	6.44	6.15	5.90	5.68	5.48	5.31	5.16	5.03	4.91	4.79	4.70	4.61
5.3	52.48	9.19	8.86	8.49	8.21	7.91	7.67	7.42	7.01	6.66	6.36	6.10	5.87	5.67	5.50	5.34	5.20	5.08	4.96	4.86	4.77
5.4	53.47	9.49	9.15	8.77	8.48	8.17	7.93	7.66	7.24	6.88	6.57	6.30	6.07	5.86	5.68	5.52	5.38	5.25	5.13	5.03	4.93
5.5	54.46	9.80	9.44	9.05	8.75	8.43	8.18	7.91	7.48	7.10	6.79	6.51	6.27	6.06	5.87	5.70	5.56	5.42	5.30	5.20	5.10
5.6	55.45	10.11	9.74	9.34	9.03	8.70	8.44	8.17	7.72	7.33	7.00	6.72	6.47	6.25	6.06	5.89	5.74	5.60	5.47	5.37	5.27
5.7	56.44	10.42	10.04	9.63	9.31	8.97	8.71	8.42	7.96	7.56	7.23	6.93	6.68	6.45	6.25	6.08	5.92	5.78	5.65	5.54	5.44
5.8	57.43	10.74	10.35	9.92	9.60	9.25	8.98	8.68	8.21	7.80	7.45	7.15	6.89	6.66	6.45	6.27	6.11	5.96	5.83	5.72	5.61
5.9	58.42	11.06	10.66	10.22	9.89	9.53	9.25	8.95	8.46	8.04	7.68	7.37	7.10	6.86	6.65	6.47	6.30	6.15	6.01	5.89	5.78
6.0	59.41	11.38	10.97	10.52	10.18	9.81	9.52	9.21	8.71	8.28	7.91	7.59	7.31	7.07	6.85	6.66	6.49	6.34	6.19	6.07	5.96
6.1	60.40	11.71	11.29	10.83	10.48	10.10	9.80	9.48	8.97	8.52	8.15	7.82	7.53	7.28	7.06	6.86	6.69	6.53	6.38	6.26	6.14
6.2	61.39	12.05	11.61	11.14	10.78	10.39	10.08	9.76	9.23	8.77	8.38	8.05	7.75	7.49	7.26	7.06	6.88	6.72	6.57	6.44	6.32
6.3	62.38	12.38	11.94	11.45	11.08	10.68	10.37	10.03	9.49	9.02	8.62	8.28	7.98	7.71	7.47	7.27	7.08	6.91	6.76	6.63	6.50
6.4	63.37	12.72	12.27	11.77	11.39	10.98	10.66	10.31	9.75	9.28	8.87	8.51	8.20	7.93	7.69	7.47	7.29	7.11	6.95	6.82	6.69
6.5	64.36	13.07	12.60	12.09	11.70	11.28	10.95	10.60	10.02	9.53	9.11	8.75	8.43	8.15	7.90	7.68	7.49	7.31	7.15	7.01	6.88
6.6	65.35	13.42	12.94	12.41	12.02	11.58	11.25	10.88	10.30	9.79	9.36	8.99	8.66	8.38	8.12	7.90	7.70	7.51	7.35	7.21	7.07
6.7	66.34	13.77	13.28	12.74	12.33	11.89	11.55	11.17	10.57	10.06	9.61	9.23	8.90	8.60	8.34	8.11	7.91	7.72	7.55	7.40	7.27
6.8	67.33	14.13	13.63	13.07	12.66	12.20	11.85	11.47	10.85	10.32	9.87	9.48	9.13	8.83	8.56	8.33	8.12	7.93	7.75	7.60	7.46
6.9	68.32	14.49	13.97	13.41	12.98	12.52	12.16	11.77	11.13	10.59	10.13	9.73	9.37	9.07	8.79	8.55	8.34	8.14	7.96	7.81	7.66
7.0	69.31	14.85	14.33	13.75	13.31	12.83	12.47	12.07	11.42	10.86	10.39	9.98	9.62	9.30	9.02	8.77	8.55	8.35	8.16	8.01	7.86
7.1	70.30	15.22	14.68	14.09	13.64	13.16	12.78	12.37	11.71	11.14	10.65	10.23	9.86	9.54	9.25	9.00	8.77	8.56	8.37	8.22	8.06
7.2	71.29	15.60	15.04	14.44	13.98	13.48	13.10	12.68	12.00	11.42	10.92	10.49	10.11	9.78	9.48	9.22	9.00	8.78	8.59	8.43	8.27
7.3	72.28	15.97	15.41	14.79	14.32	13.81	13.42	12.99	12.29	11.70	11.19	10.75	10.36	10.02	9.72	9.46	9.22	9.00	8.80	8.64	8.48
7.4	73.27	16.35	15.78	15.14	14.66	14.14	13.74	13.30	12.59	11.98	11.46	11.01	10.62	10.27	9.96	9.69	9.45	9.22	9.02	8.85	8.69
7.5	74.26	16.74	16.15	15.50	15.01	14.48	14.07	13.62	12.89	12.27	11.74	11.28	10.87	10.52	10.20	9.92	9.68	9.45	9.24	9.07	8.90
7.6	75.25	17.13	16.52	15.86	15.36	14.82	14.40	13.94	13.20	12.56	12.02	11.54	11.13	10.77	10.45	10.16	9.91	9.68	9.46	9.29	9.11
7.7	76.24	17.52	16.90	16.23	15.72	15.16	14.73	14.26	13.50	12.85	12.30	11.82	11.39	11.02	10.69	10.40	10.14	9.90	9.69	9.51	9.33
7.8	77.23	17.91	17.29	16.60	16.07	15.50	15.07	14.59	13.81	13.15	12.58	12.09	11.66	11.28	10.94	10.64	10.38	10.14	9.91	9.73	9.55
7.9	78.22	18.31	17.67	16.97	16.44	15.85	15.41	14.92	14.13	13.45	12.87	12.37	11.93	11.54	11.19	10.89	10.62	10.37	10.14	9.96	9.77
8.0	79.21	18.72	18.06	17.34	16.80	16.21	15.75	15.25	14.44	13.75	13.16	12.65	12.20	11.80	11.45	11.14	10.86	10.61	10.38	10.18	10.00

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

3" Uponor PEX-a — 100% Water — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
1.5	21.12	0.49	0.47	0.45	0.44	0.43	0.42	0.42	0.40	0.39	0.38	0.37	0.37	0.36	0.35	0.35	0.34	0.34	0.33	0.33	0.32
1.6	22.53	0.55	0.53	0.50	0.49	0.48	0.47	0.47	0.45	0.44	0.43	0.42	0.41	0.40	0.40	0.39	0.38	0.38	0.37	0.37	0.36
1.7	23.93	0.61	0.59	0.56	0.55	0.54	0.53	0.52	0.50	0.49	0.48	0.47	0.46	0.45	0.44	0.43	0.43	0.42	0.42	0.41	0.40
1.8	25.34	0.68	0.65	0.61	0.60	0.59	0.58	0.57	0.56	0.54	0.53	0.52	0.51	0.50	0.49	0.48	0.47	0.47	0.46	0.45	0.45
1.9	26.75	0.74	0.71	0.68	0.66	0.65	0.64	0.63	0.61	0.60	0.58	0.57	0.56	0.55	0.54	0.53	0.52	0.51	0.51	0.50	0.49
2.0	28.16	0.81	0.78	0.74	0.73	0.71	0.70	0.69	0.67	0.65	0.64	0.63	0.61	0.60	0.59	0.58	0.57	0.56	0.56	0.55	0.54
2.1	29.57	0.89	0.85	0.81	0.79	0.78	0.77	0.75	0.73	0.71	0.70	0.68	0.67	0.66	0.64	0.63	0.62	0.61	0.61	0.60	0.59
2.2	30.97	0.96	0.92	0.88	0.86	0.85	0.83	0.82	0.80	0.78	0.76	0.74	0.73	0.71	0.70	0.69	0.68	0.67	0.66	0.65	0.64
2.3	32.38	1.04	1.00	0.95	0.93	0.91	0.90	0.89	0.86	0.84	0.82	0.80	0.79	0.77	0.76	0.75	0.73	0.72	0.71	0.71	0.70
2.4	33.79	1.12	1.07	1.02	1.00	0.99	0.97	0.96	0.93	0.91	0.88	0.87	0.85	0.83	0.82	0.80	0.79	0.78	0.77	0.76	0.75
2.5	35.20	1.21	1.16	1.10	1.08	1.06	1.04	1.03	1.00	0.97	0.95	0.93	0.91	0.90	0.88	0.87	0.85	0.84	0.83	0.82	0.81
2.6	36.60	1.29	1.24	1.18	1.16	1.14	1.12	1.10	1.07	1.04	1.02	1.00	0.98	0.96	0.94	0.93	0.92	0.90	0.89	0.88	0.87
2.7	38.01	1.38	1.32	1.26	1.24	1.22	1.20	1.18	1.15	1.12	1.09	1.07	1.05	1.03	1.01	0.99	0.98	0.97	0.95	0.94	0.93
2.8	39.42	1.47	1.41	1.34	1.32	1.30	1.28	1.26	1.22	1.19	1.16	1.14	1.12	1.10	1.08	1.06	1.05	1.03	1.02	1.00	0.99
2.9	40.83	1.57	1.50	1.43	1.40	1.38	1.36	1.34	1.30	1.27	1.24	1.21	1.19	1.17	1.15	1.13	1.11	1.10	1.08	1.07	1.06
3.0	42.24	1.66	1.59	1.52	1.49	1.47	1.44	1.42	1.38	1.35	1.32	1.29	1.26	1.24	1.22	1.20	1.18	1.17	1.15	1.14	1.13
3.1	43.64	1.76	1.69	1.61	1.58	1.55	1.53	1.51	1.47	1.43	1.40	1.37	1.34	1.32	1.29	1.27	1.26	1.24	1.22	1.21	1.19
3.2	45.05	1.86	1.79	1.70	1.67	1.64	1.62	1.60	1.55	1.51	1.48	1.45	1.42	1.39	1.37	1.35	1.33	1.31	1.29	1.28	1.26
3.3	46.46	1.97	1.89	1.80	1.77	1.74	1.71	1.69	1.64	1.60	1.56	1.53	1.50	1.47	1.45	1.43	1.41	1.39	1.37	1.35	1.34
3.4	47.87	2.07	1.99	1.89	1.86	1.83	1.80	1.78	1.73	1.69	1.65	1.61	1.58	1.55	1.53	1.51	1.48	1.46	1.44	1.43	1.41
3.5	49.28	2.18	2.09	1.99	1.96	1.93	1.90	1.87	1.82	1.78	1.74	1.70	1.67	1.64	1.61	1.59	1.56	1.54	1.52	1.50	1.49
3.6	50.68	2.29	2.20	2.10	2.06	2.03	2.00	1.97	1.92	1.87	1.83	1.79	1.75	1.72	1.69	1.67	1.64	1.62	1.60	1.58	1.56
3.7	52.09	2.41	2.31	2.20	2.17	2.13	2.10	2.07	2.01	1.96	1.92	1.88	1.84	1.81	1.78	1.75	1.73	1.70	1.68	1.66	1.64
3.8	53.50	2.52	2.42	2.31	2.27	2.23	2.20	2.17	2.11	2.06	2.01	1.97	1.93	1.90	1.87	1.84	1.81	1.79	1.77	1.74	1.72
3.9	54.91	2.64	2.54	2.42	2.38	2.34	2.31	2.27	2.21	2.16	2.11	2.07	2.03	1.99	1.96	1.93	1.90	1.87	1.85	1.83	1.81
4.0	56.31	2.76	2.65	2.53	2.49	2.45	2.41	2.38	2.31	2.26	2.21	2.16	2.12	2.08	2.05	2.02	1.99	1.96	1.94	1.91	1.89
4.1	57.72	2.89	2.77	2.64	2.60	2.56	2.52	2.48	2.42	2.36	2.31	2.26	2.22	2.18	2.14	2.11	2.08	2.05	2.03	2.00	1.98
4.2	59.13	3.01	2.90	2.76	2.72	2.67	2.63	2.59	2.52	2.46	2.41	2.36	2.31	2.27	2.24	2.20	2.17	2.14	2.12	2.09	2.07
4.3	60.54	3.14	3.02	2.88	2.83	2.78	2.74	2.70	2.63	2.57	2.51	2.46	2.42	2.37	2.33	2.30	2.27	2.24	2.21	2.18	2.16
4.4	61.95	3.27	3.14	3.00	2.95	2.90	2.86	2.82	2.74	2.68	2.62	2.57	2.52	2.47	2.43	2.40	2.36	2.33	2.30	2.27	2.25
4.5	63.35	3.41	3.27	3.12	3.07	3.02	2.98	2.93	2.86	2.79	2.73	2.67	2.62	2.58	2.53	2.50	2.46	2.43	2.40	2.37	2.34
4.6	64.76	3.54	3.40	3.24	3.19	3.14	3.10	3.05	2.97	2.90	2.84	2.78	2.73	2.68	2.64	2.60	2.56	2.53	2.49	2.47	2.44
4.7	66.17	3.68	3.54	3.37	3.32	3.26	3.22	3.17	3.09	3.01	2.95	2.89	2.83	2.79	2.74	2.70	2.66	2.63	2.59	2.56	2.54

Continued on next page

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

Appendix G:

Hydronic friction loss tables

3" Uponor PEX-a — 100% Water — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40ºF 4ºC	45ºF 7ºC	50ºF 10ºC	55ºF 13ºC	60ºF 16ºC	65ºF 18ºC	70ºF 21ºC	80ºF 27ºC	90ºF 32ºC	100ºF 38ºC	110ºF 43ºC	120ºF 49ºC	130ºF 54ºC	140ºF 60ºC	150ºF 66ºC	160ºF 71ºC	170ºF 77ºC	180ºF 82ºC	190ºF 88ºC	200ºF 93ºC
4.8	67.58	3.82	3.67	3.50	3.45	3.39	3.34	3.29	3.21	3.13	3.06	3.00	2.94	2.89	2.85	2.80	2.77	2.73	2.69	2.66	2.63
4.9	68.99	3.96	3.81	3.63	3.58	3.52	3.47	3.42	3.33	3.25	3.18	3.11	3.06	3.00	2.96	2.91	2.87	2.83	2.80	2.76	2.73
5.0	70.39	4.11	3.95	3.77	3.71	3.65	3.60	3.54	3.45	3.37	3.30	3.23	3.17	3.12	3.07	3.02	2.98	2.94	2.90	2.87	2.84
5.1	71.80	4.25	4.09	3.90	3.84	3.78	3.73	3.67	3.57	3.49	3.41	3.35	3.28	3.23	3.18	3.13	3.09	3.04	3.01	2.97	2.94
5.2	73.21	4.40	4.23	4.04	3.98	3.91	3.86	3.80	3.70	3.61	3.54	3.47	3.40	3.34	3.29	3.24	3.20	3.15	3.12	3.08	3.05
5.3	74.62	4.56	4.38	4.18	4.11	4.05	3.99	3.93	3.83	3.74	3.66	3.59	3.52	3.46	3.41	3.36	3.31	3.26	3.23	3.19	3.15
5.4	76.02	4.71	4.53	4.32	4.25	4.18	4.13	4.07	3.96	3.87	3.79	3.71	3.64	3.58	3.52	3.47	3.42	3.38	3.34	3.30	3.26
5.5	77.43	4.87	4.68	4.46	4.40	4.32	4.26	4.20	4.09	4.00	3.91	3.83	3.76	3.70	3.64	3.59	3.54	3.49	3.45	3.41	3.37
5.6	78.84	5.02	4.83	4.61	4.54	4.47	4.40	4.34	4.23	4.13	4.04	3.96	3.89	3.82	3.76	3.71	3.66	3.61	3.56	3.52	3.49
5.7	80.25	5.19	4.99	4.76	4.69	4.61	4.55	4.48	4.37	4.26	4.17	4.09	4.02	3.95	3.89	3.83	3.78	3.73	3.68	3.64	3.60
5.8	81.66	5.35	5.14	4.91	4.83	4.76	4.69	4.62	4.50	4.40	4.31	4.22	4.14	4.07	4.01	3.95	3.90	3.84	3.80	3.76	3.72
5.9	83.06	5.51	5.30	5.06	4.99	4.90	4.84	4.77	4.65	4.54	4.44	4.35	4.27	4.20	4.14	4.07	4.02	3.97	3.92	3.87	3.83
6.0	84.47	5.68	5.47	5.22	5.14	5.05	4.99	4.91	4.79	4.68	4.58	4.49	4.41	4.33	4.26	4.20	4.14	4.09	4.04	3.99	3.95
6.1	85.88	5.85	5.63	5.37	5.29	5.21	5.14	5.06	4.93	4.82	4.72	4.62	4.54	4.46	4.39	4.33	4.27	4.21	4.16	4.12	4.07
6.2	87.29	6.02	5.79	5.53	5.45	5.36	5.29	5.21	5.08	4.96	4.86	4.76	4.67	4.60	4.52	4.46	4.40	4.34	4.29	4.24	4.19
6.3	88.70	6.20	5.96	5.69	5.61	5.52	5.44	5.36	5.23	5.11	5.00	4.90	4.81	4.73	4.66	4.59	4.53	4.47	4.41	4.36	4.32
6.4	90.10	6.37	6.13	5.86	5.77	5.67	5.60	5.52	5.38	5.25	5.14	5.04	4.95	4.87	4.79	4.72	4.66	4.60	4.54	4.49	4.44
6.5	91.51	6.55	6.30	6.02	5.93	5.83	5.76	5.67	5.53	5.40	5.29	5.19	5.09	5.01	4.93	4.86	4.79	4.73	4.67	4.62	4.57
6.6	92.92	6.73	6.48	6.19	6.09	6.00	5.92	5.83	5.68	5.55	5.44	5.33	5.23	5.15	5.07	4.99	4.93	4.86	4.80	4.75	4.70
6.7	94.33	6.92	6.66	6.36	6.26	6.16	6.08	5.99	5.84	5.71	5.59	5.48	5.38	5.29	5.21	5.13	5.06	5.00	4.94	4.88	4.83
6.8	95.73	7.10	6.83	6.53	6.43	6.33	6.24	6.15	6.00	5.86	5.74	5.63	5.52	5.43	5.35	5.27	5.20	5.13	5.07	5.02	4.96
6.9	97.14	7.29	7.02	6.70	6.60	6.50	6.41	6.32	6.16	6.02	5.89	5.78	5.67	5.58	5.49	5.41	5.34	5.27	5.21	5.15	5.10
7.0	98.55	7.48	7.20	6.88	6.77	6.67	6.58	6.48	6.32	6.17	6.05	5.93	5.82	5.73	5.64	5.56	5.48	5.41	5.35	5.29	5.23
7.1	99.96	7.67	7.38	7.05	6.95	6.84	6.75	6.65	6.48	6.34	6.20	6.08	5.97	5.87	5.78	5.70	5.62	5.55	5.49	5.43	5.37
7.2	101.37	7.86	7.57	7.23	7.13	7.01	6.92	6.82	6.65	6.50	6.36	6.24	6.13	6.03	5.93	5.85	5.77	5.70	5.63	5.57	5.51
7.3	102.77	8.06	7.76	7.41	7.30	7.19	7.09	6.99	6.82	6.66	6.52	6.40	6.28	6.18	6.08	6.00	5.92	5.84	5.77	5.71	5.65
7.4	104.18	8.26	7.95	7.60	7.48	7.37	7.27	7.16	6.99	6.83	6.68	6.56	6.44	6.33	6.24	6.15	6.06	5.99	5.92	5.85	5.79
7.5	105.59	8.46	8.14	7.78	7.67	7.55	7.44	7.34	7.16	6.99	6.85	6.72	6.60	6.49	6.39	6.30	6.21	6.13	6.06	6.00	5.93
7.6	107.00	8.66	8.34	7.97	7.85	7.73	7.62	7.52	7.33	7.16	7.01	6.88	6.76	6.65	6.55	6.45	6.37	6.28	6.21	6.14	6.08
7.7	108.41	8.87	8.54	8.16	8.04	7.91	7.81	7.70	7.50	7.33	7.18	7.04	6.92	6.81	6.70	6.61	6.52	6.44	6.36	6.29	6.23
7.8	109.81	9.07	8.74	8.35	8.23	8.10	7.99	7.88	7.68	7.51	7.35	7.21	7.08	6.97	6.86	6.76	6.67	6.59	6.51	6.44	6.37
7.9	111.22	9.28	8.94	8.54	8.42	8.28	8.17	8.06	7.86	7.68	7.52	7.38	7.25	7.13	7.02	6.92	6.83	6.74	6.67	6.59	6.52
8.0	112.63	9.49	9.14	8.74	8.61	8.47	8.36	8.24	8.04	7.86	7.70	7.55	7.42	7.29	7.18	7.08	6.99	6.90	6.82	6.74	6.68

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

3" Uponor PEX-a — 30% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
1.5	21.12	0.65	0.63	0.61	0.59	0.57	0.56	0.54	0.52	0.49	0.48	0.46	0.44	0.43	0.42	0.41	0.40	0.39	0.38	0.38	0.37
1.6	22.53	0.73	0.71	0.68	0.66	0.64	0.63	0.61	0.58	0.55	0.53	0.51	0.50	0.48	0.47	0.46	0.45	0.44	0.43	0.42	0.41
1.7	23.93	0.81	0.78	0.76	0.74	0.71	0.70	0.68	0.64	0.62	0.59	0.57	0.55	0.54	0.52	0.51	0.50	0.49	0.48	0.47	0.46
1.8	25.34	0.89	0.87	0.84	0.81	0.79	0.77	0.75	0.71	0.68	0.65	0.63	0.61	0.59	0.58	0.56	0.55	0.54	0.53	0.52	0.51
1.9	26.75	0.98	0.95	0.92	0.89	0.87	0.84	0.82	0.78	0.75	0.72	0.69	0.67	0.65	0.63	0.62	0.61	0.59	0.58	0.57	0.56
2.0	28.16	1.07	1.04	1.00	0.98	0.95	0.92	0.90	0.85	0.82	0.79	0.76	0.74	0.71	0.70	0.68	0.66	0.65	0.64	0.63	0.62
2.1	29.57	1.16	1.13	1.09	1.06	1.03	1.00	0.98	0.93	0.89	0.86	0.83	0.80	0.78	0.76	0.74	0.72	0.71	0.70	0.68	0.67
2.2	30.97	1.26	1.22	1.18	1.15	1.12	1.09	1.06	1.01	0.97	0.93	0.90	0.87	0.85	0.82	0.80	0.79	0.77	0.76	0.74	0.73
2.3	32.38	1.36	1.32	1.28	1.24	1.21	1.18	1.14	1.09	1.05	1.01	0.97	0.94	0.92	0.89	0.87	0.85	0.83	0.82	0.80	0.79
2.4	33.79	1.47	1.42	1.38	1.34	1.30	1.27	1.23	1.18	1.13	1.09	1.05	1.02	0.99	0.96	0.94	0.92	0.90	0.88	0.87	0.85
2.5	35.20	1.57	1.53	1.48	1.44	1.39	1.36	1.32	1.26	1.21	1.17	1.13	1.09	1.06	1.03	1.01	0.99	0.97	0.95	0.93	0.92
2.6	36.60	1.68	1.63	1.58	1.54	1.49	1.46	1.42	1.35	1.30	1.25	1.21	1.17	1.14	1.11	1.08	1.06	1.04	1.02	1.00	0.99
2.7	38.01	1.80	1.75	1.69	1.64	1.60	1.56	1.51	1.45	1.39	1.34	1.29	1.25	1.22	1.18	1.16	1.13	1.11	1.09	1.07	1.06
2.8	39.42	1.91	1.86	1.80	1.75	1.70	1.66	1.61	1.54	1.48	1.42	1.38	1.33	1.30	1.26	1.24	1.21	1.18	1.16	1.14	1.13
2.9	40.83	2.03	1.98	1.91	1.86	1.81	1.76	1.72	1.64	1.57	1.52	1.46	1.42	1.38	1.34	1.32	1.29	1.26	1.24	1.22	1.20
3.0	42.24	2.16	2.10	2.03	1.97	1.92	1.87	1.82	1.74	1.67	1.61	1.55	1.51	1.47	1.43	1.40	1.37	1.34	1.31	1.29	1.27
3.1	43.64	2.28	2.22	2.15	2.09	2.03	1.98	1.93	1.84	1.77	1.70	1.65	1.60	1.55	1.51	1.48	1.45	1.42	1.39	1.37	1.35
3.2	45.05	2.41	2.34	2.27	2.21	2.15	2.10	2.04	1.95	1.87	1.80	1.74	1.69	1.64	1.60	1.57	1.53	1.50	1.48	1.45	1.43
3.3	46.46	2.55	2.47	2.39	2.33	2.27	2.21	2.15	2.06	1.98	1.90	1.84	1.79	1.74	1.69	1.66	1.62	1.59	1.56	1.53	1.51
3.4	47.87	2.68	2.61	2.52	2.46	2.39	2.33	2.27	2.17	2.08	2.01	1.94	1.88	1.83	1.78	1.75	1.71	1.67	1.64	1.62	1.59
3.5	49.28	2.82	2.74	2.65	2.59	2.51	2.45	2.39	2.28	2.19	2.11	2.04	1.98	1.93	1.88	1.84	1.80	1.76	1.73	1.70	1.68
3.6	50.68	2.96	2.88	2.79	2.72	2.64	2.58	2.51	2.40	2.30	2.22	2.15	2.08	2.03	1.98	1.93	1.89	1.85	1.82	1.79	1.77
3.7	52.09	3.11	3.02	2.92	2.85	2.77	2.70	2.63	2.52	2.42	2.33	2.25	2.19	2.13	2.07	2.03	1.99	1.95	1.91	1.88	1.86
3.8	53.50	3.26	3.16	3.06	2.99	2.90	2.83	2.76	2.64	2.54	2.44	2.36	2.30	2.23	2.18	2.13	2.08	2.04	2.01	1.97	1.95
3.9	54.91	3.41	3.31	3.21	3.12	3.04	2.97	2.89	2.76	2.66	2.56	2.48	2.40	2.34	2.28	2.23	2.18	2.14	2.10	2.07	2.04
4.0	56.31	3.56	3.46	3.35	3.27	3.18	3.10	3.02	2.89	2.78	2.68	2.59	2.51	2.45	2.38	2.33	2.29	2.24	2.20	2.16	2.13
4.1	57.72	3.72	3.61	3.50	3.41	3.32	3.24	3.16	3.02	2.90	2.80	2.71	2.63	2.56	2.49	2.44	2.39	2.34	2.30	2.26	2.23
4.2	59.13	3.88	3.77	3.65	3.56	3.46	3.38	3.29	3.15	3.03	2.92	2.82	2.74	2.67	2.60	2.55	2.49	2.44	2.40	2.36	2.33
4.3	60.54	4.04	3.93	3.80	3.71	3.61	3.52	3.43	3.28	3.16	3.04	2.95	2.86	2.78	2.71	2.66	2.60	2.55	2.51	2.46	2.43
4.4	61.95	4.20	4.09	3.96	3.86	3.75	3.67	3.57	3.42	3.29	3.17	3.07	2.98	2.90	2.83	2.77	2.71	2.66	2.61	2.57	2.53
4.5	63.35	4.37	4.25	4.12	4.02	3.91	3.82	3.72	3.56	3.42	3.30	3.19	3.10	3.02	2.94	2.88	2.82	2.77	2.72	2.67	2.64
4.6	64.76	4.54	4.42	4.28	4.17	4.06	3.97	3.87	3.70	3.56	3.43	3.32	3.23	3.14	3.06	3.00	2.94	2.88	2.83	2.78	2.74
4.7	66.17	4.72	4.59	4.45	4.34	4.22	4.12	4.02	3.84	3.70	3.57	3.45	3.35	3.26	3.18	3.12	3.05	2.99	2.94	2.89	2.85

Continued on next page

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

3" Uponor PEX-a — 30% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40ºF 4ºC	45ºF 7ºC	50ºF 10ºC	55ºF 13ºC	60ºF 16ºC	65ºF 18ºC	70ºF 21ºC	80ºF 27ºC	90ºF 32ºC	100ºF 38ºC	110ºF 43ºC	120ºF 49ºC	130ºF 54ºC	140ºF 60ºC	150ºF 66ºC	160ºF 71ºC	170ºF 77ºC	180ºF 82ºC	190ºF 88ºC	200ºF 93ºC
4.8	67.58	4.89	4.76	4.61	4.50	4.38	4.28	4.17	3.99	3.84	3.70	3.58	3.48	3.39	3.30	3.24	3.17	3.11	3.05	3.00	2.96
4.9	68.99	5.07	4.93	4.78	4.67	4.54	4.43	4.32	4.14	3.98	3.84	3.72	3.61	3.52	3.43	3.36	3.29	3.22	3.17	3.12	3.08
5.0	70.39	5.26	5.11	4.96	4.83	4.70	4.59	4.48	4.29	4.12	3.98	3.85	3.74	3.64	3.55	3.48	3.41	3.34	3.29	3.23	3.19
5.1	71.80	5.44	5.29	5.13	5.01	4.87	4.76	4.64	4.44	4.27	4.12	3.99	3.88	3.78	3.68	3.61	3.53	3.46	3.41	3.35	3.31
5.2	73.21	5.63	5.48	5.31	5.18	5.04	4.92	4.80	4.60	4.42	4.27	4.13	4.02	3.91	3.81	3.73	3.66	3.59	3.53	3.47	3.42
5.3	74.62	5.82	5.66	5.49	5.36	5.21	5.09	4.97	4.76	4.57	4.42	4.28	4.15	4.05	3.95	3.86	3.78	3.71	3.65	3.59	3.54
5.4	76.02	6.02	5.85	5.67	5.54	5.39	5.26	5.13	4.92	4.73	4.57	4.42	4.30	4.18	4.08	4.00	3.91	3.84	3.77	3.71	3.66
5.5	77.43	6.21	6.04	5.86	5.72	5.56	5.44	5.30	5.08	4.89	4.72	4.57	4.44	4.32	4.22	4.13	4.05	3.97	3.90	3.84	3.79
5.6	78.84	6.41	6.24	6.05	5.90	5.74	5.61	5.47	5.24	5.05	4.87	4.72	4.58	4.46	4.35	4.27	4.18	4.10	4.03	3.96	3.91
5.7	80.25	6.61	6.43	6.24	6.09	5.92	5.79	5.65	5.41	5.21	5.03	4.87	4.73	4.61	4.50	4.40	4.31	4.23	4.16	4.09	4.04
5.8	81.66	6.82	6.63	6.43	6.28	6.11	5.97	5.82	5.58	5.37	5.19	5.02	4.88	4.75	4.64	4.54	4.45	4.36	4.29	4.22	4.17
5.9	83.06	7.03	6.84	6.63	6.47	6.30	6.15	6.00	5.75	5.54	5.35	5.18	5.03	4.90	4.78	4.69	4.59	4.50	4.43	4.35	4.30
6.0	84.47	7.24	7.04	6.83	6.66	6.49	6.34	6.18	5.93	5.70	5.51	5.34	5.19	5.05	4.93	4.83	4.73	4.64	4.56	4.49	4.43
6.1	85.88	7.45	7.25	7.03	6.86	6.68	6.53	6.37	6.10	5.87	5.67	5.50	5.34	5.20	5.08	4.97	4.87	4.78	4.70	4.62	4.57
6.2	87.29	7.67	7.46	7.24	7.06	6.87	6.72	6.55	6.28	6.05	5.84	5.66	5.50	5.36	5.23	5.12	5.02	4.92	4.84	4.76	4.70
6.3	88.70	7.88	7.67	7.44	7.26	7.07	6.91	6.74	6.46	6.22	6.01	5.82	5.66	5.51	5.38	5.27	5.16	5.07	4.98	4.90	4.84
6.4	90.10	8.10	7.89	7.65	7.47	7.27	7.11	6.93	6.65	6.40	6.18	5.99	5.82	5.67	5.53	5.42	5.31	5.21	5.13	5.04	4.98
6.5	91.51	8.33	8.11	7.87	7.68	7.47	7.31	7.13	6.83	6.58	6.35	6.16	5.99	5.83	5.69	5.58	5.46	5.36	5.27	5.18	5.12
6.6	92.92	8.56	8.33	8.08	7.89	7.68	7.51	7.32	7.02	6.76	6.53	6.33	6.15	5.99	5.85	5.73	5.62	5.51	5.42	5.33	5.26
6.7	94.33	8.78	8.55	8.30	8.10	7.88	7.71	7.52	7.21	6.94	6.71	6.50	6.32	6.16	6.01	5.89	5.77	5.66	5.57	5.48	5.41
6.8	95.73	9.02	8.78	8.52	8.31	8.09	7.91	7.72	7.41	7.13	6.89	6.67	6.49	6.32	6.17	6.05	5.93	5.81	5.72	5.62	5.55
6.9	97.14	9.25	9.01	8.74	8.53	8.30	8.12	7.92	7.60	7.32	7.07	6.85	6.66	6.49	6.33	6.21	6.08	5.97	5.87	5.77	5.70
7.0	98.55	9.49	9.24	8.96	8.75	8.52	8.33	8.13	7.80	7.51	7.25	7.03	6.84	6.66	6.50	6.37	6.24	6.12	6.03	5.93	5.85
7.1	99.96	9.73	9.47	9.19	8.97	8.74	8.54	8.34	8.00	7.70	7.44	7.21	7.01	6.83	6.67	6.54	6.40	6.28	6.18	6.08	6.01
7.2	101.37	9.97	9.71	9.42	9.20	8.95	8.76	8.55	8.20	7.89	7.63	7.39	7.19	7.01	6.84	6.70	6.57	6.44	6.34	6.24	6.16
7.3	102.77	10.21	9.95	9.65	9.42	9.18	8.97	8.76	8.40	8.09	7.82	7.58	7.37	7.18	7.01	6.87	6.73	6.61	6.50	6.39	6.31
7.4	104.18	10.46	10.19	9.89	9.65	9.40	9.19	8.97	8.61	8.29	8.01	7.76	7.55	7.36	7.18	7.04	6.90	6.77	6.66	6.55	6.47
7.5	105.59	10.71	10.43	10.13	9.89	9.63	9.42	9.19	8.82	8.49	8.21	7.95	7.74	7.54	7.36	7.21	7.07	6.94	6.82	6.71	6.63
7.6	107.00	10.97	10.68	10.36	10.12	9.86	9.64	9.41	9.03	8.69	8.40	8.14	7.92	7.72	7.54	7.39	7.24	7.10	6.99	6.88	6.79
7.7	108.41	11.22	10.93	10.61	10.36	10.09	9.87	9.63	9.24	8.90	8.60	8.34	8.11	7.90	7.72	7.56	7.41	7.27	7.16	7.04	6.95
7.8	109.81	11.48	11.18	10.85	10.60	10.32	10.09	9.85	9.45	9.11	8.80	8.53	8.30	8.09	7.90	7.74	7.59	7.45	7.33	7.21	7.12
7.9	111.22	11.74	11.43	11.10	10.84	10.56	10.33	10.08	9.67	9.32	9.00	8.73	8.49	8.28	8.08	7.92	7.76	7.62	7.50	7.38	7.29
8.0	112.63	12.00	11.69	11.35	11.08	10.79	10.56	10.31	9.89	9.53	9.21	8.93	8.69	8.47	8.27	8.10	7.94	7.79	7.67	7.54	7.45

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

3" Uponor PEX-a — 40% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
1.5	21.12	0.76	0.73	0.70	0.67	0.65	0.63	0.60	0.57	0.54	0.52	0.49	0.48	0.46	0.44	0.43	0.42	0.41	0.40	0.39	0.39
1.6	22.53	0.85	0.81	0.78	0.75	0.72	0.70	0.68	0.64	0.60	0.58	0.55	0.53	0.51	0.50	0.48	0.47	0.46	0.45	0.44	0.43
1.7	23.93	0.94	0.90	0.86	0.83	0.80	0.78	0.75	0.71	0.67	0.64	0.62	0.59	0.57	0.55	0.54	0.53	0.51	0.50	0.49	0.48
1.8	25.34	1.03	0.99	0.95	0.92	0.88	0.86	0.83	0.78	0.74	0.71	0.68	0.65	0.63	0.61	0.60	0.58	0.57	0.56	0.54	0.54
1.9	26.75	1.13	1.09	1.04	1.01	0.97	0.94	0.91	0.86	0.82	0.78	0.75	0.72	0.70	0.67	0.66	0.64	0.62	0.61	0.60	0.59
2.0	28.16	1.24	1.19	1.14	1.10	1.06	1.03	0.99	0.94	0.89	0.85	0.82	0.79	0.76	0.74	0.72	0.70	0.68	0.67	0.66	0.65
2.1	29.57	1.34	1.29	1.24	1.20	1.15	1.12	1.08	1.02	0.97	0.93	0.89	0.86	0.83	0.80	0.78	0.76	0.75	0.73	0.72	0.70
2.2	30.97	1.46	1.40	1.34	1.30	1.25	1.21	1.17	1.11	1.05	1.01	0.97	0.93	0.90	0.87	0.85	0.83	0.81	0.79	0.78	0.77
2.3	32.38	1.57	1.51	1.45	1.40	1.35	1.31	1.27	1.20	1.14	1.09	1.05	1.01	0.97	0.94	0.92	0.90	0.88	0.86	0.84	0.83
2.4	33.79	1.69	1.63	1.56	1.51	1.45	1.41	1.36	1.29	1.23	1.17	1.13	1.09	1.05	1.02	0.99	0.97	0.95	0.93	0.91	0.89
2.5	35.20	1.81	1.74	1.67	1.62	1.56	1.51	1.46	1.38	1.32	1.26	1.21	1.17	1.13	1.10	1.07	1.04	1.02	1.00	0.98	0.96
2.6	36.60	1.94	1.87	1.79	1.73	1.67	1.62	1.57	1.48	1.41	1.35	1.30	1.25	1.21	1.17	1.14	1.12	1.09	1.07	1.05	1.03
2.7	38.01	2.07	1.99	1.91	1.85	1.78	1.73	1.67	1.58	1.51	1.44	1.39	1.34	1.29	1.26	1.22	1.19	1.17	1.14	1.12	1.10
2.8	39.42	2.20	2.12	2.03	1.97	1.90	1.84	1.78	1.69	1.61	1.54	1.48	1.42	1.38	1.34	1.30	1.27	1.24	1.22	1.20	1.18
2.9	40.83	2.34	2.25	2.16	2.09	2.02	1.96	1.90	1.79	1.71	1.64	1.57	1.52	1.47	1.42	1.39	1.36	1.32	1.30	1.27	1.25
3.0	42.24	2.48	2.39	2.29	2.22	2.14	2.08	2.01	1.90	1.81	1.74	1.67	1.61	1.56	1.51	1.47	1.44	1.41	1.38	1.35	1.33
3.1	43.64	2.62	2.53	2.42	2.35	2.26	2.20	2.13	2.02	1.92	1.84	1.77	1.71	1.65	1.60	1.56	1.53	1.49	1.46	1.43	1.41
3.2	45.05	2.77	2.67	2.56	2.48	2.39	2.32	2.25	2.13	2.03	1.95	1.87	1.80	1.75	1.70	1.65	1.62	1.58	1.55	1.52	1.49
3.3	46.46	2.92	2.81	2.70	2.62	2.52	2.45	2.37	2.25	2.14	2.05	1.98	1.91	1.85	1.79	1.75	1.71	1.67	1.64	1.60	1.58
3.4	47.87	3.07	2.96	2.84	2.75	2.66	2.58	2.50	2.37	2.26	2.16	2.08	2.01	1.95	1.89	1.84	1.80	1.76	1.73	1.69	1.67
3.5	49.28	3.23	3.12	2.99	2.90	2.79	2.72	2.63	2.49	2.38	2.28	2.19	2.11	2.05	1.99	1.94	1.90	1.85	1.82	1.78	1.75
3.6	50.68	3.39	3.27	3.14	3.04	2.94	2.85	2.76	2.62	2.50	2.39	2.30	2.22	2.15	2.09	2.04	1.99	1.95	1.91	1.87	1.84
3.7	52.09	3.55	3.43	3.29	3.19	3.08	2.99	2.90	2.75	2.62	2.51	2.42	2.33	2.26	2.20	2.14	2.09	2.04	2.01	1.97	1.94
3.8	53.50	3.72	3.59	3.45	3.34	3.23	3.14	3.04	2.88	2.75	2.63	2.53	2.45	2.37	2.30	2.24	2.19	2.14	2.11	2.06	2.03
3.9	54.91	3.89	3.76	3.61	3.50	3.38	3.28	3.18	3.02	2.88	2.76	2.65	2.56	2.48	2.41	2.35	2.30	2.25	2.21	2.16	2.13
4.0	56.31	4.07	3.93	3.77	3.65	3.53	3.43	3.32	3.15	3.01	2.88	2.78	2.68	2.60	2.52	2.46	2.41	2.35	2.31	2.26	2.23
4.1	57.72	4.24	4.10	3.94	3.81	3.68	3.58	3.47	3.29	3.14	3.01	2.90	2.80	2.71	2.64	2.57	2.51	2.46	2.41	2.37	2.33
4.2	59.13	4.42	4.27	4.10	3.98	3.84	3.74	3.62	3.44	3.28	3.14	3.03	2.92	2.83	2.75	2.68	2.62	2.56	2.52	2.47	2.43
4.3	60.54	4.61	4.45	4.28	4.14	4.00	3.89	3.77	3.58	3.42	3.28	3.16	3.05	2.95	2.87	2.80	2.74	2.67	2.63	2.58	2.54
4.4	61.95	4.80	4.63	4.45	4.31	4.17	4.05	3.93	3.73	3.56	3.41	3.29	3.17	3.08	2.99	2.92	2.85	2.79	2.74	2.68	2.64
4.5	63.35	4.99	4.82	4.63	4.49	4.33	4.22	4.09	3.88	3.70	3.55	3.42	3.30	3.20	3.11	3.04	2.97	2.90	2.85	2.79	2.75
4.6	64.76	5.18	5.00	4.81	4.66	4.50	4.38	4.25	4.03	3.85	3.69	3.56	3.44	3.33	3.24	3.16	3.09	3.02	2.97	2.91	2.86

Continued on next page

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

3" Uponor PEX-a — 40% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40ºF 4ºC	45ºF 7ºC	50ºF 10ºC	55ºF 13ºC	60ºF 16ºC	65ºF 18ºC	70ºF 21ºC	80ºF 27ºC	90ºF 32ºC	100ºF 38ºC	110ºF 43ºC	120ºF 49ºC	130ºF 54ºC	140ºF 60ºC	150ºF 66ºC	160ºF 71ºC	170ºF 77ºC	180ºF 82ºC	190ºF 88ºC	200ºF 93ºC
4.7	66.17	5.38	5.19	4.99	4.84	4.68	4.55	4.41	4.19	4.00	3.84	3.69	3.57	3.46	3.36	3.28	3.21	3.14	3.08	3.02	2.98
4.8	67.58	5.58	5.39	5.18	5.02	4.85	4.72	4.58	4.35	4.15	3.98	3.84	3.71	3.59	3.49	3.41	3.33	3.26	3.20	3.14	3.09
4.9	68.99	5.78	5.58	5.37	5.21	5.03	4.89	4.75	4.51	4.30	4.13	3.98	3.84	3.73	3.62	3.53	3.46	3.38	3.32	3.26	3.21
5.0	70.39	5.99	5.78	5.56	5.39	5.21	5.07	4.92	4.67	4.46	4.28	4.12	3.98	3.86	3.76	3.66	3.59	3.50	3.44	3.38	3.33
5.1	71.80	6.20	5.99	5.76	5.58	5.39	5.25	5.09	4.84	4.62	4.43	4.27	4.13	4.00	3.89	3.80	3.71	3.63	3.57	3.50	3.45
5.2	73.21	6.41	6.19	5.95	5.78	5.58	5.43	5.27	5.01	4.78	4.59	4.42	4.27	4.14	4.03	3.93	3.85	3.76	3.70	3.62	3.57
5.3	74.62	6.62	6.40	6.16	5.97	5.77	5.62	5.45	5.18	4.94	4.75	4.57	4.42	4.29	4.17	4.07	3.98	3.89	3.82	3.75	3.70
5.4	76.02	6.84	6.61	6.36	6.17	5.96	5.80	5.63	5.35	5.11	4.91	4.73	4.57	4.43	4.31	4.21	4.12	4.02	3.96	3.88	3.82
5.5	77.43	7.06	6.83	6.57	6.37	6.16	5.99	5.82	5.53	5.28	5.07	4.89	4.72	4.58	4.45	4.35	4.25	4.16	4.09	4.01	3.95
5.6	78.84	7.29	7.04	6.78	6.58	6.36	6.19	6.00	5.71	5.45	5.23	5.04	4.88	4.73	4.60	4.49	4.39	4.30	4.22	4.14	4.08
5.7	80.25	7.52	7.27	6.99	6.78	6.56	6.38	6.19	5.89	5.62	5.40	5.21	5.03	4.88	4.75	4.63	4.53	4.43	4.36	4.27	4.21
5.8	81.66	7.75	7.49	7.21	6.99	6.76	6.58	6.39	6.07	5.80	5.57	5.37	5.19	5.04	4.90	4.78	4.68	4.57	4.50	4.41	4.35
5.9	83.06	7.98	7.72	7.42	7.20	6.97	6.78	6.58	6.26	5.98	5.74	5.54	5.35	5.19	5.05	4.93	4.82	4.72	4.64	4.55	4.48
6.0	84.47	8.22	7.95	7.65	7.42	7.17	6.98	6.78	6.44	6.16	5.92	5.70	5.51	5.35	5.20	5.08	4.97	4.86	4.78	4.69	4.62
6.1	85.88	8.46	8.18	7.87	7.64	7.39	7.19	6.98	6.64	6.34	6.09	5.87	5.68	5.51	5.36	5.23	5.12	5.01	4.92	4.83	4.76
6.2	87.29	8.70	8.41	8.10	7.86	7.60	7.40	7.18	6.83	6.53	6.27	6.05	5.85	5.67	5.52	5.39	5.27	5.16	5.07	4.97	4.90
6.3	88.70	8.95	8.65	8.33	8.08	7.82	7.61	7.39	7.03	6.72	6.45	6.22	6.02	5.84	5.68	5.54	5.43	5.31	5.22	5.12	5.05
6.4	90.10	9.20	8.89	8.56	8.31	8.04	7.82	7.60	7.22	6.91	6.63	6.40	6.19	6.01	5.84	5.70	5.58	5.46	5.37	5.27	5.19
6.5	91.51	9.45	9.14	8.80	8.54	8.26	8.04	7.81	7.43	7.10	6.82	6.58	6.36	6.18	6.01	5.86	5.74	5.61	5.52	5.42	5.34
6.6	92.92	9.70	9.38	9.03	8.77	8.48	8.26	8.02	7.63	7.29	7.01	6.76	6.54	6.35	6.17	6.03	5.90	5.77	5.68	5.57	5.49
6.7	94.33	9.96	9.63	9.27	9.00	8.71	8.48	8.24	7.83	7.49	7.20	6.94	6.72	6.52	6.34	6.19	6.06	5.93	5.83	5.72	5.64
6.8	95.73	10.22	9.89	9.52	9.24	8.94	8.71	8.45	8.04	7.69	7.39	7.13	6.90	6.69	6.51	6.36	6.22	6.09	5.99	5.87	5.79
6.9	97.14	10.49	10.14	9.77	9.48	9.17	8.93	8.68	8.25	7.89	7.59	7.32	7.08	6.87	6.69	6.53	6.39	6.25	6.15	6.03	5.95
7.0	98.55	10.75	10.40	10.01	9.72	9.41	9.16	8.90	8.47	8.10	7.78	7.51	7.26	7.05	6.86	6.70	6.56	6.42	6.31	6.19	6.10
7.1	99.96	11.02	10.66	10.27	9.97	9.65	9.40	9.12	8.68	8.30	7.98	7.70	7.45	7.23	7.04	6.87	6.73	6.58	6.47	6.35	6.26
7.2	101.37	11.29	10.93	10.52	10.22	9.89	9.63	9.35	8.90	8.51	8.18	7.89	7.64	7.42	7.22	7.05	6.90	6.75	6.64	6.51	6.42
7.3	102.77	11.57	11.19	10.78	10.47	10.13	9.87	9.58	9.12	8.72	8.39	8.09	7.83	7.60	7.40	7.22	7.07	6.92	6.81	6.68	6.58
7.4	104.18	11.85	11.46	11.04	10.72	10.38	10.11	9.82	9.34	8.94	8.59	8.29	8.02	7.79	7.58	7.40	7.25	7.09	6.98	6.84	6.75
7.5	105.59	12.13	11.74	11.30	10.98	10.62	10.35	10.05	9.57	9.15	8.80	8.49	8.22	7.98	7.77	7.58	7.42	7.27	7.15	7.01	6.91
7.6	107.00	12.41	12.01	11.57	11.24	10.87	10.59	10.29	9.80	9.37	9.01	8.69	8.41	8.17	7.95	7.77	7.60	7.44	7.32	7.18	7.08
7.7	108.41	12.70	12.29	11.84	11.50	11.13	10.84	10.53	10.02	9.59	9.22	8.90	8.61	8.36	8.14	7.95	7.78	7.62	7.49	7.35	7.25
7.8	109.81	12.99	12.57	12.11	11.76	11.38	11.09	10.77	10.26	9.81	9.44	9.11	8.81	8.56	8.33	8.14	7.97	7.80	7.67	7.53	7.42
7.9	111.22	13.28	12.85	12.38	12.03	11.64	11.34	11.02	10.49	10.04	9.65	9.32	9.02	8.76	8.52	8.33	8.15	7.98	7.85	7.70	7.59
8.0	112.63	13.58	13.14	12.66	12.30	11.90	11.60	11.27	10.73	10.27	9.87	9.53	9.22	8.96	8.72	8.52	8.34	8.16	8.03	7.88	7.77

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

3" Uponor PEX-a — 50% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
1.5	21.12	0.86	0.82	0.78	0.75	0.72	0.70	0.67	0.63	0.59	0.56	0.54	0.51	0.49	0.48	0.46	0.45	0.44	0.43	0.42	0.41
1.6	22.53	0.95	0.91	0.87	0.84	0.80	0.78	0.75	0.70	0.66	0.63	0.60	0.57	0.55	0.53	0.52	0.50	0.49	0.48	0.47	0.46
1.7	23.93	1.06	1.01	0.97	0.93	0.89	0.86	0.83	0.78	0.74	0.70	0.67	0.64	0.62	0.59	0.58	0.56	0.54	0.53	0.52	0.51
1.8	25.34	1.16	1.12	1.06	1.02	0.98	0.95	0.92	0.86	0.81	0.77	0.74	0.71	0.68	0.66	0.64	0.62	0.60	0.59	0.57	0.56
1.9	26.75	1.27	1.22	1.17	1.12	1.08	1.04	1.00	0.94	0.89	0.85	0.81	0.78	0.75	0.72	0.70	0.68	0.66	0.65	0.63	0.62
2.0	28.16	1.39	1.33	1.27	1.23	1.18	1.14	1.10	1.03	0.97	0.93	0.88	0.85	0.82	0.79	0.77	0.74	0.72	0.71	0.69	0.68
2.1	29.57	1.51	1.45	1.38	1.33	1.28	1.24	1.19	1.12	1.06	1.01	0.96	0.92	0.89	0.86	0.83	0.81	0.79	0.77	0.75	0.74
2.2	30.97	1.63	1.57	1.50	1.44	1.38	1.34	1.29	1.21	1.15	1.09	1.05	1.00	0.97	0.93	0.91	0.88	0.86	0.84	0.82	0.80
2.3	32.38	1.76	1.69	1.61	1.56	1.49	1.45	1.40	1.31	1.24	1.18	1.13	1.08	1.05	1.01	0.98	0.95	0.93	0.90	0.89	0.87
2.4	33.79	1.89	1.82	1.74	1.67	1.61	1.56	1.50	1.41	1.34	1.27	1.22	1.17	1.13	1.09	1.06	1.03	1.00	0.98	0.96	0.94
2.5	35.20	2.03	1.95	1.86	1.80	1.72	1.67	1.61	1.52	1.44	1.37	1.31	1.26	1.21	1.17	1.13	1.10	1.08	1.05	1.03	1.01
2.6	36.60	2.17	2.08	1.99	1.92	1.84	1.79	1.72	1.62	1.54	1.46	1.40	1.34	1.30	1.25	1.22	1.18	1.15	1.12	1.10	1.08
2.7	38.01	2.31	2.22	2.12	2.05	1.97	1.91	1.84	1.73	1.64	1.56	1.50	1.44	1.39	1.34	1.30	1.27	1.23	1.20	1.18	1.15
2.8	39.42	2.46	2.36	2.26	2.18	2.10	2.03	1.96	1.85	1.75	1.67	1.59	1.53	1.48	1.43	1.39	1.35	1.31	1.28	1.26	1.23
2.9	40.83	2.61	2.51	2.40	2.32	2.23	2.16	2.08	1.96	1.86	1.77	1.70	1.63	1.57	1.52	1.48	1.44	1.40	1.37	1.34	1.31
3.0	42.24	2.77	2.66	2.54	2.46	2.36	2.29	2.21	2.08	1.97	1.88	1.80	1.73	1.67	1.61	1.57	1.52	1.49	1.45	1.42	1.39
3.1	43.64	2.92	2.81	2.69	2.60	2.50	2.42	2.34	2.20	2.09	1.99	1.91	1.83	1.77	1.71	1.66	1.62	1.57	1.54	1.51	1.48
3.2	45.05	3.09	2.97	2.84	2.74	2.64	2.56	2.47	2.33	2.21	2.10	2.02	1.94	1.87	1.81	1.76	1.71	1.67	1.63	1.59	1.56
3.3	46.46	3.25	3.13	3.00	2.89	2.78	2.70	2.61	2.46	2.33	2.22	2.13	2.05	1.97	1.91	1.86	1.81	1.76	1.72	1.68	1.65
3.4	47.87	3.42	3.30	3.15	3.05	2.93	2.84	2.74	2.59	2.45	2.34	2.24	2.16	2.08	2.01	1.96	1.90	1.86	1.81	1.78	1.74
3.5	49.28	3.60	3.46	3.31	3.20	3.08	2.99	2.89	2.72	2.58	2.46	2.36	2.27	2.19	2.12	2.06	2.00	1.95	1.91	1.87	1.83
3.6	50.68	3.78	3.63	3.48	3.36	3.23	3.14	3.03	2.86	2.71	2.59	2.48	2.39	2.30	2.23	2.16	2.11	2.05	2.01	1.97	1.93
3.7	52.09	3.96	3.81	3.65	3.53	3.39	3.29	3.18	3.00	2.85	2.71	2.60	2.50	2.42	2.34	2.27	2.21	2.16	2.11	2.07	2.03
3.8	53.50	4.14	3.99	3.82	3.69	3.55	3.45	3.33	3.14	2.98	2.84	2.73	2.62	2.53	2.45	2.38	2.32	2.26	2.21	2.17	2.12
3.9	54.91	4.33	4.17	3.99	3.86	3.72	3.60	3.48	3.29	3.12	2.98	2.85	2.75	2.65	2.57	2.50	2.43	2.37	2.31	2.27	2.23
4.0	56.31	4.52	4.36	4.17	4.03	3.88	3.77	3.64	3.44	3.26	3.11	2.99	2.87	2.77	2.69	2.61	2.54	2.48	2.42	2.37	2.33
4.1	57.72	4.72	4.55	4.35	4.21	4.05	3.93	3.80	3.59	3.41	3.25	3.12	3.00	2.90	2.81	2.73	2.66	2.59	2.53	2.48	2.43
4.2	59.13	4.92	4.74	4.54	4.39	4.23	4.10	3.96	3.74	3.55	3.39	3.25	3.13	3.03	2.93	2.85	2.77	2.70	2.64	2.59	2.54
4.3	60.54	5.12	4.93	4.73	4.57	4.40	4.27	4.13	3.90	3.70	3.54	3.39	3.26	3.15	3.06	2.97	2.89	2.82	2.76	2.70	2.65
4.4	61.95	5.33	5.13	4.92	4.76	4.58	4.45	4.30	4.06	3.86	3.68	3.53	3.40	3.29	3.18	3.09	3.01	2.94	2.87	2.82	2.76
4.5	63.35	5.54	5.34	5.11	4.95	4.76	4.62	4.47	4.22	4.01	3.83	3.68	3.54	3.42	3.31	3.22	3.14	3.06	2.99	2.93	2.88
4.6	64.76	5.75	5.54	5.31	5.14	4.95	4.80	4.64	4.39	4.17	3.98	3.82	3.68	3.55	3.44	3.35	3.26	3.18	3.11	3.05	2.99
4.7	66.17	5.97	5.75	5.51	5.33	5.14	4.99	4.82	4.56	4.33	4.14	3.97	3.82	3.69	3.58	3.48	3.39	3.31	3.23	3.17	3.11

Continued on next page

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

Appendix G:

Hydronic friction loss tables

3" Uponor PEX-a — 50% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
4.8	67.58	6.19	5.96	5.72	5.53	5.33	5.17	5.00	4.73	4.49	4.29	4.12	3.97	3.83	3.72	3.61	3.52	3.43	3.36	3.29	3.23
4.9	68.99	6.41	6.18	5.93	5.73	5.52	5.36	5.19	4.90	4.66	4.45	4.27	4.11	3.98	3.85	3.75	3.65	3.56	3.48	3.41	3.35
5.0	70.39	6.64	6.40	6.14	5.94	5.72	5.55	5.37	5.08	4.83	4.61	4.43	4.26	4.12	4.00	3.88	3.78	3.69	3.61	3.54	3.47
5.1	71.80	6.87	6.62	6.35	6.15	5.92	5.75	5.56	5.26	5.00	4.78	4.59	4.42	4.27	4.14	4.02	3.92	3.83	3.74	3.67	3.60
5.2	73.21	7.11	6.85	6.57	6.36	6.13	5.95	5.75	5.44	5.17	4.94	4.75	4.57	4.42	4.28	4.16	4.06	3.96	3.87	3.80	3.73
5.3	74.62	7.34	7.08	6.79	6.57	6.33	6.15	5.95	5.63	5.35	5.11	4.91	4.73	4.57	4.43	4.31	4.20	4.10	4.01	3.93	3.86
5.4	76.02	7.58	7.31	7.01	6.79	6.54	6.35	6.15	5.81	5.53	5.28	5.07	4.89	4.73	4.58	4.46	4.34	4.24	4.14	4.06	3.99
5.5	77.43	7.83	7.55	7.24	7.01	6.75	6.56	6.35	6.00	5.71	5.46	5.24	5.05	4.88	4.73	4.60	4.49	4.38	4.28	4.20	4.12
5.6	78.84	8.07	7.79	7.47	7.23	6.97	6.77	6.55	6.20	5.89	5.64	5.41	5.21	5.04	4.89	4.75	4.63	4.52	4.42	4.34	4.26
5.7	80.25	8.33	8.03	7.70	7.46	7.19	6.98	6.76	6.39	6.08	5.81	5.58	5.38	5.20	5.05	4.91	4.78	4.67	4.56	4.48	4.39
5.8	81.66	8.58	8.27	7.94	7.69	7.41	7.20	6.97	6.59	6.27	6.00	5.76	5.55	5.37	5.20	5.06	4.93	4.82	4.71	4.62	4.53
5.9	83.06	8.84	8.52	8.18	7.92	7.64	7.42	7.18	6.79	6.46	6.18	5.94	5.72	5.53	5.37	5.22	5.09	4.97	4.86	4.76	4.68
6.0	84.47	9.10	8.78	8.42	8.15	7.86	7.64	7.39	7.00	6.66	6.37	6.12	5.89	5.70	5.53	5.38	5.24	5.12	5.00	4.91	4.82
6.1	85.88	9.36	9.03	8.67	8.39	8.09	7.86	7.61	7.20	6.85	6.56	6.30	6.07	5.87	5.69	5.54	5.40	5.27	5.16	5.06	4.96
6.2	87.29	9.63	9.29	8.92	8.63	8.33	8.09	7.83	7.41	7.05	6.75	6.48	6.25	6.04	5.86	5.70	5.56	5.43	5.31	5.21	5.11
6.3	88.70	9.90	9.55	9.17	8.88	8.56	8.32	8.05	7.62	7.26	6.94	6.67	6.43	6.22	6.03	5.87	5.72	5.59	5.46	5.36	5.26
6.4	90.10	10.17	9.81	9.42	9.13	8.80	8.55	8.28	7.84	7.46	7.14	6.86	6.61	6.40	6.20	6.03	5.89	5.75	5.62	5.51	5.41
6.5	91.51	10.45	10.08	9.68	9.38	9.04	8.79	8.51	8.06	7.67	7.34	7.05	6.80	6.58	6.38	6.20	6.05	5.91	5.78	5.67	5.57
6.6	92.92	10.73	10.35	9.94	9.63	9.29	9.02	8.74	8.28	7.88	7.54	7.24	6.98	6.76	6.55	6.38	6.22	6.07	5.94	5.83	5.72
6.7	94.33	11.01	10.63	10.20	9.88	9.53	9.27	8.97	8.50	8.09	7.74	7.44	7.17	6.94	6.73	6.55	6.39	6.24	6.10	5.99	5.88
6.8	95.73	11.30	10.90	10.47	10.14	9.79	9.51	9.21	8.72	8.30	7.95	7.64	7.36	7.13	6.91	6.73	6.56	6.41	6.27	6.15	6.04
6.9	97.14	11.59	11.18	10.74	10.41	10.04	9.76	9.45	8.95	8.52	8.15	7.84	7.56	7.31	7.10	6.90	6.73	6.58	6.43	6.31	6.20
7.0	98.55	11.88	11.47	11.01	10.67	10.29	10.00	9.69	9.18	8.74	8.37	8.04	7.75	7.50	7.28	7.08	6.91	6.75	6.60	6.48	6.36
7.1	99.96	12.18	11.75	11.29	10.94	10.55	10.26	9.93	9.41	8.96	8.58	8.25	7.95	7.70	7.47	7.27	7.09	6.92	6.77	6.65	6.52
7.2	101.37	12.48	12.04	11.57	11.21	10.82	10.51	10.18	9.65	9.19	8.79	8.45	8.15	7.89	7.66	7.45	7.27	7.10	6.94	6.82	6.69
7.3	102.77	12.78	12.34	11.85	11.48	11.08	10.77	10.43	9.88	9.42	9.01	8.66	8.36	8.09	7.85	7.64	7.45	7.28	7.12	6.99	6.86
7.4	104.18	13.08	12.63	12.13	11.76	11.35	11.03	10.68	10.12	9.64	9.23	8.88	8.56	8.29	8.04	7.83	7.63	7.46	7.29	7.16	7.03
7.5	105.59	13.39	12.93	12.42	12.04	11.62	11.29	10.94	10.37	9.88	9.45	9.09	8.77	8.49	8.24	8.02	7.82	7.64	7.47	7.34	7.20
7.6	107.00	13.70	13.23	12.71	12.32	11.89	11.56	11.20	10.61	10.11	9.68	9.31	8.98	8.69	8.43	8.21	8.01	7.82	7.65	7.51	7.38
7.7	108.41	14.02	13.54	13.01	12.60	12.17	11.83	11.46	10.86	10.35	9.91	9.53	9.19	8.90	8.63	8.40	8.20	8.01	7.84	7.69	7.55
7.8	109.81	14.34	13.84	13.30	12.89	12.44	12.10	11.72	11.11	10.59	10.14	9.75	9.40	9.10	8.84	8.60	8.39	8.20	8.02	7.87	7.73
7.9	111.22	14.66	14.15	13.60	13.18	12.72	12.37	11.99	11.36	10.83	10.37	9.97	9.62	9.31	9.04	8.80	8.59	8.39	8.21	8.06	7.91
8.0	112.63	14.98	14.47	13.90	13.48	13.01	12.65	12.26	11.62	11.07	10.60	10.20	9.84	9.53	9.25	9.00	8.78	8.58	8.39	8.24	8.09

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

Appendix G:

Hydronic friction loss tables

3½" Uponor PEX-a — 100% Water — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
1.5	28.46	0.41	0.39	0.37	0.36	0.36	0.35	0.35	0.34	0.33	0.32	0.31	0.31	0.30	0.29	0.29	0.29	0.28	0.28	0.27	0.27
1.6	30.36	0.46	0.44	0.42	0.41	0.40	0.39	0.39	0.38	0.37	0.36	0.35	0.34	0.34	0.33	0.32	0.32	0.32	0.31	0.31	0.30
1.7	32.26	0.51	0.49	0.46	0.45	0.45	0.44	0.43	0.42	0.41	0.40	0.39	0.38	0.37	0.37	0.36	0.36	0.35	0.35	0.34	0.34
1.8	34.16	0.56	0.54	0.51	0.50	0.49	0.49	0.48	0.46	0.45	0.44	0.43	0.42	0.42	0.41	0.40	0.40	0.39	0.38	0.38	0.37
1.9	36.05	0.62	0.59	0.56	0.55	0.54	0.53	0.53	0.51	0.50	0.49	0.48	0.47	0.46	0.45	0.44	0.44	0.43	0.42	0.42	0.41
2.0	37.95	0.68	0.65	0.62	0.61	0.59	0.59	0.58	0.56	0.55	0.53	0.52	0.51	0.50	0.49	0.48	0.48	0.47	0.46	0.46	0.45
2.1	39.85	0.74	0.71	0.67	0.66	0.65	0.64	0.63	0.61	0.60	0.58	0.57	0.56	0.55	0.54	0.53	0.52	0.51	0.51	0.50	0.49
2.2	41.75	0.80	0.77	0.73	0.72	0.70	0.69	0.68	0.66	0.65	0.63	0.62	0.61	0.59	0.58	0.57	0.57	0.56	0.55	0.54	0.54
2.3	43.64	0.87	0.83	0.79	0.78	0.76	0.75	0.74	0.72	0.70	0.68	0.67	0.66	0.64	0.63	0.62	0.61	0.60	0.60	0.59	0.58
2.4	45.54	0.93	0.89	0.85	0.84	0.82	0.81	0.80	0.77	0.76	0.74	0.72	0.71	0.69	0.68	0.67	0.66	0.65	0.64	0.64	0.63
2.5	47.44	1.00	0.96	0.91	0.90	0.88	0.87	0.86	0.83	0.81	0.79	0.78	0.76	0.75	0.73	0.72	0.71	0.70	0.69	0.68	0.68
2.6	49.34	1.07	1.03	0.98	0.96	0.95	0.93	0.92	0.89	0.87	0.85	0.83	0.82	0.80	0.79	0.78	0.76	0.75	0.74	0.74	0.73
2.7	51.23	1.15	1.10	1.05	1.03	1.01	1.00	0.98	0.96	0.93	0.91	0.89	0.87	0.86	0.84	0.83	0.82	0.81	0.80	0.79	0.78
2.8	53.13	1.22	1.17	1.12	1.10	1.08	1.06	1.05	1.02	0.99	0.97	0.95	0.93	0.92	0.90	0.89	0.87	0.86	0.85	0.84	0.83
2.9	55.03	1.30	1.25	1.19	1.17	1.15	1.13	1.12	1.09	1.06	1.03	1.01	0.99	0.98	0.96	0.94	0.93	0.92	0.91	0.90	0.88
3.0	56.93	1.38	1.33	1.26	1.24	1.22	1.20	1.19	1.15	1.13	1.10	1.08	1.06	1.04	1.02	1.00	0.99	0.98	0.96	0.95	0.94
3.1	58.82	1.47	1.41	1.34	1.32	1.29	1.28	1.26	1.22	1.19	1.17	1.14	1.12	1.10	1.08	1.07	1.05	1.04	1.02	1.01	1.00
3.2	60.72	1.55	1.49	1.42	1.39	1.37	1.35	1.33	1.29	1.26	1.23	1.21	1.19	1.16	1.15	1.13	1.11	1.10	1.08	1.07	1.06
3.3	62.62	1.64	1.57	1.50	1.47	1.45	1.43	1.41	1.37	1.33	1.30	1.28	1.25	1.23	1.21	1.19	1.18	1.16	1.14	1.13	1.12
3.4	64.52	1.73	1.66	1.58	1.55	1.53	1.50	1.48	1.44	1.41	1.38	1.35	1.32	1.30	1.28	1.26	1.24	1.22	1.21	1.19	1.18
3.5	66.42	1.82	1.74	1.66	1.64	1.61	1.58	1.56	1.52	1.48	1.45	1.42	1.39	1.37	1.35	1.33	1.31	1.29	1.27	1.26	1.24
3.6	68.31	1.91	1.83	1.75	1.72	1.69	1.67	1.64	1.60	1.56	1.53	1.49	1.47	1.44	1.42	1.39	1.37	1.36	1.34	1.32	1.31
3.7	70.21	2.00	1.93	1.83	1.81	1.78	1.75	1.72	1.68	1.64	1.60	1.57	1.54	1.51	1.49	1.47	1.44	1.43	1.41	1.39	1.38
3.8	72.11	2.10	2.02	1.92	1.89	1.86	1.84	1.81	1.76	1.72	1.68	1.65	1.62	1.59	1.56	1.54	1.52	1.50	1.48	1.46	1.44
3.9	74.01	2.20	2.11	2.02	1.98	1.95	1.92	1.89	1.84	1.80	1.76	1.73	1.69	1.66	1.64	1.61	1.59	1.57	1.55	1.53	1.51
4.0	75.90	2.30	2.21	2.11	2.08	2.04	2.01	1.98	1.93	1.88	1.84	1.81	1.77	1.74	1.71	1.69	1.66	1.64	1.62	1.60	1.58
4.1	77.80	2.40	2.31	2.20	2.17	2.13	2.10	2.07	2.02	1.97	1.93	1.89	1.85	1.82	1.79	1.76	1.74	1.72	1.69	1.68	1.66
4.2	79.70	2.51	2.41	2.30	2.26	2.23	2.20	2.16	2.11	2.06	2.01	1.97	1.93	1.90	1.87	1.84	1.82	1.79	1.77	1.75	1.73
4.3	81.60	2.62	2.52	2.40	2.36	2.32	2.29	2.26	2.20	2.15	2.10	2.06	2.02	1.98	1.95	1.92	1.90	1.87	1.85	1.83	1.81
4.4	83.49	2.73	2.62	2.50	2.46	2.42	2.39	2.35	2.29	2.24	2.19	2.14	2.10	2.07	2.04	2.00	1.98	1.95	1.93	1.90	1.88
4.5	85.39	2.84	2.73	2.60	2.56	2.52	2.48	2.45	2.38	2.33	2.28	2.23	2.19	2.15	2.12	2.09	2.06	2.03	2.01	1.98	1.96
4.6	87.29	2.95	2.84	2.71	2.66	2.62	2.58	2.55	2.48	2.42	2.37	2.32	2.28	2.24	2.21	2.17	2.14	2.11	2.09	2.06	2.04
4.7	89.19	3.07	2.95	2.81	2.77	2.72	2.69	2.65	2.58	2.52	2.46	2.41	2.37	2.33	2.29	2.26	2.23	2.20	2.17	2.15	2.12

Continued on next page

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

Appendix G:

Hydronic friction loss tables

3½" Uponor PEX-a — 100% Water — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40ºF 4ºC	45ºF 7ºC	50ºF 10ºC	55ºF 13ºC	60ºF 16ºC	65ºF 18ºC	70ºF 21ºC	80ºF 27ºC	90ºF 32ºC	100ºF 38ºC	110ºF 43ºC	120ºF 49ºC	130ºF 54ºC	140ºF 60ºC	150ºF 66ºC	160ºF 71ºC	170ºF 77ºC	180ºF 82ºC	190ºF 88ºC	200ºF 93ºC
4.8	91.08	3.18	3.06	2.92	2.88	2.83	2.79	2.75	2.68	2.62	2.56	2.51	2.46	2.42	2.38	2.35	2.31	2.28	2.26	2.23	2.21
4.9	92.98	3.30	3.17	3.03	2.98	2.93	2.89	2.85	2.78	2.71	2.66	2.60	2.56	2.51	2.47	2.44	2.40	2.37	2.34	2.31	2.29
5.0	94.88	3.42	3.29	3.14	3.09	3.04	3.00	2.96	2.88	2.81	2.75	2.70	2.65	2.61	2.56	2.53	2.49	2.46	2.43	2.40	2.38
5.1	96.78	3.55	3.41	3.25	3.21	3.15	3.11	3.06	2.99	2.92	2.85	2.80	2.75	2.70	2.66	2.62	2.58	2.55	2.52	2.49	2.46
5.2	98.67	3.67	3.53	3.37	3.32	3.26	3.22	3.17	3.09	3.02	2.96	2.90	2.84	2.80	2.75	2.71	2.68	2.64	2.61	2.58	2.55
5.3	100.57	3.80	3.65	3.49	3.43	3.38	3.33	3.28	3.20	3.13	3.06	3.00	2.94	2.89	2.85	2.81	2.77	2.73	2.70	2.67	2.64
5.4	102.47	3.93	3.78	3.61	3.55	3.49	3.45	3.40	3.31	3.23	3.16	3.10	3.05	2.99	2.95	2.90	2.86	2.83	2.79	2.76	2.73
5.5	104.37	4.06	3.90	3.73	3.67	3.61	3.56	3.51	3.42	3.34	3.27	3.21	3.15	3.10	3.05	3.00	2.96	2.92	2.89	2.86	2.83
5.6	106.26	4.19	4.03	3.85	3.79	3.73	3.68	3.63	3.53	3.45	3.38	3.31	3.25	3.20	3.15	3.10	3.06	3.02	2.98	2.95	2.92
5.7	108.16	4.32	4.16	3.97	3.91	3.85	3.80	3.74	3.65	3.56	3.49	3.42	3.36	3.30	3.25	3.20	3.16	3.12	3.08	3.05	3.02
5.8	110.06	4.46	4.29	4.10	4.04	3.97	3.92	3.86	3.76	3.68	3.60	3.53	3.47	3.41	3.36	3.31	3.26	3.22	3.18	3.15	3.11
5.9	111.96	4.60	4.42	4.23	4.16	4.10	4.04	3.98	3.88	3.79	3.71	3.64	3.57	3.52	3.46	3.41	3.36	3.32	3.28	3.24	3.21
6.0	113.85	4.74	4.56	4.35	4.29	4.22	4.16	4.10	4.00	3.91	3.83	3.75	3.69	3.62	3.57	3.52	3.47	3.42	3.38	3.35	3.31
6.1	115.75	4.88	4.70	4.49	4.42	4.35	4.29	4.23	4.12	4.03	3.94	3.87	3.80	3.73	3.68	3.62	3.57	3.53	3.49	3.45	3.41
6.2	117.65	5.02	4.83	4.62	4.55	4.48	4.42	4.35	4.24	4.15	4.06	3.98	3.91	3.85	3.79	3.73	3.68	3.63	3.59	3.55	3.51
6.3	119.55	5.17	4.97	4.75	4.68	4.61	4.55	4.48	4.37	4.27	4.18	4.10	4.03	3.96	3.90	3.84	3.79	3.74	3.70	3.66	3.62
6.4	121.45	5.32	5.12	4.89	4.82	4.74	4.68	4.61	4.49	4.39	4.30	4.22	4.14	4.07	4.01	3.95	3.90	3.85	3.81	3.76	3.72
6.5	123.34	5.46	5.26	5.03	4.95	4.87	4.81	4.74	4.62	4.52	4.42	4.34	4.26	4.19	4.13	4.07	4.01	3.96	3.91	3.87	3.83
6.6	125.24	5.62	5.41	5.17	5.09	5.01	4.94	4.87	4.75	4.64	4.55	4.46	4.38	4.31	4.24	4.18	4.12	4.07	4.02	3.98	3.94
6.7	127.14	5.77	5.55	5.31	5.23	5.15	5.08	5.01	4.88	4.77	4.67	4.58	4.50	4.43	4.36	4.30	4.24	4.19	4.14	4.09	4.05
6.8	129.04	5.92	5.70	5.45	5.37	5.29	5.22	5.14	5.01	4.90	4.80	4.71	4.62	4.55	4.48	4.41	4.35	4.30	4.25	4.20	4.16
6.9	130.93	6.08	5.85	5.60	5.51	5.43	5.35	5.28	5.15	5.03	4.93	4.83	4.75	4.67	4.60	4.53	4.47	4.42	4.36	4.32	4.27
7.0	132.83	6.24	6.01	5.74	5.66	5.57	5.49	5.42	5.28	5.16	5.06	4.96	4.87	4.79	4.72	4.65	4.59	4.53	4.48	4.43	4.38
7.1	134.73	6.40	6.16	5.89	5.80	5.71	5.64	5.56	5.42	5.30	5.19	5.09	5.00	4.92	4.84	4.77	4.71	4.65	4.60	4.55	4.50
7.2	136.63	6.56	6.32	6.04	5.95	5.86	5.78	5.70	5.56	5.43	5.32	5.22	5.13	5.04	4.97	4.90	4.83	4.77	4.72	4.66	4.62
7.3	138.52	6.72	6.48	6.19	6.10	6.01	5.93	5.84	5.70	5.57	5.46	5.35	5.26	5.17	5.09	5.02	4.96	4.89	4.84	4.78	4.73
7.4	140.42	6.89	6.64	6.35	6.25	6.15	6.07	5.99	5.84	5.71	5.59	5.49	5.39	5.30	5.22	5.15	5.08	5.02	4.96	4.90	4.85
7.5	142.32	7.06	6.80	6.50	6.40	6.30	6.22	6.13	5.98	5.85	5.73	5.62	5.52	5.43	5.35	5.27	5.21	5.14	5.08	5.02	4.97
7.6	144.22	7.23	6.96	6.66	6.56	6.46	6.37	6.28	6.13	5.99	5.87	5.76	5.66	5.56	5.48	5.40	5.33	5.27	5.20	5.15	5.09
7.7	146.11	7.40	7.13	6.82	6.72	6.61	6.52	6.43	6.28	6.13	6.01	5.90	5.79	5.70	5.61	5.53	5.46	5.39	5.33	5.27	5.22
7.8	148.01	7.57	7.29	6.98	6.87	6.77	6.68	6.58	6.42	6.28	6.15	6.04	5.93	5.83	5.75	5.66	5.59	5.52	5.46	5.40	5.34
7.9	149.91	7.75	7.46	7.14	7.03	6.92	6.83	6.74	6.57	6.43	6.29	6.18	6.07	5.97	5.88	5.80	5.72	5.65	5.59	5.52	5.47
8.0	151.81	7.92	7.63	7.30	7.19	7.08	6.99	6.89	6.72	6.57	6.44	6.32	6.21	6.11	6.02	5.93	5.85	5.78	5.71	5.65	5.60

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

3½" Uponor PEX-a — 30% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
1.5	28.46	0.54	0.52	0.50	0.49	0.48	0.46	0.45	0.43	0.41	0.39	0.38	0.37	0.36	0.35	0.34	0.33	0.32	0.32	0.31	0.31
1.6	30.36	0.60	0.58	0.56	0.55	0.53	0.52	0.50	0.48	0.46	0.44	0.43	0.41	0.40	0.39	0.38	0.37	0.36	0.36	0.35	0.35
1.7	32.26	0.67	0.65	0.63	0.61	0.59	0.58	0.56	0.53	0.51	0.49	0.47	0.46	0.45	0.43	0.42	0.41	0.41	0.40	0.39	0.39
1.8	34.16	0.74	0.72	0.69	0.67	0.65	0.64	0.62	0.59	0.57	0.54	0.52	0.51	0.49	0.48	0.47	0.46	0.45	0.44	0.43	0.43
1.9	36.05	0.81	0.79	0.76	0.74	0.72	0.70	0.68	0.65	0.62	0.60	0.58	0.56	0.54	0.53	0.52	0.51	0.49	0.49	0.48	0.47
2.0	37.95	0.89	0.86	0.83	0.81	0.78	0.76	0.74	0.71	0.68	0.65	0.63	0.61	0.60	0.58	0.57	0.55	0.54	0.53	0.52	0.52
2.1	39.85	0.96	0.93	0.90	0.88	0.85	0.83	0.81	0.77	0.74	0.71	0.69	0.67	0.65	0.63	0.62	0.60	0.59	0.58	0.57	0.56
2.2	41.75	1.04	1.01	0.98	0.95	0.93	0.90	0.88	0.84	0.80	0.77	0.75	0.73	0.70	0.69	0.67	0.66	0.64	0.63	0.62	0.61
2.3	43.64	1.13	1.09	1.06	1.03	1.00	0.98	0.95	0.91	0.87	0.84	0.81	0.78	0.76	0.74	0.73	0.71	0.70	0.68	0.67	0.66
2.4	45.54	1.21	1.18	1.14	1.11	1.08	1.05	1.02	0.98	0.94	0.90	0.87	0.85	0.82	0.80	0.78	0.77	0.75	0.74	0.72	0.71
2.5	47.44	1.30	1.26	1.22	1.19	1.16	1.13	1.10	1.05	1.01	0.97	0.94	0.91	0.88	0.86	0.84	0.82	0.81	0.79	0.78	0.77
2.6	49.34	1.39	1.35	1.31	1.28	1.24	1.21	1.18	1.12	1.08	1.04	1.00	0.97	0.95	0.92	0.90	0.88	0.87	0.85	0.84	0.82
2.7	51.23	1.49	1.45	1.40	1.36	1.32	1.29	1.26	1.20	1.15	1.11	1.07	1.04	1.01	0.99	0.97	0.95	0.93	0.91	0.89	0.88
2.8	53.13	1.59	1.54	1.49	1.45	1.41	1.38	1.34	1.28	1.23	1.19	1.15	1.11	1.08	1.05	1.03	1.01	0.99	0.97	0.95	0.94
2.9	55.03	1.69	1.64	1.59	1.54	1.50	1.46	1.43	1.36	1.31	1.26	1.22	1.18	1.15	1.12	1.10	1.07	1.05	1.03	1.02	1.00
3.0	56.93	1.79	1.74	1.68	1.64	1.59	1.55	1.51	1.45	1.39	1.34	1.30	1.26	1.22	1.19	1.17	1.14	1.12	1.10	1.08	1.07
3.1	58.82	1.89	1.84	1.78	1.74	1.69	1.65	1.60	1.53	1.47	1.42	1.37	1.33	1.30	1.26	1.24	1.21	1.19	1.17	1.15	1.13
3.2	60.72	2.00	1.94	1.88	1.83	1.78	1.74	1.70	1.62	1.56	1.50	1.45	1.41	1.37	1.34	1.31	1.28	1.26	1.23	1.21	1.20
3.3	62.62	2.11	2.05	1.99	1.94	1.88	1.84	1.79	1.71	1.64	1.59	1.53	1.49	1.45	1.41	1.38	1.35	1.33	1.30	1.28	1.26
3.4	64.52	2.22	2.16	2.09	2.04	1.98	1.94	1.89	1.81	1.73	1.67	1.62	1.57	1.53	1.49	1.46	1.43	1.40	1.38	1.35	1.33
3.5	66.42	2.34	2.27	2.20	2.15	2.09	2.04	1.99	1.90	1.83	1.76	1.70	1.65	1.61	1.57	1.54	1.50	1.47	1.45	1.42	1.41
3.6	68.31	2.46	2.39	2.31	2.26	2.19	2.14	2.09	2.00	1.92	1.85	1.79	1.74	1.69	1.65	1.62	1.58	1.55	1.52	1.50	1.48
3.7	70.21	2.58	2.51	2.43	2.37	2.30	2.25	2.19	2.10	2.01	1.94	1.88	1.83	1.78	1.73	1.70	1.66	1.63	1.60	1.57	1.55
3.8	72.11	2.70	2.62	2.54	2.48	2.41	2.36	2.30	2.20	2.11	2.04	1.97	1.92	1.86	1.82	1.78	1.74	1.71	1.68	1.65	1.63
3.9	74.01	2.83	2.75	2.66	2.60	2.52	2.47	2.40	2.30	2.21	2.13	2.07	2.01	1.95	1.90	1.86	1.83	1.79	1.76	1.73	1.71
4.0	75.90	2.95	2.87	2.78	2.71	2.64	2.58	2.51	2.41	2.31	2.23	2.16	2.10	2.04	1.99	1.95	1.91	1.87	1.84	1.81	1.79
4.1	77.80	3.08	3.00	2.91	2.83	2.76	2.69	2.63	2.51	2.42	2.33	2.26	2.19	2.14	2.08	2.04	2.00	1.96	1.93	1.89	1.87
4.2	79.70	3.22	3.13	3.03	2.96	2.88	2.81	2.74	2.62	2.52	2.43	2.36	2.29	2.23	2.17	2.13	2.09	2.04	2.01	1.98	1.95
4.3	81.60	3.35	3.26	3.16	3.08	3.00	2.93	2.86	2.74	2.63	2.54	2.46	2.39	2.33	2.27	2.22	2.18	2.13	2.10	2.06	2.04
4.4	83.49	3.49	3.39	3.29	3.21	3.12	3.05	2.97	2.85	2.74	2.64	2.56	2.49	2.42	2.36	2.31	2.27	2.22	2.19	2.15	2.12
4.5	85.39	3.63	3.53	3.42	3.34	3.25	3.17	3.09	2.96	2.85	2.75	2.67	2.59	2.52	2.46	2.41	2.36	2.31	2.28	2.24	2.21
4.6	87.29	3.77	3.67	3.56	3.47	3.38	3.30	3.22	3.08	2.97	2.86	2.77	2.69	2.62	2.56	2.51	2.46	2.41	2.37	2.33	2.30
4.7	89.19	3.92	3.81	3.69	3.60	3.51	3.43	3.34	3.20	3.08	2.97	2.88	2.80	2.73	2.66	2.61	2.55	2.50	2.46	2.42	2.39

Continued on next page

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

3½" Uponor PEX-a — 30% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
4.8	91.08	4.06	3.95	3.83	3.74	3.64	3.56	3.47	3.32	3.20	3.09	2.99	2.91	2.83	2.76	2.71	2.65	2.60	2.56	2.51	2.48
4.9	92.98	4.21	4.10	3.98	3.88	3.77	3.69	3.60	3.45	3.32	3.20	3.10	3.02	2.94	2.87	2.81	2.75	2.70	2.65	2.61	2.58
5.0	94.88	4.37	4.25	4.12	4.02	3.91	3.82	3.73	3.57	3.44	3.32	3.22	3.13	3.05	2.97	2.91	2.85	2.80	2.75	2.71	2.67
5.1	96.78	4.52	4.40	4.27	4.16	4.05	3.96	3.86	3.70	3.56	3.44	3.33	3.24	3.16	3.08	3.02	2.96	2.90	2.85	2.80	2.77
5.2	98.67	4.68	4.55	4.41	4.31	4.19	4.10	4.00	3.83	3.69	3.56	3.45	3.35	3.27	3.19	3.12	3.06	3.00	2.95	2.91	2.87
5.3	100.57	4.84	4.71	4.57	4.45	4.34	4.24	4.14	3.96	3.82	3.69	3.57	3.47	3.38	3.30	3.23	3.17	3.11	3.06	3.01	2.97
5.4	102.47	5.00	4.86	4.72	4.60	4.48	4.38	4.27	4.10	3.94	3.81	3.69	3.59	3.50	3.41	3.34	3.28	3.21	3.16	3.11	3.07
5.5	104.37	5.16	5.02	4.87	4.76	4.63	4.53	4.42	4.23	4.08	3.94	3.81	3.71	3.61	3.53	3.46	3.39	3.32	3.27	3.21	3.17
5.6	106.26	5.33	5.18	5.03	4.91	4.78	4.67	4.56	4.37	4.21	4.07	3.94	3.83	3.73	3.64	3.57	3.50	3.43	3.38	3.32	3.28
5.7	108.16	5.49	5.35	5.19	5.07	4.93	4.82	4.70	4.51	4.34	4.20	4.07	3.95	3.85	3.76	3.69	3.61	3.54	3.49	3.43	3.39
5.8	110.06	5.67	5.51	5.35	5.22	5.09	4.97	4.85	4.65	4.48	4.33	4.19	4.08	3.98	3.88	3.80	3.73	3.66	3.60	3.54	3.49
5.9	111.96	5.84	5.68	5.52	5.38	5.24	5.13	5.00	4.80	4.62	4.46	4.33	4.21	4.10	4.00	3.92	3.84	3.77	3.71	3.65	3.60
6.0	113.85	6.01	5.85	5.68	5.55	5.40	5.28	5.15	4.94	4.76	4.60	4.46	4.34	4.22	4.12	4.04	3.96	3.89	3.82	3.76	3.72
6.1	115.75	6.19	6.03	5.85	5.71	5.56	5.44	5.31	5.09	4.90	4.74	4.59	4.47	4.35	4.25	4.16	4.08	4.00	3.94	3.88	3.83
6.2	117.65	6.37	6.20	6.02	5.88	5.72	5.60	5.46	5.24	5.05	4.88	4.73	4.60	4.48	4.37	4.29	4.20	4.12	4.06	3.99	3.94
6.3	119.55	6.55	6.38	6.19	6.05	5.89	5.76	5.62	5.39	5.19	5.02	4.86	4.73	4.61	4.50	4.41	4.33	4.24	4.18	4.11	4.06
6.4	121.45	6.74	6.56	6.37	6.22	6.05	5.92	5.78	5.55	5.34	5.16	5.00	4.87	4.74	4.63	4.54	4.45	4.37	4.30	4.23	4.18
6.5	123.34	6.92	6.74	6.54	6.39	6.22	6.09	5.94	5.70	5.49	5.31	5.14	5.00	4.88	4.76	4.67	4.58	4.49	4.42	4.35	4.30
6.6	125.24	7.11	6.93	6.72	6.56	6.39	6.25	6.10	5.86	5.64	5.45	5.29	5.14	5.01	4.90	4.80	4.70	4.62	4.54	4.47	4.42
6.7	127.14	7.30	7.11	6.90	6.74	6.57	6.42	6.27	6.02	5.80	5.60	5.43	5.28	5.15	5.03	4.93	4.83	4.74	4.67	4.59	4.54
6.8	129.04	7.50	7.30	7.09	6.92	6.74	6.59	6.44	6.18	5.95	5.75	5.58	5.43	5.29	5.17	5.06	4.96	4.87	4.79	4.72	4.66
6.9	130.93	7.69	7.49	7.27	7.10	6.92	6.77	6.61	6.34	6.11	5.91	5.73	5.57	5.43	5.30	5.20	5.10	5.00	4.92	4.84	4.79
7.0	132.83	7.89	7.68	7.46	7.29	7.10	6.94	6.78	6.51	6.27	6.06	5.88	5.72	5.57	5.44	5.34	5.23	5.13	5.05	4.97	4.91
7.1	134.73	8.09	7.88	7.65	7.47	7.28	7.12	6.95	6.67	6.43	6.22	6.03	5.86	5.72	5.58	5.47	5.37	5.27	5.18	5.10	5.04
7.2	136.63	8.29	8.08	7.84	7.66	7.46	7.30	7.13	6.84	6.59	6.37	6.18	6.01	5.86	5.73	5.61	5.50	5.40	5.32	5.23	5.17
7.3	138.52	8.50	8.28	8.04	7.85	7.65	7.48	7.30	7.01	6.76	6.53	6.34	6.17	6.01	5.87	5.76	5.64	5.54	5.45	5.37	5.30
7.4	140.42	8.70	8.48	8.23	8.04	7.83	7.66	7.48	7.18	6.92	6.69	6.49	6.32	6.16	6.02	5.90	5.78	5.68	5.59	5.50	5.43
7.5	142.32	8.91	8.68	8.43	8.23	8.02	7.85	7.66	7.36	7.09	6.86	6.65	6.47	6.31	6.16	6.04	5.93	5.82	5.73	5.63	5.57
7.6	144.22	9.12	8.89	8.63	8.43	8.21	8.04	7.85	7.53	7.26	7.02	6.81	6.63	6.46	6.31	6.19	6.07	5.96	5.86	5.77	5.70
7.7	146.11	9.33	9.09	8.83	8.63	8.41	8.23	8.03	7.71	7.43	7.19	6.97	6.79	6.62	6.46	6.34	6.21	6.10	6.00	5.91	5.84
7.8	148.01	9.55	9.30	9.04	8.83	8.60	8.42	8.22	7.89	7.61	7.36	7.14	6.95	6.77	6.61	6.49	6.36	6.24	6.15	6.05	5.98
7.9	149.91	9.77	9.52	9.24	9.03	8.80	8.61	8.41	8.07	7.78	7.53	7.30	7.11	6.93	6.77	6.64	6.51	6.39	6.29	6.19	6.12
8.0	151.81	9.99	9.73	9.45	9.23	9.00	8.80	8.60	8.26	7.96	7.70	7.47	7.27	7.09	6.92	6.79	6.66	6.54	6.44	6.33	6.26

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

3½" Uponor PEX-a — 40% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
1.5	28.46	0.62	0.60	0.57	0.55	0.53	0.52	0.50	0.47	0.45	0.43	0.41	0.39	0.38	0.37	0.36	0.35	0.34	0.34	0.33	0.32
1.6	30.36	0.70	0.67	0.64	0.62	0.60	0.58	0.56	0.53	0.50	0.48	0.46	0.44	0.43	0.41	0.40	0.39	0.38	0.38	0.37	0.36
1.7	32.26	0.77	0.74	0.71	0.69	0.66	0.64	0.62	0.59	0.56	0.53	0.51	0.49	0.48	0.46	0.45	0.44	0.43	0.42	0.41	0.40
1.8	34.16	0.85	0.82	0.78	0.76	0.73	0.71	0.69	0.65	0.62	0.59	0.56	0.54	0.53	0.51	0.50	0.48	0.47	0.46	0.45	0.45
1.9	36.05	0.93	0.90	0.86	0.83	0.80	0.78	0.75	0.71	0.68	0.65	0.62	0.60	0.58	0.56	0.55	0.53	0.52	0.51	0.50	0.49
2.0	37.95	1.02	0.98	0.94	0.91	0.88	0.85	0.82	0.78	0.74	0.71	0.68	0.65	0.63	0.61	0.60	0.58	0.57	0.56	0.55	0.54
2.1	39.85	1.11	1.07	1.02	0.99	0.95	0.93	0.90	0.85	0.81	0.77	0.74	0.71	0.69	0.67	0.65	0.64	0.62	0.61	0.60	0.59
2.2	41.75	1.20	1.16	1.11	1.07	1.03	1.00	0.97	0.92	0.87	0.84	0.80	0.77	0.75	0.73	0.71	0.69	0.67	0.66	0.65	0.64
2.3	43.64	1.30	1.25	1.20	1.16	1.12	1.08	1.05	0.99	0.94	0.90	0.87	0.84	0.81	0.79	0.77	0.75	0.73	0.72	0.70	0.69
2.4	45.54	1.39	1.34	1.29	1.25	1.20	1.17	1.13	1.07	1.02	0.97	0.94	0.90	0.87	0.85	0.83	0.81	0.79	0.77	0.76	0.75
2.5	47.44	1.50	1.44	1.38	1.34	1.29	1.25	1.21	1.15	1.09	1.05	1.01	0.97	0.94	0.91	0.89	0.87	0.85	0.83	0.81	0.80
2.6	49.34	1.60	1.54	1.48	1.43	1.38	1.34	1.30	1.23	1.17	1.12	1.08	1.04	1.01	0.98	0.95	0.93	0.91	0.89	0.87	0.86
2.7	51.23	1.71	1.65	1.58	1.53	1.47	1.43	1.39	1.31	1.25	1.20	1.15	1.11	1.08	1.04	1.02	0.99	0.97	0.95	0.93	0.92
2.8	53.13	1.82	1.75	1.68	1.63	1.57	1.53	1.48	1.40	1.33	1.28	1.23	1.19	1.15	1.11	1.09	1.06	1.04	1.02	1.00	0.98
2.9	55.03	1.93	1.86	1.79	1.73	1.67	1.62	1.57	1.49	1.42	1.36	1.31	1.26	1.22	1.19	1.16	1.13	1.10	1.08	1.06	1.05
3.0	56.93	2.05	1.97	1.89	1.84	1.77	1.72	1.67	1.58	1.51	1.44	1.39	1.34	1.30	1.26	1.23	1.20	1.17	1.15	1.13	1.11
3.1	58.82	2.17	2.09	2.01	1.94	1.87	1.82	1.77	1.67	1.60	1.53	1.47	1.42	1.38	1.34	1.30	1.27	1.24	1.22	1.20	1.18
3.2	60.72	2.29	2.21	2.12	2.05	1.98	1.93	1.87	1.77	1.69	1.62	1.56	1.50	1.46	1.41	1.38	1.35	1.32	1.29	1.27	1.25
3.3	62.62	2.41	2.33	2.24	2.17	2.09	2.03	1.97	1.87	1.78	1.71	1.64	1.59	1.54	1.49	1.46	1.42	1.39	1.37	1.34	1.32
3.4	64.52	2.54	2.45	2.35	2.28	2.20	2.14	2.08	1.97	1.88	1.80	1.73	1.67	1.62	1.57	1.53	1.50	1.47	1.44	1.41	1.39
3.5	66.42	2.67	2.58	2.48	2.40	2.32	2.25	2.18	2.07	1.98	1.89	1.82	1.76	1.71	1.66	1.62	1.58	1.54	1.52	1.49	1.46
3.6	68.31	2.80	2.71	2.60	2.52	2.43	2.37	2.29	2.18	2.08	1.99	1.92	1.85	1.79	1.74	1.70	1.66	1.62	1.60	1.56	1.54
3.7	70.21	2.94	2.84	2.73	2.64	2.55	2.48	2.41	2.28	2.18	2.09	2.01	1.94	1.88	1.83	1.78	1.75	1.71	1.68	1.64	1.62
3.8	72.11	3.08	2.97	2.86	2.77	2.67	2.60	2.52	2.39	2.28	2.19	2.11	2.04	1.98	1.92	1.87	1.83	1.79	1.76	1.72	1.70
3.9	74.01	3.22	3.11	2.99	2.90	2.80	2.72	2.64	2.51	2.39	2.29	2.21	2.13	2.07	2.01	1.96	1.92	1.87	1.84	1.81	1.78
4.0	75.90	3.37	3.25	3.12	3.03	2.93	2.85	2.76	2.62	2.50	2.40	2.31	2.23	2.16	2.10	2.05	2.01	1.96	1.93	1.89	1.86
4.1	77.80	3.51	3.39	3.26	3.16	3.05	2.97	2.88	2.74	2.61	2.51	2.41	2.33	2.26	2.20	2.14	2.10	2.05	2.01	1.97	1.95
4.2	79.70	3.66	3.54	3.40	3.30	3.19	3.10	3.01	2.86	2.73	2.62	2.52	2.43	2.36	2.29	2.24	2.19	2.14	2.10	2.06	2.03
4.3	81.60	3.81	3.69	3.54	3.44	3.32	3.23	3.13	2.98	2.84	2.73	2.63	2.54	2.46	2.39	2.33	2.28	2.23	2.19	2.15	2.12
4.4	83.49	3.97	3.84	3.69	3.58	3.46	3.36	3.26	3.10	2.96	2.84	2.74	2.64	2.57	2.49	2.43	2.38	2.33	2.29	2.24	2.21
4.5	85.39	4.13	3.99	3.84	3.72	3.60	3.50	3.39	3.22	3.08	2.96	2.85	2.75	2.67	2.60	2.53	2.48	2.42	2.38	2.33	2.30
4.6	87.29	4.29	4.14	3.99	3.87	3.74	3.64	3.53	3.35	3.20	3.07	2.96	2.86	2.78	2.70	2.63	2.58	2.52	2.48	2.43	2.39

Continued on next page

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

3½" Uponor PEX-a — 40% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
4.7	89.19	4.45	4.30	4.14	4.01	3.88	3.78	3.66	3.48	3.33	3.19	3.08	2.97	2.89	2.81	2.74	2.68	2.62	2.57	2.52	2.49
4.8	91.08	4.62	4.46	4.29	4.17	4.03	3.92	3.80	3.61	3.45	3.31	3.20	3.09	3.00	2.91	2.84	2.78	2.72	2.67	2.62	2.58
4.9	92.98	4.79	4.63	4.45	4.32	4.18	4.06	3.94	3.75	3.58	3.44	3.31	3.20	3.11	3.02	2.95	2.89	2.82	2.77	2.72	2.68
5.0	94.88	4.96	4.79	4.61	4.47	4.33	4.21	4.09	3.88	3.71	3.56	3.44	3.32	3.22	3.13	3.06	2.99	2.93	2.88	2.82	2.78
5.1	96.78	5.13	4.96	4.77	4.63	4.48	4.36	4.23	4.02	3.84	3.69	3.56	3.44	3.34	3.25	3.17	3.10	3.03	2.98	2.92	2.88
5.2	98.67	5.31	5.13	4.94	4.79	4.63	4.51	4.38	4.16	3.98	3.82	3.68	3.56	3.46	3.36	3.28	3.21	3.14	3.09	3.03	2.98
5.3	100.57	5.49	5.31	5.11	4.96	4.79	4.67	4.53	4.31	4.11	3.95	3.81	3.69	3.58	3.48	3.40	3.32	3.25	3.20	3.13	3.09
5.4	102.47	5.67	5.48	5.28	5.12	4.95	4.82	4.68	4.45	4.25	4.09	3.94	3.81	3.70	3.60	3.51	3.44	3.36	3.30	3.24	3.19
5.5	104.37	5.85	5.66	5.45	5.29	5.11	4.98	4.83	4.60	4.39	4.22	4.07	3.94	3.82	3.72	3.63	3.55	3.47	3.42	3.35	3.30
5.6	106.26	6.04	5.84	5.62	5.46	5.28	5.14	4.99	4.75	4.54	4.36	4.20	4.07	3.95	3.84	3.75	3.67	3.59	3.53	3.46	3.41
5.7	108.16	6.23	6.02	5.80	5.63	5.45	5.30	5.15	4.90	4.68	4.50	4.34	4.20	4.07	3.96	3.87	3.79	3.70	3.64	3.57	3.52
5.8	110.06	6.42	6.21	5.98	5.80	5.61	5.47	5.31	5.05	4.83	4.64	4.48	4.33	4.20	4.09	3.99	3.91	3.82	3.76	3.69	3.63
5.9	111.96	6.62	6.40	6.16	5.98	5.79	5.64	5.47	5.21	4.98	4.78	4.61	4.46	4.33	4.22	4.12	4.03	3.94	3.88	3.80	3.75
6.0	113.85	6.81	6.59	6.34	6.16	5.96	5.80	5.64	5.36	5.13	4.93	4.75	4.60	4.47	4.34	4.24	4.15	4.06	4.00	3.92	3.86
6.1	115.75	7.01	6.78	6.53	6.34	6.14	5.98	5.80	5.52	5.28	5.08	4.90	4.74	4.60	4.48	4.37	4.28	4.19	4.12	4.04	3.98
6.2	117.65	7.21	6.98	6.72	6.53	6.31	6.15	5.97	5.68	5.44	5.23	5.04	4.88	4.74	4.61	4.50	4.40	4.31	4.24	4.16	4.10
6.3	119.55	7.42	7.18	6.91	6.71	6.49	6.33	6.14	5.85	5.59	5.38	5.19	5.02	4.87	4.74	4.63	4.53	4.44	4.36	4.28	4.22
6.4	121.45	7.63	7.38	7.11	6.90	6.68	6.50	6.32	6.01	5.75	5.53	5.34	5.16	5.01	4.88	4.76	4.66	4.56	4.49	4.40	4.34
6.5	123.34	7.83	7.58	7.30	7.09	6.86	6.69	6.49	6.18	5.91	5.68	5.48	5.31	5.15	5.02	4.90	4.80	4.69	4.62	4.53	4.46
6.6	125.24	8.05	7.79	7.50	7.28	7.05	6.87	6.67	6.35	6.07	5.84	5.64	5.45	5.30	5.15	5.03	4.93	4.82	4.74	4.65	4.59
6.7	127.14	8.26	7.99	7.70	7.48	7.24	7.05	6.85	6.52	6.24	6.00	5.79	5.60	5.44	5.30	5.17	5.06	4.96	4.87	4.78	4.72
6.8	129.04	8.48	8.20	7.90	7.68	7.43	7.24	7.03	6.70	6.41	6.16	5.95	5.75	5.59	5.44	5.31	5.20	5.09	5.01	4.91	4.84
6.9	130.93	8.70	8.42	8.11	7.88	7.62	7.43	7.22	6.87	6.57	6.32	6.10	5.91	5.74	5.58	5.45	5.34	5.23	5.14	5.04	4.97
7.0	132.83	8.92	8.63	8.32	8.08	7.82	7.62	7.40	7.05	6.75	6.49	6.26	6.06	5.89	5.73	5.60	5.48	5.36	5.28	5.18	5.10
7.1	134.73	9.14	8.85	8.53	8.28	8.02	7.81	7.59	7.23	6.92	6.65	6.42	6.22	6.04	5.88	5.74	5.62	5.50	5.41	5.31	5.24
7.2	136.63	9.37	9.07	8.74	8.49	8.22	8.01	7.78	7.41	7.09	6.82	6.58	6.37	6.19	6.03	5.89	5.77	5.64	5.55	5.45	5.37
7.3	138.52	9.60	9.29	8.95	8.70	8.42	8.21	7.97	7.59	7.27	6.99	6.75	6.53	6.35	6.18	6.03	5.91	5.78	5.69	5.58	5.51
7.4	140.42	9.83	9.52	9.17	8.91	8.63	8.41	8.17	7.78	7.45	7.16	6.92	6.69	6.50	6.33	6.18	6.06	5.93	5.83	5.72	5.64
7.5	142.32	10.06	9.74	9.39	9.12	8.83	8.61	8.37	7.97	7.63	7.34	7.08	6.86	6.66	6.49	6.34	6.21	6.07	5.98	5.86	5.78
7.6	144.22	10.30	9.97	9.61	9.34	9.04	8.81	8.56	8.16	7.81	7.51	7.25	7.02	6.82	6.64	6.49	6.36	6.22	6.12	6.01	5.92
7.7	146.11	10.54	10.20	9.83	9.56	9.25	9.02	8.76	8.35	7.99	7.69	7.43	7.19	6.98	6.80	6.64	6.51	6.37	6.27	6.15	6.06
7.8	148.01	10.78	10.44	10.06	9.78	9.47	9.23	8.97	8.54	8.18	7.87	7.60	7.36	7.15	6.96	6.80	6.66	6.52	6.41	6.30	6.21
7.9	149.91	11.02	10.67	10.29	10.00	9.68	9.44	9.17	8.74	8.37	8.05	7.77	7.53	7.31	7.12	6.96	6.81	6.67	6.56	6.44	6.35
8.0	151.81	11.27	10.91	10.52	10.22	9.90	9.65	9.38	8.94	8.56	8.23	7.95	7.70	7.48	7.28	7.12	6.97	6.82	6.71	6.59	6.50

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

3½" Uponor PEX-a — 50% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
1.5	28.46	0.70	0.67	0.64	0.62	0.59	0.57	0.55	0.52	0.49	0.47	0.44	0.43	0.41	0.40	0.38	0.37	0.36	0.35	0.35	0.34
1.6	30.36	0.78	0.75	0.72	0.69	0.66	0.64	0.62	0.58	0.55	0.52	0.50	0.48	0.46	0.44	0.43	0.42	0.41	0.40	0.39	0.38
1.7	32.26	0.87	0.83	0.79	0.77	0.73	0.71	0.68	0.64	0.61	0.58	0.55	0.53	0.51	0.49	0.48	0.46	0.45	0.44	0.43	0.42
1.8	34.16	0.96	0.92	0.88	0.84	0.81	0.78	0.76	0.71	0.67	0.64	0.61	0.59	0.56	0.55	0.53	0.51	0.50	0.49	0.48	0.47
1.9	36.05	1.05	1.01	0.96	0.93	0.89	0.86	0.83	0.78	0.74	0.70	0.67	0.64	0.62	0.60	0.58	0.57	0.55	0.54	0.53	0.51
2.0	37.95	1.14	1.10	1.05	1.01	0.97	0.94	0.91	0.85	0.81	0.77	0.73	0.70	0.68	0.66	0.64	0.62	0.60	0.59	0.58	0.56
2.1	39.85	1.24	1.19	1.14	1.10	1.06	1.02	0.99	0.93	0.88	0.84	0.80	0.77	0.74	0.72	0.69	0.67	0.66	0.64	0.63	0.61
2.2	41.75	1.34	1.29	1.23	1.19	1.14	1.11	1.07	1.01	0.95	0.91	0.87	0.83	0.80	0.78	0.75	0.73	0.71	0.70	0.68	0.67
2.3	43.64	1.45	1.39	1.33	1.28	1.23	1.20	1.15	1.09	1.03	0.98	0.94	0.90	0.87	0.84	0.81	0.79	0.77	0.75	0.74	0.72
2.4	45.54	1.56	1.50	1.43	1.38	1.33	1.29	1.24	1.17	1.11	1.06	1.01	0.97	0.94	0.91	0.88	0.85	0.83	0.81	0.80	0.78
2.5	47.44	1.67	1.61	1.54	1.48	1.42	1.38	1.33	1.26	1.19	1.13	1.08	1.04	1.01	0.97	0.94	0.92	0.90	0.87	0.86	0.84
2.6	49.34	1.79	1.72	1.64	1.59	1.52	1.48	1.43	1.34	1.27	1.21	1.16	1.12	1.08	1.04	1.01	0.98	0.96	0.94	0.92	0.90
2.7	51.23	1.90	1.83	1.75	1.69	1.63	1.58	1.52	1.44	1.36	1.30	1.24	1.19	1.15	1.11	1.08	1.05	1.03	1.00	0.98	0.96
2.8	53.13	2.03	1.95	1.87	1.80	1.73	1.68	1.62	1.53	1.45	1.38	1.32	1.27	1.23	1.19	1.15	1.12	1.09	1.07	1.05	1.03
2.9	55.03	2.15	2.07	1.98	1.91	1.84	1.78	1.72	1.63	1.54	1.47	1.41	1.35	1.31	1.26	1.23	1.20	1.17	1.14	1.12	1.09
3.0	56.93	2.28	2.19	2.10	2.03	1.95	1.89	1.83	1.72	1.64	1.56	1.49	1.44	1.39	1.34	1.30	1.27	1.24	1.21	1.18	1.16
3.1	58.82	2.41	2.32	2.22	2.15	2.07	2.00	1.94	1.83	1.73	1.65	1.58	1.52	1.47	1.42	1.38	1.35	1.31	1.28	1.26	1.23
3.2	60.72	2.55	2.45	2.35	2.27	2.18	2.12	2.05	1.93	1.83	1.75	1.67	1.61	1.56	1.51	1.46	1.42	1.39	1.36	1.33	1.30
3.3	62.62	2.69	2.58	2.48	2.39	2.30	2.23	2.16	2.04	1.93	1.84	1.77	1.70	1.64	1.59	1.54	1.50	1.47	1.43	1.40	1.38
3.4	64.52	2.83	2.72	2.61	2.52	2.42	2.35	2.27	2.15	2.04	1.94	1.86	1.79	1.73	1.68	1.63	1.59	1.55	1.51	1.48	1.45
3.5	66.42	2.97	2.86	2.74	2.65	2.55	2.47	2.39	2.26	2.14	2.05	1.96	1.89	1.82	1.77	1.72	1.67	1.63	1.59	1.56	1.53
3.6	68.31	3.12	3.00	2.88	2.78	2.68	2.60	2.51	2.37	2.25	2.15	2.06	1.98	1.92	1.86	1.80	1.76	1.71	1.67	1.64	1.61
3.7	70.21	3.27	3.15	3.02	2.92	2.81	2.72	2.63	2.49	2.36	2.26	2.16	2.08	2.01	1.95	1.89	1.84	1.80	1.76	1.72	1.69
3.8	72.11	3.42	3.30	3.16	3.05	2.94	2.85	2.76	2.61	2.48	2.36	2.27	2.18	2.11	2.04	1.99	1.93	1.89	1.84	1.81	1.77
3.9	74.01	3.58	3.45	3.30	3.19	3.08	2.99	2.89	2.73	2.59	2.47	2.37	2.29	2.21	2.14	2.08	2.03	1.98	1.93	1.89	1.86
4.0	75.90	3.74	3.60	3.45	3.34	3.21	3.12	3.02	2.85	2.71	2.59	2.48	2.39	2.31	2.24	2.18	2.12	2.07	2.02	1.98	1.94
4.1	77.80	3.90	3.76	3.60	3.48	3.36	3.26	3.15	2.98	2.83	2.70	2.59	2.50	2.41	2.34	2.27	2.21	2.16	2.11	2.07	2.03
4.2	79.70	4.06	3.92	3.75	3.63	3.50	3.40	3.29	3.11	2.95	2.82	2.71	2.61	2.52	2.44	2.37	2.31	2.26	2.20	2.16	2.12
4.3	81.60	4.23	4.08	3.91	3.78	3.65	3.54	3.42	3.24	3.08	2.94	2.82	2.72	2.63	2.55	2.47	2.41	2.35	2.30	2.26	2.21
4.4	83.49	4.40	4.24	4.07	3.94	3.79	3.68	3.56	3.37	3.20	3.06	2.94	2.83	2.74	2.65	2.58	2.51	2.45	2.40	2.35	2.31
4.5	85.39	4.58	4.41	4.23	4.10	3.95	3.83	3.71	3.51	3.33	3.19	3.06	2.95	2.85	2.76	2.68	2.62	2.55	2.49	2.45	2.40
4.6	87.29	4.75	4.58	4.40	4.25	4.10	3.98	3.85	3.64	3.46	3.31	3.18	3.06	2.96	2.87	2.79	2.72	2.65	2.59	2.55	2.50
4.7	89.19	4.93	4.76	4.56	4.42	4.26	4.13	4.00	3.78	3.60	3.44	3.30	3.18	3.08	2.98	2.90	2.83	2.76	2.70	2.65	2.60

Continued on next page

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

Appendix G:

Hydronic friction loss tables

3½" Uponor PEX-a — 50% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40ºF 4ºC	45ºF 7ºC	50ºF 10ºC	55ºF 13ºC	60ºF 16ºC	65ºF 18ºC	70ºF 21ºC	80ºF 27ºC	90ºF 32ºC	100ºF 38ºC	110ºF 43ºC	120ºF 49ºC	130ºF 54ºC	140ºF 60ºC	150ºF 66ºC	160ºF 71ºC	170ºF 77ºC	180ºF 82ºC	190ºF 88ºC	200ºF 93ºC
4.8	91.08	5.12	4.93	4.73	4.58	4.42	4.29	4.15	3.93	3.73	3.57	3.43	3.30	3.19	3.10	3.01	2.93	2.86	2.80	2.75	2.70
4.9	92.98	5.30	5.11	4.91	4.75	4.58	4.45	4.30	4.07	3.87	3.70	3.56	3.43	3.31	3.21	3.12	3.05	2.97	2.91	2.85	2.80
5.0	94.88	5.49	5.30	5.08	4.92	4.74	4.61	4.46	4.22	4.01	3.84	3.68	3.55	3.43	3.33	3.24	3.16	3.08	3.01	2.96	2.90
5.1	96.78	5.68	5.48	5.26	5.09	4.91	4.77	4.62	4.37	4.16	3.97	3.82	3.68	3.56	3.45	3.35	3.27	3.19	3.12	3.06	3.01
5.2	98.67	5.88	5.67	5.44	5.27	5.08	4.93	4.78	4.52	4.30	4.11	3.95	3.81	3.68	3.57	3.47	3.39	3.31	3.23	3.17	3.11
5.3	100.57	6.07	5.86	5.62	5.44	5.25	5.10	4.94	4.67	4.45	4.25	4.09	3.94	3.81	3.69	3.59	3.50	3.42	3.34	3.28	3.22
5.4	102.47	6.27	6.05	5.81	5.62	5.42	5.27	5.10	4.83	4.60	4.40	4.22	4.07	3.94	3.82	3.72	3.62	3.54	3.46	3.39	3.33
5.5	104.37	6.47	6.25	6.00	5.81	5.60	5.44	5.27	4.99	4.75	4.54	4.36	4.21	4.07	3.95	3.84	3.74	3.66	3.57	3.51	3.44
5.6	106.26	6.68	6.45	6.19	5.99	5.78	5.62	5.44	5.15	4.90	4.69	4.51	4.34	4.20	4.08	3.97	3.87	3.78	3.69	3.62	3.56
5.7	108.16	6.89	6.65	6.38	6.18	5.96	5.79	5.61	5.31	5.06	4.84	4.65	4.48	4.34	4.21	4.09	3.99	3.90	3.81	3.74	3.67
5.8	110.06	7.10	6.85	6.58	6.37	6.15	5.97	5.78	5.48	5.22	4.99	4.79	4.62	4.47	4.34	4.22	4.12	4.02	3.93	3.86	3.79
5.9	111.96	7.31	7.06	6.78	6.56	6.33	6.15	5.96	5.65	5.38	5.14	4.94	4.77	4.61	4.47	4.35	4.25	4.15	4.06	3.98	3.91
6.0	113.85	7.53	7.27	6.98	6.76	6.52	6.34	6.14	5.82	5.54	5.30	5.09	4.91	4.75	4.61	4.49	4.38	4.27	4.18	4.10	4.03
6.1	115.75	7.75	7.48	7.18	6.96	6.71	6.52	6.32	5.99	5.70	5.46	5.24	5.06	4.89	4.75	4.62	4.51	4.40	4.31	4.23	4.15
6.2	117.65	7.97	7.69	7.39	7.16	6.91	6.71	6.50	6.16	5.87	5.62	5.40	5.21	5.04	4.89	4.76	4.64	4.53	4.43	4.35	4.27
6.3	119.55	8.19	7.91	7.60	7.36	7.10	6.90	6.69	6.34	6.04	5.78	5.55	5.36	5.19	5.03	4.90	4.78	4.66	4.56	4.48	4.40
6.4	121.45	8.42	8.13	7.81	7.57	7.30	7.10	6.88	6.52	6.21	5.94	5.71	5.51	5.33	5.18	5.04	4.91	4.80	4.69	4.61	4.52
6.5	123.34	8.65	8.35	8.02	7.77	7.50	7.29	7.07	6.70	6.38	6.11	5.87	5.66	5.48	5.32	5.18	5.05	4.93	4.83	4.74	4.65
6.6	125.24	8.88	8.58	8.24	7.99	7.71	7.49	7.26	6.88	6.55	6.27	6.03	5.82	5.63	5.47	5.32	5.19	5.07	4.96	4.87	4.78
6.7	127.14	9.12	8.80	8.46	8.20	7.91	7.69	7.45	7.06	6.73	6.44	6.20	5.98	5.79	5.62	5.47	5.33	5.21	5.10	5.00	4.91
6.8	129.04	9.36	9.03	8.68	8.41	8.12	7.90	7.65	7.25	6.91	6.62	6.36	6.14	5.94	5.77	5.61	5.48	5.35	5.23	5.14	5.05
6.9	130.93	9.60	9.27	8.91	8.63	8.33	8.10	7.85	7.44	7.09	6.79	6.53	6.30	6.10	5.92	5.76	5.62	5.49	5.37	5.28	5.18
7.0	132.83	9.84	9.50	9.13	8.85	8.54	8.31	8.05	7.63	7.27	6.97	6.70	6.46	6.26	6.08	5.91	5.77	5.64	5.52	5.42	5.32
7.1	134.73	10.08	9.74	9.36	9.07	8.76	8.52	8.25	7.83	7.46	7.14	6.87	6.63	6.42	6.23	6.07	5.92	5.78	5.66	5.56	5.45
7.2	136.63	10.33	9.98	9.59	9.30	8.98	8.73	8.46	8.02	7.65	7.32	7.04	6.80	6.58	6.39	6.22	6.07	5.93	5.80	5.70	5.59
7.3	138.52	10.58	10.22	9.83	9.53	9.20	8.94	8.67	8.22	7.84	7.51	7.22	6.97	6.75	6.55	6.38	6.22	6.08	5.95	5.84	5.73
7.4	140.42	10.84	10.47	10.06	9.76	9.42	9.16	8.88	8.42	8.03	7.69	7.40	7.14	6.91	6.71	6.53	6.38	6.23	6.10	5.99	5.88
7.5	142.32	11.09	10.72	10.30	9.99	9.65	9.38	9.09	8.62	8.22	7.87	7.58	7.31	7.08	6.87	6.69	6.53	6.38	6.24	6.13	6.02
7.6	144.22	11.35	10.97	10.54	10.22	9.87	9.60	9.31	8.83	8.42	8.06	7.76	7.49	7.25	7.04	6.85	6.69	6.54	6.40	6.28	6.17
7.7	146.11	11.61	11.22	10.79	10.46	10.10	9.82	9.52	9.03	8.61	8.25	7.94	7.66	7.42	7.21	7.02	6.85	6.69	6.55	6.43	6.31
7.8	148.01	11.88	11.48	11.03	10.70	10.33	10.05	9.74	9.24	8.81	8.44	8.12	7.84	7.60	7.37	7.18	7.01	6.85	6.70	6.58	6.46
7.9	149.91	12.14	11.73	11.28	10.94	10.57	10.28	9.96	9.45	9.01	8.64	8.31	8.02	7.77	7.55	7.35	7.17	7.01	6.86	6.73	6.61
8.0	151.81	12.41	11.99	11.53	11.19	10.80	10.51	10.19	9.67	9.22	8.83	8.50	8.21	7.95	7.72	7.51	7.34	7.17	7.02	6.89	6.77

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

4" Uponor PEX-a — 100% Water — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
1.5	36.88	0.35	0.33	0.32	0.31	0.30	0.30	0.29	0.29	0.28	0.27	0.27	0.26	0.26	0.25	0.25	0.24	0.24	0.24	0.23	0.23
1.6	39.34	0.39	0.37	0.35	0.35	0.34	0.34	0.33	0.32	0.31	0.31	0.30	0.29	0.29	0.28	0.28	0.27	0.27	0.27	0.26	0.26
1.7	41.80	0.43	0.41	0.39	0.39	0.38	0.37	0.37	0.36	0.35	0.34	0.33	0.33	0.32	0.31	0.31	0.30	0.30	0.30	0.29	0.29
1.8	44.26	0.48	0.46	0.44	0.43	0.42	0.41	0.41	0.40	0.39	0.38	0.37	0.36	0.35	0.35	0.34	0.34	0.33	0.33	0.32	0.32
1.9	46.72	0.53	0.50	0.48	0.47	0.46	0.46	0.45	0.44	0.43	0.42	0.41	0.40	0.39	0.38	0.38	0.37	0.37	0.36	0.36	0.35
2.0	49.17	0.58	0.55	0.52	0.52	0.51	0.50	0.49	0.48	0.47	0.45	0.45	0.44	0.43	0.42	0.41	0.41	0.40	0.40	0.39	0.39
2.1	51.63	0.63	0.60	0.57	0.56	0.55	0.54	0.54	0.52	0.51	0.50	0.49	0.48	0.47	0.46	0.45	0.45	0.44	0.43	0.43	0.42
2.2	54.09	0.68	0.65	0.62	0.61	0.60	0.59	0.58	0.57	0.55	0.54	0.53	0.52	0.51	0.50	0.49	0.48	0.48	0.47	0.47	0.46
2.3	56.55	0.74	0.71	0.67	0.66	0.65	0.64	0.63	0.61	0.60	0.58	0.57	0.56	0.55	0.54	0.53	0.52	0.52	0.51	0.50	0.50
2.4	59.01	0.79	0.76	0.73	0.71	0.70	0.69	0.68	0.66	0.65	0.63	0.62	0.61	0.59	0.58	0.57	0.57	0.56	0.55	0.54	0.54
2.5	61.47	0.85	0.82	0.78	0.77	0.75	0.74	0.73	0.71	0.69	0.68	0.66	0.65	0.64	0.63	0.62	0.61	0.60	0.59	0.59	0.58
2.6	63.93	0.92	0.88	0.84	0.82	0.81	0.80	0.78	0.76	0.74	0.73	0.71	0.70	0.69	0.67	0.66	0.65	0.65	0.64	0.63	0.62
2.7	66.38	0.98	0.94	0.89	0.88	0.86	0.85	0.84	0.82	0.80	0.78	0.76	0.75	0.73	0.72	0.71	0.70	0.69	0.68	0.67	0.67
2.8	68.84	1.04	1.00	0.95	0.94	0.92	0.91	0.90	0.87	0.85	0.83	0.81	0.80	0.78	0.77	0.76	0.75	0.74	0.73	0.72	0.71
2.9	71.30	1.11	1.07	1.02	1.00	0.98	0.97	0.95	0.93	0.91	0.88	0.87	0.85	0.83	0.82	0.81	0.80	0.79	0.78	0.77	0.76
3.0	73.76	1.18	1.13	1.08	1.06	1.04	1.03	1.01	0.99	0.96	0.94	0.92	0.90	0.89	0.87	0.86	0.85	0.84	0.82	0.82	0.81
3.1	76.22	1.25	1.20	1.14	1.12	1.11	1.09	1.07	1.05	1.02	1.00	0.98	0.96	0.94	0.93	0.91	0.90	0.89	0.88	0.86	0.86
3.2	78.68	1.32	1.27	1.21	1.19	1.17	1.15	1.14	1.11	1.08	1.06	1.03	1.01	1.00	0.98	0.97	0.95	0.94	0.93	0.92	0.91
3.3	81.14	1.40	1.34	1.28	1.26	1.24	1.22	1.20	1.17	1.14	1.12	1.09	1.07	1.05	1.04	1.02	1.01	0.99	0.98	0.97	0.96
3.4	83.60	1.47	1.41	1.35	1.33	1.30	1.29	1.27	1.23	1.20	1.18	1.15	1.13	1.11	1.09	1.08	1.06	1.05	1.03	1.02	1.01
3.5	86.05	1.55	1.49	1.42	1.40	1.37	1.35	1.33	1.30	1.27	1.24	1.22	1.19	1.17	1.15	1.14	1.12	1.10	1.09	1.08	1.07
3.6	88.51	1.63	1.57	1.49	1.47	1.44	1.42	1.40	1.37	1.33	1.30	1.28	1.25	1.23	1.21	1.19	1.18	1.16	1.15	1.13	1.12
3.7	90.97	1.71	1.64	1.57	1.54	1.52	1.50	1.47	1.44	1.40	1.37	1.34	1.32	1.30	1.27	1.26	1.24	1.22	1.21	1.19	1.18
3.8	93.43	1.79	1.72	1.64	1.62	1.59	1.57	1.55	1.51	1.47	1.44	1.41	1.38	1.36	1.34	1.32	1.30	1.28	1.27	1.25	1.24
3.9	95.89	1.88	1.80	1.72	1.69	1.67	1.64	1.62	1.58	1.54	1.51	1.48	1.45	1.42	1.40	1.38	1.36	1.34	1.33	1.31	1.30
4.0	98.35	1.96	1.89	1.80	1.77	1.74	1.72	1.69	1.65	1.61	1.58	1.55	1.52	1.49	1.47	1.45	1.42	1.41	1.39	1.37	1.36
4.1	100.81	2.05	1.97	1.88	1.85	1.82	1.80	1.77	1.73	1.69	1.65	1.62	1.59	1.56	1.53	1.51	1.49	1.47	1.45	1.44	1.42
4.2	103.27	2.14	2.06	1.97	1.94	1.90	1.88	1.85	1.80	1.76	1.72	1.69	1.66	1.63	1.60	1.58	1.56	1.54	1.52	1.50	1.48
4.3	105.72	2.23	2.15	2.05	2.02	1.99	1.96	1.93	1.88	1.84	1.80	1.76	1.73	1.70	1.67	1.65	1.62	1.60	1.58	1.57	1.55
4.4	108.18	2.33	2.24	2.14	2.10	2.07	2.04	2.01	1.96	1.91	1.87	1.84	1.80	1.77	1.74	1.72	1.69	1.67	1.65	1.63	1.61
4.5	110.64	2.42	2.33	2.22	2.19	2.15	2.12	2.09	2.04	1.99	1.95	1.91	1.88	1.84	1.82	1.79	1.76	1.74	1.72	1.70	1.68
4.6	113.10	2.52	2.42	2.31	2.28	2.24	2.21	2.18	2.12	2.07	2.03	1.99	1.95	1.92	1.89	1.86	1.84	1.81	1.79	1.77	1.75
4.7	115.56	2.62	2.52	2.40	2.37	2.33	2.30	2.26	2.21	2.15	2.11	2.07	2.03	2.00	1.96	1.94	1.91	1.88	1.86	1.84	1.82

Continued on next page

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

Appendix G:

Hydronic friction loss tables

4" Uponor PEX-a — 100% Water — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
4.8	118.02	2.72	2.61	2.50	2.46	2.42	2.39	2.35	2.29	2.24	2.19	2.15	2.11	2.07	2.04	2.01	1.98	1.96	1.93	1.91	1.89
4.9	120.48	2.82	2.71	2.59	2.55	2.51	2.48	2.44	2.38	2.32	2.27	2.23	2.19	2.15	2.12	2.09	2.06	2.03	2.01	1.98	1.96
5.0	122.94	2.92	2.81	2.69	2.64	2.60	2.57	2.53	2.47	2.41	2.36	2.31	2.27	2.23	2.20	2.16	2.14	2.11	2.08	2.06	2.04
5.1	125.39	3.03	2.91	2.78	2.74	2.70	2.66	2.62	2.56	2.50	2.44	2.40	2.35	2.31	2.28	2.24	2.21	2.18	2.16	2.13	2.11
5.2	127.85	3.13	3.02	2.88	2.84	2.79	2.75	2.71	2.65	2.59	2.53	2.48	2.44	2.40	2.36	2.32	2.29	2.26	2.24	2.21	2.19
5.3	130.31	3.24	3.12	2.98	2.94	2.89	2.85	2.81	2.74	2.68	2.62	2.57	2.52	2.48	2.44	2.41	2.37	2.34	2.32	2.29	2.26
5.4	132.77	3.35	3.23	3.08	3.04	2.99	2.95	2.91	2.83	2.77	2.71	2.66	2.61	2.57	2.53	2.49	2.46	2.42	2.40	2.37	2.34
5.5	135.23	3.46	3.33	3.19	3.14	3.09	3.05	3.00	2.93	2.86	2.80	2.75	2.70	2.65	2.61	2.57	2.54	2.51	2.48	2.45	2.42
5.6	137.69	3.58	3.44	3.29	3.24	3.19	3.15	3.10	3.02	2.96	2.89	2.84	2.79	2.74	2.70	2.66	2.62	2.59	2.56	2.53	2.50
5.7	140.15	3.69	3.55	3.40	3.35	3.29	3.25	3.20	3.12	3.05	2.99	2.93	2.88	2.83	2.79	2.75	2.71	2.67	2.64	2.61	2.59
5.8	142.60	3.81	3.67	3.50	3.45	3.40	3.35	3.30	3.22	3.15	3.08	3.02	2.97	2.92	2.88	2.83	2.80	2.76	2.73	2.70	2.67
5.9	145.06	3.93	3.78	3.61	3.56	3.50	3.46	3.41	3.32	3.25	3.18	3.12	3.06	3.01	2.97	2.92	2.88	2.85	2.81	2.78	2.75
6.0	147.52	4.05	3.90	3.72	3.67	3.61	3.56	3.51	3.42	3.35	3.28	3.21	3.16	3.11	3.06	3.01	2.97	2.94	2.90	2.87	2.84
6.1	149.98	4.17	4.01	3.84	3.78	3.72	3.67	3.62	3.53	3.45	3.38	3.31	3.25	3.20	3.15	3.11	3.06	3.03	2.99	2.96	2.93
6.2	152.44	4.29	4.13	3.95	3.89	3.83	3.78	3.73	3.63	3.55	3.48	3.41	3.35	3.30	3.25	3.20	3.16	3.12	3.08	3.05	3.01
6.3	154.90	4.42	4.25	4.06	4.00	3.94	3.89	3.83	3.74	3.66	3.58	3.51	3.45	3.39	3.34	3.29	3.25	3.21	3.17	3.14	3.10
6.4	157.36	4.54	4.37	4.18	4.12	4.06	4.00	3.95	3.85	3.76	3.68	3.61	3.55	3.49	3.44	3.39	3.34	3.30	3.26	3.23	3.19
6.5	159.82	4.67	4.50	4.30	4.24	4.17	4.11	4.06	3.96	3.87	3.79	3.72	3.65	3.59	3.54	3.49	3.44	3.40	3.36	3.32	3.29
6.6	162.27	4.80	4.62	4.42	4.35	4.29	4.23	4.17	4.07	3.98	3.89	3.82	3.75	3.69	3.64	3.58	3.54	3.49	3.45	3.41	3.38
6.7	164.73	4.93	4.75	4.54	4.47	4.40	4.35	4.28	4.18	4.09	4.00	3.93	3.86	3.79	3.74	3.68	3.64	3.59	3.55	3.51	3.47
6.8	167.19	5.06	4.88	4.66	4.59	4.52	4.46	4.40	4.29	4.20	4.11	4.03	3.96	3.90	3.84	3.78	3.73	3.69	3.65	3.61	3.57
6.9	169.65	5.20	5.01	4.79	4.72	4.64	4.58	4.52	4.41	4.31	4.22	4.14	4.07	4.00	3.94	3.89	3.84	3.79	3.74	3.70	3.66
7.0	172.11	5.33	5.14	4.91	4.84	4.77	4.70	4.64	4.52	4.42	4.33	4.25	4.18	4.11	4.05	3.99	3.94	3.89	3.84	3.80	3.76
7.1	174.57	5.47	5.27	5.04	4.97	4.89	4.82	4.76	4.64	4.54	4.44	4.36	4.29	4.22	4.15	4.09	4.04	3.99	3.94	3.90	3.86
7.2	177.03	5.61	5.40	5.17	5.09	5.01	4.95	4.88	4.76	4.65	4.56	4.47	4.40	4.32	4.26	4.20	4.14	4.09	4.05	4.00	3.96
7.3	179.49	5.75	5.54	5.30	5.22	5.14	5.07	5.00	4.88	4.77	4.67	4.59	4.51	4.43	4.37	4.31	4.25	4.20	4.15	4.10	4.06
7.4	181.94	5.89	5.67	5.43	5.35	5.27	5.20	5.13	5.00	4.89	4.79	4.70	4.62	4.55	4.48	4.41	4.36	4.30	4.25	4.21	4.16
7.5	184.40	6.03	5.81	5.56	5.48	5.40	5.33	5.25	5.12	5.01	4.91	4.82	4.73	4.66	4.59	4.52	4.46	4.41	4.36	4.31	4.27
7.6	186.86	6.18	5.95	5.70	5.61	5.53	5.45	5.38	5.25	5.13	5.03	4.93	4.85	4.77	4.70	4.63	4.57	4.52	4.47	4.42	4.37
7.7	189.32	6.32	6.09	5.83	5.75	5.66	5.59	5.51	5.37	5.26	5.15	5.05	4.97	4.89	4.81	4.75	4.68	4.63	4.57	4.52	4.48
7.8	191.78	6.47	6.24	5.97	5.88	5.79	5.72	5.64	5.50	5.38	5.27	5.17	5.08	5.00	4.93	4.86	4.80	4.74	4.68	4.63	4.58
7.9	194.24	6.62	6.38	6.11	6.02	5.93	5.85	5.77	5.63	5.51	5.39	5.29	5.20	5.12	5.04	4.97	4.91	4.85	4.79	4.74	4.69
8.0	196.70	6.77	6.53	6.25	6.16	6.06	5.98	5.90	5.76	5.63	5.52	5.42	5.32	5.24	5.16	5.09	5.02	4.96	4.90	4.85	4.80

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

4" Uponor PEX-a — 30% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
1.5	36.88	0.46	0.44	0.43	0.42	0.40	0.39	0.38	0.36	0.35	0.34	0.32	0.31	0.30	0.30	0.29	0.28	0.28	0.27	0.27	0.26
1.6	39.34	0.51	0.50	0.48	0.47	0.45	0.44	0.43	0.41	0.39	0.38	0.36	0.35	0.34	0.33	0.33	0.32	0.31	0.31	0.30	0.30
1.7	41.80	0.57	0.55	0.53	0.52	0.50	0.49	0.48	0.45	0.44	0.42	0.40	0.39	0.38	0.37	0.36	0.35	0.35	0.34	0.33	0.33
1.8	44.26	0.63	0.61	0.59	0.57	0.55	0.54	0.53	0.50	0.48	0.46	0.45	0.43	0.42	0.41	0.40	0.39	0.38	0.38	0.37	0.36
1.9	46.72	0.69	0.67	0.64	0.63	0.61	0.59	0.58	0.55	0.53	0.51	0.49	0.48	0.46	0.45	0.44	0.43	0.42	0.41	0.41	0.40
2.0	49.17	0.75	0.73	0.70	0.69	0.67	0.65	0.63	0.60	0.58	0.56	0.54	0.52	0.51	0.49	0.48	0.47	0.46	0.45	0.45	0.44
2.1	51.63	0.82	0.79	0.77	0.75	0.73	0.71	0.69	0.66	0.63	0.61	0.59	0.57	0.55	0.54	0.53	0.52	0.50	0.50	0.49	0.48
2.2	54.09	0.89	0.86	0.83	0.81	0.79	0.77	0.75	0.71	0.68	0.66	0.64	0.62	0.60	0.59	0.57	0.56	0.55	0.54	0.53	0.52
2.3	56.55	0.96	0.93	0.90	0.88	0.85	0.83	0.81	0.77	0.74	0.71	0.69	0.67	0.65	0.63	0.62	0.61	0.59	0.58	0.57	0.57
2.4	59.01	1.03	1.00	0.97	0.94	0.92	0.89	0.87	0.83	0.80	0.77	0.74	0.72	0.70	0.68	0.67	0.65	0.64	0.63	0.62	0.61
2.5	61.47	1.11	1.07	1.04	1.01	0.98	0.96	0.94	0.89	0.86	0.83	0.80	0.78	0.75	0.74	0.72	0.70	0.69	0.68	0.67	0.66
2.6	63.93	1.18	1.15	1.11	1.08	1.05	1.03	1.00	0.96	0.92	0.89	0.86	0.83	0.81	0.79	0.77	0.75	0.74	0.73	0.71	0.70
2.7	66.38	1.26	1.23	1.19	1.16	1.13	1.10	1.07	1.02	0.98	0.95	0.92	0.89	0.87	0.84	0.83	0.81	0.79	0.78	0.76	0.75
2.8	68.84	1.35	1.31	1.27	1.24	1.20	1.17	1.14	1.09	1.05	1.01	0.98	0.95	0.92	0.90	0.88	0.86	0.84	0.83	0.82	0.81
2.9	71.30	1.43	1.39	1.35	1.31	1.28	1.25	1.21	1.16	1.12	1.08	1.04	1.01	0.98	0.96	0.94	0.92	0.90	0.88	0.87	0.86
3.0	73.76	1.52	1.48	1.43	1.39	1.35	1.32	1.29	1.23	1.18	1.14	1.11	1.07	1.04	1.02	1.00	0.98	0.96	0.94	0.92	0.91
3.1	76.22	1.61	1.56	1.51	1.48	1.44	1.40	1.37	1.31	1.26	1.21	1.17	1.14	1.11	1.08	1.06	1.03	1.01	1.00	0.98	0.97
3.2	78.68	1.70	1.65	1.60	1.56	1.52	1.48	1.44	1.38	1.33	1.28	1.24	1.20	1.17	1.14	1.12	1.09	1.07	1.05	1.04	1.02
3.3	81.14	1.79	1.74	1.69	1.65	1.60	1.56	1.52	1.46	1.40	1.35	1.31	1.27	1.24	1.21	1.18	1.16	1.13	1.11	1.10	1.08
3.4	83.60	1.89	1.84	1.78	1.74	1.69	1.65	1.61	1.54	1.48	1.43	1.38	1.34	1.31	1.27	1.25	1.22	1.20	1.18	1.16	1.14
3.5	86.05	1.99	1.93	1.87	1.83	1.78	1.74	1.69	1.62	1.56	1.50	1.45	1.41	1.38	1.34	1.31	1.29	1.26	1.24	1.22	1.20
3.6	88.51	2.09	2.03	1.97	1.92	1.87	1.82	1.78	1.70	1.64	1.58	1.53	1.49	1.45	1.41	1.38	1.35	1.33	1.30	1.28	1.27
3.7	90.97	2.19	2.13	2.07	2.01	1.96	1.91	1.87	1.79	1.72	1.66	1.61	1.56	1.52	1.48	1.45	1.42	1.39	1.37	1.35	1.33
3.8	93.43	2.30	2.23	2.16	2.11	2.05	2.01	1.96	1.87	1.80	1.74	1.68	1.64	1.59	1.55	1.52	1.49	1.46	1.44	1.41	1.39
3.9	95.89	2.40	2.34	2.27	2.21	2.15	2.10	2.05	1.96	1.89	1.82	1.76	1.71	1.67	1.63	1.59	1.56	1.53	1.51	1.48	1.46
4.0	98.35	2.51	2.44	2.37	2.31	2.25	2.20	2.14	2.05	1.97	1.91	1.84	1.79	1.75	1.70	1.67	1.63	1.60	1.58	1.55	1.53
4.1	100.81	2.62	2.55	2.47	2.41	2.35	2.29	2.24	2.14	2.06	1.99	1.93	1.87	1.82	1.78	1.74	1.71	1.68	1.65	1.62	1.60
4.2	103.27	2.74	2.66	2.58	2.52	2.45	2.39	2.34	2.24	2.15	2.08	2.01	1.96	1.91	1.86	1.82	1.78	1.75	1.72	1.69	1.67
4.3	105.72	2.85	2.77	2.69	2.62	2.55	2.50	2.43	2.33	2.24	2.17	2.10	2.04	1.99	1.94	1.90	1.86	1.82	1.79	1.77	1.74
4.4	108.18	2.97	2.89	2.80	2.73	2.66	2.60	2.54	2.43	2.34	2.26	2.19	2.13	2.07	2.02	1.98	1.94	1.90	1.87	1.84	1.82
4.5	110.64	3.09	3.00	2.91	2.84	2.77	2.71	2.64	2.53	2.43	2.35	2.28	2.21	2.16	2.10	2.06	2.02	1.98	1.95	1.92	1.89
4.6	113.10	3.21	3.12	3.03	2.96	2.88	2.81	2.74	2.63	2.53	2.44	2.37	2.30	2.24	2.19	2.14	2.10	2.06	2.03	1.99	1.97
4.7	115.56	3.33	3.24	3.15	3.07	2.99	2.92	2.85	2.73	2.63	2.54	2.46	2.39	2.33	2.27	2.23	2.18	2.14	2.11	2.07	2.05

Continued on next page

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

4" Uponor PEX-a — 30% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
4.8	118.02	3.46	3.37	3.27	3.19	3.10	3.03	2.96	2.84	2.73	2.64	2.56	2.48	2.42	2.36	2.31	2.27	2.22	2.19	2.15	2.13
4.9	120.48	3.59	3.49	3.39	3.30	3.22	3.15	3.07	2.94	2.83	2.74	2.65	2.58	2.51	2.45	2.40	2.35	2.31	2.27	2.23	2.21
5.0	122.94	3.72	3.62	3.51	3.42	3.33	3.26	3.18	3.05	2.94	2.84	2.75	2.67	2.60	2.54	2.49	2.44	2.39	2.36	2.32	2.29
5.1	125.39	3.85	3.74	3.63	3.55	3.45	3.38	3.29	3.16	3.04	2.94	2.85	2.77	2.70	2.63	2.58	2.53	2.48	2.44	2.40	2.37
5.2	127.85	3.98	3.88	3.76	3.67	3.57	3.50	3.41	3.27	3.15	3.04	2.95	2.87	2.79	2.73	2.67	2.62	2.57	2.53	2.49	2.46
5.3	130.31	4.12	4.01	3.89	3.80	3.70	3.62	3.53	3.38	3.26	3.15	3.05	2.97	2.89	2.82	2.77	2.71	2.66	2.62	2.57	2.54
5.4	132.77	4.25	4.14	4.02	3.92	3.82	3.74	3.65	3.50	3.37	3.26	3.15	3.07	2.99	2.92	2.86	2.80	2.75	2.71	2.66	2.63
5.5	135.23	4.39	4.28	4.15	4.05	3.95	3.86	3.77	3.61	3.48	3.36	3.26	3.17	3.09	3.02	2.96	2.90	2.84	2.80	2.75	2.72
5.6	137.69	4.54	4.42	4.29	4.18	4.08	3.99	3.89	3.73	3.59	3.47	3.37	3.28	3.19	3.12	3.05	2.99	2.94	2.89	2.84	2.81
5.7	140.15	4.68	4.56	4.42	4.32	4.21	4.11	4.01	3.85	3.71	3.59	3.48	3.38	3.30	3.22	3.15	3.09	3.03	2.99	2.94	2.90
5.8	142.60	4.82	4.70	4.56	4.45	4.34	4.24	4.14	3.97	3.83	3.70	3.59	3.49	3.40	3.32	3.25	3.19	3.13	3.08	3.03	2.99
5.9	145.06	4.97	4.84	4.70	4.59	4.47	4.37	4.27	4.10	3.95	3.81	3.70	3.60	3.51	3.42	3.36	3.29	3.23	3.18	3.13	3.09
6.0	147.52	5.12	4.99	4.84	4.73	4.61	4.51	4.40	4.22	4.07	3.93	3.81	3.71	3.61	3.53	3.46	3.39	3.33	3.28	3.22	3.18
6.1	149.98	5.27	5.14	4.99	4.87	4.74	4.64	4.53	4.35	4.19	4.05	3.93	3.82	3.72	3.64	3.56	3.49	3.43	3.37	3.32	3.28
6.2	152.44	5.43	5.28	5.13	5.01	4.88	4.78	4.66	4.47	4.31	4.17	4.04	3.93	3.83	3.74	3.67	3.60	3.53	3.48	3.42	3.38
6.3	154.90	5.58	5.44	5.28	5.16	5.02	4.91	4.80	4.60	4.44	4.29	4.16	4.05	3.95	3.85	3.78	3.70	3.63	3.58	3.52	3.48
6.4	157.36	5.74	5.59	5.43	5.30	5.16	5.05	4.93	4.74	4.56	4.41	4.28	4.16	4.06	3.96	3.89	3.81	3.74	3.68	3.62	3.58
6.5	159.82	5.90	5.74	5.58	5.45	5.31	5.19	5.07	4.87	4.69	4.54	4.40	4.28	4.17	4.08	4.00	3.92	3.85	3.79	3.73	3.68
6.6	162.27	6.06	5.90	5.73	5.60	5.45	5.34	5.21	5.00	4.82	4.66	4.52	4.40	4.29	4.19	4.11	4.03	3.95	3.89	3.83	3.78
6.7	164.73	6.22	6.06	5.89	5.75	5.60	5.48	5.35	5.14	4.95	4.79	4.64	4.52	4.41	4.30	4.22	4.14	4.06	4.00	3.94	3.89
6.8	167.19	6.39	6.22	6.04	5.90	5.75	5.63	5.50	5.28	5.09	4.92	4.77	4.64	4.53	4.42	4.34	4.25	4.17	4.11	4.04	3.99
6.9	169.65	6.55	6.38	6.20	6.06	5.90	5.78	5.64	5.42	5.22	5.05	4.90	4.77	4.65	4.54	4.45	4.37	4.29	4.22	4.15	4.10
7.0	172.11	6.72	6.55	6.36	6.21	6.06	5.93	5.79	5.56	5.36	5.18	5.03	4.89	4.77	4.66	4.57	4.48	4.40	4.33	4.26	4.21
7.1	174.57	6.89	6.72	6.52	6.37	6.21	6.08	5.93	5.70	5.49	5.31	5.15	5.02	4.89	4.78	4.69	4.60	4.51	4.44	4.37	4.32
7.2	177.03	7.07	6.88	6.69	6.53	6.37	6.23	6.08	5.84	5.63	5.45	5.29	5.15	5.02	4.90	4.81	4.71	4.63	4.56	4.48	4.43
7.3	179.49	7.24	7.05	6.85	6.70	6.52	6.39	6.24	5.99	5.77	5.59	5.42	5.27	5.14	5.03	4.93	4.83	4.75	4.67	4.60	4.54
7.4	181.94	7.42	7.23	7.02	6.86	6.68	6.54	6.39	6.14	5.92	5.72	5.55	5.41	5.27	5.15	5.05	4.95	4.86	4.79	4.71	4.66
7.5	184.40	7.59	7.40	7.19	7.02	6.85	6.70	6.54	6.29	6.06	5.86	5.69	5.54	5.40	5.28	5.18	5.08	4.98	4.91	4.83	4.77
7.6	186.86	7.77	7.58	7.36	7.19	7.01	6.86	6.70	6.44	6.21	6.00	5.83	5.67	5.53	5.40	5.30	5.20	5.10	5.02	4.95	4.89
7.7	189.32	7.96	7.75	7.53	7.36	7.17	7.02	6.86	6.59	6.35	6.15	5.96	5.81	5.66	5.53	5.43	5.32	5.23	5.15	5.06	5.01
7.8	191.78	8.14	7.93	7.71	7.53	7.34	7.19	7.02	6.74	6.50	6.29	6.10	5.94	5.80	5.66	5.56	5.45	5.35	5.27	5.19	5.12
7.9	194.24	8.32	8.11	7.88	7.70	7.51	7.35	7.18	6.90	6.65	6.44	6.25	6.08	5.93	5.80	5.69	5.58	5.48	5.39	5.31	5.24
8.0	196.70	8.51	8.30	8.06	7.88	7.68	7.52	7.34	7.06	6.80	6.58	6.39	6.22	6.07	5.93	5.82	5.70	5.60	5.51	5.43	5.37

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

4" Uponor PEX-a — 40% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
1.5	36.88	0.53	0.51	0.49	0.47	0.45	0.44	0.42	0.40	0.38	0.36	0.35	0.34	0.32	0.31	0.31	0.30	0.29	0.29	0.28	0.28
1.6	39.34	0.59	0.57	0.54	0.52	0.51	0.49	0.47	0.45	0.43	0.41	0.39	0.38	0.36	0.35	0.34	0.34	0.33	0.32	0.31	0.31
1.7	41.80	0.65	0.63	0.60	0.58	0.56	0.54	0.53	0.50	0.47	0.45	0.43	0.42	0.40	0.39	0.38	0.37	0.36	0.36	0.35	0.34
1.8	44.26	0.72	0.69	0.66	0.64	0.62	0.60	0.58	0.55	0.52	0.50	0.48	0.46	0.45	0.43	0.42	0.41	0.40	0.40	0.39	0.38
1.9	46.72	0.79	0.76	0.73	0.71	0.68	0.66	0.64	0.60	0.57	0.55	0.53	0.51	0.49	0.48	0.47	0.45	0.44	0.44	0.43	0.42
2.0	49.17	0.86	0.83	0.80	0.77	0.74	0.72	0.70	0.66	0.63	0.60	0.58	0.56	0.54	0.52	0.51	0.50	0.49	0.48	0.47	0.46
2.1	51.63	0.94	0.90	0.87	0.84	0.81	0.79	0.76	0.72	0.69	0.66	0.63	0.61	0.59	0.57	0.56	0.54	0.53	0.52	0.51	0.50
2.2	54.09	1.02	0.98	0.94	0.91	0.88	0.85	0.82	0.78	0.74	0.71	0.68	0.66	0.64	0.62	0.60	0.59	0.58	0.57	0.55	0.55
2.3	56.55	1.10	1.06	1.01	0.98	0.95	0.92	0.89	0.84	0.80	0.77	0.74	0.71	0.69	0.67	0.65	0.64	0.62	0.61	0.60	0.59
2.4	59.01	1.18	1.14	1.09	1.06	1.02	0.99	0.96	0.91	0.87	0.83	0.80	0.77	0.75	0.72	0.70	0.69	0.67	0.66	0.65	0.64
2.5	61.47	1.27	1.22	1.17	1.14	1.10	1.06	1.03	0.98	0.93	0.89	0.86	0.83	0.80	0.78	0.76	0.74	0.72	0.71	0.70	0.69
2.6	63.93	1.36	1.31	1.25	1.22	1.17	1.14	1.10	1.05	1.00	0.96	0.92	0.89	0.86	0.83	0.81	0.79	0.78	0.76	0.75	0.73
2.7	66.38	1.45	1.40	1.34	1.30	1.25	1.22	1.18	1.12	1.07	1.02	0.98	0.95	0.92	0.89	0.87	0.85	0.83	0.82	0.80	0.79
2.8	68.84	1.54	1.49	1.43	1.38	1.33	1.30	1.26	1.19	1.14	1.09	1.05	1.01	0.98	0.95	0.93	0.91	0.89	0.87	0.85	0.84
2.9	71.30	1.64	1.58	1.52	1.47	1.42	1.38	1.34	1.27	1.21	1.16	1.11	1.08	1.04	1.01	0.99	0.97	0.94	0.93	0.91	0.89
3.0	73.76	1.74	1.67	1.61	1.56	1.50	1.46	1.42	1.34	1.28	1.23	1.18	1.14	1.11	1.08	1.05	1.03	1.00	0.98	0.96	0.95
3.1	76.22	1.84	1.77	1.70	1.65	1.59	1.55	1.50	1.42	1.36	1.30	1.25	1.21	1.17	1.14	1.11	1.09	1.06	1.04	1.02	1.01
3.2	78.68	1.94	1.87	1.80	1.74	1.68	1.64	1.59	1.51	1.44	1.38	1.33	1.28	1.24	1.21	1.18	1.15	1.12	1.10	1.08	1.07
3.3	81.14	2.05	1.98	1.90	1.84	1.78	1.73	1.68	1.59	1.52	1.46	1.40	1.35	1.31	1.27	1.24	1.22	1.19	1.17	1.14	1.13
3.4	83.60	2.15	2.08	2.00	1.94	1.87	1.82	1.77	1.68	1.60	1.53	1.48	1.43	1.38	1.34	1.31	1.28	1.25	1.23	1.21	1.19
3.5	86.05	2.27	2.19	2.10	2.04	1.97	1.92	1.86	1.76	1.68	1.61	1.56	1.50	1.46	1.42	1.38	1.35	1.32	1.30	1.27	1.25
3.6	88.51	2.38	2.30	2.21	2.14	2.07	2.01	1.95	1.85	1.77	1.70	1.64	1.58	1.53	1.49	1.45	1.42	1.39	1.36	1.34	1.32
3.7	90.97	2.49	2.41	2.32	2.25	2.17	2.11	2.05	1.95	1.86	1.78	1.72	1.66	1.61	1.56	1.52	1.49	1.46	1.43	1.40	1.38
3.8	93.43	2.61	2.52	2.43	2.35	2.27	2.21	2.15	2.04	1.95	1.87	1.80	1.74	1.69	1.64	1.60	1.56	1.53	1.50	1.47	1.45
3.9	95.89	2.73	2.64	2.54	2.46	2.38	2.32	2.25	2.13	2.04	1.96	1.89	1.82	1.77	1.72	1.68	1.64	1.60	1.58	1.54	1.52
4.0	98.35	2.86	2.76	2.65	2.57	2.49	2.42	2.35	2.23	2.13	2.05	1.97	1.91	1.85	1.80	1.75	1.72	1.68	1.65	1.62	1.59
4.1	100.81	2.98	2.88	2.77	2.69	2.60	2.53	2.45	2.33	2.23	2.14	2.06	1.99	1.93	1.88	1.83	1.79	1.75	1.72	1.69	1.66
4.2	103.27	3.11	3.00	2.89	2.80	2.71	2.64	2.56	2.43	2.32	2.23	2.15	2.08	2.02	1.96	1.91	1.87	1.83	1.80	1.76	1.74
4.3	105.72	3.24	3.13	3.01	2.92	2.83	2.75	2.67	2.54	2.42	2.33	2.24	2.17	2.10	2.05	2.00	1.95	1.91	1.88	1.84	1.81
4.4	108.18	3.37	3.26	3.14	3.04	2.94	2.86	2.78	2.64	2.52	2.42	2.34	2.26	2.19	2.13	2.08	2.03	1.99	1.96	1.92	1.89
4.5	110.64	3.51	3.39	3.26	3.16	3.06	2.98	2.89	2.75	2.63	2.52	2.43	2.35	2.28	2.22	2.16	2.12	2.07	2.04	2.00	1.97
4.6	113.10	3.64	3.52	3.39	3.29	3.18	3.10	3.01	2.86	2.73	2.62	2.53	2.44	2.37	2.31	2.25	2.20	2.16	2.12	2.08	2.05
4.7	115.56	3.78	3.66	3.52	3.42	3.30	3.22	3.12	2.97	2.84	2.72	2.63	2.54	2.47	2.40	2.34	2.29	2.24	2.20	2.16	2.13

Continued on next page

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

4" Uponor PEX-a — 40% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40ºF 4ºC	45ºF 7ºC	50ºF 10ºC	55ºF 13ºC	60ºF 16ºC	65ºF 18ºC	70ºF 21ºC	80ºF 27ºC	90ºF 32ºC	100ºF 38ºC	110ºF 43ºC	120ºF 49ºC	130ºF 54ºC	140ºF 60ºC	150ºF 66ºC	160ºF 71ºC	170ºF 77ºC	180ºF 82ºC	190ºF 88ºC	200ºF 93ºC
4.8	118.02	3.92	3.79	3.65	3.54	3.43	3.34	3.24	3.08	2.94	2.83	2.73	2.64	2.56	2.49	2.43	2.38	2.33	2.29	2.24	2.21
4.9	120.48	4.07	3.93	3.79	3.67	3.55	3.46	3.36	3.19	3.05	2.93	2.83	2.74	2.66	2.58	2.52	2.47	2.41	2.37	2.33	2.30
5.0	122.94	4.21	4.07	3.92	3.81	3.68	3.59	3.48	3.31	3.17	3.04	2.93	2.84	2.75	2.68	2.62	2.56	2.50	2.46	2.41	2.38
5.1	125.39	4.36	4.22	4.06	3.94	3.81	3.71	3.61	3.43	3.28	3.15	3.04	2.94	2.85	2.78	2.71	2.65	2.59	2.55	2.50	2.47
5.2	127.85	4.51	4.36	4.20	4.08	3.95	3.84	3.73	3.55	3.39	3.26	3.15	3.04	2.95	2.87	2.81	2.75	2.69	2.64	2.59	2.55
5.3	130.31	4.66	4.51	4.34	4.22	4.08	3.97	3.86	3.67	3.51	3.37	3.25	3.15	3.06	2.97	2.90	2.84	2.78	2.73	2.68	2.64
5.4	132.77	4.82	4.66	4.49	4.36	4.22	4.11	3.99	3.79	3.63	3.49	3.37	3.26	3.16	3.08	3.00	2.94	2.88	2.83	2.77	2.73
5.5	135.23	4.97	4.81	4.63	4.50	4.35	4.24	4.12	3.92	3.75	3.60	3.48	3.36	3.27	3.18	3.10	3.04	2.97	2.92	2.87	2.83
5.6	137.69	5.13	4.97	4.78	4.65	4.50	4.38	4.25	4.05	3.87	3.72	3.59	3.47	3.37	3.28	3.21	3.14	3.07	3.02	2.96	2.92
5.7	140.15	5.29	5.12	4.93	4.79	4.64	4.52	4.39	4.18	4.00	3.84	3.71	3.59	3.48	3.39	3.31	3.24	3.17	3.12	3.06	3.02
5.8	142.60	5.46	5.28	5.09	4.94	4.78	4.66	4.53	4.31	4.12	3.96	3.82	3.70	3.59	3.50	3.41	3.34	3.27	3.22	3.16	3.11
5.9	145.06	5.62	5.44	5.24	5.09	4.93	4.80	4.66	4.44	4.25	4.08	3.94	3.81	3.70	3.61	3.52	3.45	3.37	3.32	3.26	3.21
6.0	147.52	5.79	5.60	5.40	5.24	5.08	4.95	4.80	4.57	4.38	4.21	4.06	3.93	3.82	3.72	3.63	3.55	3.48	3.42	3.36	3.31
6.1	149.98	5.96	5.77	5.56	5.40	5.23	5.09	4.95	4.71	4.51	4.33	4.18	4.05	3.93	3.83	3.74	3.66	3.58	3.52	3.46	3.41
6.2	152.44	6.13	5.94	5.72	5.56	5.38	5.24	5.09	4.85	4.64	4.46	4.31	4.17	4.05	3.94	3.85	3.77	3.69	3.63	3.56	3.51
6.3	154.90	6.31	6.11	5.88	5.72	5.53	5.39	5.24	4.99	4.77	4.59	4.43	4.29	4.17	4.06	3.96	3.88	3.80	3.73	3.66	3.61
6.4	157.36	6.48	6.28	6.05	5.88	5.69	5.54	5.39	5.13	4.91	4.72	4.56	4.41	4.29	4.17	4.08	3.99	3.91	3.84	3.77	3.72
6.5	159.82	6.66	6.45	6.22	6.04	5.85	5.70	5.54	5.27	5.05	4.85	4.69	4.54	4.41	4.29	4.19	4.10	4.02	3.95	3.88	3.82
6.6	162.27	6.84	6.62	6.38	6.20	6.01	5.85	5.69	5.42	5.19	4.99	4.82	4.66	4.53	4.41	4.31	4.22	4.13	4.06	3.99	3.93
6.7	164.73	7.03	6.80	6.56	6.37	6.17	6.01	5.84	5.56	5.33	5.12	4.95	4.79	4.65	4.53	4.43	4.33	4.24	4.17	4.10	4.04
6.8	167.19	7.21	6.98	6.73	6.54	6.33	6.17	6.00	5.71	5.47	5.26	5.08	4.92	4.78	4.65	4.55	4.45	4.36	4.29	4.21	4.15
6.9	169.65	7.40	7.16	6.90	6.71	6.50	6.33	6.15	5.86	5.61	5.40	5.21	5.05	4.91	4.78	4.67	4.57	4.47	4.40	4.32	4.26
7.0	172.11	7.59	7.35	7.08	6.88	6.66	6.50	6.31	6.01	5.76	5.54	5.35	5.18	5.03	4.90	4.79	4.69	4.59	4.52	4.43	4.37
7.1	174.57	7.78	7.53	7.26	7.06	6.83	6.66	6.47	6.17	5.91	5.68	5.49	5.31	5.16	5.03	4.91	4.81	4.71	4.63	4.55	4.49
7.2	177.03	7.97	7.72	7.44	7.23	7.00	6.83	6.64	6.32	6.06	5.83	5.63	5.45	5.30	5.16	5.04	4.93	4.83	4.75	4.67	4.60
7.3	179.49	8.17	7.91	7.62	7.41	7.18	7.00	6.80	6.48	6.21	5.97	5.77	5.59	5.43	5.29	5.16	5.06	4.95	4.87	4.78	4.72
7.4	181.94	8.36	8.10	7.81	7.59	7.35	7.17	6.97	6.64	6.36	6.12	5.91	5.72	5.56	5.42	5.29	5.18	5.08	4.99	4.90	4.84
7.5	184.40	8.56	8.29	8.00	7.77	7.53	7.34	7.14	6.80	6.51	6.27	6.05	5.86	5.70	5.55	5.42	5.31	5.20	5.12	5.02	4.95
7.6	186.86	8.76	8.49	8.19	7.96	7.71	7.51	7.30	6.96	6.67	6.42	6.20	6.00	5.84	5.68	5.55	5.44	5.33	5.24	5.15	5.07
7.7	189.32	8.97	8.69	8.38	8.14	7.89	7.69	7.48	7.13	6.83	6.57	6.35	6.15	5.97	5.82	5.69	5.57	5.45	5.37	5.27	5.20
7.8	191.78	9.17	8.89	8.57	8.33	8.07	7.87	7.65	7.29	6.99	6.72	6.50	6.29	6.11	5.96	5.82	5.70	5.58	5.49	5.39	5.32
7.9	194.24	9.38	9.09	8.76	8.52	8.25	8.05	7.82	7.46	7.15	6.88	6.65	6.44	6.26	6.09	5.96	5.83	5.71	5.62	5.52	5.44
8.0	196.70	9.59	9.29	8.96	8.71	8.44	8.23	8.00	7.63	7.31	7.04	6.80	6.58	6.40	6.23	6.09	5.97	5.84	5.75	5.65	5.57

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

4" Uponor PEX-a — 50% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
1.5	36.88	0.59	0.57	0.54	0.52	0.50	0.49	0.47	0.44	0.42	0.39	0.38	0.36	0.35	0.34	0.33	0.32	0.31	0.30	0.29	0.29
1.6	39.34	0.66	0.63	0.61	0.58	0.56	0.54	0.52	0.49	0.46	0.44	0.42	0.41	0.39	0.38	0.37	0.36	0.35	0.34	0.33	0.32
1.7	41.80	0.73	0.70	0.67	0.65	0.62	0.60	0.58	0.55	0.52	0.49	0.47	0.45	0.43	0.42	0.41	0.40	0.39	0.38	0.37	0.36
1.8	44.26	0.81	0.78	0.74	0.71	0.69	0.66	0.64	0.60	0.57	0.54	0.52	0.50	0.48	0.46	0.45	0.44	0.43	0.42	0.41	0.40
1.9	46.72	0.89	0.85	0.81	0.78	0.75	0.73	0.70	0.66	0.63	0.60	0.57	0.55	0.53	0.51	0.50	0.48	0.47	0.46	0.45	0.44
2.0	49.17	0.97	0.93	0.89	0.86	0.82	0.80	0.77	0.72	0.68	0.65	0.62	0.60	0.58	0.56	0.54	0.53	0.51	0.50	0.49	0.48
2.1	51.63	1.05	1.01	0.96	0.93	0.89	0.87	0.84	0.79	0.75	0.71	0.68	0.65	0.63	0.61	0.59	0.58	0.56	0.55	0.54	0.52
2.2	54.09	1.14	1.09	1.04	1.01	0.97	0.94	0.91	0.85	0.81	0.77	0.74	0.71	0.68	0.66	0.64	0.62	0.61	0.59	0.58	0.57
2.3	56.55	1.23	1.18	1.13	1.09	1.05	1.01	0.98	0.92	0.87	0.83	0.80	0.77	0.74	0.72	0.69	0.68	0.66	0.64	0.63	0.62
2.4	59.01	1.32	1.27	1.21	1.17	1.13	1.09	1.05	0.99	0.94	0.90	0.86	0.83	0.80	0.77	0.75	0.73	0.71	0.69	0.68	0.67
2.5	61.47	1.41	1.36	1.30	1.26	1.21	1.17	1.13	1.07	1.01	0.96	0.92	0.89	0.86	0.83	0.81	0.78	0.76	0.75	0.73	0.72
2.6	63.93	1.51	1.45	1.39	1.34	1.29	1.25	1.21	1.14	1.08	1.03	0.99	0.95	0.92	0.89	0.86	0.84	0.82	0.80	0.78	0.77
2.7	66.38	1.61	1.55	1.48	1.43	1.38	1.34	1.29	1.22	1.16	1.10	1.06	1.02	0.98	0.95	0.92	0.90	0.88	0.86	0.84	0.82
2.8	68.84	1.72	1.65	1.58	1.53	1.47	1.43	1.38	1.30	1.23	1.18	1.13	1.08	1.05	1.01	0.98	0.96	0.93	0.91	0.89	0.88
2.9	71.30	1.82	1.75	1.68	1.62	1.56	1.51	1.46	1.38	1.31	1.25	1.20	1.15	1.11	1.08	1.05	1.02	0.99	0.97	0.95	0.93
3.0	73.76	1.93	1.86	1.78	1.72	1.66	1.61	1.55	1.47	1.39	1.33	1.27	1.23	1.18	1.15	1.11	1.08	1.06	1.03	1.01	0.99
3.1	76.22	2.04	1.97	1.88	1.82	1.75	1.70	1.64	1.55	1.47	1.41	1.35	1.30	1.25	1.21	1.18	1.15	1.12	1.09	1.07	1.05
3.2	78.68	2.16	2.08	1.99	1.92	1.85	1.80	1.74	1.64	1.56	1.49	1.43	1.37	1.33	1.28	1.25	1.22	1.19	1.16	1.14	1.11
3.3	81.14	2.27	2.19	2.10	2.03	1.95	1.90	1.83	1.73	1.64	1.57	1.51	1.45	1.40	1.36	1.32	1.28	1.25	1.22	1.20	1.18
3.4	83.60	2.39	2.31	2.21	2.14	2.06	2.00	1.93	1.82	1.73	1.66	1.59	1.53	1.48	1.43	1.39	1.35	1.32	1.29	1.27	1.24
3.5	86.05	2.52	2.42	2.32	2.25	2.16	2.10	2.03	1.92	1.82	1.74	1.67	1.61	1.55	1.51	1.46	1.43	1.39	1.36	1.33	1.31
3.6	88.51	2.64	2.54	2.44	2.36	2.27	2.21	2.13	2.02	1.92	1.83	1.76	1.69	1.63	1.58	1.54	1.50	1.46	1.43	1.40	1.38
3.7	90.97	2.77	2.67	2.56	2.47	2.38	2.31	2.24	2.12	2.01	1.92	1.84	1.78	1.72	1.66	1.62	1.58	1.54	1.50	1.47	1.44
3.8	93.43	2.90	2.79	2.68	2.59	2.50	2.42	2.35	2.22	2.11	2.01	1.93	1.86	1.80	1.74	1.70	1.65	1.61	1.58	1.55	1.52
3.9	95.89	3.03	2.92	2.80	2.71	2.61	2.54	2.45	2.32	2.21	2.11	2.02	1.95	1.88	1.83	1.78	1.73	1.69	1.65	1.62	1.59
4.0	98.35	3.17	3.05	2.93	2.83	2.73	2.65	2.57	2.43	2.31	2.20	2.12	2.04	1.97	1.91	1.86	1.81	1.77	1.73	1.69	1.66
4.1	100.81	3.30	3.19	3.06	2.96	2.85	2.77	2.68	2.53	2.41	2.30	2.21	2.13	2.06	2.00	1.94	1.89	1.85	1.80	1.77	1.74
4.2	103.27	3.45	3.32	3.19	3.08	2.97	2.89	2.79	2.64	2.51	2.40	2.31	2.22	2.15	2.08	2.03	1.98	1.93	1.88	1.85	1.81
4.3	105.72	3.59	3.46	3.32	3.21	3.10	3.01	2.91	2.75	2.62	2.51	2.41	2.32	2.24	2.17	2.11	2.06	2.01	1.97	1.93	1.89
4.4	108.18	3.73	3.60	3.46	3.34	3.22	3.13	3.03	2.87	2.73	2.61	2.51	2.41	2.34	2.26	2.20	2.15	2.10	2.05	2.01	1.97
4.5	110.64	3.88	3.74	3.59	3.48	3.35	3.26	3.15	2.98	2.84	2.71	2.61	2.51	2.43	2.36	2.29	2.23	2.18	2.13	2.09	2.05
4.6	113.10	4.03	3.89	3.73	3.61	3.48	3.39	3.28	3.10	2.95	2.82	2.71	2.61	2.53	2.45	2.38	2.32	2.27	2.22	2.18	2.14
4.7	115.56	4.18	4.04	3.87	3.75	3.62	3.52	3.40	3.22	3.07	2.93	2.82	2.72	2.63	2.55	2.48	2.42	2.36	2.31	2.26	2.22

Continued on next page

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

4" Uponor PEX-a — 50% Propylene glycol — feet of head per 100 feet of piping

Velocity (ft./sec.)	GPM	40°F 4°C	45°F 7°C	50°F 10°C	55°F 13°C	60°F 16°C	65°F 18°C	70°F 21°C	80°F 27°C	90°F 32°C	100°F 38°C	110°F 43°C	120°F 49°C	130°F 54°C	140°F 60°C	150°F 66°C	160°F 71°C	170°F 77°C	180°F 82°C	190°F 88°C	200°F 93°C
4.8	118.02	4.34	4.19	4.02	3.89	3.75	3.65	3.53	3.34	3.18	3.04	2.92	2.82	2.73	2.64	2.57	2.51	2.45	2.39	2.35	2.31
4.9	120.48	4.50	4.34	4.17	4.03	3.89	3.78	3.66	3.47	3.30	3.16	3.03	2.92	2.83	2.74	2.67	2.60	2.54	2.48	2.44	2.39
5.0	122.94	4.66	4.49	4.32	4.18	4.03	3.92	3.79	3.59	3.42	3.27	3.14	3.03	2.93	2.84	2.77	2.70	2.63	2.58	2.53	2.48
5.1	125.39	4.82	4.65	4.47	4.33	4.17	4.06	3.93	3.72	3.54	3.39	3.26	3.14	3.04	2.95	2.87	2.80	2.73	2.67	2.62	2.57
5.2	127.85	4.99	4.81	4.62	4.48	4.32	4.20	4.06	3.85	3.66	3.51	3.37	3.25	3.14	3.05	2.97	2.89	2.83	2.76	2.71	2.66
5.3	130.31	5.15	4.97	4.78	4.63	4.46	4.34	4.20	3.98	3.79	3.63	3.49	3.36	3.25	3.16	3.07	3.00	2.92	2.86	2.81	2.76
5.4	132.77	5.32	5.14	4.93	4.78	4.61	4.48	4.34	4.11	3.92	3.75	3.60	3.48	3.36	3.26	3.18	3.10	3.02	2.96	2.90	2.85
5.5	135.23	5.49	5.30	5.10	4.94	4.76	4.63	4.48	4.25	4.05	3.87	3.72	3.59	3.48	3.37	3.28	3.20	3.13	3.06	3.00	2.95
5.6	137.69	5.67	5.47	5.26	5.09	4.92	4.78	4.63	4.39	4.18	4.00	3.84	3.71	3.59	3.48	3.39	3.31	3.23	3.16	3.10	3.04
5.7	140.15	5.85	5.64	5.42	5.25	5.07	4.93	4.78	4.53	4.31	4.13	3.97	3.83	3.70	3.59	3.50	3.41	3.33	3.26	3.20	3.14
5.8	142.60	6.03	5.82	5.59	5.42	5.23	5.08	4.92	4.67	4.45	4.26	4.09	3.95	3.82	3.71	3.61	3.52	3.44	3.36	3.30	3.24
5.9	145.06	6.21	5.99	5.76	5.58	5.39	5.24	5.07	4.81	4.58	4.39	4.22	4.07	3.94	3.82	3.72	3.63	3.55	3.47	3.41	3.34
6.0	147.52	6.39	6.17	5.93	5.75	5.55	5.39	5.23	4.95	4.72	4.52	4.35	4.19	4.06	3.94	3.84	3.74	3.66	3.58	3.51	3.45
6.1	149.98	6.58	6.35	6.10	5.92	5.71	5.55	5.38	5.10	4.86	4.65	4.48	4.32	4.18	4.06	3.95	3.85	3.77	3.68	3.62	3.55
6.2	152.44	6.77	6.53	6.28	6.09	5.88	5.71	5.54	5.25	5.00	4.79	4.61	4.45	4.30	4.18	4.07	3.97	3.88	3.79	3.72	3.66
6.3	154.90	6.96	6.72	6.46	6.26	6.04	5.88	5.70	5.40	5.15	4.93	4.74	4.58	4.43	4.30	4.19	4.08	3.99	3.90	3.83	3.76
6.4	157.36	7.15	6.91	6.64	6.44	6.21	6.04	5.86	5.55	5.29	5.07	4.88	4.71	4.56	4.42	4.31	4.20	4.10	4.02	3.94	3.87
6.5	159.82	7.35	7.10	6.82	6.61	6.39	6.21	6.02	5.71	5.44	5.21	5.01	4.84	4.68	4.55	4.43	4.32	4.22	4.13	4.06	3.98
6.6	162.27	7.54	7.29	7.01	6.79	6.56	6.38	6.18	5.86	5.59	5.35	5.15	4.97	4.81	4.67	4.55	4.44	4.34	4.25	4.17	4.09
6.7	164.73	7.74	7.48	7.19	6.97	6.73	6.55	6.35	6.02	5.74	5.50	5.29	5.11	4.95	4.80	4.67	4.56	4.46	4.36	4.28	4.21
6.8	167.19	7.95	7.68	7.38	7.16	6.91	6.72	6.52	6.18	5.89	5.65	5.43	5.24	5.08	4.93	4.80	4.69	4.58	4.48	4.40	4.32
6.9	169.65	8.15	7.87	7.57	7.34	7.09	6.90	6.69	6.34	6.05	5.79	5.58	5.38	5.21	5.06	4.93	4.81	4.70	4.60	4.52	4.44
7.0	172.11	8.36	8.08	7.77	7.53	7.27	7.07	6.86	6.51	6.20	5.95	5.72	5.52	5.35	5.19	5.06	4.94	4.82	4.72	4.64	4.55
7.1	174.57	8.57	8.28	7.96	7.72	7.46	7.25	7.03	6.67	6.36	6.10	5.87	5.66	5.49	5.33	5.19	5.06	4.95	4.84	4.76	4.67
7.2	177.03	8.78	8.48	8.16	7.91	7.64	7.43	7.21	6.84	6.52	6.25	6.02	5.81	5.63	5.46	5.32	5.19	5.07	4.97	4.88	4.79
7.3	179.49	8.99	8.69	8.36	8.11	7.83	7.62	7.39	7.01	6.68	6.41	6.16	5.95	5.77	5.60	5.45	5.32	5.20	5.09	5.00	4.91
7.4	181.94	9.21	8.90	8.56	8.30	8.02	7.80	7.57	7.18	6.85	6.56	6.32	6.10	5.91	5.74	5.59	5.45	5.33	5.22	5.12	5.03
7.5	184.40	9.43	9.11	8.76	8.50	8.21	7.99	7.75	7.35	7.01	6.72	6.47	6.25	6.05	5.88	5.72	5.59	5.46	5.35	5.25	5.16
7.6	186.86	9.65	9.32	8.97	8.70	8.41	8.18	7.93	7.53	7.18	6.88	6.62	6.40	6.20	6.02	5.86	5.72	5.59	5.48	5.38	5.28
7.7	189.32	9.87	9.54	9.18	8.90	8.60	8.37	8.12	7.70	7.35	7.04	6.78	6.55	6.34	6.16	6.00	5.86	5.73	5.61	5.51	5.41
7.8	191.78	10.09	9.76	9.39	9.11	8.80	8.56	8.30	7.88	7.52	7.21	6.94	6.70	6.49	6.31	6.14	6.00	5.86	5.74	5.64	5.54
7.9	194.24	10.32	9.98	9.60	9.31	9.00	8.76	8.49	8.06	7.69	7.37	7.10	6.86	6.64	6.45	6.28	6.14	6.00	5.87	5.77	5.66
8.0	196.70	10.55	10.20	9.81	9.52	9.20	8.95	8.68	8.24	7.87	7.54	7.26	7.01	6.79	6.60	6.43	6.28	6.13	6.01	5.90	5.79

Recommended head loss design range

5.5 ft./sec. is an industry standard for velocity limit in hydronic distribution systems.

Velocities in excess of 8 ft./sec. may cause erosion to metal components in the system.

Appendix H:

Helpful formulas

Computing flow from BTU/h	
Simplified formula	GPM = BTU/h ÷ (Δt x 500)
Example: Determine the flow of 286,000 BTU/h at a 20°F differential temperature.	GPM = 286,000 ÷ (20 x 500) GPM = 286,000 ÷ 10,000 GPM = 28.6

Calculating active loop length	
Note: The leader length must be added to the active loop length in order to obtain the total loop length.	Room ft^2 x 1.0 = active loop at 12" o.c. Room ft^2 x 1.2 = active loop at 10" o.c. Room ft^2 x 1.33 = active loop at 9" o.c. Room ft^2 x 1.5 = active loop at 8" o.c. Room ft^2 x 1.7 = active loop at 7" o.c. Room ft^2 x 2.0 = active loop at 6" o.c.

Amount of Joist Trak™ panels (A5080375, A5080500)
Active loop length x 0.2125
Amount of Quik Trak® panels (A5060701) and returns (A5060702)
Room ft^2 x 0.386 (panels) Room ft^2 x 0.043 (returns)
Amount of PEX clips (F7060375, F7051258, F7057500, F7051001)
Active Loop Length ÷ 3
Floor surface temperature
(BTU/h/ft^2 ÷ 2.0) + Room setpoint

Supply fluid temp. after first injection point on primary loop	
$(F_A \times T_A) + (F_B \times T_B) = (F_C \times T_C)$	
F_A = Primary flow rate after injection leg F_B = Flow rate for return injection leg F_C = Primary flow rate after return leg T_A = Primary temp. after injection leg T_B = Return temp. on return injection leg T_C = Primary temp. after return leg	
Example: Given the detail above, calculate the primary loop (boiler loop) temperature after the first injection location.	(7 x 180) + (3 x 160) = 10x 1260 + 480 = 10x 1740 = 10x 174 = x The primary loop temperature after the first injection location is 174°F.

Injection pump flow rates	
Refer to **Appendix I** for more information $F_V = (F_1 \times T_D) \div (T_1 - T_R)$	
F_V = Flow rate (injection loop) in gpm F_1 = Radiant (secondary loop) flow rate in gpm T_1 = Boiler (primary loop) supply temp. T_2 = Radiant (secondary loop) supply temp. T_R = Radiant (secondary loop) return temp. T_D = Radiant (secondary loop) differential temp.	
Example: If values at design condition are: F_1 = 30 gpm T_1 = 180°F T_2 = 130°F T_R = 120°F T_D = 10°F	Find the injection pump flow rate. F_V = (30 x 10) ÷ (180-120) F_V = (300) ÷ (60) F_V = 5 gpm

Appendix H:
Helpful formulas

Fuel consumption based on degree day:

$$F = \frac{HL \times 24 \times DD}{E \times P \times TD}$$

HL= Heating load (BTU/h)

24 = Hours in a day

DD = Degree day

E = Boiler efficiency (AFUE)

P = Heating value of fuel (BTU)

TD= Temperature differential

F = Annual fuel consumption

Example: A 40,000-square- foot hangar in Bangor, Maine using an 82% AFUE oil boiler (Number 2 fuel oil). The heat load for the hangar is 1,288,128 BTU/h at design. Outside design temperature is -11°F with an indoor setpoint temperature of 65°F. Number 2 fuel oil is priced at $0.80 per gallon.

$$F = \frac{1{,}288{,}128 \times 24 \times 8{,}220}{0.82 \times 138{,}000 \times 76}$$

$$F = \frac{254{,}121{,}891.840}{8{,}662{,}480}$$

F = 29,335.93 gallons of fuel oil

F = 29,335.93 x 0.80 = $23,469/ season

Loadng for Thermal Actuators (TA) Computed at a minimum 10% line loss
TA initial draw: 0.1458 amps Amps x volts = current 0.1458 x 24 = 3.5 VA per TA
Example: 50 VA ÷ 3.5 VA = 14.29 14.29 x 0.9 = 12.83 (10% reduction) 12 TAs per 50 VA transformer 40VAC transformer = 10 TA 50VAC transformer = 12 TA 75VAC transformer = 19 TA 100VAC transformer = 25 TA

Fuel comparison in BTU

Natural gas	100,000 BTU per 1 CCF (1 therm.)
Propane	91,800 BTU per gallon
No. 2 fuel oil	139,000 BTU per gallon
Kerosene	134,000 BTU per gallon
Electric	3,412 BTU per Kilowatt Hour (KWH)
Wood	14,000,000 BTU per cord (mixed)

Supply and return pipe sizing (at a 10ºF Δt)

Piping	BTU/h	GPM	Pipe size (in.)
Copper	10K – 20K	2 – 4	¾"
	20K – 45K	4 – 9	1"
	30K – 80K	6 – 16	1¼"
	50K – 105K	10 – 21	1½
	100K – 225K	20 – 45	2""
PEX (Wirsbo hePEX™ and Uponor AquaPEX®)	2.5K – 10K	0.5 – 2	½"
	5K – 15K	1 – 3	¾"
	15K – 25K	3 – 5	1"
	20K – 45K	4 – 9	1¼"
	30K – 70K	6 – 14	1½
High-density Polyethylene (HDPE)	75K – 205K	15 – 41	2"
	150K – 575K	30 – 115	3"
	250K – 1,125K	50 – 225	4"

Boiler main pipe sizing (at a 20ºF Δt)

Piping	BTU/h	GPM	Pipe size (in.)
Copper	20K – 40K	2 – 4	¾"
	40K – 90K	4 – 9	1"
	60K – 160K	6 – 16	1¼"
	100K – 210K	10 – 21	1½"
	200K – 450K	20 – 45	2"

Appendix I:

Variable-speed injection mixing

This appendix outlines the use of variable-speed injection mixing to precisely transfer heat from the high-temperature boiler (primary) loop to the lower-temperature radiant (secondary) loop in hydronic heating systems.

Various devices and plumbing arrangements can be used to accomplish this transfer. In the past, it was common to use a mixing valve in order to temper the water between the primary and secondary loops in a system. In some instances, the heat source (condensing or electric boiler, geothermal heat pump, etc.) can be operated at lower temperatures and dedicated solely to operating a low-temperature radiant heating system. In the vast majority of systems, mixing is required because of one or more of the following:

- A boiler minimum operating temperature is required.
- High temperature water is required for other system needs.
- Water temperatures vary over a wide range (e.g. solar heat sources, waste heat utilization, wood fired boilers, etc.).

When the available heat source produces higher water temperatures than is required by the radiant heating system, a tempering device is required. To achieve the lower water temperature required for the radiant system, the high- temperature boiler water must be blended or injected into the return side of the radiant system to a level that meets the required supply water temperature for the radiant side. Technologies have evolved to the point of using small wet-rotor pumps to accurately adjust the secondary radiant supply water temperature regardless of the flow activities on either primary or secondary loops (see **Figure I-1**).

The speed of the injection pump is automatically adjusted to deliver the desired volume of hot boiler water to the lower-temperature radiant loop. The injection pump speed is constantly adjusted as the radiant heating system demand and the supply water temperature change. If the boiler return temperature becomes too cold, the injection pump can be lowed down to reduce the heat injection rate, resulting in an increased boiler return temperature.

Uponor offers a variety of controls that use variable-speed injection pump output. This output modulates the power supply to the circulator to vary its rotational speed. For residential and many commercial systems, the controls have a 120VAC 50/60Hz output to directly power small circulators.

A permanent-capacitor, impedance-protected motor (no start switch) on the circulator is required. The maximum allowable amperage for this output is 2.2 amps, which limits the allowable circulator size to ⅙ hp.

This type of system can use a small circulator to inject a high BTU/h input into a relatively large system flow. Typically, the injection pump only needs to deliver ⅙ to ¼ of the system flow for low- temperature radiant panels if high- temperature water is available for injection. In small hydronic systems, the smallest available circulator for variable-speed injection may be too large. It is important to properly size the injection pump and use a globe valve on the return injection leg.

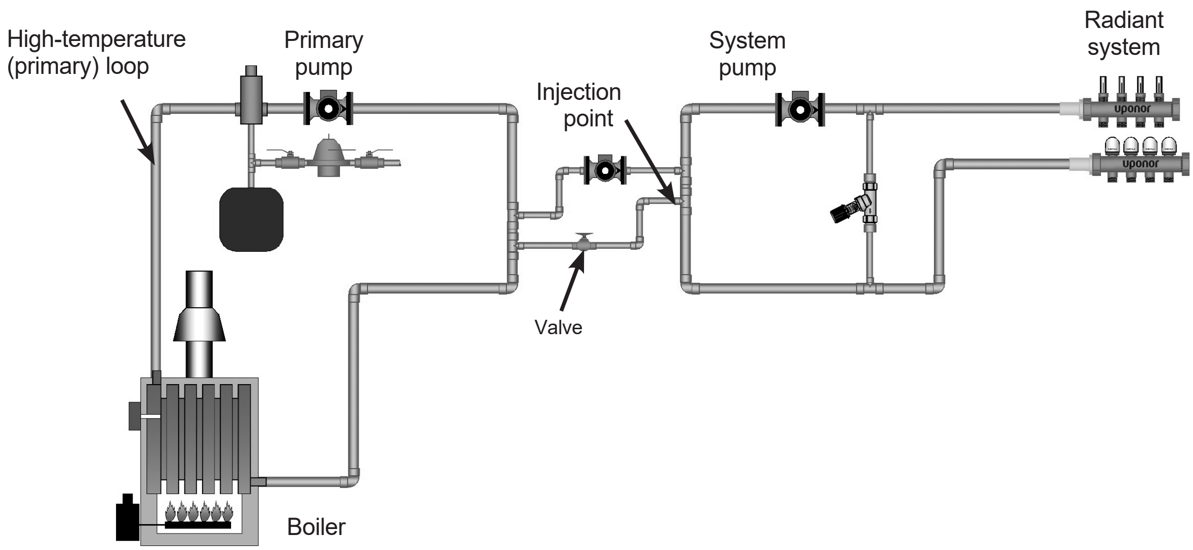


Figure I-1: Mixing with variable-speed pump

For proper injection pump sizing, the designer must know the following information (see **Figure I-2**).

F_V = Flow rate (injection loop) in gpm

F_1 = Radiant (secondary loop) flow rate in gpm

T_1 = Boiler (primary loop) supply temperature

T_2 = Radiant (secondary loop) supply temperature

T_R = Radiant (secondary loop) return temperature

T_D = Radiant (secondary loop) temperature differential ($T_2 - T_R$)

Note: All values are to be given at design conditions.
The formula used for sizing the injection pump is shown below.

$F_V = (F_1 \times T_D) / (T_1 - T_R)$

Example:
If values at design conditions are:

F_1 = Radiant (secondary) flow = 30 gpm

T_1 = Boiler (primary) supply = 180°F

T_2 = Radiant (secondary) supply = 140°F

T_R = Radiant (secondary) return = 120°F

T_D = Radiant (secondary) differential = 20°F

To find the injection pump flow rate:

$F_V = (30 \times 20) / (180 - 120)$

$F_V = (600) / (60)$

F_V = 10 gpm

In order to provide the proper amount and temperature of supply water on the radiant heating loop, the variable-speed injection pump needs only to inject 10 gpm at design conditions.

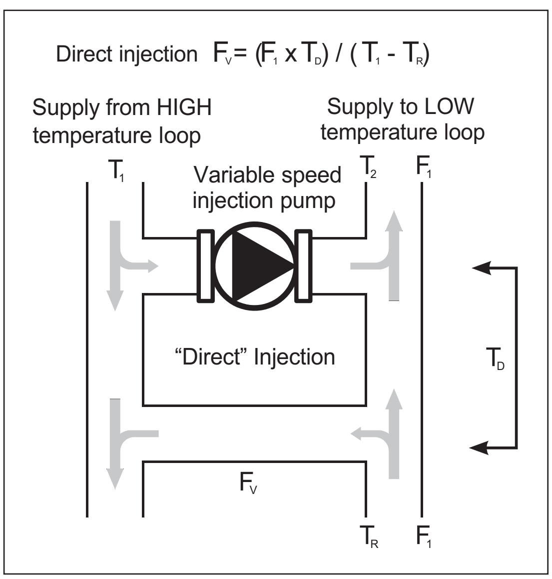


Figure I-2: Direct injection mixing (F_V Formula)

Figures I-3 and I-4 show the two most common piping layouts for variable-speed injection mixing. Pay particular attention to the drop lines (or thermal traps) shown in the injection legs. These are particularly important to prevent ”thermal siphoning“ from the primary loop into the secondary loop. Consult the pump manufacturers’ chart (below) to assist in the selection of the proper injection pump for the project.

In the piping arrangement shown, the variable-speed injection pumps are plumbed this way to limit head pressure in the injection legs to only a few feet at most. Use standard pressure drop calculations and equivalent length of feet charts for exact calculations, if required.

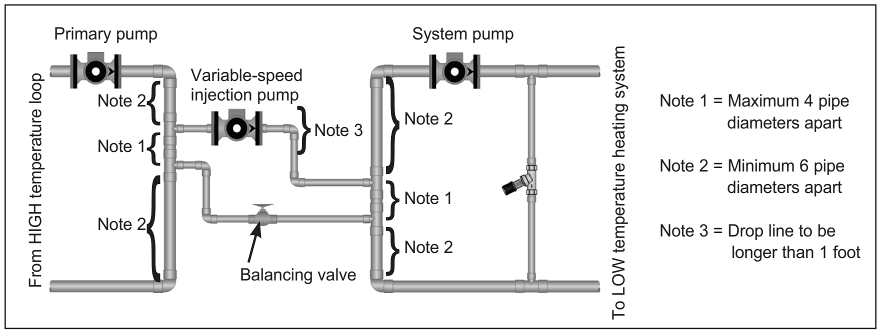


Figure I-3: Injection into a horizontal loop

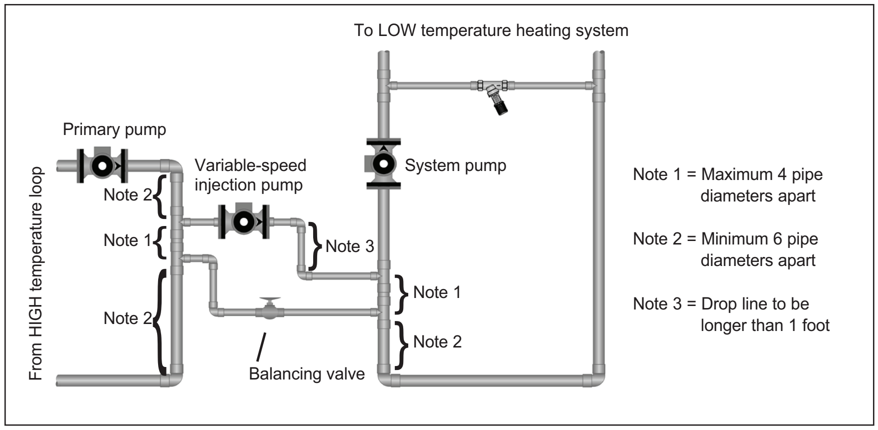


Figure I-4: Injection into a vertical loop

Variable-speed injection design flow rates

Design injection without globe valve	Flow rate (gpm) with globe valve	Turns open of the globe valve (%)	Nominal pipe diameter (inches)	Manufactured approved pump models												
				Grunfos (F)				Taco				B&G			Armstrong	
				15-42											Astro	
				2*	3**	26-64	43-75	003	007	0010	0012	NRF 9	NRF 22	NRF 33	30	50
-	1.5	20	0.5	X	X				X				X		X	
2.5	2	100	0.5					X								
4-5.5	3.0-4.5	100	0.5	X	X				X			X	X		X	
4.5-6.5	4-5.5	100	0.75					X				X				
9-10.5	7.5-8.5	100	0.75		X				X				X		X	
9	8	100	1									X				
14-15	12-13	100	1		X				X				X			
19	17	100	1.25													X
22-24	19-21	100	1.25			X				X				X		
26-28	-	100	1.5			X				X				X		
35-37	31-32	100	1.5				X				X					
33	30	100	2											X		
41-45	39-42	100	2				X				X					

*Speed 2
**Speed 3 (Brute)
Table courtesy of Tekmar®. This table assumes 5 feet of pipe, four elbows and branch trees of the listed diameter. These circulators have been tested and approved by the manufacturers for use with the Uponor controls.

Table I-1: Variable-speed injection design flow rates

Notes

Appendix J:
Circulator placement options

In any hydronic system, the location of the circulator can dramatically impact the operation. Proper circulator location relative to the expansion tank is most critical in commercial applications, but can also impact residential jobs.

Most residential boilers come packaged with the circulator piped on the "return," pumping into the boiler as shown in **Figure J-1**. Although manufacturers package the boilers to make shipping easier and less expensive, there are no performance advantages to locating the circulator on the return. **Figure J-2** shows the circulator located on the supply, pumping away from the expansion tank. This circulator location promotes a quiet and reliable system operation, eliminates potential air problems and can extend circulator life because of the circulator's location in relation to the system's "point of no pressure change."

The point of no pressure change is where the expansion tank connects to the system piping in a closed-loop hydronic system. It's the one place in the heating system where the circulator cannot change the system's pressure.

When a system is first filled, water is added to the system until the desired pressure, usually 12 psi, is reached. This pressure comes from the air cushion in the expansion tank pushing against the water.

Since air is compressible and water is not, the only way to change the system pressure at that point is to either add or remove water from the expansion tank. Because the system is completely filled with a fixed amount of water, the circulator cannot add or remove water from the expansion tank, and therefore cannot alter system pressure at that point. The two ways to change system pressure are to add more water through the fill valve or heat the water, causing it to expand. The circulator can do neither of these.

Part of a circulator's job is to create pressure differential to help overcome the friction, or "head loss" in a system. When placed on the supply, pumping away from the expansion tank, the circulator can add its pressure differential to a system. Water under higher pressure is better able to absorb air bubbles, promoting even flow and quiet operation, and preventing possible cavitation of the circulator.

When placed on the return, pumping into the expansion tank, a circulator cannot add its pressure differential to a system because of its position relative to the point of no pressure change. Therefore, to create flow, the circulator would show its pressure differential as a negative on its suction side, dropping system pressure. As a result, the system water will be less able to hold air bubbles in solution, creating gurgling sounds and uneven flow. In addition, the circulator will labor and cavitation is likely, shortening the circulator's life.

So where should the circulator be located? Commercially, **Figure J-2** is the preferred piping arrangement. Residentially, **Figure J-1** is generally acceptable, especially if the boiler circulator comes prepackaged with the boiler from the manufacturer. However, if some of the symptoms previously described occur, shifting the circulator to the supply as shown in **Figure J-2** may solve the problem.

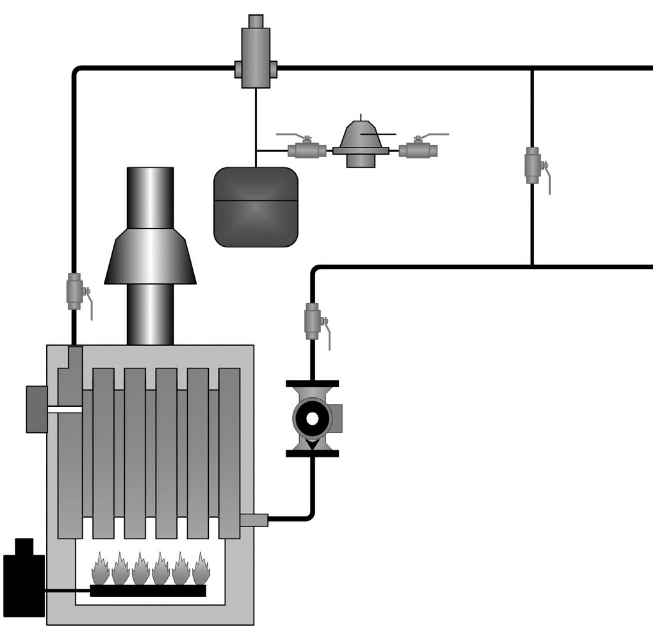


Figure J-1 : Circulator on supply piping

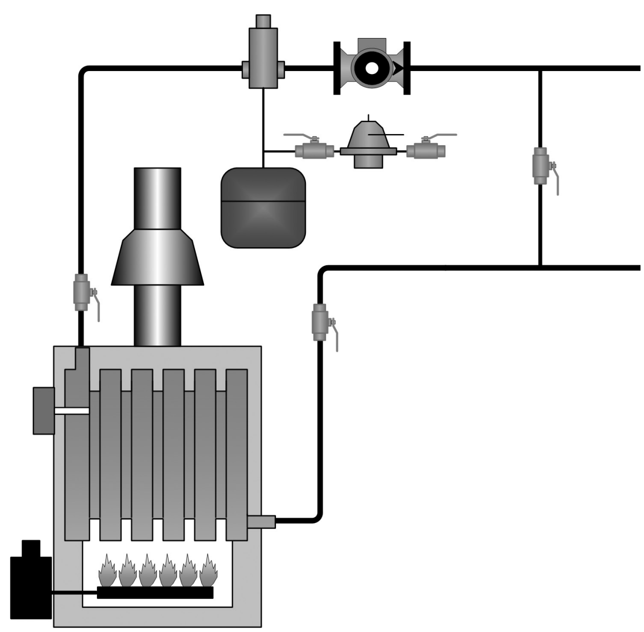


Figure J-2 : Circulator on return piping

Notes

Appendix K:
Conversion factors

To convert from	To	Multiply by
Pressure		
Atmospheres	feet of water	33.9
Atmospheres	mm of mercury	760.0
Atmospheres	pounds/square inch	14.696
Inches of mercury (32°F)	pounds/square inch	0.4335
Inches of mercury (32°F)	pounds/square inch	0.03614
Inches of water (40°F)	pounds/square inch	0.1934
mm of mercury (32°F)	feet of water (40°F)	2.3066
Pounds/square inch	feet of water (40°F)	0.1934
Pounds/square inch	inches of mercury (32°F)	2.3066
Volume		
Barrels (oil)	gallons	42.0
Barrels (brewery)	gallons	31.0
Cubic cm	cubic inches	0.061023
Cubic feet	cubic inches	1728.0
Cubic feet	cubic meters	0.02832
Cubic feet	gallons	7.481
Cubic meters	gallons	264.17
Gallons	cubic feet	0.1337
Gallons	cubic inches	231.0
Gallons	gallons (British)	0.83268
Gallons	liters	3.7853
Liters	gallons	0.2642
Liters	quarts	1.0567
Heat		
Boiler horsepower (BHP)	BTU/h	33479.0
BTU/h	calories (gram)	252.0
BTU/h	calories (kg.)	0.252
Calories (gram) gram/°C	BTU/lb/°F	1.0
Calories (gram) per gram	BTU/lb	1.8
Horsepower	BTU/h	2545.0
kW hours	BTU	3413.0

To convert from	To	Multiply by
Temperature		
Celsius degrees	Fahrenheit degrees	1.8 and add 32°
Fahrenheit degrees	Celsius degrees	Subtract 32° and multiply by 0.5555
Measurement		
Centimeters	inches	0.3937
Feet	meters	0.3048
Inches	centimeters	2.54
Kilometers	miles	0.6214
Meters	feet	3.2808
Microns	millimeters	0.001
Square meters	square feet	10.764
Weight		
Cubic feet of water (60°F)	pounds	62.37
Gallons	pounds of water (60°F)	8.34
Kilograms	pounds	2.2046
Pounds	grams	453.59
Pounds	kilograms	0.4536
Ton (long)	tons (short)	1.12
Volumetric rate		
Cubic feet/second	gallons/minute	448.83
Gallons/minute	cubic feet/second	0.00223
Power		
Horsepower	feet pounds/second	555.0
Horsepower	kW	0.745
Viscosity		
Centipoises	pounds/second/feet	0.000672
Poises	centipoises	0.01
Velocity		
Feet/second	meters/second	0.3048
Meters/second	feet/second	3.2808

Notes

Uponor Inc.
5925 148th Street West
Apple Valley, MN 55124
USA

T 800.321.4739
F 952.891.2008

Uponor Ltd.
6510 Kennedy Road
Mississauga, ON L5T 2X4
CANADA

T 888.994.7726
F 800.638.9517

uponor

uponor.com

CDAM_1023, Copyright © 2023 Uponor. Printed in the United States.