

uponor

RADIANT HEATING
AND COOLING SYSTEMS

COMPLETE DESIGN ASSISTANCE MANUAL (CDAM)



Uponor Complete Design Assistance Manual (CDAM)

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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) tubing, 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 radiant heating and cooling systems, and it assists the reader with specification, design, installation and inspection of Uponor hydronic radiant floor, ceiling and wall heating and cooling systems. Please contact Uponor for additional technical information about radiant cooling and design.

Through their versatility, Uponor hydronic heating and cooling systems are used in a variety of applications. Please direct any questions about the suitability of an application or a specific design to a local Uponor representative by calling toll free 800.321.4729 (United States) or 888.994.7726 (Canada).

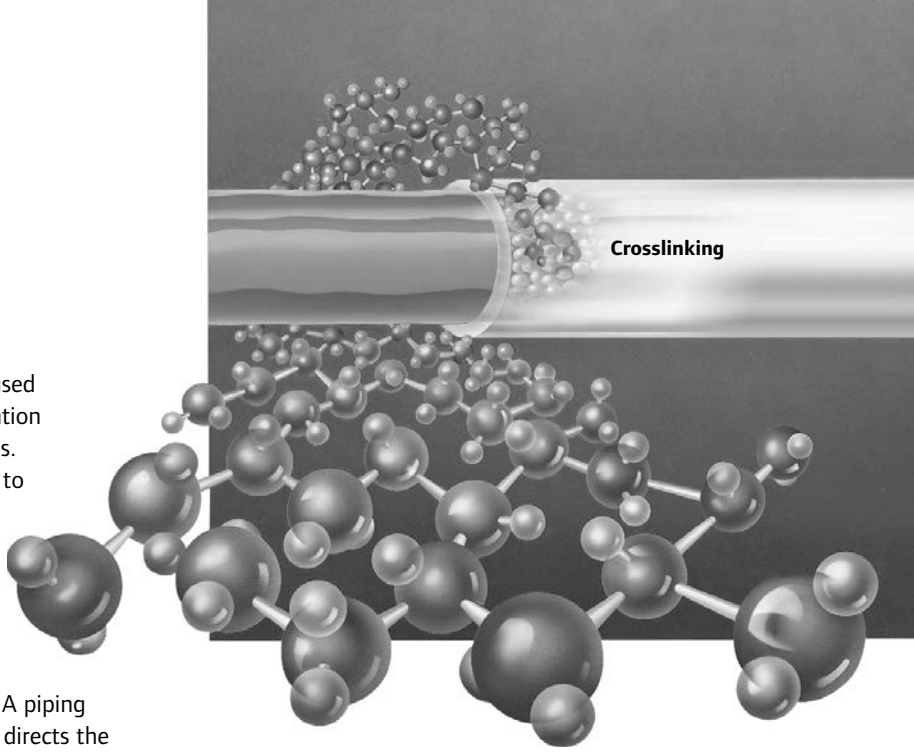
In addition to the CDAM, Uponor provides:

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- Design services
- Customer support

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



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 tubing 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) tubing. 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 tubing 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 tubing 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 tubing installed.

Olefins — Unsaturated hydrocarbon substances (double bond). The most important building blocks (monomers) of the olefins are ethylene, propylene and butylene.

Open System — A circulating hydronic system exposed to atmospheric conditions. Open systems require components resistant to oxidative corrosion. Open systems are the result of continual introduction of fresh water, open vessels or oxygen diffusion through non-metallic components.

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. The 2009 ASHRAE Handbook — Fundamentals (pages 17.3-17.4) recommends selecting a residential design temperature for a given area to be 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 tubing wall. PEX-a tubing 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 tubing wall.

PEX-c — PEX-c is produced by using an electron beam to change the molecular structure of the tubing, 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 tubing as well as result in a slightly stiffer product.

Polymer Extrusion — A method used for the continuous formation of tubing 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 tubing 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 tubing walls and is further influenced by the tubing size, length and texture of the inside wall of the tubing, 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.

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.

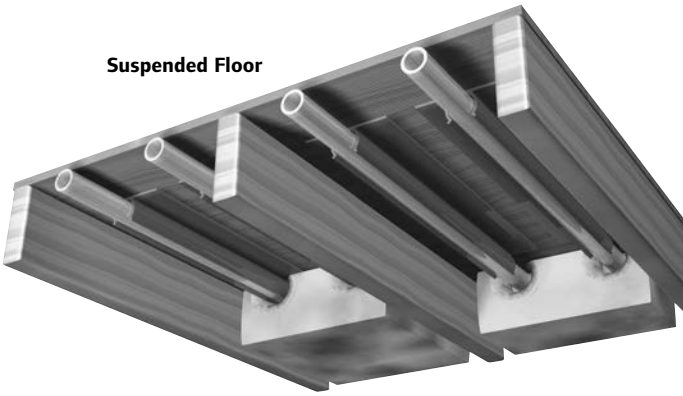
The thermal conductivity of PEX-a tubing is 0.202 BTU/hr/ft/°F.

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

Suspended Floor



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)

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 tubing 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) tubing 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 tubing for radiant heating, plumbing and fire safety systems. More than two billion feet of Uponor PEX tubing is in service in North America alone, and more than 12 billion feet of tubing 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.

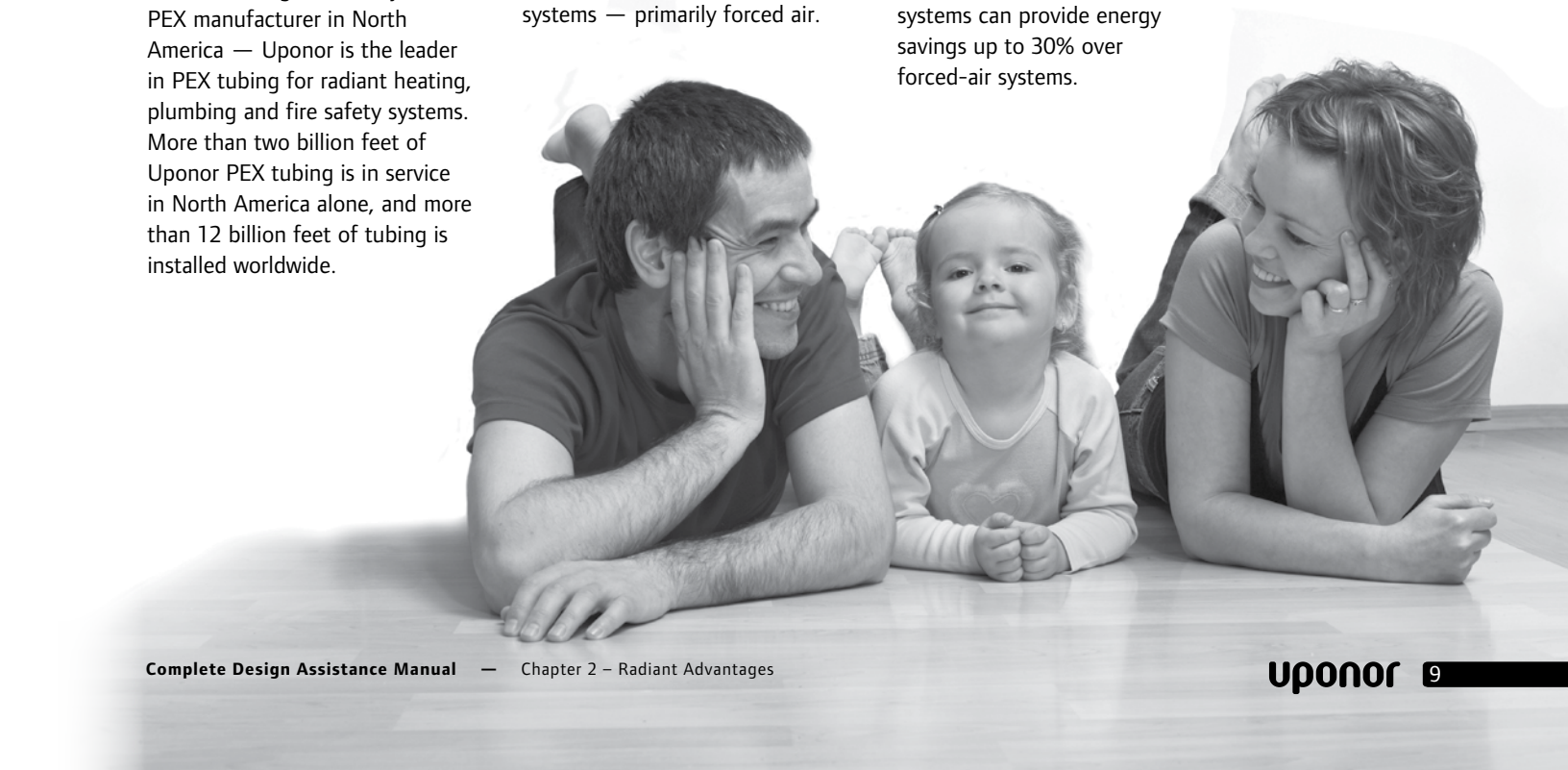
Radiant floor heating also offers increased comfort and fuel economy for office buildings and other commercial applications, such as stores, schools, airport hangars, greenhouses and more. Aware of the benefits, a greater number of building designers and owners now provide their clients with comfortable,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

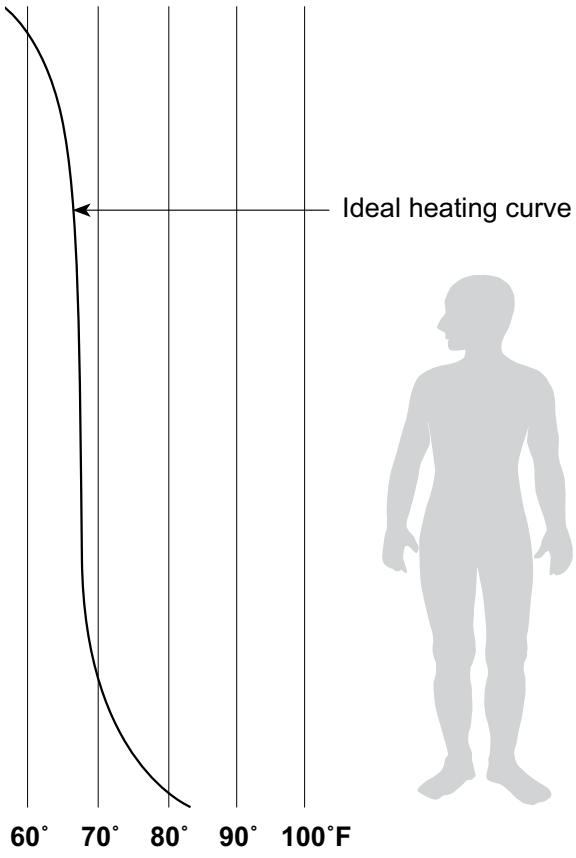


Figure 2-1: Ideal Heating Curve

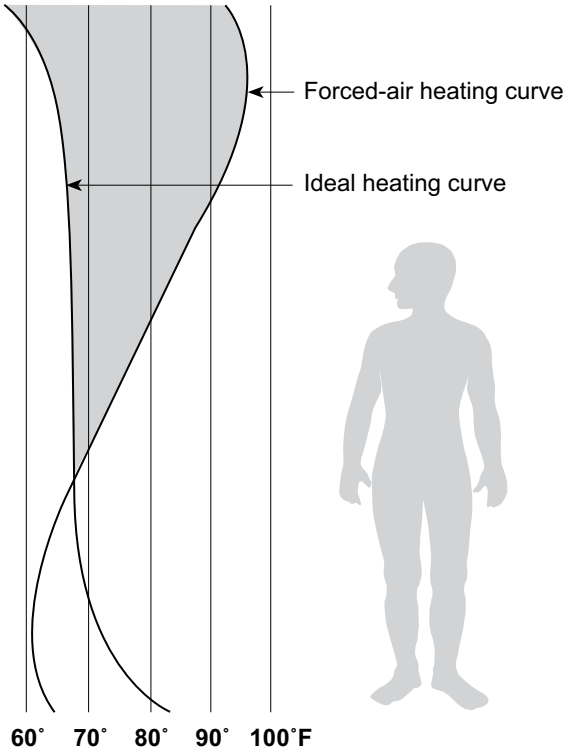


Figure 2-2: Comparison of Ideal and Forced-air Heating Curves

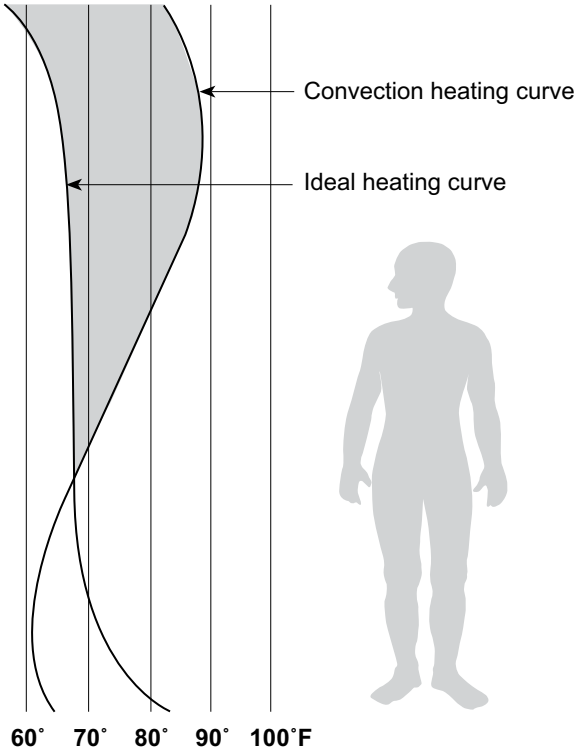


Figure 2-3: Comparison of Ideal and Convection Heating Curves

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.

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).

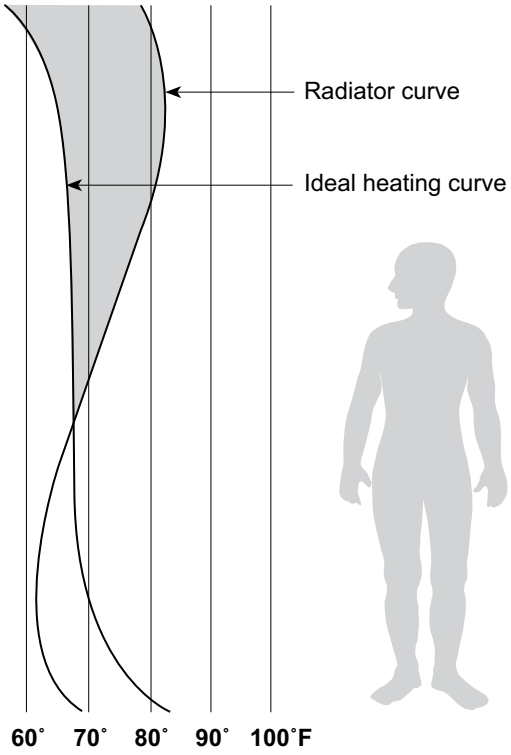


Figure 2-4: Comparison of Ideal and Radiator Heating Curves

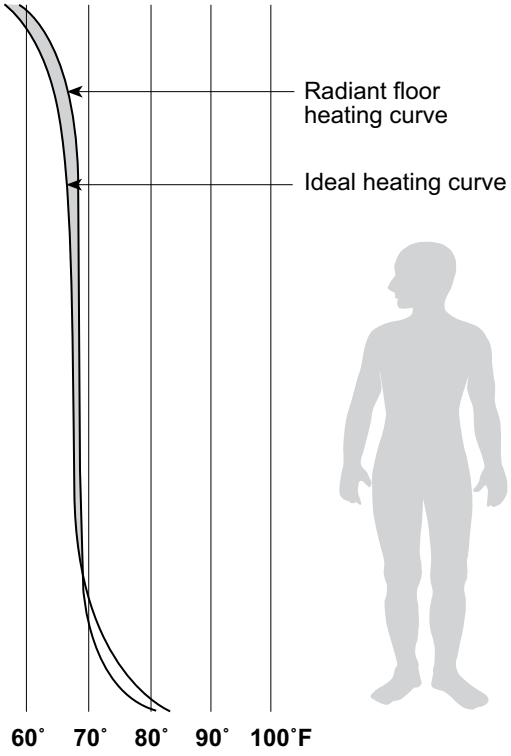


Figure 2-5: Comparison of Ideal and Radiant Floor Heating Curves

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.

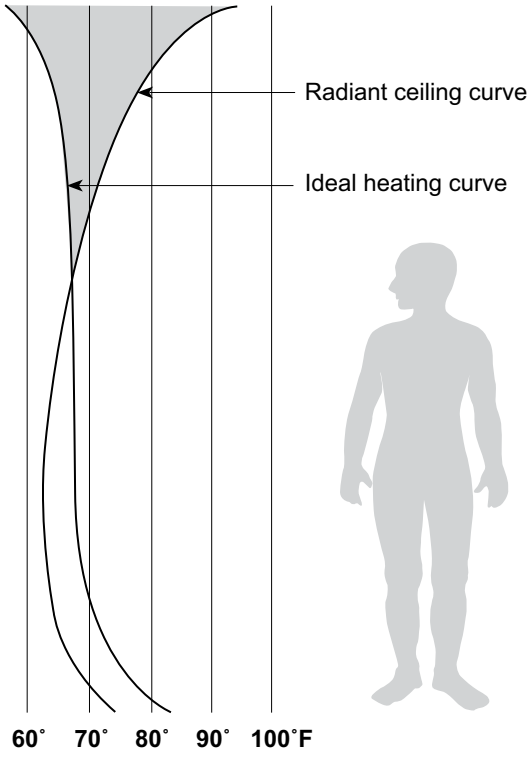


Figure 2-6: Comparison of Ideal and Radiant Ceiling Heating Curves

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/°F.

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/°F 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.

Chapter 3
Uponor Tubing 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 tubing 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 tubing. The PEX tubing industry considers this tubing 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 tubing is crosslinked after the extrusion process by placing the tubing 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 tubing 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 tubing (i.e., crosslink) after the extrusion process. The PEX-c method requires multiple passes of the tubing 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 tubing make it the most flexible PEX on the market. This flexibility allows the tightest bend radius available — 6 times the outside diameter of the tubing. Its flexibility also greatly reduces instances of kinked tubing.

However, in the rare instance of a kink, that's okay, because PEX-a tubing has thermal memory. Thermal memory allows the repair of kinked tubing with a simple shot of heat from a heat gun. The shape memory of PEX-a tubing 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 tubing offers more resistance to crack propagation (how a crack grows) than PEX-b or PEX-c tubing. A crack that occurs in PEX-a tubing is the least likely to grow over time and cause leaks or damage.

Stress Resistance

Tubing 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 tubing 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 at 800.321.4739 (U.S.) or 888.994.7726 (Canada) with questions about specific chemical resistance.

Oxygen Diffusion

Oxygen diffusion can cause corrosion problems in a heating system. All non-metallic (plastic or rubber) tubing 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 tubing, oxygen continues to enter the system through the permeable tubing. 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 tubing (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 tubing that limits the oxygen diffusion into the heat-transfer fluid to a level consistent with established standards. Use Wirsbo hePEX™ or Multi-layer Composite (MLC) tubing (formerly MultiCor®) 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® tubing, 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 Tubing

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

- Always install Uponor systems according to the installation instructions.
- Do not use PEX-a tubing where temperatures and pressures exceed ratings.
- Do not use or store PEX-a tubing where it will be exposed to direct sunlight for more than 30 days.
- Do not weld, glue or use adhesives or adhesive tape with PEX-a tubing.
- Do not apply open flame to PEX-a tubing.
- Do not install PEX-a tubing 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 tubing within 12 inches (over or under) of any recessed light fixture unless the tubing line is protected with suitable insulation.
- Do not solder within 18 inches of any PEX-a tubing 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 tubing.
- Do not use petroleum or solvent-based paints, greases or sealants on PEX-a tubing.
- During remodeling or ceiling repair, implement appropriate precautions to protect the tubing from damage.
- Do not install PEX-a tubing 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 tubing. Where such conditions are suspected, perform a chemical analysis of the soil or groundwater to ascertain the acceptability

of PEX-a tubing for the specific installation. Check local codes for additional requirements.

Reforming Kinked Tubing

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

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

Thawing Frozen Tubing

Uponor PEX-a tubing can withstand extreme freeze/thaw cycles better than other tubing or pipe. The crosslinking of the tubing allows it to expand and absorb much of the expansion energy from the freezing process. No tubing product is freeze-proof, but Uponor PEX-a tubing 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 tubing experience an ice blockage, thaw the tubing using these methods:

1. Pour hot water over the tubing's affected area.
2. Wrap hot towels around the tubing's affected area.
3. Place a small portable heating unit in the area to heat the space and thaw the ice blockage from the tubing.
4. Slowly heat the affected area with a heat gun. Rub a hand over the area while heating to ensure the tubing does not get too hot.



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

Note: Wirsbo hePEX and MLC must be used when an oxygen-diffusion barrier tubing is required.

Uponor Tubing

With more than 35 years of service — longer than any other PEX manufacturer in North America — Uponor is the leader in PEX tubing for radiant heating, plumbing and fire-protection systems. More than two billion feet of Uponor PEX tubing is in service in North America alone, and more than 12 billion feet of tubing is installed worldwide. With that kind of history, you can count on Uponor PEX to offer the highest-quality tubing 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 Tubing Product

Uponor offers the following tubing products for distribution and supply and return mains for use in radiant heating and cooling installations:

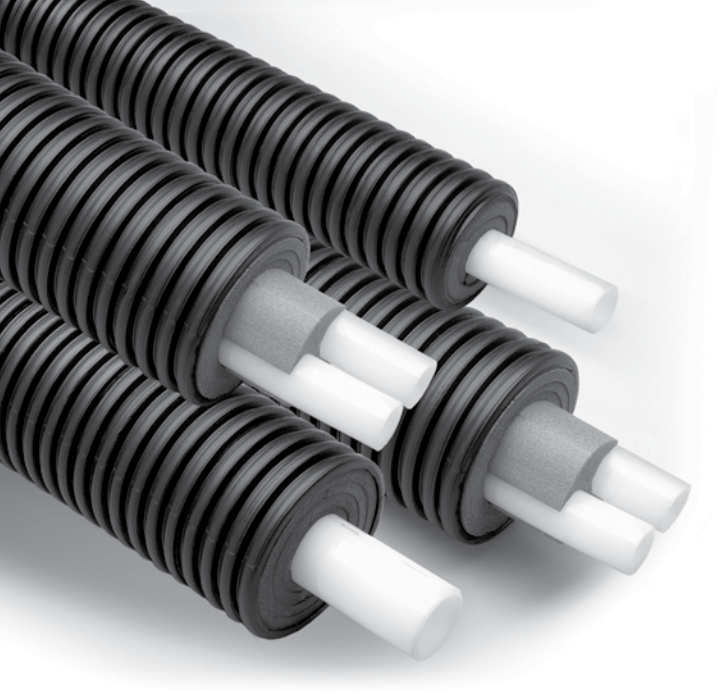
- Distribution — Wirsbo hePEX, MLC, Uponor AquaPEX and Ecoflex®
- Supply and return mains — Large-dimension Wirsbo hePEX, high-density polyethylene (HDPE) and Ecoflex

Uponor Tubing	Application and Design Considerations	Standards, Listings and Ratings	
Wirsbo hePEX Wirsbo hePEX is Engel-method PEX-a tubing 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 tubing.	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 tubing 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 ·73.4°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. Wirsbo hePEX is listed with the following agencies. · Council of America Building Officials (CABO) One and Two Family Dwelling Code · CAN/CSA B137.5, "Crosslinked Polyethylene (PEX) Tubing Systems for Pressure Applications" · ICBO Evaluation Service — ER Number 4407, 5143 · Southern Building Code Congress International (SBCCI) Standard Plumbing Code (PST and ESI Report Number 9661) · U.S. Department of Housing and Urban Development (HUD) Material Release Number 1269	
Multi-layer Composite (MLC) Tubing MLC consists of aluminum tubing sandwiched between two layers of PEX. These PEX layers are bonded to the aluminum with a special adhesive. 	**Application** — MLC is designed for use in closed-loop hydronic heating systems operating at sustained temperatures up to 200°F. Corrodible or ferrous components may be used in hot-water heating systems designed with MLC.	MLC is manufactured to ASTM F1281 as certified by NSF International. MLC has a Standard Grade Hydrostatic Pressure Rating in accordance with the temperatures and pressures listed in Section X1 of ASTM F1281. MLC is tested in accordance with PPI TR-3 and listed in PPI TR-4. The Standard Grade hydrostatic ratings are: · 200°F at 100 psi · 180°F at 125 psi · 140°F at 160 psi · 73°F at 200 psi The Hydrostatic Design Stress Board of 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. MLC is listed with the following agencies. · ICBO Evaluation Service — ER Number 5298 · Southern Building Code Congress International (SBCCI) Standard Plumbing Code (PST and ESI Report Number 9829)	

	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 tubing 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 tubing during the manufacturing process. Uponor applies another thin polyethylene layer over the EVOH barrier on the tubing to reduce possible onsite damage to the oxygen-diffusion barrier. This polyethylene layer also provides protection for the EVOH barrier if the tubing 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 tubing is approximately 1.1 inches per 10°F temperature change per 100 feet of tubing.	• 5/16" nominal inside diameter (contains 0.35 gallons/100' of tubing) • 3/8" nominal inside diameter (contains 0.50 gallons/100' of tubing) • 1/2" nominal inside diameter (contains 0.92 gallons/100' of tubing) • 5/8" nominal inside diameter (contains 1.34 gallons/100' of tubing) • 3/4" nominal inside diameter (contains 1.84 gallons/100' of tubing) • 1" nominal inside diameter (contains 3.03 gallons/100' of tubing) • 1 1/4" nominal inside diameter (contains 4.54 gallons/100' of tubing) • 1 1/2" nominal inside diameter (contains 6.33 gallons/100' of tubing) • 2"nominal inside diameter (contains 10.85 gallons/100' of tubing) • 2 1/2" nominal inside diameter (contains 16.53 gallons/100' of tubing) • 3" nominal inside diameter (contains 23.51 gallons/100' of tubing) • 4" nominal inside diameter (contains 41.05 gallons/100' of tubing)	Refer to the Uponor Product Catalog for available coil lengths.
	MLC offers 100% oxygen-diffusion protection due to the aluminum within the tubing wall.	The unrestrained linear (thermal) expansion rate for MLC is approximately 0.156 inches per 10°F temperature change per 100 feet of tubing.	• 1/2" nominal inside diameter (contains 0.98 gallons/100' of tubing) • 5/8" nominal inside diameter (contains 1.60 gallons/100' of tubing) • 3/4" nominal inside diameter (contains 2.56 gallons/100' of tubing) • 1" nominal inside diameter (contains 4.20 gallons/100' of tubing)	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 Tubing	Application and Design Considerations	Standards, Listings and Ratings	
Uponor AquaPEX Uponor AquaPEX is a registered trade name for the company's hot and cold potable water tubing. 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 tubing. **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 tubing 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 tubing 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 • 73.4°F at 160 psi The Hydrostatic Design Stress Board of 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 of the product, not for the system specification or design. Uponor AquaPEX is listed with the following agencies. • ANSI/NSF 14 and 61 Certified • Council of America Building Officials (CABO) One and Two Family Dwelling Code • ICBO Evaluation Service — ER Number 5142, 5143 • Southern Building Code Congress International (SBCCI) Standard Plumbing Code (PST and ESI Report Number 9661) • UPC Listing — Files 3558, 3946, 3960 • U.S. Department of Housing and Urban Development (HUD) Material Release Number 1269	
High-density Polyethylene (HDPE) Uponor high-density polyethylene (HDPE) tubing (PE 3408) is a non-barrier product that is joined by heat-fusion welding. Flange adapters are available to transition to nonferrous piping. Refer to the Uponor Product Catalog for additional fitting and component information. 	**Application** — Uponor HDPE can be used as supply and return mains in closed-loop hydronic heating systems operating at sustained temperatures up to 140°F, provided any issues concerning oxygen diffusion are properly addressed. Corrodible or ferrous components may not be used in a system designed with Uponor HDPE unless these components are isolated from the tubing. **Design Considerations** — HDPE tubing has an oxygen-diffusion rate greater than that allowed by the German DIN 4726. Hydronic heating systems using HDPE tubing must be designed to accept oxygen permeation or be isolated from ferrous components in the system.	Uponor HDPE tubing and fittings are manufactured by Phillips Driscopipe to meet ASTM D3350 and ASTM D3261. The HDPE tubing has the following hydrostatic pressure and temperature ratings from PPI. • 140°F at 80 psi • 120°F at 101 psi • 100°F at 125 psi • 73°F at 160 psi HDPE conforms to the following certifications. Standards: PE 3408, PE 3608, AWWA, C901/C906; ASTM F714 Listings: NSF/ANSI 61 or NSF-pw	

	Barrier Information	Linear Expansion Rate	Dimensions	Coil Lengths
	Uponor AquaPEX is a non-barrier product.	The unrestrained linear expansion (thermal) rate for Uponor AquaPEX tubing is approximately 1.1 inches per 10°F temperature change per 100 feet of tubing.	• ¼" nominal inside diameter (contains 0.24 gallons/100' of tubing) • ⅜" nominal inside diameter (contains 0.50 gallons/100' of tubing) • ½" nominal inside diameter (contains 0.92 gallons/100' of tubing) • ⅝" nominal inside diameter (contains 1.34 gallons/100' of tubing) • ¾" nominal inside diameter (contains 1.84 gallons/100' of tubing) • 1" nominal inside diameter (contains 3.03 gallons/100' of tubing) • 1¼" nominal inside diameter (contains 4.53 gallons/100' of tubing) • 1½" nominal inside diameter (contains 6.32 gallons/100' of tubing) • 2"nominal inside diameter (contains 10.85 gallons/100' of tubing) • 2½" nominal inside diameter (contains 16.53 gallons/100' of tubing) • 3" nominal inside diameter (contains 23.51 gallons/100' of tubing)	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 HDPE is a non-barrier product.	The unrestrained linear expansion (thermal) rate for HDPE tubing is approximately 1.4 inches per 10°F temperature change per 100 feet of tubing.	• 2" nominal inside diameter (contains 15.0 gallons/100' of tubing) • 3" nominal inside diameter (contains 32.6 gallons/100' of tubing) • 4" nominal inside diameter (contains 53.87 gallons/100' of tubing)	Uponor HDPE is only available in 20-foot straight lengths.



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 — now available in ASTM sizes — is virtually maintenance-free. This feature is especially important since Ecoflex usually involves an underground installation. With coil lengths available up to 600 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) tubing, protected by multi-layer, PEX-foam insulation and covered by a corrugated, watertight, HDPE jacket. Use with ProPEX fittings (up to 2") or WIPEX dezincification-resistant (DZR) brass compression fittings.

Codes and Standards — ASTM F876, F877 and F1960; CSA B137.5; NSF-rfh

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 2") or WIPEX DZR brass compression fittings.

Codes and Standards — UPC, IPC, NSPC, NPC of Canada; ASTM F876, ASTM F877; CSA B137.5; NSF-pw; PEX 5106

Ecoflex Potable HDPE

Perfect for cold potable water, cooling and low-temperature heating applications, ASTM Ecoflex Potable HDPE features HDPE service pipe protected by multi-layer, PEX-foam insulation and covered by a corrugated, watertight, HDPE jacket. Ecoflex Potable HDPE uses any industry-standard SDR11 HDPE fitting method.

Codes and Standards — UPC, IPC, NSPC, NPC of Canada; PE 3408, PE 3608 or PE 3454; AWWA C906; ASTM F714; NSF-pw

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 tubing 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 tubing 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"
  - o UL Design No. L557 rating applies to ½" to 2" Uponor AquaPEX and Wirsbo hePEX tubing, fittings and manifolds installed in one-hour wood frame floor and ceiling assemblies.
  - o UL Design No. K913 rating applies to ½" to 2" Uponor AquaPEX and Wirsbo hePEX tubing, fittings and manifolds installed in one and two-hour concrete floor/ceiling unrestrained (and restrained) assemblies.
  - o UL Design No. V444 rating applies to ½" to 2" AquaPEX and Wirbso hePEX tubing, 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"
  - o Certification of flame spread/smoke development rating of 25/50 in accordance with ASTM E84 for the following Uponor AquaPEX and Wirbso hePEX tubing sizes: 5/16", 3/8", ½", 5/8" and ¾".

Firestop Listings

Numerous firestop systems are listed with PEX tubing in one- and two-hour through penetration assemblies. Several firestop manufacturers listed their products for use with PEX tubing when installed in accordance with the listed construction assembly. Acceptable firestop systems are tested in accordance with the standard below. For the most current list of manufacturers, refer to **www.uponorpro.com** or **www.uponorengineering.com**.

- ASTM E814 (UL 1479) "Standard Test Method for Fire Tests of Through-Penetration Fire Stops"
  - o 3M Fire Protection Products
  - o HILTI, Inc.
  - o RectorSeal, Metacaulk



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.







Uponor Engineered Plastic (EP) Manifold

The Uponor Engineered Plastic (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 43 psi

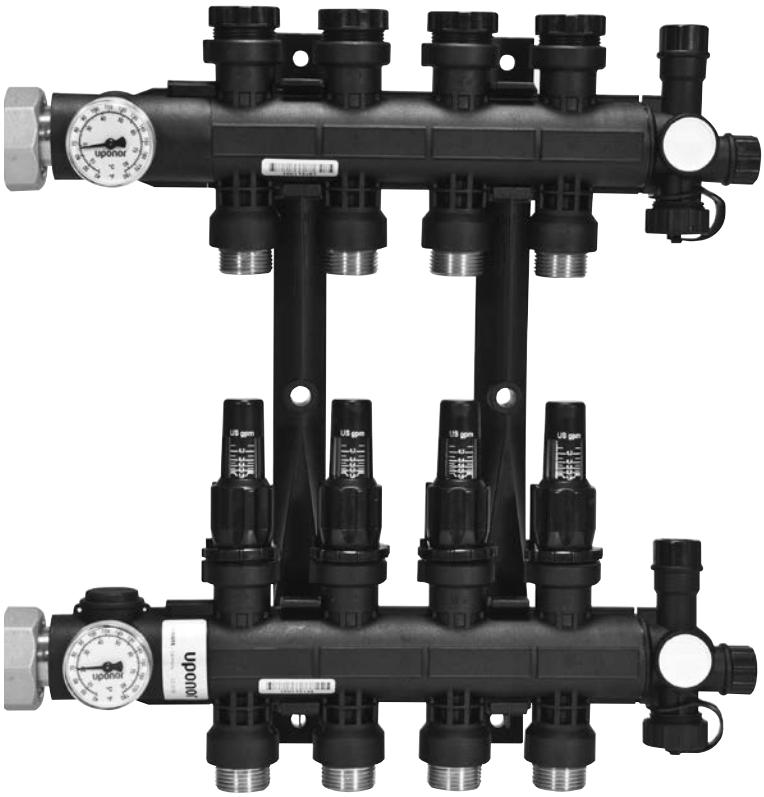
The manifold comes with a mounting bracket for fast and easy installation on a wall. Simply snap the manifold into the mounting bracket, and installation is complete.

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 27 for the exploded EP Heating Manifold view.

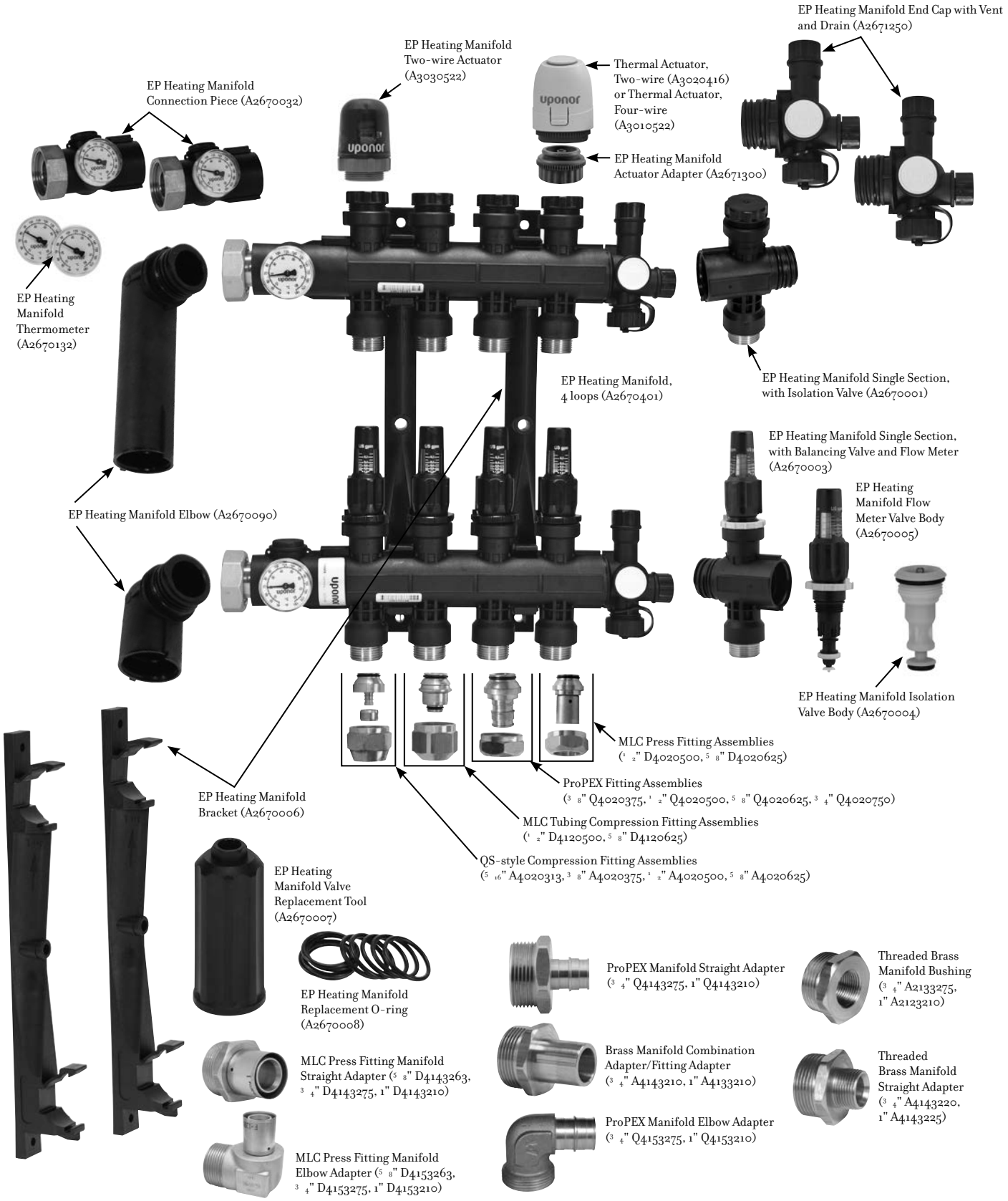
Balancing — Balance an EP Heating Manifold with the included visual flow meter.

Applicable Tubing — EP Heating Manifolds support the following tubing.

- 1/2" and 5/8" Wirsbo hePEX™ and Uponor AquaPEX® tubing with MLC press fitting assemblies
- 3/8", 1/2", 5/8" and 3/4" Wirsbo hePEX and Uponor AquaPEX tubing with ProPEX fitting assemblies
- 1/2" and 5/8" Wirsbo hePEX and Uponor AquaPEX tubing with MLC tubing compression fitting assemblies
- 5/16", 3/8", 1/2", 5/8" Wirsbo hePEX and Uponor AquaPEX tubing with QS-style compression fitting assemblies



Engineered Plastic (EP) Heating Manifold Exploded View



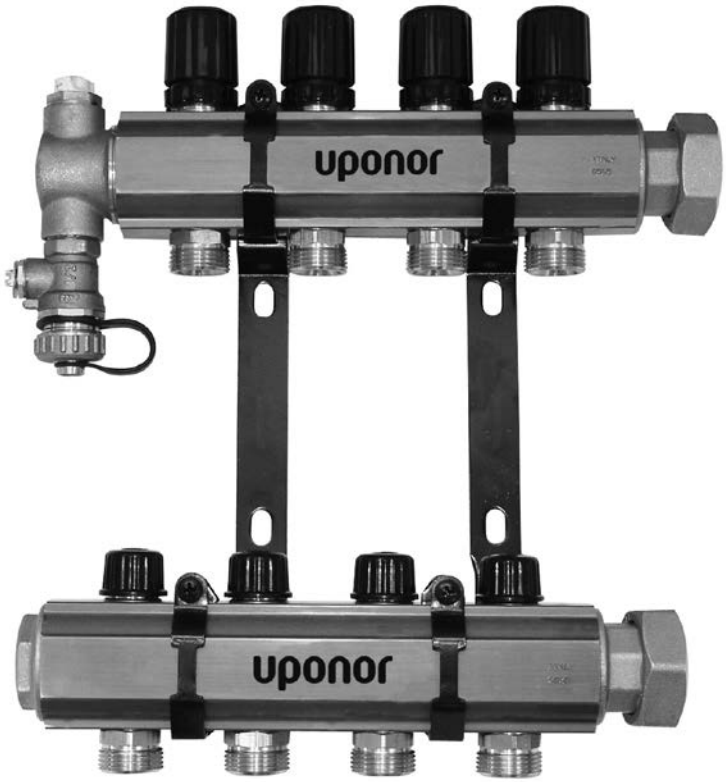
TruFLOW™ Manifolds

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 or motorized valve actuators (MVAs). 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 73.

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.

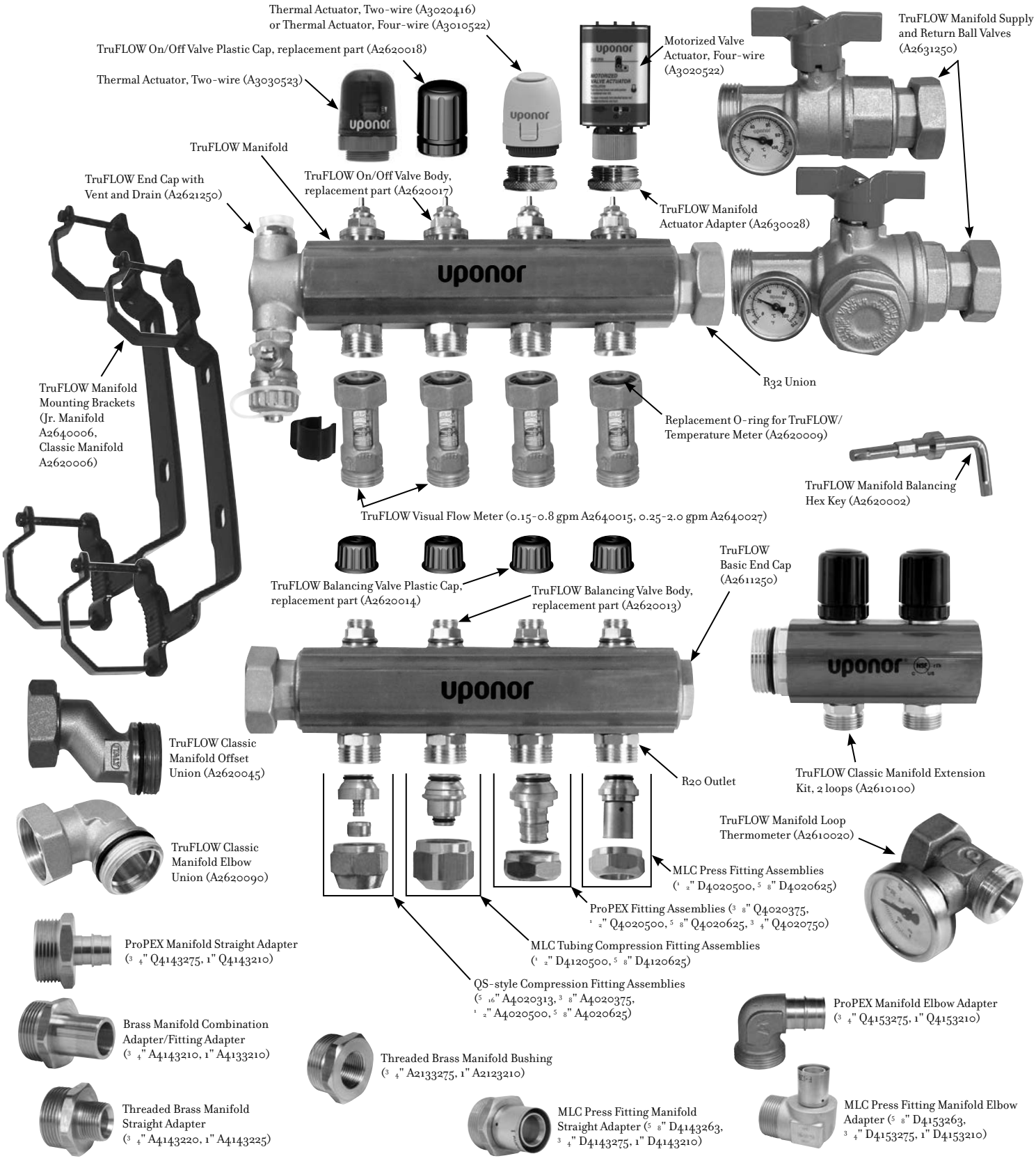
The maximum operating temperature and pressure for the TruFLOW manifolds and flow/temperature meters is 220°F at 145 psi. Refer to page 29 for the exploded TruFLOW manifold view.



Applicable Tubing — TruFLOW manifolds support the following tubing.

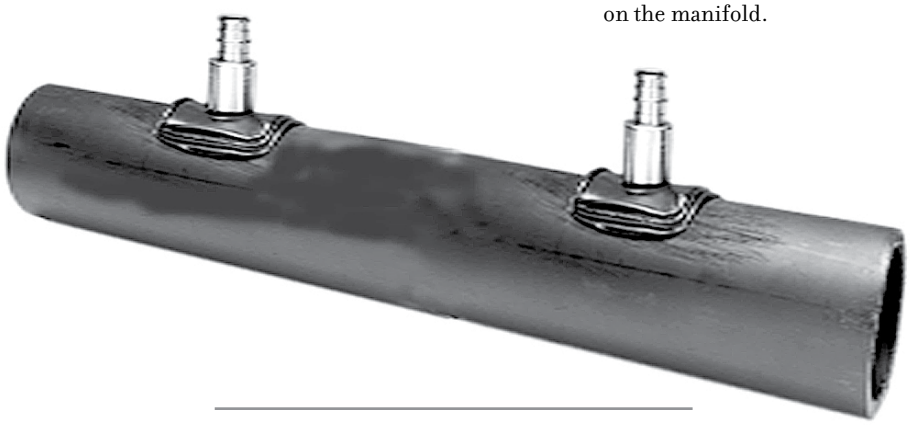
- 1/2" and 5/8" Wirsbo hePEX and Uponor AquaPEX tubing with MLC press fitting assemblies
- 1/2", 5/8" and 3/4" Wirsbo hePEX and Uponor AquaPEX tubing with ProPEX fitting assemblies
- 1/2" and 5/8" Wirsbo hePEX and Uponor AquaPEX tubing with MLC compression fitting assemblies
- 5/16", 3/8", 1/2", 5/8" Wirsbo hePEX and Uponor AquaPEX tubing with QS-style compression fitting assemblies

TruFLOW Heating Manifold Exploded View



HDPE Valveless Manifolds

The HDPE manifolds are available in 2, 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 3/4" and 1" PEX tubing. 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 Tubing — HDPE manifolds support the following tubing.

- 3/4" and 1" Wirsbo hePEX and Uponor AquaPEX tubing with ProPEX fitting assemblies

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 the 250-foot loop would be turned open 8.3 turns from closed.

Applicable Tubing — These copper valved manifolds support the following tubing.

- 5/8" and 3/4" Wirsbo hePEX and Uponor AquaPEX tubing with ProPEX or QS-style fitting assemblies
- 5/8" and 3/4" MLC tubing with QS-style fitting assemblies



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 iPods.

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.



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.



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.



Distribution Piping

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

Multi-layer Composite (MLC) tubing (formerly MultiCor®) offers another excellent opportunity to save labor and material costs for distribution tubing. MLC is aluminum tubing sandwiched between two layers of PEX. This tubing is rigid and stays in place as formed. MLC also eliminates the need for support around the tubing when making 90-degree bends.

Optimal Spacing

Typical tubing 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, tubing spacing may be increased to 18 or 24 inches on center. The key is meeting the heat loss, which determines the appropriate tubing spacing along with other design elements. Use the Uponor Advanced Design Suite™ (ADS) design program to gauge the impact on water temperatures.

Do not install tubing where it is not required. An area that will be used for cold storage would not require tubing 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 tubing may not be needed. An exception may be an interior bathroom with tile flooring. Installing tubing will provide comfort where the floor might otherwise be unpleasantly cool.





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 tubing (Wirsbo hePEX barrier tubing or Uponor AquaPEX non-barrier tubing) 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 tubing 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.

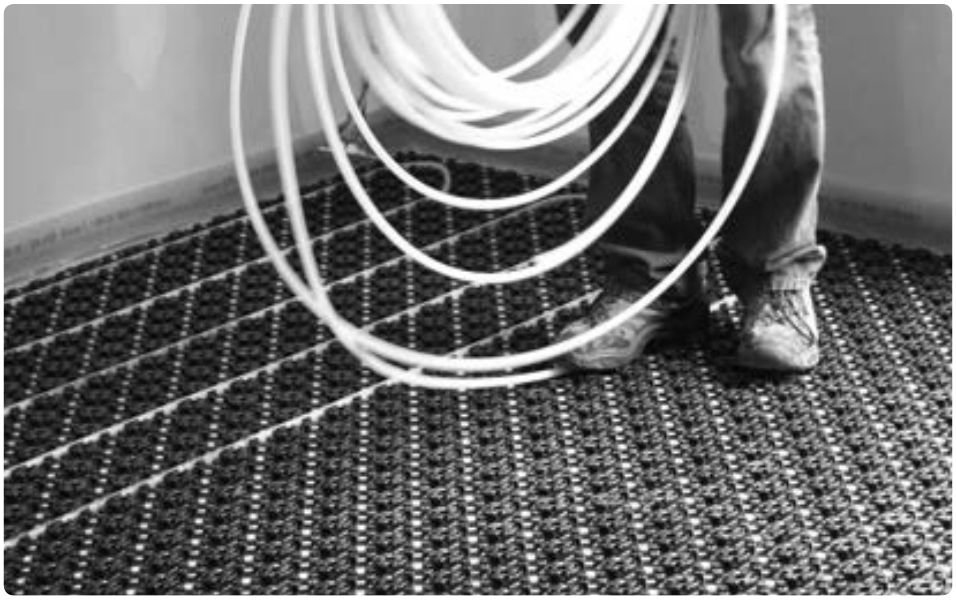
Fast Trak™

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 tubing 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 tubing 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.



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.





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 tubing coil. This effort will minimize waste tubing. Use a tubing 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 tubing 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 tubing installation to minimize other trade traffic over the exposed tubing. 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 tubing 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 tubing 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 tubing. 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.

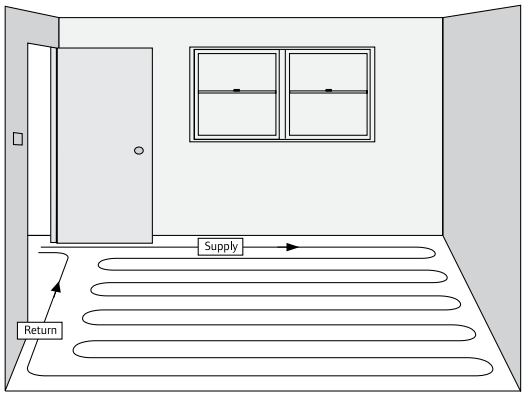


Figure 6-1: Single-wall Serpentine Tubing Layout

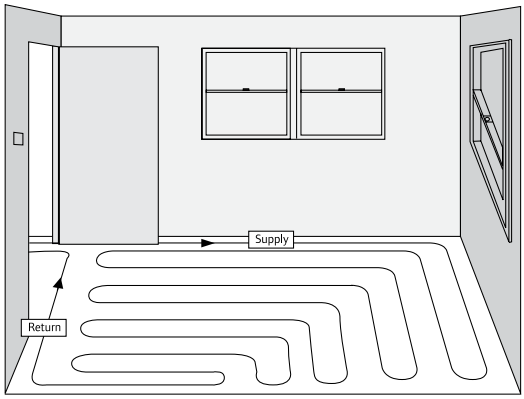


Figure 6-2: Double-wall Serpentine Tubing Layout

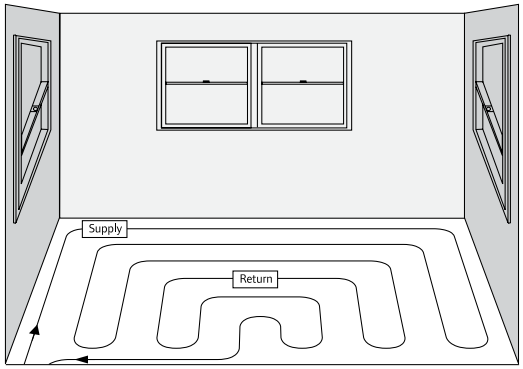


Figure 6-3: Triple-wall Serpentine Tubing Layout

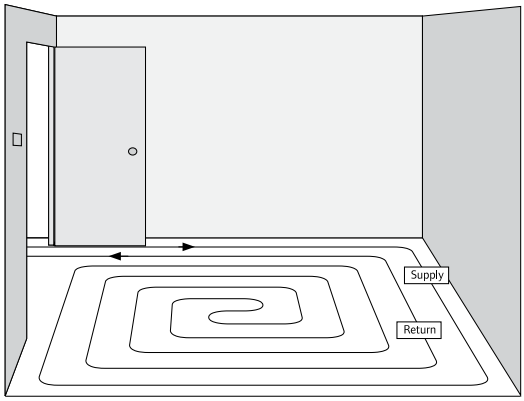


Figure 6-4: Counter Flow Tubing Layout

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.

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.

Tubing Layout Patterns

The four most common tubing 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. Tubing runs start 6 inches from walls or nailing surfaces. Six-inch on-center tubing 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. Tubing runs start 6 inches from walls or nailing surfaces. Six-inch on-center tubing 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.



Tubing runs start 6 inches from walls or nailing surfaces. Six-inch on-center tubing 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 tubing reaches the center of the room, the return spirals outward, parallel to the supply. Tubing runs start 6 inches from walls or nailing surfaces. Six-inch on-center tubing 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.

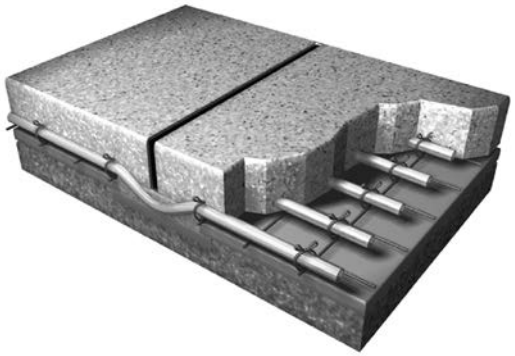


Figure 6-5: Tubing Dipped Below Construction Joint

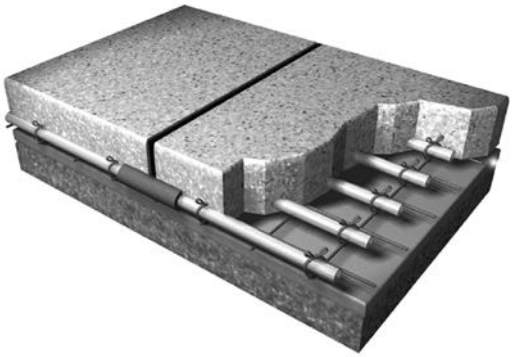


Figure 6-6: Tubing Wrapped with Pipe Insulation Near Construction Joint

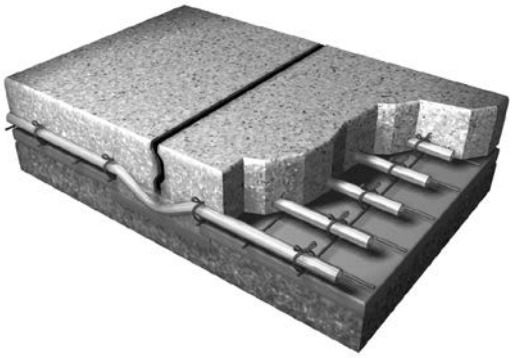


Figure 6-7: Tubing Dippped Below Expansion Joint

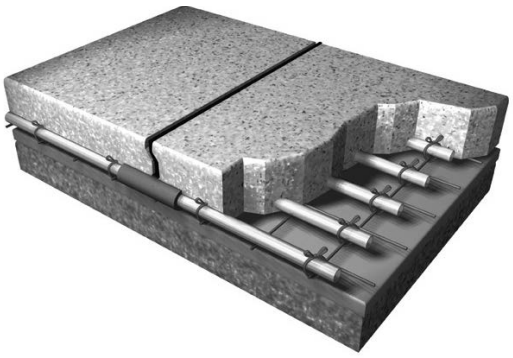


Figure 6-8: Tubing Secured on Each Side of Control Joint

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 tubing will be damaged during installation.

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

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 tubing 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**).

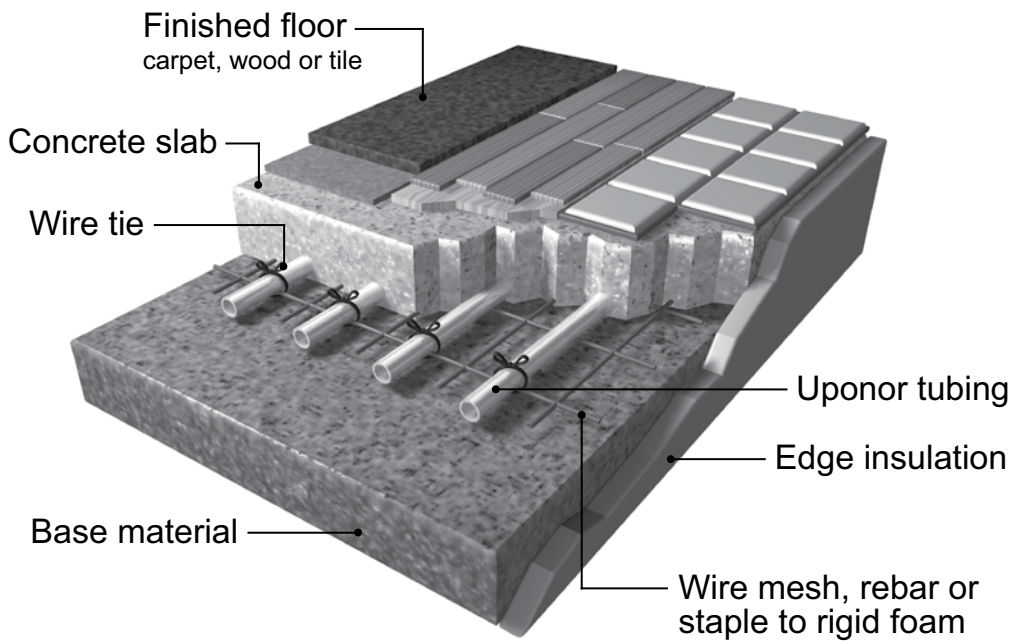
Another option is to dip the tubing below the slab into the subsoil (see **Figure 6-7**). When foam insulation is used to sleeve the PEX tubing running through an expansion joint and/or to accommodate minor shear action, minimum cover should be determined by the wall thickness of the insulation. For 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 tubing penetrating beneath a cut joint during the cracking phase of the concrete. The concern for the tubing 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 tubing is secured from the reach of the saw blade and cannot be harmed. It is recommended to secure the tubing 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 tubing through or below construction, expansion and control joints whenever possible. Coordinate the placement of these joints prior to designing the tubing 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 tubing 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 tubing at the top of the arc and once on each side, 12 inches from the top of the arc. This prevents the tubing from dislodging and/ or floating up into the pour.

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

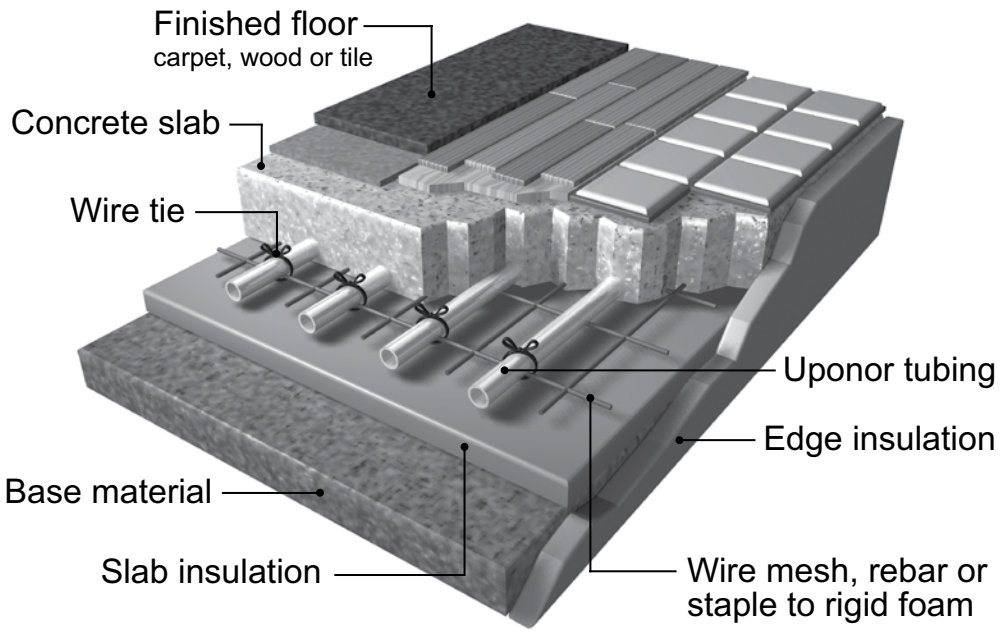
Where — This application is used primarily in commercial and light commercial construction, where room setpoint temperatures and space activities remain fairly constant. This method has several advantages including lower material costs and greater thermal storage ability. Some of the drawbacks include 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

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



with Under-slab and Edge Insulation

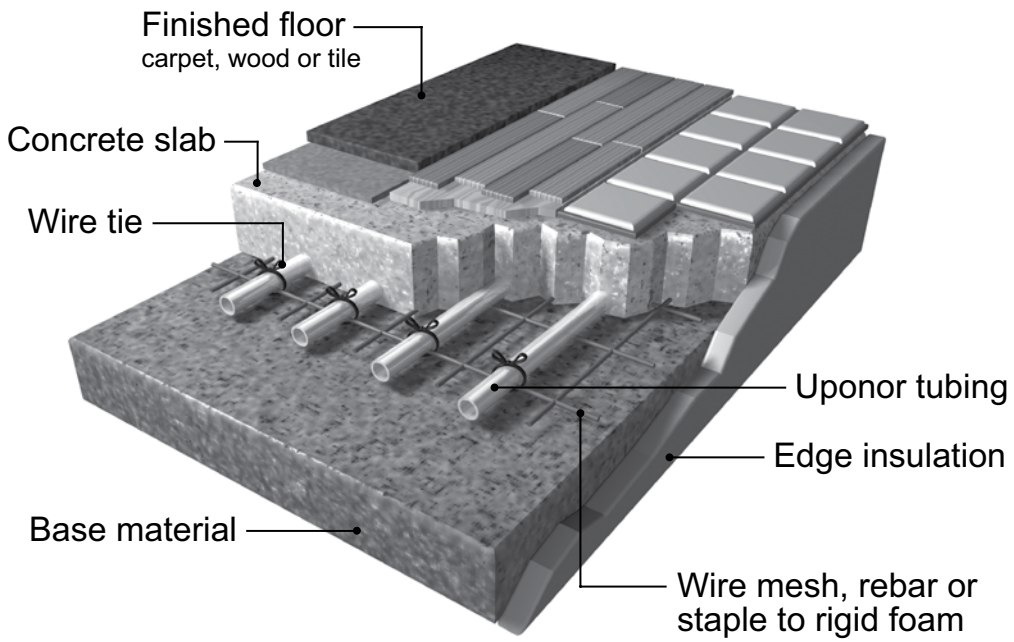
How — Place suitable, high-density rigid foam insulation over the compacted base material. Using Uponor Foam Staples with the Uponor Manual Stapler, secure the tubing to the high-density insulation. Place the staples a minimum of every 3 feet along the straight runs. At the 180-degree turns, staple the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

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

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 tubing 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 tubing at the top of the arc and once on each side, 12 inches from the top of the arc. This prevents the tubing from dislodging and/or floating up into the pour.

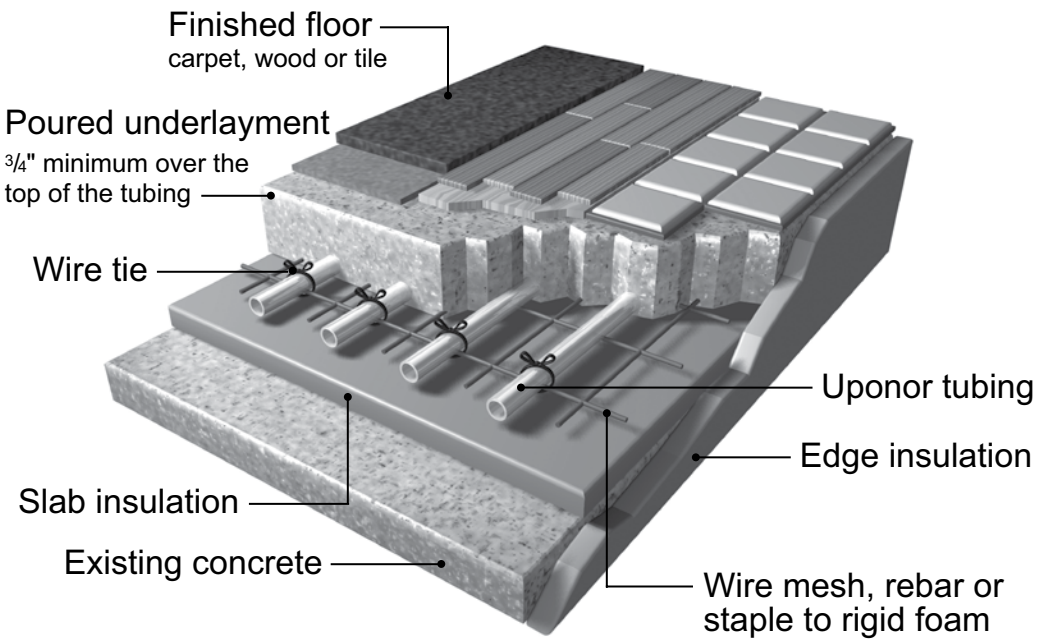
Connect the tubing to the manifold, and pressure test to a minimum of 60 psi at least overnight to ensure system integrity. Keep the tubing under pressure until after the concrete is poured.

Lay and level a 2-inch layer of medium-grade, compacted soil/sand fill over the tubing. Ensure the fill over the tubing 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 tubing in case the structural slab is drilled. The advantage of this method is that the tubing 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 tubing to the wire mesh. Place the wire ties a minimum of every 3 feet along straight runs. At the 180-degree turns, tie the tubing at the top of the arc and once on each side, 6 inches from the top of the arc. This prevents the tubing from dislodging and/or floating up into the pour.

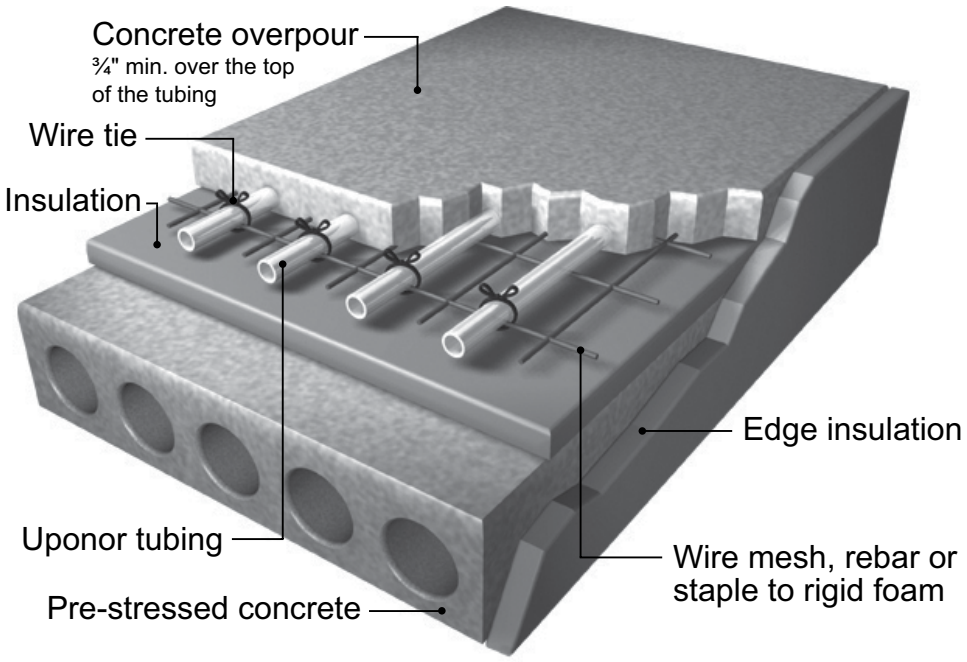
Connect the tubing to the manifold, and pressure test to a minimum of 60 psi at least overnight to ensure system integrity. Keep the tubing under pressure until after the concrete is poured.

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 tubing to the insulation. Staple the tubing 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 tubing 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 tubing 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

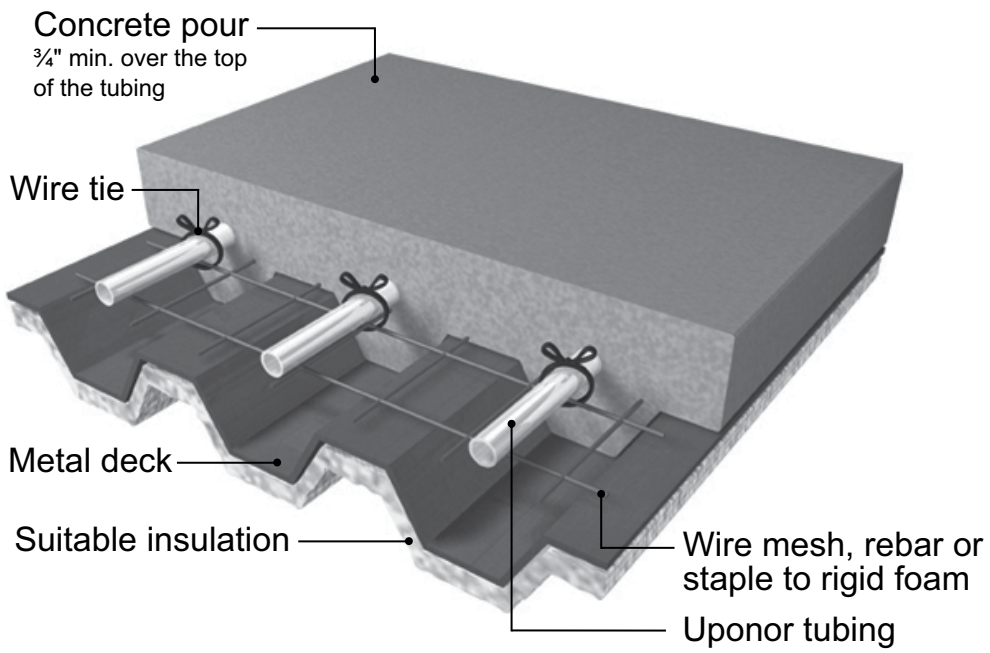
How — Secure high-density insulation (minimum thickness of 1 inch) to the precast concrete plank with suitable construction adhesive and concrete screws fitted with fender washers. Secure nonstructural flat wire mesh to the insulation. Using Uponor Fixing Wire, secure the tubing to the wire mesh. Place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

Connect the tubing to the manifold, and pressure test to a minimum of 60 psi at least overnight to ensure system integrity. Keep the tubing 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 tubing 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 tubing to rebar that is chaired above the deck. Using Uponor Fixing Wire, secure the tubing 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 tubing at the top of the arc and once on each side, 12 inches from the top of the arc. This prevents the tubing from dislodging and/or floating up into the pour.

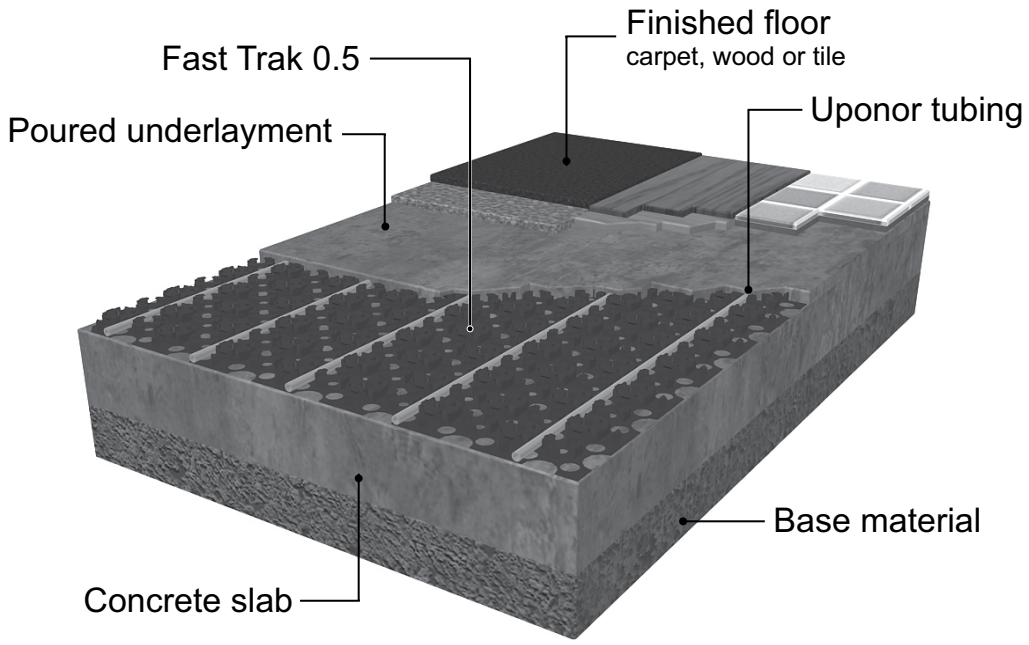
Connect the tubing to the manifold, and pressure test to a minimum of 60 psi at least overnight to ensure system integrity. Keep the tubing under pressure until after the concrete is poured.

Pour concrete over the tubing 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 tubing 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.

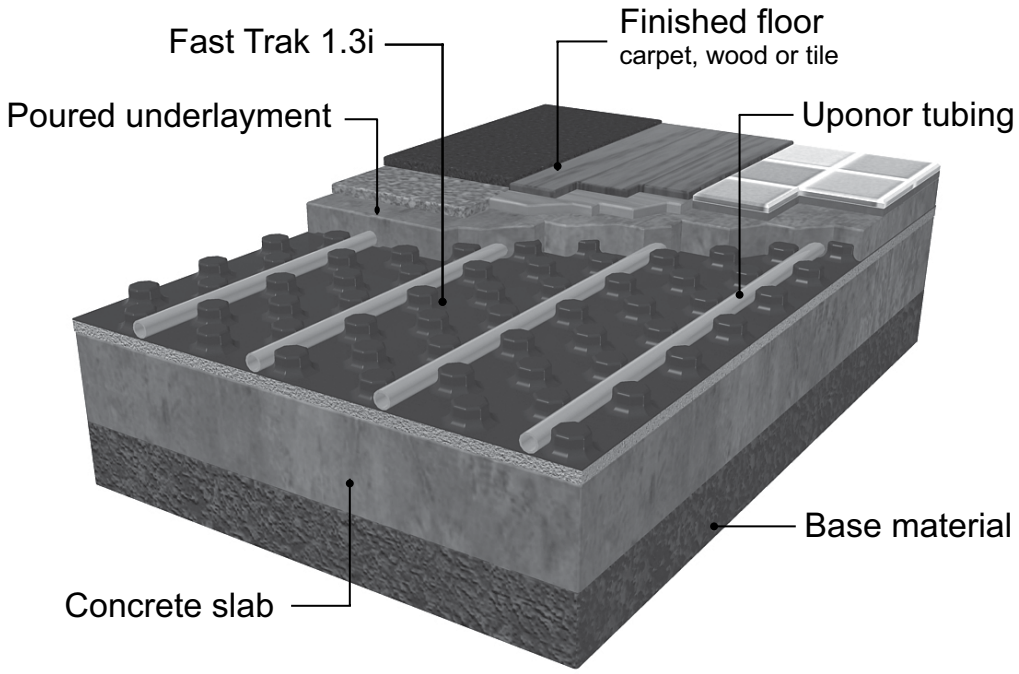
Keep a 2-inch spacing to the wall when laying down the panels. Install the tubing by walking or stepping the tubing into the knobs on the panel. Tubing spacing can be as little as 2 inches, but the turns must have a minimum radius of 3 inches.

Connect the tubing to the manifold and pressure test to a minimum of 60 psi at least overnight to ensure system integrity. Keep the tubing under pressure until after the overpour is poured. The overpour may be as thin as ¼ inch above the tubing 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 tubing 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.

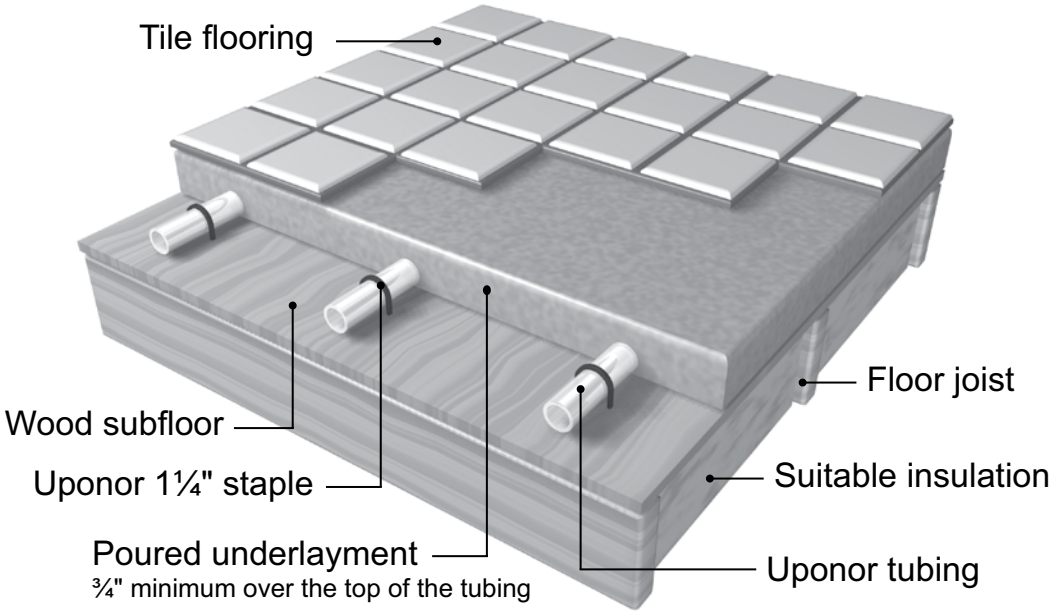
Place the panels on the floor. The panels have an interlocking feature that ensures the overpour will not seep under the panels. After panels are laid out, apply the polyethylene self-adhesive strip of the Edge Strip to the Fast Trak panels to ensure the overpour cannot seep under the edges of the panel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

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

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

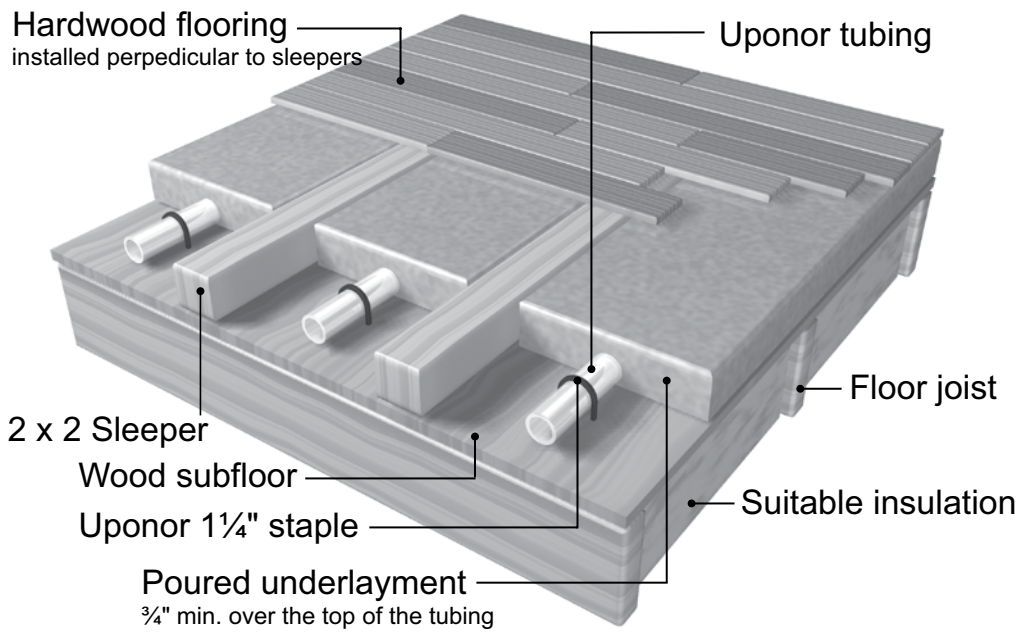
Install suitable batt insulation tightly against the subfloor between the floor joists.

Where — This common residential and light commercial installation method is used when the tubing 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 tubing. 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 tubing directly to the subfloor using the Uponor Pneumatic Stapler. Staple the tubing 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 tubing, 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 tubing to the manifold, and pressure test to a minimum of 60 psi at least overnight to ensure system integrity. Keep the tubing 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.

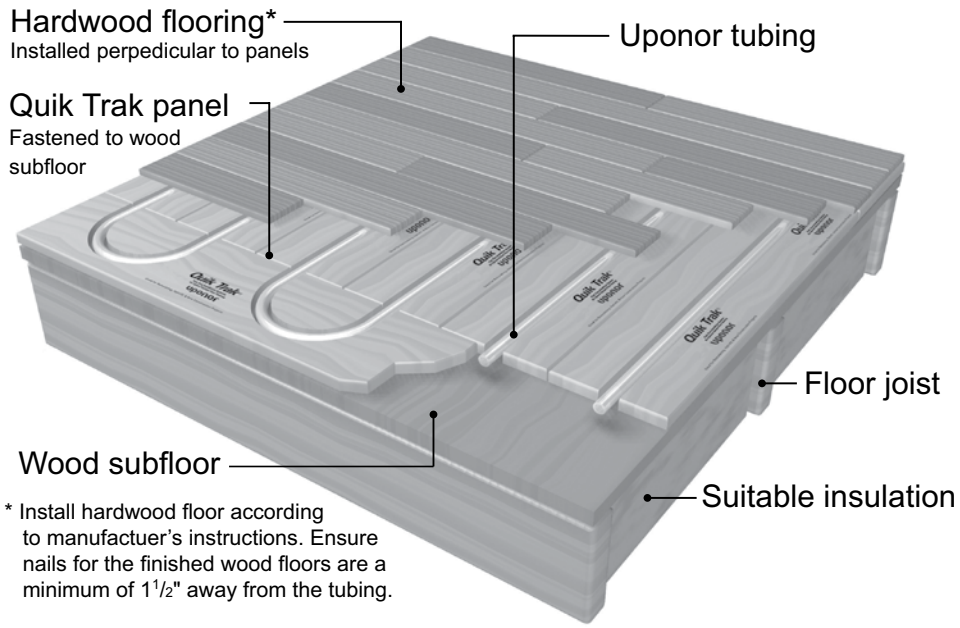
Where — This common residential and light commercial installation method is used when the tubing is installed in a poured-floor underlayment. Pours are typically 1½ inches thick and are used as an underlayment for a hardwood, tile or carpeted finished floor.

What to look for — Take special care when installing hardwood flooring over radiant 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 tubing. 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.

Note: Floor surface temperatures for hardwood floors should not exceed 80°F at design.



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 tubing to the panel.

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

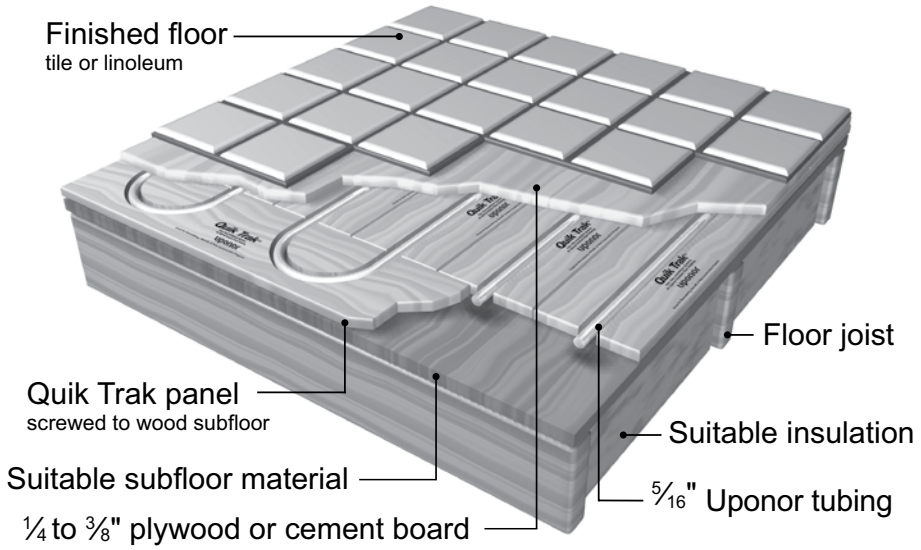
What to look for — Take special care when installing hardwood flooring over radiant floors. Please consult **Chapter 16** for detailed wood floor information.

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 tubing.

Note: Do not exceed 80ºF for hardwood floor surface temperatures.

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 ⅝" Wirsbo hePEX tubing 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 tubing to the panel.

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

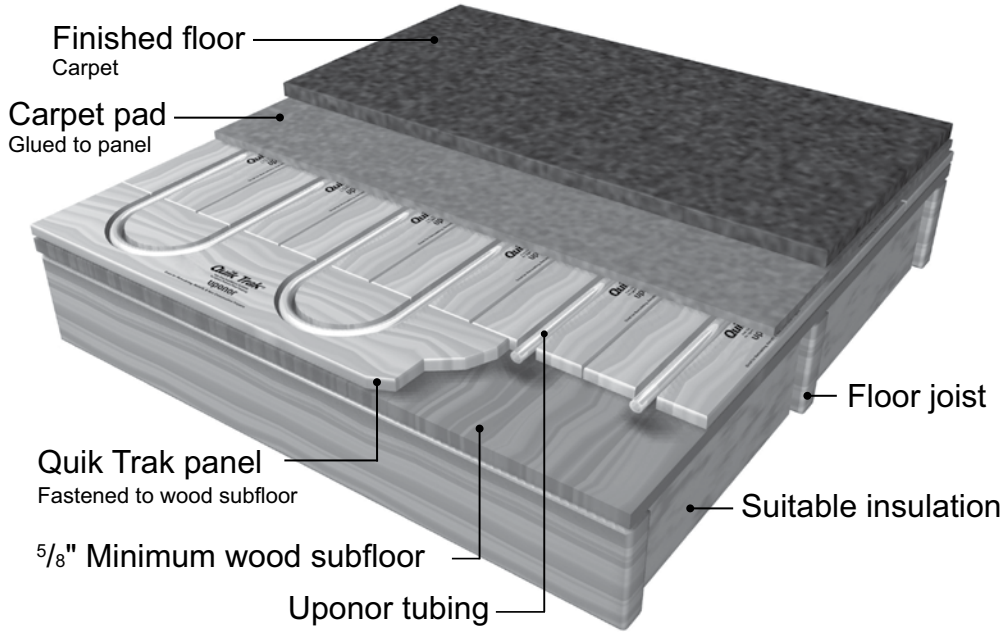
Secure panels to the subfloor with 1¼" Quik Trak Screws or 1" staples. To start, secure the middle of the panel with a screw or staple. Work from the middle to the ends, alternating from side to side.

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 tubing 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 tubing 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 tubing to the panel.

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

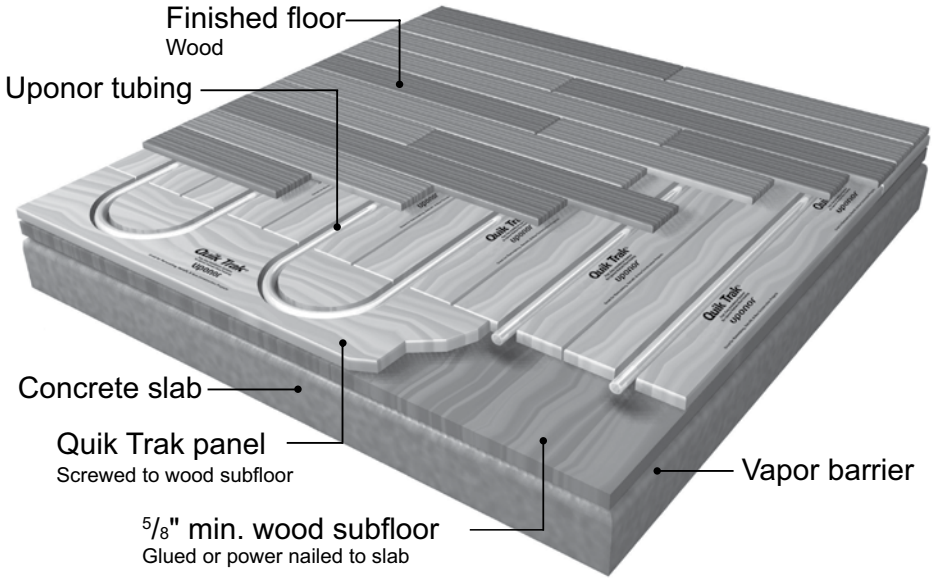
Secure panels to the subfloor with 1¼" Quik Trak Screws or 1" staples. To start, secure the middle of the panel with a screw or staple. Work from the middle to the ends, alternating from side to side.

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 tubing 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 87.5°F for carpeted floor surface temperatures.

In all Quik Trak applications, the maximum loop length for 5/16" Wirsbo hePEX tubing 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 tubing to the panel.

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

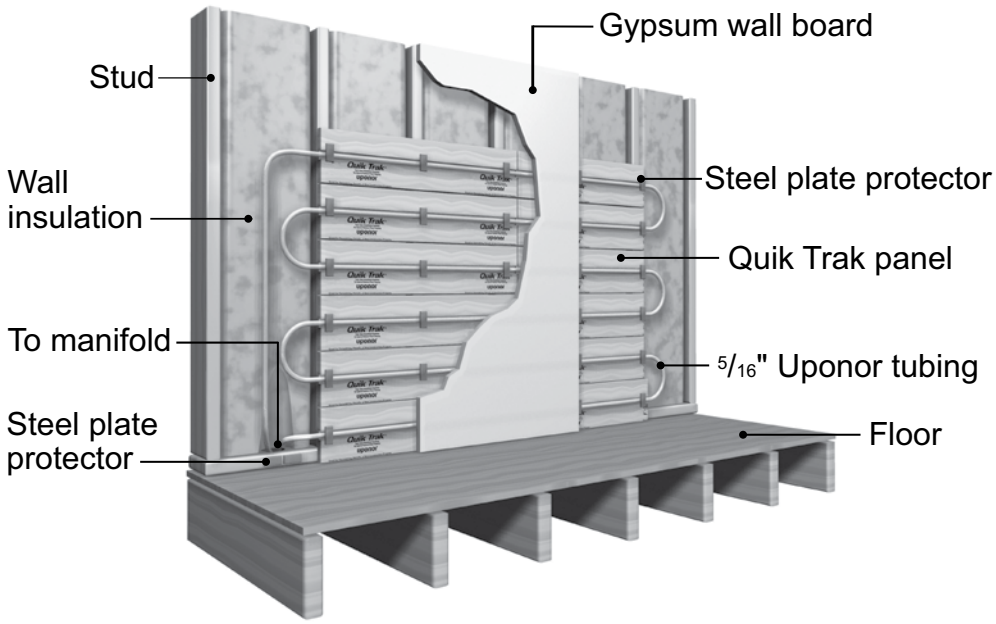
Secure the panels to the subfloor with 1" screws or 1" staples. To start, secure the middle of the panel with a screw or staple. Work from the middle to the ends, alternating from side to side.

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 tubing 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 tubing, 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 tubing 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 tubing crosses the studs to protect the tubing from puncture.

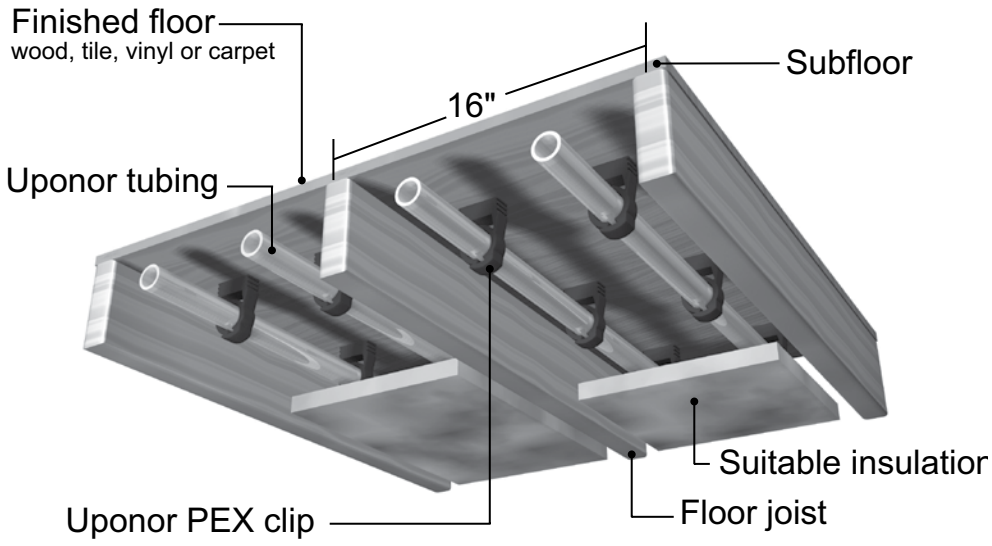
Where — Radiant wall installations are a low-cost alternative to radiant floor heating and are often installed when radiant floor is not viable. This method is routinely used in retrofit applications. In addition, radiant wall installations are most often used in supplemental heat situations when the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

What to look for — Do not install tubing 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 tubing 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 tubing in between the floor joists from below, looping from one joist cavity to the next as necessary. After installing tubing 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 tubing into the PEX Clips, which suspends the tubing 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 tubing, leaving about a 2-inch to 3-inch air gap under the subfloor. Connect the tubing 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.

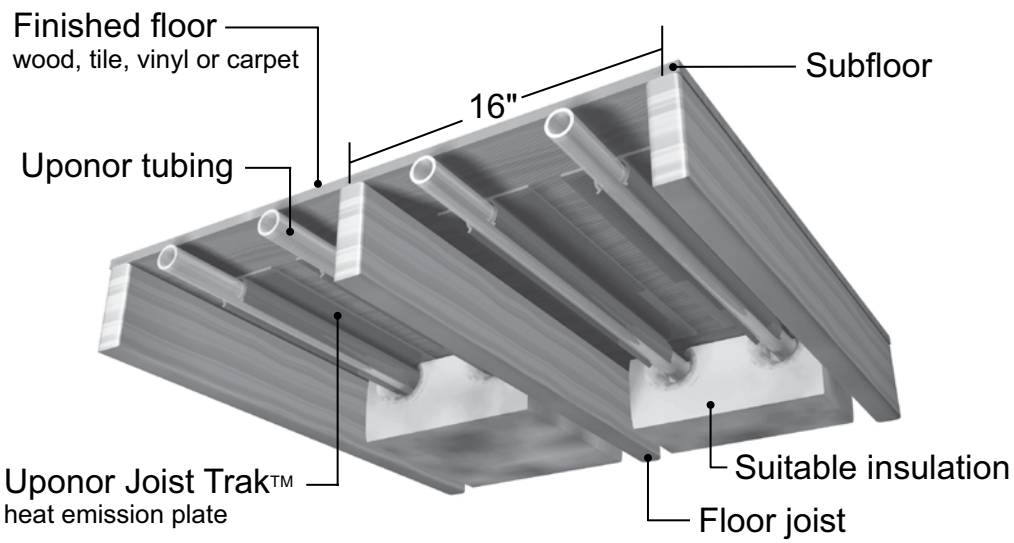
What to look for — A minimum R-11 fiberglass insulation is required even if the tubing is installed over a heated space. A minimum R-19 is recommended when the tubing is installed in a crawlspace. Standard unfaced insulation is adequate; foil-faced insulation is not necessary.

Install tubing 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 tubing in joist heating applications. It is not recommended to exceed maximum individual loop lengths.

Note: This installation method is not recommended for open-web truss construction. Joist heating applications using only the PEX tubing 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 55** of this manual.



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 tubing 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 tubing in between the floor joists from below, looping from one joist cavity to the next as necessary. After tubing 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 tubing 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 tubing 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.

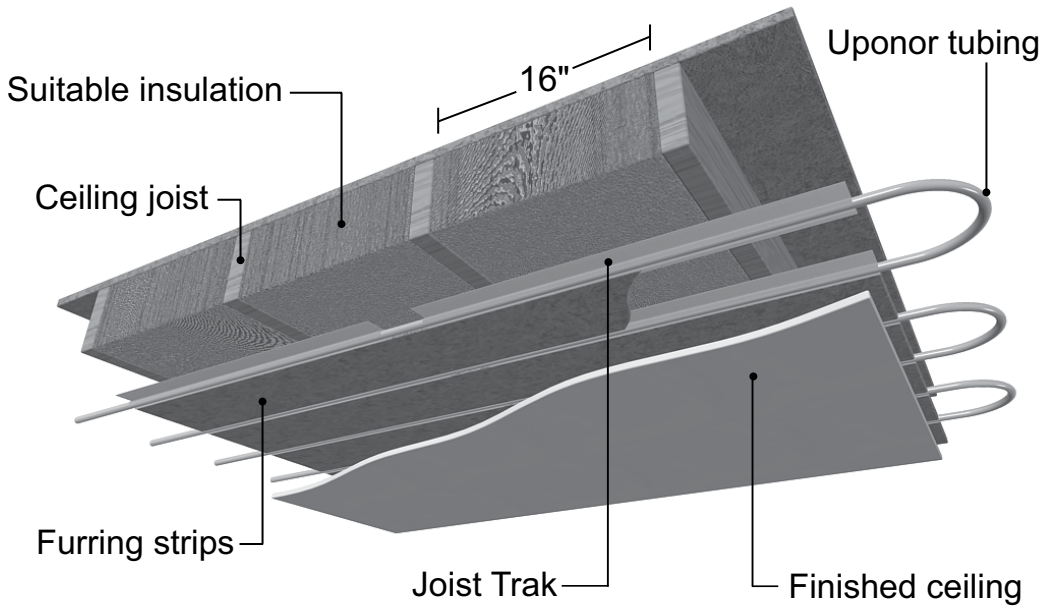
What to look for — Allow the bends of the tubing at either end of the joist bay to straighten prior to installing in the panel. This ensures the tubing enters the panels in a straight line so that it does not cause noise by rubbing against the sides of the groove during operation.

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

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

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

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



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 tubing into the Joist Trak groove to complete the room.

Connect the tubing 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.

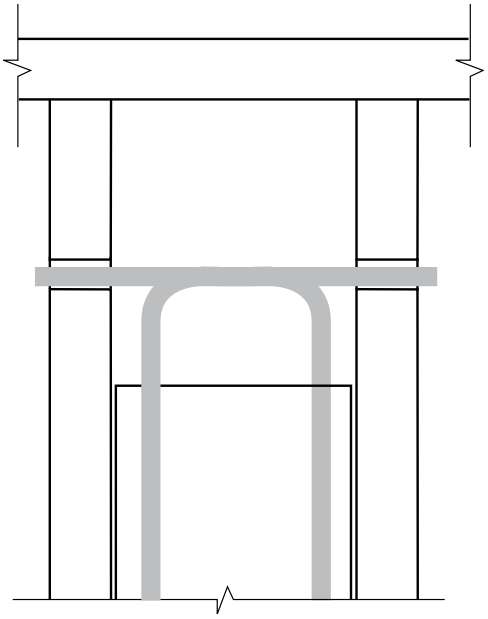
Do not exceed 120ºF water temperatures with radiant ceiling. Otherwise, flash from the ceiling, streaking and hot-head/cold-feet syndrome may develop. Because of its powerful output, it is not always necessary to install radiant ceiling over the entire ceiling area.

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.

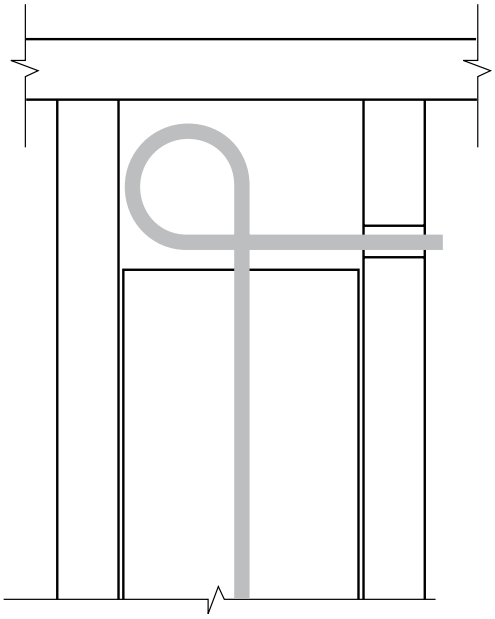
Be sure there is adequate insulation installed above the tubing and plates. Insulation required by code is generally adequate, but additional insulation is required in ceilings that aren't usually insulated.

Avoid puncturing the tubing 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.



Double-plate expansion loop



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 tubing and the stresses placed on the aluminum plates from thermal expansion.

Uponor PEX tubing products expand at a rate of 1.1 inch per 100 feet of tubing 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 tubing does not make noise when it moves in the aluminum plates. The noise is caused when the tubing 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 tubing 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 tubing 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 tubing 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.

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 Advanced Design Suite™ (ADS) design program. ADS analyzes how a building will perform under design conditions (worst-case scenario) by determining the heat loss and heat gain.

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 ADS, 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

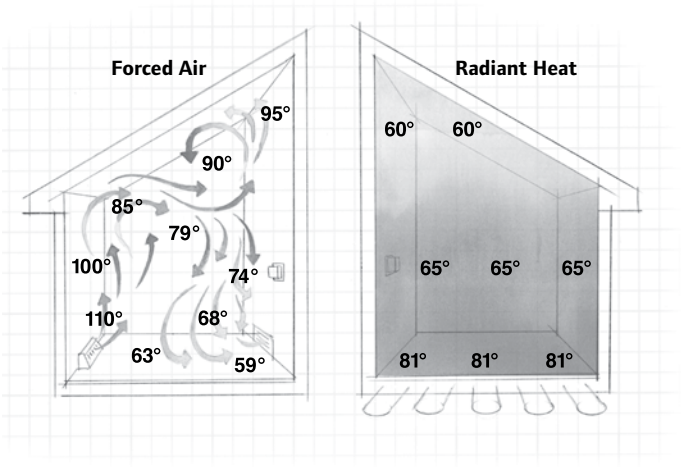
Heat follows the line of least resistance. High R-value floor coverings force heat to travel downward or laterally. Insulation will help prevent heat from traveling downward and force it into the conditioned space.

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 ADS 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).

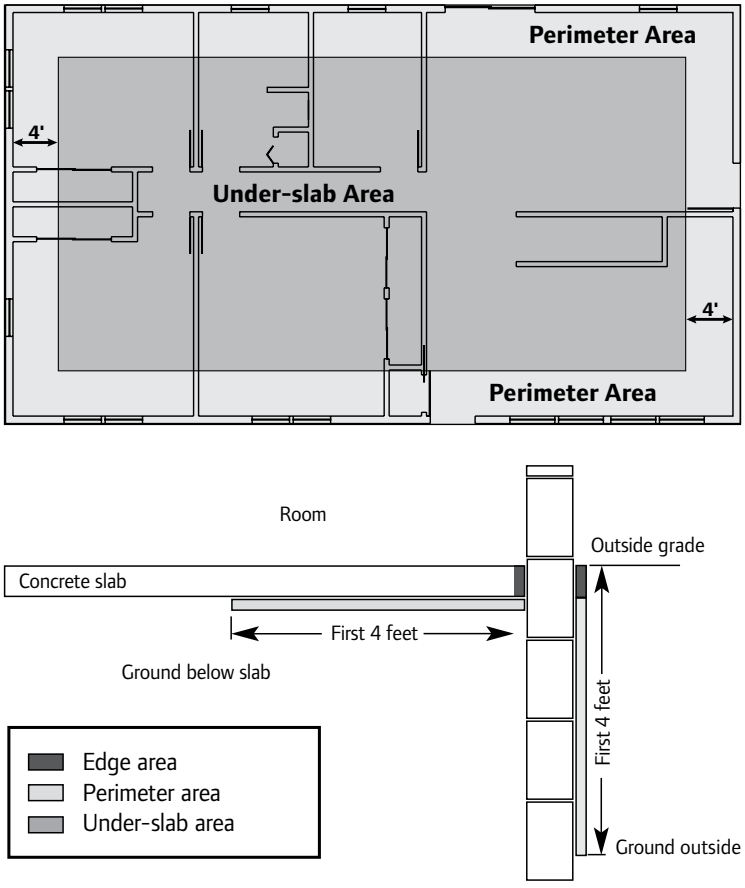


Figure 7-1: Slab Areas

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.

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 7-2**.
- **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

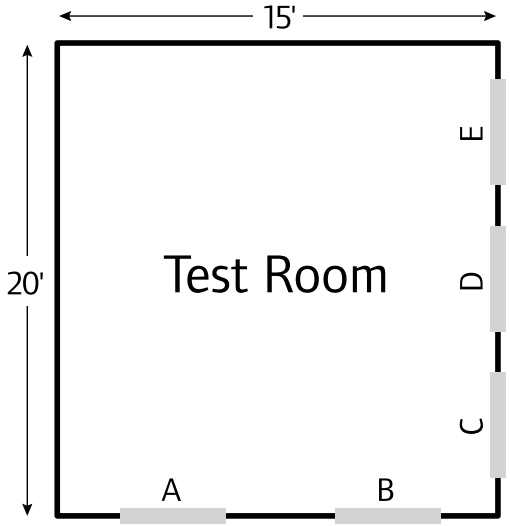
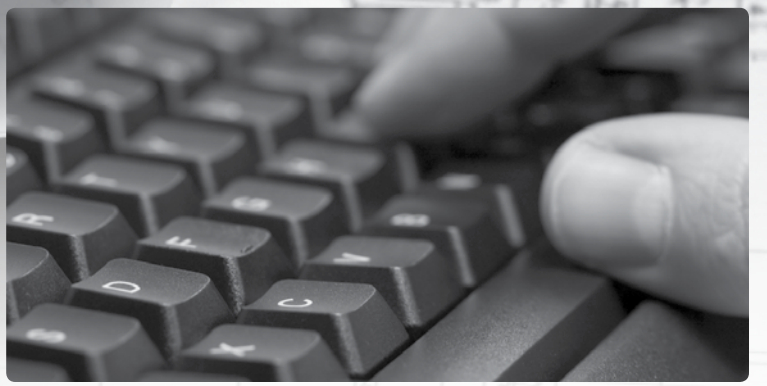


Figure 7-2: Test Room

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 0.0006
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, ADS 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 ADS prompts the user to input the type of tubing product to be used, the design differential temperature and the specifics of floor construction. ADS analyzes the information and calculates a supply water temperature and the tubing 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.

ADS Functions

The Uponor design software package 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

Features and Benefits

Quick Start — The radiant floor heating module offers a menu of house styles and room templates to begin the design.

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

Easy Navigation — Setup to look and feel like a web page, the 32-bit platform allows quick and easy movement within the program.

Piping and Wiring Diagrams and Specification Viewer — The program includes ManuSPEC® and Spec Data System Specifications as well as wiring and piping schematics.

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™ Multifunction Controller and the Climate Cŏntrol Zoning System.

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. ADS 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 tubing size, flow rate, distance, etc., and the program generates the resulting loss. PEX, Uponor Multi-layer Composite (MLC) tubing (formerly MultiCor®) 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 — ADS allows for simple adjustment of the final loop length.

Building Templates — The Heating Design Wizard allows users to create new building templates or edit existing templates. Users can add, rename or delete rooms.

Radiant Ceiling — The user can toggle between economical and normal designs in either a ceiling or supplemental heating application. Selecting the economical mode calculates the minimum amount of coverage required.

Radiant Wall — The user can use the wall area for a heated surface to meet the space heat loss. Selecting the wall option will calculate the minimum amount of coverage required.

Supplemental Heat — The supplemental heat components of the heat loss are shown in the heat-loss tree, 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. ADS 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 ADS automatically calculates 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, complete with help sections, index and graphics, which can be downloaded from **uponorpro.com**.



Chapter 8

Radiant Floor System Design

Although Uponor radiant floor heating systems are quickly and accurately designed using the Advanced Design Suite™ (ADS) software, 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/ft² heat loss for each room
- Floor surface temperature
- Project installation method
- Tubing type and size
- Finished floor material R-value
- Tubing 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 76 to 87**.

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

Step 1: Heat-loss Analysis

The ADS 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

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)**	**18.2**
E	**Total load (BTU/h/ft²)**	**21.9**
F	Floor surface temp. (°F)	
G	Installation method	
H	Tubing size	
I	Floor covering R-value	
J	Differential temp. (°F)	
K	Tubing 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)	

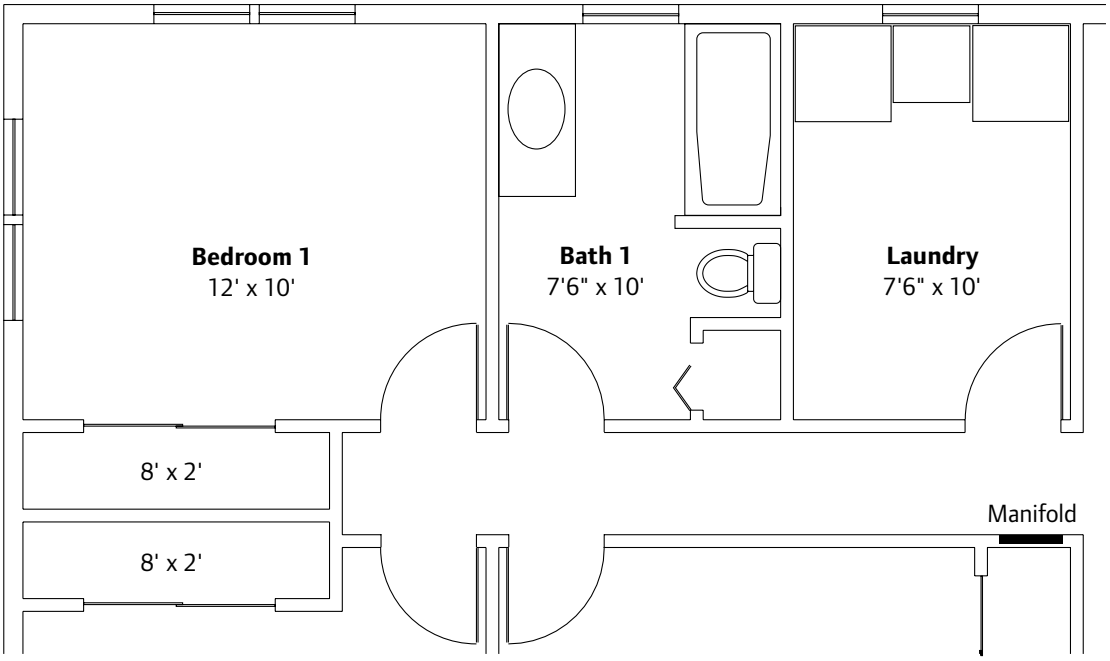


Figure 8-1: Uponor Training House (Partial)

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)	18.2
E	Total load (BTU/h/ft²)	21.9
F	**Floor surface temp. (°F)**	**74.1°F**
G	Installation method	
H	Tubing size	
I	Floor covering R-value	
J	Differential temp. (°F)	
K	Tubing 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)	

Bedroom 1 (Floor Plan 1)	
Total Area	136 ft²
Average Height	8 ft
Volume	1,088 ft²
Air Changes	0.35/hr
Room Temperature	65°F
Components	1,841 BTU/hr
Infiltration	420 BTU/hr
Ceiling Upward	213 BTU/hr
Floor Downward	499 BTU/hr
Total Heat Loss	2,974 BTU/hr
Supplemental	0 BTU/hr
Total Room Loss	2,974
Radiant to Room Load	2,475 BTU/hr
Unit Load	18.2 BTU/ft²/hr
Total Radiant Load	2,974 BTU/hr
Unit Load	21.9 BTU/ft²/hr

Figure 8-2: Heat-loss Data for Bedroom 1

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 ADS 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.

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 ADS printout or calculate manually by dividing the BTU/h by the floor area (in square feet) where tubing can be installed. Remember to subtract areas where tubing 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 tubing 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:
(18.2 BTU/h/ft² ÷ 2 BTU/h/ft²/°F) + 65°F = 74.1°F floor surface temperature.

The formula used to calculate the floor surface temperature is precise and is supplied by the ADS 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 8-3**. 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/ft^2 requirement (18.2). The chart is divided into five BTU/h/ft^2 increments. If between values, round to the next higher value. For this example of 18.2 BTU/h/ft^2, use the 20 BTU/h/ft^2 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 74.1°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 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/ft^2 for a room. To calculate the maximum upward BTU/h/ft^2 at a given room setpoint temperature, use this equation:

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

Using this formula, a room with a setpoint temperature of 65°F will support 45 BTU/h/ft^2 for a maximum upward BTU/h/ft^2 load. Conversely, if the room setpoint temperature is 70°F, then 35 BTU/h/ft^2 is the maximum upward load. Obviously, if wood flooring is used, the BTU/h/ft^2 capability is less. Remember, these loads are maximum capabilities and may be reduced by floor construction and floor covering selections.

Enter 74.1°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.

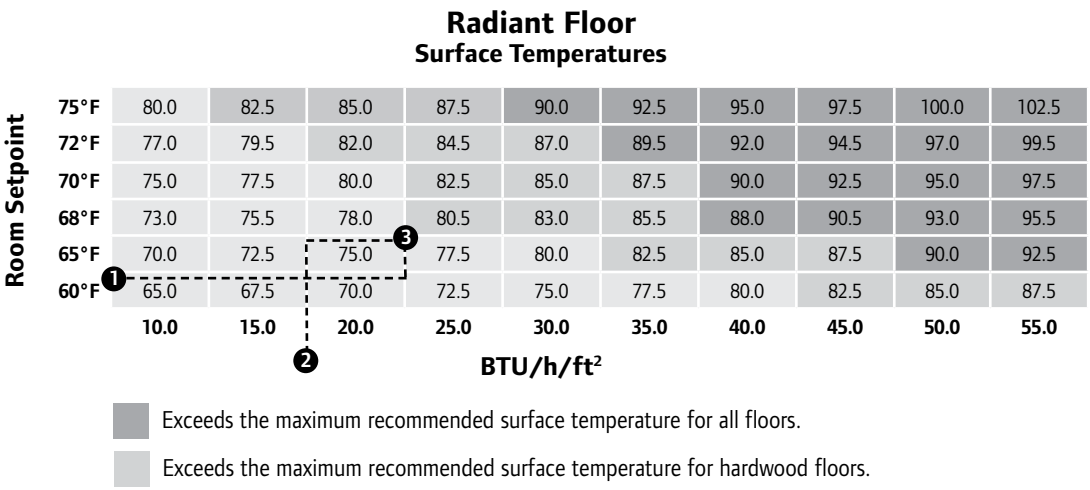


Figure 8-3: Excerpt From Radiant Floor Surface Temperatures Chart

Radial 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)	18.2
E	Total load (BTU/h/ft²)	21.9
F	Floor surface temp. (°F)	74.1°F
G	**Installation method**	**Poured floor**
H	**Tubing size**	**½" Wirsbo hePEX**
I	Floor covering R-value	
J	Differential temp. (°F)	
K	Tubing 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)	

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: Tubing Size

People often ask, "Do you get more heat out of ½" tubing than ⅜" tubing?" The surprising answer is no, not really. The most common tubing 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 tubing — is the heat emitter. The tubing merely carries water to the heat emitter.

Larger tubing 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, tubing spacing, water temperature, finished floor materials and flow are more important factors in determining performance capabilities.

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

Enter ½" Wirsbo hePEX™ in the tubing size cell on the 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 exerpt of the chart is shown in **Figure 8-4**.

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

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 8-4: Excerpt From Floor Covering R-value Chart

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 tubing 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. In this example, the R-value of ¼-inch nylon saxony is 0.88.
3. In the R-value table, find the type of carpet pad to be installed.
4. Move to the right and read the value for the appropriate thickness. In this example, the R-value of ¼-inch bonded urethane is 1.04.
5. Add the two values together to obtain the total R-value: 0.88 + 1.04 = 1.92

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

Tubing on-center distance is a function of flow, temperature and comfort. You must deliver the required flow through the tubing at the selected tubing on-center distance and be within the operational temperature range of the floor construction medium (e.g. concrete, underlayment, etc.). Decreasing the tubing spacing (bringing the tubing closer together) will lower the required supply water temperature and produce a more even surface temperature, but increases the amount of tubing used in the project.

For poured-floor underlayments, the maximum on-center distance is 9 inches. Due to the shallow depth of the pour, install the tubing 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.

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)	18.2
E	Total load (BTU/h/ft²)	21.9
F	Floor surface temp. (°F)	74.1°F
G	Installation method	Poured floor
H	Tubing size	½" Wirsbo hePEX
I	**Floor covering R-value**	**1.92**
J	**Differential temp. (°F)**	**10°F**
K	**Tubing o.c. distance (in)**	**9"**
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)	

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 8-5**).

Find: The required supply water temperature for a load of 18.2 BTU/h/ft^2 using poured-floor underlayment construction with tubing 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 tubing 9 inches on center).
2. Enter the chart in the BTU/h/ft^2 column for the given load (18.2 BTU/h/ft^2).
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 18.2 BTU/h/ft^2 line.
5. Read the required supply water temperature at the appropriate differential temperature. The required water temperature for Bedroom 1 is 125°F.

Enter 125°F in the supply water temperature cell on the worksheet.

Note: If the calculated downward loss in BTU/h/ft^2 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.

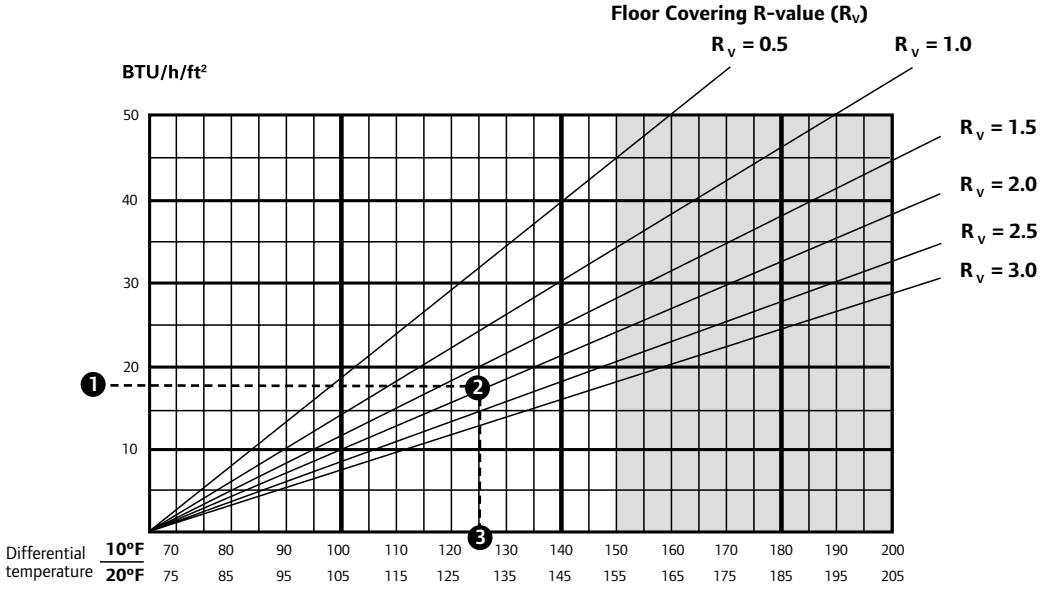
If the supply water temperature exceeds the tubing's sustained operating temperature or the floor construction limitation, the best ways to decrease the water temperature are to:

- Reduce the tubing 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 (UBC 2606©7B) and 140°F for poured-floor underlayment (verify with the product manufacturer). When installing tubing between floor joists, with or without heat emission plates, limit the supply water design temperature to 165°F.

Step 9: Determine Loop Length

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



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 8-5: Excerpt From Supply Water Temperature Chart

Active Loop Length — To determine the amount of tubing 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 tubing to install in the room.

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

Procedure:

1. Multiply the square footage of the room by the appropriate multiplier.
   136 ft^2 x 1.33 = 181 feet
2. The active loop length for Bedroom 1 is 181 feet.

Enter 181 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. Distance to the manifold from the room is 15 feet plus another 5 feet to cover the distance from the floor to the manifold and back to the floor.

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 15 feet from Bedroom 1. Multiply this distance by 2 (to account for supply and return piping) to obtain the amount of horizontal tubing in the leader length.
   15 x 2 = 30 feet
3. At the manifold location, this example will require approximately 5 feet of tubing 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 tubing amounts together.
   30 + 5 = 35 feet
4. The leader length for Bedroom 1 is 35 feet.

Enter 35 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.
   181 + 35 = 216
2. The total loop length for Bedroom 1 is 216 feet.

Enter 216 feet in the total loop length cell on the 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)
- Tubing on-center distance
- Active loop length

For Bedroom 1 of the Training House, the total load from the heat loss is 21.9 BTU/h/ft^2. The active loop length, based on 9 inches on-center spacing, is 181 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.

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)	18.2
E	Total load (BTU/h/ft^2)	21.9
F	Floor surface temp. (°F)	74.1°F
G	Installation method	Poured floor
H	Tubing size	½" Wirsbo hePEX
I	Floor covering R-value	1.92
J	Differential temp. (°F)	10°F
K	Tubing o.c. distance (in)	9"
L	**Supply water temp. (°F)**	**125°F**
M	**Active loop length**	**181'**
N	**Leader loop length**	**35'**
O	**Total loop length**	**216'**
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)	

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 8-6**).
2. Enter the chart at the total BTU/h/ft² load (21.9) in the BTU/h/ft² column. In small applications, round to the nearest BTU/h/ft² value (22 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 both 21 and 22 BTU/h/ft². Use the following formula:

   {[(F1 -F2) ÷ 10] x 7} + F2 = gpm per foot

   F1 = flow rounded up to the next whole number (22)

   F2 = flow rounded down to the next whole number (21)

   Example for 22 and 23 BTU/h/ft²

   {[(0.00334 - 0.00319) ÷ 10] x 7} + 0.00319

   [(0.00015 ÷ 10) x 7] + 0.00319

   (0.000015 x 9) + 0.00319

   0.000135 + 0.00319

   0.003325 gpm per foot of tubing

4. The actual flow value is 0.003325 gpm per foot of tubing. By rounding up to the nearest whole number (22 BTU/h/ft²), the flow value is 0.00334. As you can see, following the formula in Step 3 on small projects is not necessary. The resulting difference in flow is fairly insignificant. The ADS software program will always provide actual flow information.
5. Using the actual flow, multiply it by the active loop length. 0.003325 x 181 = 0.60 gpm

Enter 0.60 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 tubing, type of tubing, supply water temperature and fluid concentration.

The flow for this loop is 0.60 gallons per minute. The total loop length is 216 feet. The type and size of tubing is ½" Wirsbo hePEX. The supply water temperature is 125°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 (0.60 gpm).
3. Move right to the closest supply water column for the manifold (120ºF).

   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 120°F column.

4. Read the feet of head drop per foot (0.01277).
5. Multiply the feet of head value per foot by the total loop length to determine total feet of head for the loop. (0.0.01277 x 216 = 2.76 feet of head)

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.

100% WATER

10°F SUPPLY / RETURN DIFFERENTIAL

FLOW IN GPM PER FOOT OF TUBING

	Tubing 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.
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

Figure 8-6: Excerpt From 100% Water Flow Chart

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 tubing size.

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

Enter 2.76 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 **pages 88 and 90**.

Performing Initial Flow Balance Calculations

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. To calculate the setting, use the formula below.

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

Example

Calculate the balance for a 200-foot loop with the longest loop on 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

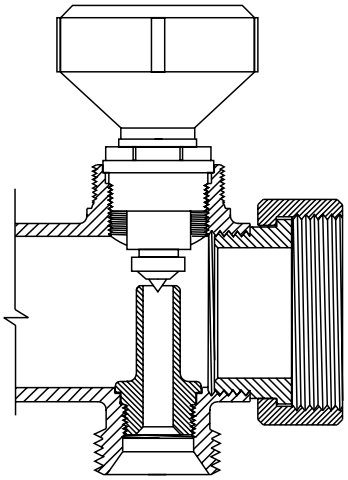
To adjust the valve setting for an individual loop, follow the steps listed below.

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

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.



Radial 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)	18.2
E	Total load (BTU/h/ft²)	21.9
F	Floor surface temp. (°F)	74.1°F
G	Installation method	Poured floor
H	Tubing size	½" Wirsbo hePEX
I	Floor covering R-value	1.92
J	Differential temp. (°F)	10°F
K	Tubing o.c. distance (in)	9"
L	Supply water temp. (°F)	125°F
M	Active loop length	181'
N	Leader loop length	35'
O	Total loop length	216'
P	**Loop flow in gpm**	**0.60**
Q	**Loop head pressure (ft)**	**2.76'**
R	Loop balancing turns	

Manifold Totals

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

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 tubing 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

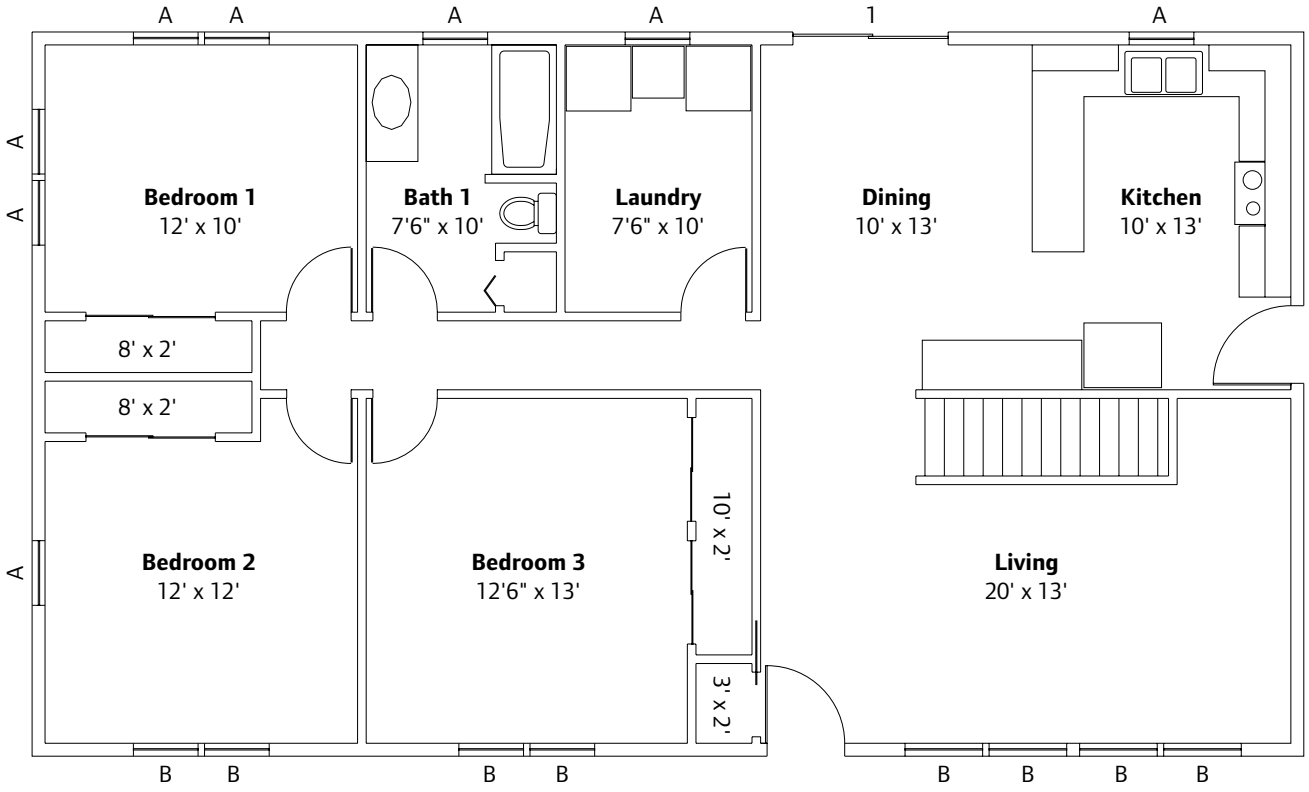
When calculating the flow and head total for a system, gpm (or total flow) is cumulative. The flow of all loops served by a single circulator should be added together. Head (or pressure loss) is not cumulative. Simply select the highest pressure drop of all the loops per manifold served by that circulator. 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.

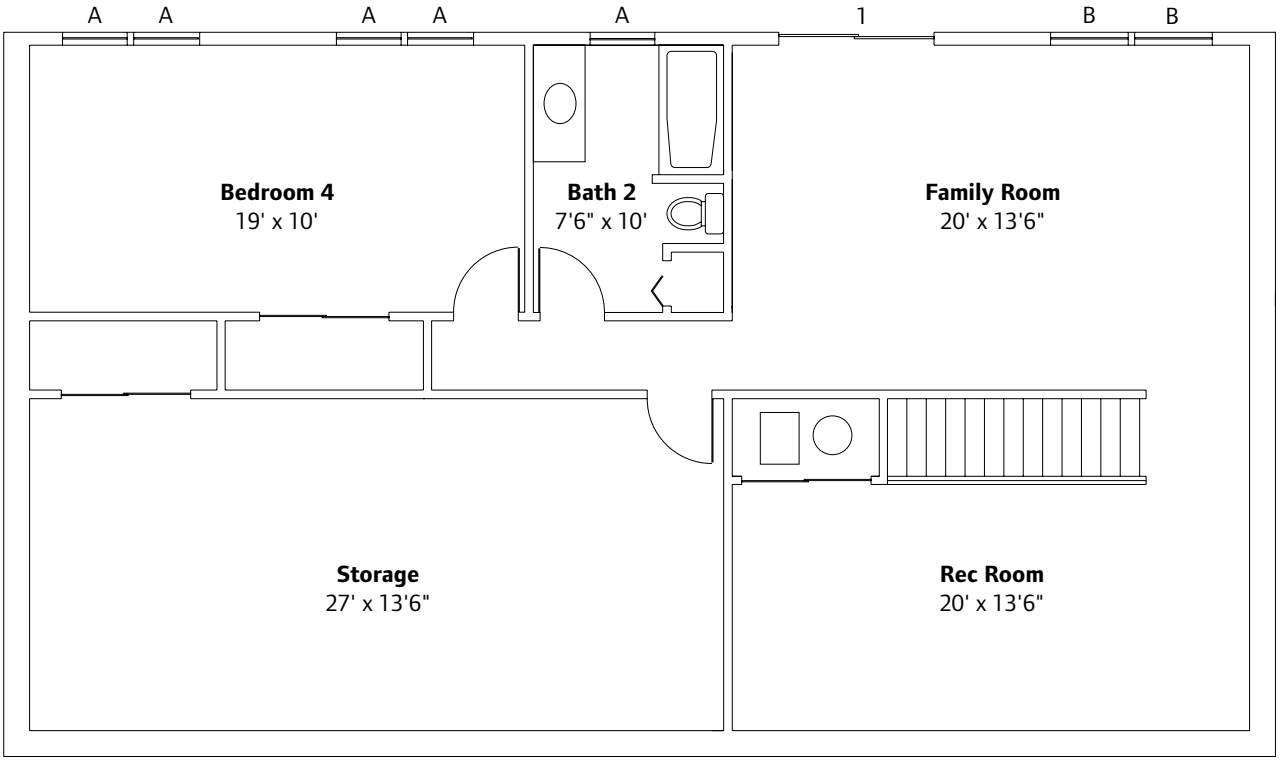
The Complete Design

The following is the entire room schedule for the Uponor Training House. The floor plans and heat-loss information appear on **pages 75 to 87**. Finish the design with the worksheet started by Bedroom 1. See **pages 88 to 91** for the completed tutorial design calculations and tubing layouts.

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



Main-level Floor Plan (No Scale)



Lower-level Floor Plan (No Scale)

Project #: 20110331-02
Date: Mar 31, 2011
Prepared For: A-Z Heating Supply

Uponor Inc. 5925 148th Street West Apple Valley, MN 55124
Prepared By: Technical Services Phone: 952-891-2000 Fax: 952-997-1731 Email:

Project Summary

Project #:	20110331-02
Project Name:	Training House
Location:	Indianapolis, Indiana
CloseDate:	
Engineer:	
Design Data Location:	Indianapolis, Indiana
Outdoor Temperature:	3 °F
Wind Speed:	22 mph
Total Area:	2,372 ft²
Construction Quality:	Best
RFH Glycol Level:	100% Water
Design Temp. Drop:	10 °F
Radiant Tubing Volume:	28.3 gallons(US)
Volume Water:	28.3 gallons(US)
Volume Glycol:	0 gallons(US)
Total-Components Load:	20,160 Btu/hr
Total Infiltration Load:	7,327 Btu/hr
Total Floor Downward Load:	6,335 Btu/hr
Total-Radiant Load:	27,487 Btu/hr
Total-Supplemental Load:	0 Btu/hr
Total-Project Heat Loss:	31,640 Btu/hr

Heat Loss Data

Bath 2 (Floorplan 1)

Total Area:	75 ft²	**Components:**	510 Btu/hr
Average Height:	8 ft	**Infiltration:**	232 Btu/hr
Volume:	600 ft³	**Ceiling Upward:**	0 Btu/hr
Air Changes:	0.35 /hr	**Floor Downward:**	321 Btu/hr
RoomTemperature:	65 °F	**Total Heat Loss:**	1,063 Btu/hr
		Supplemental:	0 Btu/hr
		Total Room Loss:	1,063
		Radiant to Room Load:	742 Btu/hr
		Unit Load:	9.9 Btu/hr/ft²
		Total Radiant Load:	1,063 Btu/hr
		Unit Load:	14.2 Btu/hr/ft²

Created using Uponor Advanced Design Suite - 6.9.3

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Floor

Total Area:	75 ft²	**Downward Load:**	321 Btu/hr
Unheated Area:	0 ft²		
Heated Area:	75 ft²		
Construction:	Concrete		
Slab Depth:	4 in		
Cover Rv:	0.5 °F·ft²·hr/Btu		
Structure Rv:	1 °F·ft²·hr/Btu		
Insulation Rv:	5 °F·ft²·hr/Btu		
Perimeter Rv:	5 °F·ft²·hr/Btu		
Edge Rv:	5 °F·ft²·hr/Btu		
Surface Temperature:	69.9 °F		
Design Temp. Drop:	10 °F		

Ceiling

Total Area:	75 ft²	**Upward Load:**	0 Btu/hr
Unheated Area:	75 ft²		
Heated Area:	0 ft²		
Construction:	Gypsum Wall board		
Cover Rv:	0.56 °F·ft²·hr/Btu		
Insulation Rv:	35 °F·ft²·hr/Btu		
Space Above Heated:	From Same Source		

Other Components

Component	Length (ft)	Width/Height (ft)	Area (ft²)	Rv (°F·ft²·hr/Btu)	Heat Loss (Btu/hr)
Wall-1	8	8	64	19	510
Window-1	4	2.5	10	1.81	343
Net Wall			54	19	167

Bath/Laundry (Floorplan 1)

Total Area:	150 ft²	**Components:**	995 Btu/hr
Average Height:	8 ft	**Infiltration:**	463 Btu/hr
Volume:	1,200 ft³	**Ceiling Upward:**	235 Btu/hr
Air Changes:	0.35 /hr	**Floor Downward:**	150 Btu/hr
RoomTemperature:	65 °F	**Total Heat Loss:**	1,844 Btu/hr
		Supplemental:	0 Btu/hr
		Total Room Loss:	1,843
		Radiant to Room Load:	1,694 Btu/hr
		Unit Load:	11.3 Btu/hr/ft²
		Total Radiant Load:	1,843 Btu/hr
		Unit Load:	12.3 Btu/hr/ft²

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Floor

Total Area:	150 ft²	**Downward Load:**	150 Btu/hr
Unheated Area:	11 ft²		
Heated Area:	139 ft²		
Construction:	Joist (16" OC)		
Cover Rv:	0.56 °F·ft²·hr/Btu		
Structure Rv:	1 °F·ft²·hr/Btu		
Insulation Rv:	11 °F·ft²·hr/Btu		
Space Below Heated:	From Same Source		
Surface Temperature:	71.1 °F		
Design Temp. Drop:	10 °F		

Ceiling

Total Area:	150 ft²	**Upward Load:**	235 Btu/hr
Unheated Area:	150 ft²		
Heated Area:	0 ft²		
Construction:	Gypsum Wall board		
Cover Rv:	0.56 °F·ft²·hr/Btu		
Insulation Rv:	38 °F·ft²·hr/Btu		
Space Above Heated:	No		

Other Components

Component	Length (ft)	Width/Height (ft)	Area (ft²)	Rv (°F·ft²·hr/Btu)	Heat Loss (Btu/hr)
Wall-1	15	8	120	19	995
Window-1	4	5	20	1.81	685
Net Wall			100	19	310

Bedroom #1 (Floorplan 1)

Total Area:	136 ft²	**Components:**	1,841 Btu/hr
Average Height:	8 ft	**Infiltration:**	420 Btu/hr
Volume:	1,088 ft³	**Ceiling Upward:**	213 Btu/hr
Air Changes:	0.35 /hr	**Floor Downward:**	499 Btu/hr
RoomTemperature:	65 °F	**Total Heat Loss:**	2,974 Btu/hr
		Supplemental:	0 Btu/hr
		Total Room Loss:	2,974
		Radiant to Room Load:	2,475 Btu/hr
		Unit Load:	18.2 Btu/hr/ft²
		Total Radiant Load:	2,974 Btu/hr
		Unit Load:	21.9 Btu/hr/ft²

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Floor

Total Area:	136 ft²	**Downward Load:**	499 Btu/hr
Unheated Area:	0 ft²		
Heated Area:	136 ft²		
Construction:	Joist (16" OC)		
Cover Rv:	1.92 °F·ft²·hr/Btu		
Structure Rv:	1 °F·ft²·hr/Btu		
Insulation Rv:	11 °F·ft²·hr/Btu		
Space Below Heated:	From Same Source		
Surface Temperature:	74.1 °F		
Design Temp. Drop:	10 °F		

Ceiling

Total Area:	136 ft²	**Upward Load:**	213 Btu/hr
Unheated Area:	136 ft²		
Heated Area:	0 ft²		
Construction:	Gypsum Wall board		
Cover Rv:	0.56 °F·ft²·hr/Btu		
Insulation Rv:	38 °F·ft²·hr/Btu		
Space Above Heated:	No		

Other Components

Component	Length (ft)	Width/Height (ft)	Area (ft²)	Rv (°F·ft²·hr/Btu)	Heat Loss (Btu/hr)
Wall-1	24	8	192	19	1841
Window-1	4	5	20	1.81	685
Window-2	4	5	20	1.81	685
Net Wall			152	19	471

Bedroom #2 (Floorplan 1)

Total Area:	160 ft²	**Components:**	1,579 Btu/hr
Average Height:	8 ft	**Infiltration:**	494 Btu/hr
Volume:	1,280 ft³	**Ceiling Upward:**	251 Btu/hr
Air Changes:	0.35 /hr	**Floor Downward:**	469 Btu/hr
RoomTemperature:	65 °F	**Total Heat Loss:**	2,793 Btu/hr
		Supplemental:	0 Btu/hr
		Total Room Loss:	2,793
		Radiant to Room Load:	2,324 Btu/hr
		Unit Load:	14.5 Btu/hr/ft²
		Total Radiant Load:	2,793 Btu/hr
		Unit Load:	17.5 Btu/hr/ft²

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Floor

Total Area:	160 ft²	**Downward Load:**	469 Btu/hr
Unheated Area:	0 ft²		
Heated Area:	160 ft²		
Construction:	Joist (16" OC)		
Cover Rv:	1.92 °F·ft²·hr/Btu		
Structure Rv:	1 °F·ft²·hr/Btu		
Insulation Rv:	11 °F·ft²·hr/Btu		
Space Below Heated:	From Same Source		
Surface Temperature:	72.3 °F		
Design Temp. Drop:	10 °F		

Ceiling

Total Area:	160 ft²	**Upward Load:**	251 Btu/hr
Unheated Area:	160 ft²		
Heated Area:	0 ft²		
Construction:	Gypsum Wall board		
Cover Rv:	0.56 °F·ft²·hr/Btu		
Insulation Rv:	38 °F·ft²·hr/Btu		
Space Above Heated:	No		

Other Components

Component	Length (ft)	Width/Height (ft)	Area (ft²)	Rv (°F·ft²·hr/Btu)	Heat Loss (Btu/hr)
Wall-1	26	8	208	19	1580
Window-1	4	5	20	1.81	685
Window-2	4	2.5	10	1.81	343
Net Wall			178	19	552

Bedroom #3 (Floorplan 1)

Total Area:	183 ft²	**Components:**	921 Btu/hr
Average Height:	8 ft	**Infiltration:**	565 Btu/hr
Volume:	1,464 ft³	**Ceiling Upward:**	287 Btu/hr
Air Changes:	0.35 /hr	**Floor Downward:**	358 Btu/hr
RoomTemperature:	65 °F	**Total Heat Loss:**	2,131 Btu/hr
		Supplemental:	0 Btu/hr
		Total Room Loss:	2,130
		Radiant to Room Load:	1,773 Btu/hr
		Unit Load:	9.7 Btu/hr/ft²
		Total Radiant Load:	2,130 Btu/hr
		Unit Load:	11.6 Btu/hr/ft²

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Floor

Total Area:	183 ft²	**Downward Load:**	358 Btu/hr
Unheated Area:	0 ft²		
Heated Area:	183 ft²		
Construction:	Joist (16" OC)		
Cover Rv:	1.92 °F·ft²·hr/Btu		
Structure Rv:	1 °F·ft²·hr/Btu		
Insulation Rv:	11 °F·ft²·hr/Btu		
Space Below Heated:	From Same Source		
Surface Temperature:	69.8 °F		
Design Temp. Drop:	10 °F		

Ceiling

Total Area:	183 ft²	**Upward Load:**	287 Btu/hr
Unheated Area:	183 ft²		
Heated Area:	0 ft²		
Construction:	Gypsum Wall board		
Cover Rv:	0.56 °F·ft²·hr/Btu		
Insulation Rv:	38 °F·ft²·hr/Btu		
Space Above Heated:	No		

Other Components

Component	Length (ft)	Width/Height (ft)	Area (ft²)	Rv (°F·ft²·hr/Btu)	Heat Loss (Btu/hr)
Wall-1	12	8	96	19	921
Window-1	4	5	20	1.81	685
Net Wall			76	19	236

Bedroom #4 (Floorplan 1)

Total Area:	209 ft²	**Components:**	1,965 Btu/hr
Average Height:	8 ft	**Infiltration:**	646 Btu/hr
Volume:	1,672 ft³	**Ceiling Upward:**	0 Btu/hr
Air Changes:	0.35 /hr	**Floor Downward:**	982 Btu/hr
RoomTemperature:	65 °F	**Total Heat Loss:**	3,593 Btu/hr
		Supplemental:	0 Btu/hr
		Total Room Loss:	3,593
		Radiant to Room Load:	2,611 Btu/hr
		Unit Load:	12.5 Btu/hr/ft²
		Total Radiant Load:	3,593 Btu/hr
		Unit Load:	17.2 Btu/hr/ft²

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Floor

Total Area:	209 ft²	**Downward Load:**	982 Btu/hr
Unheated Area:	0 ft²		
Heated Area:	209 ft²		
Construction:	Concrete		
Slab Depth:	4 in		
Cover Rv:	1.92 °F·ft²·hr/Btu		
Structure Rv:	1 °F·ft²·hr/Btu		
Insulation Rv:	10 °F·ft²·hr/Btu		
Perimeter Rv:	10 °F·ft²·hr/Btu		
Edge Rv:	10 °F·ft²·hr/Btu		
Surface Temperature:	71.2 °F		
Design Temp. Drop:	10 °F		

Ceiling

Total Area:	209 ft²	**Upward Load:**	0 Btu/hr
Unheated Area:	209 ft²		
Heated Area:	0 ft²		
Construction:	Gypsum Wall board		
Cover Rv:	0.56 °F·ft²·hr/Btu		
Insulation Rv:	35 °F·ft²·hr/Btu		
Space Above Heated:	From Same Source		

Other Components

Component	Length (ft)	Width/Height (ft)	Area (ft²)	Rv (°F·ft²·hr/Btu)	Heat Loss (Btu/hr)
Wall-1	29	8	232	19	1965
Window-1	4	5	20	1.81	685
Window-2	4	5	20	1.81	685
Net Wall			192	19	595

Family Room (Floorplan 1)

Total Area:	270 ft²	**Components:**	2,742 Btu/hr
Average Height:	8 ft	**Infiltration:**	834 Btu/hr
Volume:	2,160 ft³	**Ceiling Upward:**	0 Btu/hr
Air Changes:	0.35 /hr	**Floor Downward:**	1,253 Btu/hr
RoomTemperature:	65 °F	**Total Heat Loss:**	4,829 Btu/hr
		Supplemental:	0 Btu/hr
		Total Room Loss:	4,829
		Radiant to Room Load:	3,576 Btu/hr
		Unit Load:	13.2 Btu/hr/ft²
		Total Radiant Load:	4,829 Btu/hr
		Unit Load:	17.9 Btu/hr/ft²

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Floor

Total Area:	270 ft²	**Downward Load:**	1,253 Btu/hr
Unheated Area:	0 ft²		
Heated Area:	270 ft²		
Construction:	Concrete		
Slab Depth:	4 in		
Cover Rv:	1.92 °F·ft²·hr/Btu		
Structure Rv:	1 °F·ft²·hr/Btu		
Insulation Rv:	10 °F·ft²·hr/Btu		
Perimeter Rv:	10 °F·ft²·hr/Btu		
Edge Rv:	10 °F·ft²·hr/Btu		
Surface Temperature:	71.6 °F		
Design Temp. Drop:	10 °F		

Ceiling

Total Area:	270 ft²	**Upward Load:**	0 Btu/hr
Unheated Area:	270 ft²		
Heated Area:	0 ft²		
Construction:	Gypsum Wall board		
Cover Rv:	0.56 °F·ft²·hr/Btu		
Insulation Rv:	35 °F·ft²·hr/Btu		
Space Above Heated:	From Same Source		

Other Components

Component	Length (ft)	Width/Height (ft)	Area (ft²)	Rv (°F·ft²·hr/Btu)	Heat Loss (Btu/hr)
Wall-1	33	8	264	19	2742
Door-1	6	7	42	1.82	1431
Window-1	4	5	20	1.81	685
Net Wall			202	19	626

Kitchen/Dining (Floorplan 1)

Total Area:	266 ft²	**Components:**	2,487 Btu/hr
Average Height:	8 ft	**Infiltration:**	822 Btu/hr
Volume:	2,128 ft³	**Ceiling Upward:**	417 Btu/hr
Air Changes:	0.35 /hr	**Floor Downward:**	363 Btu/hr
RoomTemperature:	65 °F	**Total Heat Loss:**	4,089 Btu/hr
		Supplemental:	0 Btu/hr
		Total Room Loss:	4,089
		Radiant to Room Load:	3,726 Btu/hr
		Unit Load:	14 Btu/hr/ft²
		Total Radiant Load:	4,089 Btu/hr
		Unit Load:	15.4 Btu/hr/ft²

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Floor

Total Area:	266 ft²	**Downward Load:**	363 Btu/hr
Unheated Area:	36 ft²		
Heated Area:	230 ft²		
Construction:	Joist (16" OC)		
Cover Rv:	0.67 °F·ft²·hr/Btu		
Structure Rv:	1 °F·ft²·hr/Btu		
Insulation Rv:	11 °F·ft²·hr/Btu		
Space Below Heated:	From Same Source		
Surface Temperature:	73.1 °F		
Design Temp. Drop:	10 °F		

Ceiling

Total Area:	266 ft²	**Upward Load:**	417 Btu/hr
Unheated Area:	266 ft²		
Heated Area:	0 ft²		
Construction:	Gypsum Wall board		
Cover Rv:	0.56 °F·ft²·hr/Btu		
Insulation Rv:	38 °F·ft²·hr/Btu		
Space Above Heated:	No		

Other Components

Component	Length (ft)	Width/Height (ft)	Area (ft²)	Rv (°F·ft²·hr/Btu)	Heat Loss (Btu/hr)
Wall-1	33	8	264	19	2488
Door-1	3	7	21	5.29	246
Door-2	6	7	42	1.82	1431
Window-1	2	3	6	1.81	206
Net Wall			195	19	605

Living Room (Floorplan 1)

Total Area:	270 ft²	**Components:**	2,269 Btu/hr
Average Height:	8 ft	**Infiltration:**	834 Btu/hr
Volume:	2,160 ft³	**Ceiling Upward:**	429 Btu/hr
Air Changes:	0.35 /hr	**Floor Downward:**	344 Btu/hr
RoomTemperature:	65 °F	**Total Heat Loss:**	3,877 Btu/hr
		Supplemental:	0 Btu/hr
		Total Room Loss:	3,877
		Radiant to Room Load:	3,533 Btu/hr
		Unit Load:	13.1 Btu/hr/ft²
		Total Radiant Load:	3,877 Btu/hr
		Unit Load:	14.4 Btu/hr/ft²

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Floor

Total Area:	270 ft²	**Downward Load:**	344 Btu/hr
Unheated Area:	30 ft²		
Heated Area:	240 ft²		
Construction:	Joist (16" OC)		
Cover Rv:	0.67 °F·ft²·hr/Btu		
Structure Rv:	1 °F·ft²·hr/Btu		
Insulation Rv:	11 °F·ft²·hr/Btu		
Space Below Heated:	From Same Source		
Surface Temperature:	72.4 °F		
Design Temp. Drop:	10 °F		

Ceiling

Total Area:	270 ft²	**Upward Load:**	429 Btu/hr
Unheated Area:	270 ft²		
Heated Area:	0 ft²		
Construction:	Gypsum Wall board		
Cover Rv:	0 °F·ft²·hr/Btu		
Insulation Rv:	38 °F·ft²·hr/Btu		
Space Above Heated:	No		

Other Components

Component	Length (ft)	Width/Height (ft)	Area (ft²)	Rv (°F·ft²·hr/Btu)	Heat Loss (Btu/hr)
Wall-1	35	8	280	19	2269
Door-1	3	7	21	5.91	220
Window-1	4	5	20	1.81	685
Window-2	4	5	20	1.81	685
Net Wall			219	19	679

Rec Room (Floorplan 1)

Total Area:	270 ft²	**Components:**	1,364 Btu/hr
Average Height:	8 ft	**Infiltration:**	834 Btu/hr
Volume:	2,160 ft³	**Ceiling Upward:**	0 Btu/hr
Air Changes:	0.35 /hr	**Floor Downward:**	937 Btu/hr
RoomTemperature:	65 °F	**Total Heat Loss:**	3,135 Btu/hr
		Supplemental:	0 Btu/hr
		Total Room Loss:	3,135
		Radiant to Room Load:	2,198 Btu/hr
		Unit Load:	8.1 Btu/hr/ft²
		Total Radiant Load:	3,135 Btu/hr
		Unit Load:	11.6 Btu/hr/ft²

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Floor

Total Area:	270 ft²	**Downward Load:**	937 Btu/hr
Unheated Area:	0 ft²		
Heated Area:	270 ft²		
Construction:	Concrete		
Slab Depth:	4 in		
Cover Rv:	1.92 °F·ft²·hr/Btu		
Structure Rv:	1 °F·ft²·hr/Btu		
Insulation Rv:	10 °F·ft²·hr/Btu		
Perimeter Rv:	10 °F·ft²·hr/Btu		
Edge Rv:	10 °F·ft²·hr/Btu		
Surface Temperature:	69.1 °F		
Design Temp. Drop:	10 °F		

Ceiling

Total Area:	270 ft²	**Upward Load:**	0 Btu/hr
Unheated Area:	270 ft²		
Heated Area:	0 ft²		
Construction:	Gypsum Wall board		
Cover Rv:	0 °F·ft²·hr/Btu		
Insulation Rv:	35 °F·ft²·hr/Btu		
Space Above Heated:	From Same Source		

Other Components

Component	Length (ft)	Width/Height (ft)	Area (ft²)	Rv (°F·ft²·hr/Btu)	Heat Loss (Btu/hr)
Wall-1	33	8	264	11	1364
Net Wall			264	11	1364

Storage (Floorplan 1)

Total Area:	383 ft²	**Components:**	1,653 Btu/hr
Average Height:	8 ft	**Infiltration:**	1,183 Btu/hr
Volume:	3,064 ft³	**Ceiling Upward:**	0 Btu/hr
Air Changes:	0.35 /hr	**Floor Downward:**	659 Btu/hr
RoomTemperature:	65 °F	**Total Heat Loss:**	3,495 Btu/hr
		Supplemental:	0 Btu/hr
		Total Room Loss:	3,496
		Radiant to Room Load:	2,836 Btu/hr
		Unit Load:	7.4 Btu/hr/ft²
		Total Radiant Load:	3,496 Btu/hr
		Unit Load:	9.1 Btu/hr/ft²

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Floor

Total Area:	383 ft²	**Downward Load:**	659 Btu/hr
Unheated Area:	0 ft²		
Heated Area:	383 ft²		
Construction:	Concrete		
Slab Depth:	4 in		
Cover Rv:	0 °F·ft²·hr/Btu		
Structure Rv:	1 °F·ft²·hr/Btu		
Insulation Rv:	10 °F·ft²·hr/Btu		
Perimeter Rv:	10 °F·ft²·hr/Btu		
Edge Rv:	10 °F·ft²·hr/Btu		
Surface Temperature:	68.7 °F		
Design Temp. Drop:	10 °F		

Ceiling

Total Area:	383 ft²	**Upward Load:**	0 Btu/hr
Unheated Area:	383 ft²		
Heated Area:	0 ft²		
Construction:	Gypsum Wall board		
Cover Rv:	0 °F·ft²·hr/Btu		
Insulation Rv:	35 °F·ft²·hr/Btu		
Space Above Heated:	From Same Source		

Other Components

Component	Length (ft)	Width/Height (ft)	Area (ft²)	Rv (°F·ft²·hr/Btu)	Heat Loss (Btu/hr)
Wall-1	40	8	320	11	1653
Net Wall			320	11	1653

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	6	7	8	9	10					
D	Upward load (BTU/h/ft^2)	12.5	9.9	13.2	8.1	7.4					
E	Total load (BTU/h/ft^2)	17.2	14.2	17.9	11.6	9.1					
F	Floor surface temp. (°F)	71.2°F	69.9°F	71.6°F	69.1°F	68.7°F					
G	Installation method	Concrete slab	Concrete slab	Concrete slab	Concrete slab	Concrete slab					
H	Tubing 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	Tubing o.c. distance (in)	12"	6"	12"	12"	12"					
L	Supply water temp. (°F)	103°F	78°F	104°F	90°F	73°F					
M	Active loop length (ft)	209'	150'	270'	270'	383'					
N	Leader loop length (ft)	24'	18'	12'	6'	6'					
O	Total loop length (ft)	233'	168'	282'	276'	389'					
P	Loop flow in gpm	0.73	0.22	0.98	0.64	0.71					
Q	Loop head pressure (ft)	4.6'	0.4'	9.4'	4.3'	7.3'					
R	Loop balancing turns	2.4	1.7	2.9	2.8	4.0					

Manifold Totals

S	Supply water temp. (°F)	104°F
T	Manifold flow in gpm	3.28
U	Highest pressure head (ft)	9.4'

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 ADS printout (upward load).

E Enter the "Floor Unit Load" value from ADS 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 tubing 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 Tubing 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 tubing installed within the room (i.e., active loop).

N Enter the length of the tubing from the room being heated to the respective manifold.

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.

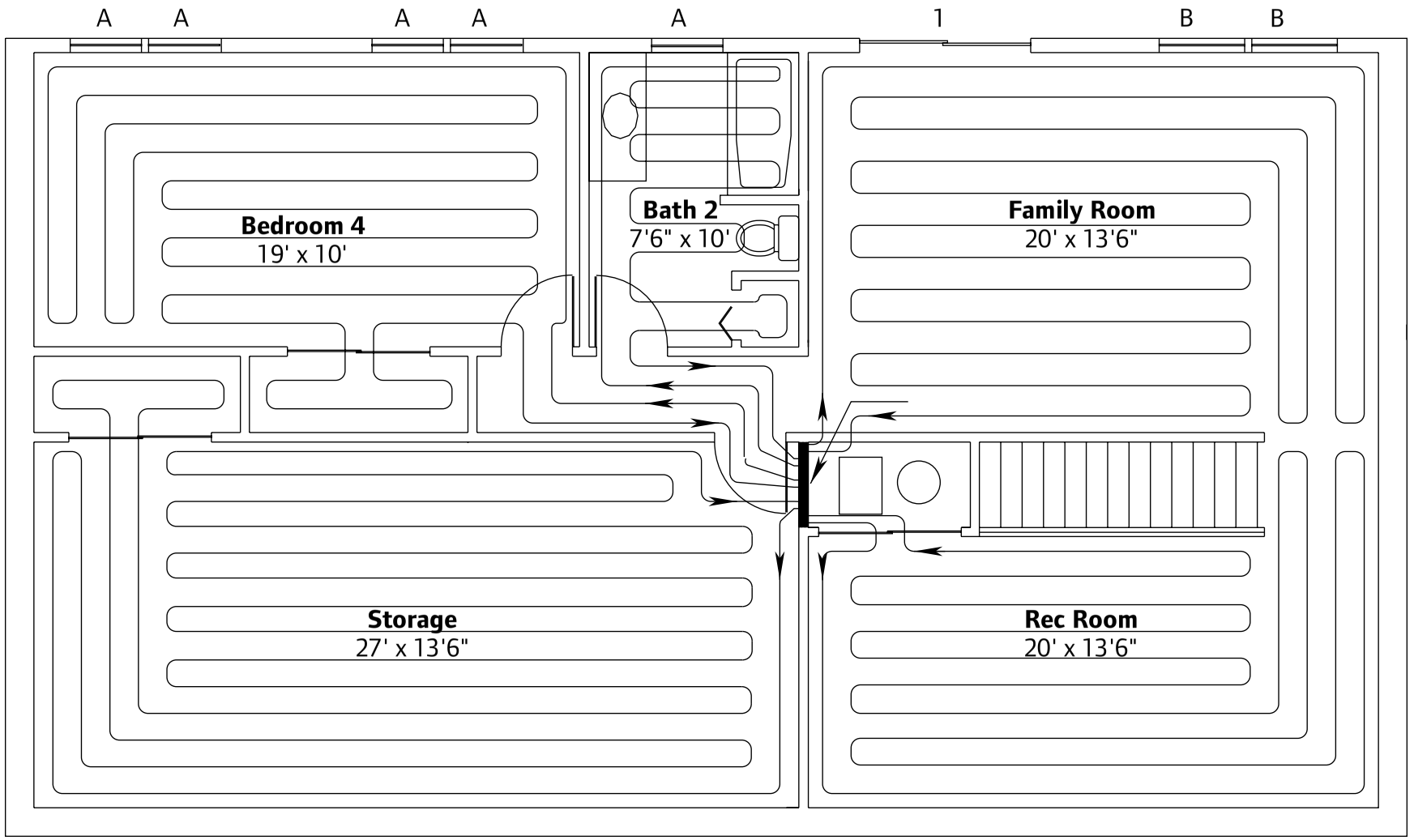
Q Use the values in **Rows H** and **P** with **Appendix G** to obtain the head pressure per loop. Choose the appropriate solution (water or water/glycol solution).

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.

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

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

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



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	5	5				
D	Upward load (BTU/h/ft²)	18.2	12.2	16.2	14.7	9.7	14.5				
E	Total load (BTU/h/ft²)	21.9	13.3	17.8	16.2	11.7	17.5				
F	Floor surface temp. (°F)	74.1°F	71.1°F	73.1°F	72.4°F	69.9°F	72.3°F				
G	Installation method	Poured floor	Poured floor	Poured floor	Poured floor	Poured floor	Poured floor				
H	Tubing 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	Tubing o.c. distance (in)	9"	9"	9"	9"	9"	9"				
L	Supply water temp. (°F)	125°F	90°F	102°F	94°F	100°F	113°F				
M	Active loop length (ft)	181'	200'	306'	313'	243'	213'				
N	Leader loop length (ft)	35'	23'	12'	6'	6'	35'				
O	Total loop length (ft)	216'	223'	318'	319'	249'	248'				
P	Loop flow in gpm	0.60	0.41	0.83	0.77	0.43	0.57				
Q	Loop head pressure (ft)	3.0'	1.6'	7.9'	6.9'	1.9'	3.1'				
R	Loop balancing turns	2.7	2.8	4.0	4.0	3.1	3.1				

Manifold Totals

S	Supply water temp. (°F)	125°F
T	Manifold flow in gpm	3.61
U	Highest pressure head (ft)	7.9'

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 ADS printout (upward load).

E Enter the "Floor Unit Load" value from ADS 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 tubing 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 Tubing 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 tubing installed within the room (i.e., active loop).

N Enter the length of the tubing from the room being heated to the respective manifold.

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.

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

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

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

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	Tubing size										
I	Floor covering R-value										
J	Differential temp. (°F)										
K	Tubing 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)	

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 ADS printout (upward load).

E Enter the "Floor Unit Load" value from ADS 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 tubing 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 Tubing 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 tubing installed within the room (i.e., active loop).

N Enter the length of the tubing from the room being heated to the respective manifold.

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.

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

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

U 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 tubing over the entire ceiling area. If the BTU/h/ft^2 requirement is low, increasing the load per square foot and concentrating the tubing 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.

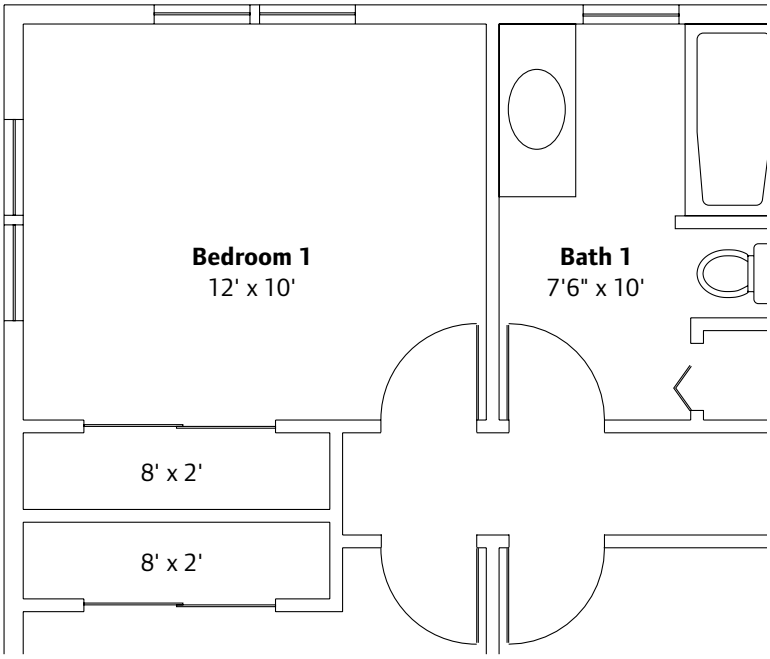


Figure 9-1: Uponor Training House (Partial)

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. The complete main floor level of the Training House and the radiant ceiling heat-loss and design information is provided on **pages 101 to 109**.

Step 1: Heat-loss Analysis

The Advanced Design Suite™ (ADS) 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 ADS 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/ft² 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 ft², which will become the active square footage.
3. Divide the heat load by active ceiling area available to find the BTU/h/ft² (3,533 BTU/h ÷ 130 = 27.2 BTU/h/ft²).

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/ft² load. Areas with differing BTU/h/ft² requirements or setpoints require different surface temperatures.

The coefficient of radiant ceiling thermal transfer is 1.1 BTU/h/ft²/°F. This transfer coefficient changes as the position of the radiant panel changes in the room.

For Bedroom 1:

Example
(27.2 BTU/h/ft² ÷ 1.1 BTU/h/ft2/°F) + 70°F = 95°F ceiling surface temperature

The formula used to calculate the ceiling surface temperature is precise and is supplied by the ADS program. 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.

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**	**27.2**
G	**Active Square Footage**	**130**
H	Ceiling surface temp. (°F)	
I	Tubing size	
J	Differential temp. (°F)	
K	Tubing 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)	

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/ft² column, move right until you reach the correct BTU/h/ft² 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.

Step 4: Tubing Size

Because Uponor radiant ceilings use Joist Trak aluminum heat emission plates, tubing size is limited to ⅜" or ½". It is important to note that increasing the tubing 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 tubing 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

Tubing spacing is 8 inches on center.

Enter the tubing 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
- Tubing 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**.

Radiant Ceiling Surface Temperatures

Ceiling Surface Temperature = (BTU/h/ft² ÷ 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 ❸	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 ❶	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

❷

BTU/h/ft²

Exceeds maximum recommended surface temperature for 8 foot ceilings.

Figure 9-3: Radiant Ceiling Surface Temperatures

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/ft^2	27.2
G	Active Square Footage	130
H	**Ceiling surface temp. (°F)**	**95°F**
I	**Tubing size**	**½"**
J	**Differential temp. (°F)**	**10°F**
K	**Tubing o.c. distance (in)**	**8"**
L	**Supply water temp. (°F)**	**122°F**
M	**Active loop length**	**195**
N	**Leader loop length**	**46**
O	**Total loop length**	**241**
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)	

Find: Required supply water temperature.

Procedure:

1. Enter the chart at the required BTU/h/ft^2 (27.2) in the BTU/h/ft^2 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 122°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 (122°F) into the design worksheet.

Step 8: Determining Loop Length

Loop length is a function of room size (or coverage area), tubing on-center distance, 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 tubing 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 27.2 BTU/h/ft^2 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 tubing (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 tubing (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 10 feet. Multiply this value by 2 to account for the supply and return tubing (10 x 2 = 20 feet).

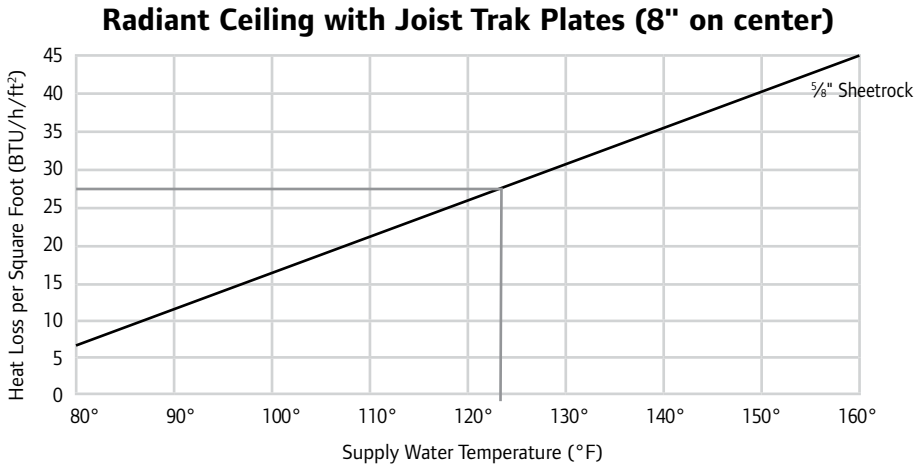


Figure 9-4: Radiant Ceiling with Joist Trak Plates (8" on center)

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 tubing (6 x 2 = 12 feet).
4. Add all the tubing lengths from the three steps above to obtain the amount of leader length for this loop (14 + 20 + 12 = 46 feet).

   Example The leader length for Bedroom 1 is 46 feet.

   Enter the leader length (46 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 + 46 = 241 feet).

The total loop length for Bedroom 1 is 241 feet.

Enter the total loop length (241 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/ft^2 load
- Tubing 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.

100% Water

10°F Supply/Return Differential
Flow in GPM Per Foot of Tubing

	Tubing On-Center Distances						
BTU/h/ft^2	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

Figure 9-5: Excerpt from 100% Water Flow Chart

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	27.2
G	Active Square Footage	130
H	Ceiling surface temp. (°F)	95°F
I	**Tubing size**	**½"**
J	Differential temp. (°F)	10°F
K	Tubing o.c. distance (in)	8"
L	Supply water temp. (°F)	122°F
M	Active loop length	195
N	Leader loop length	46
O	**Total loop length**	241
P	Loop flow in gpm	**0.71**
Q	Loop head pressure (ft)	4.8'
R	Loop balancing turns	

Manifold Totals

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

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 (27.2) in the BTU/h/ft² column.
3. To obtain the flow value per foot of active tubing, move to the right until you intersect the column for 8 inches on center (0.00365).
4. Multiply the flow per foot by the amount of active loop length 0.00365 x 195 = 0.71 gpm).

Example The flow for the loop servicing Bedroom 1 is 0.71 gpm.

Enter 0.71 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 (0.71 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 tubing. Select the chart for the correct type and size tubing, water temperature and water or water/glycol mixture.

Find: Feet of head drop.

Procedure:

1. Identify the appropriate flow chart (½" Wirsbo hePEX tubing using 100% water).
2. Enter the chart at the calculated flow value (0.71 gpm). For smaller applications such as this, round to the next whole tenth value (0.70).

Pressure Loss Per 100 Feet
½" Wirsbo hePEX and Uponor AquaPEX (100% Water)

Head (Feet of Water) Per 100 Feet of Tubing									
gpm	Velocity (ft/s)	40°F 4°C	60°F 16°C	80°F 27°C	100°F 38°C	120°F 49°C	140°F 60°C	160°F 71°C	180°F 82°C
0.1	0.18	0.07	0.06	0.06	0.06	0.05	0.05	0.05	0.05
0.2	0.36	0.24	0.22	0.21	0.21	0.20	0.19	0.19	0.18
0.3	0.54	0.52	0.48	0.45	0.44	0.42	0.40	0.40	0.39
0.4	0.72	0.88	0.81	0.77	0.74	0.71	0.69	0.68	0.66
0.5	0.91	1.33	1.23	1.16	1.12	1.07	1.04	1.02	1.00
0.6	1.09	1.86	1.72	1.63	1.57	1.50	1.46	1.43	1.40
0.7	1.27	2.47	2.28	2.17	2.09	2.00	1.94	1.90	1.86
0.8	1.45	3.17	2.92	2.78	2.68	2.56	2.48	2.44	2.39
0.9	1.63	3.94	3.63	3.45	3.33	3.18	3.09	3.03	2.97
1.0	1.81	4.79	4.42	4.20	4.05	3.87	3.75	3.68	3.61
1.1	1.99	5.71	5.27	5.01	4.83	4.61	4.48	4.39	4.30
1.2	2.17	6.70	6.19	5.88	5.67	5.42	5.26	5.16	5.05
1.3	2.35	7.78	7.18	6.82	6.58	6.28	6.10	5.98	5.86
1.4	2.53	8.92	8.23	7.82	7.55	7.20	7.00	6.86	6.72
1.5	2.72	10.13	9.35	8.88	8.57	8.18	7.95	7.79	7.64
1.6	2.90	11.42	10.54	10.01	9.66	9.22	8.96	8.78	8.61
1.7	3.08	12.77	11.79	11.20	10.81	10.32	10.02	9.82	9.63
1.8	3.26	14.20	13.10	12.45	12.01	11.47	11.14	10.92	10.70
1.9	3.44	15.69	14.48	13.76	13.28	12.67	12.31	12.07	11.83
2.0	3.62	17.25	15.92	15.13	14.60	13.93	13.54	13.27	13.00
2.1	3.80	18.88	17.43	16.56	15.98	15.25	14.81	14.52	14.23
2.2	3.98	20.58	18.99	18.04	17.41	16.62	16.15	15.83	15.51
2.3	4.16	22.34	20.62	19.59	18.90	18.04	17.53	17.19	16.84
2.4	4.35	24.17	22.31	21.20	20.45	19.52	18.97	18.59	18.22
2.5	4.53	26.07	24.06	22.86	22.06	21.05	20.45	20.05	19.65
3.0	5.43	36.52	33.72	32.03	30.91	29.50	28.66	28.10	27.53
3.5	6.34	48.58	44.84	42.60	41.10	39.24	38.11	37.37	36.62
4.0	7.24	62.19	57.41	54.54	52.62	50.23	48.80	47.84	46.88
4.5	8.15	77.33	71.38	67.81	65.43	62.46	60.68	59.49	58.30
5.0	9.05	93.97	86.74	82.41	79.52	75.90	73.73	72.29	70.84
5.5	9.96	112.09	103.47	98.30	94.85	90.54	87.95	86.23	84.50
6.0	10.86	131.67	121.54	115.47	111.41	106.35	103.31	101.29	99.26

Figure 9-6: ½" Wirsbo hePEX Pressure Loss Chart (100% Water)

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 tubing at the intersection of the flow row and water temperature column (2.00 ÷ 100 feet = 0.02).
5. Multiply the feet of head value per foot by the total loop length to determine total feet of head for the loop.

Example
0.02 feet of head per foot x 241 foot of total loop length = 4.82 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 tubing diameter. If the total loop length or tubing 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 110**. Then, perform the initial flow balancing and determine the system totals.

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. To calculate the setting, use the formula below.

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

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 (122°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.

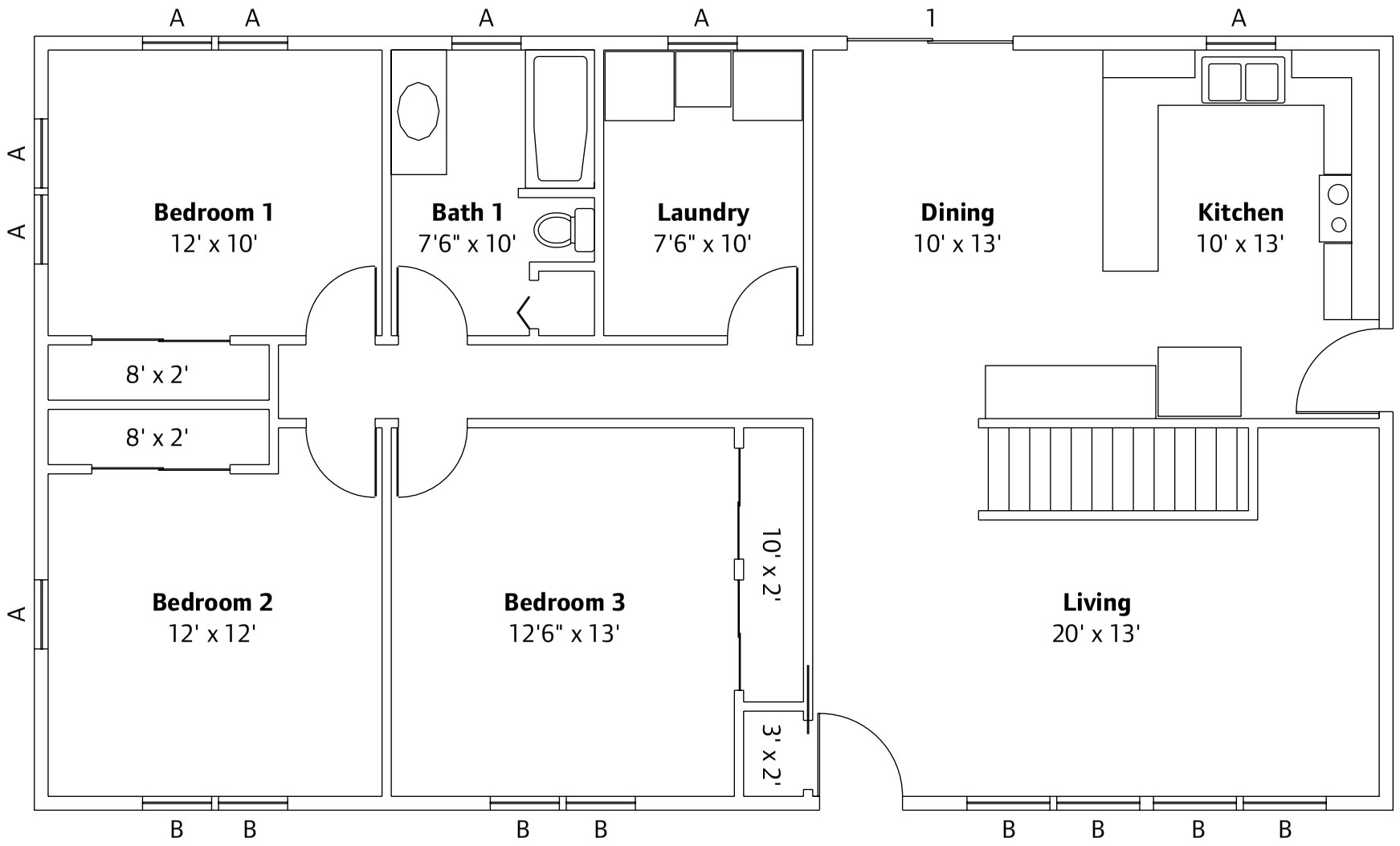
In order to size the circulator for this level of the training house, all the head pressure drops before and after the manifold location must be added together to determine the total head drop. To properly size the circulator, identify the total system flow and head.

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

The following is the room schedule for the main floor of the Uponor Training House. The floor plan and heat-loss information appear on **pages 101 to 109**. To complete the design, use the radiant ceiling worksheet found in **Appendix B**. See **pages 110 and 111** for the completed tutorial design calculations and tubing layout.

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



Main-level Floor Plan (No Scale)

Uponor Inc. 5925 148th Street West Apple Valley, MN 55124
Prepared By: Technical Services Phone: 952-891-2000 Fax: 952-997-1731 Email:

Project Summary

Project #:	20110331-01
Project Name:	Training House
Location:	Indianapolis, Indiana
CloseDate:	
Engineer:	
Design Data Location:	Indianapolis, Indiana
Outdoor Temperature:	3 °F
Wind Speed:	22 mph
Total Area:	1,160 ft²
Construction Quality:	Best
RFH Glycol Level:	100% Water
Design Temp. Drop:	10 °F
Radiant Tubing Volume:	15.3 gallons(US)
Volume Water:	15.3 gallons(US)
Volume Glycol:	0 gallons(US)
Total-Components Load:	18,885 Btu/hr
Total Infiltration Load:	3,872 Btu/hr
Total-Radiant Load:	15,624 Btu/hr
Total-Supplemental Load:	0 Btu/hr
Total-Project Heat Loss:	22,758 Btu/hr

Heat Loss Data

Bedroom #1 (Floorplan 1)

Total Area:	136 ft²	**Components:**	1,990 Btu/hr
Average Height:	8 ft	**Infiltration:**	454 Btu/hr
Volume:	1,088 ft³	**Ceiling Upward:**	1,089 Btu/hr
Air Changes:	0.35 /hr	**Floor Downward:**	0 Btu/hr
RoomTemperature:	70 °F	**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/hr/ft²
		Total Radiant Load:	3,533 Btu/hr
		Unit Load:	26 Btu/hr/ft²

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Prepared By: Technical Services Phone: 952-891-2000 Fax: 952-997-1731 Email:

Floor

Total Area:	136 ft²	**Downward Load:**	0 Btu/hr
Unheated Area:	136 ft²		
Heated Area:	0 ft²		
Construction:	Joist (16" OC)		
Cover Rv:	2.5 °F·ft²·hr/Btu		
Structure Rv:	1 °F·ft²·hr/Btu		
Insulation Rv:	11 °F·ft²·hr/Btu		
Space Below Heated:	From Same Source		

Ceiling

Total Area:	136 ft²	**Upward Load:**	1,089 Btu/hr
Unheated Area:	0 ft²		
Heated Area:	136 ft²		
Construction:	Gypsum Wall board		
Cover Rv:	0.56 °F·ft²·hr/Btu		
Insulation Rv:	38 °F·ft²·hr/Btu		
Space Above Heated:	No		
Surface Temperature:	81.2 °F		

Other Components

Component	Length (ft)	Width/Height (ft)	Area (ft²)	Rv (°F·ft²·hr/Btu)	Heat Loss (Btu/hr)
Wall-1	12	8	96	19	995
Window-1	4	2.5	10	1.81	370
Window-2	4	2.5	10	1.81	370
Net Wall			76	19	255
Wall-2	12	8	96	19	995
Window-1	4	2.5	10	1.81	370
Window-2	4	2.5	10	1.81	370
Net Wall			76	19	255

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Bedroom #2 (Floorplan 1)

Total Area:	165 ft²	**Components:**	1,841 Btu/hr
Average Height:	8 ft	**Infiltration:**	551 Btu/hr
Volume:	1,320 ft³	**Ceiling Upward:**	1,114 Btu/hr
Air Changes:	0.35 /hr	**Floor Downward:**	0 Btu/hr
RoomTemperature:	70 °F	**Total Heat Loss:**	3,506 Btu/hr
		Supplemental:	0 Btu/hr
		Total Room Loss:	3,506
		Radiant to Room Load:	2,392 Btu/hr
		Unit Load:	14.5 Btu/hr/ft²
		Total Radiant Load:	3,506 Btu/hr
		Unit Load:	21.2 Btu/hr/ft²

Floor

Total Area:	165 ft²	**Downward Load:**	0 Btu/hr
Unheated Area:	165 ft²		
Heated Area:	0 ft²		
Construction:	Joist (16" OC)		
Cover Rv:	2.5 °F·ft²·hr/Btu		
Structure Rv:	1 °F·ft²·hr/Btu		
Insulation Rv:	11 °F·ft²·hr/Btu		
Space Below Heated:	From Same Source		

Ceiling

Total Area:	165 ft²	**Upward Load:**	1,114 Btu/hr
Unheated Area:	0 ft²		
Heated Area:	165 ft²		
Construction:	Gypsum Wall board		
Cover Rv:	0.56 °F·ft²·hr/Btu		
Insulation Rv:	38 °F·ft²·hr/Btu		
Space Above Heated:	No		
Surface Temperature:	79.1 °F		

Other Components

Component	Length (ft)	Width/Height (ft)	Area (ft²)	Rv (°F·ft²·hr/Btu)	Heat Loss (Btu/hr)
Wall-1	14	8	112	19	712
Window-1	4	2.5	10	1.81	370
Net Wall			102	19	342
Wall-2	12	8	96	19	1129
Window-1	4	3	12	1.81	444
Window-2	4	3	12	1.81	444
Net Wall			72	19	241

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Bedroom #3 (Floorplan 1)

Total Area:	183 ft²	**Components:**	1,143 Btu/hr
Average Height:	8 ft	**Infiltration:**	611 Btu/hr
Volume:	1,464 ft³	**Ceiling Upward:**	909 Btu/hr
Air Changes:	0.35 /hr	**Floor Downward:**	0 Btu/hr
RoomTemperature:	70 °F	**Total Heat Loss:**	2,663 Btu/hr
		Supplemental:	0 Btu/hr
		Total Room Loss:	2,663
		Radiant to Room Load:	1,754 Btu/hr
		Unit Load:	9.6 Btu/hr/ft²
		Total Radiant Load:	2,663 Btu/hr
		Unit Load:	14.6 Btu/hr/ft²

Floor

Total Area:	183 ft²	**Downward Load:**	0 Btu/hr
Unheated Area:	183 ft²		
Heated Area:	0 ft²		
Construction:	Joist (16" OC)		
Cover Rv:	2.5 °F·ft²·hr/Btu		
Structure Rv:	1 °F·ft²·hr/Btu		
Insulation Rv:	11 °F·ft²·hr/Btu		
Space Below Heated:	From Same Source		

Ceiling

Total Area:	183 ft²	**Upward Load:**	909 Btu/hr
Unheated Area:	0 ft²		
Heated Area:	183 ft²		
Construction:	Gypsum Wall board		
Cover Rv:	0.56 °F·ft²·hr/Btu		
Insulation Rv:	38 °F·ft²·hr/Btu		
Space Above Heated:	No		
Surface Temperature:	76 °F		

Other Components

Component	Length (ft)	Width/Height (ft)	Area (ft²)	Rv (°F·ft²·hr/Btu)	Heat Loss (Btu/hr)
Wall-1	12.5	8	100	19	1143
Window-1	4	3	12	1.81	444
Window-2	4	3	12	1.81	444
Net Wall			76	19	255

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Laundry/ Bath (Floorplan 1)

Total Area:	150 ft²	**Components:**	1,075 Btu/hr
Average Height:	8 ft	**Infiltration:**	501 Btu/hr
Volume:	1,200 ft³	**Ceiling Upward:**	796 Btu/hr
Air Changes:	0.35 /hr	**Floor Downward:**	0 Btu/hr
RoomTemperature:	70 °F	**Total Heat Loss:**	2,372 Btu/hr
		Supplemental:	0 Btu/hr
		Total Room Loss:	2,372
		Radiant to Room Load:	1,576 Btu/hr
		Unit Load:	10.5 Btu/hr/ft²
		Total Radiant Load:	2,372 Btu/hr
		Unit Load:	15.8 Btu/hr/ft²

Floor

Total Area:	150 ft²	**Downward Load:**	0 Btu/hr
Unheated Area:	150 ft²		
Heated Area:	0 ft²		
Construction:	Joist (16" OC)		
Cover Rv:	2.5 °F·ft²·hr/Btu		
Structure Rv:	1 °F·ft²·hr/Btu		
Insulation Rv:	11 °F·ft²·hr/Btu		
Space Below Heated:	From Same Source		

Ceiling

Total Area:	150 ft²	**Upward Load:**	796 Btu/hr
Unheated Area:	0 ft²		
Heated Area:	150 ft²		
Construction:	Gypsum Wall board		
Cover Rv:	0.56 °F·ft²·hr/Btu		
Insulation Rv:	38 °F·ft²·hr/Btu		
Space Above Heated:	No		
Surface Temperature:	76.6 °F		

Other Components

Component	Length (ft)	Width/Height (ft)	Area (ft²)	Rv (°F·ft²·hr/Btu)	Heat Loss (Btu/hr)
Wall-1	15	8	120	19	1075
Window-1	4	2.5	10	1.81	370
Window-2	4	2.5	10	1.81	370
Net Wall			100	19	335

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Living Room (Floorplan 1)

Total Area:	266 ft²	**Components:**	2,722 Btu/hr
Average Height:	8 ft	**Infiltration:**	888 Btu/hr
Volume:	2,128 ft³	**Ceiling Upward:**	1,706 Btu/hr
Air Changes:	0.35 /hr	**Floor Downward:**	0 Btu/hr
RoomTemperature:	70 °F	**Total Heat Loss:**	5,316 Btu/hr
		Supplemental:	0 Btu/hr
		Total Room Loss:	5,316
		Radiant to Room Load:	3,610 Btu/hr
		Unit Load:	13.6 Btu/hr/ft²
		Total Radiant Load:	5,316 Btu/hr
		Unit Load:	20 Btu/hr/ft²

Floor

Total Area:	266 ft²	**Downward Load:**	0 Btu/hr
Unheated Area:	266 ft²		
Heated Area:	0 ft²		
Construction:	Joist (16" OC)		
Cover Rv:	2.5 °F·ft²·hr/Btu		
Structure Rv:	1 °F·ft²·hr/Btu		
Insulation Rv:	11 °F·ft²·hr/Btu		
Space Below Heated:	From Same Source		

Ceiling

Total Area:	266 ft²	**Upward Load:**	1,706 Btu/hr
Unheated Area:	0 ft²		
Heated Area:	266 ft²		
Construction:	Gypsum Wall board		
Cover Rv:	0.56 °F·ft²·hr/Btu		
Insulation Rv:	38 °F·ft²·hr/Btu		
Space Above Heated:	No		
Surface Temperature:	78.5 °F		

Other Components

Component	Length (ft)	Width/Height (ft)	Area (ft²)	Rv (°F·ft²·hr/Btu)	Heat Loss (Btu/hr)
Wall-1	22	8	176	19	2372
Door-1	3	7	21	5.91	238
Window-1	4	3	12	1.81	444
Window-2	4	3	12	1.81	444
Window-3	4	3	12	1.81	444
Window-4	4	3	12	1.81	444
Net Wall			107	19	358

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Wall-2	13	8	104	19	348
Net Wall			104	19	348

Dining Room/Kitchen (Floorplan 1)

Total Area:	260 ft²	**Components:**	2,683 Btu/hr
Average Height:	8 ft	**Infiltration:**	868 Btu/hr
Volume:	2,080 ft³	**Ceiling Upward:**	1,520 Btu/hr
Air Changes:	0.35 /hr	**Floor Downward:**	0 Btu/hr
RoomTemperature:	70 °F	**Total Heat Loss:**	5,368 Btu/hr
		Supplemental:	0 Btu/hr
		Total Room Loss:	5,369
		Radiant to Room Load:	3,848 Btu/hr
		Unit Load:	14.8 Btu/hr/ft²
		Total Radiant Load:	5,369 Btu/hr
		Unit Load:	20.6 Btu/hr/ft²

Floor

Total Area:	260 ft²	**Downward Load:**	0 Btu/hr
Unheated Area:	260 ft²		
Heated Area:	0 ft²		
Construction:	Joist (16" OC)		
Cover Rv:	2.5 °F·ft²·hr/Btu		
Structure Rv:	1 °F·ft²·hr/Btu		
Insulation Rv:	11 °F·ft²·hr/Btu		
Space Below Heated:	From Same Source		

Ceiling

Total Area:	260 ft²	**Upward Load:**	1,818 Btu/hr
Unheated Area:	176 ft²		
Heated Area:	84 ft²		
Construction:	Gypsum Wall board		
Cover Rv:	0.56 °F·ft²·hr/Btu		
Insulation Rv:	38 °F·ft²·hr/Btu		
Space Above Heated:	No		
Surface Temperature:	98.5 °F		

Other Components

Component	Length (ft)	Width/Height (ft)	Area (ft²)	Rv (°F·ft²·hr/Btu)	Heat Loss (Btu/hr)
Wall-1	13	8	104	19	544
Kitchen Door	3	7	21	5.29	266
Net Wall			83	19	278
Wall-2	20	8	160	19	2139
Patio Door	6	7	42	2	1407

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Window-1	4	2.5	10	1.81	370
Net Wall			108	19	362

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	27	40	40	40	40	22				
G	Active square footage	130	47	106	105	53	155				
H	Ceiling surface temp. (°F)	87°F	95°F	95°F	95°F	95°F	84°F				
I	Tubing size	½"	½"	½"	½"	½"	½"				
J	Differential temp. (°F)	10°F	10°F	10°F	10°F	10°F	10°F				
K	Tubing o.c. distance (in)	8"	8"	8"	8"	8"	8"				
L	Supply water temp. (°F)	122°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	46	30	38	25	25	50				
O	Total loop length	241	77	144	130	78	282				
P	Loop flow in gpm	0.72	0.38	0.86	0.85	0.43	0.72				
Q	Feet of head drop per loop	4.4	0.5	4.1	3.7	0.7	5.2				
R	Loop balancing turns	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)	5.2'									

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 ADS 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.

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 tubing for project (½" Wirsbo hePEX tubing).

J Use 10°F differential temperature for all radiant ceiling applications.

K Tubing 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 Multiply the all-inclusive distance from loop in the room to the respective manifold by 2.

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.

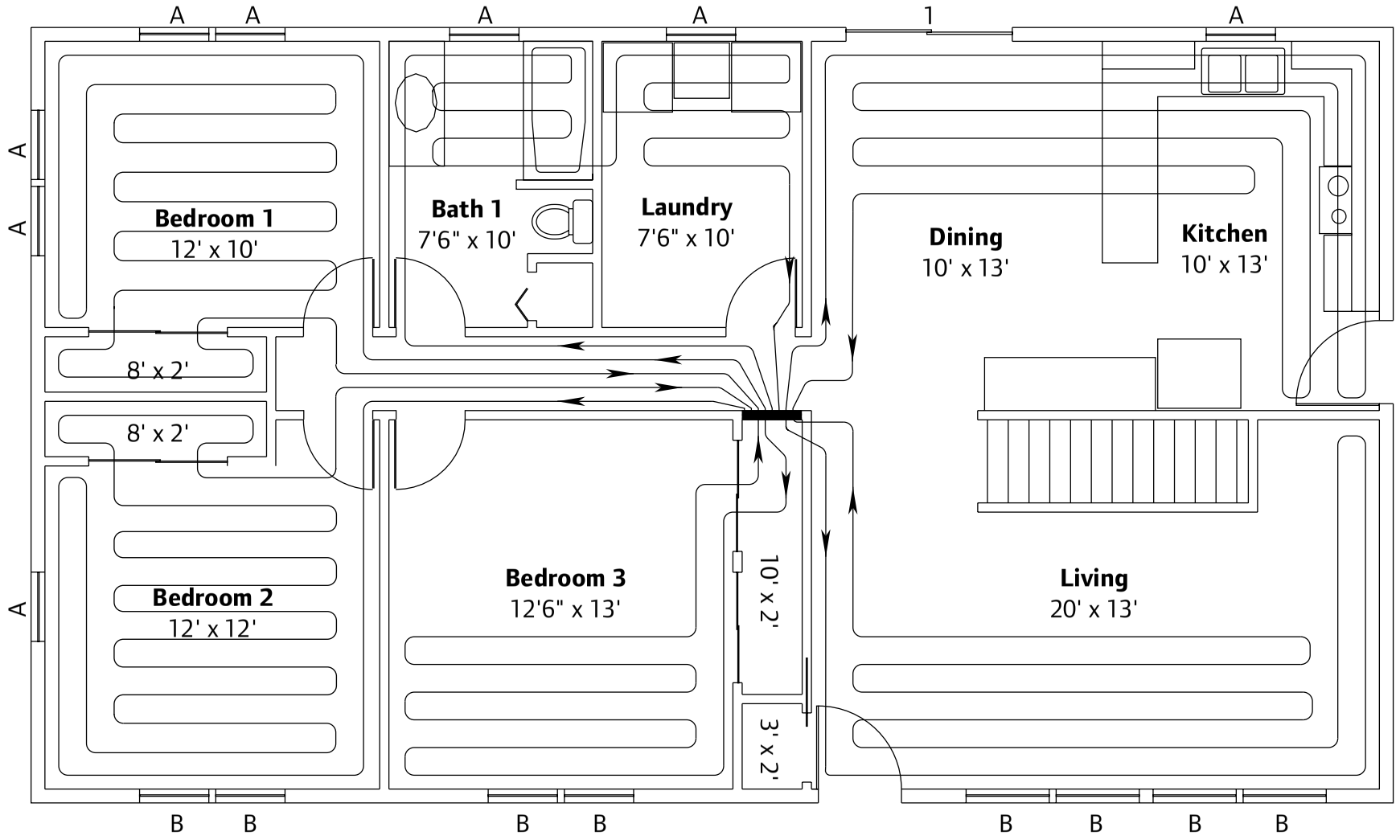
Q Use the values in **Rows I, L** and **P** with **Appendix G** to obtain the feet of head pressure drop per foot. Next, multiply this value by **Row O** to obtain the feet of head drop per loop.

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**.



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	Tubing size										
J	Differential temp. (°F)										
K	Tubing 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										

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 ADS 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.

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 tubing for project (½" Wirsbo hePEX tubing).

J Use 10°F differential temperature for all radiant ceiling applications.

K Tubing 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 Multiply the all-inclusive distance from loop in the room to the respective manifold by 2.

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 Advanced Design Suite™ (ADS) software 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 ADS software.

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 tubing prior to the pour. Minimum cover for tubing is detailed in the local building codes. Generally, pour a minimum of 1½ inches of concrete over the top of the tubing 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 tubing 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 tubing 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 tubing parallel to the beams (perpendicular to the deck)
- Keeping sufficient distance outside the effective design width which is (2 x span)/8
- Placing the tubing 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 tubing 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 tubing is ¾ inch over the top of the tubing.

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 tubing near the tendons without the approval of the structural engineer. Radiant floor tubing 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 tubing. 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.

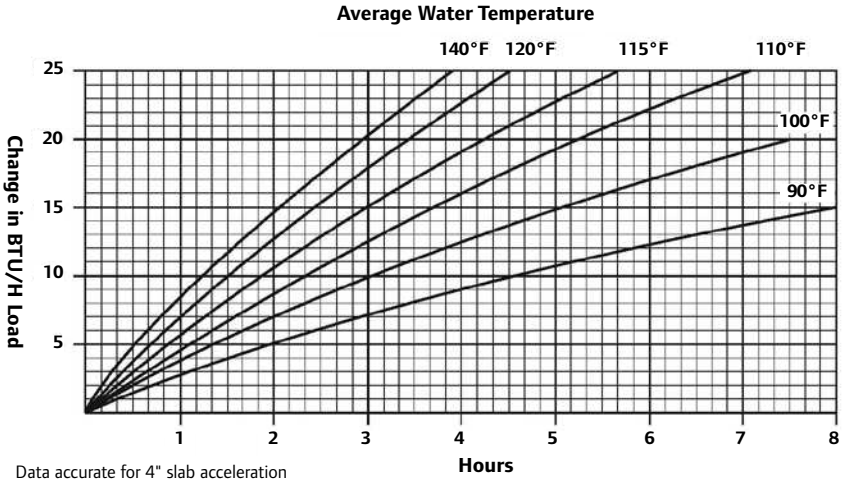


Figure 10-1: Acceleration Times

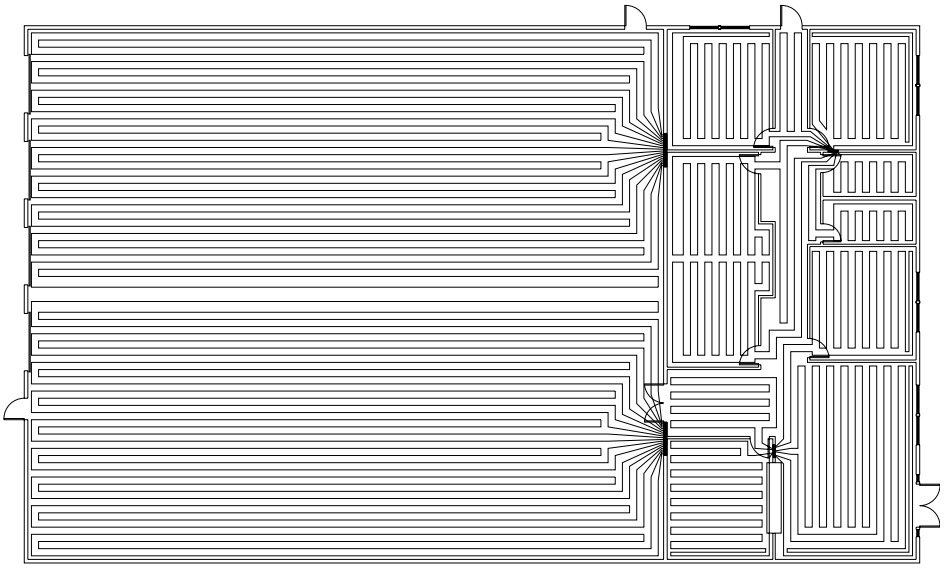
Tubing Installation Options

Several factors determine how much tubing is needed for installation. The following sections provide some general guidelines. Refer to the Uponor ADS software to determine the amount of required tubing.

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 tubing 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 ADS software. 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 tubing inside and along the perimeter walls of the building. Do not install tubing 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.



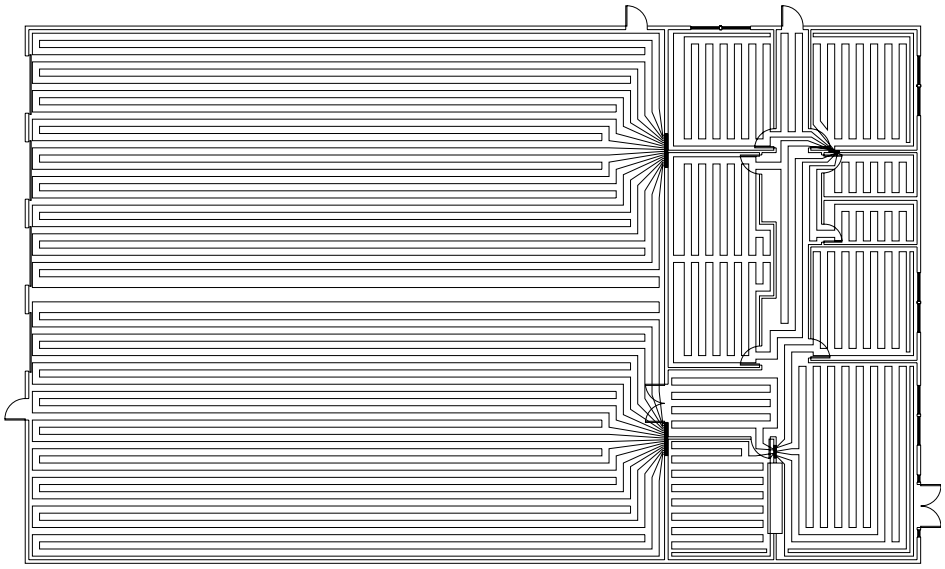
1. Building square footage: 9,375
2. Tubing installed on center: 12"
3. Feet of tubing installed: 9,016
4. Number of loops: 28
5. Number of manifold locations: 4
6. Number of zones: 3

Figure 10-2: Full Coverage Tubing Installation



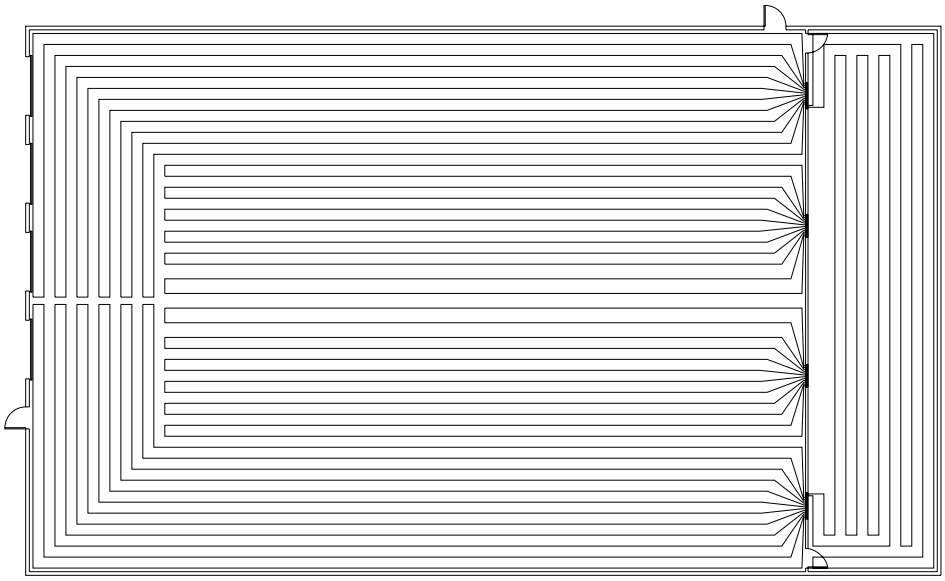
1. Building square footage: 9,375
2. Tubing installed on center: 12"
3. Feet of tubing installed: 4,860
4. Number of loops: 18
5. Number of manifold locations: 2
6. Number of zones: 1

Figure 10-3: Perimeter-only Coverage Tubing Installation



1. Building square footage: 9,375
2. Tubing installed on center: 12" and 18"
3. Feet of tubing installed: 7,624
4. Number of loops: 32
5. Number of manifold locations: 4
6. Number of zones: 1

Figure 10-4: Varied Coverage Tubing Installation



1. Building square footage: 9,375
2. Tubing installed on center: 18"
3. Feet of tubing installed: 6,075
4. Number of loops: 26
5. Number of manifold locations: 4
6. Number of zones: 1

Figure 10-5: Reduced Coverage Tubing Installation

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 tubing 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 tubing throughout the floor at distances greater than 12 inches on center.

Tubing Layout Patterns

The designer determines the tubing 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 tubing run in these areas. Additionally, shorter tubing 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 ADS design software 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 tubing 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 tubing 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.

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 tubing 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 tubing 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" tubing and can connect to either ½" or ⅝" tubing using Uponor Engineered Plastic (EP) Reducing Tee fittings. Each mat is equipped with one supply-and-return line and SpaceGuard support strips that allow tubing 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
- Tubing: Wirsbo hePEX™ (oxygen barrier) or Uponor AquaPEX® (barrier-free), ½" or ⅝" tubing
- Distribution Flow Options: 1) In-slab with ¾" reverse-return header option or 2) Wall manifold featuring the Uponor TruFLOW™ Classic
- Supports: Acetal polymer SpaceGuard support braces with pre-drilled holes for stake and anchor points

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)

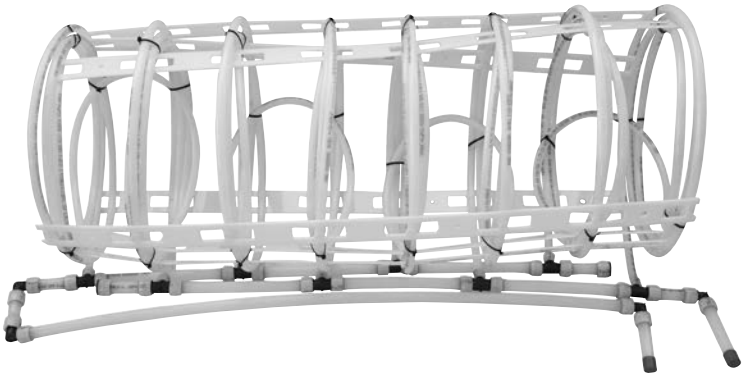


Figure 10-6: Uponor Radiant Rollout Mat

compliant] and NSF International [Uniform Mechanical Code (UMC) compliant]

- Helps projects stay on schedule
- Reduces and eliminates tubing 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 Tubing Modules — A self-balancing reverse-return header system can also be customized using a tubing module. The tubing 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)

Conventional Wall Manifolds — Commercial distribution flow systems have traditionally been designed with wall manifolds. Uponor offers the following types of wall manifolds:

- TruFLOW Classic R32/R20/R32 (21 gpm)
- TruFLOW Jr. R32/R20/R32 (14 gpm)
- Engineered Plastic (EP) Heating Manifolds R32/R20/R32 (14 gpm)

Refer to **Chapter 4** for more information about Uponor wall manifolds.

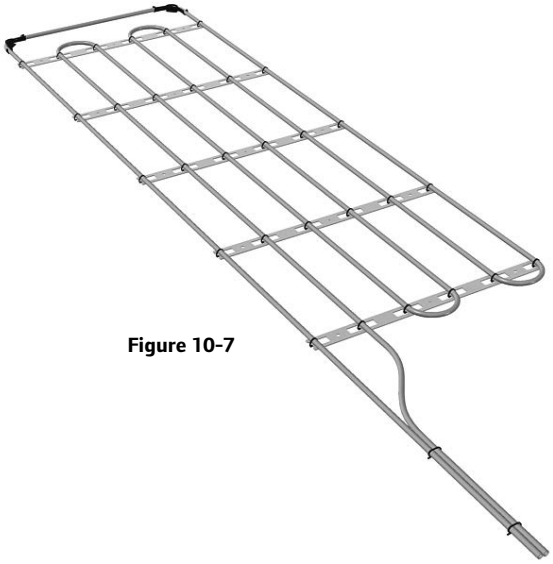


Figure 10-7

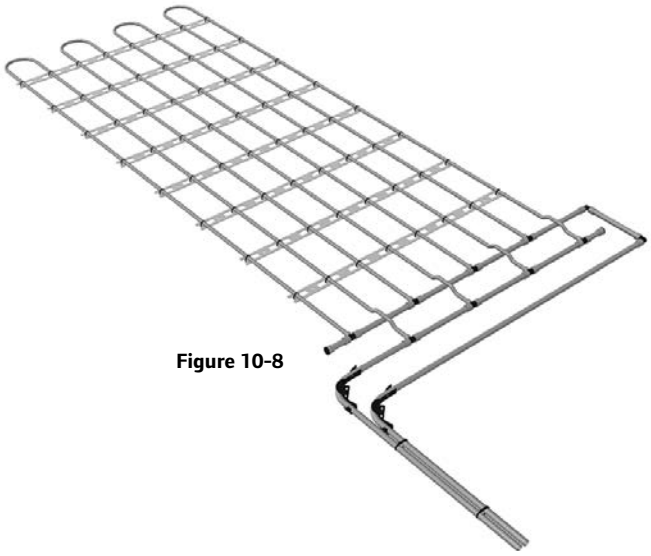


Figure 10-8

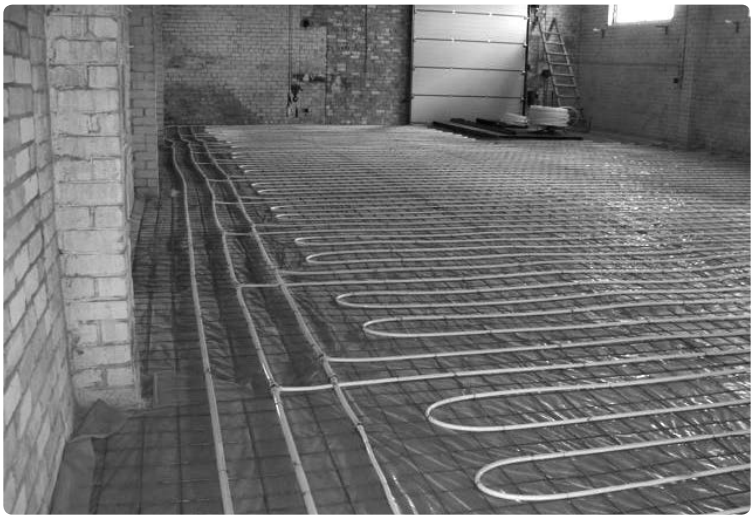


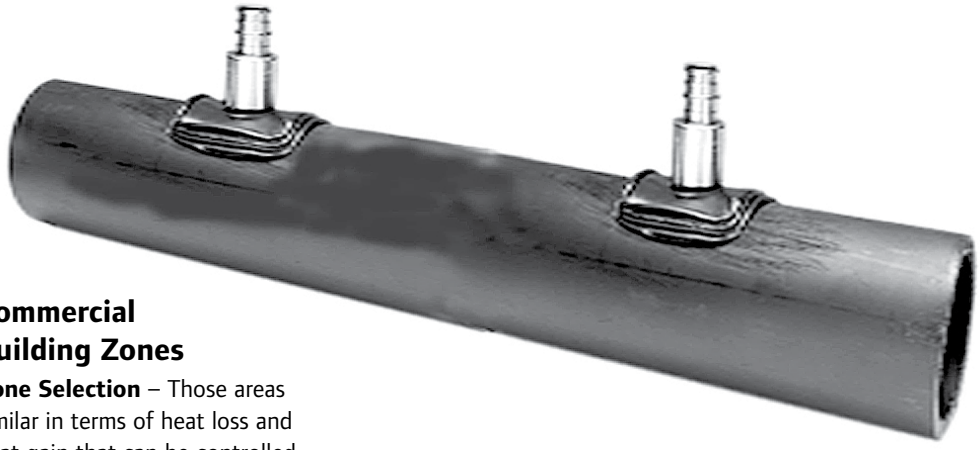
Figure 10-9

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 tubing module system. Significant flow can be balanced, controlled and distributed through a copper manifold and then routed to a self-balancing tubing layout. Copper manifolds come with the following accessories: ball valves, balancing valves, and end caps with vent and drain. 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.





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.

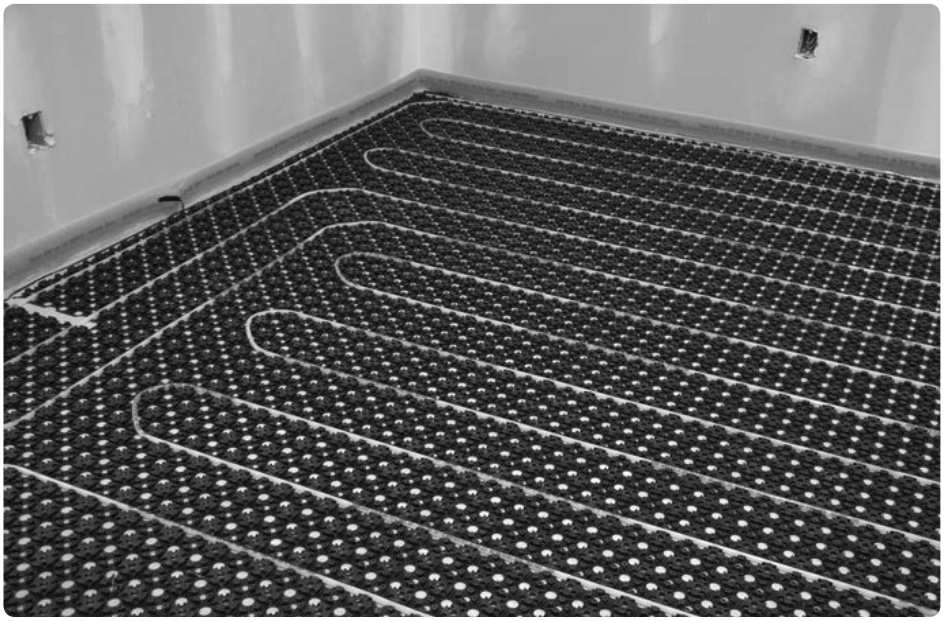
Capacitor Effect

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 tubing 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.

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.

Uponor WT series thermostats are digital and use an integrated circuit board. WT series thermostats provide a simple switched output (or contact) that closes to operate other devices that provide heating or cooling. Uponor also offers wireless thermostats that can transmit a heating or cooling call up to 75 feet through normal construction. These wireless thermostats also have a unique feature: a mean radiant temperature (MRT) sensor. This sensor averages the air temperature with the temperature of the surfaces in that space (walls, ceiling, floors, etc.), providing a higher level of comfort in the space. Both types of thermostats (wired and wireless) maintain the space temperature within 1°F of the setpoint. When the thermostat detects a difference from setpoint of more than 1°F, it activates associated electrical devices (actuators, zone valves, pumps, etc.) within the control logic. The same electrical devices are deactivated once the space temperature returns to the desired setpoint.

The Uponor Climate Cŏntrol™ Network System uses thermostats with a modified version of the MRT sensor, and it operates and communicates slightly differently. The air sensor, or thermistor, is set against the inside cover using a heat-conductive compound. These thermostats operate heating and other HVAC functionality (air conditioning, humidity, ventilation, etc.) over two wires, making it a true network thermostat. The temperature of the radiant conditioned space will be maintained within 0.5°F of the setpoint. When the Network thermostat detects a difference from setpoint of more than 0.5°F, it activates associated electrical devices (actuators, zone valves, pumps, etc.) within the control logic. The same electrical devices are deactivated once the space temperature rises 0.5°F above the desired setpoints. The Network thermostats also have the ability to control seond-stage heating, supplemental heating, cooling, humidity and ventilation control for a fully integrated system.



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.

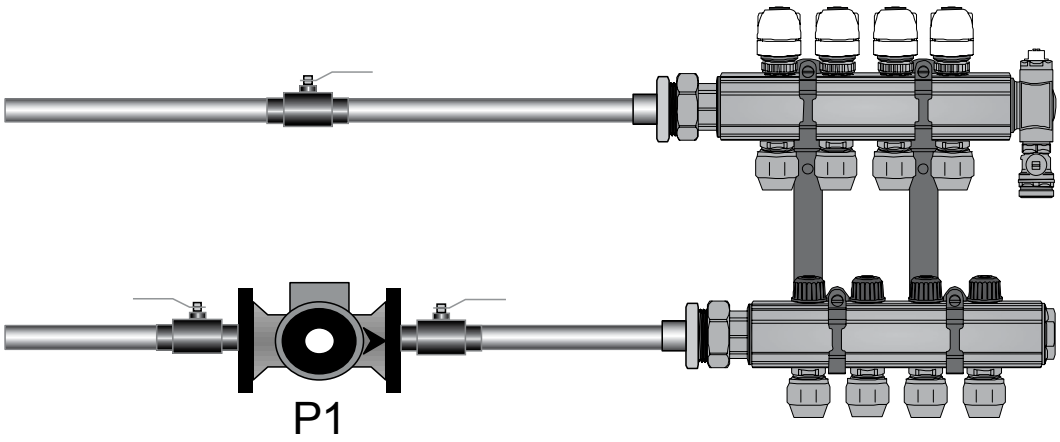
Option 1:

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).
- Refer to **page 163** for the specific wiring schematic.

Advantages:

- Allows for zoning flexibility within a single manifold
- Makes room-by-room zoning simple and cost effective



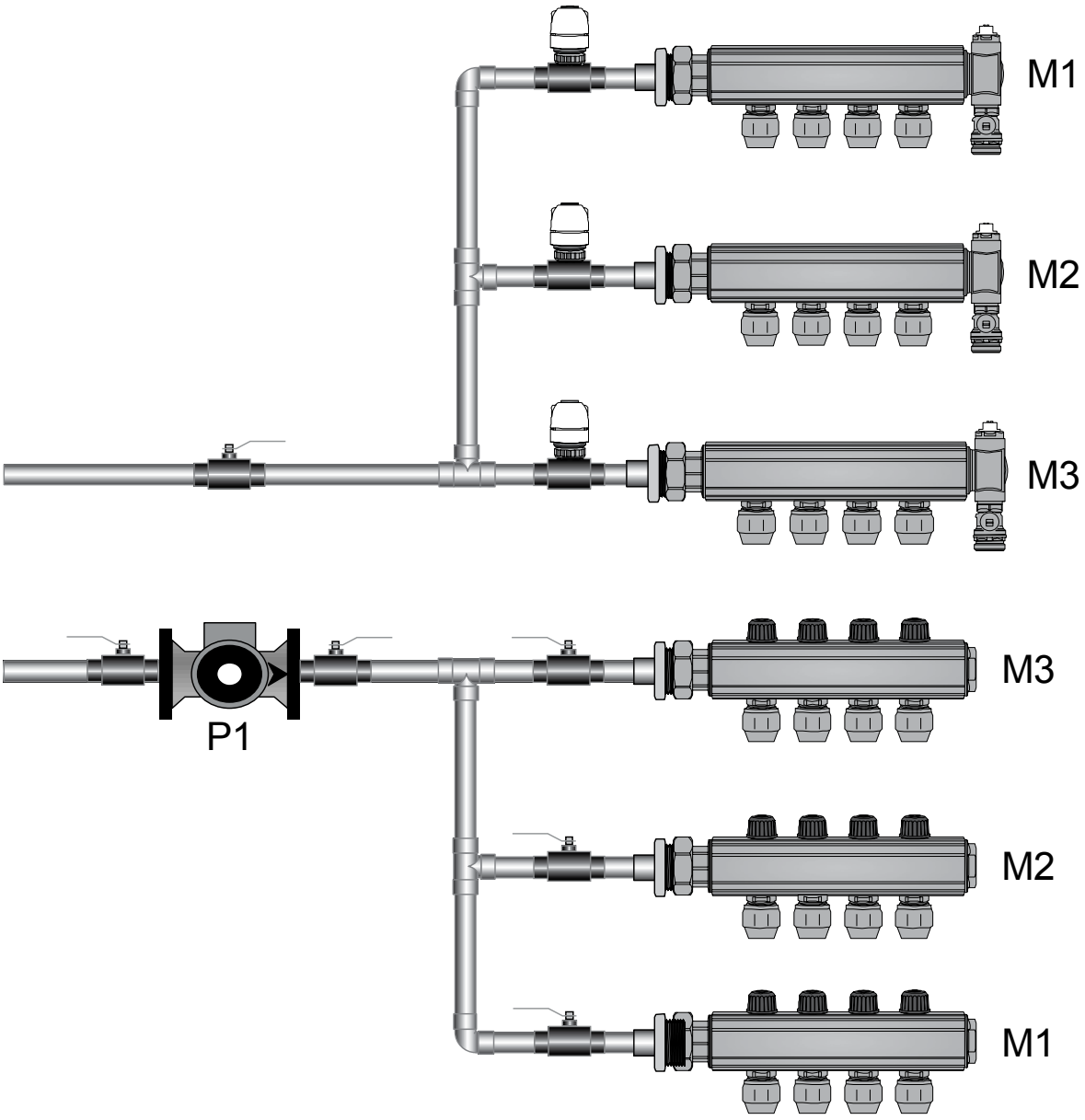
Option 2:

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 164-165** 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



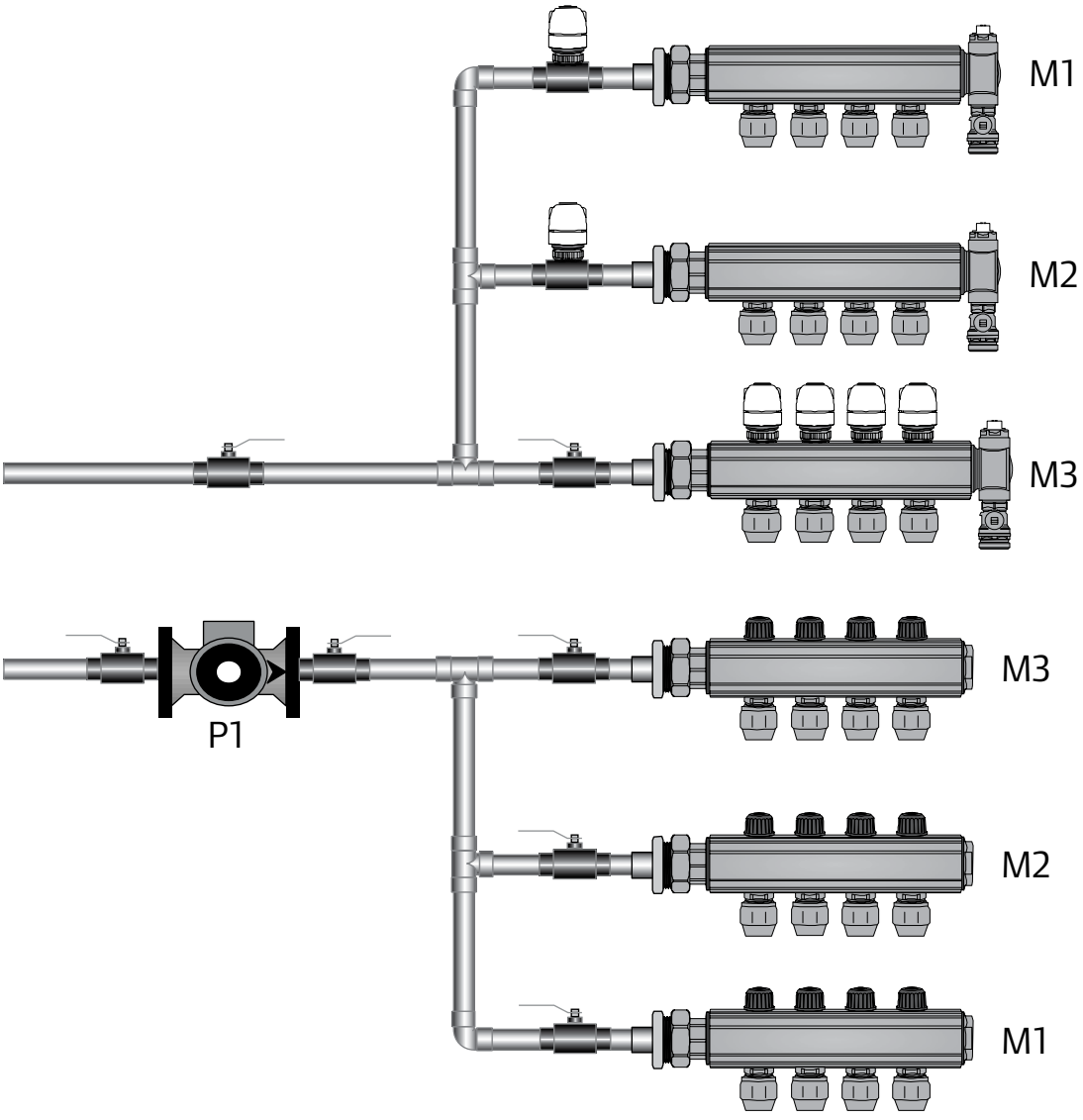
Option 3:

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).
- Refer to **pages 166-167** 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



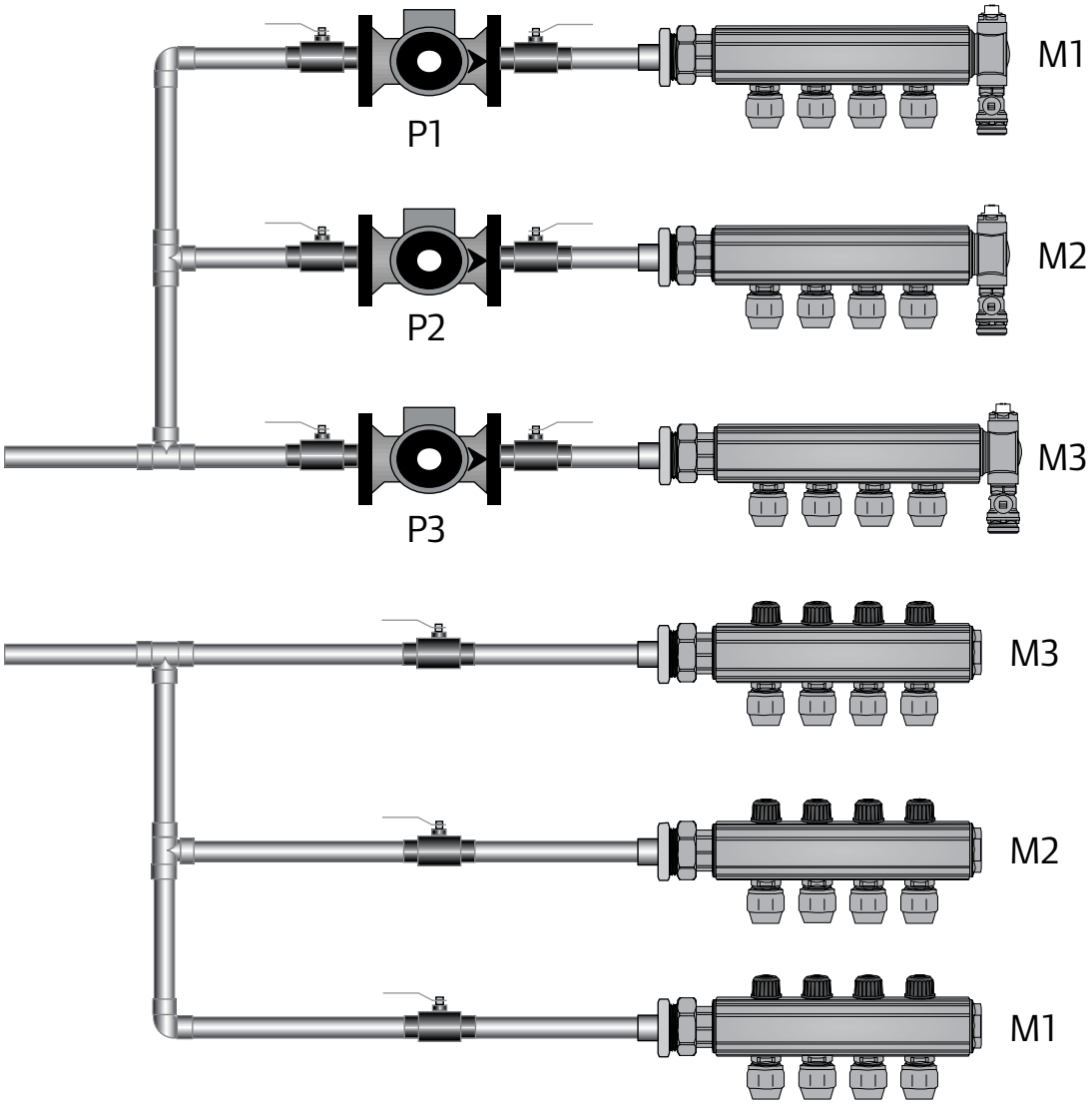
Option 4:

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 168-169** for the specific wiring schematic.

Advantages:

- Each zone controlled with its own circulator
- Circulator only needs sizing for its particular zone



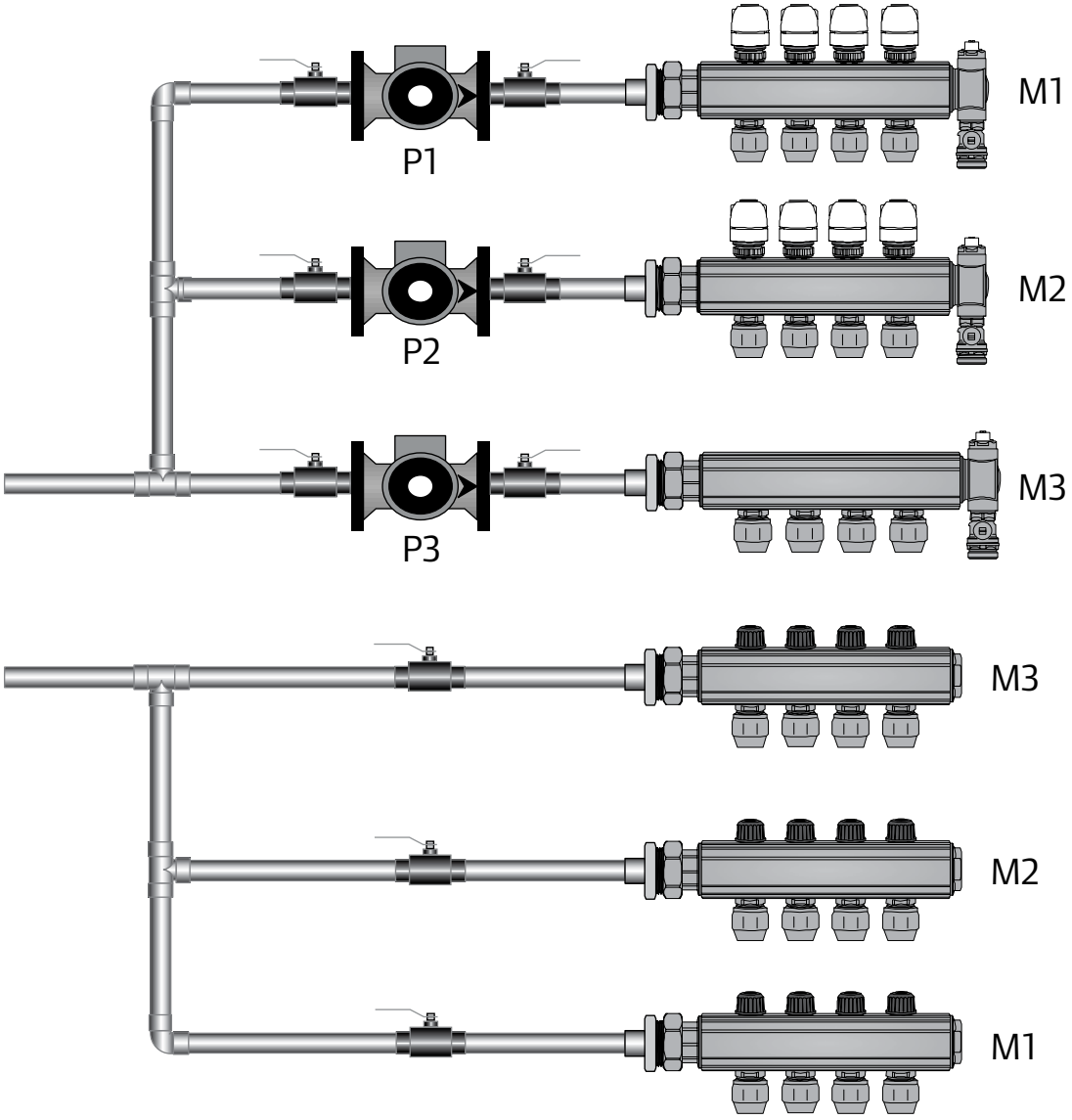
Option 5:

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 170-171** 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



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 Tempering Valve — A three-way tempering valve is the simplest and most effective



way to achieve Level 2 control. The Uponor Three-way Tempering Valve provides a constant, fixed water temperature for radiant floor heating, without affecting boiler operation.

The Uponor Three-way Tempering 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 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 Uponor Three-way Tempering 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.

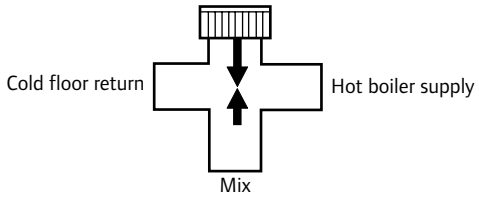
The Uponor Three-way Tempering Valve is considered a reactive valve in that it supplies a constant water temperature to the radiant heating system, despite potential drops in boiler supply water temperature. A reactive valve works well with intermittent, or on-off, zone control.

There are several advantages to the Uponor Three-way Tempering 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 80 to 160°F

The Uponor Three-way Tempering 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.

Three-way Tempering Valve

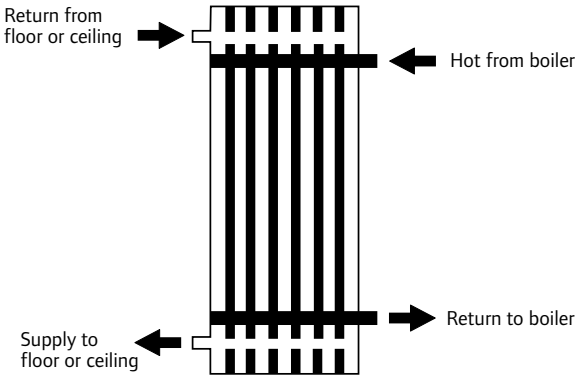


Other Level 2 Options — There are several other methods of achieving Level 2 control, including mixing tanks, heat exchangers, four-way motorized mixing valves and injection mixing. Motorized mixing valves and injection mixing controls can also be made weather responsive; see the Level 3 section on **page 135** 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® tubing is used for radiant heating or snow melting. Non-ferrous components are used with the non-barrier tubing 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 tubing.

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 tubing on non-ferrous components) from the boiler system.



Heat Exchanger

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.

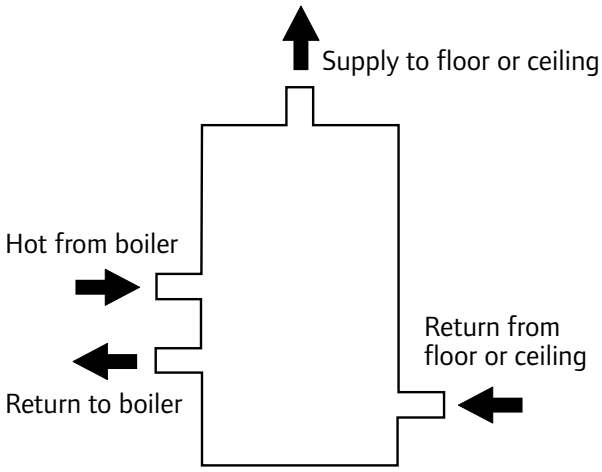
Water temperature on the radiant side of the heat exchanger is controlled by an aquastat, which is set to maintain a fixed supply temperature. When the aquastat remote sensor detects the supply water temperature dropping below that fixed temperature, the aquastat will fire a circulator on the boiler 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 tubing
- 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.



Mixing Tank

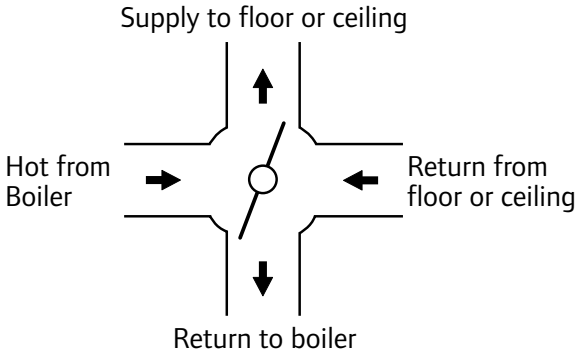
A mixing tank is often used with extremely low mass, or "flash" type, boilers. The mixing tank adds water to the system and can prevent the boiler from short cycling. Any insulated tank is suitable for use as a mixing tank.

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.

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.

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, less 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. Uponor offers two weather-responsive control packages, the Climate Cŏntrol Multifunction Controller and the Climate Cŏntrol Network System. Both allow full outdoor reset of a radiant system while protecting a non-condensing boiler.

Climate Cŏntrol Multifunction Controller — The Multifunction Controller uses integrated control logic to operate both modulating valves and injection pumps to control the radiant system supply water temperature in a secondary loop. (See **pages 154-161** for piping schematic and **pages 186-193** for wiring schematic.)



The Multifunction Controller uses sensors to measure:

- Radiant supply and return temperatures
- Boiler supply and return temperatures (only when boiler protection is required)
- Outdoor temperature

Based on these sensor readings, the Multifunction Controller adjusts the supply water temperature to the radiant system in response to changing conditions.

When the Multifunction Controller senses changes in the outdoor temperature, it will change the valve position or the injection pump speed, allowing more or less hot boiler water to mix into the radiant system, raising or lowering the radiant supply water temperature.

The Multifunction Controller is a fully integrated energy management system. It can control a combination of up to eight of the following devices:

- Four boilers, on/off and modulating
- One primary pump
- Three mixing devices (combination of valves and pumps)
- Three secondary pumps
- One domestic hot water (DHW) tank
- Two snow melting zones
- Eight zone pumps

Boiler protection is provided by both a primary (or boiler) supply water temperature sensor and a return water temperature sensor. The Multifunction Controller monitors the primary supply and return water temperatures constantly. When the controller senses temperatures lower than the allowable minimum, it will actually start closing the three-way modulating valve or lowering the speed of the injection pump, providing more high-temperature flow through the boiler bypass. When the boiler return water temperature increases enough, the controller allows the valve to open or the injection pump to ramp up speed.

Sensing both the supply and return temperature on the primary (if needed) or the secondary loop(s) not only offers winter-long boiler protection, but also enables the system to respond more quickly during startup and when heating requirements change dramatically.

The Multifunction Controller will allow the supply water temperature to increase based on the return sensor. For example, assume the current target water temperature is 100°F based on outdoor temperature, the maximum water temperature is set for 135°F and design Delta T (ΔT) is 10°F. If the supply sensor reads 110°F and the return sensor reads 70°F, the Multifunction Controller will identify a high demand on the system and control the mixing device to add hot boiler water to make the supply temperature 130°F. As the return temperature rises, the supply temperature will automatically lower. This is a huge benefit for system operation and response.

The Multifunction Controller calculates the proper target temperature internally based on user input. The installer merely sets the following information:

- Design room temperature
- Design water temperature
- Design outdoor temperature

- Warm weather outdoor temperature
- Warm weather mix temperature
- Maximum supply temperature
- Minimum supply temperature
- Mix design Delta T (ΔT°F)

The Multifunction Controller not only protects the boiler from low return water temperatures, but it also provides intelligent boiler control. To minimize boiler short cycling, the controller will not enable the boiler to fire unless the boiler temperature cannot meet the mixing requirements. On a call for heat, the system tries to satisfy that call with energy already in the system without firing the boiler. Once that residual boiler heat is used up and the system still cannot satisfy the call for heat, only then will the boiler fire. This approach makes excellent use of latent boiler heat that would otherwise be wasted up the chimney or lost through the boiler jacket. By reducing the risk of short cycling, the Multifunction Controller helps maximize the length of boiler on-cycles and off-cycles, which increases boiler efficiency and lengthens the lives of all boiler and system components.

Climate Cŏntrol Network System — The Climate Cŏntrol Network System also provides mixing for radiant systems. It operates in the same manner as the Climate Cŏntrol Multifunction Controller, except the Network System will control up to five mixing devices (combination of modulating valves and injection pumps) along with using thermostat feedback to adjust the water temperature(s). When a thermostat calls for heating and activates a water channel for mixing, the Network System will compare the current room temperature to the current setpoint and adjust the target mix temperature accordingly. This is another feature that increases comfort and optimizes efficiency, specifically on system startup and changing from setback to normal setpoints.

The Network System provides a wider scope of HVAC functionality, supporting not only radiant systems, but also the integration of forced-air heating, cooling, ventilation and humidity systems for optimal control, comfort and efficiency. In addition, the Network System can be expanded to include wall-mounted touch panels, integration into third-party home automation systems and remote access over the internet. Visit **www.uponorpro.com** for more information.



Chapter 13
Piping Schematics

Piping Schematic Level 1 Control

- Water heater
- Closed system
- Single-temperature radiant floor heating

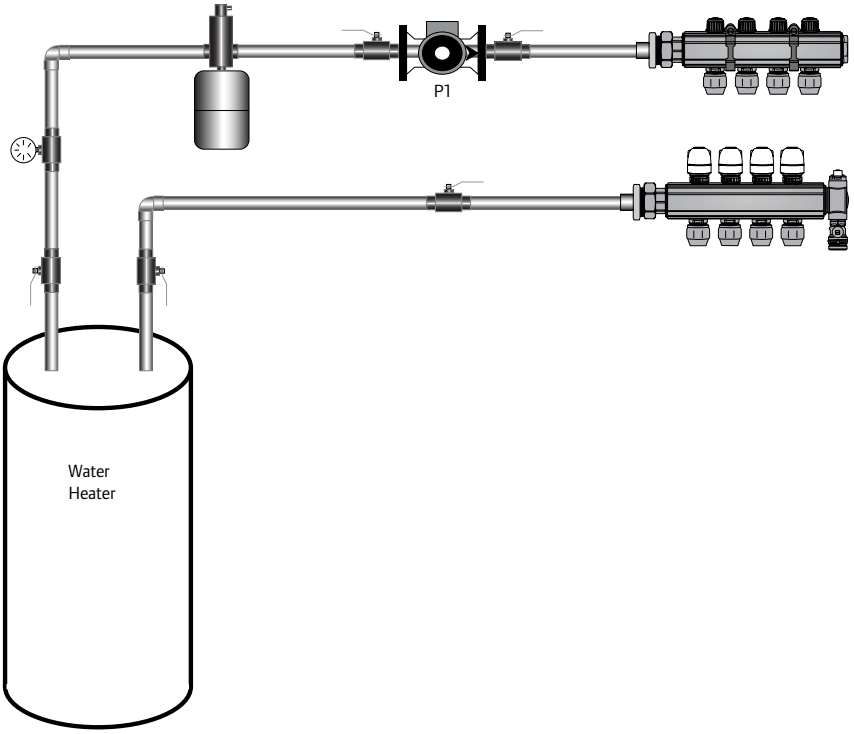
Where: All low-temperature radiant applications (< 145˚F)

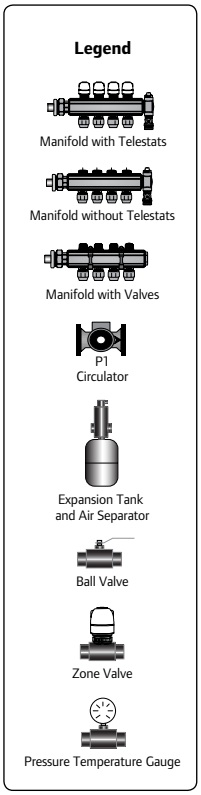
Why: This illustration shows a dedicated water heater supplying water for a single radiant manifold. The water heater provides the required supply water temperature directly to the radiant panel, with the water temperature controlled by the water heater's internal aquastat. As a result, no additional 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** – See **pages 127-131**.
- **Specific wiring schematic** – See **pages 182-183**.





Piping Schematic Level I Control

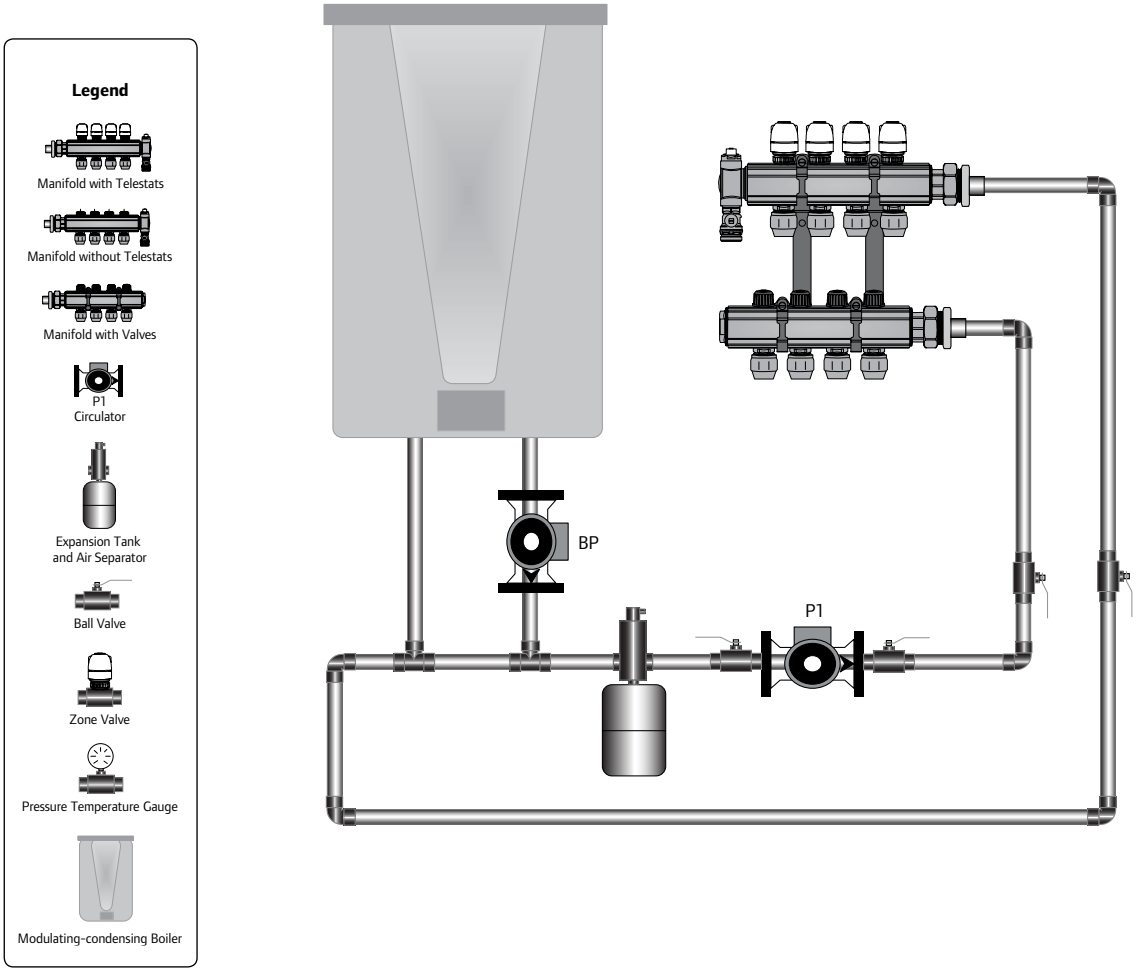
- Modulating-condensing boiler
- Single-temperature radiant floor heating

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 options** – See **pages 137-131**.
- **Specific wiring schematic** – See **page 163**.



Piping Schematic Level I Control

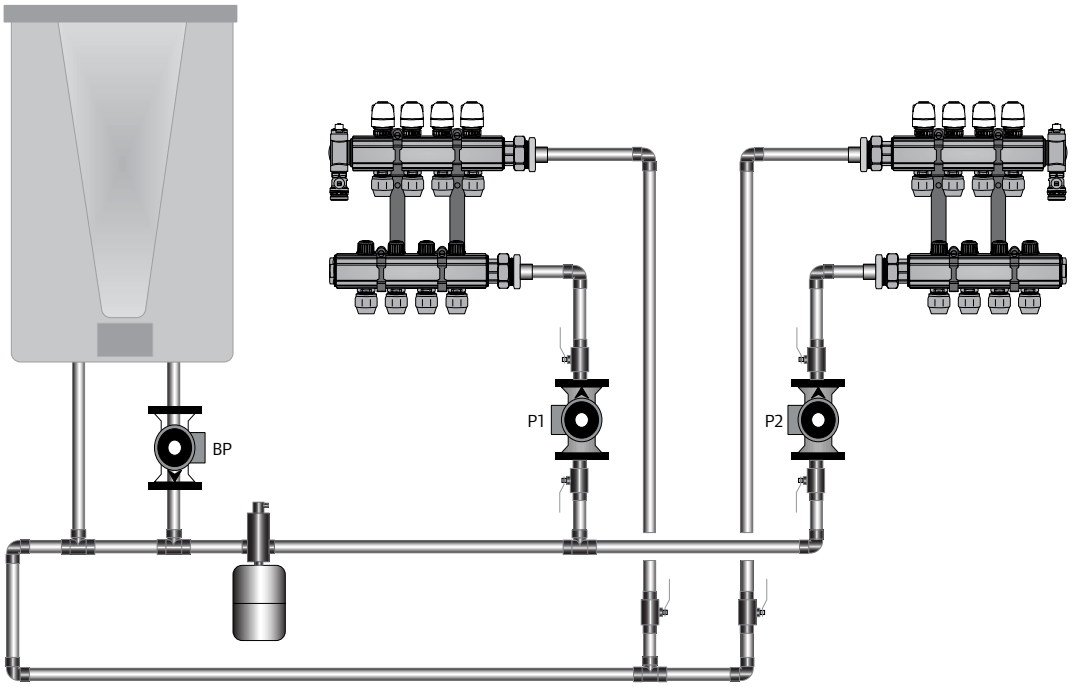
- Modulating-condensing boiler
- Single-temperature radiant floor heating
- Multiple manifolds

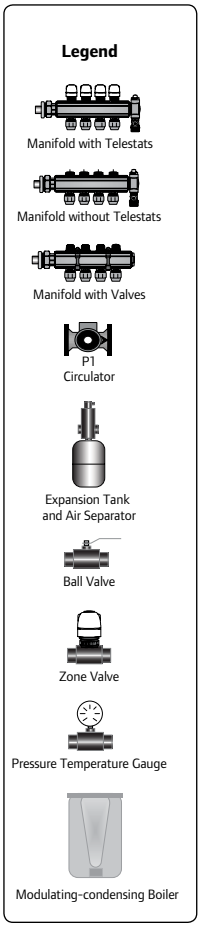
Where: All radiant and snow melt applications

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** — See **pages 127-131**.
- **Specific wiring schematic** — See **pages 178-179**.





Piping Schematic Level I Control

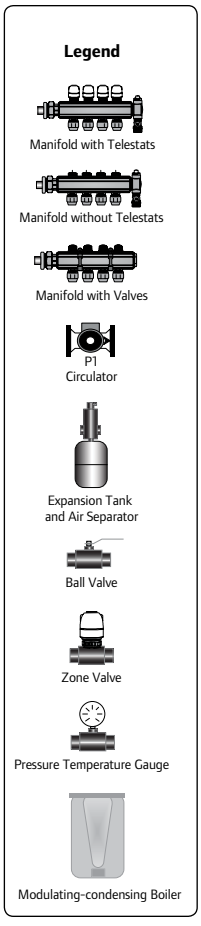
- Modulating-condensing boiler
- Dual-temperature radiant floor heating
- Three-way tempering valve

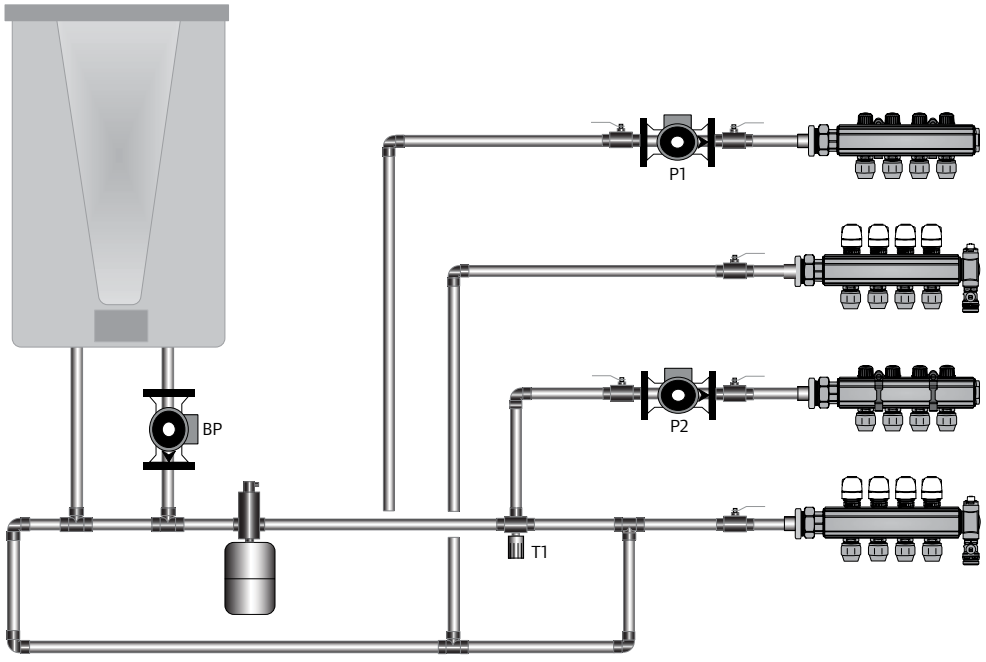
Where: Multiple temperature radiant applications

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** — See **pages 127-131**.
- **Specific wiring schematic** — See **pages 178-179**.





Piping Schematic Level I Control

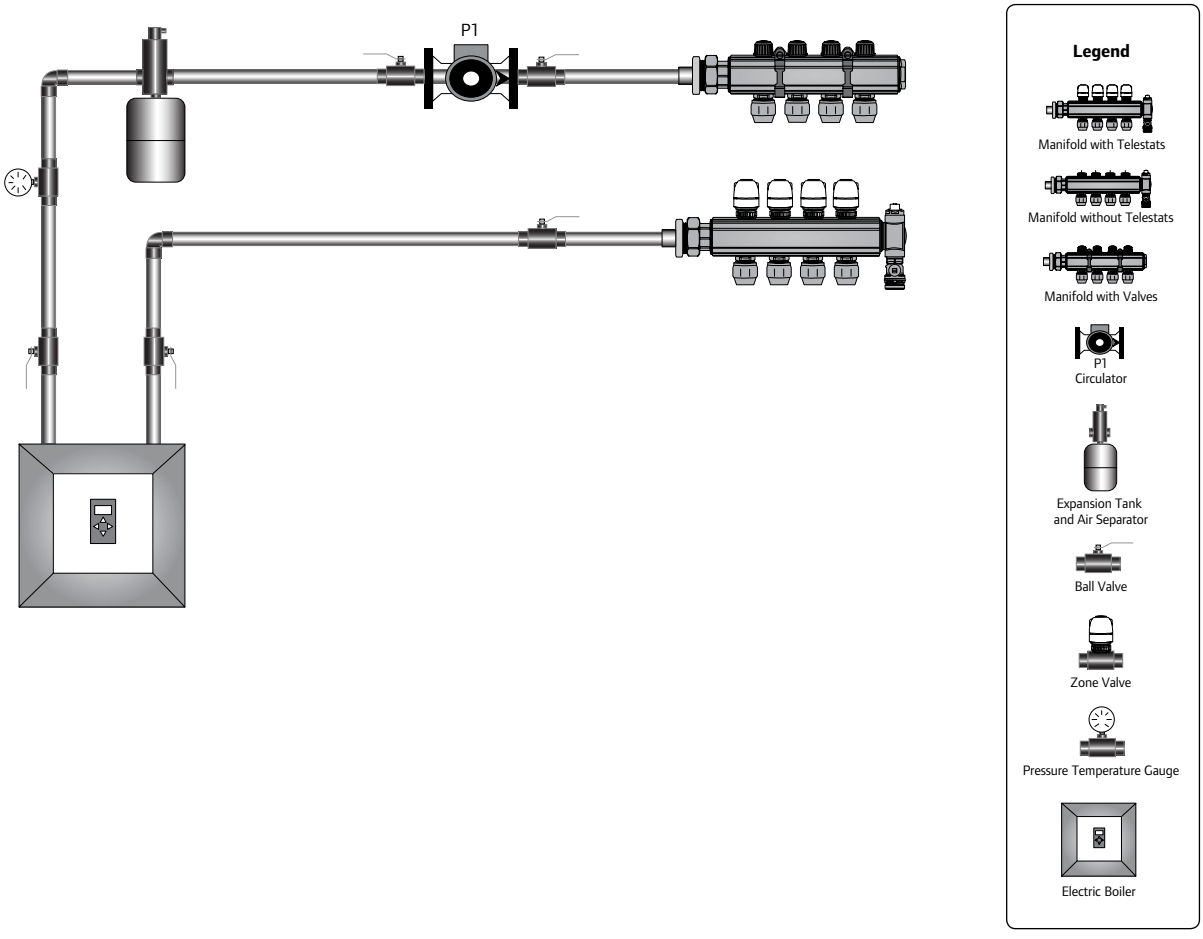
- Electric boiler
- Single-temperature radiant floor heating

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** — See **pages 127-131**.
- **Specific wiring schematic** — See **page 163**.



Piping Schematic Level I Control

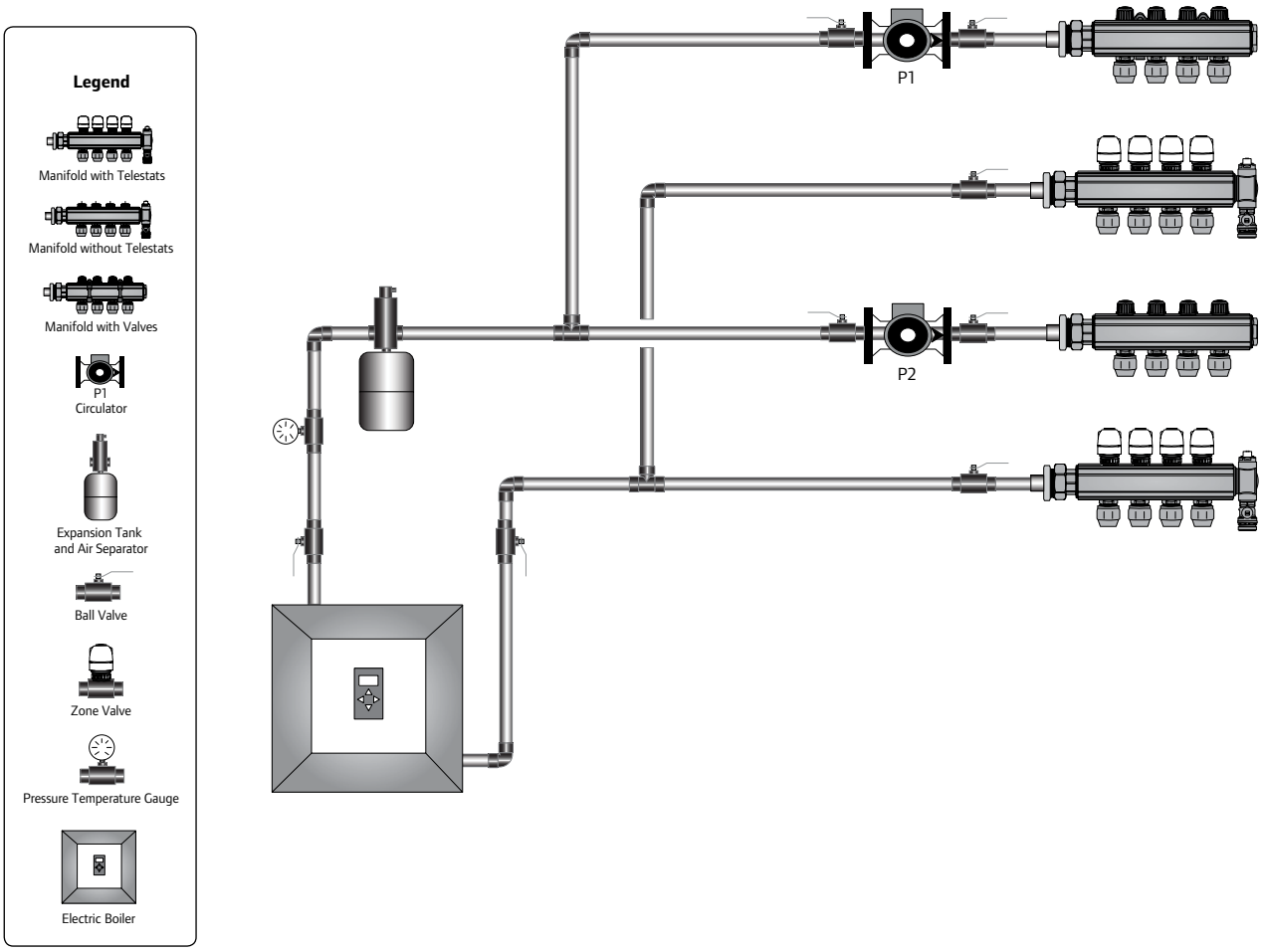
- Electric boiler
- Single-temperature radiant floor heating
- Multiple manifolds

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** — See **pages 127-131**.
- **Specific wiring schematic** - See **pages 178-179**.



Piping Schematic Level I Control

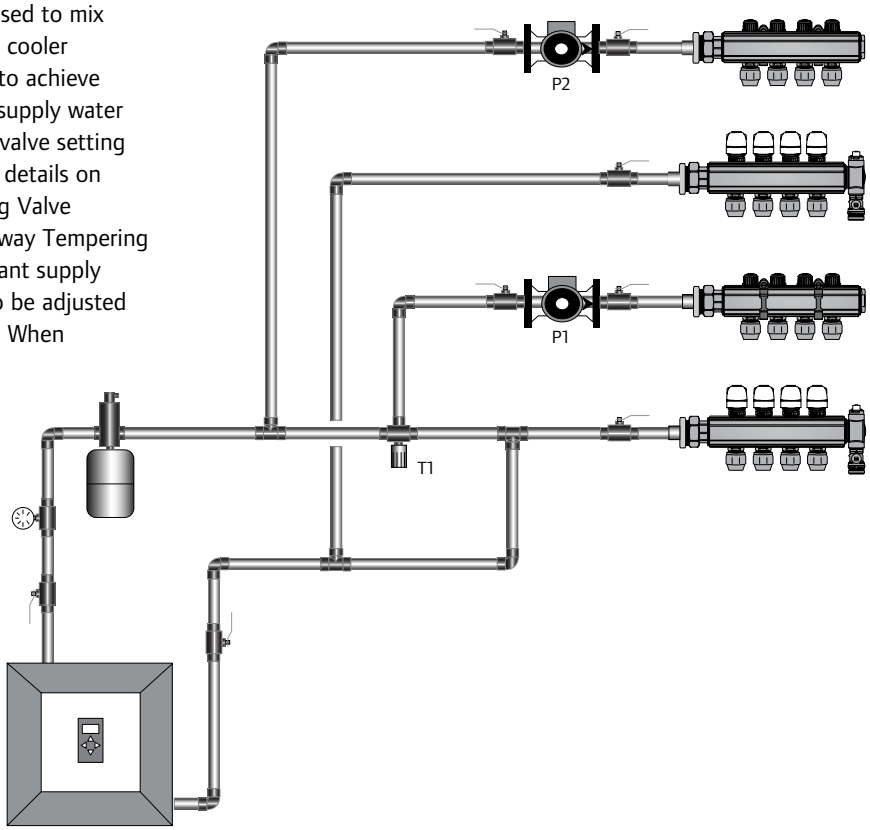
- Electric boiler
- Multiple-temperature radiant floor heating
- Three-way tempering valve

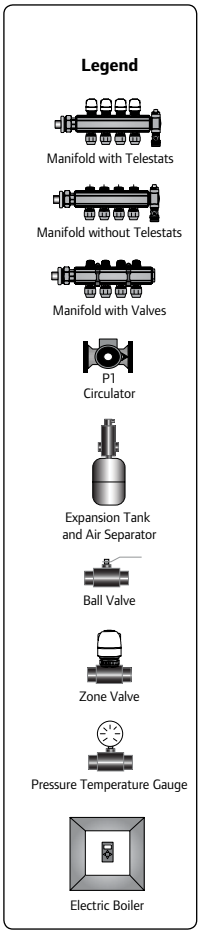
Where: Multiple temperature radiant applications

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** — See **pages 127-131**.
- **Specific wiring schematic** — See **pages 178-179**.





Piping Schematic Level II Control

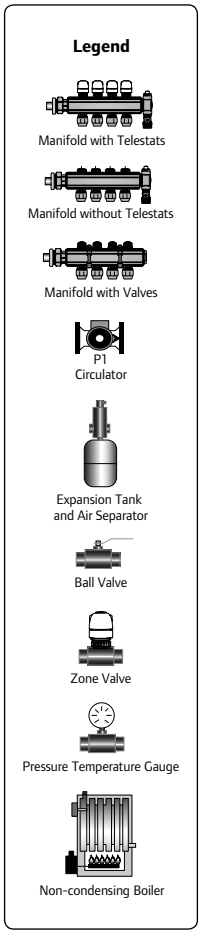
- Non-condensing boiler
- Three-way tempering valve

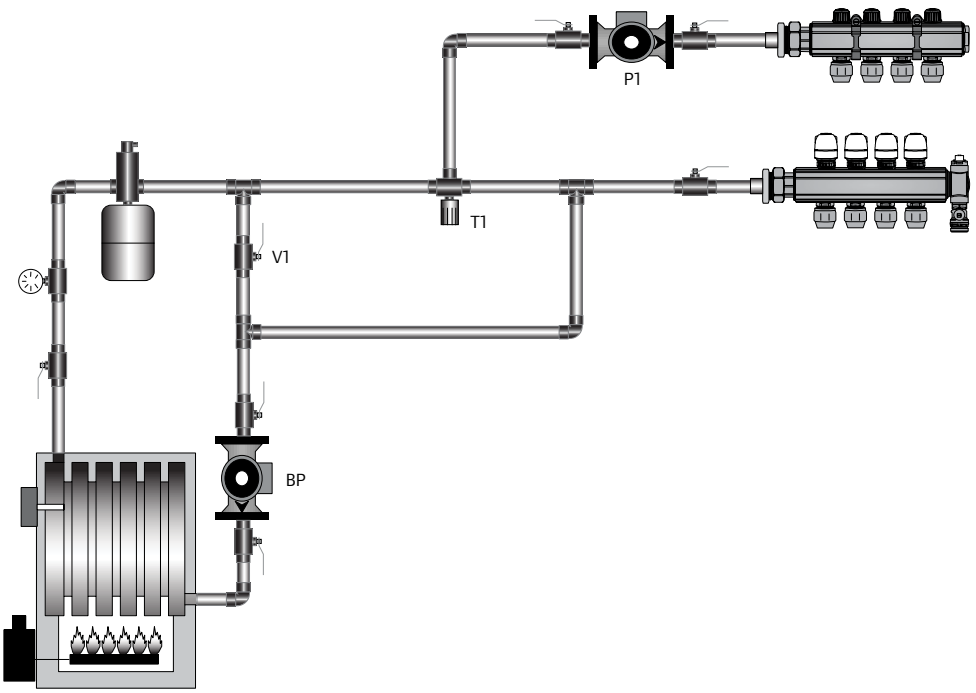
Where: All low-temperature radiant applications (< 160° F)

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** — See **pages 127-131**.
- **Specific wiring schematic** — See **page 163**.





Piping Schematic Level II Control

- Non-condensing boiler
- Three-way tempering valve
- Dual-temperature radiant floor heating

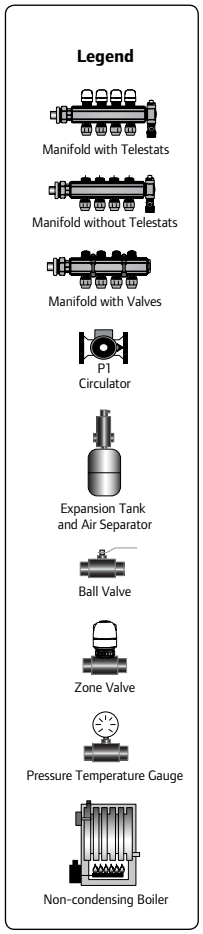
Where: All low-temperature radiant applications (< 160°F)

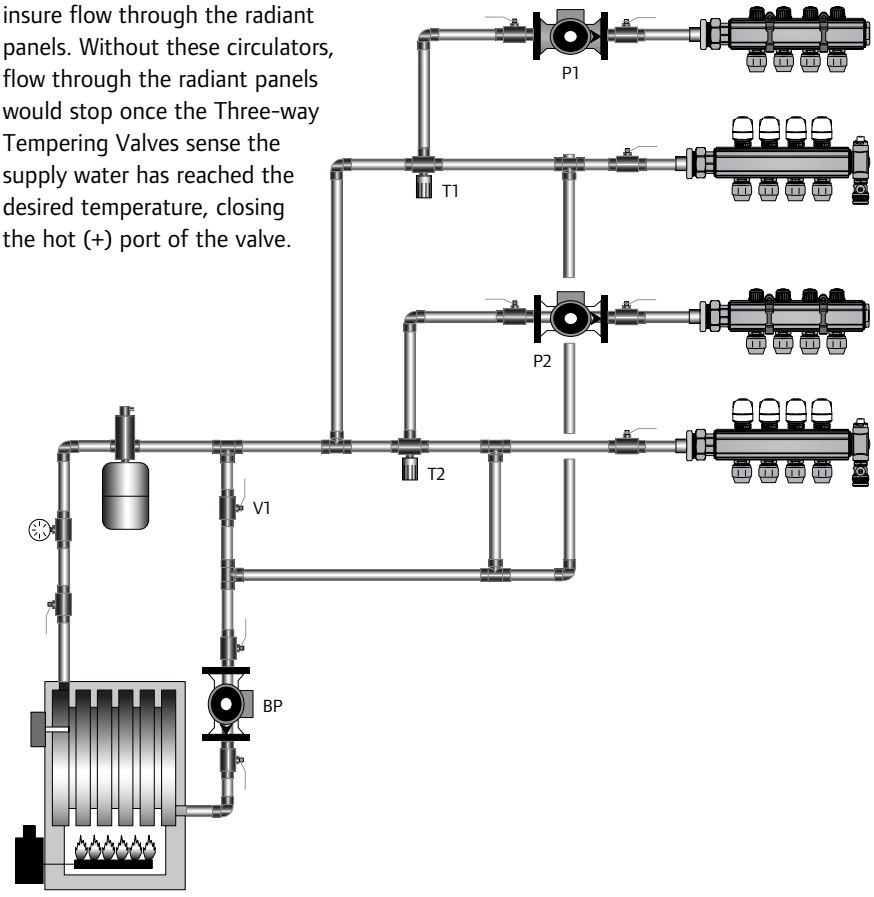
Why: This illustration shows a non-condensing boiler supplying water to a multiple radiant panels requiring dramatically different supply water temperatures, or having different installation methods (i.e. concrete vs. Joist Trak). The Uponor Three-way Tempering Valves (T1 and T2) will mix hot boiler 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** — See **pages 127-131**.
- **Specific Wiring Schematic** — See **pages 178-179**.





Piping Schematic Level II Control

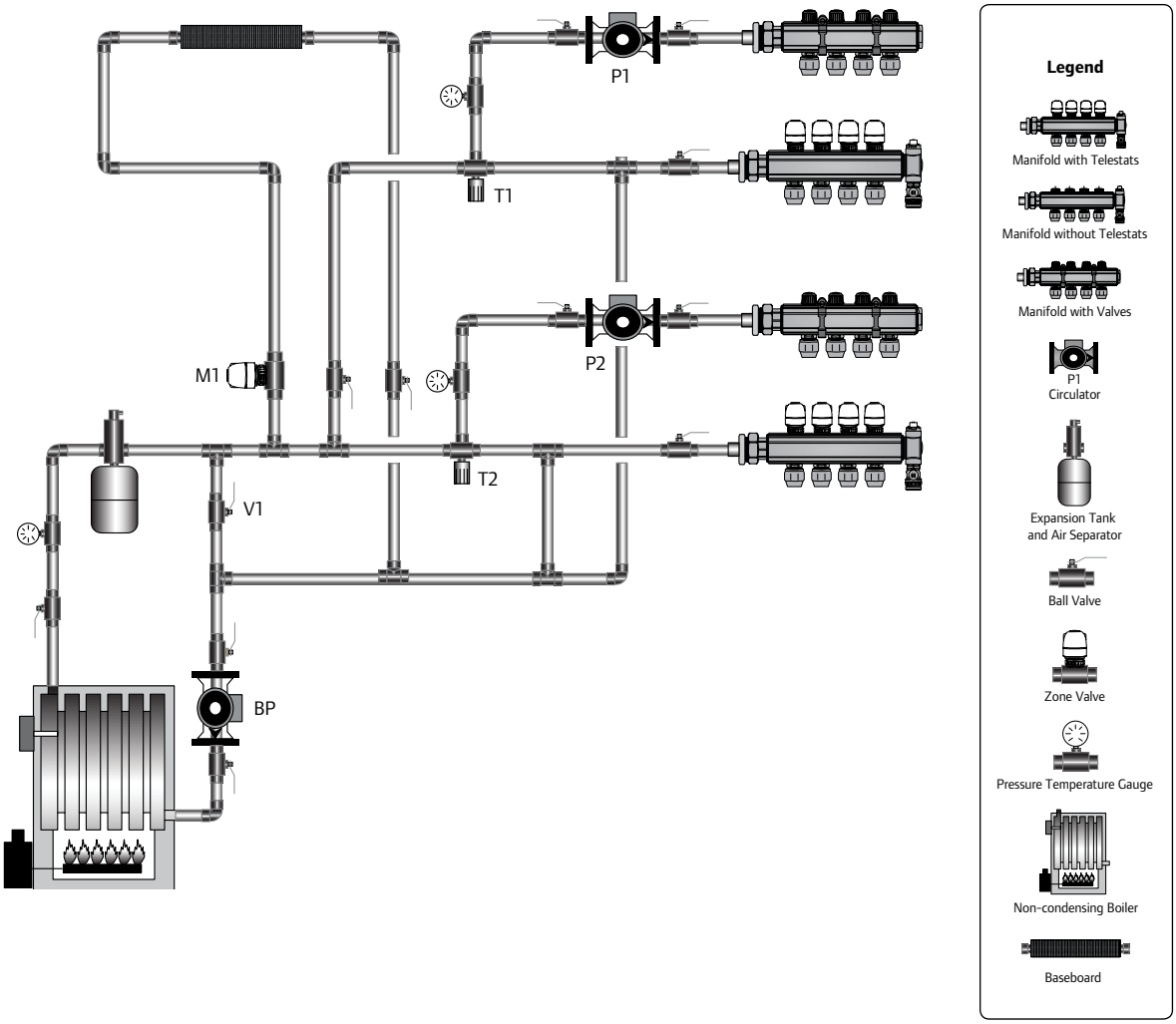
- Non-condensing boiler
- Three-way tempering valve
- Dual-temperature radiant floor heating
- High-temperature radiation

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** — See **pages 127-131**.
- **Specific Wiring Schematic** — See **pages 174-175**.


P1
T1
P2
M1
T2
V1
BP
Legend
Manifold with Telestats
Manifold without Telestats
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

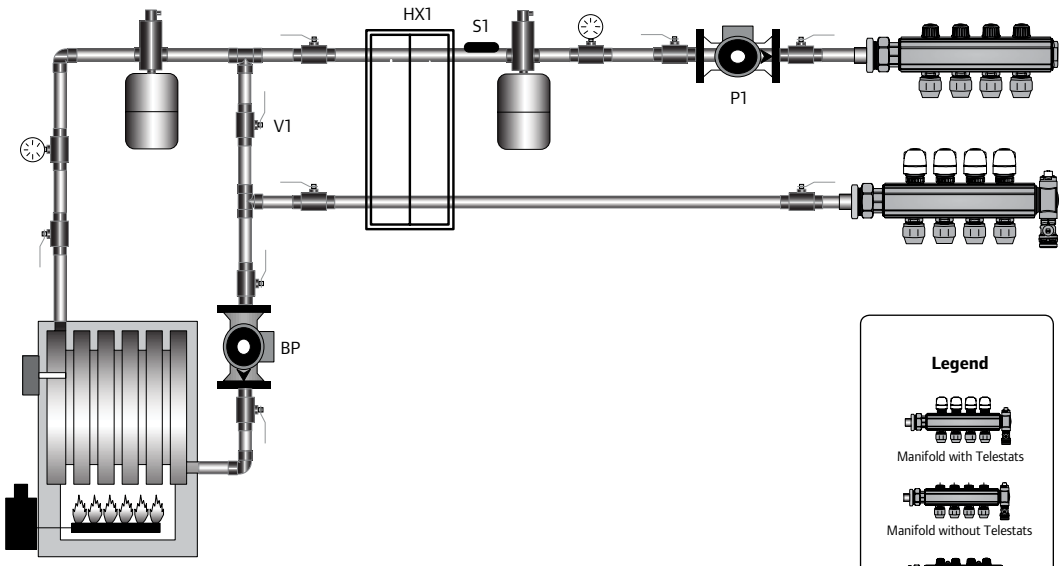
- Non-condensing boiler
- Heat exchanger

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) tubing 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** — See **pages 127-131**.
- **Specific wiring schematic** — See **page 163**.



Legend

Manifold with Telestats

Manifold without Telestats

Manifold with Valves

P1
Circulator

Expansion Tank
and Air Separator

Ball Valve

Zone Valve

Pressure Temperature Gauge

Non-condensing Boiler

Piping Schematic Level II Control

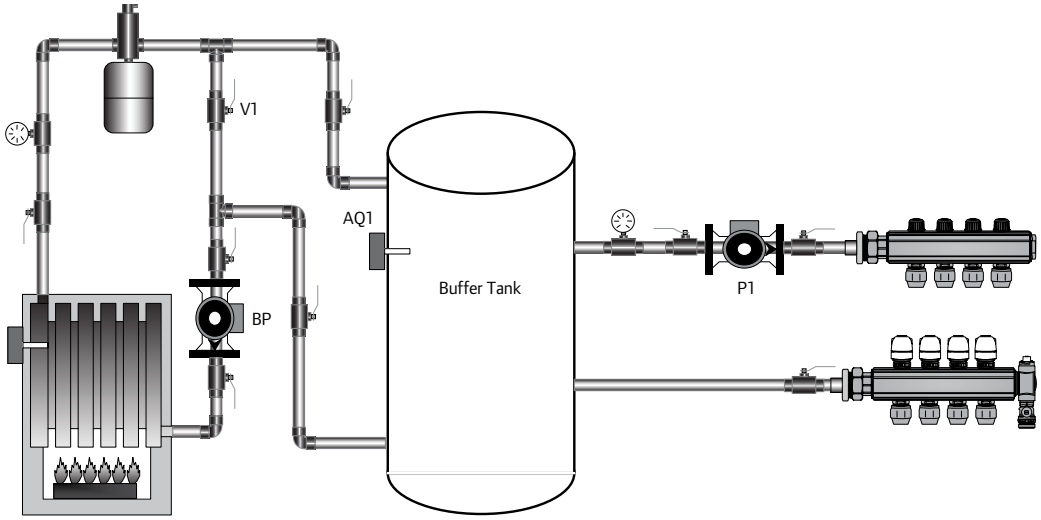
- Wood boiler
- Mixing tank
- Single-temperature radiant floor heating

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:

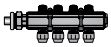
- **Bypass loop** — This piping schematic includes a "bypass" loop at the boiler. The installation of a bypass will allow an amount of hot boiler supply water (depending on bypass valve position) to circulate through the boiler to prevent low boiler return water temperatures, preventing the boiler's 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** — See **pages 127-131**.
- **Specific wiring schematic** — See **pages 180-181**.



Legend


Manifold with Telestats


Manifold without Telestats


Manifold with Valves


P1
Circulator


Expansion Tank and Air Separator


Ball Valve


Zone Valve


Pressure Temperature Gauge


Non-condensing Boiler

Piping Schematic Level II Control

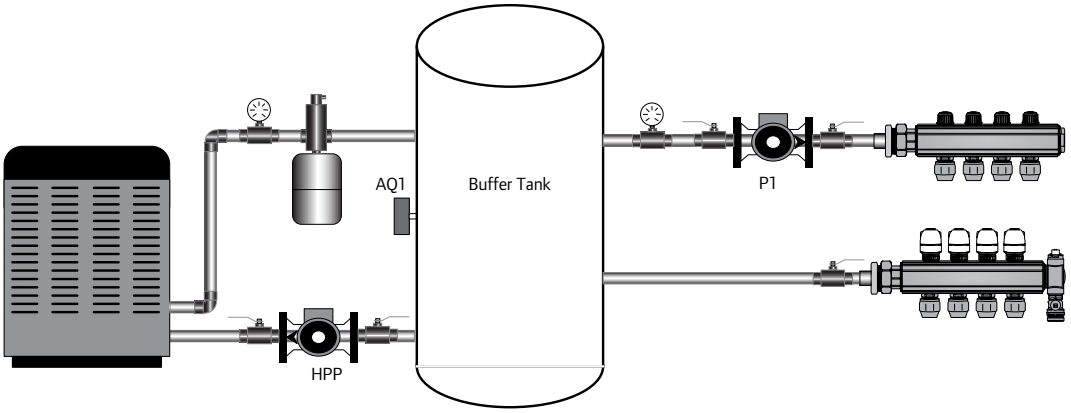
- Heat pump
- Mixing tank
- Single-temperature radiant floor heating

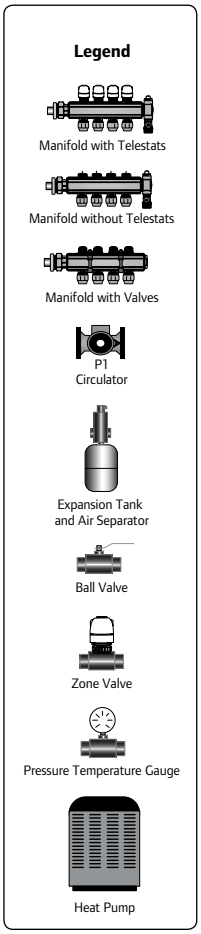
Where: All low-temperature radiant applications (< 120°F)

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** — See **pages 127-131**.
- **Specific wiring schematic** — See **pages 180-181**.





Piping Schematic Level III Control

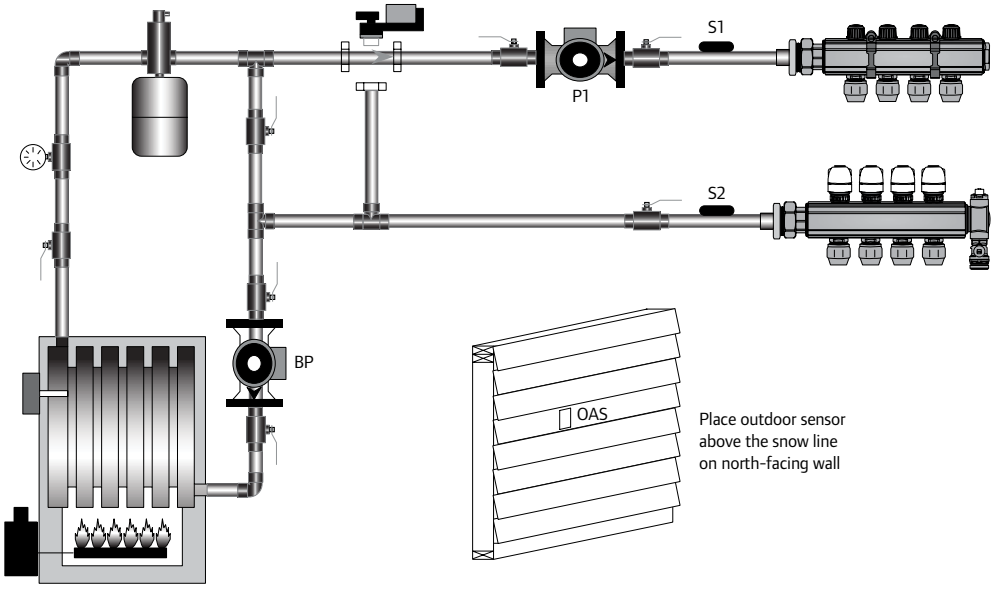
- Non-condensing boiler
- Three-way modulating valve
- Single-temperature radiant floor heating

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. The radiant loop supply water temperature is controlled by the use of the Climate Cŏntrol Multifunction Controller and Three-way Modulating Valve. The Multifunction Controller is a weather-responsive reset controller that senses changes in outdoor temperatures and adjusts the radiant supply water temperature accordingly, while providing adequate heat to satisfy the structure's heat loss requirements (see **Chapter 12** for further information on weather responsive reset control). The Multifunction Controller also controls the radiant loop circulator and the boiler loop circulator, and also enables the boiler.

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** — See **pages 127-131**.
- **Specific Wiring Schematic** — See **pages 186-187**.



Legend

Manifold with Telestats

Manifold without Telestats

Manifold with Valves

P1
Circulator

Expansion Tank
and Air Separator

Ball Valve

Zone Valve

Pressure Temperature Gauge

Non-condensing Boiler

Three-way Modulating
Valve (0-10v)

Piping Schematic Level III Control

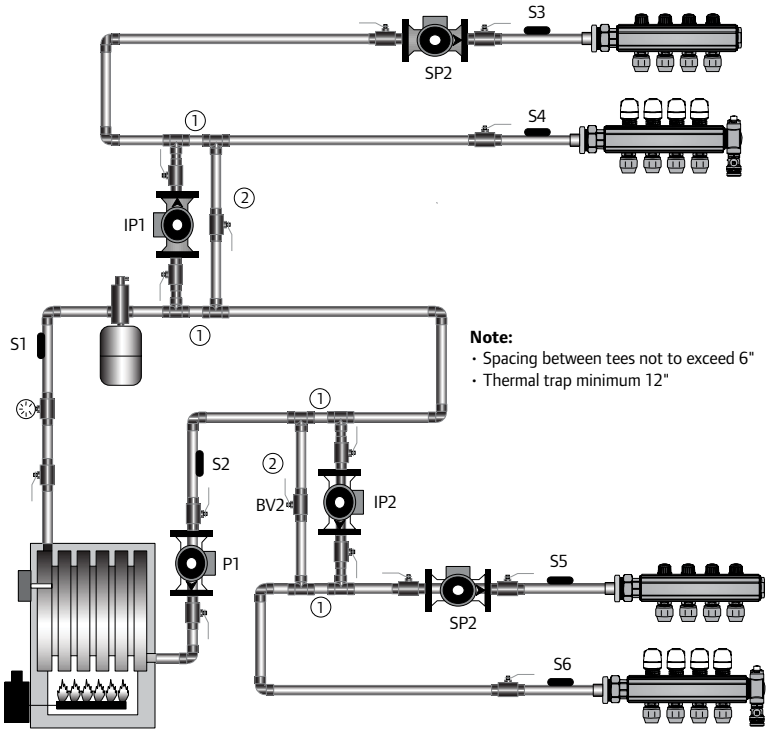
- Non-condensing boiler
- Dual-temperature radiant floor heating
- Variable-speed injection mixing

Where: All radiant and other hydronic applications where two separate temperatures of full outdoor reset with a weather-responsive control is desirable, using primary/secondary piping

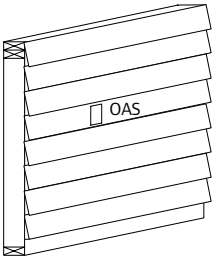
Why: This illustration shows a non-condensing boiler supplying water to multiple radiant panels requiring dramatically different supply water temperatures, or having different installation methods (i.e. concrete vs. Joist Trak). The Climate Cŏntrol Multifunction Controller separately controls the radiant loop temperatures based on outdoor temperatures. The controller senses changes in outdoor weather conditions and changes the supply water temperatures in each radiant manifold independently using variable-speed injection mixing (see **Appendix I** for information on variable-speed injection mixing), while providing adequate heat to satisfy the structure's heat loss requirements (see **Chapter 12** for further information on weather-responsive reset controls). The Multifunction Controller controls each radiant loop circulator (SP1 and SP2) independently based on calls for heat, and varies the speed of each injection circulator (IP1 and IP2) based on the required supply water temperature for each radiant loop. The Multifunction Controller also enables the boiler and fires the primary circulator (PP1).

What to look for:

- **Bypass loop** — Even though a non-condensing boiler is used in this applications, an additional bypass loop is not required. The Primary loop will suffice as a bypass loop. The Climate Cŏntrol Multifunction Controller uses primary sensors (S5 and S6) to provide boiler operation, maintaining return water temperatures above the boiler manufacturer's recommended minimum and preventing flue gas condensation in non-condensing boilers.
- **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 loop circulators** — These 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. Based on input from the Multifunction Controller, the speed of the circulators will vary. This variable speed injection mixing will change the radiant supply water temperature based on outdoor weather conditions.
- **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 effecting radiant supply water temperature control.
- **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 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 supply and return piping near the boiler, on the secondary radiant loops (S3 through S6) 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** — See **pages 127-131**.
- **Specific wiring Schematic** — See **pages 188-189**.

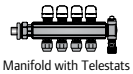


Note:
- Spacing between tees not to exceed 6"
- Thermal trap minimum 12"

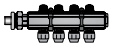


Place outdoor sensor above the snow line on north-facing wall

Legend


Manifold with Telestats


Manifold without Telestats


Manifold with Valves



Circulator


Expansion Tank and Air Separator


Ball Valve


Zone Valve


Pressure Temperature Gauge


Non-condensing Boiler

Piping Schematic Level III Control

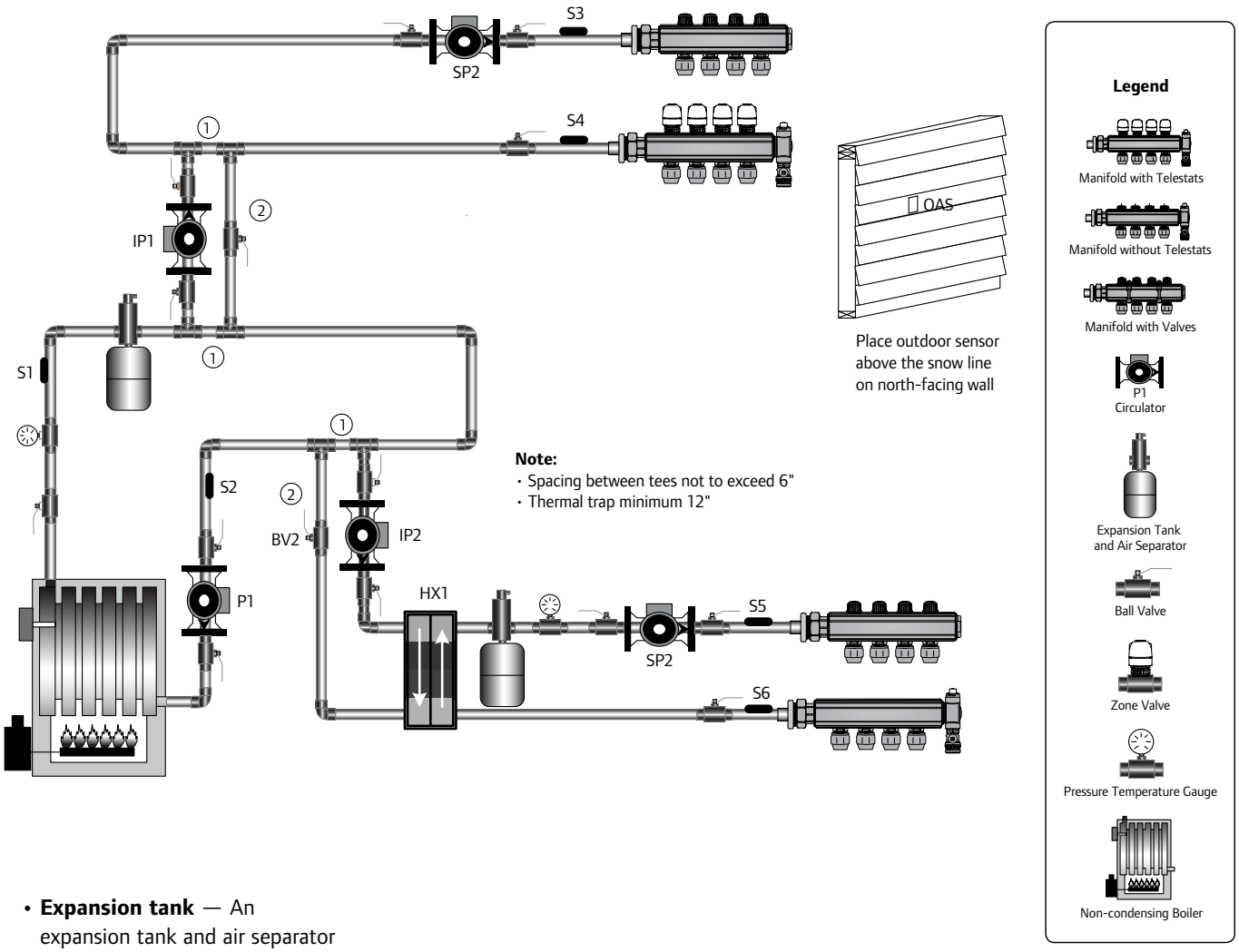
- Non-condensing boiler
- Multiple-temperature radiant floor heating and snow melting
- Variable-speed injection mixing

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. The Climate Cõntrol Multifunction Controller controls the radiant loop temperature. The controller senses changes in outdoor weather conditions and changes the supply water temperature in the radiant loop using variable-speed injection mixing (see **Appendix I** for information on variable-speed injection mixing), while providing adequate heat to satisfy the structure's heat loss requirements (see **Chapter 12** for further information on weather-responsive reset controls). The Multifunction Controller also controls an integrated snow melting system, using variable-speed injection mixing in conjunction with a heat exchanger (HX1). The Multifunction Controller controls the radiant and snow melt circulators (SP1 and SP2) independently based on calls for heat, and varies the speed of each injection circulator (IP1 and IP2) independently, based on the required supply water temperatures for the radiant and snow melt loops. The Multifunction Controller also enables the boiler and fires the primary circulator (P1).

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. The Multifunction Controller uses boiler sensors (S1 and S2) to provide boiler operation, maintaining return water temperatures above the boiler manufacturer's recommended minimum and preventing flue gas condensation in non-condensing boilers.
- **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. Based on input from the Climate Cõntrol Multifunction Controller, the speed of these circulators will vary. 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** — See **pages 127-131**.
- **Specific wiring Schematic** — See **pages 190-191**.

Piping Schematic Level III Control

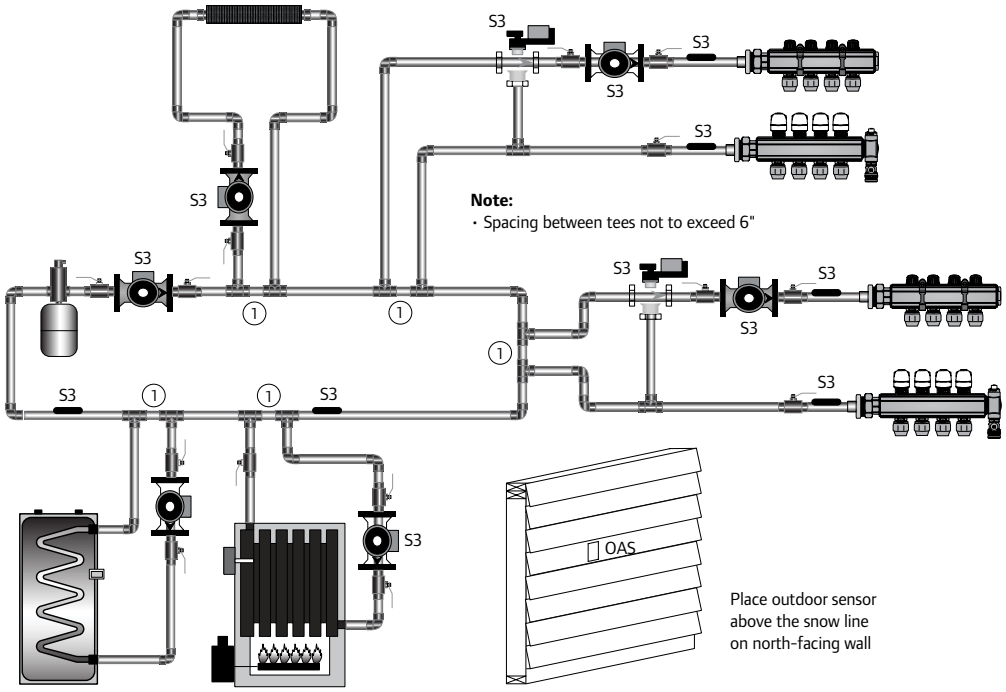
- Non-condensing boiler
- Three-way modulating valve
- Dual-temperature radiant floor heating
- High-temperature radiation
- Domestic hot water
- Primary/secondary piping

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. All elements are controlled by the Climate Cŏntrol Multifunction Controller. 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** — See **pages 127-131**.
- **Specific wiring schematic** — See **pages 192-193**.



Note:
- Spacing between tees not to exceed 6"

Place outdoor sensor above the snow line on north-facing wall

Legend

Manifold with Telestats

Manifold without Telestats

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

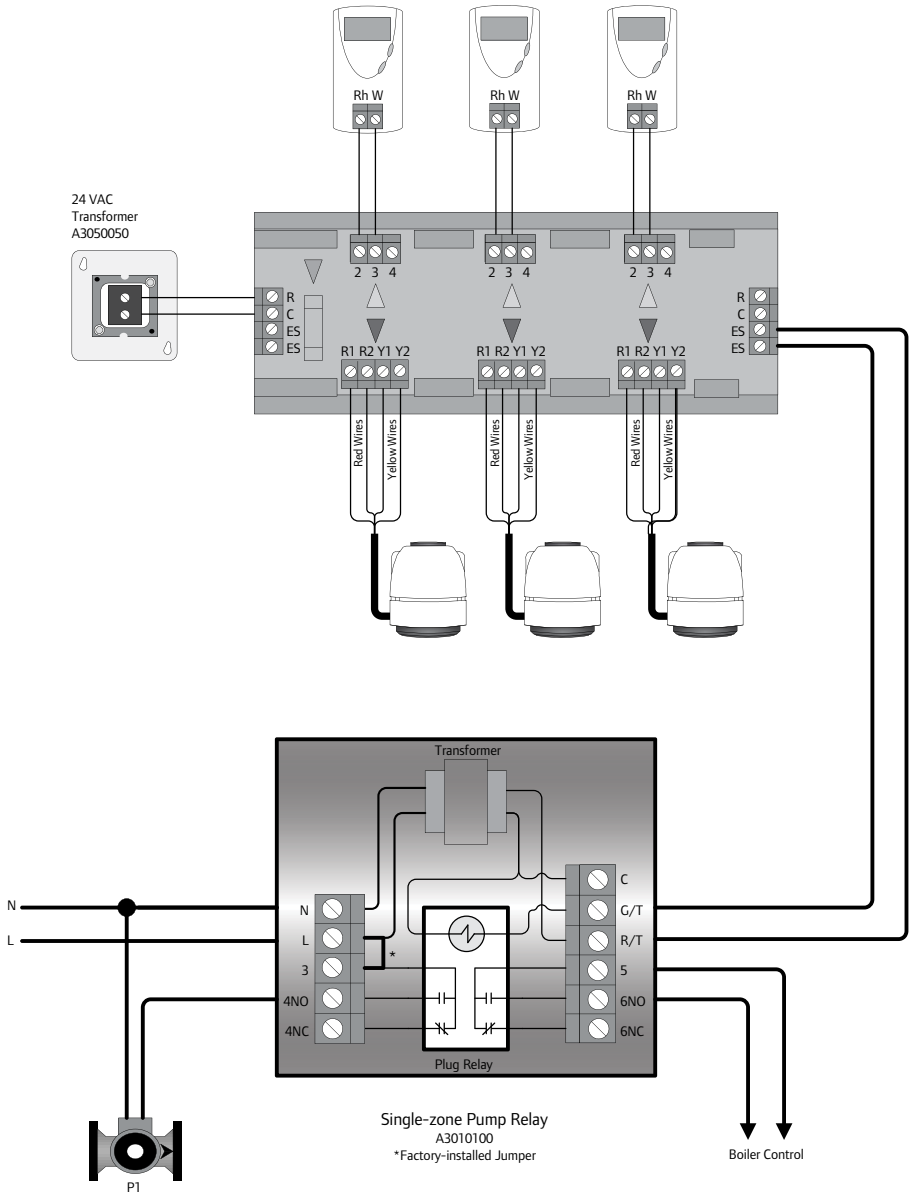
Wiring Schematic 1

- A3030101 Uponor Thermostats
- A3010522 Thermal Actuators
- A3030003/A3030004 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.



Wiring Schematic 1

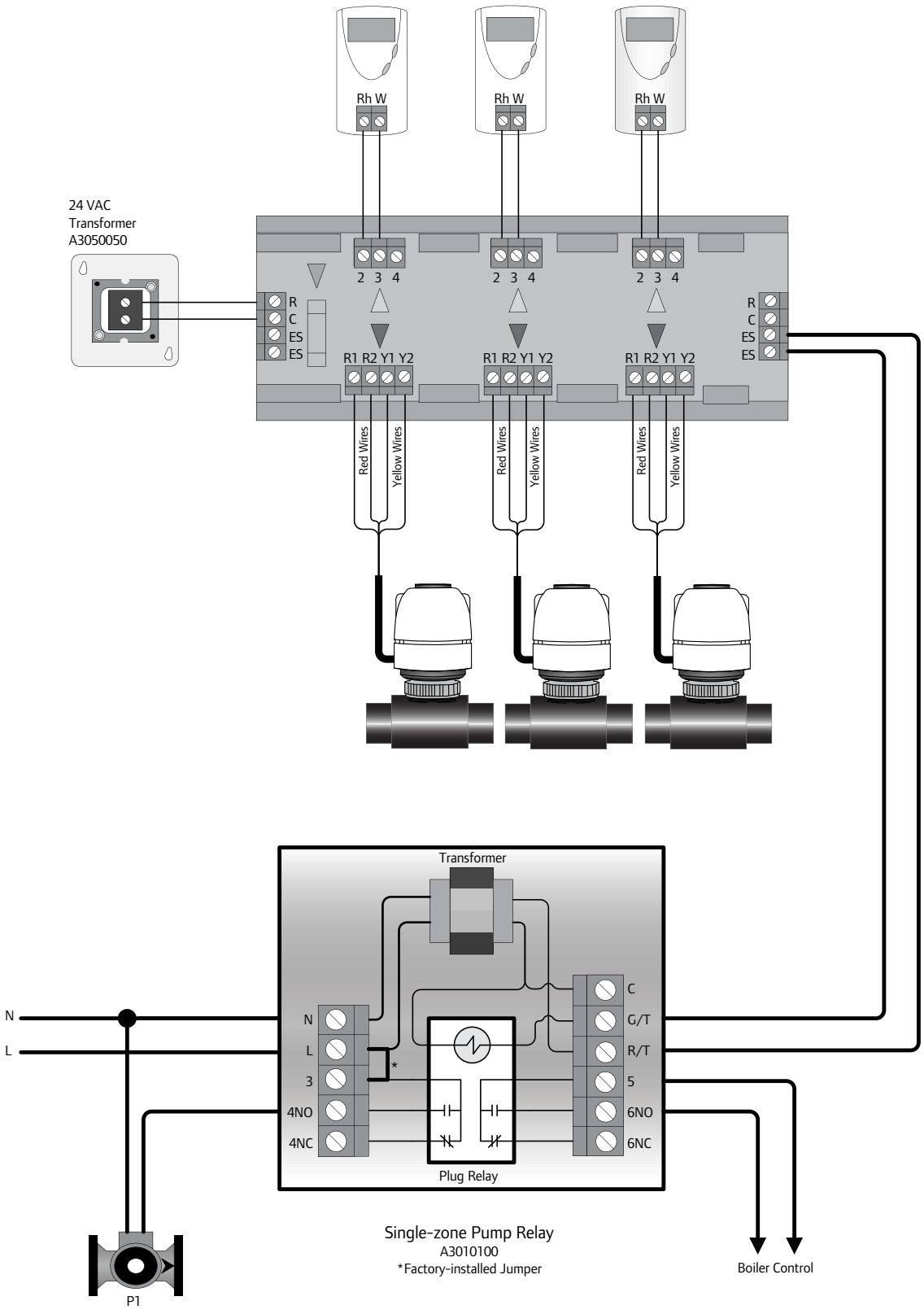
Wiring Schematic 2

- A3030101 Uponor Thermostats
- A3070526 Uponor Zone Valve
- A3030003/A3030004 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.



Wiring Schematic 2

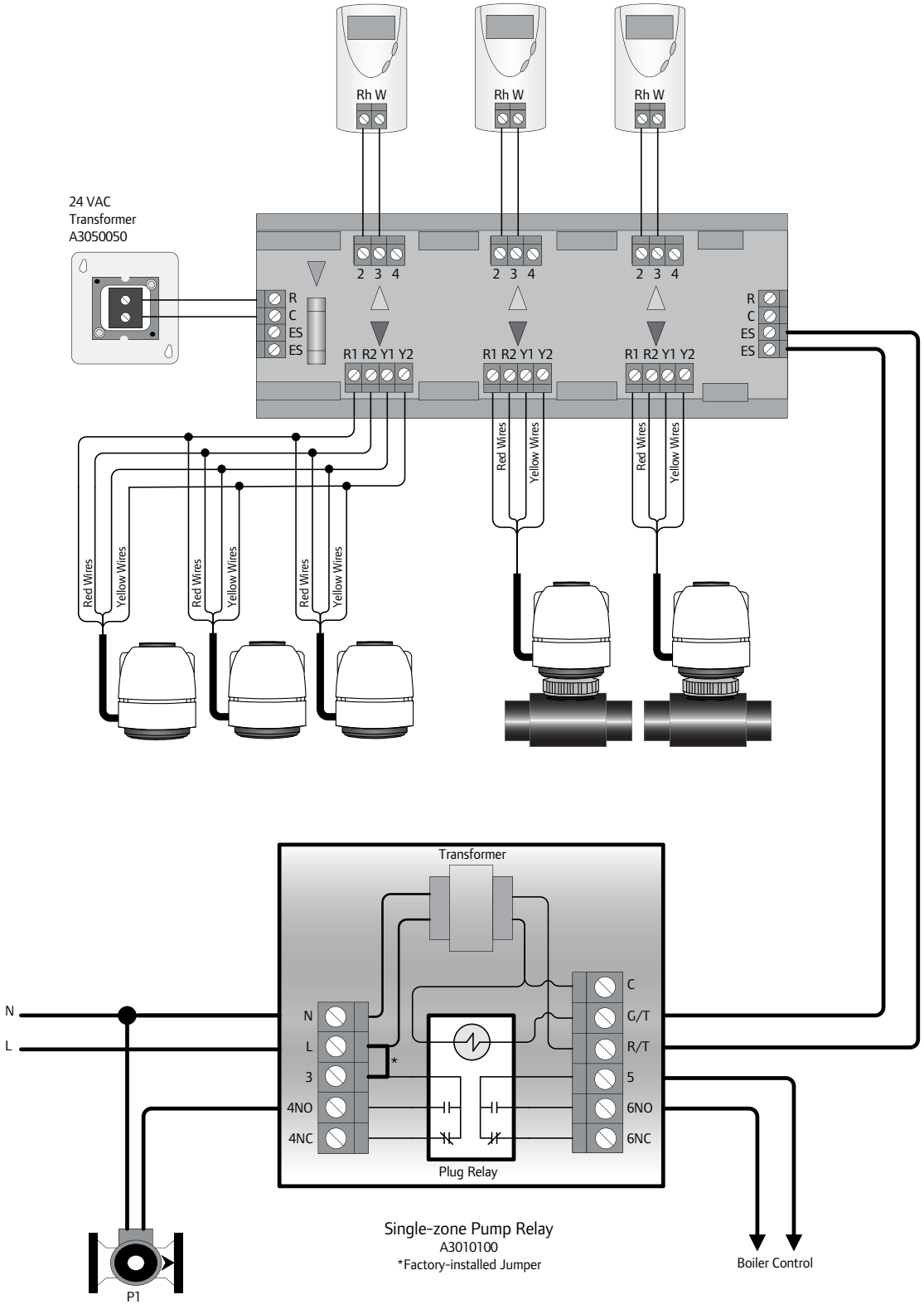
Wiring Schematic 3

- A3030101 Uponor Thermostats
- A3010522 Thermal Actuators
- A3070526 Uponor Zone Valve
- A3030003/A3030004 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.



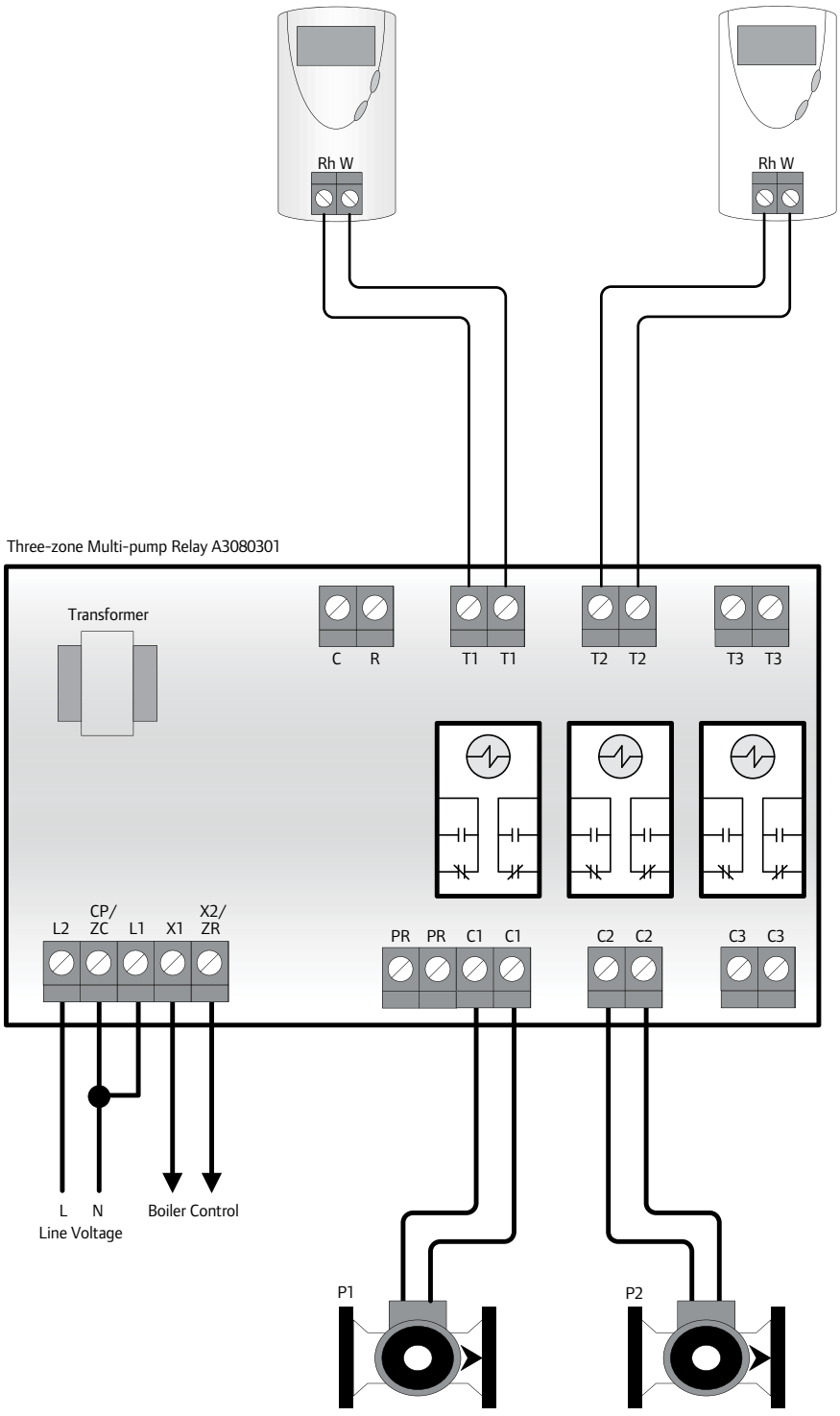
Wiring Schematic 3

Wiring Schematic 4

- A3030101 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.



Wiring Schematic 4

Wiring Schematic 5

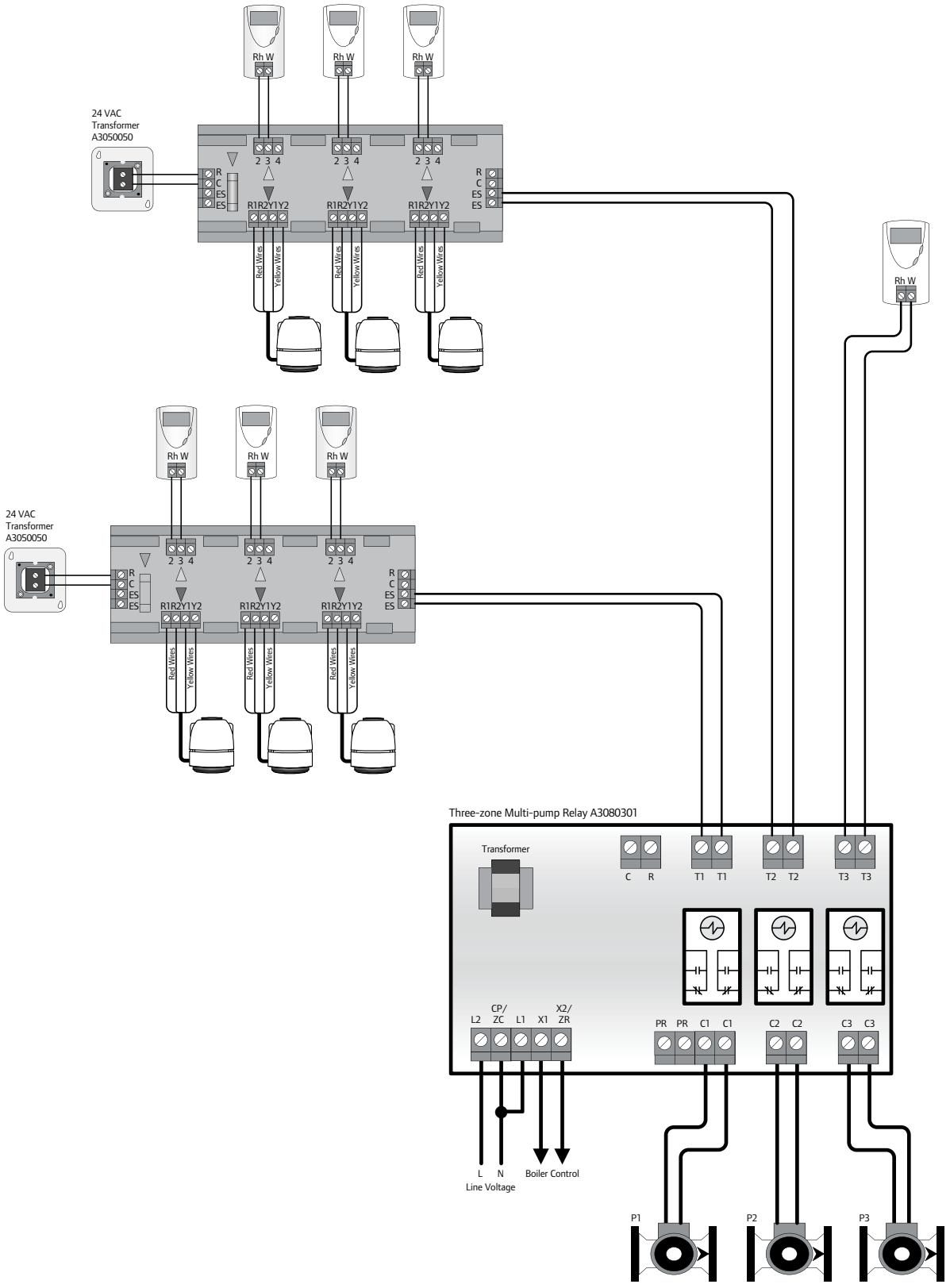
- A3030101 Uponor Thermostats
- A3010522 Thermal Actuators
- A3030003/A3030004 Zone Control Module (ZCM)
- A3080301 Three-zone Multi-pump Relay
- A3050050 50 VA Transformer

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.



Wiring Schematic 5

Wiring Schematic 6

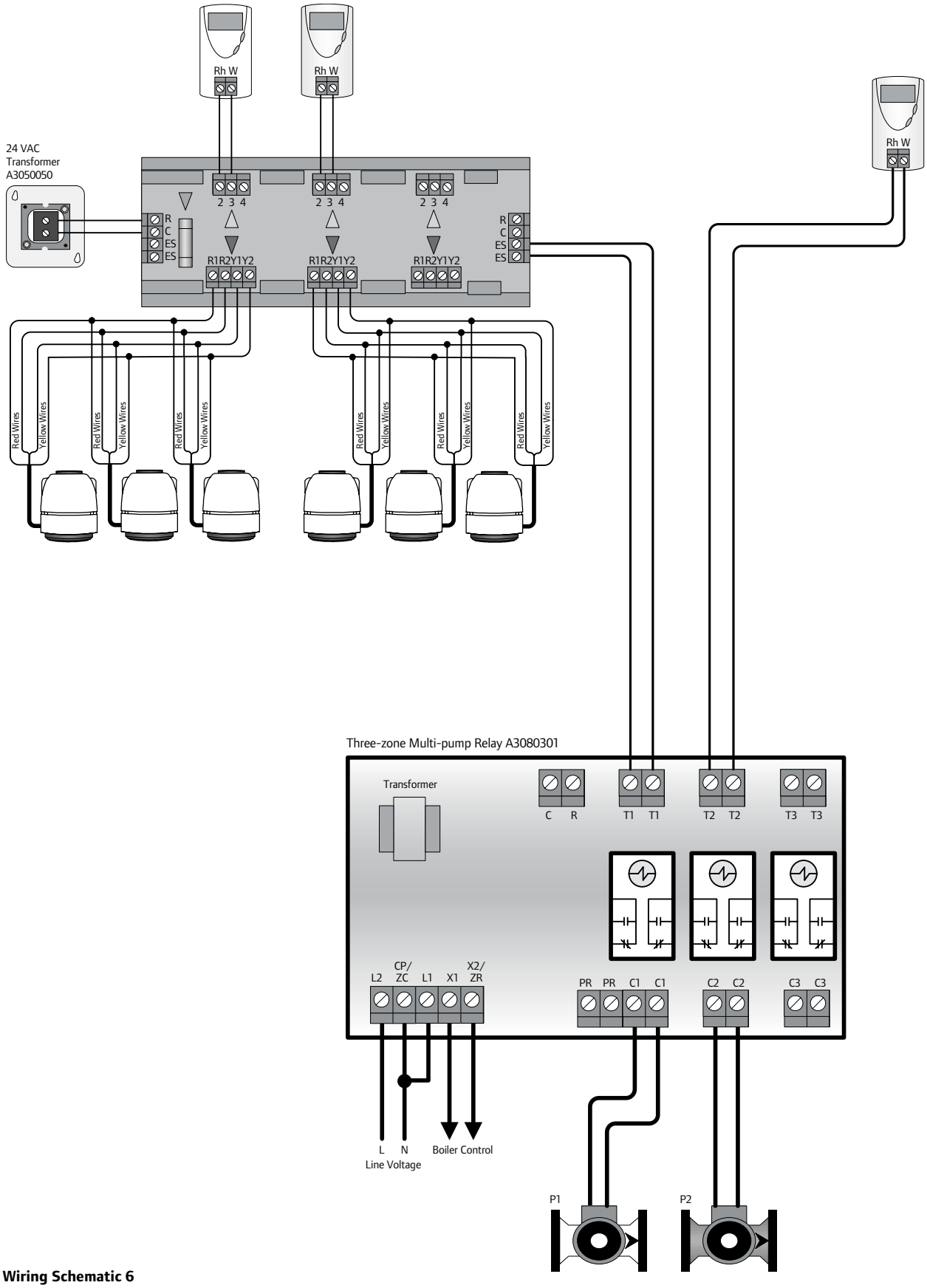
- A3030101 Uponor Thermostats
- A3010522 Thermal Actuators
- A3030003/A3030004 Zone Control Module (ZCM)
- A3080301 Three-zone Multi-pump Relay
- A3050050 50 VA Transformer

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.



Wiring Schematic 6

Wiring Schematic 7

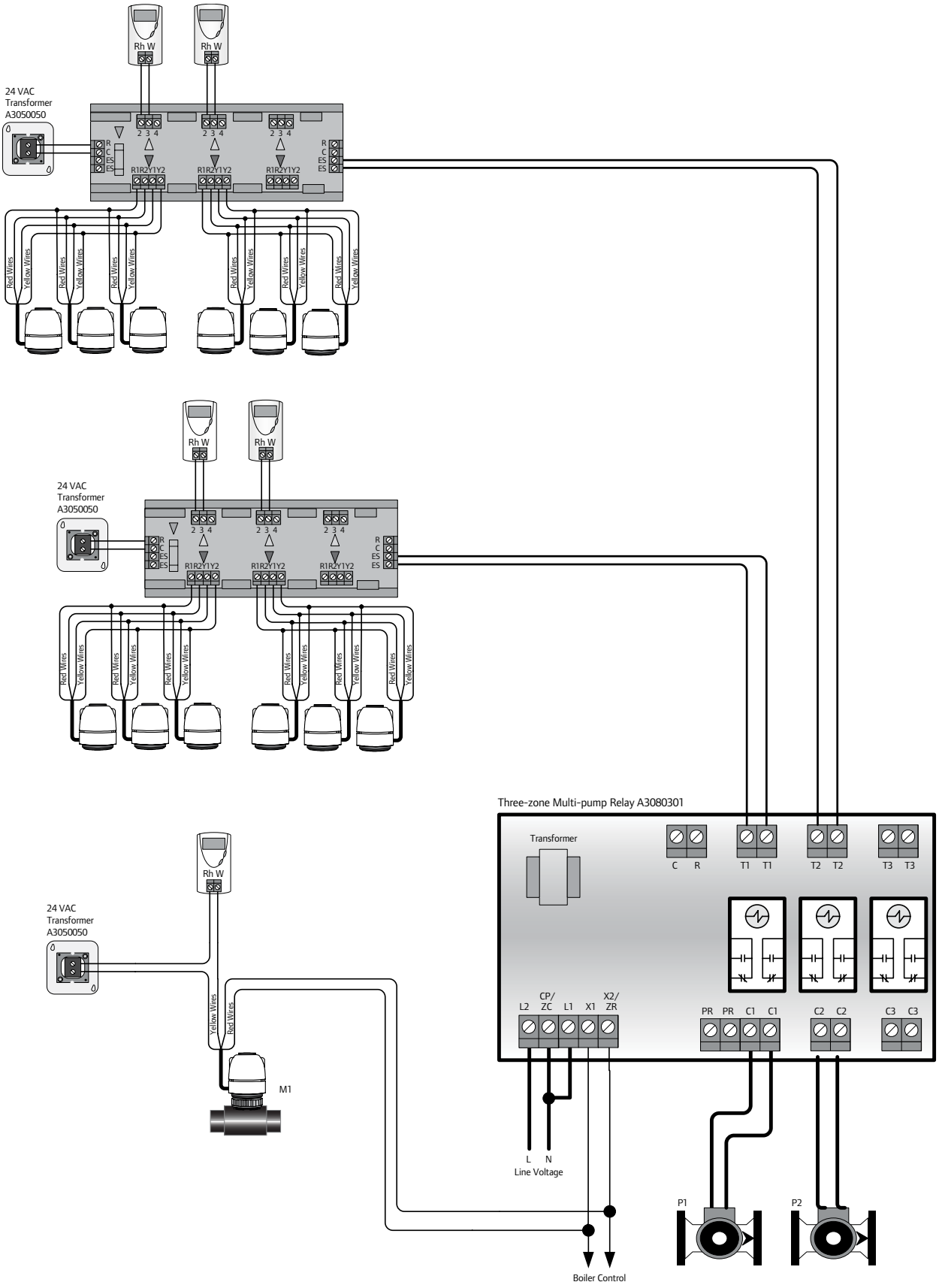
- A3030101 Uponor Thermostats
- A3010522 Thermal Actuators
- A3030003/A3030004 Zone Control Module (ZCM)
- A3080301 Three-zone Multi-pump Relay
- A3050050 50 VA Transformer
- A3070526 Uponor 1" Zone Valve

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.



Wiring Schematic 7

Wiring Schematic 8

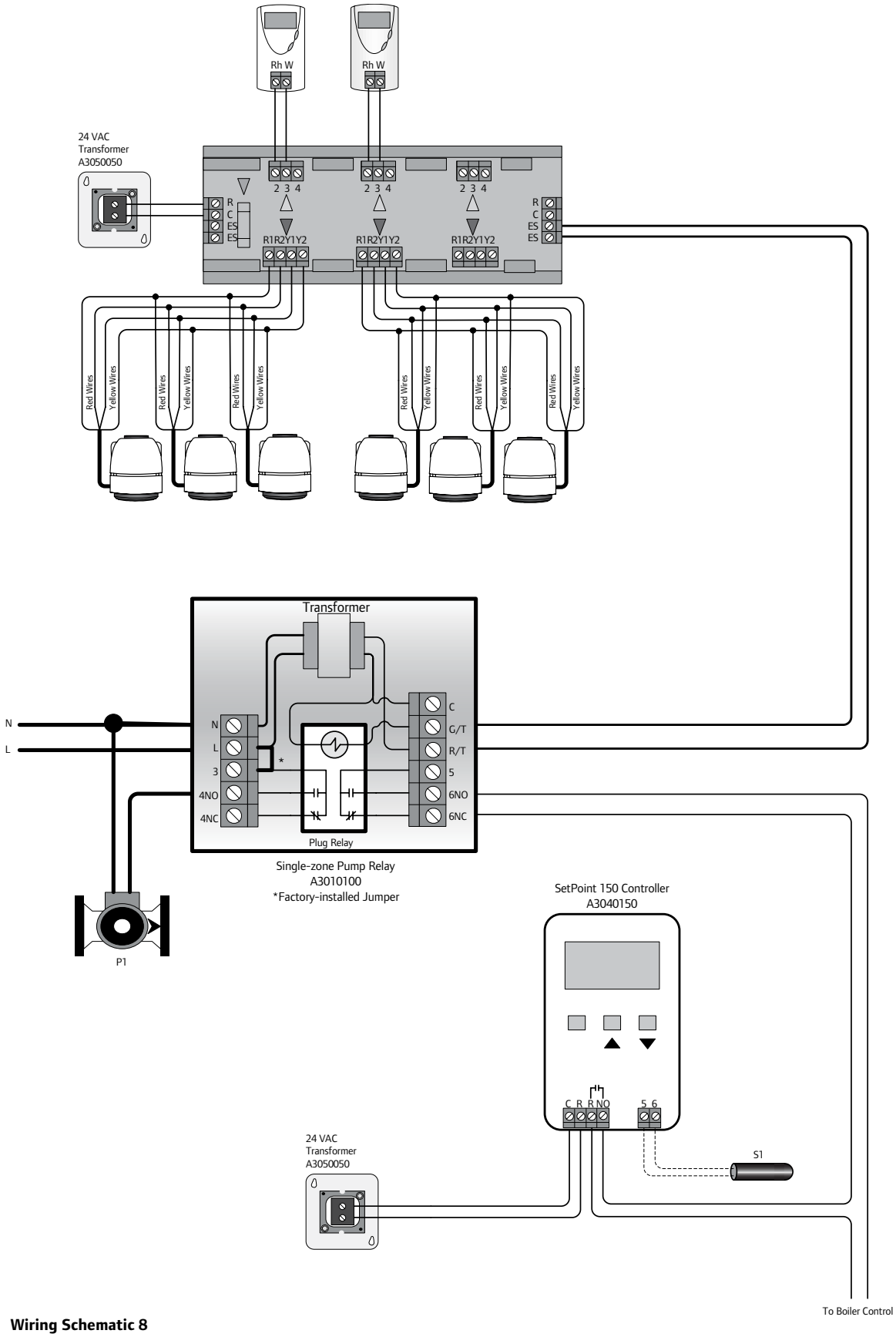
- A3030101 Uponor Thermostats
- A3010522 Thermal Actuators
- A3030003/A3030004 Zone Control Module (ZCM)
- A3010100 Single-zone Pump Relay
- A3050050 50 VA Transformer
- A3040150 Uponor SetPoint 150 Controller (SPC)

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.



Wiring Schematic 8

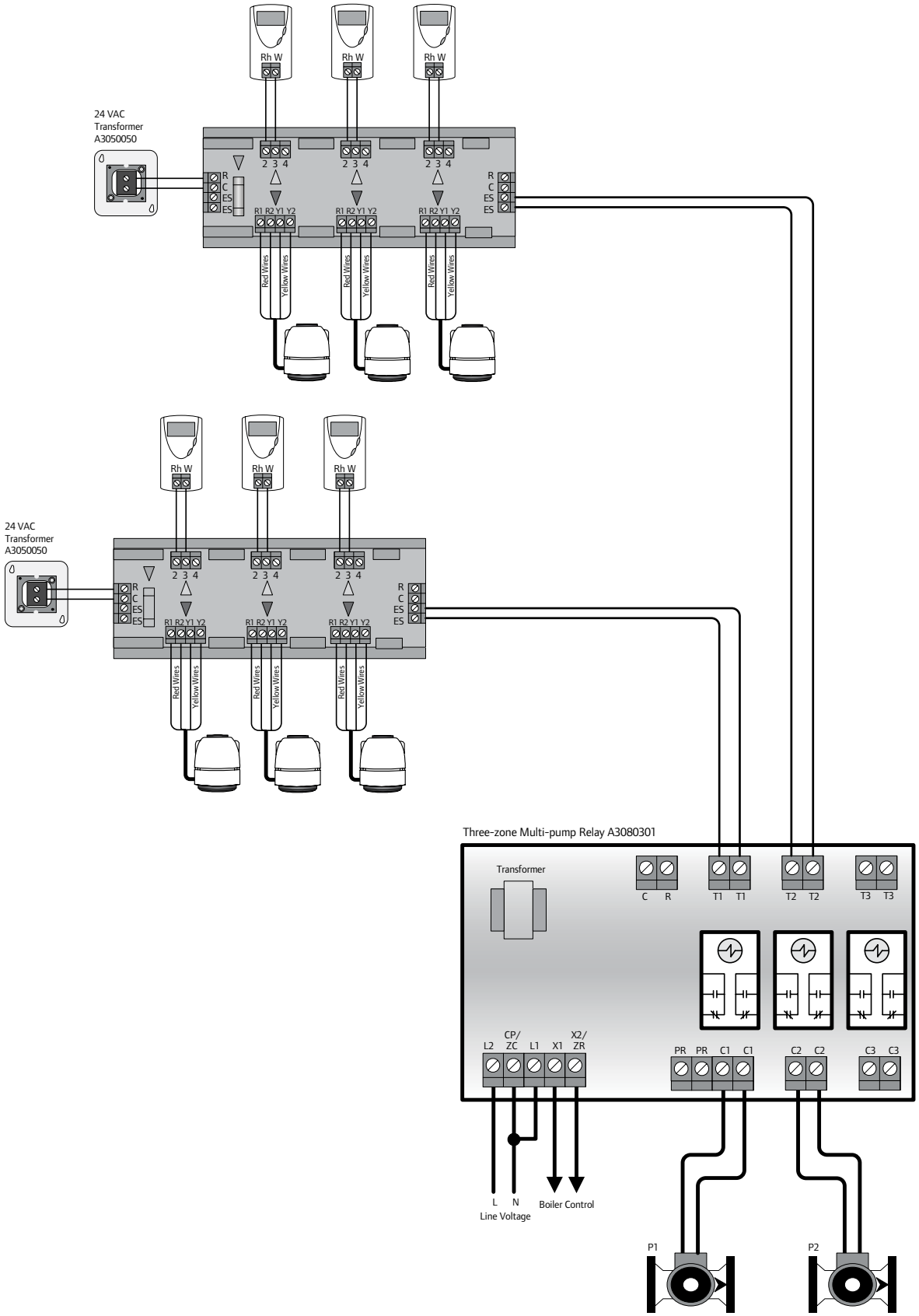
Wiring Schematic 9

- 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 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.



Wiring Schematic 9

Wiring Schematic 10

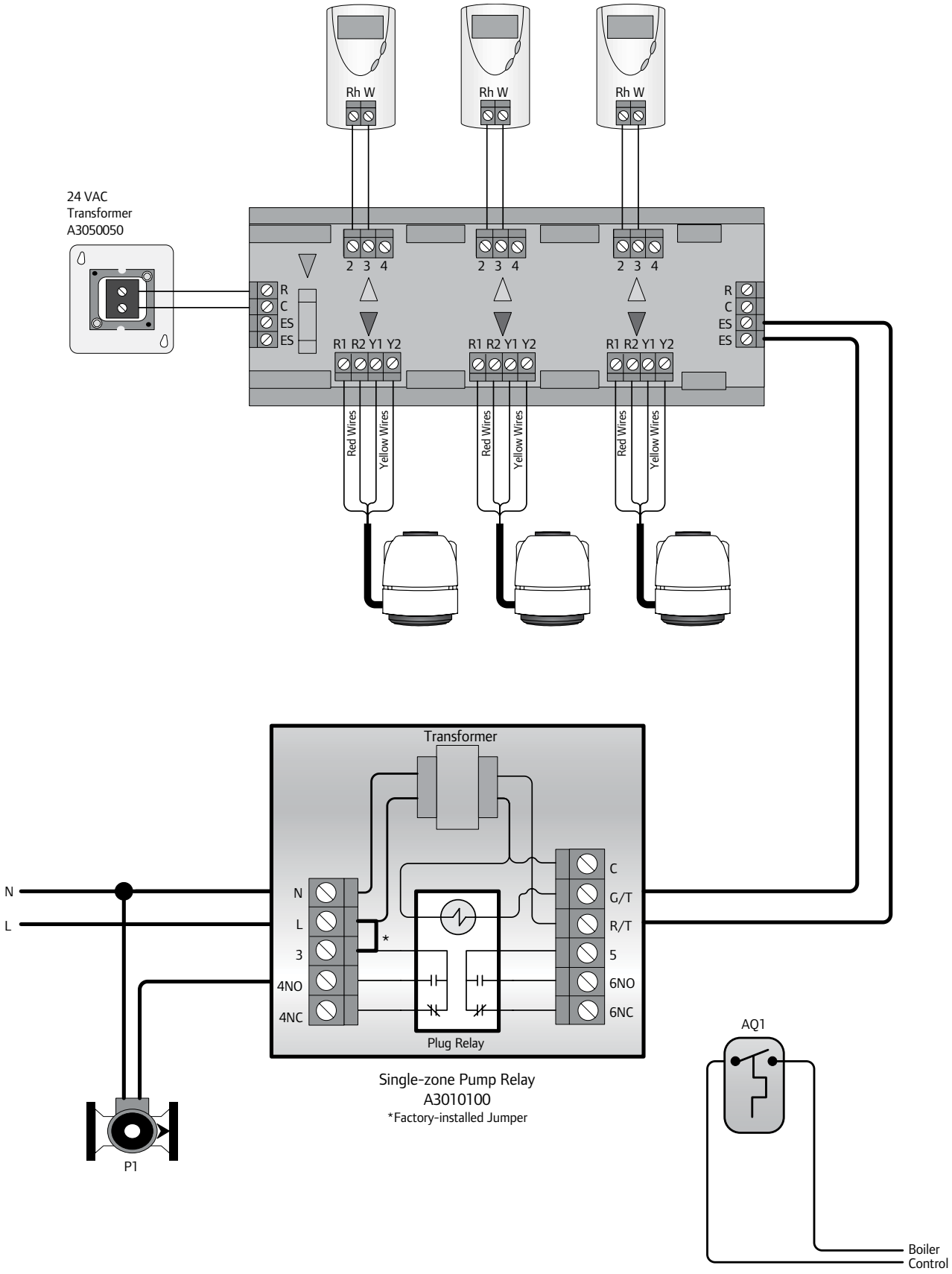
- A3030101 Uponor Thermostats
- A3010522 Thermal Actuators
- A3030003/A3030004 Zone Control Module (ZCM)
- A3010100 Single-zone Pump Relay
- A3050050 50 VA Transformer

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.



Wiring Schematic 10

Wiring Schematic 11

- A3030101 Uponor Thermostats
- A3010522 Thermal Actuators
- A3030003/A3030004 Zone Control Module (ZCM)
- A3010100 Single-zone Pump Relay
- A3050050 50 VA Transformer

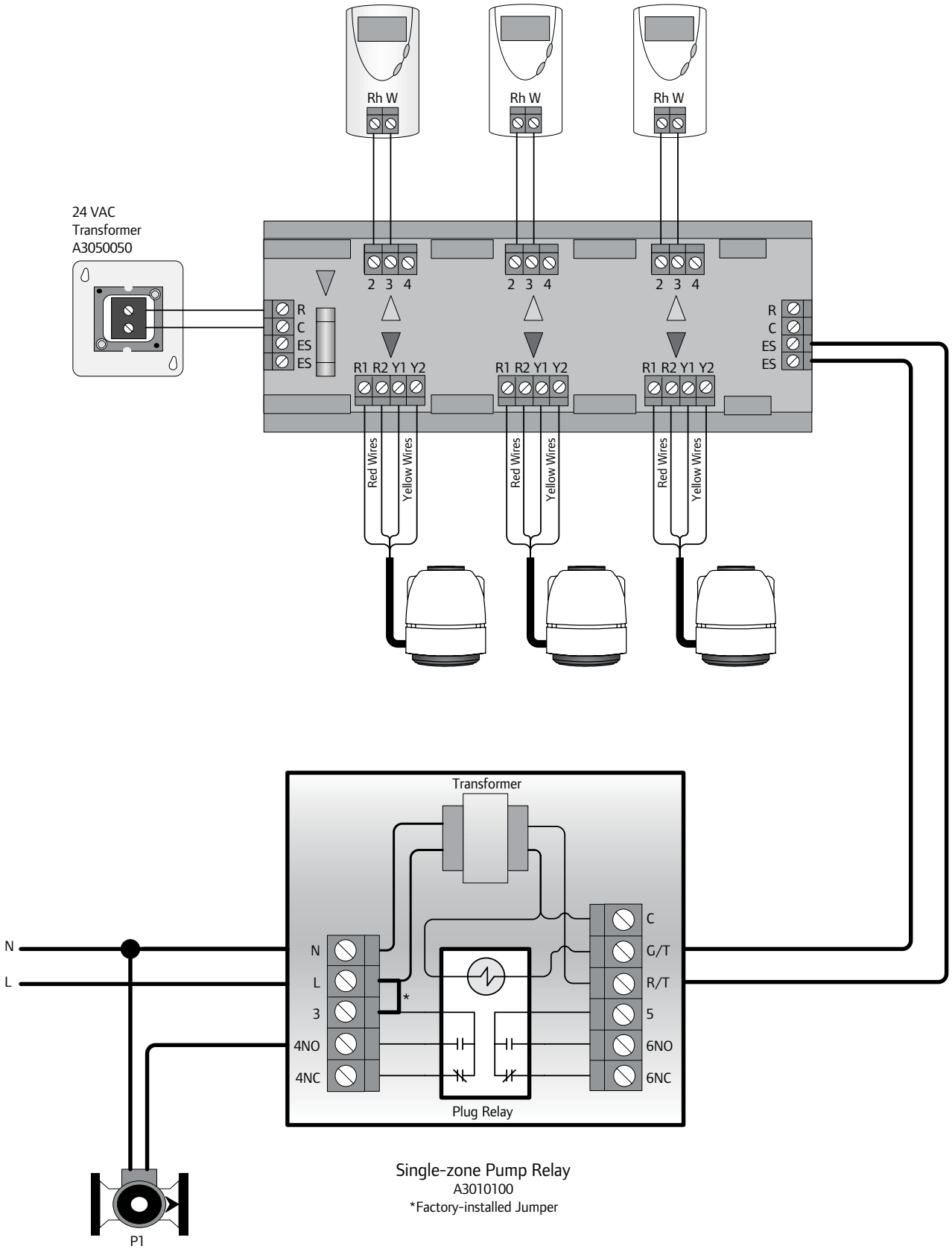
Overview: Multiple zone control and boiler enable using Uponor Thermostats, Uponor Actuators, the Uponor Zone Control Module (ZCM) and the Uponor Single-zone Pump Relay.

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 water heater for a heat plant. In this schematic, there is no wiring between the single circulator relay panel and the heat plant primarily because water heaters use milivolt controls and cannot be interfaced with low or 24-volt wiring. A call for heat from any of the zones will start the radiant circulator (P1) and begin to circulator the heat away from the water heater.

The thermostatic gas valve on the water heater controls the water temperature inside the tank, opening and closing the main gas valve depending on the water temperature inside. Once the tank temperature has dropped below the temperature setting on the tank thermostat, the main gas valve will open and begin to heat the water. After the call for heat has ended, the water heater's main burner will continue to fire until the tank thermostat setting is achieved.

Important: Consult local codes prior to using a water heater as a heat plant.



Single-zone Pump Relay
A3010100
*Factory-installed Jumper

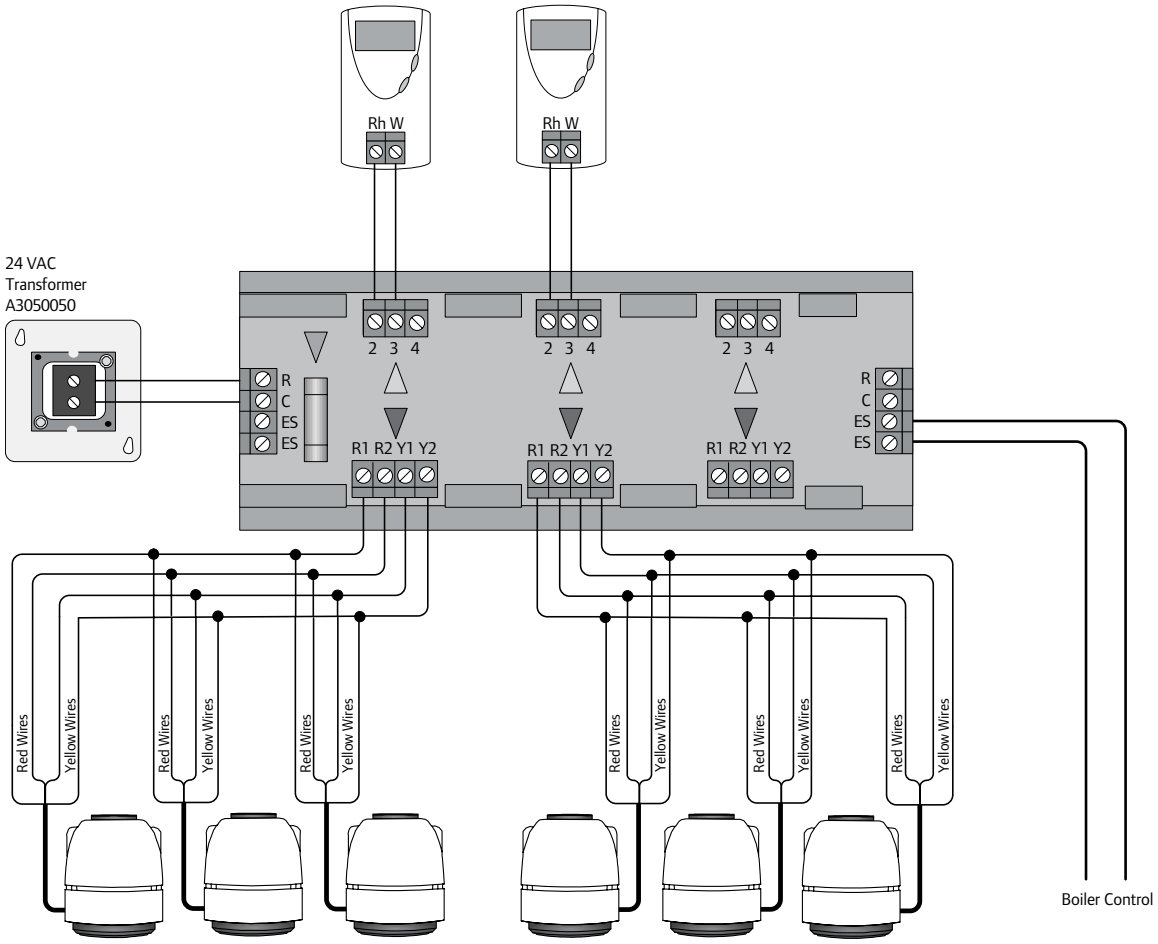
Wiring Schematic 11

Wiring Schematic 12

- A3030101 Uponor Thermostats
- A3010522 Thermal Actuators
- A3030003/A3030004 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.



Wiring Schematic 12

Wiring Schematic 13

- A3030101 Uponor Thermostats
- A3010522 Thermal Actuators
- A3030003/A3030004 Zone Control Module (ZCM)
- A3050050 50 VA Transformer
- A8020000 Climate Cŏntrol™ Multifunction Controller

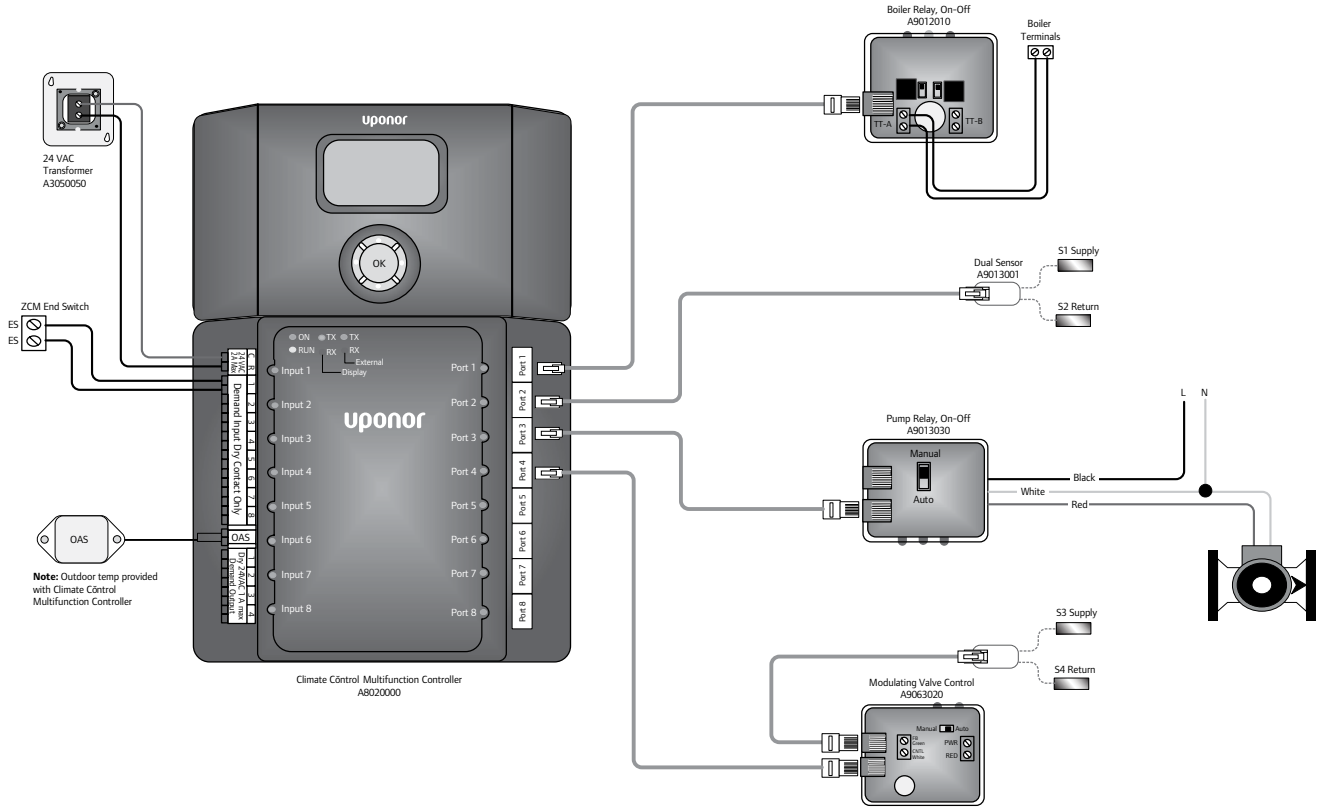
Overview: Multiple zone control and boiler enable using Uponor Thermostats, Uponor Actuators, the Uponor Zone Control Module (ZCM) and the Multifunction Controller and Modulating Valve to control the radiant supply water temperature.

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 Multifunction Controller and Modulating Valve. 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.

When the circuit is completed between the control and the ZCM, the appropriate circulator (P1) will start along with the mixing function based on the user setup. When this occurs, the secondary pump (P1) will run continuously until the heat demand has ended. At the same time, the modulating valve will become active. This valve will automatically adjust itself to deliver the correct water temperature based on the user set-up information and the current outdoor temperature. The boiler will turn on and operate as the Multifunction Controller determines that hotter water is required for mixing. Sensor S2 provides boiler return water protection. This sensor will not allow the valve to increase the water temperatures unless the minimum boiler return temperature is met, eliminating low return water temperatures and protecting the boiler from flue gas condensation.

Sensor S2 provides boiler return water protection. This sensor will not allow the Modulating Valve to increase water temperature to the radiant panel unless the set temperature for minimum return has been satisfied, eliminating low return water temperatures and protecting the boiler from flue gas condensation and thermal shock.

The boiler connections through the on/off boiler relay 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 these terminals by the boiler operating control. 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.



Wiring Schematic 13

Wiring Schematic 14

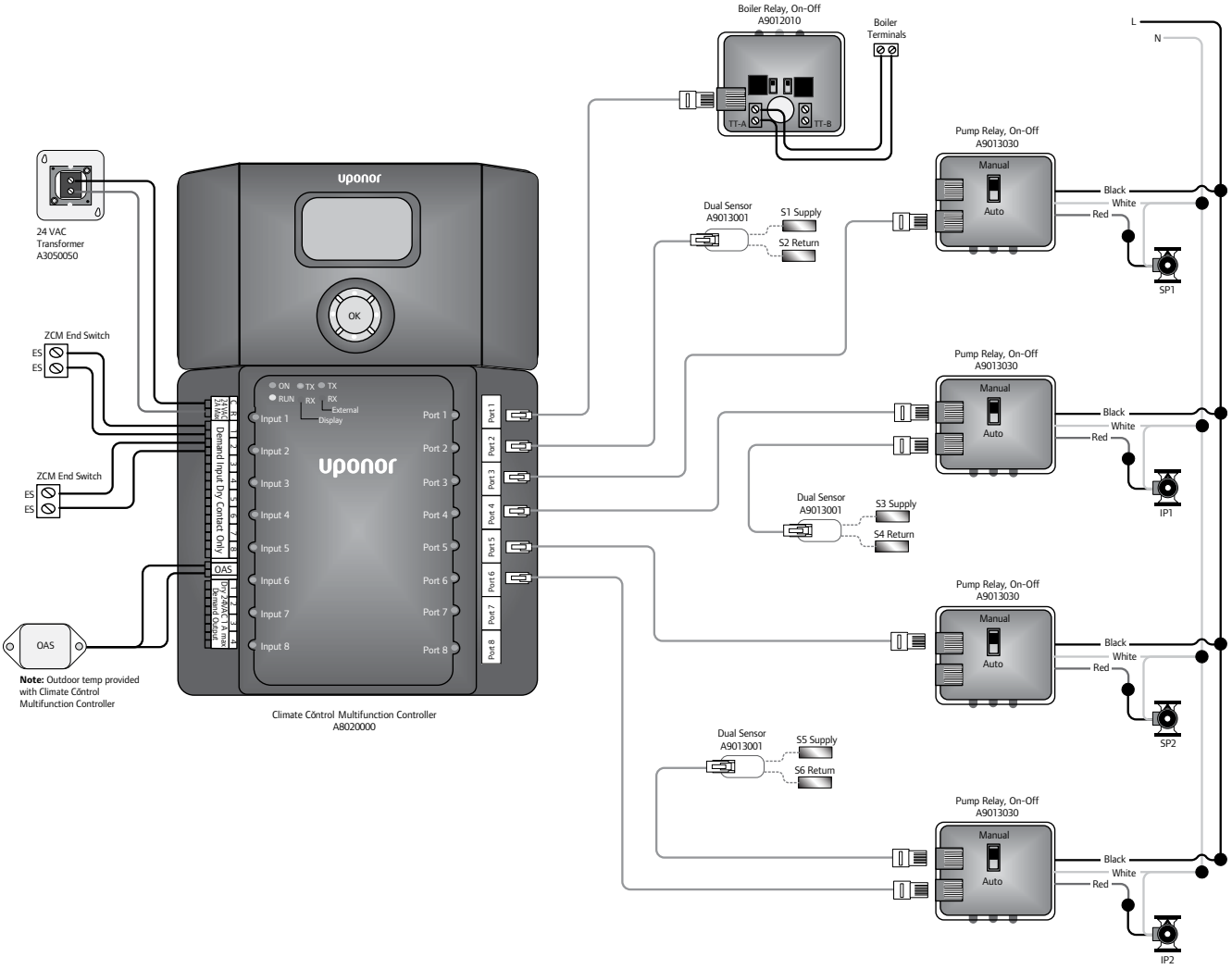
- A3030101 Uponor Thermostats
- A3020522 Thermal Actuators
- A3030003/A3030004 Zone Control Module (ZCM)
- A3050050 50 VA Transformer
- A8020000 Climate Cŏntrol Multifunction Controller

Overview: Multiple zone control and boiler enable using Uponor Thermostats, Uponor Actuators, the Uponor Zone Control Module (ZCM) and the Uponor Multifunction Controller to control two radiant supply water temperatures.

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 Multifunction Controller. Following this control procedure will eliminate any "dead-head" circulator conditions for radiant circulators (SP1 and SP2). The actuator(s) must be open before these circulators will operate.

In this schematic, power is applied to the ES terminals by the Demand terminals on the Multifunction Controller, powered by an external transformer. When the circuit is completed between the control and the ZCM, the appropriate circulator will start along with the mixing function based on the user setup. When this occurs, the secondary pump (SP1 or SP2) will run continuously until the heat demand has ended. At the same time, the mixing devices (pumps or valves) will become active. These will automatically adjust themselves to deliver the correct water temperature based on the user set-up information and the current outdoor temperature. The boiler will turn on and operate as the Multifunction Controller determines that hotter water is required for mixing. Sensor S2 provides boiler return water protection. This sensor will not allow the injection circulators to increase the water temperatures unless the minimum boiler return temperature is met, eliminating low return water temperatures and protecting the boiler from flue gas condensation.

The boiler connections through the on/off boiler relay 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 these terminals by the boiler operating control. 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.



Wiring Schematic 14

Wiring Schematic 15

- A3030101 Uponor Thermostats
- A3010522 Thermal Actuators
- A3030003/A3030004 Zone Control Module (ZCM)
- A3050050 50 VA Transformer
- A8020000 Climate Cŏntrol Multifunction Controller
- A9013061 Snow-melt Control

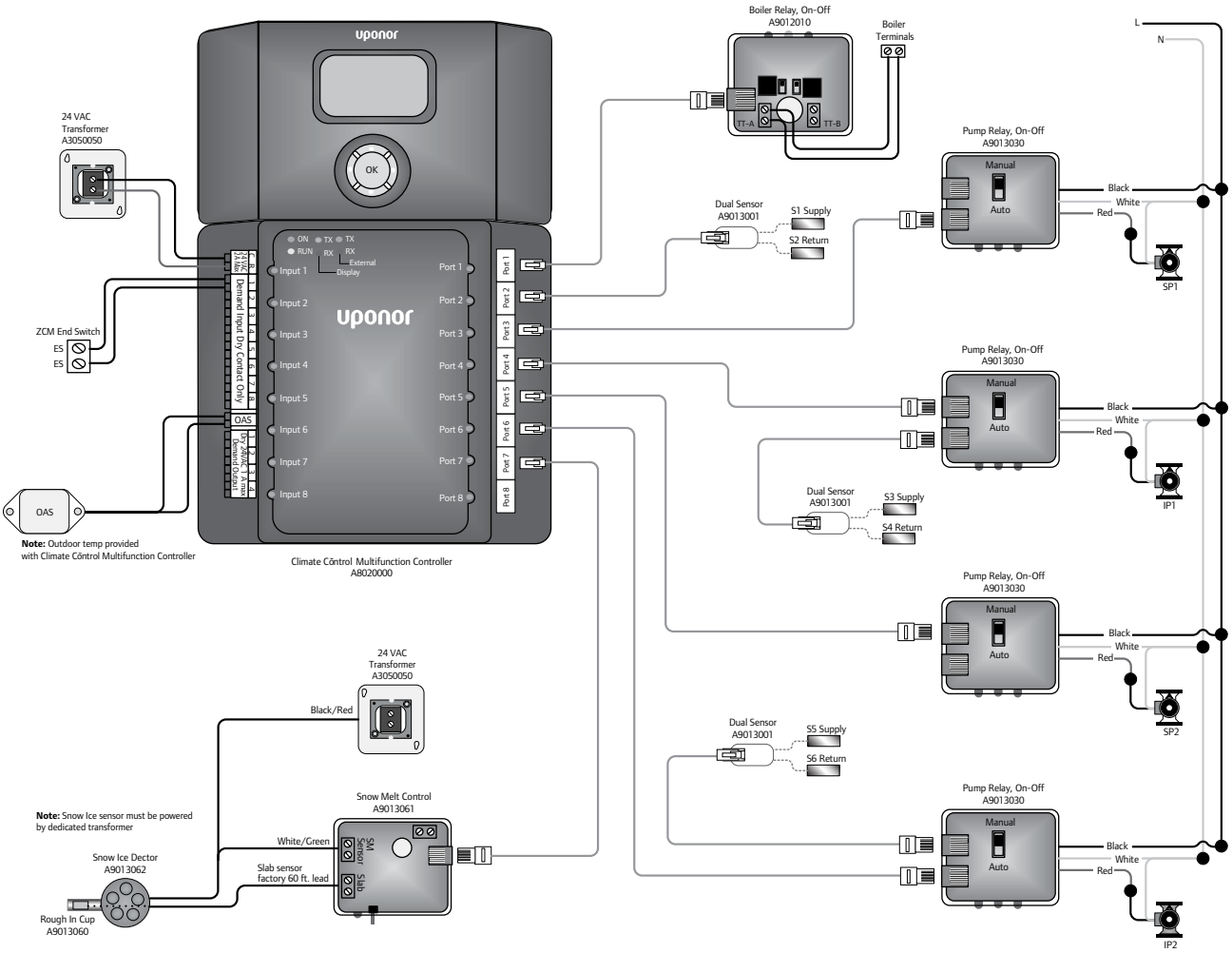
Overview: Multiple zone control and boiler enable using Uponor Thermostats, Uponor Actuators, the Uponor Zone Control Module (ZCM) and the Multifunction Controller to control radiant and snow-melt supply water temperatures.

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 Multifunction Controller. Following this control procedure will eliminate any "dead-head" circulator conditions for radiant circulators (SP1 and SP2). The actuators must be open before these circulators will operate.

In this schematic, power is applied to the ES terminals by the Demand terminals on the Multifunction Controller, powered by an external transformer. When the circuit is completed between the control and the ZCM, the appropriate circulator will start along with the mixing function based on the user setup. When this occurs, the secondary pump (SP1 or SP2) will run continuously until the heat demand has ended. At the same time, the mixing devices (IP1 and IP2) will become active. These will automatically adjust themselves to deliver the correct water temperature based on the user set-up information and the current outdoor temperature. The boiler will turn on and operate as the Multifunction Controller determines that hotter water is required for mixing. Sensor S2 provides boiler return water protection. This sensor will not allow the injection circulators to increase the water temperatures unless the minimum boiler return temperature is met, eliminating low return water temperatures and protecting the boiler from flue gas condensation.

In this schematic, snow melting is set up for automatic operation using the Automatic Snow Ice Sensor. However, snow melting can be started manually if the Snow-melt Control (A9013061) and an optional remote push button are installed. For automatic operation, when moisture is detected on the sensor, a contact (green/white wires) will close to start snow-melting operation. When this happens, SP2 will turn on and run until the sensor is clear and the minimum run timer (user-adjustable setting) has timed out. Once the snow-melting operation begins, the slab will heat to the target melting temperature (user adjustable setting). Once this setting is reached, SP2 will continue to run, but the injection pump will turn off as to not add any additional heat.

The boiler connections through the on/off boiler relay 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 these terminals by the boiler operating control. 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.



Wiring Schematic 15

Wiring Schematic 16

- A3030101 Uponor Thermostats
- A3010522 Thermal Actuators
- A3030003/A3030004 Zone Control Module (ZCM)
- A3050050 50 VA Transformer
- A8020000 Climate Cŏntrol Multifunction Controller

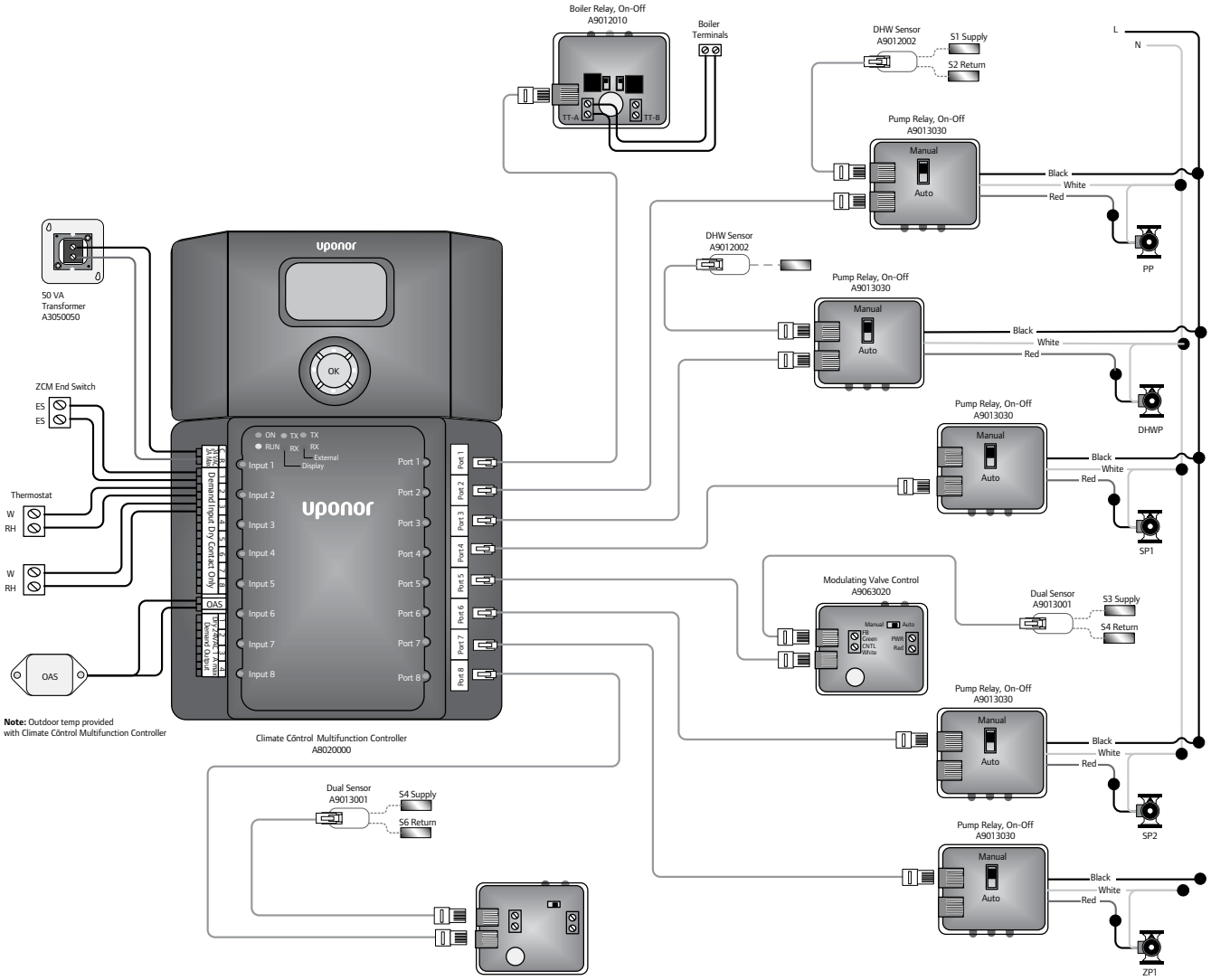
Overview: Multiple zone control, multiple circulator control (SP1 and SP2) and boiler enable using Uponor Thermostats, Uponor Actuators, the Uponor Zone Control Module (ZCM) and the Multifunction Controller to control radiant and domestic hot water (DHW).

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 Multifunction Controller. Following this control procedure will eliminate any "dead-head" circulator conditions for radiant circulators (SP1 and SP2). The actuator(s) must be open before the circulator(s) will operate.

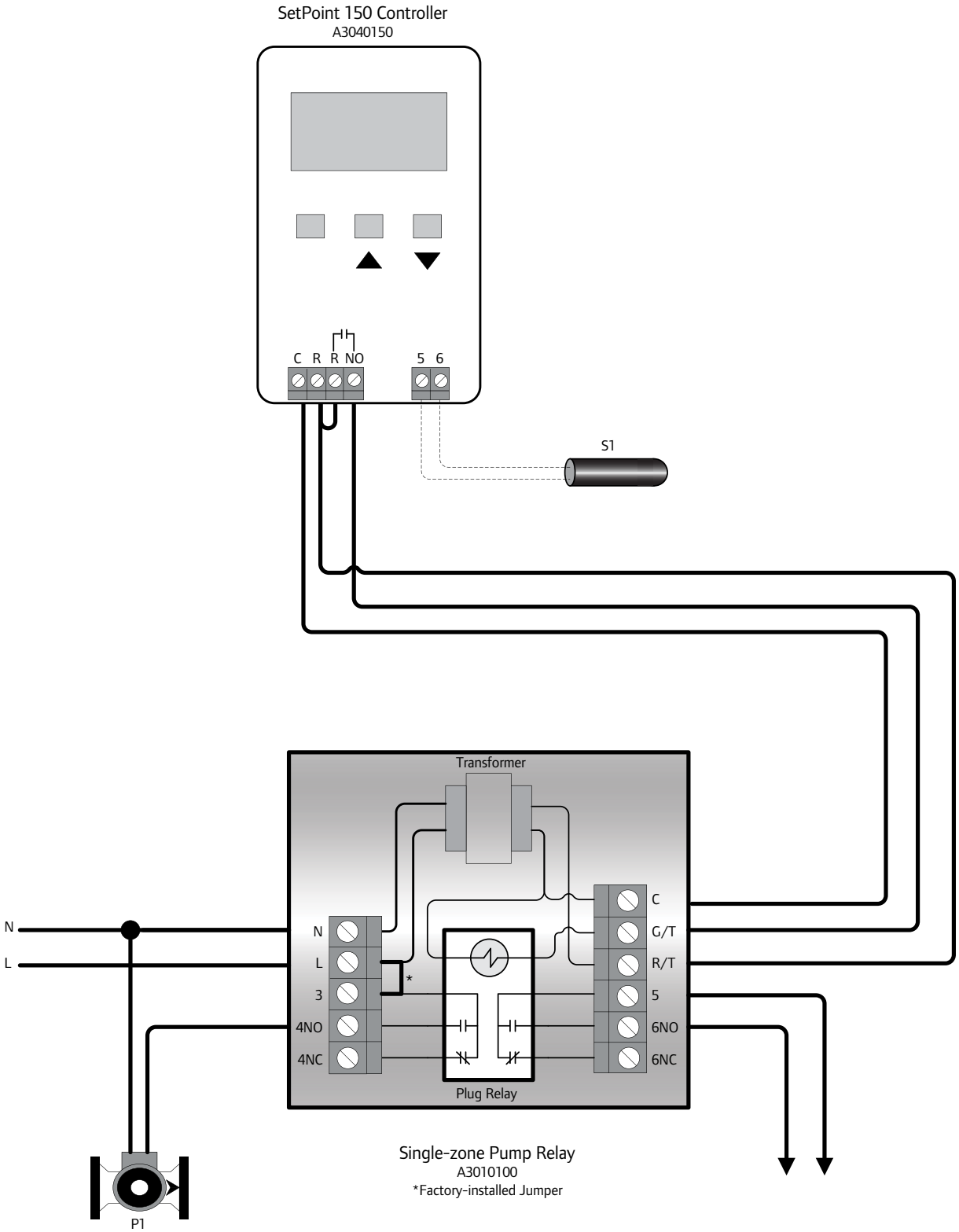
The ES terminals are considered "dry contacts." This means any wiring connected to these terminals is unpowered and will require an auxiliary power source. In this schematic, power is applied to the ES terminals by the Demand terminals on the Multifunction Controller, powered by an external transformer. When the circuit is completed between the control and the ZCM, the appropriate circulator will start along with the mixing function based on the user setup. When this occurs, the secondary pump (SP1 or SP2) will run continuously until the heat demand has ended. At the same time, the mixing devices (valves) will become active. These will automatically adjust themselves to deliver the correct water temperature based on the user setup information and the current outdoor temperature. The boiler will turn on and operate as the Multifunction Controller determines that hotter water is required for mixing. Sensor S2 provides boiler return water protection. This sensor will not allow the modulating valves to increase the water temperatures unless the minimum boiler return temperature is met, eliminating low return water temperatures and protecting the boiler from flue gas condensation.

Also connected to the Multifunction Controller is domestic hot water (DHW) when using an indirect water tank. The Multifunction Controller can control the DHW either through a 10K sensor (as shown) or an internal aquastat included with the hot water tank. When piped off of a primary loop, the control will automatically manage both the hot water production and space heating. If the internal target for the primary loop cannot be met, the control will begin to close the mixing device(s). Once the DHW tank is heated, the mixing device(s) will return to normal operation.

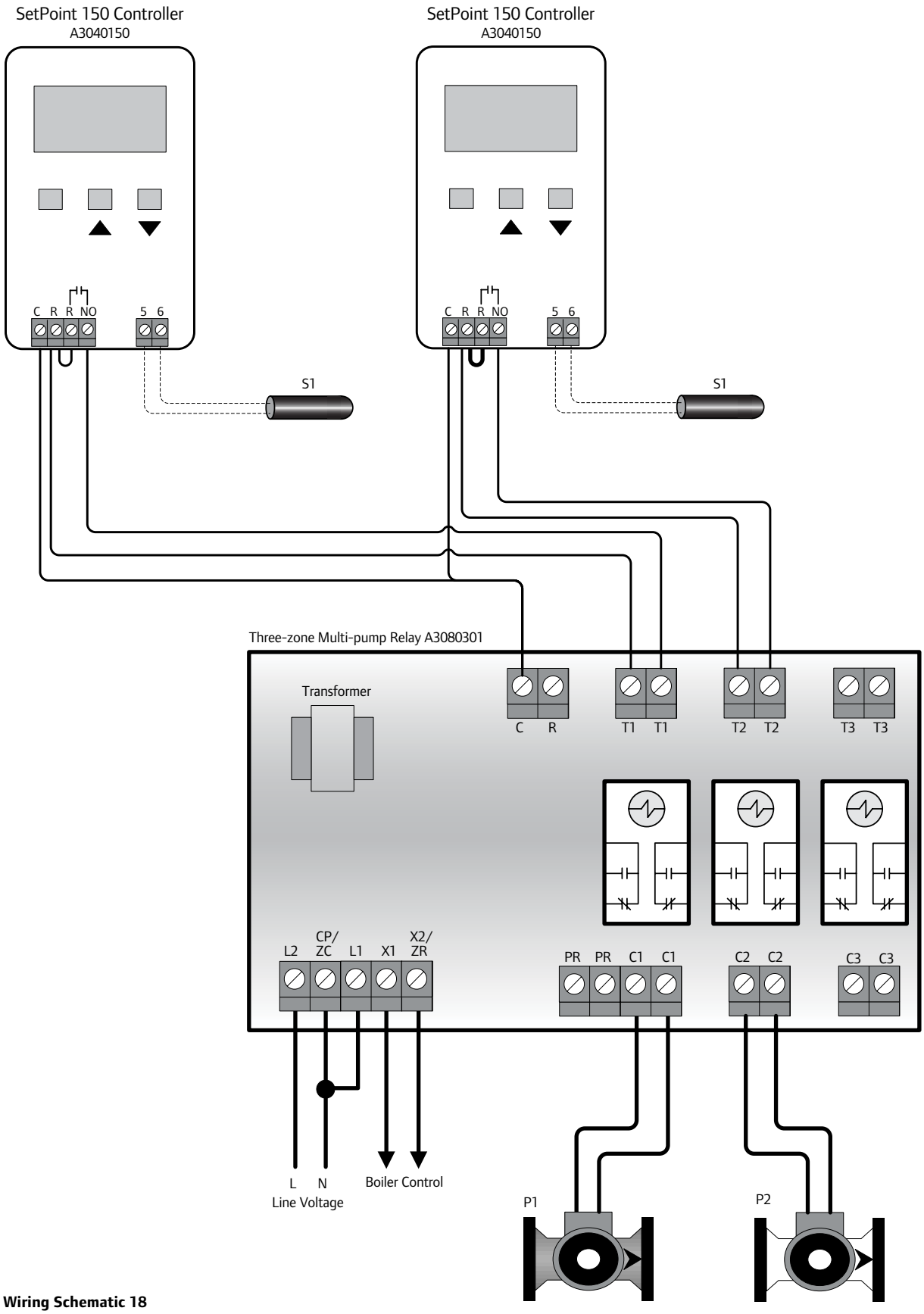
Also shown in this schematic is a separate Uponor Thermostat used to control a separate radiant circulator (ZP1). Power is supplied to the thermostat from the demand terminals of the Multifunction Controller. When the thermostat calls for heat and completes that circuit, the circulator will start and fire the boiler for the high temperature requirement for the baseboard.



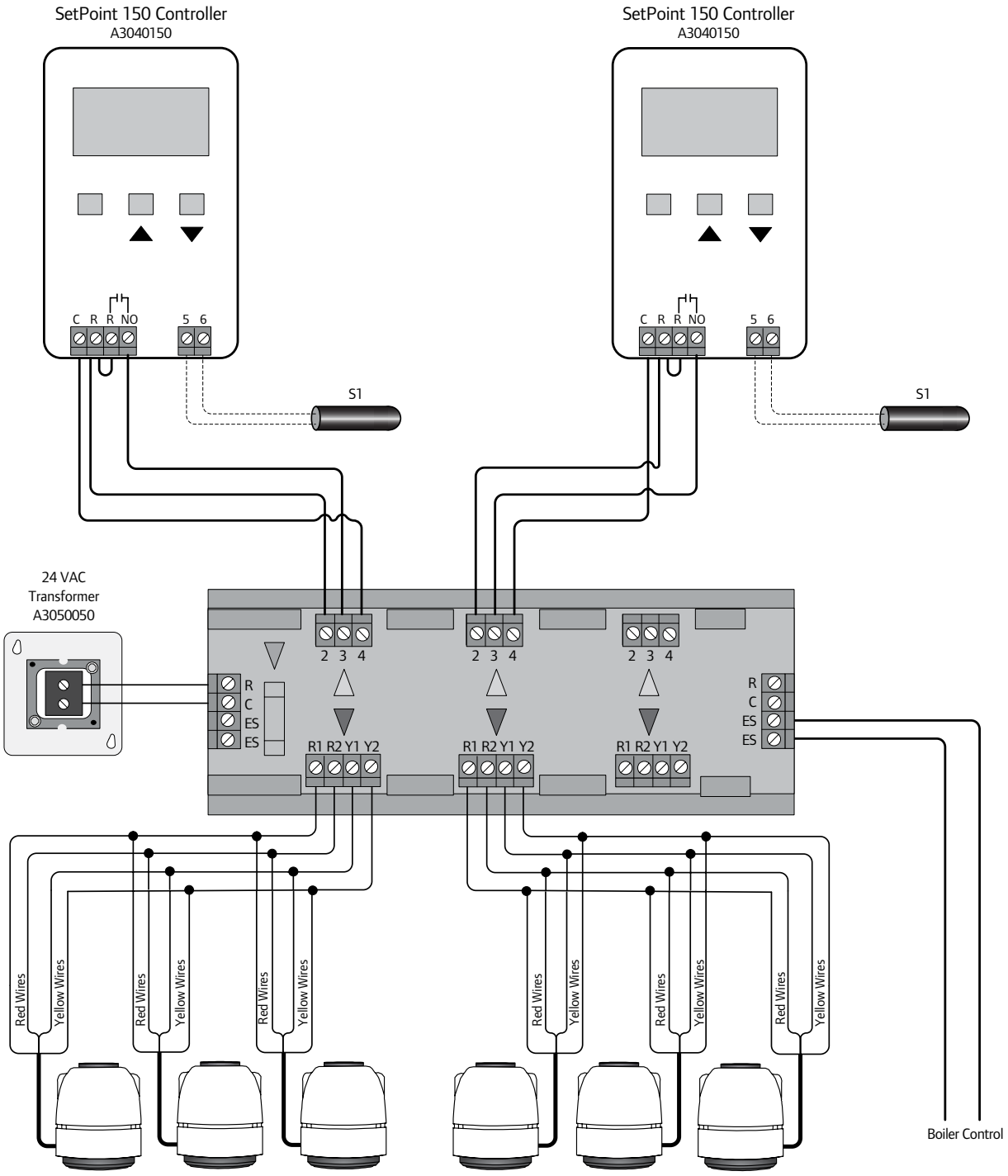
Wiring Schematic 16



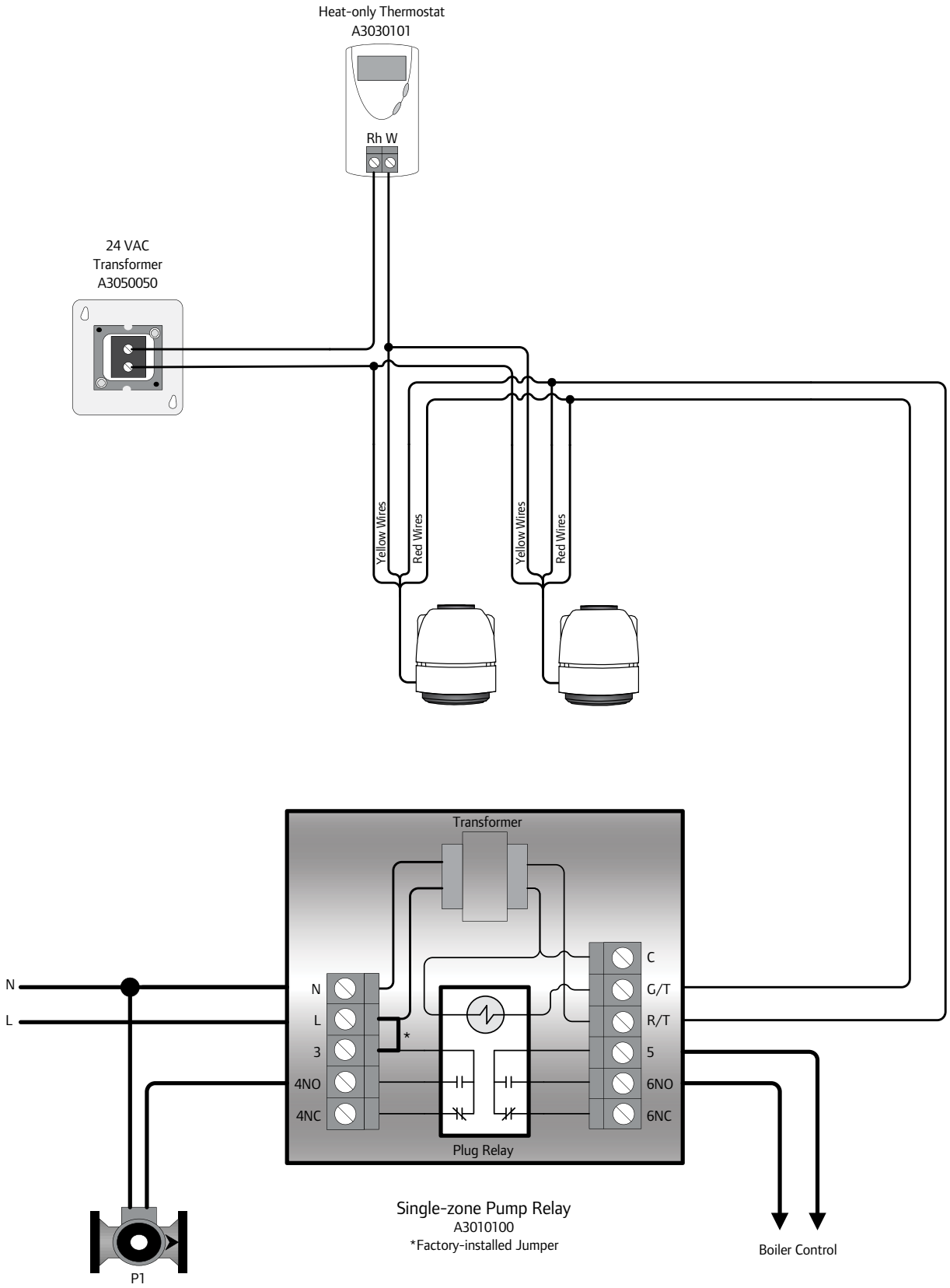
Wiring Schematic 17



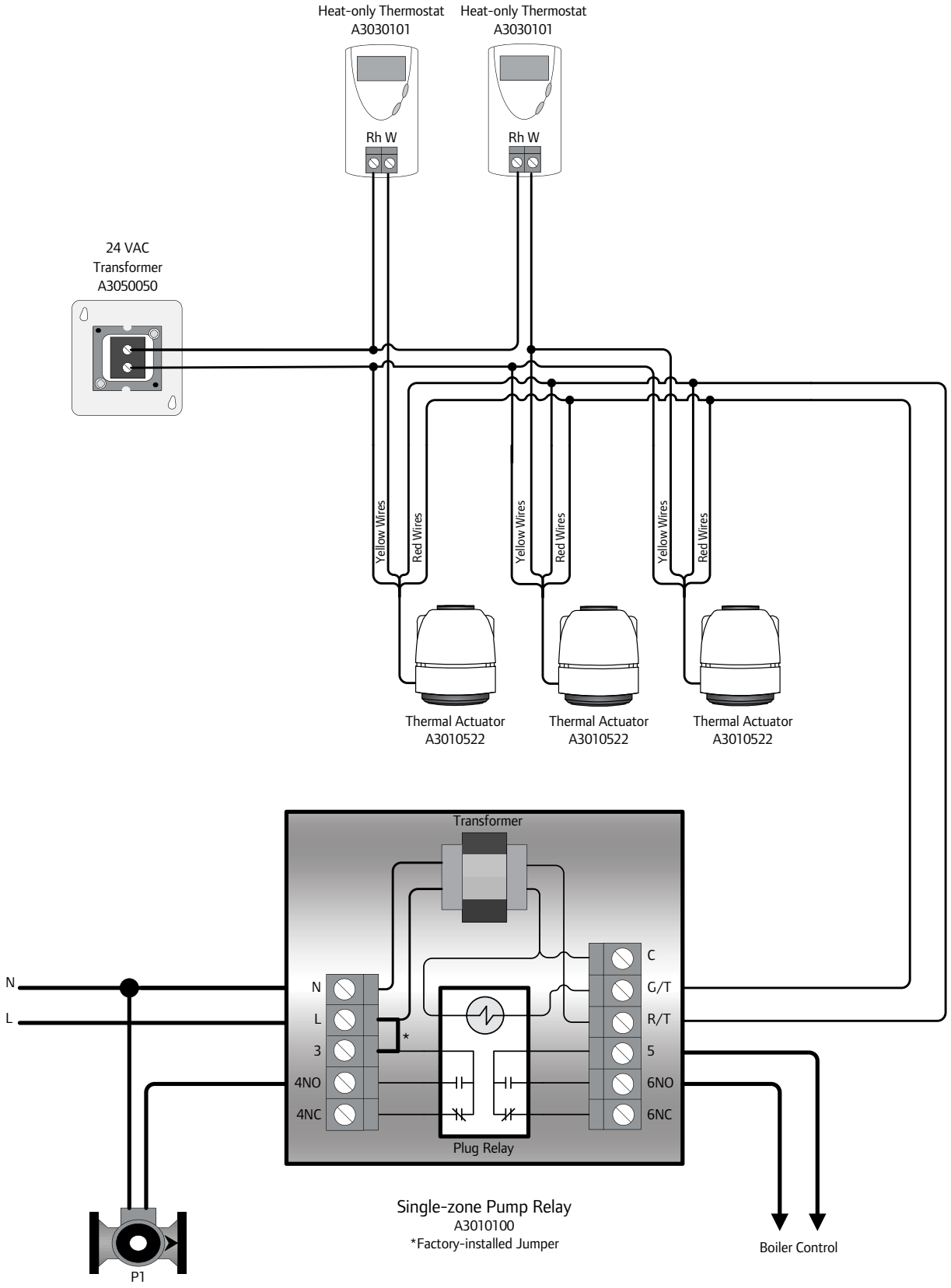
Wiring Schematic 18



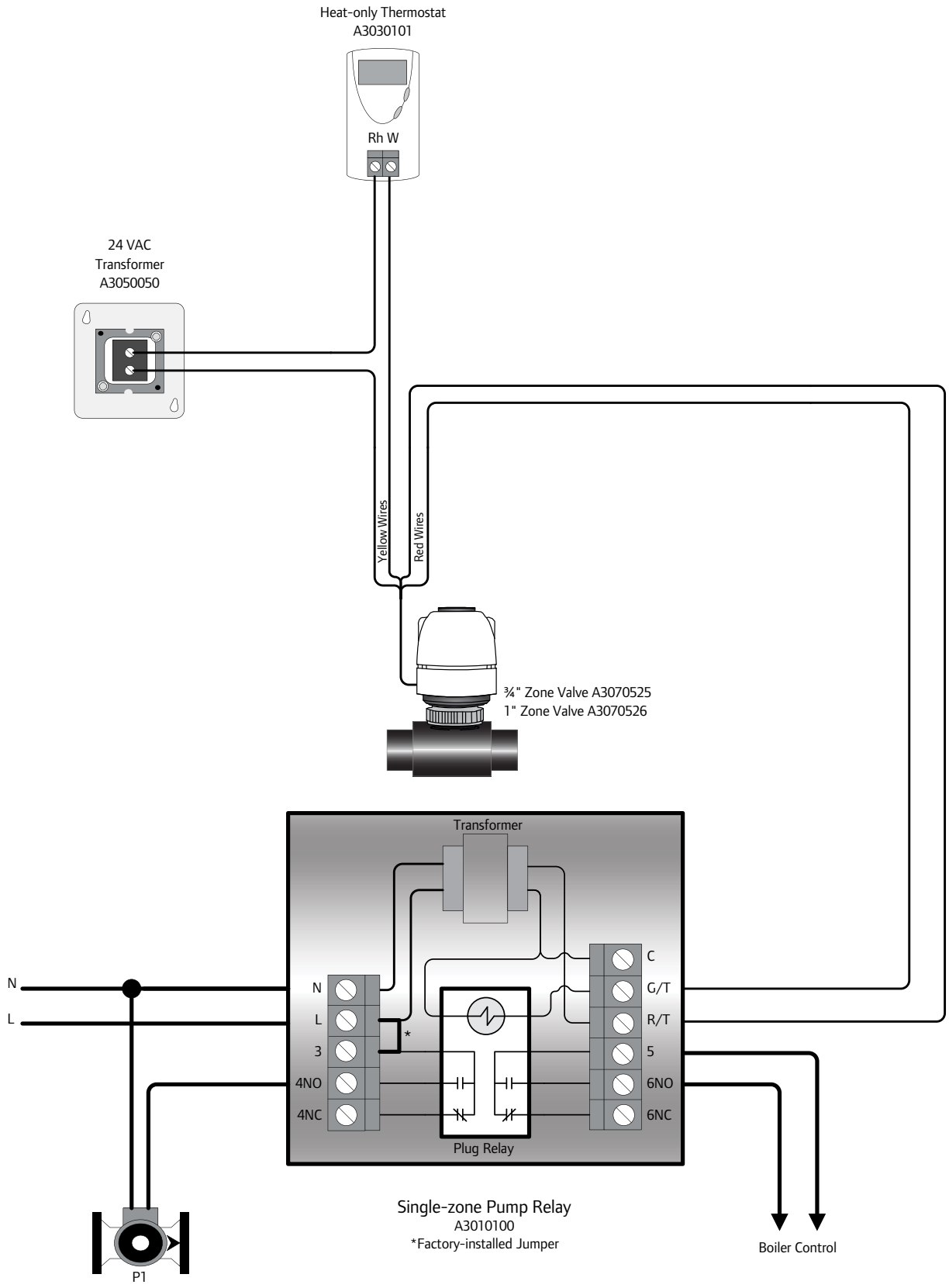
Wiring Schematic 19



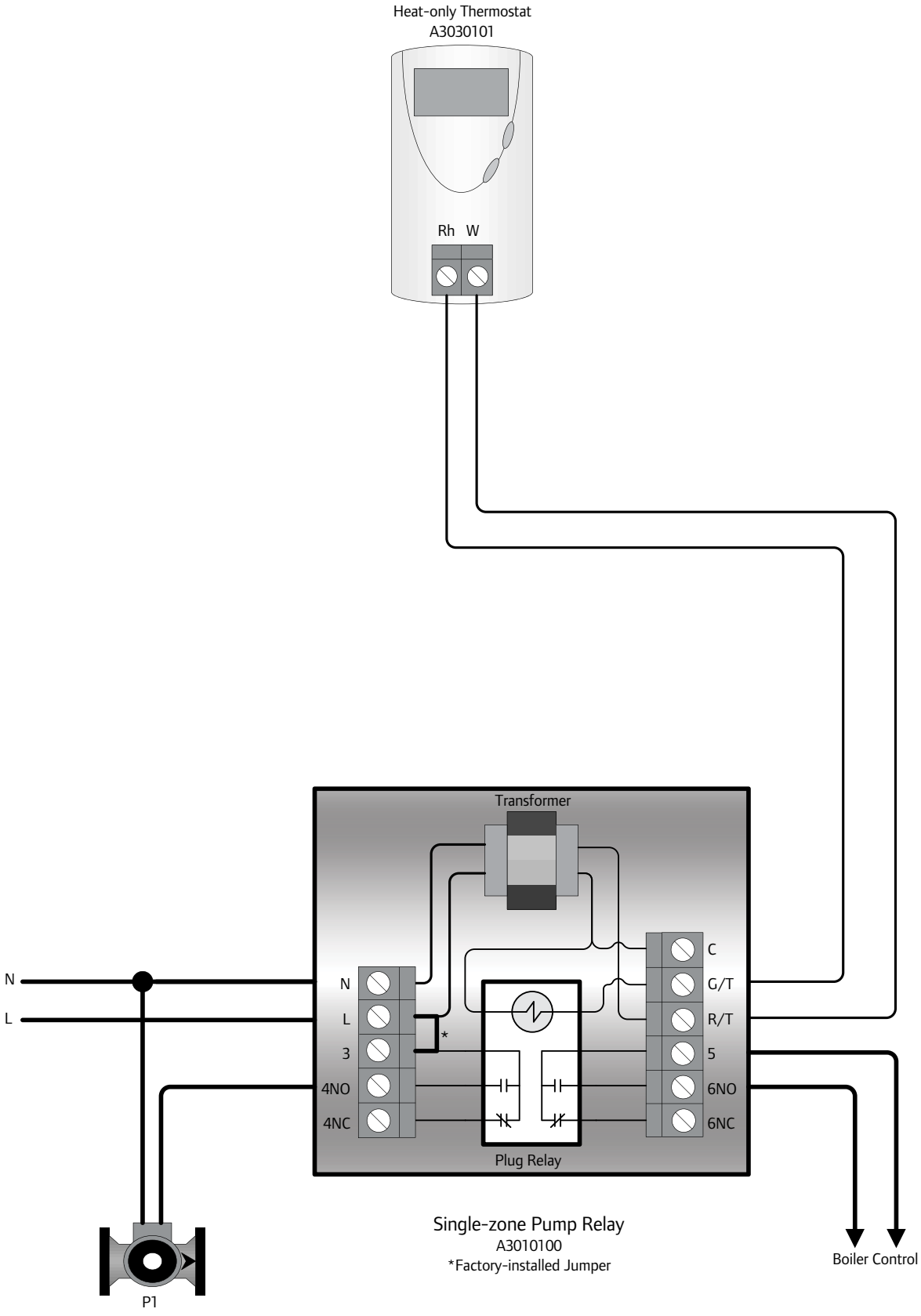
Wiring Schematic 20



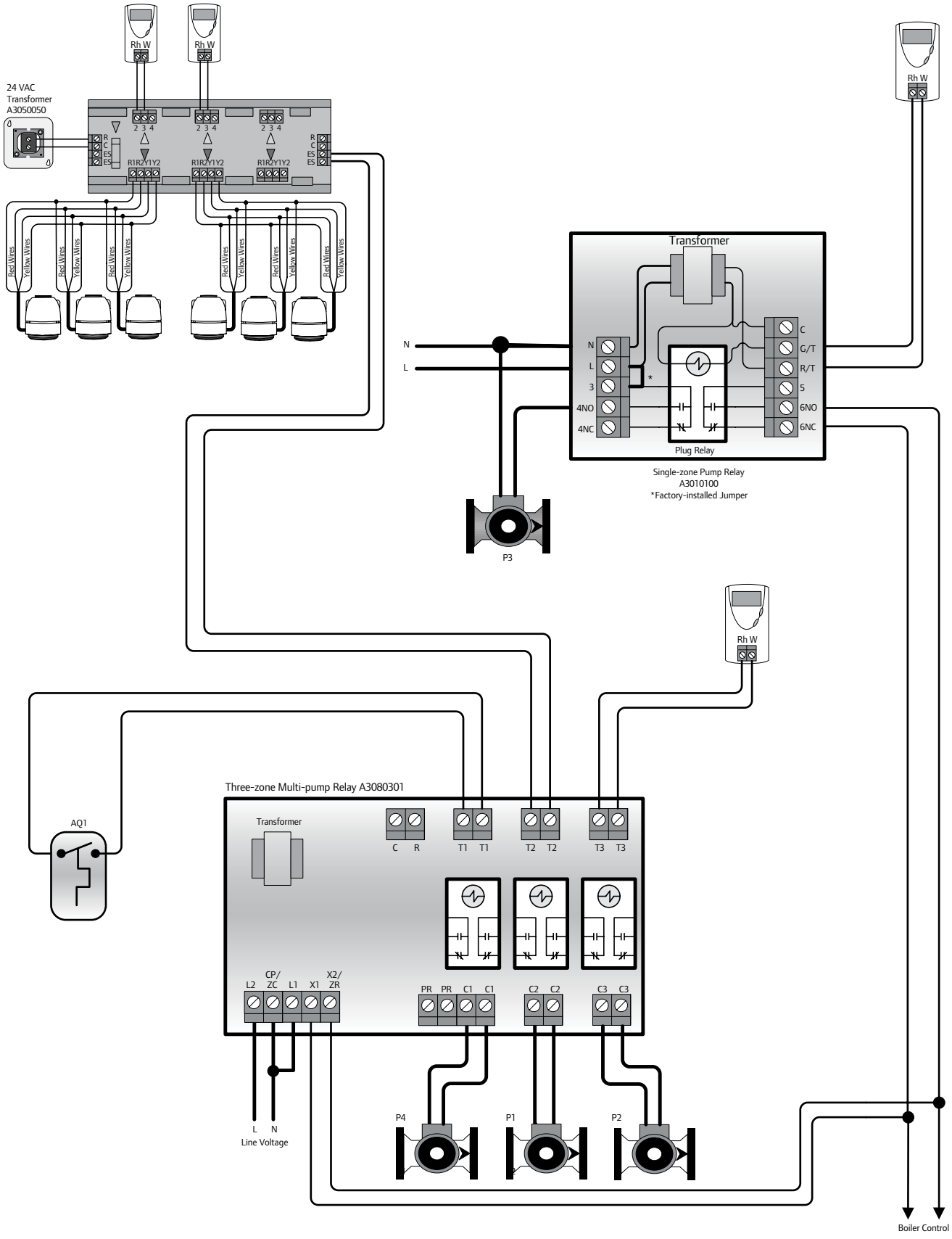
Wiring Schematic 21



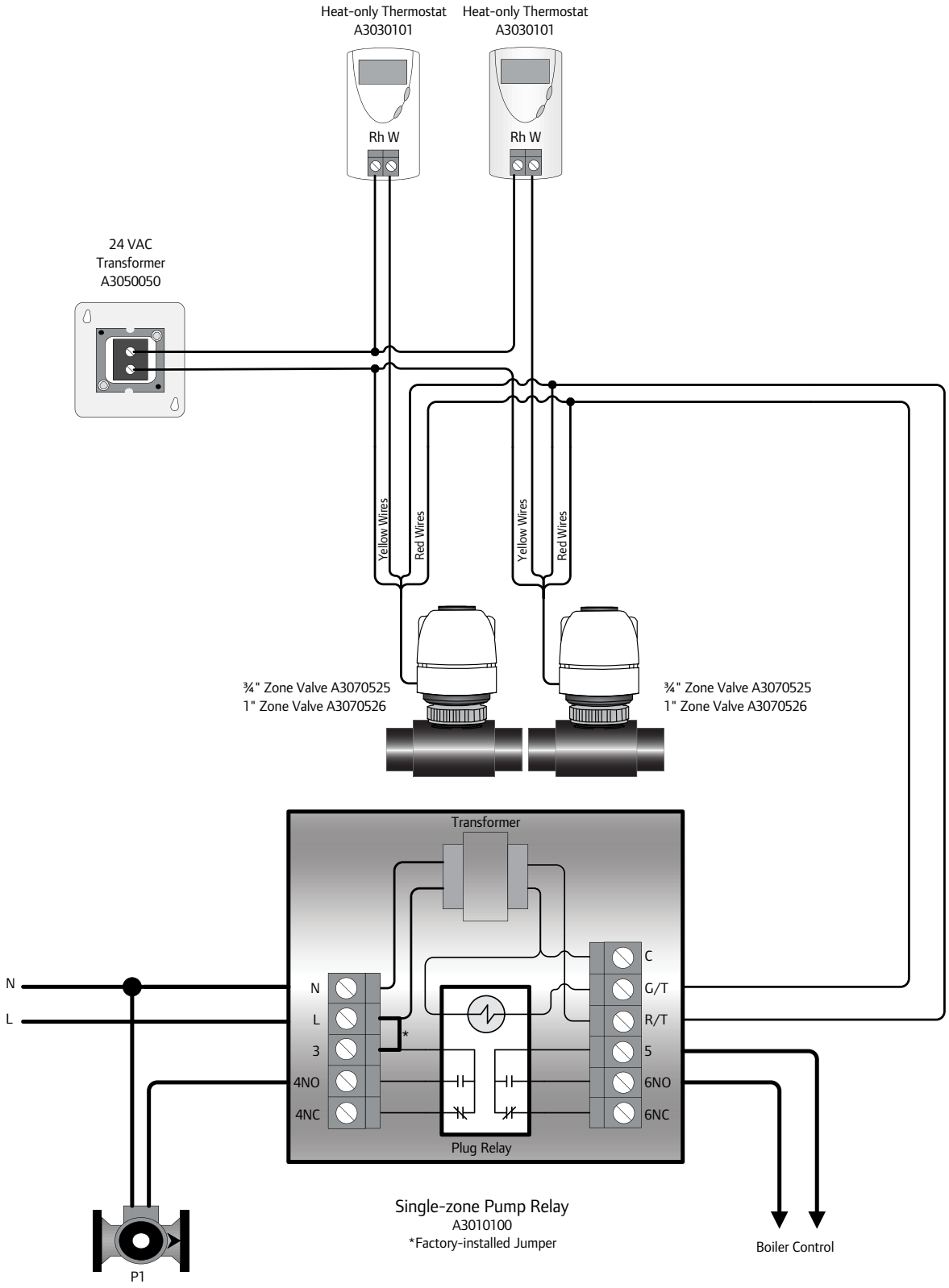
Wiring Schematic 22



Wiring Schematic 23



Wiring Schematic 24



Wiring Schematic 25

Chapter 15

Uponor Distribution Piping

Uponor distribution piping is the use of Wirsbo hePEX™, Uponor Multi-layer Composite (MLC) tubing 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 tubing 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 in ⅝", ¾", 1", 1¼", 1½" and 2" 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 tubing.

For longer continuous runs or other applications in which tubing is embedded in a slab, Uponor offers a wide variety of coil lengths with the various diameters. See the Uponor Product Catalog for more information.

Ecoflex is a pre-insulated, jacketed product that uses Wirsbo hePEX, Uponor AquaPEX® or HDPE designed for direct burial. Ecoflex is ideal for applications where traditional overhung pipe is expensive or space is at a premium.

MLC tubing has features similar to traditional soft-copper products. MLC tubing can help minimize the number of supports needed in many distribution piping applications. It also reduces the total number of joints because it is sold in coils. MLC tubing is available in ½", ⅝", ¾" and 1" diameters and various coil lengths. Please see the Uponor Product Catalog for more information.

PEX Tubing Operating Limits

The following tables detail the upper and lower limits for PEX tubing of various diameters.

Tubing 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	6.18
	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
⅝"	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 Tubing Size Limits

MLC Tubing Operating Limits

Tubing Size	Operating Limit	BTU/h	Gallons Per Minute (gpm)	Velocity (feet per second)	Head Loss (per 100 ft)
½"	Lower Limit	10,000	1.0	1.70	2.71
	Upper Limit	45,000	4.5	7.66	43.85
⅝"	Lower Limit	20,000	1.5	2.08	2.95
	Upper Limit	75,000	7.5	7.79	34.00
¾"	Lower Limit	30,000	3.0	1.95	2.00
	Upper Limit	115,000	11.5	7.49	24.05
1"	Lower Limit	45,000	4.5	1.79	1.27
	Upper Limit	200,000	20.0	7.95	20.12

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 15-2: Recommended MLC Tubing Size Limits



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.

   $gpm = BTU/h \div (\Delta T \times 500)$
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.

   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 15-4: Glycol Correction Factors

See **Appendix G** for pressure loss and velocity tables.

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

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.

Figure 15-1 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.

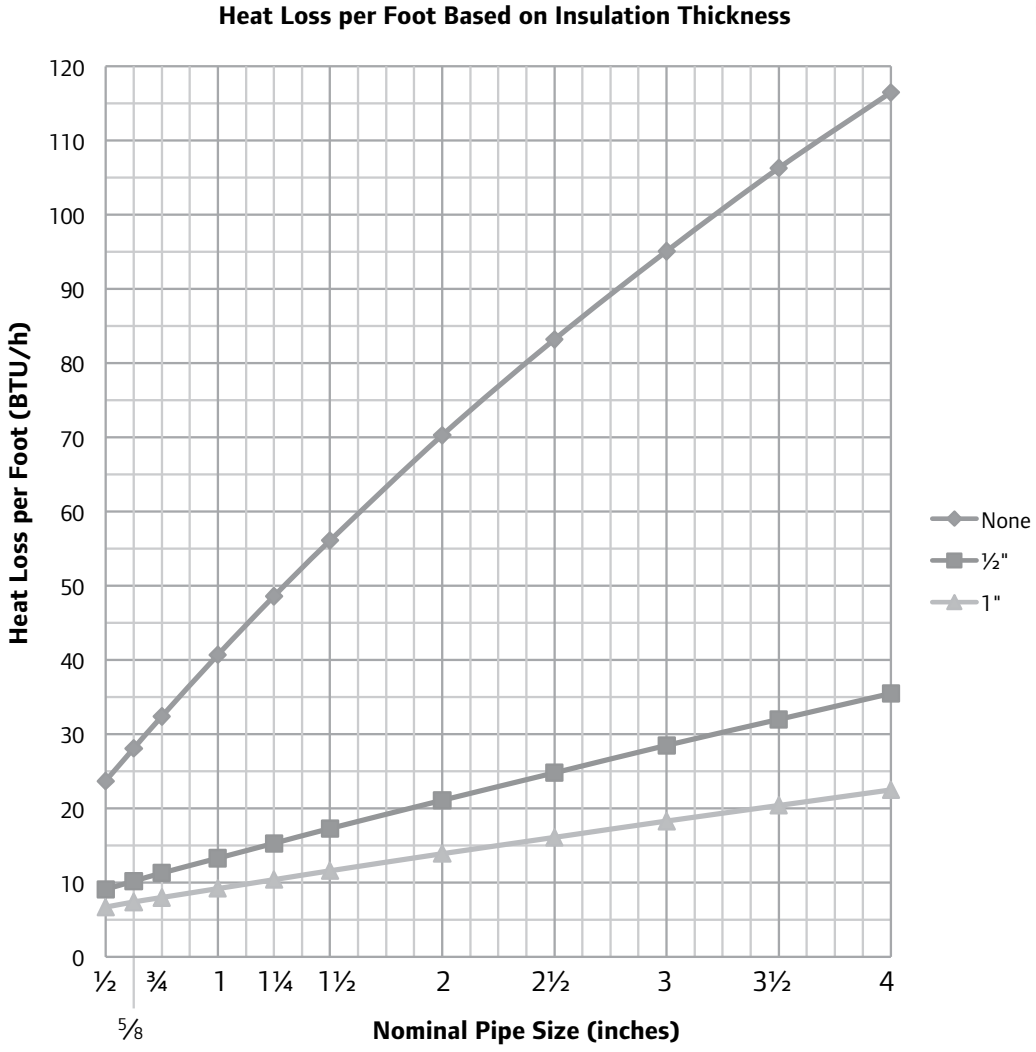




Figure 15-1: Distribution Pipe Heat Loss per Foot

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 Advanced Design Suite™ (ADS) 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.

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**).

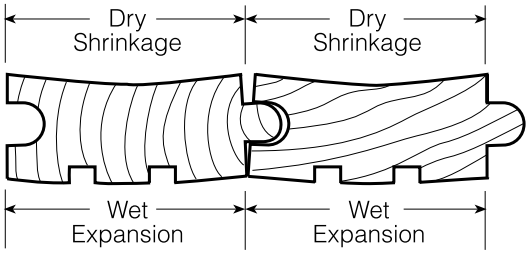


Figure 16-1: Cupping of Wood Floor

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**).

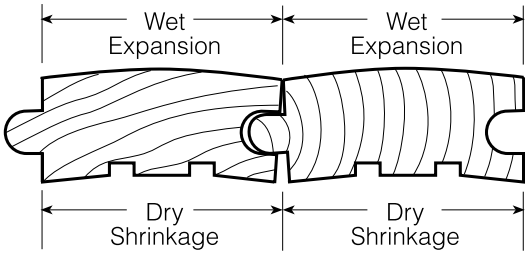


Figure 16-2: Crowning of Wood Floor

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.

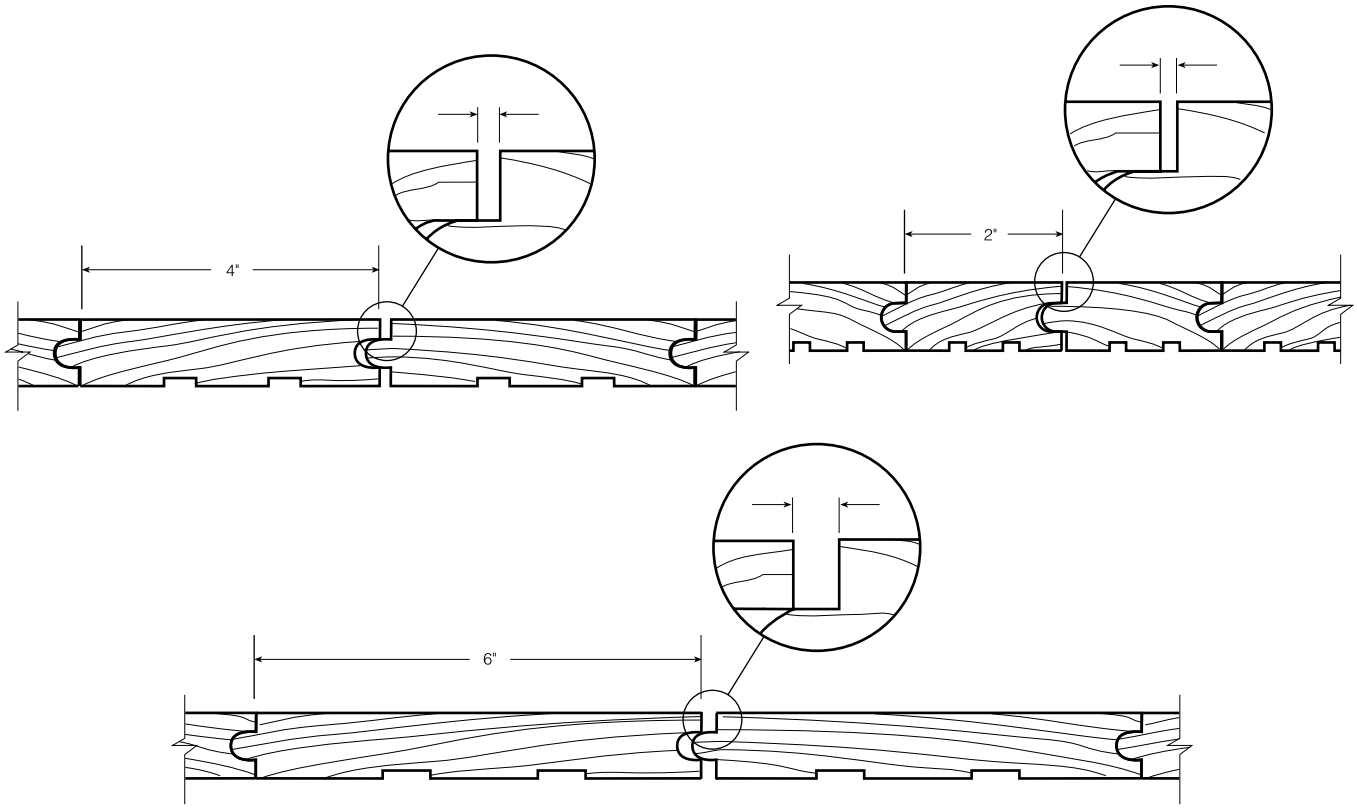


Figure 16-3: Board Shrinkage and Separation

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**).

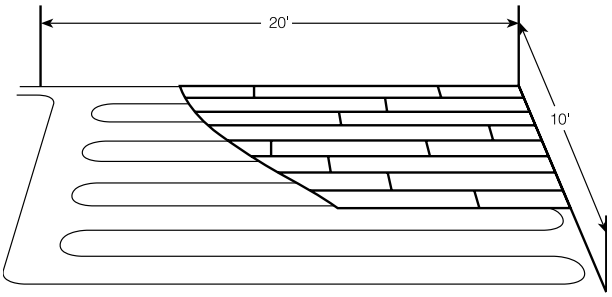


Figure 16-4: Wood Floor Installation to Minimize Cumulative Separation

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**).

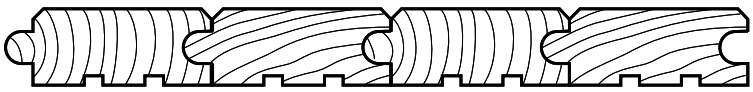


Figure 16-5: Wood Floor With Beveled Edge

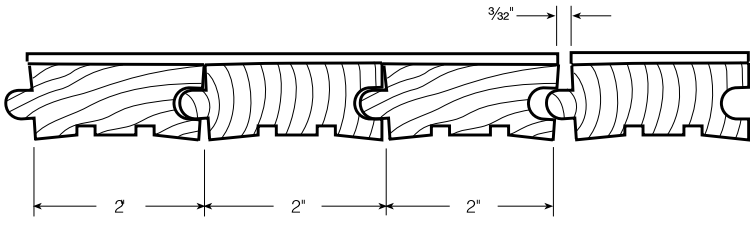


Figure 16-6: Panelization of Wood Floor

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**).

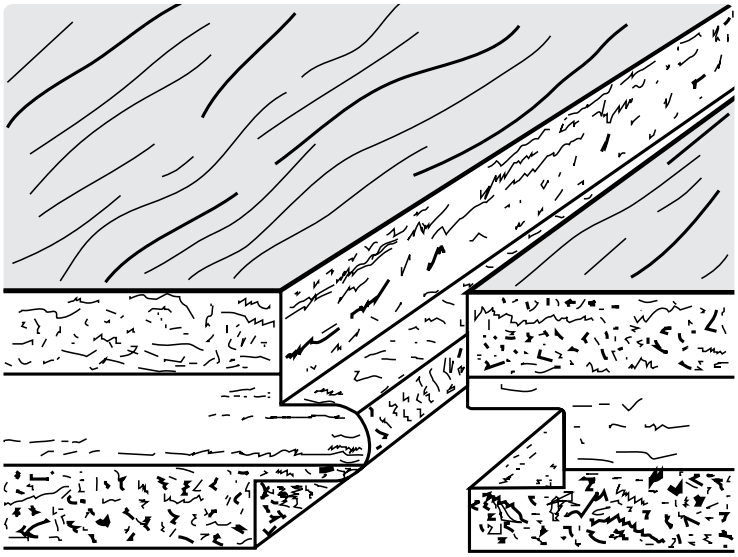


Figure 16-7: Laminate Wood Floor

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 tubing 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**).

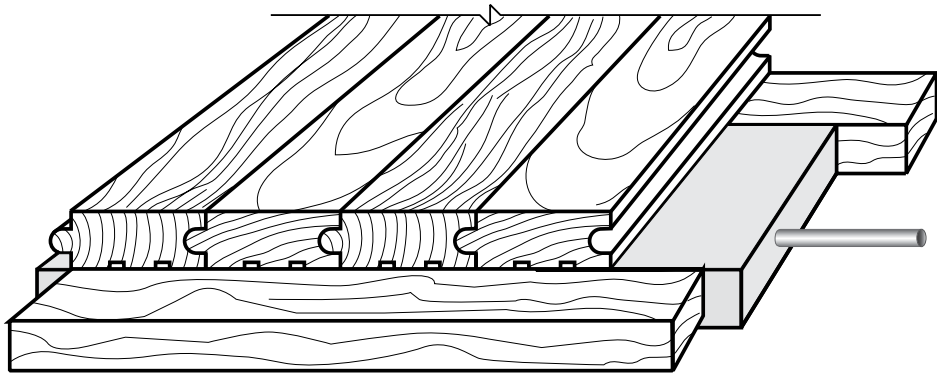


Figure 16-8: Wood Floor Nailed to Sleepers in Poured Floor

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**).

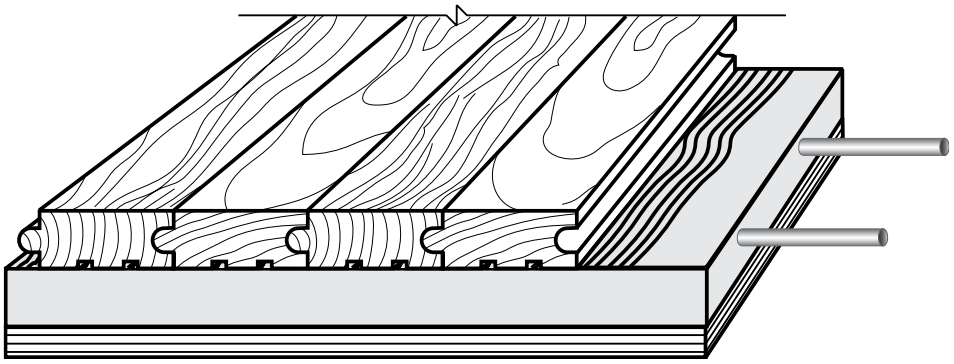


Figure 16-9: Wood Floor Glued to Underlayment

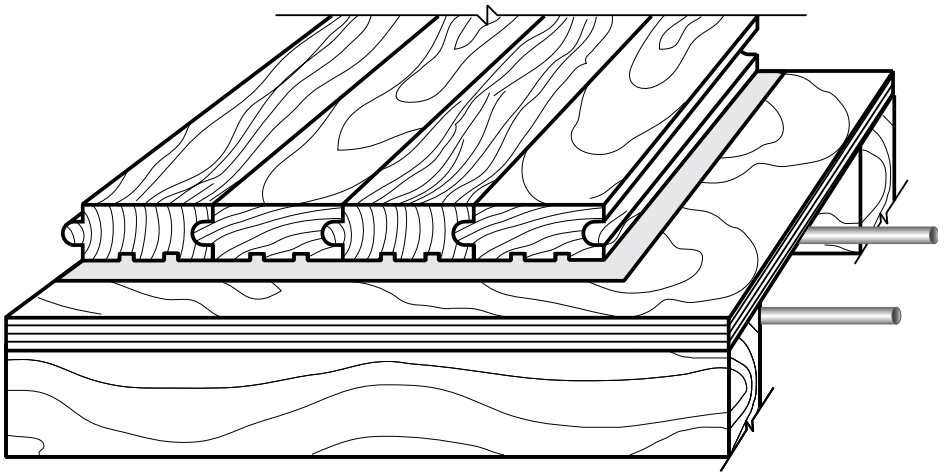


Figure 16-10: Wood Floor Nailed to Subfloor

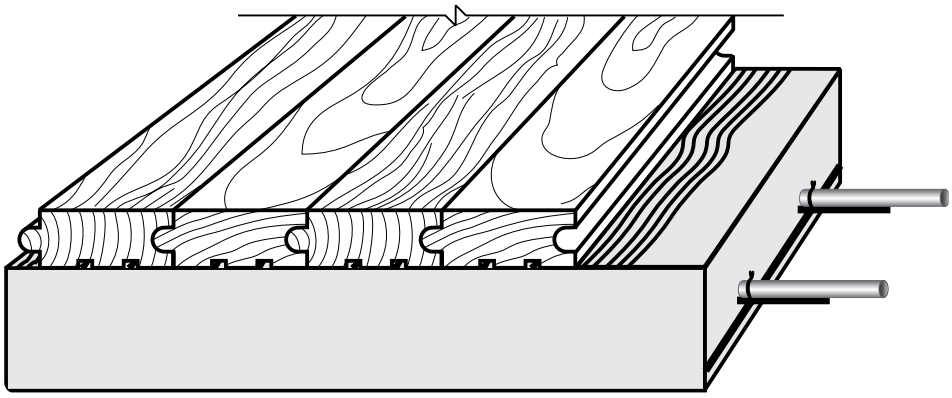


Figure 16-11: Wood Floor Over Concrete

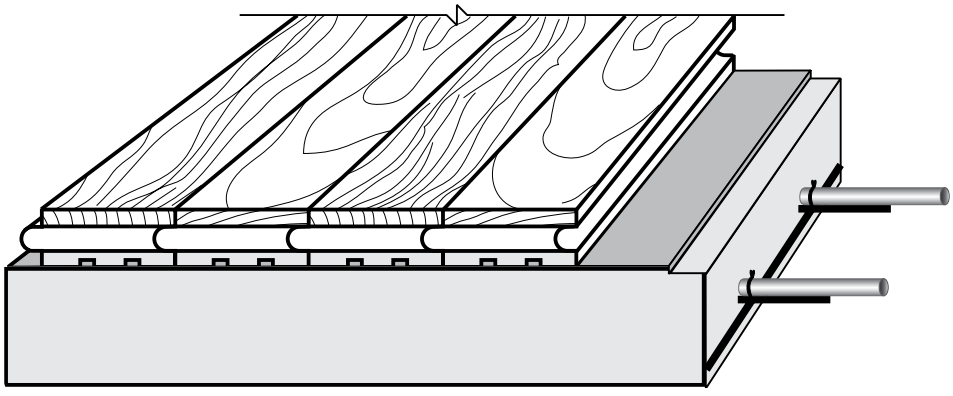


Figure 16-12: Floating Wood Floor

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 tubing is mounted to the subfloor, the contractor must mark the tubing location so the wood floor installer does not puncture the tubing 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**).

Appendix A

Advanced Design Suite™ (ADS) Worksheet

Project Information

Project Name _____ Date Received _____

Project Location _____ Date Design Due _____

Contact Person _____ Contact Number _____

Design Information

Outdoor design temperature	

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 number								
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 (tubing alone) = J
Joist Trak™ = JT
Quik Trak® = QT

***R-values are in Appendix D.

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	Tubing size										
I	Floor covering R-value										
J	Differential temp. (°F)										
K	Tubing 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)	

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 ADS printout (upward load).

E Enter the "Floor Unit Load" value from ADS 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 tubing 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 Tubing 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 tubing installed within the room (i.e., active loop).

N Enter the length of the tubing from the room being heated to the respective manifold.

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.

S Enter highest temperature from Row L.

T Add and enter all values from Row P.

U Enter highest value from Row Q.

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	Tubing size										
I	Floor covering R-value										
J	Differential temp. (°F)										
K	Tubing 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 ADS printout (upward load).

F Enter the "Floor Unit Load" value from ADS 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 tubing 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 Tubing 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 tubing installed within the room (i.e., active loop).

N Enter the length of the tubing from the room being heated to the respective manifold.

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.

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	Tubing size										
J	Differential temp. (°F)										
K	Tubing 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										

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 ADS 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.

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 tubing for project (½" Wirsbo hePEX tubing).

J Use 10°F differential temperature for all radiant ceiling applications.

K Tubing 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 Multiply the all-inclusive distance from loop in the room to the respective manifold by 2.

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.

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	Tubing size										
I	Floor covering R-value										
J	Differential temp. (°F)										
K	Tubing 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)	

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 ADS printout (upward load).

E Enter the "Floor Unit Load" value from ADS 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 tubing 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 Tubing 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 tubing installed within the room (i.e., active loop).

N Enter the length of the tubing from the room being heated to the respective manifold.

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.

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

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.

Appendix D
R-value Charts

Construction Materials	1/8"	1/4"	3/8"	1/2"	5/8"	3/4"
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	1/8"	1/4"	3/8"	1/2"	5/8"	3/4"
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				

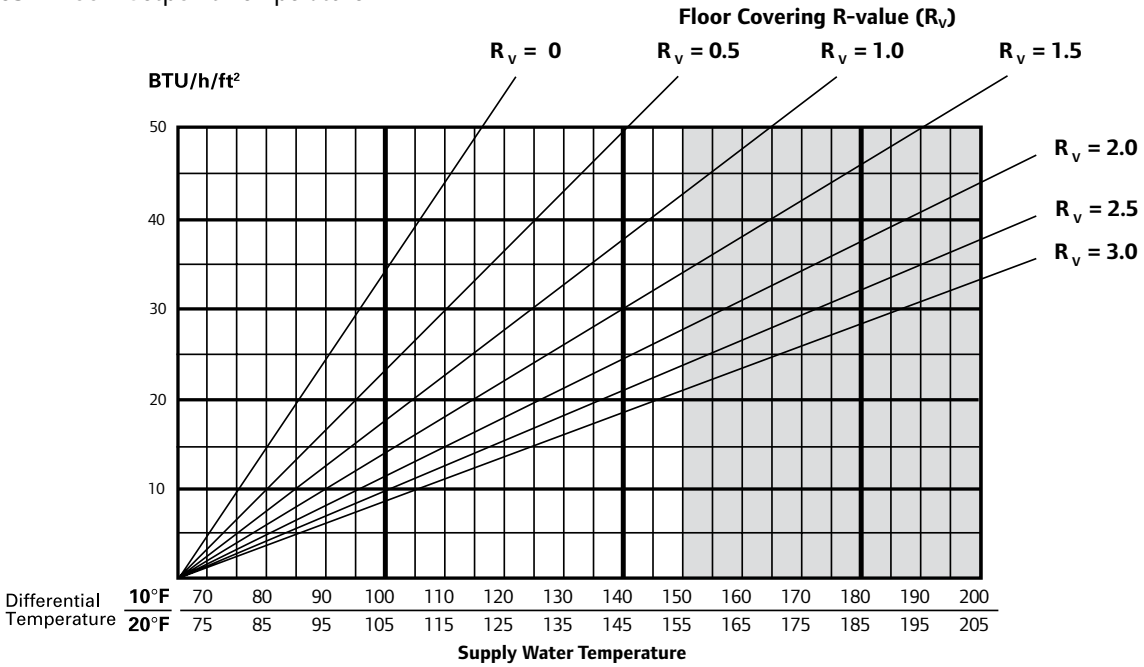
Windows	
Single glass	0.91
Single glass with storm	2.00
Double glazed – 3/16" air space	1.61
Double glazed – 1/4" air space	1.69
Double glazed – 1/2" air space	2.04
Double glazed – 3/4" air space	2.38
Double glazed – with suspended film	2.77
Double glazed – with 2 suspended films	3.85
Low-E	3.13
Low-E – 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.

Appendix E
Supply Water Temperature Charts

Concrete — 4" Slab (12" on center)

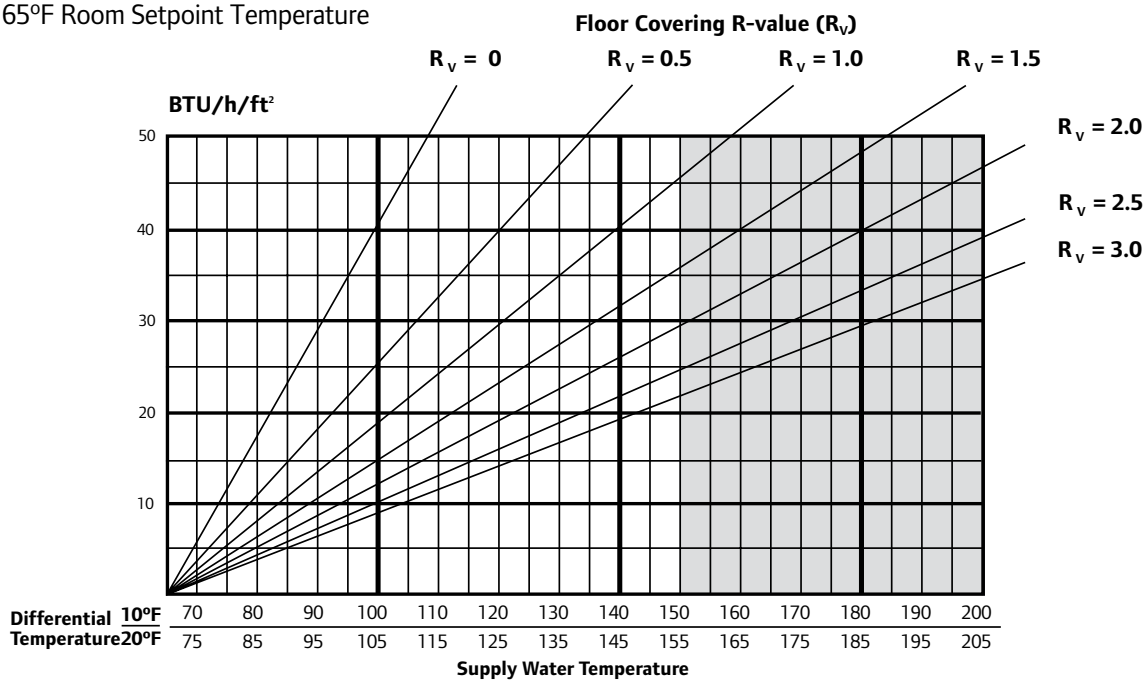
65ºF Room Setpoint Temperature



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



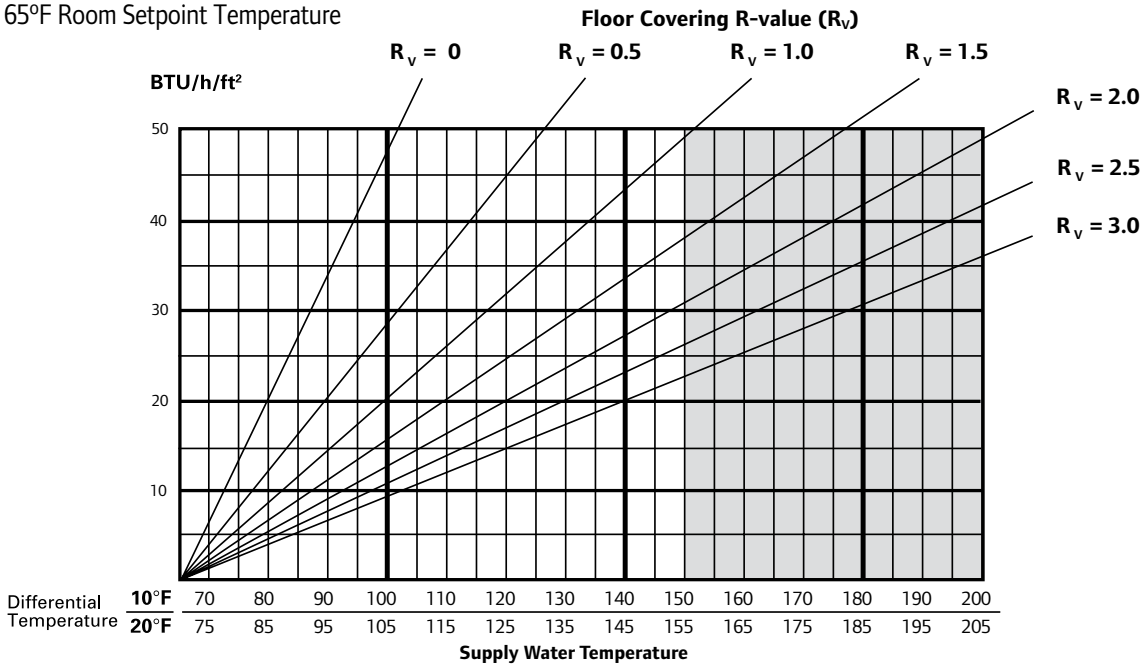
Note: Uponor's recommended maximum fluid temperature for all concrete applications is 150°F, in accordance with the UBC. This data assumes negligible downward loss in accordance with good insulation practices.

Appendix E

Supply Water Temperature Charts

Concrete — 4" Slab (6" on center)

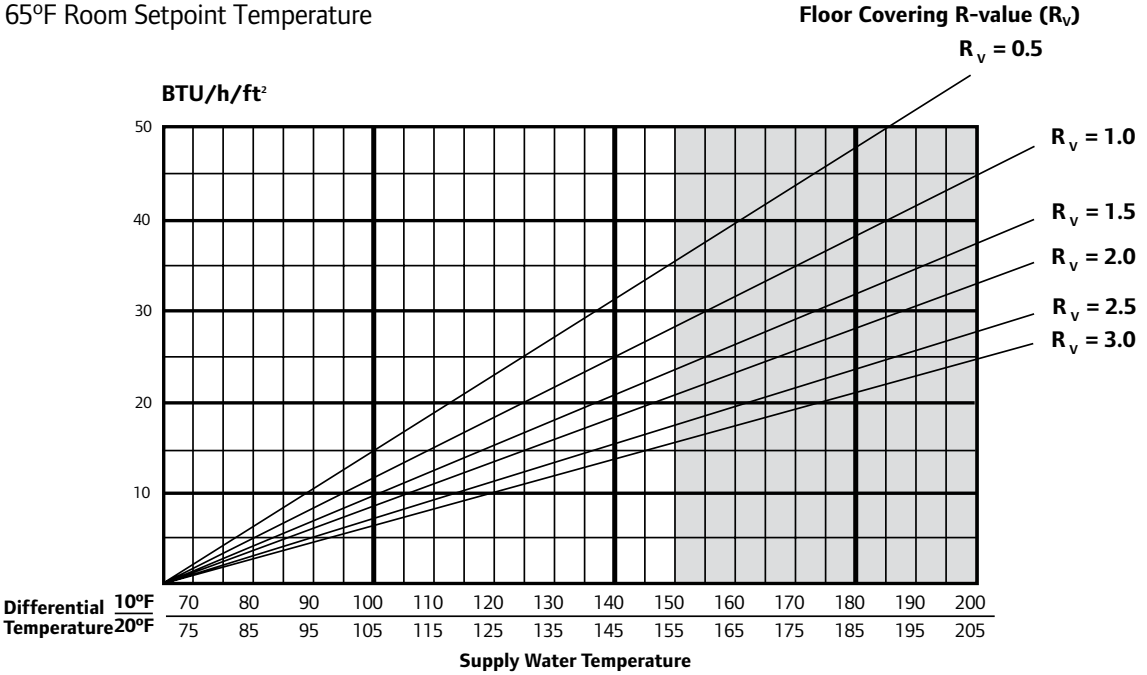
65ºF Room Setpoint Temperature



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



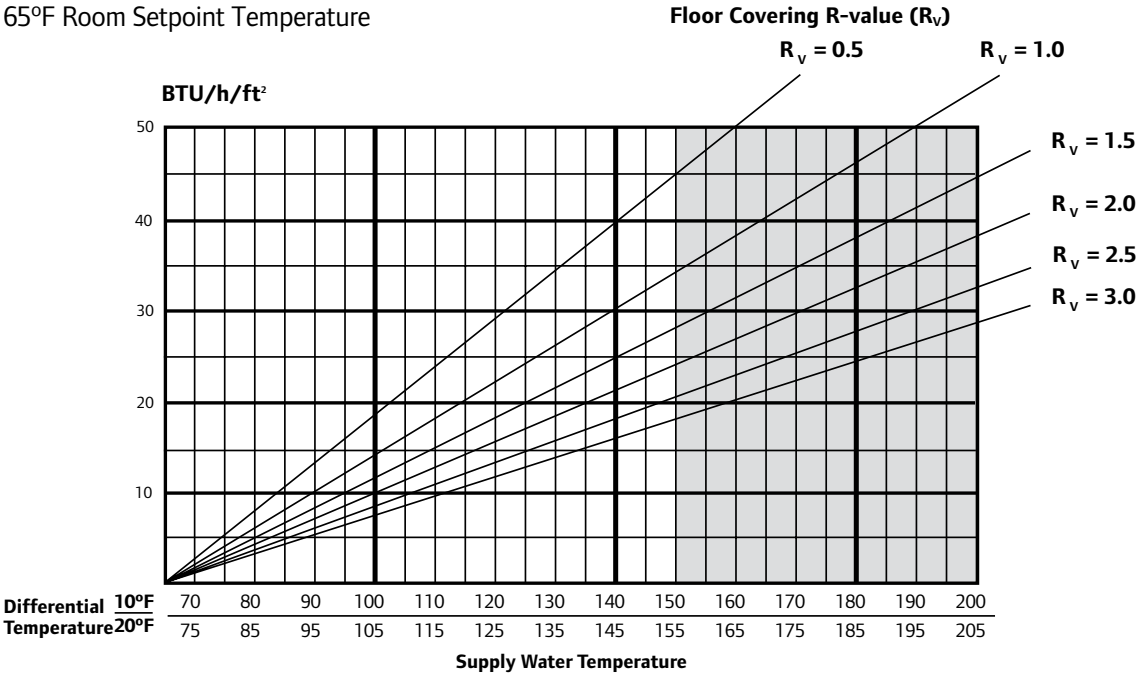
Note: Uponor's recommended maximum fluid temperature for all concrete applications is 150°F, in accordance with the UBC. Consult underlayment manufacturer's recommended temperature limitations. This data assumes negligible downward loss in accordance with good insulation practices.

Appendix E

Supply Water Temperature Charts

1½" Poured Floor Underlayment (9" on center)

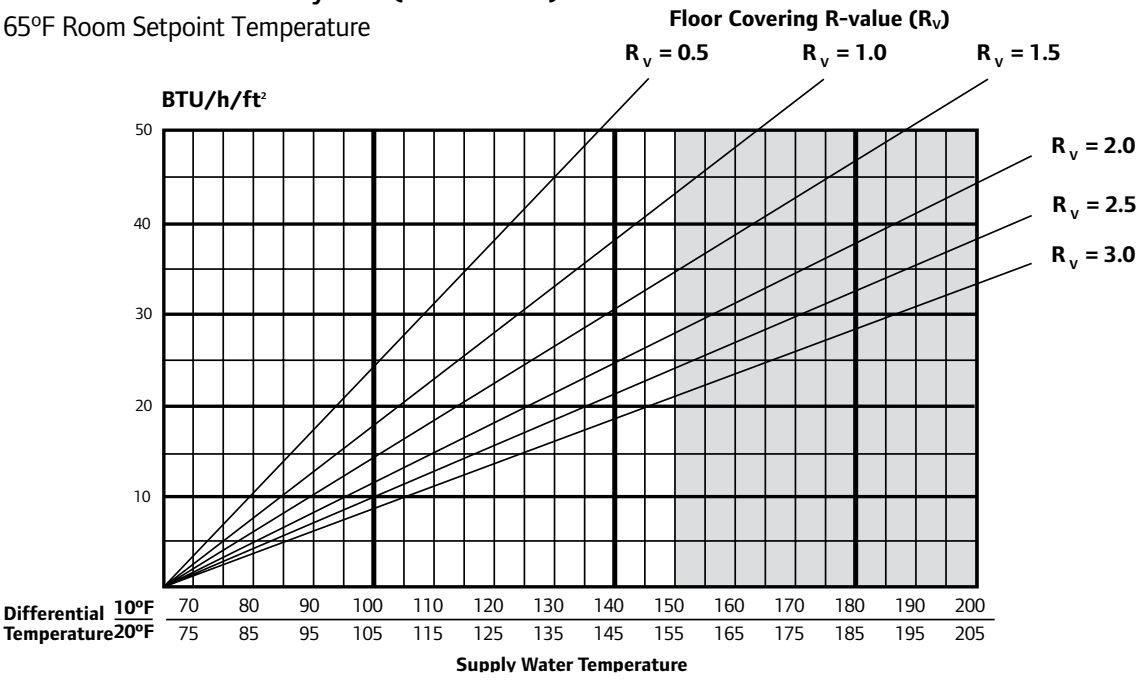
65ºF Room Setpoint Temperature



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'srecommended 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

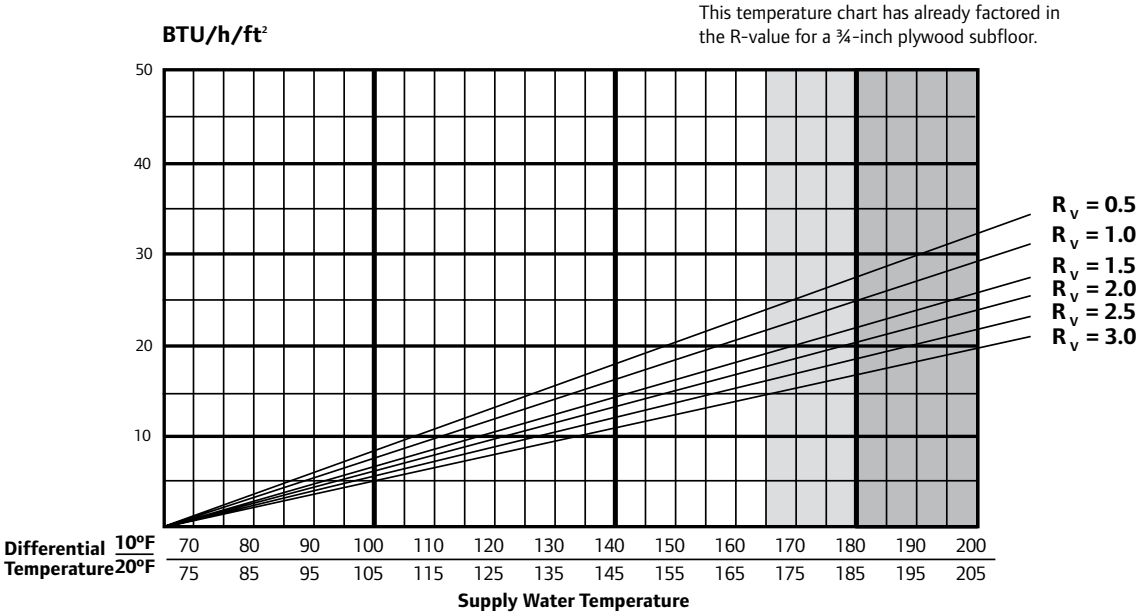
Supply Water Temperature Charts

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.



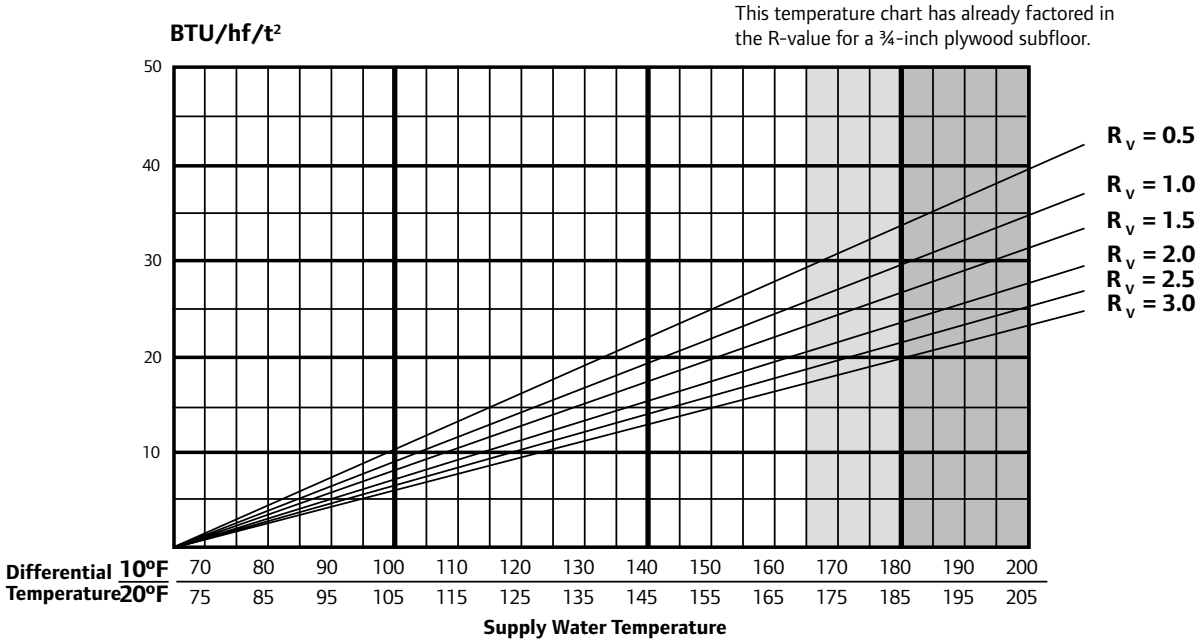
Note: The maximum fluid temperature for all joist applications is 180°F. Uponor's recommended maximum design temperature is 165°F. This data assumes negligible downward loss in accordance with good insulation practices.

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

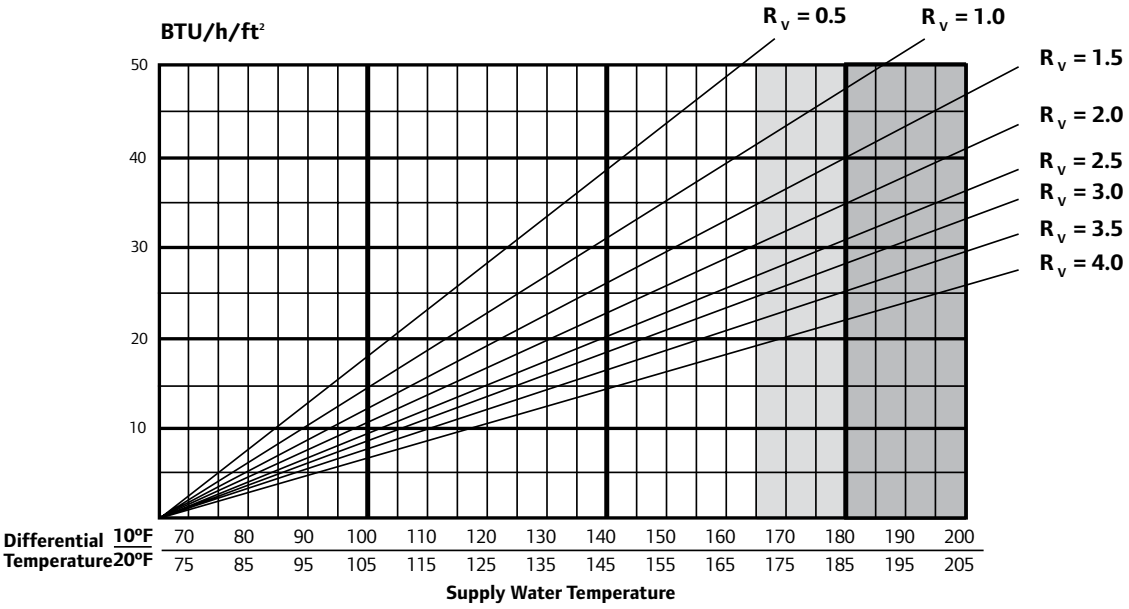
Supply Water Temperature Charts

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.



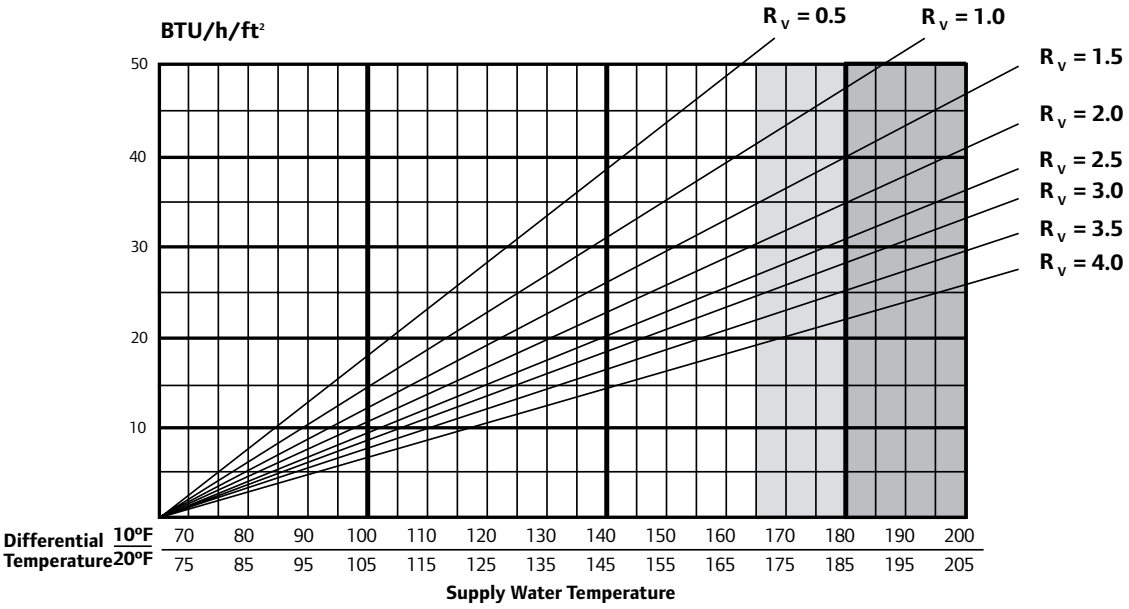
Note: The maximum fluid temperature for all joist applications is 180°F. Uponor's recommended maximum design temperature is 165°F. This data assumes negligible downward loss in accordance with good insulation practices.

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.



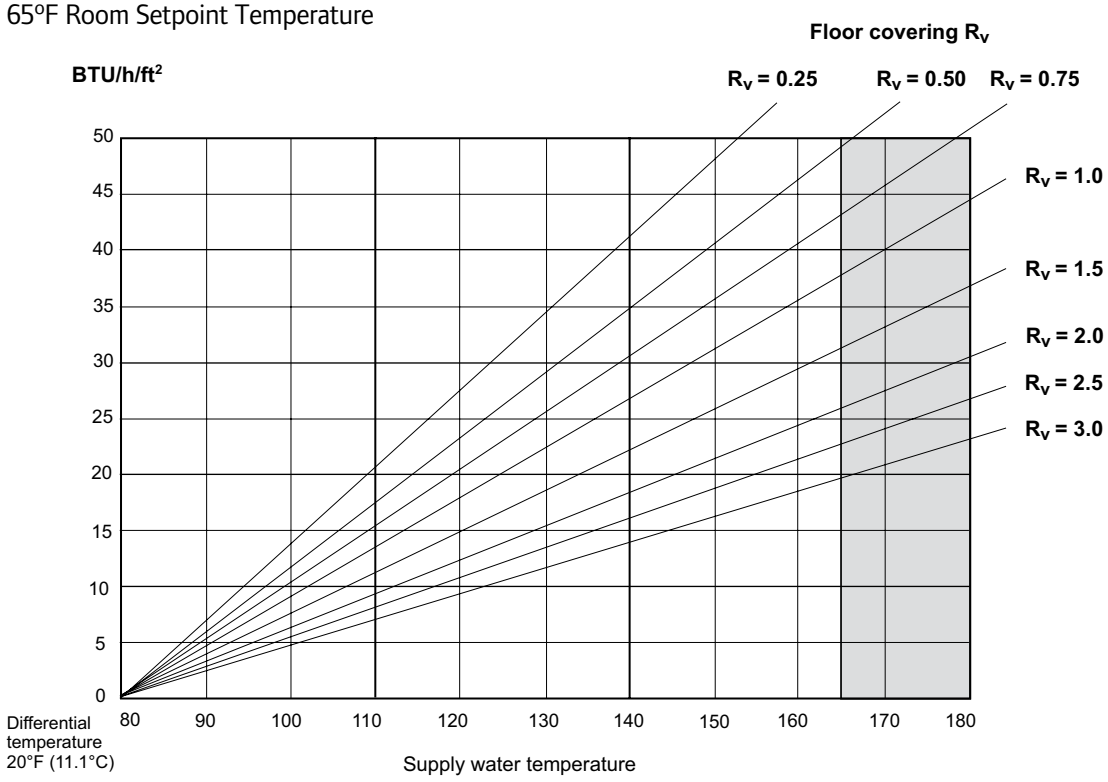
Note: The maximum fluid temperature for all joist applications is 180°F. Uponor's recommended maximum design temperature is 165°F. This data assumes negligible downward loss in accordance with good insulation practices.

Appendix E

Supply Water Temperature Charts

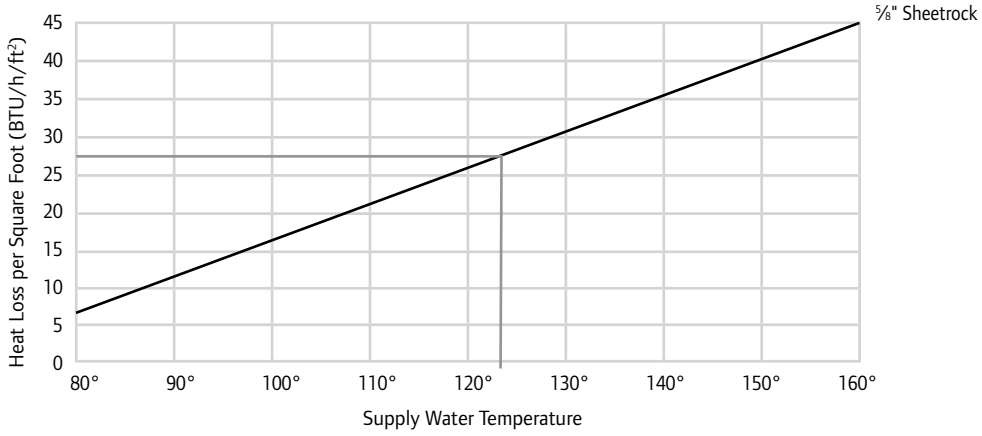
Quik Trak® Radiant Floor (7" on center)

65ºF Room Setpoint Temperature



Note: Uponor's recommended maximum design temperature is 165ºF.

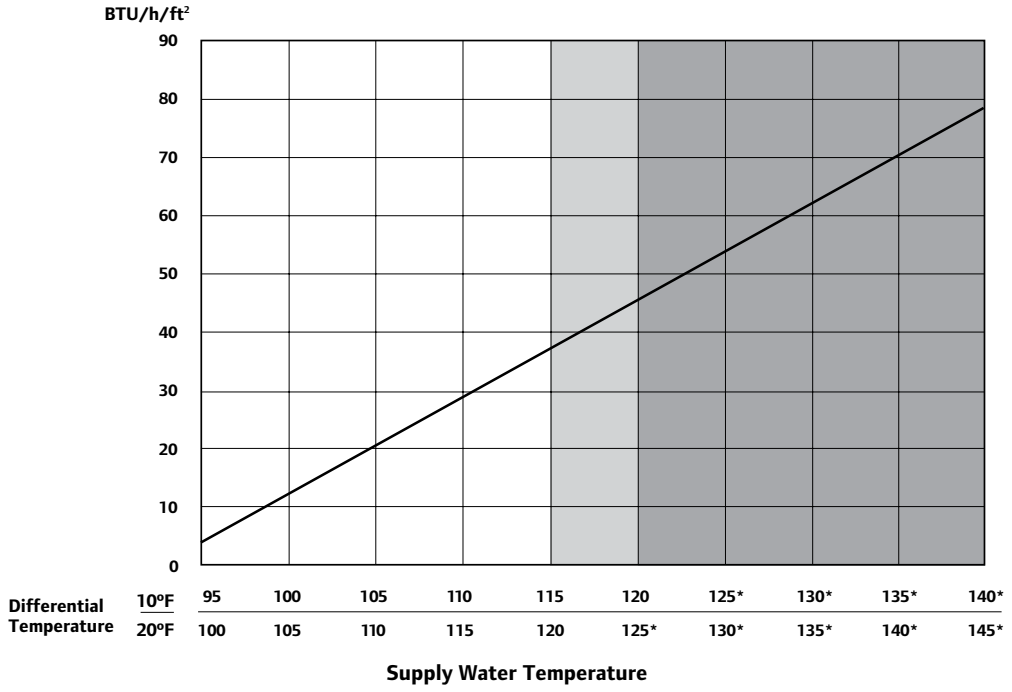
Radiant Ceiling with Joist Trak Plates (8" on center)



Appendix E
Supply Water Temperature Charts

Radiant Ceiling with Single-groove Aluminum Plates (12" on center)

70ºF Room Setpoint Temperature



*Exceeds maximum supply temperature of 120ºF for Uponor radiant ceiling applications.

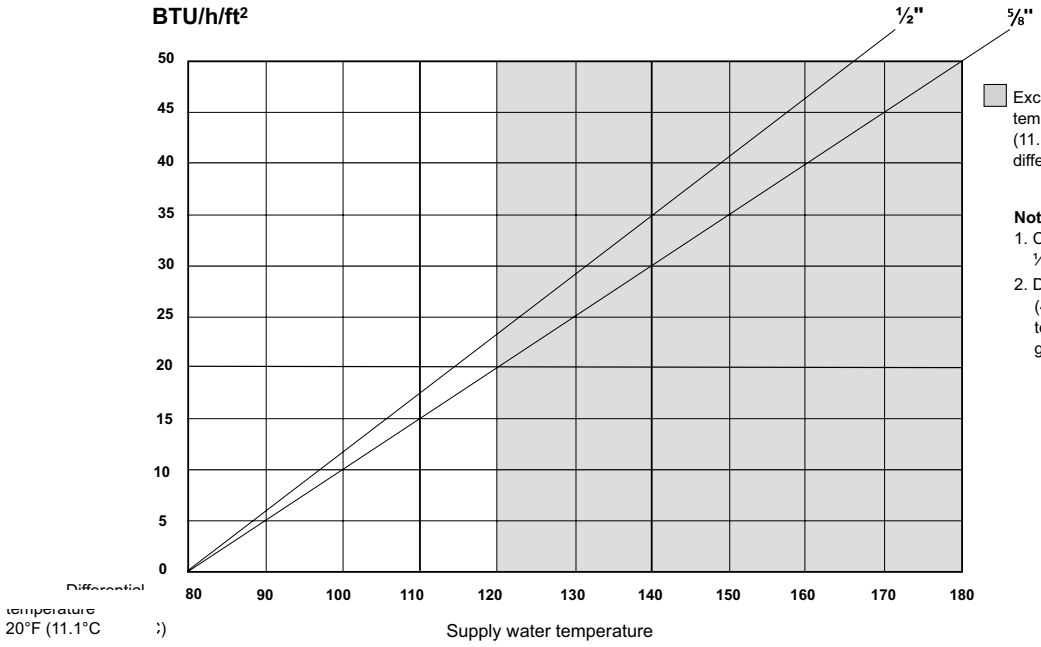
Exceeds supply water temperature at 10ºF supply/return differential temperature

Exceeds supply water temperature at 20ºF supply/return differential temperature

This chart is based on installations using single-groove aluminum heat-emission plates installed at 12 inches on center with ½" gypsum sheetrock. This chart is applicable for ceiling heights up to 12 feet.

Quik Trak Radiant Wall (7" on center)

70ºF Room Setpoint Temperature



Exceeds supply water temperature at 20°F (11.1°C) supply/return differential temperature

Notes:

1. Chart lines represent ½" and ⅝" sheetrock.
2. Do not exceed 120ºF (48.9°C) supply water temperature under gypsum sheetrock.

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 tubing. On the left side of each chart is the BTU/h/ft^2 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 tubing installed at 9 inches on center. The load for the room is 40 BTU/h/ft^2.The room is 15 feet from the manifold location.
- First determine the amount of tubing 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 tubing.

  15 x 2 = 30 feet
  Vertical distance of tubing 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.

❶ Enter the chart at the BTU/h/ft^2 for the room (40).

❷ Move to the right to the 9" o.c. column.

❸ Where the two lines intersect is the value in gallons per minute (gpm) per foot of tubing (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 Tubing

	Tubing On-Center Distances						
BTU/h/ft^2	**6" o.c.**	**7" o.c.**	**8" o.c.**	**9" o.c.** ❷	**10" o.c.**	**12" o.c.**	**15" o.c.**
❶ **40**	0.00405	0.00473	0.00541	0.00608	0.00676	0.00811	0.01014
39	0.00395	0.00461	0.00527	0.00593	❸ 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: Flow Chart Example

Appendix F

Flow Charts

100% Water

10º Supply/Return Differential Flow in GPM Per Foot of Tubing

	Tubing On-Center Distances						
BTU/h/ft^2	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 100% water at 120ºF.

Do not use 15" o.c. with residential applications.

Appendix F

Flow Charts

100% Water

20º Supply/Return Differential Flow in GPM Per Foot of Tubing

	Tubing On-Center Distances						
BTU/h/ft^2	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.

Do not use 15" o.c. with residential applications.

Appendix F

Flow Charts

30% Water

10º Supply/Return Differential Flow in GPM Per Foot of Tubing

	Tubing On-Center Distances						
BTU/h/ft^2	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.

Do not use 15" o.c. with residential applications.

Appendix F

Flow Charts

30% Water

20º Supply/Return Differential Flow in GPM Per Foot of Tubing

	Tubing On-Center Distances						
BTU/h/ft^2	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	0.00174	0.00203	0.00232	0.00261	0.00290	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.

Do not use 15" o.c. with residential applications.

Appendix F

Flow Charts

40% Water

10º Supply/Return Differential Flow in GPM Per Foot of Tubing

	Tubing On-Center Distances						
BTU/h/ft^2	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.

Do not use 15" o.c. with residential applications.

Appendix F
Flow Charts

40% Water

20º Supply/Return Differential Flow in GPM Per Foot of Tubing

	Tubing On-Center Distances						
BTU/h/ft^2	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.

Do not use 15" o.c. with residential applications.

Appendix F

Flow Charts

50% Water

10º Supply/Return Differential Flow in GPM Per Foot of Tubing

Tubing On-Center Distances							
BTU/h/ft^2	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.

Do not use 15" o.c. with residential applications.

Appendix F

Flow Charts

50% Water

20º Supply/Return Differential Flow in GPM Per Foot of Tubing

Tubing On-Center Distances							
BTU/h/ft^2	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.

Do not use 15" o.c. with residential applications.

Appendix G

Hydronic Friction Loss Tables

5/16" Uponor PEX-a — 100% Water — Feet of Head per Foot of Tubing

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.

Appendix G

Hydronic Friction Loss Tables

5/16" Uponor PEX-a — 30% Propylene Glycol — Feet of Head per Foot of Tubing

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	0.01318	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 Tubing

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	0.01528	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 Tubing

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	0.01774	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 Tubing

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
0.6	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 Tubing

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	0.15	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 Tubing

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	0.15	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

⅜" Uponor PEX-a — 50% Propylene Glycol — Feet of Head per Foot of Tubing

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	0.15	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 Tubing

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

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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 Tubing

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.

Appendix G
Hydronic Friction Loss Tables

½" Uponor PEX-a — 30% Propylene Glycol — Feet of Head per Foot of Tubing

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

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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 — 30% Propylene Glycol — Feet of Head per Foot of Tubing

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	0.240044	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 — 50% Propylene Glycol — Feet of Head per Foot of Tubing

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	0.01170	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 Tubing

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	0.01398	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.

Appendix G
Hydronic Friction Loss Tables

⅝" Uponor PEX-a — 100% Water — Feet of Head per Foot of Tubing

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
3.9	3.15	0.15736	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

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 — 100% Water — Feet of Head per Foot of Tubing

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
4.0	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 Tubing

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
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

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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 Tubing

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
4.0	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	0.23354	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 Tubing

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
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

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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 Tubing

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
4.0	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 Tubing

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	0.09664	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	0.14333	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
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

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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 Tubing

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
4.0	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.

¾" Uponor PEX-a — 100% Water — Feet of Head per Foot of Tubing

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
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

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

¾" Uponor PEX-a — 100% Water — Feet of Head per Foot of Tubing

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	0.12929	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 Tubing

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	0.12666	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
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

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

¾" Uponor PEX-a — 30% Propylene Glycol — Feet of Head per Foot of Tubing

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
4.0	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	0.23967	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	0.14935	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.

Appendix G
Hydronic Friction Loss Tables

¾" Uponor PEX-a — 40% Propylene Glycol — Feet of Head per Foot of Tubing

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
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

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

¾" Uponor PEX-a — 40% Propylene Glycol — Feet of Head per Foot of Tubing

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
4.0	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 Tubing

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	0.16932	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
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

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

¾" Uponor PEX-a — 50% Propylene Glycol — Feet of Head per Foot of Tubing

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
4.0	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 Tubing

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
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

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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 Tubing

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
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 Tubing

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
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

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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 — 30% Propylene Glycol — Feet of Head per 100 Feet of Tubing

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
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 Tubing

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	2.95	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
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

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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 Tubing

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
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.

1" Uponor PEX-a — 50% Propylene Glycol — Feet of Head per 100 Feet of Tubing

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	2.95	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
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

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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 Tubing

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
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 Tubing

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	1.39	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
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

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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 Tubing

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
4.9	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 Tubing

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
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

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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 — 30% Propylene Glycol — Feet of Head per 100 Feet of Tubing

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
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.

Appendix G
Hydronic Friction Loss Tables

1¼" Uponor PEX-a — 40% Propylene Glycol — Feet of Head per 100 Feet of Tubing

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
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

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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 Tubing

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
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.

1¼" Uponor PEX-a — 50% Propylene Glycol — Feet of Head per 100 Feet of Tubing

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	2.58	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
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

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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 Tubing

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
4.9	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 Tubing

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
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

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 Tubing

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
4.9	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 Tubing

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
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

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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 — 30% Propylene Glycol — Feet of Head per 100 Feet of Tubing

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
4.9	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 Tubing

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
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

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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 — 40% Propylene Glycol — Feet of Head per 100 Feet of Tubing

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
4.9	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.

1½" Uponor PEX-a — 50% Propylene Glycol — Feet of Head per 100 Feet of Tubing

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
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

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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 Tubing

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
4.9	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.

2" Uponor PEX-a — 100% Water — Feet of Head per 100 Feet of Tubing

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
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

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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 Tubing

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
4.9	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 Tubing

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
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

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 Tubing

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
4.9	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 Tubing

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	1.26	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
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

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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 — 40% Propylene Glycol — Feet of Head per 100 Feet of Tubing

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
4.9	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 Tubing

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
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

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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 — 50% Propylene Glycol — Feet of Head per 100 Feet of Tubing

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
4.9	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 Tubing

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
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

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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 Tubing

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
4.9	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 Tubing

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	0.82	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
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

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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 — 30% Propylene Glycol — Feet of Head per 100 Feet of Tubing

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
4.9	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 Tubing

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
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

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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 — 40% Propylene Glycol — Feet of Head per 100 Feet of Tubing

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
4.9	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 Tubing

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
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

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 — 50% Propylene Glycol — Feet of Head per 100 Feet of Tubing

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
4.9	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 Tubing

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
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

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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 Tubing

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
4.9	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 Tubing

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
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

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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 — 30% Propylene Glycol — Feet of Head per 100 Feet of Tubing

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
4.9	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 Tubing

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
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

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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 — 40% Propylene Glycol — Feet of Head per 100 Feet of Tubing

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
4.9	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 Tubing

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
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

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 — 50% Propylene Glycol — Feet of Head per 100 Feet of Tubing

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
4.9	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.

3½" Uponor PEX-a — 100% Water — Feet of Head per 100 Feet of Tubing

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
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

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 — 100% Water — Feet of Head per 100 Feet of Tubing

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
4.9	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 Tubing

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
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

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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 — 30% Propylene Glycol — Feet of Head per 100 Feet of Tubing

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
4.9	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 Tubing

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
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

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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 — 40% Propylene Glycol — Feet of Head per 100 Feet of Tubing

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
4.9	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 Tubing

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
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

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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 Tubing

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
4.9	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 Tubing

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
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

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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 Tubing

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
4.9	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 Tubing

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
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

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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 — 30% Propylene Glycol — Feet of Head per 100 Feet of Tubing

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
4.9	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 Tubing

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
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

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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 — 40% Propylene Glycol — Feet of Head per 100 Feet of Tubing

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
4.9	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 Tubing

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
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

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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 — 50% Propylene Glycol — Feet of Head per 100 Feet of Tubing

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
4.9	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 G
Hydronic Friction Loss Tables

½" Uponor MLC — 100% Water — Feet of Head per Foot of Tubing

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	0.29	0.0060	0.0056	0.0052	0.0051	0.0050	0.0049	0.0048	0.0046	0.0044	0.0042	0.0041	0.0040	0.0039	0.0038	0.0037	0.0036	0.0036	0.0035	0.0034	0.0034
0.6	0.35	0.0081	0.0076	0.0071	0.0069	0.0067	0.0066	0.0065	0.0062	0.0060	0.0058	0.0056	0.0055	0.0053	0.0052	0.0051	0.0050	0.0049	0.0048	0.0047	0.0046
0.7	0.41	0.0105	0.0099	0.0092	0.0090	0.0087	0.0086	0.0084	0.0080	0.0078	0.0075	0.0073	0.0071	0.0069	0.0068	0.0066	0.0065	0.0063	0.0062	0.0061	0.0060
0.8	0.47	0.0131	0.0123	0.0115	0.0112	0.0109	0.0107	0.0105	0.0101	0.0097	0.0094	0.0092	0.0089	0.0087	0.0085	0.0083	0.0082	0.0080	0.0079	0.0077	0.0076
0.9	0.53	0.0159	0.0150	0.0140	0.0137	0.0134	0.0131	0.0128	0.0123	0.0119	0.0115	0.0112	0.0109	0.0107	0.0104	0.0102	0.0100	0.0098	0.0096	0.0095	0.0093
1.0	0.59	0.0190	0.0179	0.0167	0.0164	0.0160	0.0157	0.0153	0.0148	0.0143	0.0138	0.0134	0.0131	0.0128	0.0125	0.0122	0.0120	0.0118	0.0116	0.0114	0.0112
1.1	0.65	0.0223	0.0210	0.0197	0.0192	0.0188	0.0184	0.0180	0.0174	0.0168	0.0163	0.0158	0.0154	0.0151	0.0147	0.0144	0.0142	0.0139	0.0137	0.0134	0.0132
1.2	0.71	0.0258	0.0244	0.0228	0.0223	0.0218	0.0214	0.0209	0.0202	0.0195	0.0189	0.0184	0.0179	0.0175	0.0171	0.0168	0.0165	0.0162	0.0159	0.0156	0.0154
1.3	0.76	0.0295	0.0279	0.0261	0.0256	0.0250	0.0245	0.0240	0.0231	0.0224	0.0217	0.0211	0.0206	0.0201	0.0197	0.0193	0.0189	0.0186	0.0183	0.0180	0.0177
1.4	0.82	0.0334	0.0316	0.0296	0.0290	0.0284	0.0278	0.0273	0.0263	0.0255	0.0247	0.0240	0.0234	0.0229	0.0224	0.0219	0.0215	0.0212	0.0208	0.0205	0.0202
1.5	0.88	0.0376	0.0356	0.0333	0.0326	0.0319	0.0313	0.0307	0.0296	0.0287	0.0278	0.0271	0.0264	0.0258	0.0253	0.0248	0.0243	0.0239	0.0235	0.0231	0.0228
1.6	0.94	0.0419	0.0397	0.0372	0.0365	0.0356	0.0350	0.0343	0.0331	0.0321	0.0311	0.0303	0.0296	0.0289	0.0283	0.0277	0.0272	0.0267	0.0263	0.0259	0.0255
1.7	1.00	0.0465	0.0440	0.0413	0.0405	0.0396	0.0388	0.0381	0.0368	0.0356	0.0346	0.0337	0.0328	0.0321	0.0314	0.0308	0.0302	0.0297	0.0292	0.0288	0.0284
1.8	1.06	0.0512	0.0485	0.0456	0.0446	0.0436	0.0428	0.0420	0.0406	0.0393	0.0382	0.0372	0.0363	0.0355	0.0347	0.0340	0.0334	0.0328	0.0323	0.0318	0.0314
1.9	1.12	0.0561	0.0532	0.0500	0.0490	0.0479	0.0470	0.0461	0.0445	0.0432	0.0419	0.0409	0.0399	0.0390	0.0382	0.0374	0.0367	0.0361	0.0355	0.0350	0.0345
2.0	1.18	0.0612	0.0581	0.0546	0.0535	0.0523	0.0514	0.0504	0.0487	0.0472	0.0459	0.0447	0.0436	0.0426	0.0418	0.0409	0.0402	0.0395	0.0389	0.0383	0.0378
2.1	1.23	0.0666	0.0632	0.0594	0.0582	0.0569	0.0559	0.0548	0.0530	0.0514	0.0499	0.0486	0.0475	0.0464	0.0455	0.0446	0.0438	0.0431	0.0424	0.0418	0.0412
2.2	1.29	0.0721	0.0684	0.0643	0.0630	0.0617	0.0606	0.0594	0.0574	0.0557	0.0541	0.0528	0.0515	0.0504	0.0493	0.0484	0.0475	0.0467	0.0460	0.0453	0.0447
2.3	1.35	0.0777	0.0738	0.0694	0.0681	0.0666	0.0654	0.0642	0.0620	0.0602	0.0585	0.0570	0.0557	0.0544	0.0533	0.0523	0.0514	0.0505	0.0498	0.0490	0.0484
2.4	1.41	0.0836	0.0794	0.0747	0.0732	0.0717	0.0704	0.0691	0.0668	0.0648	0.0630	0.0614	0.0600	0.0587	0.0575	0.0564	0.0554	0.0545	0.0536	0.0529	0.0521
2.5	1.47	0.0897	0.0852	0.0802	0.0786	0.0769	0.0756	0.0742	0.0717	0.0696	0.0677	0.0660	0.0644	0.0630	0.0618	0.0606	0.0595	0.0585	0.0576	0.0568	0.0560
2.6	1.53	0.0959	0.0911	0.0858	0.0841	0.0823	0.0809	0.0794	0.0768	0.0745	0.0725	0.0706	0.0690	0.0675	0.0662	0.0649	0.0638	0.0627	0.0618	0.0609	0.0601
2.7	1.59	0.1023	0.0973	0.0916	0.0898	0.0879	0.0864	0.0848	0.0820	0.0796	0.0774	0.0755	0.0737	0.0721	0.0707	0.0694	0.0682	0.0671	0.0660	0.0651	0.0642
2.8	1.65	0.1089	0.1035	0.0975	0.0956	0.0936	0.0920	0.0903	0.0874	0.0848	0.0825	0.0804	0.0786	0.0769	0.0754	0.0740	0.0727	0.0715	0.0704	0.0694	0.0685
2.9	1.70	0.1157	0.1100	0.1036	0.1016	0.0995	0.0978	0.0960	0.0929	0.0902	0.0877	0.0855	0.0836	0.0818	0.0802	0.0787	0.0774	0.0761	0.0749	0.0739	0.0729
3.0	1.76	0.1226	0.1166	0.1099	0.1078	0.1056	0.1037	0.1018	0.0985	0.0957	0.0931	0.0908	0.0887	0.0868	0.0851	0.0836	0.0821	0.0808	0.0796	0.0784	0.0774
3.1	1.82	0.1297	0.1234	0.1163	0.1141	0.1117	0.1098	0.1078	0.1043	0.1013	0.0986	0.0962	0.0940	0.0920	0.0902	0.0885	0.0870	0.0856	0.0843	0.0831	0.0820
3.2	1.88	0.1370	0.1304	0.1229	0.1206	0.1181	0.1161	0.1139	0.1103	0.1071	0.1042	0.1017	0.0994	0.0973	0.0954	0.0936	0.0921	0.0906	0.0892	0.0880	0.0868
3.3	1.94	0.1444	0.1375	0.1296	0.1272	0.1246	0.1224	0.1202	0.1164	0.1130	0.1100	0.1073	0.1049	0.1027	0.1007	0.0989	0.0972	0.0956	0.0942	0.0929	0.0917
3.4	2.00	0.1521	0.1448	0.1365	0.1339	0.1312	0.1290	0.1266	0.1226	0.1191	0.1159	0.1131	0.1106	0.1083	0.1062	0.1042	0.1025	0.1008	0.0993	0.0979	0.0967
3.5	2.06	0.1598	0.1522	0.1436	0.1409	0.1380	0.1357	0.1332	0.1290	0.1253	0.1220	0.1190	0.1164	0.1139	0.1117	0.1097	0.1079	0.1061	0.1046	0.1031	0.1018
3.6	2.12	0.1678	0.1598	0.1508	0.1479	0.1450	0.1425	0.1399	0.1355	0.1316	0.1282	0.1251	0.1223	0.1197	0.1174	0.1153	0.1134	0.1116	0.1099	0.1084	0.1070
3.7	2.17	0.1759	0.1676	0.1582	0.1552	0.1521	0.1495	0.1468	0.1422	0.1381	0.1345	0.1313	0.1283	0.1257	0.1233	0.1211	0.1190	0.1171	0.1154	0.1138	0.1123
3.8	2.23	0.1842	0.1755	0.1657	0.1626	0.1593	0.1566	0.1538	0.1490	0.1447	0.1410	0.1376	0.1345	0.1317	0.1292	0.1269	0.1248	0.1228	0.1210	0.1194	0.1178

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

½" Uponor MLC — 100% Water — Feet of Head per Foot of Tubing

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	2.29	0.1927	0.1836	0.1733	0.1701	0.1667	0.1639	0.1610	0.1559	0.1515	0.1476	0.1440	0.1408	0.1379	0.1353	0.1329	0.1307	0.1286	0.1267	0.1250	0.1234
4.0	2.35	0.2013	0.1918	0.1811	0.1778	0.1742	0.1713	0.1682	0.1630	0.1584	0.1543	0.1506	0.1473	0.1442	0.1415	0.1390	0.1367	0.1345	0.1326	0.1308	0.1291
4.1	2.41	0.2101	0.2002	0.1891	0.1856	0.1819	0.1788	0.1757	0.1702	0.1654	0.1611	0.1573	0.1538	0.1507	0.1478	0.1452	0.1428	0.1406	0.1385	0.1366	0.1349
4.2	2.47	0.2190	0.2088	0.1972	0.1935	0.1897	0.1865	0.1832	0.1776	0.1726	0.1681	0.1641	0.1605	0.1573	0.1543	0.1515	0.1491	0.1467	0.1446	0.1426	0.1408
4.3	2.53	0.2281	0.2175	0.2055	0.2017	0.1977	0.1944	0.1910	0.1851	0.1799	0.1752	0.1711	0.1673	0.1639	0.1609	0.1580	0.1554	0.1530	0.1508	0.1487	0.1468
4.4	2.59	0.2374	0.2263	0.2139	0.2099	0.2058	0.2024	0.1988	0.1927	0.1873	0.1825	0.1782	0.1743	0.1708	0.1676	0.1646	0.1619	0.1594	0.1571	0.1550	0.1530
4.5	2.65	0.2468	0.2354	0.2224	0.2183	0.2140	0.2105	0.2068	0.2005	0.1949	0.1899	0.1854	0.1813	0.1777	0.1744	0.1713	0.1685	0.1659	0.1635	0.1613	0.1592
4.6	2.70	0.2564	0.2445	0.2311	0.2269	0.2224	0.2188	0.2149	0.2084	0.2026	0.1974	0.1927	0.1885	0.1847	0.1813	0.1781	0.1752	0.1725	0.1700	0.1677	0.1656

Recommended Head Loss Design Range

Sizing in this region will lead to excessive head loss conditions.

½" Uponor MLC — 30% Propylene Glycol — Feet of Head per Foot of Tubing

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	0.29	0.0090	0.0086	0.0082	0.0078	0.0075	0.0072	0.0069	0.0064	0.0061	0.0057	0.0054	0.0052	0.0050	0.0048	0.0046	0.0045	0.0044	0.0042	0.0041	0.0041
0.6	0.35	0.0120	0.0115	0.0109	0.0105	0.0100	0.0097	0.0093	0.0087	0.0082	0.0077	0.0074	0.0070	0.0068	0.0065	0.0063	0.0061	0.0059	0.0058	0.0056	0.0055
0.7	0.41	0.0154	0.0147	0.0140	0.0135	0.0129	0.0124	0.0120	0.0112	0.0105	0.0100	0.0095	0.0091	0.0088	0.0084	0.0082	0.0079	0.0077	0.0075	0.0073	0.0072
0.8	0.47	0.0191	0.0183	0.0174	0.0167	0.0160	0.0155	0.0149	0.0140	0.0132	0.0125	0.0119	0.0114	0.0110	0.0106	0.0103	0.0099	0.0097	0.0094	0.0092	0.0090
0.9	0.53	0.0231	0.0221	0.0211	0.0203	0.0195	0.0188	0.0181	0.0170	0.0160	0.0152	0.0145	0.0139	0.0134	0.0129	0.0125	0.0122	0.0118	0.0115	0.0113	0.0111
1.0	0.59	0.0273	0.0262	0.0250	0.0241	0.0232	0.0224	0.0216	0.0202	0.0191	0.0182	0.0173	0.0166	0.0160	0.0154	0.0150	0.0146	0.0142	0.0138	0.0135	0.0133
1.1	0.65	0.0319	0.0306	0.0293	0.0282	0.0271	0.0262	0.0253	0.0237	0.0224	0.0213	0.0204	0.0195	0.0188	0.0182	0.0176	0.0171	0.0167	0.0163	0.0159	0.0156
1.2	0.71	0.0368	0.0353	0.0338	0.0326	0.0313	0.0303	0.0292	0.0274	0.0260	0.0247	0.0236	0.0227	0.0218	0.0211	0.0205	0.0199	0.0194	0.0189	0.0185	0.0182
1.3	0.76	0.0420	0.0403	0.0385	0.0372	0.0357	0.0346	0.0334	0.0314	0.0297	0.0283	0.0270	0.0260	0.0250	0.0242	0.0235	0.0228	0.0222	0.0217	0.0212	0.0209
1.4	0.82	0.0474	0.0455	0.0436	0.0420	0.0404	0.0391	0.0378	0.0356	0.0337	0.0320	0.0306	0.0295	0.0284	0.0274	0.0267	0.0259	0.0252	0.0247	0.0241	0.0237
1.5	0.88	0.0531	0.0510	0.0488	0.0471	0.0454	0.0439	0.0424	0.0399	0.0378	0.0360	0.0345	0.0331	0.0320	0.0309	0.0300	0.0292	0.0284	0.0278	0.0272	0.0267
1.6	0.94	0.0590	0.0568	0.0544	0.0525	0.0505	0.0489	0.0472	0.0445	0.0422	0.0402	0.0385	0.0370	0.0357	0.0345	0.0336	0.0326	0.0318	0.0311	0.0304	0.0299
1.7	1.00	0.0652	0.0628	0.0601	0.0581	0.0559	0.0542	0.0523	0.0493	0.0468	0.0446	0.0427	0.0411	0.0396	0.0383	0.0373	0.0363	0.0353	0.0345	0.0338	0.0332
1.8	1.06	0.0717	0.0690	0.0661	0.0639	0.0615	0.0596	0.0576	0.0543	0.0515	0.0491	0.0471	0.0453	0.0437	0.0423	0.0411	0.0400	0.0390	0.0381	0.0373	0.0367
1.9	1.12	0.0784	0.0755	0.0724	0.0699	0.0674	0.0653	0.0631	0.0595	0.0565	0.0539	0.0516	0.0497	0.0480	0.0464	0.0452	0.0439	0.0428	0.0419	0.0410	0.0403
2.0	1.18	0.0854	0.0822	0.0788	0.0762	0.0734	0.0712	0.0688	0.0649	0.0616	0.0588	0.0564	0.0543	0.0524	0.0507	0.0494	0.0480	0.0468	0.0458	0.0448	0.0441
2.1	1.23	0.0926	0.0892	0.0855	0.0827	0.0797	0.0773	0.0747	0.0706	0.0670	0.0639	0.0613	0.0590	0.0570	0.0552	0.0537	0.0523	0.0510	0.0499	0.0488	0.0480
2.2	1.29	0.1000	0.0964	0.0925	0.0894	0.0862	0.0836	0.0808	0.0764	0.0725	0.0692	0.0664	0.0639	0.0618	0.0598	0.0582	0.0567	0.0553	0.0541	0.0529	0.0521
2.3	1.35	0.1077	0.1038	0.0996	0.0964	0.0929	0.0901	0.0871	0.0824	0.0782	0.0747	0.0716	0.0690	0.0667	0.0646	0.0629	0.0612	0.0597	0.0584	0.0572	0.0563
2.4	1.41	0.1156	0.1115	0.1070	0.1035	0.0998	0.0968	0.0937	0.0885	0.0842	0.0804	0.0771	0.0743	0.0718	0.0695	0.0677	0.0659	0.0643	0.0629	0.0616	0.0606
2.5	1.47	0.1238	0.1193	0.1146	0.1109	0.1069	0.1038	0.1004	0.0949	0.0902	0.0862	0.0827	0.0797	0.0770	0.0746	0.0727	0.0708	0.0690	0.0676	0.0662	0.0651
2.6	1.53	0.1322	0.1274	0.1224	0.1184	0.1143	0.1109	0.1073	0.1015	0.0965	0.0922	0.0885	0.0853	0.0825	0.0799	0.0778	0.0758	0.0739	0.0724	0.0709	0.0697
2.7	1.59	0.1408	0.1358	0.1304	0.1262	0.1218	0.1182	0.1144	0.1082	0.1030	0.0984	0.0944	0.0911	0.0880	0.0853	0.0831	0.0809	0.0790	0.0773	0.0757	0.0745
2.8	1.65	0.1496	0.1443	0.1386	0.1342	0.1295	0.1257	0.1217	0.1152	0.1096	0.1048	0.1005	0.0970	0.0938	0.0909	0.0885	0.0862	0.0842	0.0824	0.0807	0.0794
2.9	1.70	0.1587	0.1531	0.1471	0.1424	0.1375	0.1335	0.1292	0.1223	0.1164	0.1113	0.1068	0.1030	0.0997	0.0966	0.0941	0.0917	0.0895	0.0876	0.0858	0.0845
3.0	1.76	0.1680	0.1621	0.1558	0.1508	0.1456	0.1414	0.1369	0.1296	0.1234	0.1180	0.1133	0.1093	0.1057	0.1024	0.0998	0.0973	0.0949	0.0930	0.0911	0.0896
3.1	1.82	0.1775	0.1713	0.1646	0.1595	0.1539	0.1495	0.1448	0.1371	0.1305	0.1248	0.1199	0.1157	0.1119	0.1085	0.1057	0.1030	0.1006	0.0985	0.0965	0.0950
3.2	1.88	0.1872	0.1807	0.1737	0.1683	0.1625	0.1578	0.1528	0.1448	0.1378	0.1319	0.1266	0.1222	0.1182	0.1146	0.1117	0.1089	0.1063	0.1041	0.1020	0.1004
3.3	1.94	0.1972	0.1903	0.1830	0.1773	0.1712	0.1663	0.1611	0.1526	0.1453	0.1391	0.1336	0.1289	0.1247	0.1209	0.1179	0.1149	0.1122	0.1099	0.1077	0.1060
3.4	2.00	0.2073	0.2002	0.1925	0.1865	0.1801	0.1750	0.1695	0.1606	0.1530	0.1464	0.1407	0.1358	0.1314	0.1274	0.1242	0.1211	0.1182	0.1158	0.1135	0.1117
3.5	2.06	0.2177	0.2102	0.2021	0.1959	0.1892	0.1839	0.1781	0.1688	0.1608	0.1539	0.1479	0.1428	0.1382	0.1340	0.1307	0.1274	0.1244	0.1219	0.1194	0.1176
3.6	2.12	0.2283	0.2204	0.2120	0.2055	0.1985	0.1929	0.1869	0.1772	0.1688	0.1616	0.1553	0.1500	0.1452	0.1408	0.1373	0.1338	0.1307	0.1281	0.1255	0.1236
3.7	2.17	0.2391	0.2309	0.2221	0.2153	0.2080	0.2022	0.1959	0.1857	0.1770	0.1695	0.1629	0.1573	0.1523	0.1477	0.1440	0.1404	0.1371	0.1344	0.1317	0.1297
3.8	2.23	0.2501	0.2416	0.2324	0.2253	0.2177	0.2116	0.2051	0.1945	0.1853	0.1775	0.1706	0.1647	0.1595	0.1547	0.1509	0.1472	0.1437	0.1408	0.1380	0.1359

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Recommended Head Loss Design Range

Sizing in this region will lead to excessive head loss conditions.

Appendix G
Hydronic Friction Loss Tables

½" Uponor MLC — 30% Propylene Glycol — Feet of Head per Foot of Tubing

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	2.29	0.2613	0.2524	0.2429	0.2355	0.2276	0.2212	0.2144	0.2034	0.1938	0.1857	0.1785	0.1724	0.1669	0.1619	0.1579	0.1540	0.1504	0.1474	0.1445	0.1423
4.0	2.35	0.2727	0.2635	0.2536	0.2459	0.2376	0.2310	0.2239	0.2124	0.2025	0.1940	0.1865	0.1801	0.1744	0.1692	0.1651	0.1610	0.1573	0.1541	0.1511	0.1488
4.1	2.41	0.2844	0.2747	0.2644	0.2564	0.2479	0.2410	0.2336	0.2216	0.2113	0.2025	0.1947	0.1881	0.1821	0.1767	0.1724	0.1681	0.1642	0.1610	0.1578	0.1554
4.2	2.47	0.2962	0.2862	0.2755	0.2672	0.2583	0.2511	0.2435	0.2310	0.2203	0.2111	0.2030	0.1961	0.1900	0.1843	0.1798	0.1754	0.1714	0.1680	0.1646	0.1622

Recommended Head Loss Design Range

Sizing in this region will lead to excessive head loss conditions.

Appendix G
Hydronic Friction Loss Tables

½" Uponor MLC — 40% Propylene Glycol — Feet of Head per Foot of Tubing

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	0.29	0.0112	0.0105	0.0099	0.0094	0.0089	0.0085	0.0080	0.0074	0.0069	0.0064	0.0060	0.0057	0.0054	0.0052	0.0050	0.0048	0.0047	0.0049	0.0047	0.0046
0.6	0.35	0.0149	0.0140	0.0132	0.0125	0.0118	0.0113	0.0108	0.0099	0.0092	0.0086	0.0082	0.0077	0.0074	0.0071	0.0068	0.0066	0.0064	0.0066	0.0064	0.0063
0.7	0.41	0.0189	0.0179	0.0168	0.0160	0.0152	0.0145	0.0138	0.0128	0.0119	0.0111	0.0105	0.0100	0.0095	0.0091	0.0088	0.0085	0.0082	0.0086	0.0084	0.0081
0.8	0.47	0.0233	0.0221	0.0208	0.0198	0.0188	0.0180	0.0172	0.0159	0.0148	0.0139	0.0131	0.0125	0.0119	0.0114	0.0110	0.0107	0.0103	0.0108	0.0105	0.0102
0.9	0.53	0.0281	0.0267	0.0251	0.0240	0.0227	0.0218	0.0208	0.0193	0.0180	0.0169	0.0160	0.0152	0.0145	0.0140	0.0135	0.0130	0.0126	0.0132	0.0128	0.0125
1.0	0.59	0.0333	0.0316	0.0297	0.0284	0.0270	0.0259	0.0247	0.0229	0.0214	0.0201	0.0191	0.0182	0.0174	0.0167	0.0161	0.0156	0.0151	0.0157	0.0153	0.0149
1.1	0.65	0.0388	0.0368	0.0347	0.0331	0.0315	0.0302	0.0289	0.0268	0.0251	0.0236	0.0224	0.0213	0.0204	0.0196	0.0189	0.0183	0.0178	0.0185	0.0180	0.0175
1.2	0.71	0.0446	0.0423	0.0399	0.0382	0.0363	0.0349	0.0334	0.0310	0.0290	0.0273	0.0259	0.0247	0.0236	0.0227	0.0219	0.0213	0.0206	0.0215	0.0209	0.0204
1.3	0.76	0.0507	0.0482	0.0455	0.0435	0.0414	0.0398	0.0381	0.0354	0.0331	0.0313	0.0297	0.0283	0.0271	0.0260	0.0252	0.0244	0.0237	0.0246	0.0240	0.0234
1.4	0.82	0.0571	0.0543	0.0513	0.0491	0.0468	0.0450	0.0431	0.0400	0.0375	0.0354	0.0336	0.0320	0.0307	0.0295	0.0286	0.0277	0.0269	0.0280	0.0272	0.0265
1.5	0.88	0.0639	0.0608	0.0574	0.0550	0.0524	0.0504	0.0483	0.0449	0.0421	0.0398	0.0378	0.0360	0.0346	0.0332	0.0321	0.0312	0.0303	0.0315	0.0307	0.0299
1.6	0.94	0.0709	0.0675	0.0638	0.0611	0.0583	0.0561	0.0537	0.0500	0.0469	0.0443	0.0421	0.0402	0.0386	0.0371	0.0359	0.0349	0.0338	0.0352	0.0343	0.0334
1.7	1.00	0.0782	0.0745	0.0705	0.0676	0.0644	0.0620	0.0594	0.0554	0.0519	0.0491	0.0467	0.0446	0.0428	0.0412	0.0398	0.0387	0.0375	0.0390	0.0380	0.0371
1.8	1.06	0.0859	0.0818	0.0775	0.0742	0.0708	0.0682	0.0654	0.0609	0.0572	0.0541	0.0515	0.0491	0.0472	0.0454	0.0439	0.0427	0.0414	0.0431	0.0420	0.0409
1.9	1.12	0.0938	0.0894	0.0847	0.0812	0.0774	0.0746	0.0716	0.0667	0.0627	0.0593	0.0564	0.0539	0.0517	0.0498	0.0482	0.0469	0.0455	0.0473	0.0461	0.0449
2.0	1.18	0.1020	0.0972	0.0921	0.0884	0.0843	0.0812	0.0780	0.0727	0.0683	0.0647	0.0616	0.0588	0.0565	0.0544	0.0527	0.0512	0.0497	0.0516	0.0504	0.0491
2.1	1.23	0.1105	0.1054	0.0999	0.0958	0.0914	0.0881	0.0846	0.0789	0.0742	0.0703	0.0669	0.0639	0.0614	0.0592	0.0573	0.0557	0.0541	0.0562	0.0548	0.0534
2.2	1.29	0.1192	0.1137	0.1078	0.1035	0.0988	0.0952	0.0914	0.0854	0.0803	0.0761	0.0724	0.0692	0.0665	0.0641	0.0621	0.0604	0.0586	0.0609	0.0594	0.0579
2.3	1.35	0.1282	0.1224	0.1161	0.1114	0.1064	0.1026	0.0985	0.0920	0.0866	0.0820	0.0781	0.0747	0.0718	0.0692	0.0671	0.0652	0.0633	0.0657	0.0641	0.0626
2.4	1.41	0.1375	0.1313	0.1245	0.1196	0.1142	0.1102	0.1058	0.0989	0.0930	0.0882	0.0840	0.0804	0.0773	0.0745	0.0722	0.0702	0.0682	0.0708	0.0691	0.0674
2.5	1.47	0.1471	0.1404	0.1333	0.1280	0.1223	0.1180	0.1133	0.1059	0.0997	0.0946	0.0901	0.0862	0.0829	0.0799	0.0775	0.0753	0.0732	0.0760	0.0741	0.0723
2.6	1.53	0.1569	0.1498	0.1422	0.1366	0.1306	0.1260	0.1211	0.1132	0.1066	0.1011	0.0964	0.0922	0.0887	0.0855	0.0829	0.0806	0.0783	0.0813	0.0793	0.0774
2.7	1.59	0.1670	0.1595	0.1515	0.1455	0.1391	0.1342	0.1290	0.1207	0.1137	0.1078	0.1028	0.0984	0.0947	0.0913	0.0885	0.0861	0.0836	0.0868	0.0847	0.0827
2.8	1.65	0.1773	0.1694	0.1609	0.1546	0.1479	0.1427	0.1372	0.1283	0.1209	0.1147	0.1094	0.1048	0.1008	0.0972	0.0943	0.0917	0.0891	0.0925	0.0903	0.0881
2.9	1.70	0.1879	0.1796	0.1706	0.1640	0.1568	0.1514	0.1455	0.1362	0.1284	0.1218	0.1162	0.1113	0.1071	0.1033	0.1002	0.0974	0.0947	0.0983	0.0959	0.0937
3.0	1.76	0.1987	0.1900	0.1805	0.1735	0.1660	0.1603	0.1541	0.1443	0.1360	0.1291	0.1232	0.1180	0.1135	0.1096	0.1062	0.1034	0.1005	0.1042	0.1018	0.0994
3.1	1.82	0.2098	0.2006	0.1907	0.1833	0.1754	0.1694	0.1629	0.1525	0.1439	0.1366	0.1303	0.1248	0.1202	0.1160	0.1125	0.1094	0.1064	0.1104	0.1078	0.1052
3.2	1.88	0.2211	0.2115	0.2011	0.1933	0.1850	0.1787	0.1719	0.1610	0.1519	0.1442	0.1377	0.1319	0.1269	0.1226	0.1188	0.1157	0.1125	0.1166	0.1139	0.1112
3.3	1.94	0.2327	0.2226	0.2117	0.2036	0.1949	0.1882	0.1811	0.1697	0.1601	0.1520	0.1451	0.1391	0.1339	0.1293	0.1254	0.1220	0.1187	0.1230	0.1202	0.1173
3.4	2.00	0.2445	0.2340	0.2225	0.2140	0.2049	0.1979	0.1905	0.1785	0.1684	0.1600	0.1528	0.1464	0.1410	0.1362	0.1321	0.1285	0.1250	0.1296	0.1266	0.1236
3.5	2.06	0.2566	0.2456	0.2336	0.2247	0.2152	0.2079	0.2001	0.1875	0.1770	0.1682	0.1606	0.1539	0.1483	0.1432	0.1389	0.1352	0.1315	0.1363	0.1332	0.1301
3.6	2.12	0.2689	0.2574	0.2449	0.2356	0.2256	0.2180	0.2099	0.1968	0.1858	0.1765	0.1686	0.1616	0.1557	0.1504	0.1459	0.1420	0.1382	0.1432	0.1399	0.1366
3.7	2.17	0.2815	0.2694	0.2564	0.2467	0.2363	0.2284	0.2199	0.2062	0.1947	0.1851	0.1768	0.1695	0.1633	0.1577	0.1530	0.1490	0.1449	0.1502	0.1467	0.1433
3.8	2.23	0.2943	0.2817	0.2681	0.2581	0.2472	0.2389	0.2301	0.2158	0.2038	0.1937	0.1851	0.1775	0.1710	0.1652	0.1603	0.1561	0.1519	0.1574	0.1537	0.1502
3.9	2.29	0.3073	0.2942	0.2801	0.2696	0.2583	0.2497	0.2404	0.2256	0.2131	0.2026	0.1936	0.1856	0.1789	0.1728	0.1677	0.1633	0.1589	0.1647	0.1609	0.1572
4.0	2.35	0.3205	0.3070	0.2923	0.2814	0.2696	0.2606	0.2510	0.2355	0.2225	0.2116	0.2023	0.1940	0.1869	0.1806	0.1753	0.1707	0.1661	0.1721	0.1682	0.1643

Recommended Head Loss Design Range

Sizing in this region will lead to excessive head loss conditions.

Appendix G
Hydronic Friction Loss Tables

½" Uponor MLC — 50% Propylene Glycol — Feet of Head per Foot of Tubing

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	0.29	0.0134	0.0125	0.0117	0.0110	0.0104	0.0099	0.0093	0.0085	0.0078	0.0072	0.0068	0.0064	0.0060	0.0057	0.0055	0.0053	0.0051	0.0049	0.0047	0.0046
0.6	0.35	0.0177	0.0166	0.0155	0.0147	0.0138	0.0131	0.0124	0.0114	0.0105	0.0097	0.0091	0.0086	0.0082	0.0078	0.0074	0.0071	0.0069	0.0066	0.0064	0.0063
0.7	0.41	0.0224	0.0211	0.0197	0.0187	0.0176	0.0168	0.0159	0.0146	0.0134	0.0125	0.0117	0.0111	0.0105	0.0100	0.0096	0.0092	0.0089	0.0086	0.0084	0.0081
0.8	0.47	0.0275	0.0260	0.0243	0.0231	0.0217	0.0208	0.0197	0.0181	0.0167	0.0156	0.0146	0.0138	0.0131	0.0125	0.0120	0.0116	0.0112	0.0108	0.0105	0.0102
0.9	0.53	0.0331	0.0312	0.0293	0.0278	0.0262	0.0251	0.0238	0.0219	0.0202	0.0189	0.0178	0.0168	0.0160	0.0153	0.0146	0.0141	0.0136	0.0132	0.0128	0.0125
1.0	0.59	0.0391	0.0369	0.0346	0.0329	0.0311	0.0297	0.0282	0.0260	0.0241	0.0225	0.0212	0.0200	0.0191	0.0182	0.0175	0.0169	0.0163	0.0157	0.0153	0.0149
1.1	0.65	0.0454	0.0429	0.0402	0.0383	0.0362	0.0346	0.0330	0.0303	0.0281	0.0263	0.0248	0.0235	0.0224	0.0214	0.0205	0.0198	0.0191	0.0185	0.0180	0.0175
1.2	0.71	0.0521	0.0493	0.0463	0.0440	0.0417	0.0399	0.0380	0.0350	0.0325	0.0304	0.0287	0.0272	0.0259	0.0248	0.0238	0.0230	0.0222	0.0215	0.0209	0.0204
1.3	0.76	0.0591	0.0560	0.0526	0.0501	0.0474	0.0454	0.0433	0.0399	0.0371	0.0348	0.0328	0.0311	0.0296	0.0284	0.0273	0.0263	0.0254	0.0246	0.0240	0.0234
1.4	0.82	0.0665	0.0630	0.0592	0.0565	0.0535	0.0512	0.0489	0.0451	0.0419	0.0393	0.0371	0.0352	0.0336	0.0322	0.0309	0.0299	0.0289	0.0280	0.0272	0.0265
1.5	0.88	0.0742	0.0704	0.0662	0.0631	0.0598	0.0574	0.0547	0.0505	0.0470	0.0441	0.0417	0.0396	0.0377	0.0362	0.0348	0.0336	0.0325	0.0315	0.0307	0.0299
1.6	0.94	0.0823	0.0780	0.0735	0.0701	0.0665	0.0637	0.0608	0.0562	0.0524	0.0492	0.0464	0.0441	0.0421	0.0404	0.0388	0.0375	0.0363	0.0352	0.0343	0.0334
1.7	1.00	0.0907	0.0861	0.0811	0.0774	0.0734	0.0704	0.0672	0.0622	0.0579	0.0544	0.0514	0.0489	0.0467	0.0447	0.0431	0.0416	0.0402	0.0390	0.0380	0.0371
1.8	1.06	0.0994	0.0944	0.0889	0.0849	0.0806	0.0773	0.0739	0.0683	0.0637	0.0599	0.0566	0.0538	0.0514	0.0493	0.0475	0.0459	0.0444	0.0431	0.0420	0.0409
1.9	1.12	0.1085	0.1030	0.0971	0.0927	0.0881	0.0845	0.0808	0.0748	0.0698	0.0656	0.0621	0.0590	0.0564	0.0541	0.0521	0.0503	0.0487	0.0473	0.0461	0.0449
2.0	1.18	0.1178	0.1119	0.1056	0.1009	0.0958	0.0920	0.0879	0.0814	0.0760	0.0715	0.0677	0.0644	0.0615	0.0590	0.0569	0.0550	0.0532	0.0516	0.0504	0.0491
2.1	1.23	0.1275	0.1211	0.1143	0.1093	0.1038	0.0997	0.0953	0.0883	0.0825	0.0776	0.0735	0.0699	0.0669	0.0642	0.0618	0.0598	0.0579	0.0562	0.0548	0.0534
2.2	1.29	0.1374	0.1306	0.1233	0.1179	0.1121	0.1077	0.1030	0.0955	0.0892	0.0840	0.0795	0.0757	0.0724	0.0695	0.0670	0.0648	0.0627	0.0609	0.0594	0.0579
2.3	1.35	0.1477	0.1404	0.1326	0.1268	0.1206	0.1159	0.1109	0.1028	0.0961	0.0905	0.0858	0.0816	0.0781	0.0750	0.0723	0.0699	0.0677	0.0657	0.0641	0.0626
2.4	1.41	0.1583	0.1505	0.1422	0.1360	0.1294	0.1244	0.1190	0.1104	0.1033	0.0973	0.0922	0.0878	0.0840	0.0807	0.0778	0.0752	0.0729	0.0708	0.0691	0.0674
2.5	1.47	0.1691	0.1609	0.1521	0.1455	0.1384	0.1331	0.1274	0.1183	0.1106	0.1042	0.0988	0.0941	0.0901	0.0865	0.0834	0.0807	0.0782	0.0760	0.0741	0.0723
2.6	1.53	0.1803	0.1716	0.1622	0.1552	0.1477	0.1421	0.1360	0.1263	0.1182	0.1114	0.1056	0.1006	0.0963	0.0925	0.0892	0.0864	0.0837	0.0813	0.0793	0.0774
2.7	1.59	0.1917	0.1825	0.1726	0.1652	0.1573	0.1513	0.1448	0.1346	0.1260	0.1187	0.1126	0.1073	0.1028	0.0987	0.0952	0.0922	0.0893	0.0868	0.0847	0.0827
2.8	1.65	0.2034	0.1937	0.1832	0.1754	0.1671	0.1607	0.1539	0.1430	0.1339	0.1263	0.1198	0.1142	0.1094	0.1051	0.1014	0.0982	0.0952	0.0925	0.0903	0.0881
2.9	1.70	0.2154	0.2052	0.1941	0.1859	0.1771	0.1704	0.1632	0.1517	0.1421	0.1341	0.1272	0.1213	0.1162	0.1117	0.1077	0.1043	0.1011	0.0983	0.0959	0.0937
3.0	1.76	0.2277	0.2169	0.2053	0.1966	0.1873	0.1803	0.1727	0.1606	0.1505	0.1420	0.1348	0.1285	0.1231	0.1184	0.1142	0.1106	0.1073	0.1042	0.1018	0.0994
3.1	1.82	0.2402	0.2289	0.2167	0.2076	0.1979	0.1904	0.1825	0.1698	0.1591	0.1502	0.1425	0.1360	0.1303	0.1253	0.1209	0.1171	0.1135	0.1104	0.1078	0.1052
3.2	1.88	0.2531	0.2412	0.2284	0.2189	0.2086	0.2008	0.1924	0.1791	0.1679	0.1585	0.1505	0.1436	0.1376	0.1323	0.1277	0.1237	0.1200	0.1166	0.1139	0.1112
3.3	1.94	0.2662	0.2537	0.2403	0.2303	0.2196	0.2114	0.2026	0.1886	0.1769	0.1670	0.1586	0.1514	0.1451	0.1395	0.1347	0.1305	0.1266	0.1230	0.1202	0.1173
3.4	2.00	0.2795	0.2665	0.2525	0.2420	0.2308	0.2222	0.2130	0.1984	0.1861	0.1757	0.1669	0.1593	0.1527	0.1469	0.1418	0.1374	0.1333	0.1296	0.1266	0.1236
3.5	2.06	0.2932	0.2796	0.2649	0.2540	0.2422	0.2333	0.2237	0.2084	0.1955	0.1847	0.1754	0.1675	0.1605	0.1545	0.1491	0.1445	0.1402	0.1363	0.1332	0.1301
3.6	2.12	0.3071	0.2929	0.2776	0.2662	0.2539	0.2446	0.2345	0.2185	0.2051	0.1937	0.1841	0.1758	0.1685	0.1622	0.1566	0.1517	0.1472	0.1432	0.1399	0.1366
3.7	2.17	0.3212	0.3065	0.2905	0.2786	0.2658	0.2561	0.2456	0.2289	0.2149	0.2030	0.1930	0.1842	0.1767	0.1700	0.1642	0.1591	0.1544	0.1502	0.1467	0.1433
3.8	2.23	0.3357	0.3203	0.3037	0.2913	0.2780	0.2678	0.2569	0.2395	0.2248	0.2125	0.2020	0.1929	0.1850	0.1781	0.1720	0.1667	0.1618	0.1574	0.1537	0.1502
3.9	2.29	0.3503	0.3344	0.3171	0.3042	0.2903	0.2797	0.2684	0.2503	0.2350	0.2221	0.2112	0.2017	0.1935	0.1863	0.1799	0.1744	0.1693	0.1647	0.1609	0.1572
4.0	2.35	0.3653	0.3487	0.3307	0.3173	0.3029	0.2919	0.2801	0.2612	0.2454	0.2320	0.2206	0.2107	0.2021	0.1946	0.1880	0.1823	0.1769	0.1721	0.1682	0.1643

Recommended Head Loss Design Range

Sizing in this region will lead to excessive head loss conditions.

⅝" Uponor MLC — 100% Water — Feet of Head per Foot of Tubing

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	0.48	0.0043	0.0040	0.0038	0.0037	0.0036	0.0035	0.0034	0.0033	0.0032	0.0031	0.0030	0.0029	0.0028	0.0028	0.0027	0.0026	0.0026	0.0025	0.0025	0.0025
0.6	0.58	0.0058	0.0055	0.0051	0.0050	0.0049	0.0048	0.0047	0.0045	0.0043	0.0042	0.0041	0.0040	0.0039	0.0038	0.0037	0.0036	0.0036	0.0035	0.0034	0.0034
0.7	0.67	0.0075	0.0071	0.0066	0.0065	0.0063	0.0062	0.0061	0.0058	0.0056	0.0055	0.0053	0.0052	0.0050	0.0049	0.0048	0.0047	0.0046	0.0046	0.0045	0.0044
0.8	0.77	0.0094	0.0089	0.0083	0.0081	0.0079	0.0078	0.0076	0.0073	0.0071	0.0069	0.0067	0.0065	0.0063	0.0062	0.0061	0.0060	0.0058	0.0057	0.0057	0.0056
0.9	0.87	0.0115	0.0108	0.0101	0.0099	0.0097	0.0095	0.0093	0.0090	0.0087	0.0084	0.0082	0.0080	0.0078	0.0076	0.0075	0.0073	0.0072	0.0071	0.0069	0.0068
1.0	0.96	0.0137	0.0130	0.0121	0.0119	0.0116	0.0114	0.0111	0.0107	0.0104	0.0101	0.0098	0.0096	0.0093	0.0091	0.0090	0.0088	0.0086	0.0085	0.0083	0.0082
1.1	1.06	0.0161	0.0152	0.0143	0.0140	0.0137	0.0134	0.0131	0.0127	0.0123	0.0119	0.0116	0.0113	0.0110	0.0108	0.0106	0.0104	0.0102	0.0100	0.0099	0.0097
1.2	1.15	0.0187	0.0177	0.0166	0.0162	0.0159	0.0156	0.0152	0.0147	0.0142	0.0138	0.0135	0.0131	0.0128	0.0126	0.0123	0.0121	0.0119	0.0117	0.0115	0.0113
1.3	1.25	0.0214	0.0202	0.0190	0.0186	0.0182	0.0178	0.0175	0.0169	0.0164	0.0159	0.0155	0.0151	0.0147	0.0144	0.0141	0.0139	0.0136	0.0134	0.0132	0.0130
1.4	1.35	0.0242	0.0230	0.0216	0.0211	0.0207	0.0203	0.0199	0.0192	0.0186	0.0181	0.0176	0.0172	0.0168	0.0164	0.0161	0.0158	0.0155	0.0153	0.0151	0.0148
1.5	1.44	0.0272	0.0258	0.0243	0.0238	0.0233	0.0228	0.0224	0.0216	0.0210	0.0204	0.0198	0.0194	0.0189	0.0185	0.0182	0.0178	0.0175	0.0173	0.0170	0.0168
1.6	1.54	0.0304	0.0289	0.0271	0.0266	0.0260	0.0255	0.0250	0.0242	0.0234	0.0228	0.0222	0.0217	0.0212	0.0207	0.0203	0.0200	0.0196	0.0193	0.0190	0.0188
1.7	1.64	0.0337	0.0320	0.0301	0.0295	0.0289	0.0283	0.0278	0.0269	0.0260	0.0253	0.0247	0.0241	0.0236	0.0231	0.0226	0.0222	0.0218	0.0215	0.0212	0.0209
1.8	1.73	0.0372	0.0353	0.0332	0.0325	0.0319	0.0313	0.0307	0.0297	0.0288	0.0280	0.0273	0.0266	0.0260	0.0255	0.0250	0.0246	0.0242	0.0238	0.0234	0.0231
1.9	1.83	0.0408	0.0388	0.0365	0.0357	0.0350	0.0344	0.0337	0.0326	0.0316	0.0307	0.0300	0.0293	0.0286	0.0280	0.0275	0.0270	0.0266	0.0262	0.0258	0.0254
2.0	1.92	0.0445	0.0423	0.0398	0.0390	0.0382	0.0375	0.0368	0.0356	0.0346	0.0336	0.0328	0.0320	0.0313	0.0307	0.0301	0.0296	0.0291	0.0286	0.0282	0.0278
2.1	2.02	0.0484	0.0460	0.0433	0.0425	0.0416	0.0409	0.0401	0.0388	0.0376	0.0366	0.0357	0.0349	0.0341	0.0334	0.0328	0.0322	0.0317	0.0312	0.0308	0.0304
2.2	2.12	0.0524	0.0499	0.0470	0.0461	0.0451	0.0443	0.0435	0.0421	0.0408	0.0397	0.0387	0.0378	0.0370	0.0363	0.0356	0.0350	0.0344	0.0339	0.0334	0.0330
2.3	2.21	0.0566	0.0538	0.0507	0.0497	0.0487	0.0479	0.0470	0.0455	0.0441	0.0429	0.0419	0.0409	0.0400	0.0392	0.0385	0.0379	0.0372	0.0367	0.0361	0.0357
2.4	2.31	0.0609	0.0579	0.0546	0.0535	0.0524	0.0515	0.0506	0.0490	0.0475	0.0463	0.0451	0.0441	0.0431	0.0423	0.0415	0.0408	0.0401	0.0395	0.0390	0.0385
2.5	2.41	0.0653	0.0622	0.0586	0.0575	0.0563	0.0553	0.0543	0.0526	0.0511	0.0497	0.0485	0.0474	0.0464	0.0455	0.0446	0.0439	0.0431	0.0425	0.0419	0.0413
2.6	2.50	0.0699	0.0665	0.0627	0.0615	0.0603	0.0592	0.0582	0.0563	0.0547	0.0532	0.0519	0.0507	0.0497	0.0487	0.0478	0.0470	0.0462	0.0456	0.0449	0.0443
2.7	2.60	0.0746	0.0710	0.0670	0.0657	0.0644	0.0633	0.0621	0.0602	0.0584	0.0569	0.0555	0.0542	0.0531	0.0521	0.0511	0.0503	0.0494	0.0487	0.0480	0.0474
2.8	2.69	0.0794	0.0756	0.0713	0.0700	0.0686	0.0674	0.0662	0.0641	0.0623	0.0606	0.0592	0.0578	0.0566	0.0555	0.0545	0.0536	0.0527	0.0520	0.0512	0.0506
2.9	2.79	0.0844	0.0804	0.0758	0.0744	0.0729	0.0717	0.0704	0.0682	0.0662	0.0645	0.0629	0.0615	0.0602	0.0591	0.0580	0.0570	0.0561	0.0553	0.0545	0.0538
3.0	2.89	0.0894	0.0852	0.0804	0.0789	0.0773	0.0760	0.0747	0.0723	0.0703	0.0684	0.0668	0.0653	0.0640	0.0627	0.0616	0.0606	0.0596	0.0587	0.0579	0.0572
3.1	2.98	0.0947	0.0902	0.0852	0.0836	0.0819	0.0805	0.0791	0.0766	0.0744	0.0725	0.0708	0.0692	0.0678	0.0665	0.0653	0.0642	0.0632	0.0623	0.0614	0.0606
3.2	3.08	0.1000	0.0953	0.0900	0.0883	0.0866	0.0851	0.0836	0.0810	0.0787	0.0767	0.0748	0.0732	0.0717	0.0703	0.0691	0.0679	0.0668	0.0659	0.0650	0.0641
3.3	3.18	0.1055	0.1005	0.0950	0.0932	0.0913	0.0898	0.0882	0.0855	0.0831	0.0809	0.0790	0.0773	0.0757	0.0743	0.0729	0.0717	0.0706	0.0696	0.0686	0.0677
3.4	3.27	0.1111	0.1059	0.1000	0.0982	0.0962	0.0946	0.0930	0.0901	0.0876	0.0853	0.0833	0.0815	0.0798	0.0783	0.0769	0.0756	0.0744	0.0734	0.0724	0.0714
3.5	3.37	0.1168	0.1114	0.1052	0.1033	0.1012	0.0996	0.0978	0.0948	0.0921	0.0898	0.0877	0.0857	0.0840	0.0824	0.0810	0.0796	0.0784	0.0773	0.0762	0.0752
3.6	3.46	0.1226	0.1169	0.1105	0.1085	0.1064	0.1046	0.1028	0.0996	0.0968	0.0943	0.0921	0.0901	0.0883	0.0866	0.0851	0.0837	0.0824	0.0812	0.0801	0.0791
3.7	3.56	0.1286	0.1226	0.1159	0.1138	0.1116	0.1097	0.1078	0.1045	0.1016	0.0990	0.0967	0.0946	0.0927	0.0910	0.0894	0.0879	0.0865	0.0853	0.0841	0.0831
3.8	3.66	0.1347	0.1285	0.1215	0.1192	0.1169	0.1150	0.1130	0.1095	0.1065	0.1038	0.1014	0.0992	0.0972	0.0954	0.0937	0.0922	0.0907	0.0894	0.0882	0.0871

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 MLC — 100% Water — Feet of Head per Foot of Tubing

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	3.75	0.1409	0.1344	0.1271	0.1248	0.1224	0.1204	0.1183	0.1147	0.1115	0.1087	0.1061	0.1038	0.1017	0.0999	0.0981	0.0965	0.0950	0.0937	0.0924	0.0913
4.0	3.85	0.1472	0.1405	0.1328	0.1304	0.1279	0.1258	0.1236	0.1199	0.1166	0.1136	0.1110	0.1086	0.1064	0.1045	0.1026	0.1010	0.0994	0.0980	0.0967	0.0955
4.1	3.95	0.1537	0.1466	0.1387	0.1362	0.1336	0.1314	0.1291	0.1252	0.1218	0.1187	0.1159	0.1134	0.1112	0.1091	0.1072	0.1055	0.1039	0.1024	0.1011	0.0998
4.2	4.04	0.1602	0.1529	0.1447	0.1421	0.1393	0.1371	0.1347	0.1306	0.1271	0.1239	0.1210	0.1184	0.1160	0.1139	0.1119	0.1101	0.1085	0.1069	0.1055	0.1042
4.3	4.14	0.1669	0.1593	0.1508	0.1481	0.1452	0.1429	0.1404	0.1362	0.1325	0.1291	0.1261	0.1234	0.1210	0.1188	0.1167	0.1149	0.1131	0.1115	0.1100	0.1087
4.4	4.23	0.1737	0.1659	0.1570	0.1541	0.1512	0.1487	0.1462	0.1418	0.1379	0.1345	0.1314	0.1286	0.1260	0.1237	0.1216	0.1197	0.1178	0.1162	0.1147	0.1132
4.5	4.33	0.1806	0.1725	0.1633	0.1603	0.1573	0.1547	0.1521	0.1475	0.1435	0.1399	0.1367	0.1338	0.1312	0.1288	0.1266	0.1246	0.1227	0.1209	0.1194	0.1179
4.6	4.43	0.1877	0.1792	0.1697	0.1666	0.1635	0.1608	0.1581	0.1534	0.1492	0.1455	0.1422	0.1391	0.1364	0.1339	0.1316	0.1295	0.1276	0.1258	0.1241	0.1226
4.7	4.52	0.1949	0.1861	0.1762	0.1730	0.1698	0.1670	0.1642	0.1593	0.1550	0.1511	0.1477	0.1446	0.1417	0.1391	0.1368	0.1346	0.1326	0.1307	0.1290	0.1274
4.8	4.62	0.2021	0.1931	0.1828	0.1796	0.1762	0.1733	0.1704	0.1653	0.1609	0.1569	0.1533	0.1501	0.1471	0.1445	0.1420	0.1398	0.1376	0.1357	0.1340	0.1323
4.9	4.72	0.2095	0.2002	0.1895	0.1862	0.1827	0.1797	0.1767	0.1715	0.1668	0.1627	0.1590	0.1557	0.1526	0.1499	0.1473	0.1450	0.1428	0.1408	0.1390	0.1373
5.0	4.81	0.2170	0.2074	0.1964	0.1929	0.1893	0.1863	0.1831	0.1777	0.1729	0.1686	0.1648	0.1614	0.1582	0.1554	0.1527	0.1503	0.1481	0.1460	0.1441	0.1424
5.1	4.91	0.2247	0.2147	0.2033	0.1997	0.1960	0.1929	0.1896	0.1840	0.1791	0.1747	0.1707	0.1671	0.1639	0.1609	0.1582	0.1557	0.1534	0.1513	0.1493	0.1475
5.2	5.00	0.2324	0.2221	0.2104	0.2067	0.2028	0.1996	0.1962	0.1904	0.1854	0.1808	0.1767	0.1730	0.1697	0.1666	0.1638	0.1612	0.1588	0.1566	0.1546	0.1527
5.3	5.10	0.2402	0.2296	0.2175	0.2137	0.2097	0.2064	0.2029	0.1970	0.1917	0.1870	0.1828	0.1790	0.1755	0.1724	0.1695	0.1668	0.1643	0.1621	0.1600	0.1580
5.4	5.20	0.2482	0.2372	0.2248	0.2209	0.2167	0.2133	0.2097	0.2036	0.1982	0.1933	0.1890	0.1850	0.1815	0.1782	0.1752	0.1725	0.1699	0.1676	0.1654	0.1634

Recommended Head Loss Design Range

Sizing in this region will lead to excessive head loss conditions.

Appendix G
Hydronic Friction Loss Tables

⅝" Uponor MLC — 30% Propylene Glycol — Feet of Head per Foot of Tubing

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	0.48	0.0064	0.0061	0.0058	0.0056	0.0053	0.0051	0.0049	0.0046	0.0043	0.0041	0.0039	0.0037	0.0036	0.0035	0.0034	0.0032	0.0032	0.0031	0.0030	0.0029
0.6	0.58	0.0085	0.0082	0.0078	0.0075	0.0072	0.0069	0.0066	0.0062	0.0059	0.0056	0.0053	0.0051	0.0049	0.0047	0.0046	0.0044	0.0043	0.0042	0.0041	0.0040
0.7	0.67	0.0109	0.0105	0.0100	0.0096	0.0092	0.0089	0.0086	0.0080	0.0076	0.0072	0.0069	0.0066	0.0063	0.0061	0.0059	0.0058	0.0056	0.0055	0.0053	0.0052
0.8	0.77	0.0136	0.0130	0.0124	0.0120	0.0115	0.0111	0.0107	0.0100	0.0095	0.0090	0.0086	0.0083	0.0079	0.0077	0.0074	0.0072	0.0070	0.0069	0.0067	0.0066
0.9	0.87	0.0164	0.0158	0.0151	0.0145	0.0140	0.0135	0.0130	0.0122	0.0116	0.0110	0.0105	0.0101	0.0097	0.0094	0.0091	0.0088	0.0086	0.0084	0.0082	0.0081
1.0	0.96	0.0195	0.0187	0.0179	0.0173	0.0166	0.0161	0.0155	0.0146	0.0138	0.0131	0.0125	0.0121	0.0116	0.0112	0.0109	0.0106	0.0103	0.0101	0.0098	0.0097
1.1	1.06	0.0228	0.0219	0.0210	0.0202	0.0195	0.0188	0.0182	0.0171	0.0162	0.0154	0.0148	0.0142	0.0137	0.0132	0.0128	0.0125	0.0122	0.0119	0.0116	0.0114
1.2	1.15	0.0263	0.0253	0.0242	0.0234	0.0225	0.0218	0.0210	0.0198	0.0188	0.0179	0.0171	0.0165	0.0159	0.0153	0.0149	0.0145	0.0141	0.0138	0.0135	0.0133
1.3	1.25	0.0300	0.0289	0.0277	0.0267	0.0257	0.0249	0.0241	0.0227	0.0215	0.0205	0.0196	0.0189	0.0182	0.0176	0.0171	0.0167	0.0162	0.0159	0.0155	0.0153
1.4	1.35	0.0340	0.0327	0.0313	0.0302	0.0291	0.0282	0.0273	0.0257	0.0244	0.0233	0.0223	0.0214	0.0207	0.0200	0.0195	0.0189	0.0185	0.0180	0.0176	0.0174
1.5	1.44	0.0381	0.0366	0.0351	0.0339	0.0327	0.0317	0.0306	0.0289	0.0274	0.0262	0.0251	0.0241	0.0233	0.0225	0.0219	0.0213	0.0208	0.0203	0.0199	0.0196
1.6	1.54	0.0424	0.0408	0.0391	0.0378	0.0364	0.0353	0.0342	0.0322	0.0306	0.0292	0.0280	0.0270	0.0260	0.0252	0.0245	0.0239	0.0233	0.0228	0.0223	0.0219
1.7	1.64	0.0469	0.0451	0.0433	0.0419	0.0404	0.0391	0.0378	0.0357	0.0339	0.0324	0.0311	0.0299	0.0289	0.0280	0.0272	0.0265	0.0258	0.0253	0.0248	0.0243
1.8	1.73	0.0515	0.0497	0.0476	0.0461	0.0444	0.0431	0.0417	0.0394	0.0374	0.0357	0.0343	0.0330	0.0319	0.0309	0.0301	0.0293	0.0286	0.0279	0.0273	0.0269
1.9	1.83	0.0564	0.0544	0.0522	0.0505	0.0487	0.0472	0.0457	0.0432	0.0411	0.0392	0.0376	0.0362	0.0350	0.0339	0.0330	0.0322	0.0314	0.0307	0.0301	0.0296
2.0	1.92	0.0614	0.0592	0.0569	0.0550	0.0531	0.0515	0.0498	0.0471	0.0448	0.0428	0.0411	0.0396	0.0383	0.0371	0.0361	0.0352	0.0343	0.0336	0.0329	0.0324
2.1	2.02	0.0667	0.0643	0.0617	0.0598	0.0577	0.0560	0.0542	0.0512	0.0487	0.0466	0.0447	0.0431	0.0417	0.0404	0.0393	0.0383	0.0374	0.0366	0.0358	0.0352
2.2	2.12	0.0721	0.0695	0.0668	0.0646	0.0624	0.0606	0.0586	0.0555	0.0528	0.0504	0.0484	0.0467	0.0452	0.0437	0.0426	0.0415	0.0405	0.0397	0.0389	0.0382
2.3	2.21	0.0776	0.0749	0.0720	0.0697	0.0673	0.0653	0.0632	0.0599	0.0570	0.0545	0.0523	0.0504	0.0488	0.0473	0.0461	0.0449	0.0438	0.0429	0.0420	0.0413
2.4	2.31	0.0834	0.0805	0.0773	0.0749	0.0723	0.0702	0.0680	0.0644	0.0613	0.0586	0.0563	0.0543	0.0525	0.0509	0.0496	0.0483	0.0472	0.0462	0.0453	0.0445
2.5	2.41	0.0893	0.0862	0.0828	0.0803	0.0775	0.0753	0.0729	0.0690	0.0657	0.0629	0.0604	0.0583	0.0564	0.0547	0.0533	0.0519	0.0507	0.0496	0.0486	0.0479
2.6	2.50	0.0954	0.0921	0.0885	0.0858	0.0828	0.0805	0.0779	0.0738	0.0703	0.0673	0.0646	0.0624	0.0604	0.0585	0.0570	0.0556	0.0543	0.0532	0.0521	0.0513
2.7	2.60	0.1016	0.0981	0.0944	0.0914	0.0883	0.0858	0.0831	0.0788	0.0750	0.0718	0.0690	0.0666	0.0645	0.0625	0.0609	0.0594	0.0580	0.0568	0.0557	0.0548
2.8	2.69	0.1081	0.1044	0.1004	0.0973	0.0940	0.0913	0.0885	0.0839	0.0799	0.0765	0.0735	0.0709	0.0687	0.0666	0.0649	0.0633	0.0618	0.0606	0.0593	0.0584
2.9	2.79	0.1147	0.1107	0.1065	0.1033	0.0998	0.0969	0.0939	0.0891	0.0849	0.0813	0.0781	0.0754	0.0730	0.0708	0.0690	0.0673	0.0657	0.0644	0.0631	0.0621
3.0	2.89	0.1214	0.1173	0.1128	0.1094	0.1057	0.1027	0.0996	0.0944	0.0900	0.0862	0.0828	0.0800	0.0774	0.0751	0.0733	0.0714	0.0698	0.0684	0.0670	0.0660
3.1	2.98	0.1283	0.1240	0.1193	0.1157	0.1118	0.1087	0.1053	0.0999	0.0952	0.0912	0.0877	0.0847	0.0820	0.0796	0.0776	0.0757	0.0739	0.0724	0.0710	0.0699
3.2	3.08	0.1354	0.1308	0.1259	0.1221	0.1180	0.1147	0.1112	0.1055	0.1006	0.0964	0.0927	0.0895	0.0867	0.0841	0.0820	0.0800	0.0781	0.0766	0.0751	0.0739
3.3	3.18	0.1426	0.1378	0.1327	0.1287	0.1244	0.1209	0.1172	0.1113	0.1061	0.1017	0.0978	0.0944	0.0915	0.0888	0.0866	0.0845	0.0825	0.0809	0.0792	0.0781
3.4	3.27	0.1500	0.1450	0.1396	0.1354	0.1309	0.1273	0.1234	0.1171	0.1117	0.1071	0.1030	0.0995	0.0964	0.0935	0.0912	0.0890	0.0869	0.0852	0.0835	0.0823
3.5	3.37	0.1576	0.1523	0.1467	0.1423	0.1376	0.1338	0.1297	0.1231	0.1175	0.1126	0.1083	0.1046	0.1014	0.0984	0.0960	0.0937	0.0915	0.0897	0.0879	0.0866
3.6	3.46	0.1653	0.1598	0.1539	0.1493	0.1444	0.1404	0.1362	0.1293	0.1234	0.1182	0.1137	0.1099	0.1065	0.1034	0.1009	0.0984	0.0961	0.0943	0.0924	0.0910
3.7	3.56	0.1732	0.1674	0.1612	0.1564	0.1513	0.1472	0.1427	0.1355	0.1293	0.1240	0.1193	0.1153	0.1117	0.1085	0.1058	0.1033	0.1009	0.0989	0.0970	0.0955
3.8	3.66	0.1812	0.1752	0.1687	0.1637	0.1584	0.1541	0.1494	0.1419	0.1355	0.1299	0.1250	0.1208	0.1171	0.1136	0.1109	0.1082	0.1058	0.1037	0.1017	0.1002
3.9	3.75	0.1893	0.1831	0.1764	0.1712	0.1656	0.1611	0.1563	0.1485	0.1417	0.1359	0.1308	0.1264	0.1225	0.1189	0.1161	0.1133	0.1107	0.1086	0.1064	0.1049

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 MLC — 30% Propylene Glycol — Feet of Head per Foot of Tubing

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
4.0	3.85	0.1977	0.1912	0.1842	0.1788	0.1729	0.1683	0.1632	0.1551	0.1481	0.1420	0.1367	0.1321	0.1281	0.1244	0.1214	0.1185	0.1158	0.1135	0.1113	0.1097
4.1	3.95	0.2061	0.1994	0.1921	0.1865	0.1804	0.1756	0.1703	0.1619	0.1546	0.1482	0.1427	0.1380	0.1337	0.1299	0.1268	0.1237	0.1209	0.1186	0.1163	0.1146
4.2	4.04	0.2148	0.2077	0.2002	0.1943	0.1881	0.1830	0.1776	0.1688	0.1612	0.1546	0.1488	0.1439	0.1395	0.1355	0.1323	0.1291	0.1262	0.1238	0.1214	0.1196
4.3	4.14	0.2235	0.2163	0.2084	0.2023	0.1958	0.1906	0.1849	0.1758	0.1679	0.1611	0.1551	0.1500	0.1454	0.1412	0.1379	0.1346	0.1315	0.1290	0.1265	0.1247
4.4	4.23	0.2325	0.2249	0.2168	0.2105	0.2037	0.1983	0.1924	0.1829	0.1747	0.1677	0.1614	0.1561	0.1514	0.1470	0.1435	0.1401	0.1370	0.1344	0.1318	0.1299
4.5	4.33	0.2415	0.2337	0.2253	0.2188	0.2118	0.2061	0.2000	0.1902	0.1817	0.1744	0.1679	0.1624	0.1575	0.1530	0.1493	0.1458	0.1425	0.1398	0.1371	0.1351
4.6	4.43	0.2508	0.2427	0.2340	0.2272	0.2199	0.2141	0.2078	0.1976	0.1888	0.1812	0.1745	0.1688	0.1637	0.1590	0.1552	0.1516	0.1482	0.1454	0.1426	0.1405
4.7	4.52	0.2601	0.2517	0.2427	0.2357	0.2282	0.2221	0.2157	0.2051	0.1960	0.1881	0.1812	0.1753	0.1700	0.1651	0.1612	0.1574	0.1539	0.1510	0.1481	0.1460
4.8	4.62	0.2696	0.2610	0.2517	0.2444	0.2366	0.2304	0.2237	0.2127	0.2033	0.1951	0.1880	0.1819	0.1764	0.1714	0.1673	0.1634	0.1598	0.1567	0.1537	0.1515
4.9	4.72	0.2793	0.2704	0.2607	0.2532	0.2452	0.2387	0.2318	0.2205	0.2107	0.2023	0.1949	0.1886	0.1829	0.1777	0.1735	0.1695	0.1657	0.1626	0.1595	0.1572
5.0	4.81	0.2891	0.2799	0.2699	0.2622	0.2539	0.2472	0.2400	0.2284	0.2183	0.2096	0.2019	0.1954	0.1895	0.1841	0.1798	0.1756	0.1717	0.1685	0.1653	0.1629

Recommended Head Loss Design Range

Sizing in this region will lead to excessive head loss conditions.

Appendix G
Hydronic Friction Loss Tables

⅝" Uponor MLC — 40% Propylene Glycol — Feet of Head per Foot of Tubing

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	0.48	0.0078	0.0074	0.0070	0.0066	0.0063	0.0060	0.0057	0.0053	0.0049	0.0046	0.0043	0.0041	0.0039	0.0038	0.0036	0.0035	0.0034	0.0035	0.0034	0.0033
0.6	0.58	0.0104	0.0099	0.0093	0.0089	0.0084	0.0080	0.0077	0.0071	0.0066	0.0062	0.0059	0.0056	0.0053	0.0051	0.0049	0.0048	0.0046	0.0048	0.0047	0.0045
0.7	0.67	0.0133	0.0126	0.0119	0.0113	0.0108	0.0103	0.0099	0.0091	0.0085	0.0080	0.0076	0.0072	0.0069	0.0066	0.0064	0.0062	0.0060	0.0062	0.0061	0.0059
0.8	0.77	0.0165	0.0156	0.0147	0.0141	0.0134	0.0128	0.0123	0.0114	0.0106	0.0100	0.0095	0.0090	0.0086	0.0083	0.0080	0.0077	0.0075	0.0078	0.0076	0.0074
0.9	0.87	0.0199	0.0189	0.0178	0.0170	0.0162	0.0156	0.0149	0.0138	0.0129	0.0122	0.0115	0.0110	0.0105	0.0101	0.0098	0.0095	0.0092	0.0096	0.0093	0.0091
1.0	0.96	0.0236	0.0224	0.0212	0.0202	0.0193	0.0185	0.0177	0.0164	0.0154	0.0145	0.0138	0.0131	0.0126	0.0121	0.0117	0.0113	0.0110	0.0114	0.0111	0.0108
1.1	1.06	0.0275	0.0262	0.0247	0.0236	0.0225	0.0217	0.0207	0.0193	0.0181	0.0170	0.0162	0.0154	0.0148	0.0142	0.0138	0.0133	0.0129	0.0135	0.0131	0.0128
1.2	1.15	0.0317	0.0301	0.0285	0.0273	0.0260	0.0250	0.0240	0.0223	0.0209	0.0197	0.0188	0.0179	0.0172	0.0165	0.0160	0.0155	0.0150	0.0156	0.0152	0.0148
1.3	1.25	0.0360	0.0343	0.0325	0.0311	0.0297	0.0285	0.0274	0.0255	0.0239	0.0226	0.0215	0.0205	0.0197	0.0189	0.0183	0.0178	0.0172	0.0179	0.0175	0.0170
1.4	1.35	0.0407	0.0387	0.0367	0.0352	0.0335	0.0323	0.0310	0.0288	0.0271	0.0256	0.0244	0.0233	0.0223	0.0215	0.0208	0.0202	0.0196	0.0204	0.0199	0.0194
1.5	1.44	0.0455	0.0434	0.0411	0.0394	0.0376	0.0362	0.0347	0.0324	0.0304	0.0288	0.0274	0.0262	0.0251	0.0242	0.0234	0.0227	0.0221	0.0230	0.0224	0.0218
1.6	1.54	0.0506	0.0482	0.0457	0.0438	0.0418	0.0403	0.0387	0.0361	0.0339	0.0321	0.0306	0.0292	0.0281	0.0270	0.0262	0.0254	0.0247	0.0257	0.0250	0.0244
1.7	1.64	0.0558	0.0533	0.0505	0.0485	0.0463	0.0446	0.0428	0.0400	0.0376	0.0356	0.0339	0.0324	0.0311	0.0300	0.0291	0.0282	0.0274	0.0285	0.0278	0.0271
1.8	1.73	0.0613	0.0585	0.0555	0.0533	0.0509	0.0491	0.0471	0.0440	0.0414	0.0392	0.0374	0.0357	0.0344	0.0331	0.0321	0.0312	0.0303	0.0314	0.0307	0.0299
1.9	1.83	0.0670	0.0640	0.0607	0.0583	0.0557	0.0537	0.0516	0.0482	0.0454	0.0430	0.0410	0.0392	0.0377	0.0363	0.0352	0.0342	0.0333	0.0345	0.0337	0.0329
2.0	1.92	0.0729	0.0697	0.0661	0.0635	0.0607	0.0586	0.0563	0.0526	0.0495	0.0470	0.0448	0.0428	0.0412	0.0397	0.0385	0.0374	0.0364	0.0377	0.0368	0.0359
2.1	2.02	0.0791	0.0755	0.0717	0.0689	0.0659	0.0635	0.0611	0.0571	0.0538	0.0510	0.0487	0.0466	0.0448	0.0432	0.0419	0.0407	0.0396	0.0411	0.0401	0.0391
2.2	2.12	0.0854	0.0816	0.0775	0.0745	0.0712	0.0687	0.0661	0.0618	0.0582	0.0553	0.0527	0.0504	0.0485	0.0468	0.0454	0.0441	0.0429	0.0445	0.0435	0.0424
2.3	2.21	0.0919	0.0878	0.0834	0.0802	0.0767	0.0741	0.0712	0.0666	0.0628	0.0596	0.0569	0.0545	0.0524	0.0506	0.0490	0.0477	0.0464	0.0481	0.0470	0.0458
2.4	2.31	0.0986	0.0943	0.0896	0.0861	0.0824	0.0796	0.0765	0.0716	0.0675	0.0641	0.0612	0.0586	0.0564	0.0544	0.0528	0.0514	0.0499	0.0518	0.0506	0.0494
2.5	2.41	0.1055	0.1009	0.0959	0.0922	0.0883	0.0852	0.0820	0.0768	0.0724	0.0688	0.0656	0.0629	0.0605	0.0584	0.0567	0.0551	0.0536	0.0556	0.0543	0.0530
2.6	2.50	0.1126	0.1077	0.1024	0.0985	0.0943	0.0911	0.0876	0.0821	0.0774	0.0736	0.0702	0.0673	0.0648	0.0625	0.0607	0.0590	0.0574	0.0595	0.0581	0.0568
2.7	2.60	0.1199	0.1147	0.1091	0.1049	0.1005	0.0971	0.0934	0.0875	0.0826	0.0785	0.0749	0.0718	0.0692	0.0668	0.0648	0.0631	0.0613	0.0636	0.0621	0.0606
2.8	2.69	0.1273	0.1219	0.1159	0.1115	0.1068	0.1032	0.0993	0.0931	0.0879	0.0835	0.0798	0.0765	0.0737	0.0711	0.0690	0.0672	0.0653	0.0677	0.0662	0.0646
2.9	2.79	0.1350	0.1292	0.1230	0.1183	0.1133	0.1095	0.1054	0.0989	0.0934	0.0887	0.0848	0.0813	0.0783	0.0756	0.0734	0.0714	0.0695	0.0720	0.0703	0.0687
3.0	2.89	0.1428	0.1367	0.1302	0.1253	0.1200	0.1160	0.1117	0.1048	0.0989	0.0941	0.0899	0.0862	0.0830	0.0802	0.0778	0.0758	0.0737	0.0764	0.0746	0.0729
3.1	2.98	0.1509	0.1445	0.1375	0.1324	0.1269	0.1226	0.1181	0.1108	0.1047	0.0995	0.0951	0.0912	0.0879	0.0849	0.0824	0.0802	0.0781	0.0809	0.0790	0.0772
3.2	3.08	0.1591	0.1523	0.1451	0.1397	0.1339	0.1294	0.1246	0.1170	0.1105	0.1051	0.1005	0.0964	0.0929	0.0897	0.0871	0.0848	0.0826	0.0855	0.0836	0.0817
3.3	3.18	0.1674	0.1604	0.1528	0.1471	0.1410	0.1363	0.1313	0.1233	0.1165	0.1109	0.1060	0.1017	0.0980	0.0947	0.0919	0.0895	0.0871	0.0902	0.0882	0.0862
3.4	3.27	0.1760	0.1686	0.1607	0.1547	0.1483	0.1434	0.1382	0.1298	0.1227	0.1167	0.1116	0.1071	0.1032	0.0998	0.0968	0.0943	0.0918	0.0951	0.0929	0.0908
3.5	3.37	0.1848	0.1771	0.1687	0.1625	0.1558	0.1507	0.1452	0.1364	0.1289	0.1227	0.1173	0.1126	0.1085	0.1049	0.1019	0.0992	0.0966	0.1000	0.0978	0.0956
3.6	3.46	0.1937	0.1856	0.1769	0.1704	0.1634	0.1581	0.1523	0.1431	0.1353	0.1288	0.1232	0.1182	0.1140	0.1102	0.1070	0.1043	0.1015	0.1051	0.1027	0.1004
3.7	3.56	0.2028	0.1944	0.1853	0.1785	0.1712	0.1656	0.1596	0.1500	0.1419	0.1351	0.1292	0.1240	0.1196	0.1156	0.1123	0.1094	0.1065	0.1103	0.1078	0.1054
3.8	3.66	0.2121	0.2033	0.1938	0.1868	0.1791	0.1733	0.1671	0.1570	0.1485	0.1414	0.1353	0.1299	0.1253	0.1211	0.1176	0.1146	0.1116	0.1155	0.1129	0.1104
3.9	3.75	0.2215	0.2124	0.2025	0.1952	0.1872	0.1812	0.1747	0.1642	0.1553	0.1479	0.1415	0.1359	0.1311	0.1267	0.1231	0.1200	0.1168	0.1209	0.1182	0.1156

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Recommended Head Loss Design Range

Sizing in this region will lead to excessive head loss conditions.

Appendix G
Hydronic Friction Loss Tables

⅝" Uponor MLC — 40% Propylene Glycol — Feet of Head per Foot of Tubing

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
4.0	3.85	0.2311	0.2216	0.2114	0.2037	0.1955	0.1892	0.1824	0.1715	0.1623	0.1546	0.1479	0.1420	0.1370	0.1325	0.1287	0.1254	0.1221	0.1264	0.1236	0.1208
4.1	3.95	0.2409	0.2311	0.2204	0.2124	0.2039	0.1973	0.1903	0.1789	0.1693	0.1613	0.1544	0.1482	0.1430	0.1383	0.1344	0.1310	0.1275	0.1320	0.1291	0.1262
4.2	4.04	0.2509	0.2406	0.2296	0.2213	0.2124	0.2056	0.1983	0.1865	0.1765	0.1682	0.1610	0.1546	0.1492	0.1443	0.1402	0.1366	0.1331	0.1377	0.1347	0.1317
4.3	4.14	0.2610	0.2504	0.2389	0.2303	0.2211	0.2140	0.2064	0.1942	0.1838	0.1752	0.1677	0.1611	0.1554	0.1504	0.1461	0.1424	0.1387	0.1435	0.1403	0.1372
4.4	4.23	0.2713	0.2603	0.2484	0.2395	0.2299	0.2226	0.2147	0.2020	0.1913	0.1823	0.1745	0.1676	0.1618	0.1565	0.1521	0.1483	0.1444	0.1494	0.1461	0.1429
4.5	4.33	0.2818	0.2704	0.2580	0.2488	0.2389	0.2313	0.2231	0.2100	0.1989	0.1895	0.1815	0.1743	0.1683	0.1628	0.1582	0.1542	0.1503	0.1554	0.1520	0.1487
4.6	4.43	0.2924	0.2806	0.2678	0.2583	0.2480	0.2402	0.2317	0.2181	0.2066	0.1969	0.1886	0.1812	0.1749	0.1692	0.1644	0.1603	0.1562	0.1616	0.1580	0.1546
4.7	4.52	0.3032	0.2910	0.2778	0.2679	0.2573	0.2492	0.2404	0.2263	0.2144	0.2044	0.1957	0.1881	0.1816	0.1757	0.1708	0.1665	0.1622	0.1678	0.1641	0.1605

Recommended Head Loss Design Range

Sizing in this region will lead to excessive head loss conditions.

Appendix G
Hydronic Friction Loss Tables

⅝" Uponor MLC — 50% Propylene Glycol — Feet of Head per Foot of Tubing

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	0.48	0.0093	0.0088	0.0082	0.0077	0.0073	0.0069	0.0066	0.0060	0.0055	0.0052	0.0048	0.0046	0.0043	0.0041	0.0039	0.0038	0.0037	0.0035	0.0034	0.0033
0.6	0.58	0.0123	0.0116	0.0109	0.0103	0.0097	0.0093	0.0088	0.0081	0.0075	0.0069	0.0065	0.0062	0.0059	0.0056	0.0054	0.0052	0.0050	0.0048	0.0047	0.0045
0.7	0.67	0.0157	0.0148	0.0139	0.0132	0.0124	0.0119	0.0113	0.0104	0.0096	0.0090	0.0084	0.0080	0.0076	0.0072	0.0069	0.0067	0.0064	0.0062	0.0061	0.0059
0.8	0.77	0.0193	0.0183	0.0171	0.0163	0.0154	0.0147	0.0140	0.0129	0.0119	0.0112	0.0105	0.0099	0.0095	0.0090	0.0087	0.0084	0.0081	0.0078	0.0076	0.0074
0.9	0.87	0.0233	0.0220	0.0207	0.0197	0.0186	0.0178	0.0170	0.0156	0.0145	0.0136	0.0128	0.0121	0.0115	0.0110	0.0106	0.0102	0.0099	0.0096	0.0093	0.0091
1.0	0.96	0.0275	0.0260	0.0245	0.0233	0.0221	0.0211	0.0201	0.0186	0.0172	0.0162	0.0152	0.0145	0.0138	0.0132	0.0127	0.0122	0.0118	0.0114	0.0111	0.0108
1.1	1.06	0.0320	0.0303	0.0285	0.0272	0.0258	0.0247	0.0235	0.0217	0.0202	0.0189	0.0179	0.0170	0.0162	0.0155	0.0149	0.0144	0.0139	0.0135	0.0131	0.0128
1.2	1.15	0.0368	0.0349	0.0328	0.0313	0.0297	0.0284	0.0271	0.0251	0.0233	0.0219	0.0207	0.0196	0.0187	0.0180	0.0173	0.0167	0.0161	0.0156	0.0152	0.0148
1.3	1.25	0.0418	0.0397	0.0374	0.0356	0.0338	0.0324	0.0310	0.0286	0.0267	0.0250	0.0237	0.0225	0.0215	0.0206	0.0198	0.0191	0.0185	0.0179	0.0175	0.0170
1.4	1.35	0.0471	0.0447	0.0421	0.0402	0.0382	0.0366	0.0350	0.0324	0.0302	0.0284	0.0268	0.0255	0.0243	0.0233	0.0225	0.0217	0.0210	0.0204	0.0199	0.0194
1.5	1.44	0.0526	0.0500	0.0471	0.0450	0.0427	0.0410	0.0392	0.0363	0.0339	0.0318	0.0301	0.0286	0.0274	0.0263	0.0253	0.0244	0.0237	0.0230	0.0224	0.0218
1.6	1.54	0.0584	0.0555	0.0523	0.0500	0.0475	0.0456	0.0436	0.0404	0.0377	0.0355	0.0336	0.0320	0.0306	0.0293	0.0282	0.0273	0.0264	0.0257	0.0250	0.0244
1.7	1.64	0.0644	0.0612	0.0578	0.0552	0.0525	0.0504	0.0482	0.0447	0.0418	0.0393	0.0372	0.0354	0.0339	0.0325	0.0313	0.0303	0.0293	0.0285	0.0278	0.0271
1.8	1.73	0.0707	0.0672	0.0635	0.0607	0.0577	0.0554	0.0530	0.0492	0.0460	0.0433	0.0410	0.0391	0.0374	0.0359	0.0346	0.0334	0.0324	0.0314	0.0307	0.0299
1.9	1.83	0.0771	0.0734	0.0693	0.0663	0.0631	0.0606	0.0580	0.0539	0.0504	0.0474	0.0450	0.0428	0.0410	0.0393	0.0379	0.0367	0.0356	0.0345	0.0337	0.0329
2.0	1.92	0.0838	0.0798	0.0754	0.0722	0.0687	0.0660	0.0632	0.0587	0.0549	0.0517	0.0491	0.0467	0.0447	0.0430	0.0414	0.0401	0.0389	0.0377	0.0368	0.0359
2.1	2.02	0.0908	0.0864	0.0817	0.0782	0.0745	0.0716	0.0686	0.0637	0.0596	0.0562	0.0533	0.0508	0.0486	0.0467	0.0451	0.0436	0.0423	0.0411	0.0401	0.0391
2.2	2.12	0.0979	0.0933	0.0882	0.0845	0.0804	0.0774	0.0741	0.0689	0.0645	0.0608	0.0577	0.0550	0.0527	0.0506	0.0488	0.0473	0.0458	0.0445	0.0435	0.0424
2.3	2.21	0.1053	0.1003	0.0949	0.0909	0.0866	0.0833	0.0798	0.0742	0.0695	0.0656	0.0622	0.0594	0.0568	0.0546	0.0527	0.0510	0.0495	0.0481	0.0470	0.0458
2.4	2.31	0.1129	0.1076	0.1018	0.0976	0.0930	0.0895	0.0857	0.0797	0.0747	0.0705	0.0669	0.0638	0.0612	0.0588	0.0567	0.0550	0.0533	0.0518	0.0506	0.0494
2.5	2.41	0.1207	0.1150	0.1089	0.1044	0.0995	0.0958	0.0918	0.0854	0.0801	0.0756	0.0718	0.0685	0.0656	0.0631	0.0609	0.0590	0.0572	0.0556	0.0543	0.0530
2.6	2.50	0.1287	0.1227	0.1162	0.1114	0.1062	0.1023	0.0980	0.0913	0.0856	0.0808	0.0767	0.0732	0.0702	0.0675	0.0652	0.0631	0.0612	0.0595	0.0581	0.0568
2.7	2.60	0.1370	0.1306	0.1237	0.1186	0.1131	0.1089	0.1044	0.0973	0.0913	0.0862	0.0819	0.0781	0.0749	0.0721	0.0696	0.0674	0.0654	0.0636	0.0621	0.0606
2.8	2.69	0.1454	0.1387	0.1314	0.1260	0.1202	0.1158	0.1110	0.1034	0.0971	0.0917	0.0871	0.0832	0.0797	0.0767	0.0741	0.0718	0.0697	0.0677	0.0662	0.0646
2.9	2.79	0.1540	0.1470	0.1393	0.1336	0.1275	0.1228	0.1178	0.1098	0.1030	0.0974	0.0925	0.0884	0.0847	0.0815	0.0787	0.0763	0.0740	0.0720	0.0703	0.0687
3.0	2.89	0.1629	0.1554	0.1474	0.1414	0.1349	0.1300	0.1247	0.1163	0.1092	0.1032	0.0981	0.0937	0.0898	0.0865	0.0835	0.0809	0.0786	0.0764	0.0746	0.0729
3.1	2.98	0.1719	0.1641	0.1557	0.1493	0.1425	0.1374	0.1318	0.1229	0.1154	0.1091	0.1037	0.0991	0.0951	0.0915	0.0884	0.0857	0.0832	0.0809	0.0790	0.0772
3.2	3.08	0.1812	0.1730	0.1641	0.1575	0.1503	0.1449	0.1390	0.1297	0.1218	0.1152	0.1096	0.1047	0.1004	0.0967	0.0934	0.0906	0.0879	0.0855	0.0836	0.0817
3.3	3.18	0.1906	0.1820	0.1727	0.1658	0.1583	0.1526	0.1465	0.1367	0.1284	0.1214	0.1155	0.1104	0.1059	0.1020	0.0986	0.0955	0.0928	0.0902	0.0882	0.0862
3.4	3.27	0.2003	0.1913	0.1816	0.1743	0.1664	0.1604	0.1540	0.1438	0.1351	0.1278	0.1216	0.1162	0.1115	0.1074	0.1038	0.1006	0.0977	0.0951	0.0929	0.0908
3.5	3.37	0.2101	0.2007	0.1906	0.1829	0.1747	0.1685	0.1618	0.1510	0.1420	0.1343	0.1278	0.1222	0.1173	0.1129	0.1092	0.1059	0.1028	0.1000	0.0978	0.0956
3.6	3.46	0.2202	0.2104	0.1997	0.1918	0.1832	0.1767	0.1697	0.1584	0.1490	0.1410	0.1342	0.1283	0.1231	0.1186	0.1147	0.1112	0.1080	0.1051	0.1027	0.1004
3.7	3.56	0.2304	0.2202	0.2091	0.2008	0.1919	0.1850	0.1777	0.1660	0.1561	0.1478	0.1407	0.1345	0.1291	0.1244	0.1203	0.1166	0.1133	0.1103	0.1078	0.1054
3.8	3.66	0.2408	0.2302	0.2186	0.2100	0.2007	0.1936	0.1859	0.1737	0.1634	0.1547	0.1473	0.1408	0.1352	0.1303	0.1260	0.1222	0.1187	0.1155	0.1129	0.1104
3.9	3.75	0.2514	0.2404	0.2283	0.2193	0.2097	0.2023	0.1943	0.1816	0.1708	0.1618	0.1540	0.1473	0.1415	0.1363	0.1318	0.1279	0.1242	0.1209	0.1182	0.1156

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Recommended Head Loss Design Range

Sizing in this region will lead to excessive head loss conditions.

Appendix G
Hydronic Friction Loss Tables

⅝" Uponor MLC — 50% Propylene Glycol — Feet of Head per Foot of Tubing

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
4.0	3.85	0.2622	0.2507	0.2382	0.2289	0.2188	0.2111	0.2028	0.1896	0.1784	0.1690	0.1609	0.1539	0.1478	0.1424	0.1378	0.1337	0.1298	0.1264	0.1236	0.1208
4.1	3.95	0.2732	0.2613	0.2483	0.2386	0.2281	0.2201	0.2115	0.1977	0.1861	0.1763	0.1679	0.1606	0.1543	0.1487	0.1438	0.1395	0.1356	0.1320	0.1291	0.1262
4.2	4.04	0.2844	0.2720	0.2585	0.2485	0.2376	0.2293	0.2203	0.2060	0.1940	0.1837	0.1750	0.1675	0.1609	0.1551	0.1500	0.1456	0.1414	0.1377	0.1347	0.1317
4.3	4.14	0.2958	0.2829	0.2689	0.2585	0.2472	0.2386	0.2293	0.2145	0.2019	0.1913	0.1823	0.1744	0.1676	0.1616	0.1563	0.1517	0.1474	0.1435	0.1403	0.1372
4.4	4.23	0.3073	0.2940	0.2795	0.2687	0.2570	0.2481	0.2385	0.2231	0.2101	0.1991	0.1897	0.1815	0.1744	0.1682	0.1627	0.1579	0.1534	0.1494	0.1461	0.1429
4.5	4.33	0.3191	0.3053	0.2903	0.2791	0.2670	0.2577	0.2478	0.2318	0.2183	0.2069	0.1972	0.1887	0.1814	0.1749	0.1692	0.1642	0.1596	0.1554	0.1520	0.1487
4.6	4.43	0.3310	0.3167	0.3012	0.2896	0.2771	0.2675	0.2572	0.2407	0.2267	0.2149	0.2048	0.1961	0.1885	0.1817	0.1758	0.1707	0.1659	0.1616	0.1580	0.1546
4.7	4.52	0.3431	0.3283	0.3123	0.3003	0.2873	0.2774	0.2668	0.2497	0.2353	0.2230	0.2126	0.2035	0.1956	0.1887	0.1826	0.1772	0.1723	0.1678	0.1641	0.1605

Recommended Head Loss Design Range

Sizing in this region will lead to excessive head loss conditions.

Appendix G
Hydronic Friction Loss Tables

¾" Uponor MLC — 100% Water — Feet of Head per Foot of Tubing

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	0.77	0.0031	0.0030	0.0028	0.0027	0.0026	0.0026	0.0025	0.0024	0.0023	0.0023	0.0022	0.0021	0.0021	0.0020	0.0020	0.0020	0.0019	0.0019	0.0019	0.0018
0.6	0.92	0.0043	0.0040	0.0038	0.0037	0.0036	0.0035	0.0034	0.0033	0.0032	0.0031	0.0030	0.0029	0.0029	0.0028	0.0027	0.0027	0.0026	0.0026	0.0026	0.0025
0.7	1.08	0.0055	0.0052	0.0049	0.0048	0.0047	0.0046	0.0045	0.0043	0.0042	0.0040	0.0039	0.0038	0.0037	0.0037	0.0036	0.0035	0.0035	0.0034	0.0033	0.0033
0.8	1.23	0.0069	0.0065	0.0061	0.0060	0.0059	0.0057	0.0056	0.0054	0.0053	0.0051	0.0050	0.0048	0.0047	0.0046	0.0045	0.0044	0.0044	0.0043	0.0042	0.0042
0.9	1.38	0.0084	0.0080	0.0075	0.0073	0.0072	0.0070	0.0069	0.0066	0.0064	0.0062	0.0061	0.0059	0.0058	0.0057	0.0056	0.0054	0.0054	0.0053	0.0052	0.0051
1.0	1.54	0.0101	0.0096	0.0090	0.0088	0.0086	0.0084	0.0083	0.0080	0.0077	0.0075	0.0073	0.0071	0.0070	0.0068	0.0067	0.0065	0.0064	0.0063	0.0062	0.0061
1.1	1.69	0.0119	0.0112	0.0106	0.0103	0.0101	0.0099	0.0097	0.0094	0.0091	0.0088	0.0086	0.0084	0.0082	0.0080	0.0079	0.0077	0.0076	0.0075	0.0074	0.0073
1.2	1.84	0.0138	0.0131	0.0123	0.0120	0.0117	0.0115	0.0113	0.0109	0.0106	0.0103	0.0100	0.0098	0.0096	0.0094	0.0092	0.0090	0.0089	0.0087	0.0086	0.0085
1.3	2.00	0.0158	0.0150	0.0141	0.0138	0.0135	0.0132	0.0130	0.0125	0.0122	0.0118	0.0115	0.0112	0.0110	0.0108	0.0106	0.0104	0.0102	0.0100	0.0099	0.0097
1.4	2.15	0.0179	0.0170	0.0160	0.0157	0.0153	0.0150	0.0148	0.0143	0.0138	0.0135	0.0131	0.0128	0.0125	0.0123	0.0120	0.0118	0.0116	0.0114	0.0113	0.0111
1.5	2.30	0.0201	0.0191	0.0180	0.0176	0.0173	0.0170	0.0166	0.0161	0.0156	0.0152	0.0148	0.0144	0.0141	0.0138	0.0136	0.0133	0.0131	0.0129	0.0127	0.0125
1.6	2.46	0.0225	0.0214	0.0201	0.0197	0.0193	0.0190	0.0186	0.0180	0.0175	0.0170	0.0166	0.0162	0.0158	0.0155	0.0152	0.0149	0.0147	0.0145	0.0143	0.0141
1.7	2.61	0.0250	0.0237	0.0223	0.0219	0.0214	0.0211	0.0207	0.0200	0.0194	0.0189	0.0184	0.0180	0.0176	0.0172	0.0169	0.0166	0.0163	0.0161	0.0159	0.0157
1.8	2.76	0.0275	0.0262	0.0247	0.0242	0.0237	0.0233	0.0228	0.0221	0.0214	0.0209	0.0203	0.0199	0.0195	0.0191	0.0187	0.0184	0.0181	0.0178	0.0176	0.0173
1.9	2.92	0.0302	0.0287	0.0271	0.0266	0.0260	0.0256	0.0251	0.0243	0.0236	0.0229	0.0224	0.0219	0.0214	0.0210	0.0206	0.0202	0.0199	0.0196	0.0193	0.0191
2.0	3.07	0.0330	0.0314	0.0296	0.0290	0.0284	0.0279	0.0274	0.0266	0.0258	0.0251	0.0245	0.0239	0.0234	0.0230	0.0225	0.0222	0.0218	0.0215	0.0212	0.0209
2.1	3.23	0.0359	0.0342	0.0322	0.0316	0.0310	0.0304	0.0299	0.0289	0.0281	0.0273	0.0267	0.0261	0.0255	0.0250	0.0246	0.0241	0.0238	0.0234	0.0231	0.0228
2.2	3.38	0.0389	0.0370	0.0349	0.0343	0.0336	0.0330	0.0324	0.0314	0.0305	0.0297	0.0289	0.0283	0.0277	0.0272	0.0267	0.0262	0.0258	0.0254	0.0251	0.0247
2.3	3.53	0.0420	0.0400	0.0377	0.0370	0.0363	0.0357	0.0350	0.0339	0.0329	0.0321	0.0313	0.0306	0.0300	0.0294	0.0289	0.0284	0.0279	0.0275	0.0271	0.0268
2.4	3.69	0.0452	0.0430	0.0406	0.0399	0.0391	0.0384	0.0377	0.0365	0.0355	0.0346	0.0337	0.0330	0.0323	0.0317	0.0311	0.0306	0.0301	0.0297	0.0292	0.0289
2.5	3.84	0.0485	0.0462	0.0436	0.0428	0.0419	0.0412	0.0405	0.0392	0.0381	0.0371	0.0362	0.0354	0.0347	0.0341	0.0334	0.0329	0.0324	0.0319	0.0314	0.0310
2.6	3.99	0.0519	0.0495	0.0467	0.0458	0.0449	0.0442	0.0434	0.0420	0.0409	0.0398	0.0388	0.0380	0.0372	0.0365	0.0358	0.0353	0.0347	0.0342	0.0337	0.0333
2.7	4.15	0.0554	0.0528	0.0499	0.0490	0.0480	0.0472	0.0464	0.0449	0.0437	0.0425	0.0415	0.0406	0.0398	0.0390	0.0383	0.0377	0.0371	0.0366	0.0361	0.0356
2.8	4.30	0.0590	0.0562	0.0531	0.0522	0.0511	0.0503	0.0494	0.0479	0.0465	0.0453	0.0443	0.0433	0.0424	0.0416	0.0409	0.0402	0.0396	0.0390	0.0385	0.0380
2.9	4.45	0.0627	0.0598	0.0565	0.0555	0.0544	0.0535	0.0525	0.0509	0.0495	0.0482	0.0471	0.0461	0.0451	0.0443	0.0435	0.0428	0.0421	0.0415	0.0410	0.0404
3.0	4.61	0.0665	0.0634	0.0599	0.0588	0.0577	0.0567	0.0558	0.0541	0.0526	0.0512	0.0500	0.0489	0.0479	0.0470	0.0462	0.0455	0.0447	0.0441	0.0435	0.0430
3.1	4.76	0.0704	0.0671	0.0635	0.0623	0.0611	0.0601	0.0591	0.0573	0.0557	0.0543	0.0530	0.0518	0.0508	0.0499	0.0490	0.0482	0.0474	0.0468	0.0461	0.0455
3.2	4.91	0.0744	0.0710	0.0671	0.0659	0.0646	0.0635	0.0624	0.0606	0.0589	0.0574	0.0561	0.0548	0.0537	0.0527	0.0518	0.0510	0.0502	0.0495	0.0488	0.0482
3.3	5.07	0.0784	0.0749	0.0708	0.0695	0.0682	0.0671	0.0659	0.0639	0.0622	0.0606	0.0592	0.0579	0.0568	0.0557	0.0547	0.0539	0.0530	0.0523	0.0516	0.0509
3.4	5.22	0.0826	0.0789	0.0746	0.0733	0.0718	0.0707	0.0695	0.0674	0.0655	0.0639	0.0624	0.0611	0.0598	0.0587	0.0577	0.0568	0.0559	0.0551	0.0544	0.0537
3.5	5.38	0.0869	0.0829	0.0785	0.0771	0.0756	0.0744	0.0731	0.0709	0.0690	0.0672	0.0657	0.0643	0.0630	0.0618	0.0608	0.0598	0.0589	0.0581	0.0573	0.0566
3.6	5.53	0.0912	0.0871	0.0825	0.0810	0.0794	0.0782	0.0768	0.0745	0.0725	0.0707	0.0690	0.0676	0.0662	0.0650	0.0639	0.0629	0.0619	0.0611	0.0603	0.0595
3.7	5.68	0.0957	0.0914	0.0865	0.0850	0.0833	0.0820	0.0806	0.0782	0.0761	0.0742	0.0725	0.0709	0.0695	0.0683	0.0671	0.0660	0.0650	0.0641	0.0633	0.0625
3.8	5.84	0.1002	0.0958	0.0907	0.0890	0.0873	0.0859	0.0845	0.0820	0.0798	0.0778	0.0760	0.0744	0.0729	0.0716	0.0704	0.0693	0.0682	0.0672	0.0664	0.0655
3.9	5.99	0.1049	0.1002	0.0949	0.0932	0.0914	0.0900	0.0884	0.0858	0.0835	0.0814	0.0796	0.0779	0.0764	0.0750	0.0737	0.0725	0.0714	0.0704	0.0695	0.0687

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

¾" Uponor MLC — 100% Water — Feet of Head per Foot of Tubing

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
4.0	6.14	0.1096	0.1047	0.0992	0.0974	0.0956	0.0941	0.0925	0.0897	0.0873	0.0852	0.0832	0.0815	0.0799	0.0784	0.0771	0.0759	0.0747	0.0737	0.0727	0.0718
4.1	6.30	0.1144	0.1094	0.1036	0.1018	0.0998	0.0982	0.0966	0.0937	0.0912	0.0890	0.0870	0.0851	0.0835	0.0820	0.0806	0.0793	0.0781	0.0770	0.0760	0.0751
4.2	6.45	0.1194	0.1141	0.1081	0.1062	0.1042	0.1025	0.1008	0.0978	0.0952	0.0929	0.0908	0.0889	0.0871	0.0856	0.0841	0.0828	0.0816	0.0804	0.0794	0.0784
4.3	6.60	0.1244	0.1189	0.1126	0.1106	0.1086	0.1069	0.1051	0.1020	0.0993	0.0968	0.0946	0.0927	0.0909	0.0892	0.0877	0.0864	0.0851	0.0839	0.0828	0.0818
4.4	6.76	0.1294	0.1237	0.1173	0.1152	0.1130	0.1113	0.1094	0.1062	0.1034	0.1008	0.0986	0.0965	0.0947	0.0930	0.0914	0.0900	0.0886	0.0874	0.0863	0.0852
4.5	6.91	0.1346	0.1287	0.1220	0.1199	0.1176	0.1158	0.1138	0.1105	0.1076	0.1049	0.1026	0.1005	0.0985	0.0968	0.0951	0.0937	0.0923	0.0910	0.0898	0.0887
4.6	7.06	0.1399	0.1338	0.1268	0.1246	0.1223	0.1203	0.1183	0.1149	0.1119	0.1091	0.1067	0.1045	0.1025	0.1006	0.0990	0.0974	0.0960	0.0947	0.0934	0.0923
4.7	7.22	0.1453	0.1389	0.1317	0.1294	0.1270	0.1250	0.1229	0.1194	0.1162	0.1134	0.1108	0.1085	0.1065	0.1046	0.1028	0.1012	0.0997	0.0984	0.0971	0.0959
4.8	7.37	0.1507	0.1441	0.1367	0.1343	0.1318	0.1297	0.1276	0.1239	0.1206	0.1177	0.1151	0.1127	0.1105	0.1086	0.1068	0.1051	0.1036	0.1022	0.1009	0.0996
4.9	7.53	0.1562	0.1494	0.1417	0.1392	0.1367	0.1345	0.1323	0.1285	0.1251	0.1221	0.1194	0.1169	0.1147	0.1127	0.1108	0.1091	0.1075	0.1060	0.1047	0.1034
5.0	7.68	0.1619	0.1548	0.1468	0.1443	0.1416	0.1394	0.1371	0.1332	0.1297	0.1265	0.1237	0.1212	0.1189	0.1168	0.1149	0.1131	0.1114	0.1099	0.1085	0.1072
5.1	7.83	0.1676	0.1603	0.1520	0.1494	0.1467	0.1444	0.1420	0.1379	0.1343	0.1311	0.1282	0.1256	0.1232	0.1210	0.1190	0.1172	0.1155	0.1139	0.1125	0.1111
5.2	7.99	0.1734	0.1659	0.1573	0.1546	0.1518	0.1494	0.1470	0.1428	0.1390	0.1357	0.1327	0.1300	0.1275	0.1253	0.1232	0.1213	0.1195	0.1179	0.1165	0.1151
5.3	8.14	0.1792	0.1715	0.1627	0.1599	0.1570	0.1546	0.1520	0.1477	0.1438	0.1404	0.1373	0.1345	0.1319	0.1296	0.1275	0.1255	0.1237	0.1220	0.1205	0.1191
5.4	8.29	0.1852	0.1772	0.1682	0.1653	0.1623	0.1598	0.1571	0.1526	0.1487	0.1451	0.1419	0.1390	0.1364	0.1340	0.1318	0.1298	0.1279	0.1262	0.1246	0.1231
5.5	8.45	0.1913	0.1830	0.1737	0.1707	0.1676	0.1650	0.1623	0.1577	0.1536	0.1499	0.1466	0.1437	0.1410	0.1385	0.1362	0.1342	0.1322	0.1304	0.1288	0.1273
5.6	8.60	0.1974	0.1889	0.1793	0.1762	0.1730	0.1704	0.1676	0.1628	0.1586	0.1548	0.1514	0.1484	0.1456	0.1430	0.1407	0.1386	0.1365	0.1347	0.1330	0.1315
5.7	8.75	0.2036	0.1949	0.1850	0.1818	0.1785	0.1758	0.1729	0.1680	0.1637	0.1598	0.1563	0.1531	0.1503	0.1476	0.1452	0.1430	0.1410	0.1391	0.1373	0.1357
5.8	8.91	0.2099	0.2009	0.1907	0.1875	0.1841	0.1813	0.1784	0.1733	0.1688	0.1648	0.1612	0.1580	0.1550	0.1523	0.1498	0.1476	0.1454	0.1435	0.1417	0.1400
5.9	9.06	0.2163	0.2071	0.1966	0.1933	0.1898	0.1869	0.1838	0.1786	0.1740	0.1699	0.1662	0.1629	0.1598	0.1570	0.1545	0.1522	0.1500	0.1480	0.1461	0.1444
6.0	9.21	0.2228	0.2133	0.2025	0.1991	0.1955	0.1925	0.1894	0.1840	0.1793	0.1751	0.1713	0.1678	0.1647	0.1618	0.1592	0.1568	0.1546	0.1525	0.1506	0.1489
6.1	9.37	0.2293	0.2196	0.2085	0.2050	0.2013	0.1982	0.1950	0.1895	0.1847	0.1803	0.1764	0.1728	0.1696	0.1667	0.1640	0.1615	0.1592	0.1571	0.1552	0.1534
6.2	9.52	0.2360	0.2260	0.2146	0.2110	0.2072	0.2040	0.2007	0.1951	0.1901	0.1856	0.1816	0.1779	0.1746	0.1716	0.1689	0.1663	0.1639	0.1618	0.1598	0.1579
6.3	9.68	0.2427	0.2324	0.2207	0.2170	0.2131	0.2099	0.2065	0.2007	0.1956	0.1910	0.1869	0.1831	0.1797	0.1766	0.1738	0.1712	0.1687	0.1665	0.1645	0.1625

Recommended Head Loss Design Range

Sizing in this region will lead to excessive head loss conditions.

Appendix G
Hydronic Friction Loss Tables

¾" Uponor MLC — 30% Propylene Glycol — Feet of Head per Foot of Tubing

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	0.77	0.0046	0.0044	0.0042	0.0040	0.0039	0.0037	0.0036	0.0034	0.0032	0.0030	0.0029	0.0027	0.0026	0.0025	0.0025	0.0024	0.0023	0.0023	0.0022	0.0022
0.6	0.92	0.0062	0.0059	0.0056	0.0054	0.0052	0.0050	0.0049	0.0046	0.0043	0.0041	0.0039	0.0037	0.0036	0.0035	0.0034	0.0033	0.0032	0.0031	0.0030	0.0030
0.7	1.08	0.0079	0.0076	0.0073	0.0070	0.0067	0.0065	0.0063	0.0059	0.0056	0.0053	0.0051	0.0049	0.0047	0.0045	0.0044	0.0043	0.0041	0.0040	0.0040	0.0039
0.8	1.23	0.0098	0.0095	0.0090	0.0087	0.0084	0.0081	0.0078	0.0074	0.0070	0.0066	0.0063	0.0061	0.0059	0.0057	0.0055	0.0054	0.0052	0.0051	0.0050	0.0049
0.9	1.38	0.0119	0.0115	0.0110	0.0106	0.0102	0.0099	0.0095	0.0090	0.0085	0.0081	0.0077	0.0074	0.0072	0.0069	0.0067	0.0066	0.0064	0.0062	0.0061	0.0060
1.0	1.54	0.0142	0.0137	0.0131	0.0126	0.0122	0.0118	0.0114	0.0107	0.0102	0.0097	0.0093	0.0089	0.0086	0.0083	0.0081	0.0079	0.0077	0.0075	0.0073	0.0072
1.1	1.69	0.0166	0.0160	0.0153	0.0148	0.0143	0.0138	0.0134	0.0126	0.0119	0.0114	0.0109	0.0105	0.0101	0.0098	0.0095	0.0093	0.0090	0.0088	0.0086	0.0085
1.2	1.84	0.0192	0.0185	0.0177	0.0171	0.0165	0.0160	0.0155	0.0146	0.0139	0.0132	0.0127	0.0122	0.0118	0.0114	0.0111	0.0108	0.0105	0.0103	0.0101	0.0099
1.3	2.00	0.0219	0.0211	0.0203	0.0196	0.0189	0.0183	0.0177	0.0167	0.0159	0.0151	0.0145	0.0140	0.0135	0.0131	0.0127	0.0124	0.0121	0.0118	0.0116	0.0114
1.4	2.15	0.0248	0.0239	0.0229	0.0222	0.0214	0.0208	0.0201	0.0190	0.0180	0.0172	0.0165	0.0159	0.0153	0.0149	0.0145	0.0141	0.0137	0.0134	0.0132	0.0129
1.5	2.30	0.0278	0.0268	0.0258	0.0249	0.0240	0.0233	0.0226	0.0213	0.0203	0.0194	0.0186	0.0179	0.0173	0.0167	0.0163	0.0159	0.0155	0.0152	0.0148	0.0146
1.6	2.46	0.0310	0.0299	0.0287	0.0278	0.0268	0.0260	0.0252	0.0238	0.0226	0.0216	0.0207	0.0200	0.0193	0.0187	0.0182	0.0178	0.0173	0.0170	0.0166	0.0163
1.7	2.61	0.0343	0.0331	0.0318	0.0308	0.0297	0.0288	0.0279	0.0264	0.0251	0.0240	0.0230	0.0222	0.0215	0.0208	0.0203	0.0197	0.0193	0.0189	0.0185	0.0182
1.8	2.76	0.0378	0.0364	0.0350	0.0339	0.0327	0.0318	0.0308	0.0291	0.0277	0.0265	0.0254	0.0245	0.0237	0.0230	0.0224	0.0218	0.0213	0.0208	0.0204	0.0201
1.9	2.92	0.0414	0.0399	0.0384	0.0372	0.0359	0.0348	0.0337	0.0319	0.0304	0.0291	0.0279	0.0269	0.0260	0.0252	0.0246	0.0240	0.0234	0.0229	0.0224	0.0221
2.0	3.07	0.0451	0.0435	0.0418	0.0405	0.0391	0.0380	0.0368	0.0349	0.0332	0.0318	0.0305	0.0294	0.0285	0.0276	0.0269	0.0262	0.0256	0.0251	0.0246	0.0242
2.1	3.23	0.0489	0.0472	0.0454	0.0440	0.0425	0.0413	0.0400	0.0379	0.0361	0.0346	0.0332	0.0320	0.0310	0.0301	0.0293	0.0286	0.0279	0.0273	0.0268	0.0263
2.2	3.38	0.0529	0.0511	0.0492	0.0476	0.0460	0.0447	0.0433	0.0411	0.0391	0.0374	0.0360	0.0347	0.0336	0.0326	0.0318	0.0310	0.0302	0.0296	0.0290	0.0286
2.3	3.53	0.0571	0.0551	0.0530	0.0514	0.0496	0.0482	0.0467	0.0443	0.0422	0.0404	0.0389	0.0375	0.0363	0.0352	0.0343	0.0335	0.0327	0.0320	0.0314	0.0309
2.4	3.69	0.0613	0.0592	0.0570	0.0552	0.0534	0.0519	0.0503	0.0477	0.0455	0.0435	0.0418	0.0404	0.0391	0.0379	0.0370	0.0361	0.0352	0.0345	0.0338	0.0333
2.5	3.84	0.0657	0.0635	0.0611	0.0592	0.0572	0.0556	0.0539	0.0512	0.0488	0.0467	0.0449	0.0434	0.0420	0.0408	0.0397	0.0388	0.0379	0.0371	0.0364	0.0358
2.6	3.99	0.0702	0.0678	0.0653	0.0633	0.0612	0.0595	0.0577	0.0547	0.0522	0.0500	0.0481	0.0464	0.0450	0.0436	0.0426	0.0415	0.0406	0.0398	0.0390	0.0384
2.7	4.15	0.0748	0.0723	0.0696	0.0675	0.0653	0.0635	0.0615	0.0584	0.0557	0.0534	0.0513	0.0496	0.0480	0.0466	0.0455	0.0444	0.0433	0.0425	0.0416	0.0410
2.8	4.30	0.0796	0.0769	0.0741	0.0718	0.0695	0.0676	0.0655	0.0622	0.0593	0.0569	0.0547	0.0529	0.0512	0.0497	0.0485	0.0473	0.0462	0.0453	0.0444	0.0437
2.9	4.45	0.0845	0.0816	0.0786	0.0763	0.0738	0.0718	0.0696	0.0661	0.0631	0.0604	0.0581	0.0562	0.0544	0.0528	0.0516	0.0503	0.0492	0.0482	0.0472	0.0465
3.0	4.61	0.0895	0.0865	0.0833	0.0808	0.0782	0.0761	0.0738	0.0701	0.0669	0.0641	0.0617	0.0596	0.0578	0.0561	0.0547	0.0534	0.0522	0.0512	0.0502	0.0494
3.1	4.76	0.0946	0.0915	0.0881	0.0855	0.0827	0.0805	0.0781	0.0742	0.0708	0.0679	0.0653	0.0631	0.0612	0.0594	0.0580	0.0566	0.0553	0.0542	0.0531	0.0524
3.2	4.91	0.0998	0.0965	0.0930	0.0903	0.0873	0.0850	0.0825	0.0783	0.0748	0.0717	0.0690	0.0667	0.0647	0.0628	0.0613	0.0598	0.0585	0.0573	0.0562	0.0554
3.3	5.07	0.1052	0.1017	0.0980	0.0952	0.0921	0.0896	0.0869	0.0826	0.0789	0.0757	0.0728	0.0704	0.0683	0.0663	0.0647	0.0632	0.0617	0.0605	0.0594	0.0585
3.4	5.22	0.1107	0.1071	0.1032	0.1002	0.0969	0.0943	0.0915	0.0870	0.0831	0.0797	0.0767	0.0742	0.0719	0.0699	0.0682	0.0666	0.0651	0.0638	0.0626	0.0617
3.5	5.38	0.1163	0.1125	0.1084	0.1053	0.1019	0.0992	0.0962	0.0915	0.0874	0.0838	0.0807	0.0781	0.0757	0.0735	0.0718	0.0701	0.0685	0.0672	0.0659	0.0649
3.6	5.53	0.1220	0.1180	0.1138	0.1105	0.1069	0.1041	0.1010	0.0961	0.0918	0.0881	0.0848	0.0820	0.0795	0.0773	0.0754	0.0736	0.0720	0.0706	0.0692	0.0682
3.7	5.68	0.1278	0.1237	0.1193	0.1158	0.1121	0.1091	0.1059	0.1007	0.0963	0.0924	0.0890	0.0861	0.0834	0.0811	0.0792	0.0773	0.0756	0.0741	0.0727	0.0716
3.8	5.84	0.1338	0.1295	0.1248	0.1212	0.1174	0.1143	0.1109	0.1055	0.1008	0.0968	0.0932	0.0902	0.0875	0.0850	0.0830	0.0810	0.0792	0.0777	0.0762	0.0751
3.9	5.99	0.1398	0.1353	0.1305	0.1268	0.1228	0.1195	0.1160	0.1104	0.1055	0.1013	0.0975	0.0944	0.0915	0.0889	0.0869	0.0848	0.0829	0.0814	0.0798	0.0787

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

¾" Uponor MLC — 30% Propylene Glycol — Feet of Head per Foot of Tubing

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
4.0	6.14	0.1460	0.1413	0.1363	0.1324	0.1282	0.1248	0.1212	0.1153	0.1103	0.1058	0.1020	0.0987	0.0957	0.0930	0.0908	0.0887	0.0867	0.0851	0.0835	0.0823
4.1	6.30	0.1523	0.1474	0.1422	0.1382	0.1338	0.1303	0.1265	0.1204	0.1151	0.1105	0.1065	0.1030	0.1000	0.0971	0.0949	0.0927	0.0906	0.0889	0.0872	0.0860
4.2	6.45	0.1587	0.1537	0.1482	0.1440	0.1395	0.1358	0.1319	0.1255	0.1200	0.1153	0.1111	0.1075	0.1043	0.1014	0.0990	0.0967	0.0946	0.0928	0.0910	0.0897
4.3	6.60	0.1652	0.1600	0.1544	0.1500	0.1453	0.1415	0.1374	0.1308	0.1251	0.1201	0.1158	0.1120	0.1087	0.1056	0.1032	0.1008	0.0986	0.0967	0.0949	0.0936
4.4	6.76	0.1719	0.1664	0.1606	0.1560	0.1512	0.1472	0.1430	0.1361	0.1302	0.1250	0.1205	0.1167	0.1132	0.1100	0.1075	0.1050	0.1027	0.1008	0.0989	0.0975
4.5	6.91	0.1786	0.1730	0.1669	0.1622	0.1572	0.1531	0.1487	0.1416	0.1354	0.1301	0.1254	0.1214	0.1178	0.1145	0.1118	0.1092	0.1069	0.1049	0.1029	0.1014
4.6	7.06	0.1855	0.1796	0.1734	0.1685	0.1632	0.1590	0.1545	0.1471	0.1407	0.1352	0.1303	0.1261	0.1224	0.1190	0.1163	0.1136	0.1111	0.1090	0.1070	0.1055
4.7	7.22	0.1924	0.1864	0.1799	0.1748	0.1694	0.1650	0.1603	0.1527	0.1461	0.1403	0.1353	0.1310	0.1271	0.1236	0.1208	0.1180	0.1154	0.1133	0.1112	0.1096
4.8	7.37	0.1995	0.1933	0.1865	0.1813	0.1757	0.1712	0.1663	0.1584	0.1516	0.1456	0.1404	0.1360	0.1319	0.1283	0.1254	0.1225	0.1198	0.1176	0.1154	0.1138
4.9	7.53	0.2067	0.2002	0.1933	0.1879	0.1821	0.1774	0.1724	0.1642	0.1571	0.1510	0.1456	0.1410	0.1368	0.1331	0.1300	0.1270	0.1243	0.1220	0.1197	0.1180
5.0	7.68	0.2140	0.2073	0.2001	0.1946	0.1886	0.1837	0.1785	0.1701	0.1628	0.1564	0.1508	0.1461	0.1418	0.1379	0.1347	0.1317	0.1288	0.1264	0.1241	0.1224
5.1	7.83	0.2214	0.2145	0.2071	0.2013	0.1952	0.1901	0.1848	0.1761	0.1685	0.1620	0.1562	0.1513	0.1468	0.1428	0.1396	0.1364	0.1334	0.1310	0.1285	0.1267
5.2	7.99	0.2289	0.2218	0.2142	0.2082	0.2018	0.1967	0.1911	0.1821	0.1743	0.1676	0.1616	0.1565	0.1520	0.1478	0.1444	0.1412	0.1381	0.1356	0.1331	0.1312
5.3	8.14	0.2365	0.2292	0.2213	0.2152	0.2086	0.2033	0.1976	0.1883	0.1802	0.1733	0.1671	0.1619	0.1572	0.1529	0.1494	0.1460	0.1429	0.1403	0.1377	0.1357
5.4	8.29	0.2442	0.2367	0.2286	0.2223	0.2155	0.2100	0.2041	0.1945	0.1862	0.1790	0.1727	0.1673	0.1624	0.1580	0.1544	0.1509	0.1477	0.1450	0.1423	0.1403
5.5	8.45	0.2520	0.2443	0.2359	0.2294	0.2225	0.2168	0.2107	0.2009	0.1923	0.1849	0.1784	0.1728	0.1678	0.1632	0.1595	0.1559	0.1526	0.1498	0.1471	0.1450
5.6	8.60	0.2600	0.2520	0.2434	0.2367	0.2295	0.2237	0.2175	0.2073	0.1985	0.1909	0.1841	0.1784	0.1732	0.1685	0.1647	0.1610	0.1576	0.1547	0.1519	0.1498
5.7	8.75	0.2680	0.2598	0.2510	0.2441	0.2367	0.2307	0.2243	0.2138	0.2047	0.1969	0.1900	0.1841	0.1787	0.1739	0.1700	0.1661	0.1626	0.1596	0.1567	0.1546
5.8	8.91	0.2762	0.2677	0.2586	0.2515	0.2439	0.2378	0.2312	0.2204	0.2111	0.2030	0.1959	0.1898	0.1843	0.1793	0.1753	0.1714	0.1677	0.1647	0.1617	0.1594
5.9	9.06	0.2844	0.2757	0.2664	0.2591	0.2513	0.2449	0.2382	0.2271	0.2175	0.2092	0.2019	0.1956	0.1900	0.1848	0.1807	0.1766	0.1729	0.1698	0.1667	0.1644

Recommended Head Loss Design Range

Sizing in this region will lead to excessive head loss conditions.

Appendix G
Hydronic Friction Loss Tables

¾" Uponor MLC — 40% Propylene Glycol — Feet of Head per Foot of Tubing

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	0.77	0.0056	0.0053	0.0050	0.0048	0.0045	0.0043	0.0041	0.0038	0.0036	0.0033	0.0032	0.0030	0.0029	0.0028	0.0027	0.0026	0.0025	0.0026	0.0025	0.0025
0.6	0.92	0.0075	0.0071	0.0067	0.0064	0.0061	0.0058	0.0056	0.0052	0.0048	0.0045	0.0043	0.0041	0.0039	0.0037	0.0036	0.0035	0.0034	0.0035	0.0034	0.0033
0.7	1.08	0.0096	0.0091	0.0086	0.0082	0.0078	0.0075	0.0072	0.0067	0.0062	0.0059	0.0056	0.0053	0.0051	0.0049	0.0047	0.0046	0.0044	0.0046	0.0045	0.0044
0.8	1.23	0.0119	0.0113	0.0107	0.0102	0.0097	0.0093	0.0089	0.0083	0.0078	0.0073	0.0070	0.0066	0.0064	0.0061	0.0059	0.0057	0.0055	0.0058	0.0056	0.0055
0.9	1.38	0.0144	0.0137	0.0129	0.0124	0.0118	0.0113	0.0109	0.0101	0.0095	0.0089	0.0085	0.0081	0.0078	0.0075	0.0072	0.0070	0.0068	0.0071	0.0069	0.0067
1.0	1.54	0.0171	0.0162	0.0154	0.0147	0.0140	0.0135	0.0129	0.0120	0.0113	0.0107	0.0101	0.0097	0.0093	0.0089	0.0086	0.0084	0.0081	0.0085	0.0083	0.0080
1.1	1.69	0.0199	0.0190	0.0180	0.0172	0.0164	0.0158	0.0152	0.0141	0.0133	0.0125	0.0119	0.0114	0.0109	0.0105	0.0102	0.0099	0.0096	0.0100	0.0097	0.0095
1.2	1.84	0.0230	0.0219	0.0207	0.0199	0.0190	0.0183	0.0175	0.0163	0.0154	0.0145	0.0138	0.0132	0.0127	0.0122	0.0118	0.0115	0.0112	0.0116	0.0113	0.0110
1.3	2.00	0.0262	0.0250	0.0237	0.0227	0.0217	0.0209	0.0200	0.0187	0.0176	0.0167	0.0159	0.0151	0.0146	0.0140	0.0136	0.0132	0.0128	0.0133	0.0130	0.0127
1.4	2.15	0.0296	0.0282	0.0268	0.0257	0.0245	0.0236	0.0227	0.0212	0.0199	0.0189	0.0180	0.0172	0.0165	0.0159	0.0154	0.0150	0.0146	0.0151	0.0148	0.0144
1.5	2.30	0.0331	0.0316	0.0300	0.0288	0.0275	0.0265	0.0255	0.0238	0.0224	0.0212	0.0202	0.0194	0.0186	0.0179	0.0174	0.0169	0.0164	0.0170	0.0166	0.0162
1.6	2.46	0.0368	0.0352	0.0334	0.0321	0.0306	0.0296	0.0284	0.0266	0.0250	0.0237	0.0226	0.0216	0.0208	0.0201	0.0194	0.0189	0.0184	0.0191	0.0186	0.0182
1.7	2.61	0.0407	0.0389	0.0369	0.0355	0.0339	0.0327	0.0315	0.0294	0.0277	0.0263	0.0251	0.0240	0.0231	0.0223	0.0216	0.0210	0.0204	0.0212	0.0207	0.0202
1.8	2.76	0.0447	0.0427	0.0406	0.0390	0.0373	0.0360	0.0346	0.0324	0.0306	0.0290	0.0277	0.0265	0.0255	0.0246	0.0238	0.0232	0.0225	0.0234	0.0228	0.0223
1.9	2.92	0.0489	0.0468	0.0444	0.0427	0.0409	0.0395	0.0380	0.0355	0.0335	0.0318	0.0304	0.0291	0.0280	0.0270	0.0262	0.0255	0.0248	0.0257	0.0251	0.0245
2.0	3.07	0.0532	0.0509	0.0484	0.0466	0.0446	0.0430	0.0414	0.0388	0.0366	0.0347	0.0332	0.0318	0.0306	0.0295	0.0286	0.0279	0.0271	0.0281	0.0274	0.0268
2.1	3.23	0.0577	0.0552	0.0525	0.0505	0.0484	0.0467	0.0450	0.0421	0.0398	0.0378	0.0361	0.0345	0.0333	0.0321	0.0312	0.0303	0.0295	0.0306	0.0299	0.0292
2.2	3.38	0.0624	0.0597	0.0568	0.0546	0.0523	0.0506	0.0487	0.0456	0.0431	0.0409	0.0391	0.0374	0.0361	0.0348	0.0338	0.0329	0.0320	0.0332	0.0324	0.0316
2.3	3.53	0.0672	0.0643	0.0612	0.0589	0.0564	0.0545	0.0525	0.0492	0.0465	0.0442	0.0422	0.0404	0.0389	0.0376	0.0365	0.0355	0.0346	0.0358	0.0350	0.0342
2.4	3.69	0.0721	0.0690	0.0657	0.0633	0.0606	0.0586	0.0564	0.0529	0.0500	0.0475	0.0454	0.0435	0.0419	0.0405	0.0393	0.0383	0.0372	0.0386	0.0377	0.0368
2.5	3.84	0.0772	0.0739	0.0704	0.0678	0.0649	0.0628	0.0605	0.0567	0.0536	0.0510	0.0487	0.0467	0.0450	0.0435	0.0422	0.0411	0.0400	0.0414	0.0405	0.0396
2.6	3.99	0.0824	0.0789	0.0752	0.0724	0.0694	0.0671	0.0646	0.0607	0.0573	0.0545	0.0521	0.0500	0.0482	0.0466	0.0452	0.0440	0.0428	0.0444	0.0434	0.0424
2.7	4.15	0.0878	0.0841	0.0801	0.0772	0.0740	0.0715	0.0689	0.0647	0.0612	0.0582	0.0556	0.0534	0.0515	0.0497	0.0483	0.0470	0.0458	0.0474	0.0463	0.0453
2.8	4.30	0.0933	0.0894	0.0852	0.0821	0.0787	0.0761	0.0733	0.0689	0.0651	0.0620	0.0593	0.0569	0.0548	0.0530	0.0515	0.0501	0.0488	0.0505	0.0494	0.0483
2.9	4.45	0.0989	0.0948	0.0904	0.0871	0.0835	0.0808	0.0779	0.0731	0.0692	0.0658	0.0630	0.0604	0.0583	0.0563	0.0547	0.0533	0.0519	0.0537	0.0525	0.0513
3.0	4.61	0.1047	0.1004	0.0957	0.0922	0.0885	0.0856	0.0825	0.0775	0.0733	0.0698	0.0668	0.0641	0.0618	0.0598	0.0581	0.0566	0.0551	0.0570	0.0557	0.0545
3.1	4.76	0.1106	0.1061	0.1012	0.0975	0.0935	0.0905	0.0872	0.0820	0.0776	0.0739	0.0707	0.0679	0.0655	0.0633	0.0615	0.0599	0.0583	0.0604	0.0590	0.0577
3.2	4.91	0.1167	0.1119	0.1067	0.1029	0.0987	0.0955	0.0921	0.0866	0.0820	0.0781	0.0747	0.0717	0.0692	0.0669	0.0650	0.0633	0.0617	0.0638	0.0624	0.0610
3.3	5.07	0.1229	0.1179	0.1124	0.1084	0.1040	0.1007	0.0971	0.0913	0.0864	0.0823	0.0788	0.0757	0.0730	0.0706	0.0686	0.0669	0.0651	0.0674	0.0659	0.0644
3.4	5.22	0.1292	0.1240	0.1183	0.1140	0.1094	0.1059	0.1022	0.0961	0.0910	0.0867	0.0830	0.0797	0.0769	0.0744	0.0723	0.0705	0.0686	0.0710	0.0694	0.0679
3.5	5.38	0.1357	0.1302	0.1242	0.1198	0.1150	0.1113	0.1074	0.1010	0.0957	0.0912	0.0873	0.0838	0.0809	0.0783	0.0761	0.0741	0.0722	0.0747	0.0731	0.0715
3.6	5.53	0.1423	0.1365	0.1303	0.1257	0.1207	0.1168	0.1127	0.1061	0.1004	0.0957	0.0917	0.0881	0.0850	0.0822	0.0799	0.0779	0.0759	0.0785	0.0768	0.0751
3.7	5.68	0.1490	0.1430	0.1365	0.1317	0.1264	0.1224	0.1181	0.1112	0.1053	0.1004	0.0961	0.0924	0.0892	0.0863	0.0838	0.0817	0.0796	0.0824	0.0806	0.0788
3.8	5.84	0.1558	0.1496	0.1428	0.1378	0.1323	0.1281	0.1236	0.1164	0.1103	0.1051	0.1007	0.0968	0.0934	0.0904	0.0879	0.0857	0.0835	0.0863	0.0845	0.0826
3.9	5.99	0.1628	0.1563	0.1493	0.1440	0.1383	0.1340	0.1293	0.1217	0.1154	0.1100	0.1054	0.1013	0.0978	0.0946	0.0920	0.0897	0.0874	0.0904	0.0884	0.0865

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Recommended Head Loss Design Range

Sizing in this region will lead to excessive head loss conditions.

Appendix G
Hydronic Friction Loss Tables

¾" Uponor MLC — 40% Propylene Glycol — Feet of Head per Foot of Tubing

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
4.0	6.14	0.1699	0.1632	0.1558	0.1504	0.1444	0.1399	0.1350	0.1272	0.1205	0.1149	0.1101	0.1058	0.1022	0.0989	0.0962	0.0938	0.0914	0.0945	0.0924	0.0904
4.1	6.30	0.1772	0.1701	0.1625	0.1568	0.1507	0.1460	0.1409	0.1327	0.1258	0.1200	0.1150	0.1105	0.1067	0.1033	0.1004	0.0979	0.0954	0.0987	0.0966	0.0945
4.2	6.45	0.1845	0.1772	0.1693	0.1634	0.1570	0.1521	0.1468	0.1383	0.1312	0.1251	0.1199	0.1153	0.1113	0.1078	0.1048	0.1022	0.0996	0.1030	0.1007	0.0986
4.3	6.60	0.1920	0.1845	0.1762	0.1701	0.1635	0.1584	0.1529	0.1441	0.1366	0.1303	0.1249	0.1201	0.1160	0.1123	0.1092	0.1065	0.1038	0.1073	0.1050	0.1027
4.4	6.76	0.1997	0.1918	0.1833	0.1769	0.1700	0.1648	0.1591	0.1499	0.1422	0.1357	0.1300	0.1250	0.1208	0.1170	0.1137	0.1109	0.1081	0.1118	0.1094	0.1070
4.5	6.91	0.2074	0.1993	0.1904	0.1838	0.1767	0.1712	0.1654	0.1559	0.1478	0.1411	0.1352	0.1301	0.1256	0.1217	0.1183	0.1154	0.1125	0.1163	0.1138	0.1113
4.6	7.06	0.2153	0.2068	0.1977	0.1909	0.1835	0.1778	0.1717	0.1619	0.1536	0.1466	0.1405	0.1352	0.1306	0.1265	0.1230	0.1200	0.1169	0.1209	0.1183	0.1158
4.7	7.22	0.2233	0.2146	0.2051	0.1980	0.1904	0.1845	0.1782	0.1680	0.1594	0.1522	0.1459	0.1403	0.1356	0.1313	0.1277	0.1246	0.1215	0.1256	0.1229	0.1202
4.8	7.37	0.2314	0.2224	0.2126	0.2053	0.1974	0.1913	0.1848	0.1743	0.1654	0.1579	0.1514	0.1456	0.1407	0.1363	0.1326	0.1293	0.1261	0.1303	0.1275	0.1248
4.9	7.53	0.2396	0.2303	0.2202	0.2127	0.2045	0.1982	0.1915	0.1806	0.1714	0.1636	0.1569	0.1510	0.1459	0.1413	0.1375	0.1341	0.1308	0.1351	0.1323	0.1295
5.0	7.68	0.2480	0.2384	0.2279	0.2201	0.2117	0.2053	0.1983	0.1871	0.1775	0.1695	0.1626	0.1564	0.1512	0.1464	0.1425	0.1390	0.1355	0.1401	0.1371	0.1342
5.1	7.83	0.2565	0.2466	0.2358	0.2277	0.2191	0.2124	0.2052	0.1936	0.1838	0.1755	0.1683	0.1619	0.1565	0.1516	0.1475	0.1440	0.1404	0.1450	0.1420	0.1390
5.2	7.99	0.2651	0.2548	0.2437	0.2355	0.2265	0.2196	0.2122	0.2002	0.1901	0.1815	0.1741	0.1676	0.1620	0.1569	0.1527	0.1490	0.1453	0.1501	0.1469	0.1438
5.3	8.14	0.2738	0.2633	0.2518	0.2433	0.2340	0.2269	0.2193	0.2069	0.1965	0.1877	0.1800	0.1733	0.1675	0.1623	0.1579	0.1541	0.1503	0.1552	0.1520	0.1488
5.4	8.29	0.2826	0.2718	0.2600	0.2512	0.2417	0.2344	0.2265	0.2138	0.2030	0.1939	0.1860	0.1790	0.1731	0.1677	0.1632	0.1593	0.1553	0.1605	0.1571	0.1538
5.5	8.45	0.2916	0.2804	0.2683	0.2592	0.2494	0.2419	0.2338	0.2207	0.2096	0.2002	0.1921	0.1849	0.1788	0.1732	0.1686	0.1645	0.1605	0.1657	0.1623	0.1589
5.6	8.60	0.3007	0.2892	0.2767	0.2674	0.2573	0.2495	0.2412	0.2277	0.2162	0.2066	0.1983	0.1908	0.1845	0.1788	0.1740	0.1698	0.1657	0.1711	0.1675	0.1640

Recommended Head Loss Design Range

Sizing in this region will lead to excessive head loss conditions.

Appendix G
Hydronic Friction Loss Tables

¾" Uponor MLC — 50% Propylene Glycol — Feet of Head per Foot of Tubing

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	0.77	0.0066	0.0062	0.0058	0.0055	0.0052	0.0050	0.0047	0.0043	0.0040	0.0037	0.0035	0.0033	0.0032	0.0030	0.0029	0.0028	0.0027	0.0026	0.0025	0.0025
0.6	0.92	0.0088	0.0083	0.0078	0.0074	0.0070	0.0067	0.0064	0.0058	0.0054	0.0051	0.0048	0.0045	0.0043	0.0041	0.0039	0.0038	0.0037	0.0035	0.0034	0.0033
0.7	1.08	0.0112	0.0106	0.0100	0.0095	0.0090	0.0086	0.0082	0.0075	0.0070	0.0065	0.0062	0.0058	0.0056	0.0053	0.0051	0.0049	0.0048	0.0046	0.0045	0.0044
0.8	1.23	0.0139	0.0131	0.0123	0.0118	0.0111	0.0107	0.0102	0.0094	0.0087	0.0082	0.0077	0.0073	0.0070	0.0067	0.0064	0.0062	0.0060	0.0058	0.0056	0.0055
0.9	1.38	0.0167	0.0159	0.0149	0.0142	0.0135	0.0129	0.0123	0.0114	0.0106	0.0099	0.0094	0.0089	0.0085	0.0081	0.0078	0.0075	0.0073	0.0071	0.0069	0.0067
1.0	1.54	0.0198	0.0188	0.0177	0.0169	0.0160	0.0153	0.0146	0.0135	0.0126	0.0118	0.0112	0.0106	0.0101	0.0097	0.0094	0.0090	0.0087	0.0085	0.0083	0.0080
1.1	1.69	0.0231	0.0219	0.0206	0.0197	0.0187	0.0179	0.0171	0.0159	0.0148	0.0139	0.0131	0.0125	0.0119	0.0114	0.0110	0.0106	0.0103	0.0100	0.0097	0.0095
1.2	1.84	0.0266	0.0252	0.0238	0.0227	0.0216	0.0207	0.0198	0.0183	0.0171	0.0161	0.0152	0.0145	0.0138	0.0133	0.0128	0.0123	0.0119	0.0116	0.0113	0.0110
1.3	2.00	0.0302	0.0287	0.0271	0.0259	0.0246	0.0236	0.0226	0.0209	0.0196	0.0184	0.0174	0.0166	0.0158	0.0152	0.0146	0.0142	0.0137	0.0133	0.0130	0.0127
1.4	2.15	0.0341	0.0324	0.0306	0.0292	0.0278	0.0267	0.0255	0.0237	0.0221	0.0208	0.0197	0.0188	0.0180	0.0173	0.0166	0.0161	0.0156	0.0151	0.0148	0.0144
1.5	2.30	0.0381	0.0362	0.0342	0.0328	0.0312	0.0299	0.0287	0.0266	0.0249	0.0234	0.0222	0.0211	0.0202	0.0194	0.0187	0.0181	0.0176	0.0170	0.0166	0.0162
1.6	2.46	0.0423	0.0403	0.0381	0.0364	0.0347	0.0333	0.0319	0.0296	0.0277	0.0261	0.0248	0.0236	0.0226	0.0217	0.0209	0.0203	0.0196	0.0191	0.0186	0.0182
1.7	2.61	0.0467	0.0445	0.0421	0.0403	0.0383	0.0369	0.0353	0.0328	0.0307	0.0290	0.0275	0.0262	0.0251	0.0241	0.0232	0.0225	0.0218	0.0212	0.0207	0.0202
1.8	2.76	0.0513	0.0488	0.0462	0.0443	0.0422	0.0406	0.0388	0.0361	0.0338	0.0319	0.0303	0.0289	0.0276	0.0266	0.0256	0.0248	0.0241	0.0234	0.0228	0.0223
1.9	2.92	0.0560	0.0534	0.0505	0.0484	0.0461	0.0444	0.0425	0.0396	0.0371	0.0350	0.0332	0.0317	0.0303	0.0292	0.0281	0.0273	0.0264	0.0257	0.0251	0.0245
2.0	3.07	0.0609	0.0581	0.0550	0.0527	0.0502	0.0484	0.0463	0.0431	0.0404	0.0382	0.0362	0.0346	0.0331	0.0319	0.0308	0.0298	0.0289	0.0281	0.0274	0.0268
2.1	3.23	0.0660	0.0629	0.0596	0.0571	0.0545	0.0525	0.0503	0.0468	0.0439	0.0415	0.0394	0.0376	0.0360	0.0347	0.0335	0.0324	0.0314	0.0306	0.0299	0.0292
2.2	3.38	0.0712	0.0680	0.0644	0.0617	0.0589	0.0567	0.0544	0.0507	0.0475	0.0449	0.0427	0.0407	0.0390	0.0376	0.0363	0.0351	0.0341	0.0332	0.0324	0.0316
2.3	3.53	0.0767	0.0731	0.0693	0.0665	0.0634	0.0611	0.0586	0.0546	0.0513	0.0484	0.0460	0.0440	0.0422	0.0406	0.0392	0.0380	0.0368	0.0358	0.0350	0.0342
2.4	3.69	0.0822	0.0785	0.0744	0.0714	0.0681	0.0656	0.0630	0.0587	0.0551	0.0521	0.0495	0.0473	0.0454	0.0437	0.0422	0.0409	0.0397	0.0386	0.0377	0.0368
2.5	3.84	0.0879	0.0840	0.0796	0.0764	0.0729	0.0703	0.0675	0.0629	0.0591	0.0559	0.0531	0.0507	0.0487	0.0469	0.0453	0.0439	0.0426	0.0414	0.0405	0.0396
2.6	3.99	0.0938	0.0896	0.0850	0.0816	0.0779	0.0751	0.0721	0.0672	0.0632	0.0598	0.0568	0.0543	0.0521	0.0502	0.0485	0.0470	0.0456	0.0444	0.0434	0.0424
2.7	4.15	0.0999	0.0954	0.0905	0.0869	0.0830	0.0800	0.0768	0.0717	0.0674	0.0637	0.0606	0.0580	0.0556	0.0536	0.0518	0.0502	0.0487	0.0474	0.0463	0.0453
2.8	4.30	0.1061	0.1013	0.0962	0.0924	0.0882	0.0851	0.0817	0.0763	0.0717	0.0678	0.0646	0.0617	0.0592	0.0570	0.0551	0.0535	0.0519	0.0505	0.0494	0.0483
2.9	4.45	0.1124	0.1074	0.1020	0.0980	0.0936	0.0903	0.0867	0.0810	0.0761	0.0721	0.0686	0.0656	0.0629	0.0606	0.0586	0.0568	0.0552	0.0537	0.0525	0.0513
3.0	4.61	0.1189	0.1137	0.1080	0.1037	0.0991	0.0956	0.0918	0.0858	0.0807	0.0764	0.0727	0.0695	0.0667	0.0643	0.0622	0.0603	0.0586	0.0570	0.0557	0.0545
3.1	4.76	0.1256	0.1200	0.1141	0.1096	0.1047	0.1010	0.0971	0.0907	0.0853	0.0808	0.0769	0.0736	0.0707	0.0681	0.0658	0.0639	0.0620	0.0604	0.0590	0.0577
3.2	4.91	0.1324	0.1266	0.1203	0.1156	0.1105	0.1066	0.1024	0.0957	0.0901	0.0853	0.0813	0.0777	0.0747	0.0719	0.0696	0.0675	0.0656	0.0638	0.0624	0.0610
3.3	5.07	0.1393	0.1332	0.1266	0.1217	0.1164	0.1123	0.1079	0.1009	0.0950	0.0900	0.0857	0.0820	0.0788	0.0759	0.0734	0.0712	0.0692	0.0674	0.0659	0.0644
3.4	5.22	0.1464	0.1401	0.1332	0.1280	0.1224	0.1181	0.1135	0.1062	0.1000	0.0947	0.0902	0.0863	0.0829	0.0800	0.0773	0.0751	0.0729	0.0710	0.0694	0.0679
3.5	5.38	0.1537	0.1470	0.1398	0.1344	0.1285	0.1241	0.1193	0.1116	0.1051	0.0996	0.0949	0.0908	0.0872	0.0841	0.0814	0.0790	0.0767	0.0747	0.0731	0.0715
3.6	5.53	0.1611	0.1541	0.1466	0.1409	0.1348	0.1301	0.1251	0.1171	0.1103	0.1045	0.0996	0.0953	0.0916	0.0883	0.0855	0.0830	0.0806	0.0785	0.0768	0.0751
3.7	5.68	0.1686	0.1614	0.1535	0.1476	0.1412	0.1363	0.1311	0.1227	0.1156	0.1096	0.1044	0.1000	0.0961	0.0927	0.0897	0.0870	0.0846	0.0824	0.0806	0.0788
3.8	5.84	0.1763	0.1687	0.1605	0.1544	0.1477	0.1426	0.1372	0.1284	0.1210	0.1147	0.1094	0.1047	0.1007	0.0971	0.0939	0.0912	0.0886	0.0863	0.0845	0.0826
3.9	5.99	0.1841	0.1762	0.1677	0.1613	0.1544	0.1491	0.1434	0.1343	0.1265	0.1200	0.1144	0.1095	0.1053	0.1016	0.0983	0.0954	0.0928	0.0904	0.0884	0.0865

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Recommended Head Loss Design Range

Sizing in this region will lead to excessive head loss conditions.

Appendix G
Hydronic Friction Loss Tables

¾" Uponor MLC — 50% Propylene Glycol — Feet of Head per Foot of Tubing

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
4.0	6.14	0.1921	0.1839	0.1750	0.1683	0.1611	0.1556	0.1497	0.1402	0.1322	0.1254	0.1195	0.1145	0.1101	0.1062	0.1028	0.0998	0.0970	0.0945	0.0924	0.0904
4.1	6.30	0.2002	0.1917	0.1824	0.1755	0.1680	0.1623	0.1561	0.1463	0.1379	0.1308	0.1248	0.1195	0.1149	0.1108	0.1073	0.1042	0.1013	0.0987	0.0966	0.0945
4.2	6.45	0.2084	0.1996	0.1900	0.1828	0.1750	0.1691	0.1627	0.1524	0.1437	0.1364	0.1301	0.1246	0.1198	0.1156	0.1119	0.1087	0.1057	0.1030	0.1007	0.0986
4.3	6.60	0.2168	0.2076	0.1977	0.1902	0.1822	0.1760	0.1694	0.1587	0.1497	0.1420	0.1355	0.1298	0.1249	0.1205	0.1166	0.1133	0.1102	0.1073	0.1050	0.1027
4.4	6.76	0.2253	0.2158	0.2055	0.1978	0.1894	0.1830	0.1762	0.1651	0.1557	0.1478	0.1410	0.1351	0.1300	0.1254	0.1214	0.1179	0.1147	0.1118	0.1094	0.1070
4.5	6.91	0.2340	0.2242	0.2135	0.2055	0.1968	0.1902	0.1831	0.1716	0.1619	0.1537	0.1466	0.1405	0.1352	0.1304	0.1263	0.1227	0.1193	0.1163	0.1138	0.1113
4.6	7.06	0.2428	0.2326	0.2216	0.2133	0.2043	0.1975	0.1901	0.1782	0.1682	0.1596	0.1523	0.1460	0.1405	0.1356	0.1313	0.1275	0.1240	0.1209	0.1183	0.1158
4.7	7.22	0.2517	0.2412	0.2298	0.2212	0.2119	0.2048	0.1972	0.1849	0.1745	0.1657	0.1581	0.1516	0.1458	0.1408	0.1363	0.1324	0.1288	0.1256	0.1229	0.1202
4.8	7.37	0.2608	0.2499	0.2381	0.2293	0.2197	0.2123	0.2044	0.1917	0.1810	0.1718	0.1640	0.1572	0.1513	0.1461	0.1415	0.1374	0.1337	0.1303	0.1275	0.1248
4.9	7.53	0.2700	0.2588	0.2466	0.2374	0.2275	0.2199	0.2118	0.1987	0.1875	0.1781	0.1700	0.1630	0.1569	0.1514	0.1467	0.1425	0.1386	0.1351	0.1323	0.1295
5.0	7.68	0.2793	0.2677	0.2552	0.2457	0.2355	0.2277	0.2192	0.2057	0.1942	0.1844	0.1761	0.1688	0.1625	0.1569	0.1520	0.1477	0.1437	0.1401	0.1371	0.1342
5.1	7.83	0.2888	0.2768	0.2639	0.2541	0.2436	0.2355	0.2268	0.2128	0.2010	0.1909	0.1823	0.1748	0.1682	0.1624	0.1574	0.1529	0.1488	0.1450	0.1420	0.1390
5.2	7.99	0.2984	0.2861	0.2727	0.2626	0.2518	0.2435	0.2345	0.2201	0.2078	0.1974	0.1885	0.1808	0.1740	0.1681	0.1628	0.1582	0.1540	0.1501	0.1469	0.1438
5.3	8.14	0.3081	0.2954	0.2816	0.2713	0.2601	0.2515	0.2423	0.2274	0.2148	0.2041	0.1949	0.1869	0.1799	0.1738	0.1684	0.1636	0.1592	0.1552	0.1520	0.1488
5.4	8.29	0.3179	0.3049	0.2907	0.2801	0.2685	0.2597	0.2502	0.2348	0.2218	0.2108	0.2013	0.1931	0.1859	0.1796	0.1740	0.1691	0.1646	0.1605	0.1571	0.1538
5.5	8.45	0.3279	0.3145	0.2999	0.2890	0.2771	0.2680	0.2582	0.2424	0.2290	0.2176	0.2079	0.1994	0.1920	0.1855	0.1797	0.1747	0.1700	0.1657	0.1623	0.1589
5.6	8.60	0.3380	0.3242	0.3092	0.2980	0.2857	0.2764	0.2663	0.2500	0.2363	0.2246	0.2145	0.2058	0.1982	0.1914	0.1855	0.1803	0.1755	0.1711	0.1675	0.1640

Recommended Head Loss Design Range

Sizing in this region will lead to excessive head loss conditions.

1" Uponor MLC — 100% Water — Feet of Head per 100 Feet of Tubing

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	3.78	1.47	1.39	1.31	1.29	1.26	1.24	1.22	1.18	1.14	1.11	1.09	1.06	1.04	1.02	1.00	0.98	0.97	0.95	0.94	0.92
1.6	4.03	1.64	1.56	1.47	1.44	1.41	1.39	1.36	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
1.7	4.28	1.82	1.73	1.63	1.60	1.57	1.54	1.51	1.47	1.42	1.39	1.35	1.32	1.29	1.27	1.25	1.22	1.21	1.19	1.17	1.15
1.8	4.53	2.01	1.91	1.80	1.77	1.73	1.70	1.67	1.62	1.57	1.53	1.50	1.46	1.43	1.40	1.38	1.36	1.33	1.31	1.30	1.28
1.9	4.78	2.20	2.10	1.98	1.94	1.91	1.87	1.84	1.78	1.73	1.69	1.65	1.61	1.58	1.54	1.52	1.49	1.47	1.45	1.43	1.41
2.0	5.03	2.41	2.29	2.17	2.13	2.08	2.05	2.01	1.95	1.89	1.84	1.80	1.76	1.72	1.69	1.66	1.63	1.61	1.58	1.56	1.54
2.1	5.29	2.62	2.50	2.36	2.31	2.27	2.23	2.19	2.12	2.06	2.01	1.96	1.92	1.88	1.84	1.81	1.78	1.75	1.73	1.70	1.68
2.2	5.54	2.84	2.71	2.56	2.51	2.46	2.42	2.38	2.30	2.24	2.18	2.13	2.08	2.04	2.00	1.97	1.93	1.90	1.88	1.85	1.83
2.3	5.79	3.07	2.92	2.76	2.71	2.66	2.62	2.57	2.49	2.42	2.36	2.30	2.25	2.21	2.17	2.13	2.09	2.06	2.03	2.00	1.98
2.4	6.04	3.30	3.15	2.98	2.92	2.87	2.82	2.77	2.68	2.61	2.54	2.48	2.43	2.38	2.34	2.30	2.26	2.22	2.19	2.16	2.13
2.5	6.29	3.54	3.38	3.20	3.14	3.08	3.03	2.98	2.88	2.81	2.73	2.67	2.61	2.56	2.51	2.47	2.43	2.39	2.36	2.32	2.29
2.6	6.55	3.79	3.62	3.42	3.36	3.30	3.24	3.19	3.09	3.01	2.93	2.86	2.80	2.74	2.69	2.65	2.60	2.56	2.53	2.49	2.46
2.7	6.80	4.05	3.87	3.66	3.59	3.52	3.47	3.41	3.30	3.21	3.13	3.06	2.99	2.93	2.88	2.83	2.78	2.74	2.70	2.67	2.63
2.8	7.05	4.31	4.12	3.90	3.83	3.76	3.69	3.63	3.52	3.43	3.34	3.26	3.19	3.13	3.07	3.02	2.97	2.93	2.88	2.85	2.81
2.9	7.30	4.59	4.38	4.15	4.07	3.99	3.93	3.86	3.75	3.65	3.55	3.47	3.40	3.33	3.27	3.21	3.16	3.11	3.07	3.03	2.99
3.0	7.55	4.87	4.65	4.40	4.32	4.24	4.17	4.10	3.98	3.87	3.77	3.69	3.61	3.54	3.47	3.41	3.36	3.31	3.26	3.22	3.18
3.1	7.80	5.15	4.92	4.66	4.58	4.49	4.42	4.34	4.21	4.10	4.00	3.91	3.83	3.75	3.68	3.62	3.56	3.51	3.46	3.41	3.37
3.2	8.06	5.44	5.20	4.93	4.84	4.75	4.67	4.59	4.46	4.34	4.23	4.13	4.05	3.97	3.90	3.83	3.77	3.71	3.66	3.61	3.57
3.3	8.31	5.74	5.49	5.20	5.11	5.01	4.93	4.85	4.71	4.58	4.47	4.37	4.27	4.19	4.12	4.05	3.98	3.92	3.87	3.82	3.77
3.4	8.56	6.05	5.78	5.48	5.38	5.28	5.20	5.11	4.96	4.83	4.71	4.60	4.51	4.42	4.34	4.27	4.20	4.14	4.08	4.03	3.98
3.5	8.81	6.37	6.09	5.77	5.67	5.56	5.47	5.38	5.22	5.08	4.96	4.85	4.75	4.65	4.57	4.49	4.42	4.36	4.30	4.24	4.19
3.6	9.06	6.69	6.39	6.06	5.95	5.84	5.75	5.65	5.49	5.34	5.21	5.10	4.99	4.89	4.81	4.73	4.65	4.58	4.52	4.46	4.41
3.7	9.31	7.01	6.71	6.36	6.25	6.13	6.04	5.94	5.76	5.61	5.47	5.35	5.24	5.14	5.05	4.96	4.89	4.81	4.75	4.69	4.63
3.8	9.57	7.35	7.03	6.66	6.55	6.43	6.33	6.22	6.04	5.88	5.74	5.61	5.49	5.39	5.29	5.21	5.12	5.05	4.98	4.92	4.86
3.9	9.82	7.69	7.36	6.98	6.86	6.73	6.62	6.51	6.33	6.16	6.01	5.88	5.75	5.65	5.55	5.45	5.37	5.29	5.22	5.15	5.09
4.0	10.07	8.04	7.69	7.29	7.17	7.04	6.93	6.81	6.62	6.44	6.29	6.15	6.02	5.91	5.80	5.71	5.62	5.53	5.46	5.39	5.32
4.1	10.32	8.39	8.03	7.62	7.49	7.35	7.24	7.12	6.91	6.73	6.57	6.42	6.29	6.17	6.06	5.96	5.87	5.78	5.71	5.63	5.57
4.2	10.57	8.76	8.38	7.95	7.81	7.67	7.55	7.43	7.21	7.03	6.86	6.71	6.57	6.44	6.33	6.23	6.13	6.04	5.96	5.88	5.81
4.3	10.82	9.12	8.73	8.29	8.14	7.99	7.87	7.74	7.52	7.32	7.15	6.99	6.85	6.72	6.60	6.49	6.39	6.30	6.22	6.14	6.06
4.4	11.08	9.50	9.09	8.63	8.48	8.33	8.20	8.06	7.83	7.63	7.45	7.28	7.14	7.00	6.88	6.77	6.66	6.57	6.48	6.40	6.32
4.5	11.33	9.88	9.46	8.98	8.82	8.66	8.53	8.39	8.15	7.94	7.75	7.58	7.43	7.29	7.16	7.04	6.94	6.84	6.74	6.66	6.58
4.6	11.58	10.27	9.83	9.33	9.17	9.01	8.87	8.72	8.48	8.26	8.06	7.89	7.73	7.58	7.45	7.33	7.22	7.11	7.02	6.93	6.85
4.7	11.83	10.66	10.21	9.69	9.53	9.36	9.21	9.06	8.81	8.58	8.38	8.19	8.03	7.88	7.74	7.61	7.50	7.39	7.29	7.20	7.12
4.8	12.08	11.07	10.60	10.06	9.89	9.71	9.56	9.41	9.14	8.91	8.70	8.51	8.34	8.18	8.04	7.91	7.79	7.68	7.57	7.48	7.39
4.9	12.33	11.47	10.99	10.43	10.26	10.07	9.92	9.76	9.48	9.24	9.02	8.83	8.65	8.49	8.34	8.21	8.08	7.97	7.86	7.76	7.67

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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 MLC — 100% Water — Feet of Head per 100 Feet of Tubing

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
5.0	12.59	11.89	11.38	10.81	10.63	10.44	10.28	10.12	9.83	9.58	9.35	9.15	8.97	8.80	8.65	8.51	8.38	8.26	8.15	8.05	7.95
5.1	12.84	12.31	11.79	11.20	11.01	10.81	10.65	10.48	10.18	9.92	9.69	9.48	9.29	9.12	8.96	8.82	8.68	8.56	8.45	8.34	8.24
5.2	13.09	12.74	12.20	11.59	11.39	11.19	11.02	10.84	10.54	10.27	10.03	9.81	9.62	9.44	9.28	9.13	8.99	8.86	8.75	8.64	8.54
5.3	13.34	13.17	12.62	11.99	11.78	11.57	11.40	11.22	10.90	10.63	10.38	10.15	9.95	9.77	9.60	9.45	9.31	9.17	9.05	8.94	8.84
5.4	13.59	13.61	13.04	12.39	12.18	11.96	11.78	11.60	11.27	10.99	10.73	10.50	10.29	10.10	9.93	9.77	9.62	9.49	9.36	9.25	9.14
5.5	13.85	14.06	13.47	12.80	12.58	12.36	12.17	11.98	11.65	11.35	11.09	10.85	10.63	10.44	10.26	10.10	9.95	9.80	9.68	9.56	9.45
5.6	14.10	14.51	13.90	13.21	12.99	12.76	12.57	12.37	12.03	11.72	11.45	11.20	10.98	10.78	10.60	10.43	10.27	10.13	10.00	9.87	9.76
5.7	14.35	14.97	14.34	13.63	13.41	13.17	12.97	12.77	12.41	12.10	11.82	11.56	11.34	11.13	10.94	10.76	10.61	10.45	10.32	10.19	10.07
5.8	14.60	15.43	14.79	14.06	13.83	13.58	13.38	13.17	12.80	12.48	12.19	11.93	11.69	11.48	11.29	11.11	10.94	10.79	10.65	10.52	10.40
5.9	14.85	15.91	15.24	14.49	14.25	14.00	13.79	13.57	13.20	12.87	12.57	12.30	12.06	11.84	11.64	11.45	11.28	11.12	10.98	10.85	10.72
6.0	15.10	16.38	15.70	14.93	14.68	14.42	14.21	13.98	13.60	13.26	12.95	12.68	12.43	12.20	11.99	11.80	11.63	11.47	11.32	11.18	11.05
6.1	15.36	16.87	16.17	15.37	15.12	14.85	14.63	14.40	14.01	13.65	13.34	13.06	12.80	12.57	12.36	12.16	11.98	11.81	11.66	11.52	11.39
6.2	15.61	17.36	16.64	15.82	15.56	15.29	15.06	14.82	14.42	14.06	13.73	13.44	13.18	12.94	12.72	12.52	12.34	12.16	12.01	11.86	11.73
6.3	15.86	17.85	17.12	16.28	16.01	15.73	15.50	15.25	14.83	14.46	14.13	13.83	13.56	13.32	13.09	12.89	12.70	12.52	12.36	12.21	12.07
6.4	16.11	18.36	17.60	16.74	16.46	16.17	15.94	15.69	15.26	14.88	14.53	14.23	13.95	13.70	13.47	13.26	13.06	12.88	12.72	12.56	12.42
6.5	16.36	18.86	18.09	17.20	16.92	16.63	16.38	16.13	15.68	15.29	14.94	14.63	14.34	14.09	13.85	13.63	13.43	13.25	13.08	12.92	12.77
6.6	16.61	19.38	18.58	17.68	17.39	17.08	16.83	16.57	16.12	15.72	15.36	15.04	14.74	14.48	14.24	14.01	13.81	13.62	13.44	13.28	13.13
6.7	16.87	19.90	19.08	18.15	17.86	17.55	17.29	17.02	16.56	16.15	15.78	15.45	15.15	14.87	14.63	14.40	14.19	13.99	13.81	13.65	13.49
6.8	17.12	20.43	19.59	18.64	18.33	18.02	17.75	17.48	17.00	16.58	16.20	15.86	15.55	15.28	15.02	14.79	14.57	14.37	14.19	14.02	13.86
6.9	17.37	20.96	20.10	19.13	18.82	18.49	18.22	17.94	17.45	17.02	16.63	16.28	15.97	15.68	15.42	15.18	14.96	14.75	14.57	14.39	14.23
7.0	17.62	21.50	20.62	19.62	19.30	18.97	18.69	18.40	17.90	17.46	17.06	16.71	16.39	16.09	15.83	15.58	15.35	15.14	14.95	14.77	14.60
7.1	17.87	22.05	21.15	20.12	19.80	19.45	19.17	18.87	18.36	17.91	17.50	17.14	16.81	16.51	16.23	15.98	15.75	15.53	15.34	15.15	14.98
7.2	18.12	22.60	21.68	20.63	20.29	19.94	19.65	19.35	18.83	18.36	17.95	17.57	17.24	16.93	16.65	16.39	16.15	15.93	15.73	15.54	15.37
7.3	18.38	23.15	22.21	21.14	20.80	20.44	20.14	19.83	19.30	18.82	18.40	18.02	17.67	17.35	17.07	16.80	16.56	16.33	16.13	15.94	15.76
7.4	18.63	23.72	22.75	21.66	21.31	20.94	20.64	20.32	19.77	19.29	18.85	18.46	18.11	17.78	17.49	17.22	16.97	16.74	16.53	16.33	16.15
7.5	18.88	24.29	23.30	22.18	21.82	21.45	21.14	20.81	20.25	19.76	19.31	18.91	18.55	18.22	17.92	17.64	17.39	17.15	16.93	16.73	16.55
7.6	19.13	24.86	23.86	22.71	22.34	21.96	21.64	21.31	20.74	20.23	19.77	19.37	18.99	18.66	18.35	18.07	17.81	17.56	17.34	17.14	16.95
7.7	19.38	25.44	24.41	23.24	22.87	22.48	22.15	21.81	21.23	20.71	20.24	19.83	19.45	19.10	18.79	18.50	18.23	17.98	17.76	17.55	17.35
7.8	19.64	26.03	24.98	23.78	23.40	23.00	22.67	22.32	21.72	21.19	20.72	20.29	19.90	19.55	19.23	18.93	18.66	18.41	18.18	17.96	17.76
7.9	19.89	26.62	25.55	24.33	23.94	23.53	23.19	22.83	22.22	21.68	21.20	20.76	20.36	20.00	19.68	19.37	19.10	18.84	18.60	18.38	18.18
8.0	20.14	27.22	26.13	24.88	24.48	24.06	23.72	23.35	22.73	22.18	21.68	21.23	20.83	20.46	20.13	19.82	19.54	19.27	19.03	18.81	18.60

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 MLC — 30% Propylene Glycol — Feet of Head per 100 Feet of Tubing

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	3.78	2.0067	1.9363	1.8609	1.8025	1.7401	1.6898	1.6363	1.5495	1.4749	1.4107	1.3545	1.3068	1.2640	1.2251	1.1940	1.1635	1.1355	1.1121	1.0891	1.0720
1.6	4.03	2.2366	2.1588	2.0755	2.0108	1.9418	1.8861	1.8269	1.7308	1.6481	1.5769	1.5145	1.4615	1.4141	1.3709	1.3363	1.3024	1.2713	1.2454	1.2197	1.2008
1.7	4.28	2.4769	2.3914	2.2998	2.2287	2.1528	2.0916	2.0264	1.9205	1.8294	1.7509	1.6822	1.6238	1.5714	1.5237	1.4856	1.4482	1.4138	1.3851	1.3568	1.3359
1.8	4.53	2.7275	2.6340	2.5339	2.4561	2.3731	2.3060	2.2346	2.1187	2.0189	1.9328	1.8574	1.7934	1.7359	1.6836	1.6417	1.6006	1.5629	1.5314	1.5003	1.4773
1.9	4.78	2.9881	2.8864	2.7775	2.6928	2.6024	2.5293	2.4515	2.3252	2.2163	2.1225	2.0402	1.9702	1.9075	1.8504	1.8046	1.7598	1.7185	1.6841	1.6501	1.6249
2.0	5.03	3.2588	3.1486	3.0305	2.9386	2.8406	2.7614	2.6770	2.5398	2.4217	2.3197	2.2303	2.1543	2.0861	2.0240	1.9742	1.9254	1.8805	1.8431	1.8061	1.7787
2.1	5.29	3.5392	3.4203	3.2928	3.1936	3.0877	3.0021	2.9109	2.7626	2.6348	2.5246	2.4278	2.3455	2.2717	2.2044	2.1505	2.0976	2.0490	2.0084	1.9683	1.9386
2.2	5.54	3.8295	3.7016	3.5643	3.4576	3.3436	3.2514	3.1532	2.9935	2.8557	2.7369	2.6325	2.5438	2.4641	2.3915	2.3333	2.2763	2.2237	2.1800	2.1367	2.1046
2.3	5.79	4.1293	3.9922	3.8450	3.7305	3.6082	3.5092	3.4038	3.2323	3.0843	2.9566	2.8444	2.7490	2.6633	2.5853	2.5227	2.4613	2.4048	2.3577	2.3111	2.2766
2.4	6.04	4.4387	4.2921	4.1347	4.0122	3.8813	3.7754	3.6626	3.4789	3.3205	3.1836	3.0634	2.9612	2.8693	2.7856	2.7185	2.6527	2.5921	2.5415	2.4915	2.4545
2.5	6.29	4.7576	4.6012	4.4333	4.3026	4.1630	4.0500	3.9295	3.7334	3.5641	3.4179	3.2895	3.1802	3.0820	2.9925	2.9208	2.8504	2.7855	2.7314	2.6779	2.6383
2.6	6.55	5.0857	4.9194	4.7408	4.6017	4.4530	4.3327	4.2045	3.9956	3.8153	3.6595	3.5226	3.4061	3.3014	3.2059	3.1294	3.0543	2.9851	2.9273	2.8703	2.8280
2.7	6.80	5.4232	5.2466	5.0570	4.9094	4.7515	4.6237	4.4874	4.2655	4.0738	3.9081	3.7626	3.6386	3.5273	3.4257	3.3443	3.2643	3.1907	3.1293	3.0685	3.0235
2.8	7.05	5.7698	5.5828	5.3819	5.2255	5.0582	4.9227	4.7783	4.5429	4.3397	4.1639	4.0095	3.8779	3.7597	3.6519	3.5654	3.4806	3.4023	3.3371	3.2726	3.2248
2.9	7.30	6.1256	5.9279	5.7155	5.5501	5.3731	5.2298	5.0770	4.8280	4.6128	4.4268	4.2632	4.1239	3.9987	3.8845	3.7928	3.7029	3.6200	3.5509	3.4824	3.4318
3.0	7.55	6.4904	6.2818	6.0577	5.8830	5.6962	5.5449	5.3835	5.1205	4.8932	4.6966	4.5237	4.3765	4.2441	4.1233	4.0264	3.9313	3.8436	3.7705	3.6981	3.6445
3.1	7.80	6.8641	6.6444	6.4083	6.2243	6.0274	5.8680	5.6978	5.4205	5.1807	4.9734	4.7910	4.6356	4.4959	4.3684	4.2661	4.1657	4.0731	3.9959	3.9194	3.8629
3.2	8.06	7.2468	7.0157	6.7674	6.5738	6.3666	6.1988	6.0198	5.7278	5.4754	5.2570	5.0649	4.9012	4.7540	4.6197	4.5119	4.4061	4.3085	4.2271	4.1465	4.0869
3.3	8.31	7.6383	7.3957	7.1348	6.9315	6.7139	6.5376	6.3494	6.0425	5.7772	5.5476	5.3455	5.1734	5.0185	4.8772	4.7638	4.6524	4.5497	4.4641	4.3793	4.3165
3.4	8.56	8.0385	7.7842	7.5106	7.2973	7.0690	6.8840	6.6866	6.3645	6.0860	5.8449	5.6327	5.4519	5.2893	5.1409	5.0217	4.9047	4.7968	4.7067	4.6176	4.5516
3.5	8.81	8.4475	8.1811	7.8946	7.6712	7.4320	7.2382	7.0313	6.6938	6.4018	6.1490	5.9265	5.7369	5.5663	5.4106	5.2856	5.1628	5.0496	4.9551	4.8616	4.7923
3.6	9.06	8.8652	8.5866	8.2868	8.0531	7.8029	7.6001	7.3835	7.0302	6.7245	6.4599	6.2269	6.0283	5.8496	5.6864	5.5554	5.4268	5.3082	5.2092	5.1111	5.0385
3.7	9.31	9.2914	9.0004	8.6872	8.4430	8.1815	7.9696	7.7432	7.3739	7.0542	6.7774	6.5337	6.3259	6.1390	5.9683	5.8312	5.6966	5.5724	5.4688	5.3662	5.2902
3.8	9.57	9.7262	9.4225	9.0958	8.8409	8.5679	8.3466	8.1103	7.7246	7.3908	7.1016	6.8470	6.6299	6.4345	6.2562	6.1129	5.9722	5.8424	5.7341	5.6268	5.5474
3.9	9.82	10.1695	9.8530	9.5123	9.2466	8.9620	8.7312	8.4847	8.0824	7.7342	7.4324	7.1667	6.9402	6.7362	6.5500	6.4005	6.2536	6.1180	6.0049	5.8929	5.8100
4.0	10.07	10.6213	10.2917	9.9369	9.6602	9.3637	9.1233	8.8665	8.4473	8.0843	7.7699	7.4929	7.2567	7.0440	6.8498	6.6939	6.5407	6.3993	6.2813	6.1645	6.0779
4.1	10.32	11.0814	10.7386	10.3695	10.0816	9.7730	9.5228	9.2556	8.8192	8.4413	8.1138	7.8254	7.5794	7.3579	7.1556	6.9931	6.8335	6.6862	6.5632	6.4415	6.3513
4.2	10.57	11.5499	11.1937	10.8100	10.5107	10.1899	9.9298	9.6519	9.1981	8.8050	8.4643	8.1642	7.9082	7.6777	7.4672	7.2981	7.1320	6.9786	6.8507	6.7239	6.6300
4.3	10.82	12.0268	11.6568	11.2585	10.9475	10.6144	10.3442	10.0554	9.5839	9.1754	8.8213	8.5094	8.2433	8.0036	7.7847	7.6089	7.4361	7.2767	7.1436	7.0117	6.9141
4.4	11.08	12.5119	12.1281	11.7147	11.3921	11.0463	10.7658	10.4661	9.9766	9.5525	9.1848	8.8608	8.5844	8.3355	8.1081	7.9254	7.7459	7.5802	7.4419	7.3049	7.2034
4.5	11.33	13.0052	12.6074	12.1788	11.8443	11.4857	11.1948	10.8840	10.3762	9.9362	9.5547	9.2185	8.9316	8.6733	8.4372	8.2476	8.0613	7.8893	7.7457	7.6035	7.4981
4.6	11.58	13.5068	13.0946	12.6507	12.3041	11.9325	11.6311	11.3089	10.7826	10.3265	9.9310	9.5824	9.2849	9.0170	8.7722	8.5755	8.3822	8.2038	8.0549	7.9073	7.7980
4.7	11.83	14.0164	13.5898	13.1302	12.7714	12.3867	12.0746	11.7410	11.1959	10.7234	10.3137	9.9525	9.6443	9.3666	9.1130	8.9091	8.7088	8.5238	8.3694	8.2165	8.1032
4.8	12.08	14.5342	14.0930	13.6175	13.2463	12.8483	12.5253	12.1801	11.6159	11.1269	10.7027	10.3288	10.0097	9.7222	9.4594	9.2483	9.0408	8.8493	8.6894	8.5310	8.4136
4.9	12.33	15.0601	14.6040	14.1125	13.7287	13.3172	12.9832	12.6262	12.0427	11.5369	11.0981	10.7112	10.3810	10.0835	9.8117	9.5932	9.3784	9.1802	9.0147	8.8507	8.7292

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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 MLC — 30% Propylene Glycol — Feet of Head per 100 Feet of Tubing

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
5.0	12.59	15.5940	15.1229	14.6151	14.2186	13.7934	13.4483	13.0793	12.4763	11.9534	11.4998	11.0998	10.7584	10.4507	10.1696	9.9436	9.7215	9.5165	9.3453	9.1757	9.0500
5.1	12.84	16.1359	15.6496	15.1253	14.7159	14.2768	13.9204	13.5394	12.9165	12.3764	11.9077	11.4945	11.1416	10.8237	10.5332	10.2997	10.0701	9.8582	9.6812	9.5059	9.3760
5.2	13.09	16.6858	16.1840	15.6431	15.2206	14.7675	14.3997	14.0064	13.3634	12.8058	12.3219	11.8952	11.5309	11.2025	10.9025	10.6613	10.4242	10.2053	10.0225	9.8414	9.7071
5.3	13.34	17.2436	16.7262	16.1685	15.7327	15.2654	14.8860	14.4803	13.8170	13.2416	12.7423	12.3020	11.9260	11.5871	11.2774	11.0284	10.7837	10.5577	10.3690	10.1820	10.0434
5.4	13.59	17.8094	17.2761	16.7013	16.2522	15.7704	15.3793	14.9611	14.2772	13.6839	13.1690	12.7148	12.3270	11.9774	11.6579	11.4011	11.1486	10.9154	10.7207	10.5278	10.3848
5.5	13.85	18.3830	17.8338	17.2416	16.7790	16.2826	15.8797	15.4487	14.7440	14.1325	13.6018	13.1336	12.7338	12.3735	12.0441	11.7793	11.5189	11.2785	11.0777	10.8788	10.7313
5.6	14.10	18.9644	18.3990	17.7894	17.3130	16.8020	16.3870	15.9432	15.2173	14.5875	14.0408	13.5585	13.1466	12.7753	12.4358	12.1629	11.8946	11.6469	11.4399	11.2349	11.0829
5.7	14.35	19.5537	18.9719	18.3446	17.8544	17.3284	16.9013	16.4444	15.6972	15.0488	14.4859	13.9893	13.5651	13.1827	12.8331	12.5521	12.2757	12.0205	11.8074	11.5962	11.4396
5.8	14.60	20.1507	19.5524	18.9072	18.4029	17.8619	17.4225	16.9525	16.1837	15.5165	14.9372	14.4260	13.9894	13.5959	13.2360	12.9466	12.6622	12.3994	12.1800	11.9625	11.8014
5.9	14.85	20.7555	20.1405	19.4771	18.9587	18.4024	17.9506	17.4673	16.6767	15.9904	15.3945	14.8687	14.4196	14.0146	13.6444	13.3467	13.0539	12.7836	12.5578	12.3340	12.1682
6.0	15.10	21.3680	20.7361	20.0545	19.5217	18.9500	18.4856	17.9888	17.1761	16.4706	15.8579	15.3173	14.8555	14.4391	14.0583	13.7521	13.4511	13.1730	12.9407	12.7106	12.5400
6.1	15.36	21.9882	21.3392	20.6391	20.0918	19.5045	19.0275	18.5171	17.6820	16.9570	16.3274	15.7718	15.2971	14.8691	14.4777	14.1630	13.8535	13.5676	13.3288	13.0922	12.9168
6.2	15.61	22.6161	21.9498	21.2310	20.6691	20.0660	19.5762	19.0520	18.1944	17.4497	16.8030	16.2322	15.7445	15.3048	14.9026	14.5792	14.2612	13.9674	13.7221	13.4789	13.2986
6.3	15.86	23.2516	22.5678	21.8302	21.2535	20.6345	20.1317	19.5936	18.7131	17.9486	17.2845	16.6984	16.1976	15.7460	15.3330	15.0008	14.6742	14.3725	14.1204	13.8706	13.6855
6.4	16.11	23.8947	23.1934	22.4366	21.8450	21.2099	20.6940	20.1418	19.2383	18.4537	17.7721	17.1705	16.6564	16.1928	15.7688	15.4278	15.0924	14.7827	14.5239	14.2674	14.0773
6.5	16.36	24.5454	23.8263	23.0503	22.4435	21.7922	21.2630	20.6967	19.7699	18.9650	18.2657	17.6484	17.1209	16.6452	16.2100	15.8601	15.5159	15.1980	14.9324	14.6692	14.4741
6.6	16.61	25.2037	24.4666	23.6711	23.0491	22.3814	21.8388	21.2582	20.3078	19.4824	18.7652	18.1321	17.5910	17.1031	16.6567	16.2977	15.9447	15.6185	15.3460	15.0760	14.8758
6.7	16.87	25.8696	25.1143	24.2992	23.6617	22.9774	22.4214	21.8262	20.8521	20.0059	19.2707	18.6216	18.0668	17.5665	17.1088	16.7407	16.3786	16.0441	15.7647	15.4878	15.2824
6.8	17.12	26.5429	25.7693	24.9343	24.2814	23.5803	23.0106	22.4008	21.4027	20.5356	19.7821	19.1169	18.5483	18.0354	17.5663	17.1889	16.8178	16.4749	16.1884	15.9045	15.6940
6.9	17.37	27.2238	26.4316	25.5767	24.9080	24.1900	23.6065	22.9820	21.9596	21.0714	20.2995	19.6179	19.0353	18.5099	18.0292	17.6425	17.2621	16.9108	16.6172	16.3262	16.1105
7.0	17.62	27.9121	27.1013	26.2261	25.5415	24.8065	24.2091	23.5697	22.5228	21.6132	20.8227	20.1247	19.5280	18.9898	18.4974	18.1013	17.7117	17.3517	17.0510	16.7529	16.5319
7.1	17.87	28.6078	27.7782	26.8826	26.1821	25.4298	24.8184	24.1639	23.0923	22.1611	21.3519	20.6372	20.0263	19.4751	18.9710	18.5653	18.1664	17.7978	17.4898	17.1846	16.9582
7.2	18.12	29.3110	28.4624	27.5462	26.8295	26.0598	25.4343	24.7646	23.6680	22.7151	21.8869	21.1554	20.5301	19.9660	19.4499	19.0347	18.6263	18.2489	17.9336	17.6211	17.3894
7.3	18.38	30.0216	29.1538	28.2168	27.4838	26.6966	26.0568	25.3717	24.2500	23.2751	22.4277	21.6793	21.0395	20.4623	19.9341	19.5092	19.0913	18.7051	18.3824	18.0626	17.8255
7.4	18.63	30.7396	29.8524	28.8944	28.1450	27.3401	26.6858	25.9853	24.8382	23.8412	22.9745	22.2090	21.5545	20.9640	20.4237	19.9890	19.5614	19.1663	18.8362	18.5090	18.2664
7.5	18.88	31.4650	30.5582	29.5791	28.8131	27.9903	27.3215	26.6054	25.4326	24.4132	23.5270	22.7442	22.0749	21.4711	20.9185	20.4740	20.0367	19.6326	19.2950	18.9603	18.7121
7.6	19.13	32.1977	31.2712	30.2708	29.4880	28.6472	27.9637	27.2319	26.0332	24.9912	24.0854	23.2852	22.6010	21.9836	21.4187	20.9642	20.5170	20.1039	19.7587	19.4164	19.1627
7.7	19.38	32.9377	31.9913	30.9694	30.1698	29.3108	28.6125	27.8647	26.6399	25.5752	24.6495	23.8318	23.1325	22.5015	21.9241	21.4595	21.0025	20.5802	20.2273	19.8775	19.6181
7.8	19.64	33.6850	32.7186	31.6750	30.8583	29.9810	29.2678	28.5040	27.2529	26.1652	25.2195	24.3840	23.6695	23.0248	22.4348	21.9601	21.4931	21.0615	20.7009	20.3434	20.0783
7.9	19.89	34.4396	33.4530	32.3875	31.5536	30.6579	29.9296	29.1496	27.8720	26.7611	25.7952	24.9418	24.2120	23.5534	22.9508	22.4658	21.9887	21.5478	21.1794	20.8142	20.5434
8.0	20.14	35.2015	34.1945	33.1069	32.2558	31.3413	30.5978	29.8016	28.4972	27.3630	26.3767	25.5052	24.7600	24.0874	23.4719	22.9766	22.4894	22.0391	21.6628	21.2898	21.0132

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 MLC — 40% Propylene Glycol — Feet of Head per 100 Feet of Tubing

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	3.78	2.3720	2.2680	2.1557	2.0724	1.9830	1.9147	1.8416	1.7243	1.6259	1.5437	1.4730	1.4107	1.3577	1.3104	1.2705	1.2361	1.2018	1.1763	1.1476	1.1267
1.6	4.03	2.6399	2.5252	2.4012	2.3092	2.2104	2.1349	2.0541	1.9243	1.8154	1.7243	1.6459	1.5768	1.5181	1.4656	1.4213	1.3831	1.3450	1.3166	1.2848	1.2615
1.7	4.28	2.9196	2.7937	2.6577	2.5567	2.4481	2.3651	2.2763	2.1336	2.0137	1.9134	1.8271	1.7509	1.6861	1.6282	1.5794	1.5372	1.4951	1.4638	1.4287	1.4030
1.8	4.53	3.2109	3.0735	2.9250	2.8147	2.6960	2.6053	2.5081	2.3520	2.2207	2.1108	2.0163	1.9328	1.8617	1.7983	1.7446	1.6984	1.6522	1.6178	1.5792	1.5510
1.9	4.78	3.5136	3.3644	3.2029	3.0830	2.9539	2.8552	2.7494	2.5794	2.4364	2.3166	2.2135	2.1224	2.0449	1.9756	1.9171	1.8666	1.8161	1.7785	1.7364	1.7055
2.0	5.03	3.8276	3.6661	3.4914	3.3615	3.2217	3.1147	3.0001	2.8157	2.6605	2.5306	2.4186	2.3196	2.2354	2.1601	2.0965	2.0416	1.9867	1.9459	1.9000	1.8665
2.1	5.29	4.1528	3.9787	3.7902	3.6501	3.4992	3.3838	3.2600	3.0609	2.8931	2.7526	2.6315	2.5245	2.4333	2.3518	2.2829	2.2235	2.1640	2.1198	2.0701	2.0337
2.2	5.54	4.4889	4.3019	4.0993	3.9487	3.7864	3.6622	3.5290	3.3147	3.1341	2.9827	2.8522	2.7367	2.6385	2.5506	2.4762	2.4121	2.3479	2.3002	2.2465	2.2073
2.3	5.79	4.8359	4.6356	4.4186	4.2571	4.0832	3.9500	3.8071	3.5771	3.3832	3.2206	3.0805	2.9564	2.8509	2.7563	2.6764	2.6074	2.5384	2.4870	2.4293	2.3871
2.4	6.04	5.1937	4.9797	4.7479	4.5753	4.3894	4.2470	4.0941	3.8481	3.6406	3.4665	3.3163	3.1835	3.0703	2.9690	2.8833	2.8094	2.7353	2.6803	2.6183	2.5731
2.5	6.29	5.5621	5.3342	5.0871	4.9032	4.7049	4.5531	4.3901	4.1275	3.9060	3.7201	3.5597	3.4178	3.2969	3.1886	3.0970	3.0179	2.9387	2.8799	2.8136	2.7652
2.6	6.55	5.9410	5.6988	5.4362	5.2406	5.0298	4.8682	4.6947	4.4153	4.1794	3.9814	3.8106	3.6593	3.5304	3.4150	3.3173	3.2330	3.1485	3.0857	3.0151	2.9634
2.7	6.80	6.3304	6.0736	5.7950	5.5876	5.3638	5.1923	5.0081	4.7114	4.4608	4.2504	4.0688	3.9080	3.7709	3.6481	3.5443	3.4545	3.3647	3.2978	3.2226	3.1676
2.8	7.05	6.7302	6.4584	6.1635	5.9439	5.7069	5.5253	5.3302	5.0157	4.7501	4.5270	4.3344	4.1638	4.0183	3.8880	3.7778	3.6825	3.5871	3.5161	3.4363	3.3779
2.9	7.30	7.1402	6.8531	6.5416	6.3095	6.0591	5.8670	5.6608	5.3282	5.0472	4.8111	4.6072	4.4266	4.2726	4.1346	4.0178	3.9169	3.8158	3.7406	3.6559	3.5940
3.0	7.55	7.5603	7.2577	6.9292	6.6844	6.4202	6.2176	5.9999	5.6488	5.3520	5.1026	4.8872	4.6964	4.5336	4.3877	4.2643	4.1576	4.0507	3.9711	3.8816	3.8161
3.1	7.80	7.9906	7.6721	7.3263	7.0685	6.7902	6.5768	6.3474	5.9774	5.6646	5.4016	5.1745	4.9732	4.8014	4.6475	4.5172	4.4046	4.2917	4.2078	4.1132	4.0441
3.2	8.06	8.4309	8.0962	7.7327	7.4617	7.1690	6.9446	6.7033	6.3140	5.9848	5.7080	5.4688	5.2568	5.0759	4.9138	4.7765	4.6578	4.5389	4.4504	4.3508	4.2779
3.3	8.31	8.8810	8.5299	8.1484	7.8639	7.5566	7.3209	7.0675	6.6585	6.3126	6.0217	5.7703	5.5473	5.3571	5.1866	5.0421	4.9173	4.7922	4.6991	4.5943	4.5176
3.4	8.56	9.3411	8.9731	8.5733	8.2751	7.9529	7.7058	7.4400	7.0110	6.6480	6.3427	6.0787	5.8447	5.6449	5.4658	5.3141	5.1830	5.0515	4.9537	4.8436	4.7630
3.5	8.81	9.8109	9.4259	9.0074	8.6952	8.3579	8.0990	7.8207	7.3712	6.9909	6.6709	6.3942	6.1488	5.9393	5.7515	5.5923	5.4548	5.3169	5.2143	5.0987	5.0141
3.6	9.06	10.2905	9.8880	9.4506	9.1242	8.7714	8.5007	8.2095	7.7393	7.3412	7.0062	6.7166	6.4596	6.2403	6.0435	5.8768	5.7327	5.5883	5.4807	5.3596	5.2710
3.7	9.31	10.7797	10.3596	9.9028	9.5619	9.1935	8.9107	8.6065	8.1150	7.6990	7.3488	7.0459	6.7771	6.5477	6.3419	6.1675	6.0167	5.8656	5.7530	5.6263	5.5335
3.8	9.57	11.2786	10.8404	10.3640	10.0085	9.6241	9.3289	9.0115	8.4985	8.0641	7.6984	7.3820	7.1013	6.8616	6.6466	6.4644	6.3068	6.1488	6.0312	5.8987	5.8018
3.9	9.82	11.7869	11.3305	10.8342	10.4637	10.0630	9.7554	9.4245	8.8896	8.4366	8.0551	7.7250	7.4321	7.1820	6.9576	6.7674	6.6029	6.4379	6.3151	6.1768	6.0756
4.0	10.07	12.3048	11.8298	11.3132	10.9275	10.5104	10.1901	9.8454	9.2883	8.8163	8.4188	8.0748	7.7696	7.5088	7.2748	7.0765	6.9050	6.7330	6.6049	6.4606	6.3550
4.1	10.32	12.8320	12.3383	11.8011	11.4000	10.9661	10.6329	10.2743	9.6946	9.2033	8.7896	8.4314	8.1135	7.8420	7.5982	7.3917	7.2130	7.0338	6.9004	6.7500	6.6400
4.2	10.57	13.3687	12.8558	12.2977	11.8810	11.4301	11.0838	10.7111	10.1084	9.5976	9.1672	8.7947	8.4640	8.1815	7.9279	7.7129	7.5270	7.3405	7.2016	7.0451	6.9306
4.3	10.82	13.9147	13.3824	12.8031	12.3704	11.9024	11.5428	11.1556	10.5296	9.9990	9.5518	9.1647	8.8210	8.5273	8.2637	8.0402	7.8469	7.6529	7.5085	7.3458	7.2267
4.4	11.08	14.4699	13.9179	13.3172	12.8684	12.3828	12.0097	11.6080	10.9584	10.4075	9.9433	9.5414	9.1844	8.8794	8.6056	8.3735	8.1726	7.9712	7.8211	7.6520	7.5283
4.5	11.33	15.0343	14.4625	13.8399	13.3748	12.8714	12.4846	12.0682	11.3945	10.8232	10.3417	9.9247	9.5543	9.2378	8.9536	8.7127	8.5042	8.2951	8.1394	7.9638	7.8354
4.6	11.58	15.6080	15.0159	14.3712	13.8895	13.3682	12.9675	12.5361	11.8380	11.2460	10.7469	10.3146	9.9306	9.6025	9.3078	9.0579	8.8417	8.6248	8.4632	8.2812	8.1479
4.7	11.83	16.1907	15.5781	14.9111	14.4126	13.8730	13.4583	13.0116	12.2889	11.6758	11.1588	10.7111	10.3133	9.9733	9.6679	9.4090	9.1850	8.9602	8.7927	8.6040	8.4659
4.8	12.08	16.7825	16.1492	15.4595	14.9439	14.3859	13.9569	13.4948	12.7470	12.1126	11.5776	11.1141	10.7023	10.3503	10.0342	9.7660	9.5340	9.3012	9.1278	8.9324	8.7893
4.9	12.33	17.3834	16.7291	16.0164	15.4836	14.9068	14.4633	13.9856	13.2125	12.5564	12.0031	11.5236	11.0977	10.7335	10.4064	10.1289	9.8888	9.6479	9.4685	9.2662	9.1181

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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 MLC — 40% Propylene Glycol — Feet of Head per 100 Feet of Tubing

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
5.0	12.59	17.9933	17.3176	16.5817	16.0314	15.4356	14.9775	14.4840	13.6852	13.0072	12.4353	11.9397	11.4993	11.1228	10.7846	10.4977	10.2494	10.0003	9.8146	9.6054	9.4523
5.1	12.84	18.6121	17.9149	17.1554	16.5874	15.9724	15.4995	14.9900	14.1651	13.4649	12.8742	12.3622	11.9073	11.5182	11.1687	10.8723	10.6157	10.3582	10.1664	9.9501	9.7918
5.2	13.09	19.2398	18.5208	17.7374	17.1516	16.5171	16.0292	15.5035	14.6522	13.9295	13.3197	12.7912	12.3214	11.9197	11.5588	11.2527	10.9877	10.7217	10.5236	10.3002	10.1367
5.3	13.34	19.8764	19.1354	18.3278	17.7239	17.0697	16.5666	16.0244	15.1464	14.4010	13.7719	13.2266	12.7419	12.3273	11.9548	11.6389	11.3653	11.0908	10.8863	10.6557	10.4869
5.4	13.59	20.5218	19.7585	18.9265	18.3042	17.6301	17.1116	16.5528	15.6478	14.8793	14.2307	13.6684	13.1685	12.7409	12.3567	12.0308	11.7487	11.4655	11.2544	11.0165	10.8424
5.5	13.85	21.1761	20.3901	19.5335	18.8926	18.1983	17.6643	17.0887	16.1563	15.3644	14.6960	14.1165	13.6013	13.1606	12.7645	12.4285	12.1376	11.8456	11.6281	11.3828	11.2032
5.6	14.10	21.8391	21.0303	20.1486	19.4890	18.7743	18.2245	17.6319	16.6719	15.8564	15.1680	14.5710	14.0403	13.5862	13.1782	12.8320	12.5322	12.2313	12.0071	11.7543	11.5692
5.7	14.35	22.5108	21.6789	20.7720	20.0934	19.3581	18.7924	18.1825	17.1945	16.3551	15.6464	15.0319	14.4854	14.0179	13.5977	13.2411	12.9324	12.6225	12.3916	12.1312	11.9405
5.8	14.60	23.1912	22.3360	21.4035	20.7057	19.9496	19.3677	18.7405	17.7242	16.8606	16.1314	15.4990	14.9366	14.4554	14.0230	13.6560	13.3382	13.0192	12.7814	12.5134	12.3171
5.9	14.85	23.8803	23.0015	22.0432	21.3260	20.5487	19.9506	19.3058	18.2608	17.3728	16.6229	15.9724	15.3939	14.8990	14.4540	14.0765	13.7495	13.4213	13.1767	12.9008	12.6989
6.0	15.10	24.5780	23.6753	22.6909	21.9541	21.1556	20.5410	19.8784	18.8044	17.8917	17.1208	16.4521	15.8574	15.3484	14.8909	14.5027	14.1664	13.8289	13.5773	13.2936	13.0858
6.1	15.36	25.2843	24.3575	23.3468	22.5902	21.7700	21.1388	20.4582	19.3550	18.4172	17.6252	16.9381	16.3268	15.8038	15.3336	14.9345	14.5888	14.2419	13.9832	13.6916	13.4780
6.2	15.61	25.9991	25.0481	24.0106	23.2340	22.3921	21.7441	21.0453	19.9125	18.9495	18.1360	17.4302	16.8024	16.2650	15.7819	15.3719	15.0168	14.6603	14.3945	14.0948	13.8754
6.3	15.86	26.7225	25.7469	24.6825	23.8857	23.0218	22.3568	21.6396	20.4769	19.4884	18.6532	17.9286	17.2839	16.7322	16.2360	15.8150	15.4503	15.0841	14.8111	14.5033	14.2779
6.4	16.11	27.4544	26.4539	25.3624	24.5451	23.6590	22.9768	22.2411	21.0482	20.0338	19.1768	18.4331	17.7715	17.2051	16.6959	16.2636	15.8892	15.5133	15.2330	14.9170	14.6855
6.5	16.36	28.1947	27.1692	26.0502	25.2123	24.3037	23.6042	22.8498	21.6263	20.5859	19.7068	18.9439	18.2650	17.6839	17.1614	16.7178	16.3336	15.9478	15.6602	15.3359	15.0983
6.6	16.61	28.9435	27.8927	26.7460	25.8872	24.9560	24.2390	23.4656	22.2113	21.1446	20.2431	19.4607	18.7645	18.1685	17.6326	17.1776	16.7835	16.3877	16.0927	15.7600	15.5163
6.7	16.87	29.7007	28.6243	27.4496	26.5698	25.6157	24.8810	24.0885	22.8031	21.7098	20.7858	19.9838	19.2700	18.6590	18.1094	17.6429	17.2388	16.8330	16.5304	16.1892	15.9393
6.8	17.12	30.4663	29.3641	28.1612	27.2601	26.2829	25.5304	24.7186	23.4018	22.2816	21.3347	20.5129	19.7814	19.1552	18.5919	18.1138	17.6995	17.2835	16.9734	16.6236	16.3674
6.9	17.37	31.2402	30.1120	28.8806	27.9581	26.9576	26.1870	25.3557	24.0071	22.8598	21.8900	21.0481	20.2987	19.6571	19.0801	18.5901	18.1657	17.7394	17.4216	17.0632	16.8006
7.0	17.62	32.0225	30.8680	29.6078	28.6637	27.6396	26.8509	25.9999	24.6193	23.4446	22.4515	21.5894	20.8220	20.1649	19.5738	19.0720	18.6372	18.2006	17.8750	17.5079	17.2389
7.1	17.87	32.8131	31.6321	30.3428	29.3769	28.3290	27.5219	26.6511	25.2382	24.0358	23.0193	22.1367	21.3511	20.6783	20.0732	19.5593	19.1142	18.6670	18.3337	17.9577	17.6822
7.2	18.12	33.6119	32.4042	31.0856	30.0977	29.0259	28.2002	27.3093	25.8638	24.6335	23.5934	22.6901	21.8861	21.1975	20.5781	20.0522	19.5965	19.1388	18.7975	18.4126	18.1306
7.3	18.38	34.4190	33.1844	31.8362	30.8260	29.7300	28.8857	27.9746	26.4961	25.2377	24.1736	23.2496	22.4269	21.7224	21.0886	20.5504	20.0841	19.6158	19.2665	18.8726	18.5840
7.4	18.63	35.2344	33.9725	32.5945	31.5619	30.4415	29.5783	28.6468	27.1351	25.8483	24.7601	23.8150	22.9736	22.2530	21.6047	21.0542	20.5771	20.0980	19.7407	19.3377	19.0425
7.5	18.88	36.0579	34.7686	33.3605	32.3053	31.1603	30.2781	29.3260	27.7807	26.4653	25.3527	24.3865	23.5262	22.7893	22.1263	21.5633	21.0755	20.5854	20.2200	19.8079	19.5059
7.6	19.13	36.8896	35.5726	34.1342	33.0562	31.8864	30.9850	30.0121	28.4330	27.0886	25.9516	24.9639	24.0845	23.3312	22.6535	22.0779	21.5791	21.0781	20.7045	20.2831	19.9744
7.7	19.38	37.7295	36.3846	34.9156	33.8146	32.6197	31.6990	30.7052	29.0920	27.7184	26.5565	25.5473	24.6486	23.8788	23.1862	22.5979	22.0881	21.5760	21.1942	20.7634	20.4478
7.8	19.64	38.5775	37.2045	35.7047	34.5804	33.3603	32.4200	31.4051	29.7575	28.3545	27.1677	26.1367	25.2186	24.4321	23.7244	23.1233	22.6024	22.0791	21.6889	21.2487	20.9262
7.9	19.89	39.4336	38.0322	36.5013	35.3537	34.1081	33.1482	32.1120	30.4296	28.9970	27.7849	26.7320	25.7943	24.9909	24.2680	23.6540	23.1219	22.5874	22.1888	21.7391	21.4096
8.0	20.14	40.2978	38.8678	37.3056	36.1344	34.8631	33.8834	32.8257	31.1084	29.6458	28.4083	27.3332	26.3757	25.5554	24.8172	24.1902	23.6467	23.1008	22.6937	22.2344	21.8979

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 MLC — 50% Propylene Glycol — Feet of Head per 100 Feet of Tubing

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	3.78	2.7161	2.5882	2.4503	2.3474	2.2369	2.1528	2.0627	1.9191	1.7987	1.6973	1.6111	1.5367	1.4721	1.4154	1.3660	1.3227	1.2826	1.2466	1.2171	1.1882
1.6	4.03	3.0192	2.8783	2.7262	2.6128	2.4908	2.3980	2.2985	2.1398	2.0066	1.8944	1.7990	1.7165	1.6450	1.5821	1.5273	1.4792	1.4348	1.3947	1.3620	1.3299
1.7	4.28	3.3353	3.1809	3.0142	2.8898	2.7560	2.6541	2.5449	2.3706	2.2241	2.1007	1.9957	1.9048	1.8260	1.7567	1.6963	1.6433	1.5942	1.5501	1.5139	1.4785
1.8	4.53	3.6642	3.4959	3.3142	3.1784	3.0324	2.9211	2.8018	2.6112	2.4510	2.3160	2.2010	2.1015	2.0151	1.9391	1.8729	1.8148	1.7609	1.7125	1.6728	1.6340
1.9	4.78	4.0057	3.8231	3.6258	3.4783	3.3197	3.1987	3.0689	2.8617	2.6873	2.5402	2.4149	2.3064	2.2122	2.1293	2.0570	1.9936	1.9348	1.8819	1.8386	1.7962
2.0	5.03	4.3596	4.1623	3.9489	3.7895	3.6177	3.4868	3.3463	3.1217	2.9327	2.7732	2.6372	2.5195	2.4172	2.3272	2.2486	2.1797	2.1158	2.0583	2.0112	1.9650
2.1	5.29	4.7258	4.5133	4.2835	4.1116	3.9265	3.7853	3.6337	3.3913	3.1872	3.0148	2.8680	2.7407	2.6301	2.5326	2.4476	2.3730	2.3039	2.2416	2.1905	2.1405
2.2	5.54	5.1041	4.8760	4.6293	4.4447	4.2458	4.0940	3.9310	3.6704	3.4507	3.2651	3.1069	2.9698	2.8506	2.7455	2.6539	2.5734	2.4988	2.4316	2.3765	2.3226
2.3	5.79	5.4944	5.2504	4.9862	4.7886	4.5755	4.4129	4.2382	3.9587	3.7231	3.5239	3.3541	3.2068	3.0788	2.9659	2.8674	2.7809	2.7007	2.6284	2.5691	2.5111
2.4	6.04	5.8966	5.6361	5.3542	5.1431	4.9156	4.7418	4.5551	4.2563	4.0042	3.7912	3.6094	3.4517	3.3145	3.1936	3.0881	2.9954	2.9094	2.8319	2.7683	2.7061
2.5	6.29	6.3104	6.0332	5.7331	5.5083	5.2658	5.0806	4.8817	4.5630	4.2941	4.0668	3.8727	3.7043	3.5578	3.4286	3.3158	3.2167	3.1249	3.0420	2.9740	2.9075
2.6	6.55	6.7359	6.4415	6.1227	5.8838	5.6262	5.4293	5.2177	4.8788	4.5927	4.3506	4.1440	3.9646	3.8085	3.6709	3.5506	3.4450	3.3470	3.2587	3.1862	3.1152
2.7	6.80	7.1728	6.8609	6.5230	6.2698	5.9965	5.7877	5.5633	5.2036	4.8998	4.6427	4.4231	4.2325	4.0666	3.9203	3.7924	3.6801	3.5759	3.4819	3.4047	3.3292
2.8	7.05	7.6211	7.2913	6.9339	6.6660	6.3768	6.1558	5.9182	5.5372	5.2153	4.9429	4.7101	4.5080	4.3320	4.1768	4.0411	3.9219	3.8113	3.7115	3.6296	3.5495
2.9	7.30	8.0806	7.7326	7.3553	7.0724	6.7670	6.5335	6.2823	5.8797	5.5393	5.2511	5.0049	4.7910	4.6047	4.4404	4.2967	4.1705	4.0533	3.9476	3.8608	3.7759
3.0	7.55	8.5514	8.1847	7.7871	7.4889	7.1669	6.9206	6.6557	6.2309	5.8717	5.5674	5.3074	5.0814	4.8847	4.7110	4.5592	4.4257	4.3018	4.1901	4.0983	4.0085
3.1	7.80	9.0332	8.6475	8.2292	7.9154	7.5765	7.3172	7.0383	6.5908	6.2123	5.8917	5.6175	5.3793	5.1717	4.9885	4.8284	4.6875	4.5568	4.4389	4.3420	4.2472
3.2	8.06	9.5259	9.1210	8.6815	8.3519	7.9957	7.7232	7.4299	6.9593	6.5612	6.2238	5.9353	5.6845	5.4660	5.2730	5.1043	4.9560	4.8183	4.6940	4.5919	4.4920
3.3	8.31	10.0296	9.6050	9.1440	8.7982	8.4244	8.1384	7.8305	7.3364	6.9183	6.5638	6.2605	5.9969	5.7672	5.5643	5.3870	5.2309	5.0861	4.9554	4.8480	4.7428
3.4	8.56	10.5441	10.0994	9.6166	9.2543	8.8626	8.5628	8.2401	7.7220	7.2834	6.9115	6.5933	6.3167	6.0755	5.8625	5.6763	5.5124	5.3603	5.2229	5.1101	4.9997
3.5	8.81	11.0694	10.6043	10.0992	9.7201	9.3102	8.9964	8.6586	8.1161	7.6567	7.2670	6.9336	6.6436	6.3908	6.1675	5.9722	5.8003	5.6408	5.4967	5.3784	5.2625
3.6	9.06	11.6053	11.1194	10.5918	10.1955	9.7671	9.4391	9.0859	8.5185	8.0379	7.6302	7.2813	6.9777	6.7131	6.4792	6.2747	6.0947	5.9275	5.7766	5.6526	5.5312
3.7	9.31	12.1518	11.6449	11.0942	10.6806	10.2333	9.8908	9.5219	8.9293	8.4272	8.0011	7.6363	7.3190	7.0422	6.7977	6.5837	6.3954	6.2206	6.0627	5.9329	5.8059
3.8	9.57	12.7088	12.1805	11.6064	11.1752	10.7088	10.3515	9.9667	9.3484	8.8243	8.3795	7.9987	7.6673	7.3782	7.1228	6.8993	6.7025	6.5198	6.3548	6.2192	6.0864
3.9	9.82	13.2763	12.7262	12.1284	11.6793	11.1934	10.8212	10.4202	9.7757	9.2293	8.7655	8.3683	8.0226	7.7211	7.4545	7.2213	7.0160	6.8252	6.6530	6.5115	6.3728
4.0	10.07	13.8541	13.2820	12.6601	12.1927	11.6871	11.2997	10.8823	10.2112	9.6422	9.1591	8.7452	8.3850	8.0707	7.7929	7.5497	7.3357	7.1368	6.9572	6.8096	6.6650
4.1	10.32	14.4423	13.8477	13.2014	12.7156	12.1898	11.7870	11.3529	10.6548	10.0628	9.5601	9.1293	8.7543	8.4271	8.1378	7.8846	7.6616	7.4545	7.2675	7.1137	6.9631
4.2	10.57	15.0407	14.4235	13.7523	13.2477	12.7016	12.2831	11.8320	11.1066	10.4912	9.9685	9.5206	9.1306	8.7902	8.4893	8.2258	7.9939	7.7783	7.5837	7.4236	7.2668
4.3	10.82	15.6494	15.0090	14.3127	13.7891	13.2223	12.7879	12.3197	11.5664	10.9273	10.3844	9.9190	9.5137	9.1601	8.8472	8.5734	8.3323	8.1082	7.9058	7.7394	7.5764
4.4	11.08	16.2681	15.6045	14.8826	14.3397	13.7520	13.3014	12.8157	12.0343	11.3711	10.8076	10.3245	9.9038	9.5365	9.2117	8.9273	8.6769	8.4441	8.2339	8.0610	7.8916
4.5	11.33	16.8970	16.2096	15.4619	14.8995	14.2905	13.8236	13.3202	12.5101	11.8225	11.2381	10.7371	10.3007	9.9197	9.5826	9.2875	9.0276	8.7860	8.5678	8.3884	8.2125
4.6	11.58	17.5359	16.8246	16.0505	15.4683	14.8378	14.3543	13.8330	12.9939	12.2815	11.6759	11.1567	10.7043	10.3094	9.9600	9.6540	9.3845	9.1339	8.9076	8.7215	8.5391
4.7	11.83	18.1848	17.4491	16.6485	16.0462	15.3939	14.8936	14.3541	13.4856	12.7481	12.1210	11.5833	11.1148	10.7057	10.3437	10.0267	9.7474	9.4878	9.2533	9.0604	8.8714
4.8	12.08	18.8436	18.0833	17.2558	16.6332	15.9587	15.4414	14.8834	13.9851	13.2222	12.5734	12.0169	11.5320	11.1085	10.7338	10.4056	10.1164	9.8476	9.6048	9.4050	9.2093
4.9	12.33	19.5123	18.7271	17.8723	17.2291	16.5322	15.9977	15.4210	14.4925	13.7037	13.0329	12.4575	11.9559	11.5179	11.1302	10.7907	10.4915	10.2134	9.9621	9.7553	9.5528

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 MLC — 50% Propylene Glycol — Feet of Head per 100 Feet of Tubing

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
5.0	12.59	20.1909	19.3804	18.4980	17.8340	17.1144	16.5624	15.9668	15.0077	14.1928	13.4996	12.9049	12.3865	11.9337	11.5330	11.1819	10.8726	10.5850	10.3251	10.1113	9.9018
5.1	12.84	20.8792	20.0432	19.1329	18.4477	17.7051	17.1354	16.5207	15.5306	14.6893	13.9735	13.3593	12.8238	12.3561	11.9420	11.5793	11.2597	10.9625	10.6939	10.4730	10.2565
5.2	13.09	21.5772	20.7154	19.7769	19.0703	18.3045	17.7169	17.0828	16.0613	15.1931	14.4544	13.8205	13.2677	12.7848	12.3573	11.9828	11.6528	11.3459	11.0685	10.8403	10.6167
5.3	13.34	22.2850	21.3970	20.4299	19.7017	18.9124	18.3066	17.6529	16.5997	15.7044	14.9424	14.2885	13.7183	13.2200	12.7789	12.3924	12.0518	11.7350	11.4487	11.2132	10.9824
5.4	13.59	23.0024	22.0880	21.0919	20.3419	19.5288	18.9047	18.2311	17.1457	16.2230	15.4375	14.7633	14.1754	13.6616	13.2067	12.8081	12.4567	12.1300	11.8347	11.5917	11.3536
5.5	13.85	23.7294	22.7883	21.7630	20.9908	20.1536	19.5110	18.8173	17.6994	16.7488	15.9396	15.2450	14.6390	14.1095	13.6407	13.2298	12.8676	12.5308	12.2263	11.9758	11.7303
5.6	14.10	24.4660	23.4979	22.4430	21.6484	20.7869	20.1255	19.4115	18.2607	17.2820	16.4488	15.7333	15.1093	14.5638	14.0808	13.6575	13.2844	12.9373	12.6236	12.3655	12.1124
5.7	14.35	25.2122	24.2167	23.1319	22.3147	21.4285	20.7482	20.0137	18.8296	17.8224	16.9649	16.2284	15.5860	15.0245	14.5271	14.0913	13.7070	13.3496	13.0265	12.7607	12.5001
5.8	14.60	25.9678	24.9447	23.8297	22.9896	22.0786	21.3791	20.6238	19.4061	18.3701	17.4879	16.7303	16.0692	15.4914	14.9796	14.5310	14.1355	13.7677	13.4351	13.1614	12.8931
5.9	14.85	26.7329	25.6819	24.5363	23.6731	22.7369	22.0180	21.2417	19.9900	18.9250	18.0179	17.2387	16.5589	15.9646	15.4382	14.9767	14.5699	14.1914	13.8492	13.5677	13.2916
6.0	15.10	27.5073	26.4282	25.2517	24.3652	23.4036	22.6651	21.8676	20.5815	19.4870	18.5547	17.7539	17.0551	16.4441	15.9028	15.4284	15.0100	14.6208	14.2690	13.9794	13.6955
6.1	15.36	28.2912	27.1836	25.9759	25.0659	24.0785	23.3202	22.5013	21.1804	20.0562	19.0985	18.2757	17.5576	16.9298	16.3736	15.8859	15.4560	15.0560	14.6943	14.3966	14.1047
6.2	15.61	29.0844	27.9480	26.7089	25.7750	24.7617	23.9834	23.1427	21.7868	20.6325	19.6491	18.8041	18.0666	17.4217	16.8504	16.3494	15.9077	15.4967	15.1251	14.8193	14.5194
6.3	15.86	29.8869	28.7215	27.4506	26.4926	25.4531	24.6546	23.7920	22.4006	21.2159	20.2065	19.3391	18.5820	17.9199	17.3332	16.8188	16.3652	15.9432	15.5615	15.2474	14.9394
6.4	16.11	30.6987	29.5039	28.2009	27.2186	26.1526	25.3337	24.4491	23.0217	21.8065	20.7707	19.8807	19.1037	18.4242	17.8221	17.2941	16.8284	16.3952	16.0034	15.6809	15.3647
6.5	16.36	31.5197	30.2954	28.9599	27.9531	26.8604	26.0208	25.1138	23.6503	22.4040	21.3418	20.4289	19.6318	18.9347	18.3169	17.7752	17.2974	16.8529	16.4508	16.1199	15.7953
6.6	16.61	32.3500	31.0957	29.7275	28.6959	27.5762	26.7159	25.7863	24.2862	23.0086	21.9196	20.9835	20.1662	19.4513	18.8178	18.2622	17.7721	17.3161	16.9037	16.5642	16.2313
6.7	16.87	33.1894	31.9050	30.5037	29.4471	28.3001	27.4188	26.4664	24.9294	23.6202	22.5041	21.5447	20.7070	19.9741	19.3246	18.7549	18.2525	17.7849	17.3620	17.0139	16.6726
6.8	17.12	34.0379	32.7231	31.2885	30.2066	29.0321	28.1296	27.1542	25.5800	24.2389	23.0954	22.1124	21.2540	20.5030	19.8373	19.2535	18.7386	18.2593	17.8259	17.4690	17.1191
6.9	17.37	34.8956	33.5500	32.0818	30.9744	29.7722	28.8482	27.8497	26.2378	24.8644	23.6934	22.6866	21.8073	21.0379	20.3560	19.7579	19.2303	18.7393	18.2951	17.9295	17.5709
7.0	17.62	35.7623	34.3858	32.8836	31.7505	30.5203	29.5747	28.5527	26.9028	25.4970	24.2981	23.2672	22.3668	21.5790	20.8807	20.2681	19.7277	19.2248	18.7698	18.3953	18.0280
7.1	17.87	36.6381	35.2303	33.6939	32.5349	31.2763	30.3090	29.2633	27.5751	26.1364	24.9094	23.8543	22.9326	22.1261	21.4112	20.7840	20.2307	19.7158	19.2499	18.8664	18.4903
7.2	18.12	37.5229	36.0836	34.5126	33.3274	32.0404	31.0510	29.9815	28.2546	26.7828	25.5274	24.4477	23.5046	22.6793	21.9476	21.3057	20.7394	20.2123	19.7355	19.3429	18.9579
7.3	18.38	38.4167	36.9456	35.3398	34.1282	32.8124	31.8008	30.7073	28.9413	27.4361	26.1520	25.0476	24.0828	23.2385	22.4899	21.8331	21.2537	20.7143	20.2264	19.8246	19.4306
7.4	18.63	39.3195	37.8163	36.1753	34.9371	33.5923	32.5583	31.4405	29.6352	28.0962	26.7832	25.6539	24.6672	23.8037	23.0380	22.3662	21.7735	21.2218	20.7226	20.3117	19.9086
7.5	18.88	40.2312	38.6957	37.0192	35.7542	34.3801	33.3236	32.1813	30.3362	28.7632	27.4211	26.2666	25.2578	24.3749	23.5920	22.9051	22.2990	21.7348	21.2243	20.8040	20.3917
7.6	19.13	41.1518	39.5837	37.8715	36.5794	35.1758	34.0965	32.9295	31.0444	29.4370	28.0655	26.8856	25.8545	24.9520	24.1518	23.4496	22.8300	22.2532	21.7313	21.3016	20.8801
7.7	19.38	42.0813	40.4803	38.7321	37.4127	35.9793	34.8770	33.6851	31.7597	30.1177	28.7164	27.5109	26.4574	25.5352	24.7174	23.9998	23.3665	22.7770	22.2436	21.8044	21.3736
7.8	19.64	43.0197	41.3856	39.6010	38.2541	36.7907	35.6653	34.4483	32.4820	30.8051	29.3740	28.1426	27.0664	26.1243	25.2888	24.5556	23.9086	23.3063	22.7613	22.3125	21.8722
7.9	19.89	43.9668	42.2994	40.4782	39.1035	37.6099	36.4611	35.2188	33.2115	31.4993	30.0380	28.7805	27.6815	26.7193	25.8660	25.1171	24.4563	23.8410	23.2842	22.8258	22.3761
8.0	20.14	44.9228	43.2217	41.3636	39.9610	38.4369	37.2646	35.9967	33.9479	32.2003	30.7085	29.4248	28.3027	27.3203	26.4490	25.6843	25.0094	24.3811	23.8125	23.3443	22.8850

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. $F_V = (30 \times 10) \div (180\text{-}120)$ $F_V = (300) \div (60)$ F_V = 5 gpm

Loading for Motorized Valve Actuators (MVA)
Computed at a minimum 10% line loss

MVA draw: 0.29 amps
Amps x volts = current
0.29 x 24 = 6.96 VA per MVA

Example:
50 VA ÷ 6.96 VA = 7.18 x 0.9 = 6.5 (10%)
6 MVA per 50 VA transformer
40VAC transformer = 5 MVA
50VAC transformer = 6 MVA
75VAC transformer = 9 MVA
100VAC transformer = 12 MVA

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

Continued on next page

Appendix H
Helpful Formulas

Continued...

Loadng for Thermal Actuators (TA) Computed at a minimum 10% line loss

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

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)

Tubing	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""
Multi-layer Composite (MLC)	10K – 20K	2 – 4	¾"
	20K – 45K	4 – 8	1"
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)

Tubing	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 slowed 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 1/6 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 1/6 to 1/4 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.

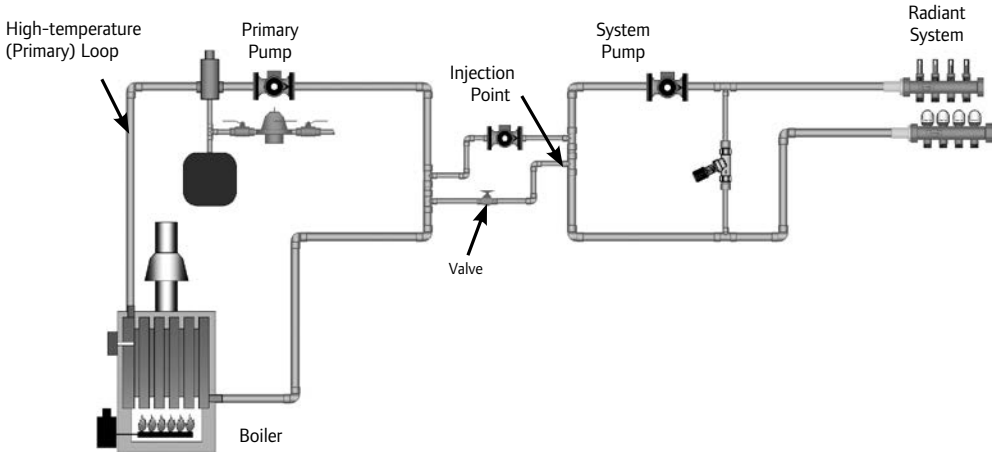


Figure I-1: Mixing with Variable-speed Pump

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.

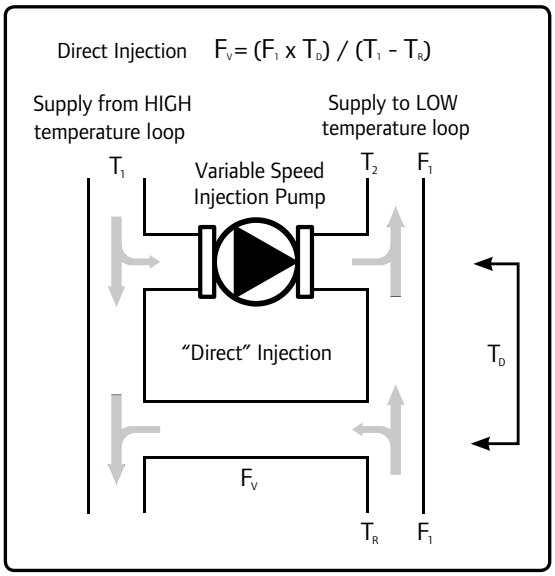


Figure I-2: Direct Injection Mixing (F_V Formula)

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.

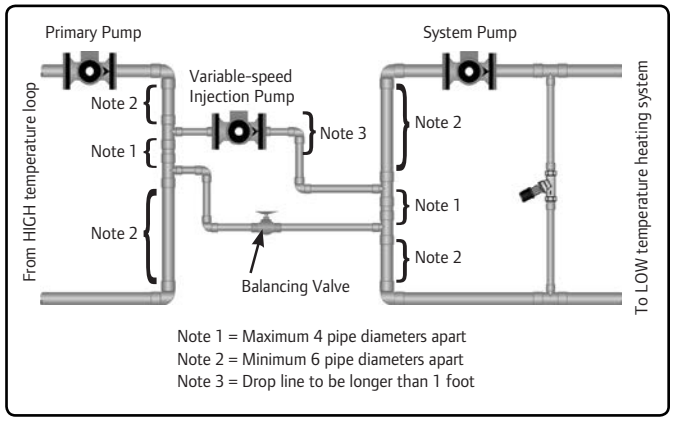


Figure I-3: Injection into a Horizontal Loop

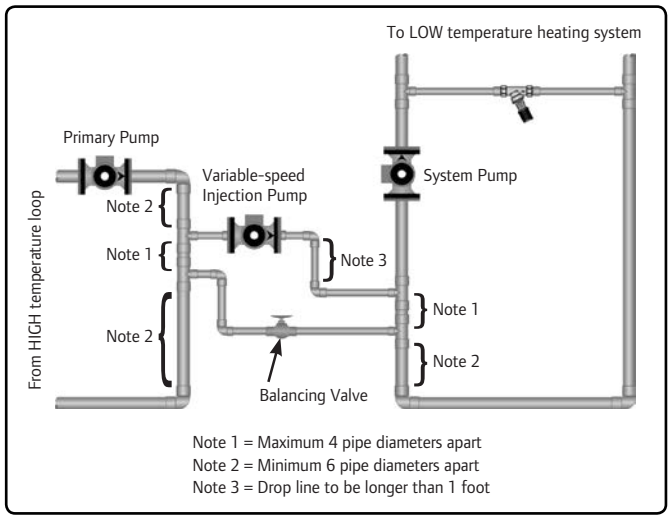


Figure I-4: Injection into a Vertical Loop

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		26-64	43-75	003	007	0010	0012	NRF 9	NRF 22	NRF 33	Astro	
				2*	3**										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.

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.

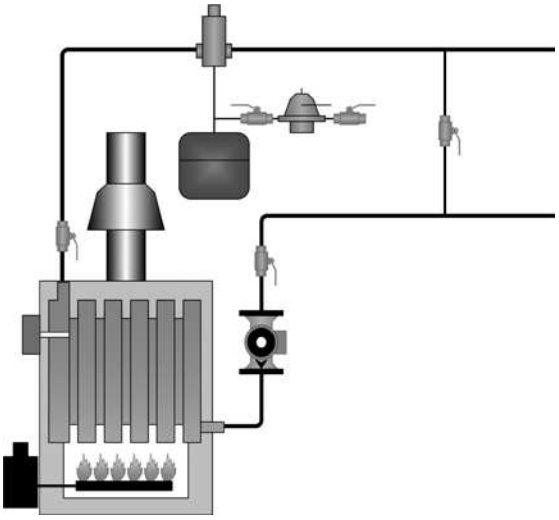


Figure J-1

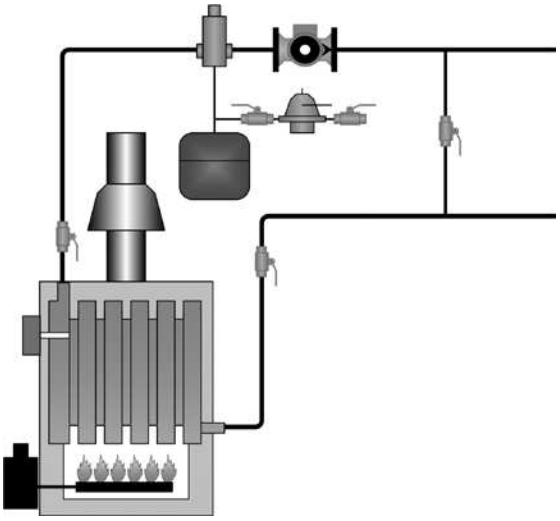


Figure J-2

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.

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
K.W. hours	BTU	3413.0

To Convert from	To	Multiply by
Temperature		
Centigrade degrees	Fahrenheit degrees	1.8 and add 32°
Fahrenheit degrees	Centigrade 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
Grains	pounds	1/7000
Grains/gallon	parts per million	17.12
Grams	grains	15.43
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	K.W.	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







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