Chapter 10:

Commercial radiant heating and cooling applications

This chapter summarizes aspects of radiant floor design that are specific to commercial projects. Before reading this chapter, study **Chapters 7 and 8** to obtain more detailed information about heat loss and radiant floor design. **Chapter 8** provides step-by-step instructions for the design process and explains how to correctly calculate surface temperature, water temperature, fluid flow and head pressure. The design process is essentially the same for commercial as for residential. Take note to use the correct charts as necessary.

Commercial radiant cooling

Hydronic radiant cooling has significant potential for reducing space-conditioning energy use while improving indoor environmental quality (IEQ). Radiant cooling uses active surfaces to absorb thermal energy and remove it from a space — more or less the inverse of radiant heating systems. In the case of radiant cooling, thermal energy flows from the occupants, equipment, lights and other interior surfaces to the actively cooled surface. Since there are typically internal latent loads (humidity) from occupants and infiltration, plus sensible and latent loads associated with outside ventilation air, radiant cooling is often part of a hybrid system that includes conditioning of ventilation air to address these loads.

Commercial design considerations

A commercial building design is the art of balancing heat losses with heat gains in a manner that provides a consistent temperature.

Heat-loss

Commercial buildings experience the same envelope losses as residential buildings. The thermodynamics of commercial buildings are easily calculated with the radiant design program. However, commercial buildings differ from residential buildings in the magnitude of heat-loss.

The ratio of floor surface area to exterior surface area is generally larger in commercial buildings than in residential ones. The result is lower overall heat load per square foot. Lower heat loads offer some opportunity to reduce the heated floor area in the building. Less heated area reduces the overall cost of a project. A room-by-room heat-loss analysis identifies those areas with little or no heat-loss. Some internal rooms may not require heat.

Envelope losses are not the only losses to consider in commercial buildings. In general, the greatest single heat-loss results from air exchanges.

Air exchange

Air exchange requirements are high for buildings in which fumes from automotive exhaust, paint, adhesives, etc. are present. Buildings that house industrial processes often need a high number of air exchanges because of chemical use. These types of commercial buildings require heated make-up air to counter the loss from fresh air intake.

Air exchange requirements are also affected by the occupancy of commercial buildings. Many buildings are designed to accommodate a large number of people. These buildings

must provide adequate air exchanges to keep the air fresh. Air exchanges remove both the heat and moisture produced by occupants.

Most air exchange requirements are stated as “must be capable of providing at least X number of air changes per hour.” This statement does not mean the air exchange system must continually operate at these exchange rates. Some buildings have high air exchange requirements even though they rarely meet the maximum occupancy rates. Gymnasiums, churches, stadiums and other similar buildings should only operate at maximum air exchange rates when they are filled to capacity. When the building is not filled to maximum occupancy, the air exchange rate should be proportionately reduced to reduce the heating load and increase operating efficiency.

When designing a commercial radiant floor heating system, it is helpful to understand the proper method of computing air exchanges. Since the air handling system is not used in combination with forced-air heating, it is much smaller and less costly. Air exchange requirements, expressed in cubic feet per minute (CFM) of outside air, are stated in any locally accepted mechanical code. The actual requirements are based on the maximum number of occupants multiplied by the minimum CFM of fresh air for the particular type of structure, and the activity levels, of the occupants.

For example, a particular mechanical code requires a minimum of 10 CFM per student in a classroom. If the projected maximum number of persons in the classroom is 30, the minimum requirement is 300 CFM. Therefore, the air handling system must provide 300 CFM of fresh air. This is much smaller than a similar system using forced-air heat distribution, where the air handling system must also move sufficient air to heat the structure.

Note: Smoke-free designated buildings require fewer air exchanges than buildings where smoking is permitted. The requirement for buildings where smoking is permitted may be five times higher than in a building designated as a smoke-free environment. Many state and local building governments are legislating smoke-free environments in public buildings.

Additional heat requirements for air exchanges

The introduction of fresh air from outside the building results in an additional heating load. In the previous example, 300 CFM is equal to 18,000 cubic feet per hour, and the heat ability of air is 0.0182 BTU per cubic foot per degree Fahrenheit. Therefore, the air exchange requires 327.6 BTU for every degree Fahrenheit that the incoming air is below room setpoint. If the incoming air is 50°F below setpoint, then about 16,380 BTU/h is needed to offset the load. Each student adds about 400 BTU/h from normal body heat, accounting for approximately 12,000 BTU/h for 30 occupants. Therefore, an additional 4,380 BTU/h is required to offset the load from the introduction of fresh air into the classroom.

The best way to provide the additional heat is through the use of a hydronic fan coil in the air exchange ductwork. The fan coil is controlled from an air discharge sensor. This control strategy adjusts to changes in the outside temperature, as well as intermittent operation of the ventilation system.

Other significant losses may exist in commercial buildings as a result of the activity that takes place within the building.

Heat requirements for additional internal loads

Fresh air infiltration rates are very high when large doors are opened. Shipping and receiving areas are a perfect example. When loading dock doors are open, the heating load increases greatly. Receiving large quantities of cold, raw materials also places a large internal heating load on the building. The heating load from cold objects is calculated by multiplying the weight of the object by its specific heat and again by the differential temperature.

Example: A 40,000-pound delivery of iron with a specific heat of 0.12 BTU/h/lb and a differential temperature of 60°F results in an approximate load of 288,000 BTU/h.

(40,000 lb x 0.12 BTU/h/lb) x 60°F = 288,000 BTU/h

Airplane hangars and vehicle repair facilities contain similar loads. Cold, heavy machinery adds internal loads that the heating system must overcome. Some of these loads are offset by engines and other components that may add heat during operation.

Radiant floor heating systems are uniquely capable of recovering setpoint temperature after an influx of cold air. The concrete mass takes a considerable time to cool off. As a result, when the doors of an airplane hangar close, the temperature quickly returns to setpoint because the heat is retained in the concrete.

Internal gains in commercial buildings also result from activities within the building. For example, fleet parking facilities that bring in warm vehicles may experience an overall heat gain from their operations. Often these same gains exist in residential buildings, but the levels of activity within the commercial building make the factors much more significant.

Another example of an internal gain is lighting and electrical appliances. Every kilowatt of electrical energy use not vented to the exterior results in 3,412 BTU/h of heat. The constant use of tools, machinery, lighting, hot water and even refrigeration produces considerable heat energy.

Fossil-fuel burning tools and appliances such as ovens, ranges, torches and dryers also produce large amounts of heat energy. Consider subtracting that amount from the heat load.

Heat gains, such as fireplaces, are also considered supplemental heat. Subtract these gains from the total heat loss. Information on adding supplemental heat (subtracting from the total heat load) is available in the heat-loss section of the radiant design program.

Structural factors in commercial buildings

Commercial buildings are generally constructed with concrete floors and concrete or steel structures. The stresses in this type of construction are carefully calculated. An engineer's involvement is essential to ensure the integrity of the structure.

Concrete floor construction in commercial buildings

Typical concrete commercial floors include pour-in-place slabs, composite beam construction, precast concrete planking with an overpour and post-tensioned slabs.

Pour-in-place slabs — Pour-in-place slabs are placed on compacted earth or on planking above grade. Radiant floor heating is easily integrated into pour-in-place slabs and is generally reinforced with steel bars or 6x6 wire mesh. The reinforcement provides a convenient fastening system to support the piping prior to the pour. Minimum cover for piping is detailed in the local building codes. Generally, pour a minimum of 1½ inches of concrete over the top of the piping when the slab is exposed to the soil or weather (1997 UBC Sec. 1906.3.10.). When the slab is not exposed to the soil or weather, a ¾-inch concrete pour over the piping is generally acceptable (1997 UBC Sec. 1906.3.10.).

Composite beam construction — In composite beam construction, slabs are poured over decking and supported by planking on concrete or steel beams. In composite beam construction, place the piping on the steel decking prior to the pour, and secure to wire mesh. Typically, weld the wire to the decking. Avoid diminishing the structural integrity by:

- Placing the radiant piping parallel to the beams (perpendicular to the deck)
- Keeping sufficient distance outside the effective design width which is (2 x span)/8
- Placing the piping in a concrete slab with a minimum 1½-inch cover over the top

Insulate the decking to prevent excessive downward heat transfer. Ensure the insulation R-value is at least equivalent to the composite R-value above. Be alert for situations in the structure where heat may conduct through the steel structure to the outside without an adequate thermal break.

Precast concrete planks — Precast concrete construction consists of pre-formed concrete planks delivered to the construction site and put in place. Two ways to install a radiant floor system over precast concrete include:

1. Lay wire mesh over the concrete and pour over the top.
2. Place high-density foam insulation over the precast concrete and staple the piping to the insulation. Insulation placed between the precast planks and the overpour reduces the thermal transfer to the concrete planks and increases the response capability of the heated overpour. Generally, the concrete pour over precast with radiant floor piping is ¾ inch over the top of the piping.

Post-tensioned concrete slabs — Post-tensioned concrete slabs are those in which tendons are placed within the slab prior to the pour. After the pour is sufficiently cured, the tendons are tightened to very high stresses, placing the entire slab under a compressive load. Do not place the piping near the tendons without the approval of the structural engineer. Radiant floor piping is often installed within a second pour over the top of the post-tensioned slab.

See **Chapter 6** for more information on the various installation methods for Uponor radiant floor heating systems.

Under-slab insulation

Insulation below heated concrete slabs must withstand the weight of the slab along with any additional dead or live loads. When concrete is applied over the insulation, the weight of the concrete causes the insulation to compress. The amount of compression depends on the weight of the concrete, the thickness of the insulation and the compressibility of the insulation.

Although compression reduces the insulating effect of the foam, it presents little structural effect because it remains relatively constant over the life of the structure. A more important structural factor is the long-term compressive creep that occurs within the insulation. Creep should be accommodated in the ability of the slab to move relative to the plane of its surface. Foam insulation manufacturers provide specific recommendations regarding the limits of live and dead loads, compressive creep and the proper application of their products. Check with the foam insulation manufacturer for more information.

Fire-rated structures

Many commercial buildings are fire rated according to the activity within or the occupancy of the building. Fire-rated structures require firewalls that do not allow fire or smoke to spread past them for a period of time. Firewall penetrations must be rated so they do not reduce the overall rating of the wall. Install fire penetration devices in accordance with the manufacturers' recommendations. Note that fire-stop materials designed for metal pipe penetrations are not necessarily suitable for PEX piping. See **Chapter 3** for a list of firestop materials.

Controls for commercial radiant floor systems

Control of a commercial building is similar to that of a residential building except that the controls are integrated with air handling systems designed to provide air exchanges. Many commercial buildings feature computer interfacing input/output devices used for that purpose. It is important that such systems do not work against each other, causing excess energy use.

See **Chapter 12** for more information about controls for radiant floor heating systems.

Acceleration

Large-mass radiant slabs respond at a predictable rate when heat energy is applied to them. Consider the acceleration rate in the control strategy. Because concrete weighs approximately 120 pounds per cubic foot and has a specific heat amount of about 0.21 BTU/h/lb, the amount of energy necessary to accelerate radiant slabs of various thickness can be calculated (assuming there is adequate insulation below to prevent downward loss).

- A 4-inch slab requires about 8.4 BTU/h/ft^2 to accelerate 1°F
- A 5-inch slab requires about 10.5 BTU/h/ft^2 to accelerate 1°F
- A 6-inch slab requires about 12.6 BTU/h/ft^2 to accelerate 1°F
- A 7-inch slab requires about 14.7 BTU/h/ft^2 to accelerate 1°F
- An 8-inch slab requires about 16.8 BTU/h/ft^2 to accelerate 1°F
- A 9-inch slab requires about 18.9 BTU/h/ft^2 to accelerate 1°F

Average water temperature has the greatest effect on acceleration. Average water temperature is increased by increasing the supply water temperature and/or decreasing the return differential temperature (increasing flow). It is best to provide the maximum supply water temperature during acceleration phases. The graph in **Figure 10-1** shows acceleration times at various increases in heating load for various average water temperatures. The higher the average water temperature, the shorter time required to accelerate. As the building reaches maximum design load, the acceleration requirements are negligible.

Average water temperature

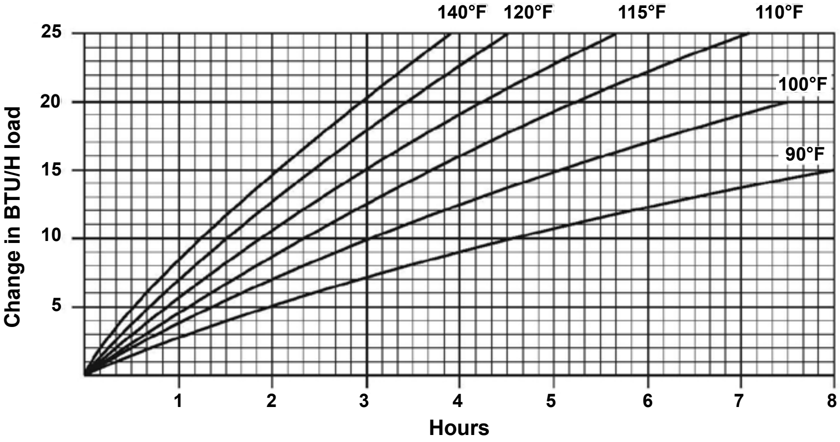


Figure 10-1: Acceleration times (Data accurate for 4" slab acceleration)

Piping installation options

Several factors determine how much piping is needed for installation. The following sections provide some general guidelines. Refer to the Uponor radiant design program to determine the amount of required piping.

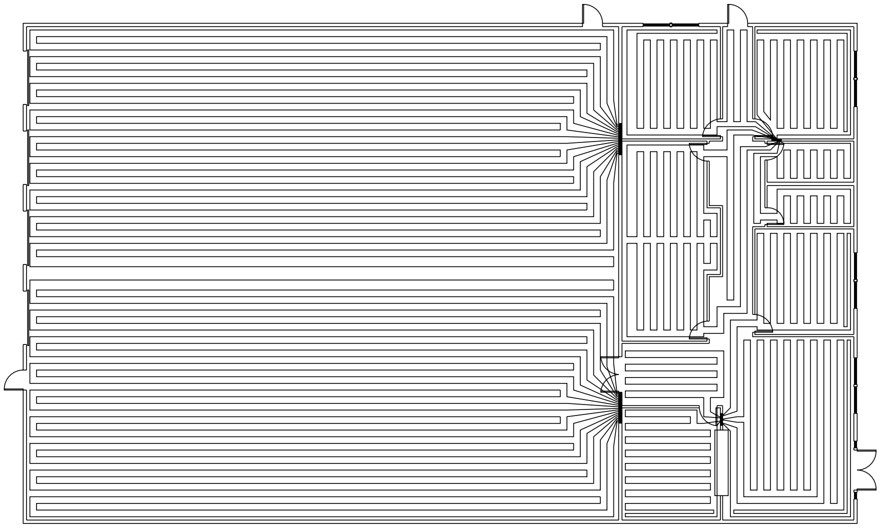
Full coverage — Use full coverage when the major heat load is evenly distributed, such as when internal heat loads and/or unheated air exchanges are excessively high or when high-resistance floor coverings are used. The full coverage option features piping installed 12 inches on center throughout the entire floor.

Perimeter-only coverage — To determine the suitability of a perimeter-only design, use the heat-loss section of the Uponor radiant design program. The goal is to increase the heated floor surface area of the room without exceeding the floor temperature or supply water temperature limitations. For perimeter-only coverage, install piping inside and along the perimeter walls of the building. Do not install piping in the interior areas of the room.

Commercial and industrial projects usually install minimal floor coverings, resulting in diminished upward resistance to heat transfer. This improves the effectiveness of the radiant floor system so that perimeter-only designs are both effective and efficient.

Varied coverage — Use this method when the major heat load is at the perimeter, but a small load is anticipated in the interior of the building. Small loads may come from air changes or heat losses through the ceiling. Install the piping 12 inches on center near the perimeter and at increased distances (18 to 24 inches on center) in the interior areas.

Reduced coverage — Use this method when the heat loss is minimal and evenly distributed throughout the building. Install the piping throughout the floor at distances greater than 12 inches on center.



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

Figure 10-2: Full coverage piping installation

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

Figure 10-3: Perimeter-only coverage piping linstallation

Piping layout patterns

The designer determines the piping layout pattern for a specific project. Although the pattern is influenced by a number of factors, some general guidelines are helpful.

The most significant envelope heat losses occur near the exterior walls, especially near exterior windows and doors. Begin the piping run in these areas. Additionally, shorter piping runs in high heat-loss areas result in higher average water temperatures. Higher average water temperatures satisfy the heat load faster.

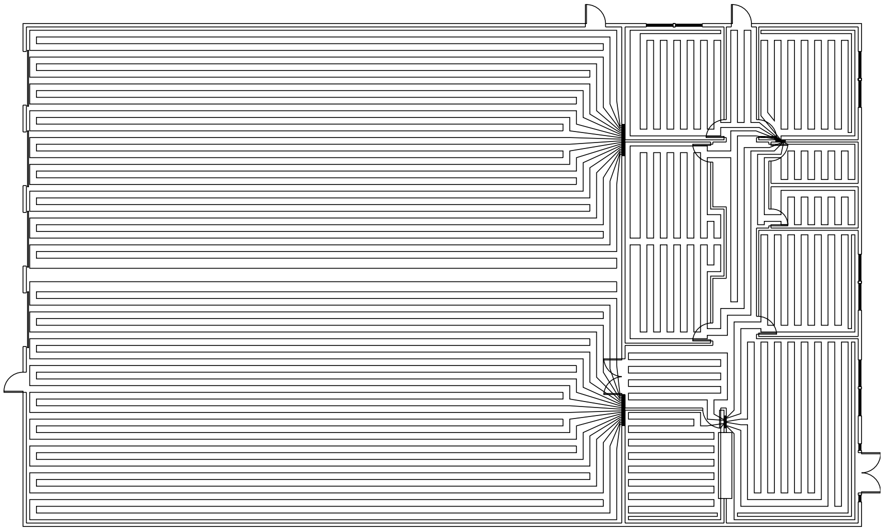
When the primary heat loss of the structure is from the building envelope, areas without exterior walls or ceilings have little or no heat loss and do not need to be heated. The only exception is to counter the effects of unheated make-up air. Again, the radiant design program identifies areas that do not require heat.

Tall buildings typically produce diminishing heat loads at the upper levels due to the buoyancy of heated air.

Uponor recommends full piping coverage for shipping and receiving areas. Infiltration from open doors, additional heat loss from cold materials entering the building, and the loss of effective floor area due to materials placed on the floor that reduce heat transfer all contribute to the heat load of shipping and receiving areas.

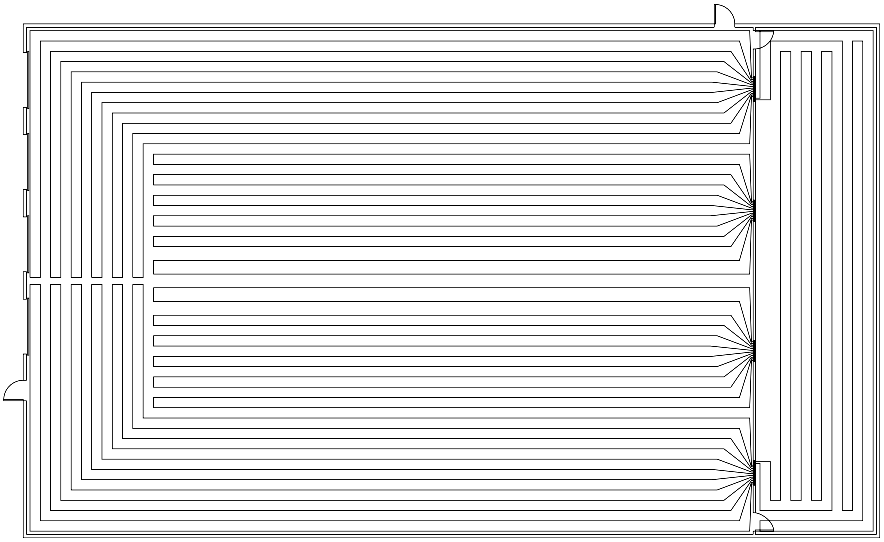
Full piping coverage is also recommended for restrooms, showers and locker rooms because of the high air exchange rates and because people often wear little or no clothing in these areas.

Never overlook the possibility that the original intended use of a building may change in the future. Design the system so that adequate heat is provided regardless of the intended use.



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

Figure 10-4: Varied coverage piping installation



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

Figure 10-5: Reduced coverage piping installation

Distribution flow options

Reverse-return header system with Radiant Rollout™ Mat — Commercial buildings are a prime candidate for value engineering the water distribution system that supplies radiant piping and panels. A self-balancing reverse-return header system can be specified to reduce the number of wall manifolds and wall-manifold loops that are needed to balance and distribute water to piping loops. This type of system can save money by simplifying and reducing the amount of distribution piping from the heating and cooling sources in the mechanical room. In those commercial buildings, or zones within buildings, that lack adequate space to install wall manifolds, the self-balancing reverse-return header system can increase available space and eliminate difficult decisions on how and where to place wall manifolds.

The reverse-return header system:

- Is self-balancing
- Prevents long leader lengths and crowding near wall-mounted manifolds
- Economizes design by requiring fewer wall manifolds
- Offers space savings as wall manifolds can be eliminated
- Reduces length of distribution piping (less branch distribution piping to wall manifolds)

The reverse-return header is a feature of the Uponor Radiant Rollout mat, which is shown in **Figure 10-6**.

The reverse-return header in the mat uses ¾" piping and can connect to either ½" or ⅝" piping using Uponor engineered polymer (EP) reducing tee fittings. Each mat is equipped with one supply-and-return line and SpaceGuard support strips that allow piping in the mat to be accurately spaced and fastened. Mats are pre-pressurized at the factory. **Figure 10-7** shows a two-dimensional drawing of a reverse-return header system. The system uses one central wall manifold, which serves as an origination for the distribution flow system. There are four mats with the reverse-return header connected to the central wall manifold; each mat contains 10 single-pass loops.

The mat is available in the following construction options:

- Length: Customizable from 40 to 225 feet
- Width: From 5 to 10 feet
- Piping: Wirsbo hePEX (oxygen barrier) or Uponor AquaPEX (barrier free), ½" or ⅝" piping
- Distribution flow options:
  1) In-slab with ¾" reverse-return header option or
  2) Wall manifold featuring the Uponor TruFLOW Classic
- Supports: Acetal polymer support braces with pre-drilled holes for stake and anchor points

Figure 10-7: Reverse-return header system

Figure 10-6: Uponor Radiant Rollout Mat

Figure 10-8: Radiant Rollout Mat featuring reverse-return header with piping module

The Uponor Radiant Rollout Mat offers the following advantages in commercial installations:

- Reduces installation time by up to 85% versus conventional installation methods
- Reduces installation errors, promotes worker safety and offers fast commissioning and start up through pre-fabrication and pre-pressurized testing
- Features durable Uponor ProPEX fittings, which are approved for direct burial. The EP fittings used in the reverse-return header assembly are approved with listings from the International Association of Plumbing and Mechanical Officials (IAMPO) [International Mechanical Code (IMC) compliant] and NSF International [Uniform Mechanical Code (UMC) compliant]
- Helps projects stay on schedule
- Reduces and eliminates piping waste
- Comes with Uponor design and technical support assistance

For any questions about Uponor Radiant Rollout mats or for design assistance to quote a project, contact Uponor Technical Services toll free at 888.594.7726.

Reverse-return header system with piping modules — A self-balancing reverse-return header system can also be customized using a piping module. The piping is laid out in a "module" pattern, as shown in **Figures 10-8** and **10-9**.

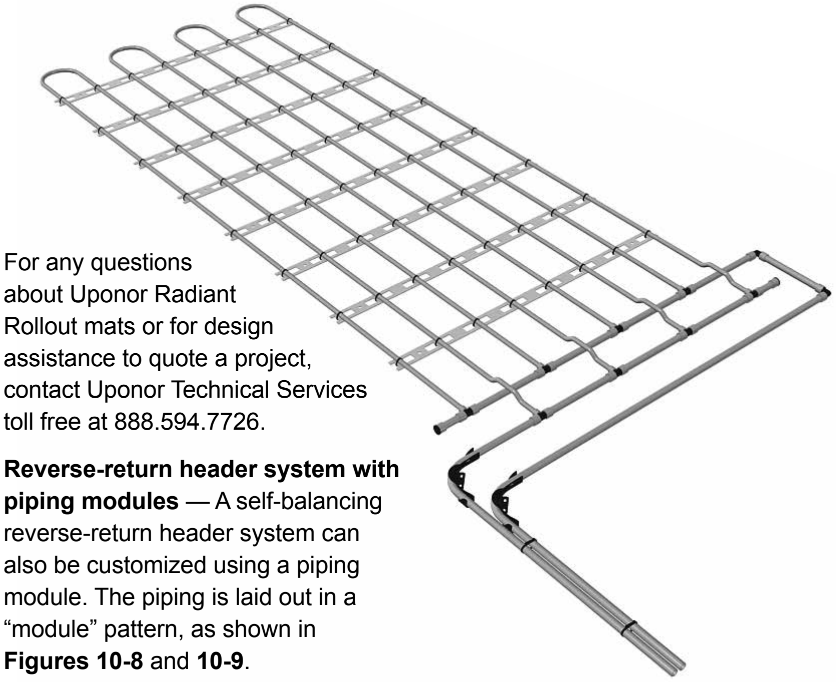


Figure 10-9: Reverse-return header with piping module

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 (21 gpm)
- TruFLOW Jr. (14 gpm)
- Engineered polymer (EP) heating manifolds (14 gpm)
- 1¼" stainless-steel manifolds (21 gpm)
- 1" stainless-steel manifolds (14 gpm)

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

HDPE manifolds — Uponor offers high-density polyethylene (HDPE) manifolds, which are effective distribution flow products for large snow-melt and turf-conditioning projects. The HDPE manifolds are valve-less manifolds manufactured with ¾" or 1" stainless steel ProPEX fittings. The HDPE manifolds are typically buried and can be designed with HDPE leader piping to provide a reverse-return type of system.

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

Copper manifolds — Uponor offers 2" copper manifolds that are effective distribution flow products for large commercial and snow-melt projects, handling flows up to 45 gpm. The copper manifold offers economic advantages when combined with a reverse-return Radiant Rollout mat or piping module system. Significant flow can be balanced, controlled and distributed through a copper manifold and then routed to a self-balancing piping layout. Copper manifolds come with the following accessories: ball valves, balancing valves, and end caps with vent and drain.

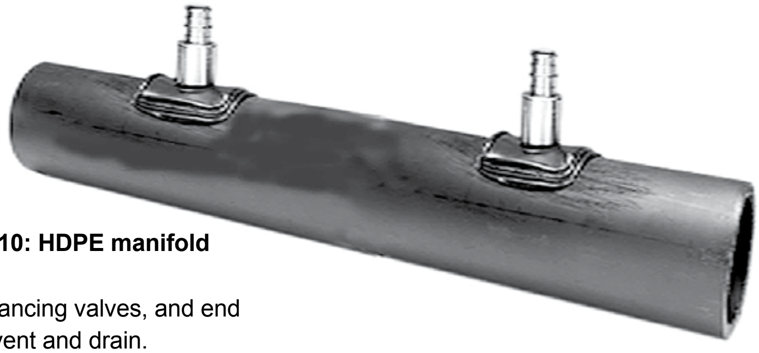


Figure 10-10: HDPE manifold

Copper manifolds are available in ⅝", ¾", R20 and R25 sizes.

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

Commercial building zones

Zone selection – Those areas similar in terms of heat loss and heat gain that can be controlled from the same thermostat. For more detailed information on zone selection, see **Chapter 11**.

Zone control – Commercial projects typically involve large panel areas, so the use of actuators on individual loops is usually impractical. The alternative is to zone by manifold using zone valves or zone circulators. Small independent areas on the same manifold, such as restrooms and conference rooms, can be sub-zoned with individual thermostats and actuators to meet their requirements. In any case, the Uponor manifold system is extremely versatile and able to accommodate virtually any control strategy.

Manifold pressure bypass – Large commercial projects often require large circulator pumps. When a small zone calls for heat, release the excess pressure from the pump through a pressure bypass. In systems with short distribution piping to the manifold, install a bypass in the mechanical room near the circulator. In systems with long or large distribution piping to the manifolds, install a bypass near the manifold. A bypass at the manifold allows heat energy to reach the zone more rapidly than if the flow for a single zone was used to fill a large distribution pipe.


Figure 10-11: Copper manifold


NOBODY