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 Control™ 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 second-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 ensure proper flow through the radiant system. The best location for this circulator is between the MIX port and the supply manifold. In addition, a temperature gauge should be installed downstream of the MIX port to monitor supply water temperature. Refer to Chapter 13 for a piping schematic.

Other Level 2 Options — There are several other methods of achieving Level 2 control, including mixing tanks, heat exchangers, four-way motorized mixing valves and injection mixing. Motorized mixing valves and injection mixing controls can also be made weather responsive; see the Level 3 section on page 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 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.

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 controls

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 Control Multifunction Controller and the Climate Control Network System. Both allow full outdoor reset of a radiant system while protecting a non-condensing boiler.

**Climate Control 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 (∆T) 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 Control Network System** — The Climate Control Network System also provides mixing for radiant systems. It operates in the same manner as the Climate Control 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](http://www.uponorpro.com) for more information.