Choosing Boilers and Controls for Warm Floors

by John Siegenthaler

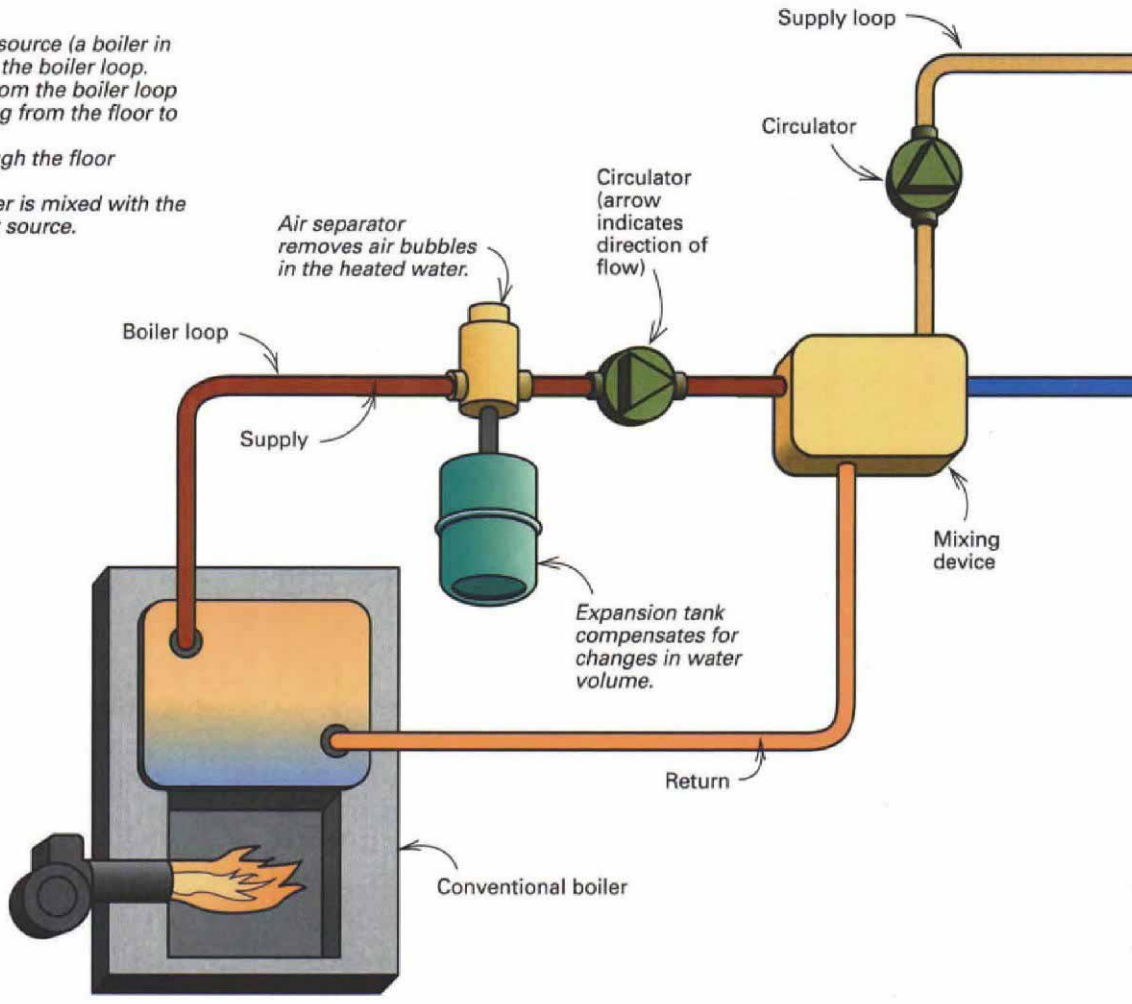
When people think of radiant-floor heating, the first image that comes to mind is a labyrinth of tubing filled with warm water snaking its way beneath a floor. But a warm floor is only part of the overall heating system. How that warm water is produced, controlled and delivered to different parts of the house is equally important. The comfort that radiant-floor heating is famous for is achieved only when all parts of a system are properly matched, installed and functioning in unison (bottom photo, facing page).

In my last article (*FHB* #105, pp. 58-63), I discussed ways of installing hydronic radiant-floor heating. Now I'll describe ways of producing and delivering heat to the floors and point you toward the system that will work best for you.

The basic parts of the system–In the simplest terms the typical hydronic radiant-floor heating system operates by first producing heat and then transferring that heat to water inside

HERE'S HOW A CONVENTIONAL RADIANT-FLOOR SYSTEM WORKS

1. Water is first heated by a heat source (a boiler in this case) and circulated through the boiler loop.
2. In a mixing device hot water from the boiler loop is mixed with cool water returning from the floor to attain the desired temperature.
3. Warm water is circulated through the floor circuits via the supply loop.
4. The remainder of the cool water is mixed with the warm water returning to the heat source.



Drawings: Mark Hannon. Photos: Roe A. Osborn.

You don't want the noise and dust associated with furnaces; you want the comfort of radiant heat. Here are some options for heating the water and getting it to your floors.

the heat source (drawing below). Heat sources include conventional boilers, condensing boilers and hydronic heat pumps.

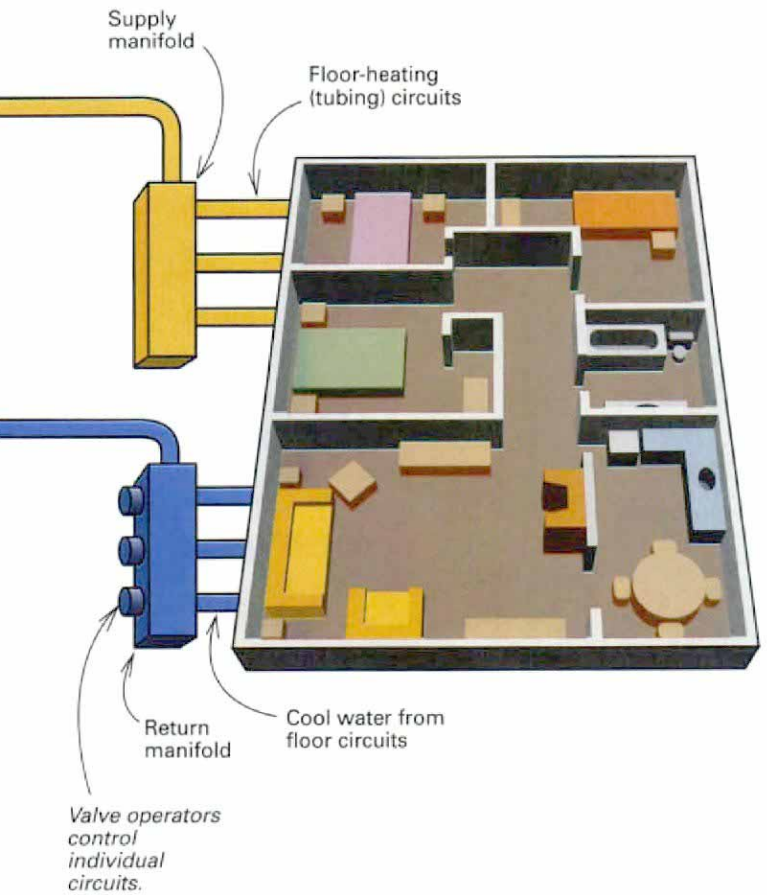
A circulator (a special type of pump) then pushes the heated water to the supply piping. But because heated floors require warm water instead of hot water, the heated water usually passes through a mixing device that reduces its temperature by blending it .with cool water returning from tubing circuits in the floor.

The warm water is then pumped through the distribution piping and eventually enters one or more manifold stations (top photo). The supply manifold further divides the flow among several floor-tubing circuits, where heat is released to the flooring materials as the water flows through the tubing. Each circuit is connected to a return manifold that collects the cooled water. The remainder of the cooled water that isn't mixed with the incoming water is routed back to the heat source to begin the cycle again.

Conventional boilers adapt easily to radiant-floor heat–Conventional cast-iron and steel boilers have long been the staple heat source for hydronic heating. Although they produce relatively high-temperature water, conventional boilers easily adapt to lower-temperature requirements of floor-heating systems by the mixing process I just described. Their ability to produce high-temperature water makes them a good choice in homes that have both radiant-floor heat and high-temperature heat.

In a conventional boiler, the water is heated in a steel or cast-iron heat exchanger, a series of chambers suspended above an oil or gas flame. Other high-temperature boilers called low-mass boilers use copper tubing with fins instead of a chamber. Low-mass boilers heat water more quickly, and they have a definite size and weight advantage over their cast-iron and steel cousins., But the overall efficiency of low-mass boilers is about the same as conventional boilers.

Modern gas-fired and oil-fired boilers operate with average efficiencies in the 80% to 85%



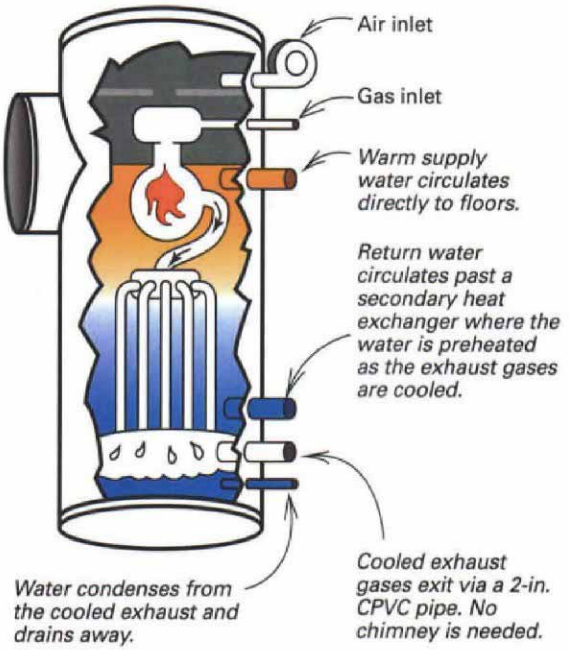
Manifold distributes warm water to and from the floors. Each pair of ports on this manifold represent the supply and return for a specific floor area in the house.

The heart of a hydronic system. This boiler setup provides domestic hot water, hot-water baseboard heat and warm water for radiant floors.

TWO EFFICIENT ALTERNATIVES TO CONVENTIONAL BOILERS

A condensing boiler

increases efficiency by drawing heat out of the combustion gases with the cool water returning from the floor-heating circuits.



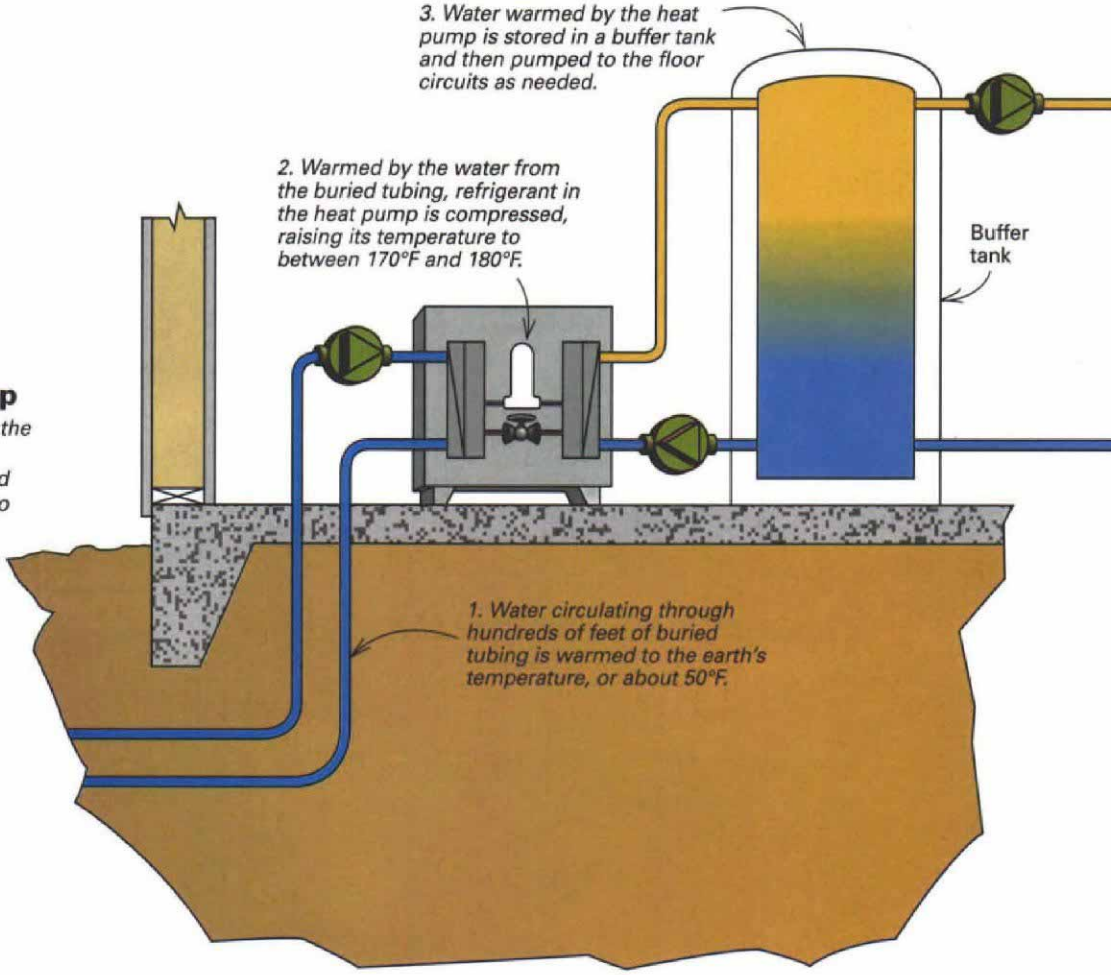
range. There are dozens of manufacturers and hundreds of models to select from, so don't make your choice based on price alone. A well-designed, properly serviced cast-iron boiler can last for over 30 years. So make sure you can get local service for the boiler you choose.

A little more piping is involved if you opt for a conventional gas-fired or oil-fired boiler. A separate boiler loop needs to be installed to prevent the cool water returning from the floor from being piped directly back to the boiler. If the internal surfaces of the boiler become too cool from the return water, water vapor in the exhaust gases will condense inside the boiler and the flue pipe. The acidic nature of this condensate will rapidly corrode the boiler and can eat holes through the flue pipe. Instead, the returning water is mixed into the boiler loop, where it is warmed before re-entering the boiler.

Every hydronic-heating system with a closed piping path should have an air separator and an expansion tank. The air separator removes tiny air bubbles in the heated water. The expansion tank compensates for increases in the water volume due to expansion from being heated.

A geothermal heat pump

extracts low-temperature heat from the earth. Operating like a refrigeration system in reverse, heat is transferred from water in subterranean tubing to water in the radiant-floor tubing.



Alternative heat sources–Gas-fired condensing boilers depend on cold water returning from the floor to attain maximum efficiency (top drawing, facing page). Although more complicated and more expensive than most conventional boilers, condensing boilers are well suited for hydronic radiant-floor heating. Unlike conventional boilers and geothermal heat pumps, condensing boilers don't need mixing devices between boiler and floor circuits.

Another heat source, one that eliminates the need to burn fuel, is a geothermal heat pump (bottom drawing, facing page). Instead of generating heat through combustion, heat pumps extract low-temperature heat from the earth.

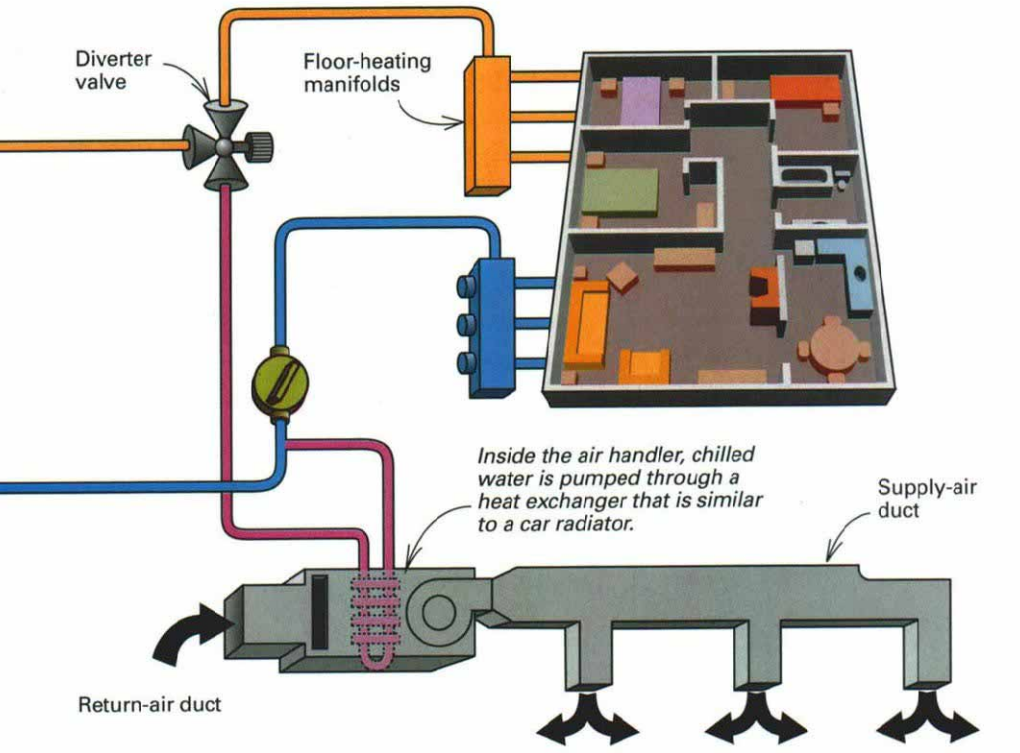
A unique feature of geothermal heat pumps is that they can also be used for cooling during warmer months (drawing below). Just sending the chilled water through the floor circuits might cause moisture to condense on the cooled floors, so the chilled water cools the air instead.

A fixed-temperature control system is the easiest to install–Once the water has been heated, it must then be delivered to the flooring circuits at the right rate and temperature to keep the house comfortable. Systems for connecting heat source to floor circuits can be grouped into two categories: those that operate with a .fixed water temperature supplied to the floor and those that vary the water temperature.

A fixed-temperature system will work with any kind of heat source, and it is simpler and usually less expensive to install than a variable-temperature system (drawing p. 74). With a fixed-temperature system, the temperature of water going to the floors is monitored continually, and a thermostatic mixing valve adjusts to keep this temperature constant.

The thermostat on the mixing valve is set to keep the supply water warm enough for the coldest days of winter. To prevent overheating on milder days, fixed-temperature systems rely on individual room or zone thermostats to regulate heat output. The thermostat controls an electrically operated valve on the return manifold called a valve operator.

A fixed-temperature system is well suited for houses where individual-room temperature control is desired. The system also works well when



Air cooling *is a natural byproduct of a geothermal heat-pump system. In warm months, the heat pump is reversed, producing chilled water that is routed through an air handler.*

As room air is pulled past the heat exchanger, it is cooled and dehumidified before being distributed to the house.

Oil, gas, electric? You do the math.

Before you select a heat source for your system, compare the fuels available at your site. A simple procedure will give you the unit cost of each fuel in dollars per million Btus, sort of like comparing prices on different-size boxes of cereal at the grocery store. The formulas below will tell you how much you will spend to get 1,000,000 Btus of heat delivered to your house from each type of fuel with adjustments made for the efficiency of the various heat sources. The dividends of such a calculation can literally be thousands of dollars saved over the life of the system.

Sometimes the cost of fuel will depend on how much you use. For example, in many locations the more natural gas you consume per month, the lower its cost per therm (the unit by which natural gas is sold). In these cases you can estimate an average fuel cost by starting with the billed amount of fuel per month in dollars. Subtract any fixed monthly fee, such as a basic service charge that stays the same regardless of how much fuel you use. Do not subtract sales taxes, fuel-adjustment charges, etc., that are determined based on the amount of fuel consumed. Divide the adjusted fuel charge by the number of fuel units purchased to get the average cost per unit of fuel. This figure gets plugged into the following formulas.

One million Btus is abbreviated as MMBtu. A typical seasonal efficiency (S.E.) decimal for old equipment is 0.70; for new standard equipment, 080; and for a new condensing boiler, 0.90.—*J. S.*

Electric resistance heat

____¢/kwh x 2.93 = $____/MMBtu

Geothermal heat pump

$$\frac{\text{____¢/kwh x 2.93}}{\text{3.0 S. E.}} = \text{\$\_\_\_\_/MMBtu}$$

No. 2 fuel oil

$$\frac{\text{\$\_\_\_\_/gal. x 7.14}}{\text{\_\_\_ S. E.}} = \text{\$\_\_\_\_/MMBtu}$$

Propane

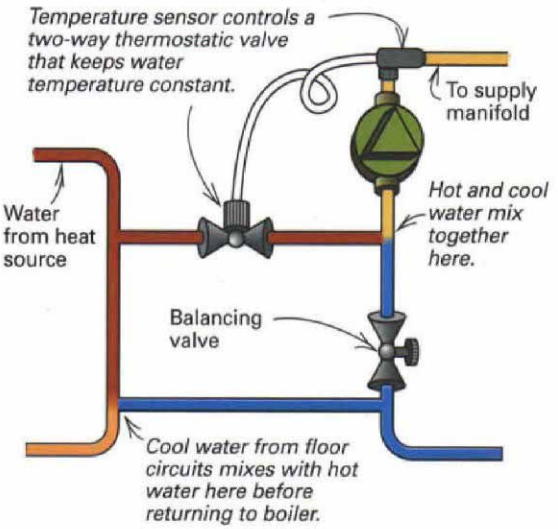
$$\frac{\text{\$\_\_\_\_/gal. x 10.9}}{\text{\_\_\_ S. E.}} = \text{\$\_\_\_\_/MMBtu}$$

Natural gas

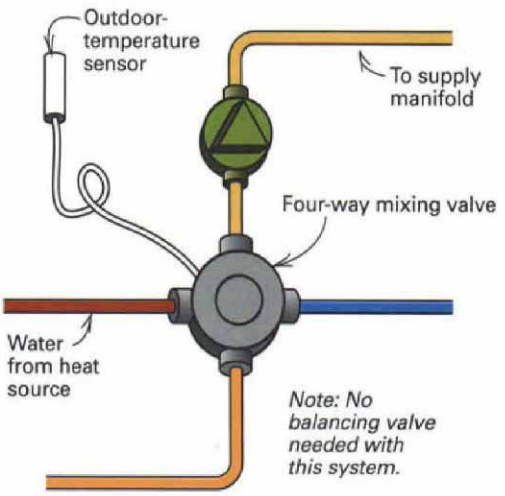
$$\frac{\text{\_\_\_\_¢/therm x 0.1}}{\text{\_\_\_ S. E.}} = \text{\$\_\_\_\_/MMBtu}$$

TWO CHOICES FOR CONTROLLING THE FLOW

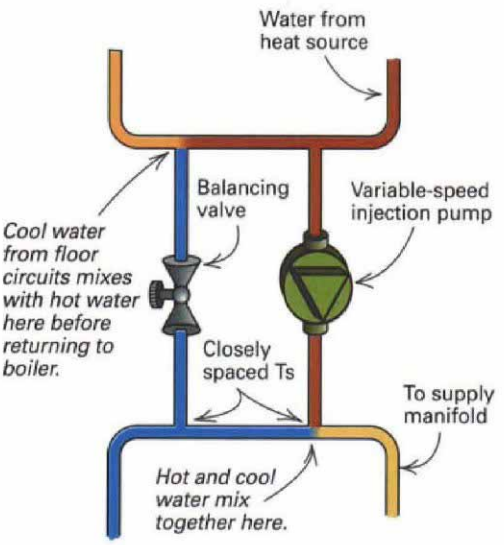
A fixed-temperature system *maintains water temperature at a constant level while varying the rate and frequency of delivery to the floors. A thermostatically controlled mixing valve blends hot water from the boiler with cool return water to keep the temperature uniform.*



Variable-temperature systems *circulate water continuously and turn up the heat when outdoor temperatures drop.*



A four-way mixing valve. *One type of variable-temperature control adjusts to temperature changes by rotating slowly to vary the temperature in the system while keeping the water returning to the boiler warm.*



An injection system. *Another type of variable-temperature control adjusts supply-water temperature by injecting or pumping hot water from the boiler loop into the floor-heating loop with a variable-speed pump.*

a single zone of floor heating, such as in a new bathroom, is tied to an existing hydronic system. However, because heated water does not circulate constantly with a fixed-temperature system, relatively rapid changes in floor temperature can occur during startup conditions. Consequently, the system is not recommended when solid-sawn hardwood is to be used for the finished floor.

Cruise control for your heating system— Variable-temperature systems continuously adjust water temperature supplied to the floor circuits based on outdoor temperature (bottom drawings). As outside temperature drops, water temperature is increased and vice versa, sort of like your car's cruise control regulating speed up and down hills. When properly applied and , adjusted, variable-temperature controls can maintain extremely stable indoor temperatures.

Although fixed-temperature systems circulate water only when demanded by a thermostat, most variable-temperature systems circulate water continuously through the floor circuits. The pump that provides this flow usually stays on throughout the heating season. Because the water temperature in the floor is just right to match the heating requirements of the house, there is no need to turn the circulator on and off to control heat output.

Continuous circulation also greatly reduces expansion noises that can occur with rapid temperature changes in piping or flooring materials. And because variable water-temperature control along with constant circulation encourages gentle but continuous temperature changes in the floor, the thermal lag often associated with bringing a large concrete-slab floor up to temperature is minimized. And with wide temperature swings eliminated, variable-temperature systems work well under solid-sawn hardwood flooring.

The method for regulating the temperature in a variable-temperature system depends on the type of heat source. With a condensing boiler the water temperature is controlled at the boiler itself. A geothermal system controls the water temperature in the buffer tank. With a conventional boiler, though, hot water in the boiler loop must be blended with cool water returning from the floor circuits to attain the right temperature. The two most common mixing devices for conventional boilers with variable-temperature systems are a four-way mixing valve or an injection system (drawings left). □

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Radiant systems are easily tailored to your specific needs

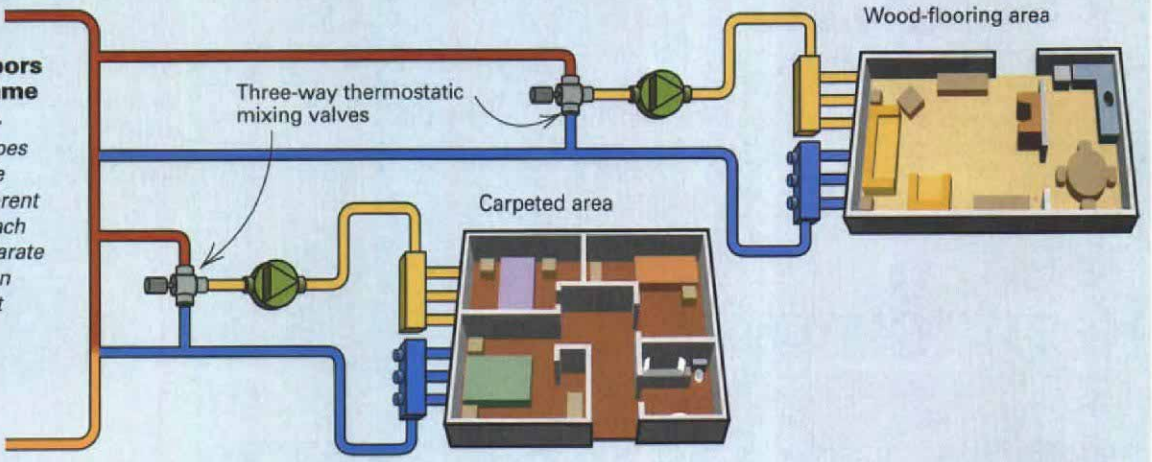
A properly designed floor-heating system can serve many different heating situations within the same house. Heating situations can vary for each room depending on the type of floor covering as well as the heating-load requirements in that room. For example, floors covered with high-thermal-resistance coverings, such as carpet, usually receive higher-temperature water than low-thermal-resistance flooring, such as ceramic tile. But an interior room with no windows won't require as much heat as a room with exterior walls and lots of glazing.

The first step is determining the heating requirements of each flooring circuit supplied by a manifold station. If your system has multiple manifold stations that will operate at the same water temperature (±5°F), then they can be piped in parallel with each manifold station drawing its supply from the same heating loop. The temperature of each room can still be governed by a thermostat-controlled valve operator on the return-manifold port to fine-tune each room's heating requirements.

If different areas of the house have different floor coverings and different heat-load requirements, a multiple-temperature system with multiple mixing devices will probably be required (top drawing). This type of system will help to prevent some areas from overheating while others are kept cool. Many mixing methods can be used, although cost constraints usually tend to favor simple fixed-temperature mixing valves.

Radiant-floor heating can also be combined with other types of hydronic heating loads (bottom drawing). Elaborate systems can be laid out that supply floor heating using an injection-pump mixing device, a zone of high-temperature heating using fin-tube baseboard and panel radiators, and domestic hot water using an indirectly fired water heater. Such systems provide design flexibility in situations where floor heating might be inappropriate or too expensive for the entire house.—*J. S.*

Tile floors, wood floors and carpet in the same house? No problem. *Each of these flooring types has different temperature requirements, as do different areas of the house. So each area can be put on a separate loop controlled by its own mixing valve for the right comfort level.*



Or combine radiant heat with your other heating requirements. *With proper piping and controls, modern boilers can fill a wide variety of heating needs simultaneously, such as domestic hot water, hot-water baseboard heat and warm-water radiant-floor heat.*