Radiant Slab Techniques

by John Siegenthaler

During the pour, at least one mason, shown far right, is assigned the sole task of lifting the welded-wire mesh to make sure the reinforcement and the hydronic tubing end up in the center of the slab section.

Careful tubing layout, ample slab insulation, and special boiler controls will ensure superior comfort and a long system life

A great deal has been written in recent years about the rebirth of hydronic radiant floor heating. There has been considerable controversy over what type of plastic tubing to use and how much energy is saved by a hydronic radiant floor (HRF) system. But nearly everyone agrees on at least some of its advantages. Radiant floor heating systems provide a very comfortable way to heat. The entire floor radiates heat, so occupants never feel far from the heat source. Moreover, floors wetted by foot or vehicle traffic dry quickly. And there are no floor registers, exposed pipes, or radiators to interfere with furniture placement and room layouts. For these reasons, homeowners and architects have become interested in these systems, and contractors are being asked to install them.

Although there are several ways to install hydronic radiant floor heating, the most economical HRF systems are installed in concrete floor slabs. This article will focus on how to install this type of heating system.

HRF Characteristics

There are several characteristics of HRF heating you should consider before installing this system. First, slab-on-grade HRF systems are slow to respond to changes in thermostat settings. If the homeowner leaves for an extended time during the winter and sets back the thermostat, an HRF system can take several hours to warm up a space when the owner returns. This is because the heat source must warm the thermal mass of the floor slab as it also warms the air and other materials in the room. This is not a problem when an occupant's schedule is known, since setback controls can be programmed to begin warming the space several hours before the owner comes home. Likewise, space heated by a slab-on-grade HRF system can take several hours to cool down following a thermostat setback or power outage. This is a desirable characteristic because it allows the radiant slab to be tied into an intermittent heat source, such as a wood furnace, or an off-peak electrical or active solar system.

A second consideration affects the choice of floor coverings. HRF systems can be covered with a variety of finish floor materials, including certain types of hardwood,

Table 1. Heat Resistance of Common Floor Coverings

Floor Covering	Floor System R-Value	Average Water Temp. in Tubing
nylon carpet over 1/4-inch bonded urethane pad	2.5	135°F
3/8-inch floating hardwood over 1/8-inch foam pad	1.87	122
ceramic tile	1.00	105
1/8-inch vinyl	0.99	105
bare concrete	0.78	101

Note: *This table shows the thermal resistances of some common radiant floor systems, including covering, slab and tubing, and estimates of the average water temperature needed to maintain a room air temperature of 68°F. The table assumes a 4-inch insulated slab with nominal 3/4-inch tubing spaced 12 inches on-center, and a slab heat output of 20 btu/sq. ft. per hour.*

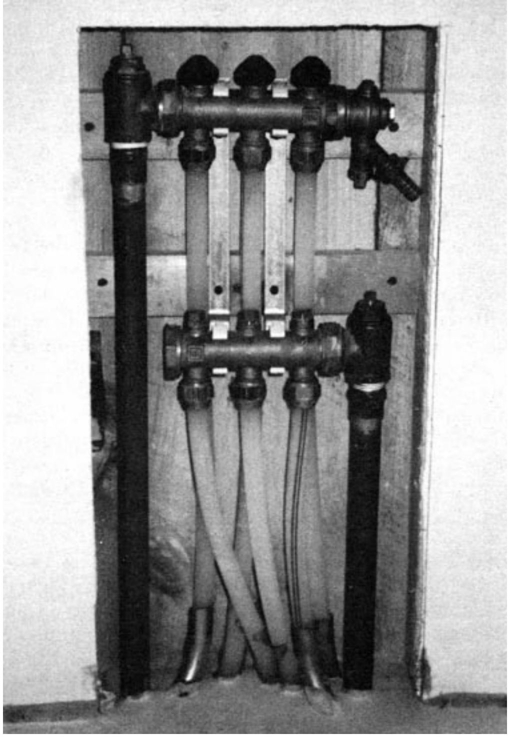

Figure 1. *All hydronic radiant floor circuits begin at a supply manifold and end at a return manifold. These two manifolds are usually located, one over the other, within an accessible wall cavity.*

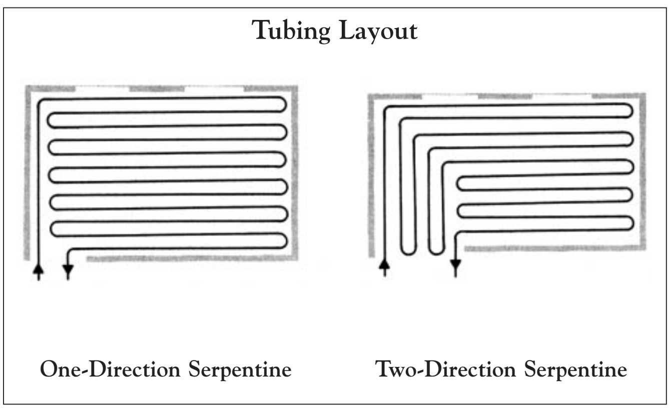

Figure 2. *The author uses a one- or two-direction serpentine circuit layout pattern. In each case, the tubing circuits first run adjacent to the exposed walls, and then work their way toward the interior. This allows for a slightly higher heat output near the coldest areas of the room.*

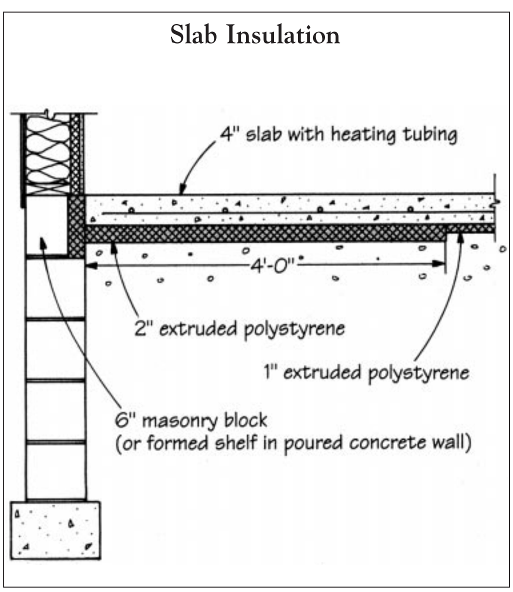

Figure 3. *The exposed edges of a radiant slab must be insulated with a minimum of 2-inch extruded polystyrene. Under the slab, the author uses 2-inch rigid foam for the first 4 feet in from the edge and 1-inch foam under the rest of the slab.*

carpet, or tile. Each of these materials adds a different amount of thermal resistance to upward heat flow (see Table 1). The average water temperature in the floor circuits must be increased as finish materials with higher thermal resistances are used over the slab. This is usually not a problem when a boiler is the heat source. But if you are relying on a hydronic heat pump, an active solar system, or another low-temperature heat source, the efficiency of the heat source will drop as the circuit temperature rises.

Also, if different areas of a slab are covered with different materials, each having a significantly different thermal resistance, you should make each of these areas a separate zone with its own distribution temperature. This will require additional mixing valves and higher associated costs (more on this later.) If you have more than two distribution water temperatures, it might be best to look at another type of distribution system.

Despite misconceptions to the contrary, wood floors can be installed over radiant slabs. Unfortunately, conventional wood flooring products that are either nailed or glued to an underlayment over the slab are often not warranted if used over a radiant floor heating system. The temperature fluctuations will reportedly cause problems with shrinkage or cupping. I recommend using a floating hardwood floor (see "Floating Hardwood Floors," 9/90). These floors are typically made with three plies of laminated wood, so the material is dimensionally stable. And since the floors are not rigidly attached to a slab, they can expand and contract with temperature changes.

Most manufacturers of floating hardwood flooring will guarantee the use of their products over radiant slabs, provided the surface temperature of the slab is limited to about 85°F. However, this limits the upward heat flow to about 16 Btu per square foot per hour — sufficient to maintain a 68°F room temperature *only* in a very well insulated house.

Planning and Layout

Before beginning an HRF installation, make a scaled drawing of the tubing circuit layout over the floor plan of the building. This is essential for specifying the right circuit length in each zone, ordering the proper length coils, and eliminating a trial-and-error tubing placement at the job site.

An easy way of doing this is to overlay a copy of the 1/4-inch scale floor plan with a sheet of vellum having a 1/8-inch grid. This grid corresponds to the 6 x 6-inch pattern formed by the welded-wire reinforcement. Some tubing manufacturers even provide templates to expedite the drawing of serpentine patterns. Circuit layouts done in this manner are easy to duplicate in the field since the installer can easily relate the plan to the welded wire grid.

Circuit layout. All HRF circuits begin at a supply manifold and end at a return manifold. These two manifolds are usually located, one over the other, within an accessible wall cavity (see Figure 1). I always try to choose a central manifold location. This minimizes the need to use long lengths of tubing between the manifold and individual rooms. The manifolds must be accessible through a removable or hinged wall panel. If it is objectionable to have the access panel exposed to finished space, try locating the manifolds in a closet.

Circuits using nominal 3/4-inch tubing should be limited to about 400 feet in length. Shorter circuits will have a smaller temperature drop from supply to return, which yields a higher average heat output per square foot. Longer circuits increase pump pressure requirements and yield lower average heat output per square foot due to the greater temperature drop from supply to return.

Also keep in mind that each floor circuit can be treated as an independent zone by controlling the circuit's flow rate either manually or automatically at the manifold. If you want to control each of several rooms independently, use a separate circuit for each room.

There are a number of circuit layout patterns for the HRF tubing. The simplest of these, and the one I use most often, is a "one-direction serpentine" (see Figure 2). In this pattern, the straight portions of the circuit run along the length of the room. This speeds up installation since it minimizes the number of return bends. Note that the tubing circuits first run adjacent to the exposed walls and then work their way toward the interior. This allows for a slightly higher heat output near the coldest areas of the room. Similarly, if the space has two exposed walls with large areas of glass, use a "two-directional serpentine" to keep the higher heating output near the exposed surfaces.

As a general rule, the tubing runs should be spaced 12 inches on-center. Occasionally, I might space the runs near the center of a slab 18 inches on-center. However, keeping the runs 12 inches apart ensures a quicker response rate.

Try to avoid running tubing under partitions if there is any chance the partitions will be fastened to the floor slab with mechanical fasteners. If I can't avoid placing the tubing under the partition, I try to avoid using mechanical fasteners. On a recent job for a Sunday school that

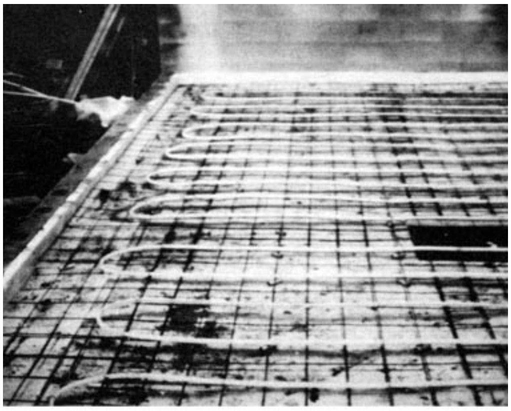

Figure 4. *The tubing is secured to the welded-wire reinforcement to keep everything in place during the pour. The insulation below the slab has been cut out for bearing pads.*

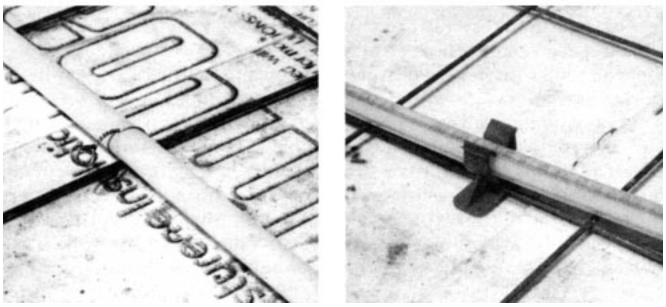

Figure 5. *To secure the hydronic tubing to the welded wire, manufacturers supply either twisted wire ties (left) or snap-in-place plastic clips (right).*

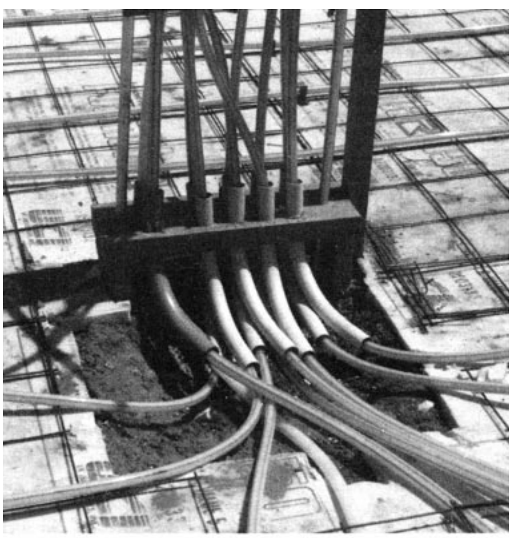

Figure 6. *At the manifold location, the author uses a 2x6 template and bend supports where the tubing rises out of the slab. The template is located in line with a partition, so the manifold can be set in the wall. The bend supports, available from tubing manufacturers, prevent the tubing from kinking during the pour.*

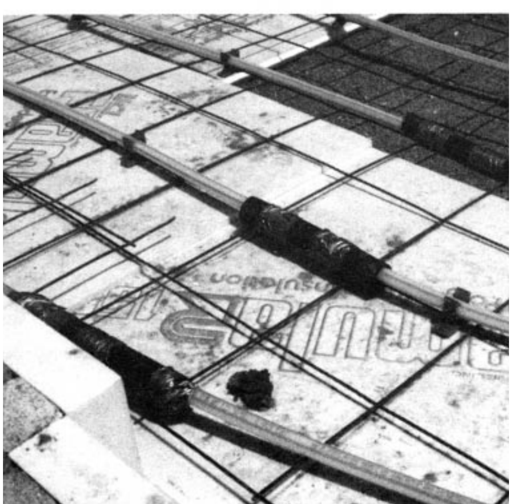

Figure 7. *To prevent damage to the tubing at a control joint, the author protects the tubing with 1-inch polyethylene pipe and holds the tubing at the bottom of the slab to keep it out of the concrete saw's path.*

had several smaller rooms over a common floor slab, I specified that the partitions should be attached to the floor slab with construction adhesive. This allowed the circuits to pass under the partitions wherever necessary, greatly simplifying the tubing layout.

Ordering the tubing. Once you have a sketch of the circuits, number each circuit and measure their lengths. Measuring off the plans can be a bit tedious, but it allows you to order the proper coil lengths and minimize waste. I use a small gear-driven measuring wheel to speed this work. I add an extra 10 feet to the measured length of each circuit to account for the risers to the manifold and for small measurement errors. Just like in measuring for electrical cable, it's better to be too long than too short.

To minimize waste, I usually order long, continuous coils and cut the lengths I need for each circuit. Some manufacturers, however, only offer tubing in incremental lengths. Unless your circuits are equal to or just slightly shorter than the coil, you end up with a lot of expensive waste. You should never lay out circuits that require a buried joint.

There have been problems reported, mainly in Europe, with boiler corrosion from oxygen diffusing into the tubing. Although I haven't experienced this, I always use tubing with an oxygen diffusion barrier just in case — it's cheap insurance.

Slab Insulation

Any exposed edges should be insulated with a minimum of 2-inch extruded polystyrene. Figure 3 shows the edge detail I use most often. I also specify 2-inch extruded polystyrene under the slab, 4 feet in from the edge, and 1-inch extruded polystyrene under the rest of the slab, except under any bearing pads. Although the downward heat loss from the interior of a floor slab is quite small, insulation in this area uncouples the thermal mass of the floor slab from the soil beneath it. This improves the thermal response of the slab. It is also good practice to install rigid insulation under door thresholds that abut exterior slabs to prevent melting snow and subsequent ice formation outside the door.

Placing the Tubing

Before uncoiling the tubing, I mark portions of the circuit path on the underslab insulation with a bright spray paint. It is not necessary to spray the entire circuit path, just the corners, return bends, or where other more intricate portions of the circuit will run.

Always secure the HRF tubing to the welded-wire reinforcement to keep everything in place during the pour (see Figure 4). The methods for securing the tubing to the reinforcement vary, but most manufacturers supply either twisted wire ties or snap-in-place plastic clips (see Figure 5). In my experience, it works best to place the ties every 2 to $2\frac{1}{2}$ feet on straight runs, and as close as needed to hold the tubing in a single plane on tight turns.

The template shown in Figure 6 provides an orderly way of routing the tubing into the slab at the manifold. It's made from a 2x4 or 2x6, and allows the concrete to be smoothly troweled near the tubing. Position the template in line, under where the manifold station will end up on the partition, and use a level or transit to set the top of the template flush with the slab surface. Be careful when operating a power trowel next to this area, as you could sever the projecting tubing.

I take two precautions to help minimize any damage to the tubing at control joints in the slab. First, I duct-tape a 1-foot-long piece of 1-inch polyethylene pipe centered over the tubing at the location of the joint (see Figure 7). Second, I hold down the tubing and welded-wire reinforcement at the control joint location, using a piece of $\frac{3}{8}$-inch rebar driven into the soil and bent back over the welded wire. This prevents the tubing from being lifted to a height where the concrete saw could hit it.

After the tubing has been placed, always perform a pressure test before pouring the slab. You can use either water or compressed air. To connect the individual circuits in a series for the pressure test, I temporarily install plastic or copper elbows with hose clamps where the tubes rise for the manifold. Pressurize the tubing to at least 50 psi and monitor the pressure for a minimum of 24 hours. Commonly, the pressure will drop slightly during the first couple of hours of the test as the tubing expands slightly. If a noticeable drop in pressure occurs, first check the temporary joints set up for the test, as they are the most likely culprits.

Finally, if pressure testing is done in cold weather, it is better to use compressed air to eliminate the possibility of freezing. I prefer not to use antifreeze in the system. Some antifreezes are toxic, and all have a way of getting on tools and creating a mess. However, for garage zones or vacation homes, you might consider putting antifreeze in the system permanently. This allows the homeowner to shut down the zone or the system to save energy without the danger of freezing. However, antifreeze is not as efficient as water in transferring heat, and it increases the pumping power requirement.

During the Pour

I keep the system pressurized during the pour to keep the tubing rigid. This is enough to allow for wheelbarrow traffic, so planks over the tubing aren't necessary.

A common concern during the pour is that a mason will chop through the tube with his shovel or hoe. But, in fact, the tubing is amazingly durable and this hasn't happened on any of our jobs. I still recommend keeping a few double-ended brass couplings on hand, just in case. Most tubing manufacturers provide these couplings.

If a tube is punctured during the pour, we would have to cut the tubing, insert the coupling, and then try to dam the concrete around that section so we could maintain access to the coupling. I explain this to the masons to urge caution.

The biggest challenge during the pour is to make sure the welded wire and tubing end up near the center of the slab section. We usually have at least one person in charge of hooking the wire mesh and pulling it up.

Connecting to a Heat Source

Because of the low water temperature requirements of an HRF system, consideration must be given to how the tubing is interfaced with a high-temperature heat source, such as a gas or oil-fired boiler. Failing to do this properly will result in possible damage to the boiler from internal condensation.

Condensation occurs when water vapor in the exhaust is cooled below its dew-point temperature. In a gas-fired boiler the dew-point temperature is typically around 130°F. Since return water in a HRF circuit is often below 100°F, continuous condensation within the boiler is almost guaranteed if the distribution is directly connected to the boiler. If the boiler is specifically designed as a condensing boiler, this effect is desired and significantly adds to the efficiency of the boiler. However, standard boilers are *not* designed for prolonged operation in a condensing mode, and the acidic condensation can quickly corrode galvanized exhaust stacks and promote corrosion on the outside of the boiler.

To prevent condensation in standard boilers, install a four-way mixing valve between the boiler and the manifolds (see Figure 8). This valve mixes cooler water with the hot supply water to bring it to the right temperature for the floor circuits. This allows the boiler to operate above the dew-point temperature, while also limiting the water temperature in the tubing. The circulator runs continuously. Although the mixing valve can be operated manually, an electronic control can be installed to control a motor in the valve. Sensors in the control measure outside temperature and the water temperature in the supply line and adjust the water mix accordingly. Several manufacturers offer complete systems of valves and controllers (see "Sources of Supply").

HRF Boiler Hookup

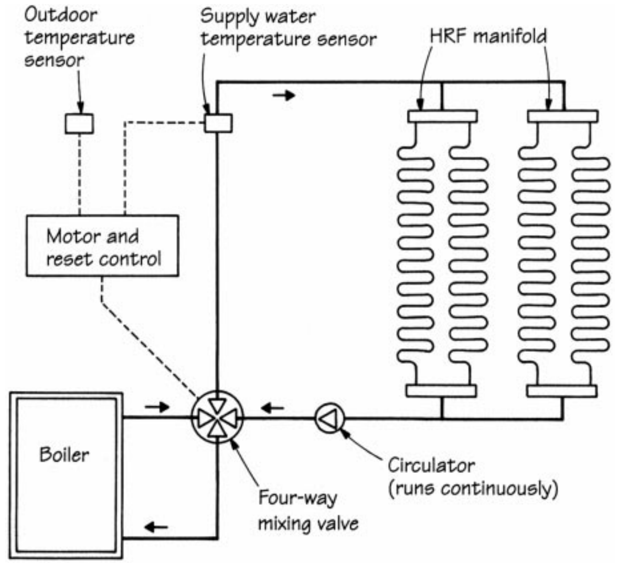

Figure 8. *The author installs a four-way mixing valve between the boiler and the tubing to lower the water temperature in the tubing. This valve allows the boiler to operate above the dew-point temperature, preventing condensation problems. The valve is connected to a "motor/electronic," which automatically adjusts the water mix according to temperature sensings from outdoors and in the supply line.*

Design Assistance

HRF manufacturers recognize that design assistance is vital to proper installation of this relatively new technology. Most manufacturers offer some form of design assistance through manufacturer's representatives or direct from the factory. Some will take your floor plans and prepare a suitable design and cost estimate for a nominal charge. Others use design software to check special cases. Most manufacturers also publish design assistance tables in their catalogs. If you are new to this form of hydronic heating, I strongly urge you to take advantage of these services. Proper planning and installation will ensure a long system life. ■

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Sources of Supply

Tubing and Components

EHT Siegmund
14771-E New Myford Rd.
Tustin, CA 92680
714/731-5706

Euro-Tech
P.O. Box 5
North Marsfield, MA 02059
617/837-3111

Heatway
3131 W. Chestnut Expressway
Springfield, MO 65802
800/255-1996

Infloor Heating Systems
920 Hamel Rd.
Hamel, MN 55340
612/478-6072

Stadler Corp.
3 Yankee Div. Rd.
Bedford, MA 01730
617/275-3122

Thermal Ease
Hydronic Systems
P.O. Box 11787
Bainbridge Island, WA 98110
206/842-9552

Wirsbo Co.
5925 148th St. W.
Apple Valley, MN 55124
800/321-4739

Four-Way Mixing Valve Systems

Enerjee
32 So. Lafayette Ave.
Morrisville, PA 19067
215/295-0557

ISTA Energy Systems Corp.
407 Hope Ave.
Roselle, NJ 07203
908/241-8880

Tekmar Control Systems
4611 23rd St.
Vernon, BC V1T 4K7, Canada
604/545-7749