

Heating a Home With a Tankless Water Heater

Even in a cold climate, these efficient units can provide both domestic hot water and whole-house heating

by Bob Gleason

I recently retired after 30 years as a residential contractor. My wife and I now live in a new home I built in Colorado. It's high in the mountains (elevation: 10,000 feet; heating degree days: 8,500) and has 2,000 square feet of conditioned space heated by a radiant-floor heating system.

While most radiant systems get their hot water from either a tank-type water heater or a cast-iron boiler, my home's heat and domestic hot water (DHW) are both provided by a single Rinnai tankless — or “on demand” — water heater. The Rinnai uses considerably less energy than a tank-type heater and costs less to install than a boiler with a heat exchanger.

Tankless water heaters are a proven technology with a track record of many years for heating DHW (see “Installing On-Demand Water Heaters,” 2/06). But since few contractors have experience using them for radiant heat, information about reliable system design can be hard to find. In my case, perfecting a system took some trial and error.

I consider the effort worthwhile: During the two years I've had the system, heat and hot-water costs for two people have averaged less than \$20 per month.

It's important to note, though, that my house is super-insulated (R-35 walls, R-50



The author's Colorado home has 2,000 square feet of conditioned space. His combined average costs for heat and hot water are only \$20 per month, a figure he credits to tight construction, programmed thermostats, and the efficiency of his tankless water heater.

to R-60 in the roof) and takes advantage of excellent solar exposure. If the sun is out, which it often is in this area, we don't need heat at all during the day. We also supplement our heating needs in the evening with a wood stove, which we enjoy for both comfort and ambience.

Finally, we use a programmed thermostat that limits the temperature to 62°F in the middle of the day and at night, and 70°F from 6 to 8 a.m. and 6 to 10 p.m.

Why Tankless?

Tankless water heaters take up very little space (mine measures 13½ inches wide by 23 inches high by 9 inches deep), can be mounted on any exterior wall, and offer nearly endless hot water.

Despite the fact that the units are not commonly used for radiant heat, they're an ideal heat source for this application because their output temperatures can be easily matched to the needs of the

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radiant system. My Rinnai provides water of up to 180°F, which is more than sufficient for the 110°F to 120°F needed to run my radiant system. (Many of the tankless units for DHW have a maximum output temperature of 140°F, but those used for heating should have higher limits.)

The economics of using a tankless water heater to supply both DHW and heating are also quite attractive. Total cost for my system was around \$5,000, not including labor: \$1,100 for the tankless heater, \$1,400 for the PEX tubing, and \$2,400 for the various components, controls, and fittings.

Although I could have gotten a tank-type unit for as little as \$200, the extra cost of the tankless model is more than offset by its energy savings. The energy efficiency of a heating appliance is expressed as a decimal called its energy factor, or EF. A tankless water heater has an EF between .82 and .87, which means it converts 82 percent to 87 percent of its energy input to heat. Tank-type units have an EF around .59, so they use considerably more energy than their tankless counterparts.

One exception is the Polaris by American Water Heater Co., which has an EF of approximately .95. However, its \$3,000 cost — almost three times as much as my Rinnai — was too high for me to justify. I could also have used a cast-iron boiler; its EF of .80 is close to that of a tankless, but the cost was more than \$3,000.

Selecting a Tankless Heater

A tankless water heater can be powered by electricity, natural gas, or propane. I considered only propane-powered models because I don't have natural gas where I live, and because the price I pay for electricity didn't make an electric unit economically feasible.

My unit is a direct-vent model, which uses outside air for combustion, an



Figure 1. The compact Rinnai heater, pumps, mixing valves, and controls fit neatly on a utility-room wall. The wall-mounted box to the left of the unit is an LCD temperature adjustment control that lets the user match the heater's output to the needs of the house.

important feature in a tight, well-insulated home. Theoretically, it can be installed on any outside wall, and even outside in some warm climates. I installed mine in the mudroom near the electric circuit panel (see Figure 1).

My only complaint is that the noise level of my heater can be objectionable at times. The mudroom in my house is next to the first-floor bedroom, and in times of heavy demand, the tankless unit “surges,” creating quite a loud noise. If I had to do it over again, I would not

place the unit next to a bedroom.

The heater includes a remote controller with a digital monitor that lets me raise or lower the temperature of the water coming out of the unit. I set it at 140°F, which is hot enough to meet all my needs with wood and tile floors. But a plumber friend who installed one in a home with carpeted floors had to raise the output temperature to 170°F, as carpeted floors are about the most difficult to heat with an in-floor radiant system.

The remote controller performs other

How to Size a Tankless Heater

Proper sizing requires that you know how much water the home will use during peak periods, the approximate temperature of the city water supply or well water, and how much the heater needs to heat that water to reach the needed temperature.

The table at right shows sample flow rates for various appliances and fixtures. The graph below it shows the temperature flow curve for a sample heater, in this case one with an output of 180,000 Btu. Determine how many fixtures or appliances will be operated at the same time, add up their flow rates, then look at the curve to determine if that unit will meet the home's needs.

Assume that the home will require a temperature rise of 75°F. (That's the difference in temperature between the 40°F well water and the required output temperature of 115°F.) The vertical 75°F line meets the curve at a flow rate of about 4.5 gallons per minute (gpm).

This unit would be sufficient to run a shower (2.5 gpm) and a faucet (1.5 gpm) at the same time. However, it would not provide enough hot water for two showers at 5 gpm each. In that case, the solution would be to install two heaters, or to install one heater with a larger capacity.

Though they are sold primarily for domestic hot water, tankless heaters are actually well-suited for radiant heating, which operates at low temperatures compared with, for example, hot-water baseboard. So using the unit for radiant heating generally has little or no effect on the sizing calculation.

The output in Btu of a heater large enough to supply a home's domestic hot-water needs is typically sufficient to meet its heating needs as well. If the heating circulators happen to be running at the same time as the domestic hot water, the temperature in the heating loops may drop slightly. But because domestic hot water is used only intermittently, this would rarely be a problem.

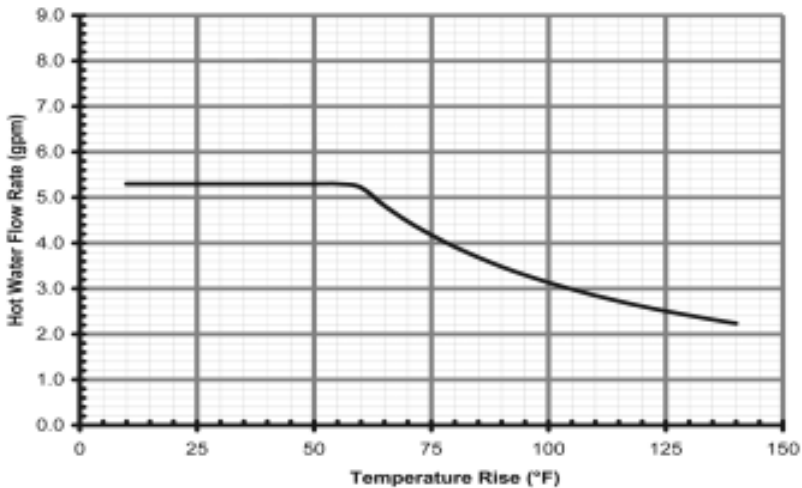
For instance, in my radiant-floor system, the water returning to the heating

unit from the heating loops is only 10°F to 20°F below the zone design output temperature of 110°F to 120°F — much higher than the incoming well water's 40°F. So once the water in the heating loops has been initially heated, the heating unit has to raise the return water only about 10°F to 20°F.

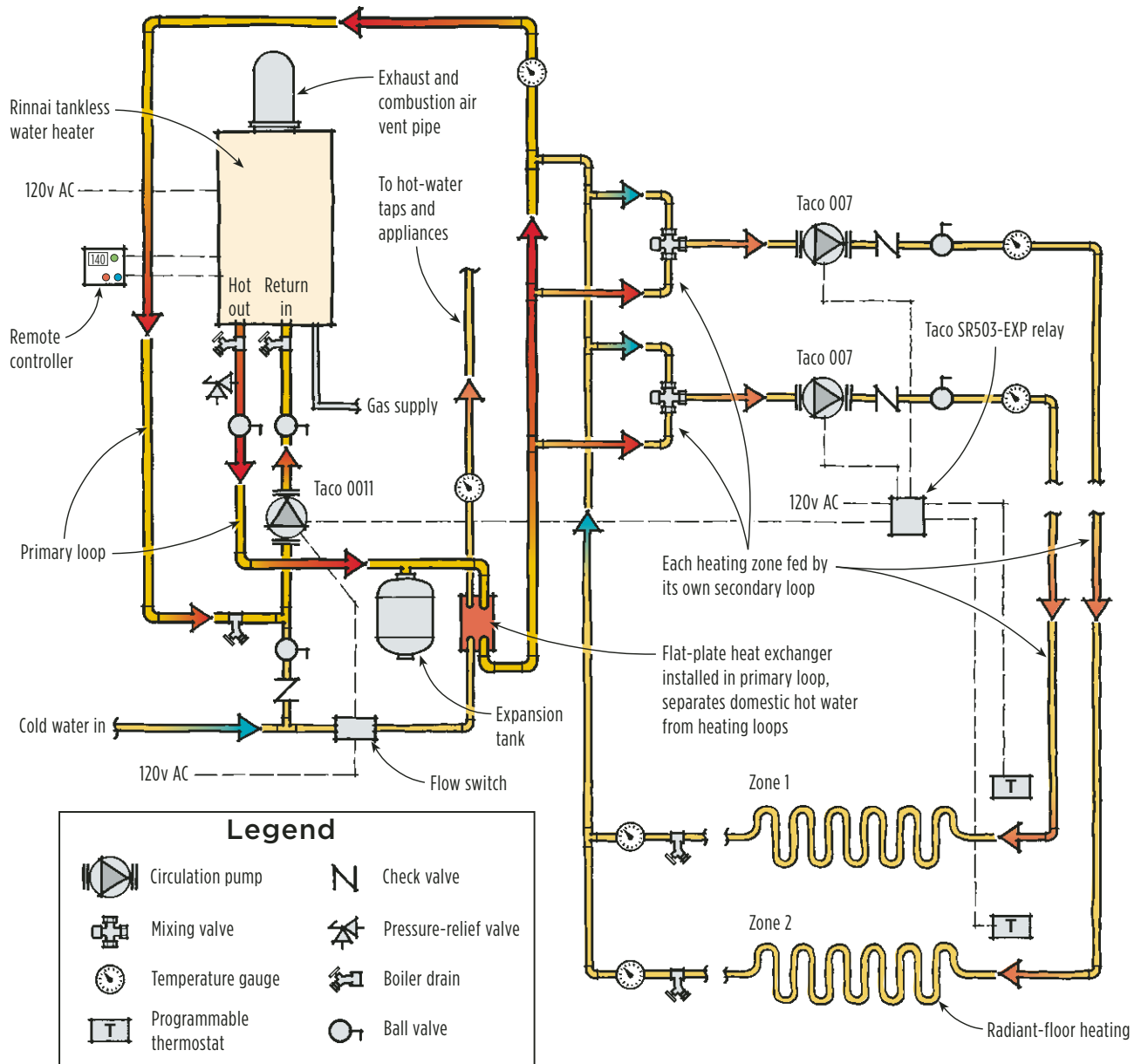
Other systems may have a higher incoming water temperature, a higher design temperature, or greater heating demand. But in almost all cases, the radiant floor water in the loops will never be lower than room temperature. Be sure to consult a manufacturer's representative before deciding which tankless heater to buy.

Fixture	Flow rate, gpm
Low-flow faucet	0.5 - 1.5
Dishwasher	1.5
Showerhead	2.5
Clothes washer	4.0
Whirlpool tub	4.0

Sample Temperature Curve for an On-Demand Unit



Piping Diagram for Closed Loop System



functions as well. It can display 12 or more error messages that alert you to operating problems. It can also display the rate that water flows through the heater, and the actual output temperature.

The most important part of selecting a tankless heater is making sure it's properly sized. Proper sizing requires that you

get an accurate picture of a particular home's heating requirements. To do that, you need to run a heat-loss calculation.

Numerous sources on the Internet offer methods of calculating heat losses — or software that can do it — either for a nominal charge or for free.

Uponor (formerly Wirsbo), a supplier

Figure 2. The author's radiant distribution system consists of a primary loop with a heat exchanger for domestic hot water, and secondary loops for each heating zone. One lesson he learned through trial and error was that the system worked properly only if the heat exchanger was installed in the primary loop.

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of polyethylene PEX tubing, offers software at www.uponor.com that will not only calculate your heat losses, but also help you design the distribution system. The software doesn't specify a heat source, but it will work as well for a tankless as for a tank-type heater or a boiler. It's available free on a trial basis, by which the company means 15 uses or design sessions. If you find the software useful, you can buy a permanent copy.

In general, a well-insulated new house shouldn't require much more than 15 Btu per square foot per hour. For 2,000 square feet, that's 30,000 Btu per hour.

Even a poorly insulated house of this size shouldn't need more than 60,000 Btu per hour. Most of the units you should be considering will have outputs of at least 150,000 Btu per hour; in most cases sizing will be determined by the home's DHW requirements (see "How to Size a Tankless Heater," page 3).

Designing the Distribution System

When I first started researching the use of tankless for radiant heat, I found several sources on the Internet that recommended using an open distribution system, in which the DHW supply flows through the radiant loops. I don't like open systems (in fact, some states prohibit them); stagnant areas may develop in the heating loops, especially in the summer, allowing the growth of bacteria — including those that cause Legionnaires' disease.

I eliminated health concerns by using a closed system, in which the DHW and heating loops are totally separate. Water heated by the tankless heater flows directly through the floor tubing, while a heat exchanger provides heat for the DHW supply (Figure 2, page 4).

The domestic hot-water system. In my DHW system, water from the well enters



Figure 3. Key components in the author's system include the flat-plate heat exchanger (at right in photo), which heats the domestic hot water loop, and a flow switch (at left), which ensures that the heater fires even at a very low flow rate.

the heat exchanger and then goes to the sinks, the showers, the dishwasher, and so on. I bought my flat-plate heat exchanger from www.houseneeds.com for \$250 (such products are also available at plumbing supply houses). Mine is rated at 240,000 Btu per hour — somewhat lower than my calculations indicated I might need. Even so, I can take a shower and run the dishwasher at the same time. I have not tried running two showers simultaneously, but the main bath, which we use frequently, has four wall-mounted jets, each of which disperses nearly as much water as a shower head. We're able to operate them with no problem.

In a well-designed closed system, the heat exchanger will be in the primary loop, while each heating zone will be fed by its own secondary loop, as in Figure 2.

I learned the hard way that the heat exchanger for the DHW must be in the primary loop. I initially installed it in its own secondary loop, but found that the heating zones would steal enough water to keep the heat exchanger from delivering sufficient hot water to the taps, and

that this happened even when the heat loops were not active. So I reconfigured the piping, and now all the water in the system flows through the heat exchanger before being sent to the secondary loops.

The primary loop needs a pump rated for at least 6 gallons per minute at 30 feet of head, which is the measure of the pressure created by a column of water 30 feet high. A pump rated at 30 feet of head will perform until that pressure is reached, at which point it can no longer supply water.

Undersizing the primary pump will cause failure. In fact, I tried to save money by using a lower-capacity pump on the primary loop, but it wouldn't deliver enough hot water to the taps; I eventually had to buy a larger-capacity pump.

You also need to know your hot-water needs before choosing a heat exchanger. As I mentioned previously, my water heater's output is set at 140°F. When supplied with the 140°F water, my heat exchanger delivers water at a temperature of about 130°F, which is high enough for showers and the dishwasher.

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Heating zones. Each of my two heating zones includes a mixing valve to throttle the temperature down — to 120°F for the basement zone and 110°F for the main-floor zone. (I wanted the main-floor temperature lower to protect prefinished hardwood floor I installed in the living room.)

Since the heat exchanger gets the hot water first, running the radiant zones at the same time does not affect the DHW temperature. It does cause a minor change in the radiant-floor water temperature, but this is of little concern because the DHW is rarely on for more

than several minutes at a time.

Occasionally, both the zone thermostats and the DHW will call for the water heater to be on, so it's important to keep all of the electrical connections on one circuit. None of the electrical components require much power.

Choosing Components

If you install a system with a combination of radiant heat and a tankless water heater, you will need a variety of pumps, switches, and fittings (see table, left).

The heater should have an intake water-filter screen and the necessary vent pipe for the combustion and exhaust air.

Rinnai sells an optional plumbing kit, which consists of two boiler drains, a pressure-relief valve, and ball valves. I bought it, and installed additional boiler drains to facilitate purging the system of air. If you're using mixing valves, you also need a temperature gauge downstream from each valve, so that you can monitor the temperature of the water in the floor system.

Because of the slow response times for in-floor radiant heat, it's essential to use programmable thermostats. For instance, I like lower room temperatures at night. It takes about two hours after the thermostat turns off the heat for the air in the room to start to cool. In the morning, the heater warms up the floor for about three hours before the room air reaches its design temperature. My programmable thermostat takes these conditions into consideration.

For my system to work properly, I've found that the thermostats that activate the zone pumps also have to turn on the primary loop pump. At first, I connected my thermostats to a pair of relays that turned on the zone pumps but not the primary loop pump. I ended up replacing them with a single Taco SR503-EXP relay that connects to as many as three

thermostats. Now, when a thermostat calls for heat, the thermostat turns on the pump for that zone as well as the primary loop pump.

I've seen some system designs that leave the primary pump on constantly, but I consider that a waste of energy.

Flow switch for domestic hot water.

Something to be aware of is that most tankless heaters have an internal flow switch that activates the burner at a flow rate of 1/2 gallon per minute (gpm) or higher. This is fine for showering, but a continuous low flow of hot water — such as you might use for rinsing dishes or while shaving — will not cause the heater to fire, which means the water will run cold after a short time.

To ensure that I can get a low flow of hot water, I added a standard 120CV flow switch (a McDonnell & Miller Series FS6, available from several sources on the Internet, including State Supply Co., www.statesupply.com) that closes contacts at 0.12 gpm (Figure 3, page 5). The flow switch activates the primary pump, which creates enough flow through the heater to cause it to fire. This has worked well, guaranteeing that the water stays hot even at a low flow rate.

Hindsight

Aside from the location of the heater, I wouldn't change anything about my system at this point. I really like the space savings and the flexibility it gives me to adjust design temperatures. And because I have a relatively small, well-insulated house, the heater runs for only six to seven hours per day — or less — on even the coldest days of the year, which should yield a fairly long operating life.

Bob Gleason was trained as a mechanical engineer and owned a general contracting business for 30 years. Now retired, he lives in Twin Lakes, Colo.

Components of the Author's System	
Five-loop supply manifolds	2
Five-loop return manifolds (one with flow control)	2
Taco 007 pumps	2
Taco 0011 pump	1
Flanges for above (two for each pump)	6
Expansion tank	1
Heat exchanger	1
Flow switch	1
Taco mixing valves	2
Temperature gauges	5
Boiler drains	4
Ball valves, 1/2 inch	18
Ball valves, 3/4 inch	5
Check valves	4
Room thermostats	2
Taco SR503-EXP relay	1