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Recirculating renewable energy

The temperature of the thermal storage tank can vary over a wide range.

Given their intermittent heat generation characteristics, many hydronic-based renewable energy systems require thermal storage. Examples include solar-thermal systems and biomass boilers. Thermal storage also is used in heating systems supplied by off-peak electricity and micro-combined heat and power systems.

The temperature of the thermal storage tank can vary over a wide range. If supplied by a solar collector array and after two or three sunny days with minimal loading, the tank temperature could be upwards of 180° F. These temperatures also are possible at the end of a tank "charging" cycle from a biomass boiler, as well as in off-peak electric thermal storage and MCHP systems.

At other times, when there's little if any heat input from the renewable energy heat source, the thermal storage tank could cool down, even down to the surrounding air temperature.

This temperature variation implies there will be times when thermal storage could supply *all* the energy needed to heat domestic water to a typical maximum delivery temperature of 120°. Heat would be passed from the "system water" in the thermal storage tank to domestic water through a stainless steel heat exchanger.

There also will be times when thermal storage could only preheat domestic water. Another heat source would be necessary to "top off" the water to the required delivery temperature.

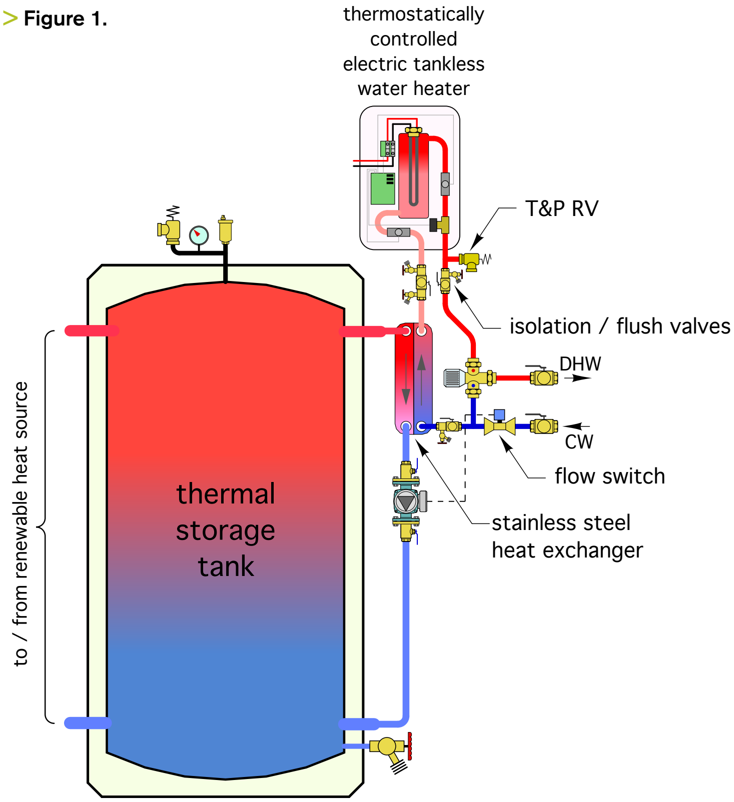
Low-temperature leverage

Even though preheating doesn't bring domestic water all the way to the final temperature, its importance shouldn't be underestimated. Keep in mind it takes just as much energy to bring a quantity of water from 50° to 60° as it does to bring that water from 150° to 160°. Thermal storage tanks, even at reduced temperatures, can "leverage" the low end of the temperature rise. Because of this, domestic water heating, where it's needed, is an enticing load to combine with renewable energy heat sources.

Figure 1 shows how heat from thermal storage can be transferred to domestic water using a single-pass stainless steel heat exchanger.

A flow switch closes its contacts when it detects a specific minimum flow rate of domestic water. This turns on a circulator that routes water from the upper portion of the thermal storage tank through the primary side of the brazed-plate stainless steel heat exchanger. Heat is transferred to "cold" domestic water entering the secondary side of the heat exchanger.

> Figure 1.



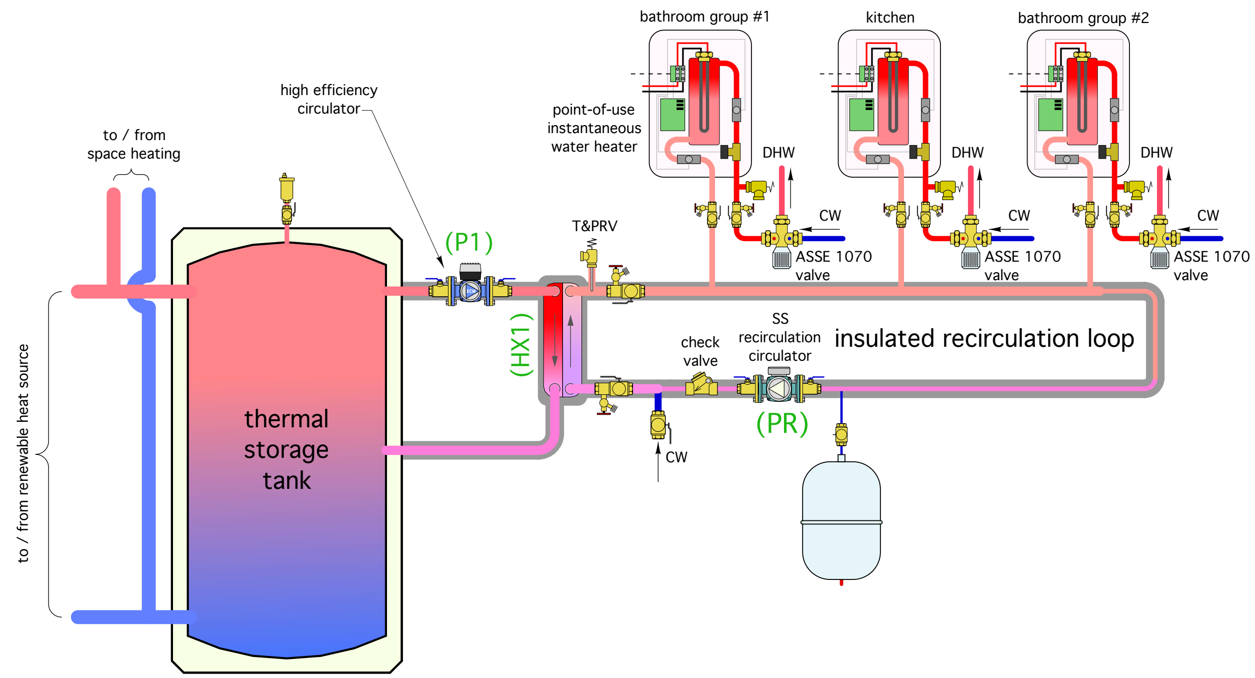
Brazed-plate heat exchangers have a high ratio of internal surface area to fluid volume and can quickly respond to temperature changes. With the heat exchanger and circulator located as close as possible to the tank to minimize piping length, the response time from when the flow switch closes to when heated domestic water emerges from the secondary side of the heat exchanger should be in the range of two to three *seconds*.

The temperature of the domestic water leaving the heat exchanger obviously depends on the temperature in the upper portion of the thermal storage tank. With a generously sized heat exchanger, the approach temperature difference should be no more than 5°. A thermal storage tank at 95° could potentially heat domestic water from 45° to 90°. That's 60% of the temperature rise and 60% of the energy required to fully heat the water from 50° to 120°.

Graphics courtesy of John Siegenthaler

Note: The views expressed here are strictly those of the author and do not necessarily represent ***pme*** *or BNP Media.*

> Figure 2.



When required, a thermostatically-controlled electric tankless water heater provides the final temperature rise. If the domestic water enters this heater at or above the required delivery temperature, the elements in the heater do not turn on.

An ASSE-1017-listed thermostatic mixing valve provides protection against high DHW delivery temperature in situations where the thermal storage tank is at an elevated temperature and thus the domestic water leaving the heat exchanger is "overheated" relative to the target delivery temperature.

Both the heat exchanger and tankless water heater are equipped with combination isolation/flushing valves. This allows for citric acid or vinegar washing if necessary to remove any accumulated scale.

Add a loop

The system in Figure 1 doesn't ensure that at the required temperature the domestic hot water instantly is available at every fixture; that requires a recirculation piping system. The system in Figure 2 adds a recirculation loop along with several point-of-use electric tankless water heaters to the heat exchanger/circulator subassembly shown in Figure 1.

Each point-of-use tankless heater draws heated water from the recirculation loop. A typical system would use one tankless heater for each bathroom group (shower/tub and lavatory). It would use separate tankless heaters for the kitchen, laundry or other areas where DHW is required. Each tankless heater would be sized to the flow and delivery temperature requirements of these loads. Each would be controlled by its internal thermostat so only the energy necessary is added to the entering water. If the entering water already is at or above the required temperature, the elements within these heaters remain off. An ASSE-1070-listed thermostatic mixing valve ensures the water delivered to the fixtures doesn't exceed a safe delivery temperature.

A small bronze or stainless steel recirculation circulator moves water around the loop whenever DHW may be required in the building. This is not necessarily 24/7. Another small high-efficiency circulator maintains flow between the thermal storage tank and stainless steel heat exchanger.

Assuming an upper tank temperature of 120°, a high-efficiency circulator between the tank and a 5-in. by 12-in. by 50-in. plate heat exchanger could yield an output of 4 gpm of domestic water heated from 50° to 115° with a power input of about 30 watts. A small recirculation circulator would add another 12 watts of power input. If both circulators *continuously* ran in a location where electricity costs $0.15 kW/h, the operating cost would be about $0.15 cents/day. This could be reduced by turning off the recirculation system during times with little or no expected demand for DHW.

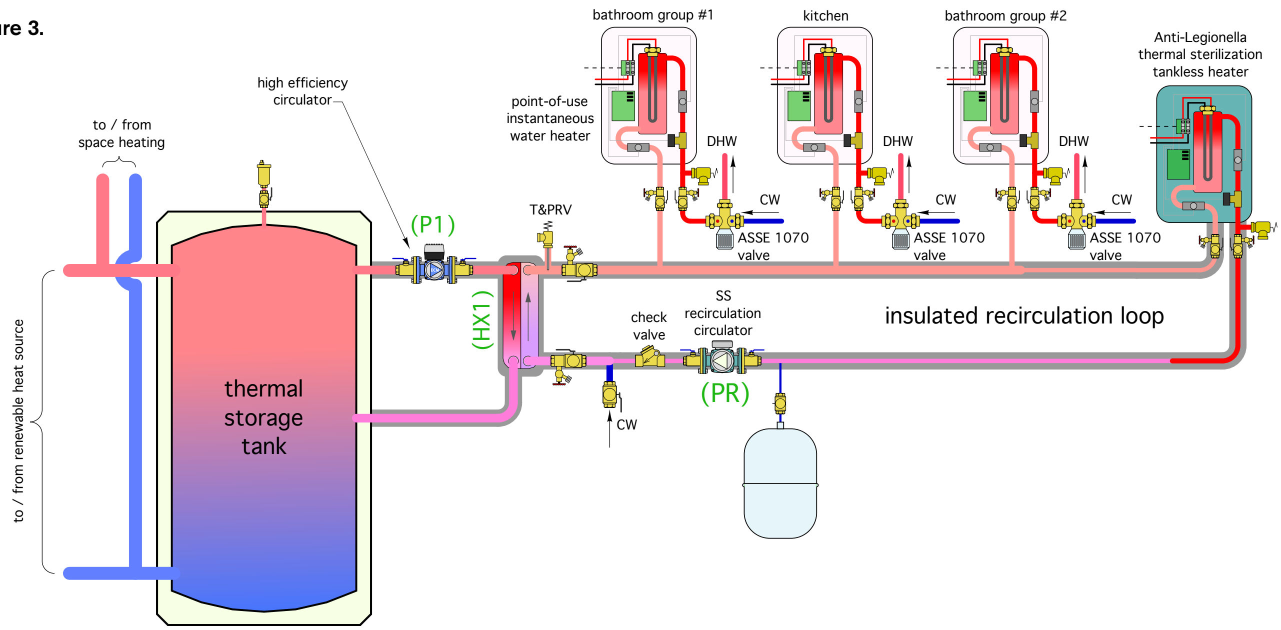
Even when the recirculation system is off, each tankless heater can provide some hot water to its associated fixture(s) with energy solely being supplied by electricity. The flow rate and delivery temperature would depend on the power rating of that heater.

The check valve downstream of the recirculation circulator forces domestic cold water through the heat exchanger whenever hot water is drawn from any fixture.

The approach has several advantages. First, the power requirement of each tankless heater is only required for the fixture group it serves. For example, a 7-kW tankless heater would provide up to a 1.9-gpm flow rate with a corresponding temperature change from a "preheat" temperature of 95° to a delivery temperature of 120°. A 7-kW tankless heater could be supplied from a 240 VAC/30 amp circuit. Higher-capacity tankless heaters could be used where higher flow rates are needed.

Second, multiple tankless units provide redundancy relative to a single higher capacity heater. A problem with one unit doesn't prevent DHW availability at the other units.

> Figure 3.



Third, when water in the recirculation loop is at a lower temperature, heat loss from the loop is reduced. Still, the recirculation loop always should be insulated.

Kill the bugs

Any domestic hot water system operating at water temperatures in the range of 68° to 122° has the potential for Legionella bacteria growth. Tempered water between 77° and 113° provides an *optimum* growth environment.

Several well-publicized Legionella outbreaks associated with domestic hot water plumbing, typically in hotel plumbing systems, have spurred interest in designing DHW plumbing systems to minimize harmful levels of the bacteria. It's possible, even likely, that *mandatory* Legionella protection standards will be coming to both commercial and residential DHW systems.

To address this, the system from Figure 2 has been further detailed with a dedicated thermal sterilization tankless heater as shown in Figure 3.

The purpose of the sterilization heater is to periodically elevate the water temperature in all portions of the recirculation loop high enough and maintain that temperature long enough to kill Legionella bacteria. In the absence of specific codes that require otherwise, typical daily thermal sterilization temperature/cycle durations are as follows:

- 158° (70° C) for 10 minutes;
- 149° (65° C) for 15 minutes; and
- 140° (60° C) for 30 minutes.

Some electric tankless water heaters can heat water as hot as 180°. Others have internal safety switches that prevent temperatures above about 140°. The stated sterilization temperatures will require a heater with the higher temperature capability.

The sterilization cycle could be programmed to occur at times of no DHW use, such as early morning hours. If one assumes no DHW draws during this relatively short sterilization cycle, the power output of the sterilization heater only is required to match the heat loss of the recirculation loop.

Here's an example: Assume the DHW loop consisted of 100 ft. of 1-in. insulated copper tubing on the supply side and 100 ft. of 1/2-in. insulated copper tubing for the recirculation piping. The insulation is 1/2-in.-thick elastomeric foam. Also, assume an average water temperature in the loop of 155° during the sterilization cycle. The total heat loss of the piping under these conditions is about 2,700 Btu/h. Add 20% to this to account for heat loss from riser piping to fixtures, heat loss from the insulated heat exchanger and from the recirculation circulator, valves, etc. The total estimated 3,240 Btu/h heat loss is just under 1 kW (3,413 Btu/h).

Even a small 3-kW electric tankless unit is more than enough capacity to achieve the (no DHW draw) sterilization requirements. Higher-capacity sterilization heaters could be used to provide sufficient heat input to allow some DHW draw during the sterilization cycle. The ASSE 1070 mixing valves on each fixture prevent scalding temperatures from reaching the fixtures.

A system controller could determine when the sterilization cycle begins and monitor the water temperature returning to the sterilization heater (e.g., the coolest water in the recirculation loop during the sterilization cycle). The cycle would continue until a prescribed minimum temperature/time criteria has been verified.

Due to its low starting temperature, domestic water heating is an "attractive" load to be supplied by renewable energy heat sources. This concept takes advantage of the low starting temperature. It also ensures consistent, safe and immediate DHW delivery at all fixtures while minimizing the potential for harmful levels of Legionella bacteria to reach any fixture.

Perhaps it can be applied in one of your upcoming renewable energy system designs? pme

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