John Siegenthaler, P.E.

Big tank, little tank

How they can work together in a wood-fired heating system.

Interest in biomass heating systems continues to rise, especially in rural areas of the United States and Canada. Although plenty of devices are available that burn wood to heat water, the state-of-the-art device is a wood-gasification boiler.

The operation of such a boiler starts out much the same as a wood stove. You make a small "tepee" at the base of the combustion chamber with newsprint or a fire starter and some dry kindling, add a few more pieces of dry split wood on top and light it. At this point, a damper in the upper portion of the combustion chamber is open and the fire is burning in an "updraft" mode. A few minutes later, after the fire has grown in intensity, the operator loads the firebox full of firewood, closes the upper damper and flips a switch that starts the combustion air blower. This is when the magic starts.

The blower forces the pyrolytic gases that are now being driven from the heated wood downward through a slot in a ceramic plate at the bottom of the combustion chamber. The blower also creates jets of hot air that discharge into the same slot. When this air meets the pyrolytic gases, the resulting combustion resembles a blow torch, as seen in Figure 1.

Figure 1

When hot air meets pyrolytic gases.

Photo credit: Econoburn

This is very efficient combustion compared to that in a typical wood stove or fireplace. Combustion zone temperatures can exceed 2,000°F, with thermal efficiencies typically in the mid- to upper-80% range. Gasification boilers with 90% thermal efficiencies are now being tested and should be on the market shortly.

So, imagine you have this wood-fired blow torch operating with an output of 150,000 Btu/hr. and its going to stay that way for the next two to four hours. What do you do with all that heat? The answer is simple: Put it into storage.

Thermal storage tanks with volumes from 250 to 1,000 gal. are commonly used with wood-gasification boilers. Some systems use unpressurized tanks with one or more internal coil copper heat exchangers. Other systems use pressurized tanks. Both types of tanks have strengths and limitations. From the standpoint of simplicity and efficiency, I like pressurized tanks. The ideal geometry for such a tank would be a vertical cylinder. However, height limitations in many residential and small commercial buildings often limits the choices.

One approach that has been adopted by many of those using wood-gasification boilers is the use of a repurposed 500 gal. propane storage tank for thermal storage. An example is shown in Figure 2 (page 14). These 500 gal. carbon steel tanks have diameters of 40 in. and are about 9 ft. long. As built, they are usually ASME-rated to 200 psi operating pressures.

However, the piping connections provided for propane storage are not at the best locations, nor of the right size, for thermal storage applications. This can be

Figure 2

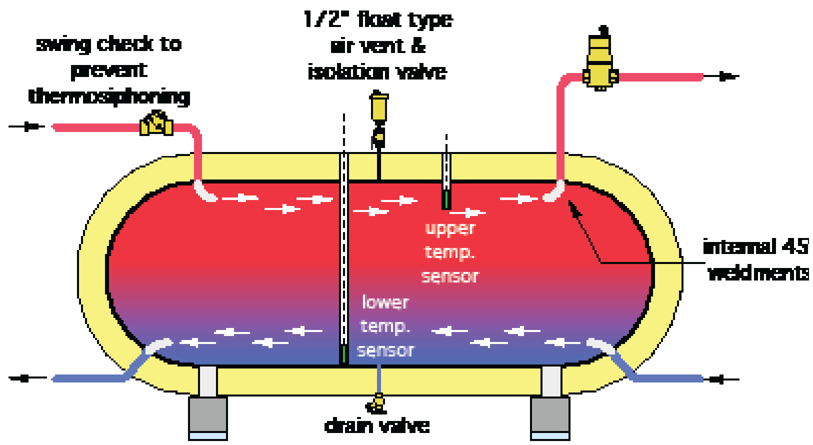
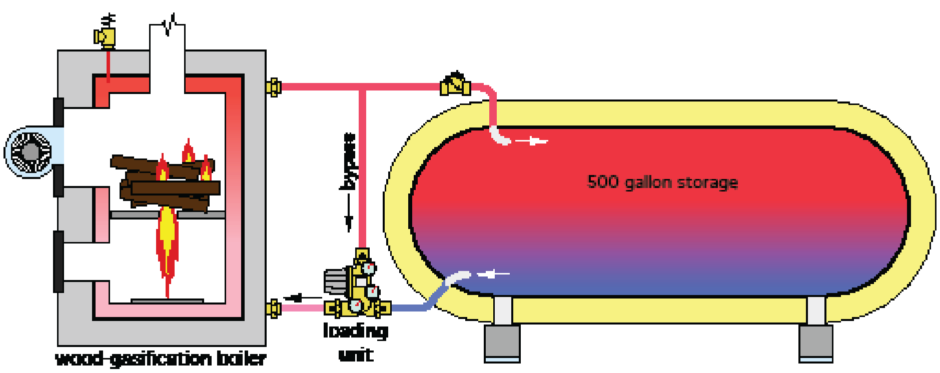


Figure 3



remedied by welding additional threaded pipe bosses to the tank shell where needed. This welding can be done to ASME Section VIII standards when necessary to meet local codes. I like to specify connections as shown in Figure 2.

These placements encourage temperature stratification within the tank (e.g., the hottest water stays at the top of the tank and the coolest water remains at the bottom). They also allow for sensor wells, air venting and drainage. They require internal sweeps (either 90° or 45°) to prevent incoming flows from creating vertical jets that disrupt stratification.

After the tank is piped up and all connections are pressure-tested, it must be thoroughly insulated. The minimum insulation spec is R-24, with even higher values preferred. These tanks have a *lot* of surface area and at times will be at high temperatures. Going cheap on insulation creates uncontrolled heat gains to surrounding spaces that really compromise system performance.

A multilayered application of spray polyurethane works well. Be sure the foam is rated for applications up to 200°. If higher tank temperatures are expected, a layer of high-temperature mineral wood or fiberglass may be required as a base between the tank and foam.

Don't go unprotected

If you've ever coupled a conventional boiler to a high-thermal-mass heating system and not equipped the mixing assembly with a boiler protection feature, you've probably witnessed the awesome heat absorption capability of a large/cool thermal mass. Boiler protection is just as important when connecting a large thermal storage tank to a wood-fired boiler. Leave it out and you're likely to see the combustion chamber walls dripping with creosote and other aggressive compounds produced during combustion.

There are several ways to provide boiler protection. Figure 3 shows a common approach using a loading unit. This assembly combines a high flow capacity three-way thermostatic mixing valve, circulator and flapper check valve. When the boiler is warming up, the three-way thermostatic valve routes all flow created by the circulator through the bypass pipe and back to the boiler inlet. This allows the boiler to warm up as fast as possible, since no heat is being sent to the load. When the water exiting this valve climbs to a minimum set temperature, such as 130°, the valve will modulate to allow some hot water flow from the boiler to the thermal storage tank.

When the water temperature leaving the valve is several degrees above the minimum temperature setting, all water leaving the boiler goes to the storage tank. Thus, the loading unit acts like a "thermal clutch" between the boiler and the tank, smoothly increasing or decreasing the rate of heat transfer as necessary to keep the boiler inlet at an appropriate temperature. The loading unit also is internally configured so that it allows thermosiphon flow between the boiler and thermal storage tank during a power outage. Thus, no external heat dump is required when the system is piped as shown in Figure 3.

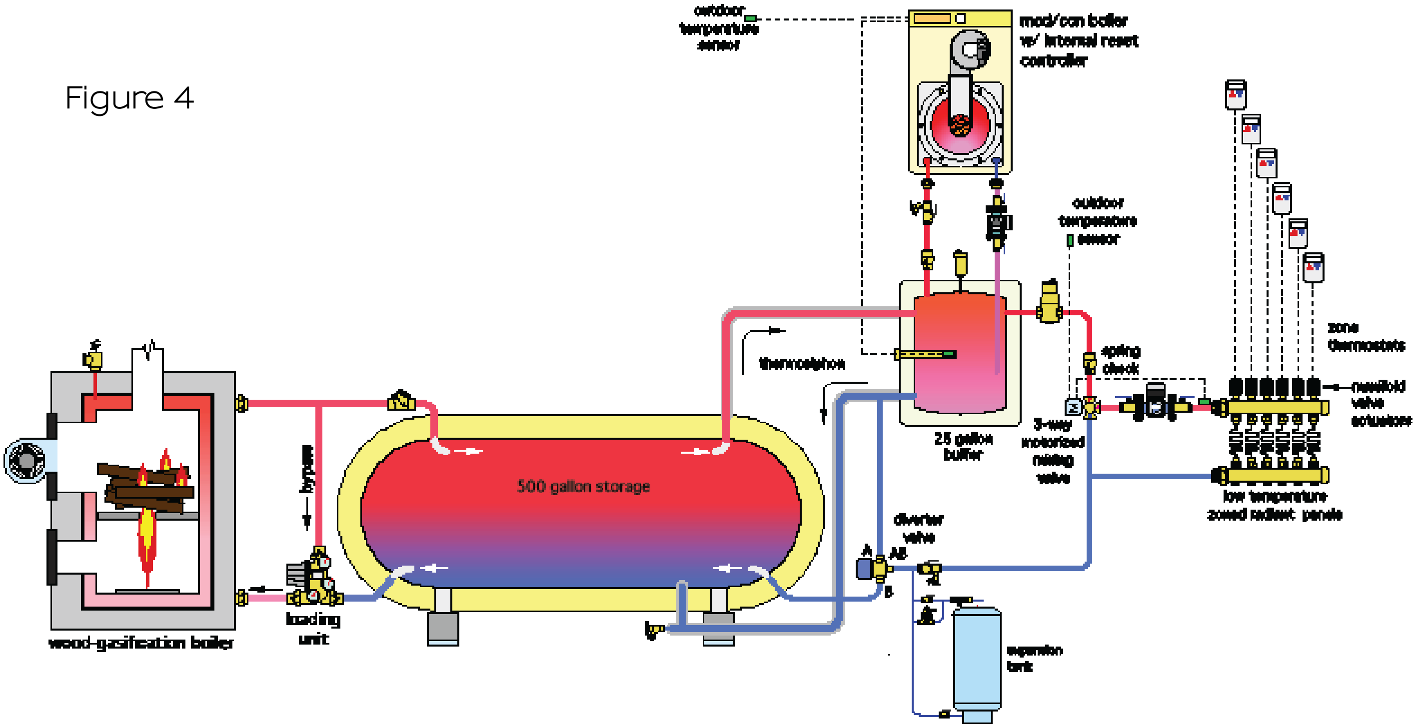
When the fire goes out

Although it's possible to use a wood gasification boiler as the *sole* heat source for a hydronic system, many owners want a backup heat source that can automatically pick up the loads when the wood boiler has insufficient output. If the distribution system has been designed around low water temperatures, a wall-hung mod/con boiler operating on propane is a likely choice.

If the distribution system is highly zoned, it's important to protect the auxiliary boiler from short-cycling. Although that 500-gal. tank looks tempting, it's not a good idea to maintain such a large volume of water at elevated temperatures using the auxiliary boiler. A better approach is to set up a small 25- to 30-gal. buffer tank, as shown in Figure 4 (page 16).

The small buffer tank is elevated at least 1 ft. above the large storage tank.

Figure 4



outdoor temperature sensor
mod/con boiler w/ internal reset controller
outdoor temperature sensor
zone thermostats
thermosiphon
spring check
manifold valve actuators
25 gallon buffer
3-way motorized mixing valve
low temperature zoned radiant panels
500 gallon storage
bypass
diverter valve
A
AB
B
expansion tank
wood-gasification boiler
loading unit

The insulated piping between these tanks allows for thermosiphon flow whenever the temperature at the top of the large tank is higher than in the small tank. Thus, the water temperature in the small tank is "maintained" by the large tank when possible.

Upon a demand for space heating, an outdoor reset controller checks the temperature near the top of the large tank. If this temperature is high enough to supply space heating, flow returning from the distribution system is routed into the lower portion of the large tank by the diverter valve. Hot water flows out the top and up to the small tank, which in this mode is essentially just a pass through. The water continues on to the three-way motorized mixing valve, where its temperature is adjusted as necessary for the heat emitters.

If the temperature at the top of the large tank is too low to supply space heating, the diverter valve is energized and water returning from the distribution system is routed to the small buffer tank. The mod/con boiler is enabled to operate on its own internal reset controller to maintain the required water temperature within the small buffer. The system is now operating as if it was "detached" from the large tank. The 25 gal. of water provides sufficient thermal mass to prevent boiler short-cycling and eliminates the need to use the large tank as a buffer.

If the wood-gasification boiler is fired back up, the large storage tank temperature will rise and eventually the outdoor reset controller will turn off the mod/con boiler and diverter valve. At that point, the large tank is again supplying the load.

Figure 5 shows how the system could be extended to include on-demand domestic water heating using the assembly discussed in my June 2012 PM column, "Sidearm revamp." The brazed-plate heat exchanger transfers as much heat as possible to the cold domestic water. A thermostatically controlled electric tankless water heater provides any necessary boost to get the desired setpoint. The ASSE 1017 mixing valve provides protection against scalding. Because this assembly is sourced from the small tank, it is always working with the hottest water available in the system.

If you removed the wood-gasification boiler and its related hardware, the balance of the system could be connected to an array of solar thermal collectors. A closed-loop, glycol-based solar subsystem is one possibility, a drainback system with a separate drainback tank is another. From the main storage tank out, the system would remain unchanged.

This system is an example of how basic hydronic hardware and control concepts can be used to provide an efficient, reliable and even "green" solution to space heating and domestic hot water. Use it where it's appropriate.

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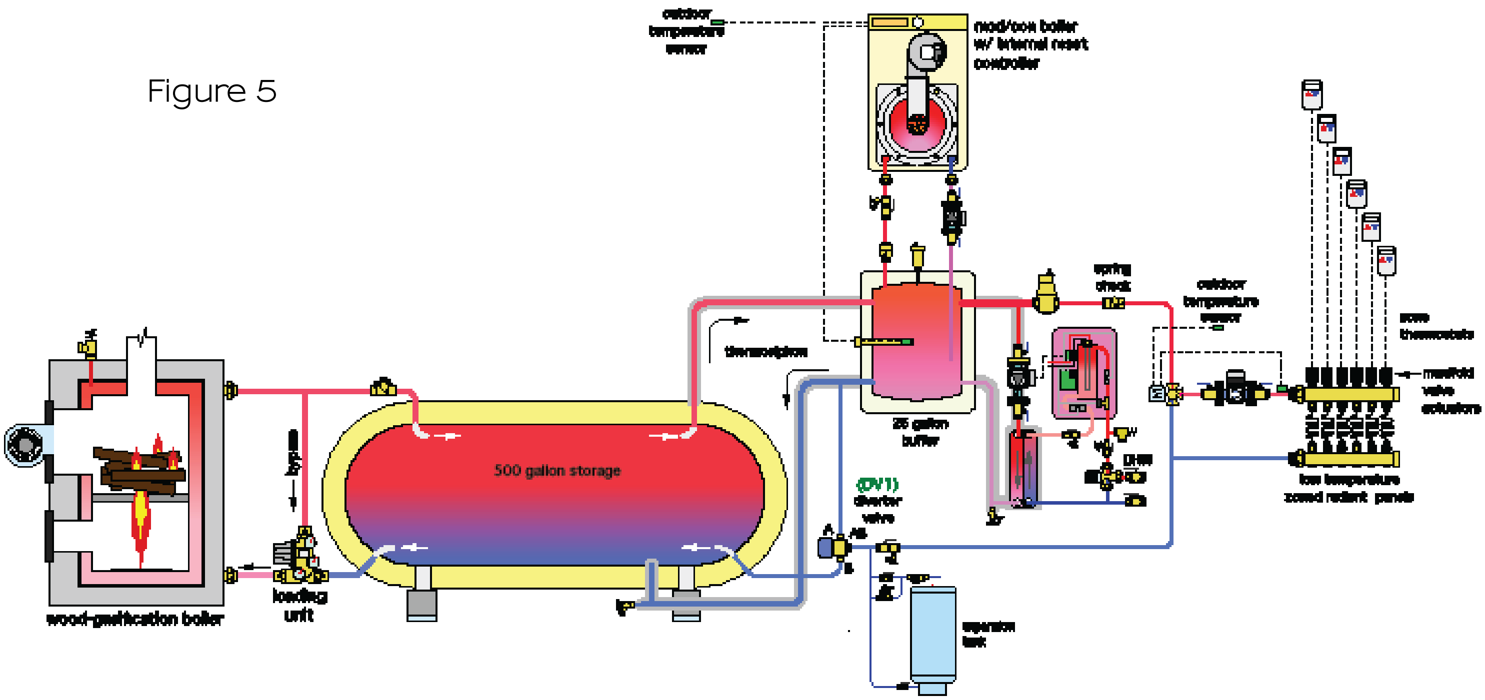

Figure 5