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Biomass heat source (part two)

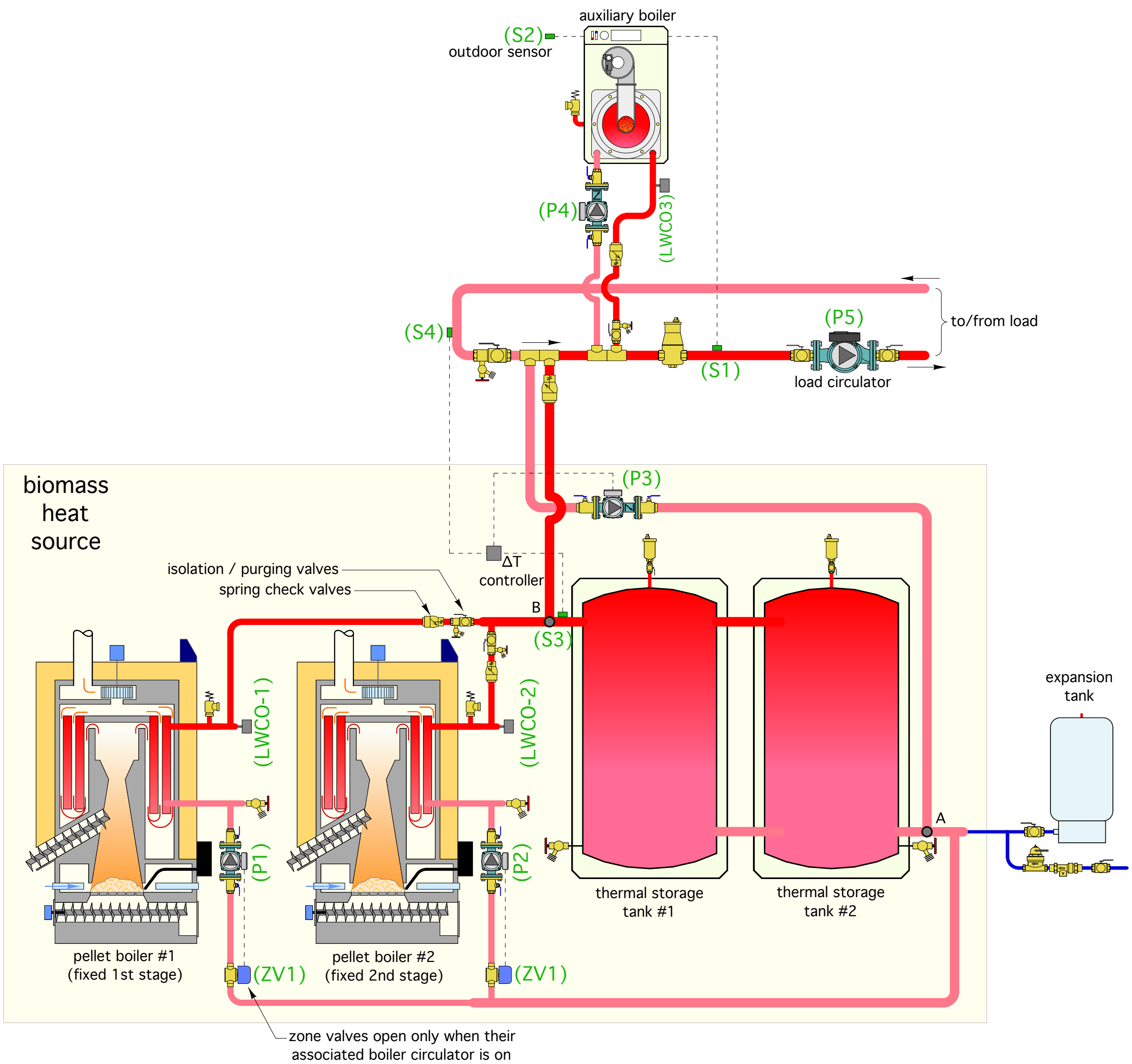
Control concepts for tandem pellet boilers.

Last month's Renewable Heating Design column showed a piping schematic for a system with two pellet boilers and a single auxiliary boiler. A portion of that schematic is shown in Figure 1.

The two pellet boilers are intended to be controlled in stages, similar to how two fossil-fuel boilers would be operated. When the load is light only one pellet boiler needs to operate. As the load increases the second pellet boiler would turn on. Finally, when the load is "pedal to the metal," both pellet boilers and the auxiliary mod/con boiler would be on, all at full output.

At first this seems like a routine control requirement: Treat the two pellet boilers as

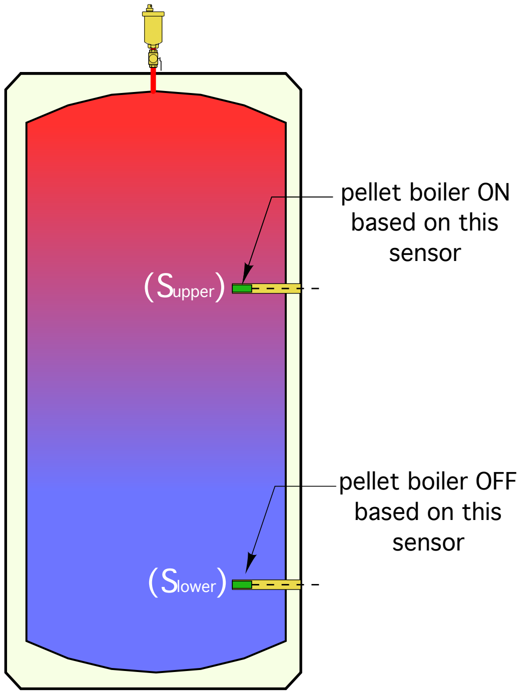
> **Figure 1.**



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.



stages 1 and 2, and the mod/con boiler as stage 3. Rotate the firing order of the two pellet boilers to keep their total run times about the same and only bring on the mod/con boiler when both pellet boilers fail to sustain the necessary supply water temperature to the load.

Not so fast

Although this control task may appear "routine," it's complicated by the fact that, unlike fossil fuel boilers, it's important to keep a pellet boiler running for an extended period once it is turned on. This keeps the majority of the pellet boiler's on-cycle at or near high steady state efficiency. It also reduces particulate emissions. One suggested criteria is to design the system so that the pellet boiler has an average run time of three hours per start.

In most systems involving low thermal mass heat emitters and multiple zones, thermal storage is essential in achieving these long pellet boiler cycles.

It's also necessary to avoid firing the pellett boiler based on calls for heat from zone thermostats. The latter can result in several calls for boiler operation per hour, which is far too frequent to achieve the desired long pellet boiler on-cycles.

Two-sensor control

When a single pellet boiler is used, it can be turned on based on the water temperature in the upper portion of thermal storage. This control action is independent of any calls for heat from zone thermostats. Once fired the pellet boiler continues to operate until the temperature in the lower portion of the thermal storage tank reaches a relatively high temperature.

This "two-sensor" control method allows the upper portion of the thermal storage tank to drop to the lowest temperature that's still useable by the load before turning on the pellet boiler. It then keeps the boiler running until the tank is packed full of heat, as evidenced by a relatively high temperature in the lower portion of the tank. Figure 2 illustrates the concept.

The temperature at which the upper tank sensors calls for the pellet boiler to fire can be based on a fixed setpoint temperature or outdoor reset control. The latter allows the upper tank temperature to drop to its lowest useful value for space heating before calling for the boiler. This is especially helpful in extending the temperature cycling range of the thermal storage tank when the distribution system uses high-temperature heat emitters such as finned-tube baseboard.

Two times two

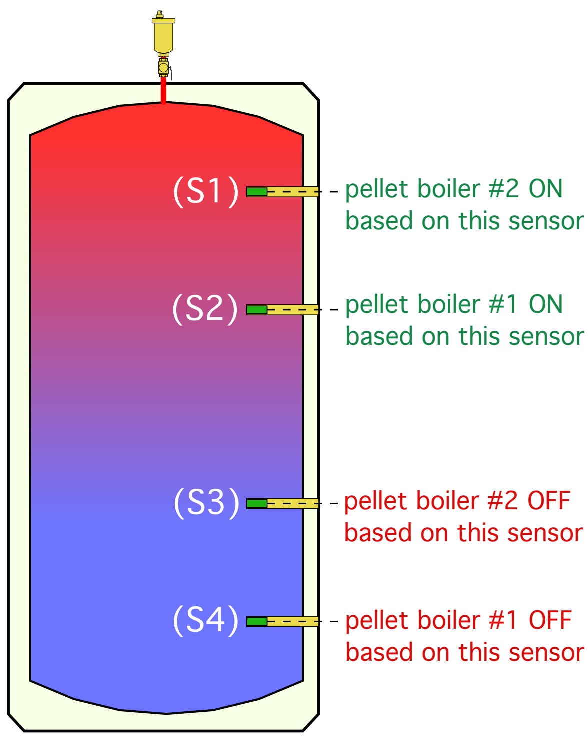
This concept can be extended to two pellet-fired boilers. Two "sets" of temperature sensors are used, one for each boiler as shown in Figure 3.

The upper sensors (S1) and (S2) are for turning the boilers on, while the lower sensors (S3) and (S4) are for turning them off.

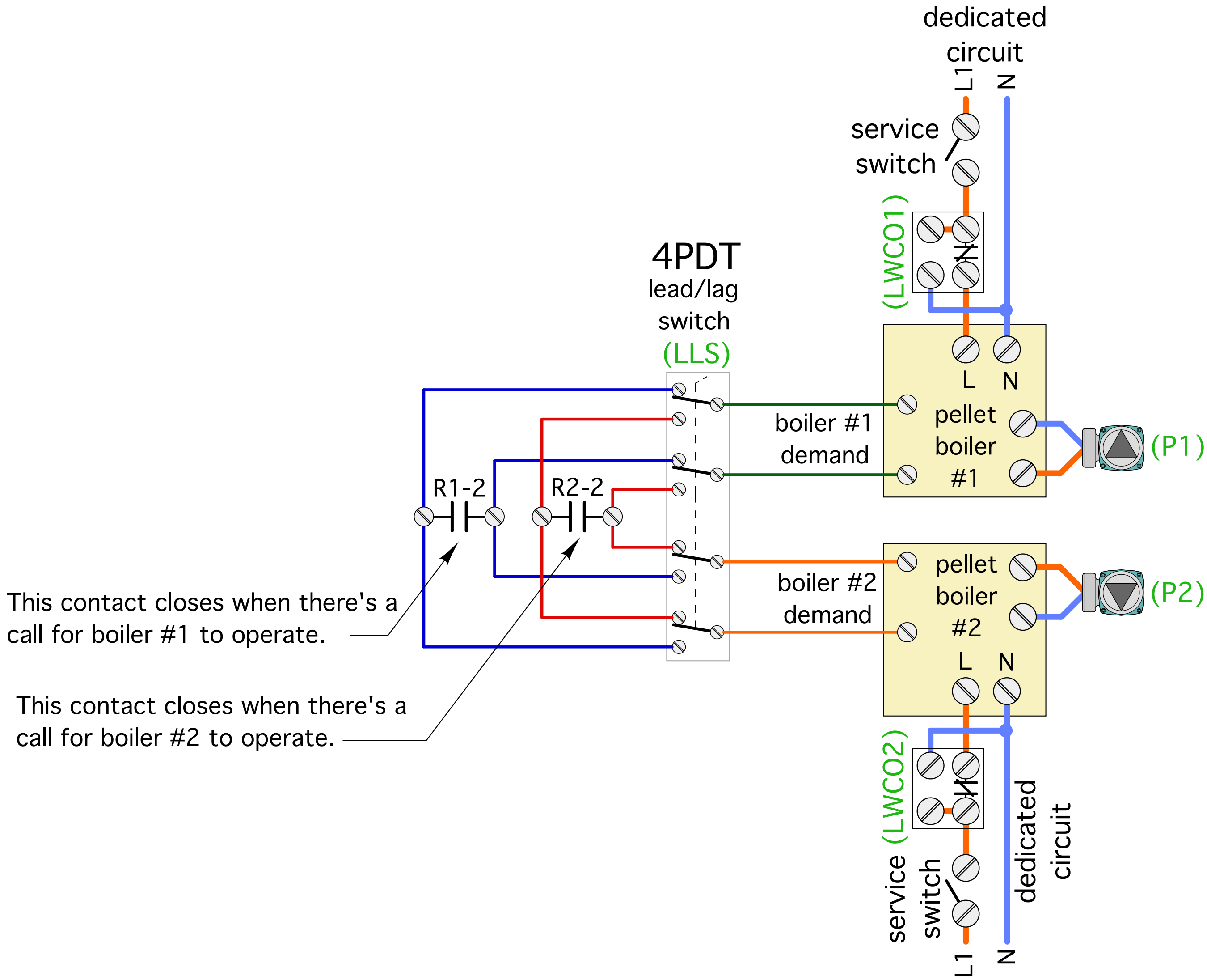
The lead pellet boiler is fired when a minimum preset value (or target temperature based on outdoor reset) is detected at sensor (S2). If the heat generated by the lead boiler is sufficient to meet the load, the temperature at sensor (S1) may not drop to a value where the other (lag) boiler needs to fire. However, if the load is such that the temperature in the upper portion of the tank continues to drop, a minimum value eventually will be detected at sensor (S1), which will fire the lag pellet boiler.

With both pellet boilers firing, the temperature in the tank may begin to increase (assuming the heat output of both pellet boilers exceeds the

> Figure 3.



> Figure 4.



load). In this case the lag boiler will turn off when some maximum temperature value is detected at sensor (S3). The lead pellet boiler will turn off when a maximum temperature value is detected at sensor (S4).

It's also possible to build time delays between firing the lead and lag pellet boilers. For example, the criteria to fire the lag pellet boiler might be that the temperature at sensor (S1) drops below some value and there has been an elapsed time of at least 20 minutes since the lead pellet boiler was fired. These time delays compensate for the 10-20 minutes it takes to bring a "cold" pellet boiler online.

If the two pellet boilers are identical, their firing order (e.g., lead vs. lag) should be periodically switched. The objective is to provide about the same total run hours on each boiler. This can be done automatically or manually. When a building automation system is used, the boiler "rotation" typically will be programmed to occur automatically. In a smaller system without BAS controls the rotation can be done using a four-pole double-throw (4PDT) switch. The setting of this switch could be altered once or twice per heating season based on the hours of operation recorded by each boiler's internal controller. Figure 4 shows the switching circuitry.

The auxiliary boiler shown in Figure 1 would fire when there's a demand for heating from one or more zones and the temperature at sensor (S1) has dropped slightly below a target value based on outdoor reset control. For example, if the heat emitters in the distribution system required a supply water temperature of 110° F when the corresponding outdoor temperature was 20°, and a zone load was active, the auxiliary boiler might turn on when the temperature at sensor (S1) dropped to 106° and remain on until the temperature at sensor (S1) reached 114°. The outdoor reset function that's typically provided by the internal controllers in most mod/con boilers can handle this function without need of external controllers.

It's also important to:

1. Not allow heat generated by the auxiliary boiler from being inadvertently routed into thermal storage.

2. Prevent flow between thermal storage and the distribution system when the temperature in thermal storage is too low to contribute heat to the load.

Both of these control criteria can be met using a simple differential temperature controller (or its equivalent programming in a building automation system). The DTC would compare the temperature on the return side of the distribution system (S4 in Figure 1) to that at the upper tank header (S3 in Figure 1).

A suggested control criteria based on these sensor temperatures is:

IF load is active, AND (S3) ≥ (S4) + 5° F THEN allow circulator (P3) to run.

IF load is active, AND (S3) ≤ (S4) + 3° F THEN do not allow (P3) to run.

Another detail worth discussing is the two zone valves (ZV1) and (ZV2) located on the inlet pipe of each pellet boiler. These valves are wired in parallel with the boiler circulators (P1) and (P2). They open when their associated circulator is on and close at all other times. Their purpose is to prevent flow through their associated boiler when it is off.

Thermal storage is essential in achieving these long pellet boiler cycles.

Without these valves or equivalent means of blocking flow, the slight pressure difference developed between points A and B on diagonally opposite sides of the thermal storage tank array could be sufficient to overcome the forward-opening pressure differential of the spring-loaded check valves in each boiler circuit. The result would be undesirable flow of heated water through an unfired pellet boiler. This dissipates heat through the boiler jacket and up the chimney(s). The latter is especially wasteful since pellet boilers don't have automatic stack dampers.

These control concepts can be implemented using relatively inexpensive, dedicated controllers for functions such as temperature set point, outdoor reset and differential temperature control. Such controllers are appropriate in smaller system applications. On large systems, the same control concepts can be scaled up and programmed into a building automation system. pme

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