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Be thorough

Proper documentation is critical for a well-functioning solar combisystem.

There's an old saying: "The devil is in the details." This could certainly be applied to almost any HVAC system, including those using hydronics technology.

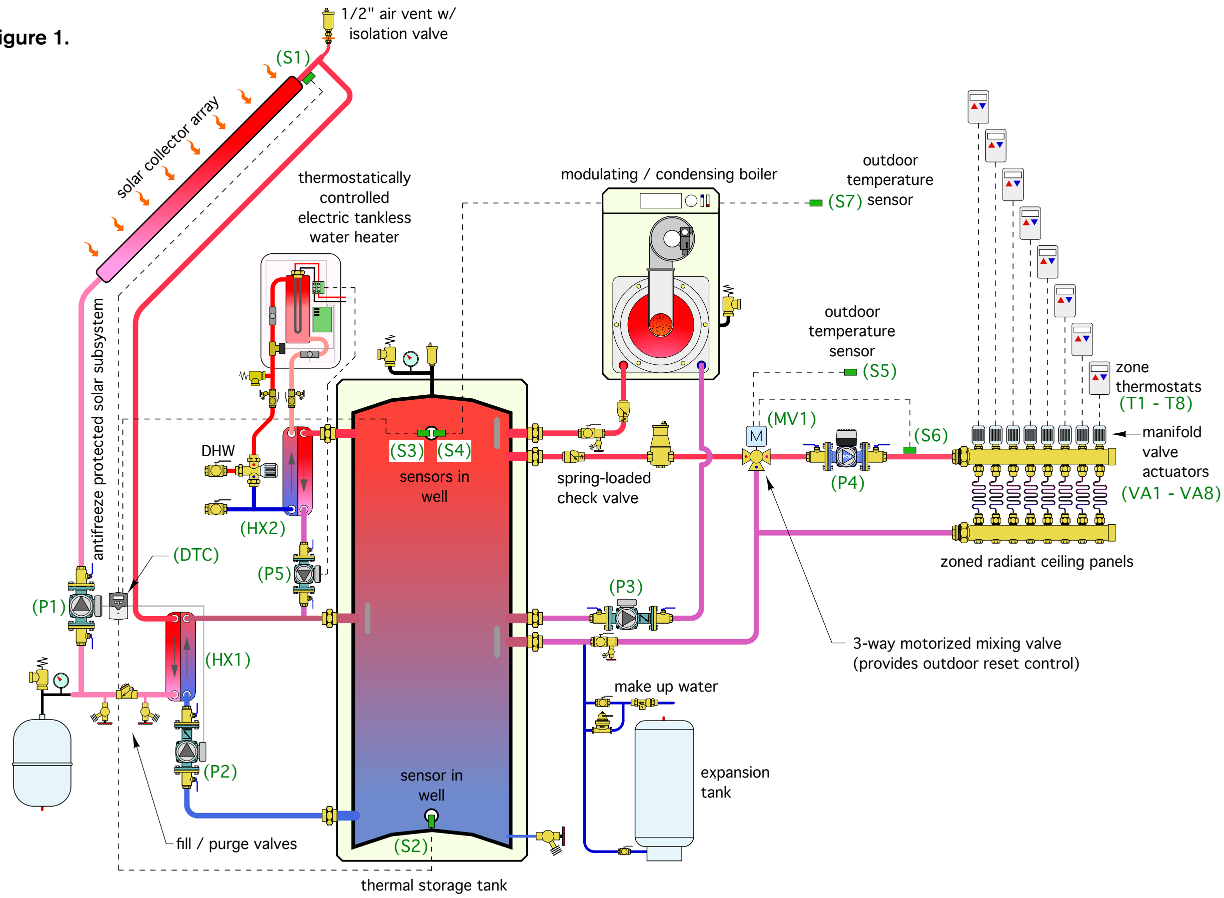
Variation in piping details, controller settings or component placement is common from one system to another. The differences often are based on personal preferences of the designer, the availability or cost of specific hardware and what the default settings of various controllers within the system have been set to by their manufacturer.

The generic concept of a solar thermal combisystem that provides domestic hot water and some amount of space heating is certainly "open to interpretation" when it comes to design detailing, component selection and controller settings. Although there are many possible combinations that likely would lead to successful applications, the pathway to success is definitely shorter and straighter when the design is well-documented.

This month, I want to show you one approach to a solar thermal combisystem that includes plenty of details and a full description of operation. The latter aspect of documentation is critically important to proper setup and maintenance over the system's life. It sequentially describes what the installer or service tech should be witnessing as the system operates in each of its various modes.

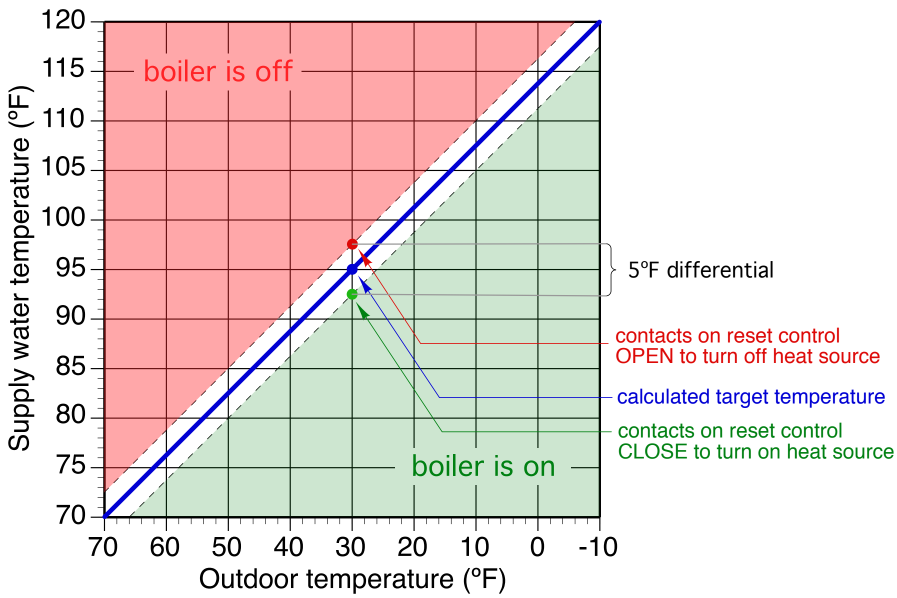
The system shown in Figure 1 is a solar combisystem that provides domestic hot water and some amount of space heating for the building it serves. It uses a propylene glycol-based antifreeze fluid within the collector circuit to protect against freezing. It also

> Figure 1.



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

> Figure 2.



uses a thermal storage tank with multiple connections that allows for proper stratification and leveraging of thermal mass to buffer both the space heating and domestic water heating loads.

Storage wars

The storage tank shown in Figure 1 is very well-insulated and has multiple connections at various heights. These connections help encourage and preserve temperature stratification within the tank. This tank also has no internal heat exchanger coils. To my knowledge, this specific tank is not a currently marketed product in the United States, although some commercially available tanks come quite close. For more details, see: "If I Made the Tanks," in the spring 2013 Solar Thermal Report, at http://digital.bnpmedia.com/publication/?i=156033.

Domestic water is partially (and sometimes fully) heated by solar heat input to the storage tank. When solar heat input is lacking, supplemental heat input is provided by a mod/con boiler. An electric tankless water heater provides the final "top off" to domestic hot water delivery temperature when necessary.

Whenever there is a demand for domestic hot water of 0.6 gpm or higher, the flow switch inside the tankless electric water heater closes. This closure is used, in combination with a relay, to turn on the circulator that routes water from the upper portion of the storage tank through the primary side of the heat exchanger.

The electric tankless water heater is thermostatically controlled. When flow through it reaches 0.6 gpm or higher, the unit measures the incoming water temperature, compares it to the outgoing water temperature and quickly calculates the necessary electrical power that must be supplied to the heating elements to keep the outgoing water temperature within 1° F of the setpoint. Thus, if solar preheated water is delivered to this heater at 115° and its setpoint temperature is 120°, the power supplied to the element will only be that required for the 5° temperature boost. If the water entering the tankless heater is already at or above the setpoint temperature, the elements are not turned on. All heated water leaving the tankless heater flows into an ASSE 1017-rated mixing valve to ensure a safe delivery temperature to the fixtures.

Because of the way domestic water is heated, the thermal storage tank in this system does not have to be maintained at a temperature suitable to provide the full temperature rise of the domestic hot water.

Instead, during periods of little or no solar energy input, the tank temperature can be maintained by the mod/con boiler based on outdoor reset control. If space heating is provided by low-temperature radiant panels, the maximum water temperature at the top of this tank may only have to be 120°. On partial load days, the boiler's internal outdoor reset controller allows for even lower tank temperatures, perhaps in the range of 90° to 95°. The lower the tank temperature is the better the chances of solar heat contribution from the collectors.

Figure 2 shows how the outdoor reset control within the boiler could be configured for this system. This reset curve assumes the heating distribution system can supply design heating load when supplied with 120° water and the corresponding outdoor design temperature is -10°.

Wired up

The thermal mass of the heated water in the upper portion of the thermal storage tank provides excellent buffering for the highly zoned heating distribution system. This desirable trait greatly reduces the chance of boiler short-cycling.

This design allows the boiler to be completely turned off during times of the year where space heating is not required. If solar input is low, the tankless water heater provides the needed boost to ensure consistent domestic hot water delivery temperature. It's long-term economic viability depends on the unit cost of electricity vs. the natural gas or propane used by the boiler. In most cases, natural gas will be less expensive, and thus it is used to supply the larger space-heating load.

The use of electricity is limited to "topping off" the temperature of domestic water that always will be partially preheated by the energy from the thermal storage tank. A complete economic analysis also should factor in the monthly service charge associated with a natural gas meter (assuming that space heating and domestic water heating is the reason the gas service would be provided). On energy-conserving homes, this monthly service charge could rival the average month usage charge.

> Figure 3.

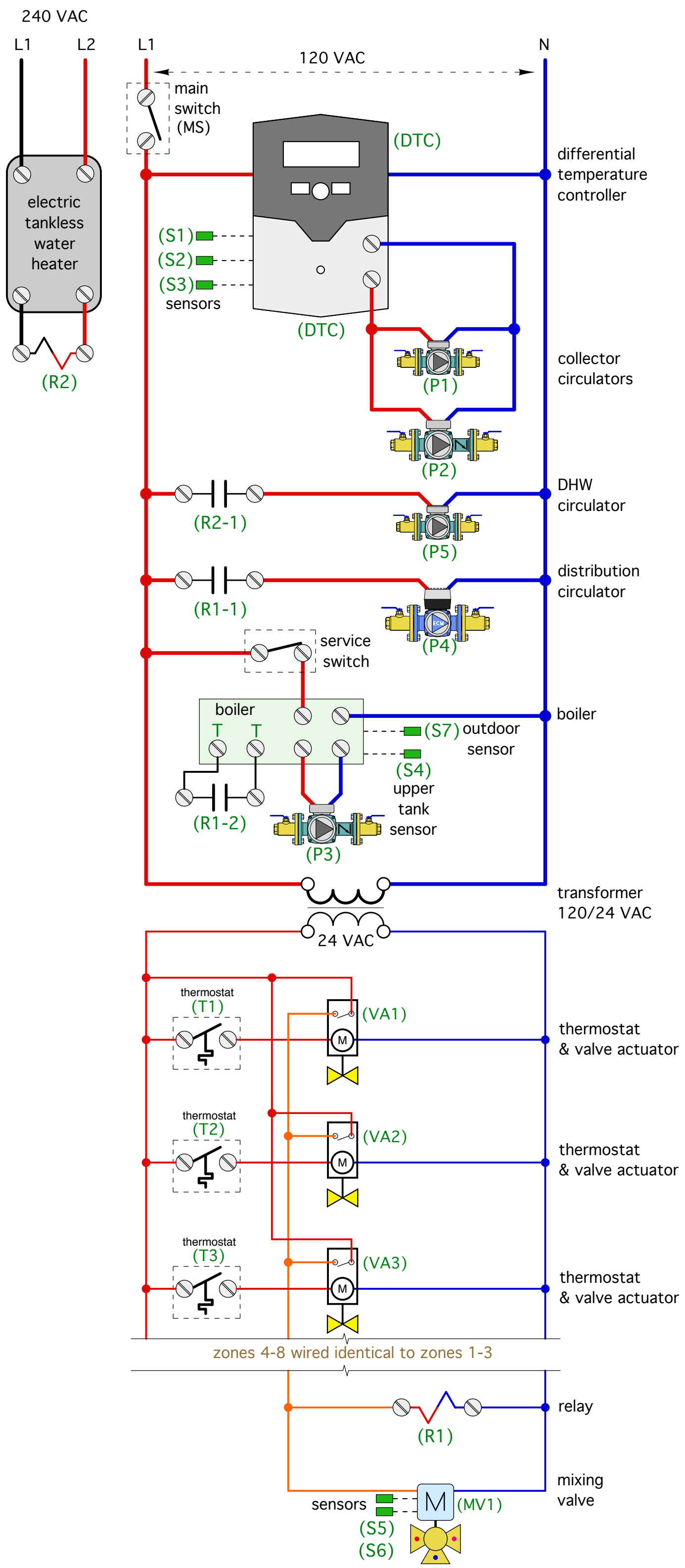


Figure 3 shows the electrical wiring for this system in the form of a ladder diagram.

Ladder diagrams are great for both design and documentation of "custom" control systems. The line voltage components are shown in the upper part of the ladder. The lower voltage (24 VAC) is shown in the lower portion below the transformer. When drawn with a CAD system, these diagrams are easily expanded to include additional control hardware if and when necessary. Note that only three of the eight independent heating zones are shown in Figure 3. All eight zones would have identical wiring.

The following is a description of operation of the system. Each mode of operation is separately described. Each description is sequential. It narrates what happens when based on the presence of various demands on the system. There is frequent reference to component designations such as (P2) or (DTC). These designations also allow easy cross-referencing between the piping and wiring diagrams.

1. Solar energy collection mode: Whenever the main switch is closed, line voltage is applied to the differential temperature controller. This controller continuously monitors the temperature of the collector sensor (S1) and the lower sensor in the thermal storage tank (S2). Whenever the temperature of the collector is 10° or more above the temperature of the lower storage temperature, the DTC turns on circulators P1 and P2. Whenever the temperature of S1 is 5° or less above the temperature of S2, the DTC turns off circulators P1 and P2. The DTC also monitors sensor S3 in the upper portion of the thermal storage tank. If the sensor reaches 180°, the DTC initiates a nocturnal cooling mode in which it operates circulators P1 and P2 to release heat through the collector array until the tank temperature drops to 160°.

2. Domestic water heating mode: Whenever there is a demand for domestic hot water of 0.6 gpm or higher, the flow switch inside the tankless electric water heater closes. This closure applies 240 VAC to the coil of relay (R2). The normally open contacts (R2-1) close to turn on circulator P5, which circulates heated water from the upper portion of the storage tank through the primary side of the domestic water heat exchanger (HX2).

The domestic water leaving HX2 is either preheated or fully heated depending on the temperature in the upper portion of the storage tank. This water passes into the thermostatically controlled tankless water heater, which measures its inlet temperature. The electronics within this heater control electrical current flow to the heat elements based on the necessary temperature rise (if any) to achieve the set domestic hot water supply temperature.

If the water entering the tankless heater is already at or above the setpoint temperature, the elements are not turned on. All heated water leaving the tankless heater flows into an ASSE1017-rated mixing valve to ensure a safe delivery temperature to the fixtures. Whenever demand for domestic hot water drops below 0.6 gpm, circulator P5 and the tankless electric water heater are turned off.

3. Space-heating mode: The distribution system has several zones — each equipped with a 24 VAC thermostat (T1, T2, T3, etc.). Upon a demand for heat from one or more of these thermostats, the associated 24 VAC manifold valve actuators (VA1, VA2, VA3, etc.) are powered on. When a valve actuator is fully open, its end switch

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the boiler room

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When testing the low-water cutoff on a steam boiler, I prefer to simulate actual jobsite conditions during the test. I will slowly drain the water from the boiler and note the level where the burner shuts off. If the control is a duplex one that also operates the feed water valve or pump, I will verify the proper water elevations at which the pump starts or stops.

Use caution when draining the low-water cutoff as "condensate-induced water hammer" could occur, which is very dangerous. Condensate-induced water hammer happens when steam is surrounded and quickly condensed by cool water.

Many boiler inspectors require that the low-water cutoff be disassembled for inspection yearly. Some manufacturers even recommend the replacement of the control every five years.

Testing hydronic system low-water cutoffs is a bit more tricky as the system is filled with water and a low-water condition may not be able to be simulated. Some of the low-water cutoffs for hydronic systems have a test button.

Who is at fault?

In some instances, the person who worked on the boiler prior to the accident could be held criminally responsible for the accident. For example, an installer in the United Kingdon who improperly installed a boiler that subsequently caused the death of a famous model was found guilty of manslaughter. His crime was that he did not install the screws in the flue pipe to secure the pipe in place and the flue came apart.

In Canada, the federal government pleaded guilty in the death of a worker who was killed in a boiler room. It will not be long before technicians in the United States could face criminal charges for their work.

According to **John F. Porcella**, chief boiler inspector of West Virginia, and other boiler inspectors, flammable items are often stored inside a boiler room and this is problematic. It is not uncommon to find lawn mowers, paper towels, cleaning solvents, dust mops, snow blowers and cans of gasoline stored inside the boiler room.

A school in our area stored student records in cardboard boxes next to the boilers and school officials were surprised when the records caught on fire.

Another danger inside a boiler room is when the combustion air openings are blocked or restricted.

Boiler inspectors can provide a wealth of information for safer operation inside boiler rooms. In most instances, all you have to do is ask. These professionals have been thoroughly trained and have seen many boiler rooms. It is a good idea to have someone with that type of experience as an ally. **pme**

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closes. This supplies 24 VAC to the coil of relay (R1). This closes the normally open contacts (R1-1), which supplied 120 VAC to circulator P4. P4 operates in constant differential pressure mode to supply the flow required by the distribution system based on how many zones are calling for heat. A call for heat also supplies 24 VAC to the integral controller operating mixing valve (MV1). The valve's controller measures outdoor temperature from sensor S5. It uses this temperature, in combination with its settings, to calculate the target supply water temperature to the distribution system. It then adjusts the valve's internal porting to steer the temperature detected by sensor S6 toward the calculated target temperature. When all thermostats are satisfied, power is removed from MV1 and circulator P4. A spring-loaded check valve near the storage tank prevents heat migration from the thermal storage tank into the space-heating distribution system.

4. Auxiliary boiler: The boiler continuously monitors the outdoor temperature detected by sensor S7. The boiler's internal reset control logic uses this temperature and its settings to calculate the target temperature required by the distribution system. It then compares the temperature in the upper portion of the thermal storage tank as detected by sensor S4 with the calculated target temperature. When necessary, the boiler turns on itself and circulator P3 to maintain the temperature in the upper portion of the thermal storage tank close to the calculated target temperature.

There you have it; a fully functional solar combisystem that, with the possible exception of the thermal storage tank, uses readily available hydronic components.

Be sure that any combisystems you create have good documentation. It's essential to a long, serviceable life, and that is critical to continued growth of solar thermal technology. **pme**

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