Control concepts for cordwood gasification and pellet boiler systems

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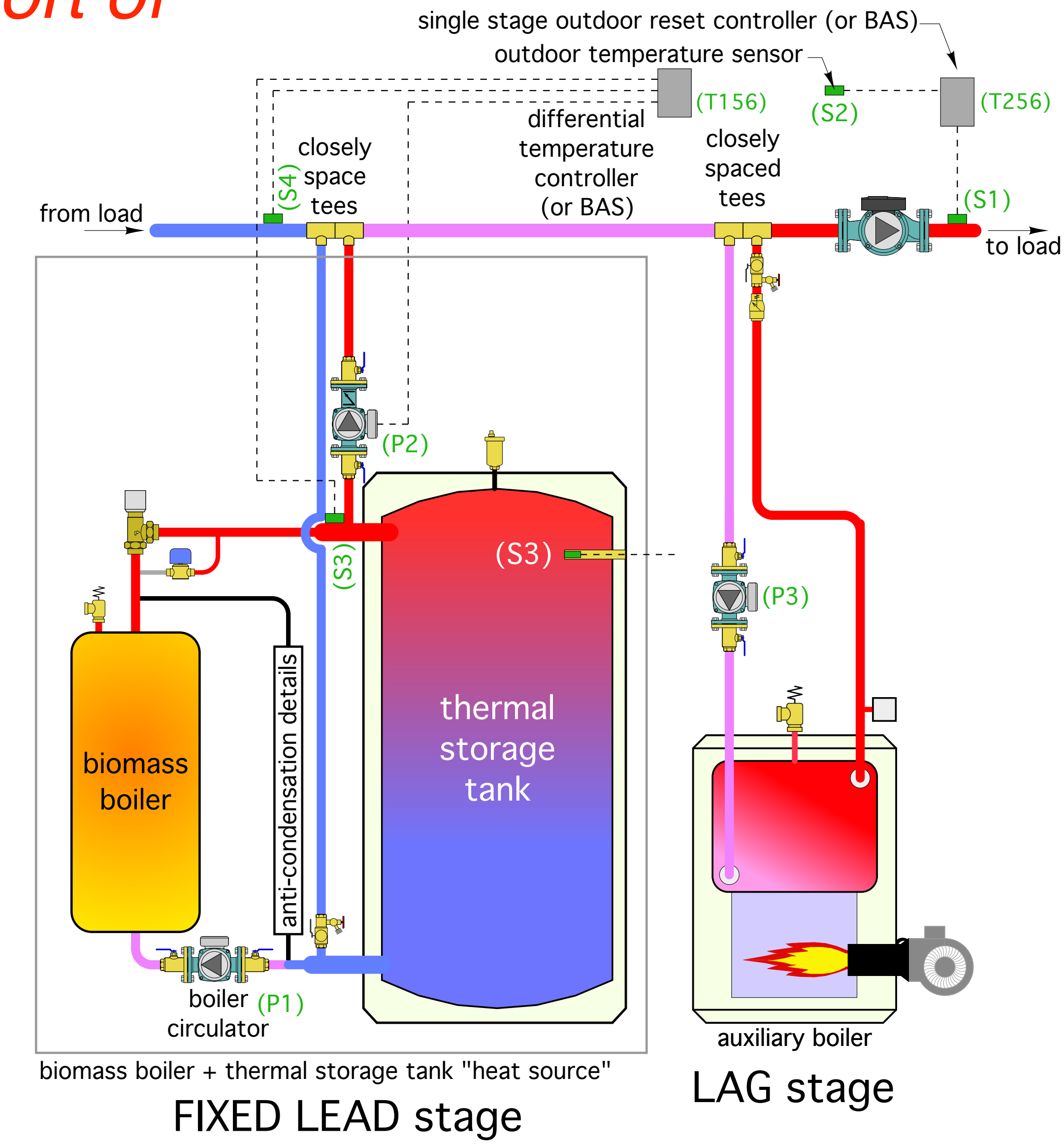

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New York State Energy Research & Development Authority (provider #I034)

Control concepts for cordwood gasification and pellet boiler systems

RHNYWEB12018

Feb 20, 2018

Control concepts for cordwood gasification and pellet boiler systems

Description: This webinar discusses several control strategies associated with cordwood gasification and pellet boiler systems. Topics include boiler firing based on thermal storage tank conditions, staging of biomass and auxiliary boilers, preventing unintentional energy flows in system, and proper sensor installation.

Learning Objectives:

1. Understand the desired "long on-cycle" operating conditions of biomass boilers

2. Learn how pellet boilers can be fired based on thermal storage tank temperatures

3. See how to combine a differential temperature control with an outdoor reset controller to intelligently manage heat flow to a load

4. Review a system example combining a cordwood gasification boiler with an auxiliary boiler

5. Learn the importance of proper sensor placement

Cordwood gasification boilers

- 2-stage combustion
- Thermal efficiency 80-85% (@high load,steady state)
- Very little ash or “clinker” residue
- Available for inside or outside placement

image courtesy of Econoburn

For highest efficiency...

- **Burn Hot & Burn fast**

Heat output often exceeds heating load

Storage is needed

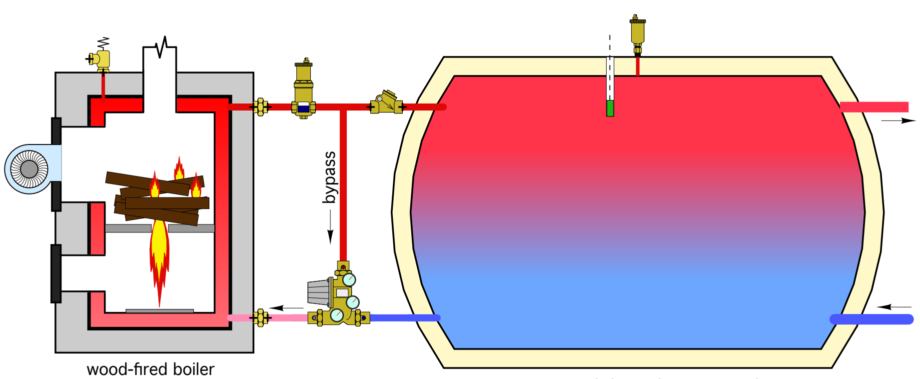


image courtesy of New Horizon Corp.

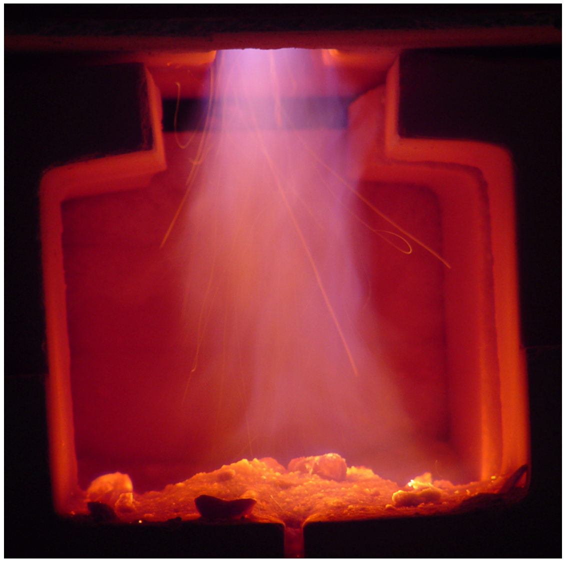
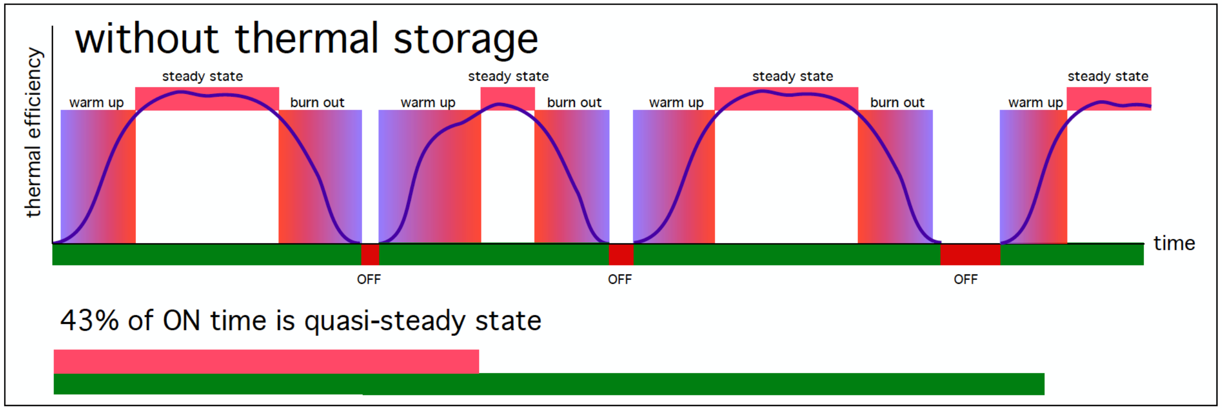
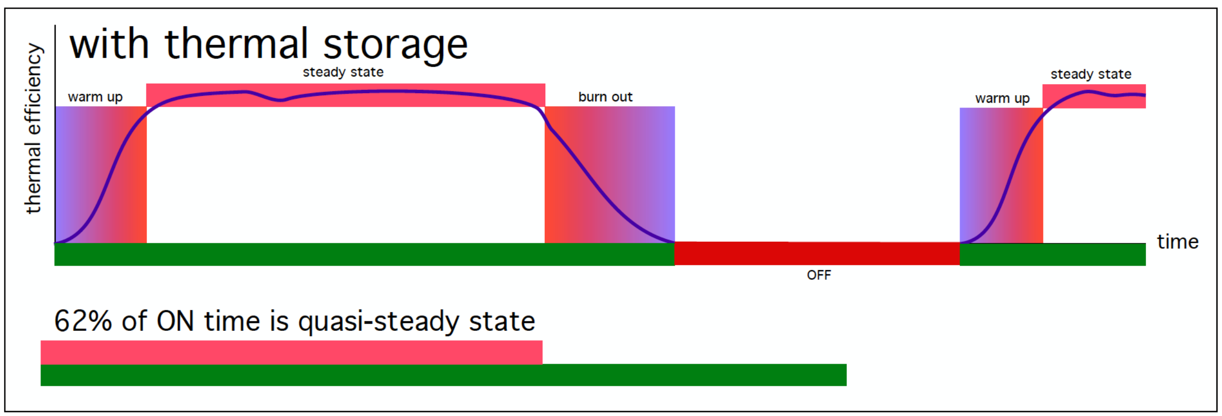
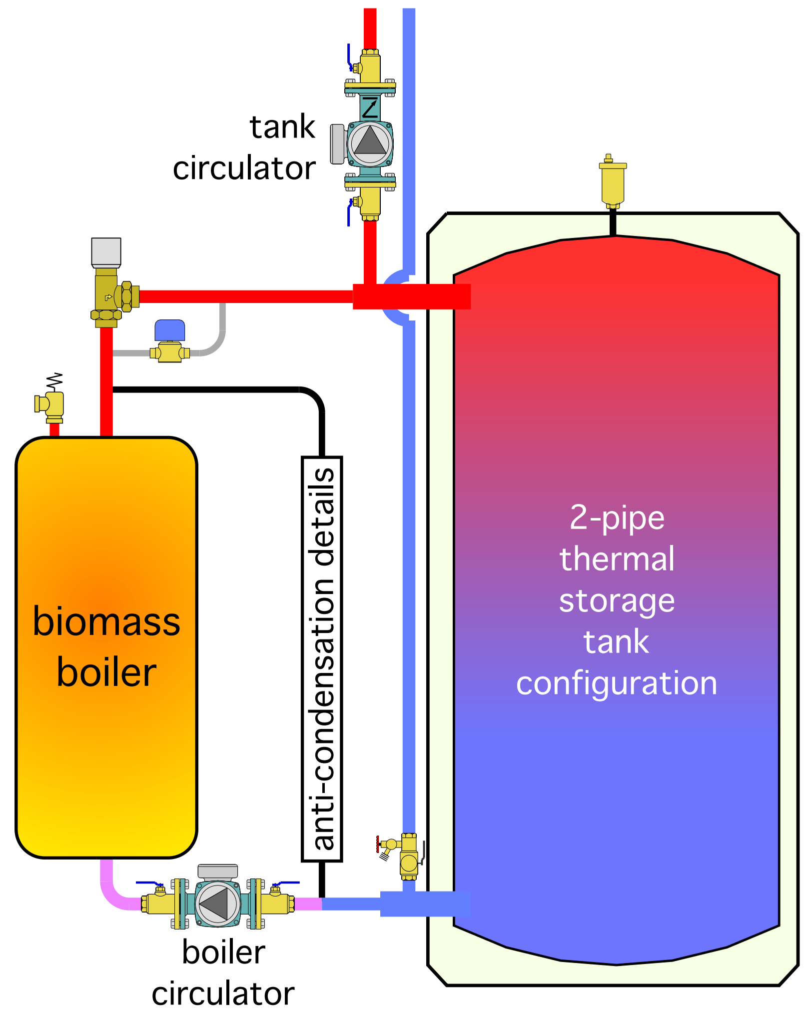


image courtesy of Tarm Biomass

To achieve **high thermal efficiency** and **low emissions**, pellet boilers should operate with long on-cycles, followed by long off-cycles.
(suggest 3 hr run time per start)

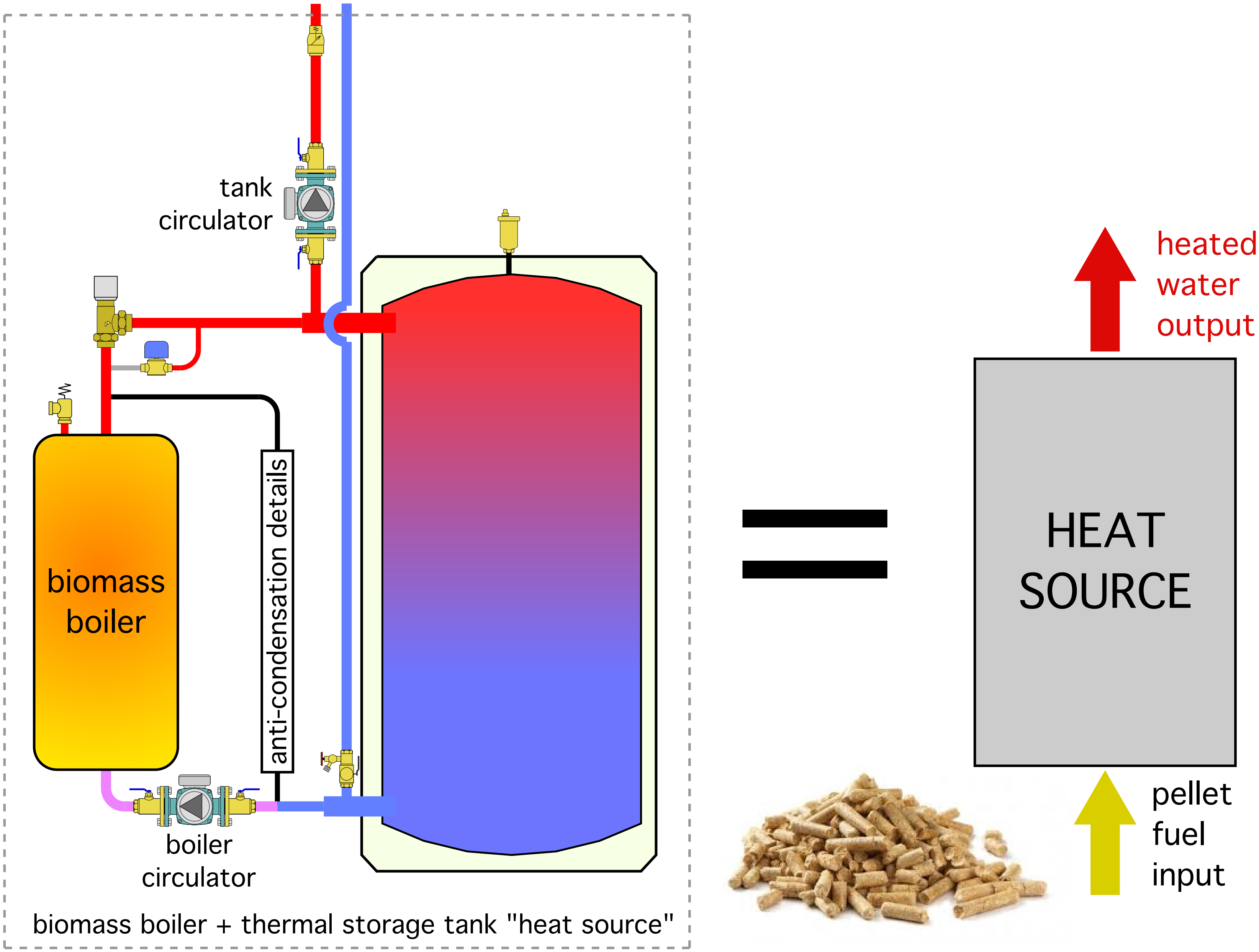






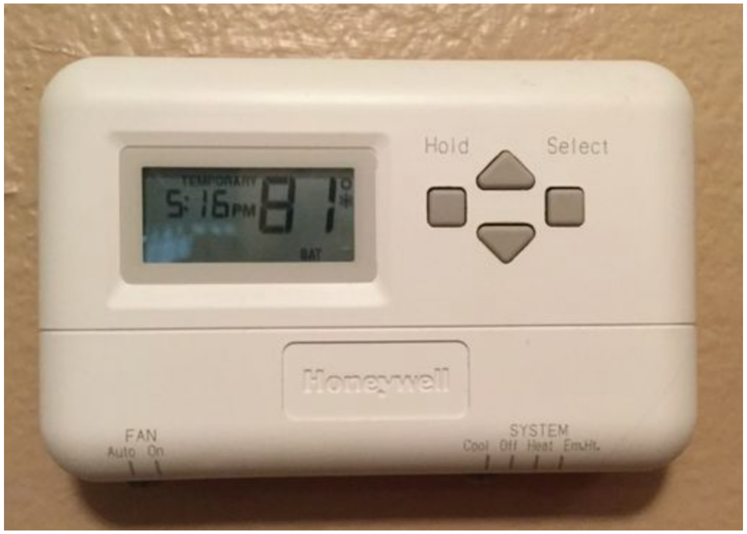
In most applications, pellet boilers require substantial thermal storage *(typically 2 gallons / 1000 Btu/hr boiler output)* to achieve these long operating cycles.

Think of the pellet boiler, combined with thermal storage as a “heat source” device



Pellet boiler operation based on storage tank temperature

A typical pellet boiler is turned on and off based on temperatures in thermal storage. **(It operates independently of "calls" for heat from zone thermostats)**



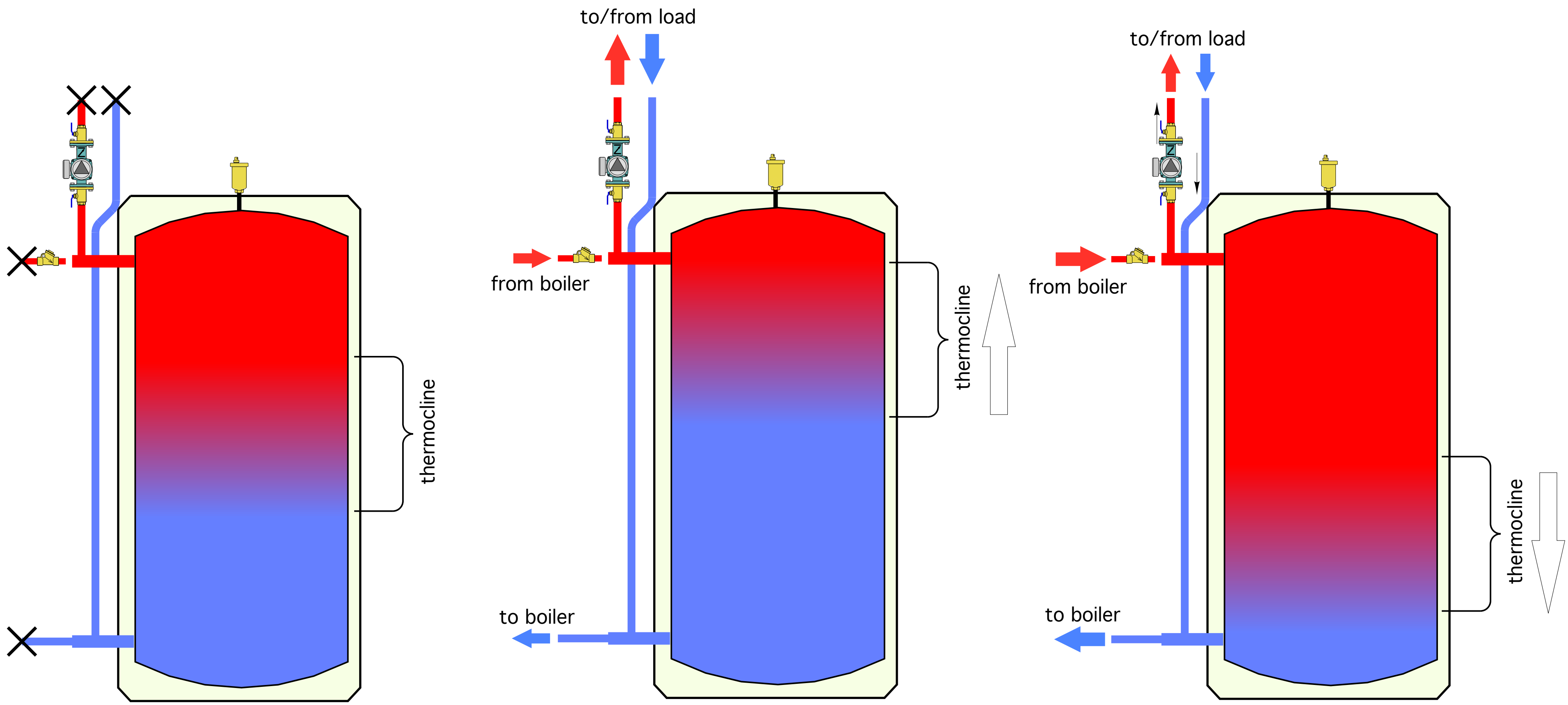
This does NOT turn the pellet boiler on and off.

The is very different from a conventional boiler that is typically fired only when there is a call for heating from a thermostat, or other load sensing device.

A different boiler on/off control concept is necessary to achieve long firing cycles.

Thermocline movement in tank

Indicates relative energy flow between boiler and load.

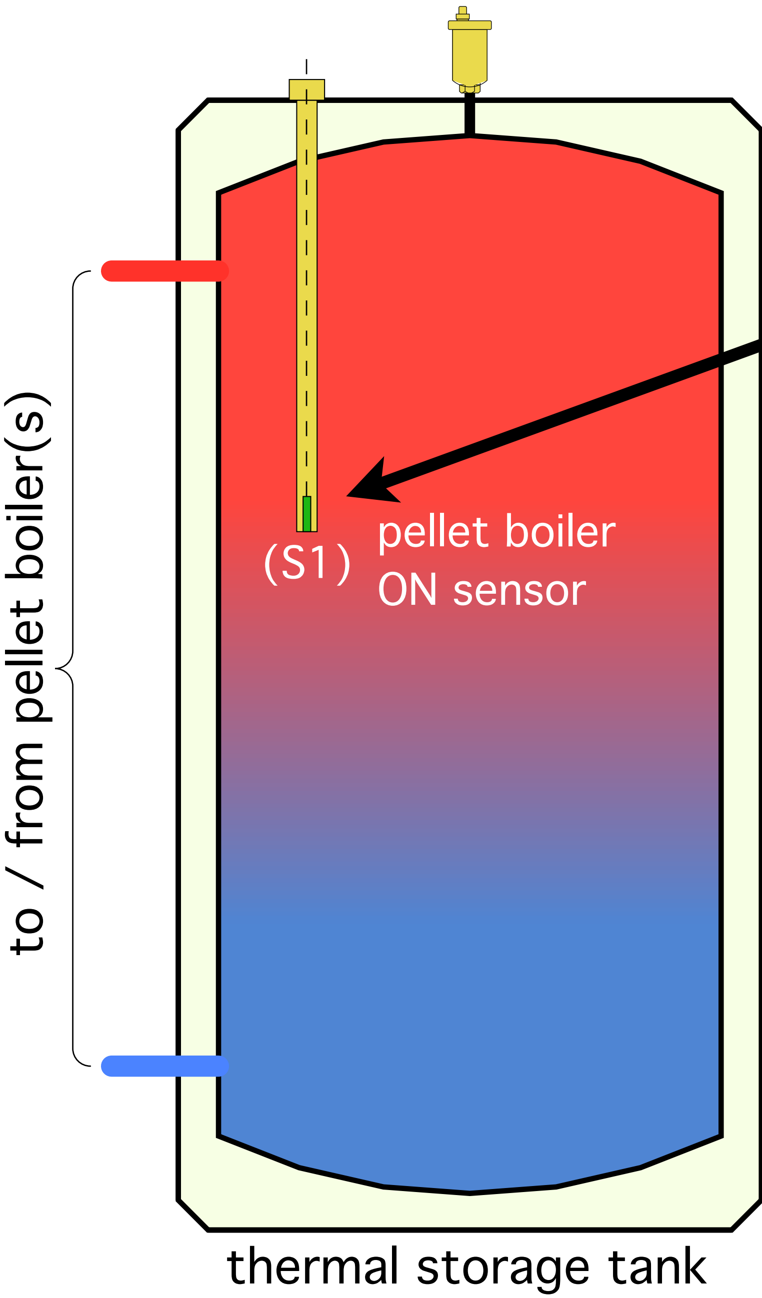


tank at rest. No flow from boiler or to load

load extracting heat at rate > rate of heat output from boiler.
Thermocline moves up

load extracting heat at rate < rate of heat output from boiler.
Thermocline moves down

The pellet fired boiler should be turned on ***before*** the hot water is depleted from top of tank.

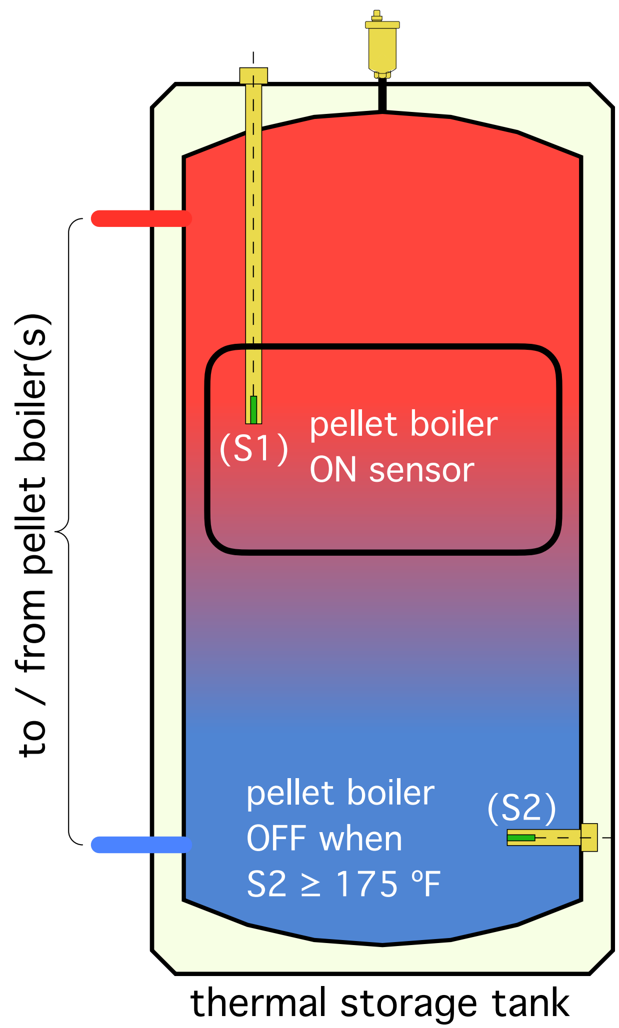


Sensor in vertical well detects "arrival" of rising cooler water. Turns on pellet fired boiler.

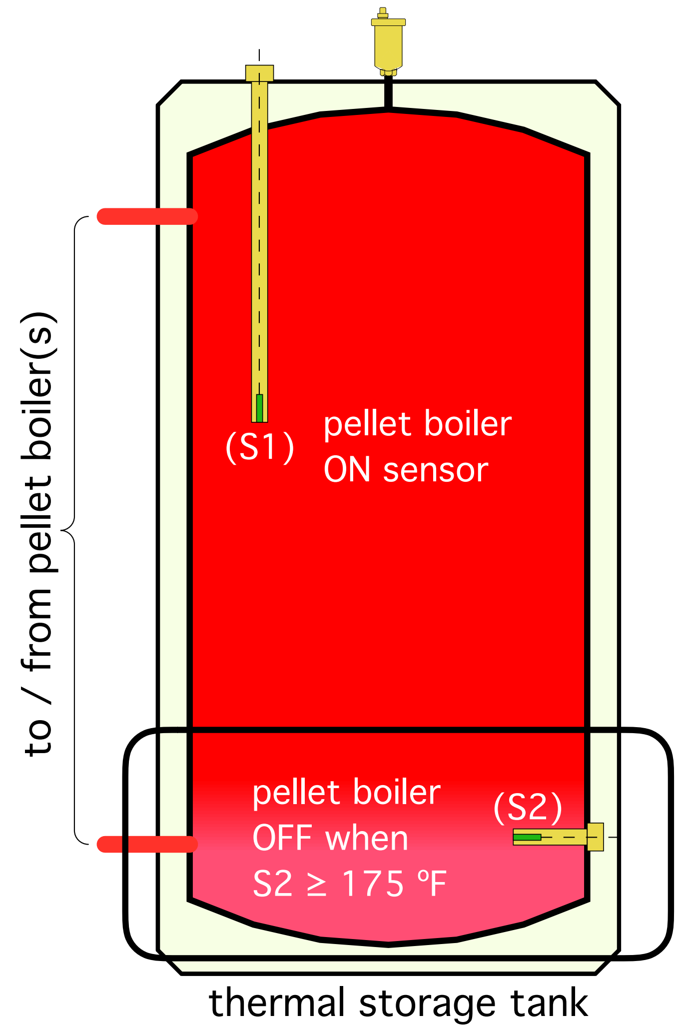
pellet boiler ON when
upper sensor temperature
≤ minimum setpoint

Temperature stacking

To lengthen pellet boiler on-cycle, keep it operating until a sensor in lower portion of tank reaches some higher preset temperature.



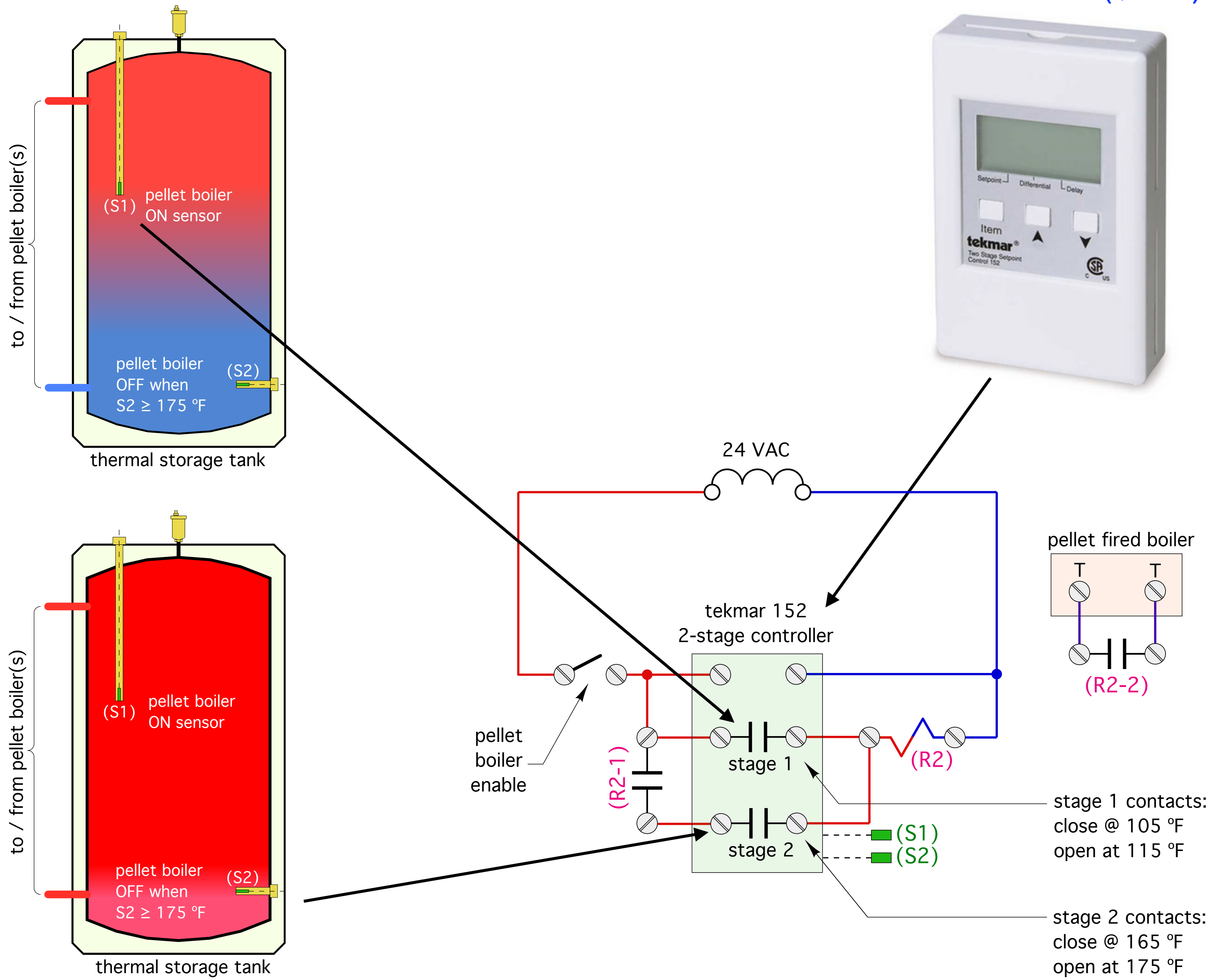
pellet boiler
“start”condition



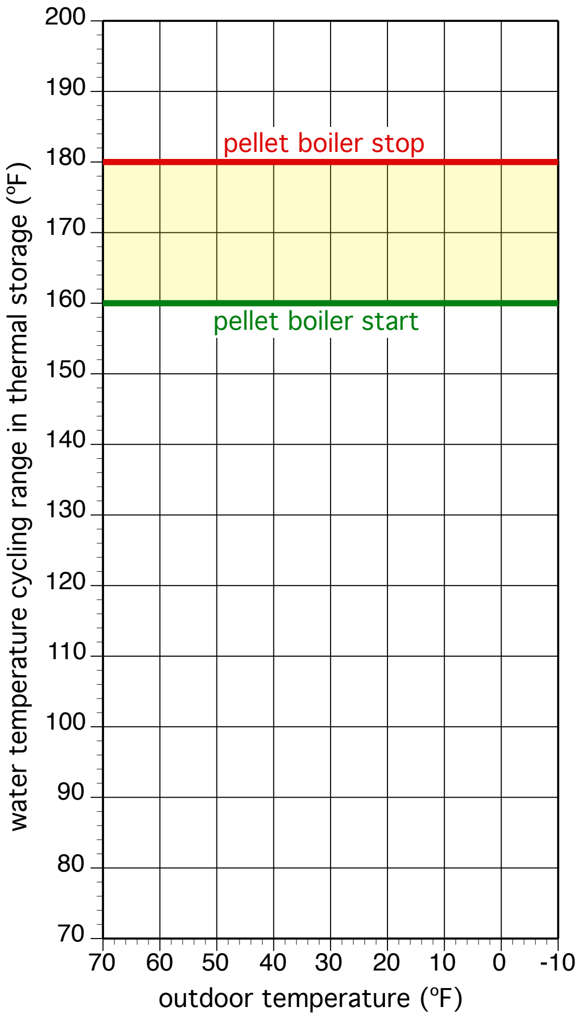
pellet boiler
“stop”condition

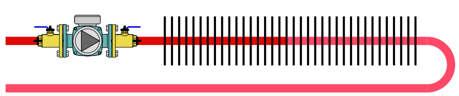
Temperature stacking *(using 2 setpoint temperatures)*

tekmar 152: ($217)



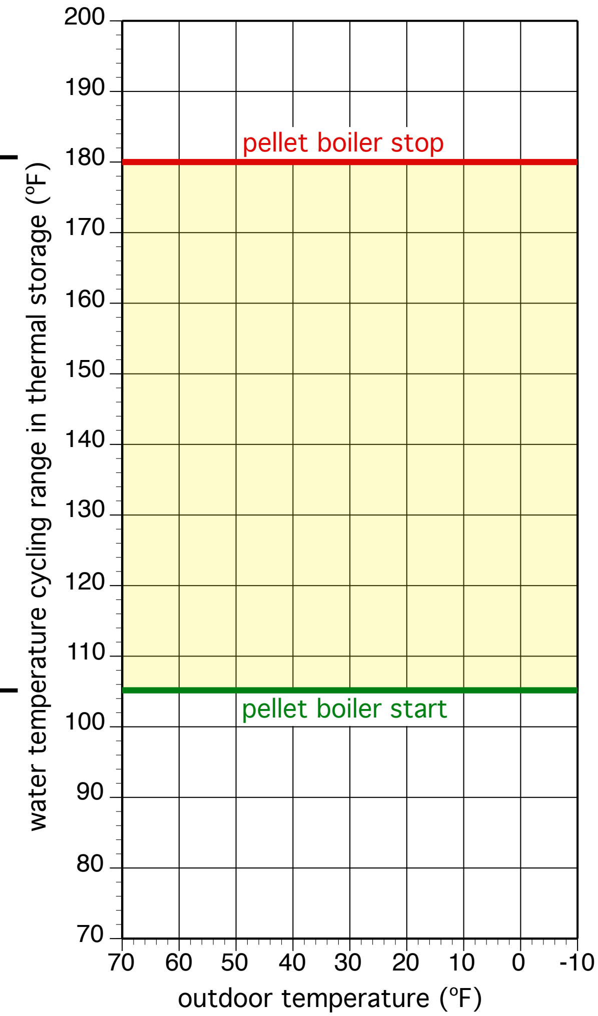
Temperature cycling range of storage is high dependent on the type of heat emitters used.

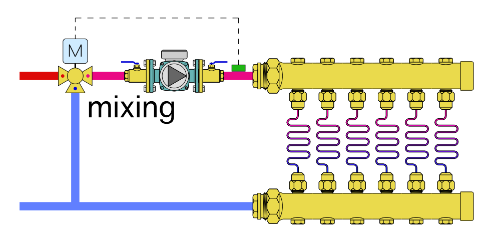




- HIGH temperature heat emitters
- No outdoor reset control of supply water temperature

Low temperature heat emitters allows for wider tank “draw down.”

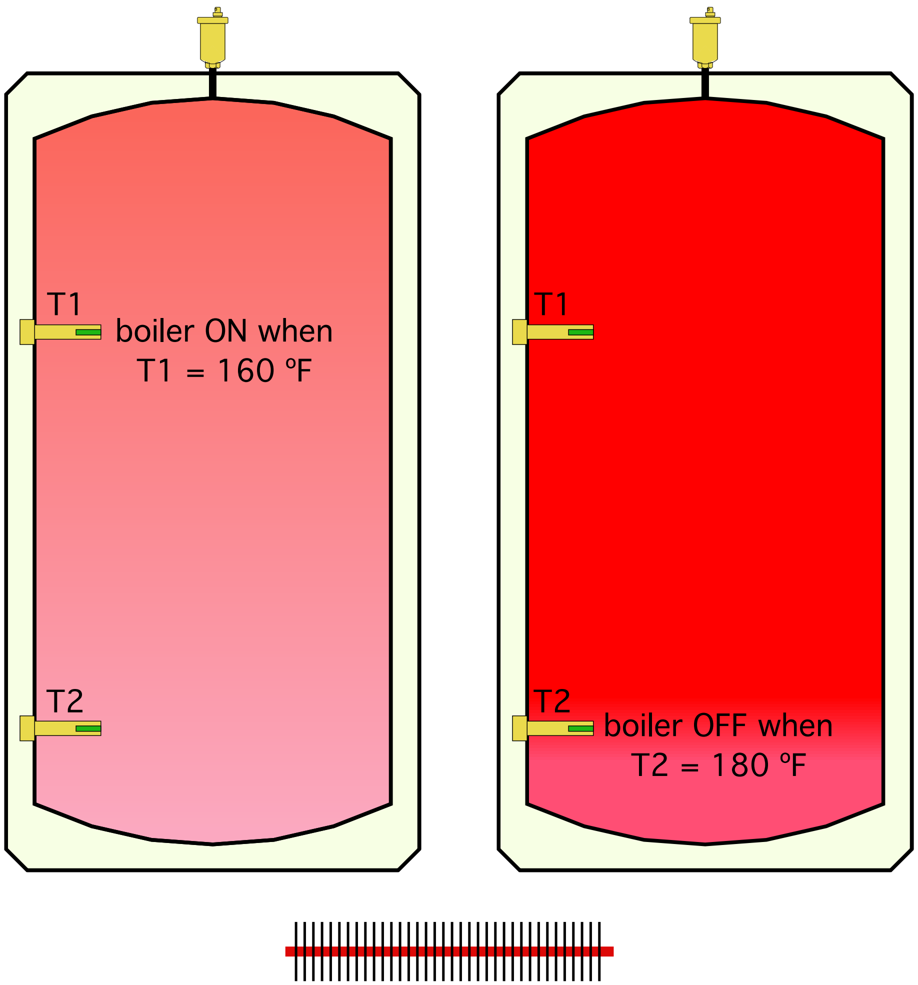




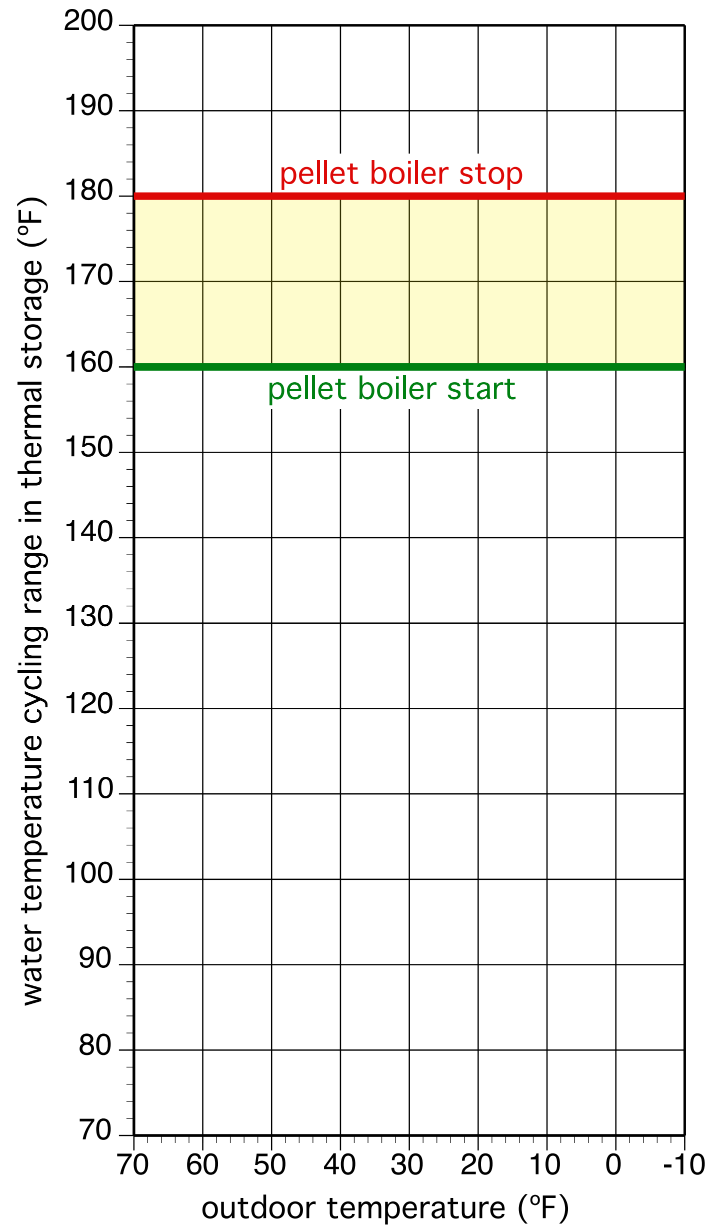
- LOW temperature heat emitters
- No outdoor reset control of supply water temperature

• **High temperature heat emitters**

• Temperature stacking (w/ upper & lower tank temp. sensors)
[*setpoint* control of both upper and lower temperatures]



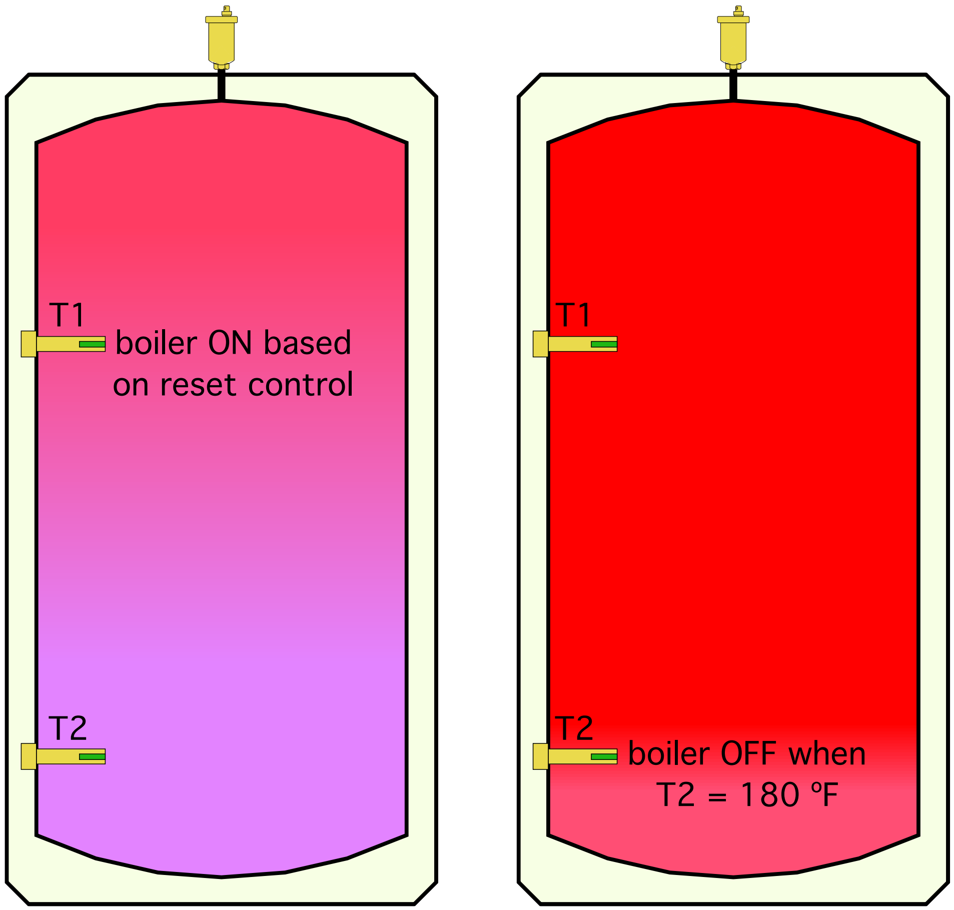
• High temperature heat emitters
• No outdoor reset control

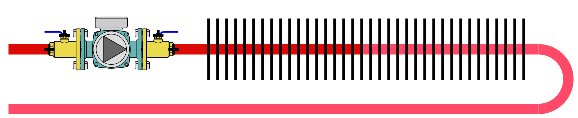


• High temperature heat emitters

• Temperature stacking (w/ upper & lower tank temp. sensors

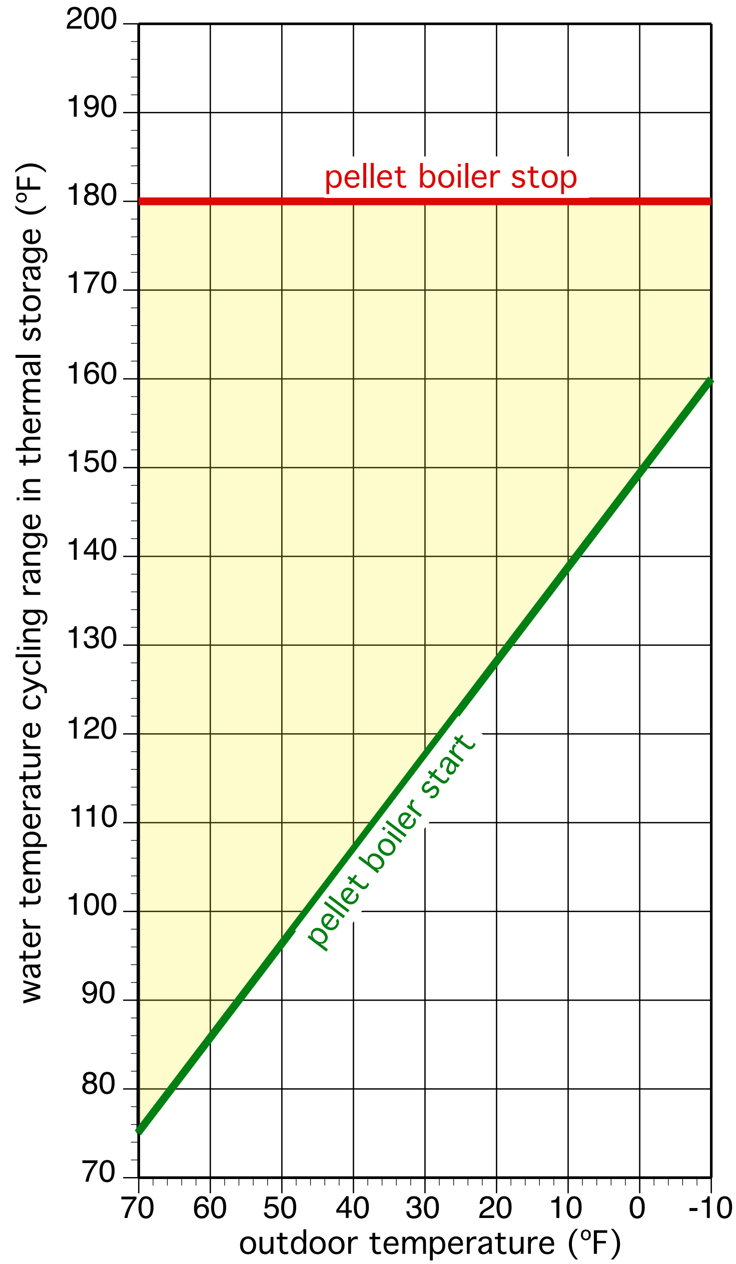
[*outdoor reset for boiler start, setpoint temperature for boiler off*]



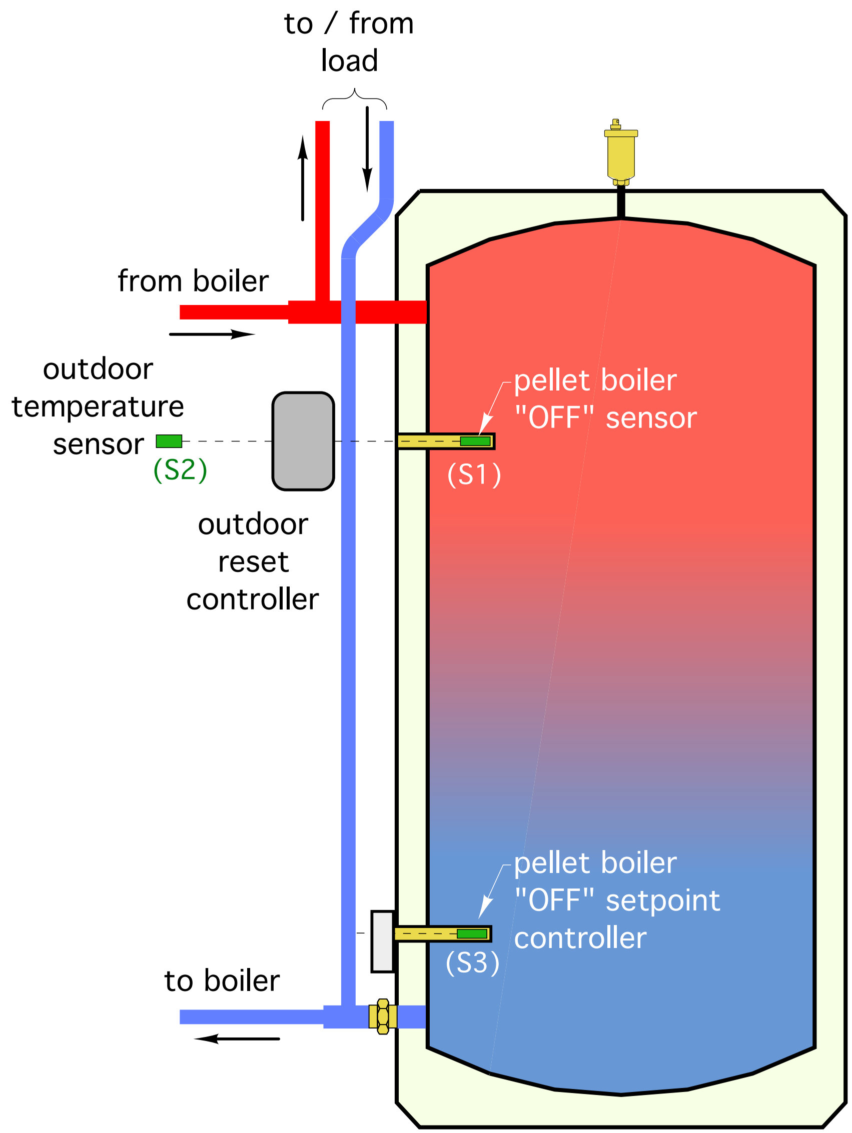


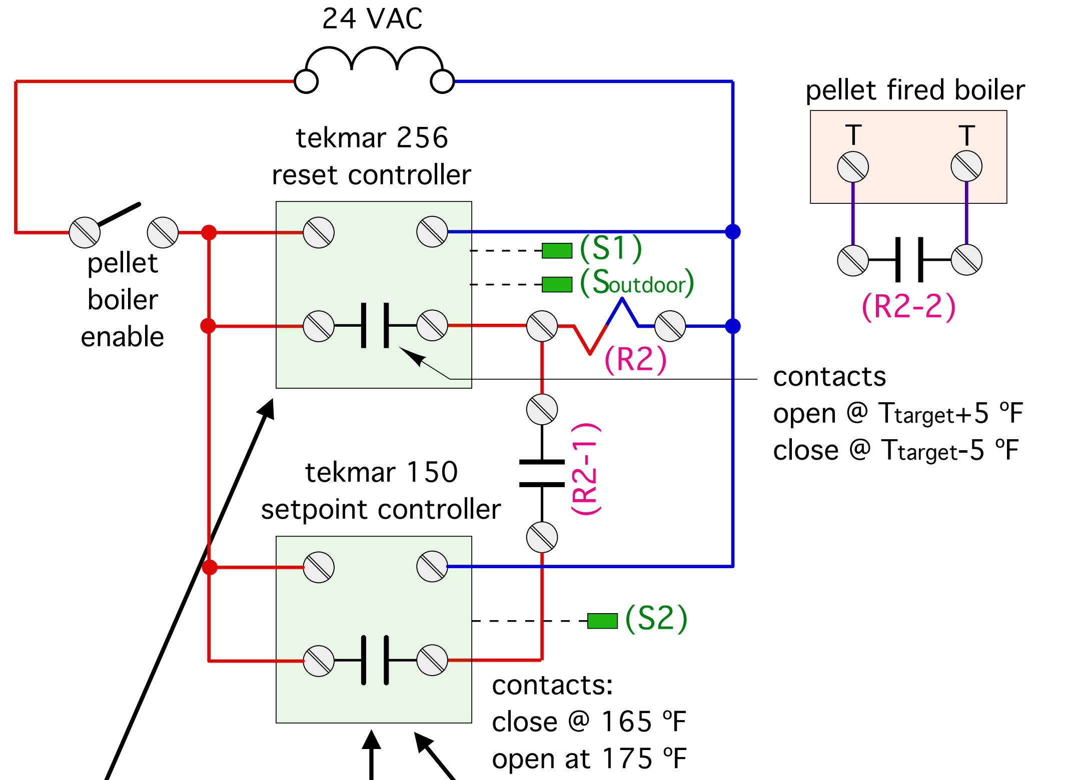
• HIGH temperature heat emitters

• Outdoor reset of pellet boiler start temperature



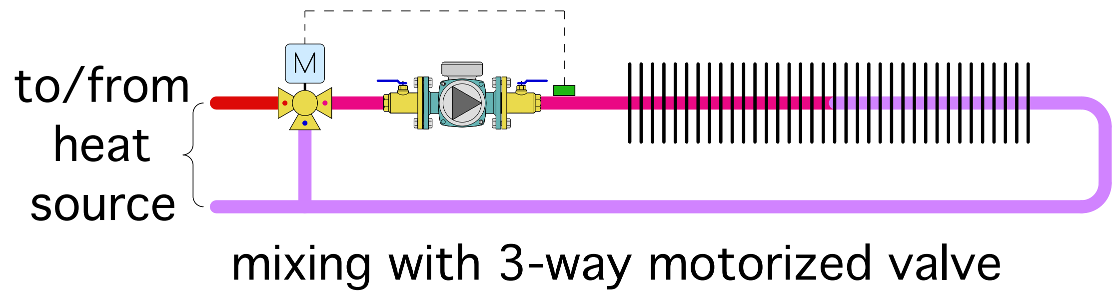
Temperature stacking *(using 1 setpoint temperature and one outdoor reset temperature)*

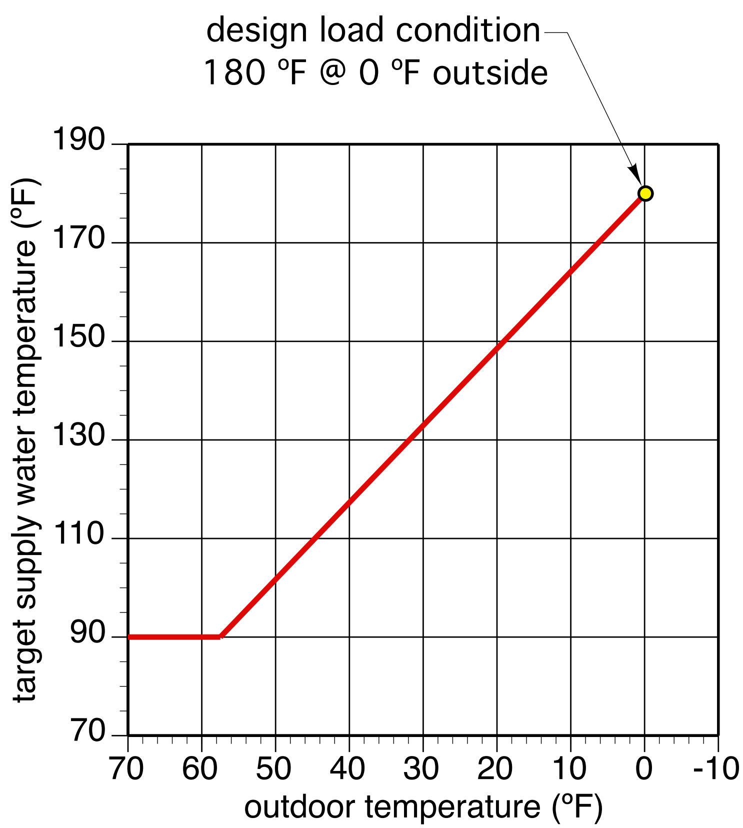


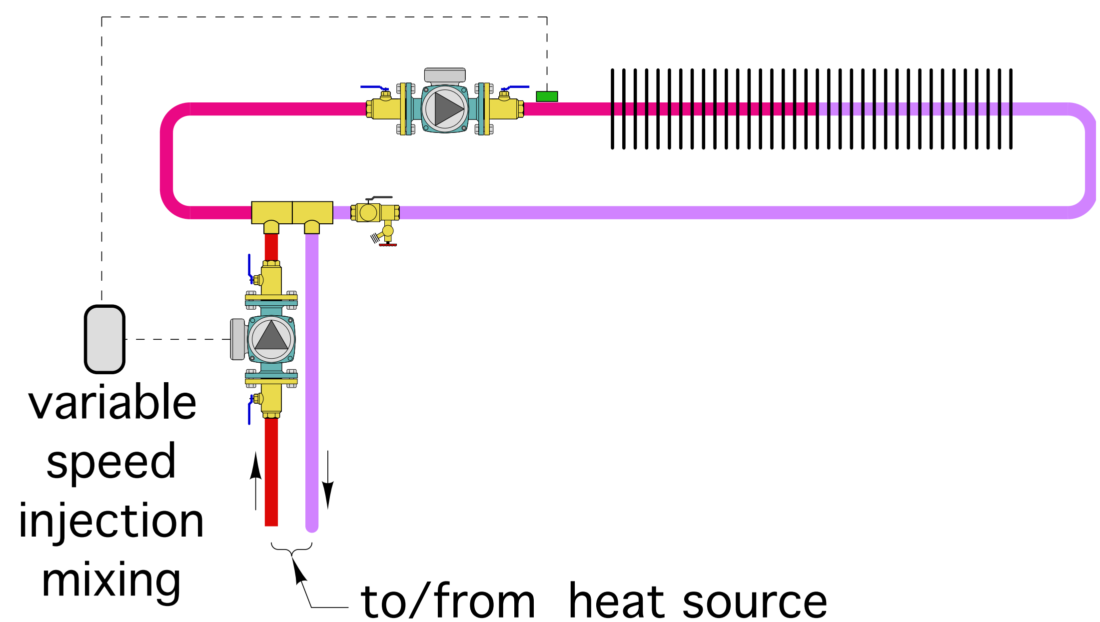


high temperature heat emitters

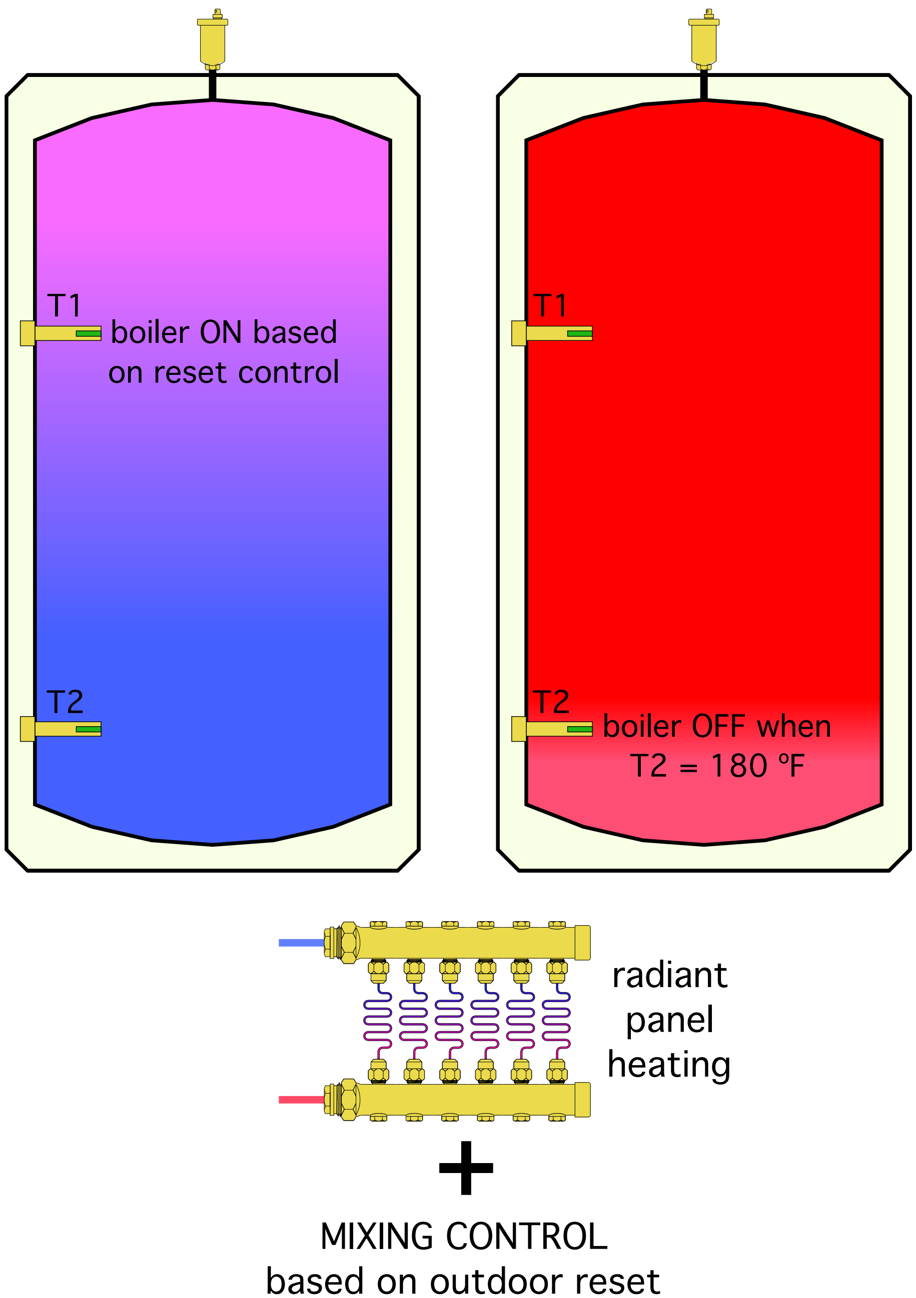
Adding ***mixing*** (based on outdoor reset) between the thermal storage tank and distribution system will smoothen heat delivery and significantly ***improve comfort***.

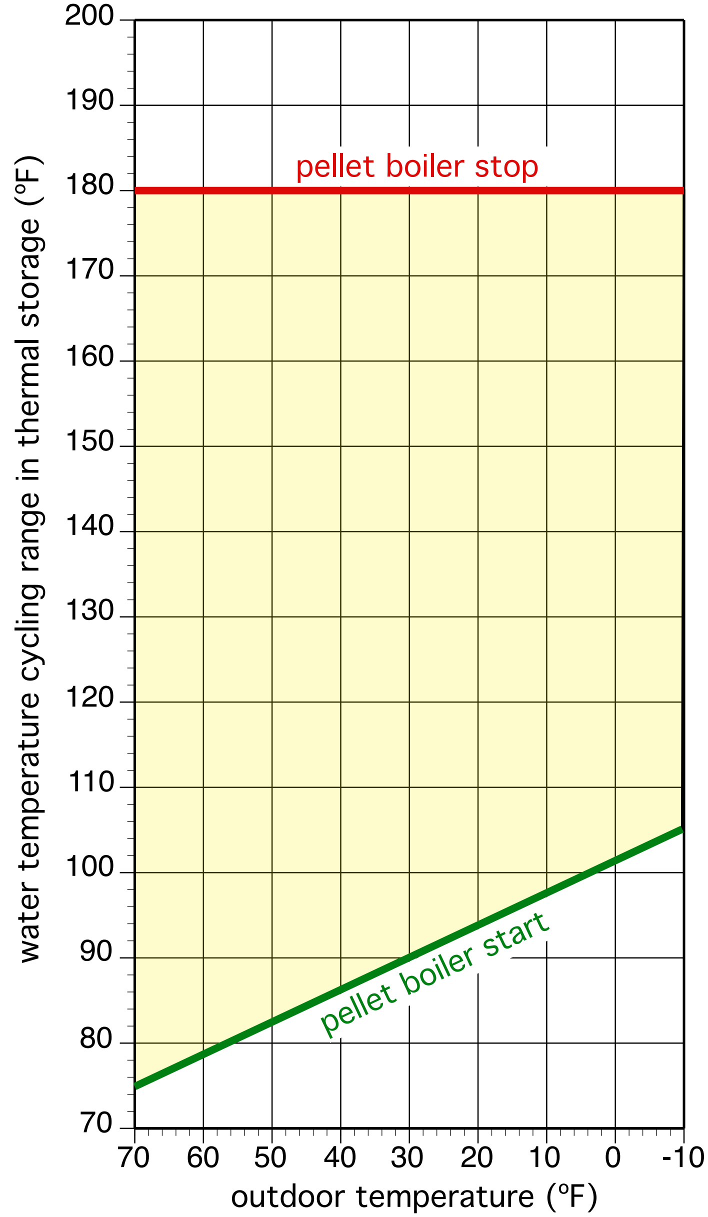






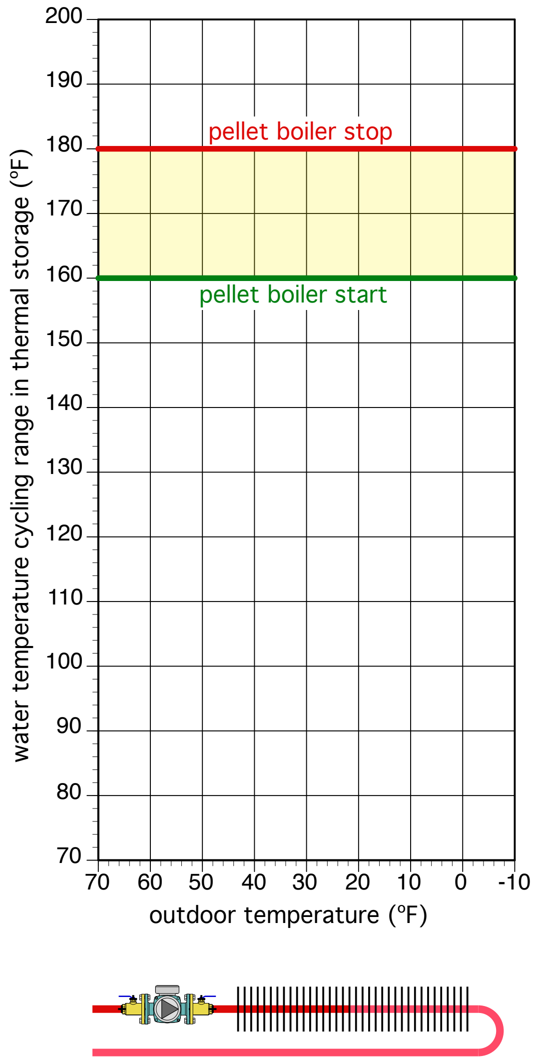
- **Low temperature heat emitters**
- Heat stacking (outdoor reset for boiler start, setpoint for boiler off)
- Mixing control of distribution water temperature



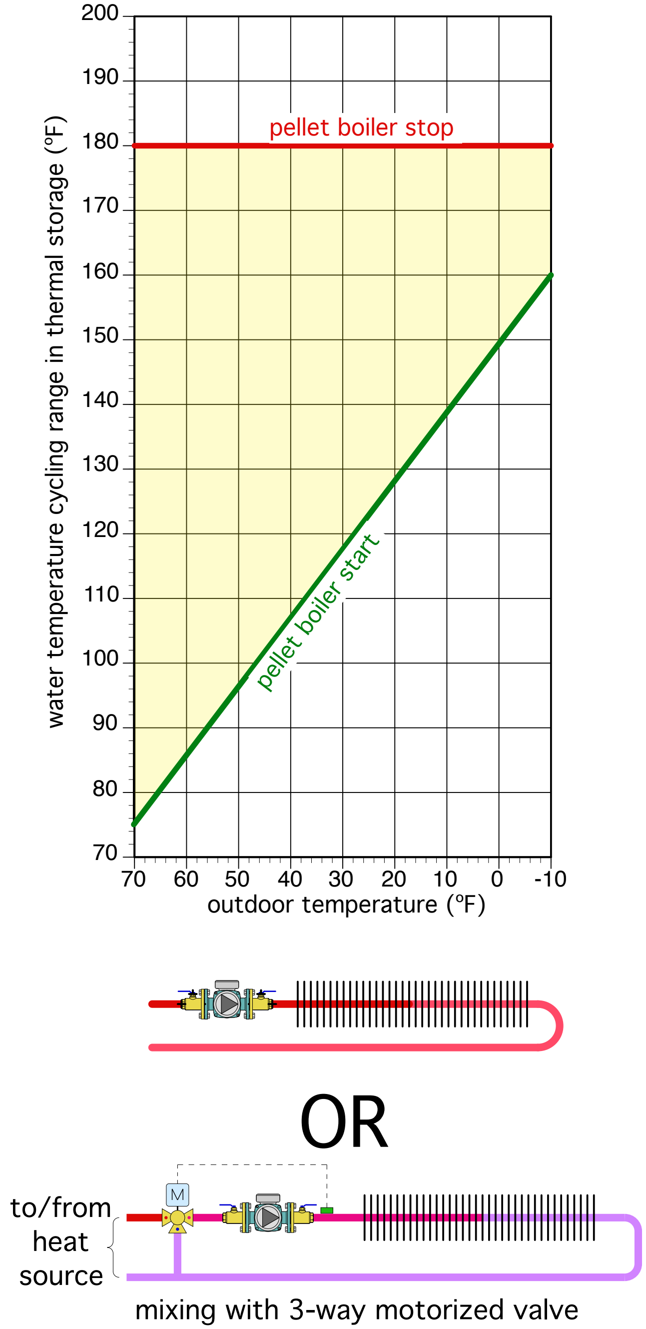


A comparison of tank temperature cycling range

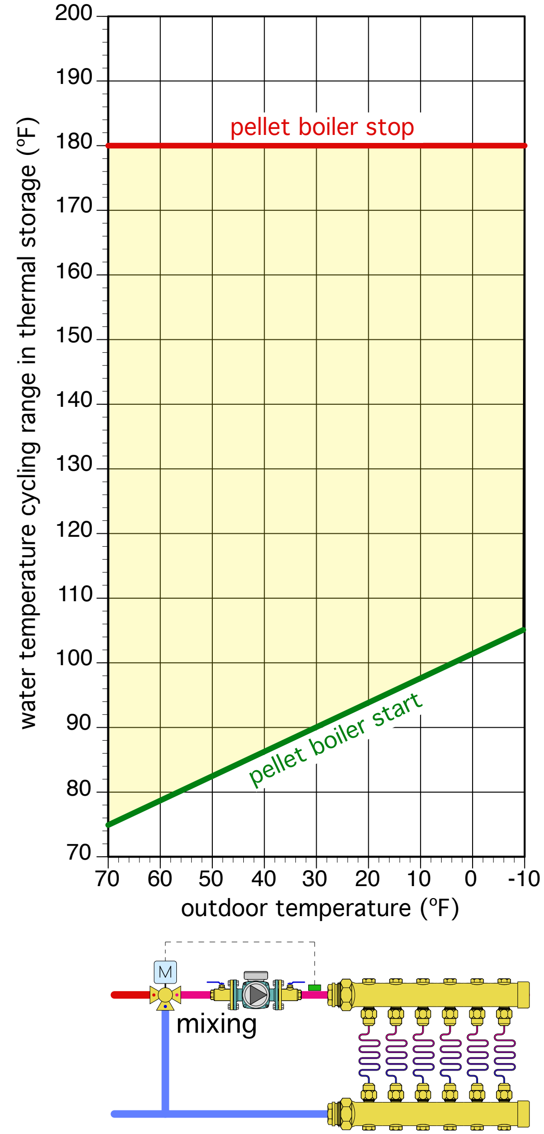
- High temperature heat emitters
- No outdoor reset control



- High temperature heat emitters
- With outdoor reset control of pellet boiler start temperature



- Low temperature heat emitters
- With outdoor reset control of pellet boiler start temperature
- Mixing of supply water temperature required



Controlling heat flow to a load in a system with a biomass boiler and an auxiliary boiler

Many biomass boilers are retrofitted into systems that having existing boilers. In new biomass boiler system an auxiliary boiler is often included as part of the overall system.

The presence of an existing or auxiliary boiler enhances the overall system in several ways:

1. The ability to maintain building comfort if the biomass boiler is not operating (either intentionally or if it is down for service).

2. The ability to supplement the heat output of the biomass boiler under peak loading conditions.

3. The ability to take advantage of energy sources that may be offered at favorable rates under specific conditions. An example being off-peak electrical rates where they are available.

The manner in which a biomass boiler and conventional boiler are integrated into the system should:

1. Respect and enhance the desired operating characteristics of the biomass boiler.

2. Respect the operating conditions of the existing/auxiliary boiler.

3. When the cost of heat provided from pellets or cordwood is less expensive than heat produced by other fuels, the biomass boiler will have preferential operation over the existing / auxiliary boiler.

4. Correct any operational issues with the existing boiler, such as reducing or eliminating short cycling.

5. Allow either boiler to be the sole heat source if necessary. This infers designs that allow either boiler to be turned off and isolated from the system, if necessary for repair.

A typical "lead/lag" multiple boiler application

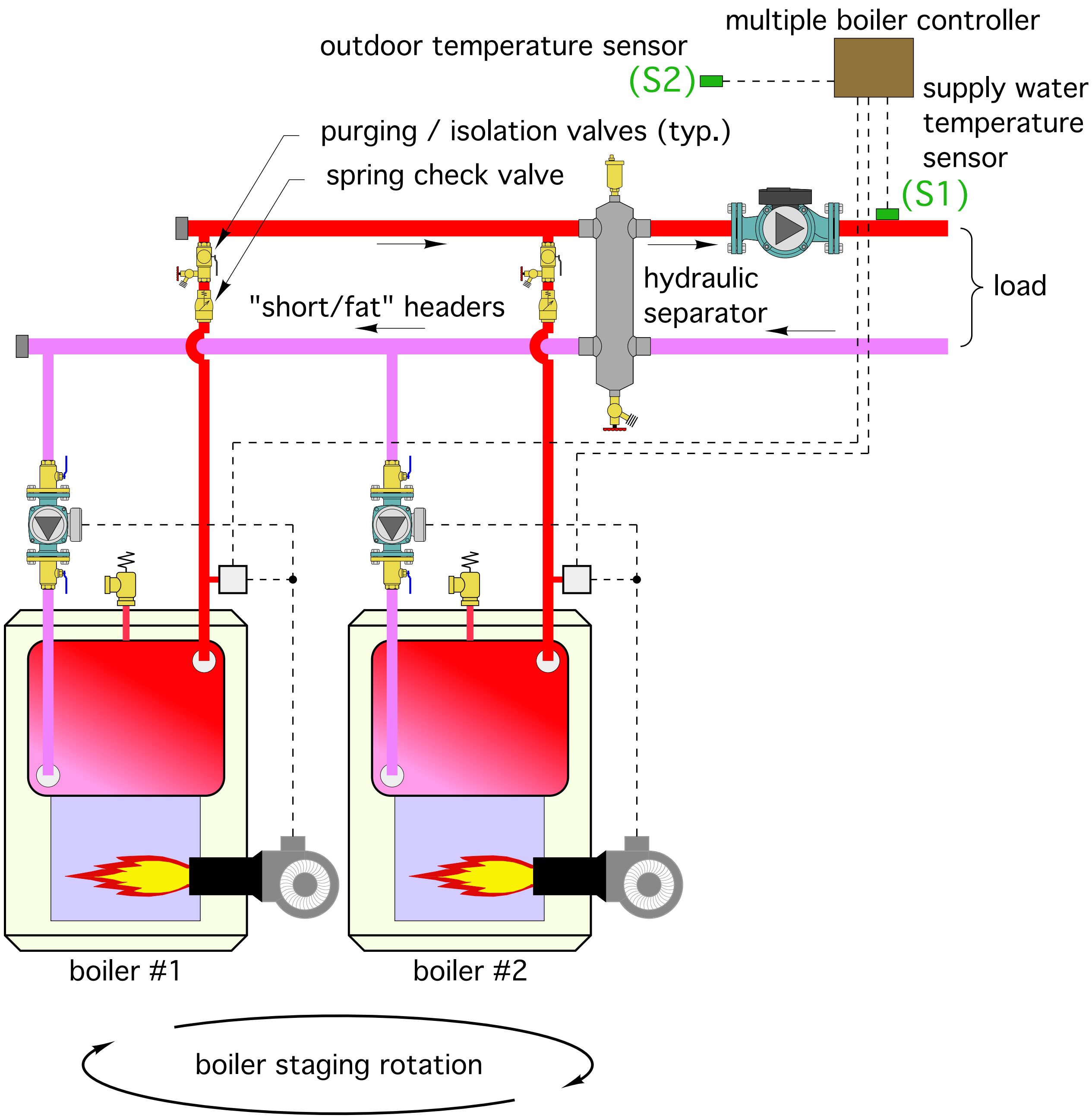
Boiler controller measures supply water temperature at sensor (S1), and compares it to the "target" supply water temperature.

If temperature at (S1) is lower than target temperature, one boiler is fired.

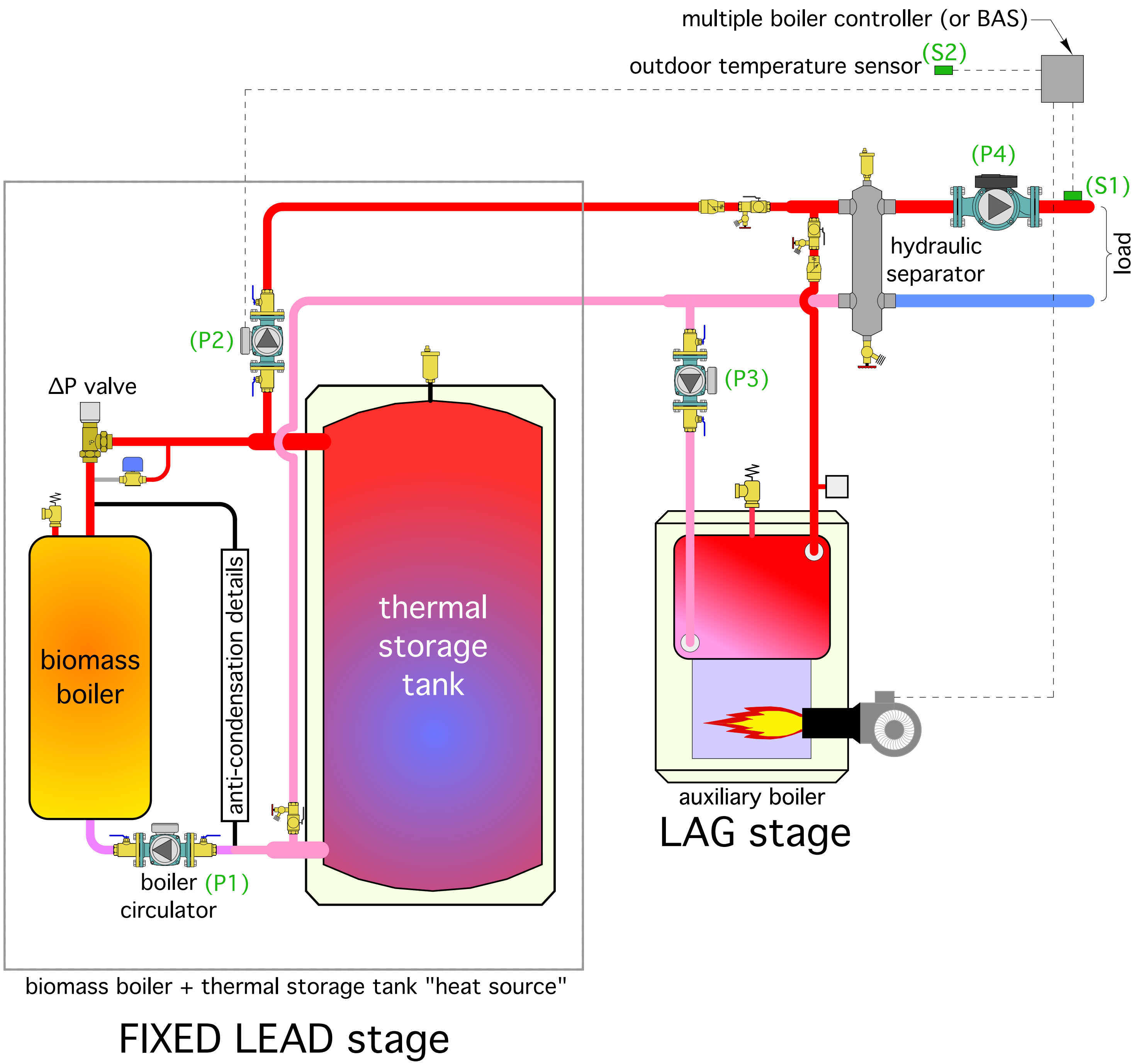
Boiler controller then uses PID logic to determine if more heat input is need. If it is, the other boiler is fired.

When all boilers are identical, the boiler controller typically "rotates" the firing order to create about the same run time for each boiler.

If boilers are different, one is designated as the "fixed lead" boiler, the other as the "lag" boiler.



It’s “intuitive” for designers to create systems where the biomass boiler is treated as a “fixed lead” stage, and the auxiliary boiler is the “lag” stage.



The glitch…

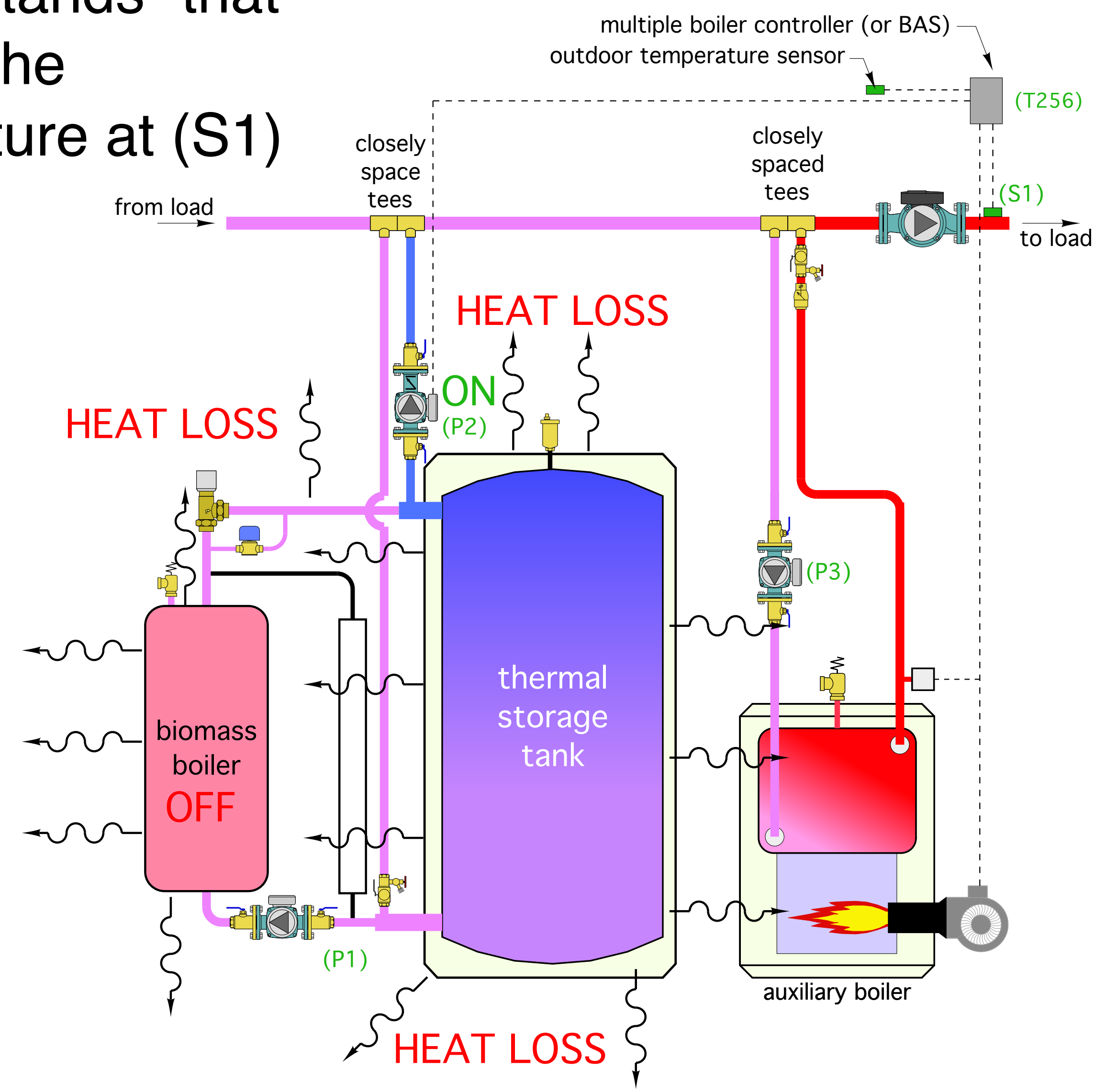
A standard multiple boiler controller “doesn’t know” if the biomass boiler is *offline*, due to a fault, or if the tank is cooler than the minimum “useable” temperature of the distribution system.

The boiler controller only “understands” that the fix lead stage is not creating the necessary supply water temperature at (S1)

The boiler controller turns on stage 2, and keeps stage 1 on.

The result: The circulator creating flow between the tank and system remains on.

Heat produced by the auxiliary boiler is inadvertently carried into thermal storage, increasing heat loss to surrounding space.



In a conventional multiple boiler system the added heat loss created by flow of heated water through an unfired boiler - ***while not desirable*** - doesn't create substantial heat loss:

Most conventional boilers use either sealed combustion or have automatic flue dampers that close whenever the boiler is off. ***NOT the case with biomass boilers.***

Most conventional multiple boiler systems do not have larger thermal storage tanks. ***Lots of added surface area for heat loss.***

4000 gallon thermal storage tank (before insulation)

1200 gallon thermal storage tank

This really happens…

This really happens…

When visited in March 2017:

- pellet boiler had been off for about 1 month awaiting service
- tank-to-load circulator was running
- boiler-to-tank circulator off at service switch, but on at BAS output
- tank temperature about 145 °F, all heat coming from electric aux boiler
- If boiler-to-tank circulator had not been manually switched off, 145 °F water would be circulating through boiler, creating jacket heat loss, and convective air currents up flue *(no flue dampers on pellet boilers).*

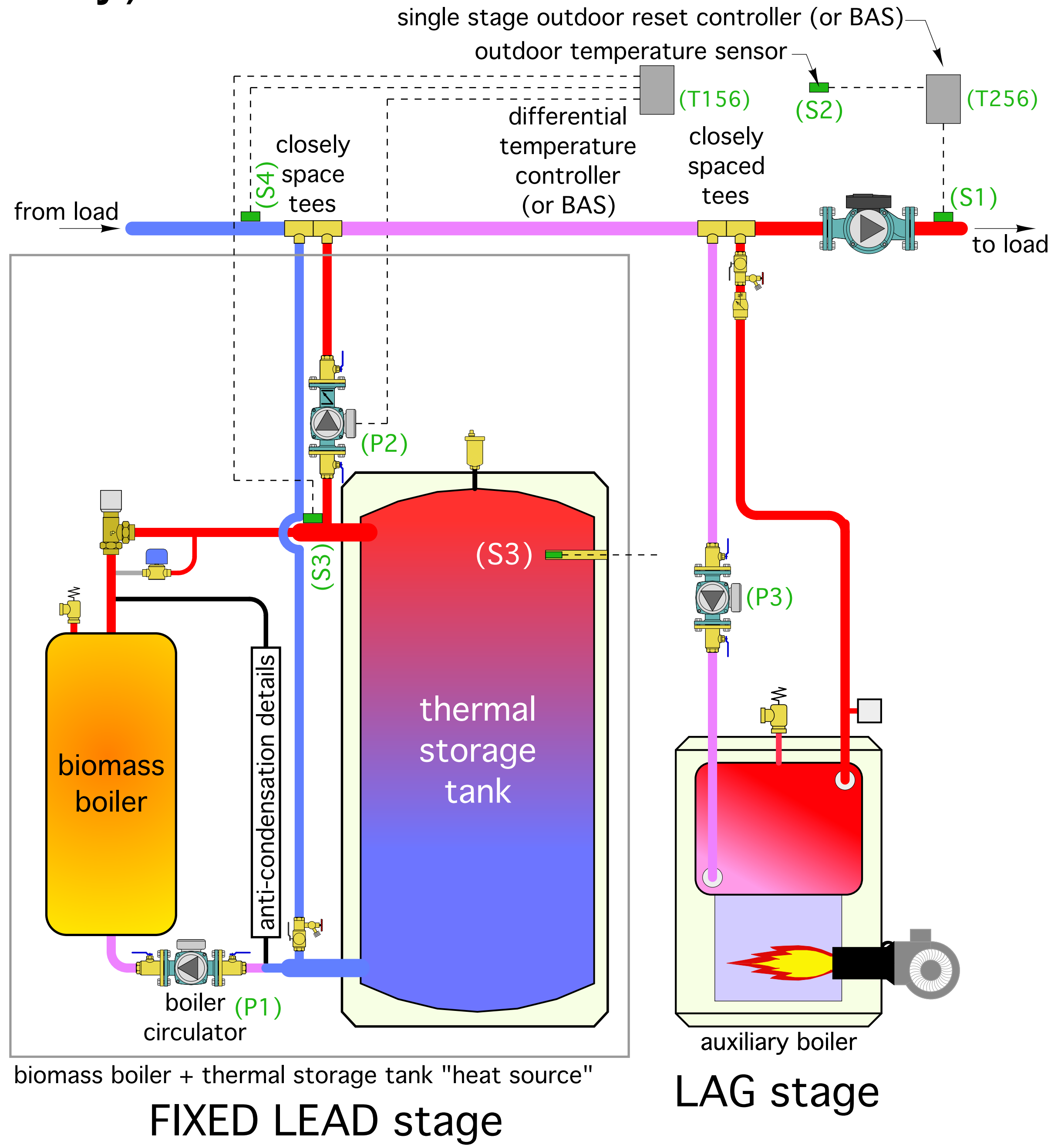
The solution is a simple *differential temperature controller* (or equivalent BAS functionality)

Compare the temperature at the upper tank header (S3) to the return temperature of the distribution system (S4).

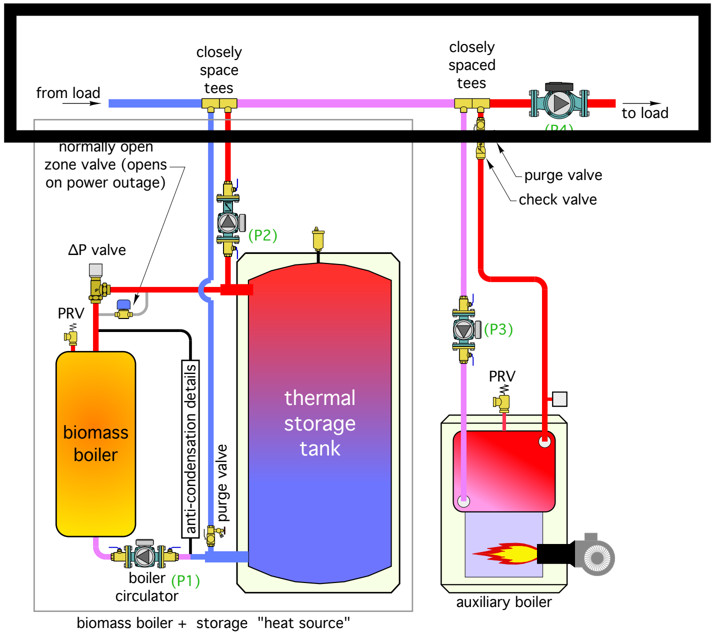
Circulator (P2) (tank to load) is only allowed to run when the tank can make a positive energy contribution to the system.

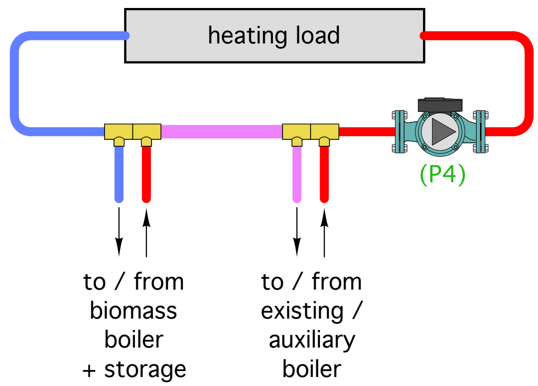
IF (S3) ≤ (S4) + 3 °F, THEN (P2) is OFF

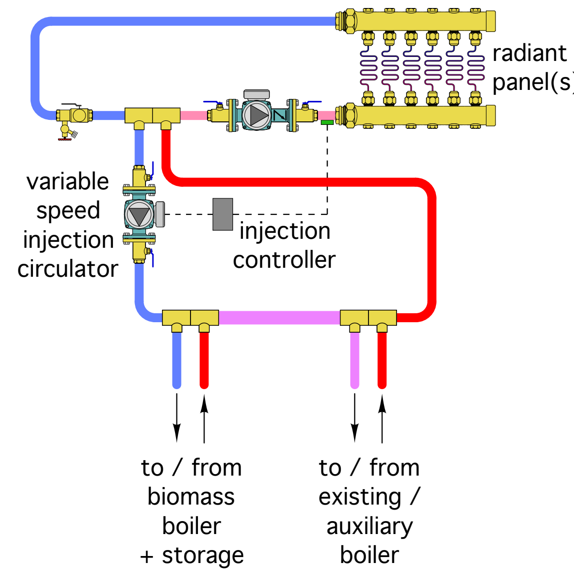
IF (S3) ≥ (S4) + 5 °F THEN (P2) is ON

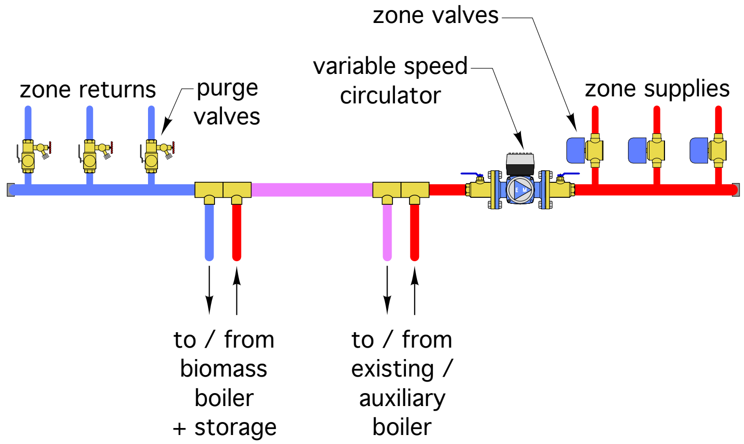


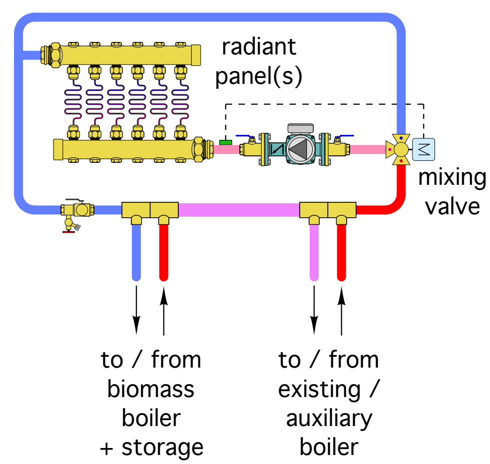
There are several possibilities for the distribution system

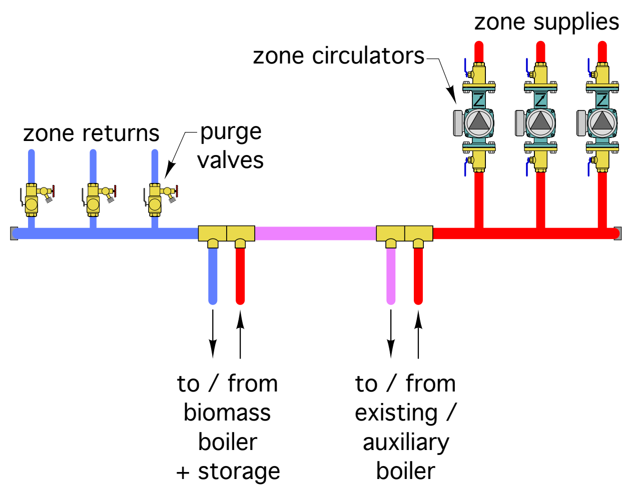




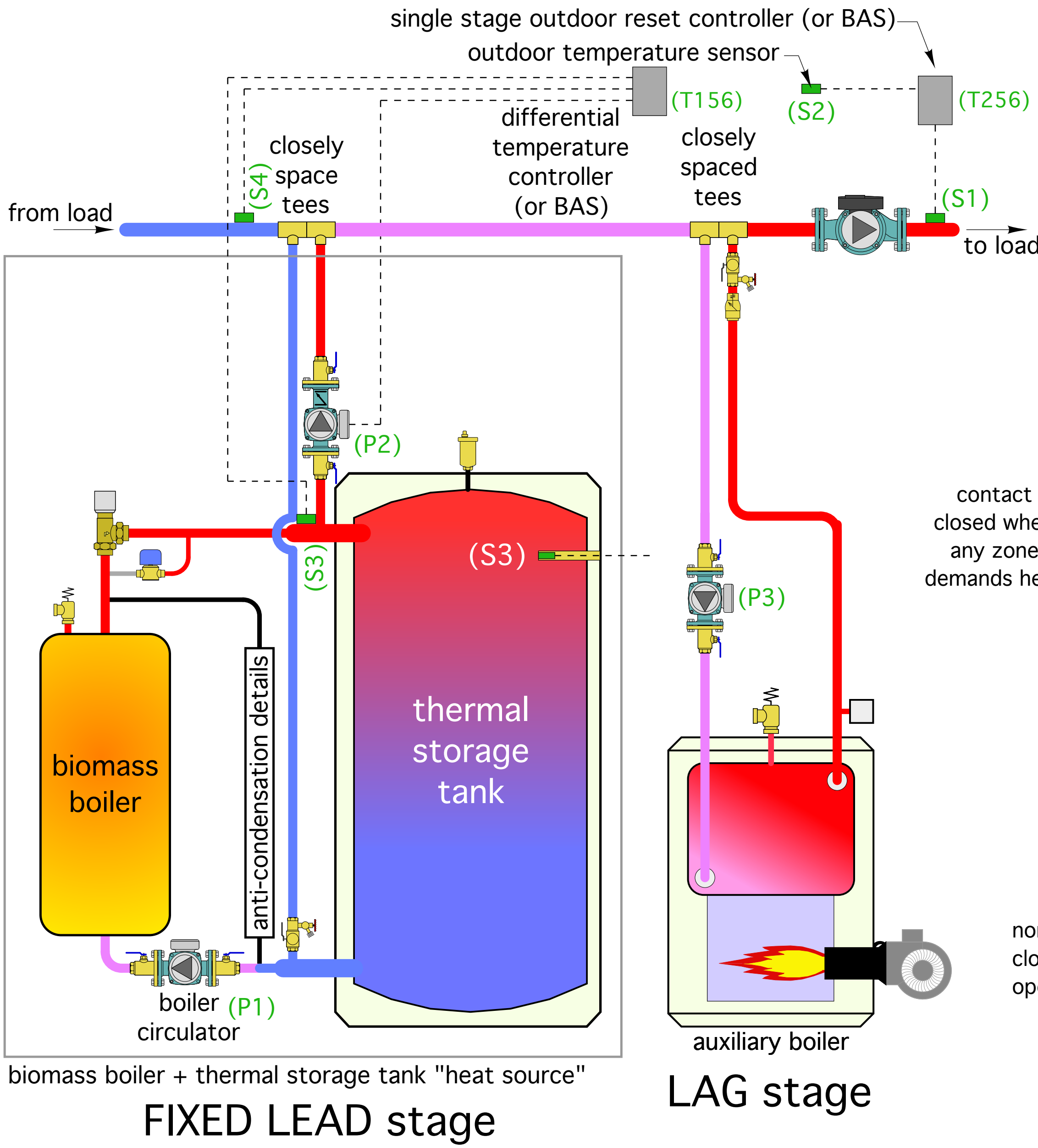




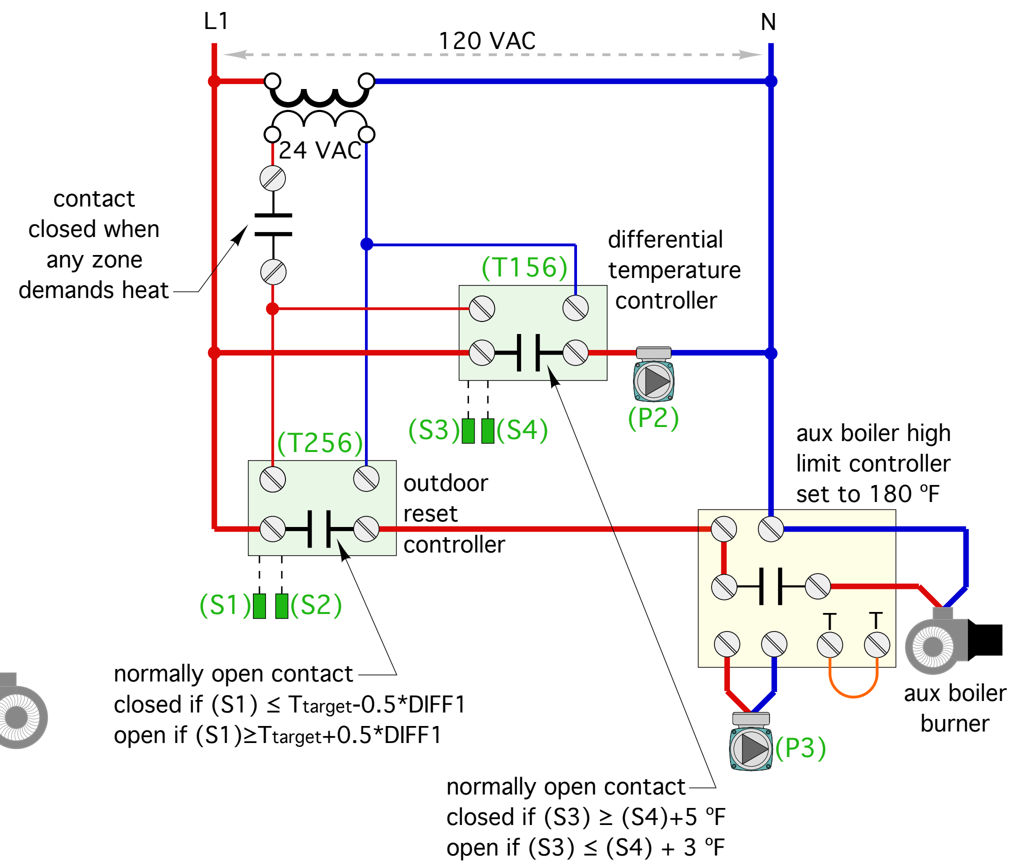




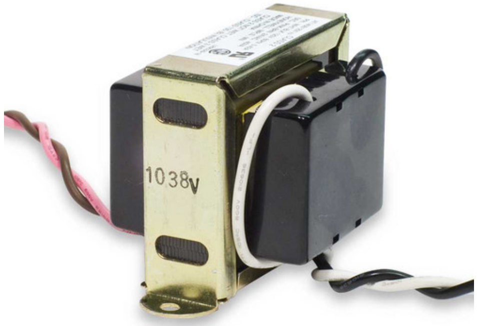
Using two simple, inexpensive controllers to manage heat flow to load



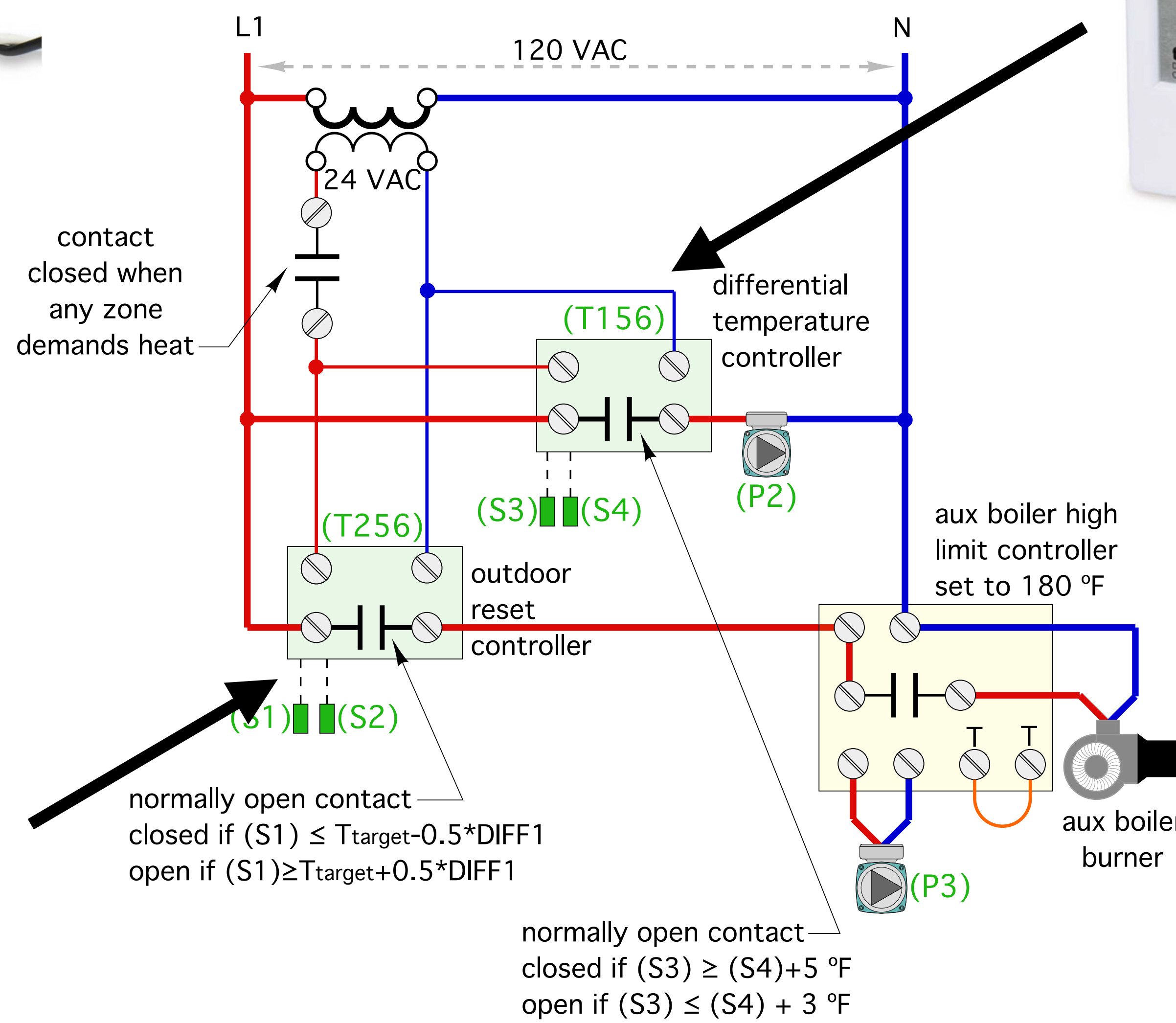
Circuitry to manage heat input to distribution system



Using two simple, inexpensive controllers to manage heat flow to load



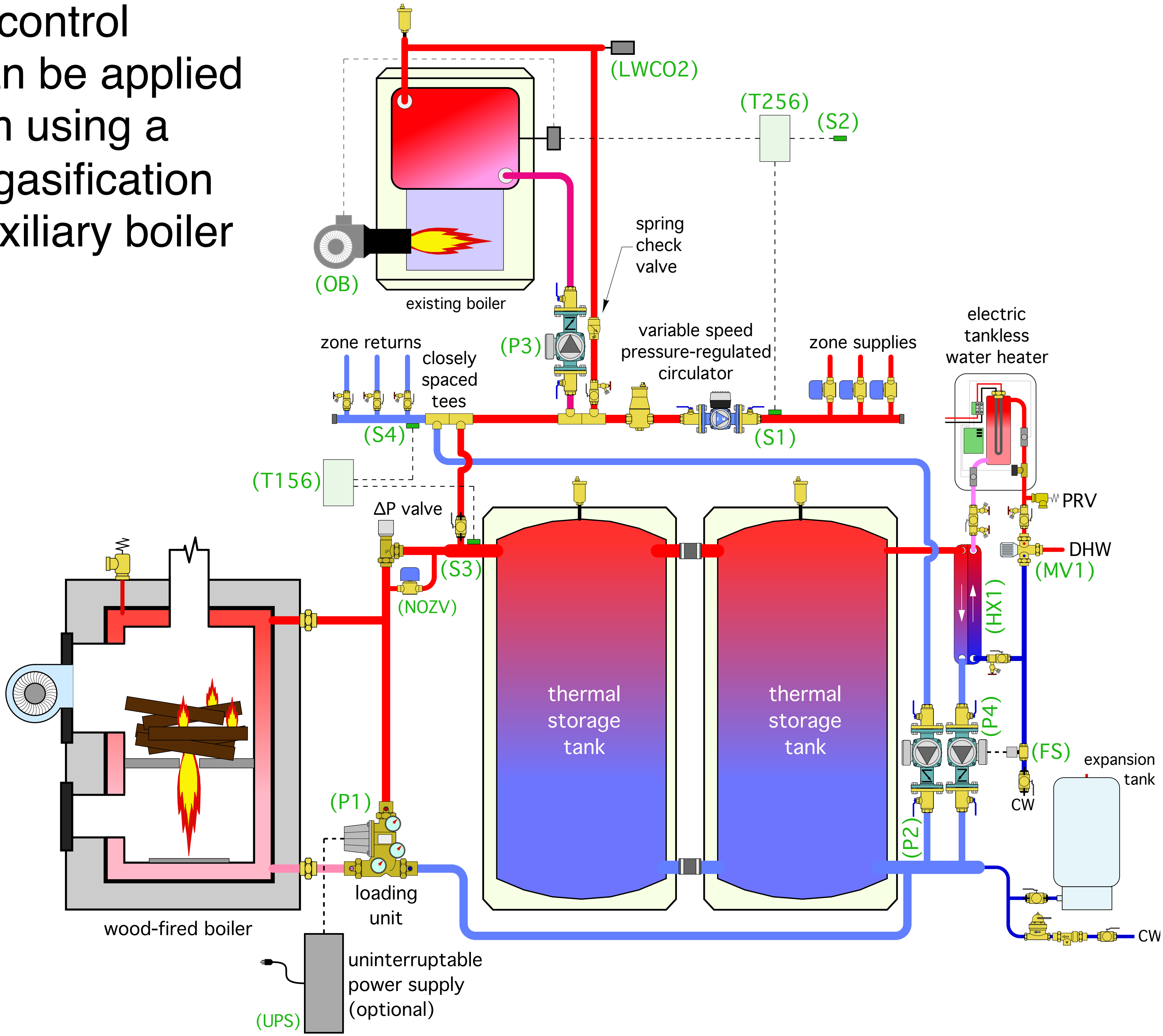
Circuitry to manage heat input to distribution system



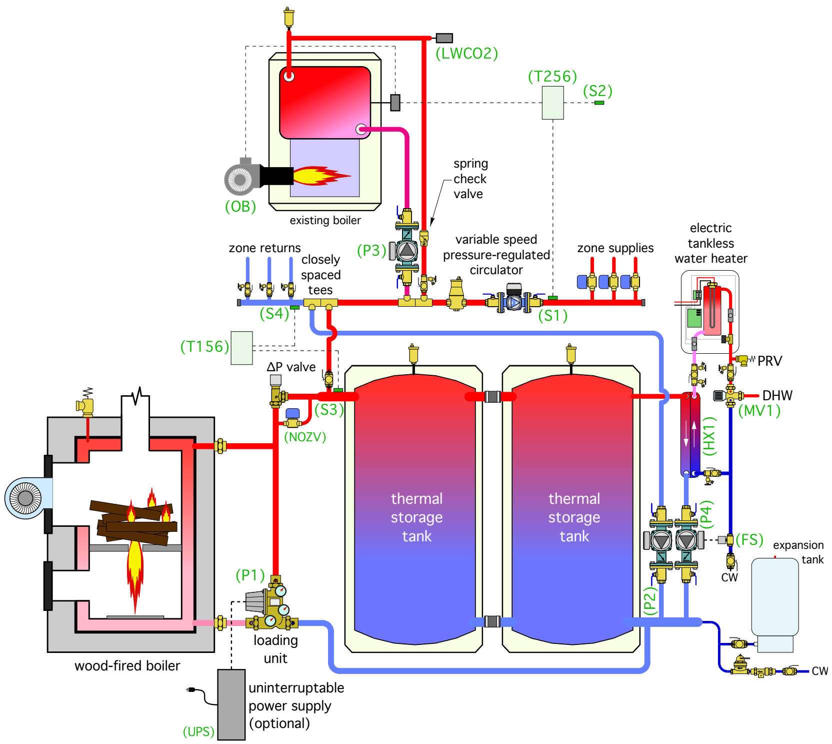
tekmar 156
$166

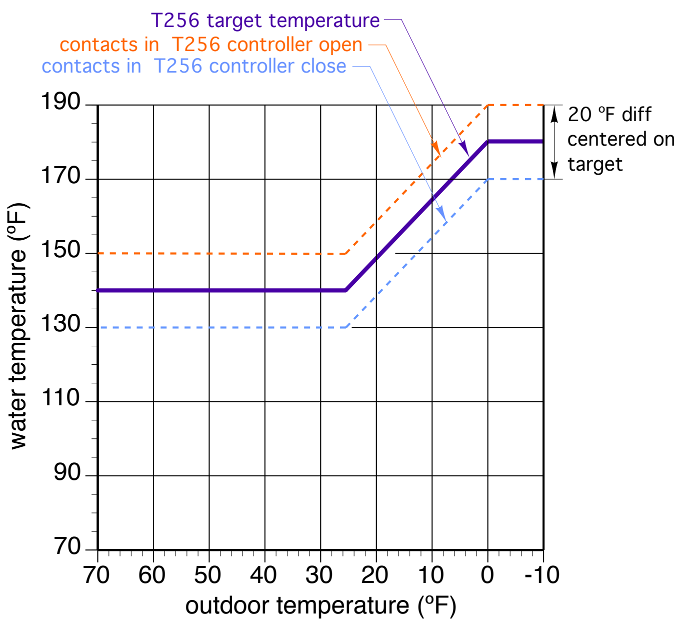
tekmar 256
$150

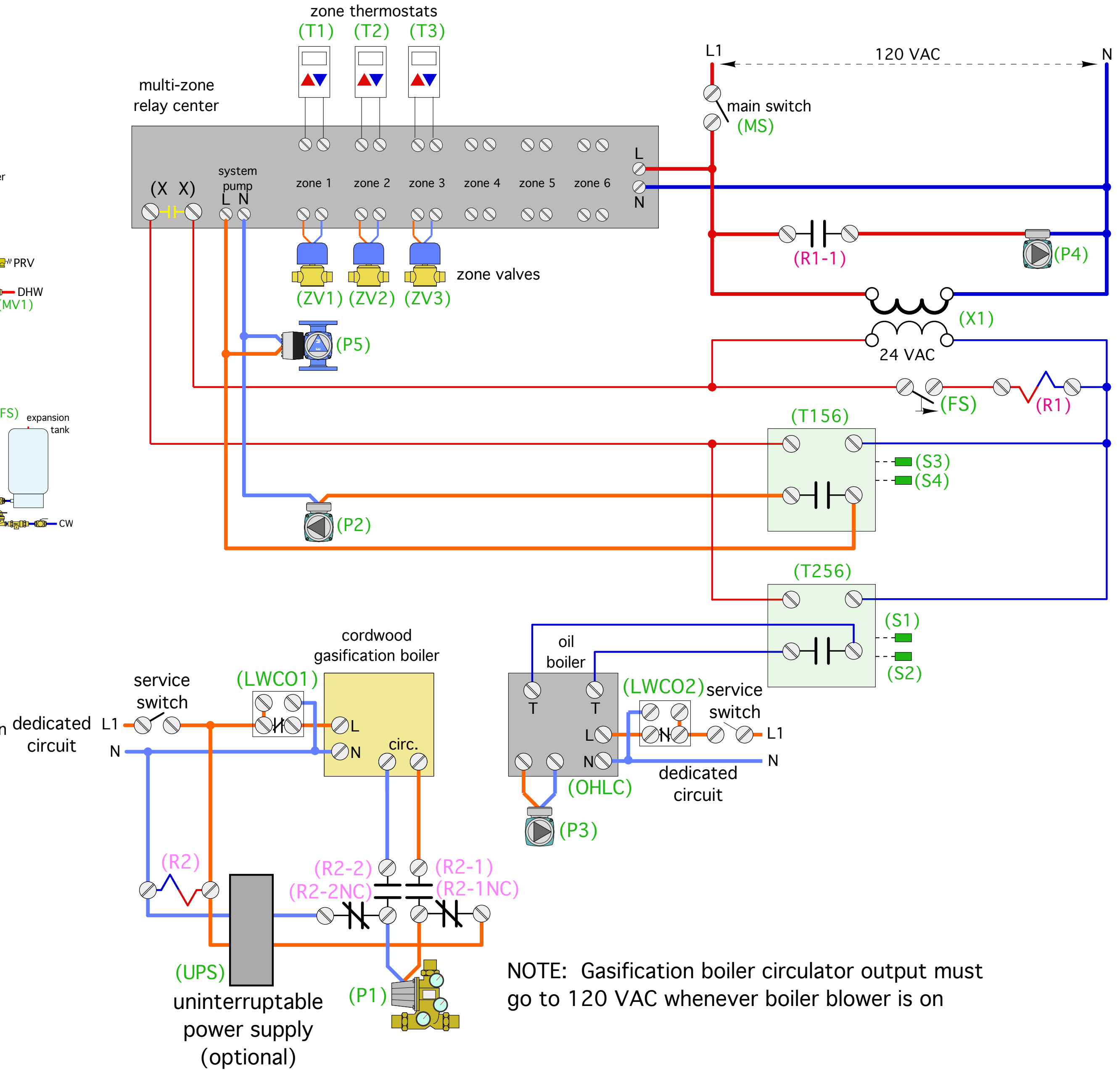
The same control concept can be applied to a system using a cordwood gasification boiler & auxiliary boiler



The same control concept can be applied to a system using a cordwood gasification boiler & auxiliary boiler







NOTE: Gasification boiler circulator output must go to 120 VAC whenever boiler blower is on

Description of operation:

Please read this later…

Power Supply: *120 VAC power for the pellet boiler is supplied from a dedicated circuit. The service switch for the pellet boiler must be closed, and the low water cutoff (LWCO1) must detect water for the pellet boiler to operate.*

120 VAC power for the oil-fired boiler is supplied from a dedicated circuit. The service switch for the auxiliary boiler must be closed, and the low water cutoff (LWCO2) must detect water for the oil-fired boiler to operate.

Power for circulators (P2) (P4) and (P5), the 24 VAC transformer (X1), the multi-zone relay center (MZRC), controllers (T156) (T256), and relay coil (R2) is supplied through another 120 VAC dedicated circuit. The main switch (MS) must be closed for these devices to operate.

Cordwood gasification boiler operation: *After a fire is kindled in the boiler, and the chamber is loaded with wood, the operator turns on the boiler's blower switch. The circulator output of the boiler must be wired to go to 120 VAC whenever the boiler's blower is on. This passes 120 VAC to the loading unit (P1). The cold port of loading unit is fully closed, and the bypass port is fully open while the boiler is warming above the dewpoint of its exhaust gases. This prevents heat from the boiler from reaching the load or thermal storage. As the water temperature leaving the loading unit rises above 130 °F, the cold port of the loading unit begins to open, allowing some hot water to flow to the load or thermal storage. When the water temperature leaving the loading unit reaches 148 °F or higher the cold port is fully closed and there is no flow into the bypass port. At that point all flow through the boiler is passing through the ΔP valve and is available to either the load or thermal storage tanks.*

During a power outage the normally open zone valve (NOZV) between the boiler and upper tank header opens to provide a thermosiphon path around the ΔP valve. Thermosiphon flow will develop between the boiler and tanks. If the optional uninterruptible power supply is used, an additional relay (R2) is installed. Upon a utility power loss relay coil (R2) is deenergized. This opens relay contacts (R2-1) and (R2-2) which disconnects both the line and neutral leads from the boiler to (P1), and connects the line and neutral leads of (P1) to the output of the UPS via contact (R2-1 NC) and (R2-2 NC). The UPS operates circulator (P1) until utility power is restored, or the battery in the UPS can no longer supply backup power to (P1). The battery in the UPS should be periodically tested to ensure it can provide the necessary backup power for at least 60 minutes. If not it should be replaced. The (NOZV) should also be periodically tested by removing power and ensuring that the valve immediately opens.

Oil-fired boiler operation: *Power is supplied to the high limit controller on the oil-fired boiler (OHLC) through the low water cutoff (LWCO-2). When there is a closed circuit across the (T T) terminals in the high limit controller, circulator (P3) is turned on, and the burner is enabled to fire. Assuming the circuit across the TT terminals remains closed the burner fires until the boiler's water temperature reaches 195 °F, at which point the burner turns off but circulator (P3) remains on. The burner will fire again when the water temperature in the boiler drops to 175 °F. NOTE: The 195 and 175 °F temperatures associated with the boiler high limit controller are in effect "safety" settings. The operating controller for the boiler is the (T256). It will only allow the burner to operate up to a supply water temperature, at sensor (S1), and under design load conditions, of 190 °F.*

Space heating distribution system operation: *Upon a call for heating from any zone thermostat (T1, T2, T3), the associated zone valve (ZV1, ZV2, ZV2) is turned on the by the multi-zone relay center (MZRC). Variable speed circulator (P5) is also turned on when any zone called for heating.*

The (X X) contacts of the (MZRC) close passing 24VAC power from transformer (X1) to differential temperature controller (T156). This controller compares the temperature at the return side of the distribution system, at sensor (S4) to the temperature of the upper tank header, at sensor (S3). If the temperature at (S3) is at least 5 °F higher than the temperature at (S4), the normally open contacts in the (T156) controller close. This passes 120 VAC to circulator (P2) to create flow between the upper tank header and the upstream pair of closely spaced tees in the distribution system. Circulator (P2) continues to operate unless the temperature at (S3) drops to 3 °F or less above the temperature at (S4), at which point the contacts in the (T156) controller open turning off circulator (P2). This control action prevents heat created by the oil-fired boiler from inadvertently entering the thermal storage tank.

The (X X) contacts of the (MZRC) also pass 24VAC power to outdoor reset controller (T256). The (T256) measures outdoor temperature at sensor (S2) and calculates a target supply water temperature for the distribution system. If the temperature of the water passing sensor (S1) on the supply side of the distribution system is 10 °F or more below the calculated target supply water temperature the contacts in the (T256) controller close across the (T T) terminals of the oil-fired boiler high limit controller (OHLC) enabling it to fire and circulator (P3) to operate. Heat from the oil-fired boiler is injected into the distribution system at the downstream pair of closely spaced tees.

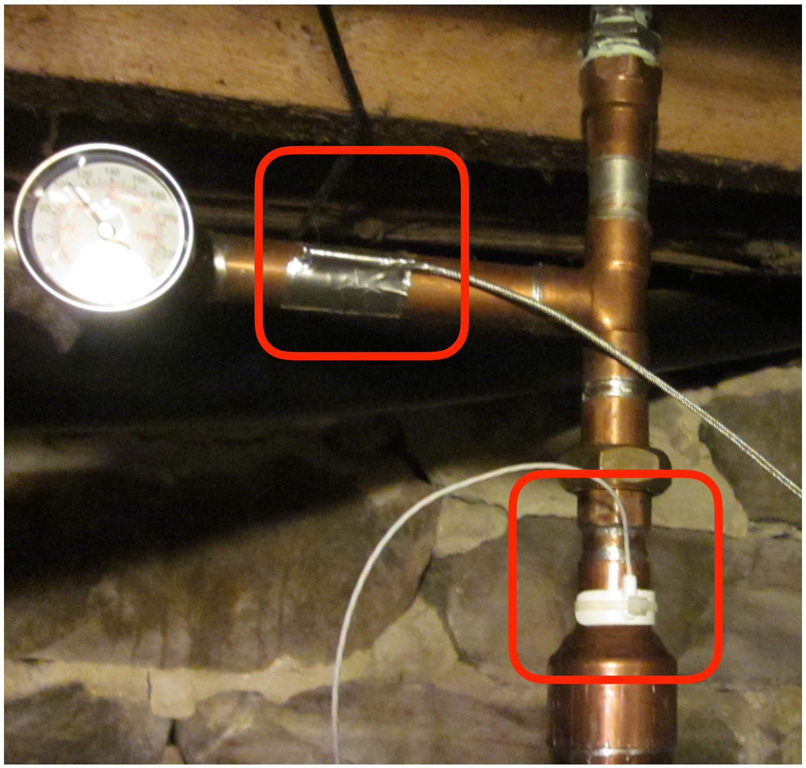
Domestic water heating: *Whenever there is a demand of domestic hot water of 0.6 gallons per minute or higher flow switch (FS) closes, passing 24VAC to the coil of relay (R1). Relay contact (R1-1) closes to turn on circulator (P4) which immediately routes hot water from the top of the thermal storage tanks through the primary side of stainless steel heat exchanger (HX1). Cold domestic water passes in counterflow through the other side of heat exchanger (HX1) and is heated to within 5 °F of the temperature at the top of the thermal storage tanks.*

The heated water leaving heat exchanger (HX1) passes through an electric tankless water heater, which is thermostatically controlled to limit heat input so that the water leaving the heater is not more than 115 °F (assuming it enters the heater at a lower temperature). If the water entering the heater is above 115 °F, the elements will not turn on. Hot water leaving the heater passes through a thermostatic mixing valve (MV1), which limits hot water delivery temperature to 115 °F.

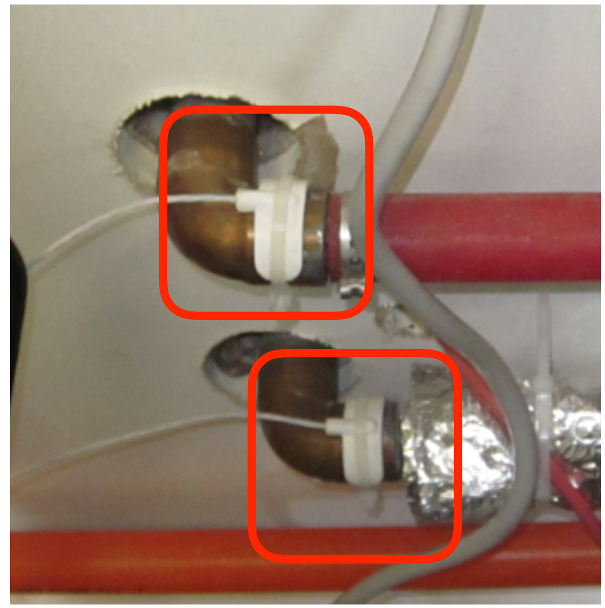
Poor sensor placement or lack of insulation

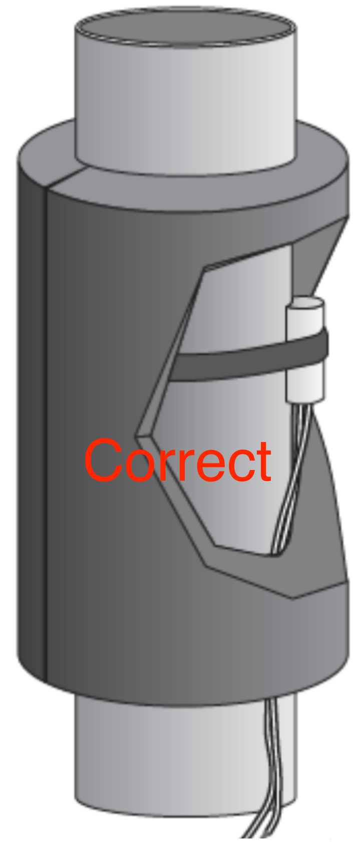
Controllers can only react to what temperatures their sensors “feel.”

Solution: Surface mount sensors must be firmly attached, stay attached at elevated temperatures, and be insulated from surrounding air temperature.



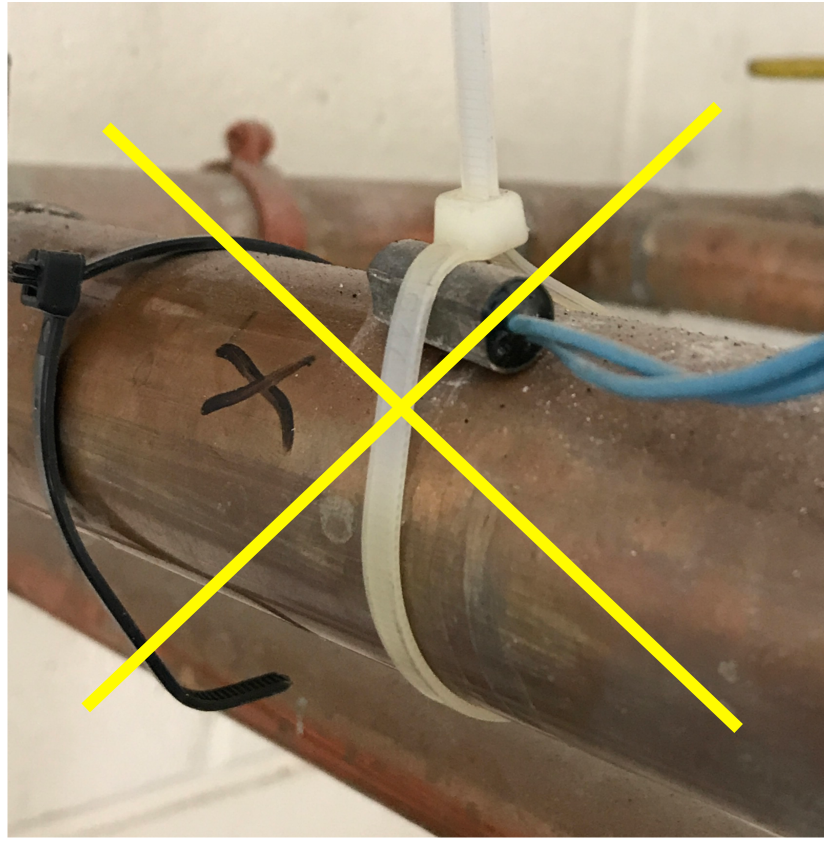
non-insulated surfaced mounted temperature sensors





Some sensors have a concave shape to fit OD of pipe.

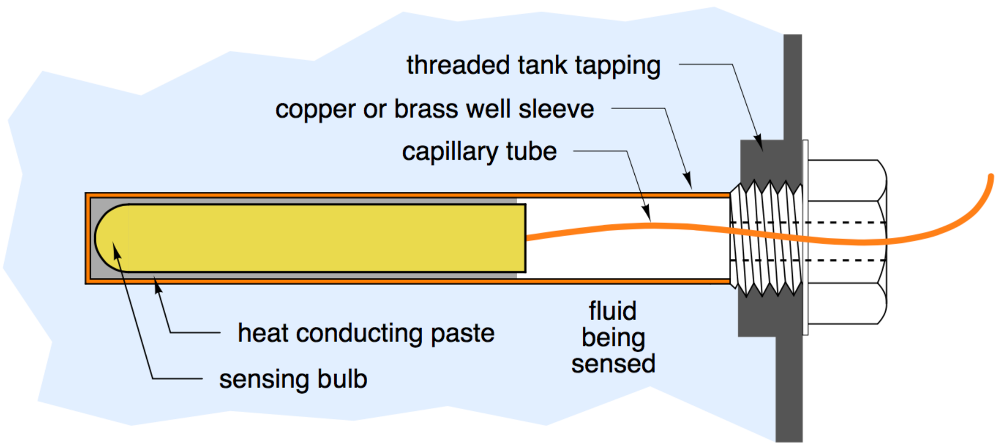
Poor sensor placement or lack of insulation



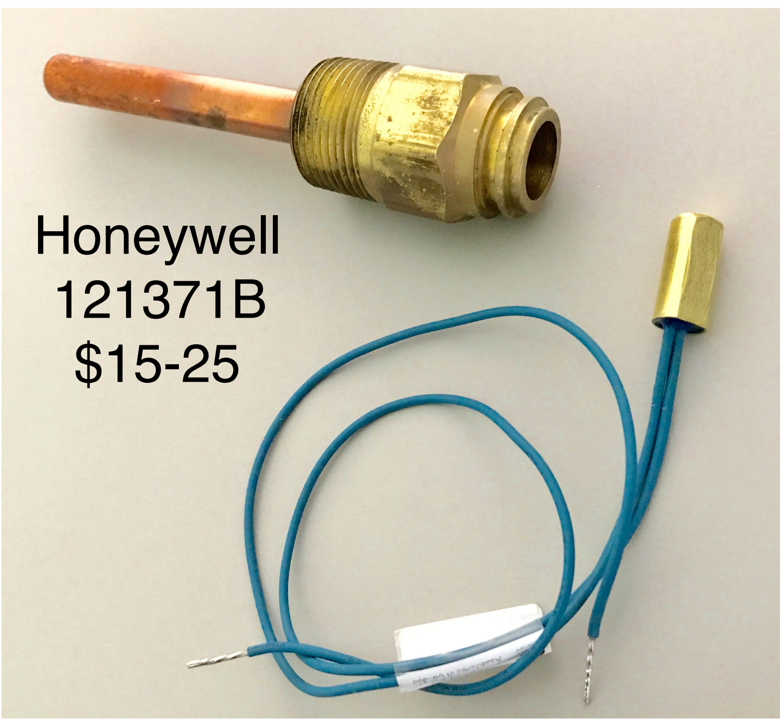
Pipe-mounted sensor with sealed insulation jacket

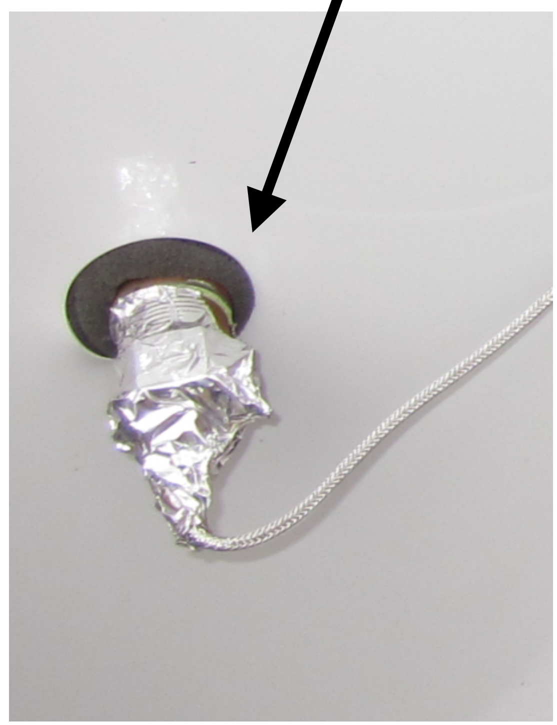
Poor sensor placement or lack of insulation

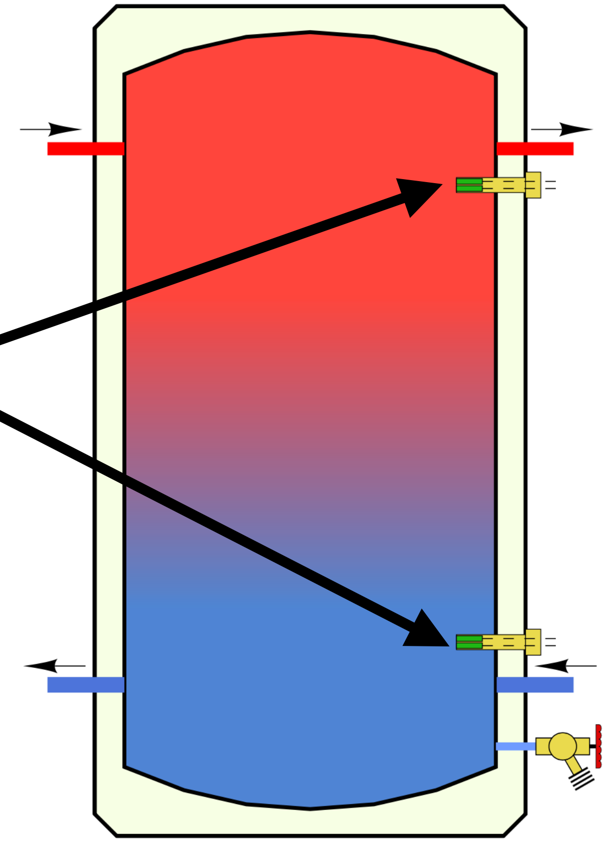
Solution: When measuring the temperature within heat sources, or thermal storage tanks, use a sensor well, and thermal grease.



sensors
in wells

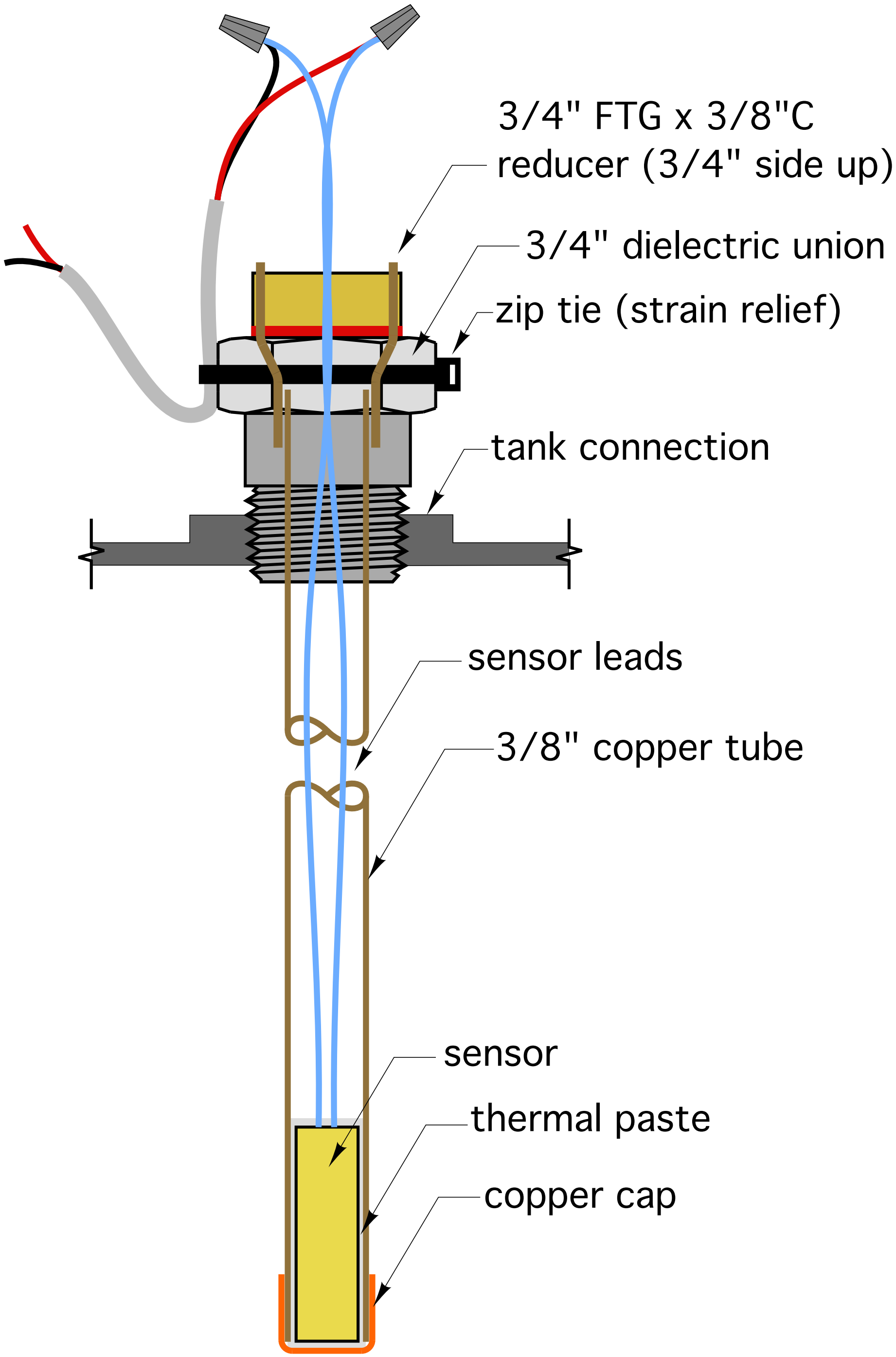


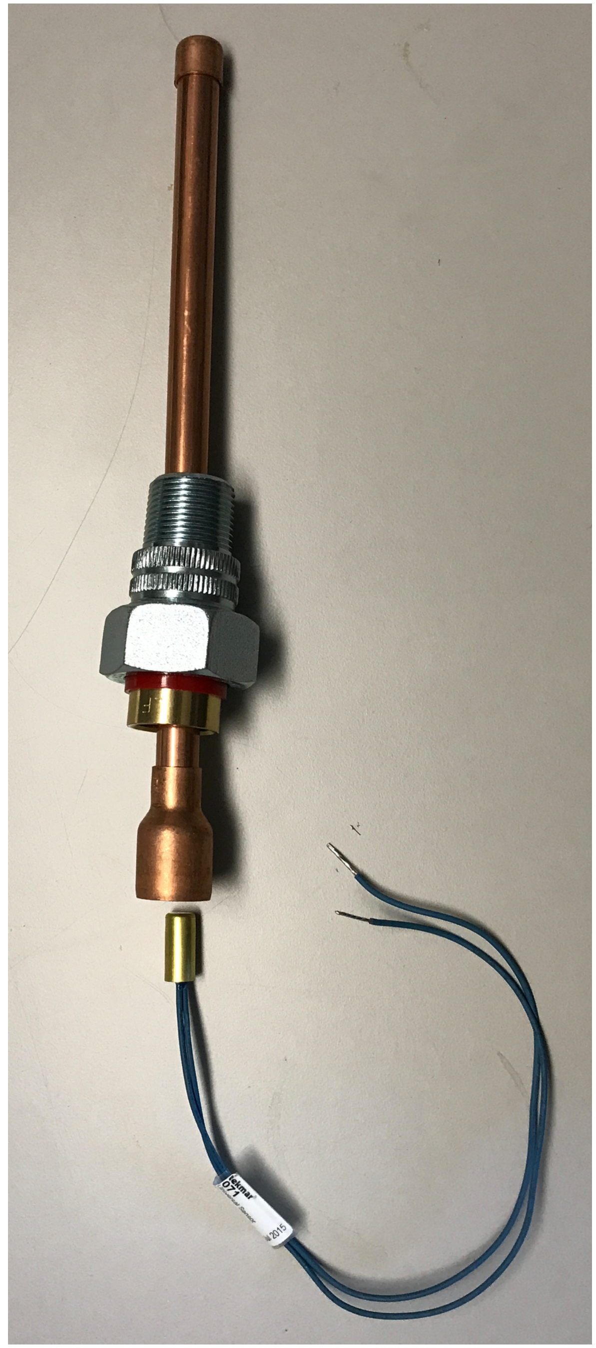




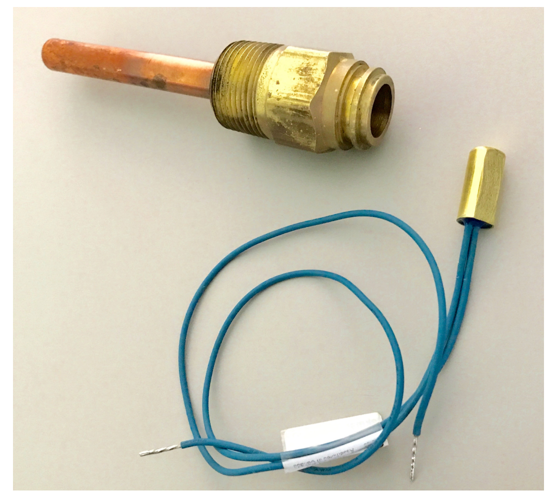
thermal storage tank

Simple way to built a sensor well





Thermal grease
in syringe:
$7, eBay



Honeywell
121371B
$15-25

Thanks for attending today's webinar

RHNY 2018 training opportunities

Check the Renewable Heat NY website (under training opportunities) for latest information on scheduled events.

WEBINARS:

May 10, 2018 1:00 PM Eastern time, 1.0 AIA continuing education credit
Title: Critical measurements to verify operation of biomass boiler systems (presented by Khaled Yousef P.E.)

Description: This webinar discusses instrumentation and measurement techniques to verify proper operation of biomass boilers. It covers lessons learned from measurement and verification work on a wide range of biomass heating systems.

September 20, 2018 1:00 PM Eastern time, 1.0 AIA continuing education credit
Title: Situations to Avoid with biomass boiler systems (presented by John Siegenthaler P.E.)

Description: This webinar discusses many lessons learned through plans review, on-site inspection, and monitoring a wide range of biomass boiler system. These lessons, when applied, can eliminate potential issues at the design stage, and thus save time and money during subsequent install and commissioning.

FULL DAY Training Workshops:

March 16, 2018 8:00 a.m. – 5:00 p.m., 7 AIA/PDH education credits
Cornell Cooperative Extension 615 Willow Avenue, Ithaca, NY 14850
https://www.regonline.com/registration/Checkin.aspx?EventID=2111891
call: 518-465-7085 X142

Fall (October) 2018 location and date TBA (Tentative Adirondacks)

Questions?

Credit(s) earned on completion of this course will be reported to AIA CES for AIA members. Certificates of Completion for both AIA members and non-AIA members are available upon request.

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

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