Integrating thermal storage with biomass boilers

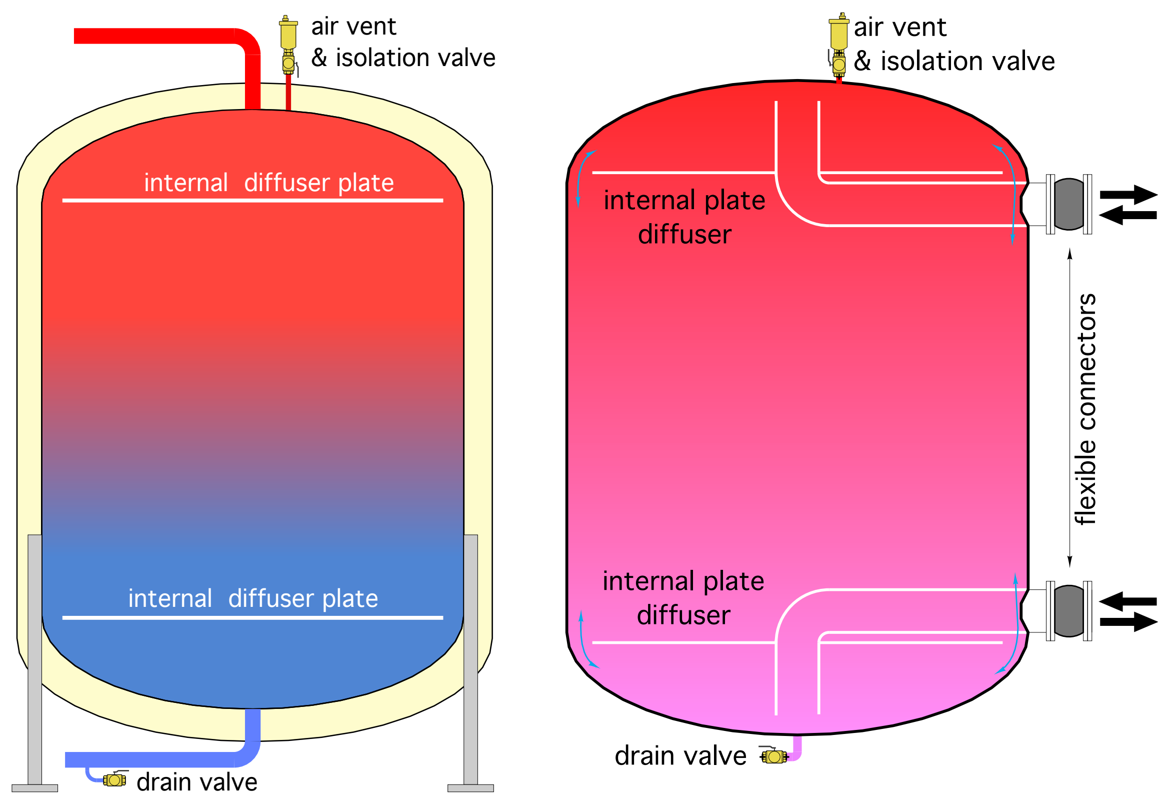
Webinar presented in support of
Renewable Heat NY

NYSERDA Sponsored

AIA approved course:
RHNYWEB22017
1.0 LU credits

presented by:

John Siegenthaler, P.E.
Appropriate Designs
Holland Patent, NY
www.hydronicpros.com



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

Integrating thermal storage with biomass boilers

RHNYWEB22017

John Siegenthaler, P.E.

September 12, 2017

Integrating thermal storage with biomass boilers

Course Description: This webinar explains how use of thermal storage enhances the operating characteristics of pellet-fired boilers and cordwood gasification boilers in residential and light commercial applications. It discusses how thermal storage should be sized, as well as optimal piping and control strategies to maximize the effectiveness of thermal storage. It also describes situations that should be avoided.

Learning Objectives:

1. Understand the need for thermal storage in biomass boiler systems.
2. Describe the importance of temperature stratification in thermal storage tanks.
3. Explain how "temperature stacking" control logic works in a pellet boiler system.
4. Describe different piping configurations for thermal storage tanks.

The full day training program: **Hydronics for High Efficiency Biomass Boilers** presents more in-depth discussion of many topics that are summarized in this webinar.

NEW YORK STATE OF OPPORTUNITY. | NYSERDA Sponsored

CONTINUING EDUCATION AIA

Why is thermal storage needed?

• Output from some biomass boilers (especially from wood gasification boilers) is often higher than current heating load. Excess heat needs to be temporarily “parked” in storage.

• *Allows the heating system to meet intermittent loads without firing the boiler, improving performance and longevity.*

• Prevents boiler short cycling during partial load conditions, (for both biomass and auxiliary boiler). **Cleaner burning / higher efficiency**

• Supplements boiler output during a period of high demand.

• May act as a heat sink for residual heat during power outage.

• Able to capture residual heat at boiler shut-down.

• Can also provide mass to stabilize domestic hot water production.

• With proper piping, tank can serve as hydraulic separator in multiple circulator systems.

• Can provide thermal storage for solar thermal input.

Water-based thermal storage options

1. unpressurized tanks
2. pressurized tanks

courtesy of Hydroflex

courtesy of American Solartechnics

courtesy of AHONA

Open (unpressurized) buffer tanks

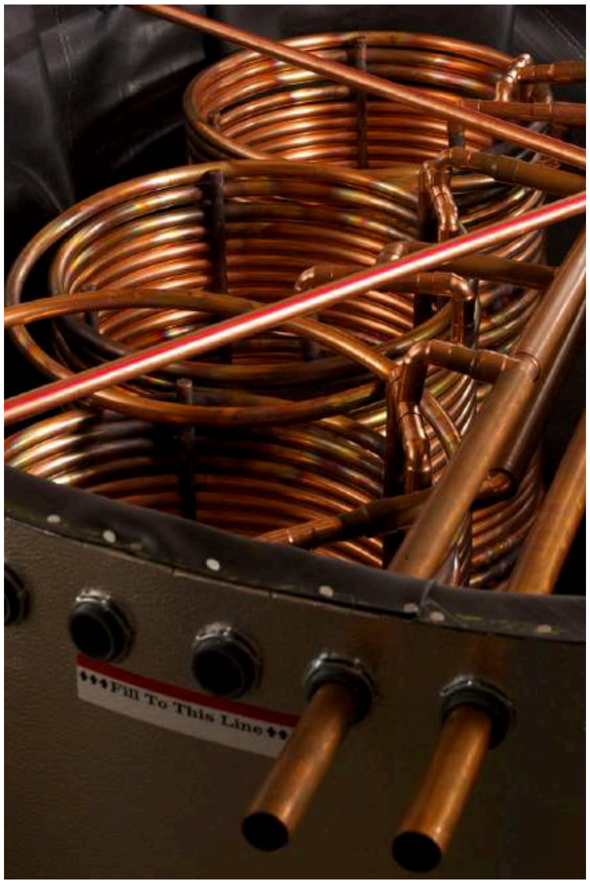
Considerations:

- Water will evaporate - water level must be monitored
- Air space above water accommodates water expansion
- Many open tanks are “knock down” construction and are assembled on site
- Typically lower cost ($/gallon) than pressurized tanks
- Requires one or more heat exchangers to interface with boiler or distribution system
- May require water treatment to control biological slime growth (use Fernox)
- Must use stainless steel or bronze circulators to handle open system water

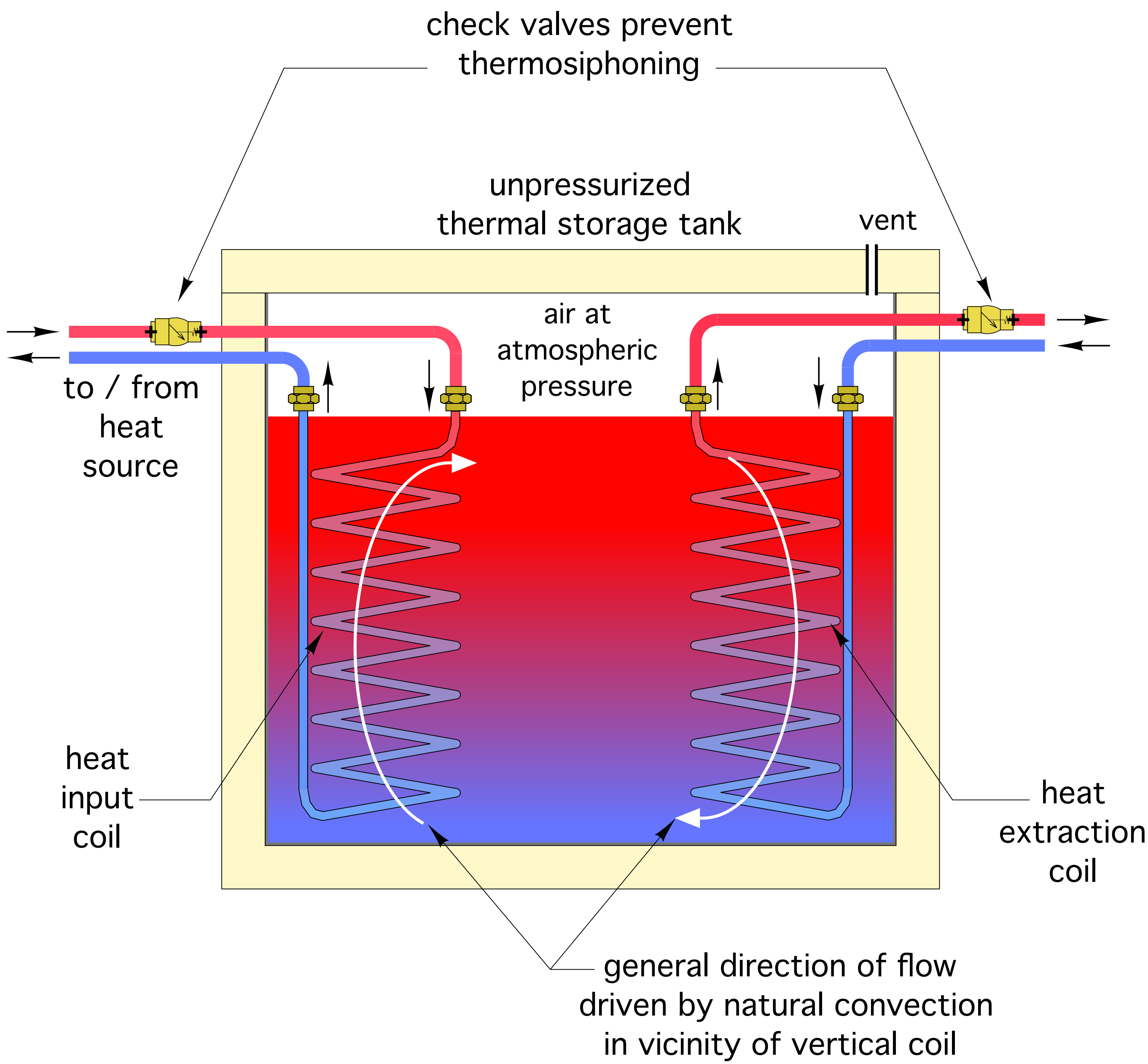
courtesy of American Solartechnics

courtesy of Hydroflex

- Flow direction should produce counterflow heat exchange
- Use check valves to prevent thermosiphoning



courtesy of Hydroflex



Closed/pressurized thermal storage tanks

courtesy of Caleffi North America

courtesy of Hydronic Specialty Supply

courtesy of Taco

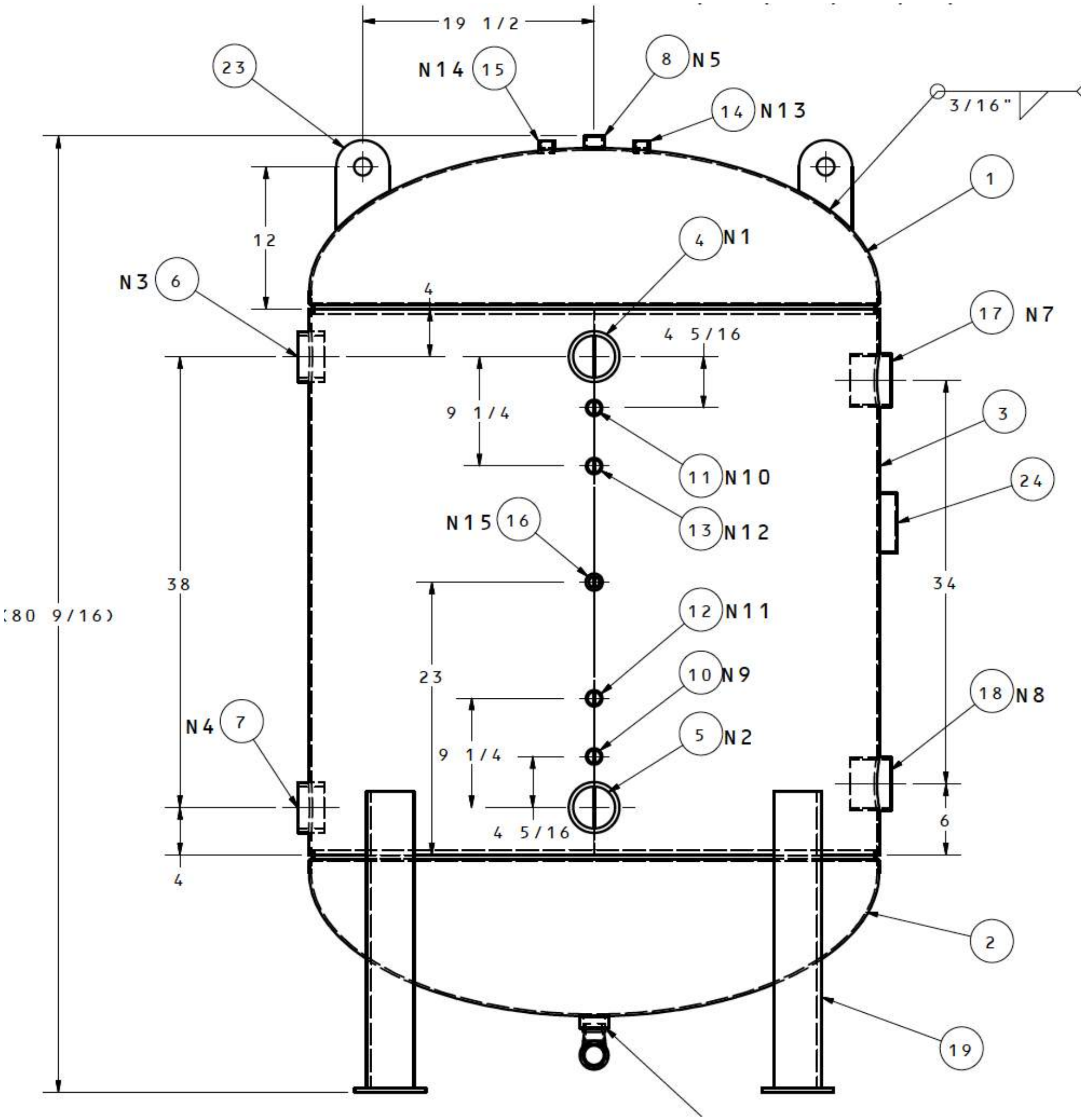
Examples of medium capacity ASME thermal storage tanks

Hydronic Specialty Supply
210 gallon, ASME
flat top & bottom

With 4+" of Spray
polyurethane insulation +
intumescent coating

Hydronic Specialty Supply
360 gallon, ASME
flat top & bottom

Examples of large capacity ASME thermal storage tanks

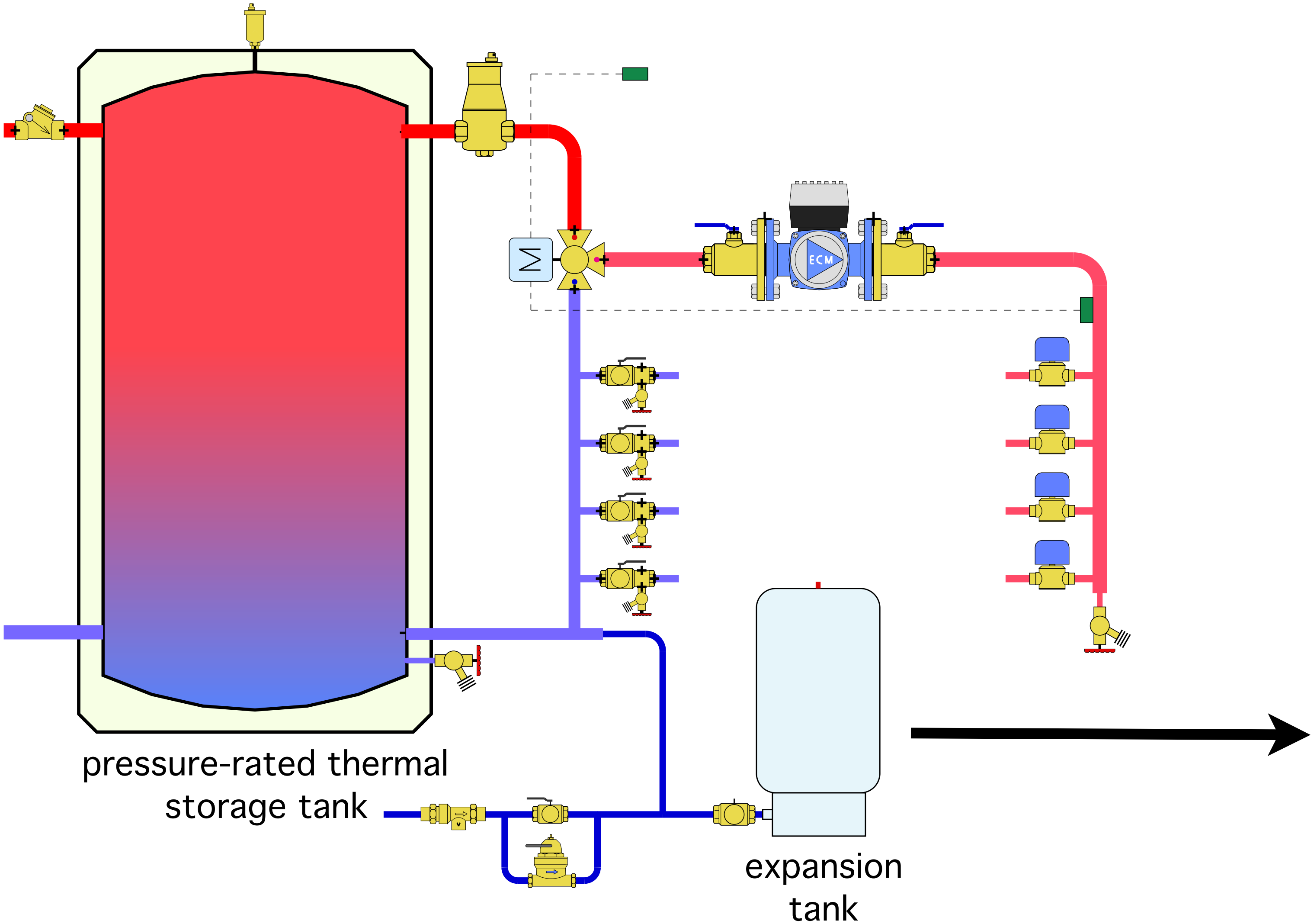


Troy Boiler Works

4000 gallon ASME tank, site insulated

Be sure tank will fit in mechanical room...

Large pressurized storage requires larger expansion tanks



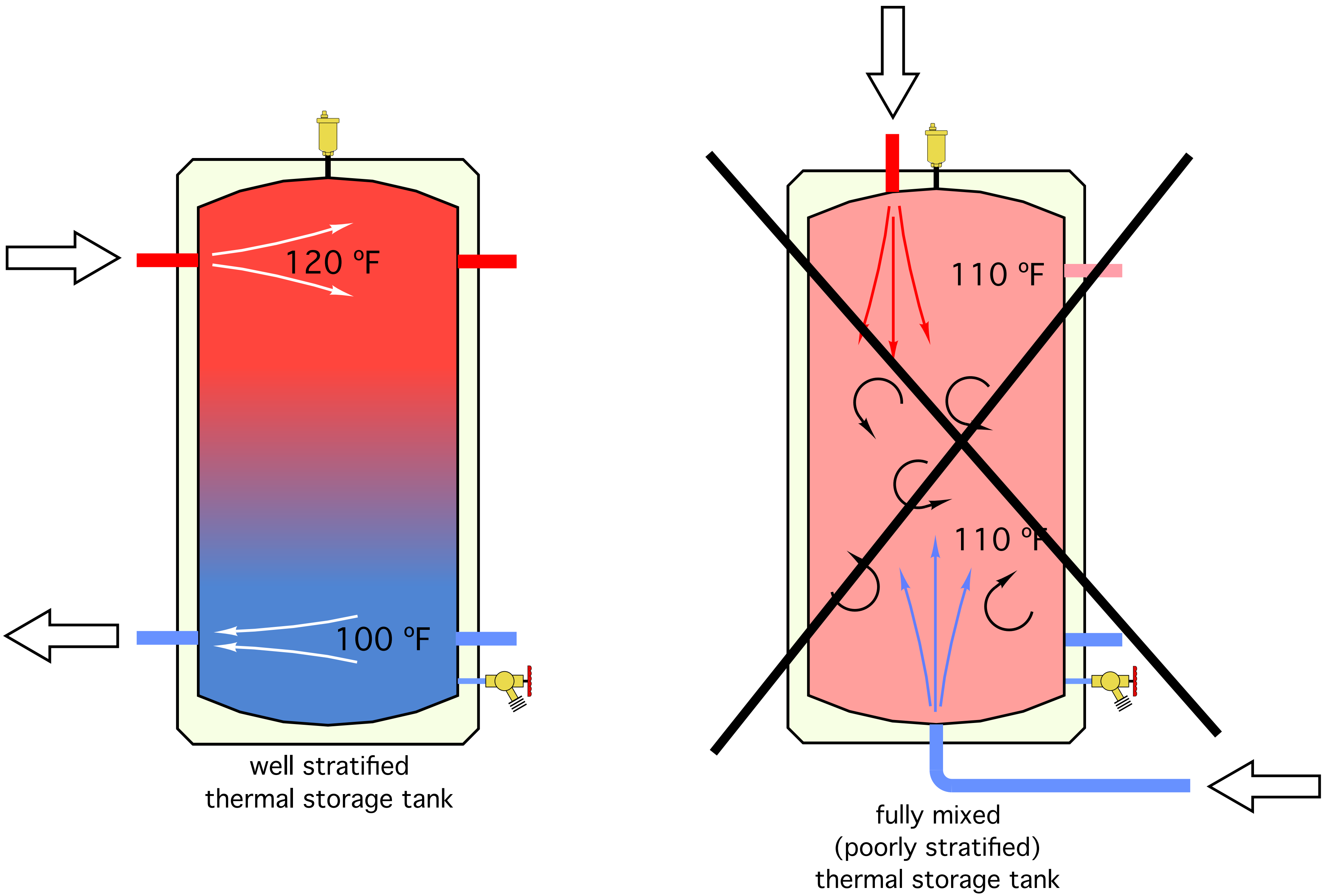
courtesy of Amtrol

First pass estimate:

Expansion tank volume = 10% of thermal storage volume.

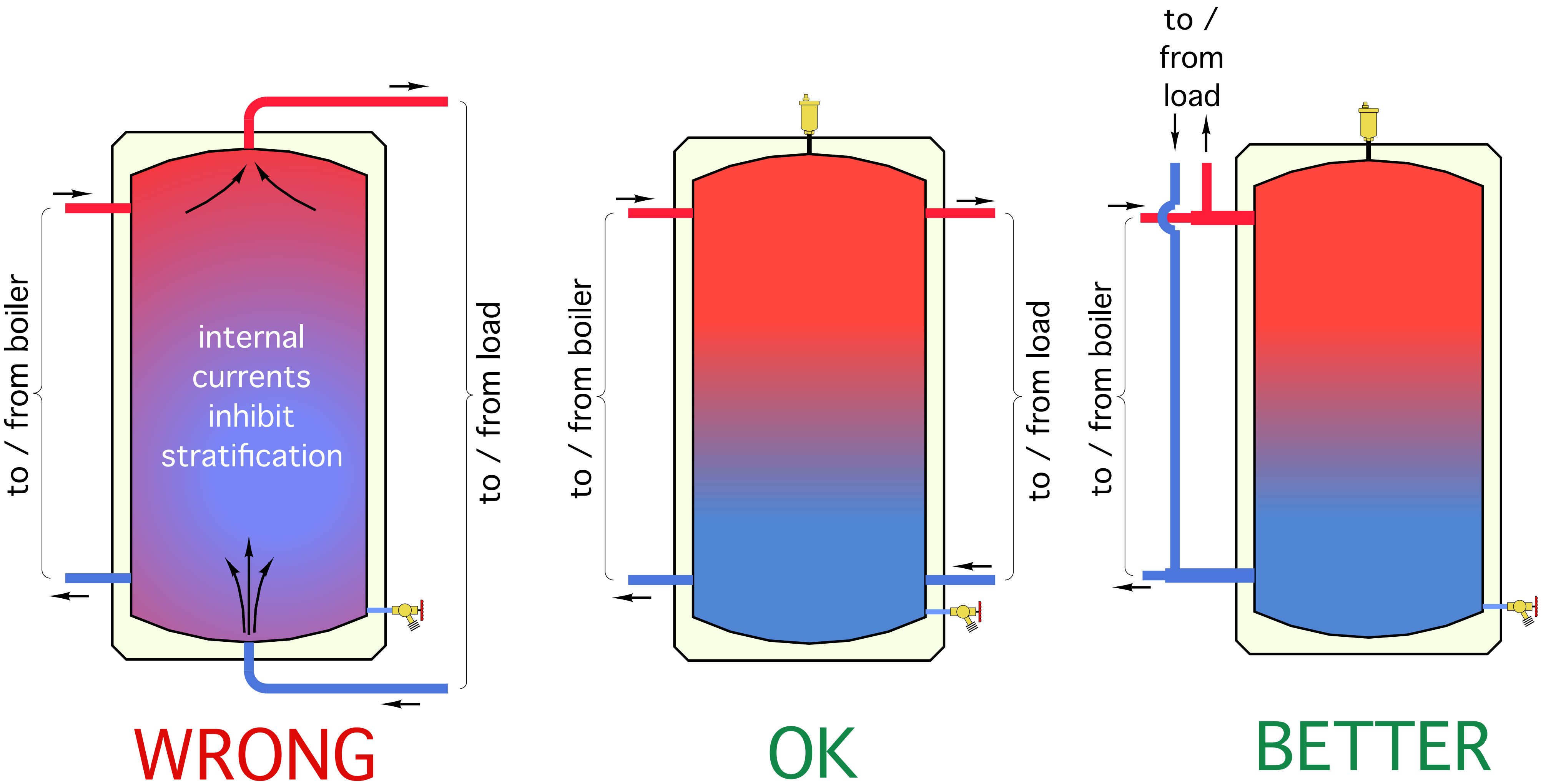
Stratification in thermal storage is DESIREABLE

Good temperature stratification preserves the "**quality**" (Exergy)of the heat available from the tank.

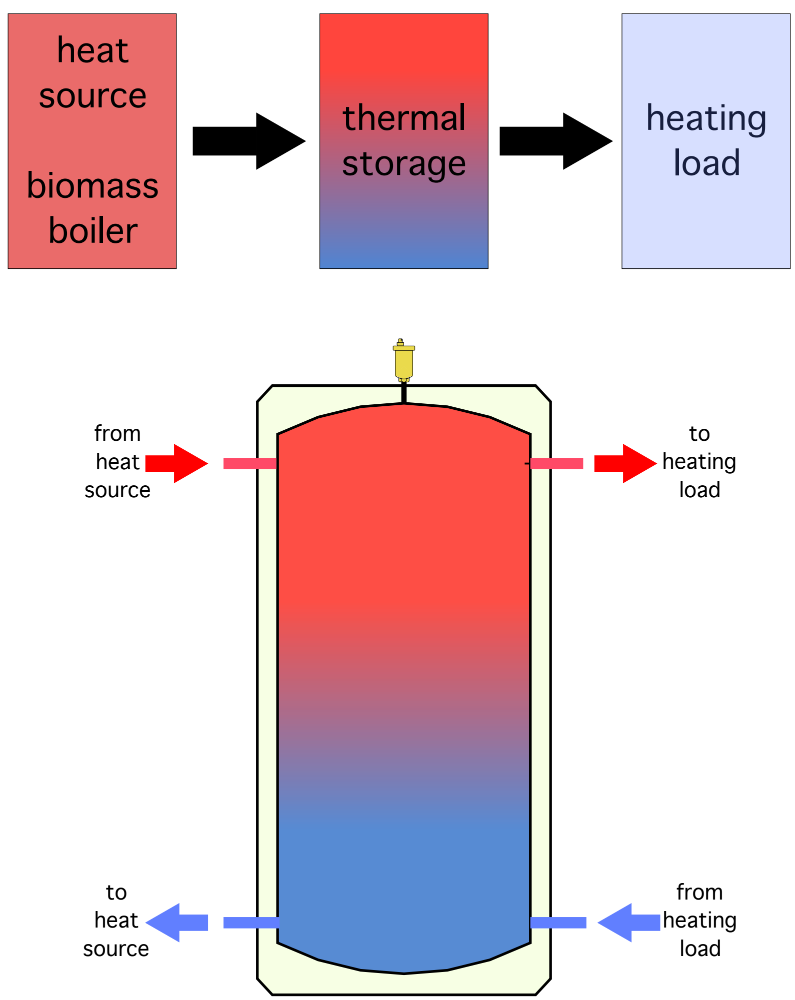


Tanks designed for good stratification

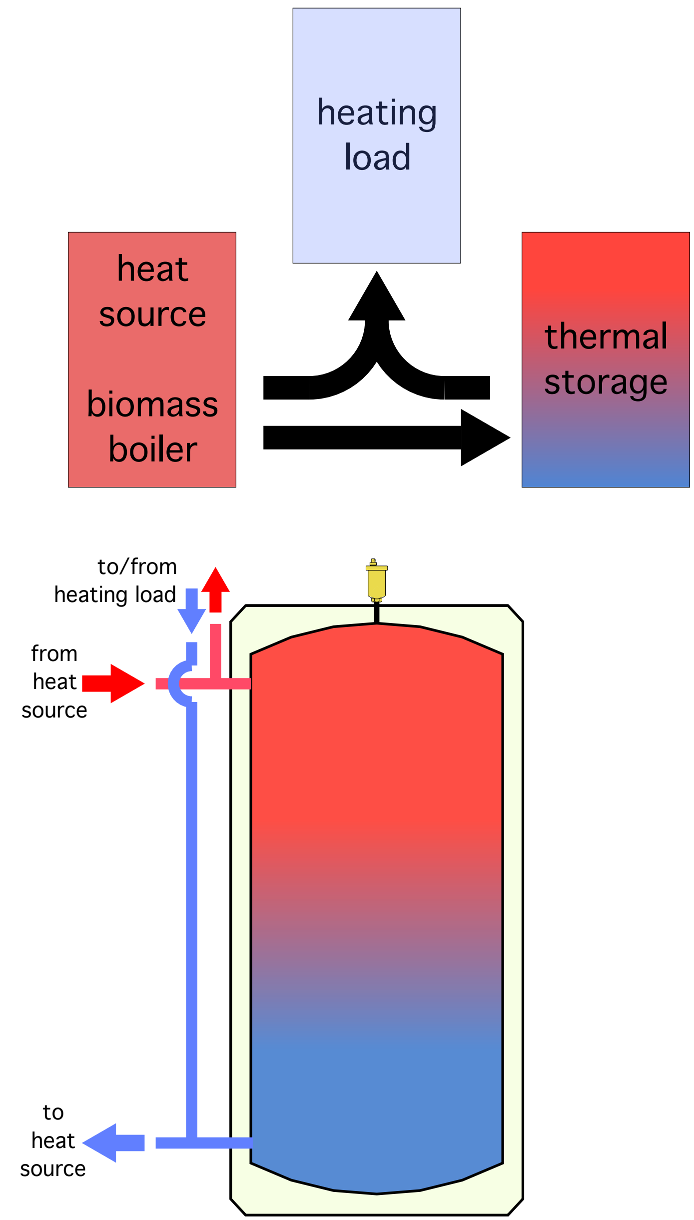
- All ingoing or exiting flow should be horizontal.



“2-pipe” versus “4-pipe buffer tank piping

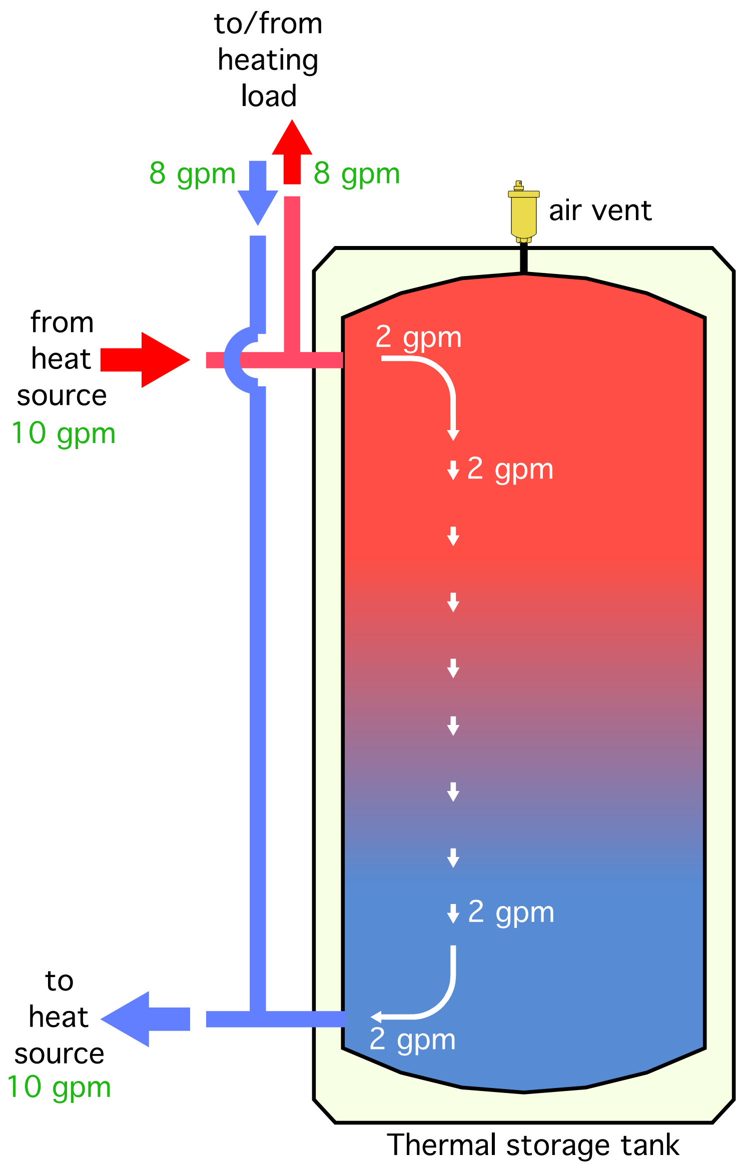


4-pipe configuration

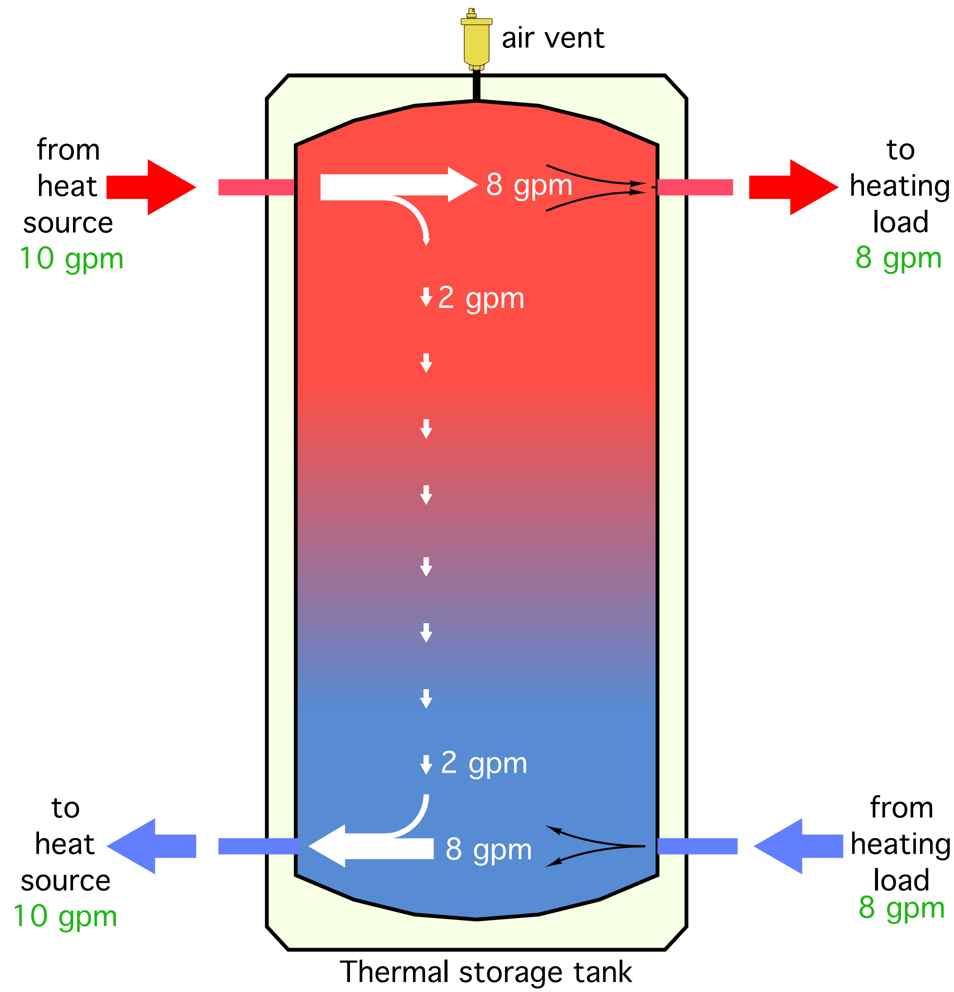


2-pipe configuration

“2-pipe” versus “4-pipe buffer tank piping



2-pipe configuration



4-pipe configuration

Tanks designed for good stratification

- **All ingoing or exiting flow should be horizontal.**

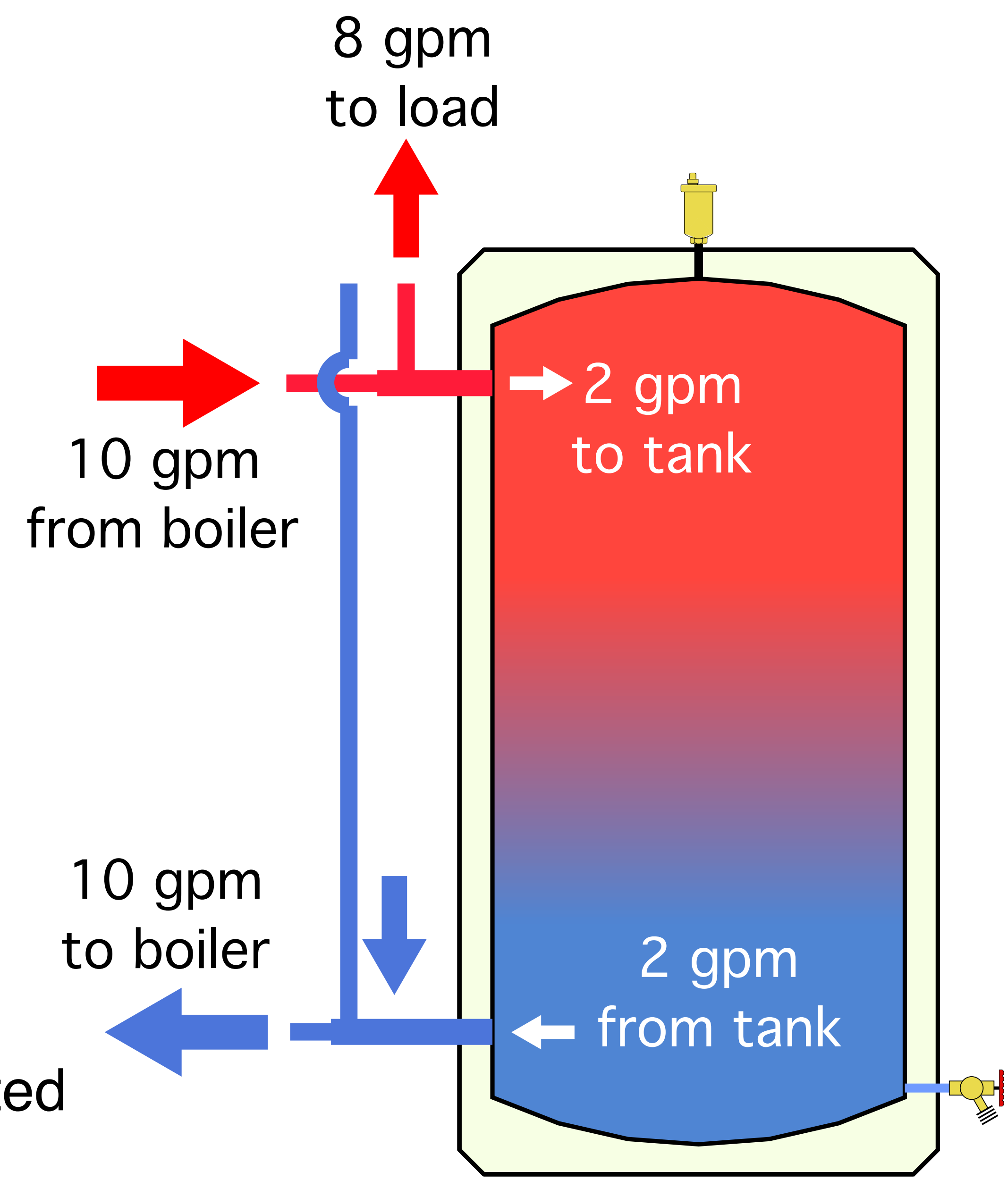
- Flow into tank = flow from boiler minus flow to load

- Lower flow velocities into & out of tank enhance temperature stratification.

- Allows rapid heat delivery to load during recovery from setback or startup.

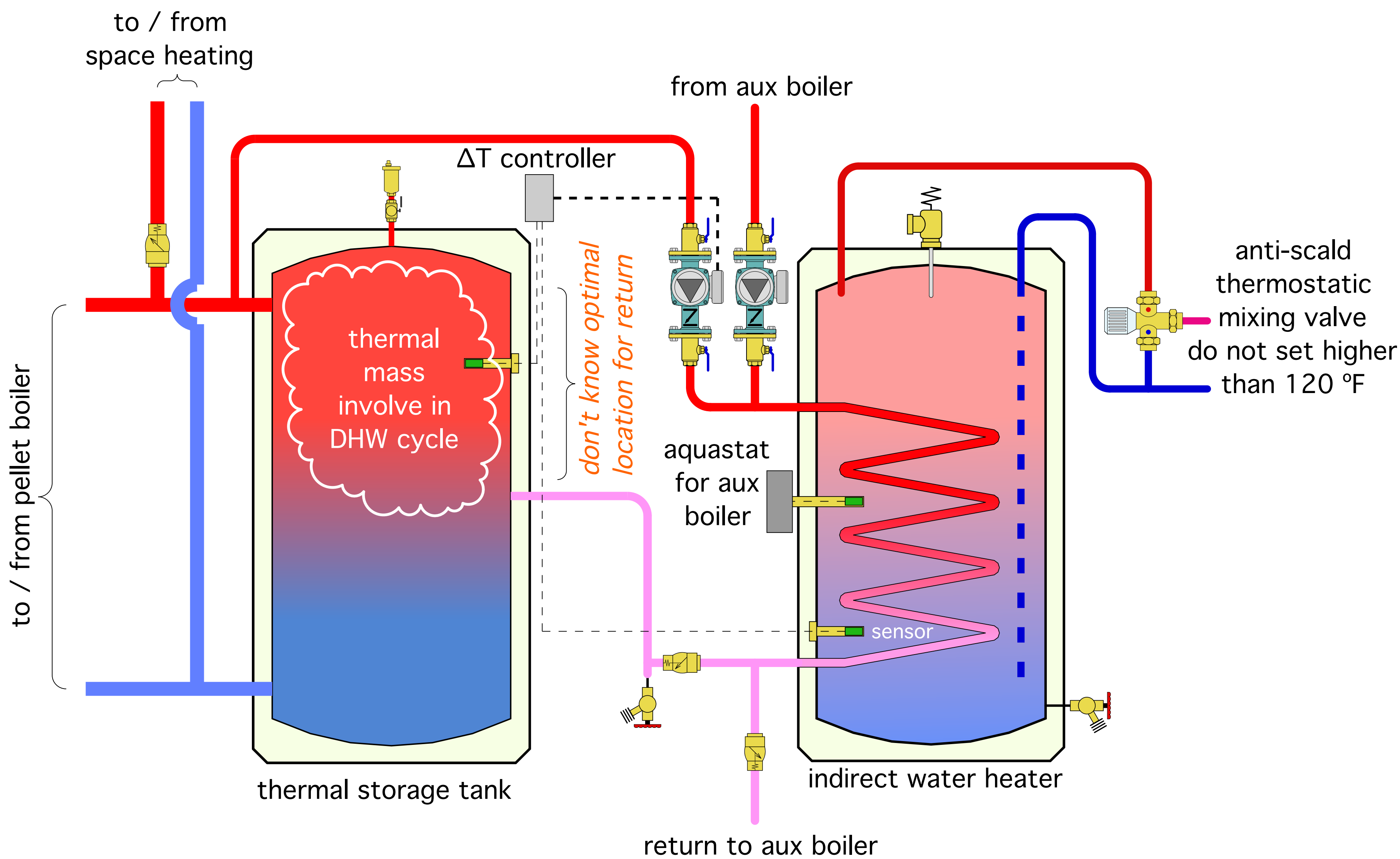
- Keep load connections close to tank, & use generous pipe sizing to tank connections, which provides hydraulic separation.

- Other side of tank can be connected for on-demand DHW subassembly.

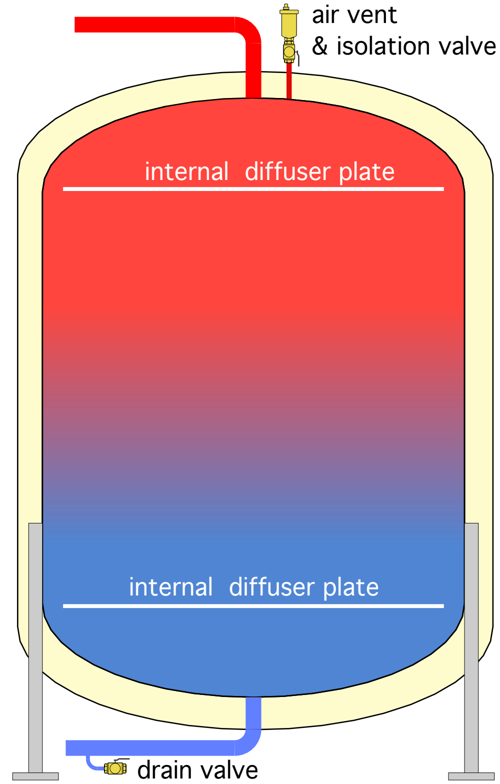


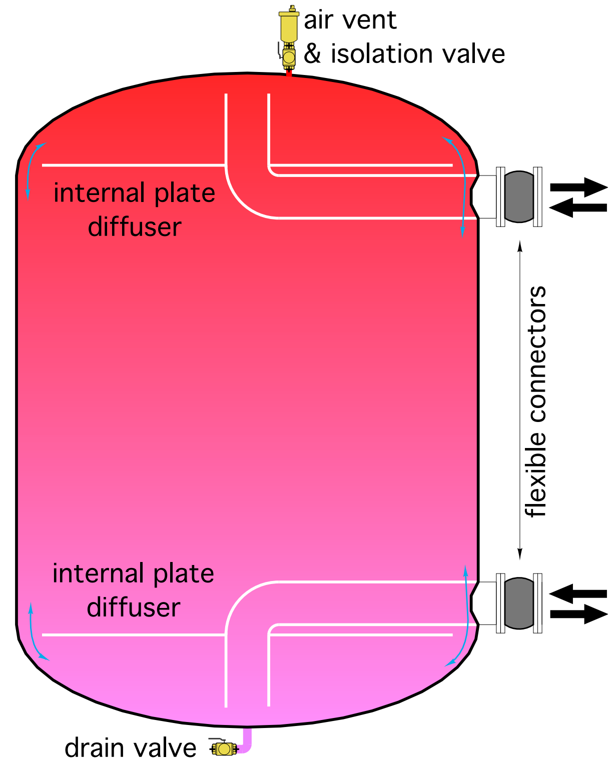
3-pipe tank configuration

A “3-pipe” configuration forces water returning from load to pass through thermal storage tank under all conditions. Good when an indirect water heater is used.



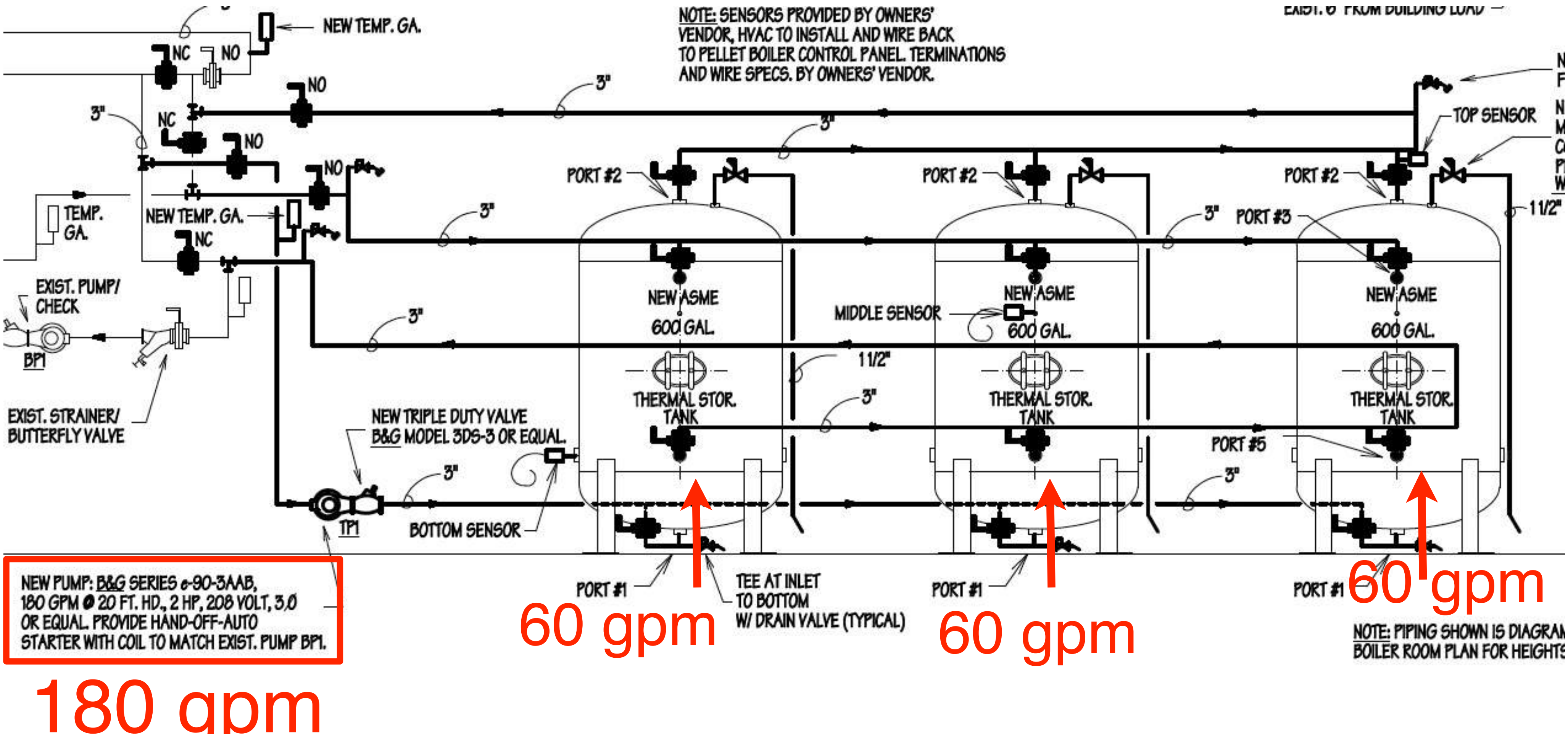
Design diffusers to access the full tank volume





Baffle plate being welded into tank head & base shell at Troy Boiler Works

Three, 600 gallon ASME tanks for storage in pellet boiler system.



This piping will destroy stratification within the tank(s)

Multiple Storage Tank Arrays

Use of multiple smaller storage tanks.

Consider the surface to volume ratio:

For a 119 gallons tank w/ h/d=3, d=22.7", h=68"

For a 119 gallons tank w/ h/d=3, A= 5659in² = 39.3 ft²

$$\left(\frac{S}{V}\right)_{4x119} = \frac{4(39.3)}{4(119)} = 0.33\frac{ft^2}{gallon}$$

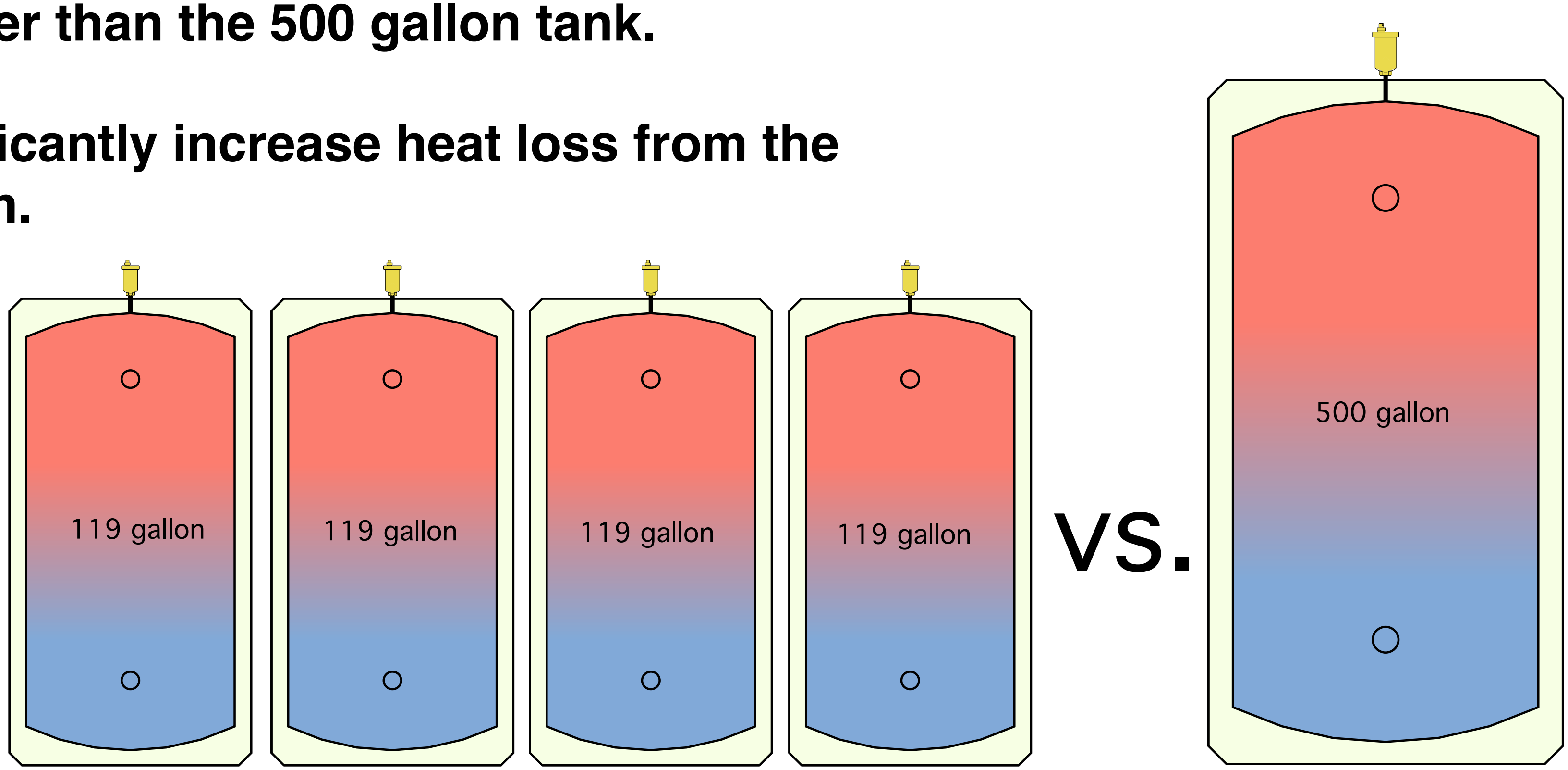
For a 500 gallons tank w/ h/d=3, d=36.6", h=109.8"

For a 500 gallons tank w/ h/d=3, A= 14728in² = 102.3 ft²

$$\left(\frac{S}{V}\right)_{500} = \frac{102.3}{500} = 0.205\frac{ft^2}{gallon}$$

In this case, the 4 smaller (119 gallon) tanks have a S/V ratio 61% higher than the 500 gallon tank.

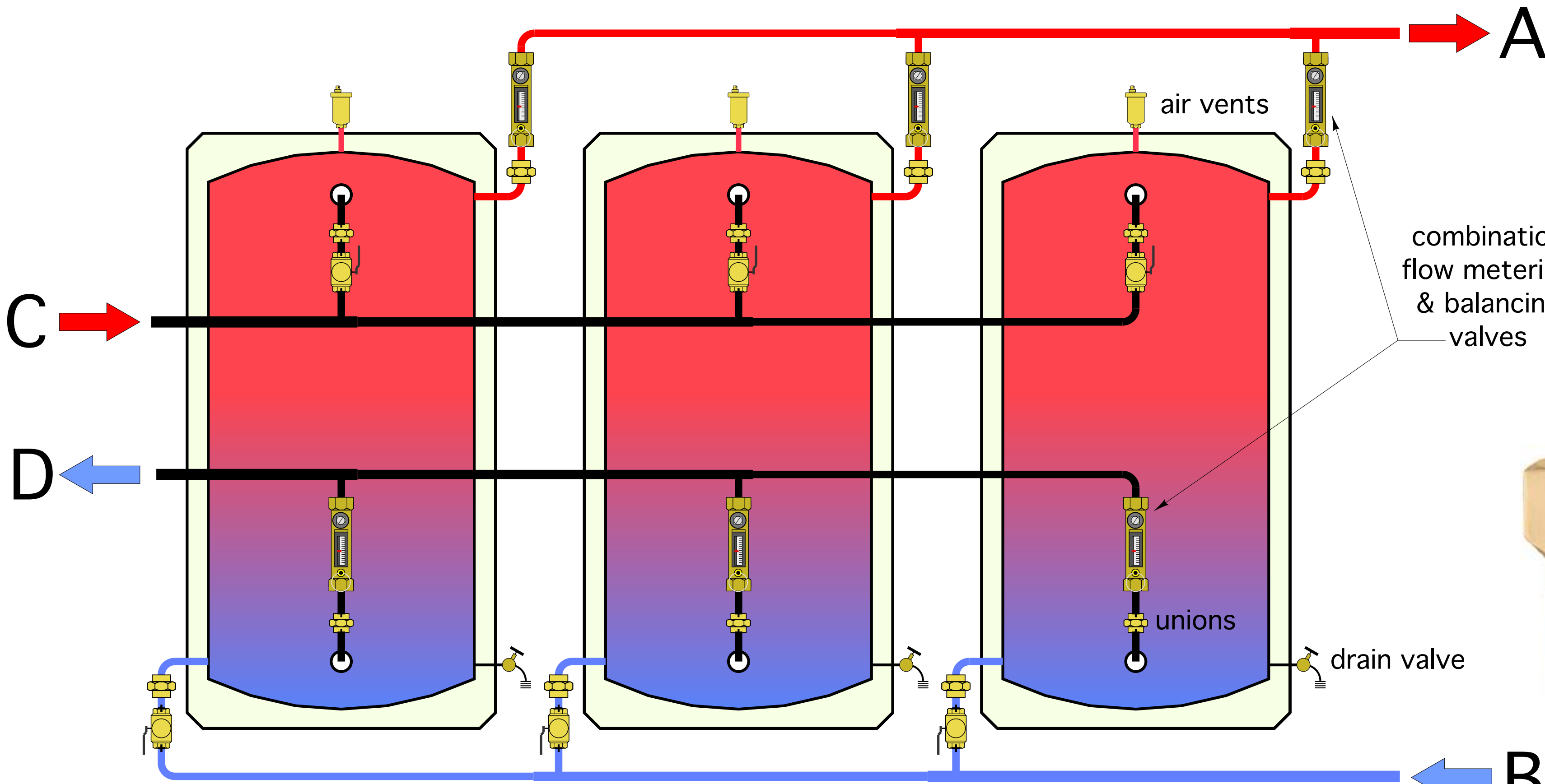
This will significantly increase heat loss from the storage system.



Piping to ensure balanced flow in multiple tanks

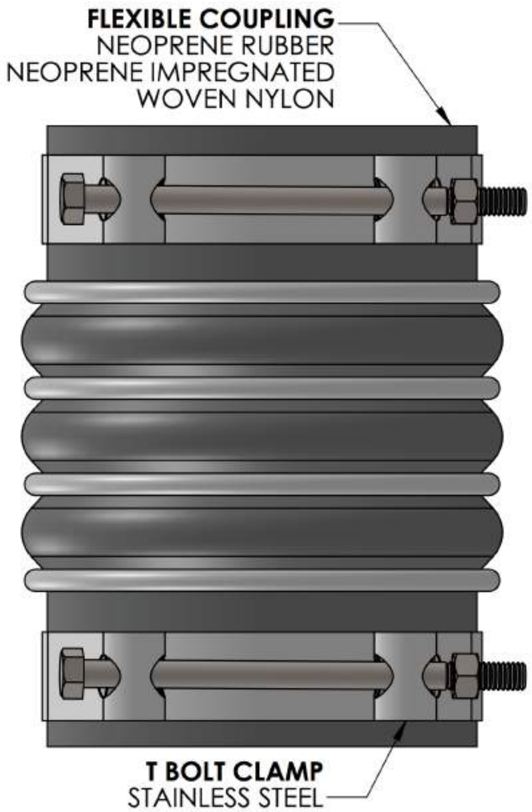
If direct return piping is used always install balancing valves

Be sure piping allows for tanks to be individually isolated and removed if necessary.



courtesy of Caleffi

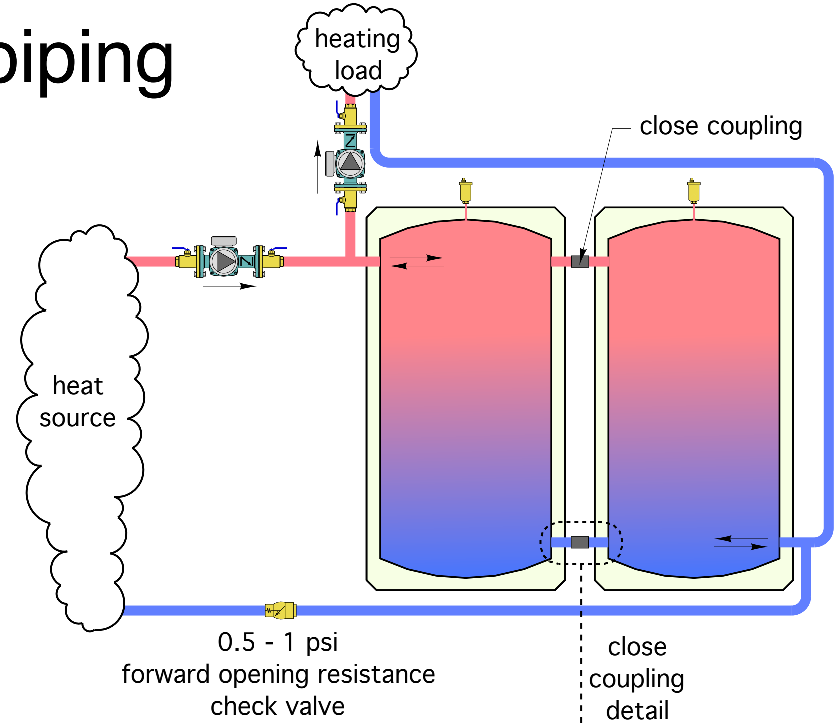
Hybrid parallel / series tank piping

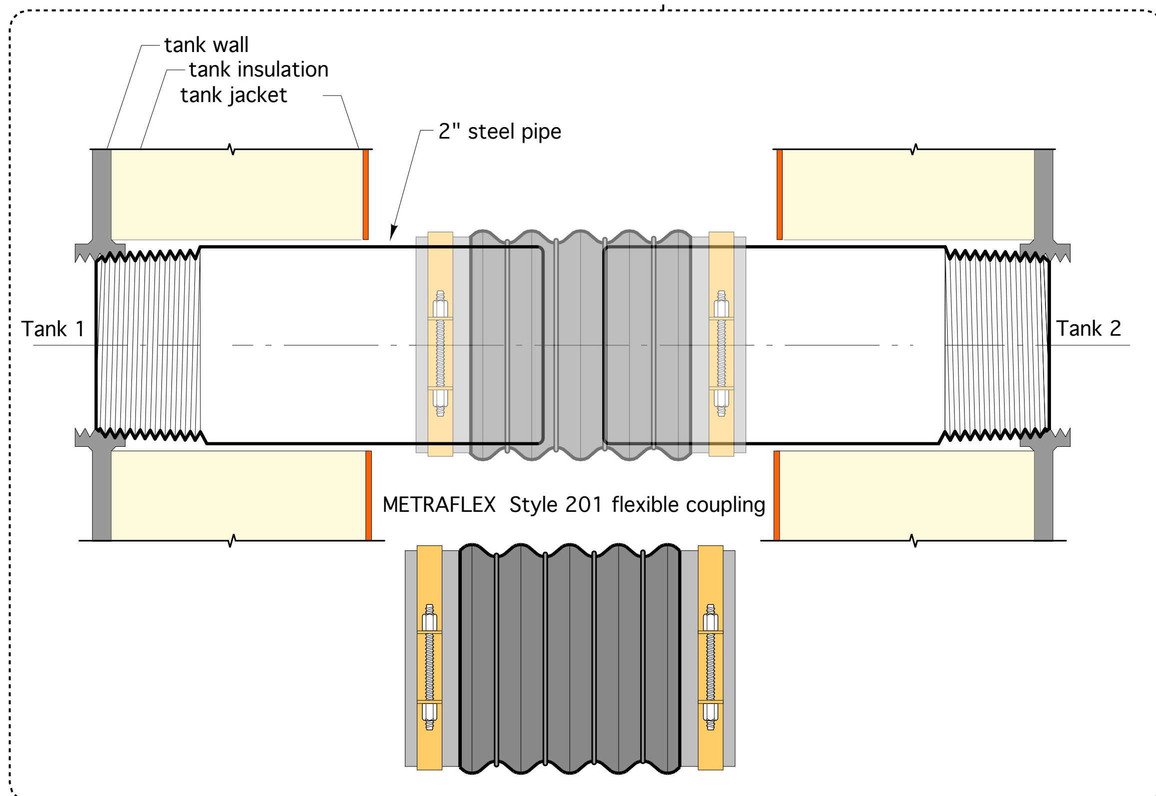


Metraflex Style 201 coupling

Rated to 225 °F / 75 psi

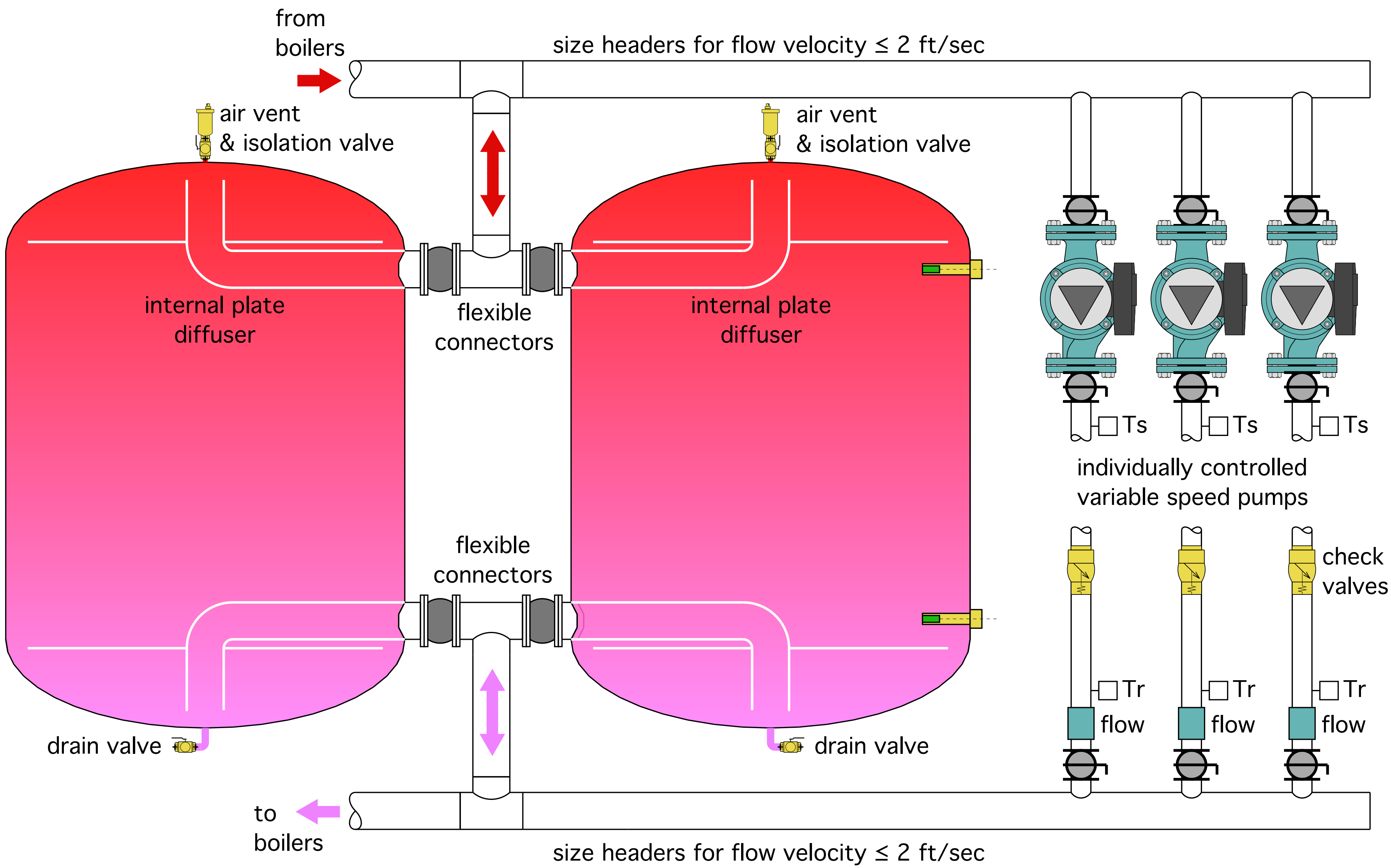
for pipe sizes 2” -12”





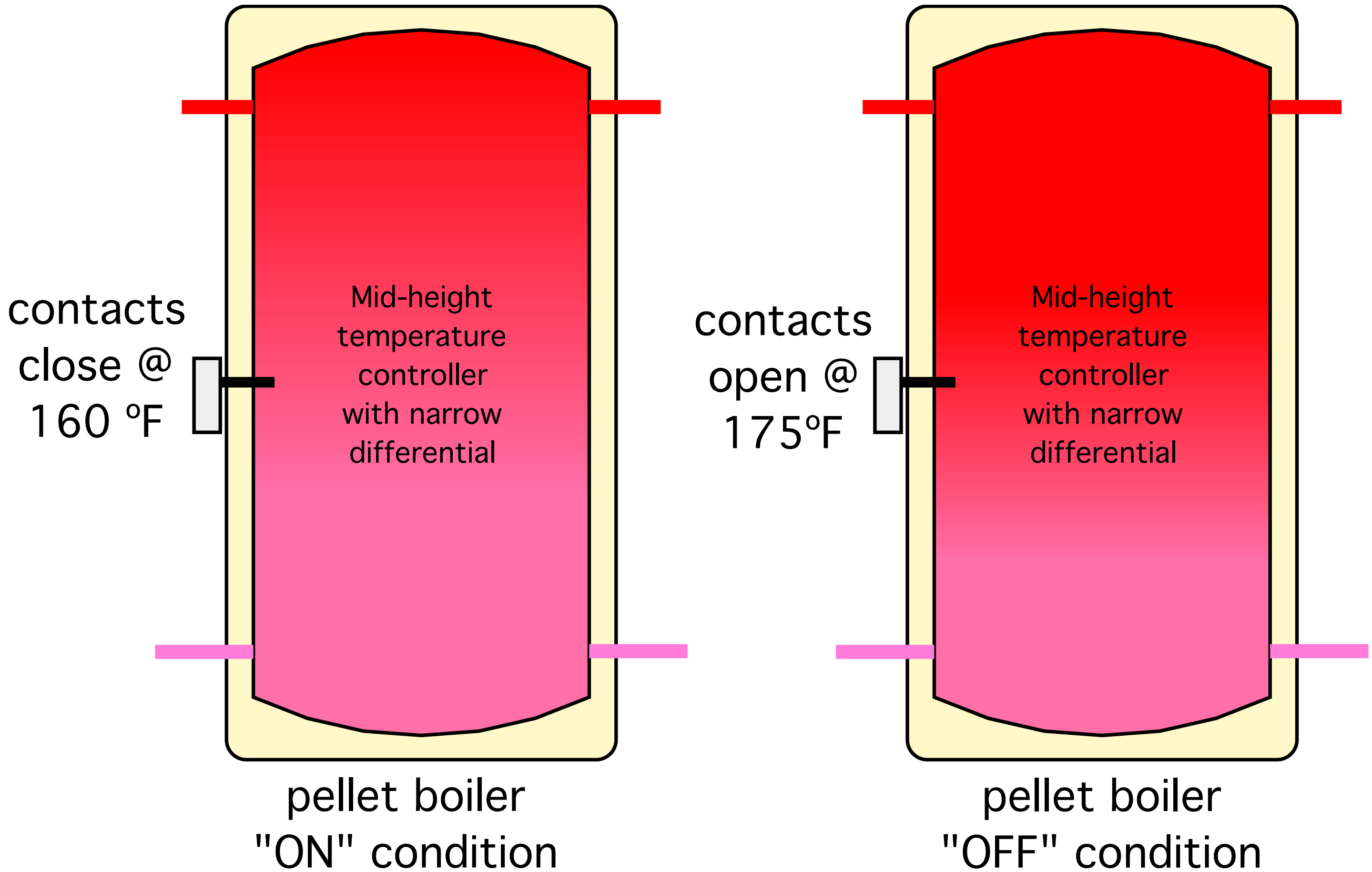
2 tanks in “close coupled” configuration

3 independently control variable speed “injection pumps” control flow to 3 loads



Temperature Stacking in Thermal Storage Tanks

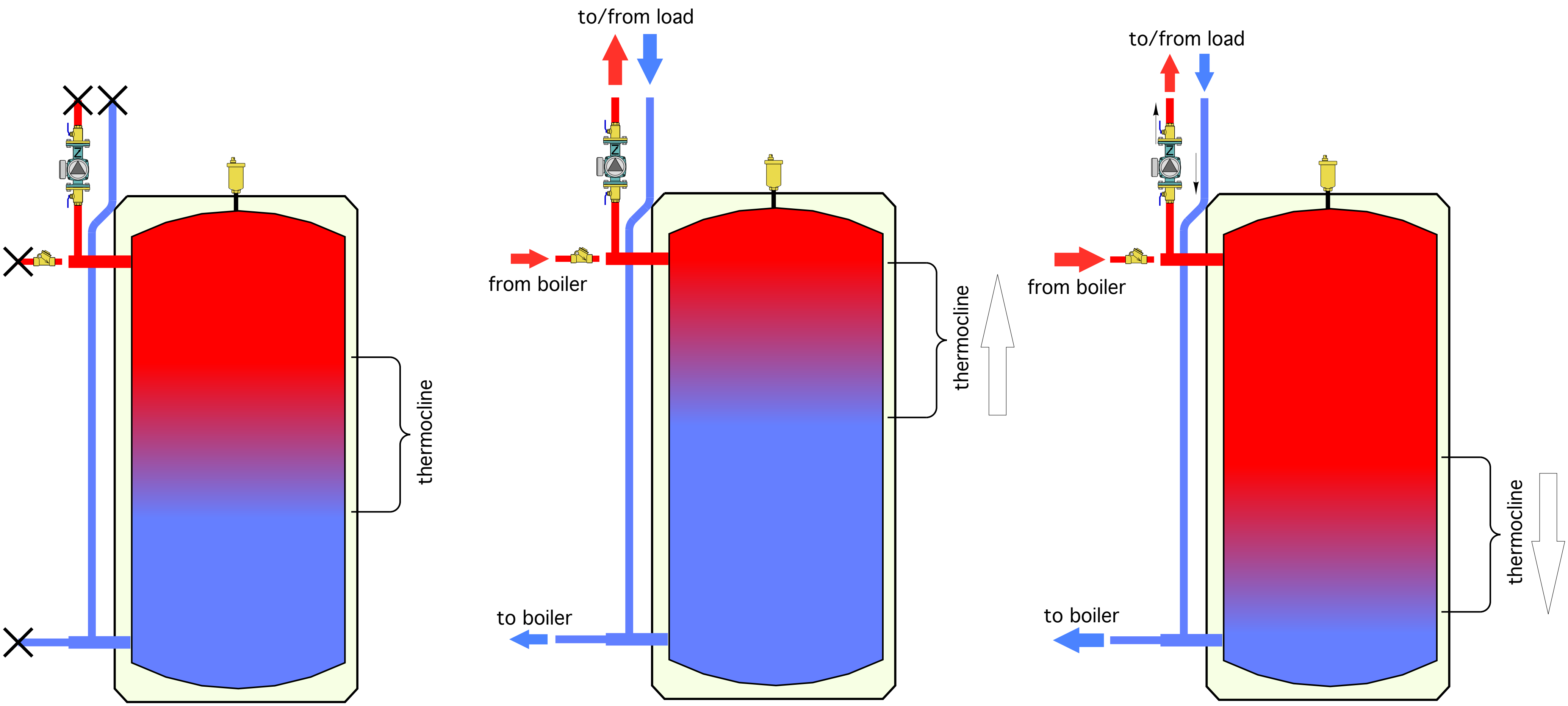
Pellet boiler controlled from single temperature measurement with narrow differential



- Problem is exasperated by high temperature heat emitters
- Problem is exasperated by lack of outdoor reset for boiler “ON” criteria
- Tank is expensive wide spot in pipe, but can provide hydraulic separation

Thermocline movement in tank

Indicates relative energy flow between boiler and load.

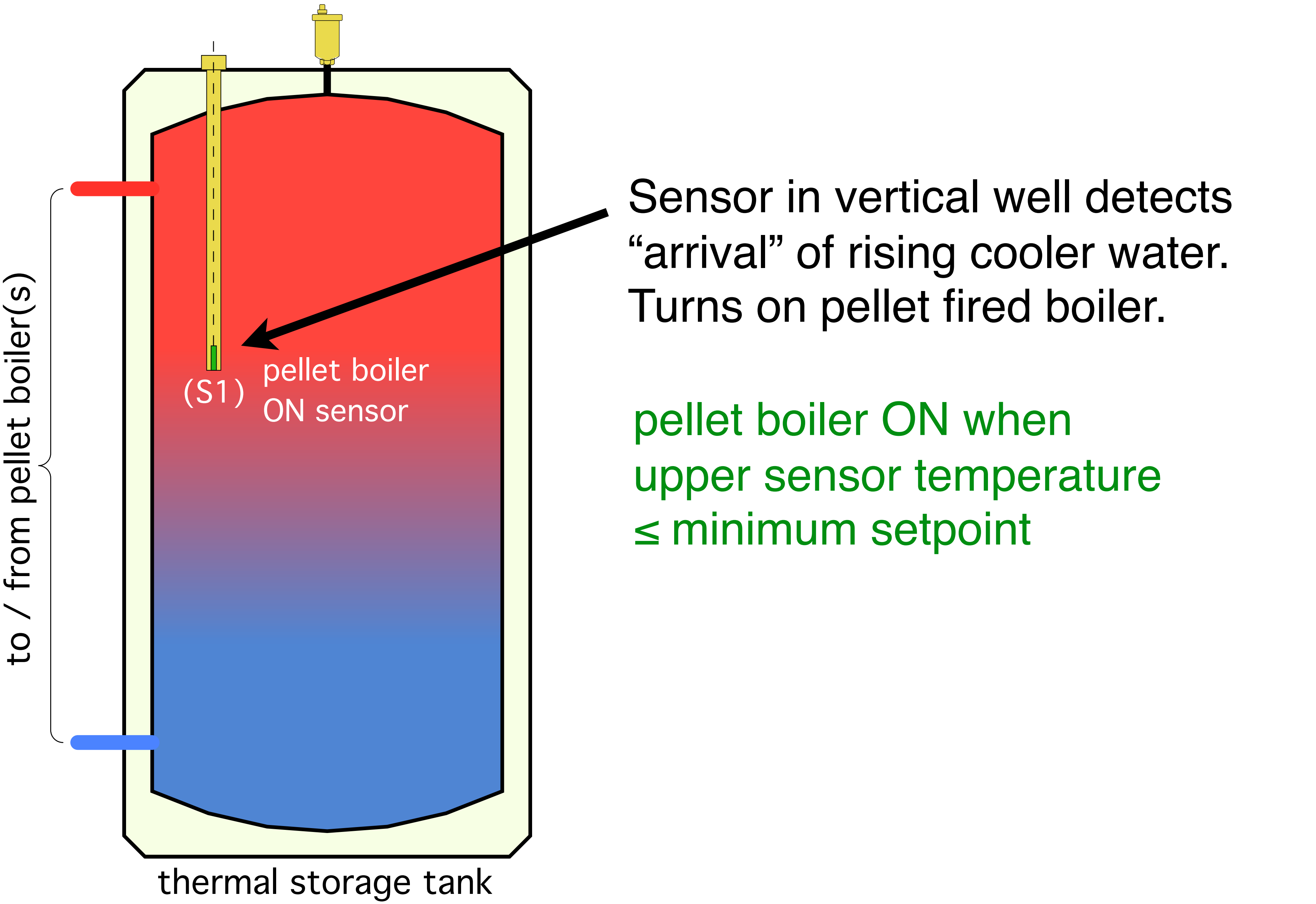


tank at rest. No flow from boiler or to load

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

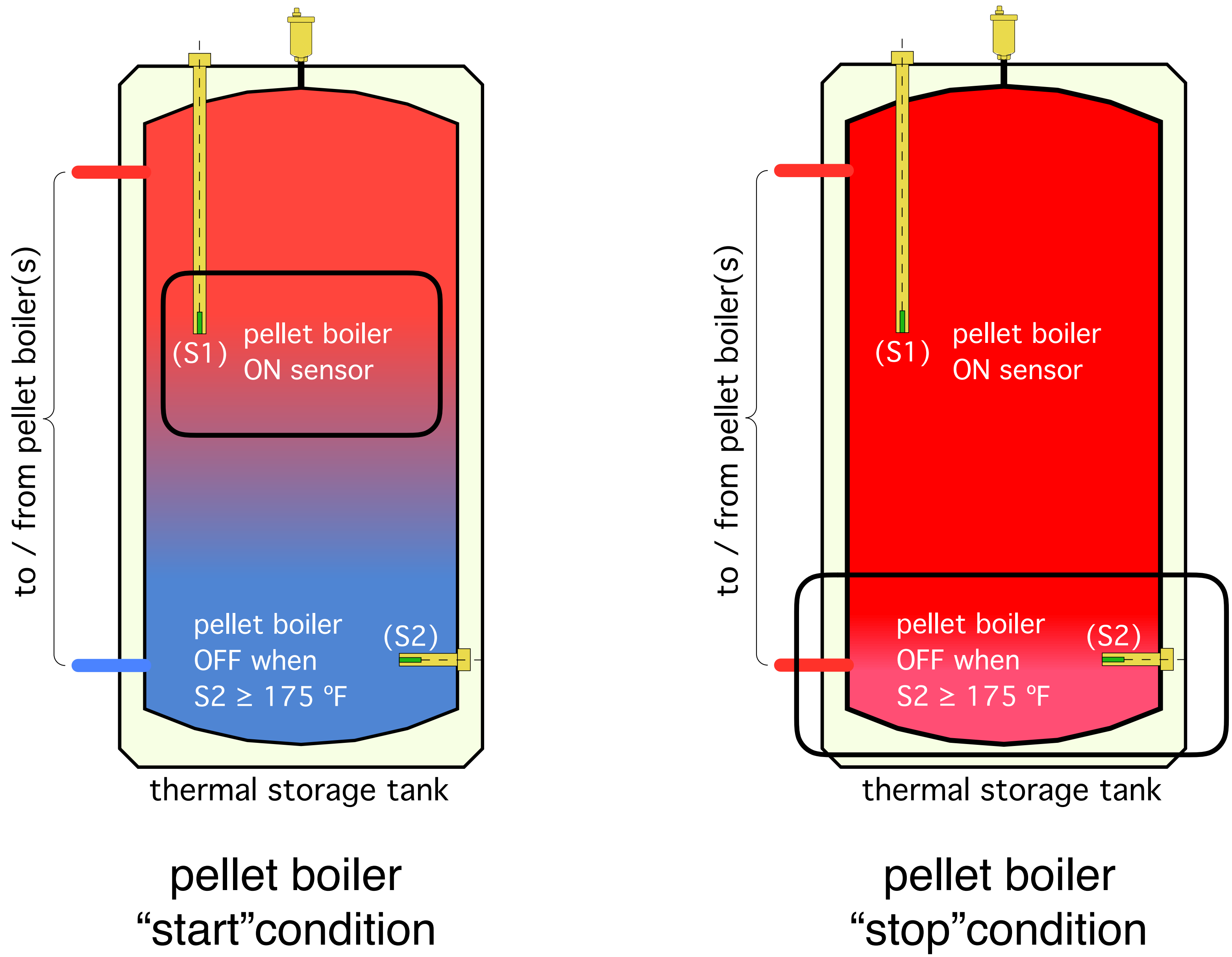
load extracting heat at rate < rate of heat output from boiler.
Thermocline moves down

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



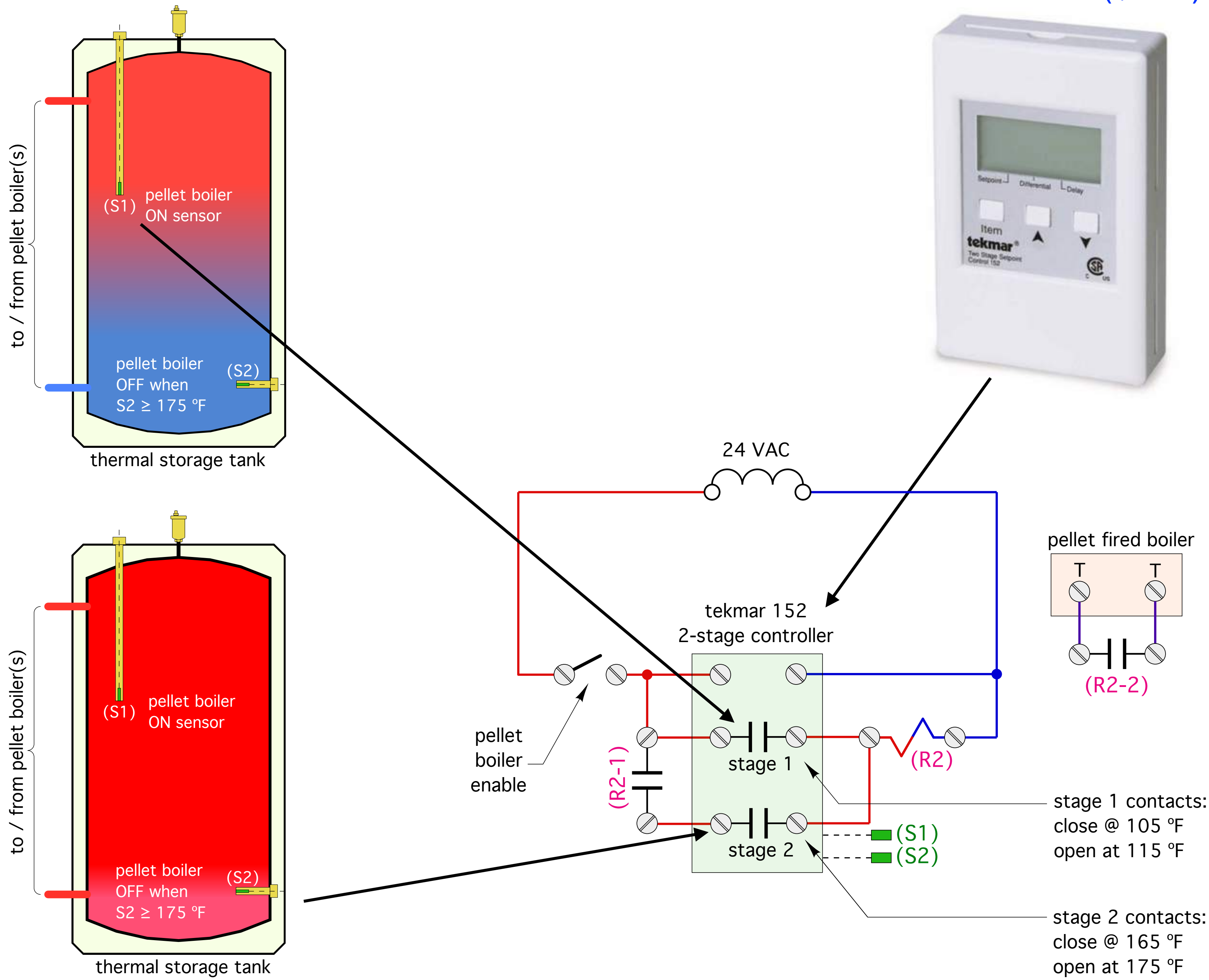
Temperature stacking

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

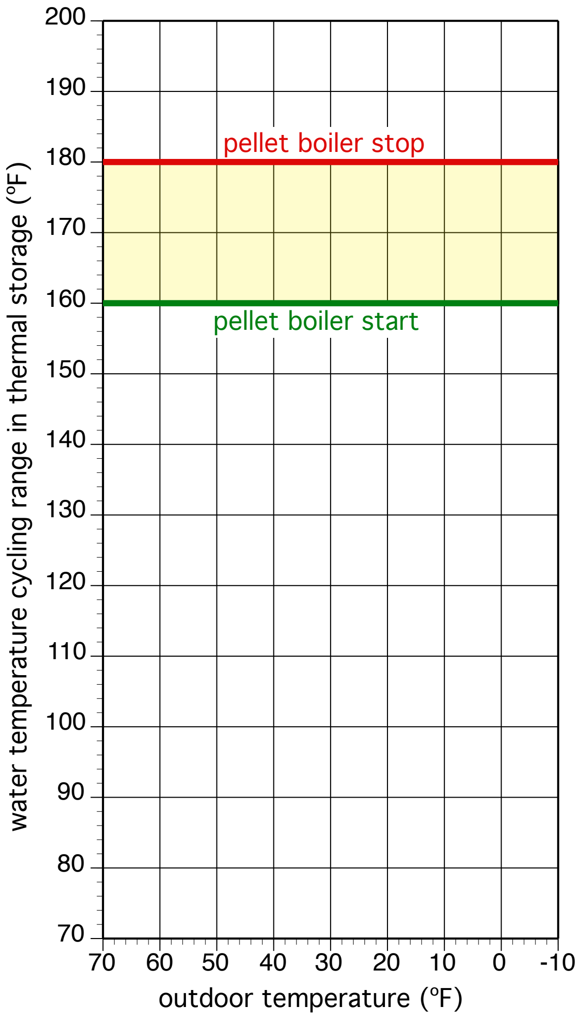


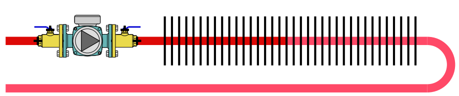
Temperature stacking *(using 2 setpoint temperatures)*

tekmar 152: ($217)



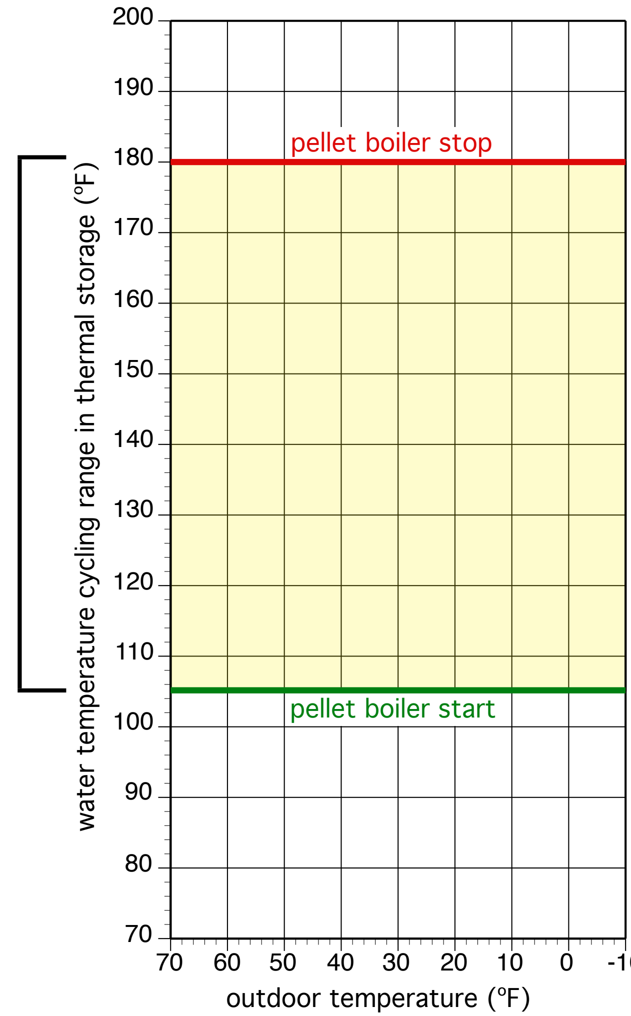
Temperature cycling range of storage is high dependent on the type of heat emitters used.

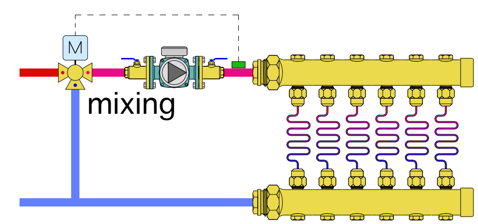




- HIGH temperature heat emitters
- No outdoor reset control of supply water temperature

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

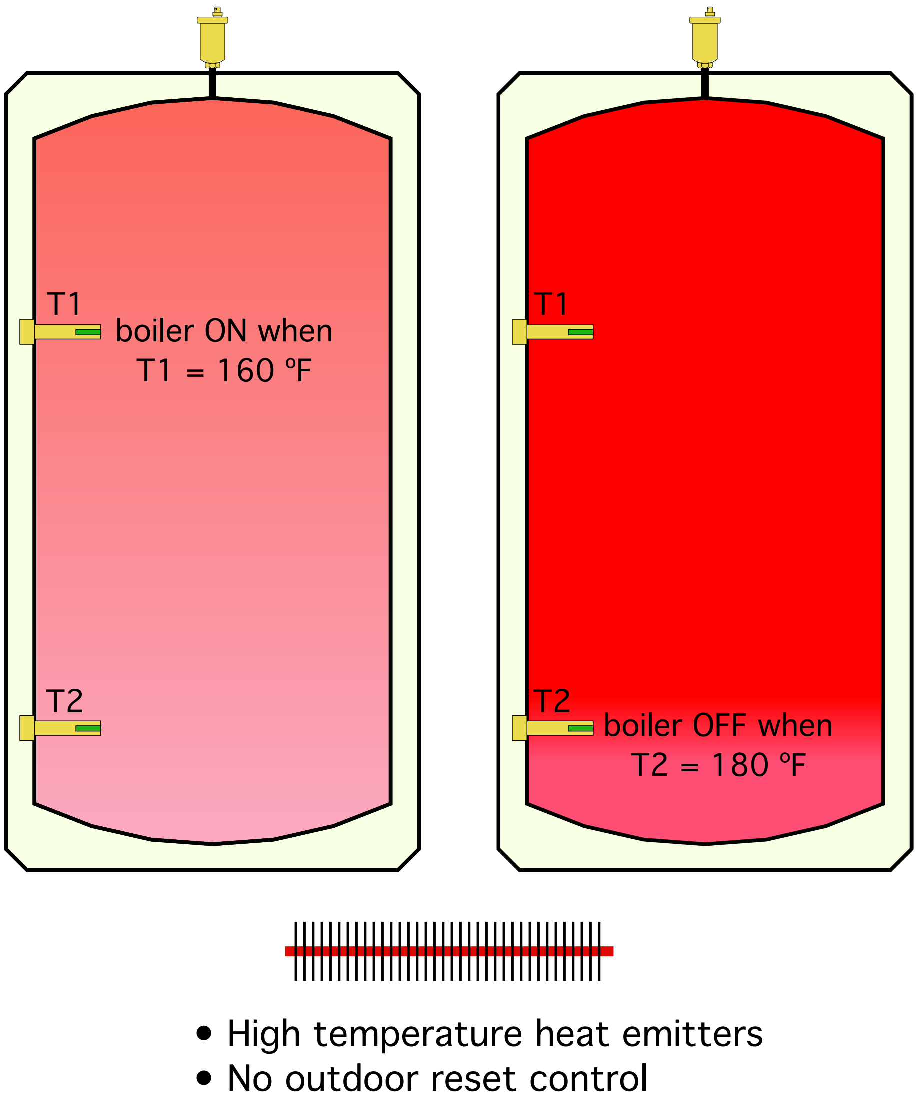


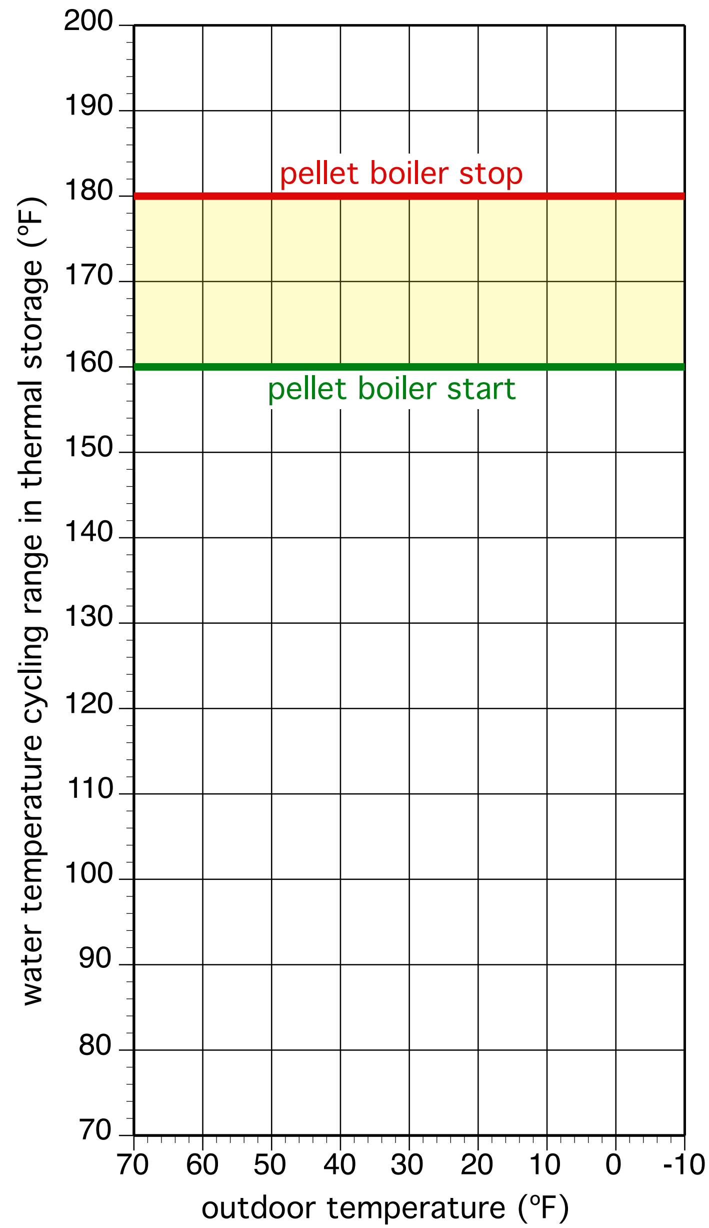


- LOW temperature heat emitters
- No outdoor reset control of supply water temperature

• **High temperature heat emitters**

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

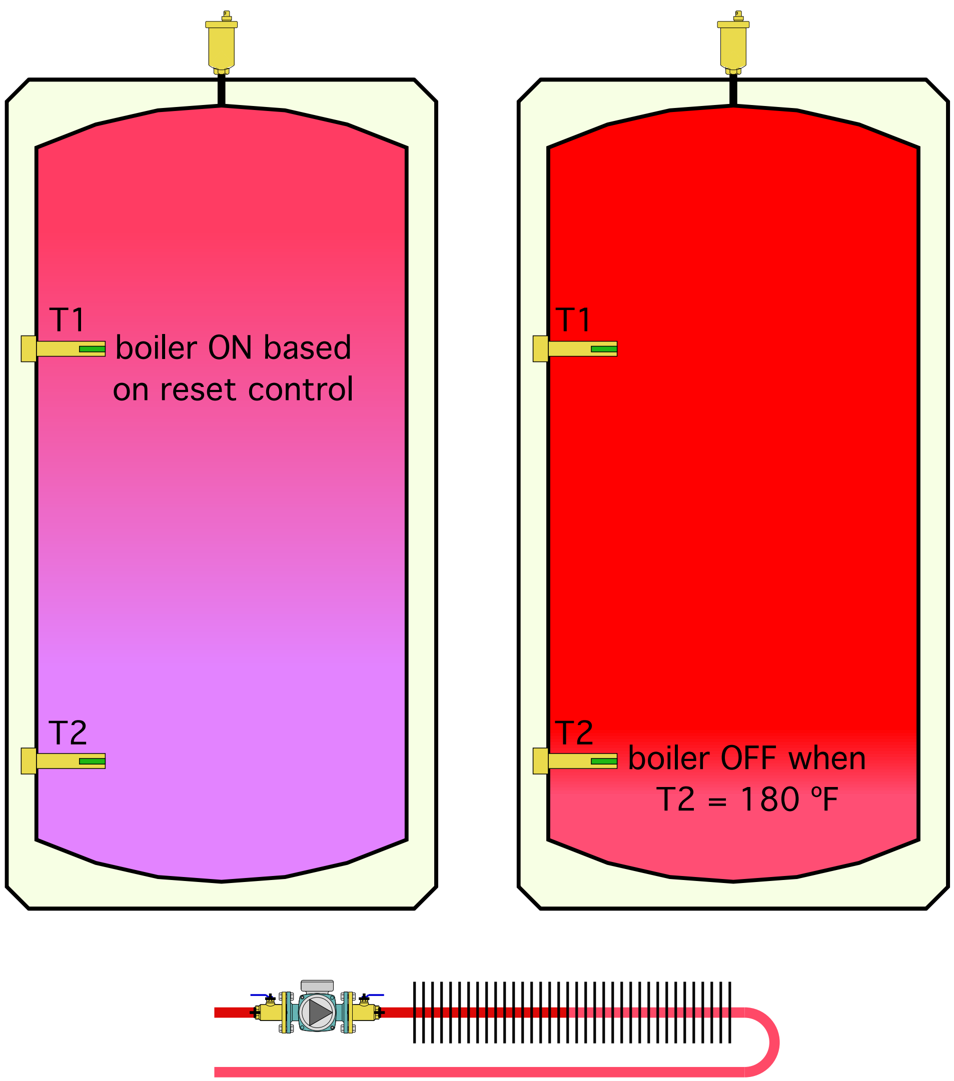


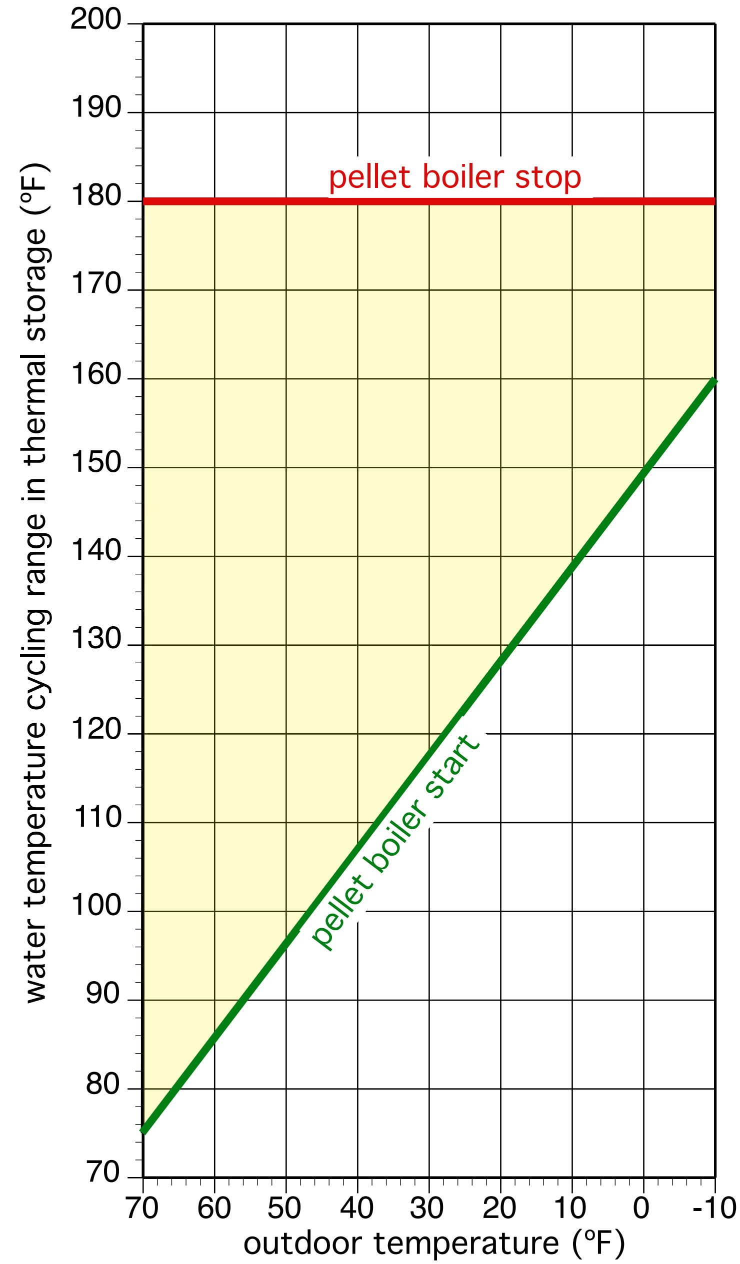


• High temperature heat emitters

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

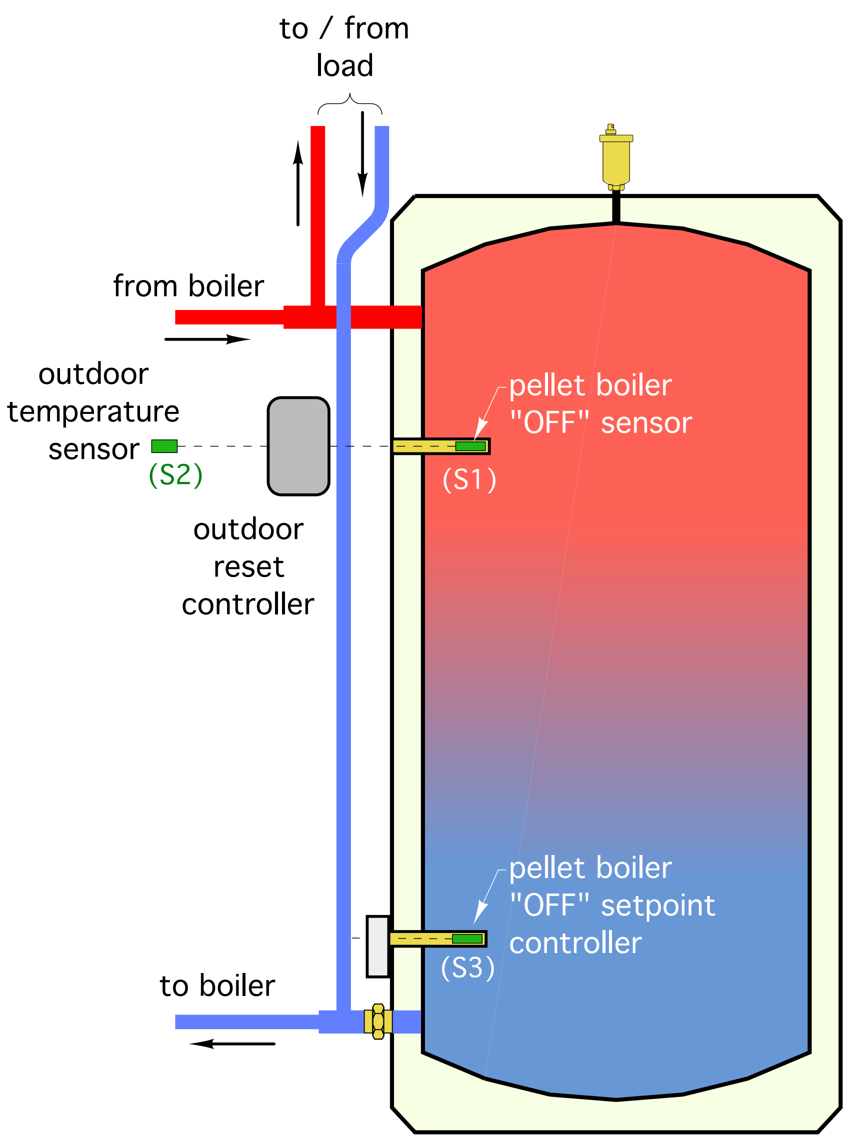
[*outdoor reset for boiler start, setpoint temperature for boiler off*]

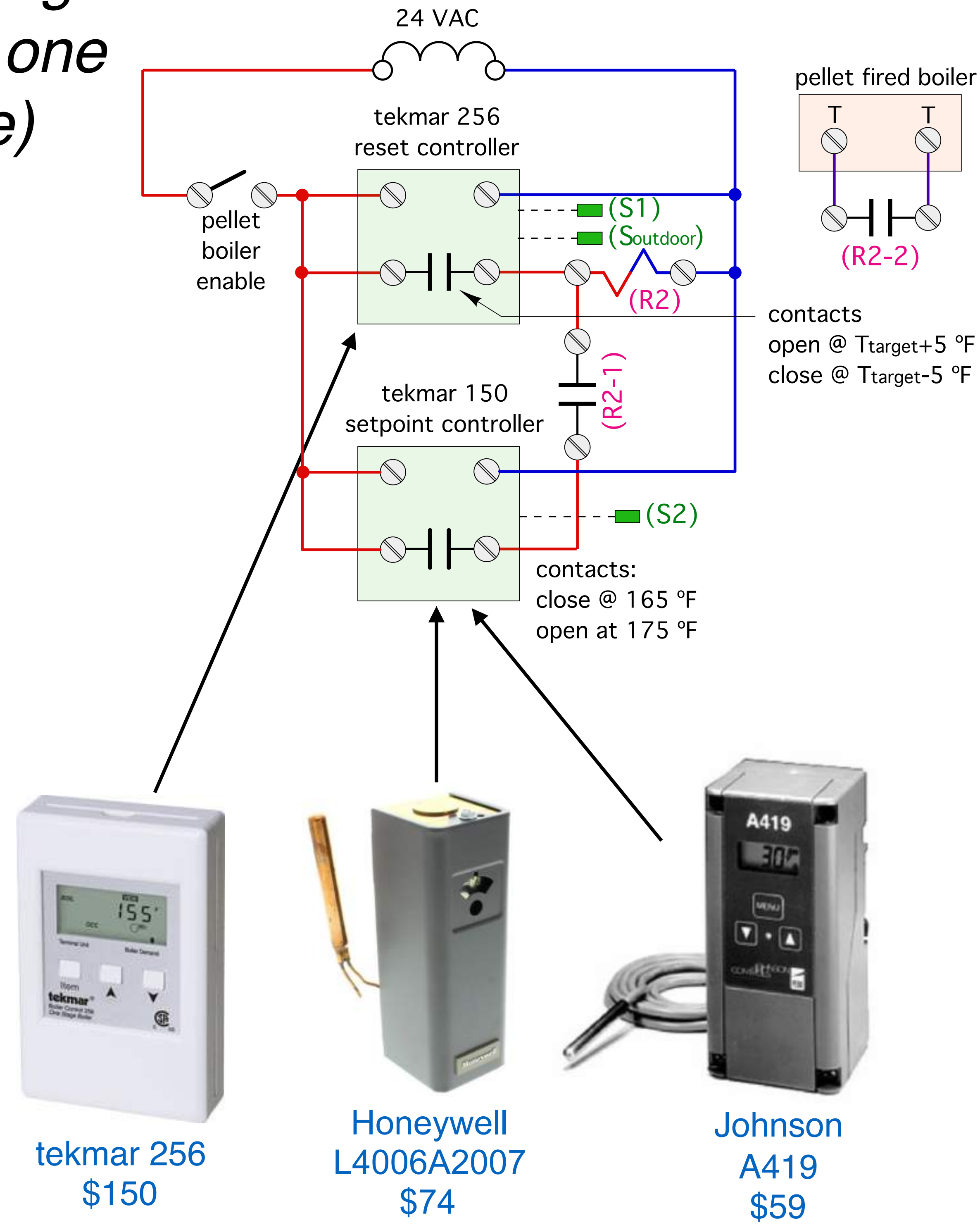




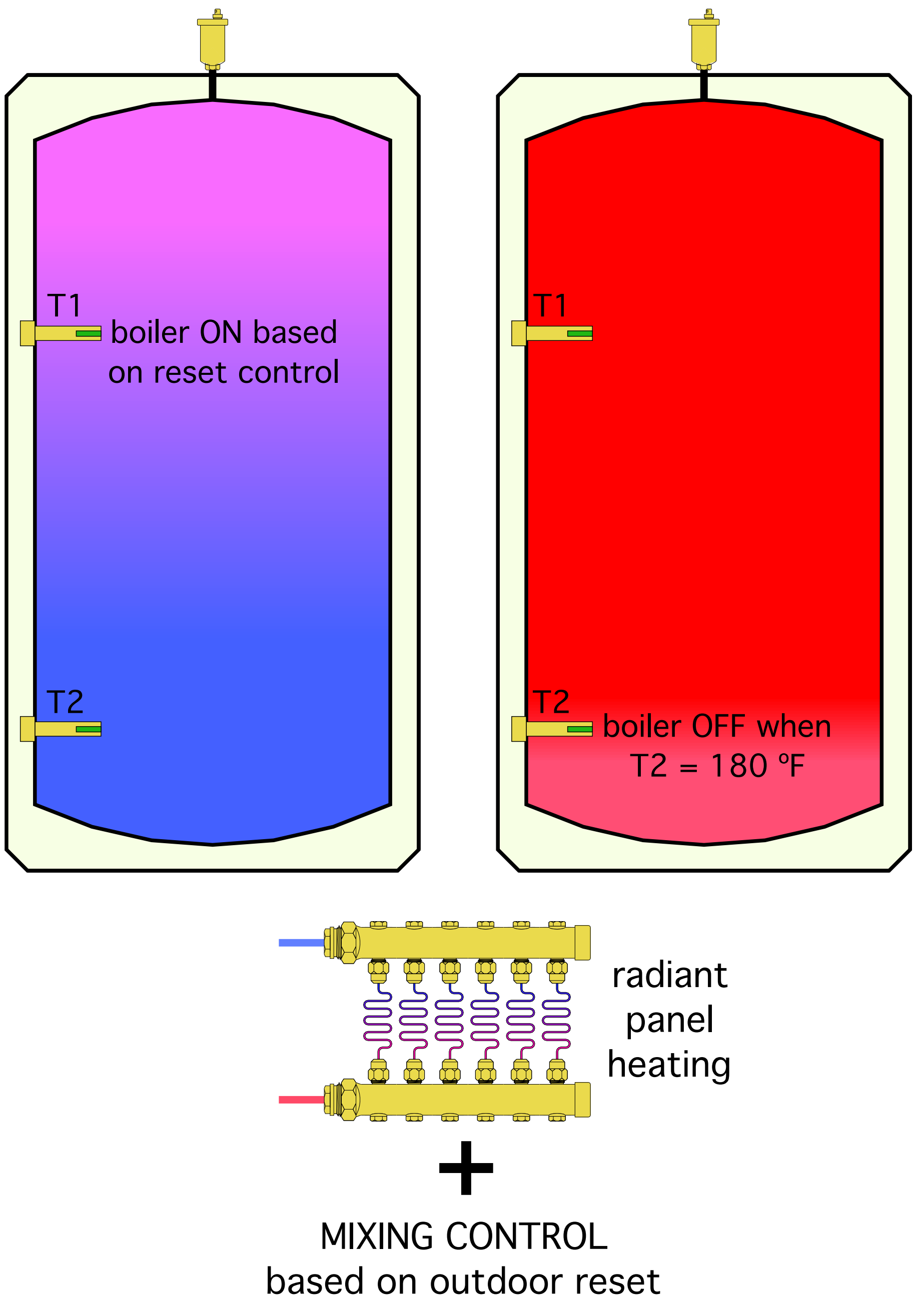
- HIGH temperature heat emitters
- Outdoor reset of pellet boiler start temperature

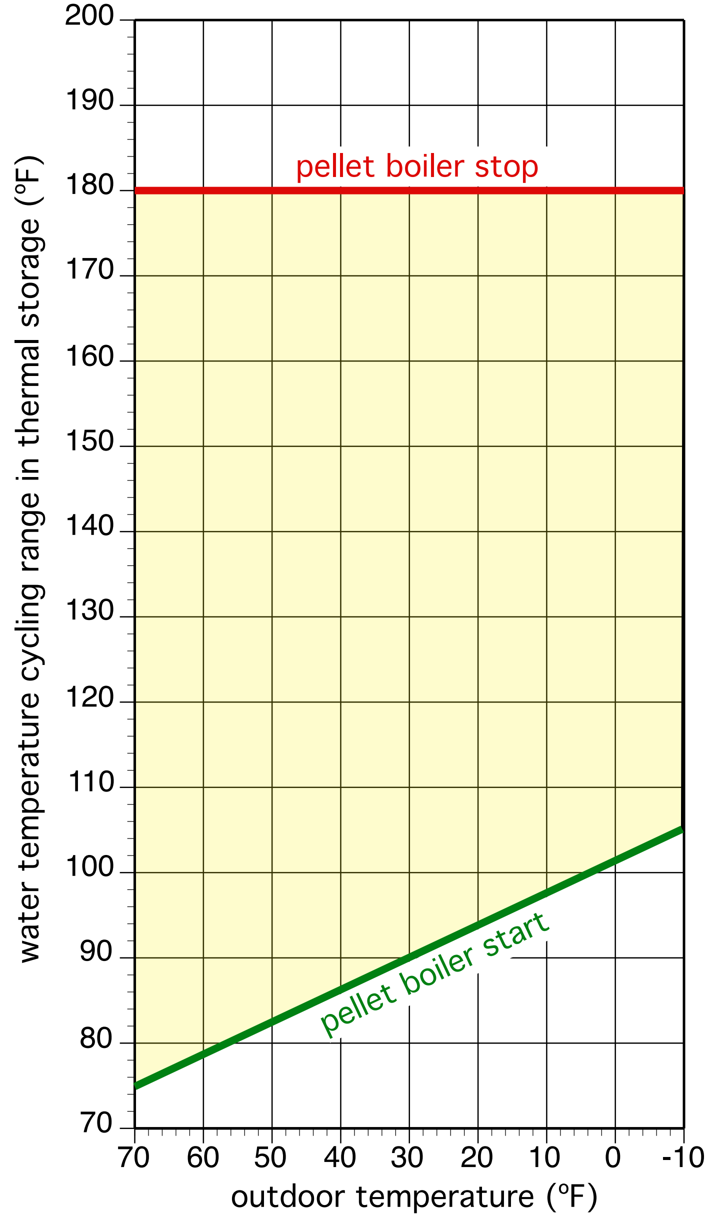
Temperature stacking *(using 1 setpoint temperature and one outdoor reset temperature)*



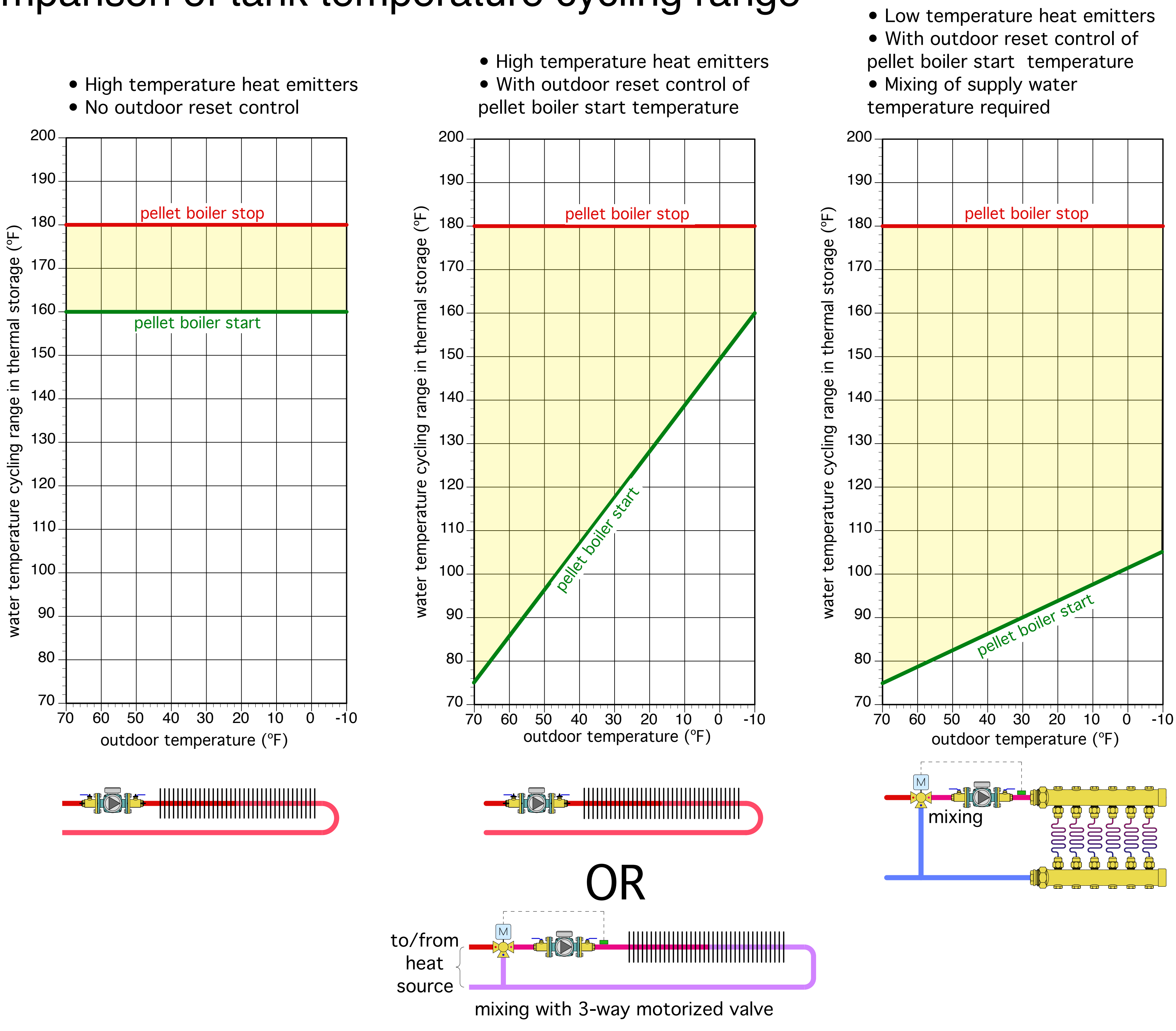


- **Low temperature heat emitters**
- Heat stacking (outdoor reset for boiler start, setpoint for boiler off)
- Mixing control of distribution water temperature



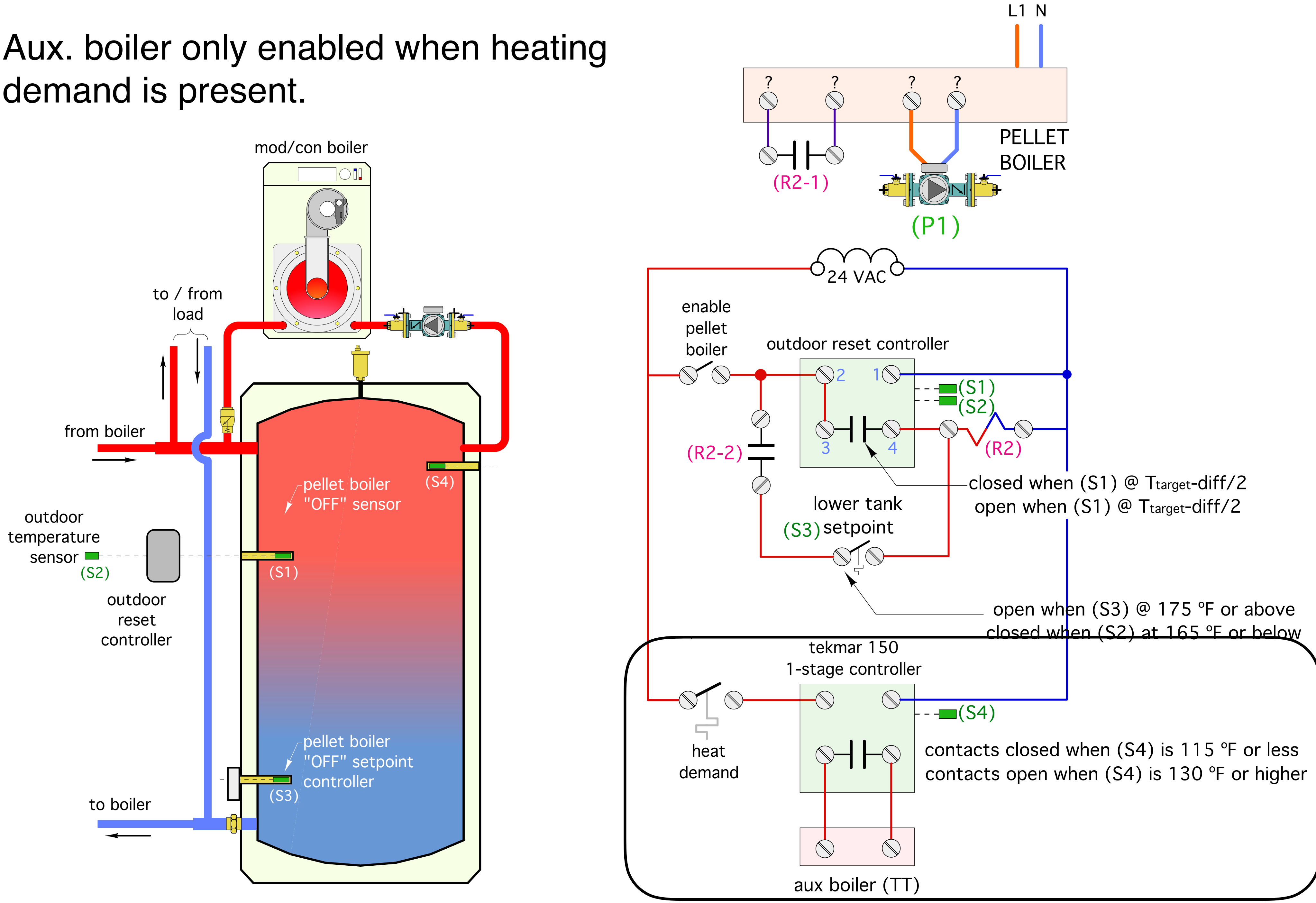


A comparison of tank temperature cycling range



Control logic for heat stacking with combination of pellet-fired boiler and auxiliary mod/con boiler.

Aux. boiler only enabled when heating demand is present.



Example System 1

A basic system

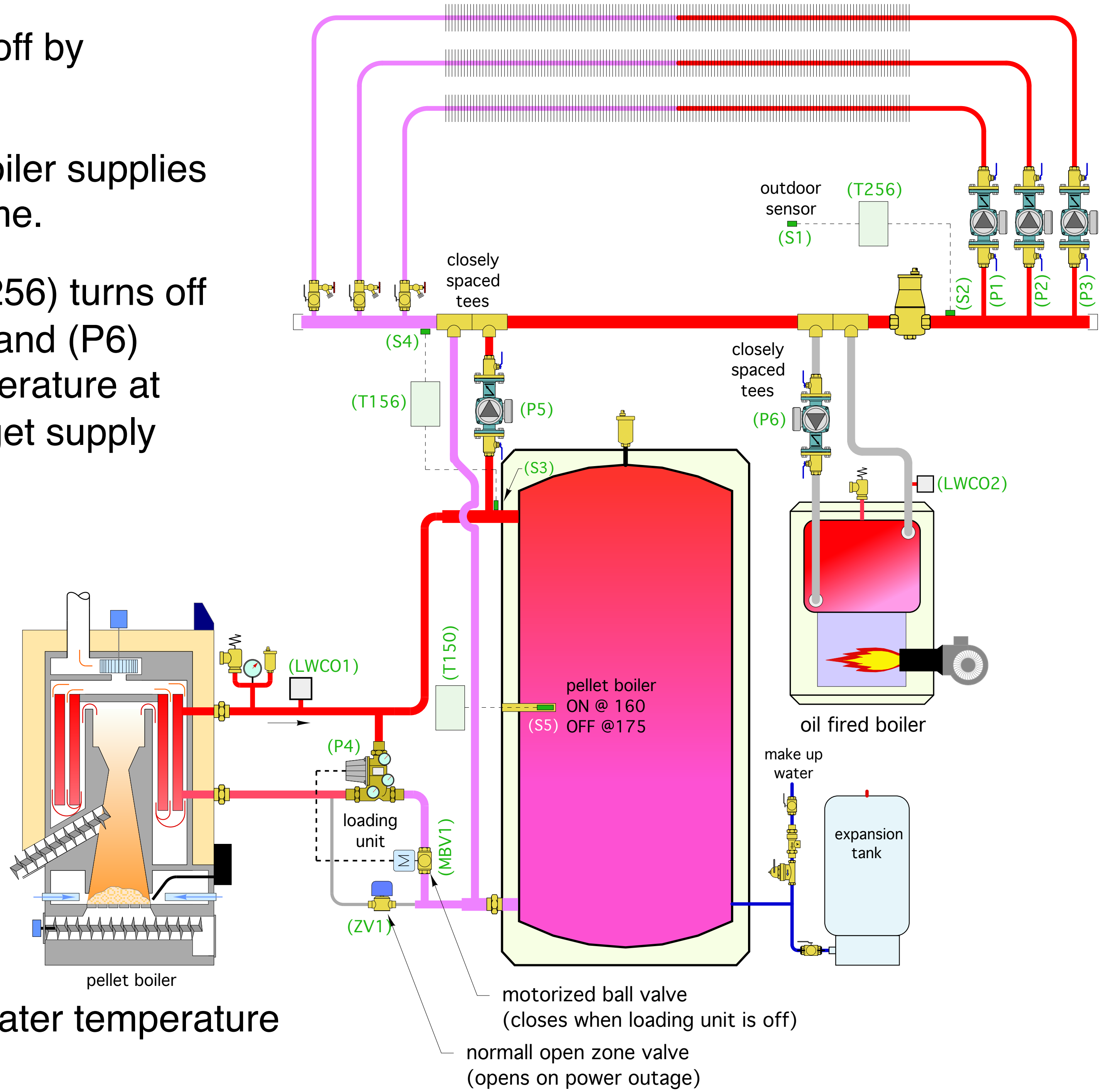
• Pellet boiler turned on and off by single tank sensor.

• Thermal storage OR aux boiler supplies heat. Never both at same time.

• Outdoor reset controller (T256) turns off (P5) and turns on aux boiler and (P6) whenever supply water temperature at (S2) drops slightly below target supply temperature

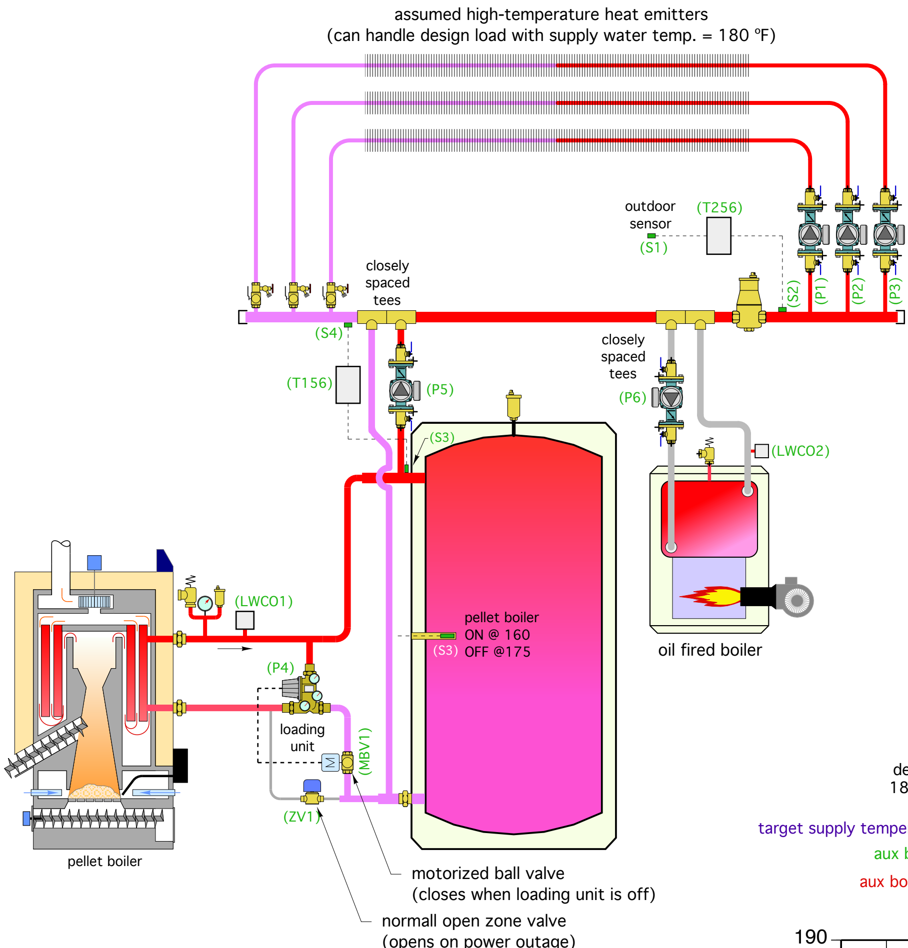
• Pellet boiler anti-condensation protection provided by loading unit.

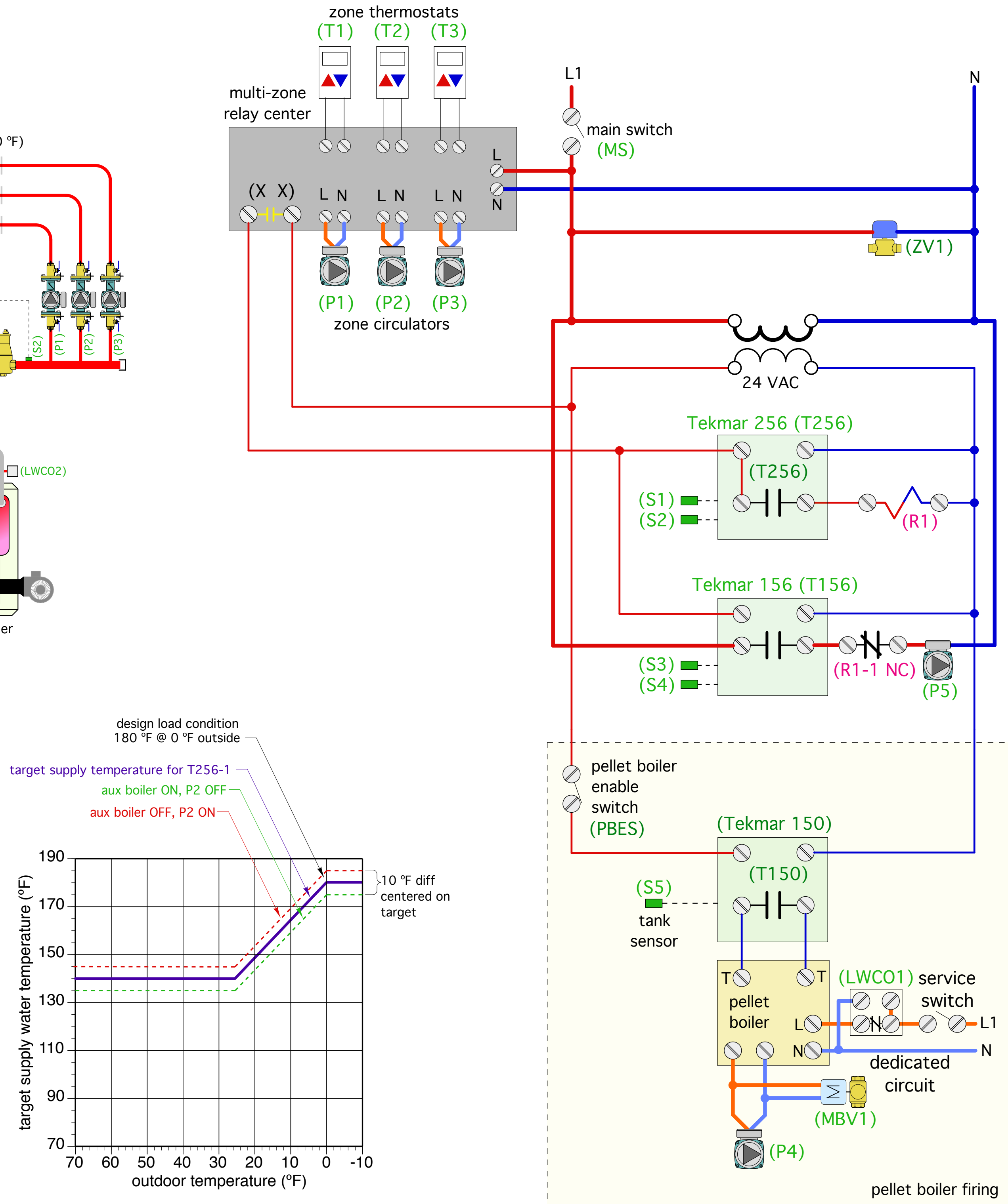
• ΔT controller prevents inadvertent heat transfer from distribution system to thermal storage tank.



• No "fine tuning" of supply water temperature to heat emitters.

A basic system





A basic system

Please read through this later....

Description of Operation:

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 auxiliary 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 pellet boiler to operate.

Power for the zone circulators, 24 VAC transformer, and controllers is supplied through another 120 VAC dedicated circuit. The main switch (MS) for this circuit must be closed.

Pellet Boiler Operation: The pellet boiler enable switch must be closed for the pellet boiler to operate. The pellet boiler is turned on an off by a temperature setpoint controller (T150), based on the temperature of sensor (S3) at the mid-height of the thermal storage tank. When the temperature at (S5) is below 160 ºF the pellet boiler, circulator in the loading unit (P4), and the motorized ball valve (MBV1) are turned on. The thermostatic valve within the loading unit maintains the inlet water temperature to the pellet boiler above 130 ºF whenever possible. When the temperature at sensor (S3) reaches 175 ºF or higher, the pellet boiler, loading unit circulator (P4), and motorized ball valve (MBV1) are turned off. Closure of (MBV1) prevents flow of heated water through the pellet boiler whenever the circulator in the loading unit (P4) is off. During a power outage, normally open valve (ZV1) opens to allow thermosiphoning flow between the pellet boiler and thermal storage tank.

Distribution system: Upon a call for heating form ay zone thermostat (T1, T2, T3), the associated zone circulator (P1, P2, P3) is turned on. The isolated relay contact (X X) in the multizone relay center closes providing 24VAC power to the tekmar 256 (T256) and tekmar 156 (T156) controllers.

Heat Input to distribution system: The (T156) controller measures the temperature difference between the water returning from the distribution system at sensor (S4) and the water temperature at the upper header of the thermal storage tank at sensor (S3). If (S3) is at least 6ºF above (S4) the contact in the (T156) closes. If (S3) is less than 3 ºF above (S4) the contacts in the (T156) opens. This prevents inadvertent heat transfer from the distribution system to the thermal storage tank.

The (T256) measure outdoor temperature at sensor (S1) and calculates a target supply water temperature for the distribution system. If the temperature of the water passing its sensor (S2) is not more than 5 ºF below this temperature, the contacts in the (T256) remain open, relay. coil (R1) remains off, and the normally closed relay contacts (R1-1 NC) remain closed.

When the contacts in (T156) are closed *and* (R1-1 NC is closed), 120 VAC is supplied to circulator (P5). Water from the upper header of the thermal storage tank is injected to the distribution system. This mode of operation continues until either all calls for heat at the thermostats are satisfied, or the temperature at sensor (S2) drops more than 5 ºF below the target supply water temperature. If the latter occurs the contacts in the (T256) close. Relay contact (R1-1 NC) opens turning off circulator (P5). Relay contact (R1-2) closes enabling the auxiliary boiler and circulator (P6) to operate. Heated water from the auxiliary boiler is now being injected to the distribution system, and there is no flow from thermal storage to the distribution system.

(condition A): If the temperature of the thermal storage tank increases, due to pellet boiler operation, and the temperature at the upper header sensor (S3) increases to 6 ºF or more above the temperature on the return side of the distribution system at (S4), the contacts in the (T156) close.

(Condition B)If the temperature at supply sensor (S2) also increases to 5 ºF or more above the target temperature, the contacts in (T256) open, relay coil (R1-1) de-energizes, and the auxiliary boiler and its circulator (P6) turn off.

If (condition A) and (condition B) occur during the same time, heat input to the distribution system shifts to circulator (P5) from the thermal storage tank.

Note: There are no conditions under which heat input *to the distribution system* from thermal storage AND the auxiliary boiler occur simultaneously. However, it is possible for the pellet boiler and auxiliary boiler to operate simultaneously.

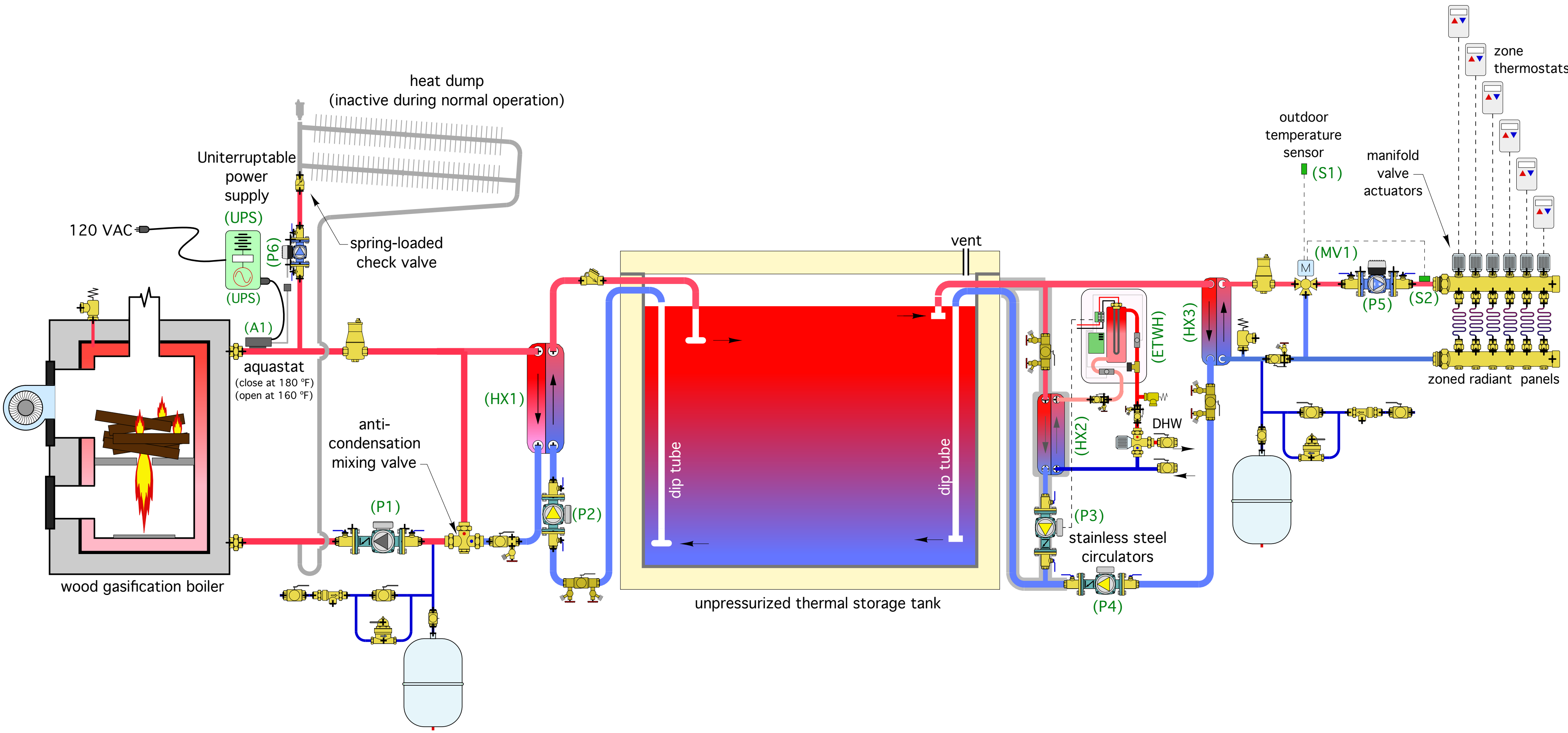
The outdoor reset line for the (T256) is set for a maximum supply water temperature of 180 ºF corresponding to an outdoor temperature of 0 ºF, and a minimum supply water temperature of 140 ºF regardless of outdoor temperature. The differential of this controller is set to 10 ºF.

The high limit controller on the auxiliary boiler should be set to at least 200 ºF to prevent interaction with the (T256) controller, but still act as a high limit safety controller.

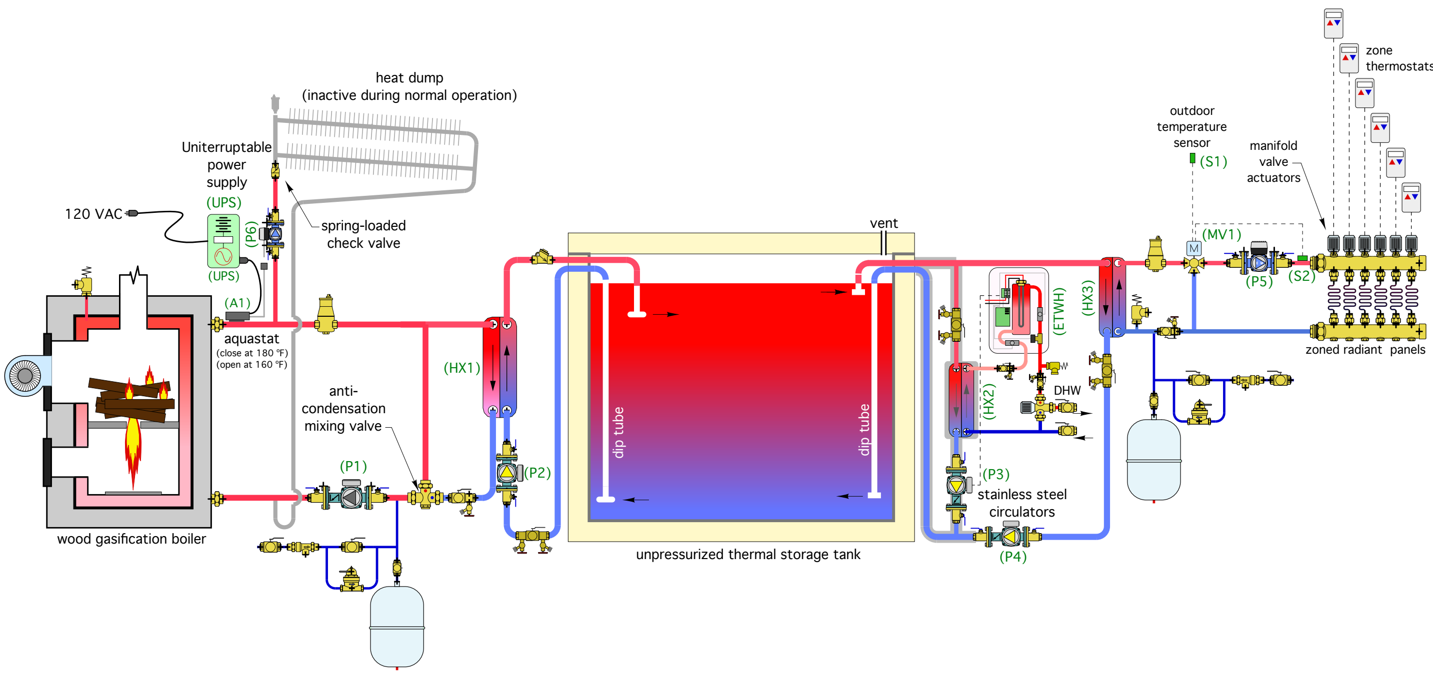
Example System 2

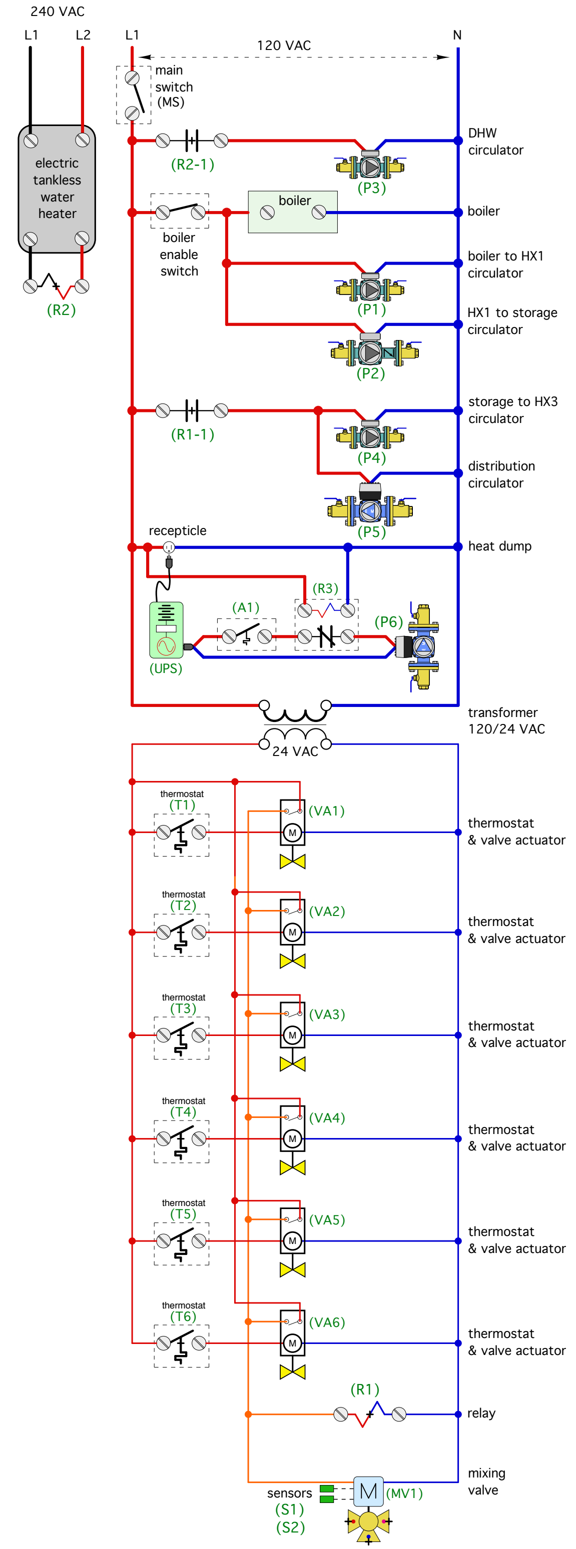
System using (unpressurized) buffer tank

- Closed loop boiler circuit
- Closed distribution system
- All external brazed plate heat exchangers
- DHW boost using electric tankless water heater



System using (unpressurized) buffer tank





System using (unpressurized) buffer tank

Description of Operation:

Please read through this later....

1. Boiler operation: When the wood-gasification boiler is fired, the operator closes a switch on the boiler, that enables 120 VAC to be supplied to the boiler. This switch closure also supplies 120 VAC to circulators (P1) and (P2). Thus, flow between the boiler and heat exchanger (HX1), as well as between (HX1) and the thermal storage tank is enabled. As the temperature at the boiler outlet climbs, the 3-way thermostat valve (MVB) modulates to allow heat flow to heat exchanger (HX1) and onward to thermal storage, while also maintaining the boiler's inlet temperature above 130 ºF (or whatever other temperature may be required) to prevent sustained flue gas condensation within the boiler.

2. Boiler overheat protection mode: In the event of a power failure, overheat protection is provided by an array of fin-tube elements sized to dissipate the residual heat within the boiler. At the onset of a power failure, 120 VAC is supplied from the uninterruptible power supply (UPS) to a normally open contact in aquastat (A1). This contact closes if the temperature at the boiler outlet rises to 180 ºF or above. This passes 120 VAC from the UPS to a normally closed contact (R3-1). The coil of relay (R3) is energized whenever utility supplied power is available. Thus contact (R3-1) remains open unless a power outage occurs. The closure of (R3-1) supplies 120 VAC power from the (UPS) to operate circulator (P6), and thus create flow through the heat dump. If the temperature at the boiler outlet drops to 160 ºF or lower, the contact in aquastat (A1) opens turning off circulator (P6). This conserves battery energy within the (UPS) when the boiler temperature is not high enough to justify operating the heat dump.

3. Space heating mode: Upon a call from any of the thermostats (T1...T6), 24 VAC is passed to the associated manifold valve actuators (VA1...VA6). When any one or more of these valve actuators reach their fully open position, an end switch within the valve actuator closes to pass 24 VAC to the coil of relay (R1), and motorized mixing valve (MV1). A normally open contact (R1-1) closes to supply 120 VAC to circulators (P4) and (P5). Circulator (P4) creates flow between the thermal storage tank, and heat exchanger (HX3). Circulator (P5) is a variable speed pressure regulated circulator that adjusts its speed to maintain a constant differential pressure across the distribution manifold as the manifold valve actuators open and close. The motorized mixing valve (MV1) measure the outdoor temperature at sensor (S1), and uses this temperature, along with its settings, to calculate the necessary target supply water temperature to the distribution system. It compares the target supply temperature to the supply temperature measured by sensor (S2), and adjusts the hot water and return water flow rates into the valve to maintain the temperature at sensor (S2) as close to the target temperature as possible.

4. Domestic water heating mode: Whenever there is a demand for domestic hot water of 0.6 gpm or higher, a flow switch within the electric tankless water heater (ETWH) closes. This closure supplies 240 VAC to the coil of relay (R2). The normally open contacts (R2-1) close to turn on circulator (P3), which circulates heated water from the upper portion of the thermal 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 thermal storage tank. This water passes into the thermostatically controlled tankless water heater (ETWH) which measures its inlet temperature. The electronics within this heater control the electrical power supplied to the heat elements based on the necessary temperature rise (if any) to achieve the set domestic hot water 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 the demand for domestic hot water drops below 0.4 gpm, circulator (P3) and the tankless electric water heater are turned off.

Thanks for attending today's webinar

Upcoming RHNY training opportunities

FULL DAY Training Workshops:

Thursday, October 10, 20178:00 a.m. – 5:00 p.m.SUNY Morrisville80 Eaton Street Design Center Room #205 (next to campus entrance) Morrisville, NY 13408, 7.0 AIA / PDH continuing education credits

https://www.regonline.com/registration/Checkin.aspx?EventID=1958203

Tuesday, October 24, 20178:00 a.m. – 5:00 p.m. Glens Falls, NY (Queensbury Hotel) pre-conference session to ANCA Clean Energy Economy Conference, 7.0 AIA / PDH continuing education credits

link posted at Renewable Heat NY website

WEBINARS:

November 16, 2017 1:00 PM Eastern time, 1.0 AIA continuing education credit

Title: Best practices for venting and chimneys on cordwood gasification and pellet boilers

Description: this webinar describes the best options for safely and efficiently connection pellet-fired boilers and cordwood gasification boilers to chimney systems. It discusses material options, draft regulation, and proper procedures for sealing venting system components against flue gas leakage.

Additional trainings will be scheduled for 2018

NEW YORK STATE OF OPPORTUNITY. | NYSERDA Sponsored

QUESTIONS ?

CONTINUING EDUCATION AIA