Control concepts for hydronic systems using renewable energy heat sources (part 2)

Sponsored by:

October 29, 2020
1:00 PM

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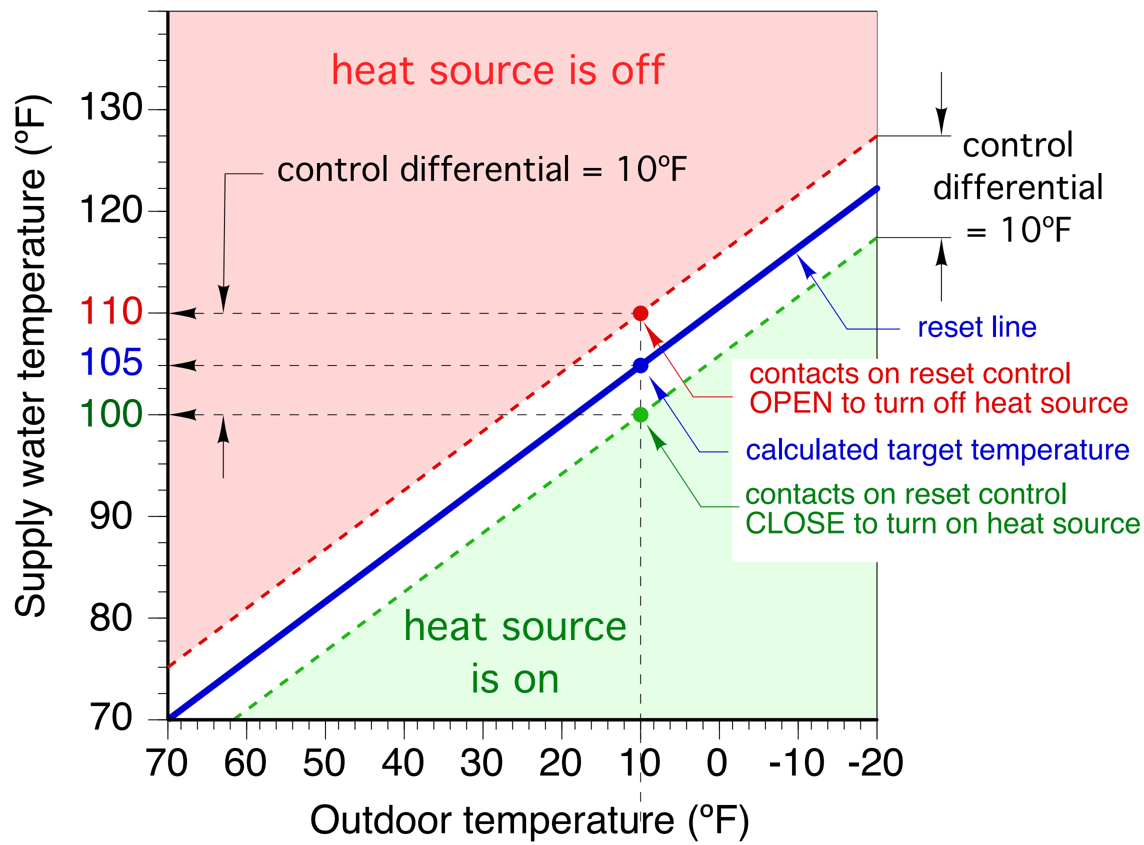


Control concepts for hydronic systems using renewable energy heat sources (part 1)

This webinar will be a continuation of the September 17th discussion.

Part 1 of this webinar is available at the Renewable Heat NY website - under training opportunities.

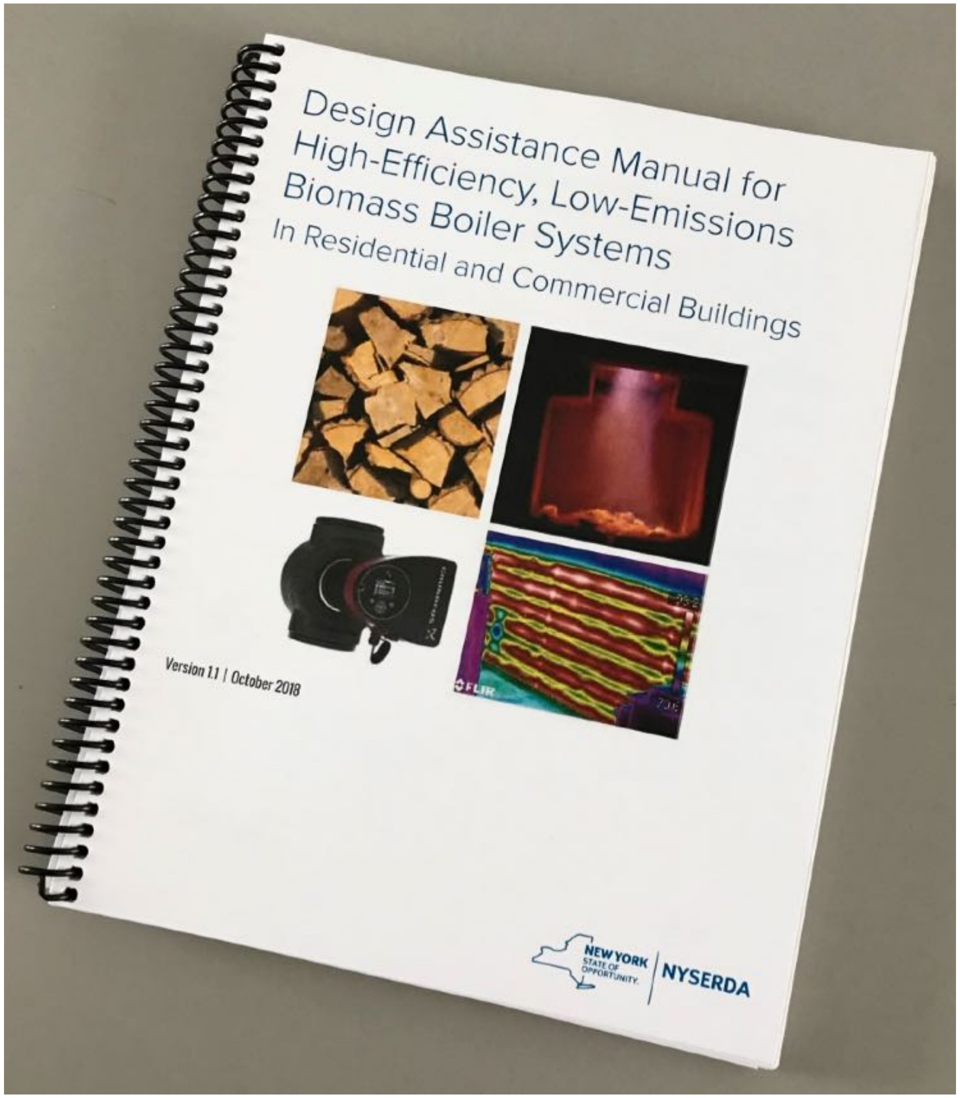
https://www.nyserda.ny.gov/All-Programs/Programs/Become-a-Contractor/Renewable-Heating-and-Cooling/Renewable-Heat-NY-Contractors

Specific topics for today's webinar:

- Outdoor reset control
- Mixing Strategies
- Ladder diagrams
- Examples of complete system

Many of these concepts can be applied in several thermally-based renewable energy systems (biomass, heat pumps, solar thermal)

Design Assistance Manual
for High Efficiency Low Emissions Biomass Boiler Systems



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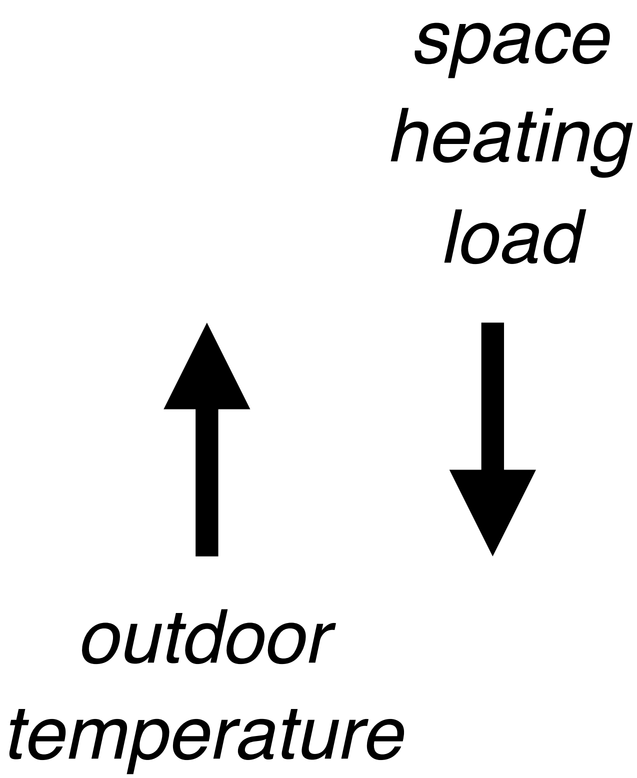
It's available as a FREE downloadable PDF at:

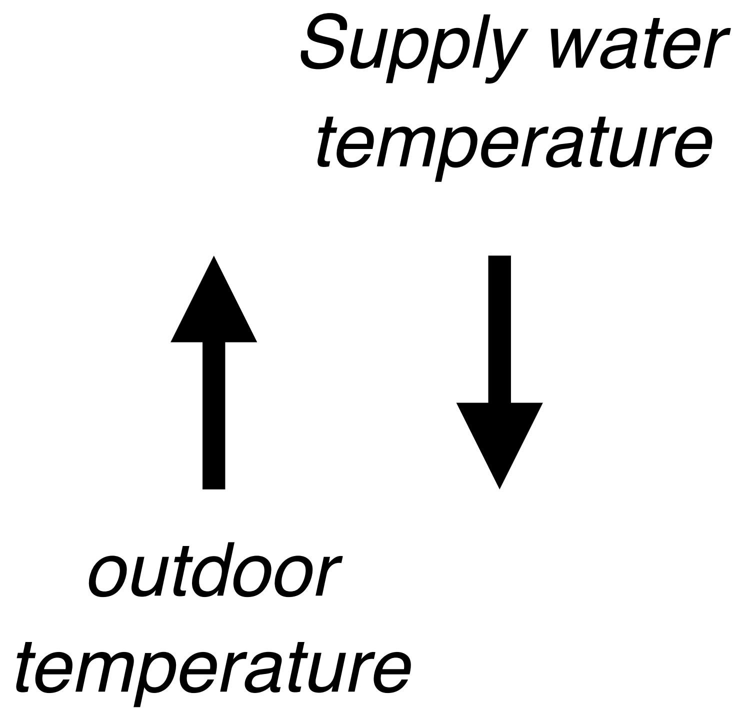
https://www.nyserda.ny.gov/-/media/Files/EERP/Renewables/Biomass/Design-Assistance-Biomass-Boiler.pdf

Outdoor reset control

Outdoor reset is based on how a typical building space heating load decreases as the outdoor temperature increases.



This implies that the supply water temperature to the hydronic distribution system can also decrease as the outdoor temperature increases.



Two ways to implement outdoor reset in biomass boilers systems

- ***Turn pellet boiler or chip boiler on based on storage tank temperature***
- ***Mixing reset (for controlling heat input to distribution system)***

Outdoor reset control

Fundamental concepts:

1. The heat output of any hydronic heat emitter is approximately proportional to the difference between supply water temperature and room air temperature.

2. The rate of heat loss from a building is proportional to the difference between inside and outside air temperature.

When these principles are combined mathematically, the resulting equation is:

$$T_{target} = T_{indoor} + (RR) \times (T_{indoor} - T_{outdoor})$$

T_{target} = the “ideal” target supply water temperature to the system
T_{indoor} = desired indoor air temperature
RR = reset ratio (slope of reset line)

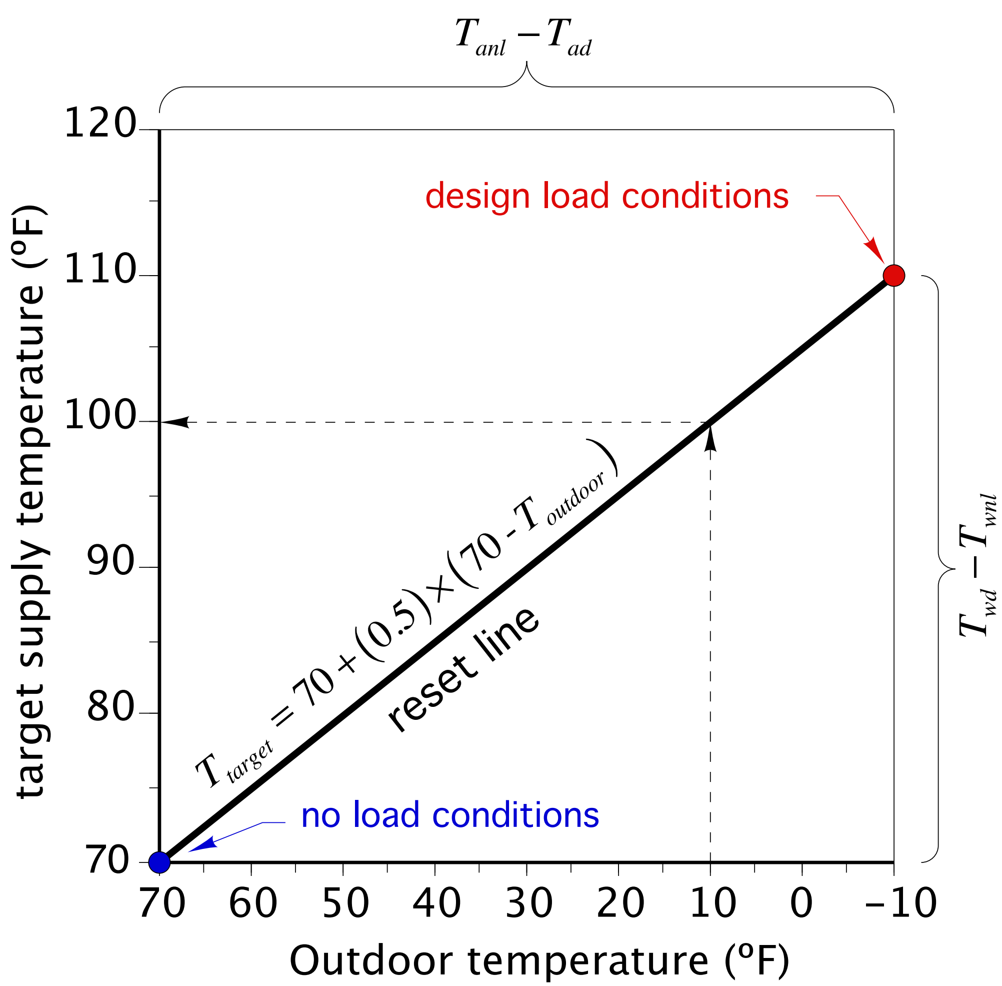
$$RR = \frac{T_{wd} - T_{wnl}}{T_{ad} - T_{anl}}$$

Where:

T_{wd} = required supply water temperature to distribution system at design load
T_{wnl} = water temperature supplied to distribution system at no load
T_{ad} = outdoor air temperature at design load
T_{anl} = outdoor air temperature at no load

Outdoor reset control

This equation can be plotted.



$$RR = \frac{(T_{wd} - T_{wnl})}{(T_{anl} - T_{ad})} = \frac{(110 - 70)}{(70 - [-10])} = \frac{40}{80} = 0.5$$

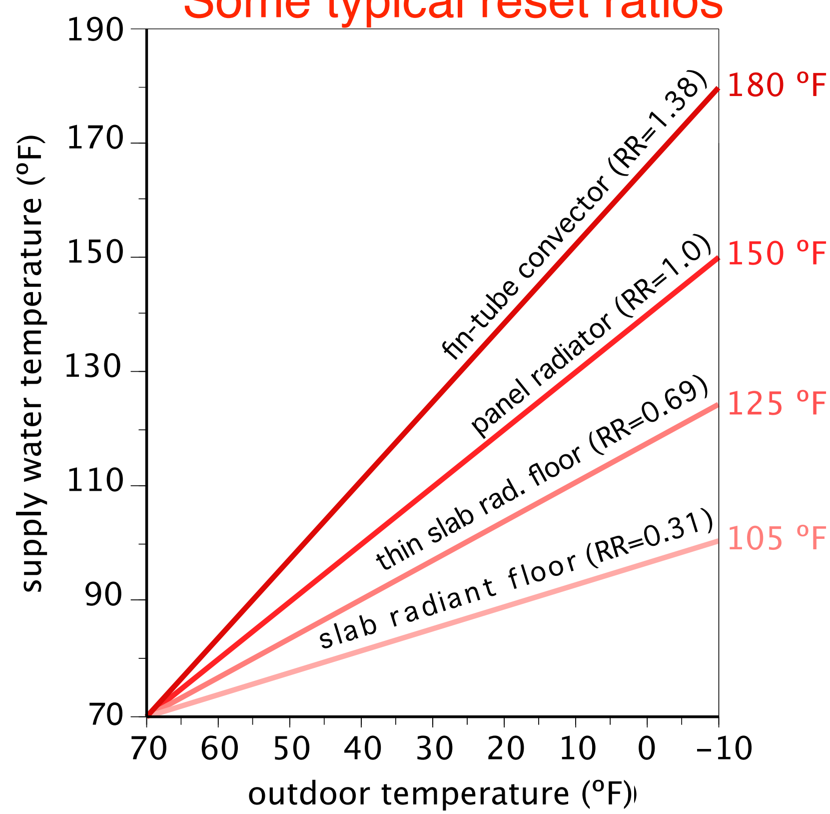
$$T_{target} = 70 + (0.5) \times (70 - T_{outdoor})$$

The sloping line is called a **reset line.**

The slope of the reset line is determined by characteristics of the heat emitters, and the building design heating load.

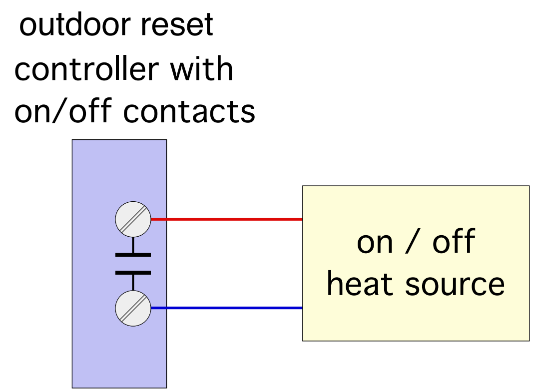
Each hydronic distribution, in its associated building, will have a specific slope (e.g. reset ratio).

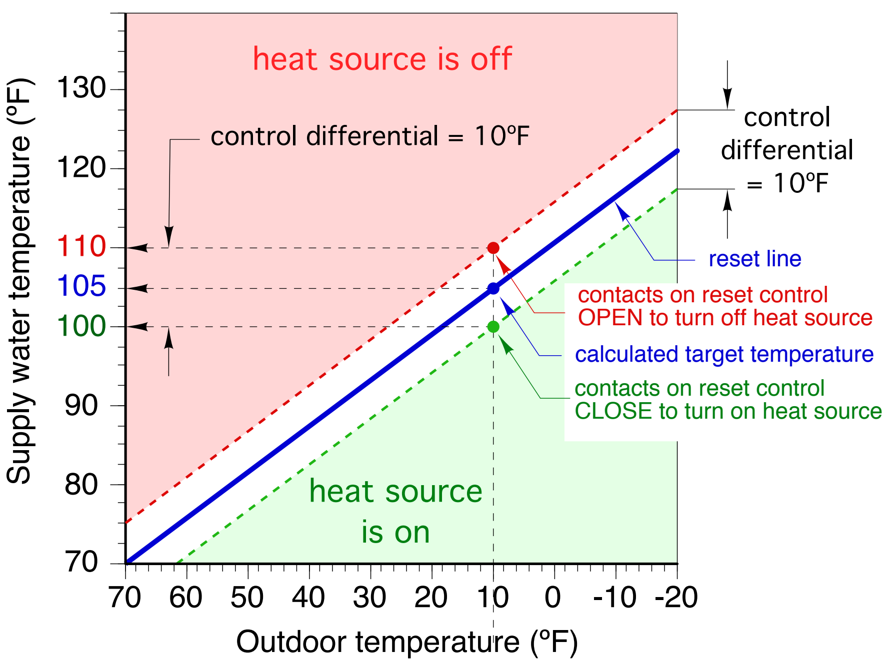
Some typical reset ratios



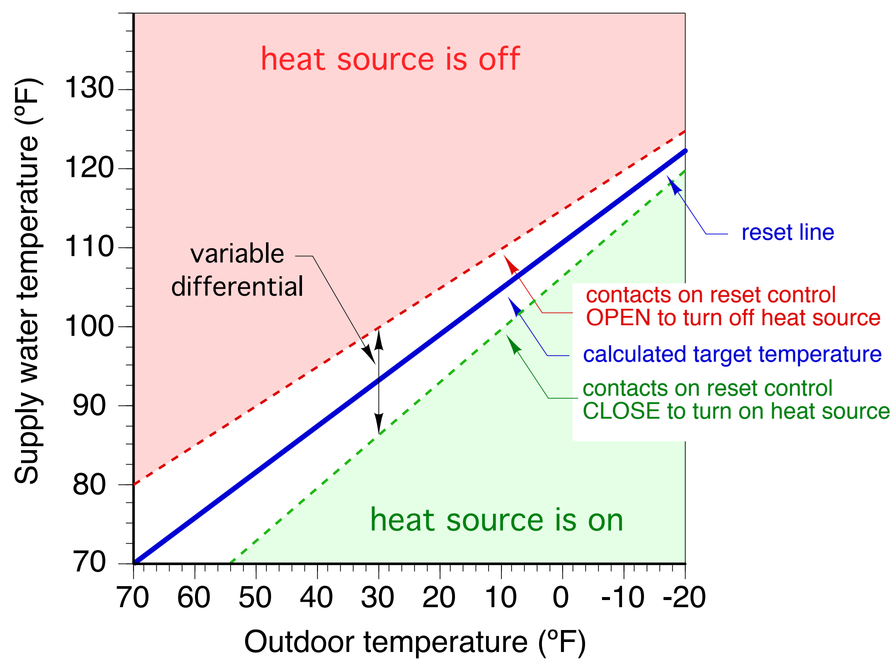
Outdoor reset control

Heat source reset (for on/off heat sources)





constant differential



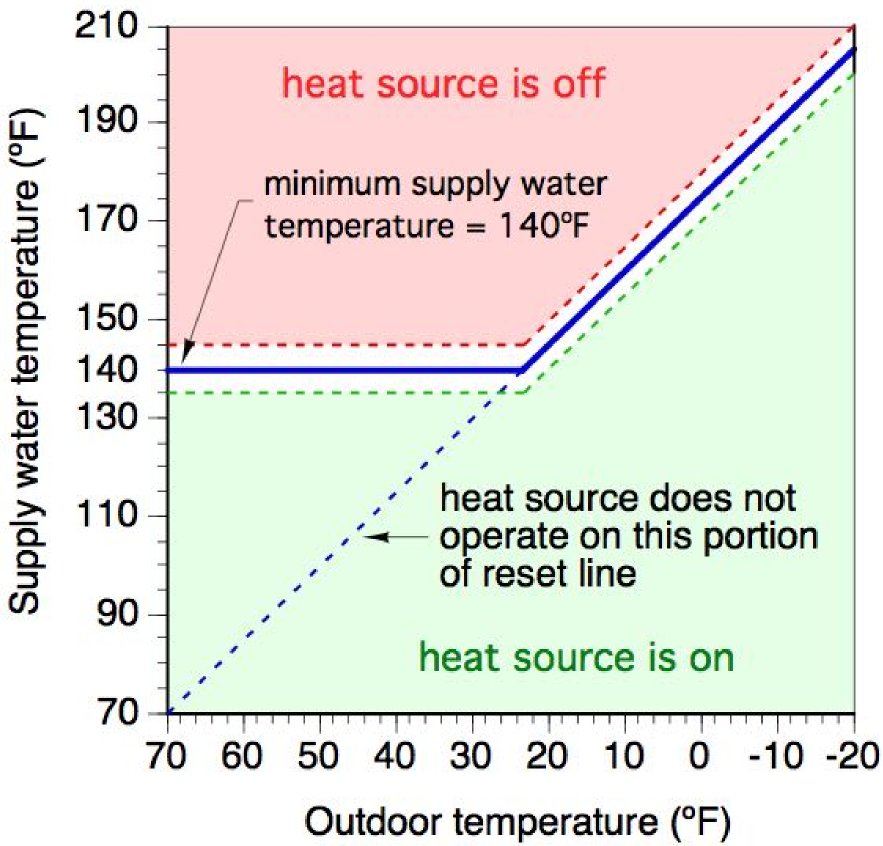
variable differential

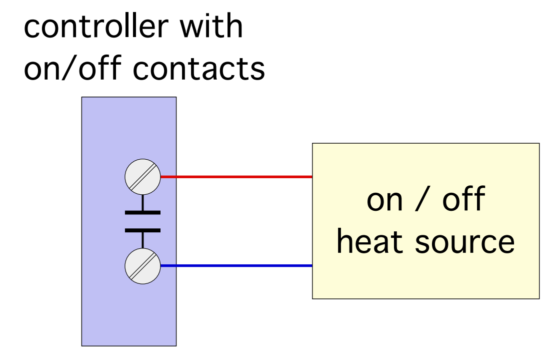
Design tip: Variable differential can reduce short cycling in systems with low mass heat sources.

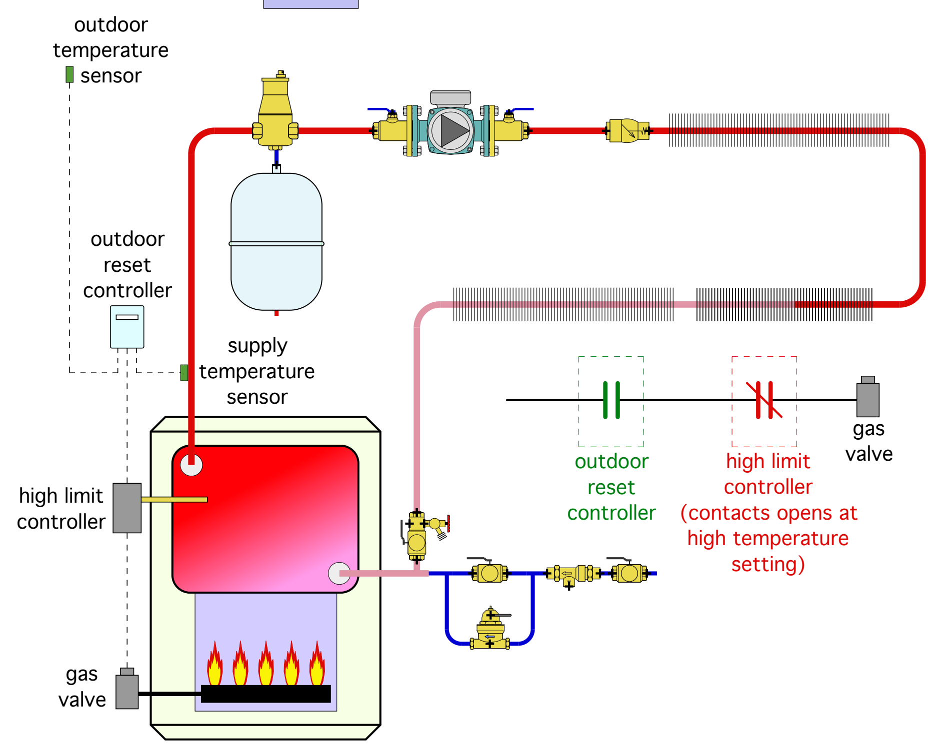
Outdoor reset control

Heat source reset (for on/off heat sources)

Most on/off heat source controllers include a minimum supply water setting.



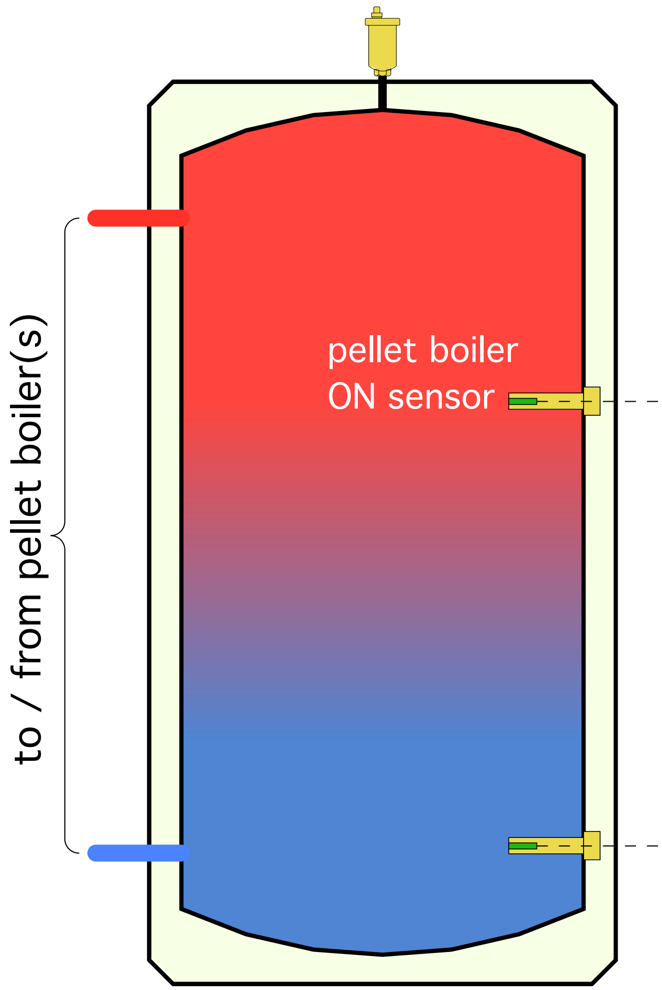




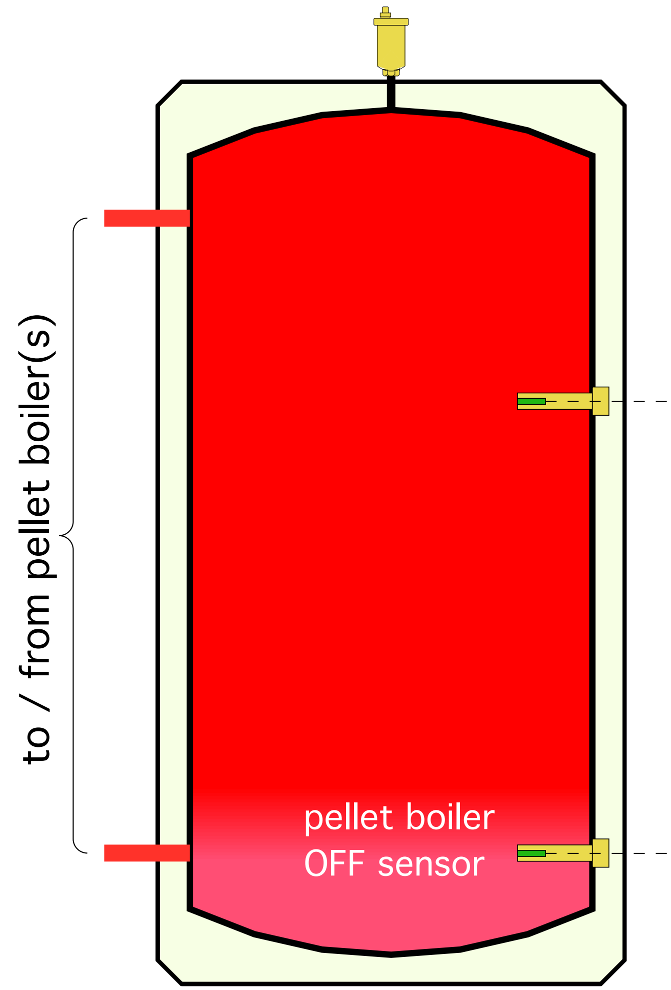
Design tip: Setting the minimum supply water temperature to 140 °F on conventional gas-fired boilers will generally provide anti-condensation protection.

Outdoor reset control

Implementing outdoor reset for a pellet boiler



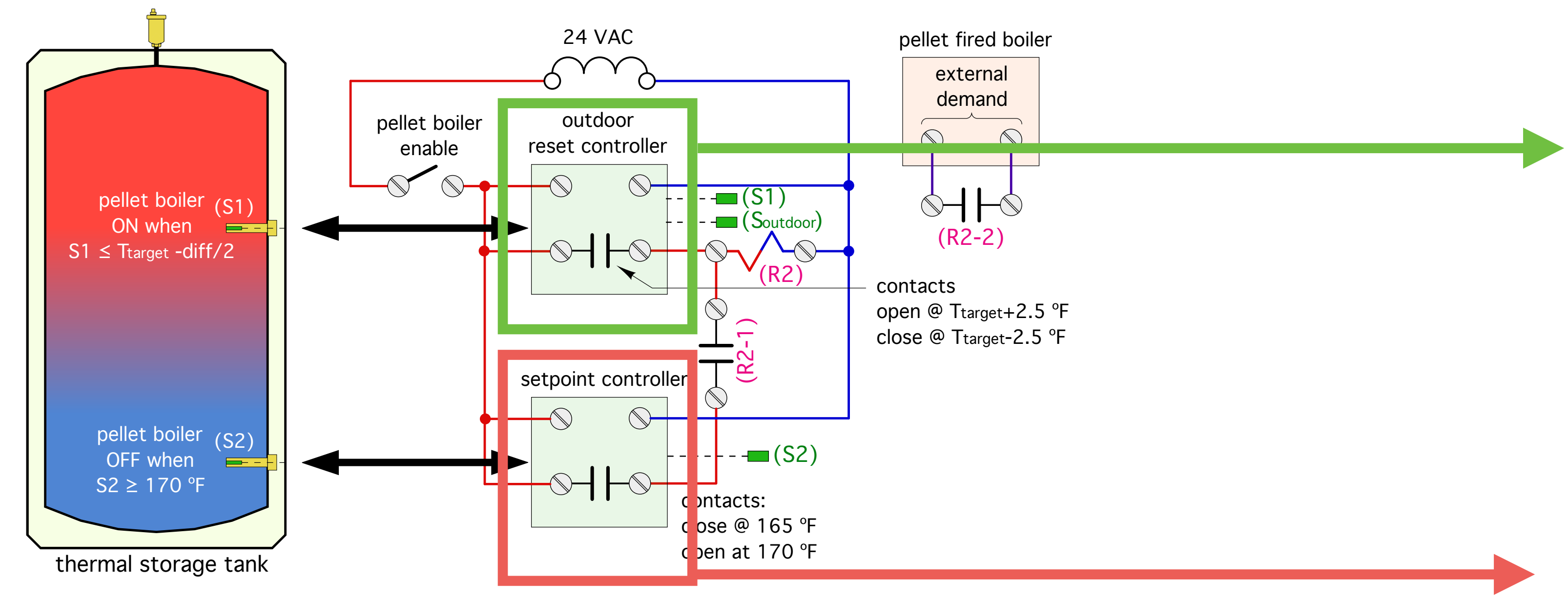
Pellet boiler fired when UPPER tank sensor drops to the target temperature of the outdoor reset controller



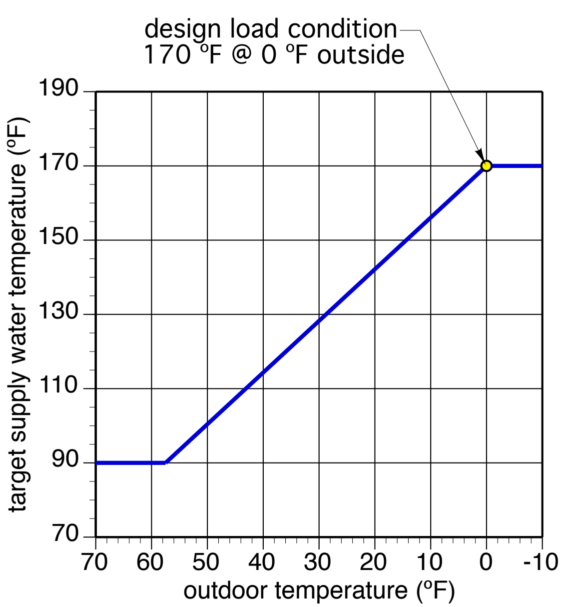
Pellet boiler turned off when LOWER tank sensor climbs to some higher setpoint temperature.

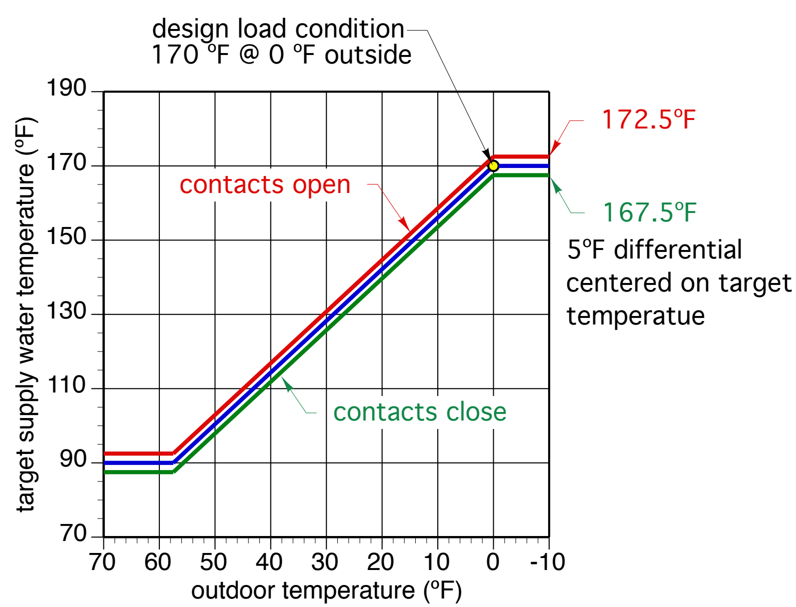
Outdoor reset control

Implementing outdoor reset for a pellet boiler



tekmar 256
outdoor reset
controller



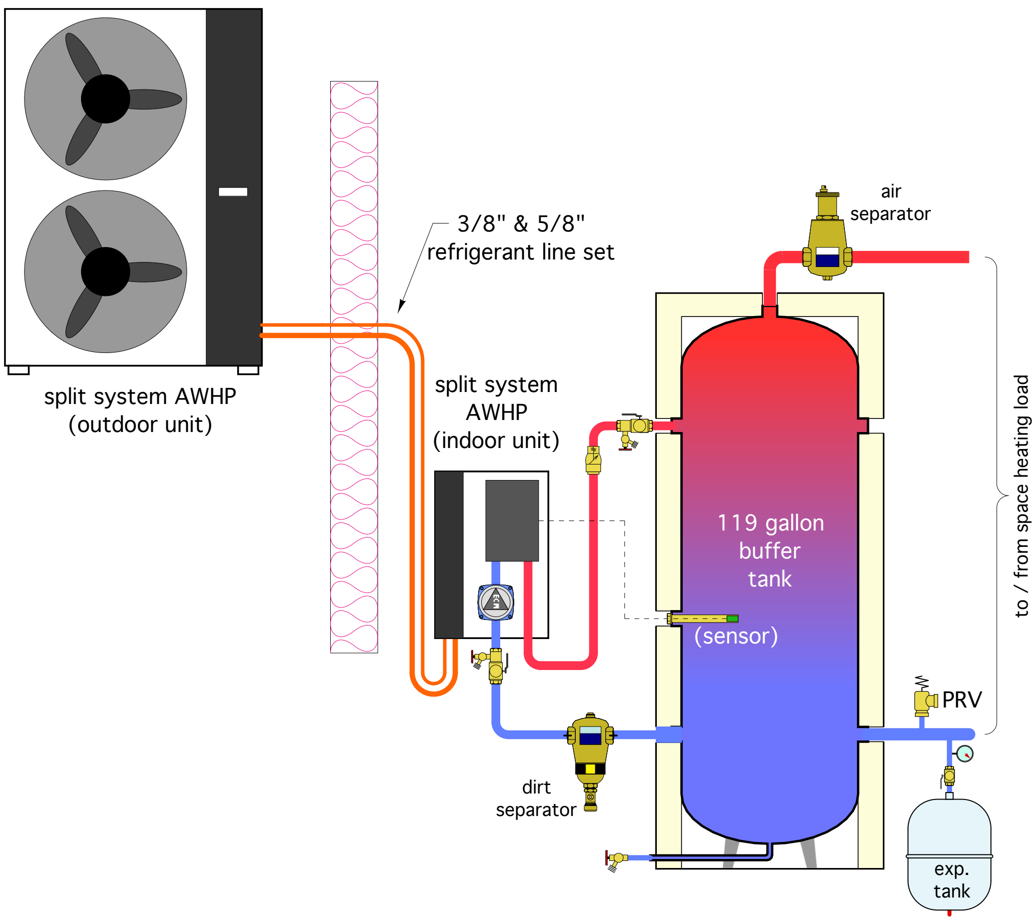


tekmar 150
temperature setpoint
controller

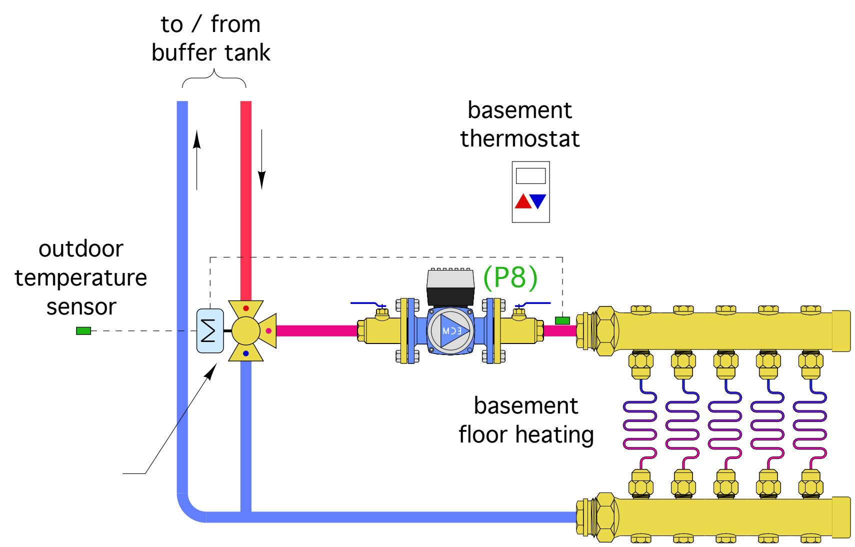
Outdoor reset control

Other ways to implement outdoor reset in systems with renewable energy heat sources

• Control the temperature of a buffer tank supplied by a water-to-water geothermal heat pump or an air-to-water heat pump.



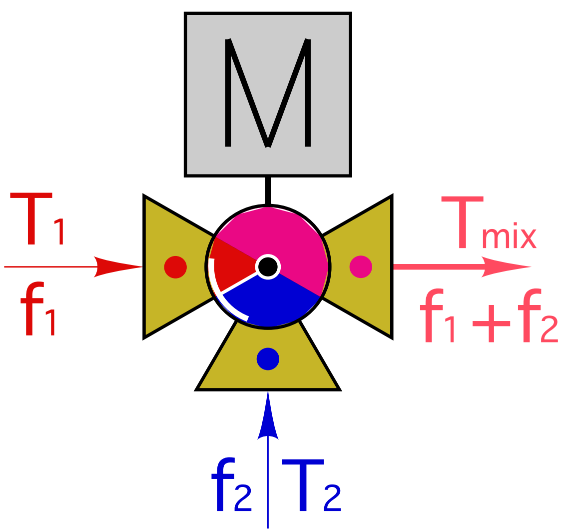
• Operate a mixing valve to lower the temperature of water from the buffer tank to a low temperature floor heating system



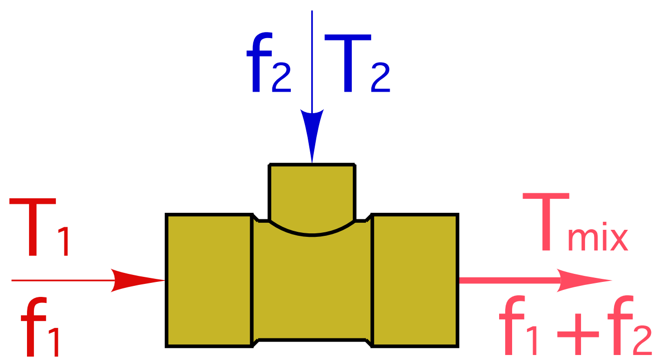
Mixing Strategies

Mixing strategies

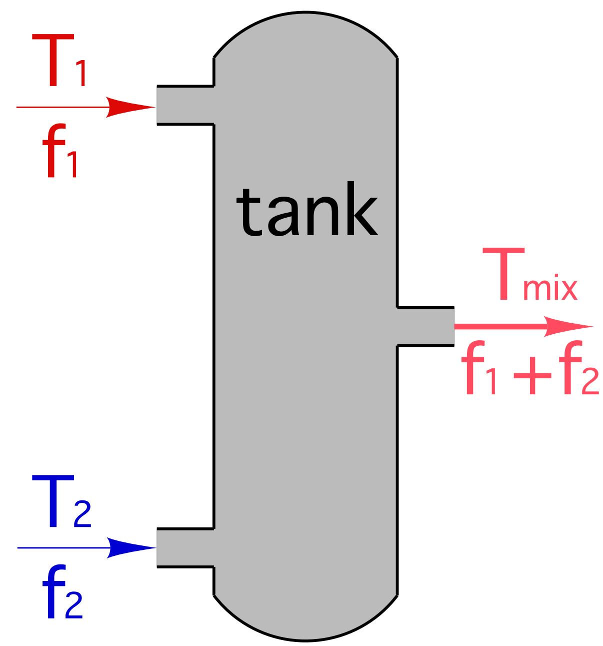
Mixing can take place in a variety of devices:



ming valve

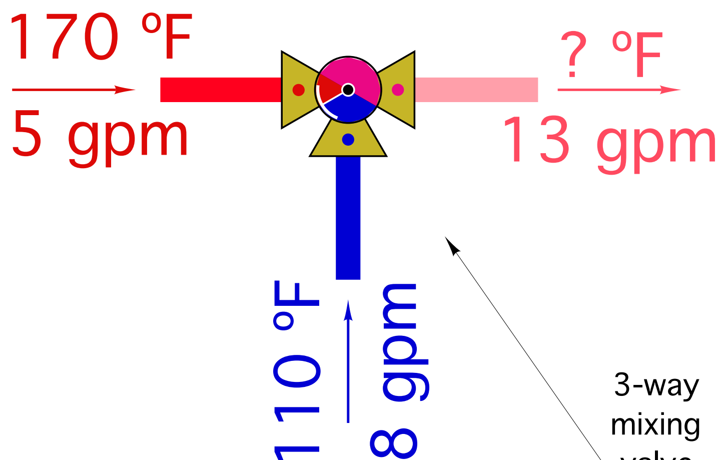


tee



tank

Mixing strategies



$$T_{mix} = \frac{(T_1 \times f_1) + (T_2 \times f_2)}{f_1 + f_2}$$

Where:

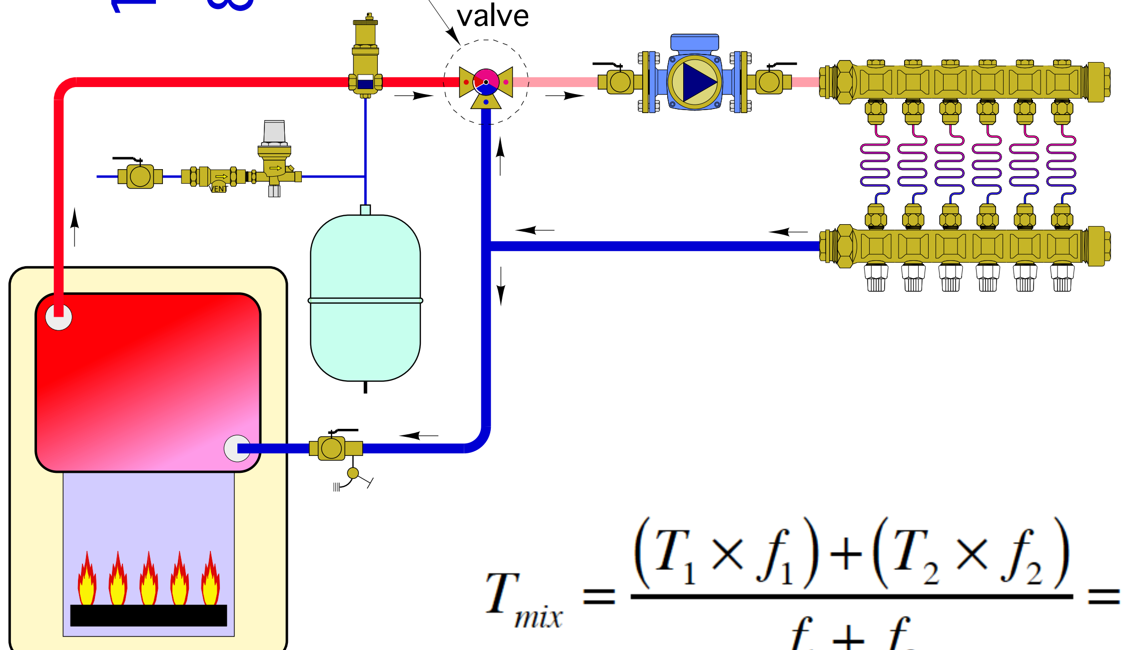
T_{mix} = resulting temperature of the mixed fluid stream

T_1 = entering temperature of fluid stream #1

T_2 = entering temperature of fluid stream #2

f_1 = flow rate of fluid stream #1

f_2 = flow rate of fluid stream #2



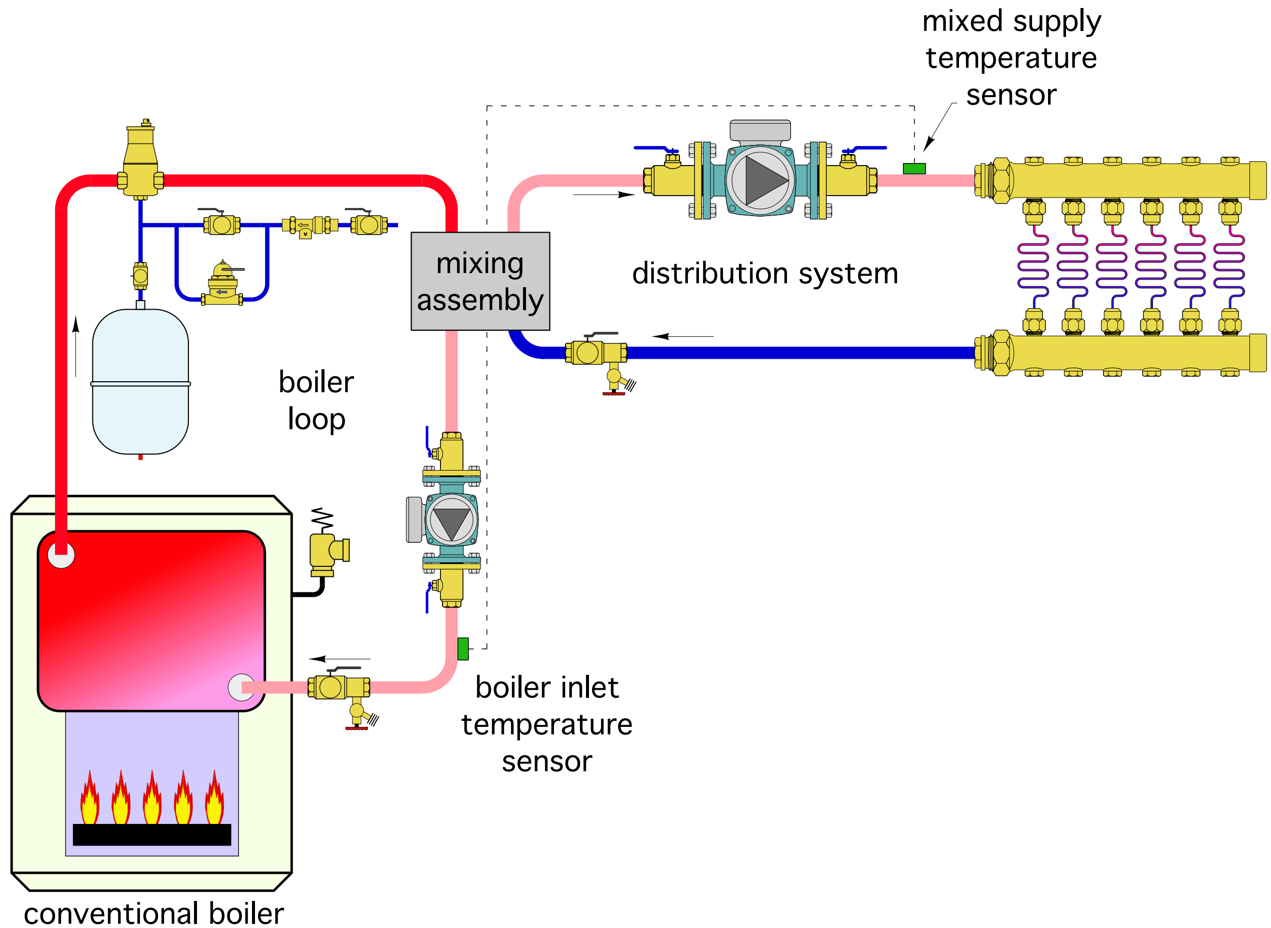
$$T_{mix} = \frac{(T_1 \times f_1) + (T_2 \times f_2)}{f_1 + f_2} = \frac{(170 \times 5) + (110 \times 8)}{5 + 8} = 133^{\circ} F$$

Mixing strategies

A mixing assembly is a collection of hardware components and control logic that regulates the rate of heat transfer from the heat source to the distribution system.

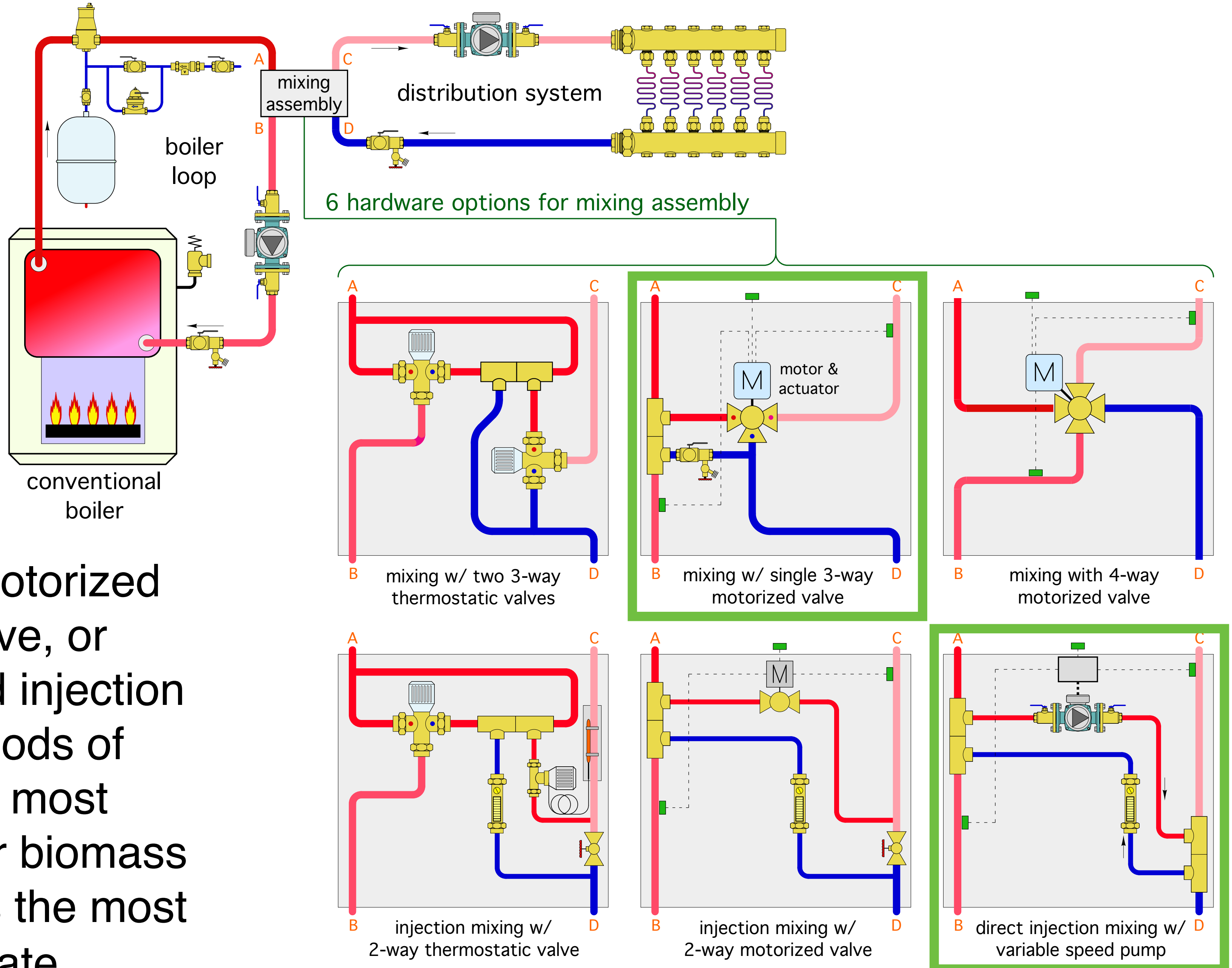
The gray box in the figure is a "container" for the various components that make up a specific mixing assembly.

It also represents a bridge between where heat is produced, and where it's released.



<u>All heat that eventually reaches the lower temperature heat emitters must pass through the mixing assembly.</u>

Mixing strategies



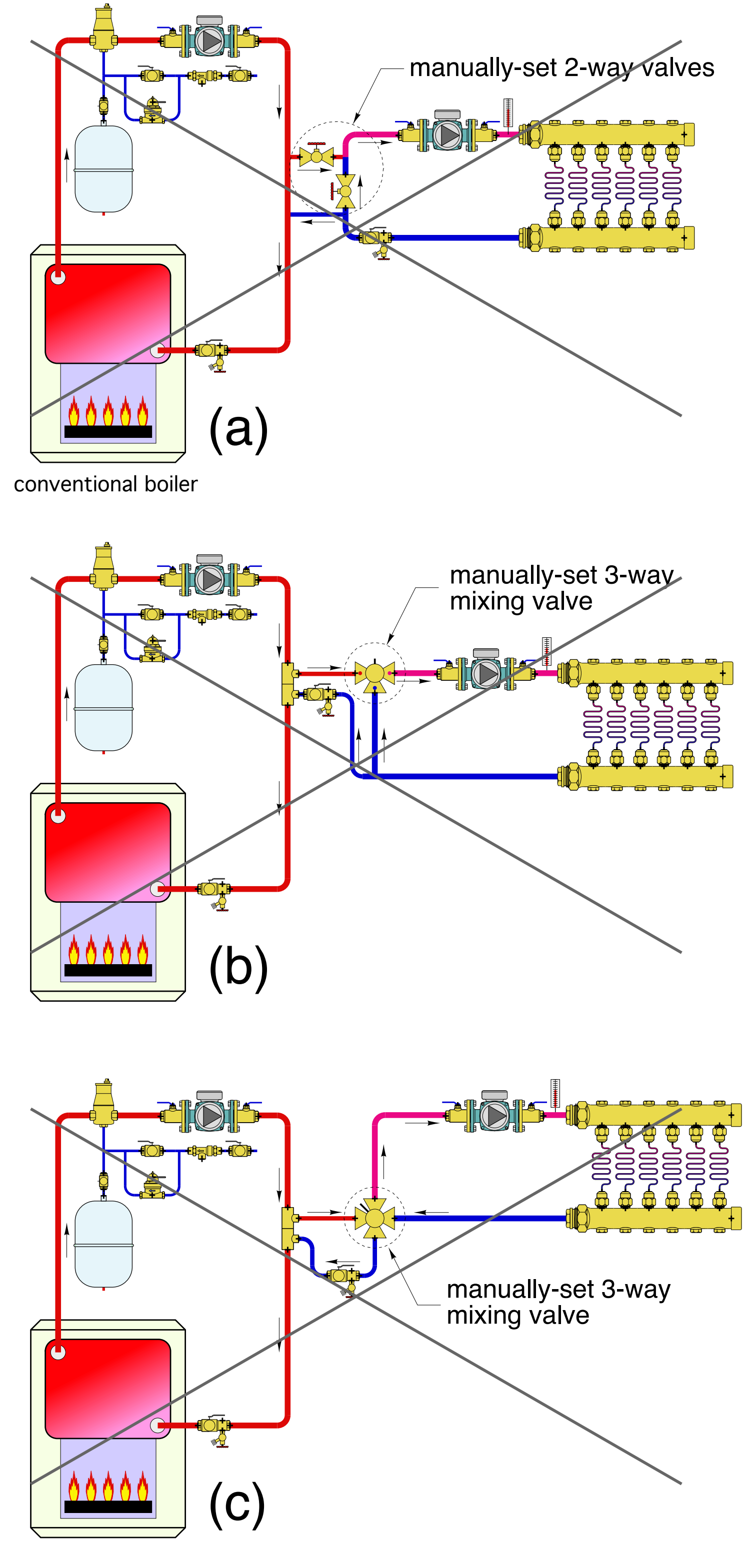
The 3-way motorized mixing valve, or variable speed injection pump methods of mixing are most appropriate for biomass boiler systems the most appropriate.

Manually set mixing devices

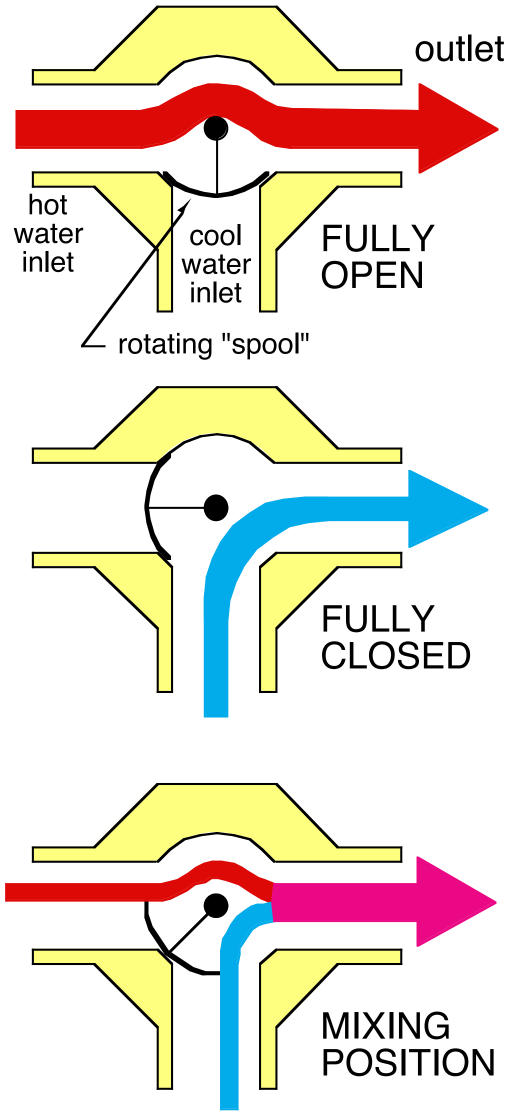
NOT RECOMMENDED !

They cannot react to changes in either supply water temperature, or return water temperature.

There will be wide variations in both supply and return water temperature.



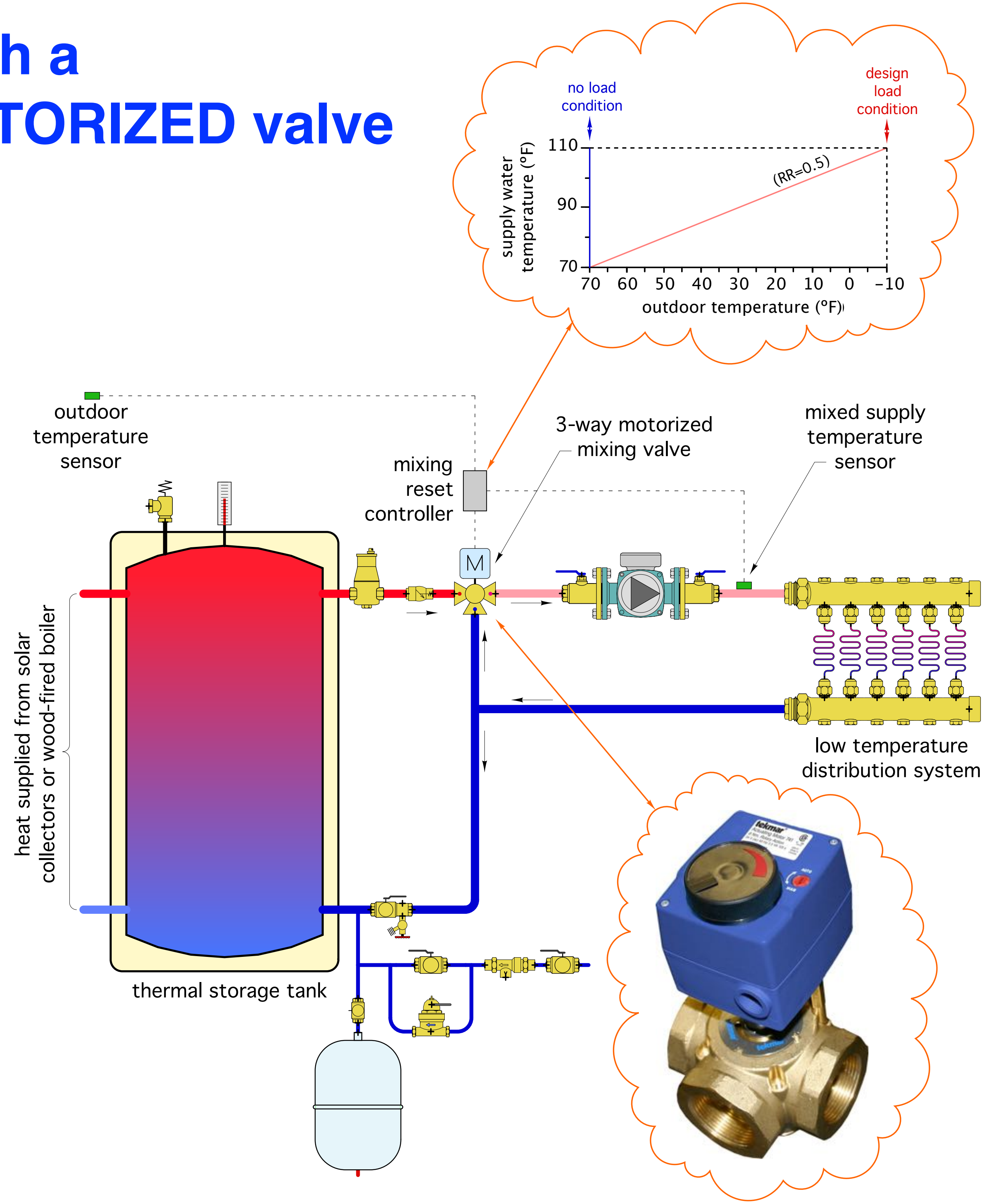
Mixing with 3-way MOTORIZED valves



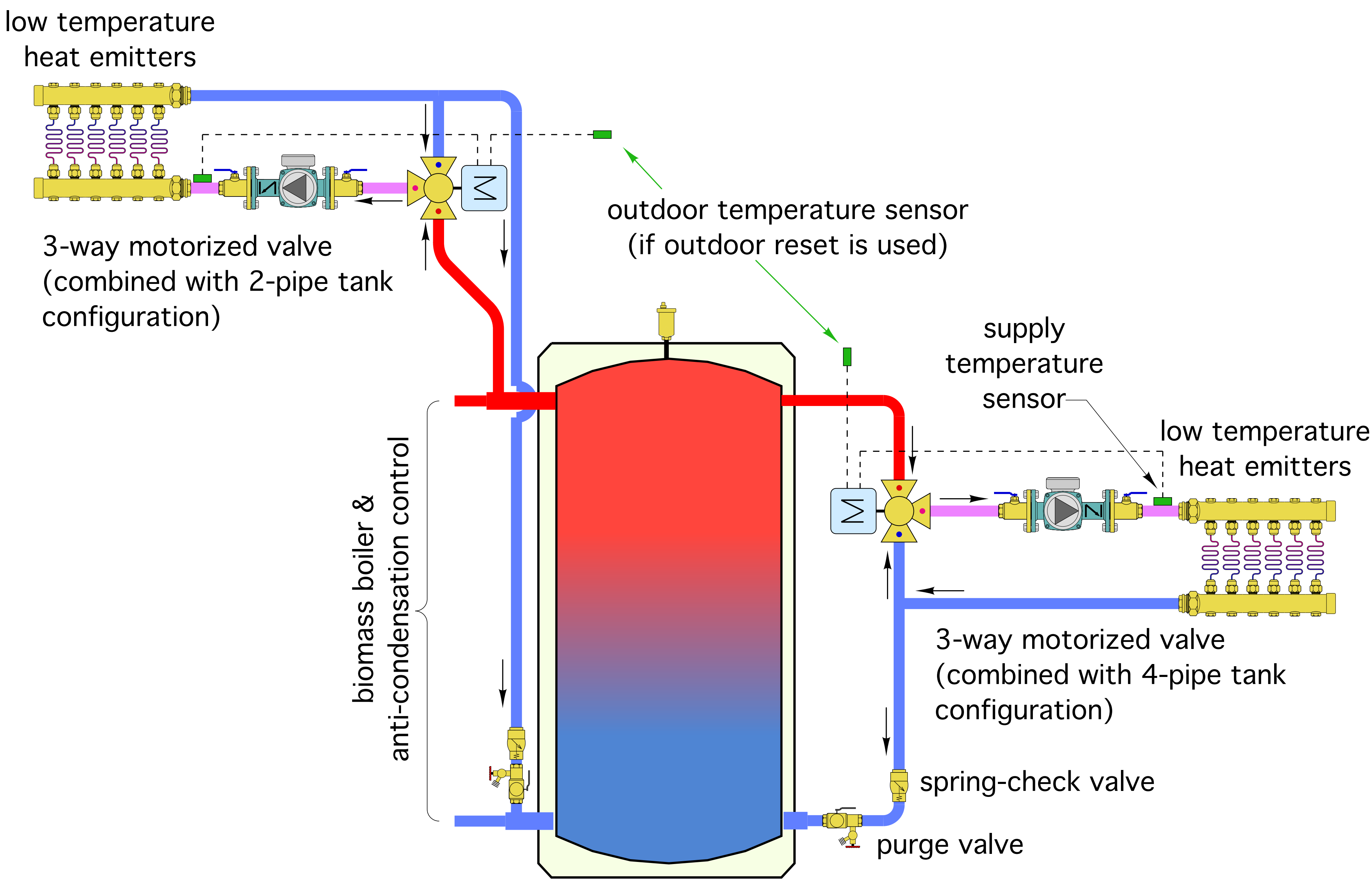
Taco iSeries
(up to 1.25” pipe size)

Paxton Corp (ESBE), up
to 6” pipe size

Mixing with a 3-way MOTORIZED valve



Mixing with 3-way MOTORIZED valves

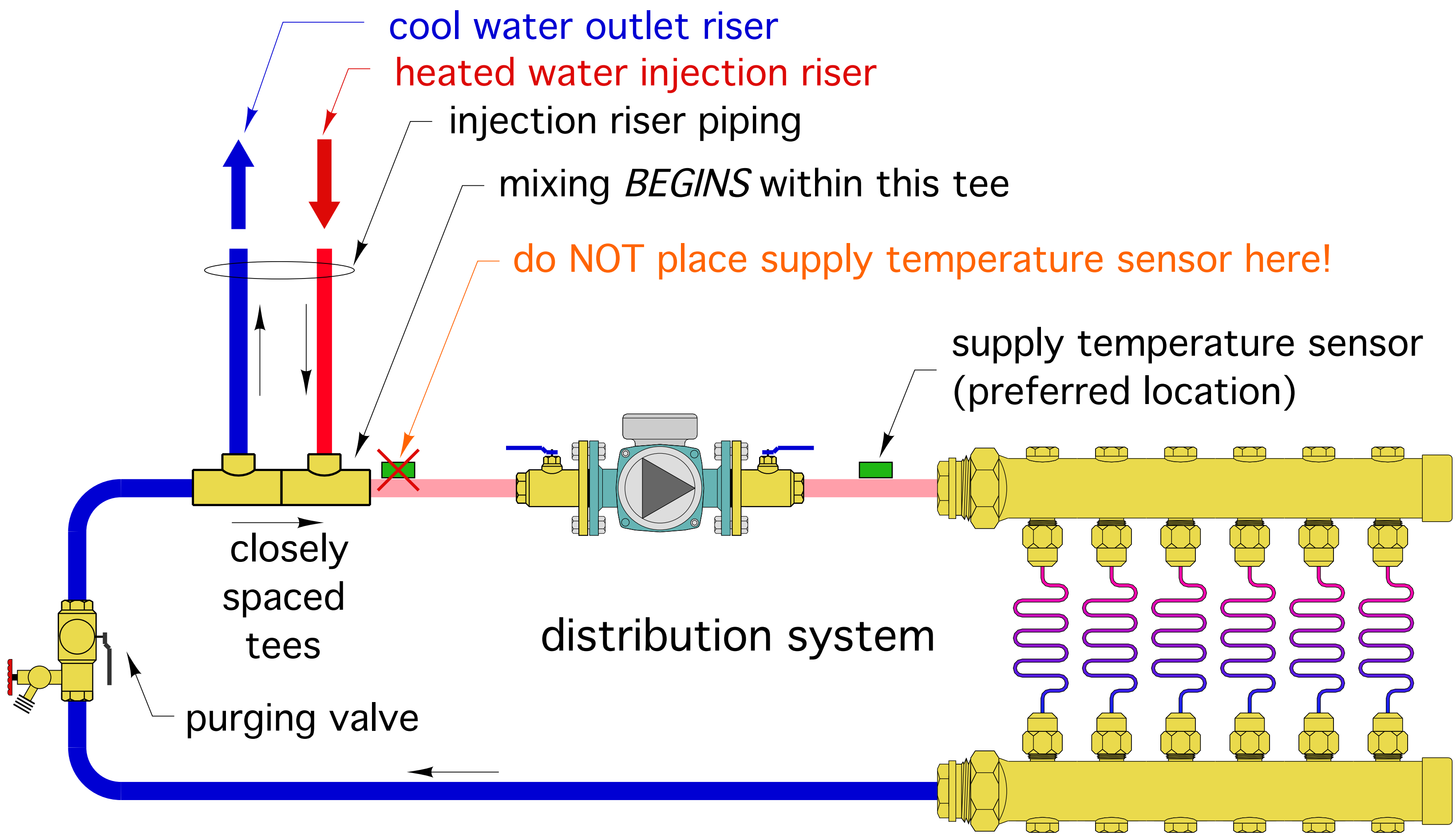


Injection mixing

The term injection mixing applies to any mixing assembly in which hot water is pushed (e.g. injected) into a circulating distribution system as shown below.

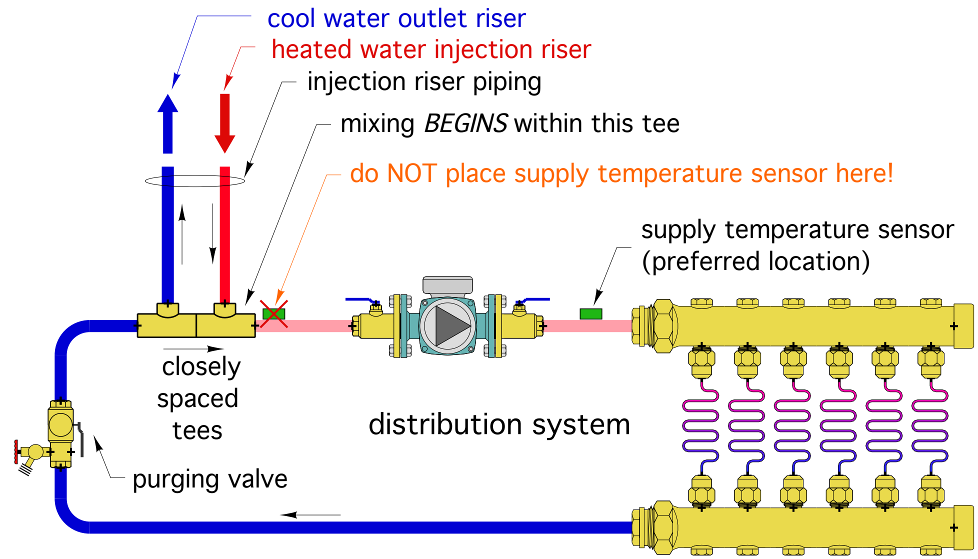
Since the distribution system is completely filled, cooler fluid must exit at the same flow rate hot water is injected.

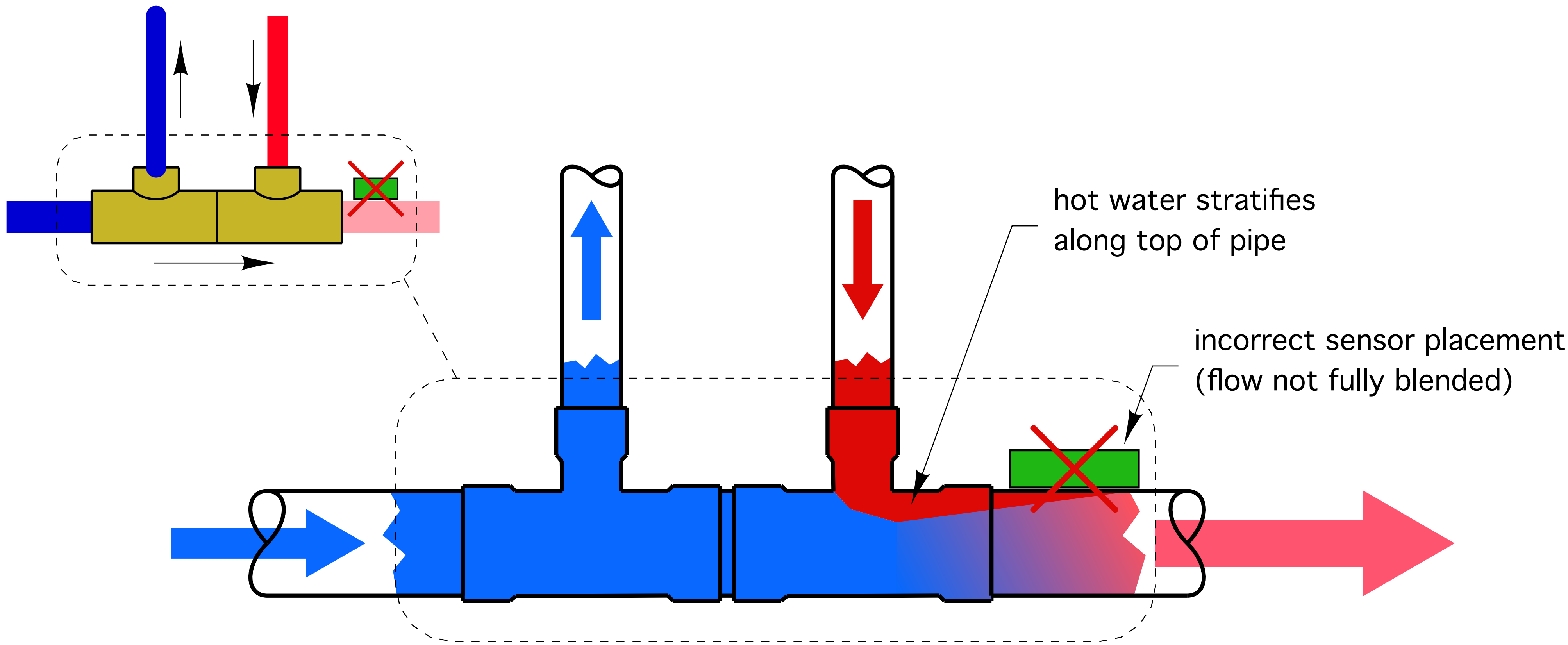
The greater the rate of hot water injection, the warmer the mixed supply temperature.



Injection mixing

Why sensor placement is important





Injection mixing

The injection flow rate needed to establish a given rate of heat transfer into the distribution system is found using the following equation.

$$f_i = \frac{Q}{k \times (T_{hot} - T_{return})}$$

Where:
if = required injection flow rate (gpm)
Q = rate of heat transfer into distribution system (gpm)
T_{hot} = temperature of fluid being injected (ºF)
T_{return} = temperature of fluid returning from distribution system (ºF)
k=a number based on the fluid used.

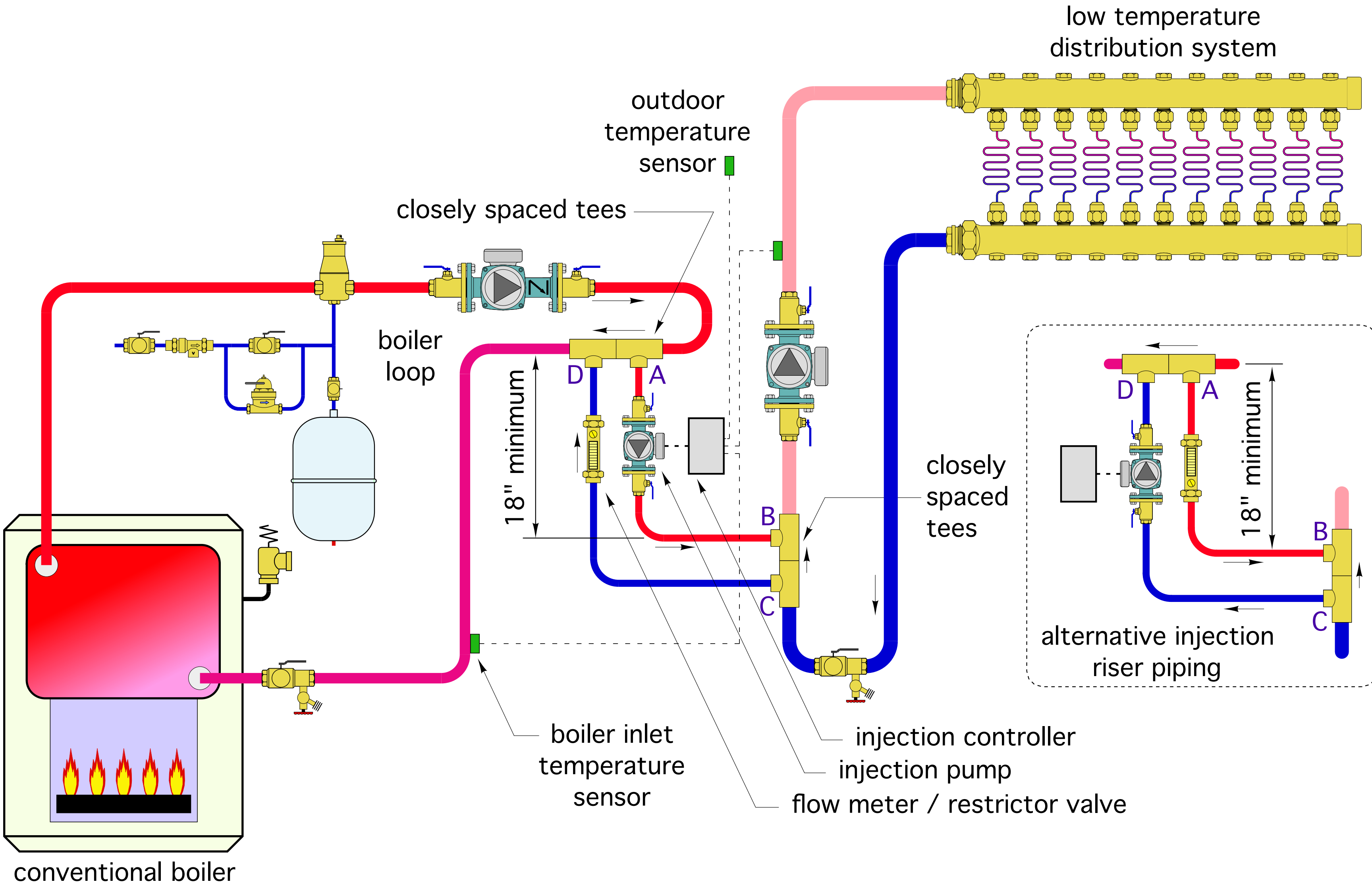
for water: k= 490
for a 30% solution of either propylene glycol or ethylene glycol: k= 479
for a 50% solution of either propylene glycol or ethylene glycol: k= 450

Keep in mind that T_{hot} will decrease as the thermal storage tank temperature drops. So calculate the injection flow rate based on minimum tank temperature.

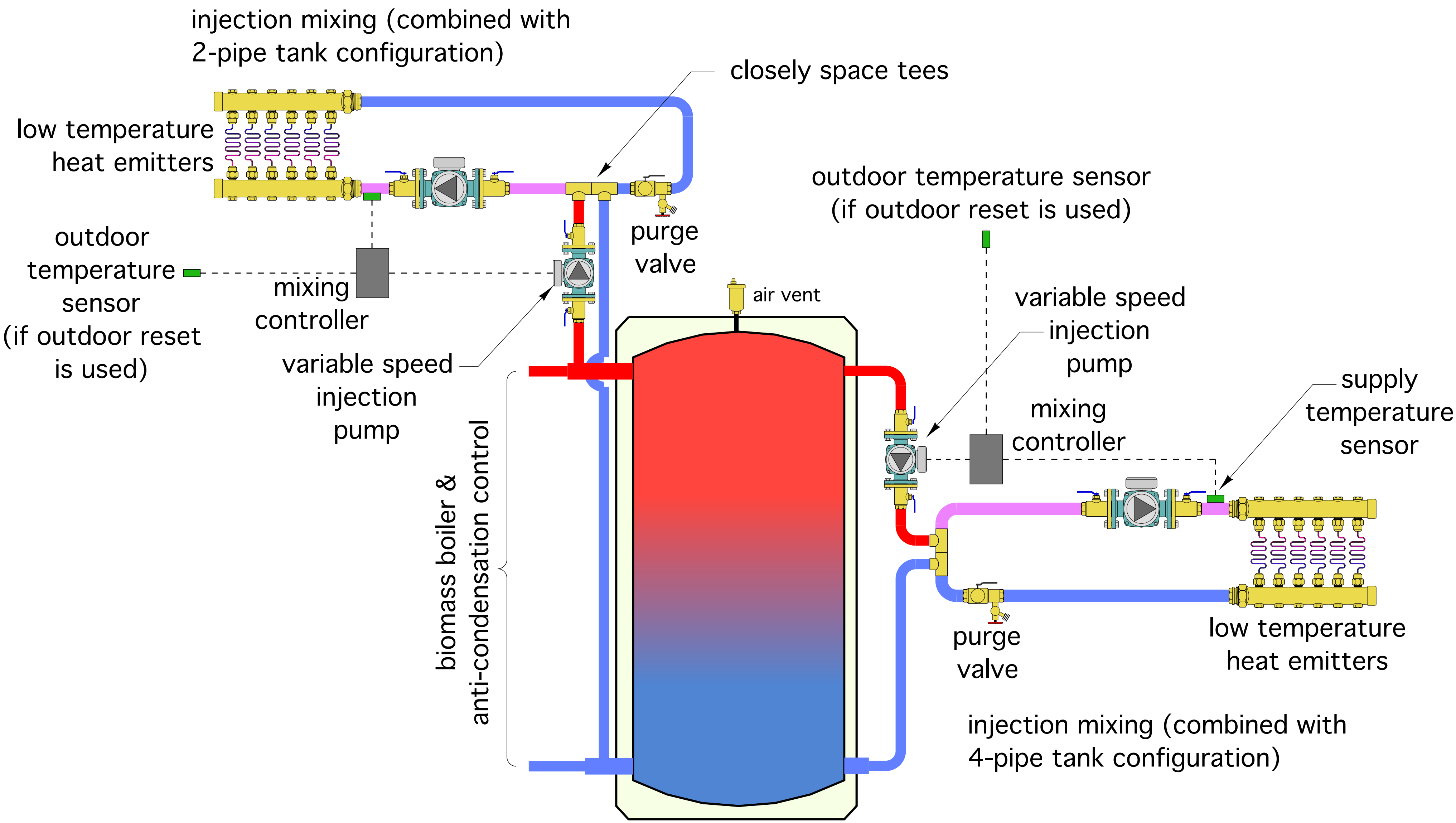
Injection Mixing Using A Variable Speed Pump

A variable speed pump can be used to regulate injection flow rate.

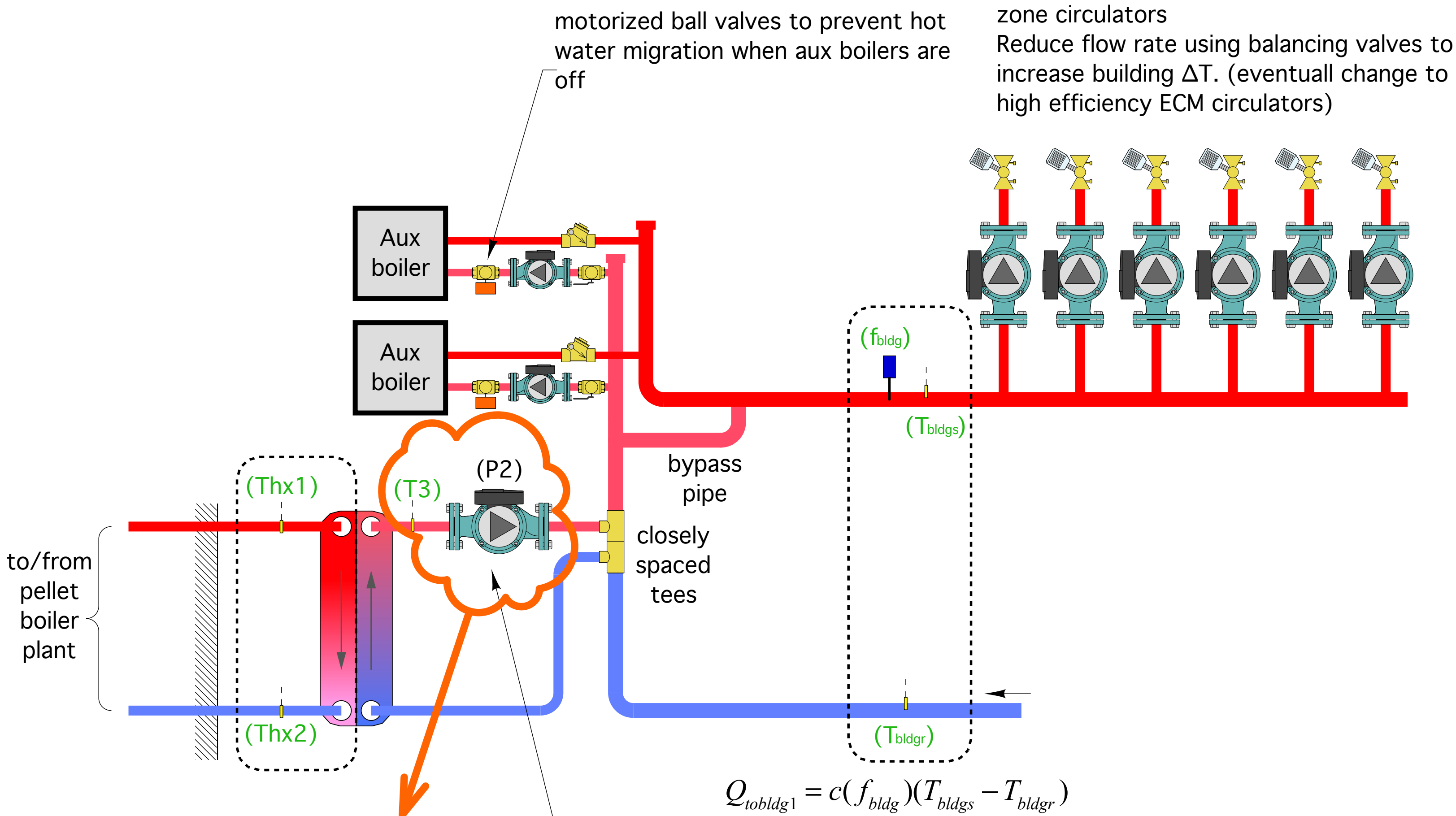
By controlling the speed of the injection pump, heat input to the distribution system can be varied from zero to full design load.



Injection Mixing Using A Variable Speed Pump



Injection Mixing Using A Variable Speed Pump



$$Q_{tobldg1} = c(f_{bldg})(T_{bldgs} - T_{bldgr})$$

(P2) allowed to start at lowest speed when

a. a load is present in the building

b. $(T3-T_{bldgr}) \geq 5°F$

(P2) is off if:

a. there is no zone calling for heat

b. $(T3-T_{bldgr}) \leq 3°F$

when on, adjust flowrate of P2 = total of all active zone flows (f_{bldg})

do not allow flowrate of (P2) to exceed total zone flow rate

High efficiency ECM Circulators - all have several speed control options such as 0-10VDC, 4-20ma, PWM, BACnet, LonWorx

Grundfos MAGNA

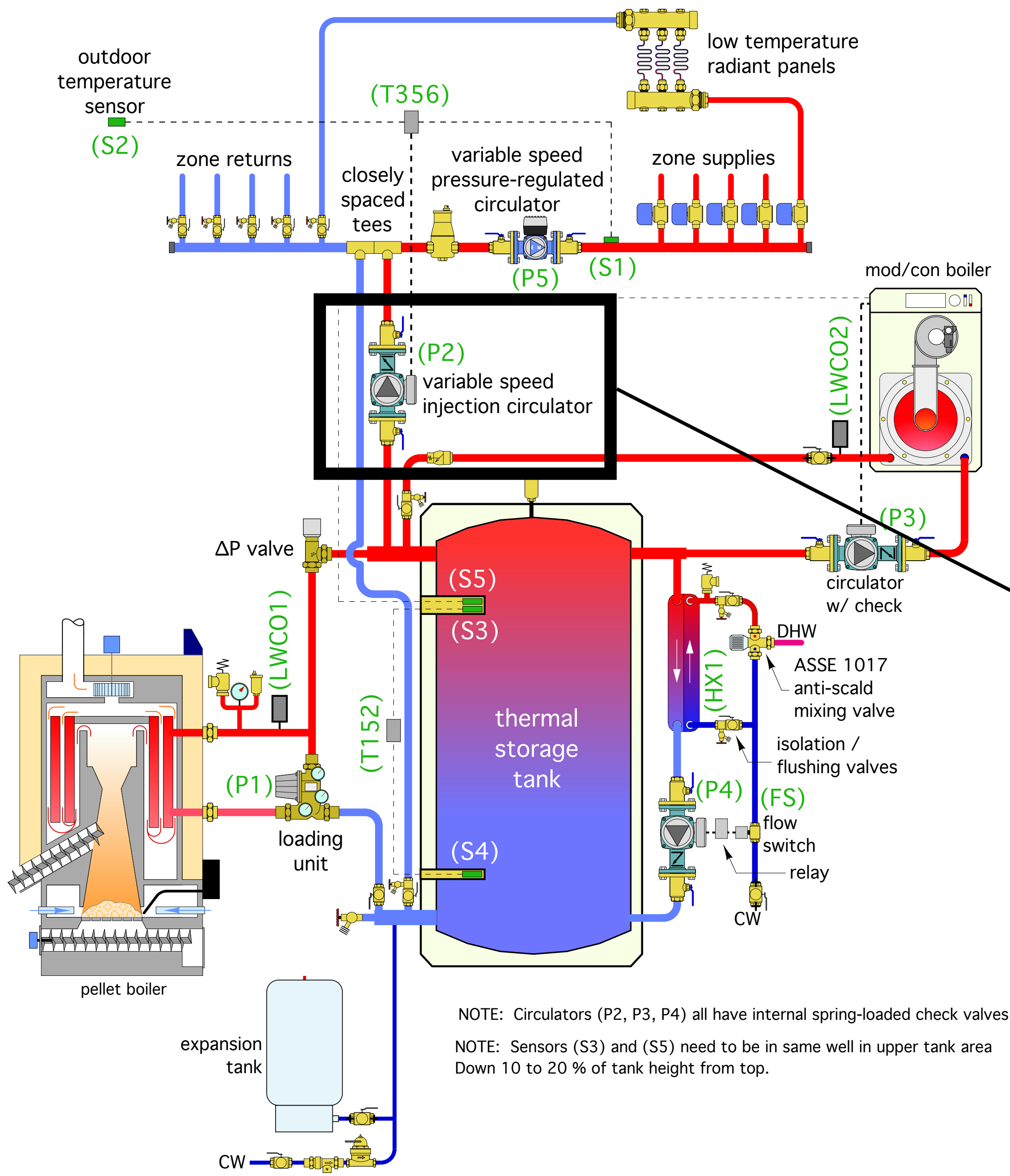
Taco 1915e

Wilo STRATOS circulators

Armstrong Compass R

B&G ECO XL

Injection Mixing Using A Variable Speed Pump

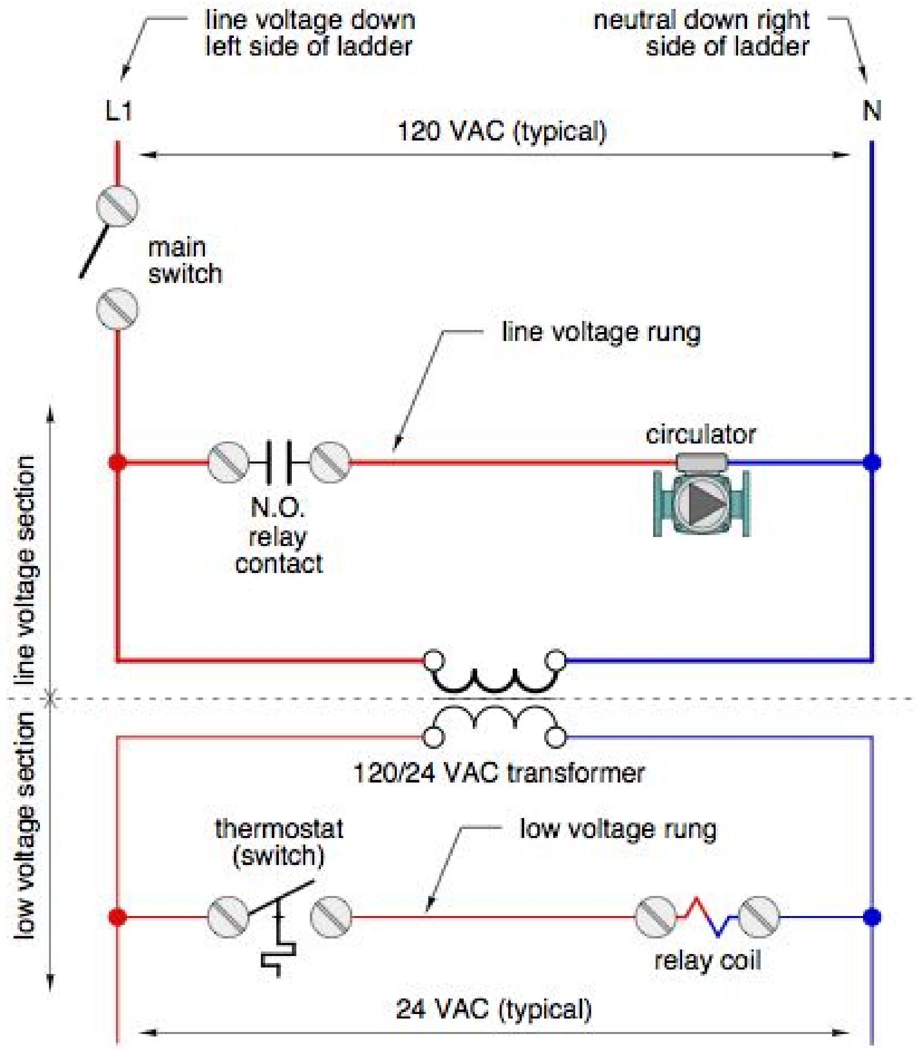


Small circulator with PSC or shaded pole motor up to 1/3 HP controlled by tekmar 356 injection mixing controller

Documenting control systems using ladder diagrams

Ladder diagrams

The basics of ladder diagrams were discussed in part 1 of this webinar



1. main switch closed to power the system.

2. thermostat contact in low voltage section close to give a demand for heat.

3. 24 VAC for transformer secondary energizes the relay coil.

4. Normally open relay contact in load section close.

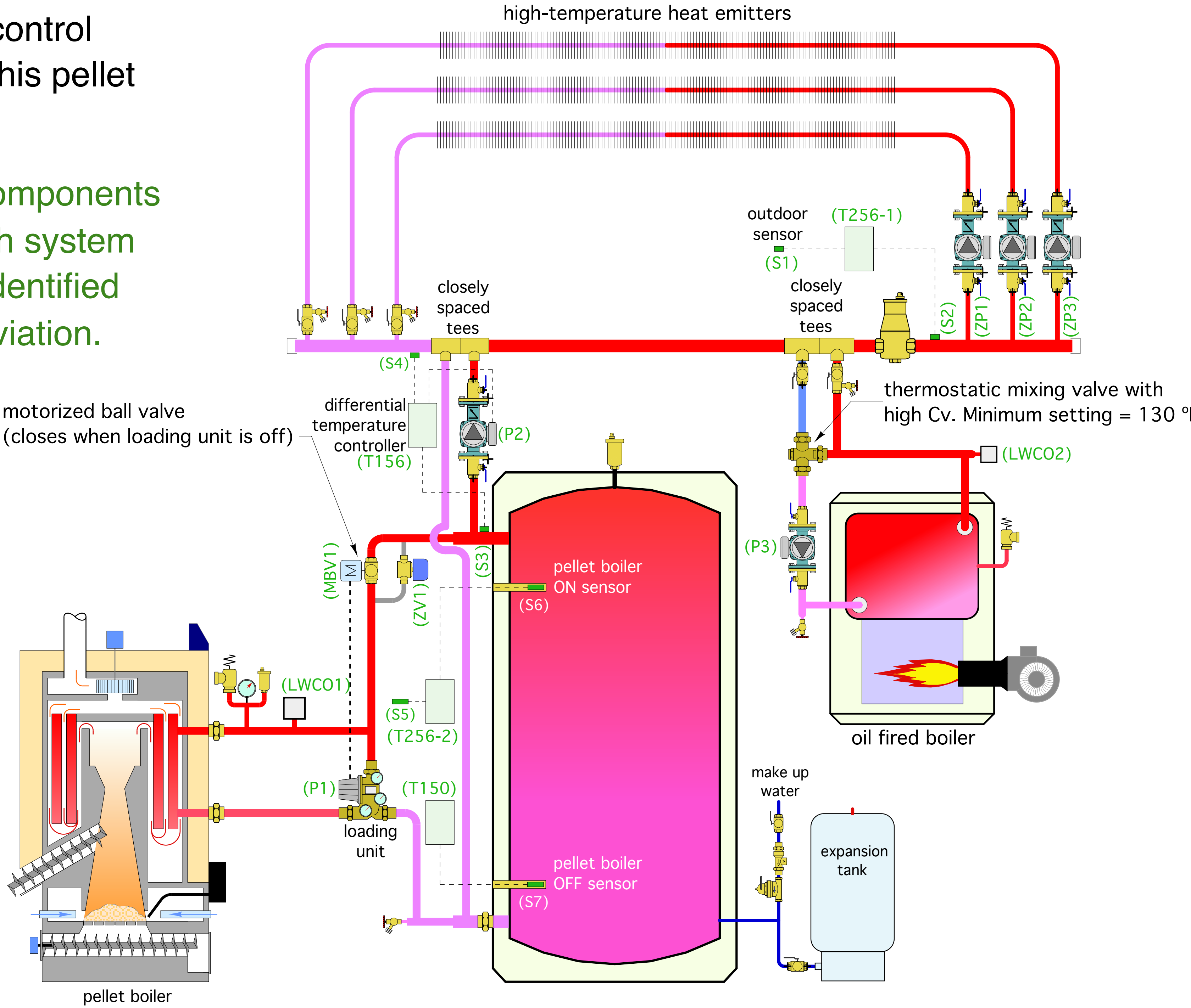
5. Line voltage is passed to operate the circulator.

Design tip: Simple concepts like this can be extended to multiple load. Just make the ladder diagram longer as necessary.

Ladder diagrams - Example

Document the control subsystem for this pellet boiler system

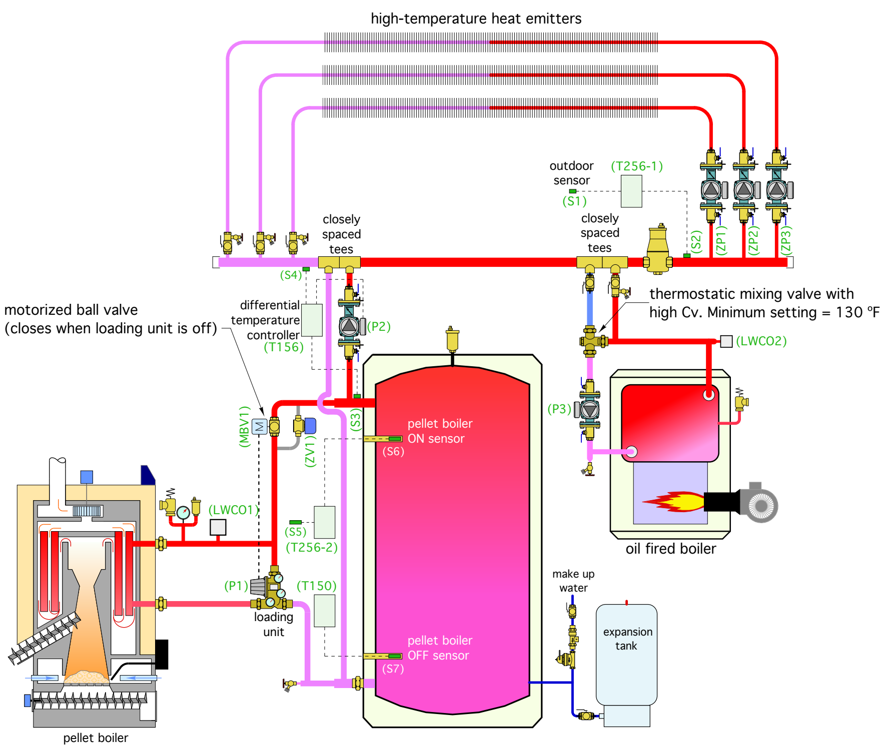
Note that the components that interact with system control are all identified using an abbreviation.

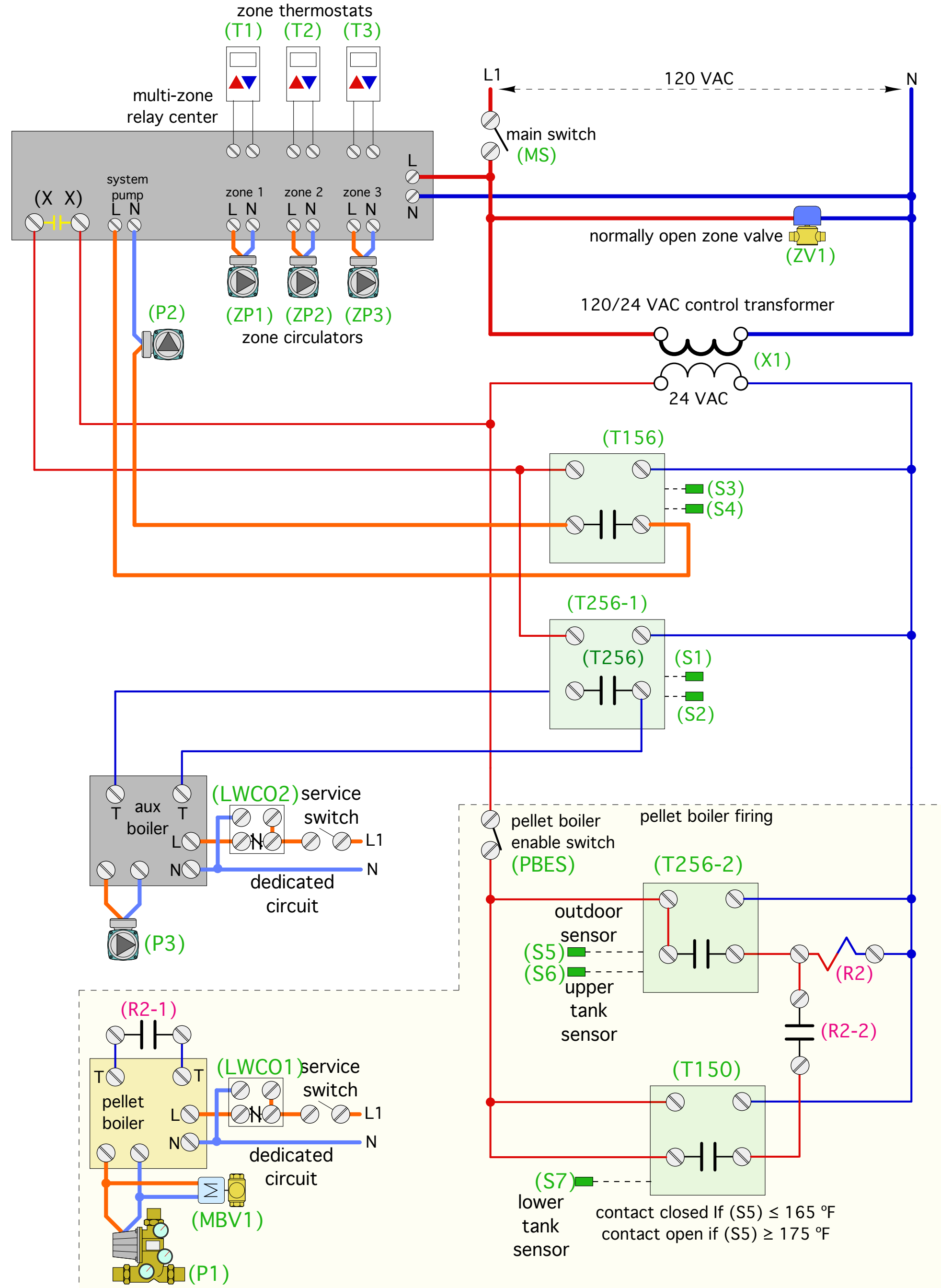


Ladder diagrams - Example

The component abbreviations allow cross-referencing between the piping schematic and the ladder diagram.

The component abbreviations also allow cross-referencing between the piping schematic, the ladder diagram, **and the description of operation.**





Description of operation

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 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 auxiliary boiler to operate.

Power for the zone circulators (ZP1, ZP2, ZP3), 24 VAC transformer, normally open zone valve (ZV1), and controllers (T156), (T256-1), (T256-2), and (T150) is supplied through another 120 VAC dedicated circuit. The main switch (MS) for this circuit must be closed for these devices to operate.

Pellet Boiler Operation: *The pellet boiler enable switch must be closed for the pellet boiler to operate. This switch would typically be closed at the start of the heating season and opened at the end of the heating season. The pellet boiler is turned on by an outdoor reset controller (T256-2). The (T256-2) controller measures the outdoor temperature at sensor (S5), and uses this temperature along with its settings to determine the "target" temperature at the upper tank sensor (S6) at which the pellet boiler will be turned on. The target temperature for this controller is shown on the graph in figure 8-1c. When the temperature at the upper tank sensor (S6) drops to 4 ºF below the target temperature, the normally open contacts in the (T256-2) controller close. This passes 24 VAC to the coil of relay (R2). Relay contact (R2-1) closes across the external demand terminal of the pellet boiler. The pellet boiler turns on loading unit circulator (P1) and initiates its start up sequence. Motorized ball valve (MBV1) opens to allow flow between the pellet boiler and thermal storage tank. Relay contact (R2-2) also closes. 24 VAC passes through the closed contacts of setpoint controller (T150) and through the closed contacts (R2-2) to provide another path for 24 VAC to relay coil (R2). When the temperature at the upper tank sensor (S6) reaches 4 ºF above the target temperature the contacts in the outdoor reset controller (T256-2) open. However, 24 VAC continues to pass through the closed contacts in controller (T150) and closed contacts (R2-2) until the lower tank sensor (S7) reaches 175 ºF. At that point the contacts in setpoint controller (T150) open, breaking 24VAC to relay coil (R2), which removes the external demand from the pellet boiler, allowing it to shut down.*

The pellet boiler is equipped with a loading unit (P1) which contains a thermostatic mixing valve that recirculates water through the pellet boiler when necessary to allow the temperature of the pellet boiler to quickly climb above the dewpoint of the exhaust gases.

During a power outage, the normally open zone valve (ZV1) opens to allow an unblocked thermosiphon piping path between the pellet boiler and thermal storage tank. A thermosiphon flow will occur that dissipate residual heat from the pellet boiler into thermal storage.

If the pellet boiler switch (PBES) is opened, such as at the end of the space heating season, the pellet boiler, its associated controllers, and its circulator (P1) will not operate.

Distribution system: *Upon a call for heating from any zone thermostat (T1, T2, T3), the associated zone circulator (ZP1, ZP2, ZP3) is turned on. 120 VAC is also present at the "system pump" terminals in the multi-zone relay center. The isolated relay contact (X X) in the multizone relay center closes passing 24VAC power from transformer (X1) to outdoor reset controller (T256-1) and differential temperature controller (T156). The (T156) compares the temperature of the upper tank header sensor (S3) to the temperature of water returning from the distribution system at sensor (S4). If the upper tank header temperature is at least 5 ºF above the return water temperature the contacts in the (T156) controller close. This allows 120VAC to reach circulator (P2) to inject heat from the upper tank header into the distribution system.*

The (T256-1) controller measures outdoor temperature at sensor (S1) and calculates a target supply water temperature for the distribution system. This is the same target temperature calculated by controller (T256-2). If the temperature of the water passing sensor (S2) on the supply side of the distribution system is 10 ºF or more below the target supply water temperature the contacts in the (T256-1) controller close across the (T T) terminals of the auxiliary boiler enabling it, and circulator (P3) to operate. Heat from the oil-fired boiler is now injected into the distribution system. Circulator (P2) continues to run unless the temperature on the return side of the distribution system at sensor (S3), climbs to within 3 ºF of the temperature of the upper tank header at sensor (S4). If this occurs, the contacts in the (T156) controller open turning off circulator (P2). Heat from the oil-fired boiler continues to flow into the distribution system until the supply water temperature reaches 10 ºF above the target temperature. At that point the oil fired boiler and circulator (P3) turn off. Assuming the heating demand from one or more zones continues, the water temperature at sensor (S1) will eventually drop to 10 ºF below the target temperature, at which time the oil-fired boiler and circulator (P3) will turn on.

Suggested (initial) controller settings

Suggested settings:

- *T256-2 outdoor reset controller (monitors upper tank sensor (S6))*
  - *Outdoor design temperature = 0 ºF*
  - *Supply water temperature at outdoor design temperature = 180 ºF*
  - *Maximum supply water temperature = 180 ºF*
  - *Minimum supply water temperature = 100 ºF*
  - *Outdoor temperature at no load condition = 70 ºF*
  - *Supply water temperature at no load condition = 70 ºF*
  - *Differential = 8 ºF (centered on target temperature)*

- *T256-1 outdoor reset controller (monitors supply temp. sensor for distribution system (S2))*
  - *Outdoor design temperature = 0 ºF*
  - *Supply water temperature at outdoor design temperature = 180 ºF*
  - *Maximum supply water temperature = 180 ºF*
  - *Minimum supply water temperature = 100 ºF*
  - *Outdoor temperature at no load condition = 70 ºF*
  - *Supply water temperature at no load condition = 70 ºF*
  - *Differential = 20 ºF (centered on target temperature)*

- *T150 setpoint controller (monitors lower tank temperature sensor (S7)*
  - *setpoint = 170 ºF*
  - *Differential = 10 ºF (centered on target temperature)*

- *T156 differential temperature controller*
  - *contacts close if high temperature sensor ≥ 5 ºF above low temperature sensor*
  - *contacts open if high temperature sensor ≤ 3 ºF above low temperature sensor*
- *Pellet Boiler high limit temperature = 200 ºF*
- *Oil-fired boiler high limit temperature = 200 ºF*
- *Oil fired boiler differential = 5 ºF (below target temperature)*

Always leave a log sheet at the site and record any changes made to controller settings:

- **date**
- **setting as found**
- **new setting**
- **reason for change**
- **who made change**

RHNY Incentives

<table>
<tr><th>Program</th><th>System Type</th><th colspan="2">Installation Incentive</th><th colspan="3">Additional Incentive</th></tr>
<tr><td rowspan="3">Small Biomass Boiler</td><td>Advanced Cordwood Boiler with Thermal Storage</td><td colspan="2">25% installed cost ($7,000 maximum)</td><td>-</td><td rowspan="5">Recycling

$5,000/unit for old indoor/ outdoor wood boiler
or
$2,500/unit for old wood furnace</td><td>-</td></tr>
<tr><td rowspan="2">Small Pellet Boiler with Thermal Storage</td><td>≤120 kBtu/h (35 kW)</td><td>45% installed cost ($16,000 maximum)</td><td rowspan="4">Thermal Storage Adder

$5/gal for each gal above the minimum thermal storage requirement</td><td>-</td></tr>
<tr><td>≤300 kBtu/h (88 kW)</td><td>45% installed cost ($36,000 maximum)</td><td>-</td></tr>
<tr><td rowspan="2">Large Biomass Boiler</td><td>Large Pellet Boiler with Thermal Storage</td><td rowspan="2">>300 kBtu/h (88 kW)</td><td>65% installed cost ($325,000 maximum)</td><td rowspan="2">Emission Control System

$40,000</td></tr>
<tr><td>Tandem Pellet Boiler with Thermal Storage</td><td>75% installed cost ($450,000 maximum)</td></tr>
<tr><td>Residential Pellet Stove</td><td>Pellet Stove</td><td colspan="2">$1,500
($2,000 for income qualified residents)</td><td>-</td><td>Recycling

$500
(income qualified residents only)</td><td>-</td></tr>
</table>

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LMI Incentives - Boilers

Program	System Type		Market Rate Installation Incentive	LMI Installation Incentive
Small Biomass Boiler	Advanced Cordwood Boiler with Thermal Storage		25% installed cost ($7,000 maximum)	65% installed cost ($18,000 maximum)
	Small Pellet Boiler with Thermal Storage	≤120 kBtu/h (35 kW)	45% installed cost ($16,000 maximum)	65% installed cost ($23,000 maximum)

For more information:

- “Google” Renewable Heat NY
- contact Sue Dougherty at NYSERDA sue.dougherty@nyserda.ny.gov

Future online training opportunities

November 12 / 1:00-2:00 PM
Topic: Case study - Pellet boiler system at the NYSDEC boat maintenance facility at Lake George
DescriptionThe NYSDEC boat service facility at Lake George uses a pellet boiler as the primary heat source for a floor heating system. This webinar exams the details used in this system, including fuel supply, boiler, thermal storage, and the distribution system. It will also discuss some of the monitored performance for the system, and some of the initial challenges met in fine tuning system operation.

All training is provided free

Register here:

https://www.nyserda.ny.gov/All-Programs/Programs/Become-a-Contractor/Renewable-Heating-and-Cooling/Renewable-Heat-NY-Contractors

Watch the RHNY website for announcements of webinars and (hopefully) face-to-face training on biomass boiler system during 2021.

QUESTIONS ?