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

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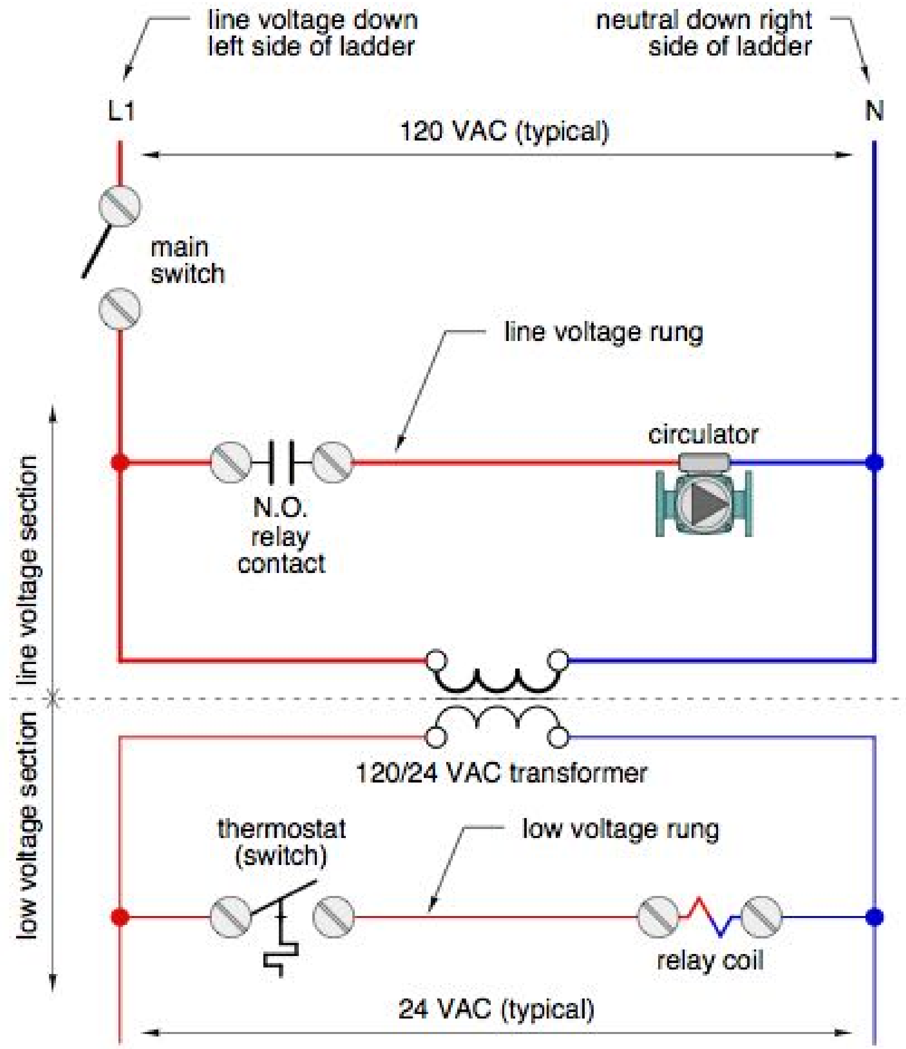


Control concepts for hydronic systems using renewable energy heat sources (part 1)

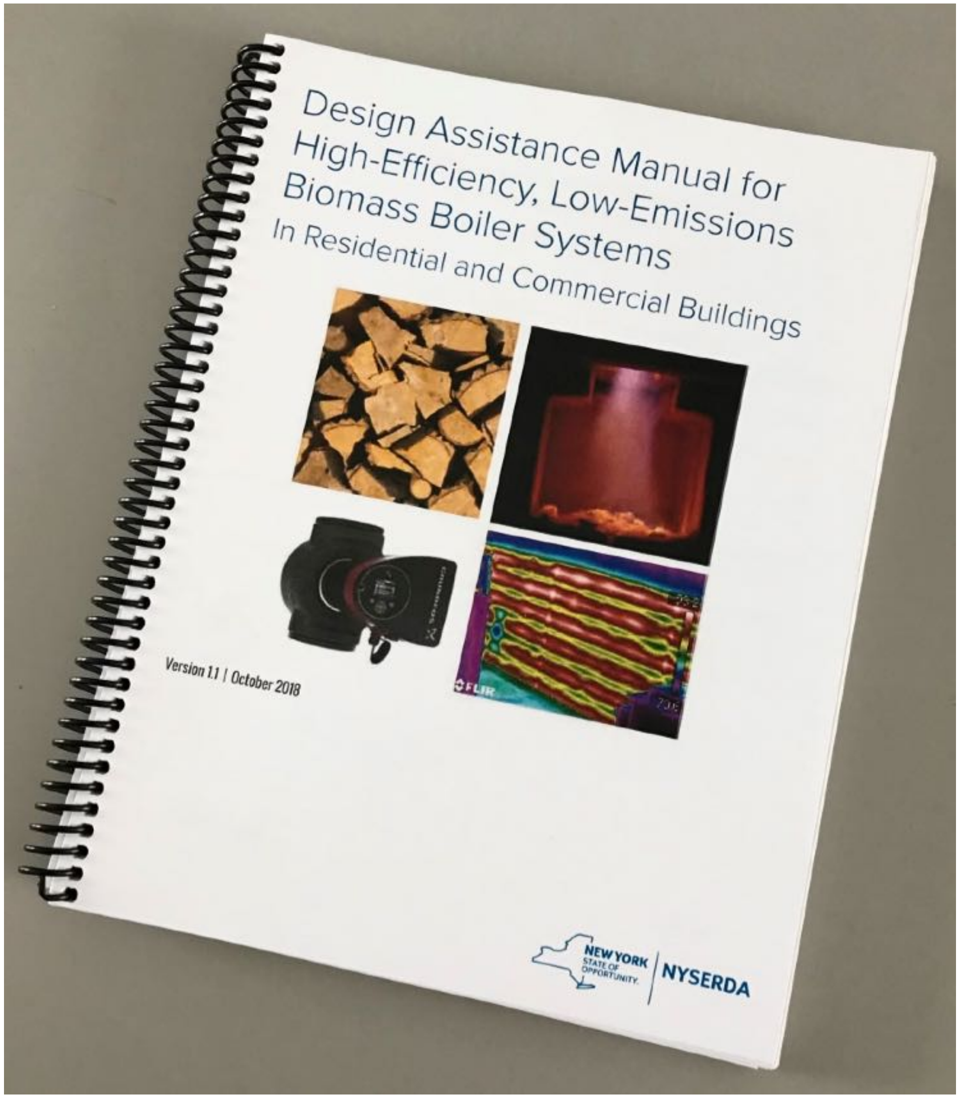
Description: The controls used in hydronic heating systems supplied by renewable energy heat sources, such as biomass boiler, heat pumps, and solar thermal collectors have proven to be an area in which installers have some difficulty. This webinar will emphasize "universal" control concepts used in these systems, and shows how they are implemented with off-the-shelf hardware.

Specific topics include:

- Basic switch and relay logic
- setpoint temperature control
- staging control
- differential temperature control
- sensor mounting

Part 2 of this webinar will cover additional control concepts such as outdoor reset control, and mixing control.

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

Switches, relays, & ladder diagrams

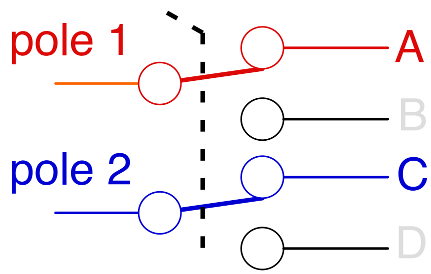
Switches: Poles and Throws

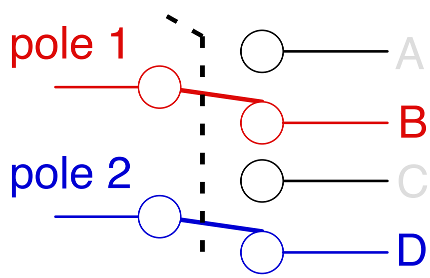
Switches and relays are classified based on their **poles** and **throws**.

The number of poles is the number of independent and simultaneous electrical paths through the switch.

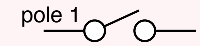
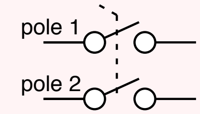
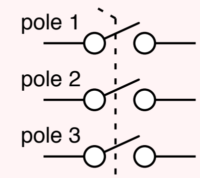
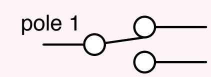
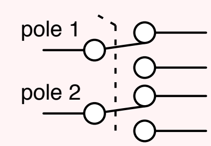
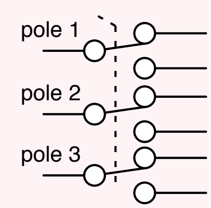
DPDT

The number of throws is the number of position settings where a current can pass through the switch.





DPDT center off

contact designation	switch contacts
Single Pole Single Throw SPST	
Double Pole Single Throw DPST	
Triple Pole Single Throw 3PST	
Single Pole Double Throw SPDT	
Double Pole Double Throw DPDT	
Triple Pole Double Throw 3PDT	

Relays

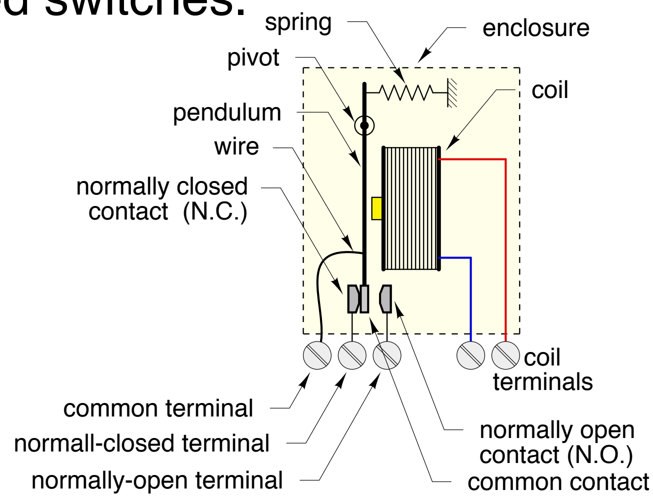
Relays are electrically operated switches.

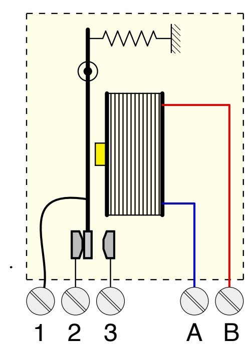
Same methods of identifying poles and throws.

Two main components of a relay:

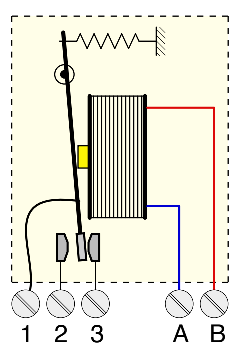
- coil
- contacts

Design tip: Always verify that loads are within the maximum current and voltage ratings of switches and relays



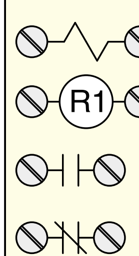


"Normal" mode: No voltage is applied to coil (terminals A and B). Spring holds pendulum so the common contact touches the normally-closed contact. Current can flow from terminal 1 to terminal 2.



Energized mode: Voltage is applied to coil (terminals A and B). Pendulum pivots toward coil. The common contact touches the normally open contact. Current can flow from terminal 1 to terminal 3.

contact designation	switch contacts	relay contacts
Single Pole Single Throw SPST	pole 1	pole 1
Double Pole Single Throw DPST	pole 1 pole 2	pole 1 pole 1
Triple Pole Single Throw 3PST	pole 1 pole 2 pole 3	pole 1 pole 2 pole 3
Single Pole Double Throw SPDT	pole 1	pole 1
Double Pole Double Throw DPDT	pole 1 pole 2	pole 1 pole 2
Triple Pole Double Throw 3PDT	pole 1 pole 2 pole 3	pole 1 pole 2 pole 3



relay coil

relay coil

relay contact, normally-open (N.O.) (closes when coil is energized)

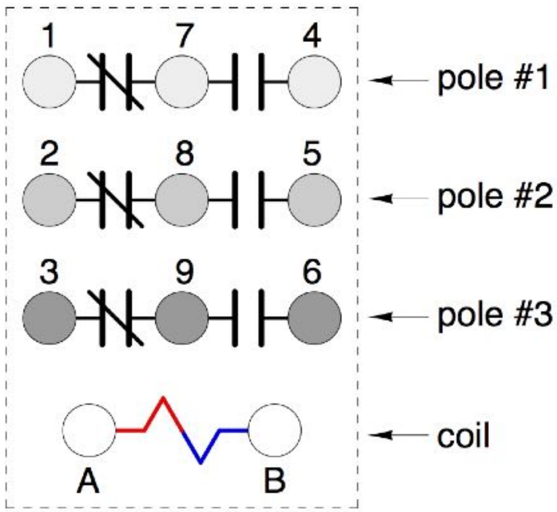
relay contact, normally-closed (N.C.) (opens when coil is energized)

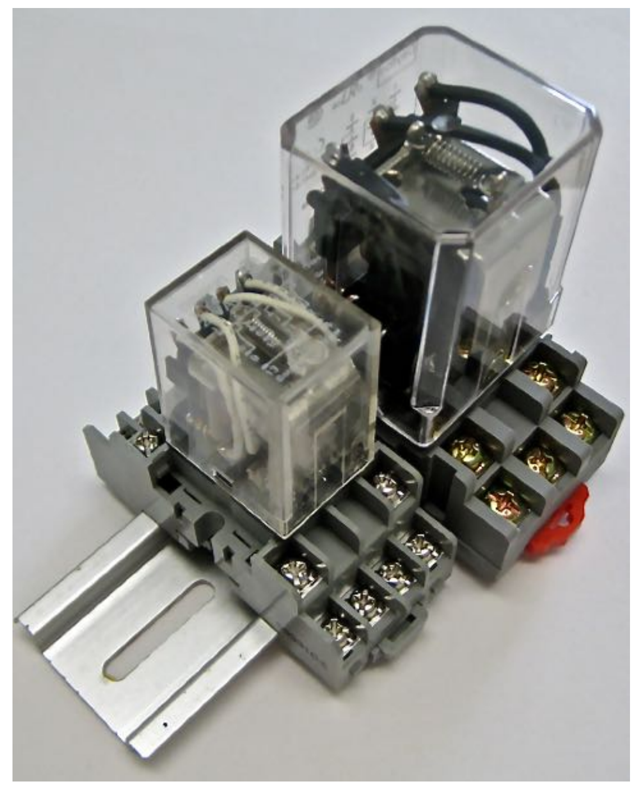
Relays

One of the most versatile relays is a "general purpose relay."

These are some time called "ice cube" relays.

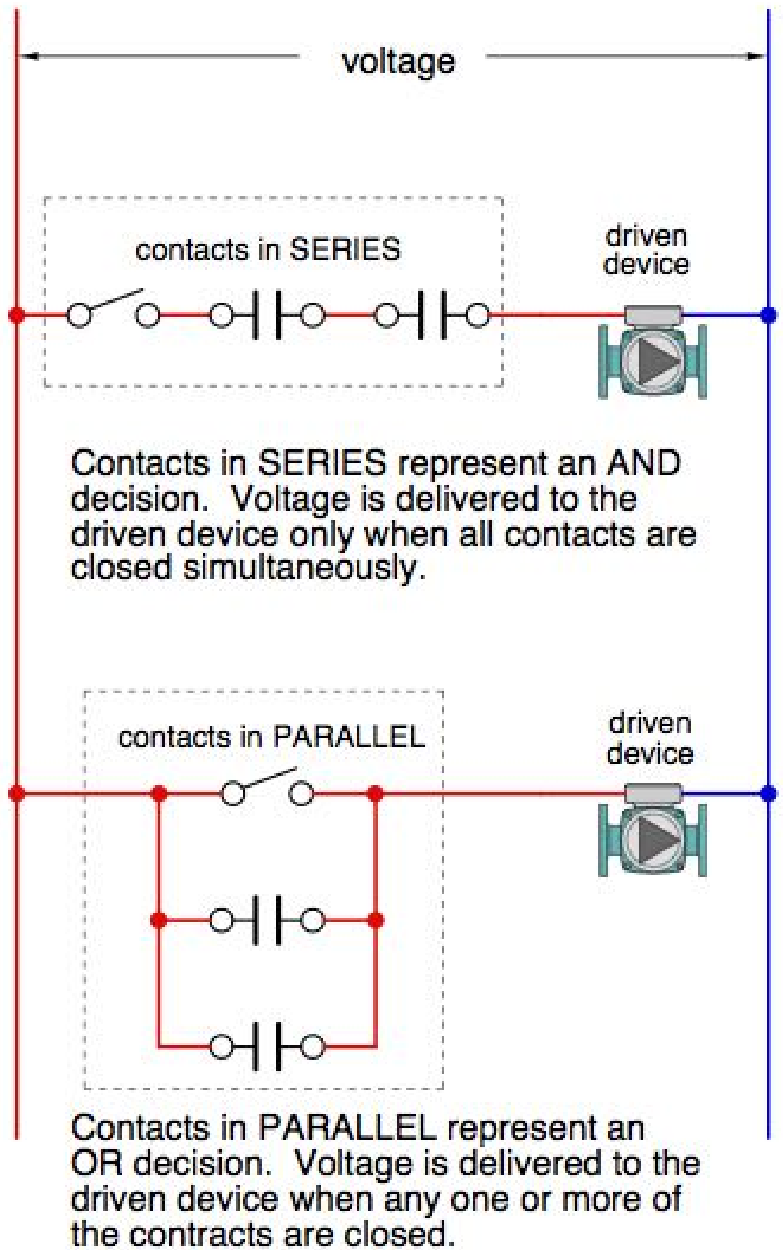
Design tip: Be sure to pay attention to the pin numbers.





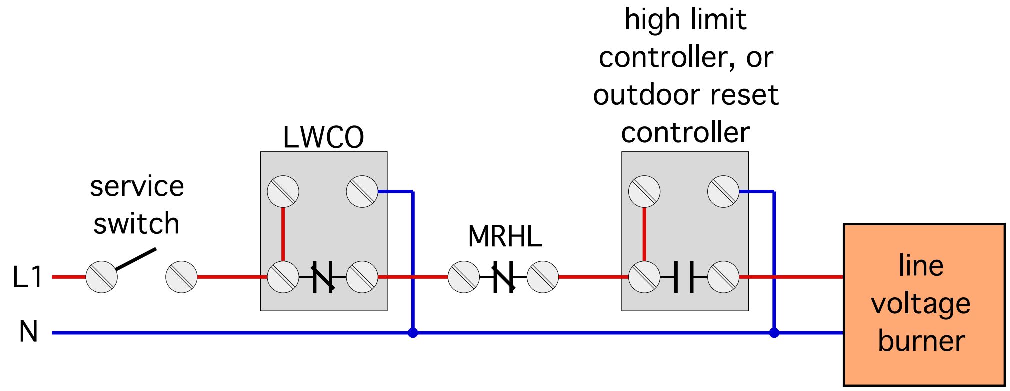
Design tip: I like a 3PDT relays from W.W.Graingers (5X840 w/ 24 VAC coil) (5X841 w/ 120 VAC coil) (5X853E socket) very versatile...

“hard wired control logic diagrams



contacts in series represent an AND decision. All contacts must be closed simultaneously for a complete circuit.

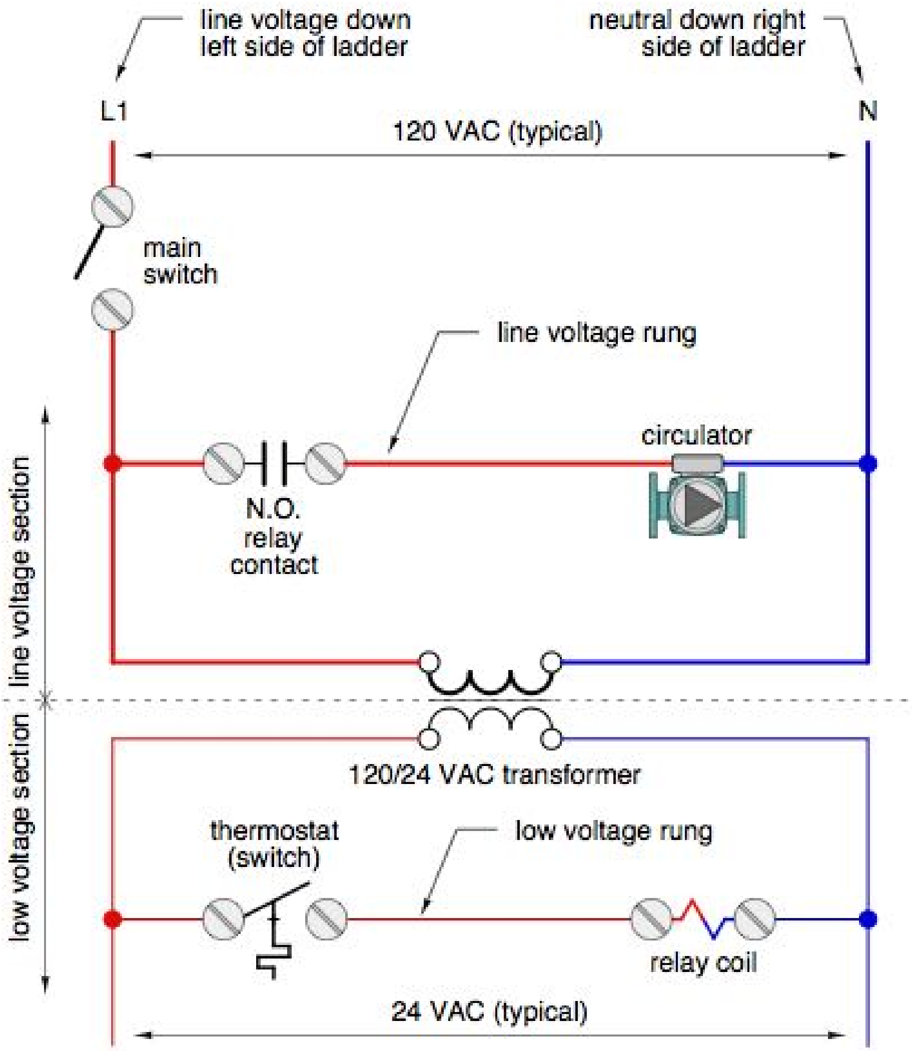
Often used for wiring multiple safety devices.



contacts in parallel represent an OR decision. Any contacts that’s closed allow the signal to pass.

Often use to operate heat source when any one or more thermostats call for heat.

Ladder diagrams



Two sections in a ladder diagram:

- **Load section** at top (line voltage)
- **Control section** at bottom (low voltage)

- Horizontal lines are called **rungs**

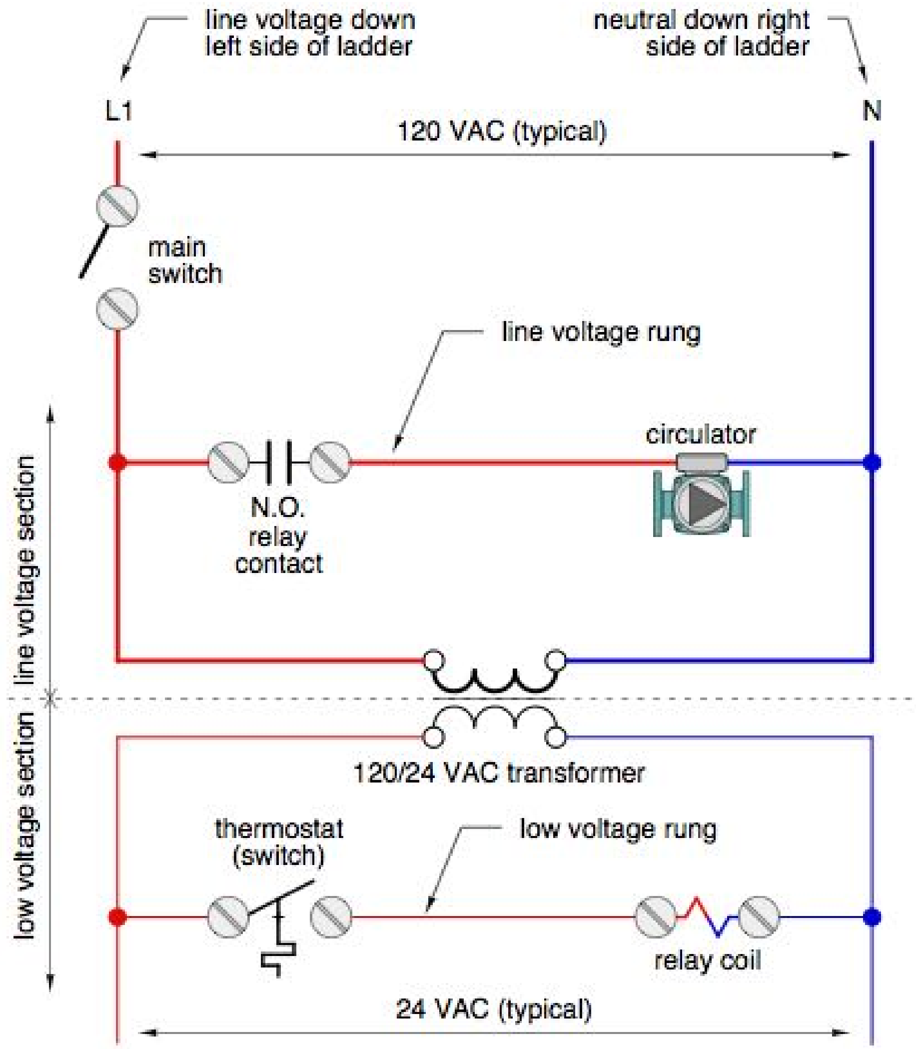
- Typically create hard wired logic in low voltage control section.

- Line voltage loads circulators, fans, line voltage controller connect across load portion of diagram.

- Main switch at top removes power from entire ladder.

Design tip: Ladder diagrams are an EXCELLENT tool to both "synthesize" the operating logic, and document it for installation and servicing.

Ladder diagrams



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.

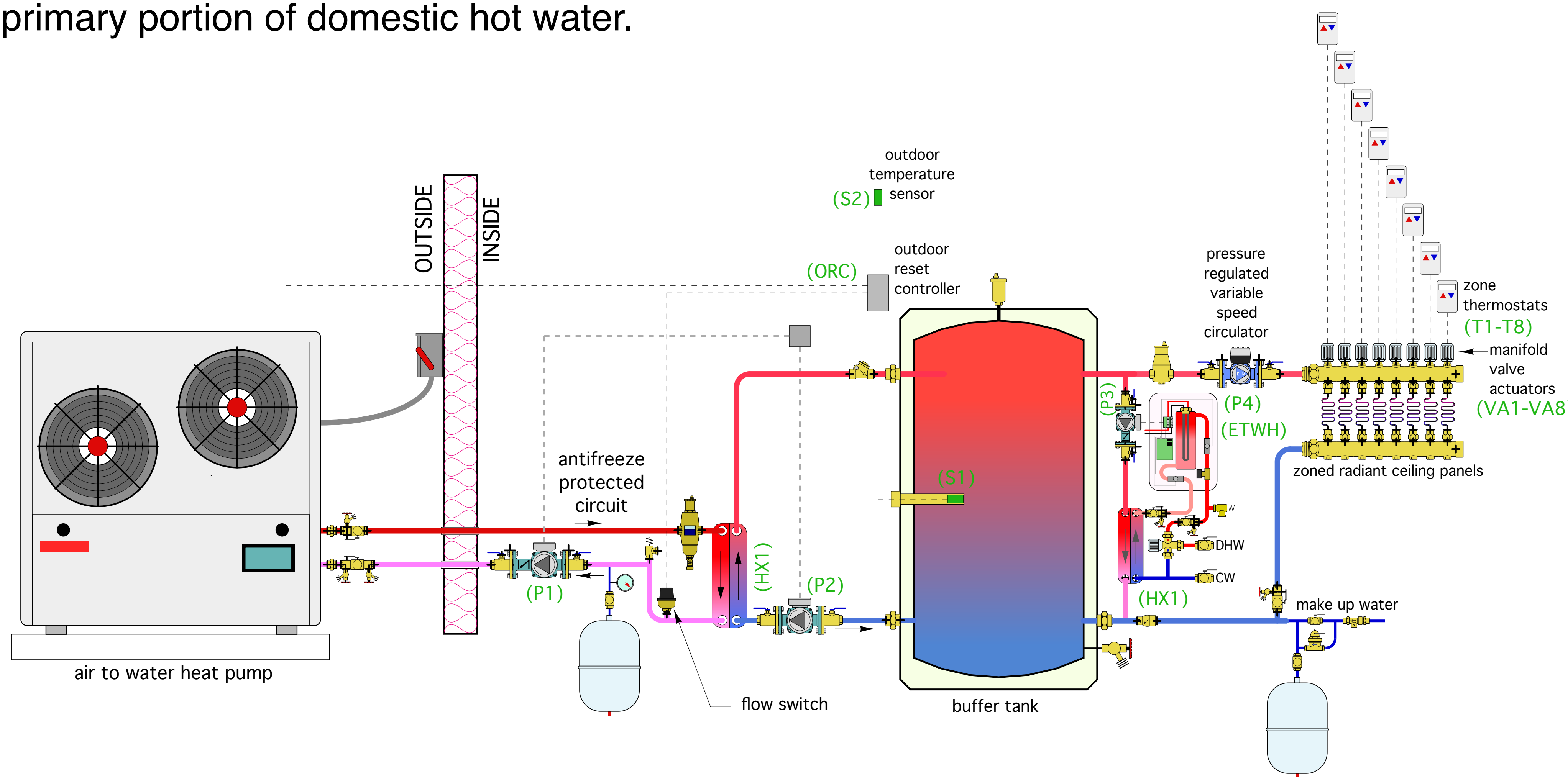
4. Normally open relay contact in load section close.

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 system)

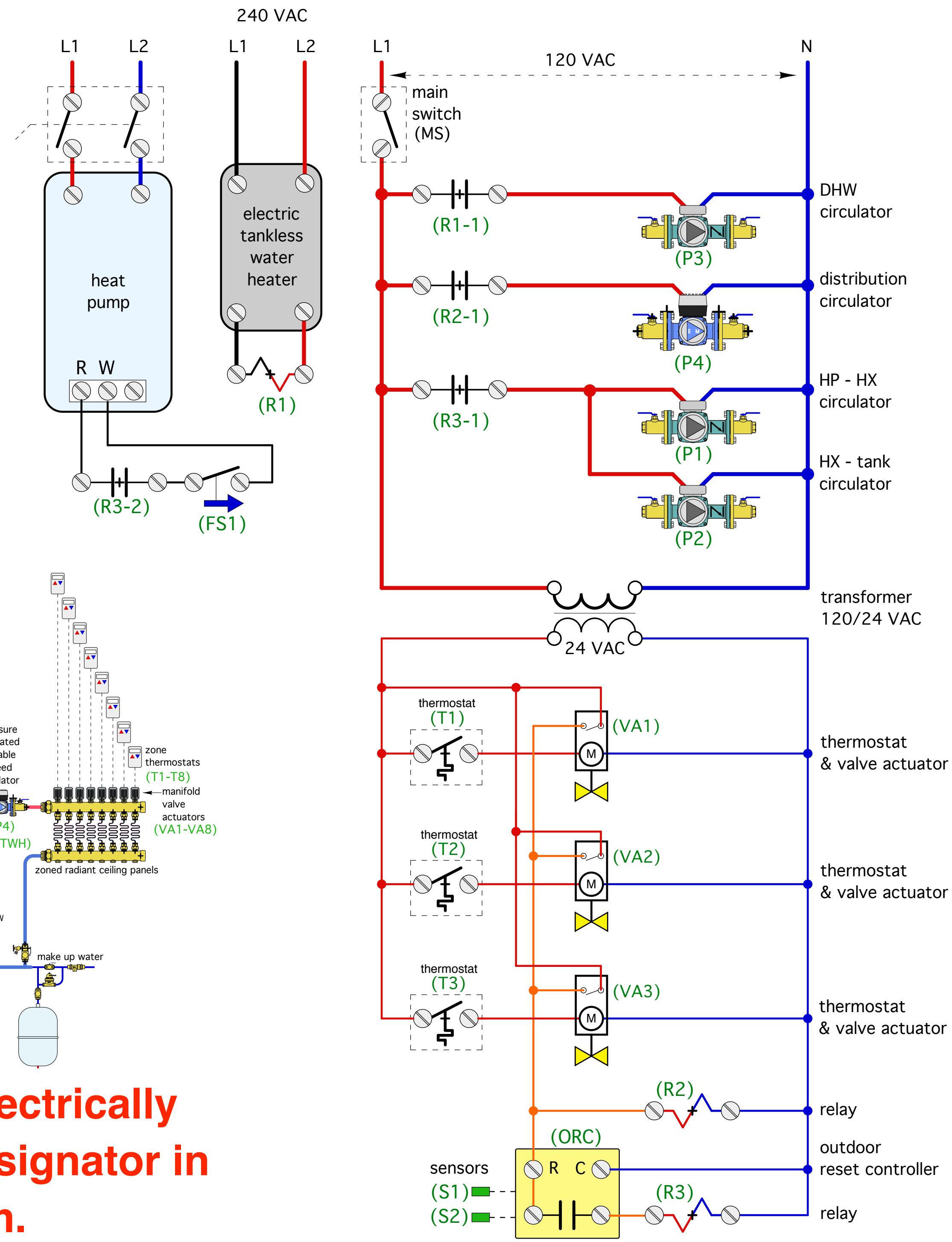
Air-to-water heat pump provides space heating and primary portion of domestic hot water.

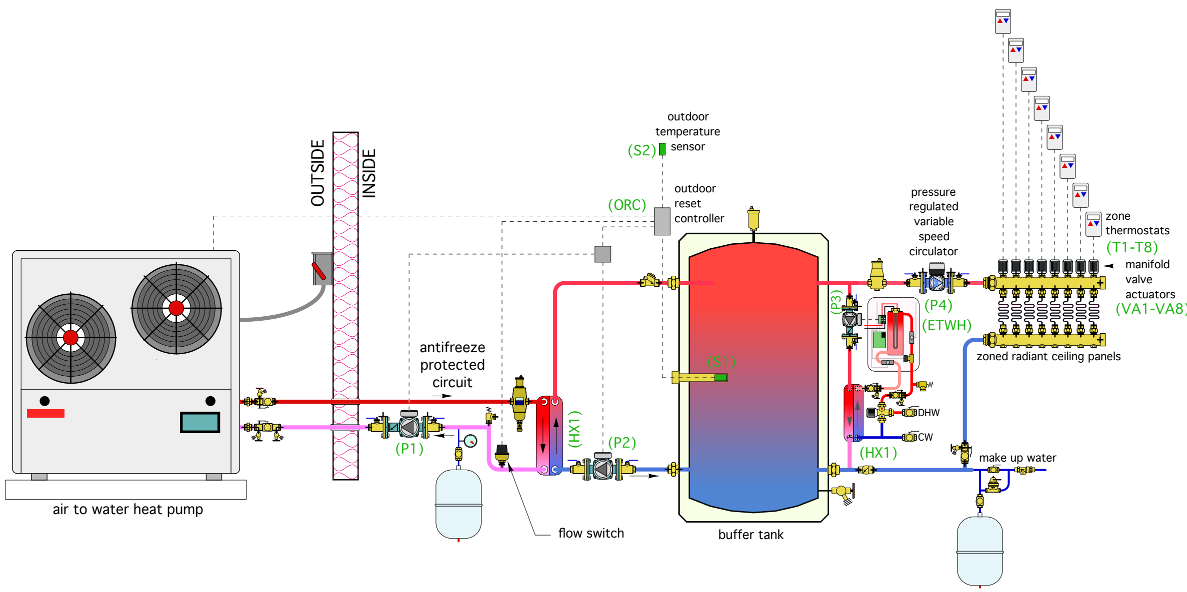


Design tip: Always make sure that all electrically powered components have the same designator in the piping schematic and ladder diagram.

Switches and relays:

Ladder diagrams (Example system)





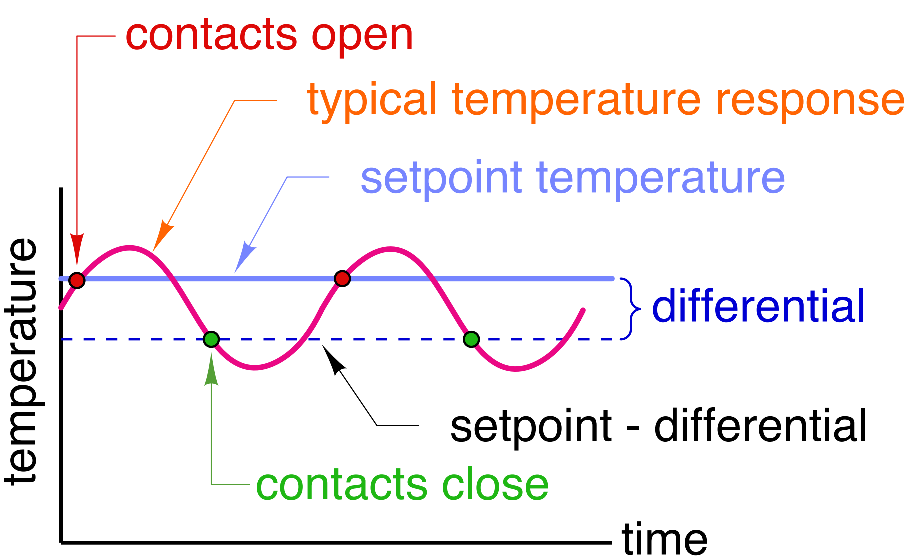
Design tip: Always make sure that all electrically powered components have the same designator in the piping schematic and ladder diagram.

Temperature setpoint control

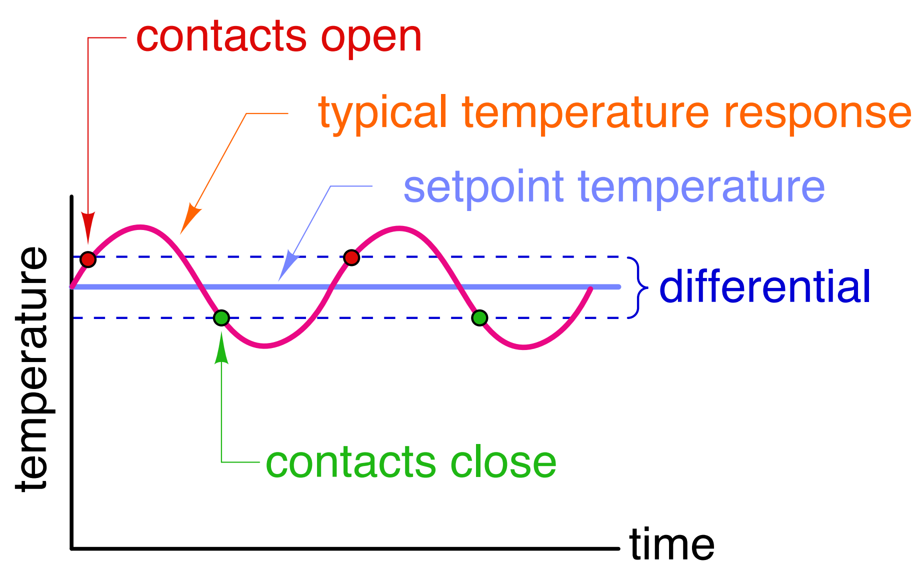
Temperature setpoint control: **Used for On/off control based on temperature**

All on/off controllers have to operate with a differential. This is the difference in the controlled variable between the process is turned on, and when it is turned off.

Differential below setpoint



Differential center on setpoint

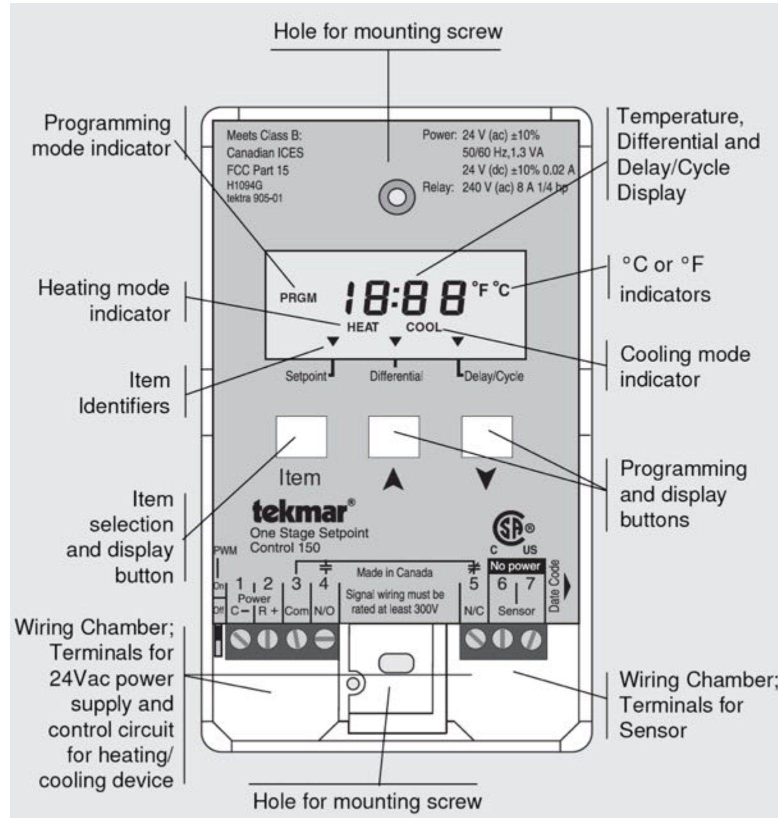


If the differential is too wide, the variable being controlled can drift far from the target.

If the differential is too narrow, the device being controller can “short cycle.”

Design tip: Common differentials for heat source temperature control are 5 to 10 °F

Temperature setpoint control: Used for On/off control based on temperature



Use a thermistor sensor

Some are powered by 120 VAC, others by 24VAC

Some can switch line voltage loads at several amps, others are limited to switching in 24 VAC circuits

Some are single stage, others are two stage

Sensor can be a long distance (several hundred feet) from controller.

Design tip: Always check max sensor wiring distance, and use 18 ga copper twisted pair or shielded cable when running long distances (minimizes electrical noise interference)

Differential temperature control

Differential temperature controller

On/off control based on difference between 2 temperatures

ON differential typically 5-10 °F

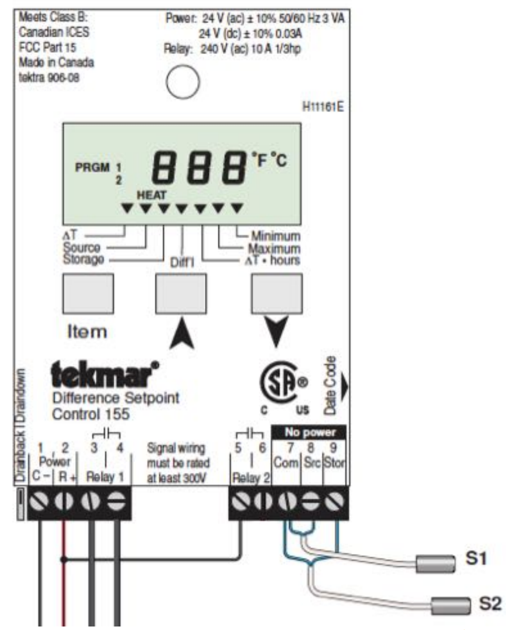
OFF differential typically 2-4 °F

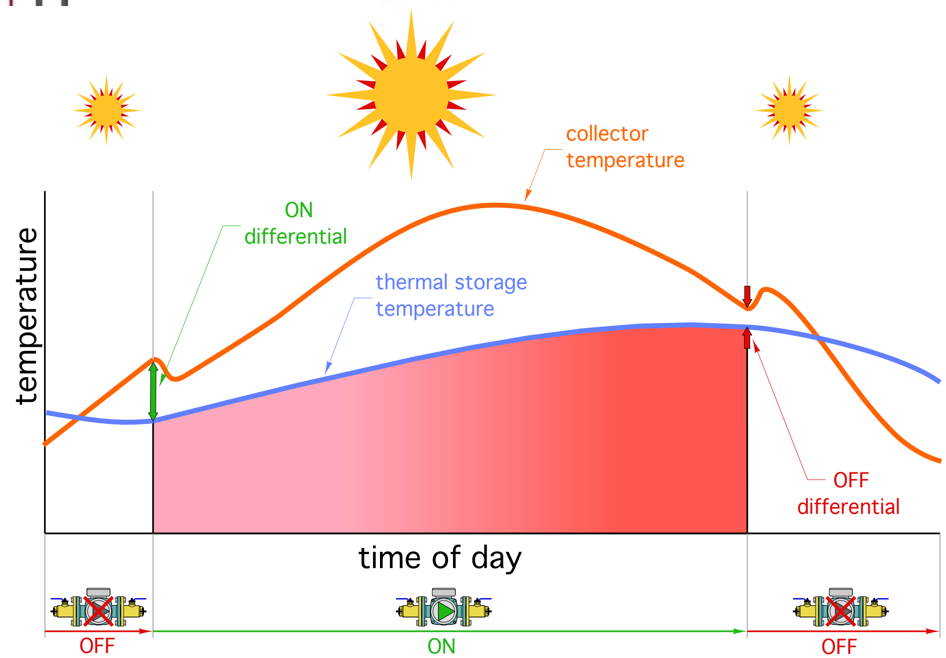
Some offer viable speed outputs via AC Triacs rather than relay contacts (only for PSC type wet rotor circulators).

Some controllers are powered by 120 VAC, others by 24VAC

Some offer 2 ΔT functions as well as I/O to handle other control aspects of system (e.g., aux. heat source, mixing valves).

Design tip: In addition to solar thermal applications, DTCs can be used in other renewable heat source applications to move heat from source to storage (wood fired boiler applications).

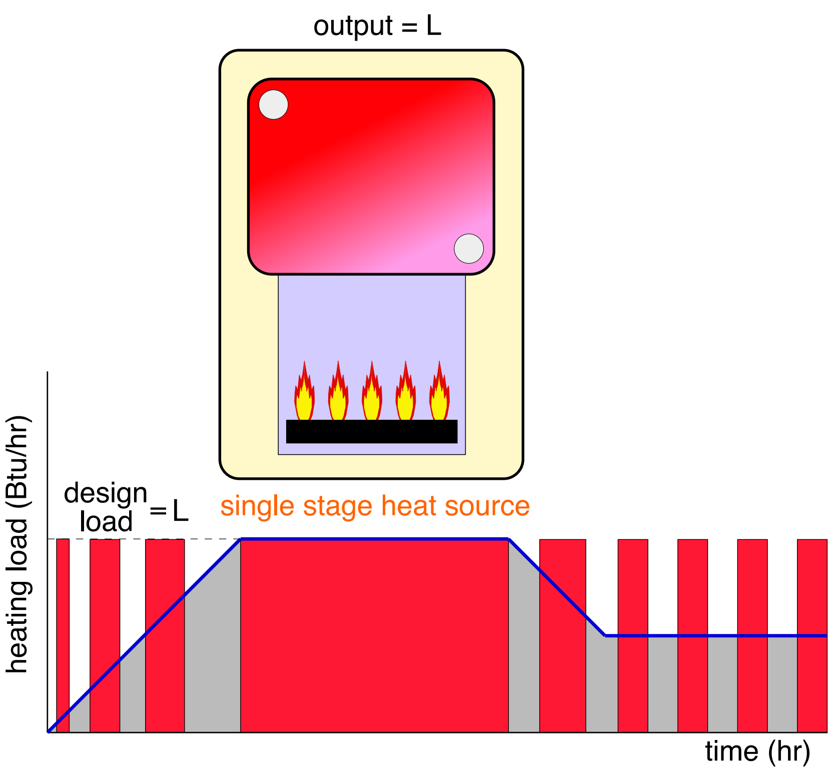




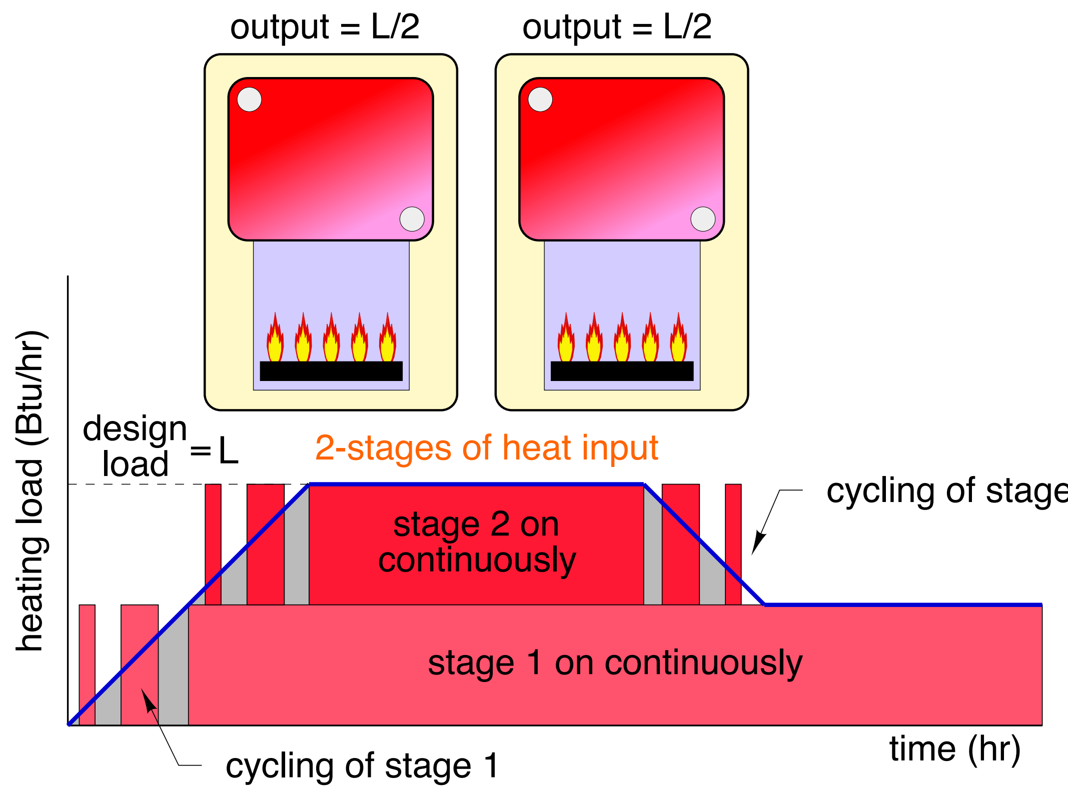
Heat source staging control

Staging control:

The ability to match heat output to load can be improved by dividing the heat output into multiple smaller parts that are independently controlled.

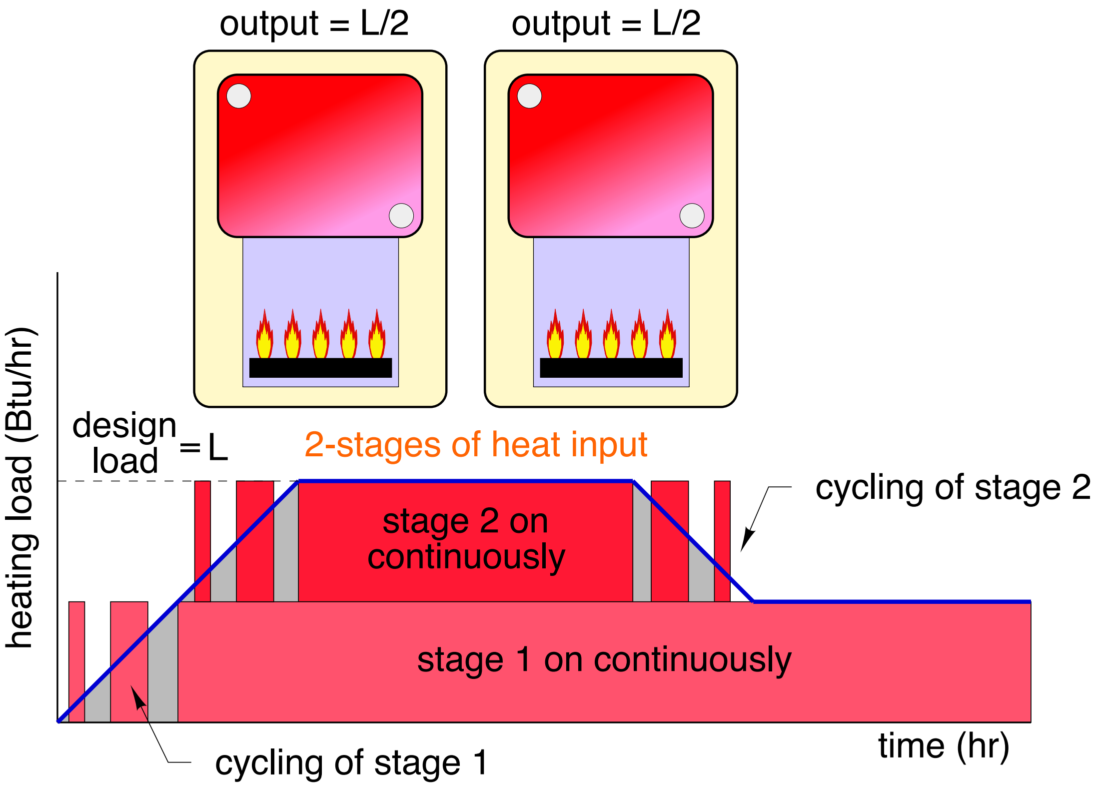


single stage control

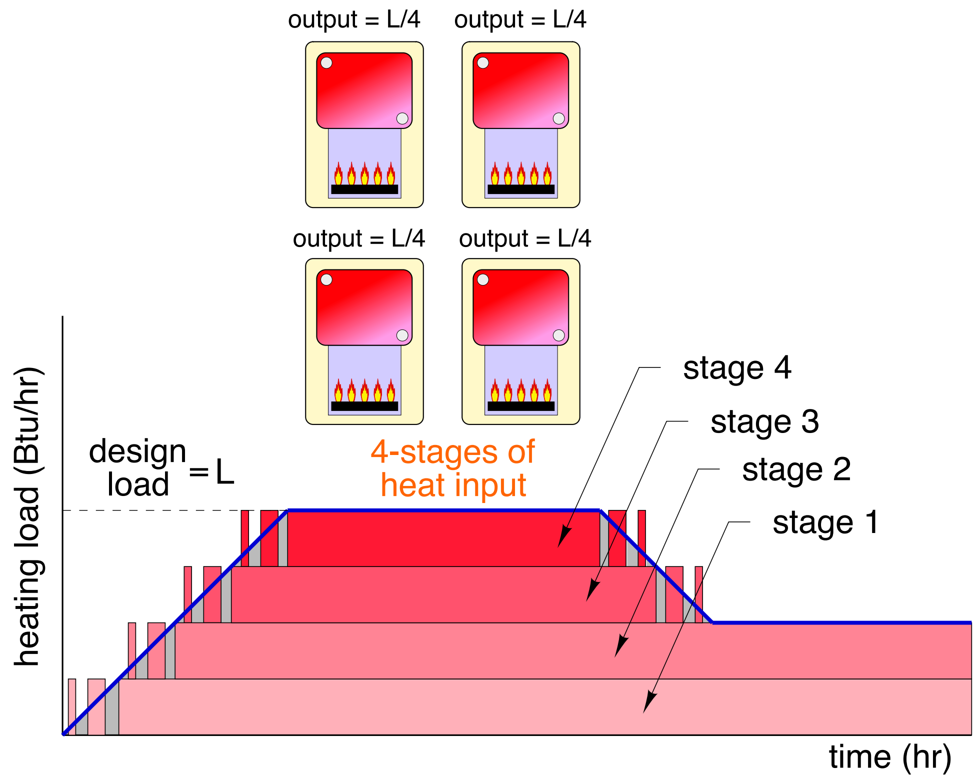


two stage control

Staging control:



two stage control



four stage control

In theory, the great the number of stages, the better the ability to match heat output to load. However, the cost of the installation also increases with increasing number of stages.

Design tip: In residential and light commercial buildings, it is generally not cost effective to use more than four stages of heat production.

Design tip: In larger buildings, up to eight stage of heat production are used in systems when all heat production takes place in a central mechanical room.

A typical “lead/lag” multiple boiler application

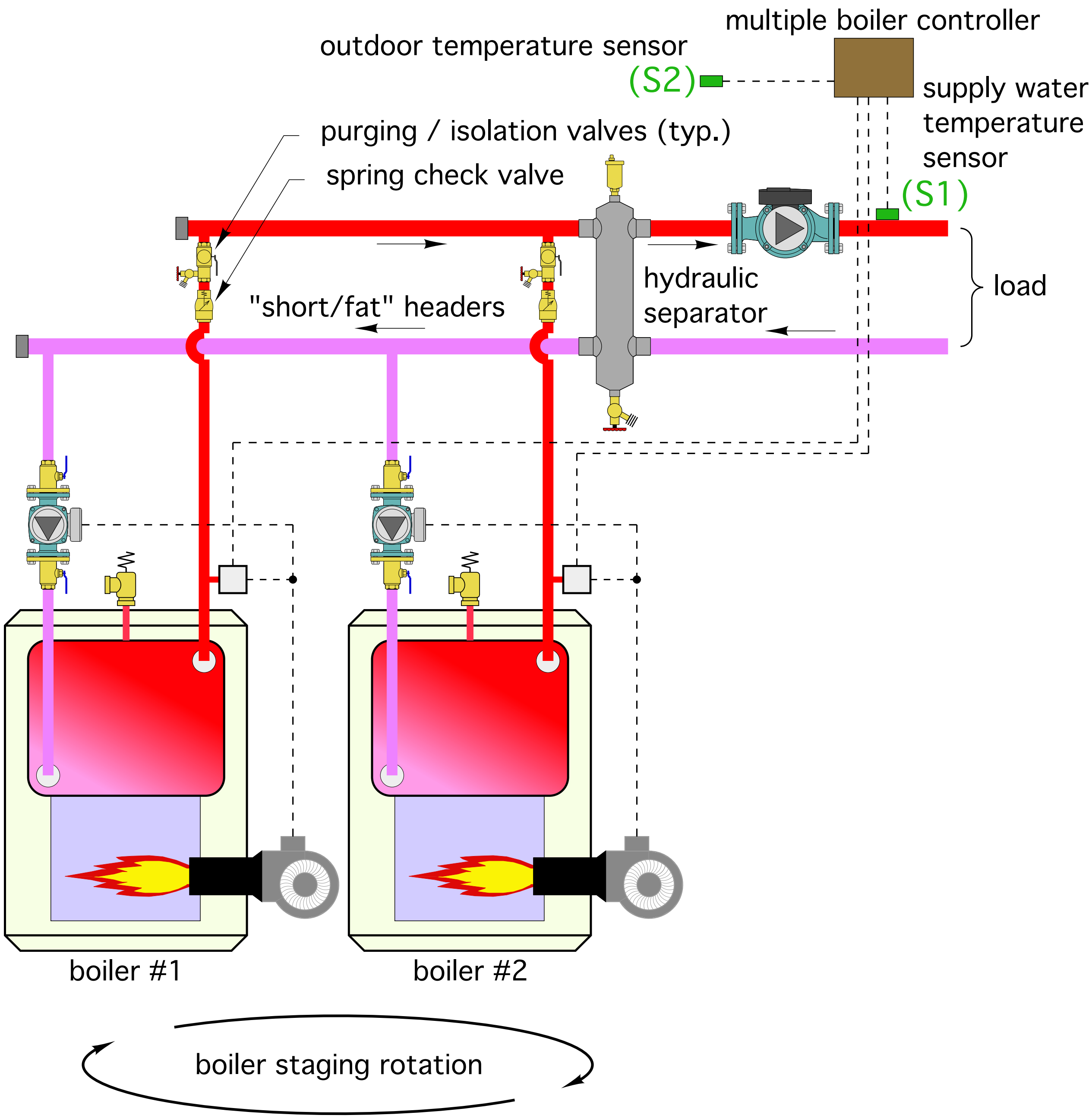
Boiler controller measures supply water temperature at sensor (S1), and compares it to the “target” supply water temperature.

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.

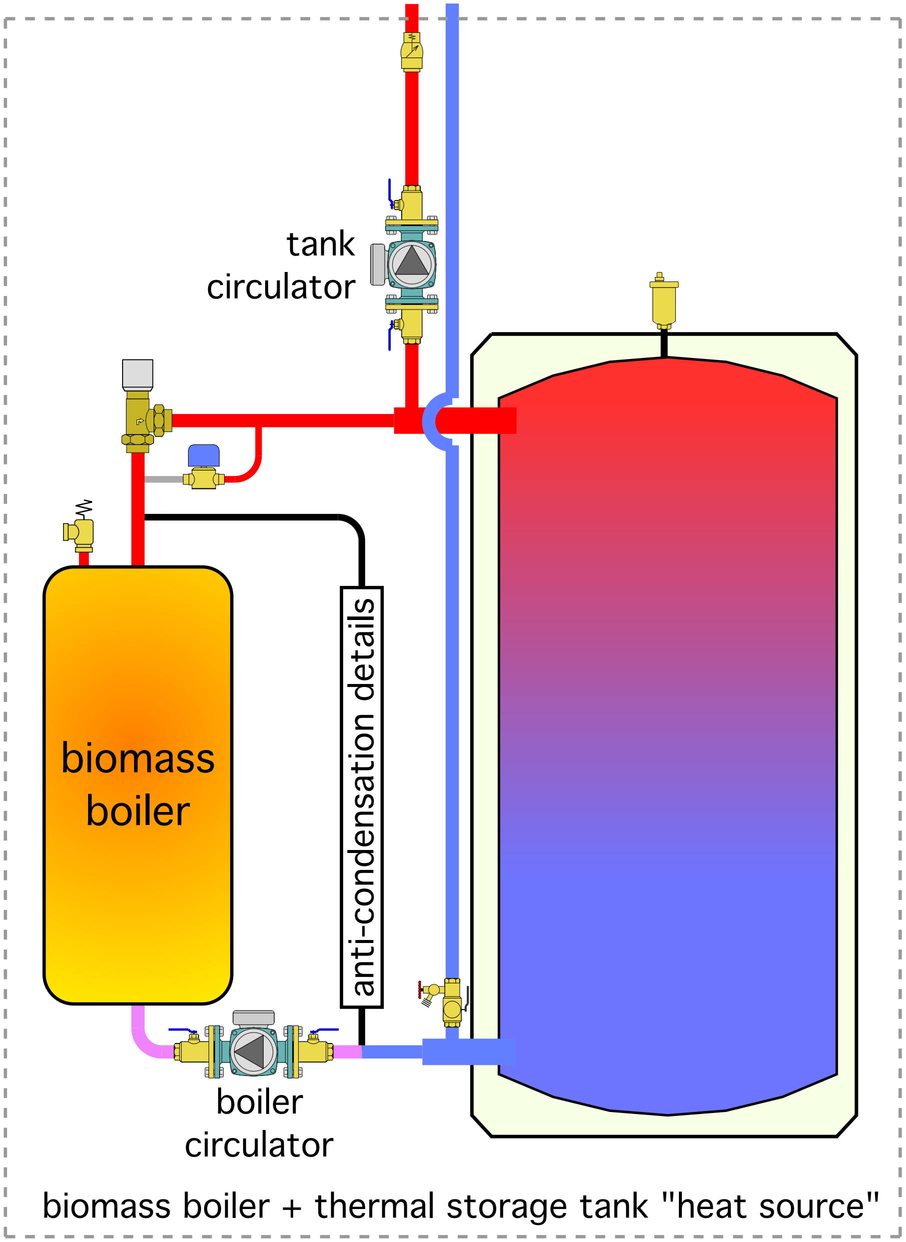
When all boilers are identical, the boiler controller typically “rotates” the firing order to create about the same run time for each boiler.

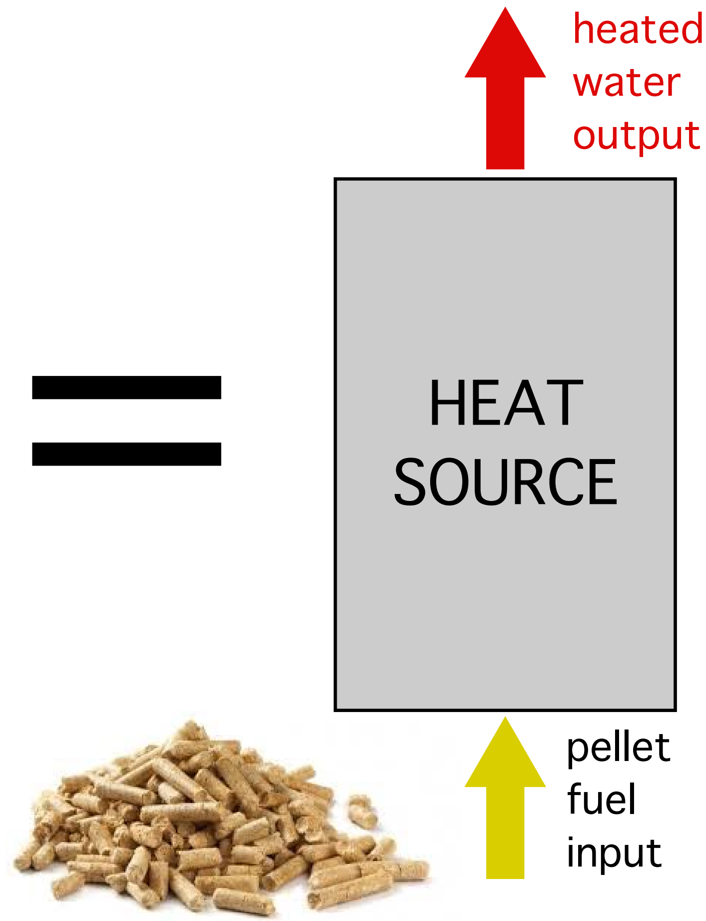
If boilers are different, one is designated as the “fixed lead” boiler, the other as the “lag” boiler.



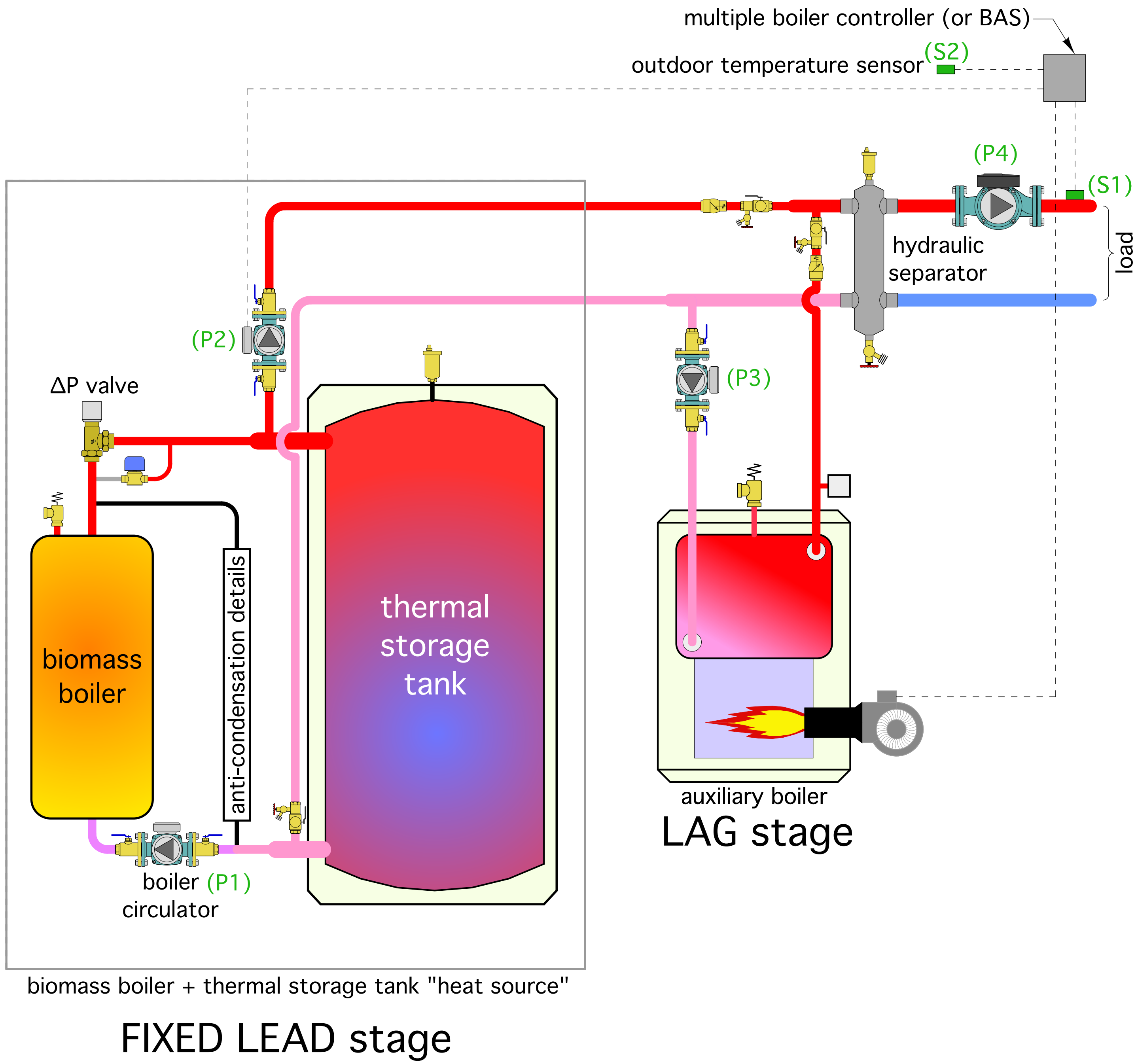
Hybrid staging of pellet boiler & auxiliary boiler

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



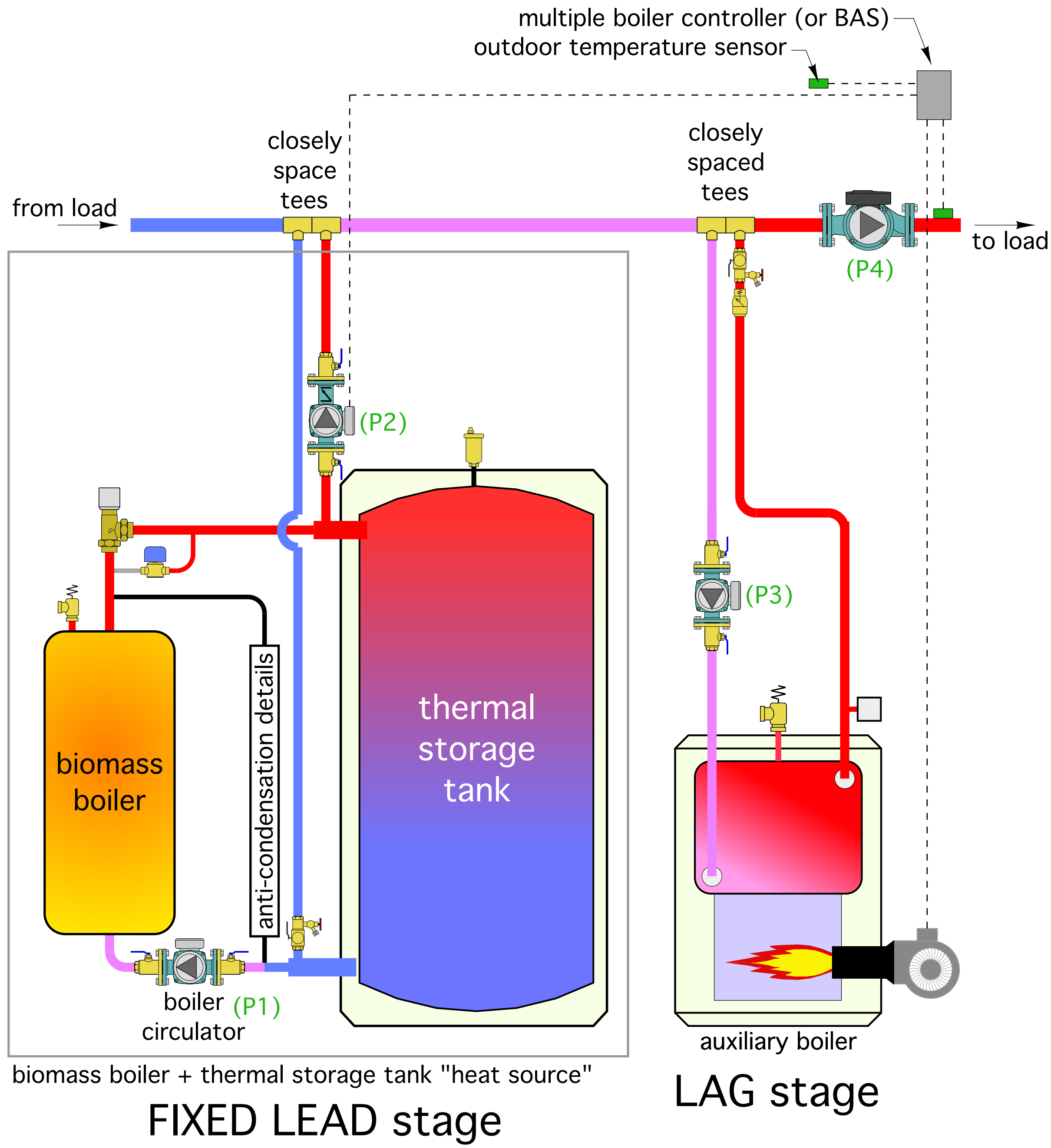


It’s “intuitive” for designers to create systems where the biomass boiler is treated as a “fixed lead” stage, and the auxiliary boiler is the “lag” stage.



Preferred piping

With this arrangement ***(and proper controls)*** energy added by aux boiler can be kept out of thermal storage. Assuming (P2) flow rate ≤ (P4) flow rate, the coolest water is returned to the lower tank connection.



The glitch…

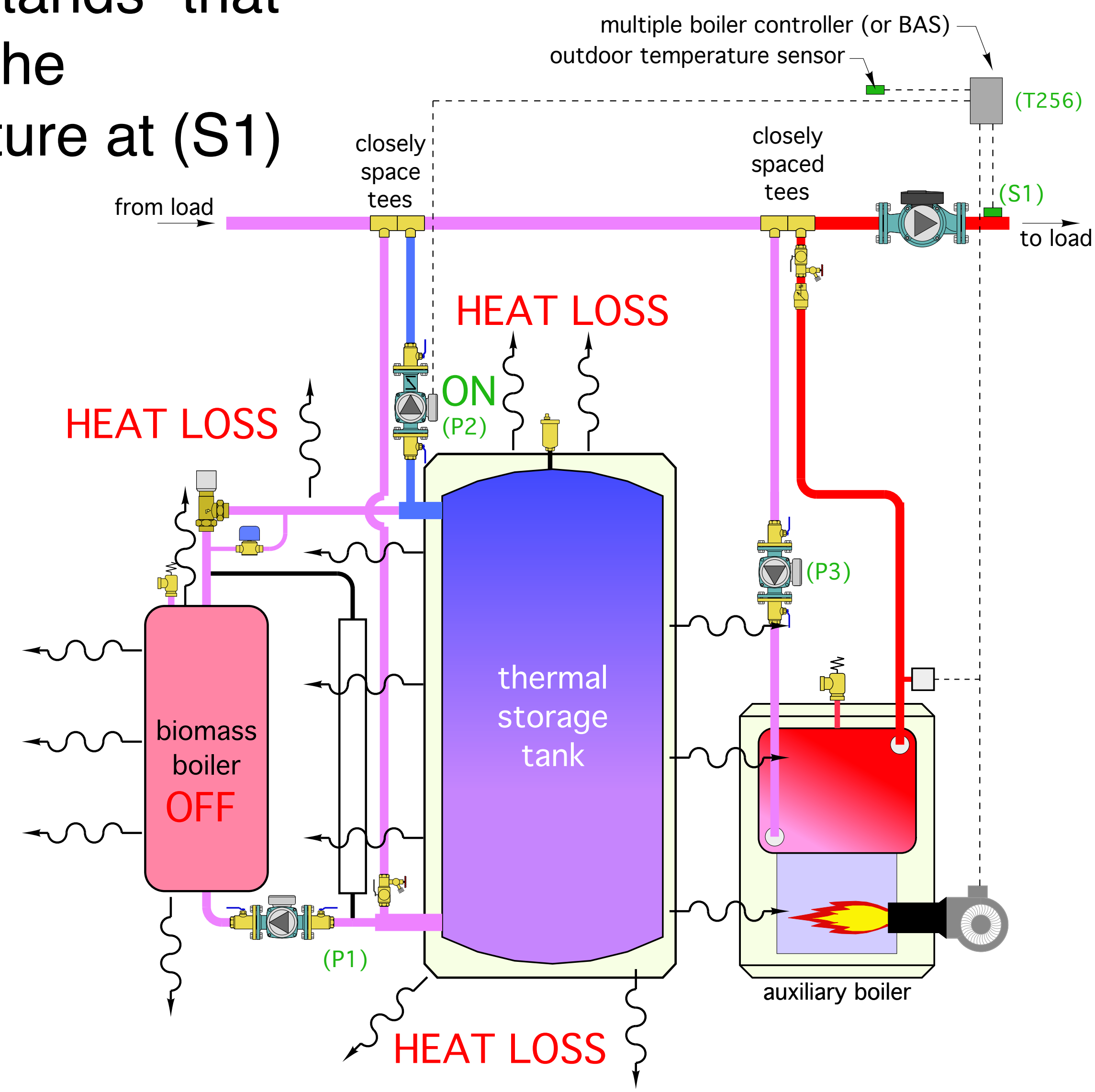
A standard multiple boiler controller "doesn't know" if the biomass boiler is *offline*, due to a fault, or if the tank is cooler than the minimum "useable" temperature of the distribution system.

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.



This really happens…

Ketchikan, AK new Public Library

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).*

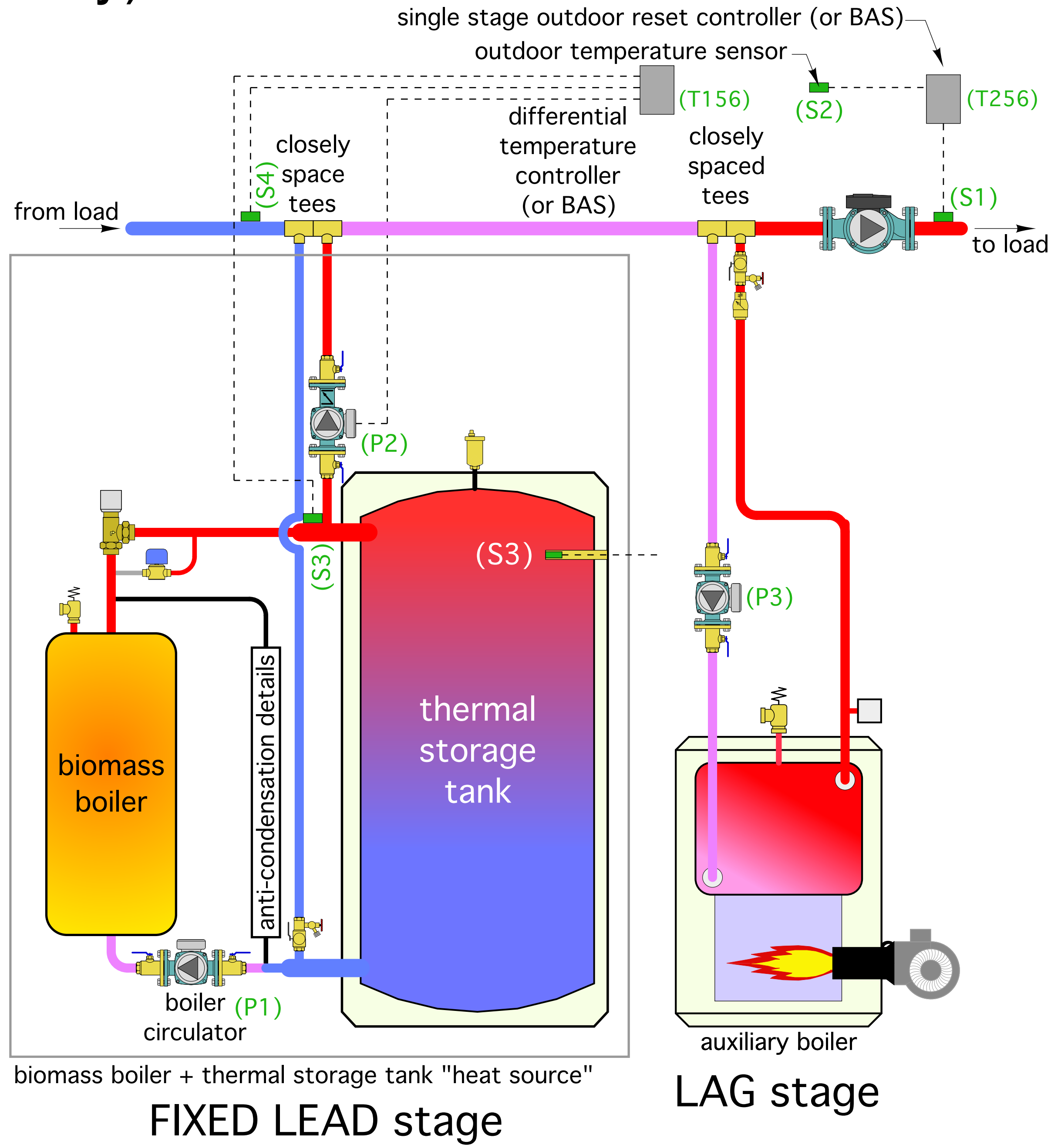
The solution is a simple *differential temperature controller* (or equivalent BAS functionality)

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

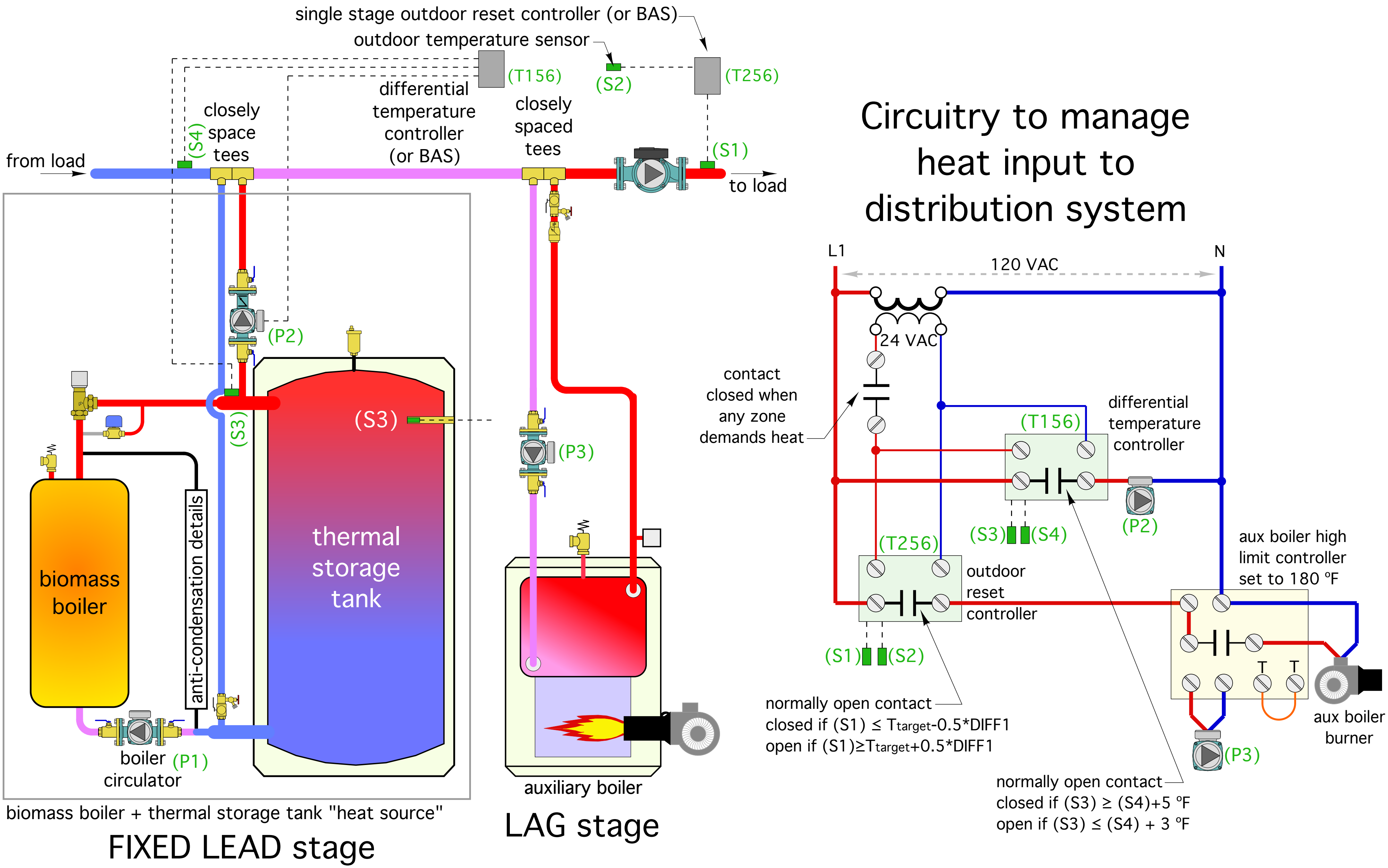
Circulator (P2) (tank to load) is only allowed to run when the tank can make a positive energy contribution to the system.

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

IF (S3) ≥ (S4) + 5 °F THEN (P2) is ON



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

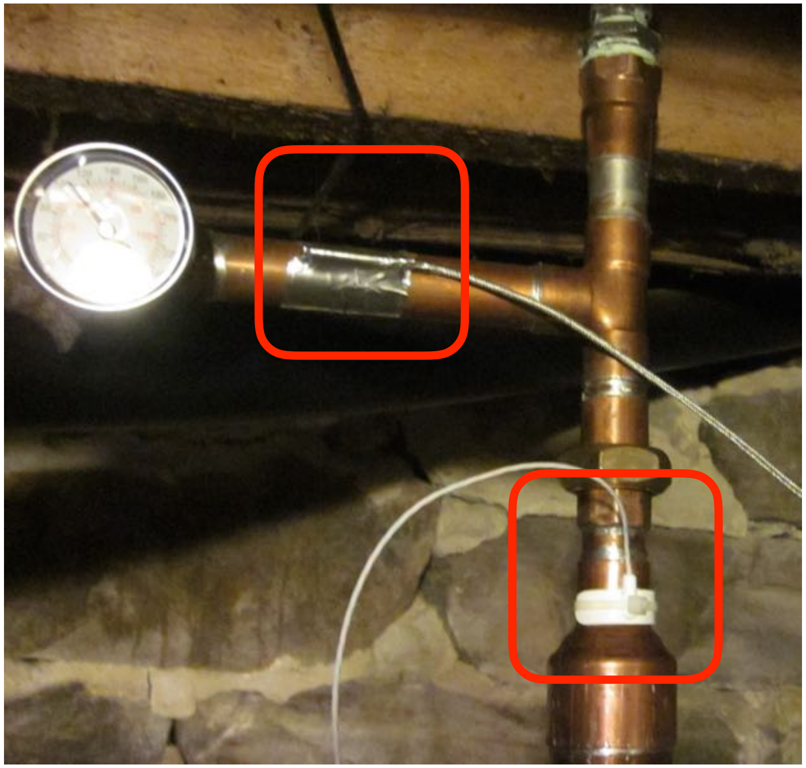


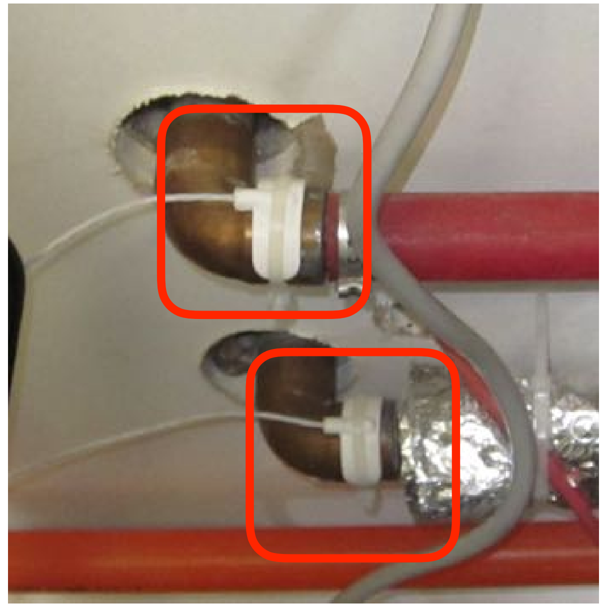
Temperature sensor placement & mounting

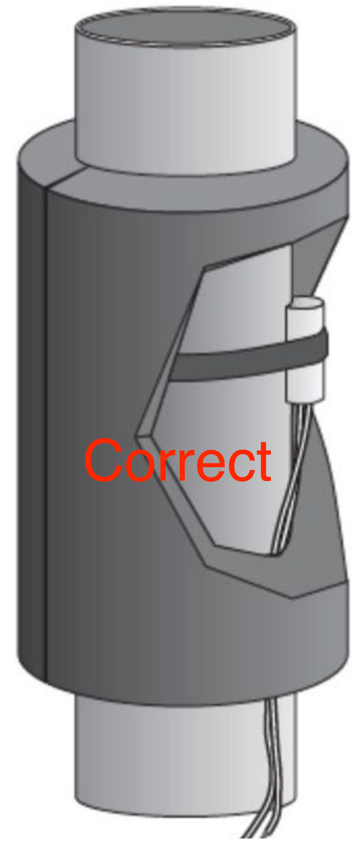
Poor sensor placement or lack of insulation

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.

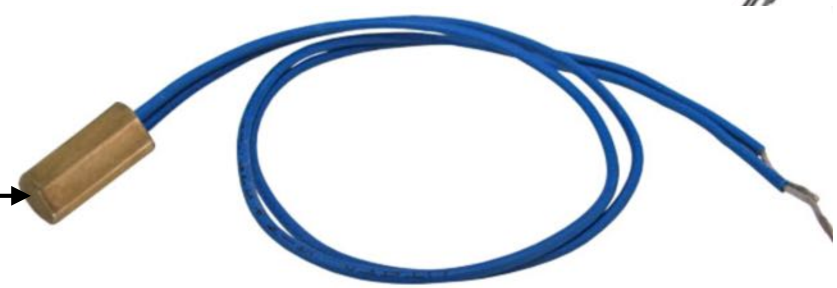






non-insulated surfaced mounted temperature sensors

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

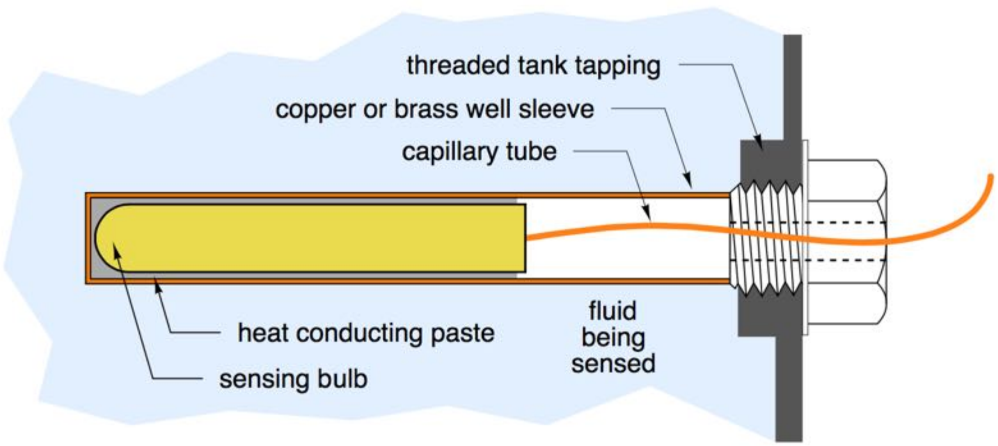


Poor sensor placement or lack of insulation

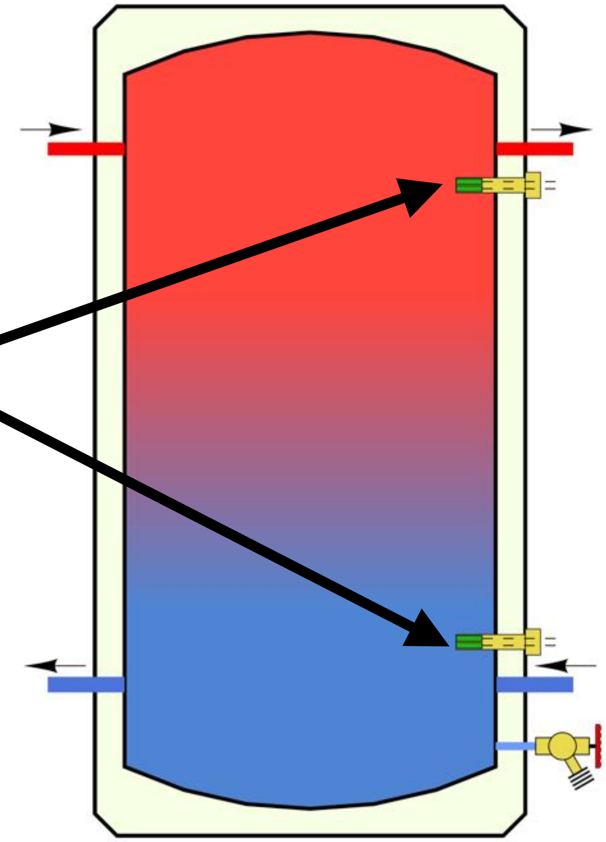
Pipe-mounted sensor with sealed insulation jacket

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.

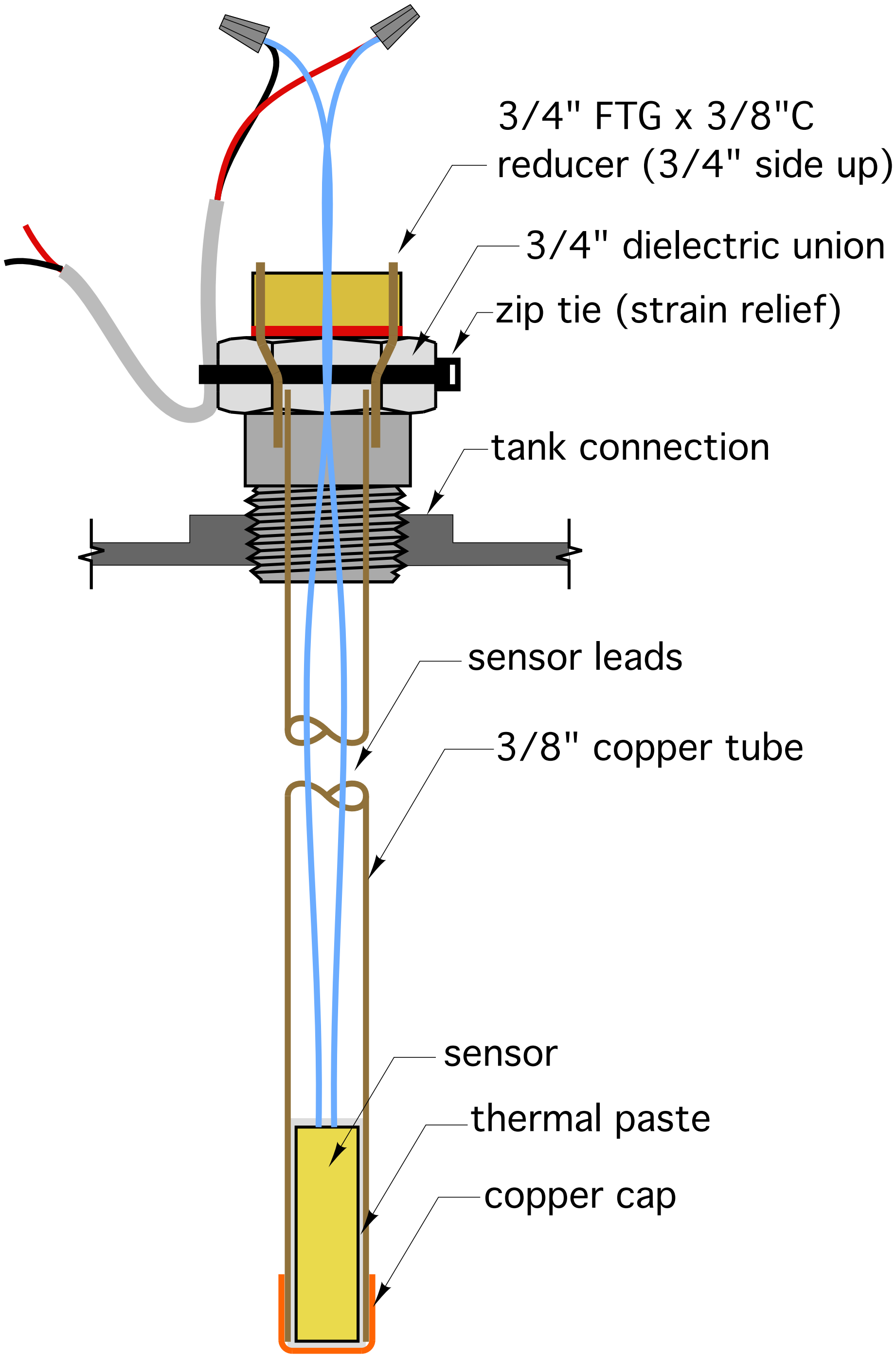


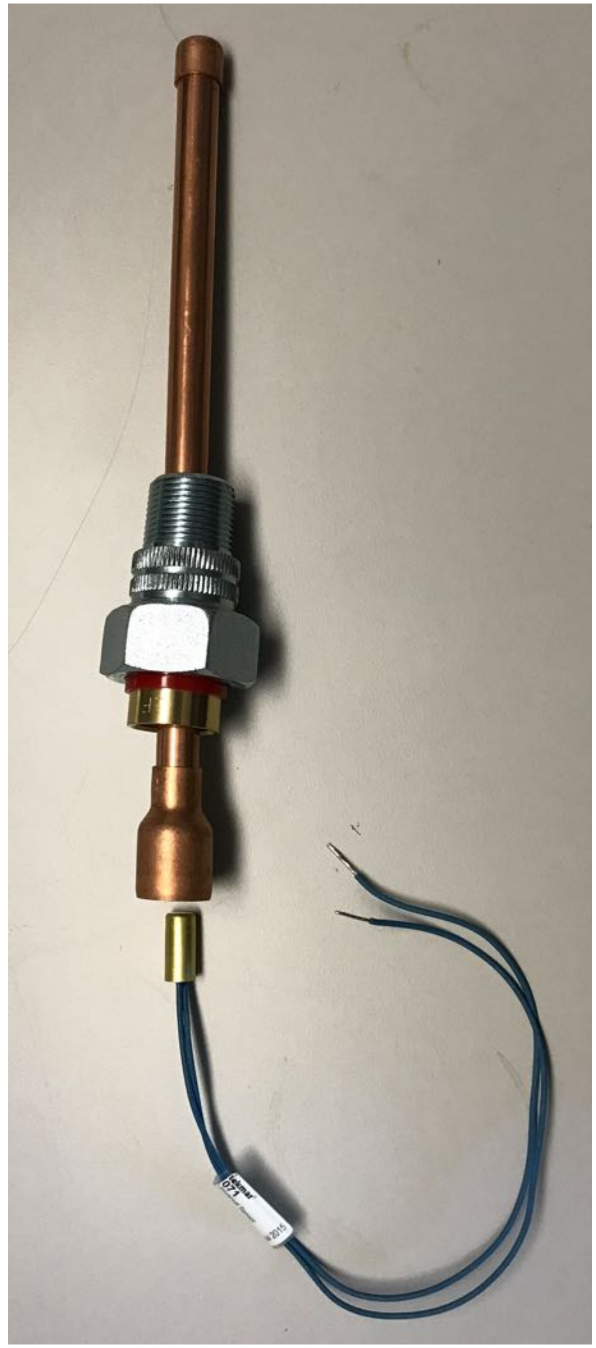
sensors in wells



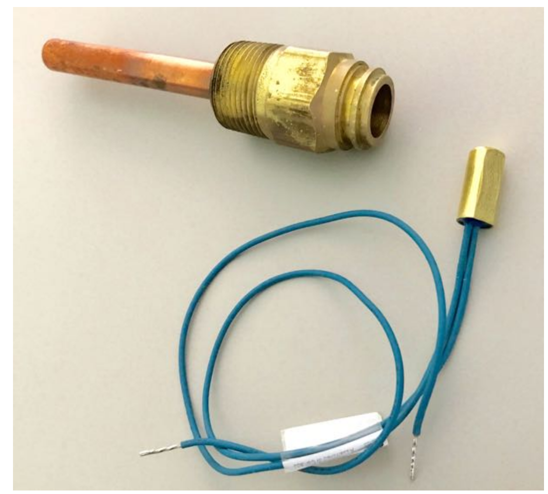
thermal storage tank

Simple way to built a sensor well





Thermal grease
in syringe:
$7, eBay



Honeywell
121371B
$15-25

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
<u>or</u>
$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>

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

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Future online training opportunities

October 29 / 1:00-2:00 PM
Topic: Control concepts for hydronic systems using renewable energy heat sources (part 2)
Description: This webinar will be a continuation of the September 17th discussion. It will discuss Outdoor reset control, mixing control, designing control systems using ladder diagrams, and present examples of complete control systems.

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

QUESTIONS ?