Situations to Avoid with Biomass Boiler Systems

Webinar presented in support of
Renewable Heat NY

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CONTINUING EDUCATION AIA

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presented by:

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

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

Situations to Avoid with Biomass Boiler Systems

RHNYWEB3-2018

September 20, 2018

Situations to Avoid with Biomass Boiler Systems

Description: This webinar discusses several errors related to the design and installation of biomass boiler systems in residential and commercial buildings. Each error is described along with methods of avoiding or correcting the problem(s) associated with it.

Learning Objectives:

1. Understand the issues associated with poor boiler venting.

2. Learn how to configure systems to avoid inadvertent transfer of heat produced by an auxiliary boiler into thermal storage.

3. Understand how piping affects temperature stratification within thermal storage.

4. Learn the importance of proper sensor placement.

Poor boiler venting practices

Most biomass boilers have draft inducing fans

Situation: Boiler starts up (draft fan on) but little if any draft established in cold chimney.

Exterior masonry chimney are the worst due to large / cold thermal mass.

Causes: *Temporary* POSITIVE pressure in vent connector piping.

Leads to: Leakage of flue gases and fly ash between joints in vent connector piping, boiler air intake, barometric damper.

This chimney was, at one time, venting both an oil-fired boiler and a pellet boiler.

A violation of NYS Mechanical code, section 801.11

The fix. UL-103 HT chimney for pellet boiler

Exterior masonry chimneys have minimum allowable combustion appliance input ratings depending on climate

54-112 NATIONAL FUEL GAS CODE ANSI Z223.1

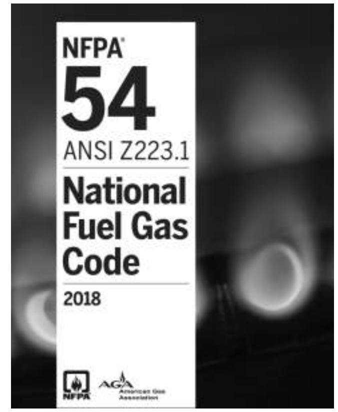
Table 13.2(g) Exterior Masonry Chimney

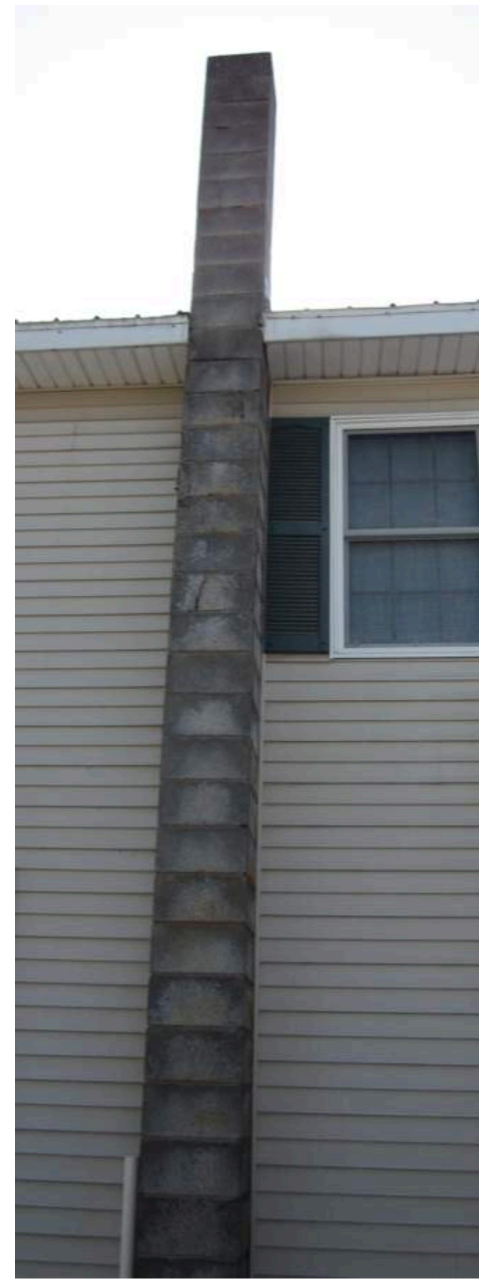
Number of Appliances:	Two or More
Appliance Type:	NAT + NAT
Appliance Vent Connection:	Type B Double-Wall Connector

Minimum Allowable Input Rating of Space-Heating Appliance in Thousands of Btu per Hour

Vent Height *H* (ft)	Internal Area of Chimney (in.²) 12	19	28	38	50	63	78	113
	Local 99% winter design temperature: 37°F or greater							
6	0	0	0	0	0	0	0	NA
8	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
15	NA	0	0	0	0	0	0	0
20	NA	NA	NA	NA	NA	184	0	0
30	NA	NA	NA	NA	NA	393	334	0
50	NA	NA	NA	NA	NA	NA	NA	579
100	NA	NA	NA	NA	NA	NA	NA	NA
	Local 99% winter design temperature: 27°F to 36°F							
6	0	0	68	NA	NA	180	212	NA
8	0	0	82	NA	NA	187	214	263
10	0	51	NA	NA	NA	201	225	265
15	NA	NA	NA	NA	NA	253	274	305
20	NA	NA	NA	NA	NA	307	330	362
30	NA	NA	NA	NA	NA	NA	445	485
50	NA	NA	NA	NA	NA	NA	NA	763
100	NA	NA	NA	NA	NA	NA	NA	NA
	Local 99% winter design temperature: 17°F to 26°F							
6	NA	NA	NA	NA	NA	NA	NA	NA
8	NA	NA	NA	NA	NA	NA	264	352
10	NA	NA	NA	NA	NA	NA	278	358
15	NA	NA	NA	NA	NA	NA	331	398
20	NA	NA	NA	NA	NA	NA	387	457
30	NA	NA	NA	NA	NA	NA	NA	581
50	NA	NA	NA	NA	NA	NA	NA	862
100	NA	NA	NA	NA	NA	NA	NA	NA
	Local 99% winter design temperature: 5°F to 16°F							
6	NA	NA	NA	NA	NA	NA	NA	NA
8	NA	NA	NA	NA	NA	NA	NA	NA
10	NA	NA	NA	NA	NA	NA	NA	430
15	NA	NA	NA	NA	NA	NA	NA	485
20	NA	NA	NA	NA	NA	NA	NA	547
30	NA	NA	NA	NA	NA	NA	NA	682
50	NA	NA	NA	NA	NA	NA	NA	NA
100	NA	NA	NA	NA	NA	NA	NA	NA
	Local 99% winter design temperature: 4°F or lower Not recommended for any vent configurations							

For SI units, 1 in. = 25.4 mm, 1 in.² = 645 mm², 1 ft = 0.305 m, 1000 Btu/hr = 0.293 kW, °C = (°F - 32)/1.8.
Note: See Figure F.2.4 for a map showing local 99 percent winter design temperatures in the United States.





Lining existing masonry chimneys with sealed ***stainless steel*** liners.

image courtesy of Interphase Energy LLC

stainless steel rigid liner pipe joined with stainless steel pop rivets

pre-insulated stainless steel liner

images courtesy of Olympia Chimney

Venting pellet-fueled boilers

Class A "all fuel" chimney (UL103-HT) chimney system from Olympia Chimney.

Always brace chimneys on metal roofs subject to snow slides

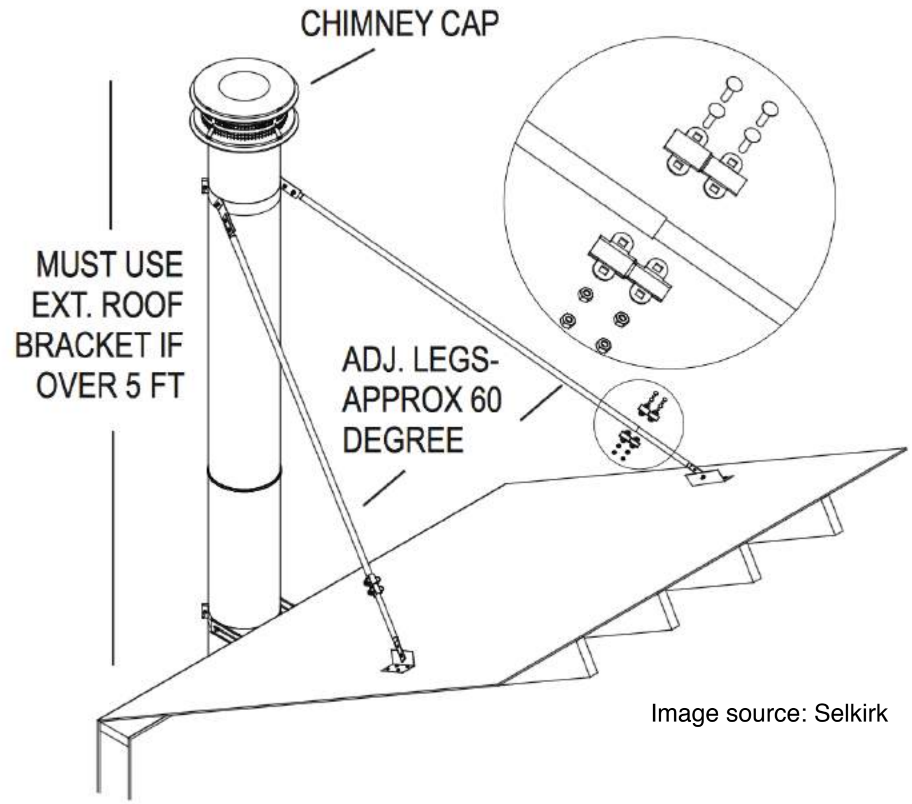
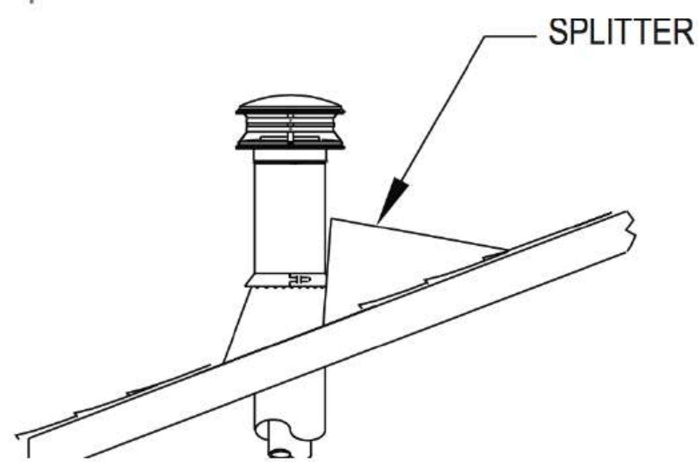


Image source: Selkirk



General NFPA requirements for vent connectors:

• Horizontal length of vent connector from solid fuel appliance to chimney not more the 50% of chimney height above the connector.

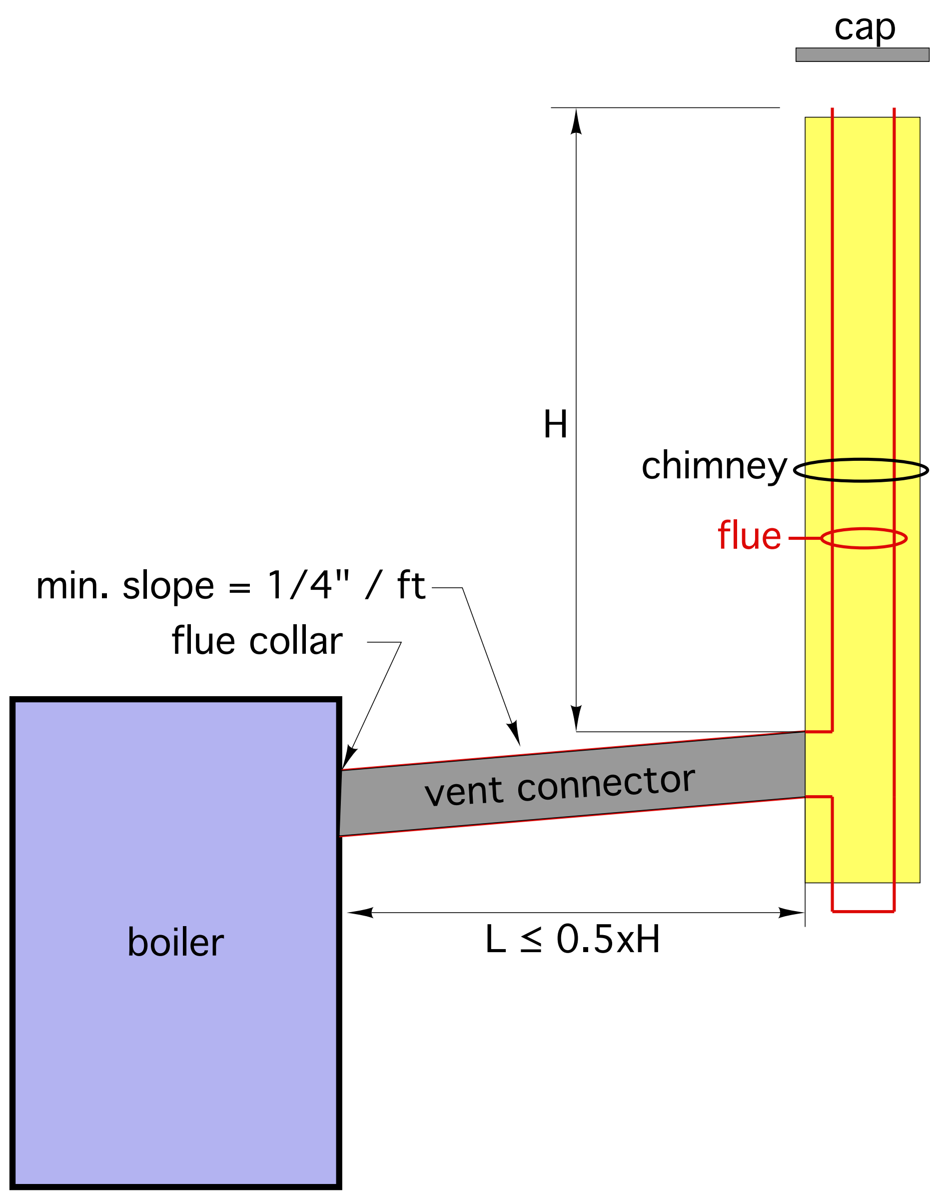
• Cross sectional area of flue for *interior chimney* (below roof line) not more than 3x appliance vent connector cross sectional area.

• If one or more walls of chimney exposed (below roof line) the cross sectional area of flue not more than 2x appliance vent connector cross sectional area.

• Minimum upward slope of vent connector = 1/4” per foot.

• Minimum clearance to combustibles for single wall vent connector = 18 inches (there are ways to reduce this clearance with shielding).

• Minimum clearance to combustibles for double wall vent connector = 6 inches.



NYS code allows solid fuel appliances to be vented through 24 gauge (minimum thickness) galvanized steel piping.

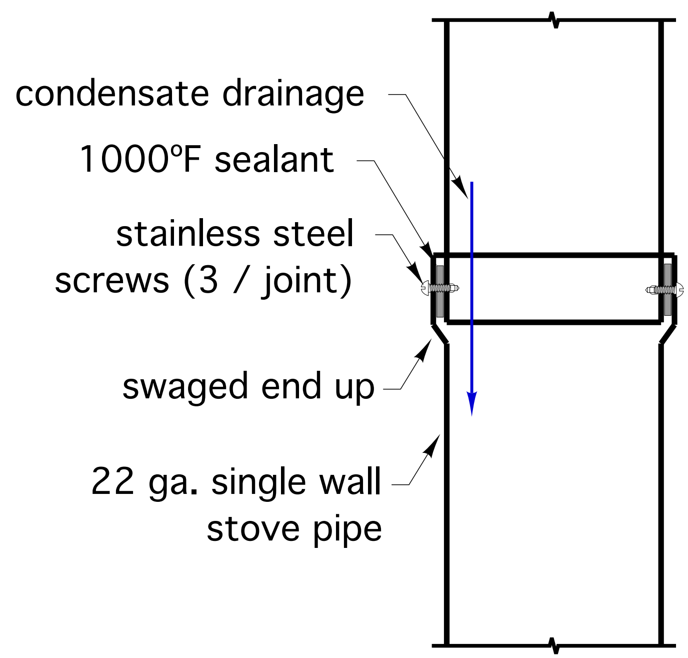
Recommendation is to **avoid use of galvanized steel connectors** due to potential leakage of ash and flue gas at seams.

RTV silicone. Will eventually separate from galvanized pipe

Single wall welded seam stovepipe (**22 gauge**) can be used.

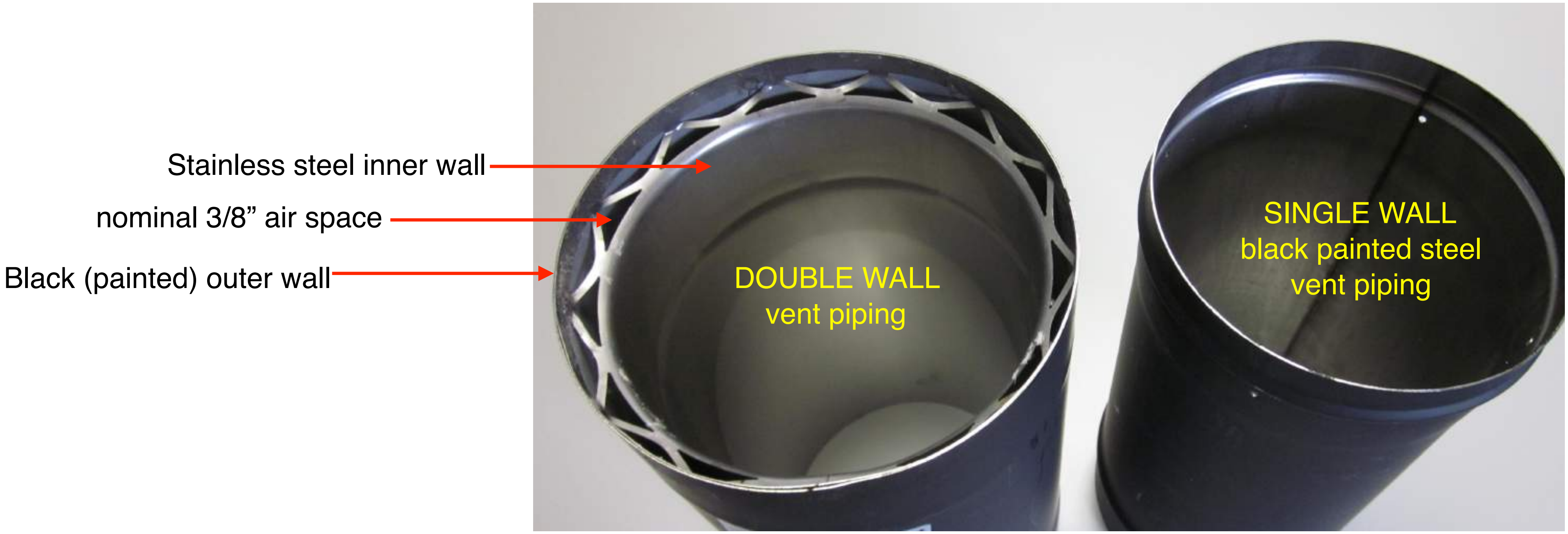
• **Seal joints with high temperature (1000 °F rated) black silicone sealant**

• Always join pipe so that any interior condensate, moving down pipe, remains in pipe.



• Secure all joints in **single wall vent** connector piping with ***<u>stainless steel sheet metal screws.</u>***

Double Wall vent connector piping allows 6” clearance to combustibles and lower surface temperature.



- Inner wall remains at higher temperature, resulting is less creosote potential.
- Outer wall remains at lower temperature, resulting in safer installation.
- Both single and double wall pipe should be ***installed in proper direction*** (see arrow on pipe).
- Outer wall of section should be mechanically joined with 3 screws (usually provided with pipe)

Unsealed seams in vent connector piping can leak flue gas and ash

Solution: Positive pressure sealing draft regulator installed

Combustion air supply

When boiler room draws air from OUTSIDE:

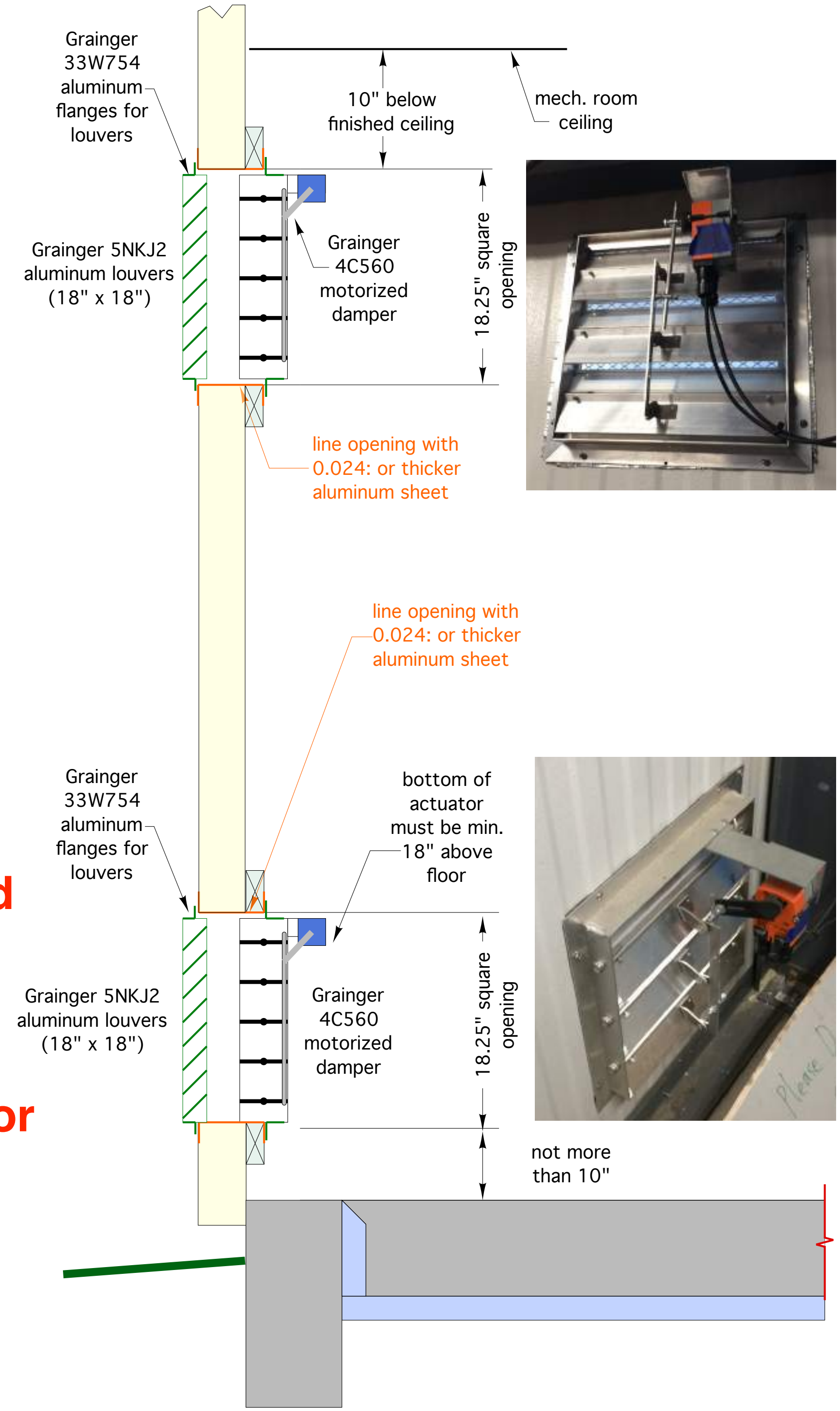
NFPA 54/2018, National Fuel Gas Code:
If air comes directly from outside, **and two openings are used:** 1 in^2 free area per 4000 Btu/hr of fuel input rating of all appliances in the space.

NFPA 54/2018, National Fuel Gas Code:
If air comes directly from outside, **and one opening (within 12” of ceiling) is used**: 1 in^2 free area per 3000 Btu/hr of fuel input rating of all appliances in the space, and not less than sum of cross section areas of all vent connectors in the space.

For wood louvers:
Free area =
opening area / 0.25

For metal louvers:
Free area =
opening area / 0.75

If motorized louvers are used they must be verified prior to burner operation.



Preventing thermal feedback into storage

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

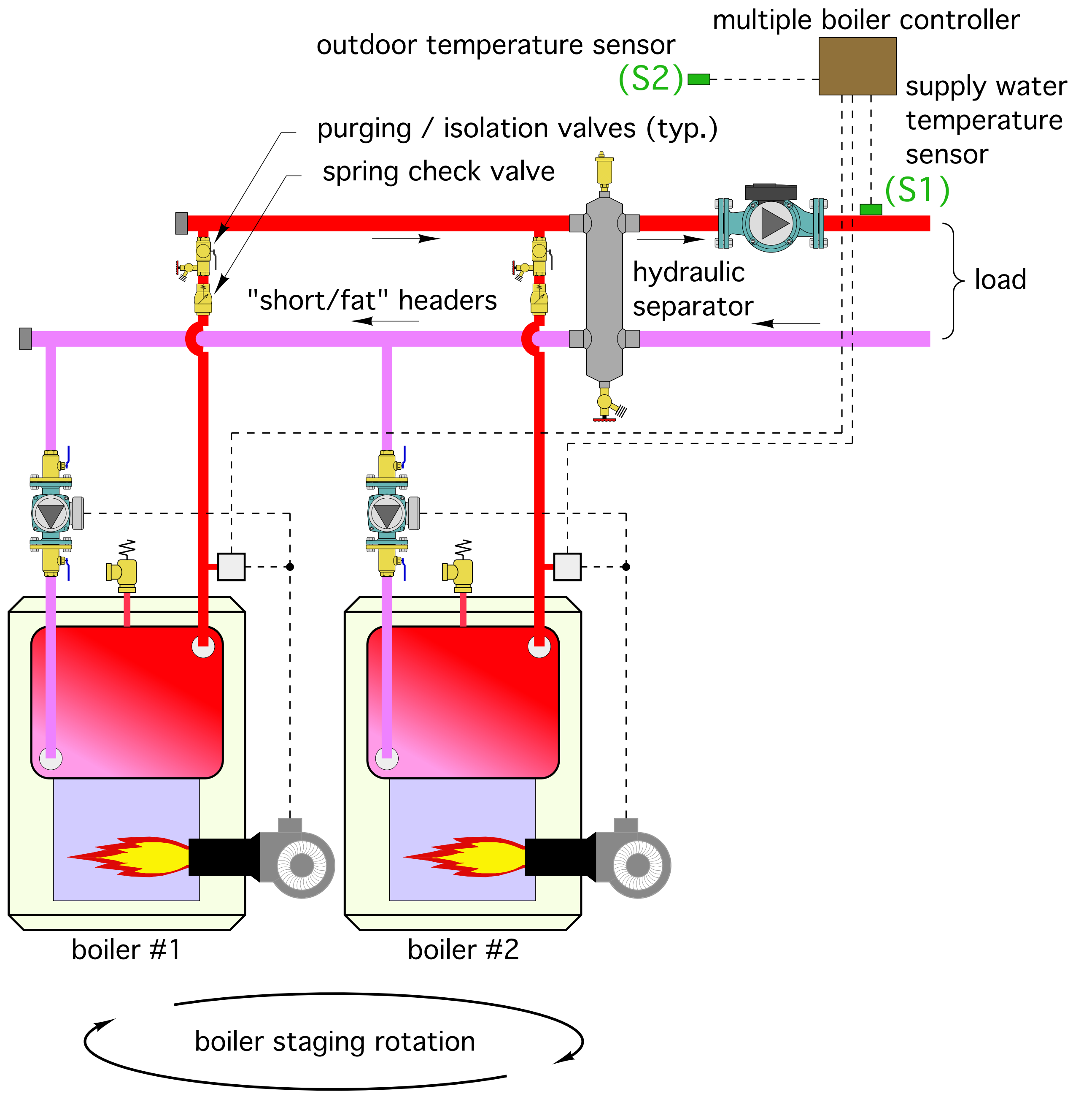
Boiler controller measures supply water temperature at sensor (S1), and compares it to the "target" supply water temperature.

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

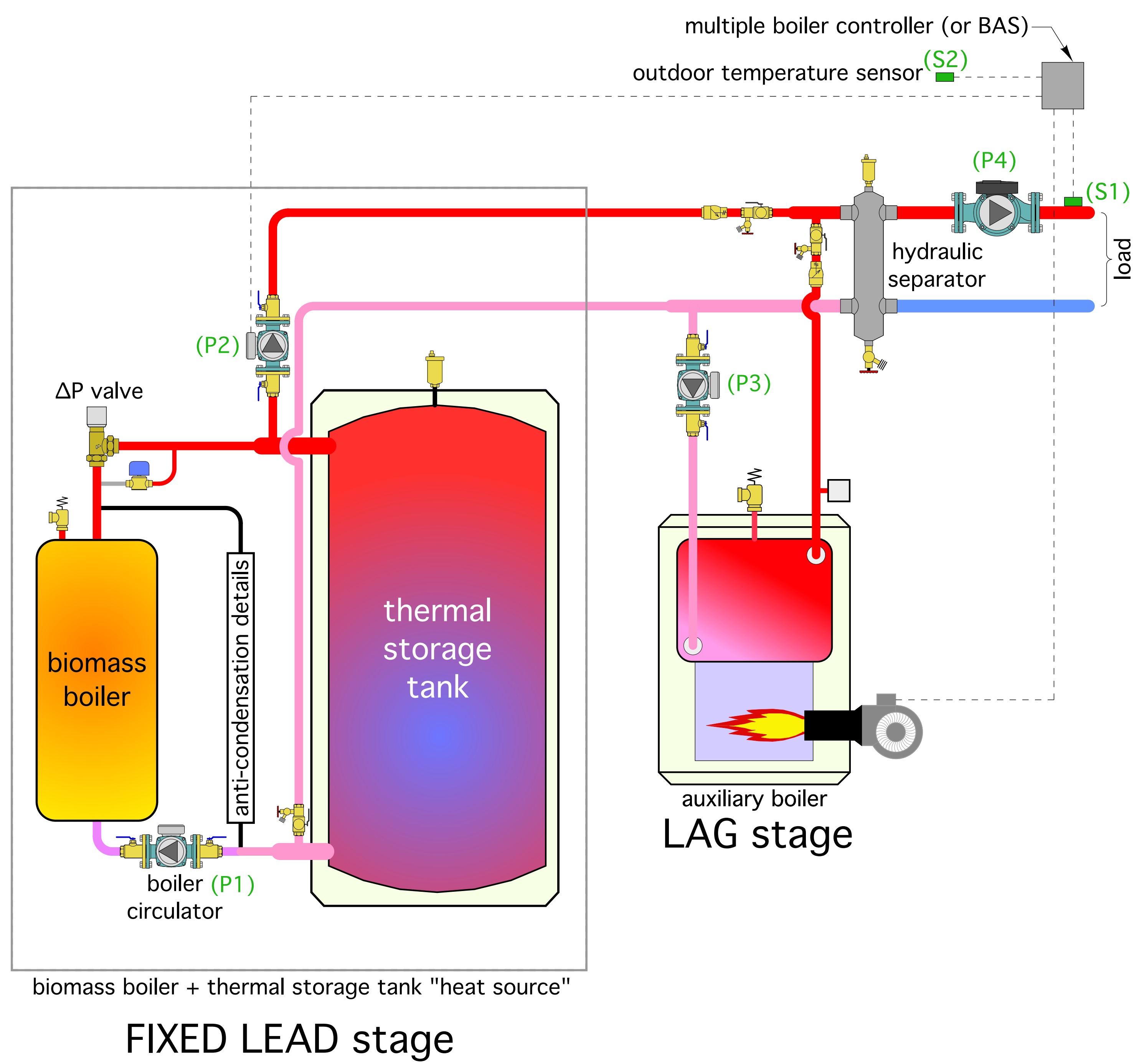
Boiler controller then uses PID logic to determine if more heat input is need. If it is, the other boiler is fired.

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…

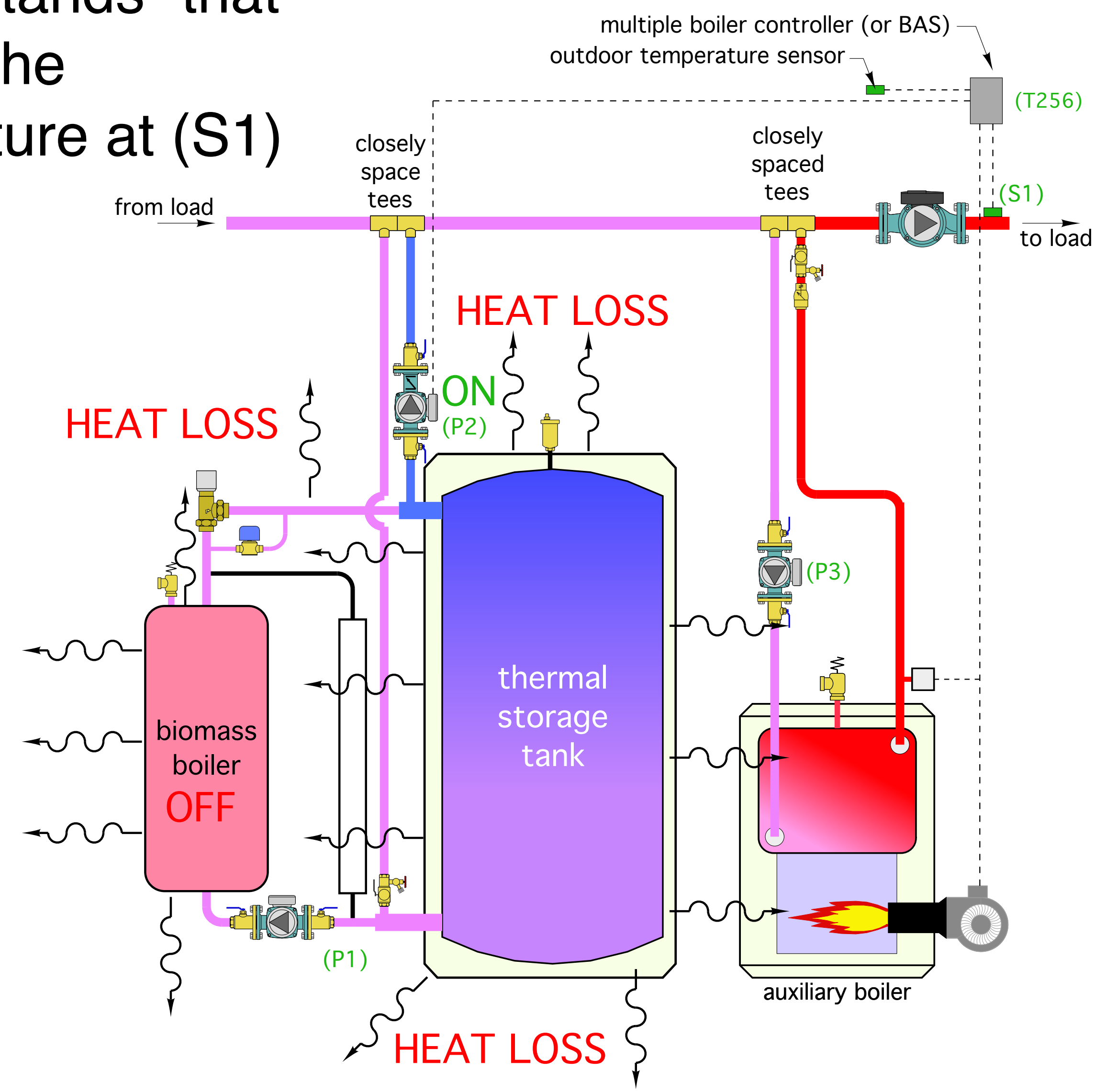
A standard multiple boiler controller "doesn't know" if the biomass boiler is *offline*, due to a fault, or if the tank is cooler than the minimum "useable" temperature of the distribution system.

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 ºF, all heat coming from electric aux boiler
- If boiler-to-tank circulator had not been manually switched off, 145 ºF water would be circulating through boiler, creating jacket heat loss, and convective air currents up flue *(no flue dampers on pellet boilers).*

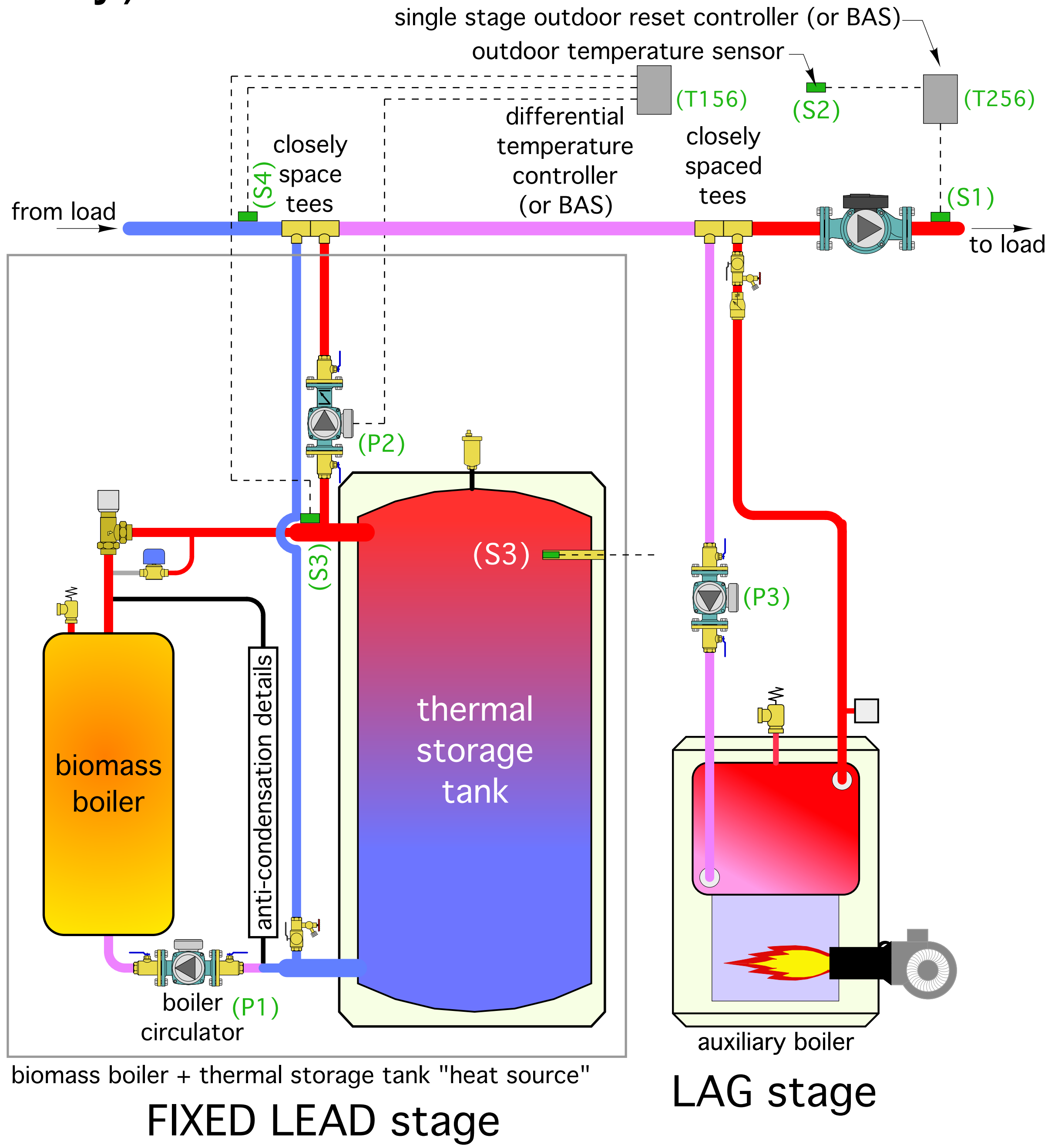
The solution is a simple *differential temperature controller* (or equivalent BAS functionality)

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

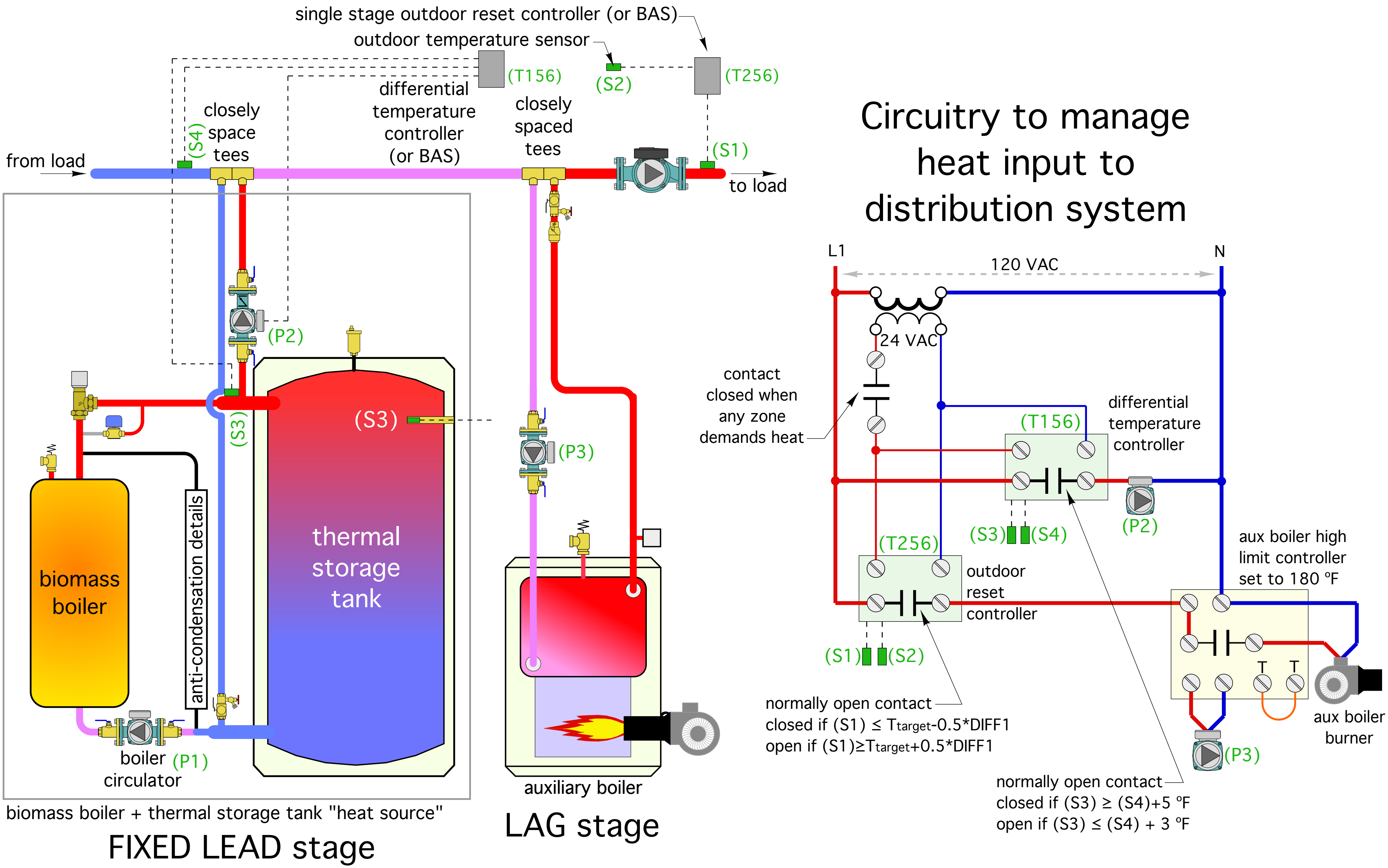
Circulator (P2) (tank to load) is only allowed to run when the tank can make a positive energy contribution to the system.

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

IF (S3) ≥ (S4) + 5 °F THEN (P2) is ON

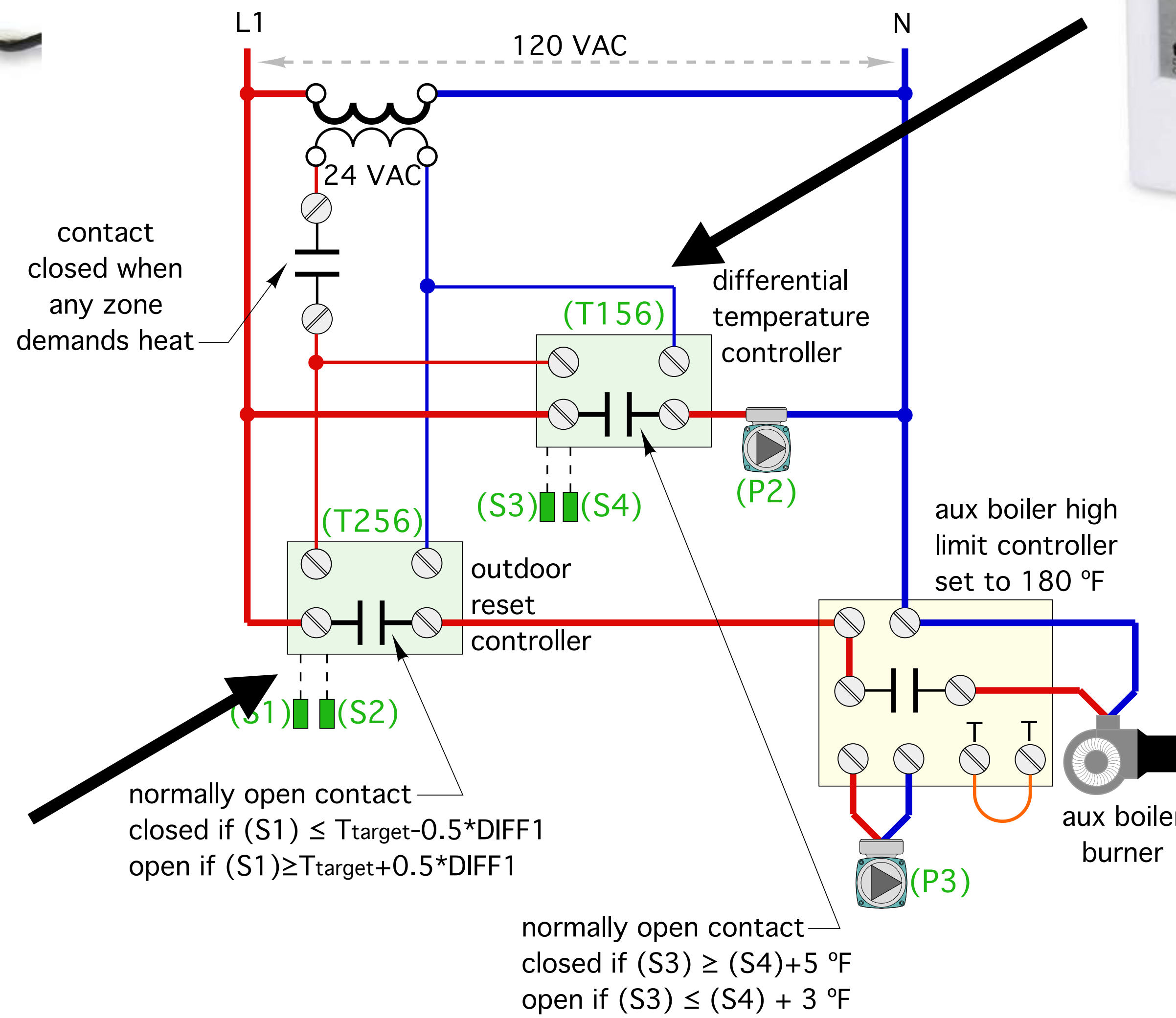


Using two simple, inexpensive controllers to manage heat flow to load



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

Circuitry to manage heat input to distribution system



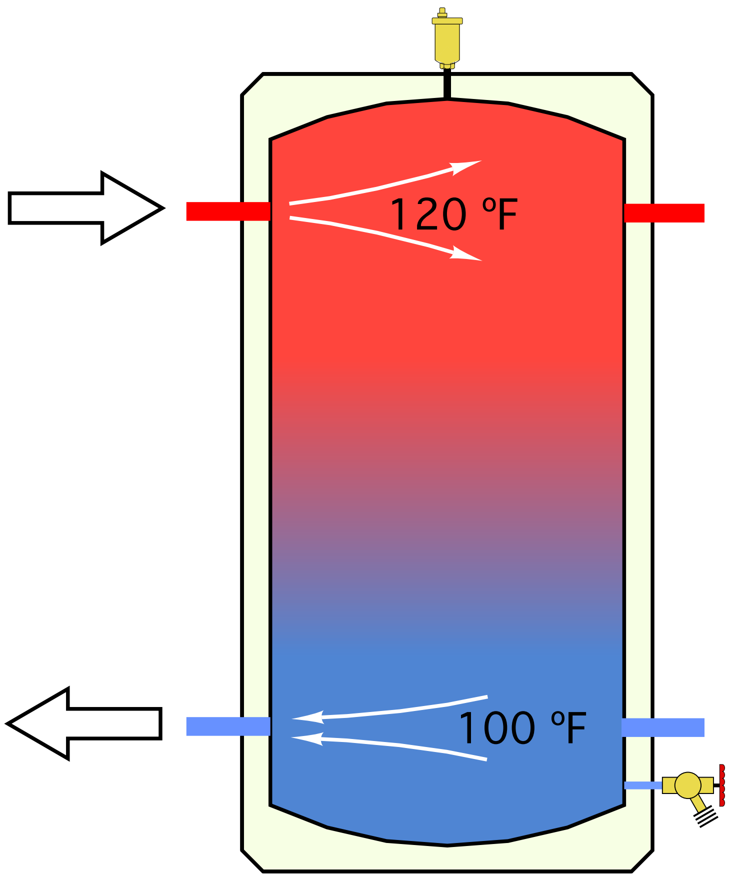
tekmar 156
$166

tekmar 256
$150

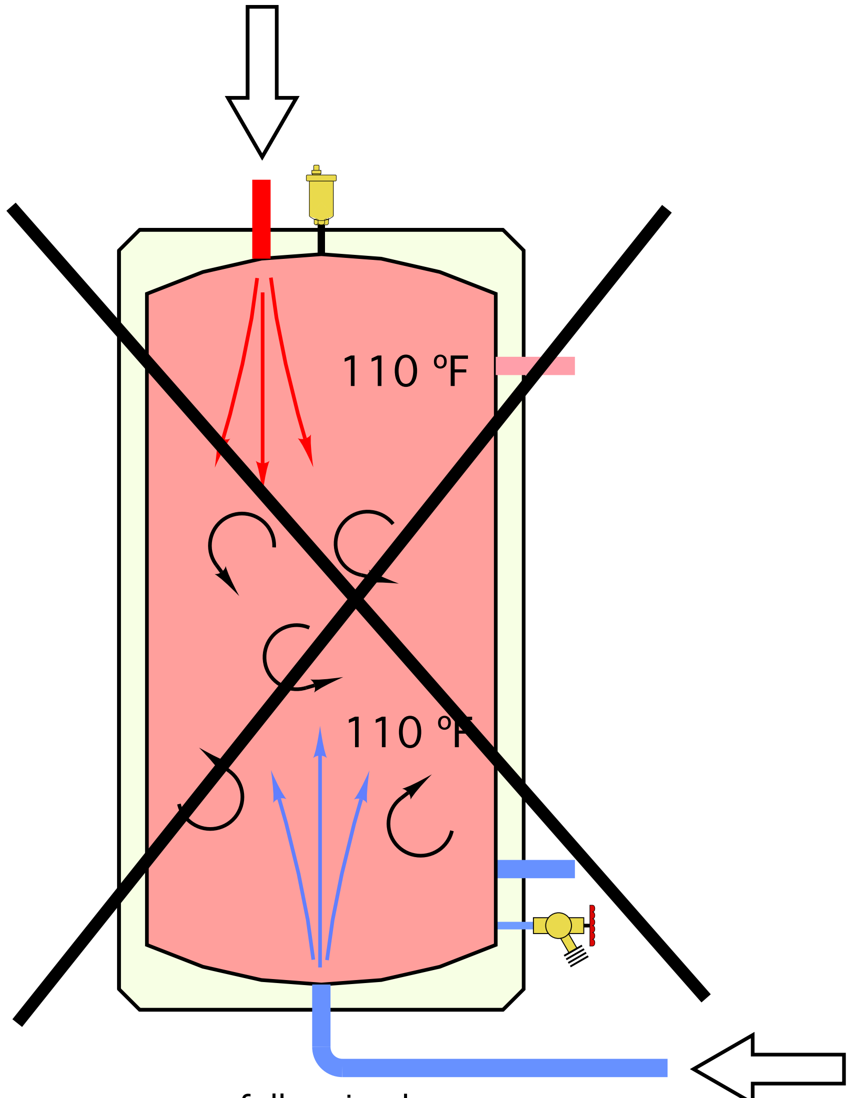
Maintaining temperature stratification in thermal storage

Stratification in thermal storage is DESIREABLE

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

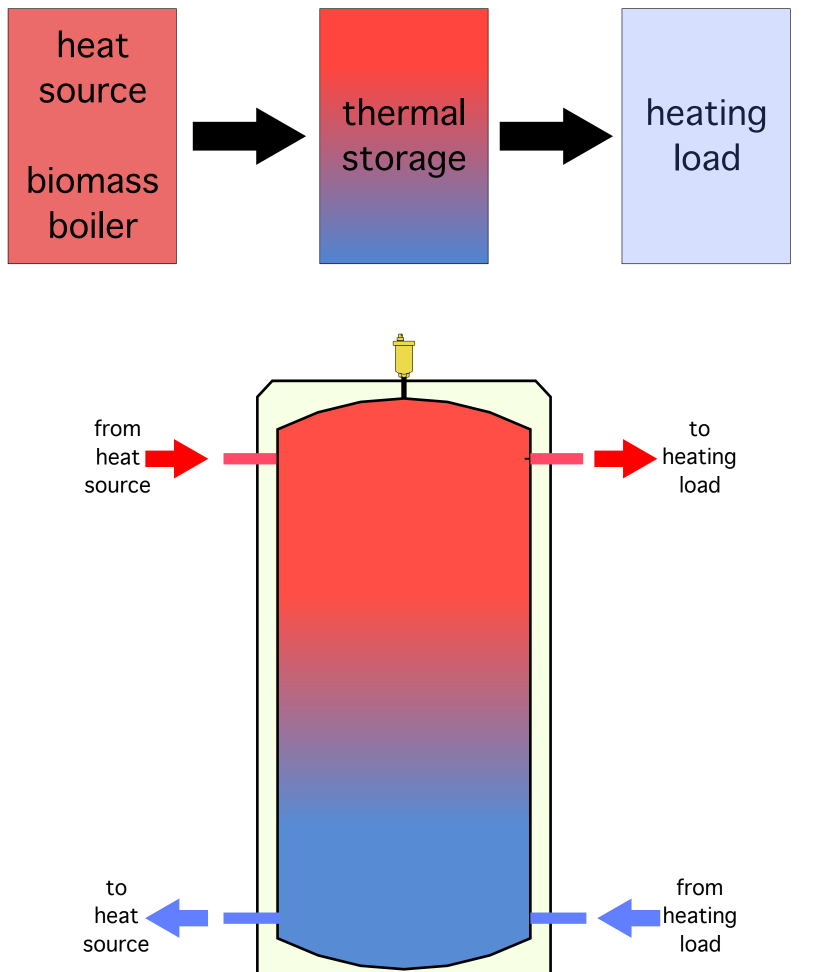


well stratified
thermal storage tank

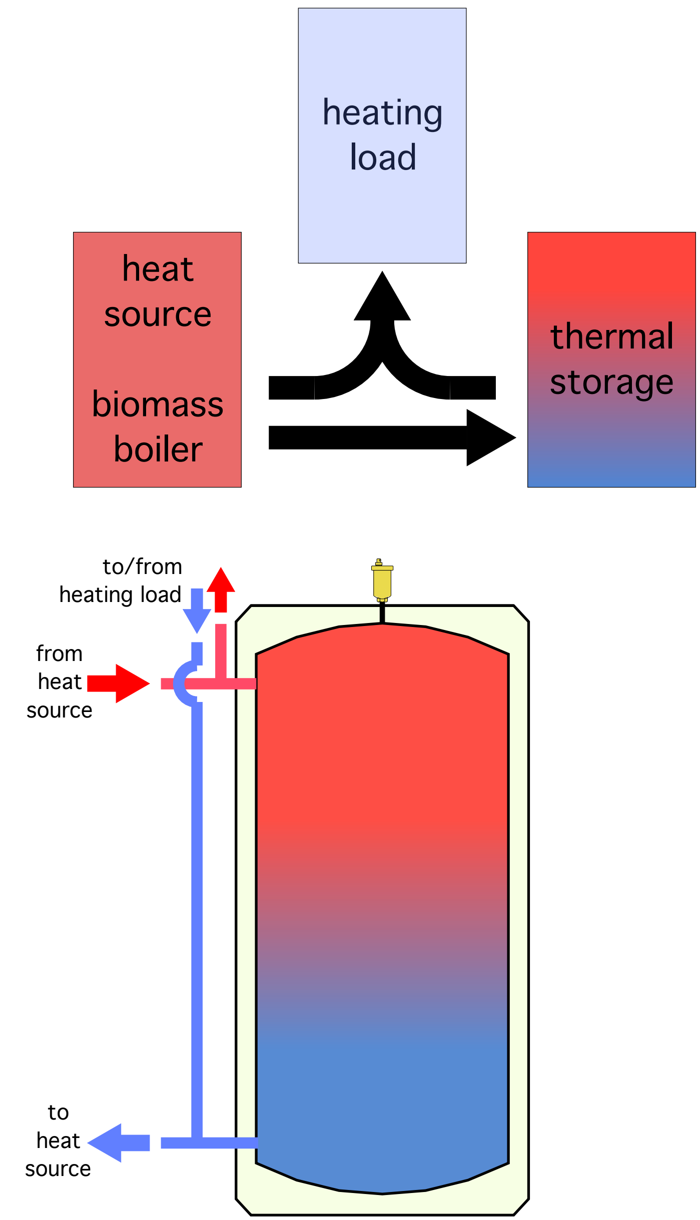


fully mixed
(poorly stratified)
thermal storage tank

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

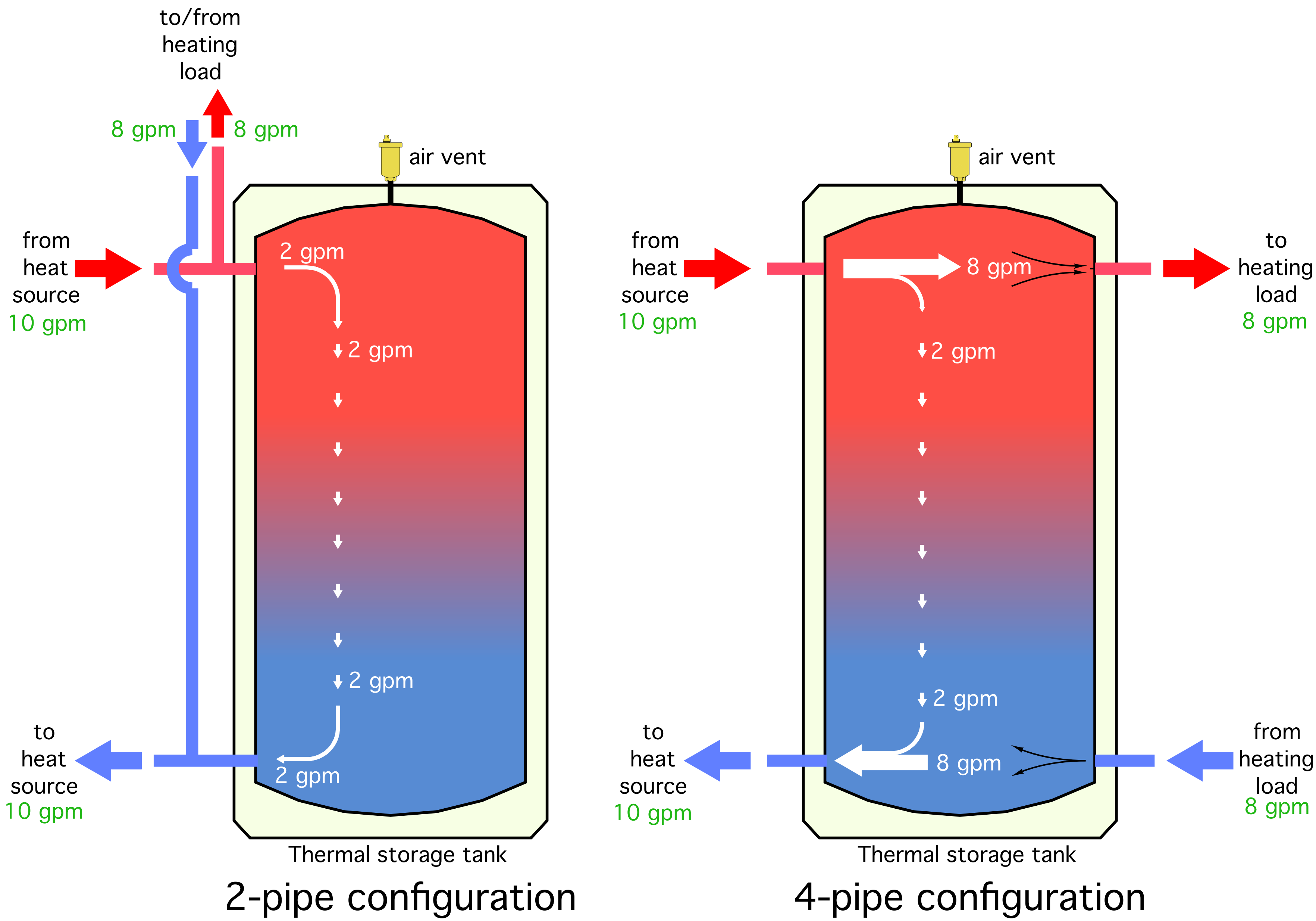


4-pipe configuration

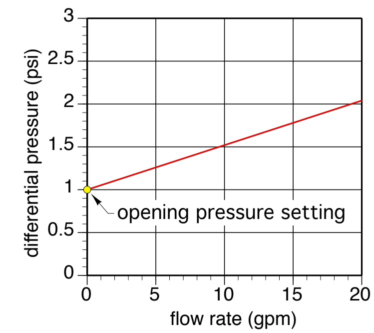


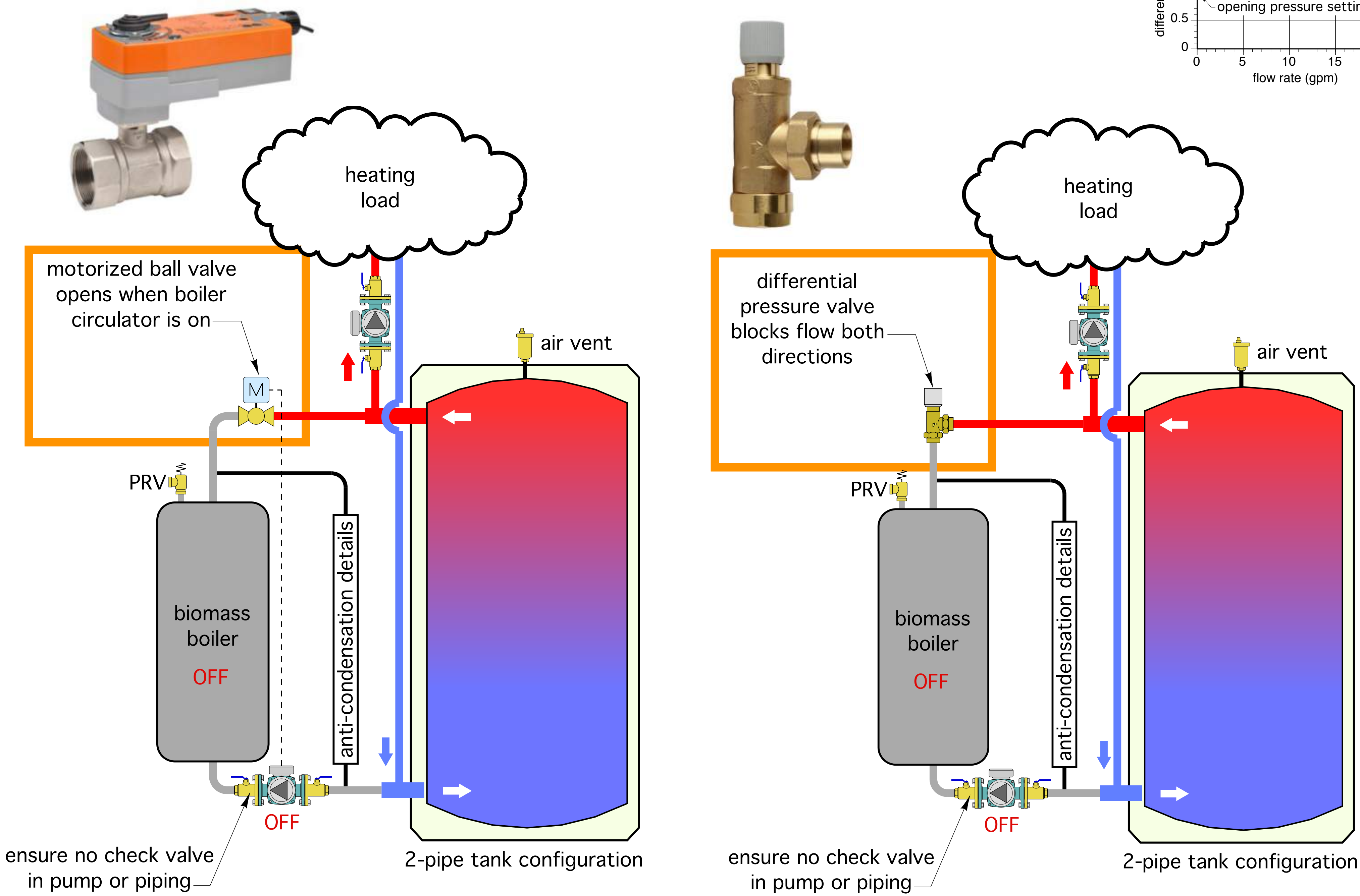
2-pipe configuration

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

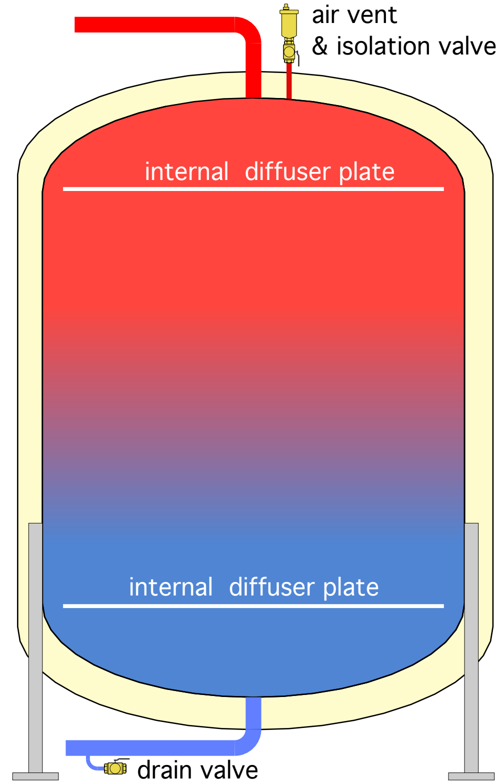


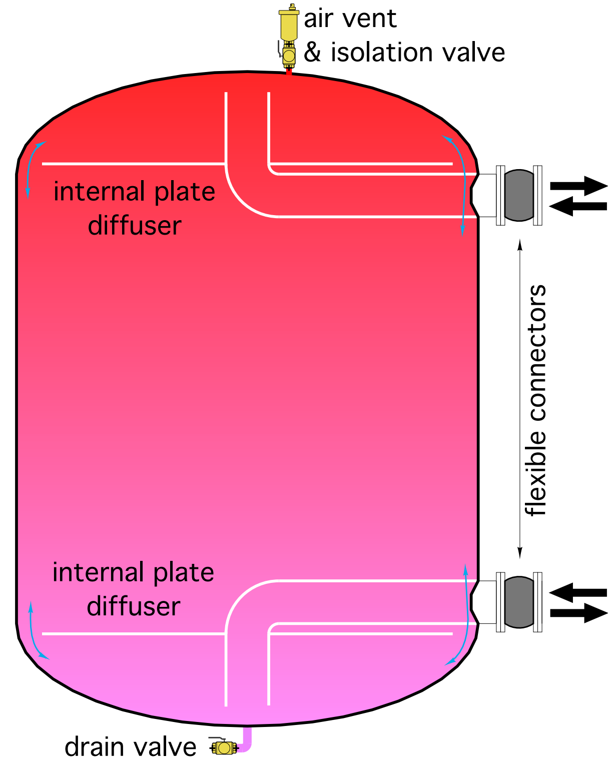
Preventing flow through unfired boiler





Design diffusers to access the full tank volume

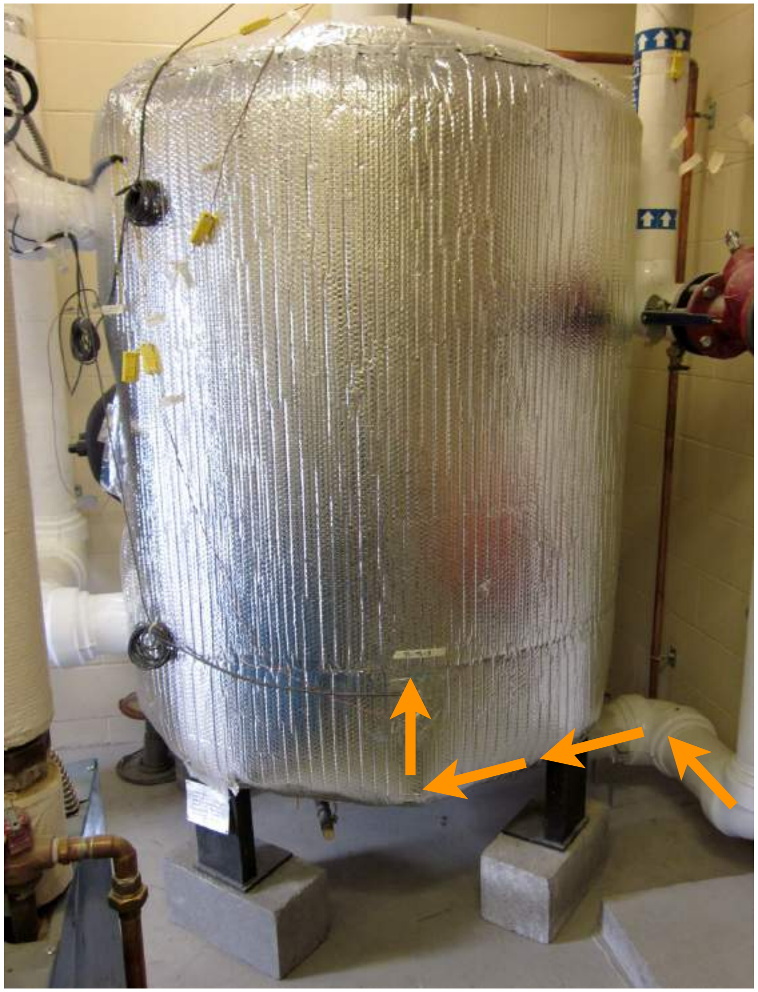


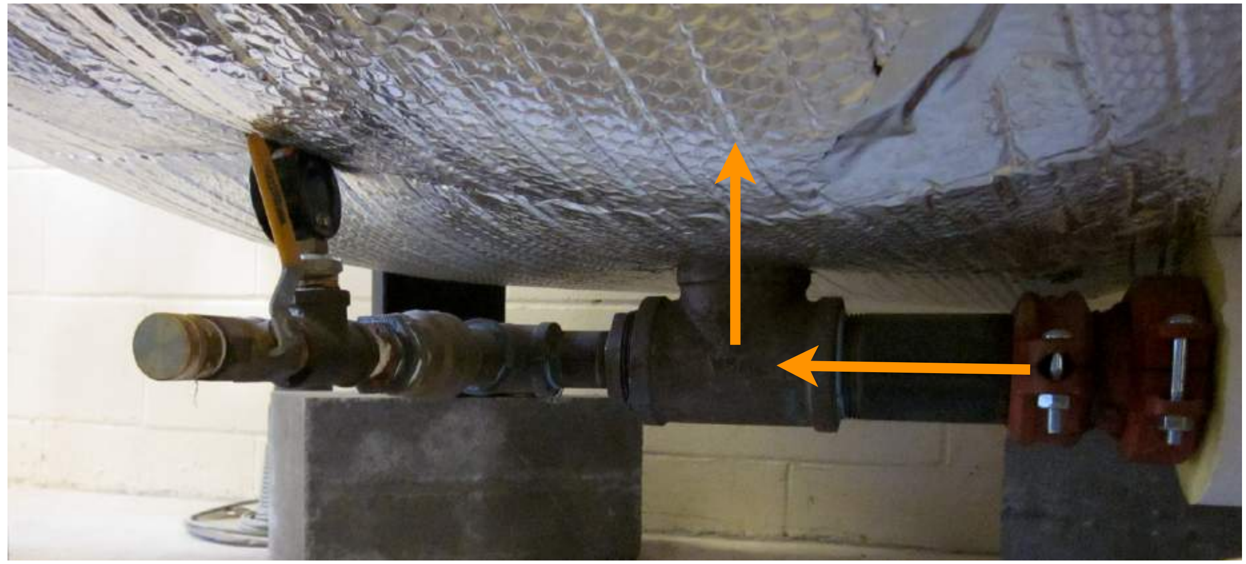


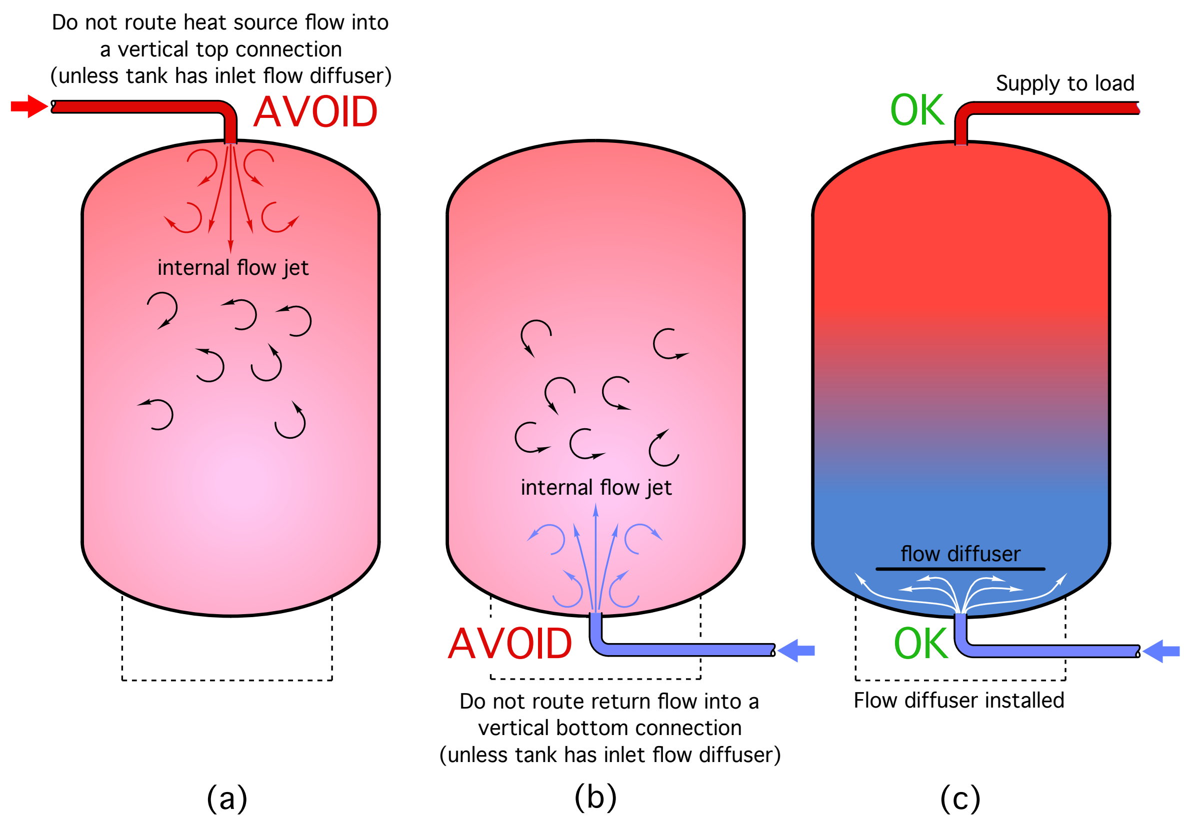
Baffle plate being welded into tank head & base shell at Troy Boiler Works

500 gallon ASME tank with poor stratification

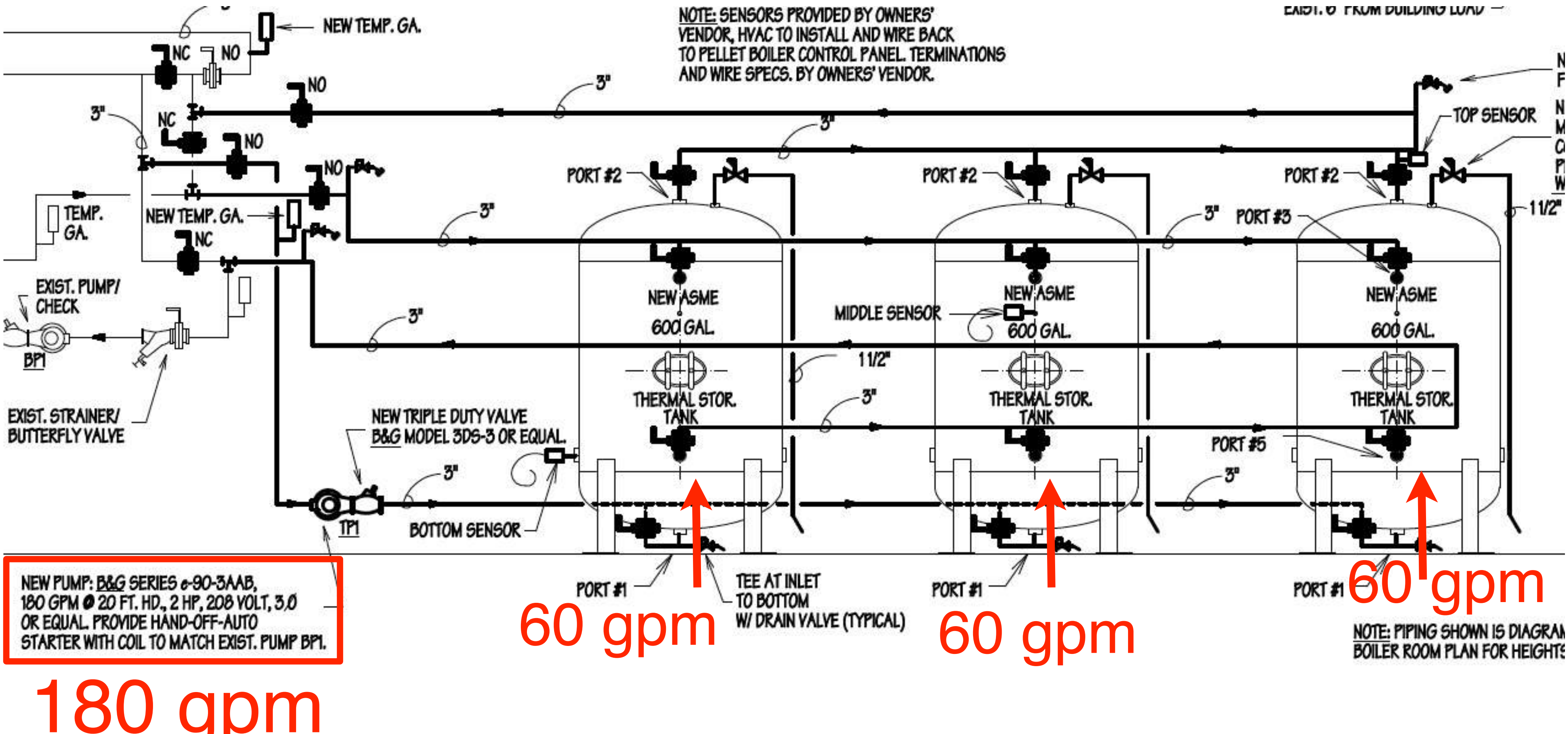
What's wrong?







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



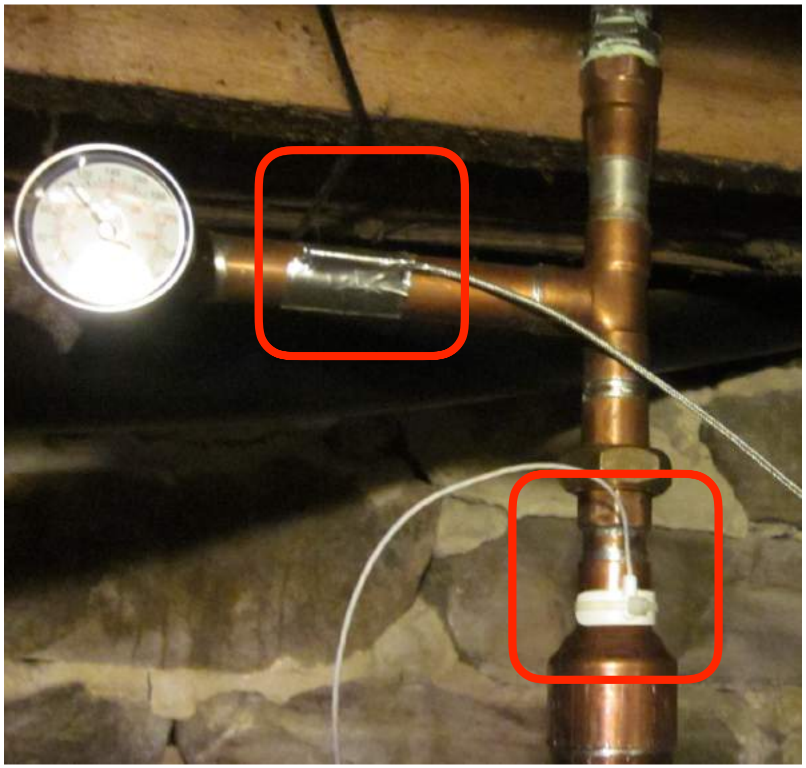
This piping will destroy stratification within the tank(s)

Poor temperature sensor placement

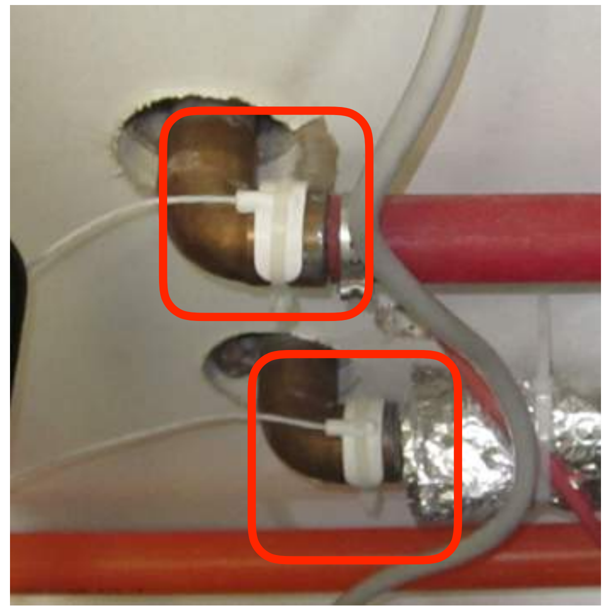
Poor sensor placement or lack of insulation

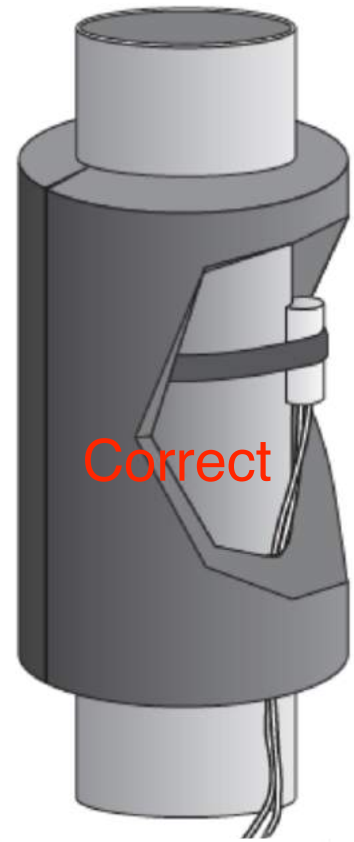
Controllers can only react to what temperatures their sensors "feel."

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





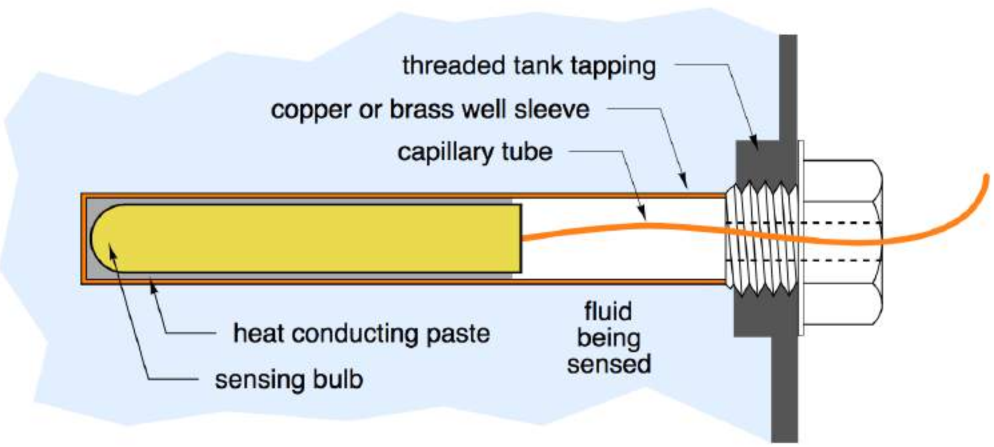
Some sensors have a concave shape to fit OD of pipe.

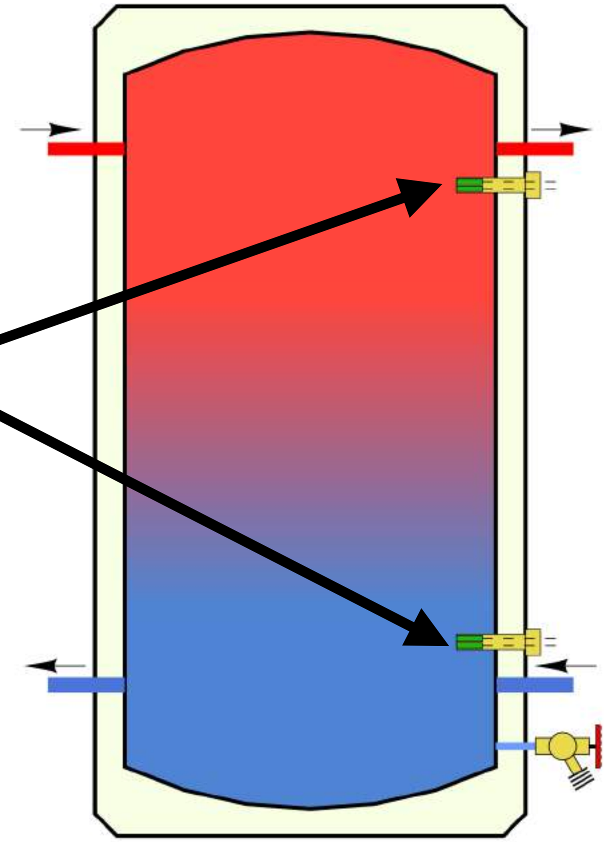
Poor sensor placement or lack of insulation

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.

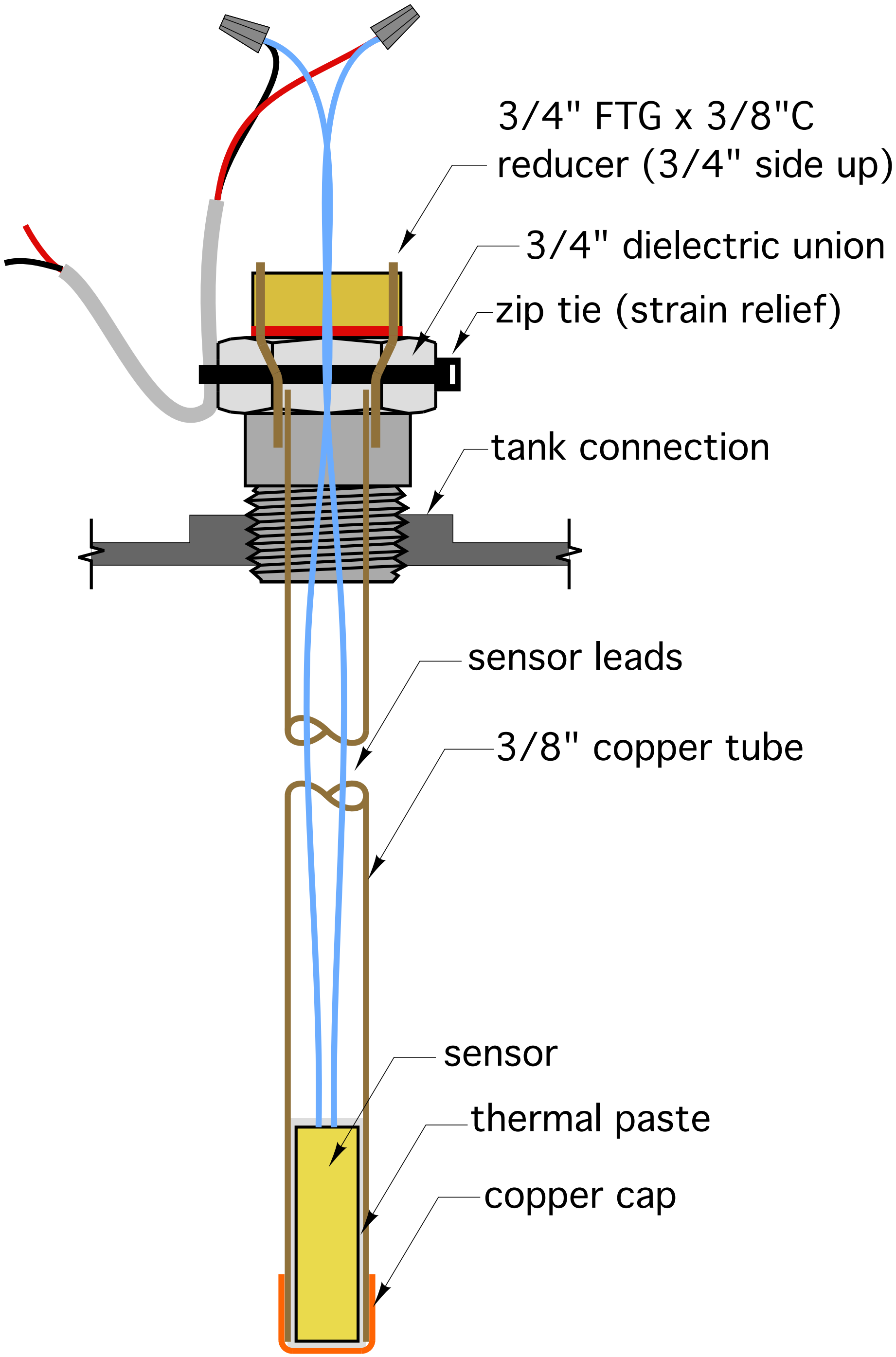


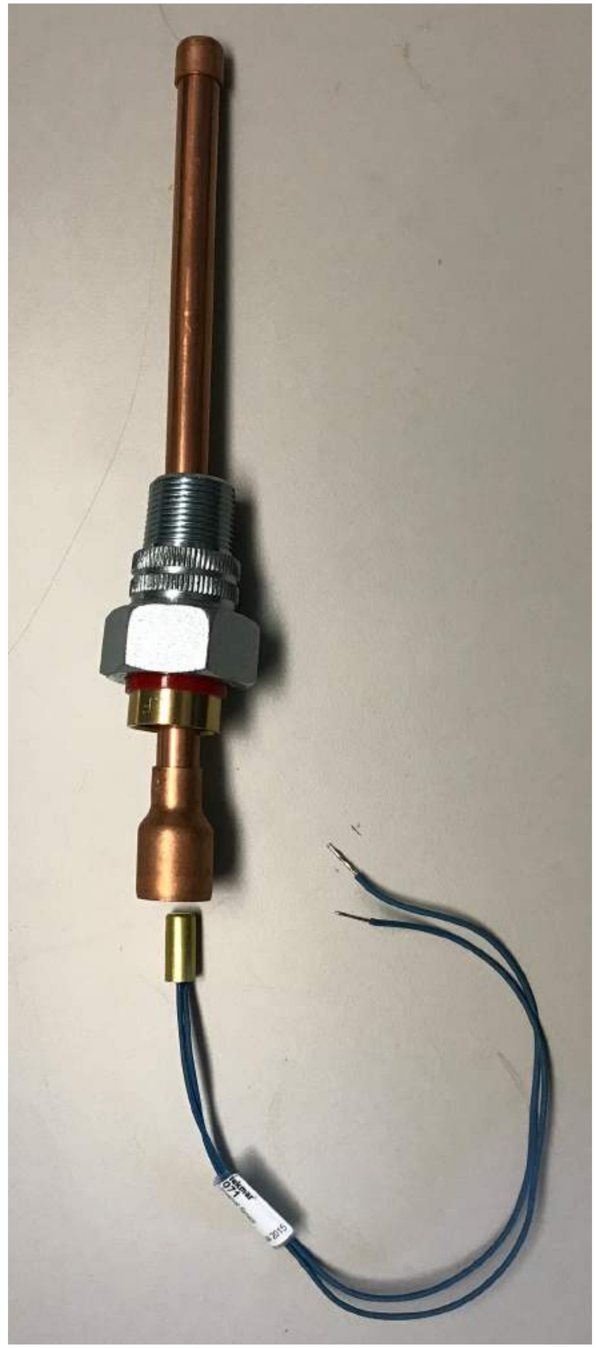


thermal storage tank

sensors
in wells

Simple way to built a sensor well

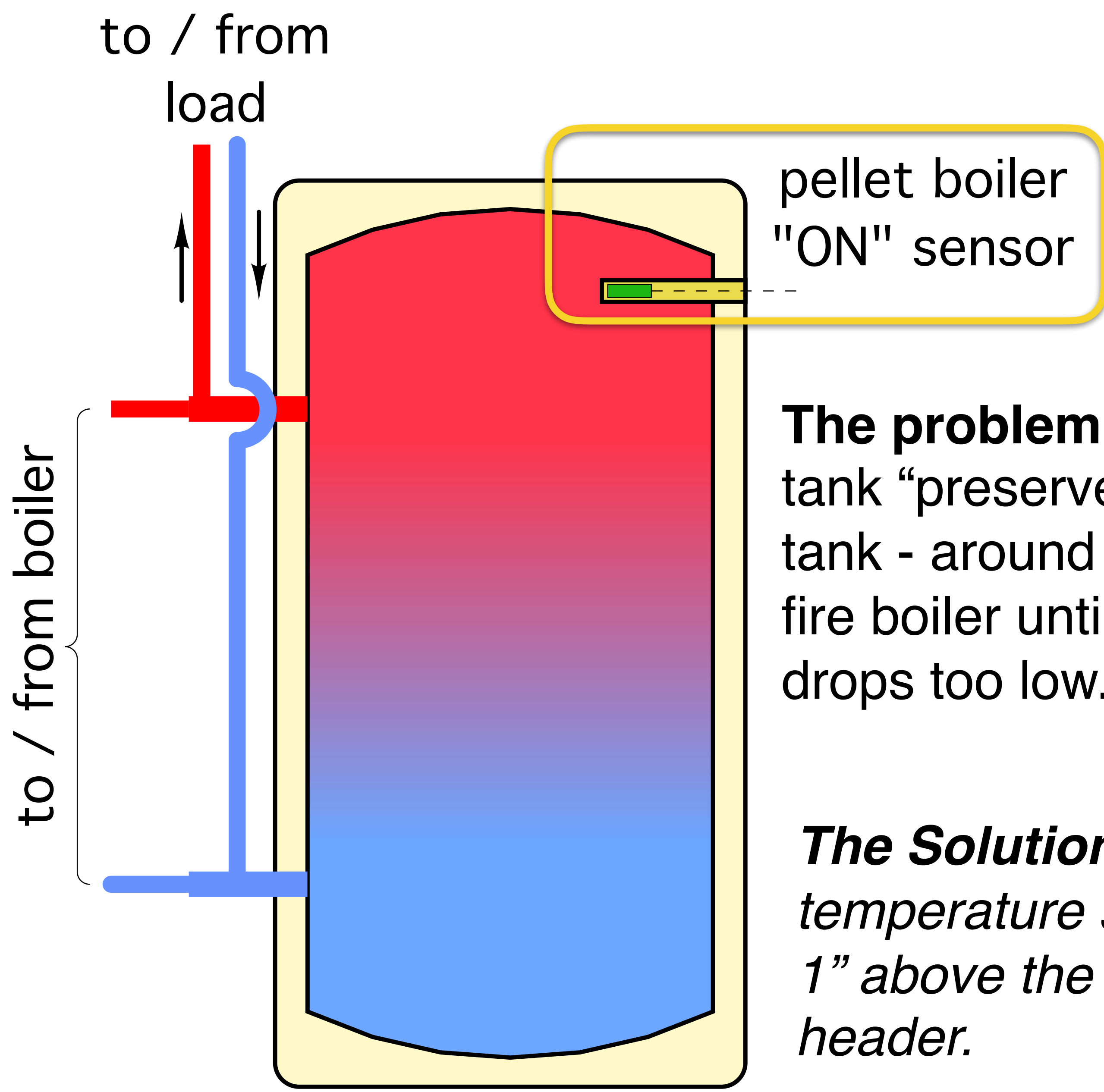




Thermal grease
in syringe:
$7, eBay

Honeywell
121371B
$15-25

Pellet boiler “ON” signal from high tank sensor with piping connections several inches below.



The problem: Stratification within tank “preserves” hot water at top of tank - around sensor - and fails to fire boiler until water temperature drops too low.

The Solution: *Keep the upper temperature sensor no more than 1” above the height of the upper header.*

Updates on NYSERDA's Renewable Heat NY program

NYSERDA incentives for H.E.L.E. pellet & cordwood gasification boilers have recently been increased…

The following incentives are available, the individual system type/technology below for more information and participation details.

<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 rowspan="3">-</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></tr>
<tr><td>≤300 kBtu/h (88 kW)</td><td>45% installed cost ($36,000 maximum)</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>-</td></tr>
<tr><td>Tandem Pellet Boiler with Thermal Storage</td><td>75% installed cost ($450,000 maximum)</td><td>Emission Control Systems

$40,000</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>

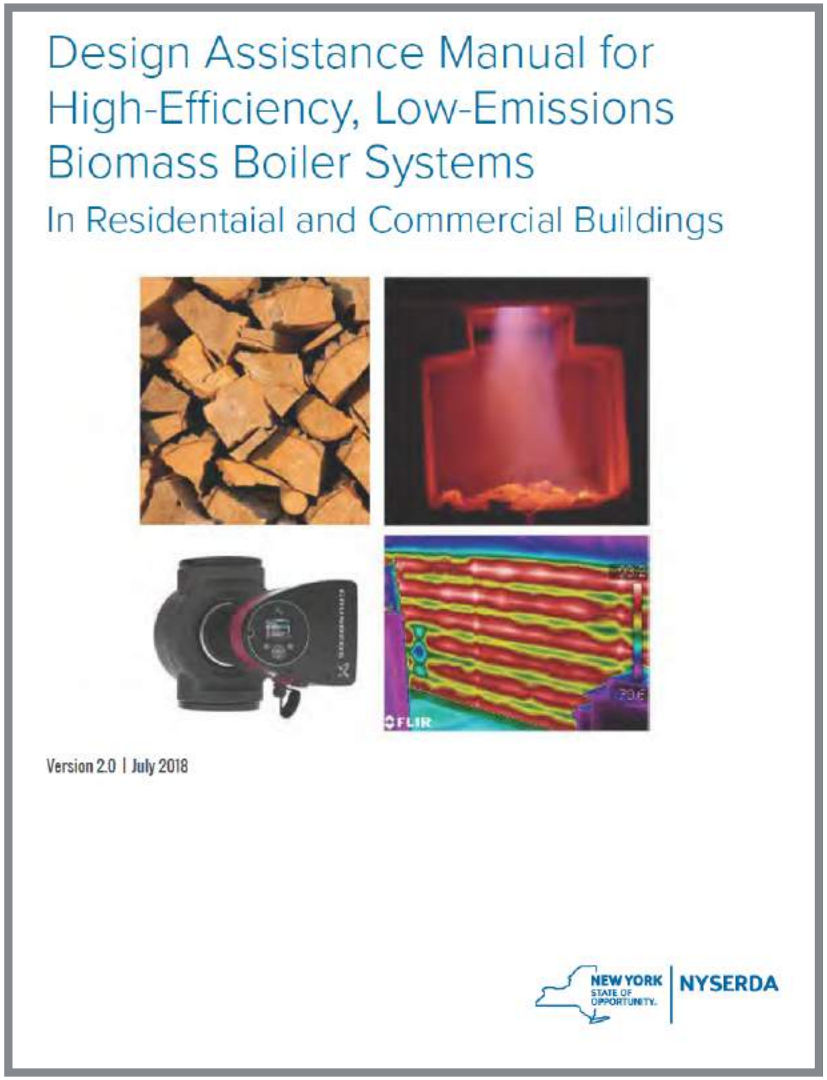
https://www.nyserda.ny.gov/All-Programs/Programs/Renewable-Heat-NY

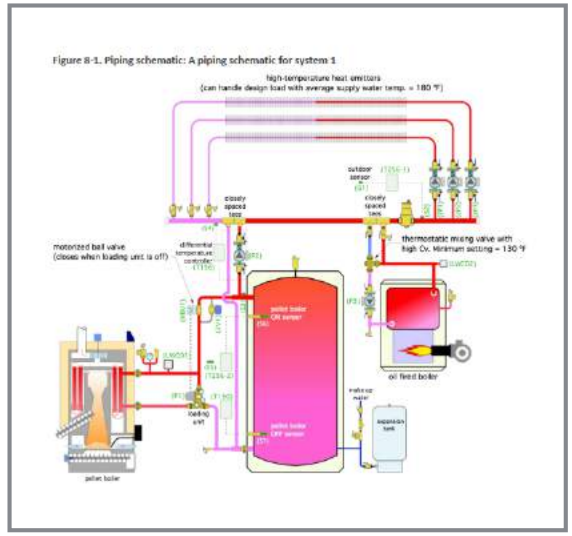
Questions on NYSERDA's RHNY program can be directed to:

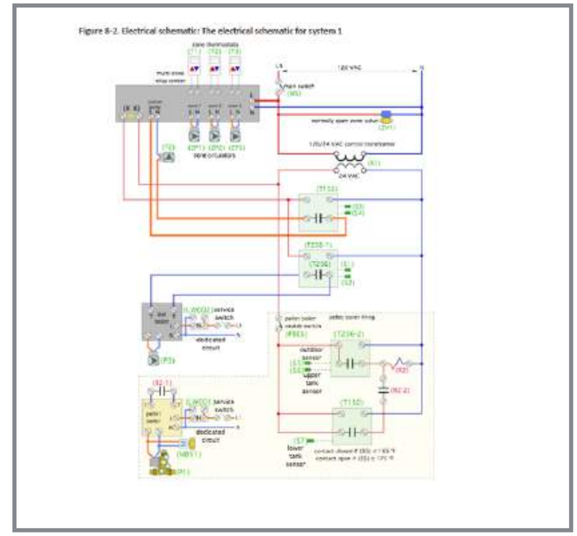
RHNY@nyserda.NY.gov
518-862-1090

Just about finished….

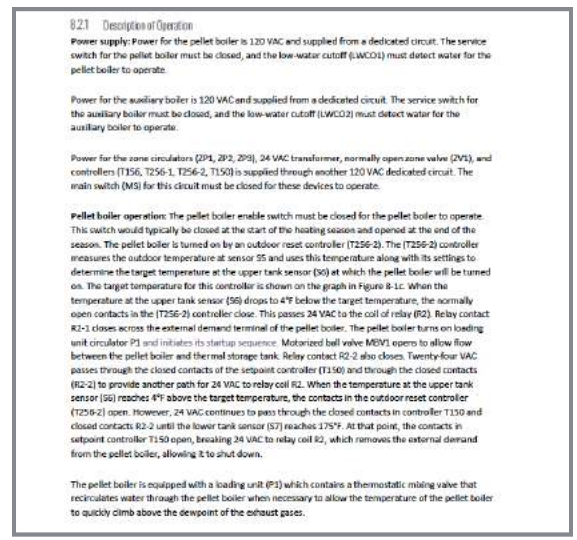
248 pages of collective “lessons learned” and practical guidance for designing & installing H.E.L.E. biomass boiler systems.







This manual concludes with 8 complete system templates, with piping & electrical schematics + description of operation.


8.2.1 Description of Operation

Power supply: Power for the pellet boiler is 120 VAC and 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.

Power for the auxiliary boiler is 120 VAC and 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, 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 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°F 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 startup sequence. Motorized ball valve MBV1 opens to allow flow between the pellet boiler and thermal storage tank. Relay contact R2-2 also closes. Twenty-four VAC passes through the closed contacts of the 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°F 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°F. At that point, the contacts in setpoint controller T150 open, breaking 24 VAC 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.

This will be a free downloadable PDF posted at NYSERDA’s Renewable Heat NY website.

Hardcopies of this manual will be used at the 10/23/18 biomass boiler systems training.

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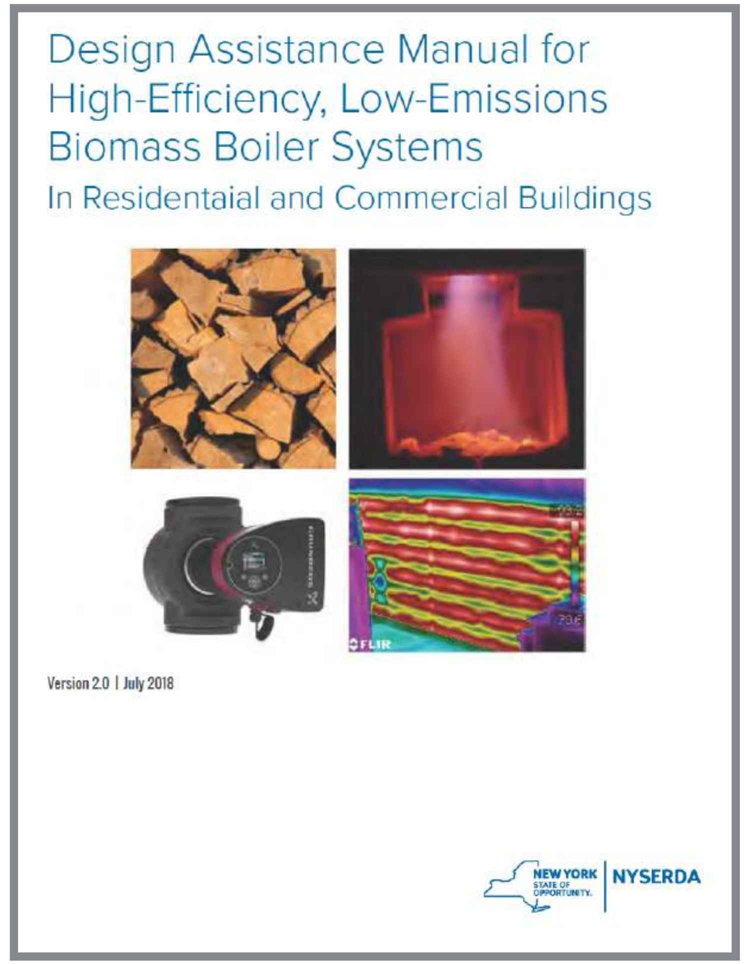
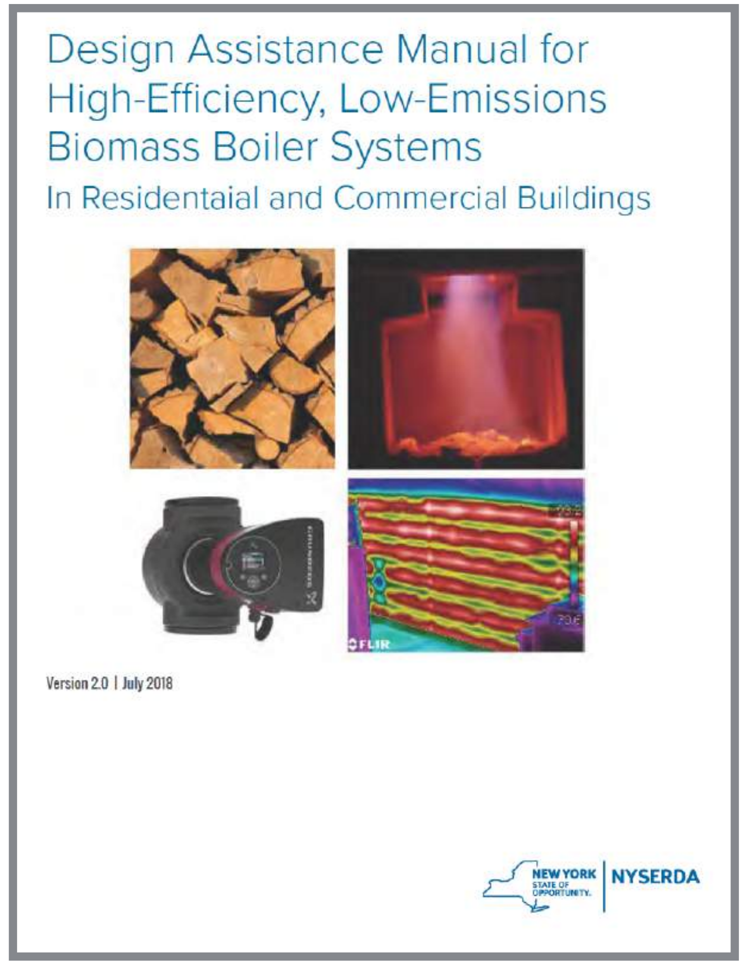


Thanks for attending today’s webinar

Special thanks to **Deb Moran** at NYSERDA for hosting this and previous RHNY webinars.

Thanks also to **Alicia Knapp** at NYSERDA for coordinating delivery of this webinar.

Questions?



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SAMPLE SLIDE

Course Description

Description: This webinar discusses several errors related to the design and installation of biomass boiler systems in residential and commercial buildings. Each error is described along with methods of avoiding or correcting the problem(s) associated with it.

Learning Objectives:

1. Understand the issues associated with poor boiler venting.

2. Learn how to configure systems to avoid inadvertent transfer of heat produced by an auxiliary boiler into thermal storage.

3. Understand how piping affects temperature stratification within thermal storage.

4. Learn the importance of proper sensor placement.

This concludes The American Institute of Architects Continuing Education Systems Course