Hydronics for High Efficiency Biomass Boilers

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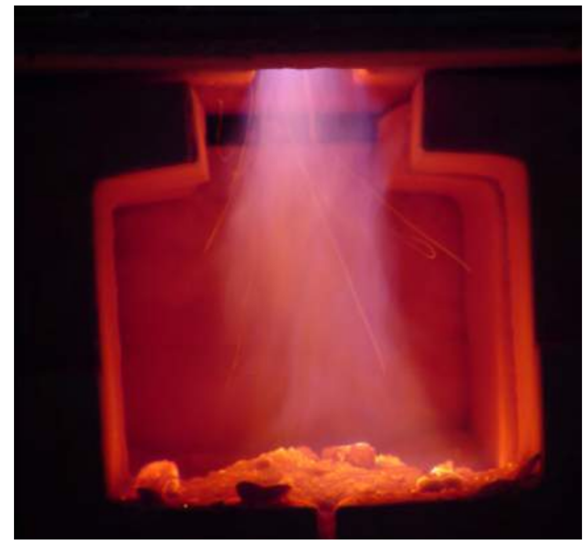
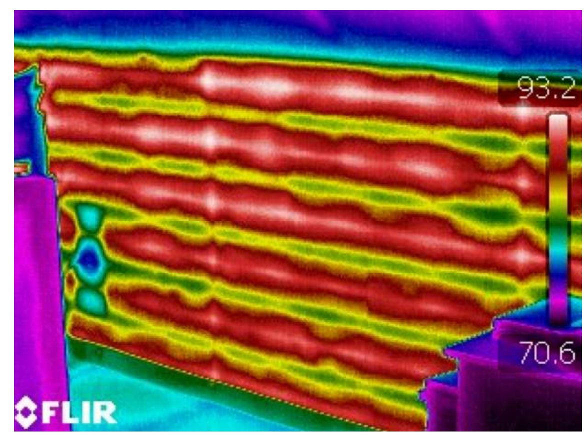


presented by:

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

AIA approved course: BIOMASS2014
7.0 LU credits

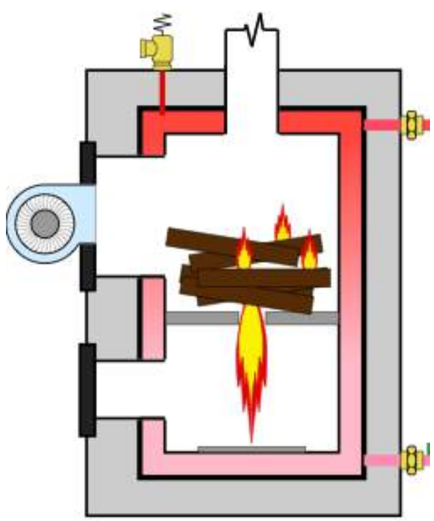
CONTINUING EDUCATION AIA



Hydronics for High Efficiency Biomass Boilers

Today's Agenda:

- Short break at 10 AM
- Lunch & visit outdoor displays noon - 12:30
- Short presentation on Renewable Heat New York
- Short break at 2:30
- ***Out of here by 9:00 PM***

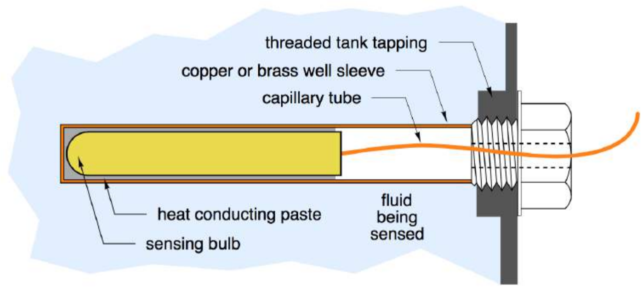


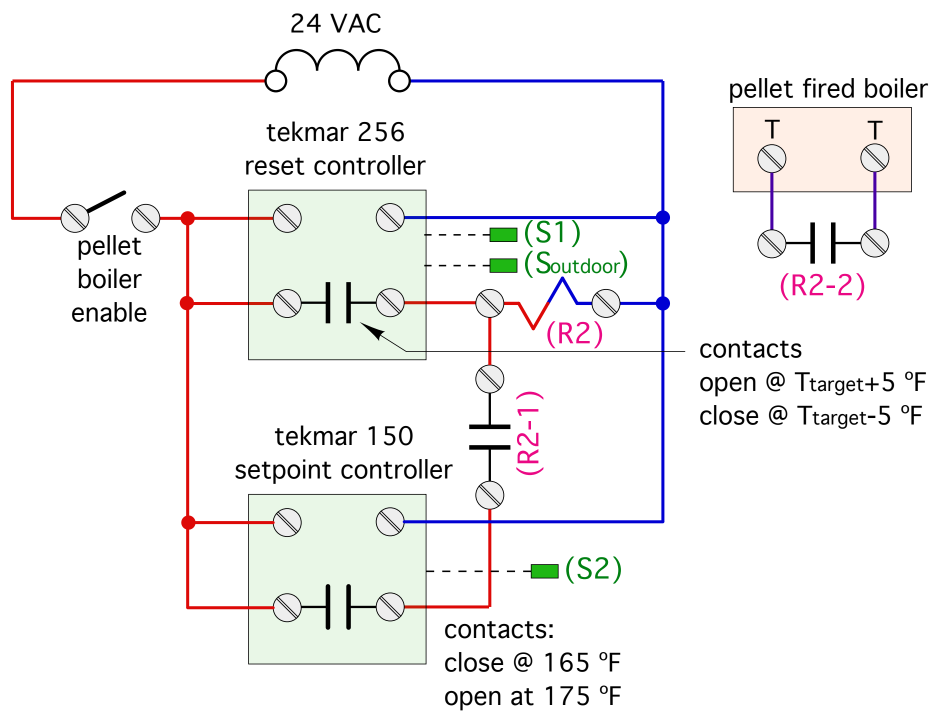
wood-gasification boiler

Hydronics for High Efficiency Biomass Boilers

Today's Topics:

- The importance of hydronics to renewable energy
- Wood as a heating fuel
- Wood gasification boilers
- Pellet-fired boilers
- Thermal storage options
- Preventing “negative energy flow”
- Boiler protection options
- Low temperature hydronic heat emitters
- Instantaneous domestic water heating
- Thermal storage control concepts
- Sizing biomass boilers & thermal storage
- System examples
- What’s wrong with this system?
- Renewable Heat NY program





New York State Energy Research & Development Authority

"Hydronics for High Efficiency Biomass Boilers"
BIOMASS2014

John Siegenthaler **7 AIA LU credits**
June /2014

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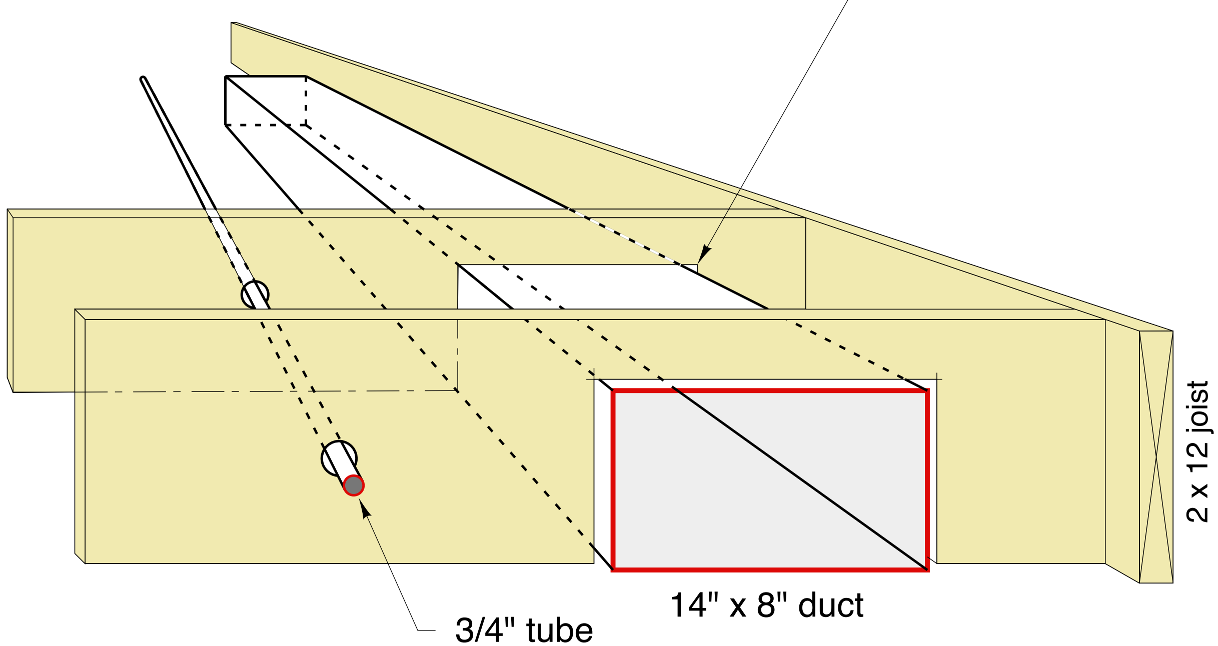
Water vs. air: It's hardly fair...

courtesy of Dan Foley

Water is vastly superior to air for conveying heat

Material	Specific heat (Btu/lb/ºF)	Density* (lb/ft³)	Heat capacity (Btu/ft³/ºF)
Water	1.00	62.4	62.4
Concrete	0.21	140	29.4
Steel	0.12	489	58.7
Wood (fir)	0.65	27	17.6
Ice	0.49	57.5	28.2
Air	0.24	0.074	0.018
Gypsum	0.26	78	20.3
Sand	0.1	94.6	9.5
Alcohol	0.68	49.3	33.5

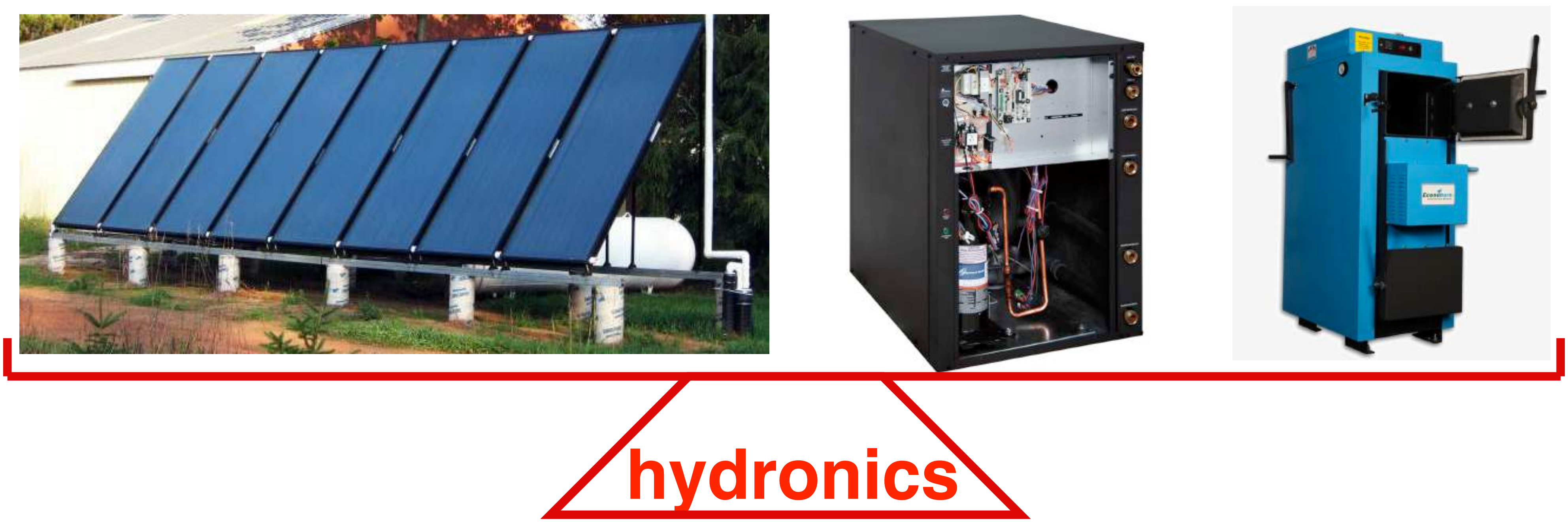


$$\frac{62.4}{0.018} = 3467 \approx 3500$$

A given volume of water can absorb almost 3500 times as much heat as the same volume of air, when both undergo the same temperature change

Hydronics & Renewable Energy

Modern hydronics is the "glue" holding together many thermally-based renewable energy systems.



Regardless of what solar collector, geothermal heat pump, or wood-fired boiler is selected, if the distribution system, controls, and heat emitters are not properly matched, that system will not perform well.

Why hydronics enhances renewable heat sources

- Superior comfort
- Low temp. operation (high heat source efficiency)
- Very high distribution efficiency
- Thermal storage potential
- Easy integration with conventional heat sources
- Minimally invasive retrofitting
- Potential for thermal metering (ASTM E44 coming soon)

I burn wood for at least 50% of my space heating needs

A growing market for wood-based biomass heating

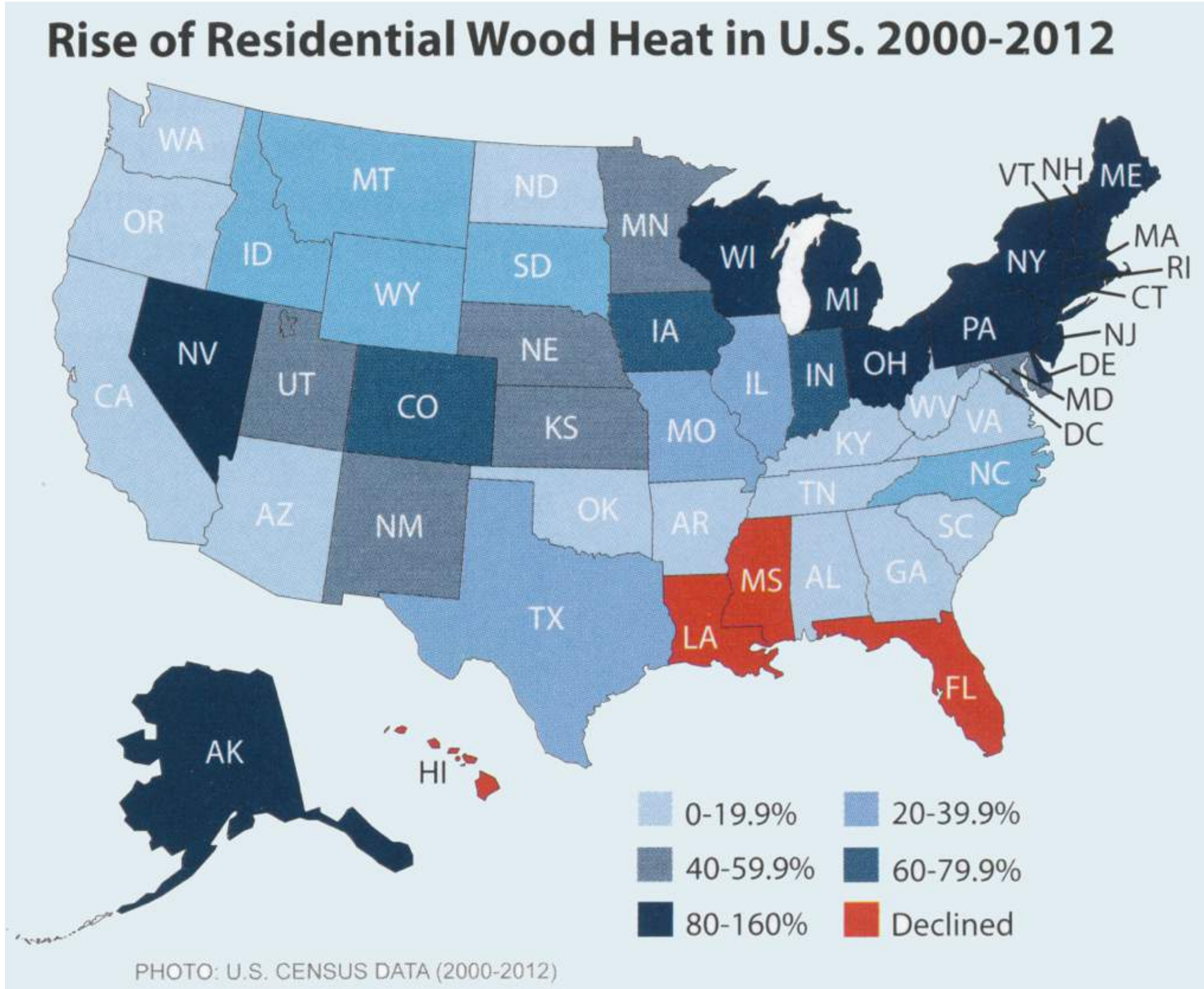
Between 2000 and 2010 use of wood or pellet for home heating grew 34%

2.5 million American households now using wood as PRIMARY heating fuel

2.1% of Americans now using wood or pellet as PRIMARY heating fuel, up from 1.6% in 2000

7.7% American household now using wood as SECONDARY heating fuel

2.6% increase in number of American households heating with wood from 2011 to 2012



information source: US Energy Information Administration

Firewood needs to be dry!

20% moisture maximum *INTERNAL* moisture content

Source: Richard Gibbs

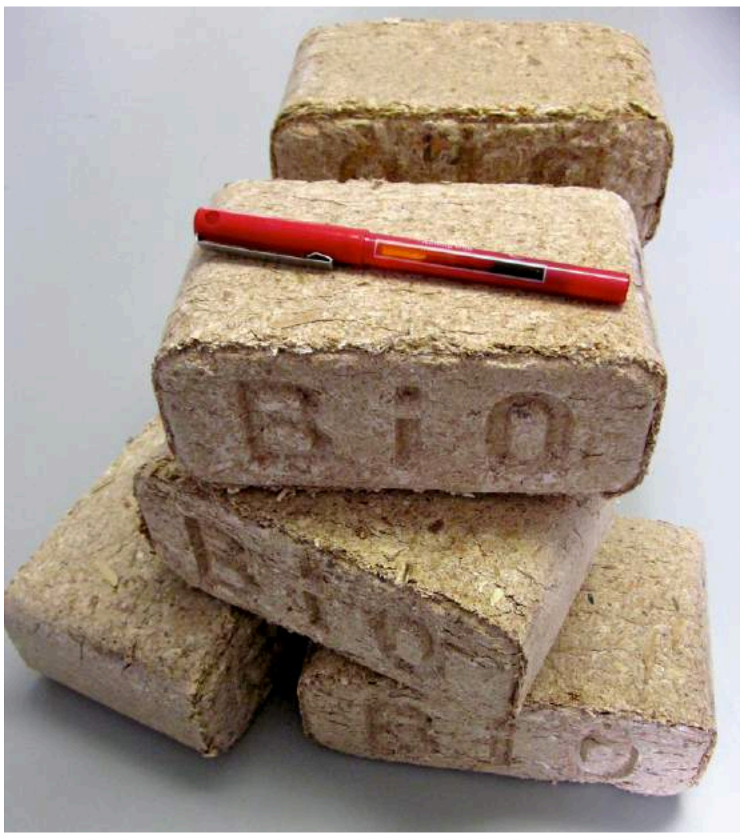
Split open several pieces of firewood from the pile to check internal moisture %

end grain moisture = 7.9%

split open internal moisture = 16.0%

Pellets & other "densified" wood fuel

Wood pellets
7600 to 8400
Btu/lb



Wood
briquettes
about
8000 Btu/lb

PFI GRADED FUEL

Pellet Fuels Institute

PFI Densified Fuel Grade: Premium

Grade Requirements:
Reg. #1234

Bulk Density:	40–46 lbs/ft^3
Diameter:	.230–.285 in/5.84–7.25 mm
Durability:	$\geq$96.5
Fines:	$\leq$0.50%
Ash Content (as received):	$\leq$1%
Length:	$\leq$1% >1.5 in.
Moisture:	$\leq$8.0%
Chlorides:	$\leq$300 ppm

Manufacturers Guaranteed Analysis:

Type of Material:	Softwood fiber
Additives:	2.0% corn oil by weight
Minimum Higher Heating Value (as received):	8,000 BTU
Other Manufacturers Guarantees:	

Approved Auditing Agency Logo
Displayed Here

© For more information, please visit the PFI website at www.pelletheat.org.

PELLET FUELS INSTITUTE www.pelletheat.org

The total "embodied" energy required to manufacture pellets is usually below 2% of their final energy content. This compares favorably to the 10-12% embodied energy required to refine common fossil fuels.

Pellet Production

New England Wood Pellet plant, Utica, NY

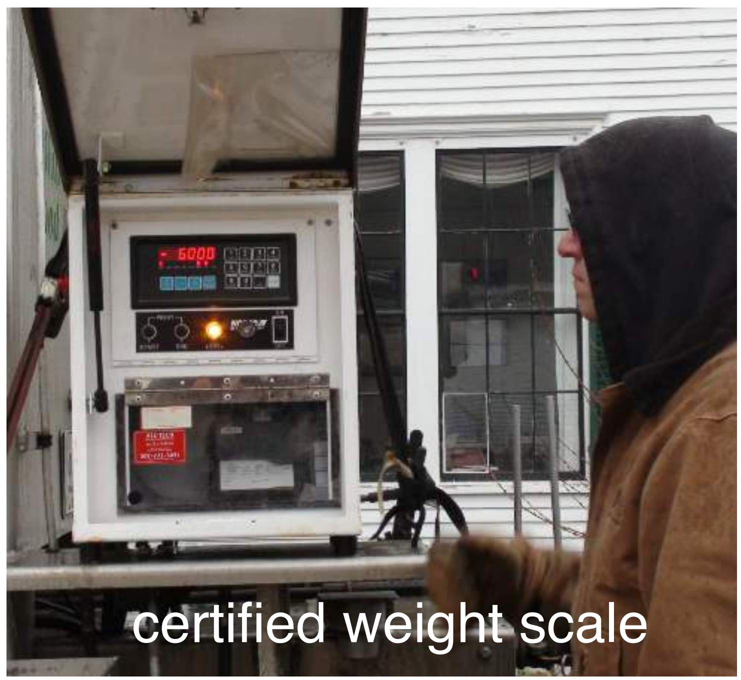
pellets emerge from mill
at about 190 °F

Bulk Pellet Delivery

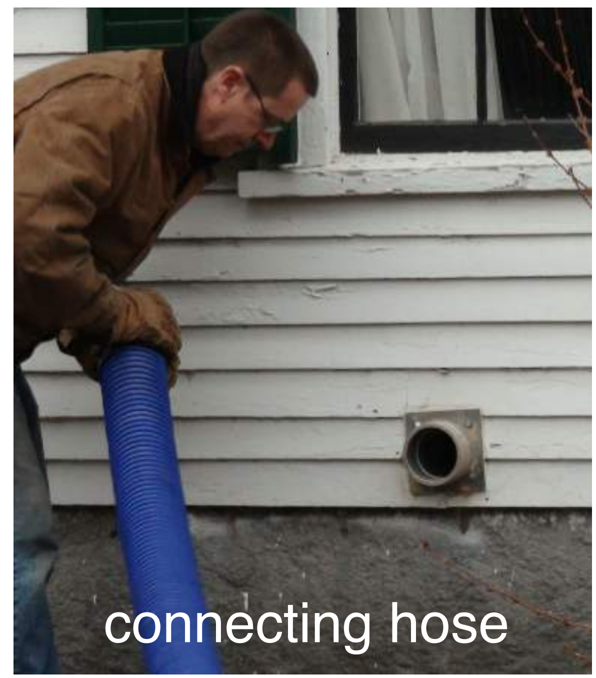
Images courtesy of Maine Energy Systems

Filling truck

preparing hose



certified weight scale



connecting hose

Wood as a heating fuel

Higher heating value (HHV) = theoretical heat available from 0% moisture content wood, burned with stoichiometric air/fuel ratio, and including recovery of latent heat (condensation and cooling of water vapor produced during combustion.

$HHV_{0\%mc}$ = 8660 Btu/lb

Higher heating value (HHV) as function of moisture content

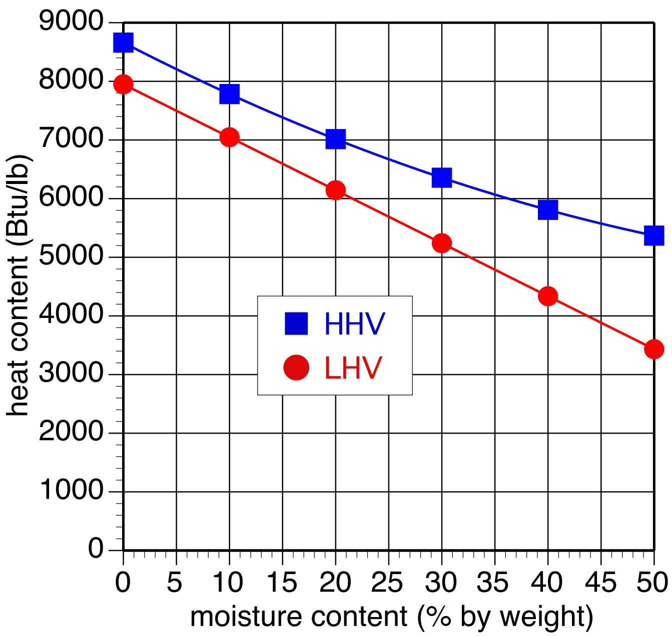
$$HHV_{BTU/lb} = 8660(1 - 0.010766w + 0.00006333w^2)$$

w = moisture content (%)

Lower heating value of wood does *not* include the latent heat associated with water vapor produced as the wood is burned.

$$LHV_{BTU/lb} = 7950 - 90.34w$$

w = moisture content (%)



Wood as a heating fuel

Thus, wood with 20% moisture content, typical of firewood that's been keep under cover and air dried for at least nine months, is approximately:

$$HHV_{BTU/lb} = 8660[1 - 0.010766(20) + 0.00006333(20)^2] = 7015\frac{Btu}{lb}$$

$$LHV_{BTU/lb} = 7950 - 90.34(20) = 6143\frac{Btu}{lb}$$

When comparing boiler efficiencies, be sure to determine if they are based on HHV or LHV of wood.

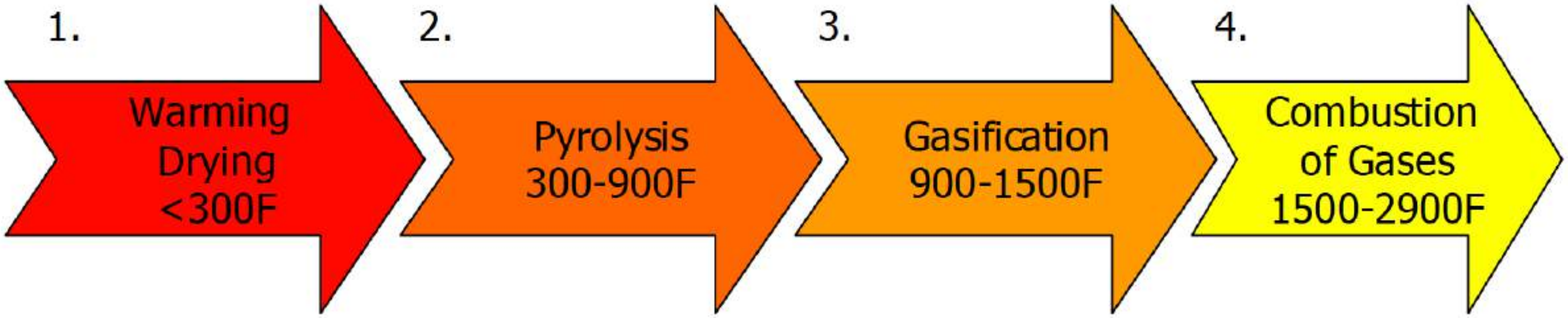
Example (assuming 20% mc wood):

A boiler rated at 70% thermal efficiency based on HHV will yield (0.70)(7015) = **4911 Btu/lb useable output**

A boiler rated at 80% thermal efficiency based on LHV will yield (0.80)(6143) = **4914 Btu/lb useable output**

Almost identical useful heat output, but two different "paths of arrival" (e.g. efficiencies based on HHV vs. LHV).

Combustion phases

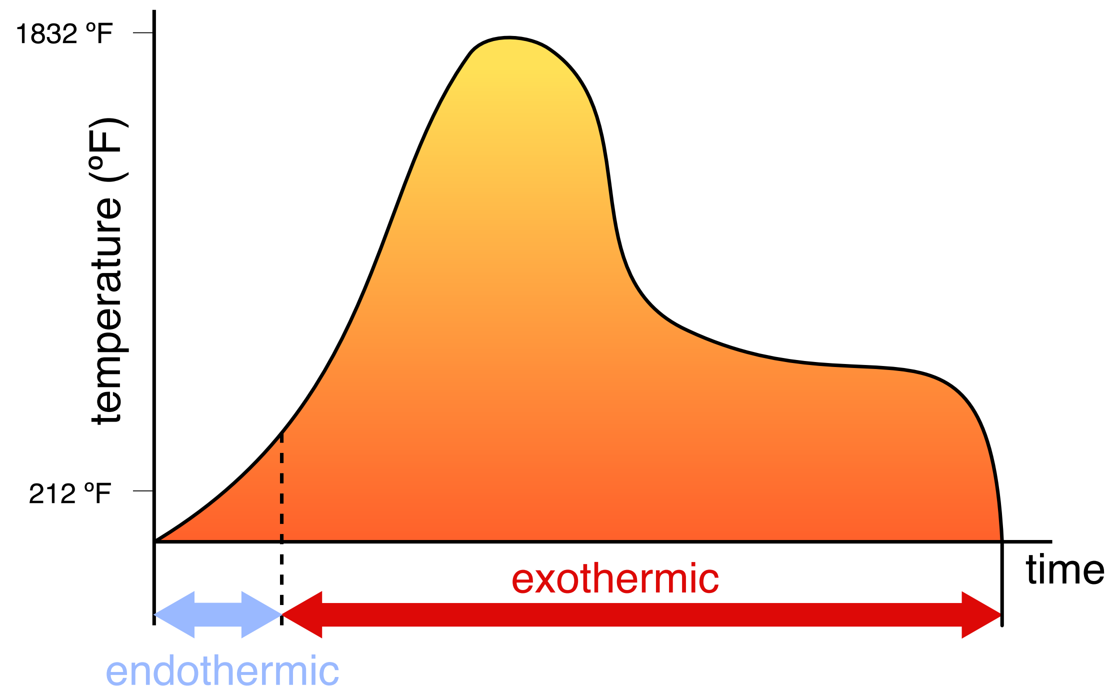


1. Water evaporating from wood

2 Volatilization & chemical composition change of compounds in the wood, low oxygen levels

3. higher temperature chemical reactions

4. combustion of high temperature gases, usually with excess oxygen



Wood as a heating fuel

Electric Resistance Heat	____cents / Kwhr x 2.93 = ____ $/MMBtu
Heat Pump	(____cents / Kwhr x 2.93) / (____average COP) = ____ $/MMBtu
#2 Fuel Oil	(____ $ / gallon x 7.14) / (___ AFUE (decimal)) = ____ $/MMBtu
Propane	(____ $ / gallon x 10.9) / (___ AFUE (decimal)) = ____ $/MMBtu
Natural Gas	(____ $/ therm x 10) / (___ AFUE (decimal)) = ____ $/MMBtu
Firewood*	(____ $ / face chord x 0.149) / (___ ave. efficiency (decimal)) = ____ $/MMBtu
Wood Pellets	(____ $ / ton x 0.06098) / (___ ave. efficiency (decimal)) = ____ $/MMBtu
Bituminous coal	(____ $ / ton x 0.03268) / (___ ave. efficiency (decimal)) = ____ $/MMBtu
Shelled Corn **	(____ $ / bushel x 2.551) / (___ ave. efficiency (decimal)) = ____ $/MMBtu

* Assumes a 50/50 mix of maple and beech dried to 20% moisture content.
Price is for 4 ft x 8 ft x 16 inch face chord split and delivered.

** Assumes 15% moisture content

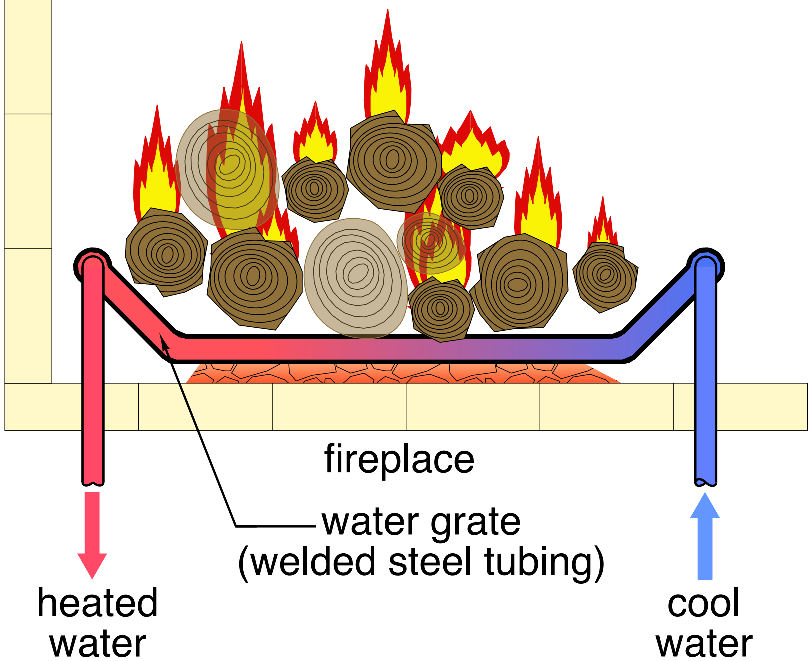
- #2 fuel oil: 138,500 Btu/gallon
- Waste oil: 125,000 Btu/gallon
- Natural gas: about 1030 Btu/ cubic foot
- Propane: 92,500 Btu per gallon
- Electricity: 3413 Btu/ kilowatt-hour
- Hard coal (anthracite): 26,000,000 Btu/ton

Wood as a heating fuel

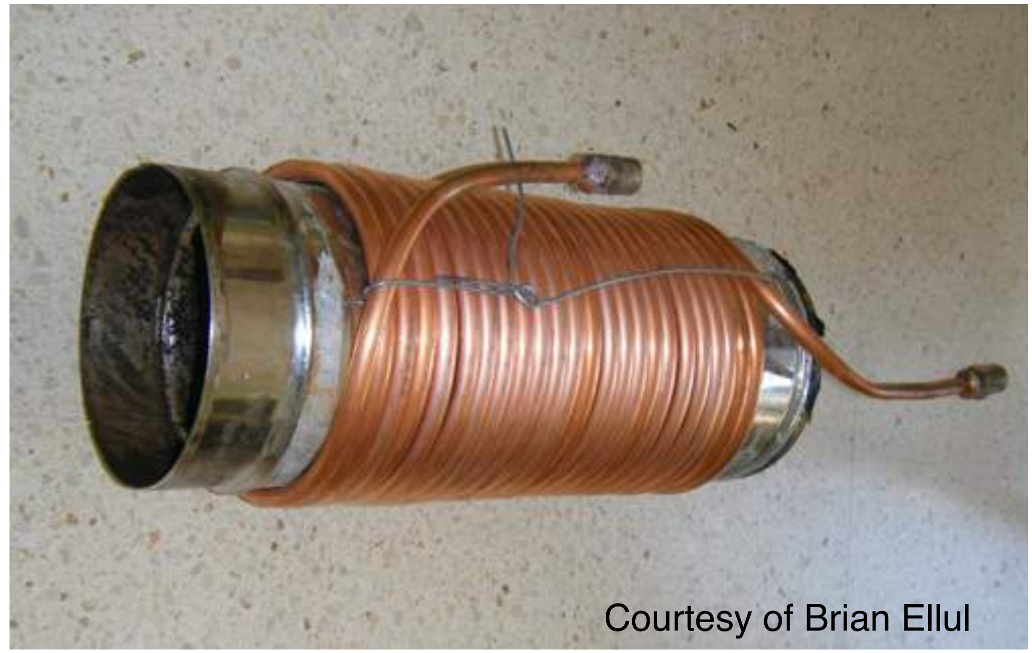
Fuel	Calculation	Result
Electric Resistance Heat	13 cents / Kwhr x 2.93	= 38.09 $/MMBtu
Heat Pump	13 cents / Kwhr x 2.93 ÷ 2.9 average COP	= 13.13 $/MMBtu
#2 Fuel Oil	2.26 $ / gallon x 7.14 ÷ 0.86 AFUE (decimal)	= 18.76 $/MMBtu
Propane	2.53 $ / gallon x 10.9 ÷ 0.92 AFUE (decimal)	= 29.98 $/MMBtu
Natural Gas	1.43 $/ therm x 10 ÷ 0.92 AFUE (decimal)	= 15.54 $/MMBtu
Firewood*	70 $ / face chord x 0.149 ÷ 0.65 ave. efficiency (decimal)	= 16.05 $/MMBtu
Wood Pellets	225 $ / ton x 0.06098 ÷ 0.75 ave. efficiency (decimal)	= 18.29 $/MMBtu
Bituminous coal	____ $ / ton x 0.03268 ÷ ___ ave. efficiency (decimal)	= ____ $/MMBtu
Shelled Corn **	____ $ / bushel x 2.551 ÷ ___ ave. efficiency (decimal)	= ____ $/MMBtu

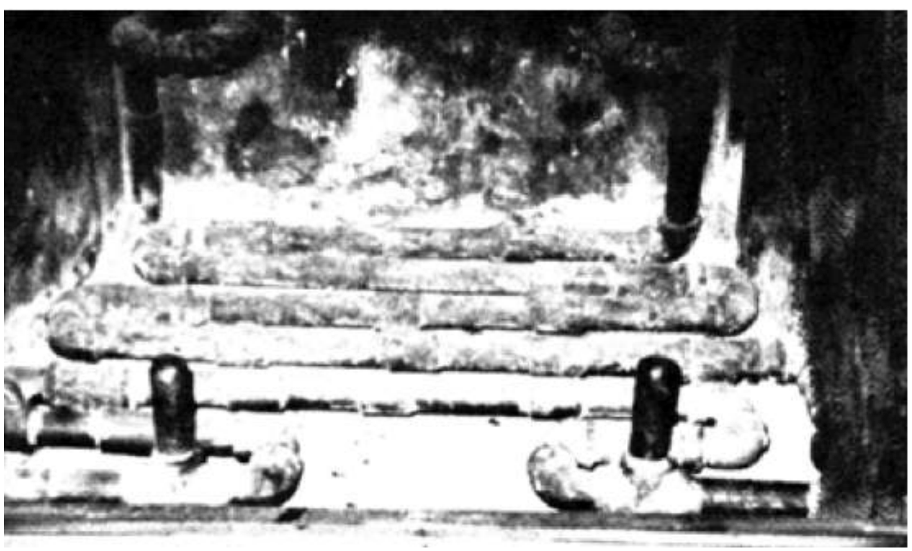
NYSERDA suggests using the 3 year average price of competing fuels when making comparisons.

Early attempts at matching wood & hydronics



water jacket for stove pipe flue





The problems:

1. Safety
2. Creosote formation
3. Scaling/corrosion/stress

Outdoor wood-fired hydronic heaters

Some progress, but issues remain...

The problems:

1. Low thermal efficiency ≤ 40%
2. Creosote formation
3. High particulate emissions
4. Poor underground piping practices

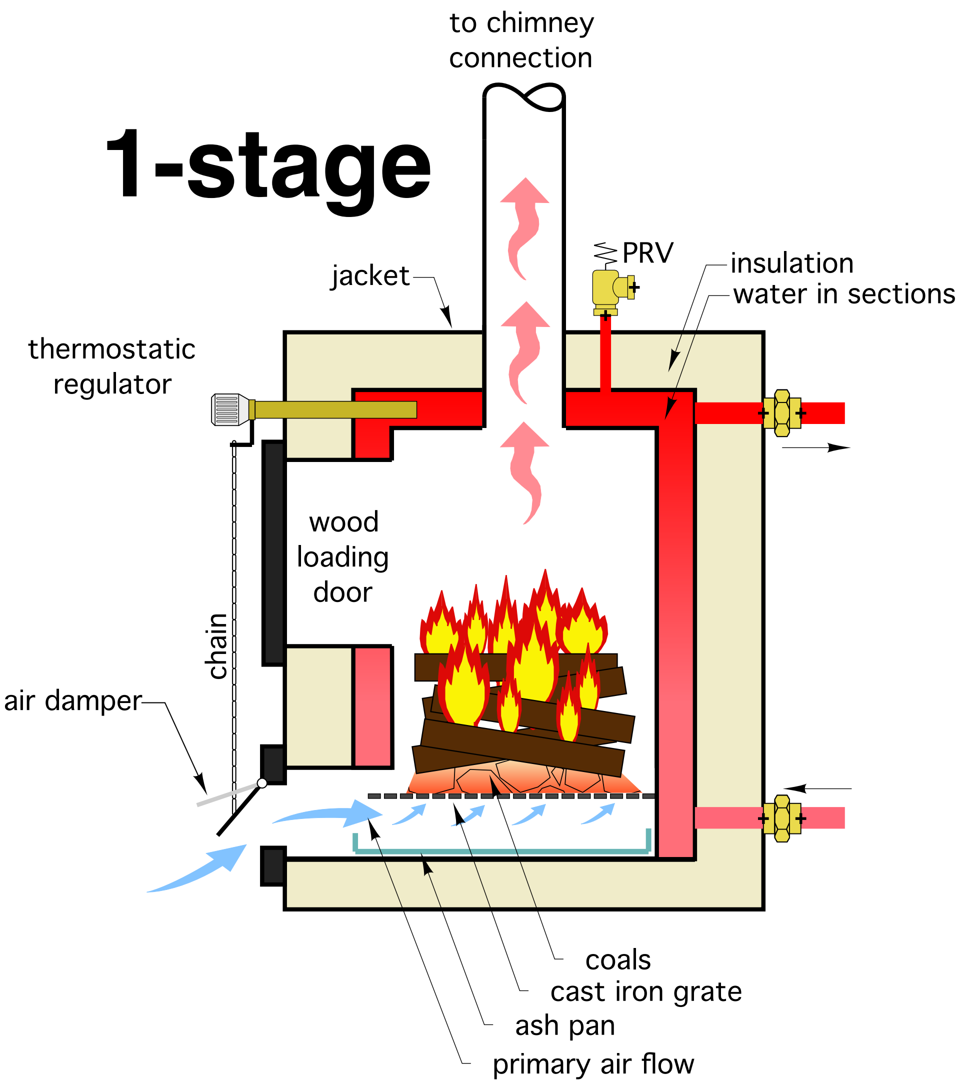
In NY state, read NYSDEC part 247

http://www.dec.ny.gov/regs/71720.html

100’ property line setback & min. 18’ chimney

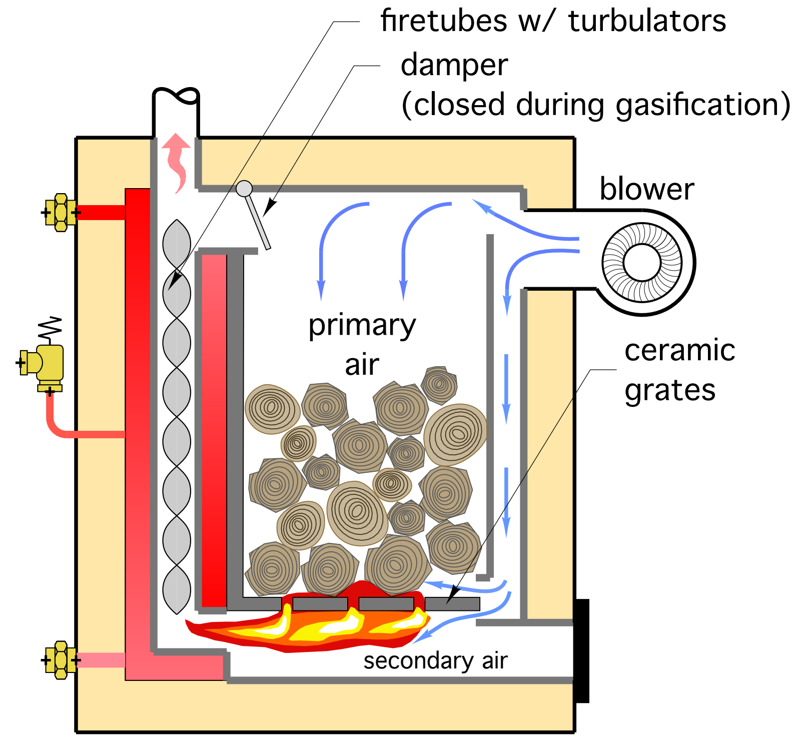
Wood-fired boiler classifications:

1-stage



- 1-stage combustion
- Thermal efficiency 40-60%
- significant ash & “clinker” residue

2-stage (gasification)



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

Wood gasification boilers

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

image courtesy of Econoburn

For highest efficiency...

- **Burn Hot & Burn fast**

Heat output often exceeds heating load

Storage is needed

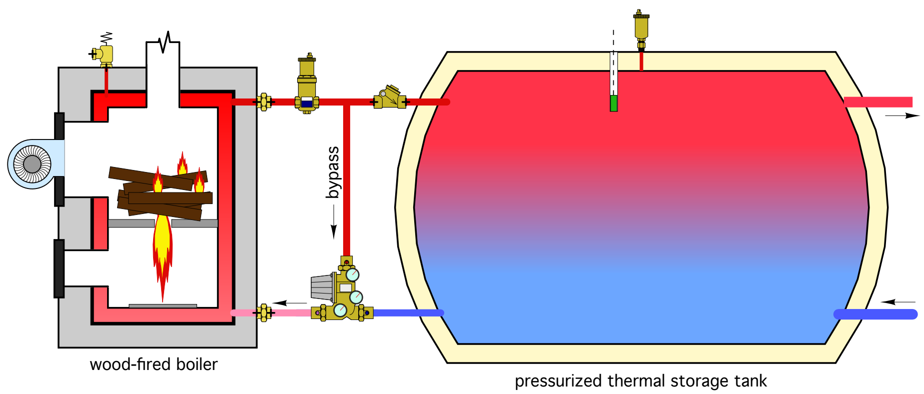


image courtesy of New Horizon Corp.

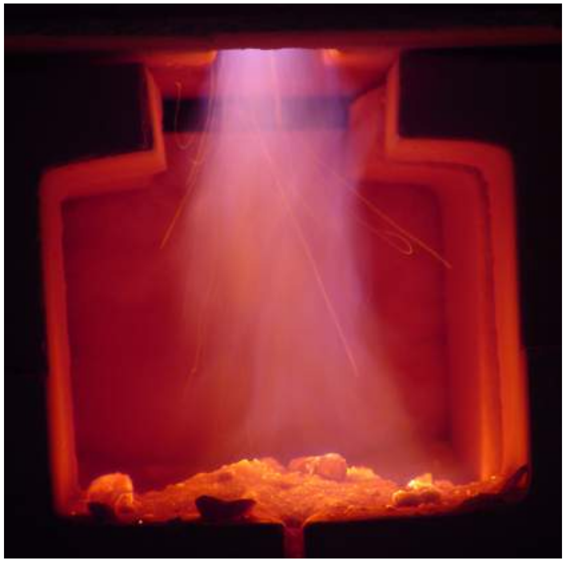


image courtesy of Tarm Biomass

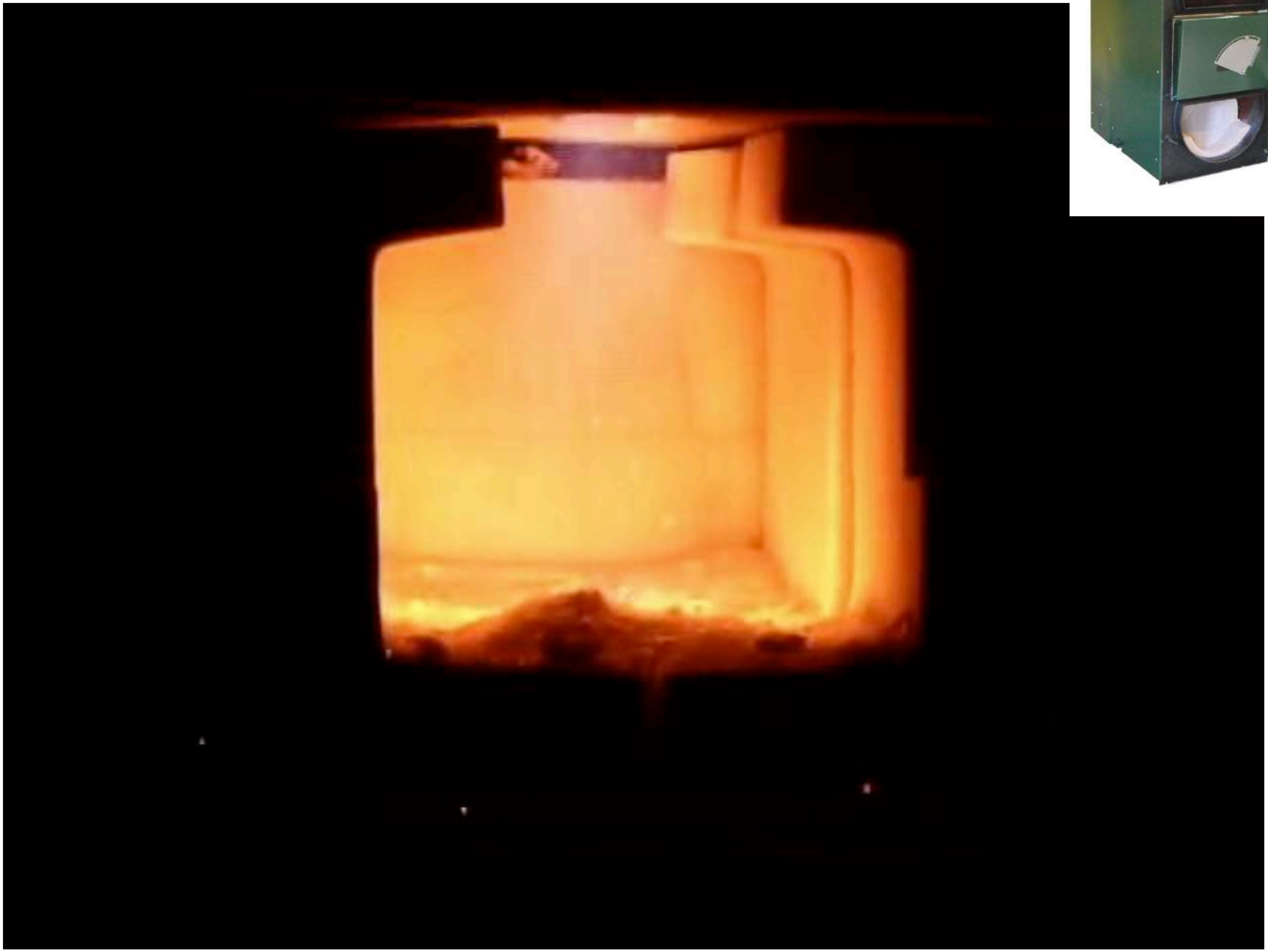
Wood gasification boilers

secondary combustion in lower chamber

video courtesy of Econoburn

Wood gasification boilers

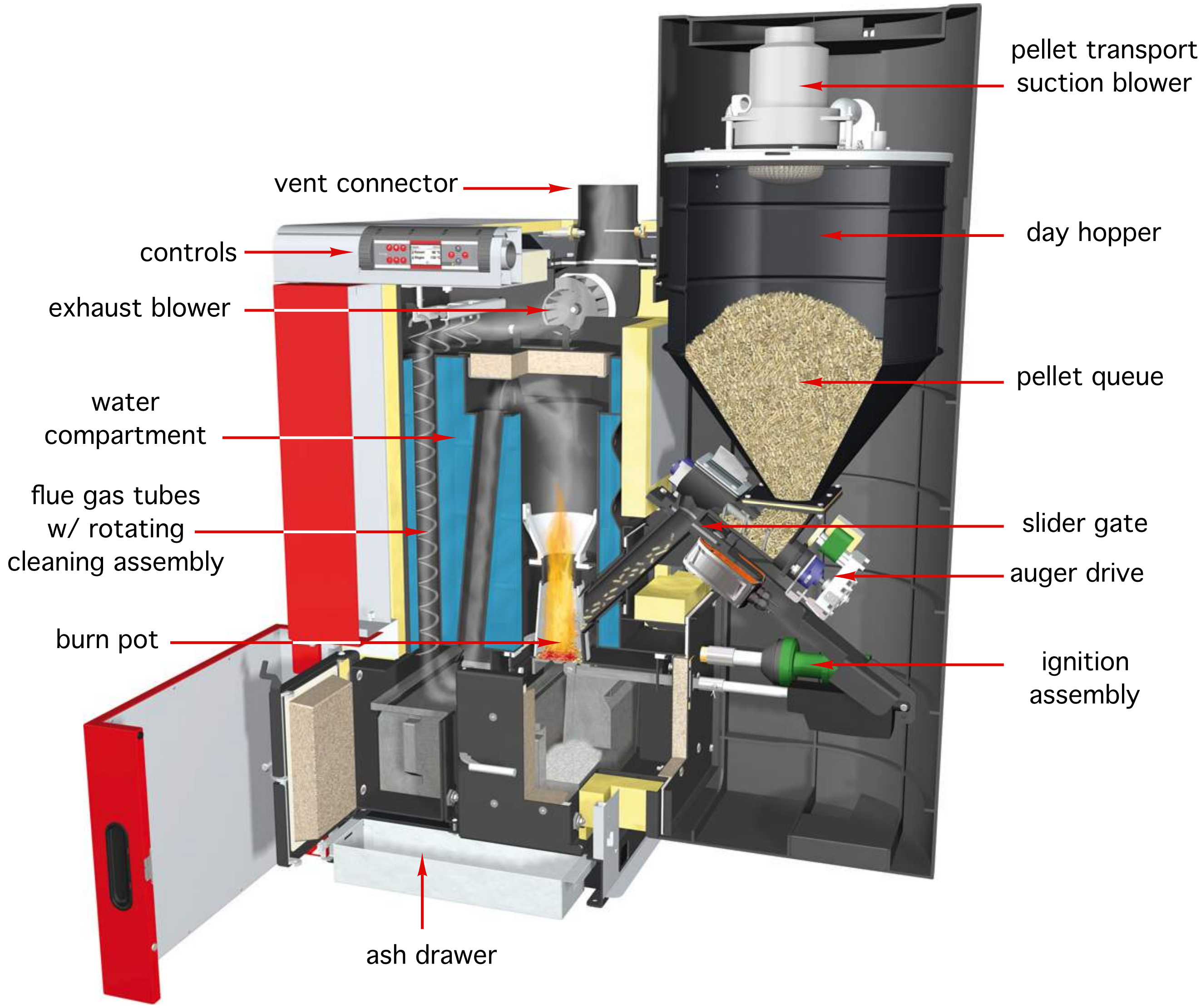
secondary combustion in lower chamber



video courtesy of New Horizon Corp.

Modern Pellet-fired Boilers

image courtesy of Tarm Biomass



Pellet Outgassing

Research from Clarkson University

Monitoring of Carbon Monoxide Off-Gassing in Wood Pellet Storage in the Northeastern US

http://www.nyserda.ny.gov/-/media/Files/Publications/Research/Biomass-Solar-Wind/Monitoring-CO-Off-gassing.pdf

Pellets made in the Northeastern U.S. can differ significantly in their composition from those pellets made in Europe or British Columbia due to the greater abundance of hardwood in the Northeastern U.S. Thus, this study has examined off-gassing from hardwood, softwood, and hardwood/softwood blended pellets through a combination of monitoring in functioning storage bins as well as through additional laboratory studies.

Conclusions

The results of this initial study demonstrate that there is off-gassing of sufficient CO from stored pellets to represent a hazard that needs to be adequately addressed. Although no concentrations that would directly produce significant short-term extreme effects in healthy adults, **concentrations above the levels set as exposure guidelines in both homes and in occupational settings were clearly exceeded.** These results do raise a real safety issue regarding in-building storage of pellets. Active ventilation clearly reduces the average concentrations although higher values are occasionally observed.

outdoor pellet storage by Vincent's Fuel Service

NOTE: Due to concerns over CO outgassing, Renewable Heat NY does not allow indoor pellet storage.

outdoor pellet storage

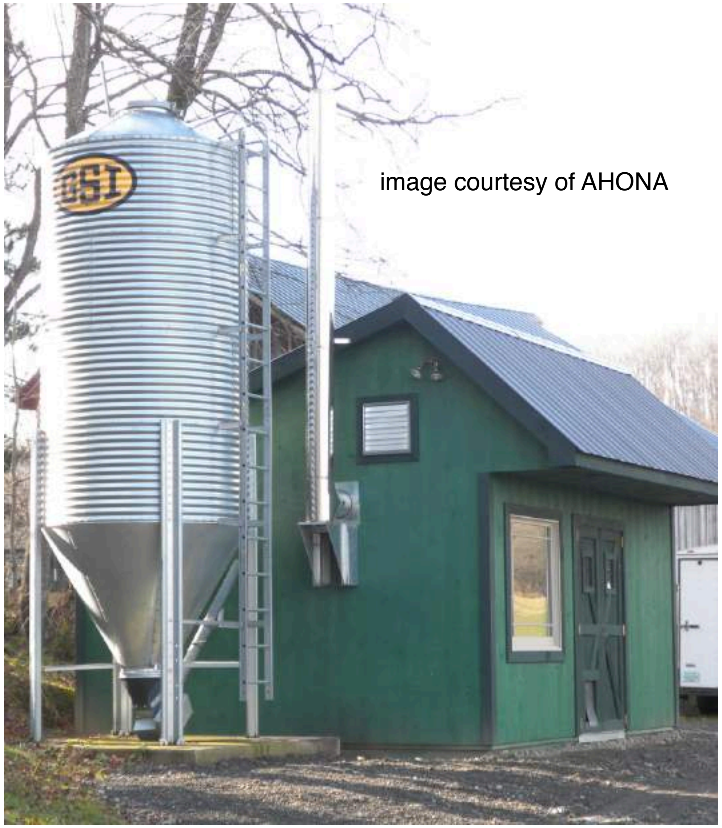


image courtesy of AHONA

image courtesy of PolyDome


image courtesy of Tarm Biomass

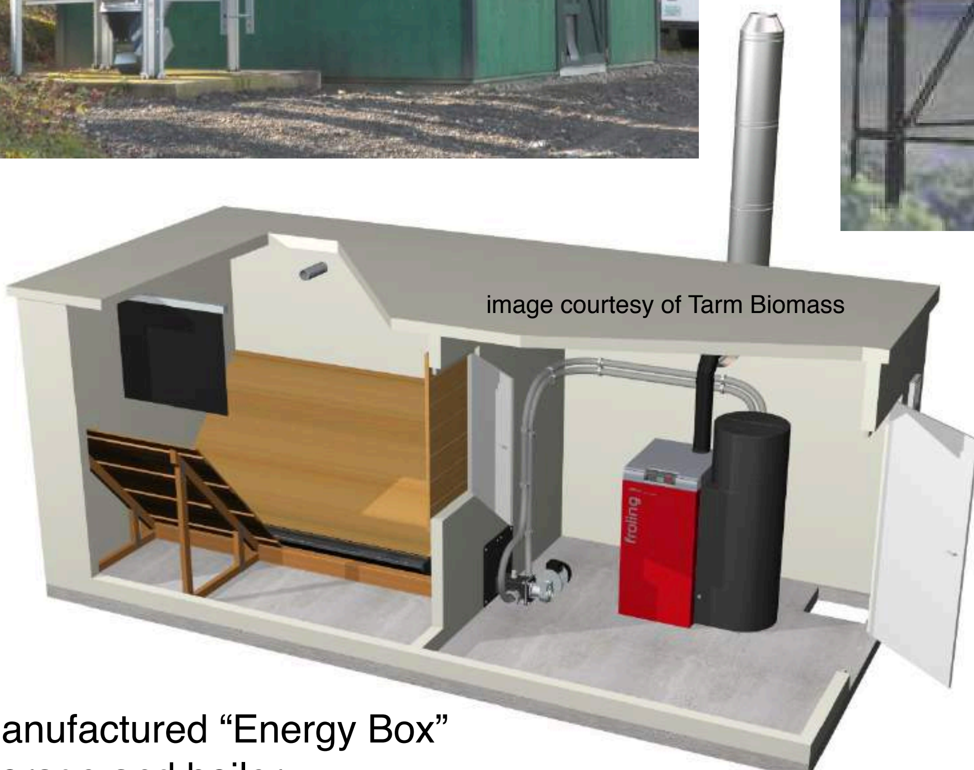


image courtesy of Tarm Biomass

Manufactured “Energy Box” storage and boiler

Boiler Venting

Venting pellet-fueled boilers

Class A “all fuel” chimney (UL103 or UL103-HT) 1000 ºF continuous @1700 ºF min. 10 minute. (stainless inner & outer wall, insulated) is typically recommended by most boiler manufacturers.

Opinions vary on the practicality of side wall venting: Most boiler suppliers don’t recommend.

One manufacturer (Webiomass) offers a boiler with built-in power venting components.

Typical code requirement: Top of chimney min. 2 feet above anything within 10 foot radius

For commercial buildings, stack heights should be consistent with good engineering practice to minimize the wake effects caused by buildings or terrain on emissions. (see www.epa.gov/ttn/scram/guidance_permit.htm for some EPA documents on good engineering stack height and modeling).

plume drifting toward school

Good entrainment of plume

Most biomass boilers have draft inducing

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.

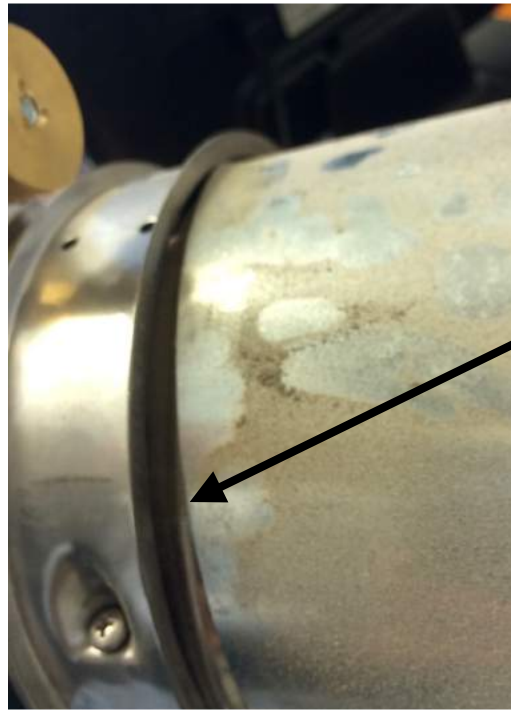
Leads to: Leakage of flue gases and fly ash between joints in vent connector piping, boiler air intake, barometric damper.

Venting pellet-fueled boilers

Class A “all fuel” chimney (UL103 or UL103-HT) 1000 ºF continuous @1700 ºF min. 10 minute. (stainless inner & outer wall, insulated) is typically recommended by most boiler manufacturers.

Recommended resource for chimney sizing:

Flue gas and ash leakage at barometric dampers



Improper fit of draft regulator into tee allows flue gas and ash to blow through gaps at start up.

Standard barometric dampers cannot seal against positive pressure inside venting system

Standard barometric damper removed and opening sealed because of ash and flue gas leakage.

Venting pellet-fueled boilers

Need to avoid flue gas & ash spillage at cold chimney start up conditions

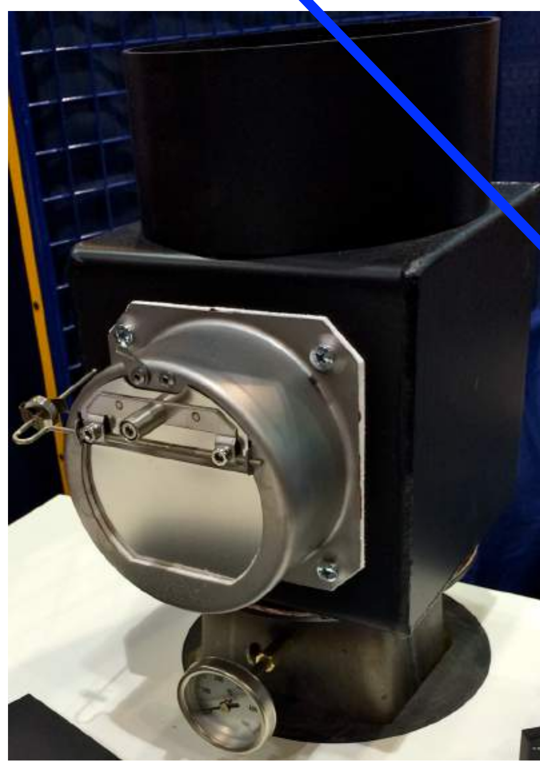
European approach using **draft regulator** (not a barometric damper) that seals against back pressure.

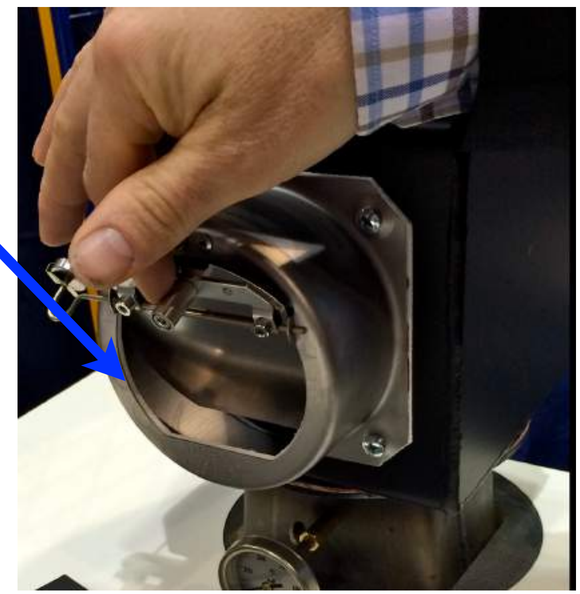
K&W ZUK150S draft regulator

gasketed opening

Barometric dampers do not seal against positive vent pressure.

This is a typical barometric damper





Mounted on Varmebaronen pellet boiler

Venting pellet-fueled boilers

UL-103 HT chimney straight up through interior space is ideal

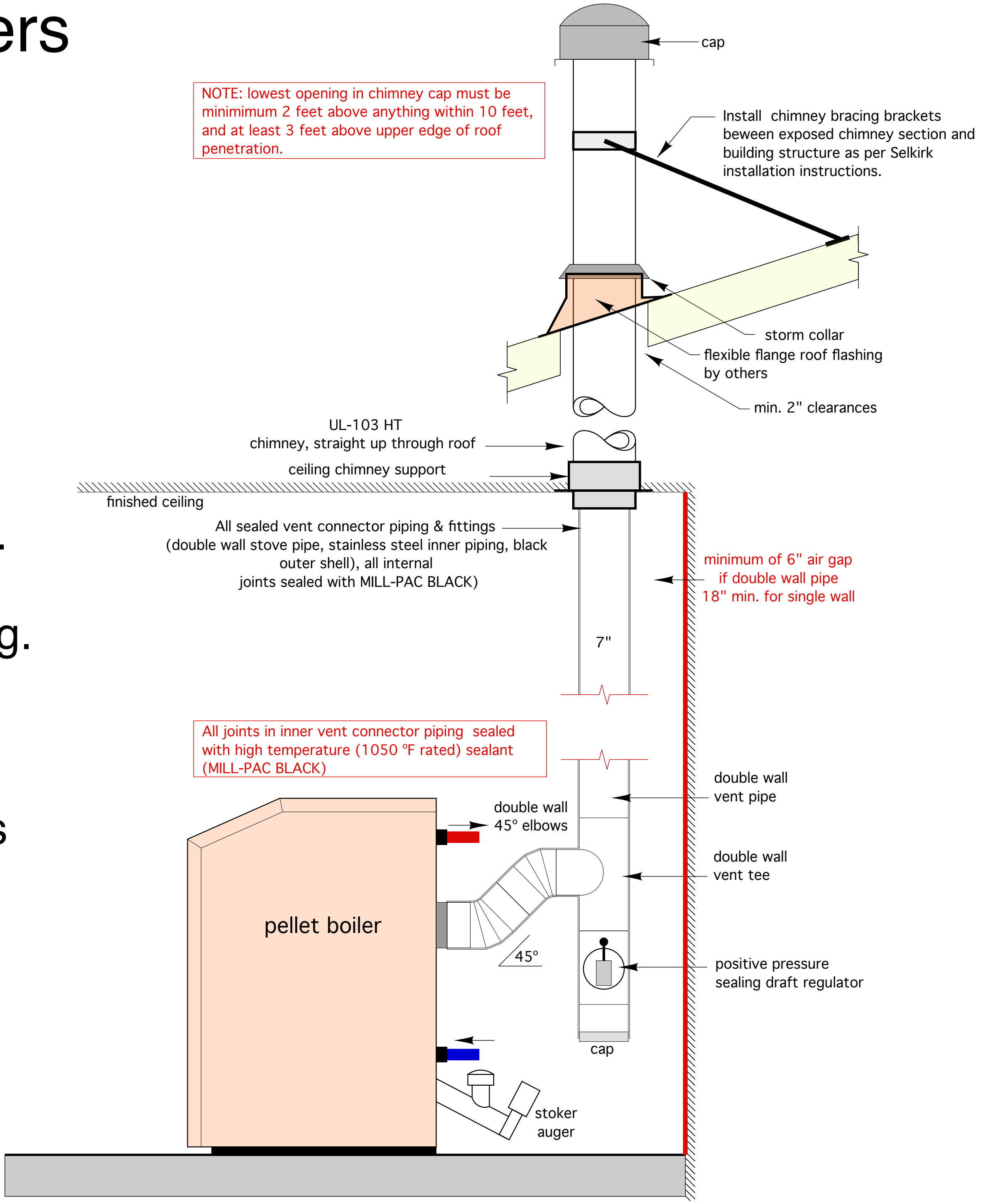
Install positive pressure sealing draft regulator at least 1 foot *below* vent connector tee.

Some boilers can be configured for "pre-purge" exhaust blower operation.

Seal all joints in vent connector piping.

Mechanically secure all joints in vent connector piping with minimum of 3 sheet metal screws (stainless screws on single wall pipe).

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



BOILER VENTING

Single wall vent connector piping

Do not use galvanized vent piping on wood-fired or pellet-fired boilers

Example: Selkirk Saf-T Pipe (black painted steel or **stainless steel**) 22 ga., no seams, built for sealed joints and wood-fired appliances.

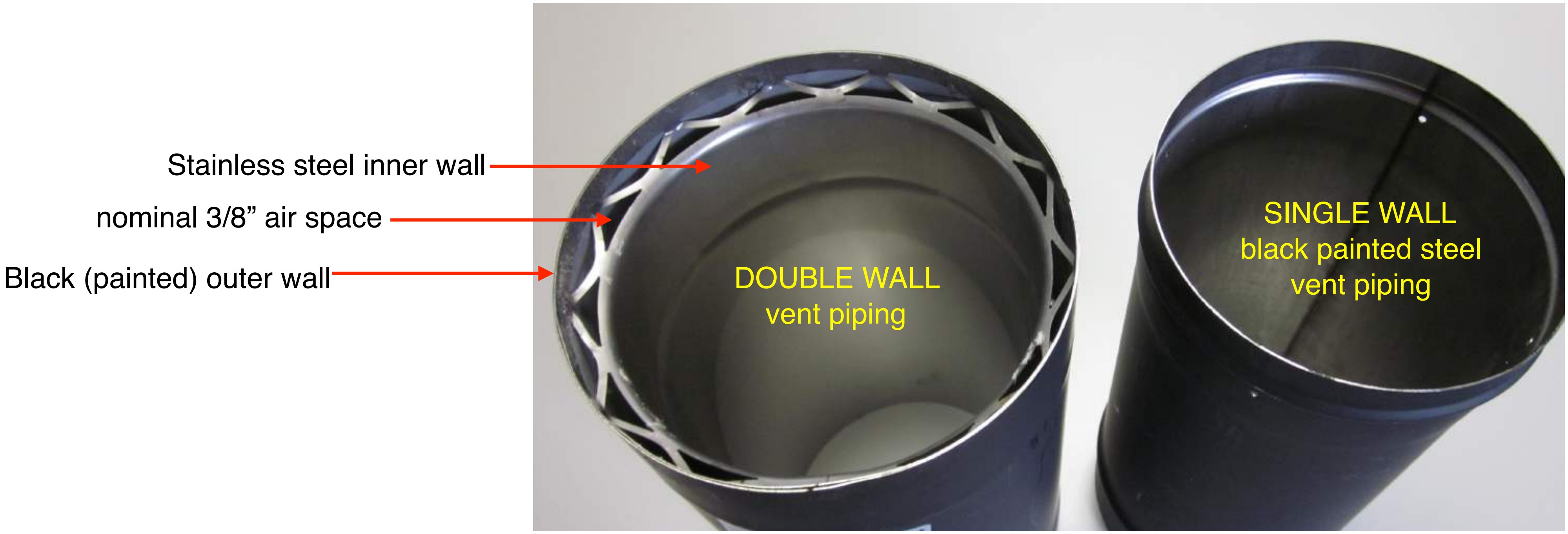
• Use positive pressure sealing black vent connector piping on wood or pellet fired boilers with induced draft blowers.

• **Install in direction indicated by manf. (allow any condensate to run back to boiler)**

• **Secure all joints with stainless steel sheet metal screws.**

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

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.
- Inner wall connections should be sealed with 1000 ºF flexible sealant to prevent leaks.
- Outer wall connections should be mechanically joined with 3 screws (usually provided with pipe)

Suggest lining all masonry chimneys with sealed ***stainless steel*** liners.

image courtesy of
Interphase Energy LLC

Stainless steel products
available for chimney relining


Saf-T Liner®

A system that works together saves time.
The Saf-T Liner® system is designed to be so easy to install, one professional on the job can do it alone – and have time to do another installation the same day. Saf-T Liner and Saf-T Wrap® are designed to make installation as trouble-free as possible.

Continuous-seam welding assures performance
Saf-T Liner is continuous-seam welded, using the most advanced laser- and resistance-welding technology in the world. Our welding expertise gives you the confidence that the system with perform in the most challenging conditions.

Smooth walls for safety
Saf-T Liner is smooth inside with obstruction-free joints, designed to minimize creosote accumulation. Porous cast or corrugated metal liners can't come close. And smooth walls make Saf-T liner the easiest to clean.

Quality fittings
Saf-T Liner is manufactured in a wide range of sizes to fit just about any application, in 304L stainless steel for wood (biomass) fuel or 316L for fossil fuels, including coal and oil. Elbows, tees, terminations, accessories and adapters are all fabricated from the same quality materials, using the same advanced manufacturing techniques.

Saf-T Wrap®
Saf-T Wrap is a high-quality insulation system engineered to prevent corrosive condensation, improve appliance performance and enhance chimney safety.

Minimize creosote
Modern heating appliances operate with much lower stack temperatures than ever before. Saf-T Wrap's ceramic-fiber insulation and reflective aluminum jacket keep the flue warm to improve draft and minimize creosote buildup. Homeowners appreciate appliances that work more efficiently as well as cleaner flues.

Maximize fire protection
Occasionally, appliances do produce excess creosote and soot. If these materials ignite, a flue fire can occur. Installed in masonry chimneys, Saf-T Liners insulated with Saf-T Wrap have been field-proven to protect buildings during these violent fires.

Fast installation, immediate performance
In easy-to-handle lengths to fit all sizes of Saf-T Liner, Saf-T Wrap is designed with a snap-lock closure to speed installation. And unlike other liner systems, which require "curing" or a "break in period" of up to a week, Saf-T Liner systems insulated with Saf-T Wrap may be used right away.

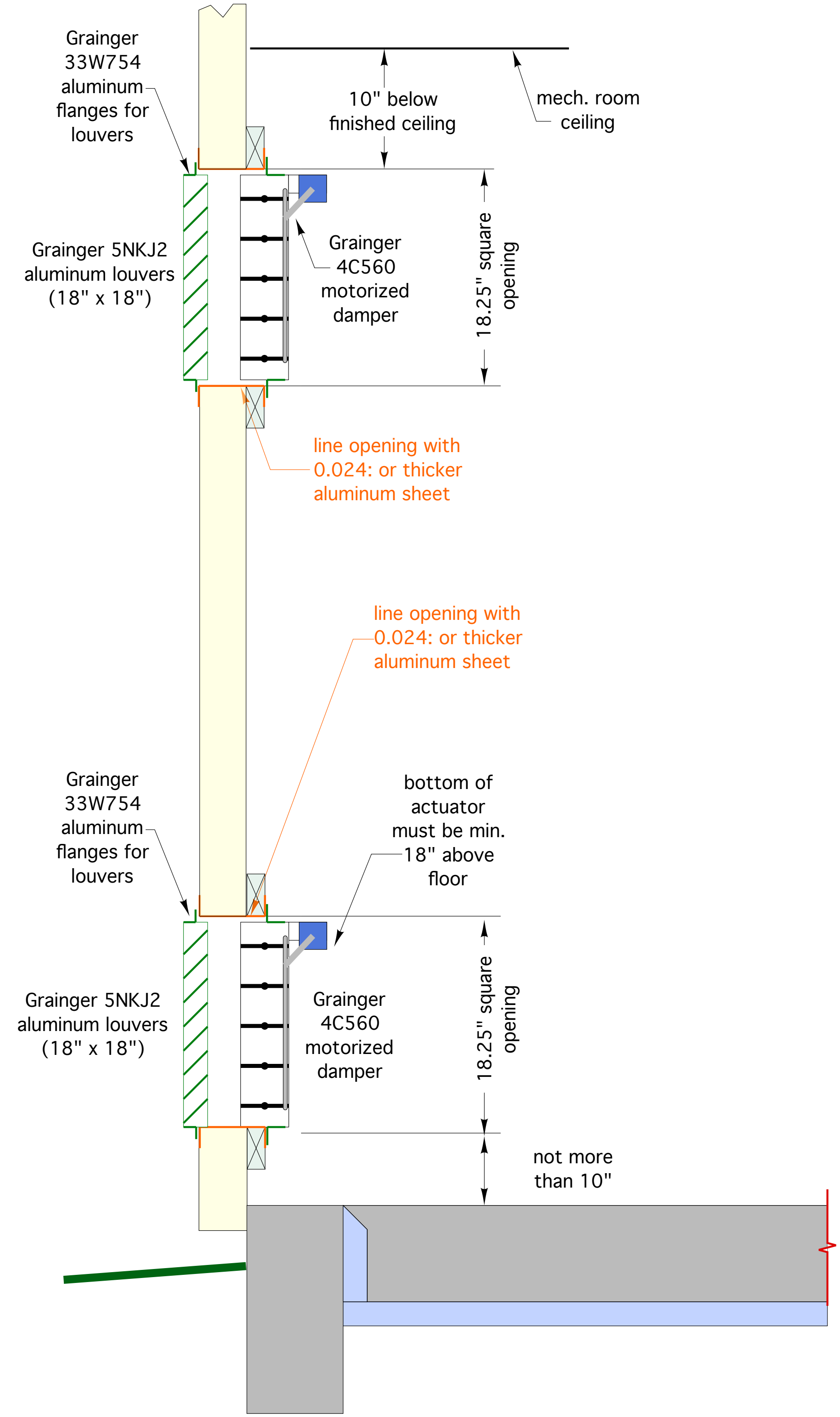
UL listed for safety
Saf-T Wrap installed with Saf-T Liner or Saf-T Vent meets the rigors of UL 1777, including a 2100° F flue-fire simulation. Use high-quality parts from Heatfab and deliver extra peace of mind to your customers.

Boiler room ventilation air

• Any local code requirements

• Canadian ANSI/ NFPA requirement is 1 in² of free area per 1000 Btu/hr of rated heat output

European ONORM H 5170 requirement for fan-assisted boilers is equivalent to 0.3 in² per 3413 Btu/hr



Thermal storage options

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**

• Prevents thermal shock to boiler by tempering the return water at start-up.

• 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 AHONA

courtesy of American Solartechnics

courtesy of Hydroflex

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

courtesy of Thermal Storage Solutions

Open (unpressurized) buffer tanks

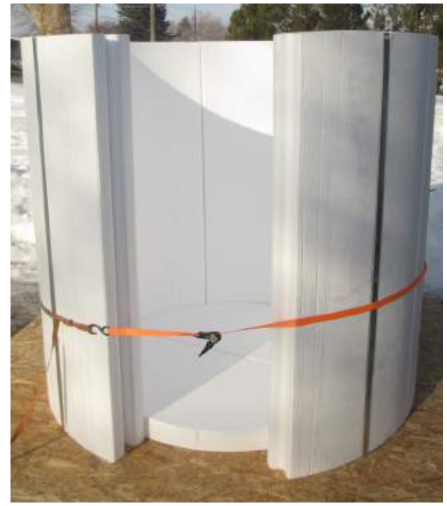




images courtesy of Hydroflex

Open (unpressurized) buffer tanks





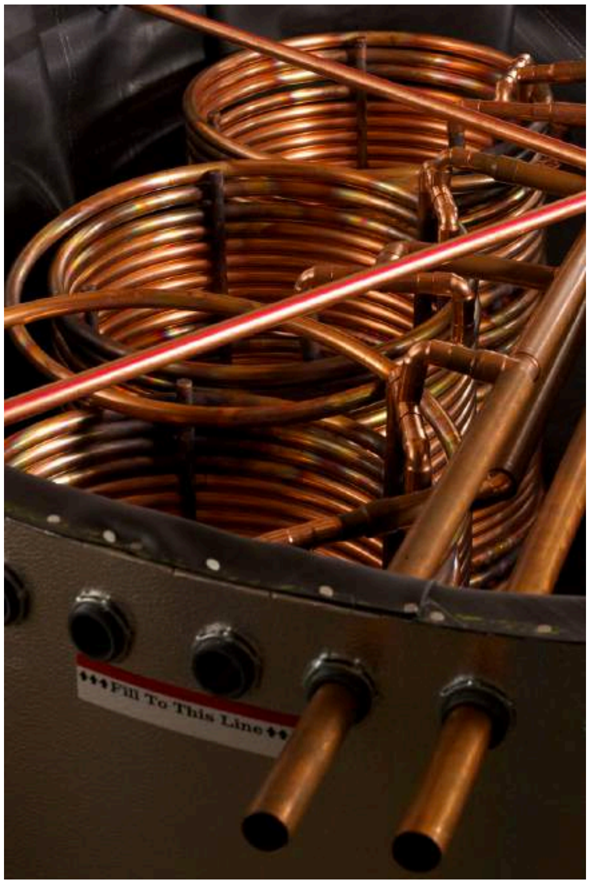



Temperature limit is 165 ºF
Outer shell of aluminum sheet fastened to steel studs
Volumes from 165 to 2014 gallons
R-30.8 walls (6” to 8” EPS)
Field tests show that evaporation is less than 1" a year.

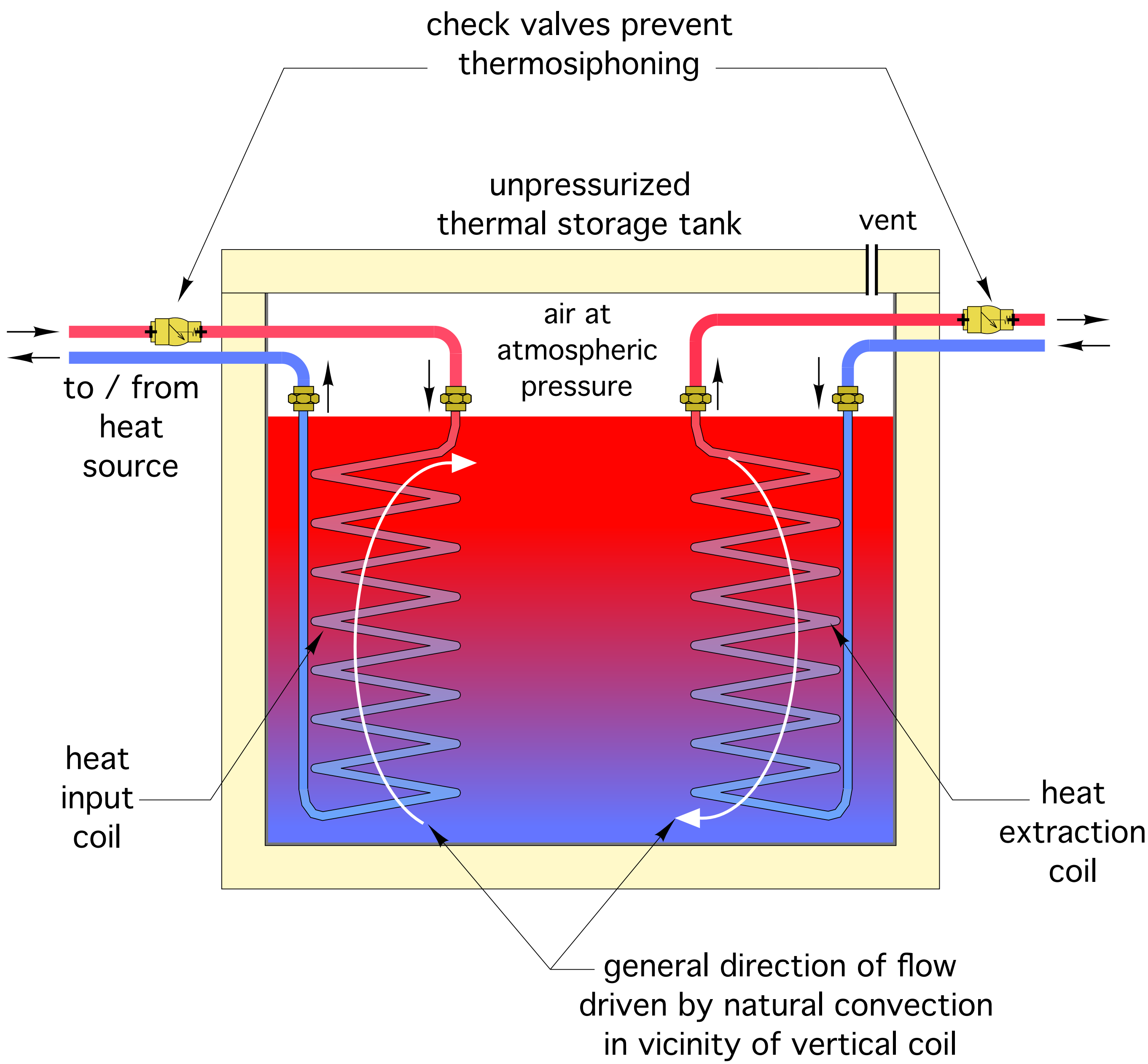
images courtesy of Cocoon tanks

http://cocoontanks.com

- 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

ASME (section VIII) certified thermal storage tanks are generally required in *public buildings*, if volume ≥ 120 gallons.

from ASME (section VIII) code

U-1(c)(2) Based on the Committee's consideration, the following classes of vessels are not included in the scope of this Division;

(f) a vessel for containing water[1] under pressure, including those containing air the compression of which serves only as a cushion, when none of the following limitations are exceeded:

(1) a design pressure of 300 psi (2 MPa);

(2) a design temperature of 210°F (99°C);

(g) a hot water supply storage tank heated by steam or any other indirect means when none of the following limitations is exceeded:

(1) a heat input of 200,000 Btu/hr (58.6 kW);

(2) a water temperature of 210°F (99°C);

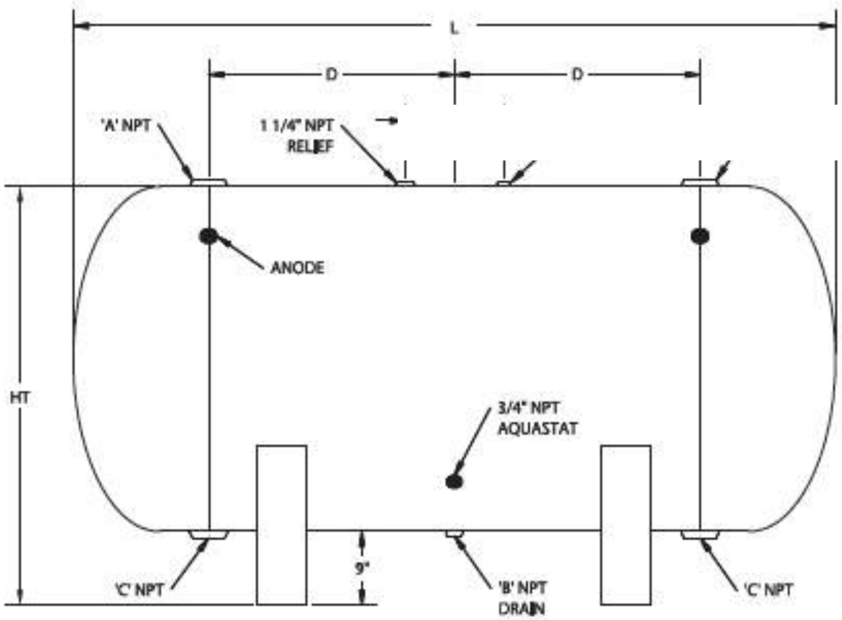
(3) a nominal water containing capacity of 120 gal (450 L);

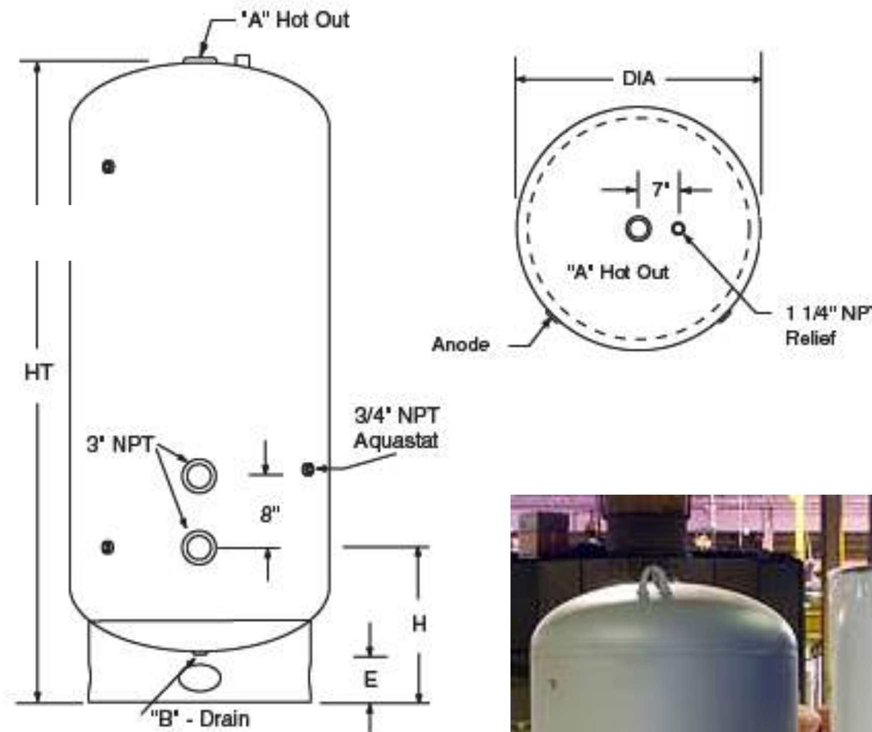
(h) vessels not exceeding the design pressure (see 3-2), at the top of the vessel, limitations below, with no limitation on size [see UG-28(f), 9-1(c)]:

(1) vessels having an internal or external pressure not exceeding 15 psi (100 kPa);

Best advice: Contact local code enforcement, see what they require...

Large ASME (section VIII) certified storage tanks intended for **domestic water heating** are not necessarily a good choice for thermal storage in hydronic systems .





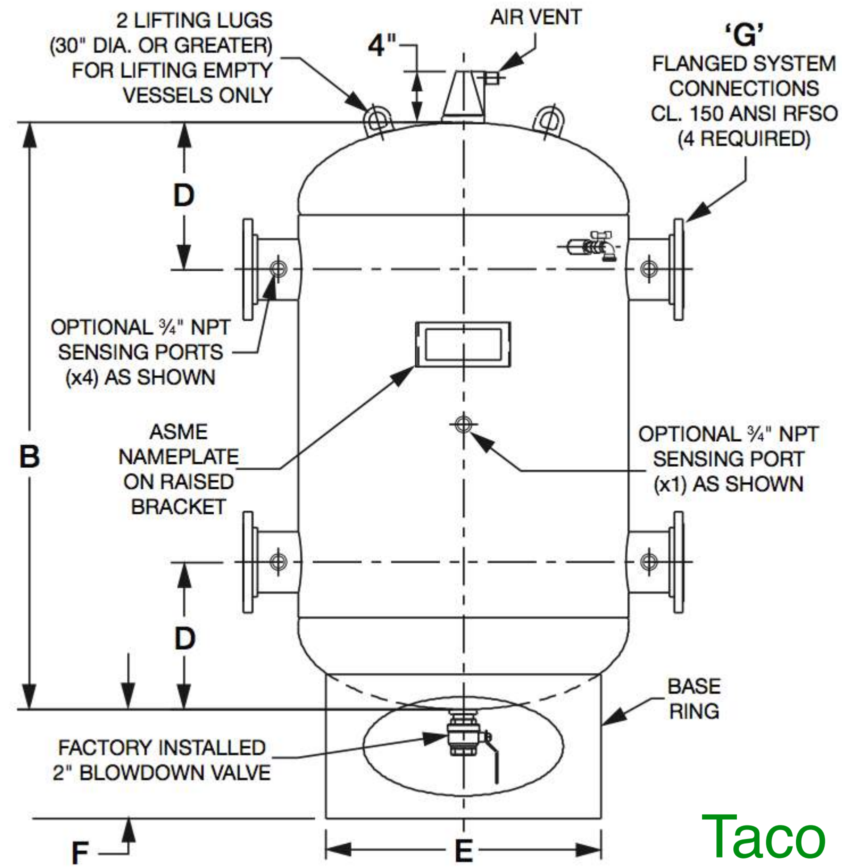
source: www.nilesst.com

The connections are usually not in the right locations, or of the size needed for hydronic systems (and good temperature stratification).

Examples of large capacity ASME thermal storage tanks

Niles Steel Tanks
(120 - 860 gallons)

Taco
(50 - 1050 gallons)



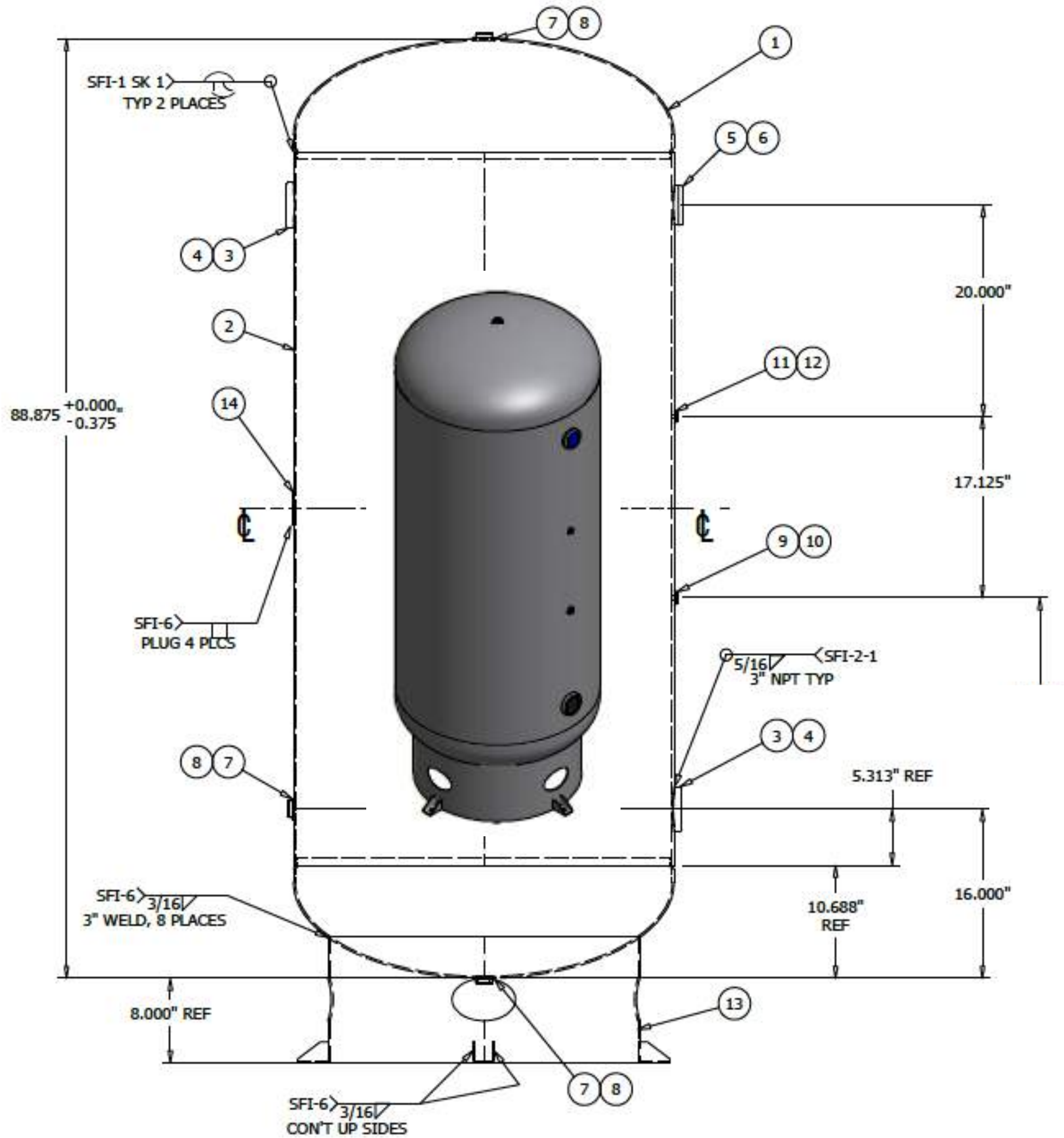
Taco

TANK VOLUME	A DIAMETER	B
GAL.	INCH	INCH
50	20	43
75	24	46
100	24	61
125	24	76
150	30	60
180	30	71
200	30	78
250	36	69
300	36	82
350	36	94
400	48	65
450	48	72
500	48	79
700	48	100
850	54	99
1050	60	99

Be sure tank will fit in mechanical room...

Examples of medium capacity ASME thermal storage tanks

Hydronic Specialty Supply
210 gallon, ASME
flat top & bottom



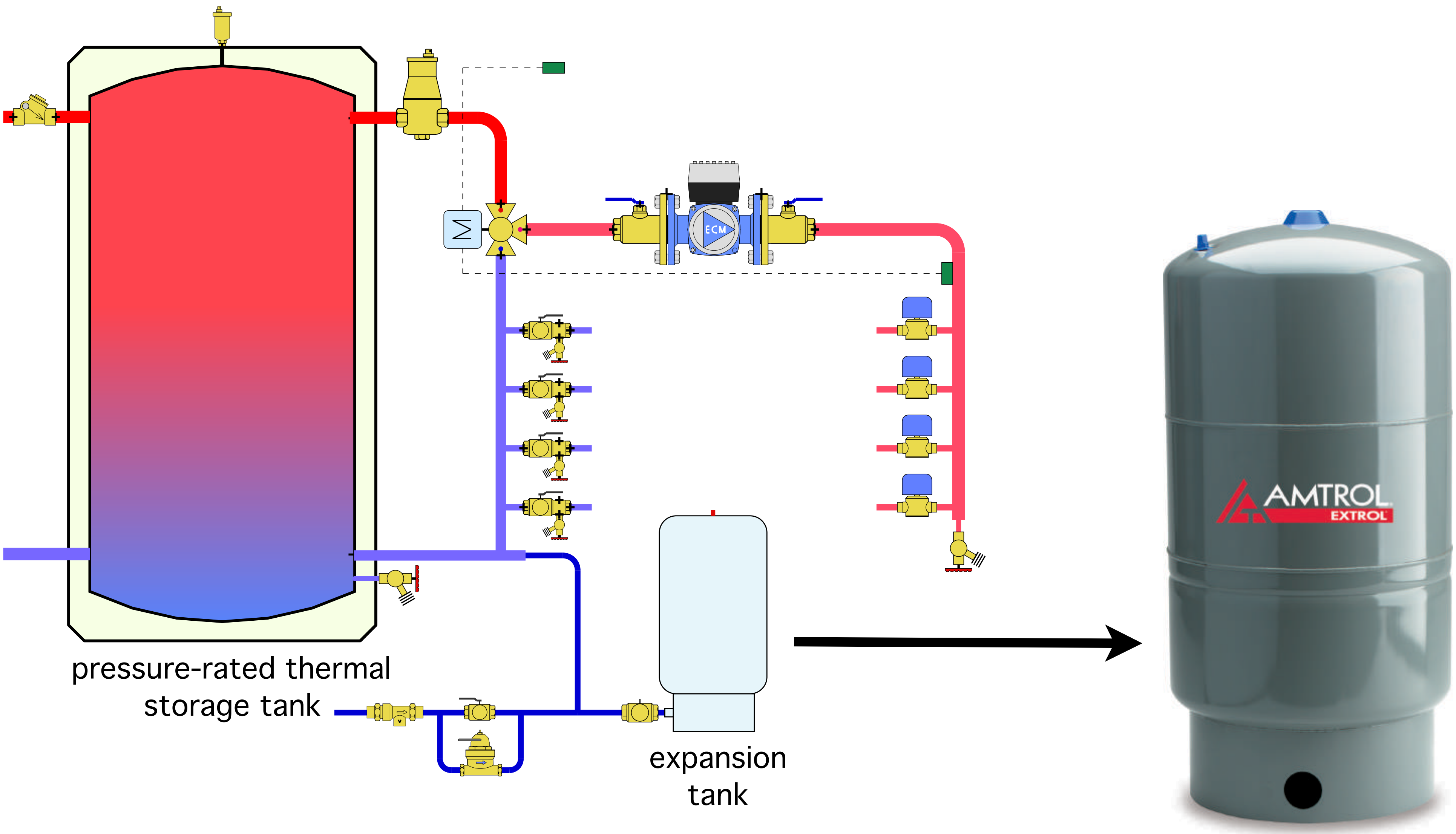
Alternate Heating of North America
400 gallon, ASME

Large thermal storage tanks...

4000 gallon ASME tank, site insulated

Suggest min. R-24 tank insulation

Large pressurized storage requires larger expansion tanks



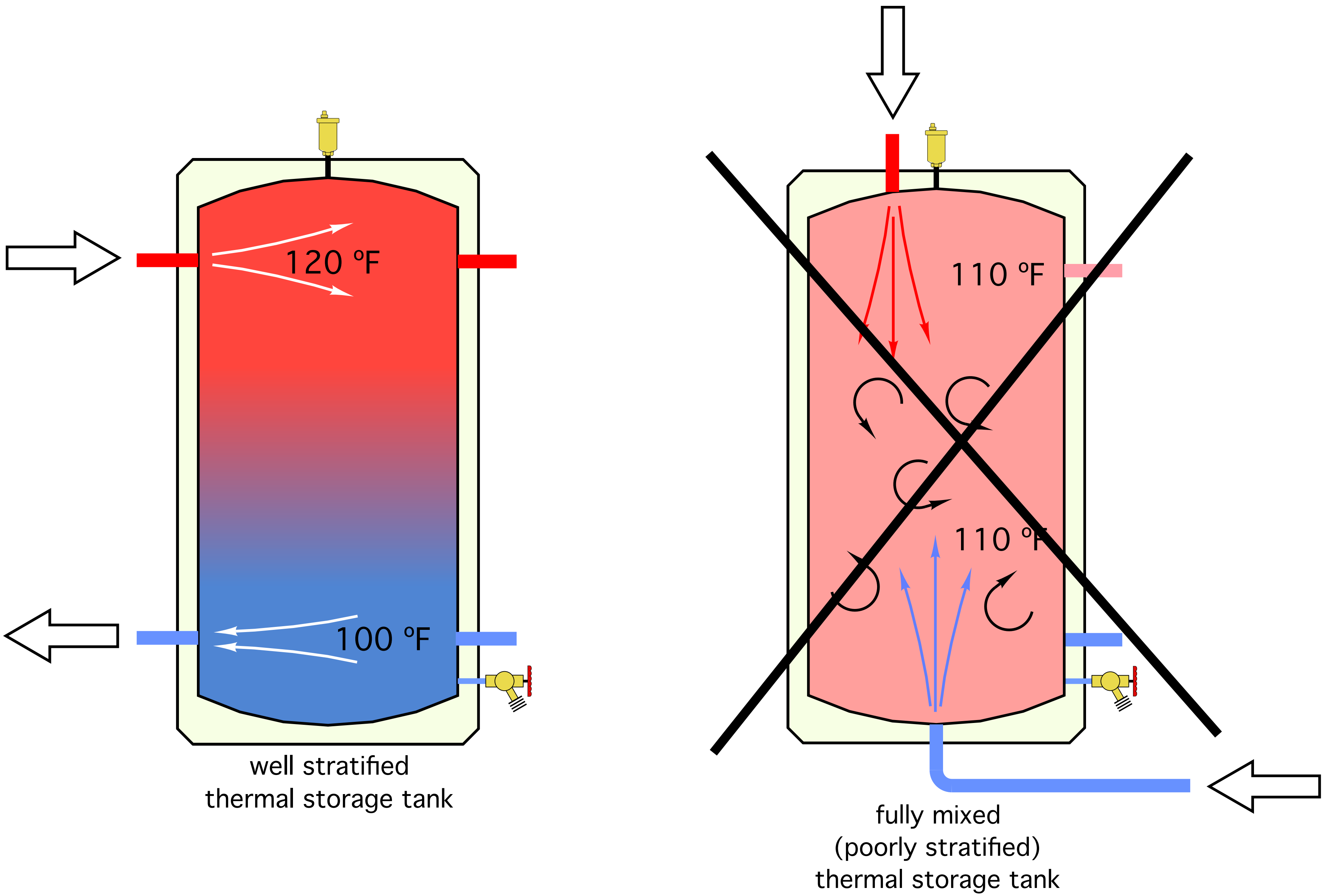
courtesy of Amtrol

First pass estimate:

Expansion tank volume = 10% of thermal storage volume.

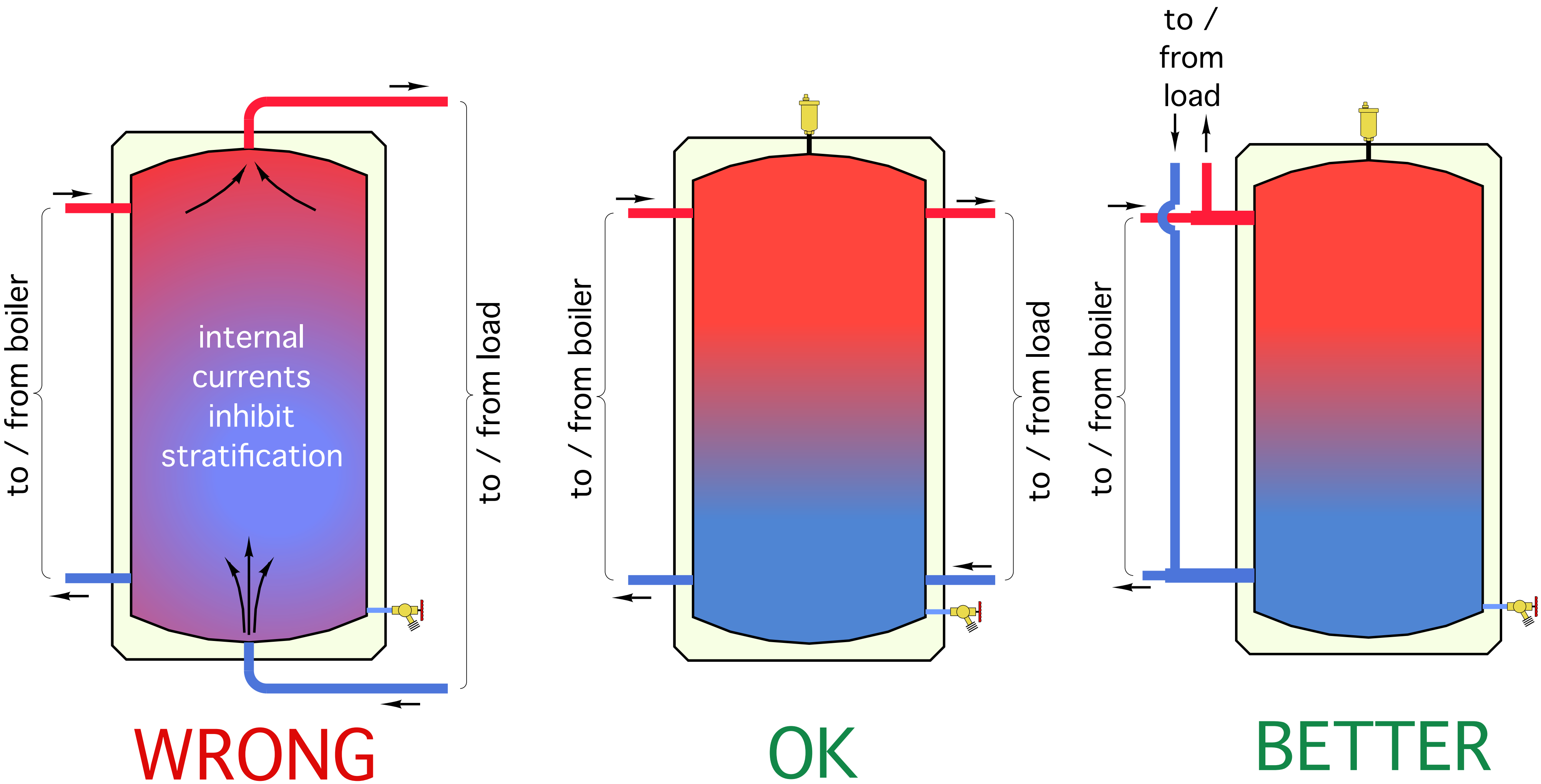
Stratification in thermal storage is DESIREABLE

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

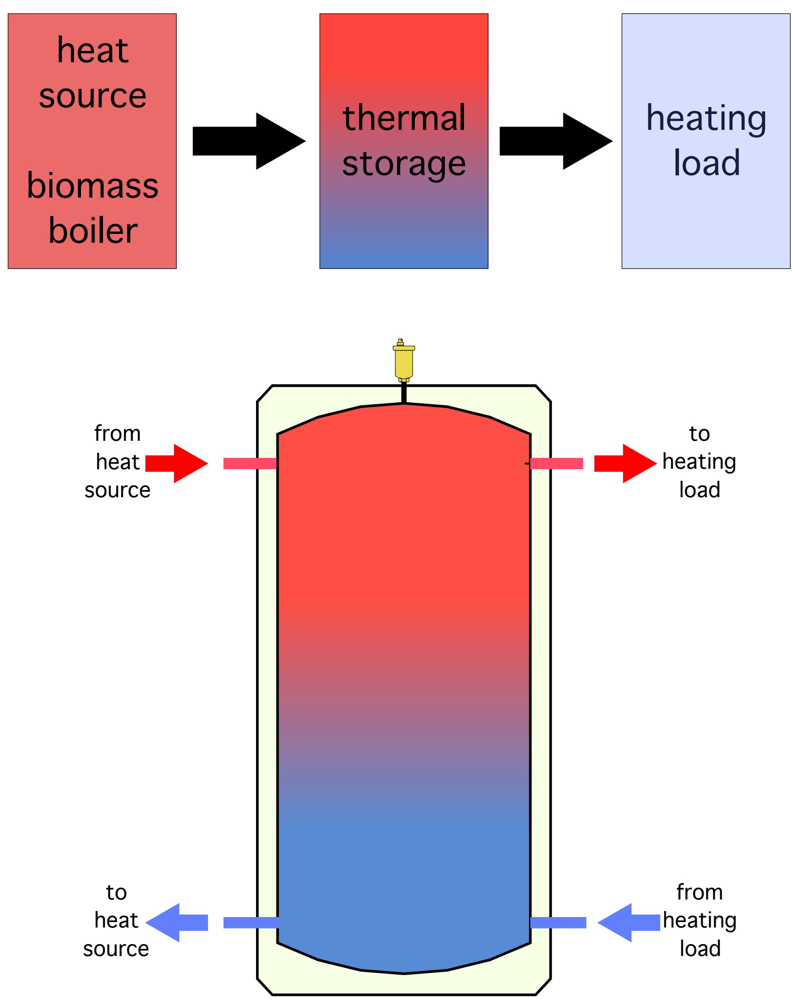


Tanks designed for good stratification

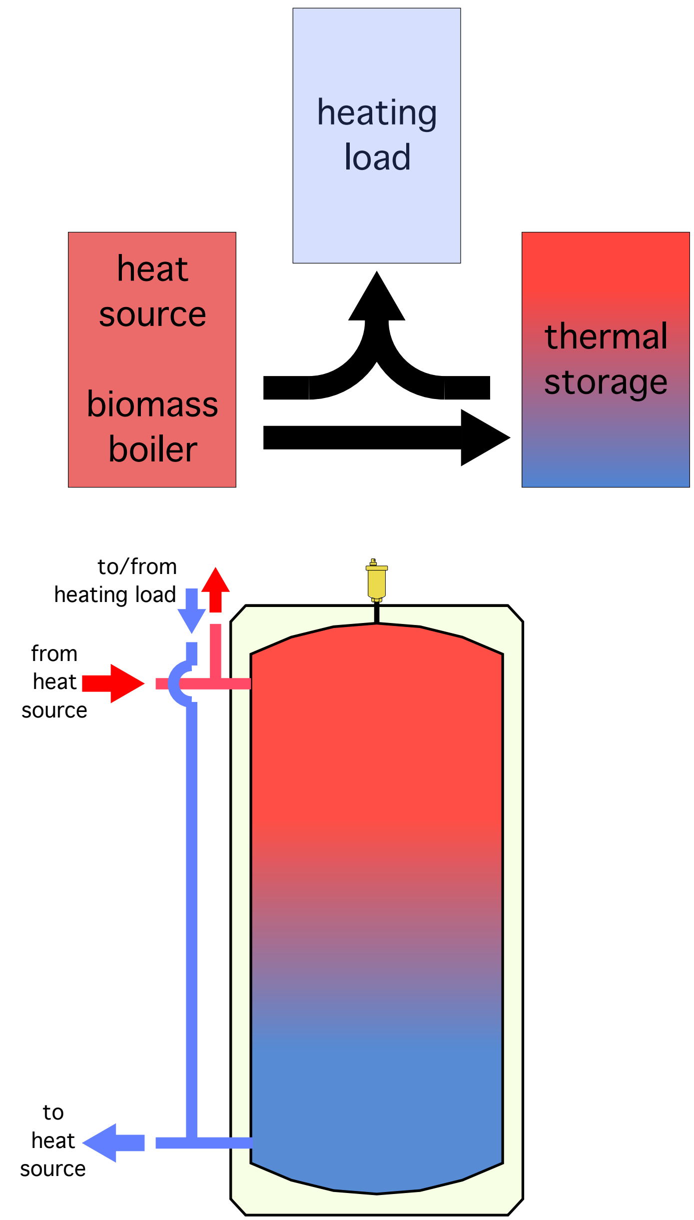
- All ingoing or exiting flow should be horizontal.



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

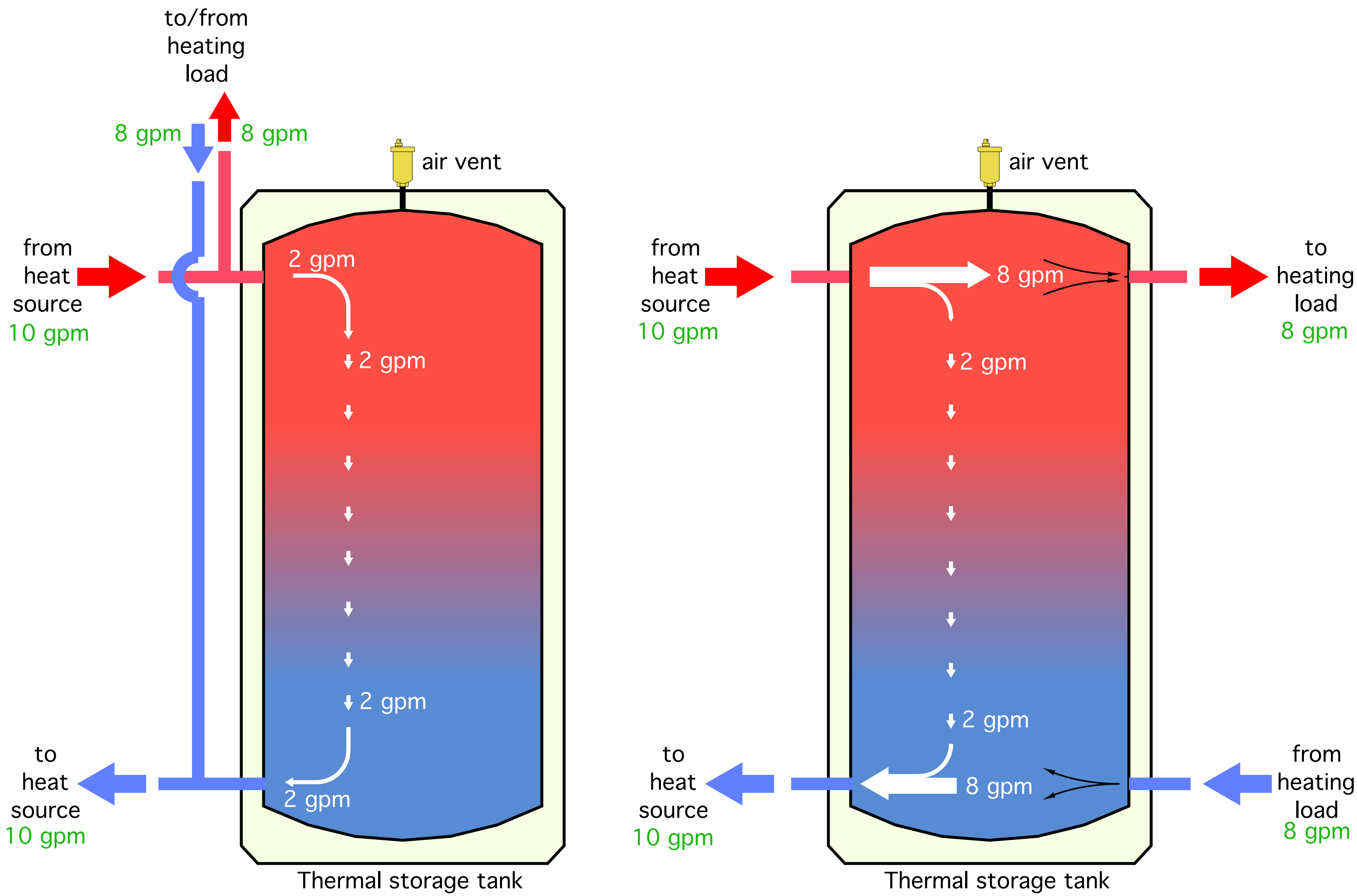


4-pipe configuration



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.**

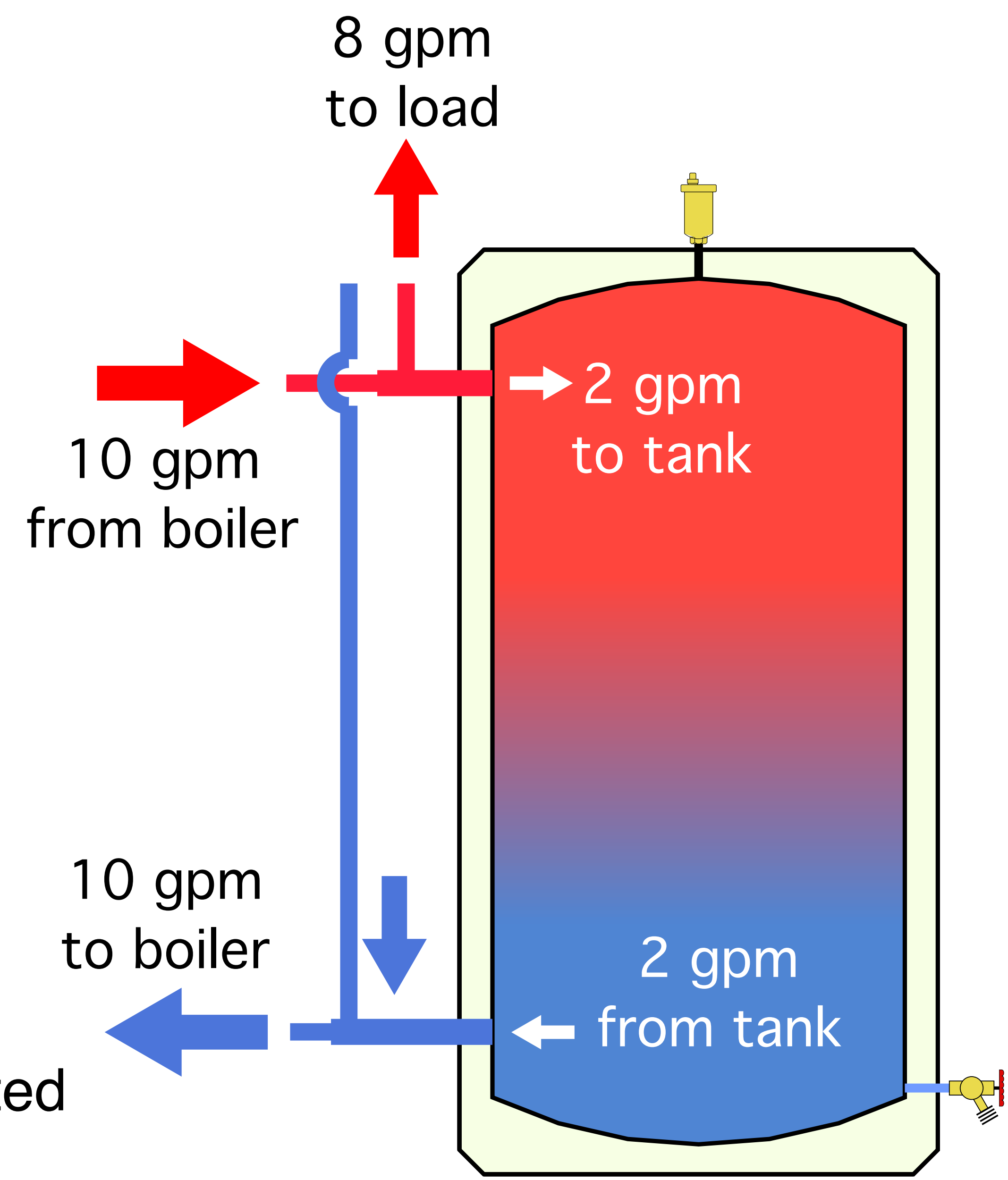
- Flow into tank = flow from boiler minus flow to load

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

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

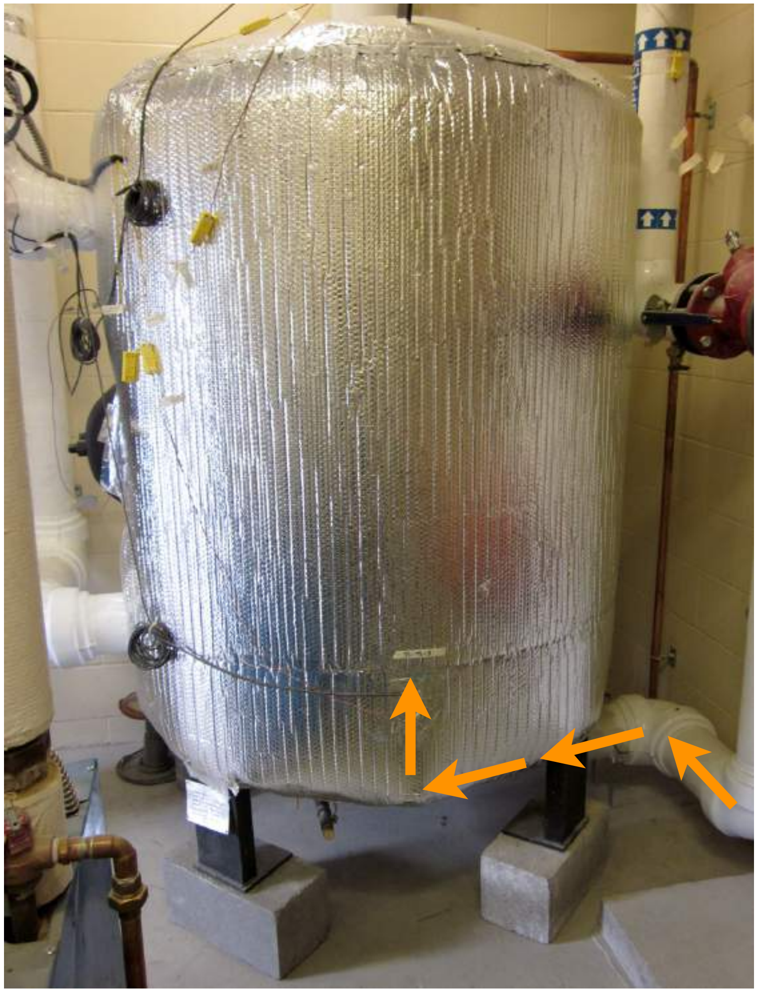
- Keep load connections close to tank, & use generous pipe sizing to tank connections, which provides hydraulic separation.

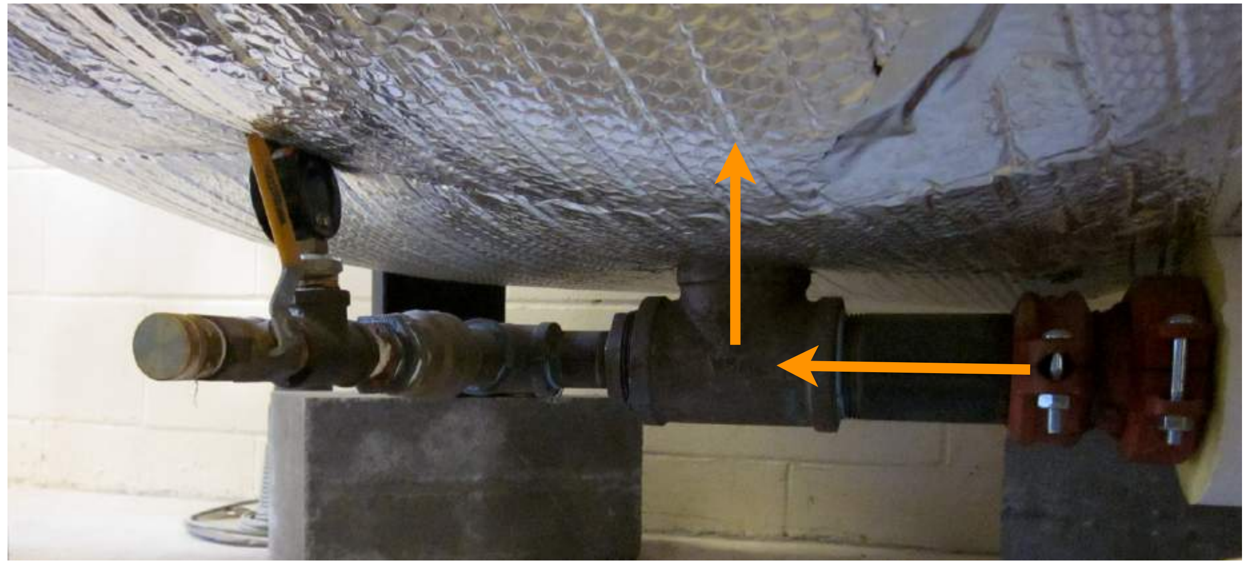
- Other side of tank can be connected for on-demand DHW subassembly.

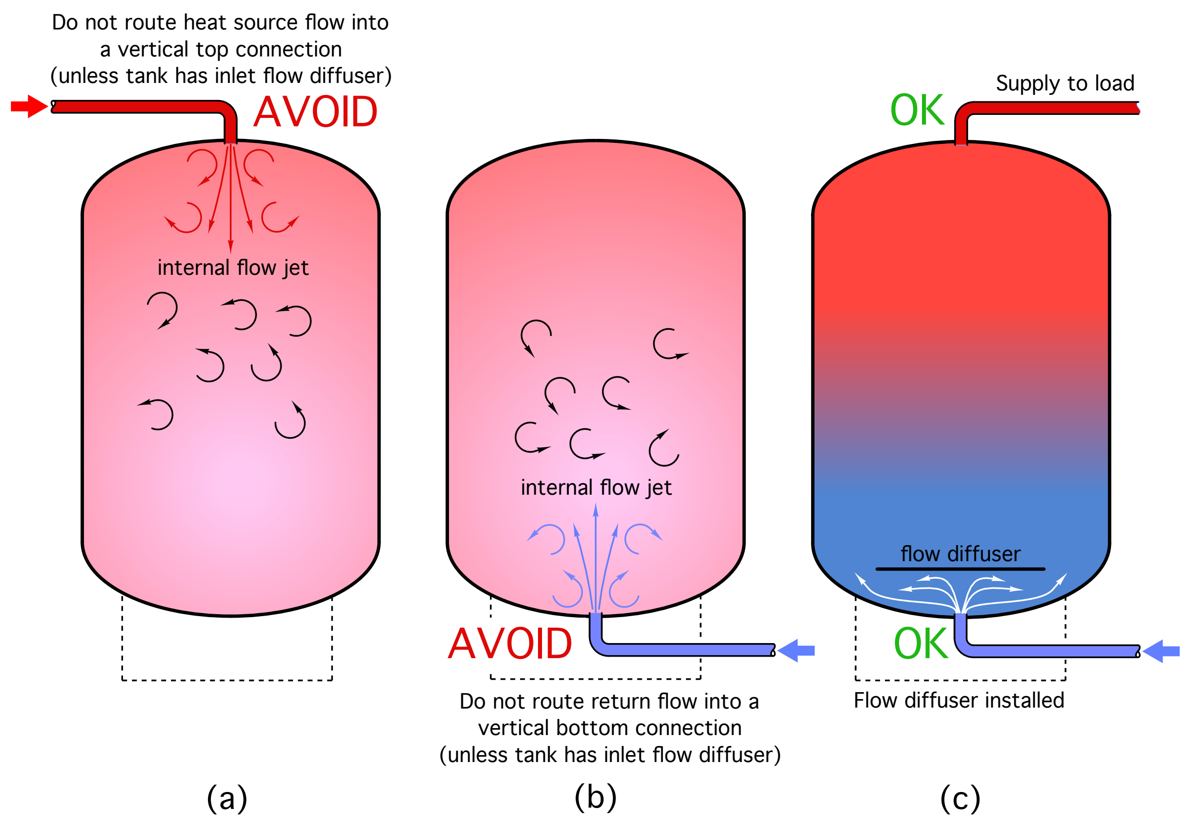


500 gallon ASME tank with poor stratification

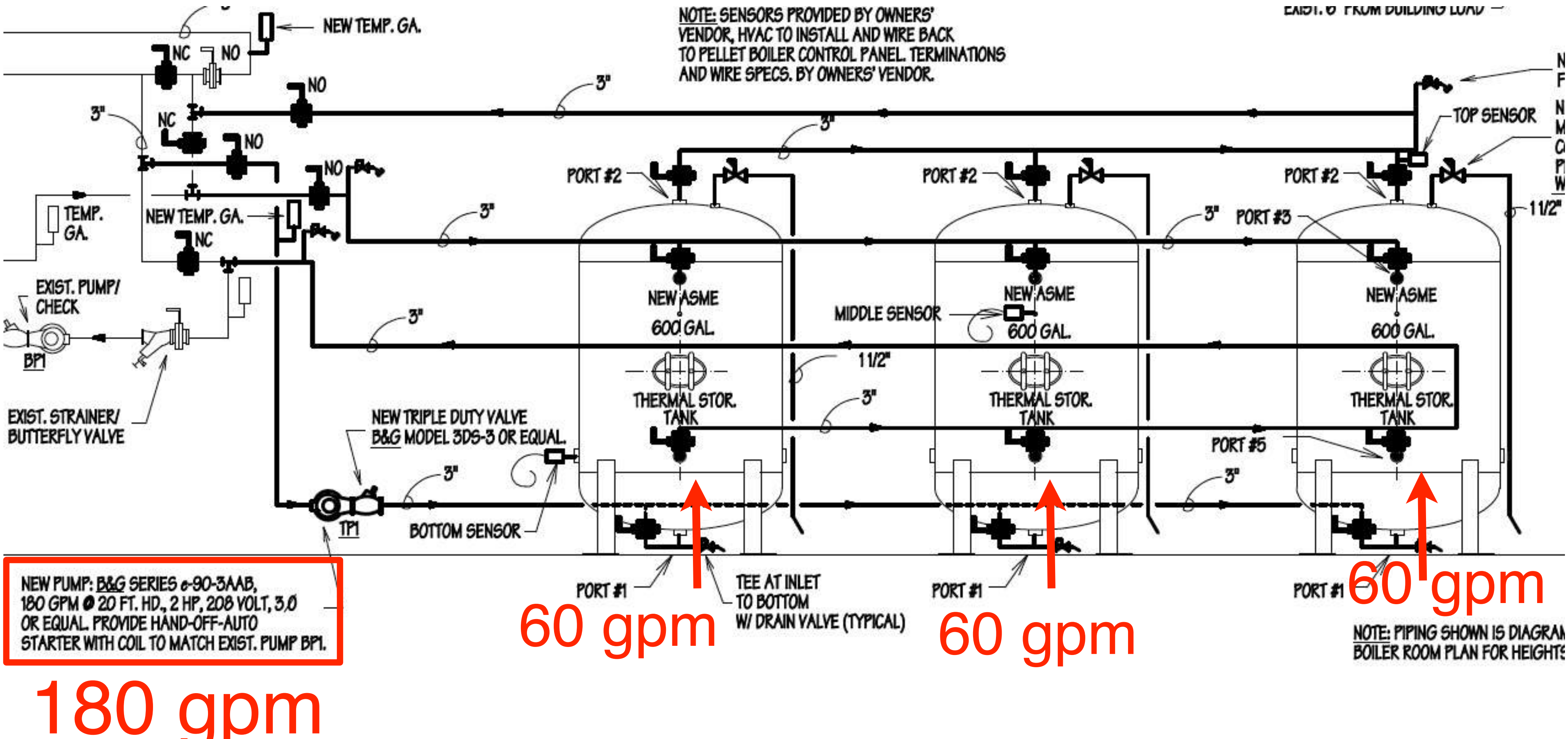
What's wrong?







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



This piping will destroy stratification within the tank(s)

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= 5659in^2 = 39.3 ft^2

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

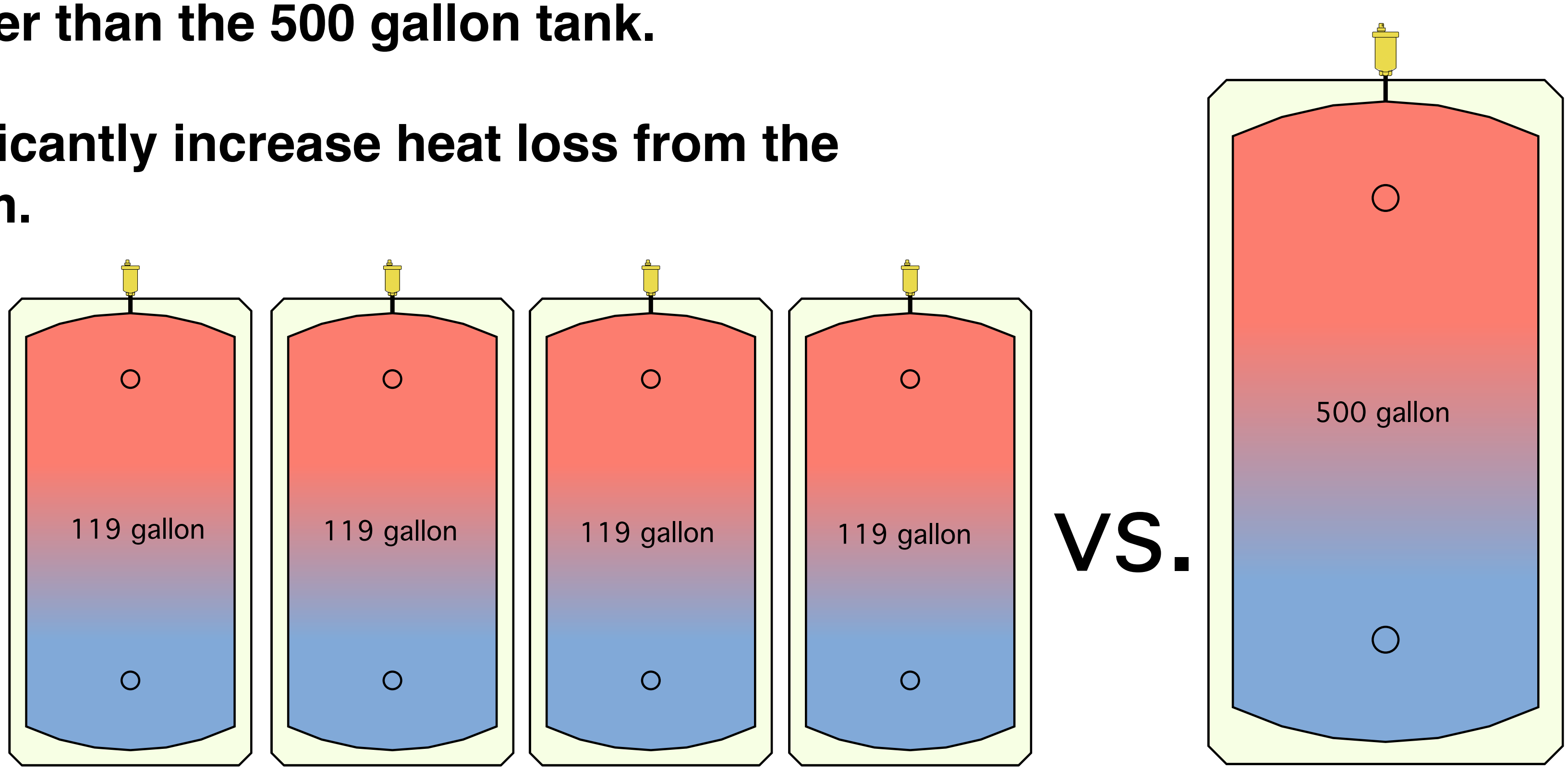
For a 500 gallons tank w/ h/d=3, d=36.6", h=109.8"

For a 500 gallons tank w/ h/d=3, A= 14728in^2 = 102.3 ft^2

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

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.



Volume & surface area of cylindrical (flat-ended) tanks:

Volume of cylindrical (flat ended) tanks:

$$V = \frac{\pi d^2 h}{924}$$

Where:
V = volume of tank (gallons)
d = inside diameter of pressure vessel (inches)
h = height of pressure vessel (inches)

Volume of cylindrical (flat ended) tank when h/d = 3:

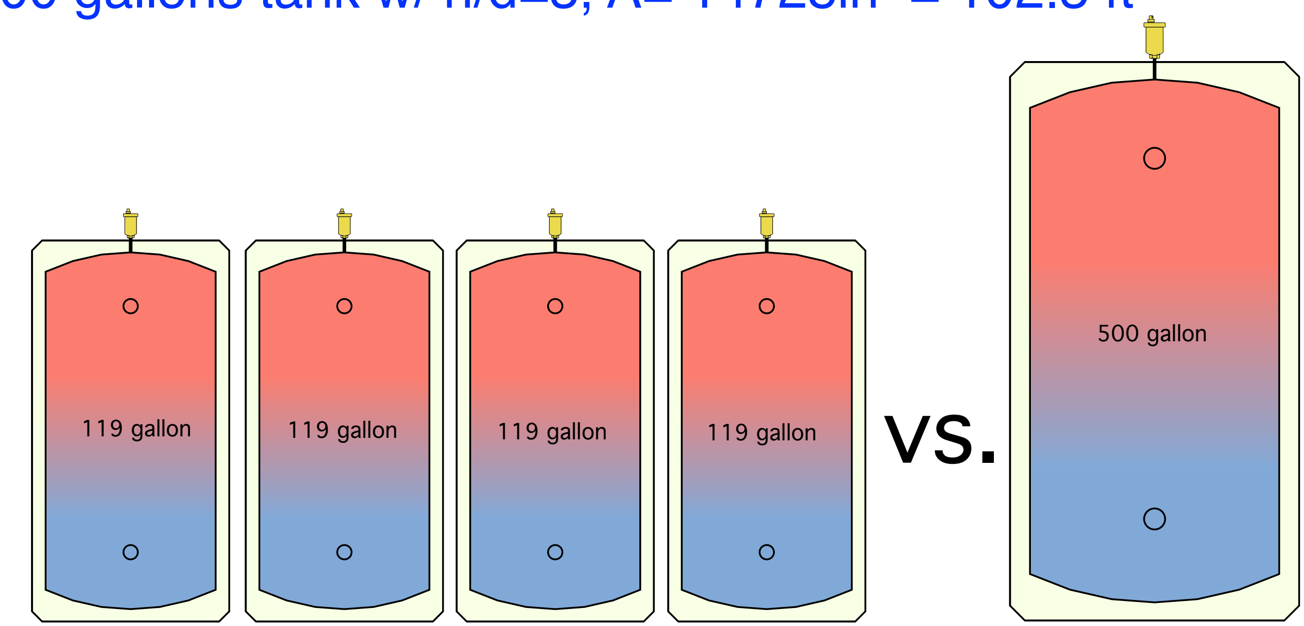
$$V = 0.0102\left(d^3\right)$$

For a 119 gallons tank w/ h/d=3, d=22.7”, h=68”
For a 500 gallons tank w/ h/d=3, d=36.6”, h=109.8”

Surface area of cylindrical (flat-ended) tanks:

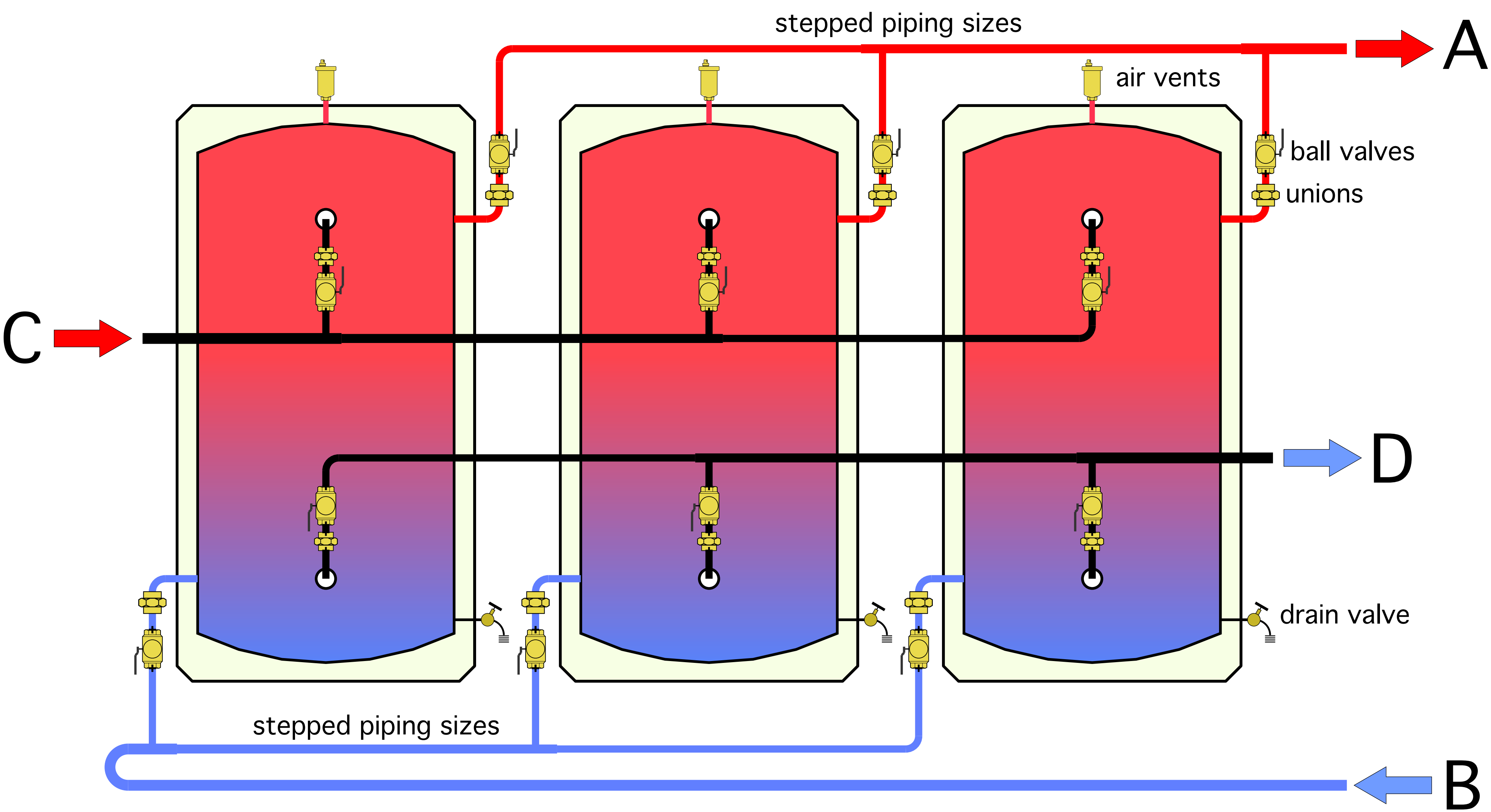
$$A_s = \pi d(h + 0.5d)$$

For a 119 gallons tank w/ h/d=3, A= 5659in^2 = 39.3 ft^2
For a 500 gallons tank w/ h/d=3, A= 14728in^2 = 102.3 ft^2



Piping to ensure balanced flow in multiple tanks

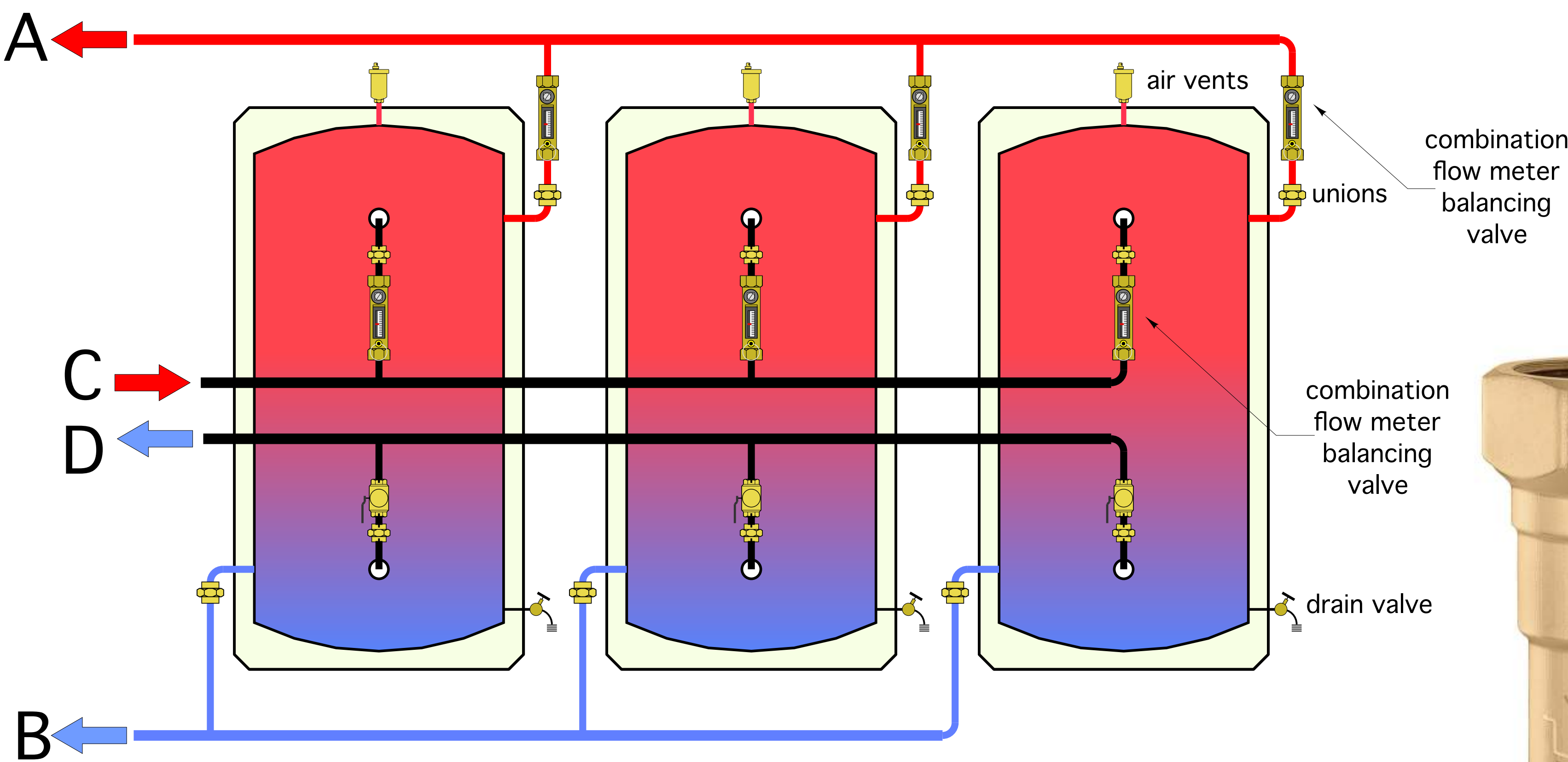
Reverse return piping with stepped header sizes



If using this piping be sure to plan for possibility of individual tank isolation and removal.

Piping to ensure balanced flow in multiple tanks

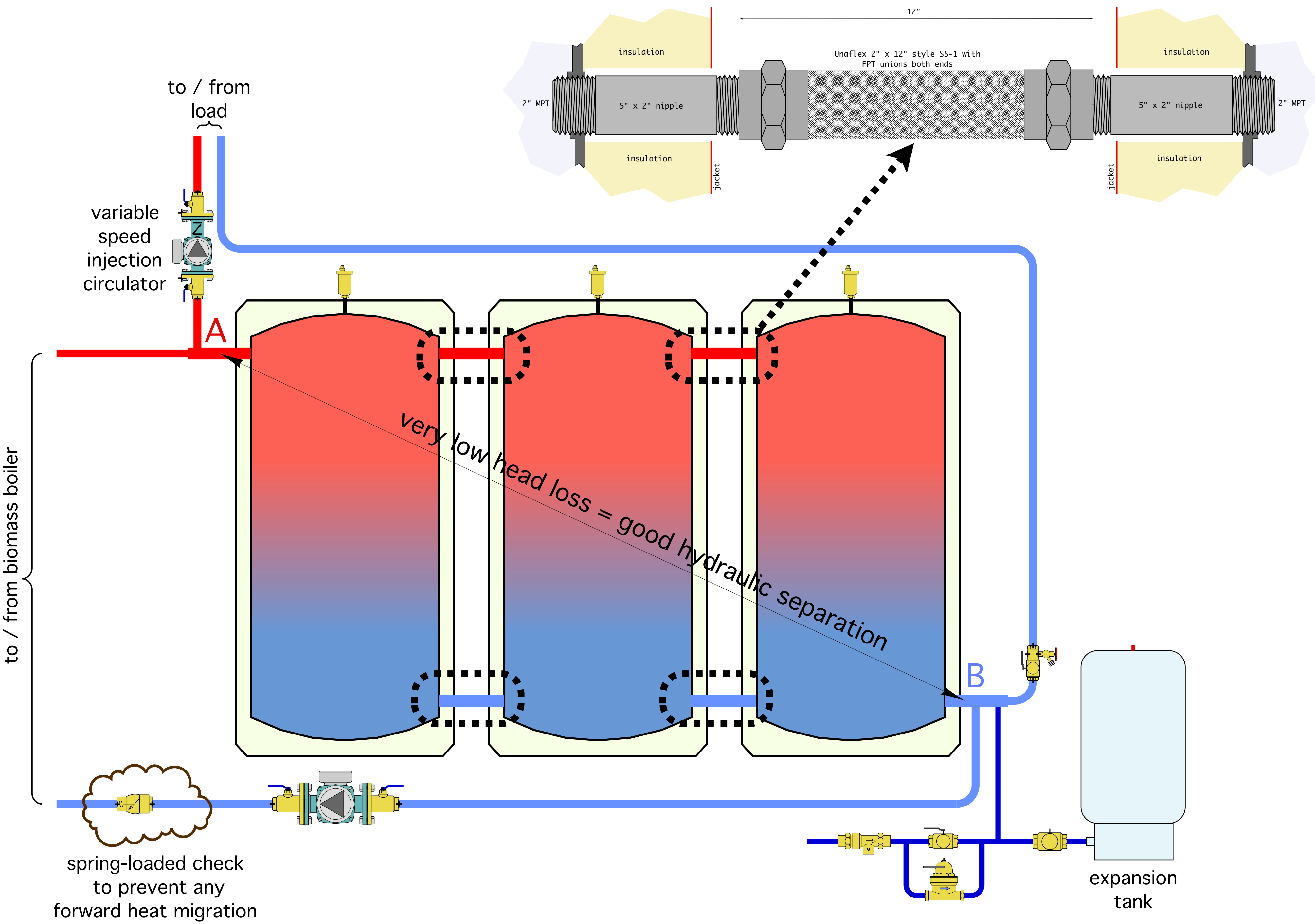
If direct return piping is used always install balancing valves



If using this piping be sure to plan for possibility of individual tank isolation and removal.

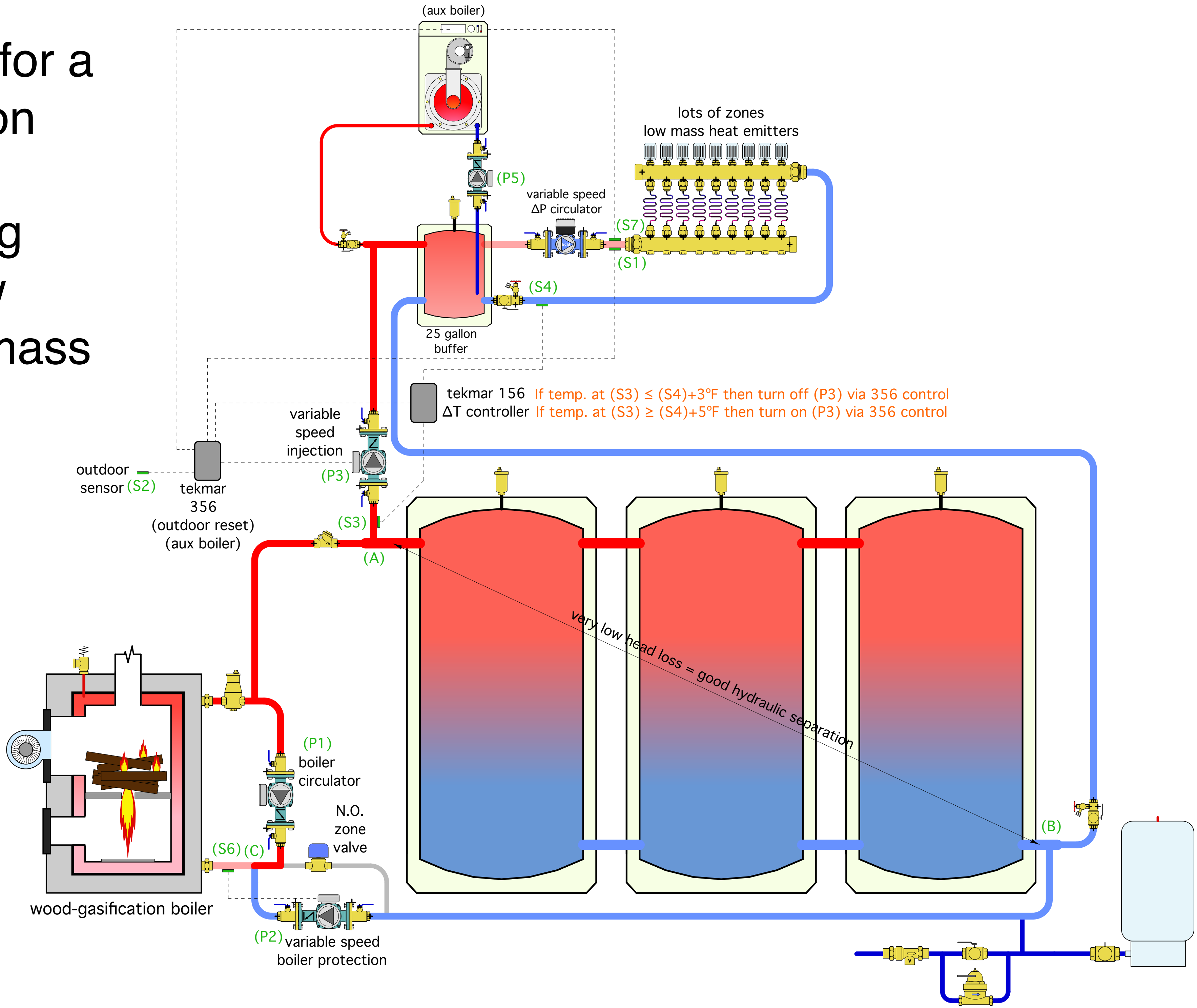
courtesy of Caleffi

Hybrid parallel / series tank piping



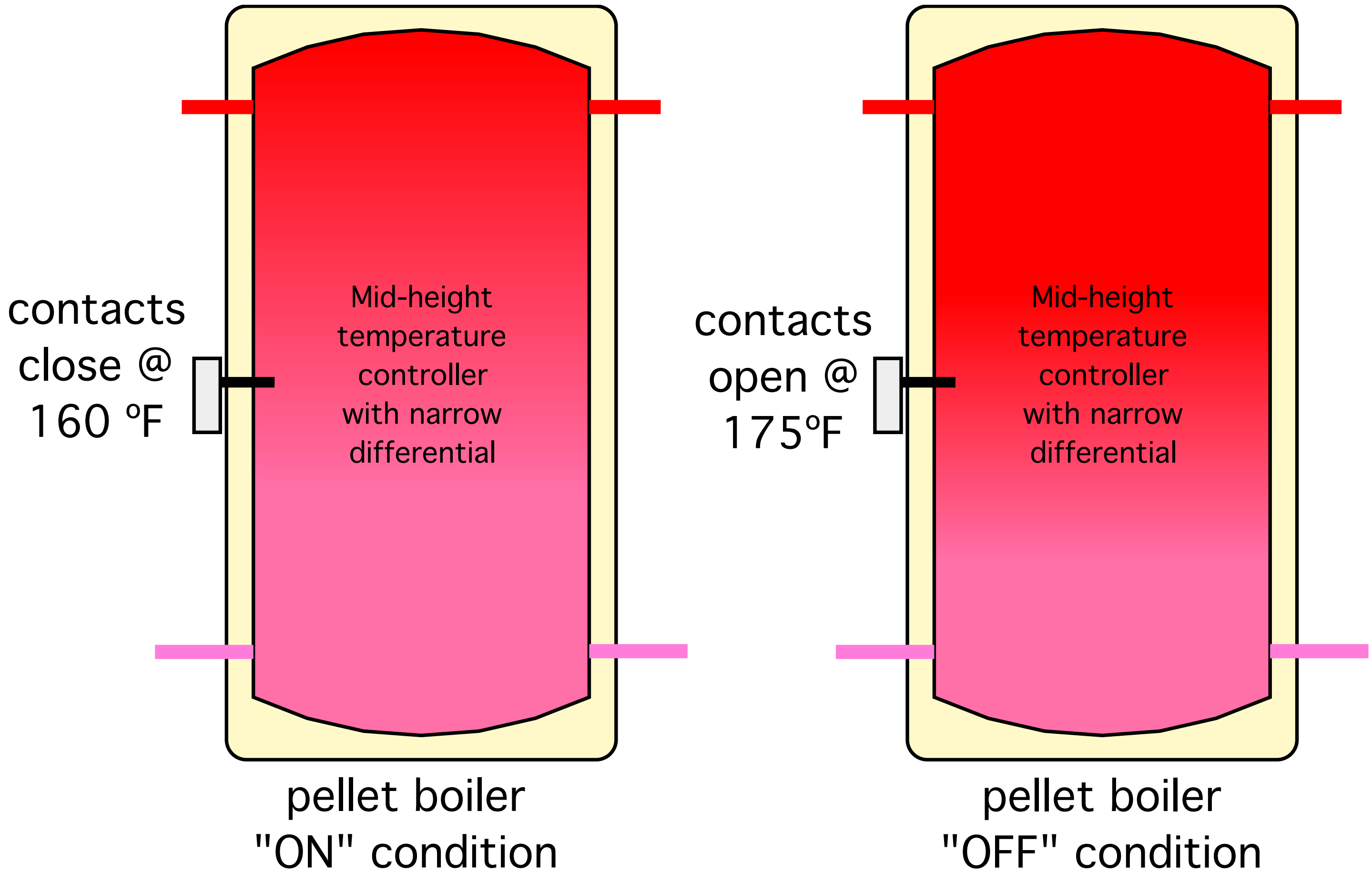
Wood gasification with multiple pressurized buffer tanks

Modified for a distribution system containing many low thermal mass zones



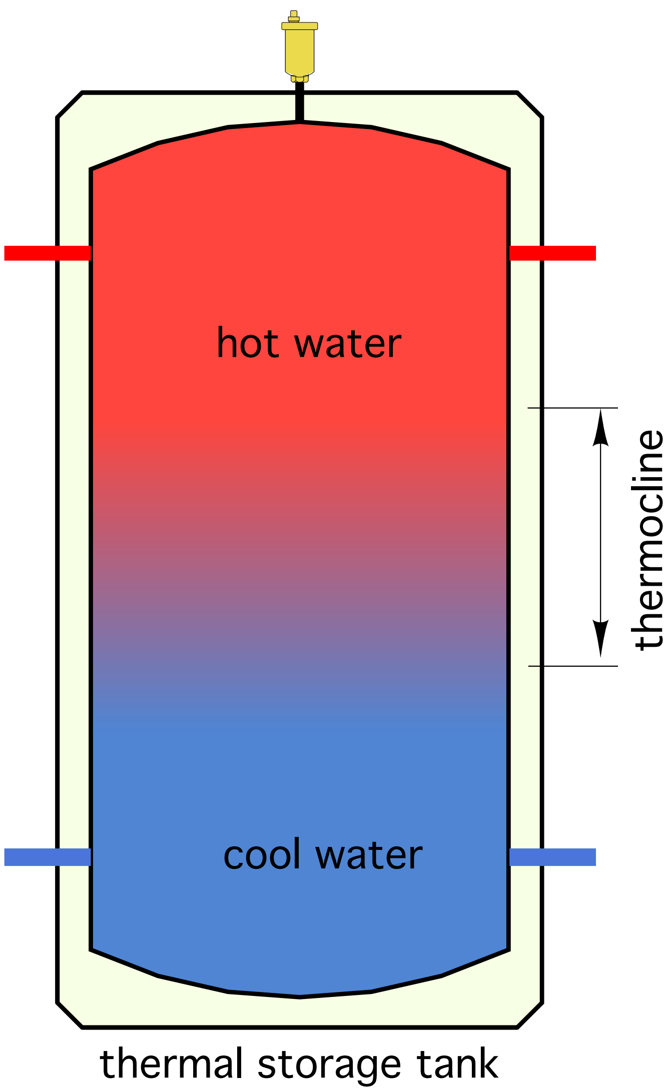
Temperature Stacking in Thermal Storage Tanks

Pellet boiler controlled from single temperature measurement with narrow differential

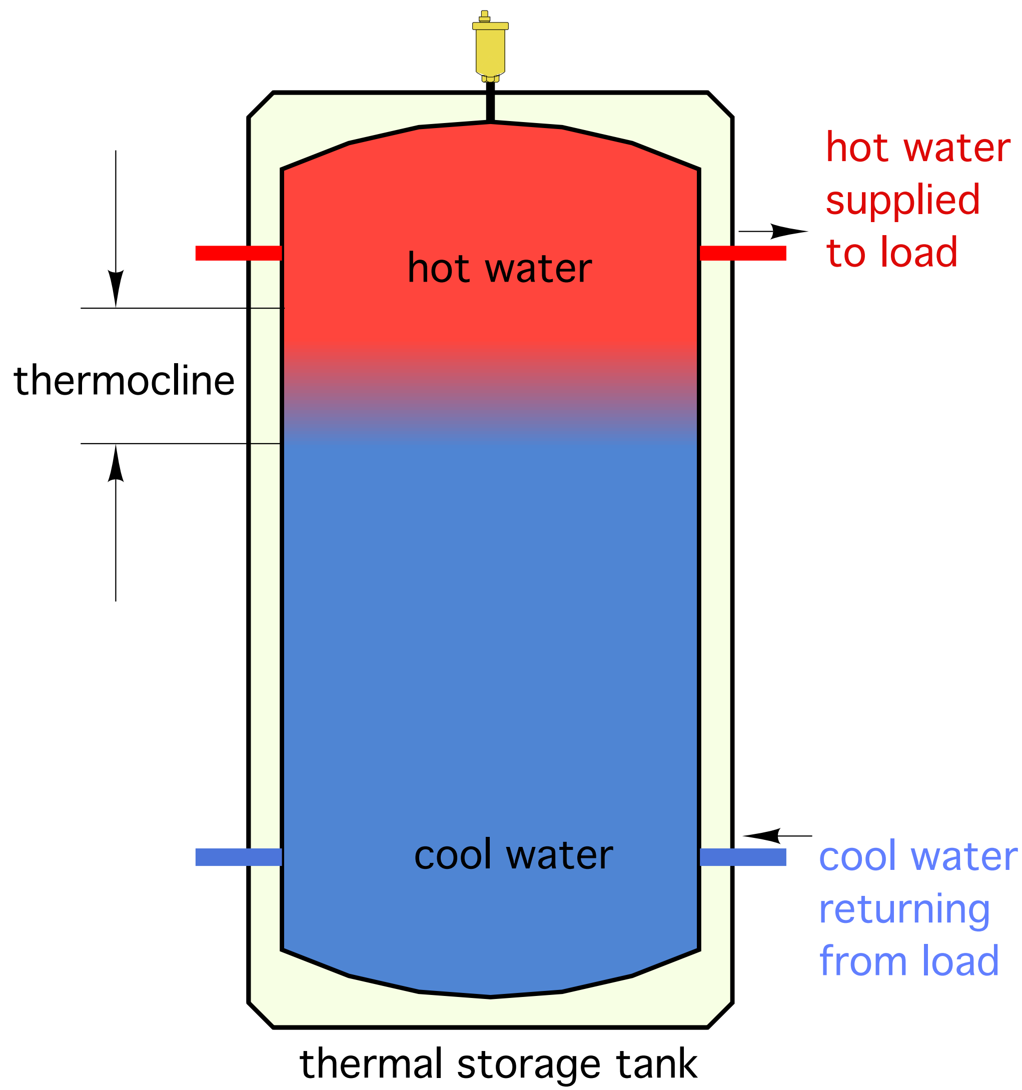


- Problem is exasperated by high temperature heat emitters
- Problem is exasperated by lack of outdoor reset for boiler “ON” criteria
- Tank is expensive wide spot in pipe, but can provide hydraulic separation

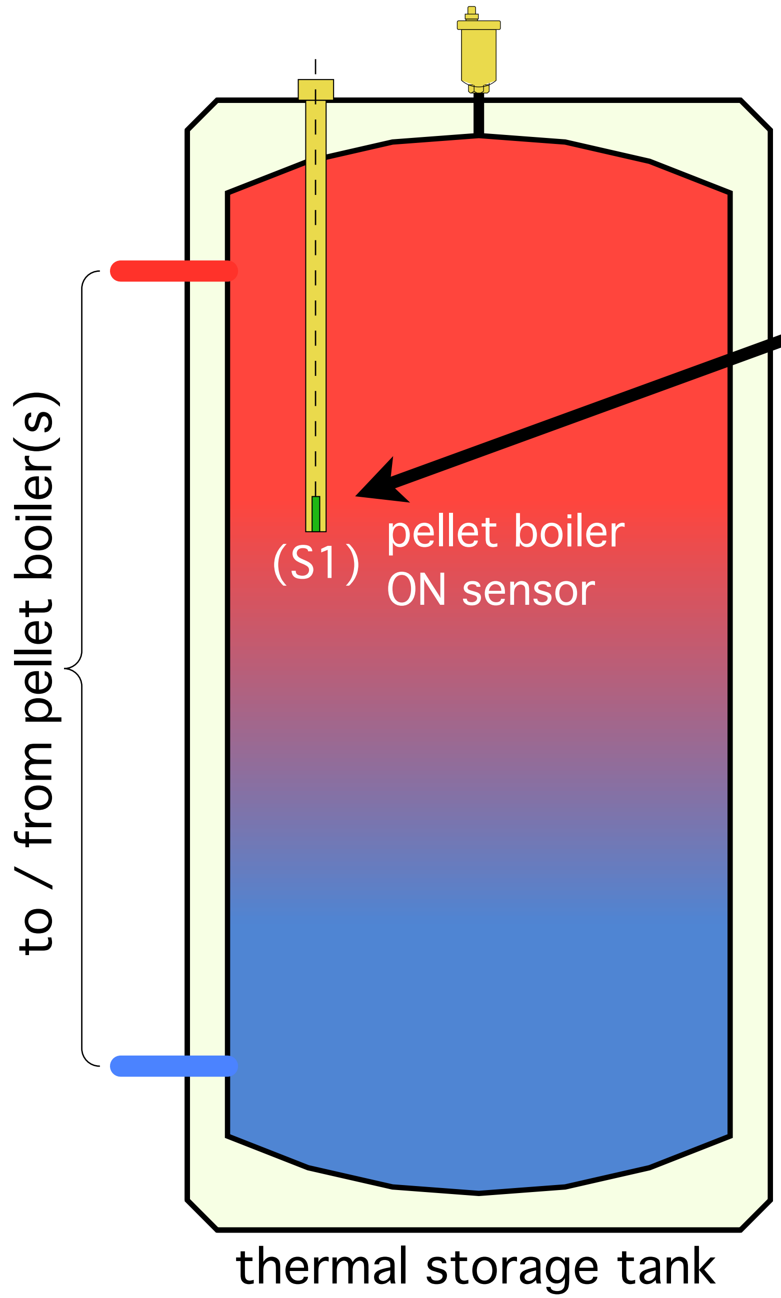
A thermal storage tank “at rest” will have a well defined **thermocline**, between cooler water at bottom, and hottest water at top.



As hot water is drawn from upper portion of tank, thermocline moves up. Cool water stacks from bottom.



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

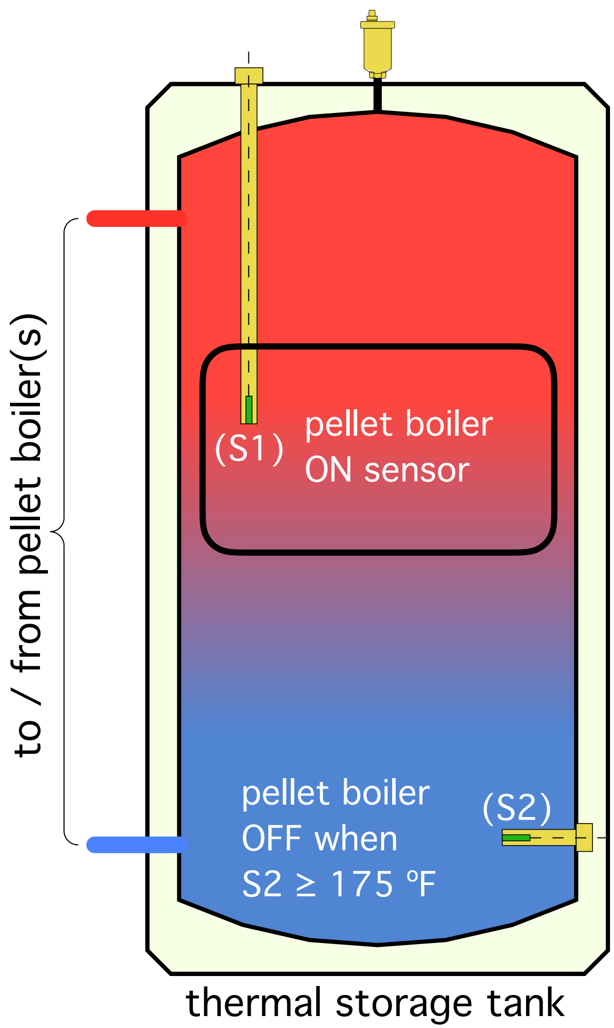


Sensor in vertical well detects "arrival" of rising cooler water. Turns on pellet fired boiler.

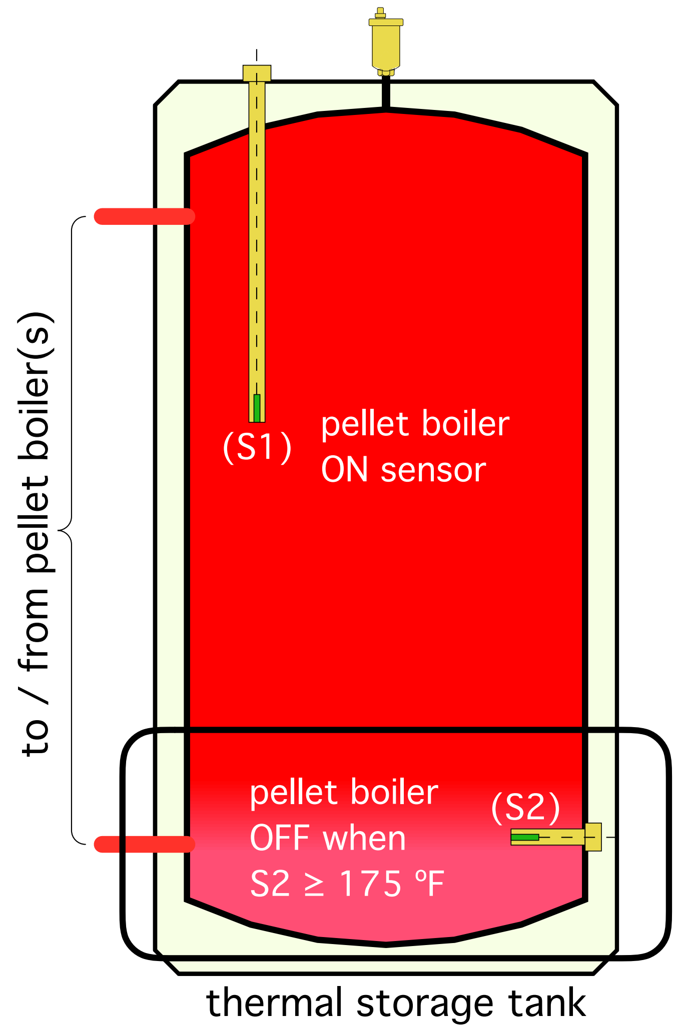
pellet boiler ON when upper sensor temperature ≤ minimum setpoint

Temperature stacking

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



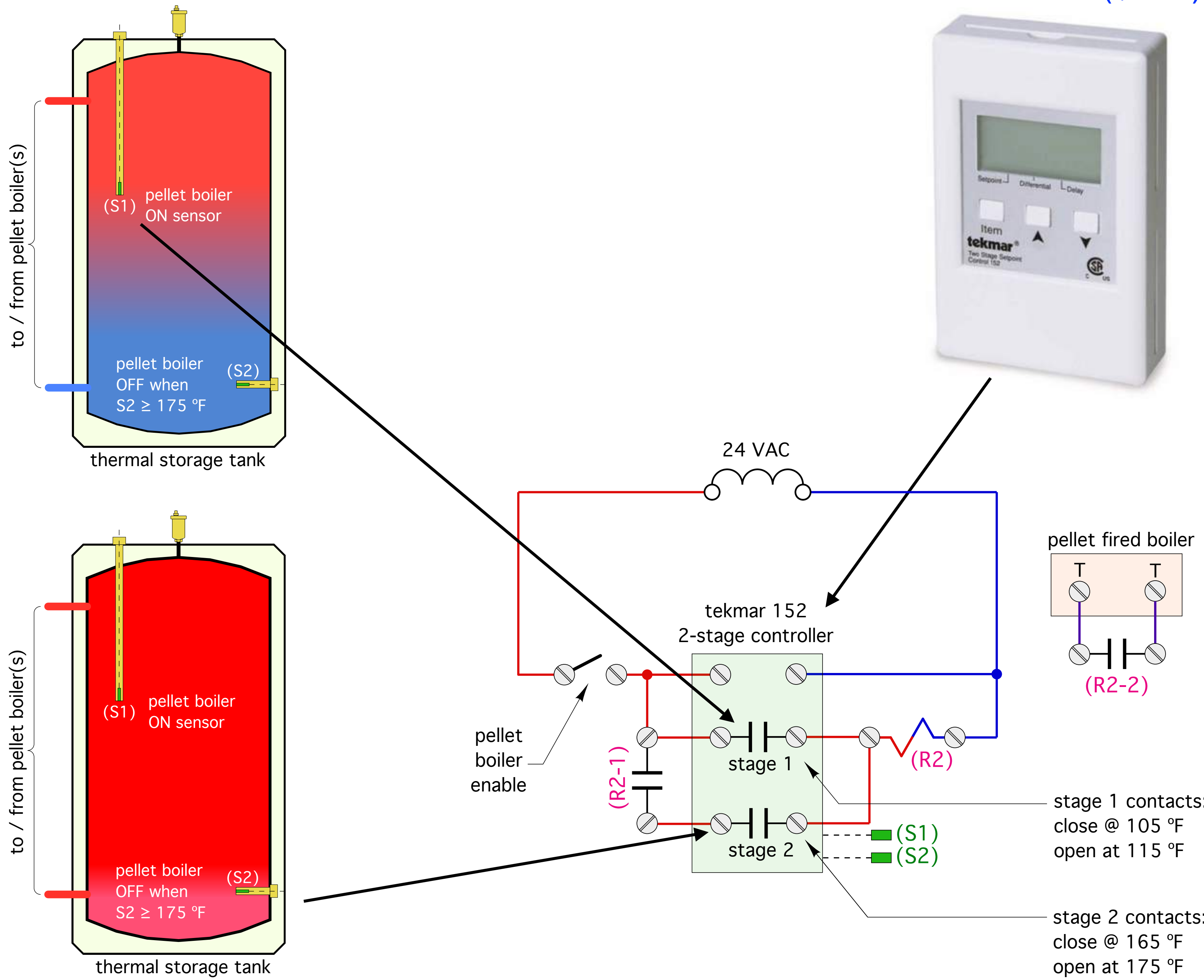
pellet boiler
“start”condition



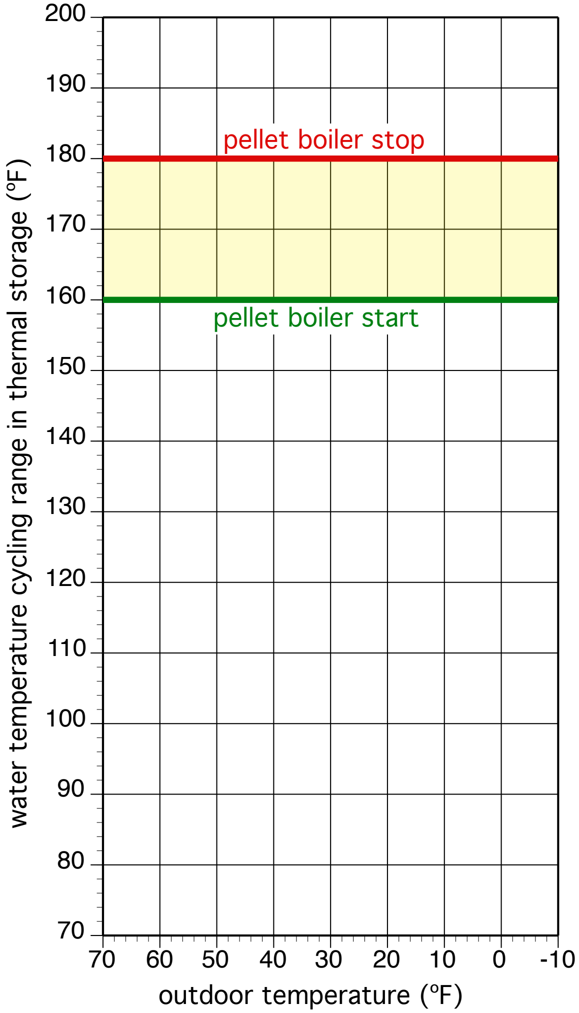
pellet boiler
“stop”condition

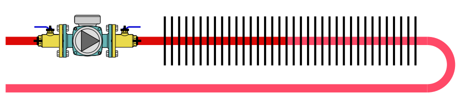
Temperature stacking *(using 2 setpoint temperatures)*

tekmar 152: ($217)



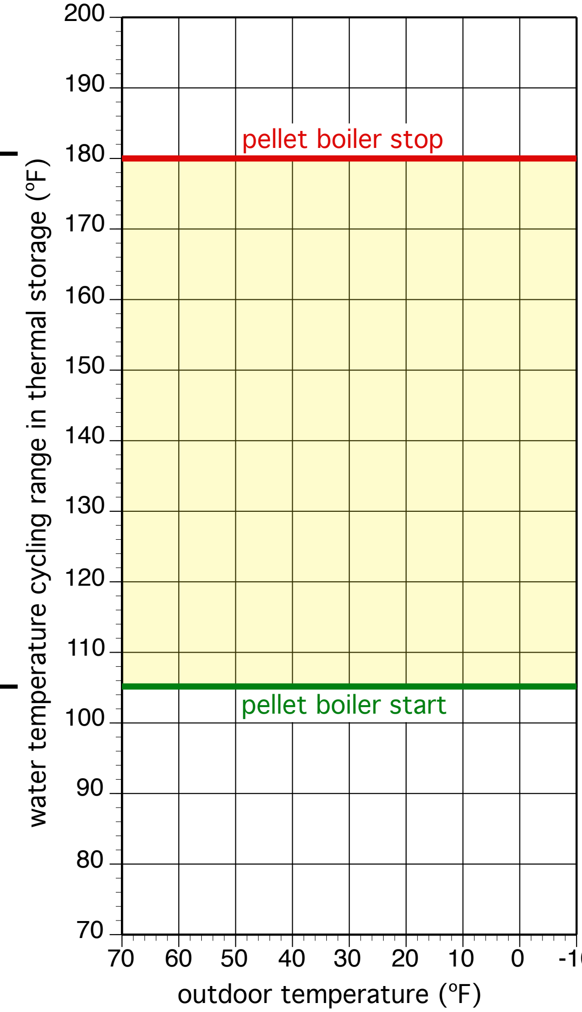
Temperature cycling range of storage is high dependent on the type of heat emitters used.

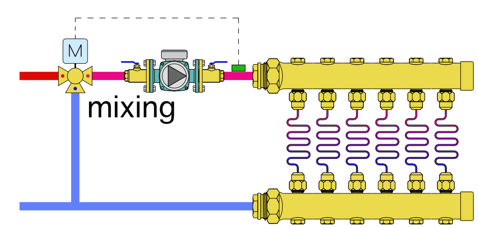




• HIGH temperature heat emitters
• No outdoor reset control of supply water temperature

Low temperature heat emitters allows for wider tank "draw down."

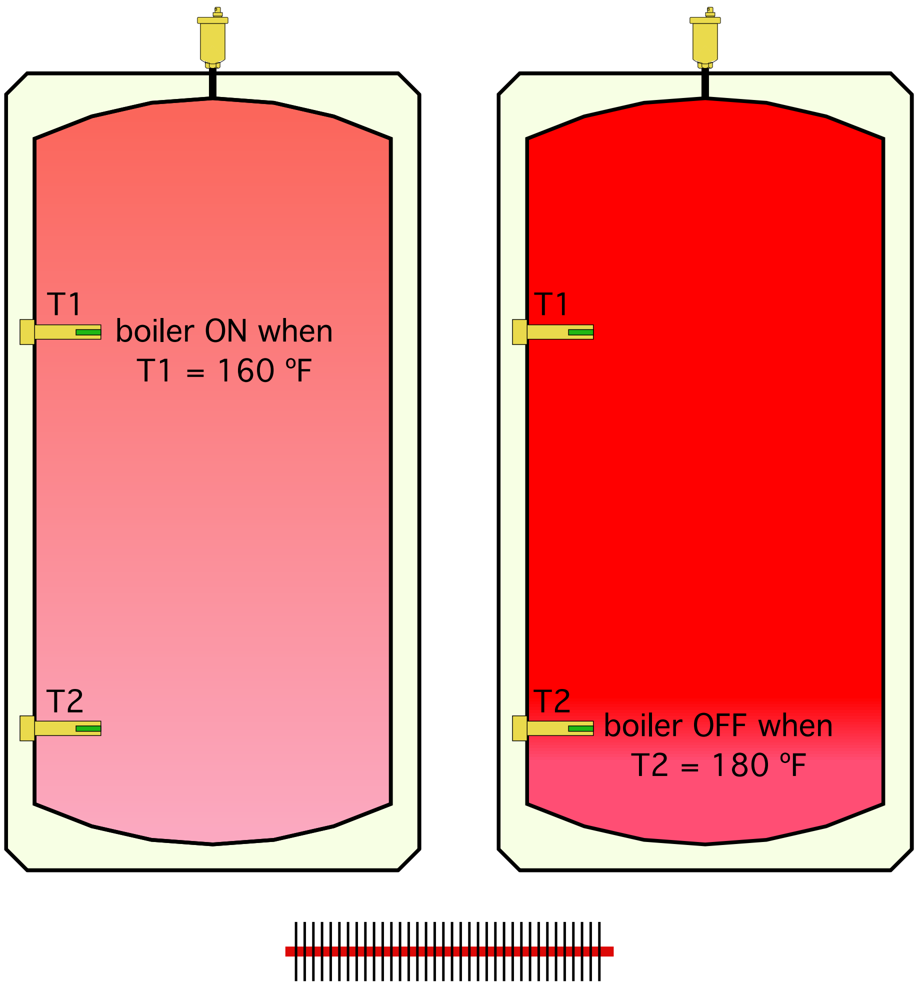




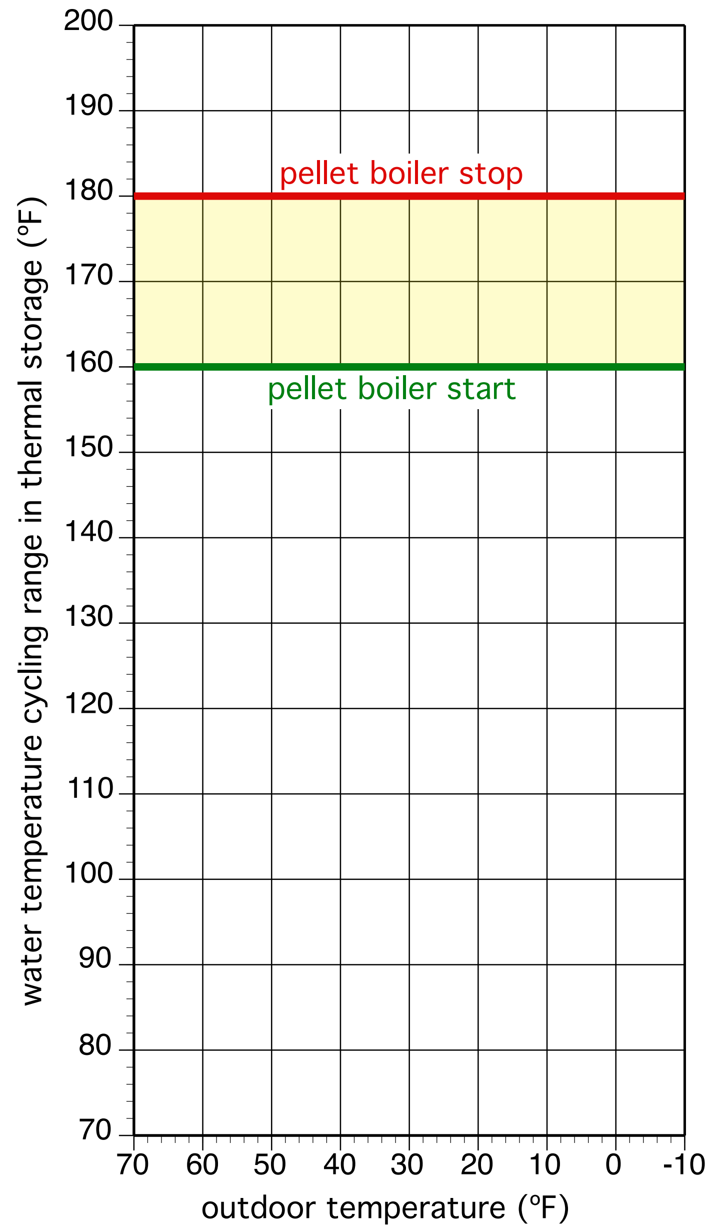
• LOW temperature heat emitters
• No outdoor reset control of supply water temperature

• **High temperature heat emitters**

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

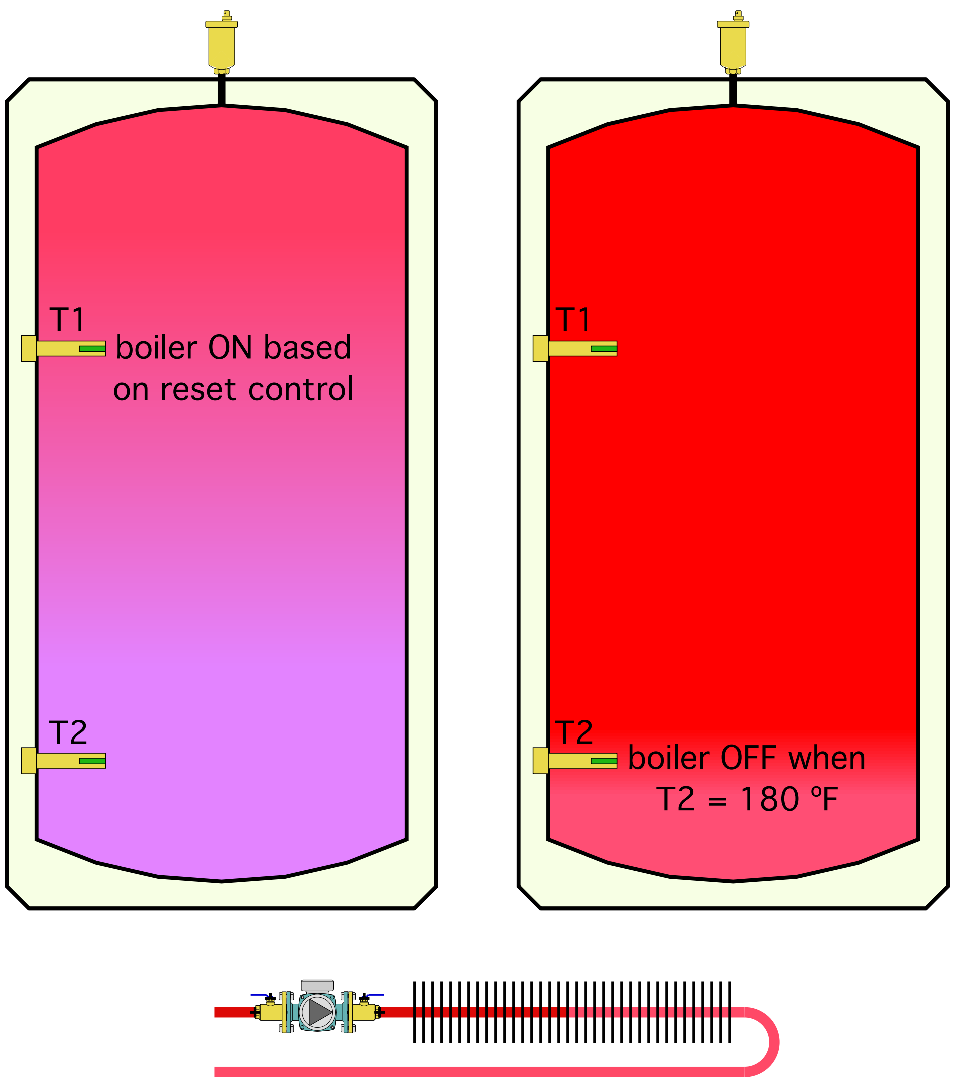


• High temperature heat emitters
• No outdoor reset control

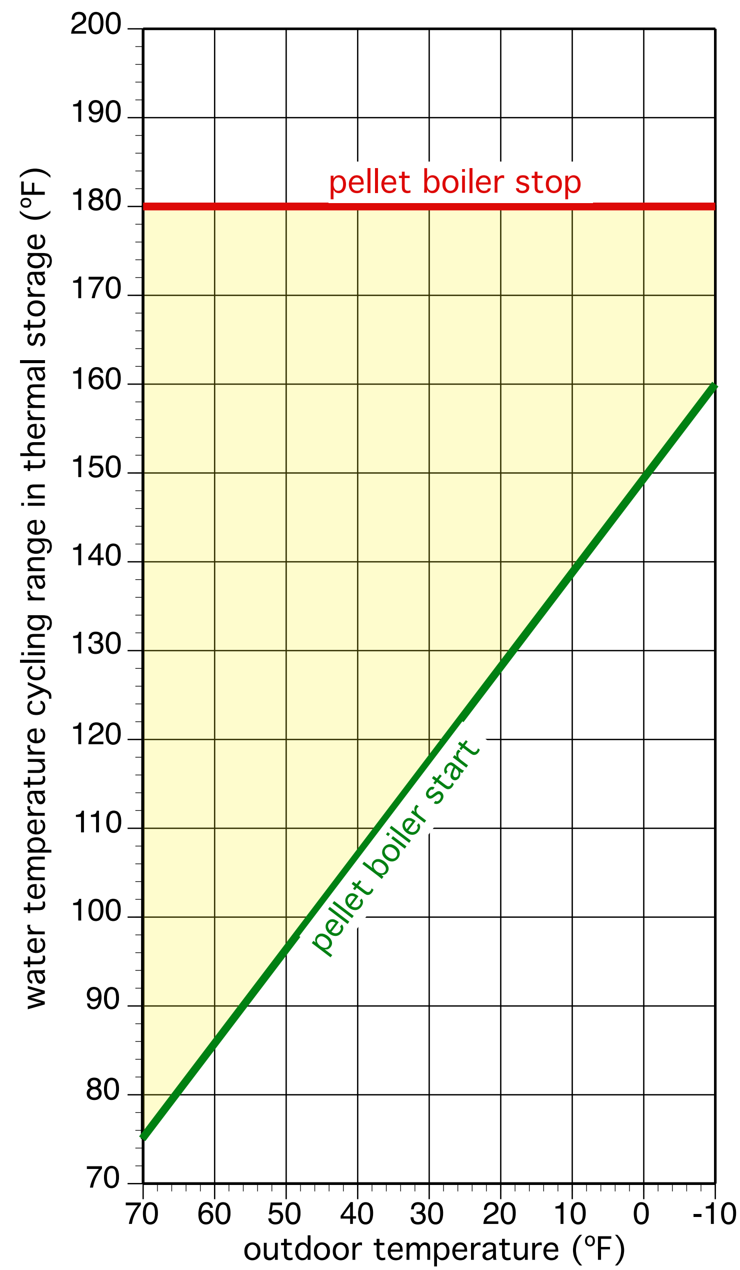


- **High temperature heat emitters**
- Temperature stacking (w/ upper & lower tank temp. sensors

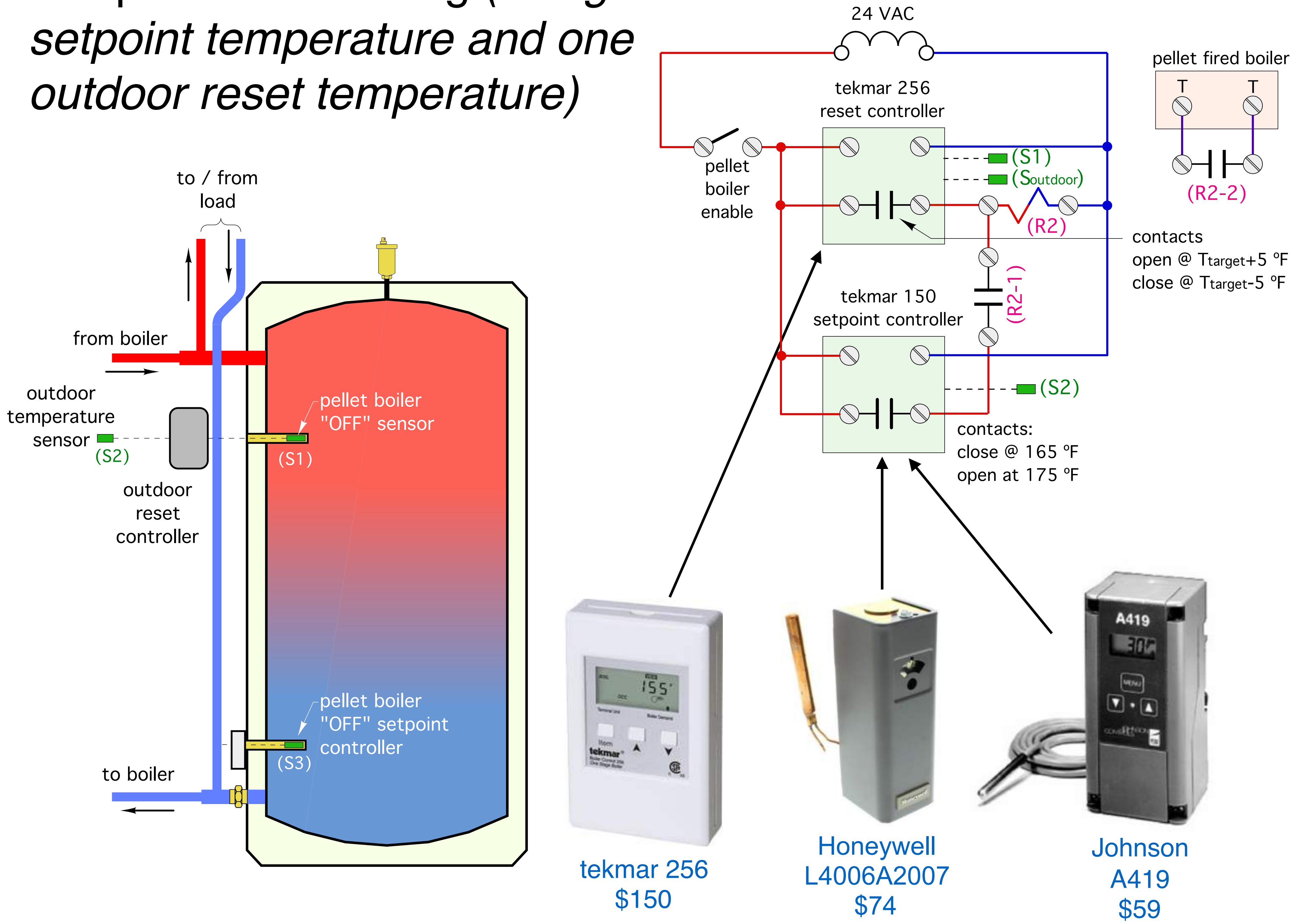
[*outdoor reset for boiler start, setpoint temperature for boiler off*]



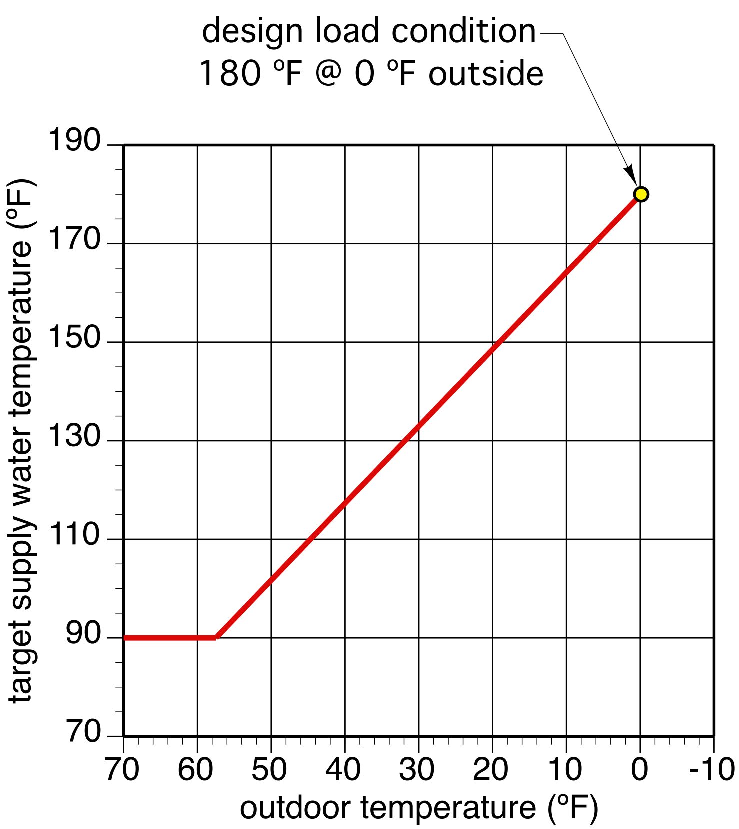
- HIGH temperature heat emitters
- Outdoor reset of pellet boiler start temperature

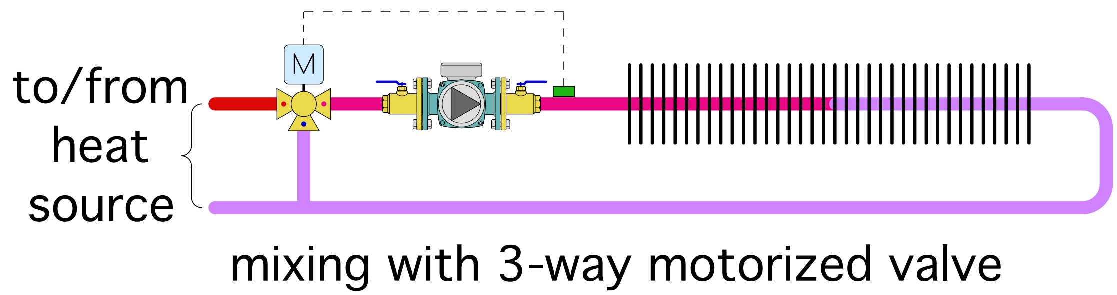


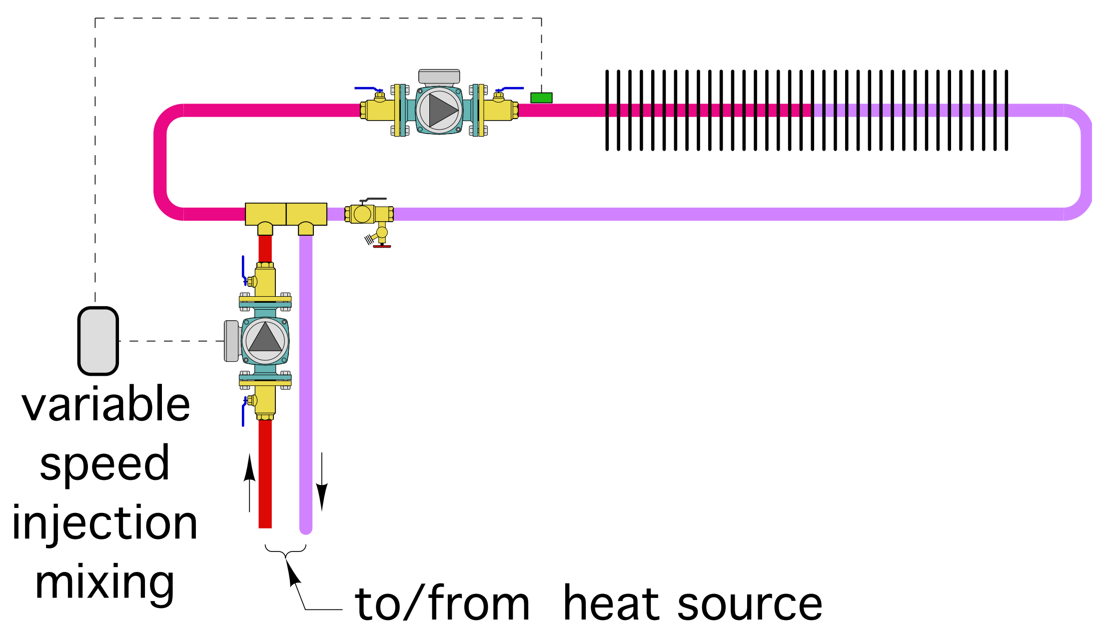
Temperature stacking *(using 1 setpoint temperature and one outdoor reset temperature)*



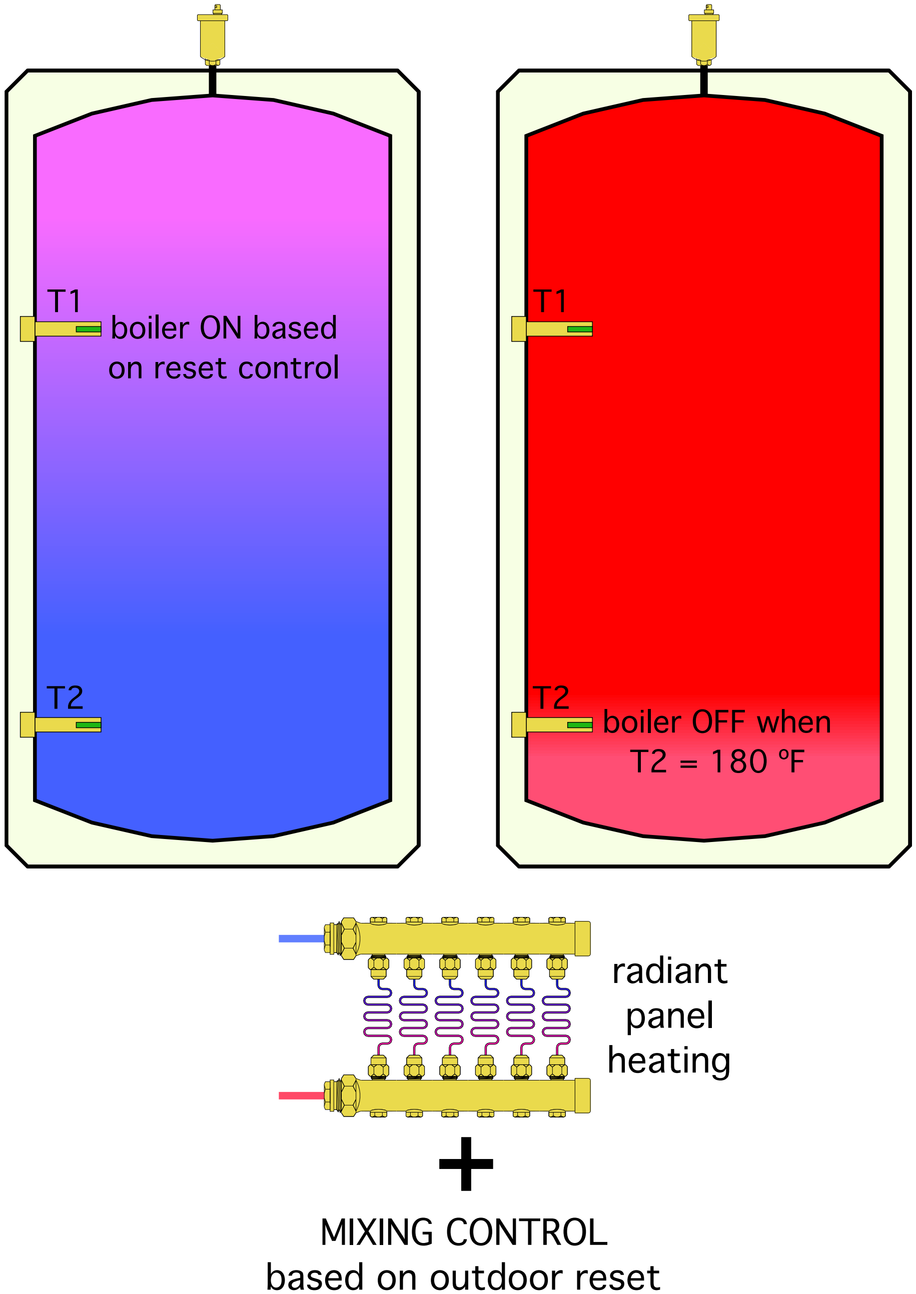
Adding ***mixing*** (based on outdoor reset) between the thermal storage tank and distribution system will smoothen heat delivery and significantly ***improve comfort***.

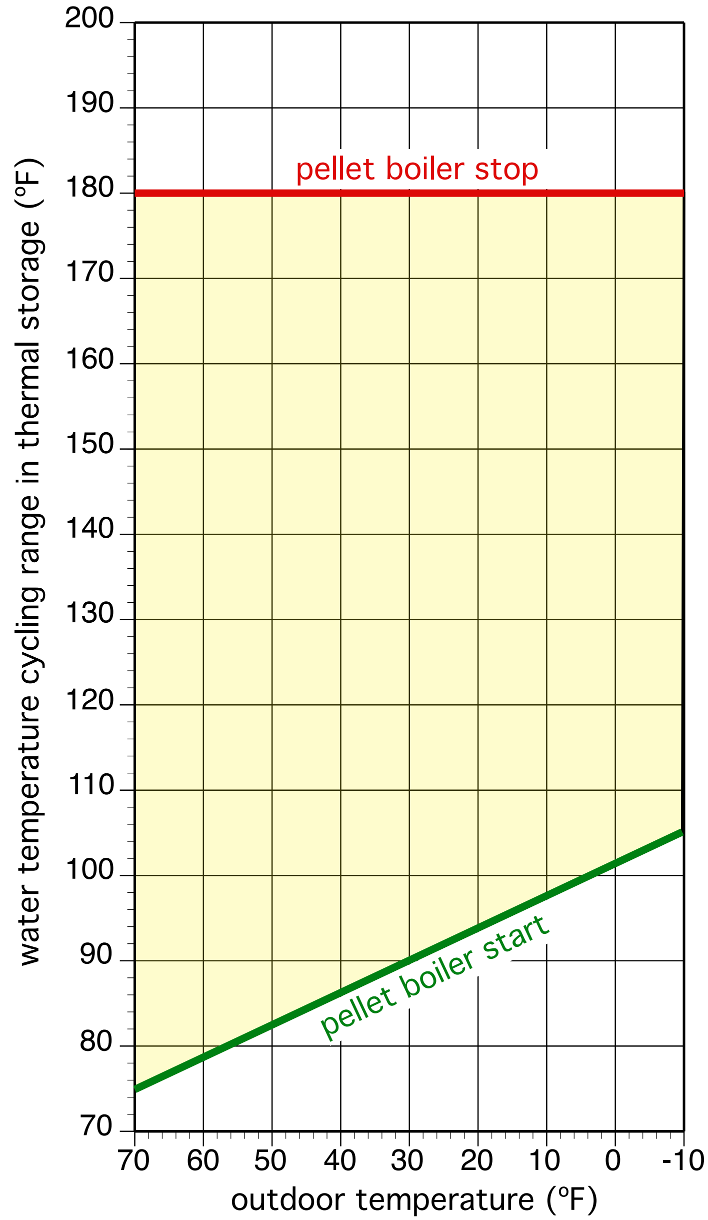




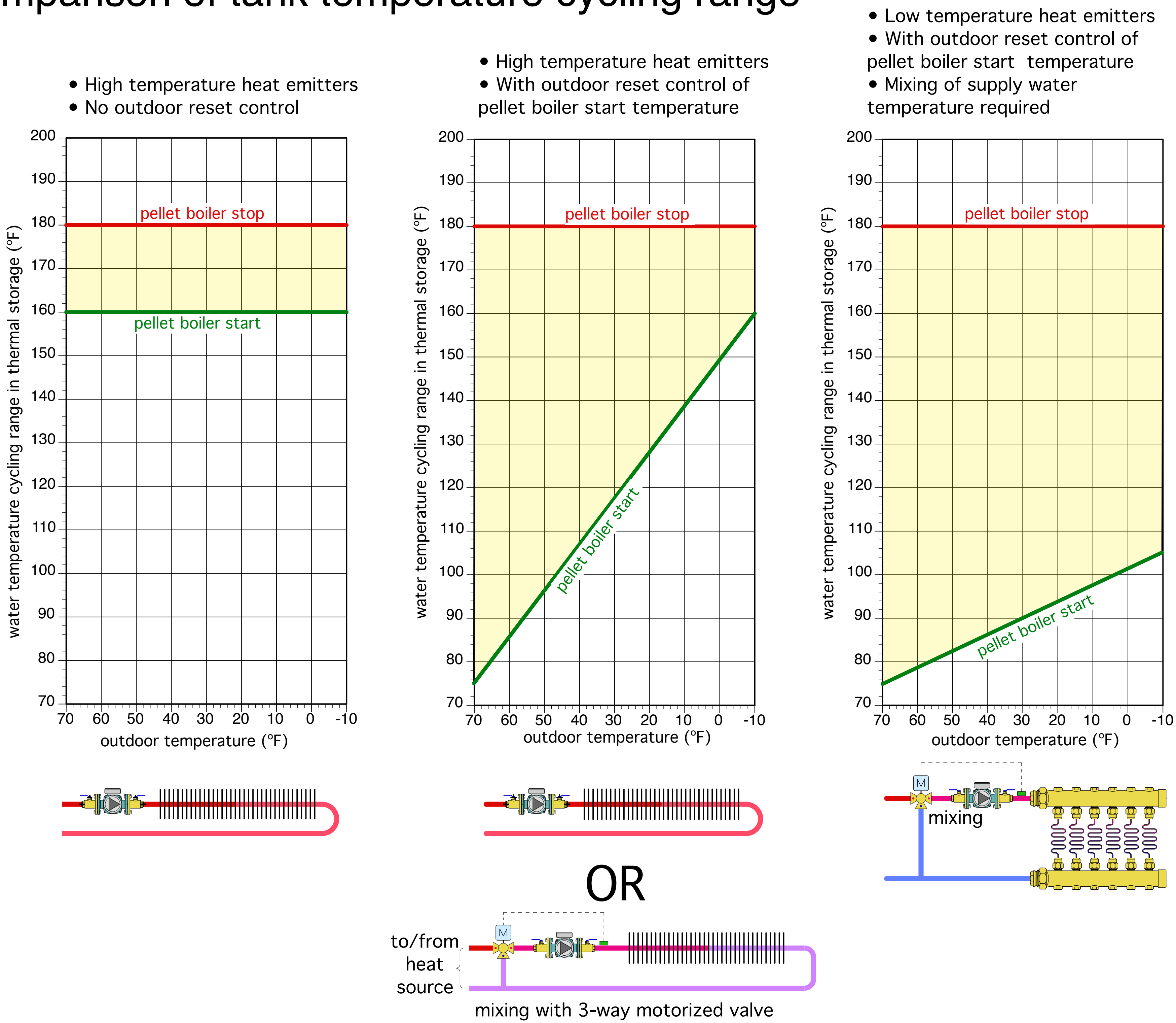


- **Low temperature heat emitters**
- Heat stacking (outdoor reset for boiler start, setpoint for boiler off)
- Mixing control of distribution water temperature



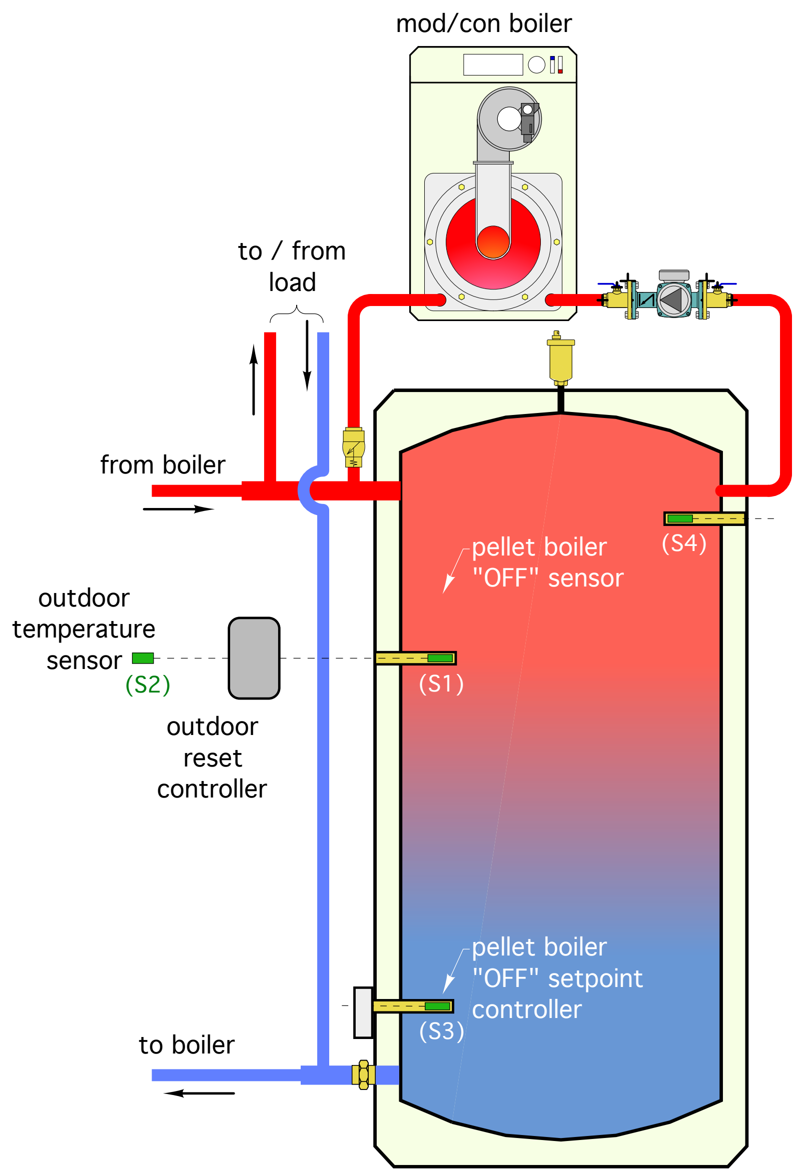


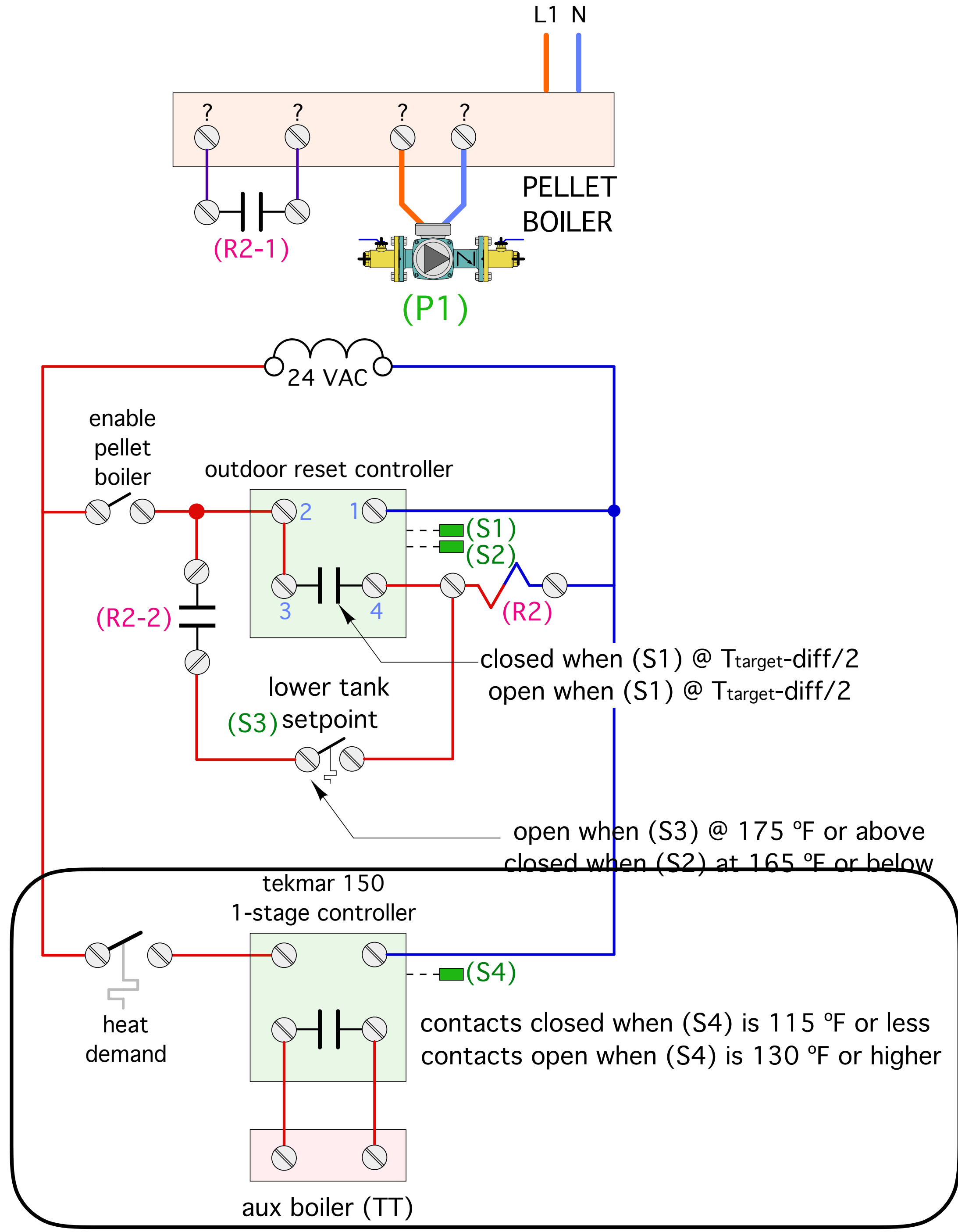
A comparison of tank temperature cycling range



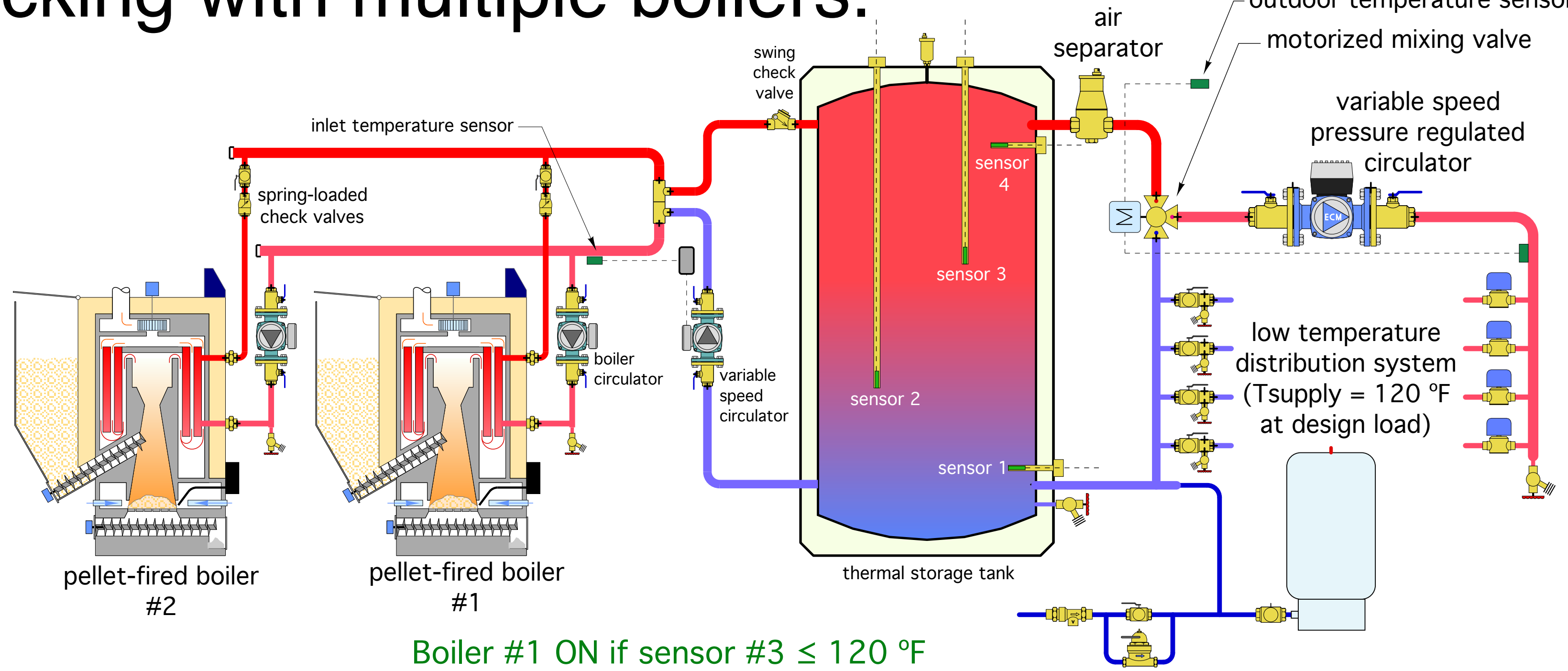
Control logic for heat stacking with combination of pellet-fired boiler and auxiliary mod/con boiler.

Aux. boiler only enabled when heating demand is present.





Heat stacking with multiple boilers.

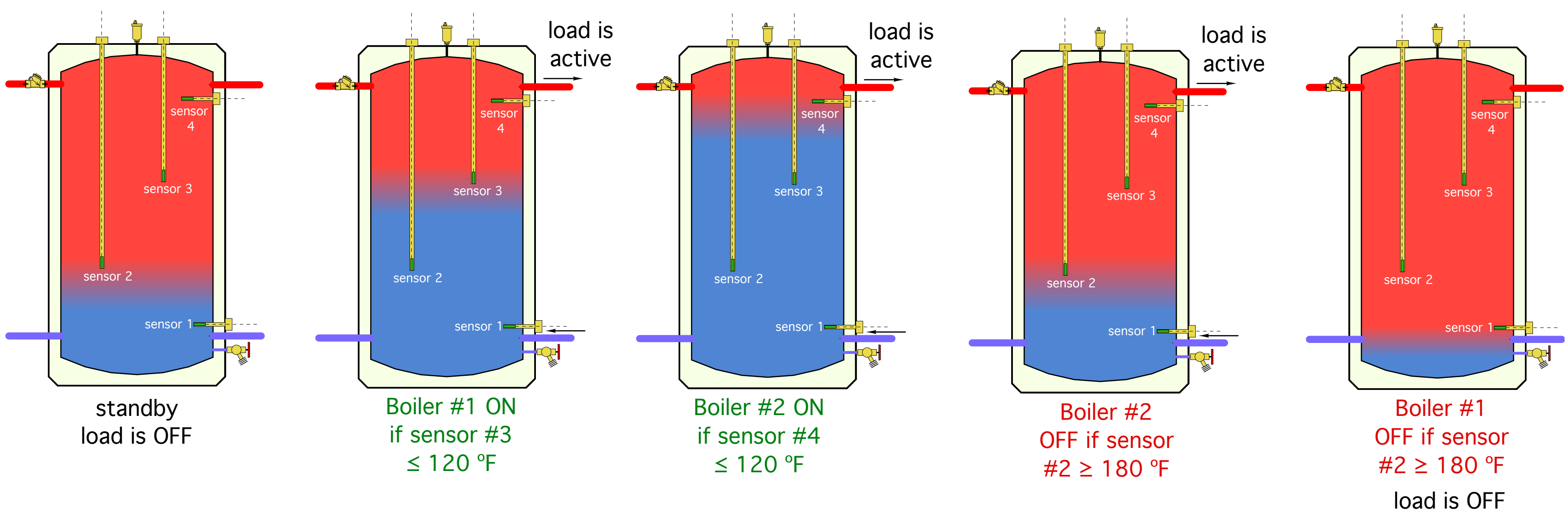


Boiler #1 ON if sensor #3 ≤ 120 ºF

Boiler #2 ON if sensor #4 ≤ 120 ºF

Boiler #2 OFF if sensor #2 ≥ 180 ºF

Boiler #1 OFF if sensor #1 ≥ 180 ºF

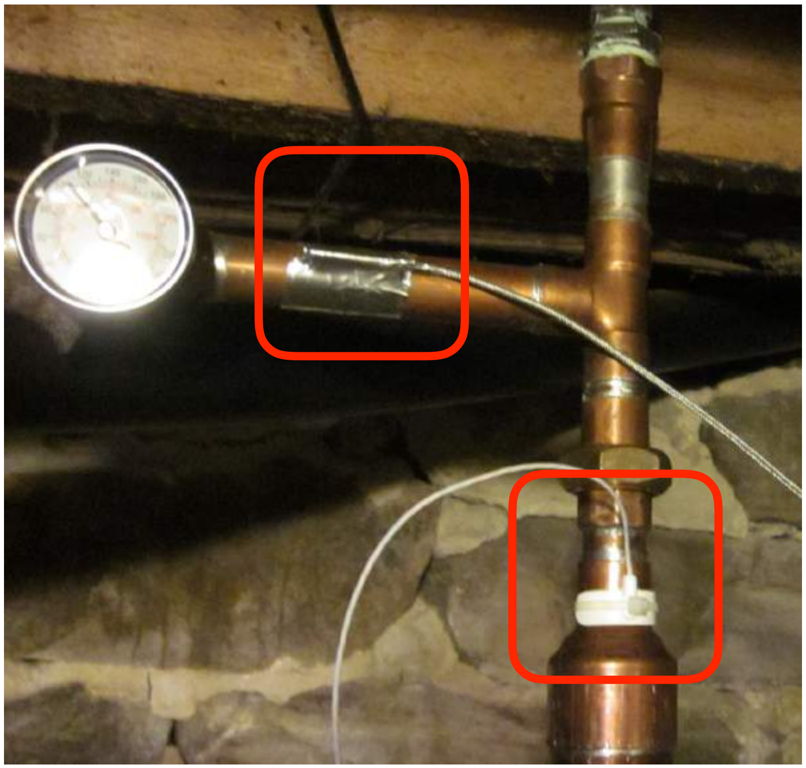


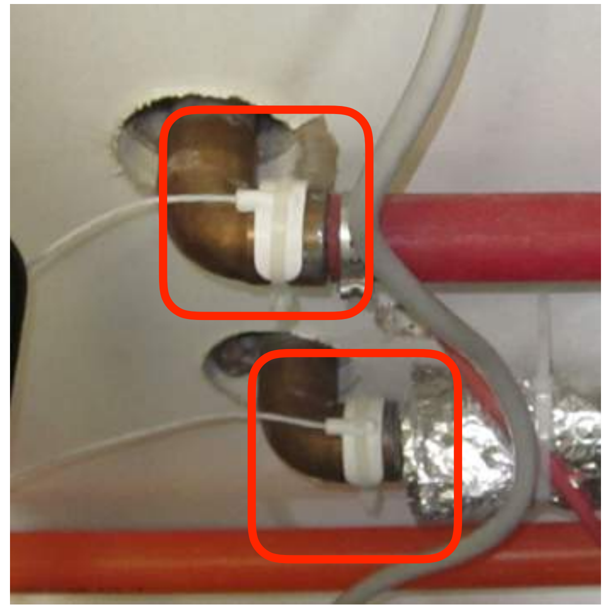
Poor temperature sensor placement

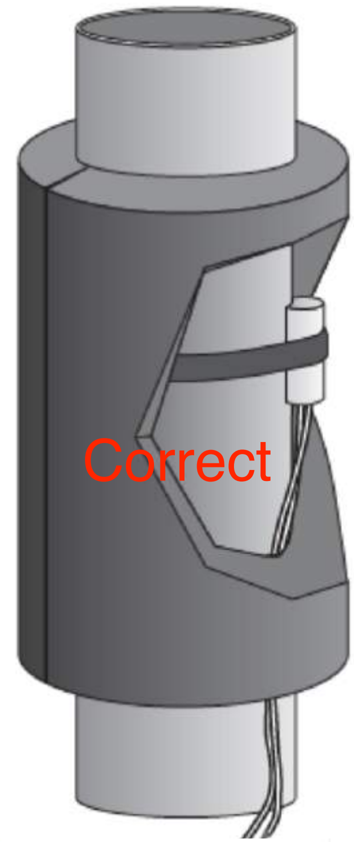
Poor sensor placement or lack of insulation

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.





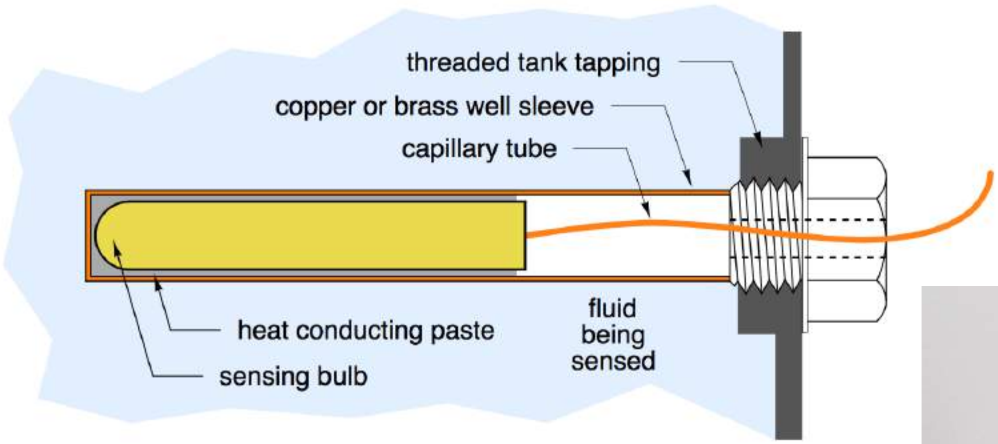


non-insulated surfaced mounted temperature sensors

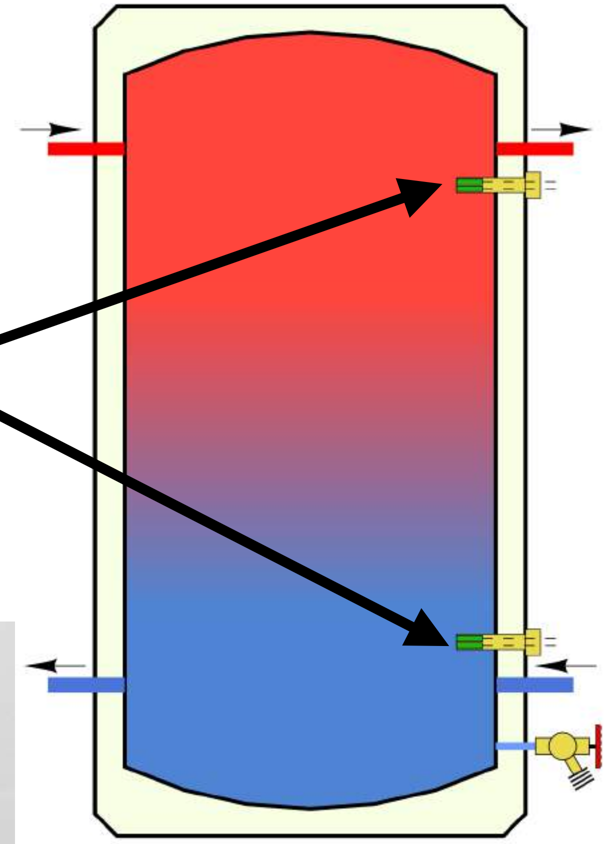
Some sensors have a concave shape to fit OD of pipe.

Poor sensor placement or lack of insulation

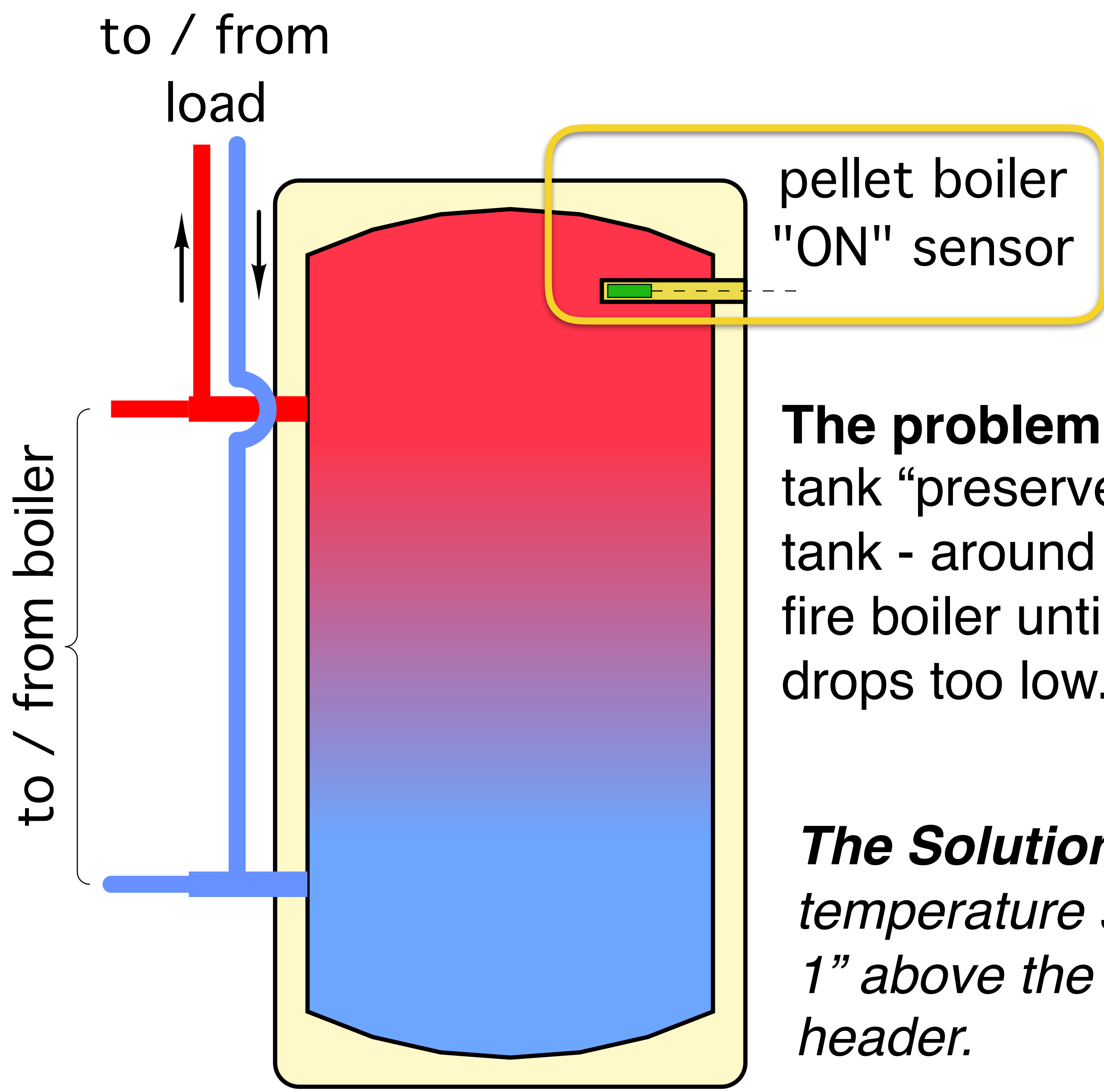
Solution: When measuring the temperature within heat sources, or thermal storage tanks, use a sensor well, and thermal grease.



sensors in wells



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



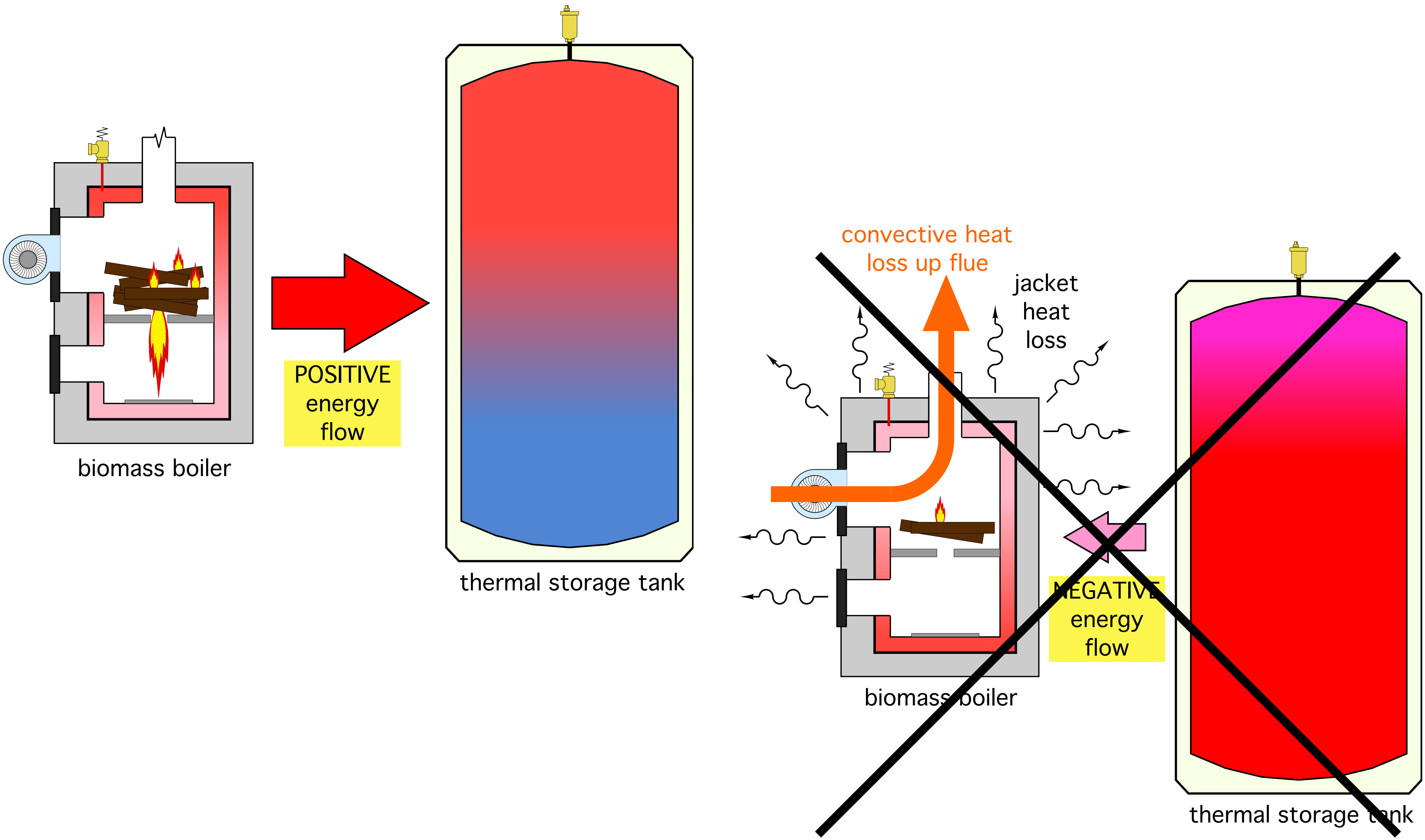
The problem: Stratification within tank “preserves” hot water at top of tank - around sensor - and fails to fire boiler until water temperature drops too low.

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

Negative Energy Flow
(from storage to biomass boiler)
&
how to prevent it

What is “Negative energy flow?”

Answer: Any condition that inadvertently transfers heat from thermal storage to the biomass boiler.

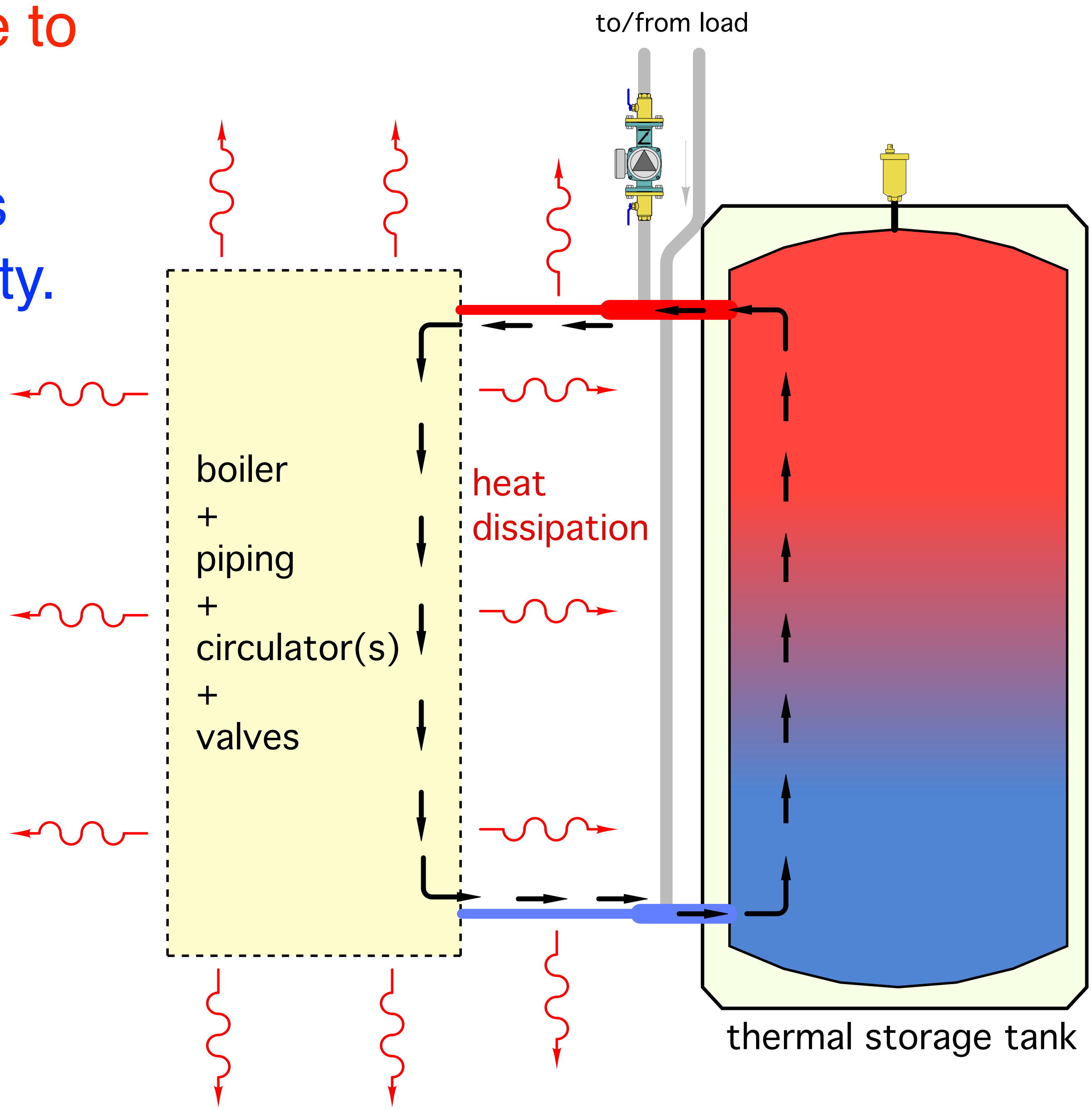


Reverse thermosiphoning is one form of negative energy flow.

Heated water rises due to reduced density.

Cooler water descends due to increased density.

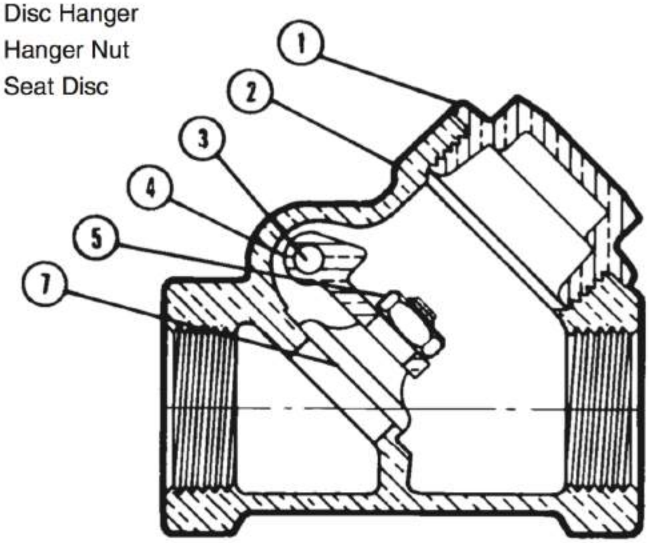
If unimpeded, warm water will flow out of tank, through any available path, dissipate heat in the process, and flow back into lower portion of tank.

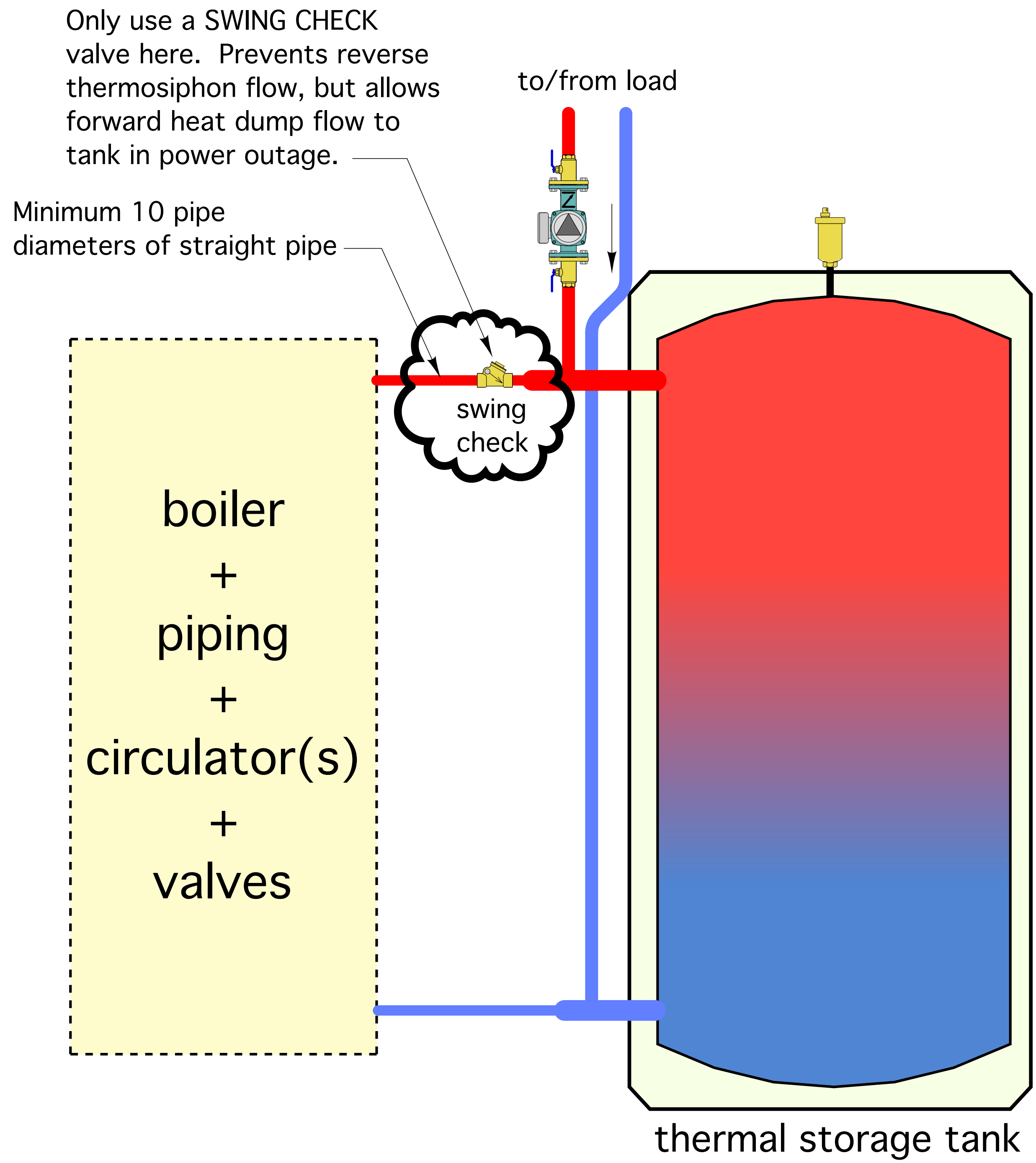


Use **swing check valve** to prevent reverse thermosiphoning.

swing check valves have virtually no resistance to forward thermosiphon flow

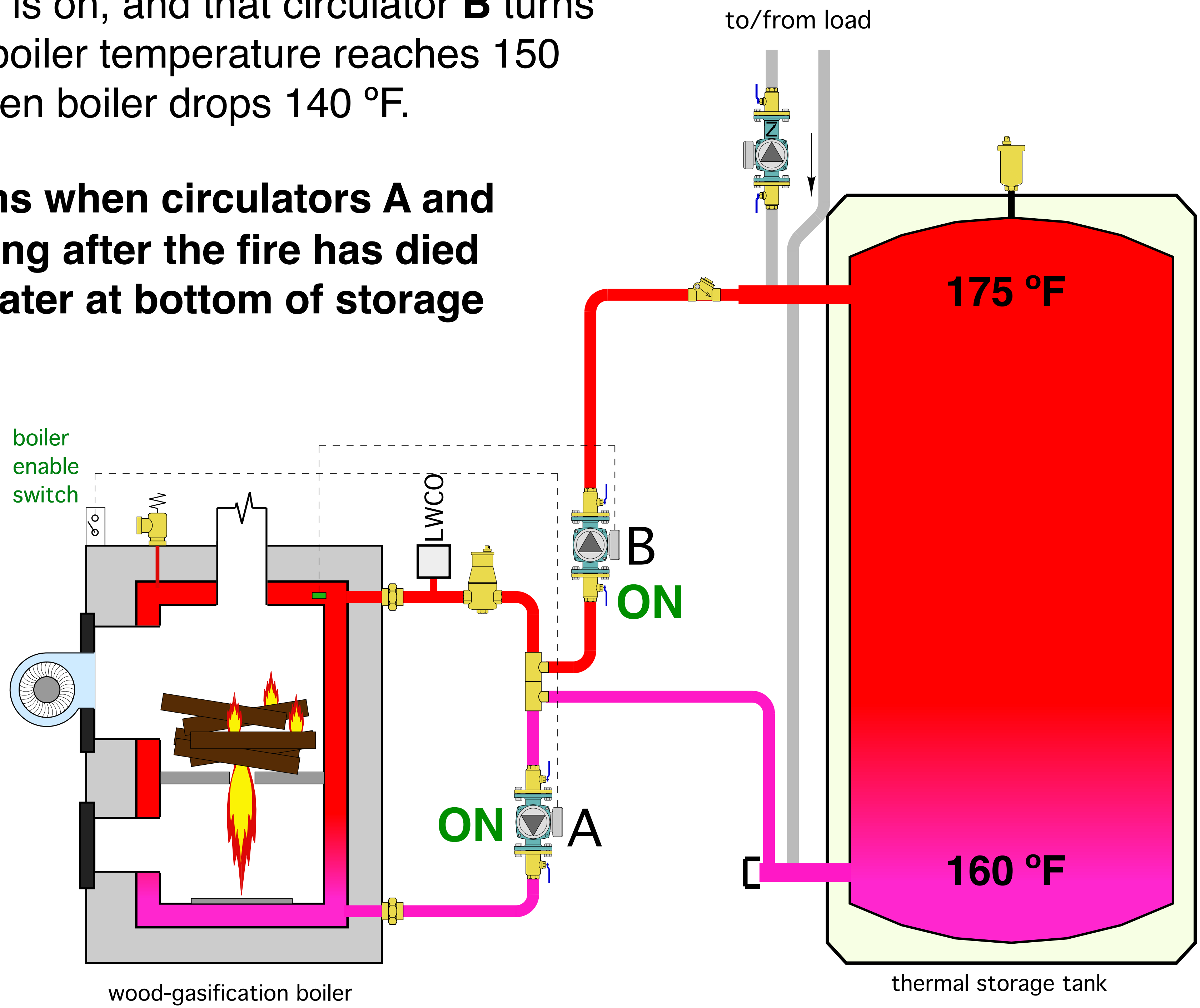
1. Bonnet
2. Body
3. Hinge Pin
4. Disc Hanger
5. Hanger Nut
7. Seat Disc





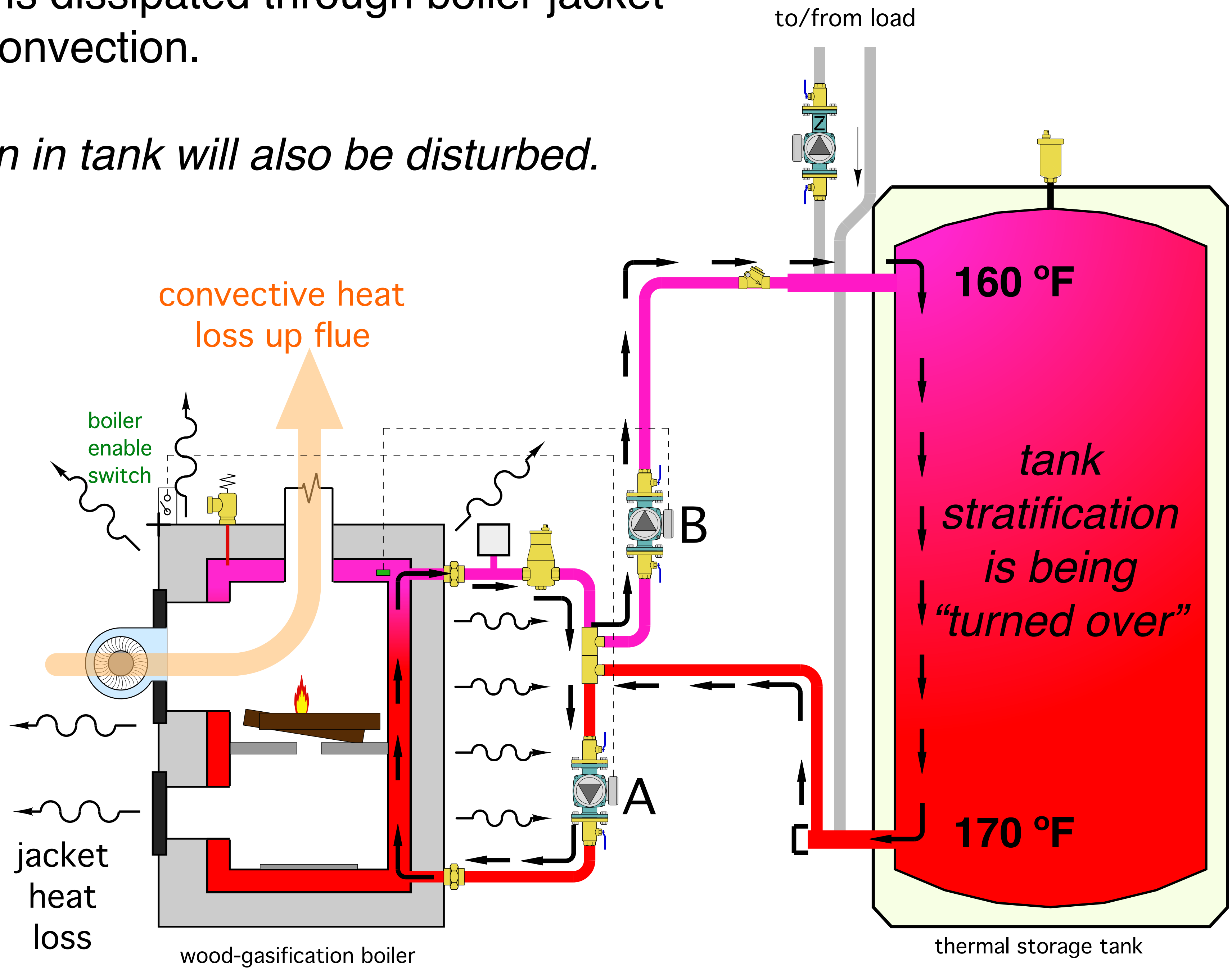
Assume circulator **A** is on whenever the boiler enable switch is on, and that circulator **B** turns on when the boiler temperature reaches 150 °F, and off when boiler drops 140 °F.

What happens when circulators A and B keep running after the fire has died down, and water at bottom of storage is 160 °F?



ANSWER: Hot water passes out the lower tank connection, through the piping and boiler, where heat is dissipated through boiler jacket and stack convection.

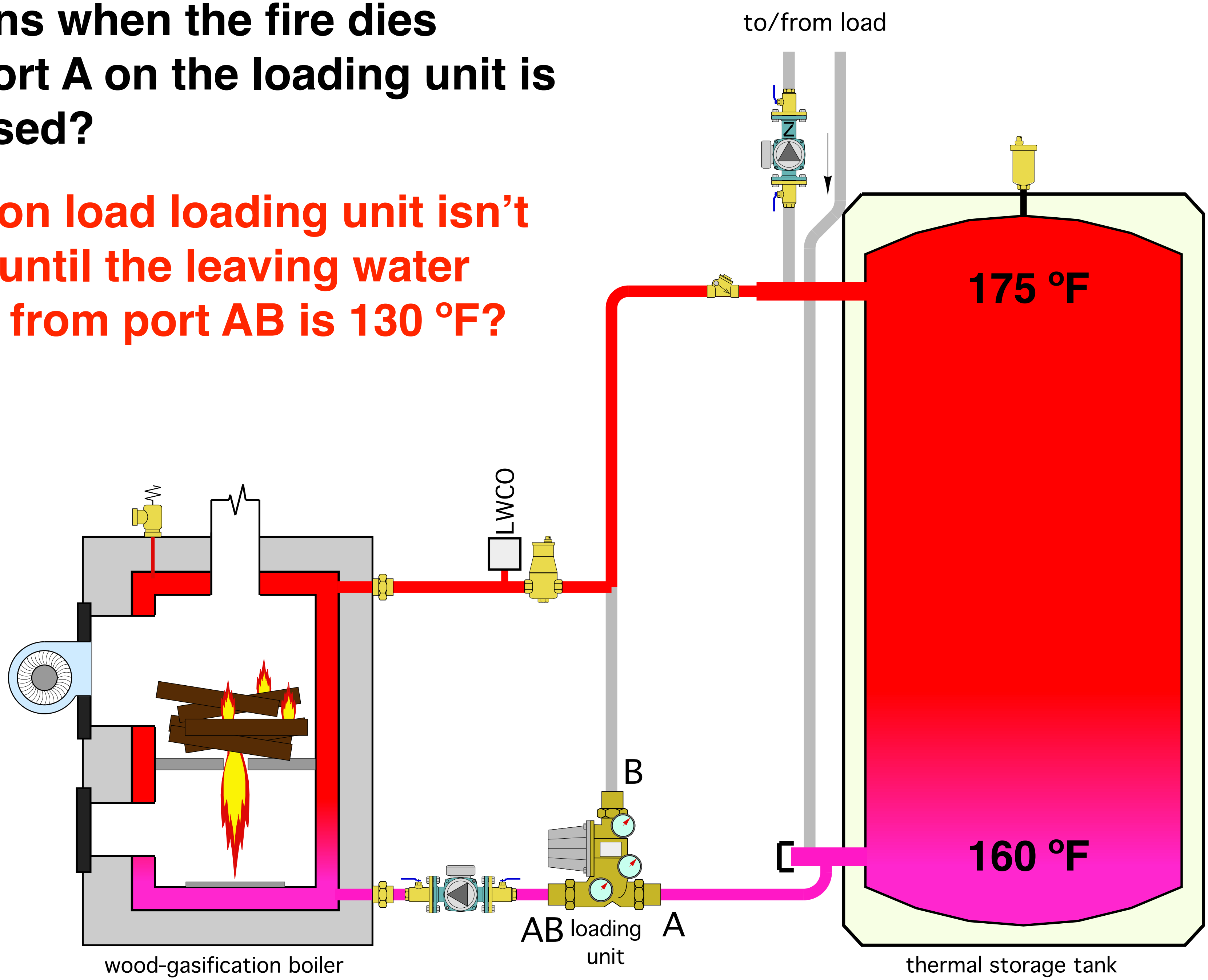
Stratification in tank will also be disturbed.



Assume that the loading unit is on whenever the boiler enable switch is on.

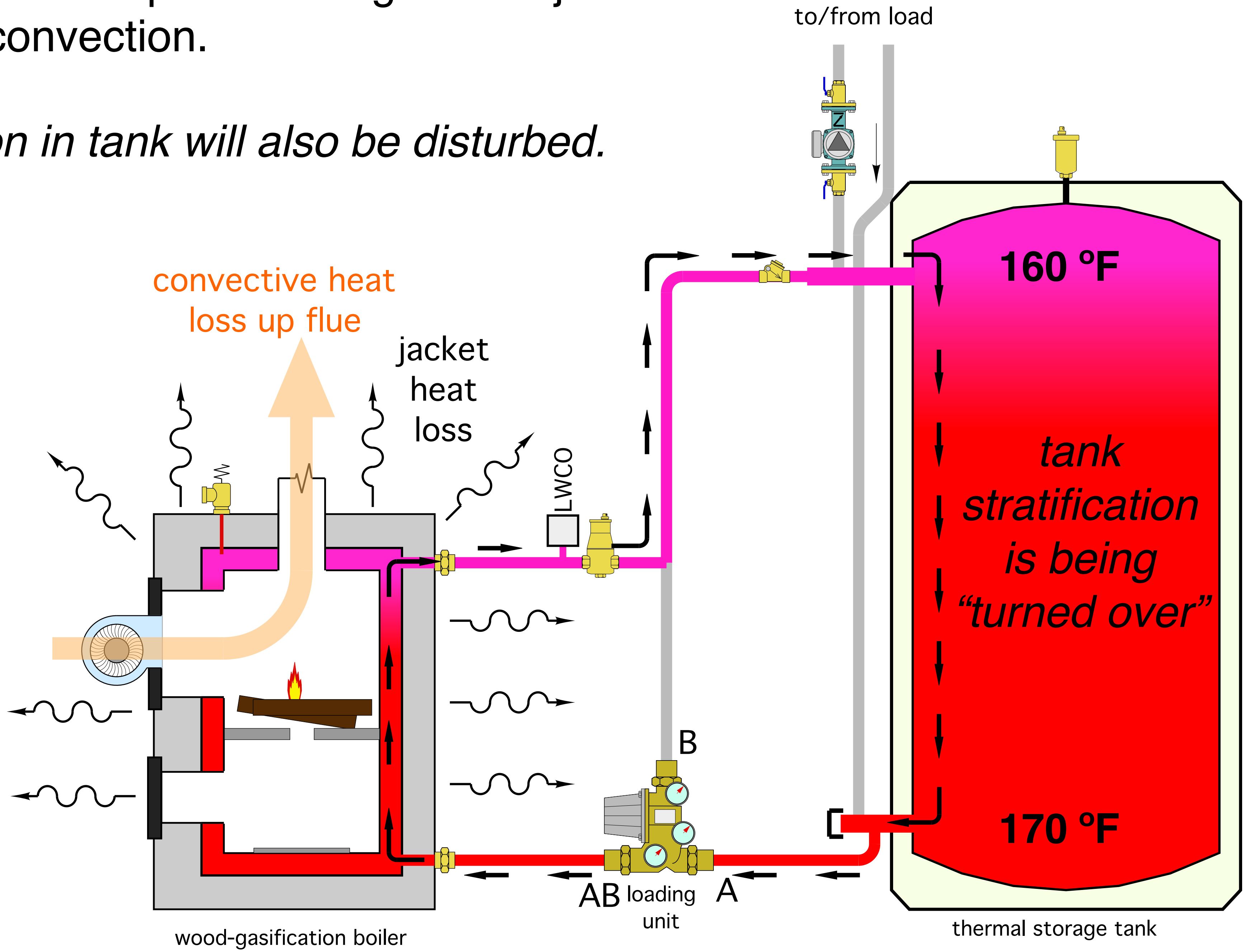
What happens when the fire dies down, but port A on the loading unit is not fully closed?

Hint: Port A on load loading unit isn't fully closed until the leaving water temperature from port AB is 130 ºF?

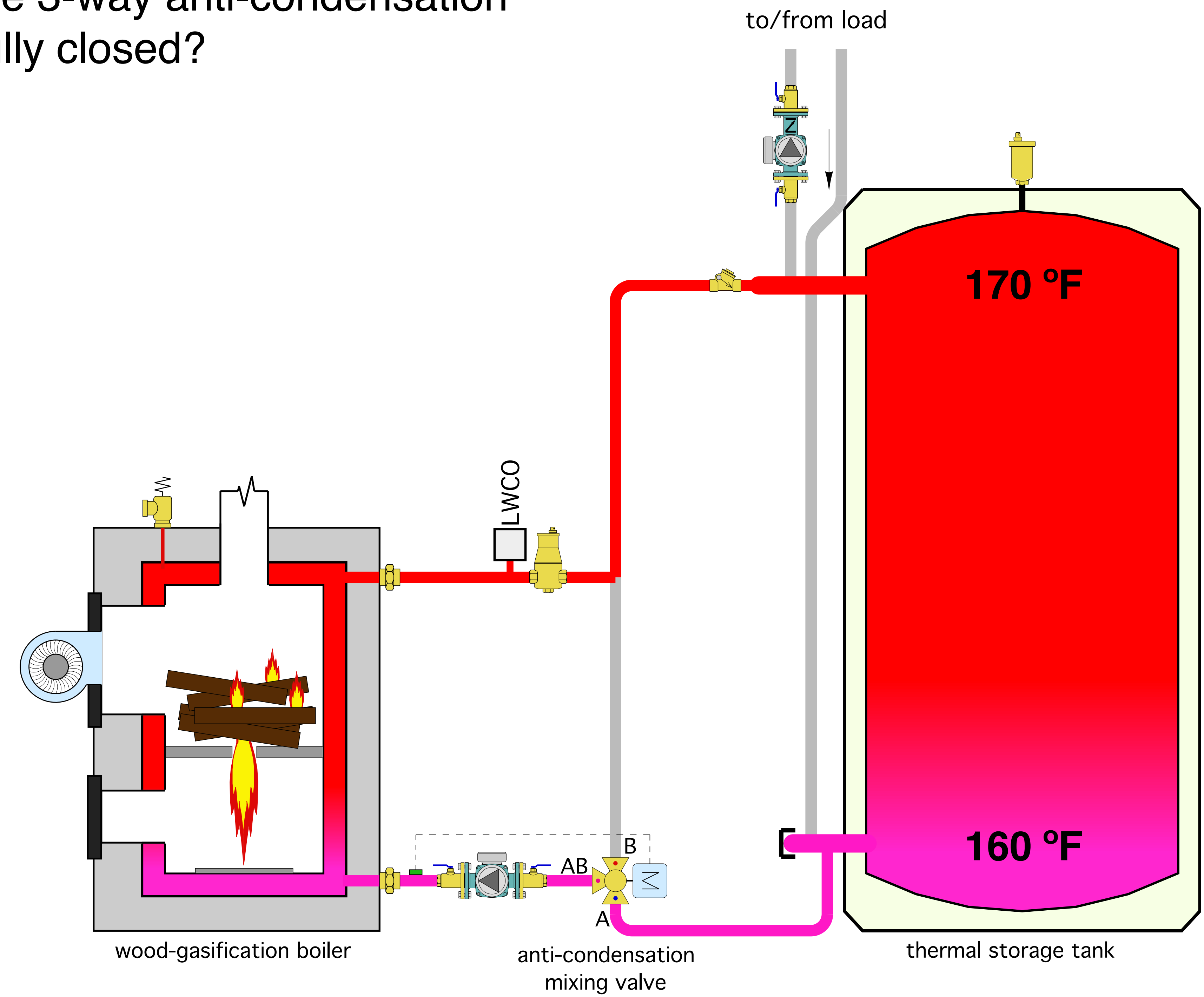


ANSWER: Hot water passes out the lower tank connection, through the piping and boiler, where heat is dissipated through boiler jacket and stack convection.

Stratification in tank will also be disturbed.

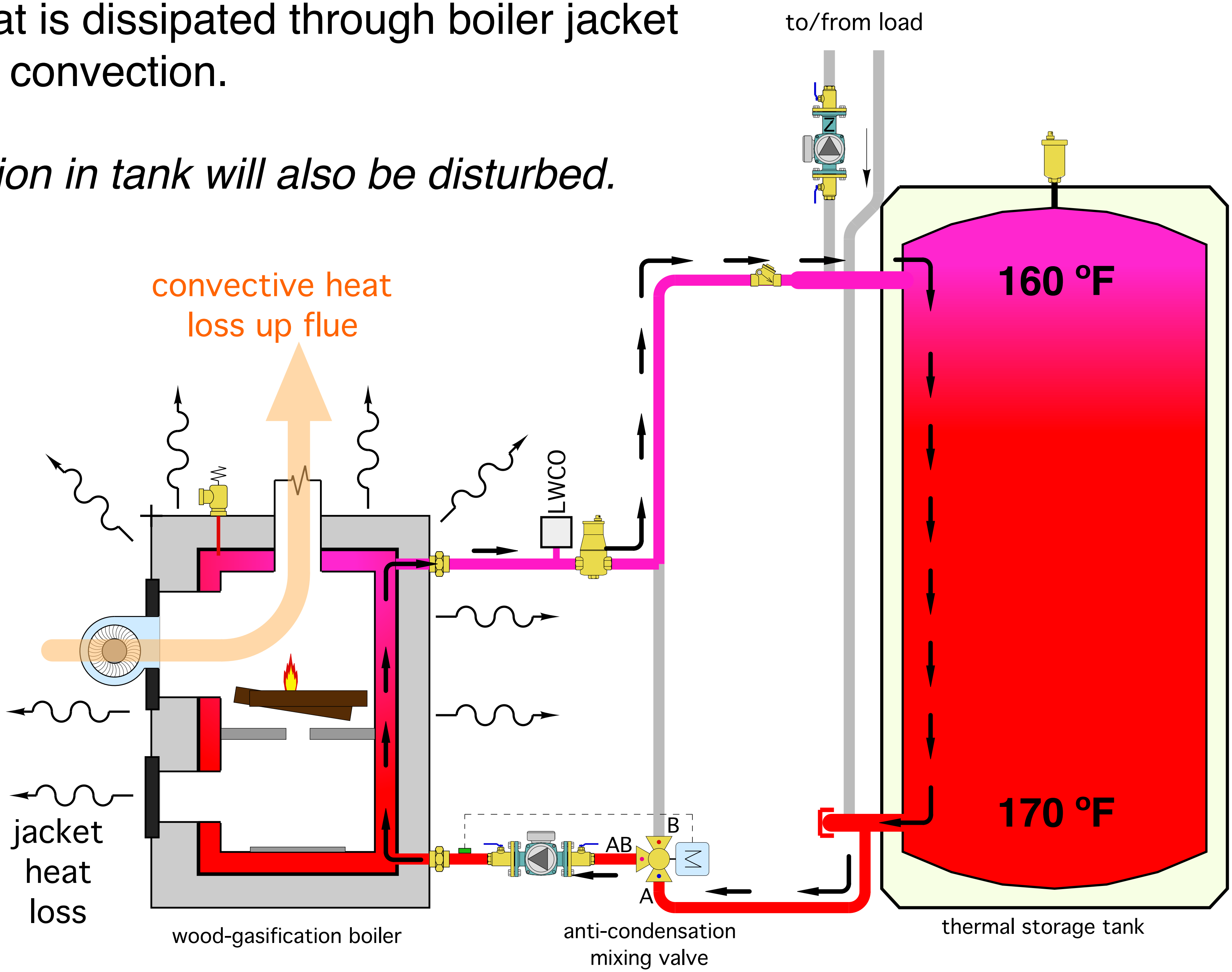


What happens as the fire dies down, but port A on the 3-way anti-condensation valve not fully closed?



ANSWER: Hot water passes out the lower tank connection, through the piping and boiler, where heat is dissipated through boiler jacket and stack convection.

Stratification in tank will also be disturbed.

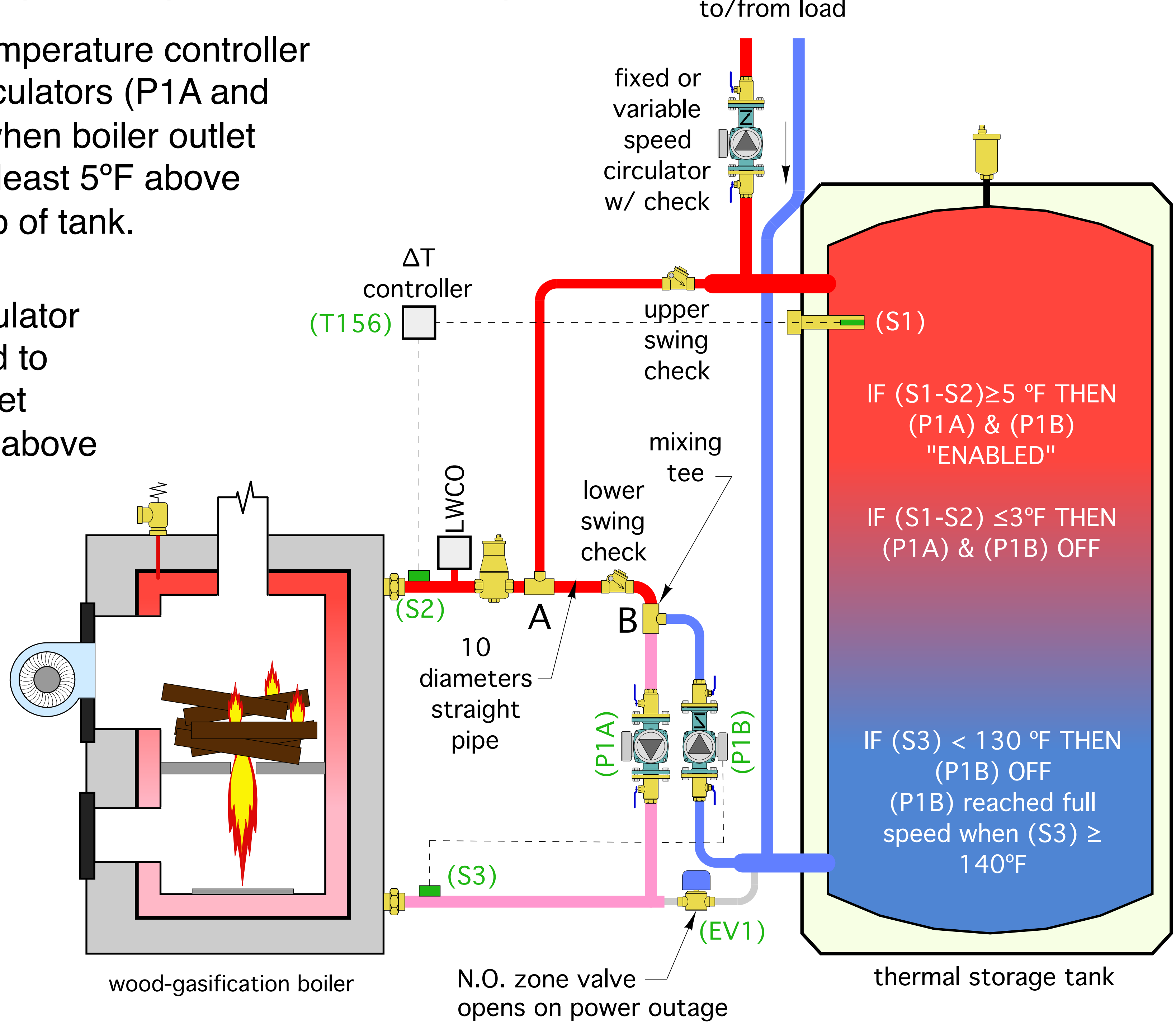


Preventing Negative energy flow

The differential temperature controller allows the two circulators (P1A and P1B) to operate when boiler outlet temperature is at least 5°F above temperature at top of tank.

The speed of circulator (P1B) is controlled to keep the boiler inlet temperature at or above 130 °F whenever possible.

Lower swing check prevents the flow created by (P1B) from “turning over” the tank (e.g., disturbing stratification).

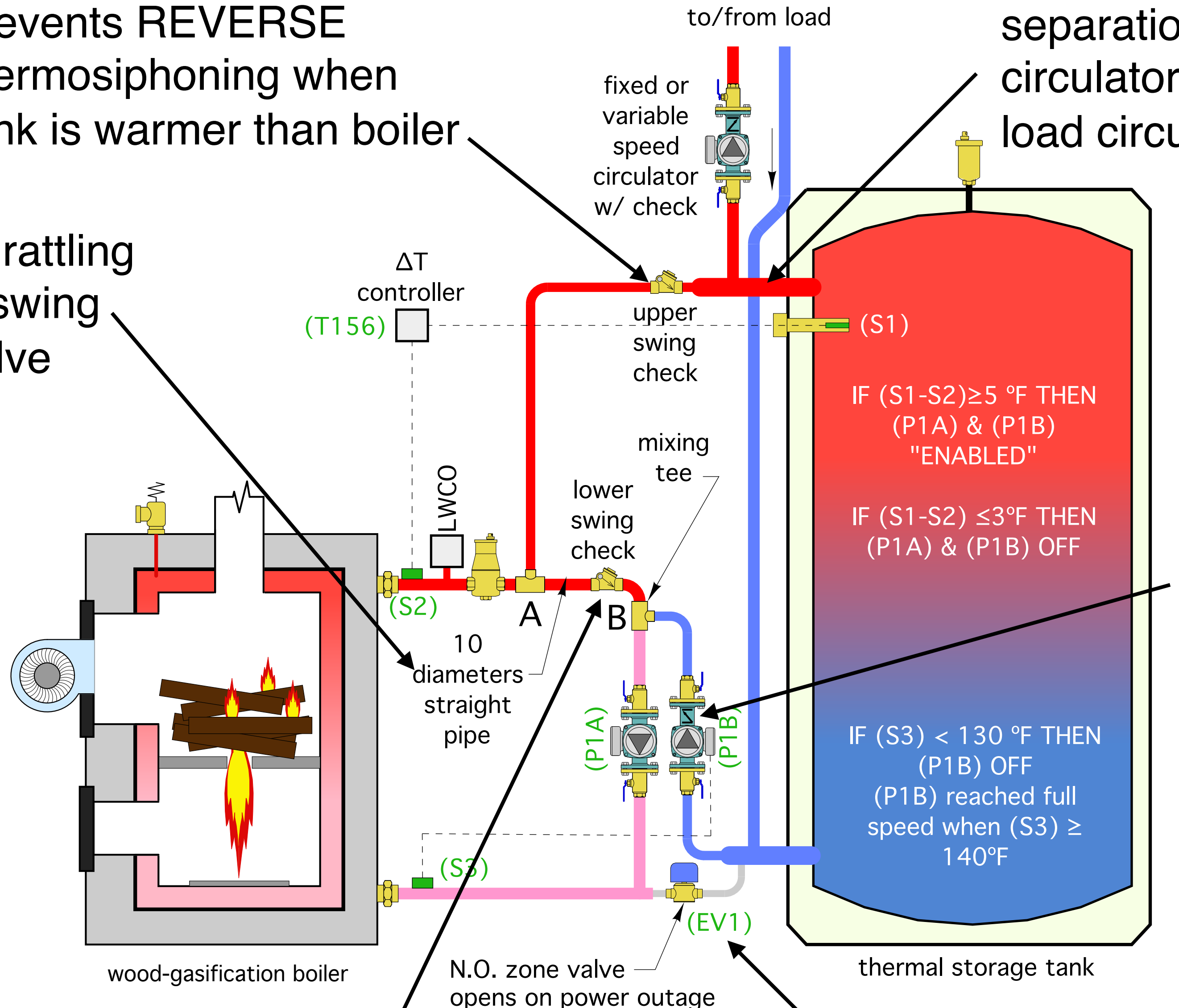


Preventing Negative energy flow

Short headers and tank provide hydraulic separation b/w load circulator and (P1B) & load circulator

prevents REVERSE thermosiphoning when tank is warmer than boiler

prevents rattling of lower swing check valve

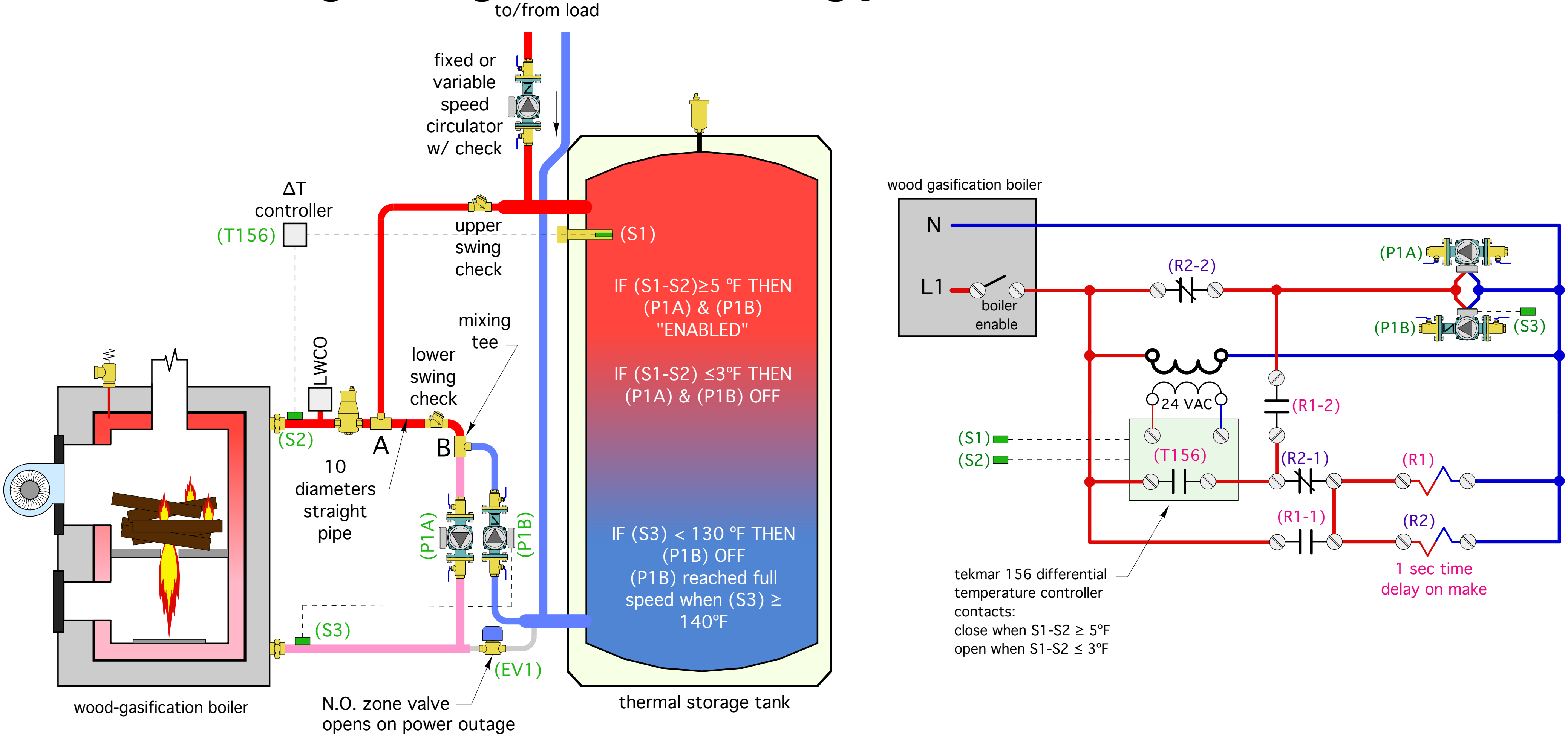


Spring check in circulator (forward 0.3 psi opening pressure) prevents return flow from load from bypassing tank.

prevents flow from bottom to top of tank if (P1B) flowrate > (P1A) flowrate

normally open zone valves opens on power outage to allow thermosiphoning

Preventing Negative energy flow



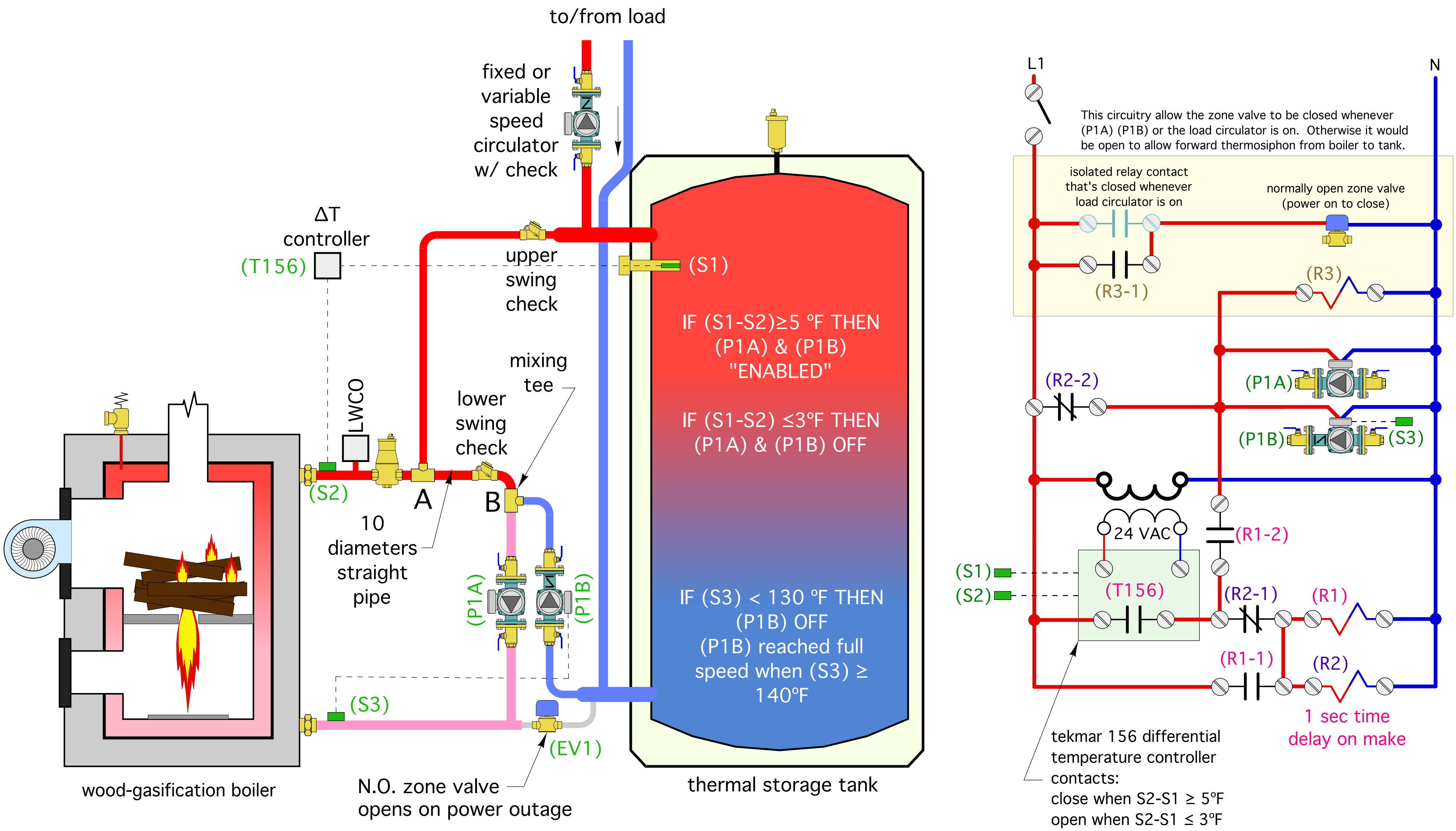
The differential temperature controller allows the two circulators (P1A and P1B) to operate when boiler outlet temperature (S2) is at least 5ºF above tank top temperature (S1).

The speed of circulator (P1B) is controlled to keep the boiler inlet temperature at or above 130 ºF whenever possible.

Preventing Negative energy flow

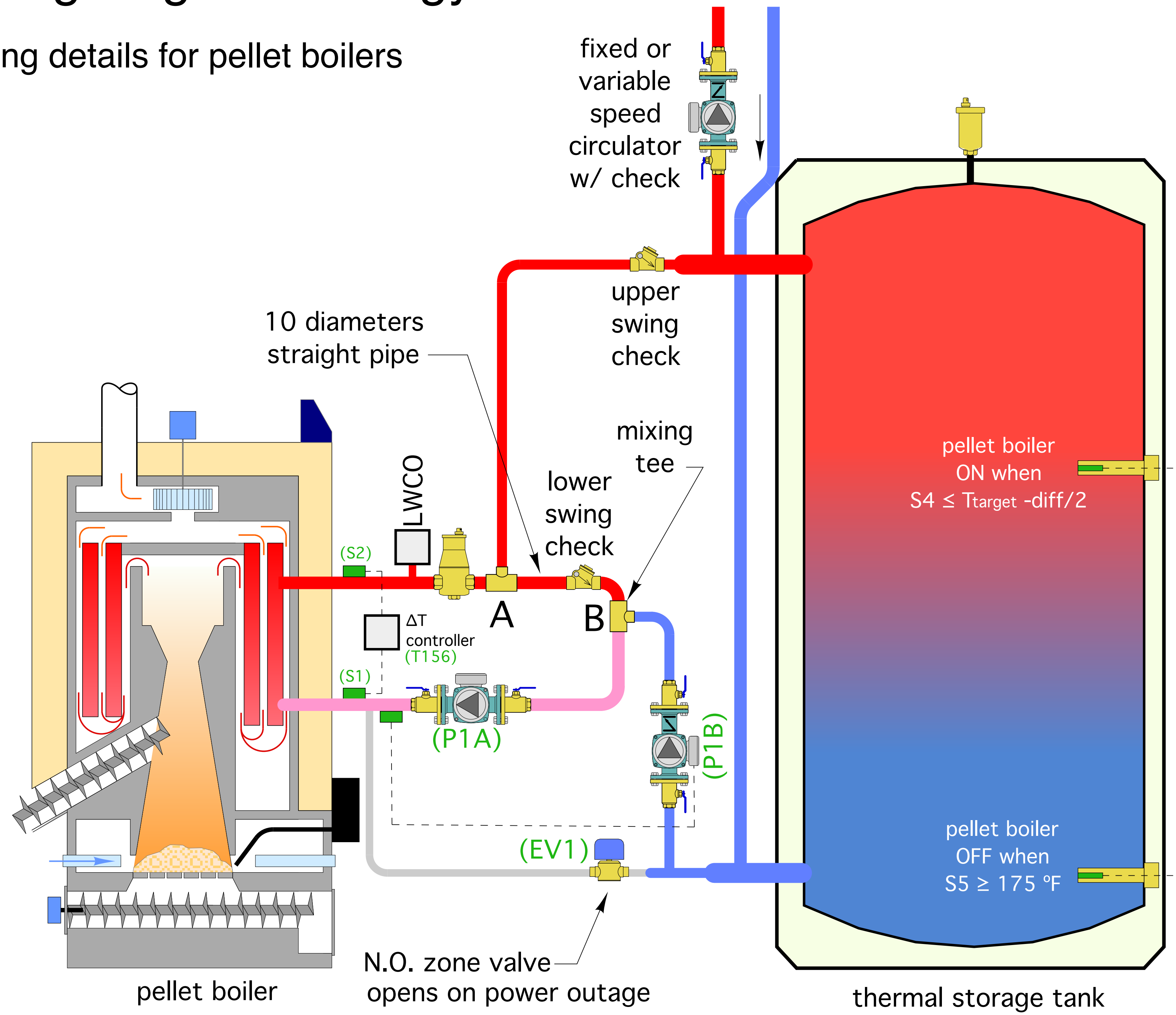
Same ΔT logic as previous slide.

The bypass valve (EV1) is open except when any of the 3 circulators is on.



Preventing Negative energy flow

Similar piping details for pellet boilers

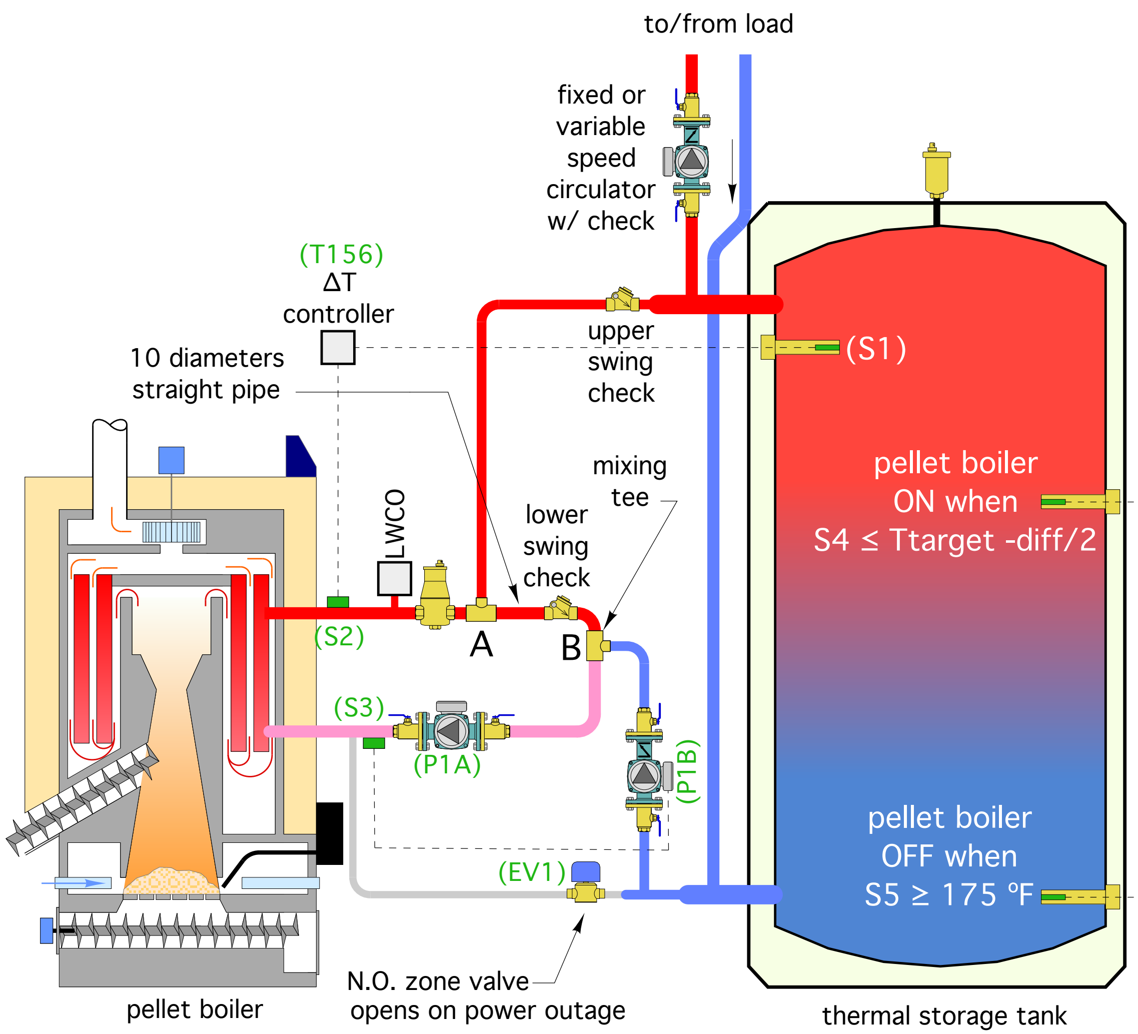


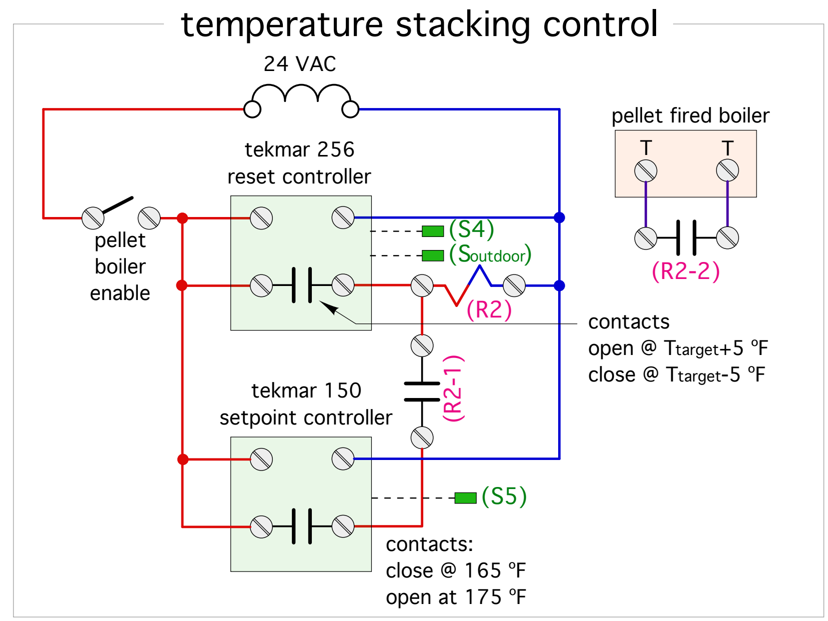
Preventing Negative energy flow

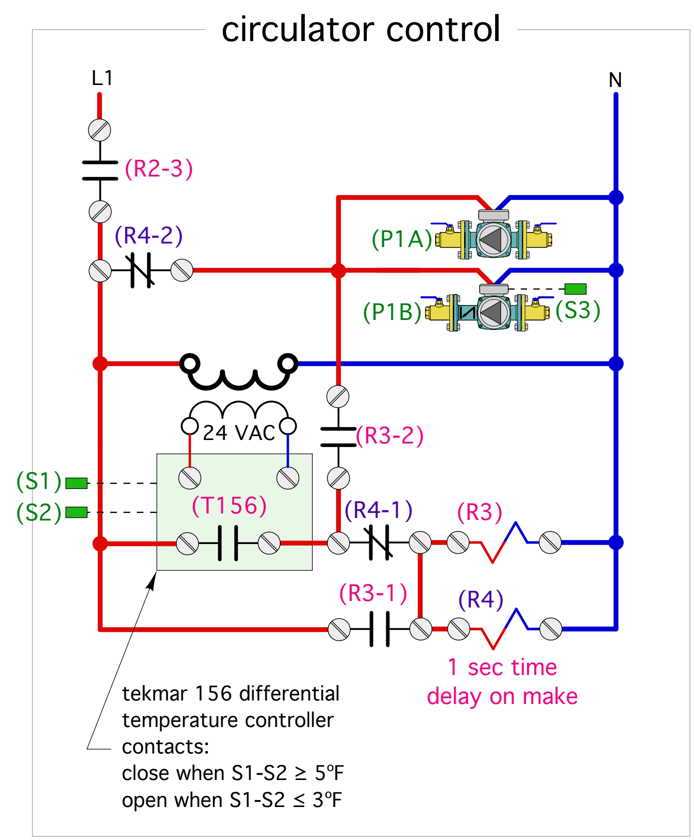
Control subsystems:

1. Manages flow between boiler and tank.

2. Uses temperature stacking logic for turn pellet boiler on / off.







Sizing thermal storage

Thermal Storage Tank Sizing for wood-gasification boilers

The sizing procedure that follows is appropriate for wood-gasification boilers. ***It assumes that the thermal storage tank absorbs 95% of the heat released from burning a full charge of firewood, without any concurrent heating load.*** The volume of the required thermal storage tank can be determined using the following formula

$$v = \frac{701(w)(n)}{\Delta T}$$

Where:
v = required thermal storage tank volume (gallons)
w = weight of firewood that can be loaded in the combustion chamber (lb)
n = average efficiency of the combustion process (decimal percent)
ΔT = temperature rise of the tank based on absorbing all heat from the combustion (°F)
701 = a constant based on the heating fuel value associated with 20% moisture content firewood.

Thermal Storage Tank Sizing for wood-gasification boilers

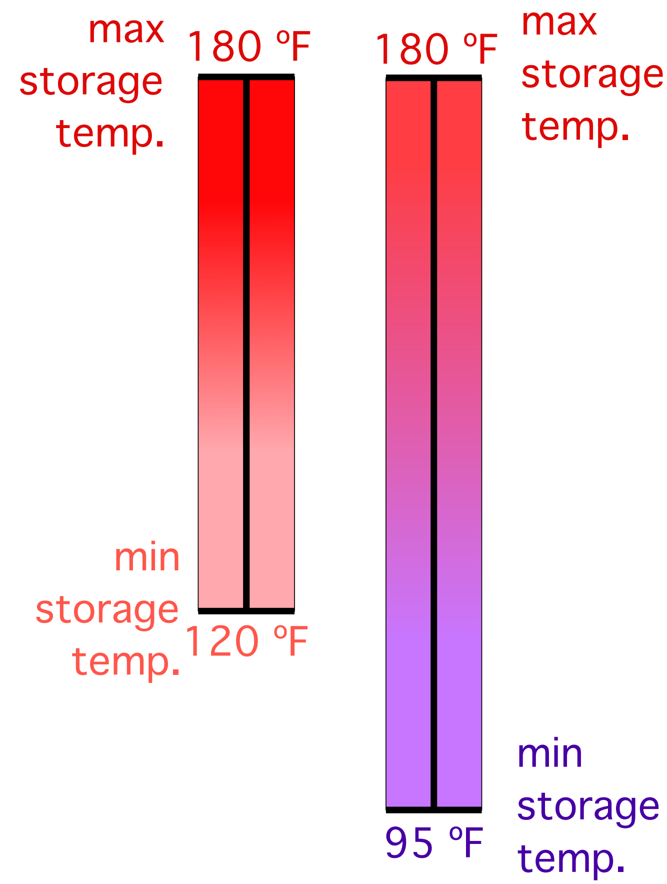
Example: Assume that the firebox of a wood-gasification boiler, when fully loaded, can hold 65 pounds of seasoned firewood (20% m.c.). The boiler's average combustion efficiency ***for a complete burn cycle*** is 70%. Determine the thermal storage tank volume needed assuming the water in the tank will rise 60 °F as it absorbs 95% of the heat generated by burning the full charge of wood.

Solution: Putting the data into the formula yields:

$$v = \frac{701(w)(n)}{\Delta T} = \frac{701(65)(0.70)}{60} = 532\,gallons$$

This result shows that a substantial tank volume may be required in systems using wood-gasification boilers.

This volume can be achieved with a single tank, or by combining multiple tanks piped in parallel.



ΔT 0f 85°F (180-95) yields 42% more Btu storage per gallon than ΔT of 60 °F (180-120)

One way to reduce the required volume is to implement a control strategy that widens the temperature range over which the tank is used. With the upper temperature typically limited to 200 °F, ***the temperature range of the thermal storage tank can be widened by reducing the temperature at which the space-heating distribution system operates.***

Renewable Heat New York tank sizing criteria for wood-gasification boilers:

$$V_{tank} = [130 \times V_{cc}] - V_{wj}$$

where:

V_{tank} = volume of thermal storage (gallons)

V_{cc} = volume of primary combustion chamber (ft^3)

Vwj = volume of boiler water jacket (gallons)

Example: A wood gasification boiler has a combustion chamber measuring 16” x 20” x 24”. Its water jacket holds 35 gallons of water. What is the required size of the thermal storage tank based on the above formula?

$$V_{cc} = (16in)(20in)(24in)\left(\frac{1ft^3}{1728in^3}\right) = 4.44\,ft^3$$

$$V_{tank} = [130 \times V_{cc}] - V_{wj} = [130 \times 4.44] - 35 = 542\,gallons$$

Boiler	Useable firebox volume (ft^3)	Multiplier (gallons/ft^3)	Water jacket volume (gallons)	=	Full thermal storage volume (gallons)	Acceptable sizing for commonly available vessels* (gallons)
A	5.0	130	32	=	618	600
B	6.3	130	42	=	777	700

* must be within 10%

http://www.nyserda.ny.gov/-/media/Files/FO/Current%20Funding%20Opportunities/PON%203010/3010alldocs.pdf

Sizing the storage tank for a modulating pellet fuel boiler

European recommendations: 1-2 gallons of buffer tank storage per 1,000 Btu/hr of boiler capacity.

Renewable Heat NY will require 2 gallons of buffer tank storage per 1,000 Btu/hr of boiler capacity.

The requirement for water-side thermal storage is also partially determined by the thermal mass and zoning of the heating distribution system.

High thermal mass + minimal zoning = minimal need for water-side thermal storage

Low thermal mass + extensive zoning = maximum need for water-side thermal storage

This topic is being researched, and the results should lead to more specific guidance on thermal storage in the near future.

Sizing considerations for wood-fired boilers

Impact of Wood Boiler Oversizing

Increased footprint requirements within limited boiler room space. (May require separate building to house boiler).

Significant capital cost premium for boiler.

Increased capital cost premium for fuel moving components.

Increased capital cost premium for flue gas treatment if necessary.

Excess hours under idle or low part-load operating conditions.

Efficiency penalty due to increased thermal mass re: start-up for morning heat during Fall/Spring shoulder seasons.

Increased emissions due to lower average flame temperature during part-load conditions.

Source: Technical and Economic Sizing Considerations for Commercial and Industrial Wood-fired Boiler Systems “Small can be beautiful”, Ray Albrecht, P.E. 2012, http://nebiomassheat.com/pdfs/2012/keyPrinciples/albrecht_boiler.pdf

Sizing a wood gasification boiler

Don't size a wood gasification boiler based on its BTU/hr rating!

These boilers operate on "batches" of combustion rather than quasi-steady operation.

The sizing of a wood-gasification boiler is based on the number of firing cycles the owner is comfortable with during a design day.

Two complete firing cycles during a design day is common.

$$W = \frac{[T_{inside} - (T_d + 5)]\left(UA_b\right)24 + E_{daily}}{eCN}$$

Where:

W = weight of firewood required to fill firebox of wood gasification boiler (lb)
T_{in} = indoor air temperature for design load conditions (ºF)
T_d = outdoor design air temperature (ºF)
UA_b = heat loss coefficient of building (Btu/hr/ºF)
24 = hour in day
E_{daily} = daily heat required for domestic hot water (Btu)
e = average efficiency of wood gasification boiler while operating (decimal %)
C = lower heating value of firewood being used (Btu/lb)
N = number of complete firing cycles per day under design load conditions
5 = the 24 hour average outdoor temperature is assumed to be 5 ºF above the outdoor design temperature

The sizing of a wood-gasification boiler is based on the number of firing cycles the owner is comfortable with during a design day.

Example: Estimate the firebox size, based on weight of wood it can contain, for a wood gasification boiler that supplies a building with a design heating load of 50,000 Btu/hr in a climate where the outdoor design temperature is -5 ºF, and the desired indoor temperature is 70 ºF. The building also requires 60 gallons per day of domestic hot water heated from 50 to 120 ºF. ***The owner wishes to have no more than two complete firing cycles during a design day.*** Assume the wood gasification boiler will be burning sugar maple at an average moisture content of 20%, and has an average combustion efficiency of 80%.

Solution: The value of UA_b is found by dividing the design heat load by the design temperature difference:

$$UA_b = \frac{50{,}000\frac{Btu}{hf}}{70^\circ F - (-5^\circ F)} = 667\frac{Btu}{hr{\cdot}^\circ F}$$

The daily energy required for domestic water heating is estimated

$$E_{daily} = (G)(8.33)(T_{hot} - T_{cold}) = (60)(8.33)(120 - 50) = 34{,}986\,Btu$$

The lower heating value of the specified wood is estimated:

$$LHV = 7950 - 90.34(w) = 7950 - 90.34(20) = 6143\frac{Btu}{lb}$$

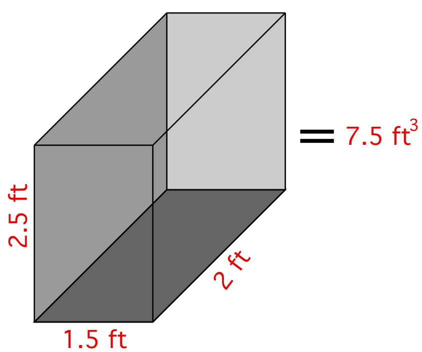
The wood capacity of the firebox is now estimated:

$$W = \frac{[T_{inside} - (T_d + 5)](UA_b)24 + E_{daily}}{eCN} = \frac{[70 - (-5 + 5)](667)24 + 34986}{(0.8)(6143)2} = 118 lb$$

Measurements have shown that typical placement of split hardwood in an operating firebox yields an *effective packing density* of about 15 lb/ft³, thus the total firebox volume required is found as follows:

$$V_{firebox} = \frac{118 lb}{15 \frac{lb}{ft^3}} = 7.9 ft^3$$

This would be the *minimum* firebox volume required, and based on the total internal dimensions of the firebox.



If 3 firings per design day were used, firebox volume = 5.3 ft³:

courtesy of Brookhaven Labs

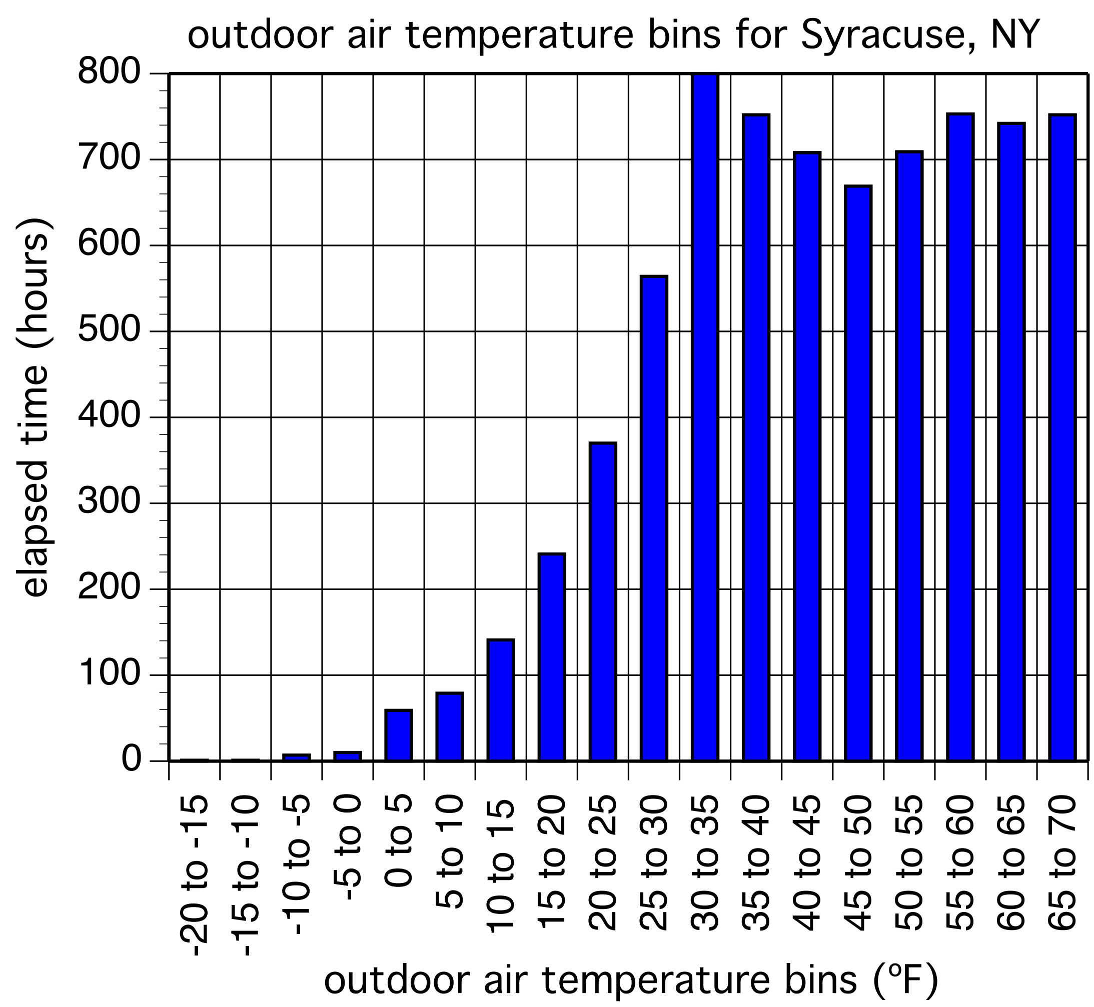
Sizing a pellet-fired boiler

(in combination with an auxiliary boiler)

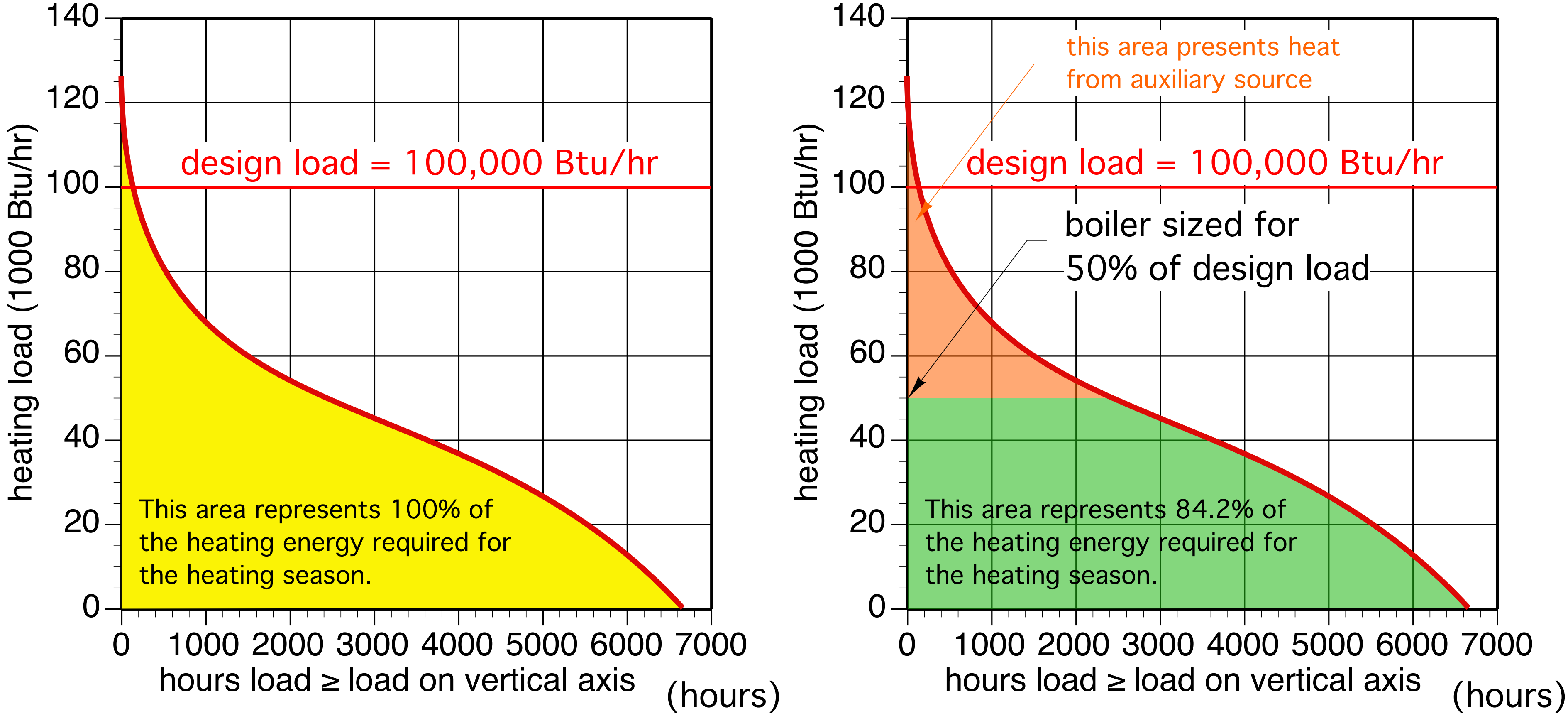
For good thermal and emissions performance, a pellet-fired boiler should operate over long cycles relative to their warm up time.

In situations where an existing boiler is present, or a new "auxiliary boiler" will be used, do not size the pellet-fired boiler to full design load.

Consider partial load analysis:



Partial load analysis:

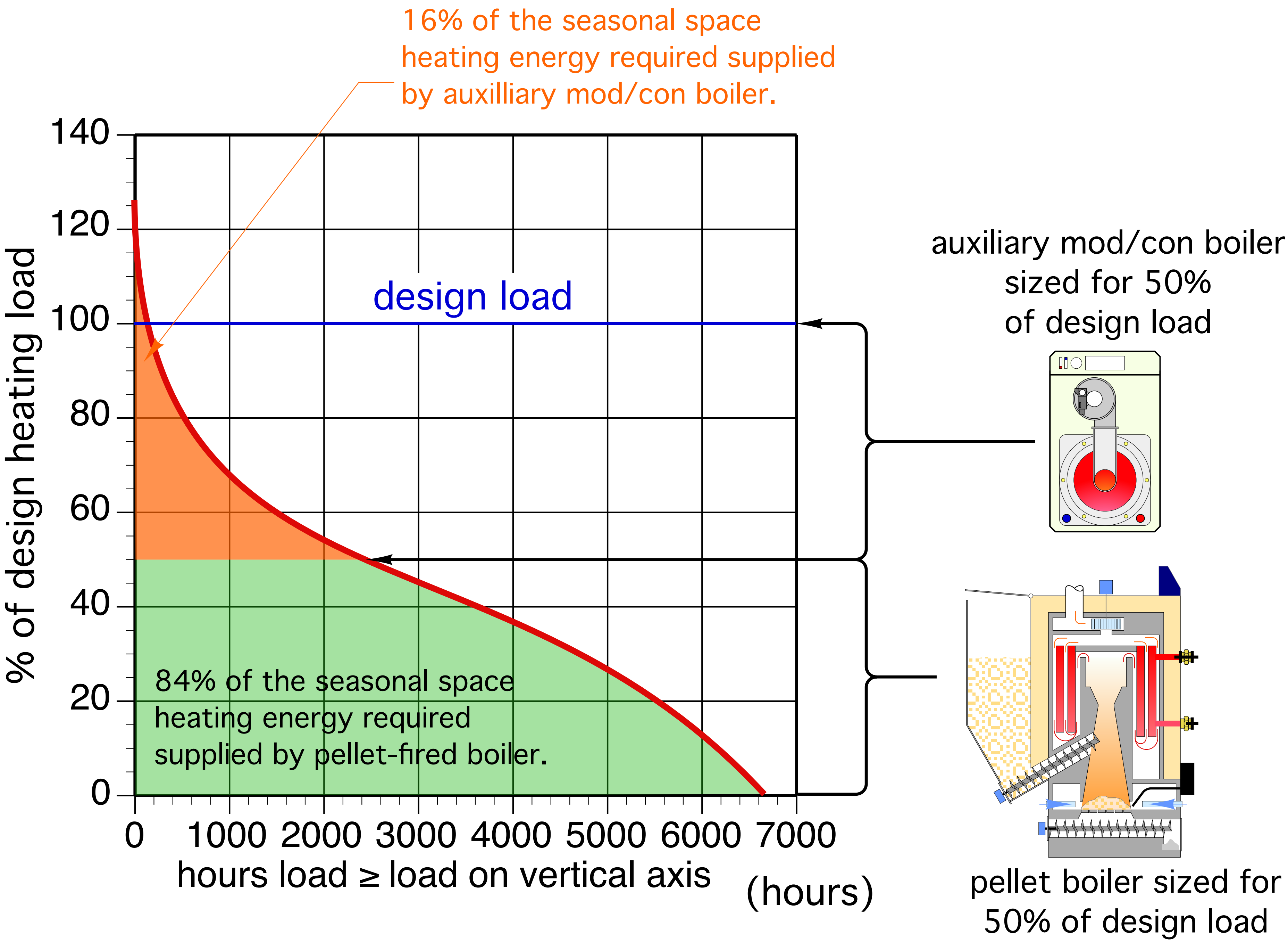


Boiler sized @ 50% of design load provides about 84% of seasonal space heating energy.

Boiler sized @ 60% of design load provides about 90% of seasonal space heating energy.

Boiler sized @ 75% of design load provides about 96% of seasonal space heating energy.

Partial load analysis:



Guidelines for sizing a pellet-fired boiler:

1. ***In systems where the pellet-fired boiler is the only heat source, the boiler is typically sized to the design load of the building.***

2. ***In systems where auxiliary heat is used, DON'T size the pellet boiler for design load.*** **Instead, size the pellet-fired boiler for 60 to at most 75% of design load.**

The higher end being for pellet boiler with wide modulation capabilities such as a 5:1 (or higher) turndown ratio.

This allows the pellet boiler to supply "base load" heating, while leaving only 5 to 10% of the total seasonal heating energy to be supplied by an auxiliary heat source.

3. ***For systems where the pellet boiler is ≥ 300,000 Btu/hr, RHNY requires that the pellet boiler capacity not exceed 60% of design load. Auxiliary heating is needed.***

4. ***For systems where the design heating load is ≥ 300,000 Btu/hr, the use of multiple pellet-fired boilers is encouraged. Higher financial incentives are available through (RHNY) for these "tandem" boiler systems.***

Using Existing Underground Piping

Using existing underground piping

With few exceptions, the insulated underground piping installed for outdoor furnaces is 1” PEX

This existing piping should be evaluated if it is being considered for carrying heat from a new biomass boiler.

For a nominal working temperature drop of 20ºF, the piping and circulator(s) should provide 1 gallon per minute (gpm) of water flow per 10,000 Btu/hr of rated biomass boiler capacity.

Head loss for 1” PEX carrying 150ºF water

$$H_L = \left(\frac{L_{total}}{100}\right)(0.2034) f^{1.75}$$

H_L = head loss (feet)
L_{total} = round trip circuit length (feet)
f = flow rate (gpm)

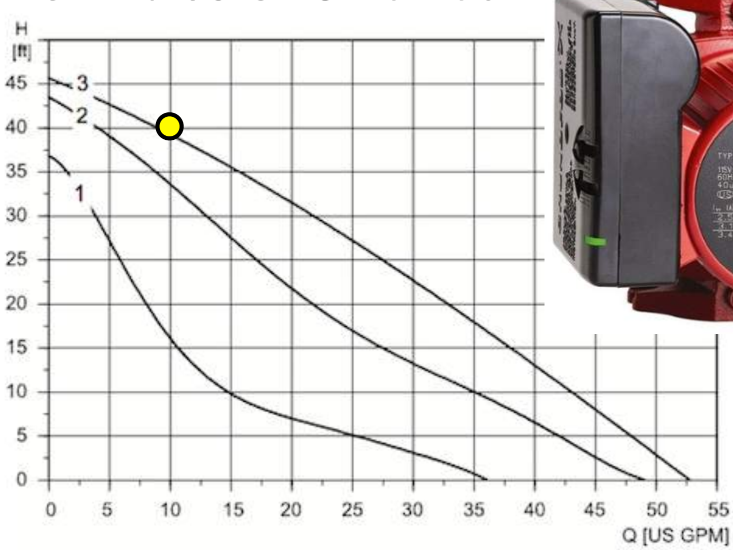
Using existing underground piping

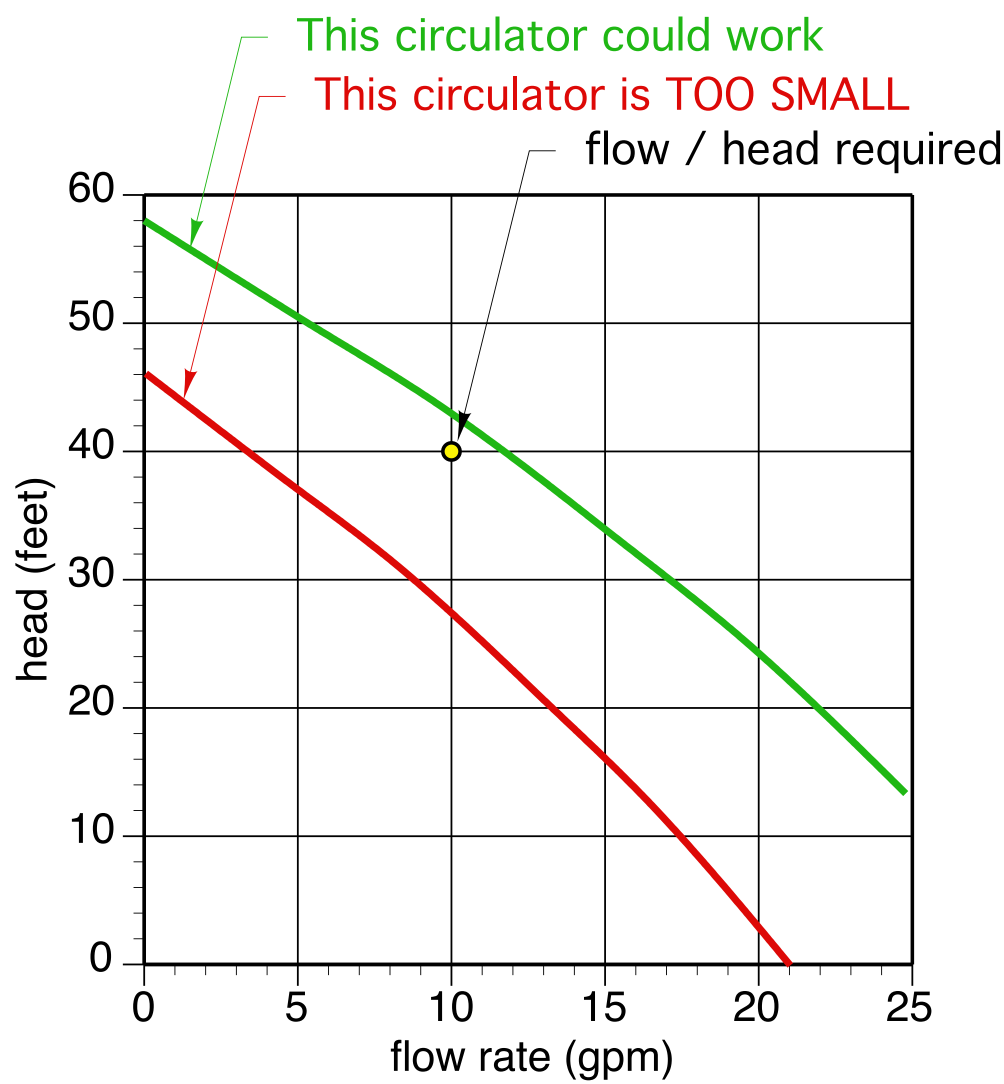
Example: Find the head loss of a 1” PEX circuit with a total length of 350 feet, and carrying water at 10 gpm.

$$H_L = \left(\frac{L_{total}}{100}\right)(0.2034)\,f^{1.75} = \left(\frac{350}{100}\right)(0.2034)[10]^{1.75} = 40\,feet$$

Now - select a circulator that can produce at about 10 gpm at 40 feet of head.

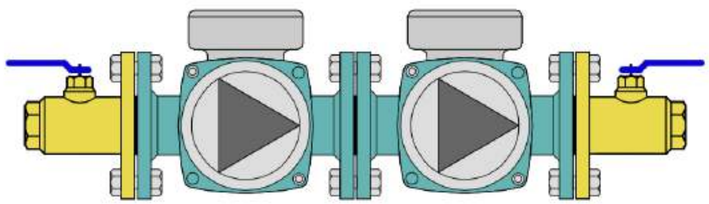
published pump curves for Grundfos UPS 26-150





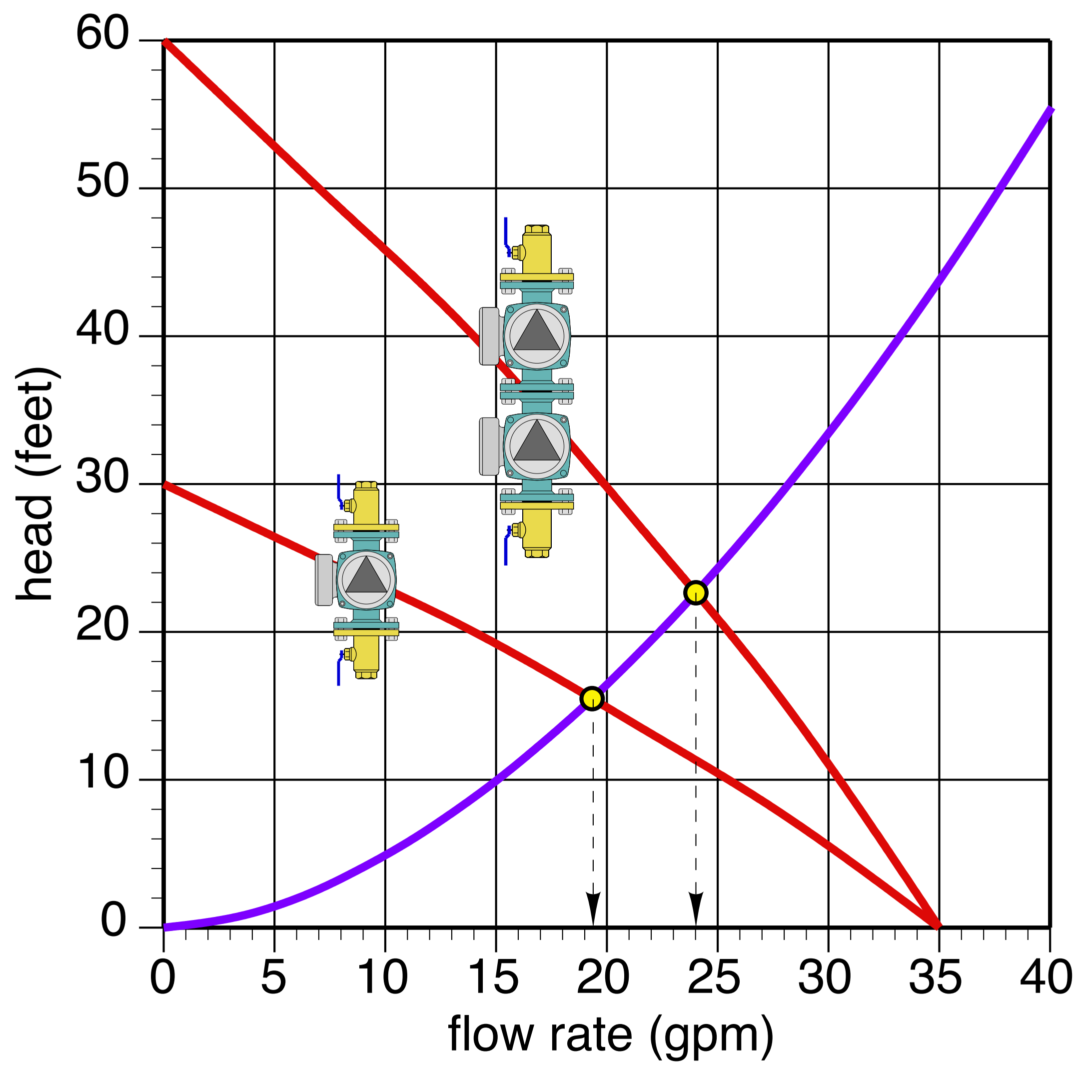
Using existing underground piping

When the head requirement is high, it's often best to use two circulators in "close coupled" series arrangement.



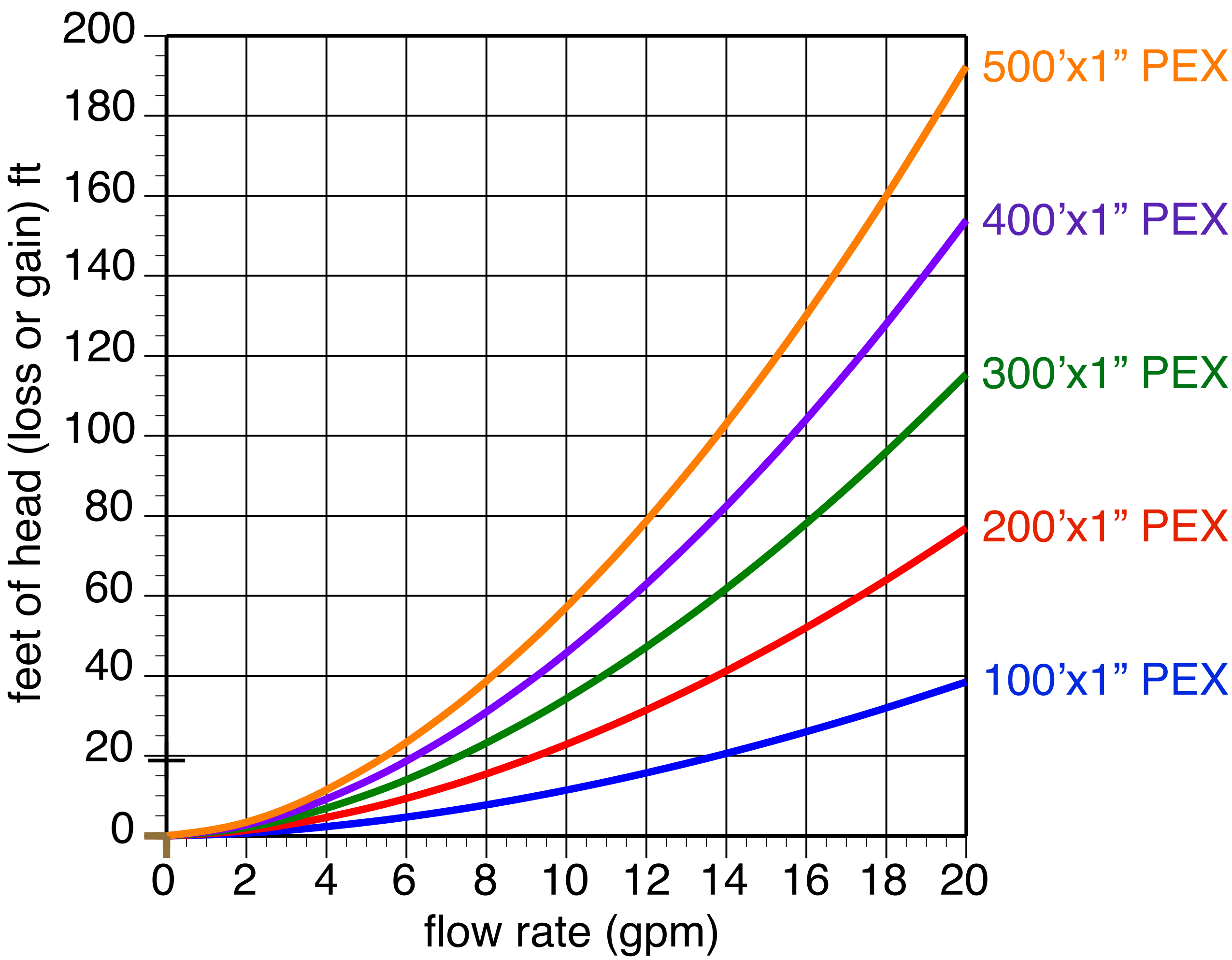
The pump curve for 2 circulators in series is found by doubling the head at each flow rate.

NOTE: 2 circulators in series will NOT double the flow rate in the circuit.



Using existing underground piping

The following graph plots head loss versus flow rate for 1” PEX tubing circuits having total (round trip) lengths from 100 to 500 feet.

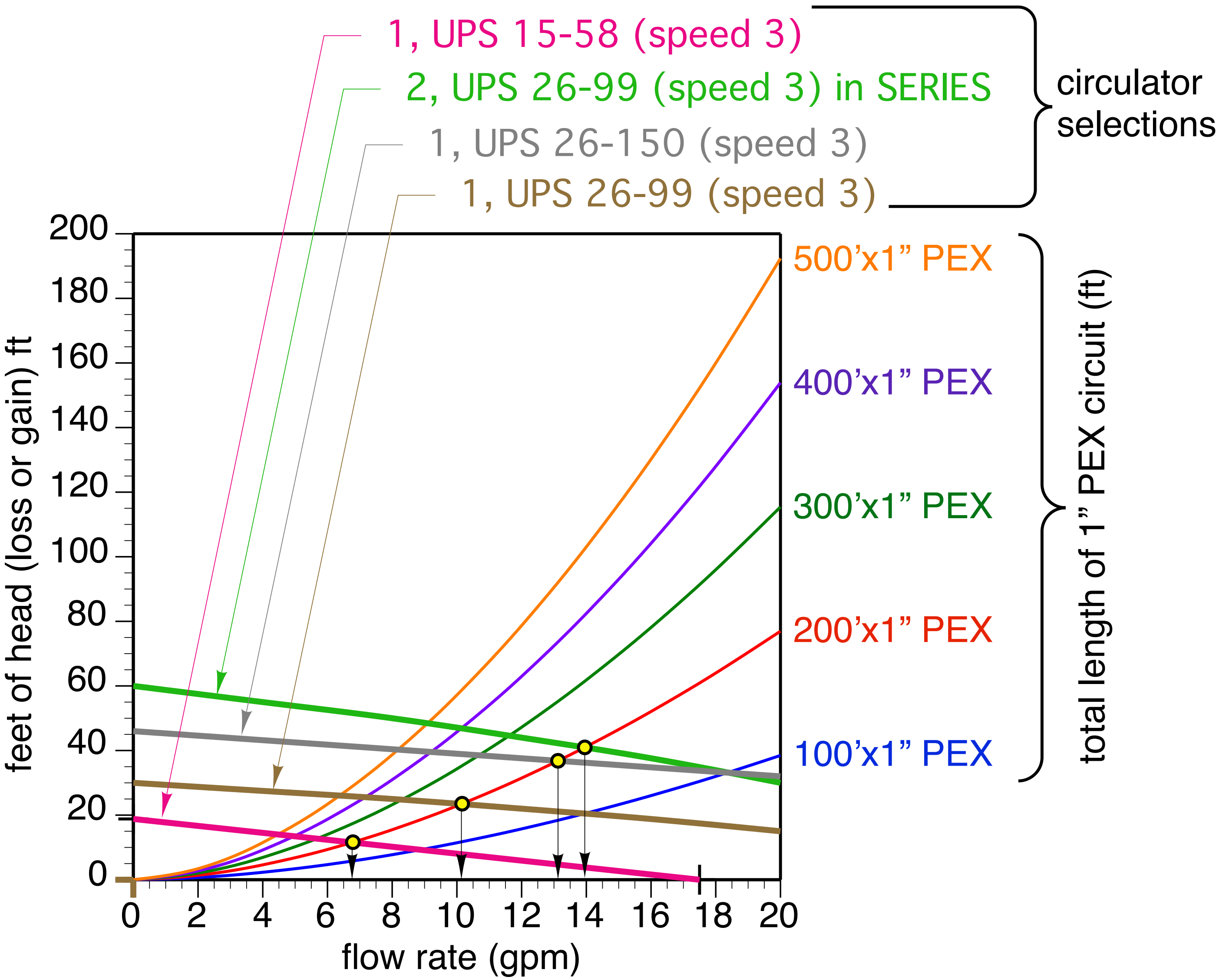


Using existing underground piping

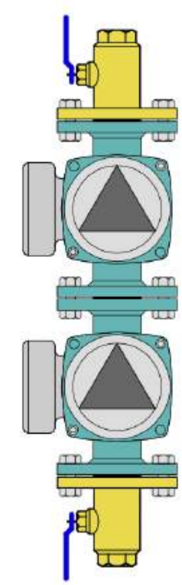
The flow in any given circuit is found at the intersection of the pump curve and circuit head loss curve…

Grundfos UPS 26-99

Grundfos UPS 26-150

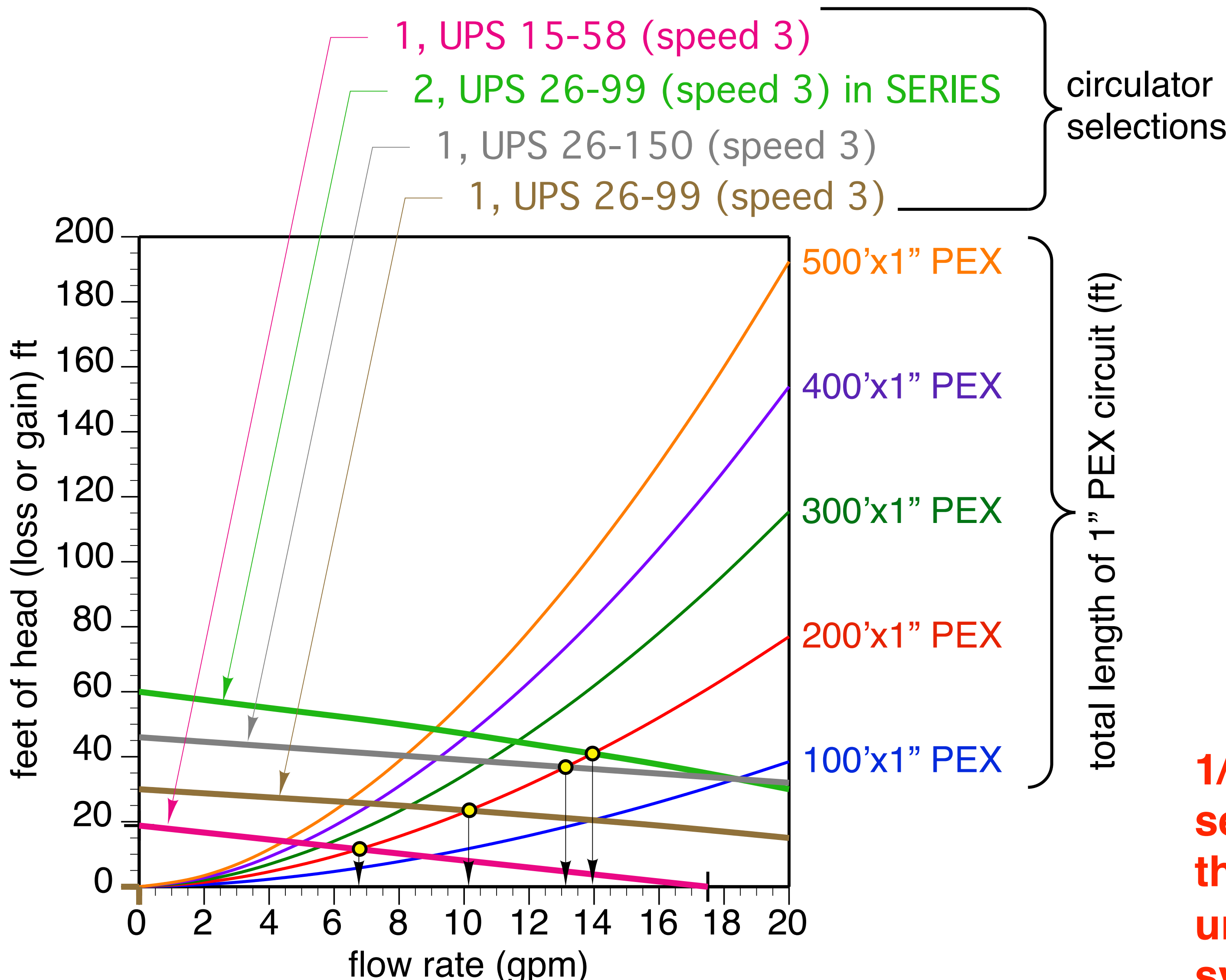


2 circulators in "close-coupled" series. ***Double the head at each flow rate.***



Using existing underground piping

Assume a 200 ft total (round trip) circuit of 1” PEX tubing:



1, UPS 15-58 (speed 3) circulator yields a flow rate of about 6.8 gpm.

1, UPS 26-99 (speed 3)circulators yields a flow rate of about 10.4 gpm.

1, UPS 26-150 (speed 3) circulator yields a flow rate of about 13.2 gpm.

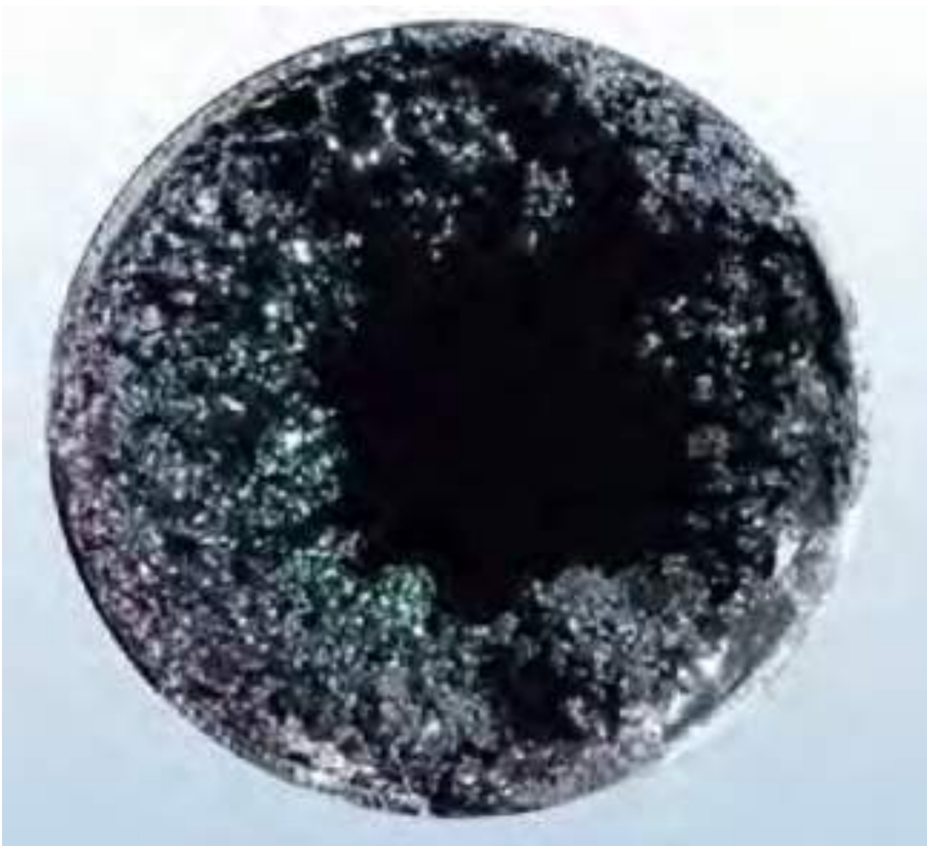
2, UPS 26-99 circulators (speed 3) **in series** yield a flow rate of about 14 gpm.

1/25 HP zone circulators are seldom capable of handling the flow requirements of underground 1” PEX piping systems…

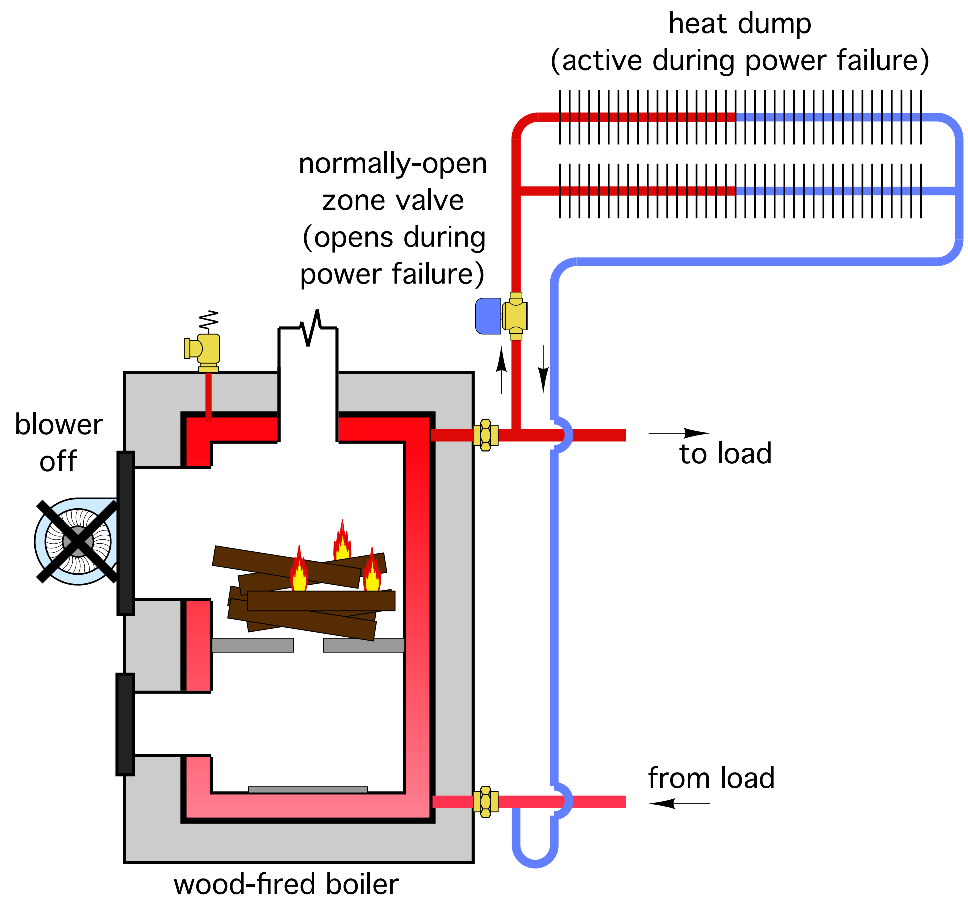
Boiler Protection Considerations

Boiler protection:

- Against low entering water temperature
- Against overheating during power failure



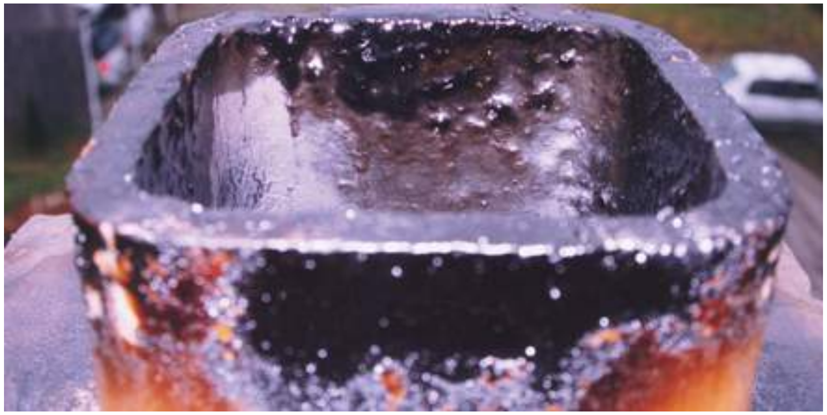
creosote



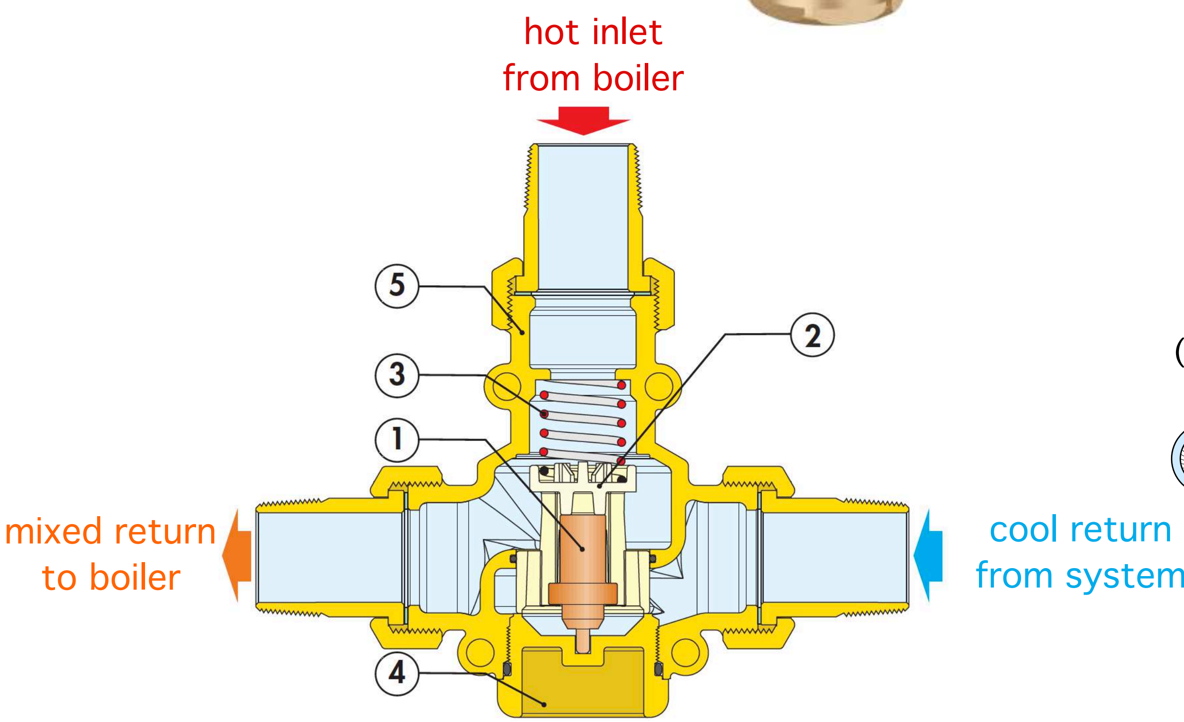
It's necessary to protect wood-fired boilers from low entering water temperatures.

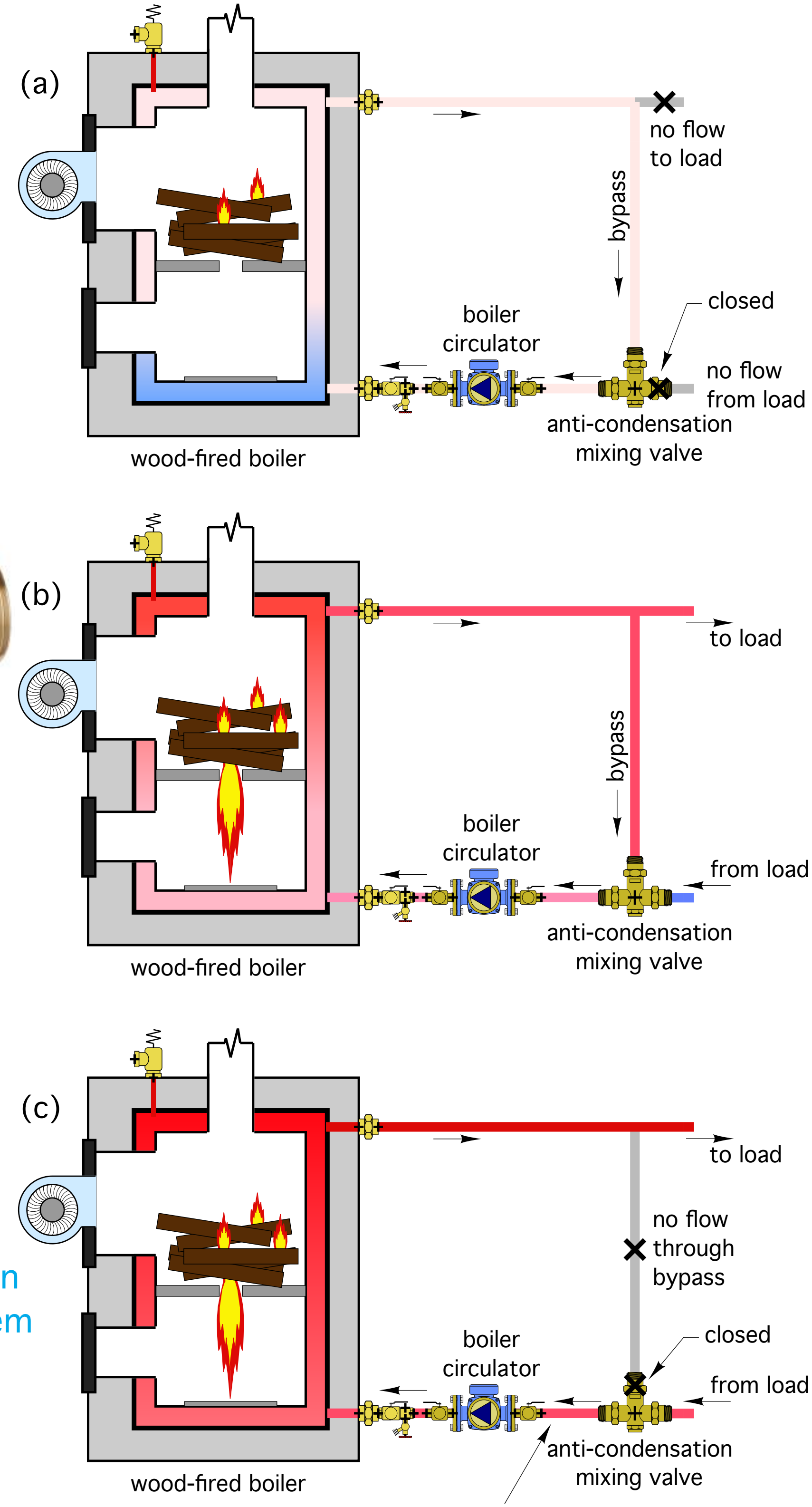
This can be done several ways:

1. Thermostatic bypass valve
2. Loading units (circulator + valve)
3. Variable speed shuttle pump
4. On/off "toggled" circulators



Thermostatic bypass valves

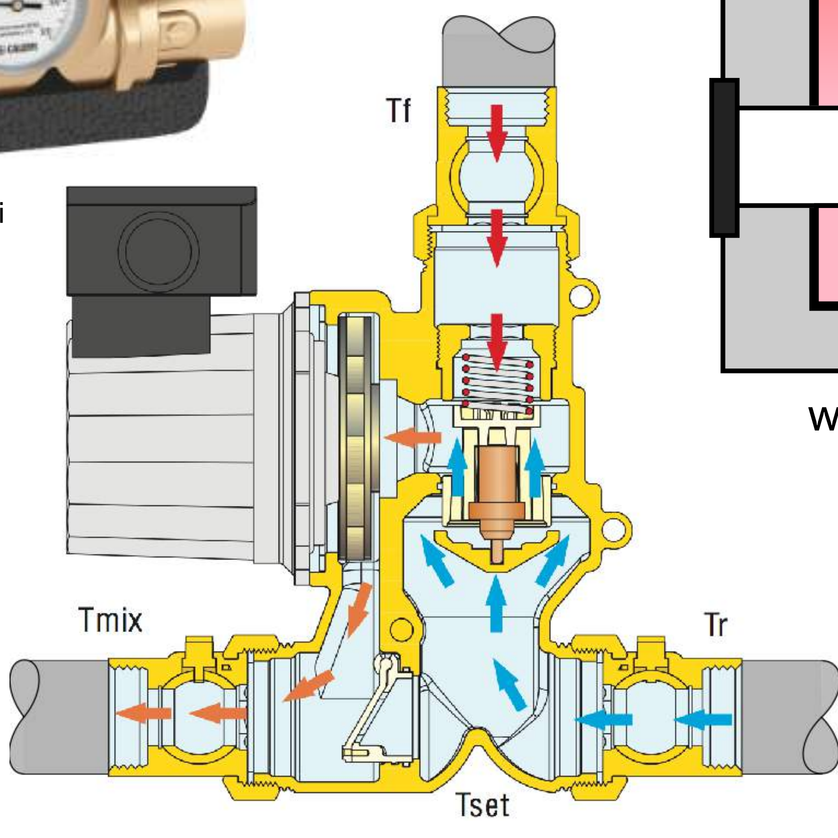


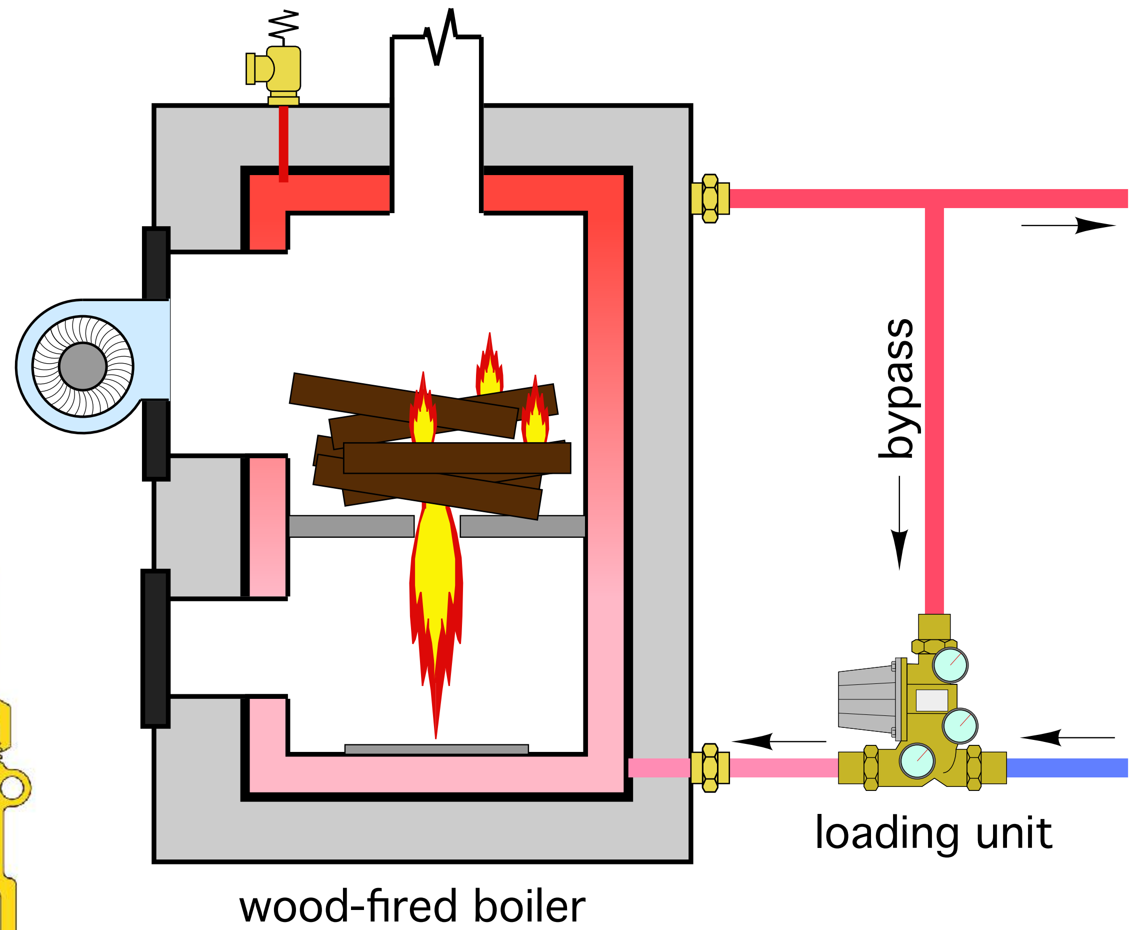


Loading units

(thermostatic mixing valve + circulator + flapper valve)

Images courtesy of Caleffi

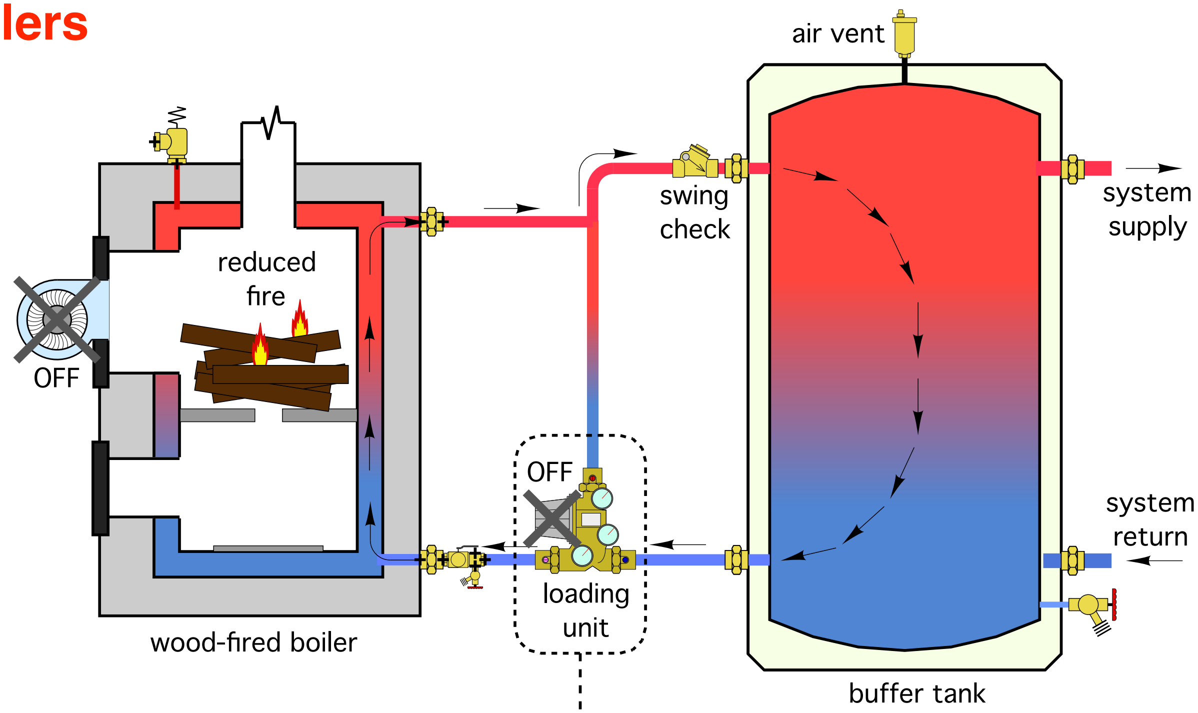


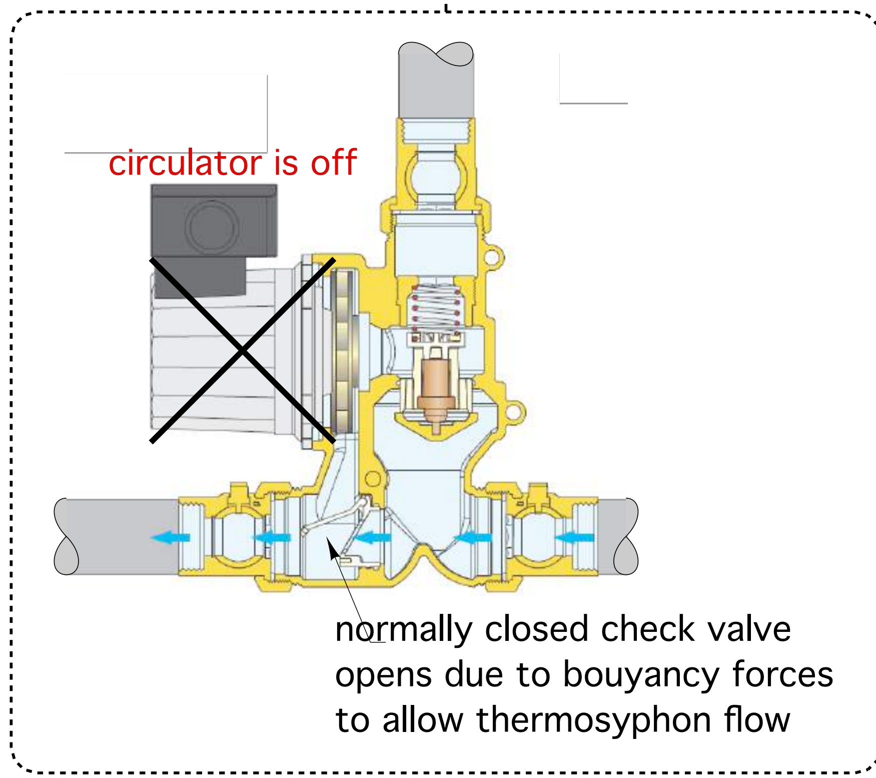


Loading units
(thermostatic mixing valve + circulator + flapper valve)

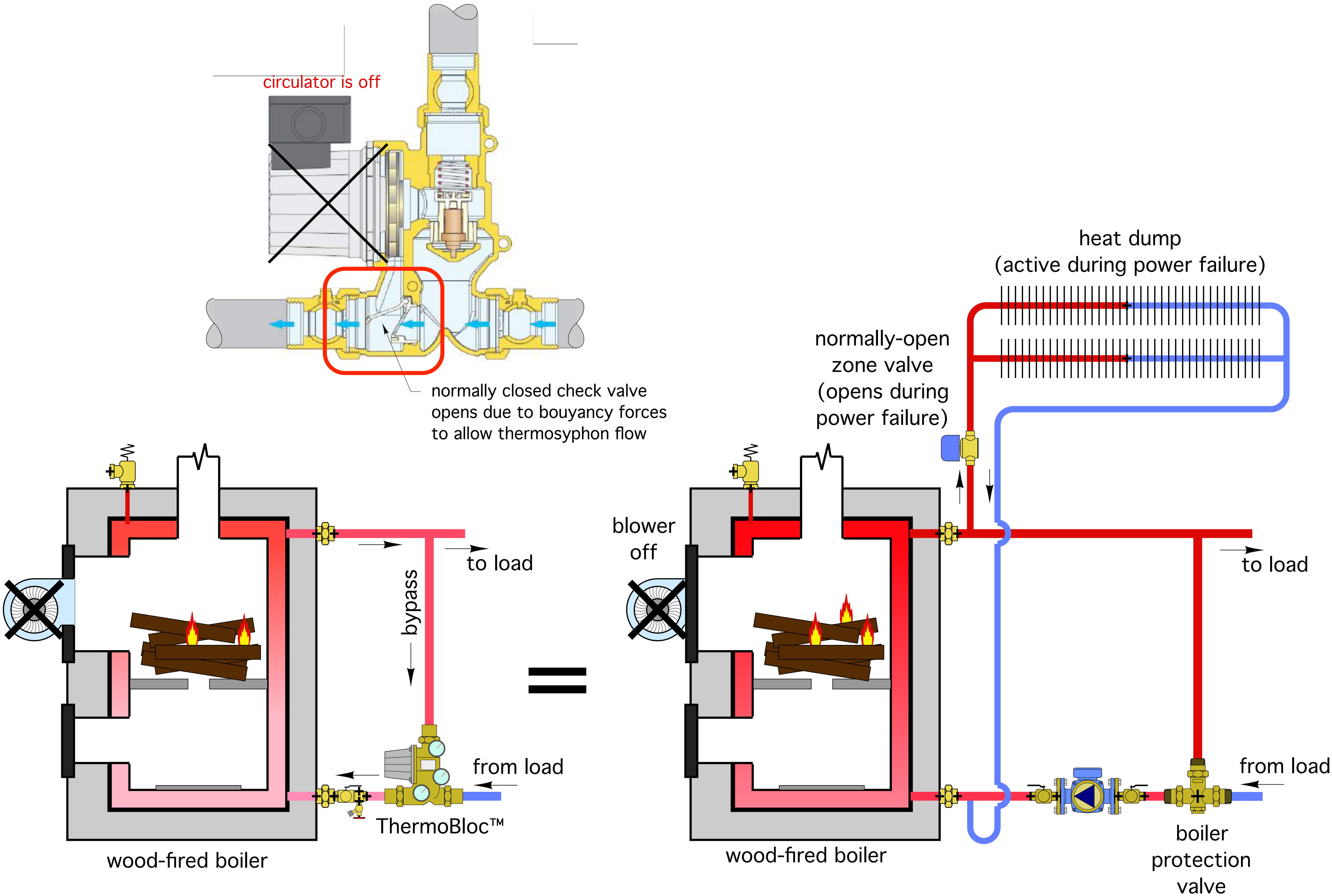
Video courtesy of LK Armatur www.precisionheating.ie

Loading units





Loading units protect against overheating during power outages.

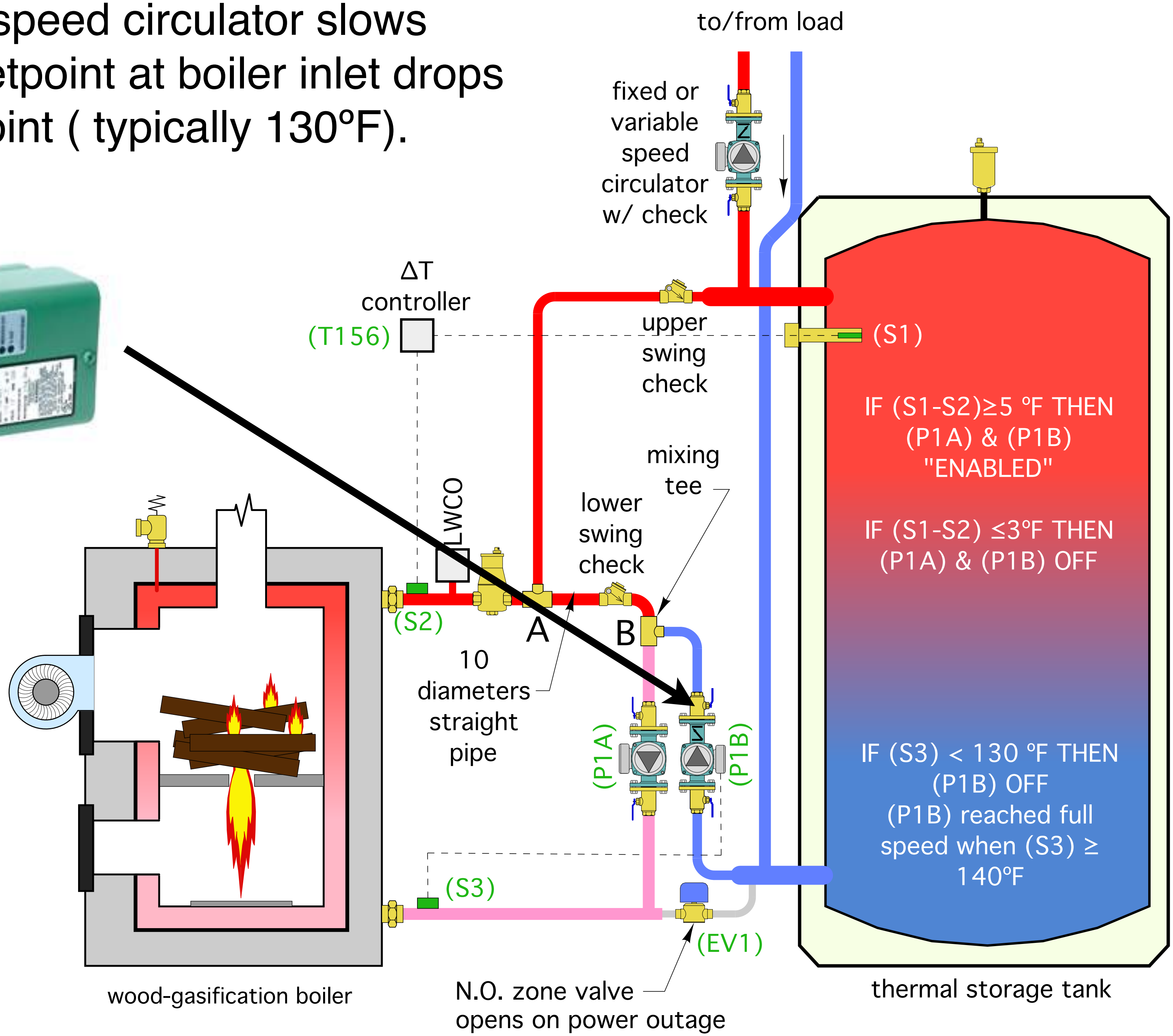


Variable speed shuttle pump

The variable speed circulator slows down if the setpoint at boiler inlet drops below a setpoint (typically 130°F).

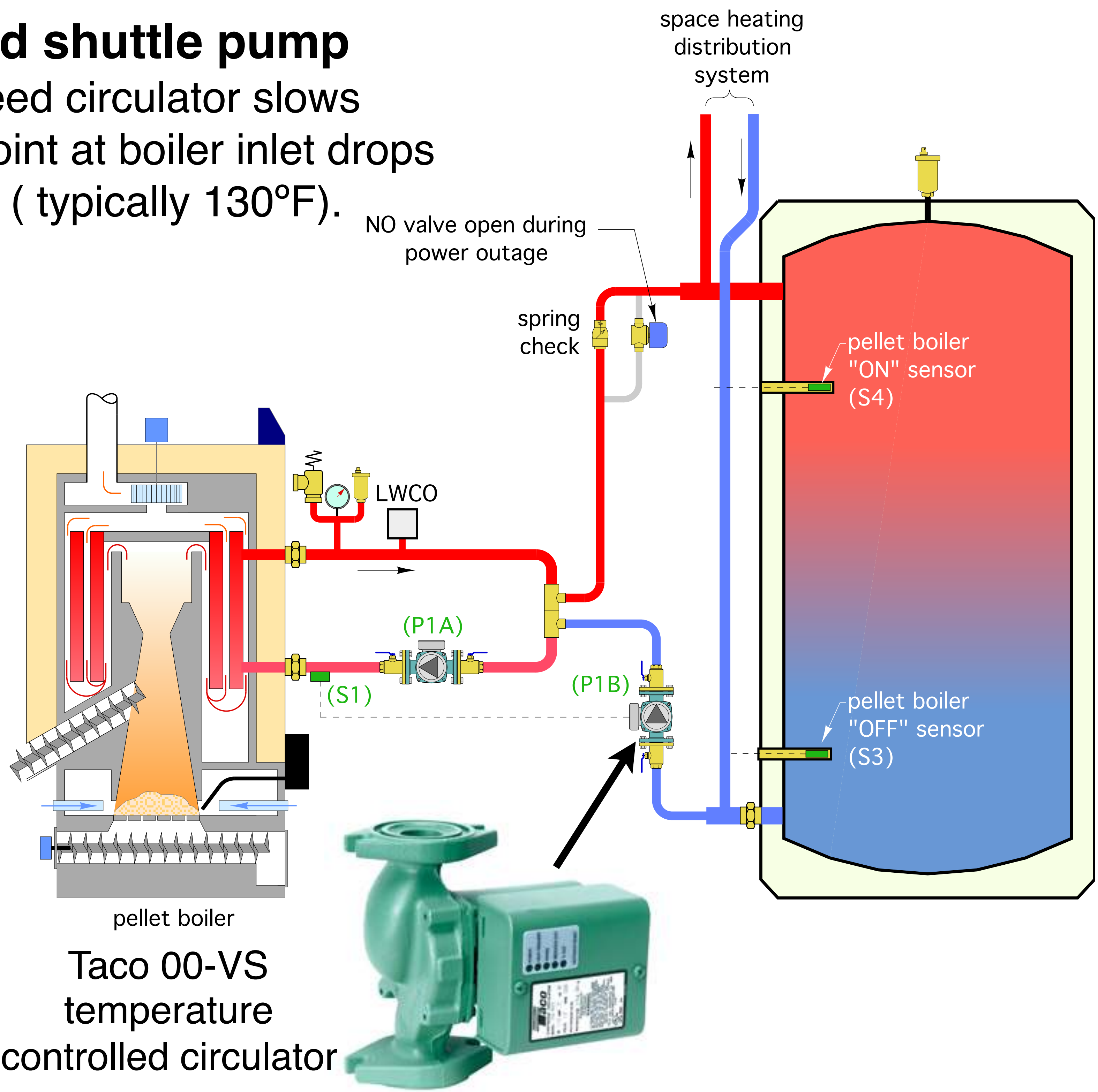
Taco 00-VS temperature controlled circulator

(or equivalent)



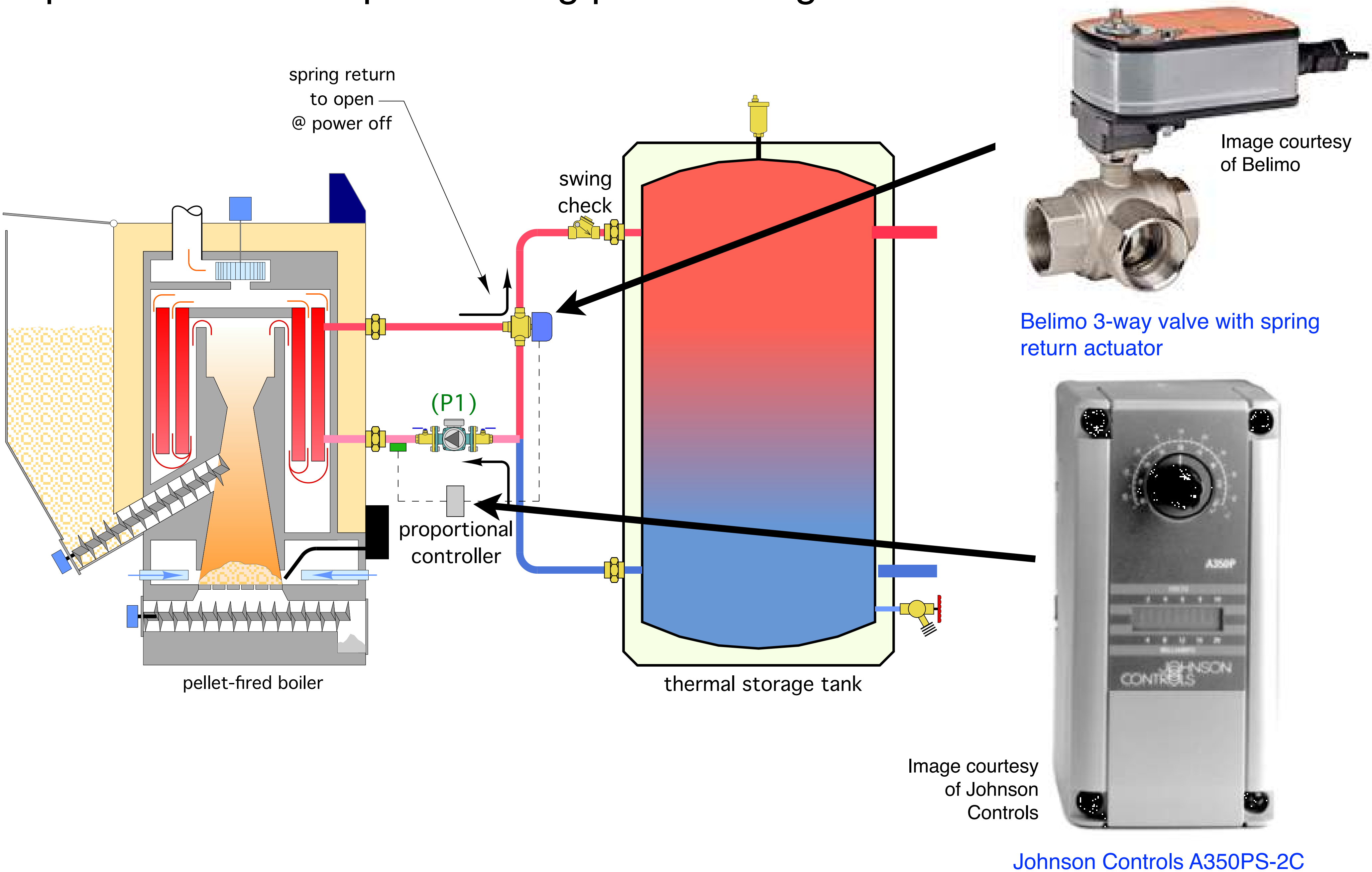
Variable speed shuttle pump

The variable speed circulator slows down if the setpoint at boiler inlet drops below a setpoint (typically 130°F).



3-way proportional mixing valve w/ spring return actuator

The actuator responds to a 2-10 VDC signal from controller. but fullv opens for thermosiphon during power outage.

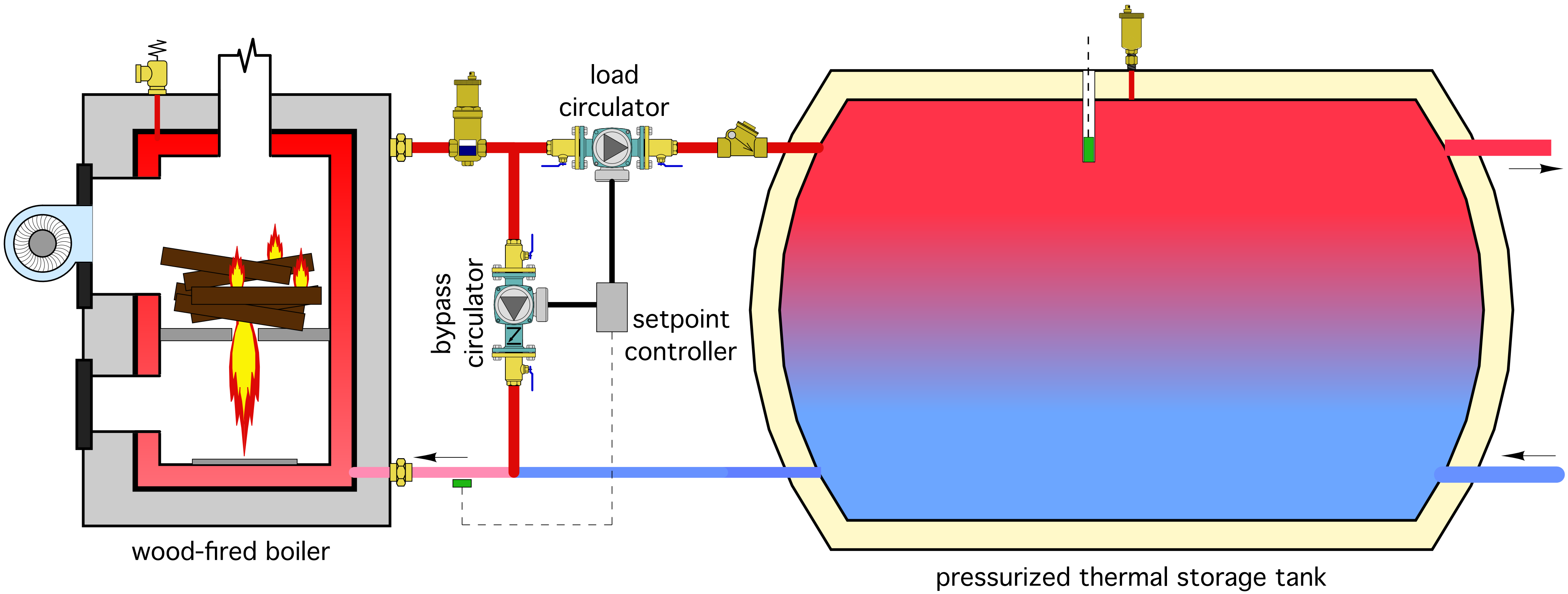


3-way motorized mixing valve supplied with & controlled by EVO WORLD boiler

On/off toggled circulators

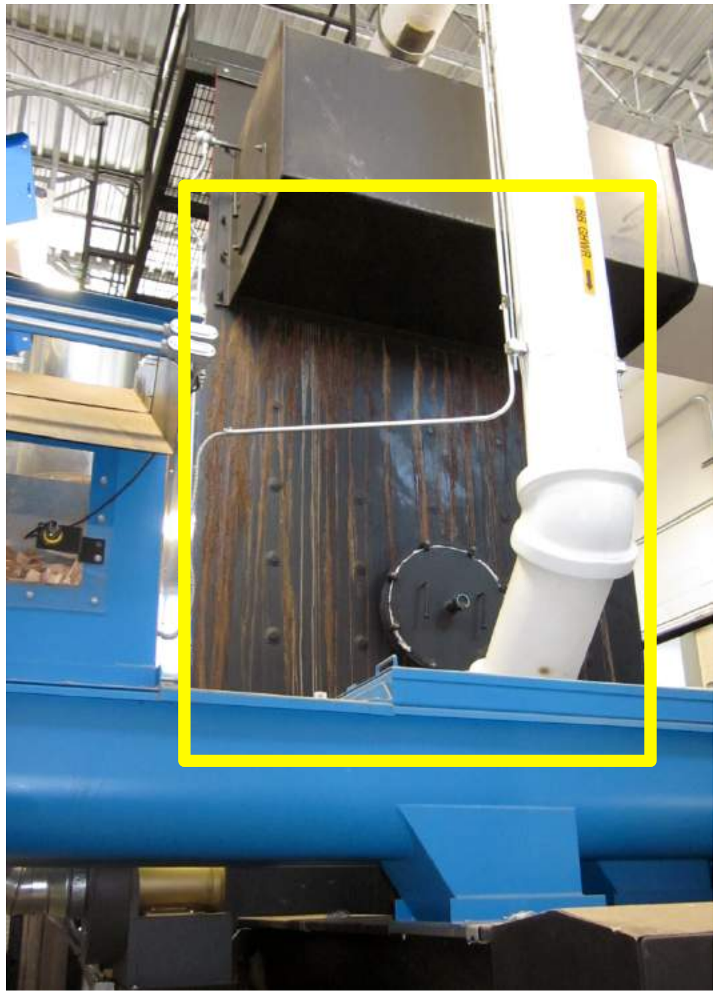
Bypass circulator ON, load circulator OFF, when boiler return <130ºF

Bypass circulator OFF, load circulator ON, when boiler return ≥140ºF



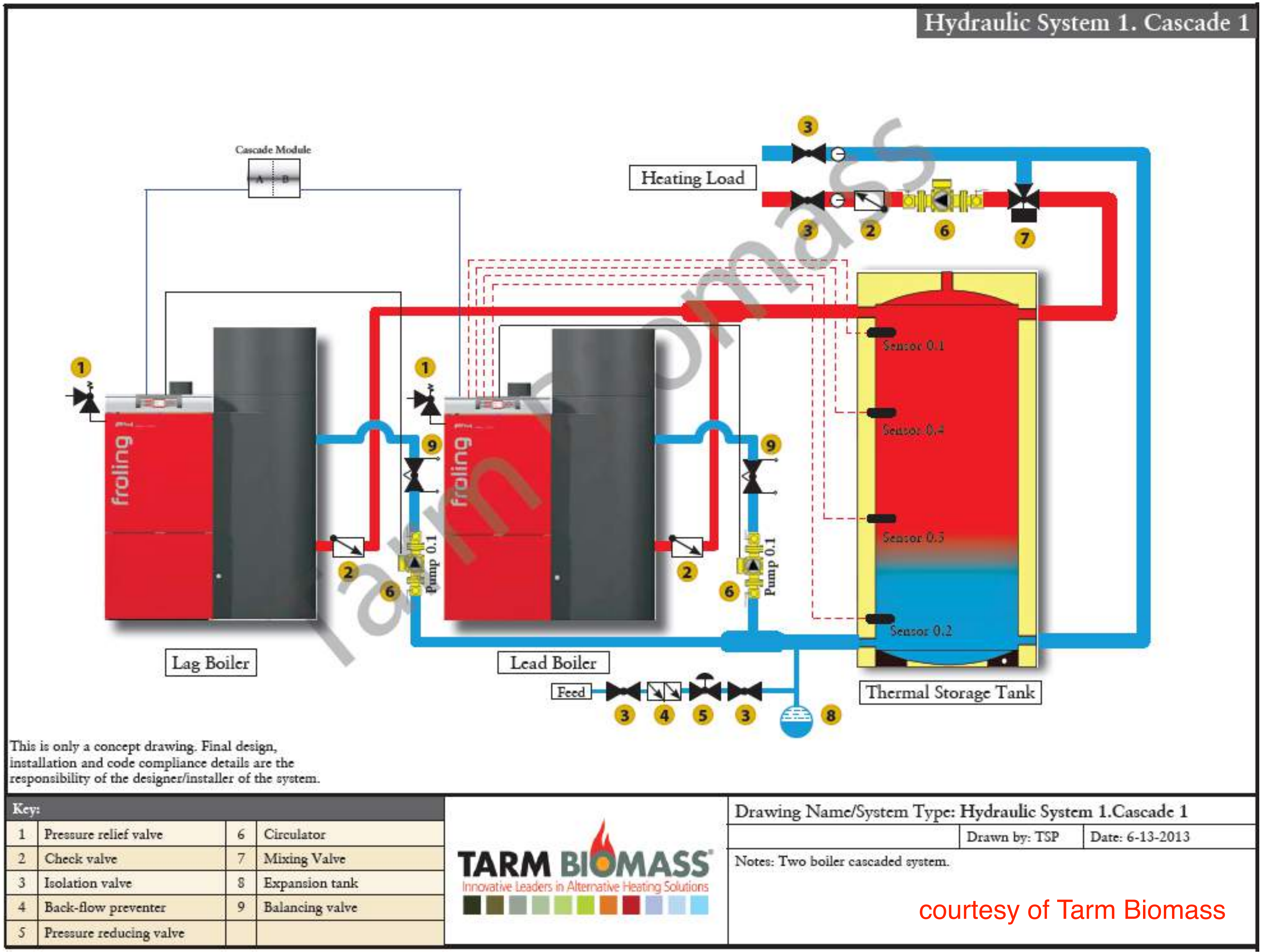
Some boilers have this control function built-in

A 12.8 MMBtu/hr wood chip boiler ($2,300,000 installation), without a mixing device to regulate inlet water temperature.



Notice the signs of flue gas condensation on rear boiler plate.

Some boilers have special internal designs combined with variable speed circulator control for anti-condensation protection.

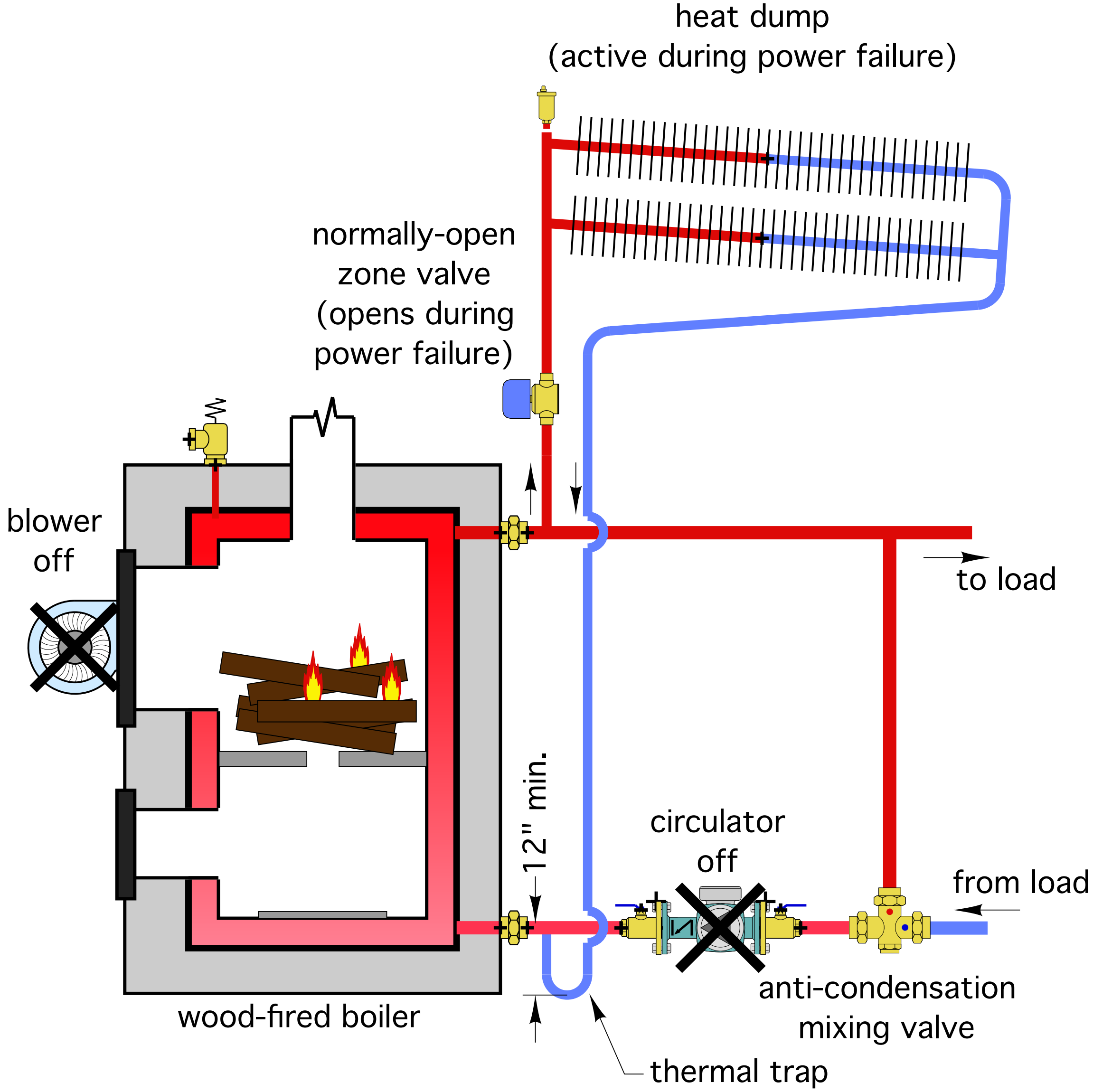


courtesy of Tarm Biomass

Boiler over-temperature protection

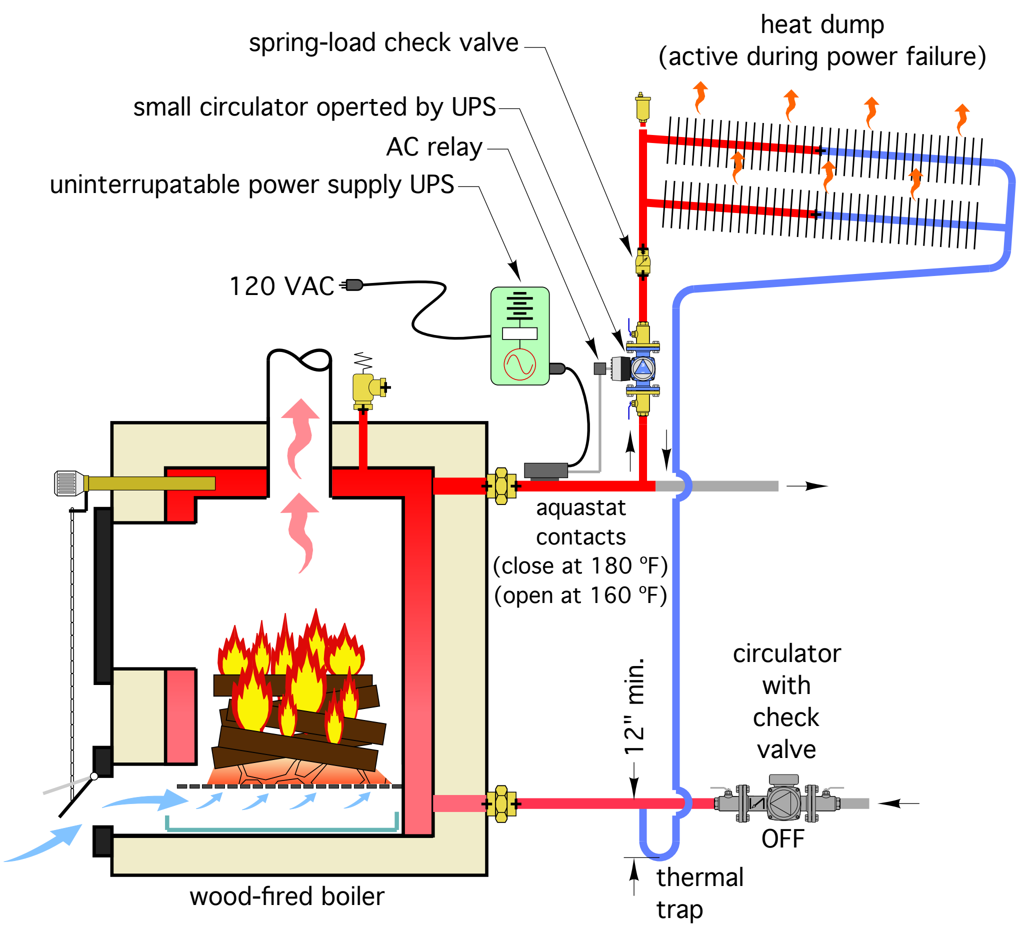
Heat dump activates upon power failure

The normally open zone valve opens at power failure to allow thermosiphon flow through sloped fin tube assembly.

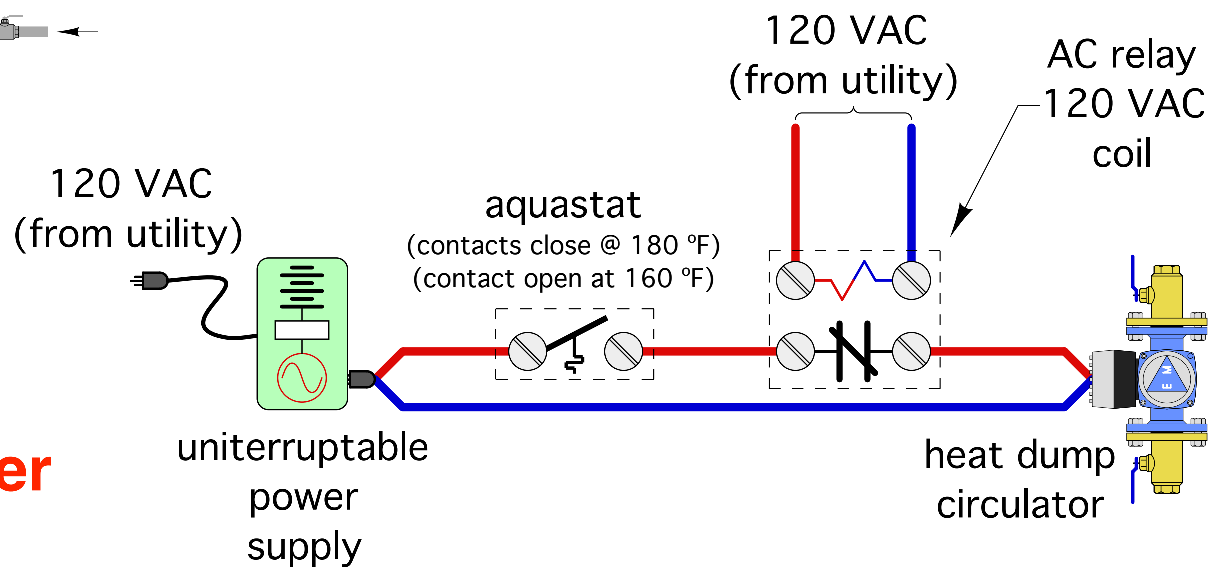


Courtesy of Mark Odell

Small circulator driven by UPS protects against overheating during power outages.



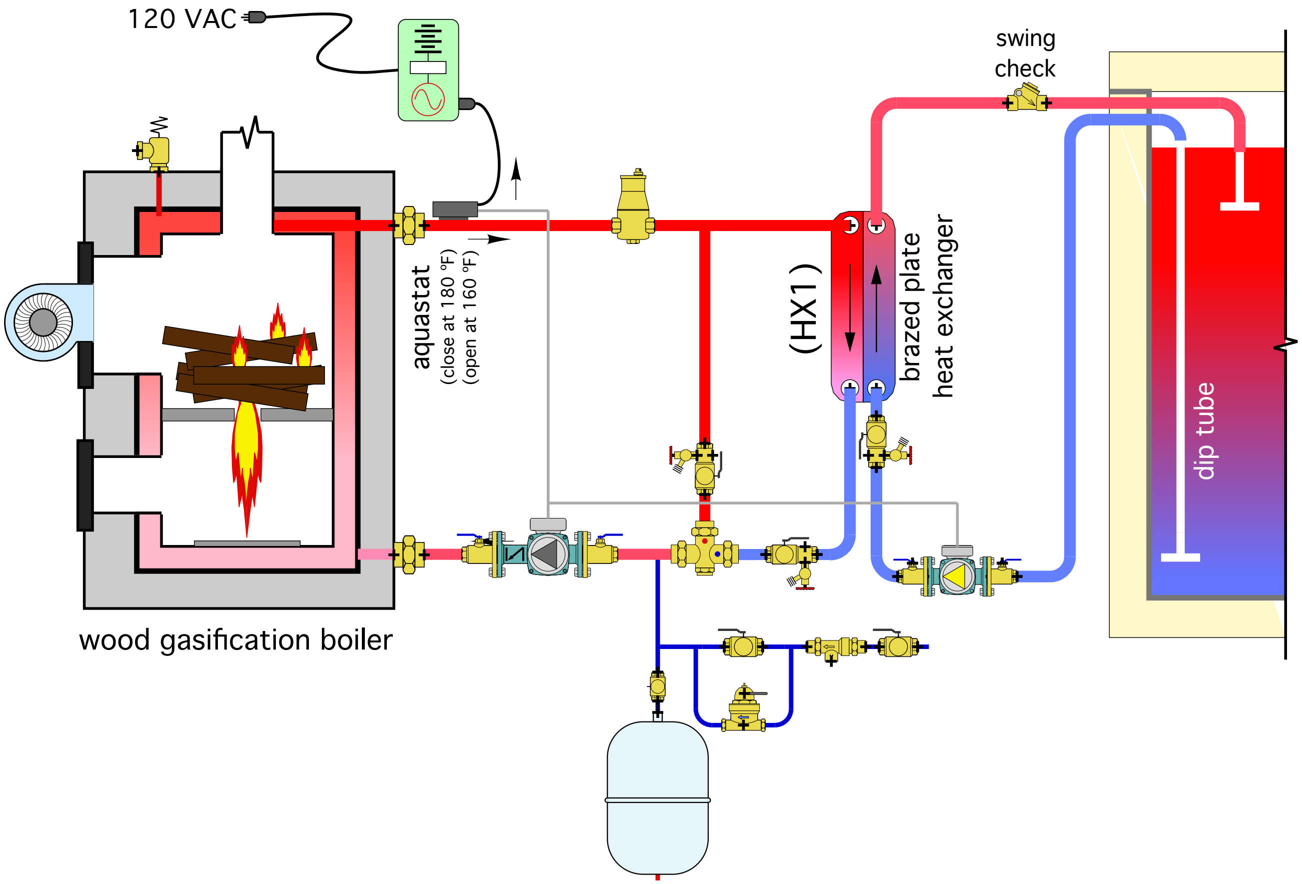
B&G Ecocirc (VARIO)
adjustable from
6-50 watts

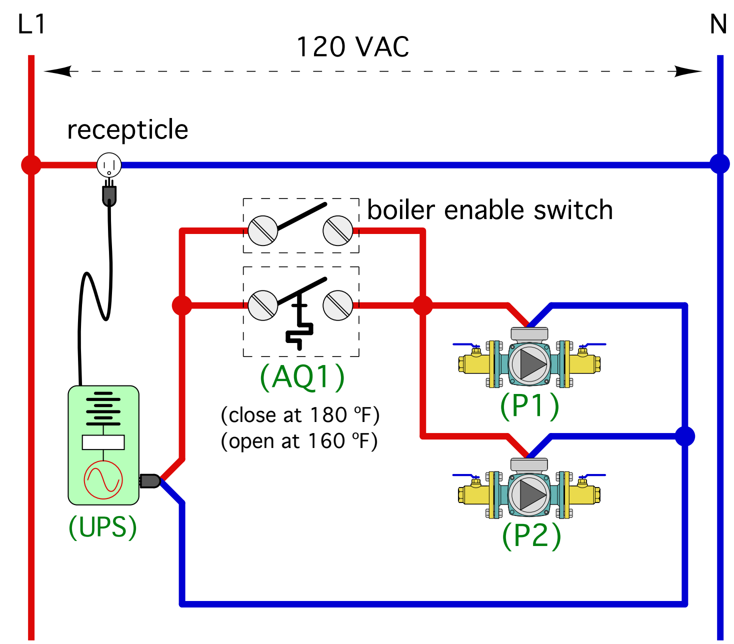


The circulator allows possibility of heat dump being underneath the boiler

Boiler over-temperature protection

UPS powers boiler-to-tank circulator(s) upon power failure



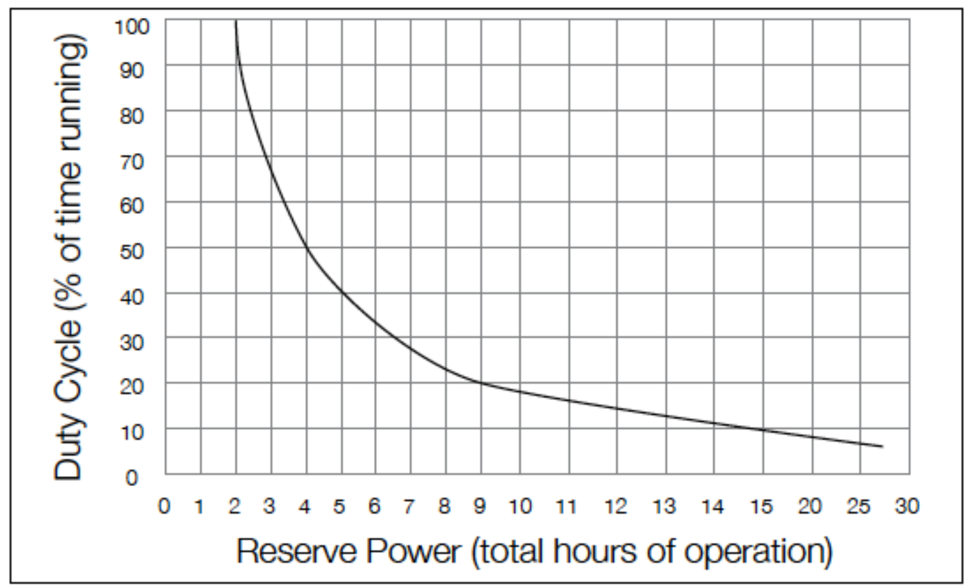


UPS must be sized to operate both boiler circulators for at least 30 minutes. Maintain battery in UPS.

High capacity uninterruptable power supplies (UPS) are available

- 24 VDC deep cycle battery bank
- rated for up to 1800 watt output
- can be recharged by solar PV

The SUMPRO® is designed to operate a load up to 12 Amps. If operating more than one pump, the combined FLA cannot exceed 12 Amps.



Performance curve results using a 3/4 HP pump with a 7.5 FLA and (2) Metropolitan Power Plus model 31P-36 batteries.

Integrating auxiliary boilers with wood-fired boilers

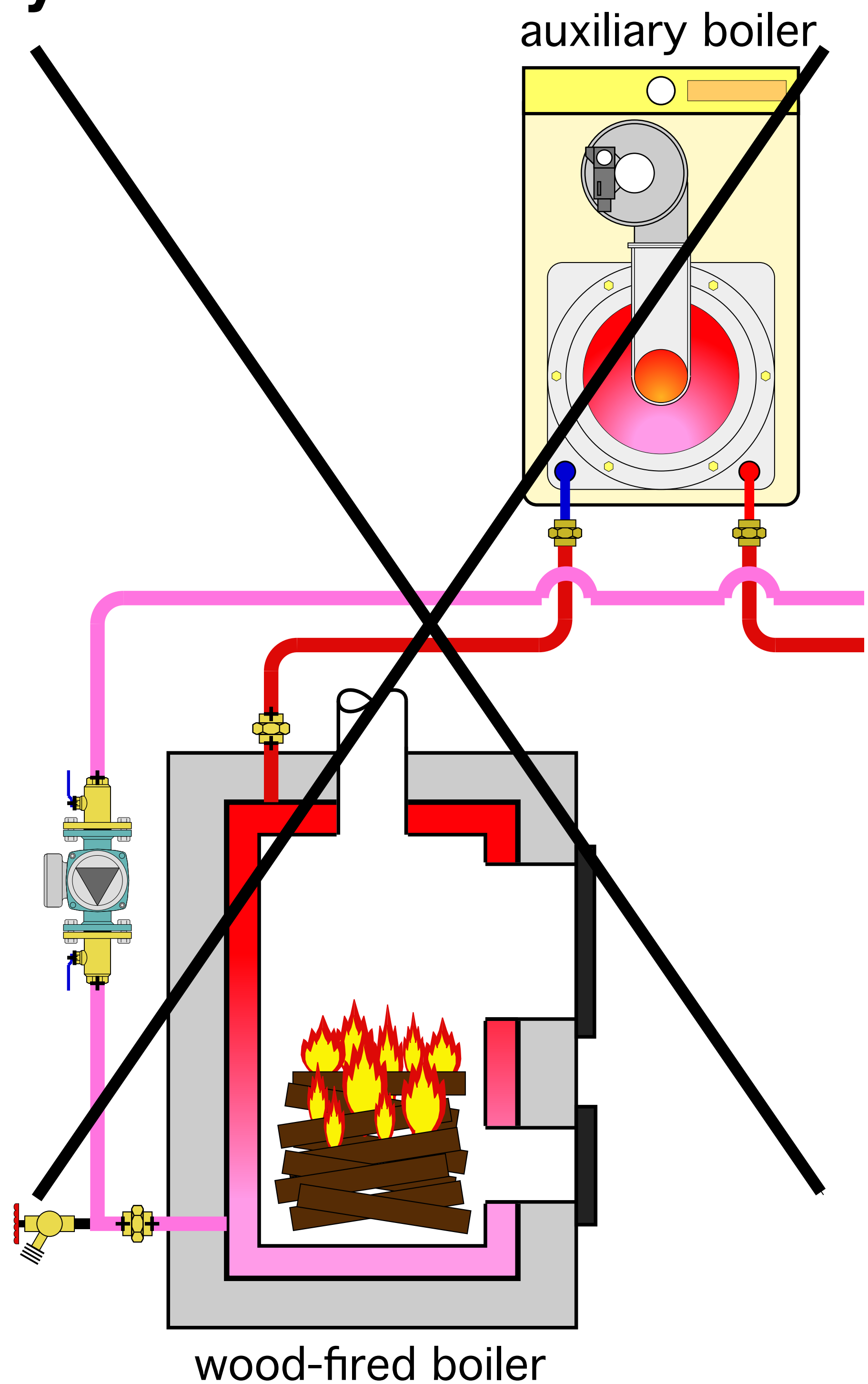
Avoid series circuiting of auxiliary boiler

• Any boiler not operating will act as a heat sink for the other boiler(s) being fired.

• Any water-side problem with either boiler requires system shut down during repair.

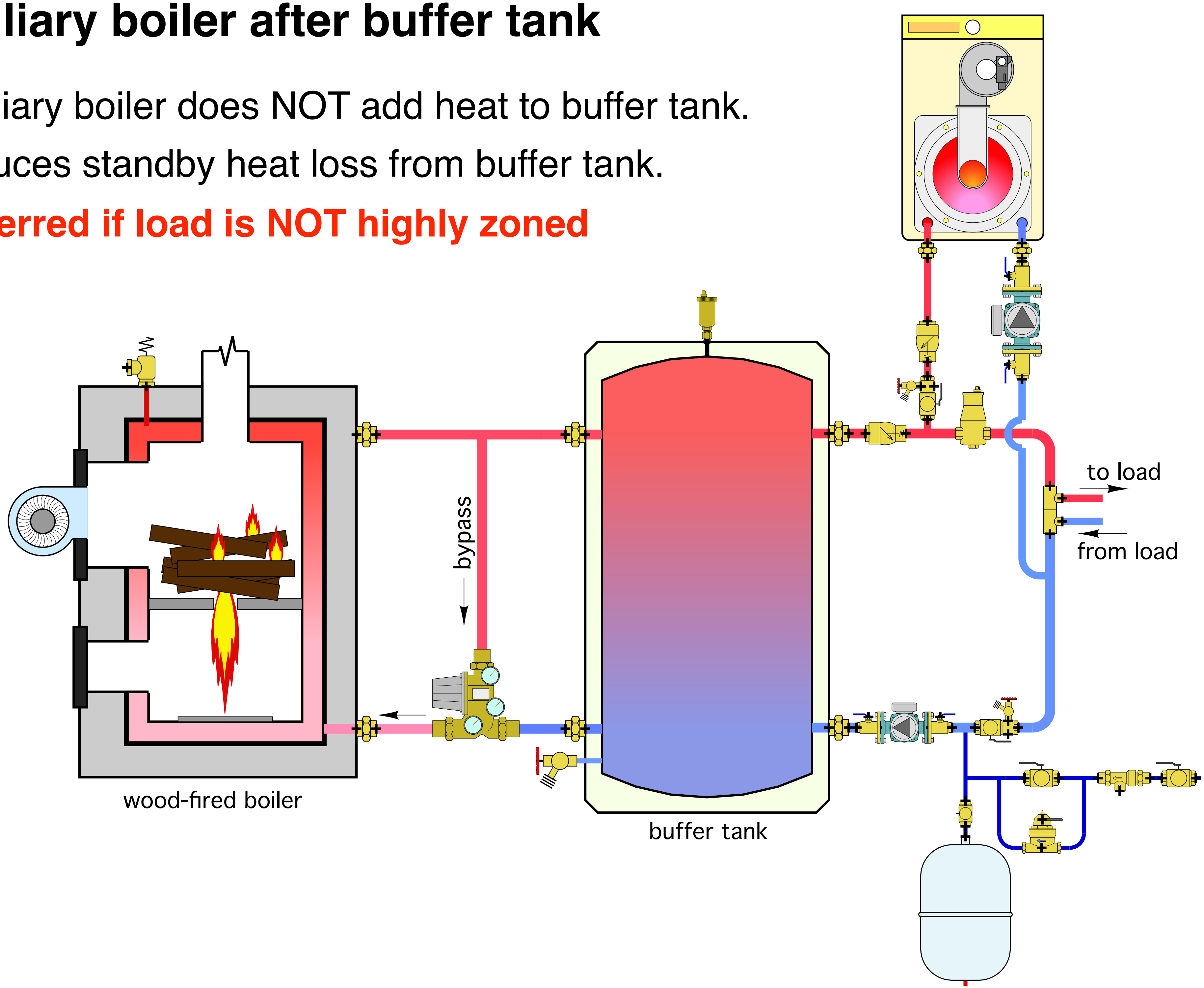
• Head loss of both boilers always present (increased circulator energy usage).

• Efficiency of downstream boiler is reduced due to higher entering water temperature.



Auxiliary boiler after buffer tank

- Auxiliary boiler does NOT add heat to buffer tank.
- Reduces standby heat loss from buffer tank.
- **Preferred if load is NOT highly zoned**

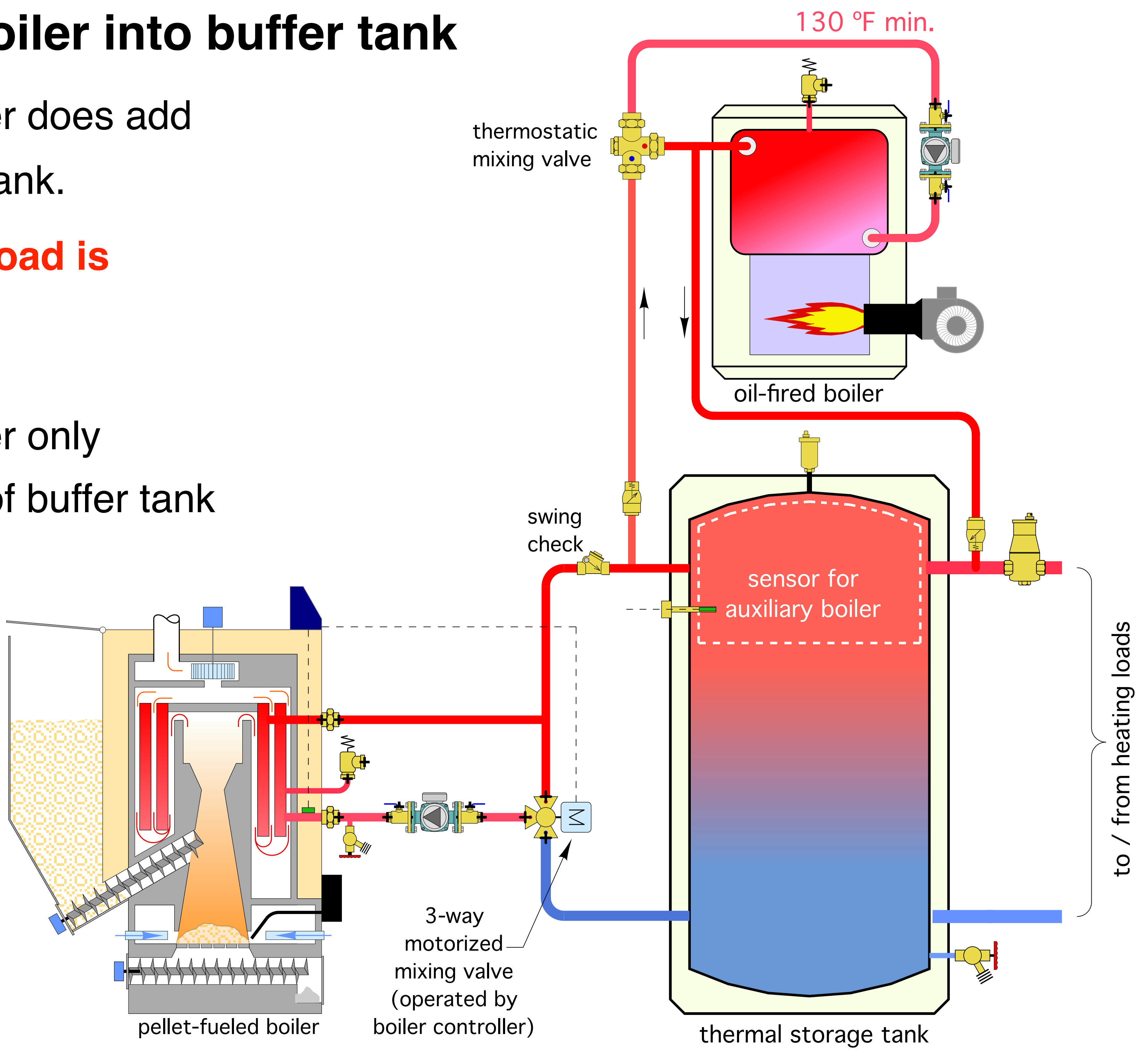


Auxiliary boiler into buffer tank

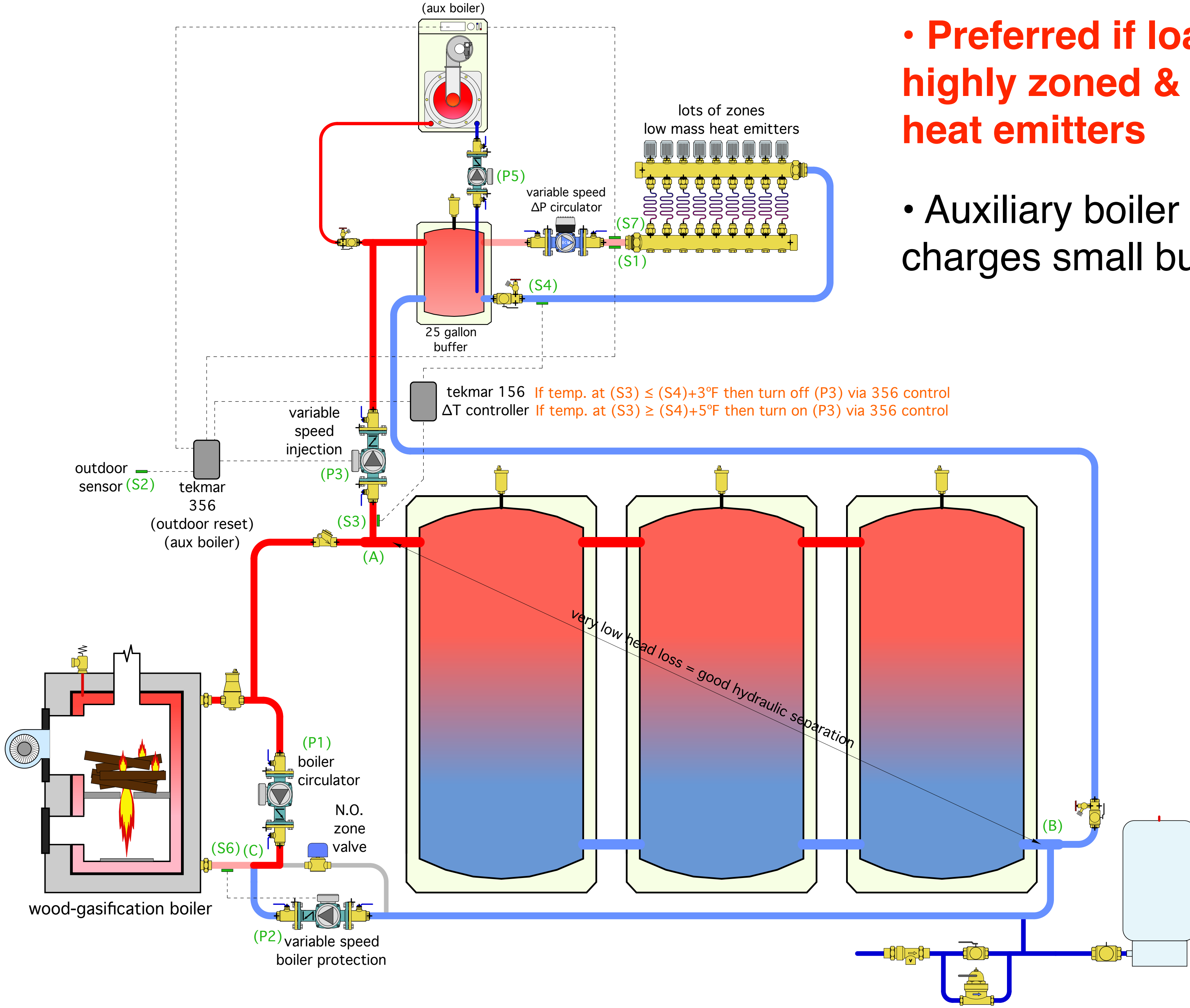
• Auxiliary boiler does add heat to buffer tank.

• Preferred if load is highly zoned

• Auxiliary boiler only maintains top of buffer tank



Mod/con auxiliary boiler into separate small buffer tank



- **Preferred if load is highly zoned & low mass heat emitters**
- Auxiliary boiler only charges small buffer tank

Low temperature / hydronic heat emitters

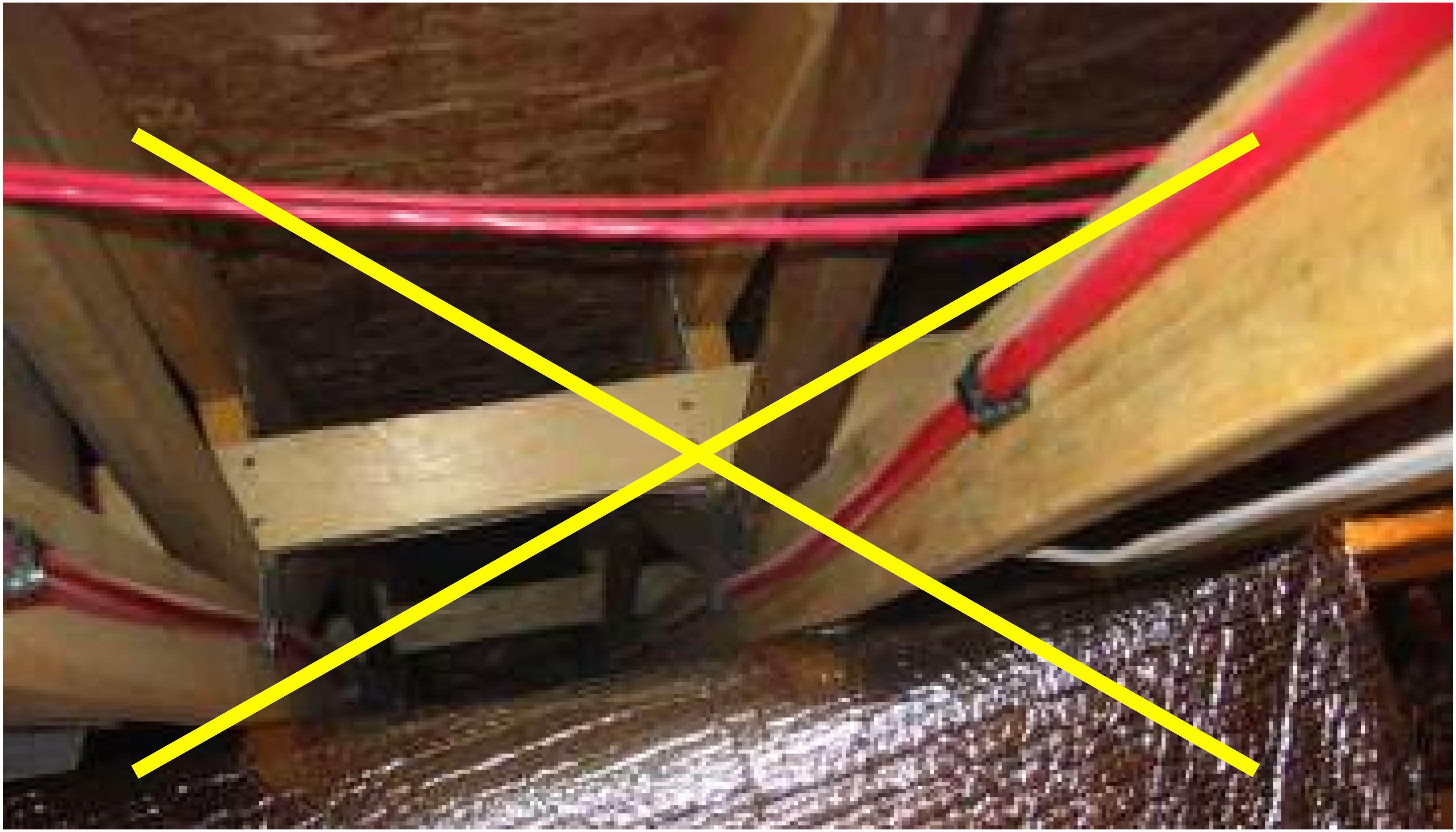
What kind of heat emitters should be used in combination with wood gasification or pellet boilers?

- They should operate at **low supply water temperatures** to allow maximum "draw down" on thermal storage.

Max suggested supply water temperature @ design load = 120 °F

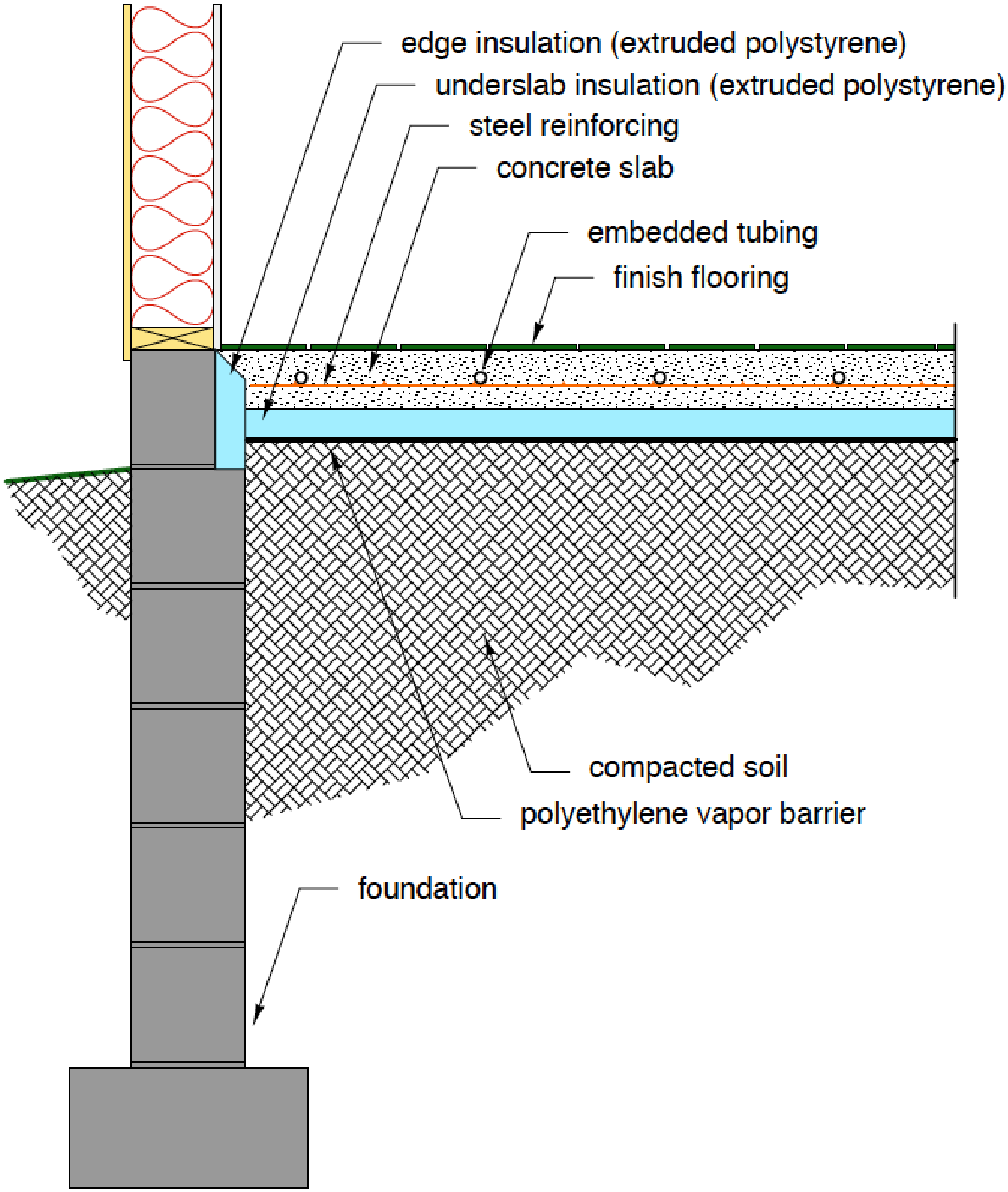
Low temperature hydronic distribution systems also help "future proof" the system for use with heat sources are likely to thrive on low water temperatures.

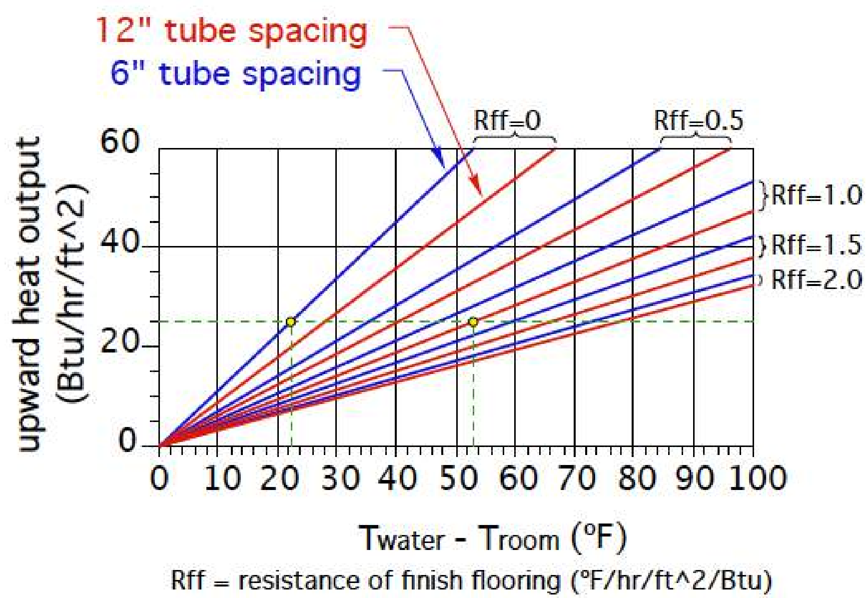
<u>Don't do this with ANY hydronic heat source!</u>



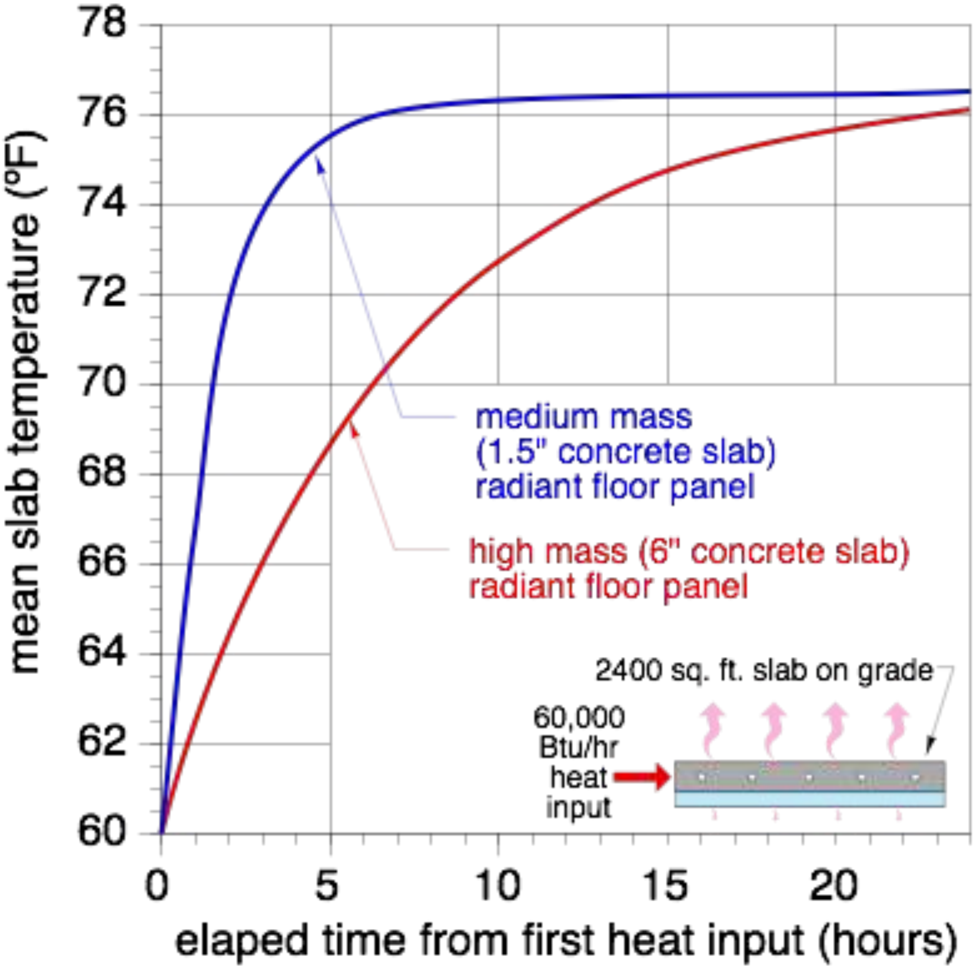
Heat transfer between the water and the upper floor surface is severely restricted!

Slab-on-grade floor heating





Heated slabs can take hours (even days) to respond to significant temperature changes.



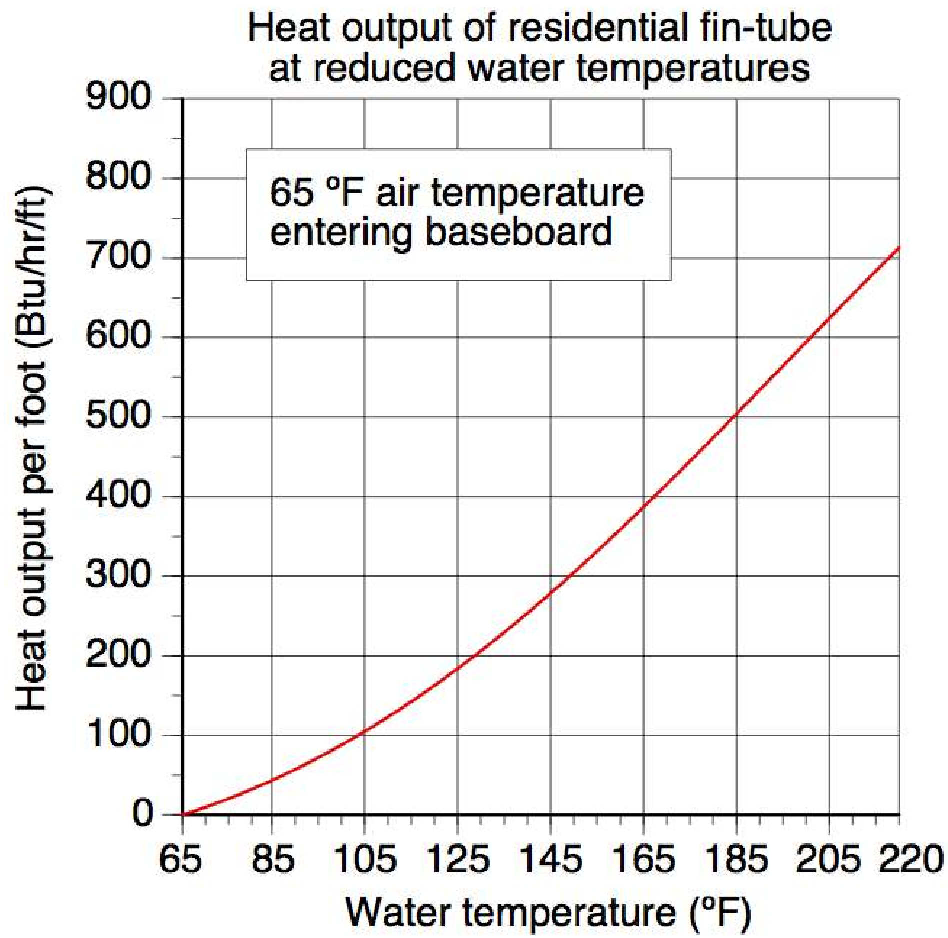
Notice where the tubing is in this 6” heated concrete slab

This is NOT recommend practice. Tubing should be near middle of typical slab.

Most CONVENTIONAL fin-tube baseboard has been sized around boiler temperatures of 160 to 200 ºF. Much too high for good thermal performance of low temperature hydronic heat sources.

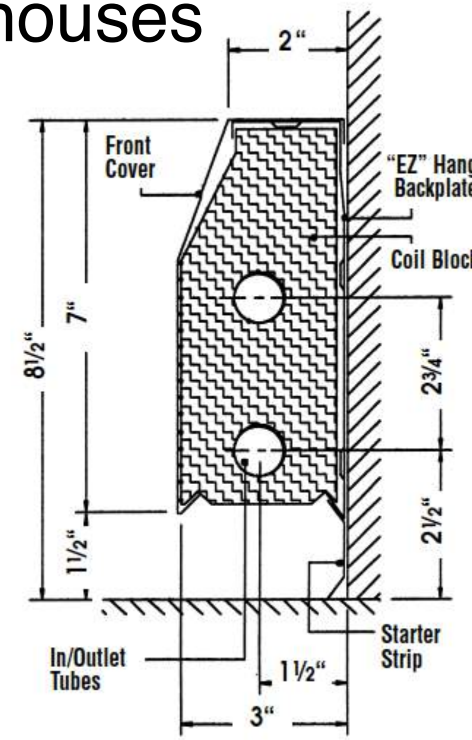
Could add fin-tube length based on lower water temperatures. BUT...

Fin-tube output at 120 ºF is only about 30% of its output at 200ºF



Hydronic heat emitters options for low energy use houses

Some low- temperature baseboard is now available



Images courtesy Emerson Swan

Heating Edge™ Hot Water Performance Ratings

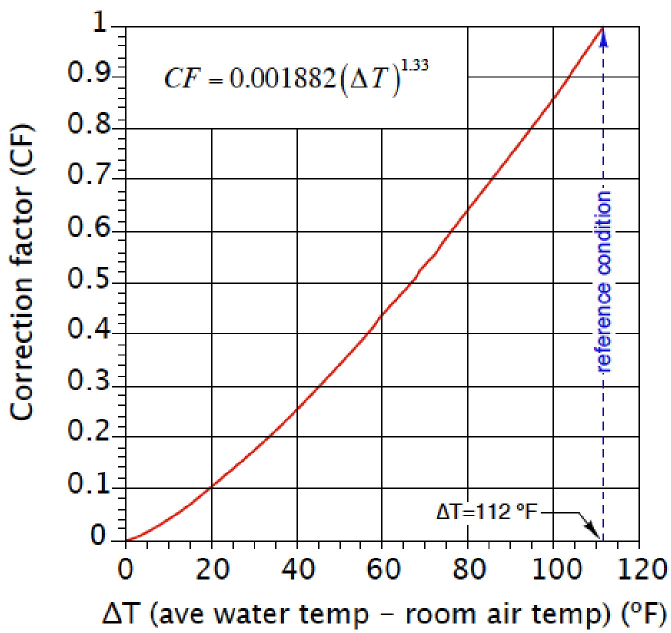
Configuration	Flow Rate GPM	PD in ft of H_2O	90°F	100°F	110°F	120°F	130°F	140°F	150°F	160°F	170°F	180°F	190°F	200°F	210°F
			Average Water Temperature (BTU/hr/ft @AWT in °F)												
TWO SUPPLIES PARALLEL	1	0.0044	130	205	290	385	460	546	637	718	813	911	1009	1113	1215
	4	0.0481	155	248	345	448	550	651	755	850	950	1040	1143	1249	1352
TOP SUPPLY BOTTOM RETURN	1	0.0088	105	169	235	305	370	423	498	570	655	745	836	924	1016
	4	0.0962	147	206	295	386	470	552	640	736	810	883	957	1034	1110
BOTTOM SUPPLY TOP RETURN	1	0.0088	103	166	230	299	363	415	488	559	642	730	819	906	996
	4	0.0962	140	212	283	350	435	524	623	722	792	865	937	1013	1093
BOTTOM SUPPLY NO RETURN	1	0.0044	75	127	169	208	260	311	362	408	470	524	576	629	685
	4	0.0481	85	140	203	265	334	410	472	536	599	662	723	788	850

Performance Notes: • All ratings include a 15% heating effect factor • Materials of construction include all aluminum "patented" fins at 47.3 per LF, mechanically bonded to two 3/4' (075) type L copper tubes ("Coil Block") covered by a 20 gauge perforated, painted cover all mounted to a backplate. Please see dimensional drawing for fin shape and dimensions • EAT=65°F • Pressure drop in feet of H_2O per LF.

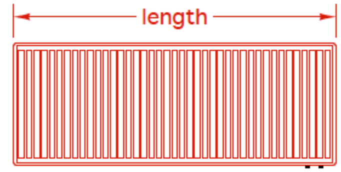
Heating Edge (HE2) has been performance tested in a BSRIA standards laboratory. The test chamber was set up according to IBR testing protocol. The above chart is shown in Average Water Temperatures (AWT) per market request.

Panel Radiators

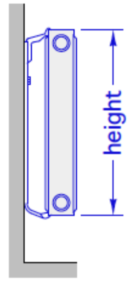
Adjust heat output for operation at lower water temperatures.



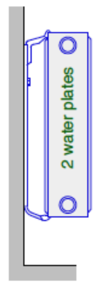
Reference condition:
Ave water temp. in panel = 180°F
Room air temperature = 68°F



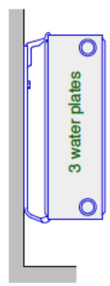
Heat output ratings (Btu/hr)
at reference conditions:
Average water temperature in panel = 180°F
Room temperature = 68°F
temperature drop across panel = 20°F



1 water plate panel thickness	16" long	24" long	36" long	48" long	64" long	72" long
24" high	1870	2817	4222	5630	7509	8447
20" high	1607	2421	3632	4842	6455	7260
16" high	1352	2032	3046	4060	5415	6091



2 water plate panel thickness	16" long	24" long	36" long	48" long	64" long	72" long
24" high	3153	4750	7127	9500	12668	14254
20" high	2733	4123	6186	8245	10994	12368
16" high	2301	3455	5180	6907	9212	10363
10" high	1491	2247	3373	4498	5995	6745

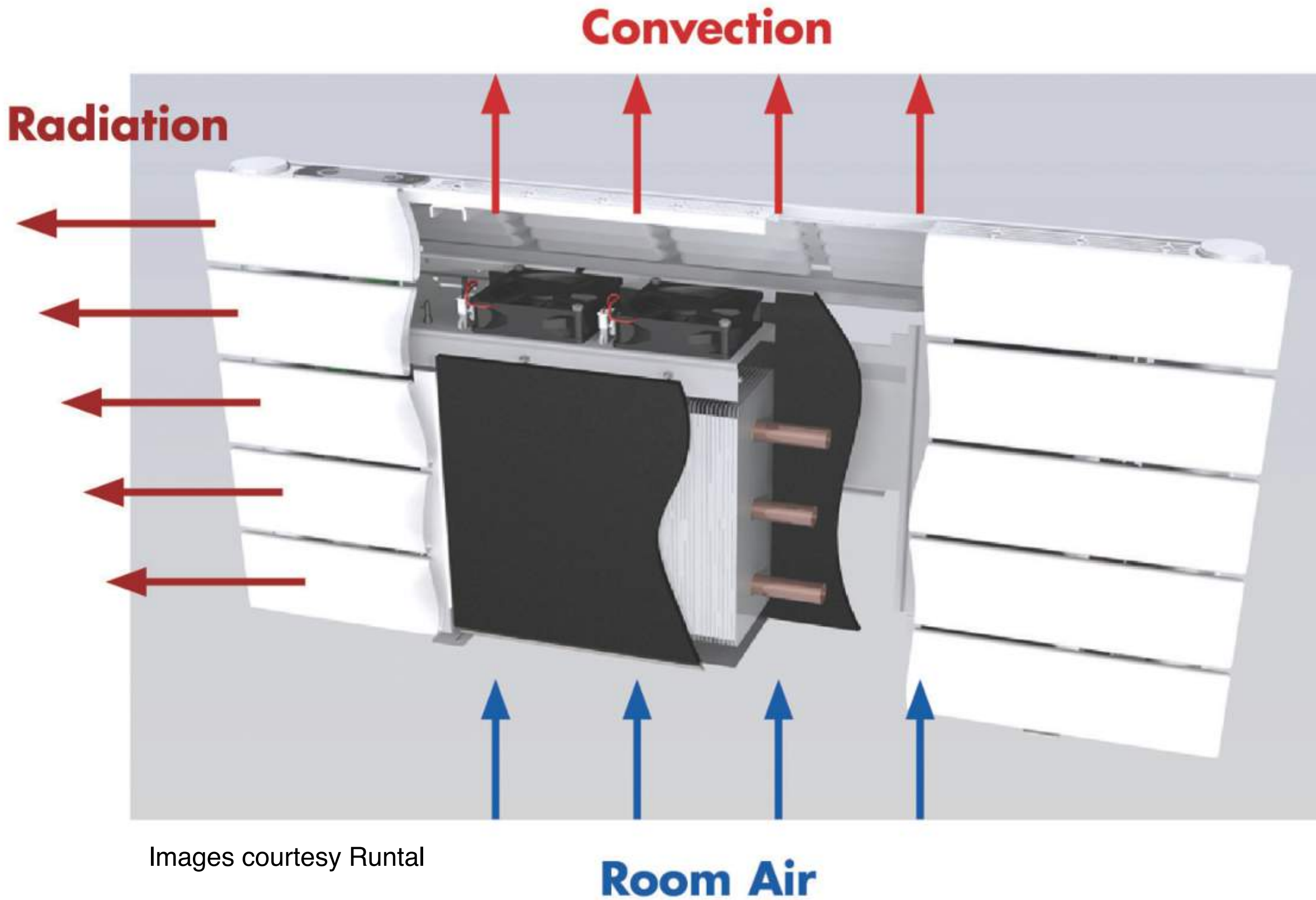


3 water plate panel thickness	16" long	24" long	36" long	48" long	64" long	72" long
24" high	4531	6830	10247	13664	18216	20494
20" high	3934	5937	9586	11870	15829	17807
16" high	3320	4978	7469	9957	13277	14938
10" high	2191	3304	4958	6609	8811	9913

As an approximation, a panel radiator operating with an average water temperature of 110 °F in a room room maintained at 68 °F, provides approximately 27 percent of the heat output it yields at an average water temperature of 180 °F.

Fan-assisted Panel Radiators

The “NEO”, from Runtal North America

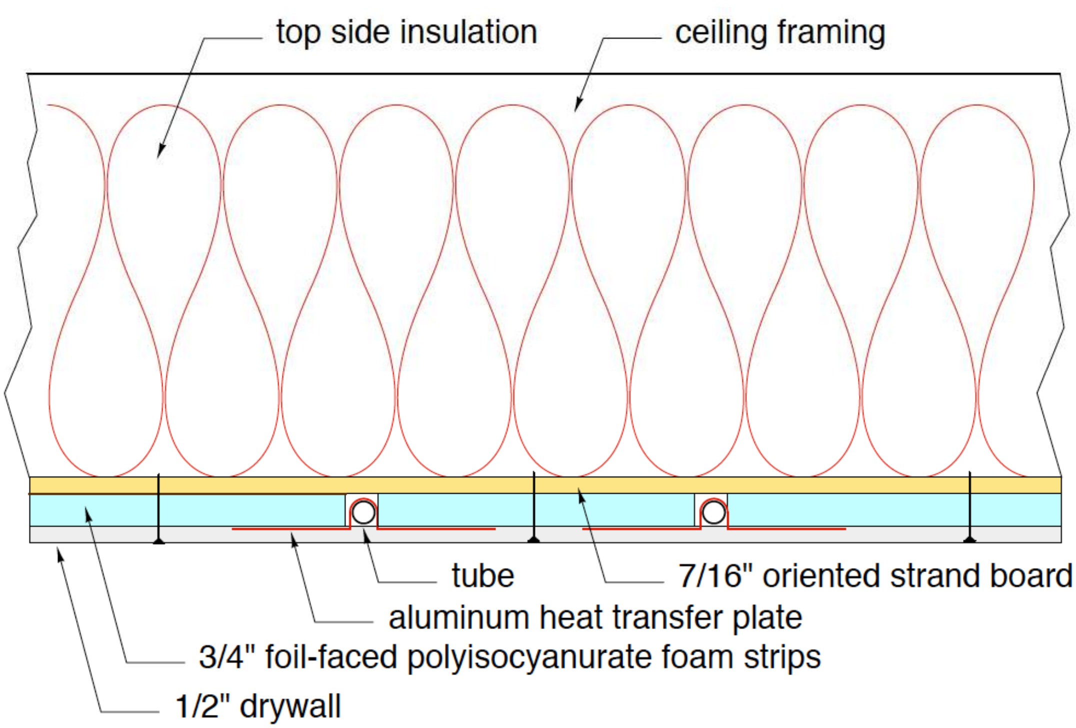


Images courtesy Runtal

8 tube high x 31.5” wide produces 2095 Btu/hr at average water temperature of 104 °F in 68°F room

8 tube high x 59” wide produces 5732 Btu/hr at average water temperature of 104 °F in 68°F room

Site built radiant CEILINGS...



Thermal image of radiant ceiling in operation

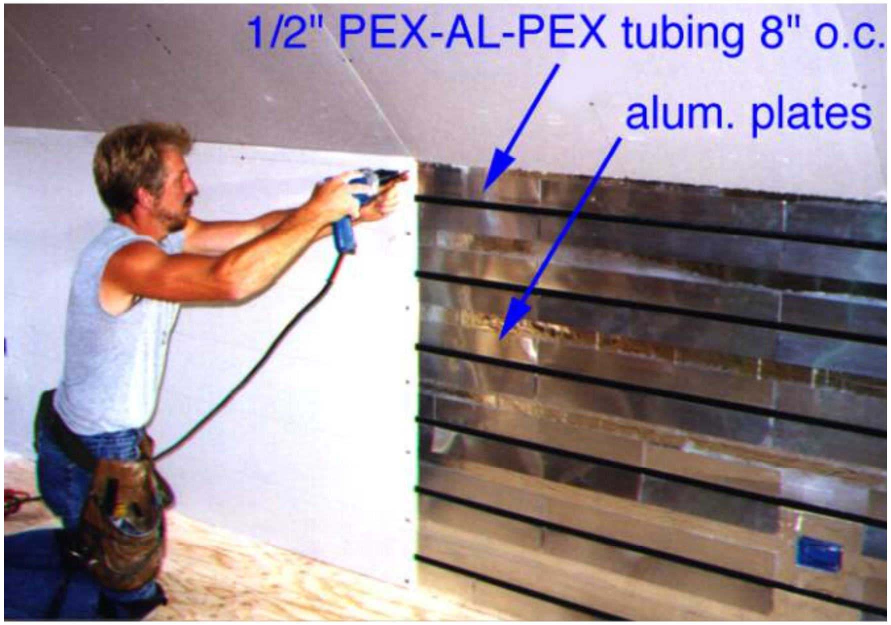
Heat output formula:

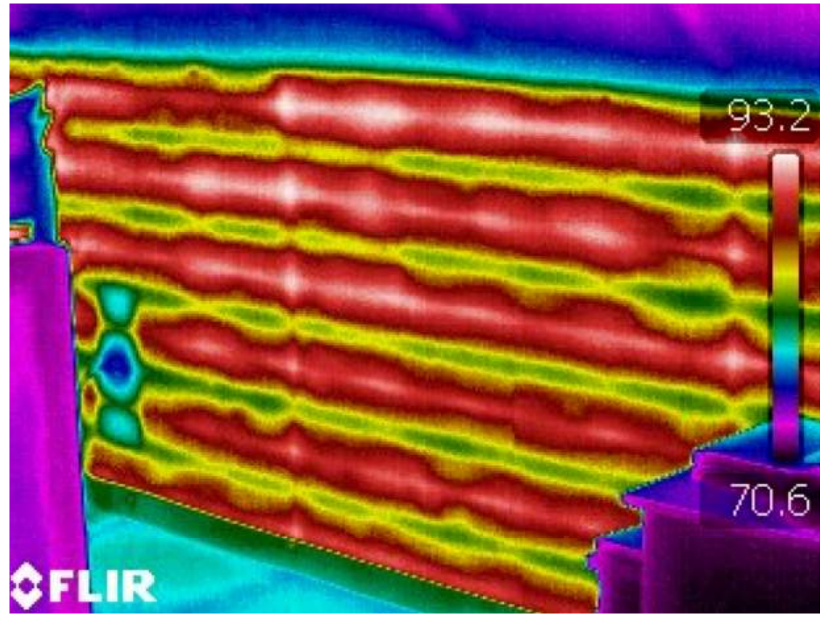
$$q = 0.71 \times (T_{water} - T_{room})$$

Where:

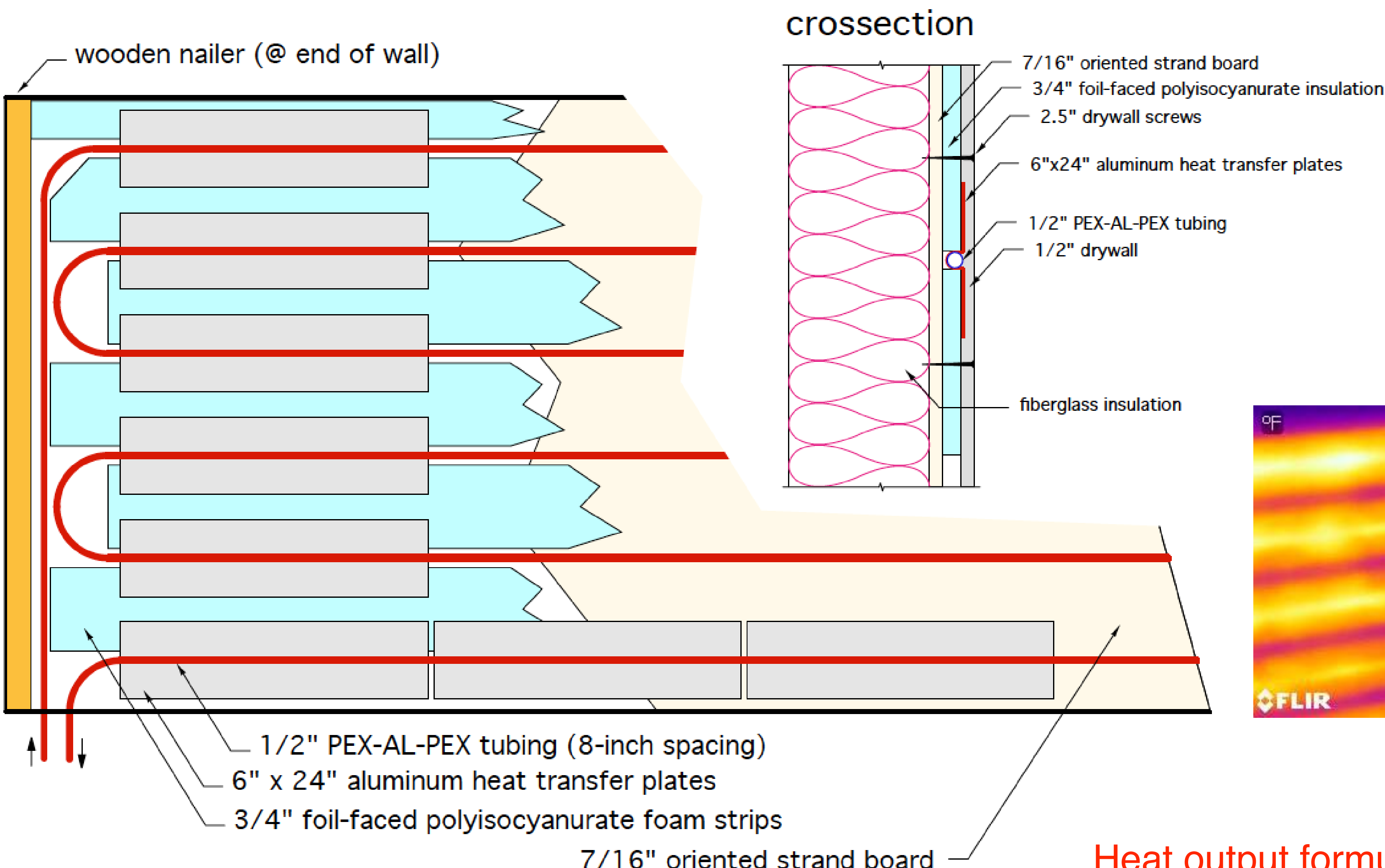
Q = heat output of ceiling (Btu/hr/ft^2)
T_{water} = average water temperature in panel (°F)
T_{room} = room air temperature (°F)

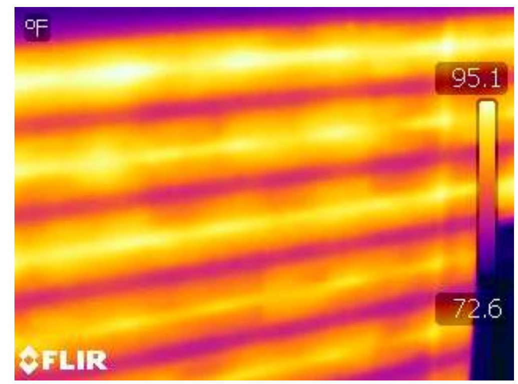
Site built radiant WALLS...





Site built radiant WALLS...





- completely out of sight
- low mass -fast response
- reasonable output at low water temperatures
- stronger than conventional drywall over studs
- don't block with furniture

Heat output formula:

$$q = 0.8 \times (T_{water} - T_{room})$$

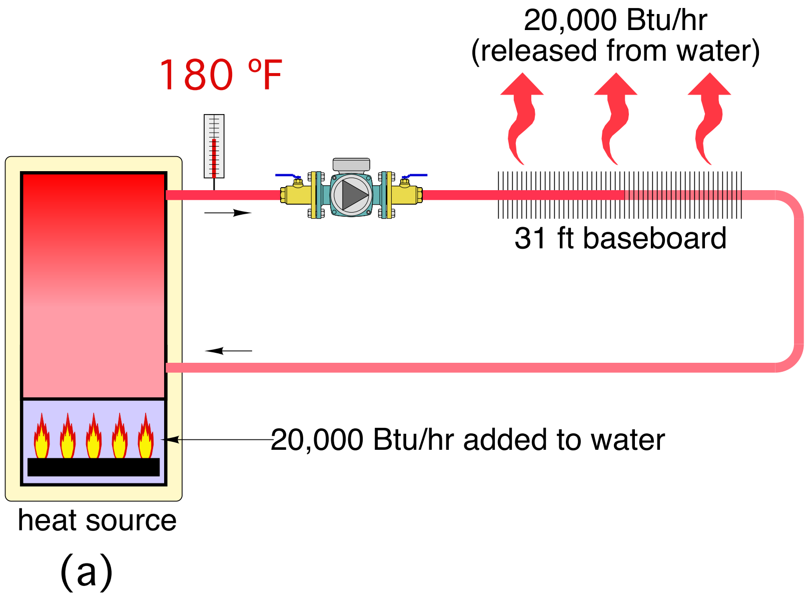
Where:

Q = heat output of wall (Btu/hr/ft^2)
T_{water} = average water temperature in panel (°F)
T_{room} = room air temperature (°F)

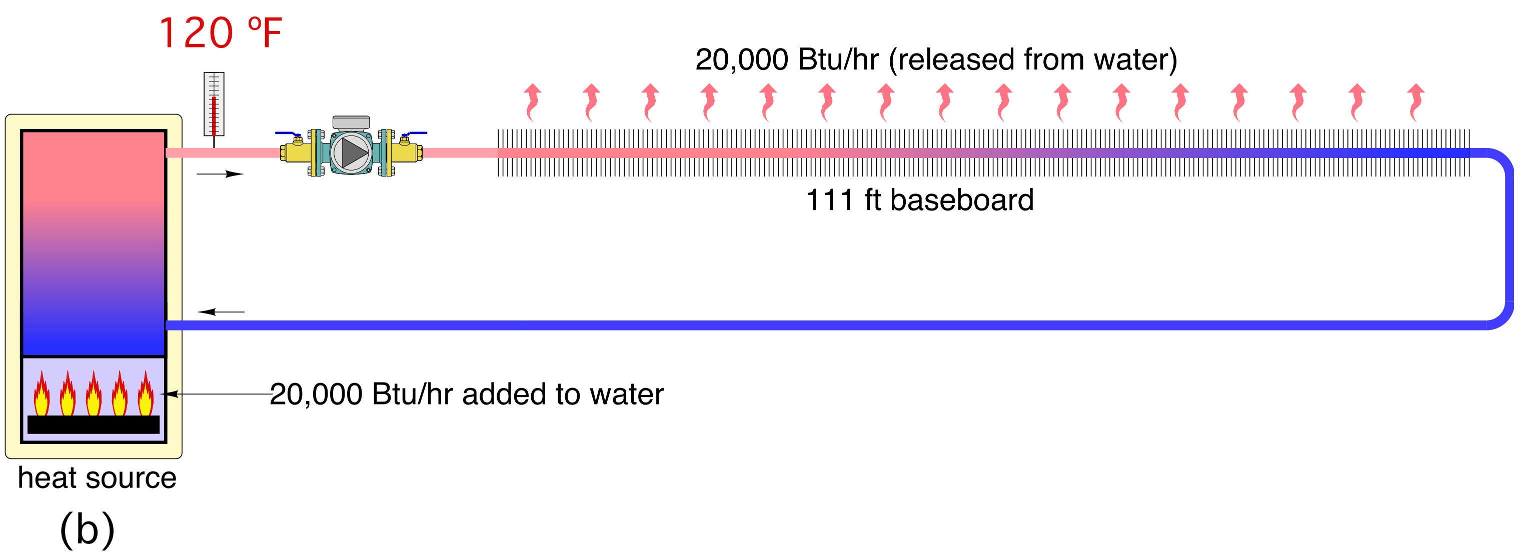
Retrofitting existing high water temperature distribution systems for lower water temperature operation

Retrofitting existing high temperature distribution systems

Increasing the total surface area of the heat emitters lowers the water temperature at which a given rate of heat deliver can occur.

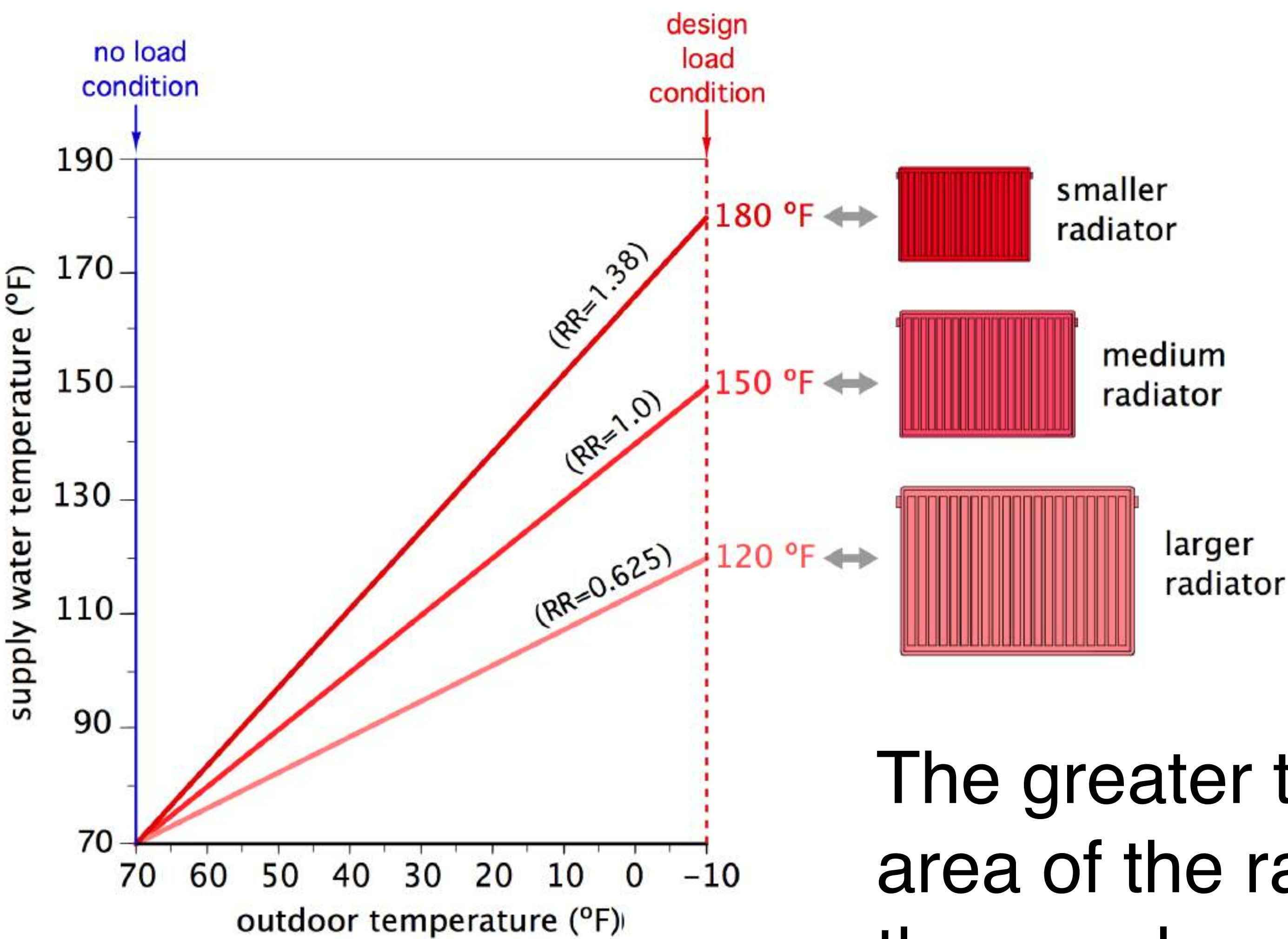


The greater the linear footage of baseboard, the lower the supply water temperature requirement.



Retrofitting existing high temperature distribution systems

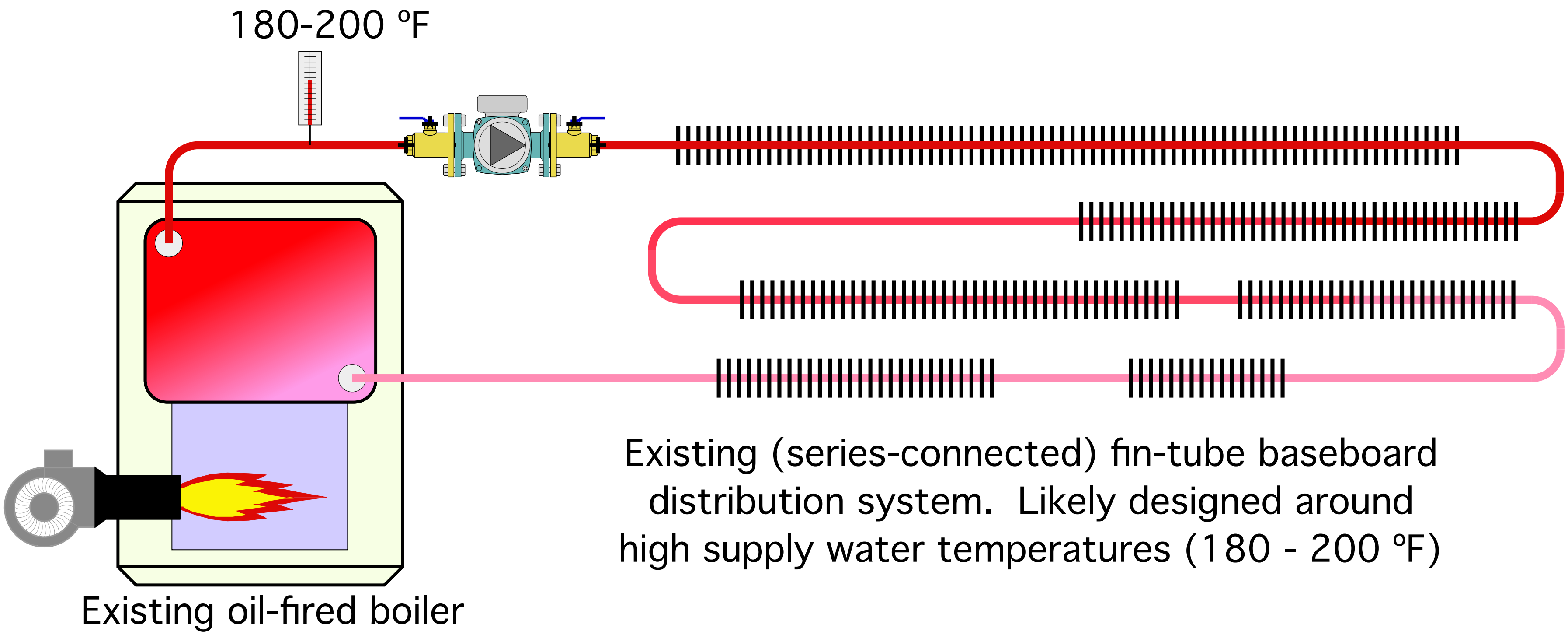
Increasing the total surface area of the heat emitters lowers the water temperature at which a given rate of heat deliver can occur.



The greater the total surface area of the radiators, the lower the supply water temperature requirement.

Retrofitting existing high temperature distribution systems

In retrofit applications the existing heat emitters and distribution system are likely to be sized based on relatively high supply water temperatures (180-200 °F) at design load conditions.



It's also likely that fin-tube baseboard will be connected in one or more series circuits as shown.

Although a biomass boiler can produce these temperatures, the thermal storage tank becomes ineffective if it cannot cycle over a reasonable range of temperature.

Retrofitting existing high temperature distribution systems

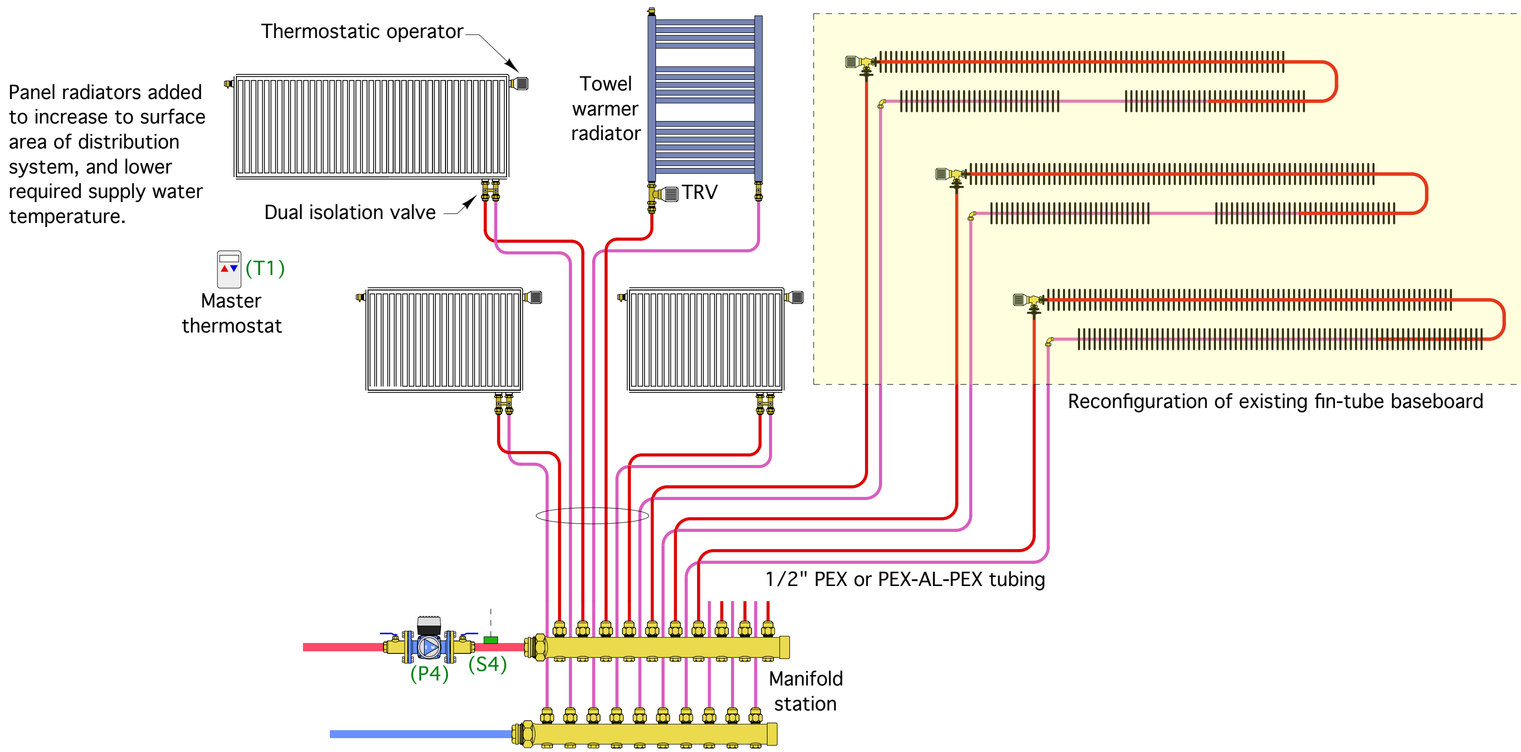
General concepts:

1. Lowering the supply water temperature at which the distribution system can deliver design load allows more heat to be “drained” from storage. This results in longer boiler operating cycles.

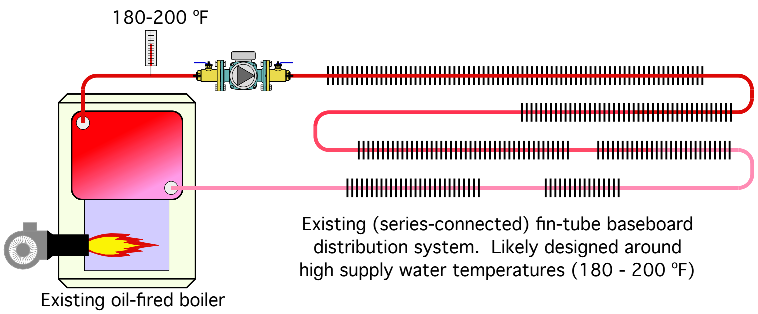
2. Parallel piping of heat emitters is preferred over series piping because is eliminates sequential temperature drop from one heat emitter to another.

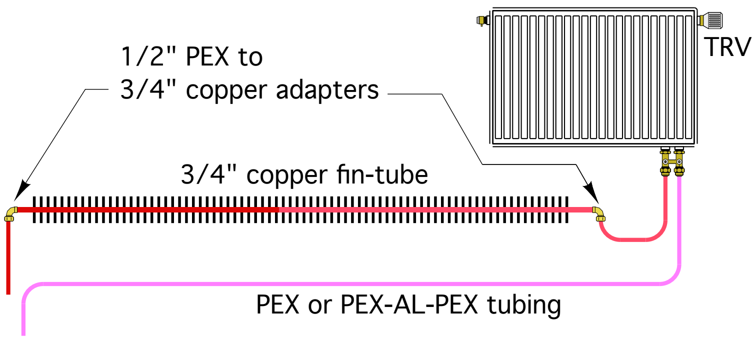
3. Parallel piping also allows for easier zoning and flow balancing.

4. Likely easier to “morph” distribution system from series to parallel using homerun circuits of 1/2” PEX or PEX-AL-PEX.

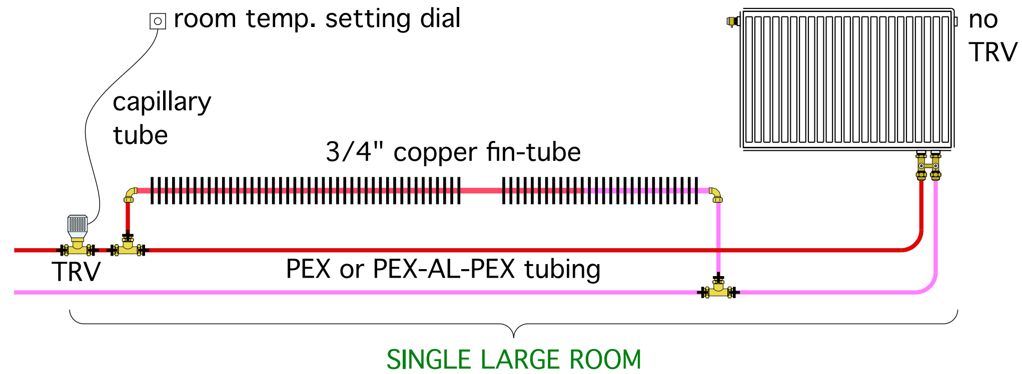


Reconfiguring higher temperature series baseboard circuits for lower supply water temperatures



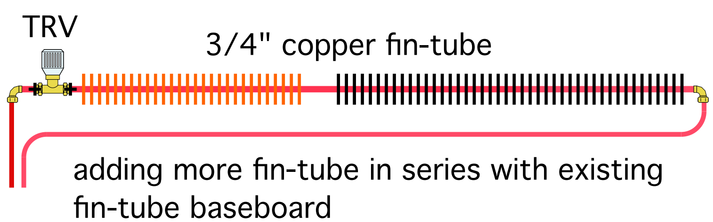


Combined heat output of existing fin-tube baseboard + panel radiator = design load of space with supply water temperature of 120 °F (preferred), or 140 °F (acceptable).



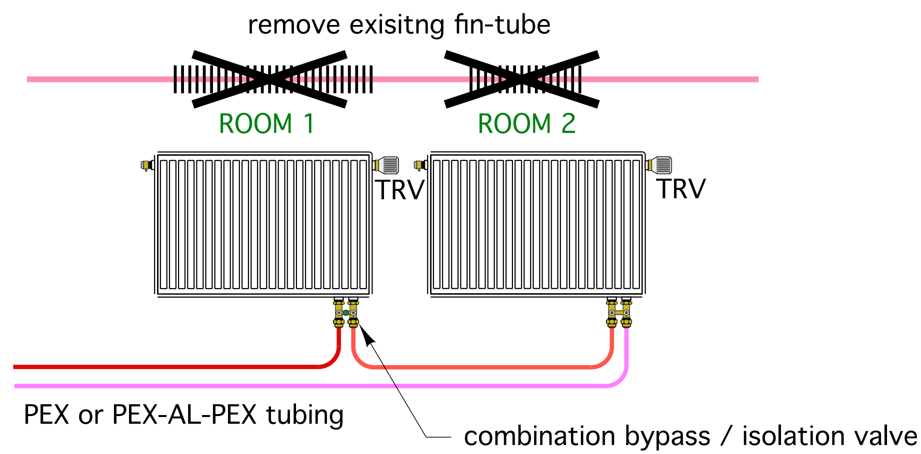
Add panel radiator in parallel with existing baseboard, both controlled by single TRV.

Combined heat output of existing fin-tube baseboard + new panel radiator = design load of space with supply water temperature of 120 °F (preferred), or 140 °F (acceptable).



Extend the fin-tube in space to lower water temperature. Both controlled by single TRV.

Combined heat output of existing fin-tube baseboard + new fin-tube = design load of space with supply water temperature of 120 °F (preferred), or 140 °F (acceptable).



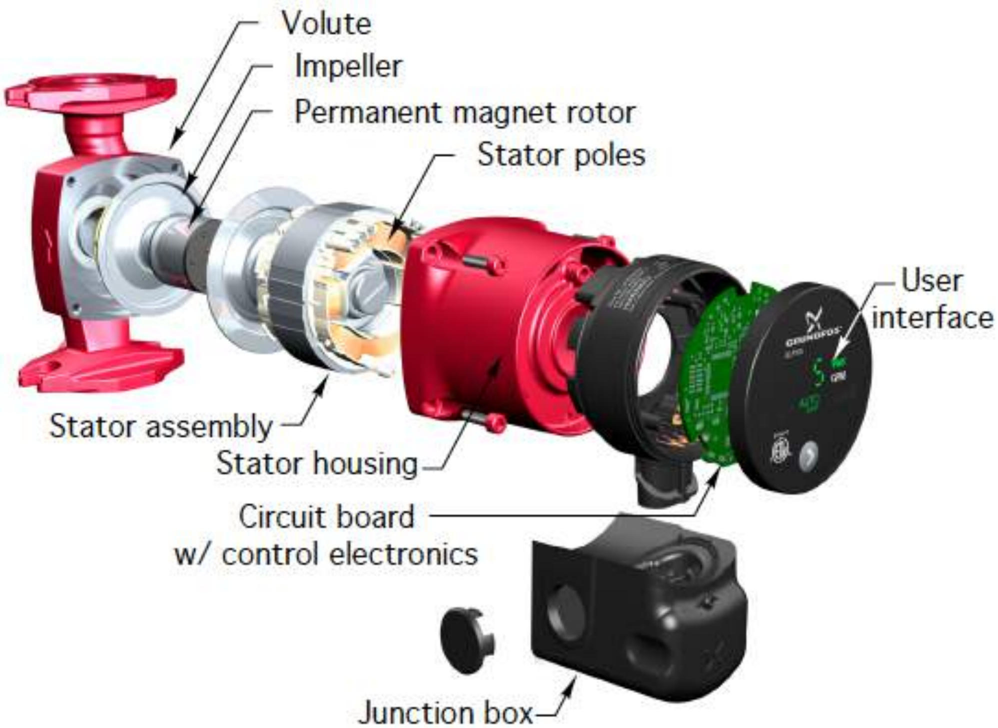
Remove exisitng baseboard and replace with two panel radiators, each individually controlled

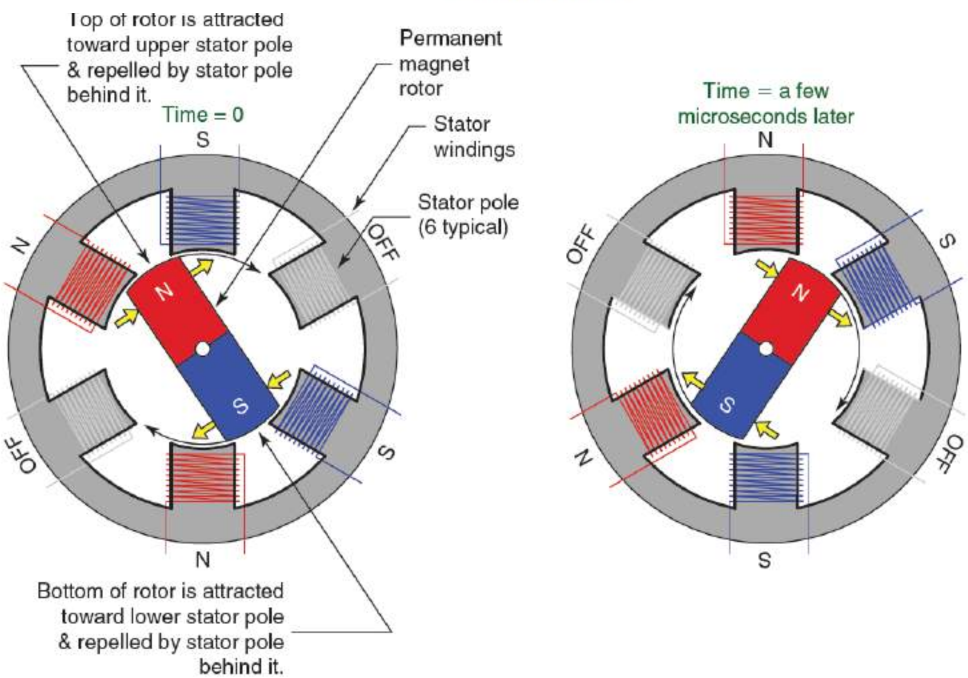
Combined heat output of new panel radiators = design load of space with supply water temperature of 120 °F (preferred), or 140 °F (acceptable).

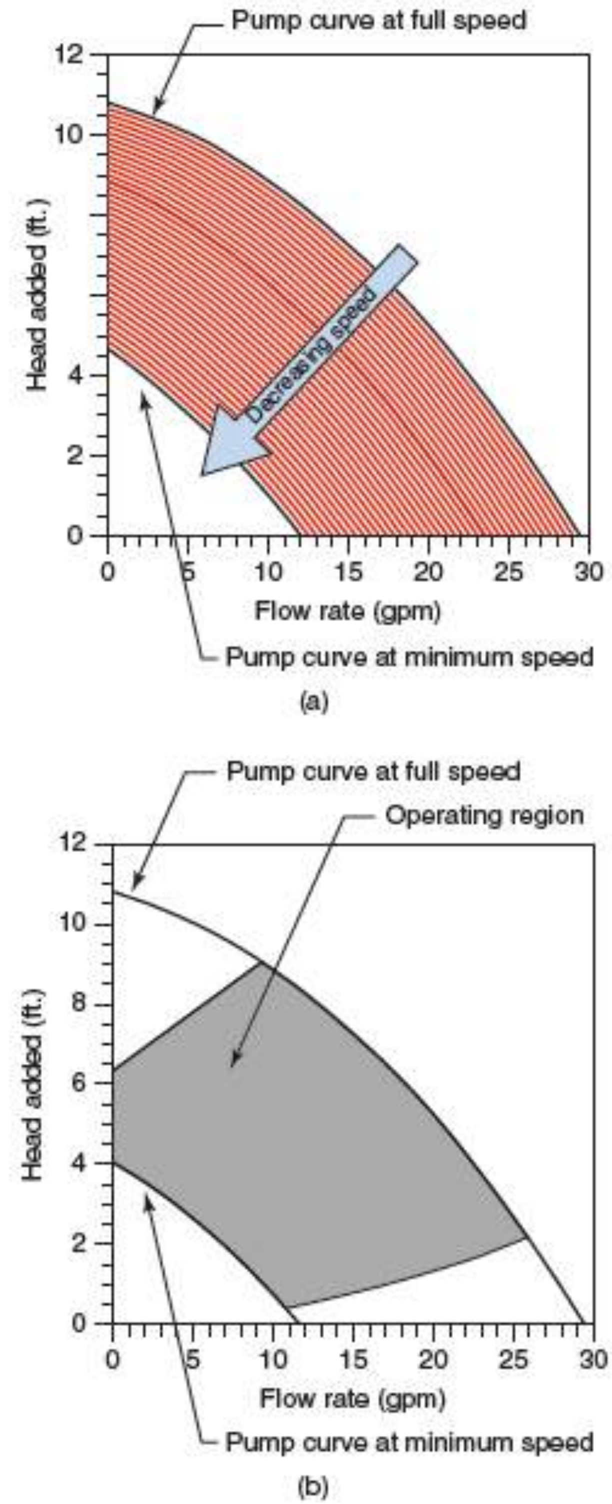
High efficiency circulators

How does a ECM Circulator work?

Image courtesy Grundfos

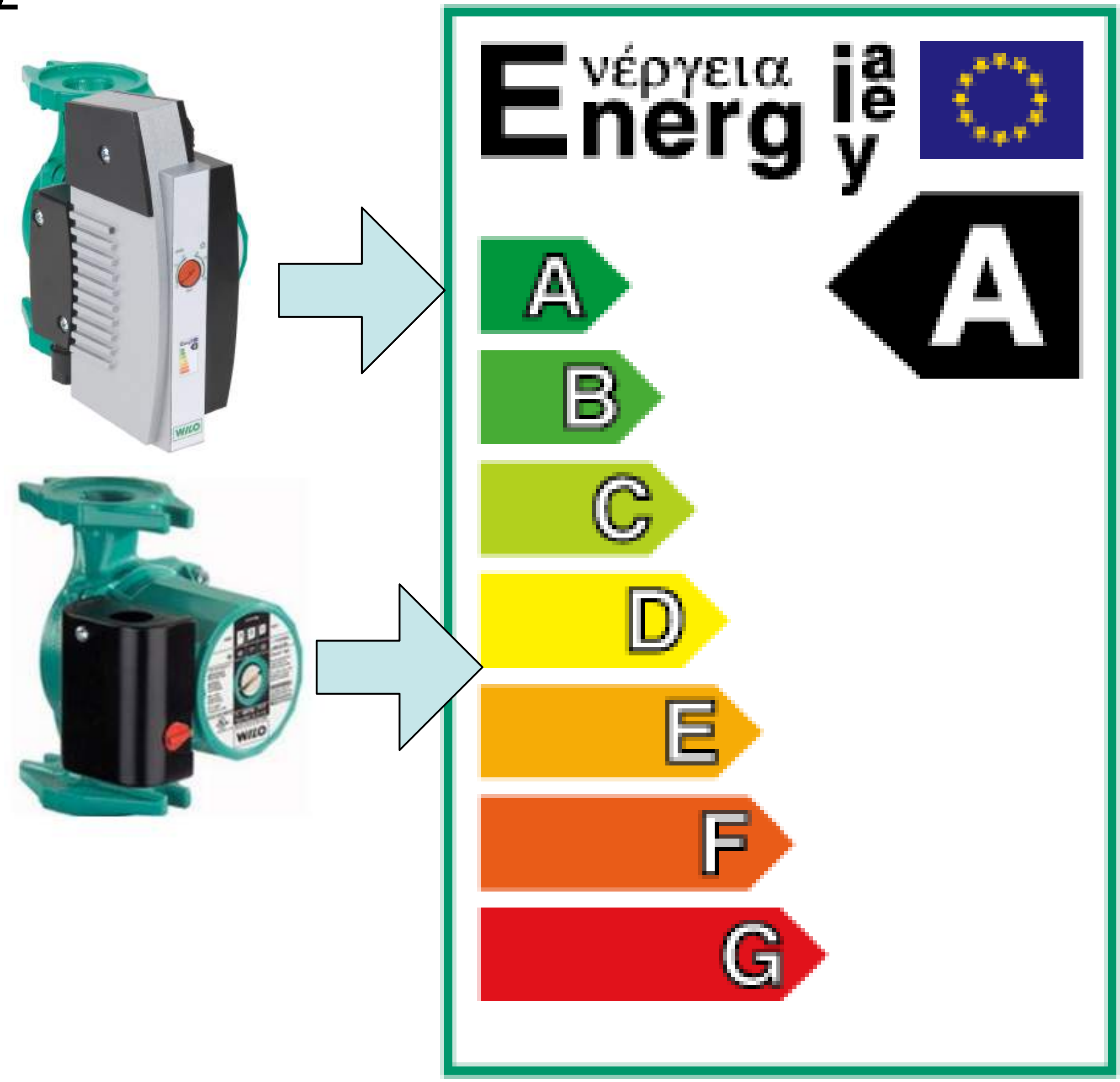






Former European circulator rating system

<u>All these circulators rated “A” on the energy labeling system from Europump (European Association of Pump Manufacturers).</u>



Single or multi-speed wet-rotor circulators like those commonly used in North America would be rated “D” or “E” on this scale.

Small ECM circulators now available in North America

Grundfos Alpha: constant and proportional differential pressure & 3 fixed speed settings. 6-50 watt input.

Wilo Stratos ECO 16F: Provide constant and proportional differential pressure. 5.8-59 watt electrical input.

Bell & Gossett ECOCIRC, Provides manual adjustable speed setting (VARIO model), and proportional differential pressure (AUTO model). 5-60 watt electrical input.

Taco VT2218 Temperature based speed control.

Armstrong COMPASS Provides constant and proportional differential pressure and three fixed speed settings. 3-45watt electrical input.

AquaMotion: Einstein series

Taco Viridian VT1816 released Nov. 2014 9-44 watts

Circulators

high efficiency ECM Circulators

Larger ECM circulators now available in US

Wilo STRATOS circulators

Grundfos MAGNA

Taco Viridian

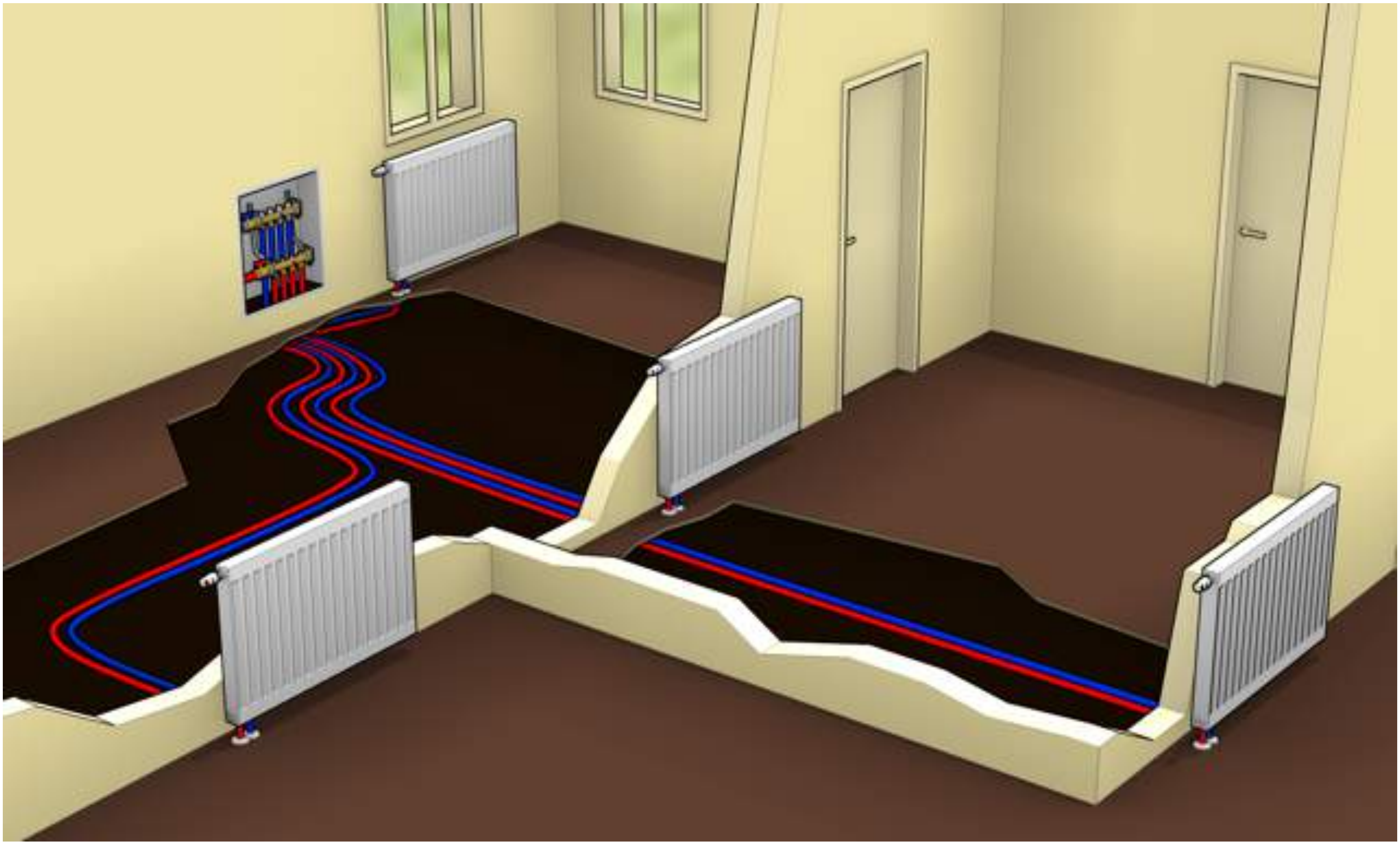
Heads to 45 feet,
flows to 345 gpm
power inputs to 1600 watts

B&G ECO XL

Homerun Distribution Systems

Many North American heating pros now recognize
PEX or PEX-AL-PEX as a universal hydronic distribution pipe.

One of the best approaches using this pipe is a “homerun” system.



Benefits of a homerun distribution system…

• The ability to "fish" tubing through framing cavities is a tremendous advantage over rigid tubing, **especially in retrofit situations.**

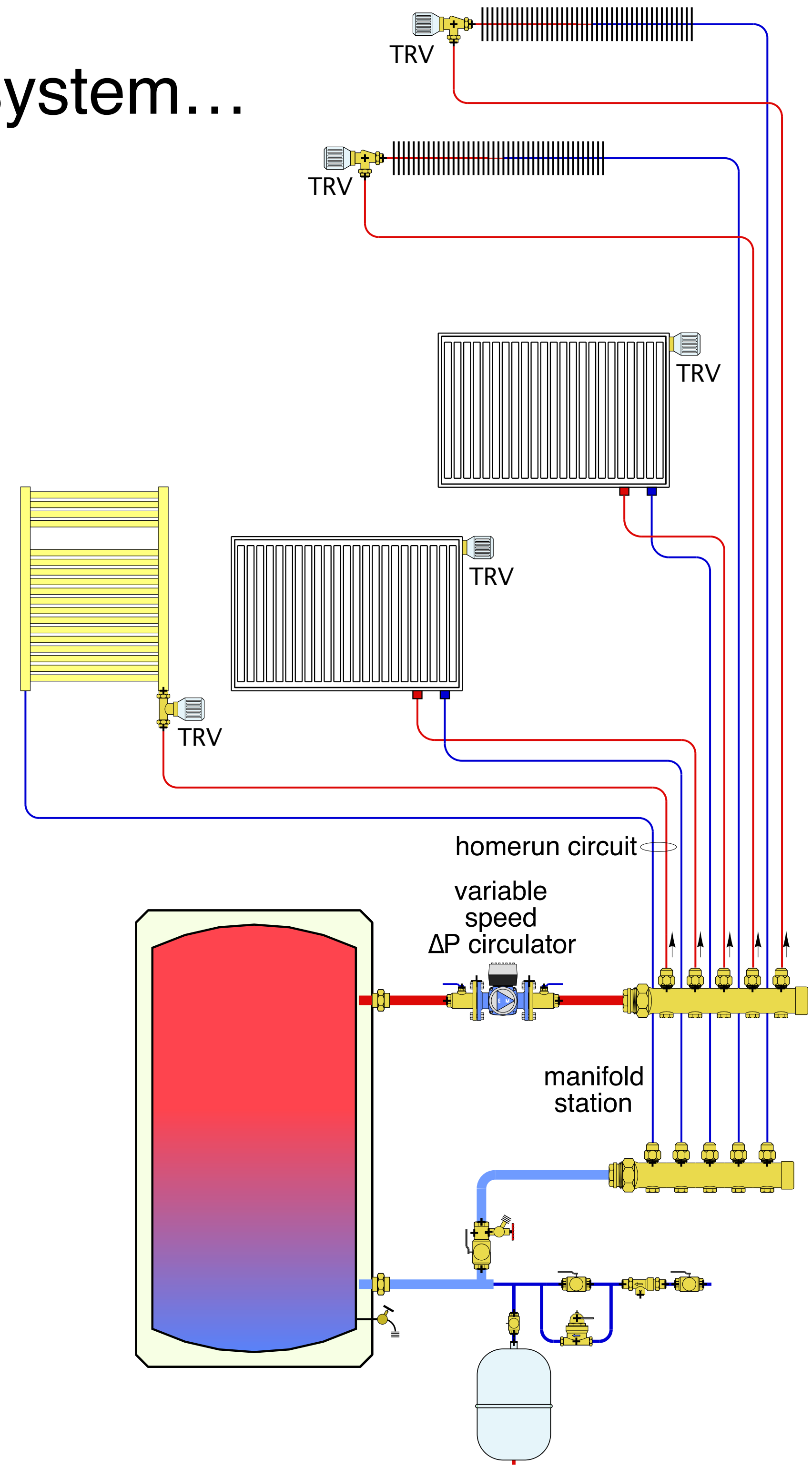
• Allows easy room-by-room zoning

• Delivers same water temperature to each heat emitter (simplifies heat emitter sizing)

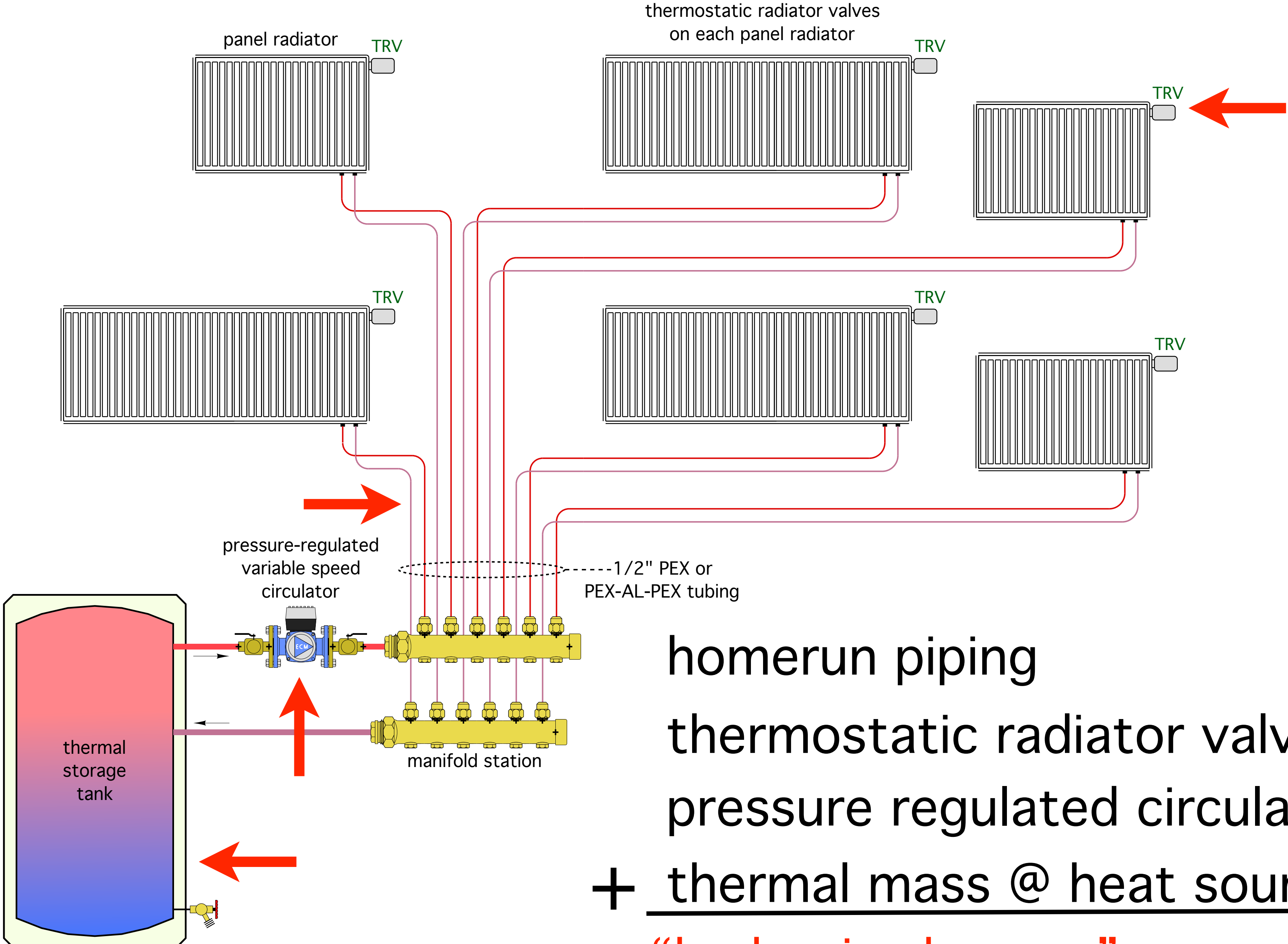
• Can be configured with several types of heat emitters (provided they all require about the same supply water temperature)

• Easy flow adjustment through any branch circuit using manifold or heat emitter valves

• Lower circulator power required relative to series piping systems



Supplying a homerun distribution system...



homerun piping

thermostatic radiator valves

pressure regulated circulator

\+ thermal mass @ heat source

“hydronics heaven”

Homerun systems allow several methods of zoning.

One approach is to install valved manifolds equipped with low voltage valve actuators on each circuit.

Another approach is to install a thermostatic radiator valve (TRV) on each heat emitter.

thermostatic radiator valves are easy to use...

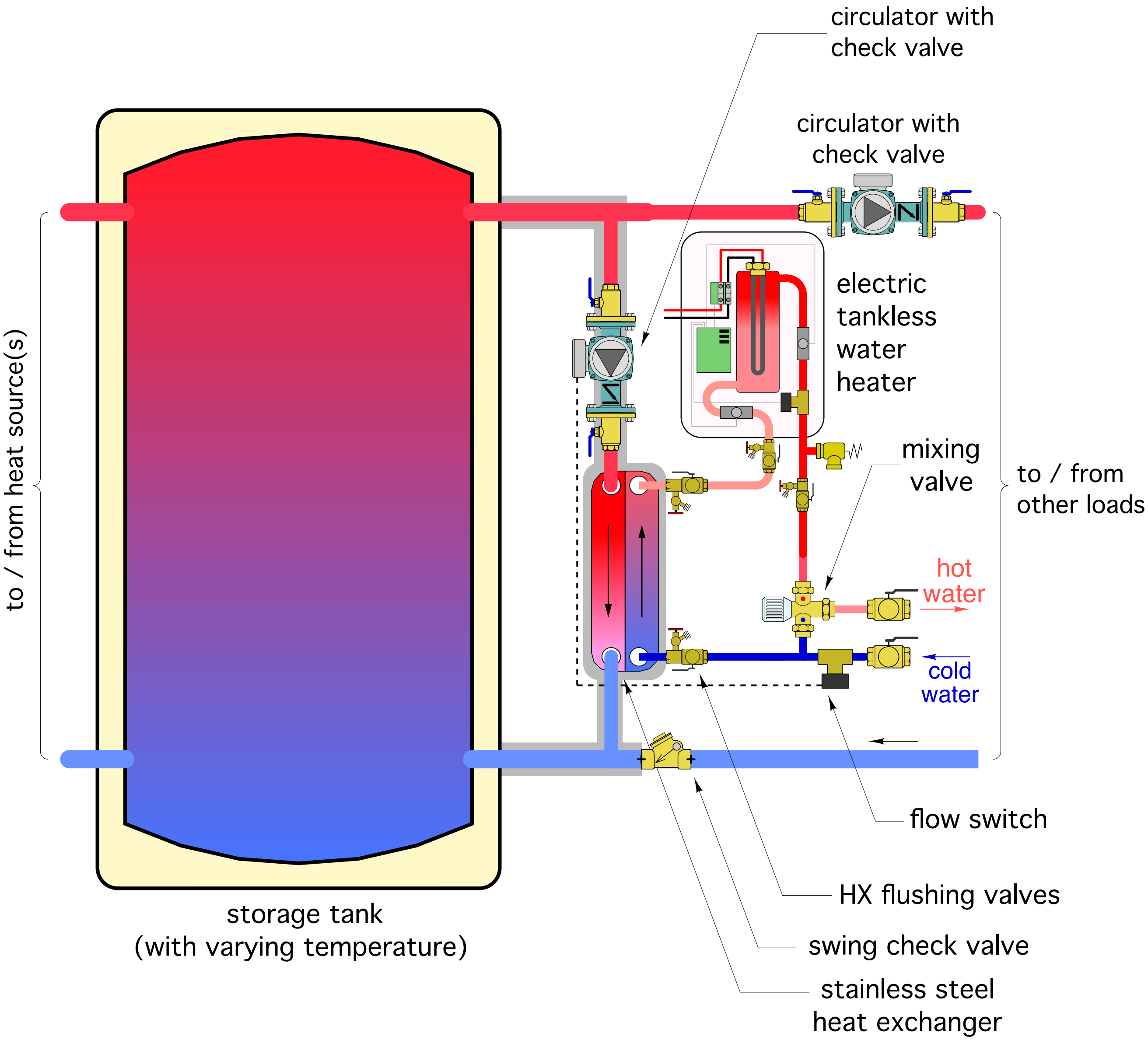
manual setback

dog reset control

dogs are "thermally discriminating."

Instantaneous DHW subassembly

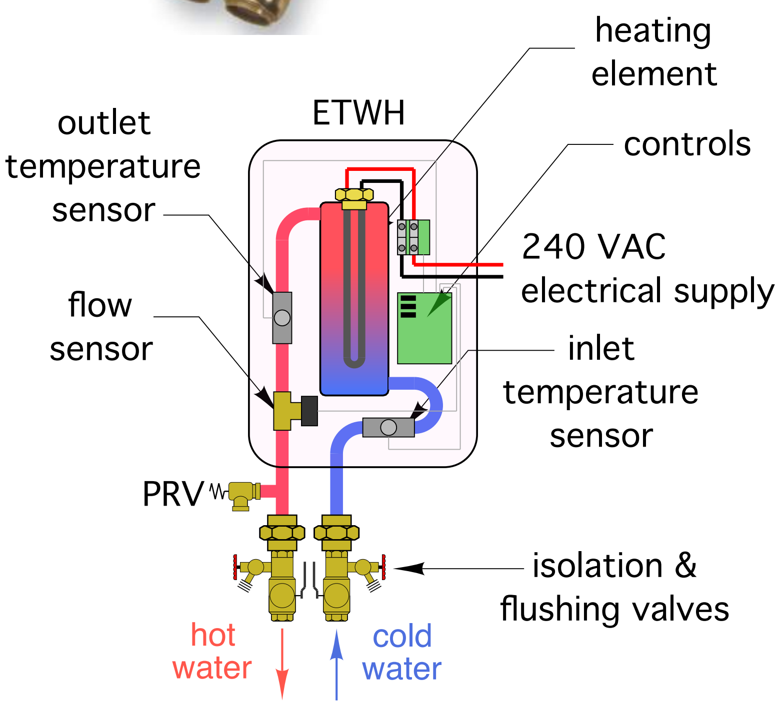
Instantaneous DHW subassembly

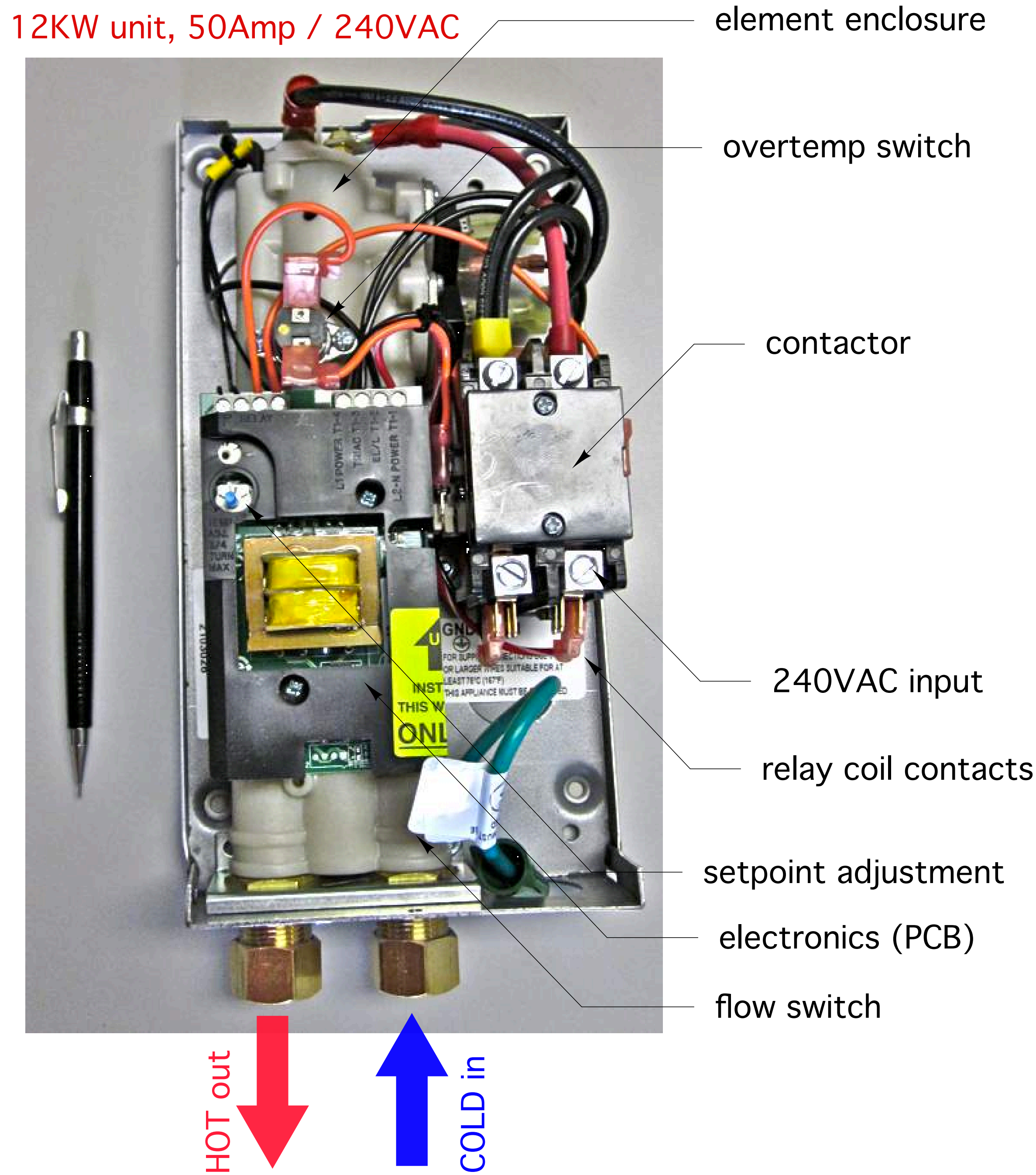


- Leverages the thermal mass for stabilizing DHW delivery.
- Brazed plate heat exchanger provides very fast response (1-2 seconds)
- Fully serviceable heat exchanger (unlike an internal coil heat exchanger) Can be cleaned or replaced if necessary.
- Predictable heat exchanger performance
- Very little heated domestic water is stored (reducing potential for Legionella growth).
- Very low wattage circulator needed on primary side of heat exchanger

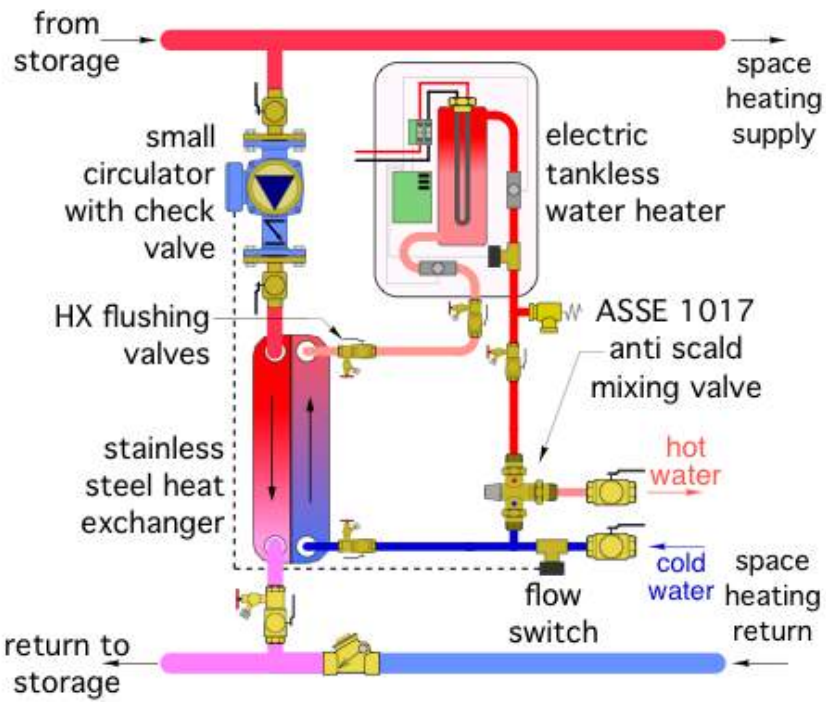
Thermostatically controlled electric tankless water heaters

Image courtesy Eemax





Instantaneous DHW subassembly



3”x5”

5”x12”

10”x20”

Brazed plate stainless steel heat exchangers are widely available.

They have very high ratio of surface area to volume.

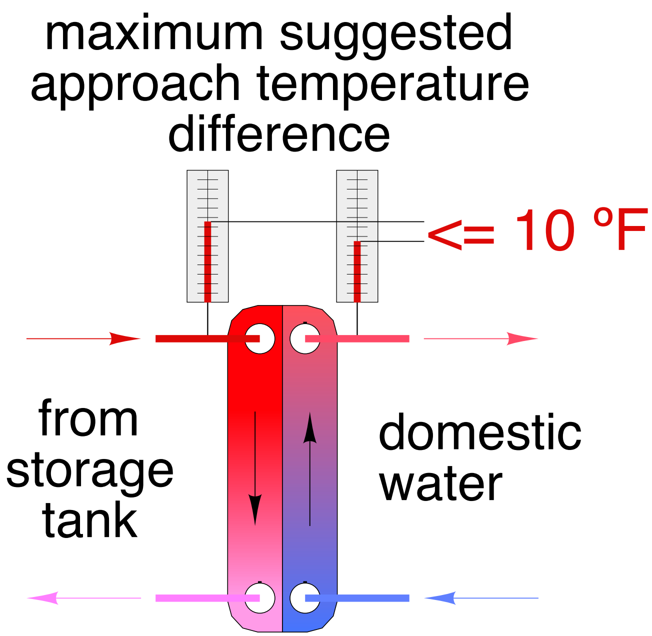
Response time to quasi steady state = 1 to 2 seconds

Response time of this subassembly is likely under 5 seconds.
(assuming short, insulated piping b/w HX and storage tank)

Images courtesy
GEA FlatPlate

Sizing the brazed plate heat exchanger

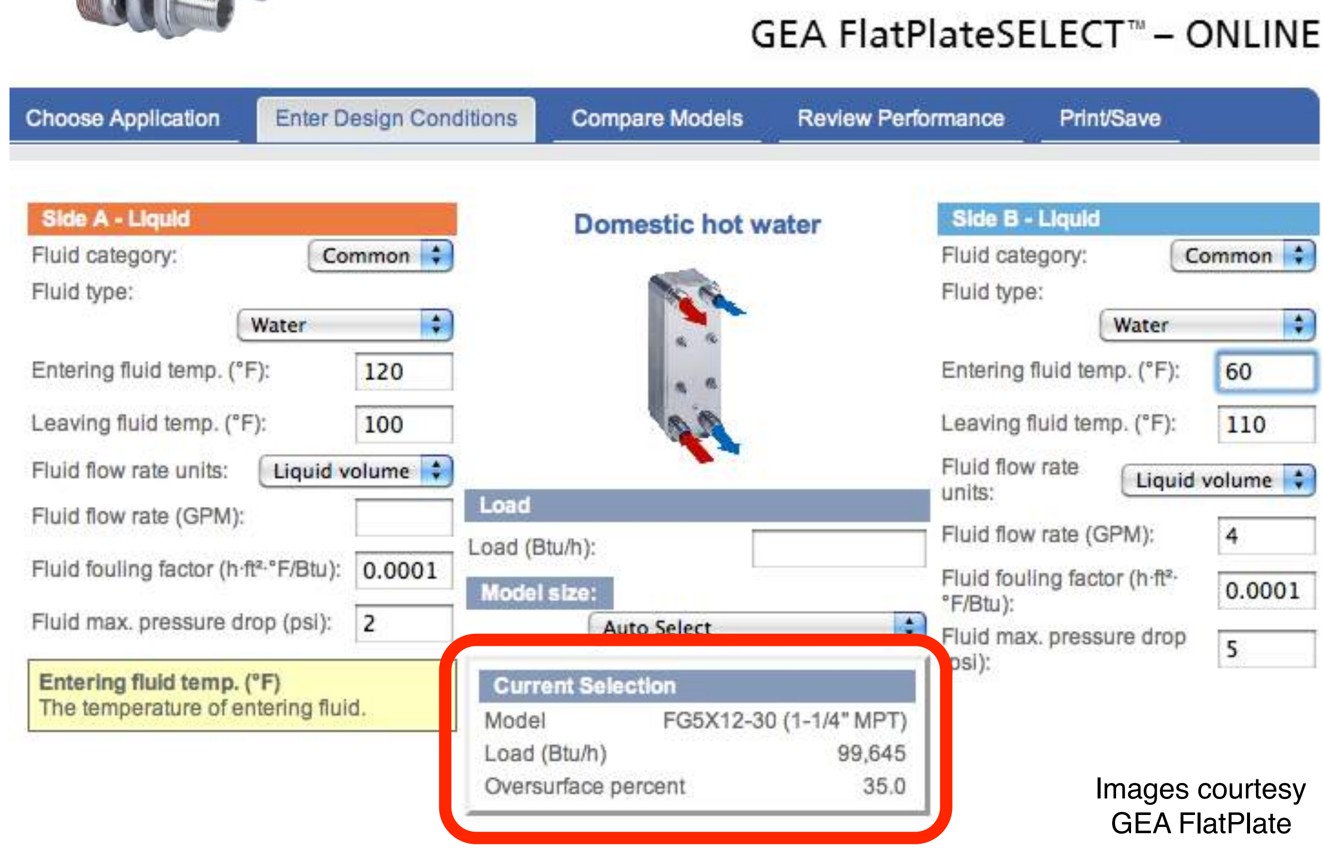
Suggest a maximum approach temperature difference of 10 °F under max. anticipated water demand, and minimum preheat inlet temperature.



FG5x12-30

5” wide x12” long -30 plates

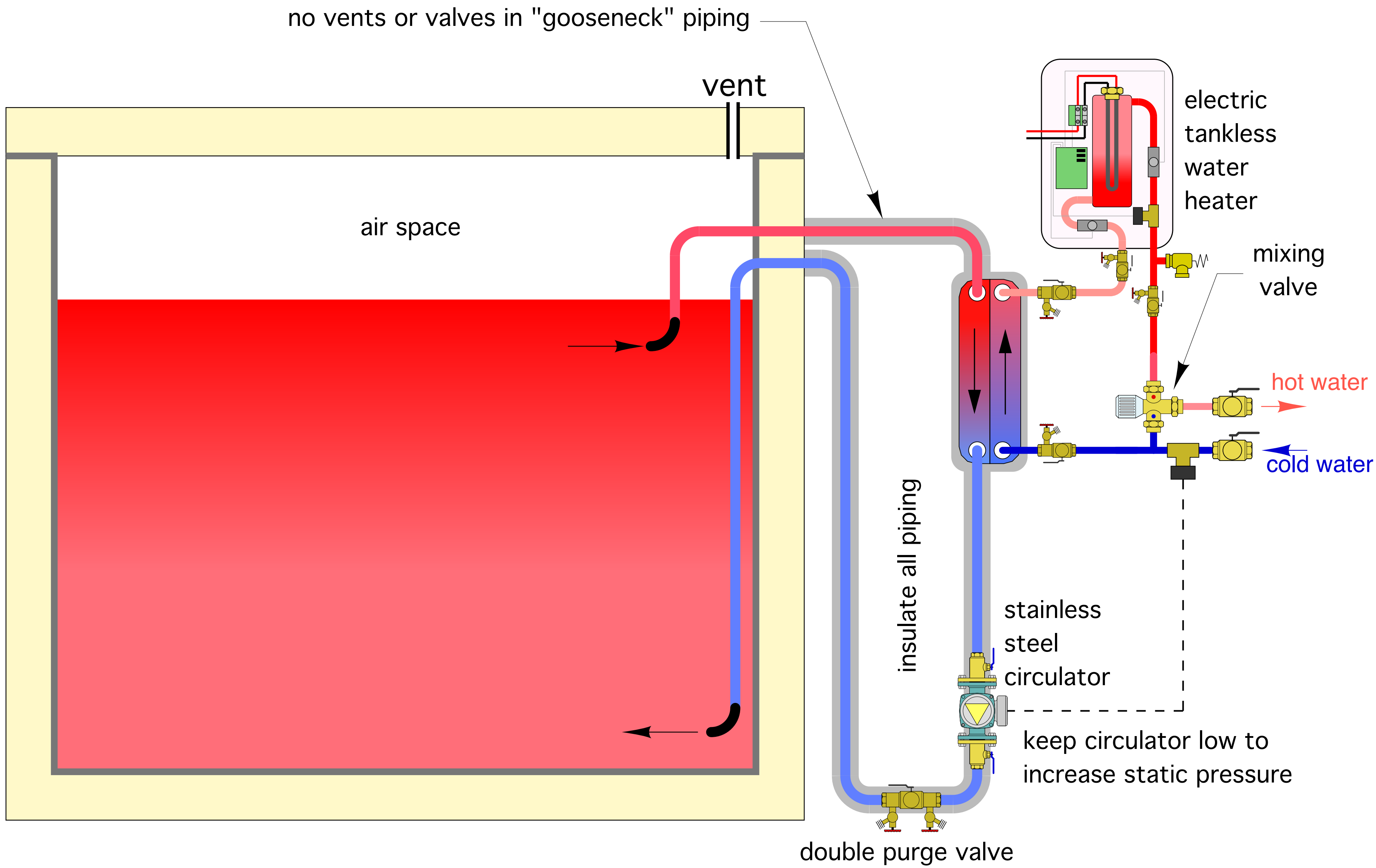
http://flatplateselect.com



Images courtesy GEA FlatPlate

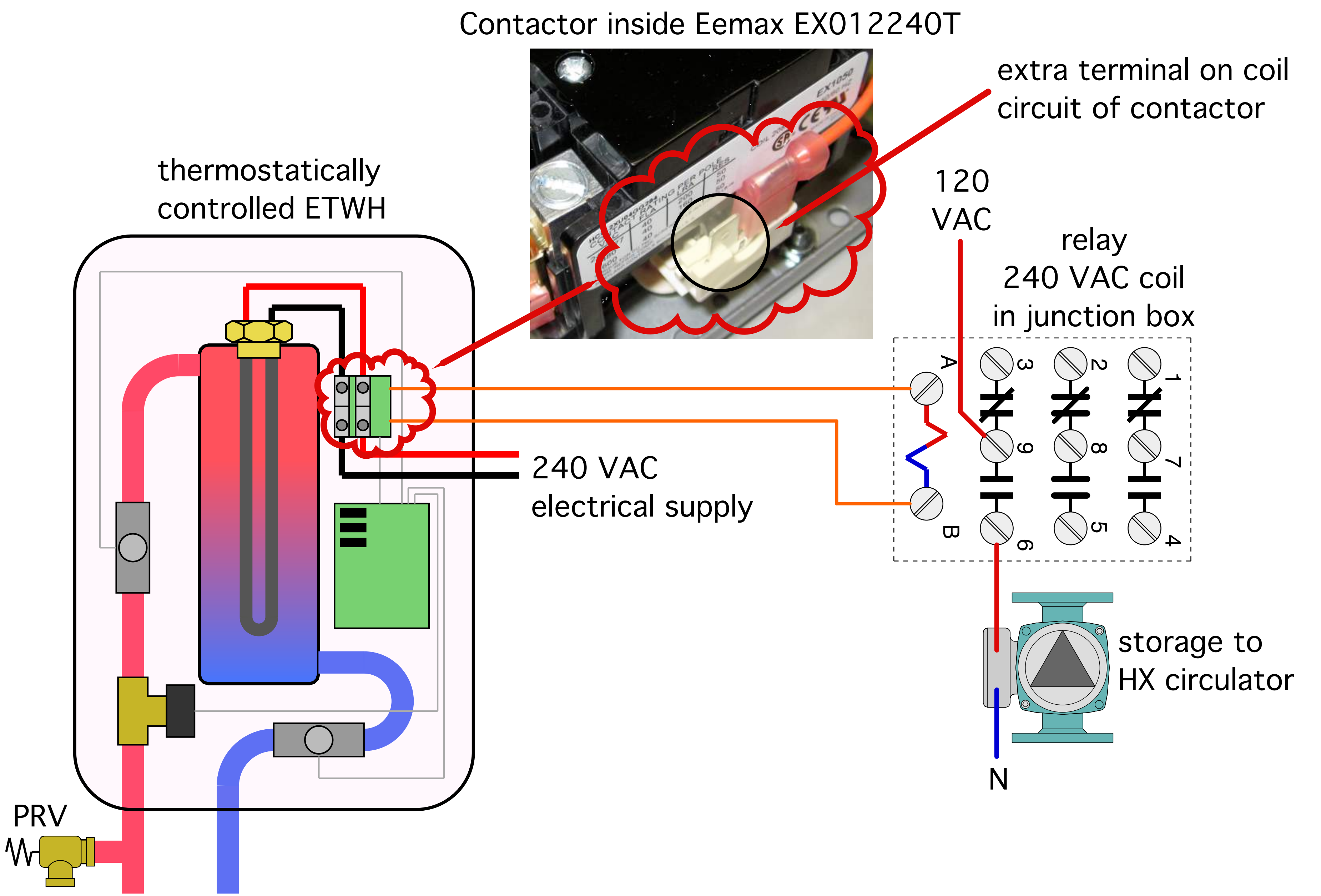
Instantaneous DHW subassembly piping

Using it with unpressurized thermal storage



Using extra terminal on ETWH contactor to operate circulator

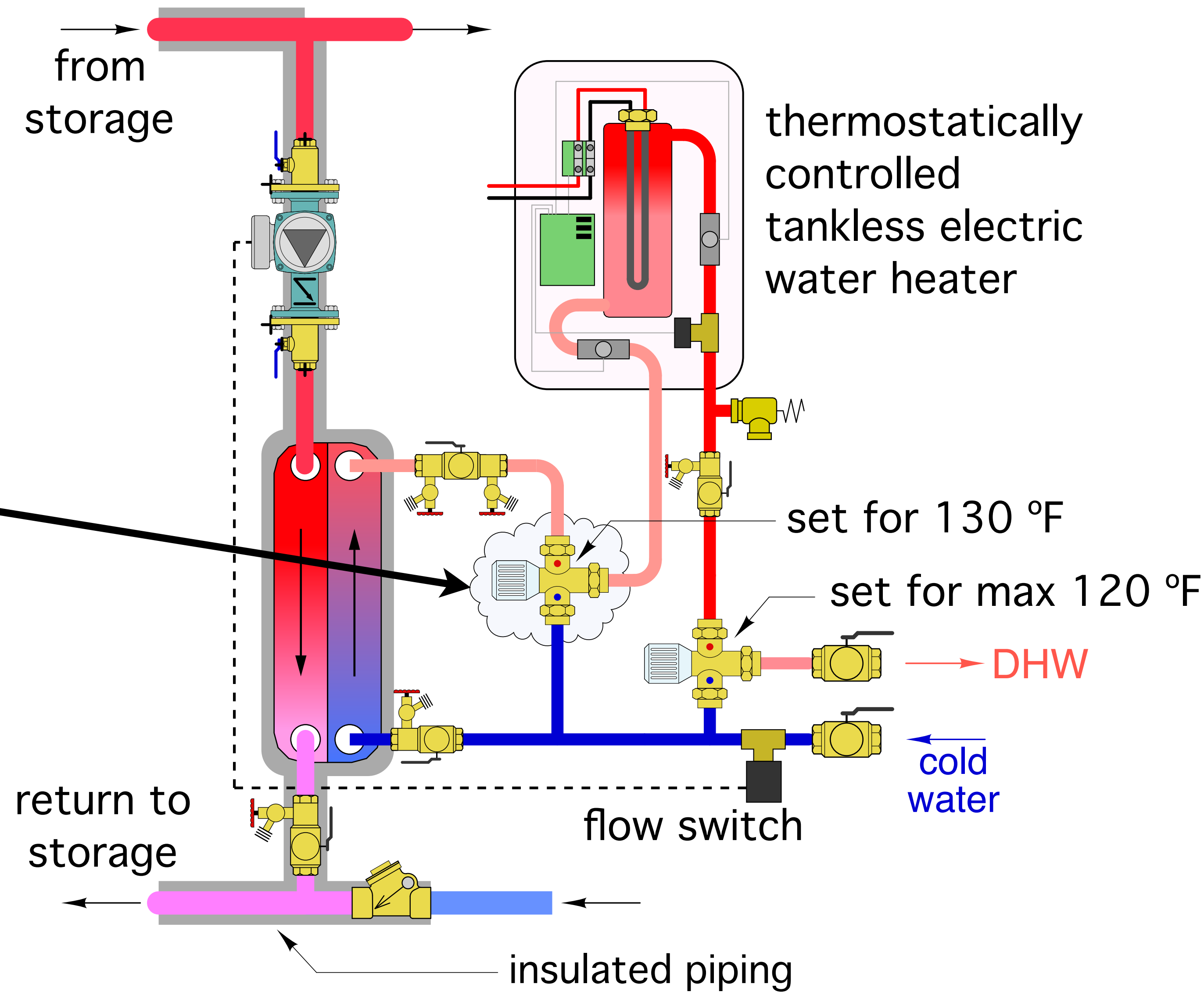
This eliminates the need for the flow switch.



Some ETWH have a safety switch that cannot be set higher than 140 ºF.

This could cause automatic shut down of the ETWH

Solution:Add 2nd thermostatic valve if the high limit switch can't be set higher than 140 ºF.



System Examples (putting the pieces together)

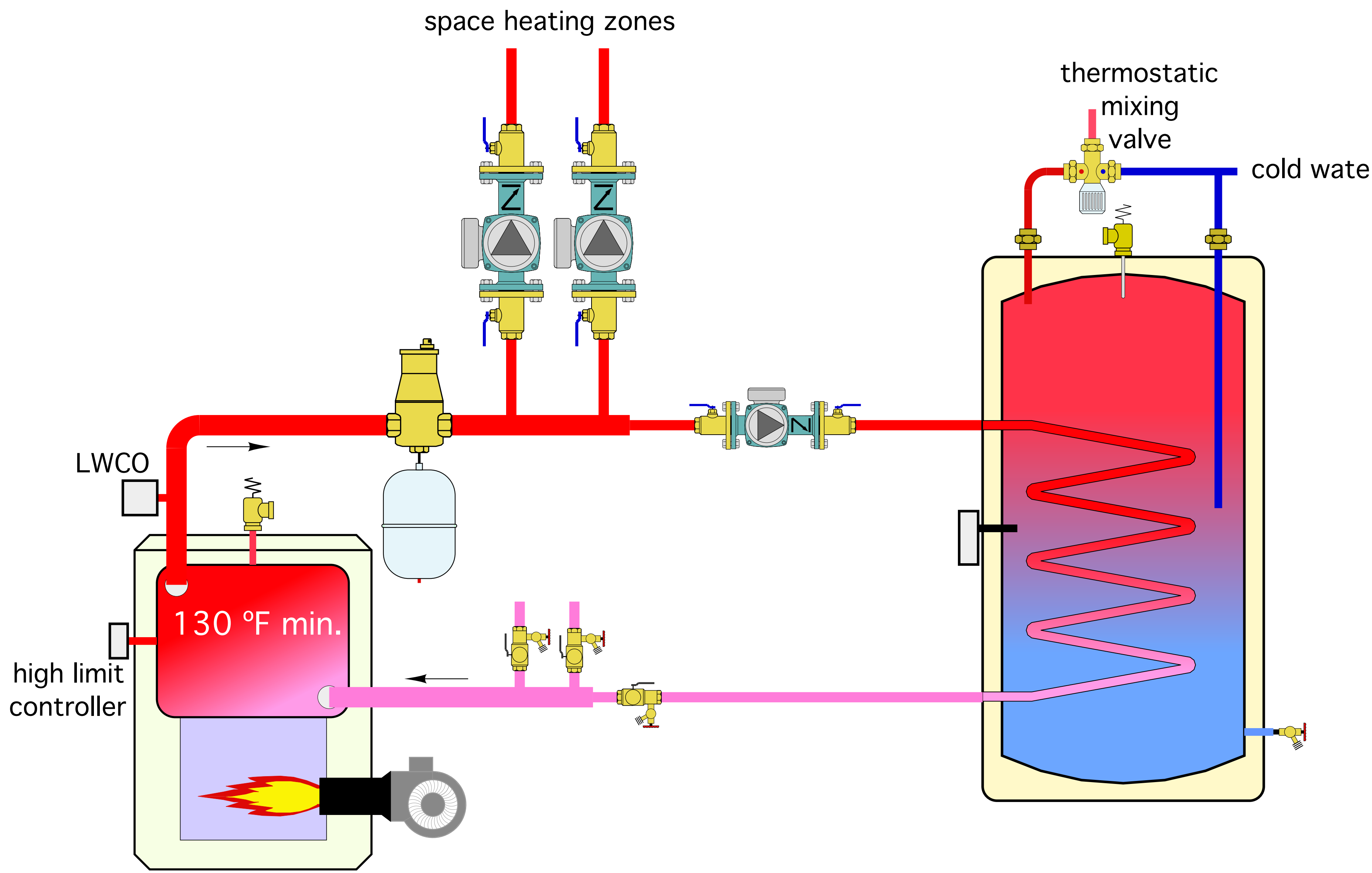
A typical retrofit application

A typical existing heating system in Northeast:

1. oil-fired boiler

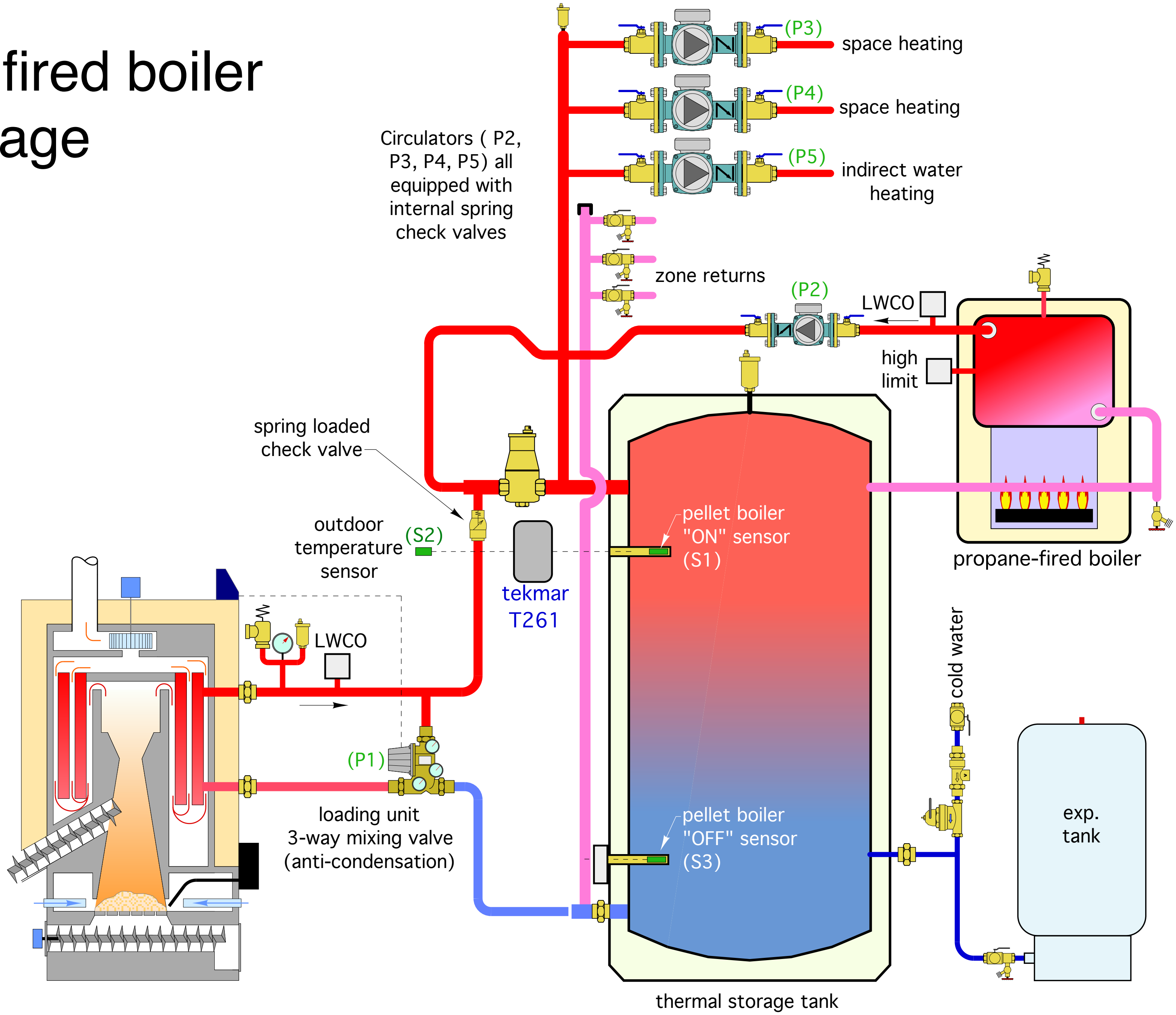
2. two or three zones of high temperature fin-tube baseboard heat emitters

3. indirect domestic water heater

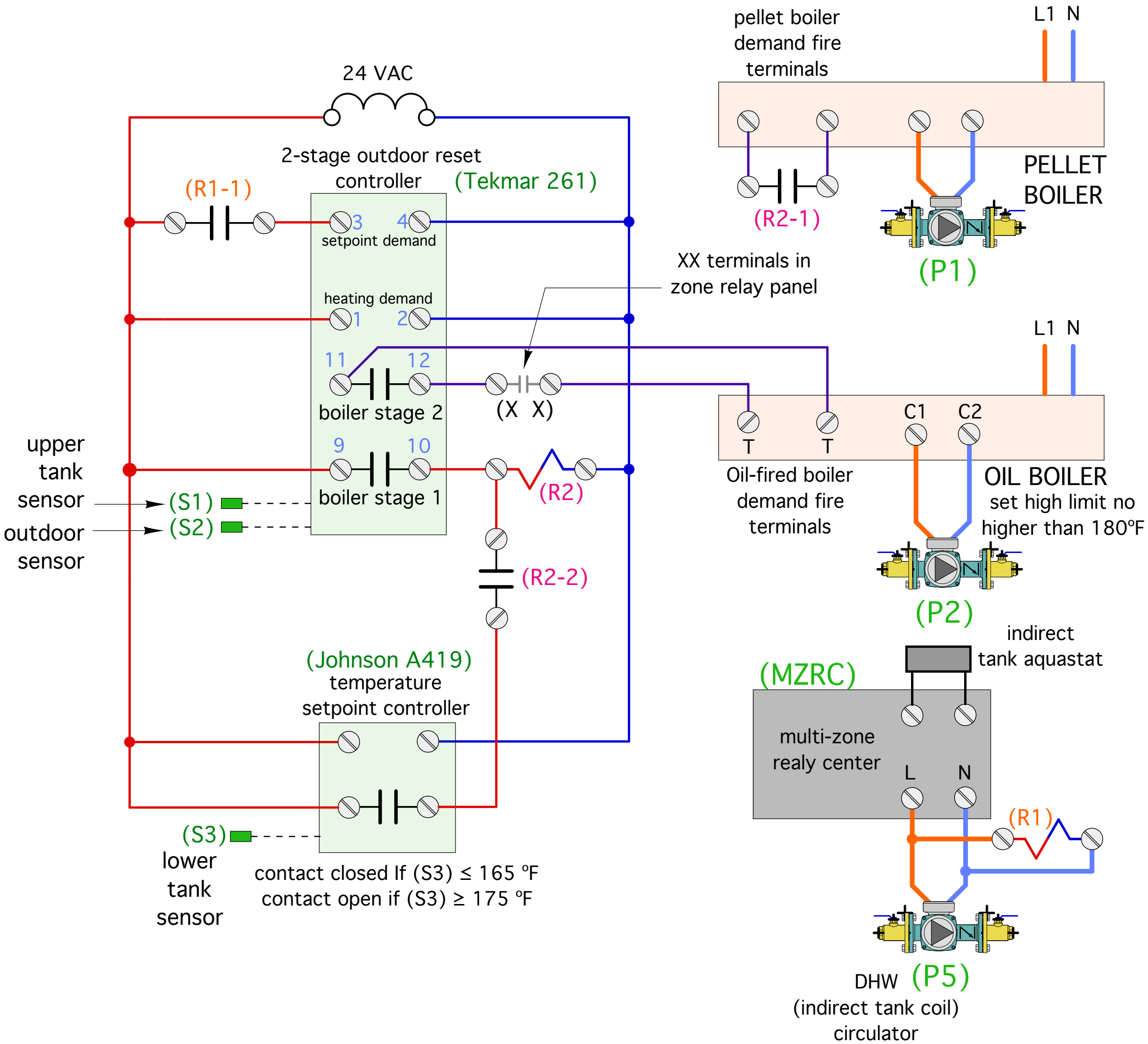


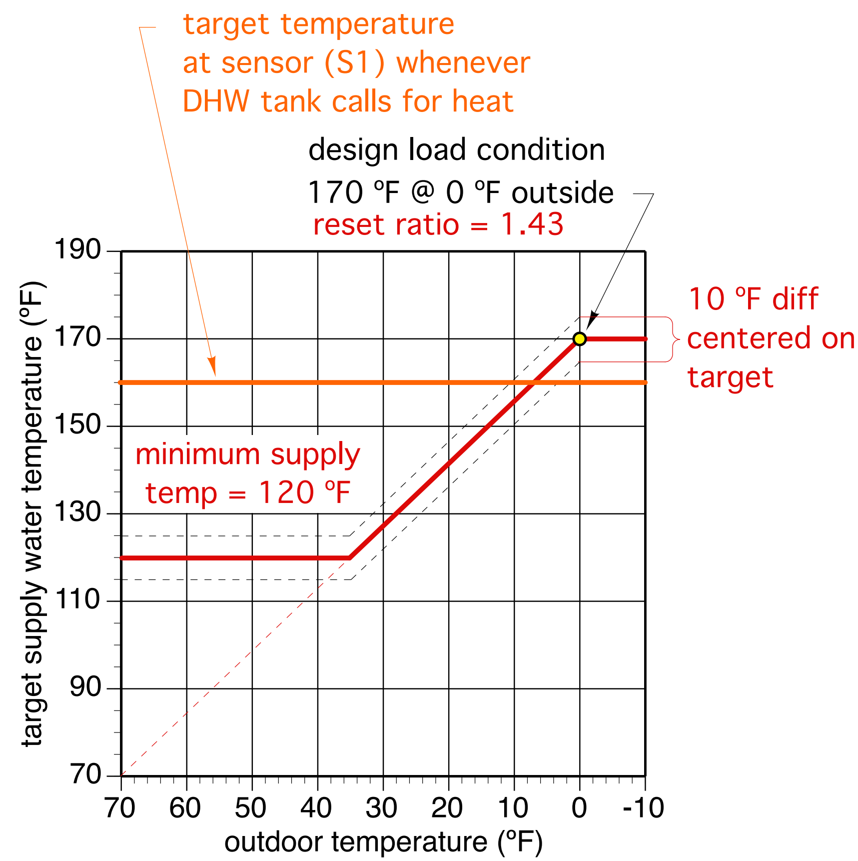
Situation: Existing (OVERSIZED) oil-fired boiler + 2 baseboard heating zones + indirect water heater

Retrofit pellet-fired boiler + thermal storage



Electrical control schematic





Description of operation **Please read through this later....**

1. **Pellet boiler operation:** The pellet-fired boiler operates completely independently of any call for space heating or domestic water heating. The tekmar 261 outdoor reset controller continually monitors the temperature of sensor (S1) in the upper portion of the thermal storage tank. When this temperature drops slightly below the target temperature indicated by the reset line, 24VAC is passed to the coil of relay (R2). Relay contact (R2-1) closes to provide a start demand to the pellet-fired boiler. The boiler provides a 120 VAC output to operate circulator (P1) in the loading unit. The normally open contact in the Johnson A419 setpoint controller will be closed whenever the temperature in the lower portion of the thermal storage tank is below 165 ºF. Thus if will be closed when the stage 1 contacts in the tekmar 261 close. 24VAc can pass through the contacts within the A419 controller and through contact (R2-2) to keep the coil of relay (R2) energized. This will maintain the pellet-fired boiler in operation until the temperature at the bottom of the thermal storage tank reaches 175 ºF, at which time the contacts in the A419 open to remove power from relay coil (R2), and shut off the pellet-fired boiler.

2. **Call for Space Heating:** Whenever there is a call for space heating, the associated zone circulator (P3) or (P4) will be turned on by the multi-zone relay center. The (XX) isolated contact in the multi-zone relay center will also close Heated water form the thermal storage tank will immediately flow to the zone circuit.

If the call was for *space heating*, AND if the water temperature at sensor (S1) in the thermal storage tank cannot meet the required target temperature, the second stage contacts in the tekmar 261 control will close. This will enable the oil-fired boiler to operate. The oil-fired boiler will continue to operate until the second stage contacts in the tekmar 261 open, or the demand for space heating stops, or if the oil-fired boiler reaches its own internal limit of 180 ºF.

3. **Call for Domestic Water Heating:** If the call was for *domestic water heating*, circulator (P5) and relay coil (R1) are turned on by the multi-zone relay center. The (XX) isolated contact in the multi-zone relay center will also close. Relay contact (R1-1) closes to provide a “setpoint demand” to the tekmar 261 controller. This changes the target temperature for sensor (S1) to a fixed 160 ºF regardless of outdoor temperature. If the temperature at sensor (S1) is high enough to meet this target, the second stage of the tekmar 261 control will not close. If the temperature at sensor (S1) is a few degrees below the 160 ºF setpoint, the second stage contacts will close to turn on the oil-fired boiler and circulator (P2).

Common oil boiler / baseboard retrofit

Situation: An existing oil-fired cast-iron boiler is connected to several zones of fin-tube baseboard and an indirect water heater.

Objectives:

1. Add a pellet fired boiler with associated storage, and optimize its performance by maximizing the duration of on-cycles and off-cycles.

2. Provide heat for domestic hot water from pellet whenever possible, but allow for high rate of domestic hot water production when needed.

3. Optimize the comfort provided by the fin-tube baseboard under all load conditions.

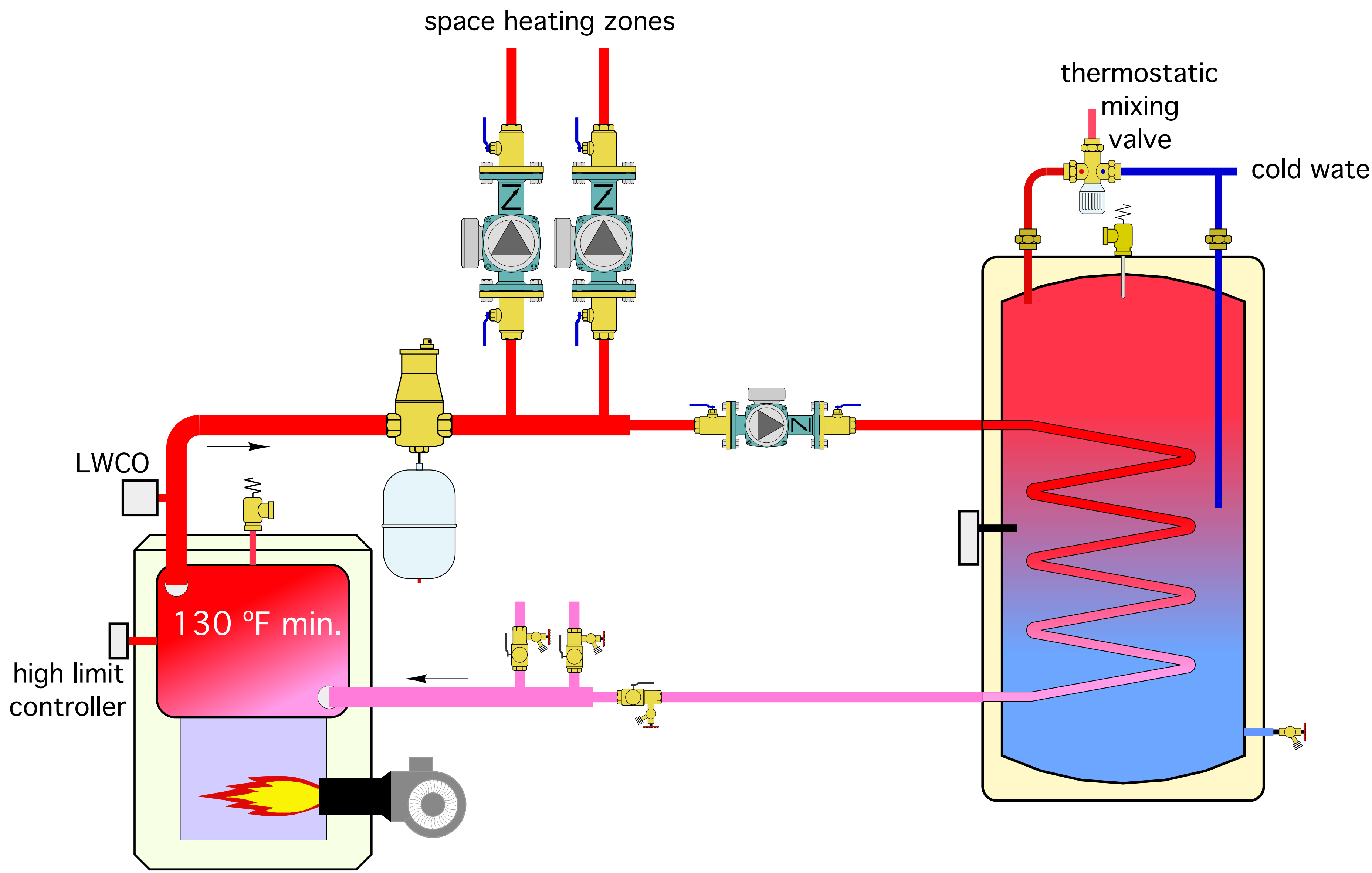
4. Provide conditions to help sterilize the DHW tank against Legionella growth

A typical existing heating system in Northeast:

1. oil-fired boiler

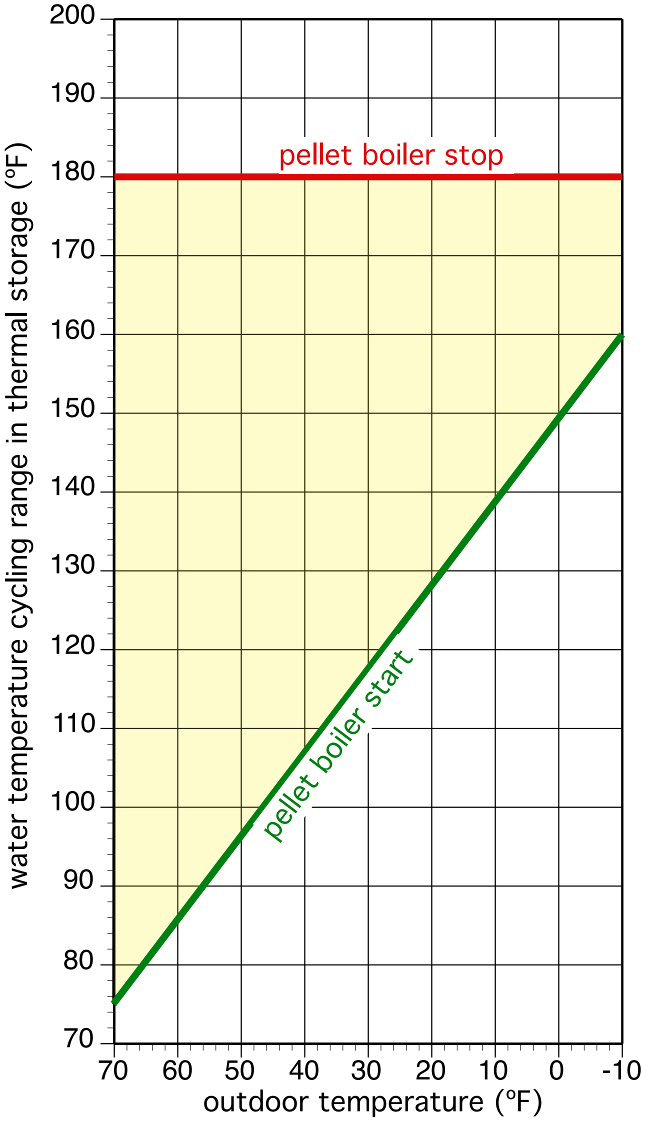
2. two or three zones of high temperature fin-tube baseboard heat emitters

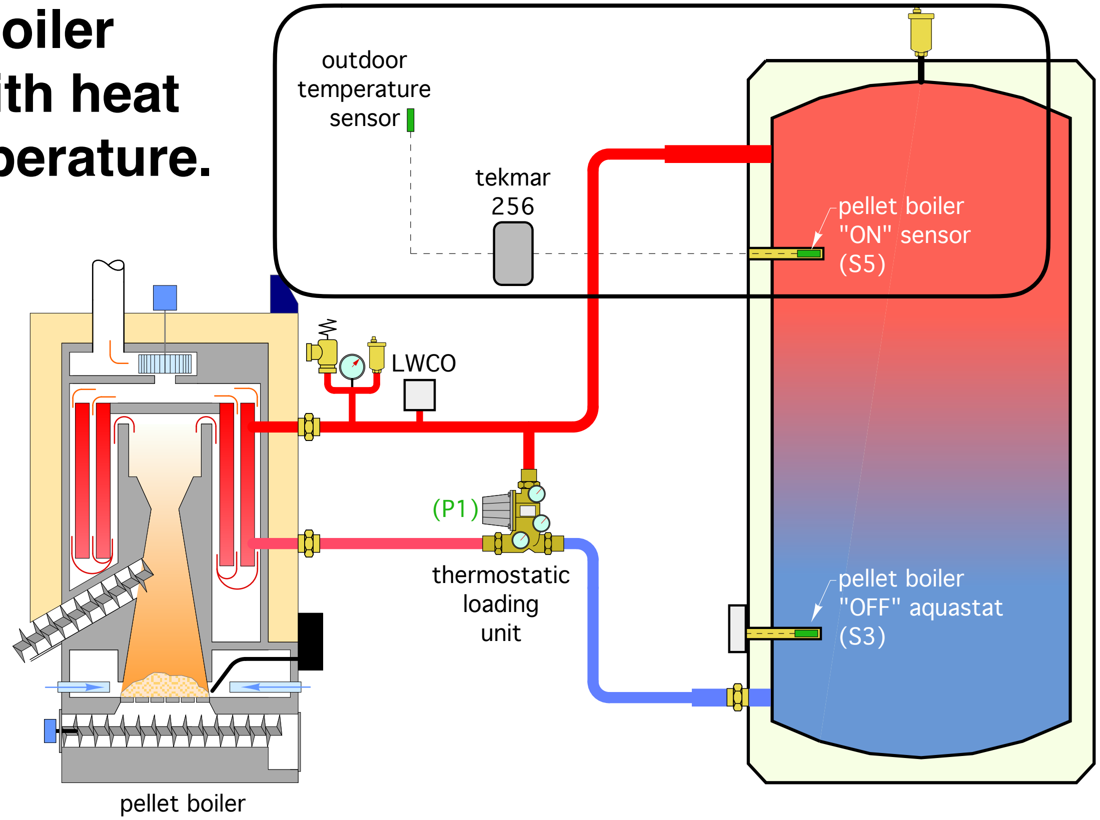
3. indirect domestic water heater



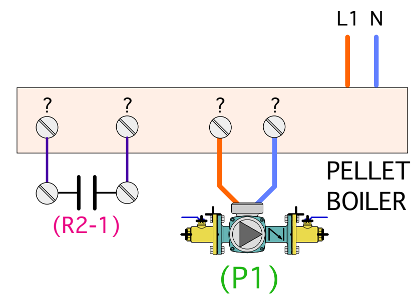
Use outdoor reset control of pellet boiler "ON" temperature in combination with heat stacking for pellet boiler "OFF" temperature.

storage tank temperature range

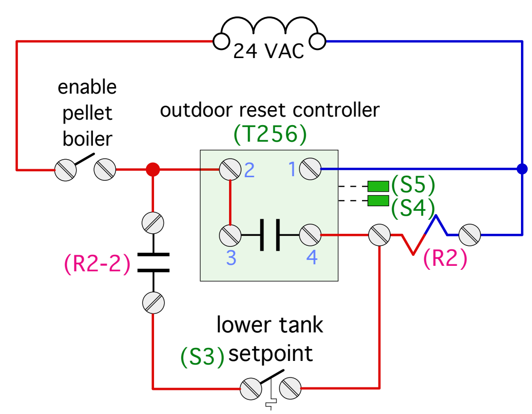




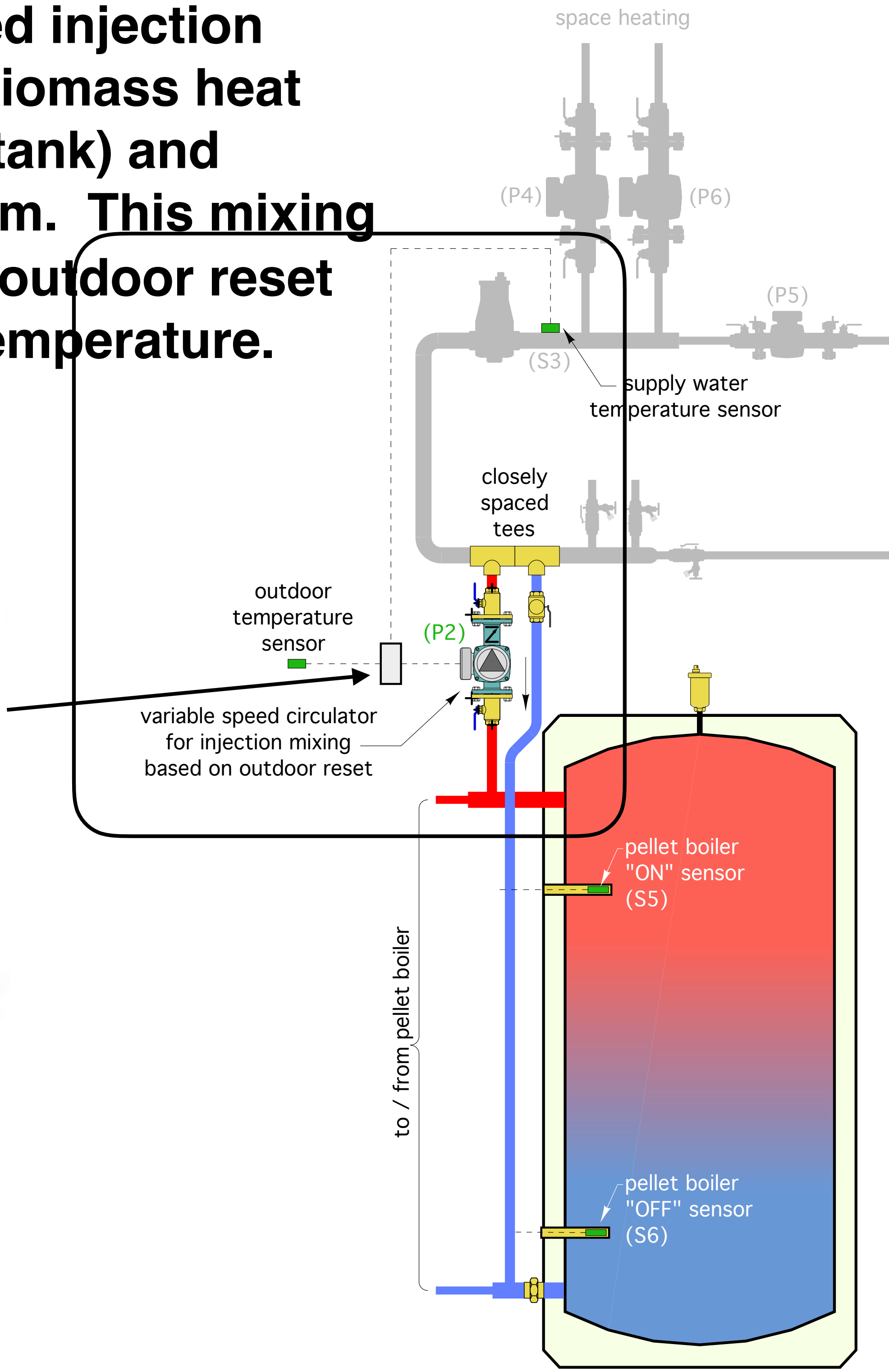
outdoor reset controller (tekmar 256) for boiler "turn on" temperature in upper portion of thermal storage tank

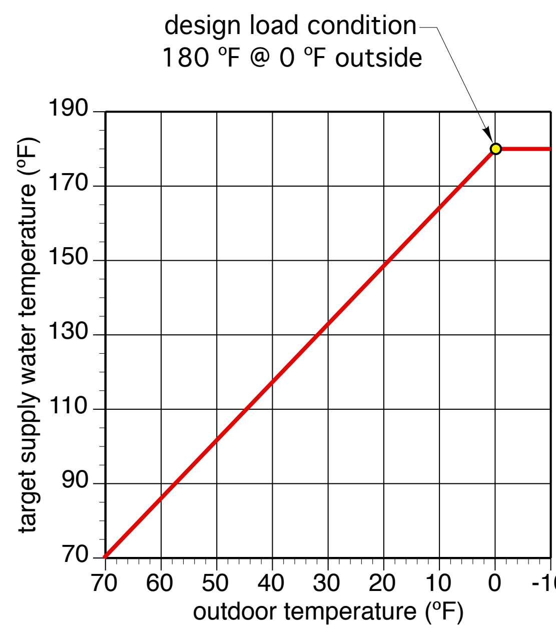


Temperature setpoint controller (tekmar 150) for boiler "turn off" temperature at lower tank sensor.



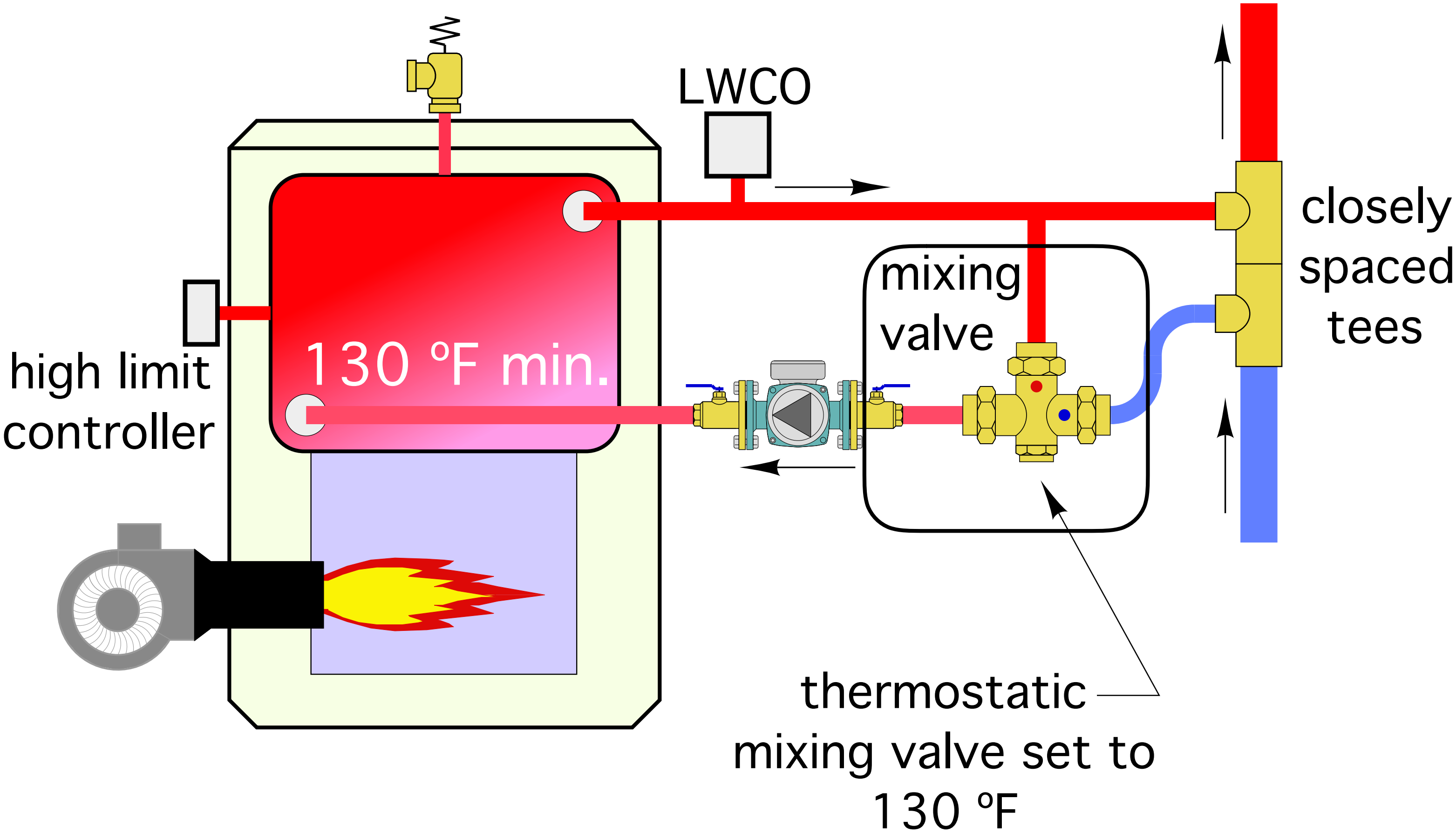
Use variable speed injection mixing between biomass heat source (boiler or tank) and distribution system. This mixing is also based on outdoor reset of supply water temperature.



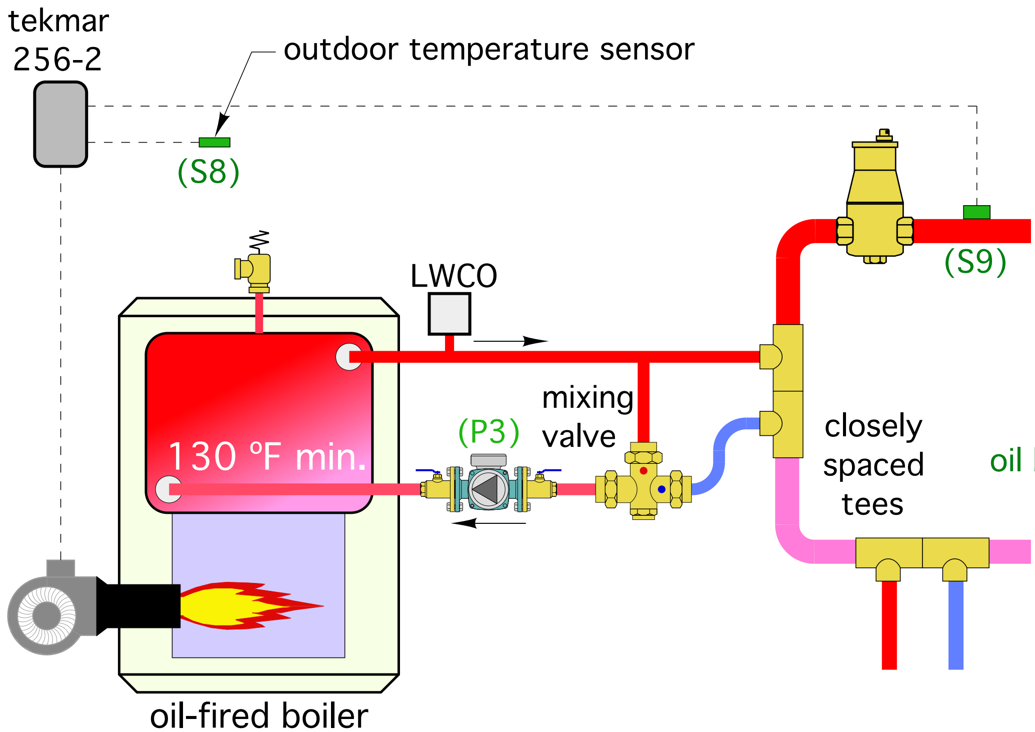


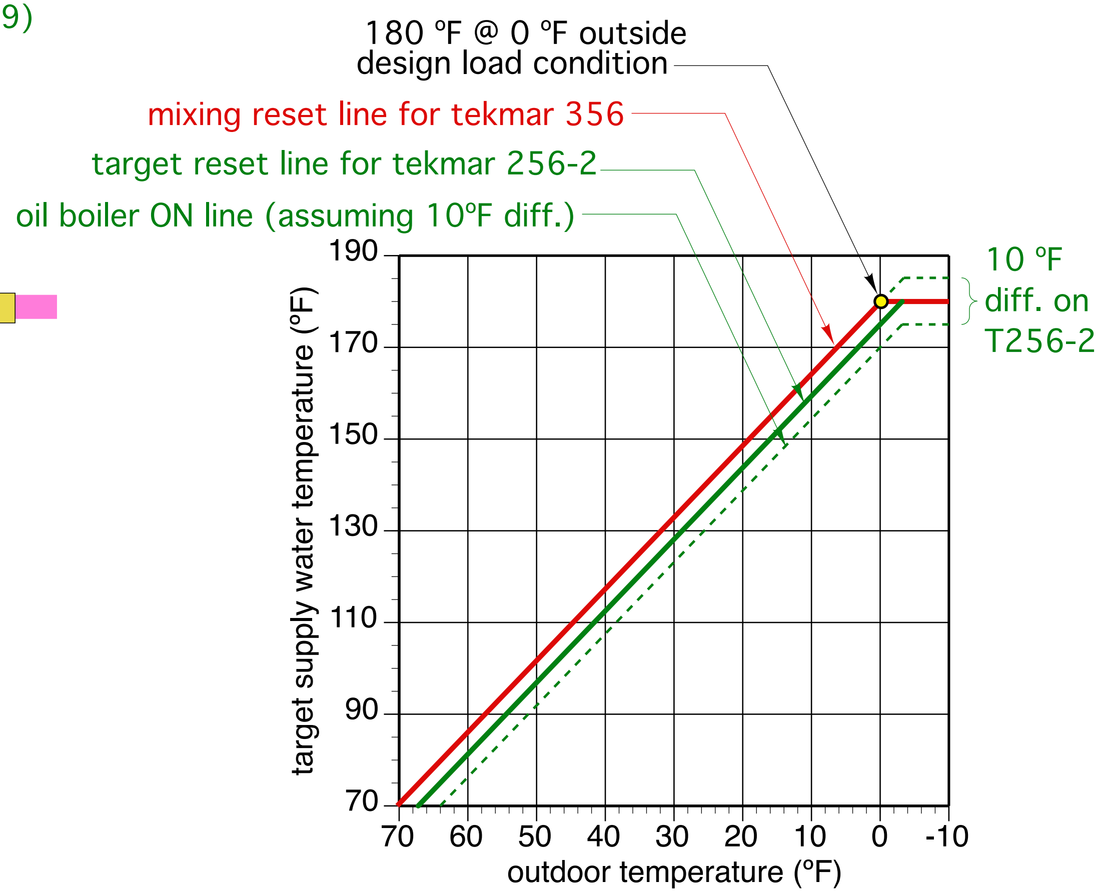
mixing reset control

Add 3-way thermostatic valve to oil-boiler circuit to protect it from sustained flue gas condensation when distribution system is operating at lower water temperatures.



The oil boiler will also be fired based on outdoor reset control, but at a slightly lower setting than the mixing system.





Common oil boiler / baseboard retrofit

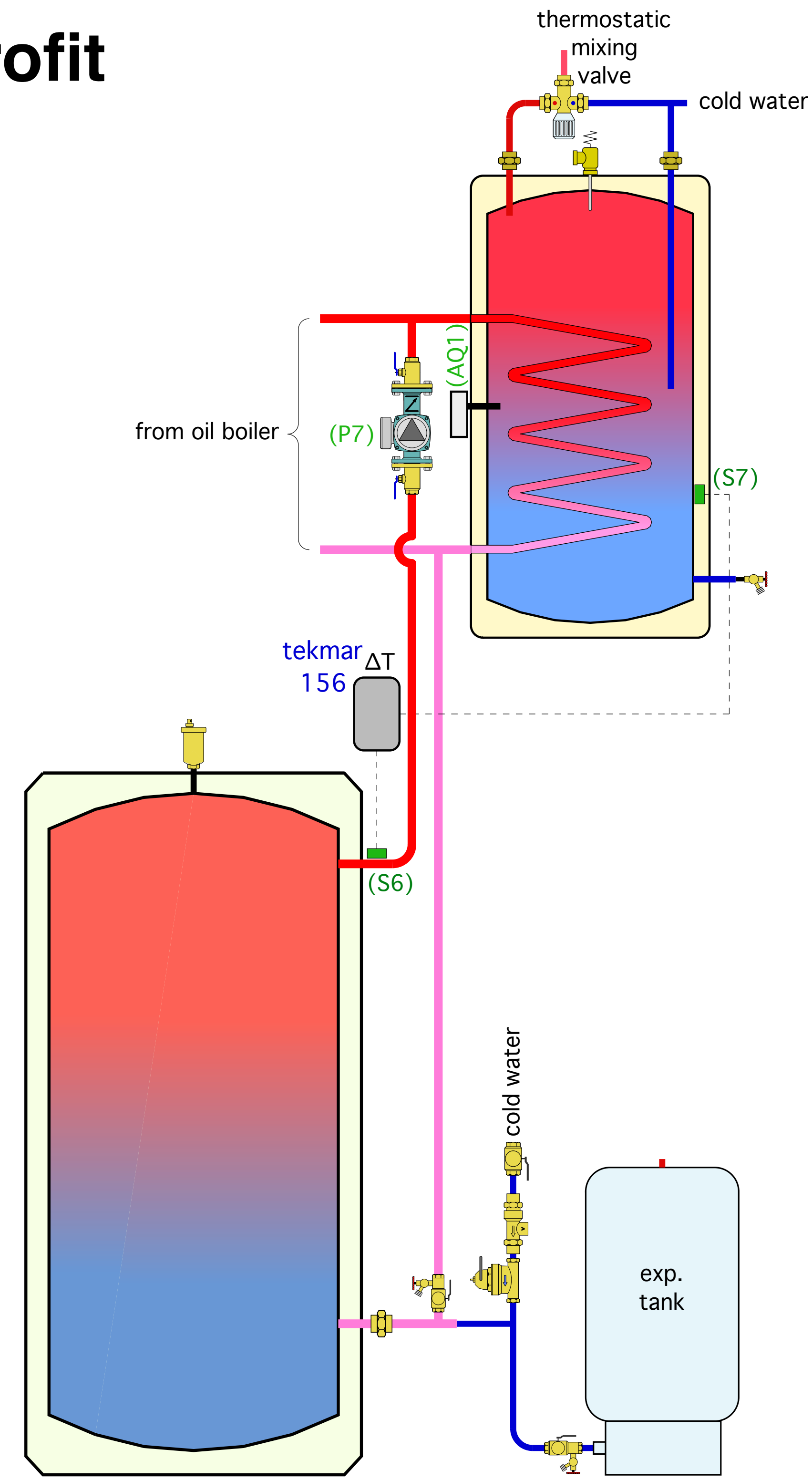
Another objective is to provide as much of the DHW load as possible with heat derived from pellets, *while also ensuring that high demands for DHW, or provisions for DHW sterilization are not limited by low coil inlet temperatures to the indirect water heater.*

The solution uses a differential temperature controller - the same as used in solar DHW systems - to transfer available energy from the thermal storage tank to the indirect water heater.

The operating logic for the differential temperature controller (T156) is as follows:

IF (S6) ≥ (S7) +5 °F THEN circulator (P7) is ON

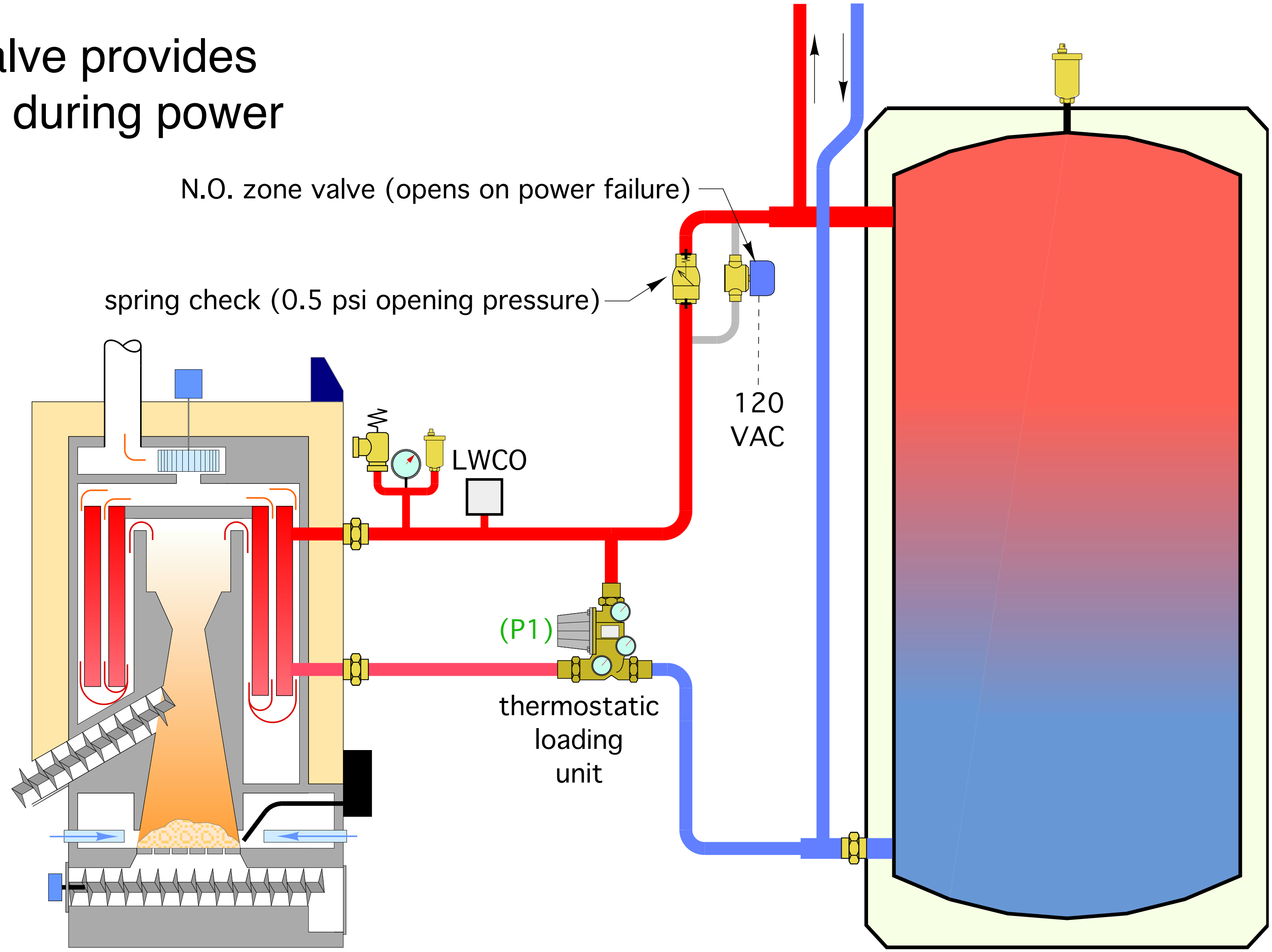
IF (S6) ≤ (S7) + 3 °F THEN circulator (P7) is OFF



Use thermostatic loading unit to protect pellet boiler from sustained flue gas condensation.

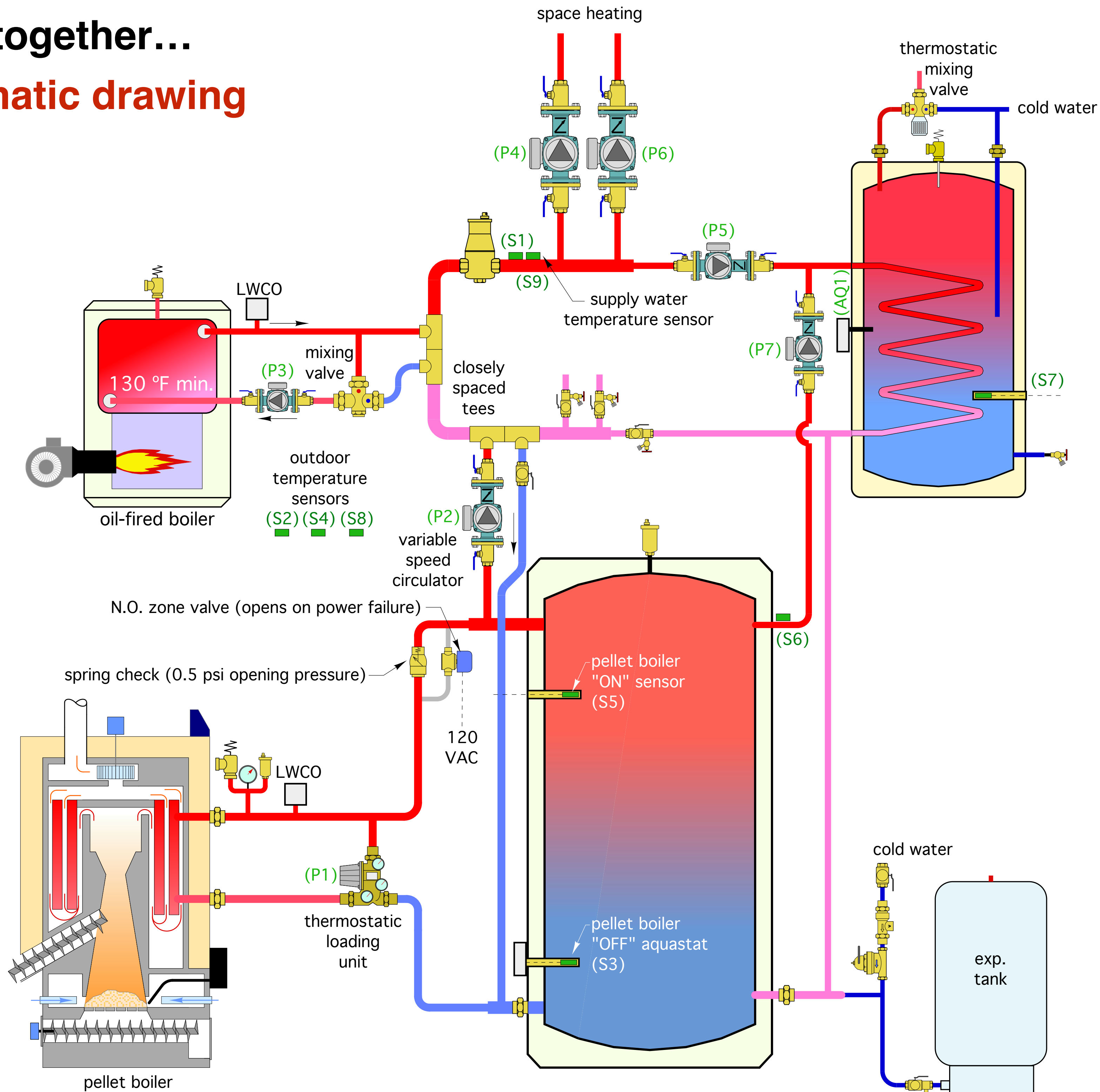
• The spring-loaded check prevents heat migration when boiler is off.

• The N.O. zone valve provides thermosiphon path during power outage.



Putting it all together…

Piping schematic drawing



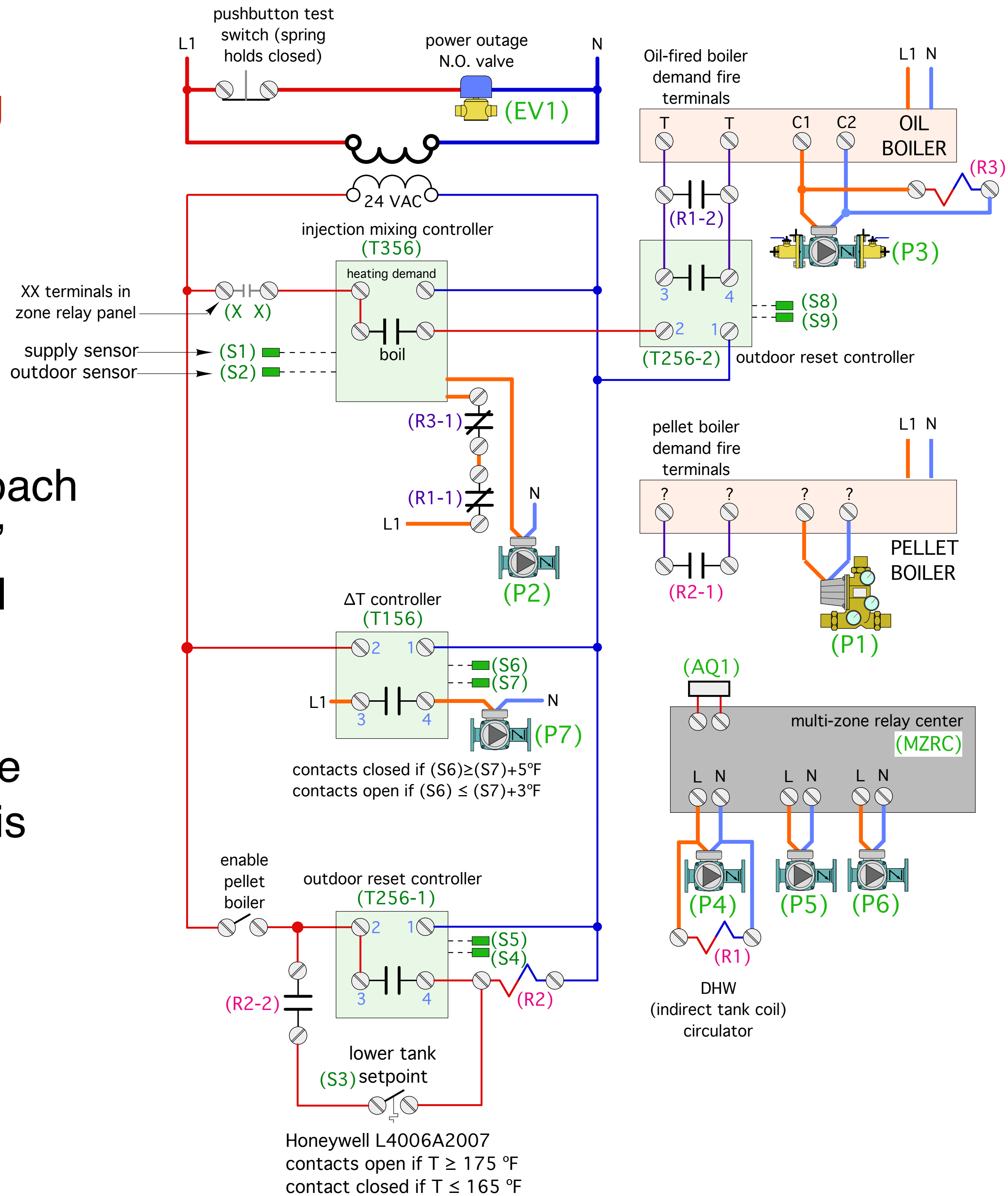
Putting it all together…

Electrical control drawing

This approach works, but it requires several individual single function controllers and 3 relays.

The “ultimate” control approach is a single box “plug & play” device that would handle all inputs and outputs.

several micro-controllers are close to, or already have this capability…



Putting it all together…

Please read through this later....

DESCRIPTION OF OPERATION:

Space heating mode: When any of the space heating zone thermostats call for heat, the associated zone circulator (P5) or (P6) is turned on by the multi-zone relay center (MZRC). The isolated (X X) contacts in the (MZRC) close to supply 24 VAC to the tekmar 356 injection mixing controller (T356). The (T356) measures outdoor temperature using sensor (S2), and calculates the necessary target supply water temperature to be established at sensor (S1). If the measured supply water temperature at sensor (S1) needs to increase, the speed of circulator (P2) is increased to inject heated water from the thermal storage tank into the distribution system. If the (T356) controller reaches 30% pump speed it closes a set of contacts marked (boil). This passes 24 VAC to an outdoor reset controller (T256-2) which determines if the oil boiler needs to fire based on its settings and the current outdoor temperature. The reset line of the (T256-2) controller is set a few degrees below the reset line of the (T356) injection controller. This delays operation of the oil boiler until the injection controller has expended its effort to meet the target supply water temperature. If (T256-2) fires the oil boiler, relay coil (R3) is also energized along with circulator (P3). The normally closed contacts (R3-1) open to turn off the injection circulator (P2). *This prevents heat derived from the oil-fired boiler from being inadvertently transferred to the thermal storage tank.* The oil boiler will fire until the (T256-2) controller determines that the supply water temperature is sufficient to meet the load. When this occurs, the injection pump (P2) will be reenabled, and heat from thermal storage will again attempt to meet the target supply water temperature at sensor (S1). This cycle will repeat, if necessary, if the thermal storage tank is unable to meet the target temperature at sensor (S1).

DHW mode: Whenever the temperature at sensor (S6) is 5 ºF or more above the temperature at sensor (S7), circulator (P7) is turned on by differential temperature controller (T156). This transfers heat from the thermal storage tank to the indirect water heater. Whenever the temperature at sensor (S6) drops to 3 ºF or less above the temperature at sensor (S7), circulator (P7) is turned off. This mode of operation should allow the indirect water heater to reach relatively high temperatures as the pellet boiler firing cycle nears completion. These temperatures should be high enough to ensure that the water in the indirect tank is sterilized against Legionella growth.

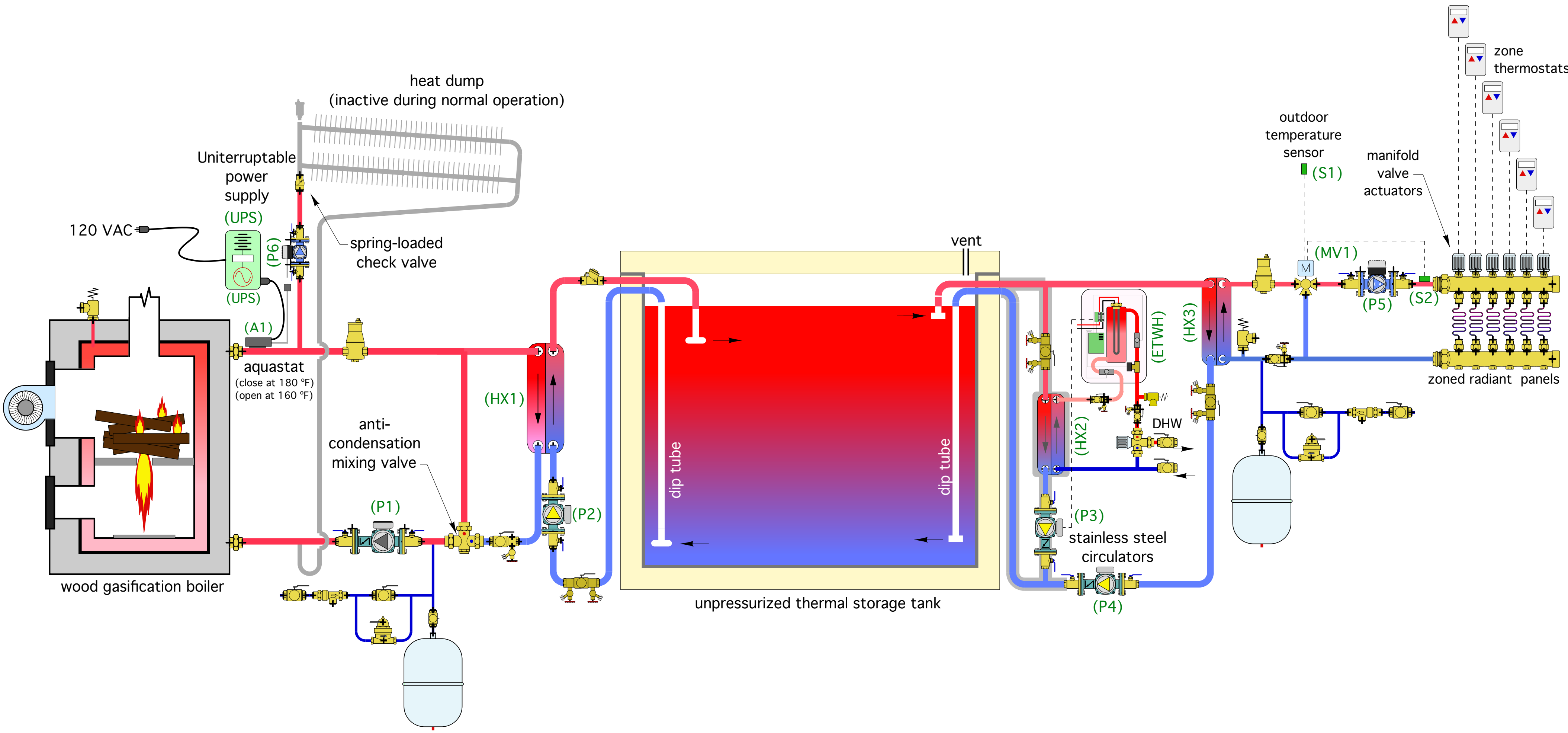
If the pellet boiler is not operating - such as in summer. The indirect water heater will be heated when the temperature of the water drops below the setting of aquastat (AQ1). This will initiate priority domestic water heating. Any space heating circulators that might be running are turned off. The oil boiler is enabled along with circulator (P3). The water temperature of the oil boiler is limited by the boiler's high limit controller. Circulator (P4) is turned on to move heat from the oil boiler to the coil of the indirect water heater. The injection circulator (P2) is also turned off during this mode.

Pellet boiler firing: The pellet boiler is fired when the upper tank sensor (S4) drops to a temperature determined by an outdoor reset controller (T256-1). It remains on, regardless of load status, until the lower tank sensor (S3) reaches a limit setting, typically in range of 170 ºF.

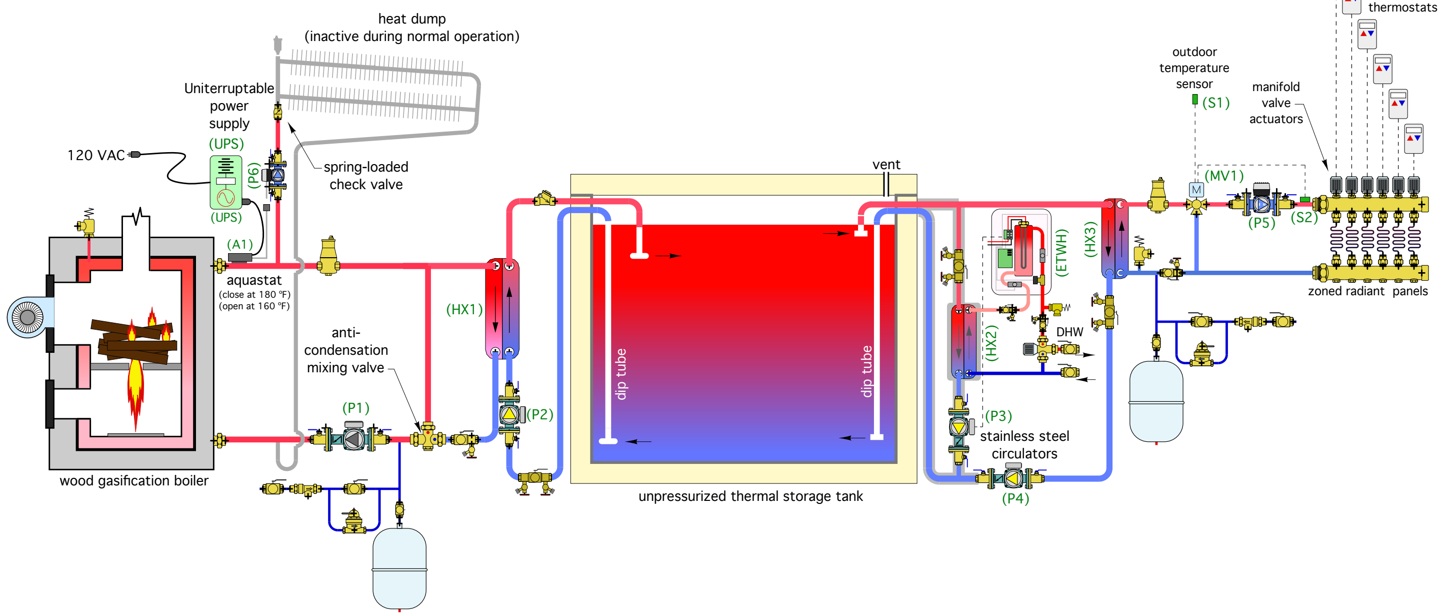
Heat dissipation during power outage: If a power outage occurs, the normally open zone valve (EV1) opens to allow thermosiphoning of residual heat from the pellet boiler to the thermal storage tank.

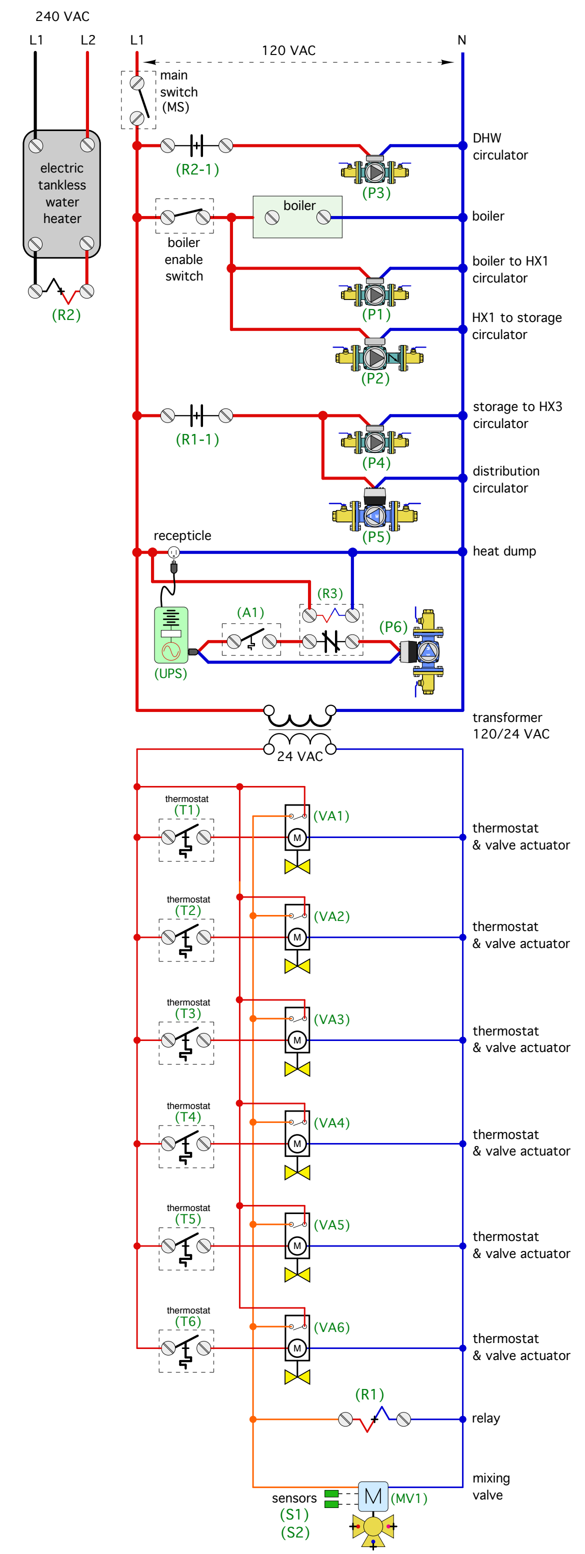
System using (unpressurized) buffer tank

- 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....**

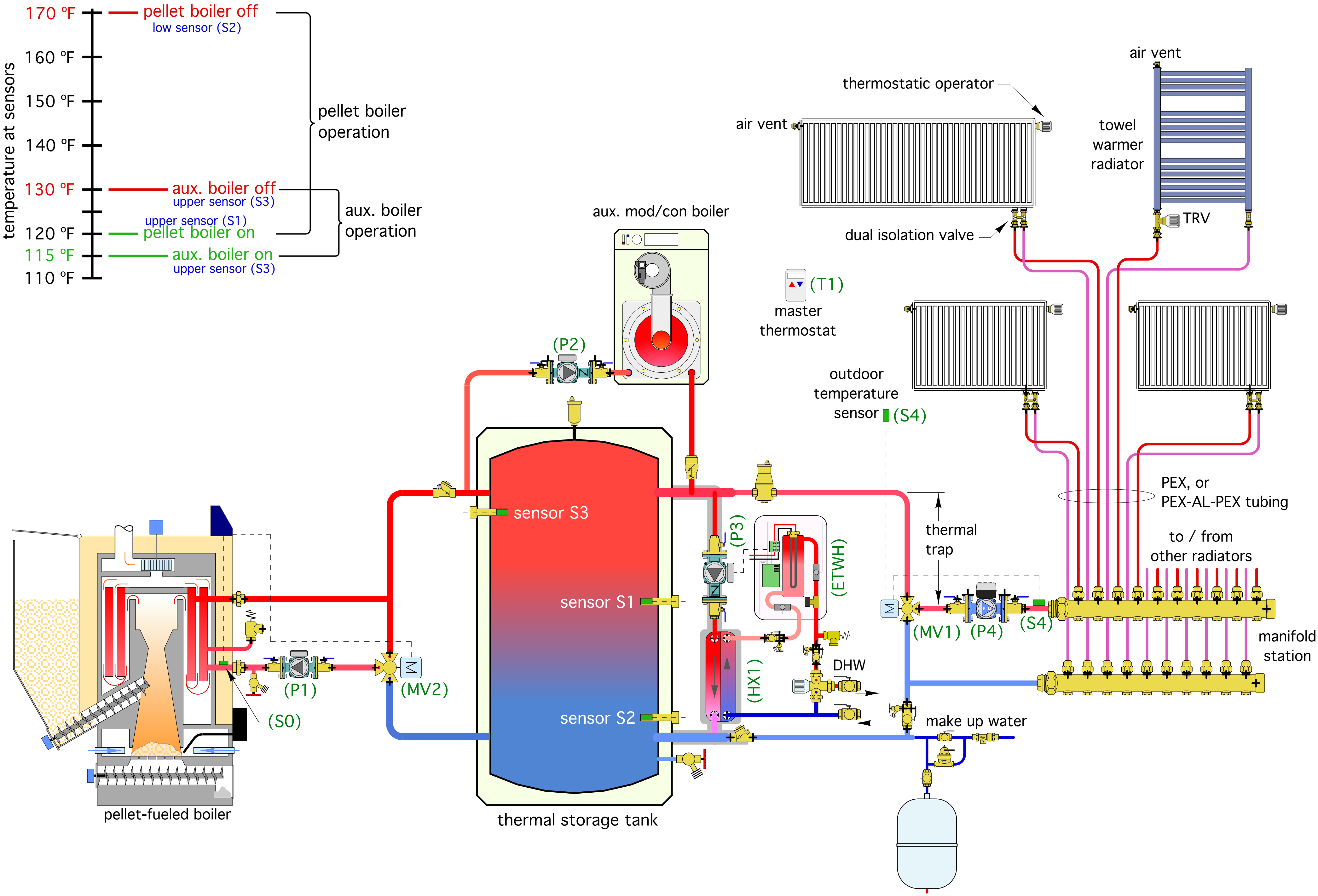
1. Boiler operation: When the wood-gasification boiler is fired, the operator closes a switch on the boiler, that enables 120 VAC to be supplied to the boiler. This switch closure also supplies 120 VAC to circulators (P1) and (P2). Thus, flow between the boiler and heat exchanger (HX1), as well as between (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.

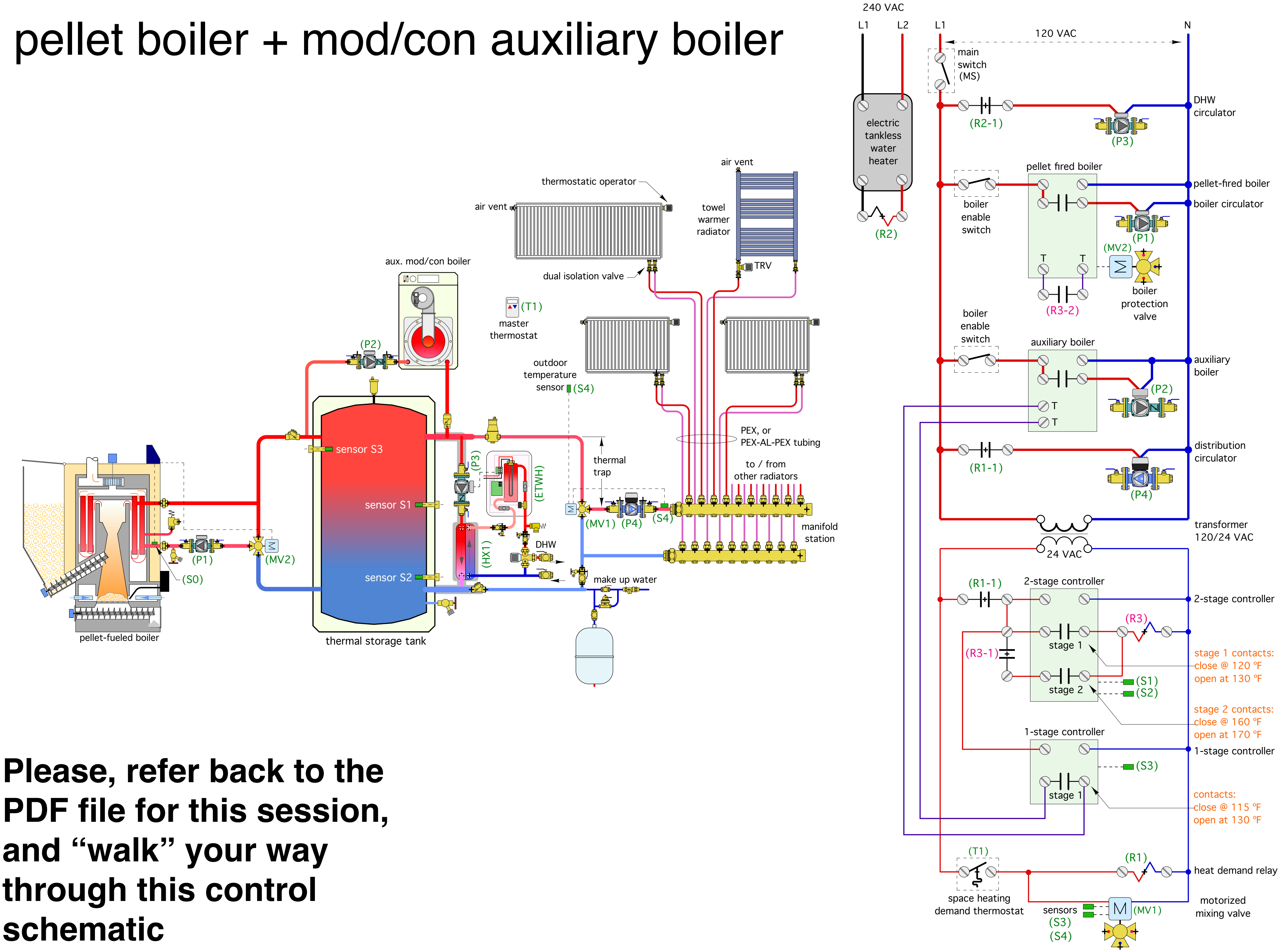
3. Space heating mode: Upon a call from any of the thermostats (T1...T6), 24 VAC is passed to the associated manifold valve actuators (VA1...VA6). When any one or more of these valve actuators reach their fully open position, an end switch within the valve actuator closes to pass 24 VAC to the coil of 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.

pellet boiler + mod/con auxiliary boiler



pellet boiler + mod/con auxiliary boiler



Please, refer back to the PDF file for this session, and "walk" your way through this control schematic

pellet boiler + mod/con auxiliary boiler

Description of Operation:

Please read through this later....

1. Boiler operation: The master thermostat (T1) creates a demand for space heating. This applies 24VAC power to the 2-stage setpoint controller (SP2) and the 1-stage temperature setpoint controller (SP1). The 2-stage controller measures the temperature of sensor (S1) in the upper portion of the storage tank. If the temperature is less than 120 ºF, the first stage contact in (SP2) closes. This passes 24 VAC to the coil of relay (R3). One normally open contact in this relay (R3-2) closes to initiate operation of the pellet-fired boiler. Another normally open contact (R3-1) closes to pass 24VAC to the stage 2 contact in the 2-stage setpoint controller (SP2). 24 VAC is now simultaneously passing through both stage 1 and stage 2 contacts in (SP2). The stage 1 contact in (SP2) will open when the temperature at the upper sensor (S1) reaches 130 ºF. However, 24VAC can still pass through contact (R3-1) to maintain relay coil (R3) in the on state. This keeps the pellet-fired boiler operating, and allows the storage tank to be fully “stacked” with hot water. The pellet-fired boiler turns off when the temperature at the lower tank sensor (S2) reaches 170 ºF, or the heating demand from master thermostat (T1)ceases.

When started, the pellet-fired boiler applies 120 VAC to circulator (P1). It also measures its entering water temperature at sensor (S0), and operates a 3-way motorized mixing valve (MV2) as necessary to quickly raise the boiler temperature to prevent sustained flue gas condensation. As the temperature at sensor (S0) climbs above the nominal 130 ºF protection limit, the motorized mixing valve (MV2) opens to allow flow from the boiler to the tank, and vice versa. If the temperature at sensor (S0) decreases toward the protection limit, mixing valve (MV2) responds by limiting flow between the pellet-fired boiler and thermal storage tank.

If the temperature at sensor (S3) in the upper portion of the storage tank drops to or below 115 ºF, the normally open contact in the 1-stage setpoint controller (SP1) closes. This enables the auxiliary boiler to fire in setpoint mode (e.g., not based on its own internal outdoor reset control mode). The auxiliary boiler supplies 120 VAC to circulator (P2), and transfers heat to the storage tank to supplement the heat output of the pellet-fired boiler. The auxiliary boiler continues to operate until the upper tank sensor (S3) reaches 130 ºF, or the heating demand ceases.

If a power failure occurs, residual heat from the boiler transfers to storage by thermosiphoning.

2. Space heating mode: Space heating is provided by panel radiators, each equipped with a wireless thermostatic radiator valve. Space heating is enabled by a master thermostat (T1). When the contacts in the master thermostat close, 24 VAC is passed to the coil of relay (R1). A normally open relay contact (R1-1) closes to supply 120 VAC to circulator (P4). This circulator operates at variable speeds to maintain a constant differential pressure across the distribution system manifold as the thermostatic radiator valves open, close, or modulate.

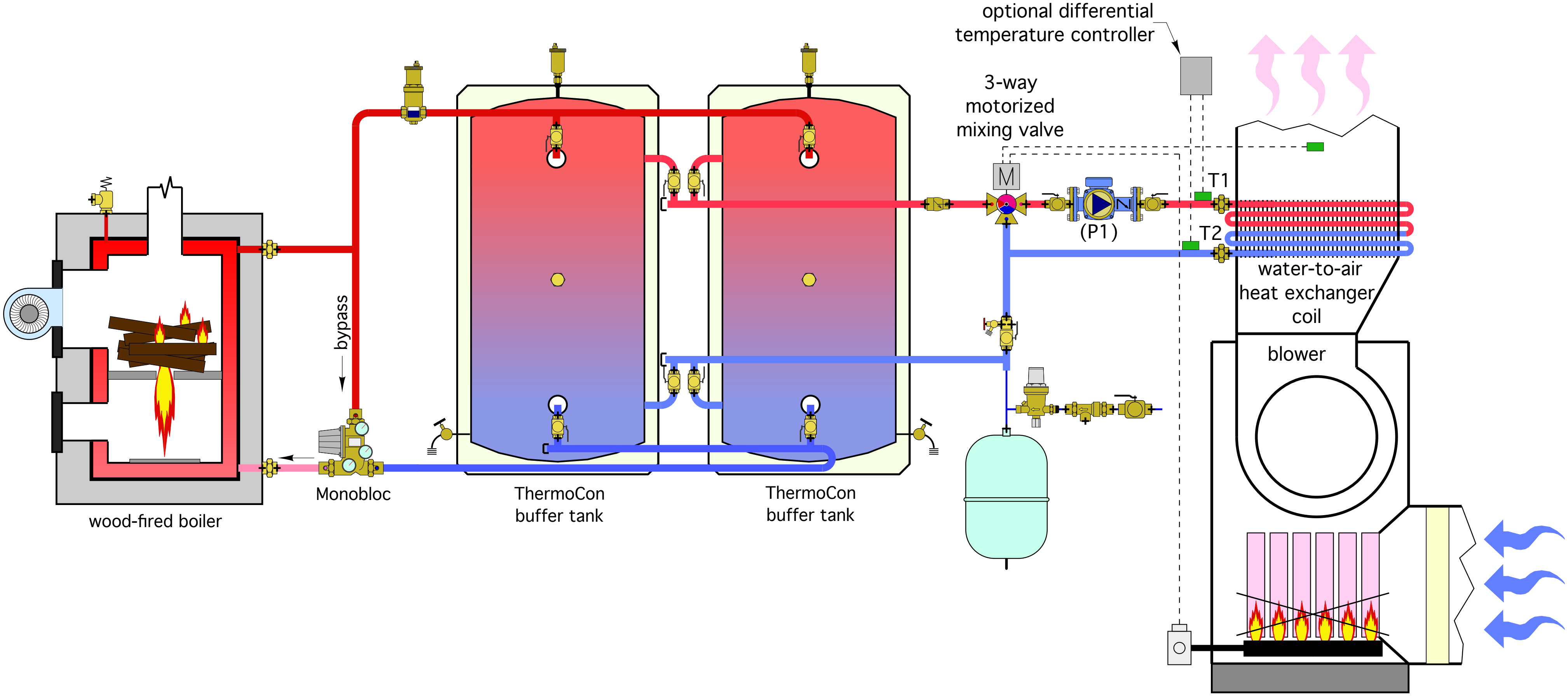
The motorized mixing valve (MV1) is also turned on by the master thermostat (T1). It measures the outdoor temperature at sensor (S3), and uses this temperature, along with its settings, to calculate the necessary target supply water temperature to the distribution system. It compares the target supply temperature to the actual supply temperature measured by sensor (S4), and adjusts the hot water and return water flow rates into the valve to maintain the temperature at sensor (S4) as close to the target temperature as possible.

3. 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 (HX1). If the domestic water leaving (HX1) is fully heated, it flows through the tankless heater, but the heating elements remain off. It flows on to an ASSE1017 rated mixing valve to ensure a safe delivery temperature to the fixtures. Whenever the demand for domestic hot water drops below 0.5 gpm, circulator (P3) and the tankless electric water heater are turned off.

During warm weather, when there is no demand for space heating, the thermal storage tank temperature will drop to room temperature. Because this temperature may still be 10-20 ºF above entering cold water temperature, the heat exchanger (HX1) can still provide a small preheating effect. The tankless electric water heater will provide the balance of the temperature rise, and thus assume the majority of the domestic water heating load.

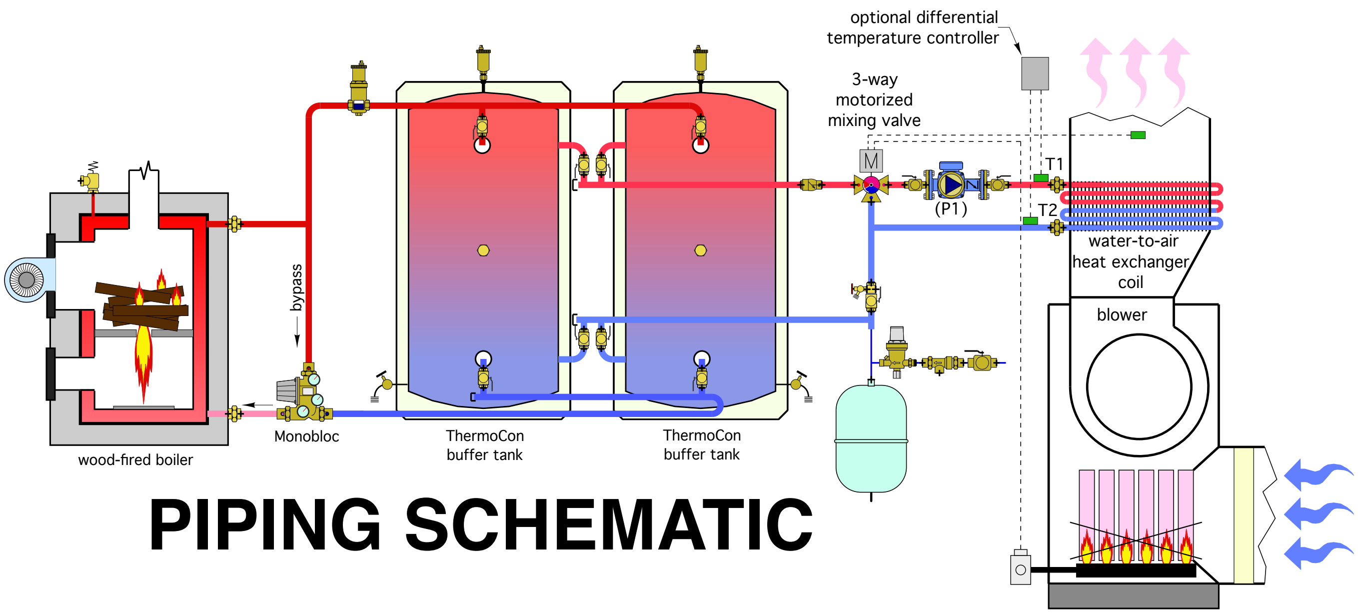
System using forced air furnace

- space heating only
- ΔT logic to operate storage to lowest temperature
- dual parallel-piped thermal storage tanks
- Could add instantaneous DHW assembly

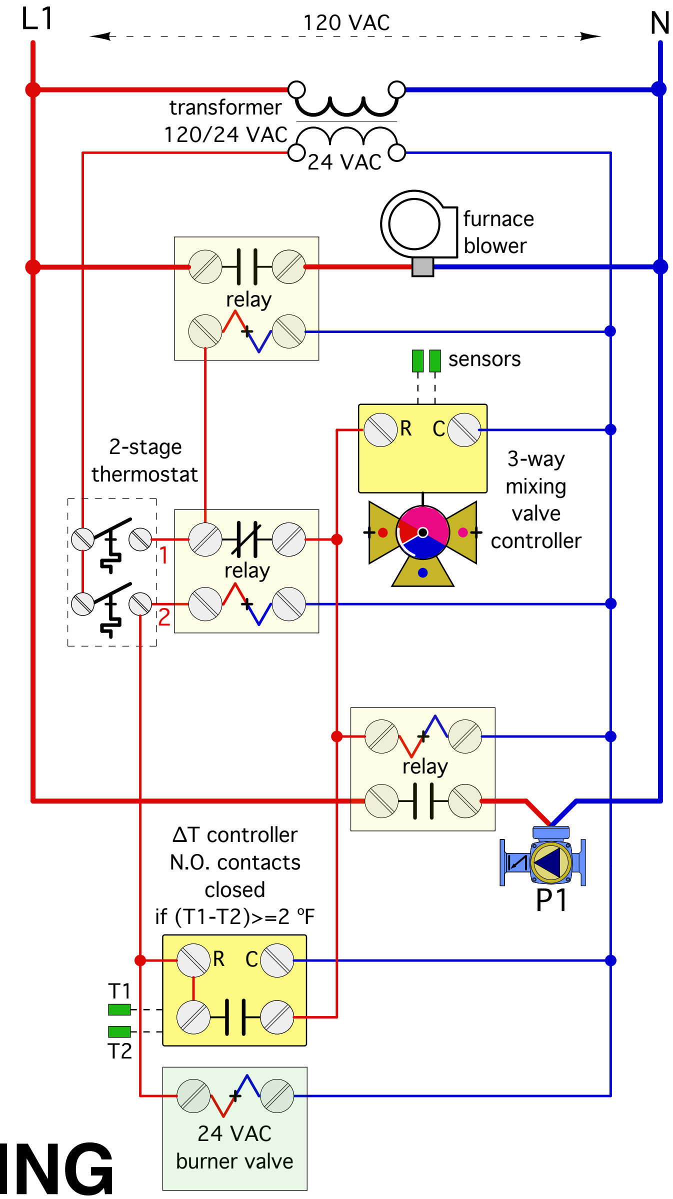


System using forced air furnace

- space heating only
- ΔT logic to operate storage to lowest temperature
- dual parallel-piped thermal storage tanks
- Could add instantaneous DHW assembly
- 2-stage thermostat



PIPING SCHEMATIC



WIRING SCHEMATIC

Please, refer back to the PDF file for this session, and "walk" your way through this control schematic

Design questions that should be addressed for biomass boiler systems

1. How is the biomass boiler protected against low entering water temperatures that would cause sustained flue gas condensation?

2. If the system uses an auxiliary boiler, how and when do the system's controls call for the auxiliary boiler to operate?

3. If the system allows for *simultaneous* heat flow from the thermal storage tank supplied by the biomass boiler, and the auxiliary boiler, how is heat generated by the auxiliary boiler prevented from being *unintentionally* routed into the thermal storage tank?

4. What is the exact operating logic of the biomass boiler? Is its operation invoked by a heat demand, or does the boiler operate independently of heat demands?

5. How flue gas leakage prevented during a cold boiler start into a cold chimney?

6. What is the mixing system used between the thermal storage tank and a low temperature distribution system?

7. If the system is zoned and has an auxiliary boiler, How is the auxiliary boiler protected against short cycling when *only the smallest zone* on the system is calling for heat?

8. How is the biomass boiler protected from overheating if a power failure occurs when the boiler is operating at full heat output?

Design questions that should be addressed for biomass boiler systems

9. If the system uses an auxiliary boiler, how is it taken "off-line" (e.g., without heated water passing through it) when all heat is being supplied from the biomass boiler.

10. How do the piping connections and inlet flows to the thermal storage tank allow for good thermal stratification? How is mixing within the thermal storage tank prevented?

11. How is heat loss from thermal storage due to thermosiphoning through external piping prevented?

12. What is the temperature cycling range of the thermal storage system under design load conditions. What are the highest and lowest water temperature in the upper portion of the thermal storage tank under design load conditions.

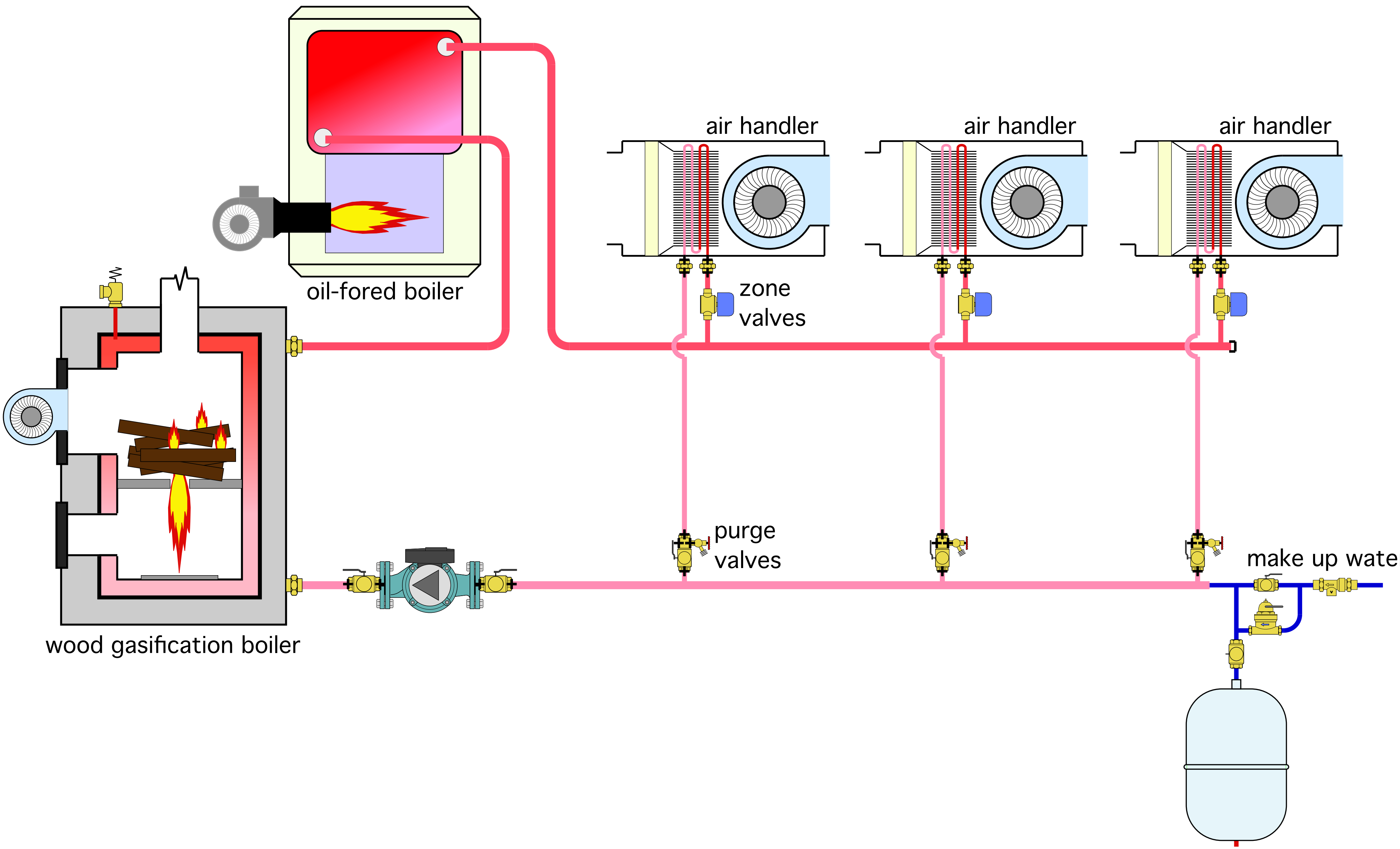
13. What is the minimum supply water temperature at which the heat emitters in the building can provide design load heat output to the building?

14. Are all required safety controls specified for both the biomass boiler and the auxiliary boiler (if present)?

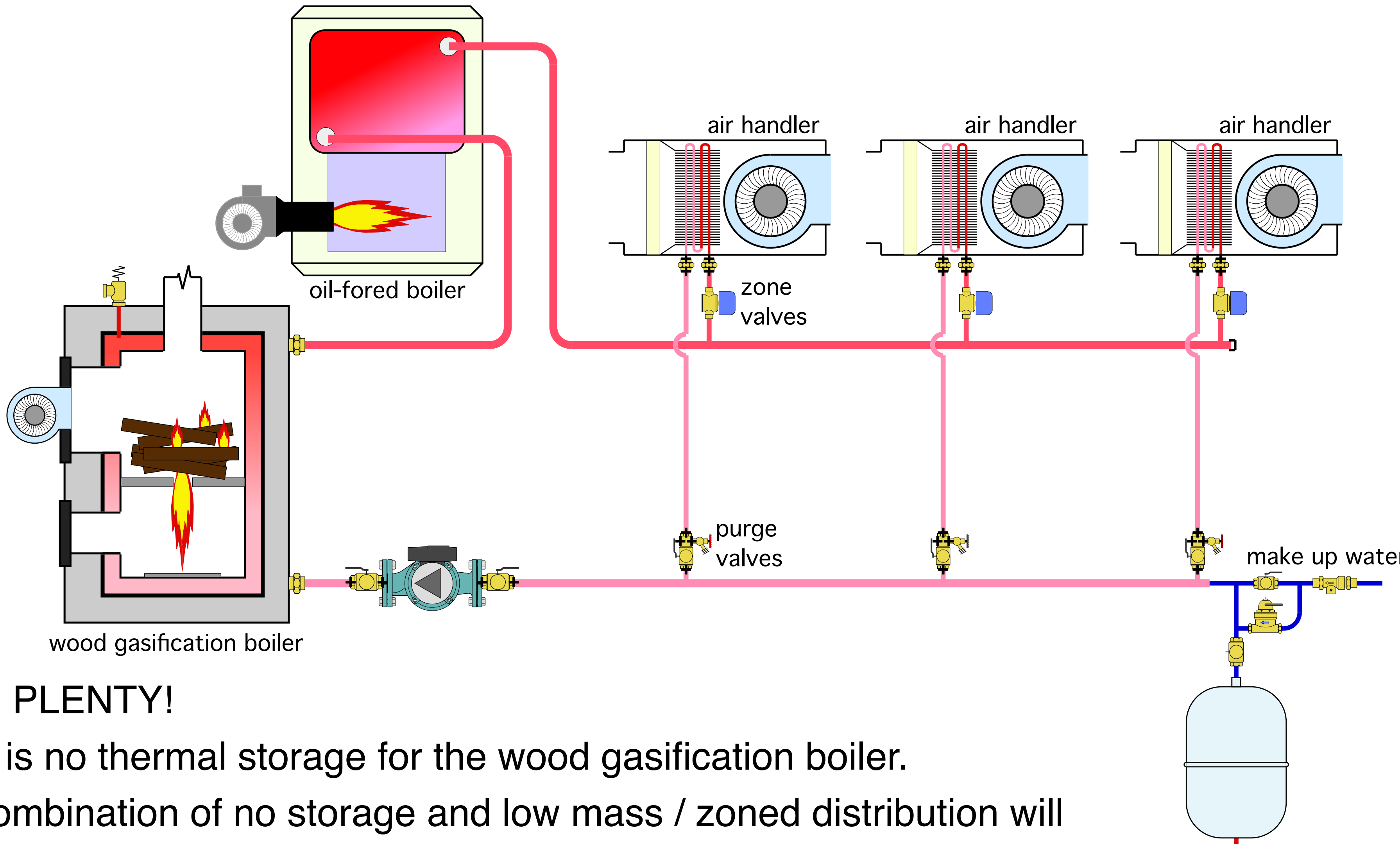
15. Is the required air for combustion and mechanical room ventilation provided?

What's Wrong With This System?

What's wrong with this system?



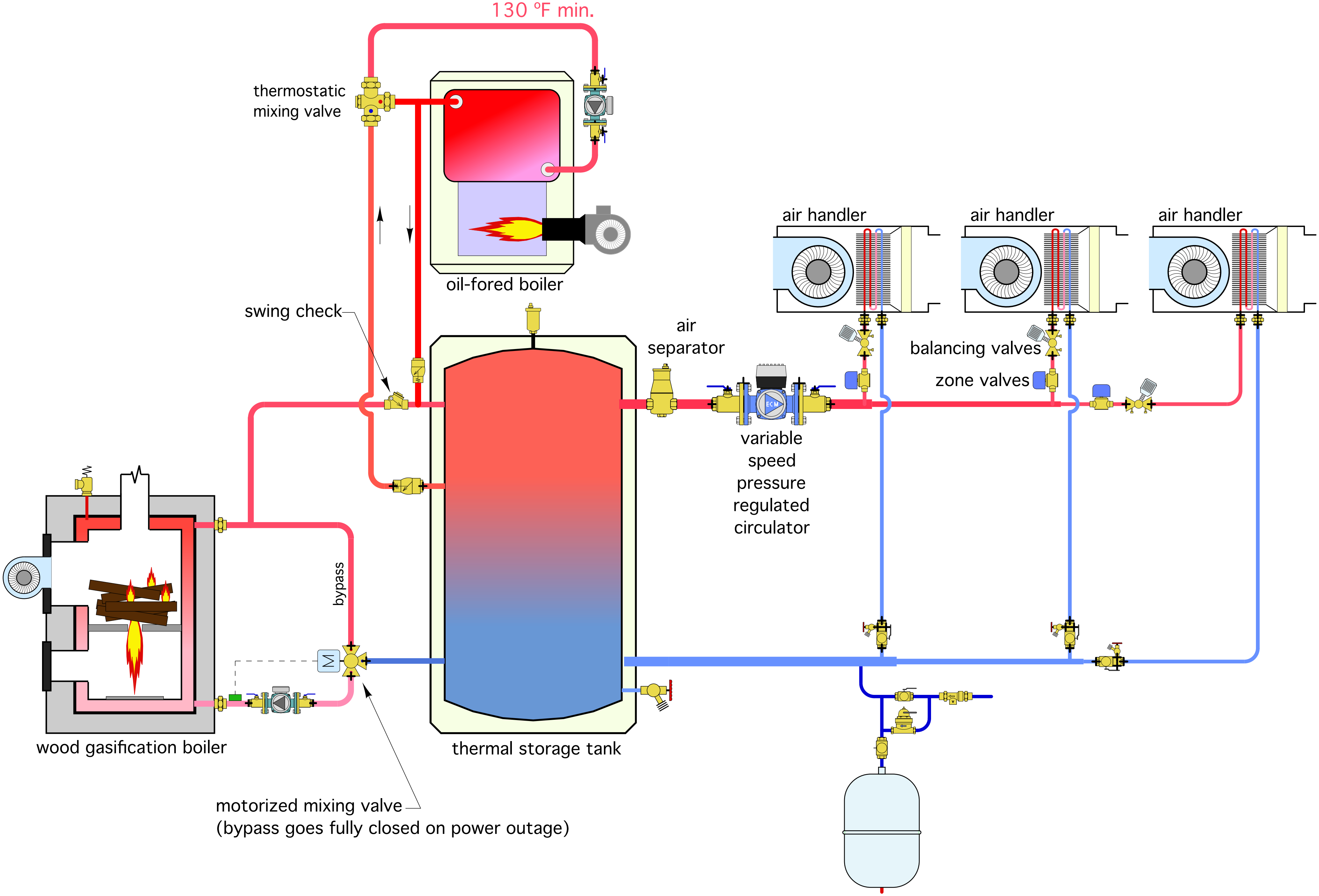
What's wrong with this system?



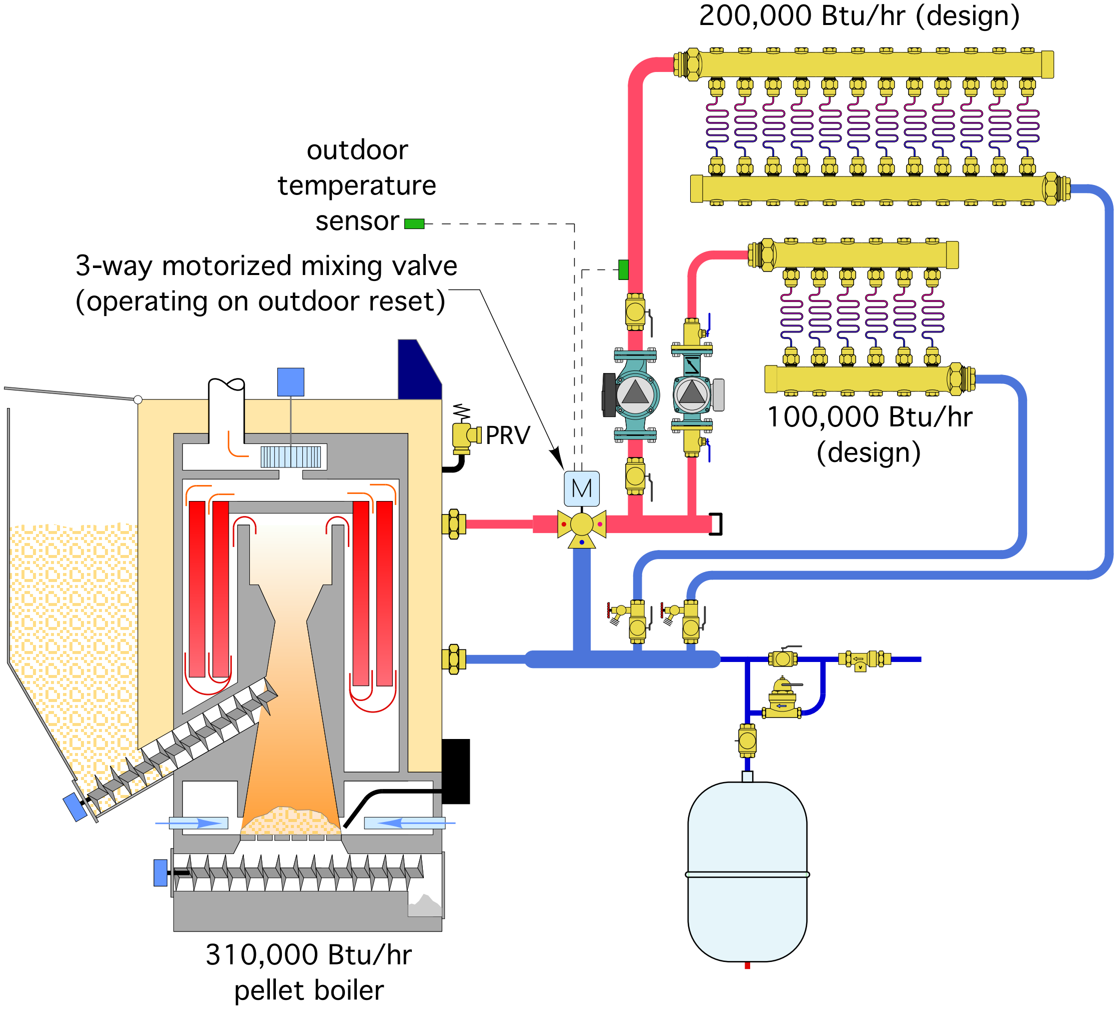
Answer: PLENTY!

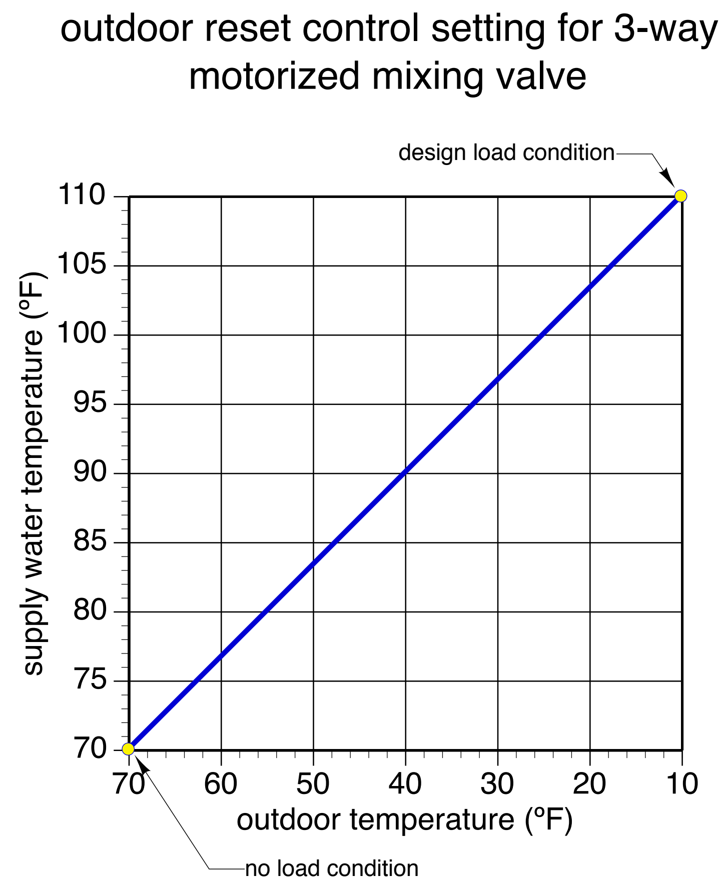
1. There is no thermal storage for the wood gasification boiler.
2. The combination of no storage and low mass / zoned distribution will surely cause boiler short cycling
3. Never connect boilers in series. Unfired boiler acts as a heat dissipator
4. There is no valves for balancing flow through the air handlers
5. There is no inlet water temperature protecting for the boilers
6. It would be better to have expansion tank (e.g., PONPC) near circulator inlet

Here is one way to correct the system



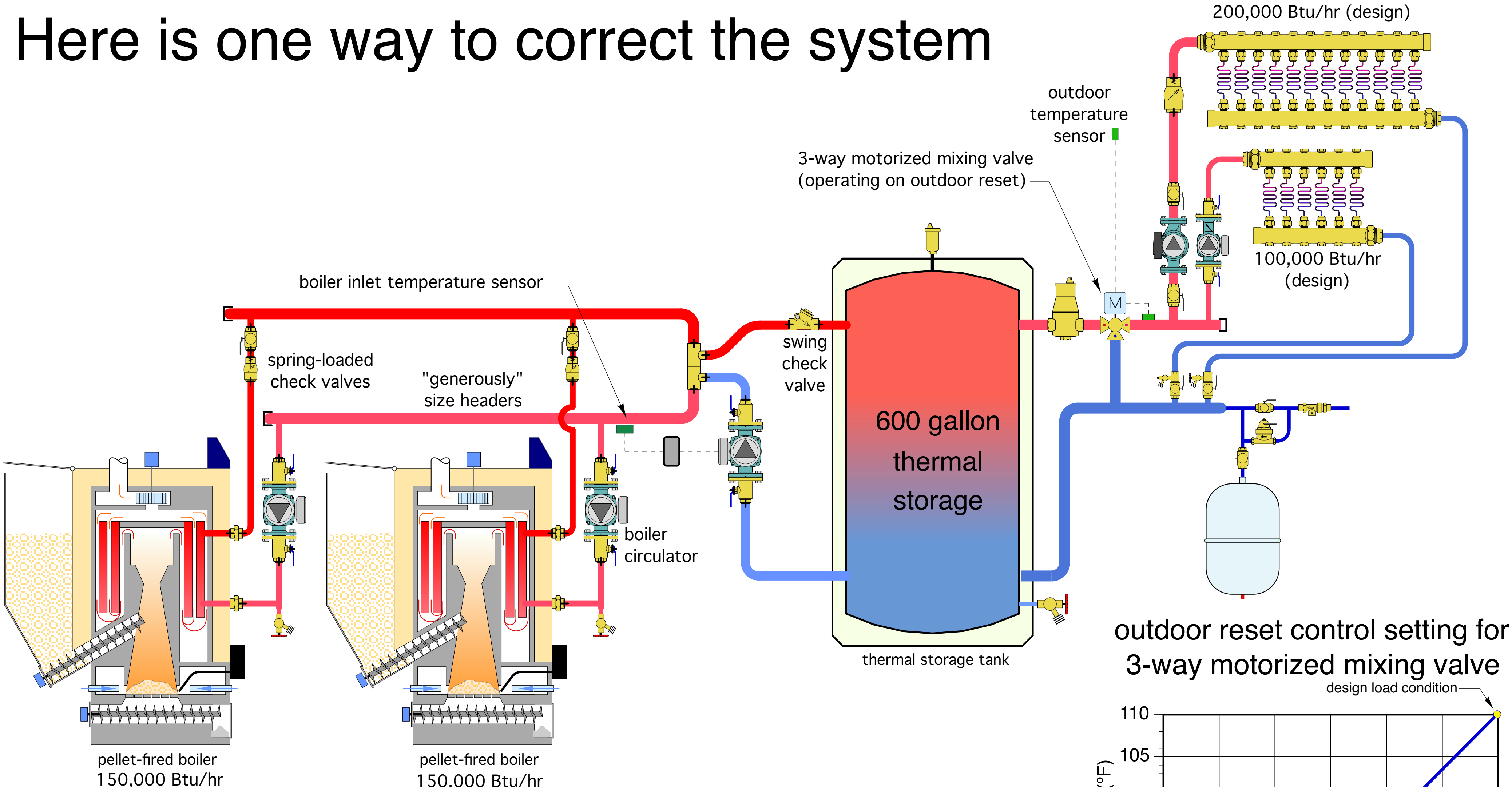
What's wrong with this system?



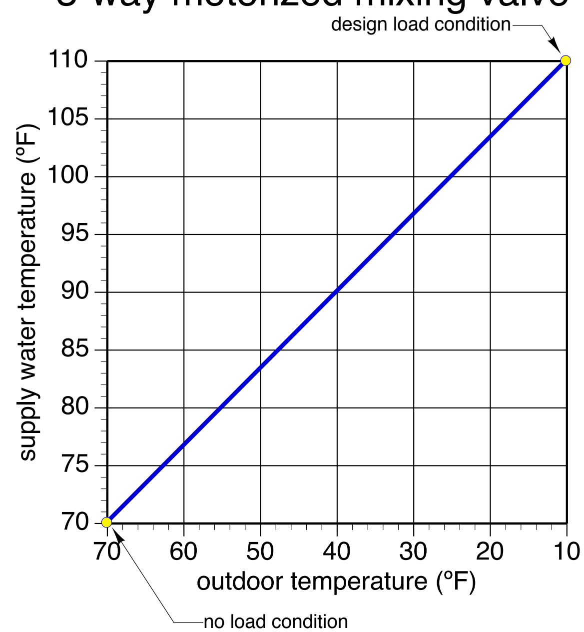


1. The boiler is oversized for the load - many hours of partial load short cycling
2. There is no thermal storage to help boiler achieve longer run cycles
3. There is no means of protecting boiler from low inlet water temperatures (condensation)
4. The supply water temperature sensor will only work for larger zone
5. There is no check valve in the larger zone circuit to prevent reverse flow
6. If boiler had high flow resistance, there's no hydraulic separation between circulators
7. No means of microbubble air separation

Here is one way to correct the system

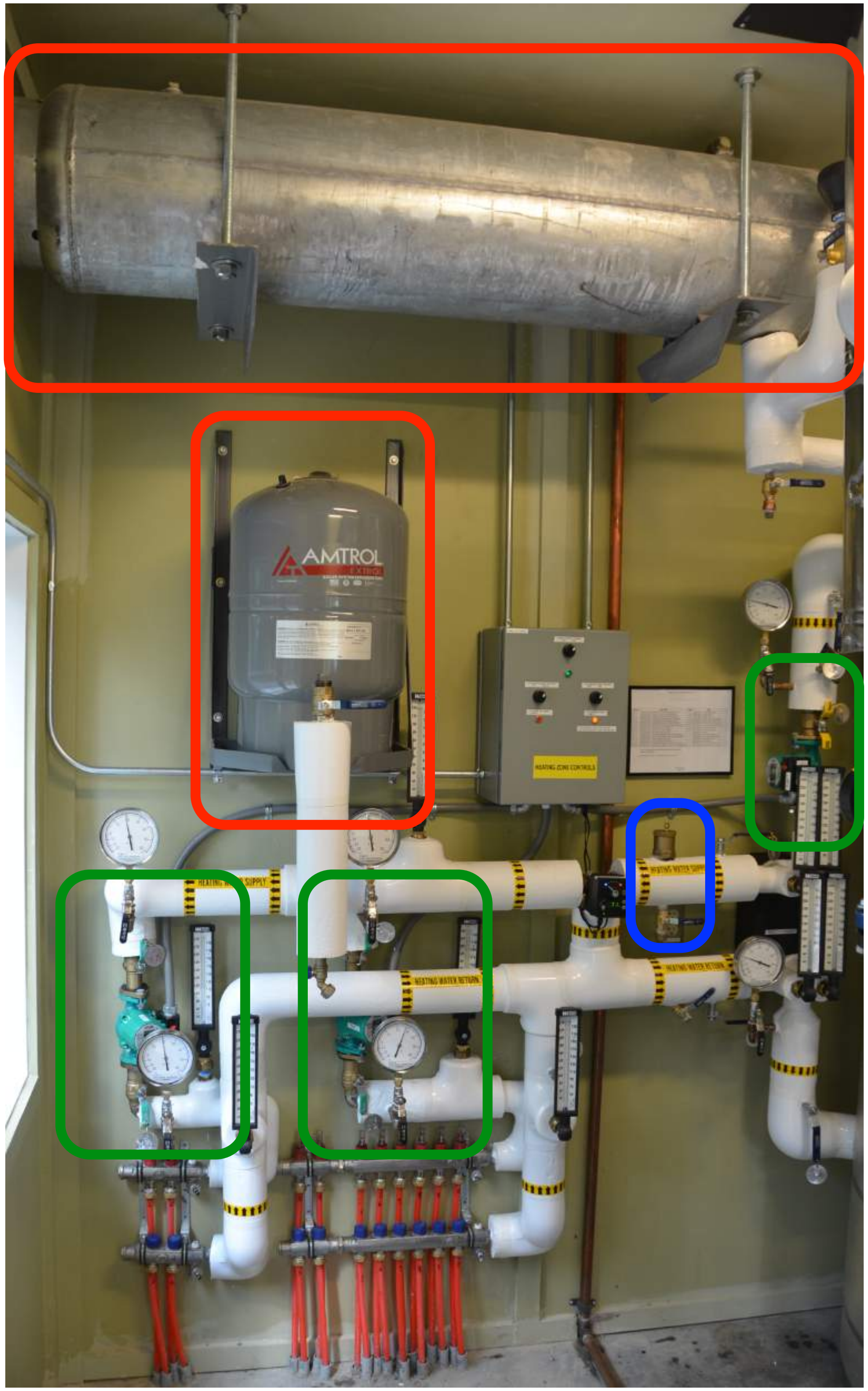


outdoor reset control setting for 3-way motorized mixing valve



1. Staged / modulating boiler plant can go as low as 12.5% of design load
2. Thermal storage allows longer boiler run time
3. Boiler is protected from low inlet water temperatures
4. The supply water temperature sensor common to both zones
5. Check valve in the larger zone circuit prevents reverse flow
6. Buffer tank and “generous” header piping provides hydraulic separation

What’s wrong with this system?

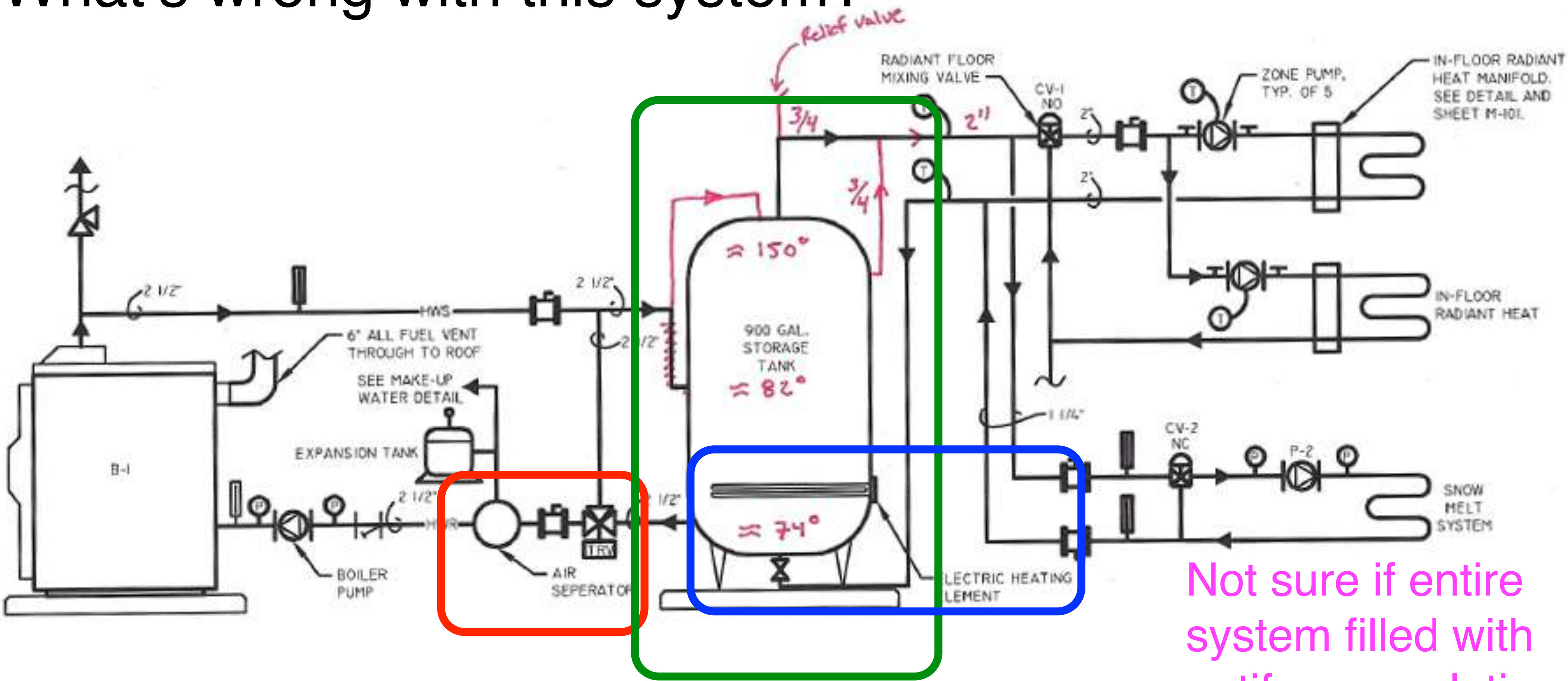


1. Two expansion tanks in system connecting at different locations.

2. Circulator from tank to 3-way mixing valve (not needed).

3. Air separator would be better at high point in piping.

What's wrong with this system?



Not sure if entire system filled with antifreeze solution.

1. Air separator belongs where fluid is hottest.

2. Vertical inlet and outlet piping inhibits stratification.

3. Aux. heating element should be at top of tank - no need to heat entire tank (unless off-peak rates)

Renewable Heat NY
Program Requirements

Renewable Heat NY Requirements

Full documentation for the RHNY program is online at:

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

or simply "google" *Renewable Heat NY*

Renewable Heat New York
Biomass Boiler Program Manual

PON 3010

July 2014

New York State Energy and Research Development Authority

17 Columbia Circle

Albany, NY 12203-6399

(518) 862-1090

PON 3010 Renewable Heat NY Biomass Boiler Program

Description

The New York State Energy Research and Development Authority (NYSERDA) requests applications from qualified Boiler Installers/Contractors to participate in a financial incentive program to install approved pellet boilers and advanced cordwood boilers with thermal storage for eligible residential and commercial customers.

Associated Documents

- PON 3010 Summary of Revisions [PDF]
- PON 3010 Renewable Heat NY Biomass Boiler Program - All Documents [PDF]
- PON 3010 Renewable Heat NY Biomass Boiler Program - Summary [PDF]
- PON 3010 Attachment A - Customer Step-by-Step Guide [PDF]
- PON 3010 Attachment B - Project Application Form [PDF]
- PON 3010 Attachment C - Incentive Payment Request Form [PDF]
- PON 3010 Attachment D - Customer Purchase Agreement Addendum [PDF]
- PON 3010 Attachment E - Recycling Form [PDF]
- PON 3010 Attachment F - Installer Application and Instructions [PDF]
- PON 3010 Attachment G - RHNY Program Manual [PDF]
- PON 3010 Attachment H - QA Checklist [PDF]
- PON 3010 Attachment I - GJGNY Financing Contractor Application [PDF]

Renewable Heat NY Rebates

Residential	Advanced Cordwood Boiler with Thermal Storage	25% installed cost up to $5,000 per unit, with an additional $5,000 for documented recycling (removal and destruction) of old outdoor or indoor wood boiler, or $2,500 for recycling whole-house wood furnace. Up to $5,000 per installed unit is available for customers with existing oil heat or propane.
	Wood Pellet Boiler with Thermal Storage	45% installed cost up to $20,000 based on system size, with an additional $5,000 for documented recycling (removal and destruction) of old outdoor or indoor wood boiler, or $2,500 for recycling whole-house wood furnace.
Small Commercial	Advanced Cordwood Boiler with Thermal Storage	25% installed cost up to $5,000 per unit, with an additional $5,000 for documented recycling (removal and destruction) of old outdoor or indoor wood boiler, or $2,500 for recycling of old wood furnace. Up to $4,000 per installed unit is available for customers with existing oil heat or propane.
	Small Pellet Boiler with Thermal Storage Less than 300 MBtu/h (88 kW)	45% installed cost up to $36,000 based on system size, with an additional $5,000 for documented recycling (removal and destruction) of old outdoor or indoor wood boiler, or $2,500 for recycling whole house wood furnace.

Table 3: Maximum funding for Pellet Boiler by Size

Boiler Size (kW)	Boiler size (Btu/hr)	Maximum Incentive
≤25	≤86,000	$10,000
≤35	≤120,000	$16,000
≤50	≤171,000	$23,000
≤88	≤300,000	$36,000

Renewable Heat NY Requirements

1. Qualified technologies: Only those boilers that meet efficiency and emissions performance requirements and have been approved by NYSERDA will be eligible for incentives. **ALWAYS CHECK FOR THE UPDATED LISTING.**

Renewable Heat NY

Manufacturer	Boiler	Boiler Size (Btu/hr)	Boiler Size (kW)*	Efficiency Based On HHV (%) >=85	PM 2.5 (lb/MMBtu)	CO at 7% O2 (PPM) <270	Link to Company Website
ACT	CP 500	510,000	150	88	0.028	43	http://www.actbioenergy.com/products
	CP 850	850,000	250	88	0.023	48	
	CP 1000	1,000,000	300	87	0.030	45	
	CP 1700	1,700,000	500	89	0.014	53	
Evo World	HP 14	48,000	14	88	0.016	57	http://www.evo-world.com/us-home.html
	P 25	85,000	25	85	0.019	194	
	P 50	170,000	50	90	0.014	26	
	P 100	340,000	100	88	0.019	67	
	P 200	680,000	200	86	0.023	18	
Kedel	RTB-16	58,000	17	85	0.030	118	www.interphaseenergy.com
	RTB-30	85,000	25	85	0.037	265	
	RTB-50	156,000	46	86	0.042	173	
Okofen	PE16	55,000	16	86	0.023	129	http://www.maineenergysystems.com/
	PE32	110,000	32	85	0.019	38	
	PE64	220,000	64	87	0.021	74	
Pellergy	A-60	51,000	15	86	0.016	21	www.pellergy.com
	A-100	88,500	26	86	0.014	63	
TARM-Froling	P4 Unit 8	27,000	8	88	0.035	17	http://www.woodboilers.com/products/pellet-boilers/froling-p4-pellet.html
	P4 Unit 15	51,000	15	87	0.030	17	
	P4 Unit 20	68,000	20	87	0.028	31	
	P4 Unit 25	85,000	25	87	0.028	44	
	P4 Unit 32	109,000	32	87	0.026	68	
	P4 Unit 38	130,000	38	86	0.023	99	
	P4 Unit 48	164,000	48	86	0.027	55	
	P4 Unit 60	200,000	60	86	0.030	10	
	P4 Unit 80	270,000	80	87	0.033	11	
	P4 Unit 100	340,000	100	88	0.033	11	
Windhager	BioWin 100	34,000	10	87	0.016	60	http://www.windhager.com/int_en/
	BioWin 150	51,000	15	87	0.016	21	
	BioWin 260	89,000	26	86	0.014	63	
	BioWin 350	120,000	35	85	0.016	40	
	BioWin 600	210,000	60	85	0.021	44	

* Kw is the unit boilers are measured by in Europe

Renewable Heat NY Requirements

2. Qualified installers: Only heating systems installed by a qualified installer according to program requirements will be eligible for incentives.

http://www.nyserda.ny.gov/Funding-Opportunities/Current-Funding-Opportunities/PON-3010-Renewable-Heat-NY-Biomass-Boiler-Program

Attachment F
RENEWABLE HEAT NY BIOMASS BOILER PROGRAM
Installer/Contractor Eligibility Application and Instructions

To qualify to participate as an Eligible Installer, an Installer/Contractor must meet one (1) of the following levels of experience:

- Have at least three (3) years of relevant experience with the design and installation of hydronic systems;
- Have at least two (2) years of experience installing hydronic systems including a minimum of one (1) successful installation of equipment meeting the full requirements of this solicitation (i.e. solid fuel pellet boilers or advanced cord wood boilers defined as low mass (low water jacket volume), staged combustion (sometimes referred to as gasification) boilers with sensors and controls to optimize system performance) and thermal storage and outside bulk pellet storage;
- Be a licensed Master Plumber or Journeyman Plumber, with at least two (2) years of relevant experience with the design and installation of hydronic systems;
- Be a New York State-licensed professional (Registered Architect or Professional Engineer) and have at least two (2) years of relevant experience with the design and installation of hydronic heating systems.

Renewable Heat NY Requirements

3. Load Calculations:

• Residential installations must have load calculation by Manual J (or equivalent).

• Commercial buildings must use baseline data established through energy audit, or an appropriate energy model.

• Don't size based on existing heating equipment ratings.

4. Proper Boiler sizing (larger commercial applications):

For systems using pellet-fired boiler(s) totaling more than 300,000 Btu/hr rated output, the pellet-fired boiler(s) rated output cannot exceed 60% of design load.

Renewable Heat NY Requirements

5. Full thermal energy storage:

For pellet-fired boilers: Minimum of 2 gallons per 1000 Btu/hr (but 119 gallon storage allowed for pellet boilers ≤ 25 KW (78,600 Btu/hr)

For wood gasification boilers: firebox volume (ft^3) X 130 gallons/ft^3 minus boiler water volume.



Renewable Heat NY Requirements

6. **Systems must have an energy management system (or programmable thermostat)** to optimize operation of the pellet boiler, auxiliary boiler, and thermal storage to meet seasonal and diurnal heating loads.
   - Designs will be reviewed and Installations will be inspected.
   - Large commercial projects (>300,000 Btu/h) will require system commissioning and one year of heating system Measurement and Verification.

7. **Stack must be carefully placed and meet building code.** For commercial buildings the stack placement must be consistent with good engineering practice and consider where air intakes and operable windows and doors are located.

8. **Pellet boilers must use premium wood pellets**

9. **Homes and boiler rooms must have a CO detector.**

10. **Bulk pellet storage must be outside building.**

residential systems contact: "Ryan T. Moore" <Ryan.Moore@nyserda.ny.gov>

commercial systems contact: "Matthew A. McQuinn" <Matt.McQuinn@nyserda.ny.gov>

Documentation Guidelines
for *Renewable Heat New York* submittals

- To help ensure proper design, successful installation, efficient operation, and long service life, all applications for RHNY funding should include proper technical documentation of the system.

- The review of submitted documentation is to check for compliance with the technical requirements of RHNY.

- The review of submitted documentation is to help avoid design or installation issues before they get much more expensive to repair in the field.

- NYSERDA will inspect installed systems to check compliance with the documentation submitted.

- The documentation required is consistent with good design practice.

Documentation Guidelines
for *Renewable Heat New York* submittals

The following information is needed for proper system evaluation:

1. Room-by-room heating loads for all rooms of the building served by the system. These calculations must be based on ACCA Manual J procedures or NYSERDA-approved equal.

2. Room-by-room description of all existing heat emitters such as fin-tube baseboard, radiators, fan-coils. The heat output of all existing heat emitters in each room shall be listed along with the supply water temperature upon which this heat output is based.

3. PIPING SCHEMATIC including the make and model of the components listed below:
    a. Heat source(s), (new and existing)
    b. Boiler inlet temperature control hardware
    c. All circulators
    d. Thermal storage tanks and associated tank insulation (list volume & insulation R-value)
    e. Water temperature control means,
    f. Means for purging and air removal
    g. Distribution system layout including zoning methods
    h. Means for accommodating water expansion (expansion tank and PRVs)
    i. Means of heating domestic water (if used)
    j. Any heat exchangers used in system
    k. Heat emitters: List all new heat emitters as well as existing heat emitters in each room

Drawings can be hand drawn or produced using software.

Documentation Guidelines

for *Renewable Heat New York* submittals

4. FUEL STORAGE & CONVEYANCE (pellet-fueled systems only) include make and model number of component(s):
   a. Exterior pellet storage device(s)
   b. Pellet conveyance hardware

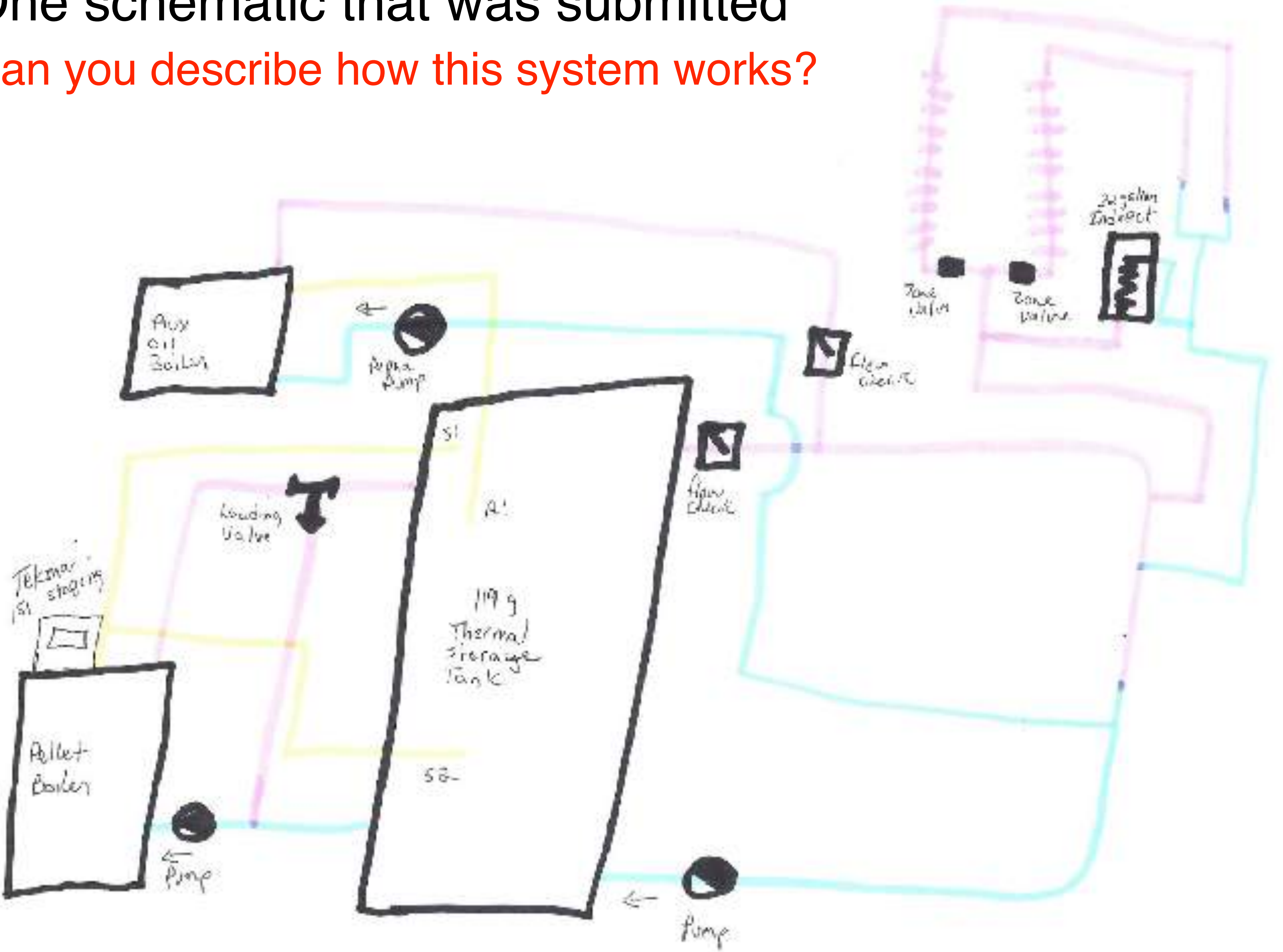
5. AIR SUPPLY AND EXHAUST HANDLING include make and model number of component(s):
   a. Means of supplying sufficient combustion air to heat source
   b. Means of exhausting combustion gases from heat source

6. SYSTEM CONTROL DOCUMENTATION include make and model number of component(s):
   a. Means of protecting the system against over-temperature and over-pressure (list all code-required safety devices)
   b. Means of protecting the boiler against sustained flue gas condensation
   c. Means for controlling water temperature in boiler and thermal storage during operation
   d. Means for controlling water temperature to distribution system
   e. Description of operating sequence for boiler(s) and distribution system

7. ASME REQUIREMENTS: Specify ASME listing for boiler and thermal storage tank:
ASME certification of boiler and thermal storage tanks of 120 gallon or more is required for any publicly accessible building, or any building with one or more employees, or multi-family buildings of 6 living uni or more, unless rated heat output of all heat sources is less than 100,000 Btu/hr. Not required for singl family residential buildings.

One schematic that was submitted

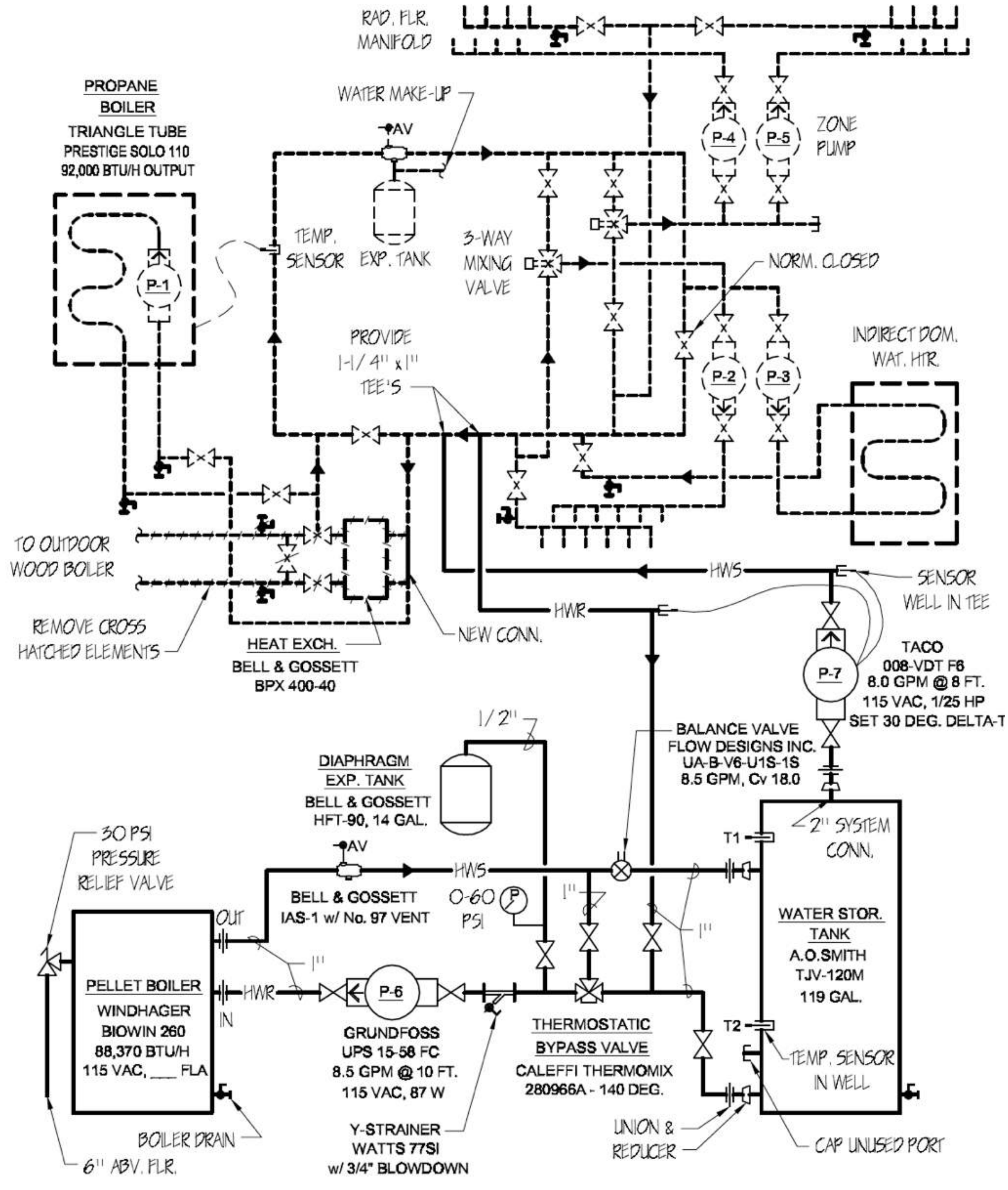
Can you describe how this system works?



Another schematic that was submitted

This is a portion of the documention submitted.

There was also documentation for electrical controls, description of operation, and installation details.



PIPING SCHEMATIC

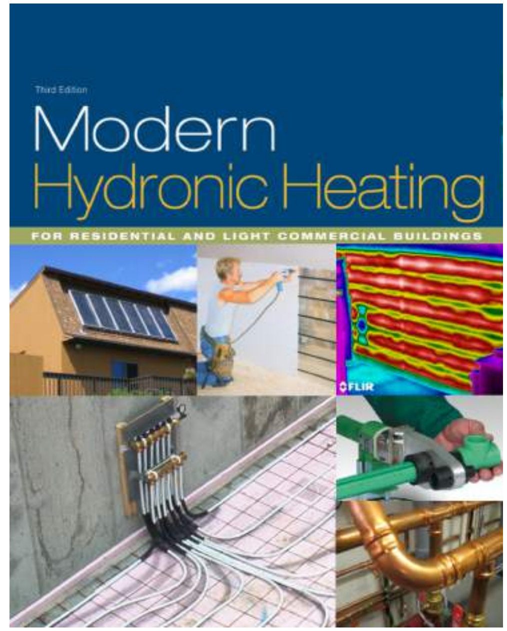
SCALE: NONE

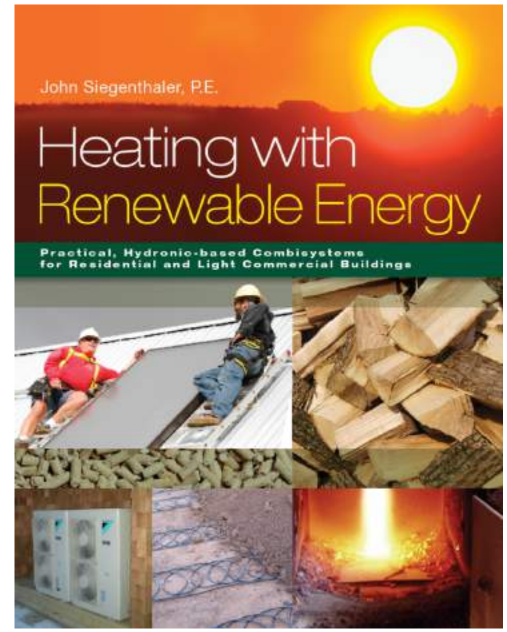
Recommended Reading:

1. ***Planning and Installing Bioenergy Systems***, 2007, The German Solar Energy Society. ISBN 978-1-88407-132-6.

2. ***Heating with Renewable Energy****, 1st Edition, 2016, ISBN -13: 978-1-285-07560-0* Cengage Learning

3. ***Modern Hydronic Heating*, **3rd Edition, Siegenthaler, 2012. ISBN-13: 978-1-4283-3515-8, Cengage Learning





Web resources:

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

http://www.nyserda.ny.gov/-/media/Files/Publications/Research/Biomass-Solar-Wind/European-wood-heating-technology-survey.pdf

https://www.biomassthermal.org/resource/

http://nebiomassheat.com/archives.php

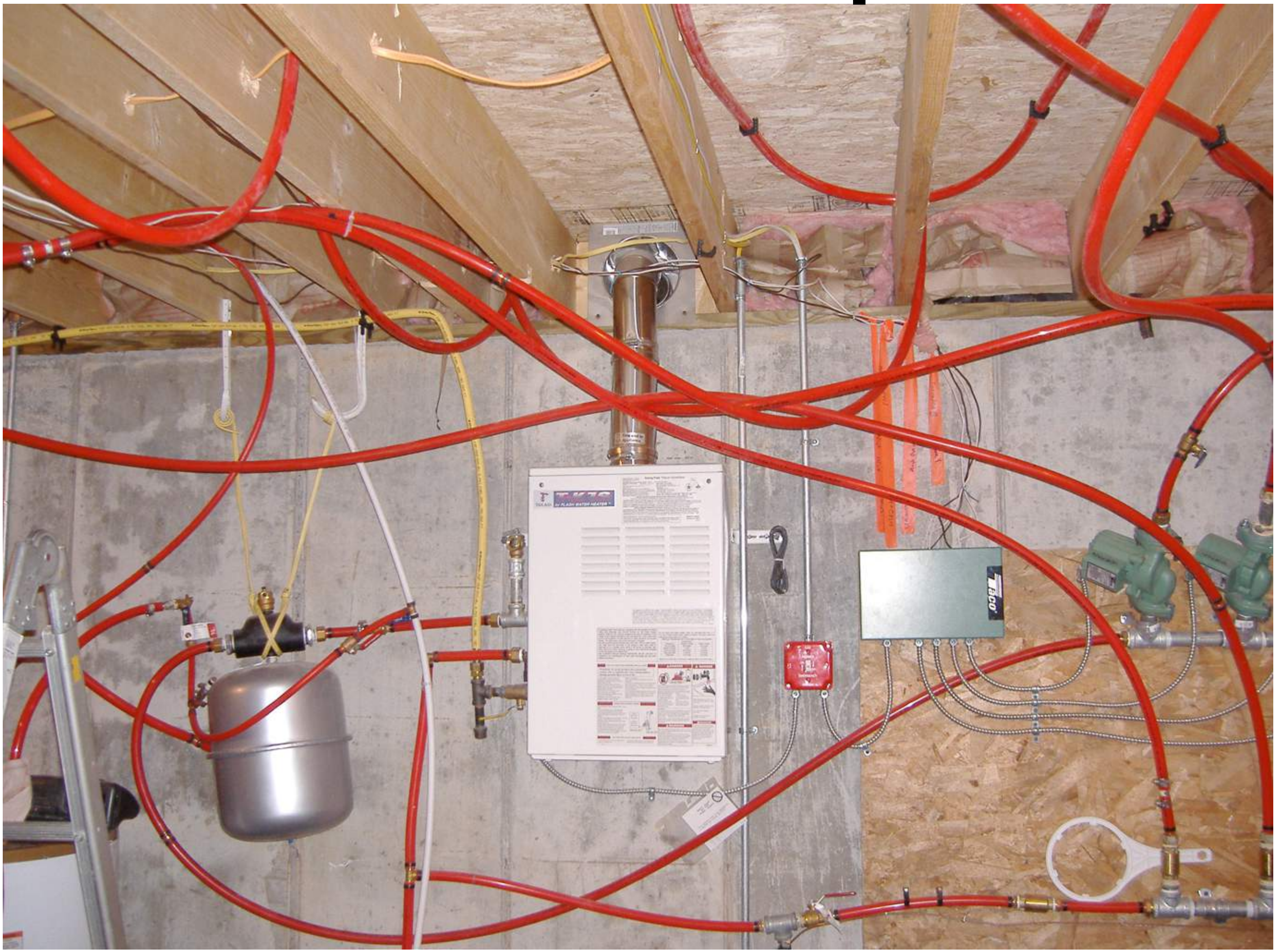
http://www.biomasscenter.org/

Parting thoughts...

1. Plan ahead...

Parting thoughts...

2. Keep it neat...



Parting thoughts...

3. Keep it simple...

Thanks for attending this training

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If you have comments or suggestions regarding this training, please feel free to e-mail them to:

John Siegenthaler
e-mail: siggy@dreamscape.com

and/or to:

Vicki Colello
e-mail: Vicki.Colello@nyserda.ny.gov>