Why low temperature distribution systems improve biomass boiler performance

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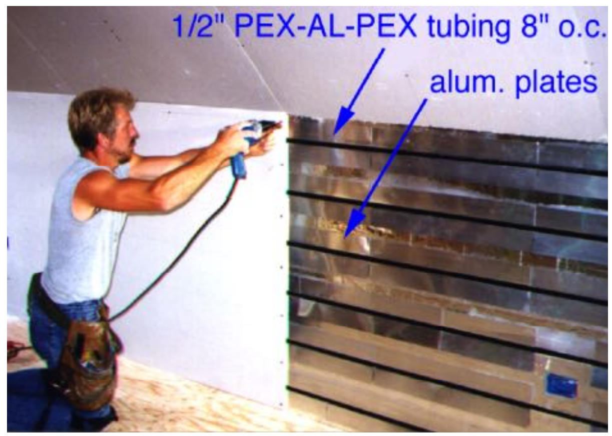
January 28, 2021
1:00 PM

Moderated by:

Sue Dougherty
Clean Heating & Cooling program
NYSERDA
sue.dougherty@nyserda.ny.gov

presented by:

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



Spring 2021 online training opportunities

January 28, 2021 / 1:00-2:00 PM

Topic: Why low temperature distribution systems improve biomass boiler performance

Description: This webinar will describe how low temperature distribution systems allow a winder range of operation for thermal storage, and how this translates to longer / more efficient and lower emission burn cycles for a pellet boiler. It will also compare control methods for enabling pellet boiler operation when the thermal storage tank can no longer sustain the heating load.

February 18, 2021 / 1:00-2:00 PM

Topic: Proper installation of temperature sensors in biomass boiler systems

Description: Improper temperature sensor placement can drastically limit the performance of both pellet boiler and cordwood gasification boilers. This webinar will show examples of incorrectly placed sensors based on field experience. It will also show correct mounting and wiring methods for both surface-mounted and well-mounted sensors.

March 18, 2021 1:00-2:00 PM

Topic: Using external heat exchangers in biomass boiler systems with non-pressurized thermal storage.

Description: Many cordwood gasification systems use unpressurized thermal storage tanks. A common approach is to use coiled copper tube heat exchangers suspended within these tanks. An alternative approach uses external brazed plate stainless steel heat exchangers. This webinar exams the advantages of the latter approach. It also shows how a single external heat exchanger can be used for both heat input to the thermal storage and heat extraction.

All training is provided free

Register here:

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

Why low temperature distribution systems improve biomass boiler performance

Session description: Low temperature distribution systems allow wider temperature swings for thermal storage. This translates into longer / more efficient and lower emission burn cycles for a pellet boiler or cordwood gasification boiler . This webinar compare control methods for enabling pellet boiler operation when the thermal storage tank can no longer sustain the heating load.

Learning objectives:

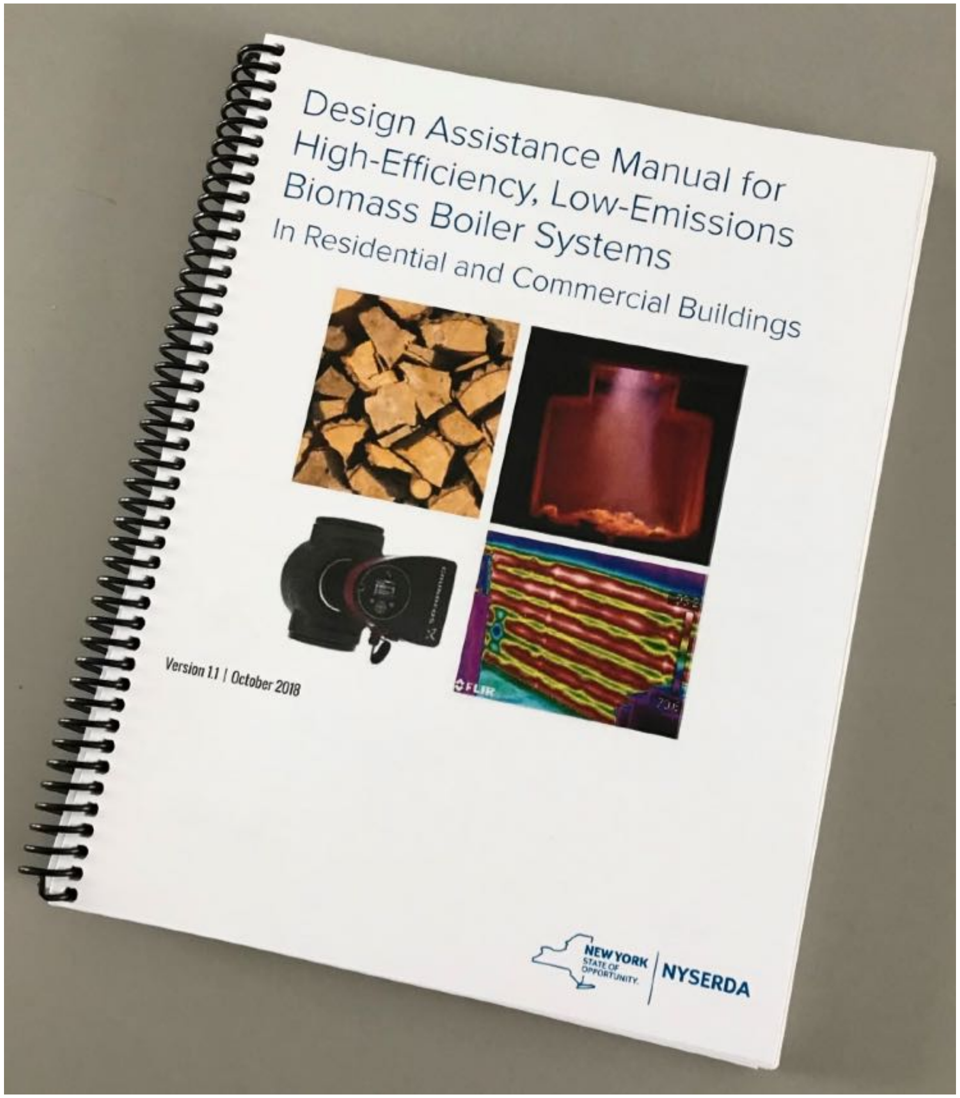
1. Understand the importance of long burn cycles in achieving beneficial operating characteristics for pellet boilers.

2. Be able to describe several low temperature hydronic heat emitters.

3. Explain simple concepts for controlling heat transfer from biomass boiler subsystem to distribution system.

4. Explain how to provide a proper supply water temperature to low temperature heat emitters, even with widely varying temperature in thermal storage.

Design Assistance Manual
for High Efficiency Low Emissions Biomass Boiler Systems



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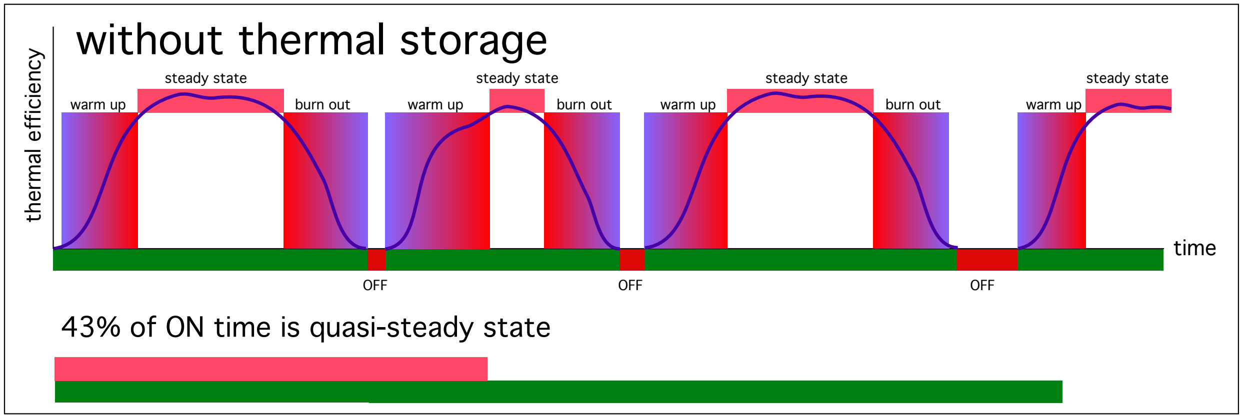
1. Introduction
2. Cordwood Gasification Boilers
3. Pellet-Fired Boilers
4. Boiler Air Supply & Venting Systems
5. Thermal Storage
6. Heat Emitters & Distribution Systems
7. System Design Details
8. System Templates

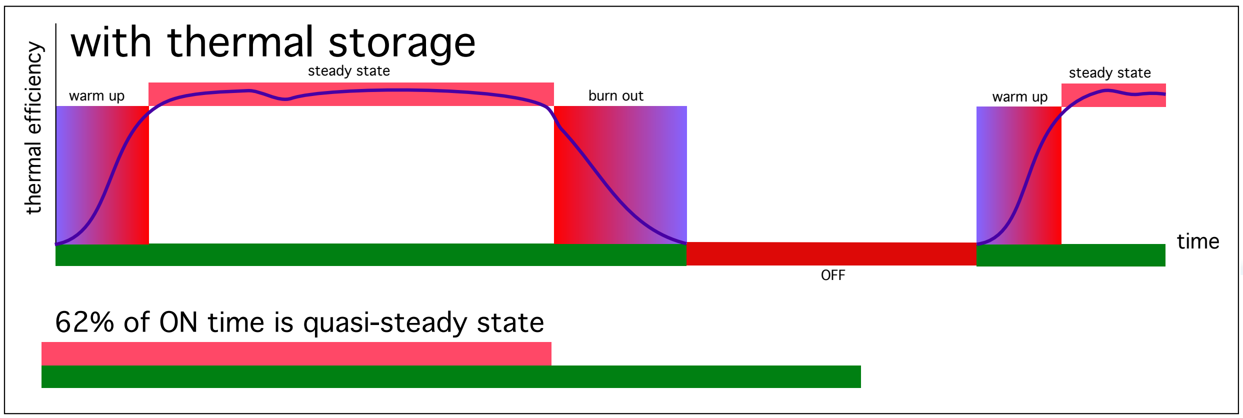
It's available as a FREE downloadable PDF at:

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

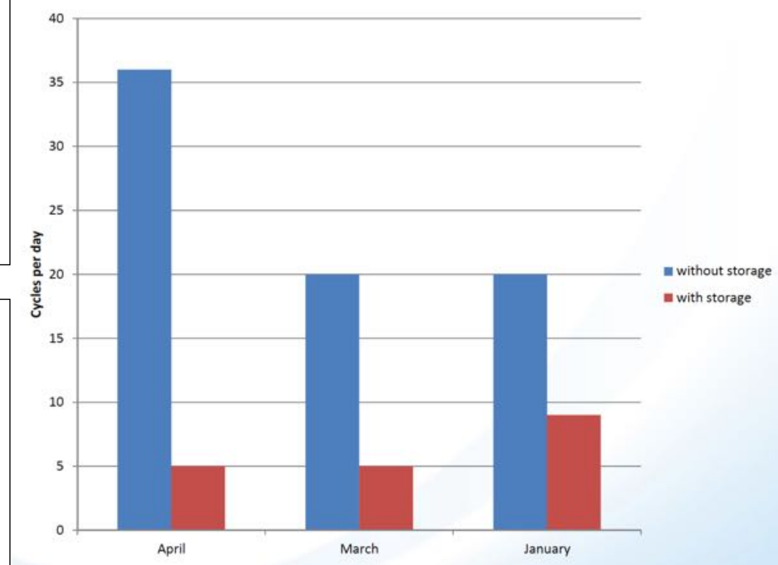
Why long burn cycles are important

Pellet boilers attain their highest thermal efficiency, and lowest emissions, when **operated for long (multiple hour) burn cycles.**





25 kW (85,300 btu/hr) rated pellet boiler supplying a heating load profile typical of an upstate NY house, with and without a 119 gallon



Brookhaven National Laboratory & Dr. Tom Butcher

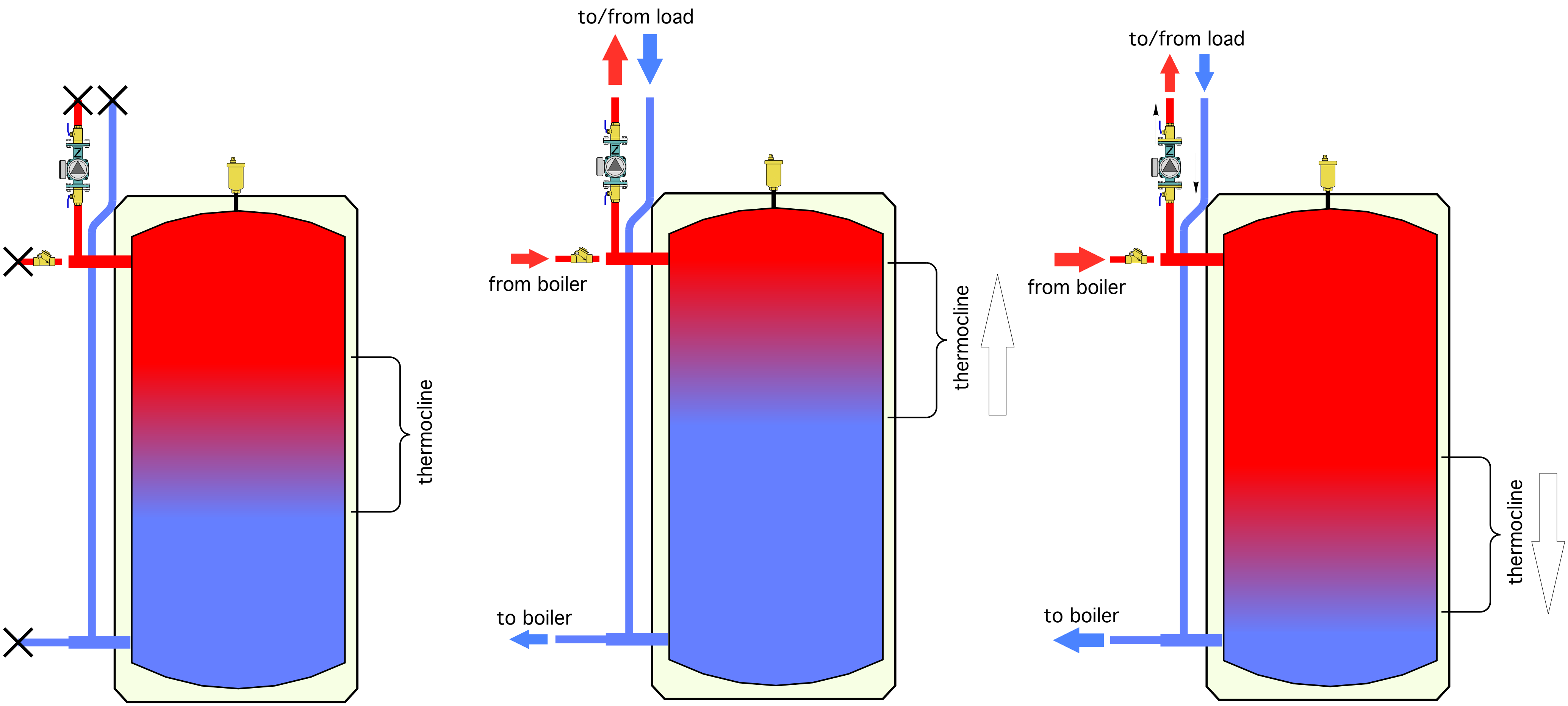
Suggested design objective: 3 hour run / start

<u>It is essential to use thermal storage to achieve long burn cycles on pellet boilers, and cordwood gasification boilers.</u>

Encouraging wide temperature swings in thermal storage

Thermocline movement in tank

Indicates relative energy flow between boiler and load.

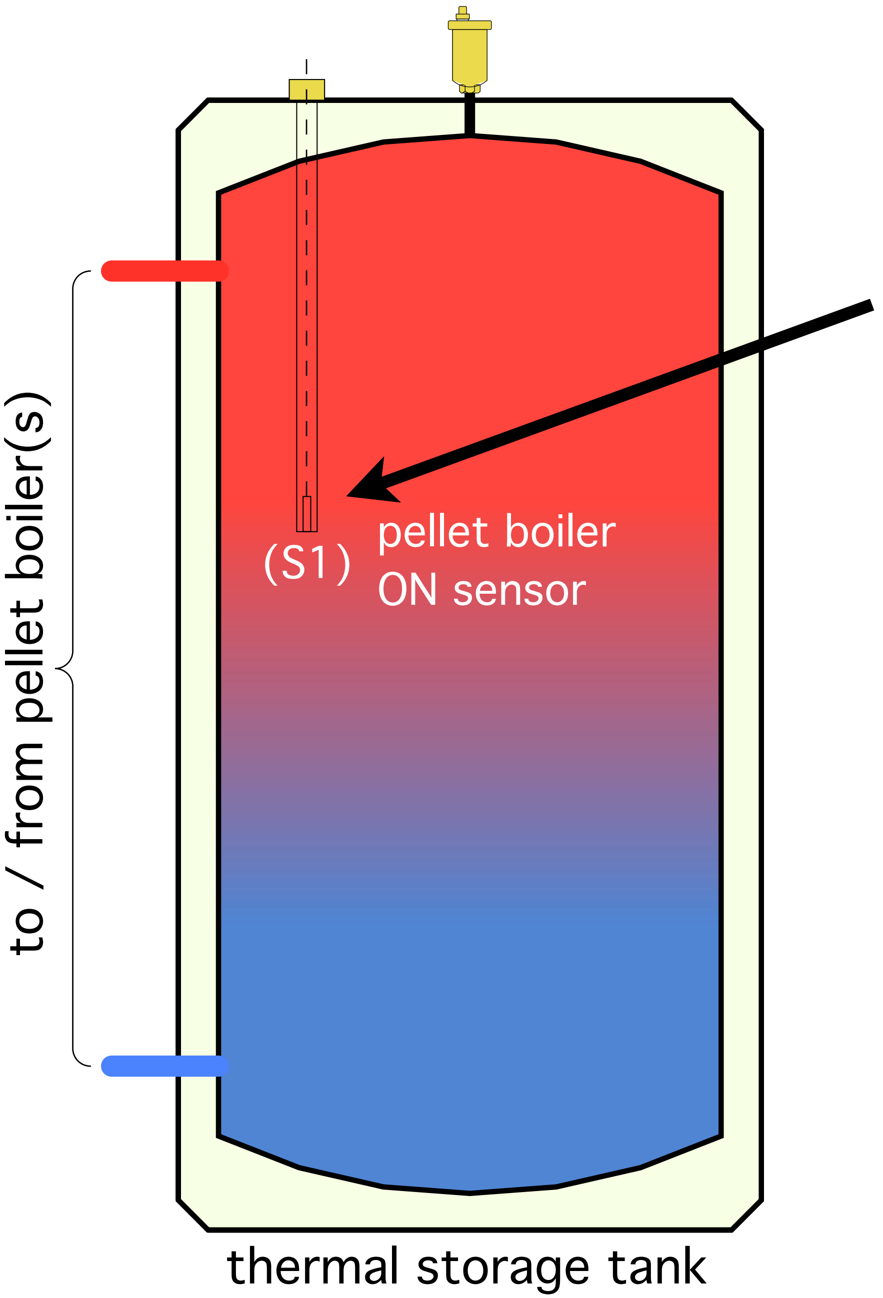


tank at rest. No flow from boiler or to load

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

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

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

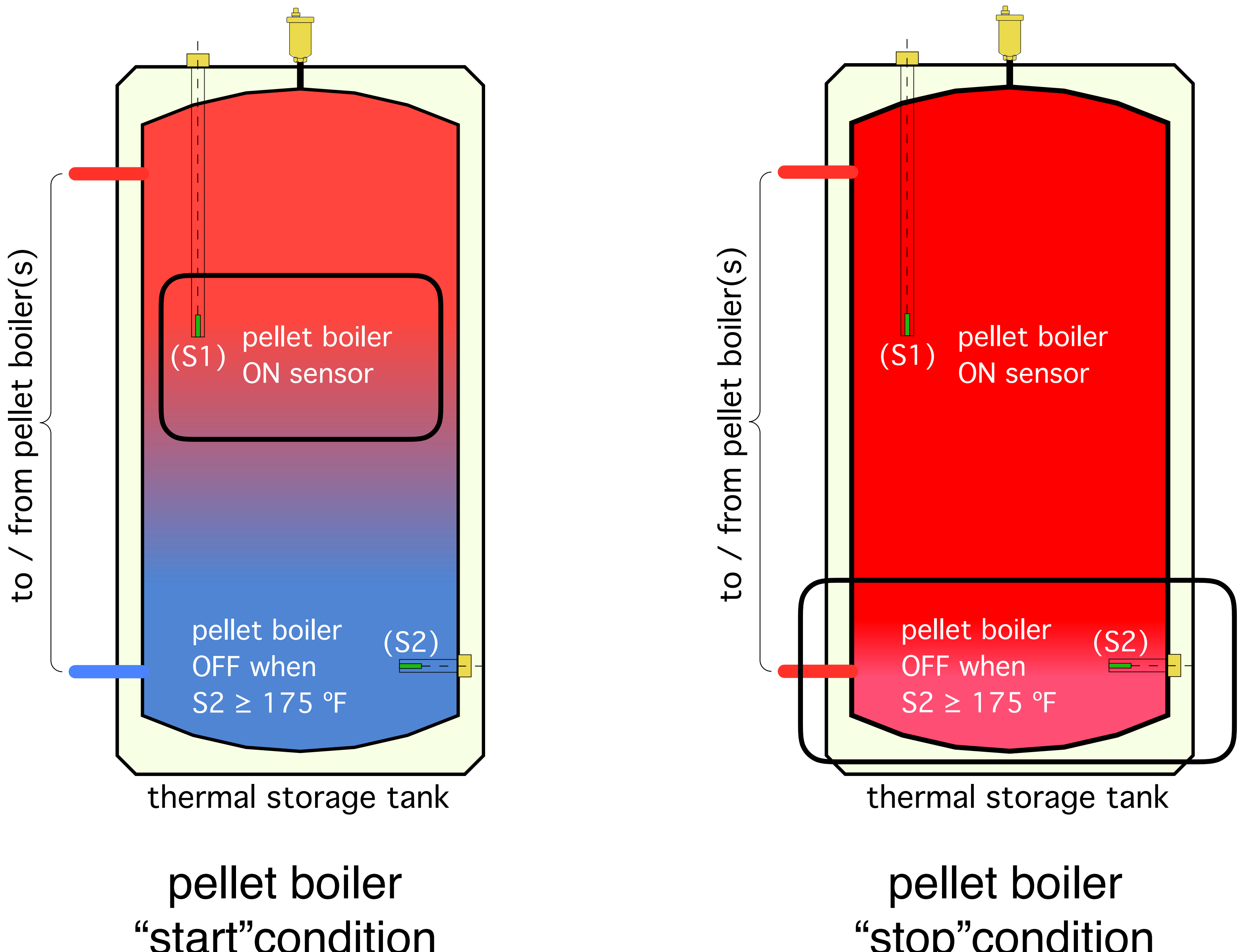


Sensor in vertical well detects "arrival" of rising cooler water. Turns on pellet fired boiler.

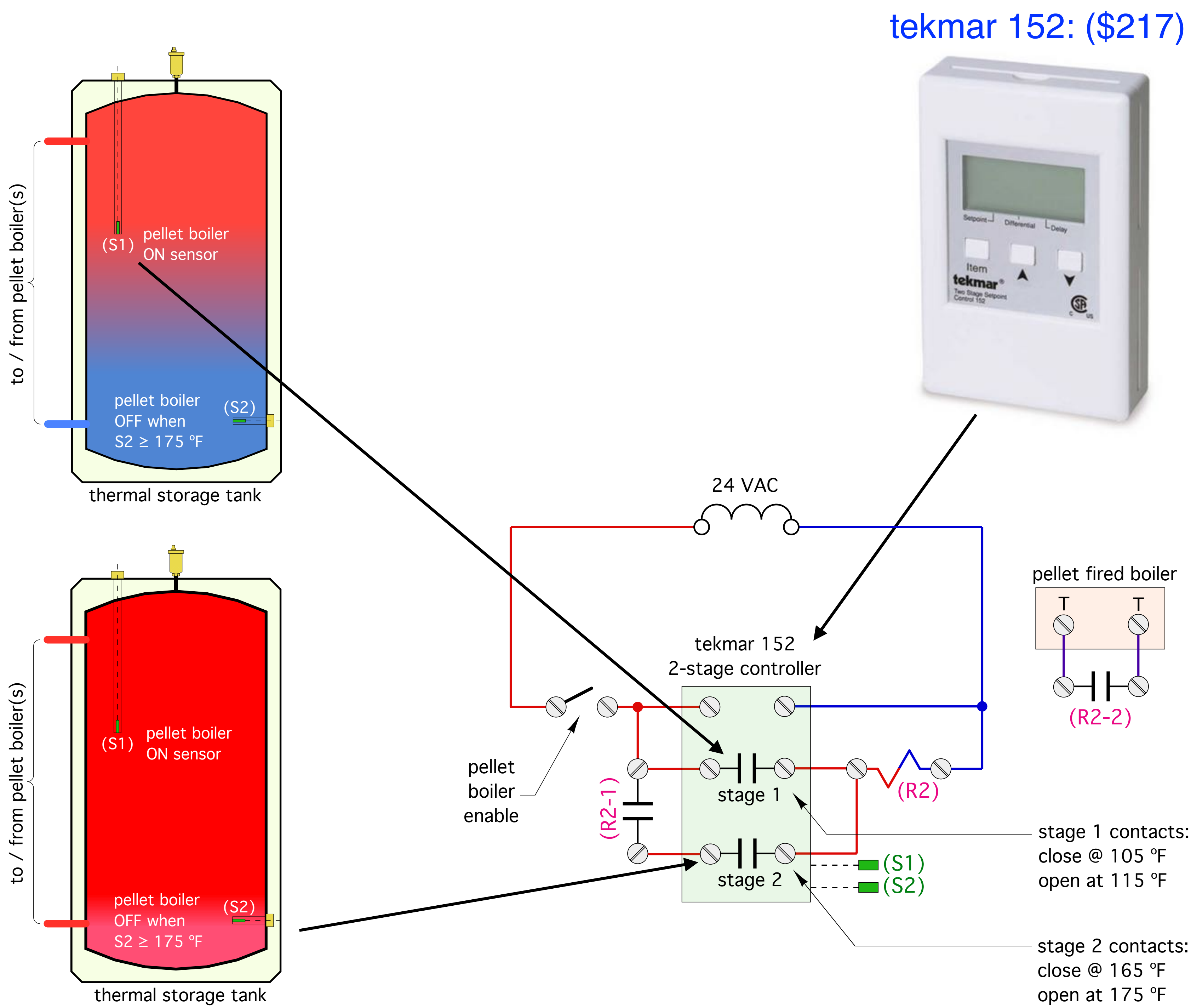
pellet boiler ON when
upper sensor temperature
≤ minimum setpoint

Temperature stacking

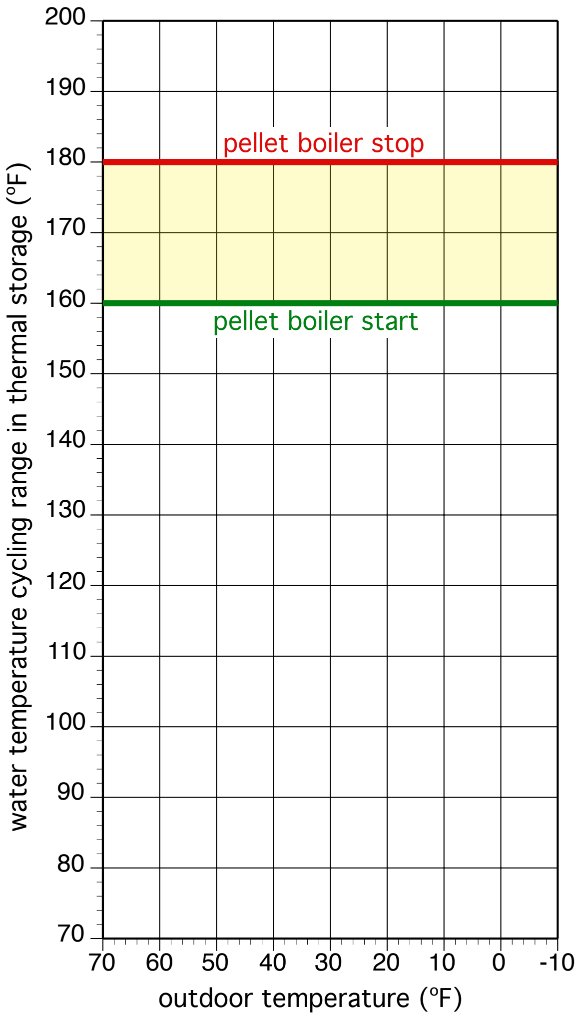
To lengthen pellet boiler on-cycle, keep it operating until a sensor in lower portion of tank reaches some higher preset temperature.

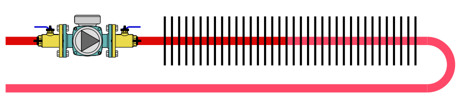


Temperature stacking *(using 2 setpoint temperatures)*



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

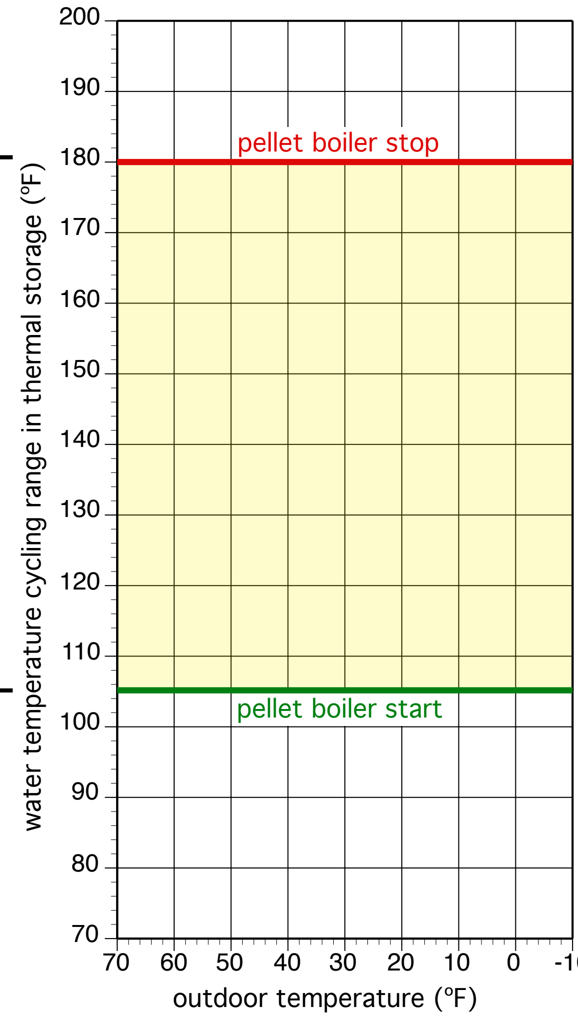


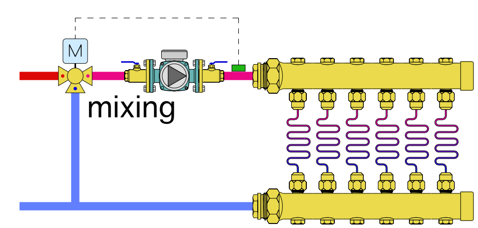


- HIGH temperature heat emitters
- No outdoor reset control of supply water temperature

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

The larger the "yellow area" in the graph, the better the thermal storage tank is being "exercized."

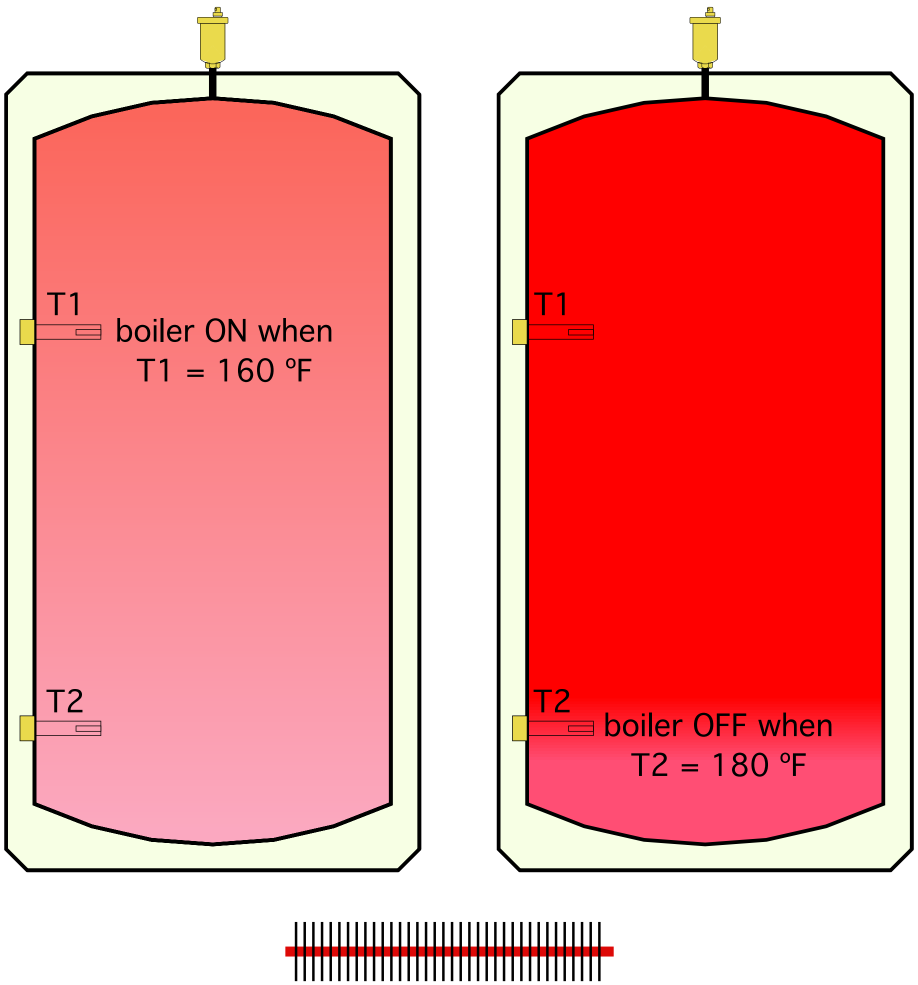




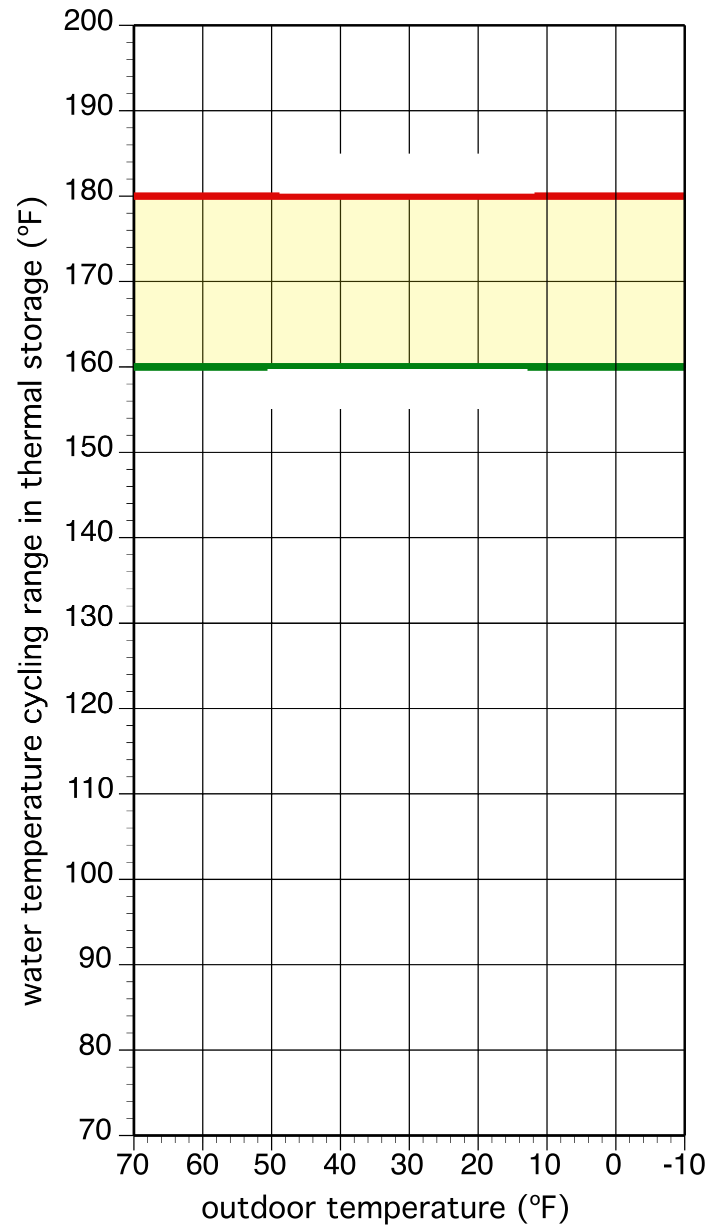
- LOW temperature heat emitters
- No outdoor reset control of supply water temperature

• High temperature heat emitters

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



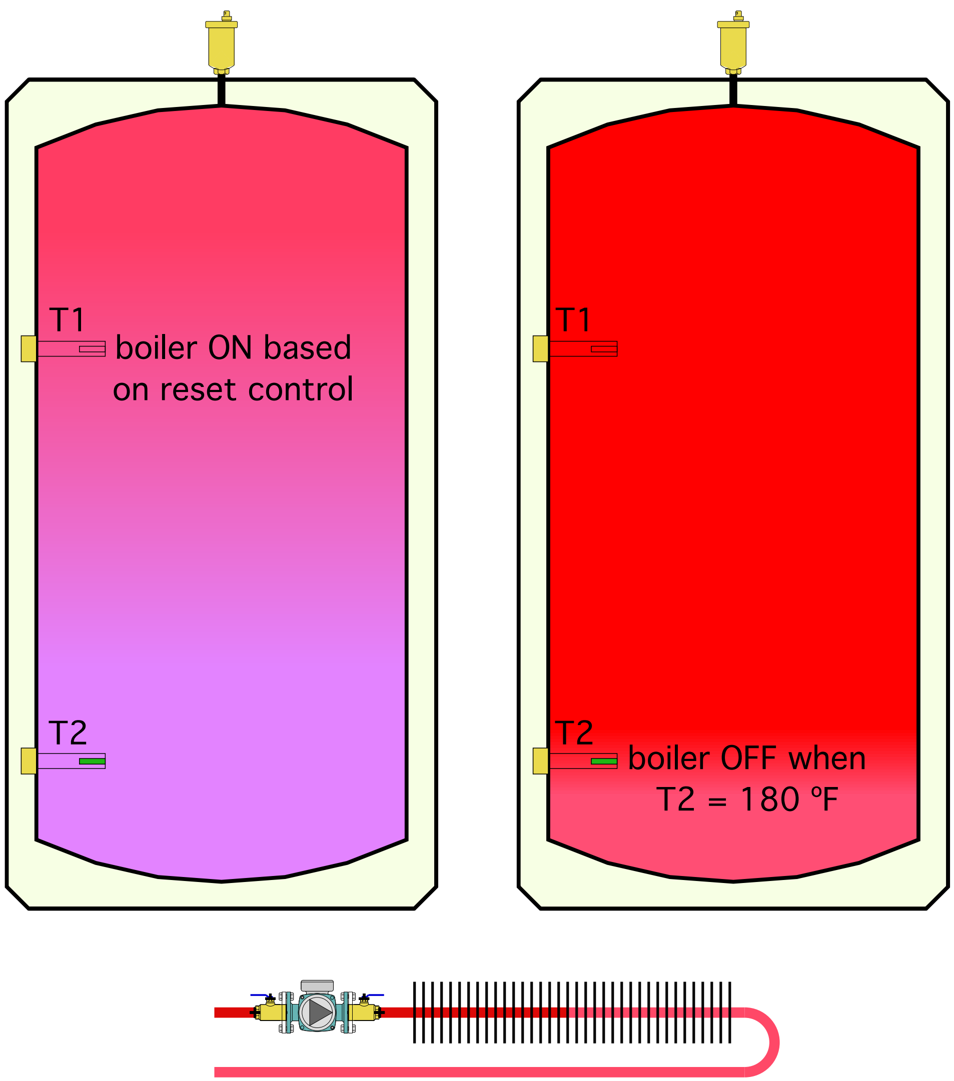
- High temperature heat emitters
- No outdoor reset control



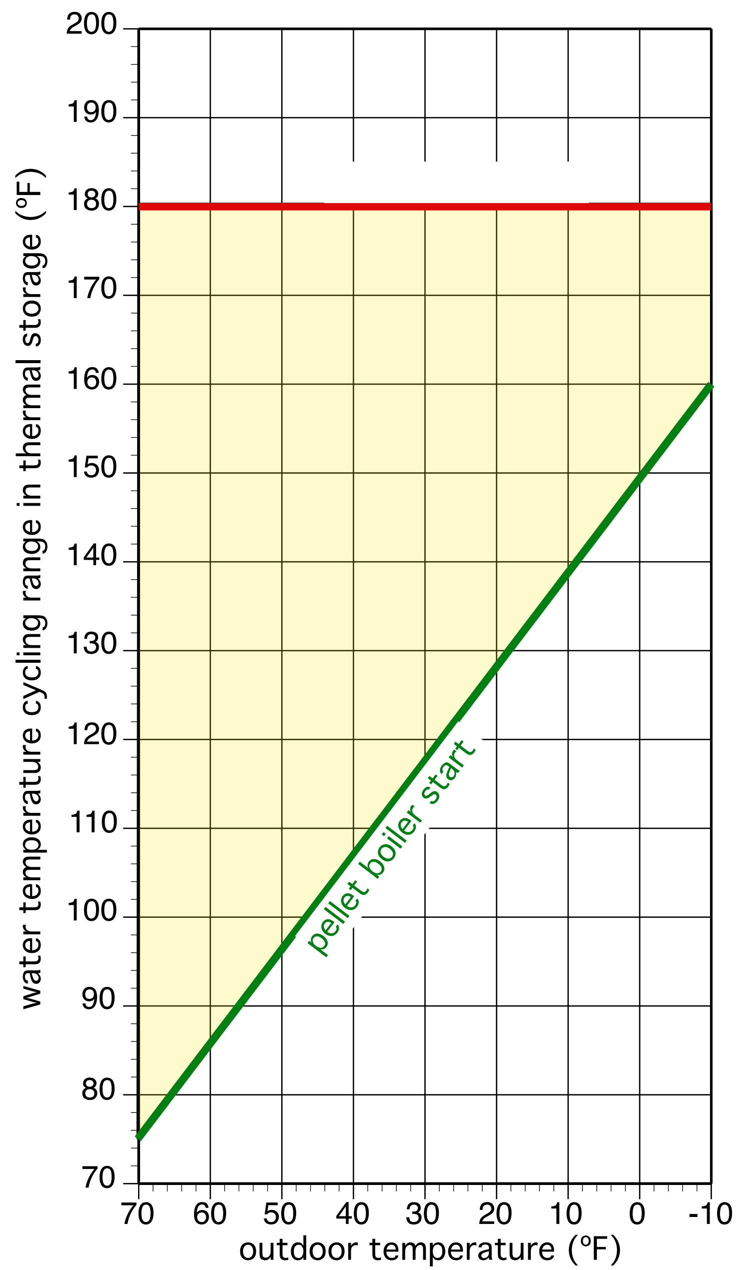
• High temperature heat emitters

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

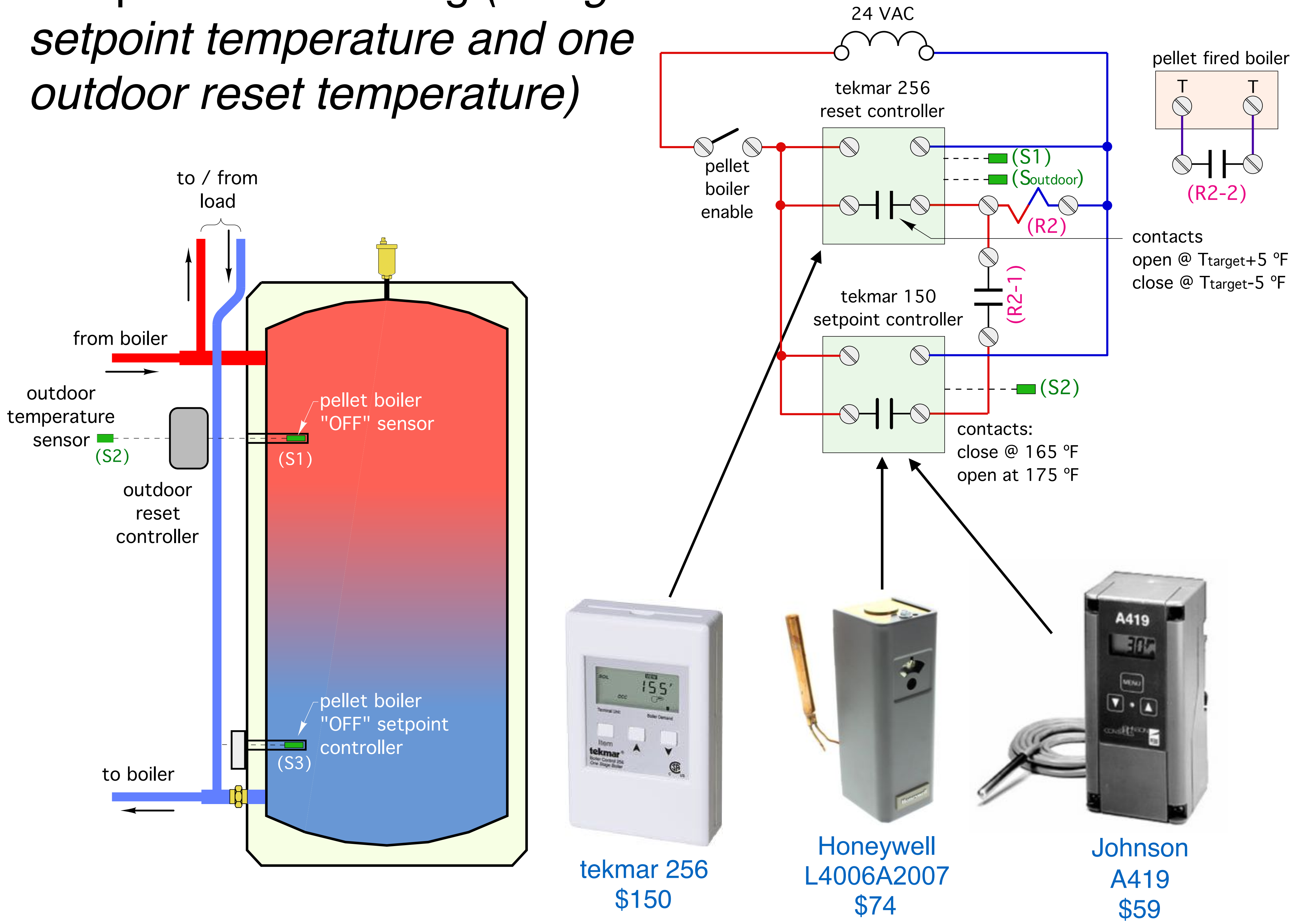
[*outdoor reset for boiler start, setpoint temperature for boiler off*]



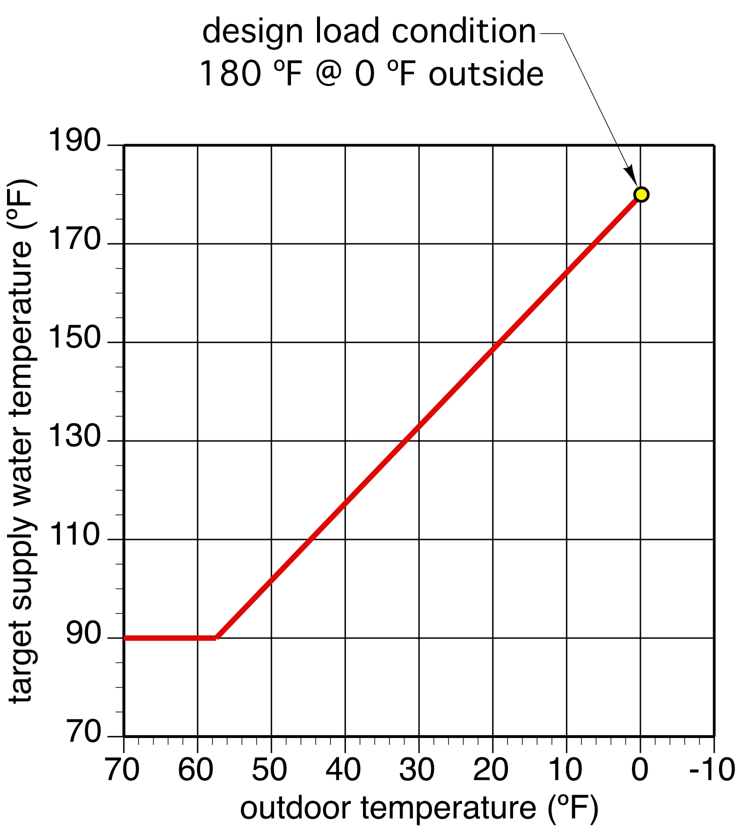
• HIGH temperature heat emitters
• Outdoor reset of pellet boiler start temperature

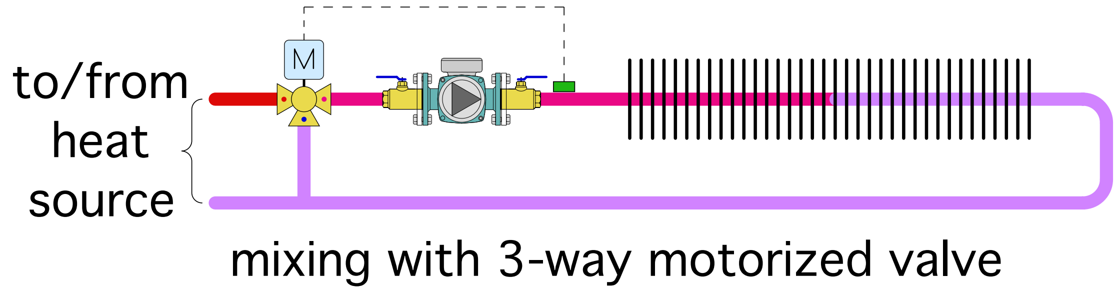


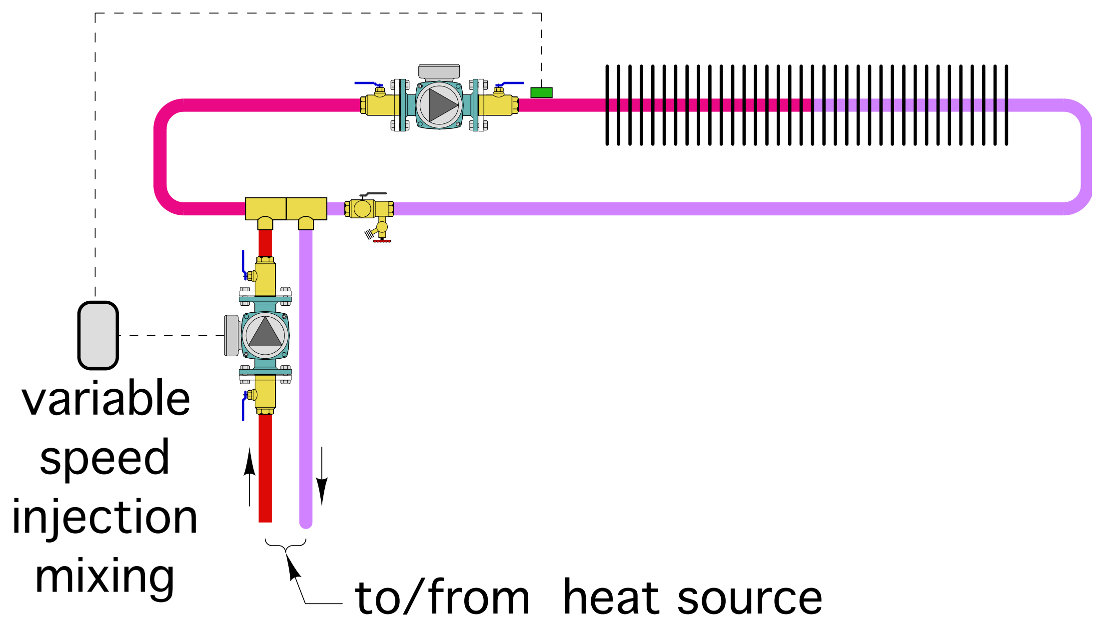
Temperature stacking *(using 1 setpoint temperature and one outdoor reset temperature)*



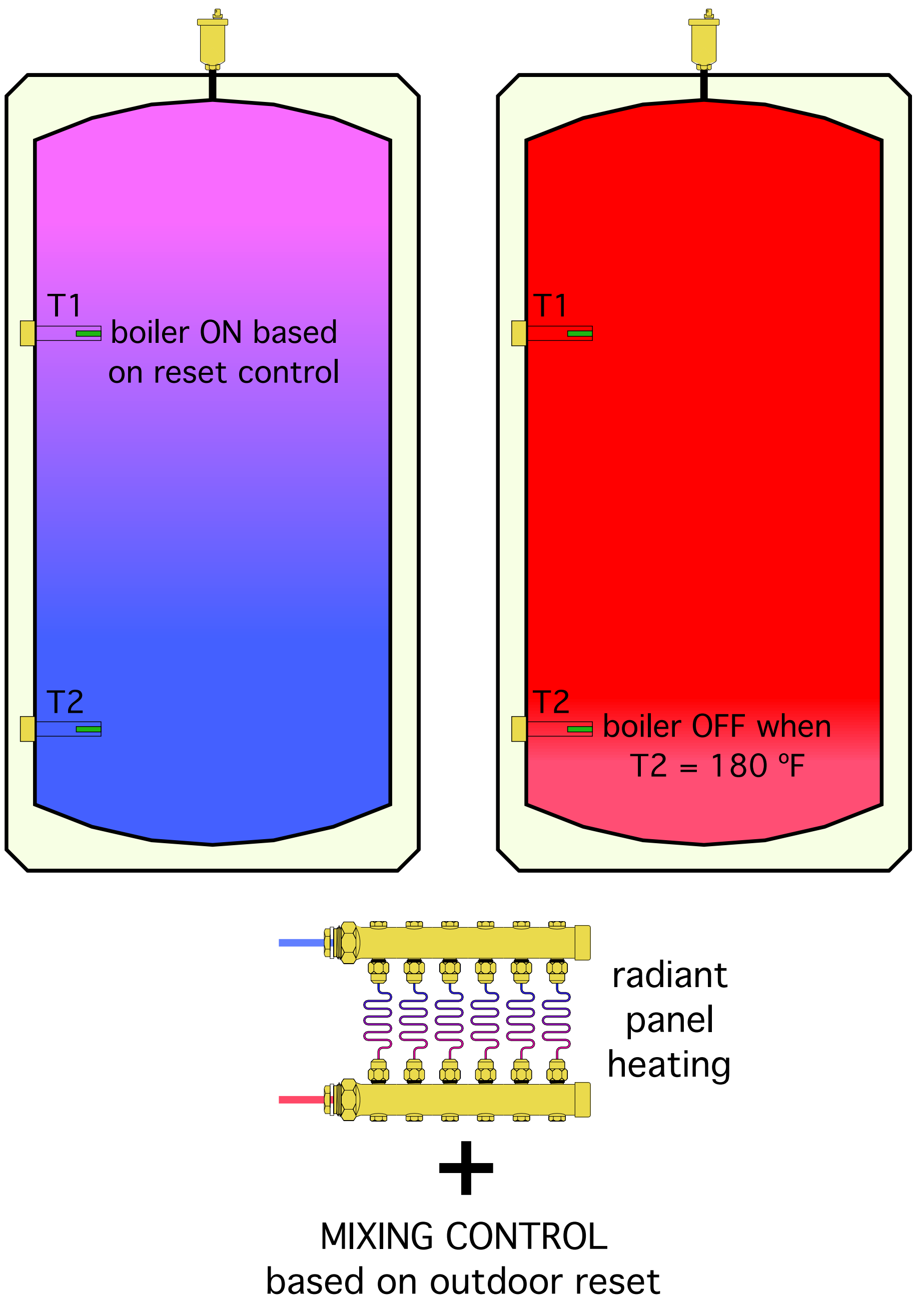
Adding ***mixing*** (based on outdoor reset) between the thermal storage tank and distribution system will smoothen heat delivery and significantly ***improve comfort***.

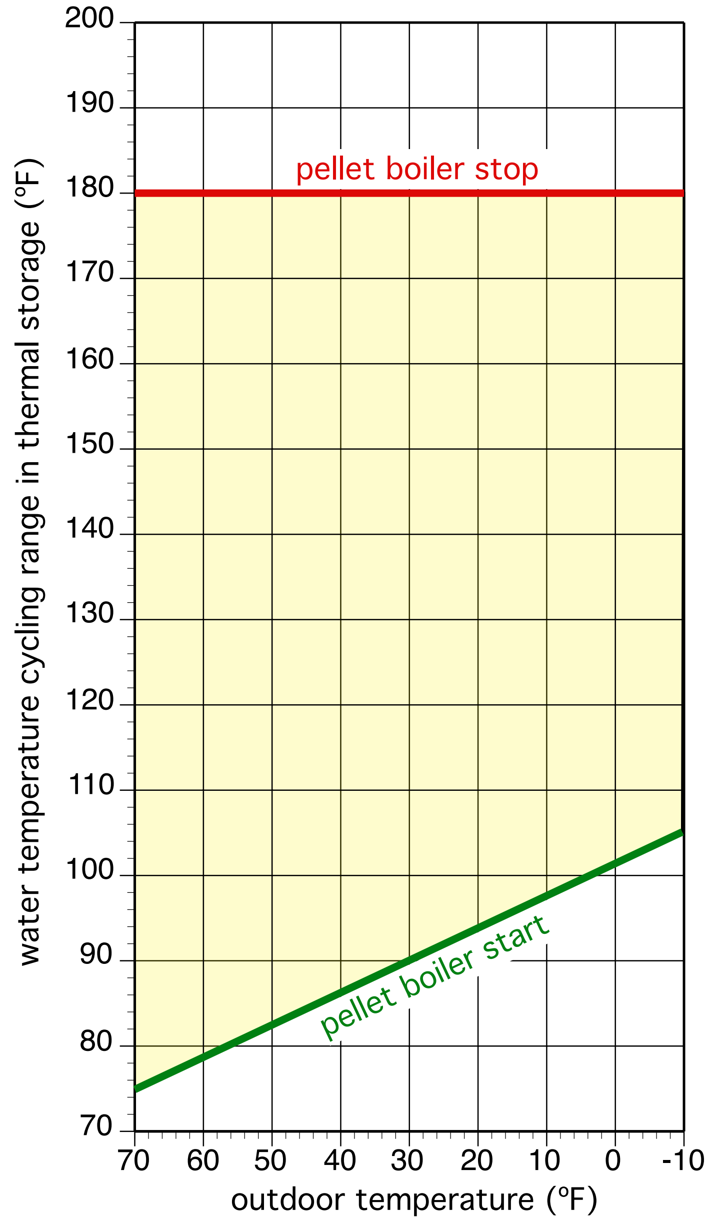




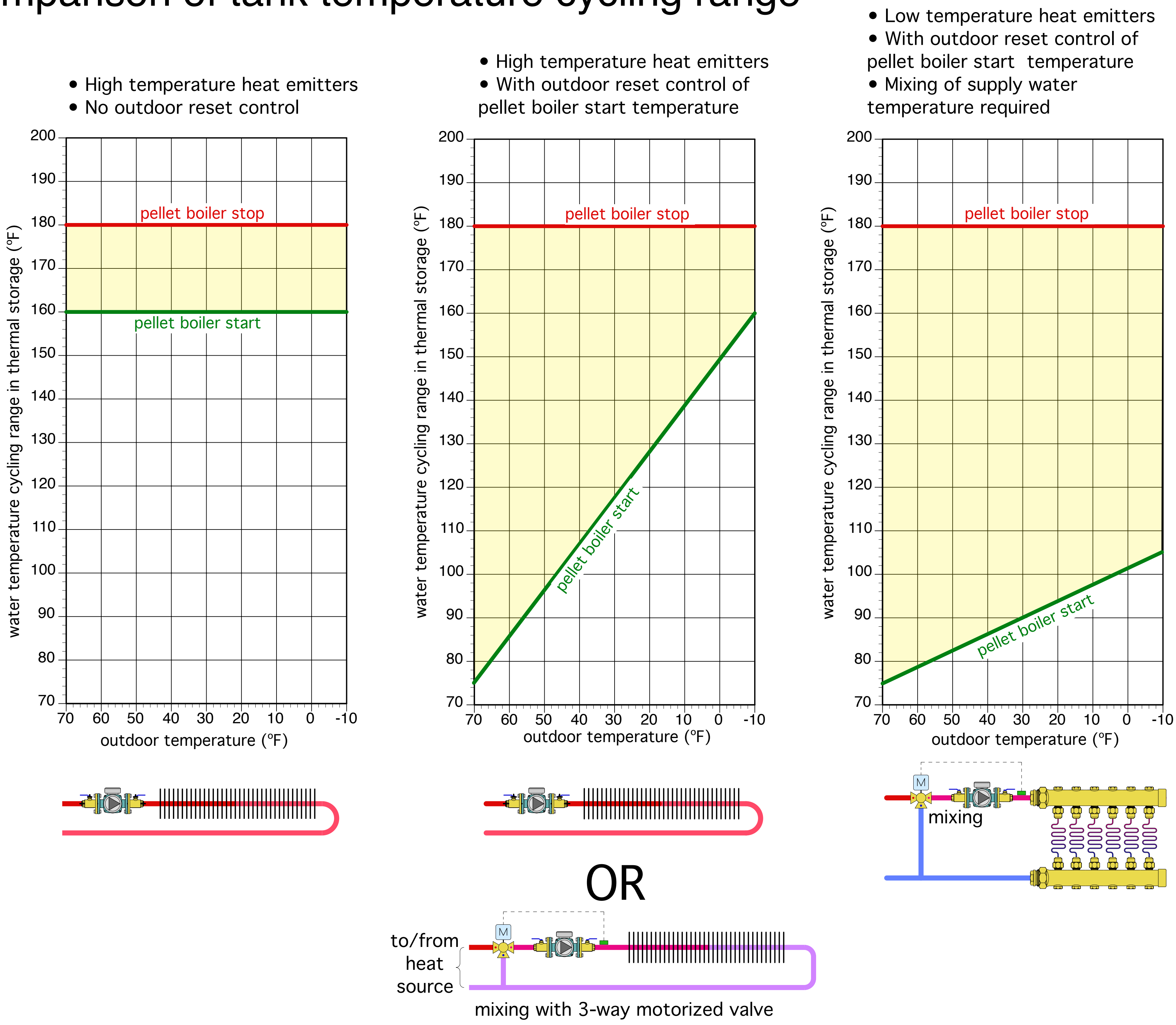


- **Low temperature heat emitters**
- Heat stacking (outdoor reset for boiler start, setpoint for boiler off)
- Mixing control of distribution water temperature





A comparison of tank temperature cycling range



Low temperature / hydronic heat emitters

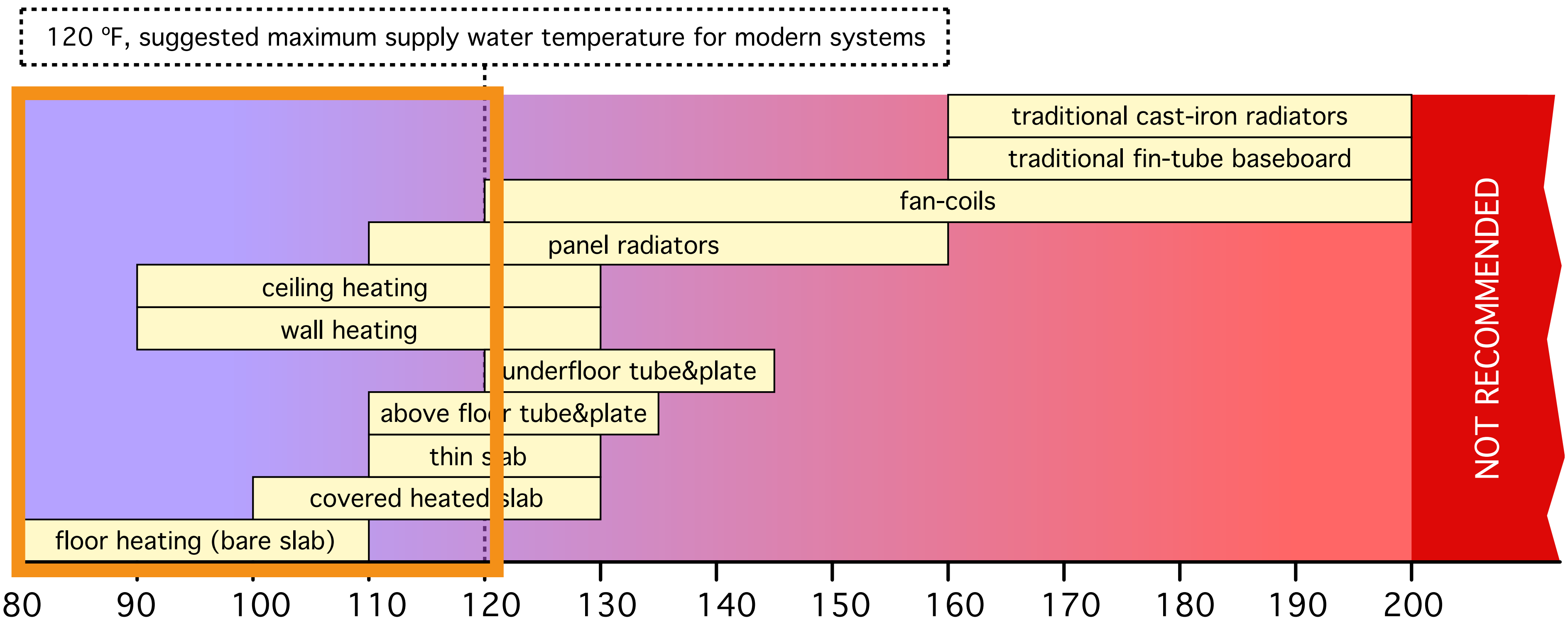
Water temperature ranges for various hydronic heat emitters

- The heat output of ***any*** heat emitter always drops with decreasing water temperature.

- There is always ***some*** output provided the supply water temperature is above the room air temperature.

- There is always a trade off between the *total surface area of the heat emitters* in the system, and the *supply water temperature* required to meet the heating load.

- ***More heat emitter area always lowers the required supply water temperature.***



- Don’t feel constrained to select heat emitters based on traditional supply water temperatures…

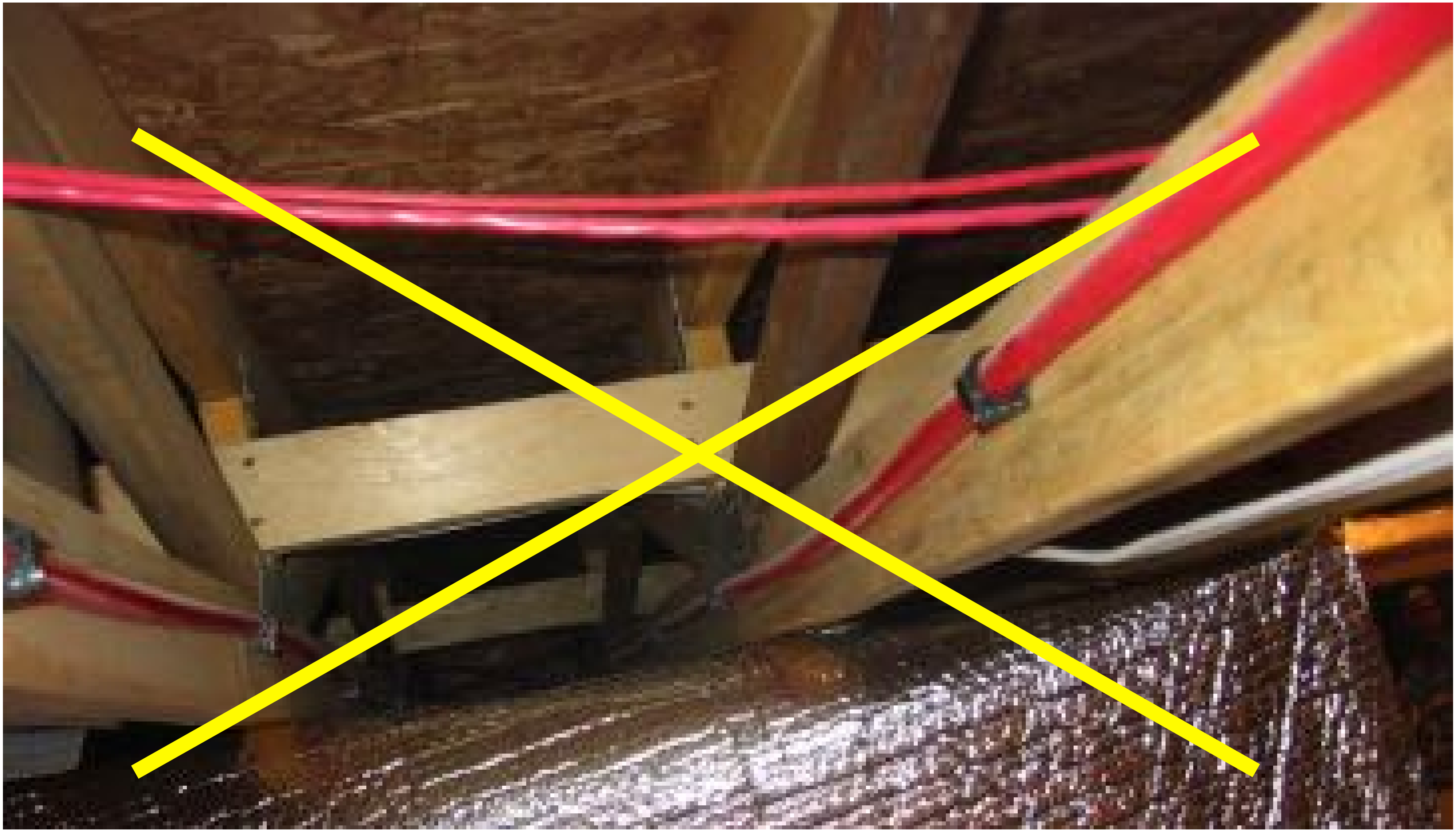
What kind of heat emitters should be used in combination with wood gasification or pellet boilers?

• They should operate at **<u>low supply water temperatures</u>** to allow maximum “draw down” on thermal storage.

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

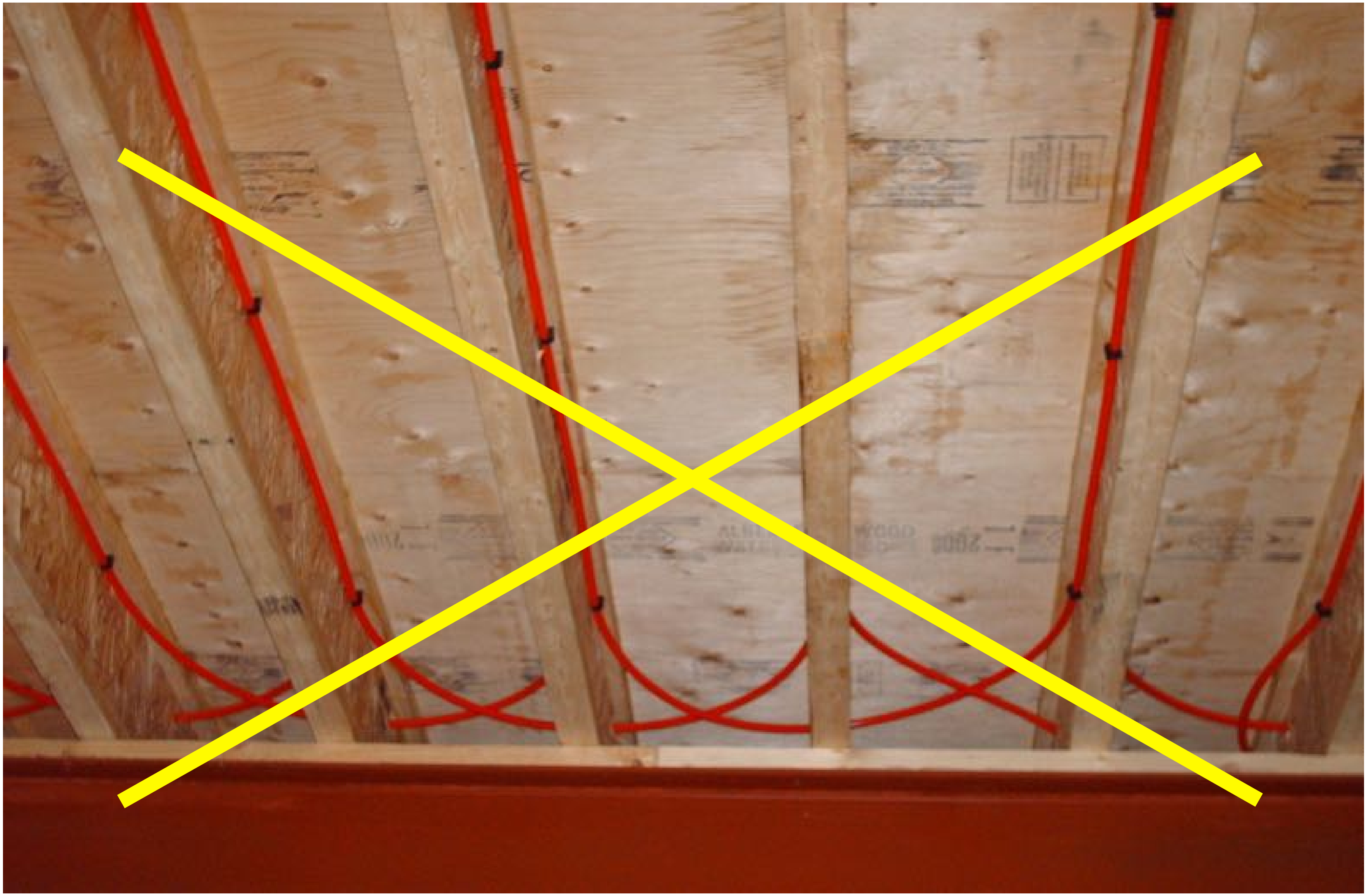
Low temperature hydronic distribution systems also help “future proof” the system for use with heat sources are likely to thrive on low water temperatures.

Don't do this with ANY hydronic heat source!



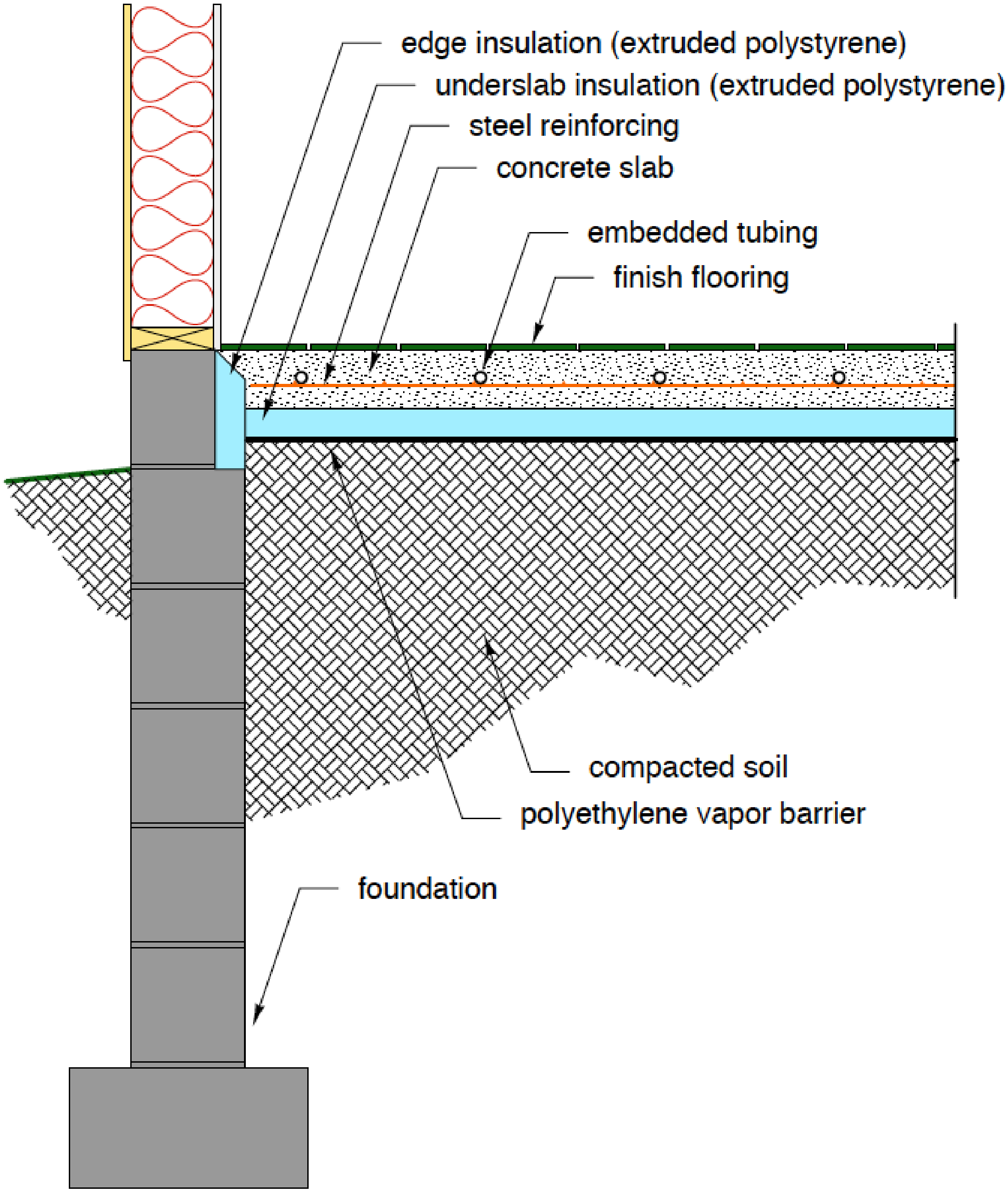
Heat transfer between the water and the upper floor surface is severely restricted!

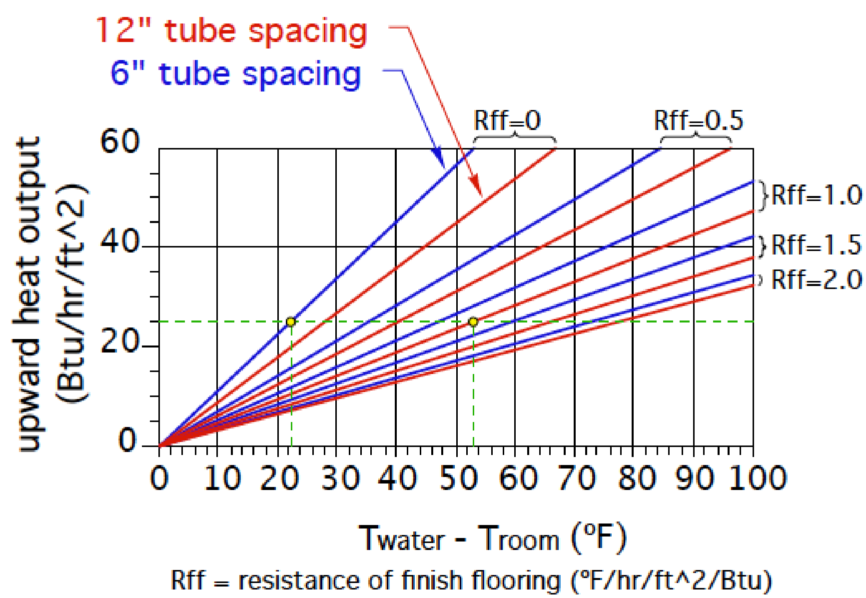
Don't do this with ANY hydronic heat source!



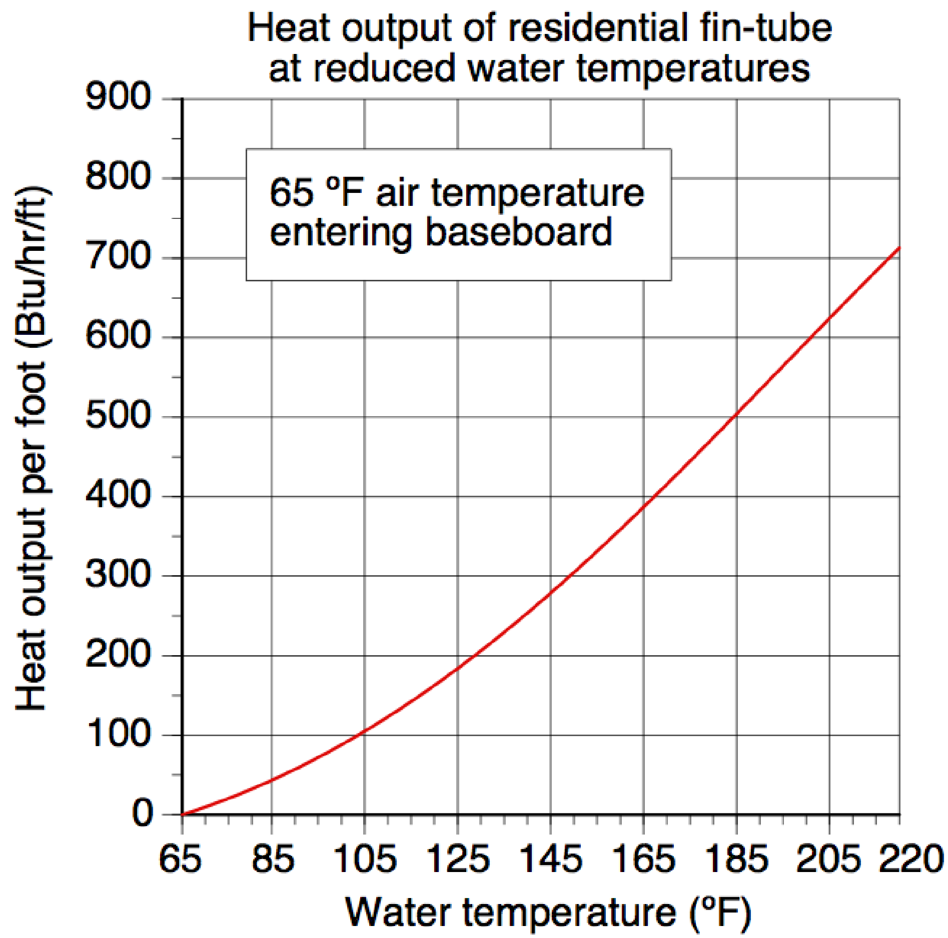
Heat transfer between the water and the upper floor surface is severely restricted!

Slab-on-grade floor heating





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



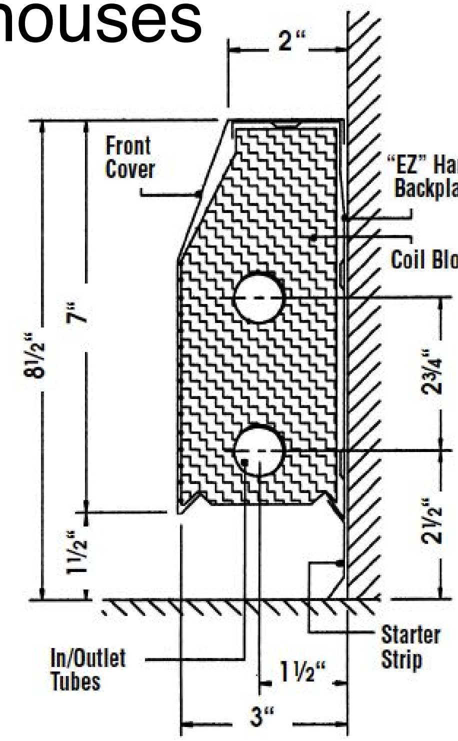
Could add fin-tube length based on lower water temperatures. BUT…

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

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

	Flow Rate GPM	PD in ft of H_20	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.

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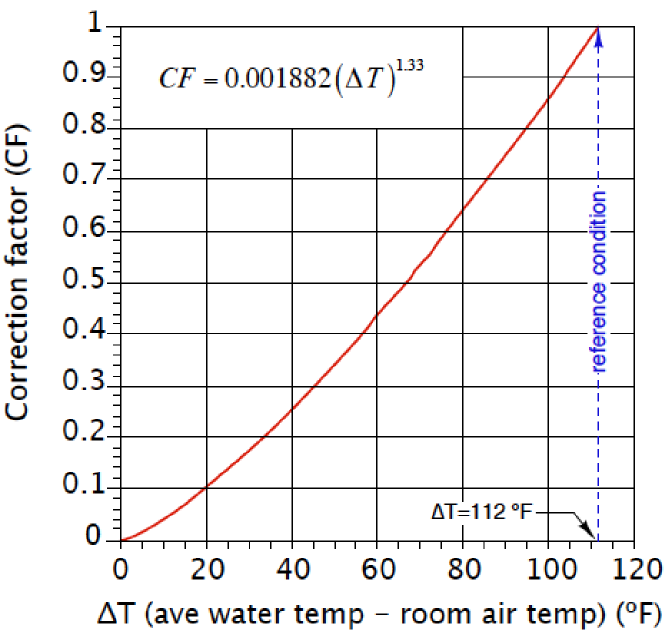
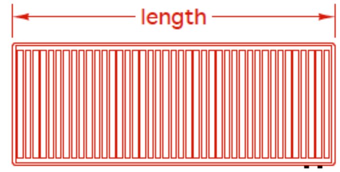
Panel Radiators

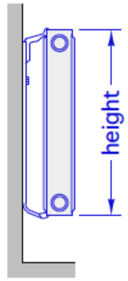
Adjust heat output for operation at lower water temperatures.



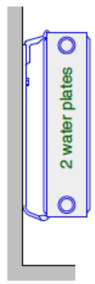
Reference condition:
Ave water temp. in panel = 180°F
Room air temperature = 68°F



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



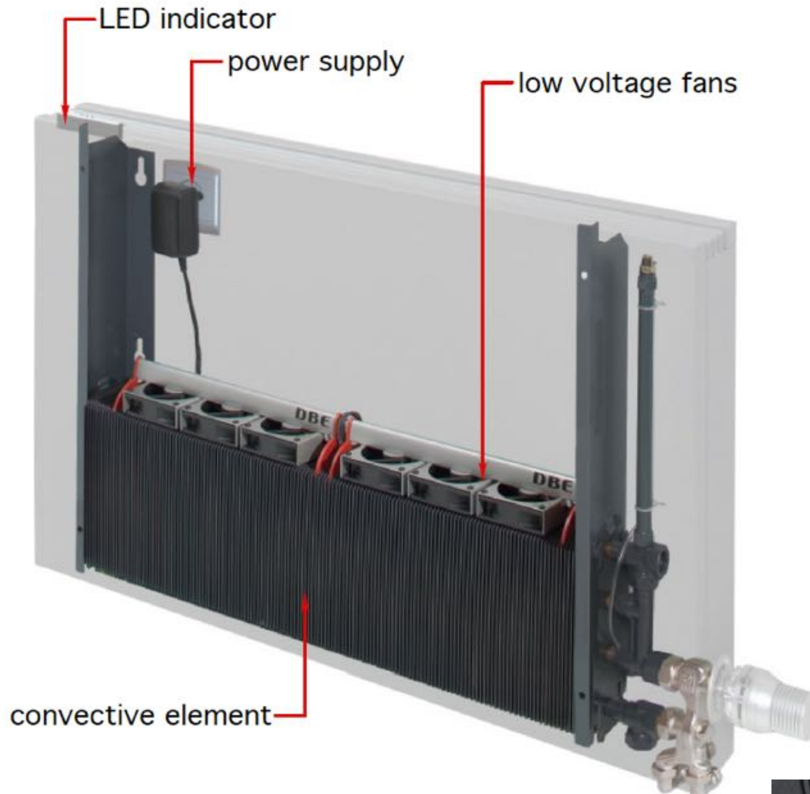
	2 water plate panel thickness					
	16" long	24" long	36" long	48" long	64" long	72" long
24" high	3153	4750	7127	9500	12668	14254
20" high	2733	4123	6186	8245	10994	12368
16" high	2301	3455	5180	6907	9212	10363
10" high	1491	2247	3373	4498	5995	6745

	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

Adding low wattage fans to a low water content panel can boost heat output 50% during normal comfort mode, and over 200% during recovery from setback conditions

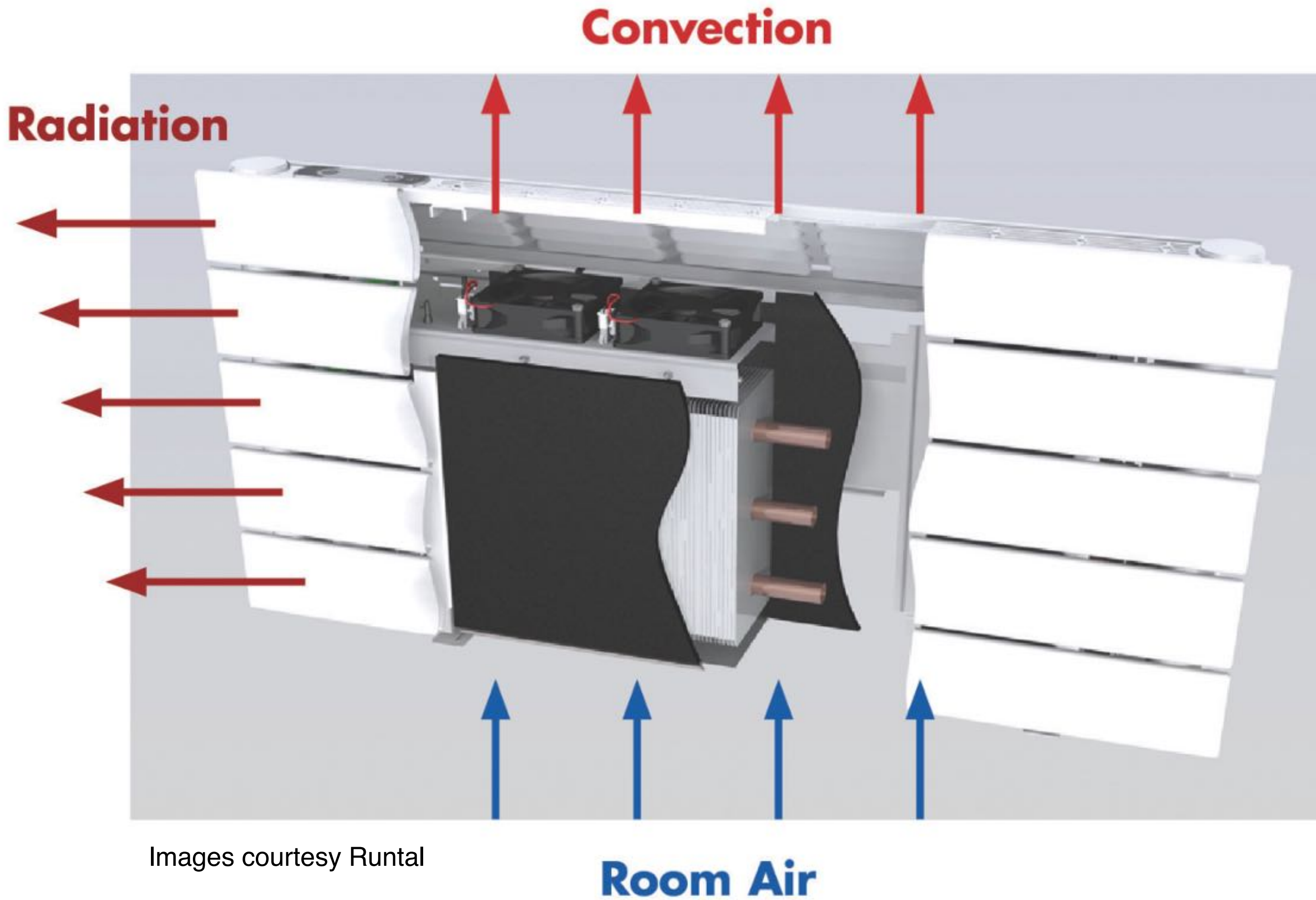


Images courtesy JAGA North America

- **At full speed these fans require about 1.5 watts each**
- **30dB (virtually undetectable sound level)**
- **Allow supply temperatures as low as 95 ºF**

Fan-assisted Panel Radiators

The "NEO", from Runtal North America

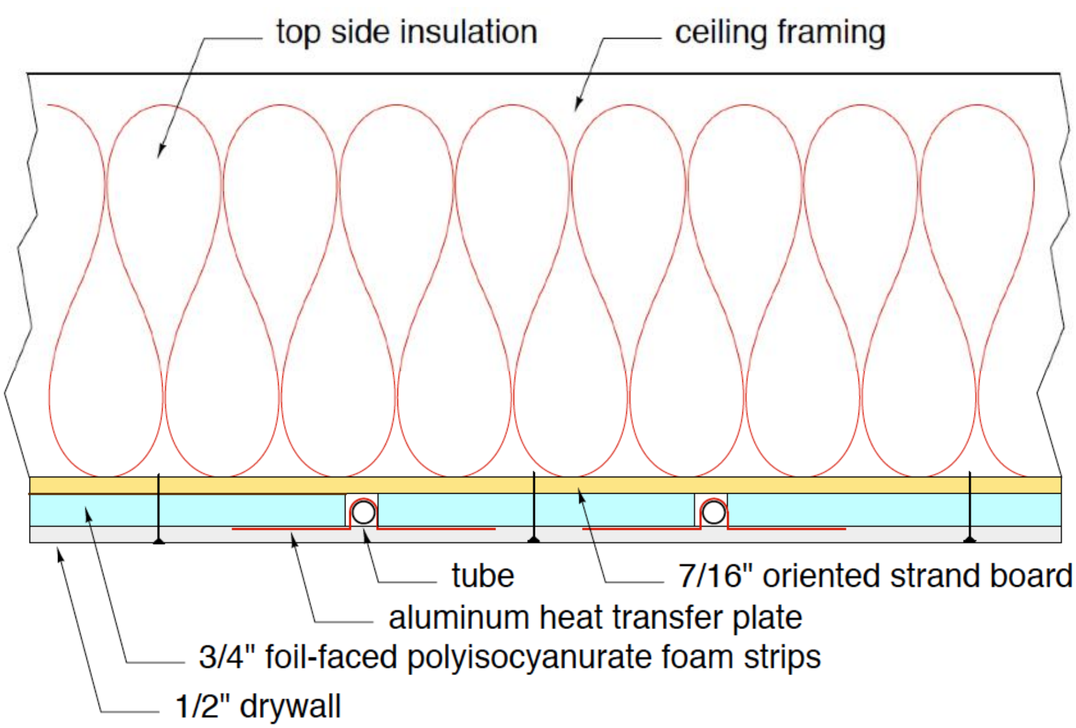


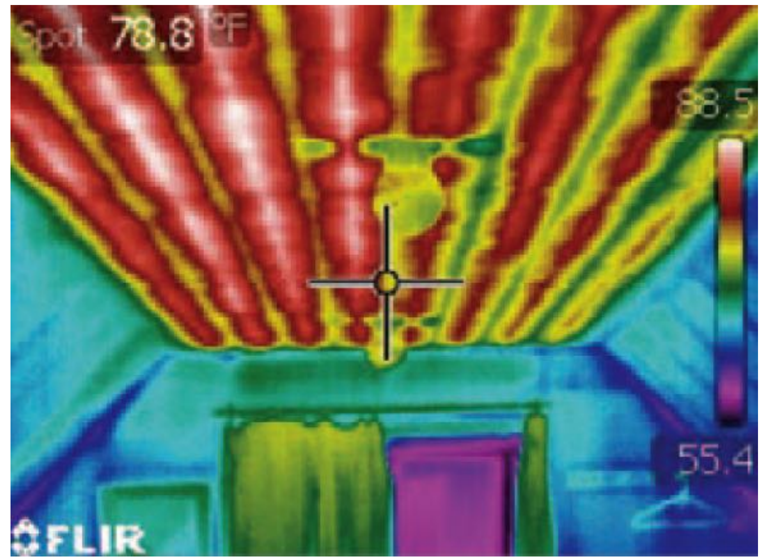
Images courtesy Runtal

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

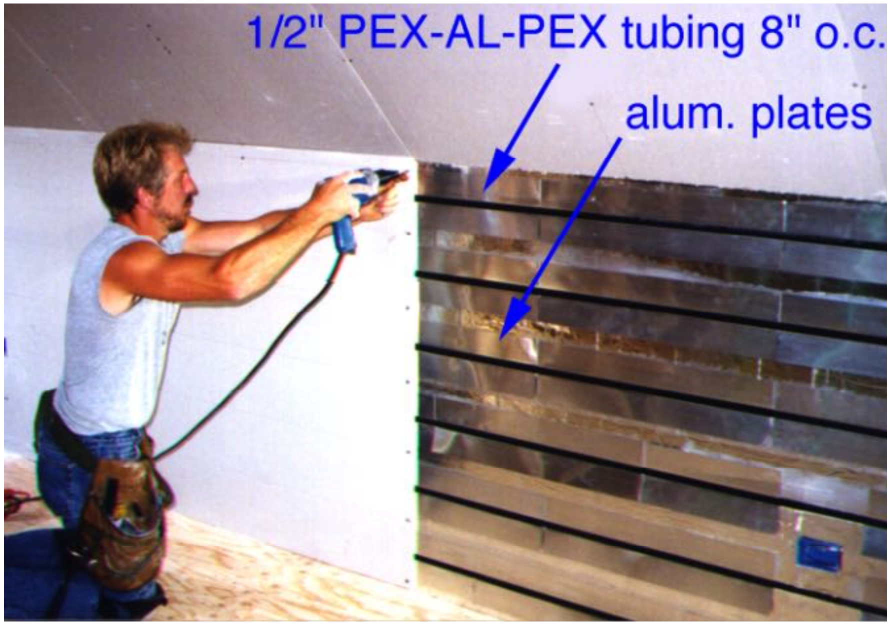
Heat output formula:

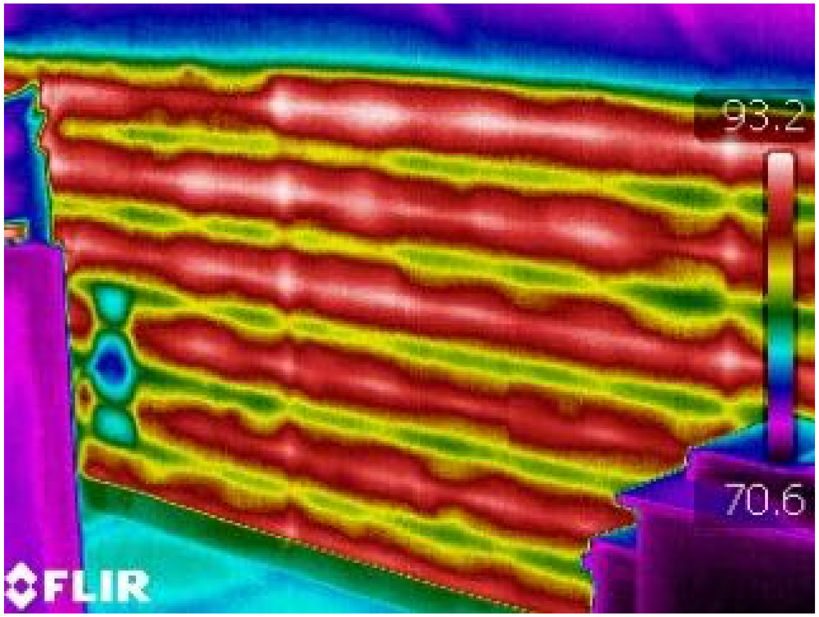
$$q = 0.71 \times (T_{water} - T_{room})$$

Where:

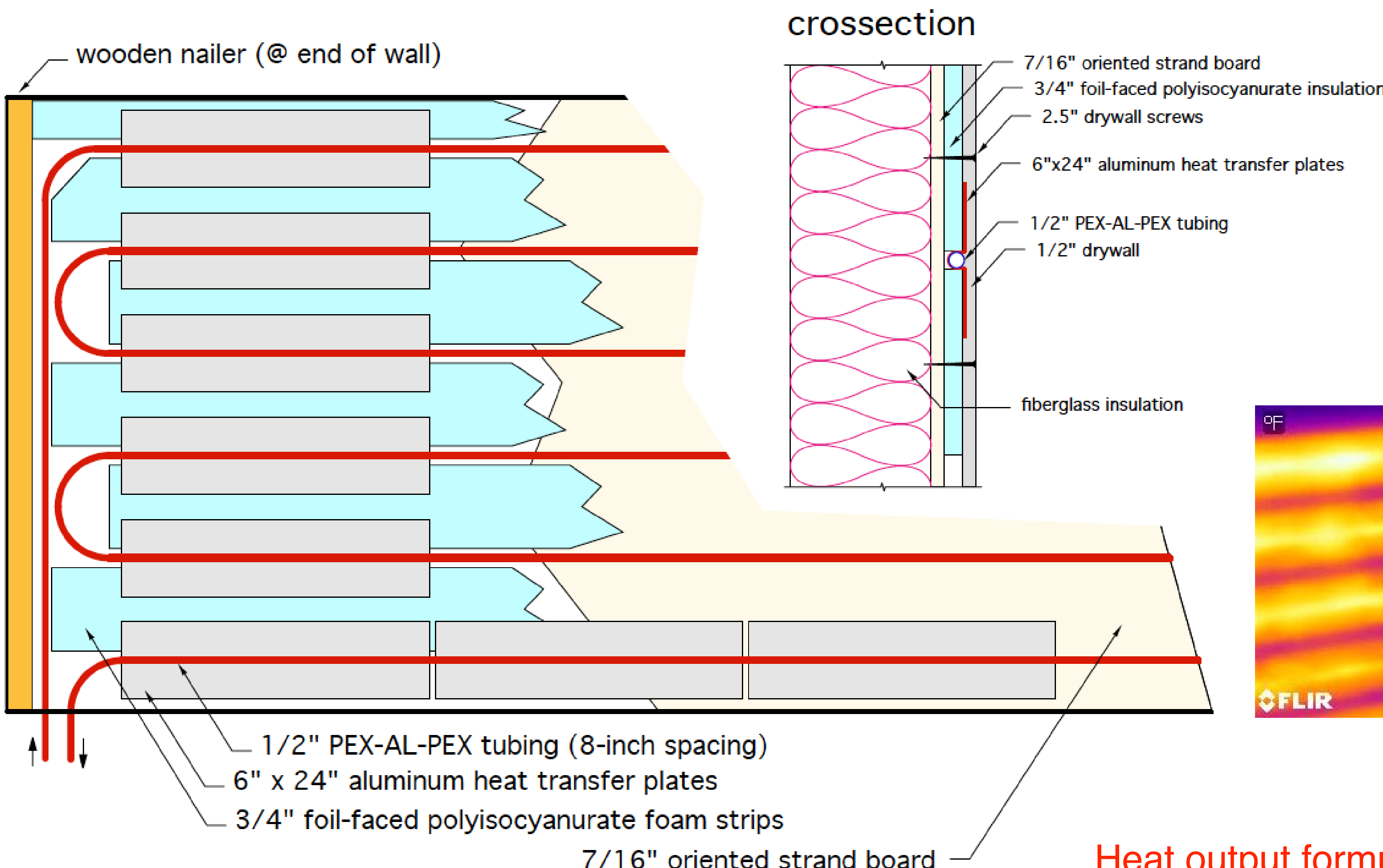
Q = heat output of ceiling (Btu/hr/ft²)
T_{water} = average water temperature in panel (°F)
T_{room} = room air temperature (°F)

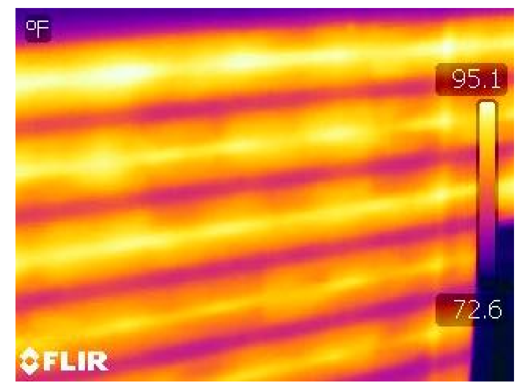
Site built radiant WALLS...





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)

Controlling heat transfer from biomass subsystem to distribution

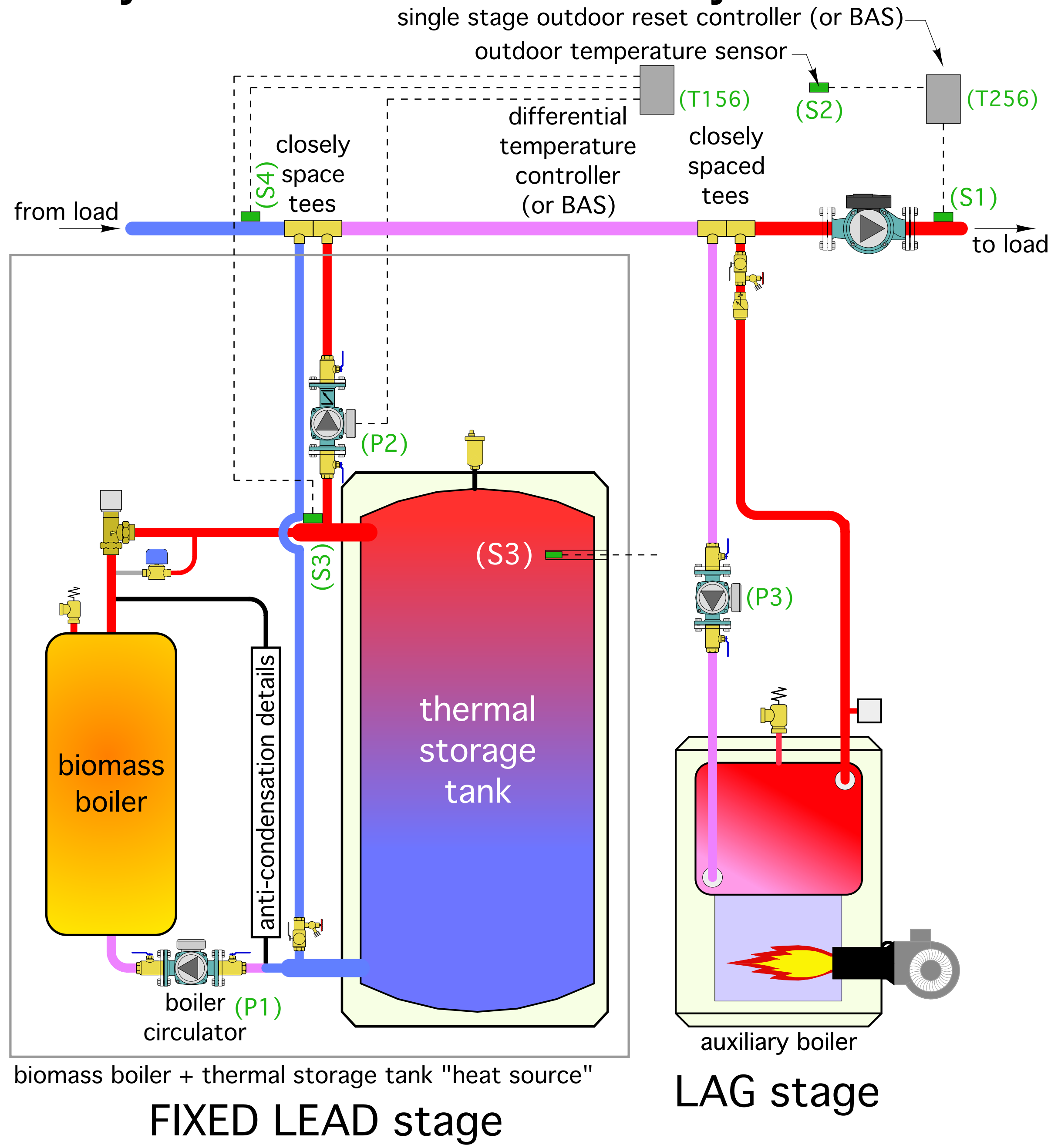
Use a simple *differential temperature controller* to enable the transfer of heat from biomass system to distribution system

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

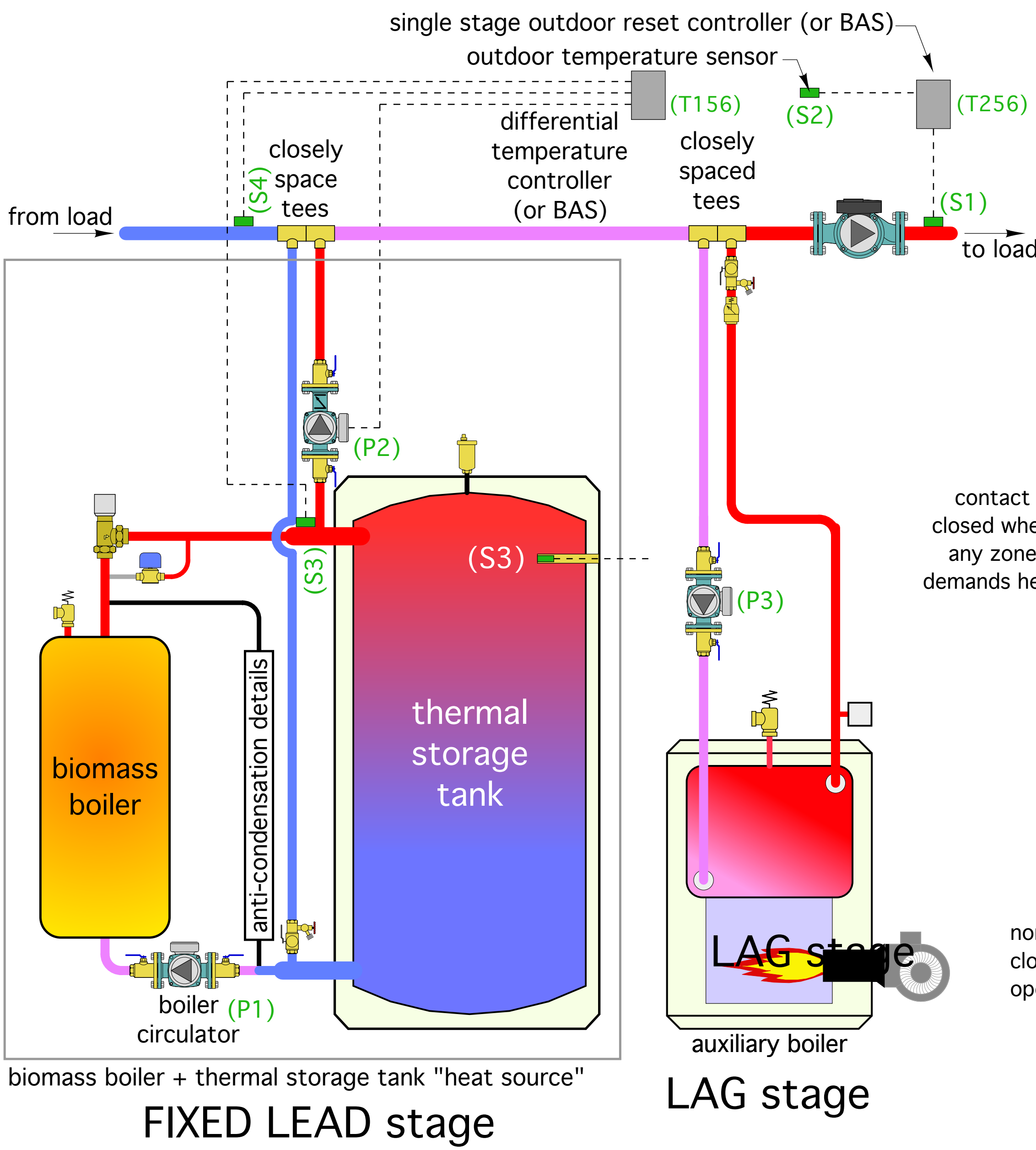
Circulator (P2) (tank to load) is only allowed to run when the tank can make a positive energy contribution to the system.

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

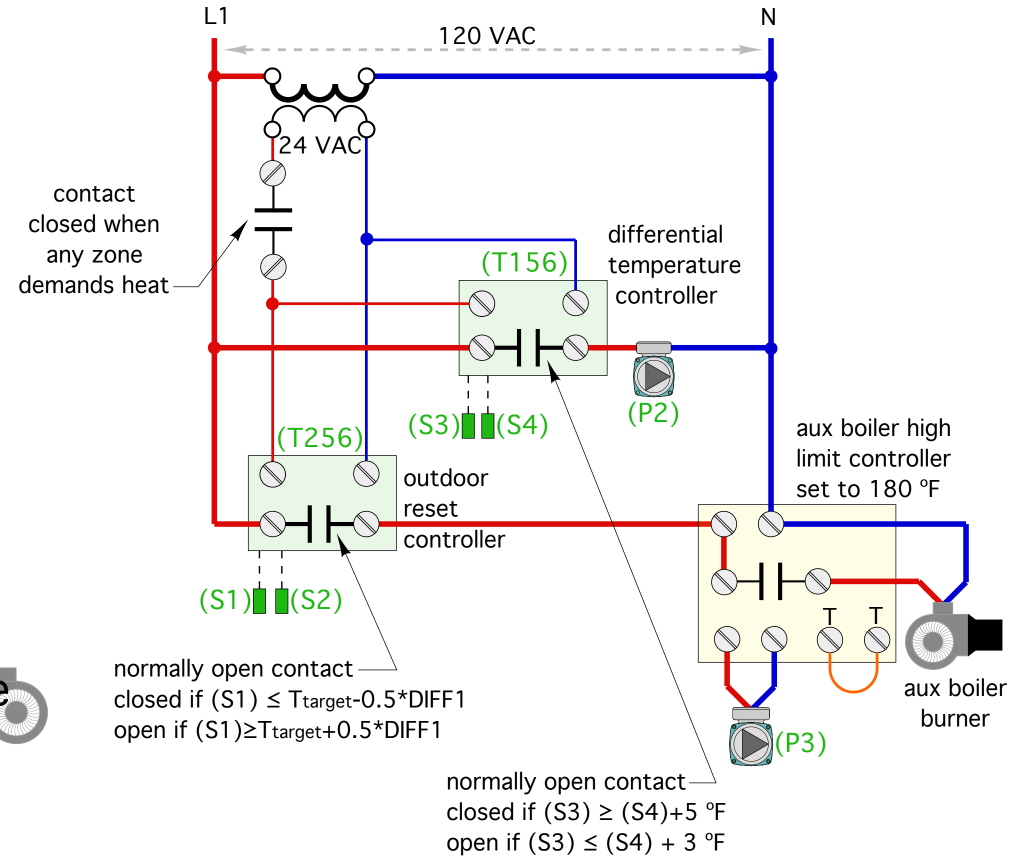
IF (S3) ≥ (S4) + 5 °F THEN (P2) is ON



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



Circuitry to manage heat input to distribution system



Example system

Example system

• 3 zones of low-temperature radiant panel (floor, wall, ceiling) heating

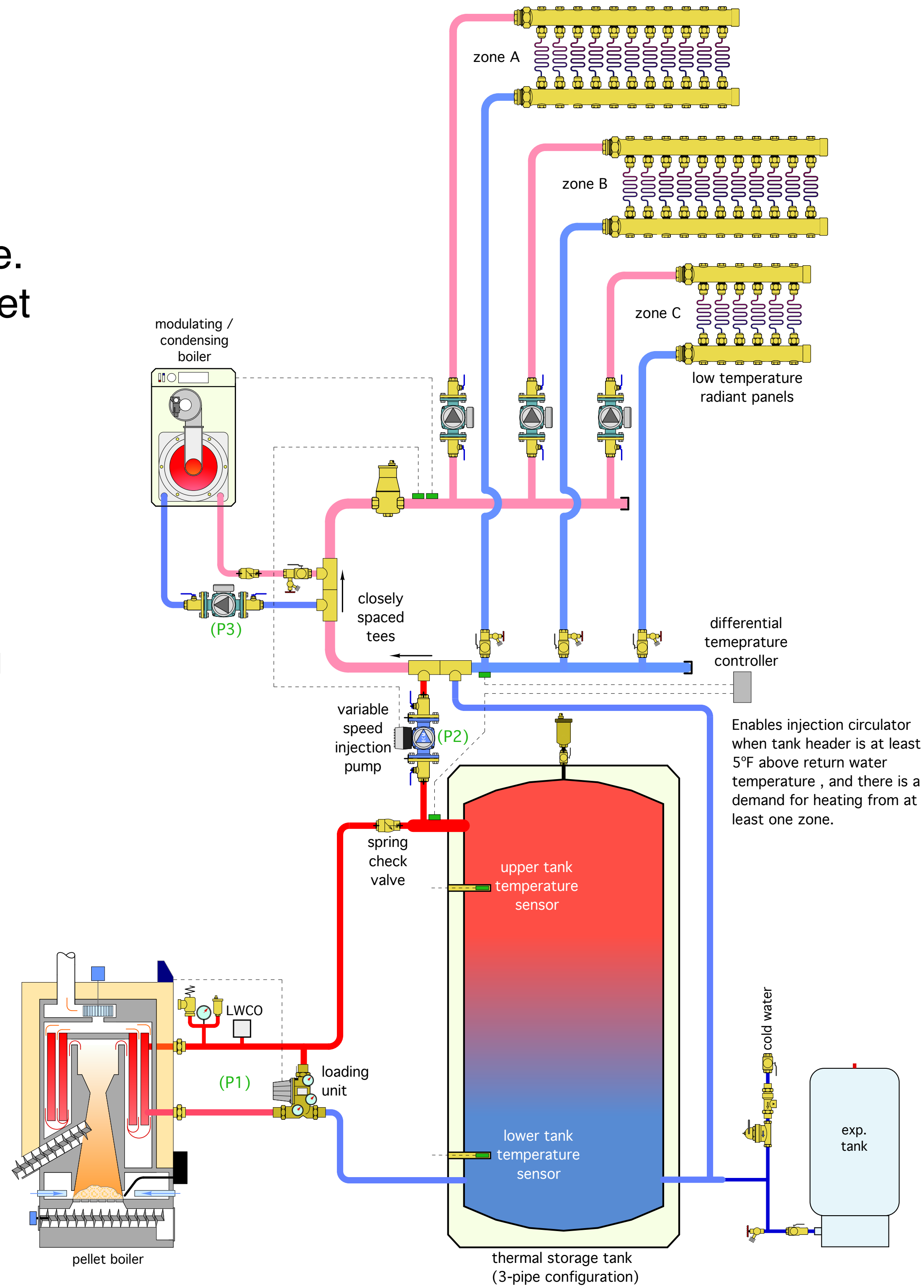
• Mod/con boiler shown as aux heat source. Operates based on its internal outdoor reset controller

• Variable-speed injection pump controls supply water temperature to heat emitters based on outdoor reset

• Differential temperature control prevents heat generated by aux boiler from entering thermal storage

• Loading unit protects pellet boiler from sustained flue gas condensation

• Simple, scalable, repeatable…



RHNY Incentives

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

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

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

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

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

LMI Incentives - Boilers

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

For more information:

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

Spring 2021 online training opportunities

January 28, 2021 / 1:00-2:00 PM
Topic: Why low temperature distribution systems improve biomass boiler performance
Description: This webinar will describe how low temperature distribution systems allow a winder range of operation for thermal storage, and how this translates to longer / more efficient and lower emission burn cycles for a pellet boiler. It will also compare control methods for enabling pellet boiler operation when the thermal storage tank can no longer sustain the heating load.

February 18, 2021 / 1:00-2:00 PM
Topic: Proper installation of temperature sensors in biomass boiler systems
Description: Improper temperature sensor placement can drastically limit the performance of both pellet boiler and cordwood gasification boilers. This webinar will show examples of incorrectly placed sensors based on field experience. It will also show correct mounting and wiring methods for both surface-mounted and well-mounted sensors.

March 18, 2021 1:00-2:00 PM
Topic: Using external heat exchangers in biomass boiler systems with non-pressurized thermal storage.
Description: Many cordwood gasification systems use unpressurized thermal storage tanks. A common approach is to use coiled copper tube heat exchangers suspended within these tanks. An alternative approach uses external brazed plate stainless steel heat exchangers. This webinar exams the advantages of the latter approach. It also shows how a single external heat exchanger can be used for both heat input to the thermal storage and heat extraction.

All training is provided free

Register here:

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

QUESTIONS ?