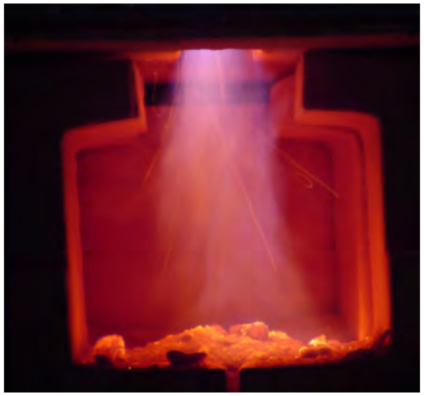
High Efficiency Hydronics for Wood-fired Boilers

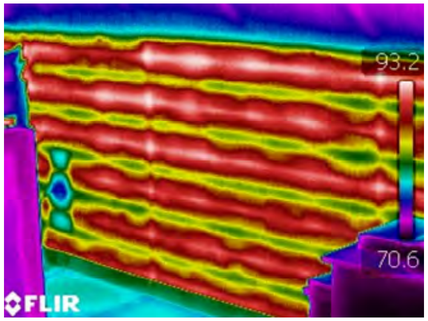
presented at:

NORTHEAST BIOMASS HEATING EXPO 2013

pellets wood crops & more

April 3 - 5, 2013
City Center - Saratoga Springs, NY





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High Efficiency Hydronics for Wood-fired Boilers

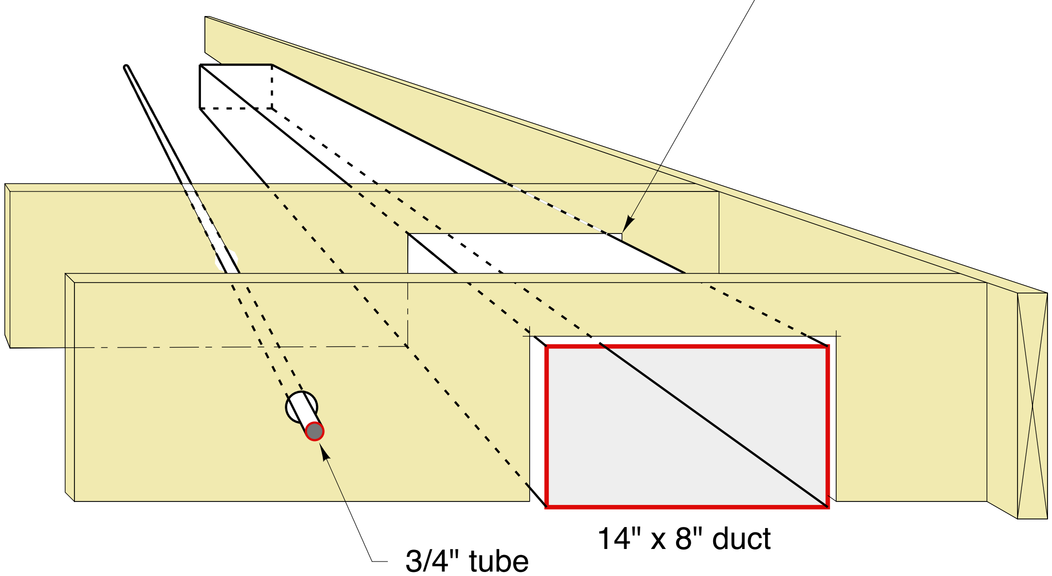
Today's Topics:

- Why hydronics?
- The importance of hydronics to renewable energy
- Wood as a heating fuel
- Wood gasification boilers
- Thermal storage options
- Boiler protection options
- Low temperature hydronic heat emitters
- Instantaneous domestic water heating assembly
- Homerun distribution systems
- High efficiency ECM-based circulators
- System examples

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

Water is vastly superior to air for conveying heat

Material	Specific heat (Btu/lb/°F)	Density* (lb/ft^3)	Heat capacity ($Btu/ft^3/°F$)
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

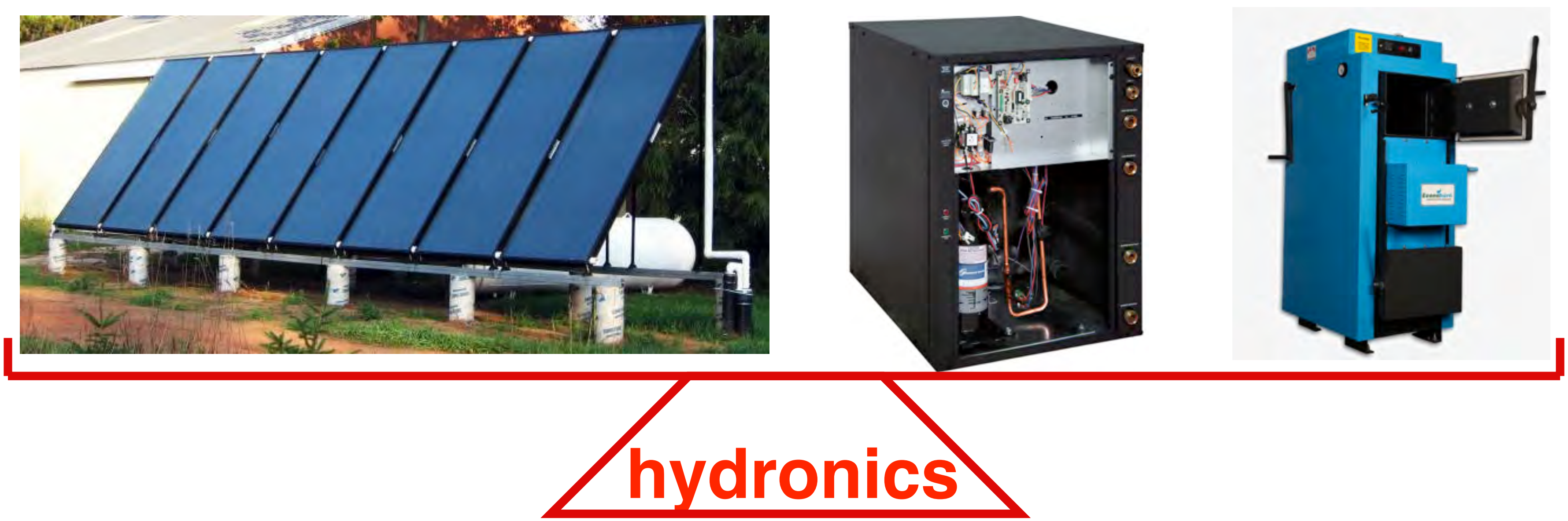


$$\frac{62.4}{0.018} = 3467 \approx 3500$$

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 "enabling technology" behind nearly all 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

Wood as a heating fuel

The fuel energy contained in oven-dried mature wood is approximately 7950 Btu per pound.

This 7950 Btu/lb is only attainable in wood that has been oven dried to **ZERO** moisture content.

The lower heating value of wood with other moisture contents can be approximated by the following formula:

$$LHV = 7950 - 90.34(w)$$

Where:
LHV = Lower heating value (Btu/lb)*
w = moisture content (%)

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

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:

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

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 1 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

Electric Resistance Heat	13 cents / Kwhr x 2.93	= 38.09 $/MMBtu
Heat Pump	13 cents / Kwhr x 2.93 / 3.4 average COP	= 11.20 $/MMBtu
#2 Fuel Oil	3.80 $ / gallon x 7.14 / 0.86 AFUE (decimal)	= 31.55 $/MMBtu
Propane	3.00 $ / gallon x 10.9 / 0.92 AFUE (decimal)	= 35.54 $/MMBtu
Natural Gas	0.75 $/ therm x 10 / 0.92 AFUE (decimal)	= 8.15 $/MMBtu
Firewood*	70.00 $ / face chord x 0.149 / 0.80 ave. efficiency (decimal)	= 13.04 $/MMBtu
Wood Pellets	200 $ / ton x 0.06098 / 0.80 ave. efficiency (decimal)	= 15.25 $/MMBtu
Bituminous coal	____ $ / ton x 0.03268 / ___ ave. efficiency (decimal)	= ____ $/MMBtu
Shelled Corn **	____ $ / bushel x 2.551 / ___ ave. efficiency (decimal)	= ____ $/MMBtu

Wood gasification boilers

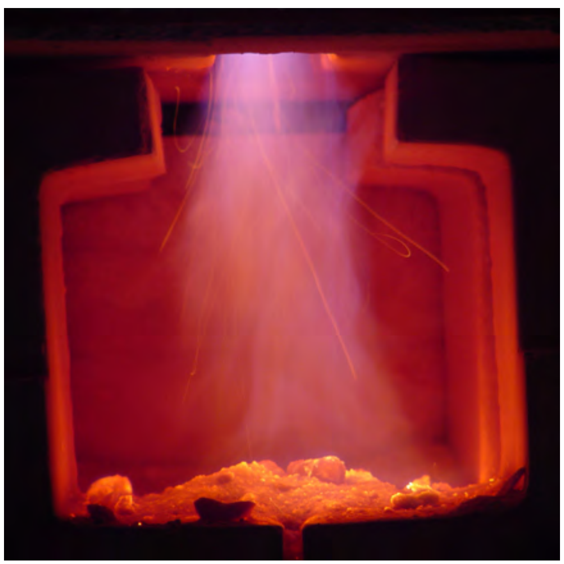
- Combustion efficiency now approaching 90%
- Very little ash or "clinker" residue
- Available for inside or outside placement

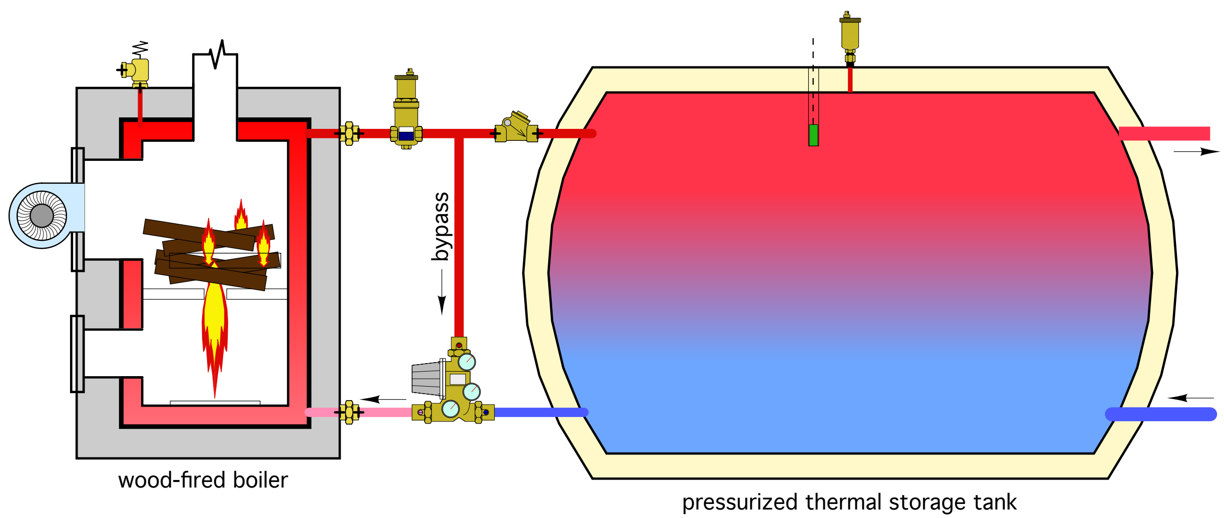
For highest efficiency...

- **Burn Hot & Burn fast**

Heat output often exceeds heating load

Storage is needed





Thermal storage tanks

Water-based thermal storage options

1. unpressurized tanks
2. pressurized tanks

courtesy of Hydroflex

courtesy of American Solartechnics

courtesy of AHONA

Open (unpressurized) buffer tanks

Considerations:

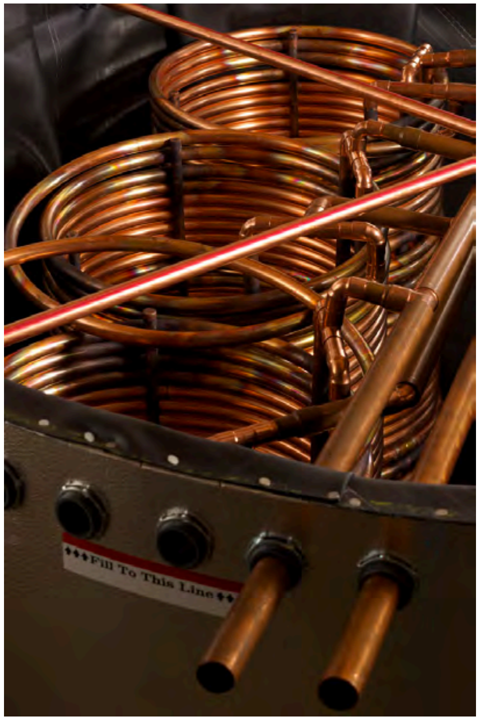
- Water will evaporate - water level must be monitored
- Air space above water accommodates water expansion
- Many open tanks are “knock down” construction and are assembled on site
- Typically lower cost ($/gallon) than pressurized tanks
- Requires one or more heat exchangers to interface with boiler 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



courtesy of AHydroFlex, Corp.

images courtesy of Hydroflex

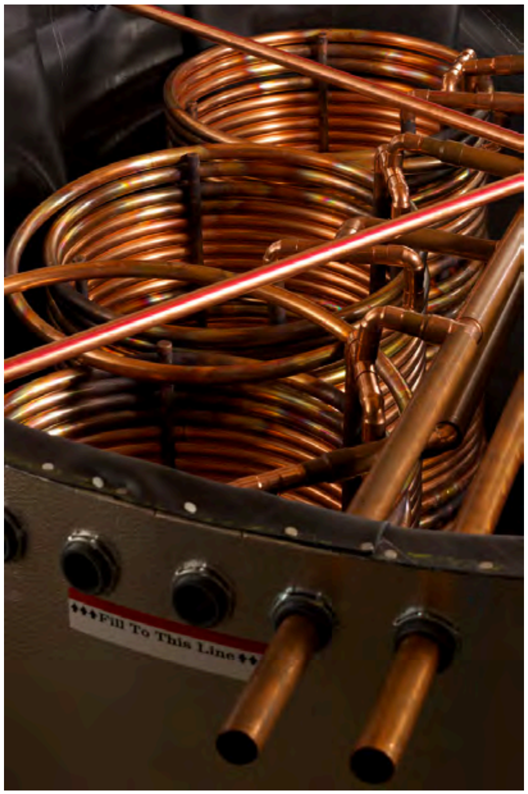
With unpressurized tanks, domestic water is usually heated (preheated) within an internal coil

courtesy of American Solartechnics

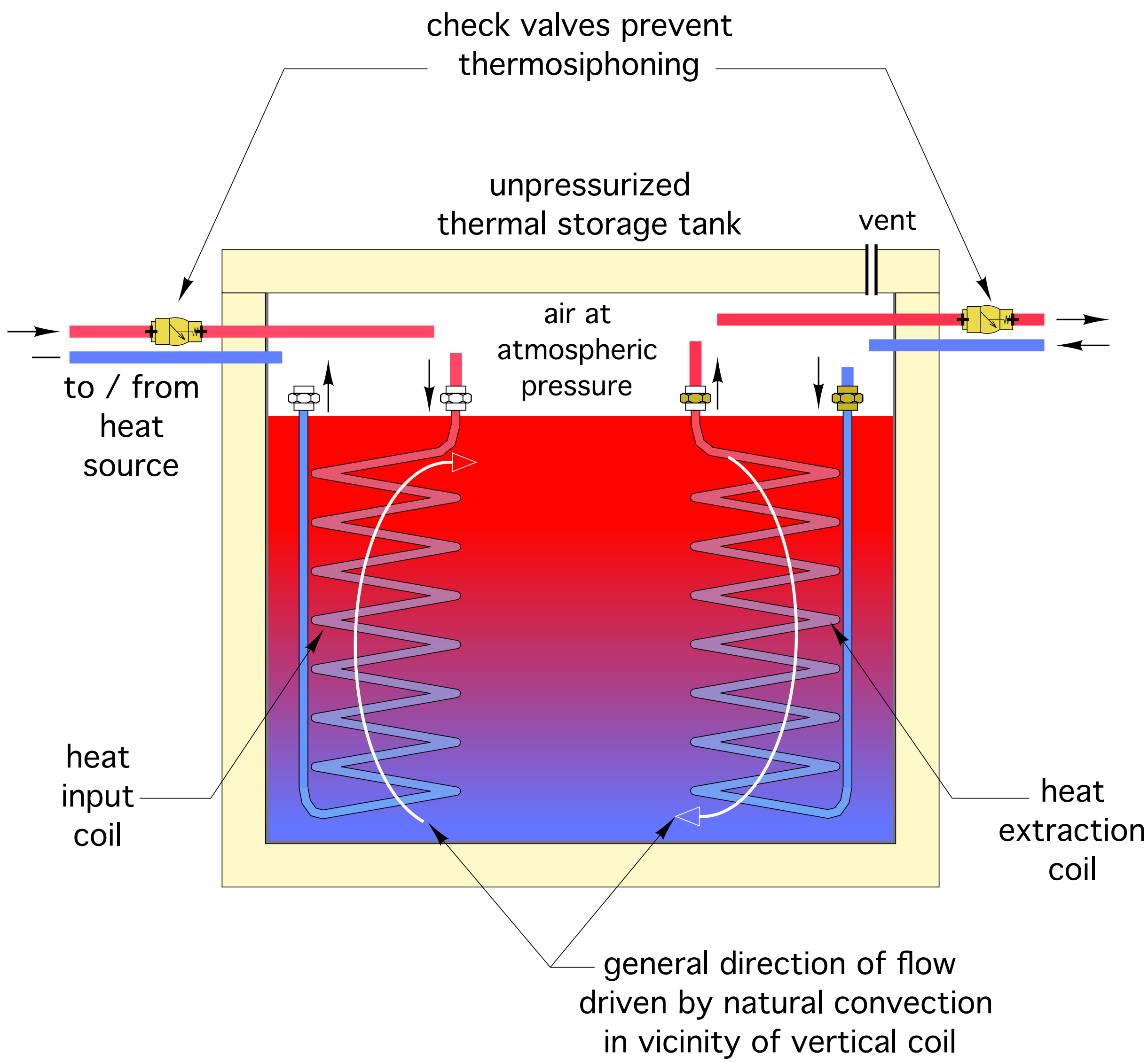
courtesy of American Solartechnics

courtesy of Solar Usage Now

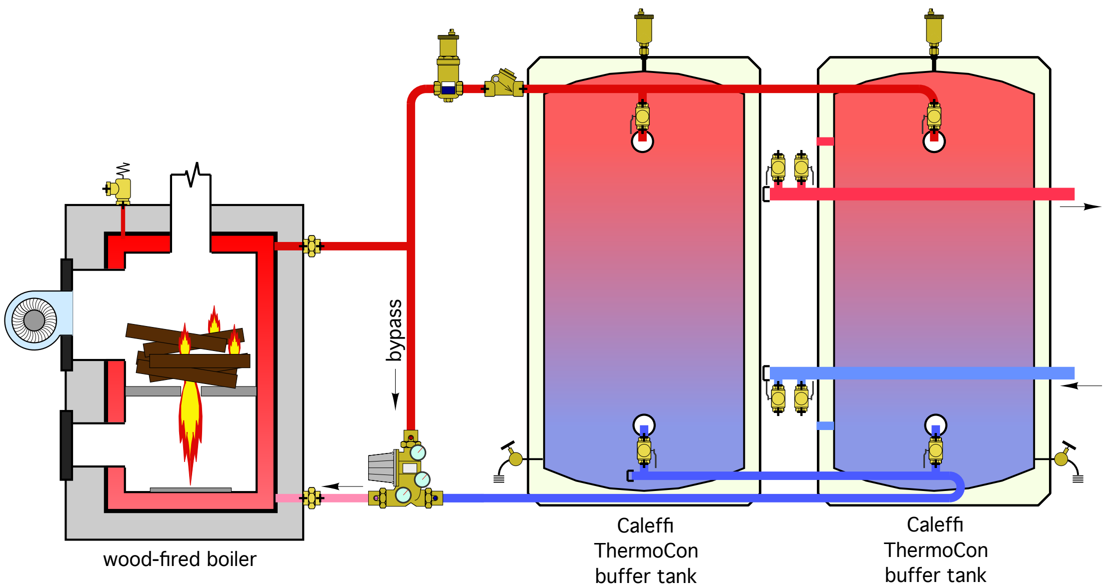
- Flow direction should produce **counterflow heat exchange**
- Use check valves to prevent thermosiphoning

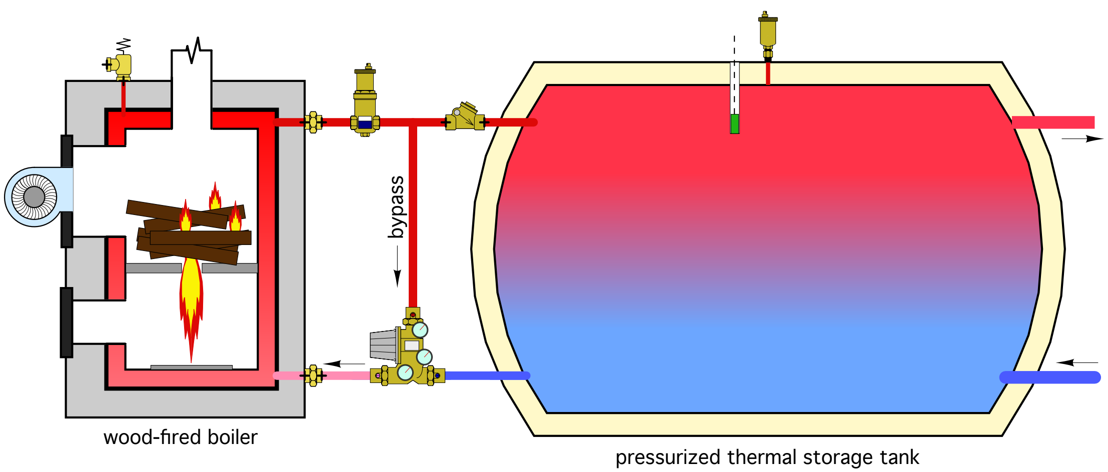


courtesy of Hydroflex



Closed/pressurized thermal storage tanks





Repurposed propane storage tanks

- Check on local requirements for ASME Section VIII pressure vessel rating
- If tank had propane in it, wash with strong detergent to remove mercaptan odorant.
- Verify fire or ignition barrier requirement for exposed spray foam insulation

courtesy of AHONA

stacked 500 gallon

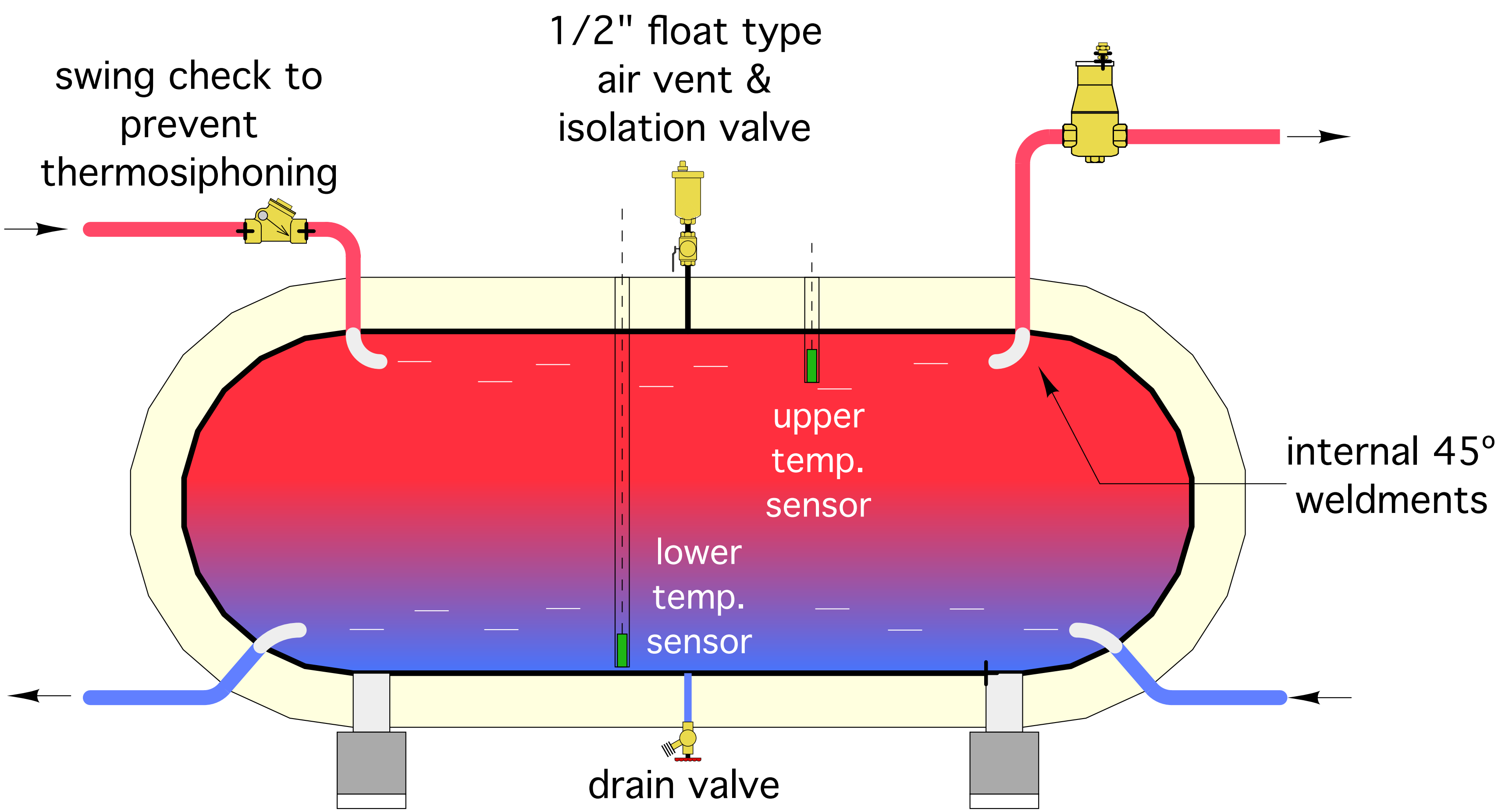
stacked tanks after spray foam insulation is applied

heating "shed"

Repurposed propane storage tanks

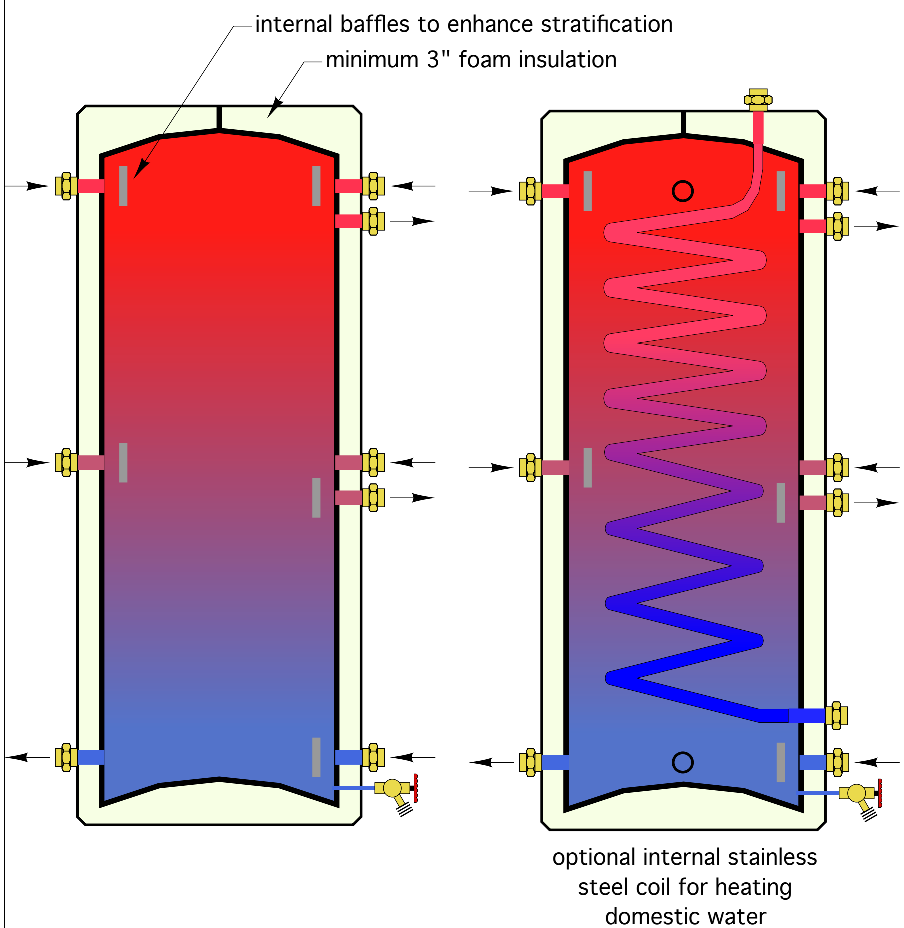
- Horizontal arrangement doesn’t allow for good stratification.

Suggested piping to aid in stratification



Tanks designed for good stratification

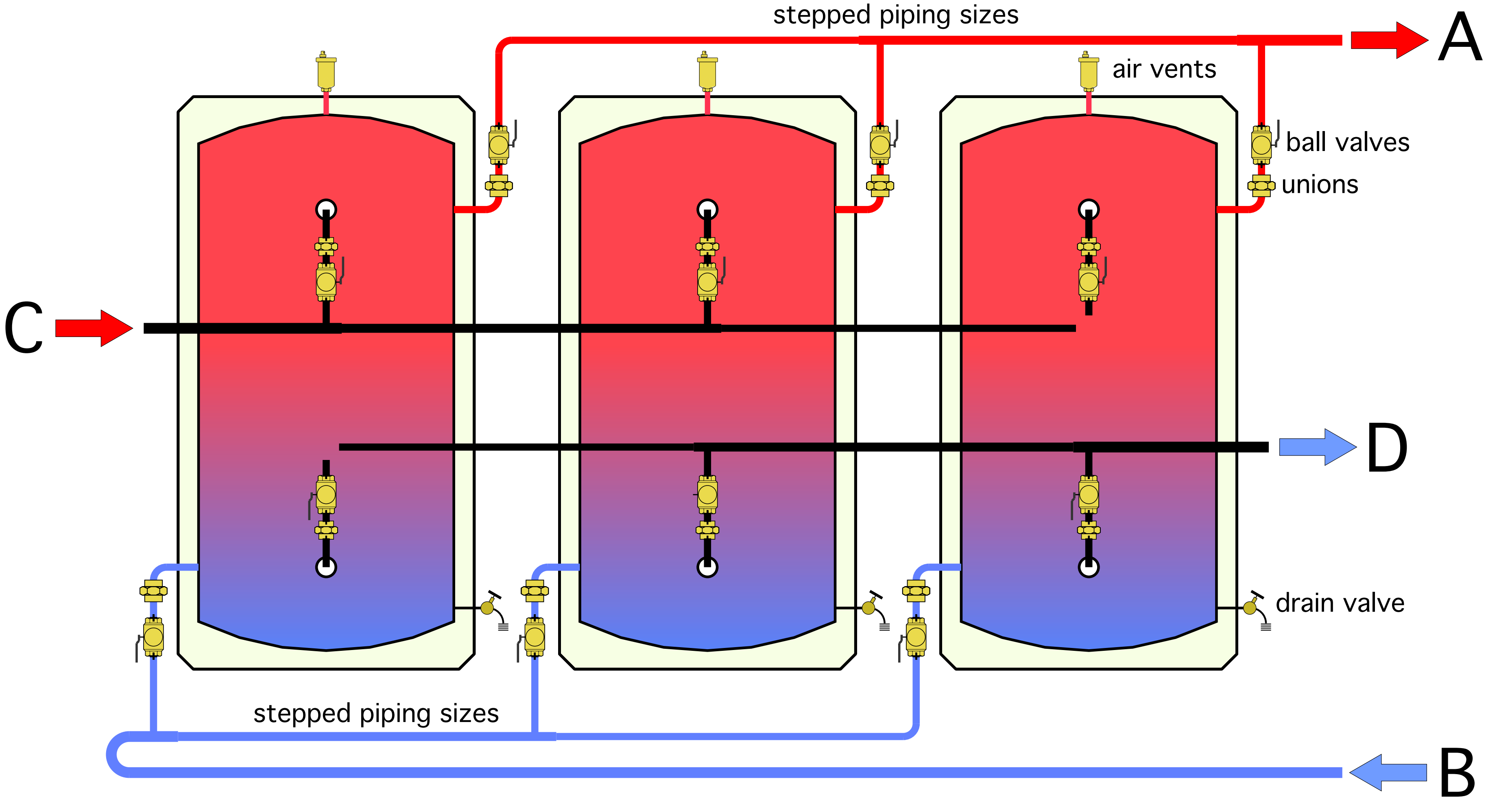
- Vertical orientation for good stratification.



StratoTherm tanks from Lochinvar

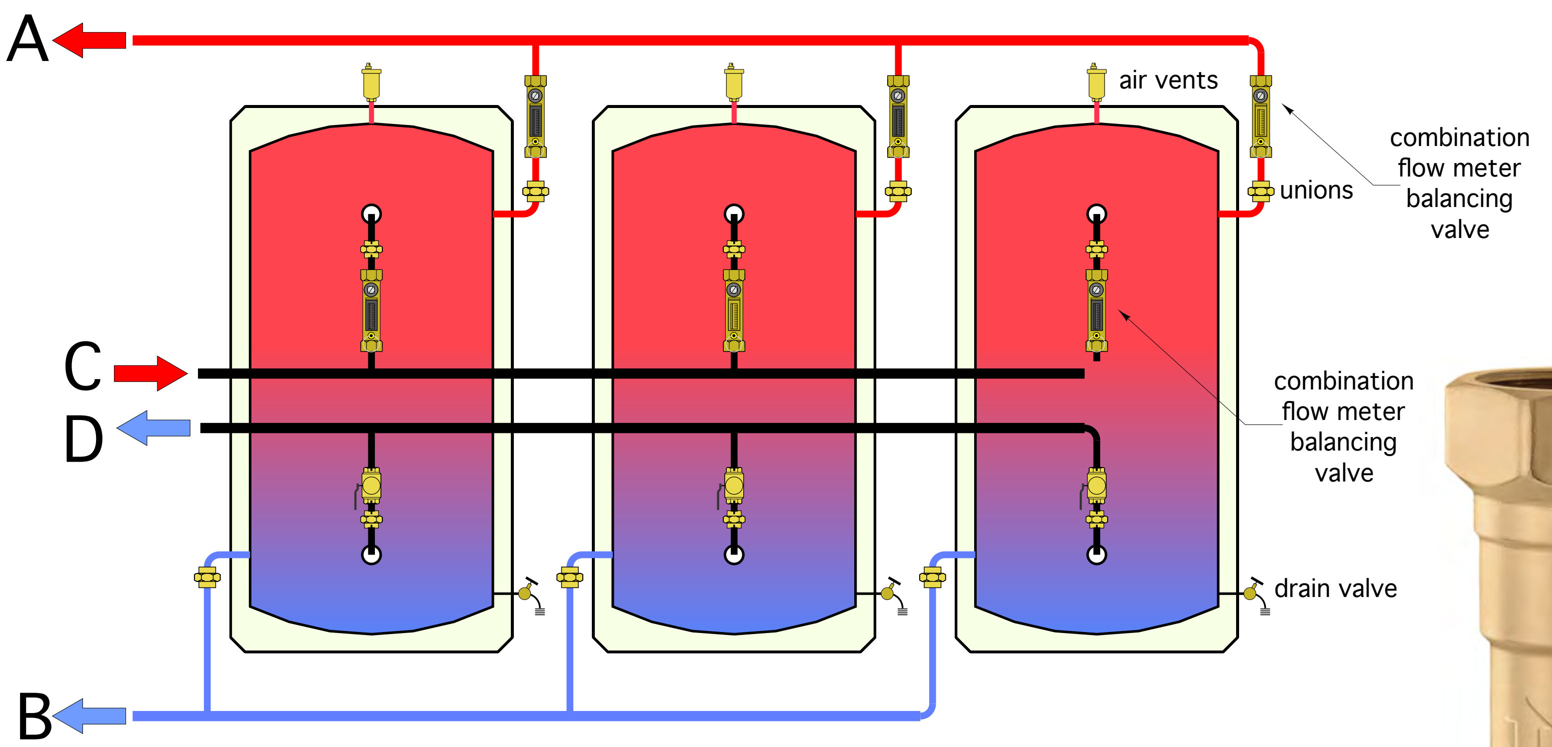
Piping to ensure balanced flow in multiple tanks

Reverse return piping with stepped header sizes

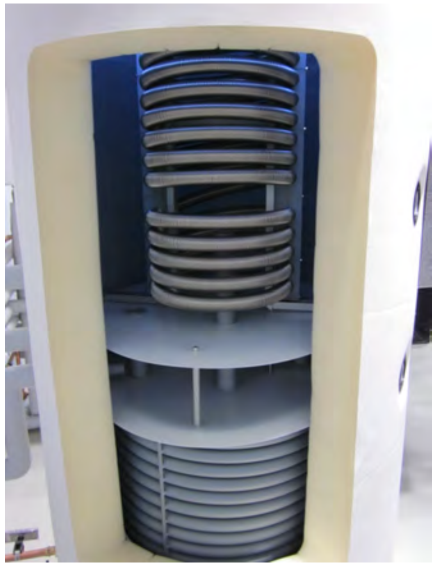


Piping to ensure balanced flow in multiple tanks

If direct return piping is used always install balancing valves



European thermal storage tanks...

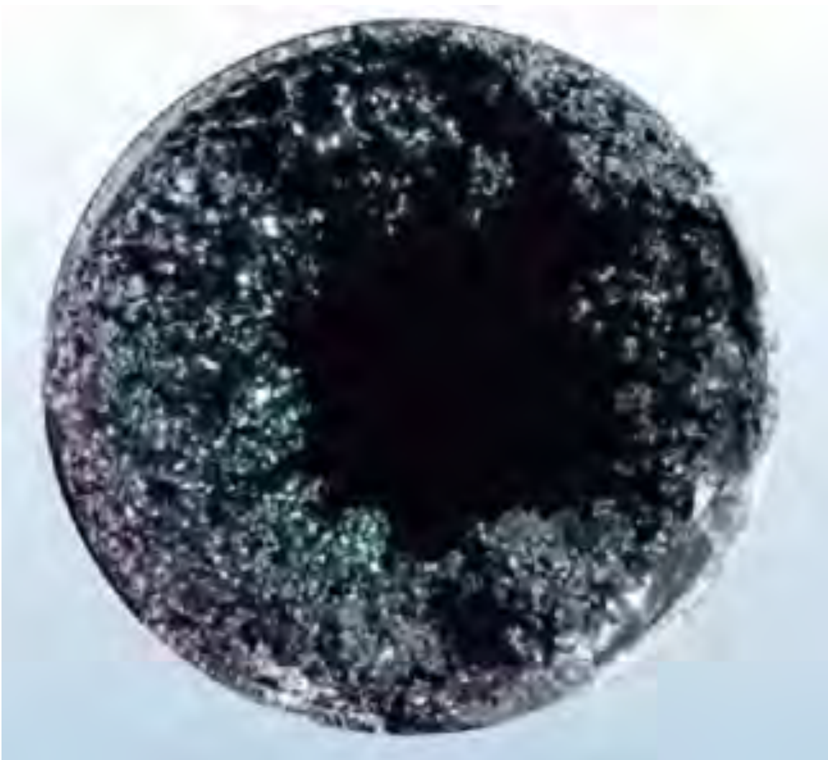


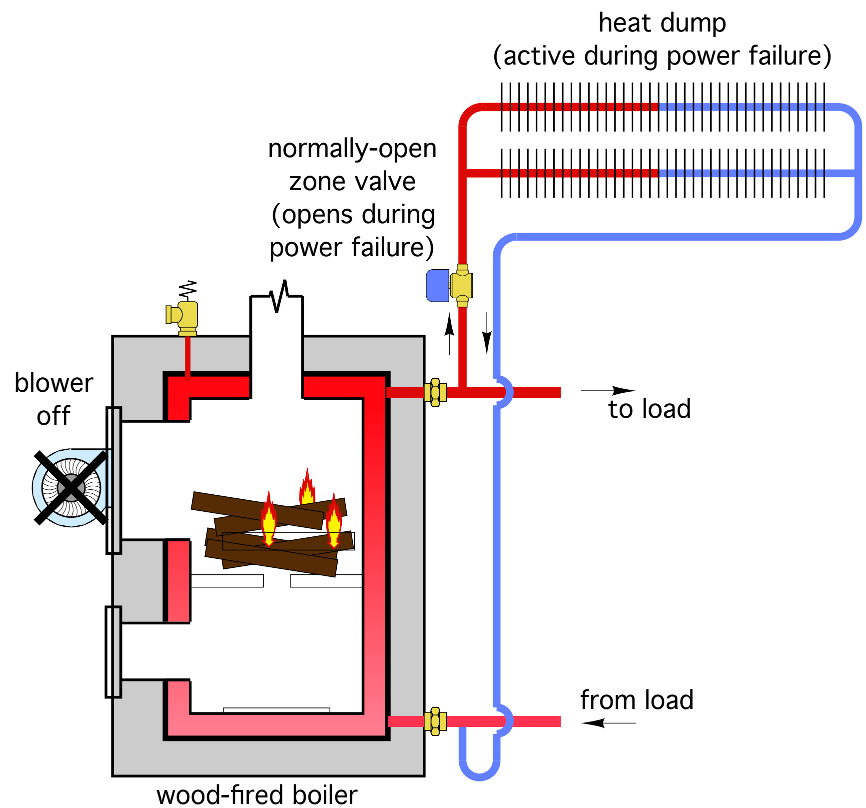
Lots of internal heat exchange coils, BUT...

What happens when a "pinhole" leak develops in one of these tanks?

Boiler protection:

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



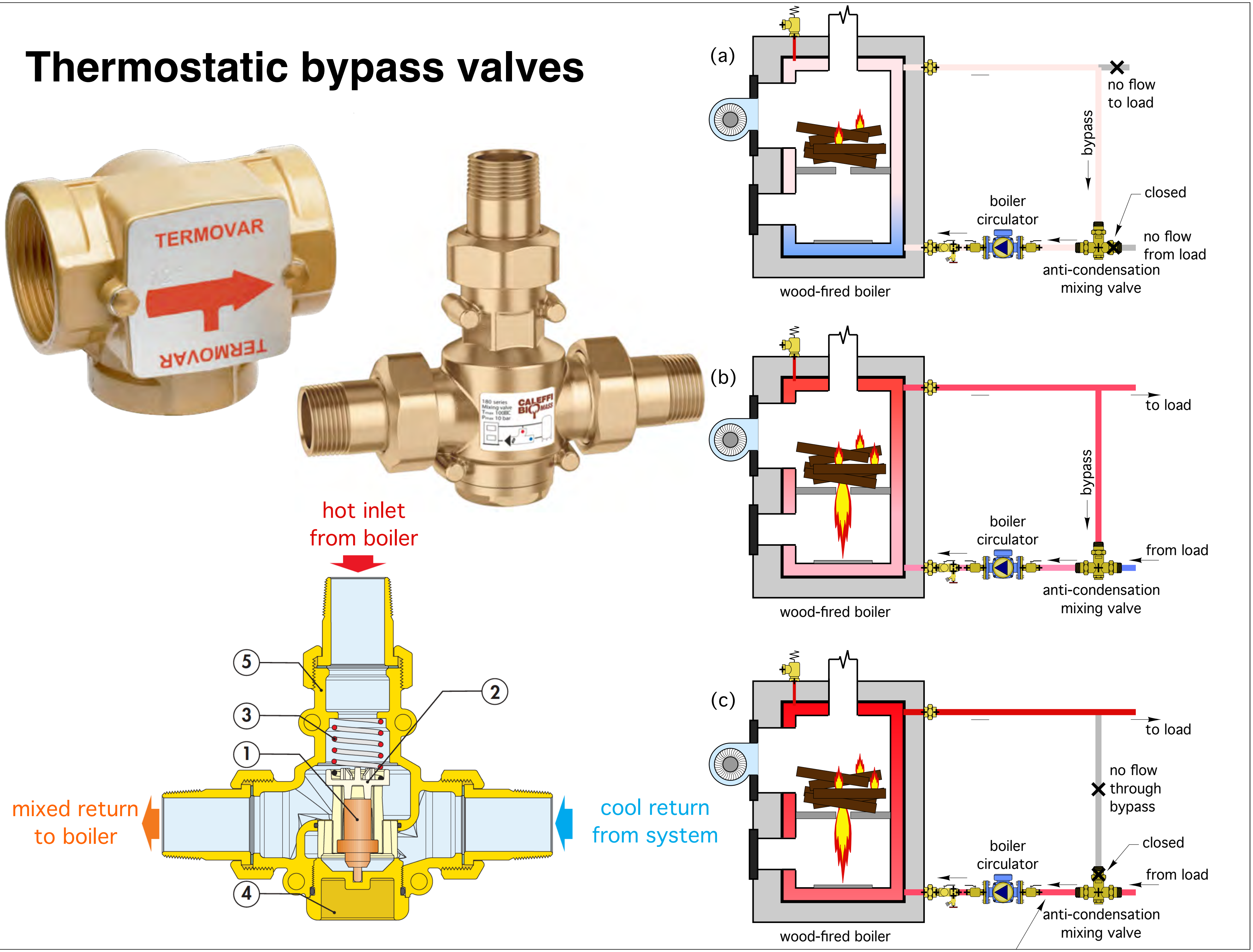


It's necessary to protect wood-fired boilers from low entering water temperatures.

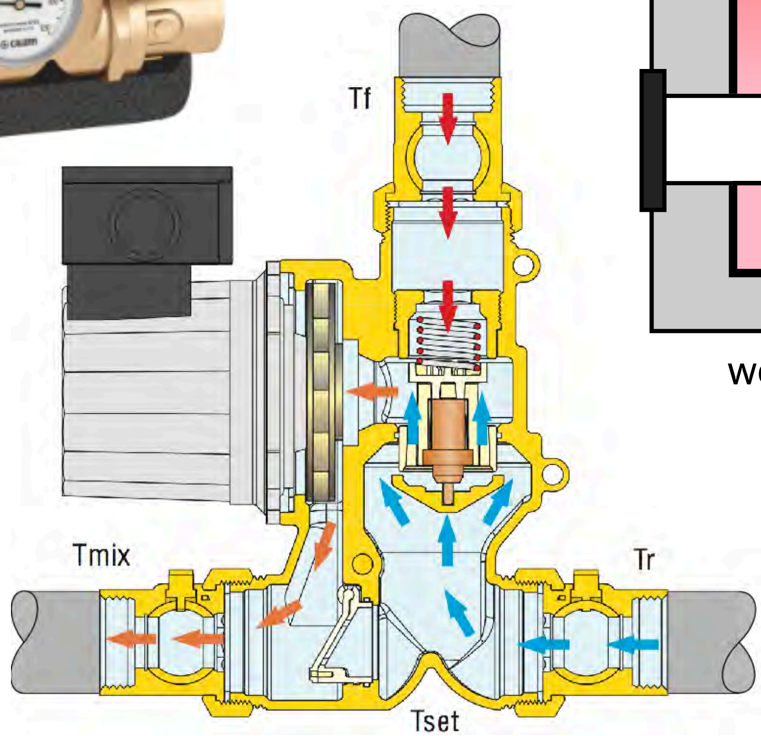
This can be done several ways:

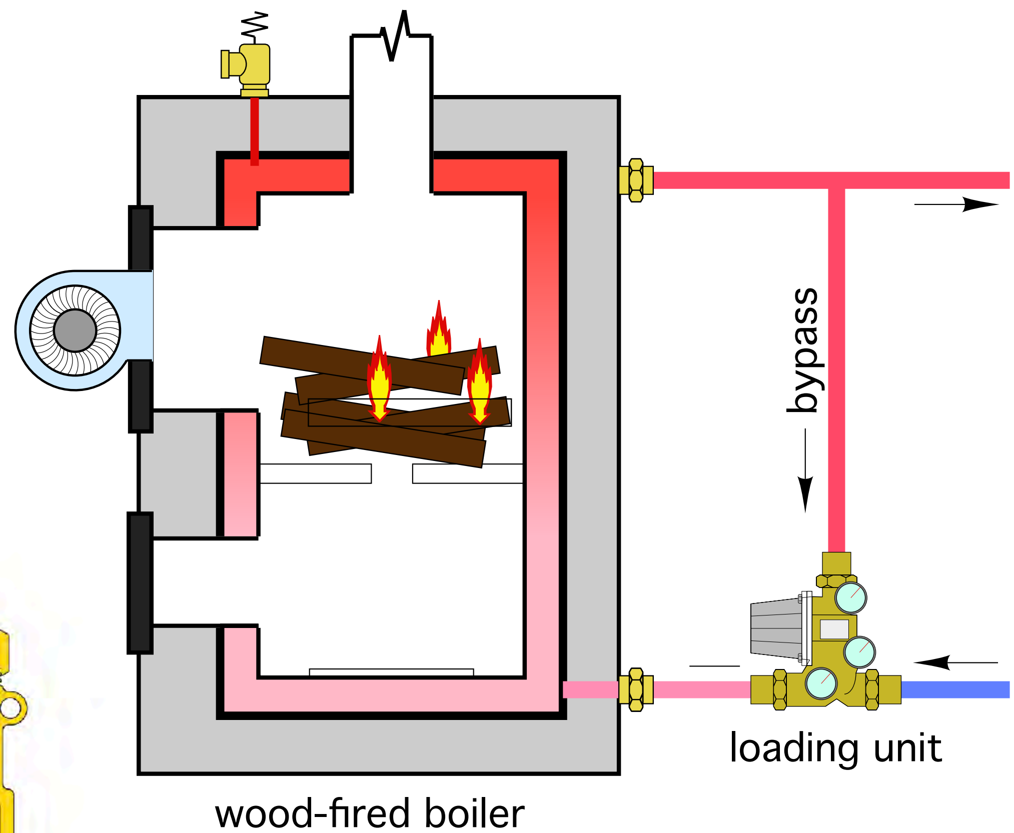
1. Thermostatic bypass valve
2. Loading units (circulator + valve)
3. Variable speed shuttle pump
4. On/off "toggled" circulators

Thermostatic bypass valves

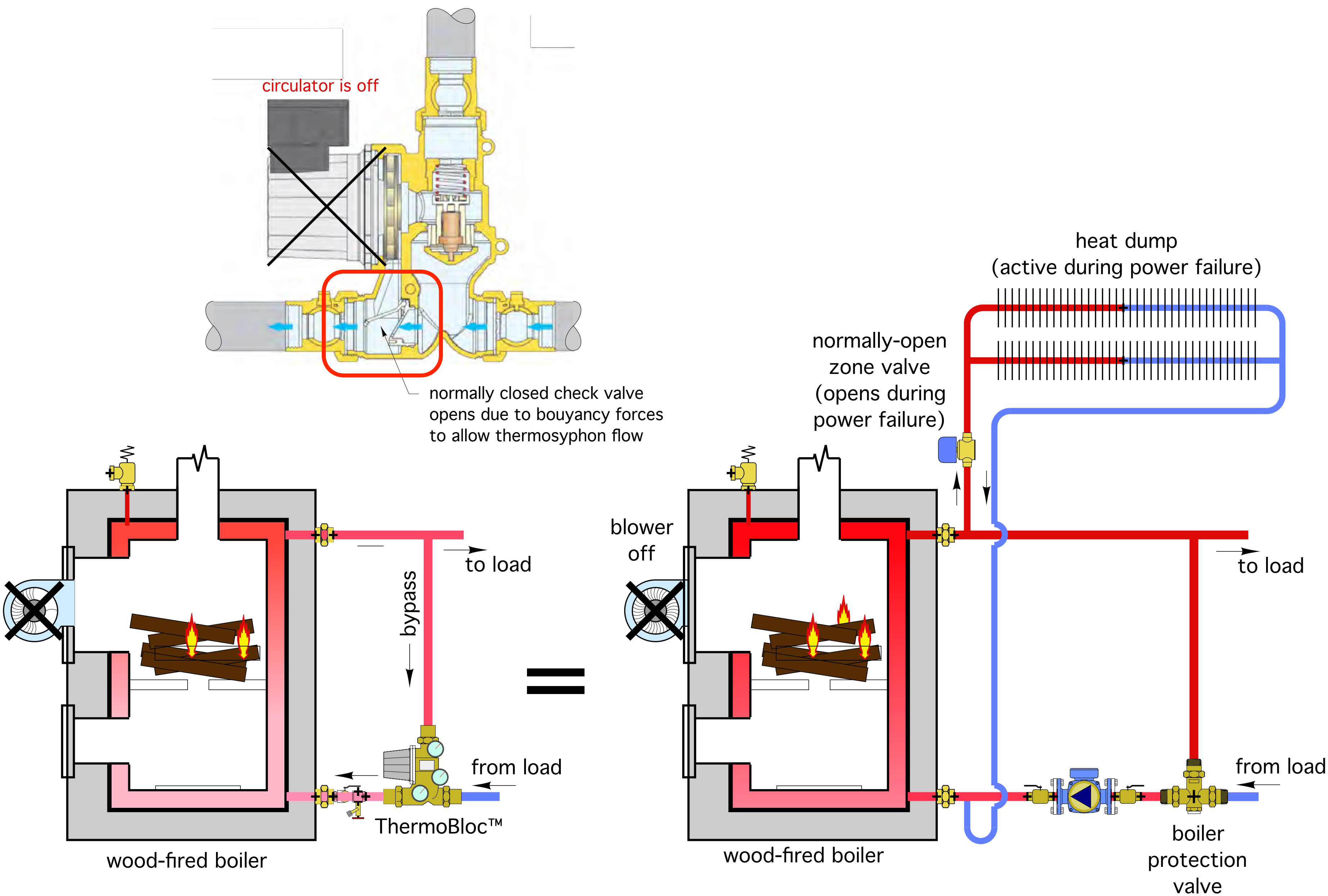


Loading units (during normal operation)
(thermostatic mixing valve + circulator + flapper valve)



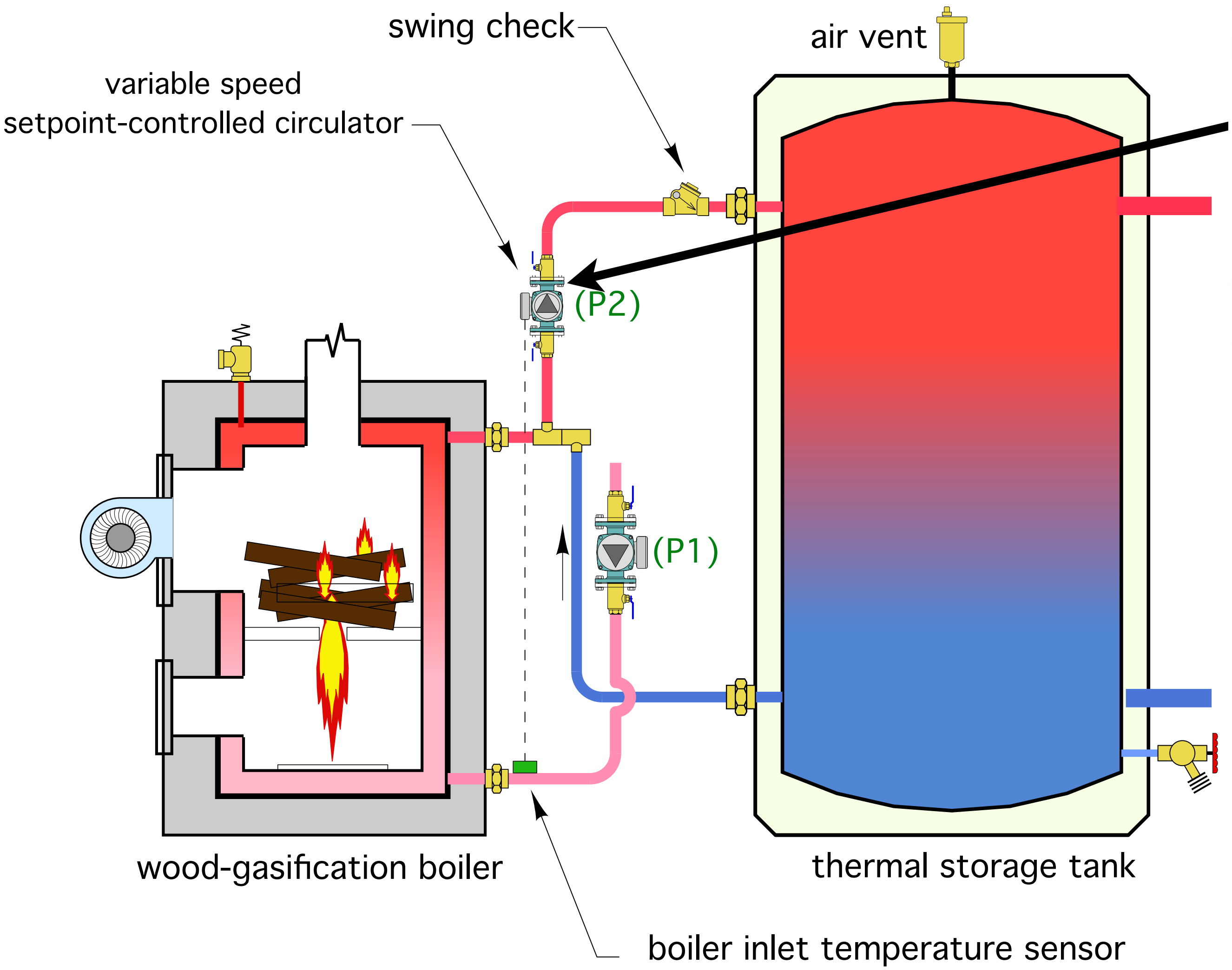


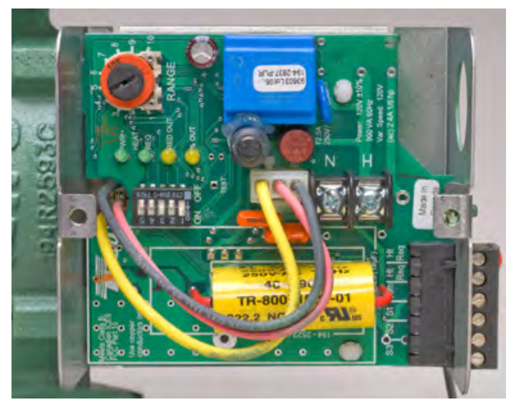
Loading units protect against overheating during power outages.



Variable speed shuttle pump

The variable speed circulator slows down if the setpoint at boiler inlet drops below a setpoint (typically 130ºF to 140ºF).





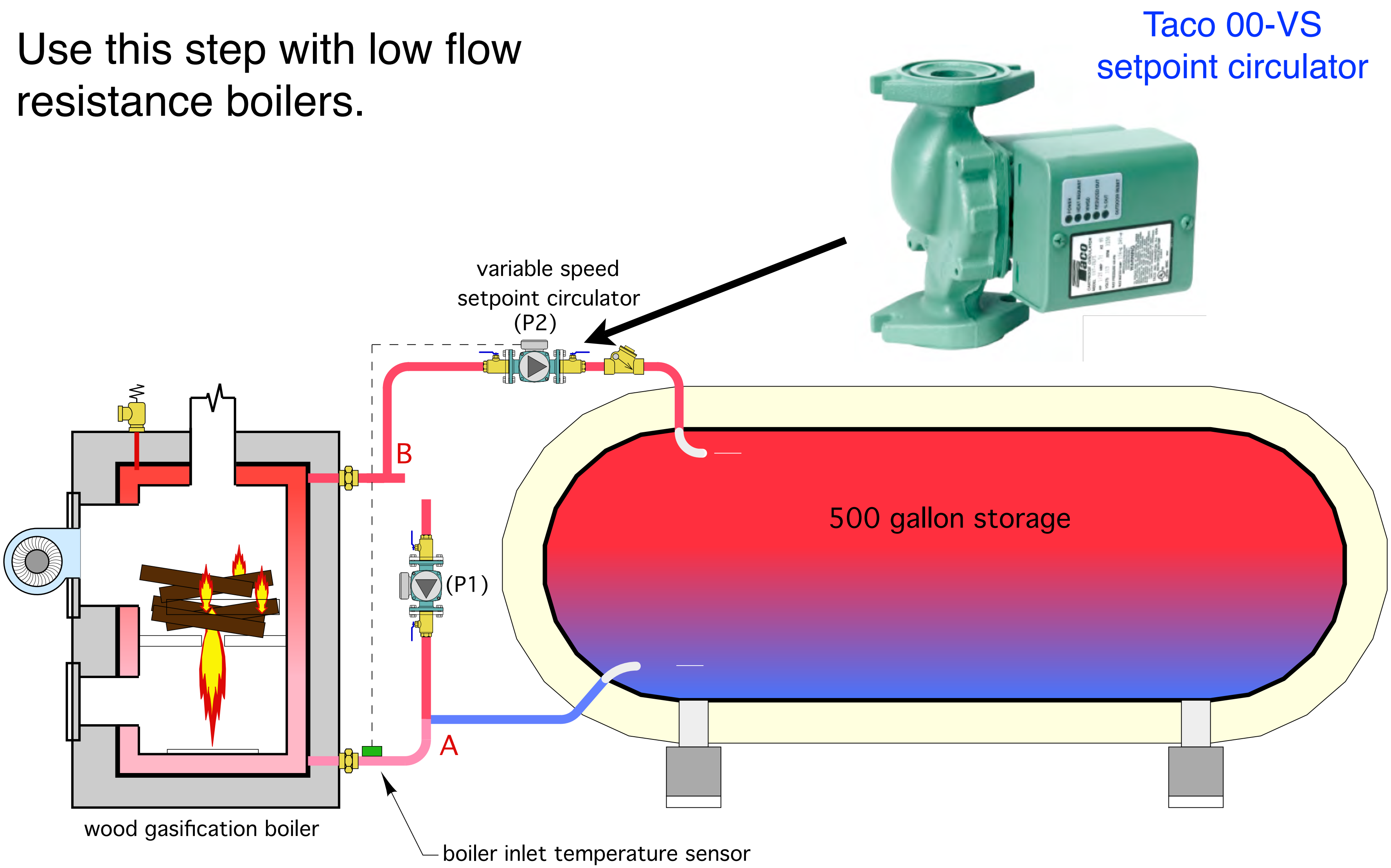
Taco 00-VS
setpoint circulator

NOTE: No internal check valves in circulators

Variable speed shuttle pump

The variable speed circulator slows down if the setpoint at boiler inlet drops below a setpoint (typically 130ºF to 140ºF).

Use this step with low flow resistance boilers.



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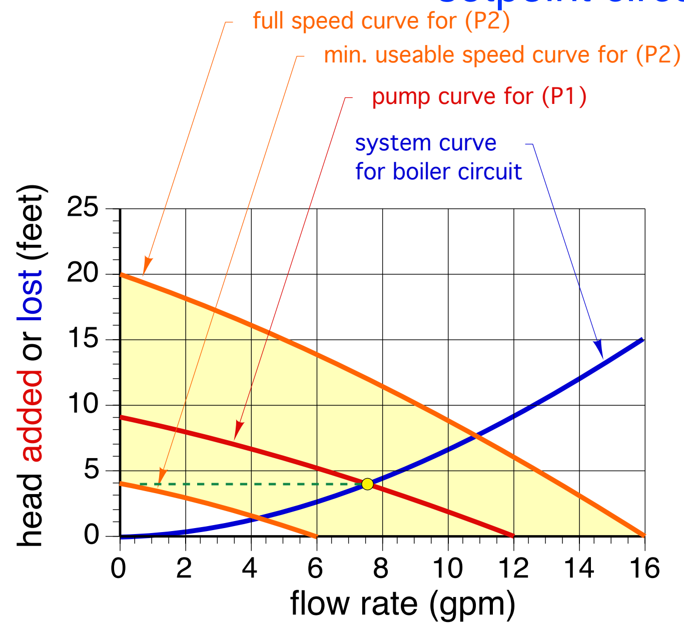

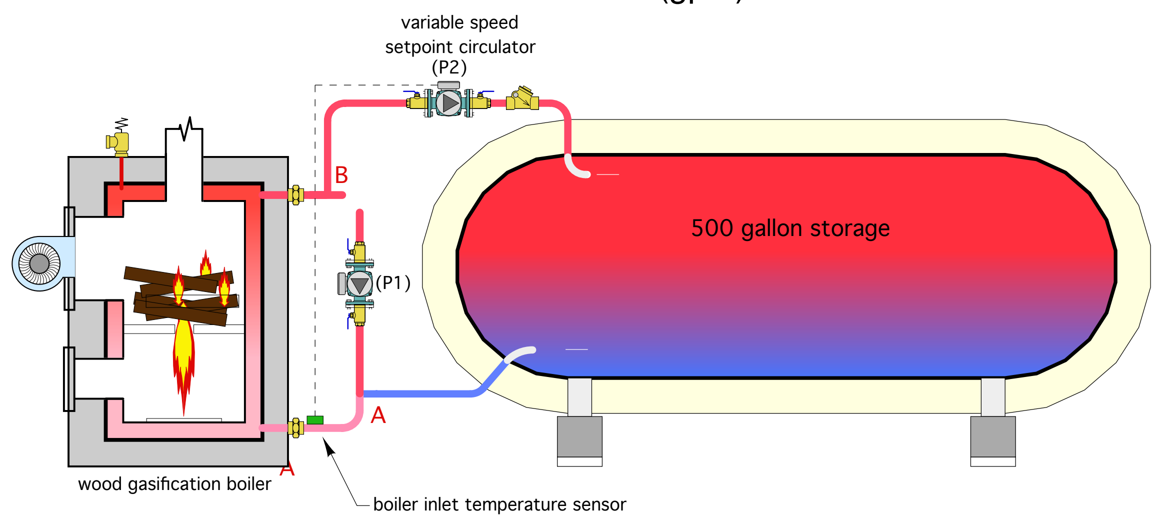

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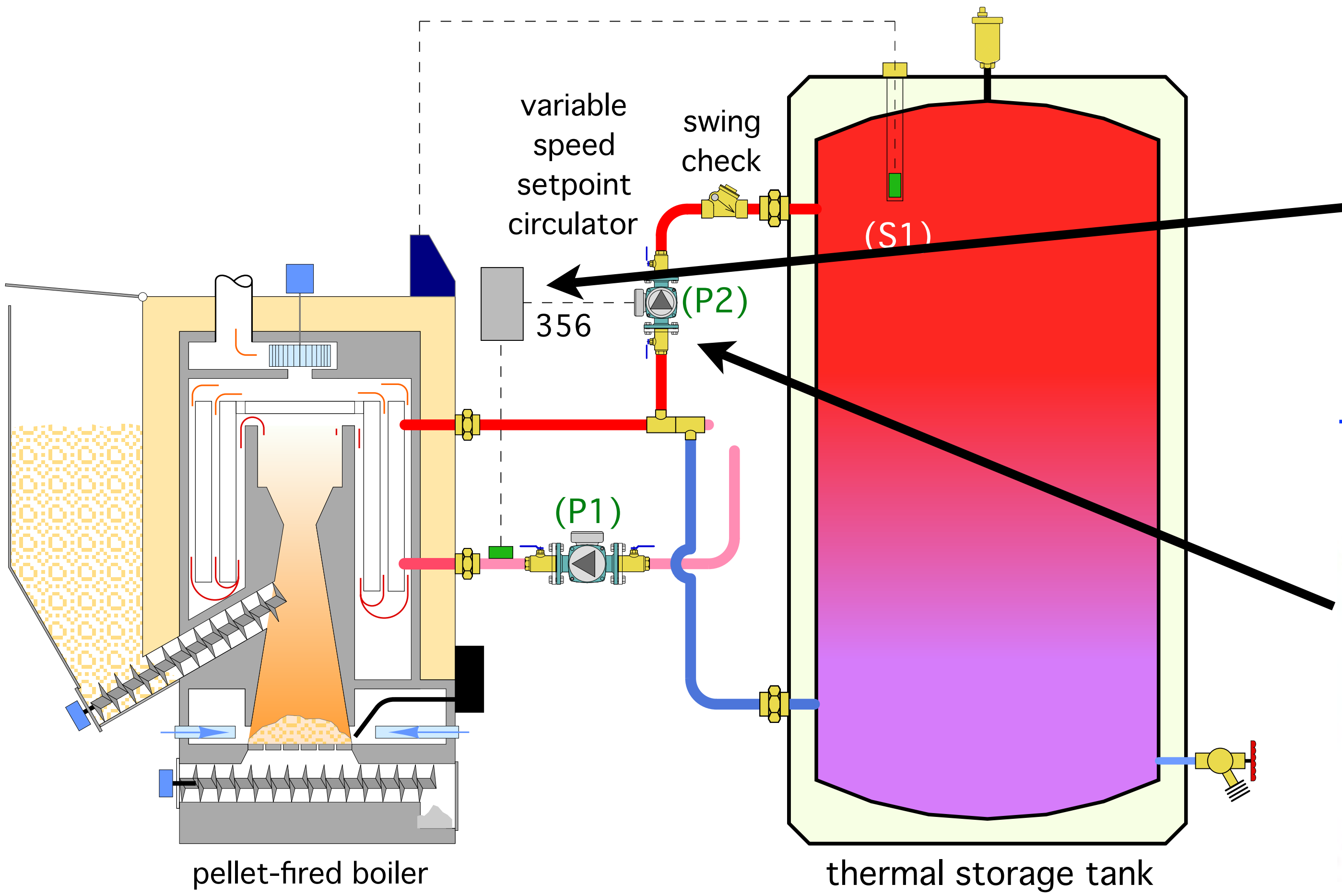


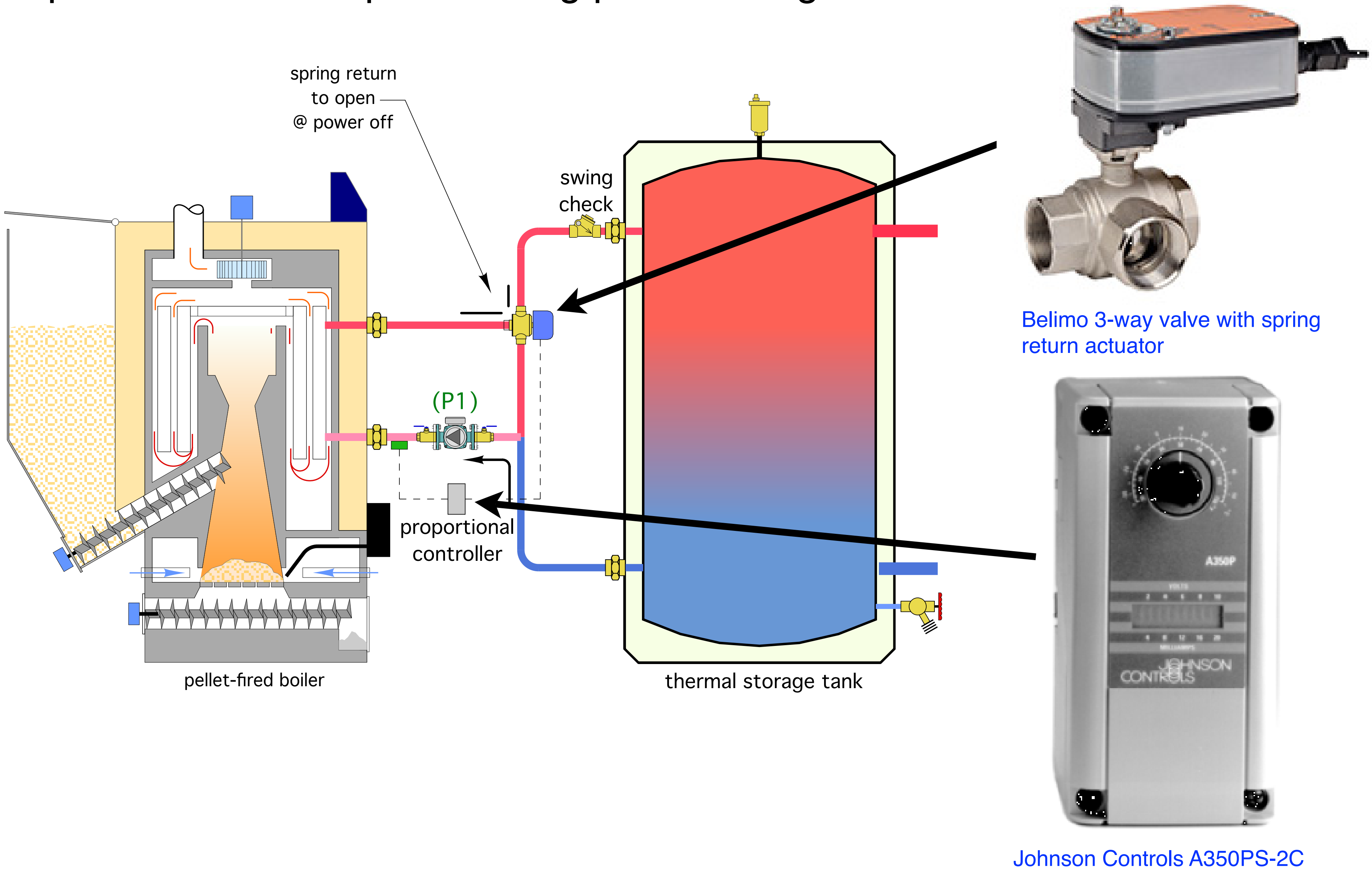
Tekmar 356 mixing controller $242

Any wet rotor circulator with PSC motor up to 1/6 HP

(Taco 0012: $251)

3-way proportional mixing valve w/ spring return actuator

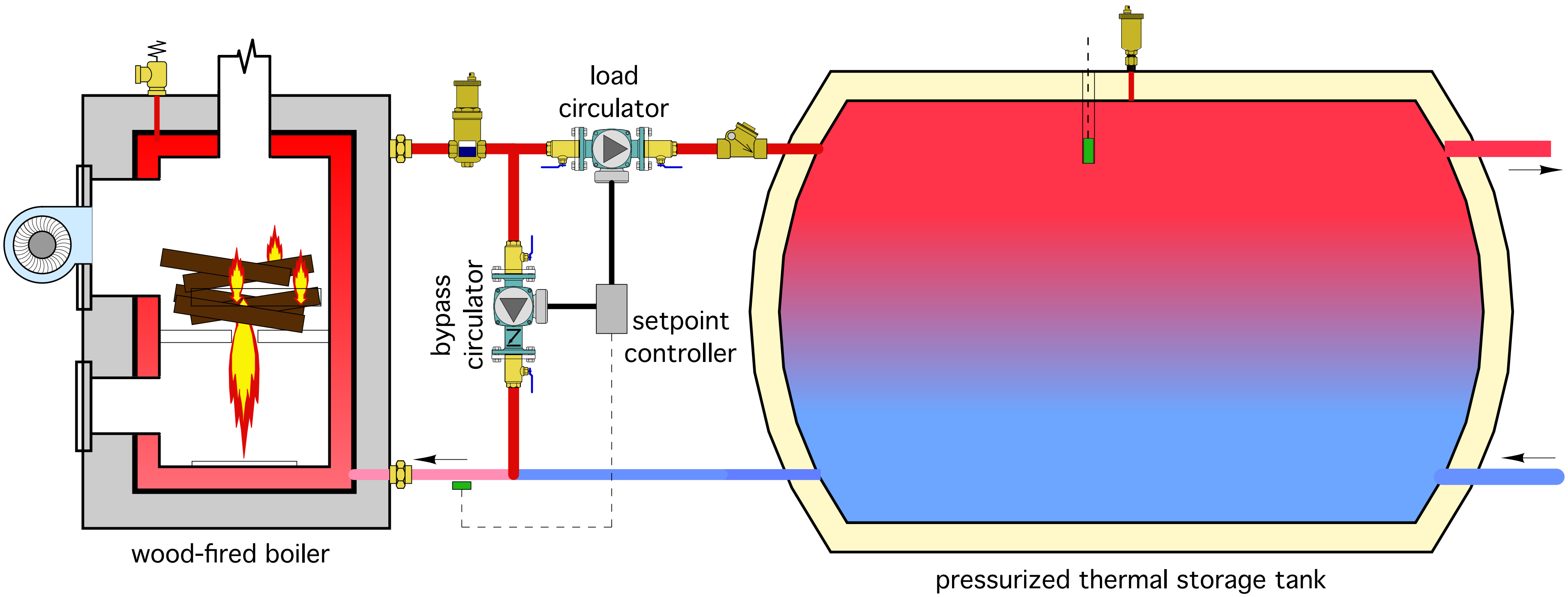
The actuator responds to a 2-10 VDC signal from controller, but fully opens for thermosiphon during power outage.



On/off toggled circulators

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

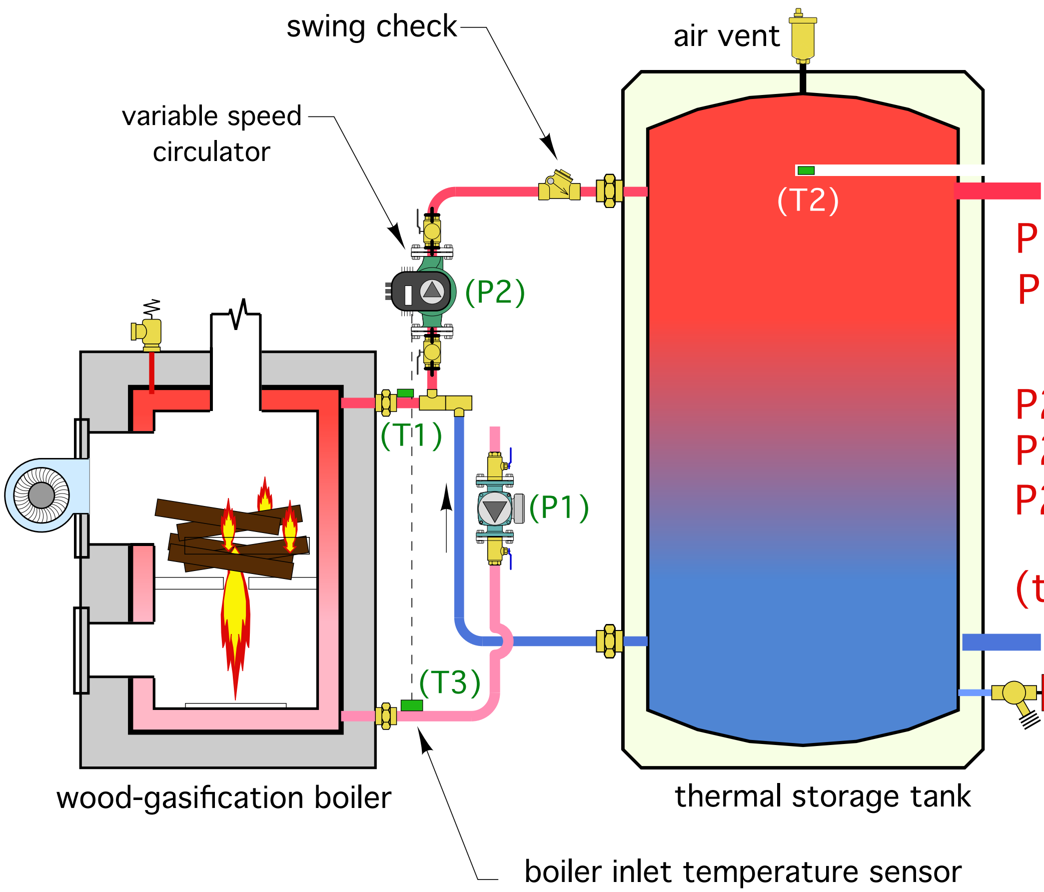
Bypass circulator OFF, load circulator ON, when boiler return ≥140ºF



Some boilers have this control function built-in

Protecting a wood gasification boiler from condensation

The variable speed circulator slows down if the setpoint at boiler inlet drops below a setpoint (typically 130ºF to 140ºF).



P1 must be on if P2 is to be on
P1 = ON, if T1>T2+5ºF

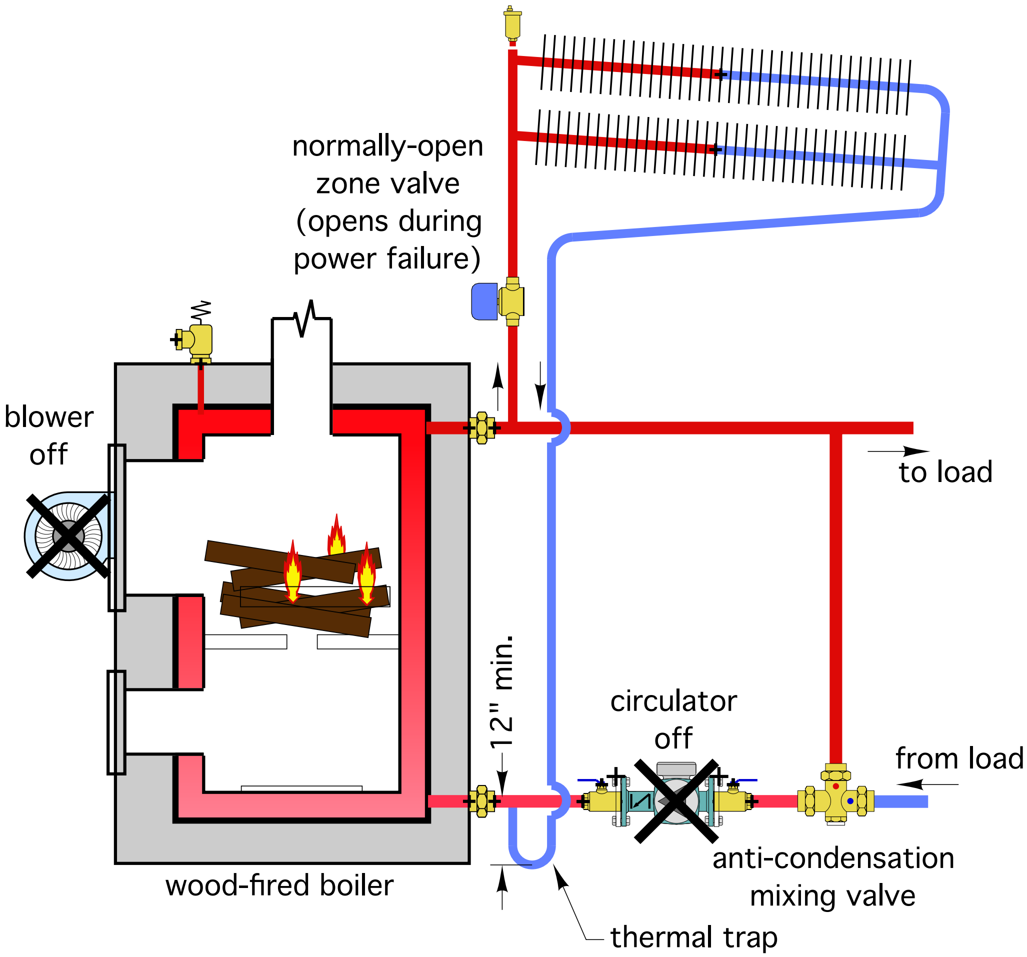
P2 = OFF if T3<Tmin
P2 = ON @ 2% minimum speed if T3= Tmin
P2 = ON @ max. if T3= Tmin+5ºF

(typical) Tmin = 130 ºF

NOTE: No internal check valves in circulators

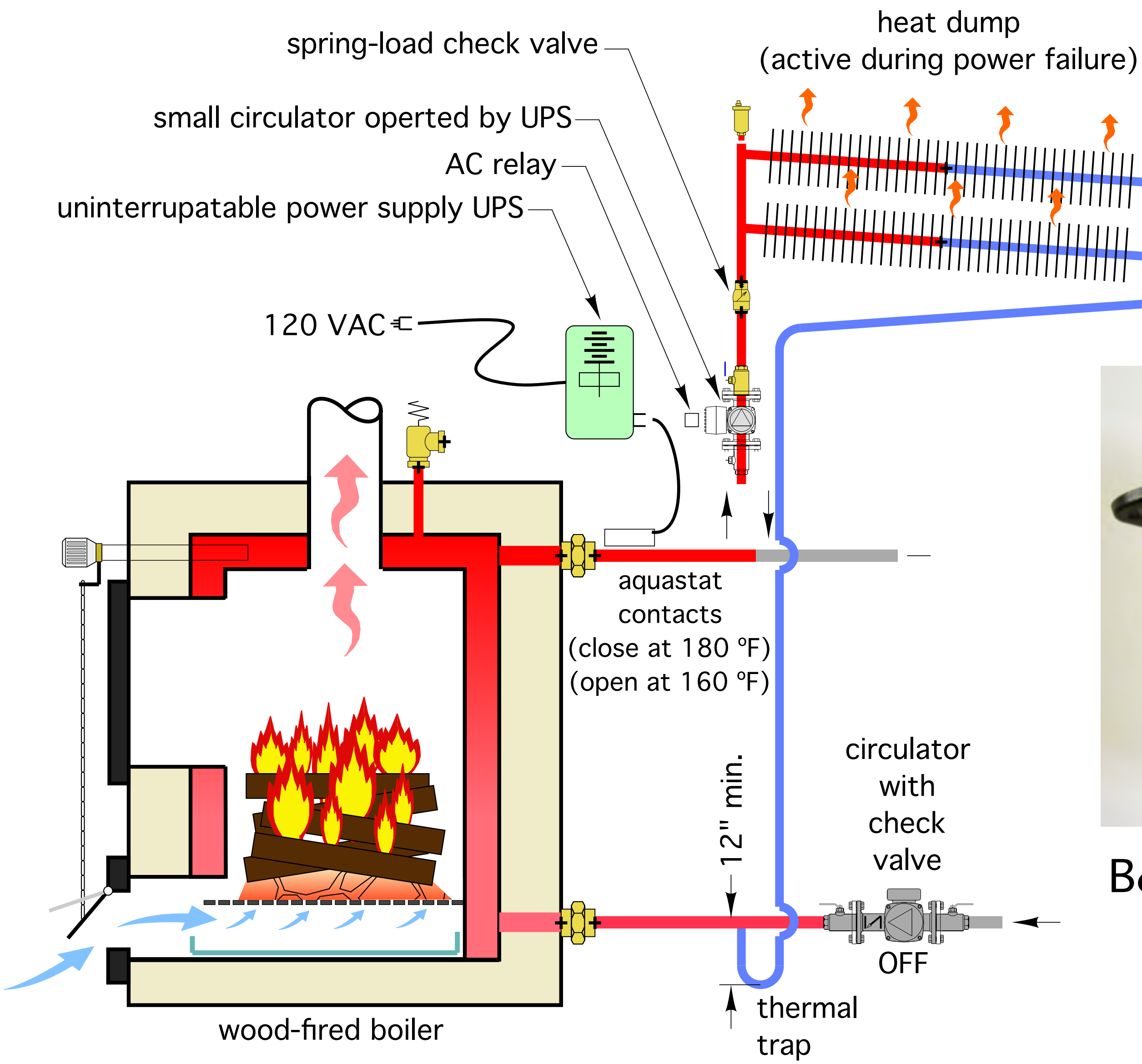
Heat dump activates upon power failure

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

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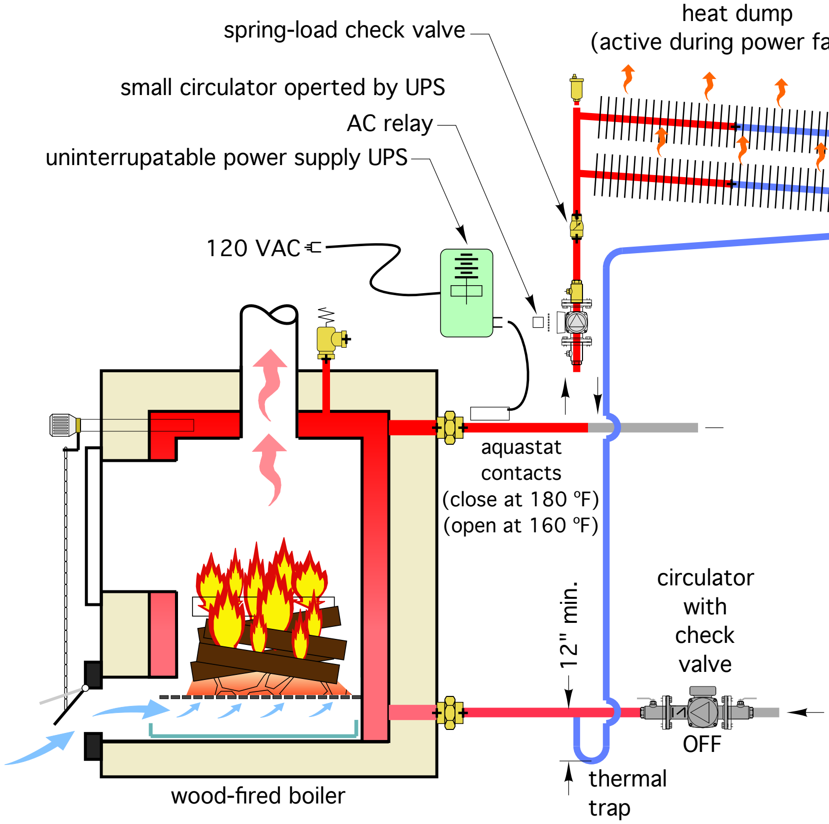

B&G Ecocirc (VARIO)
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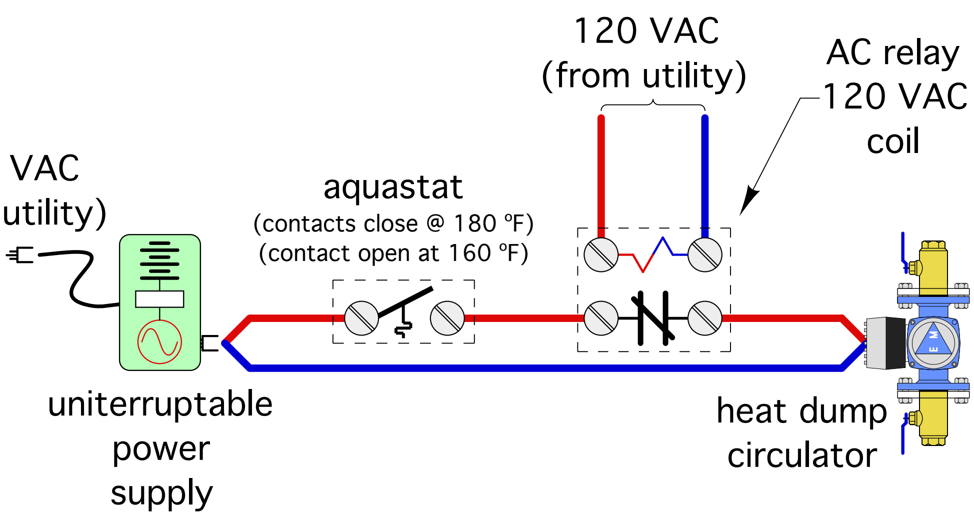


Low temperature / hydronic heat emitters

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

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

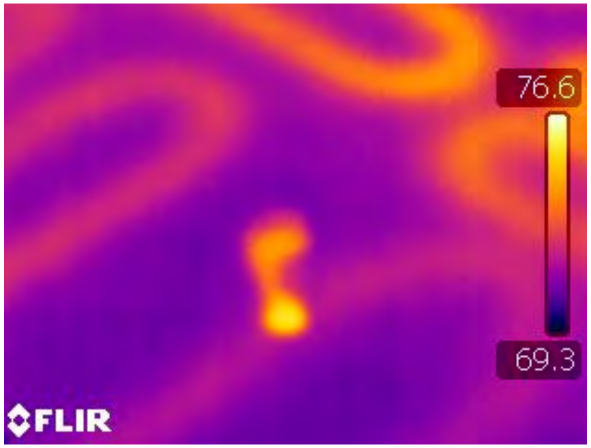
Max suggested supply water temperature @ design load = 120 °F

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

Is radiant floor heating always the answer?

Consider a 2,000 square foot well insulated home with a design heat loss of 18,000 Btu/hr. Assume that 90 percent of the floor area in this house is heated (1800 square feet). The required upward heat flux from the floor at design load conditions is:

$$\text{heat flux} = \frac{\text{design load}}{\text{floor area}} = \frac{18{,}000\ \text{Btu/hr}}{1{,}800\ \text{square feet}} = 10\,\frac{\text{Btu}}{\text{hr}\bullet\text{ft}^2}$$



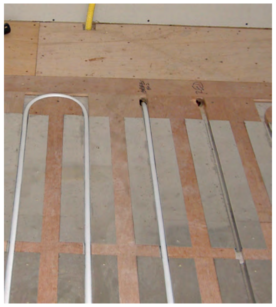
$$T_f = \frac{q}{2} + T_r$$

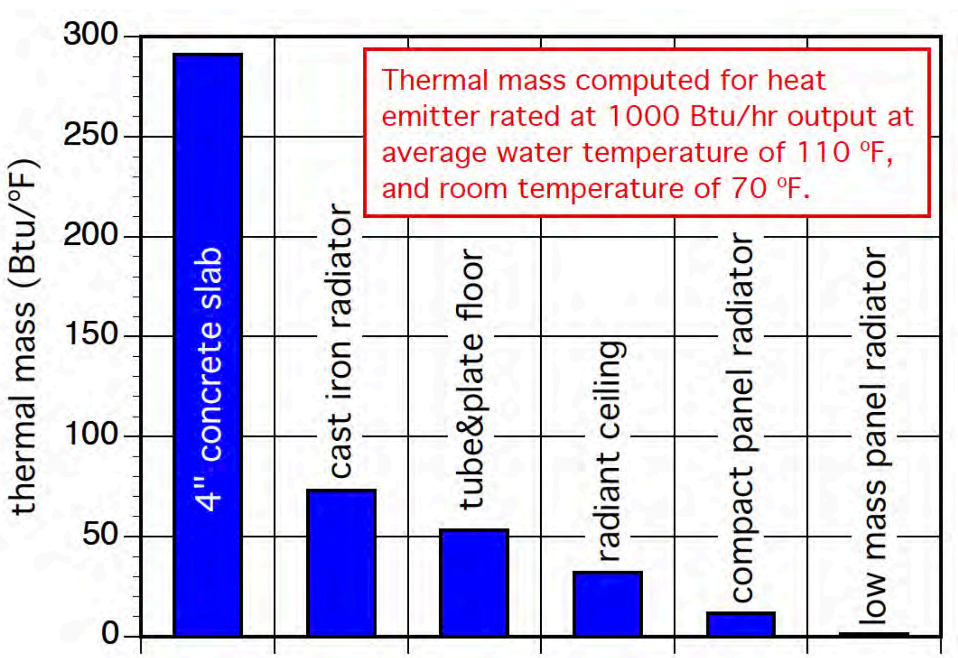
Tf = average floor surface temperature (°F)
Tr= room air temperature (°F)
q=heat flux (Btu/hr/ft^2)

To deliver 10 Btu/hr/ft^2 the floor only has to exceed the room temperature by 5 degrees F. Thus, for a room at 68 degrees F the average floor surface temperature is only about 73 degrees F.

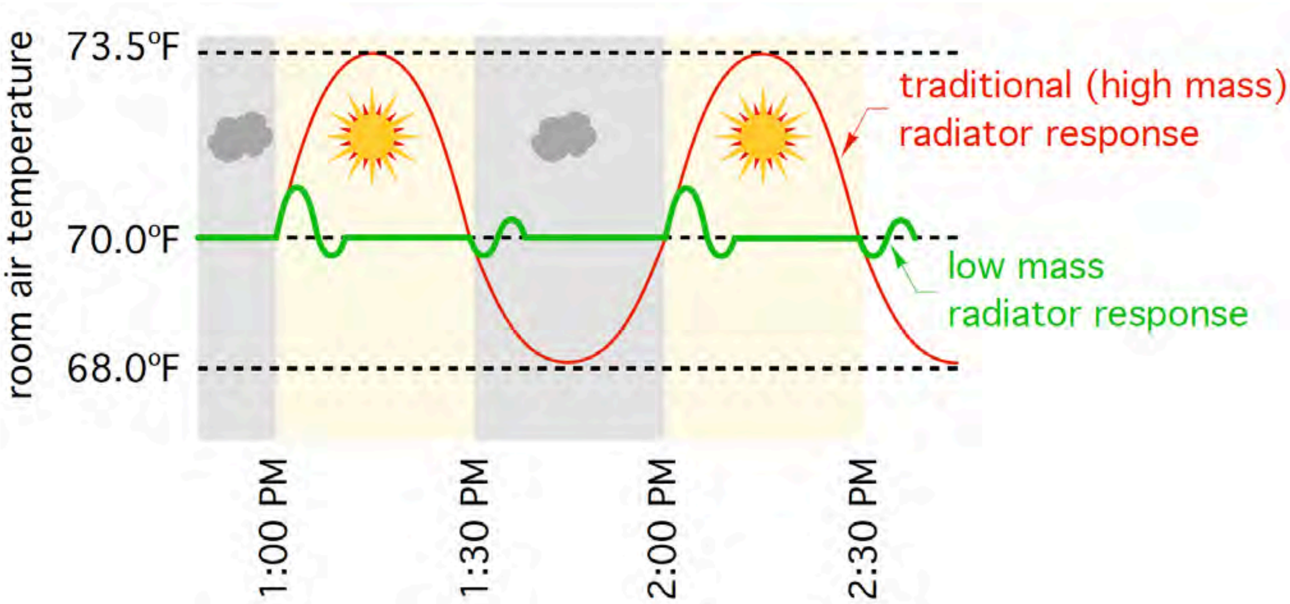
*This is not going to deliver "**barefoot friendly floors**" - as so many ads for floor heating promote.*

A comparison of THERMAL MASS for several heat emitters:
All heat emitters sized to provide 1000 Btu/hr at 110 ºF average water temperature, and 70 ºF room temperature:





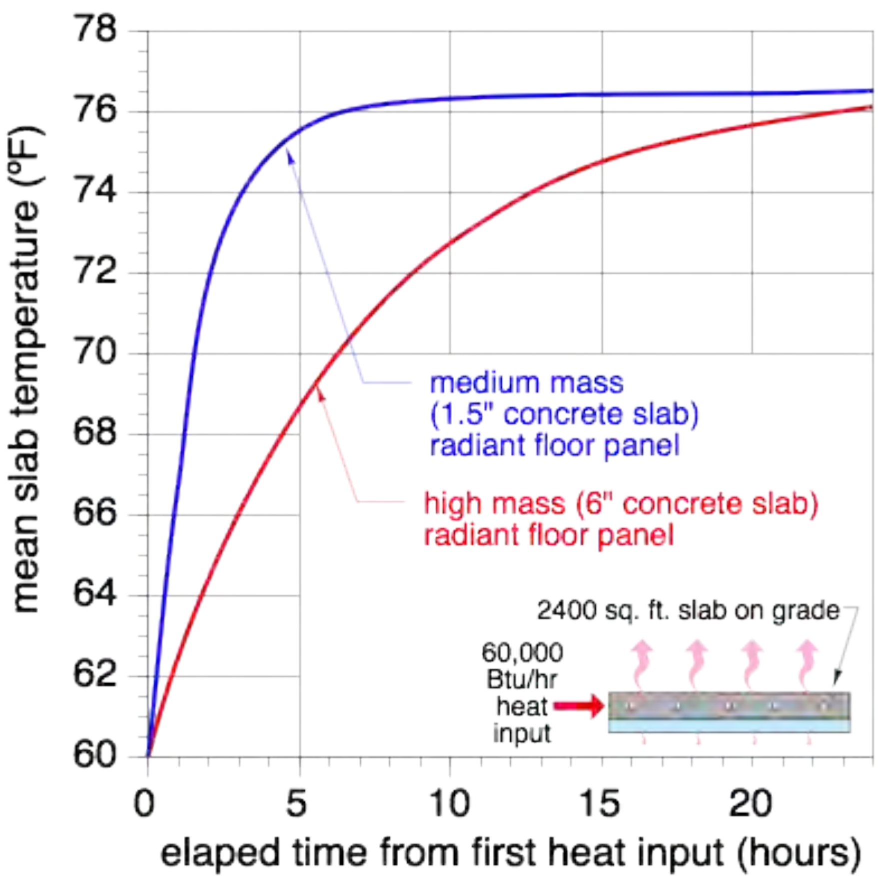
Low thermal mass allows the heat emitters to quickly respond to changing internal loads



high mass cast iron radiator

low mass panel radiators

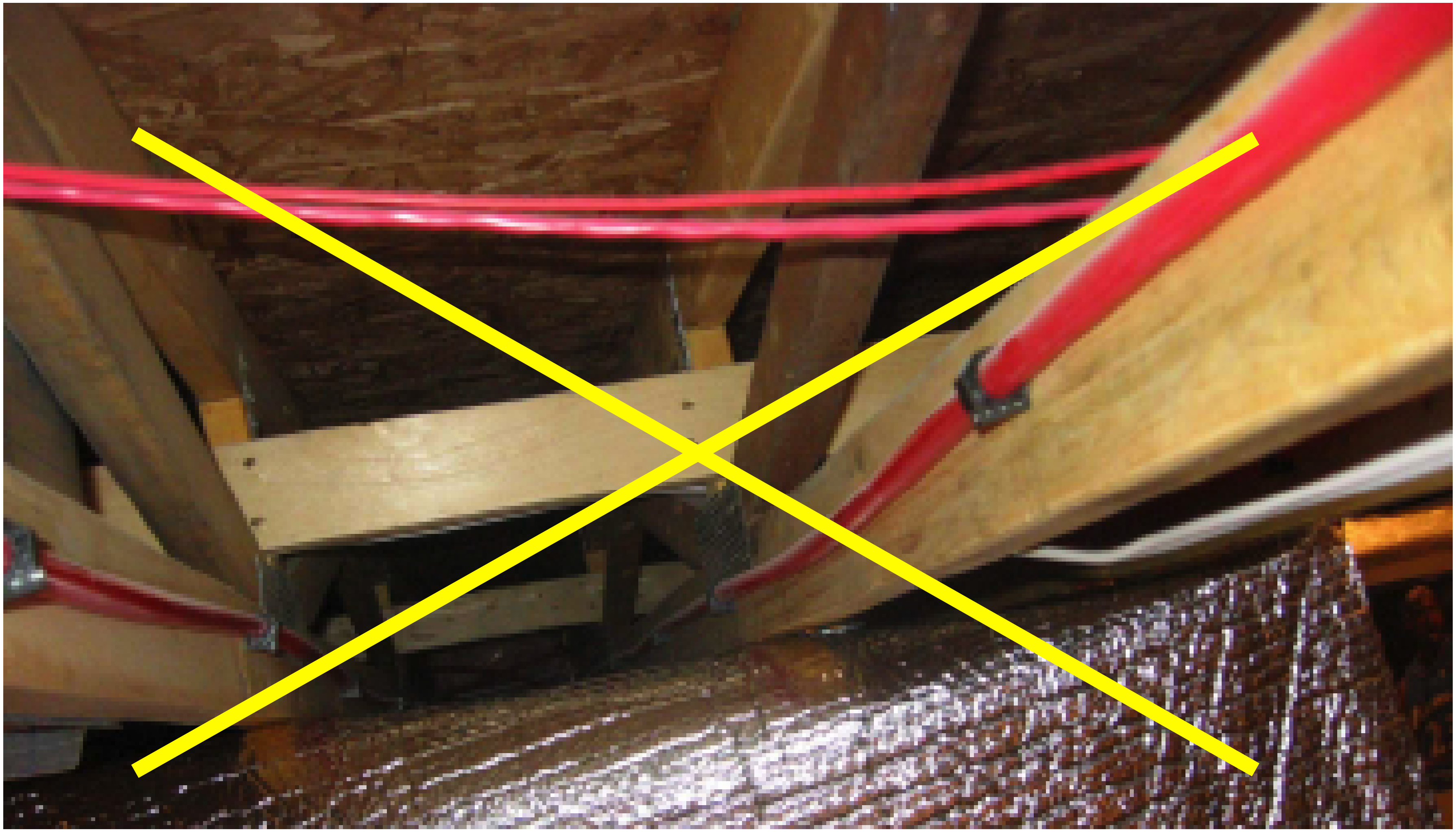
Heated slabs can take hours (even days) to respond to significant temperature changes.



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

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

Don't do this with ANY hydronic heat source!



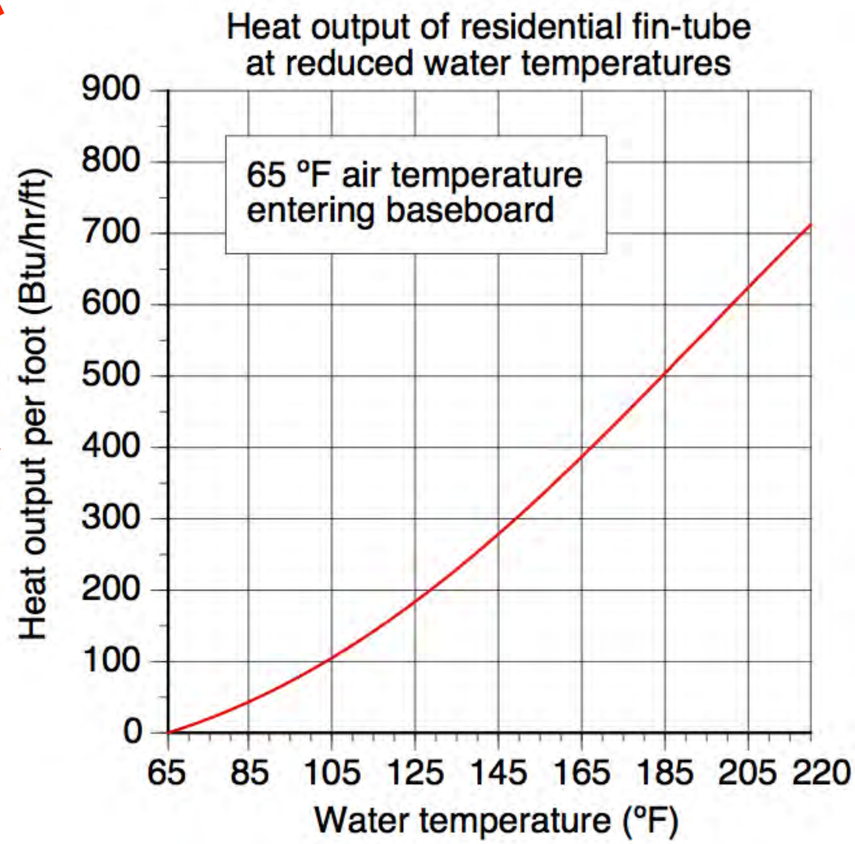
Heat transfer between the water and the upper floor surface is severely restricted!

Hydronic heat emitters options for low energy use houses

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.

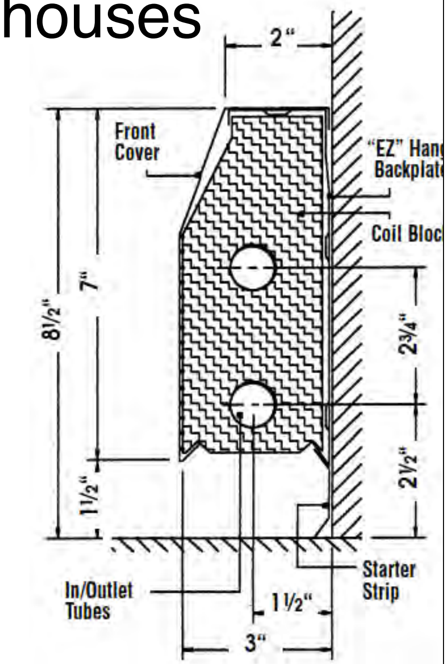
Could add fin-tube length based on lower water temperatures. BUT...

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



Heating Edge™
Hot Water Performance Ratings

	Flow Rate GPM	PD in ft of H_2O	Average Water Temperature (BTU/hr/ft @AWT in °F) 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
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

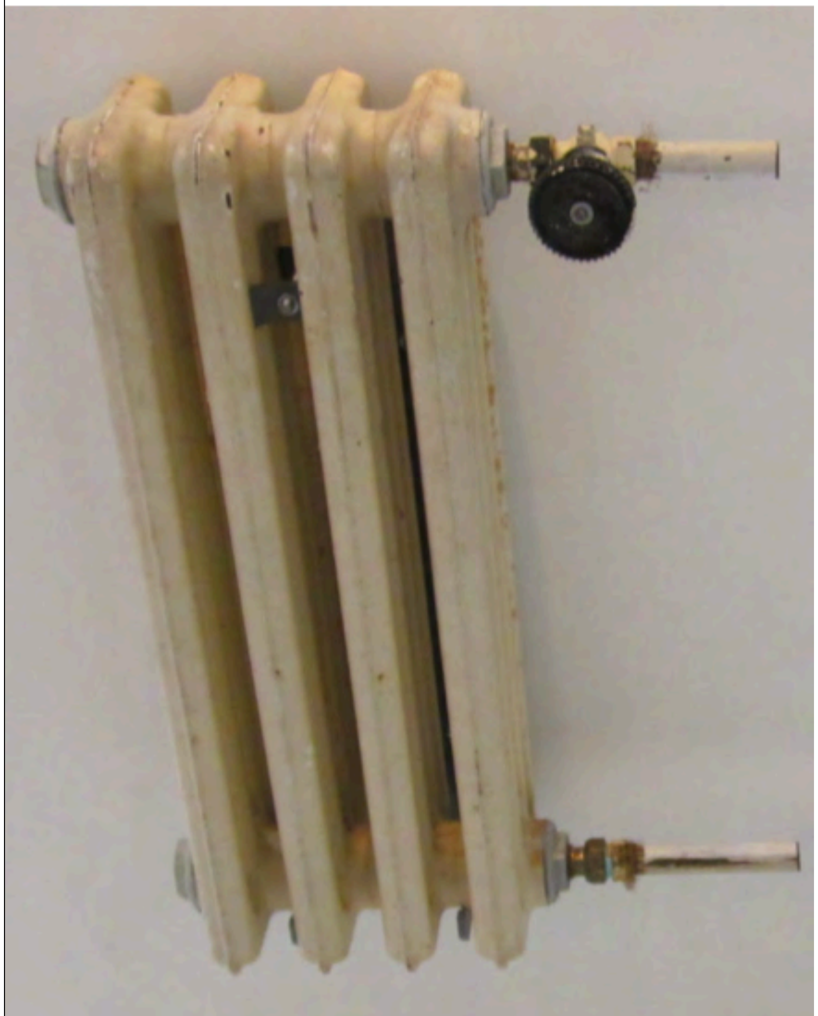
Performance Notes: • All ratings include a 15% heating effect factor • Materials of construction include all aluminum "patented" fins at 47.3 per LF, mechanically bonded to two 3/4' (075) type L copper tubes ("Coil Block") covered by a 20 gauge perforated, painted cover all mounted to a backplate. Please 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.

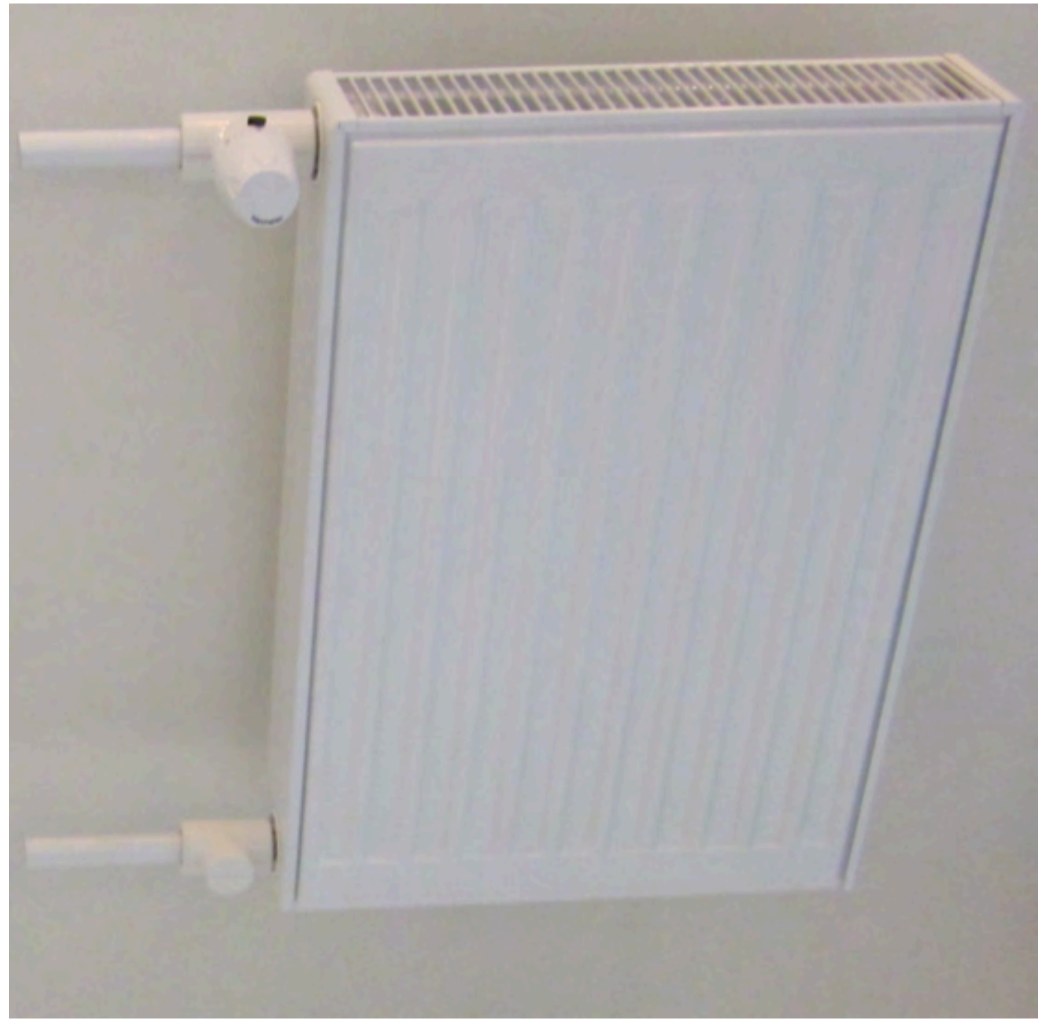
Smith's ENVIRONMENTAL PRODUCTS®
300 Pond Street, Randolph, MA 02368 • (781) 986-2525 • www.smithsenvironmental.com

Panel Radiators

Traditional cast-iron radiator

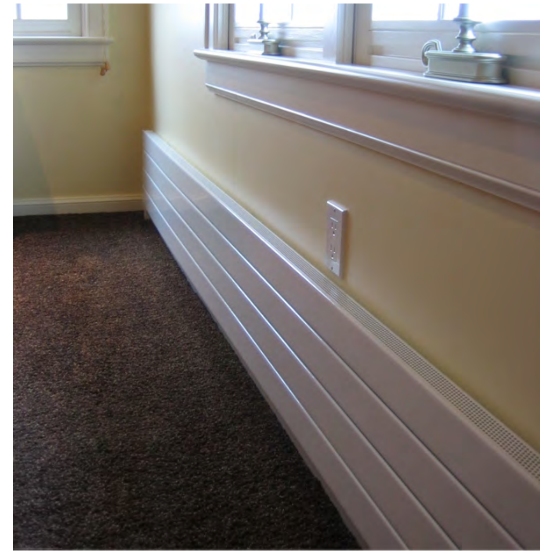


Modern panel radiator



Panel Radiators

- Low water content and relatively light - fast responding
- Some can be fitted with thermostatic radiator valves for room-by-room zoning (WITHOUT ELECTRICAL CONTROLS)
- Some are “thermal art” - but bring your VISA card...

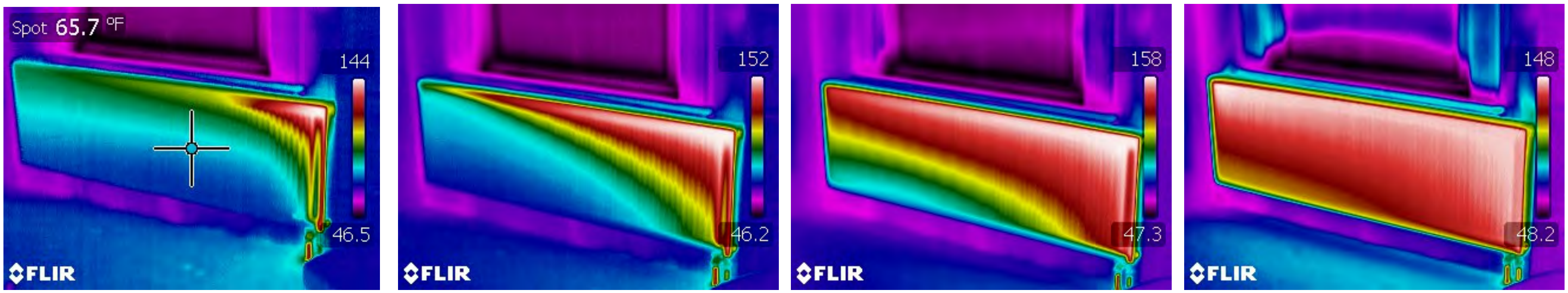





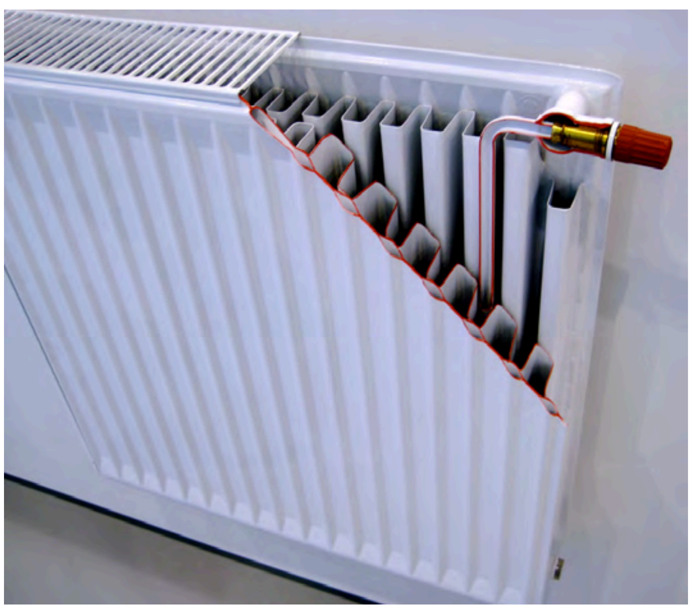
Hydronic heat emitters options for low energy use houses

Panel Radiators

One of the fastest responding hydronic heat emitters

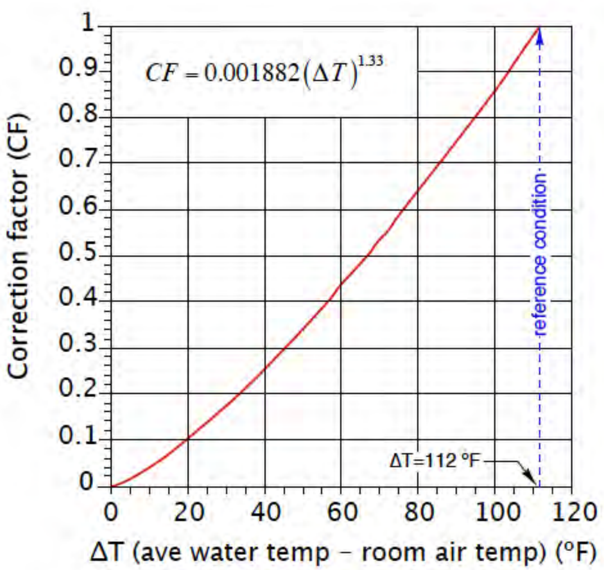


From setback to almost steady state in 4 minutes...

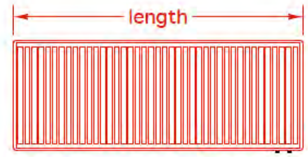


Panel Radiators

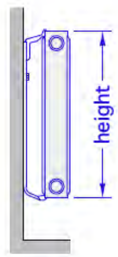
- Adjust heat output for operation at lower water temperatures.



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

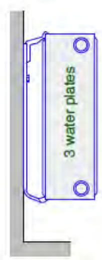


Heat output ratings (Btu/hr)
at reference conditions:
Average water temperature in panel = 180°F
Room temperature = 68°F
temperature drop across panel = 20°F



	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

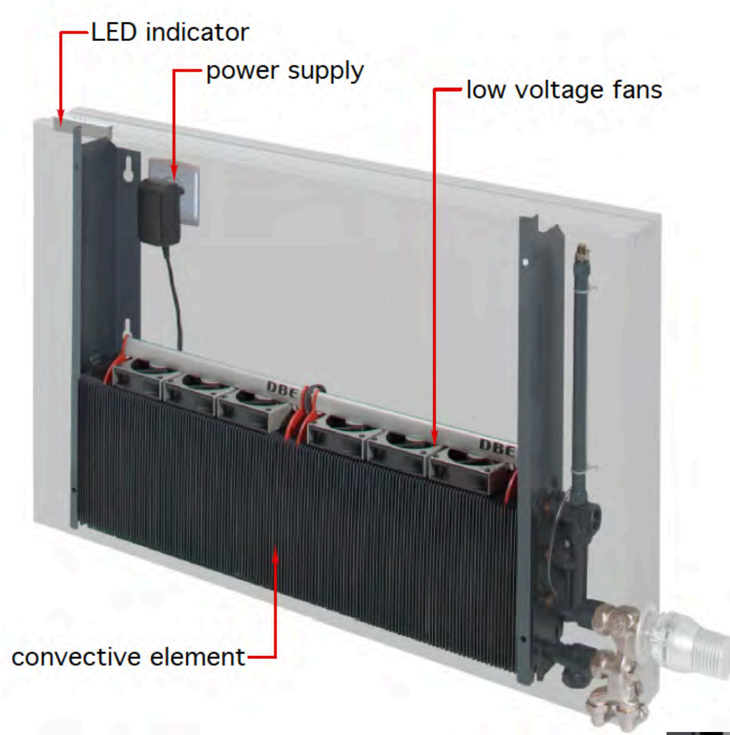
	2 water plate panel thickness					
	16" long	24" long	36" long	48" long	64" long	72" long
24" high	3153	4750	7127	9500	12668	14254
20" high	2733	4123	6186	8245	10994	12368
16" high	2301	3455	5180	6907	9212	10363
10" high	1491	2247	3373	4498	5995	6745



	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.

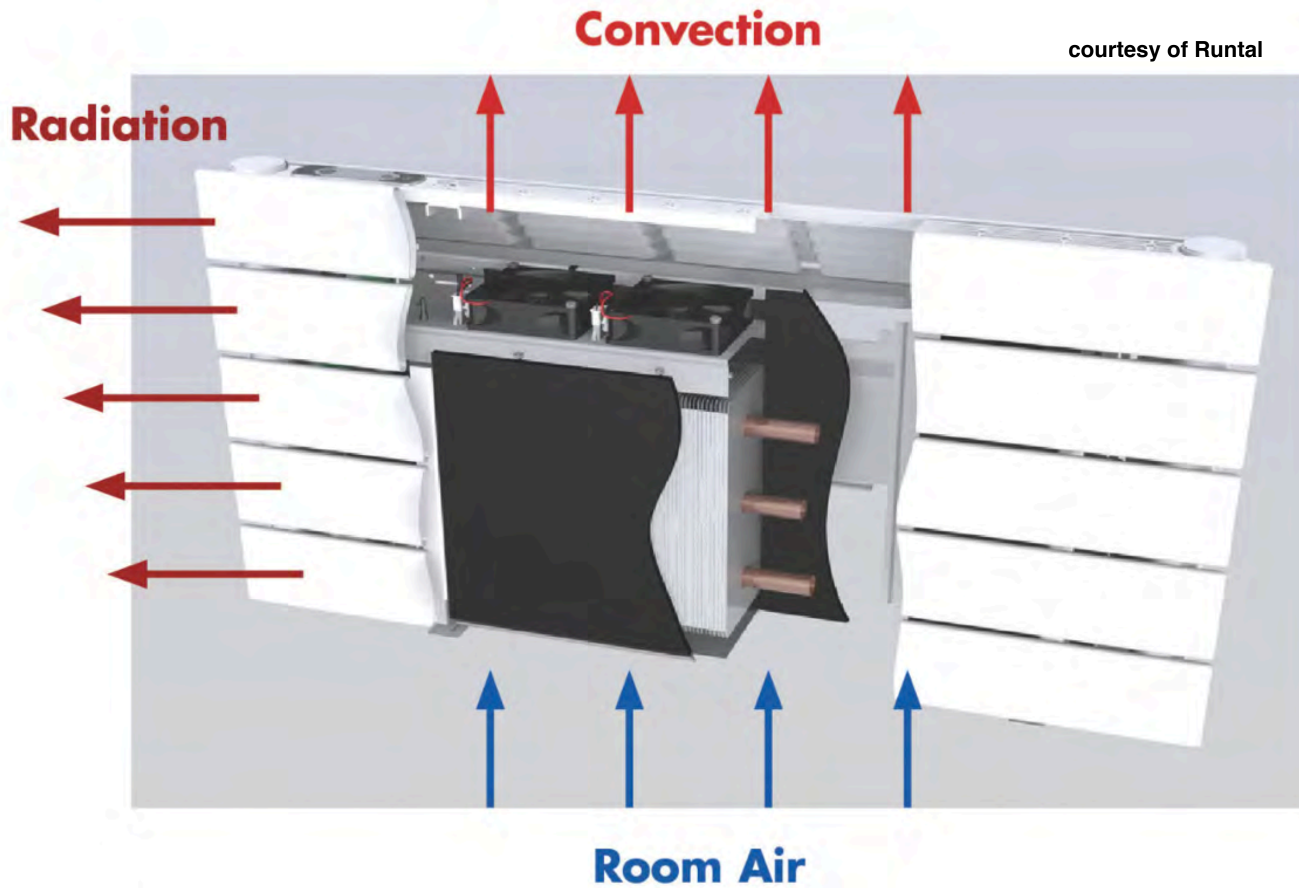
Adding low wattage fans to a low water content panel can boost heat output 50% during normal comfort mode, and over 200% during recovery from setback conditions



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

Fan-assisted Panel Radiators

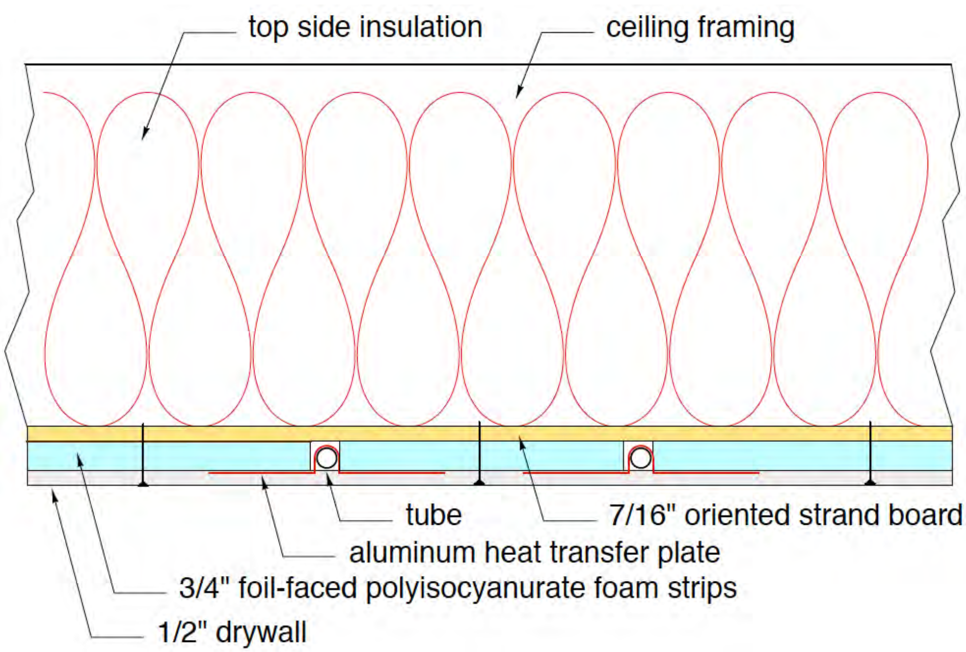
The "NEO", just released from Runtal North America

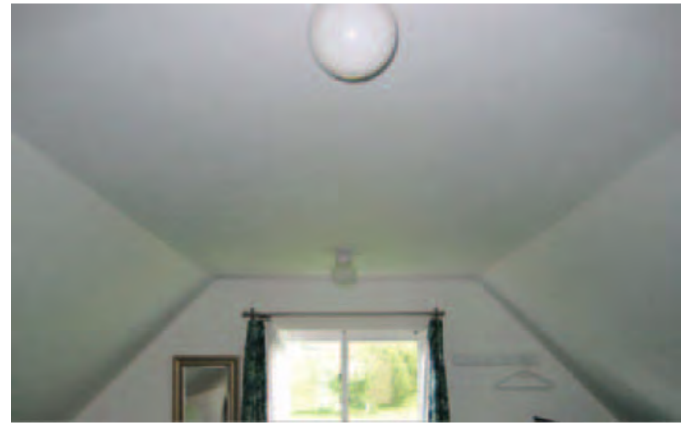


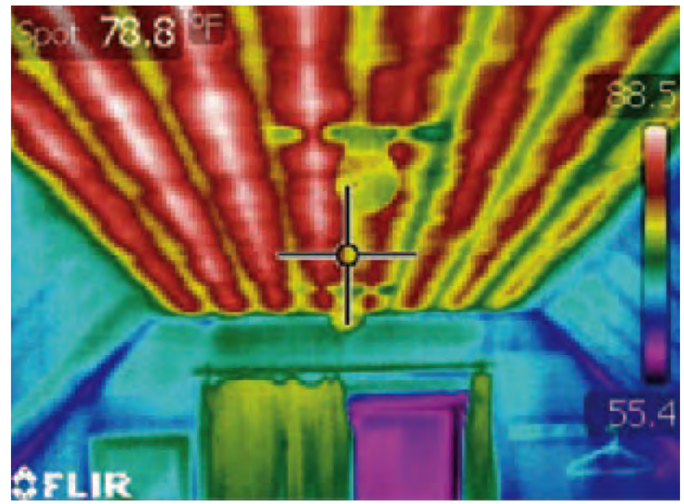
8 tube high x 31.5" wide produces 2095 Btu/hr at average water temperature of 104 ºF in 68ºF room

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

Site built radiant CEILINGS...







Thermal image of radiant ceiling in operation

Heat output formula:

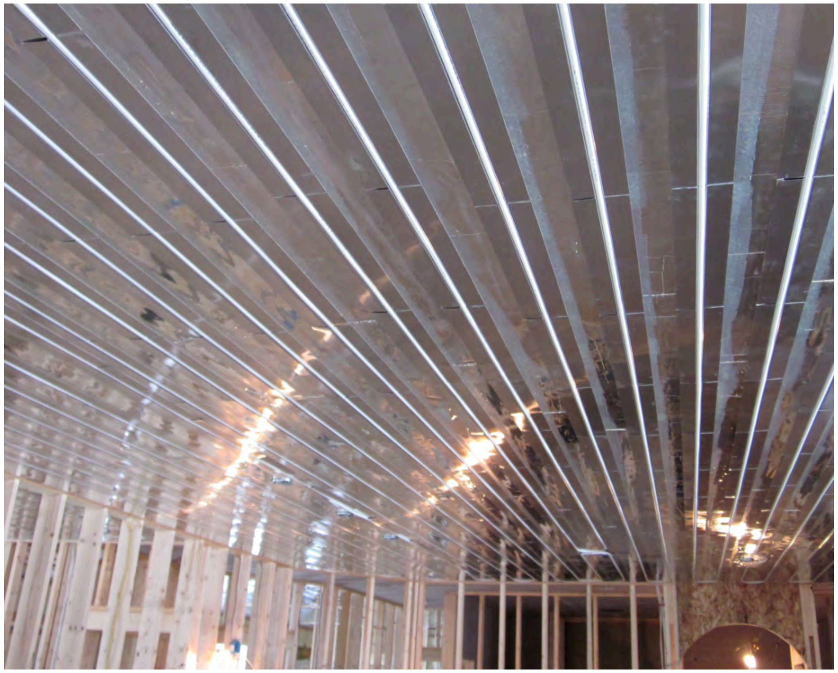
$$q = 0.71 \times (T_{water} - T_{room})$$

Where:

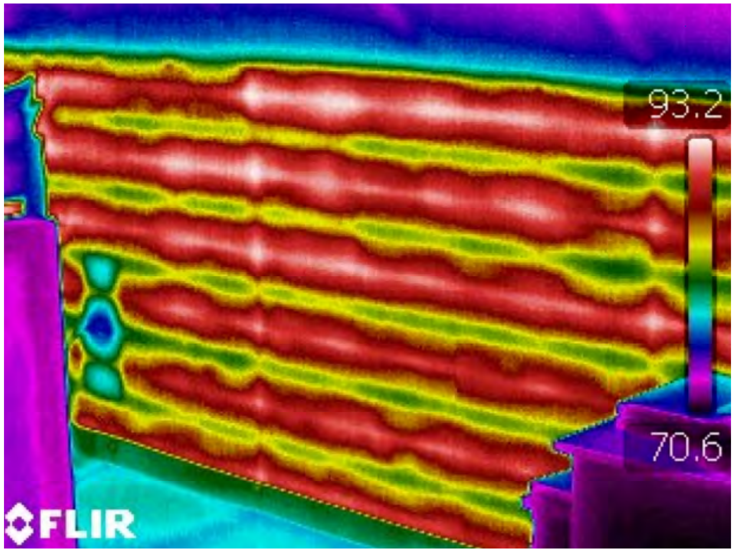
Q = heat output of ceiling (Btu/hr/ft²)
T_{water} = average water temperature in panel (ºF)
T_{room} = room air temperature (ºF)

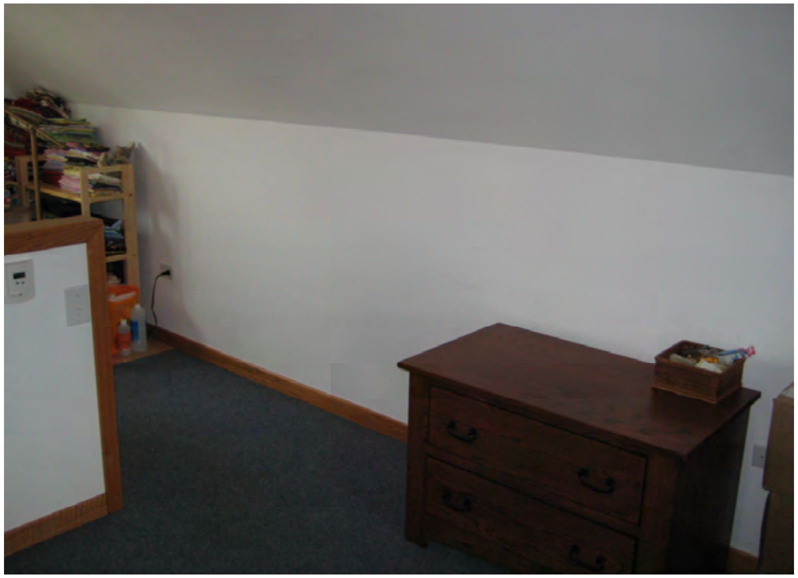
Site built radiant CEILINGS...



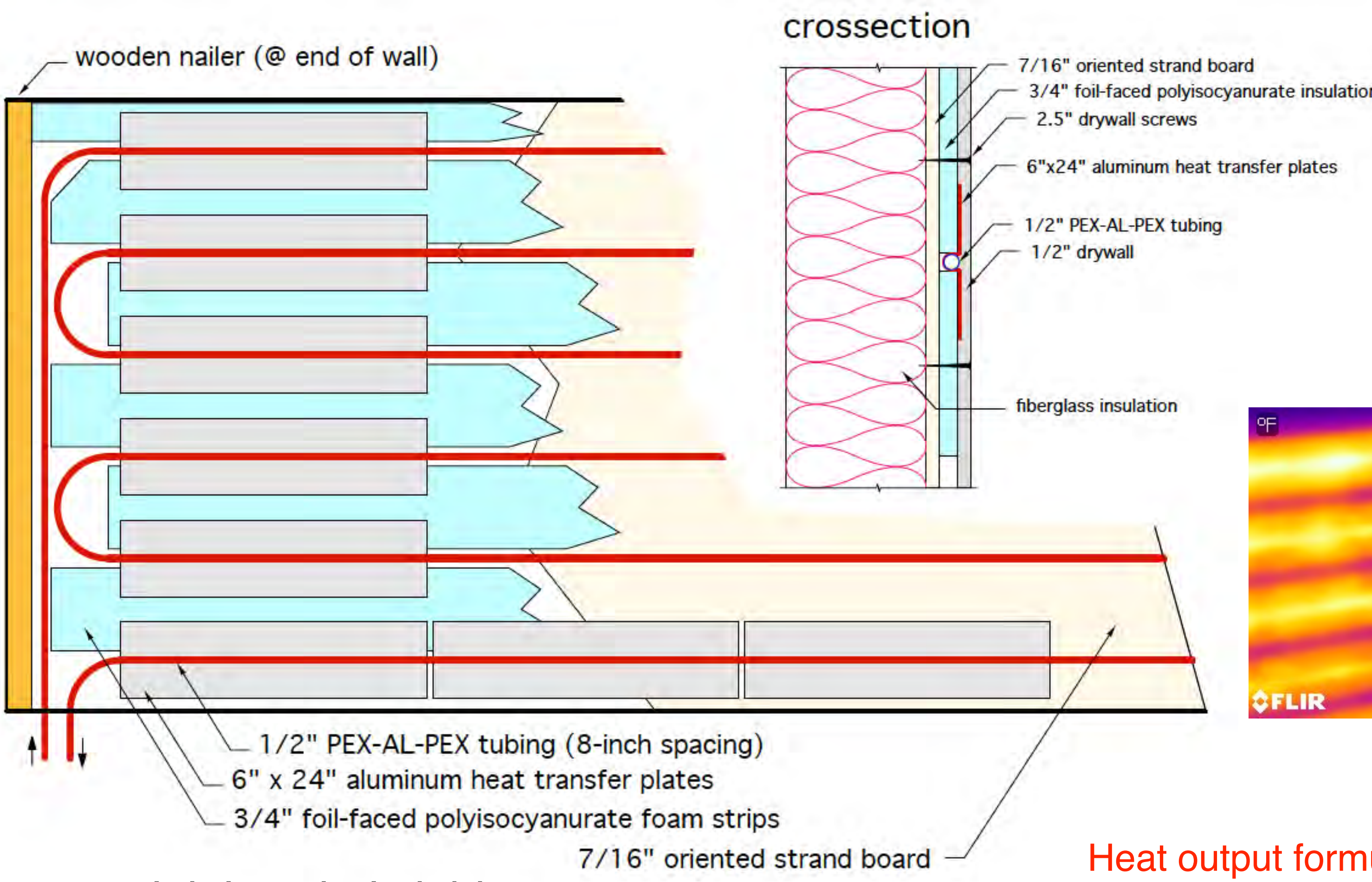



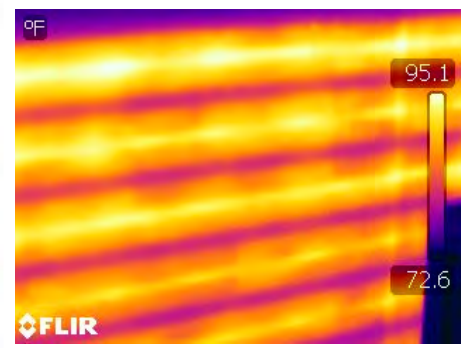
Site built radiant WALLS...





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

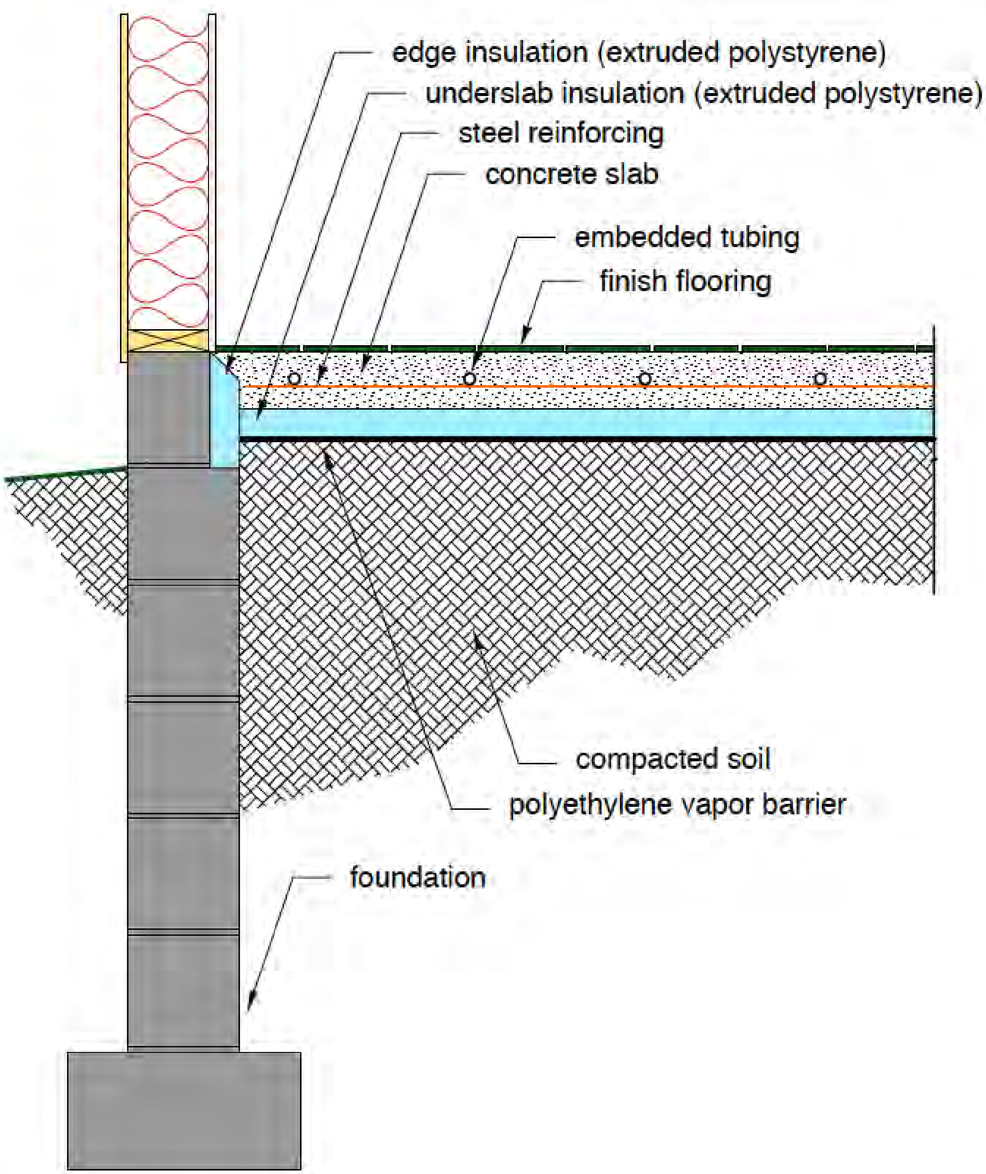
Heat output formula:

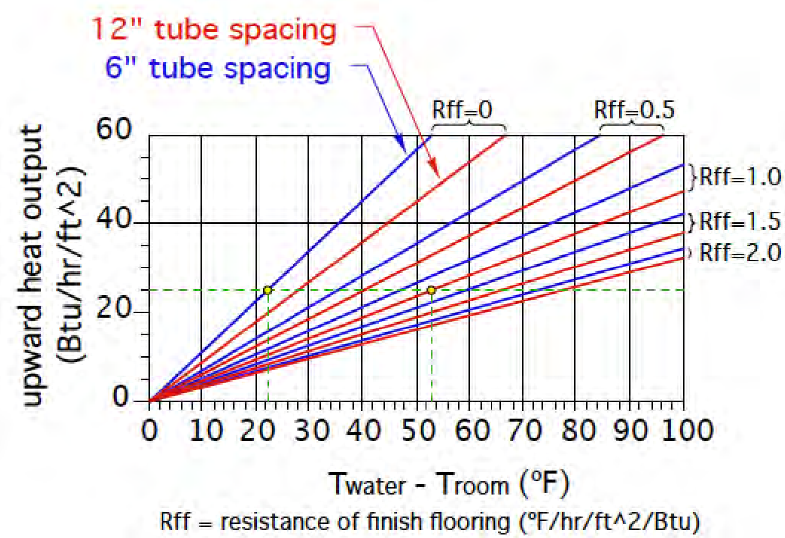
$$q = 0.8 \times (T_{water} - T_{room})$$

Where:

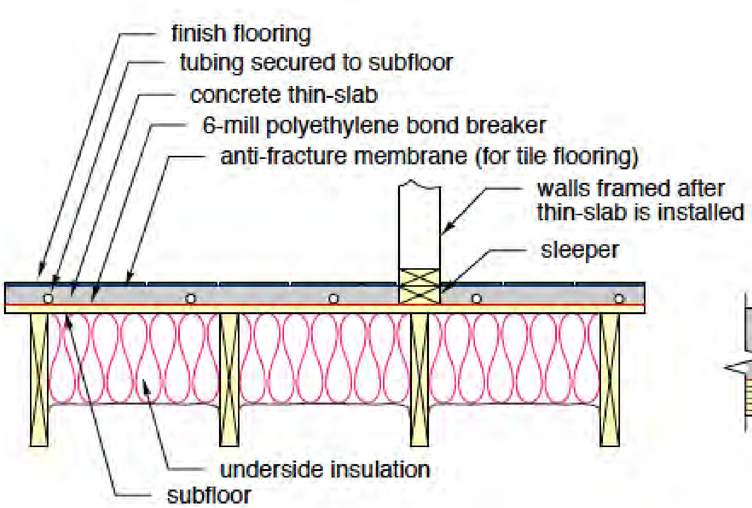
Q = heat output of wall (Btu/hr/ft^2)
T_{water} = average water temperature in panel (°F)
T_{room} = room air temperature (°F)

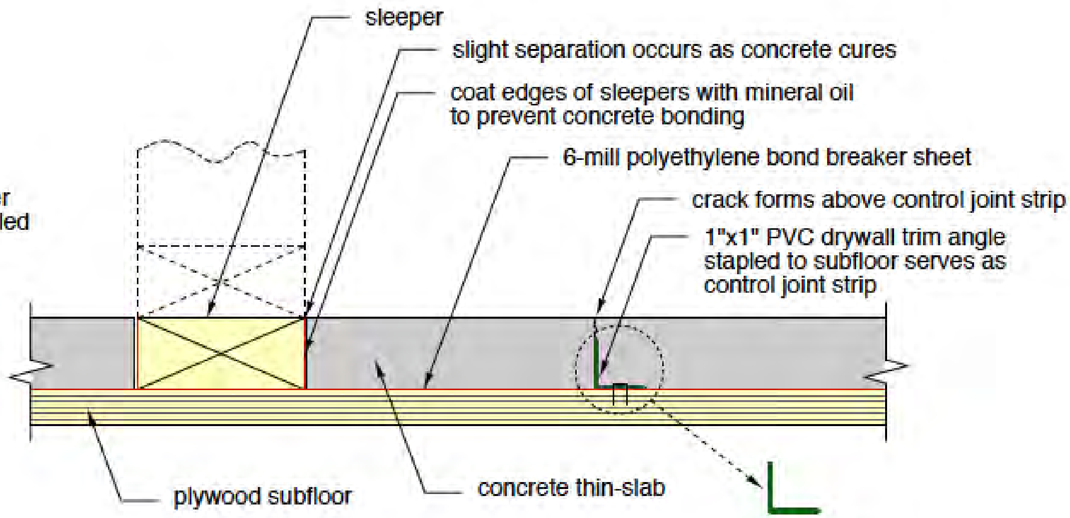
Slab-on-grade floor heating





Thin-slab floor heating (using concrete)



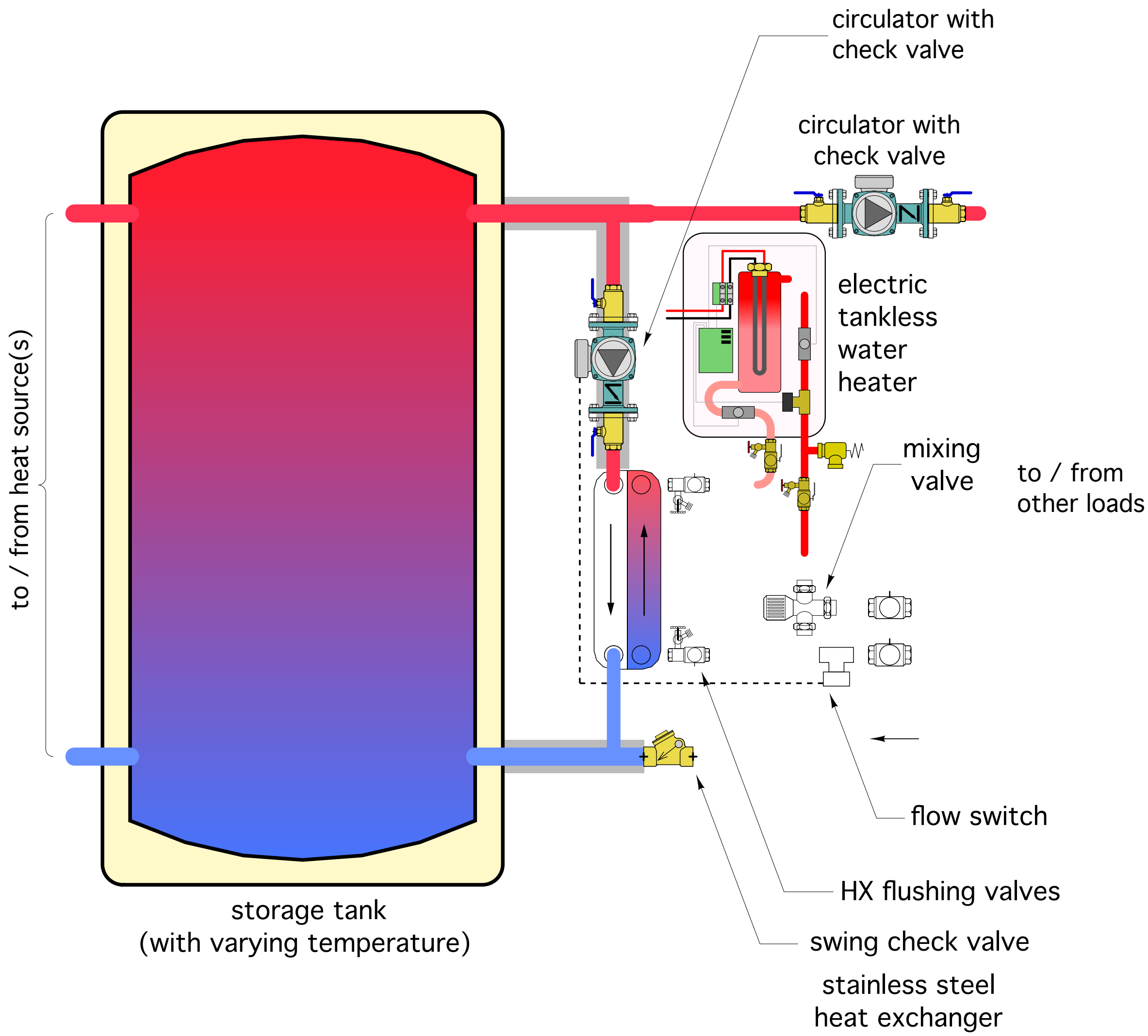


Instantaneous DHW subassembly

Starting points:

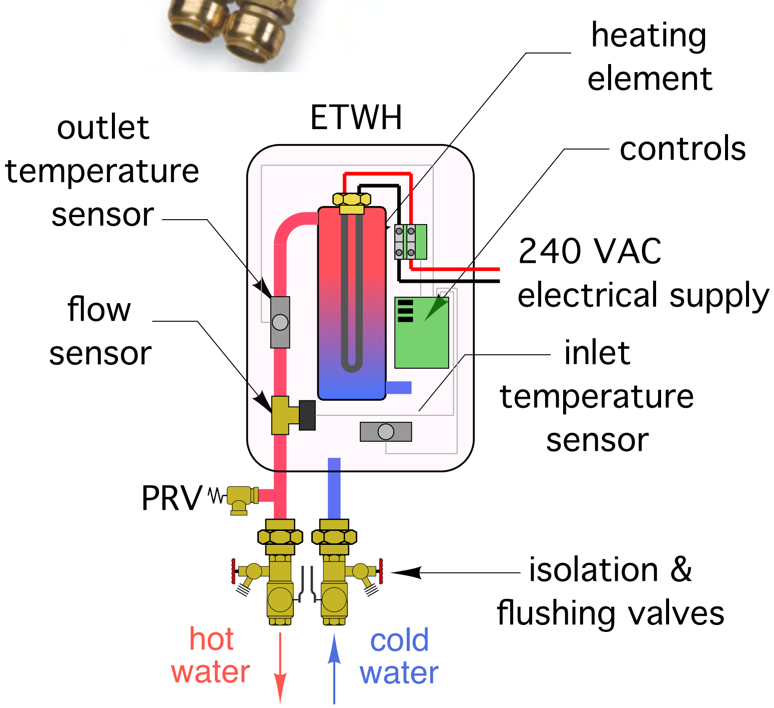
- Nearly all thermally-based renewable heat sources require significant heat storage.
    - Solar thermal system
    - Geothermal heat pump systems
    - **Wood- and pellet-fired boilers**
- Most of these systems use water for thermal storage.
- It almost always makes sense to use these heat sources to provide domestic hot water, as well as space heating.
- Even low storage tank temperatures are useful for preheating domestic hot water.
- Keeping all portions of the DHW system outside the thermal storage tank has several benefits.
- Hydronic based instantaneous domestic water heating has been used in thousands of European installations .
- Modulating electric tankless water heaters have some distinct advantages in dealing with preheated water.
- Brazed plate stainless steel heat exchangers are readily available and have very fast response times.

Instantaneous DHW subassembly

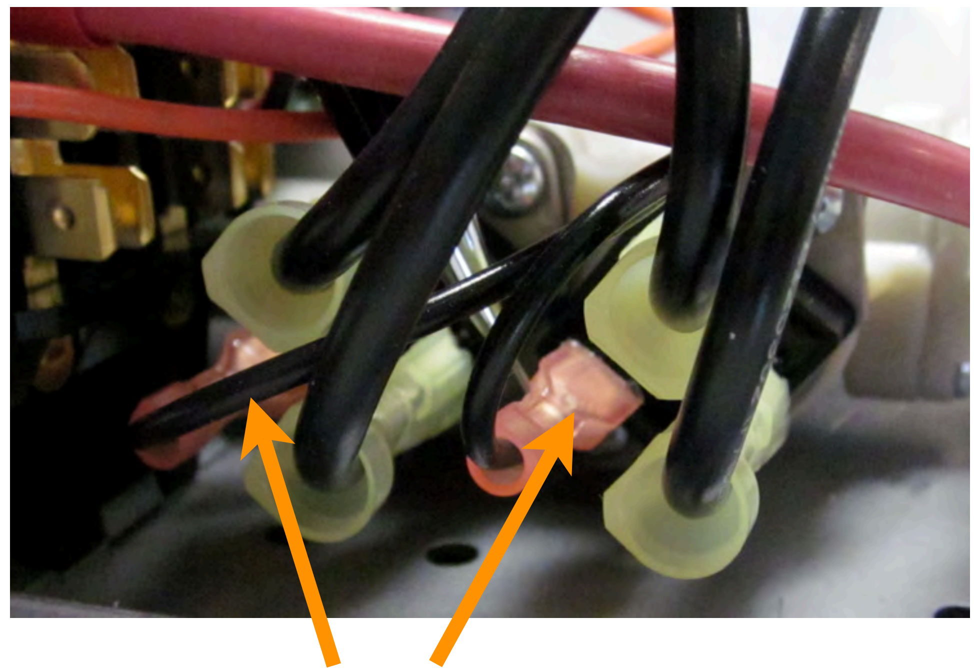


- Leverages the thermal mass for stabilizing DHW delivery.
- Brazed plate heat exchanger provides very fast response (1-2 seconds)
- Fully serviceable heat exchanger (unlike an internal coil heat exchanger) Can be cleaned or replaced if necessary.
- Predictable heat exchanger performance
- Very little 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



Thermostatically controlled electric tankless water heaters use a TRIAC to vary the wattage to their heating elements from 0 to 100%.



gates for TRIACS

They can therefor handle situations where preheated water needs a small temperature “boost” without short cycling.

Thermostatically controlled electric tankless water heaters

Electric tankless water heaters are HIGH AMPERAGE devices.

3.5 KW Requires 15 amp / 240VAC breaker

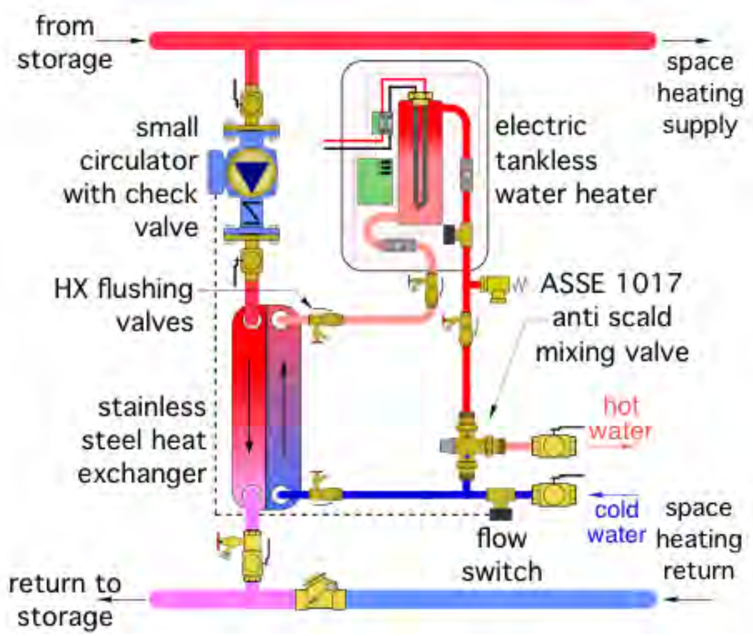
$$Amps = \frac{KW}{0.24}$$

Minimum 200 Amp breaker panel recommended.

May be an issue in some older retrofits.

23 KW Requires **TWO**, 50 amp /240VAC breakers

Instantaneous DHW subassembly



3”x5”

5”x12”

10”x20”

Brazed plate stainless steel heat exchangers are widely available.

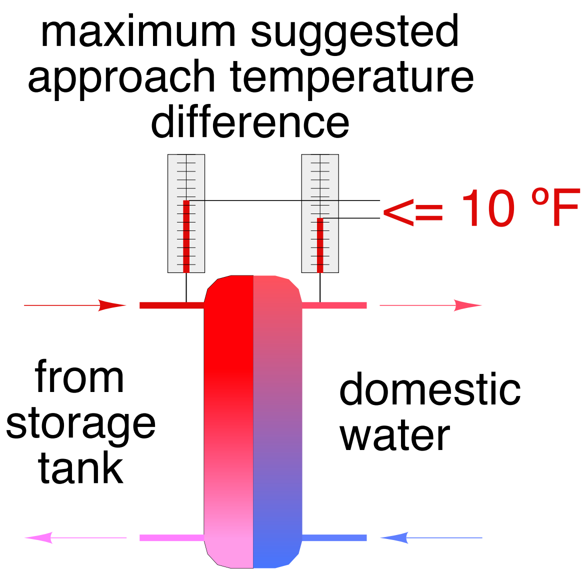
They have very high ratio of surface area to volume.

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)

Sizing the brazed plate heat exchanger

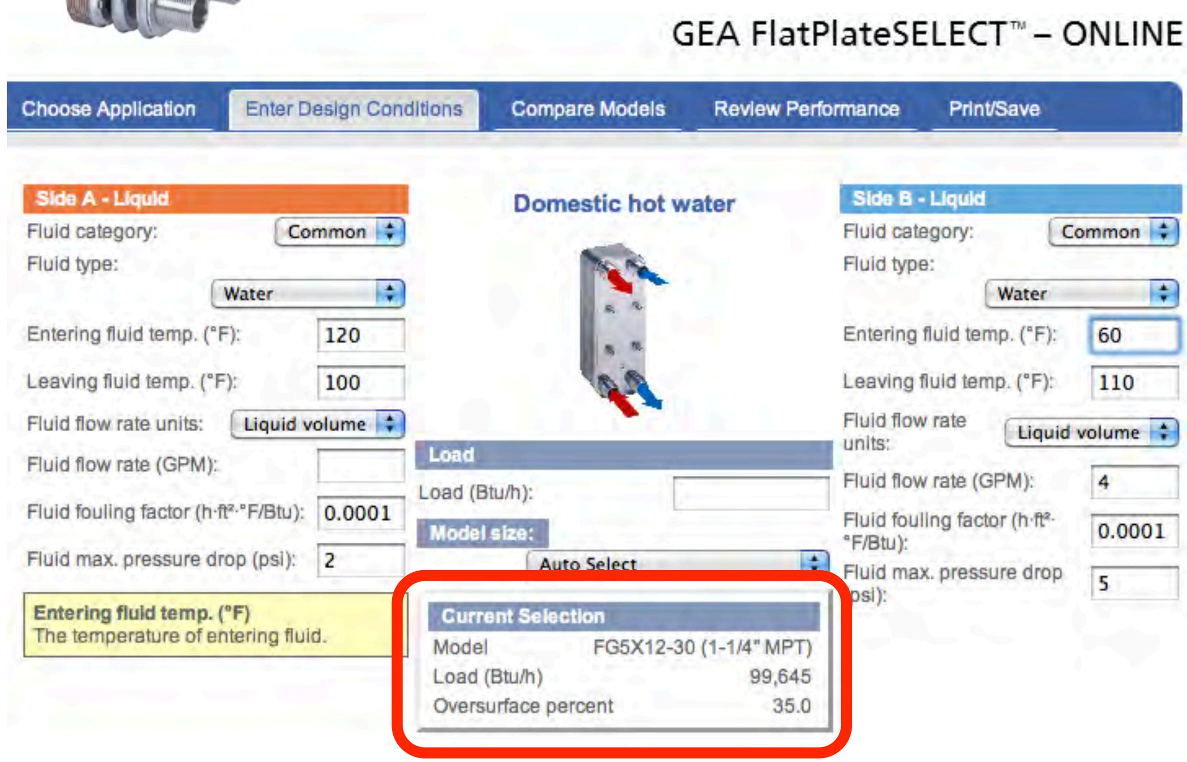
Suggest a maximum approach temperature difference of 10 °F under max. anticipated water demand, and minimum preheat inlet temperature.



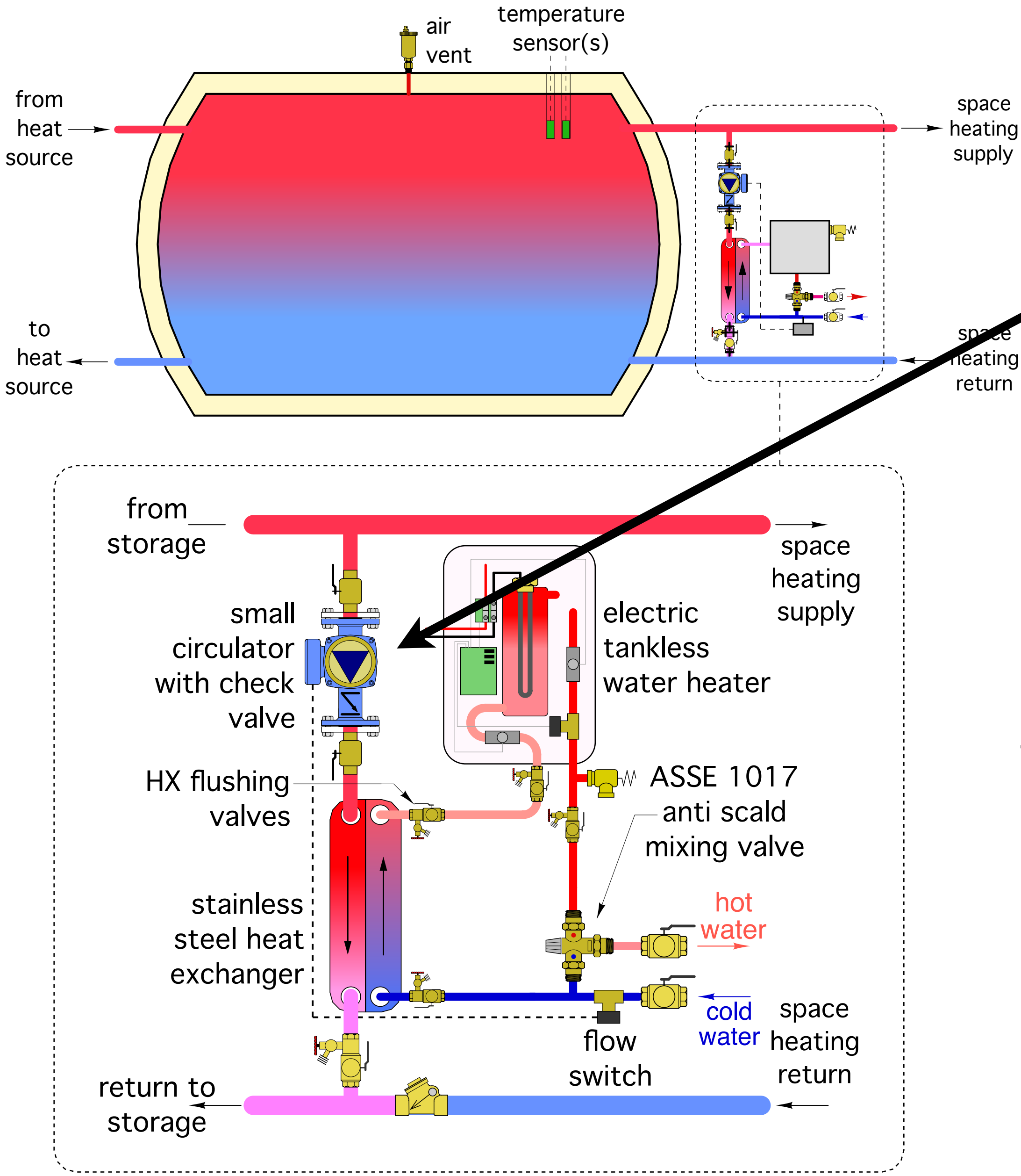
FG5x12-30

5” wide x12” long -30 plates

http://flatplateselect.com



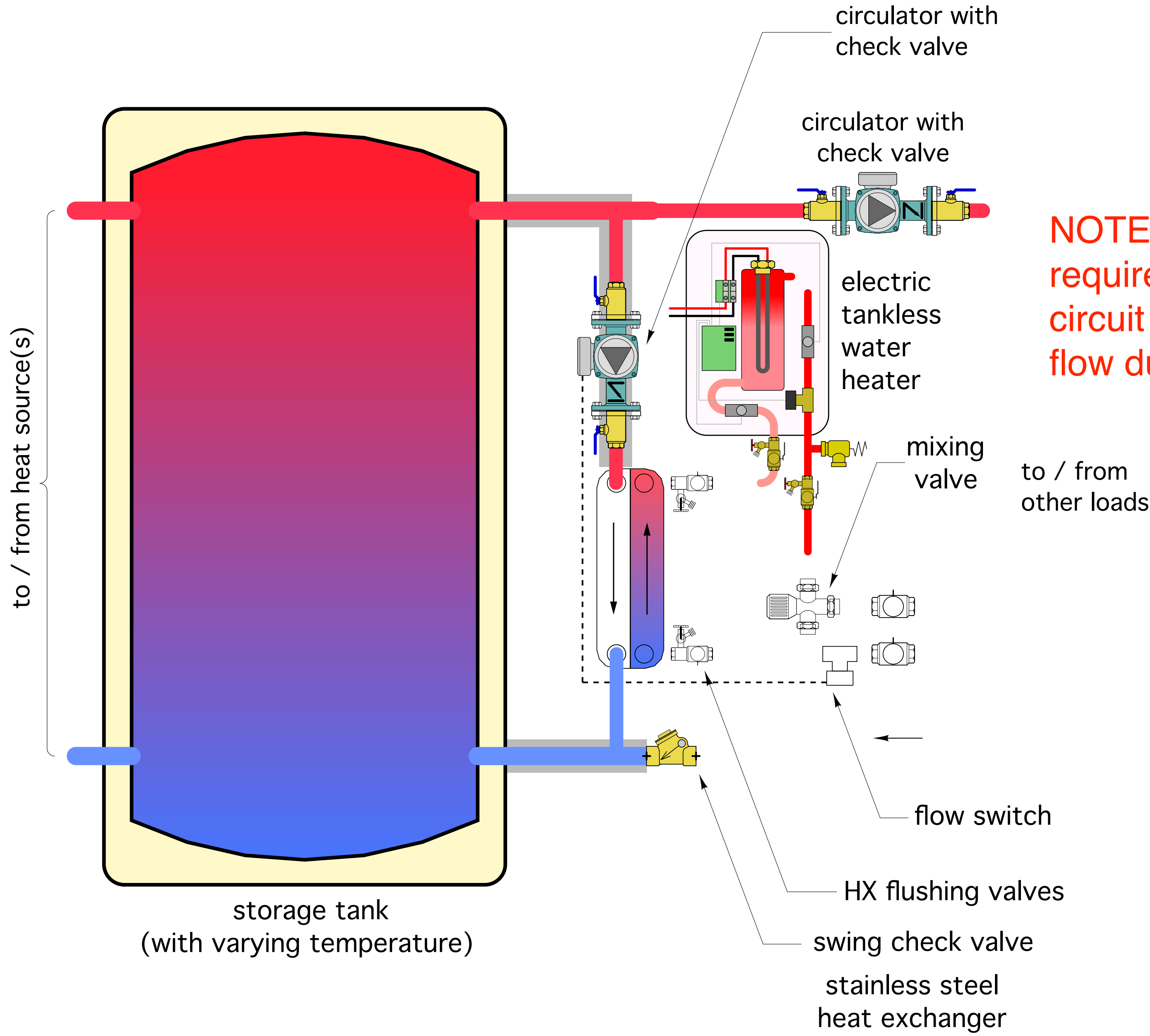
Instantaneous DHW subassembly



B&G Vario circulator operating at 33 watts yields10 gpm as required to raise 4 gpm of water from 60 to 110 ºF through FG5x12-30 heat exchanger supplied by 120ºF water from thermal storage.

To deliver 60 gallons per day at average draw rate of 2 gpm, this circulator would operate for 30 minutes, and consume 0.0165 KWHR. Operating cost of this circulator would be $0.78 per YEAR.

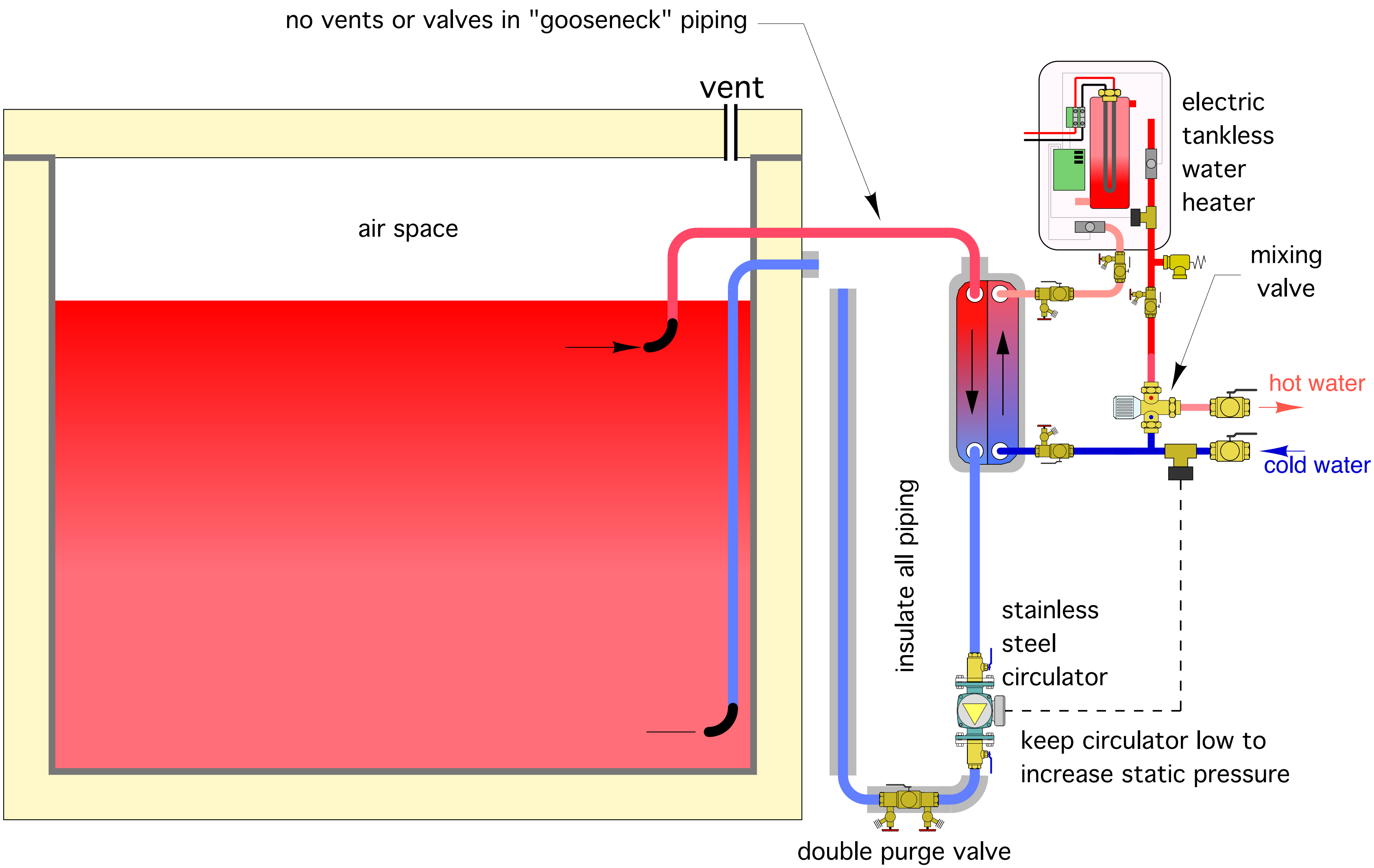
Instantaneous DHW subassembly piping



NOTE: Check valve required on tank-to-HX circuit to prevent reverse flow during space heating

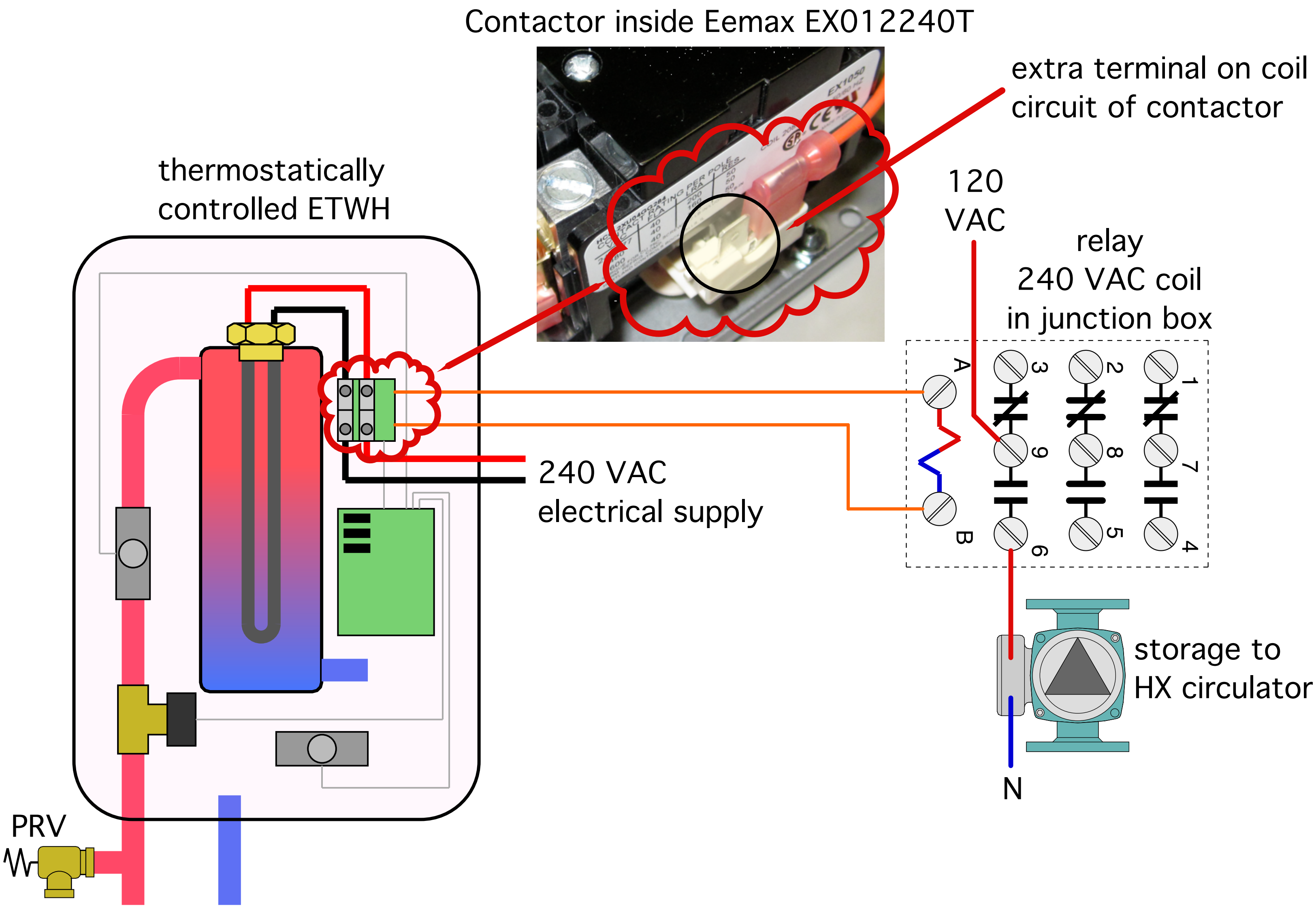
Instantaneous DHW subassembly piping

Using it with unpressurized thermal storage



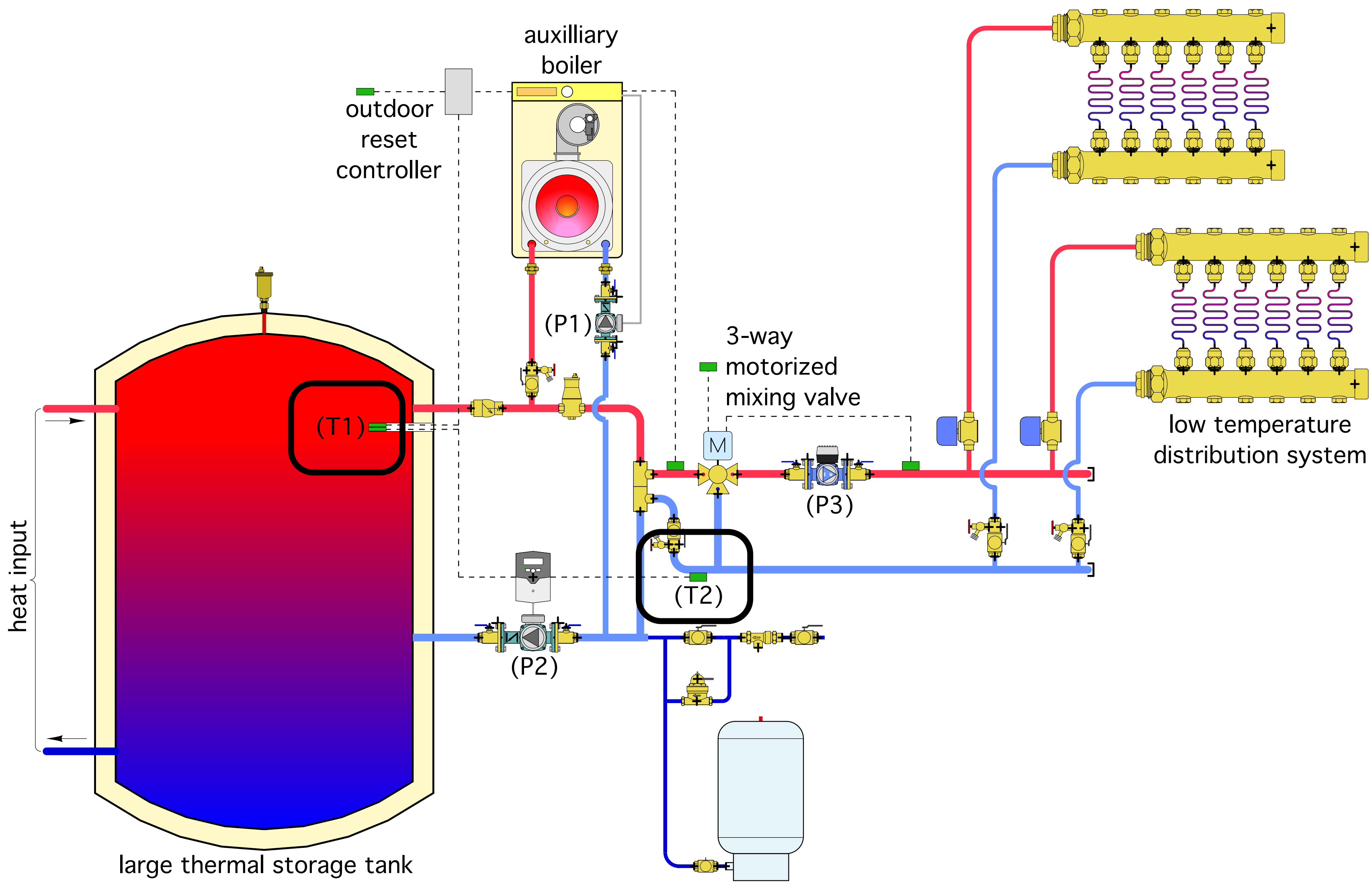
Using extra terminal on ETWH contactor to operate circulator

This eliminates the need for the flow switch.

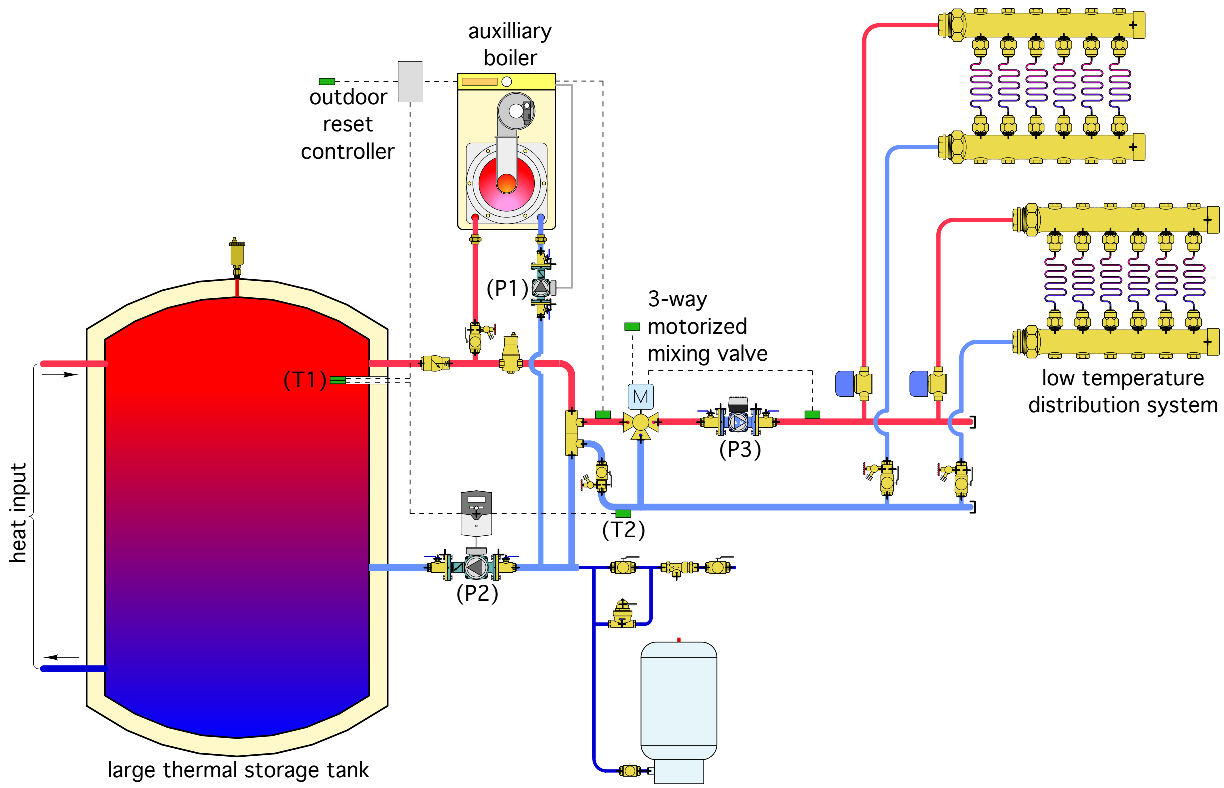


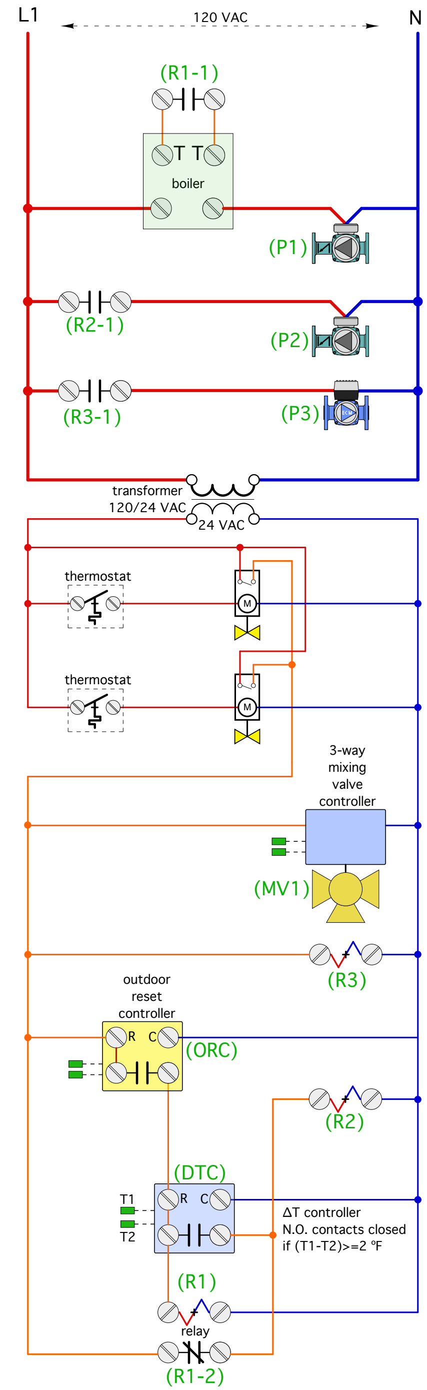
Heat scavenging from storage

Concept: As long as the temperature returning from the distribution system is lower than the temperature at top of storage, heat can be extracted from storage.



Concept: As long as the temperature returning from the distribution system is lower than the temperature at top of storage, heat can be extracted from storage.



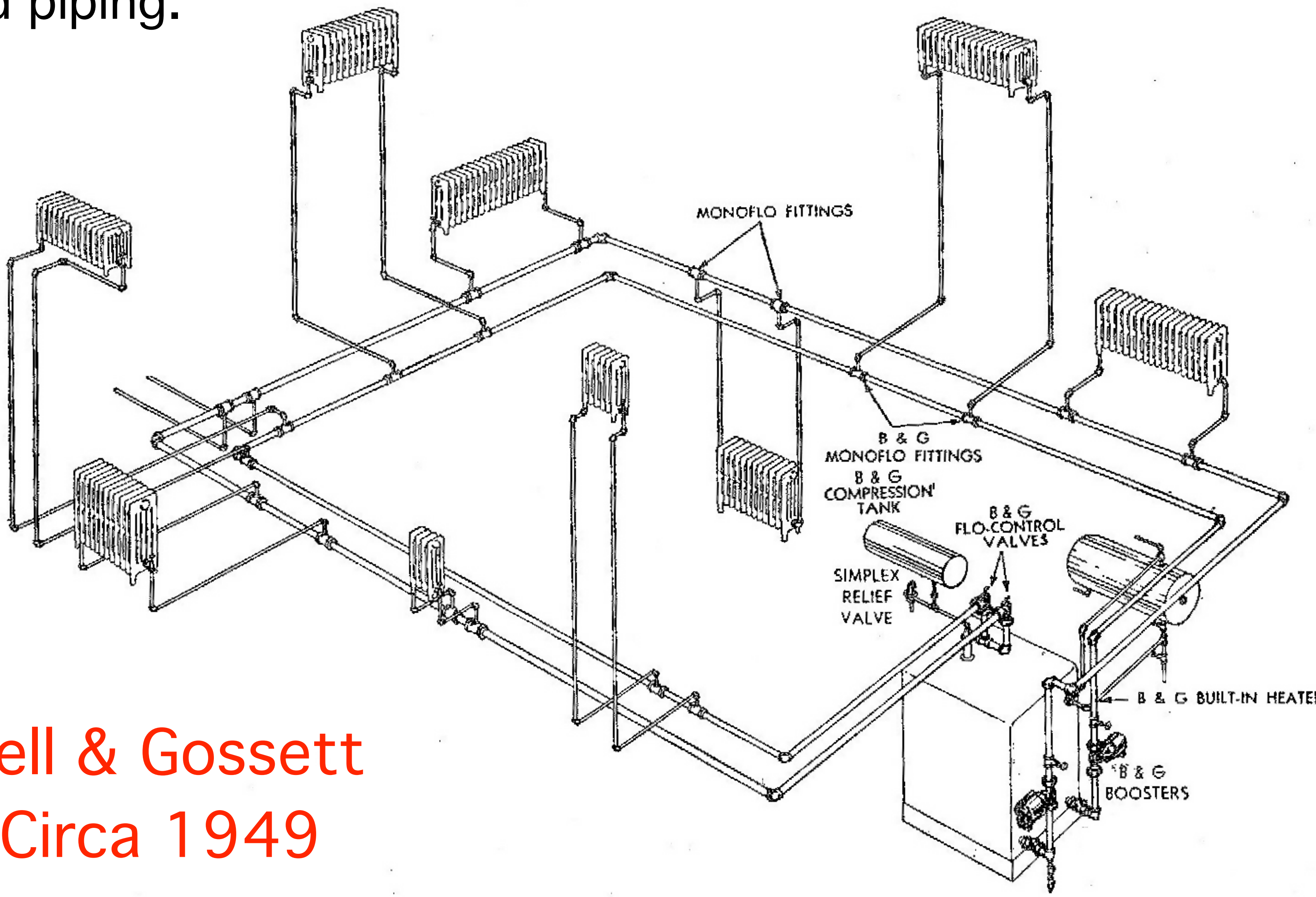


- Must use identical sensor mounting (preferably in wells)
- Practical for 500 gallon and larger tanks

$$Q = 8.33v(\Delta T) = 8.33 \times 500 \times (20) = 83{,}300\,Btu$$

Homerun Distribution Systems

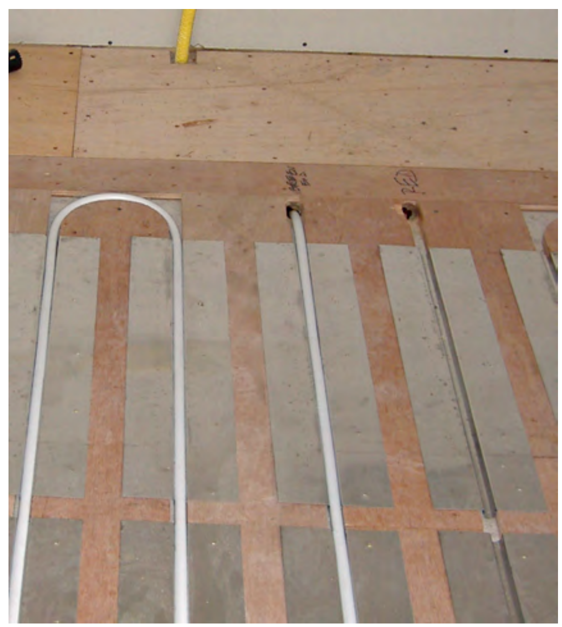
The vast majority of hydronic distribution system developed in North America over decades were based on rigid piping.



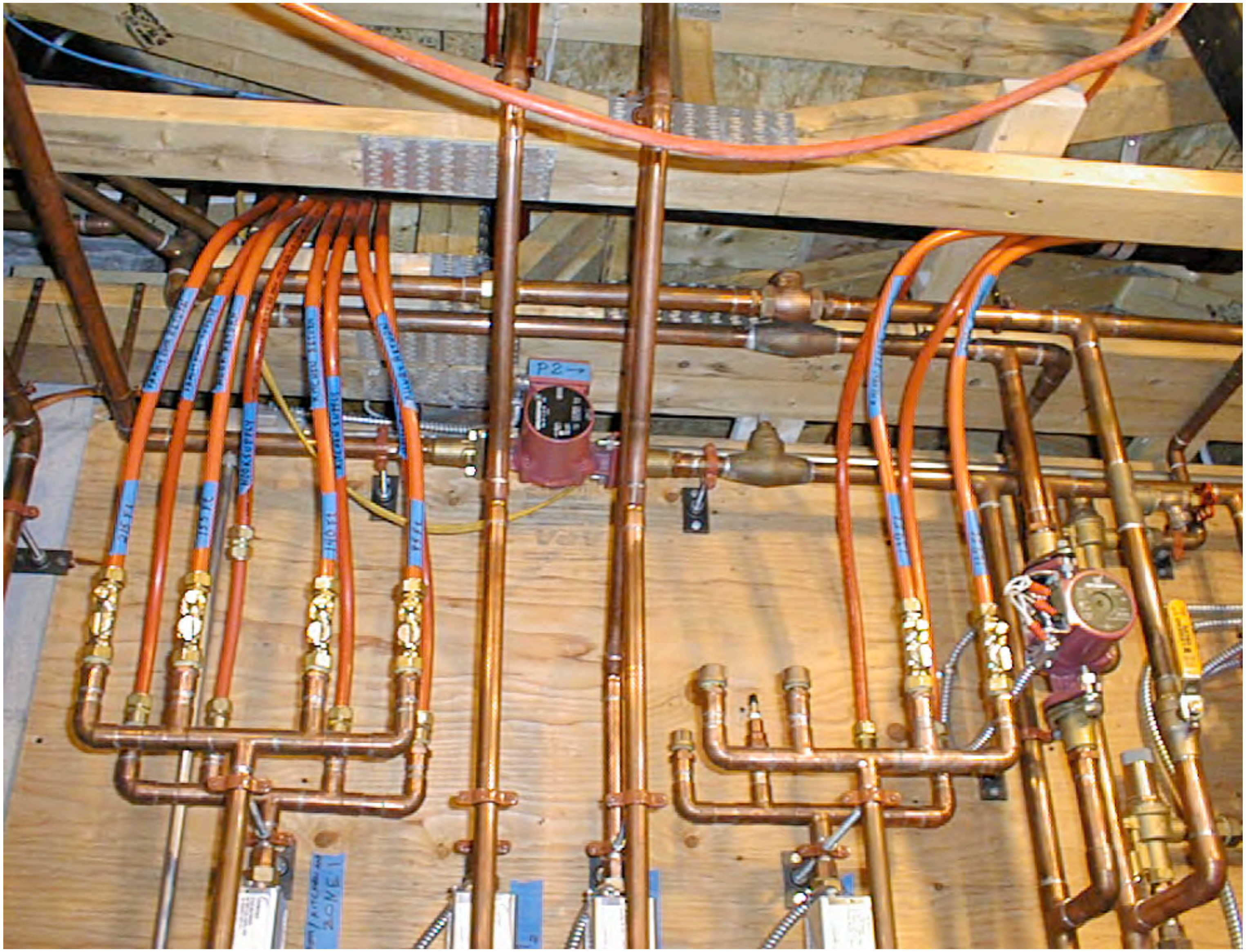
Bell & Gossett
Circa 1949

PEX tubing was introduced in North America in the early 1980s, and was viewed primarily for use in radiant floor heating applications.



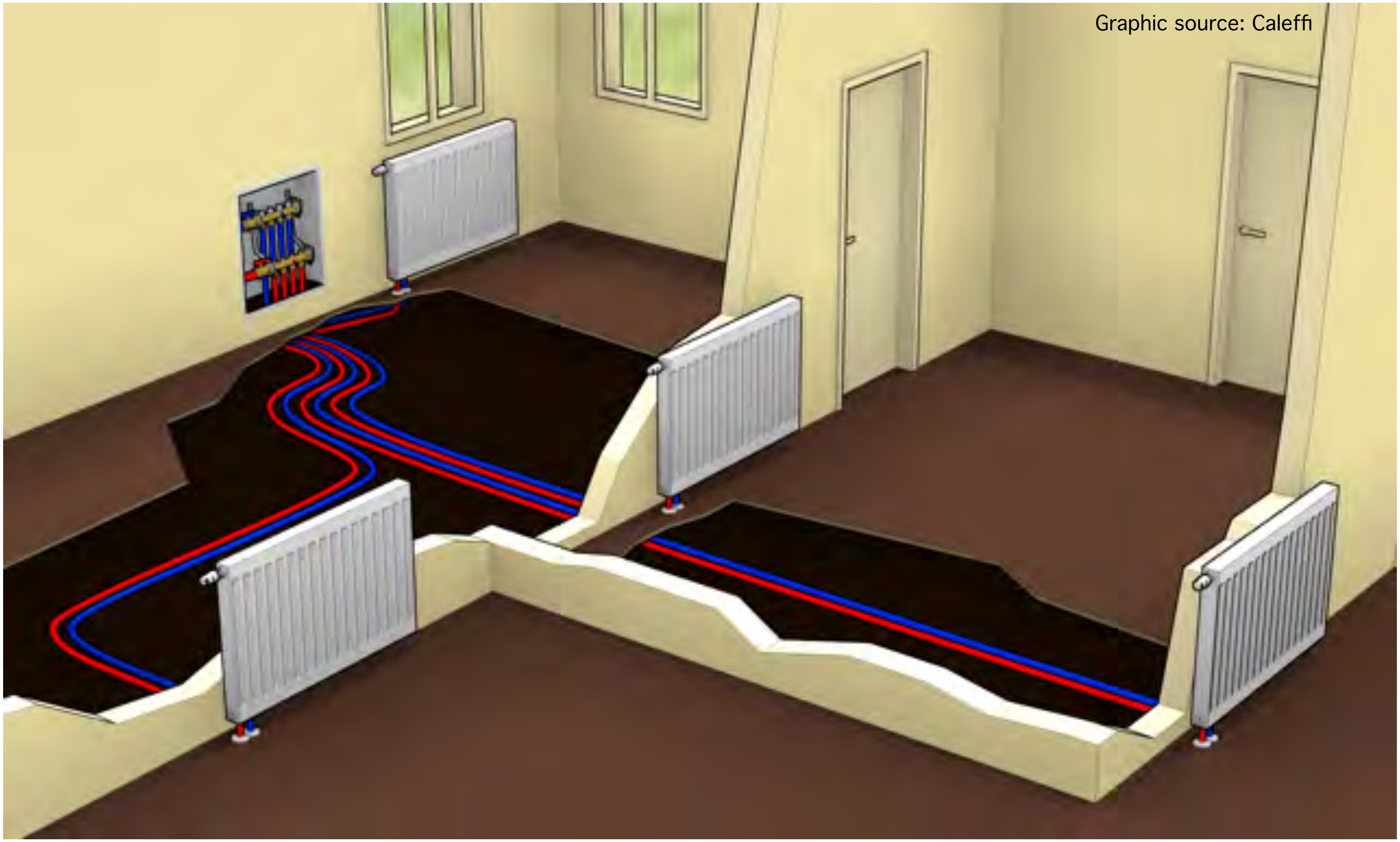



Slowly, some North American designers/installers began mixing PEX and PEX-AL-PEX tubing into system along with rigid tubing.



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

One of the best approaches using this pipe is a <u>"homerun"</u> system.


Graphic source: Caleffi

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.**

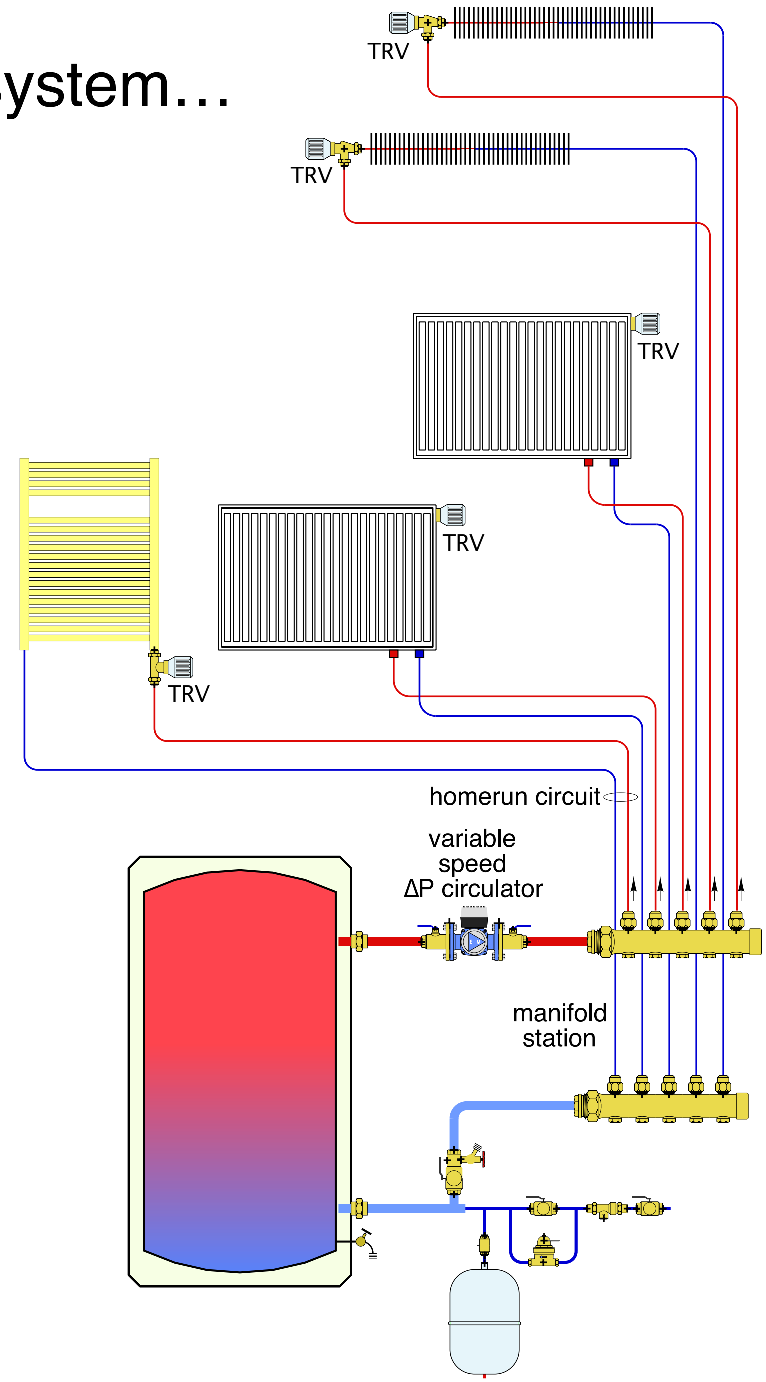
• Allows easy room-by-room zoning

• 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



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."

High efficiency circulators

Small ECM circulators now available in US

Grundfos Alpha: Provides constant and proportional differential pressure and three fixed speed settings. 6-50 watt electrical 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 Bumblebee Temperature based speed control. 9-42 watts electrical input

Larger ECM circulators now available in US

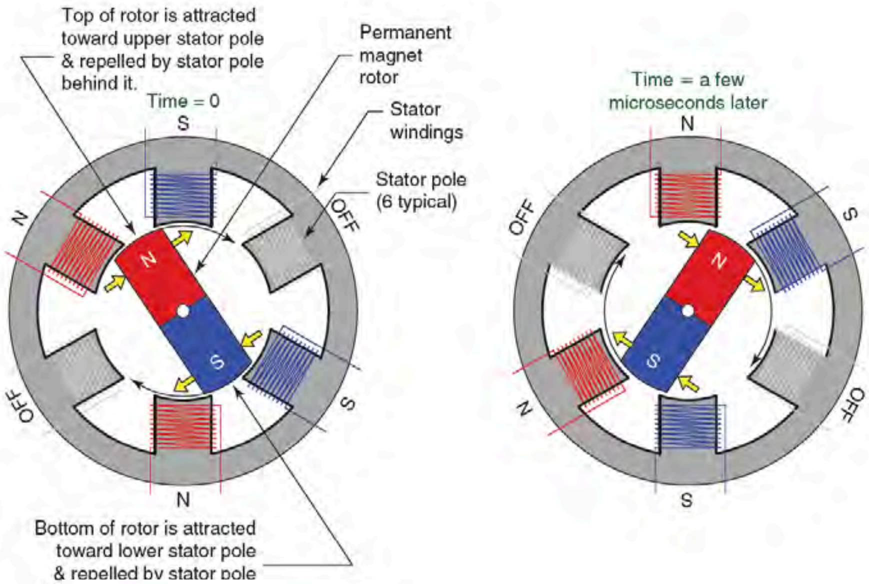
Grundfos MAGNA 3

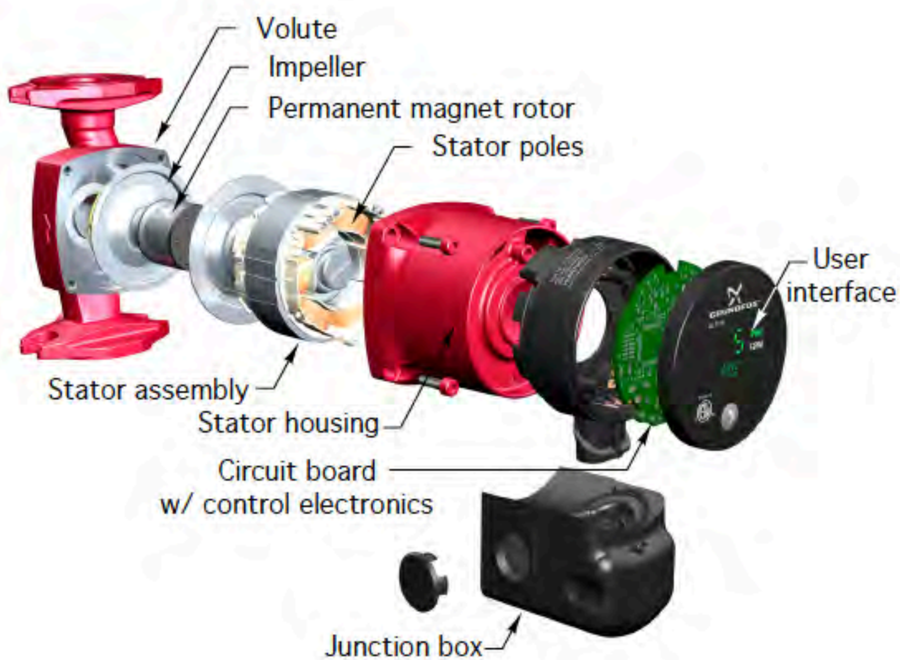
Taco
Viridian

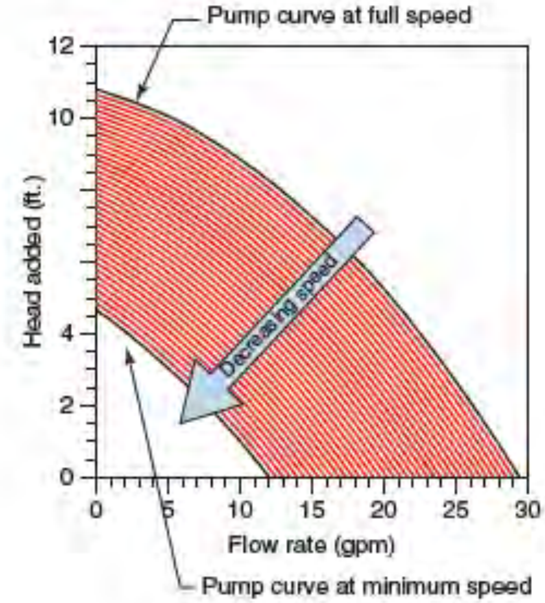
Heads to 45 feet,
flows to 345 gpm
power inputs to
1600 watts

Wilo STRATOS

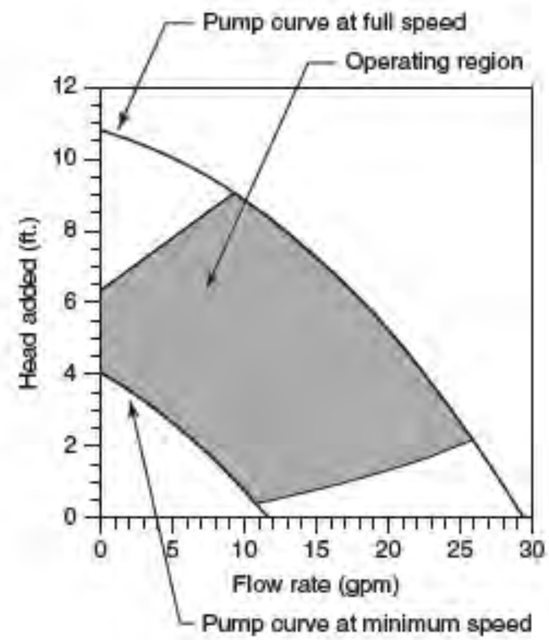
How does a ECM Circulator work?







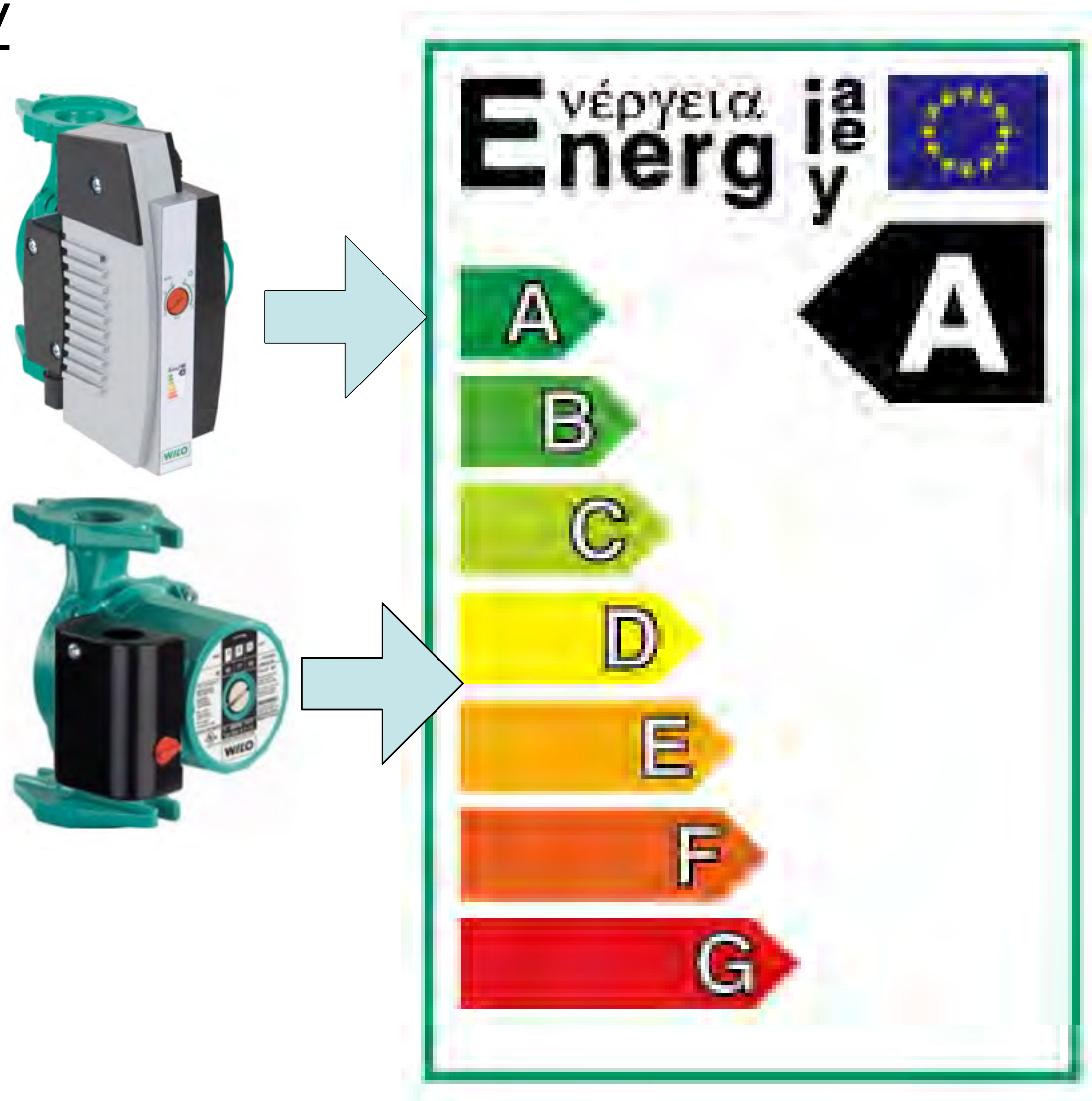
(a)



(b)

Current 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.

Sizing thermal storage

Sizing the storage tank for a wood gasification boiler

The size of the tank used with wood-fired boilers depends on several factors.
They include:

- How the boiler will be operated
- How much wood can be added to the boiler's firebox
- The potential heat content of the firewood being used
- minimum operating temperature of heating distribution system (lower is better)
- The temperature and pressure ratings of the buffer tank

Buffer tank size required to accept heat output of wood gasification boiler (assuming no concurrent load)

$$v = \frac{738(w)(n)}{\Delta T}$$

Where:
v = required buffer 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)
738 = a constant based on the heating fuel value associated with 20% moisture content firewood.

Sizing the storage tank for a wood gasification boiler

Example: Assume that the firebox of a wood-fired boiler, when fully loaded, can hold 100 pounds of seasoned firewood. The boiler's average combustion efficiency is 80%. Determine the buffer tank volume needed assuming the tank will rise 60ºF as it absorbs heat from burning the full charge of wood.

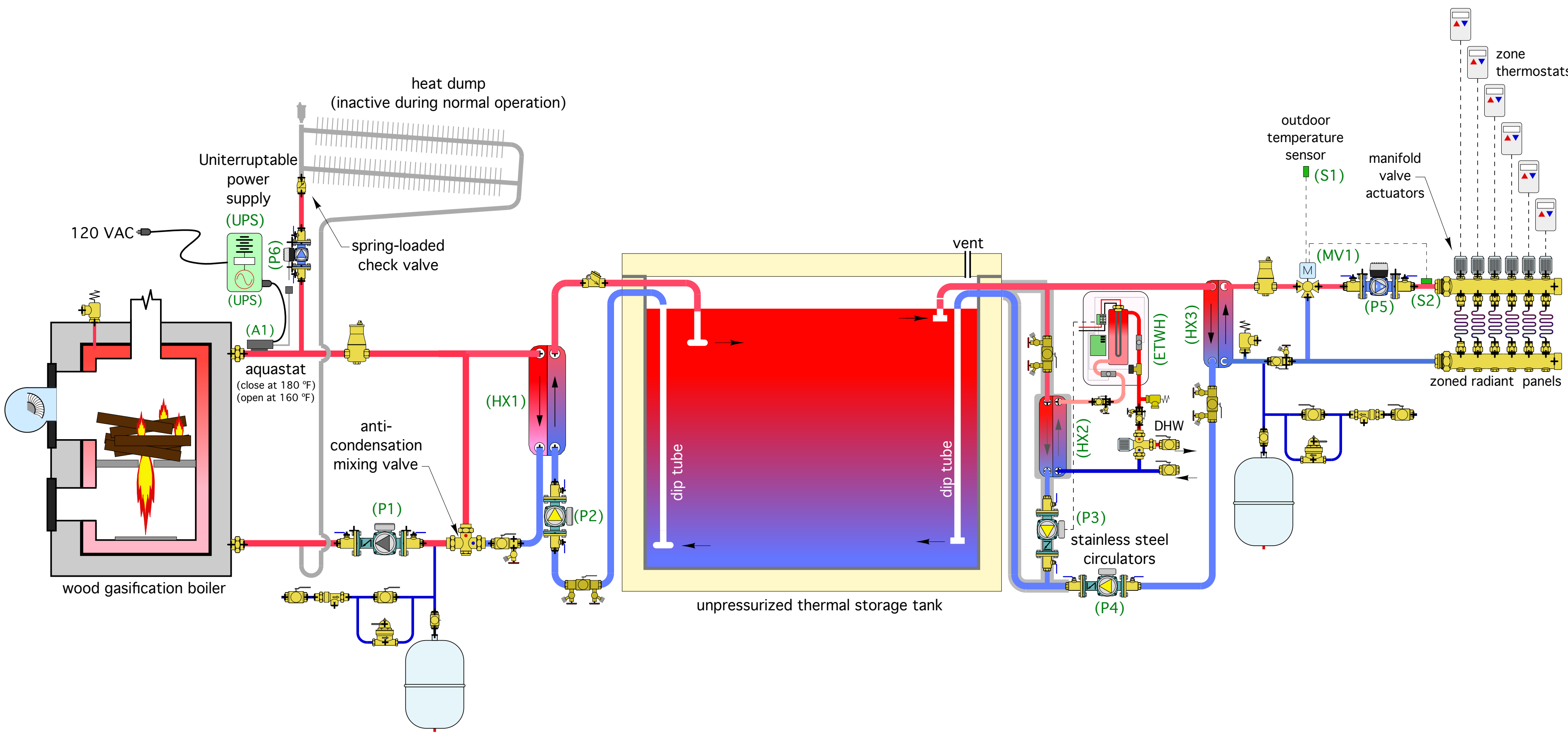
$$V = \frac{738(w)(n)}{\Delta T} = \frac{738(100)(.80)}{60} = 984\,gallons$$

Where:
v = required buffer 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 (ºF)
738 = a constant based on the heating fuel value associated with 20% moisture content firewood.

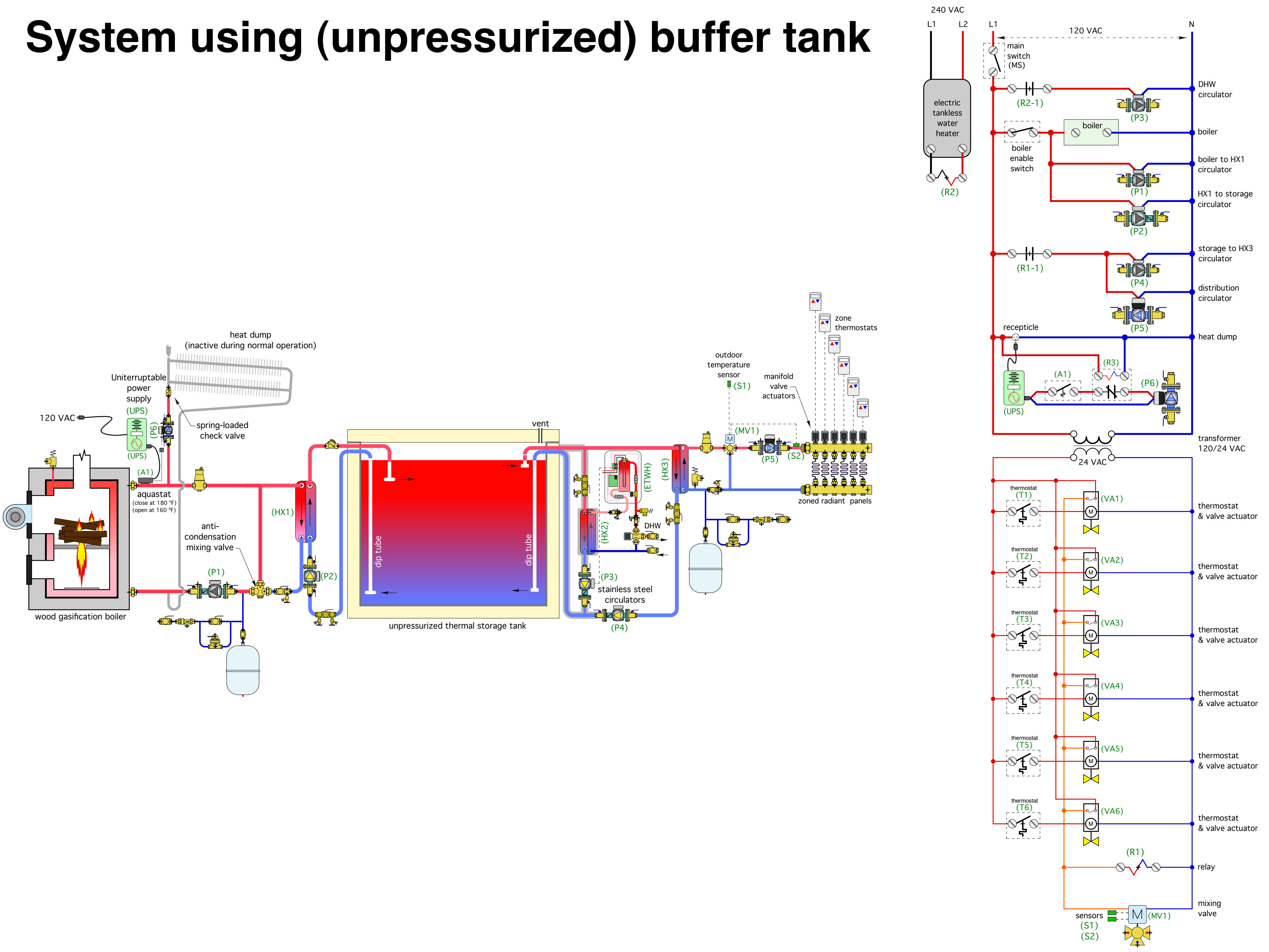
System Examples

System using (unpressurized) buffer tank

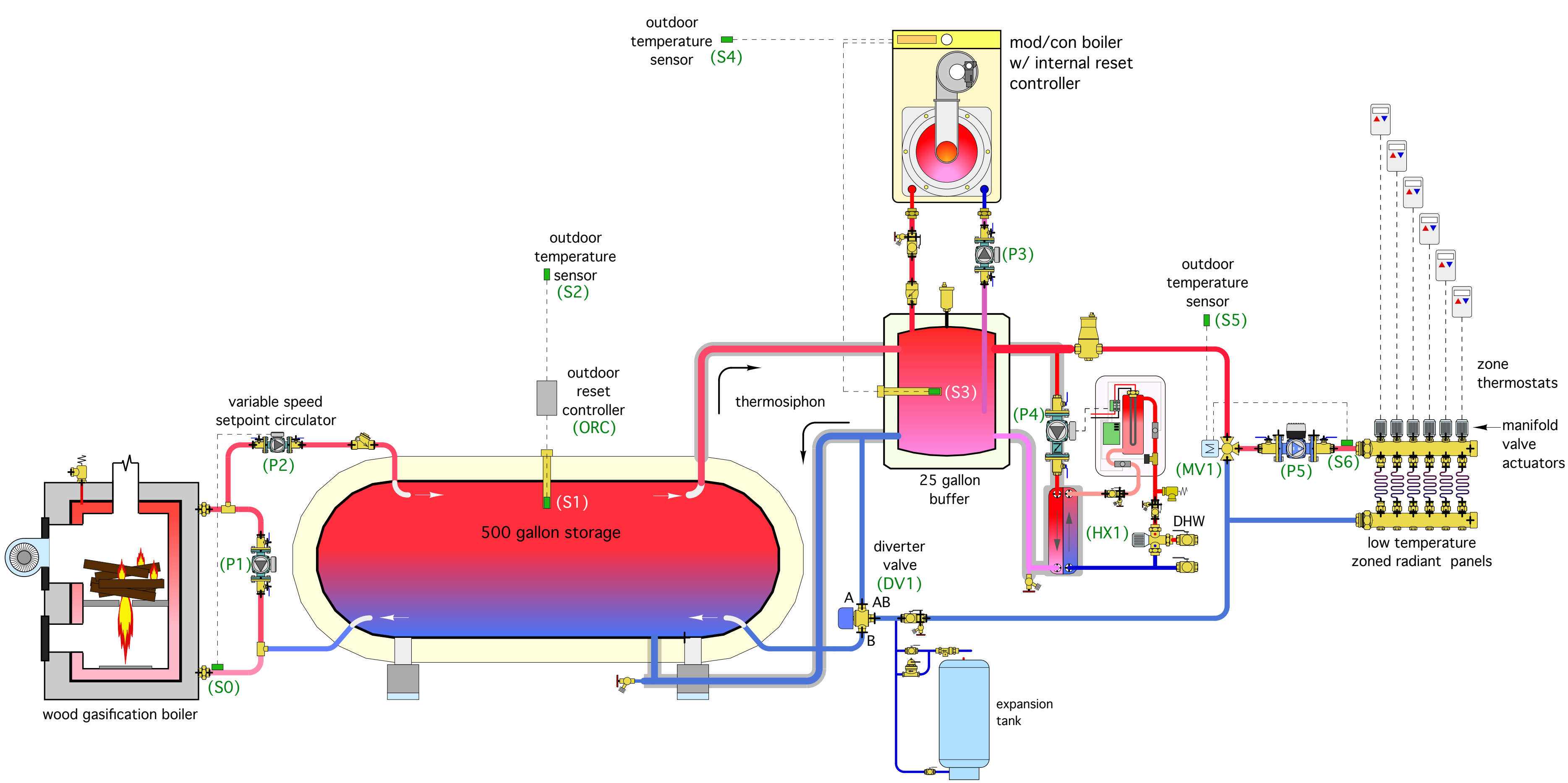
- Closed loop boiler circuit
- Closed distribution system
- All external brazed plate heat exchangers
- DHW boost using electric tankless water heater



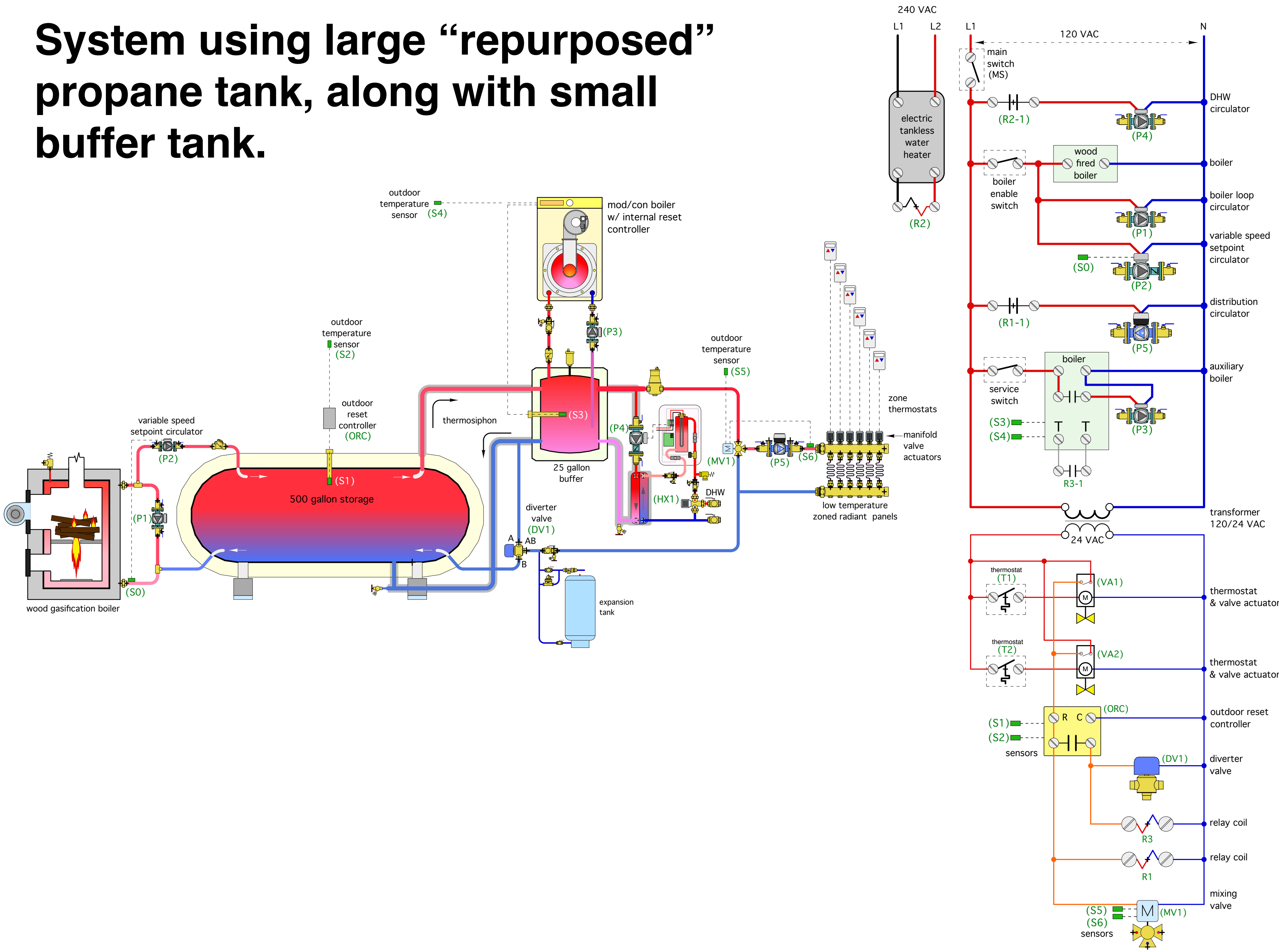
System using (unpressurized) buffer tank



System using large “repurposed” propane tank, along with small buffer tank.



System using large "repurposed" propane tank, along with small buffer tank.



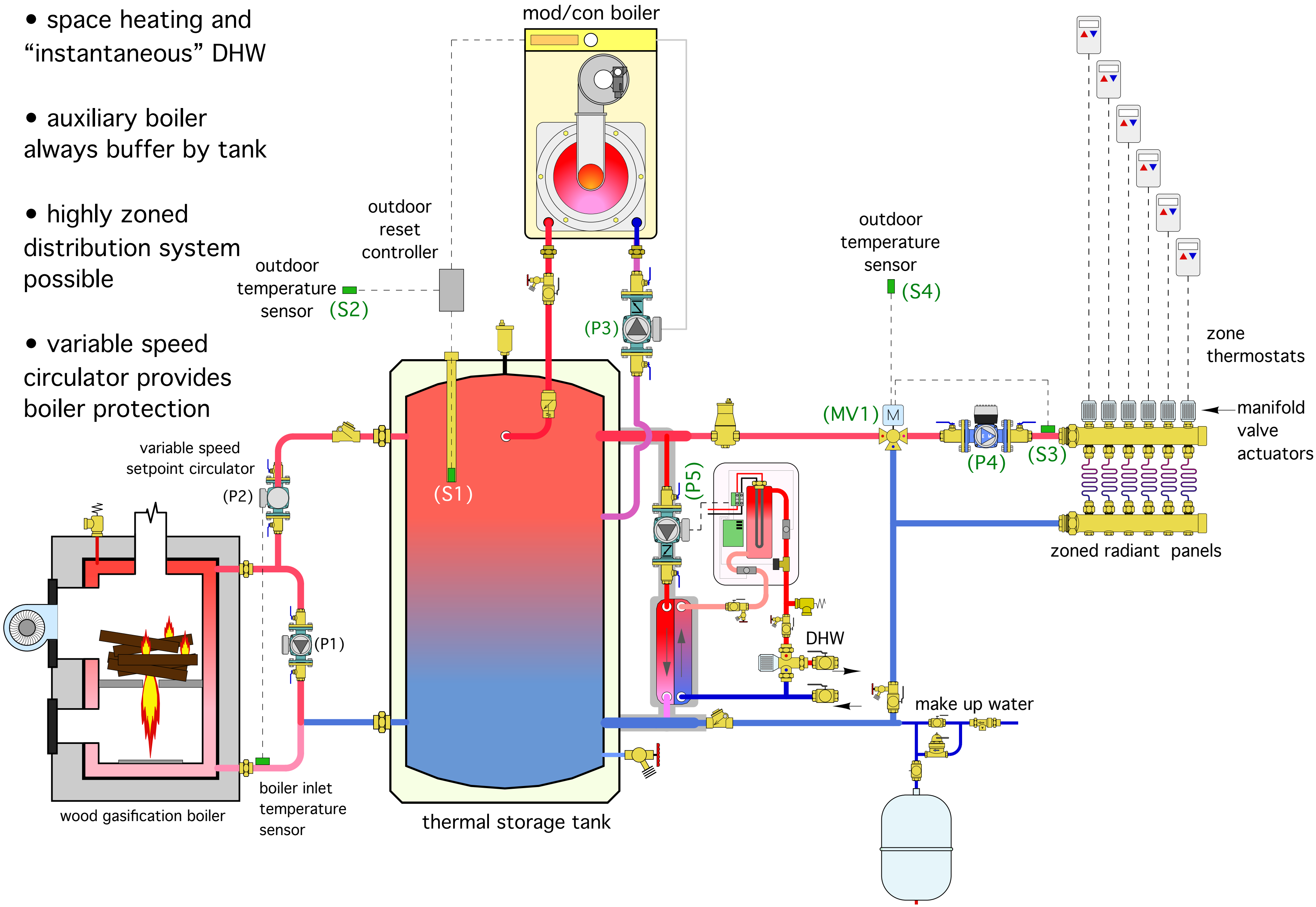
wood gasification boiler with pressurized storage

- space heating and "instantaneous" DHW

- auxiliary boiler always buffer by tank

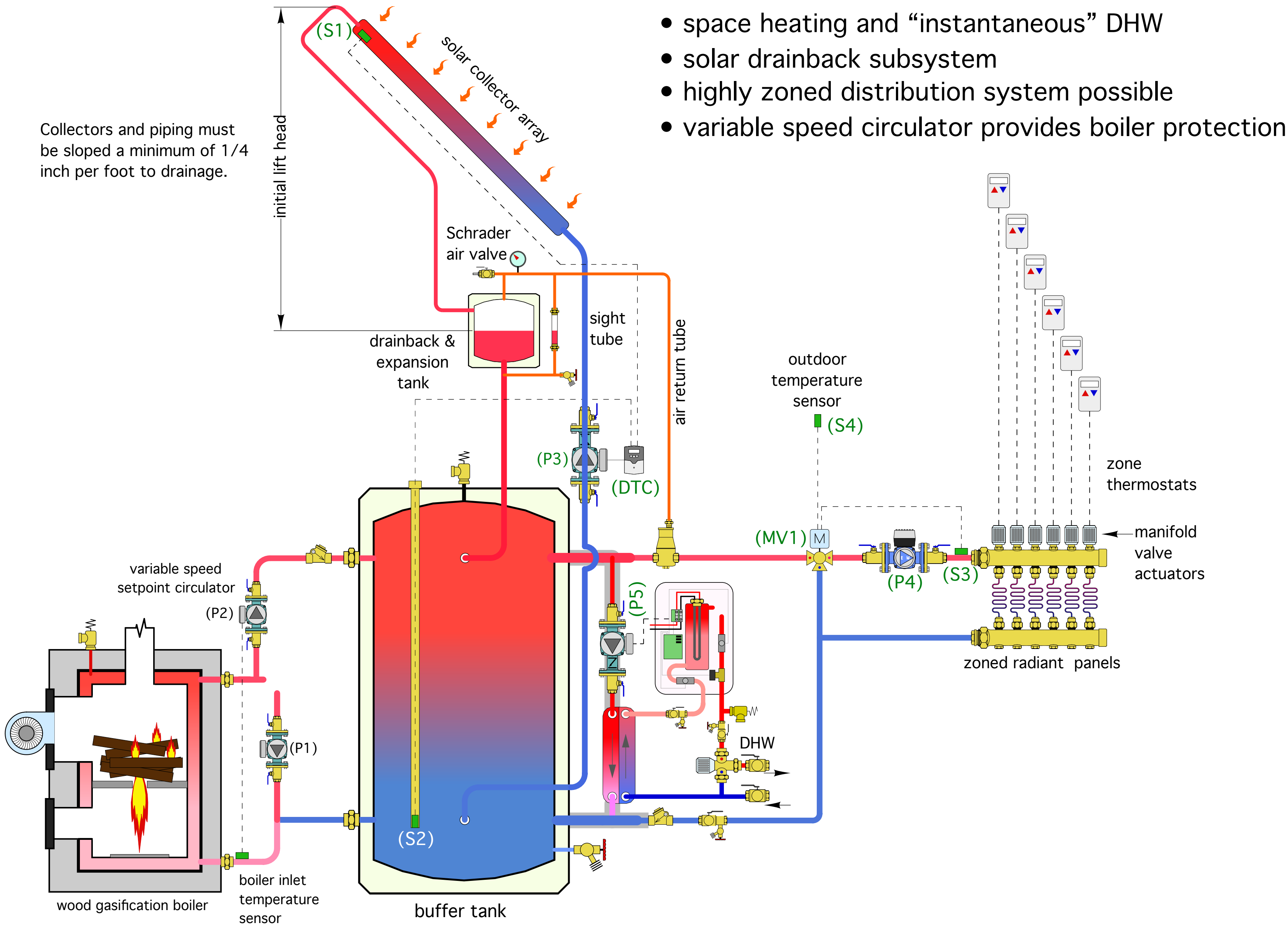
- highly zoned distribution system possible

- variable speed circulator provides boiler protection

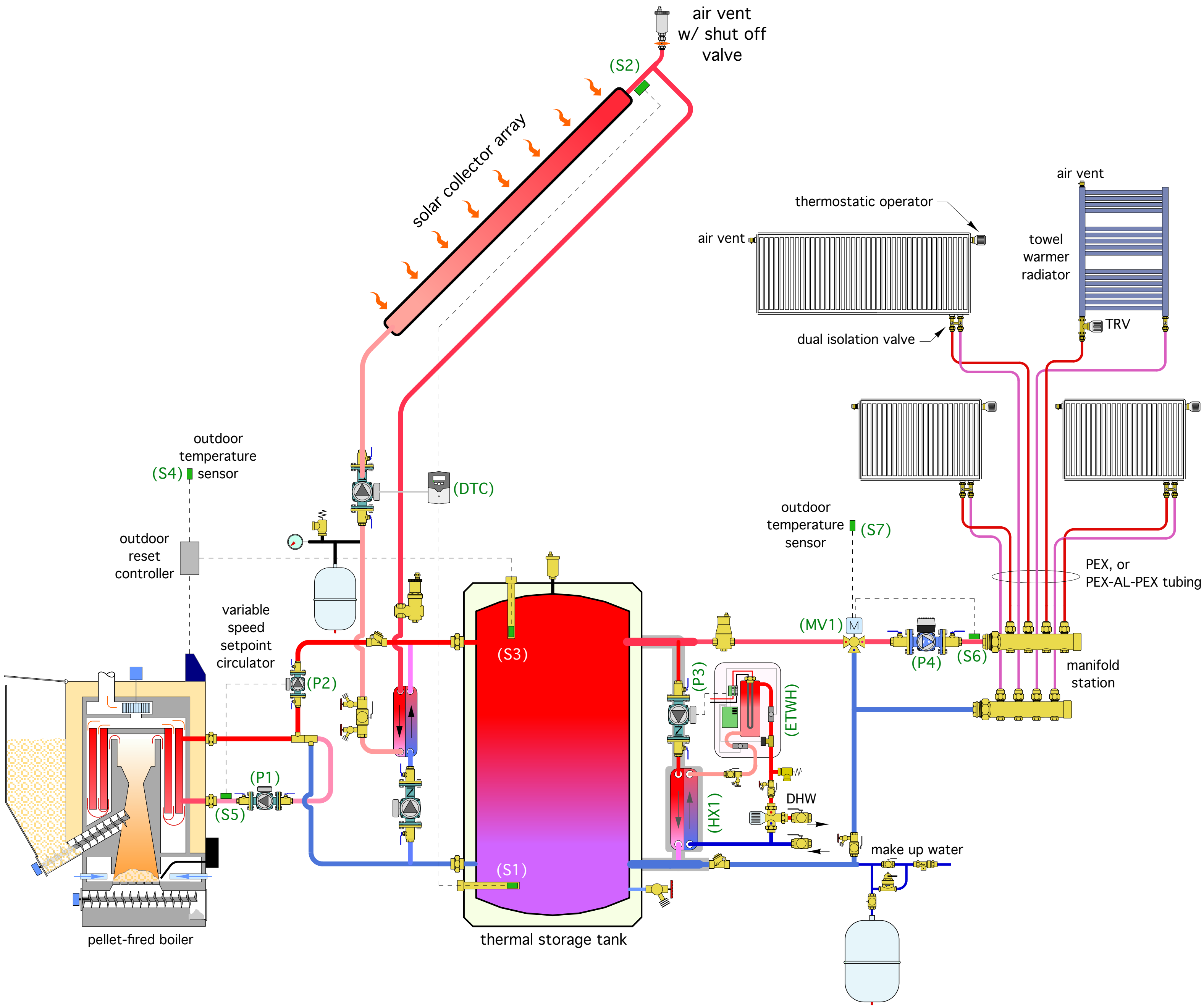


wood gasification boiler + solar with pressurized storage

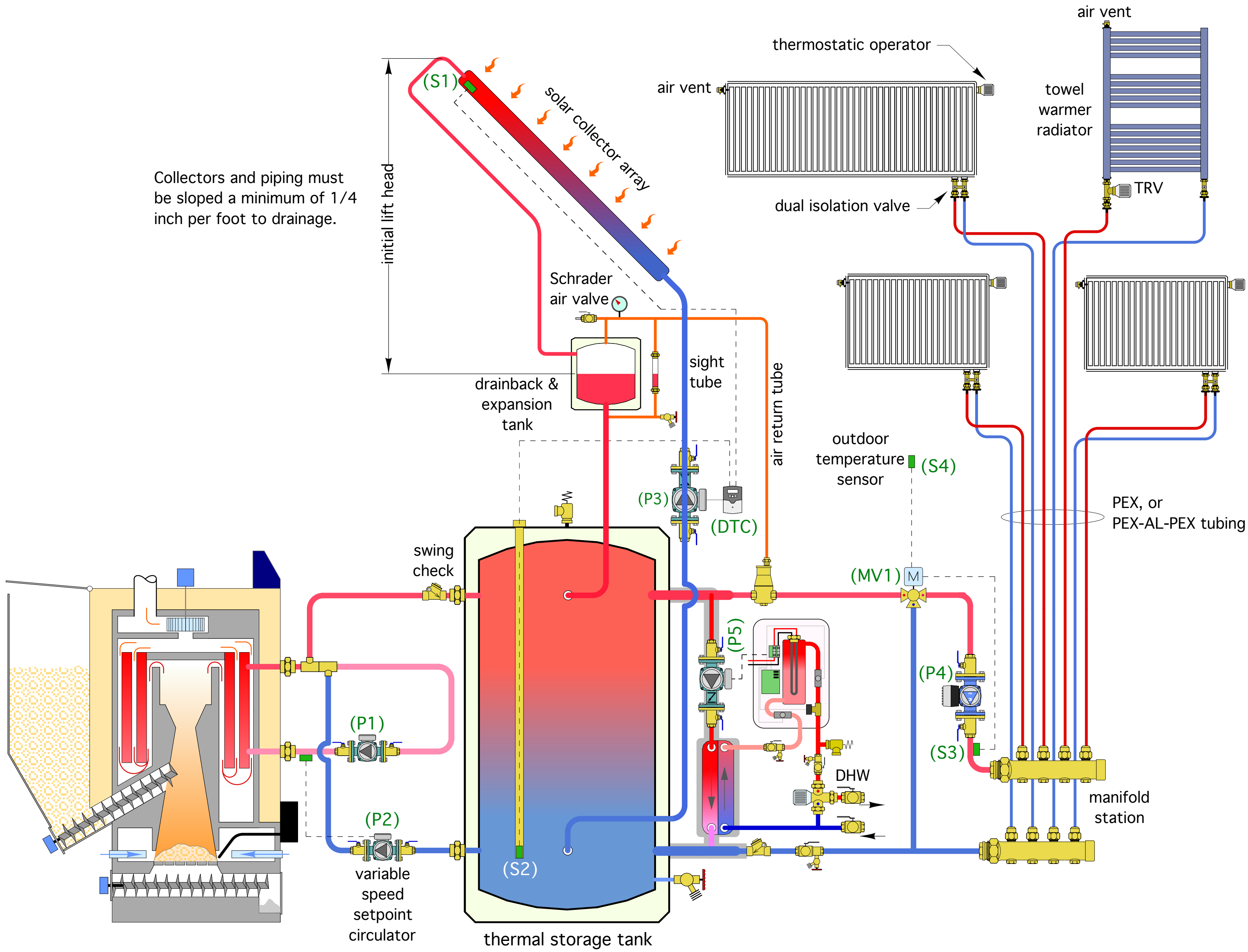
- space heating and “instantaneous” DHW
- solar drainback subsystem
- highly zoned distribution system possible
- variable speed circulator provides boiler protection



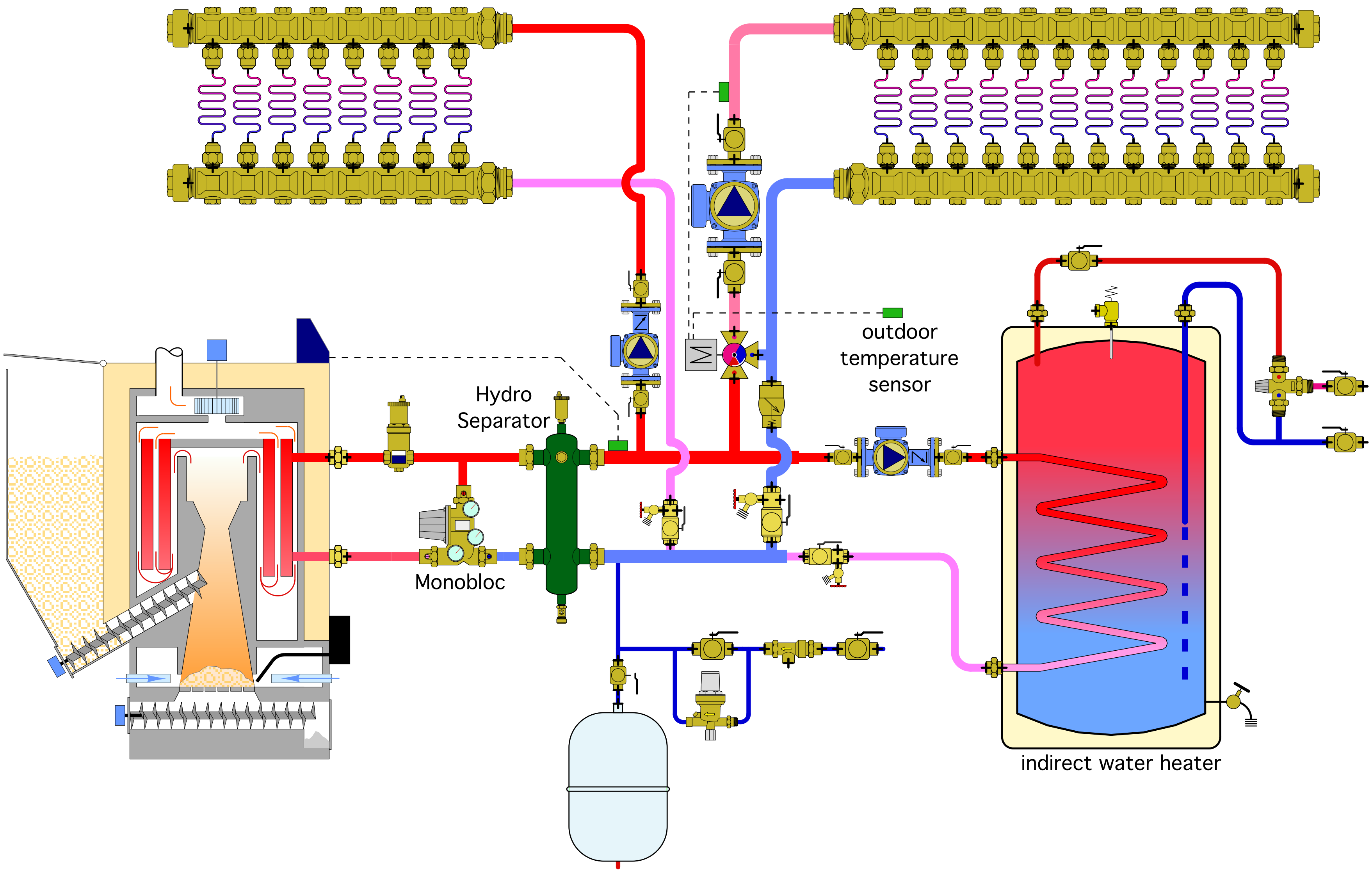
pellet boiler + solar with pressurized storage



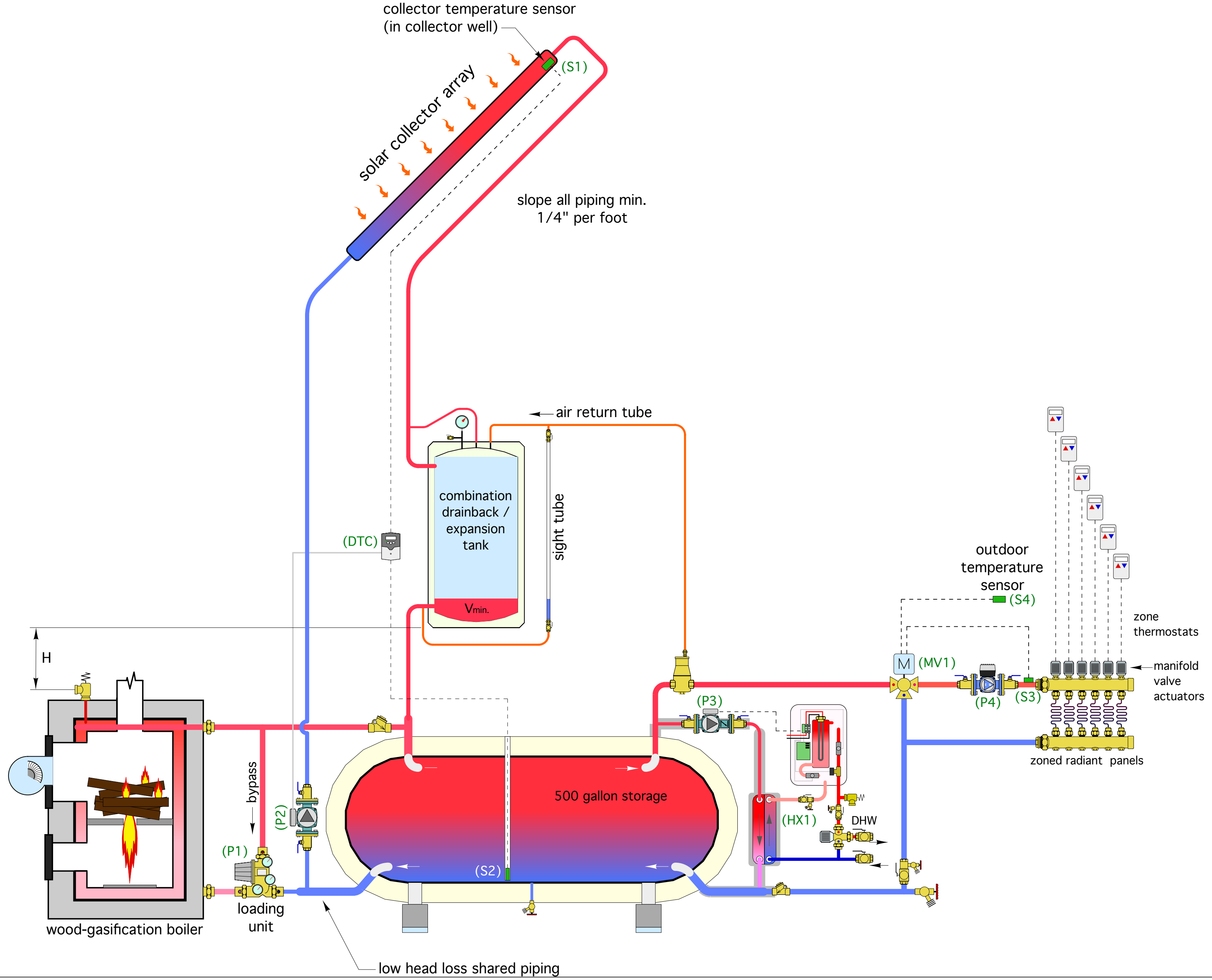
pellet boiler + solar with pressurized storage



- pellet-fired boiler as sole heat source
- no buffer tank

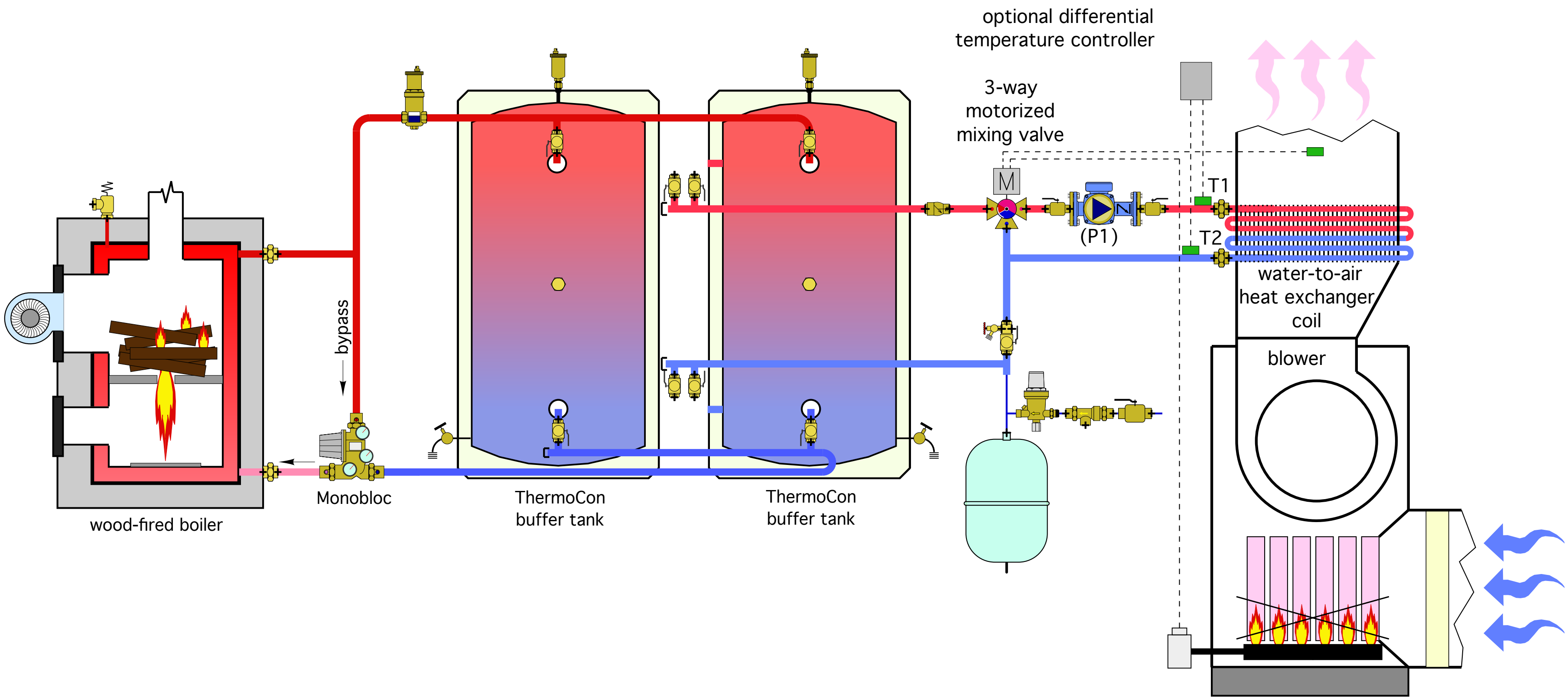


wood gasification boiler + solar with pressurized storage



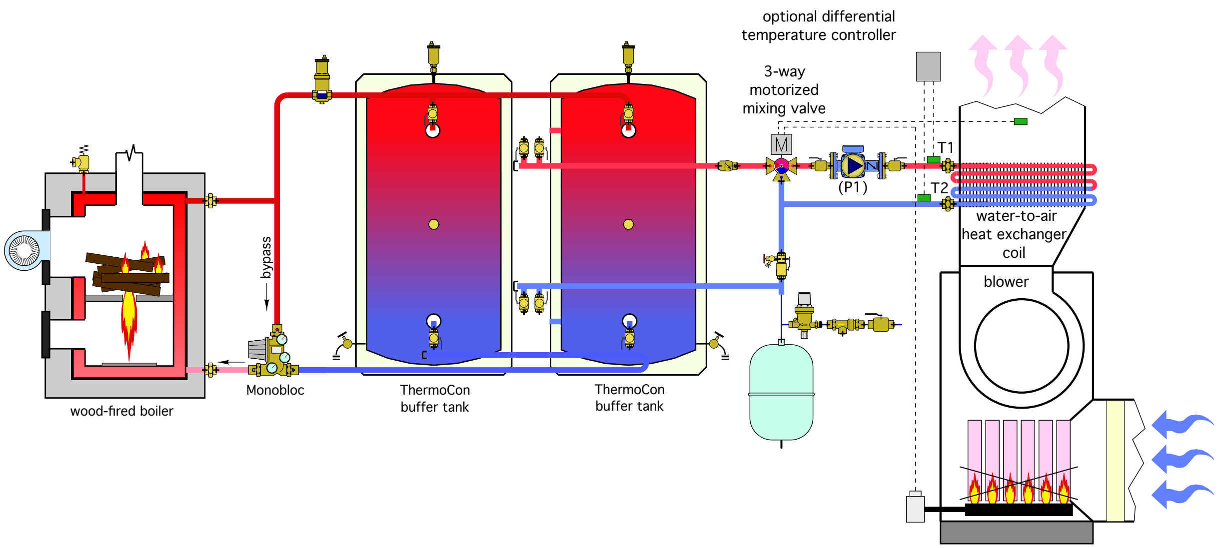
System using forced air furnace

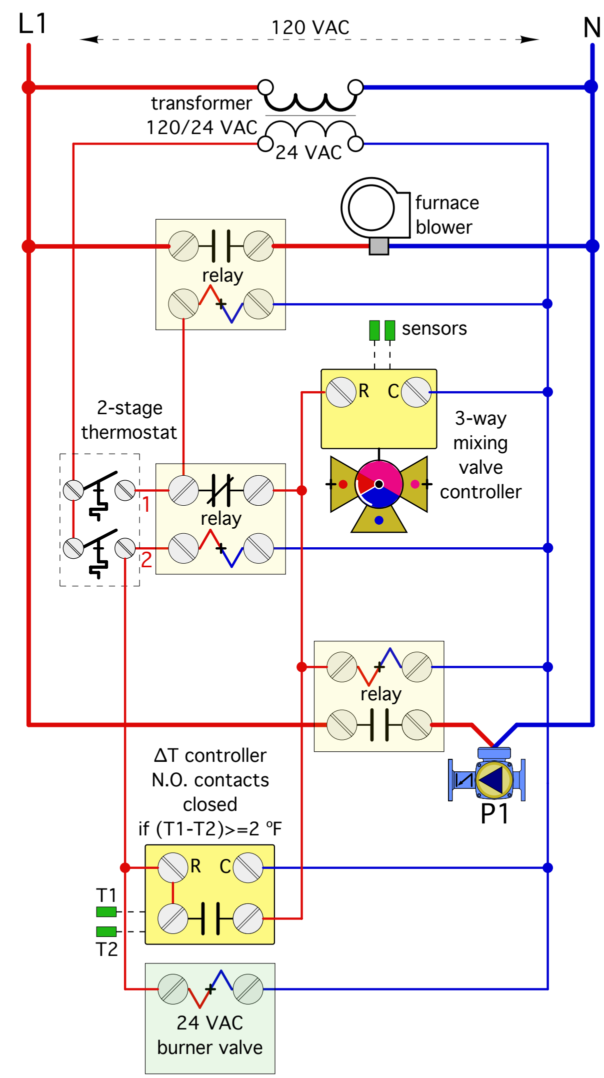
- space heating only
- ΔT logic to operate storage to lowest temperature
- dual parallel-piped thermal storage tanks
- Could add instantaneous DHW assembly



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





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