Hydronics for Renewable Energy System Applications:

Nov. 8, 2014

NYSES SHW Conference and Expo

Malta, NY

presented by:

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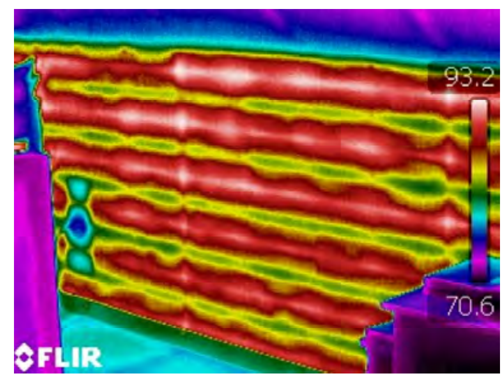


USGBC NY Upstate Chapter

R333

Hydronics for Renewable Energy Systems

STC14HRES

John Siegenthaler

November 8, 2014

Hydronics for Renewable Energy System Applications:

Course Description

Modern hydronics technology is extremely versatile. For decades it has been used to deliver unsurpassed comfort using conventional energy sources such as gas and oil-fired boilers. ***Hydronics can also serve as an ideal "conveyor belt" for heat supplied from renewable energy sources*** such as solar thermal collectors, heat pumps, and solid fuel (wood and pellet) boilers. This full day seminar will show how to use each of these renewable heat sources as the primary energy source for space heating and domestic hot water production. It will show how to implement state of the art concepts and hardware to maximize the potential of the renewable energy source. It will also show how to integrate auxiliary heat sources in ways that ensure consistent comfort, but also minimize the use of conventional energy. ***You will come away with several system concepts, and the design information needed to put them into practice.***

Hydronics for Renewable Energy System Applications:

Learning Objectives

At the end of the this course, participants will be able to:

1. Identify hardware devices that can be used to create an efficient combisystems supplied by renewable energy heat sources.

2. Identify the subassemblies that make up many combisystems supplied by a renewable energy source.

3. Describe the importance of low temperature heat emitters and distribution systems

4. Explain why modern hydronics makes reliable, stable, and efficient systems possible.

Hydronics for Renewable Energy System Applications:

Today's Topics:

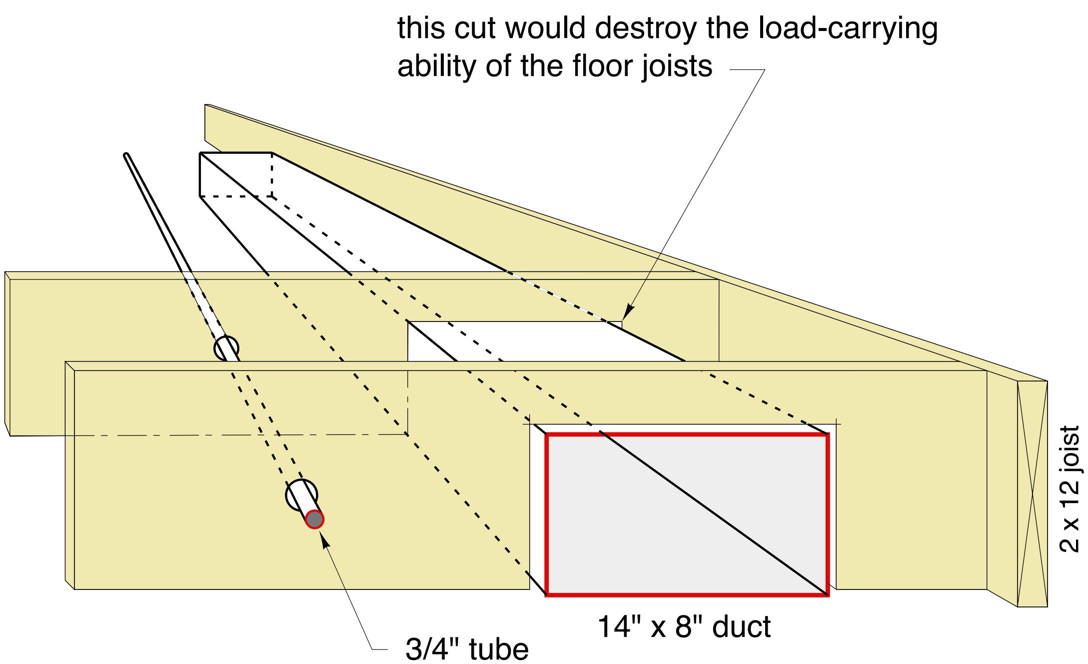
- Why hydronics?
- The importance of hydronics to renewable energy
- Low temperature heat emitters
- Water-based thermal storage options
- Distribution efficiency & high efficiency circulators
- Homerun distribution systems
- Temperature control subsystem
- On-demand DHW subsystem
- **Complete system designs**
  - **Modern hydronics meets solar thermal collectors**
  - **Modern hydronics meets air-to-water heat pump**
  - **Modern hydronics meets geothermal heat pump**
  - **Modern hydronics meets pellet-fired boiler**

Why Hydronics?

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

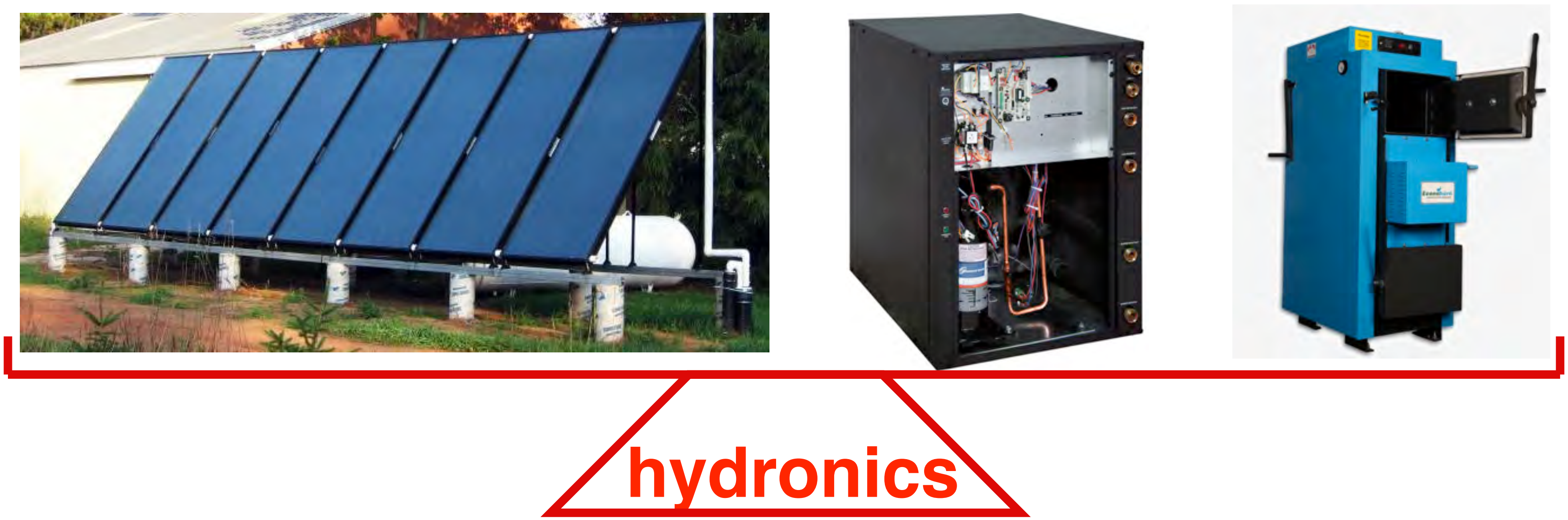


$$\frac{62.4}{0.018} = 3467 \approx 3500$$

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.



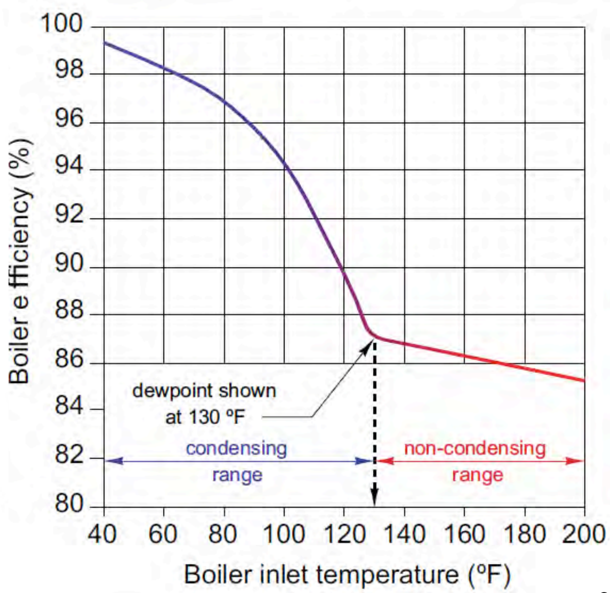
Regardless of what solar collector, geothermal heat pump, or wood-fired boiler is selected, if the distribution system, controls, and heat emitters are not properly matched, that system will not perform well.

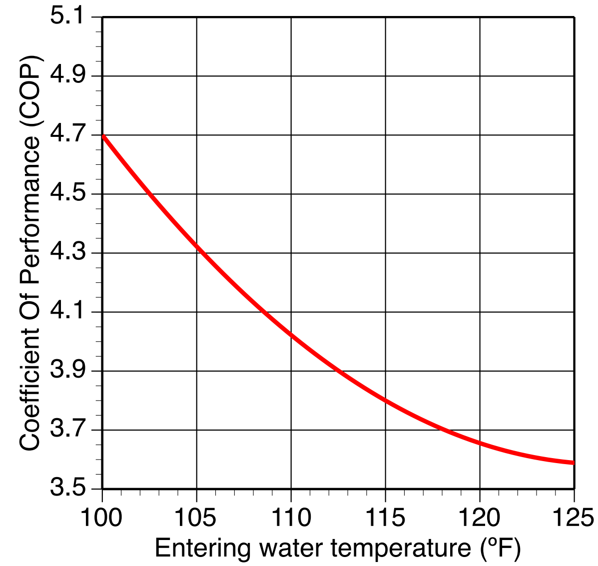
Why hydronics enhances renewable heat sources

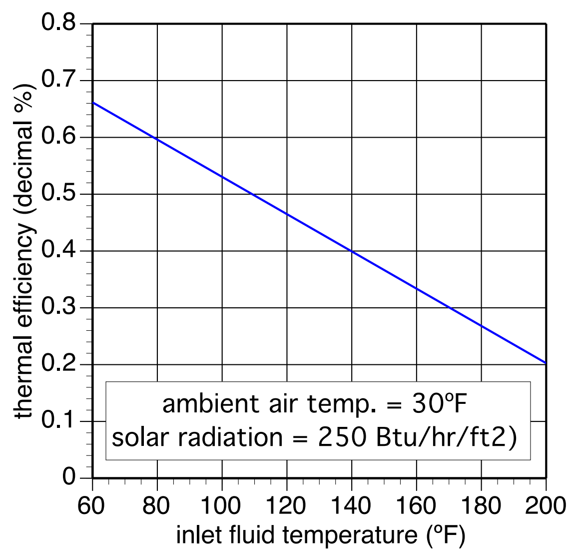
- Superior comfort
- Low temp. operation (High heat source efficiency)
- Very high distribution efficiency
- Thermal storage potential
- Easy integration with conventional heat sources
- Minimally invasive retrofitting
- Potential for thermal metering

Low temperature heat emitters

Condensing boilers, heat pumps, and solar collectors all benefit from low water temperature operation.





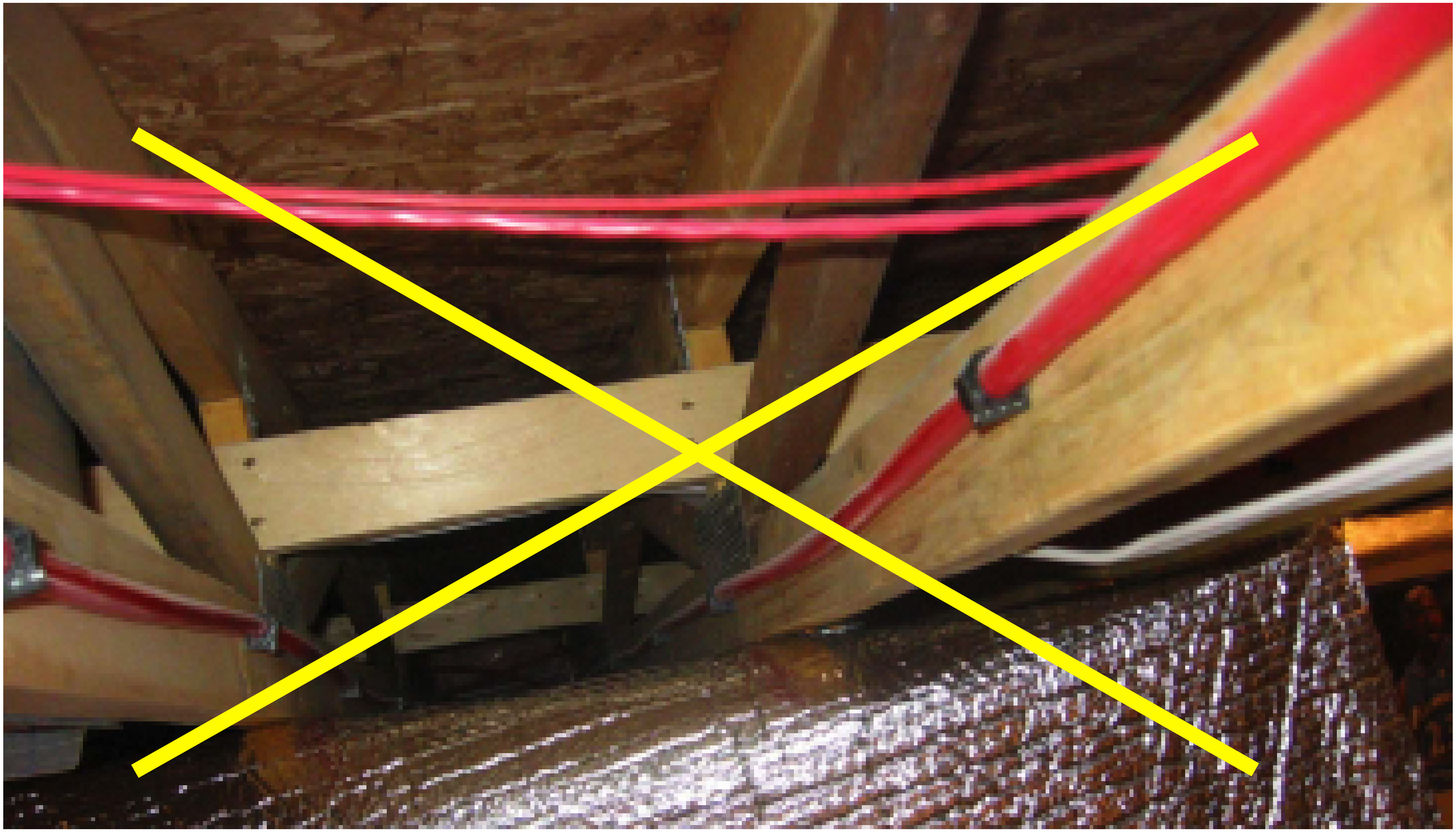


What kind of heat emitters should be used in modern hydronic systems in low energy houses?

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

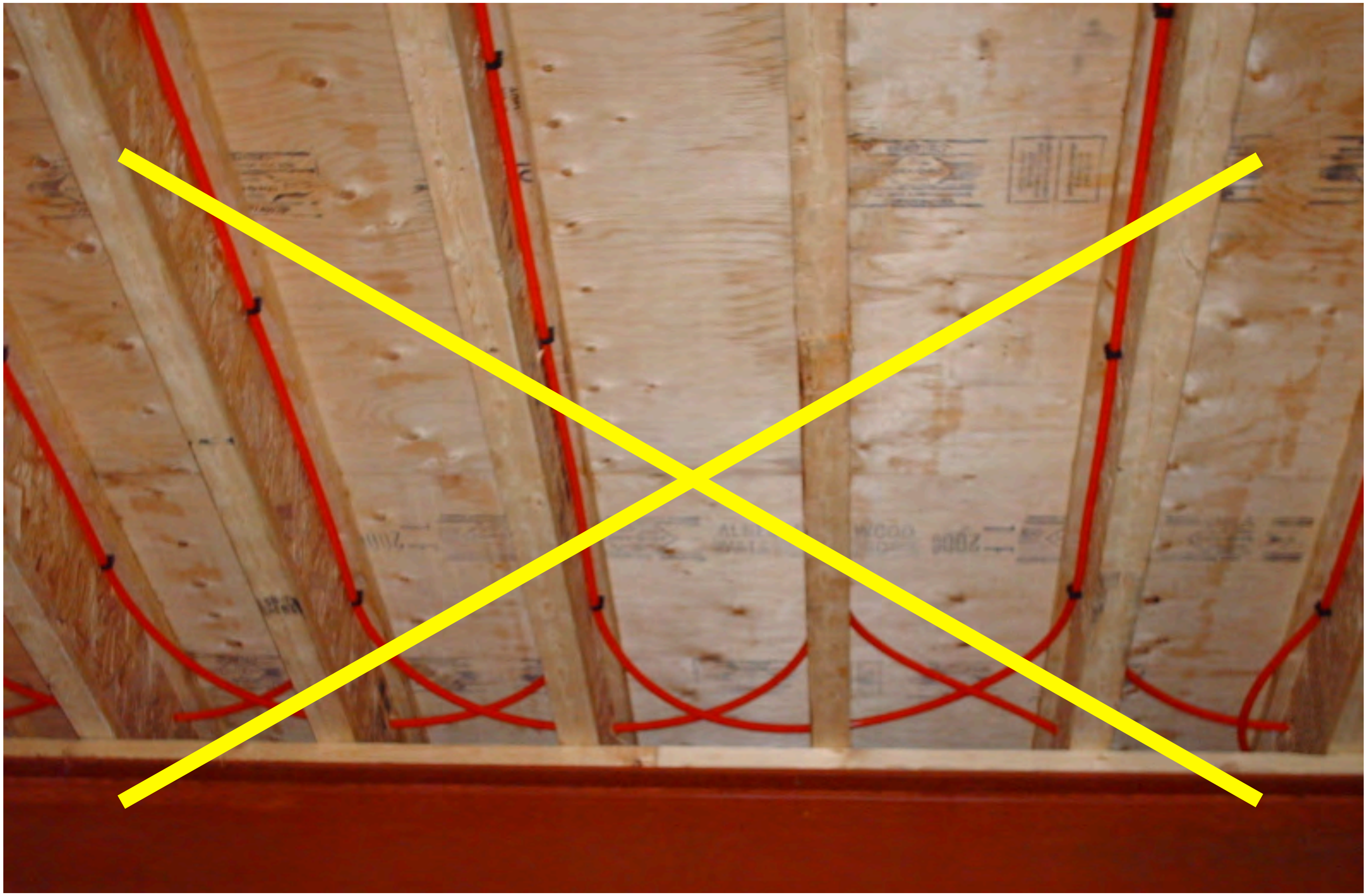
Low temperature hydronic distribution systems also help "future proof" the system for use with heat sources are likely to thrive on low water temperatures.

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!

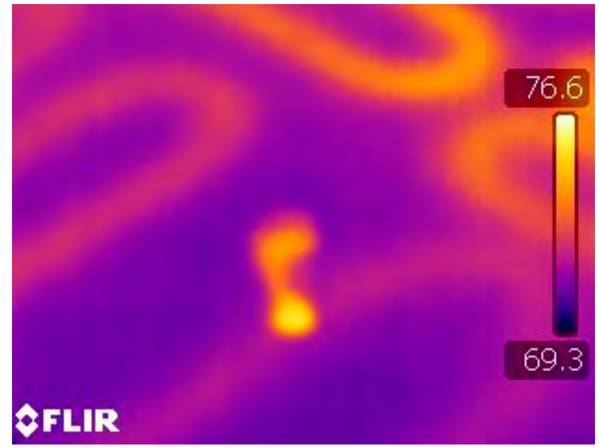


Is radiant floor heating **always** the answer?

"Barefoot friendly" floors...

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:



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

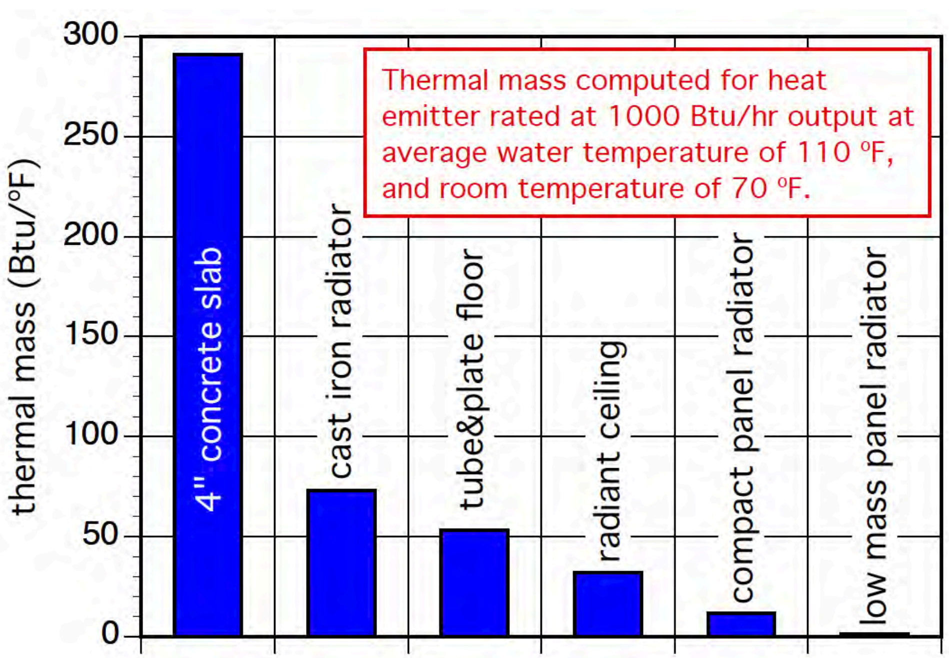
$$T_f = \frac{q}{2} + T_r$$

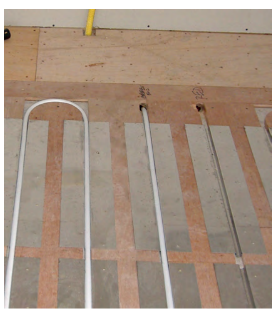
Tf = average floor surface temperature (°F)
Tr= room air temperature (°F)
q=heat flux (Btu/hr/ft^2)

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.

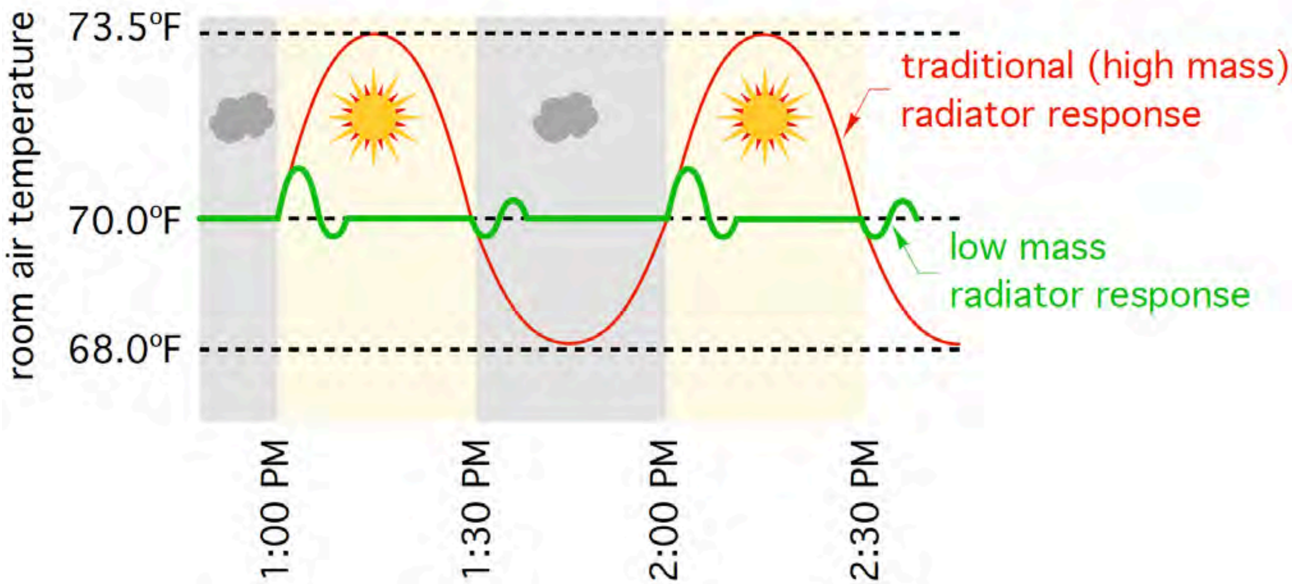
*This is not going to deliver "**barefoot friendly floors**" - as so many ads for floor heating promote.*

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:





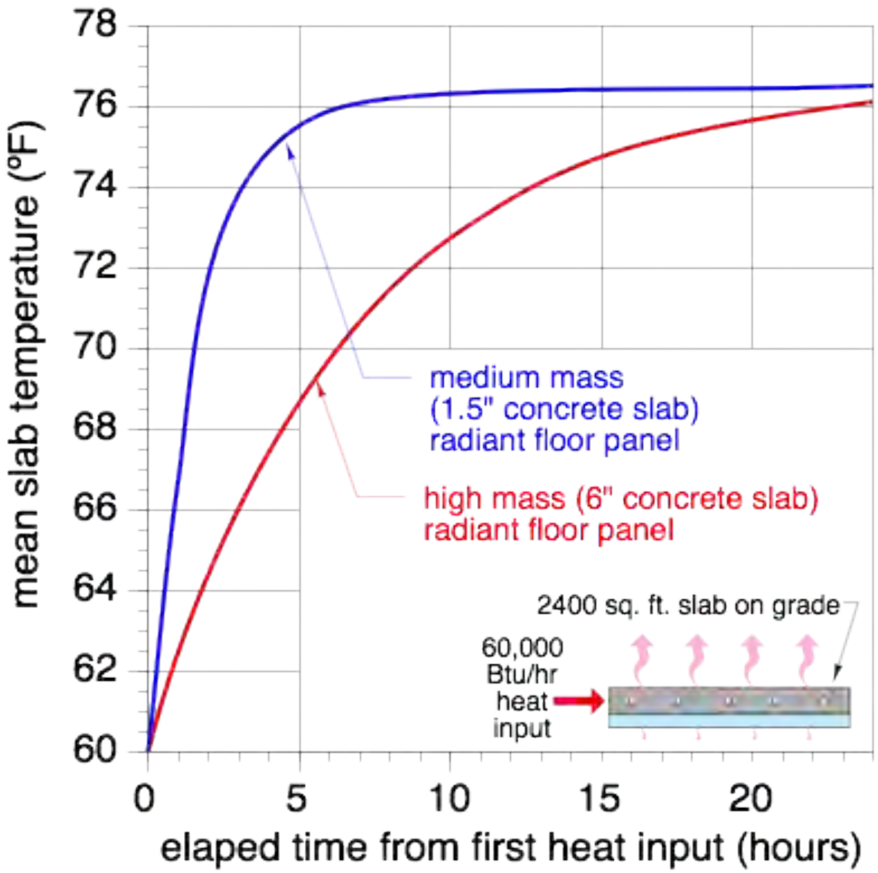
Low thermal mass allows the heat emitters to quickly respond to changing internal loads



high mass cast iron radiator

low mass panel radiators

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

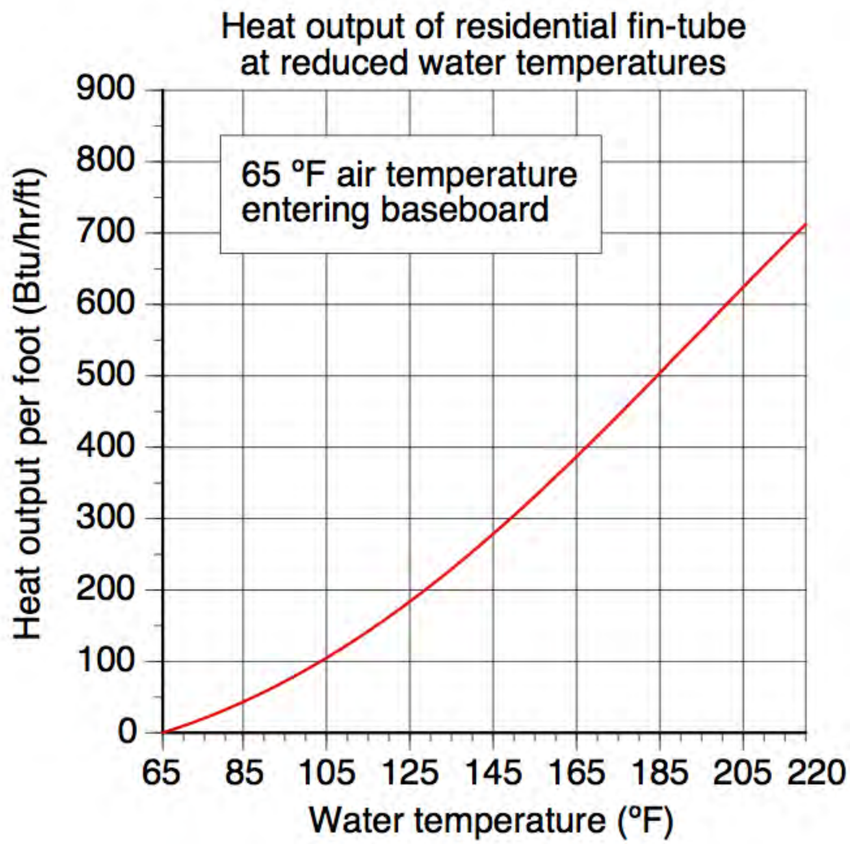


Notice where the tubing is in this 6” heated concrete slab

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

Fin-tube convectors

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

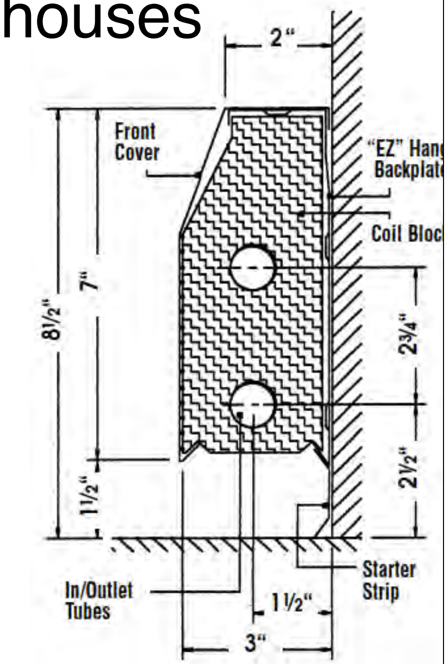


Could add fin-tube length based on lower water temperatures. BUT...

Fin-tube output at 120 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

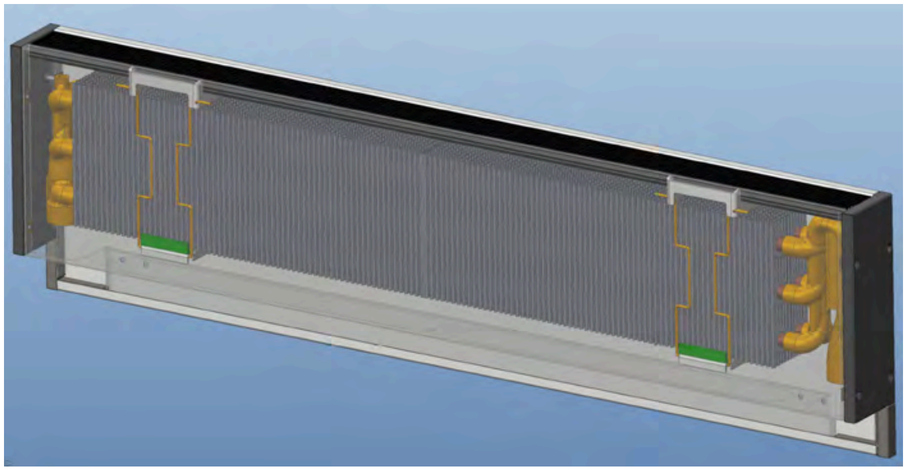
	Flow Rate GPM	PD in ft of H_2O	Average Water Temperature (BTU/hr/ft @AWT in °F) 90°F	100°F	110°F	120°F	130°F	140°F	150°F	160°F	170°F	180°F	190°F	200°F	210°F
TWO SUPPLIES PARALLEL	1	0.0044	130	205	290	385	460	546	637	718	813	911	1009	1113	1215
	4	0.0481	155	248	345	448	550	651	755	850	950	1040	1143	1249	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.

Hydronic heat emitters options for low energy use houses

New low- temperature baseboard just released in March 2014



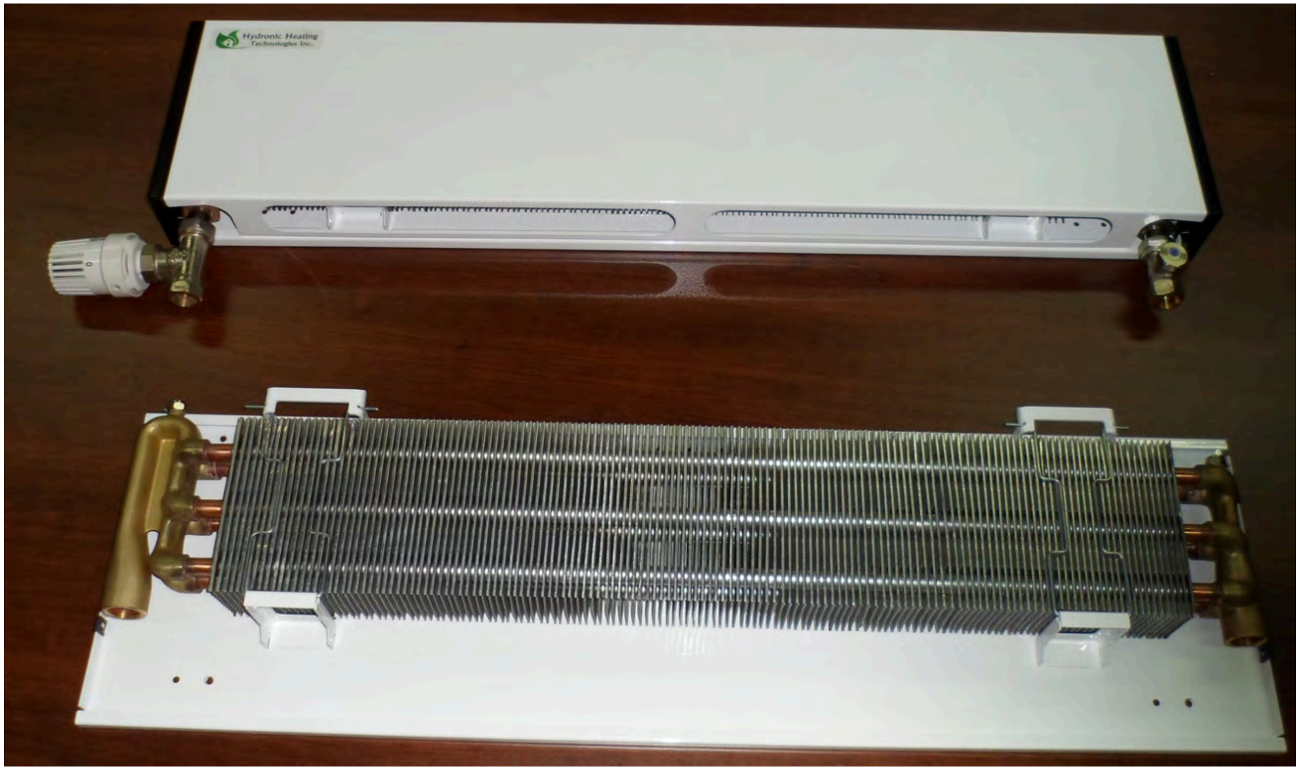
Standard BB, 500Btu/hr/ft @ 180 °F water

This product claims 512 Btu/hr/ft @ 120 °F water

Hydronic Heating Technologies, Inc. Cambridge, ON (www.hhtsystems.com)

Hydronic heat emitters options for low energy use houses

New low- temperature baseboard just released in March 2014



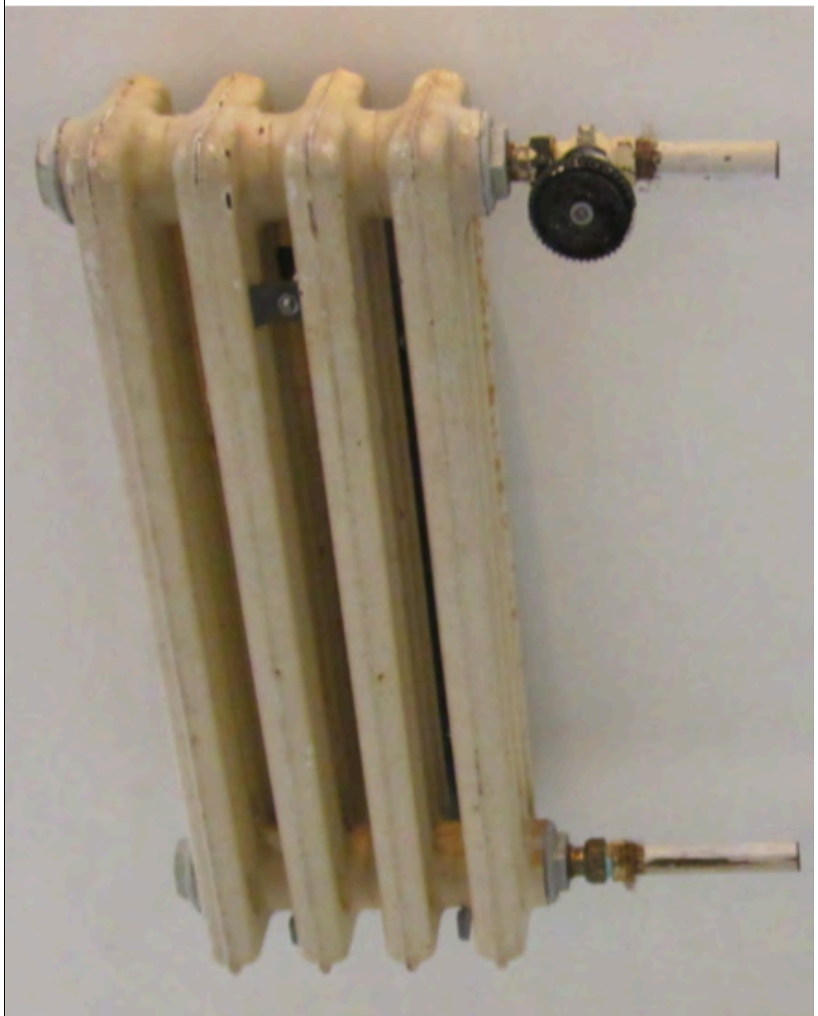
Images courtesy Hydronic Heating Technologies, Inc.

- Standard BB, 500 Btu/hr/ft @ 180 ºF water
- This product claims 502 Btu/hr/ft @ 120 ºF water
- Available in lengths from 2 to 8 feet (no 7’ length), with accessory trim

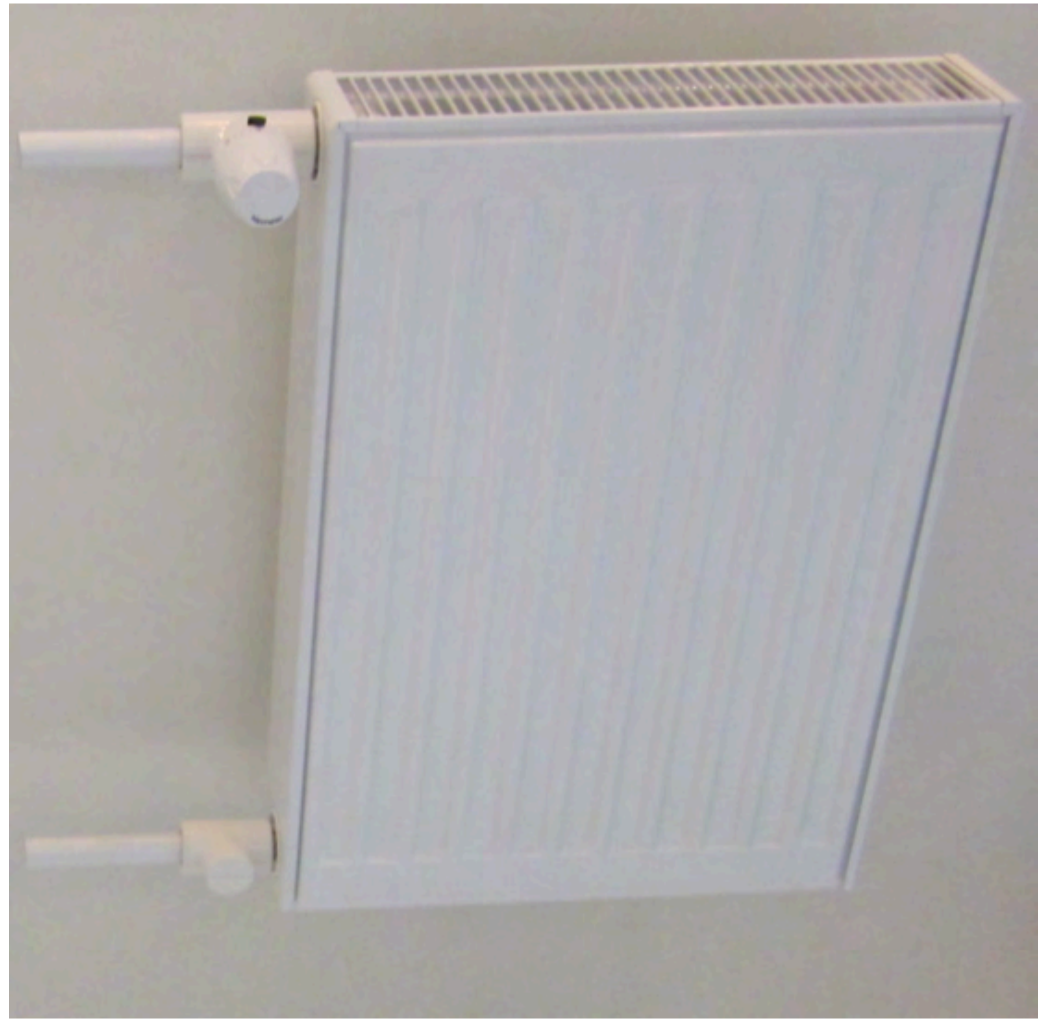
Hydronic Heating Technologies, Inc. Cambridge, ON (www.hhtsystems.com)

Panel Radiators

Traditional cast-iron radiator

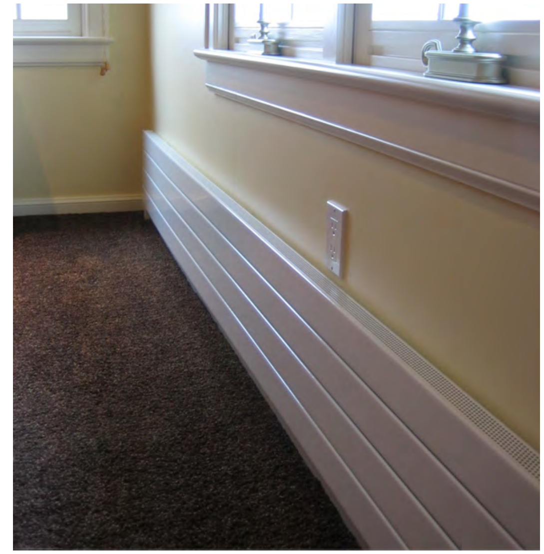


Modern panel radiator



Panel Radiators

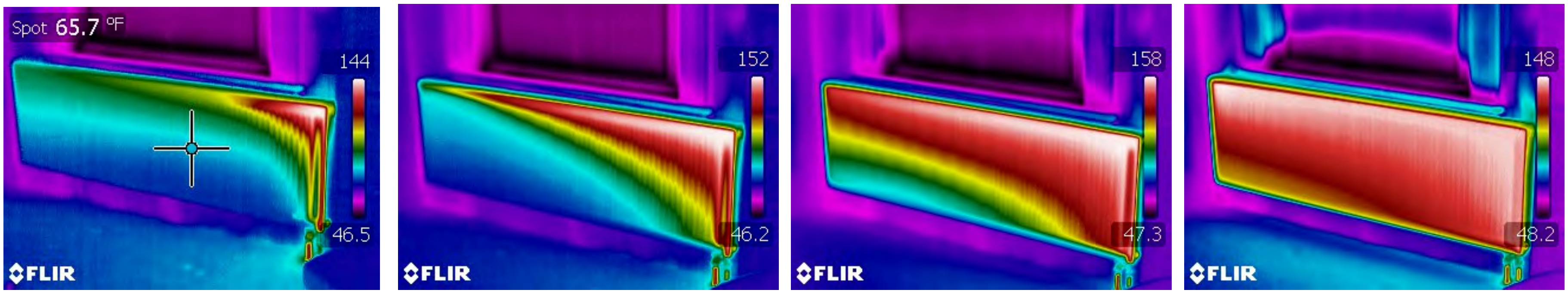
- Low water content and relatively light - fast responding
- Some can be fitted with thermostatic radiator valves for room-by-room zoning (WITHOUT ELECTRICAL CONTROLS)
- Some are “thermal art” - but bring your VISA card...



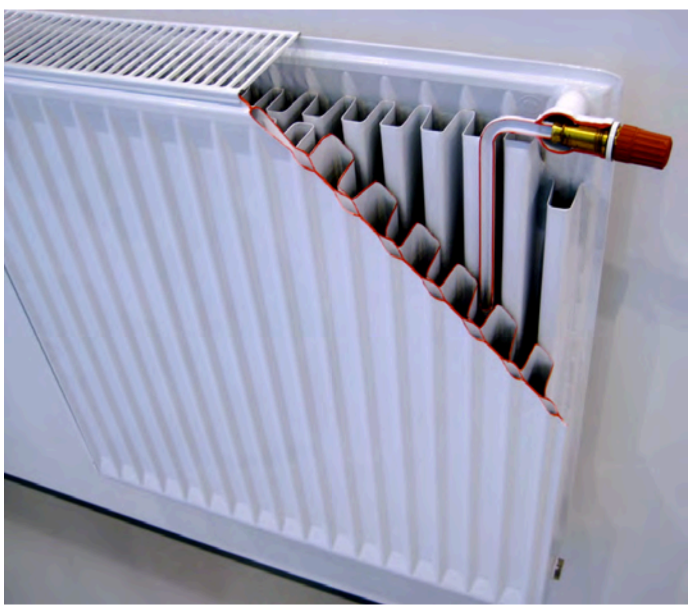
Hydronic heat emitters options for low energy use houses

Panel Radiators

One of the fastest responding hydronic heat emitters

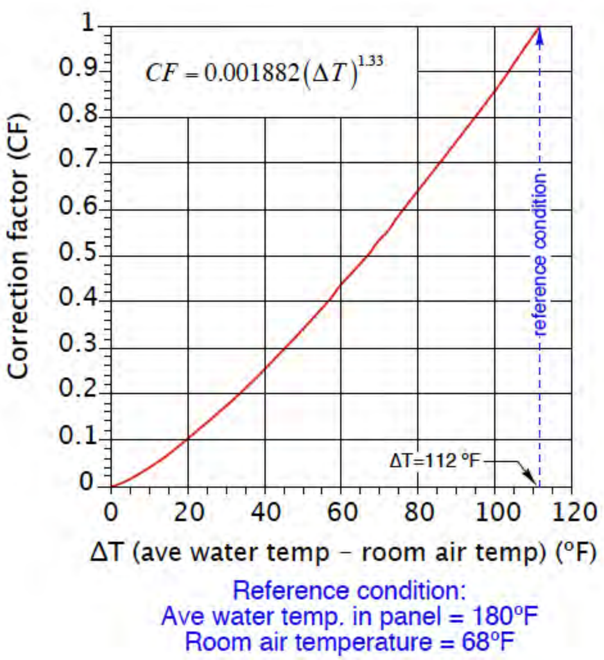


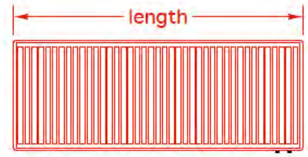
From setback to almost steady state in 4 minutes...



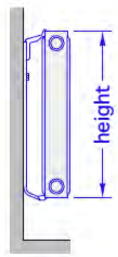
Panel Radiators

Adjust heat output for operation at lower water temperatures.



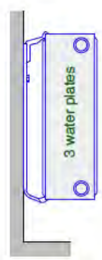


Heat output ratings (Btu/hr)
at reference conditions:
Average water temperature in panel = 180°F
Room temperature = 68°F
temperature drop across panel = 20°F



	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.

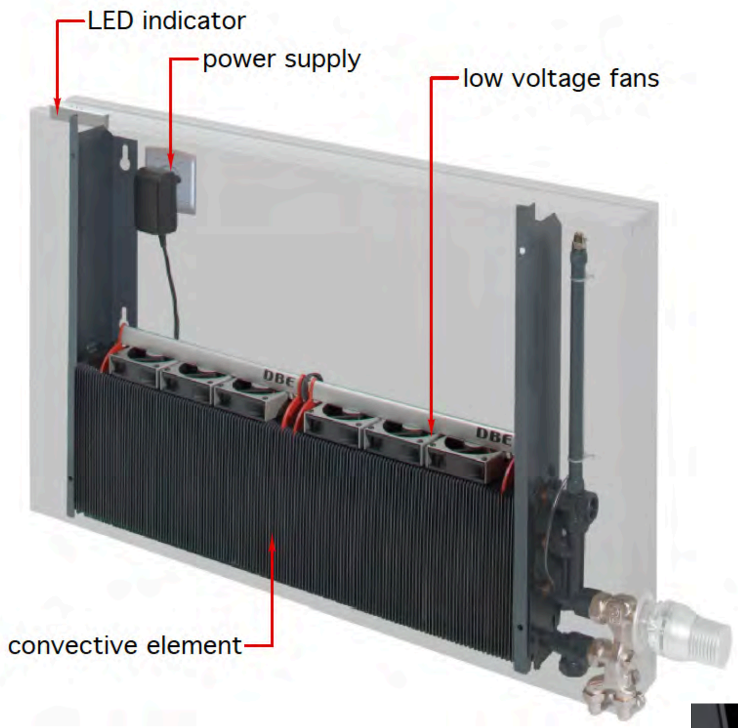
Fan-assisted Panel Radiators

- Wider availability in Europe
- Designed to operate with 104 °F water

Courtesy of Vogel & Noot

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

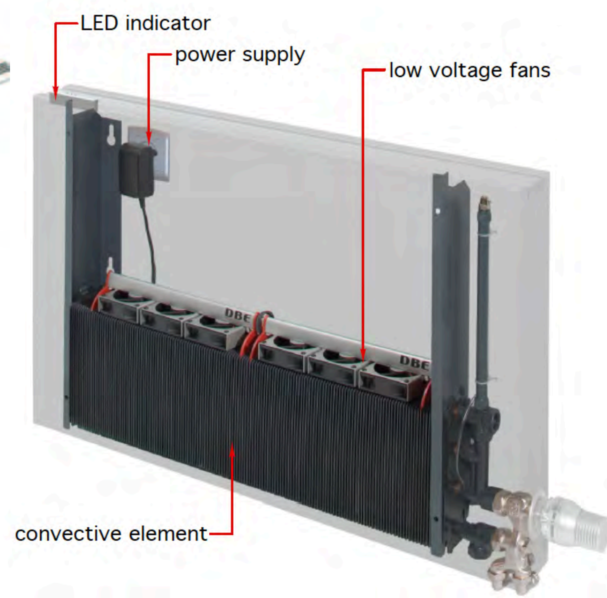
- **At full speed these 12VDC fans require 1.5 watts each**
- **30dB (virtually undetectable sound level)**
- **Allow supply temperatures as low as 95 °F**

Styles of panel radiators

Ultra Low-Mass Panel Radiators

	OUTPUT WITHOUT DBE	OUTPUT WITH DBE: COMFORT	OUTPUT WITH DBE: BOOST
158 °F	4240 BTU	6280 BTU	7640 BTU
122 °F	2033 BTU	3667 BTU	4583 BTU
90 °F		1571 BTU	1877 BTU

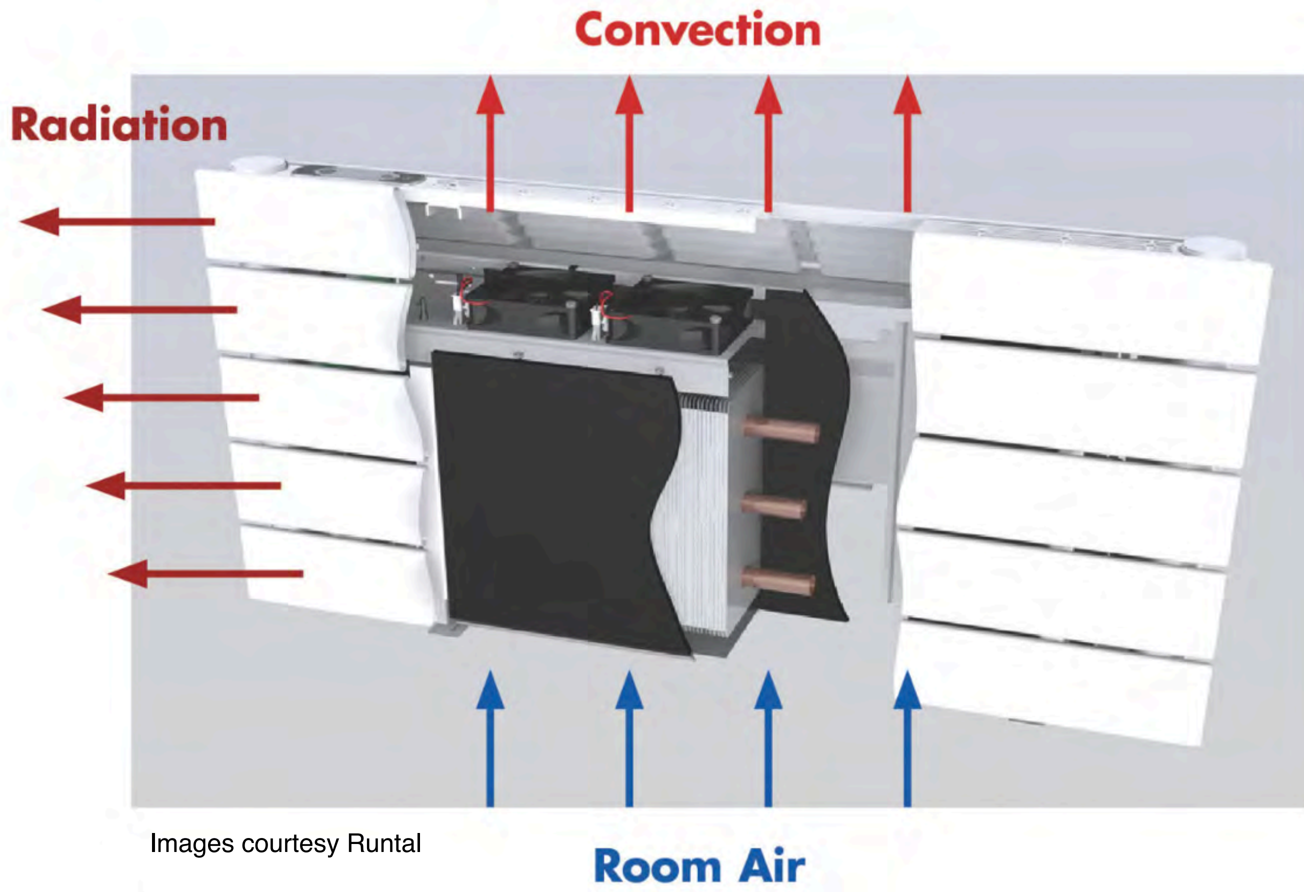
Example for Strada H50 L90 T11



2 of these “3-pack” fan block

Fan-assisted Panel Radiators

The "NEO", from Runtal North America



Images courtesy Runtal

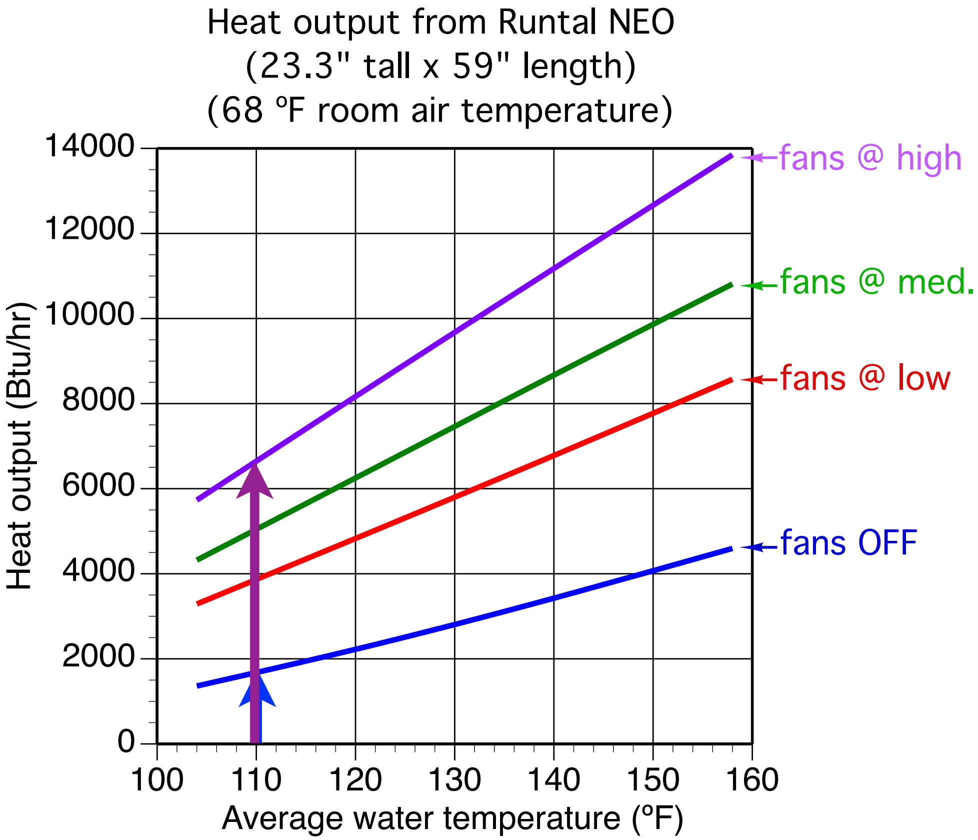
8 tube high x 31.5" wide produces 2095 Btu/hr at average water temperature of 104 ºF in 68ºF room

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

Fan-assisted Panel Radiators

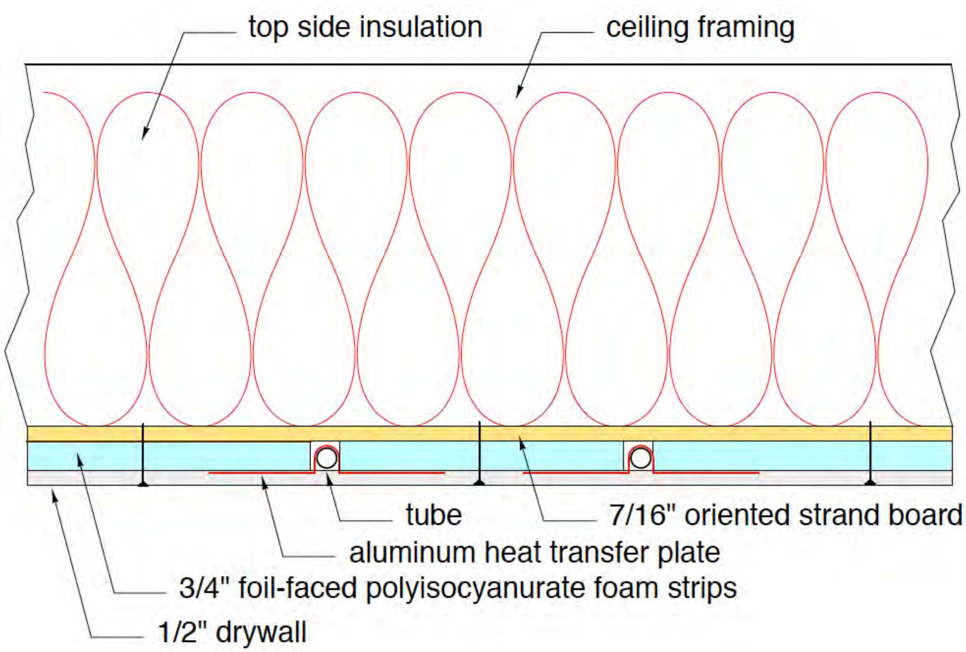
The “NEO”, from Runtal North America

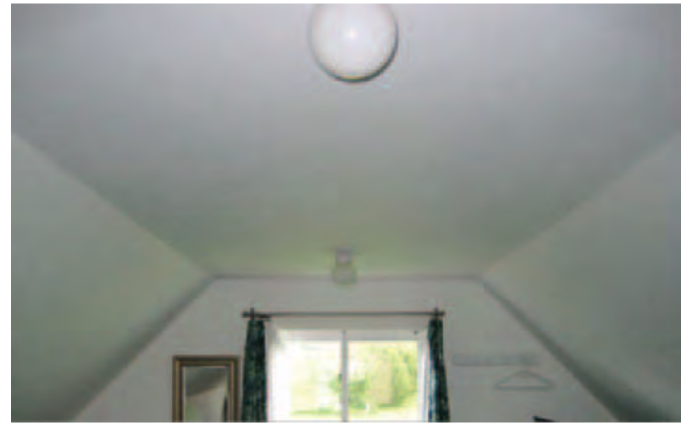
Images courtesy Runtal

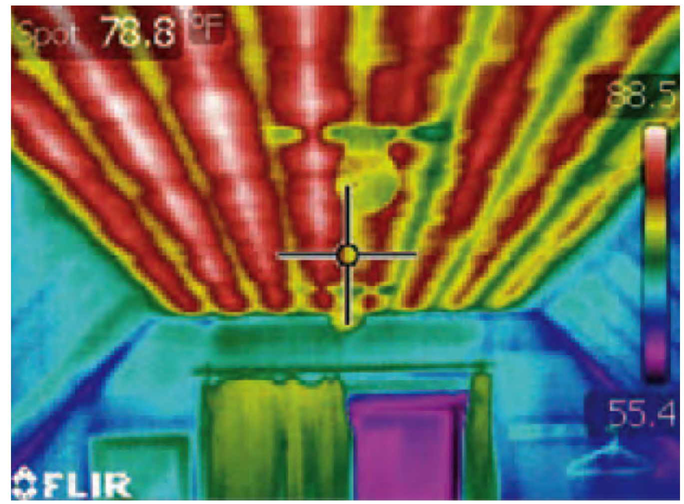


Radiant Ceiling & Wall Panels

Site built radiant CEILINGS...







Thermal image of radiant ceiling in operation

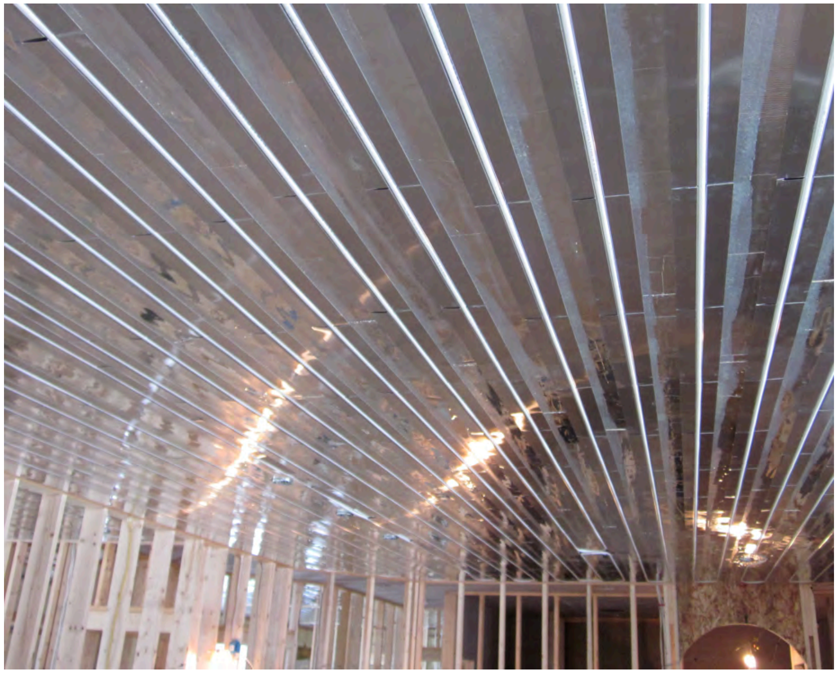
Heat output formula:

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

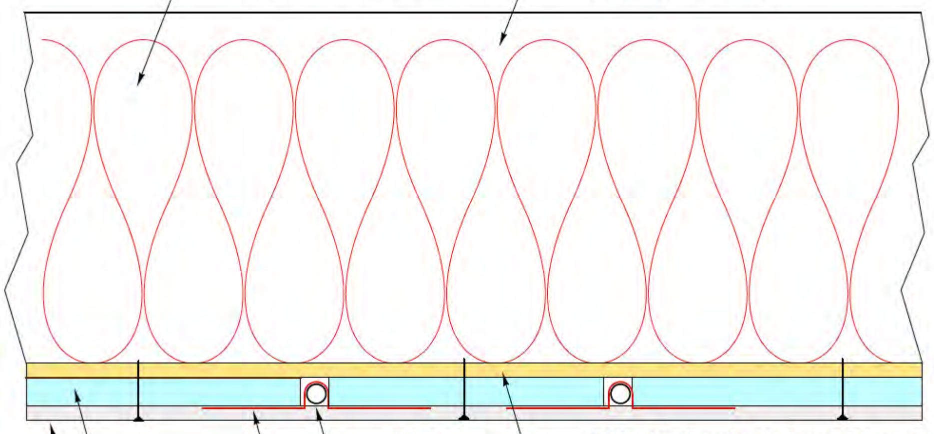
Where:

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

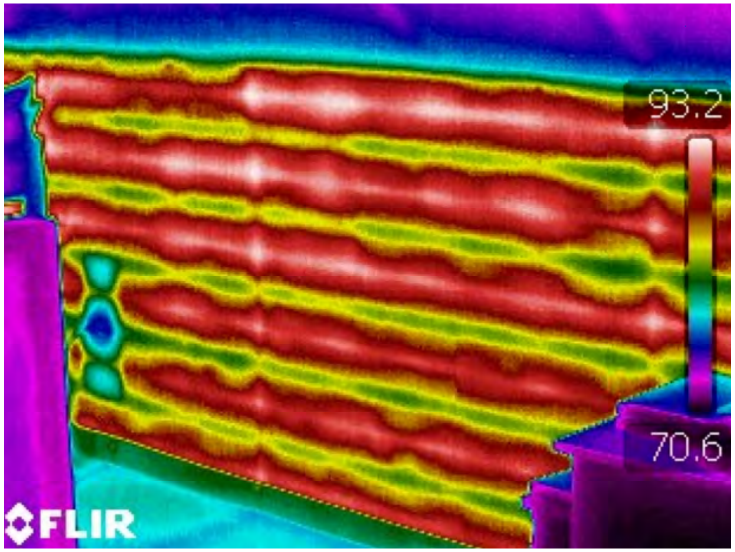
Site built radiant CEILINGS...

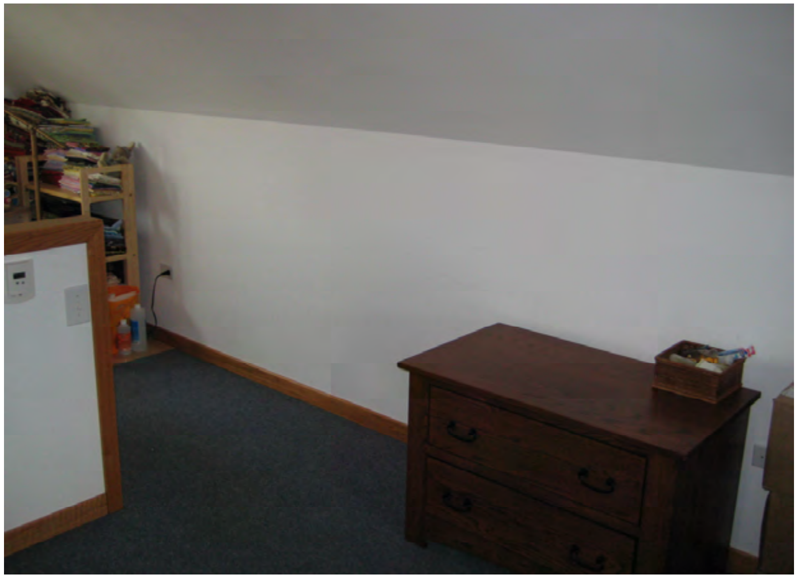


Site built radiant CEILINGS...

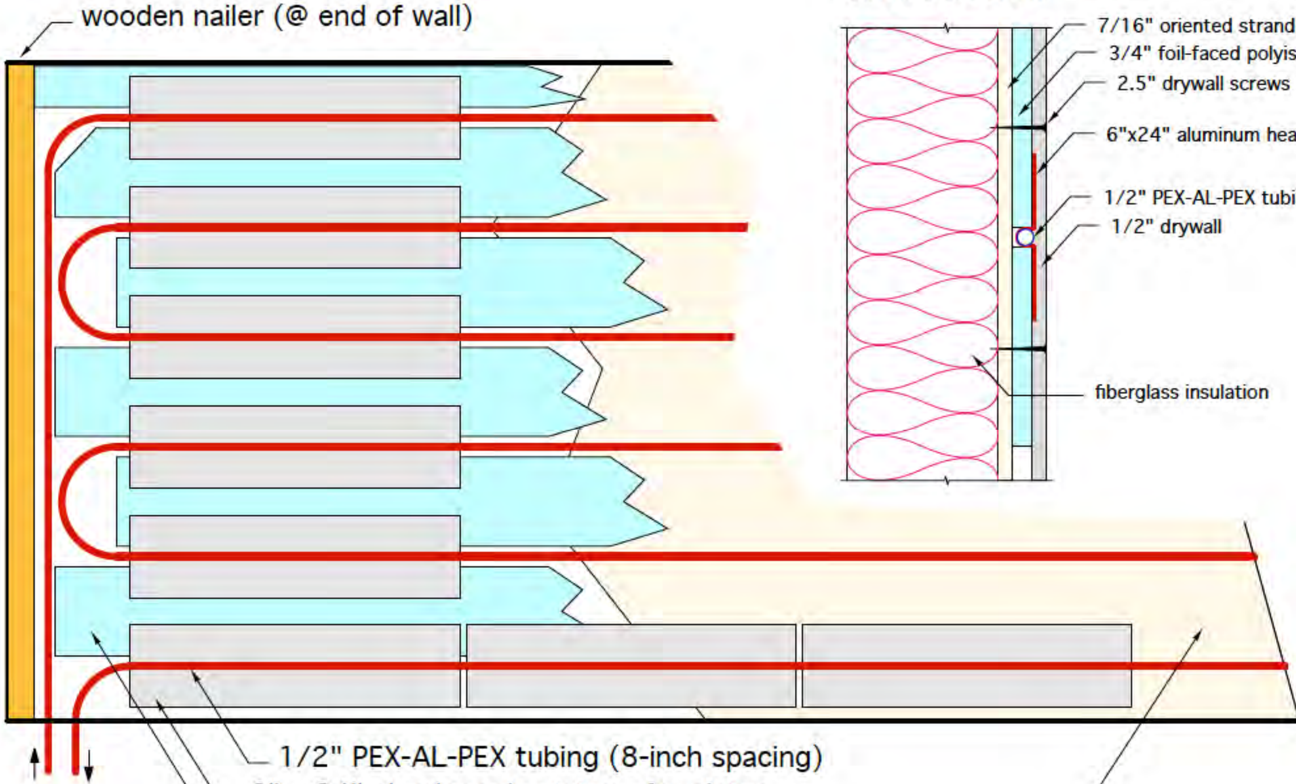


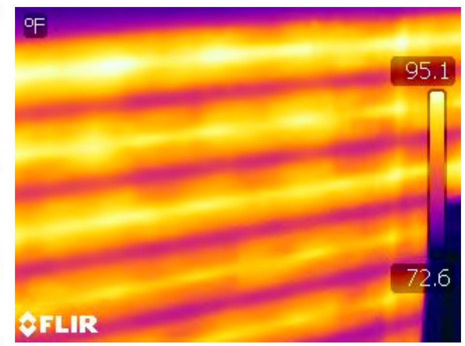
Site built radiant WALLS...





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:

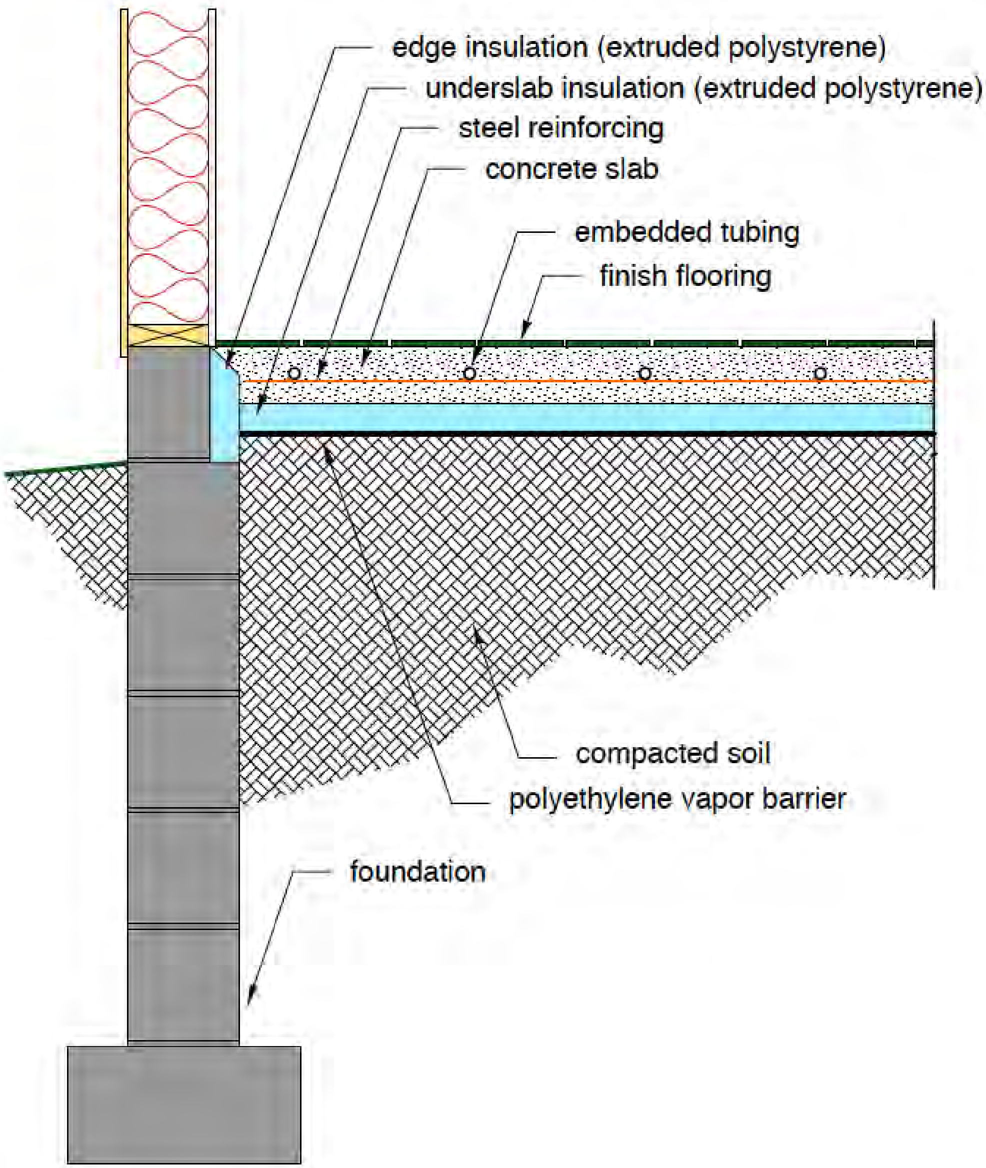
$$q = 0.8 \times (T_{water} - T_{room})$$

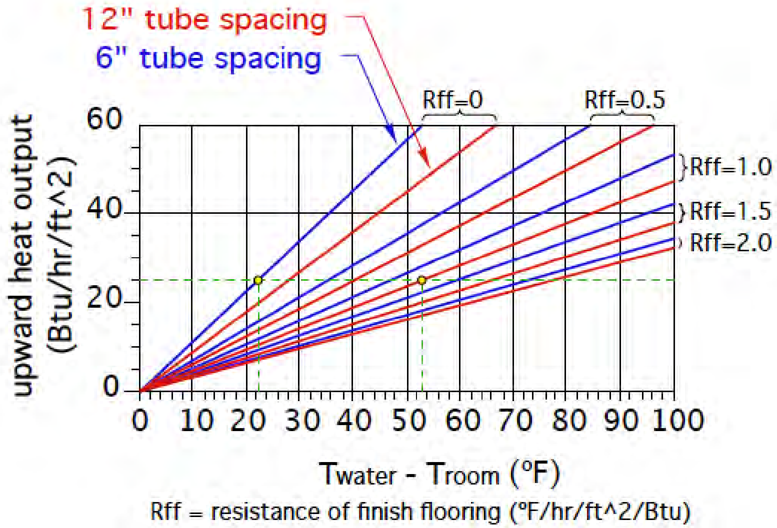
Where:

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

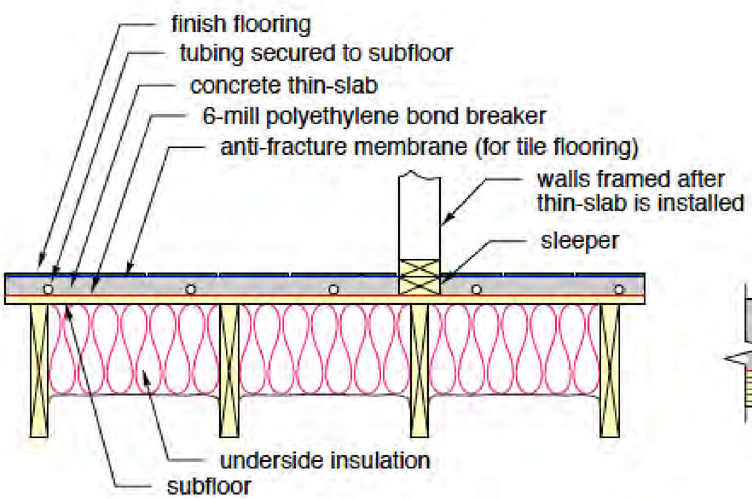
Radiant Floor Heating

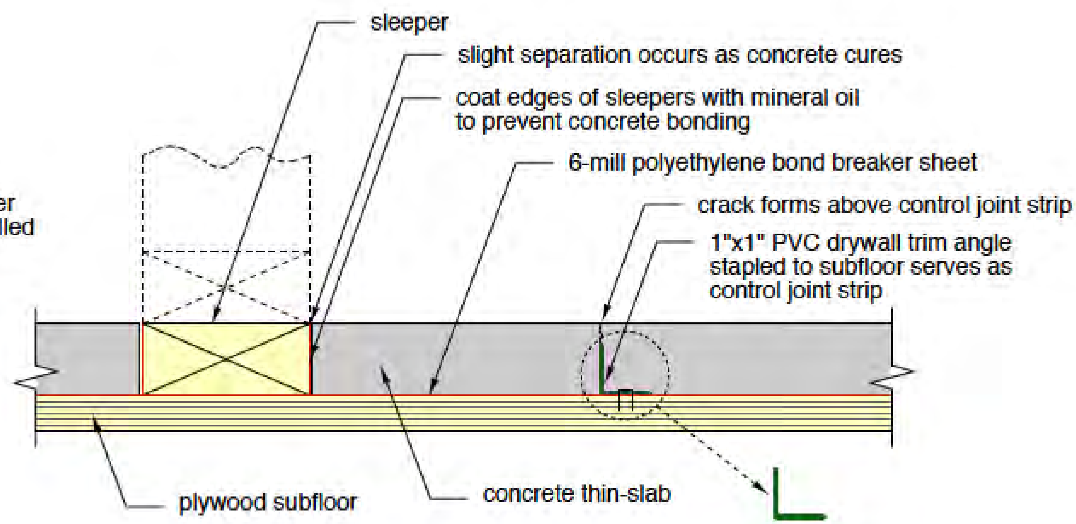
Slab-on-grade floor heating



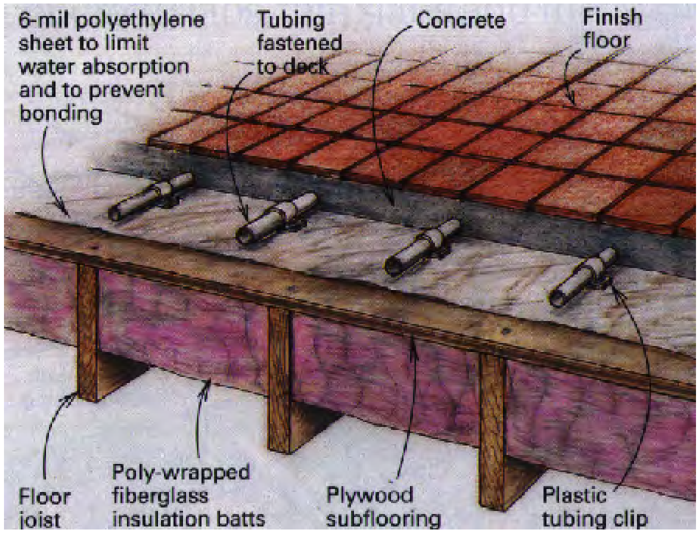


Thin-slab floor heating (using concrete)





Thin-slab floor heating (using concrete)



Strengths:

- Usually lower installed cost relative to poured gypsum thin-slab
- Operate on low water temperatures (good match to GSHP)
- Very durable, waterproof
- Medium thermal storage tends to smooth heat delivery

Limitations:

- Slower thermal response (best when loads are slow to change)
- Adds about 18 pounds/square foot to floor loading @ 1.5" thickness

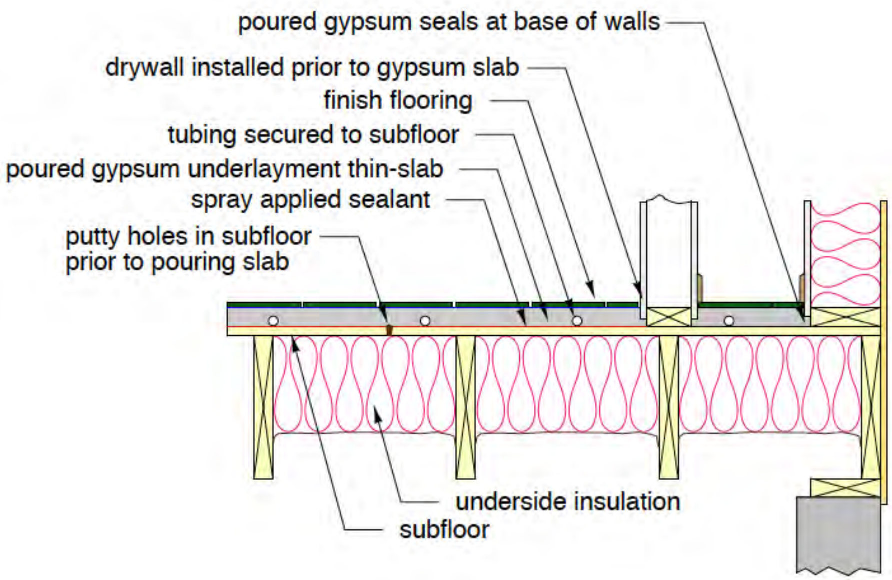
Always...

- Verify load carrying ability of floor framing
- Account for added 1.5 inches in floor height
- Install control joints and release oil on adjacent framing
- Install polyethylene bond breaker layer between subfloor and slab
- Pressure-test circuits prior to placing concrete
- Make tubing layout drawing prior to placing tubing
- Install R-11 to R-30 underside insulation

Never...

- Allow concrete to freeze prior to curing
- Pressure-test with water
- Place tubing closer than 9 inches to toilet flanges
- Cover with flooring having total R-value over 2.0°F hr/ft^2/Btu
- Use asphalt-saturated roofing felt for bond breaker layer
- Exceed 12" tube spacing

Thin-slab floor heating (using poured gypsum underlayment)



Thin-slab floor heating (using poured gypsum underlayment)

Strengths:

- Faster installation than concrete thin-slab
- Operates on low water temperatures (good match to GSHP)
- Excellent air sealing at wall/floor intersection
- Medium thermal storage tends to smooth heat delivery
- No control joints required

Limitations:

- Slower thermal response (best when loads are slow to change)
- Adds about 14.5 pounds/square foot to floor loading @ 1.5” thickness
- Not waterproof

Always...

- Verify load-carrying ability of floor framing
- Account for added 1.5 inches in floor height
- Pressure-test circuits prior to placing gypsum underlayment
- Make tubing layout drawing prior to placing tubing
- Install R-11 to R-30 underside insulation
- Use proper surface preparations prior to finish flooring

Never...

- Allow gypsum to freeze prior to curing
- Pressure-test with water
- Place tubing closer than 9 inches to toilet flanges
- Cover with flooring having total R-value over 2.0°F hr/ft^2/Btu
- Exceed 12” tube spacing
- Install in locations that could be flooded

Water-based thermal storage options

Water-based thermal storage options

1. unpressurized tanks
2. pressurized tanks

courtesy of American Solartechnics

courtesy of Hydroflex

courtesy of AHONA

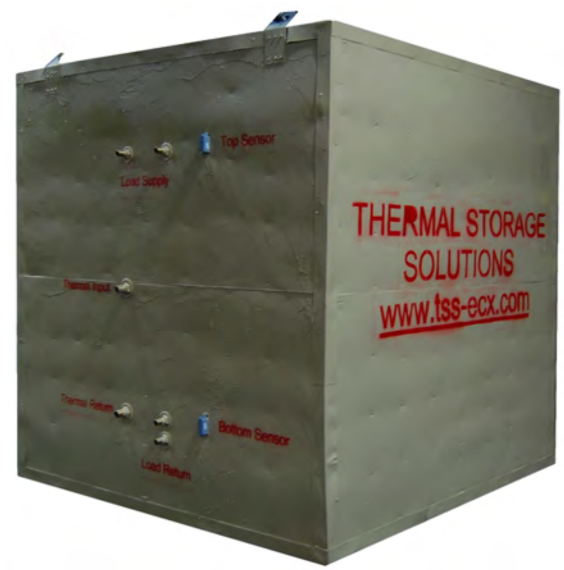
Open (unpressurized) buffer tanks

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**

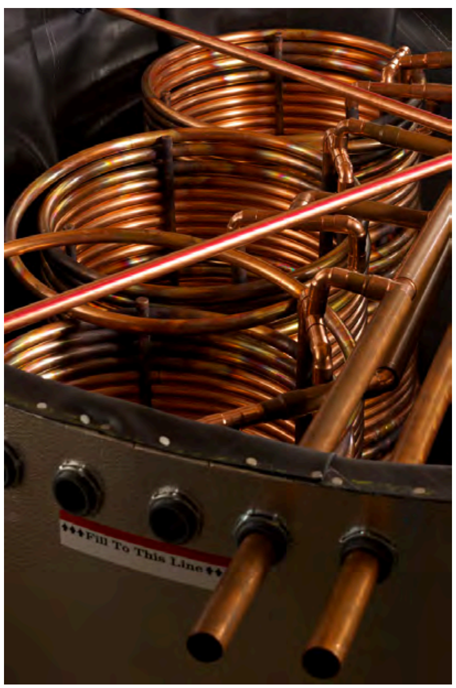
courtesy of American Solartechnics

courtesy of Hydroflex



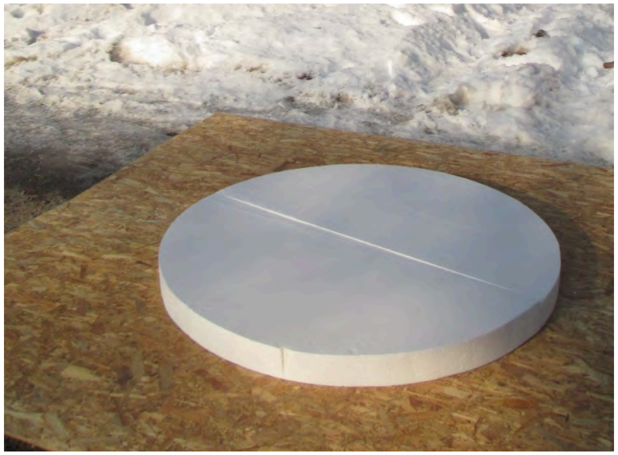
courtesy of Thermal Storage Solutions

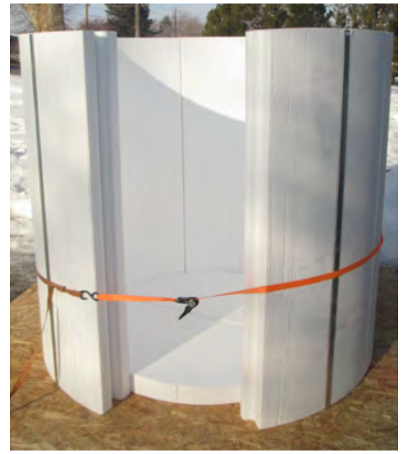
Open (unpressurized) buffer tanks

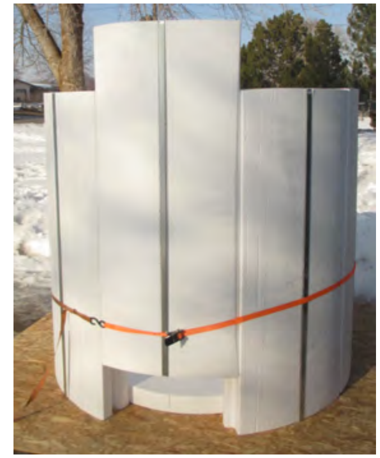


images courtesy of Hydroflex

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

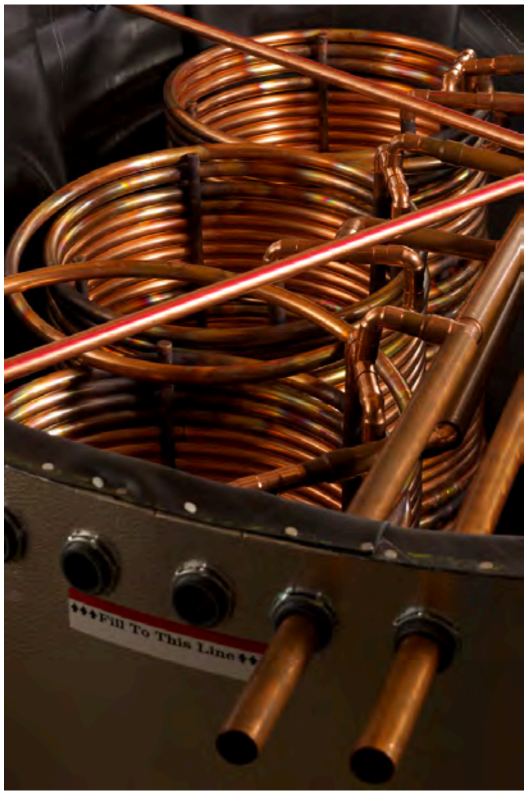
http://cocoontanks.com

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

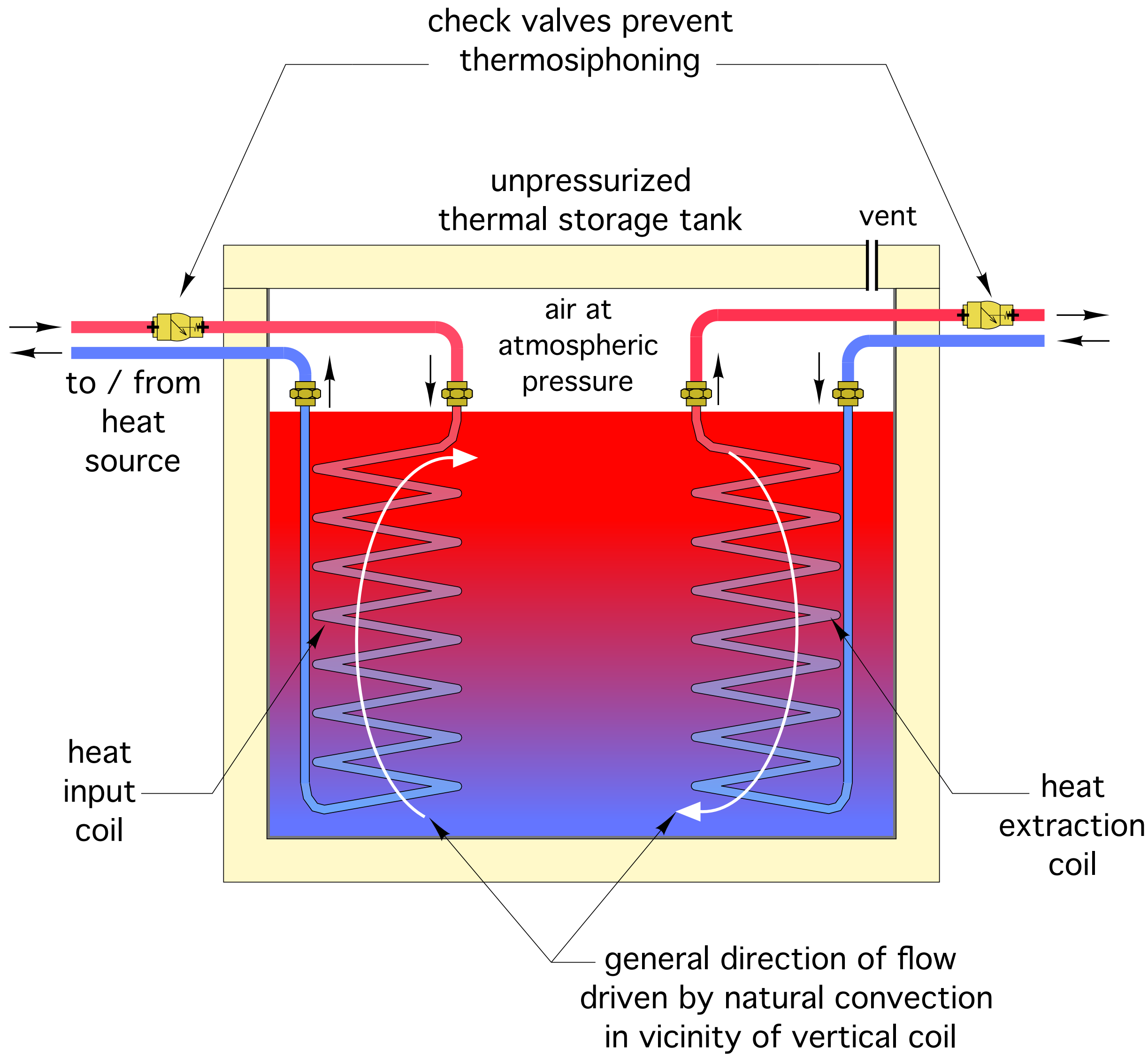
courtesy of American Solartechnics

courtesy of Solar Usage Now

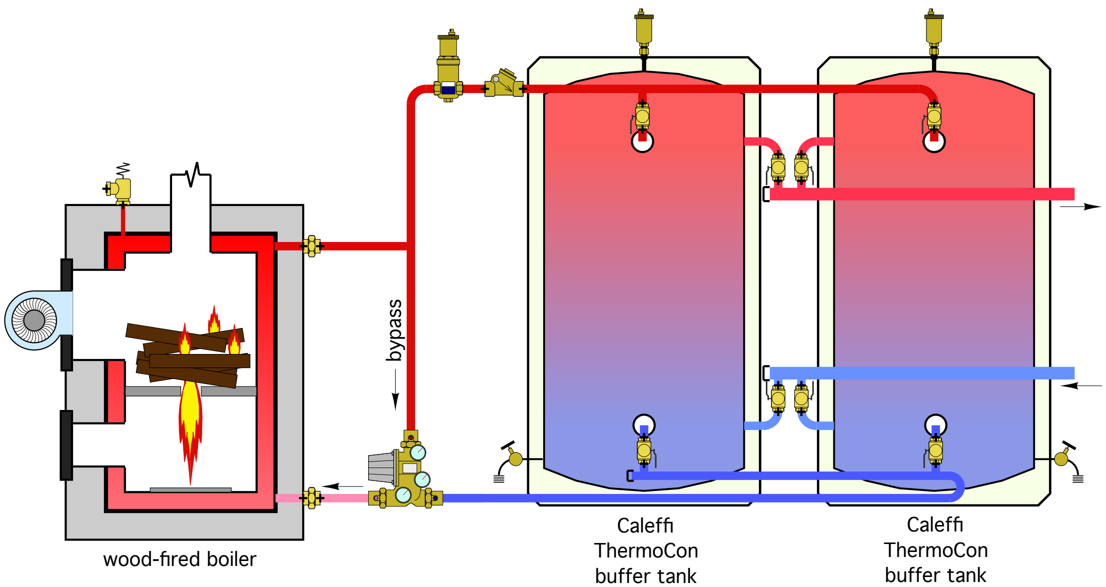
- Flow direction should produce counterflow heat exchange
- Use check valves to prevent thermosiphoning



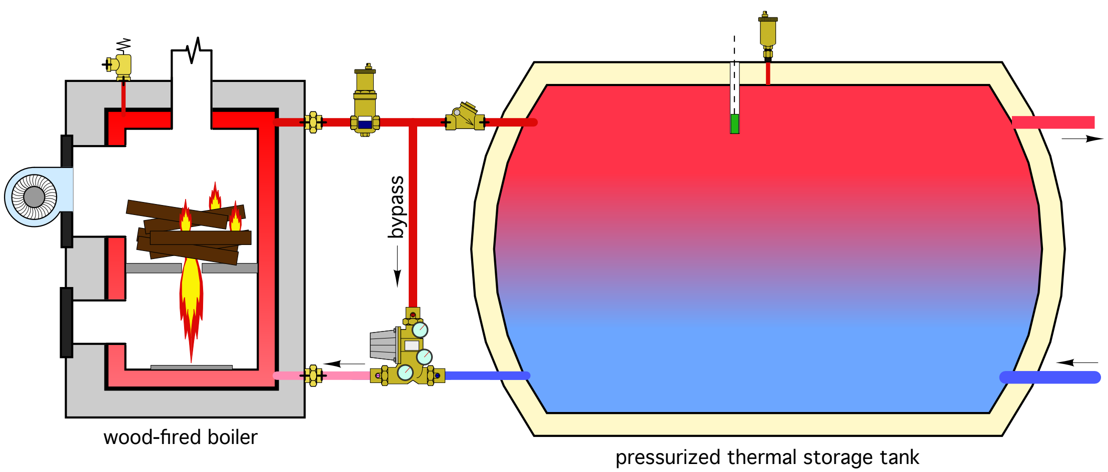
courtesy of Hydroflex



Closed/pressurized thermal storage tanks



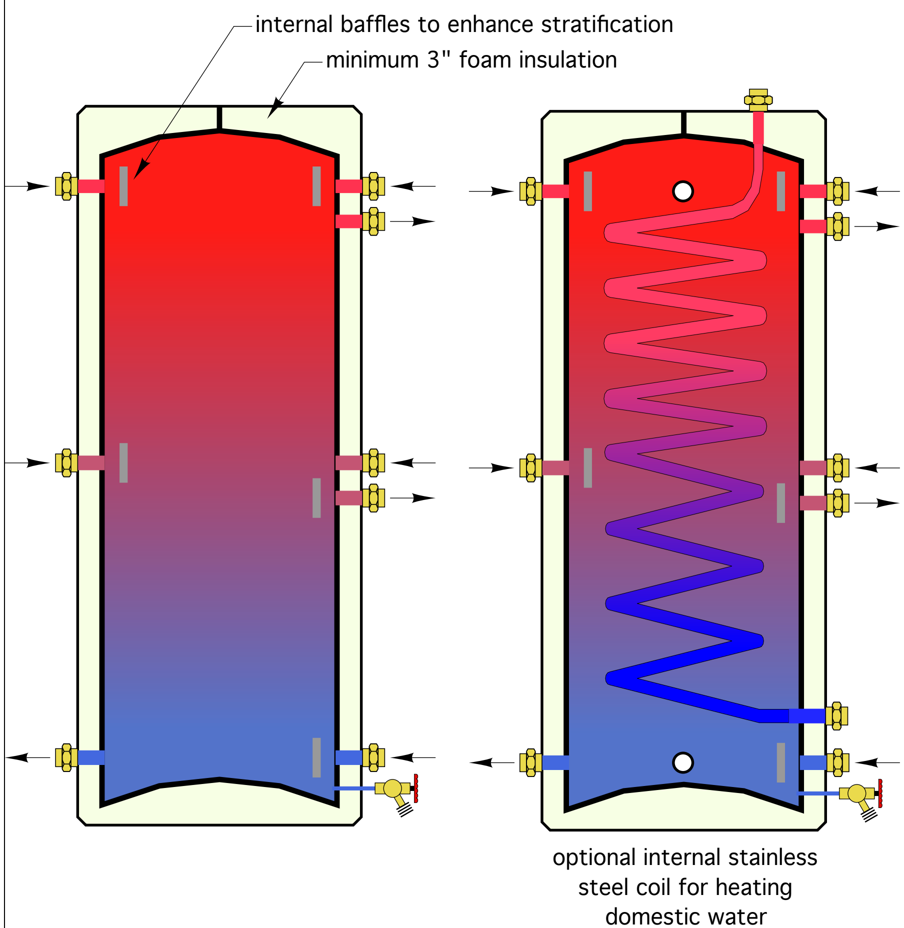
courtesy of Caleffi North America



courtesy of AHONA

Tanks designed for good stratification

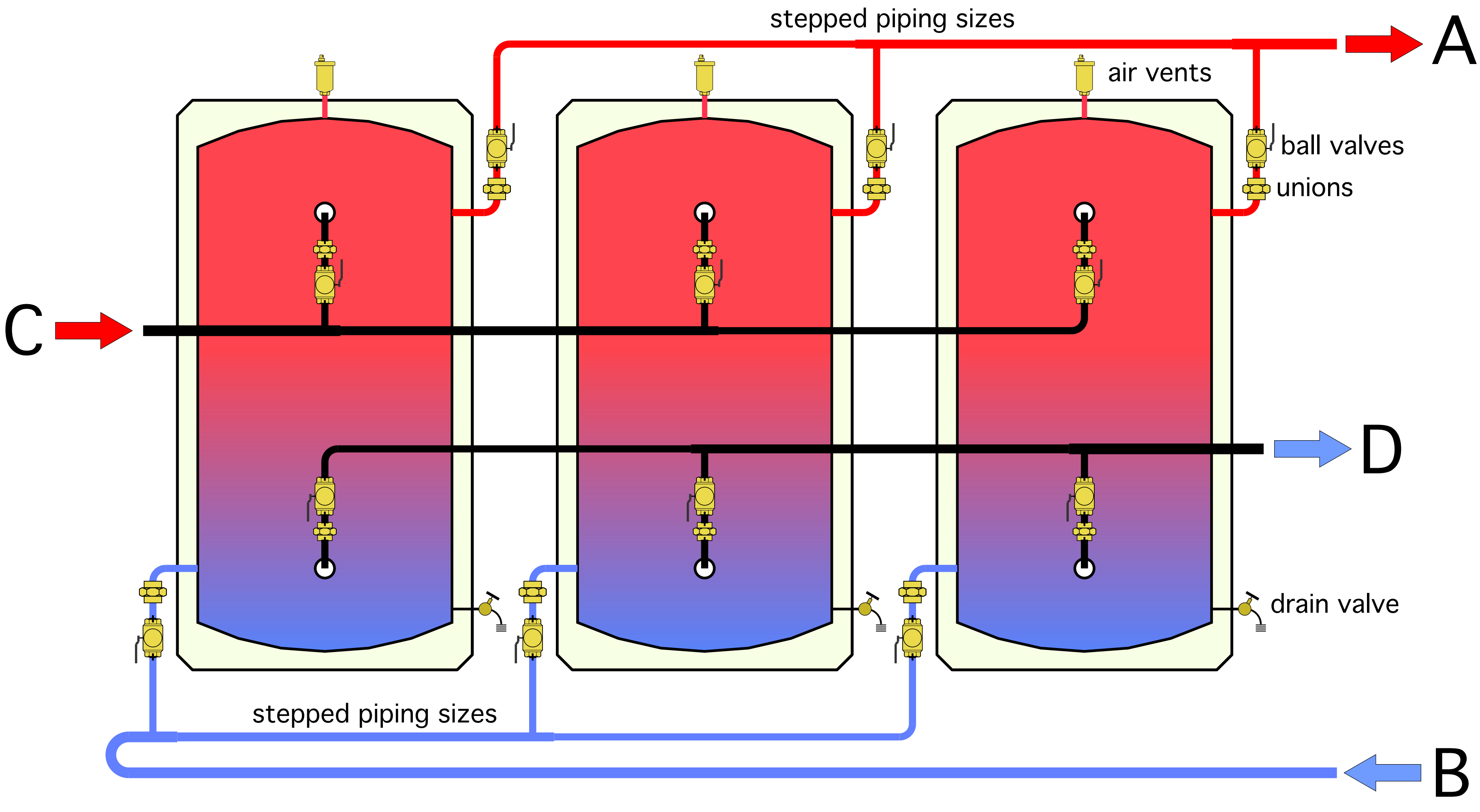
- Vertical orientation for good stratification.



StratoTherm tanks from Lochinvar
9 models 125 - 900 gallons (ASME listed)

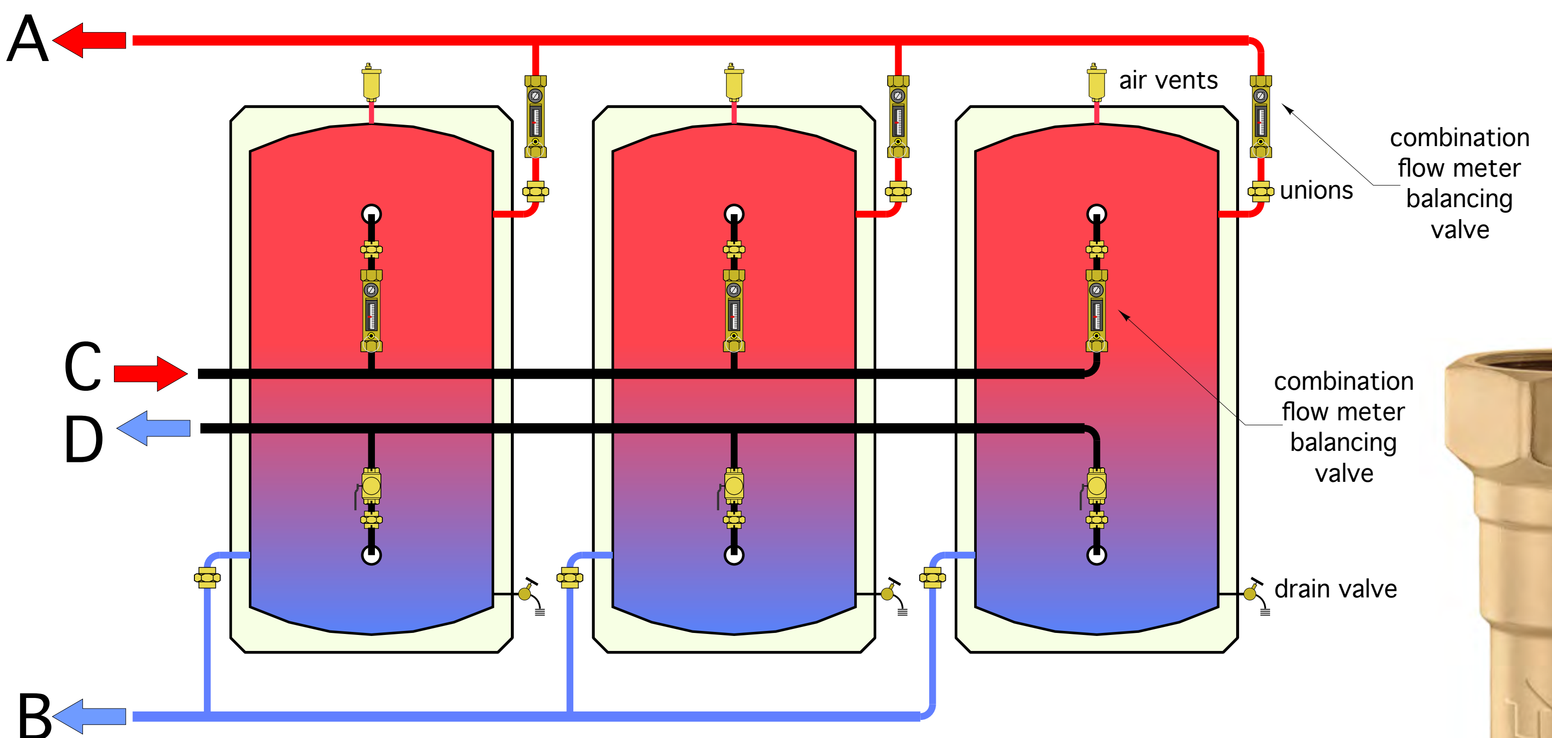
Piping to ensure balanced flow in multiple tanks

Reverse return piping with stepped header sizes



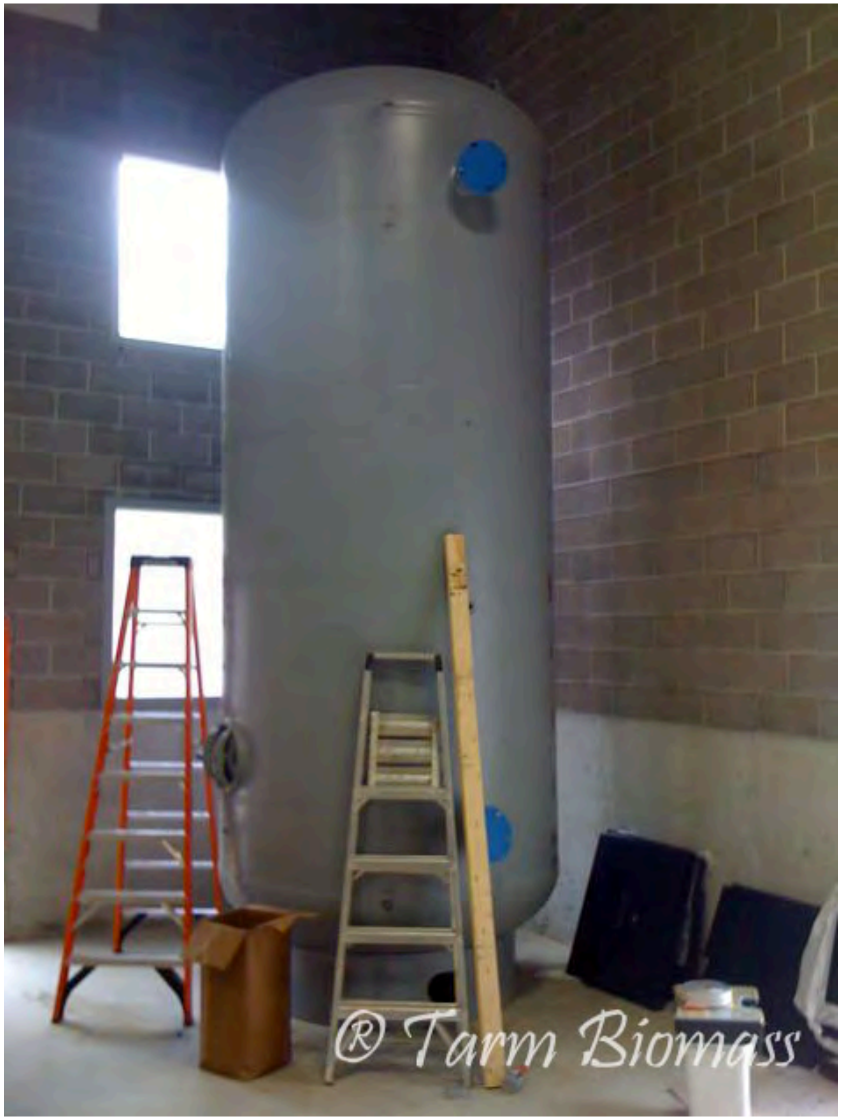
Piping to ensure balanced flow in multiple tanks

If direct return piping is used always install balancing valves



courtesy of Caleffi

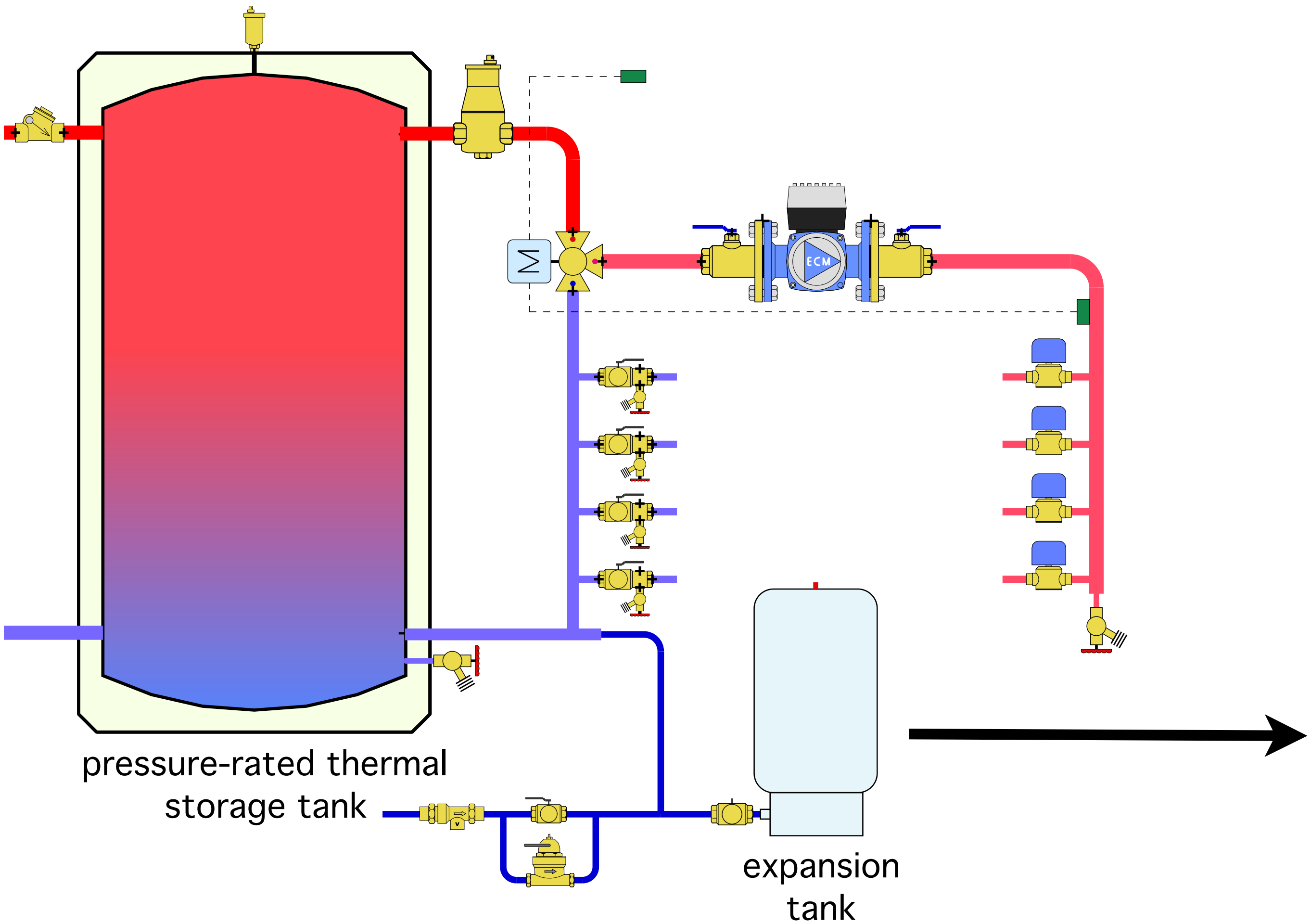
Large thermal storage tanks...



4000 gallon ASME tank, site insulated

Suggest min. R-24 tank insulation

Large pressurized storage requires larger expansion tanks



courtesy of Amtrol

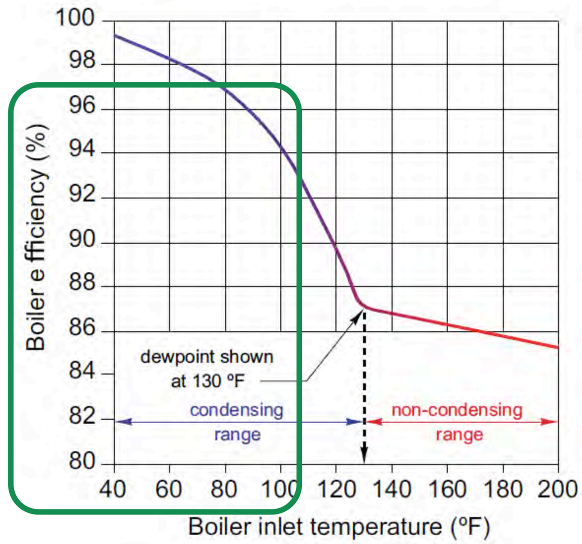
First pass estimate:

Expansion tank volume = 10% of thermal storage volume.

Distribution efficiency & low-power pumping

The North American Hydronics market has many “high efficiency” boilers

In the right applications these boilers have efficiencies in the 95+ range:



It may appear there isn’t room for improving the efficiency of hydronic systems…

At least that’s what people who focus *solely* on the boiler might conclude

For decades our industry has focused on *incremental improvements* in the thermal efficiency of heat sources.

At the same time we’ve largely ignored the hydraulic efficiency of the distribution system.

Those seeking high efficiency hydronic systems have to understand **“Its not always about the boiler!”**

The present situation:

What draws your attention in the photo below?

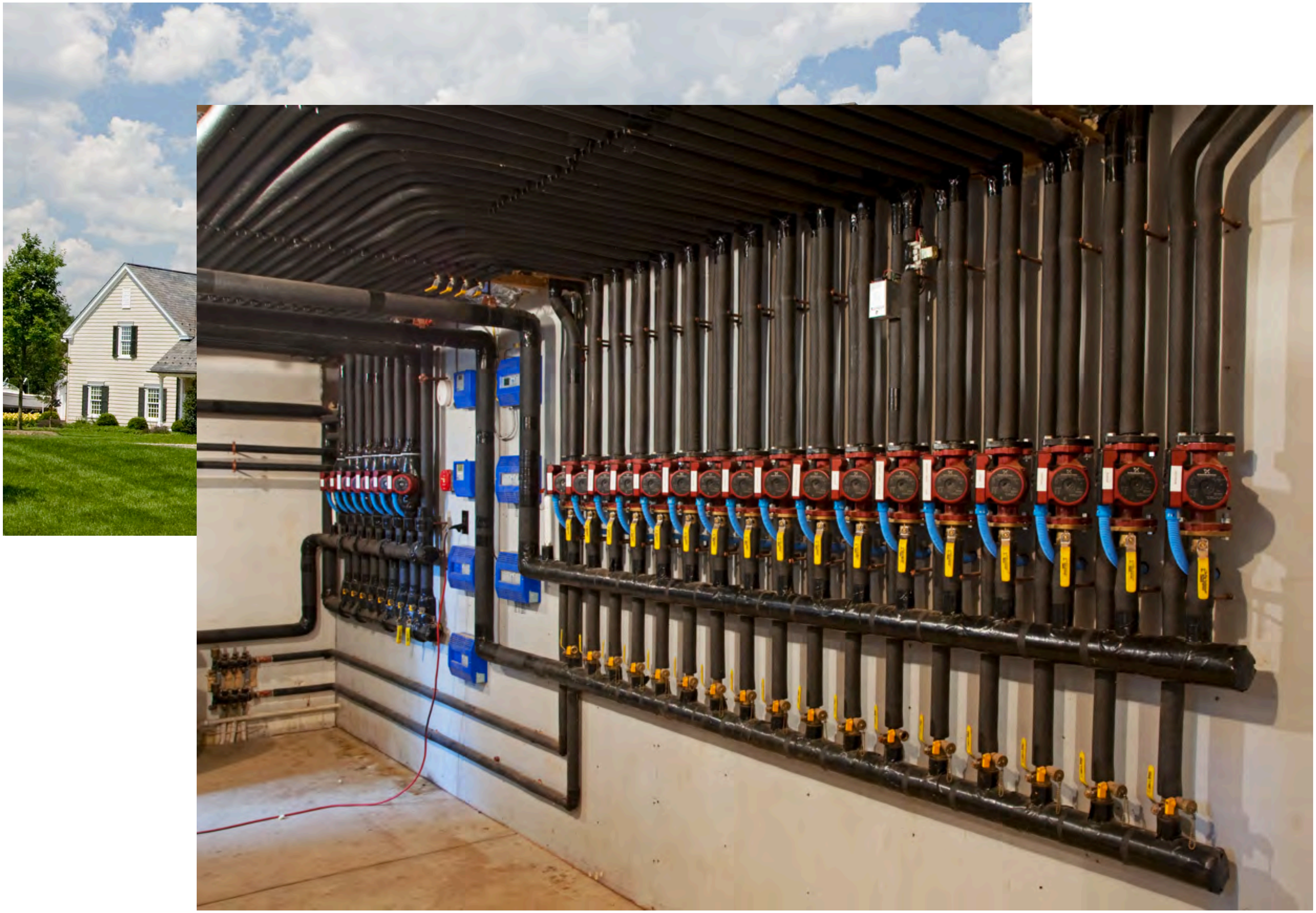
If all these circulators operate simultaneously (at design load) the electrical demand will be in excess of 5000 watts.

That’s the heating equivalent of about 17,000 Btu/hr!

Here's another example...

Great "craftsmanship" - Wrong "concept"

Here's another (award winning) example…



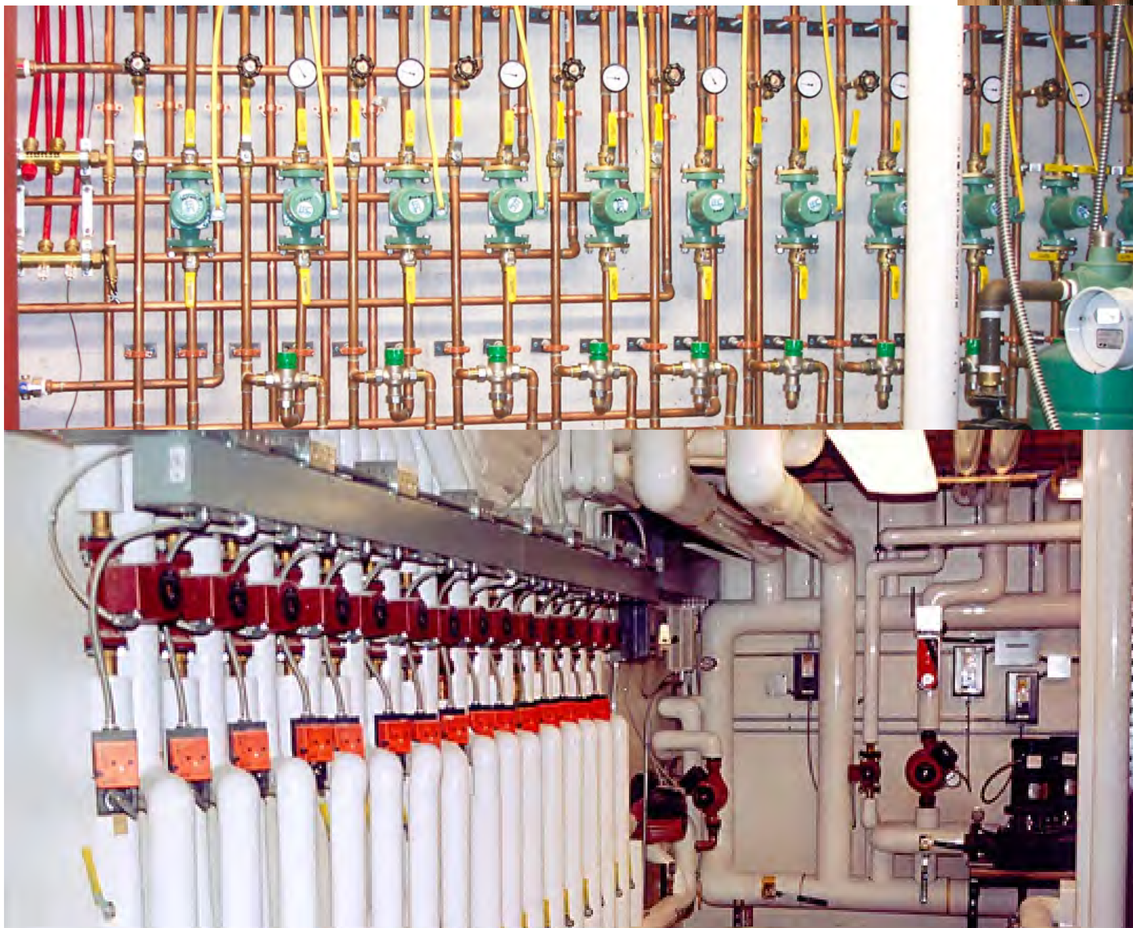
If you run out of wall space consider this installation technique...

Notice the installer left provisions for additional circulators.

So what can you conclude from these photos?

Perhaps that it's <u>GOOD</u> to be in the circulator business these days!

You might also conclude that…



The North American hydronics industry tends to "overpump" its systems!

Just to be fair to the pump guys –
there is such a thing as overzoning with zone valves…

Although as an industry we pride ourselves on ultra high efficiency and "eco-friendly" heat sources, we…

Must look beyond the efficiency of only the heat source.

We need to look at the overall **SYSTEM efficiency**.

This includes the **thermal efficiency** of converting fuel in heated water AND the **distribution efficiency** of moving that water through the building.

This is important

So is this!

Defining DISTRIBUTION EFFICIENCY

$$\text{Efficiency} = \frac{\text{desired OUTPUT quantity}}{\text{necessary INPUT quantity}}$$

Distribution efficiency for a space heating system.

$$\text{distribution efficiency} = \frac{\text{rate of heat delivery}}{\text{rate of energy use by distribution equipment}}$$

Consider a system that delivers 120,000 Btu/hr at design load conditions using four circulators operating at 85 watts each. The distribution efficiency of that system is:

$$\text{distribution efficiency} = \frac{120{,}000 \text{ Btu/hr}}{340 \text{ watts}} = 353 \ \frac{\text{Btu/hr}}{\text{watt}}$$

So is a distribution efficiency of 353 Btu/hr/watt good or bad?

To answer this you need something to compare it to.

Suppose a furnace blower operates at 850 watts while delivering 80,000 Btu/hr through a duct system. It delivery efficiency would be:

$$\text{distribution efficiency} = \frac{80{,}000 \text{ Btu/hr}}{850 \text{ watts}} = 94 \ \frac{\text{Btu/hr}}{\text{watt}}$$

The hydronic system in this comparison has a distribution efficiency almost four times higher than the forced air system.

Water is vastly superior to air as a conveyor belt for heat.

Room for Improvement…

A few years ago I inspected a malfunctioning hydronic heating system in a 10,000 square foot house that contained **40 circulators**.

Assume the average circulator wattage is 90 watts.

The design heating load is 400,000 Btu/hr

The distribution efficiency of this system at design load is:

$$\text{distribution efficiency} = \frac{400{,}000\ \text{Btu/hr}}{40 \times (90\ \text{watts})} = 111\ \frac{\text{Btu/hr}}{\text{watt}}$$

Not much better than the previous forced air system at 94 Btu/hr/watt

Water Watts...

It's hard to say if the wattage of past or current generation circulators is "where it needs to be" without knowing the mechanical power needed to move fluid through a specific circuit.

$$w_m = 0.4344 \times f \times \Delta P$$

Where:

W_m = mechanical power required to maintain flow in circuit (watts)

f= flow rate in circuit (gpm)

ΔP = pressure drop along circuit (psi)

0.4344 = units conversion factor

Example: How much mechanical power is necessary to sustain a flow of 180 ºF water flows at 5 gpm through a circuit of 3/4” copper tubing having an equivalent length of 200 feet?

Solution: The pressure drop associated with this head loss is 3.83 psi.

Putting these numbers into the formula yields:

$$w_m = 0.4344 \times f \times \Delta P = 0.4344 \times 5 \times 3.83 = 8.3 watts$$

That’s quite a bit lower than the electrical wattage of even the smallest currently-available circulator. Why?

Because it’s only the <u>mechanical wattage</u> required (power dissipation by the fluid) - <u>not the electrical input wattage</u> to the circulator’s motor.

The ratio of the mechanical wattage the impeller imparts to the water divided by the electrical input wattage to operate the motor is called wire-to-water efficiency.

$$n_{w/w} = \frac{w_m}{w_e}$$

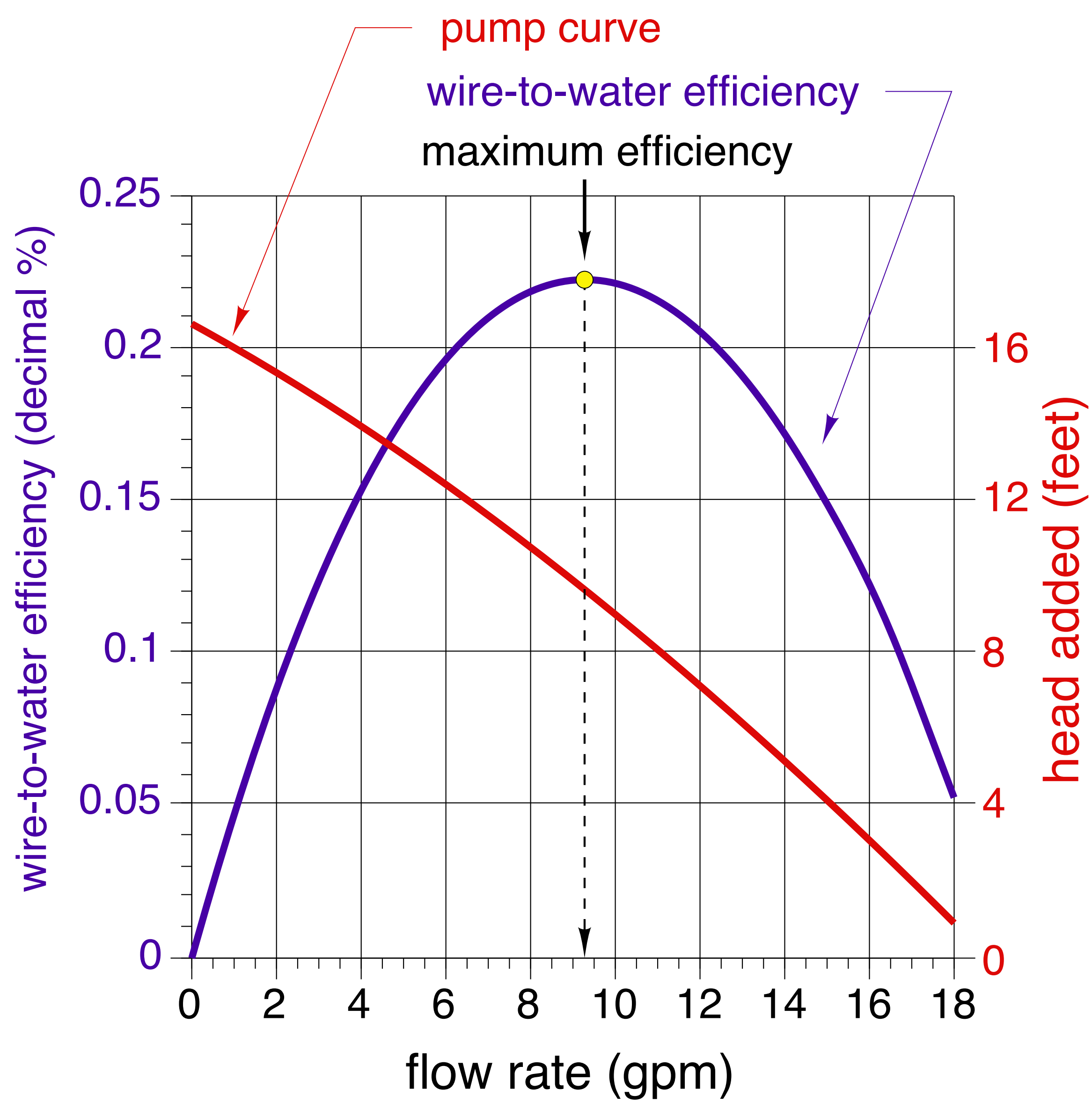
Where:

$n_{w/w}$ = wire-to-water efficiency of the circulator (decimal %)

w_m = mechanical power transferred to water by impeller (watts)

w_e = electrical power input to motor (watts)

If you take operating data for a typical 1/25 hp fixed-speed wet rotor circulator and plug it into this formula the efficiency curve looks as follows:



The electrical wattage needed by the circulator is:

$$w_e = \frac{0.4344 \times f \times \Delta P}{n_{w/w}}$$

A current-generation wet-rotor circulator has a maximum wire-to-water efficiency in the range of 25 percent. If we put the data from previous example into this formula we get the electrical wattage required to maintain flow in the circuit.

$$w_e = \frac{0.4344 \times f \times \Delta P}{n_{w/w}} = \frac{0.4344 \times 5 \times 3.83}{0.25} = 33.2 watts$$

Consider that a flow of 5 gpm in a circuit with a 20 ºF temperature drop is moving about 50,000 Btu/hr, and the electrical power to "run the conveyor belt" according to the last calculation is 33.2 watts. The distribution efficiency of such a circuit is:

$$n_d = \frac{Q}{w_e} = \frac{50{,}000\,Btu/hr}{33.2\,watt} = 1506\,\frac{Btu/hr}{watt}$$

Compare this to a 4-ton rated **geothermal water-to-air heat pump** delivering 48,000 Btu/hr using a blower operating on 1080 watts. The distribution efficiency of this delivery system is:

$$n_d = \frac{Q}{w_e} = \frac{48{,}000\,Btu/hr}{1080\,watt} = 44.4\,\frac{Btu/hr}{watt}$$

These numbers mean that the hydronic system delivers heat to the building using only 2.9 percent (e.g. 44.4/1506) of the electrical power required by the forced air delivery system.

With good design it's possible to achieve distribution efficiencies > 3000 Btu/hr/watt

<u>This will become increasingly important in low energy and net zero buildings...</u>

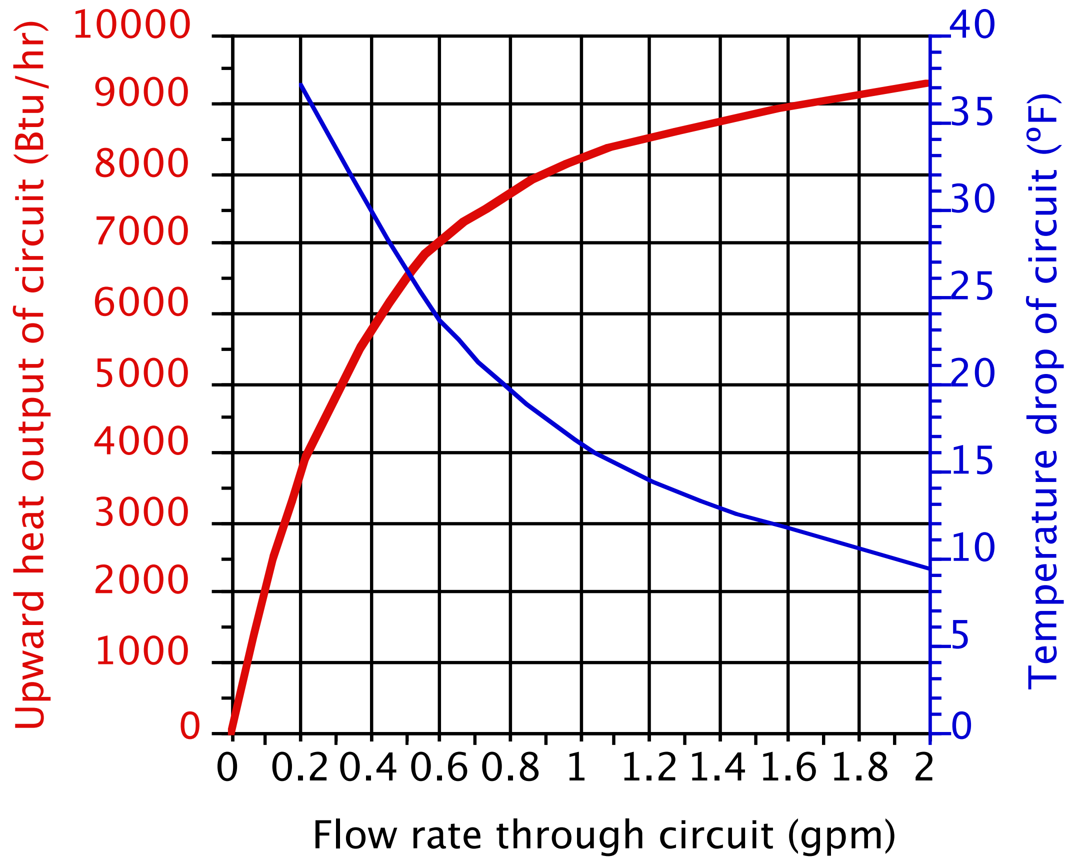
Other factors to Consider…

The heat output from most hydronic heat emitters (including radiant panel circuits) increases rapidly at low flow rates but very slowly at high flow rates (assuming constant supply temperature).

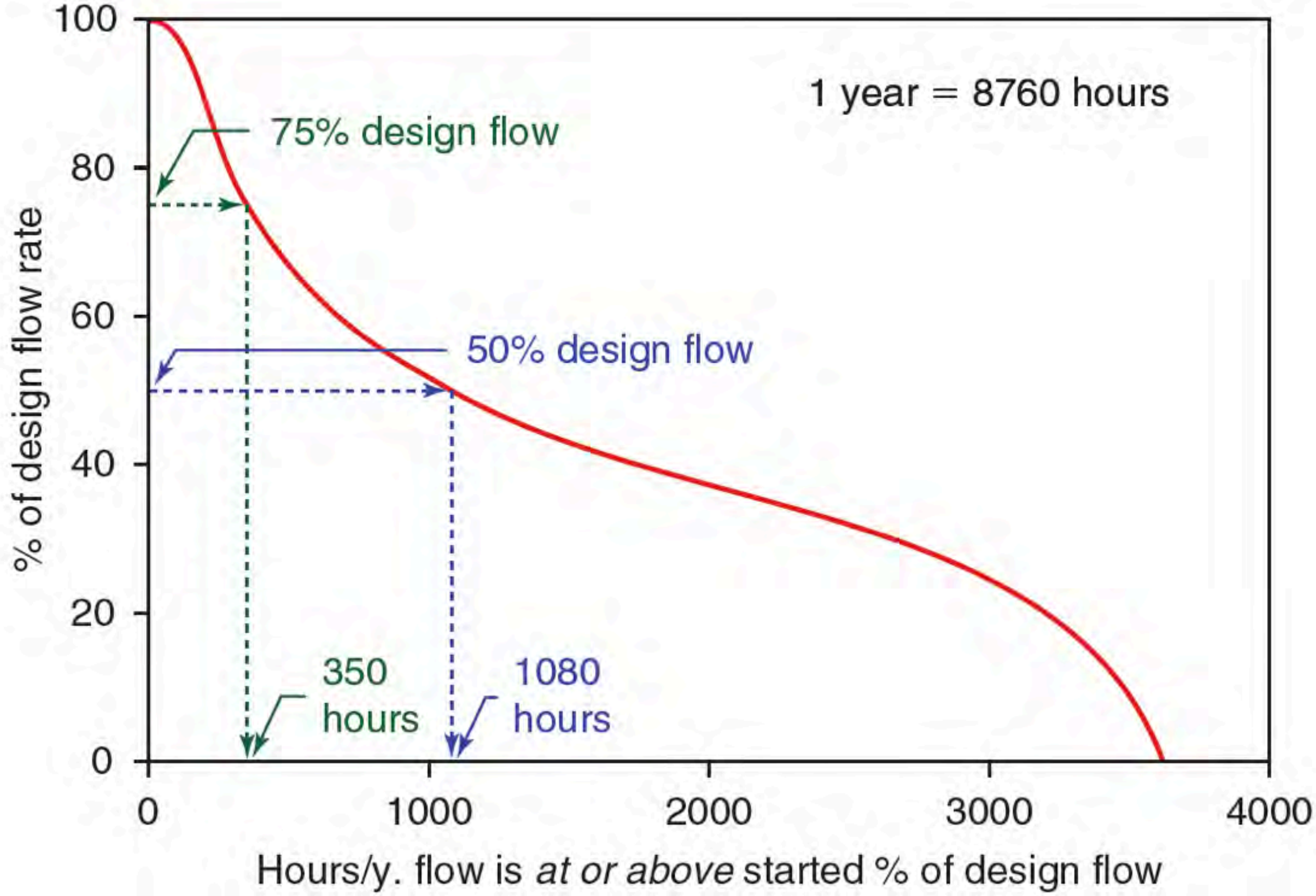
At 50 percent of design flow rate heat output is about 89 percent of design output.

Implication...

If the heat emitters are 11% or more oversized, the system could likely still deliver design load output at 50% or less of its current flow rate.

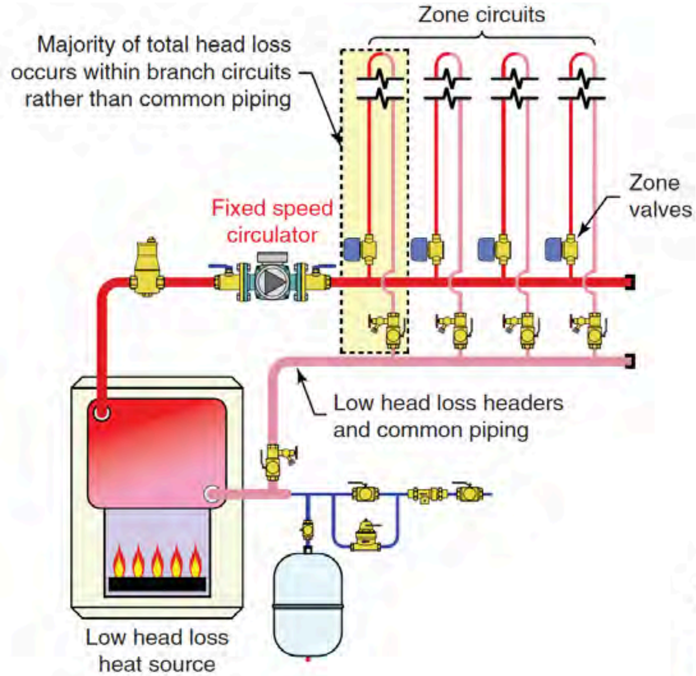


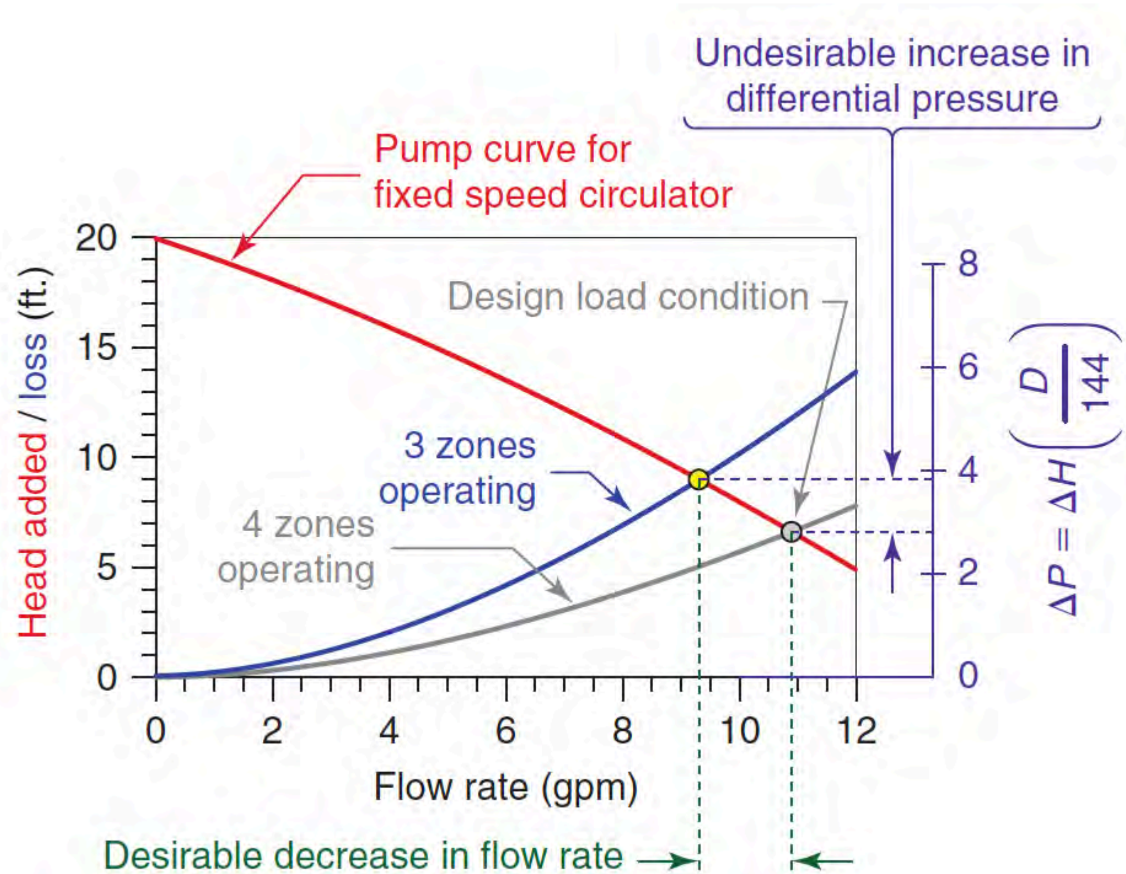
This graph shows the relationship between system flow rate vs. operating hours for a typical Northern climate.



Recognizing that partial flow is common, circulator engineers have developed "intelligent" operating algorithms for variable speed circulators.

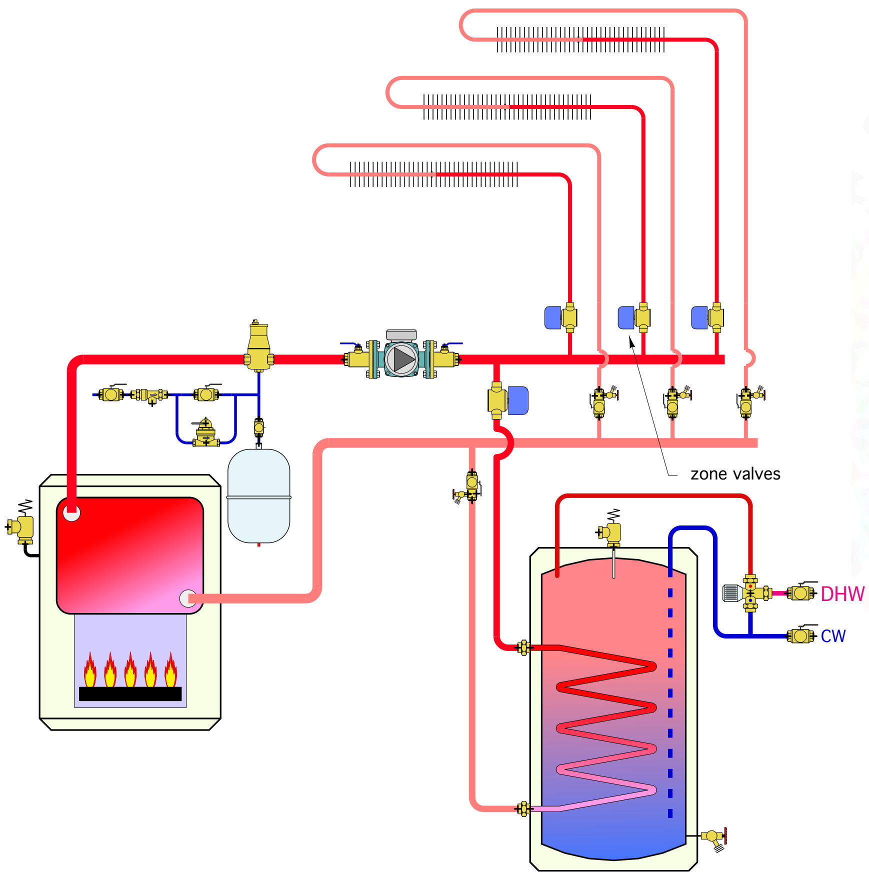
What happens when a zone valve closes?

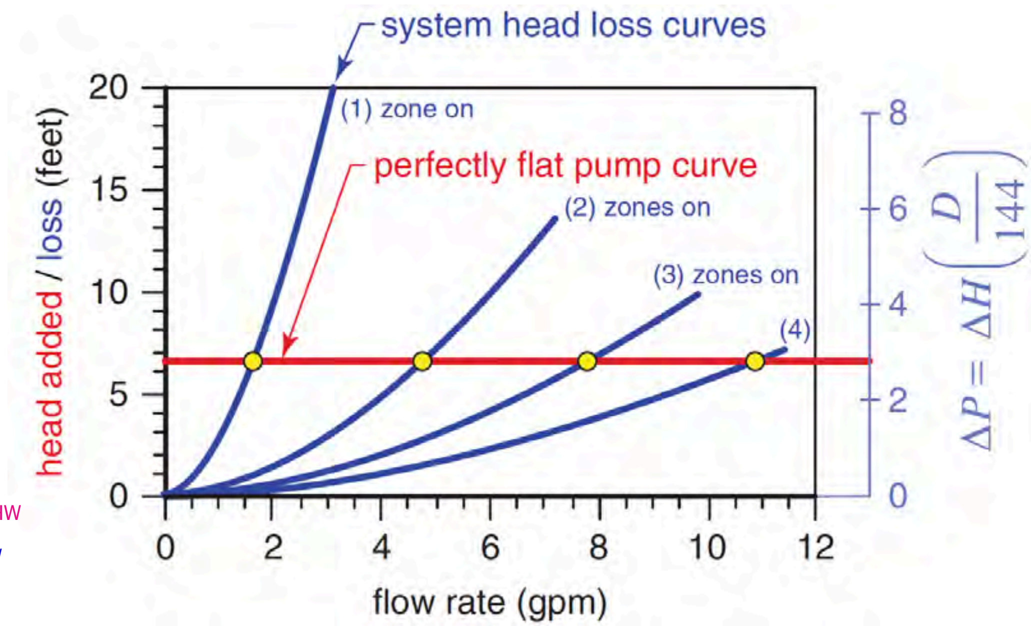




What would be the **ideal** pump curve for a hydronic system using valve based zoning?

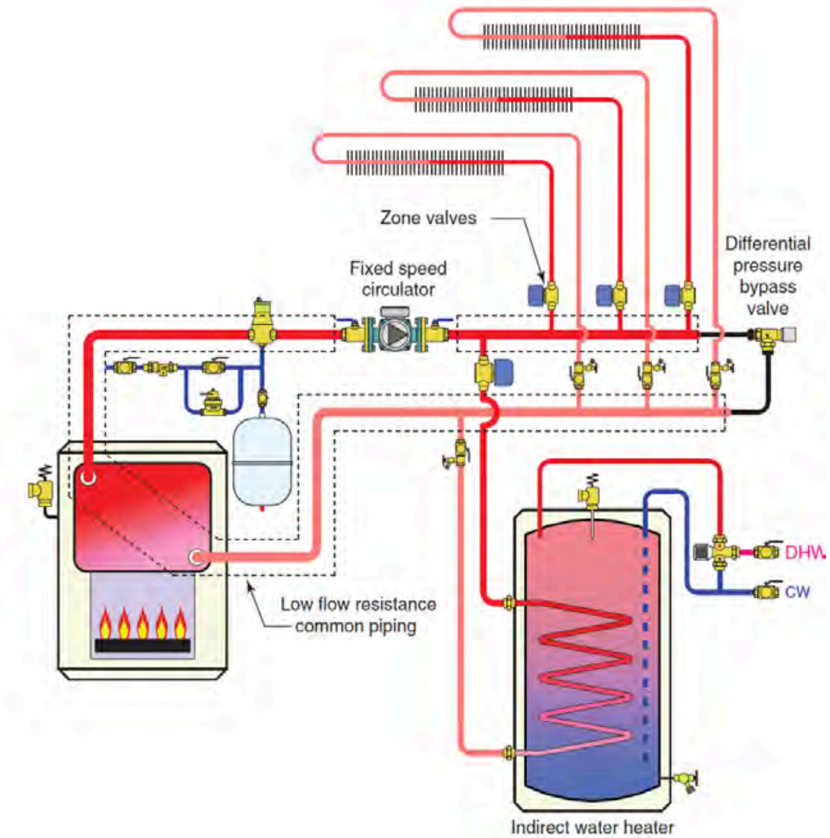
Answer: a perfectly flat pump curve

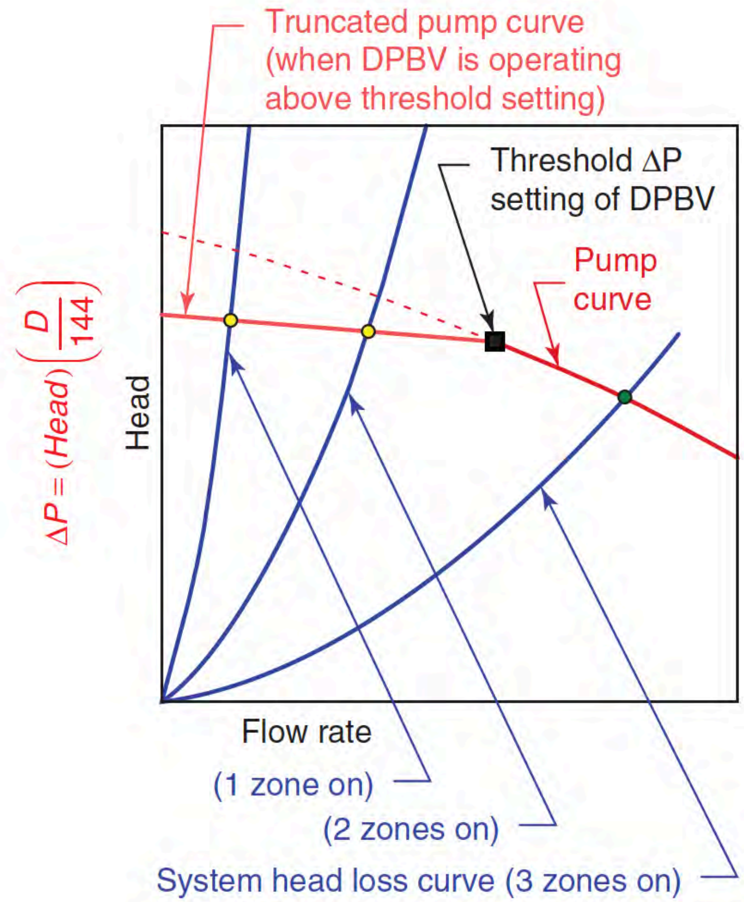




A perfectly flat pump curve would all steady flow rate in every zone circuit, regardless of which other zones are on.

Approximating a flat pump curve with ΔP bypass valve

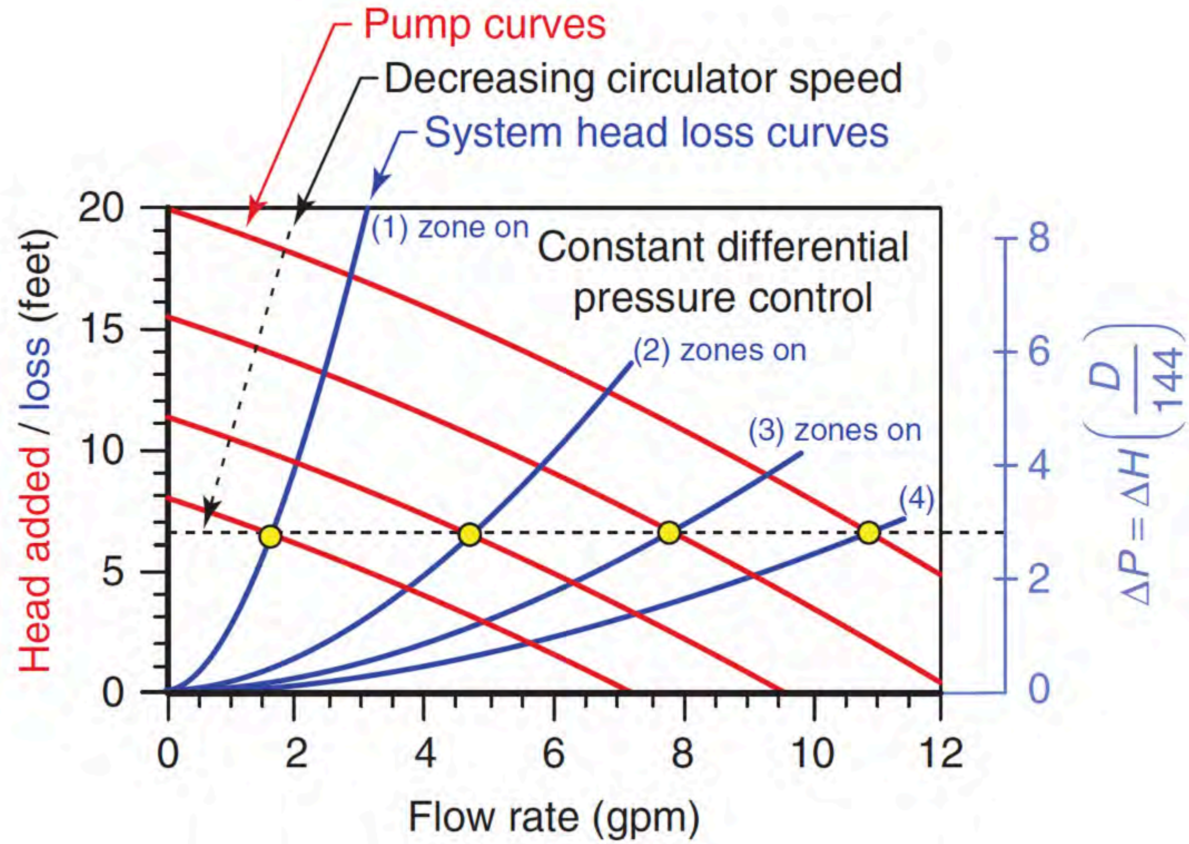




A ΔP bypass valve helps limit changes in differential pressure, but does so "parasitically" by throttling away head energy

Approximating a flat pump curve with ΔP bypass valve

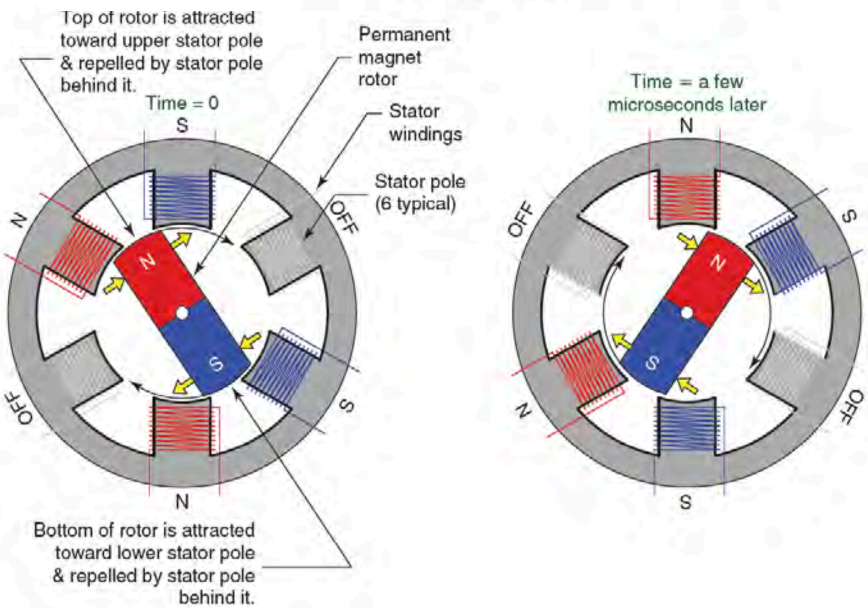
By varying the speed of the circulator it is possible to produce the same "net" effect as would be produced by a perfectly flat pump curve.

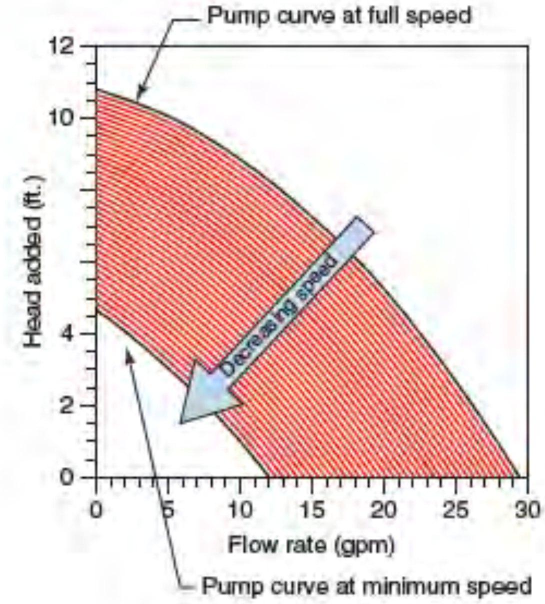


This is called
CONSTANT DIFFERENTIAL PRESSURE CONTROL

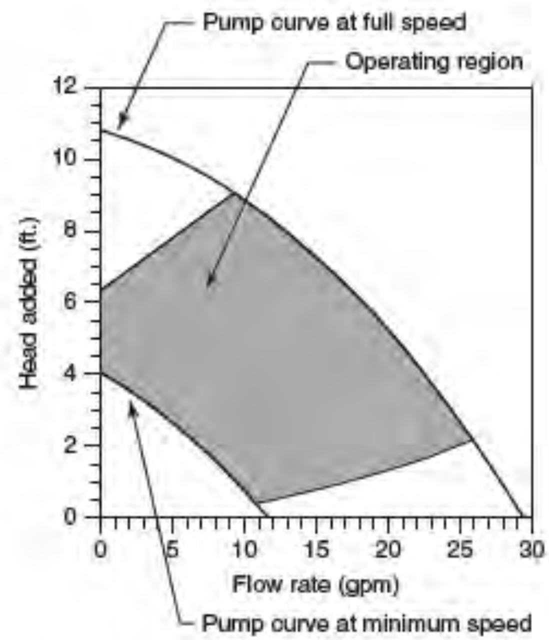
How does a ECM Circulator work?

Image courtesy Grundfos





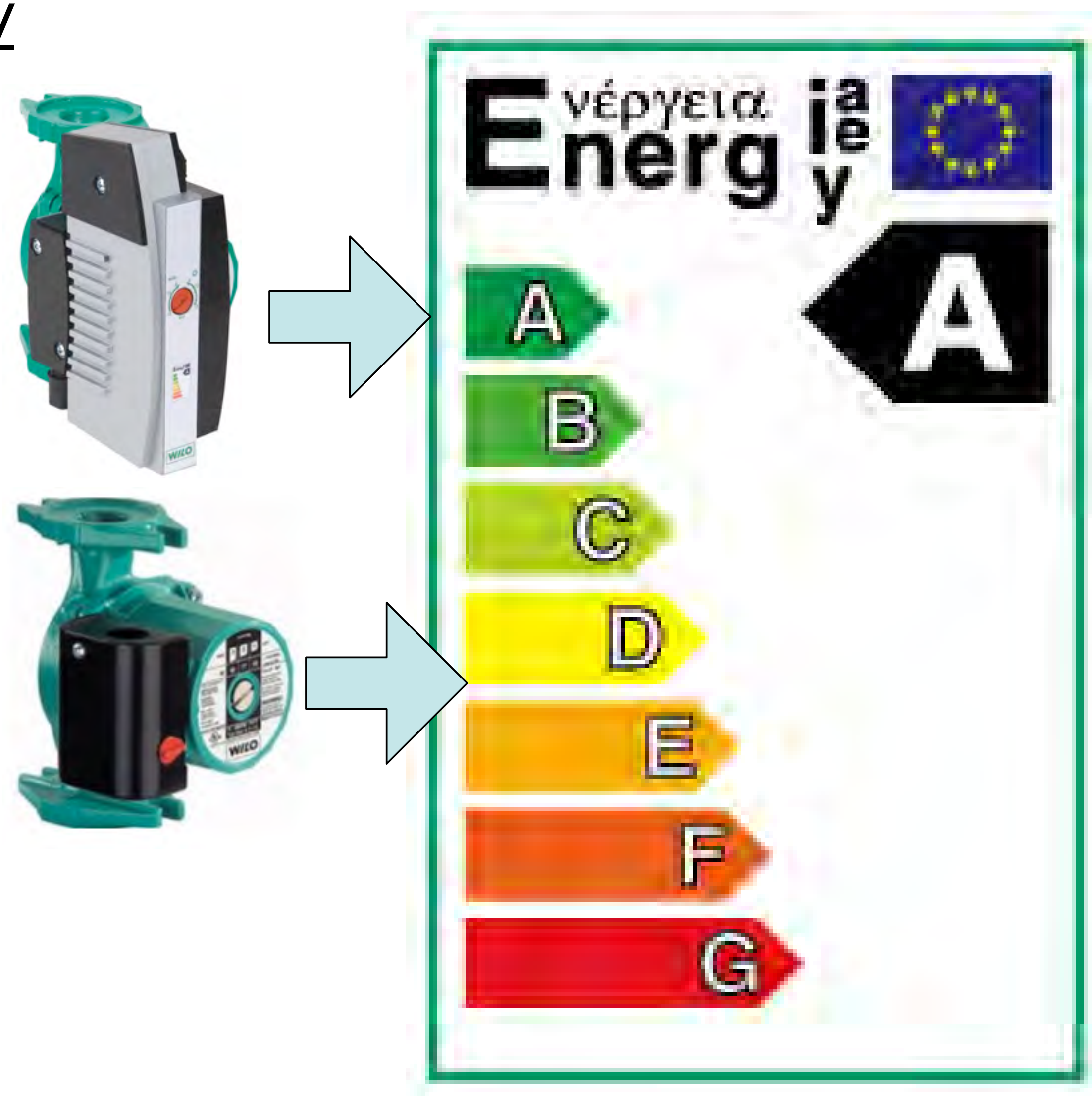
(a)



(b)

Former European circulator rating system

All these circulators rated "A" on the energy labeling system from Europump (European Association of Pump Manufacturers).



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: 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

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

Circulators

high efficiency ECM Circulators

Larger ECM circulators now available in US

Grundfos MAGNA

Taco Viridian

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

Wilo STRATOS circulators

B&G ECO XL

Outdoor reset control & mixing

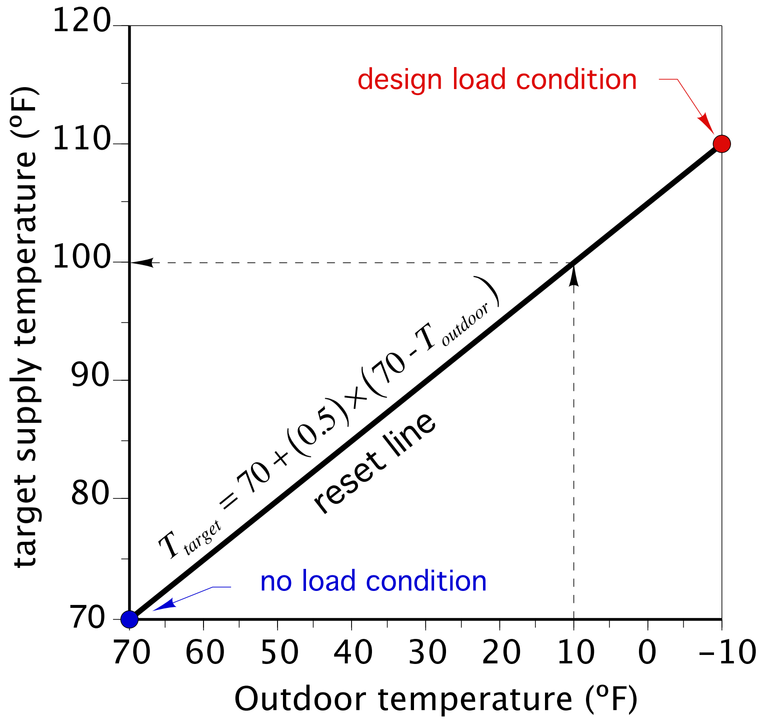
Outdoor reset control can provide two important functions in solar thermal combisystems:

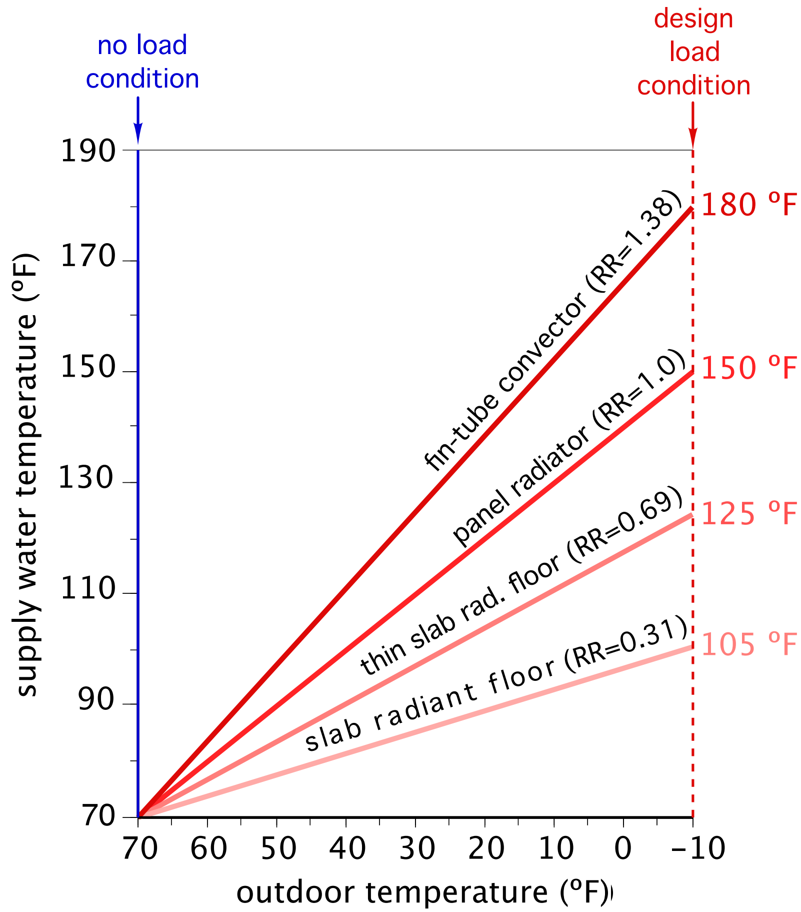
1. Determining when the water in the storage tank can satisfy the heating load.

2. Controlling the water temperature supplied to the distribution system using a 3-way motorized mixing valve.

1. Determining when the water in the storage tank can satisfy the heating load.

$$T_{target} = T_{indoor} + (RR) \times (T_{indoor} - T_{outdoor})$$

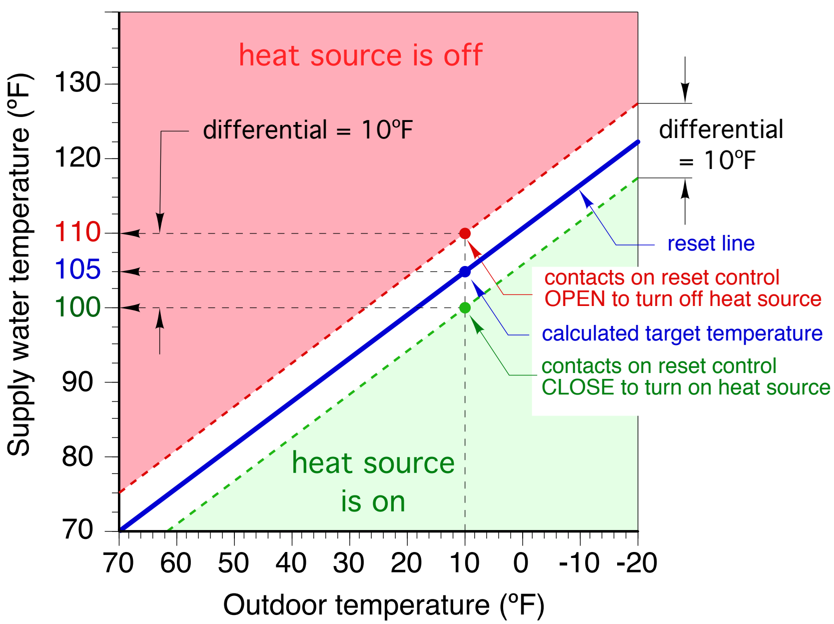


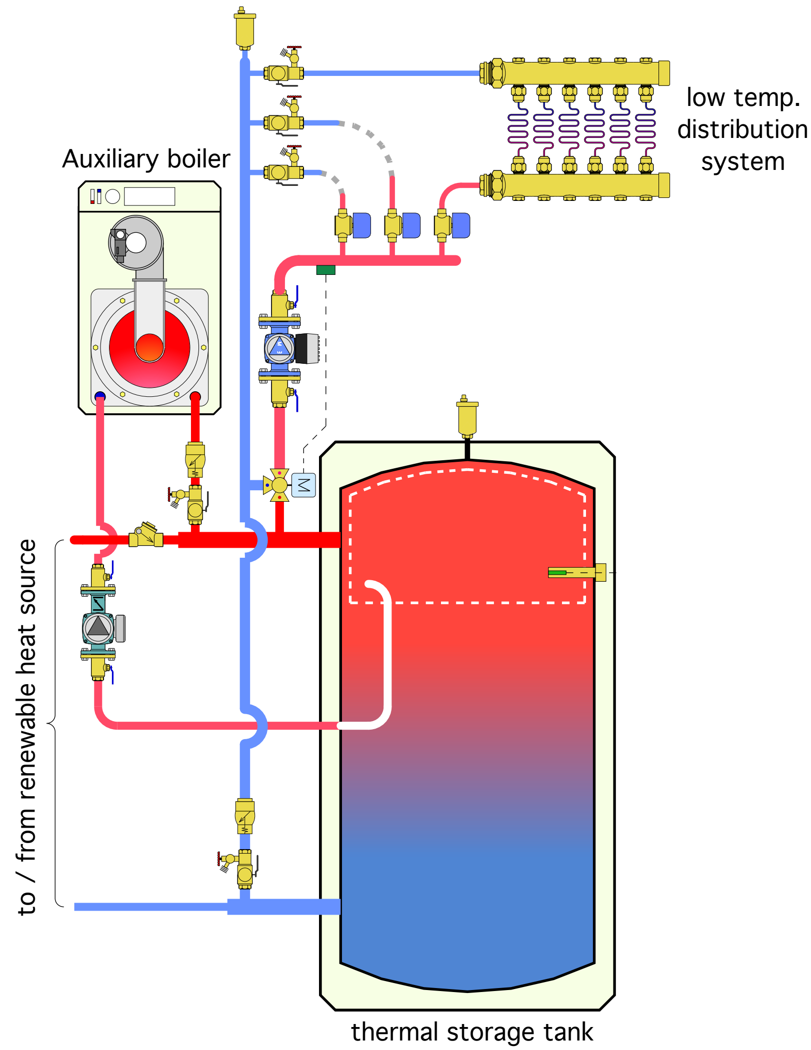


Recommended design criteria: Select heat emitters and distribution system to provide full design load output at supply water temperatures ≤ 120 °F

1. Determining when the water in the storage tank can satisfy the heating load.

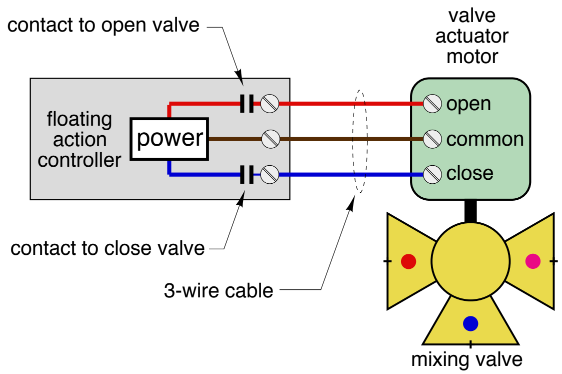
There is no point in using the boiler to maintain the tank at a higher temperature than needed by the distribution system at any given time.





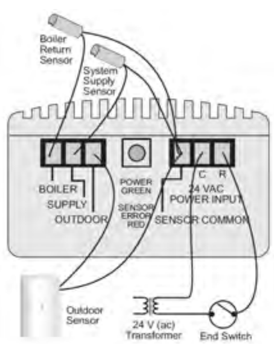
Recommended design criteria: Select heat emitters and distribution system to provide full design load output at supply water temperatures ≤ 120 °F

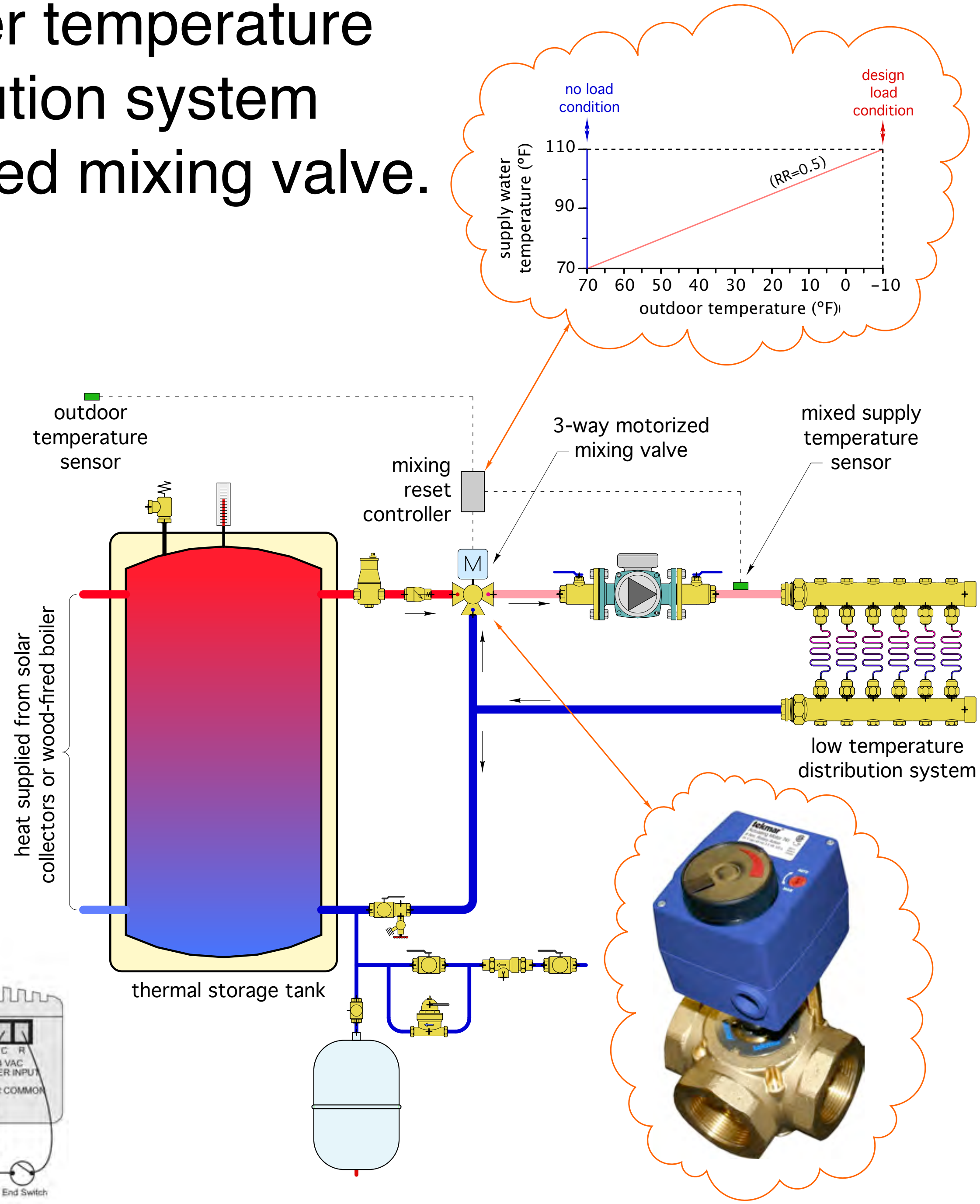
2. Controlling the water temperature supplied to the distribution system using a 3-way motorized mixing valve.



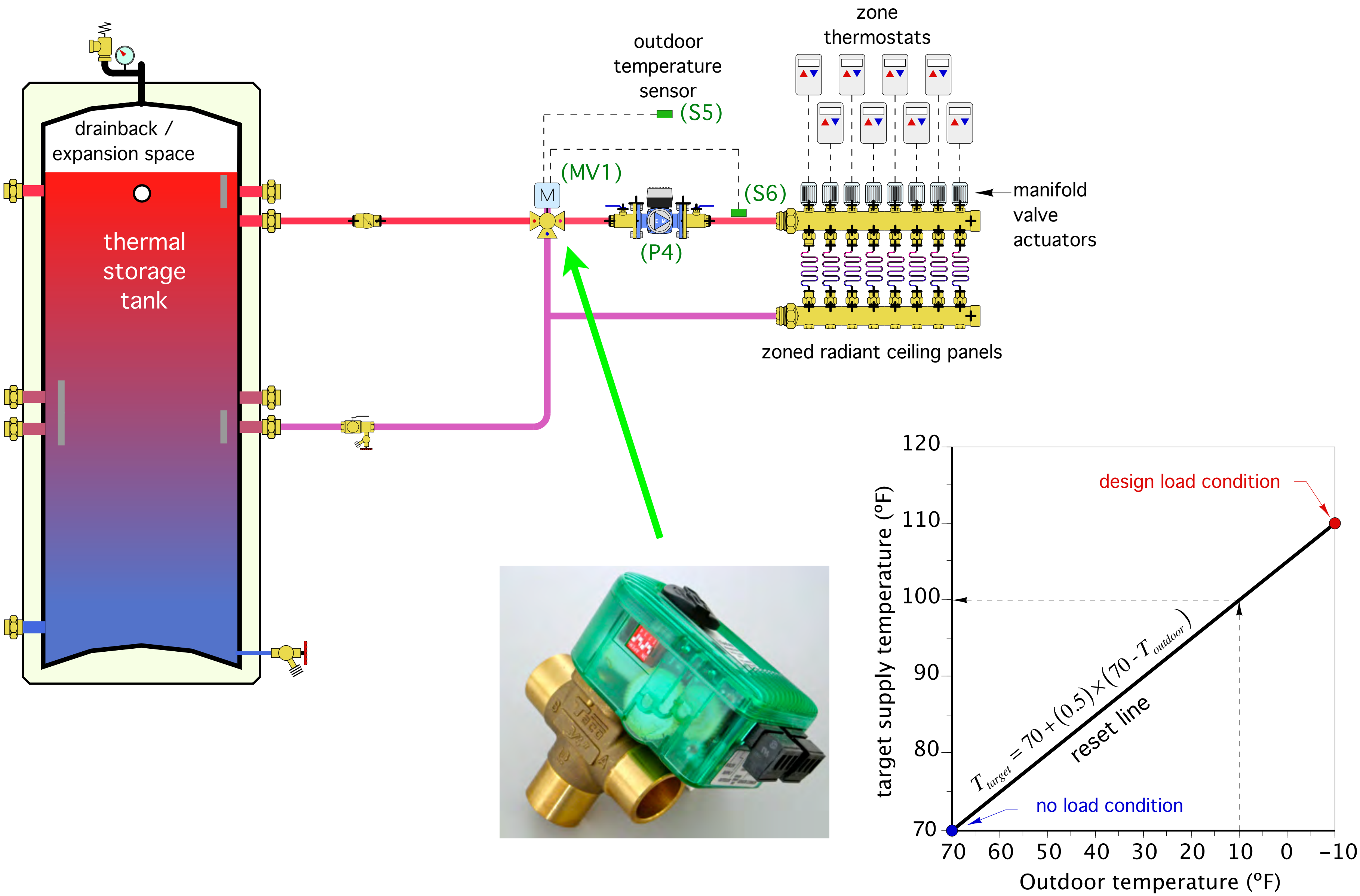
Typical 3-way motorized valve using floating control

Taco iSeries mixing valve with outdoor reset



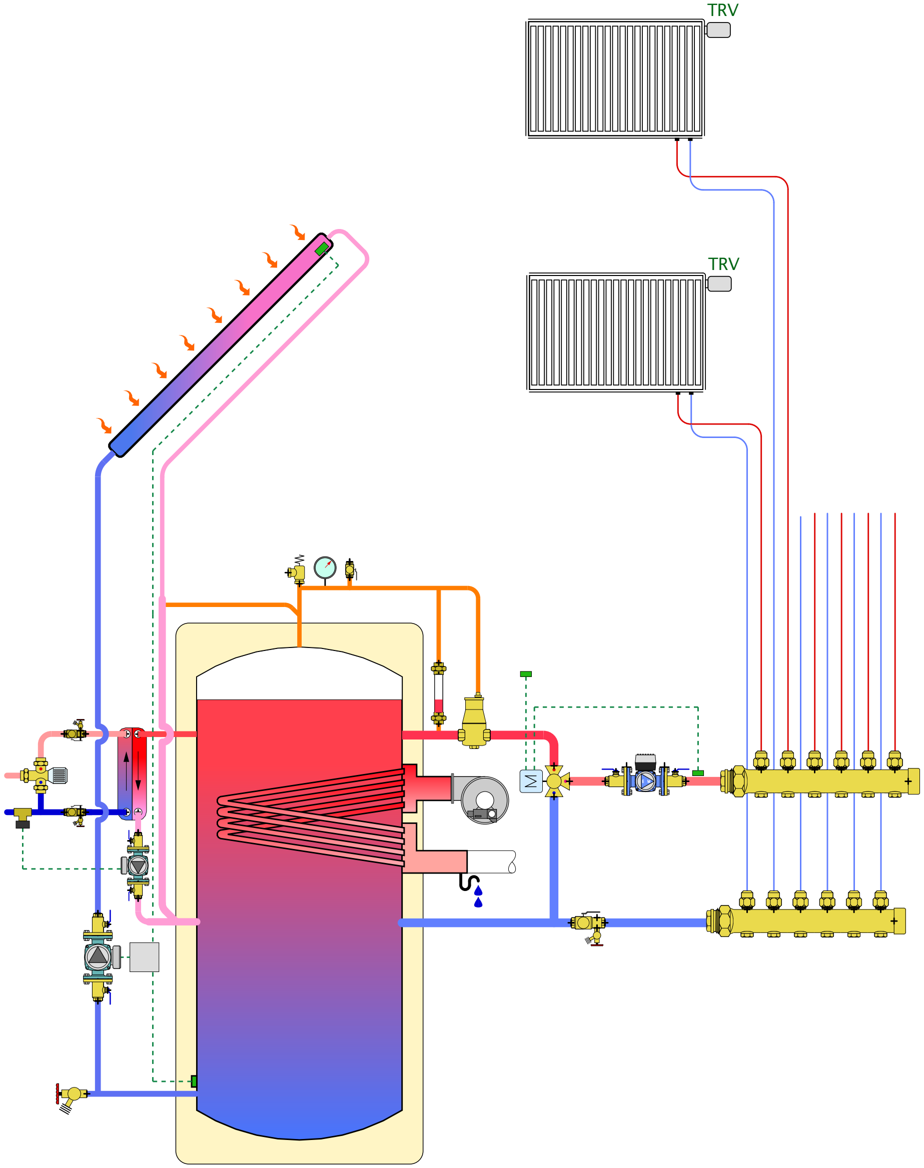


2. Controlling the water temperature supplied to the distribution system using a 3-way motorized mixing valve.

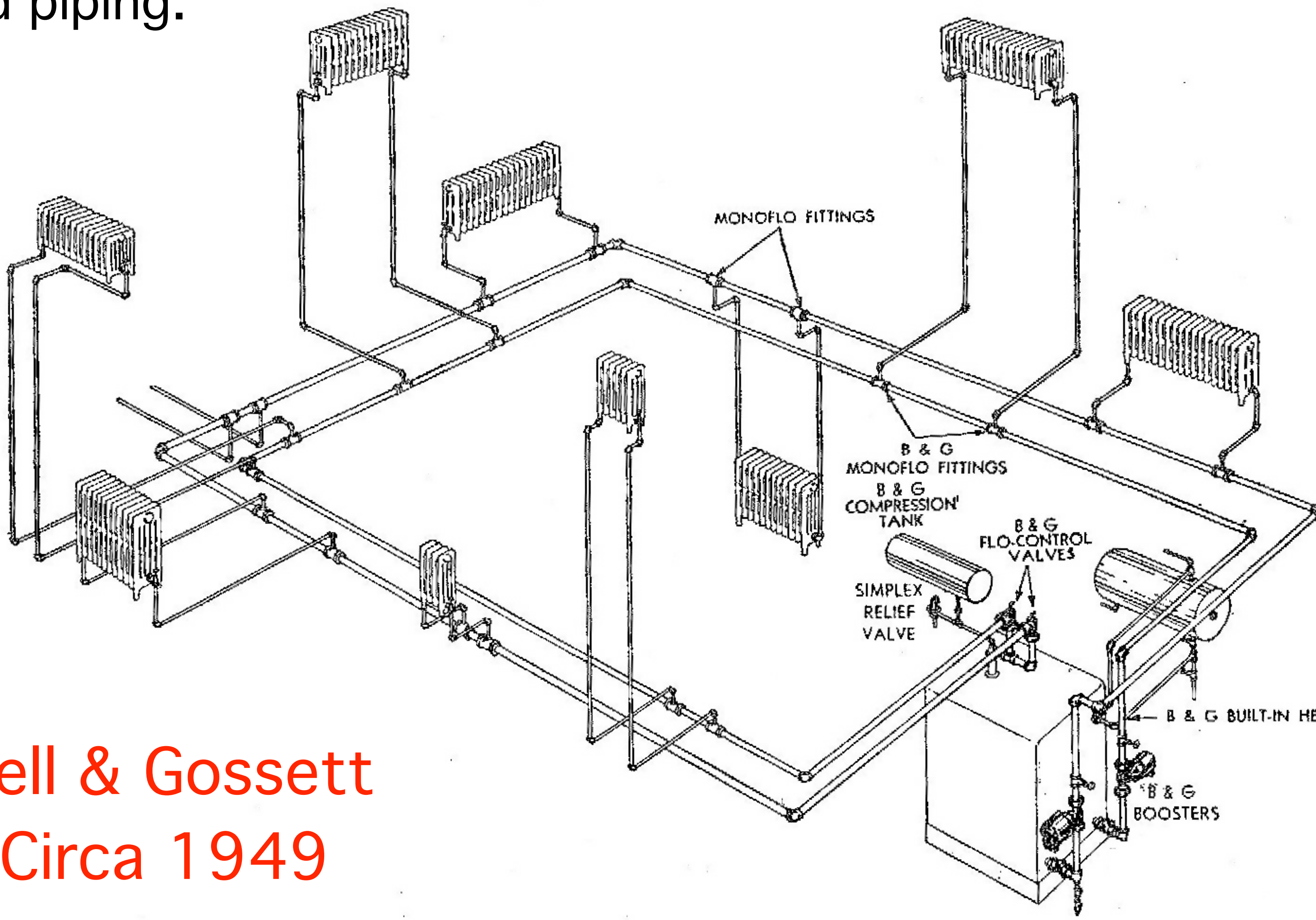


Homerun Distribution Systems

Homerun distribution systems

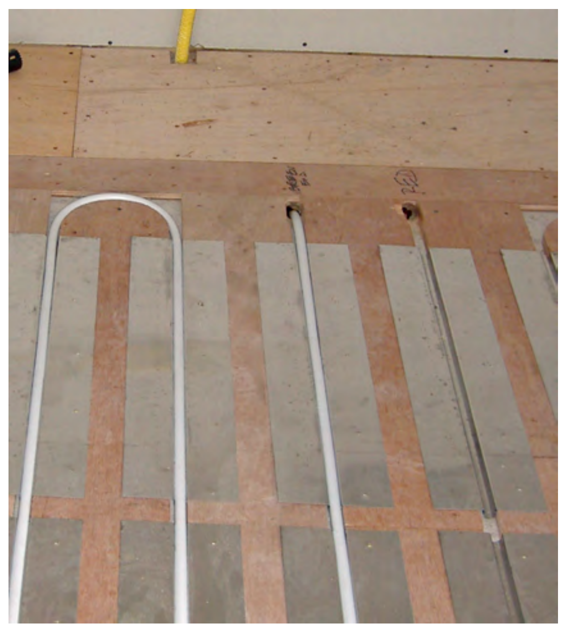


The vast majority of hydronic distribution system developed in North America over decades were based on rigid piping.



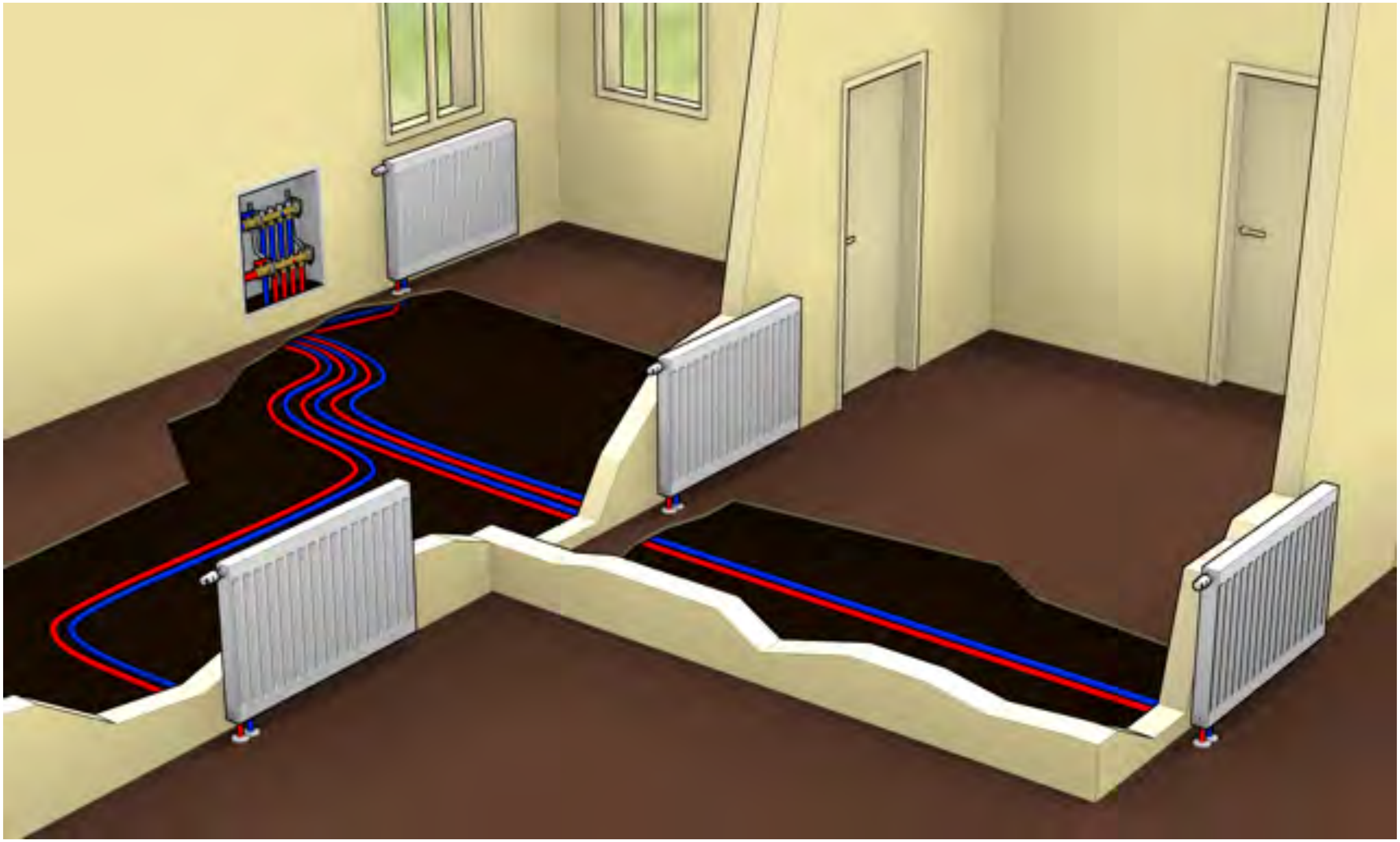
Bell & Gossett
Circa 1949

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



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.



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.**

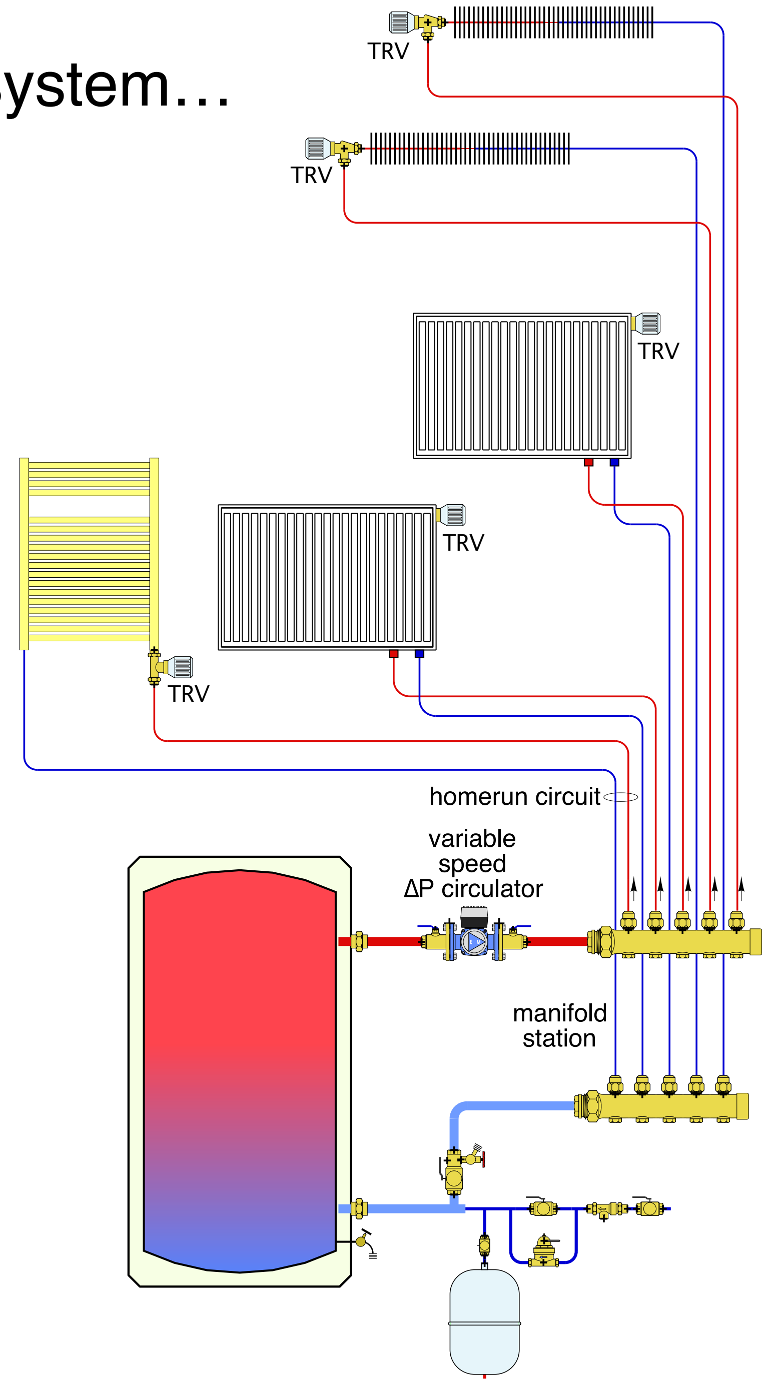
• Allows easy room-by-room zoning

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

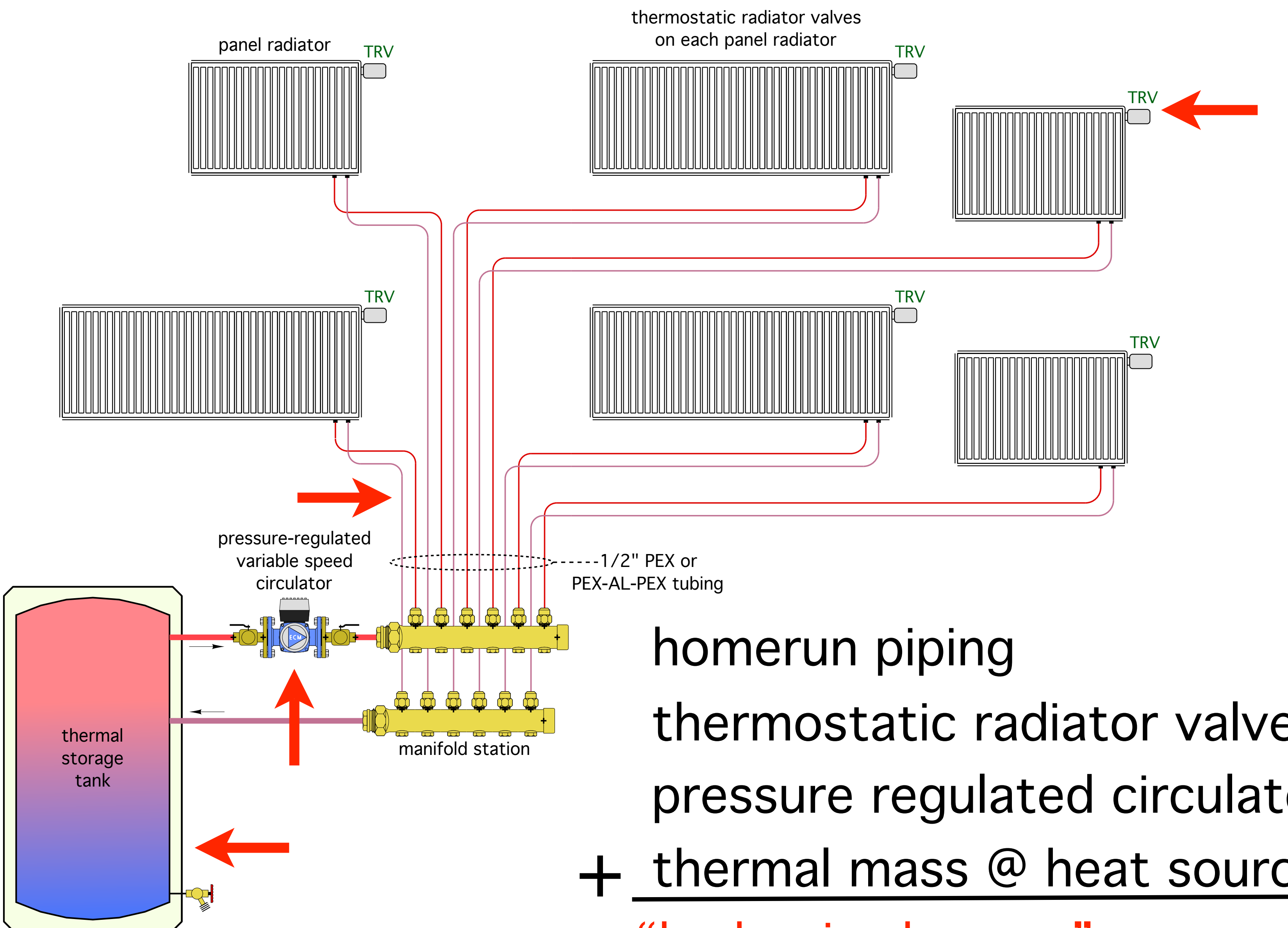
• Can be configured with several types of heat emitters (provided they all require about the same supply water temperature)

• 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...



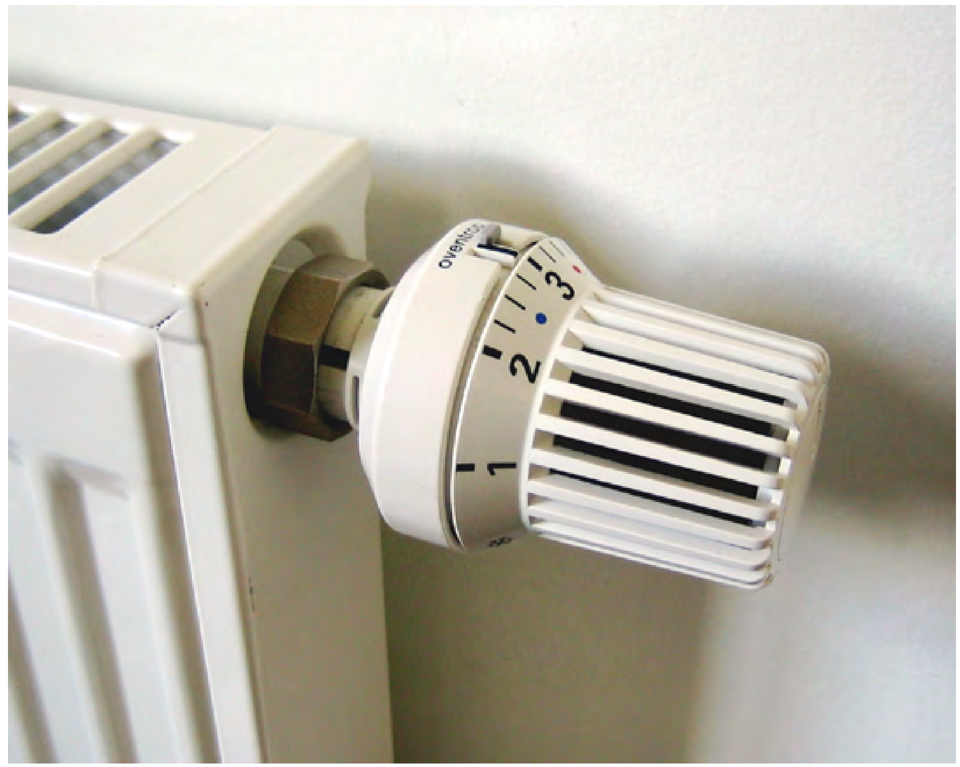
homerun piping
thermostatic radiator valves
pressure regulated circulator
\+ thermal mass @ heat source

"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

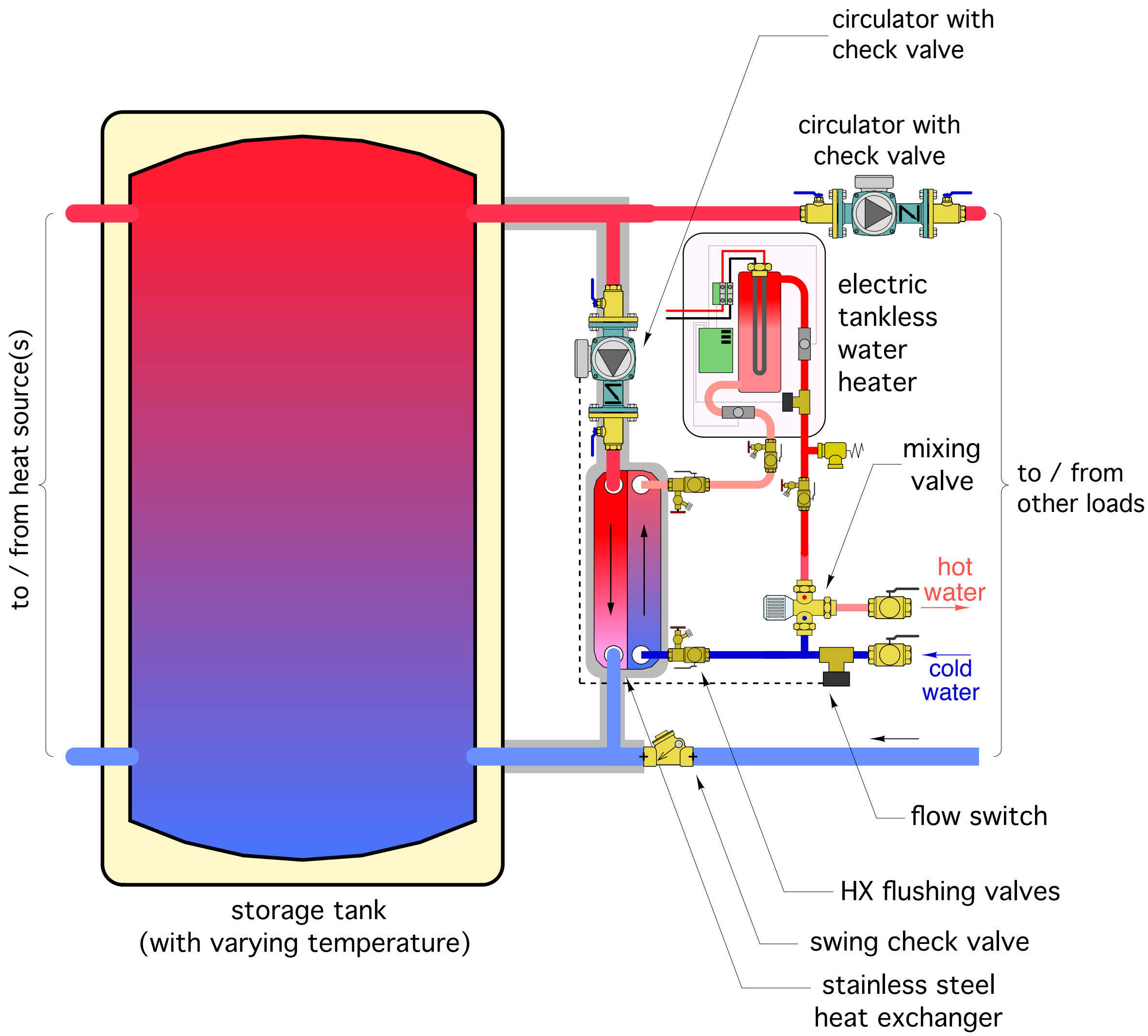
dogs are "thermally discriminating."

Instantaneous DHW subassembly

Starting points:

- Nearly all thermally-based renewable heat sources require significant heat storage.
  - **Solar thermal system**
  - **Geothermal & air-to-water 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.

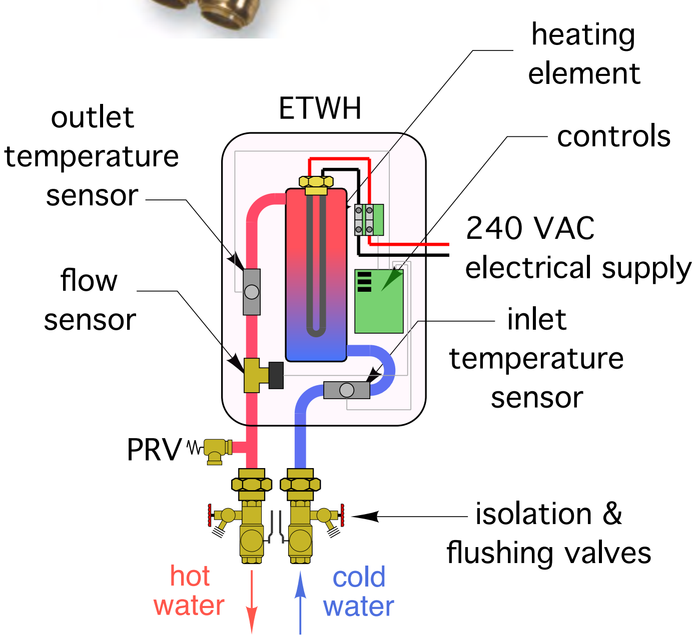
Instantaneous DHW subassembly

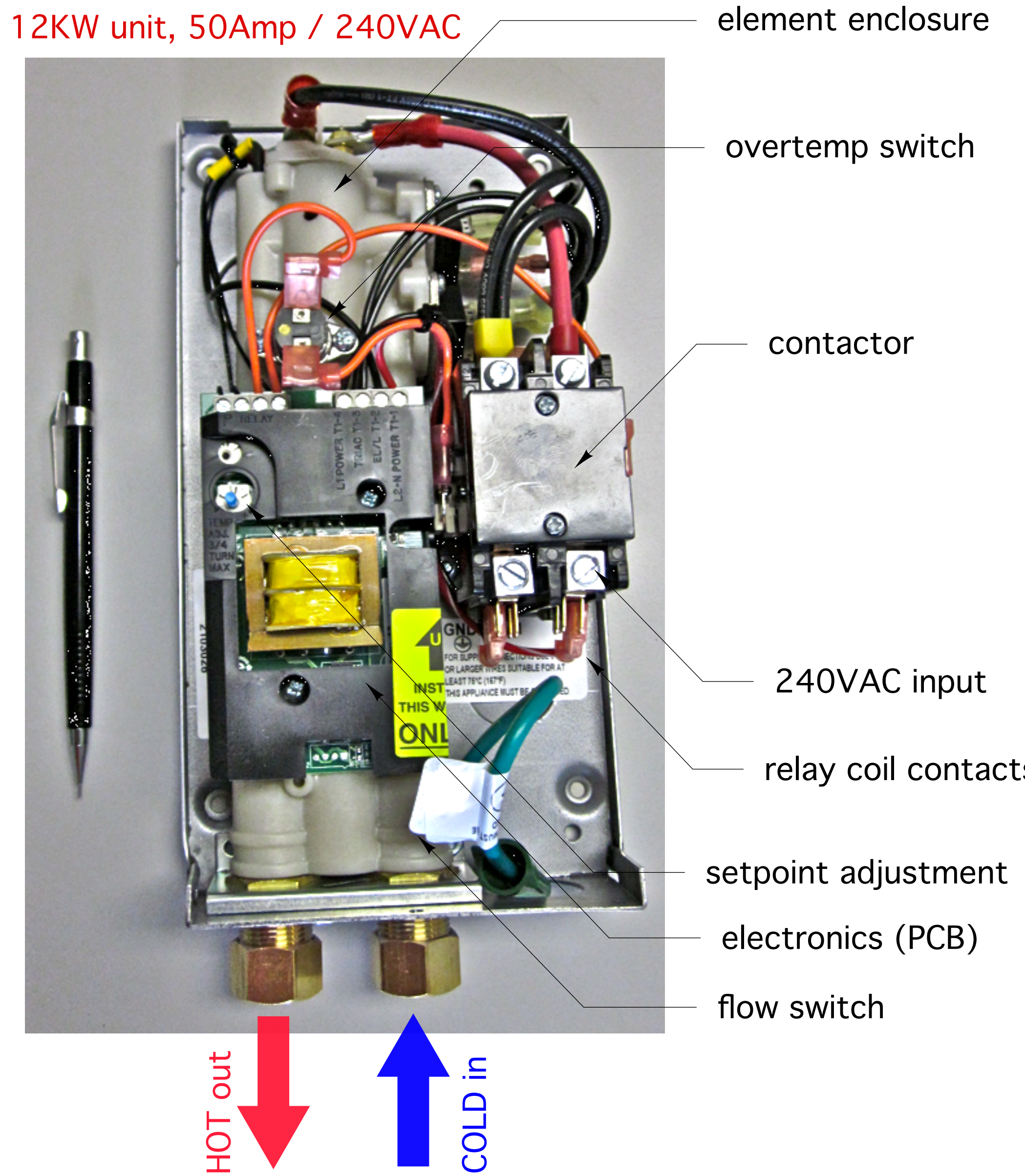


- Leverages the thermal mass for stabilizing DHW delivery.
- Brazed plate heat exchanger provides very fast response (1-2 seconds)
- Fully serviceable heat exchanger (unlike an internal coil heat exchanger) Can be cleaned or replaced if necessary.
- Predictable heat exchanger performance
- Very little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

Image courtesy Eemax





Thermostatically controlled electric tankless water heaters

Electric tankless water heaters are HIGH AMPERAGE devices.

3.5 KW Requires
15 amp / 240VAC
breaker

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

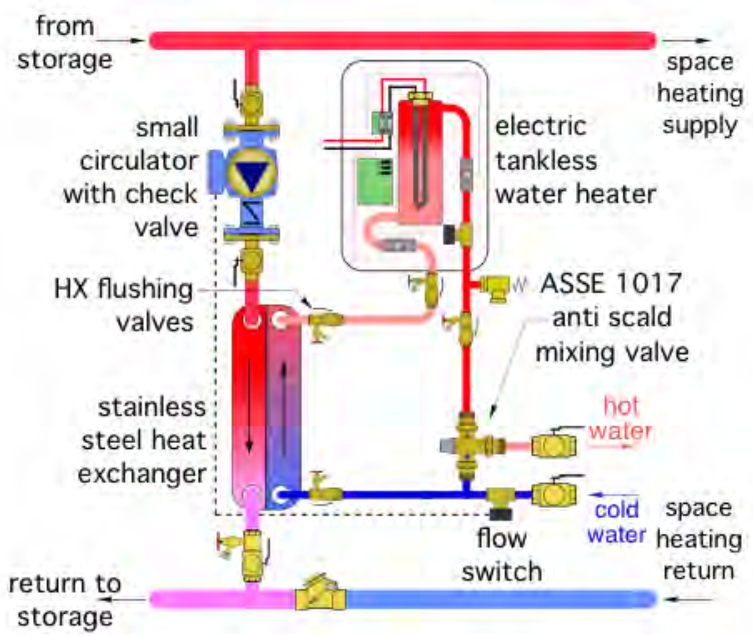
Minimum 200 Amp breaker panel recommended.

May be an issue in some older retrofits.

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

Images 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.

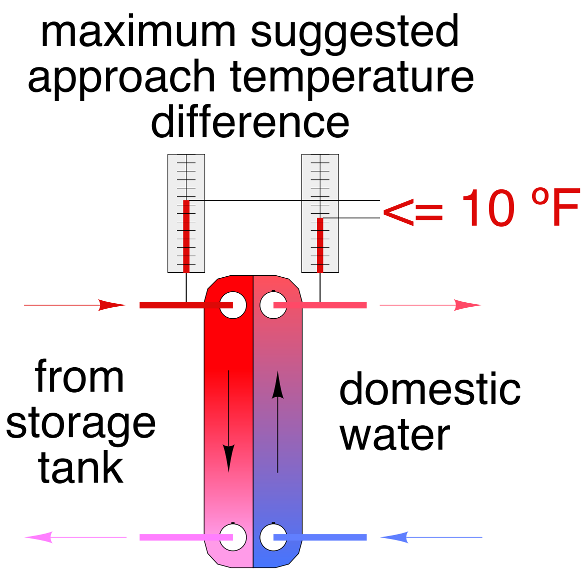
Response time to quasi steady state = 1 to 2 seconds

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

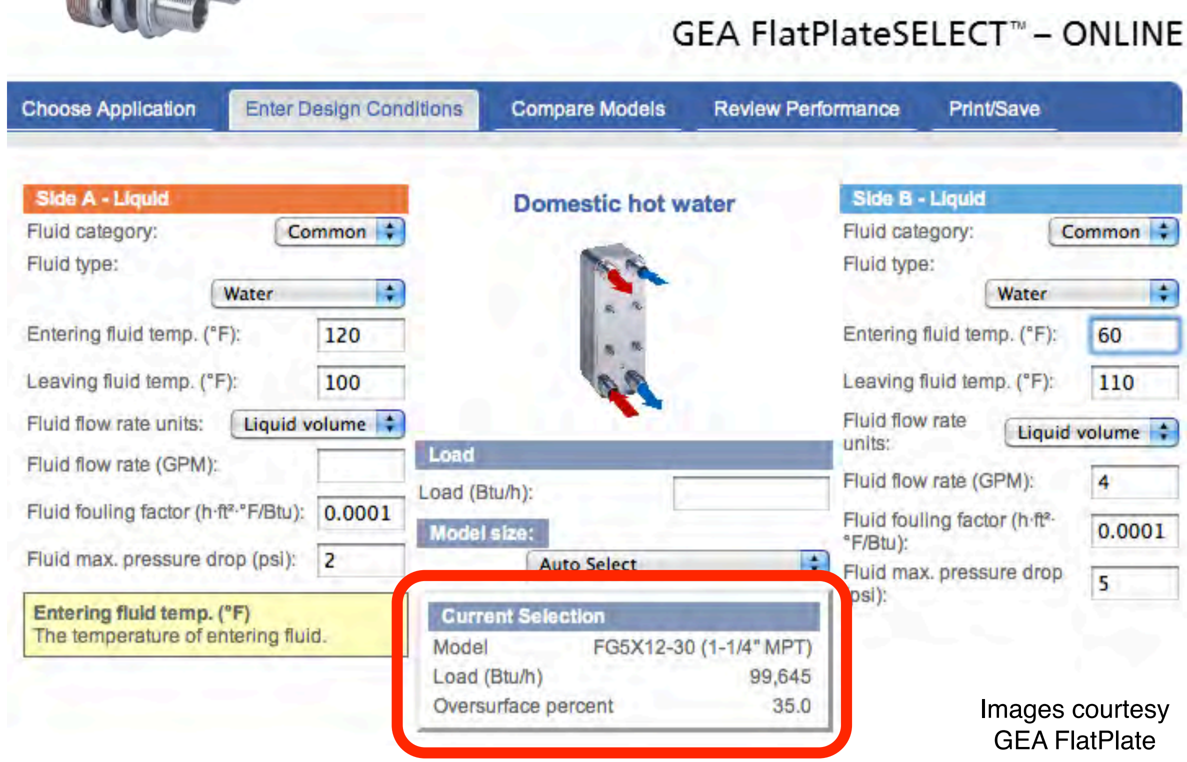
Suggest a maximum approach temperature difference of 10 °F under max. anticipated water demand, and minimum preheat inlet temperature.



FG5x12-30

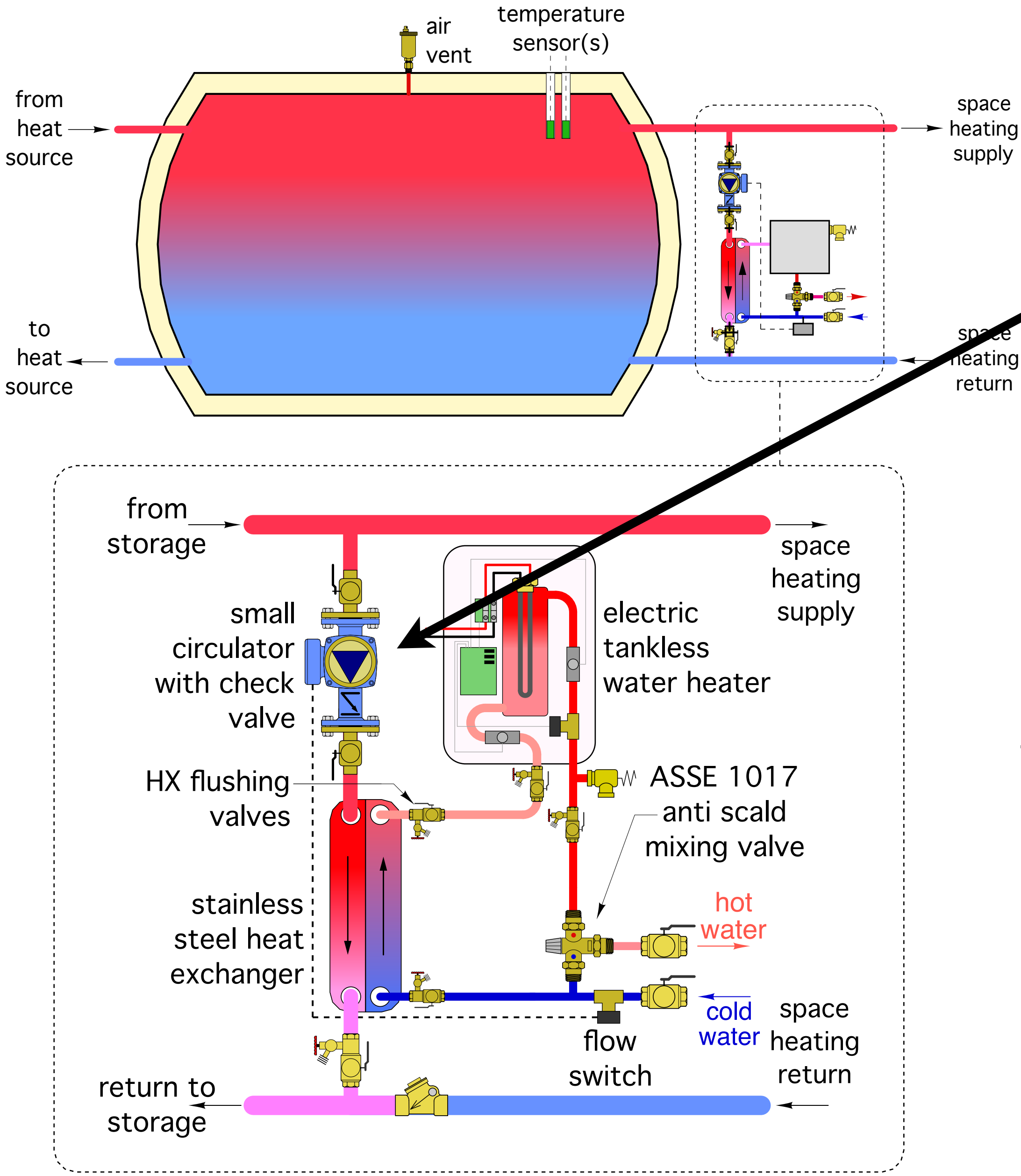
5” wide x12” long -30 plates

http://flatplateselect.com



Images courtesy GEA FlatPlate

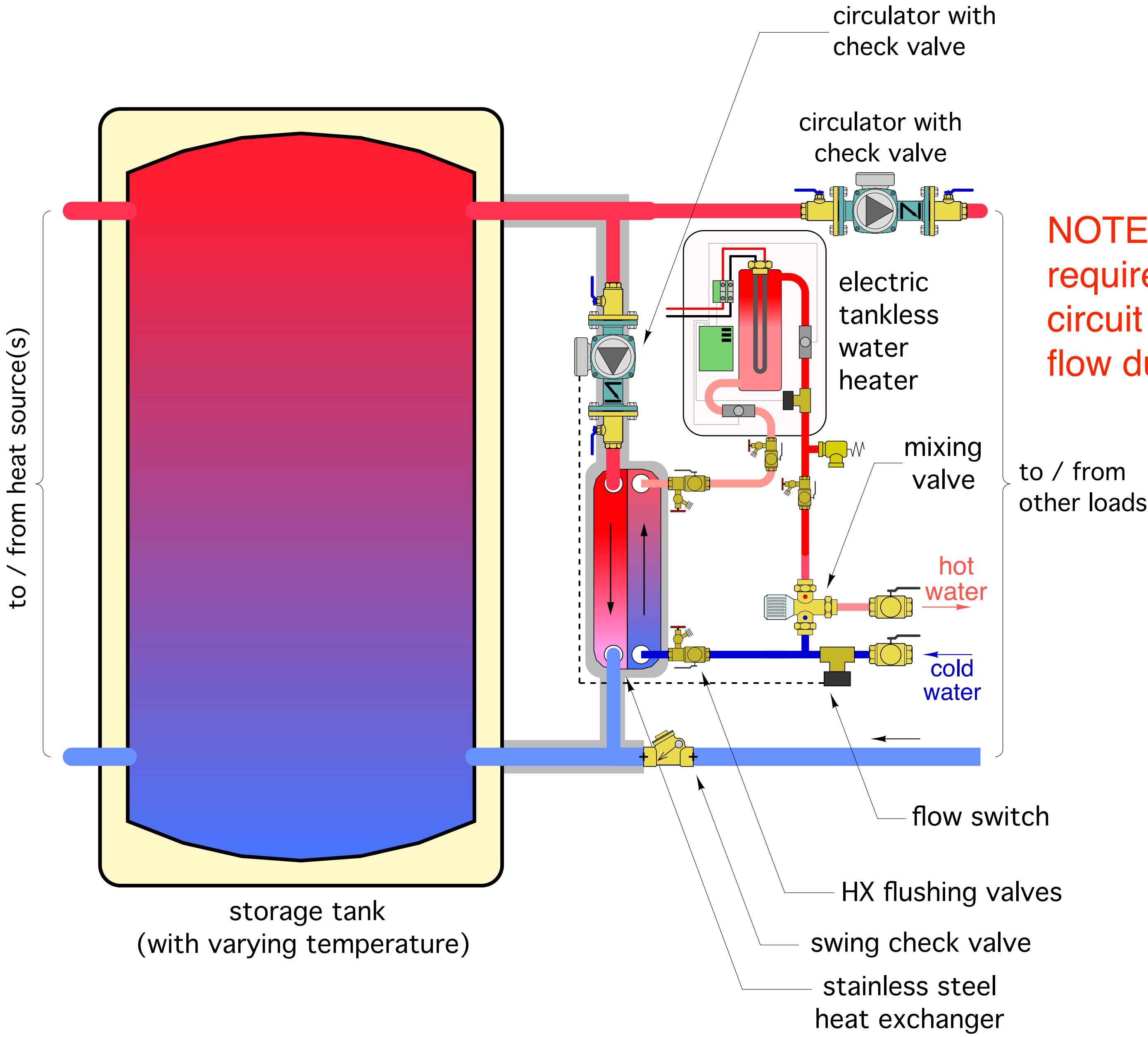
Instantaneous DHW subassembly



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.

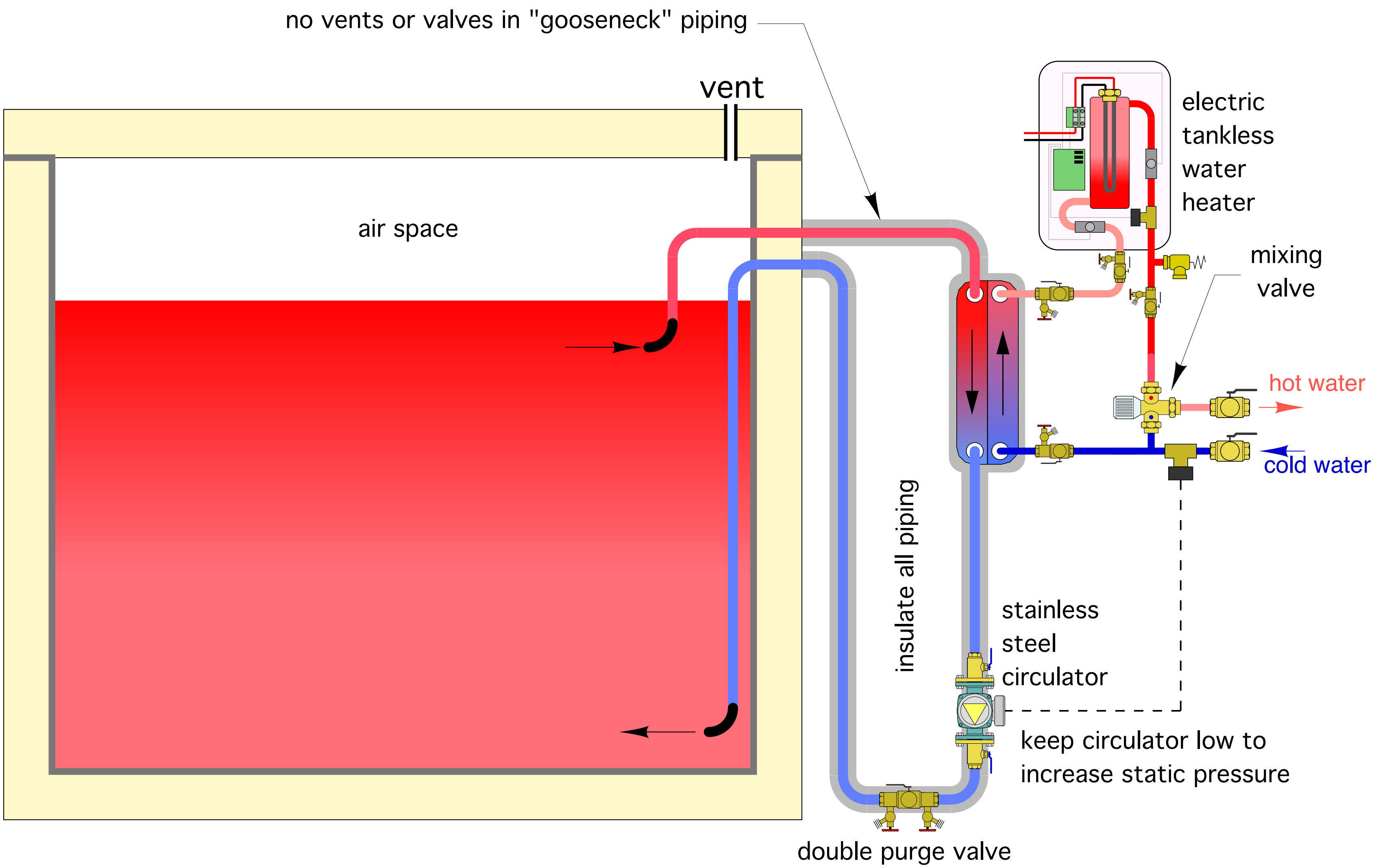
Instantaneous DHW subassembly piping



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

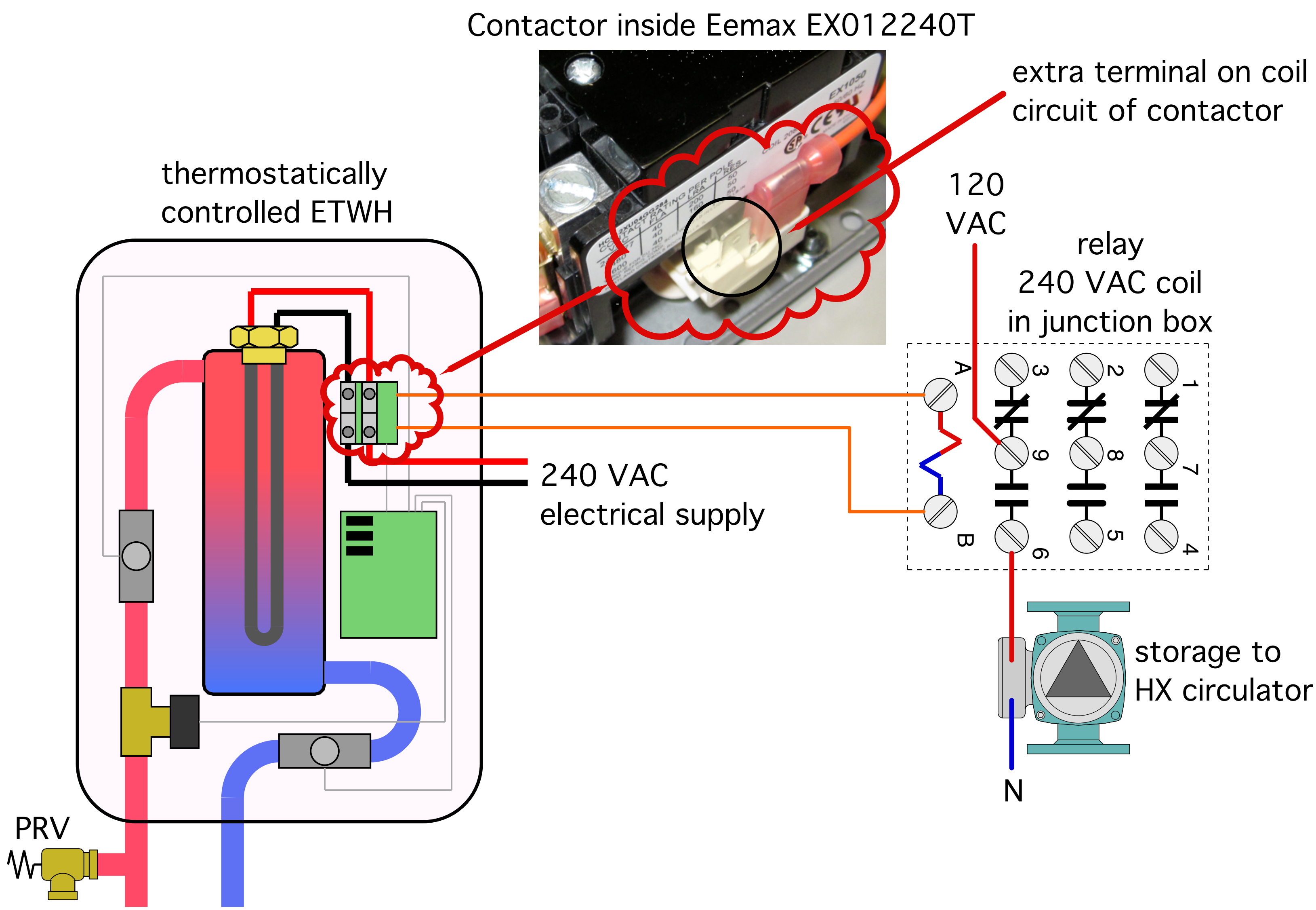
Instantaneous DHW subassembly piping

Using it with unpressurized thermal storage



Using extra terminal on ETWH contactor to operate circulator

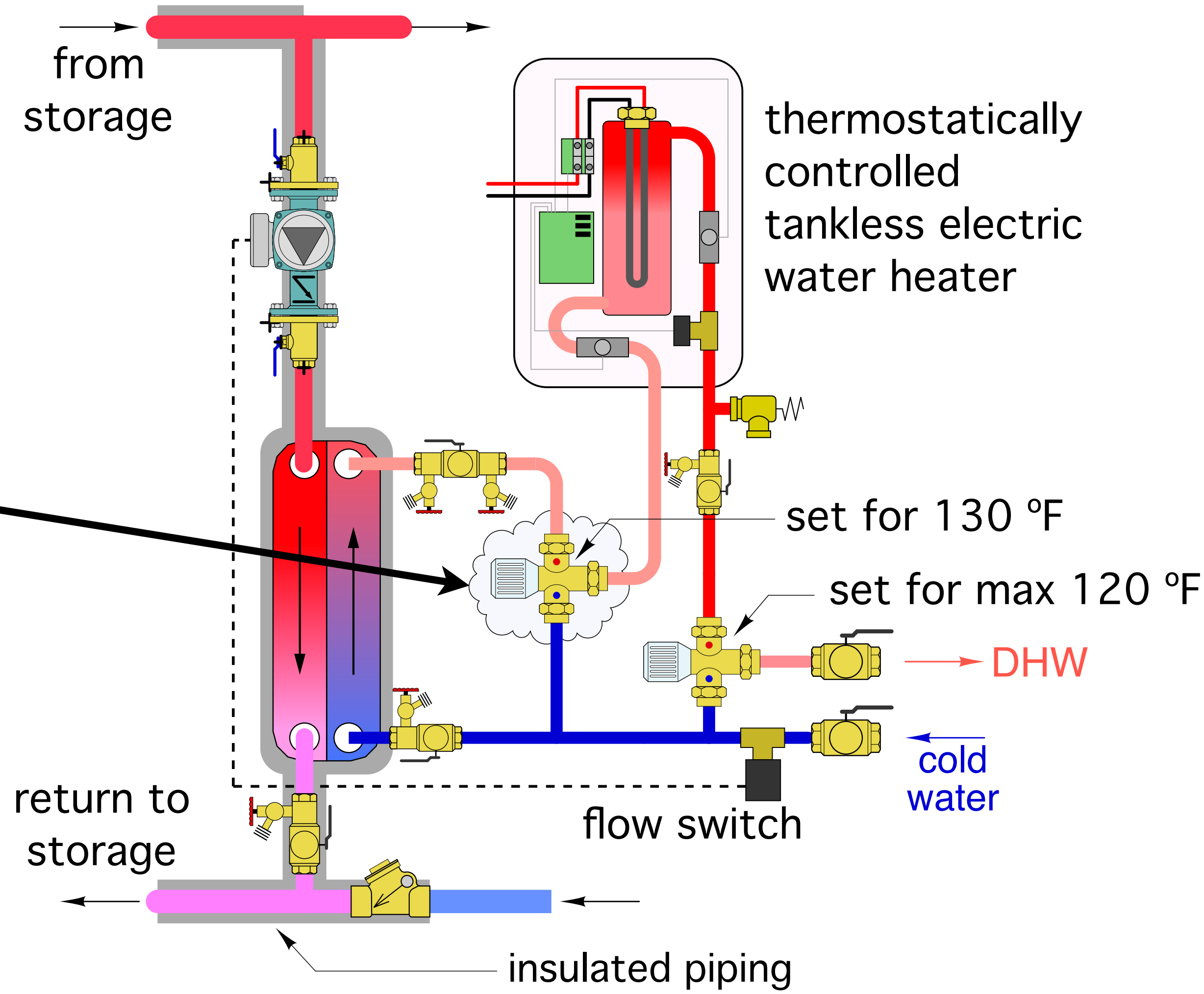
This eliminates the need for the flow switch.



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

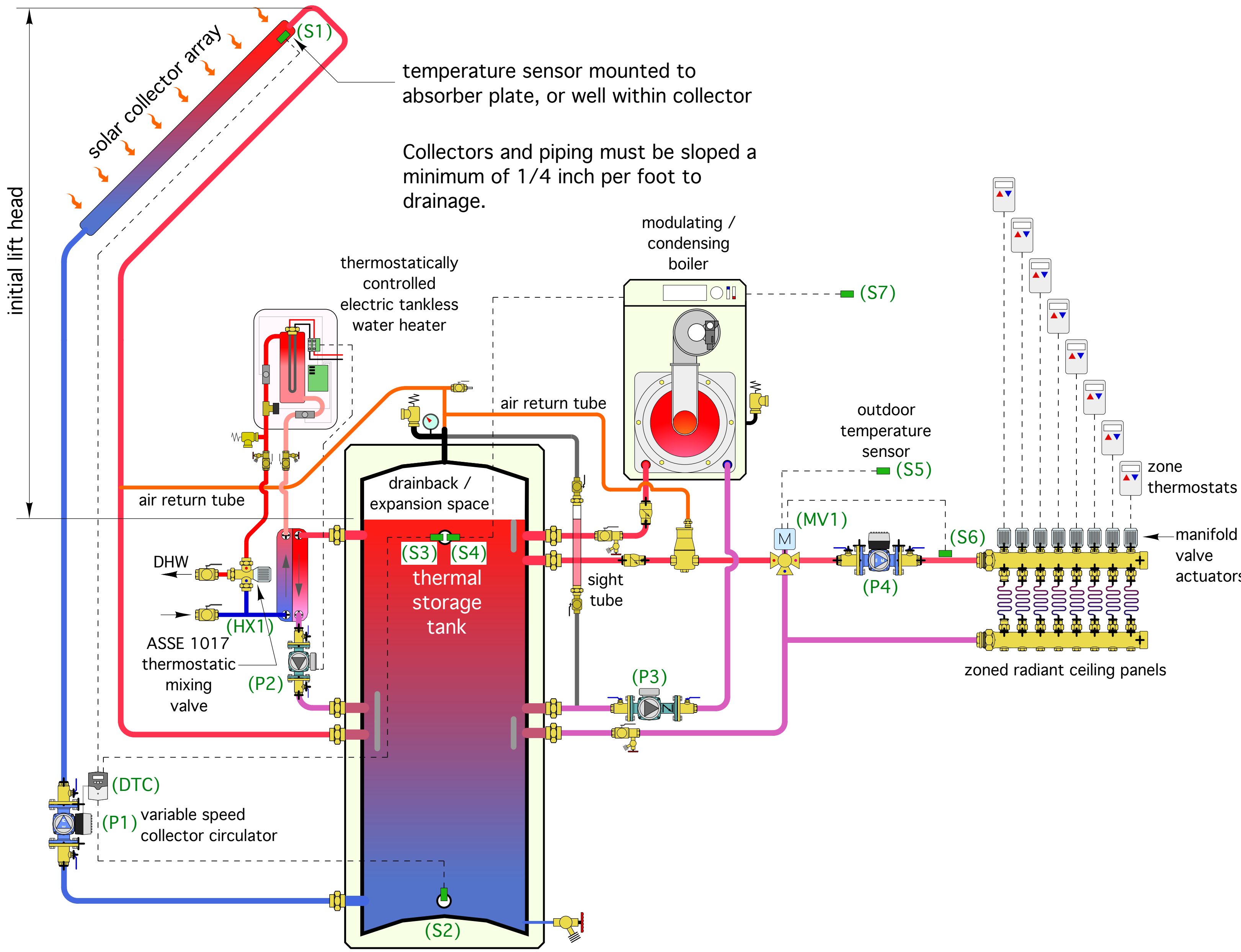
This could cause automatic shut down of the ETWH

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

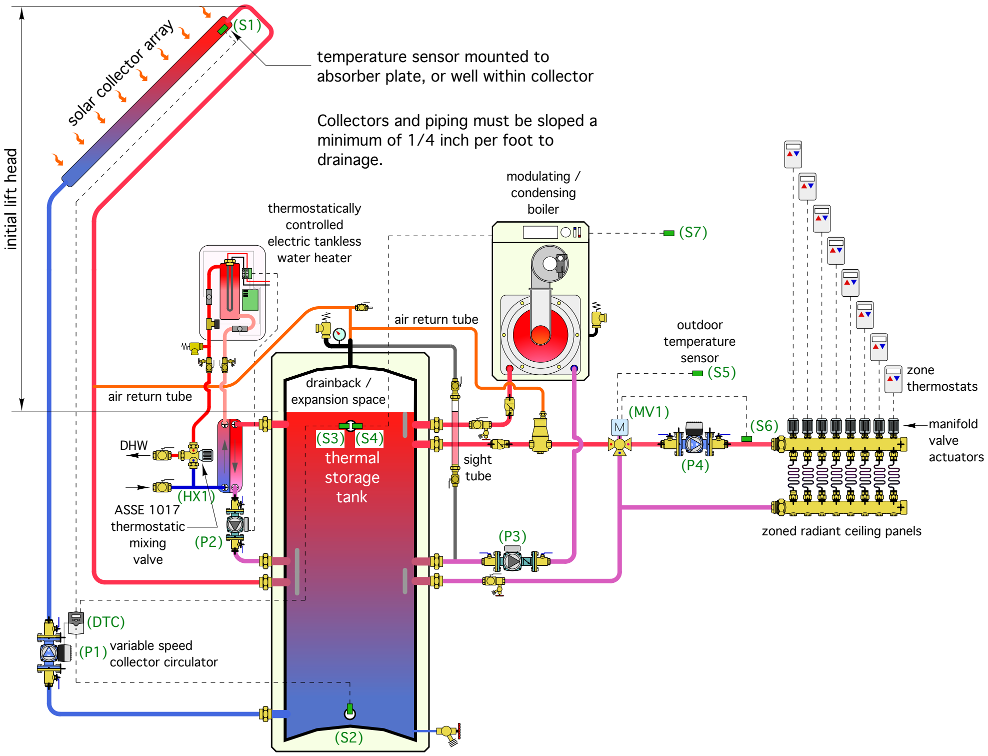


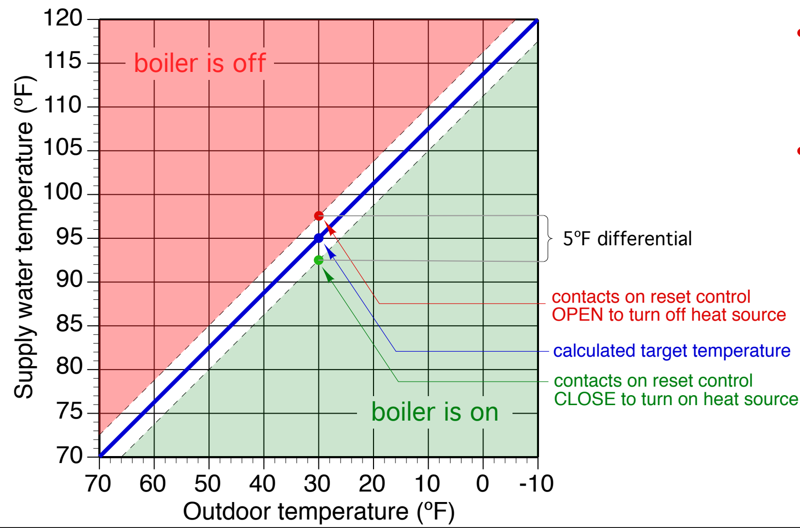
Modern Hydronics
Meets
Solar Thermal Collectors

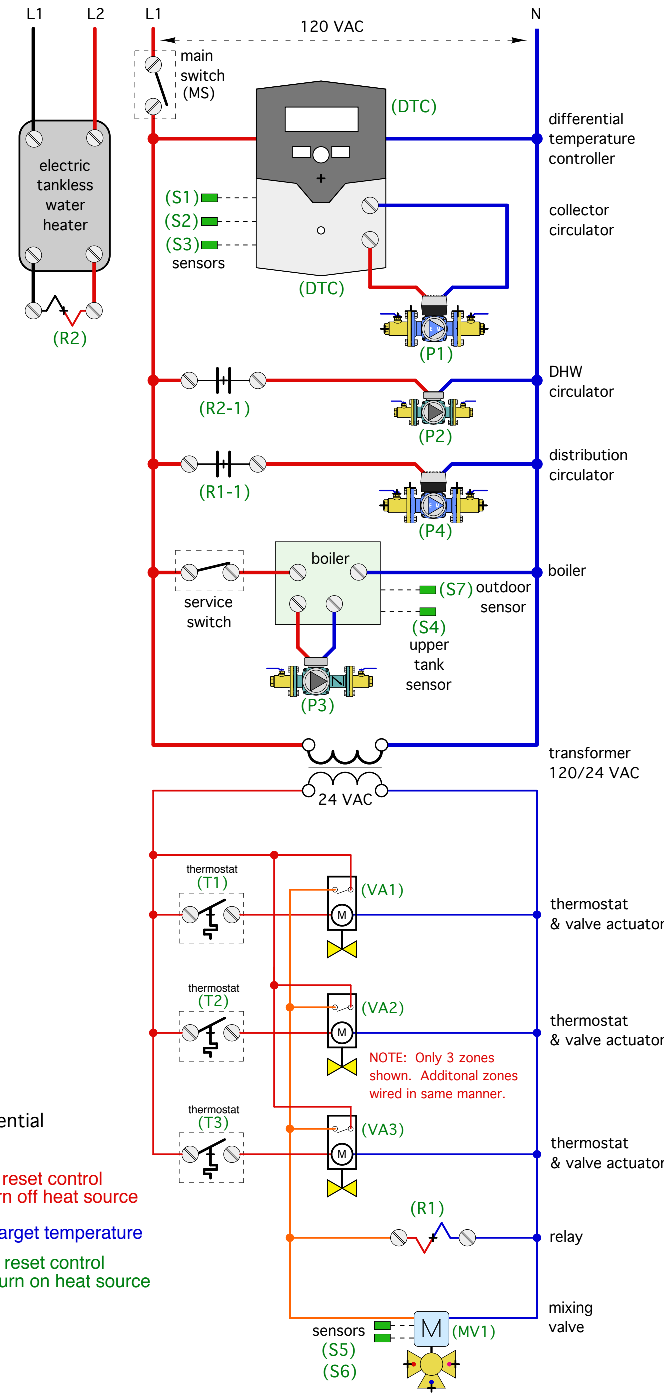
Piping schematic



Wiring schematic







Description of operation

1. Solar energy collection mode: Whenever the main switch (MS) is closed, line voltage is applied to the differential temperature controller (DTC). This controller continuously monitors the temperature of the collector sensor (S1), and the lower sensor in the thermal storage tank, (S2). Whenever the temperature of the collector is 8 ºF or more above the temperature of the lower storage temperature, the (DTC) turns on circulator (P1) at full speed. This circulator continues to run at full speed for 3 minutes, to ensure that a siphon is formed in the collector return piping. It then slows to 50% of full speed to maintain flow in the now-filled collector circuit Whenever the temperature of sensor (S1) is 8 ºF or less above the temperature of sensor (S2), the (DTC) turns of circulator (P1). The (DTC) also monitors sensor (S3) in the upper portion of the thermal storage tank. If this sensor reaches 180 ºF, the (DTC) initiates a nocturnal cooling mode in which it operates circulator (P1) to release heat through the flat plate collector array, until the tank temperature drops to 160 ºF.

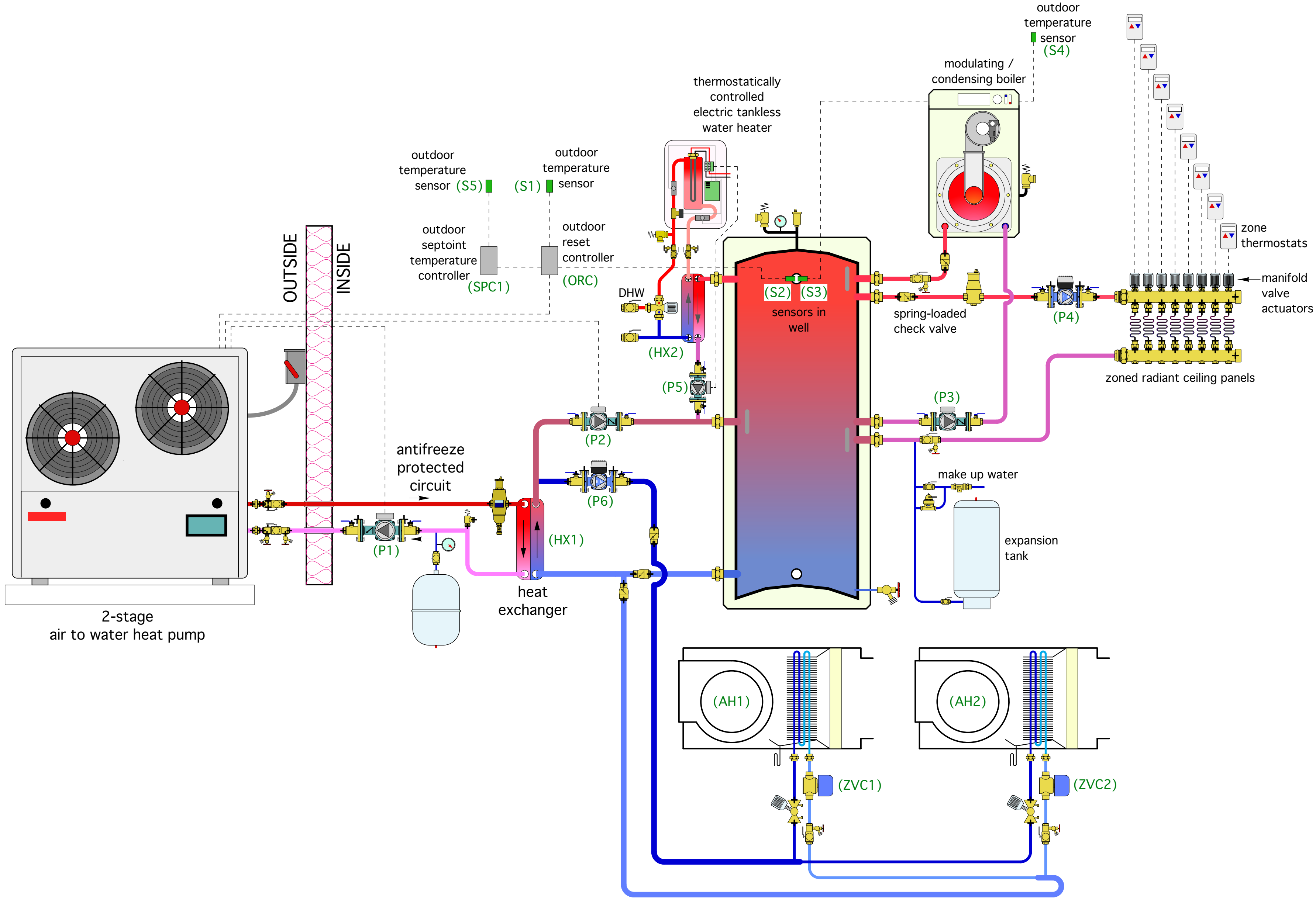
2. Domestic water heating mode: When there is a demand for domestic hot water of 0.6 gpm or higher, the flow switch inside the tankless electric water heater closes. This closure applied 240 VAC to the coil of relay (R2). The normally open contacts (R2-1) closed to turn on circulator (P2), which circulates heated water from the upper portion of the storage tank through the primary side of the domestic water heat exchanger (HX1). The domestic water leaving (HX1) is either preheated, or fully heated, depending on the temperature in the upper portion of the storage tank. This water passes into the thermostatically controlled tankless water heater, 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 to achieve the set domestic hot water supply 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. When the demand for domestic hot water drops below 0.4 gpm, circulator (P2) and the tankless electric water heater are turned off.

3. Space heating mode: The distribution system has several zones, each equipped with a 24 VAC thermostat (T1, T2, T3, etc.). Upon a demand for heat from one or more of these thermostats, the associated 24 VAC manifold valve actuators (VA1, VA2, VA3, etc.) are powered on. When a valve actuator is fully open, its end switch closes. This supplies 24 VAC to the coil of relay (R1), which closes its normally open contacts (R1-1) to supply 120 VAC to circulator (P4). Circulator (P4) operates in constant differential pressure mode to supply the flow required by the distribution system, based on how many zones are active. A call for heat also supplies 24 VAC to the controller operating mixing valve (MV1). The valve's controller measures outdoor temperature from sensor (S5). It uses this temperature, in combination with its settings, to calculate the target supply water temperature to the distribution system. The controller operates the valve's motorized actuator, which rotates the valve's stem to steer the temperature detected by sensor (S6), toward the target temperature. When all thermostats are satisfied, power is removed from mixing valve (MV1), and circulator (P4). A spring-load check valve near the storage tank prevents heat migration into the space heating distribution system.

4. Boiler: The boiler continuously monitors the outdoor temperature detected by sensor (S7). The boiler's internal reset control logic uses this temperature, and its settings, to calculate the target temperature required by the distribution system. It then compares the temperature in the upper portion of the thermal storage tank, as detected by sensor (S4), with the calculated target temperature. If the temperature in storage is more than 2.5 ºF below the target temperature, the boiler turns on, and so does circulator (P3). Heat is added to the tank until the temperature detected by sensor (s) is 2.5 ºF above the target temperature. The boiler and circulator (P3) are then turned off.

Modern Hydronics
Meets
Air-to-Water Heat Pump

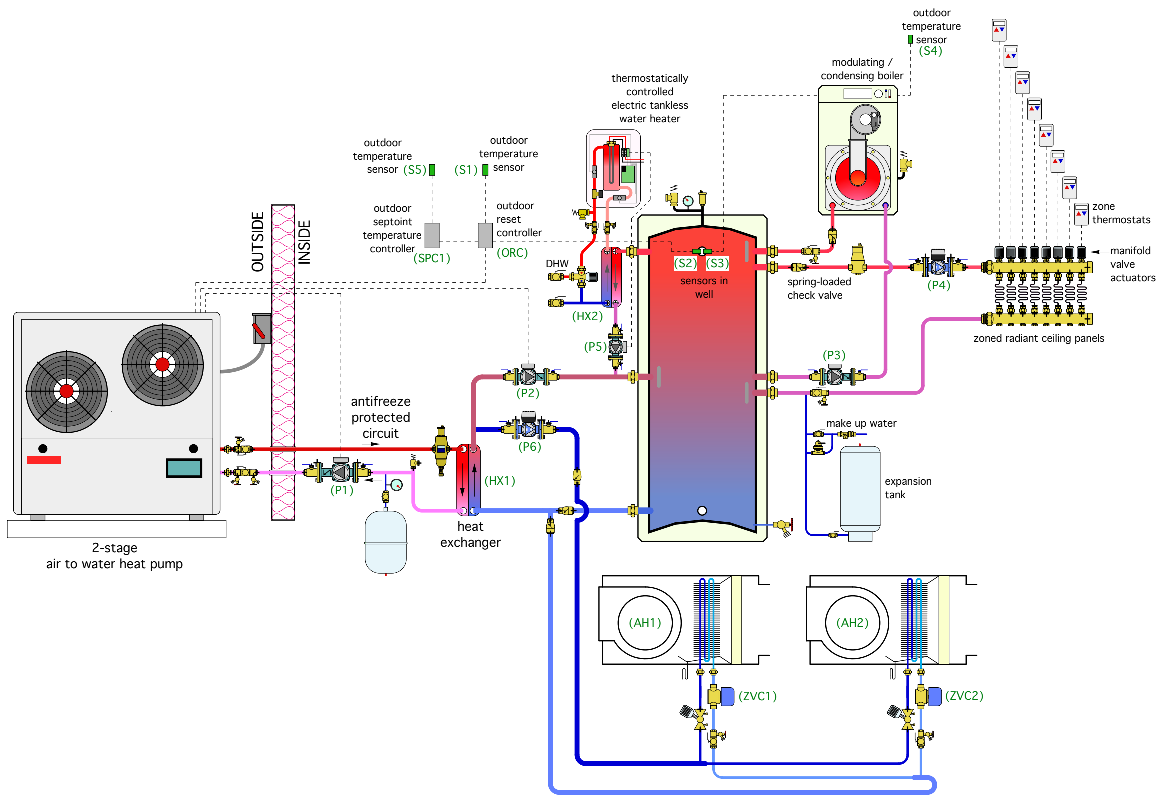
Piping schematic

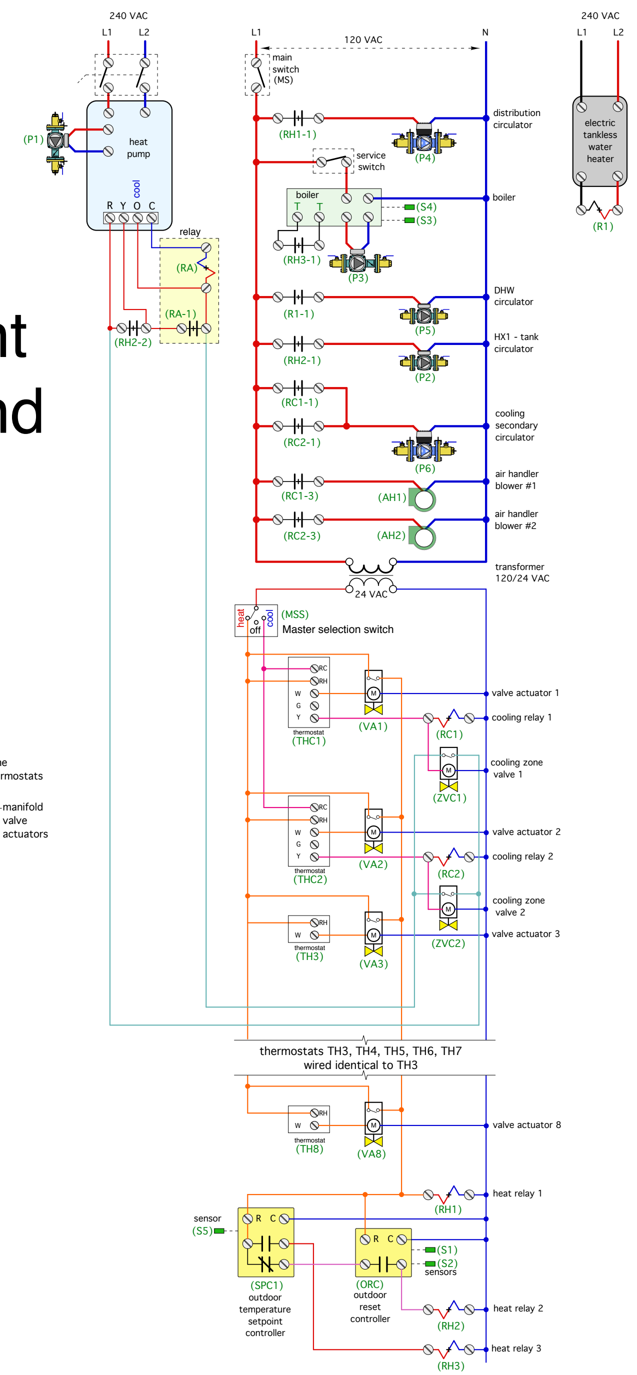


Wiring schematic

Please study the wiring diagram in detail on the PDF file for this course.

Cross reference between the component designations on the piping schematic and wiring schematic.





Description of operation

Description of Operation:

1. Space heating mode:

The mode selection switch (MSS) must be set for heating. This supplies 24 VAC to the (RH) terminals of thermostats (THC1) and (THC2). It also supplies 24 VAC to the (R) terminals of the heating-only thermostats shown (TH3, TH4, TH5, TH6, TH7, TH8). If a thermostat is set for heating mode, and it calls for heat, 24 VAC is switched to the thermostat's (W) terminal. This supplies 24VAC to the associated heating valve actuator (VA1...VA8)). When the end switch in a valve actuator closes, 24 VAC is also sent to the coil of relay (RH1). One set of normally open contacts (RH1-1) closes to energize circulator (P4), which then operates in proportional differential temperature control mode.

Upon a call for heating from any thermostat, 24 VAC is also supplied to the outdoor temperature setpoint controller (SPC1), and the outdoor reset controller (ORC). If the outdoor temperature is above the minimum value set on (SPC1), which in this system is 0 ºF + a 4 ºF differential, the heat pump will be the heat source. In this case, 24 VAC passes through the normally closed contact within (SPC1), and on to the normally open contact in the outdoor reset controller (ORC). The (ORC) measures the outdoor temperature using sensor (S1) and calculates the target temperature for the buffer tank. It measure the temperature in the upper portion of the buffer using sensor (S2). If the buffer tank temperature is too low to supply the load, the normally open contact in the (ORC) closes. This energizes relay coil (RH2). One normally open contact (RH2-1) closes to energize circulator (P2). Another normally open contact (RH2-2) closes to enable the heat pump to operate in heating mode, (e.g., contact closure between the R and Y terminals in the heat pump). The heat pump then turns on circulator (P1), and operates under it own internal control logic.

If the outdoor temperature detected by (SPC1) is below the minimum value (0 ºF), the normally open contact in (SPC1) closes, and its normally open contact opens. This turns off relay (RH2) and thus disables operation of the heat pump as well as circulator (P2). It also applies 24VAC to the coil of relay (RH3). Normally open contact (RH3-1) closes as a dry contact across the (T T) terminals in the boiler, enabling it to operate. The boiler turns on circulator (P3), and begins operating under its own internal outdoor reset controller settings. It uses these settings, in combination with the outdoor temperature measure by sensor (S4) to calculate the target temperature in the buffer tank. It measure the temperature in the upper portion of the buffer tank using sensor (S3). When necessary, the boiler fires to raise the buffer tank to a temperature that can supply the heating load.

2. Space cooling mode:

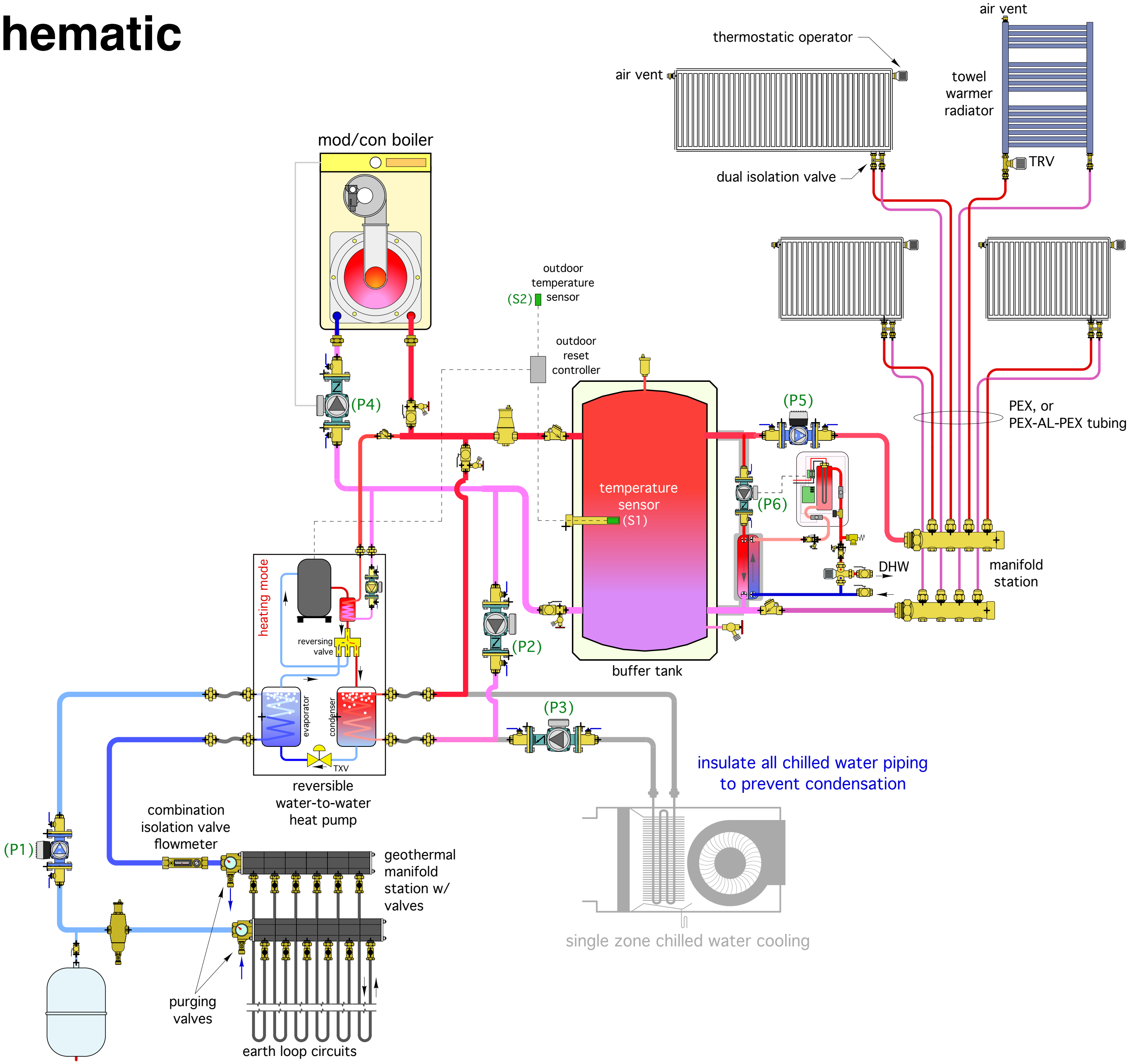
The mode selection switch (MSS) must be set for cooling. This supplies 24 VAC to the (RC) terminals of thermostats (THC1) and (THC2). If either of these thermostats is set for cooling mode, and calls for cooling, 24 VAC is switched to the thermostat's (Y) terminal. This supplies 24VAC to the associated cooling relay (RC1) or (RC2). One set of contacts (RC1-1) or (RC2-1) closes to provide line voltage to cooling circulator (P6), which then operates in proportional differential temperature control mode. Another set of contacts (RC1-2) or (RC2-2) closes to provide line voltage to the associated air handler blowers (AH1) or (AH2). The end switches in the cooling zone valves close when those valves reach their fully open position. This closure passes 24 VAC from the heat pump's internal transformer to the coil of relay (RA), and to terminal (O) which energizes the heat pump's reversing valve for cooling mode operation. Normally open contact (RA-1) closes to provide 24 VAC to terminal (Y) to enable compressor operation. The heat pump controls its compressor speed based on its own internal control system.

3. Domestic water heating mode:

Whenever there is a demand for domestic hot water of 0.6 gpm or higher, the flow switch inside the tankless electric water heater closes. This closure applied 240 VAC to the coil of relay (R1). The normally open contacts (R1-1) closed to turn on circulator (P5), which circulates heated water from the upper portion of the buffer tank through the primary side of the domestic water heat exchanger (HX2). The domestic water leaving (HX2) is preheated to a temperature a few degrees less tank the current buffer tank temperature. The domestic water leaving (HX2) passes into the thermostatically controlled tankless water heater, which measures its inlet temperature. The electronics within this heater control electrical current flow to the heat elements based on the necessary temperature rise to achieve the set domestic hot water supply temperature. All heated water leaving the tankless heater flows into an ASSE 1017 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 (P5) and the tankless electric water heater are turned off.

Modern Hydronics Meets Geothermal Heat Pump

Piping schematic



Wiring schematic

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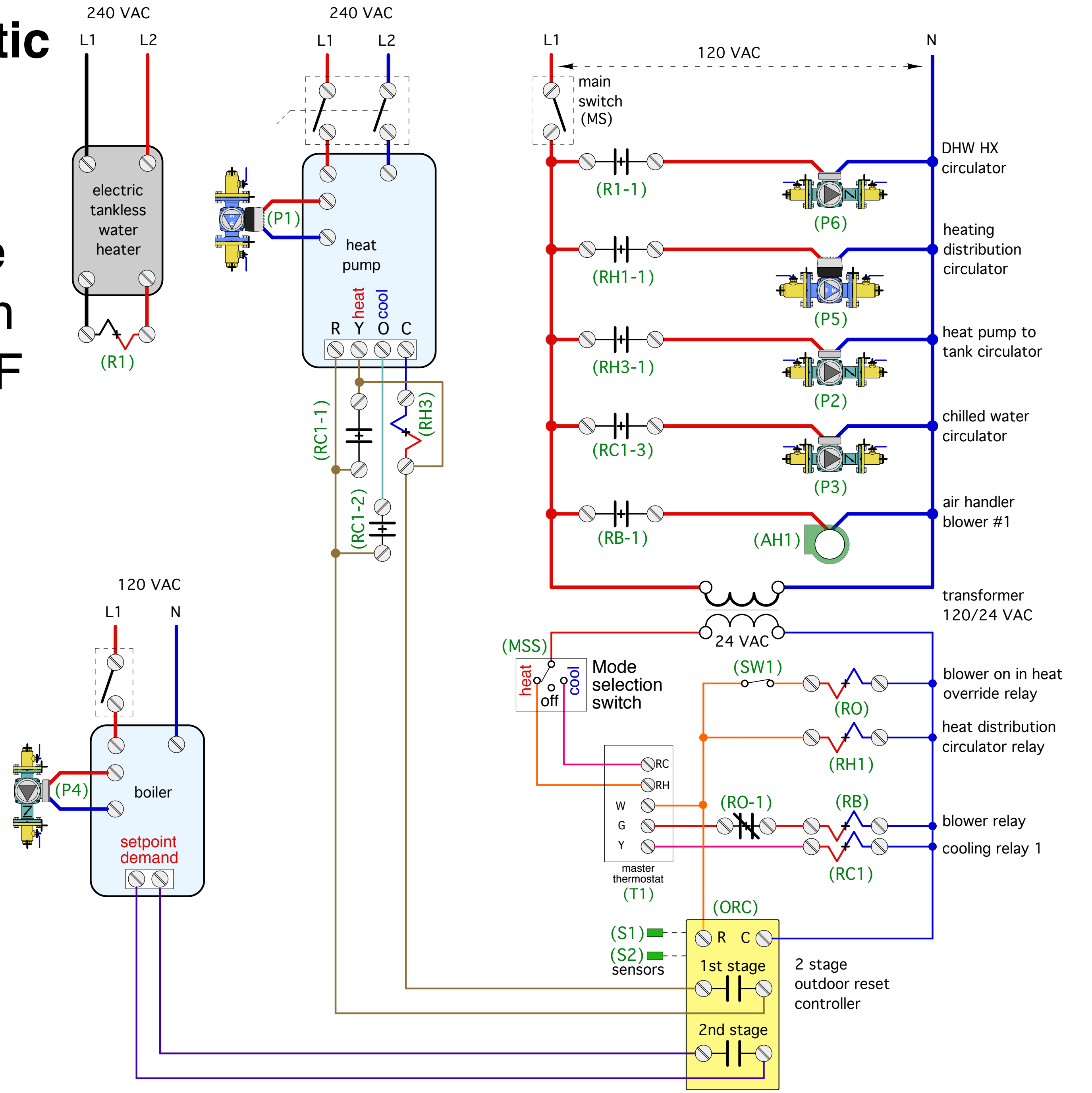
Cross reference between the component designations on the piping schematic and wiring schematic.



Description of operation

1. Space heating mode:
The mode selection switch (MSS) must be set for heating. This supplies 24 VAC to the (RH) terminal on master thermostat (T1). Upon a call for heat from (T1), 24 VAC is passed from the thermostat's (W) terminal to energize the coil of relay (RH1). Relay contact (RH1-1) closes to supply line voltage to space heating distribution circulator (P5), which then operates in constant differential pressure mode. 24VAC is also supplied to power on the 2-stage outdoor reset controller (ORC). This controller measures outdoor temperature at sensor (S2), and uses this temperature, along with its settings, to calculate the target water temperature in the buffer tank. If the actual temperature in the buffer tank, measured by sensor (S1), is slightly below the calculated target temperature, the 1st stage contacts in the (ORC) close. This completes a circuit between the (R) and (Y) terminals of the heat pump, causing it to operate in heating mode. It also supplies 24VAC from the heat pump's transformer to the coil of relay (RH3). A contact (RH3-1) closes to supply line voltage to circulator (P2), which creates flow between the heat pump and buffer tank. Earth loop circulator (P1) is turned on by the heat pump's internal circulator relay whenever the heat pump operates in either heating or cooling mode.

If the heat pump is unable to maintain the buffer tank temperature near the target value, the 2nd stage contacts in the (ORC) close. The completes a 24 VAC circuit within the boiler that allows it to operate in setpoint mode. The boiler supplies 120 VAC to operate circulator (P4) whenever boiler operation is enabled. Under this condition, both the boiler and heat pump are adding heat to the buffer tank.

The heat output from each panel radiator is regulated by a wireless thermostatic radiator valve. Each valve varies the flow rate through its associated panel radiator based on its settings and the current room temperature.

2. Space cooling mode:
The mode selection switch (MSS) must be set for cooling. This supplies 24 VAC to the (RC) terminals of thermostat (T1). When this thermostat demands cooling, 24 VAC is passed from the thermostat's (Y) terminal to the coil of relay (RC1). One set of contacts (RC1-1) close to complete a 24 VAC circuit from the heat pump's (R) terminal, to its (Y) terminal. This enables the compressor to operate. Another set of contacts (RC1-2) close to complete a 24 VAC circuit from the heat pump's (R) terminal to its (O) terminal. This powers on the heat pump's reversing valve allowing the heat pump to operate in cooling mode. Another set of contacts (RC1-3) close to apply 120 VAC to circulator (P3), which creates flow between the heat pump and air handler (AH1).

Whenever thermostat (T1) calls for cooling, 24 VAC from terminal (G) is also passed to blower relay (RB). A set of contacts (RB-1) close to supply 120 VAC to the blower in air handler (AH1).

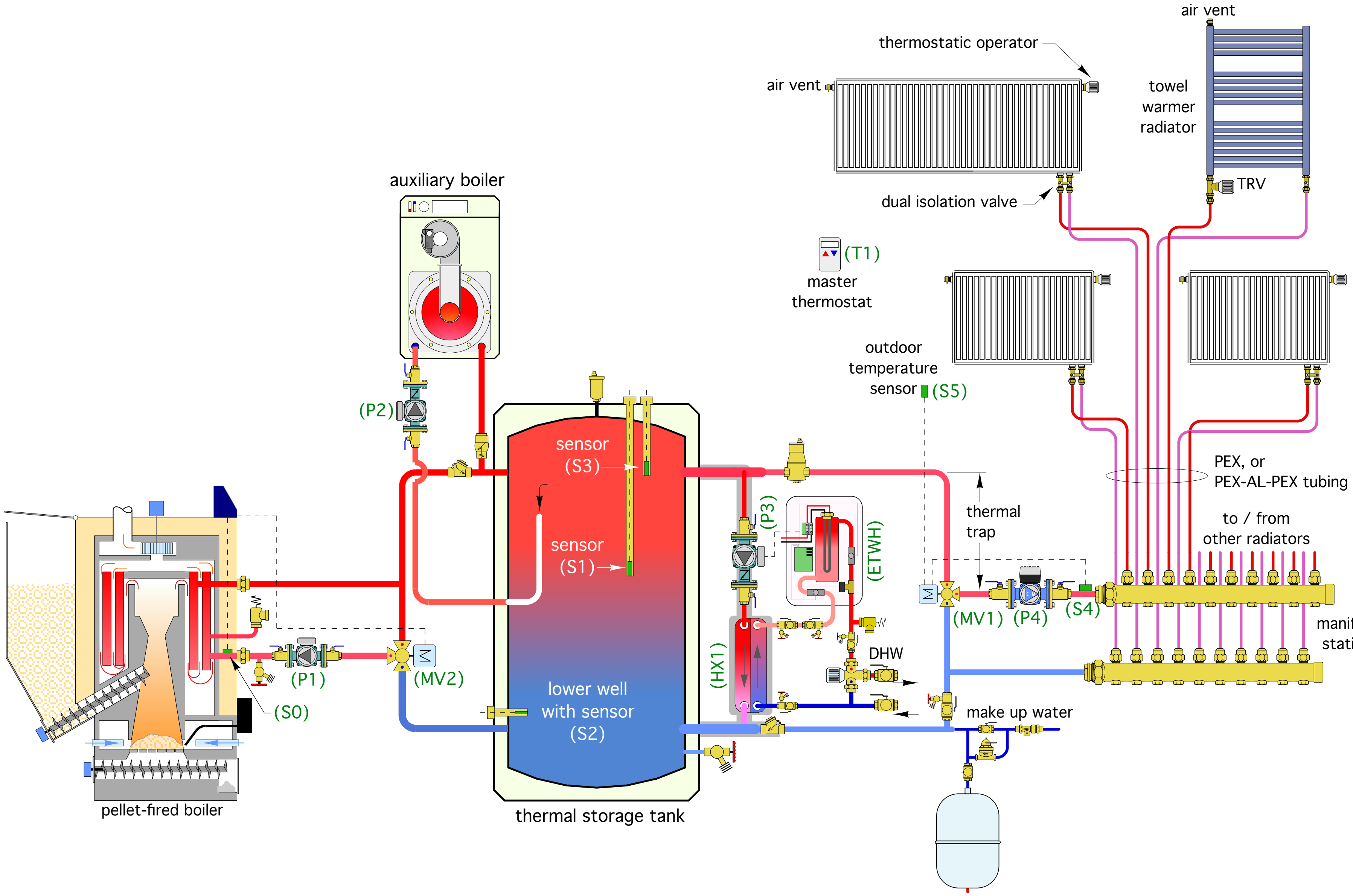
During cooling mode, heat from the heat pump's desuperheater is also transferred to the buffer tank. A small circulator within the heat pump creates the necessary flow.

3. Blower operation: The blower in the air handler will always operate in cooling mode. It may also be set for continuous operation in either heating or cooling mode by setting the fan switch on thermostat (T1) to "on." If the blower is not to run during the heating mode, switch (SW1) should be closed. This allow 24 VAC to energize the coil of relay (RO), when thermostat (T1) calls for heat. A normally closed contact (RO-1) opens, interrupting 24VAC to the blower relay (RB), and thus preventing the blower from operating. If switch (SW1) is left open, the blower will operate whenever thermostat (T1) calls for heating.

4. Domestic water heating mode: Whenever there is a demand for domestic hot water of 0.6 gpm or higher, the flow switch inside the tankless electric water heater closes. This closure applied 240 VAC to the coil of relay (R1). The normally open contacts (R1-1) close to turn on circulator (P6), which circulates heated water from the upper portion of the buffer tank through the primary side of the domestic water heat exchanger (HX1). The domestic water leaving (HX1) is preheated to a temperature a few degrees less tank the buffer tank temperature. This water passes into the thermostatically controlled tankless water heater, which measures its inlet temperature. The electronics within this heater control the electrical power supplied to the heat elements based on the temperature rise needed to achieve the set domestic hot water supply temperature. All heated water leaving the tankless heater flows into an ASSE 1017 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 (P5) and the tankless electric water heater are turned off.

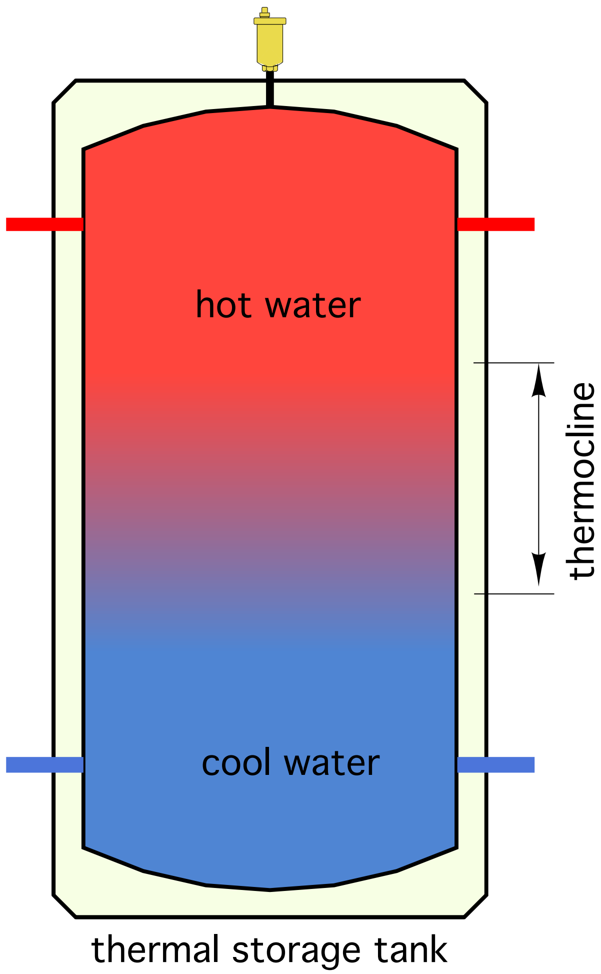
Modern Hydronics Meets Pellet-fueled Boiler

Piping schematic

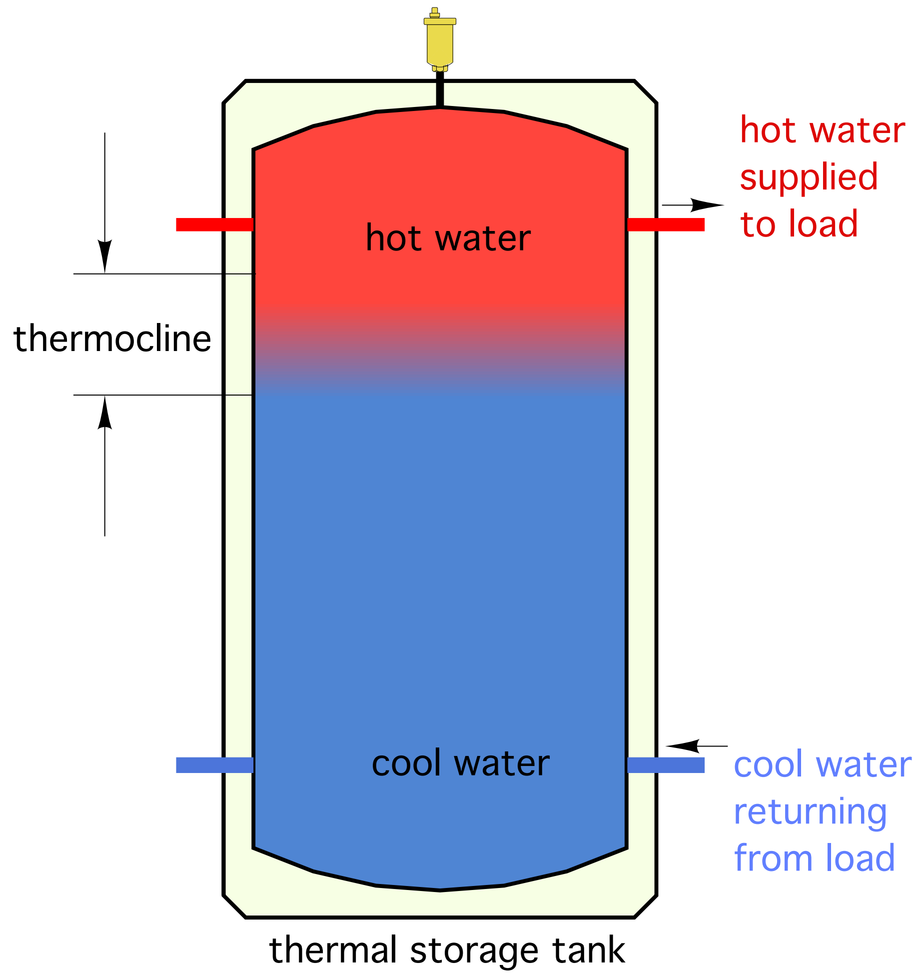


Temperature Stacking in Thermal Storage Tanks

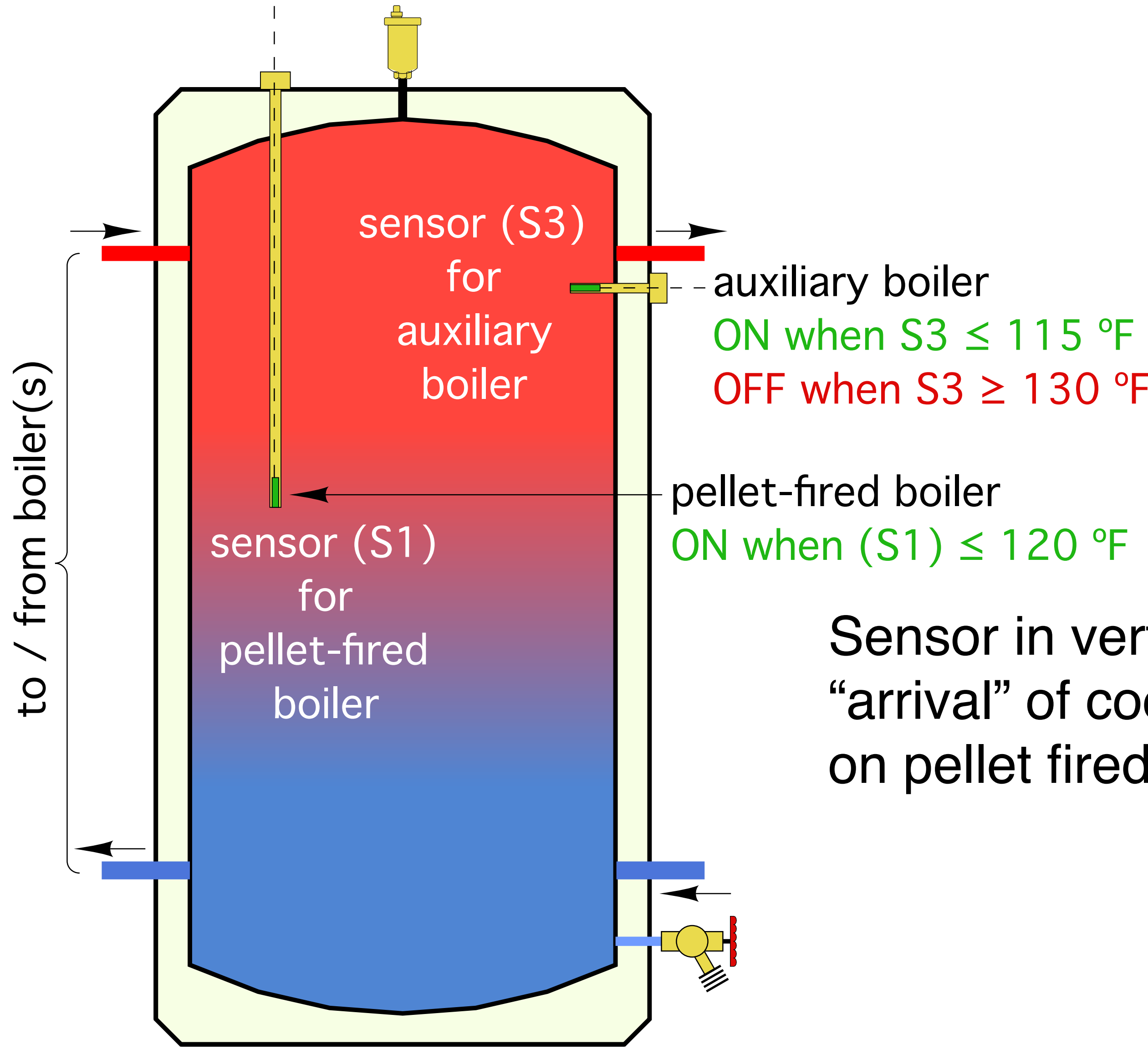
A thermal storage tank “at rest” will have a well defined **thermocline**, between cooler water at bottom, and hottest water at top.



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

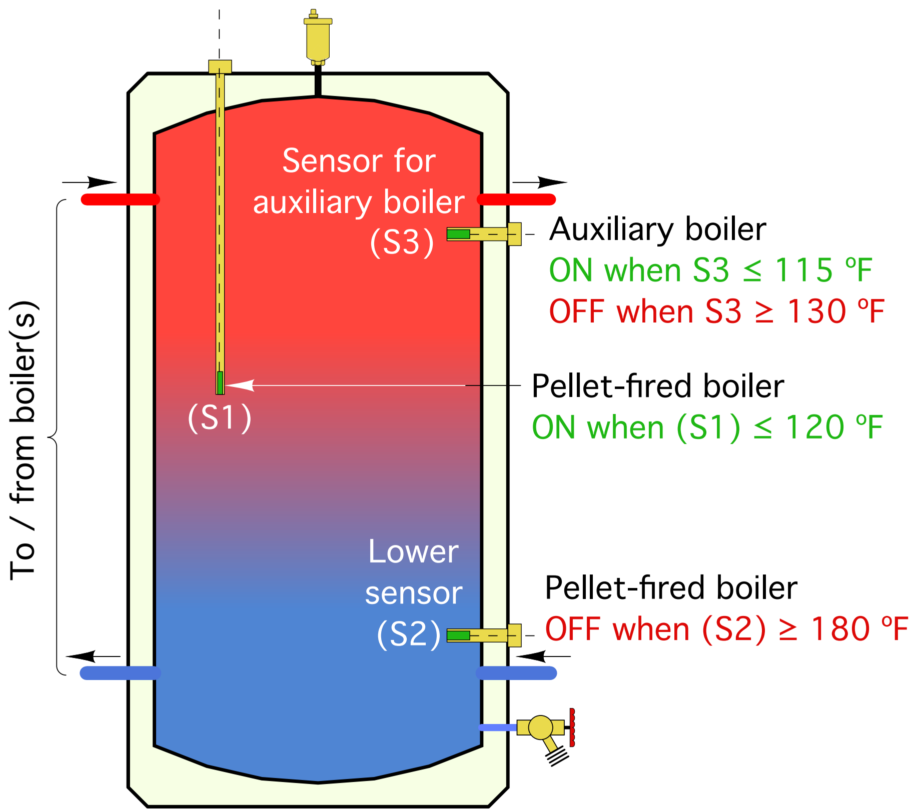


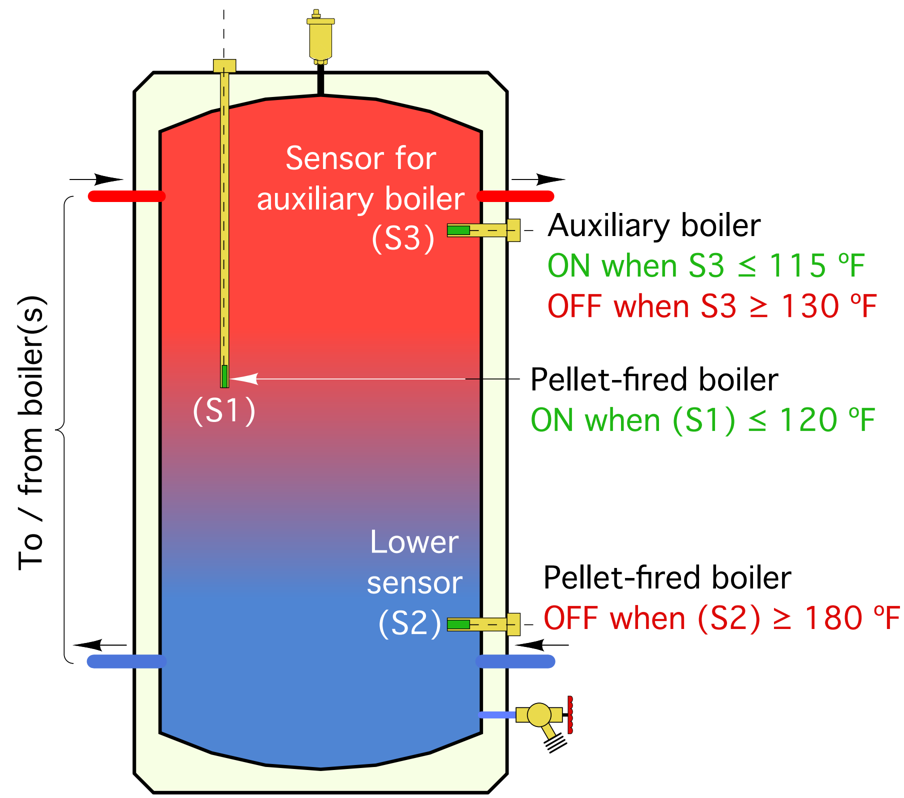
The pellet fired boiler should be turned on ***before*** the hot water is depleted from top of tank.



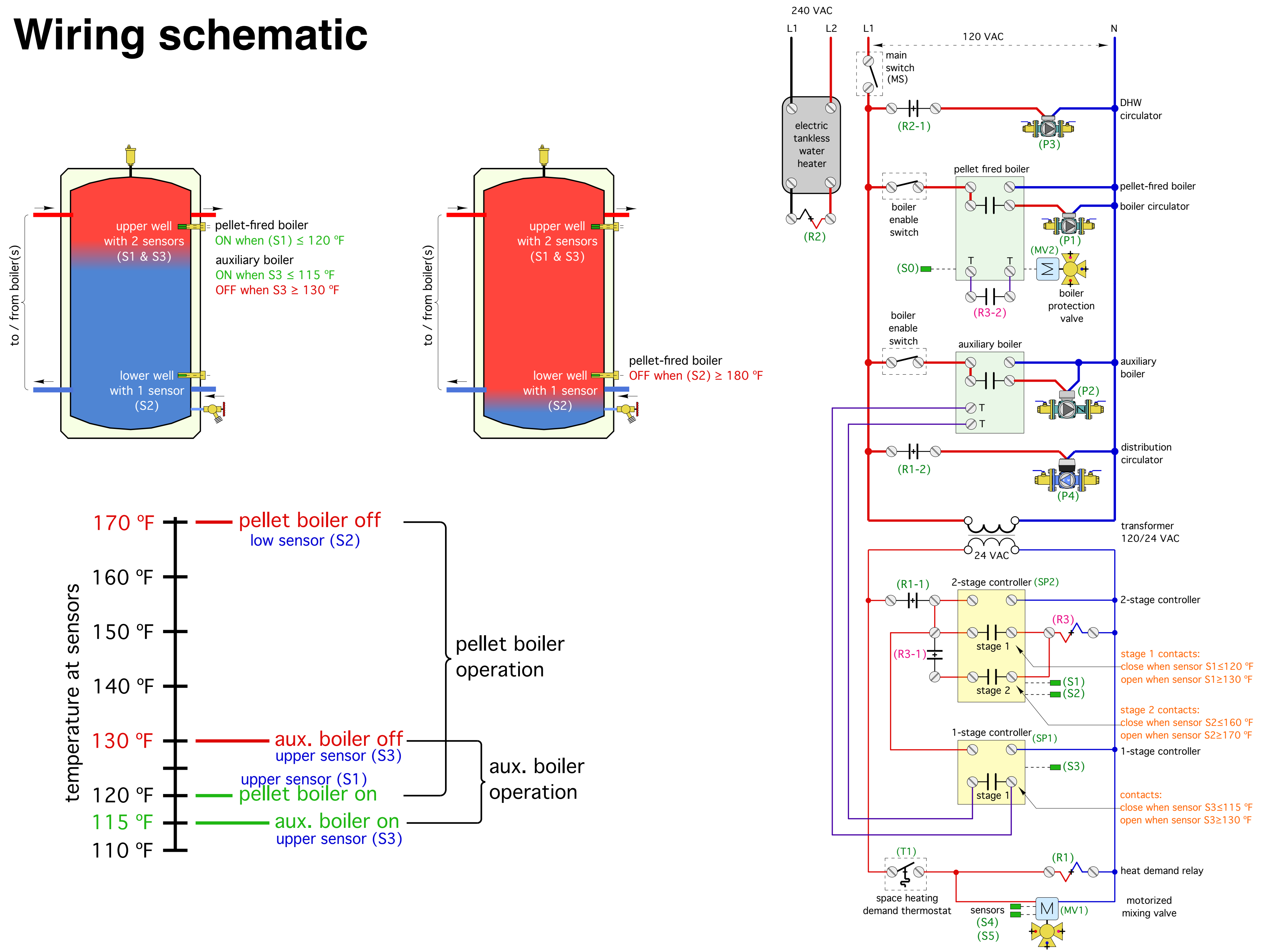
Sensor in vertical well detects "arrival" of cooler water. Turns on pellet fired boiler.

The pellet fired boiler should remain on until the tank is "stuffed full" of hot water.





Wiring schematic



Description of operation

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.

Hydronics for Renewable Energy System Applications:

Summary:

• Modern hydronics technology provides an excellent “media” for creating combisystems that use renewable energy heat sources.

• It is critically important to use low temperature distribution systems within any system supplied by a thermally-based renewable energy heat source.

• Water-based thermal storage options are ideal for these systems. Be sure the tank is well insulated: R-18 suggested on all surfaces

• Take advantage of high efficiency circulators to reduce the electrical operating cost of the system and attain high distribution efficiency

• Use homerun distribution systems in both new and retrofit installations

• Use outdoor reset to “drain” thermal storage to lowest usage temperature before using auxiliary boiler

• The on-demand DHW assembly with tankless electric auxiliary is a simple option that can be used in any system with thermal storage.

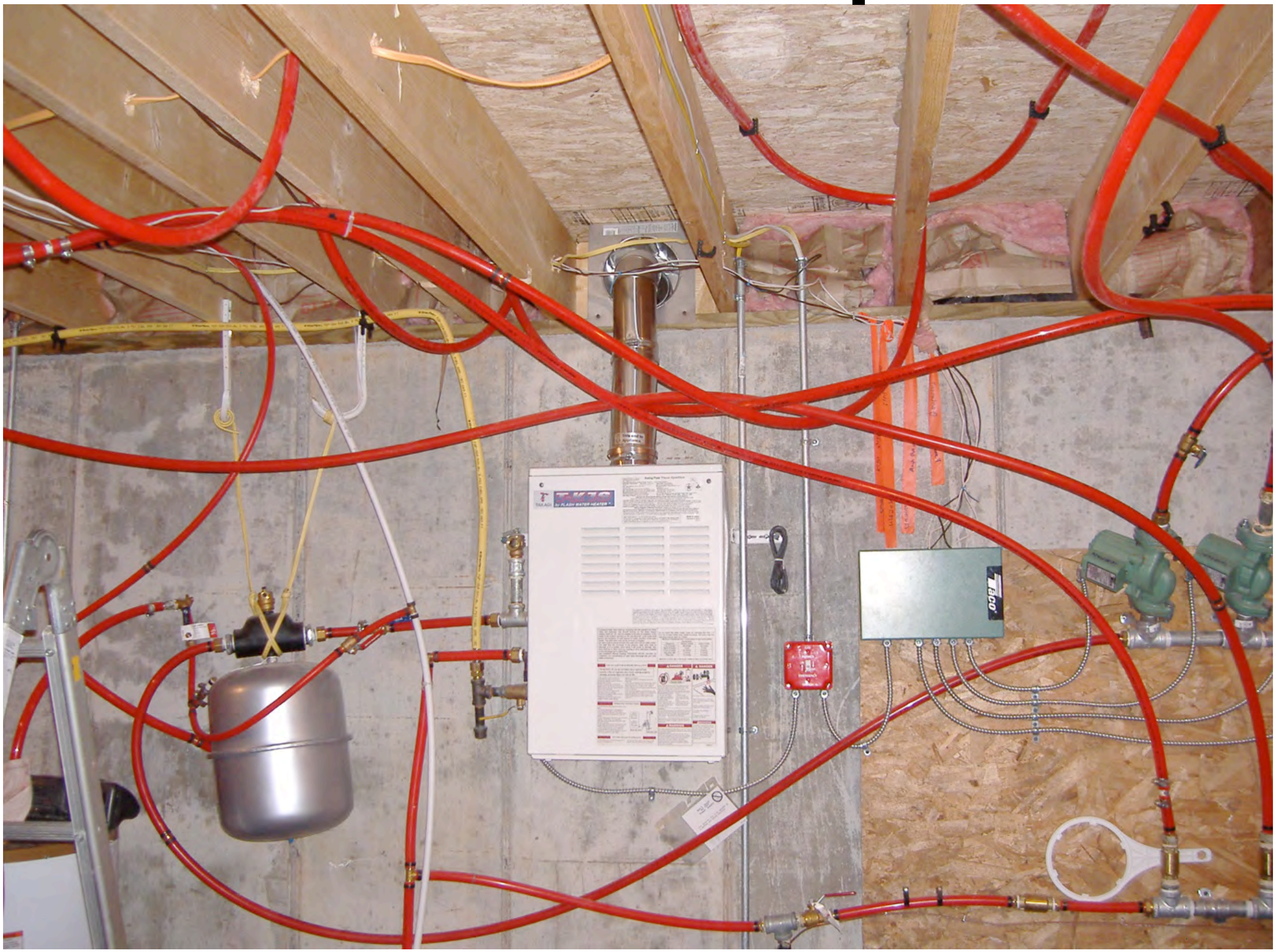
• Always create a piping schematic, wiring schematic, and description of operation for all systems. It the future “roadmap” for the system.

Parting thoughts...

1. Plan ahead...

Parting thoughts...

2. Keep it neat...



Parting thoughts...

3. Keep it simple...

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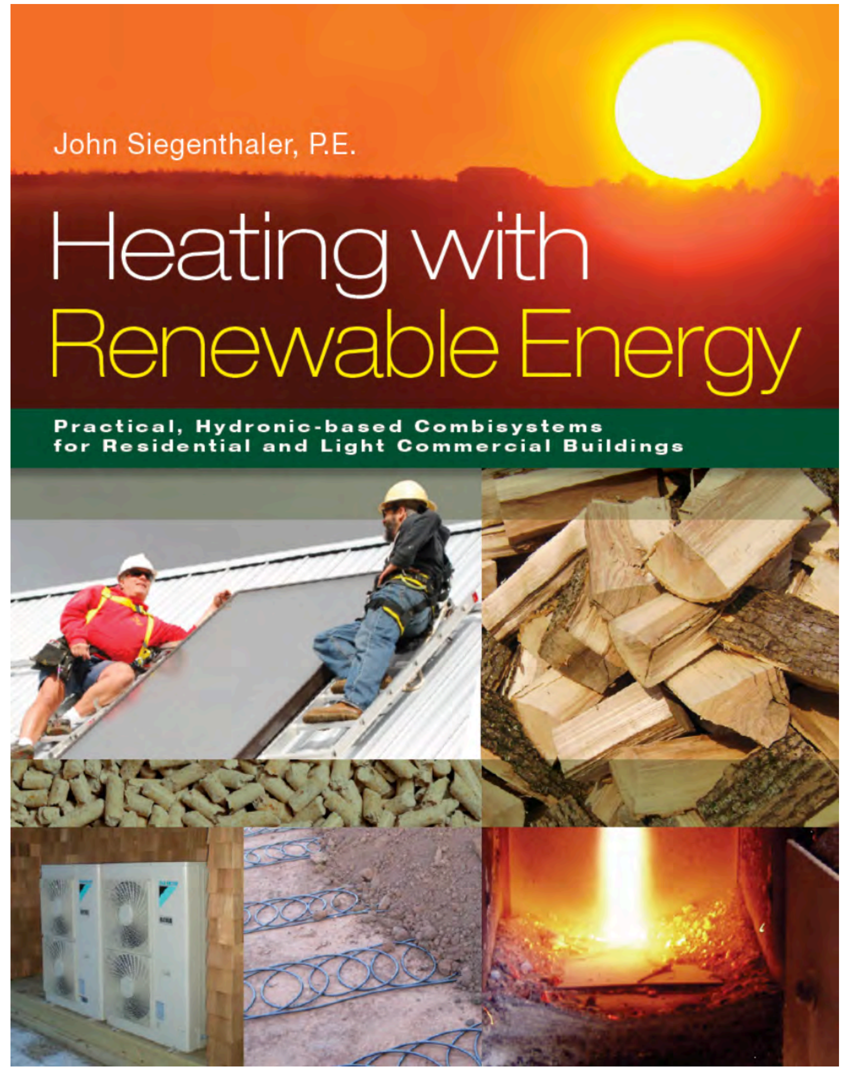

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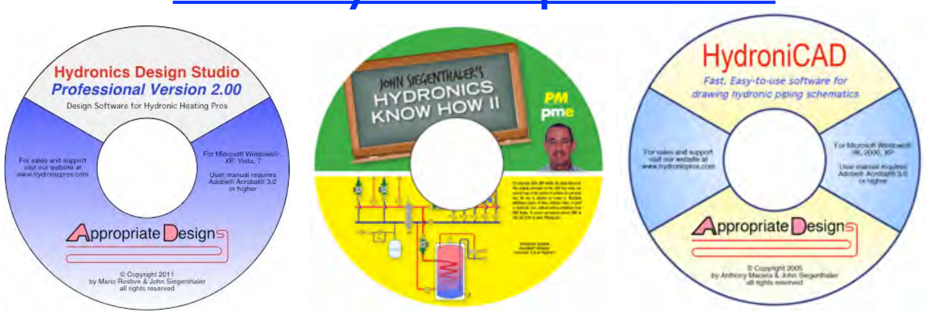

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