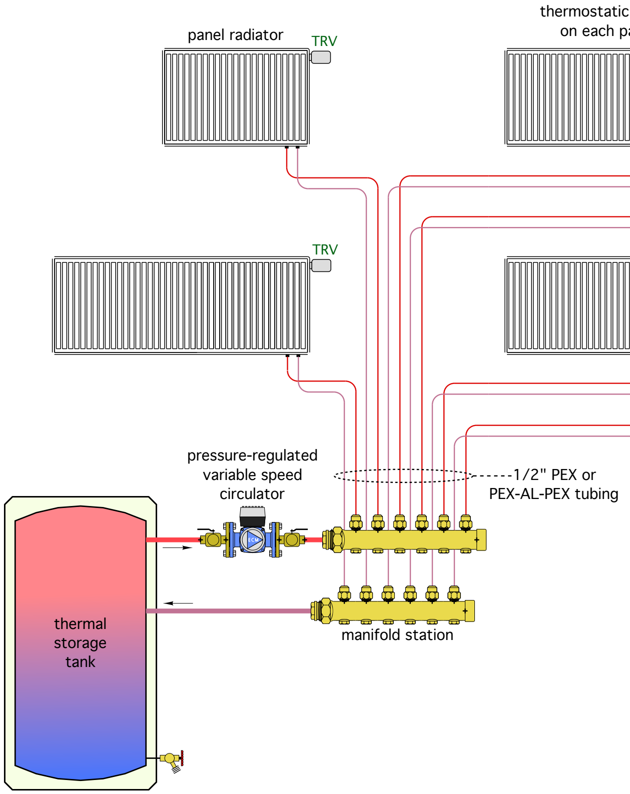
Hydronic Heating for Low Energy Houses



2013 Energy Design
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presented by:
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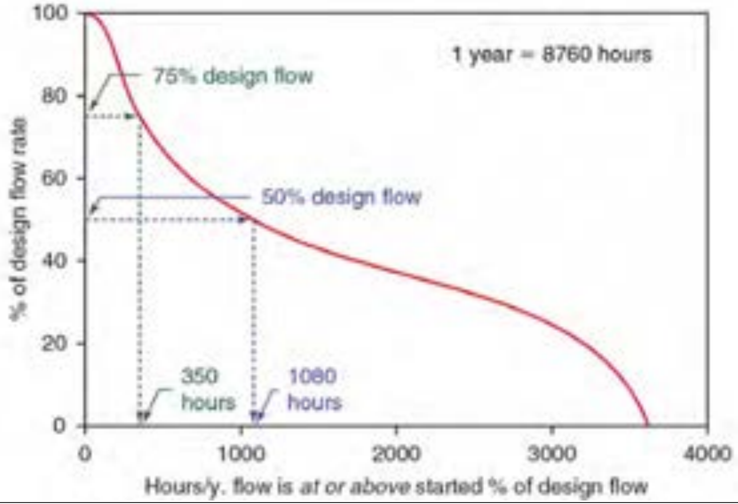
Appropriate Designs
Holland Patent, NY
www.hydronicpros.com

Hydronic Heating for Low Energy Houses

Today's topics...

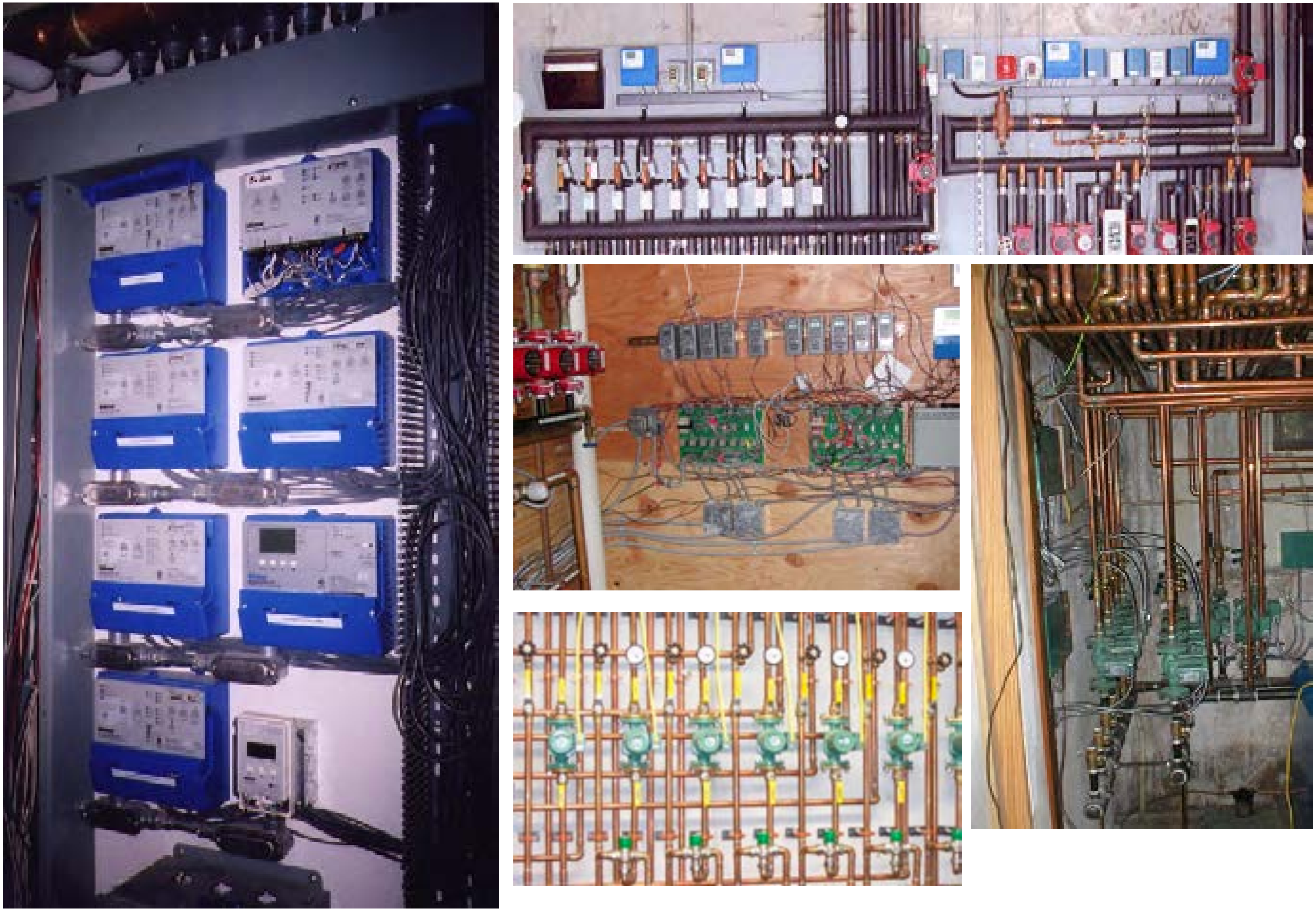
- Emerging Opportunities - Low Energy Houses
- Why is hydronic heating appropriate in low energy houses?
- What are appropriate heat sources?
- What are appropriate heat emitters?
- What are appropriate distribution systems?
- What are appropriate circulators?
- Putting it all together
    - systems with gas-fueled heat source
    - systems with solar thermal input
    - systems with air-to-water heat pump heat source
    - systems with geothermal heat pump heat source



Many hydronic systems are installed in large houses like these...

Hydronics "owns" the upscale housing market in many areas of North America.

These systems often have complicated and expensive systems



The “wall of pumps” approach is often used...

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

Is this what it takes to operate a hydronic heating system???

From this...

To this...

Image from book “The Not So Big House”, by Susan Susanka

but probably not to this...

Growth in smaller housing market...

From a recent AIA research report: (American Institute of Architects)

- *Home sizes historically have declined during housing recessions, but this downturn appears to have ushered in a more dramatic reversal of an extended period of growth in home sizes.*

- *Homeowners are switching their focus* ***from frivolous to functional*** *and paying special attention to energy-efficient features.*

- *A new mood of frugality hasn't affected demand for energy-efficient home improvements. insulation, solar panels, double- and triple-glazed windows, tankless water heaters, and geothermal heating and cooling systems have grown in popularity.*

- *Fifty-two percent of respondents reported decreases in home square footage in 2011, compared with 57 percent in 2010.*

From Builder Magazine (National Association of Homebuilders):

"The average home is currently about 2,380 square feet in size, but the NAHB expects that number will drop to 2,150 square feet by 2013."

From Times Herald Record Newspaper (April 2011):

Woodstone Development is offering a new product for its gated community of million-dollar 5,000-square-foot luxury homes in Bethel, New York: 1,250-square-foot Adirondack cabins with a starting price of $279,000. "Up until this point, we've only really addressed the top of the pyramid," Howard Schoor, Woodstone's chairman and CEO, told the newspaper. "This is designed more to meet the realities of 2011 — that people are downsizing."

Michigan retirement house: (Just won a GreenBuilder home of the year award)

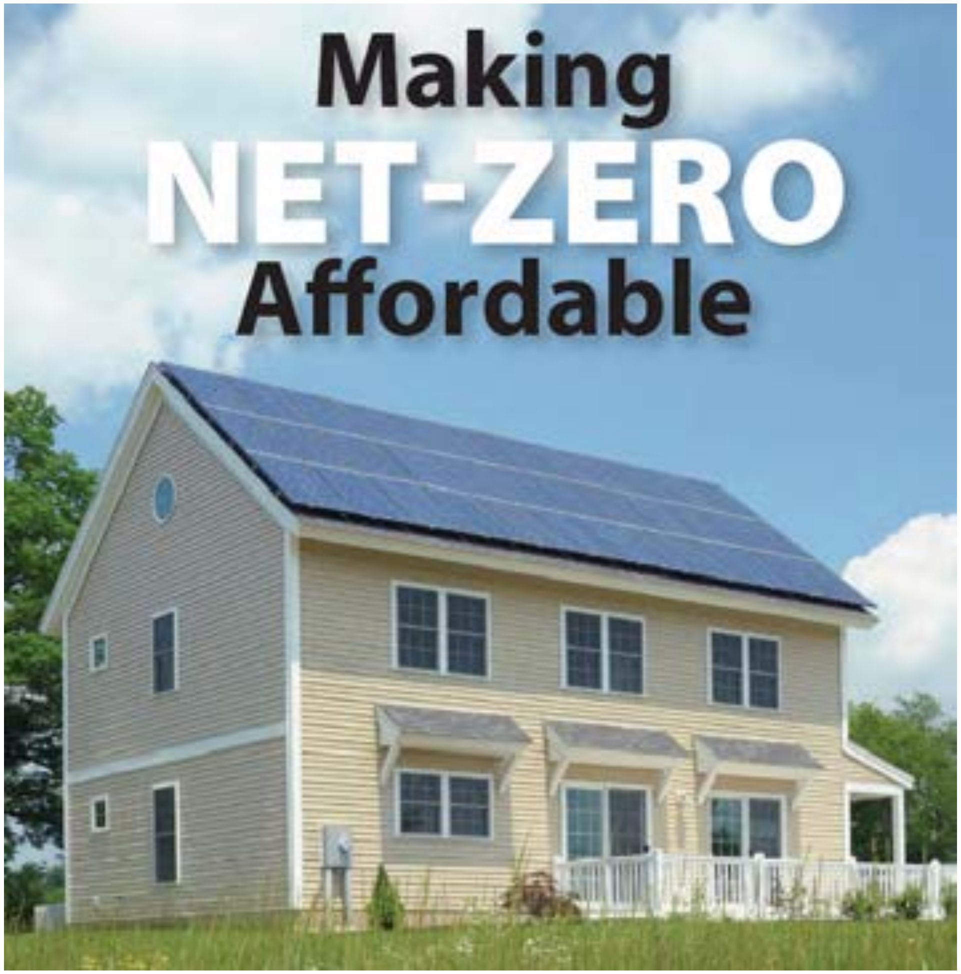
Architect's comment:

"Its seems to be a new trend with all my clients lately that the want a small house with the best building material for the shell of their home," notes architect Eric Hughes. "Then they want as much renewable energy as the budget will allow, so they can reduce their utility bills and get as close to net-zero as possible."

Zero energy, 32 points ***above*** LEED platinum rating
1,267 square foot floor area (@$142/sq ft)=$179,900
heated slab on grade floor (??), heat recovery ventilator
ICF walls, SIP ceiling, R-4 windows, Navien mod/con boiler, solar DHW

Massachusetts Net Zero house built in 2011

Images: SolarToday magazine, Nov/Dec 2011




Mitsubishi dual-stage heat pumps produce 92 percent of their capacity at 5°F (minus 15°C) and keep producing heat down to minus 13°F (minus 25°C).

Mitsubishi mini-split heat pumps
1,800 square foot floor area, 12,100 Btu/hr design load
R-46.8 walls, R-63 ceiling, R-20 basement,R-5 windows
Heat recovery ventilator   All electric house.

A growing niche in the housing market...

Emerging opportunities:

- smaller houses
- much lower design loads
- more interest in renewables
- more interest in RELIABLE solutions
- more interest in SIMPLE solutions

Has anyone here ever seen this house?

ENERGY EFFICIENT ?

YES!

AESTHETICALLY PLEASING?

“Beauty is in the eye of the beholder”

It’s doubtfull many people would go for this.

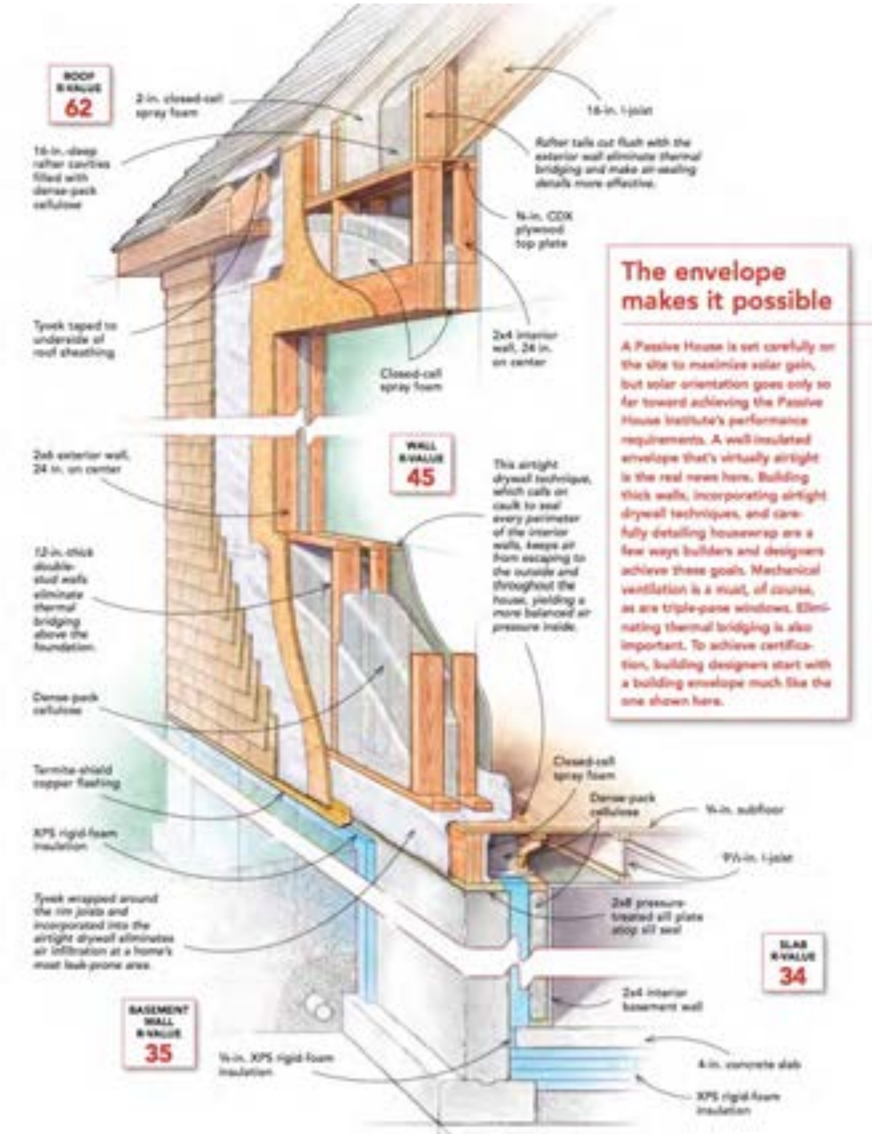
Saskatchewan Conservation House: Built 1977 - Saskatoon, Saskatchewan

R-60 ceilings, R-44 walls, homebuilt air-to-air heat exchanger

Space heating load = 10,600 Btu/hr when outdoor temperature is -10ºF

First year heating cost = $35 in 10,856 DD climate, -31ºF design temperature

PassivHaus



The envelope makes it possible

A Passive House is set carefully on the site to maximize solar gain, but solar orientation goes only so far toward achieving the Passive House Institute's performance requirements. A well-insulated envelope that's virtually airtight is the real news here. Building thick walls, incorporating airtight drywall techniques, and carefully detailing housewrap are a few ways builders and designers achieve these goals. Mechanical ventilation is a must, of course, as are triple-pane windows. Eliminating thermal bridging is also important. To achieve certification, building designers start with a building envelope much like the one shown here.

Image source: Fine Homebuilding magazine

http://www.passivehouse.us/passiveHouse/PHIUSHome.html

Houses built to the current PassivHaus standard use about 10% of the total heating and cooling energy of the same size house built to 2006 International Building Code standards.

Image courtesy of Foley Mechanical

Triple-pane windows

Walls: R-40 to R-60
Ceilings: R-60 to R-100
Windows: R-4 to R-8
Air leakage: 0.3 AC/hr @ 50pa

The evolution of home heating system
- from an architect’s point of view...

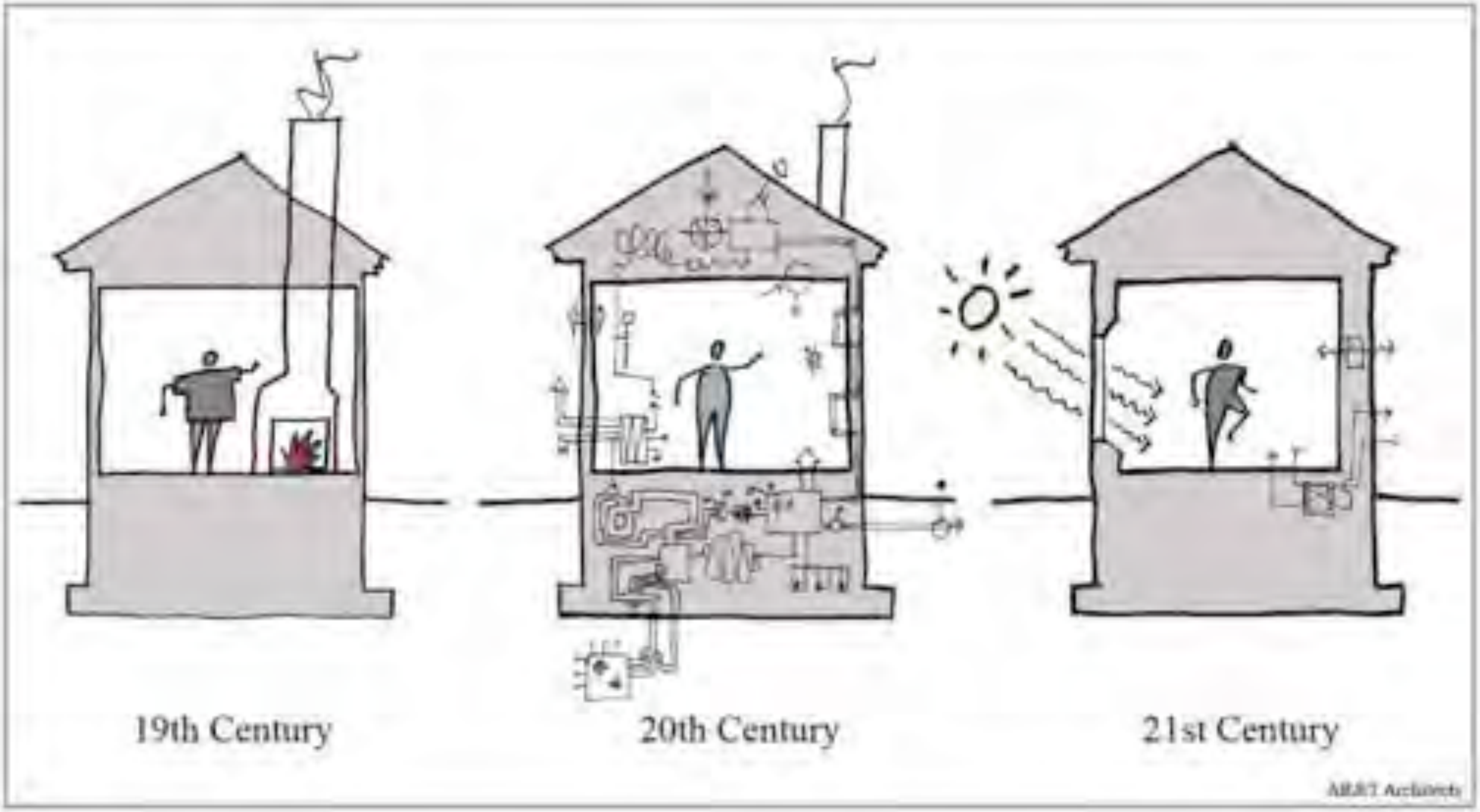


Image source: AR&T Architects

What are the “characteristics” of low energy houses that must be addressed during design of the heating system?

- Small design heating loads in the range of 10 to 15 Btu/hr/ft^2. (A 2000 ft^2 house at 10 Btu/hr/ft^2 is only 20,000 Btu/hr DESIGN load)

- Internal heat gains can have more significant impact on internal temperature. (room-by-room zoning is important to control overheating)

- Internal heat flow through open doors and uninsulated partitions helps equalize temperature differences. (difficult to maintain significant temperature differences between zones)

- **DHW load may exceed space heating load, and thus set the output requirement of the heat source.**

- Heat Recovery Ventilation will be required due to low natural air leakage

- Any large surface area radiant panels will operate at very low surface temperatures (71-75°F). (Heated floors don’t get as warm as they used to - **they don’t need to...**)

- Sometimes difficult to find a combustion type heat source with capacity well matched to load. (**will need thermal mass to prevent short cycling**)

- Monthly service charge associated with gas meter may be hard to justify based on fuel cost difference and usage. (consider “all electric” house)

- All “net-zero” houses will use solar PV system, and thus favor an “all electric” HVAC system.

Image: SolarToday magazine, Nov/Dec 2011

Hydronic solutions for low energy houses

Given that...

1. Houses are becoming smaller and more energy efficient
(nominal 5 to 15 Btu/hr/ft^2 design loads).

2. More customers are looking into the possibility of integrating renewable energy sources.

3. Builders and buyers are looking for HVAC “solutions” - not hardware.

4. **Hydronics is the “enabling technology” that underlies all thermally-based renewable energy systems.**

Question...

Can the North American hydronics industry seize upon, and leverage the opportunity to provide heating (and possibly cooling) solutions to the emerging market for low energy houses?

Here’s one contractor who did: PassivHaus, Bethesda, MD constructed in 2011, heating & cooling by Foley Mechanical, Arlington, VA

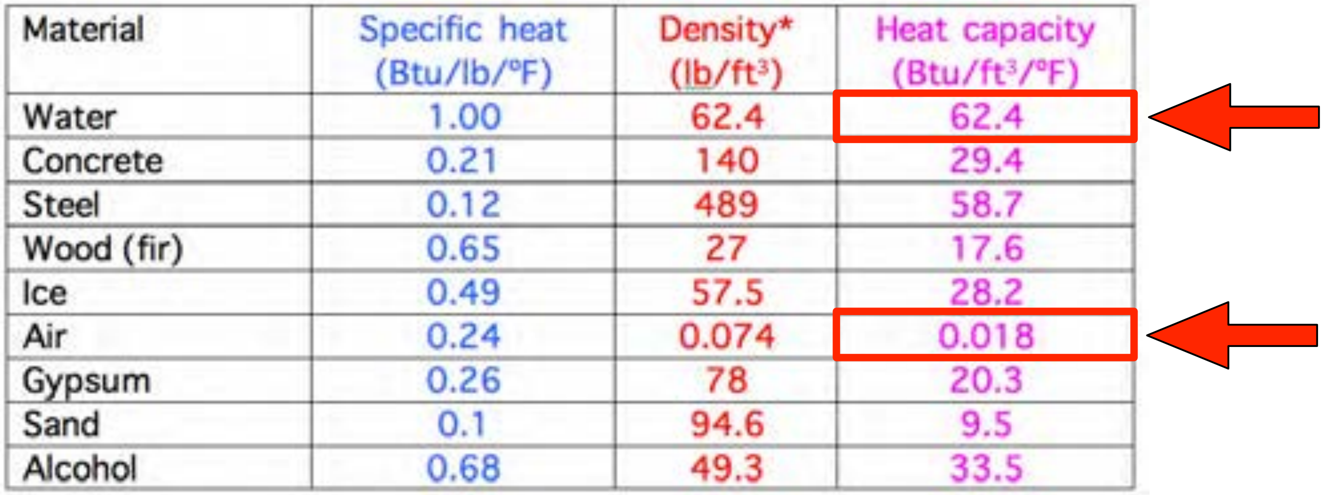
- 4600 square foot
- design heat loss = 24,000 Btu/hr, (5.2 Btu/hr/ft^2)
- mod/con boiler supplies hot deck coils in two zoned air handlers
- max water supply temperature to coil = 120 °F
- low head loss “pump through” firetube boiler 11-55 KBtu/hr modulating range
- single Grundfos Alpha circulator (18 watts at design load)

photos courtesy of Dan Foley

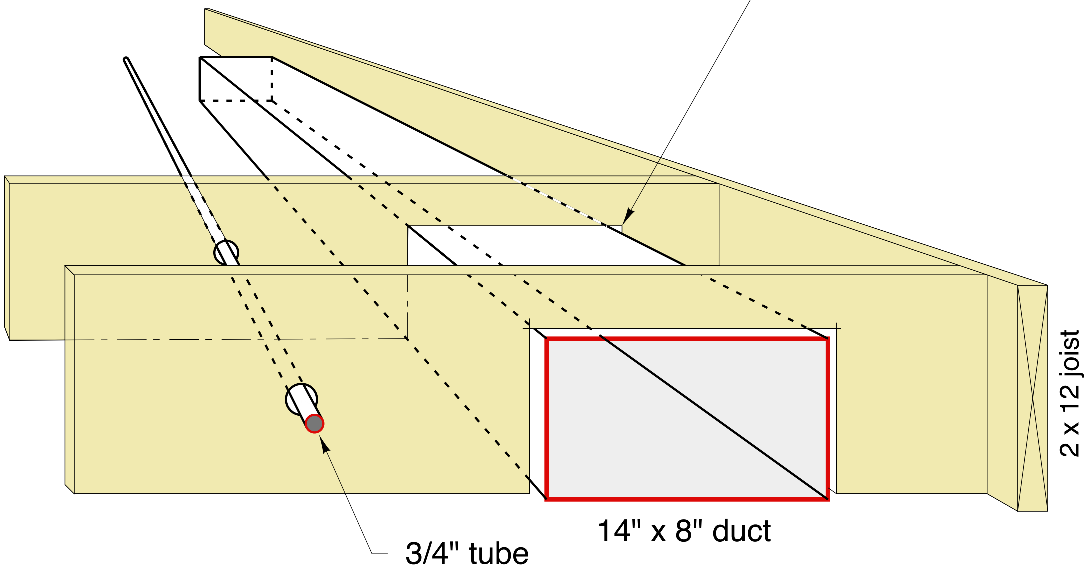
What are the advantages of using hydronic heating in these houses?

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

Water is vastly superior to air for conveying heat



Material	Specific heat (Btu/lb/°F)	Density* (lb/ft³)	Heat capacity (Btu/ft³/°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



this cut would destroy the load-carrying ability of the floor joists

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

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

What are the advantages of using hydronic heating in these houses?

- Simple room-by-room zoning is possible with many heat emitter options

Don’t have to leave all doors open for internal heat balancing. A limitation of single point heat/cool delivery such as wall cassette.

- Very low distribution energy required

(A single ECM circulator operating on 20 to 40 watts supplies all heating distribution)

- Very non-invasive installation of small tubing (3/8” & 1/2” PEX, PERT, or PEX-AL-PEX)

(Installing this tubing is like pulling electrical cable)

- Easily adapted to renewable heat sources)

(solar thermal, hydronic heat pump, off-peak)

- In some cases a single heat source can supply heating and DHW

(fewer burners, less vents, less fuel piping)

- Electric heat sources and water-based thermal storage is easily adapted to “off-peak” or coming “smart meter” rate structures.

(thermal storage hardware already available)

Consider the space heating load relative to DHW load

Example: Consider a 1,500 square foot house with a design heating load of 15 Btu/hr/ft^2.

Design load = 22,500 Btu/hr @ 75 ºF ΔT

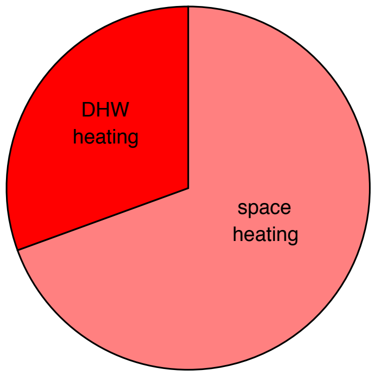
In a 7000 ºF•day climate, with some internal gains, this house used about 30.2 MMBtu/yr for space heating.

Assuming 60 gallons per day of DHW from 45-120 ºF the annual load for DHW is about 13.3 MMBtu per year (assuming 355 days per year of DHW demand)

Total thermal load = 43.5 MMBtu/yr
Space heating is 69.4%
Domestic water heating is 30.6%

Conclusion: It doesn't make sense to focus solely on high efficiency space heating, and ignore the potential for high efficiency domestic water heating.

Example:
Space heating with heat pump at seasonal C.O.P. = 3.0
Electric resistance domestic water heating at seasonal COP = 0.95
"Effective C.O.P." = (3.0)(.694) + (0.95)(.306) = 2.37

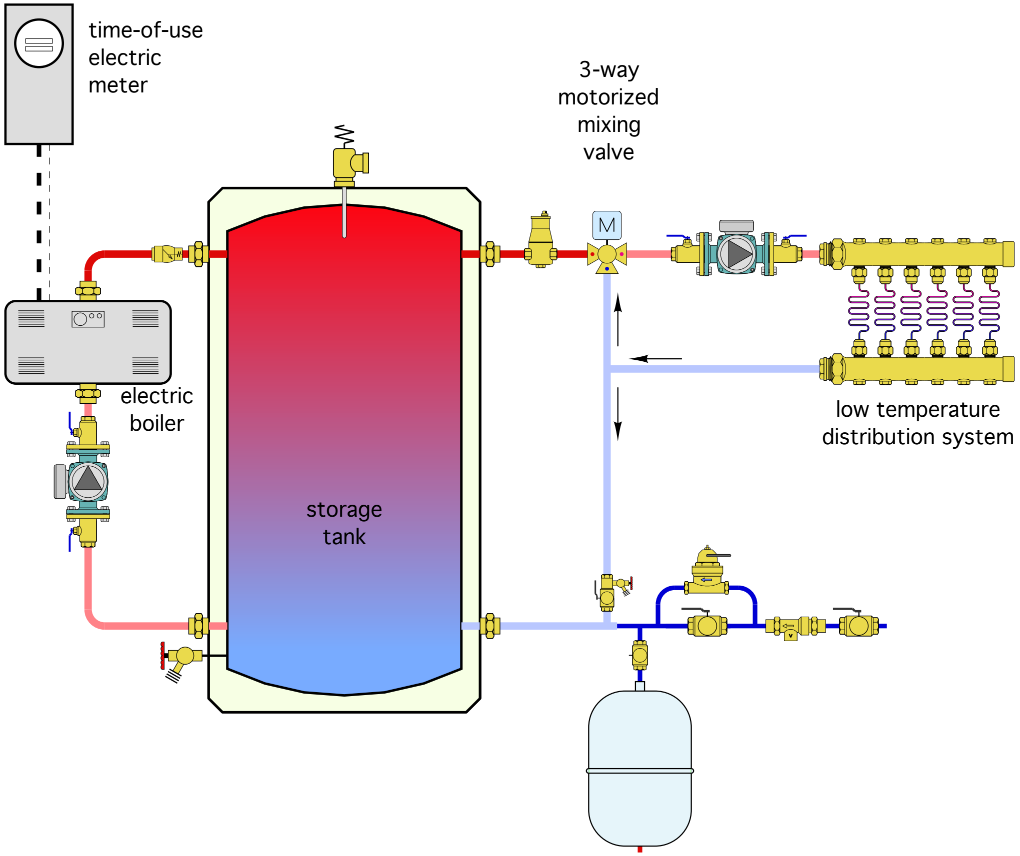


Solution: Use heat pumps for both space heating & DHW

What are the hydronic heat source options?

Electric:

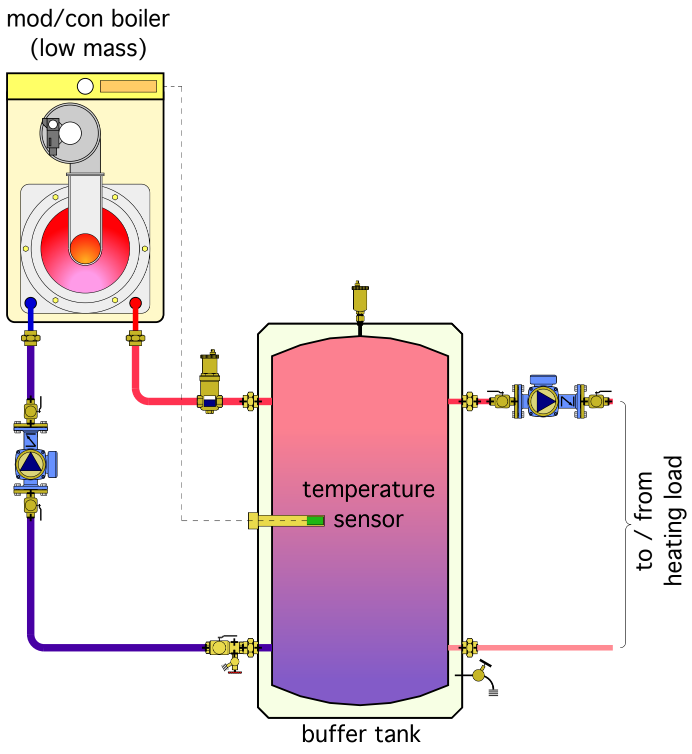
- resistance heating (electric boiler)
- off-peak electric resistance w/ thermal storage
- air-to-water heat pump
- geothermal water-to-water heat pump

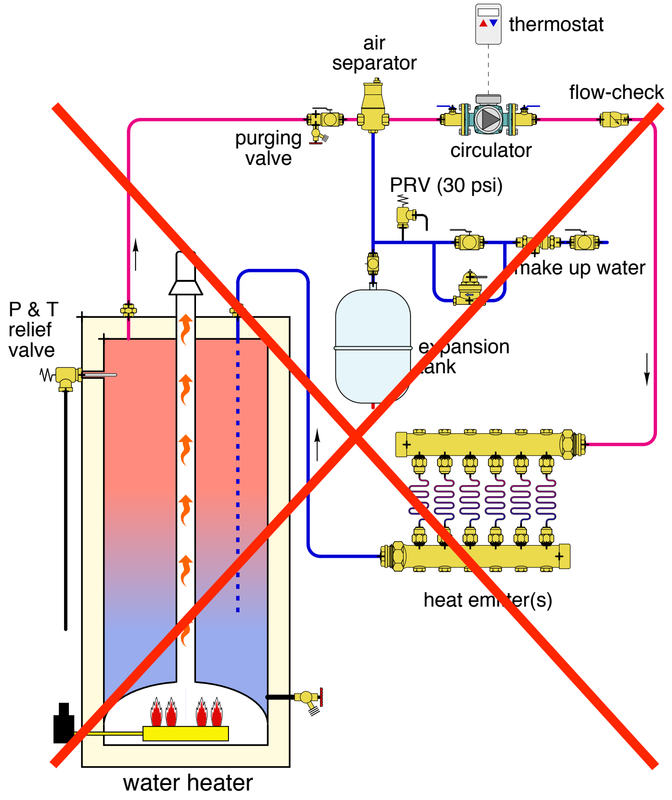


What are the hydronic heat source options?

Natural Gas or Propane:

- low mass mod/con boiler with buffer tank
- high mass mod/con boiler - “self buffering”
- domestic water heaters - not recommended



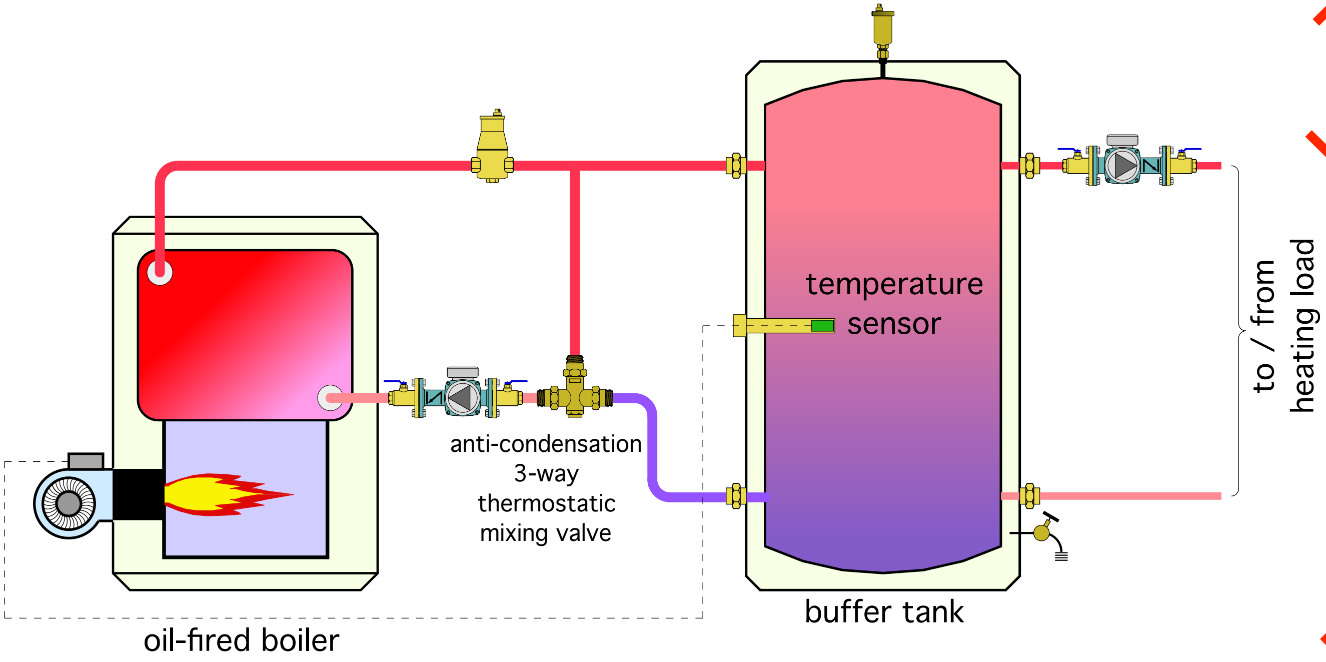


What are the hydronic heat source options?

Fuel Oil / wood-fired boiler / pellet-fired boiler:

- smallest available boiler with LARGE buffer tank

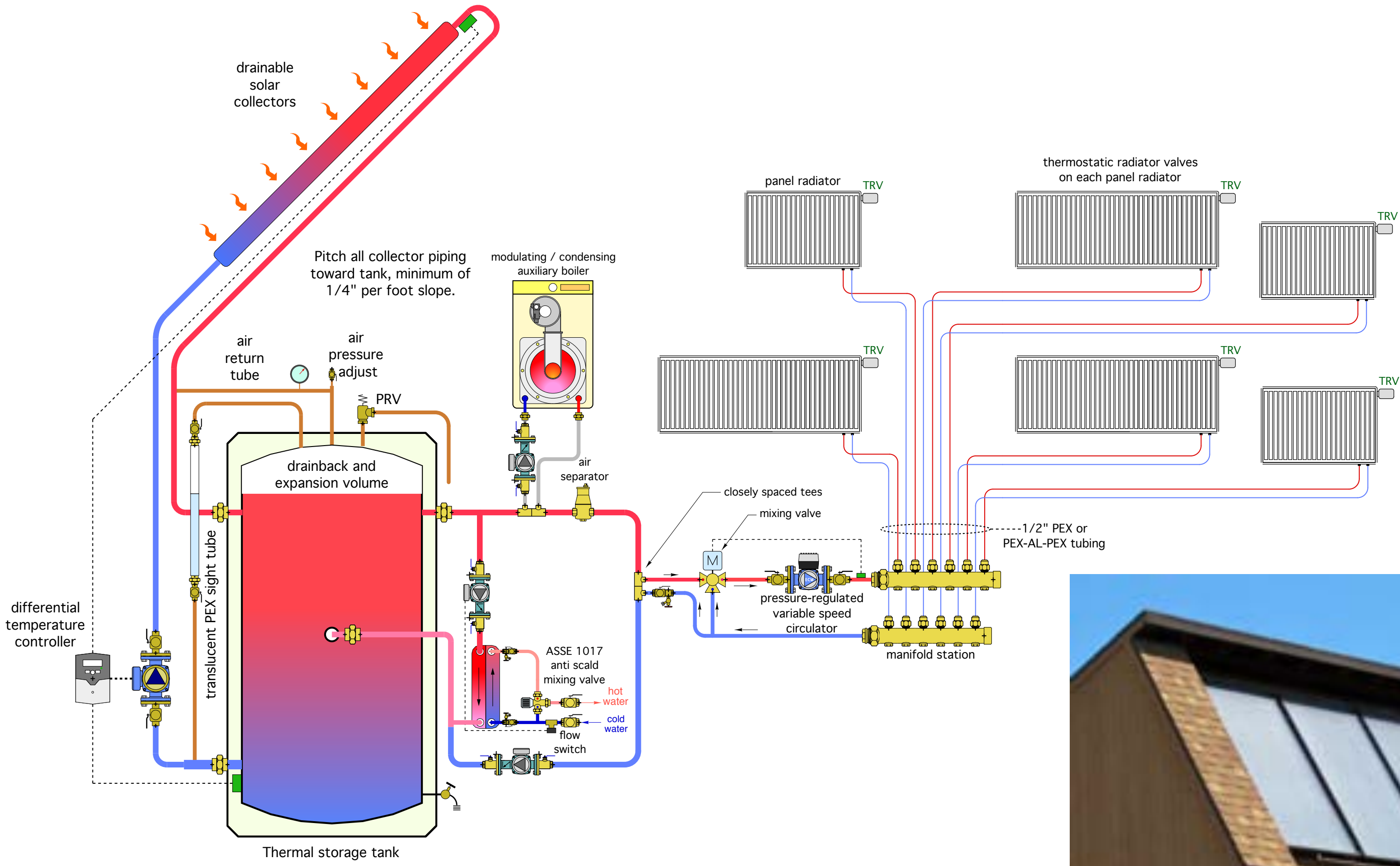
*- It's possible, but **a very hard sell** based on current fuel cost, fuel storage, venting, efficiency.*



What are the hydronic heat source options?

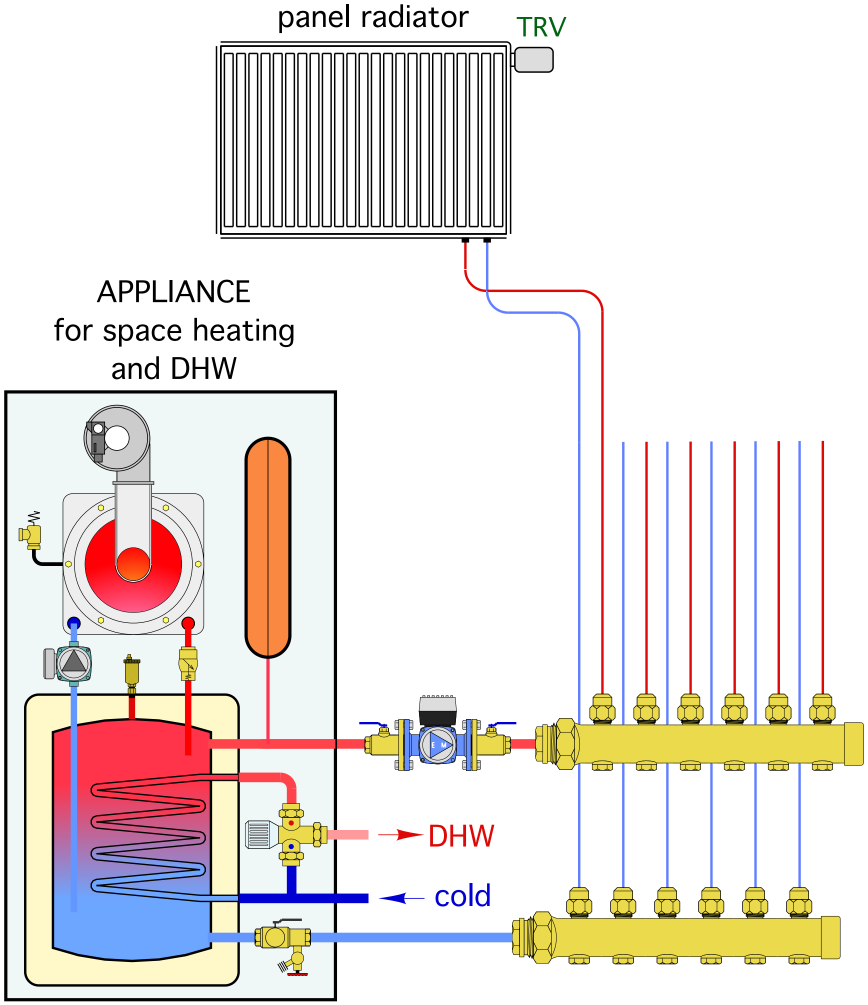
Solar:

- A solar combisystem (Solar DHW + heating) is a definite possibility. We will discuss more...



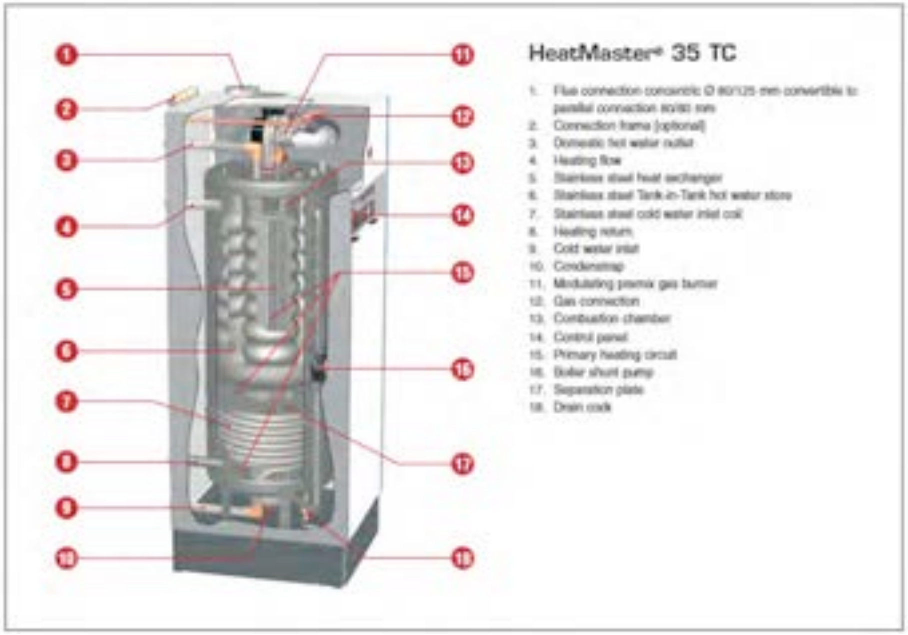
The European approach for small loads...

Combined space heating & DHW from single appliance.



ACV

Rotex



HeatMaster® 35 TC

1. Flue connection concentric Ø 80/125 mm convertible to parallel connection 80/80 mm
2. Connection frame (optional)
3. Domestic hot water outlet
4. Heating flow
5. Stainless steel heat exchanger
6. Stainless steel Tank-in-Tank hot water store
7. Stainless steel cold water inlet coil
8. Heating return
9. Cold water inlet
10. Condensetrap
11. Modulating premix gas burner
12. Gas connection
13. Combustion chamber
14. Control panel
15. Primary heating circuit
16. Boiler shunt pump
17. Separation plate
18. Drain cock

Combined space heating & DHW appliances from Europe

Do you notice anything in common among these products?

- None of them look like a boiler or water heater...

- They all look like an "appliance."

- They all have sufficient water volume to stabilize against short cycling the burner under light loading.

This is what some North American systems look like.

What kind of heat emitters should be used in these houses?

- They should operate at **low supply water temperatures** to enhance the thermal efficiency of the heat source.

For mod/con boilers: Max suggested supply water temperature @ design load= 140 °F

For solar collectors: Max suggested supply water temperature @ design load = 120 °F

For heat pumps: Max suggested supply water temperature @ design load = 120 °F

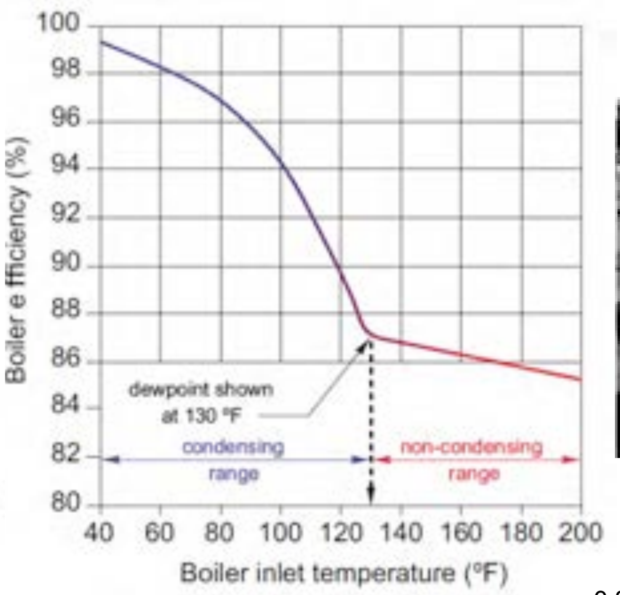
- They should have **low thermal mass** for rapid response to interior temperature changes

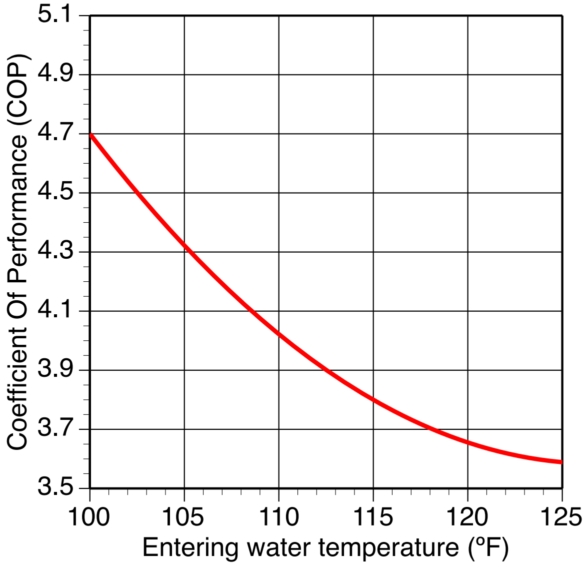
- They should permit simple **room-by-room zone control**

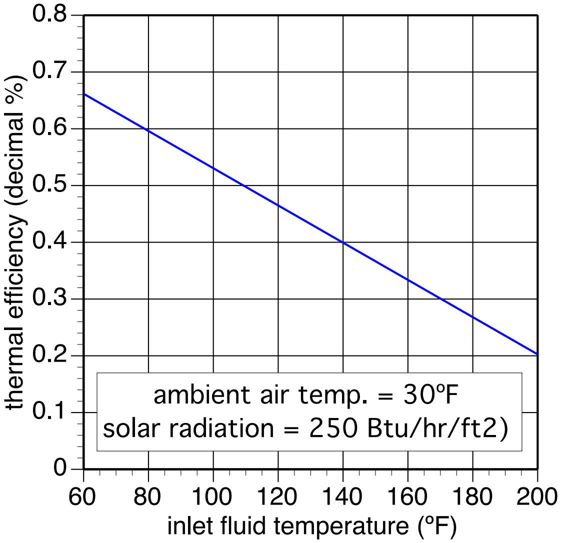
- They should not be subject to future changes that could reduce performance
(no carpet / rugs added over heated floors)

- They should not create noticeable drafts or other discomfort
(avoid operating conventional fan coils or air handlers at supply air temperatures lower than 100 °F)

Heat sources such as condensing boilers, geothermal heat pumps, and solar collectors all benefit from low water temperature operation.



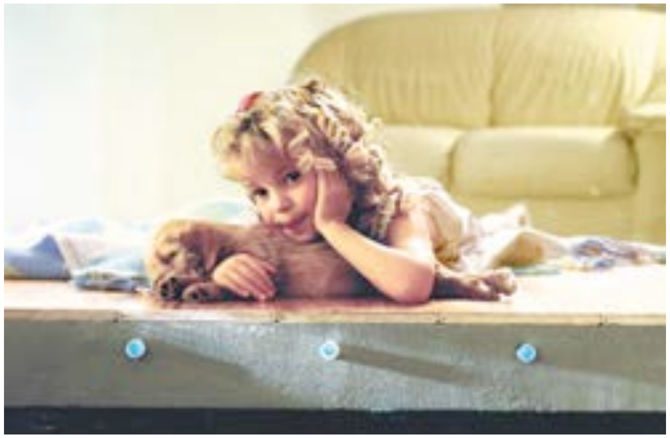




Low temperature / low mass hydronic heat emitters

Low temperature / low mass hydronic heat emitters

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

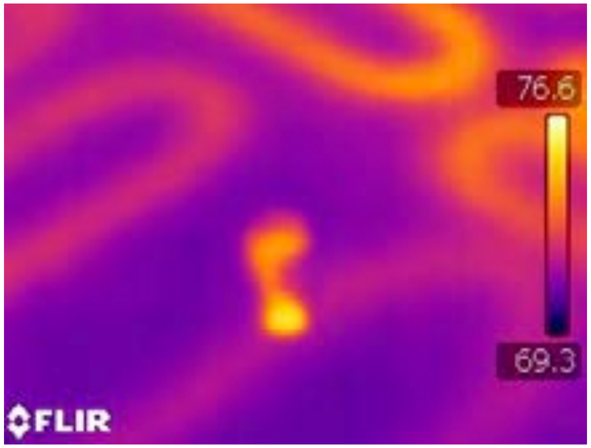


"Barefoot friendly"
floors...

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:

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



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

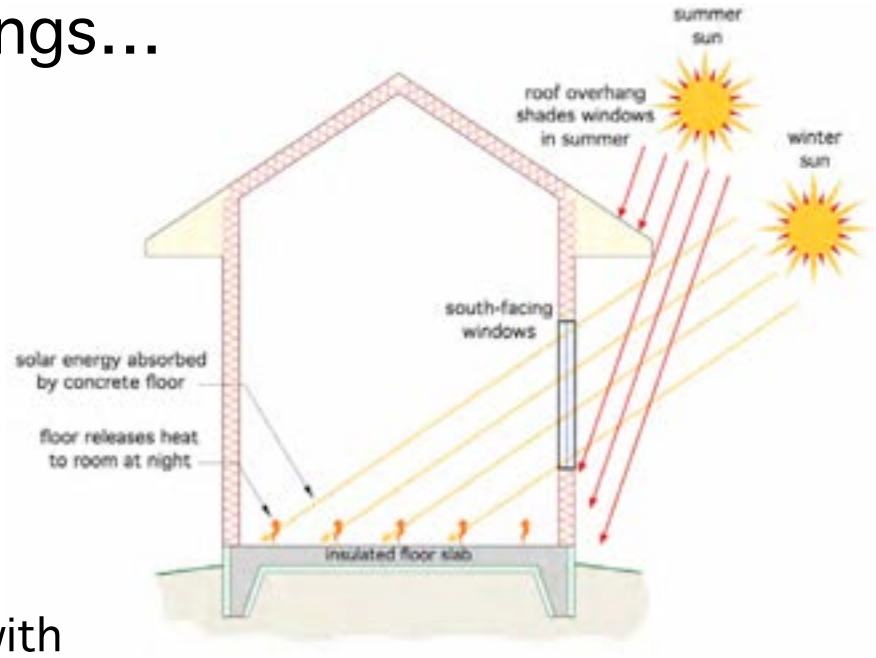
Tf = average floor surface temperature (°F)
Tr= room air temperature (°F)
q=heat flux (Btu/hr/ft^2)

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.*

Why radiant floor heating ISN'T always the best choice...

Direct gain passive solar buildings...



Initial concept: Since the insulated floor slab is already there- why not add tubing to keep it warm on cloudy days?

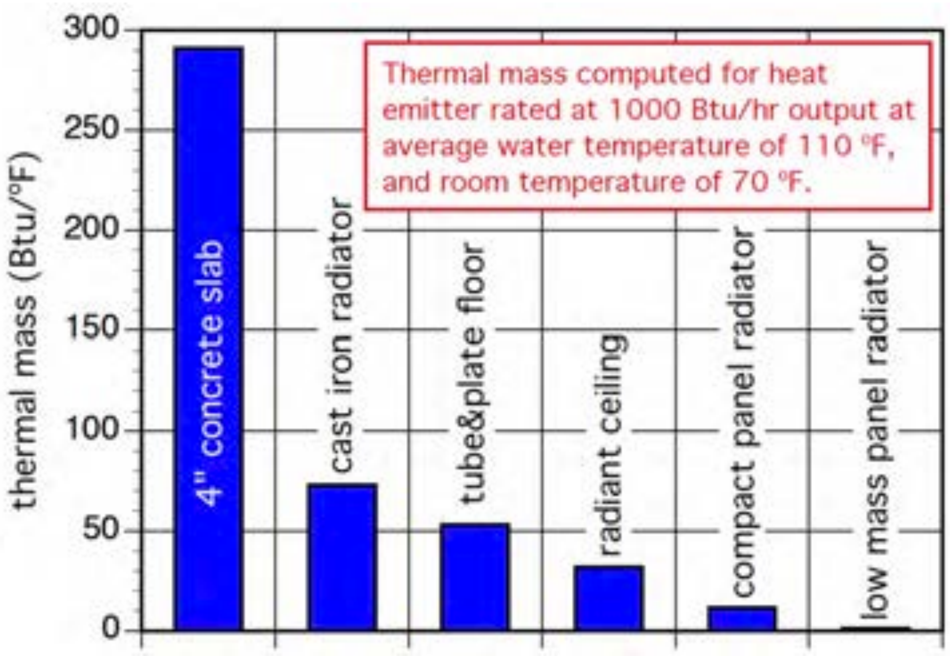
The passive solar concept relies on the floor mass giving up it’s heat at night.

If maintained at an elevated temperature with auxiliary heat ensuing solar gains cannot be absorbed.

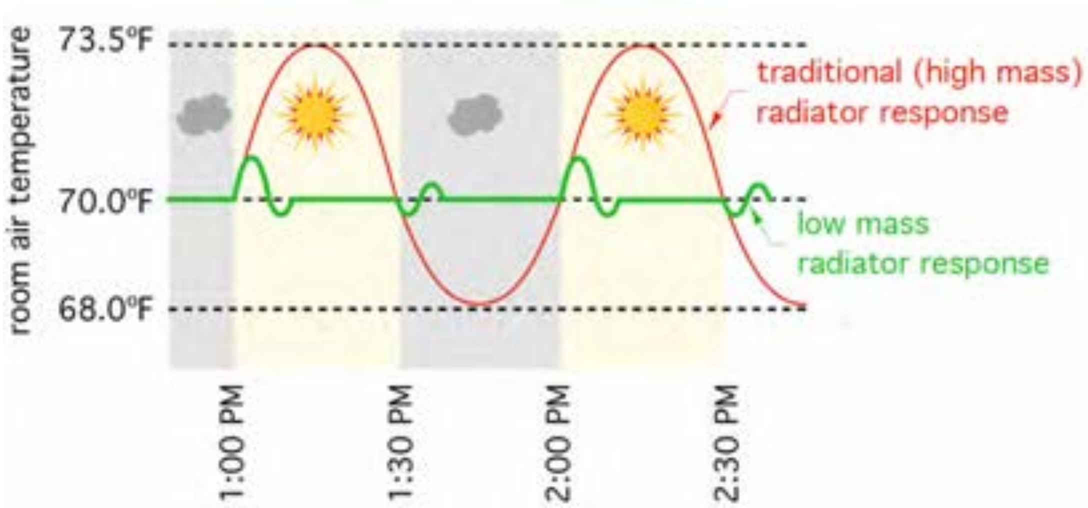
The space quickly overheats.

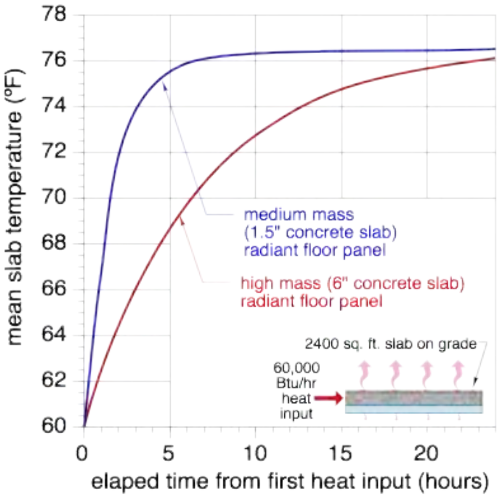
A comparison of THERMAL MASS for several heat emitters:

All heat emitters sized to provide 1000 Btu/hr at 110 ºF average water temperature, and 70 ºF room temperature:



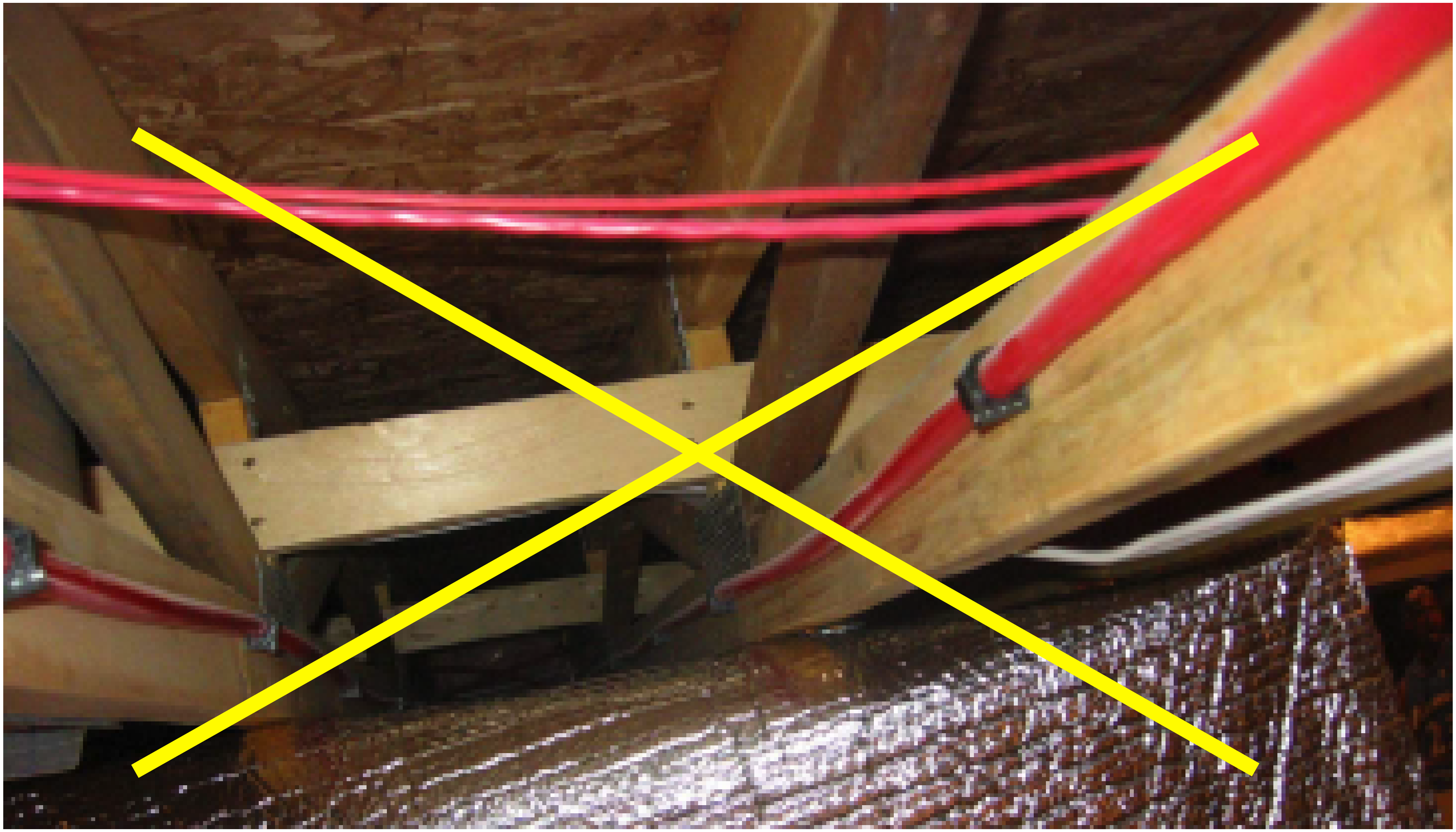
Low thermal mass allows the heat emitters to quickly respond to changing internal loads





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

Don’t do this with ANY hydronic heat source!



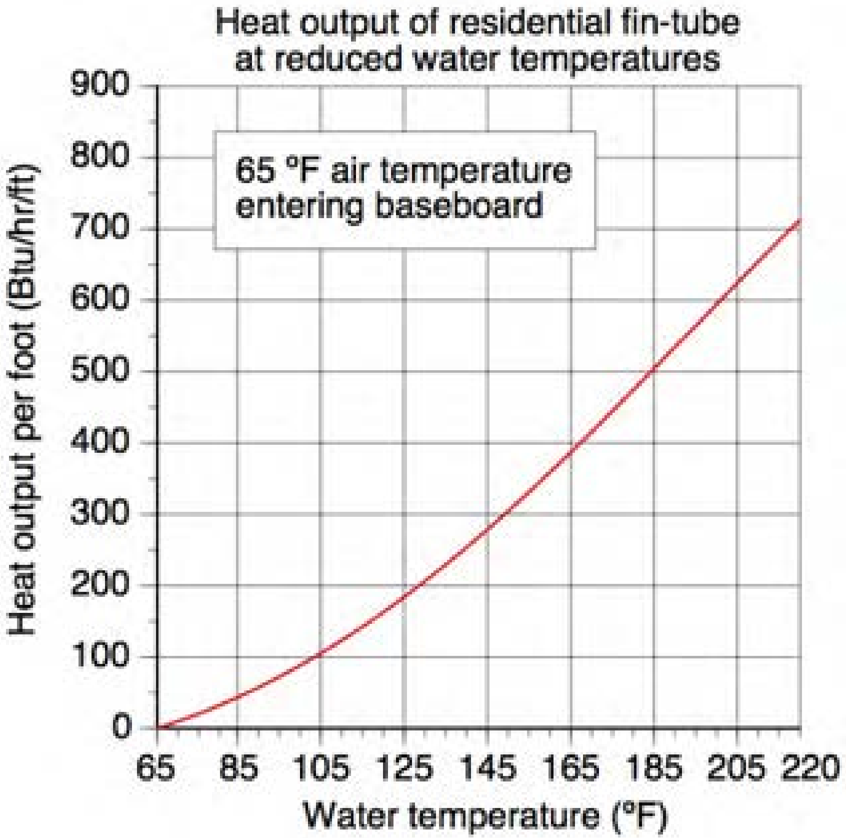
Heat transfer between the water and the upper floor surface is severely restricted!

Don't do this with ANY hydronic heat source!

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

Hydronic heat emitters options for low energy use houses

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

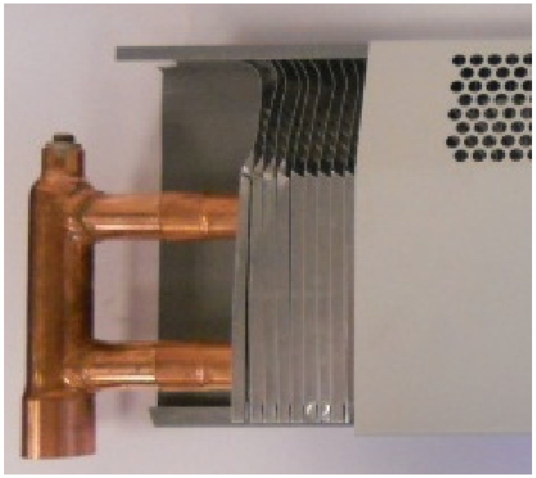


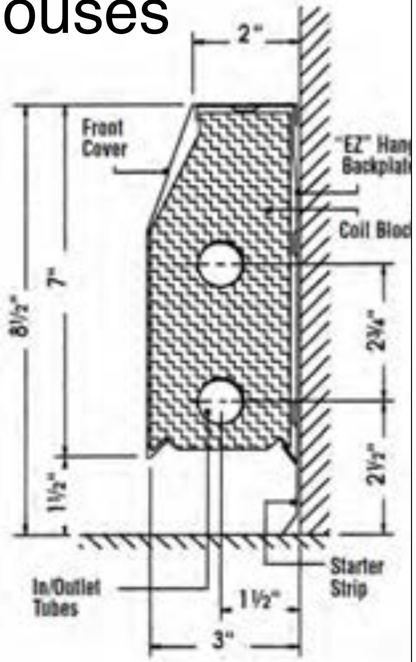
Could add fin-tube length based on lower water temperatures. BUT...

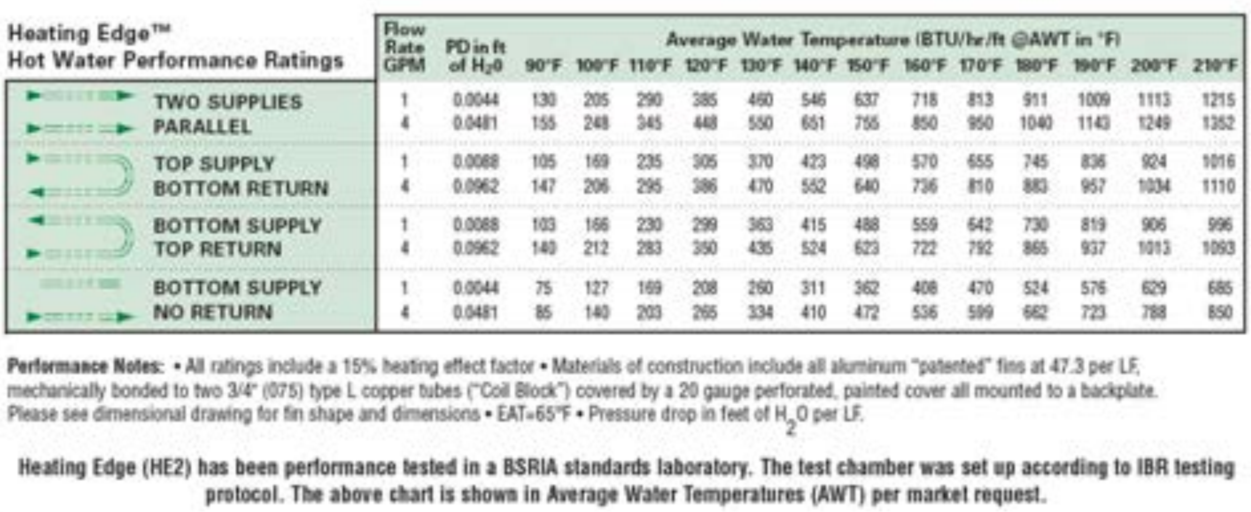
Fin-tube output at 120 °F is only about 30% of its output at 200°F

Hydronic heat emitters options for low energy use houses

Some low- temperature baseboard is now available







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.

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Panel Radiators

- Low water content and relatively light - fast responding

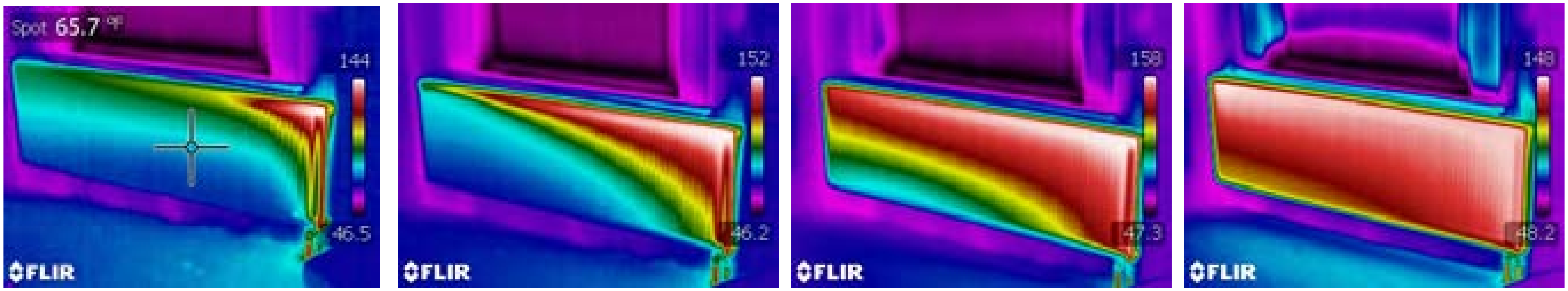
- Some can be fitted with thermostatic radiator valves for room-by-room zoning (WITHOUT ELECTRICAL CONTROLS)

- 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

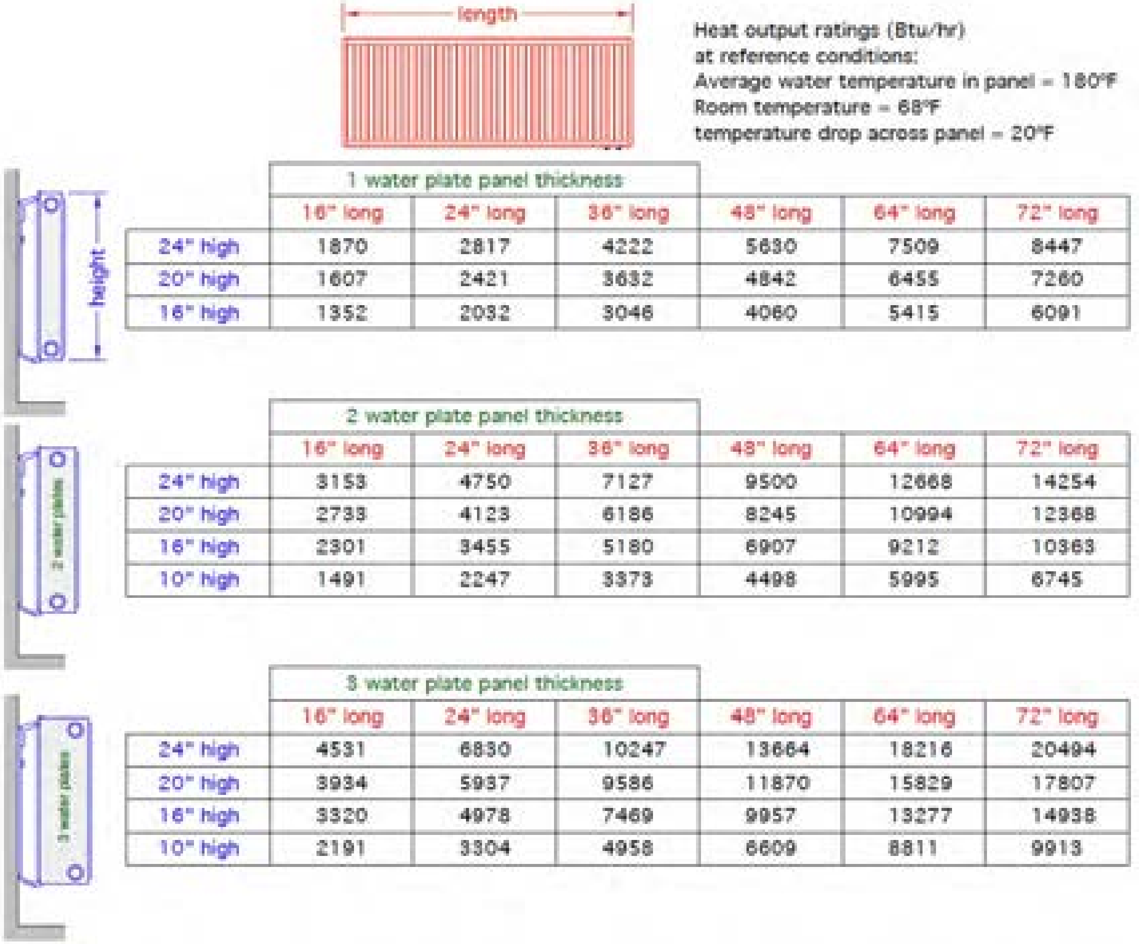


From setback to almost steady state in <u>4 minutes</u>...

Hydronic heat emitters options for low energy use houses

Panel Radiators

- Adjust heat output for operation at lower water temperatures.

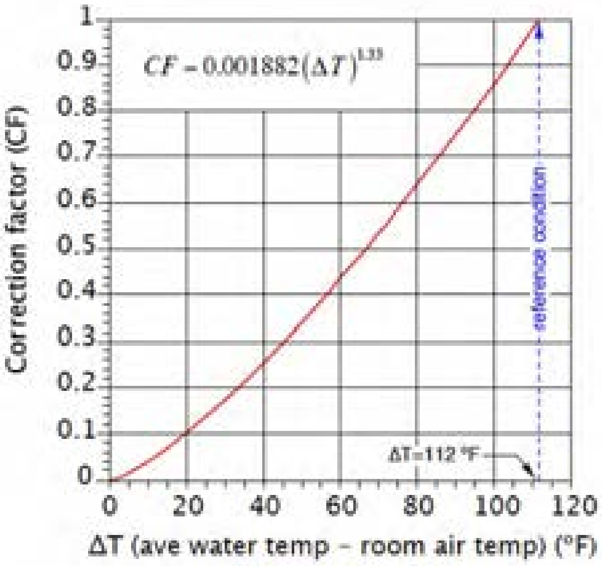


Heat output ratings (Btu/hr)
at reference conditions:
Average water temperature in panel = 180°F
Room temperature = 68°F
temperature drop across panel = 20°F

	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



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

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

Styles of panel radiators

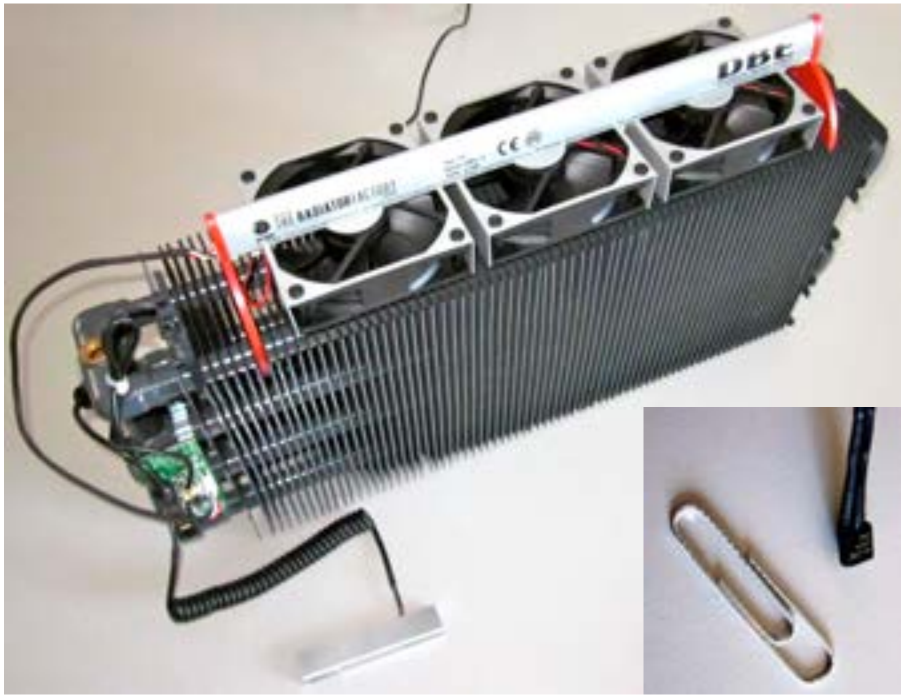
Ultra Low-Mass Panel Radiators


Image courtesy of
JAGA North America

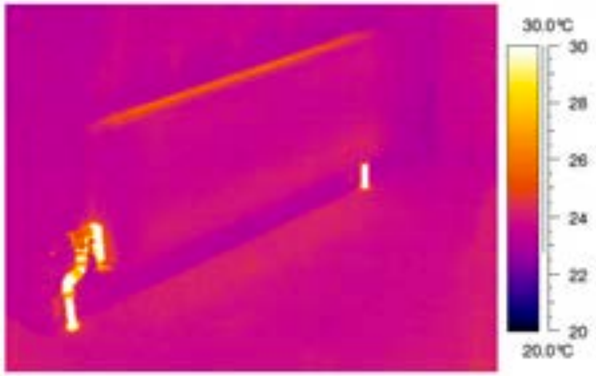
Microfan power consumption:

(3 fans in group)

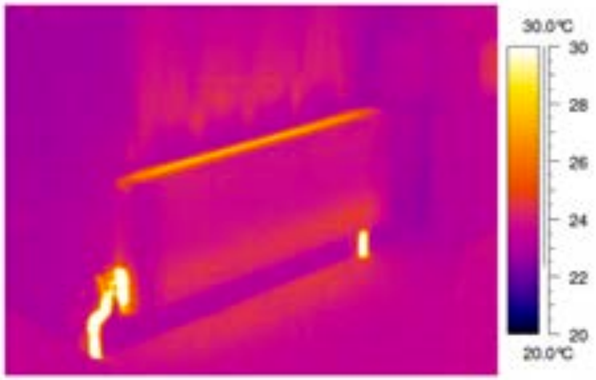
1. OFF: **1 watt** (power supply)
2. Fans at normal “comfort” setting: **4 watts**
3. Fans in “boost” mode: **5 watts**



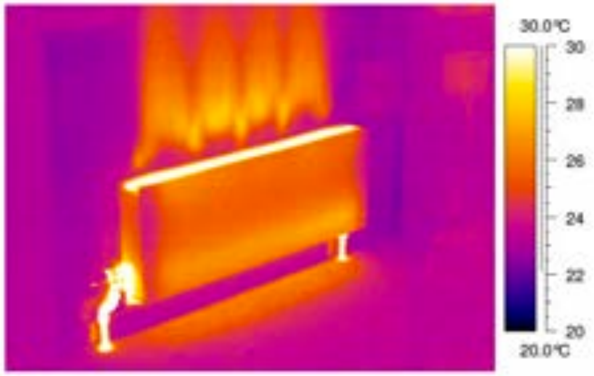
Rapid response from cold start conditions with 130°F supply water



1 minute after heated water reaches radiator warm air can be seen at the output grill.



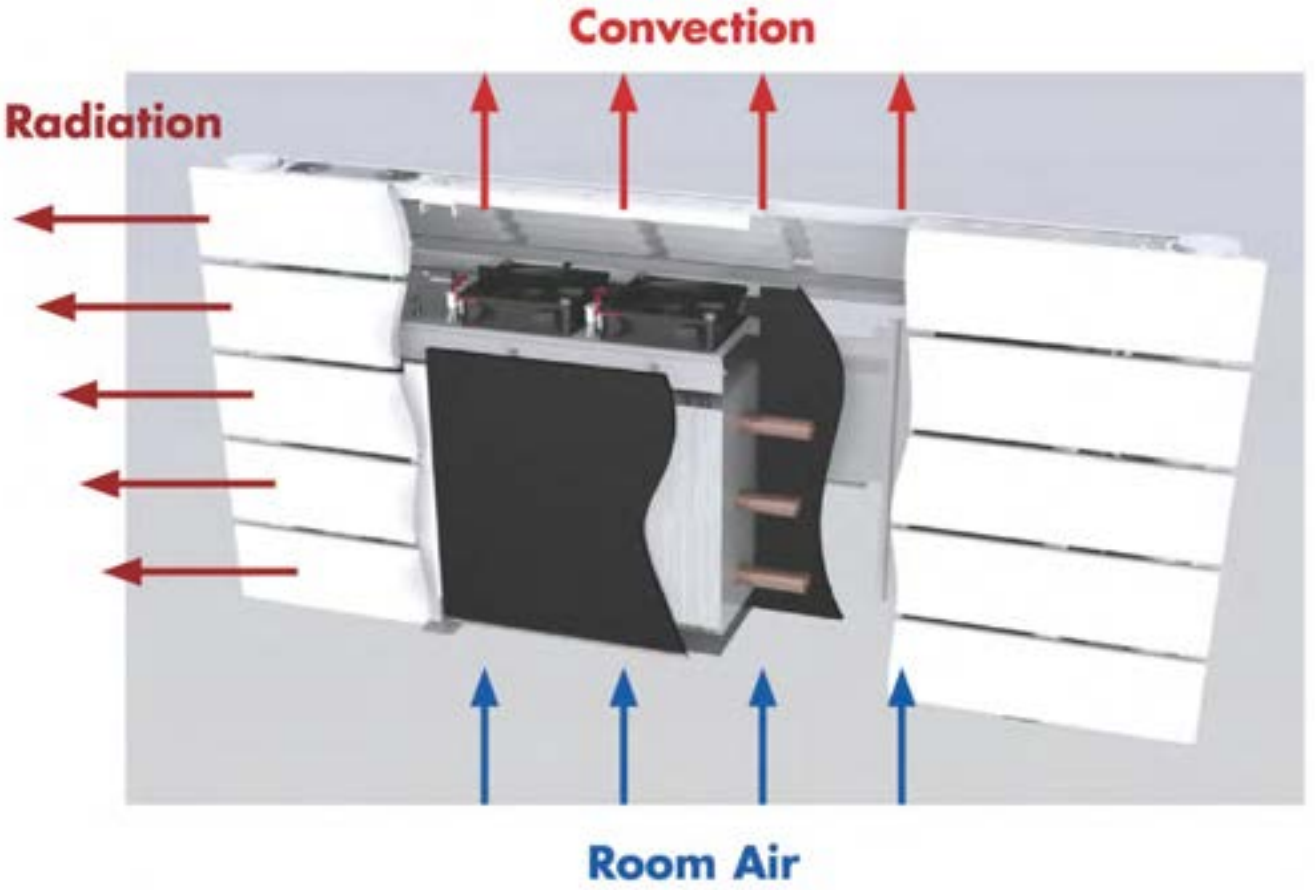
3 minutes after heated water reaches radiator the outline of the fins can be seen at the bottom of the unit. Plumes of warm air can be seen from the top.



7 minutes after heated water reaches radiator, the temperature of the casing is now moderately uniform at around 81 °F and the output plumes show a substantial output.

Fan-assisted Panel Radiators

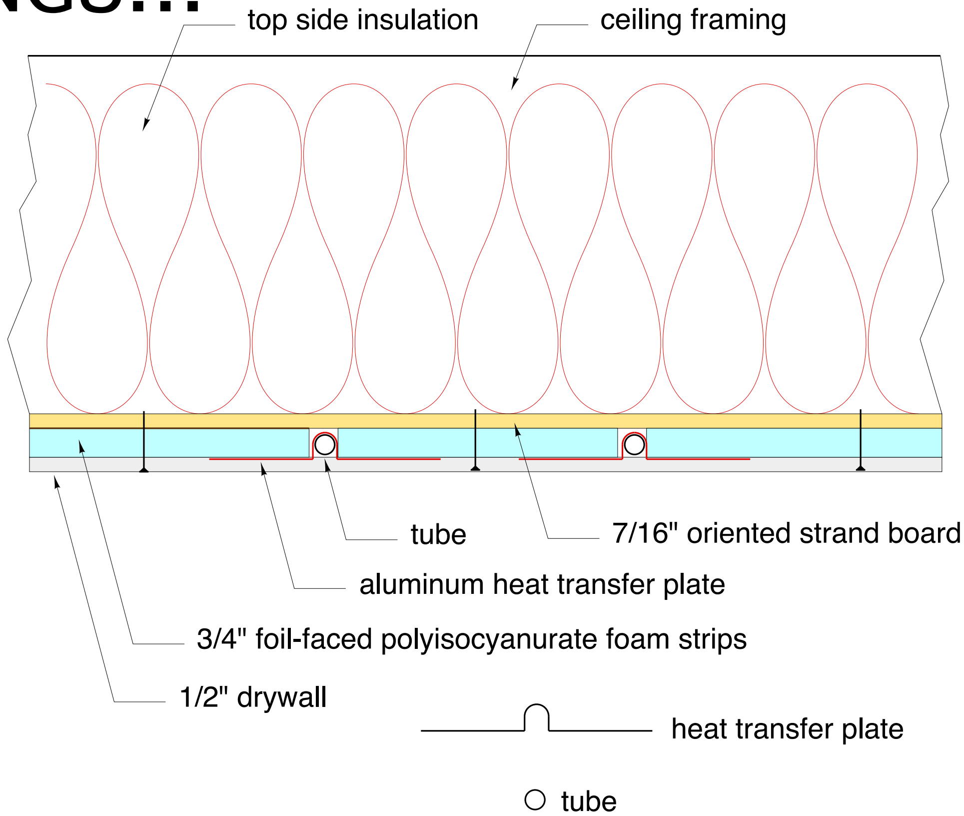
The “NEO”, just released from Runtal North America



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

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

Site built radiant CEILINGS...



Heat output formula:

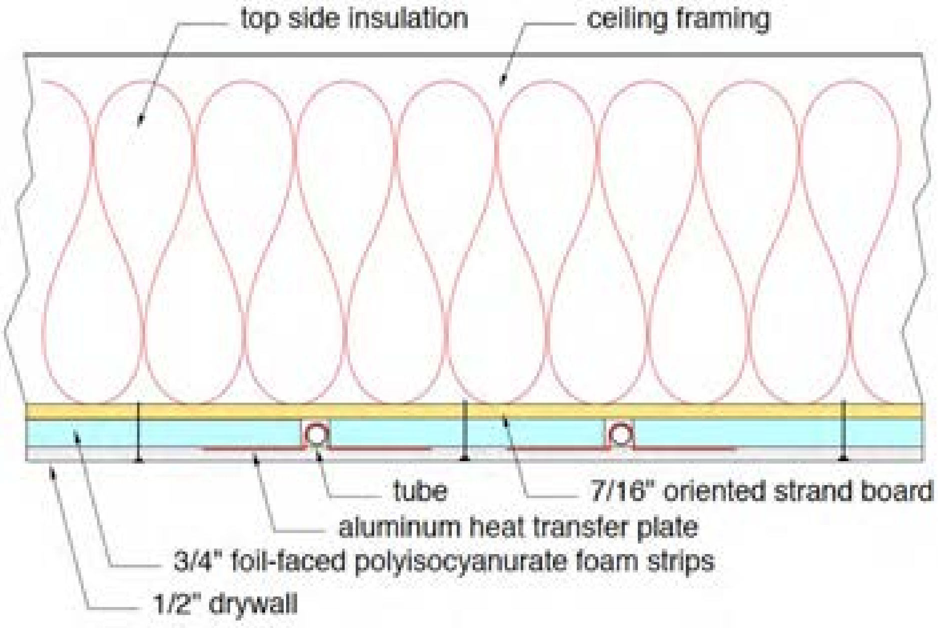
$$q = 0.71 \times (T_{water} - T_{room})$$

Where:

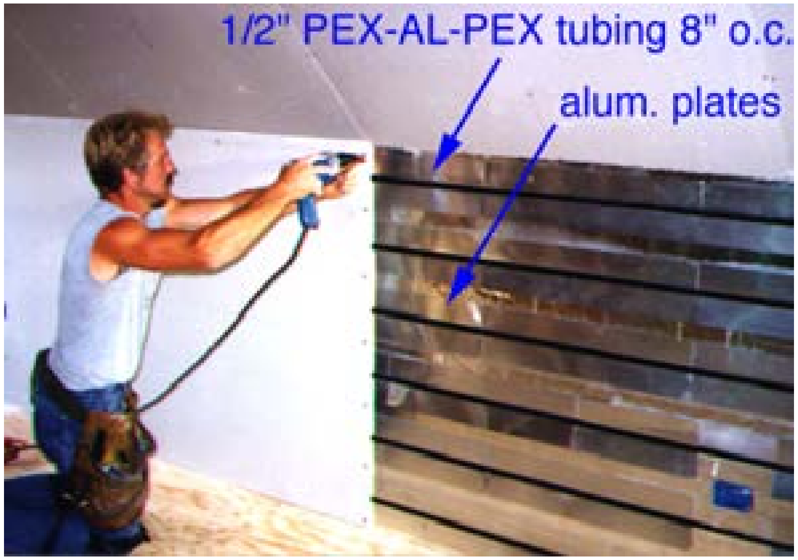
Q = heat output of ceiling (Btu/hr/ft^2)
T_{water} = average water temperature in panel (°F)
T_{room} = room air temperature (°F)

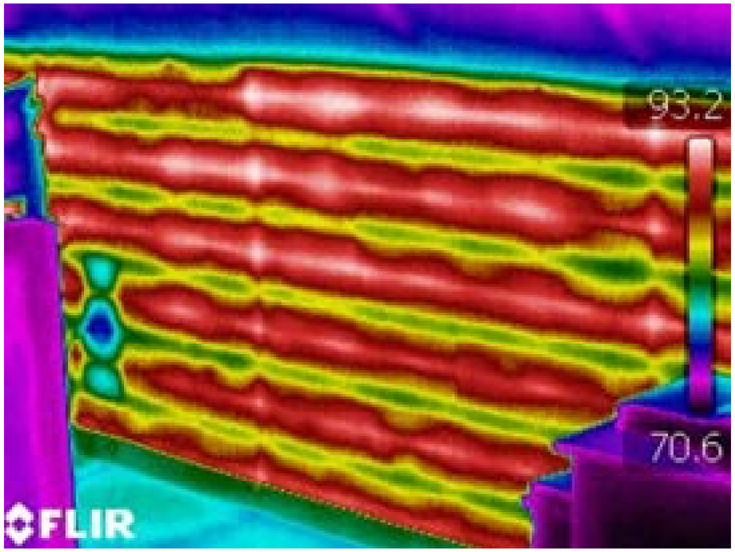
Thermal image of radiant ceiling in operation

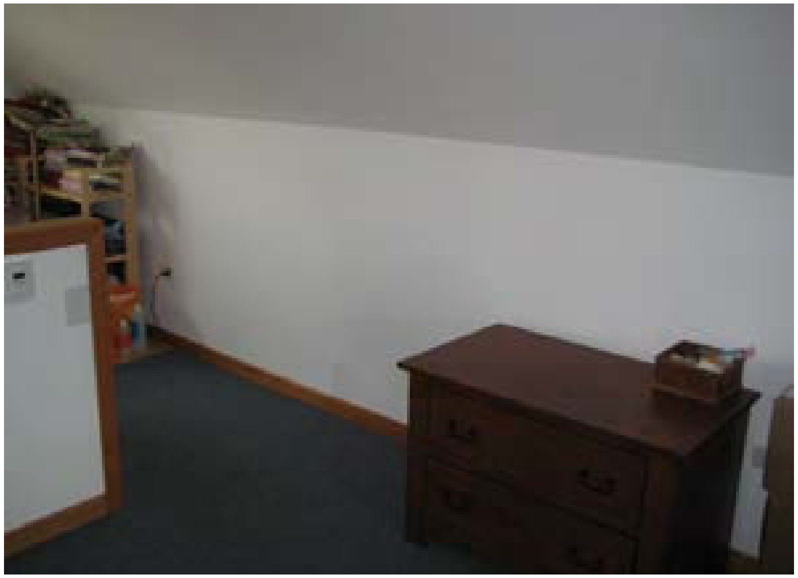
Site built radiant CEILINGS...



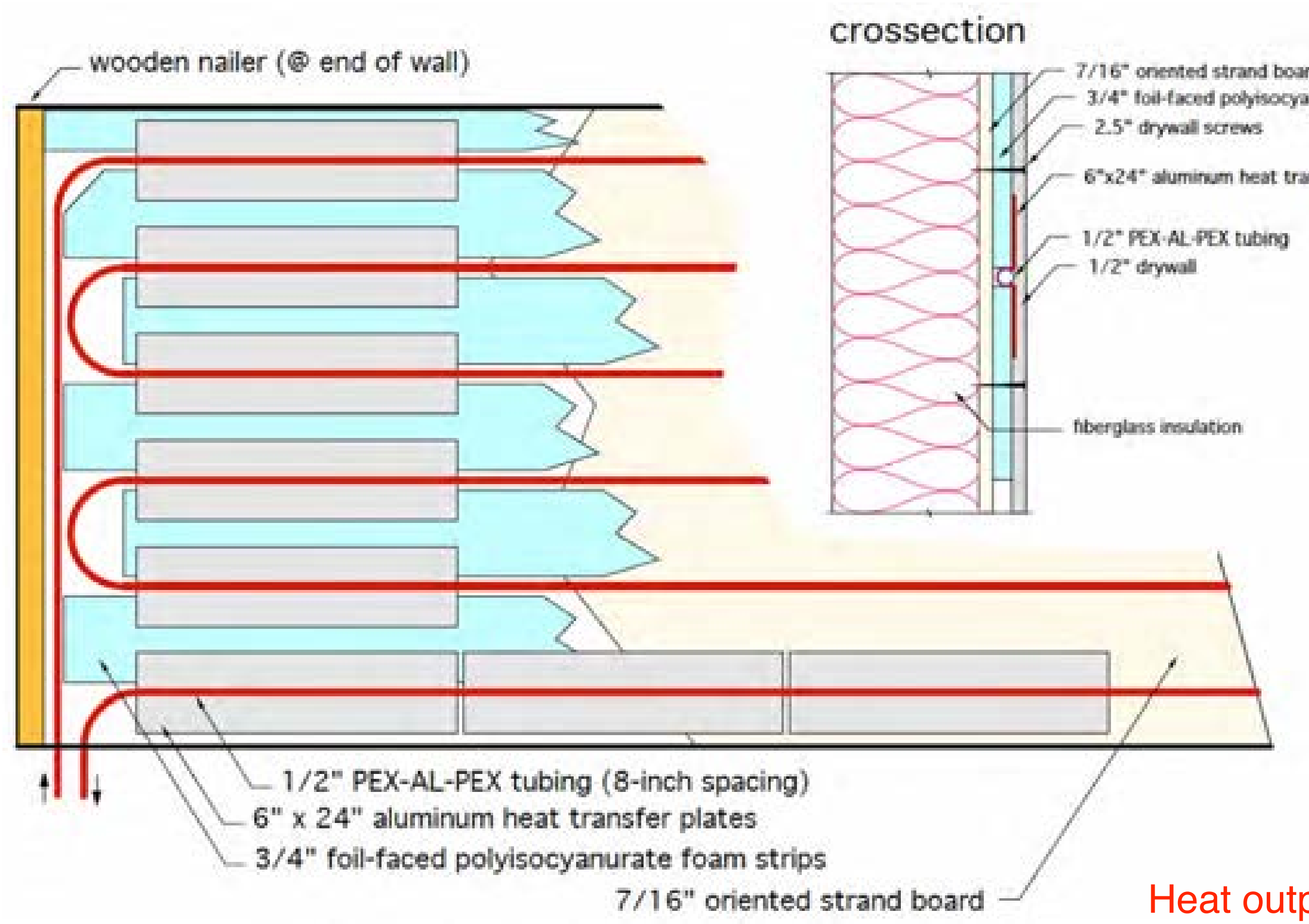
Site built radiant WALLS...

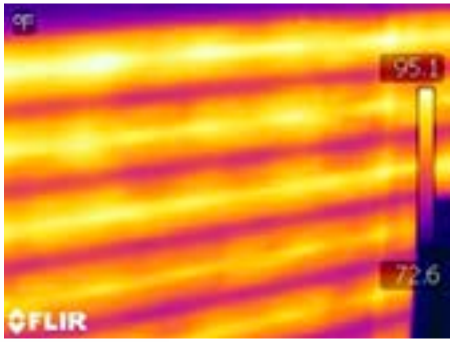






Site built radiant WALLS...





- 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)

HIGHER MASS, low & medium temperature hydronic heat emitters

NOTE: These emitters are not recommended for supplying the DESIGN LOAD in buildings with significant internal heat gain from sun, or other unpredictable sources.

Concept for low load buildings: “BASELOAD” Keep floor surface temperature limited to 4 °F above room temperature.

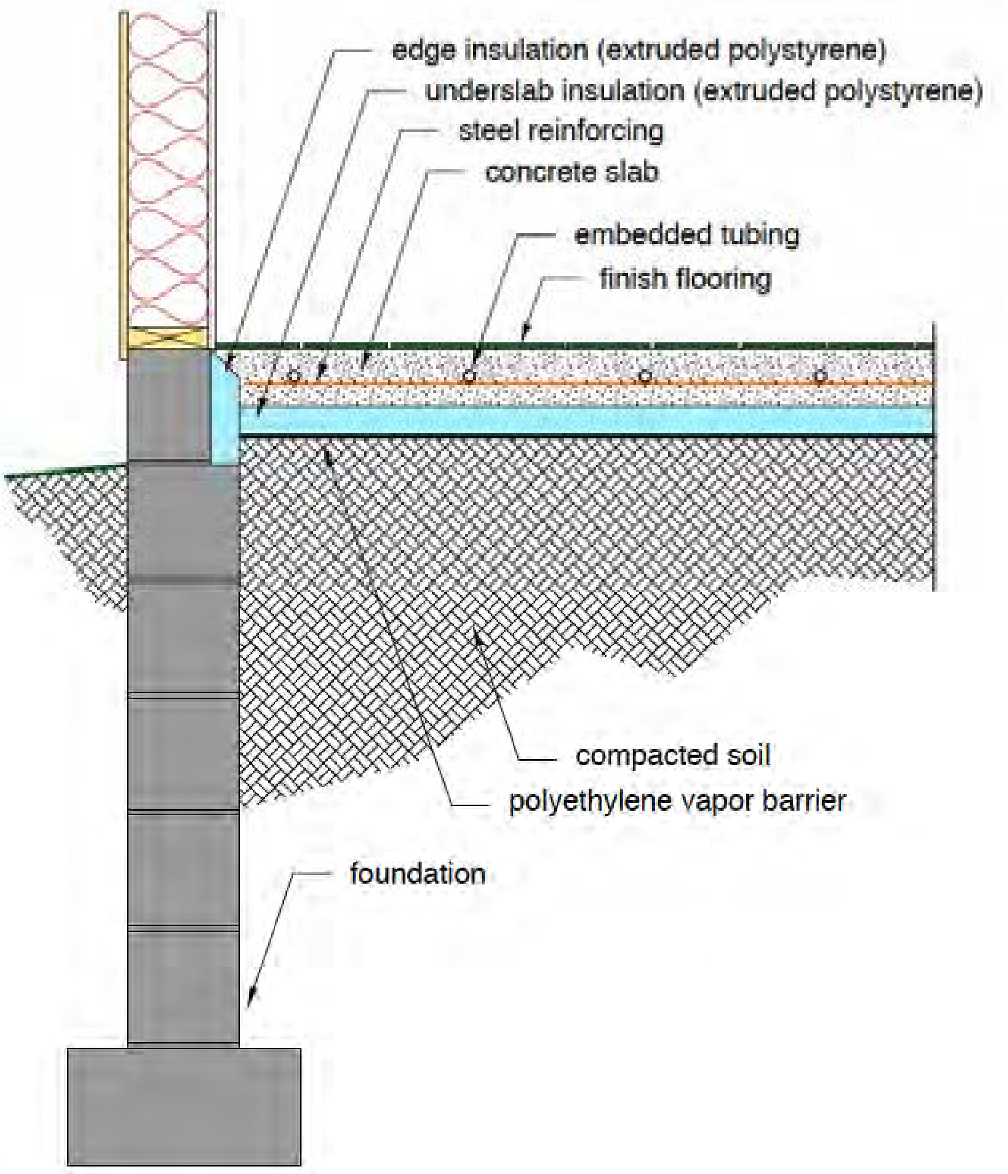
This will yield an output of about 8 Btu/hr/ft^2

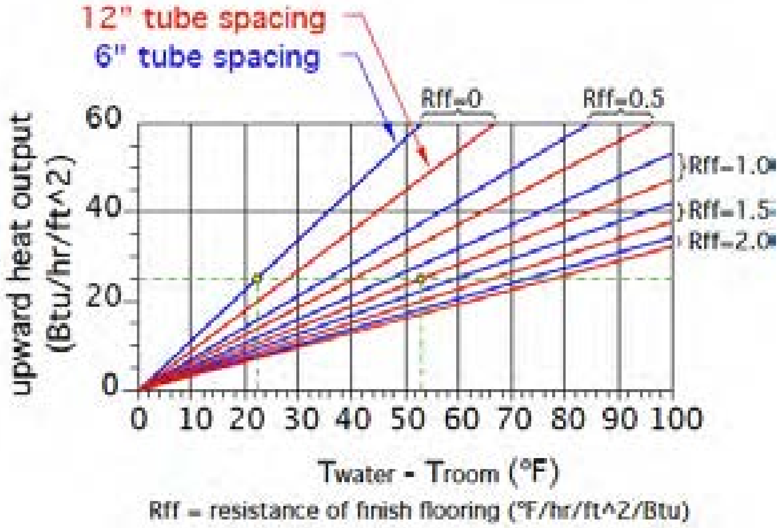
Floor surfaces will not feel warm to touch.

Will provide some thermal stability, but is not likely to produce intolerable temperature overshoot in building with passive solar gain.

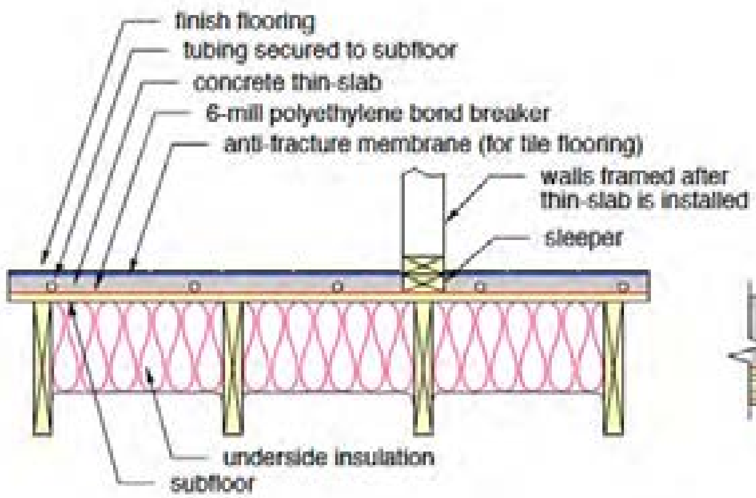
Use in combination with other low mass heat emitters to achieve balance of load.

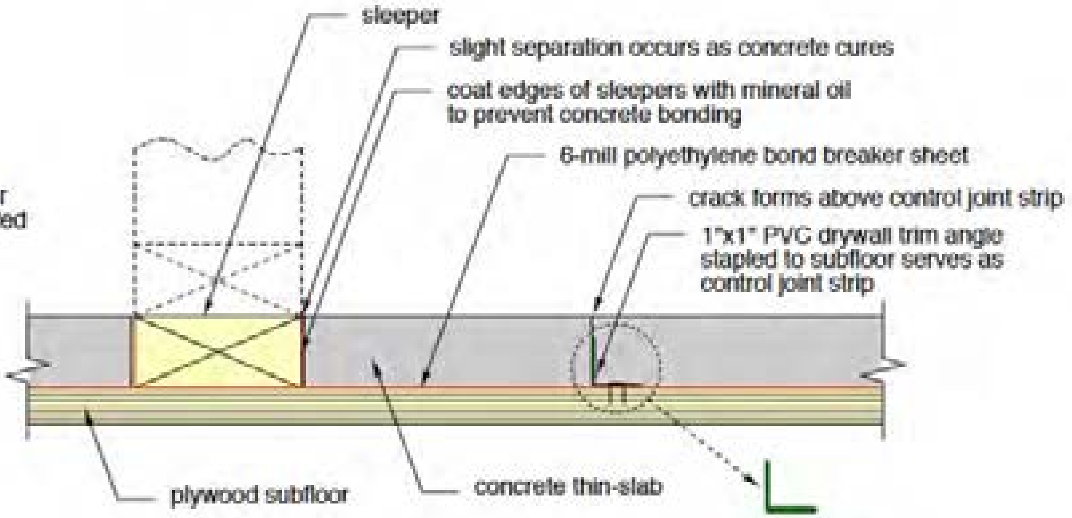
Slab-on-grade floor heating



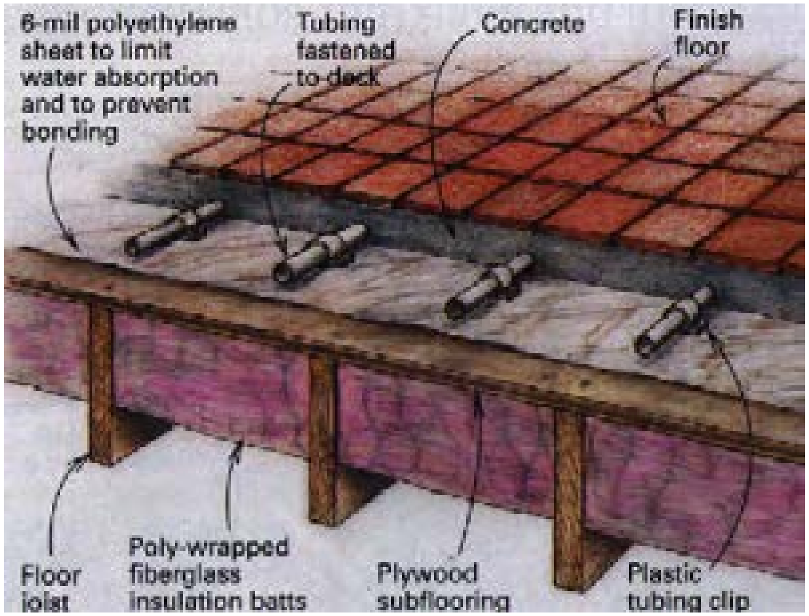


Thin-slab floor heating (using concrete)





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

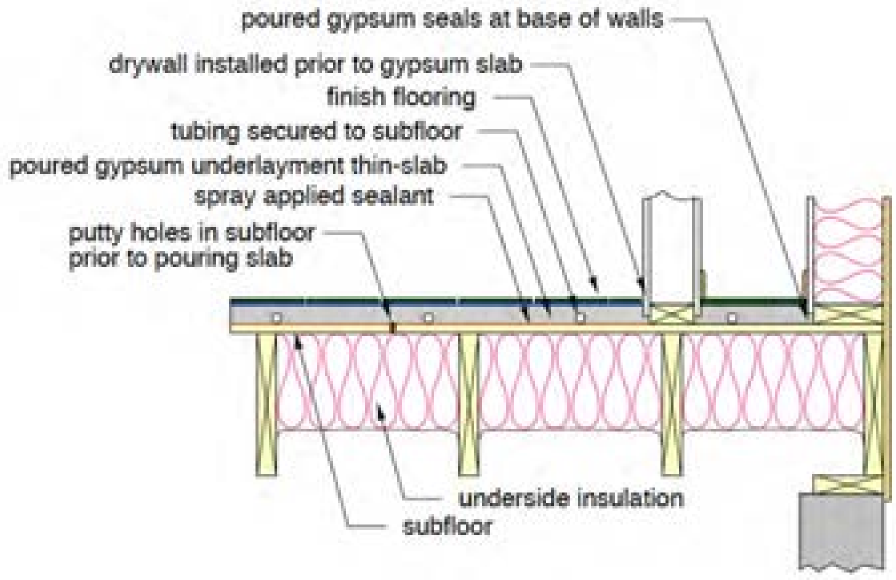
Always…

- 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...

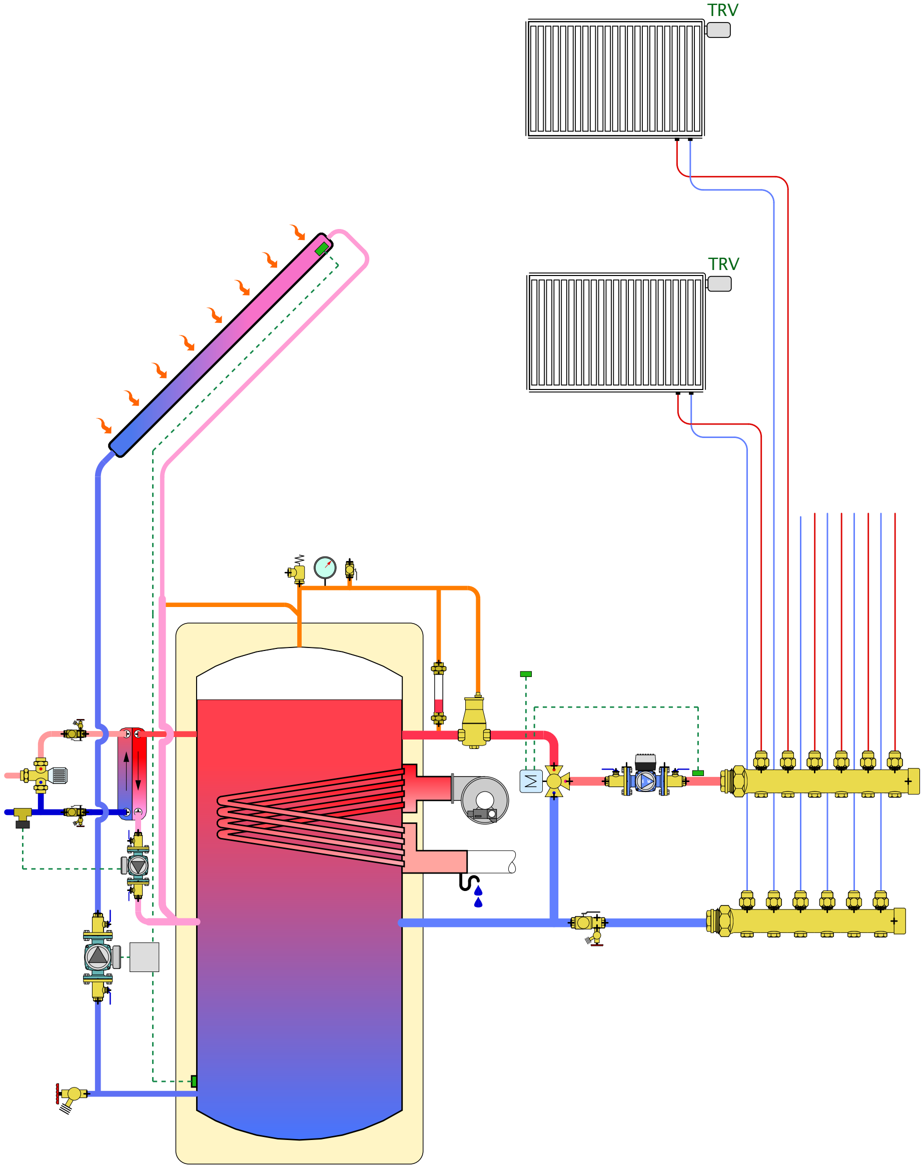
- Verify load-carrying ability of floor framing
- Account for added 1.5 inches in floor height
- Pressure-test circuits prior to placing gypsum underlayment
- Make tubing layout drawing prior to placing tubing
- Install R-11 to R-30 underside insulation
- Use proper surface preparations prior to finish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

Never...

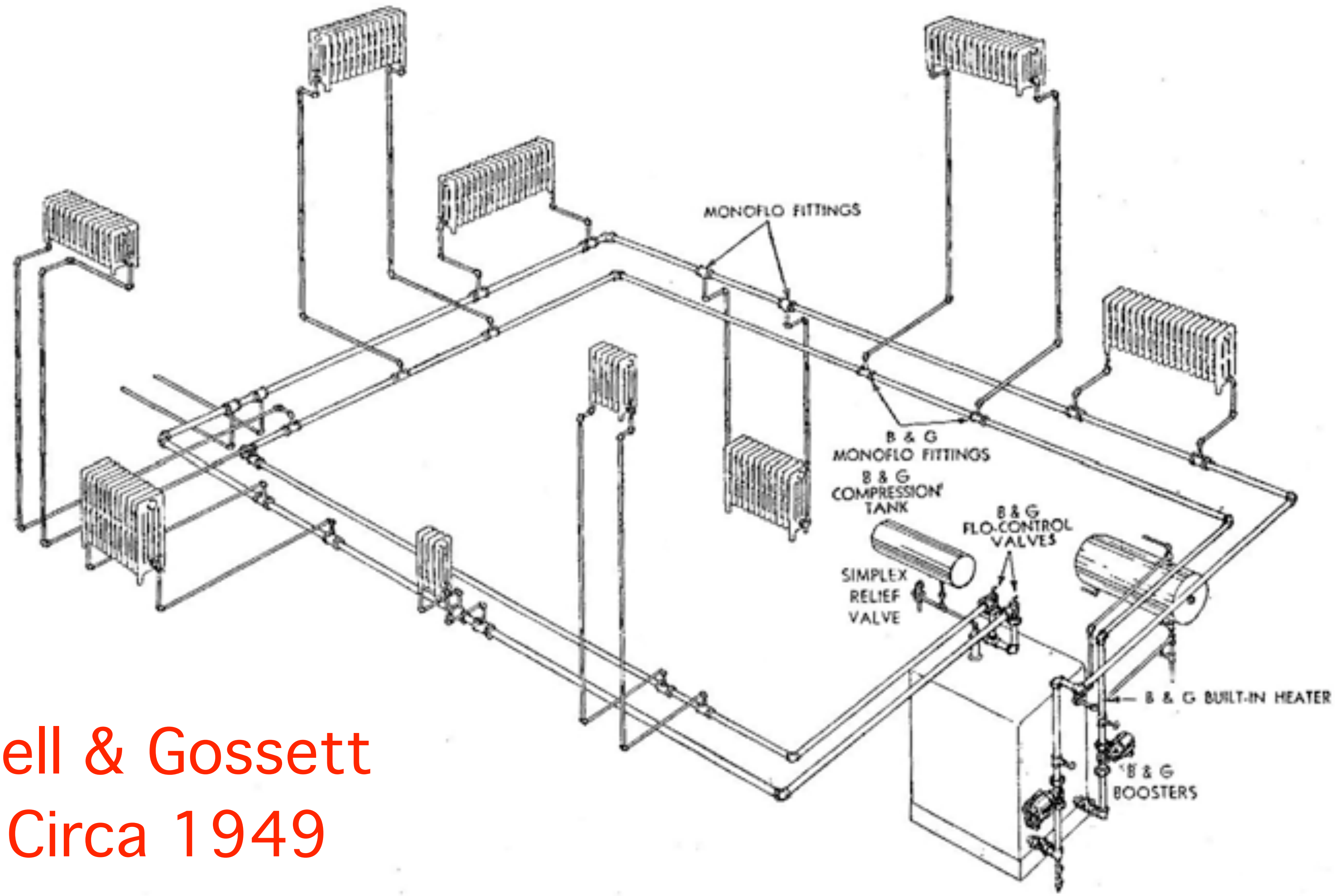
- Allow gypsum to freeze prior to curing
- Pressure-test with water
- Place tubing closer than 9 inches to toilet flanges
- Cover with flooring having total R-value over 2.0°F hr/ft^2/Btu
- Exceed 12” tube spacing
- Install in locations that could be flooded

Homerun Distribution Systems

Homerun distribution systems



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



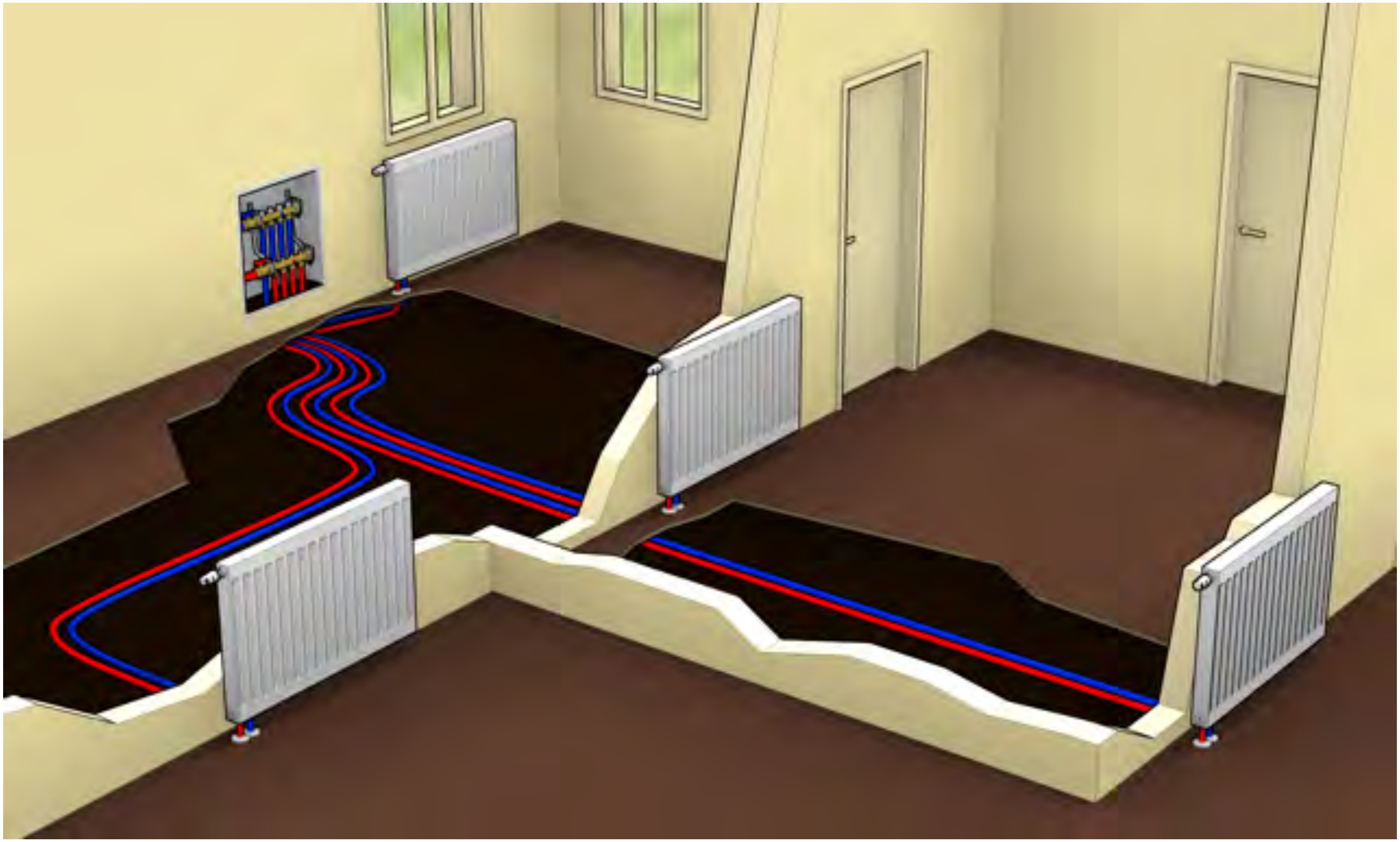
Bell & Gossett
Circa 1949

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

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

At this point, many North American heating pros recognize PEX or PEX-AL-PEX as a universal hydronic distribution pipe.

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



Benefits of a homerun distribution system…

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

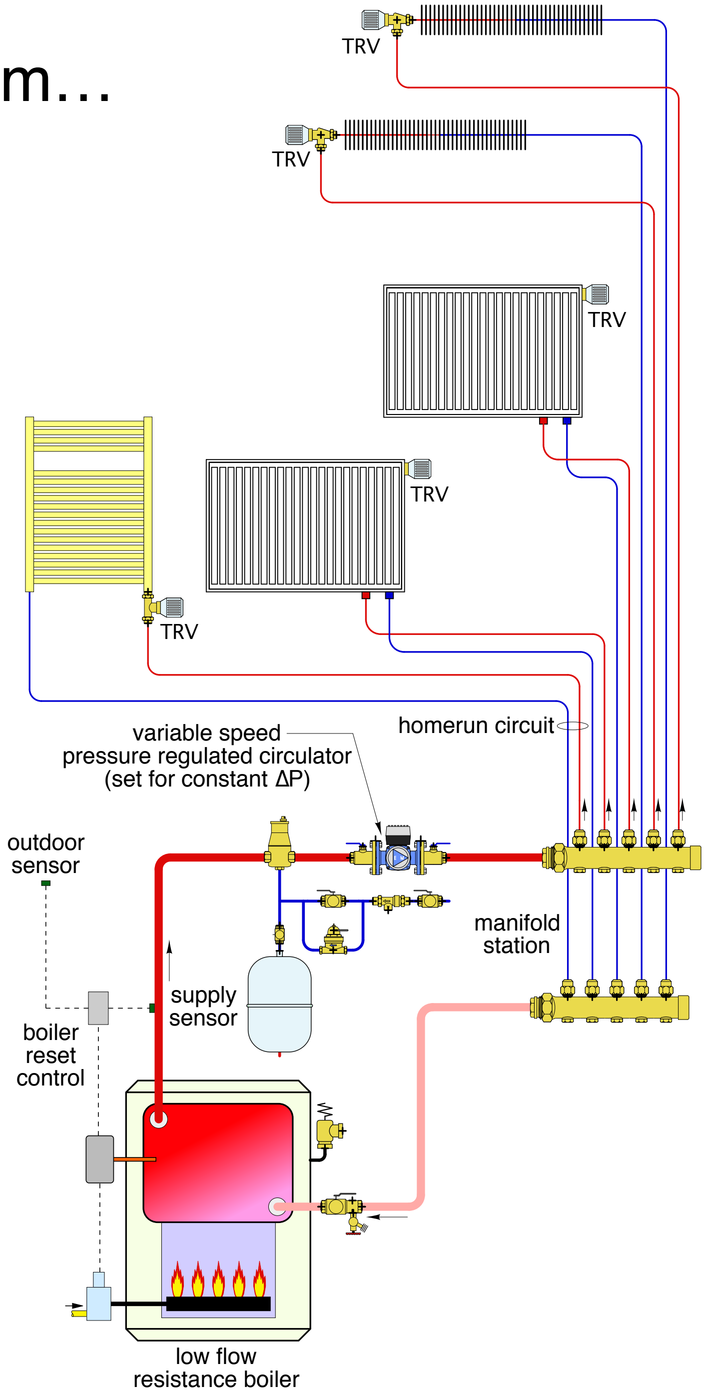
- Allows easy **room-by-room zoning.**

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

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

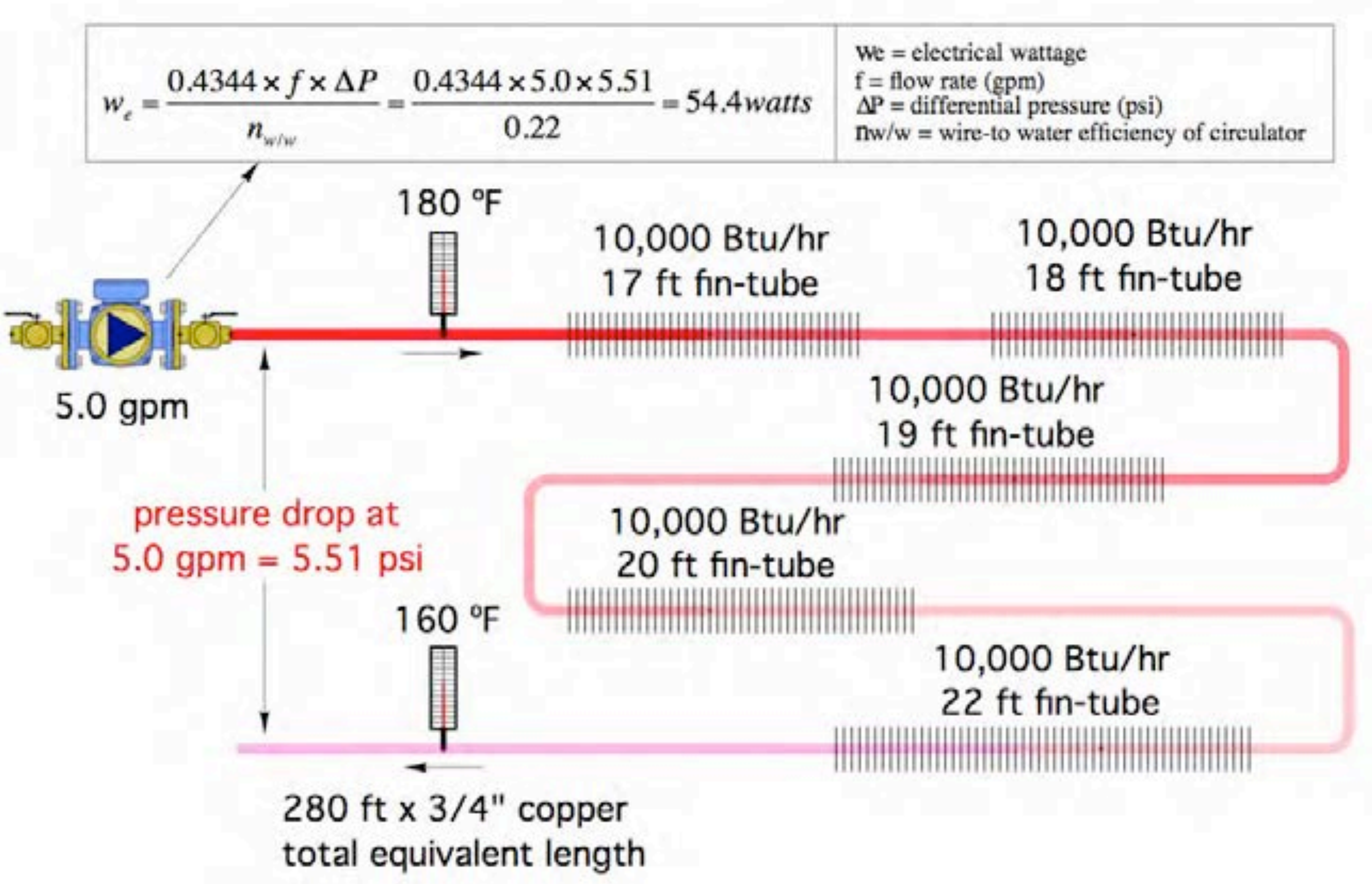
- **Easy flow adjustment** through any branch circuit using manifold or heat emitter valves

- Lower circulator power required relative to series piping systems



Homerun systems reduce distribution power requirement

Circulator energy use for ***series loop*** system

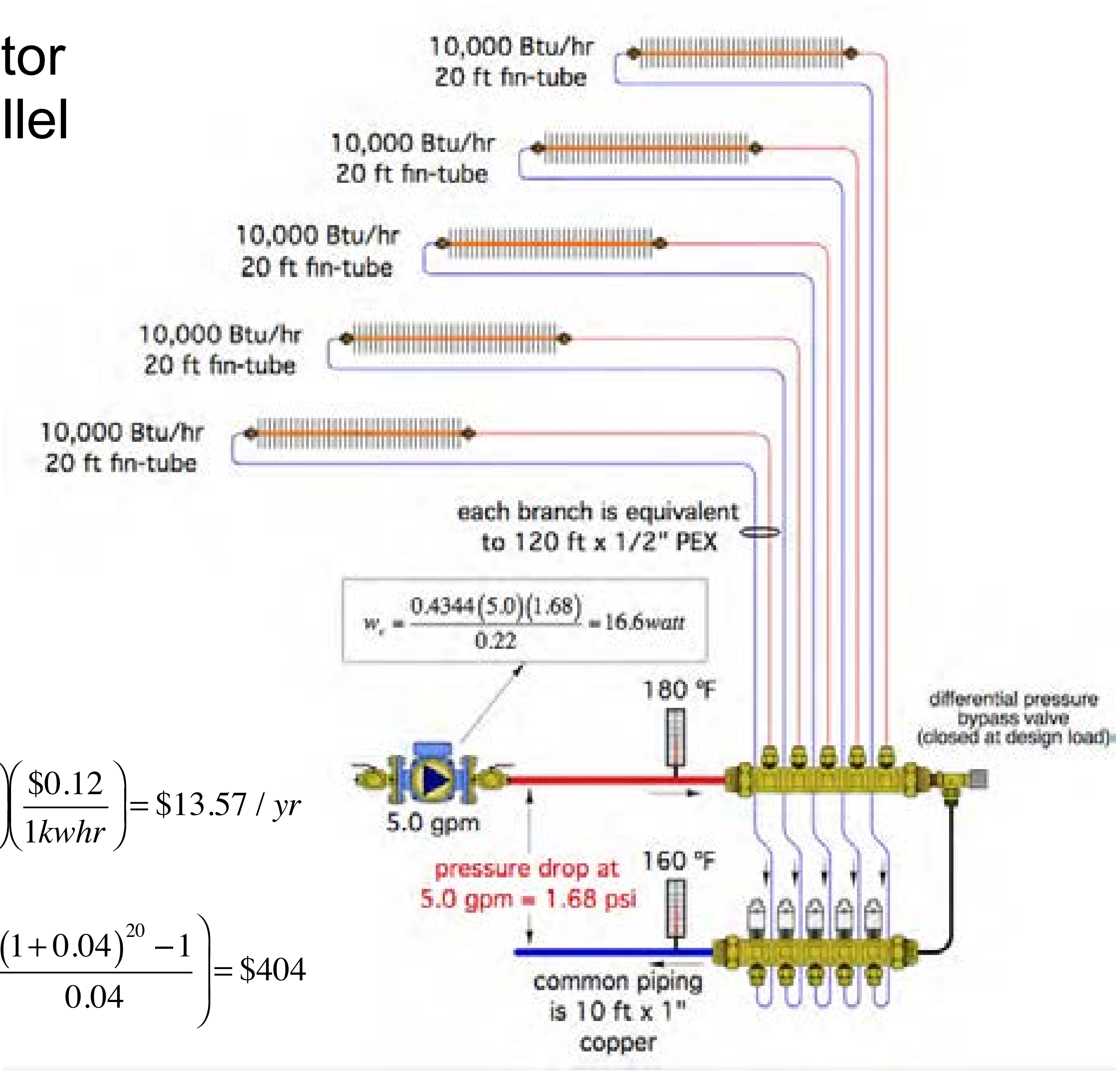


$$w_e = \frac{0.4344 \times f \times \Delta P}{n_{w/w}} = \frac{0.4344 \times 5.0 \times 5.51}{0.22} = 54.4 watts$$

We = electrical wattage
f = flow rate (gpm)
ΔP = differential pressure (psi)
ηw/w = wire-to water efficiency of circulator

Homerun systems reduce distribution power requirement

COMPARE: Circulator energy use for parallel homerun system

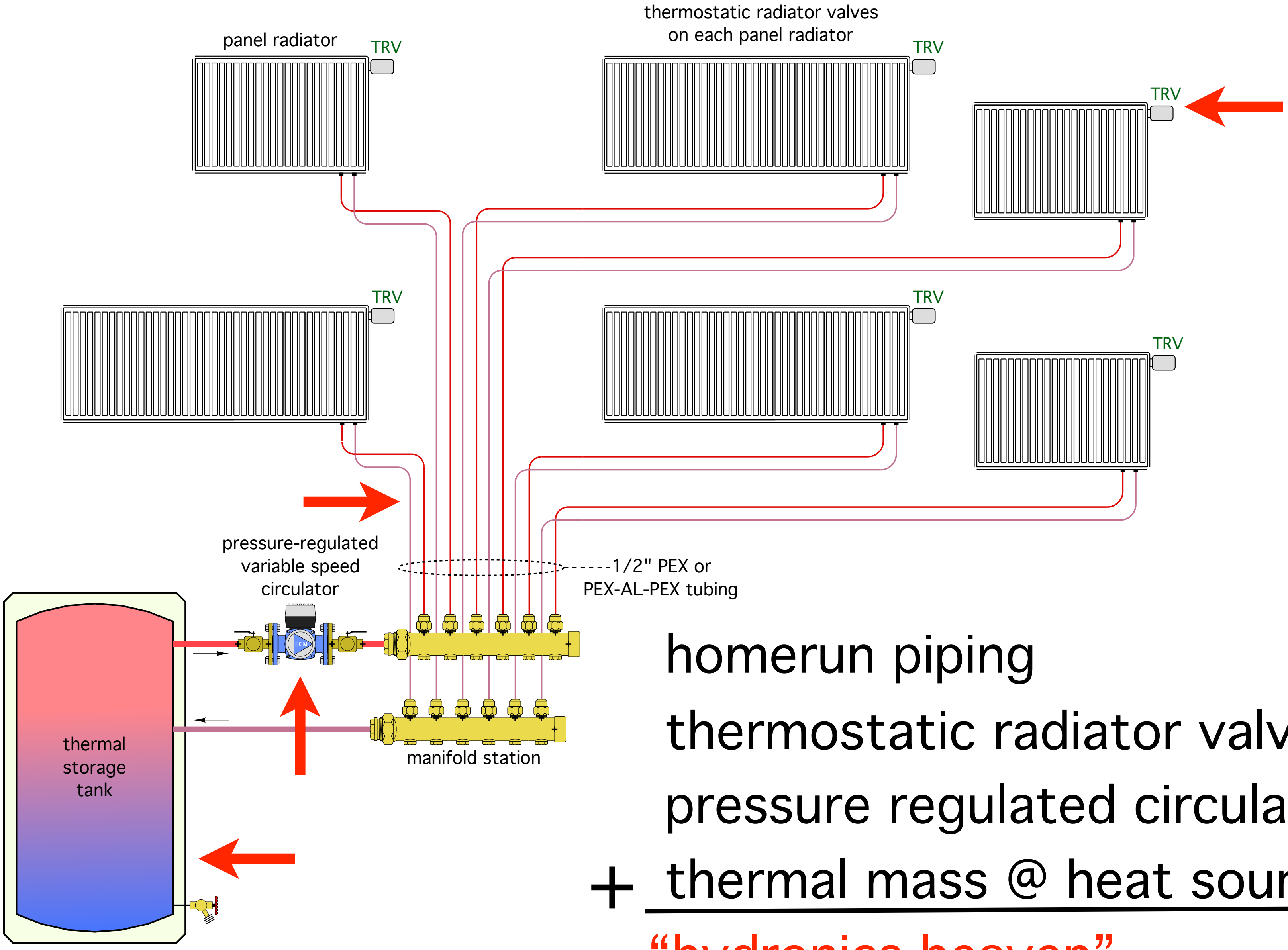


$$\Delta watts = 54.3 - 16.6 = 37.7 watts$$

$$\Delta \cos t = \left(\frac{37.7w}{1}\right)\left(\frac{3000hr}{1yr}\right)\left(\frac{1kw}{1000w}\right)\left(\frac{\$0.12}{1kwhr}\right) = \$13.57/yr$$

$$Cost_{20yr} = C_1\left(\frac{(1+i)^N - 1}{i}\right) = \$13.57\left(\frac{(1+0.04)^{20} - 1}{0.04}\right) = \$404$$

Supplying a homerun distribution system…



homerun piping

thermostatic radiator valves

pressure regulated circulator

\+ thermal mass @ heat source

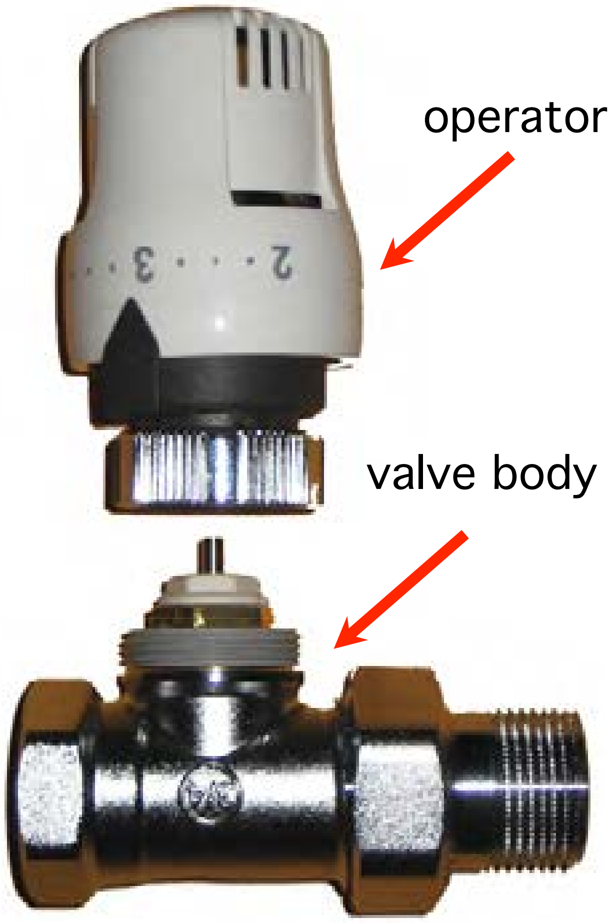
“hydronics heaven”

Homerun systems allow several methods of zoning.

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

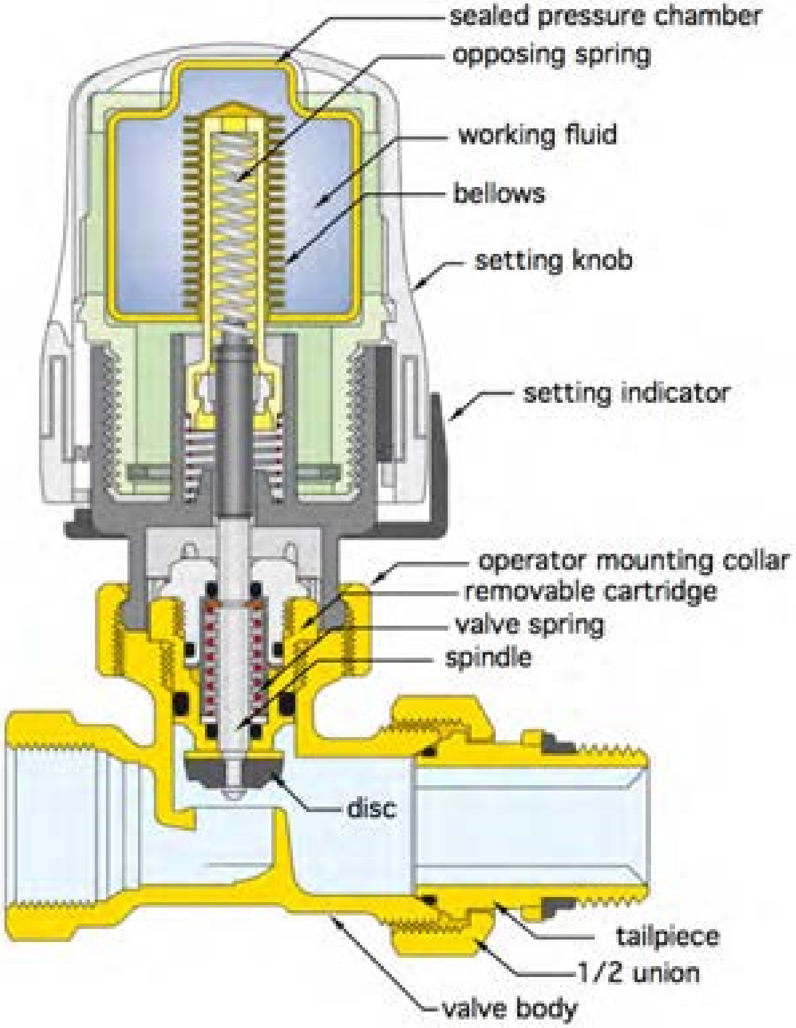
Another approach is to install a thermostatic radiator valve (TRV) on each heat emitter.

NON-ELECTRIC THERMOSTATIC RADIATOR VALVE:



operator

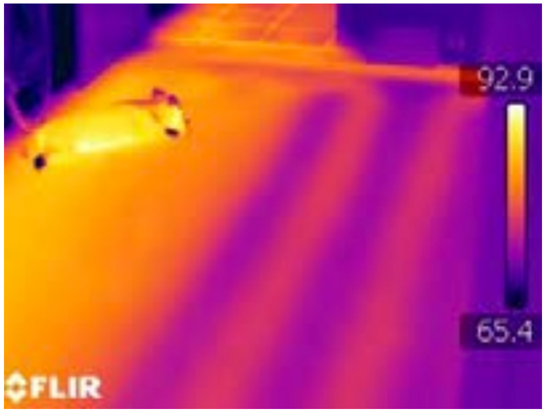
valve body



thermostatic radiator valves are easy to use...

manual setback

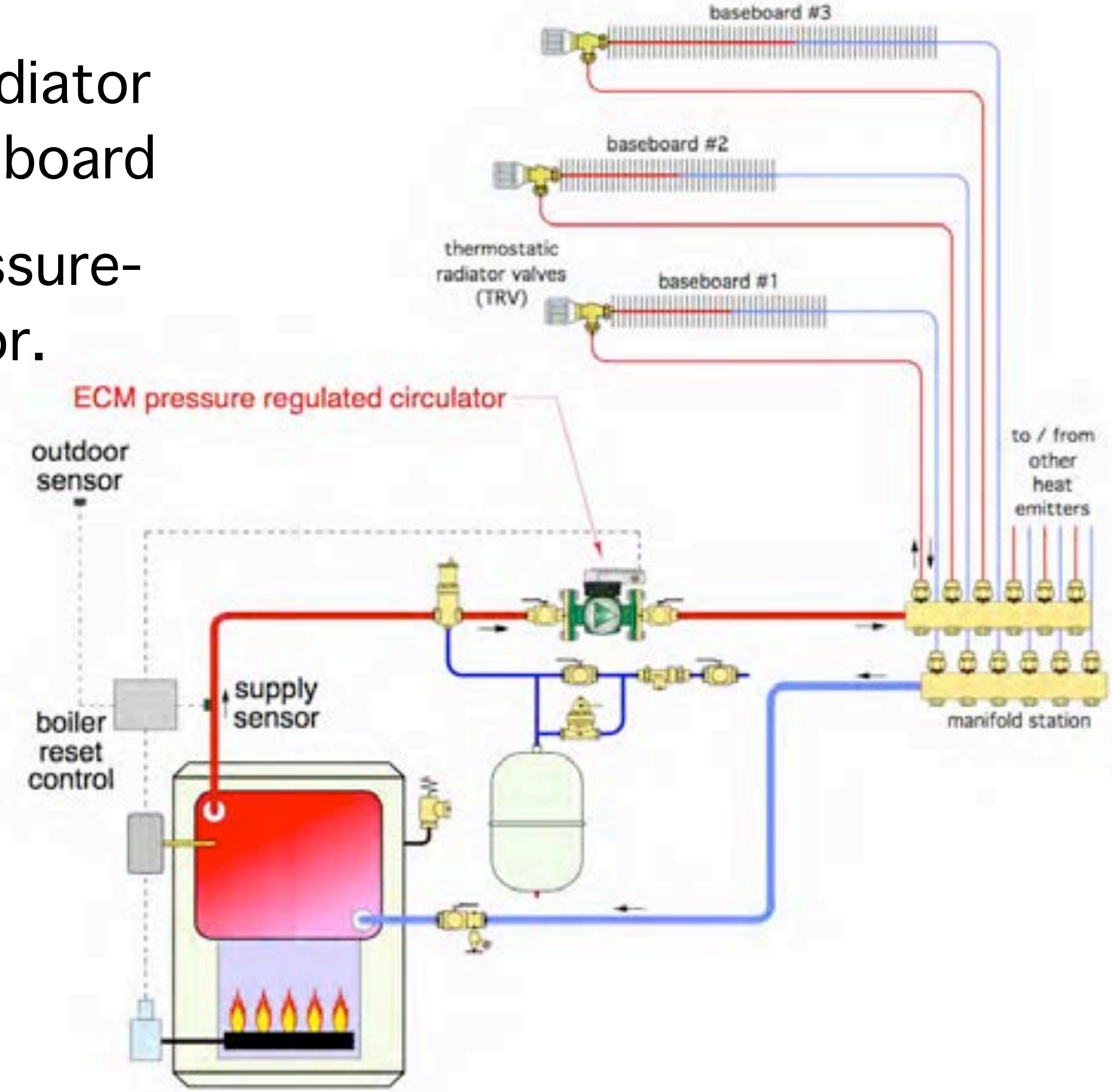
dog reset control



dogs are “thermally discriminating.”

The modern way to install fin-tube baseboard:

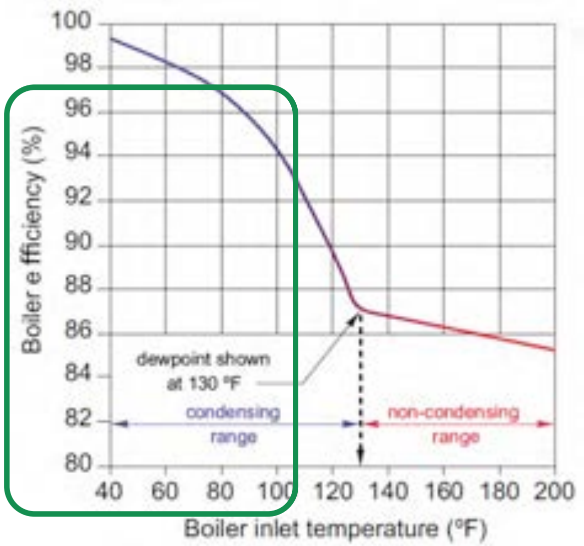
- Thermostatic radiator valve on each baseboard
- ECM-based pressure-regulated circulator.



Distribution efficiency
&
Low Energy 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!

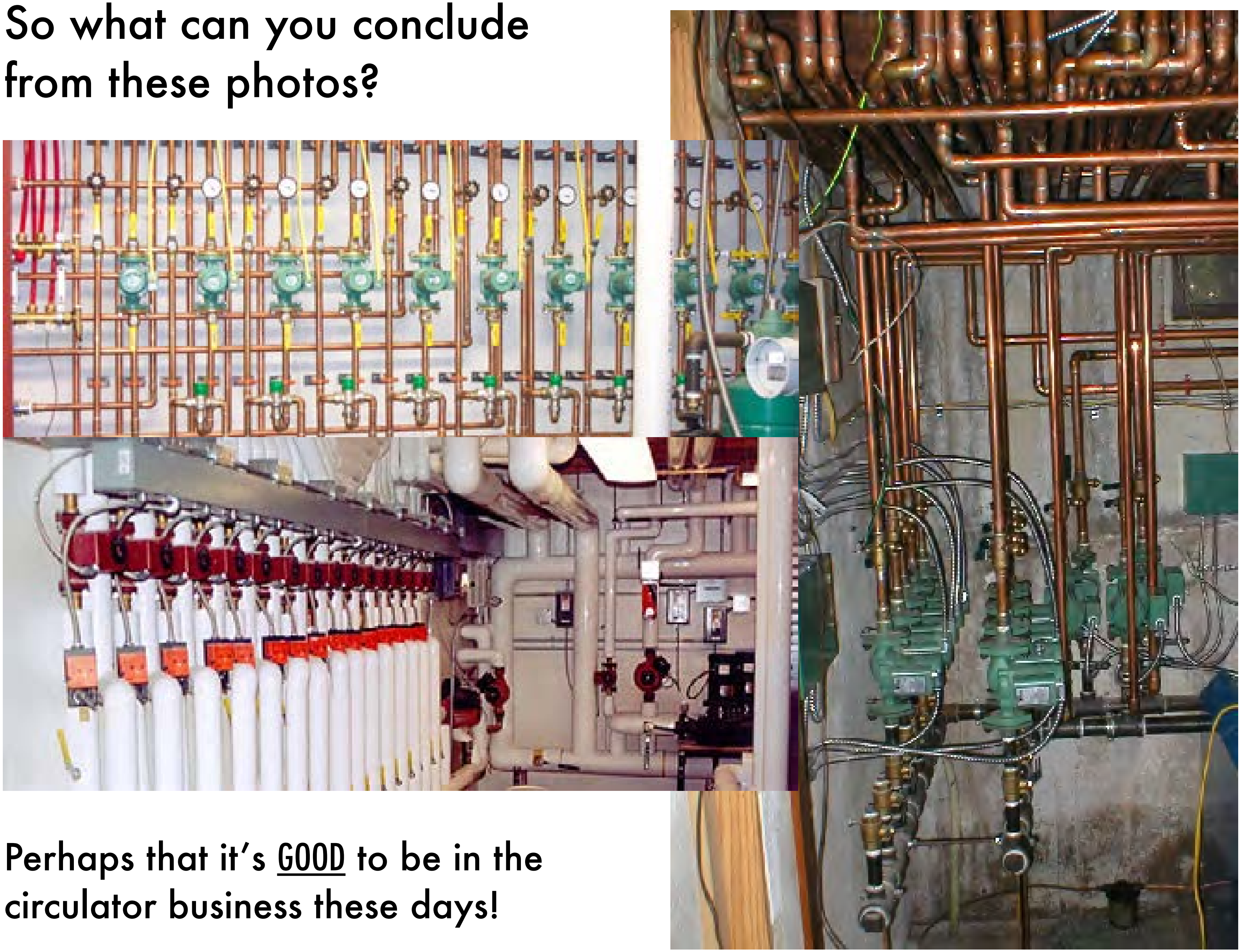
Here's another example...

Great craftsmanship - Wrong concept

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

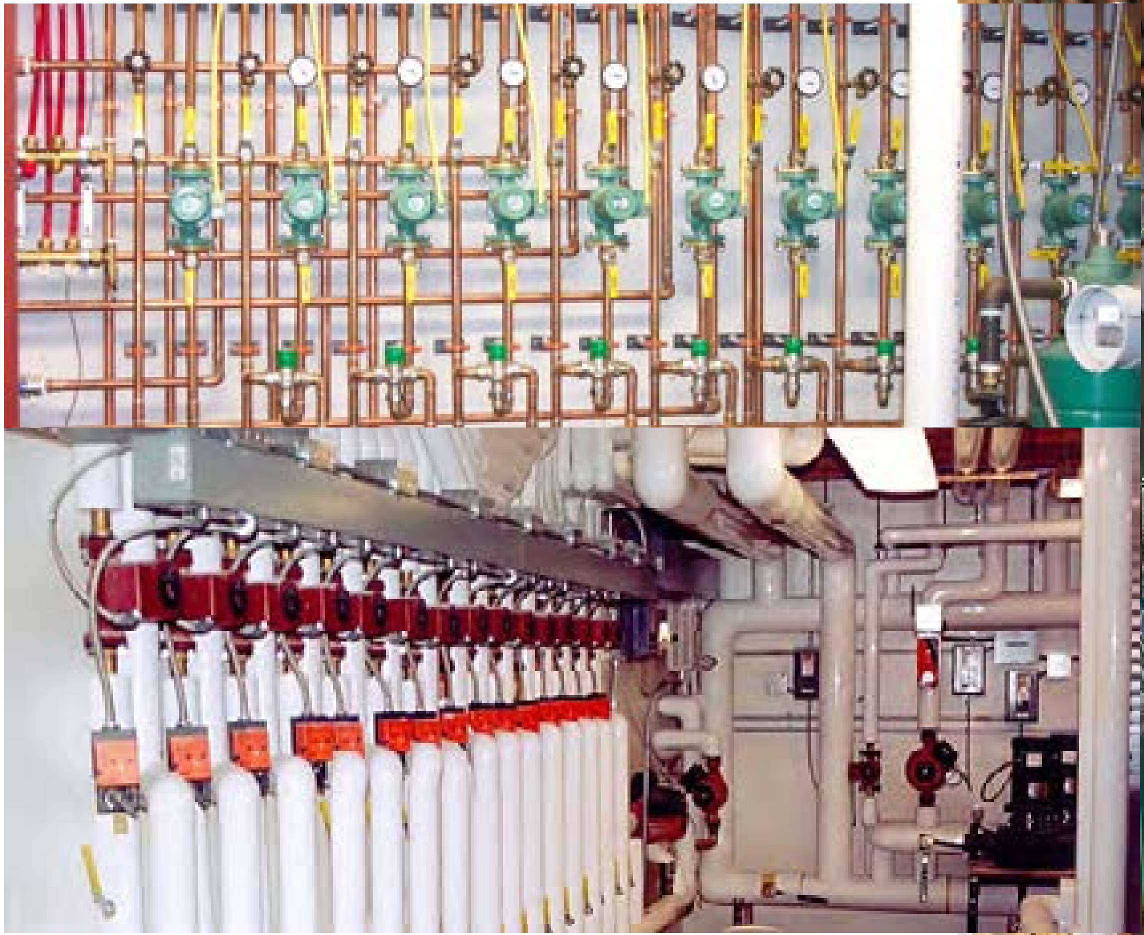
Notice the installer left provisions for additional circulators.

So what can you conclude from these photos?



Perhaps that it's GOOD to be in the circulator business these days!

You might also conclude that…



The North American hydronics industry tends to “overpump” its systems!

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 °F 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.

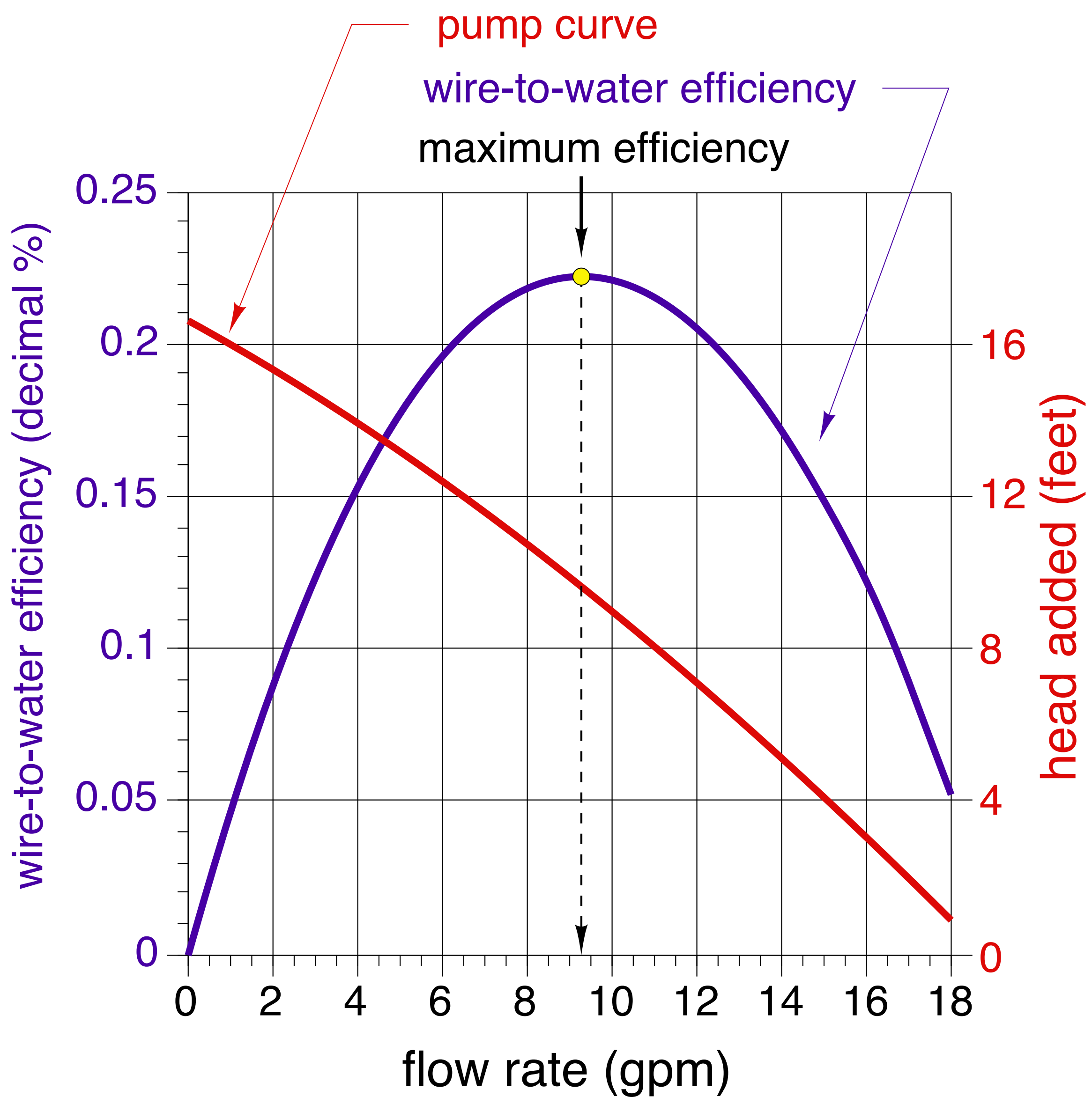
Putting these numbers into the formula yields:

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

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.

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:

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

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:

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

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:

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

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

This will become increasingly important in low energy and net zero buildings...

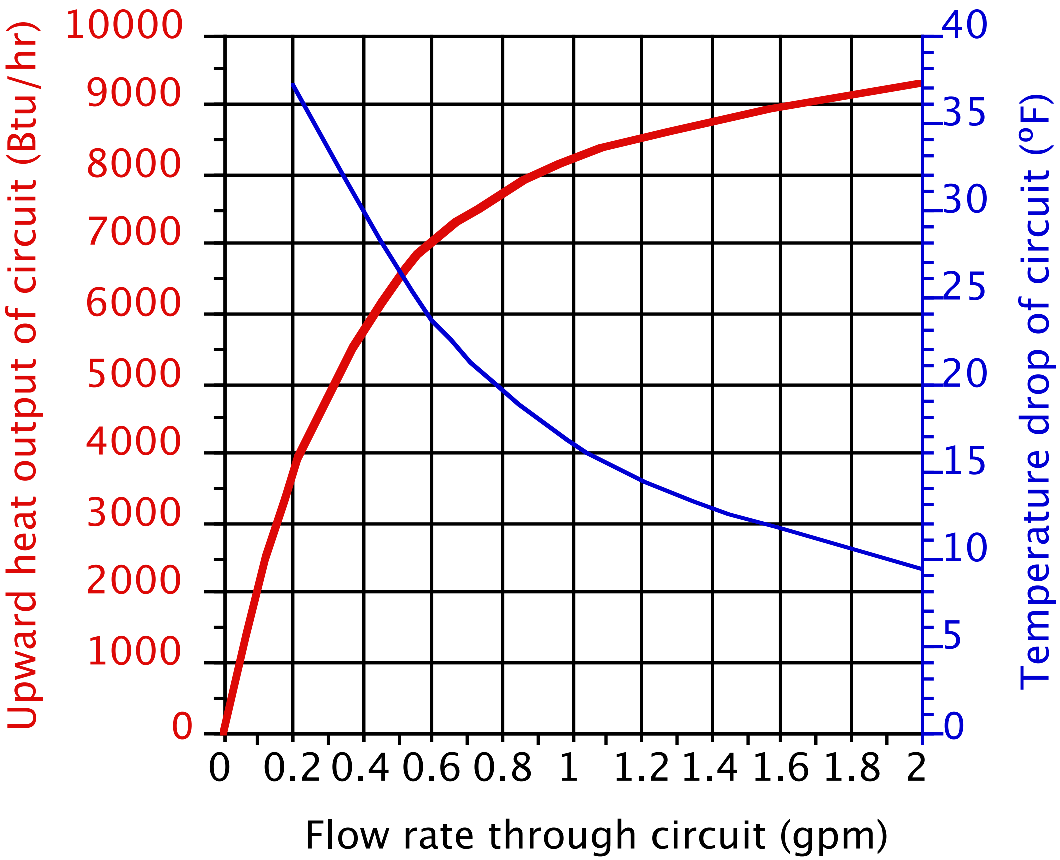
Other factors to Consider…

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.



Other factors to Consider… Reduced head loss:

Reduce Use Of Antifreeze:

"The only good thing about antifreeze is that it doesn't freeze."

- Antifreeze **increases viscosity** of system fluid and thus increases head loss.
- Antifreeze has **lower specific heat than water** and requires higher flow for same heat transfer rate.
- If not properly maintained it **can lead to corrosion damage** requiring major component replacement.

Consider a circuit of 200 feet of 3/4” copper tubing. Assume the circuit operates with a water flow rate of 5 gpm, an average water temperature of 140 °F, and a ΔT of 20 °F. Thus it conveys 50,000 Btu/hr. Assume the circulator is a standard wet rotor unit with 22% wire-to-water efficiency. The head loss of this circuit is 11.45 ft. The corresponding circuit pressure drop is **4.87 psi**.

The circulator power required for this is:

$$w_e = \frac{0.4344 \times f \times \Delta P}{n_{w/w}} = \frac{0.4344 \times 5 \times 4.87}{0.22} = 48 watts$$

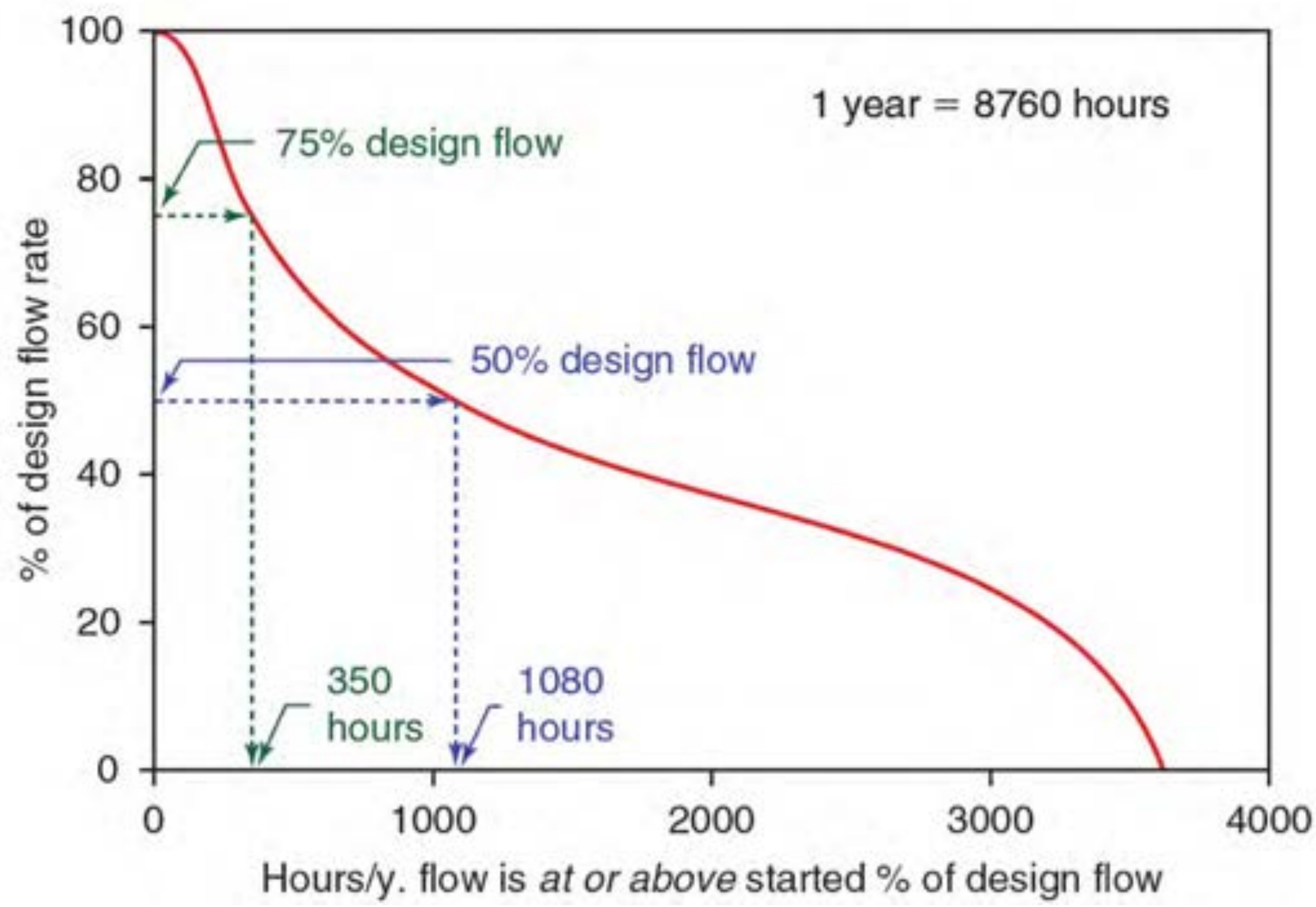
If this same circuit were operated with a 50% solution of propylene glycol, and is to maintain a heat delivery rate of 50,000 Btu/hr, the flow rate must increase to 5.62 gpm due to the lower specific heat of the antifreeze. The increases flow rate, in combination with increased viscosity and density, increases head loss to 16.3 feet, and pressure drop to **7.19 psi**.

The circulator power required for this is:

$$w_e = \frac{0.4344 \times f \times \Delta P}{n_{w/w}} = \frac{0.4344 \times 5.62 \times 7.19}{0.22} = 79.8 watts$$

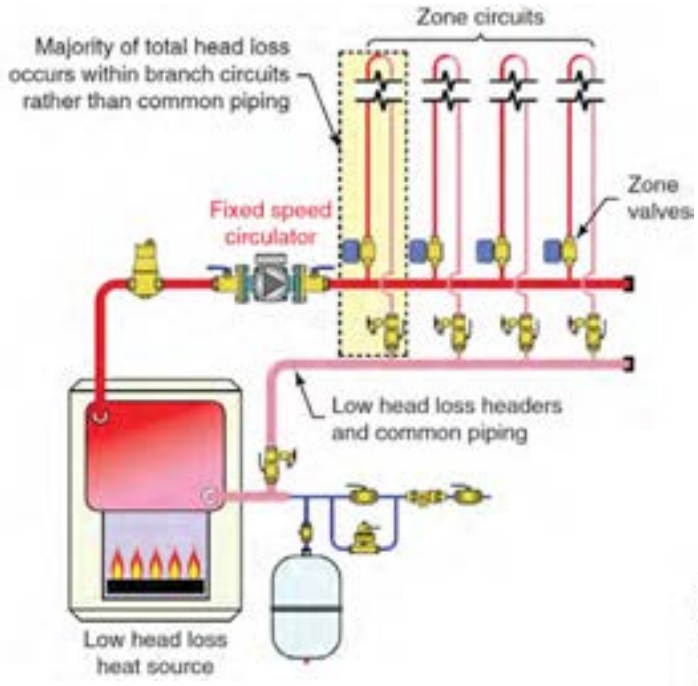
A 66% increase in circulator wattage due to use of antifreeze.

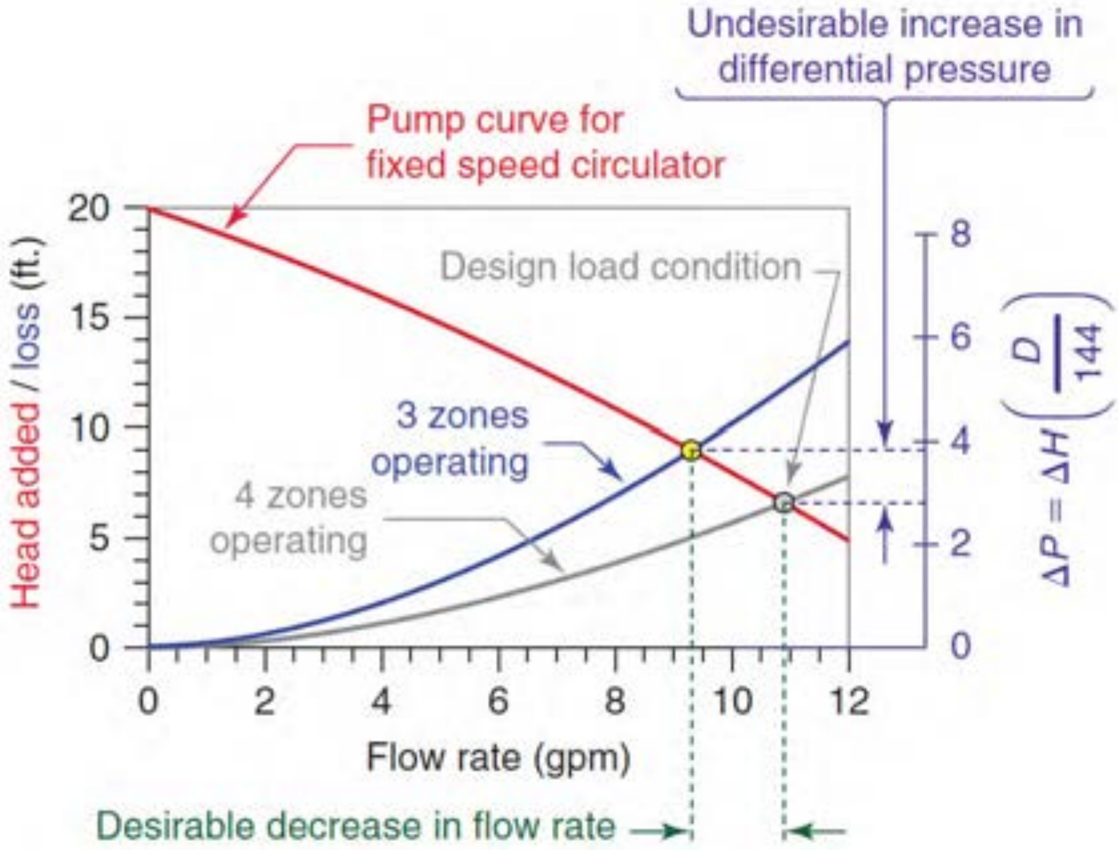
This graph shows the relationship between system flow rate vs. operating hours for a typical Northern climate.



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

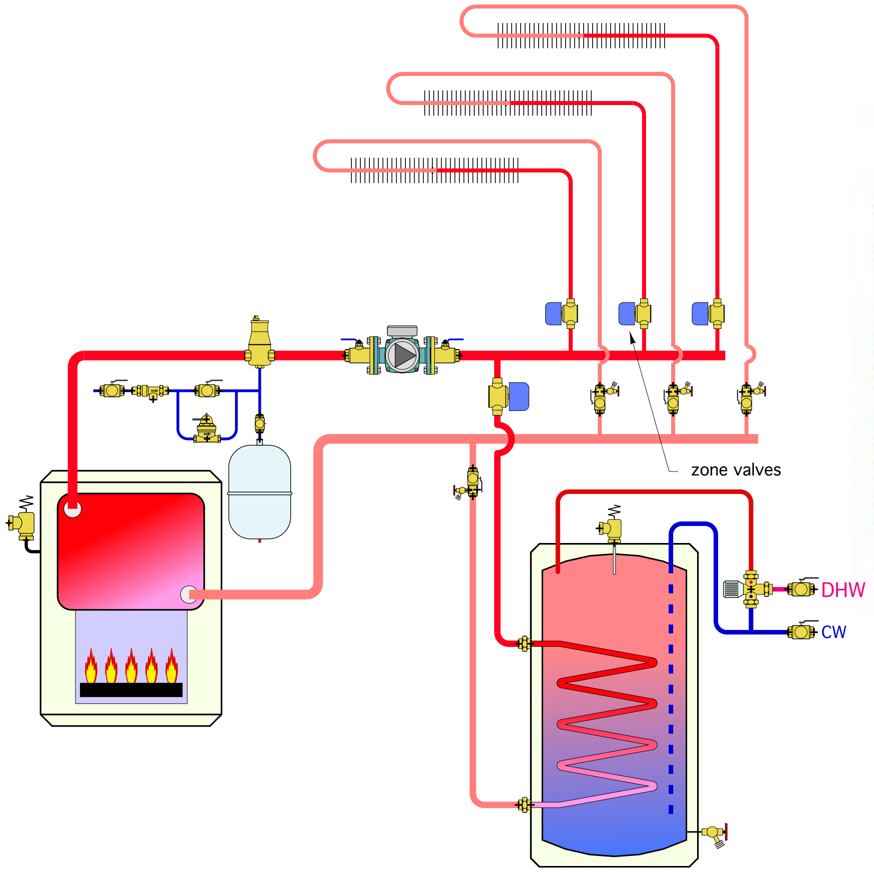
What happens when a zone valve closes?

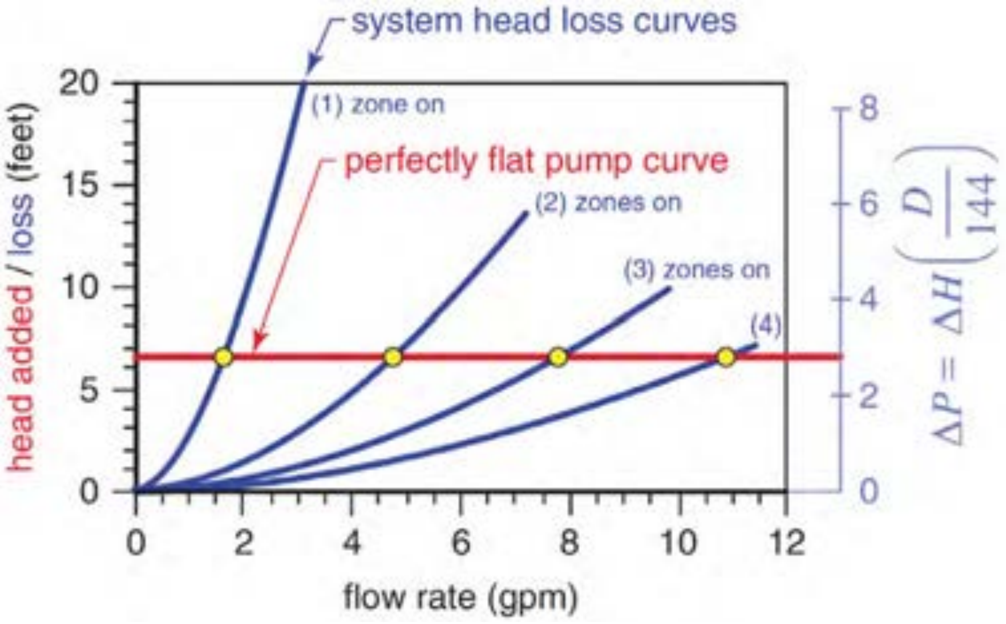




What would be the **ideal** pump curve for a hydronic system using valve based zoning?

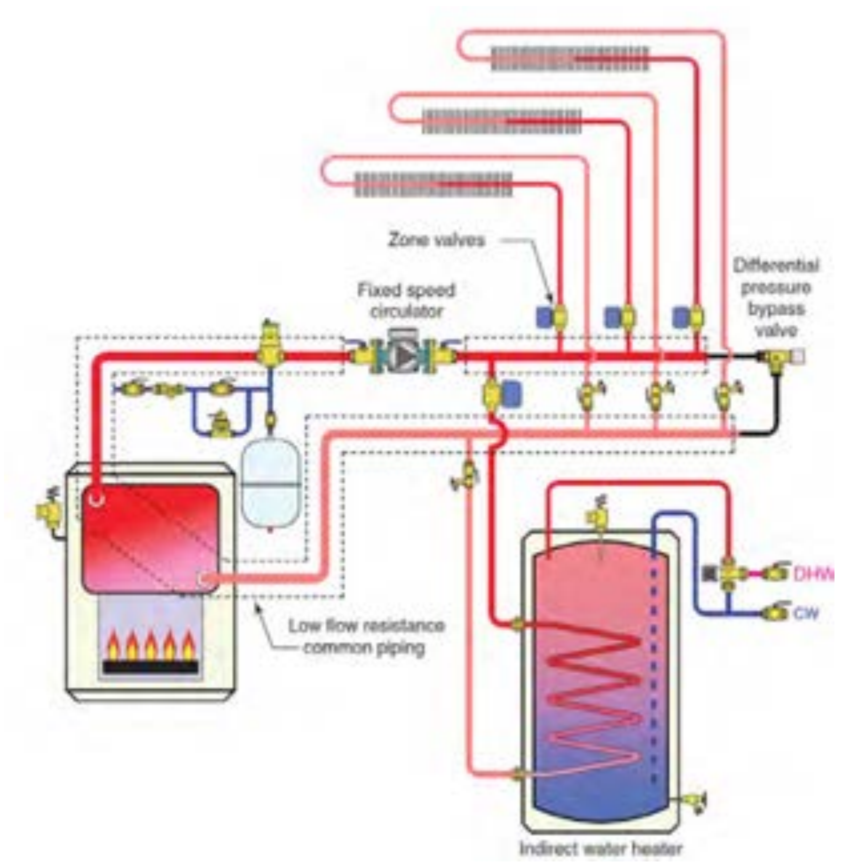
Answer: a perfectly flat pump curve

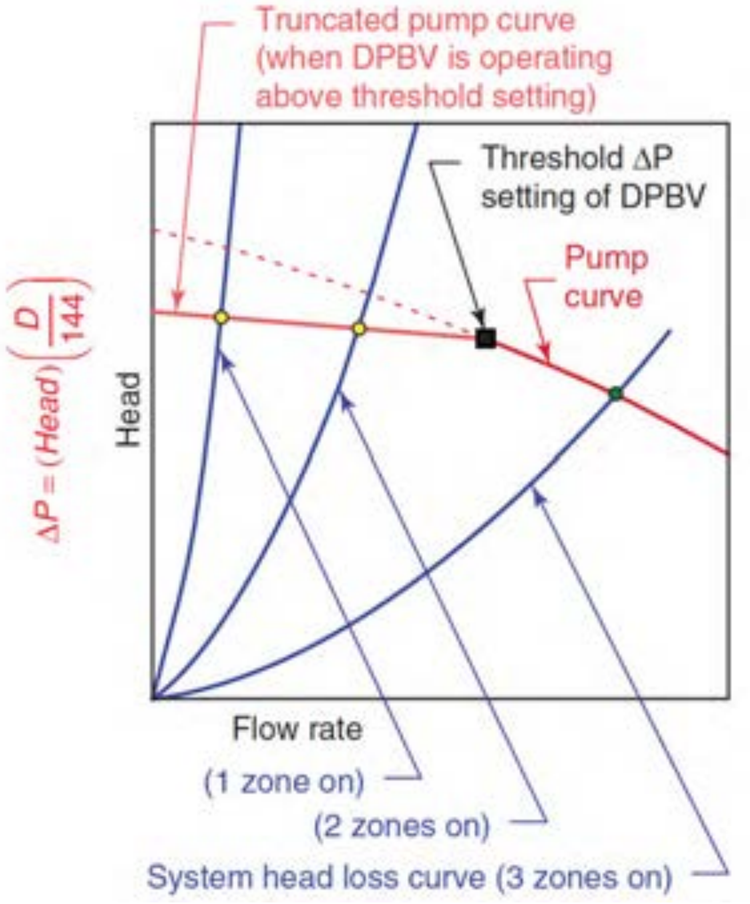




A perfectly flat pump curve would all steady flow rate in every zone circuit, regardless of which other zones are on.

Approximating a flat pump curve with ΔP bypass valve

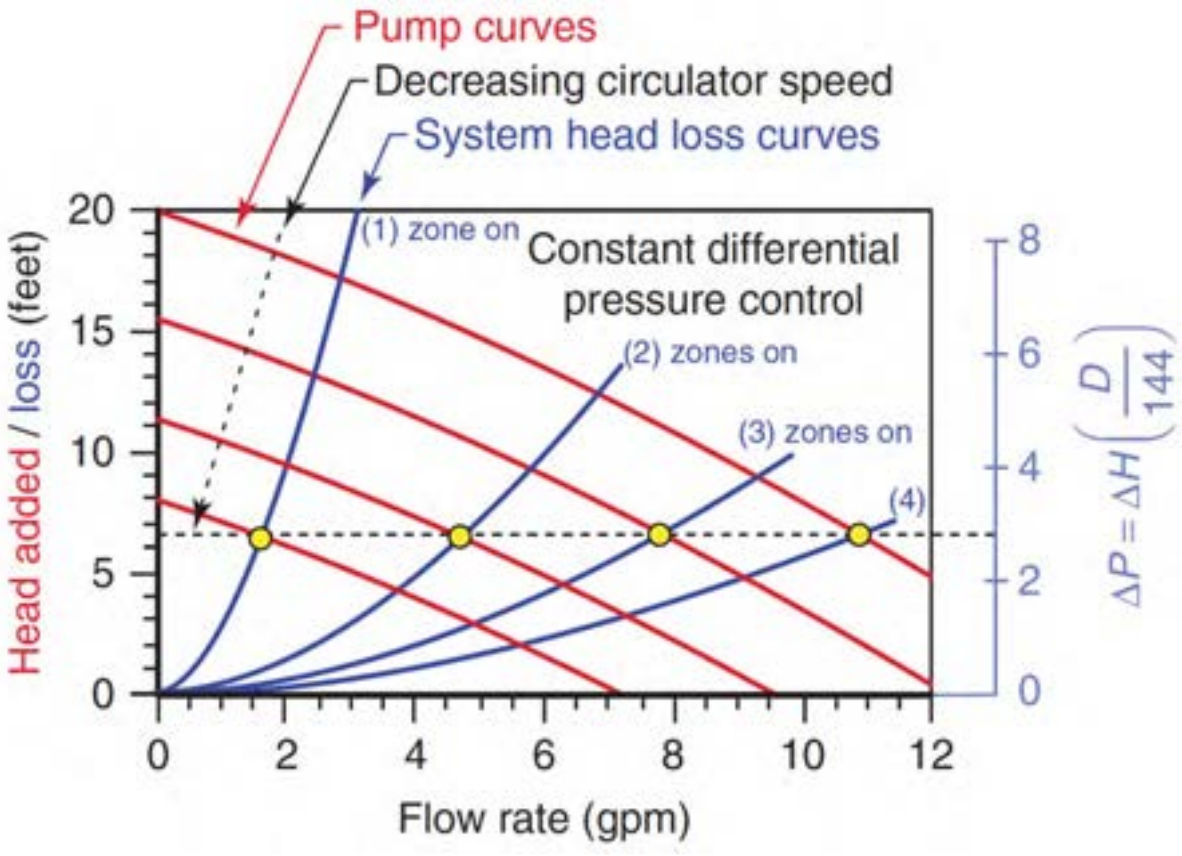




A ΔP bypass valve helps limit changes in differential pressure, but does so “parasitically” by throttling away head energy

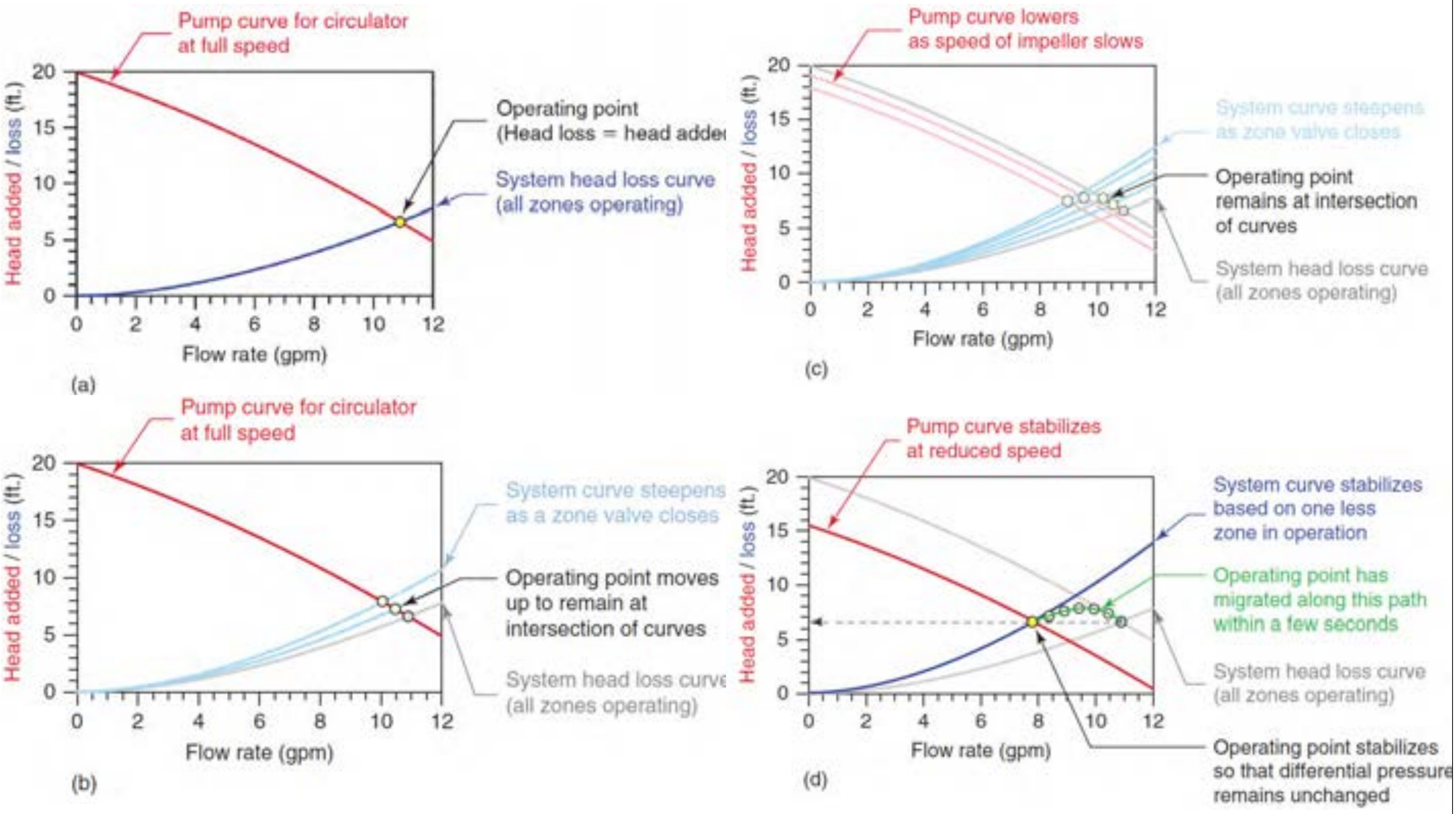
Approximating a flat pump curve with ΔP bypass valve

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

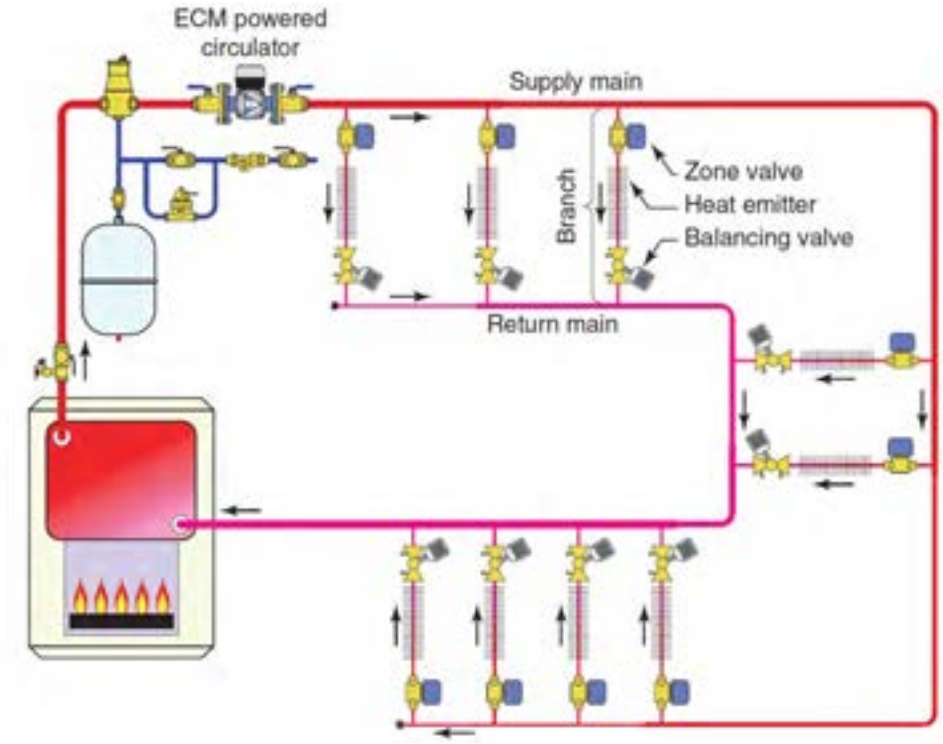
Constant differential pressure control

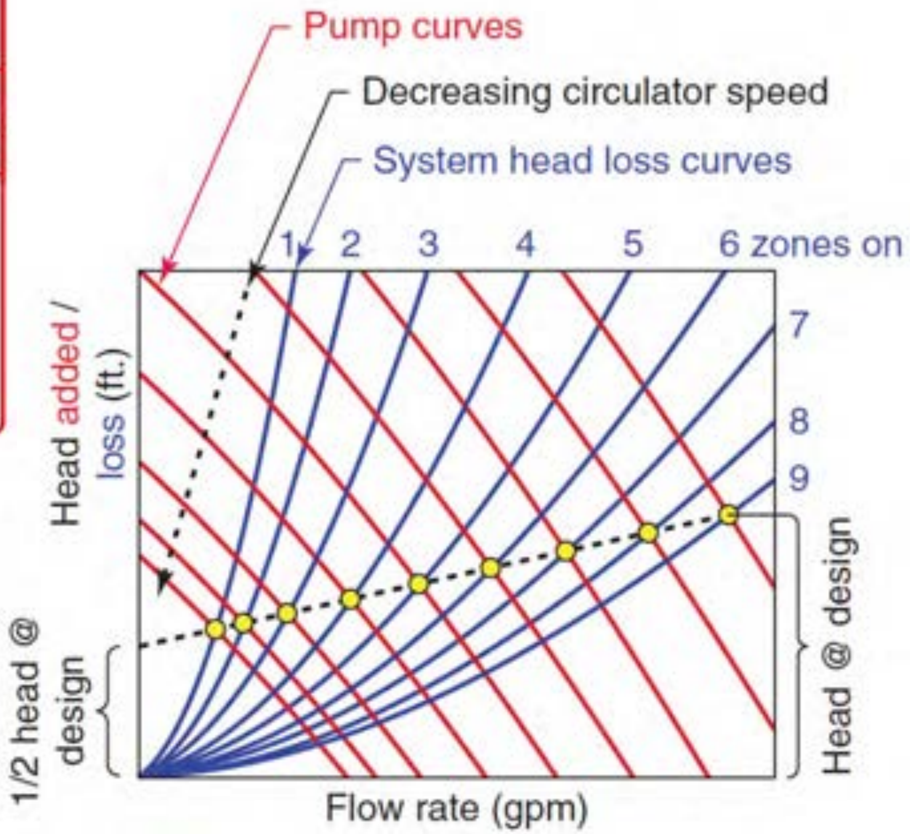


This is all regulated by P.I.D. control

PROPORTIONAL DIFFERENTIAL PRESSURE CONTROL

This method is best for systems where the heat source and/or “mains” piping leading to the load circuits dissipate a substantial portion of the circulator head.





Small ECM circulators now available in US

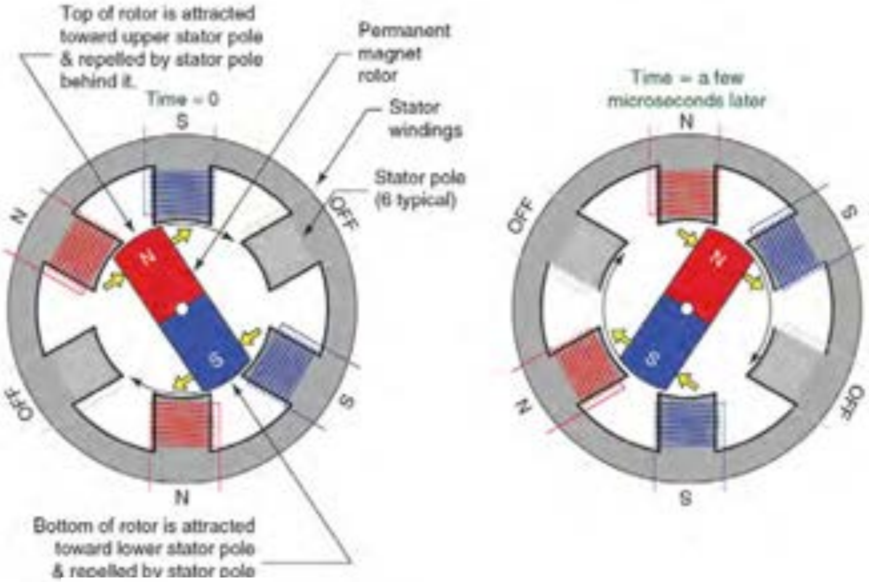
Grundfos Alpha: Provides constant and proportional differential pressure and three fixed speed settings. 6-50 watt electrical input.

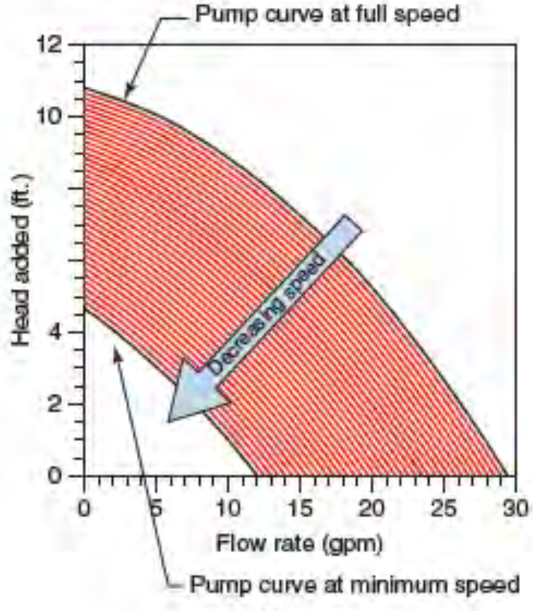
Wilo Stratos ECO 16F: Provide constant and proportional differential pressure. 5.8-59 watt electrical input.

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

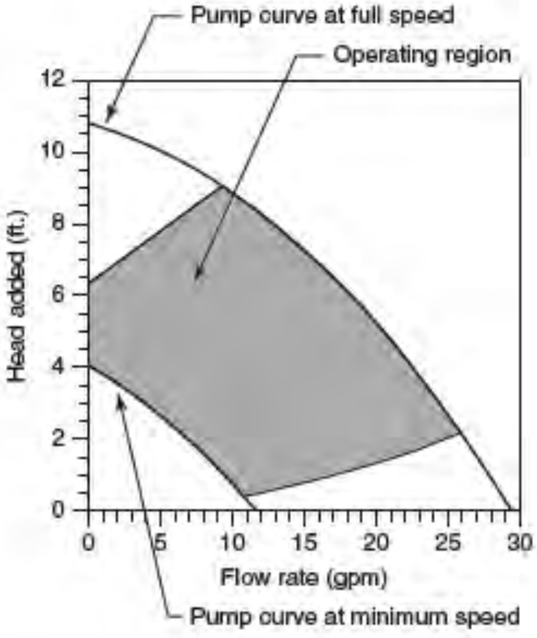
Taco Bumblebee Temperature based speed control. 9-42 watts electrical input

How does a ECM Circulator work?





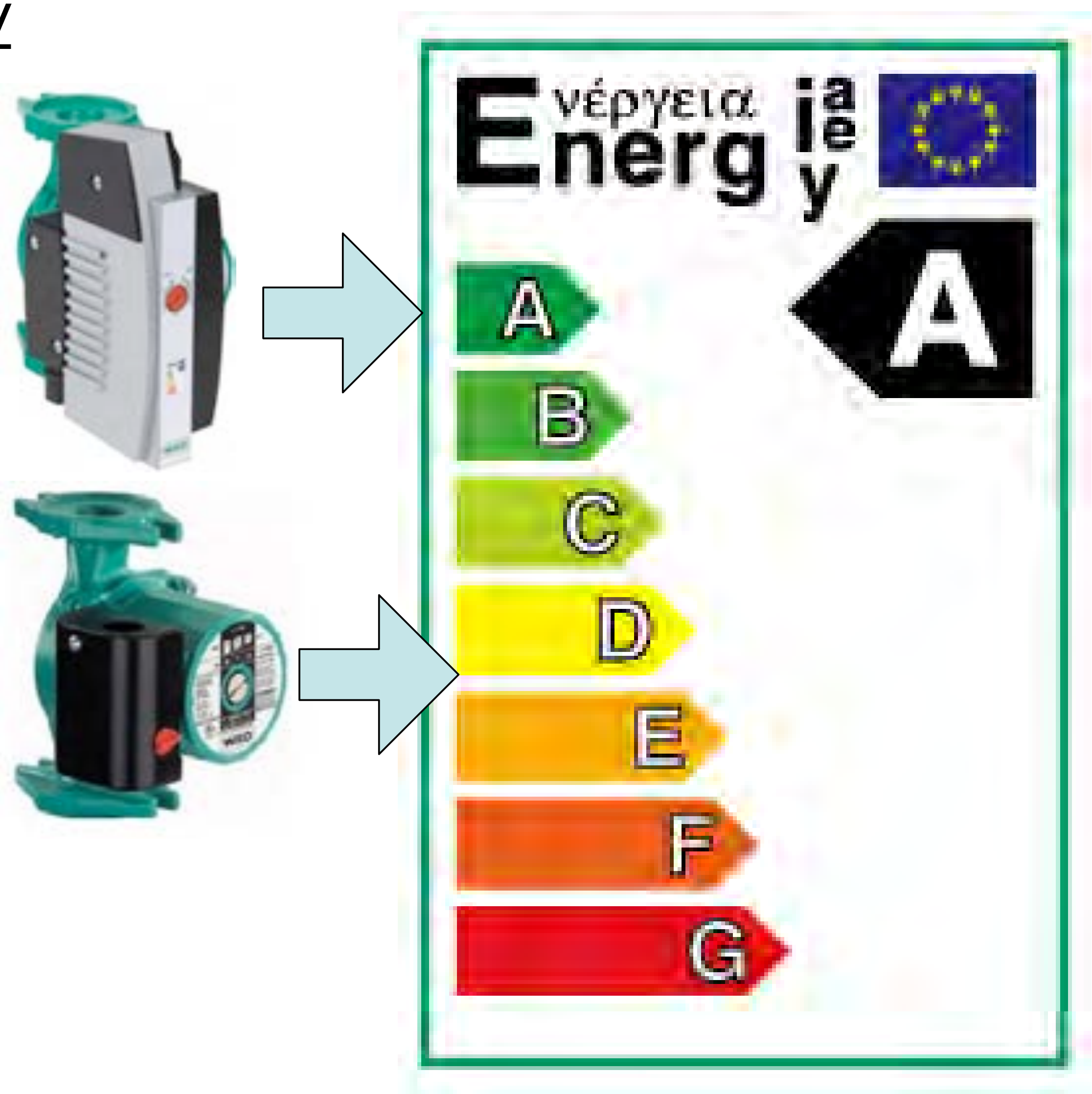
(a)



(b)

Current European circulator rating system

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

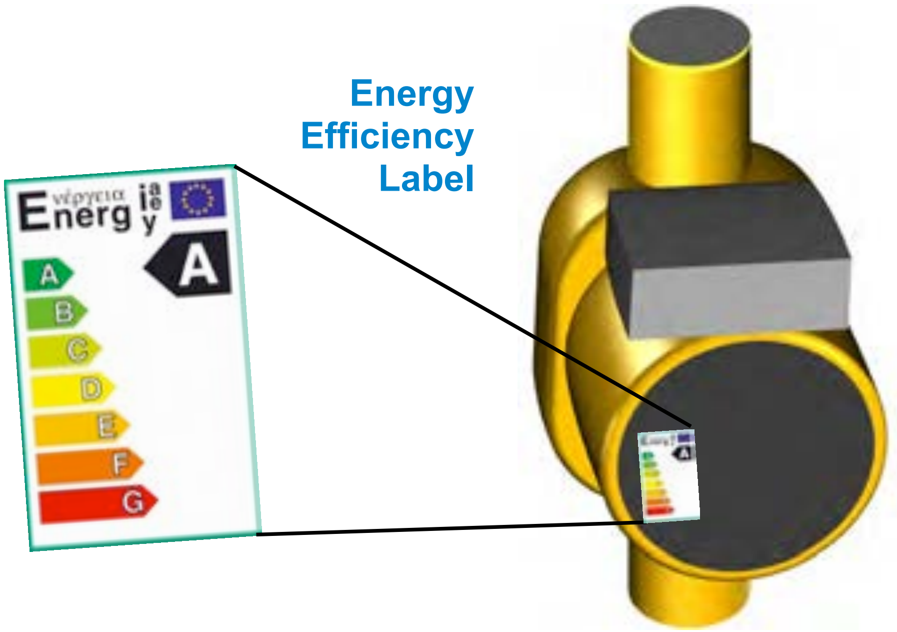


Single or multi-speed wet-rotor circulators like those commonly used in North America would be rated “D” or “E” on this scale.

The European circulator rating system

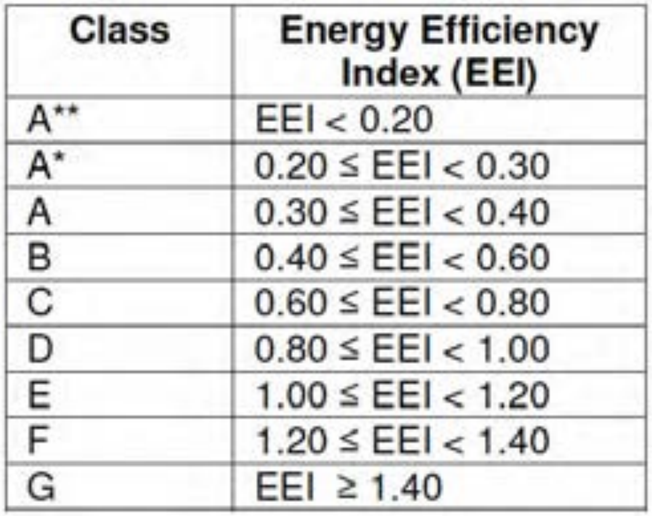
Voluntary **industry commitment (since 2005)**

In March 2005 ‘Europump’ launched the voluntary industry commitment to improve the energy performance of stand-alone circulators



Energy Efficiency Label

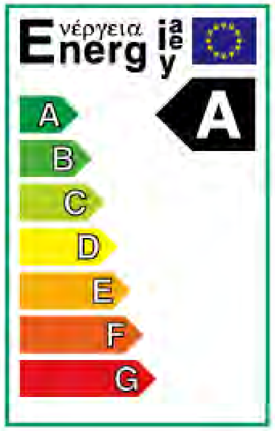
The Energy Efficiency Label (A, B, C, etc) is based on a calculated number called the Energy Efficiency Index (EEI). There is an established protocol for determining EEI based on testing and subsequent calculations.



Class	Energy Efficiency Index (EEI)
A**	EEI < 0.20
A*	0.20 ≤ EEI < 0.30
A	0.30 ≤ EEI < 0.40
B	0.40 ≤ EEI < 0.60
C	0.60 ≤ EEI < 0.80
D	0.80 ≤ EEI < 1.00
E	1.00 ≤ EEI < 1.20
F	1.20 ≤ EEI < 1.40
G	EEI ≥ 1.40

2015 European circulator standards

- Due to their high energy consumption across Europe (approx. 15% of the total consumption of electrical energy), the European Commission identifies circulation pumps as relevant for a sustainable environmental protection
- The ErP calculation shows saving effects of 23 TWh or 11 mio. t CO^2 per year
- This is why from 2013 on only highly efficient circulation pumps may be sold in Europe which achieve an energy efficiency index of < 0.27
- Then, from 2015 on, the second stage for all circulation pumps comes into effect (EEI < 0.23)



Class	Energy Efficiency Index (EEI)
A**	EEI < 0.20
A*	0.20 ≤ EEI < 0.30
A	0.30 ≤ EEI < 0.40
B	0.40 ≤ EEI < 0.60
C	0.60 ≤ EEI < 0.80
D	0.80 ≤ EEI < 1.00
E	1.00 ≤ EEI < 1.20
F	1.20 ≤ EEI < 1.40
G	EEI ≥ 1.40

ErP Directive 2013/2015

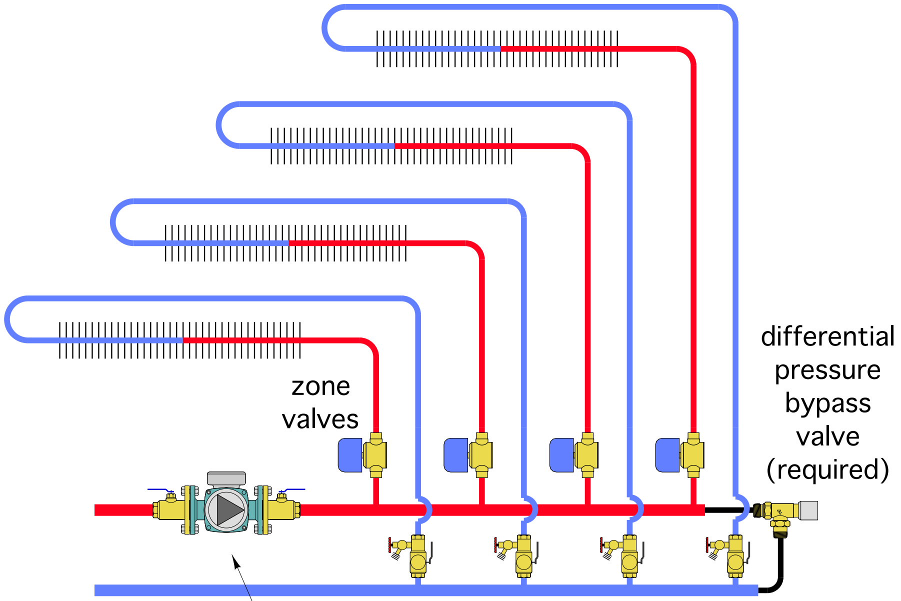
The Future is High-efficiency

EEI = Energy Efficiency Index according to EG 641/2009 directive of the European Commission (Determined by comparing the different power consumptions within the load profile to an average reference pump)

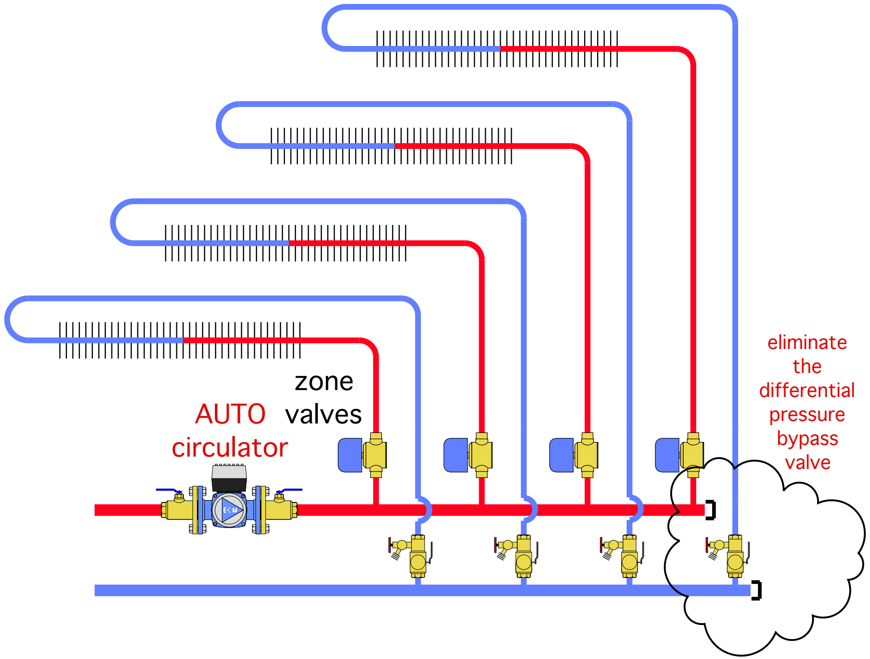
Over 90 % of the glandless circulators for heating and air conditioning, which are available on the market today, will soon be prohibited for sale. The reason for this will be the implementation of a Commission Regulation for circulators under the European Ecodesign Directive, which will introduce increasingly stricter requirements on the energy efficiency of pumps throughout the EU from 2013.

http://www.wilo.com/cps/rde/xbcr/en/henews_int__doc_01_1012_en_72dpi.pdf

Zoning with zone valves & pressure regulated circulator



standard (fixed speed) circulator



+

Zoning with valves and a fixed speed circulator requires a differential pressure bypass valve.

Zoning with valves and an ECM pressure regulated circulator eliminates need (and cost) of a differential pressure bypass valve.

A real price comparison...

All prices taken for same internet-based supplier (August 2012)

B&G NRF-22
circulator

+

B&G ΔP
bypass valve

vs.

B&G AUTO
circulator

$88.70

$58.74

$147.44

$178.20

Can you install this valve (with adapter fittings) and labor for $30.75?

This comparison ignores the saving in electrical energy associated with the ECM circulator

A real price comparison...

Energy savings comparison

Conventional zone circulator operating 3000 hours per year in area where electricity costs $0.13/kwhr.

$$(80watt)\left(\frac{3000hr}{yr}\right)\left(\frac{1kwhr}{1000whr}\right)\left(\frac{\$0.13}{kwhr}\right)=\frac{\$31.2}{yr}$$

Based on European modeling, an ECM circulator operating with proportional differential pressure control reduces electrical consumption by about 60% comparison to a conventional wet rotor circulator of same max curve performance.

$$savings=(0.6)\$31.20=\$18.72\,/\,yr$$

Simple payback on higher cost of AUTO versus NRF-22: $89.50/$18.72 = **4.8 years**

Payback on higher cost of AUTO versus NRF-22 assuming 5% per year inflation on cost of electricity = **4.4 years**

B&G AUTO 19-14

$178.20

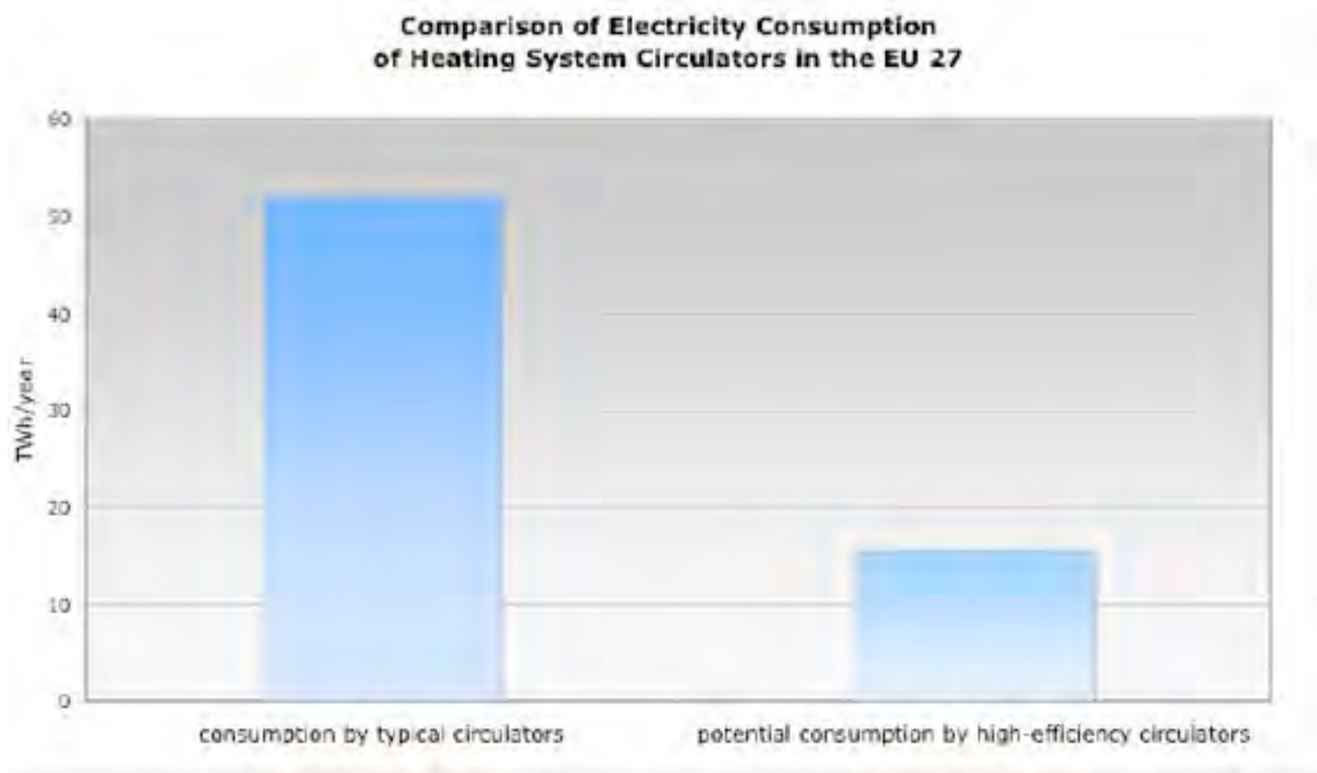
B&G NRF-22 circulator

$88.70

cost difference $89.50

Computer modeling has been used to predict electrical energy savings for an intelligently-controlled circulator with ECR motor operating in the proportional pressure mode.

Savings in electrical energy are 60 to 80 percent relative to a fixed speed circulator of equal peak performance in the same application.

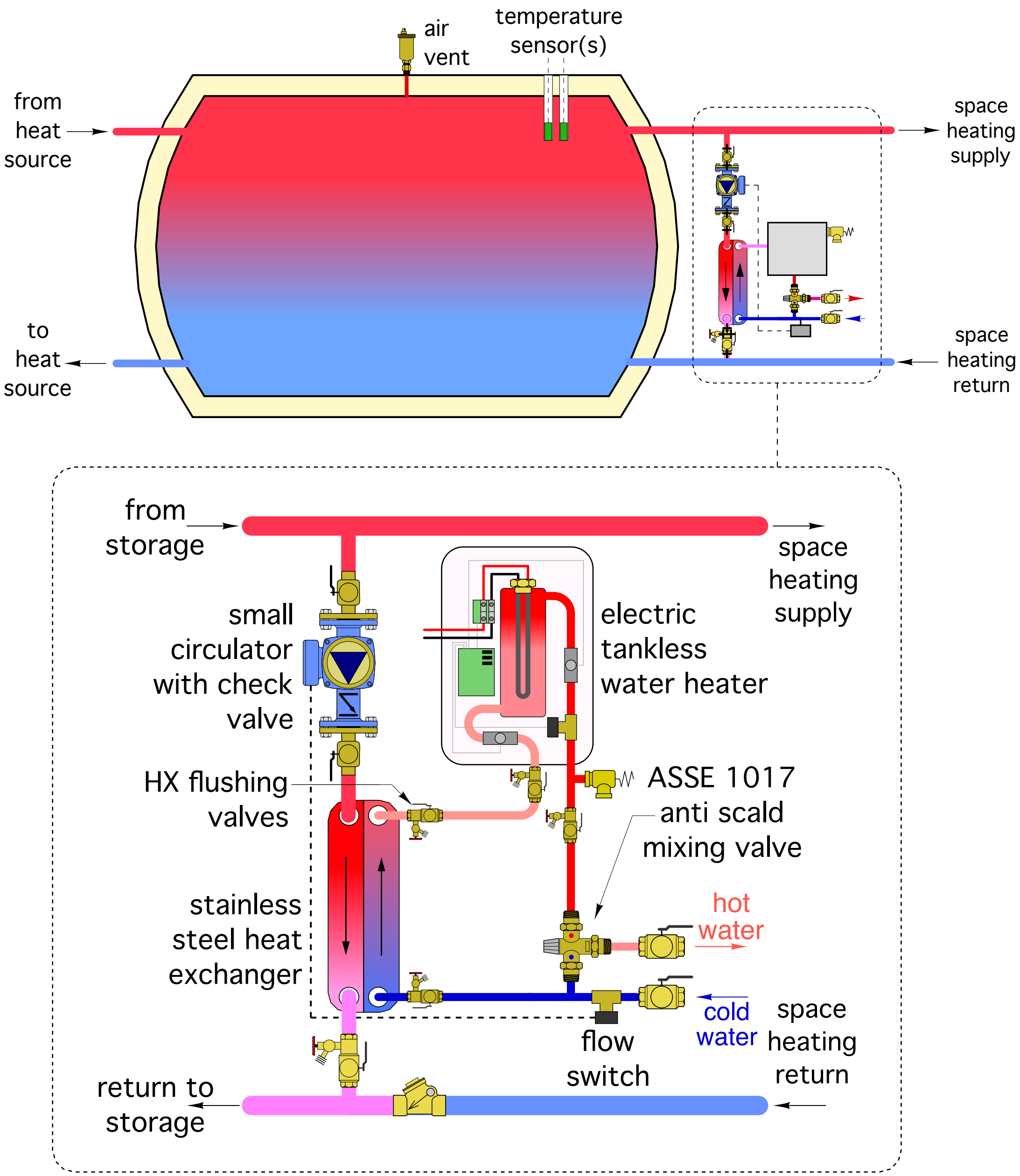


Instantaneous DHW subassembly

Starting points:

- Nearly all thermally-based renewable heat sources (solar, heat pump, solid fuel) require significant heat storage.
- Some systems with conventional heat sources also require heat storage.
- 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



air vent

temperature sensor(s)

from heat source

to heat source

space heating supply

space heating return

from storage

space heating supply

small circulator with check valve

electric tankless water heater

HX flushing valves

ASSE 1017 anti scald mixing valve

stainless steel heat exchanger

hot water

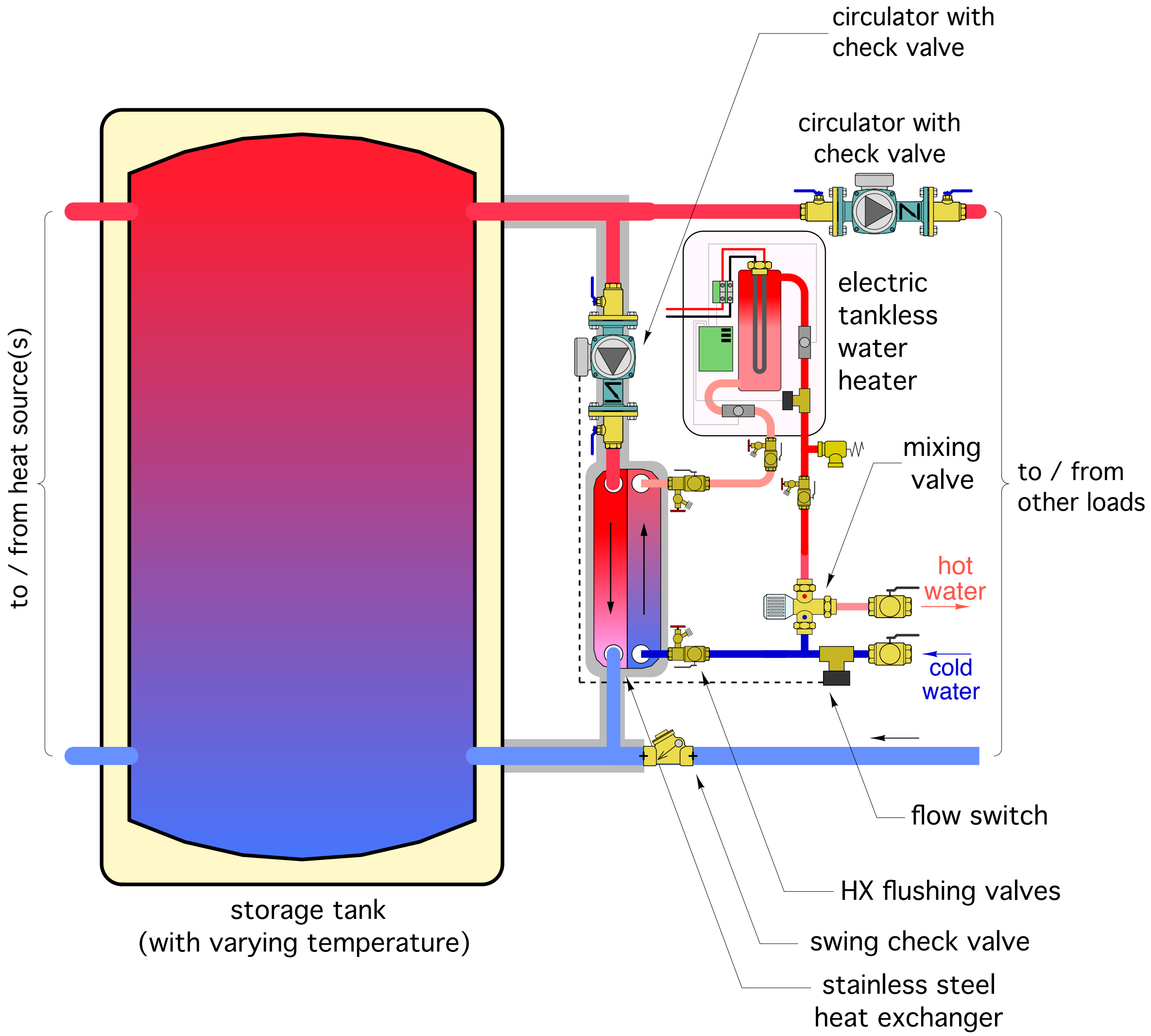
cold water

flow switch

space heating return

return to storage

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

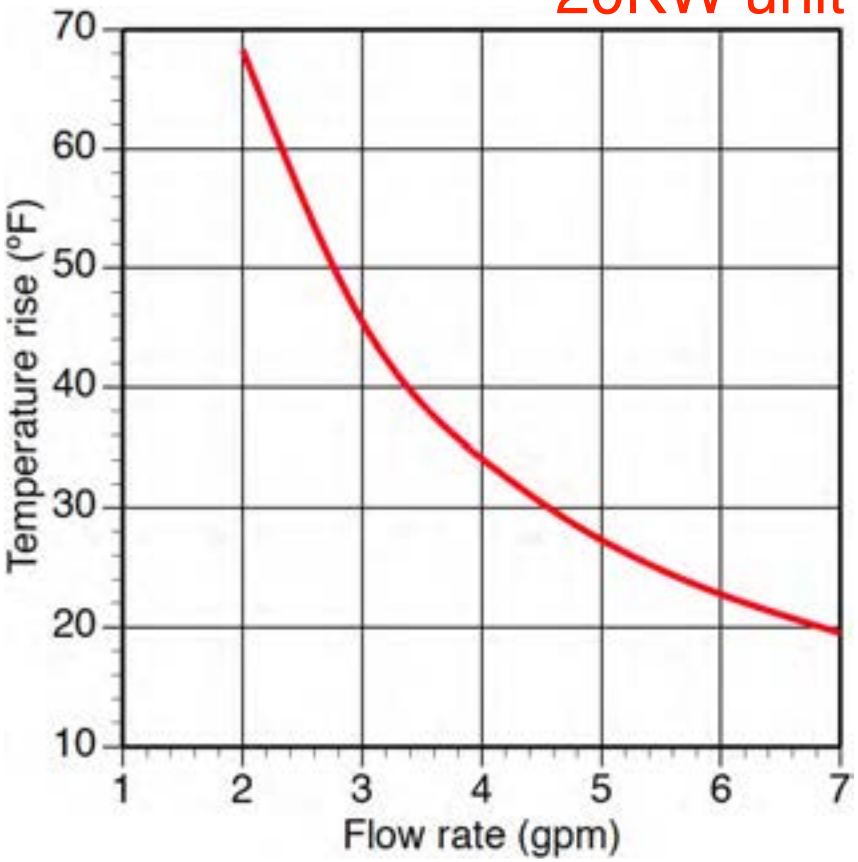
Thermostatically controlled electric tankless water heaters

Typical
“point of use”
ETWH
3-6 KW

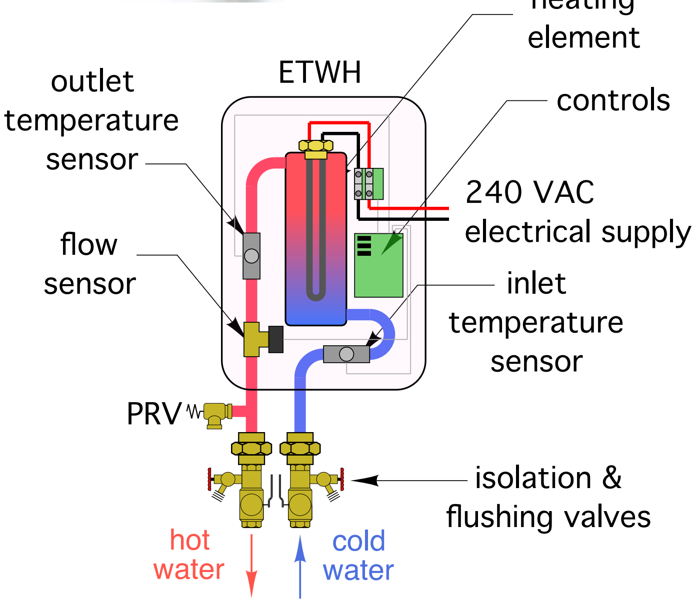
Typical
“whole
house”
ETWH
10-40 KW

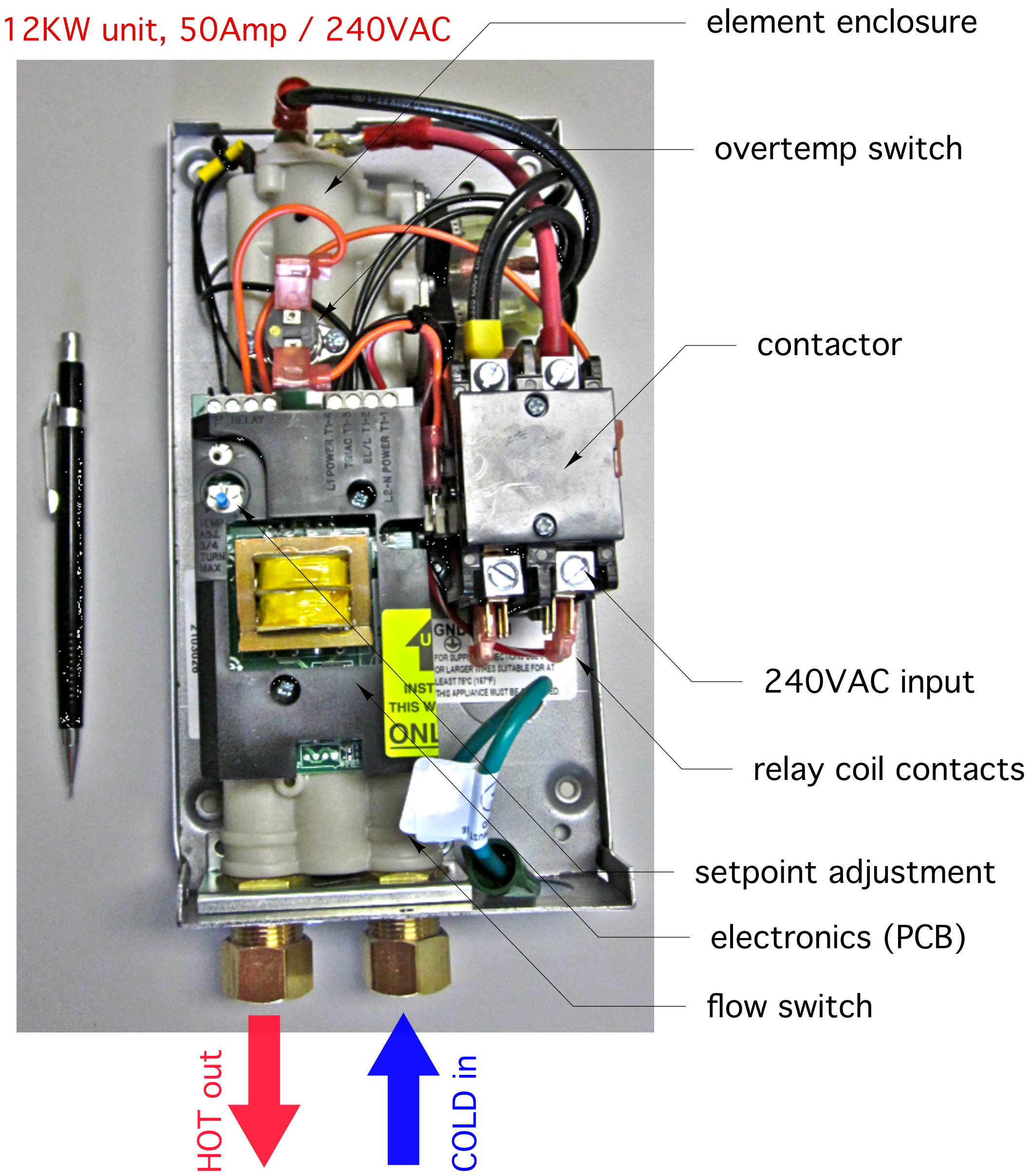
maximum possible water temperature rise always depends on flow rate

20KW unit



Thermostatically controlled electric tankless water heaters





Thermostatically controlled electric tankless water heaters

Electric tankless water heaters are HIGH AMPERAGE devices.

3.5 KW Requires
15 amp / 240VAC
breaker

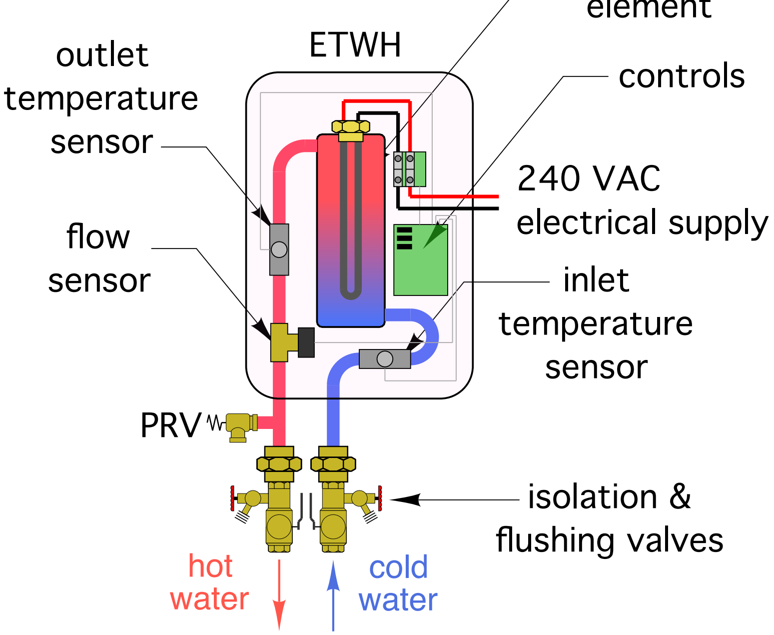
$$Amps = \frac{KW}{0.24}$$

Minimum 200 Amp breaker panel recommended.

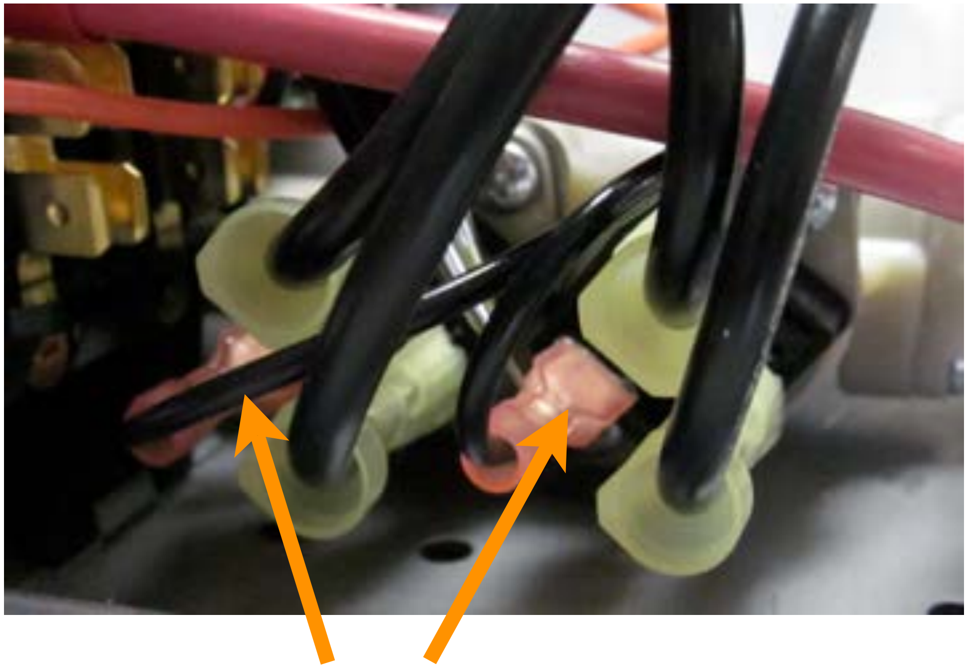
May be an issue in some retrofits.

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

Thermostatically controlled electric tankless water heaters



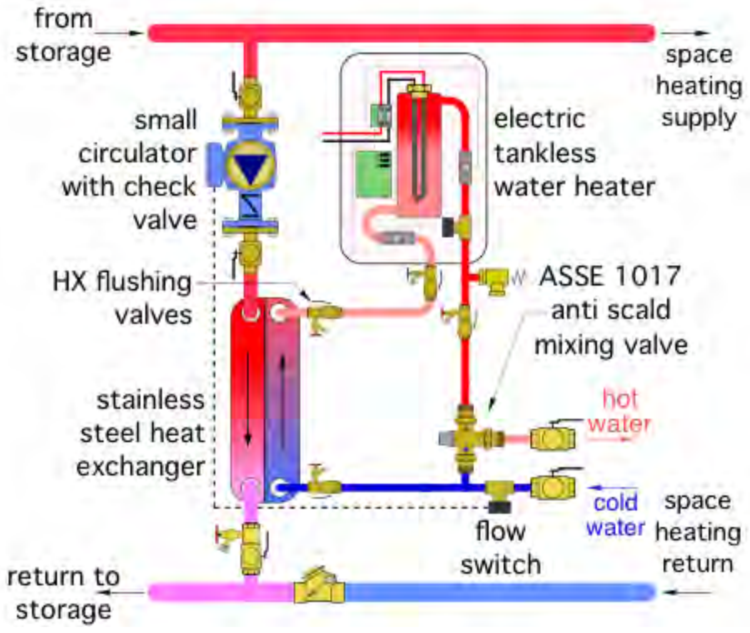
Thermostatically controlled electric tankless water heaters use a TRIAC to vary the amperage (and thus power) to their heating elements from 0 to 100%.



gates for TRIACS

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

Instantaneous DHW subassembly




3”x5”


5”x12”


10”x20”

Brazed plate stainless steel heat exchangers are widely available.

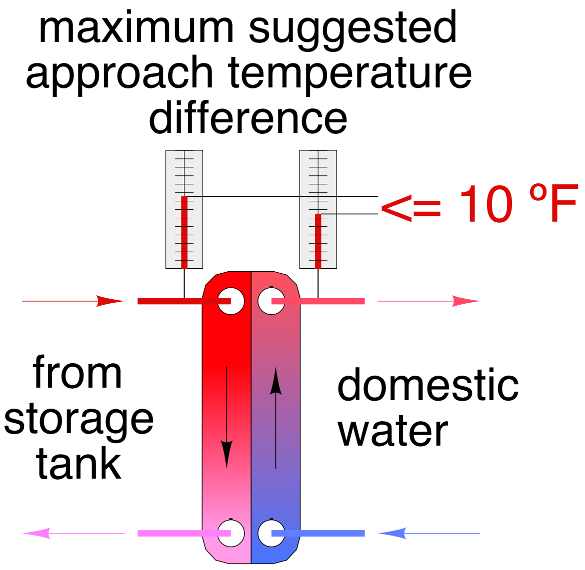
They have very high ratio of surface area to volume.

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.



maximum suggested approach temperature difference

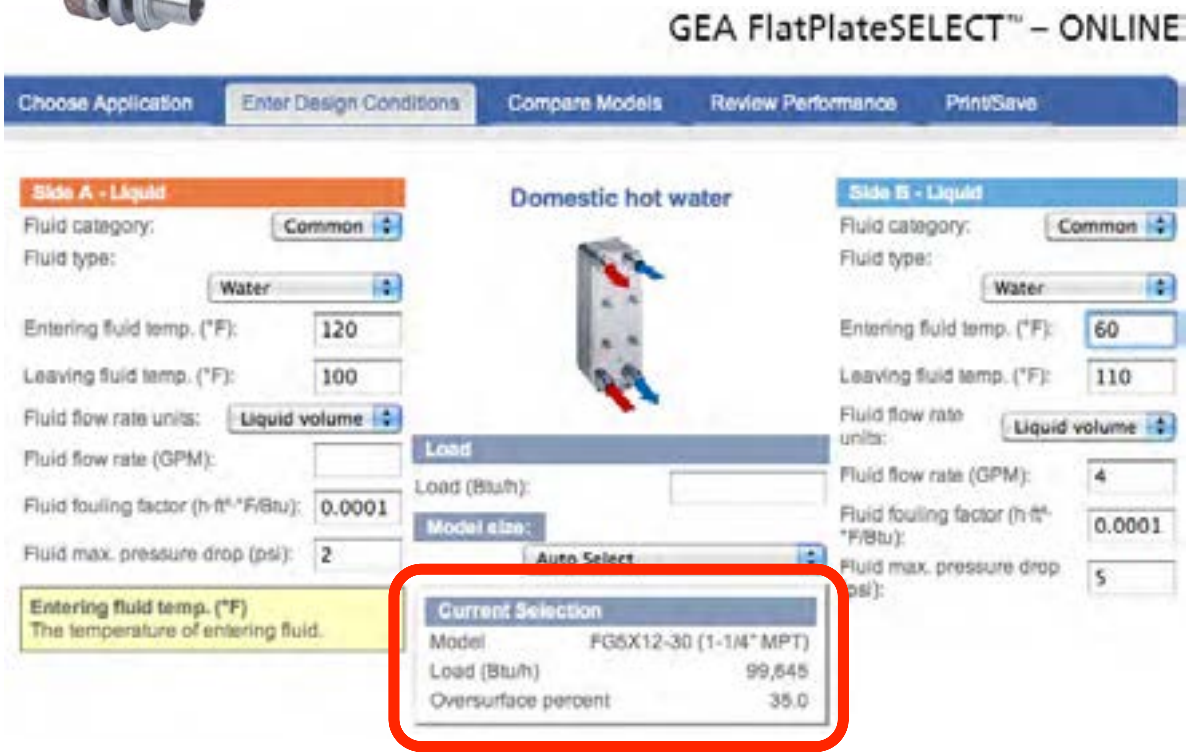
<= 10 °F

from storage tank

domestic water

FG5x12-30
5” wide x12” long -30 plates

http://flatplateselect.com



GEA FlatPlateSELECT™ – ONLINE

Side A - Liquid

Fluid category: Common
Fluid type: Water
Entering fluid temp. (°F): 120
Leaving fluid temp. (°F): 100
Fluid flow rate units: Liquid volume
Fluid flow rate (GPM):
Fluid fouling factor (h·ft²·°F/Btu): 0.0001
Fluid max. pressure drop (psi): 2

Entering fluid temp. (°F)
The temperature of entering fluid.

Domestic hot water

Load

Load (Btu/h):

Model size: Auto Select

Current Selection

Model FG5X12-30 (1-1/4" MPT)
Load (Btu/h) 99,645
Oversurface percent 35.0

Side B - Liquid

Fluid category: Common
Fluid type: Water
Entering fluid temp. (°F): 60
Leaving fluid temp. (°F): 110
Fluid flow rate units: Liquid volume
Fluid flow rate (GPM): 4
Fluid fouling factor (h·ft²·°F/Btu): 0.0001
Fluid max. pressure drop (psi): 5

Brazed plate heat exchanger - on ebay...

Back to search results | Listed in category: Home & Garden > Home Improvement > Heating, Cooling & Air > Other

GEA Flatplate Brazed 40 Plate GBE 5x12 Heat Exchanger

Item condition: New

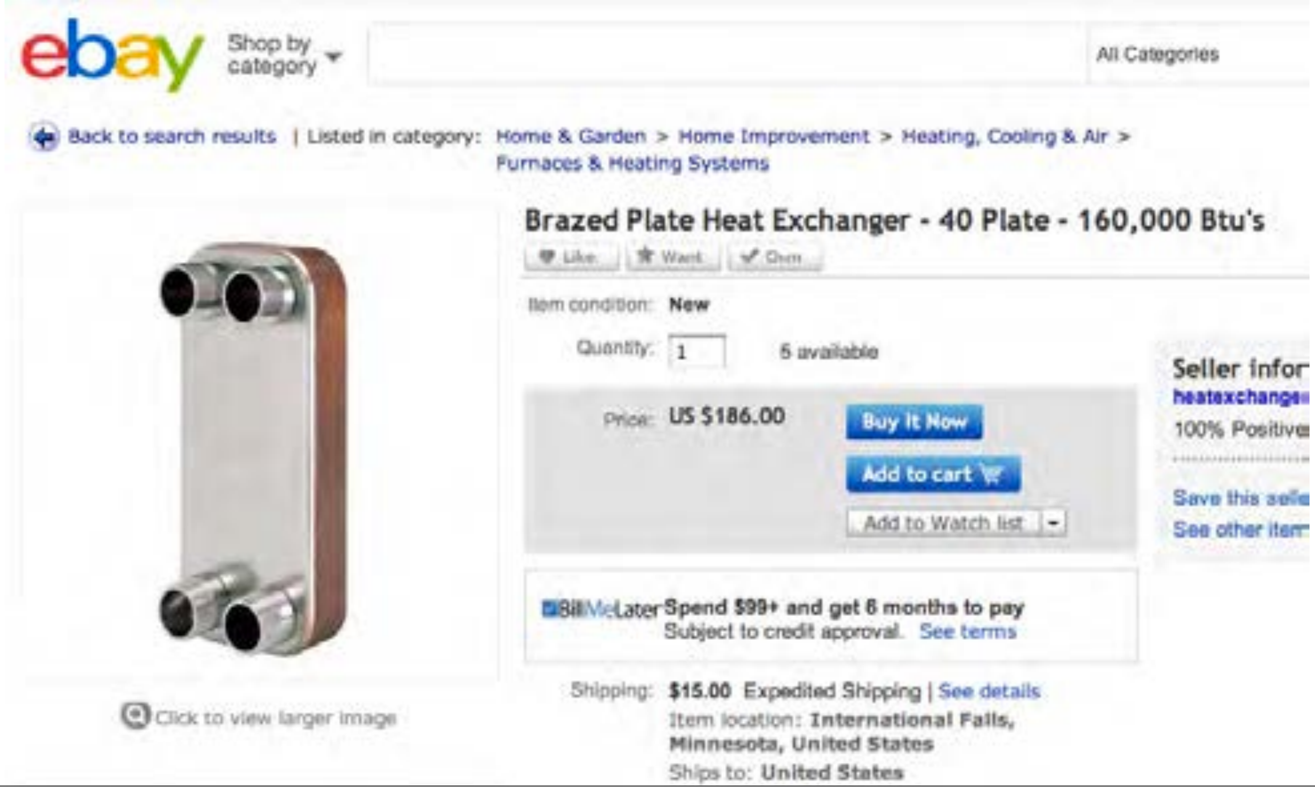
Quantity: 1 More than 10 available / 2 sold

Price: US $330.00

BillMeLater Spend $99+ and get 6 months to pay
Subject to credit approval. See terms

Shipping: FREE Standard Shipping | See details

Seller inform
alternativeheat (3
99.9% Positive fe



Back to search results | Listed in category: Home & Garden > Home Improvement > Heating, Cooling & Air > Furnaces & Heating Systems

Brazed Plate Heat Exchanger - 40 Plate - 160,000 Btu's

Item condition: New

Quantity: 1 5 available

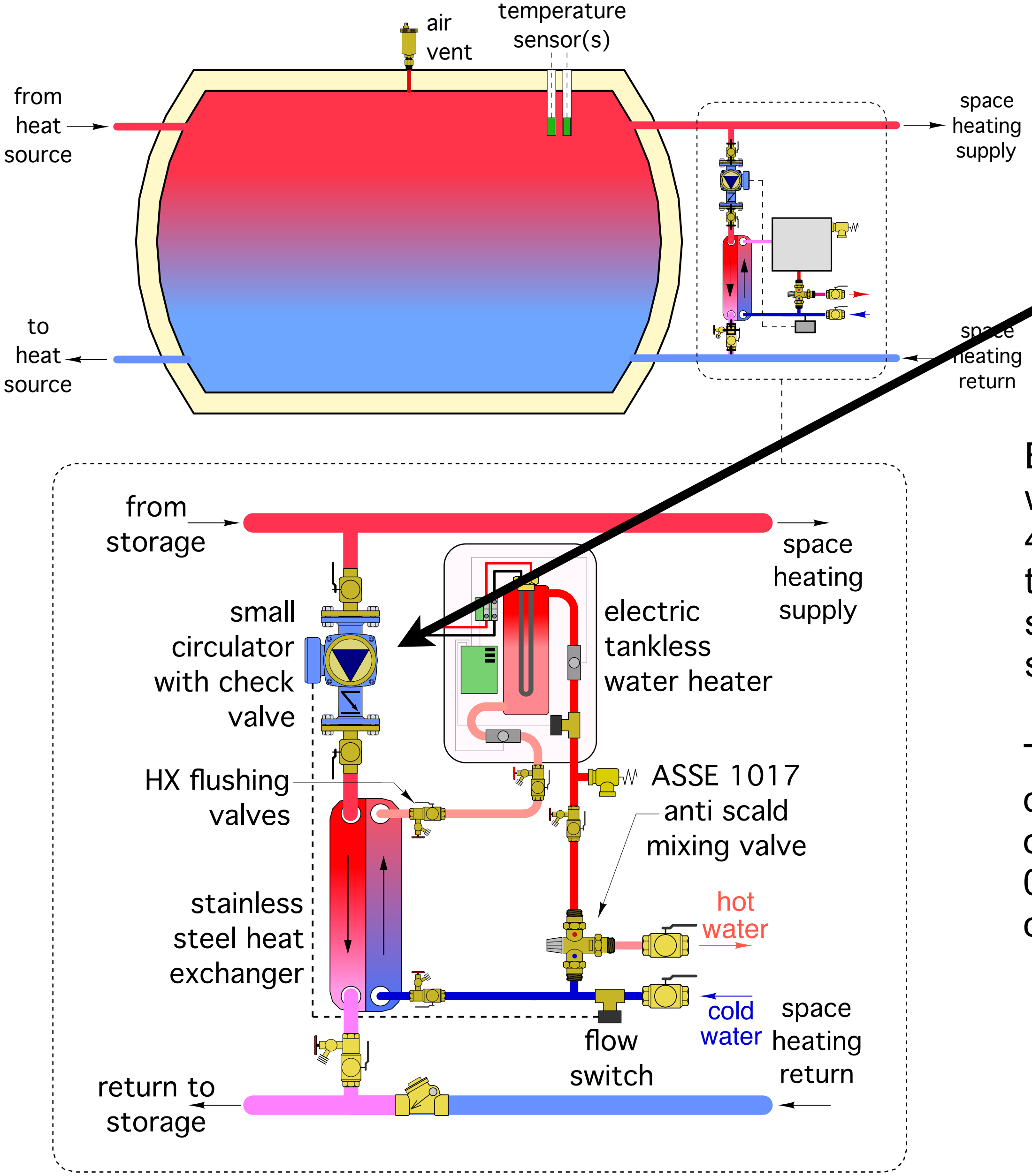
Price: US $186.00

BillMeLater Spend $99+ and get 6 months to pay
Subject to credit approval. See terms

Shipping: $15.00 Expedited Shipping | See details
Item location: International Falls, Minnesota, United States
Ships to: United States

Seller infor
heatexchange
100% Positive

Instantaneous DHW subassembly

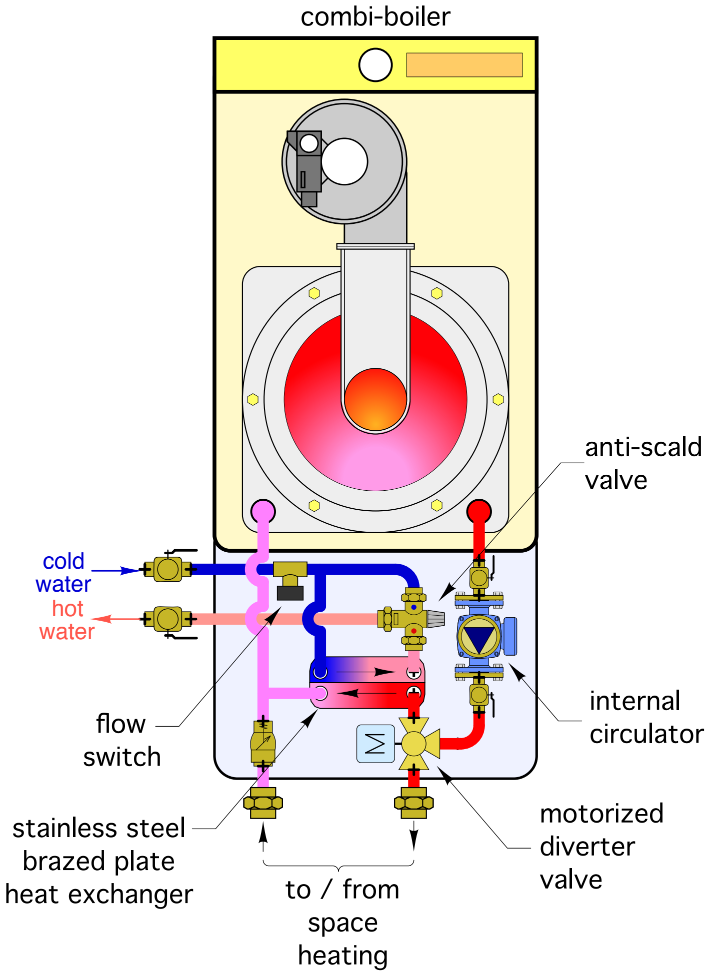


B&G Vario circulator operating at 33 watts yields10 gpm as required to raise 4 gpm of water from 60 to 110 ºF through FG5x12-30 heat exchanger supplied by 120ºF water from thermal storage.

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.

Other tankless water heater options

combi-boiler

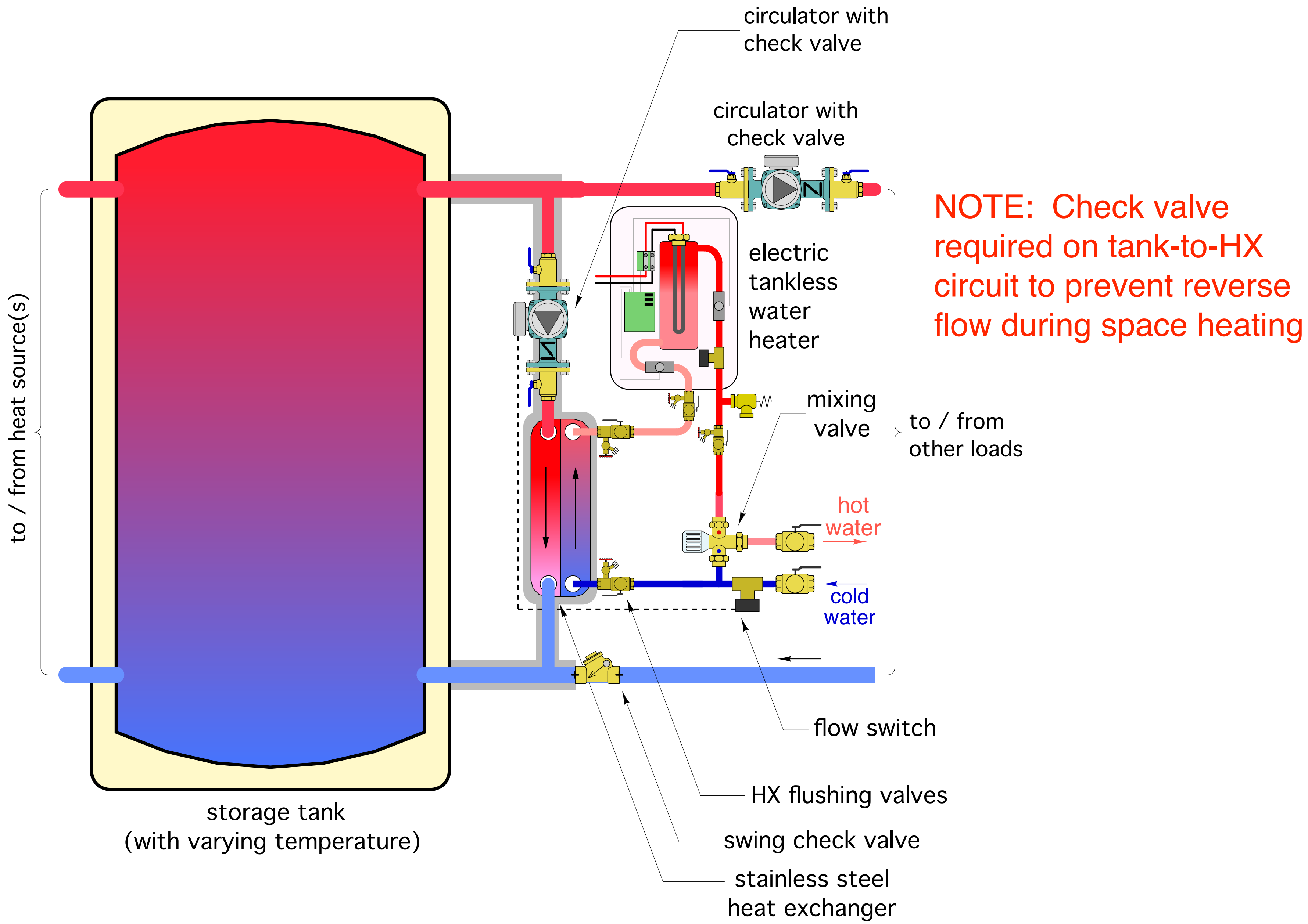


gas-fired tankless

Response time from cold start to near steady state at delivery temperature (20-30 seconds)

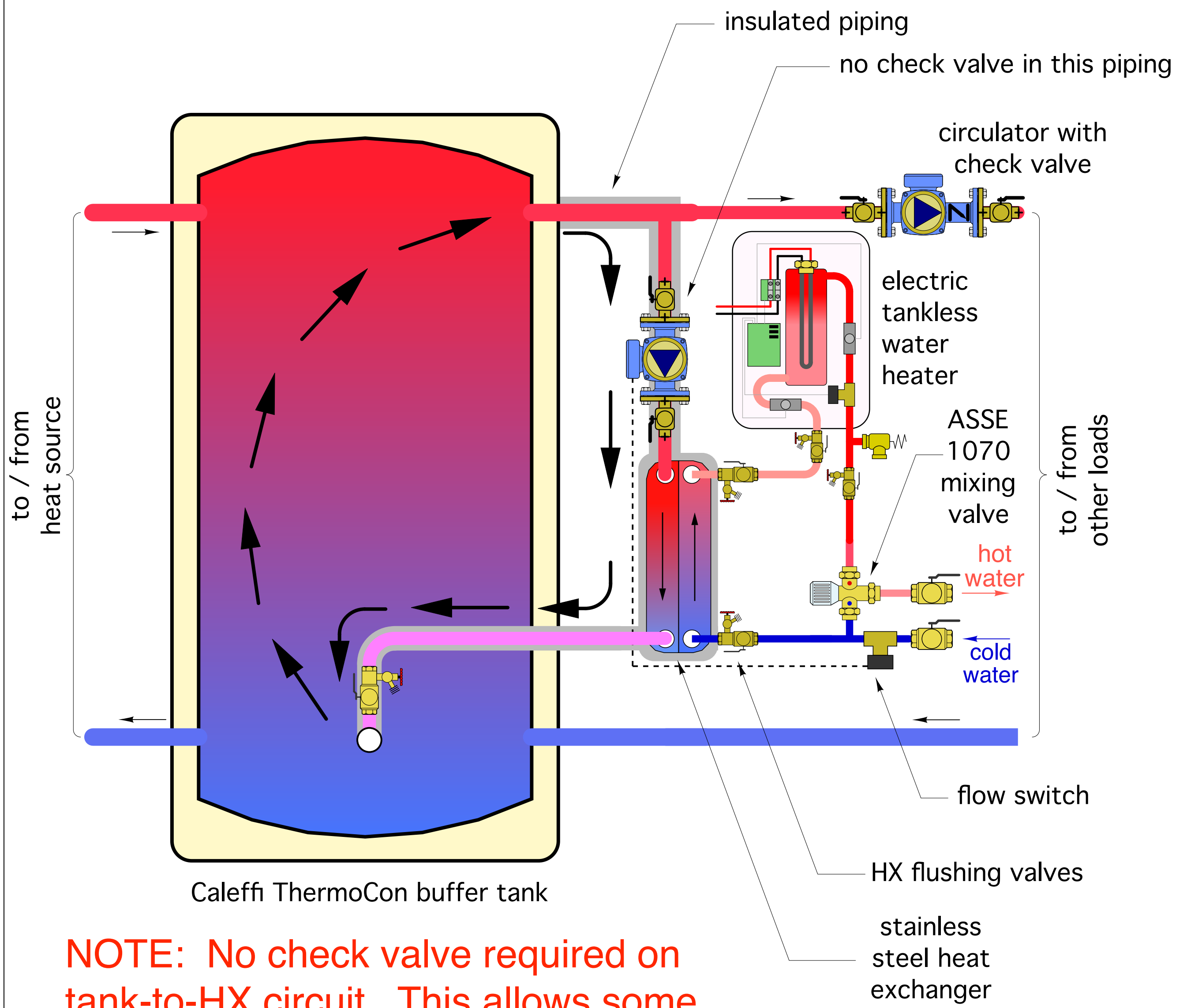
All gas fired equipment needs gas supply, venting,and electrical connections

Instantaneous DHW subassembly piping



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

Instantaneous DHW subassembly



insulated piping

no check valve in this piping

circulator with check valve

electric tankless water heater

ASSE 1070 mixing valve

hot water

cold water

to / from heat source

to / from other loads

flow switch

HX flushing valves

stainless steel heat exchanger

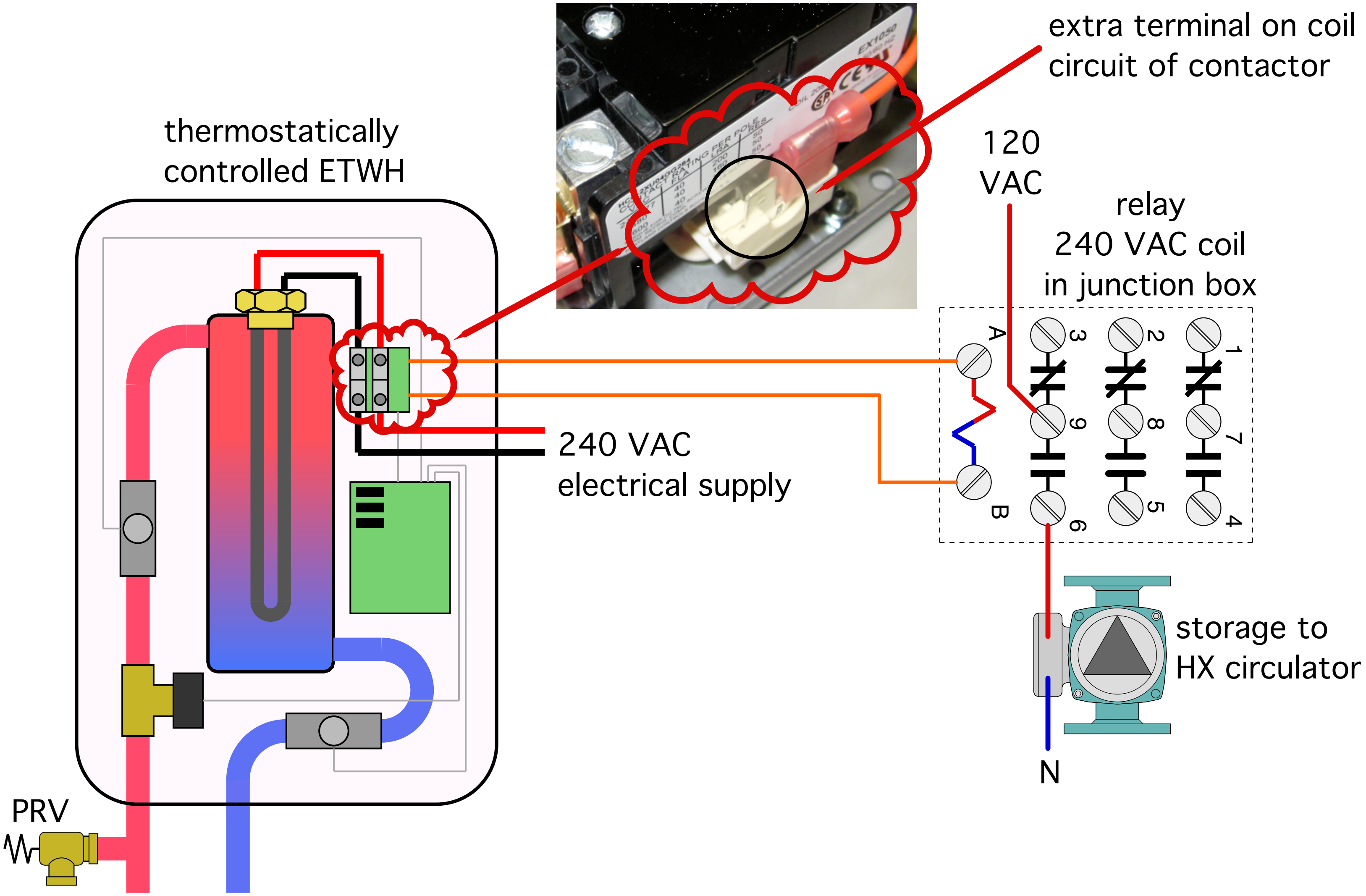
Caleffi ThermoCon buffer tank

NOTE: No check valve required on tank-to-HX circuit. This allows some thermosiphon flow through primary side of HX.

Using extra terminal on ETWH contactor to operate circulator

This eliminates the need for the flow switch.

Contactor inside Eemax EX012240T



extra terminal on coil circuit of contactor

thermostatically controlled ETWH

120 VAC

relay 240 VAC coil in junction box

240 VAC electrical supply

storage to HX circulator

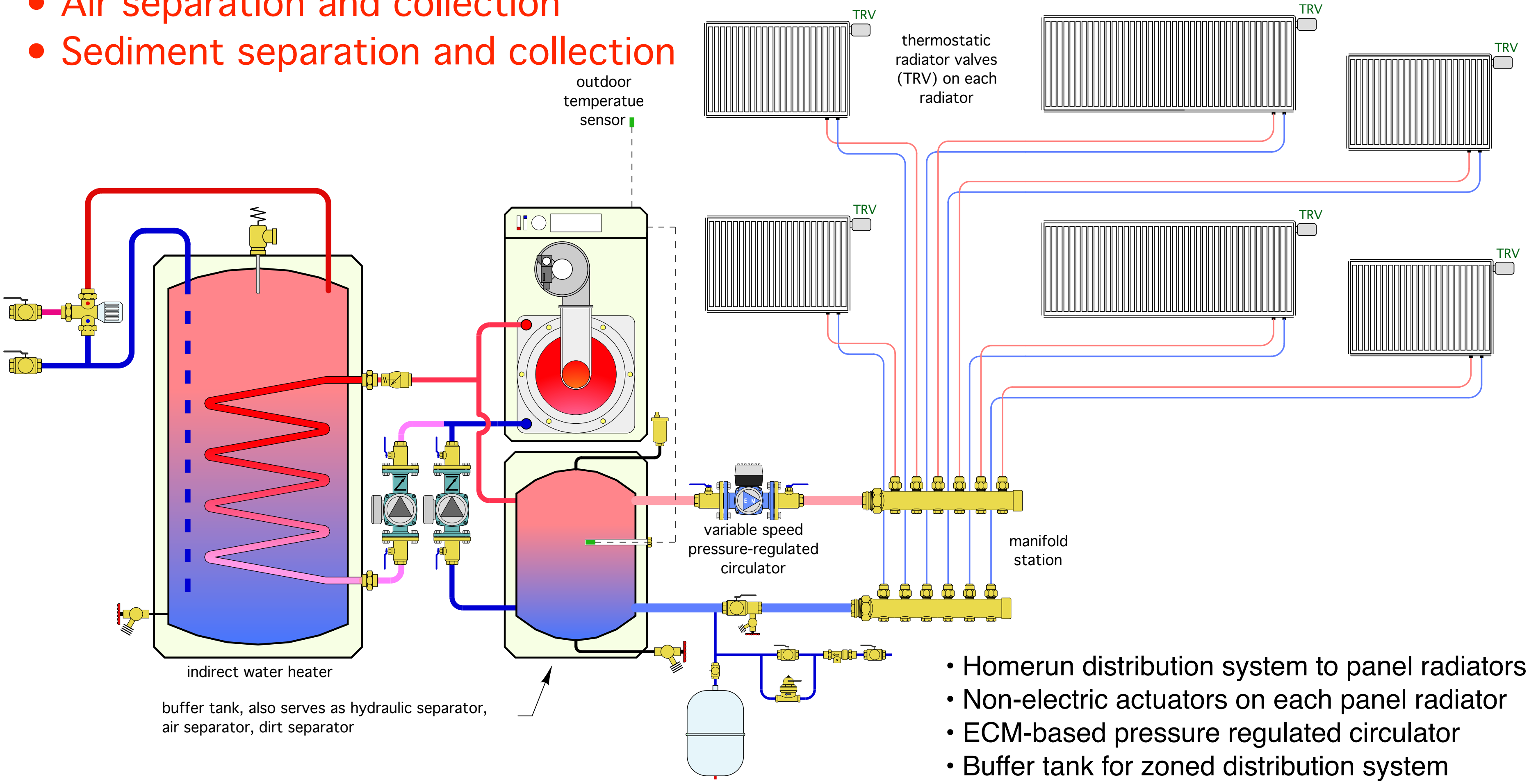
Examples of heating systems for low load homes

Time to put all the pieces together...

System using low mass mod/con boiler, buffer tank, and homerun distribution system

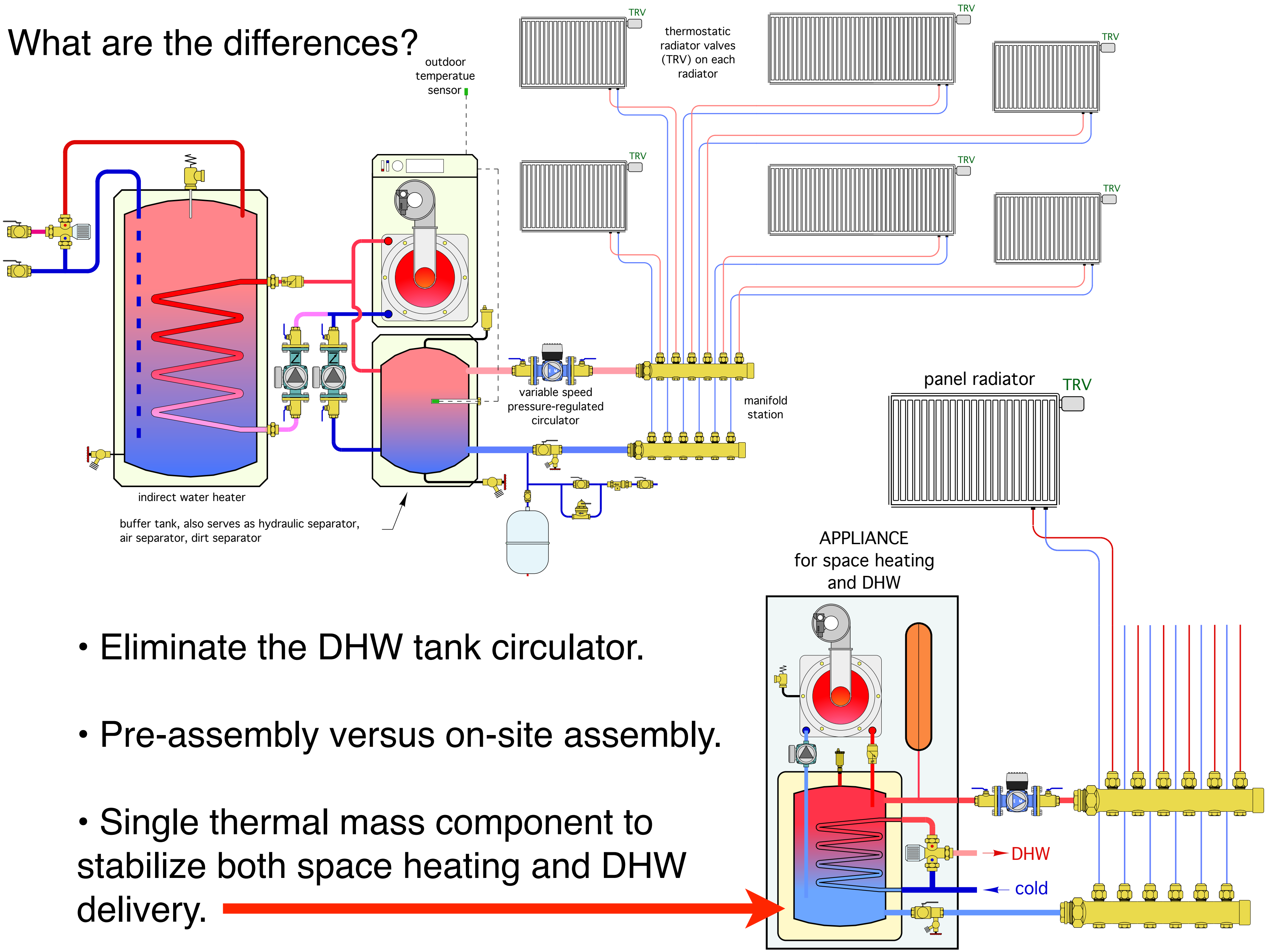
The small insulated tank provides:

- Thermal buffering
- Hydraulic separation
- Air separation and collection
- Sediment separation and collection



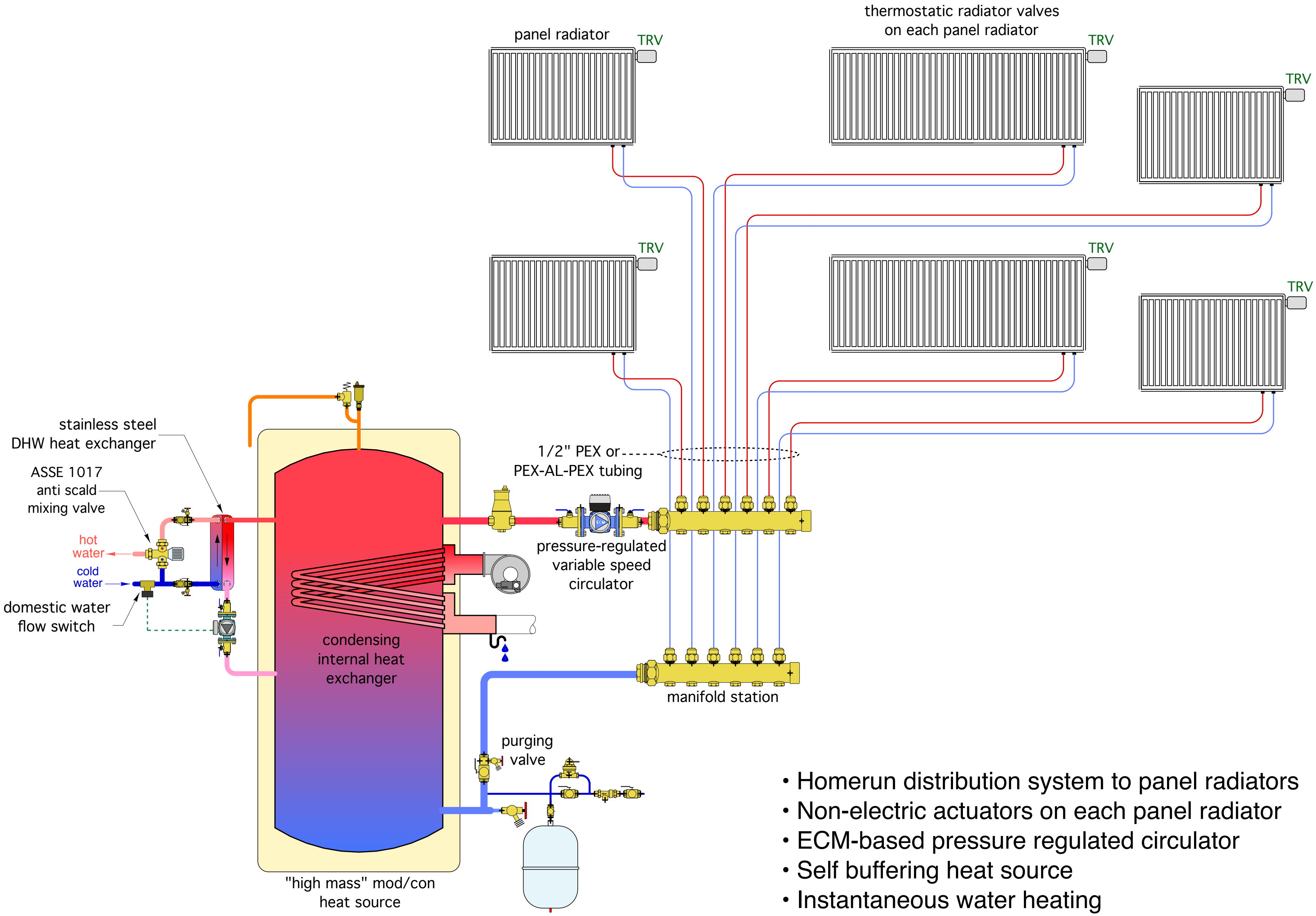
- Homerun distribution system to panel radiators
- Non-electric actuators on each panel radiator
- ECM-based pressure regulated circulator
- Buffer tank for zoned distribution system
- indirect tank for domestic water heating

What are the differences?



- Eliminate the DHW tank circulator.
- Pre-assembly versus on-site assembly.
- Single thermal mass component to stabilize both space heating and DHW delivery.

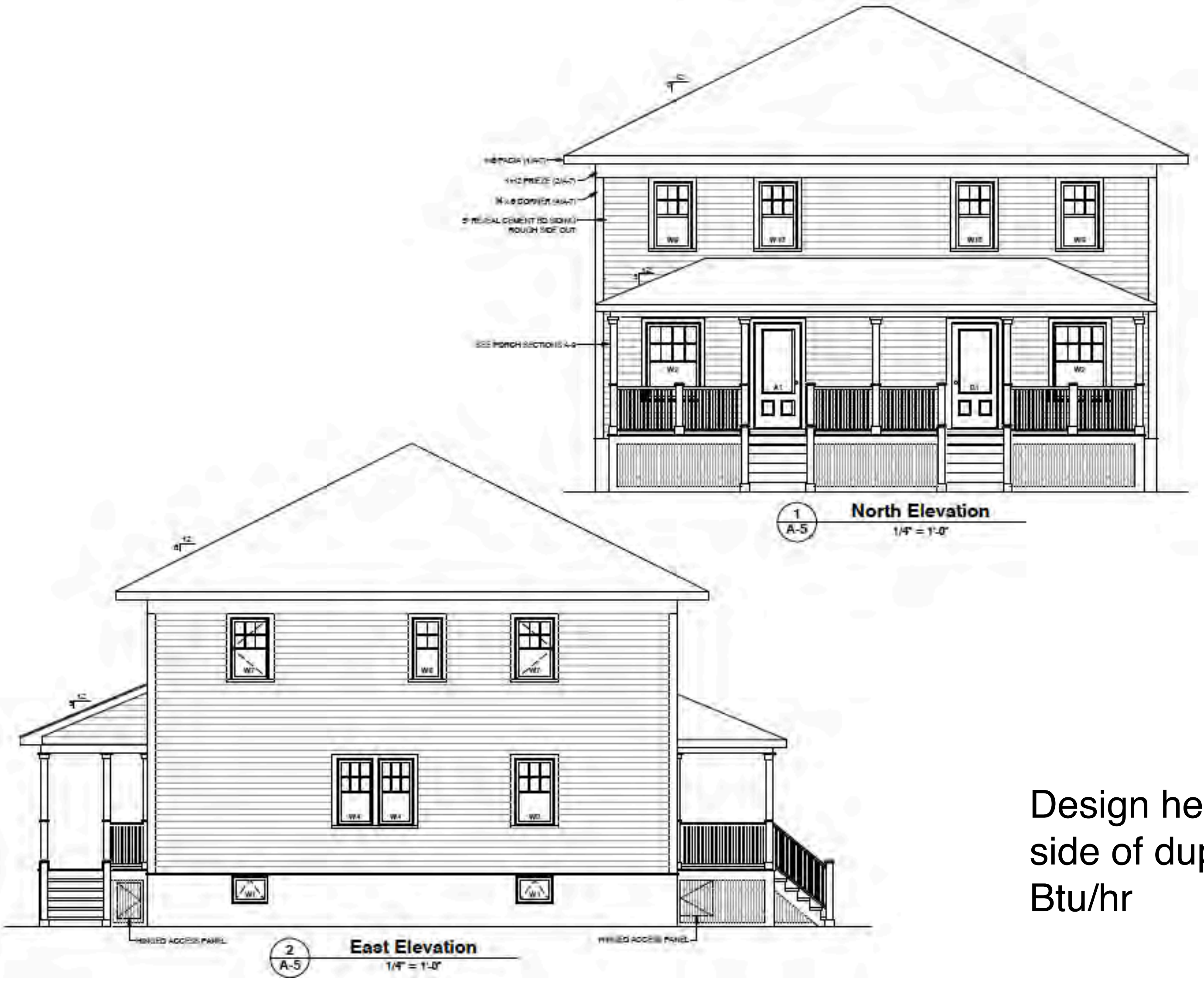
System using high mass mod/con boiler and homerun distribution system



- Homerun distribution system to panel radiators
- Non-electric actuators on each panel radiator
- ECM-based pressure regulated circulator
- Self buffering heat source
- Instantaneous water heating

Systems for a low energy Duplex in Ithaca, NY

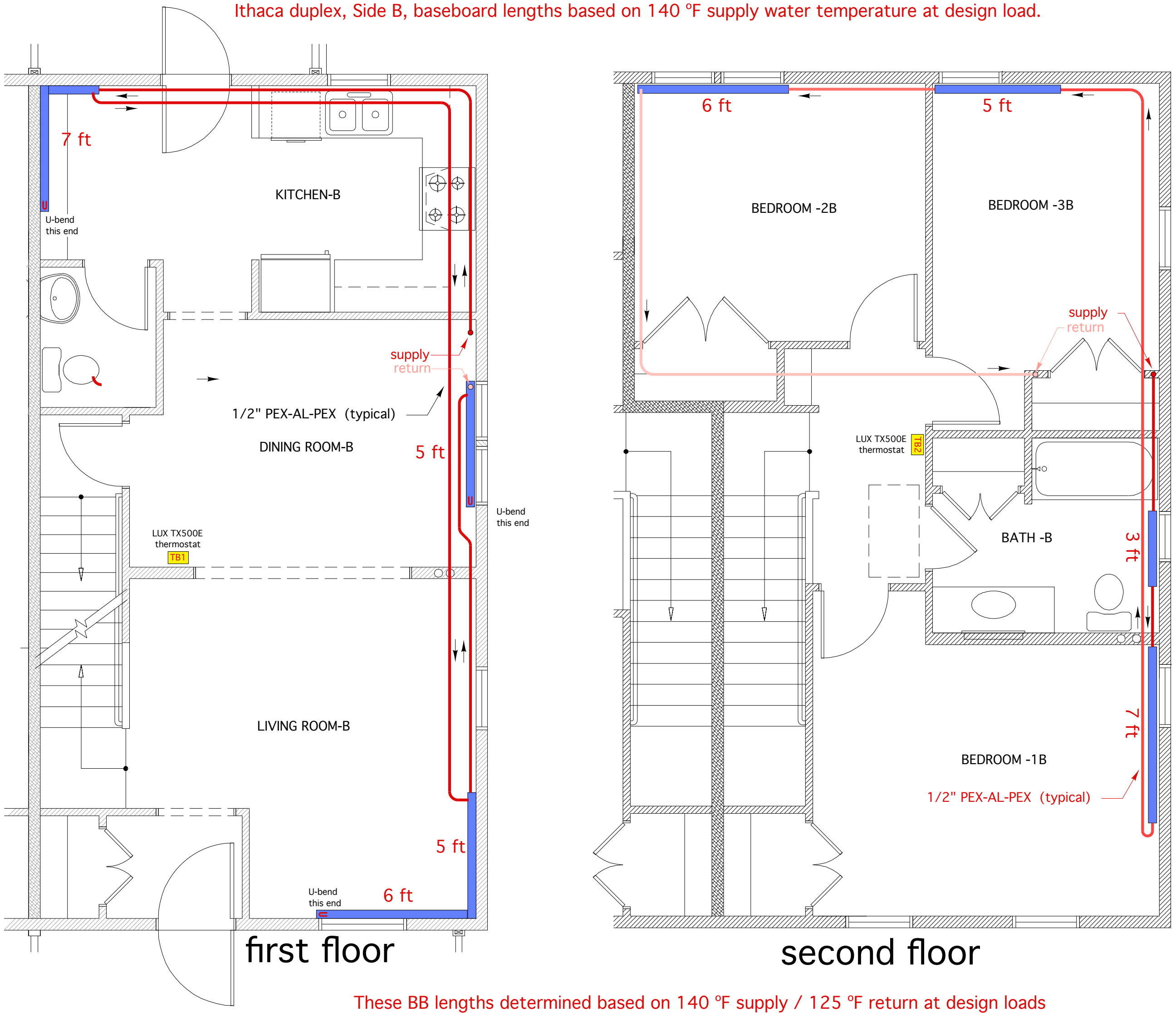
These systems are being installed in early 2012 as part of a DOE ***Building America*** research program coordinated through Steven Winter Associates.



Design heating load on each side of duplex is about 18,000 Btu/hr

Systems for a low energy Duplex in Ithaca, NY

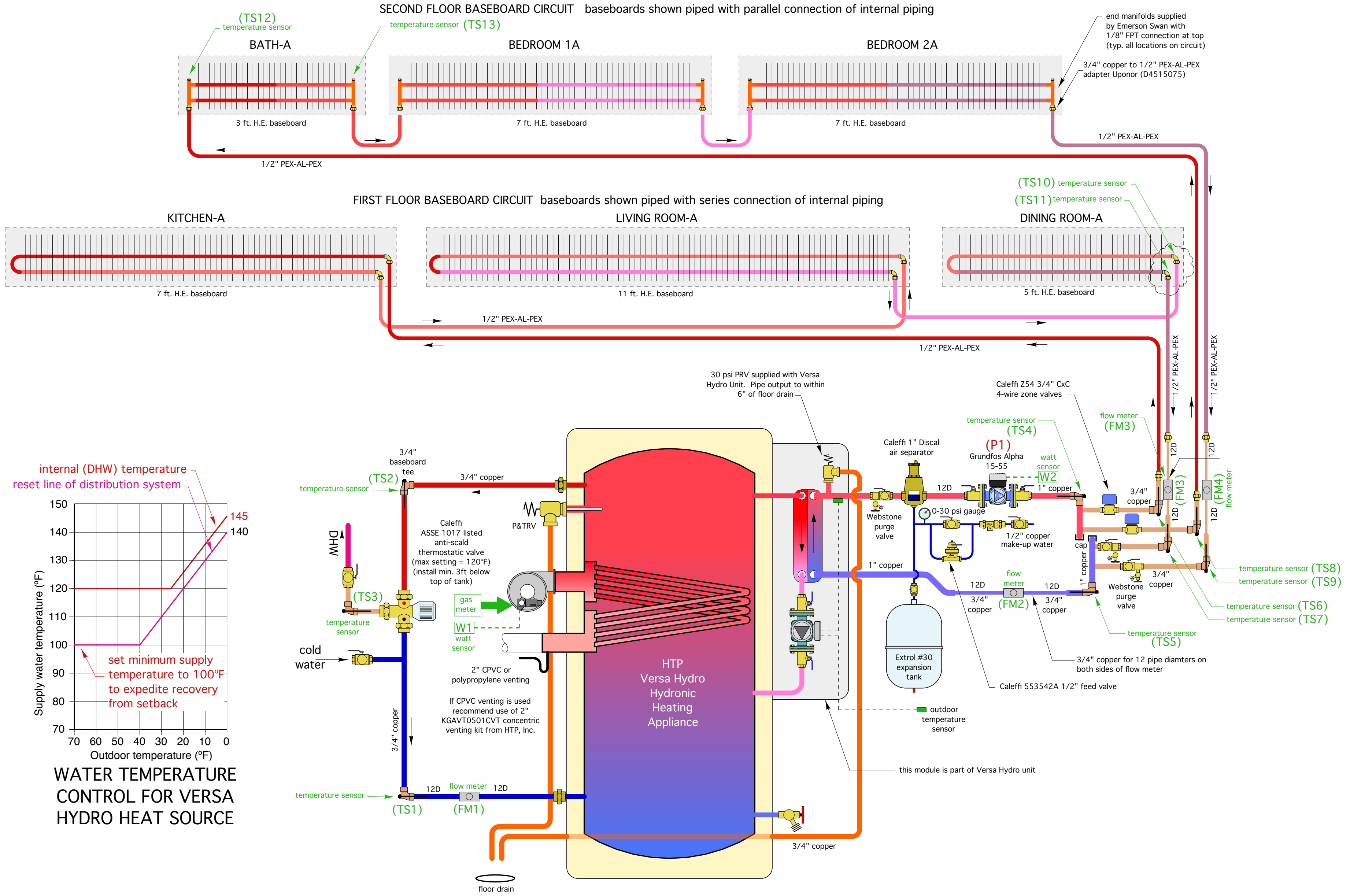
Ithaca duplex, Side B, baseboard lengths based on 140 °F supply water temperature at design load.



These BB lengths determined based on 140 °F supply / 125 °F return at design loads
1 gpm flow in each circuit.
Series baseboard piping

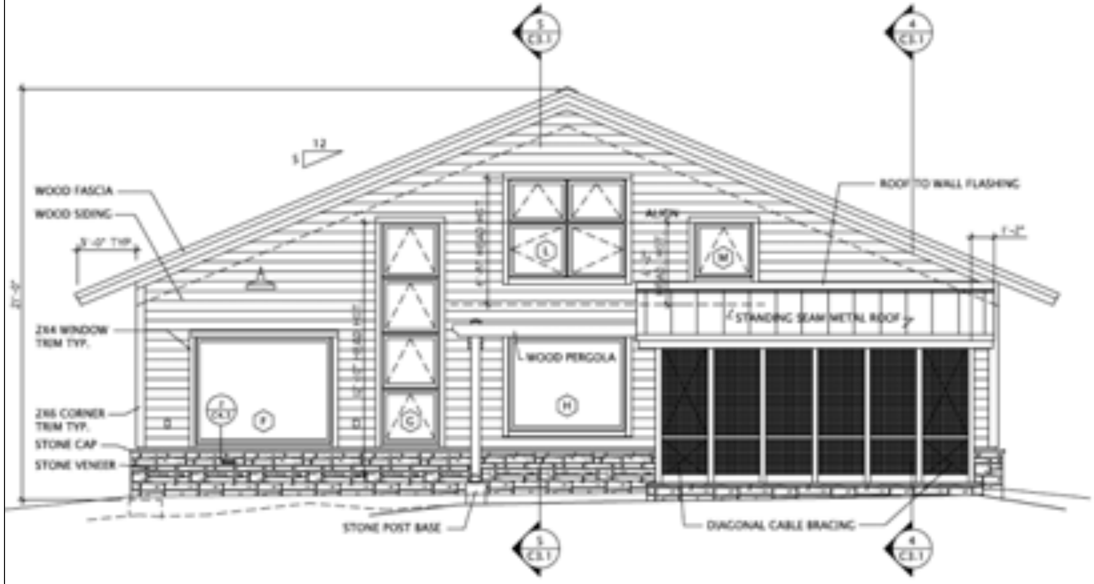
total baseboard:	
first floor:	23 ft
second floor:	21 ft
TOTAL:	44 ft.

Systems for a low energy Duplex in Ithaca, NY

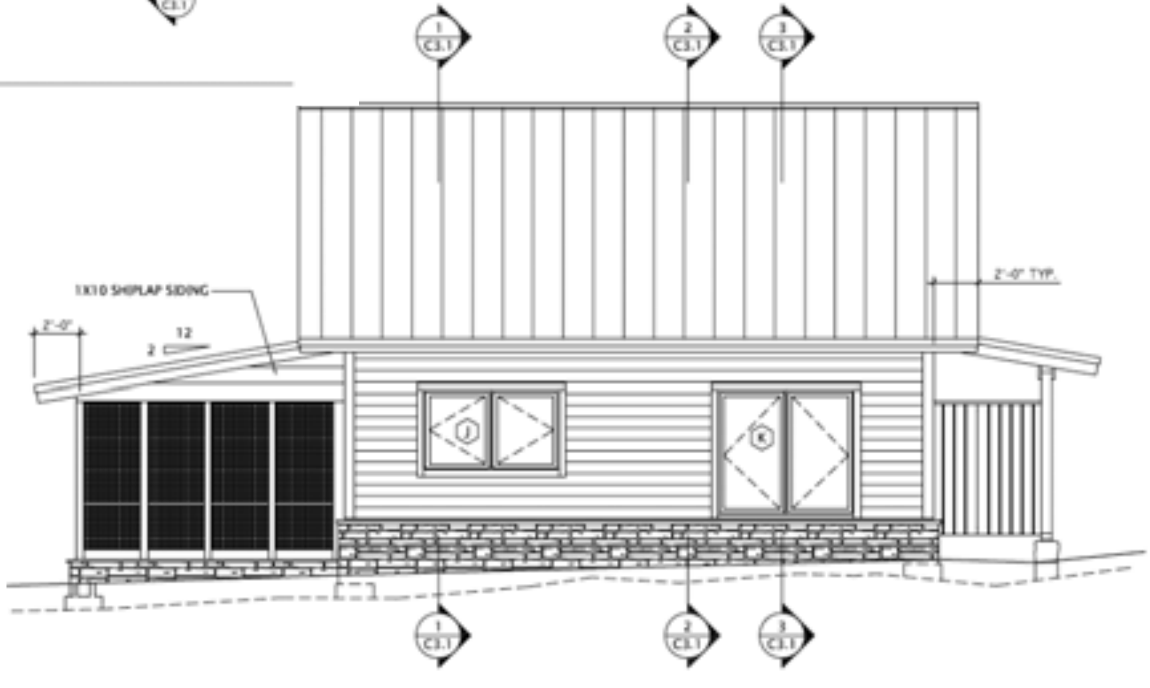


WATER TEMPERATURE CONTROL FOR VERSA HYDRO HEAT SOURCE

Ojibway Lake Cabin (by Wagner Zaun Architecture)

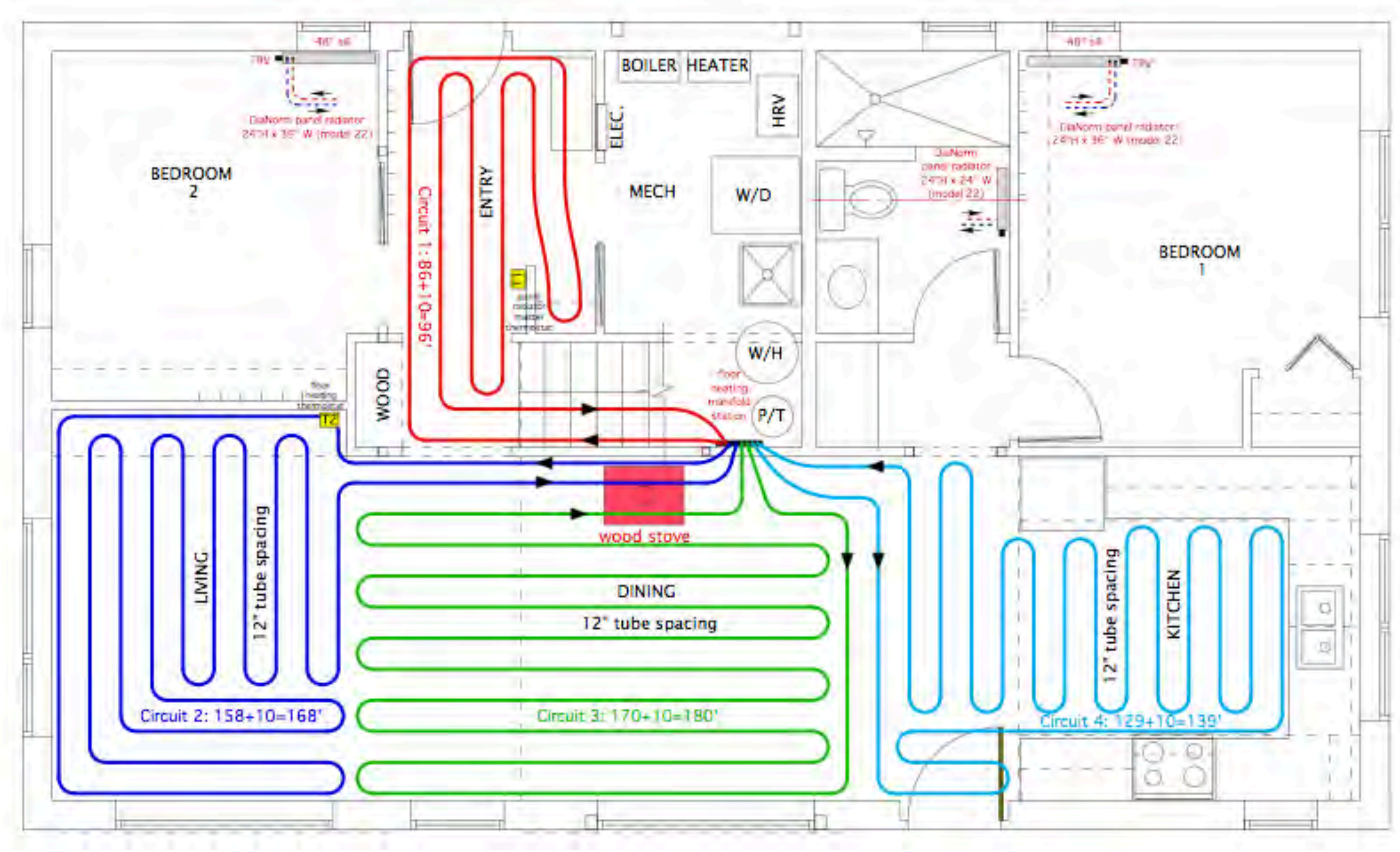


2
C2.1
SOUTH ELEVATION
1/4" = 1'-0"

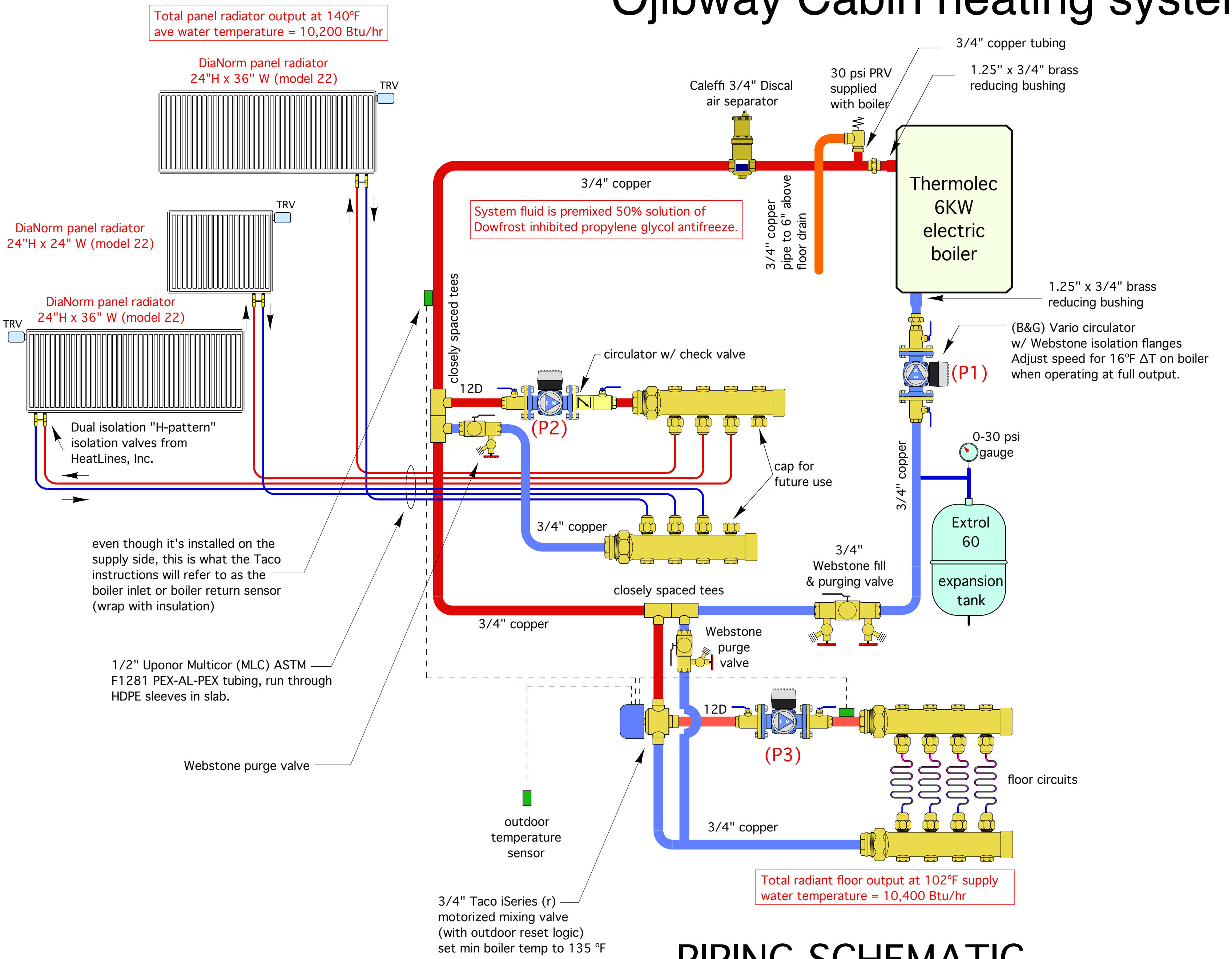


3
C2.1
EAST ELEVATION
1/4" = 1'-0"

Ojibway Cabin heating system



Ojibway Cabin heating system



PIPING SCHEMATIC

Examples of solar combisystems for low load homes

Solar Thermal Combisystems

What makes sense for modern combisystems?

Think of the system as "solar DHW +" (e.g partial space heating in shoulder months)

- 4 to perhaps 8 (4'x8') collectors
- 119 to 250 gallons very well insulated storage

Low temperature heat emitters:

- provide design load heat output at supply water temperature of 120 ºF or less

Room-by-room zoning:

- keep it simple with thermostatic radiator valves
- avoid zoning with multiple zone circulators (unless very low wattage <10 watts per zone)

Single storage mass provides:

- solar storage,
- DHW reserve capacity
- space heat buffering

High efficiency distribution circulator(s)

- ECM-based pressure regulated circulators

Highly pre-engineered / pre-assembled systems: 1. Appliance 2. Solution

- minimal "customization" on site

This is a **NOT** a realistic solar combisystem...

This is a “SOLAR MONUMENT”

Likely to produce much excess heat (& associated problems) in summer

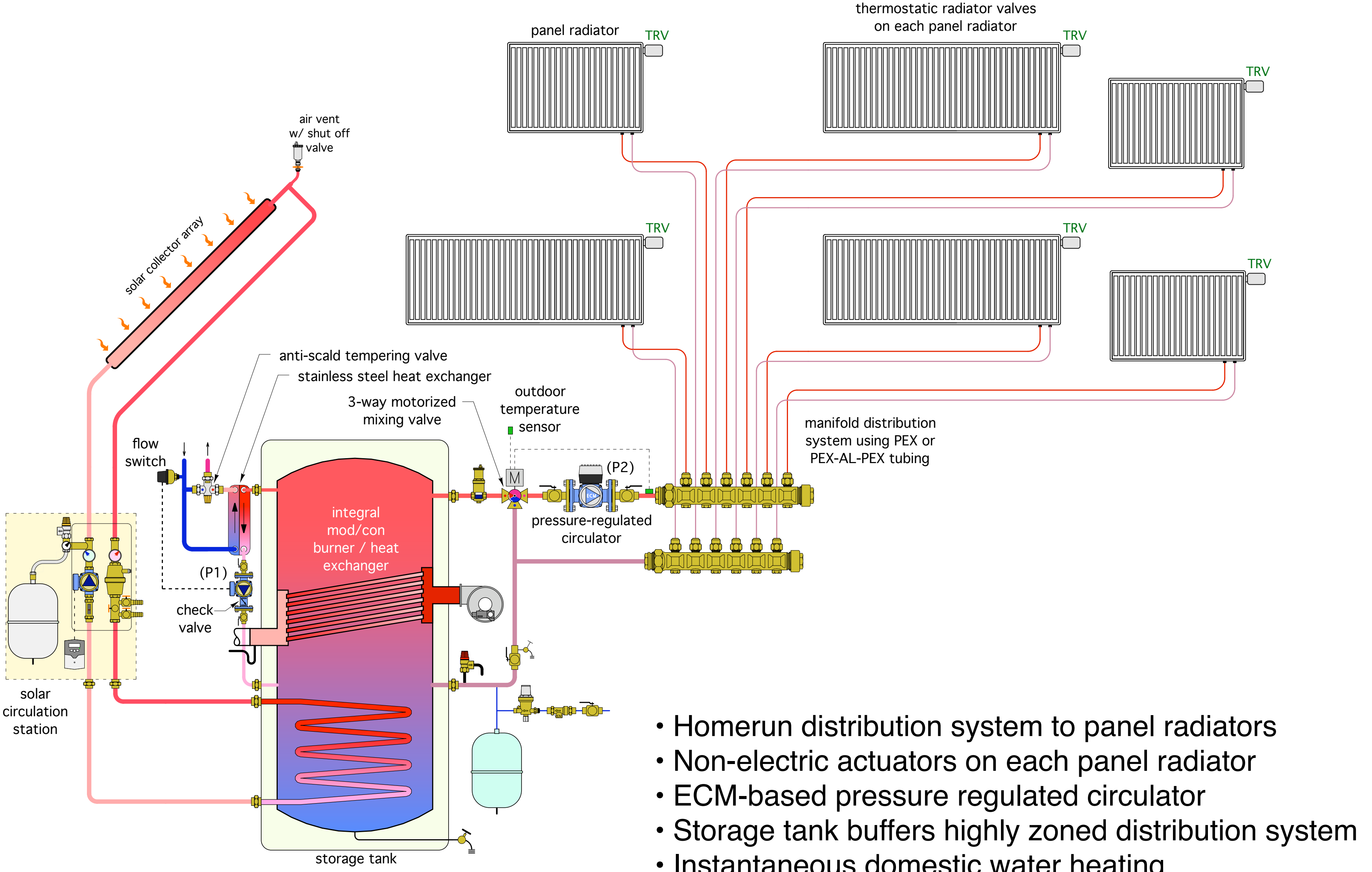
This is for owners who want to appear **GREEN**, and have a lot of **$$$,$$$.00** to work with...

My own solar drainback system


First 30 years

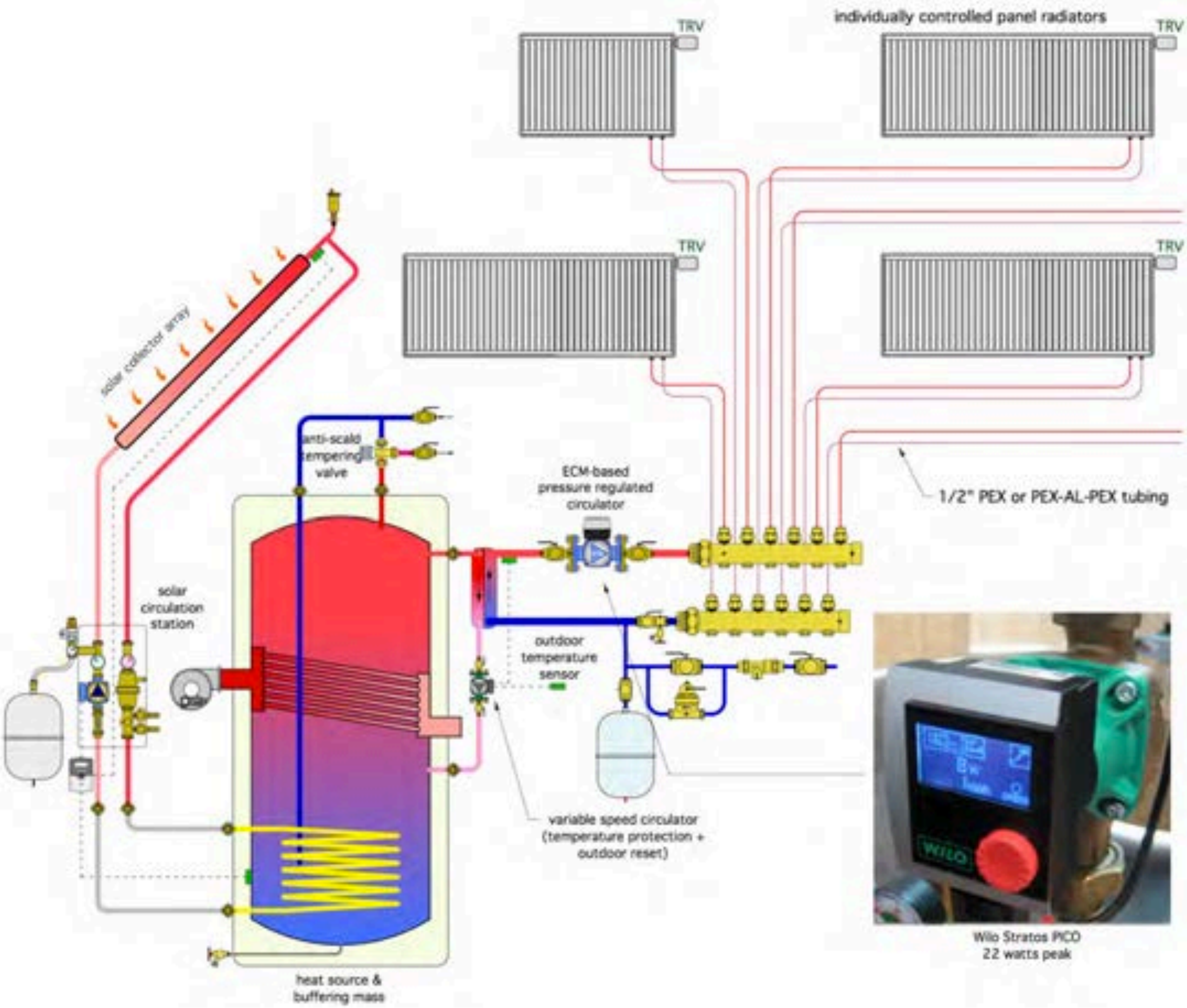

Next 30 years

Concept for solar thermal combisystem - ANTIFREEZE BASED

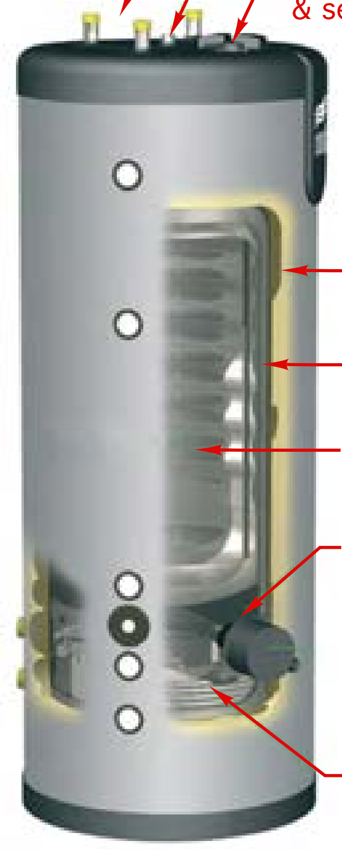


- Homerun distribution system to panel radiators
- Non-electric actuators on each panel radiator
- ECM-based pressure regulated circulator
- Storage tank buffers highly zoned distribution system
- Instantaneous domestic water heating
- Minimal domestic water storage volume

Domestic water heater with “sidearm” for space heating



System using low mass mod/con boiler, drainback solar collector array, thermal accumulator tank, and homerun distribution system



potable water connections and P&TRV connection

air vent connection

thermostat & sensor well

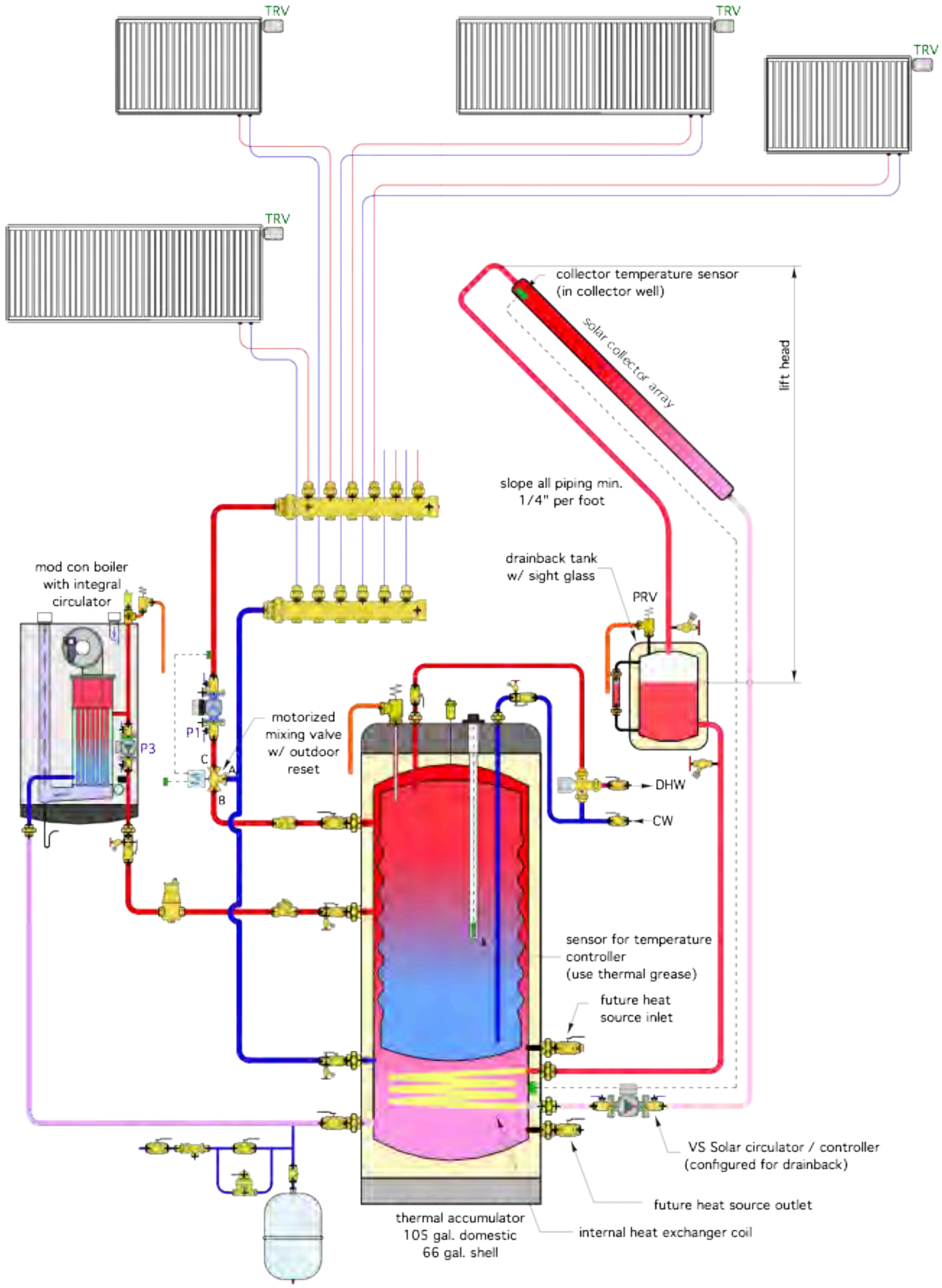
foam insulation

outer carbon steel shell

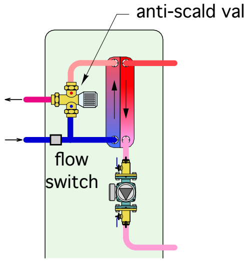
stainless steel DHW vessel

optional electric element for off-peak electrical heating

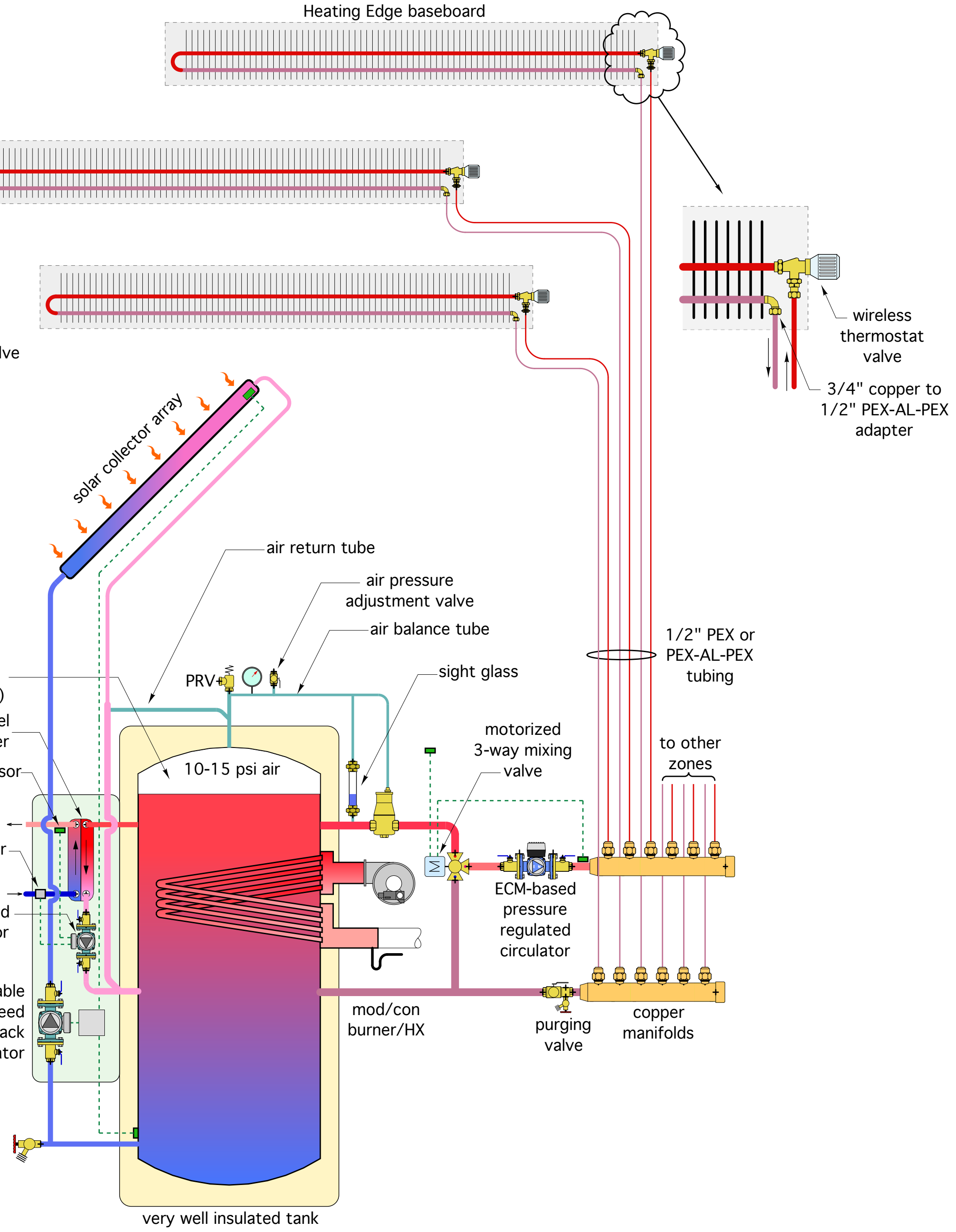
internal heat exchanger for solar heat input

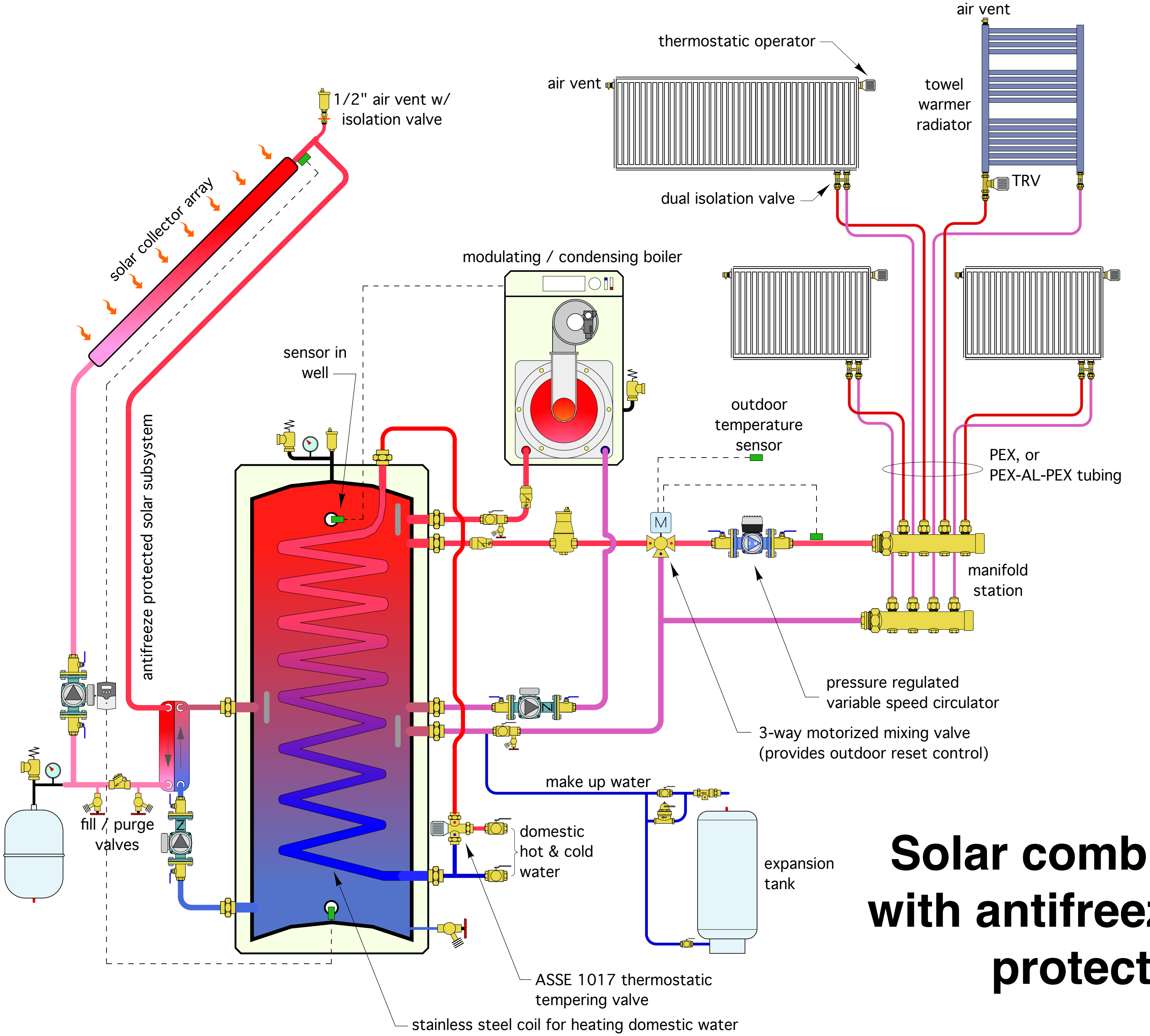


Solar combisystem with drainback freeze protection and low water temperature baseboard



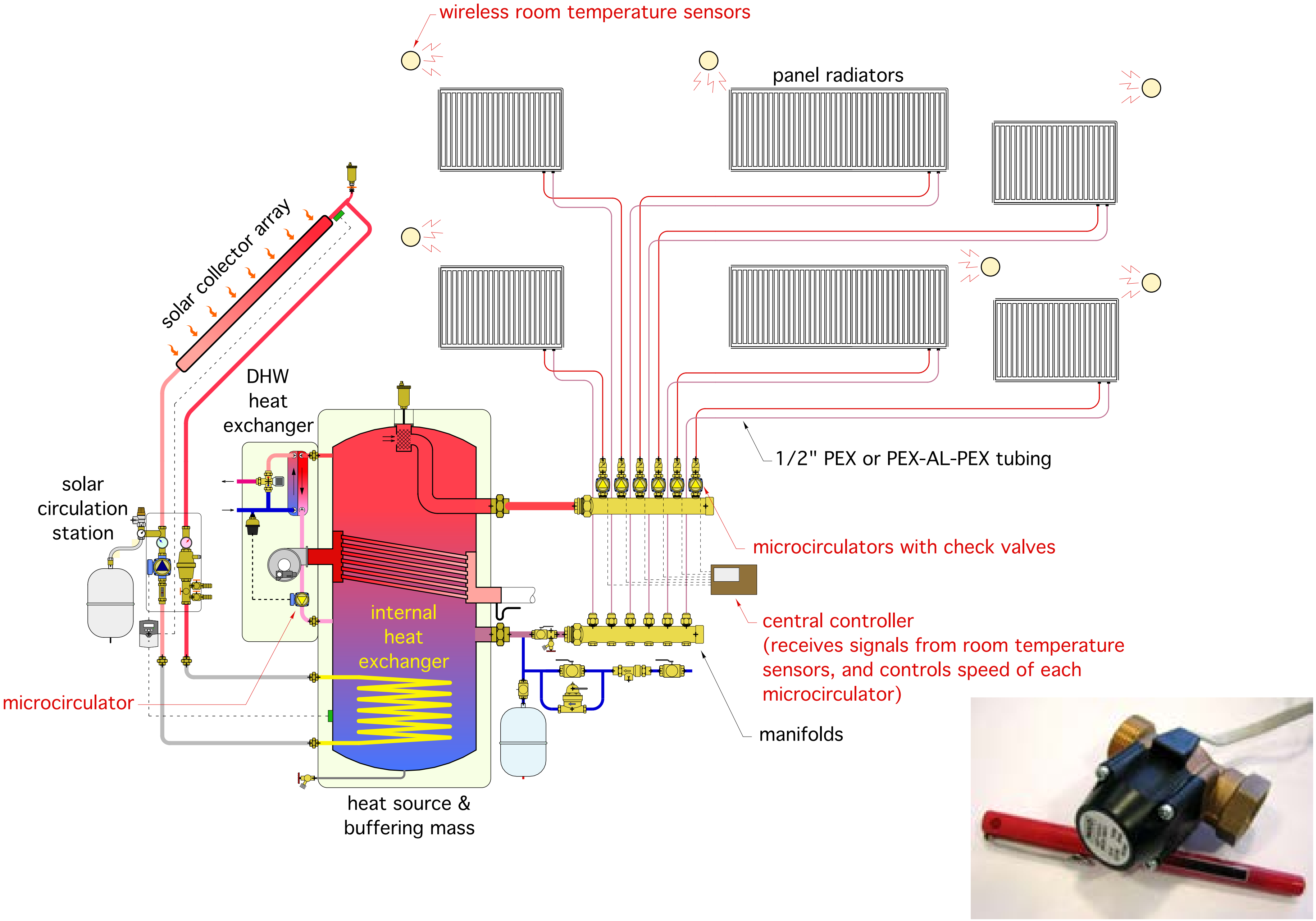
alternate DHW temperature control with thermostatic valve





Solar combisystem with antifreeze freeze protection

Zoning with micro-circulators (with a solar assist…)



wireless room temperature sensors

panel radiators

solar collector array

DHW
heat
exchanger

solar
circulation
station

1/2" PEX or PEX-AL-PEX tubing

microcirculators with check valves

internal
heat
exchanger

microcirculator

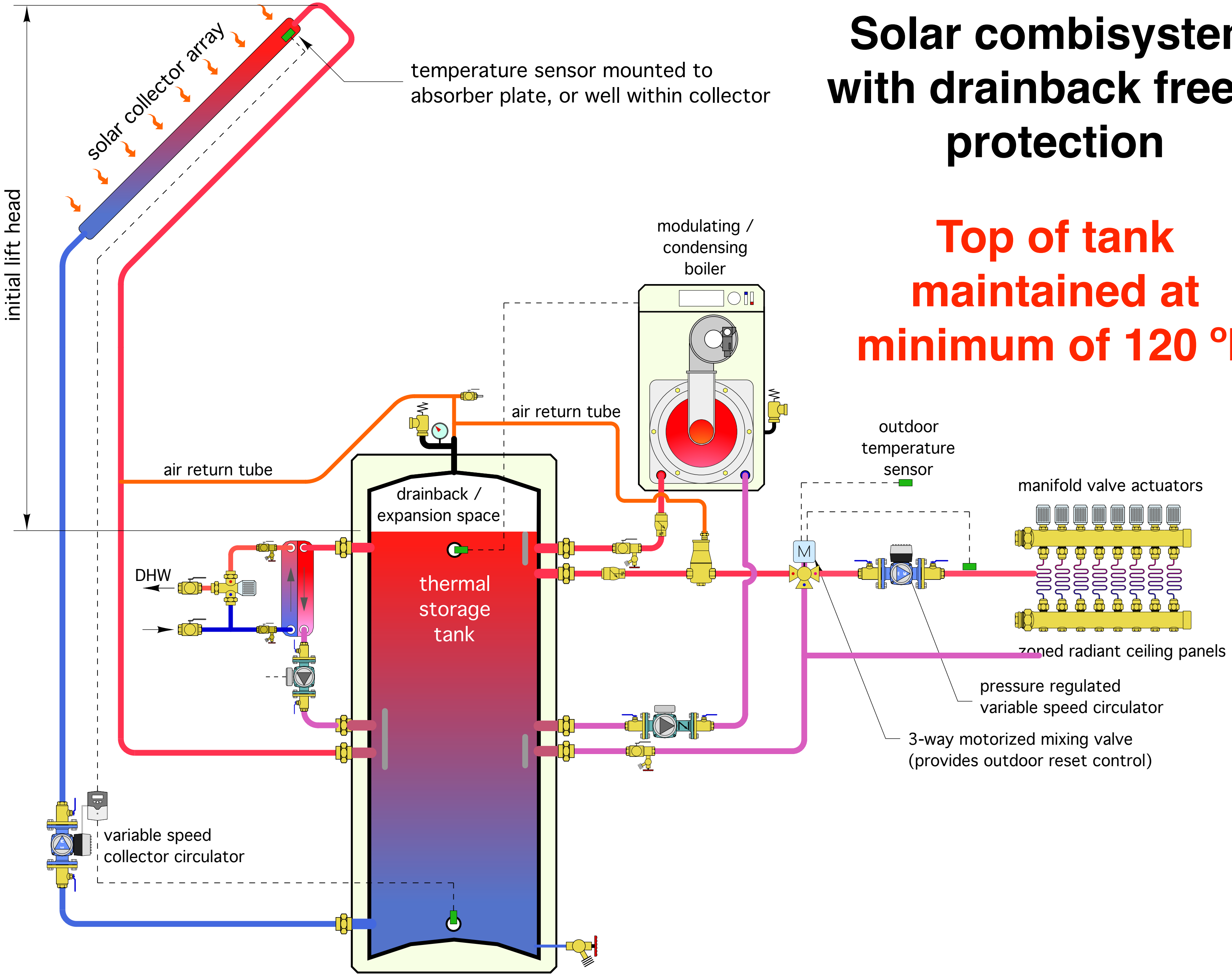
central controller
(receives signals from room temperature
sensors, and controls speed of each
microcirculator)

manifolds

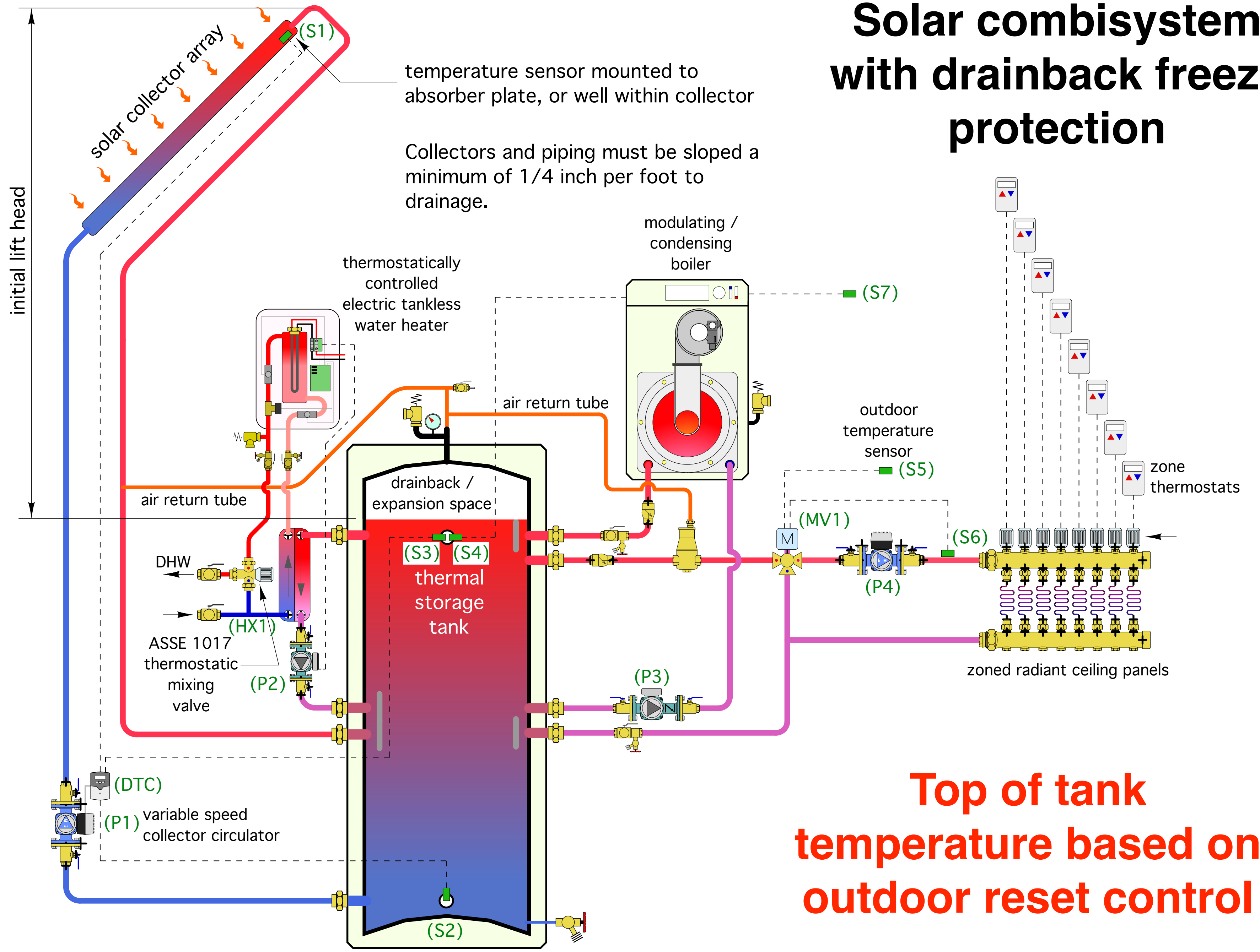
heat source &
buffering mass

Solar combisystem with drainback freeze protection

Top of tank maintained at minimum of 120 °F



Solar combisystem with drainback freeze protection

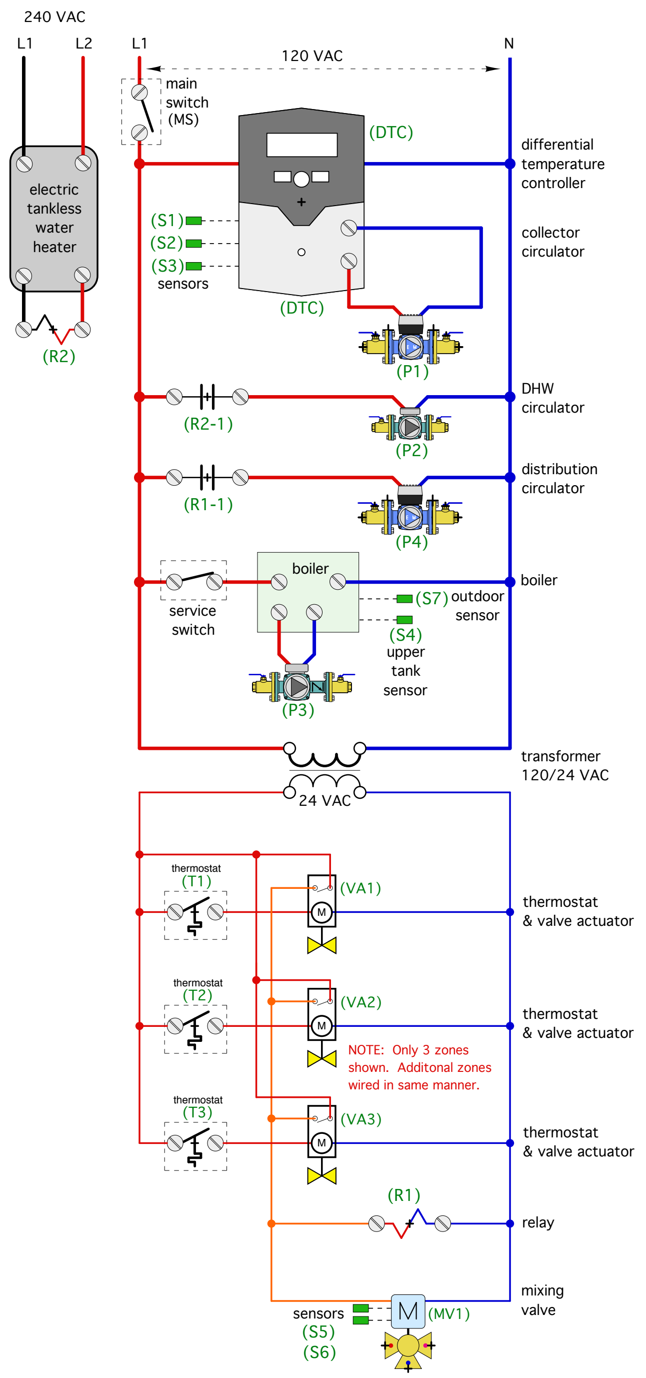


temperature sensor mounted to absorber plate, or well within collector

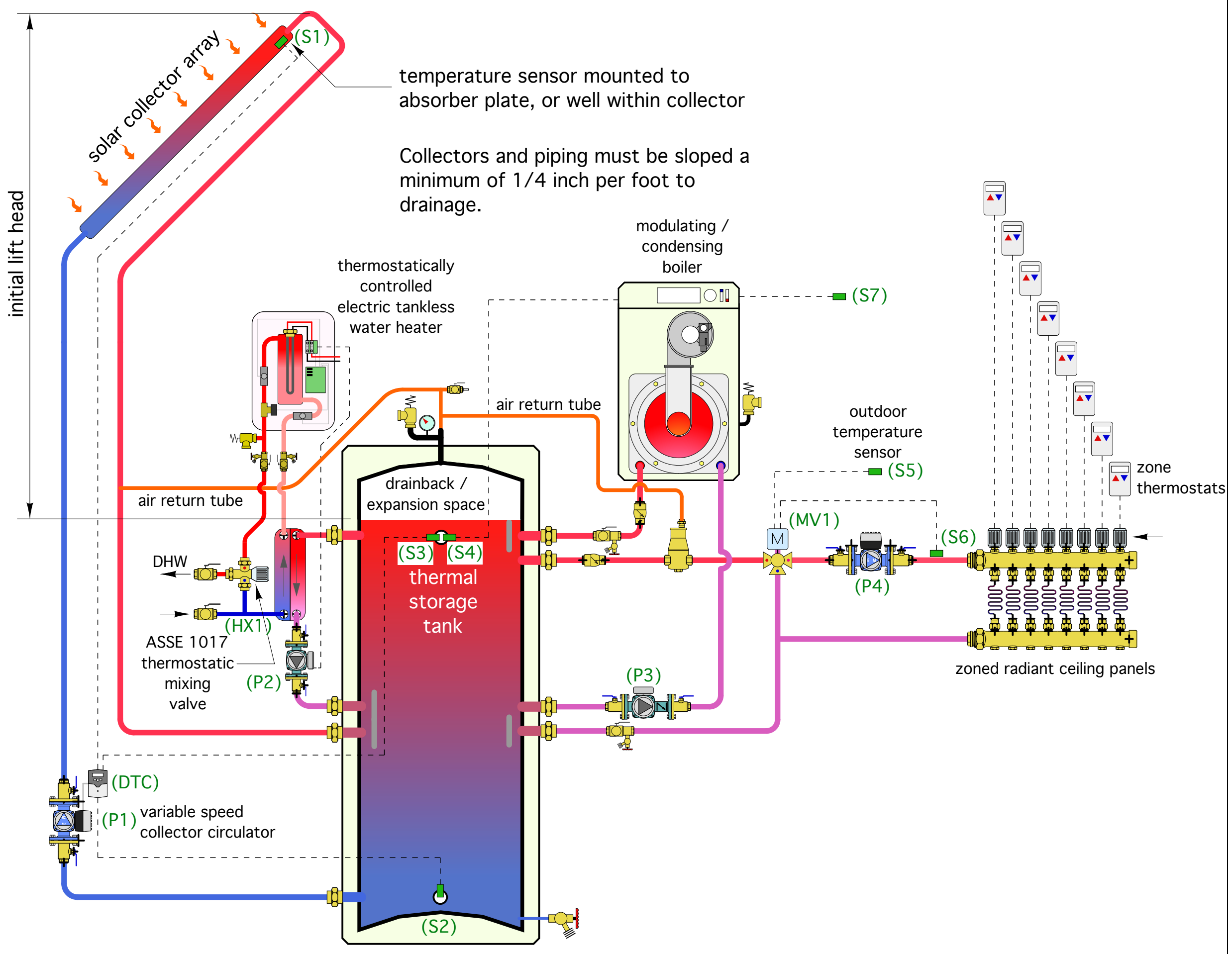
Collectors and piping must be sloped a minimum of 1/4 inch per foot to drainage.

Top of tank temperature based on outdoor reset control

Solar combisystem with drainback freeze protection



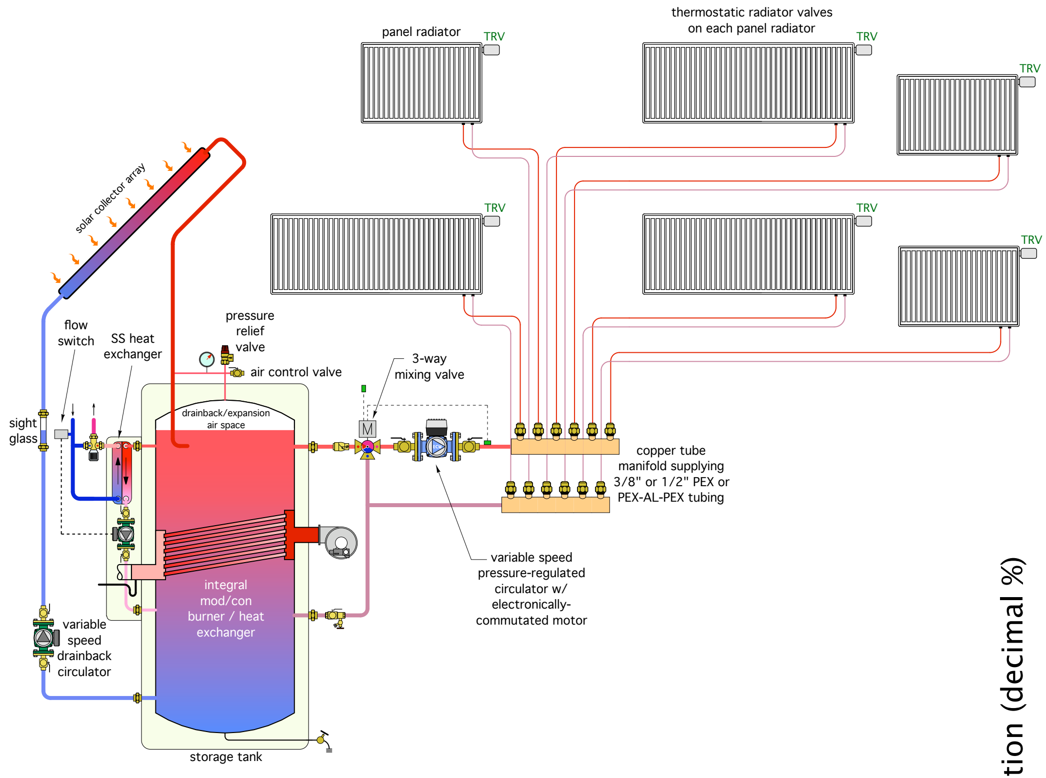
NOTE: Only 3 zones shown. Additonal zones wired in same manner.



temperature sensor mounted to absorber plate, or well within collector

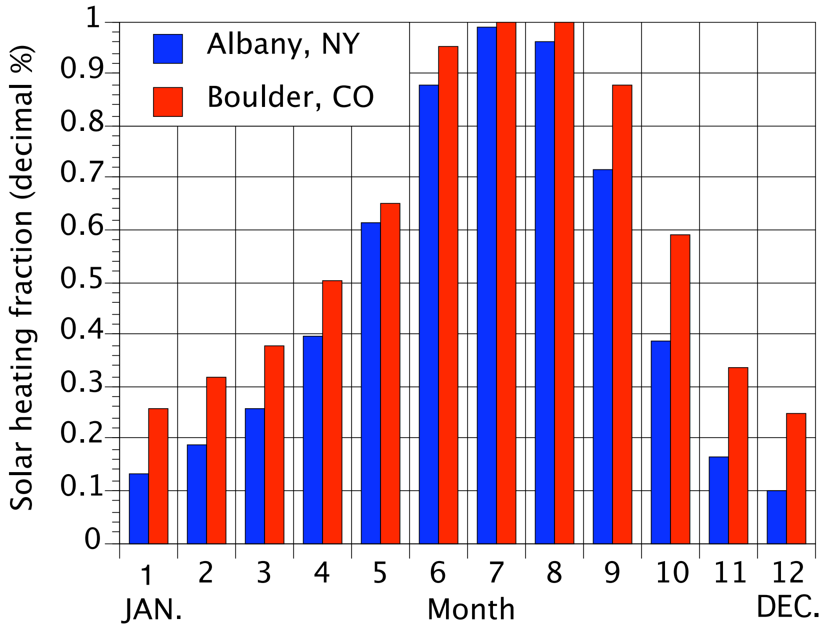
Collectors and piping must be sloped a minimum of 1/4 inch per foot to drainage.

Solar combisystem performance in a 1500 ft² well-insulated house



- four, 4x8 foot flat plate collectors
- collector efficiency line intercept = 0.76
- collector efficiency line slope = 0.865 Btu/hr/ft²/°F
- collector slope = latitude +15°
- collector azimuth = 180° (directly south)
- 119 gallon, well-insulated storage tank
- DHW = 60 gallons /day heated from 50 to 120°F

The design space heating load of the 1500 square foot well-insulated house was set at 15 Btu/hr/ft², or 22,500 Btu/hr total, with an indoor temperature of 70 °F and outdoor design temperature of 0 °F. This yields an overall heat transfer coefficient of 321 Btu/hr/°F.

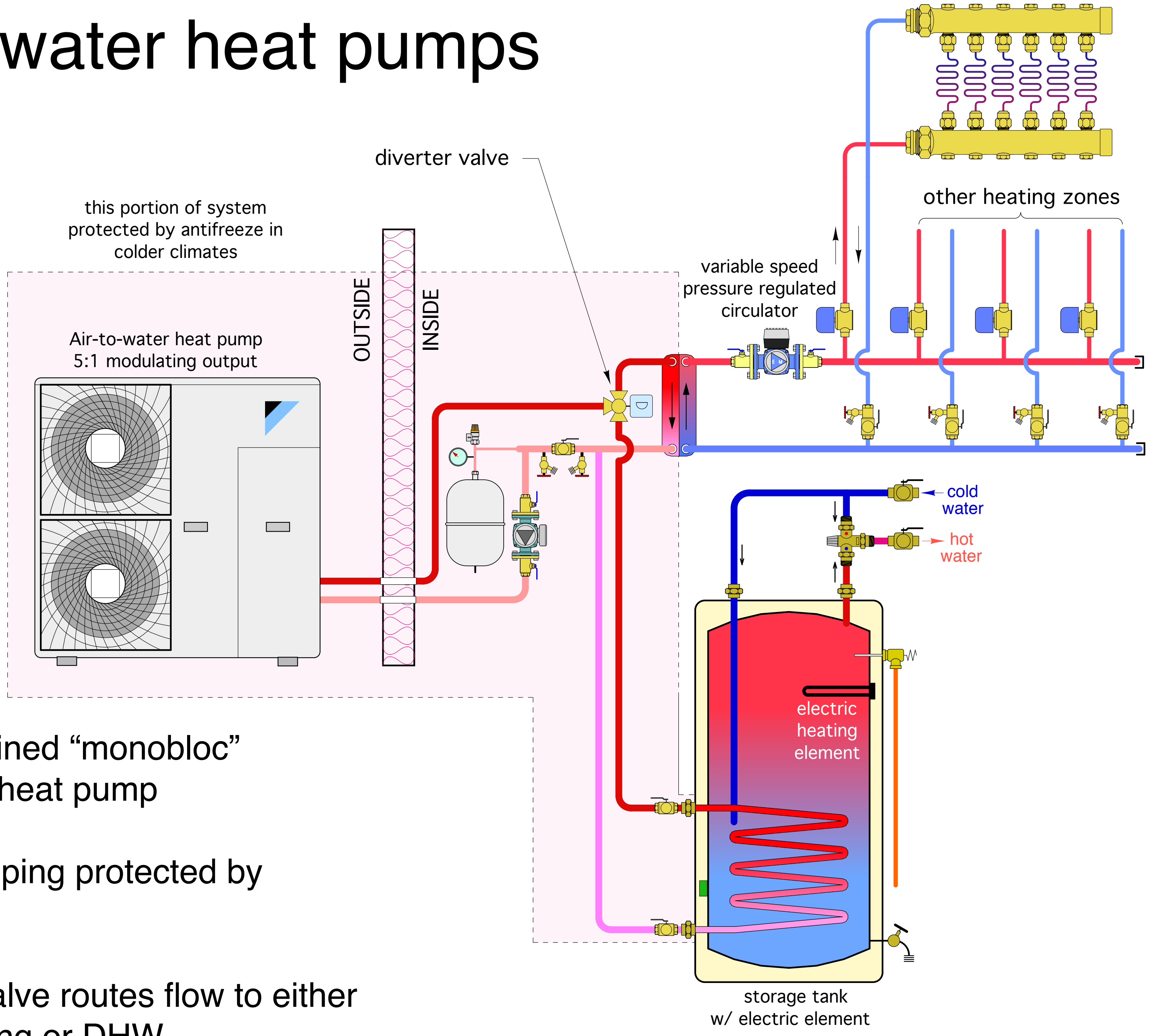


Albany, NY: Annual solar fraction = 30.8%

Boulder, CO: Annual solar fraction = 44.2%

Examples of heat pump combisystems for low load homes

Air to water heat pumps



- Self-contained “monobloc” modulating heat pump

- Outdoor piping protected by antifreeze

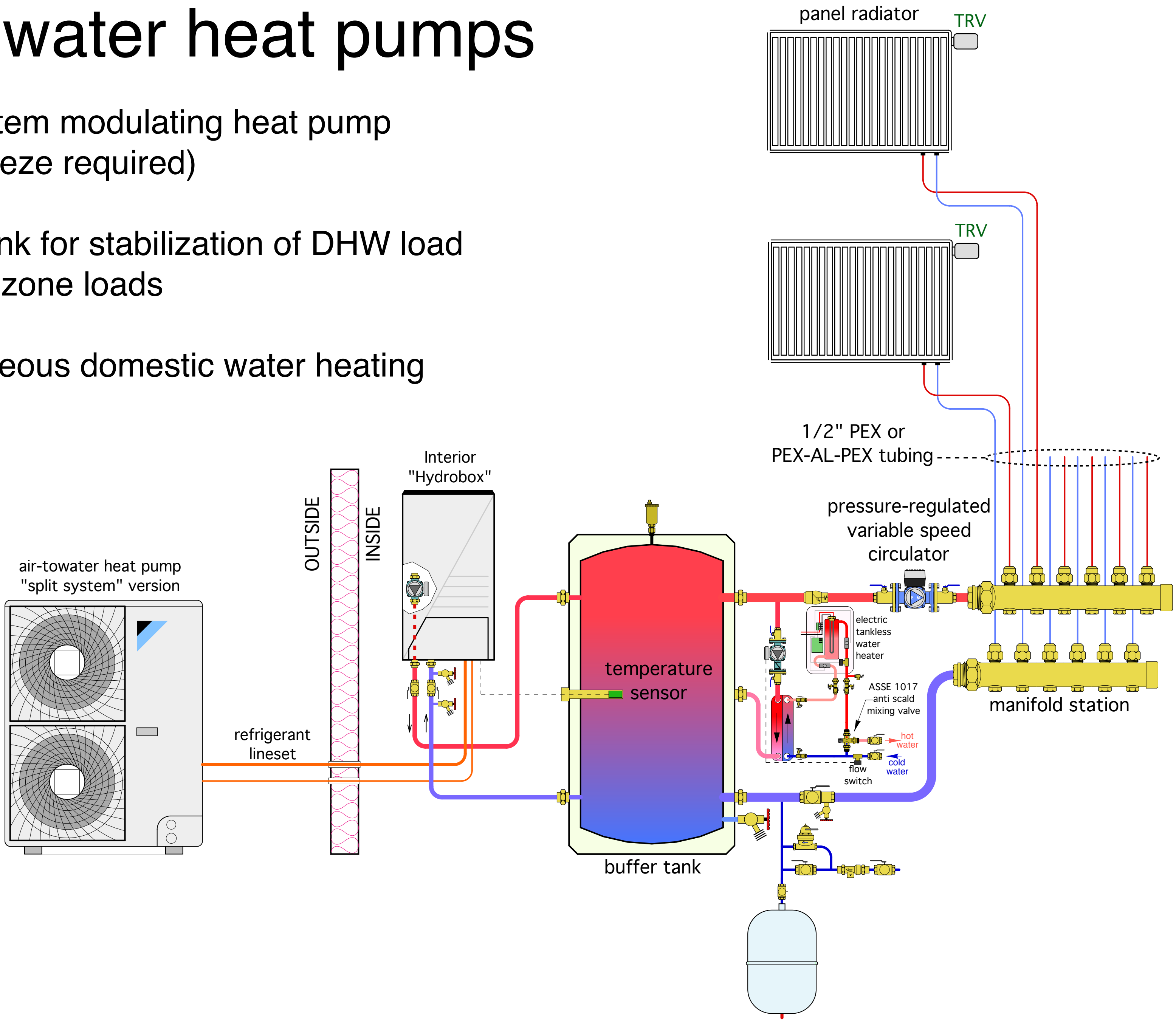
- Diverter valve routes flow to either space heating or DHW

Air to water heat pumps

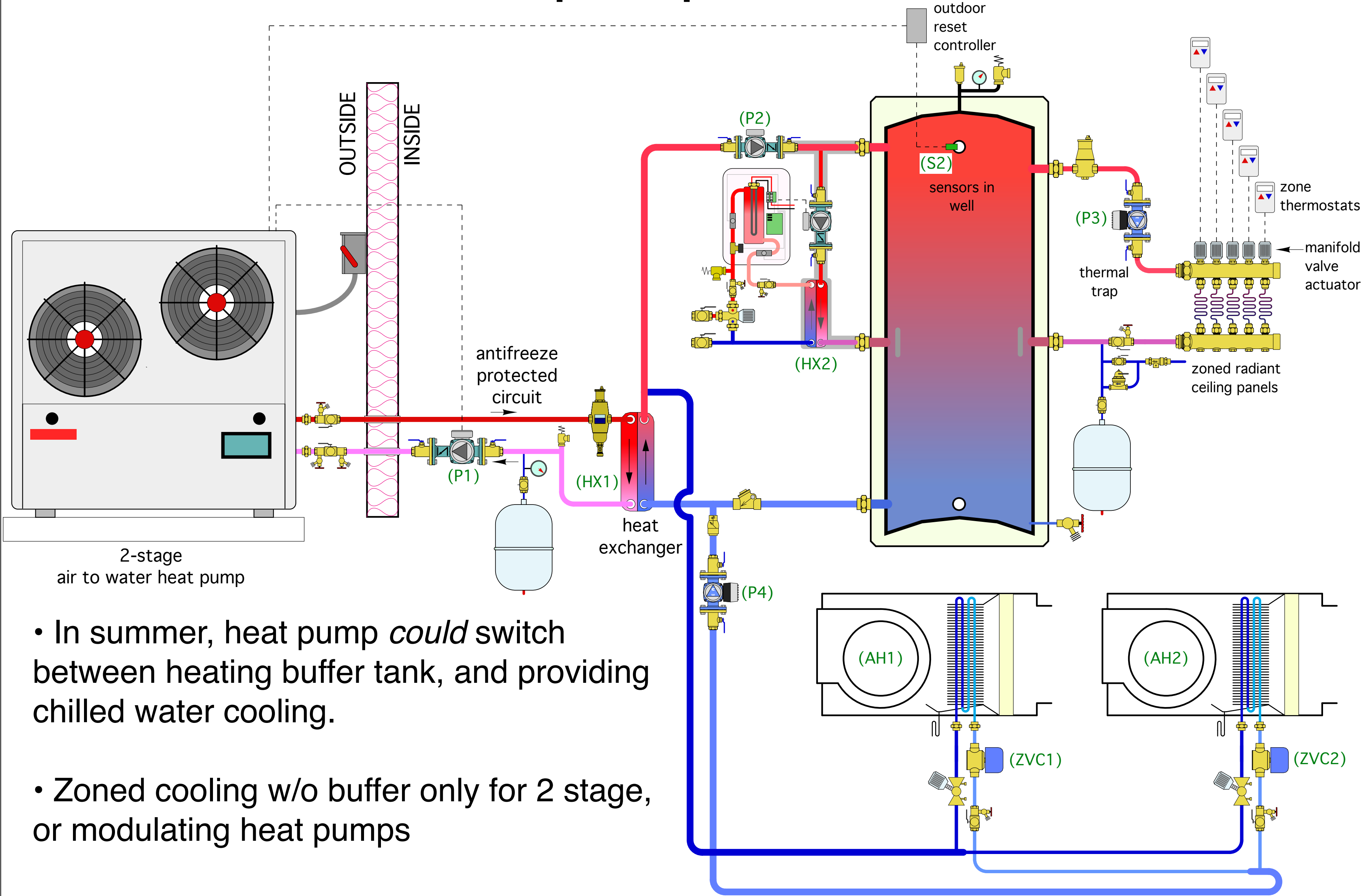
- Split system modulating heat pump (no antifreeze required)

- Buffer tank for stabilization of DHW load and small zone loads

- Instantaneous domestic water heating

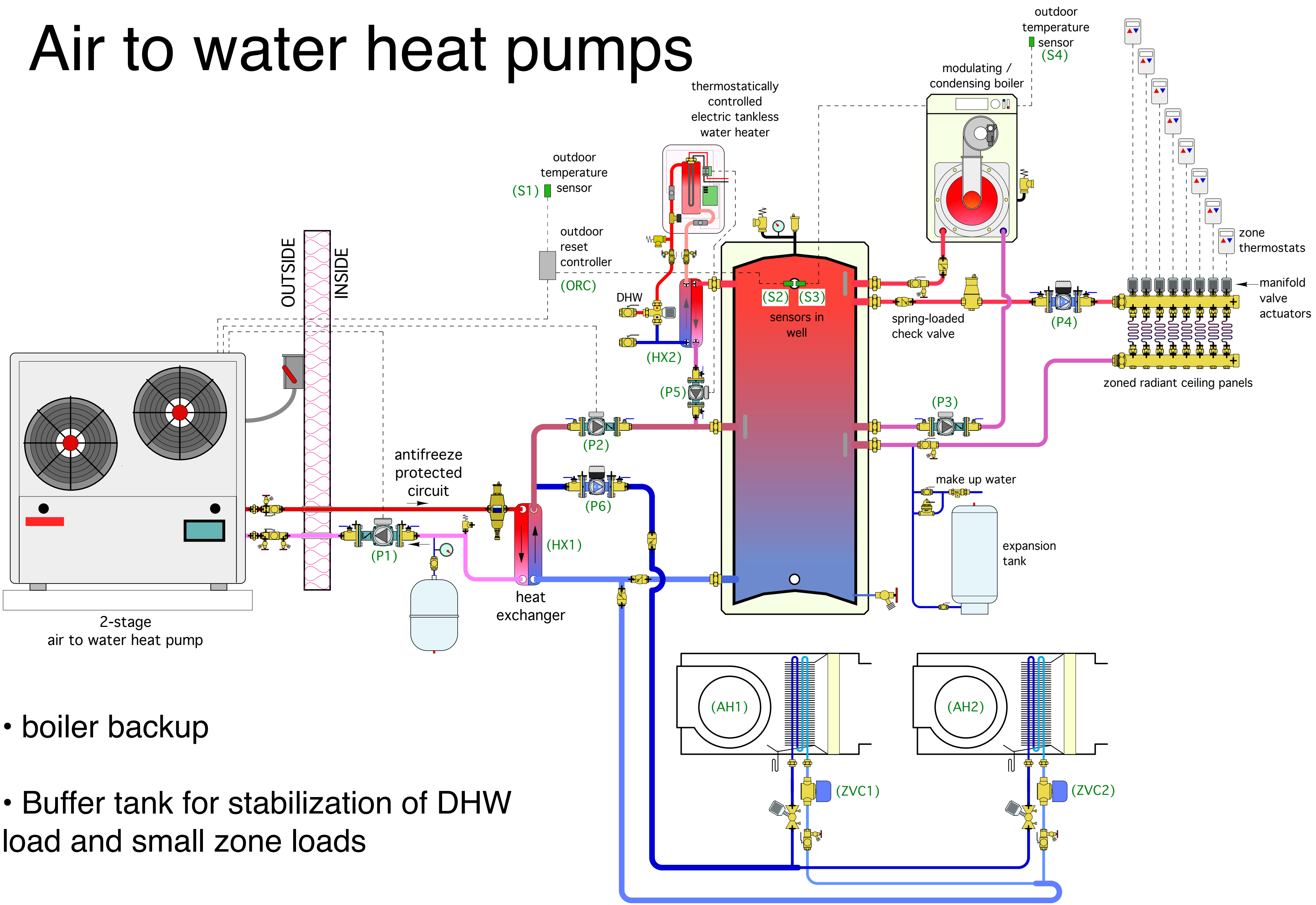


Air to water heat pumps



- In summer, heat pump *could* switch between heating buffer tank, and providing chilled water cooling.
- Zoned cooling w/o buffer only for 2 stage, or modulating heat pumps
- Instantaneous domestic water heating

Air to water heat pumps



- boiler backup

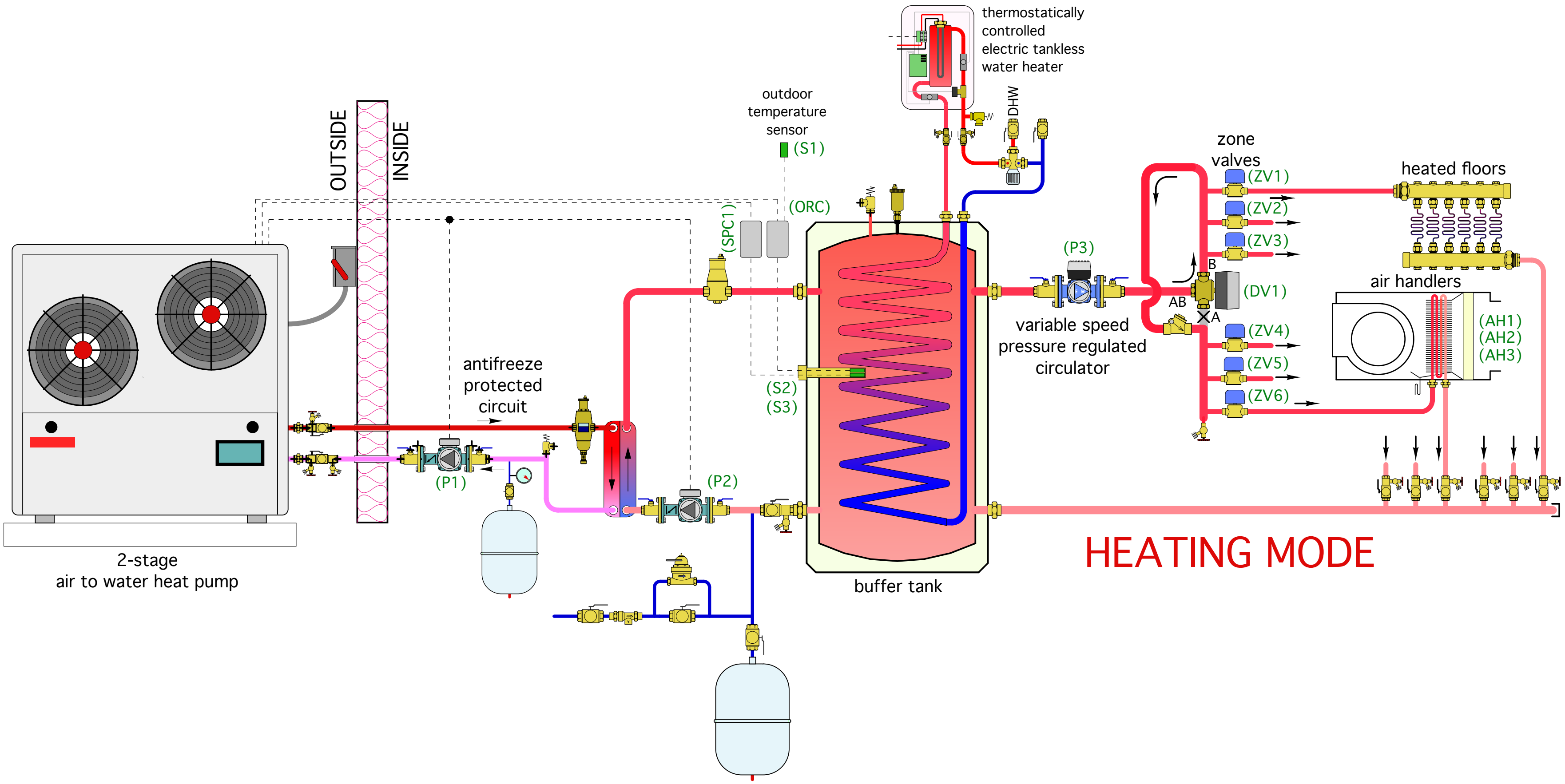
- Buffer tank for stabilization of DHW load and small zone loads

- Instantaneous domestic water heating

Air to water heat pumps

- Heated water is delivered to *both* heated floor and fan coils (more output at given water temperature), or (lower water temperature for a given output)

- ETWH provides “boost” for domestic water heating

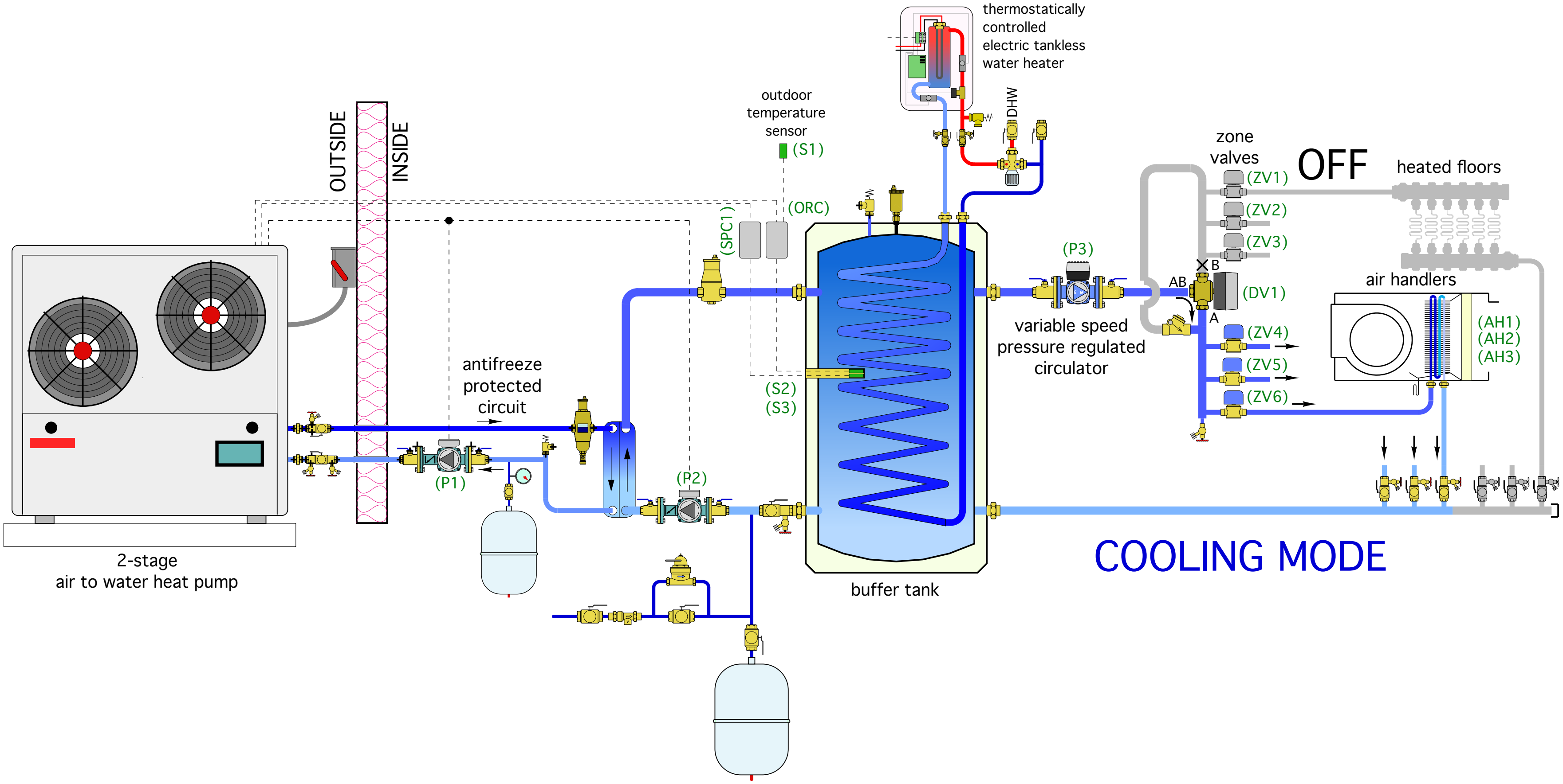


Air to water heat pump

- **Chilled water is only delivered to fan coils equipped with drip pans**

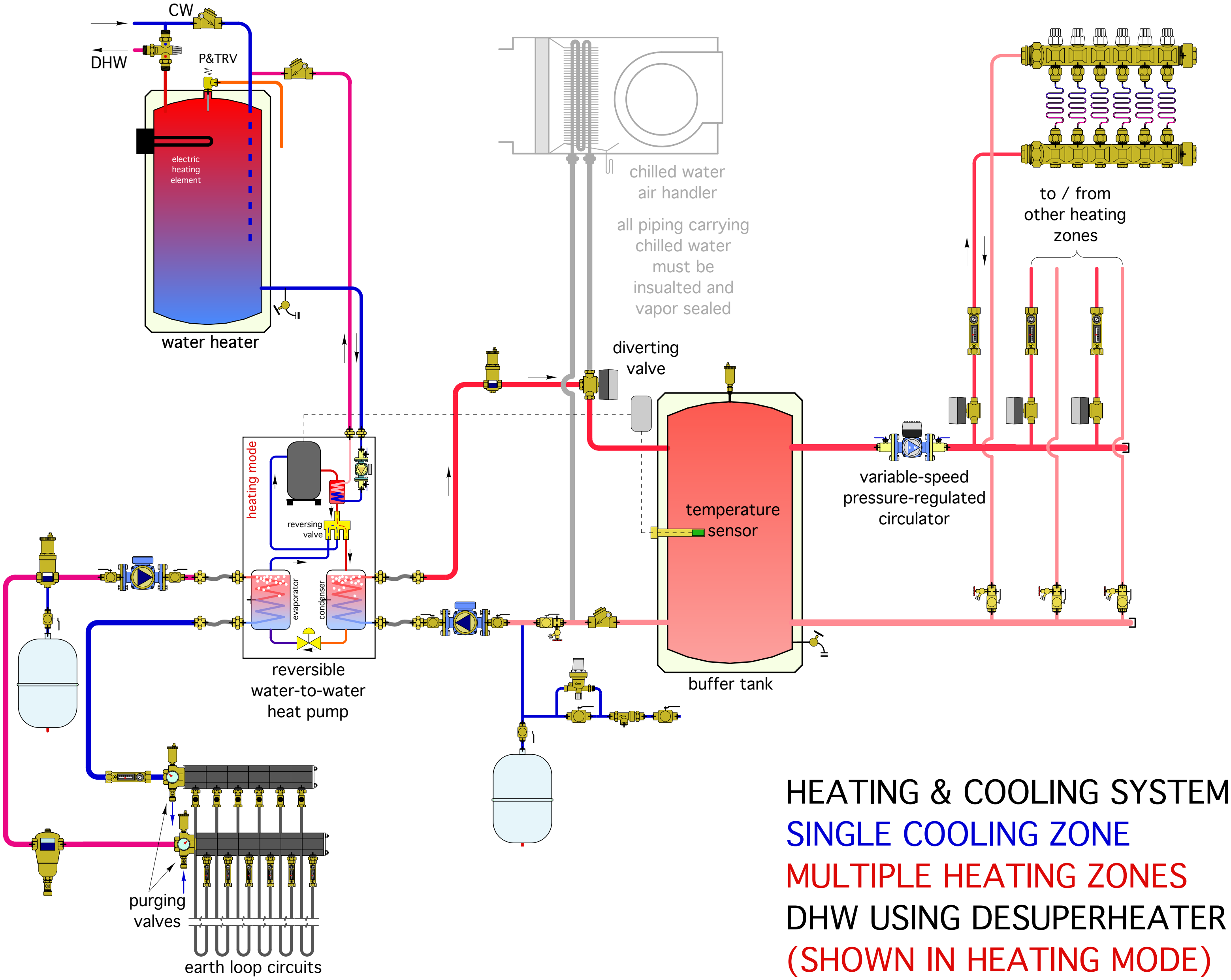
- Chilled water temperatures for cooling: 50 - 60 °F

If cold water enters at 42-45 °F it contributes to cooling the buffer tank, & slightly preheating domestic water upstream of ETWH.



Geothermal heat pump systems

Geo-hydronic system #1



HEATING & COOLING SYSTEM

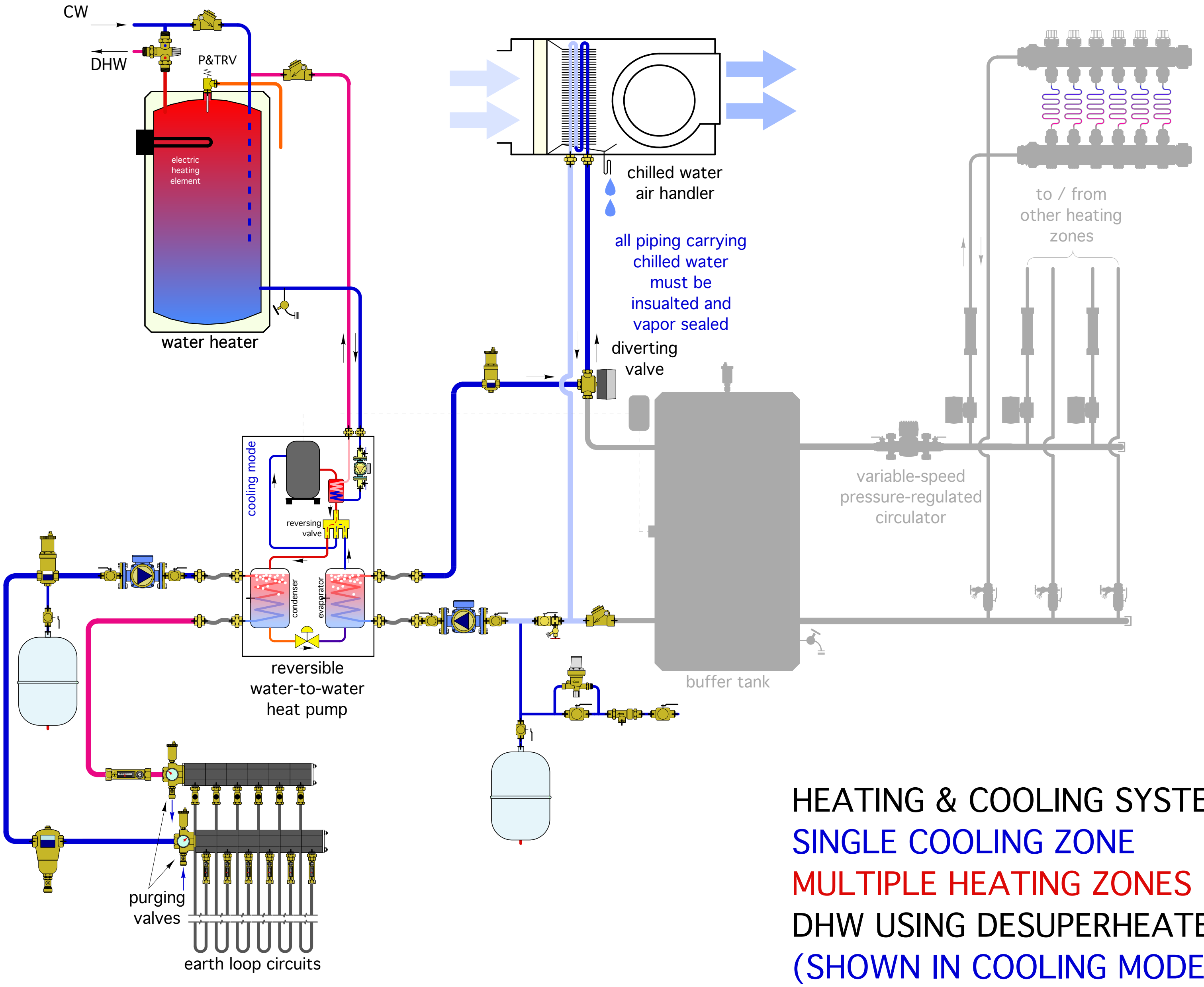
SINGLE COOLING ZONE

MULTIPLE HEATING ZONES

DHW USING DESUPERHEATER

(SHOWN IN HEATING MODE)

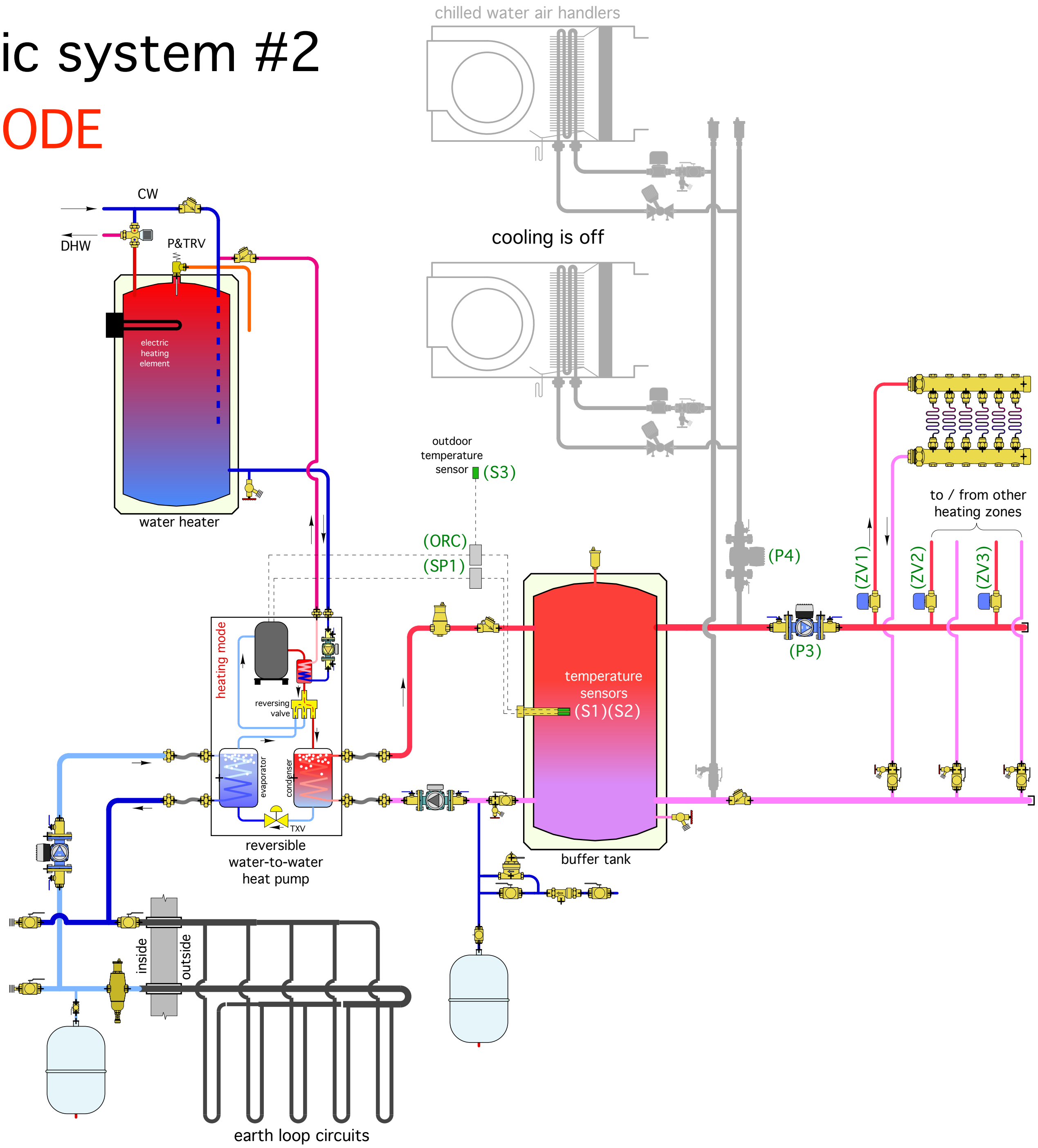
Geo-hydronic system #1



HEATING & COOLING SYSTEM
SINGLE COOLING ZONE
MULTIPLE HEATING ZONES
DHW USING DESUPERHEATER
(SHOWN IN COOLING MODE)

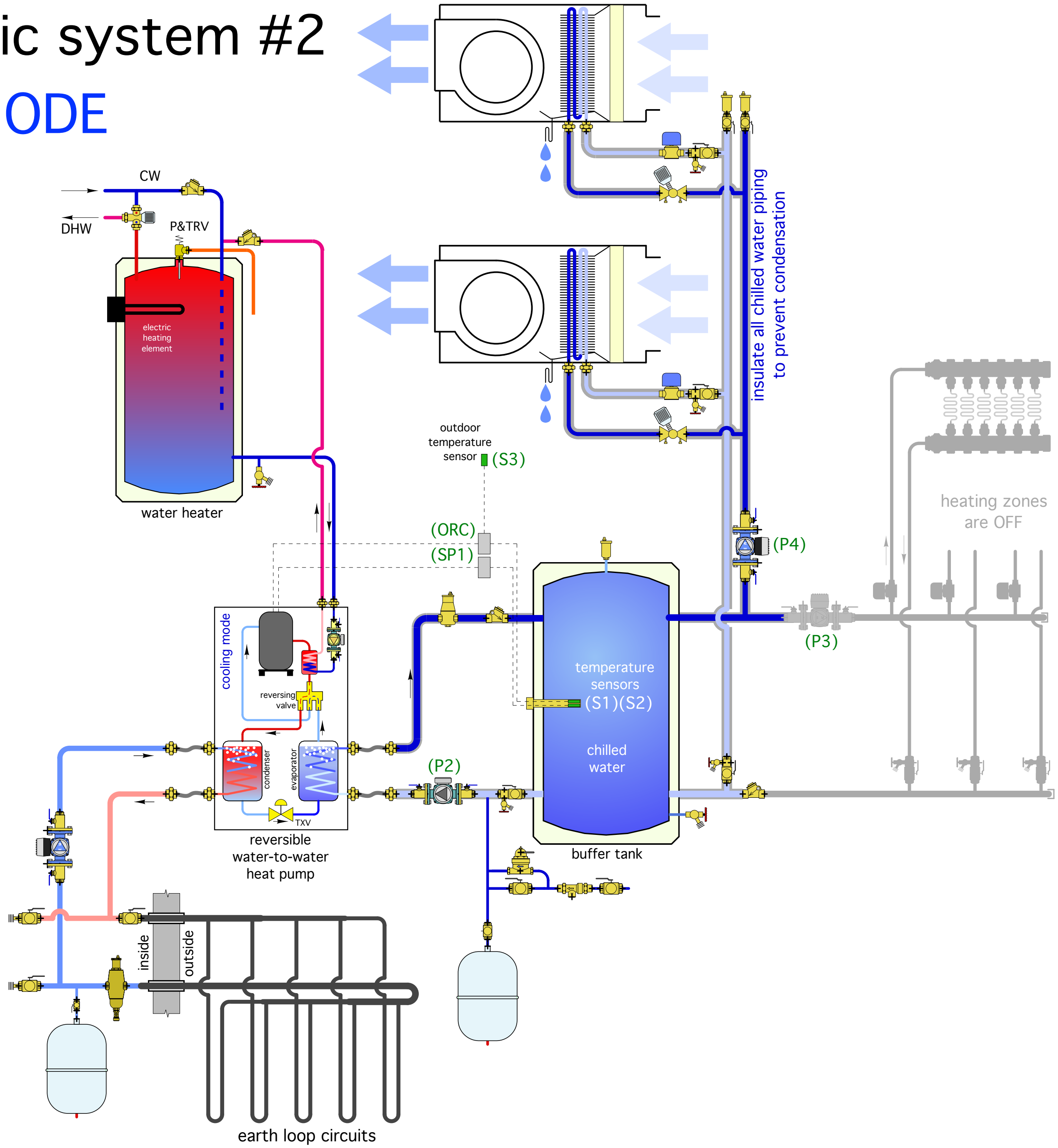
Geo-hydronic system #2

HEATING MODE



Geo-hydronic system #2

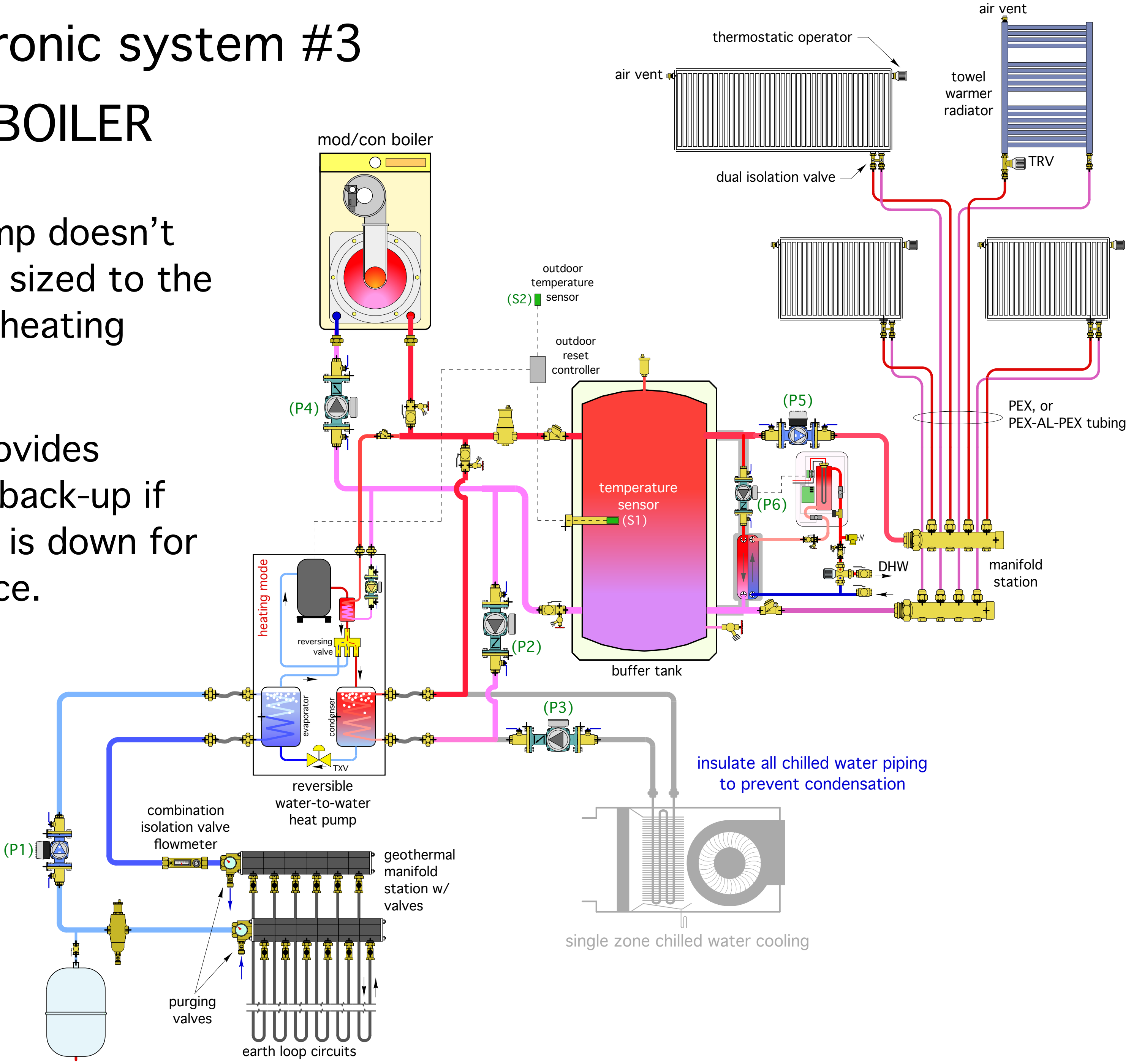
COOLING MODE



Geo-hydronic system #3

GSHP & BOILER

- Heat pump doesn't have to be sized to the full design heating load.
- Boiler provides automatic back-up if heat pump is down for maintenance.



Hydronic Heating for Low Energy Houses

Summary:

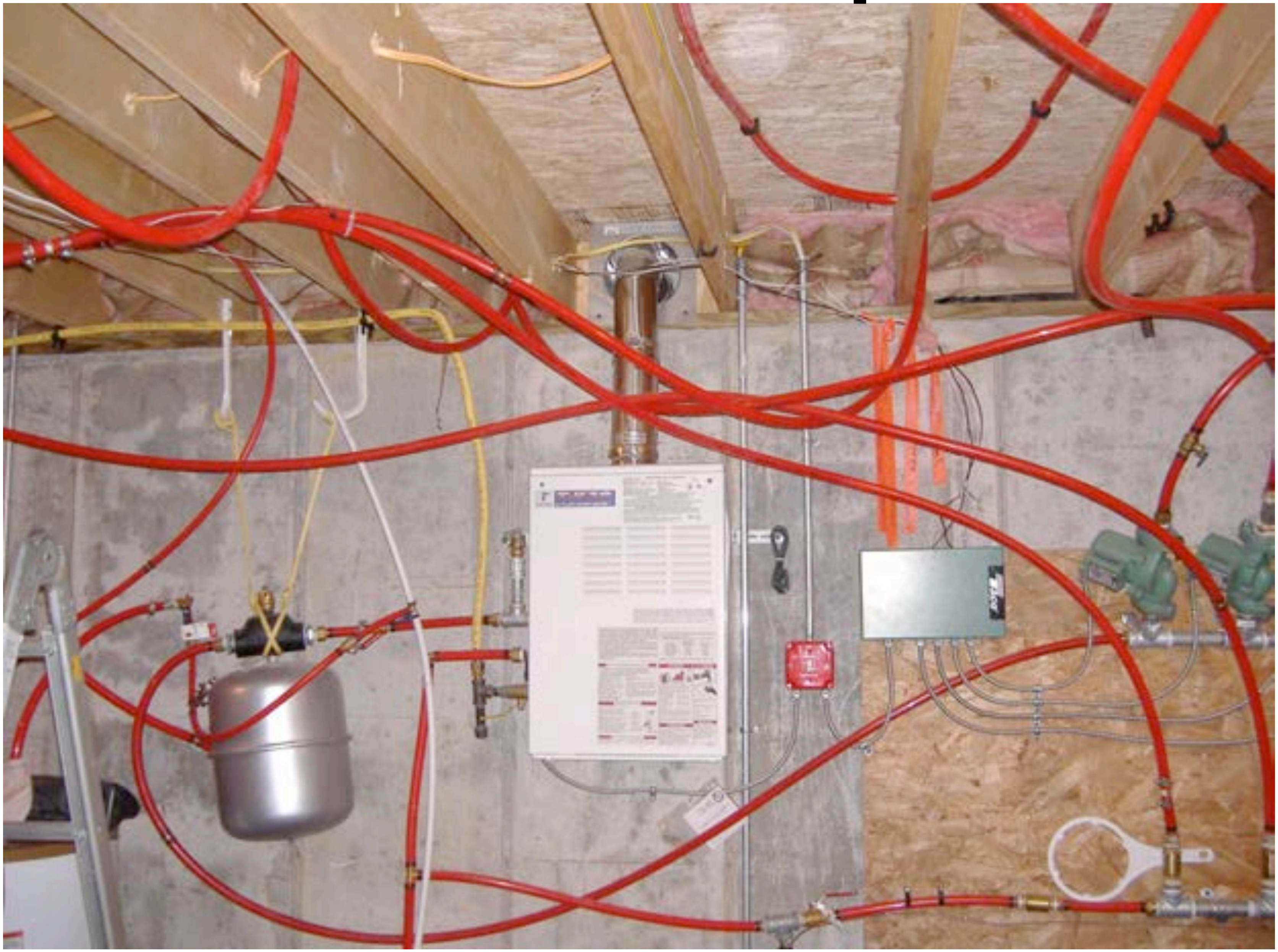
- Energy conservation comes first
- Design around low supply water temperatures (120 ºF max for renewable heat sources)
- Use low mass heat emitters for fast response
- Radiant ceilings better choice than radiant floors
- Use homerun distribution system whenever possible
- Use ECM-based high efficiency circulators
- Provide thermal mass (buffer) to stabilize combustion heat sources against small zone load
- Integrate solar for ***DHW plus*** combisystems (drainback systems preferred)
- If system has thermal mass use external HX for instantaneous domestic water heating
- Evaluate service charge for gas meter on low load and net zero houses. (saving may not justify meter cost)
- If cooling will be needed, heat pump is a good choice
- Consider air-to-water heat pump against cost of geothermal heat pump
- Net zero houses will always have solar PV, so electric based heating is preferred.
- Keep system as simple as possible

Parting thoughts...

1. Plan ahead...

Parting thoughts...

2. Keep it neat...



Parting thoughts...

3. Keep it simple...

Parting thoughts...

4. Don’t get hung up...

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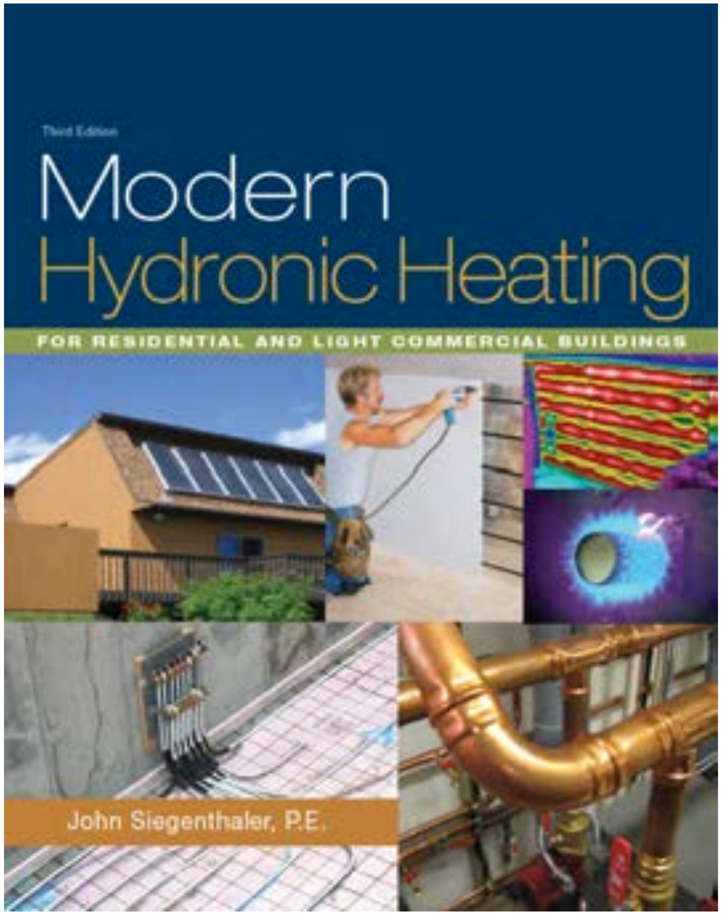
(publications & software) on hydronic systems:

www.hydronicpros.com


Third Edition

Modern Hydronic Heating

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John Siegenthaler, P.E.