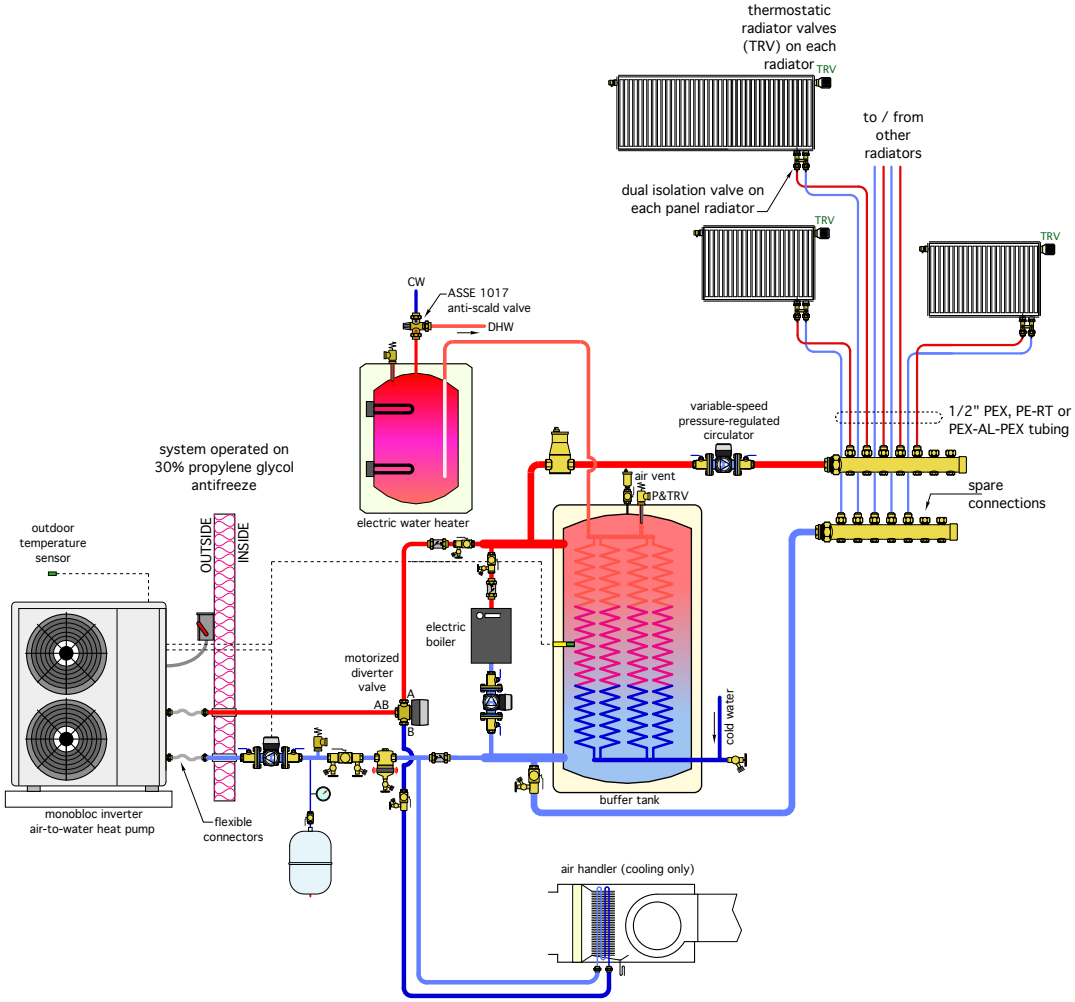
An Overview of Air-to-Water Heat Pumps



BS & Beer
Nov 3, 2022

John Siegenthaler, P.E.
Appropriate Designs
www.hydronicpros.com

- Most North America heating pros are familiar with *ductless heat pumps*.
- Most are also familiar with *geothermal heat pumps*
- ***Far fewer are currently familiar with air-to-water heat pumps.***

Ductless mini-split heat pump

geothermal heat pump

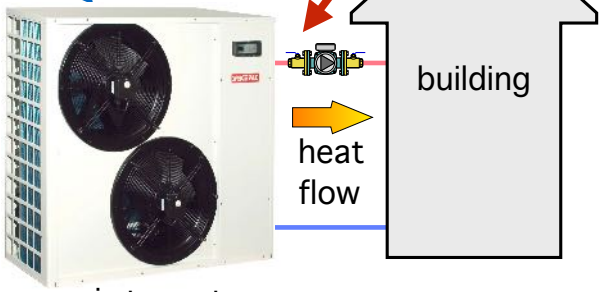
air-to-water heat pump

Heat pump “flavors”

“Ductless”, “mini-split” air-to-air heat pump

water-to-water heat pump

air is the source of the heat



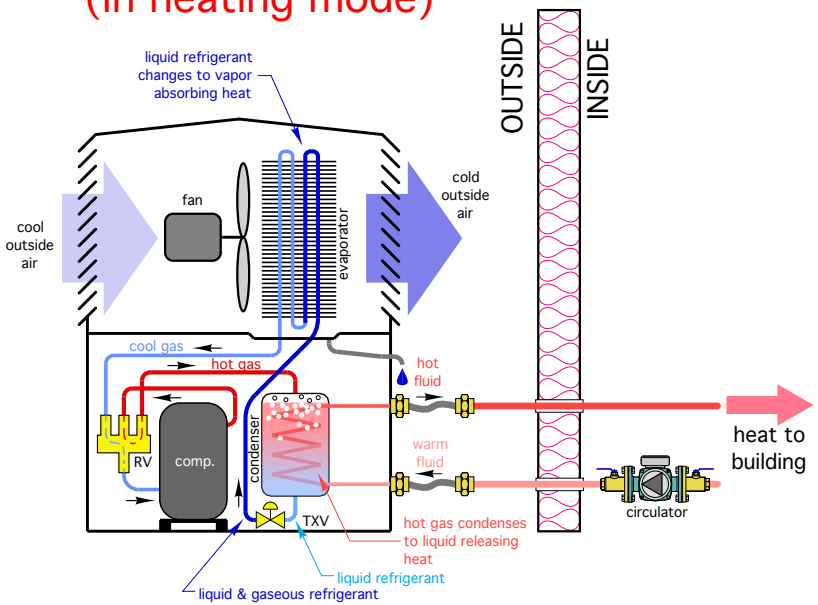
air-to-water heat pump

water is the “conveyor belt” moving heat to the building

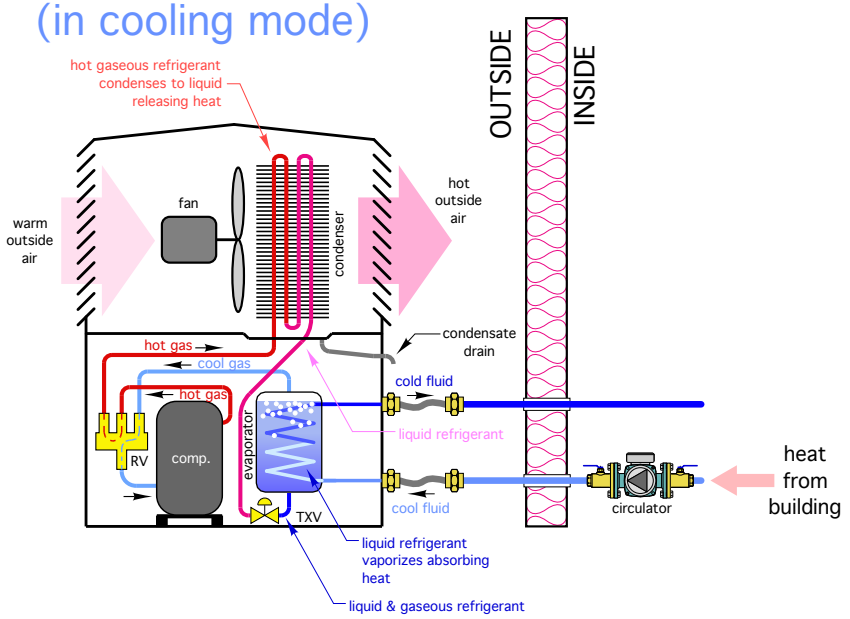
Self-contained (“monobloc”) air-to-water heat pumps

Internals of a monobloc air-to-water heat pump

air-to-water heat pump
(in heating mode)



air-to-water heat pump
(in cooling mode)

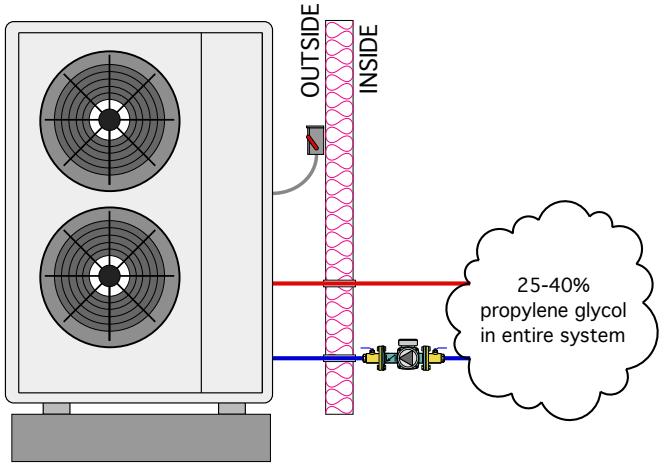


In heating mode: The heat pump extracts low temperature heat from outside air, and transfers it to a fluid stream (water or water & antifreeze) to be used by a hydronic distribution system.

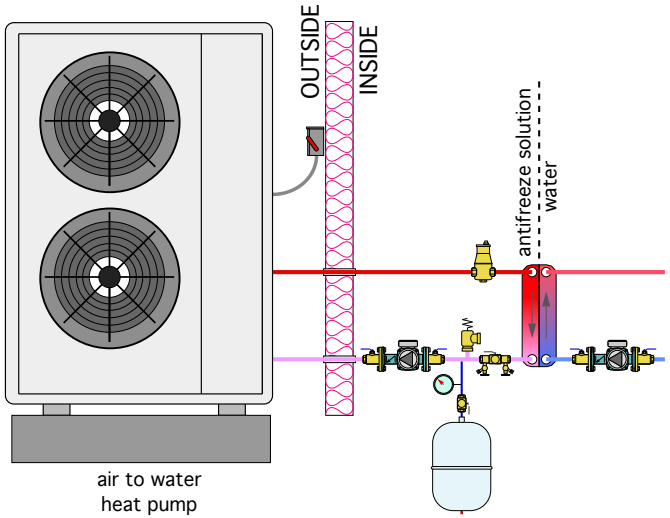
In cooling mode: The heat pump extracts low temperature heat from a fluid stream (chilling it), and dissipates that heat to outside air.

Self-contained (“monobloc”) air-to-water heat pumps

- Pre-charged refrigeration system
- Some have internal circulator, others don’t
- Should have freeze protection in North American applications



Use 25-40% propylene glycol in the entire system



Use 25-40% propylene glycol in the heat pump loop, with water in remainder of system.

The use of a heat exchanger forces the HP to operate at higher condensing temperatures, and thus lower COP.

Requires 2 circulators & additional hardware / installation labor.

Split system air-to-water heat pump

Outdoor unit

Heating mode:
1. compressor
2. evaporator
3. expansion device

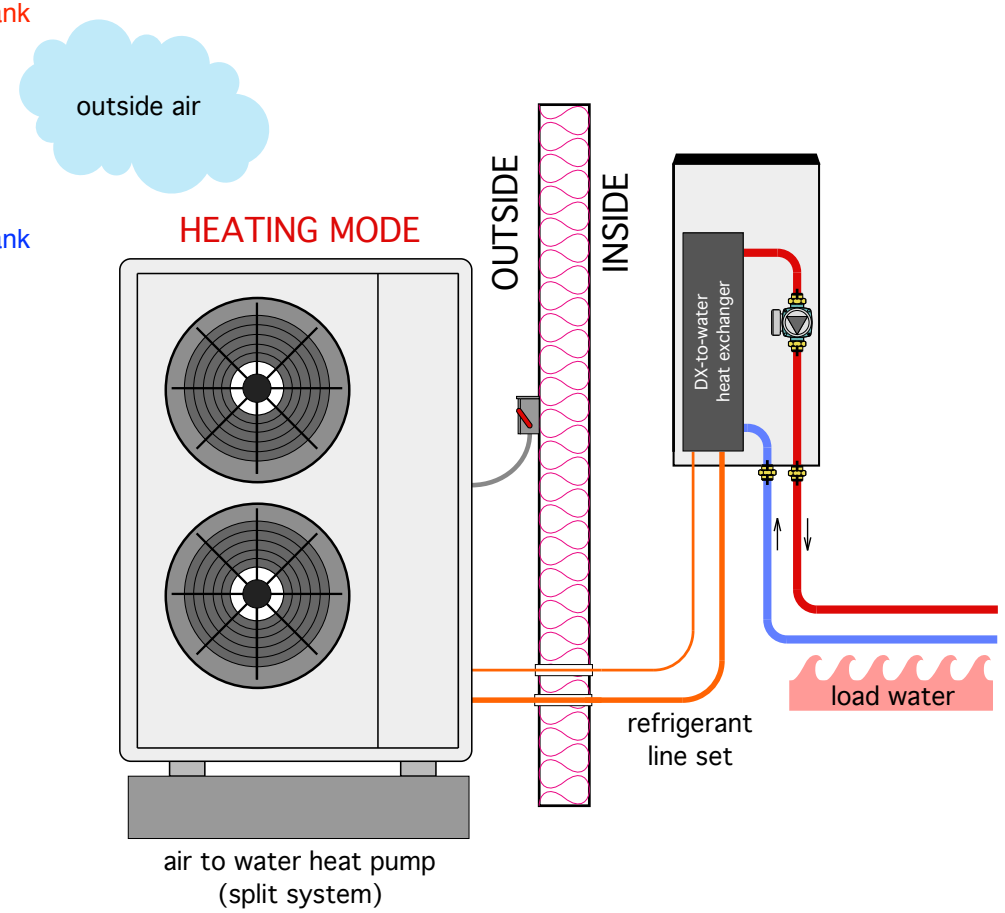
Cooling mode:
1. compressor
2. condenser
3. expansion device

Indoor unit

Heating mode:
1. condenser
2. circulator
3. expansion tank
4. aux element
5. controls

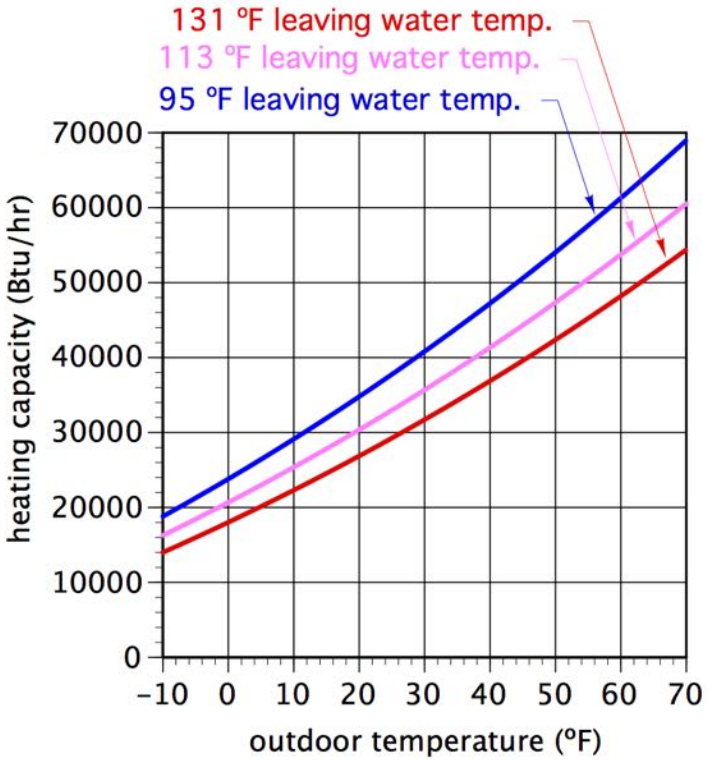
Cooling mode:
1. evaporator
2. circulator
3. expansion tank
4. controls

refrigerant line set

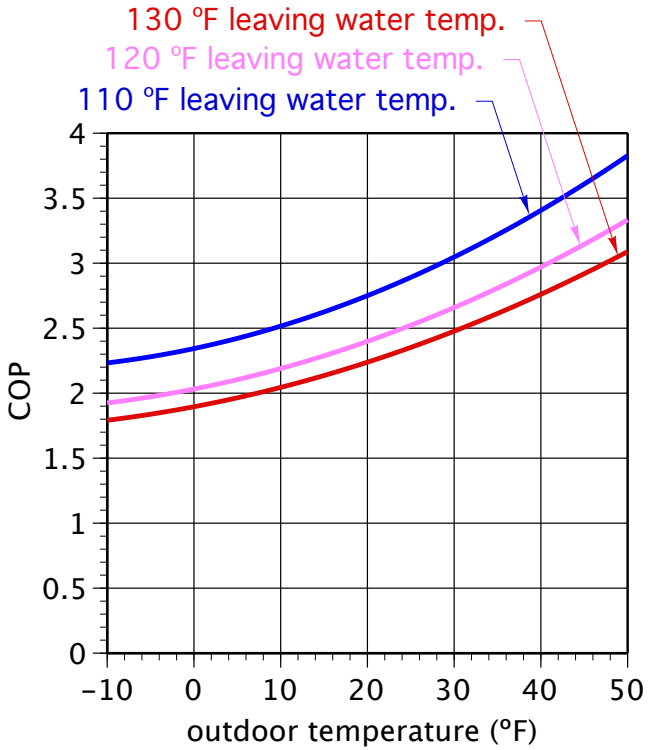


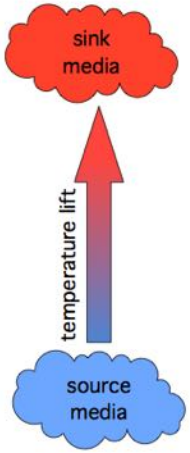
Heating Performance

The heating capacity of most AWHPs decreases with increasing condenser temperature.



The COP also decreases with increasing condenser temperature.





The smaller the "temperature lift" between evaporator and condenser, the higher the heating capacity and COP.

Panel Radiators

Panel radiator installations

“compact” style panel radiators

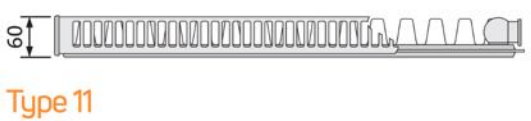
towel warmer radiator

Adaptable to different proportions of radiant & convective output

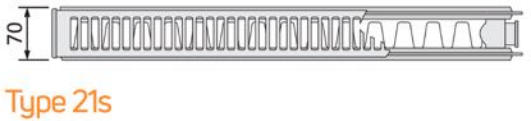
The proportions of radiant vs. convective heat output can be varied based on the configuration of water plates and fins used to construct the panel

Adding more water plates and fins increases both heat output & a higher % of convective heat output.

Higher convective output useful under large window areas (counteracting downdrafts)

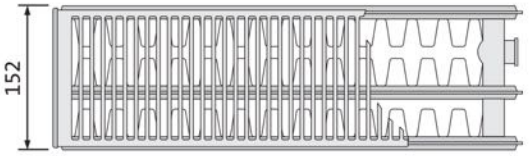


Type 11

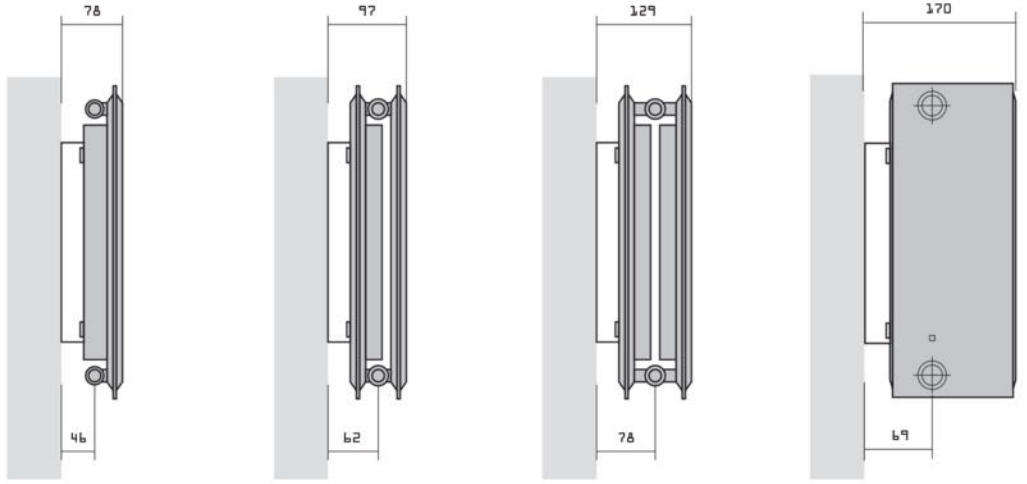


Type 21s

Type 22



Type 33



Type 11, Type 21s, Type 22, Type 33

Simple mounting to walls

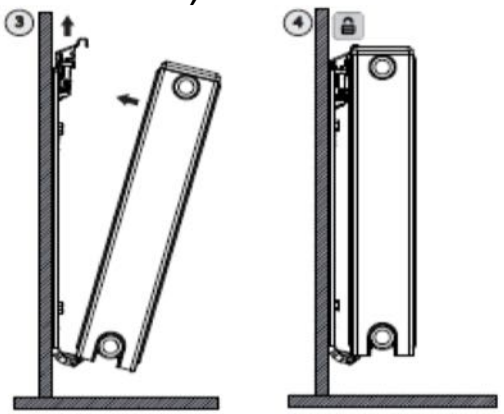
Panel radiators “hang” from simple brackets secured to walls (@ studs for framed walls)

Panel radiators are relatively light:

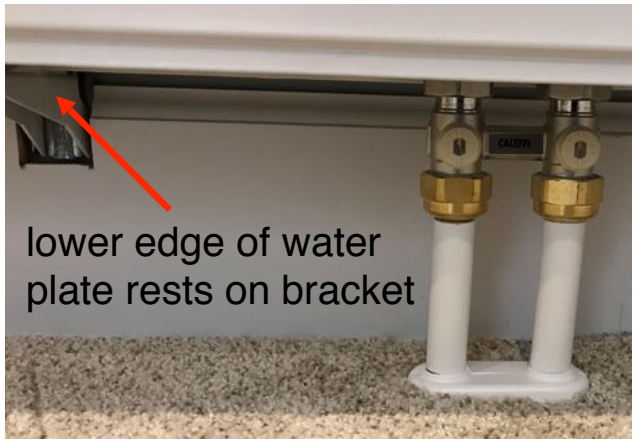
Nominal 2’ x 4’ double water plate panel weighs 89 lbs and holds 2.25 gallons of water (another 19 lbs).

Most radiators are supported on 2 wall brackets.

Piping connections are 2” center to center spacing



top of bracket “clips” into upper grill



Simple / repeatable
& highly efficient
distribution systems

Homerun distribution systems - simple & elegant

• All panels operate at the same supply water temperature (this simplifies panel sizing)

• This piping arrangement has significant lower head loss compared to series or 1-pipe systems (this reduces circulator power requirement)

• This arrangement is ideal for variable-speed constant ΔP circulator (circulator speed automatically adjusts as the TRV on each panel radiator modulates flow)

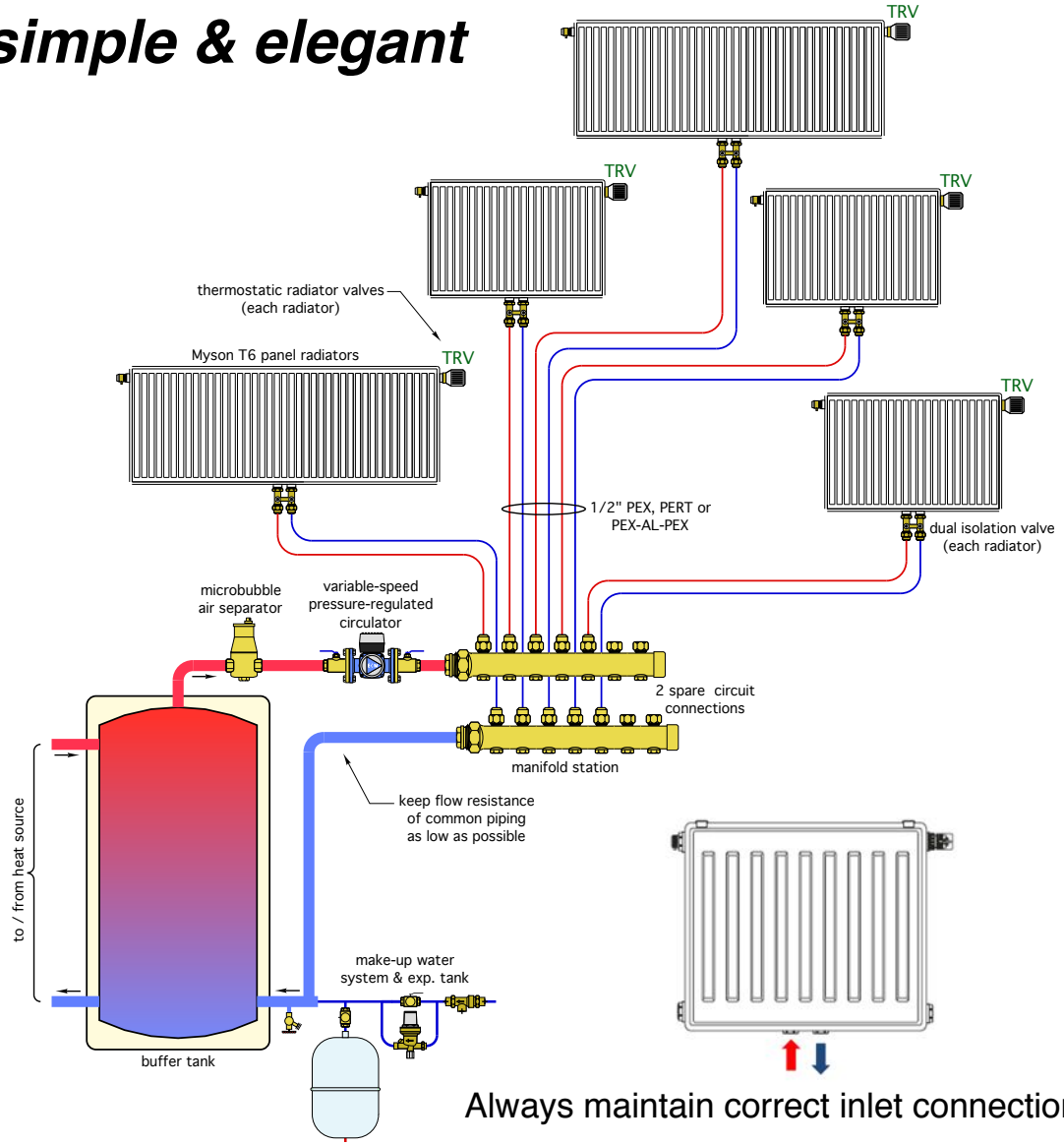
• Circulator is enabled to run 24/7 whenever the system is enabled to provide heating - on in fall / off in spring (simplifies controls)

• Buffer tank allows for “micro-zoning” without concern over short-cycling heat source (can work with on/off or variable capacity heat sources)

• Buffer tank provides hydraulic separation between variable-speed distribution circulator and heat source circulator (don’t need a “dedicated” hydraulic separator)

• Good way to use “remnant” pieces of 1/2” PEX left over from floor heating installations

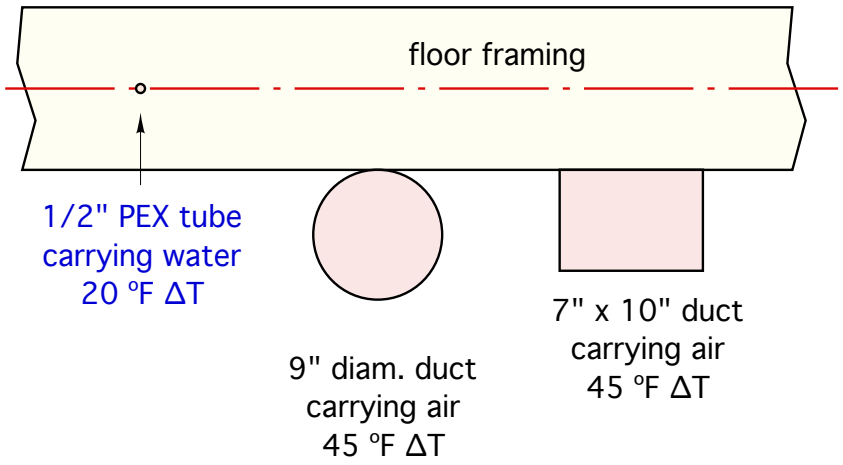
• Flow rate adjustments can be made for each circuit (allows for relatively simple balancing)

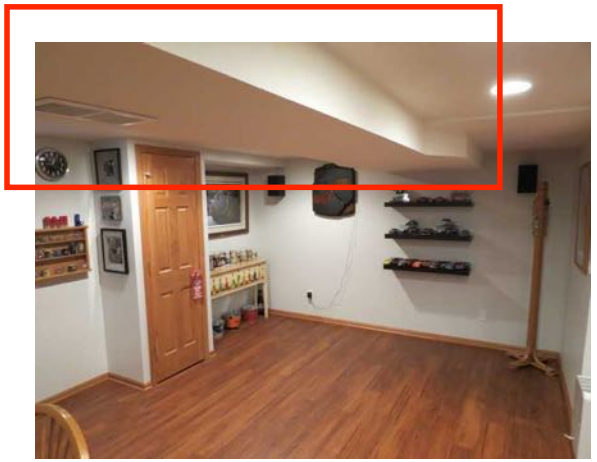


Always maintain correct inlet connection

Hydronics allows for minimally invasive installation

"Conduit" size required for
12,000 Btu/hr heat transfer rate



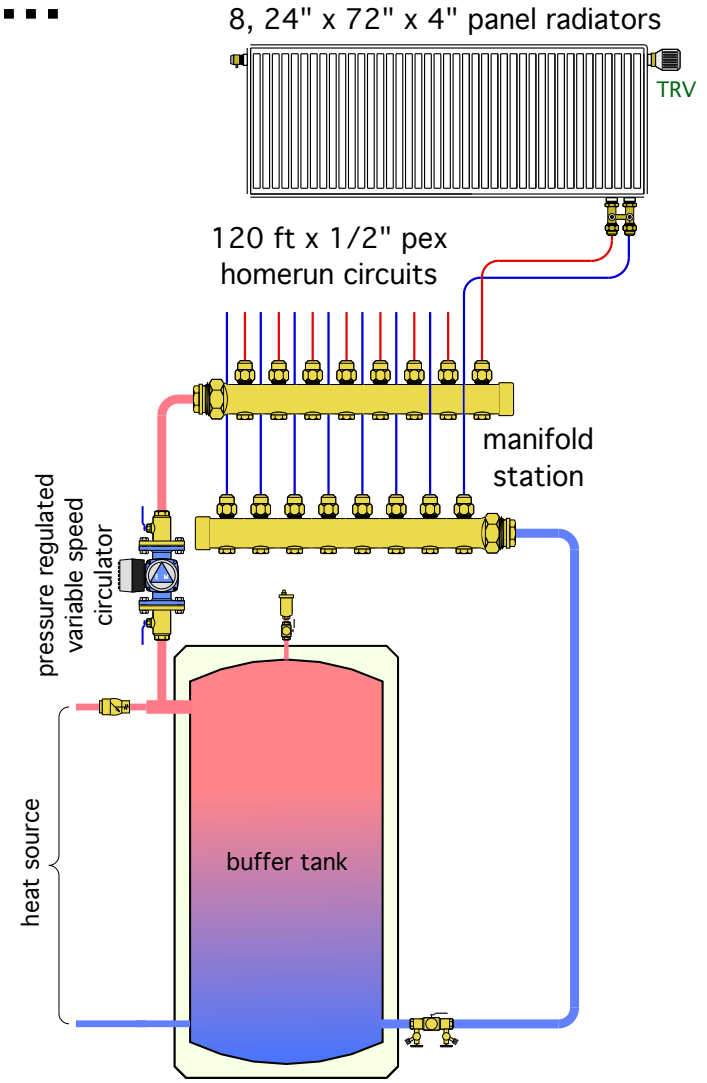


What's possible with good hydronic design…

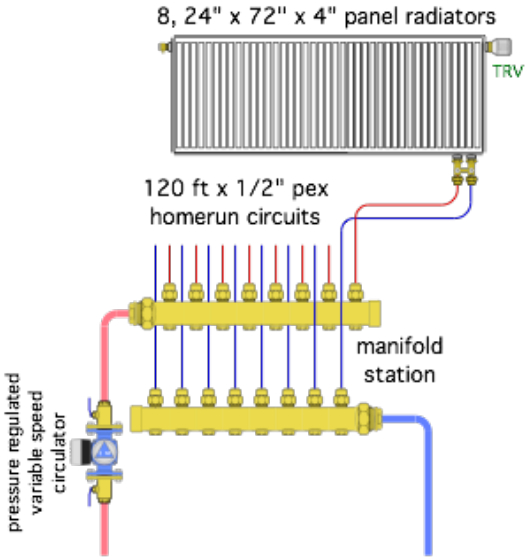
With good design and modern hardware it's possible to design a homerun distribution system for panel radiators that can supply 30,800 Btu/hr design load using only 8.6 watts of electrical power input to circulator!

Taco 0018e
4-44 watts
(Bluetooth communication)

$$\text{distribution efficiency} = \frac{30{,}800\,\frac{Btu}{hr}}{8.6 watt} = 3581\,\frac{Btu/hr}{watt}$$



The distribution efficiency possible with a well-designed hydronic system far exceeds that attainable with forced air systems



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

$$\text{distribution efficiency} = \frac{30{,}800\ \frac{Btu}{hr}}{8.6 watt} = 3581\ \frac{Btu/hr}{watt}$$

$$\frac{94}{3581} = 2.6\%$$

In this comparison the hydronic system uses only 2.6% of the electrical energy required by the forced air system for equal heat transport (source to load).

Example systems using air-to-water heat pumps

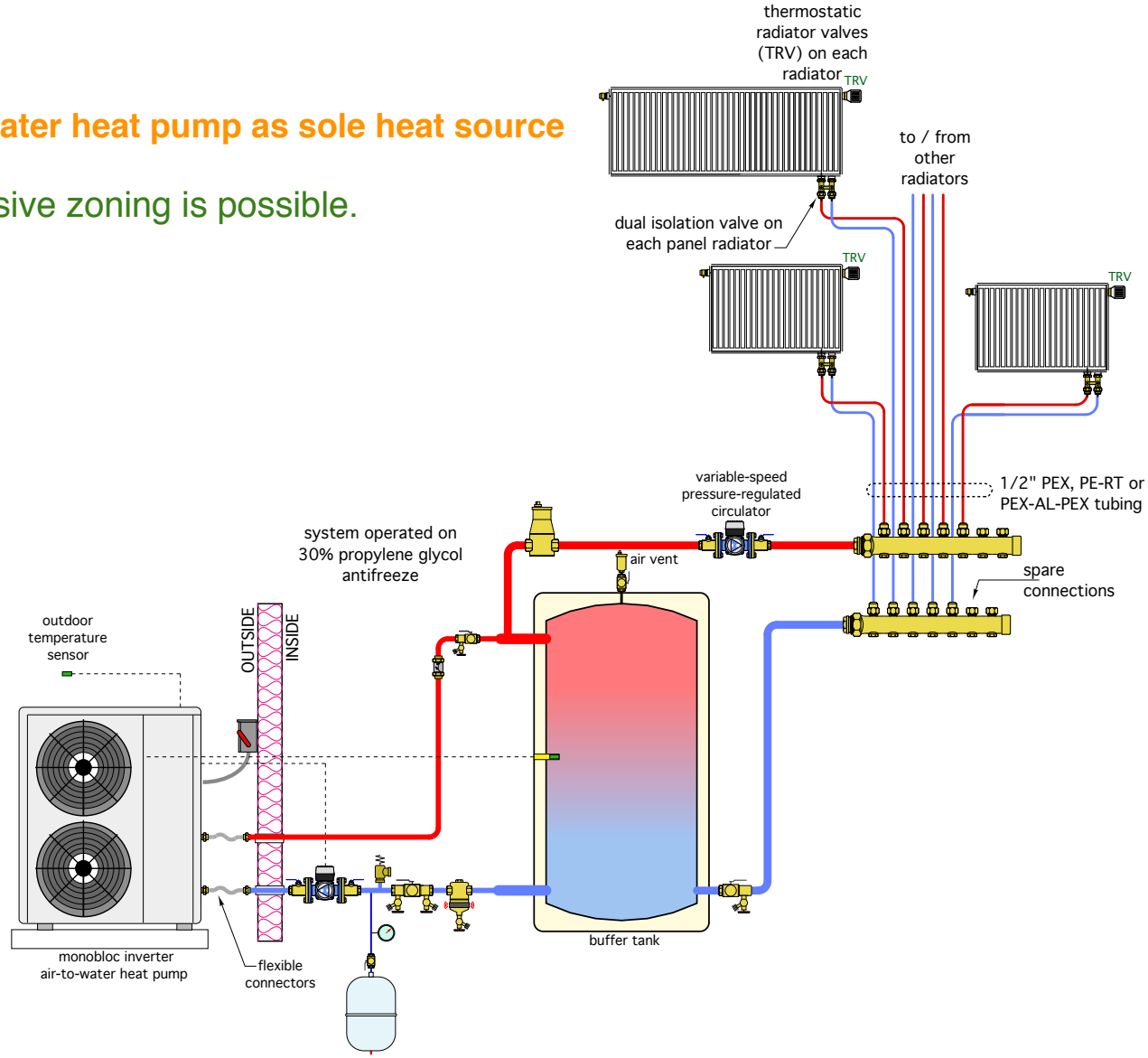
System configurations

Space heating only (zoned), with air-to-water heat pump as sole heat source

PROS: Simple, relatively low cost, extensive zoning is possible.

CONS: No cooling, no auxiliary heating, no domestic water heating, no back-up

Be sure to use a buffer tank if the distribution system is zoned.



System piping configurations

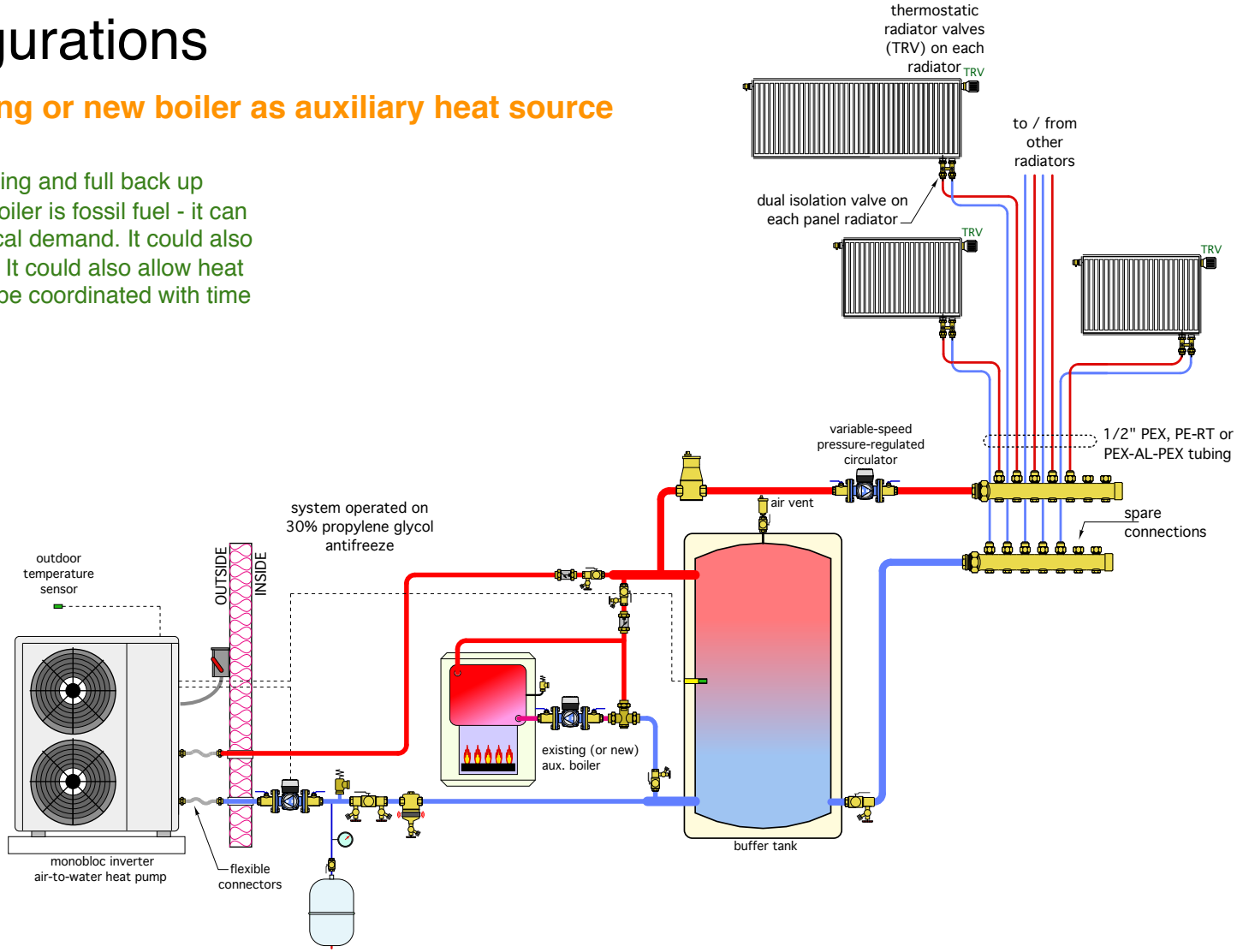
Space heating only, with an existing or new boiler as auxiliary heat source

PROS: Auxiliary boiler provides supplement heating and full back up heating if heat pump is down for service. If aux boiler is fossil fuel - it can operate with minimal impact building peak electrical demand. It could also operate on minimal emergency generator power. It could also allow heat pump to go off-line during peak utility demand or be coordinated with time of use electrical rates.

CONS: No cooling, no domestic water heating

Well-suited to retrofitting existing hydronic heating systems with conventional boilers.

Can also be used with a mod/ con boiler - would not require anti-condensation valve.

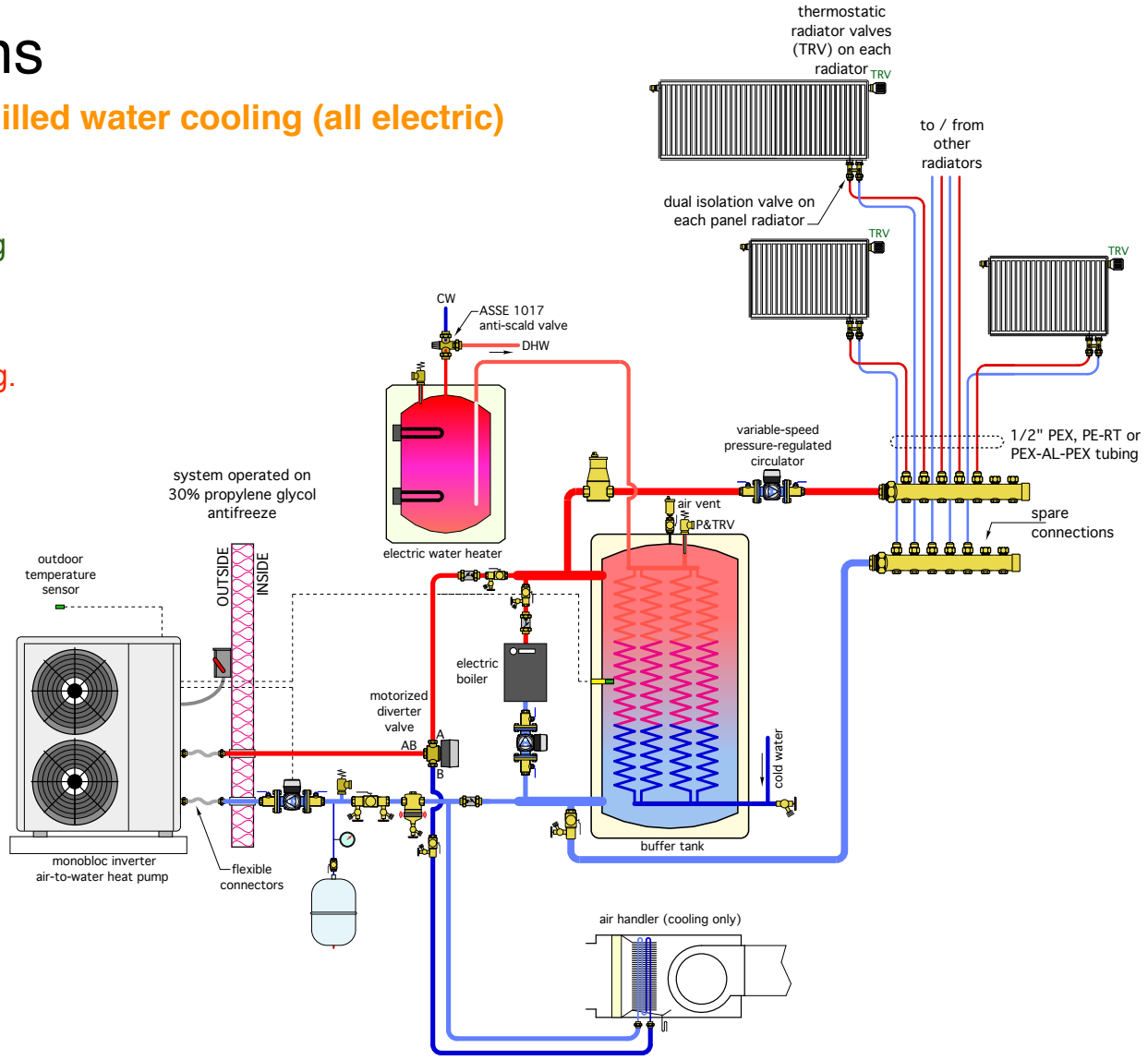


System piping configurations

Space heating + domestic water heating + chilled water cooling (all electric)

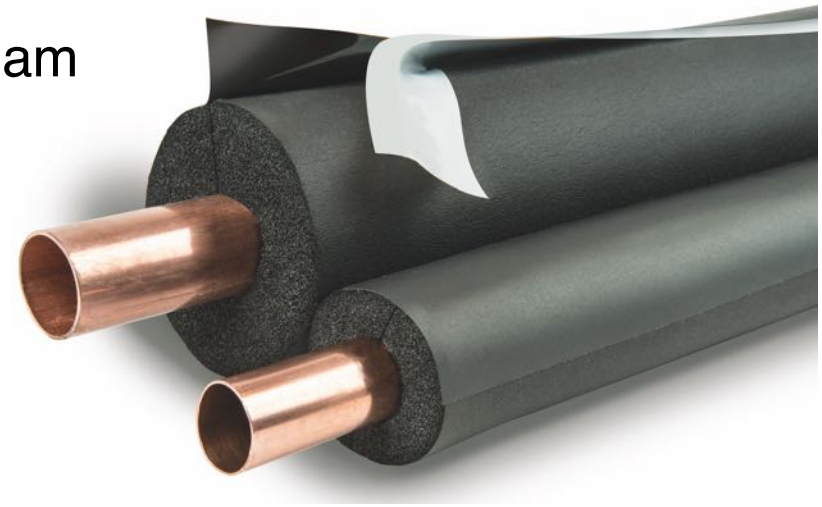
PROS: All electric, full backup capacity for space heating & domestic water heating, chilled water cooling

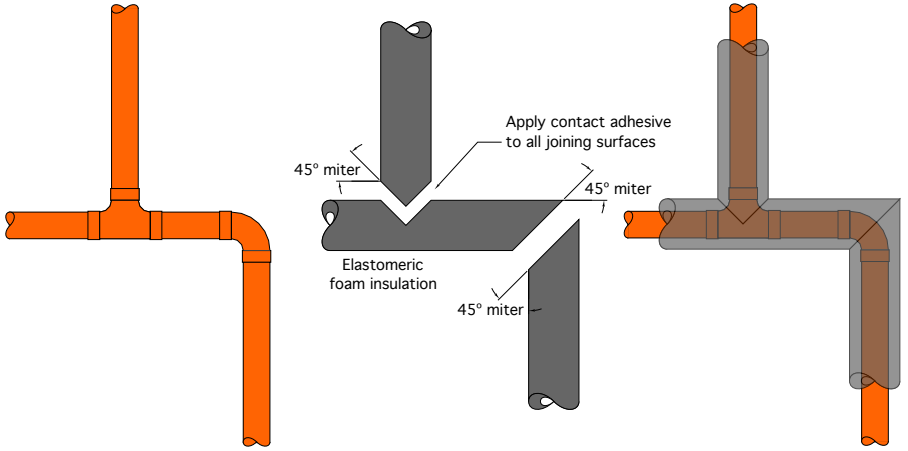
CONS: high electrical demand during lowest outdoor temperatures, when electric auxiliary boiler is operating.



All chilled water piping & components must be insulated to prevent condensation

elastomeric foam



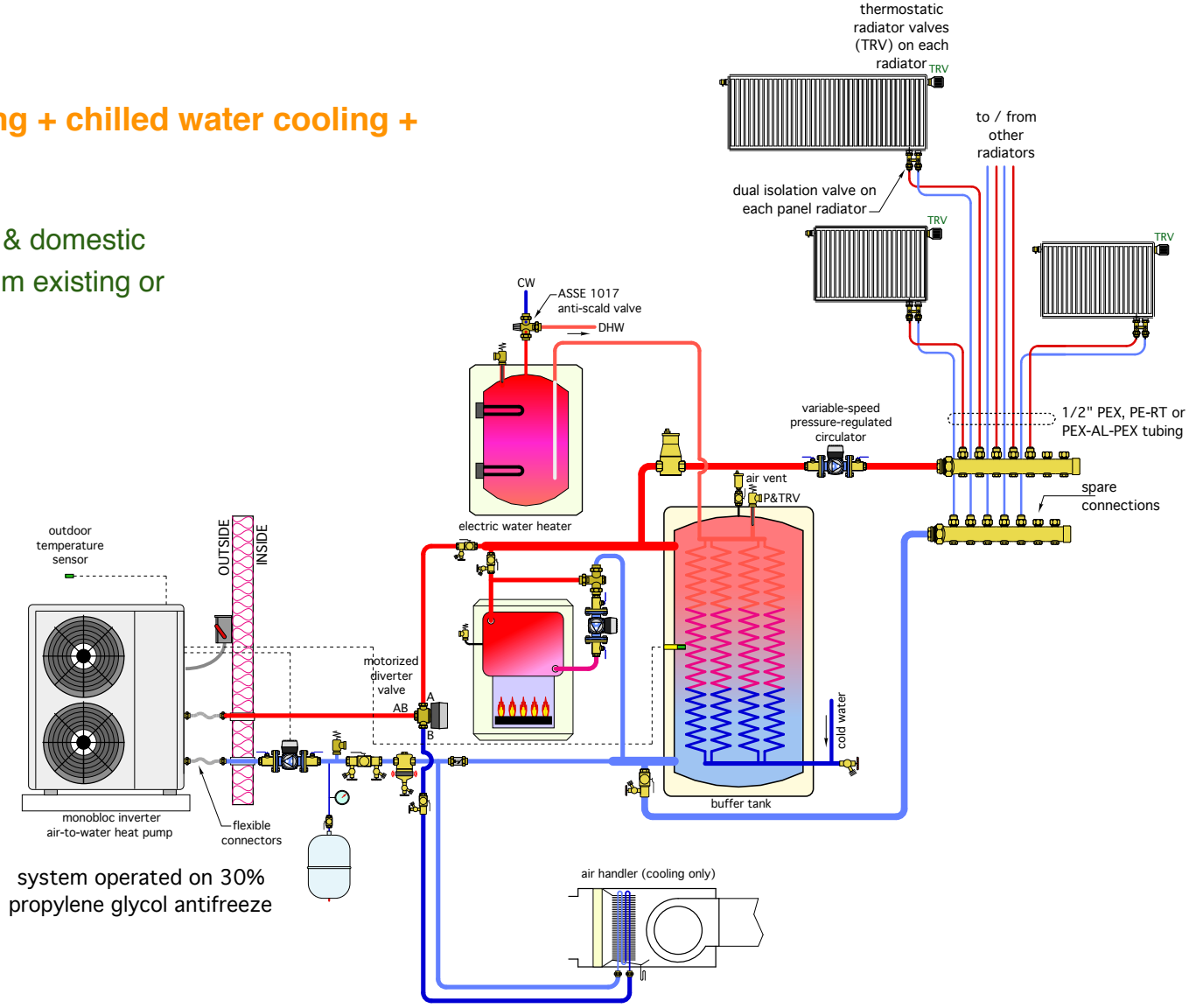


System configurations

Space heating + domestic water heating + chilled water cooling + non-electric auxiliary boiler

PROS: Full backup capacity for space heating & domestic water heating, low electrical power demand from existing or new non-electric boiler, chilled water cooling

CONS: Not all-electric



New air-to-water system installed in Poestenkill, NY, June 2021

Enertech "Advantage" system nominal 5-ton outdoor unit

Installed (unsubsidized) cost $23,000

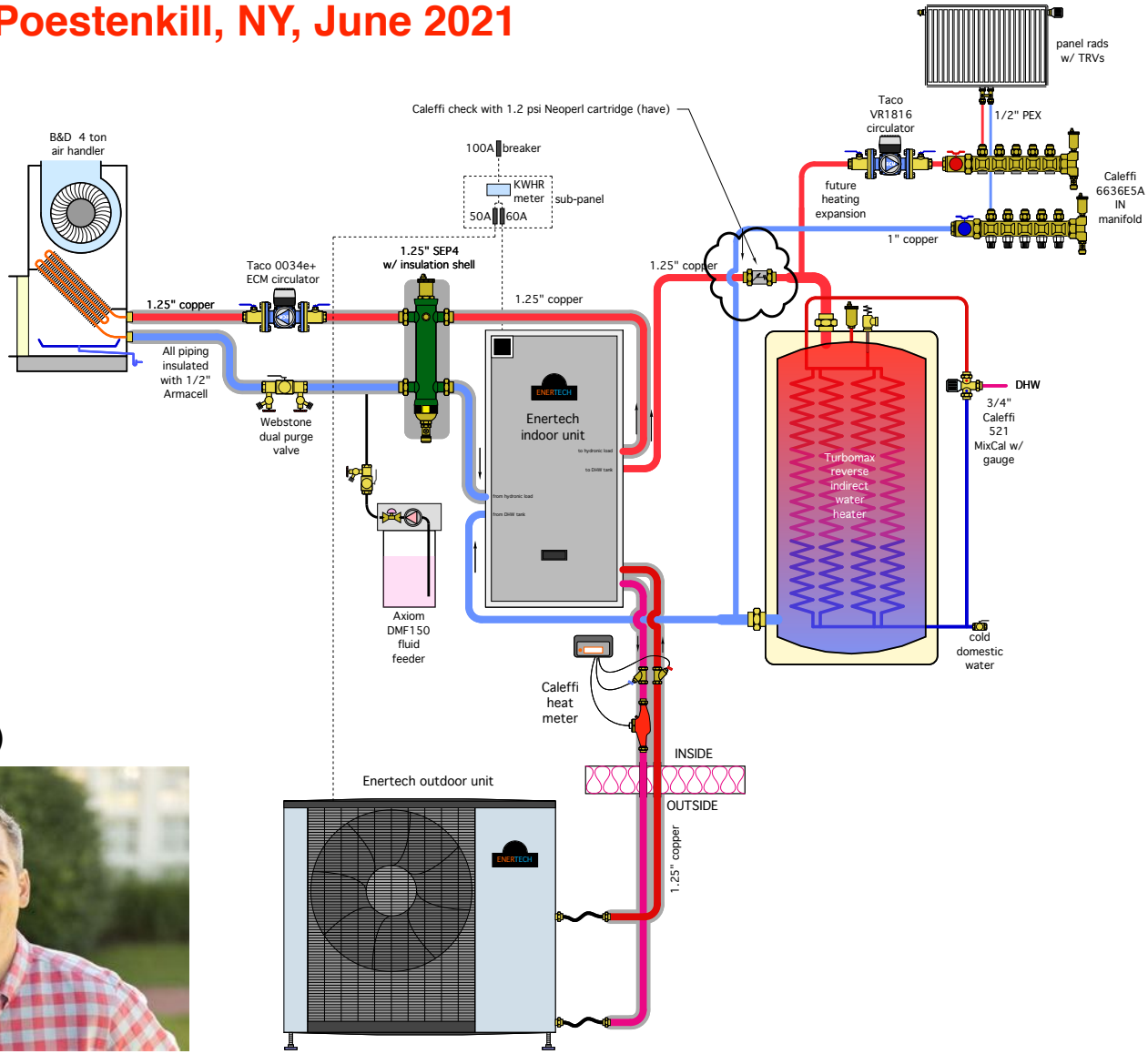
Installed by The Radiant Store (Terry Moag), Troy, NY

System has thermal and electrical energy monitoring (Caleffi CONTECA Btu meter)

Indoor portion of system

New air-to-water system installed in Poestenkill, NY, June 2021

Reverse indirect tank allows future hydronic expansion - such as panel radiators or towel warmers



Featured on
"This Old House"
January 2022 (Season 20, episode 13)

Key design concepts:

- Low water temperatures always enhance heat pump performance
(suggest design load supply water temperature ≤ 120 °F)
- Always provide 2-3 gpm / ton of flow whenever heat pump is operating
- Use antifreeze in all monobloc heat pump systems
- Use buffer tank whenever connecting to a zoned distribution system
(3-pipe buffer configuration allow direct-to-load heat transfer)
- Insulate and vapor seal all piping and piping components carrying chilled water
- Don’t locate outdoor unit where roof runoff falls on it
- Mount outdoor unit above snow line - minimum 12” above ground
- Keep piping between outdoor unit and buffer tank as short as possible