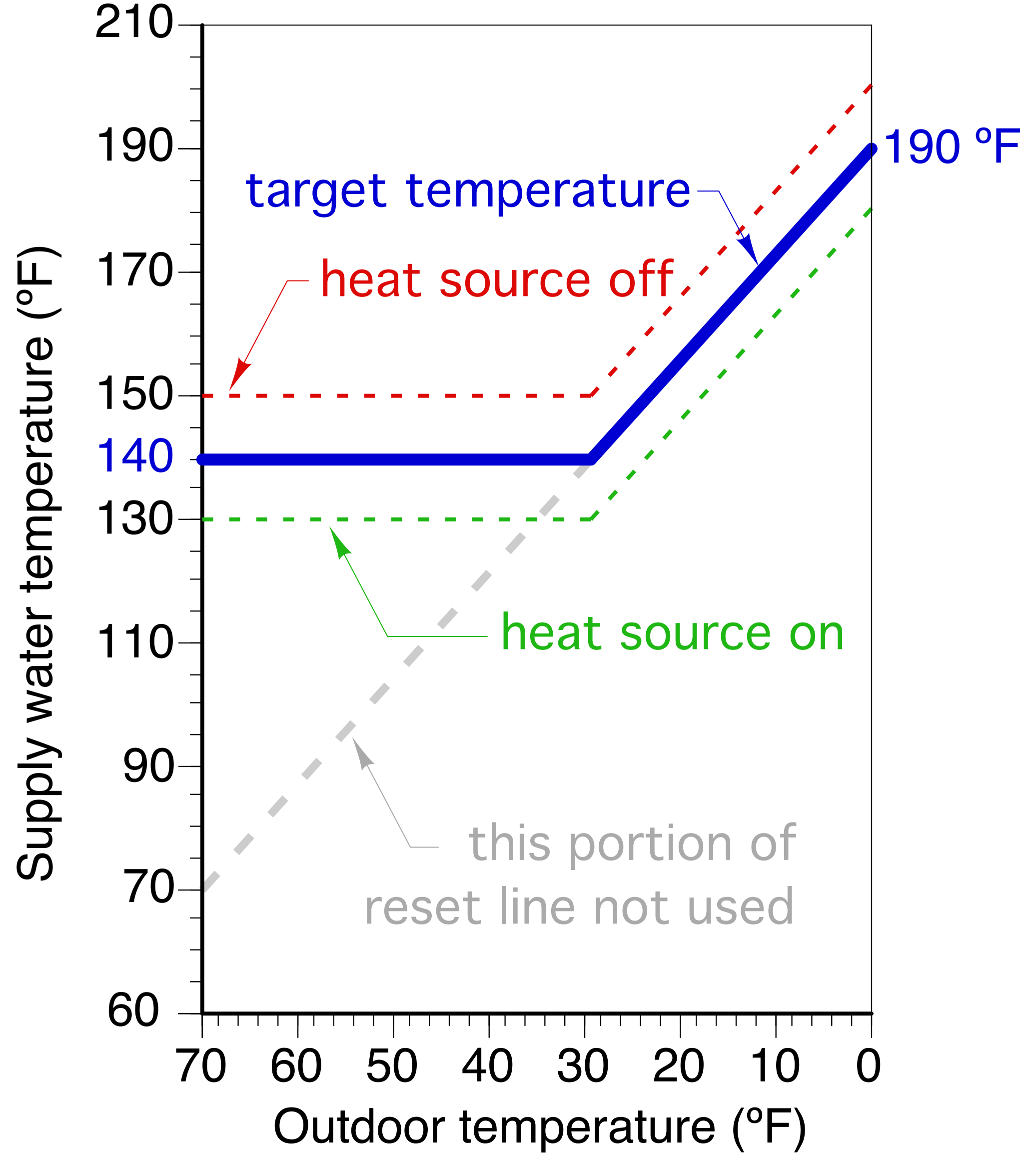
# Outdoor Reset Control Theory

## FULL versus PARTIAL reset

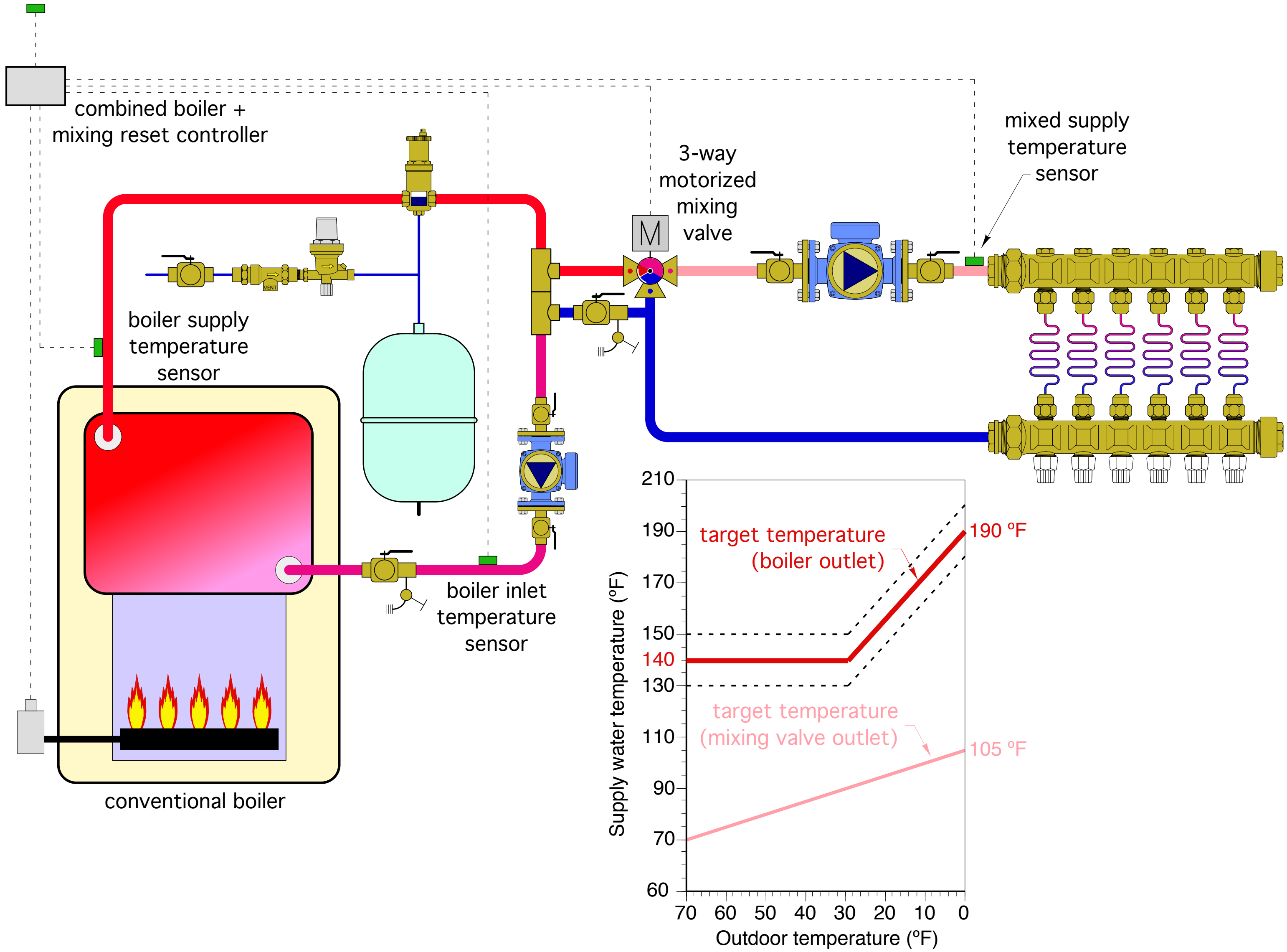
Conventional boilers must be protected against sustained operation at low water temperatures. If not, they will be damaged by sustained flue gas condensation.

The blue line shows partial reset control for a conventional, gas-fired boiler. The supply water temperature is not allowed to go below a target of 140 ºF, regardless of how warm it is outside.



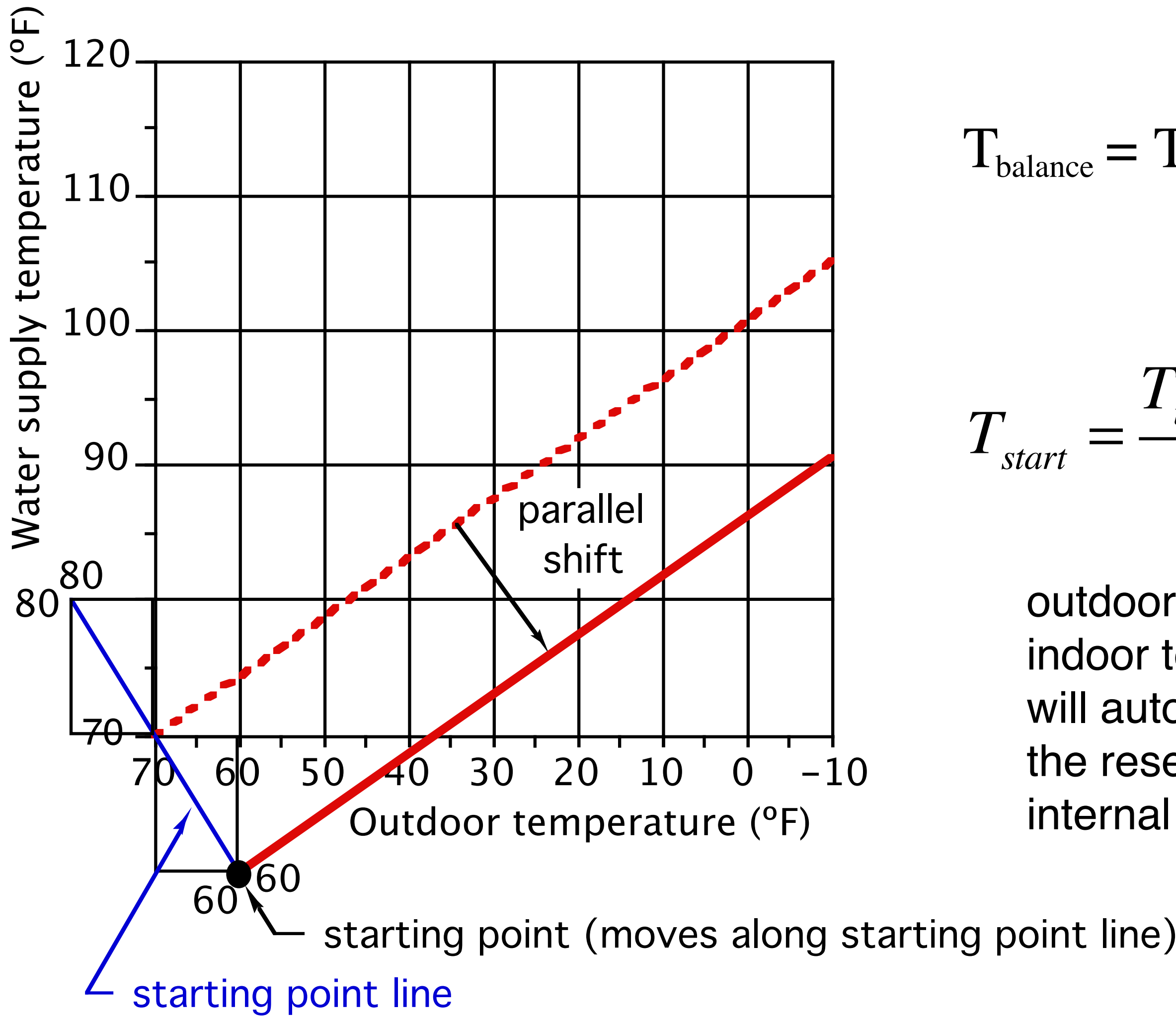
# Outdoor Reset Control Theory

## FULL and PARTIAL reset in same system



# Outdoor Reset Control Theory

## Compensation for non-proportional heat loss/gain (parallel shifting)

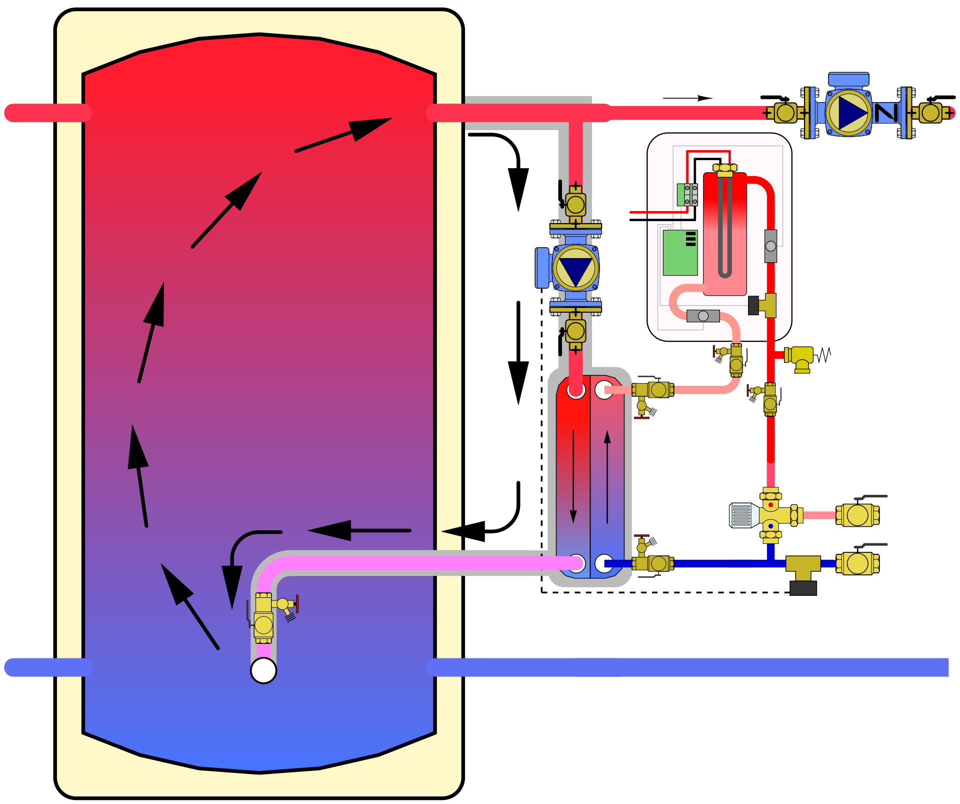



$$T_{balance} = T_{indoor} - \left(\frac{Q_{gain}}{UA_{building}}\right)$$

$$T_{start} = \frac{T_{inside} + (R \times T_{balance})}{(1 + R)}$$

outdoor reset controllers with indoor temperature sensors will automatically parallel shift the reset line based on internal gains or losses.

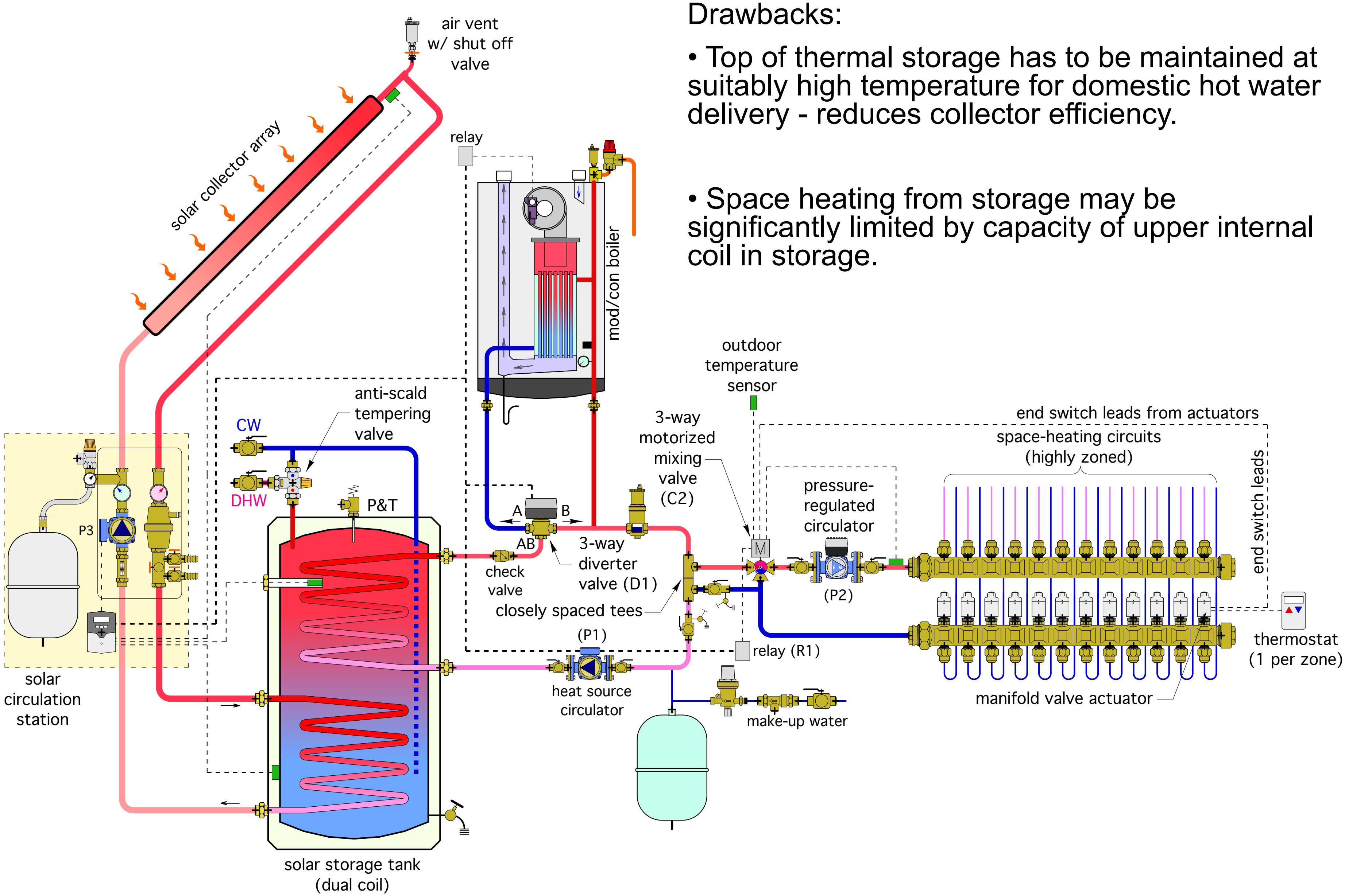
# Instantaneous Domestic Water Heating From Thermal Storage Tanks




## Starting points:

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

# One way to make a solar combisystem...



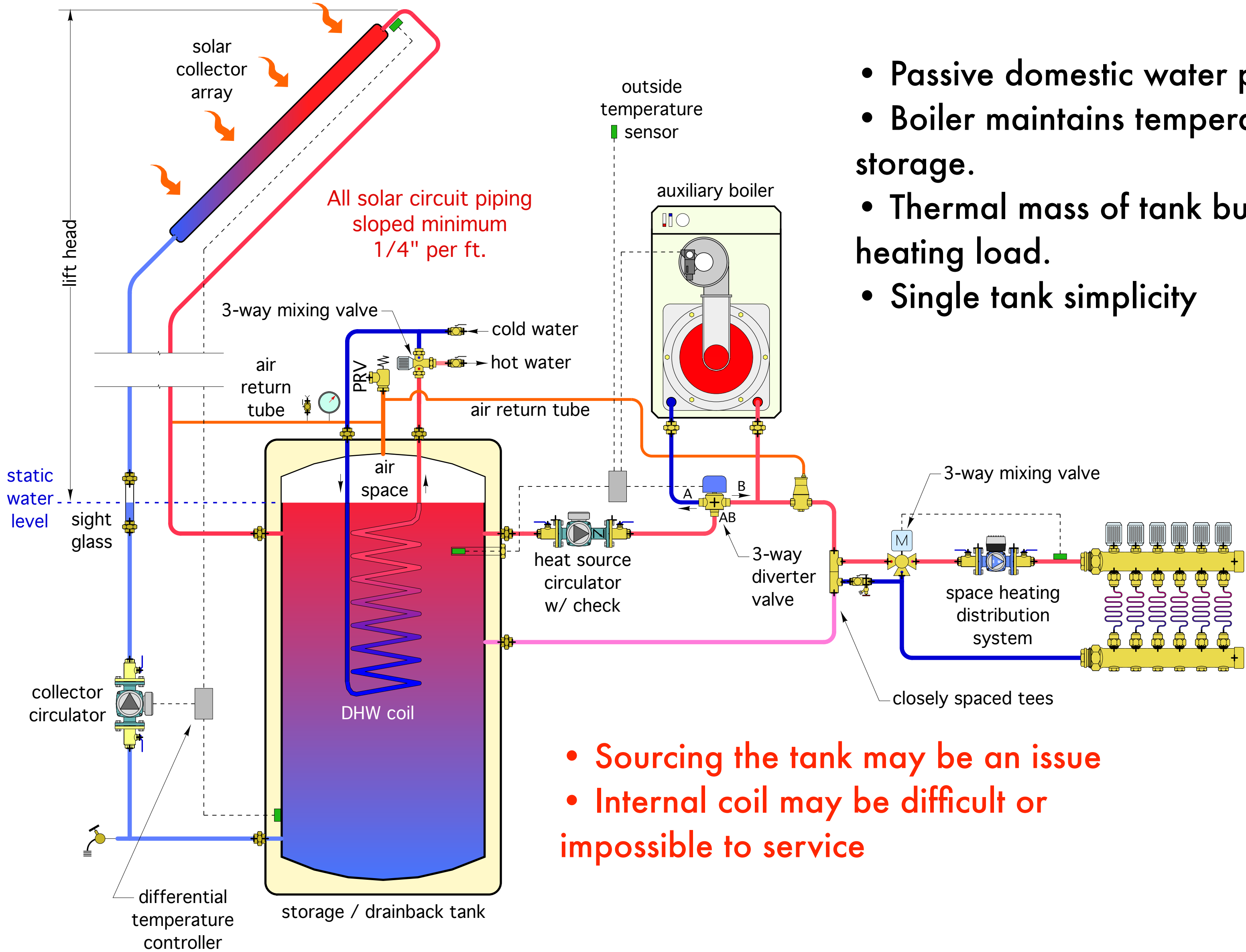

Drawbacks:

- Top of thermal storage has to be maintained at suitably high temperature for domestic hot water delivery - reduces collector efficiency.

- Space heating from storage may be significantly limited by capacity of upper internal coil in storage.

# Another way to make a solar combisystem...

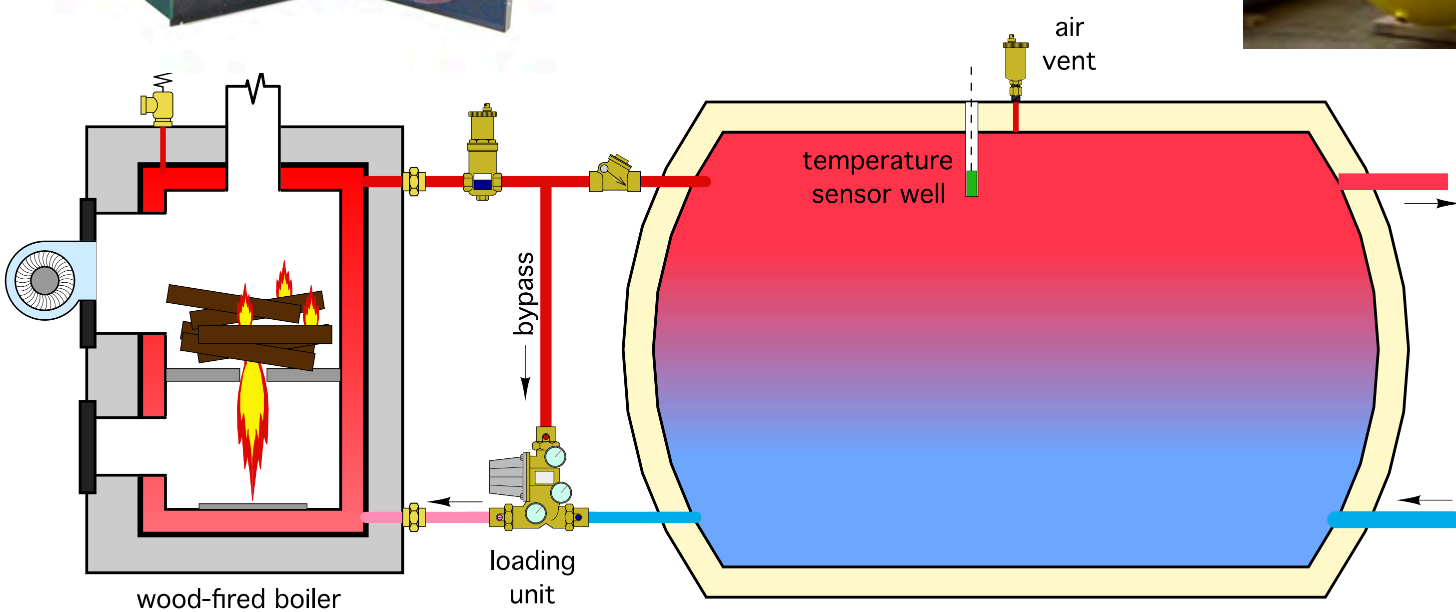
Pressurized drainback system w/ internal coil for domestic water heating.




- Passive domestic water preheating
- Boiler maintains temperature at top of storage.
- Thermal mass of tank buffers space heating load.
- Single tank simplicity

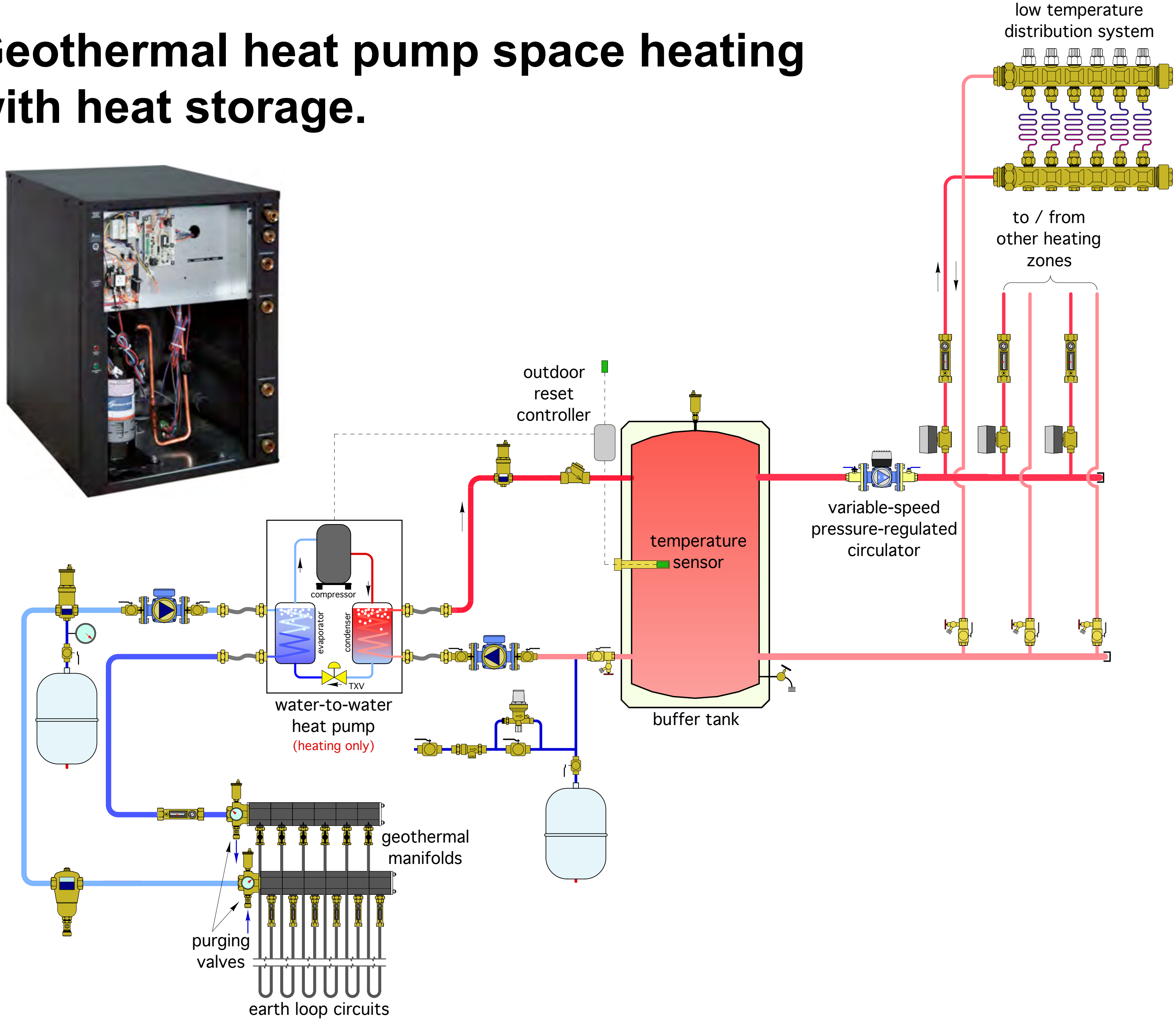
- Sourcing the tank may be an issue
- Internal coil may be difficult or impossible to service

# Wood gasification boiler with heat storage.

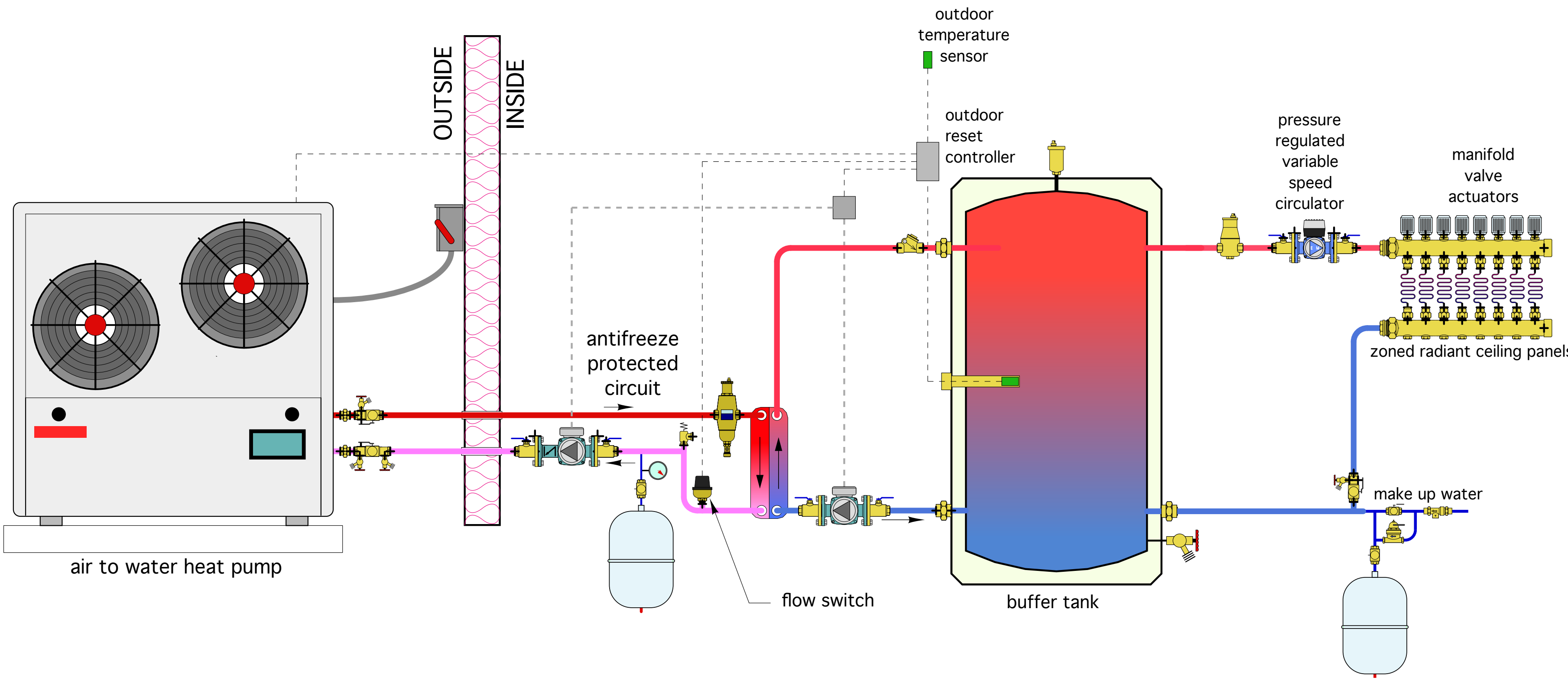



Large thermal storage is often used with wood gasification boilers.

# Geothermal heat pump space heating with heat storage.



# Air-to-water heat pump with heat storage.



# Gas-fired tankless water heaters and preheated water

- ***Many gas-fired tankless water heaters have limited modulation ability.***

- ***Most require an inlet temperature at least 20ºF lower than their setpoint as a condition to fire their combustion system.***

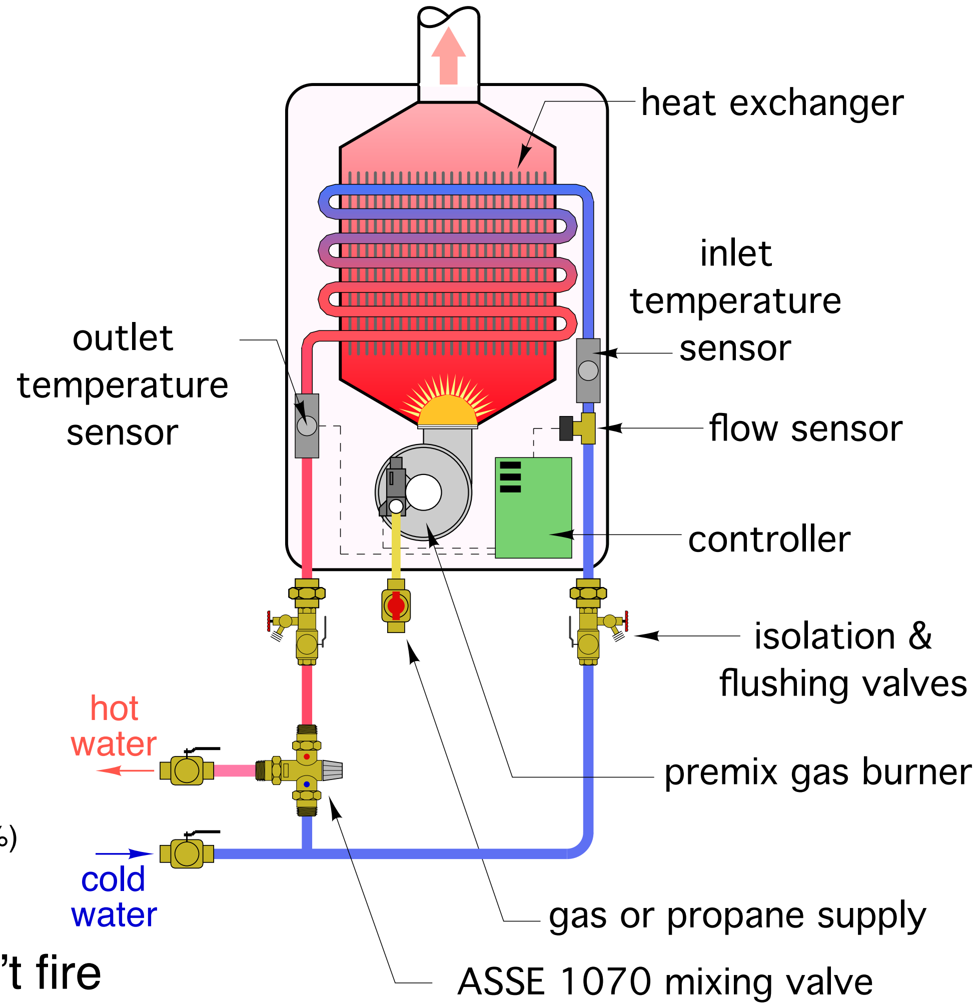
Thermal load on heater:

$$Q_{thermal} = 500 \times f \times \left(T_{setpoint} - T_{in}\right)$$

Minimum heat transfer rate of heater:

$$Q_{HT\,\min} = Q_{gas} \times n$$

Where:
$Q_{thermal}$ = current thermal load on heater (Btu/hr)
f = flow rate through heater (gpm)
$T_{septoint}$ = desired water outlet temperature leaving heater (°F)
$T_{in}$ = water inlet temperature to heater (°F)
$Q_{HTmin}$ = minimum rate of heat transfer to water (Btu/hr)
$Q_{gas}$ = minimum gas input rate to burner (Btu/hr)
n = combustion efficiency of burner / heat exchanger (decimal %)



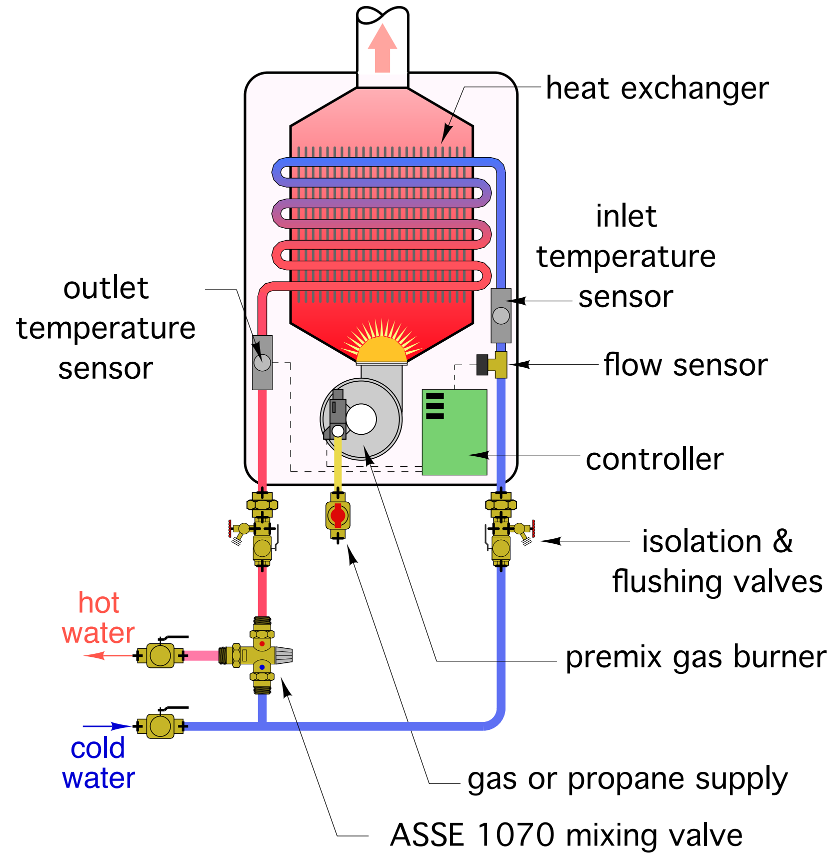

IF $Q_{thermal} \leq Q_{HTmin}$ THEN burner doesn't fire

Assume the minimum gas input to a tankless heater is 10,000 Btu/hr, and the combustion efficiency is 90%. Solar preheated water enters the unit at 110 °F and 0.8 gpm. The setpoint of the heater is 120 °F. If the controller in the unit operates as described on previous slide, will the burner fire under the stated conditions?

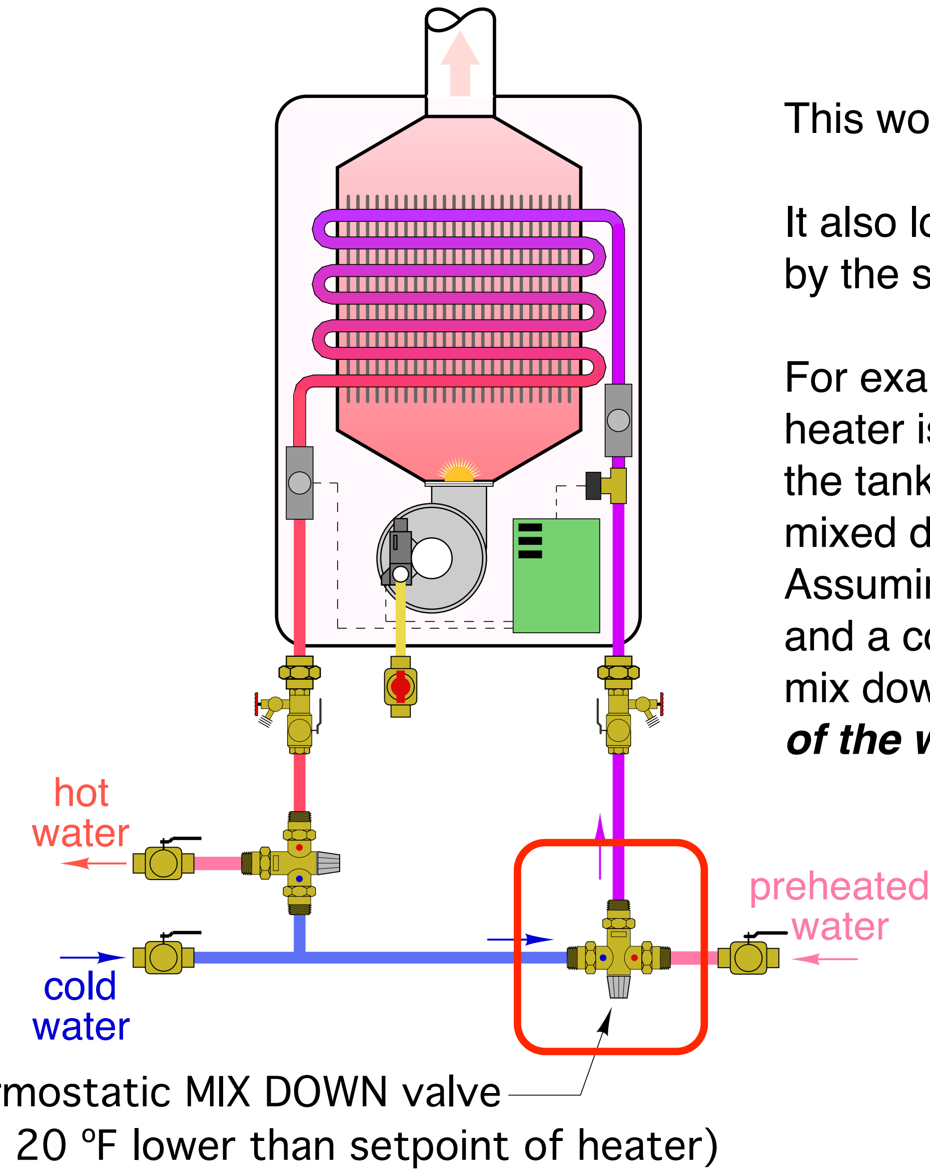
Thermal load on heater: $$Q_{thermal} = 500 \times 0.8 \times (120 - 110) = 4000\,Btu/hr$$

Minimum heat transfer rate of heater: $$Q_{HT\,\min} = 10{,}000 \times 0.90 = 9{,}000\,Btu/hr$$

Because $Q_{thermal} \leq Q_{HTmin}$ THEN burner doesn't fire



# One "work around" is to mix down the inlet temperature using a second thermostatic valve.

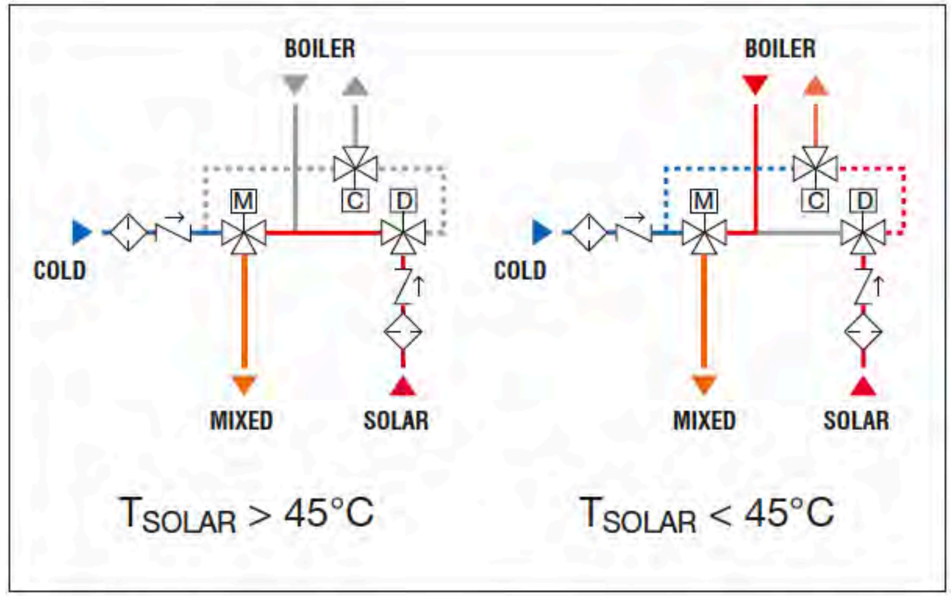


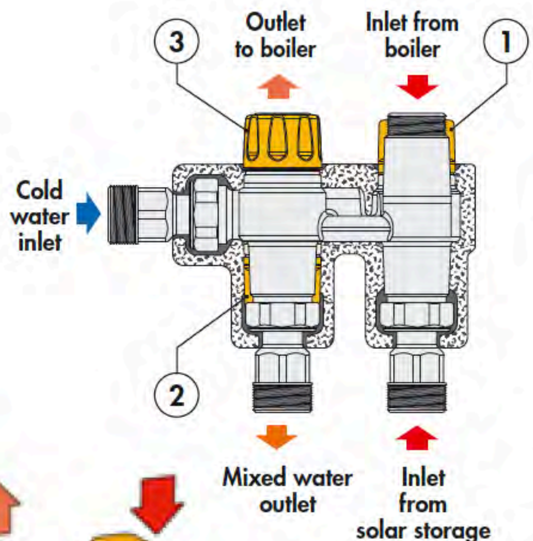

This works - BUT...

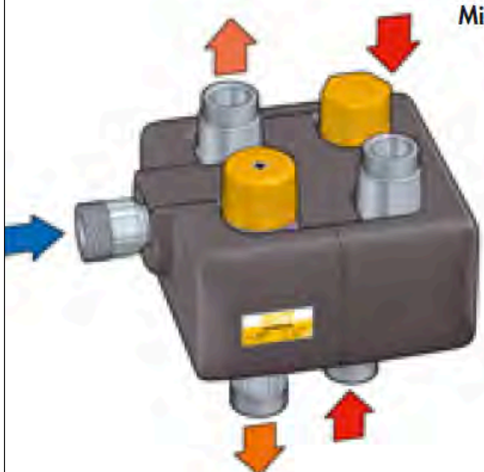
It also lowers the "net" preheating effect supplied by the solar subsystem.

For example: Assume the setpoint of the tankless heater is 120 °F. Solar preheated water arriving at the tankless heater at 110°F would have to be mixed down to 100 °F before entering the heater. Assuming a desired delivery temperature of 120°F and a cold water temperature of 50 °F, this 10 °F mix down ***decreases the solar supplied portion of the water heating load from 86% to 71%.***

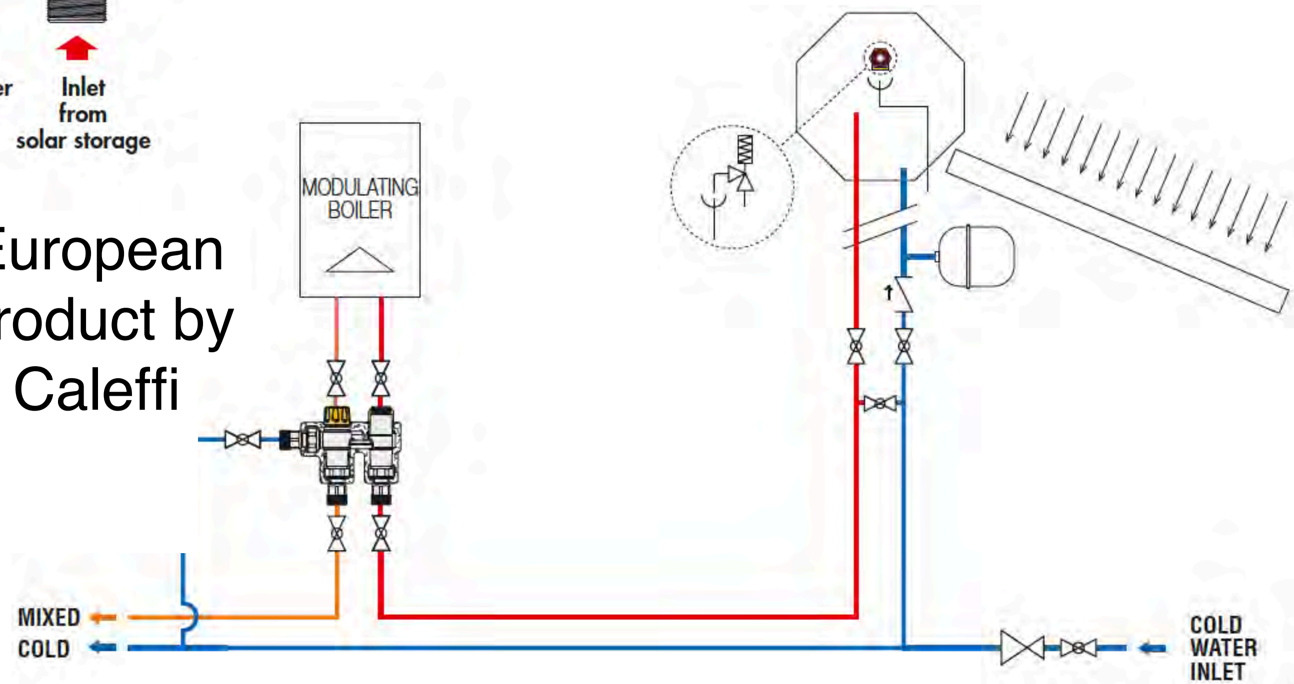
One “work around” is to mix down the inlet temperature using a second thermostatic valve



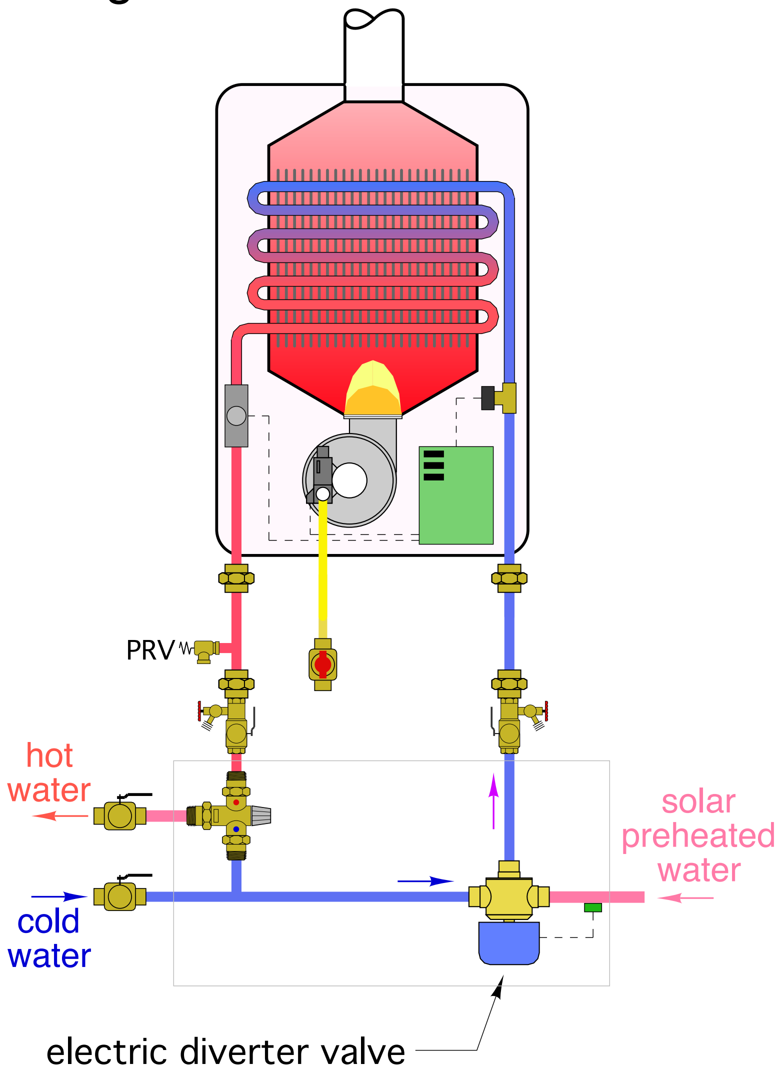



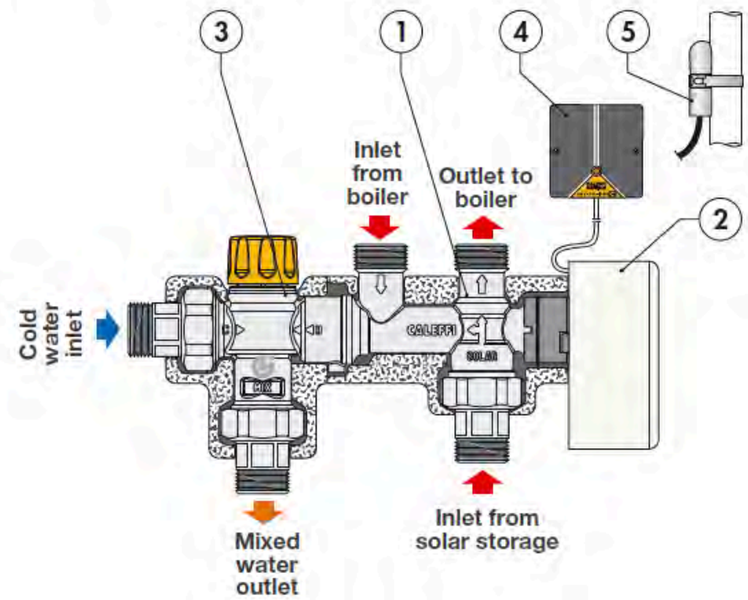
European product by Caleffi

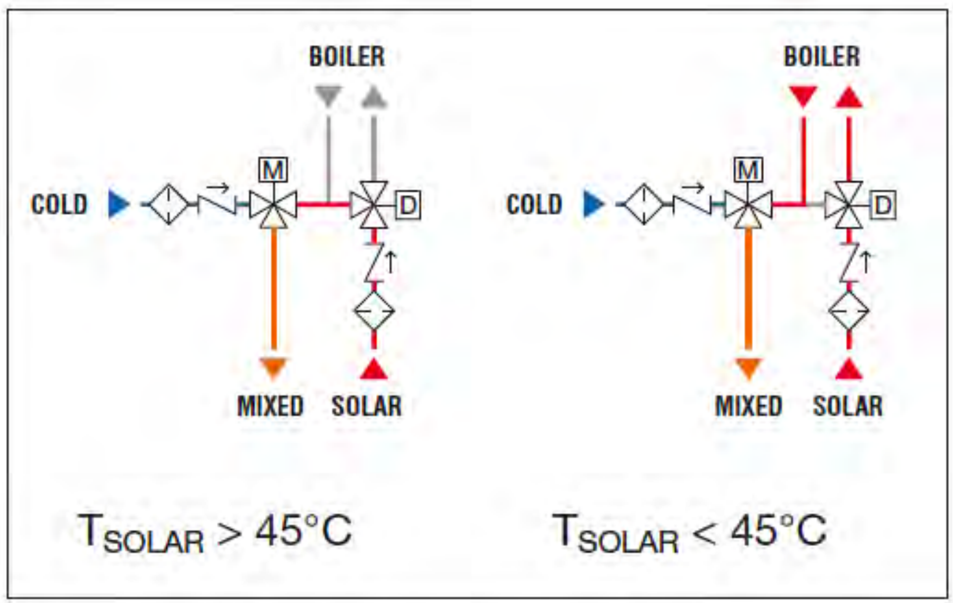


Another option is to *divert* water around the tankless heater if temperature is above a specified setting.




1) Diverter valve
2) Diverter valve actuator
3) Thermostatic mixing valve
4) Diverter valve control thermostat
5) Solar storage temperature probe



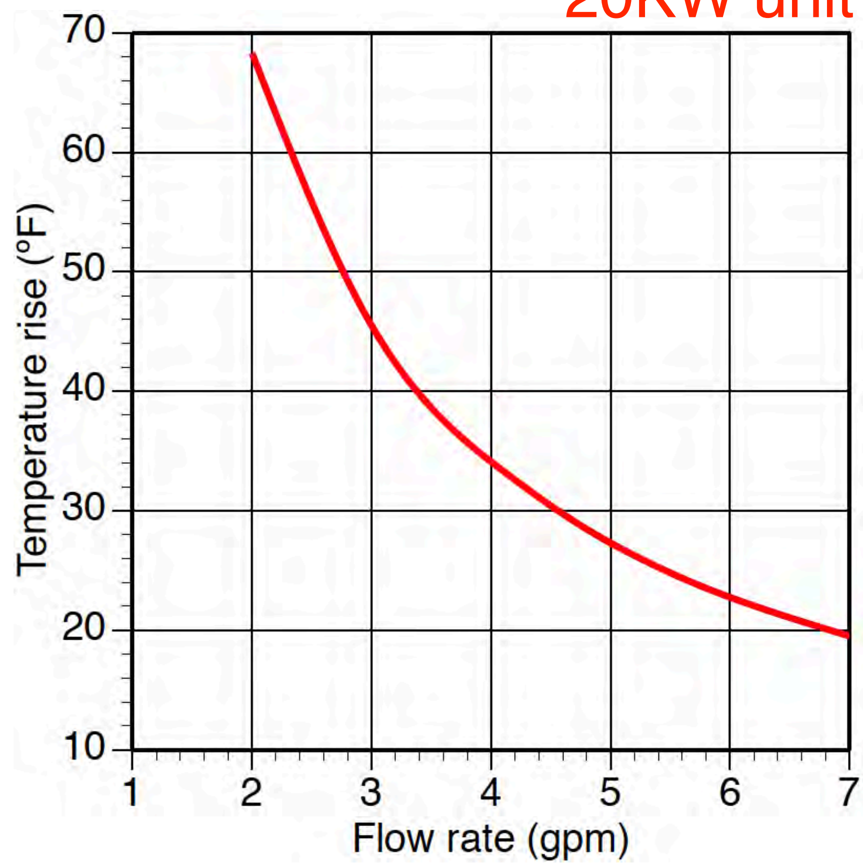
# *Thermostatically controlled* electric tankless water heaters


Typical
“point of use”
ETWH
3-6 KW

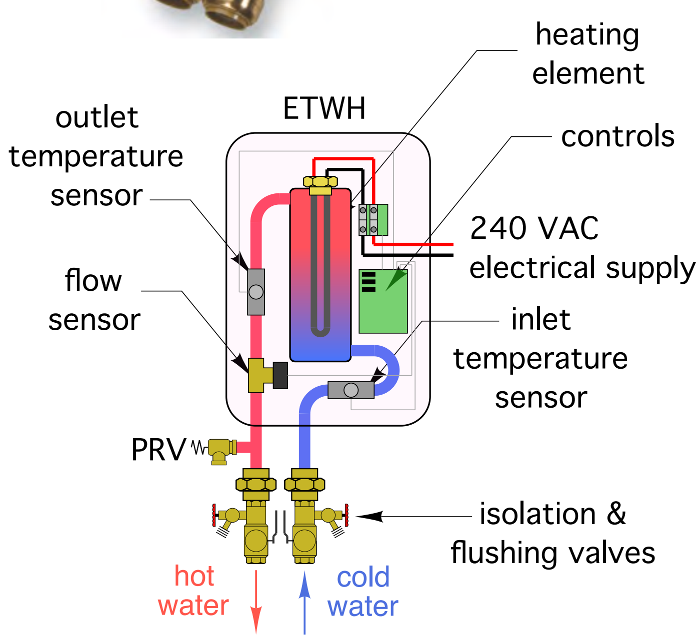
Typical
“whole
house”
ETWH
10-40 KW

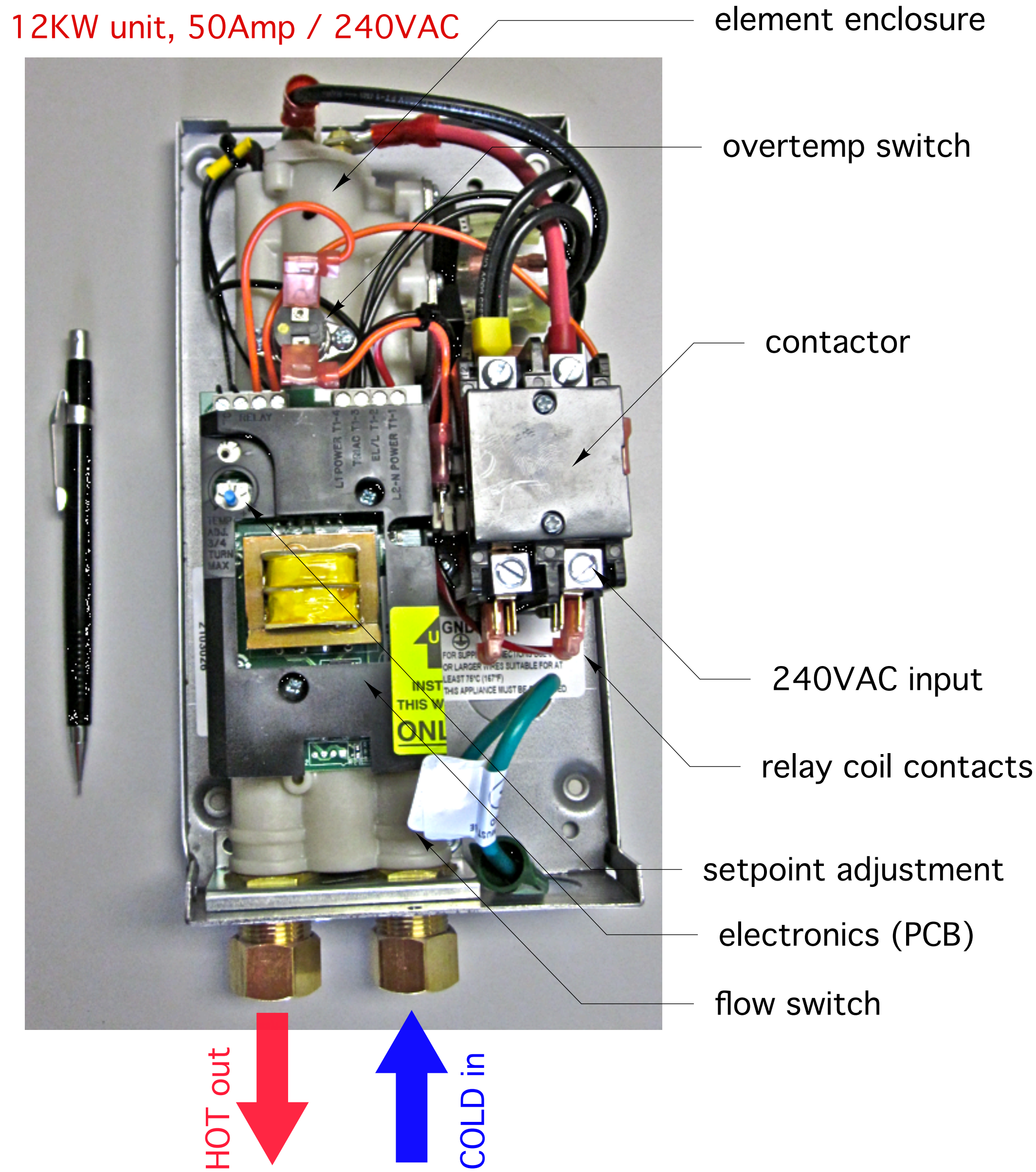
*maximum possible water temperature rise always depends on flow rate*

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

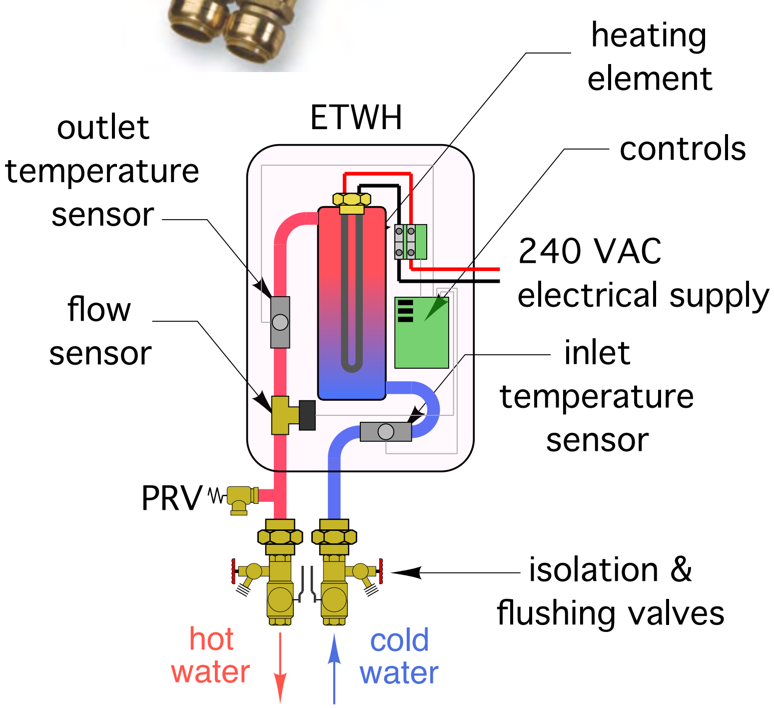
$$Amps = \frac{KW}{0.24}$$

**Minimum 200 Amp breaker panel recommended.**

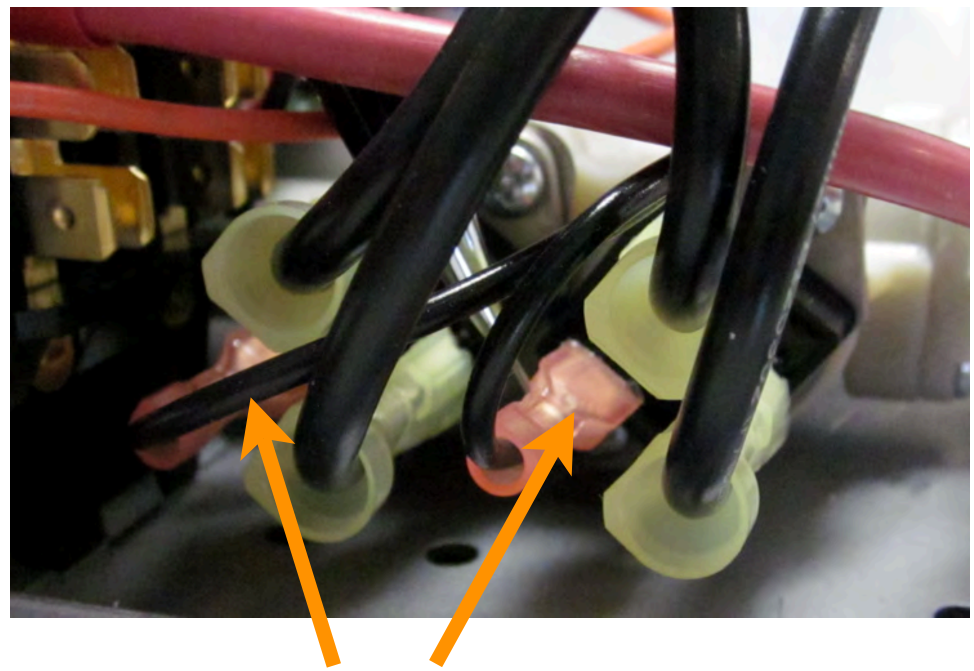
**May be an issue in some older retrofits.**

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

# *Thermostatically controlled* electric tankless water heaters

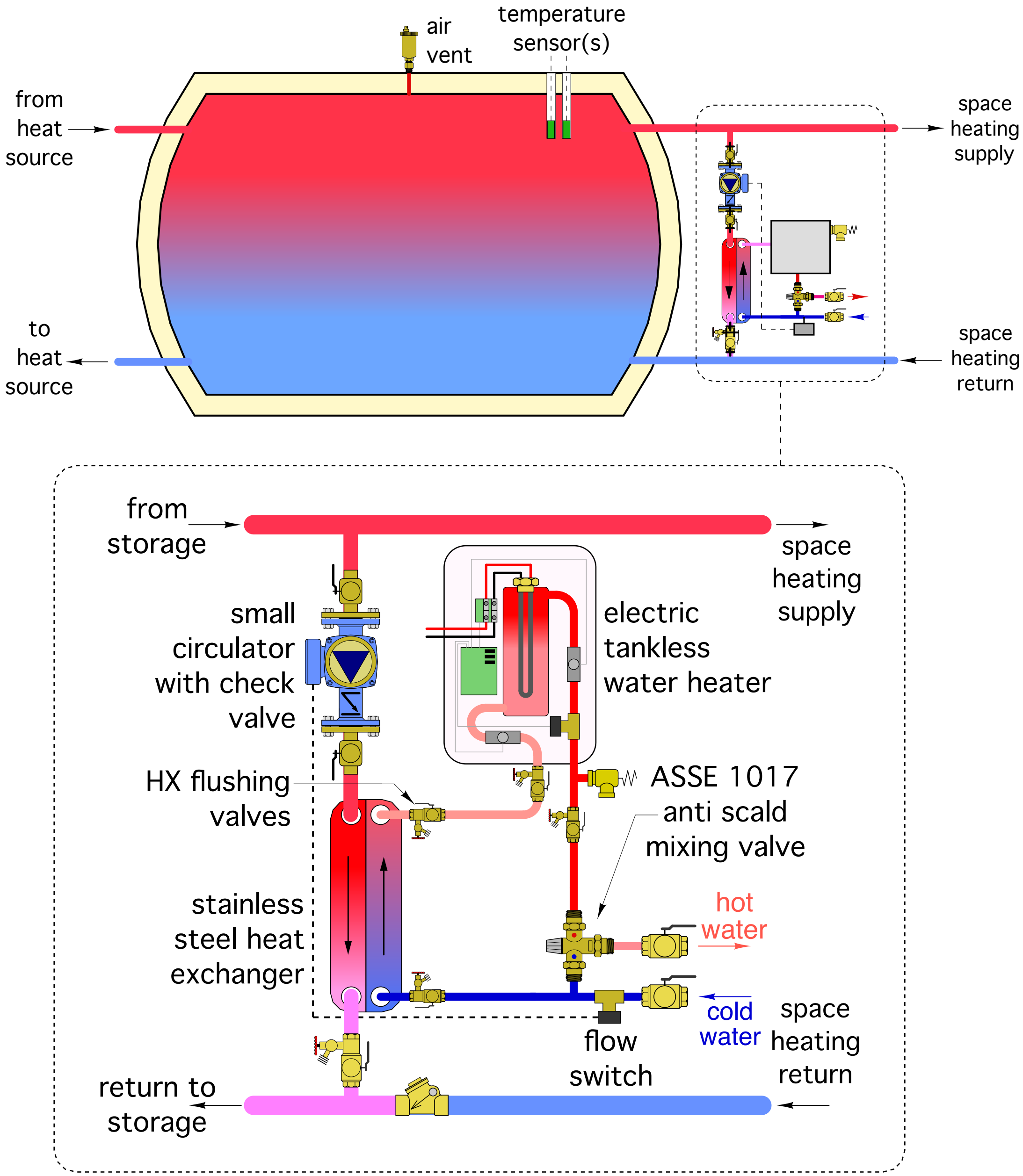



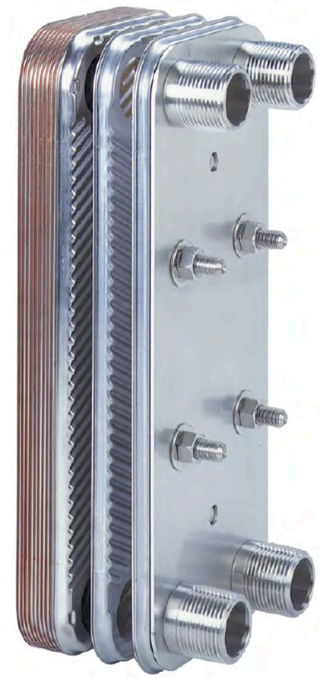

Thermostatically controlled electric tankless water heaters use a TRIAC to vary the wattage to their heating elements from 0 to 100%.



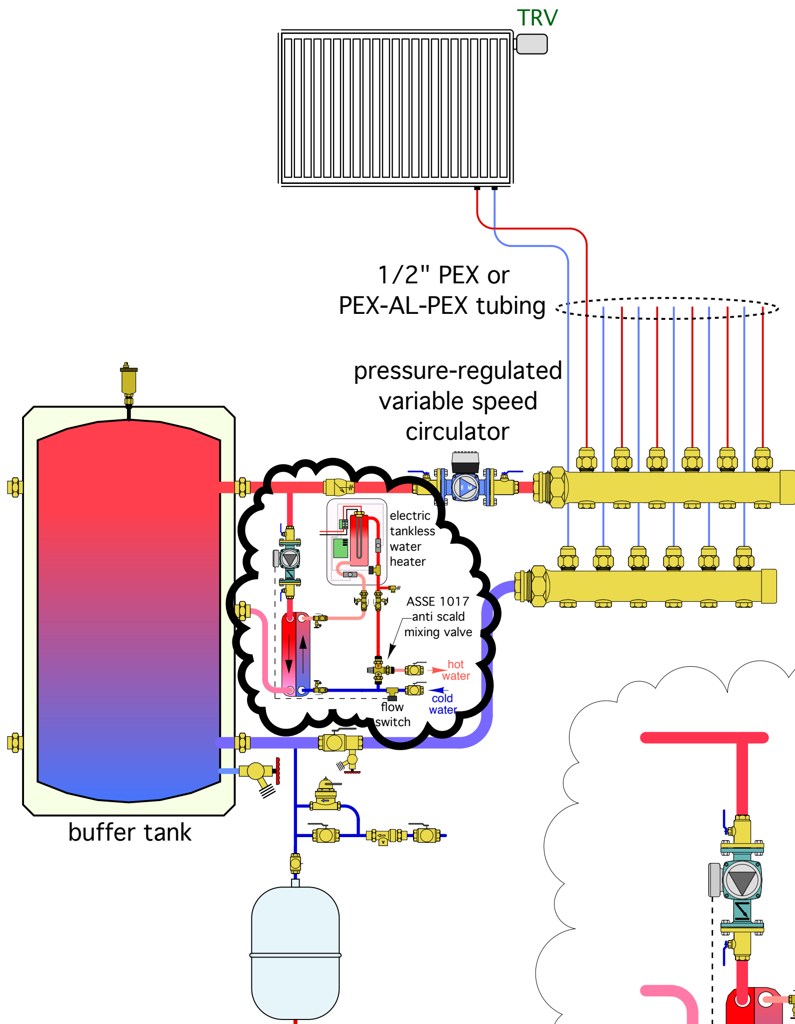

They can therefor handle situations where preheated water needs a small temperature “boost” without short cycling.

# Instantaneous DHW subassembly

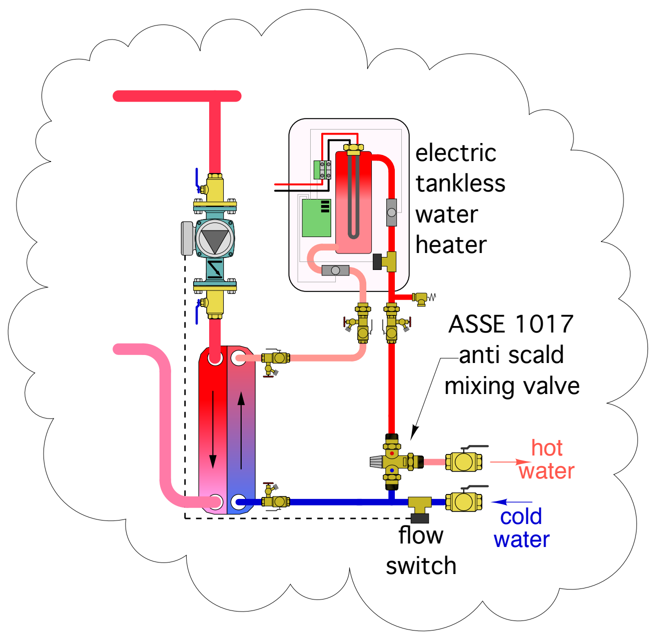



# Instantaneous DHW subassembly

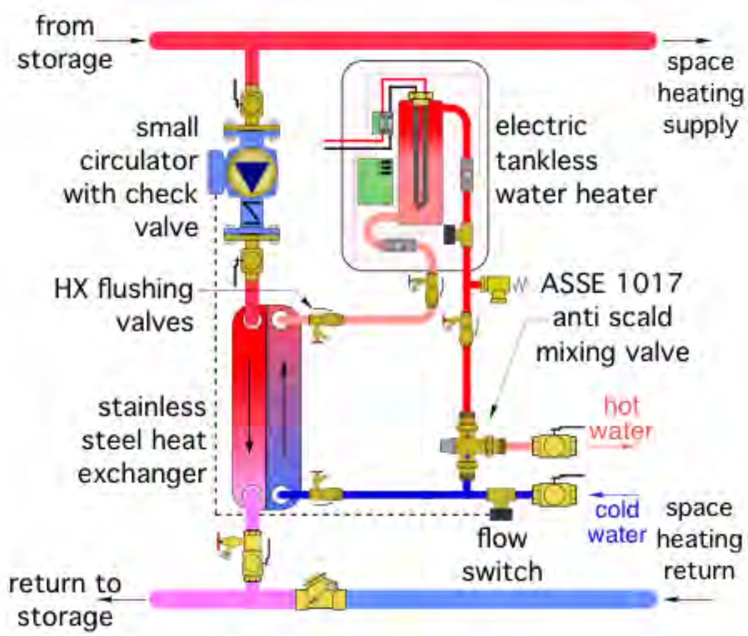



- Leverages the thermal mass for stabilizing DHW delivery.
- Brazed plate heat exchanger provides very fast response (1-2 seconds)
- Fully serviceable heat exchanger (unlike an internal coil heat exchanger) Can be cleaned or replaced if necessary.
- Predictable heat exchanger performance




- Very little heated domestic water is stored (reducing potential for Legionella growth).
- Very low wattage circulator needed on primary side of heat exchanger

# Instantaneous DHW subassembly




3”x5”

5”x12”

10”x20”

Brazed plate stainless steel heat exchangers are widely available.

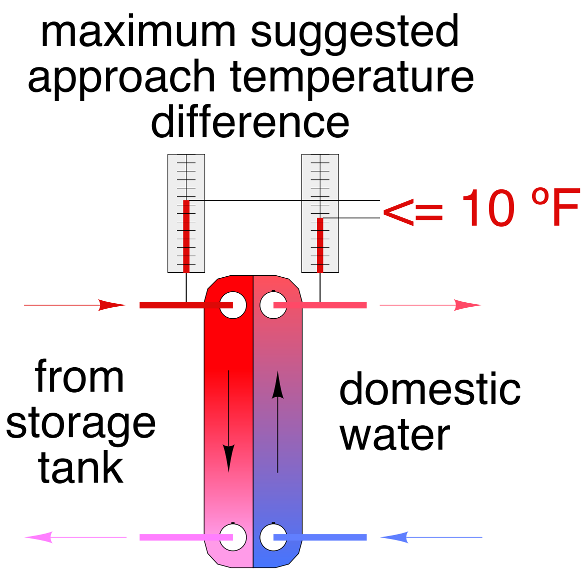
They have very high ratio of surface area to volume.

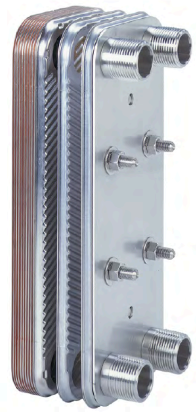
Response time to quasi steady state = 1 to 2 seconds

Response time of this subassembly is likely under 5 seconds.
(assuming short, insulated piping b/w HX and storage tank)

# Sizing the brazed plate heat exchanger

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

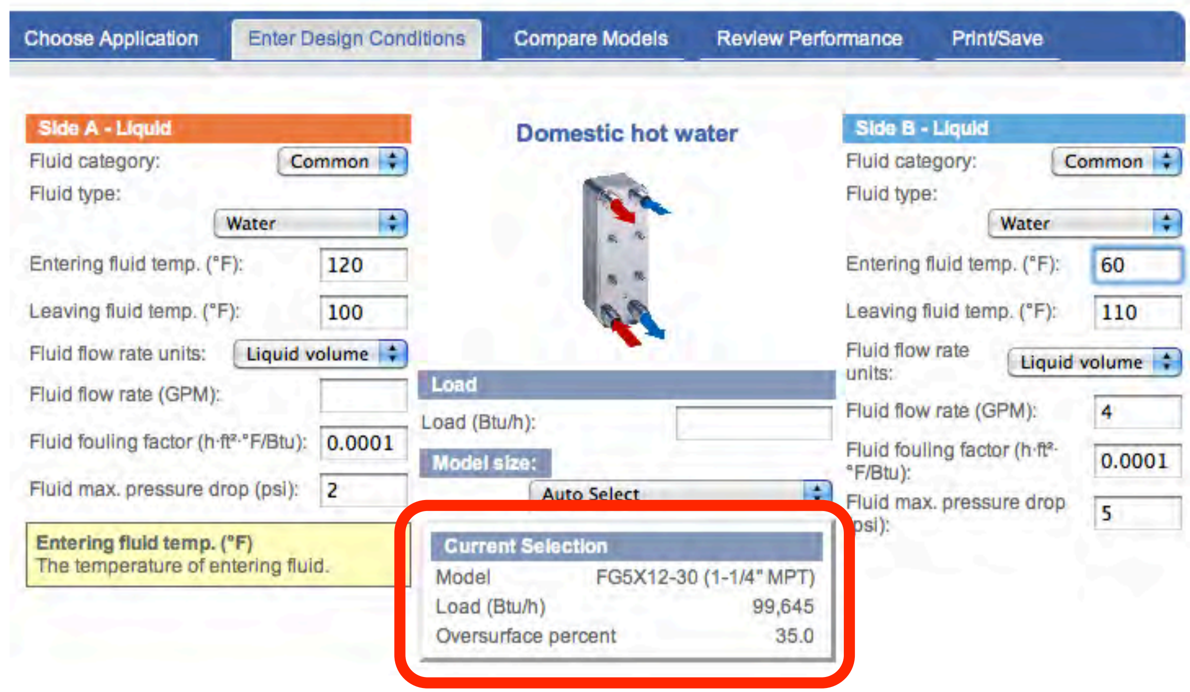


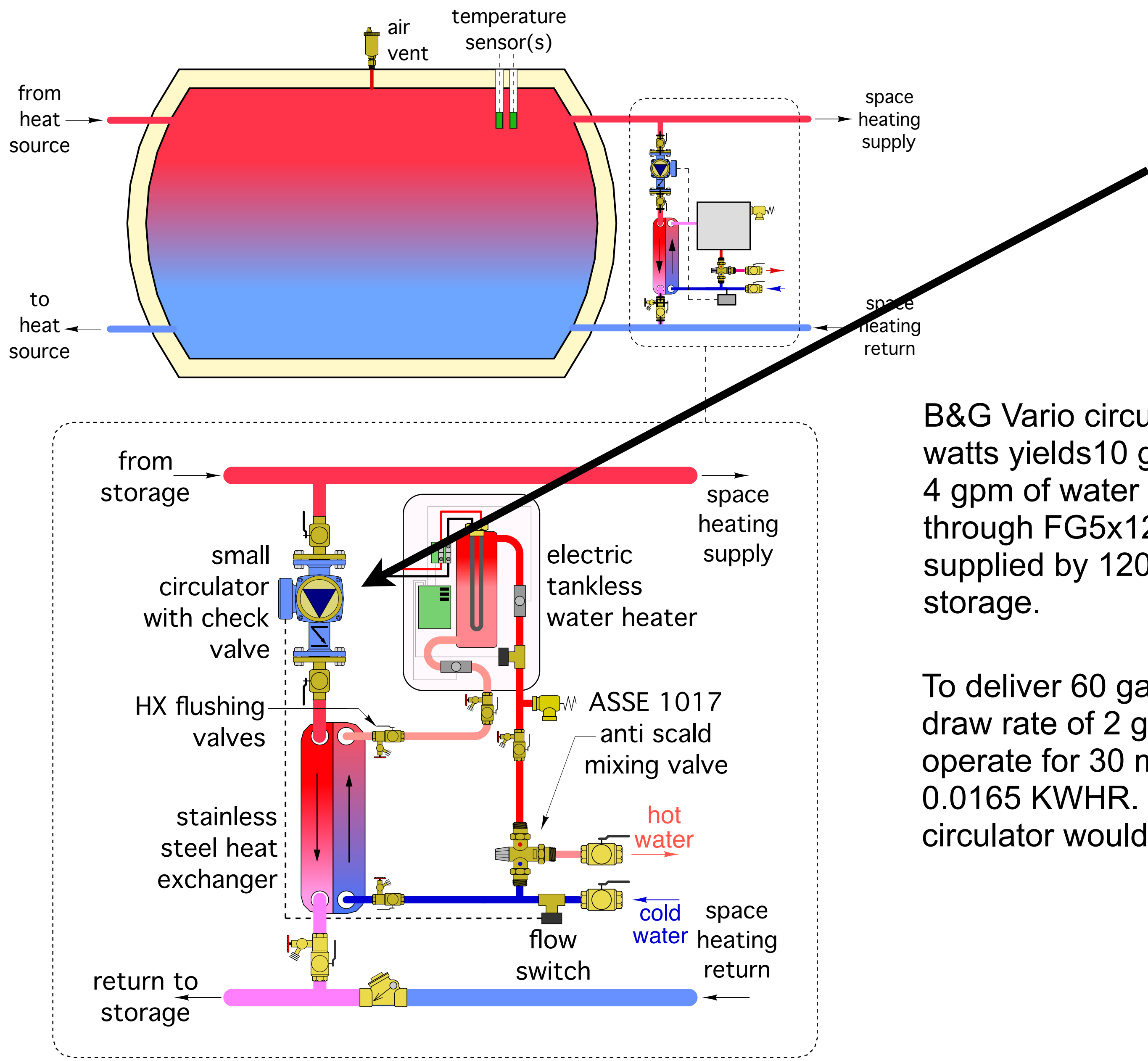
FG5x12-30
5” wide x12” long -30 plates

http://flatplateselect.com

GEA FlatPlateSELECT™ – ONLINE



# Instantaneous DHW subassembly

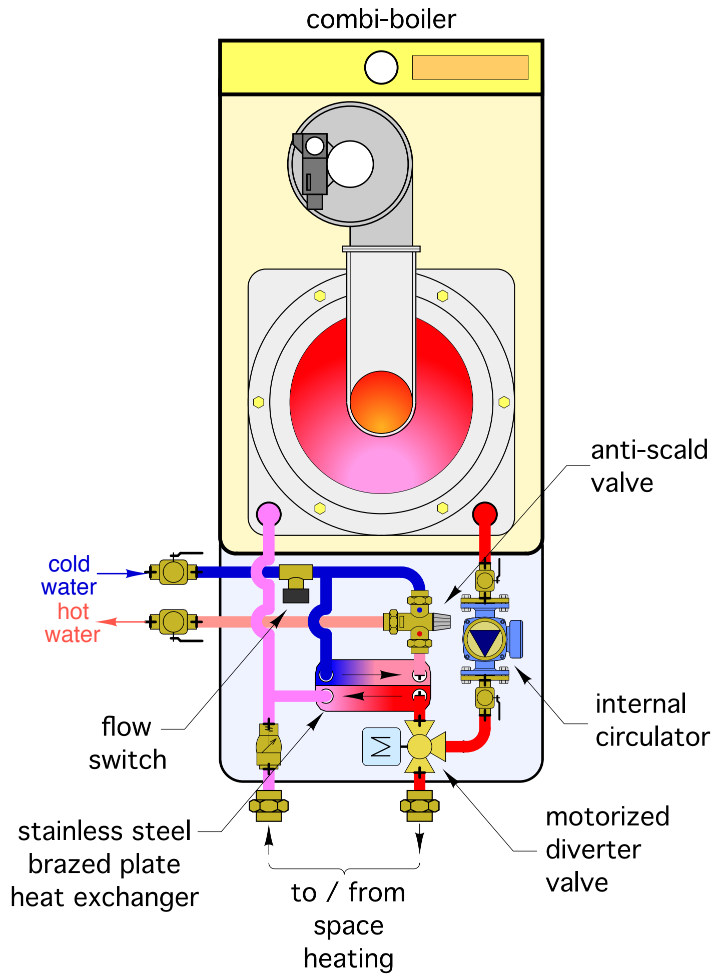



B&G Vario circulator operating at 33 watts yields10 gpm as required to raise 4 gpm of water from 60 to 110 ºF through FG5x12-30 heat exchanger supplied by 120ºF water from thermal storage.

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

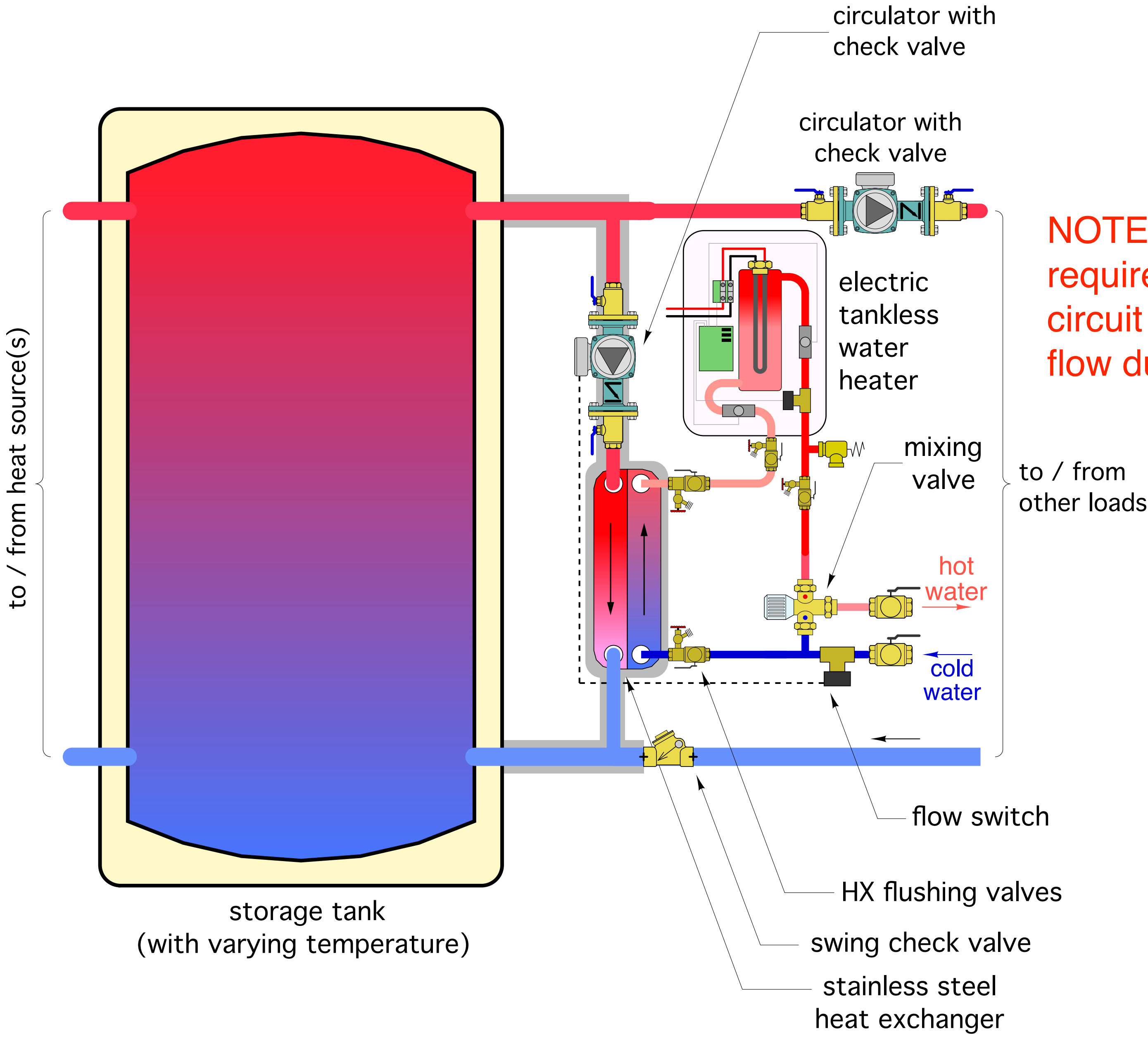



gas-fired tankless

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

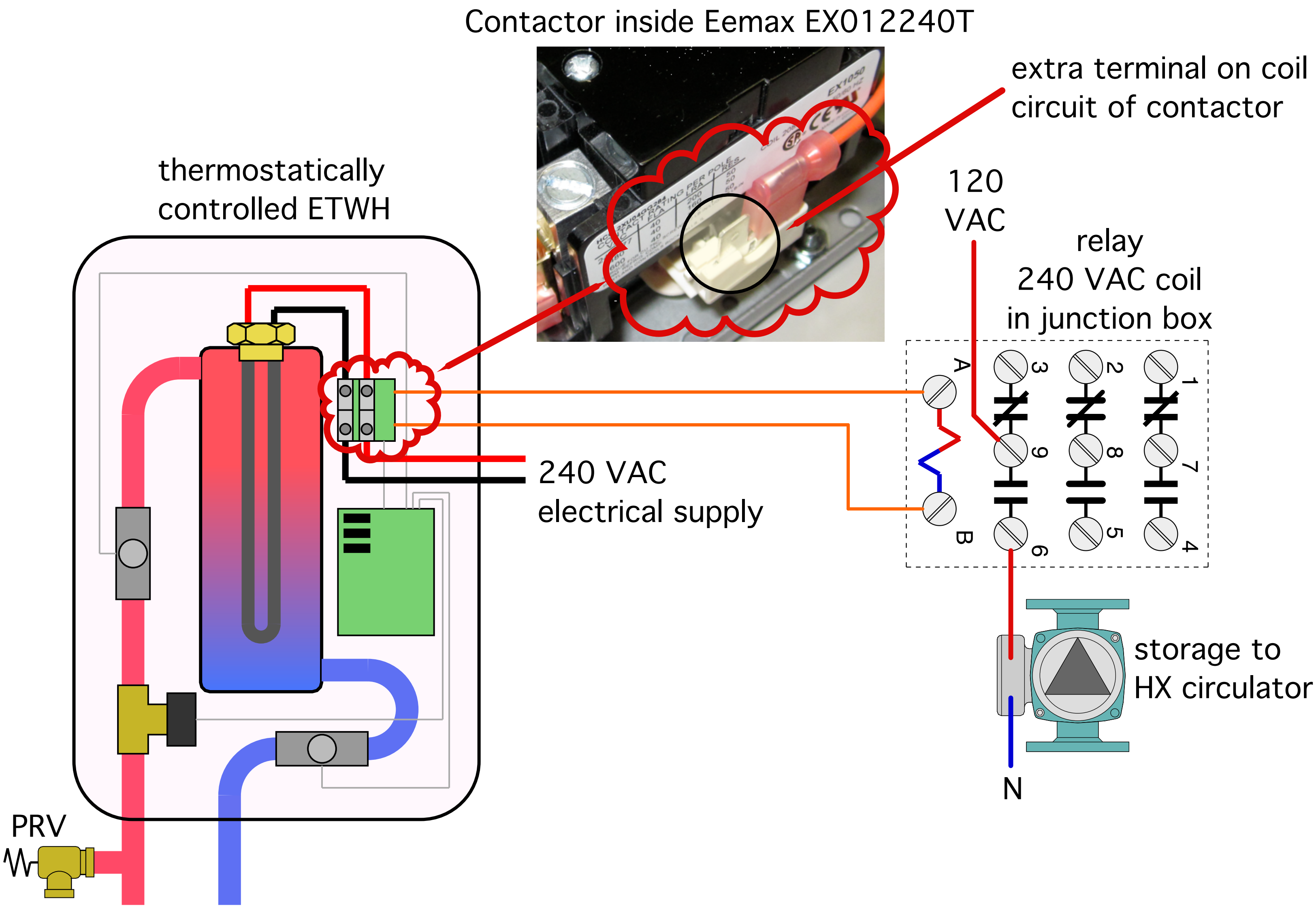
# Instantaneous DHW subassembly piping



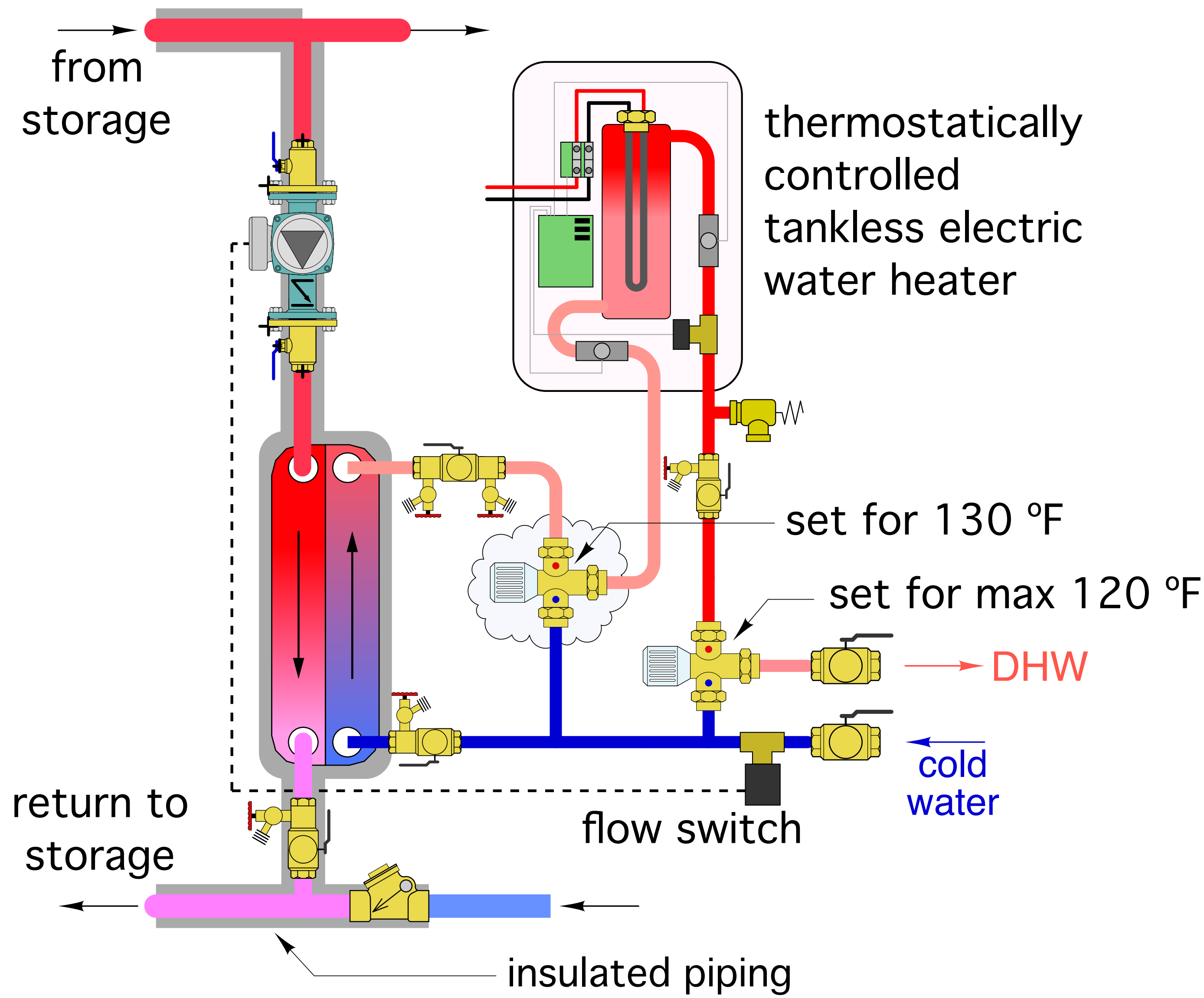

NOTE: Check valve required on tank-to-HX circuit to prevent reverse flow during space heating

# Using extra terminal on ETWH contactor to operate circulator

# This eliminates the need for the flow switch.



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



# Why not just use internal heat exchanger coils?

These are all examples of European multi-coil thermal storage tanks.


# Why not just use internal heat exchanger coils?

- These tanks cost over $4000

- What happens when a pinhole leak develops anywhere inside the tank?

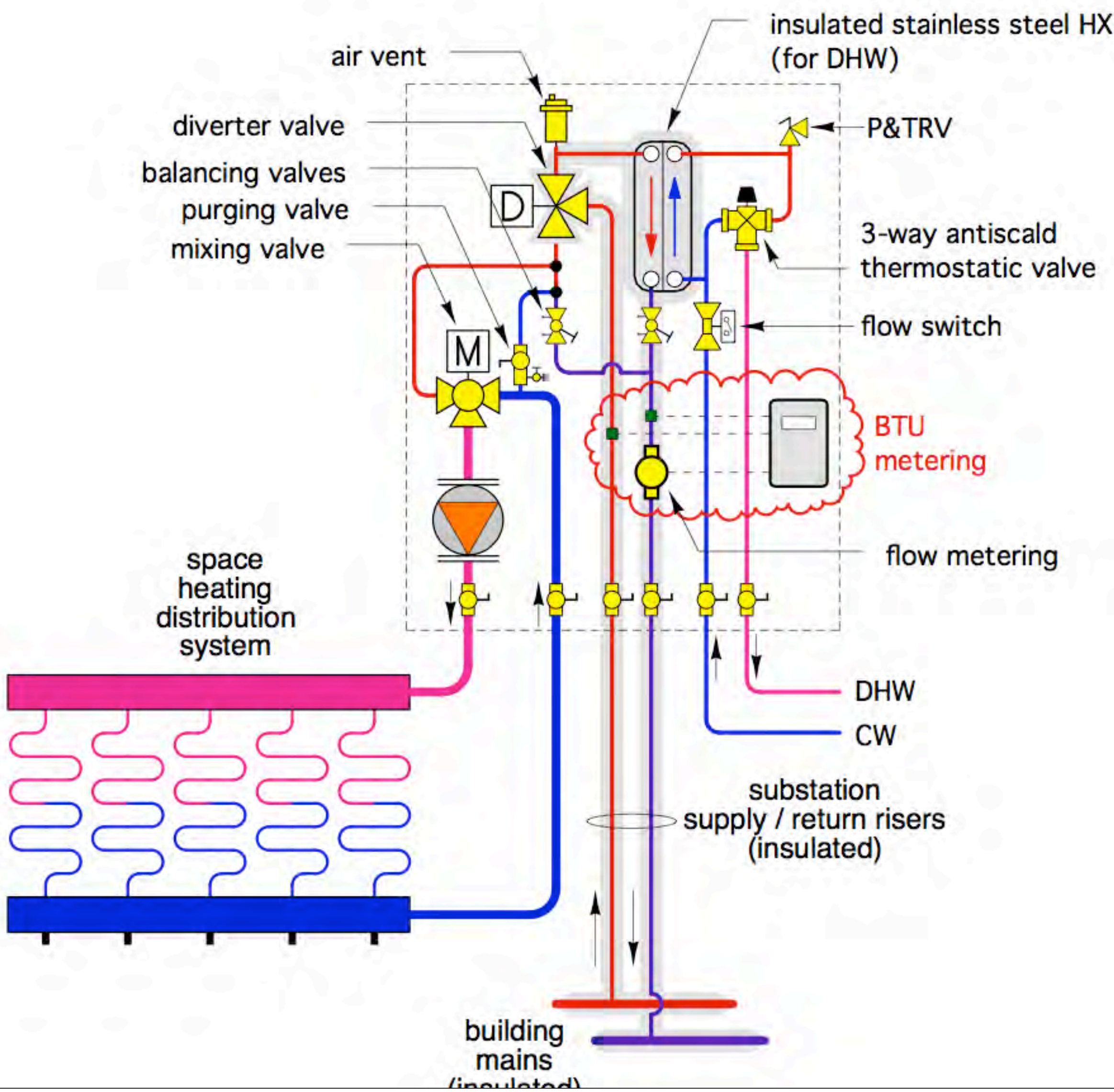
- Internal coils are limited by natural convection heat transfer.

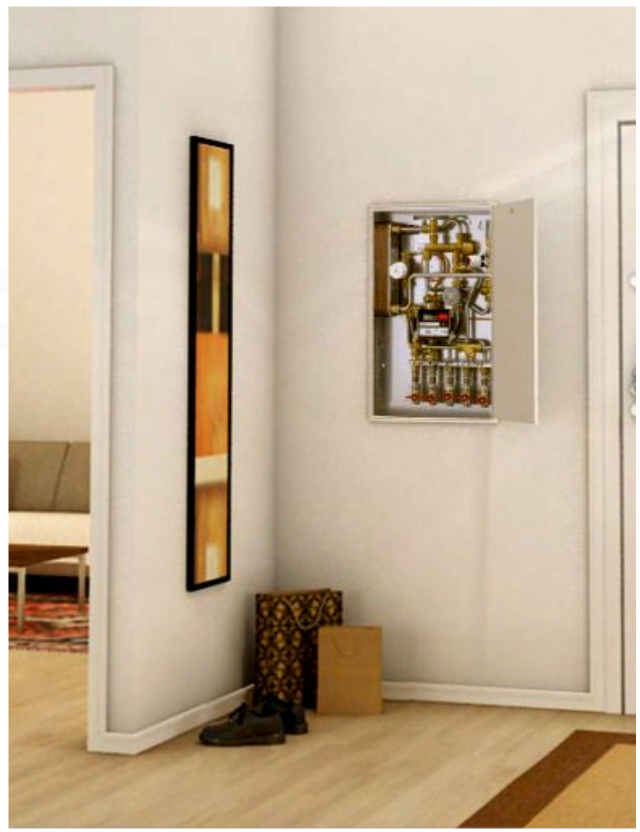
- No one offers tanks like this in North America

- Many European tanks - even if available in North America, may not meet codes (ASME).

This concept is already being used...

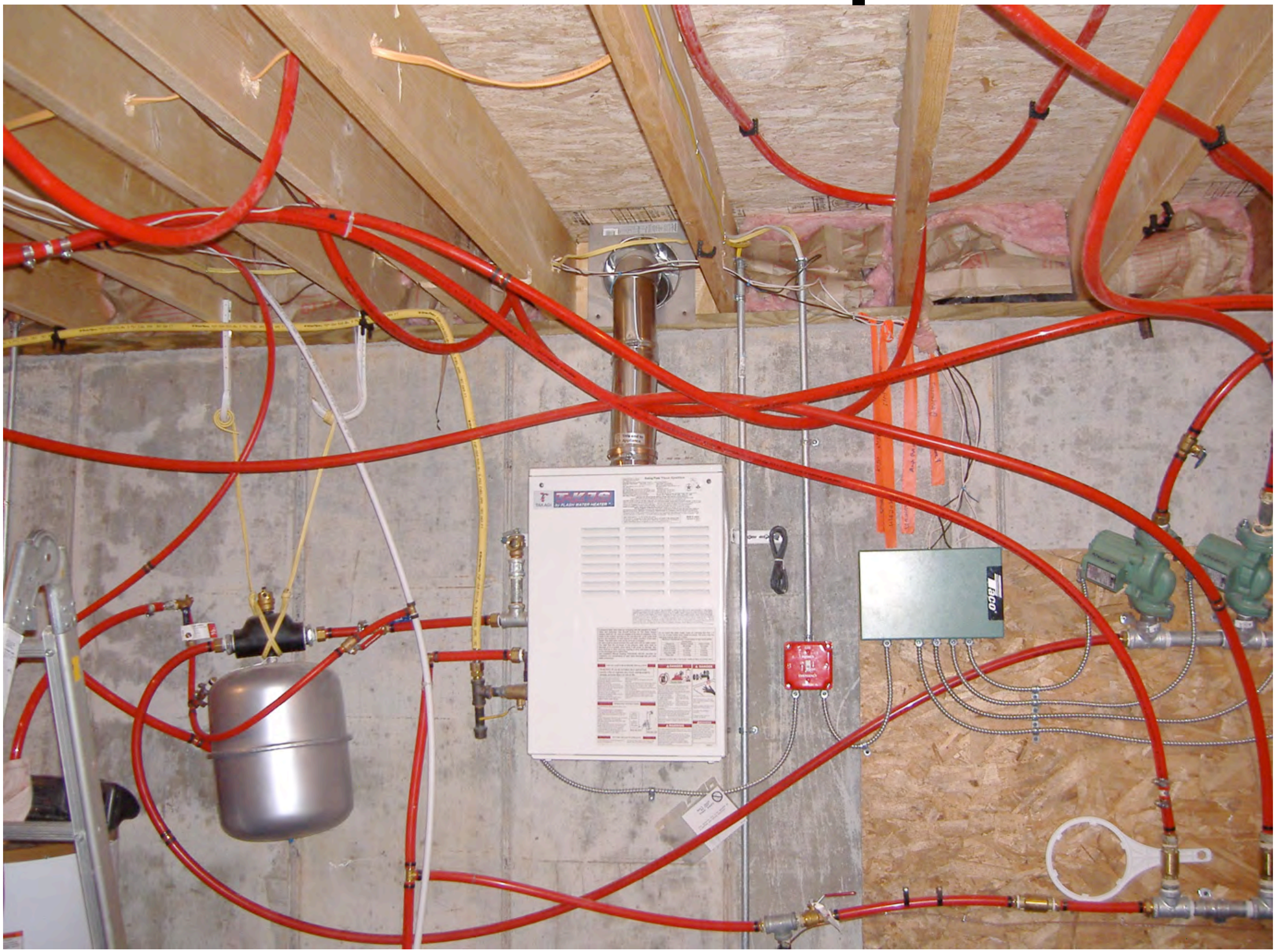
## Thermal energy substations in European flats



Parting thoughts...

# 1. Keep it neat...



Parting thoughts...

# 2. Recognize opportunity...

**Parting thoughts...**

# 3. Don’t get hung up...

"**Best Practices in Modern Hydronic Heating - THE DETAILS**

Thank you for attending today's session...

Thanks also to the planning committee, and the sponsors of this session.

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