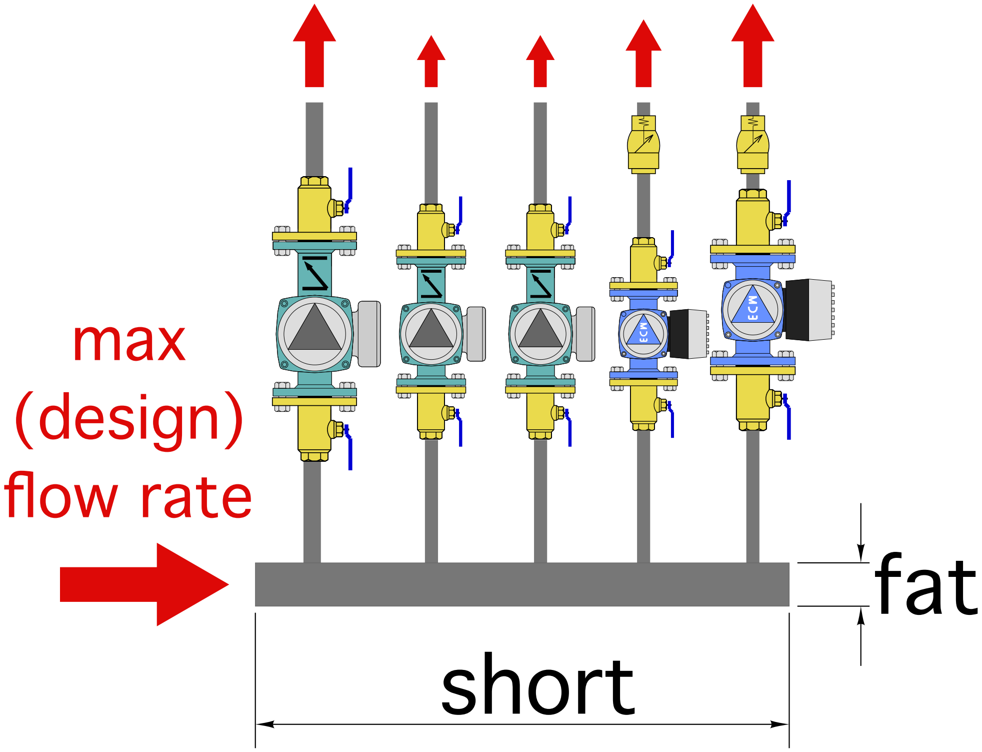
So what’s EXACTLY is a short / fat header???



max (design) flow rate

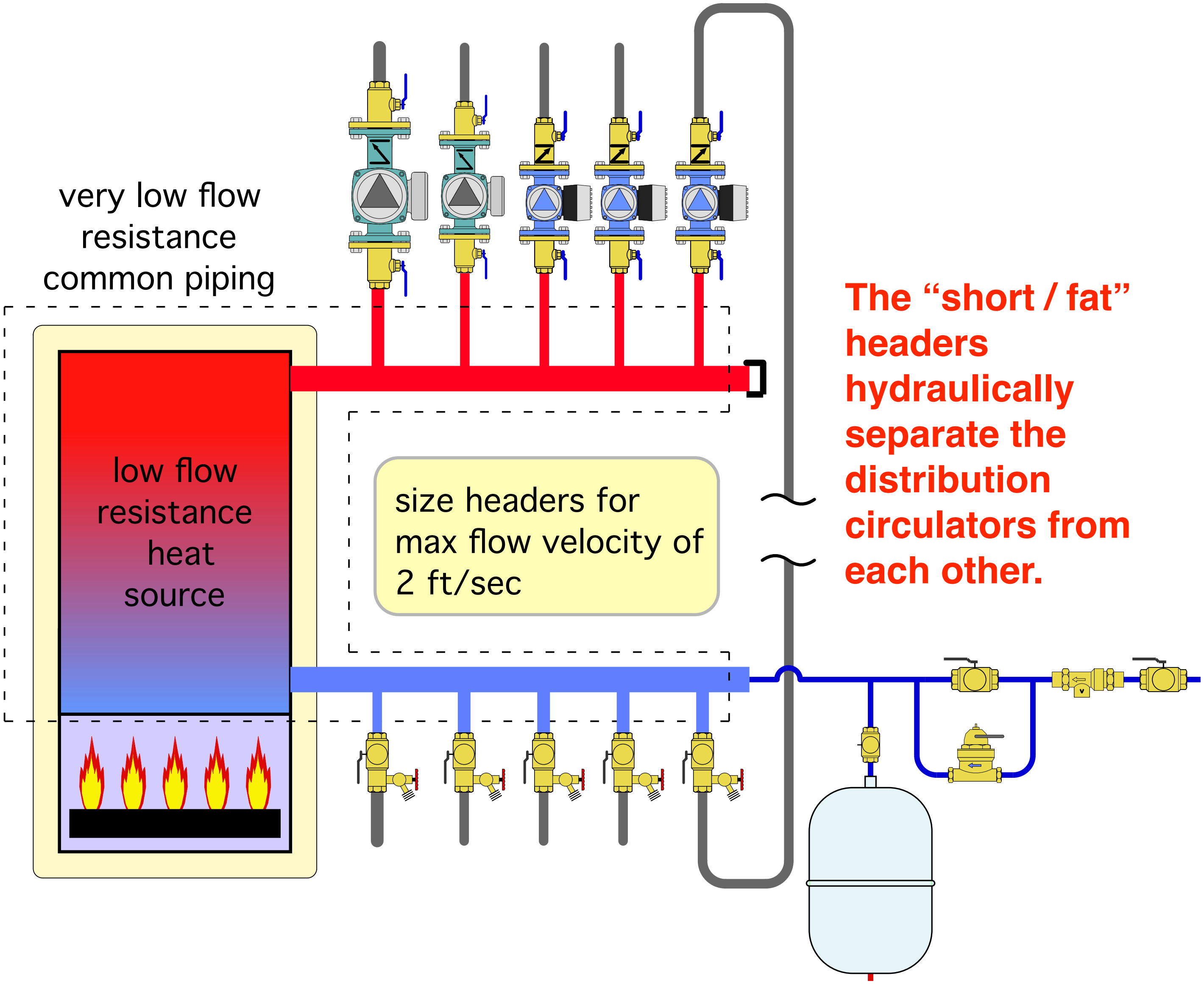
fat

short

select pipe size that yields a flow velocity no higher than 2 feet per second

Tubing	Flow rate to establish 2 ft/sec flow velocity
1/2" type M copper	1.6 gpm
3/4" type M copper	3.2 gpm
1" type M copper	5.5 gpm
1.25" type M copper	8.2 gpm
1.5" type M copper	11.4 gpm
2" type M copper	19.8 gpm
2.5" type M copper	30.5 gpm
3" type M copper	43.6 gpm

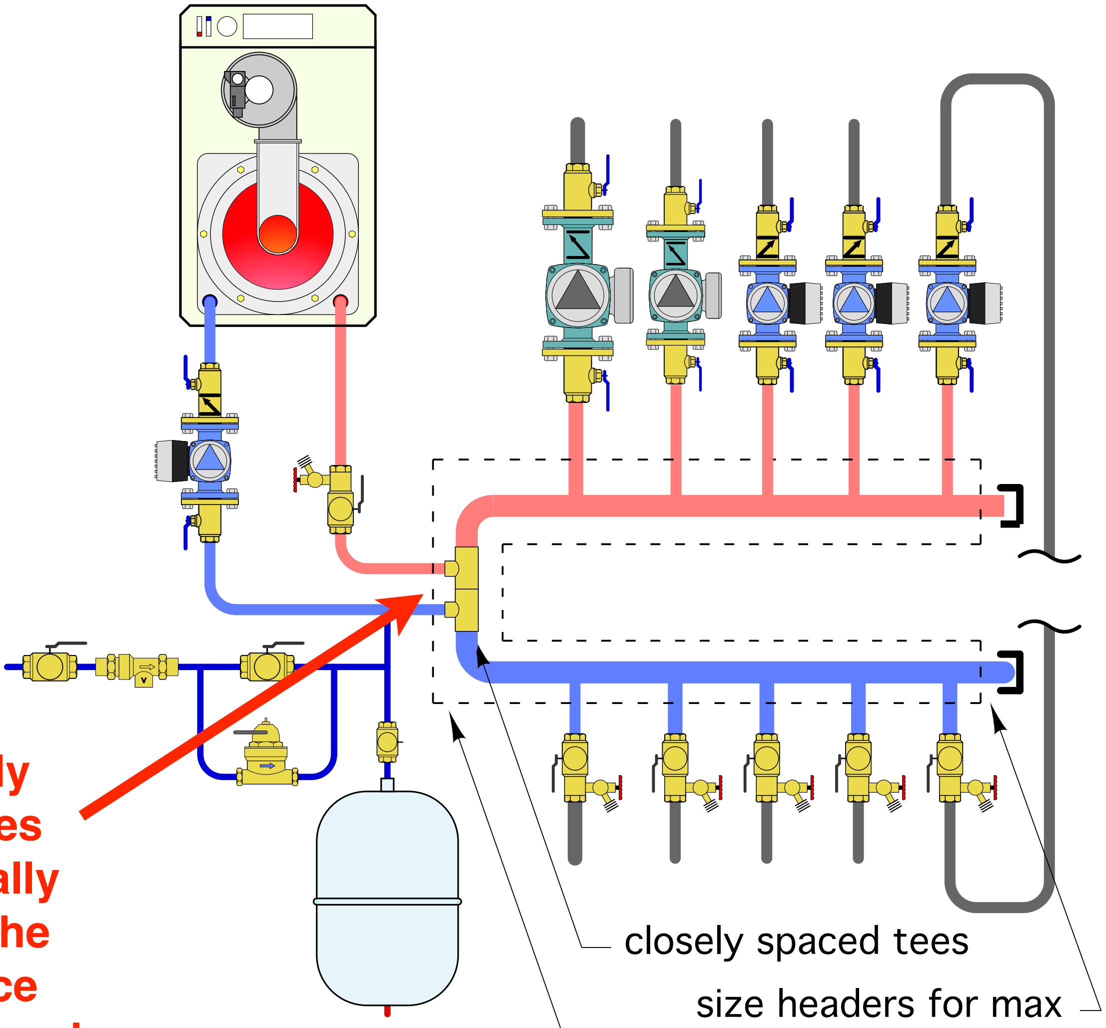
Hydraulic separation achieved by low flow resistance heat source & “short / fat” headers.



The low flow resistance heat source maintains low flow resistance of common piping

The “short / fat” headers hydraulically separate the distribution circulators from each other.

Hydraulic separation achieved by closely spaced tees & "short / fat" headers.



The closely spaced tees hydraulically separate the heat source from the header system.

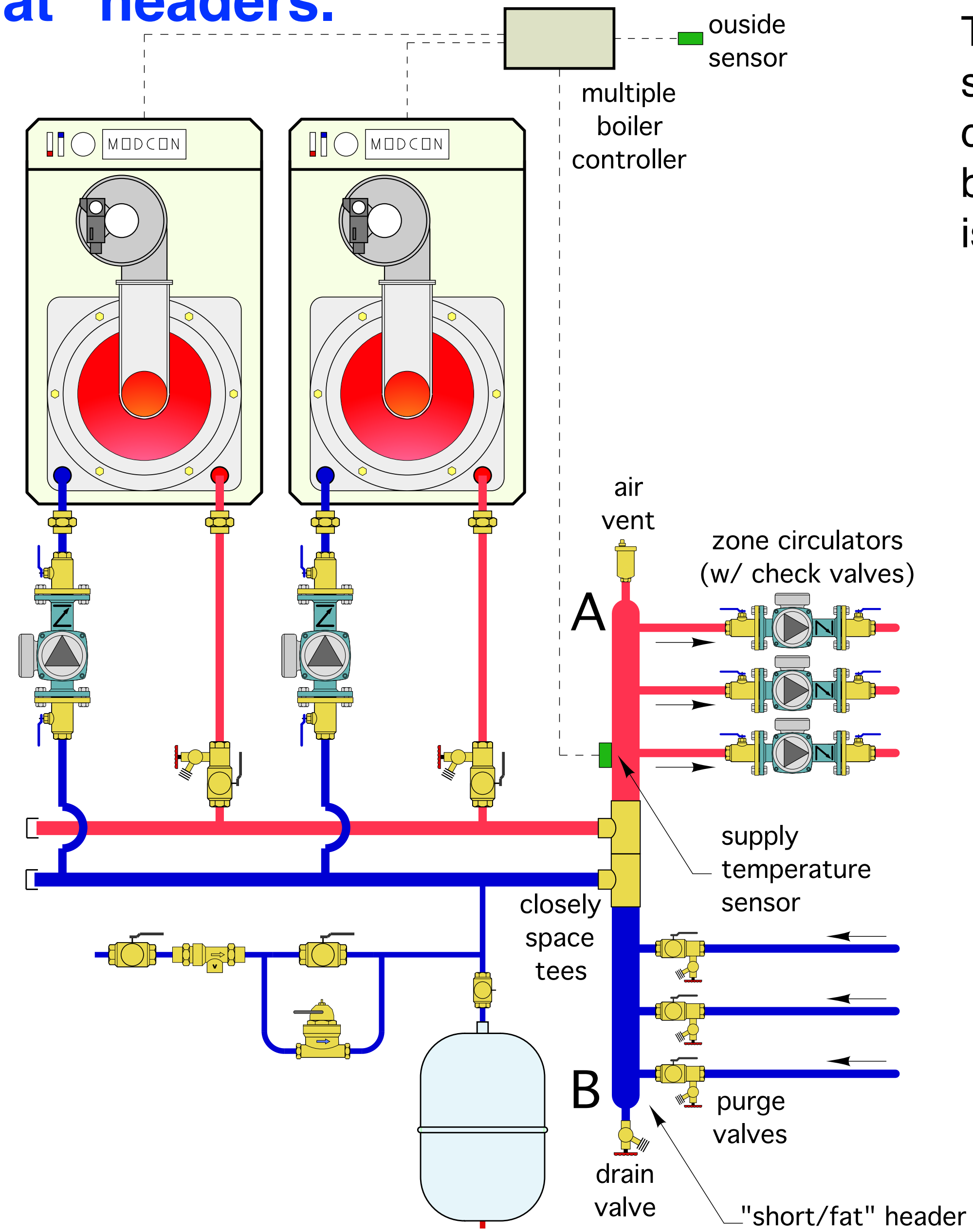
The "short / fat" headers hydraulically separate the distribution circulators from each other.

closely spaced tees

size headers for max flow velocity of 2 ft/sec

very low flow resistance common piping

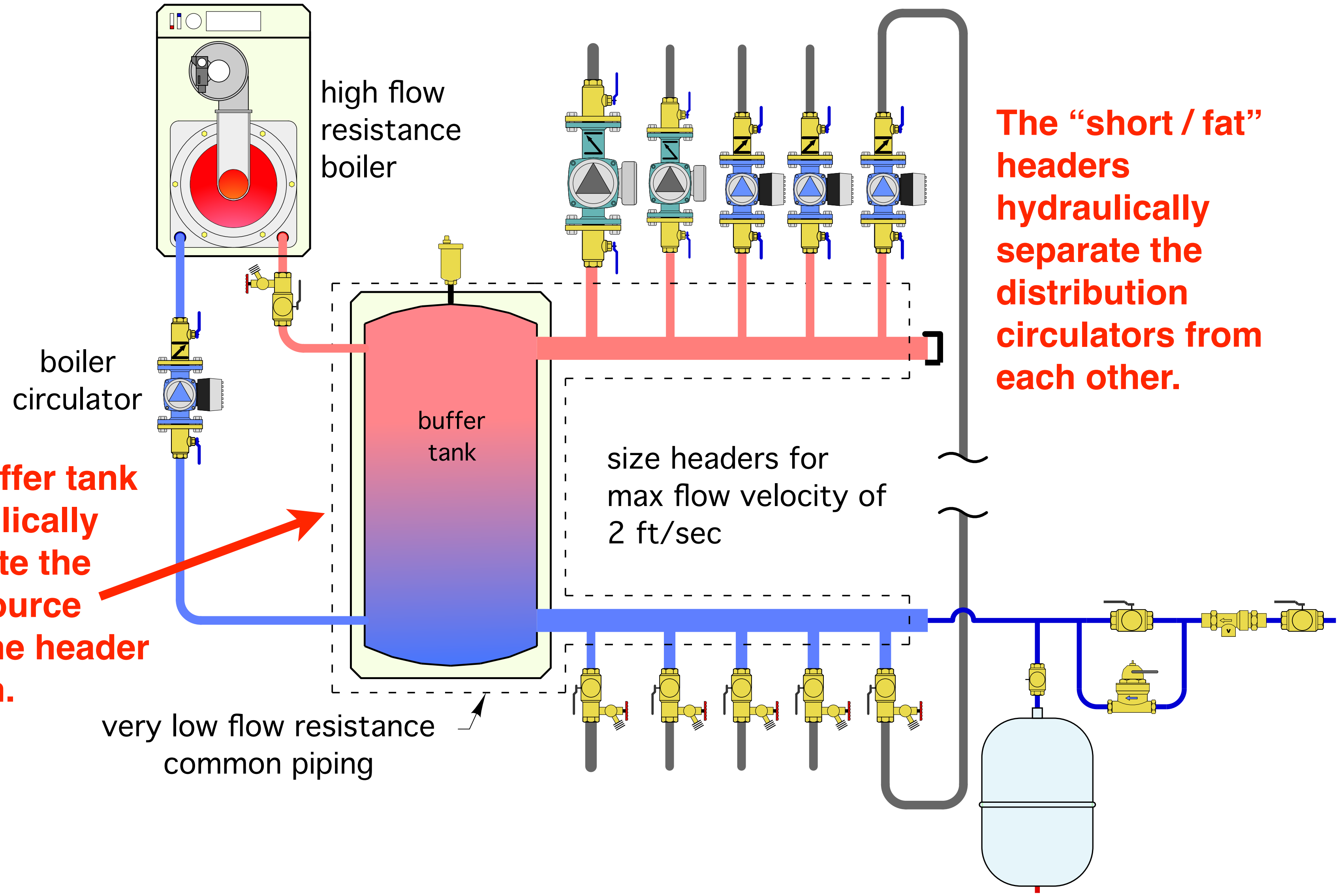
Hydraulic separation achieved by closely spaced tees & "short / fat" headers.



The "short & fat" header and close spacing between supply and return connections results in a low pressure drop between points A and B. Each load circuit is hydraulically separated from the others.

- **Header should be sized for max. flow velocity of 2 feet per second**
- **Each circuit must include a check valve.**
- **The supply temperature sensor must be downstream of the point of hydraulic separation.**
- **The header can be vertical (as shown) or horizontal.**

Hydraulic separation achieved by buffer tank (piped as shown) & "short / fat" headers.



high flow resistance boiler

boiler circulator

buffer tank

size headers for max flow velocity of 2 ft/sec

very low flow resistance common piping

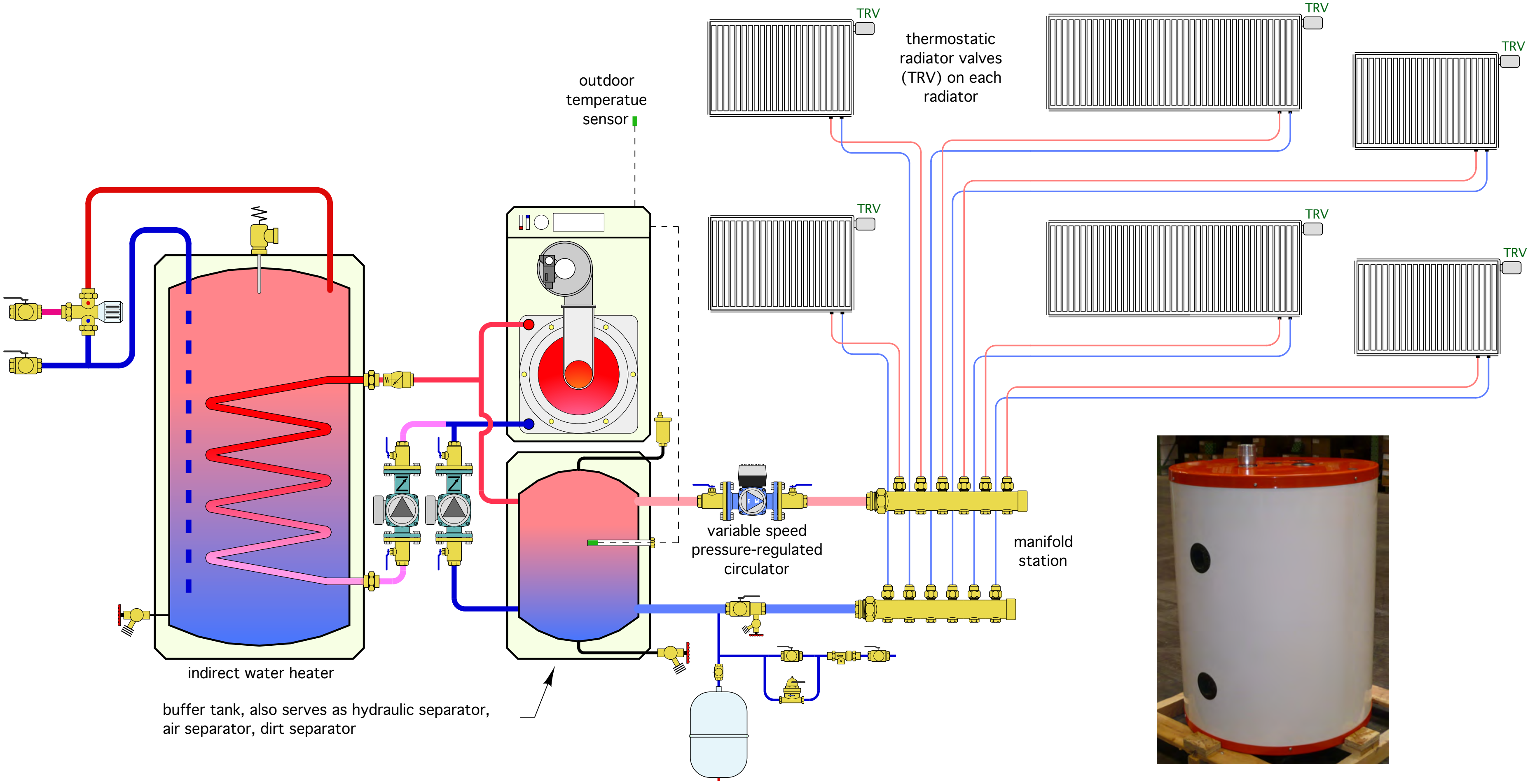
The buffer tank hydraulically separate the heat source from the header system.

The "short / fat" headers hydraulically separate the distribution circulators from each other.

Hydraulic Separation in “Micro-load” systems:

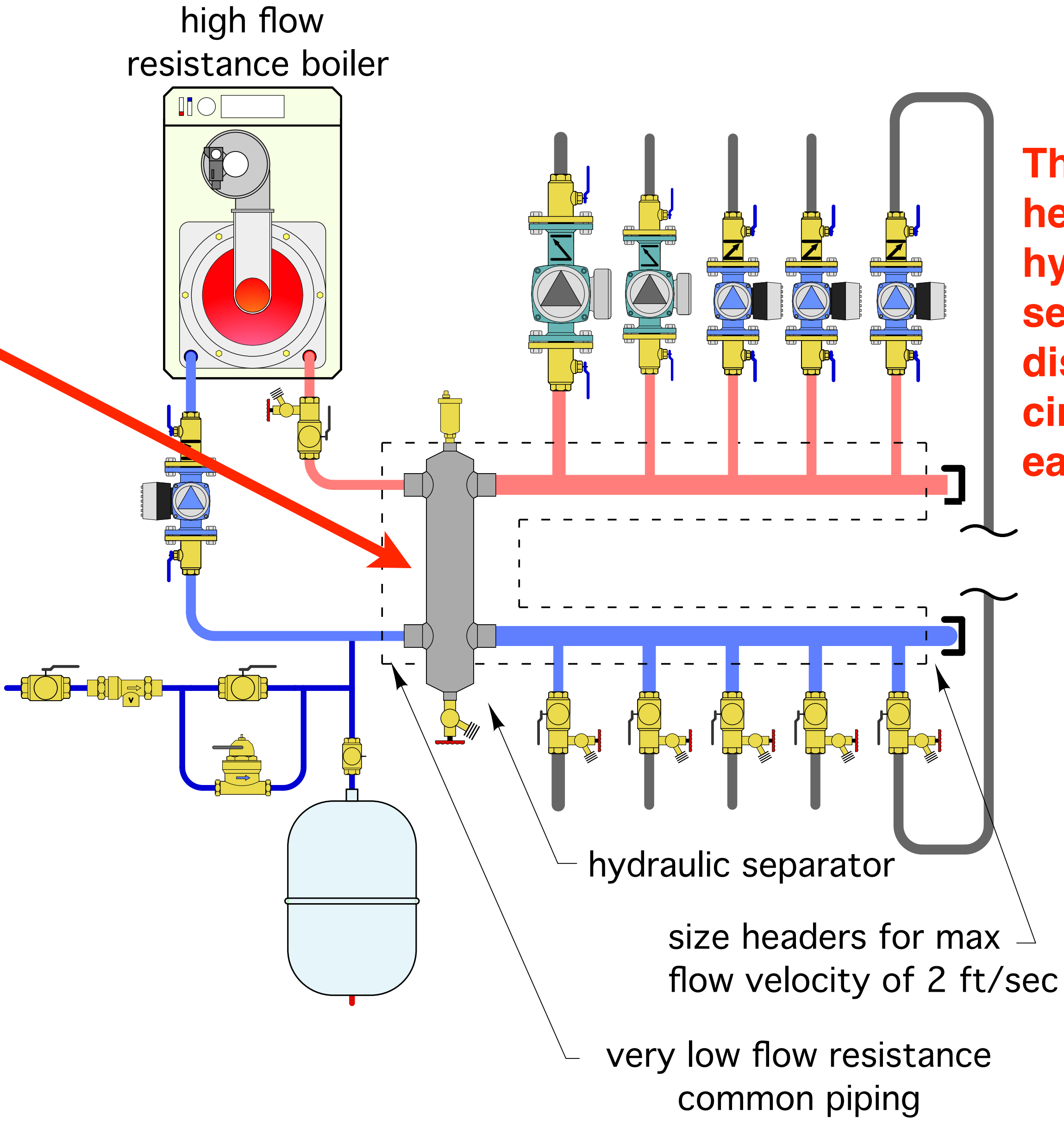
The small insulated tank provides:

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



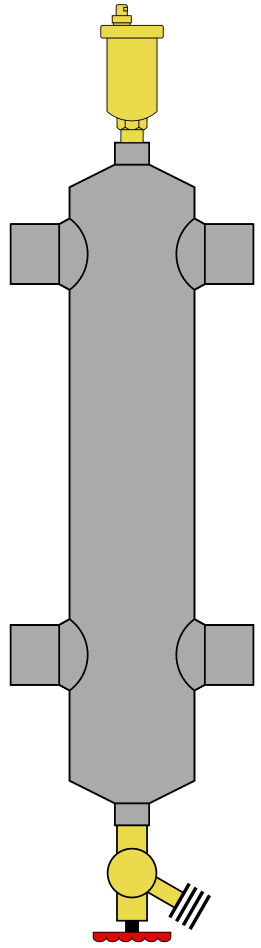
Hydraulic separation achieved by hydraulic separator.

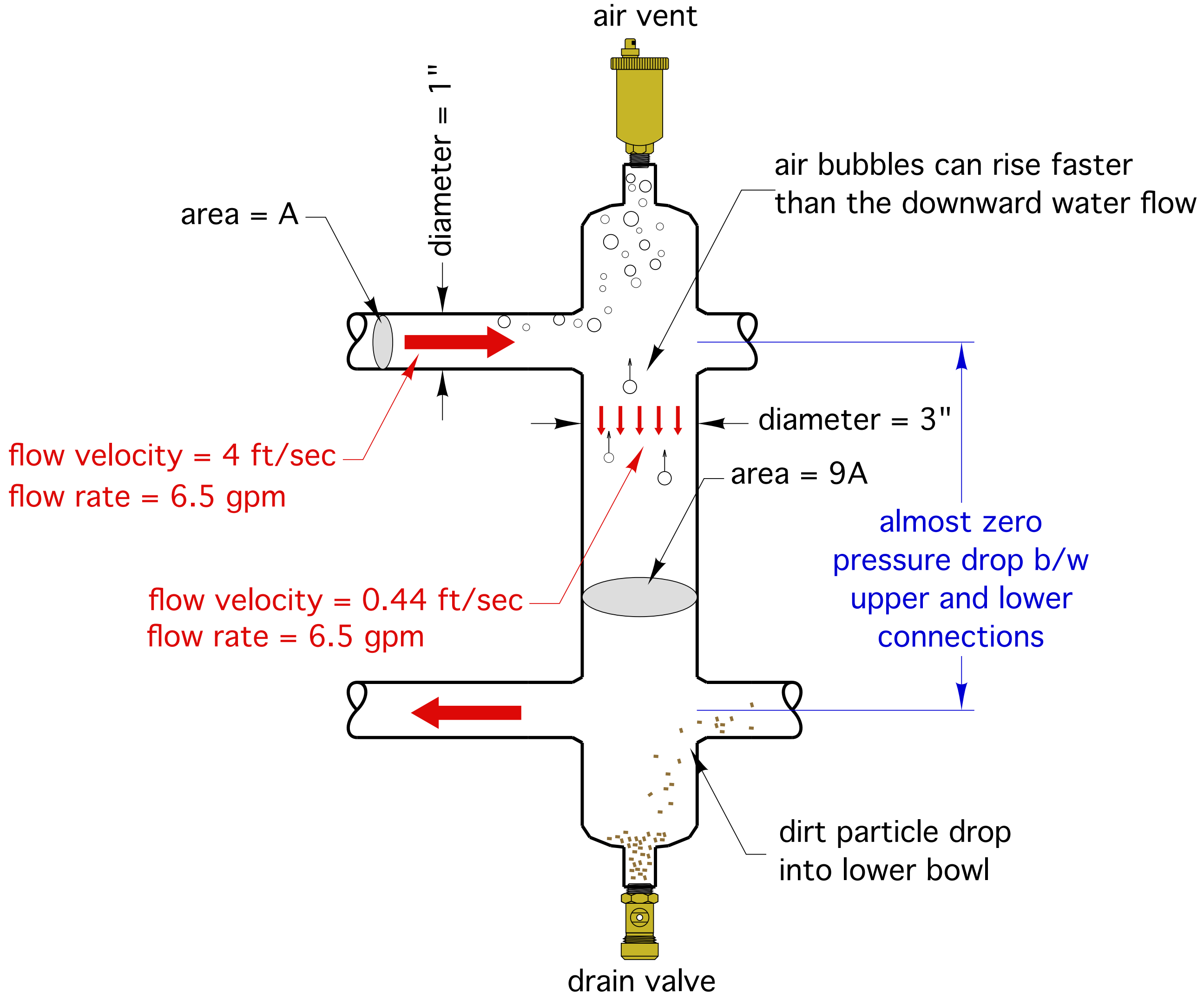
The hydraulic separator hydraulically separates the heat source from the header system.



The "short / fat" headers hydraulically separate the distribution circulators from each other.

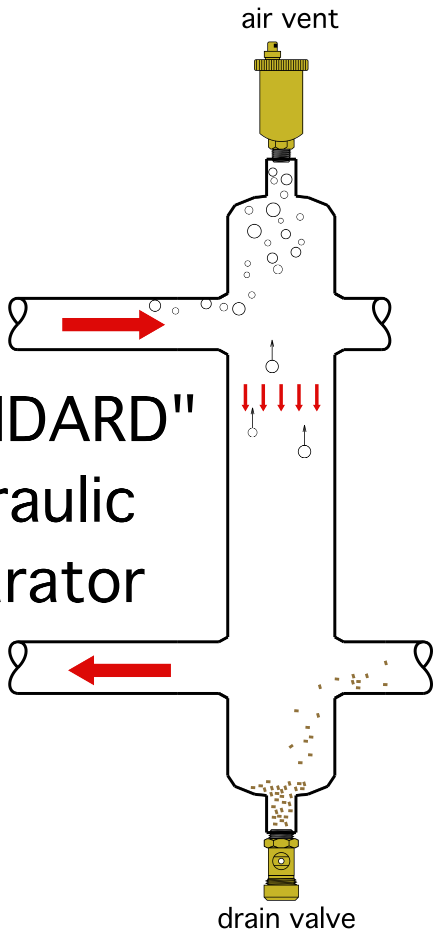
What's going on inside a hydraulic separator?





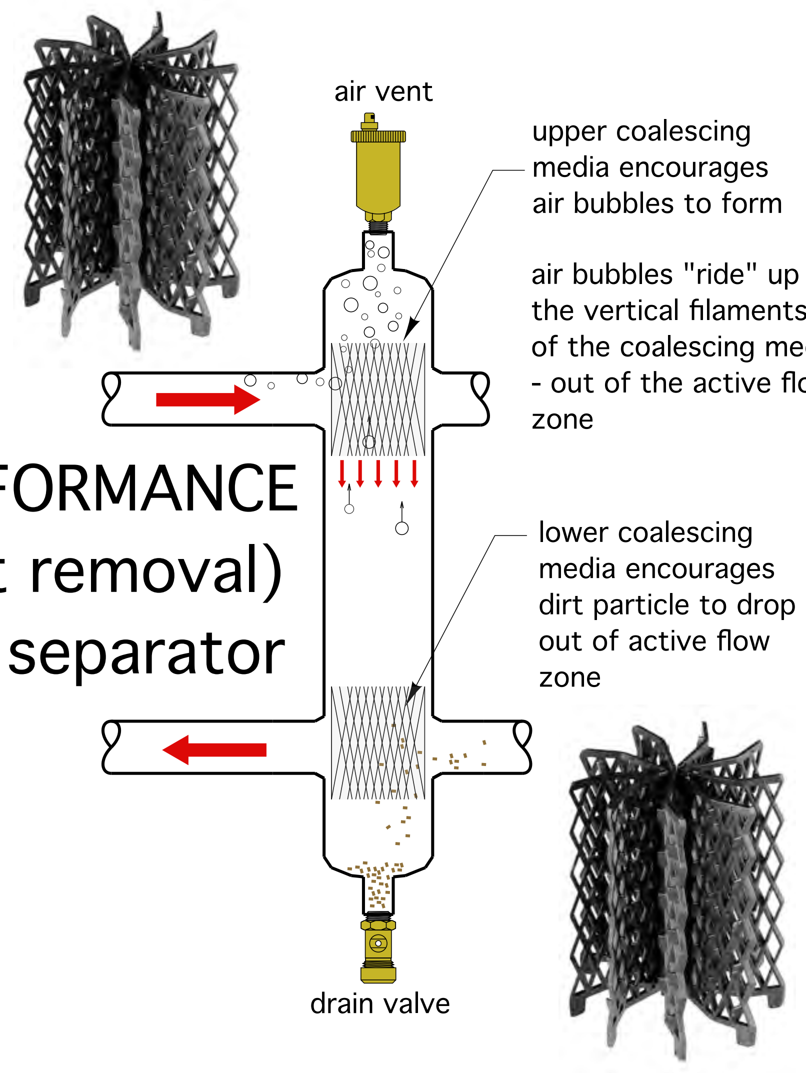
The low vertical velocity inside the separator produces minimal pressure drop top to bottom. Thus there is very little tendency to induce flow on the load side of the separator.

What does the “coalescing media” do inside a hydraulic separator?



"STANDARD"
hydraulic
separator

HIGH PERFORMANCE
(air & dirt removal)
hydraulic separator



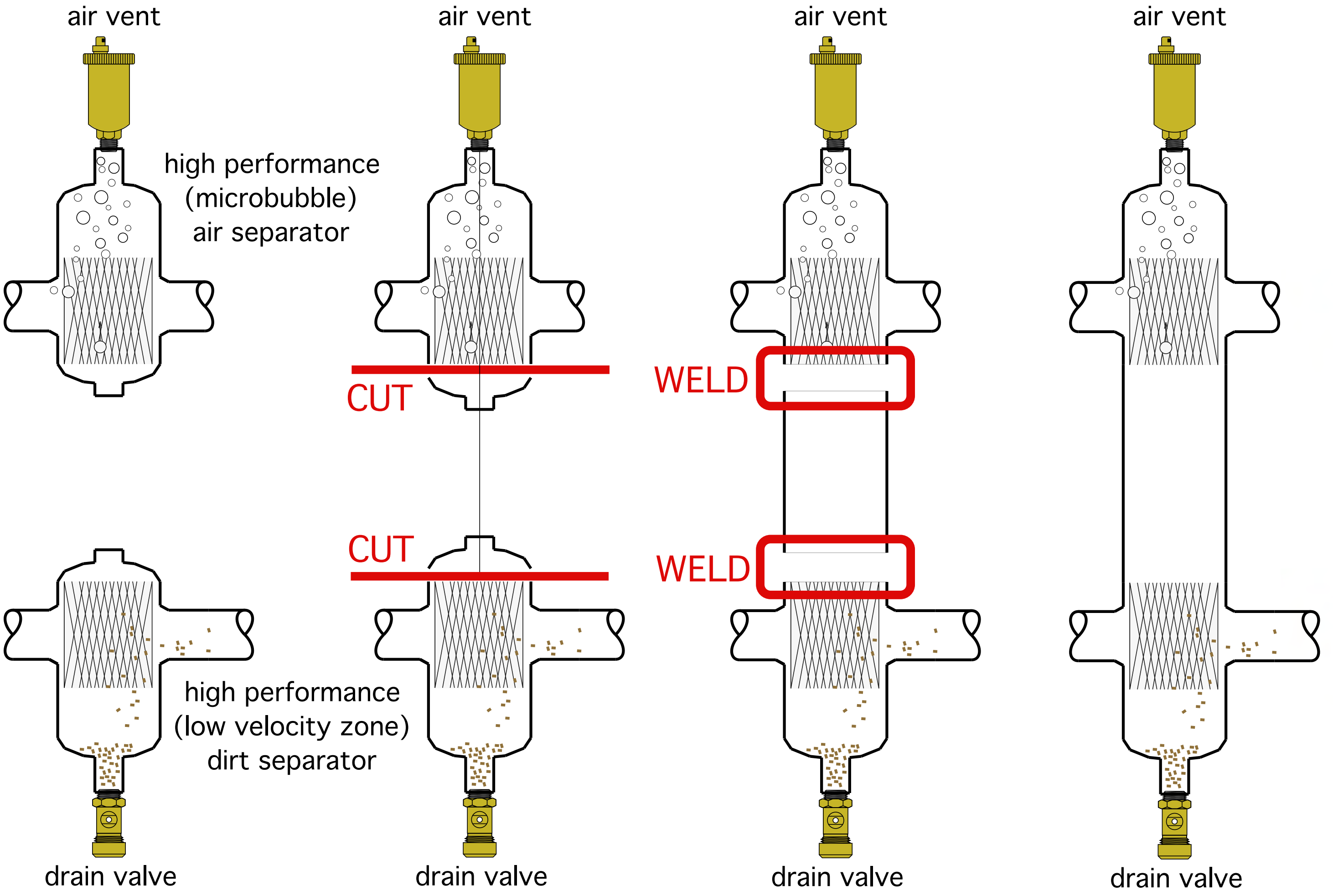
upper coalescing media encourages air bubbles to form

air bubbles "ride" up the vertical filaments of the coalescing media - out of the active flow zone

lower coalescing media encourages dirt particle to drop out of active flow zone

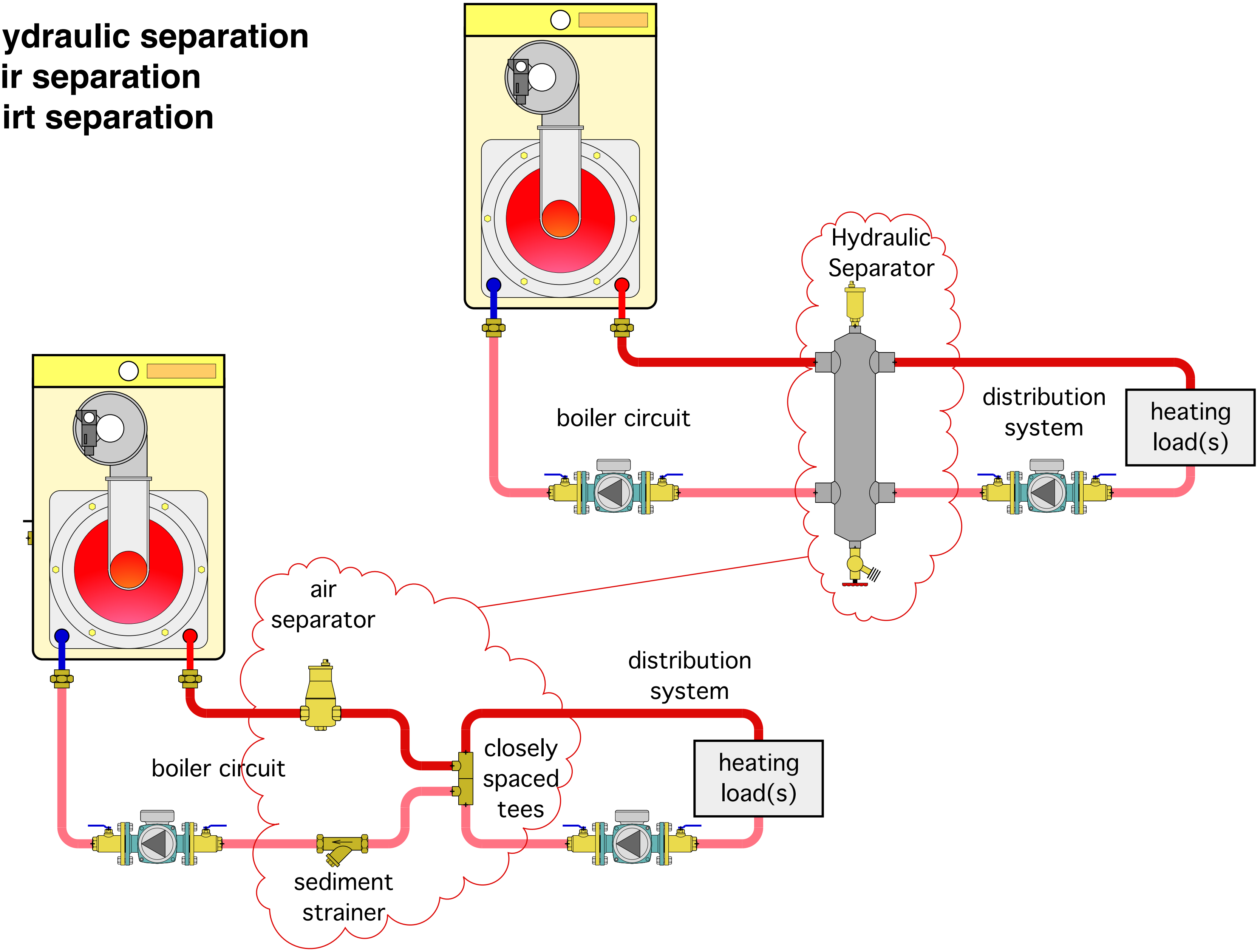
The coalescing media creates tiny vortices that cause gas molecules (mostly oxygen and nitrogen) to form microbubbles. The media also helps microbubble merge together and rise upward out of the active flow zone.

Why companies that offer air and dirt separators also offer hydraulic separators...

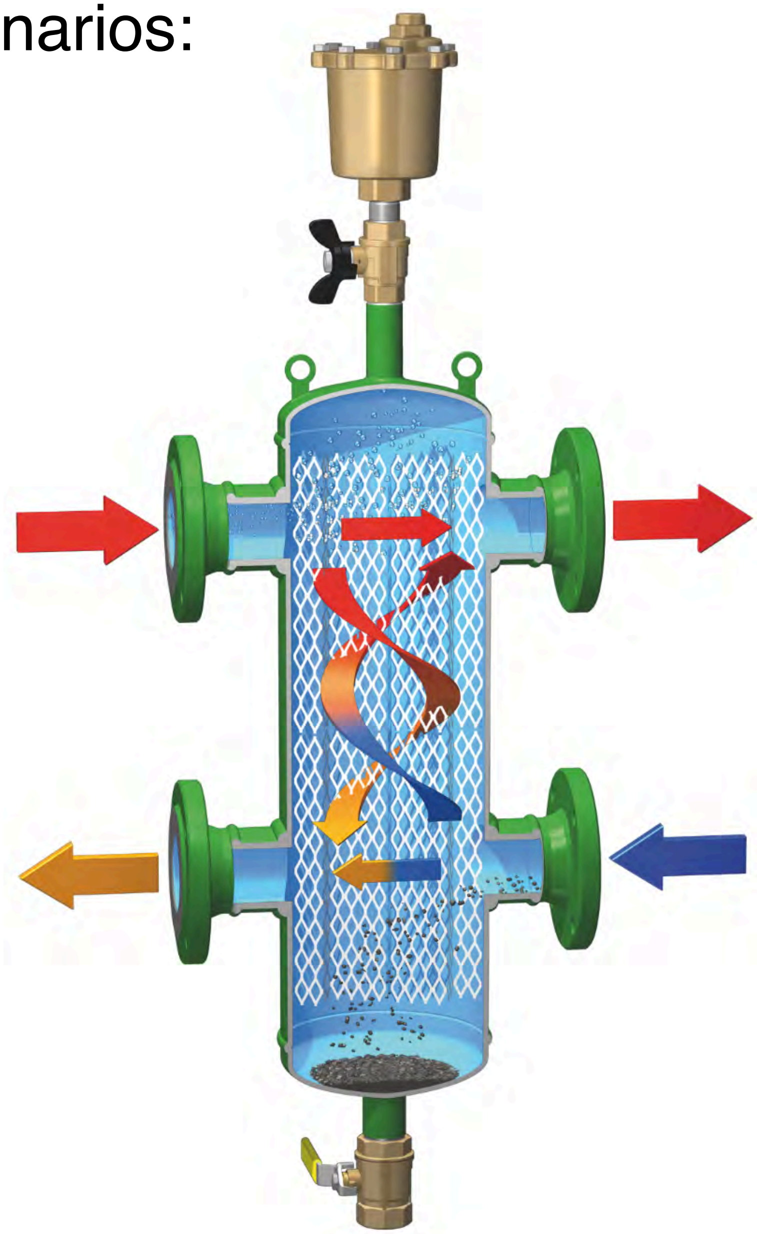


High performance hydraulic separators provide three functions:

1. **hydraulic separation**
2. **air separation**
3. **dirt separation**



As the flow rates of the boiler circuit and distribution system change there are three possible scenarios:



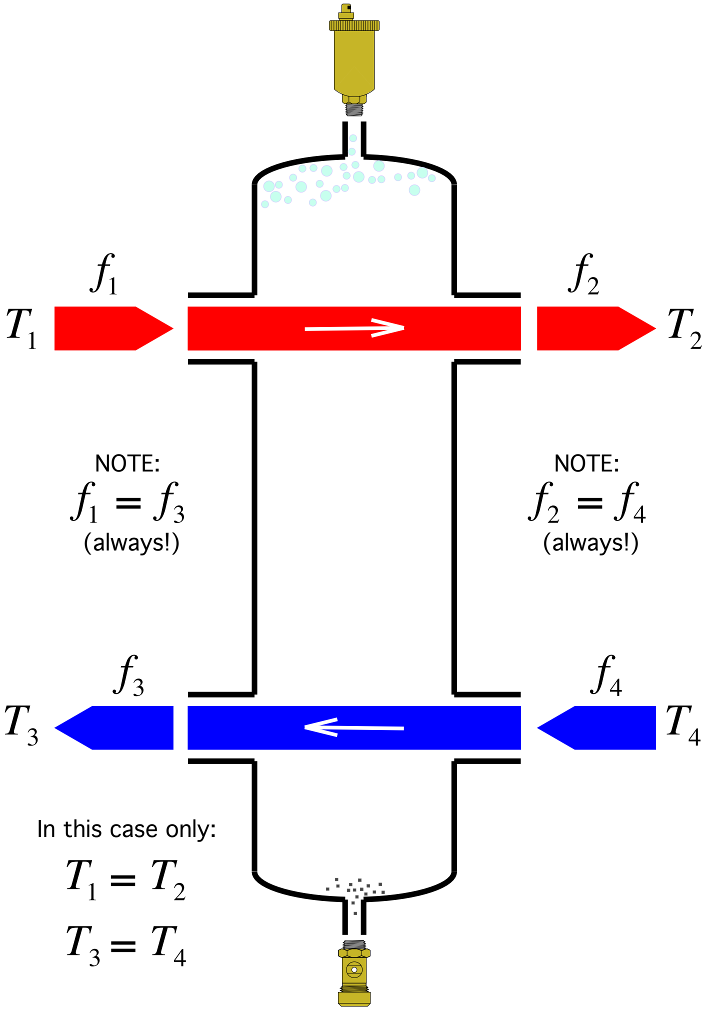
1. Flow in the distribution system is equal to the flow in the boiler circuit.

2. Flow in the distribution system is greater than flow in the boiler circuit.

3. Flow in the distribution system is less than flow in the boiler circuit.

Each case is governed by basic thermodynamic...

Case #1: Distribution flow equals boiler flow:



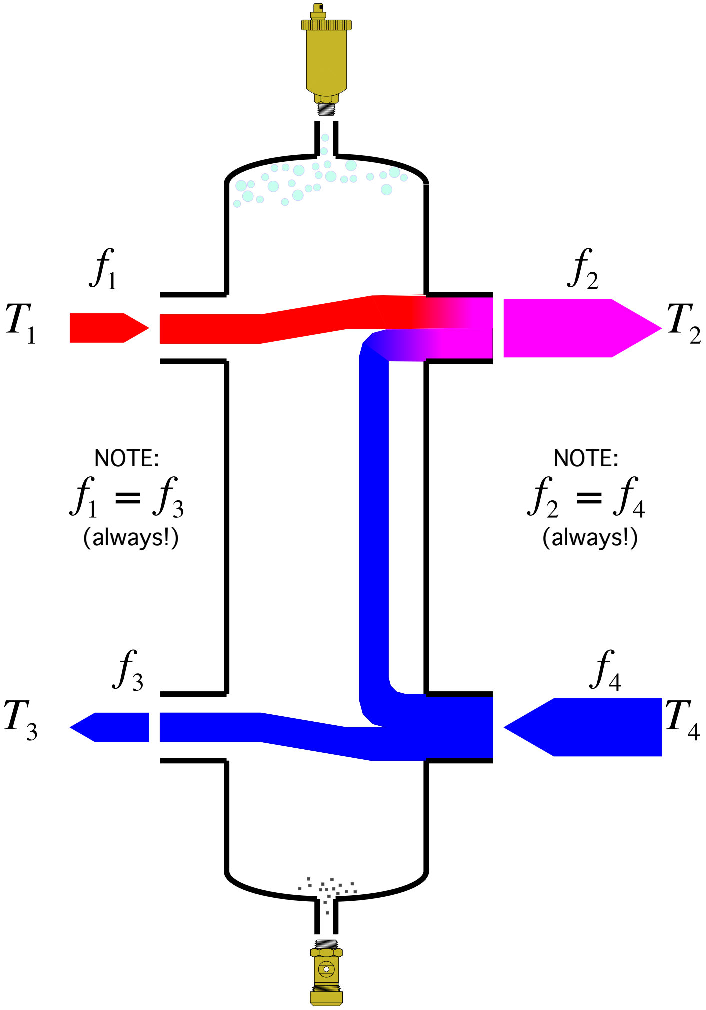
NOTE:
$f_1 = f_3$
(always!)

NOTE:
$f_2 = f_4$
(always!)

In this case only:
$T_1 = T_2$
$T_3 = T_4$

Very little mixing occurs because the flows are balanced.

Case #2: Distribution flow is greater than boiler flow:



The mixed temperature (T_2) supplied to the distribution system can be calculated with:

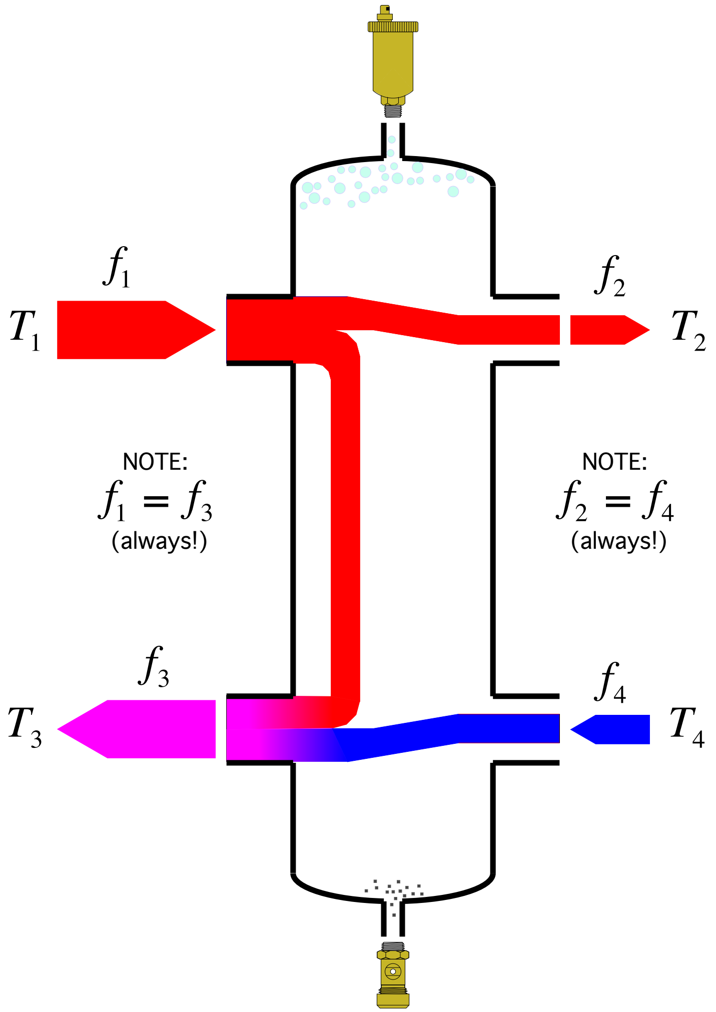
$$T_2 = \left(\frac{(f_4 - f_1)T_4 + (f_1)T_1}{f_4} \right)$$

Where:
f4 = flow rate returning from distribution system (gpm)
f1 = flow rate entering from boiler(s) (gpm)
T4 = temperature of fluid returning from distribution system (°F)
T1 = temperature of fluid entering from boiler (°F)

Mixing occurs within the hydraulic separator.

Case #3: Distribution flow is less than boiler flow:

Heat output is *temporarily* higher than current system load.



Heat is being injected faster than the load is removing heat.

The temperature returning to the boiler (T_3) can be calculated with:

$$T_2 = \left(\frac{(f_4 - f_1)T_4 + (f_1)T_1}{f_4} \right)$$

Where:
T3 = temperature of fluid returned to boiler(s) (°F)
f1 = flow rate entering from boiler(s) (gpm)
f2, f4 = flow rate of distribution system (gpm)
T1 = temperature of fluid entering from boiler (°F)
T4 = temperature of fluid returning from distribution system (°F)

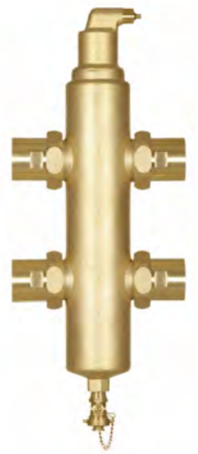
Mixing occurs within the hydraulic separator.

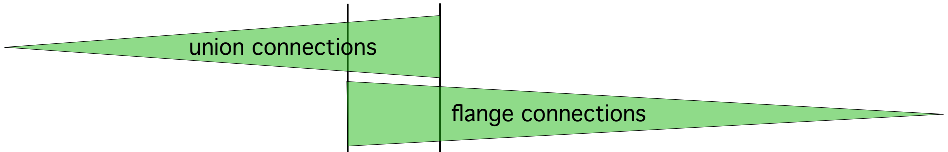
Sizing of Hydraulic Separators:

Hydraulic separators must be properly sized to provide proper hydraulic, air, and dirt separation. Excessively high flow rates will impede these functions.

The “size” of a hydraulic separator refers to the nominal piping size of the 4 side connections (not the diameter of the vertical barrel).

The piping connecting to the distribution side of the Hydro Separator should be sized for a flow of 4 feet per second or less under maximum flow rate conditions.

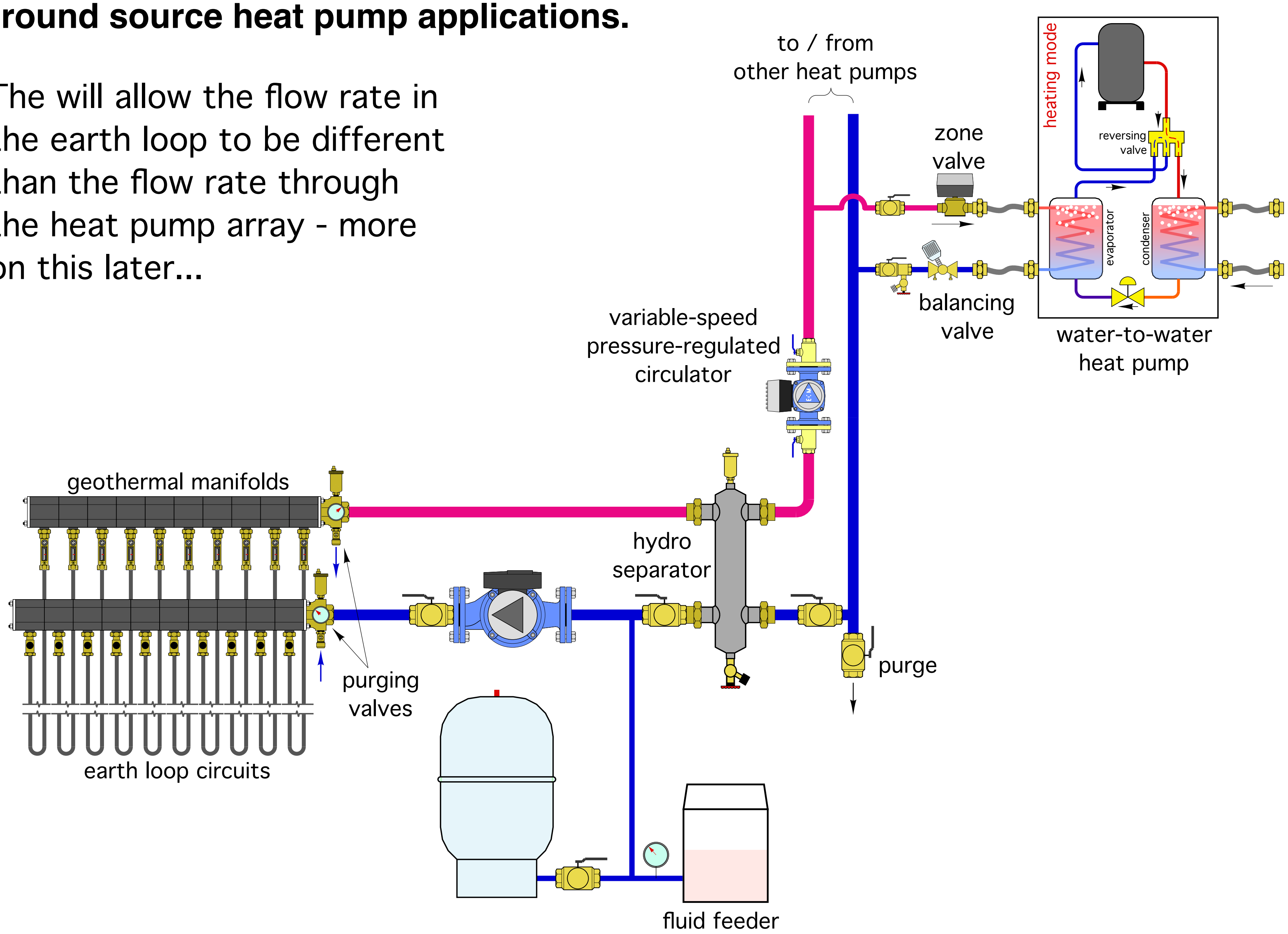




Pipe size of hydraulic separator	1”	1.25”	1.5”	2”	2.5”	3”	4”	6”
Max flow rate (GPM)	11	18	26	40	80	124	247	485

Hydraulic Separators will likely become a key component in multiple ground source heat pump applications.

The will allow the flow rate in the earth loop to be different than the flow rate through the heat pump array - more on this later...

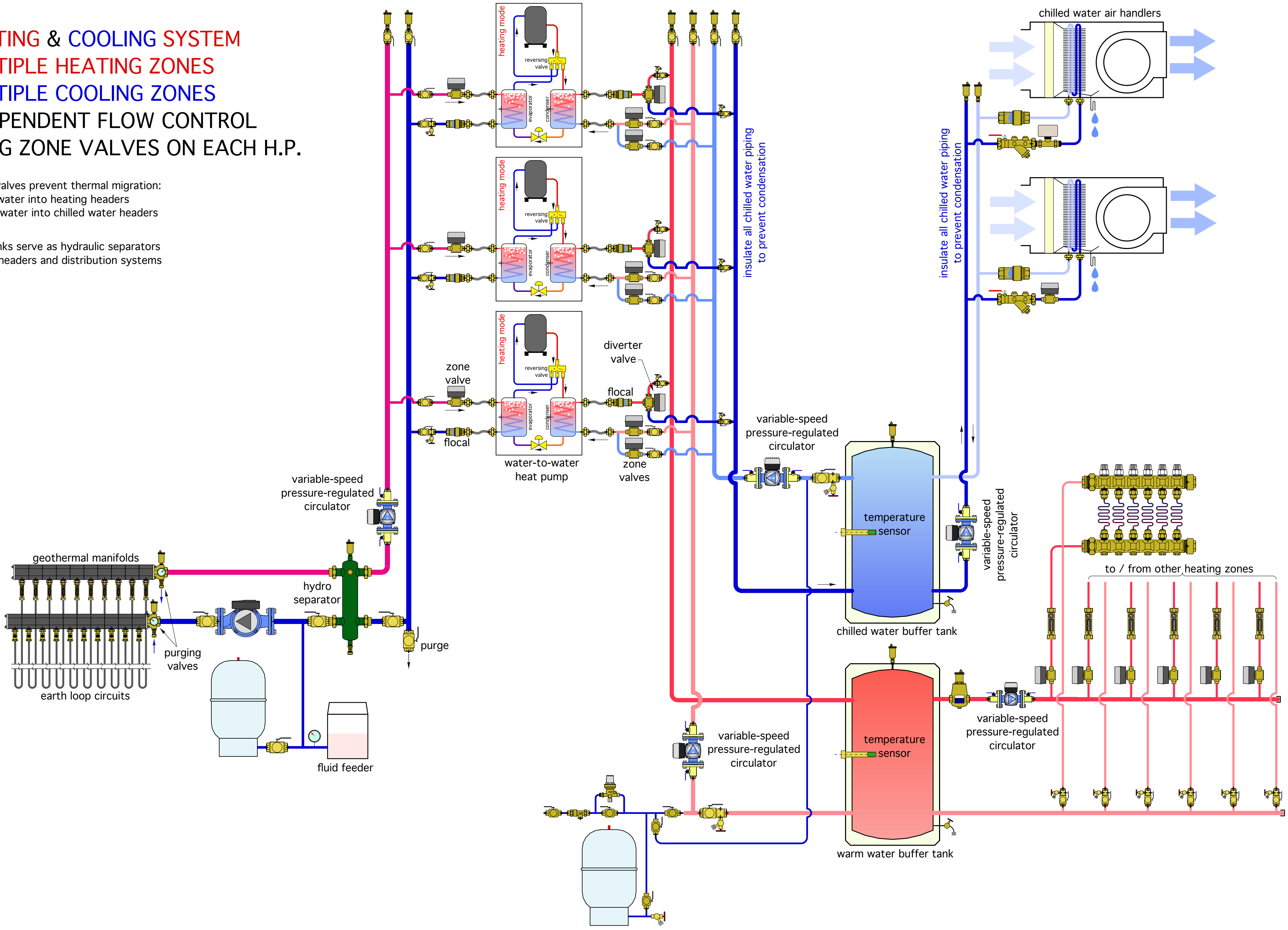


Examples of systems using pressure regulated circulators

HEATING & COOLING SYSTEM
MULTIPLE HEATING ZONES
MULTIPLE COOLING ZONES
INDEPENDENT FLOW CONTROL
USING ZONE VALVES ON EACH H.P.

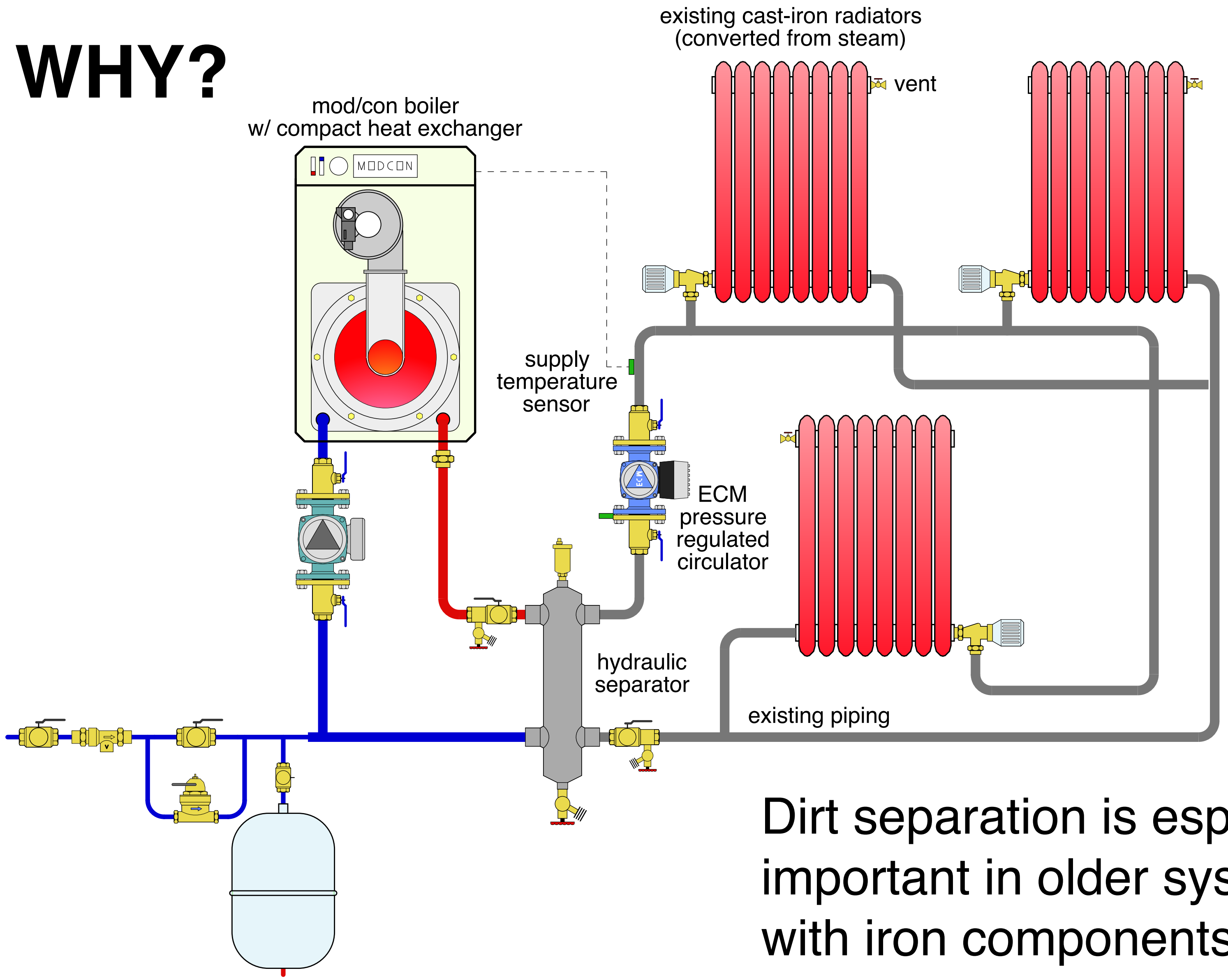
Diverter valves prevent thermal migration:
- chilled water into heating headers
- heated water into chilled water headers

Buffer tanks serve as hydraulic separators between headers and distribution systems



A hydraulic separator is a great way to interface a new mod/con boiler to a older “steam conversion” system.

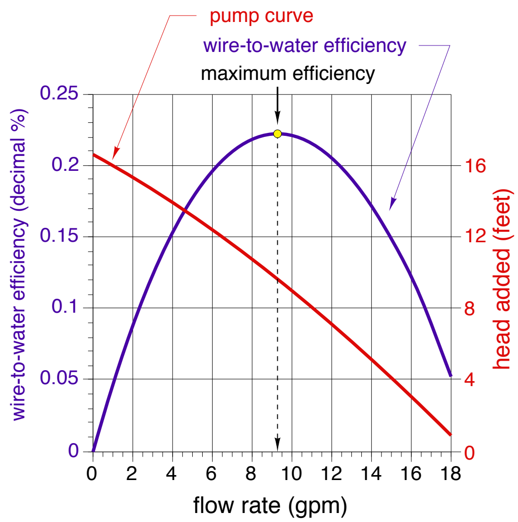
WHY?

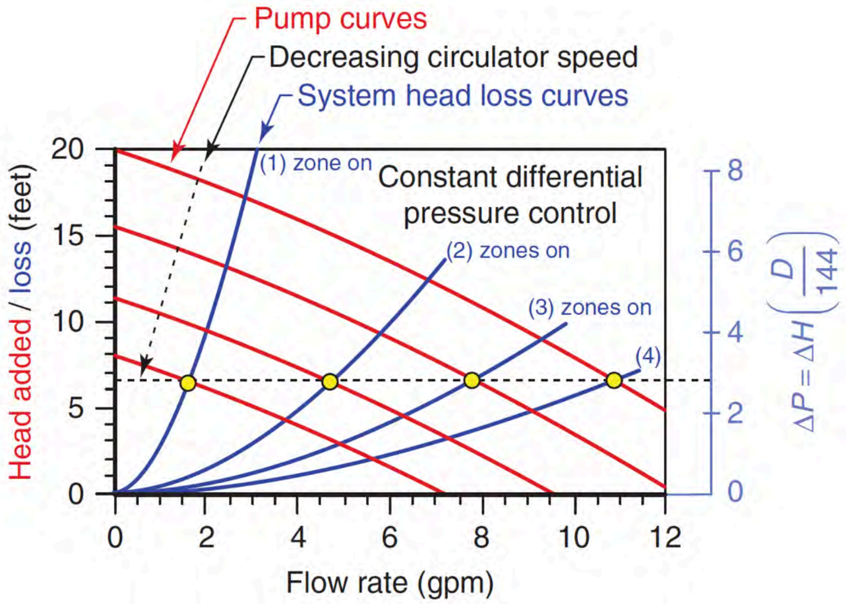


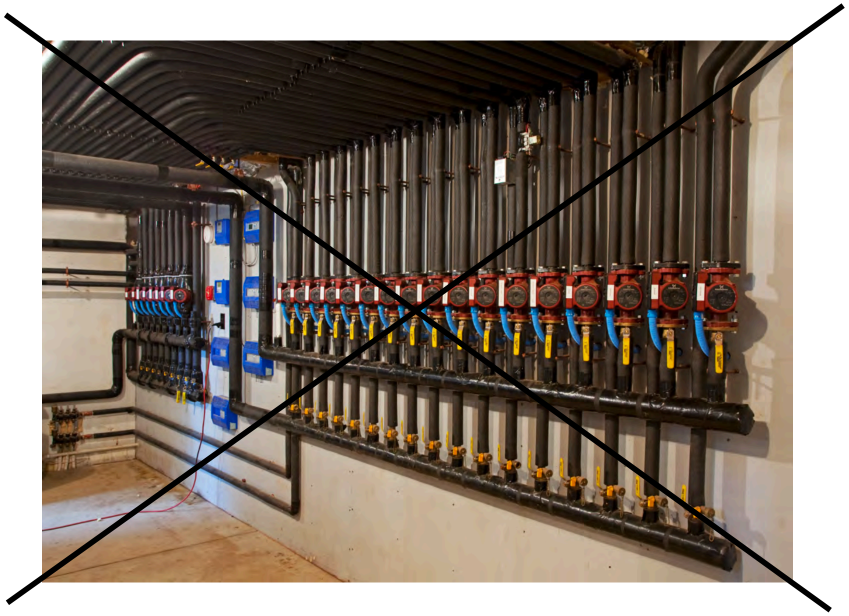
Dirt separation is especially important in older systems with iron components.

Distribution Efficiency

& Low Power Pumping...

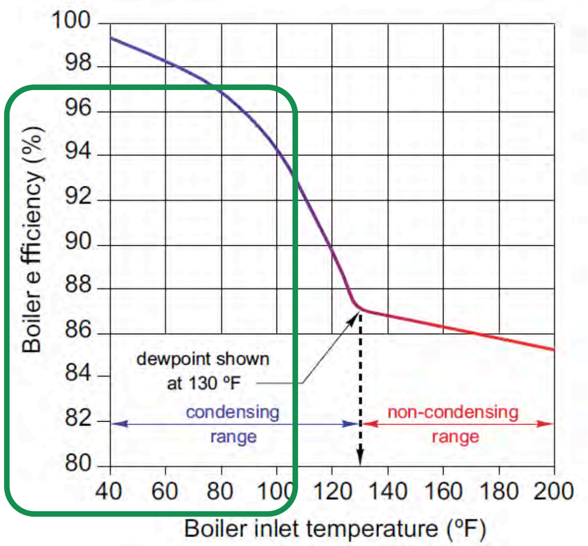






The North American Hydronics market has many “high efficiency” boilers

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



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

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

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

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

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

The present situation:

What draws your attention in the photo below?

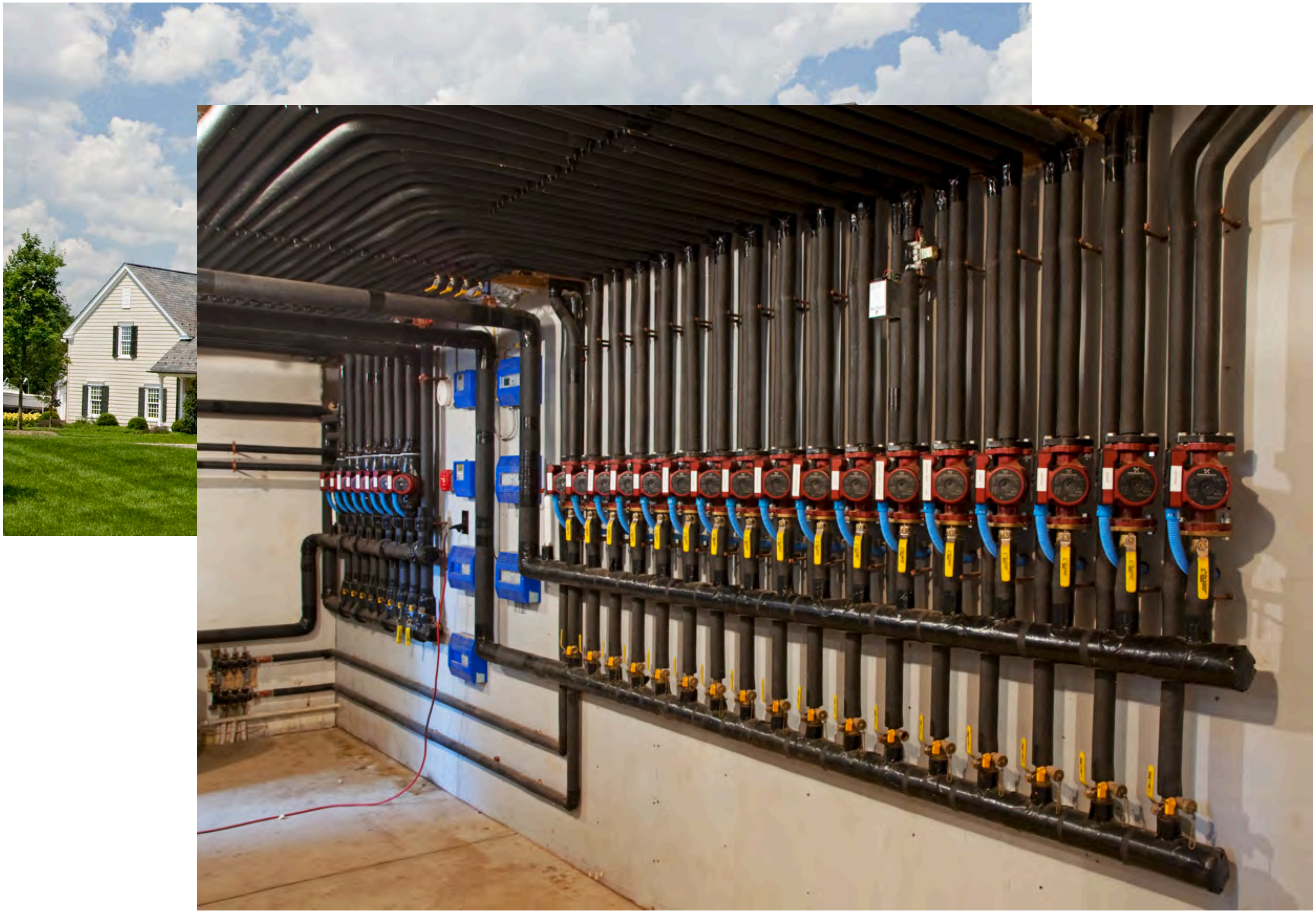
If all these circulators operate simultaneously (at design load) the electrical demand will be in excess of 5000 watts.

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

Here's another example...

Great "craftsmanship" - Wrong "concept"

Here's another (award winning) example...



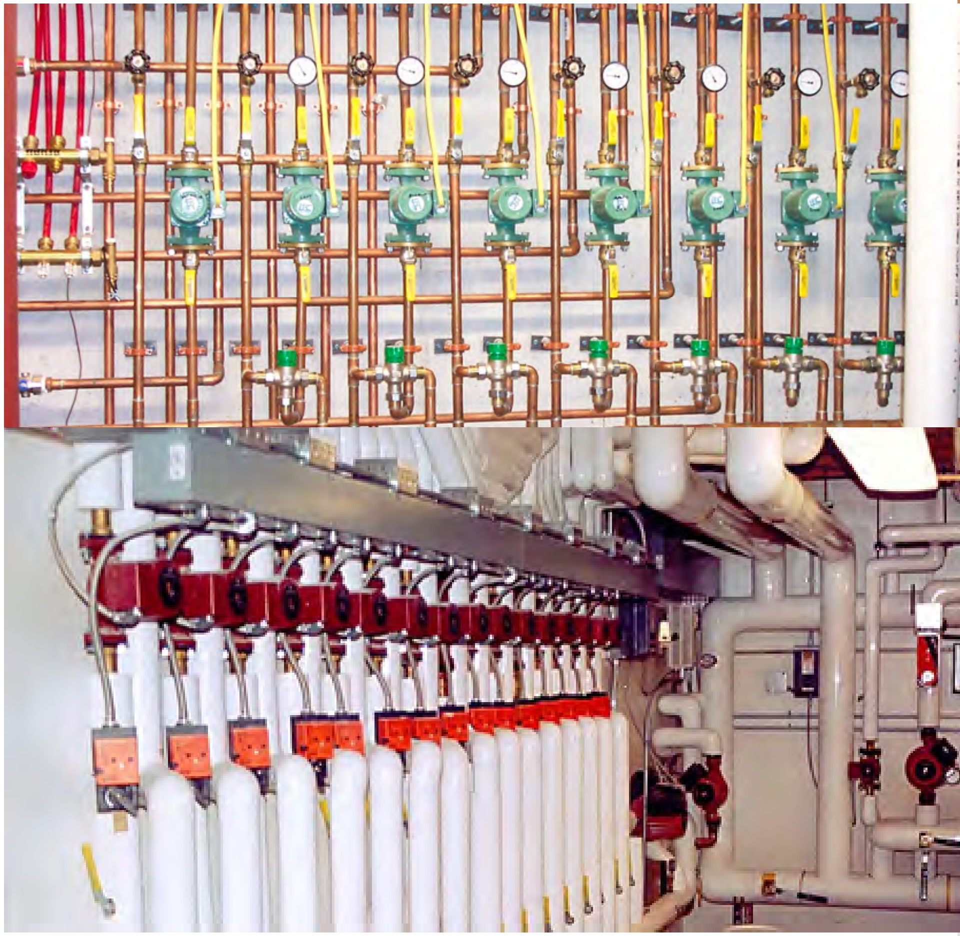
If you run out of wall space consider this installation technique...

Notice the installer left provisions for additional circulators.

So what can you conclude from these photos?

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

You might also conclude that…



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

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

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

Must look beyond the efficiency of only the heat source.

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

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

This is important

So is this!

Defining DISTRIBUTION EFFICIENCY

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

Distribution efficiency for a space heating system.

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

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

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

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

To answer this you need something to compare it to.

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

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

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

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

Room for Improvement…

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

Assume the average circulator wattage is 90 watts.

The design heating load is 400,000 Btu/hr

The distribution efficiency of this system at design load is:

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

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

Water Watts…

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

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

Where:
W_m = mechanical power required to maintain flow in circuit (watts)
f= flow rate in circuit (gpm)
ΔP = pressure drop along circuit (psi)
0.4344 = units conversion factor

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

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

Putting these numbers into the formula yields:

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

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

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

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

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

Where:
$n_{w/w}$ = wire-to-water efficiency of the circulator (decimal %)
w_m = mechanical power transferred to water by impeller (watts)
w_e = electrical power input to motor (watts)

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