System Diagram Workshop

Developing a Simple HHW System Diagram in the Field

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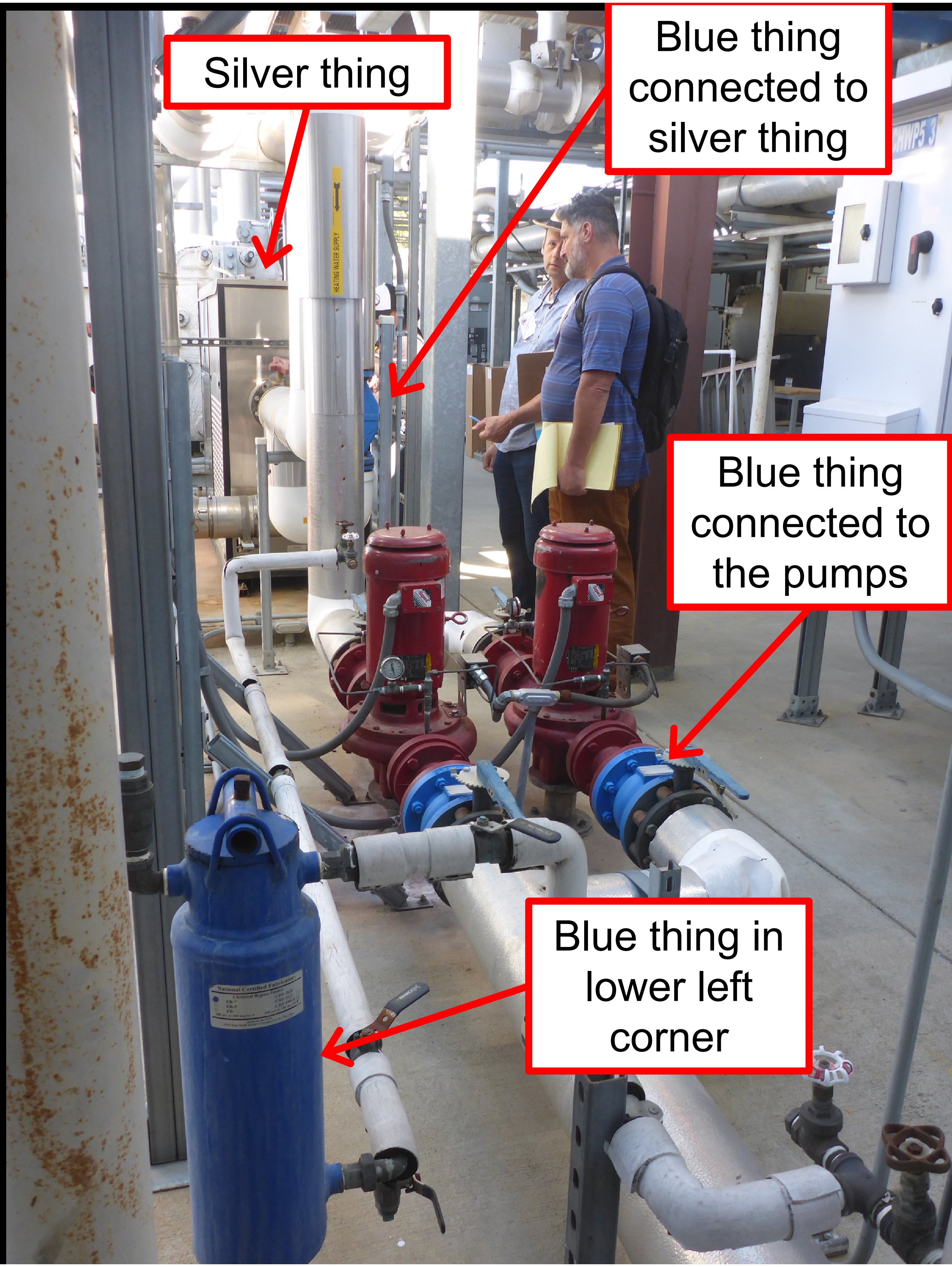
Developing A System Diagram In the Field

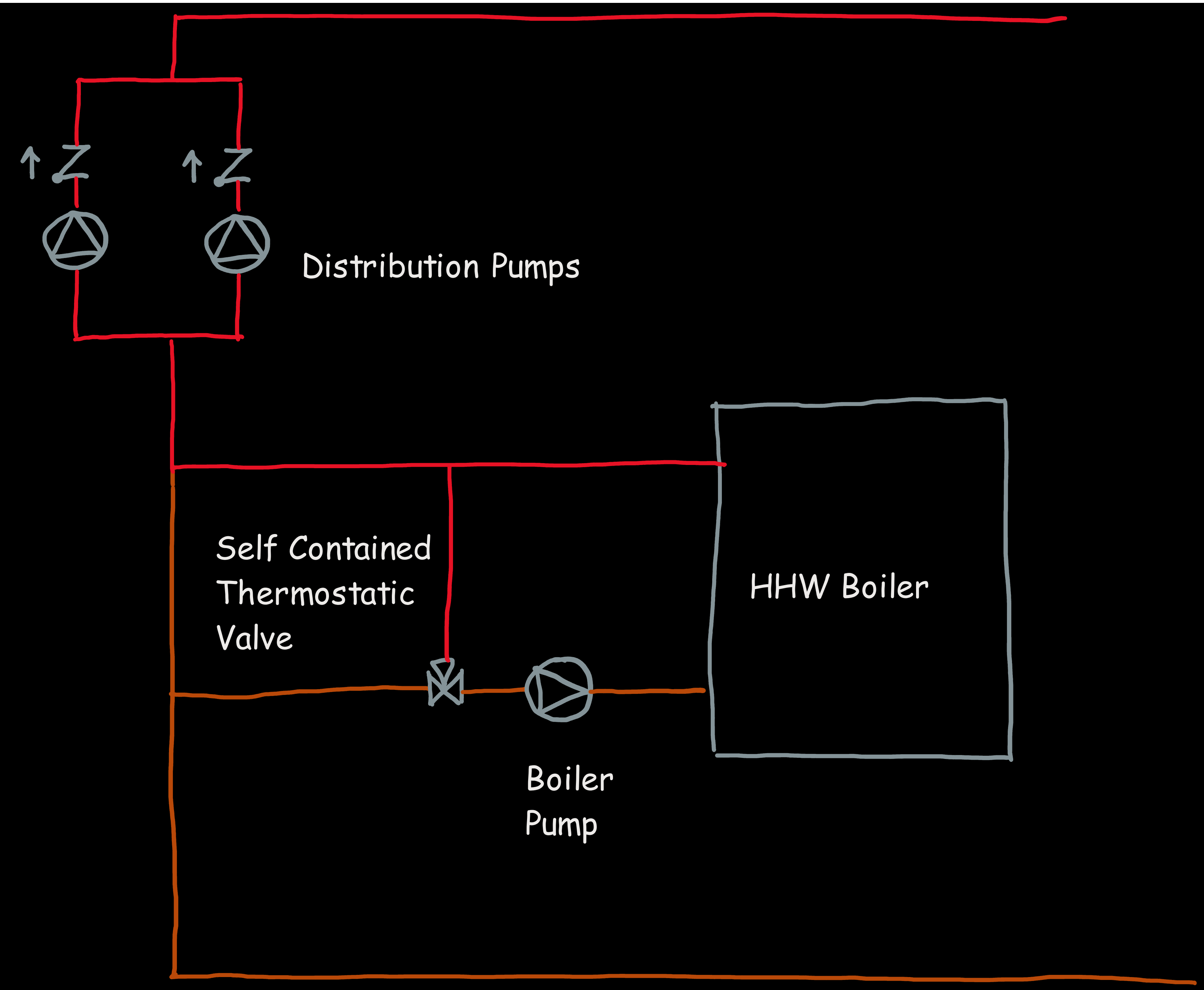
Given the 3DVista model at this link:

http://tinyurl.com/PECSysDgmSimpleWaterSystem

1. Develop a system diagram for the central plant portion of the loop
2. Identify (tell us what it is):
   a. The blue things connected to the pumps
   b. The blue thing in the lower left corner of the picture
   c. The blue thing connected to the silver thing in the background of the picture
   d. The silver thing in the background



The Answer



Note:

The thermostatic valve closes the port that connects to the system if the water temperature flowing through it is less than 140°F. As the water temperature rises above its set point, it closes the recirculation bypass port and opens the port to the system.

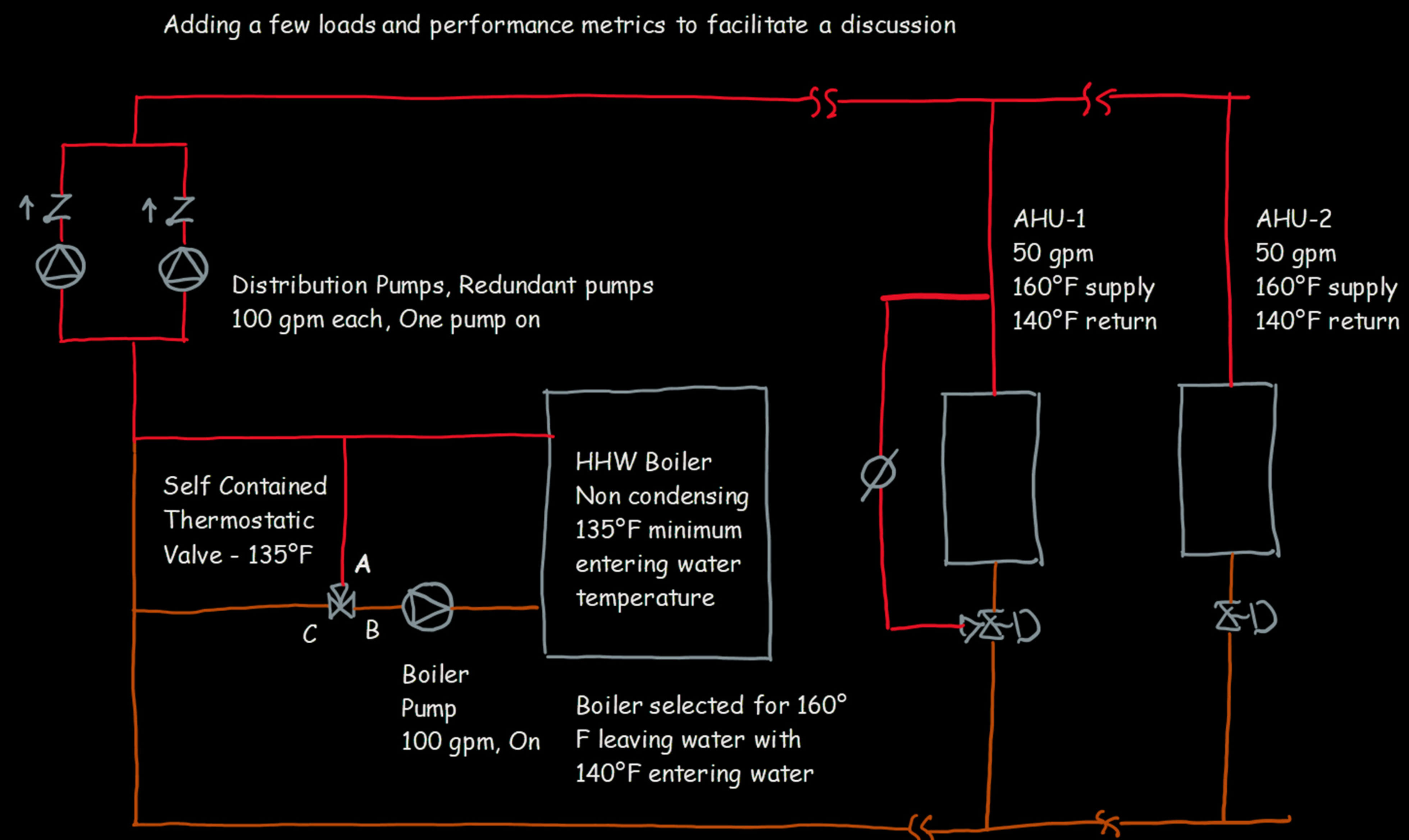
The Answer

Adding a few loads to facilitate a discussion.

The loads shown are an assumption since we did not get to see the actual loads served by the system.

But I added them so we could discuss how a system like this would work.

This system configuration is called variable flow primary/secondary.



For more information regarding how this system configuration works as well as other configurations like constant flow and variable flow primary only, visit this location:

http://tinyurl.com/VariabeFlow

The Answer

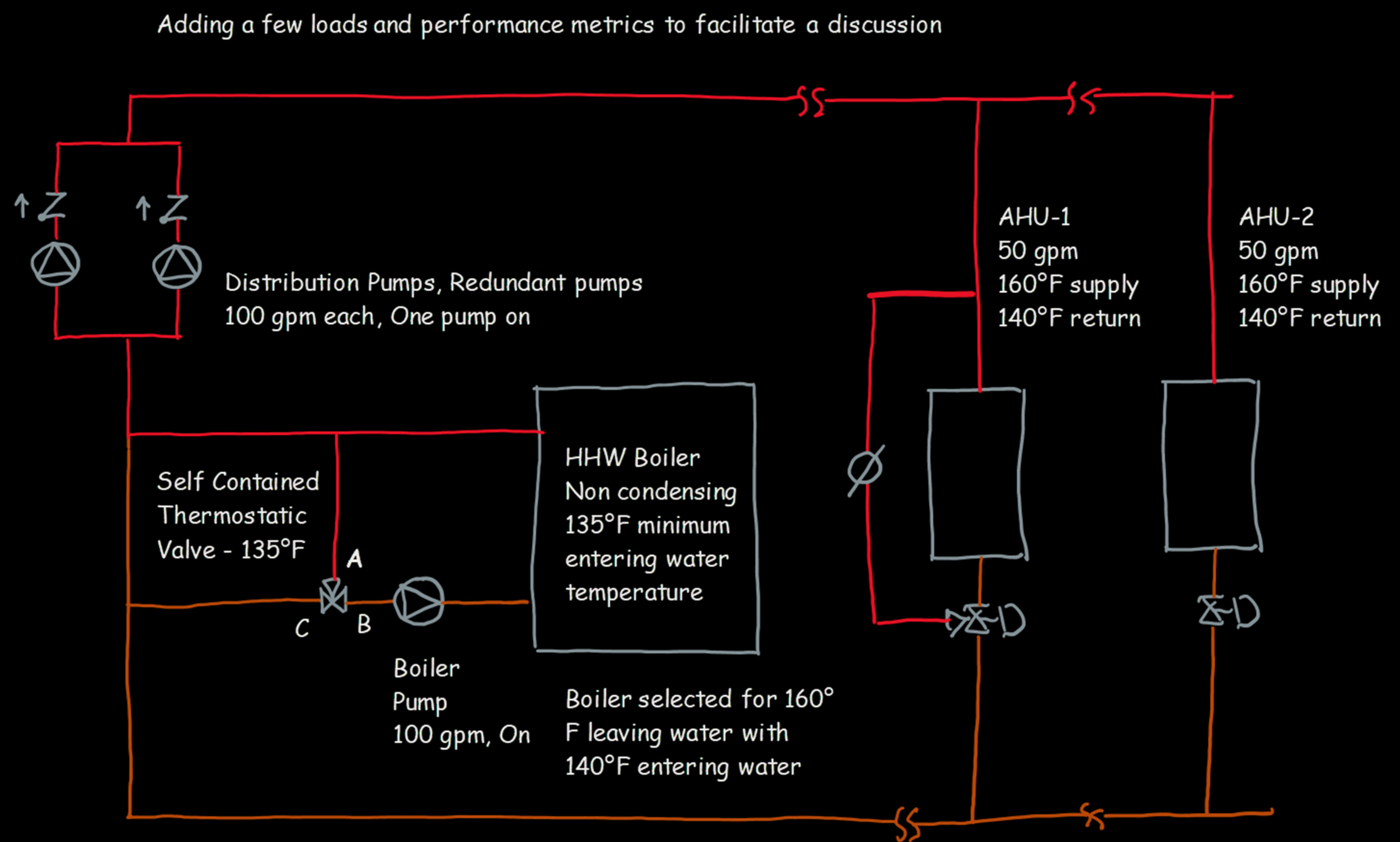
Tees are "nodes" in the system where flows converge or diverge.

Plenums are nodes in air systems.

Fundamental principles that apply to a node:

1. Conservation of mass - reflected by flows
2. Conservation of energy - reflected by temperatures

From the steady flow energy equation:



(Flow A x Temperature A) + (Flow C x Temperature C) = (Flow B x Temperature B)

For more details see http://tinyurl.com/OAPctDerived

The Answer

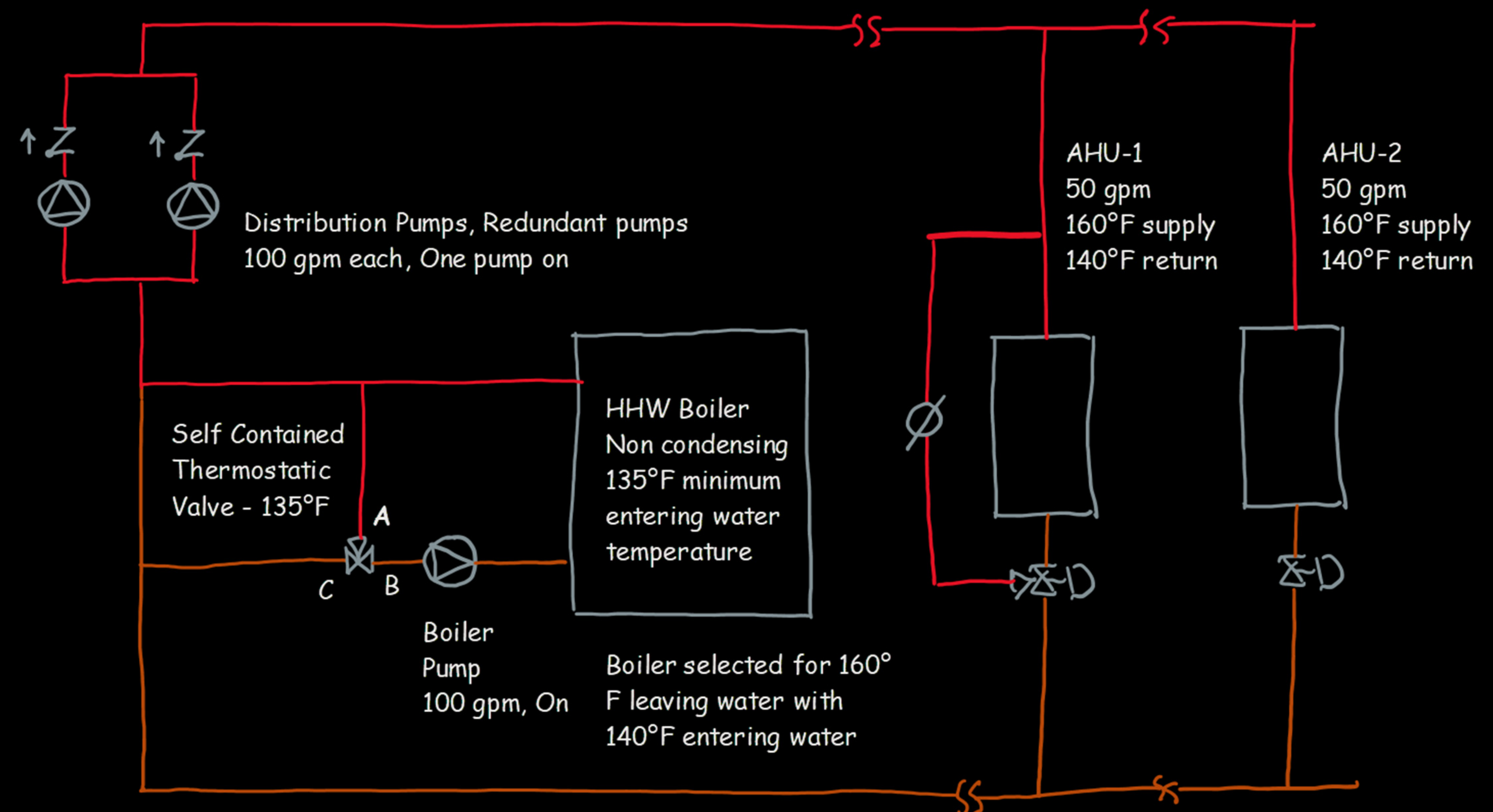
Thermostatic valve operation:

1. If the water temperature in the valve body is below 135°F, then Port A connects to Port B and Port C is blocked
2. If the water temperature in the valve body is above 135°F, the Port C connects to Port B, and Port A is blocked.

For more information on the thermostatic control valve visit

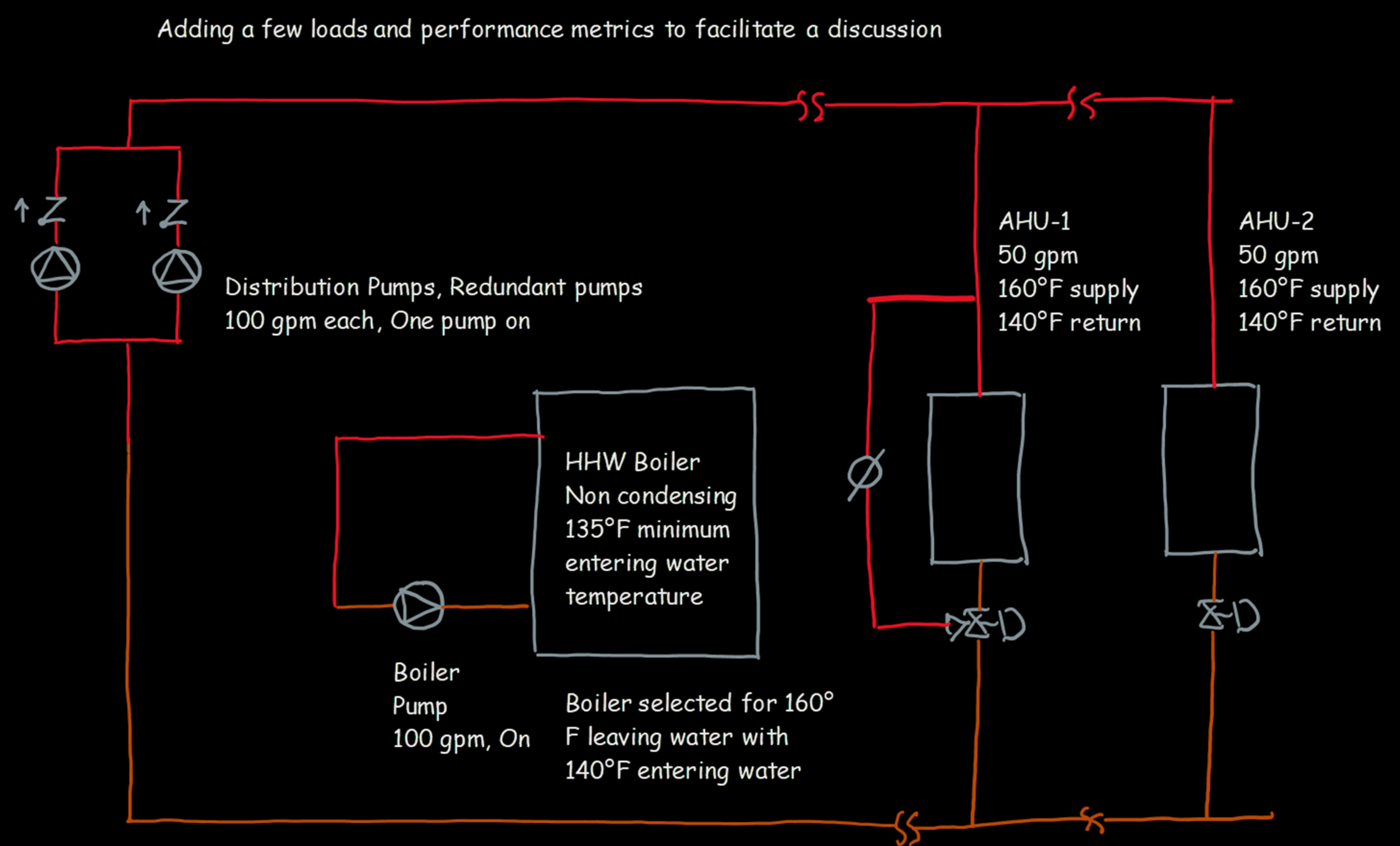
http://tinyurl.com/ThermostaticControlValve

Adding a few loads and performance metrics to facilitate a discussion



The Answer

If water temperatures and the valve body temperature is below its set point (135°F in this example), then it is as if the boiler loop is a totally separate loop from the distribution loop.

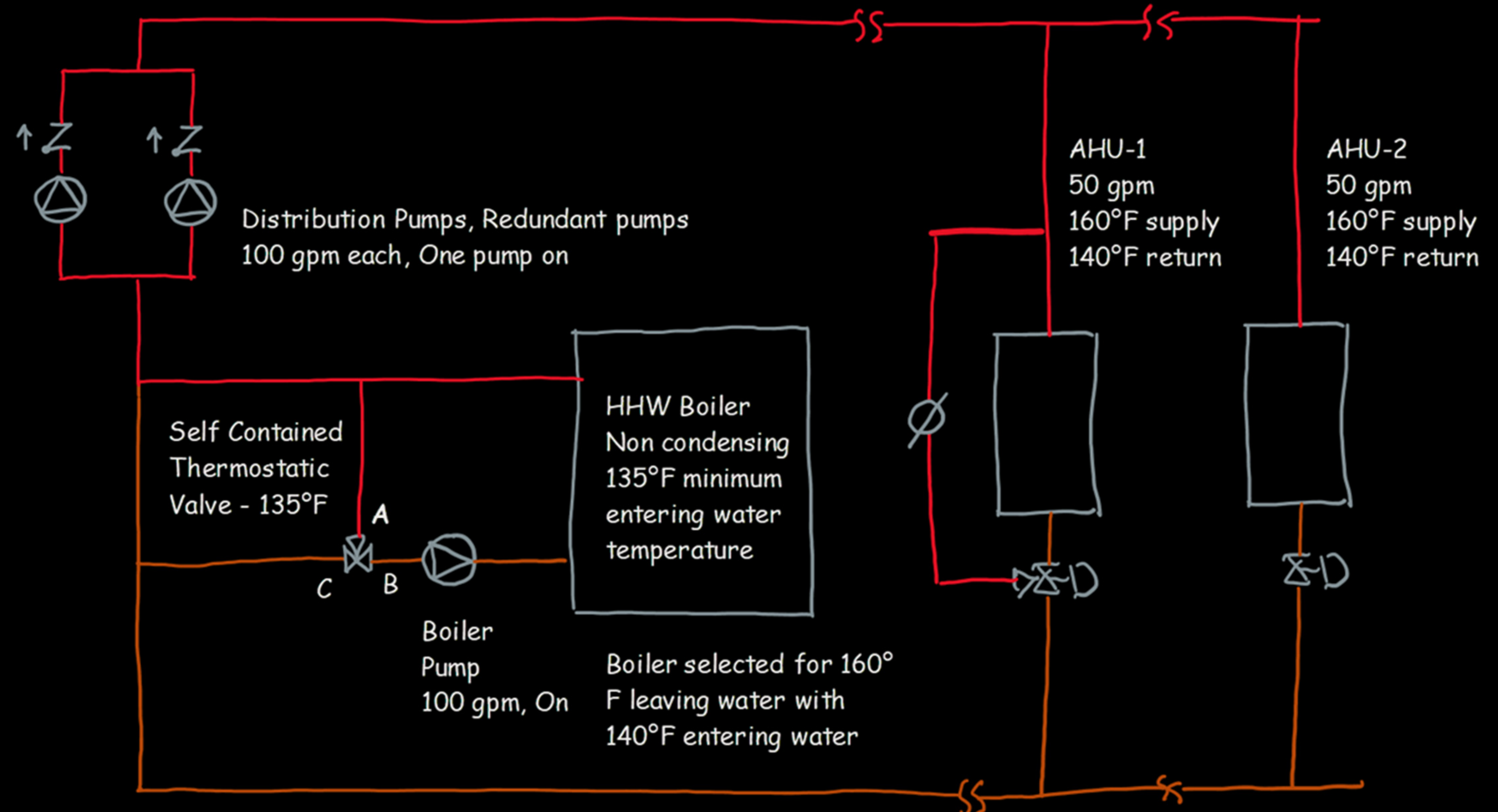


The Answer

The temperatures used in the slides that follow are approximations based on engineering experience and judgement v.s. the result of modeling the specific dynamics of the coils and piping network.

They intent is to illustrate the general dynamics of the system as it moves from a cold start to full load and then part load.

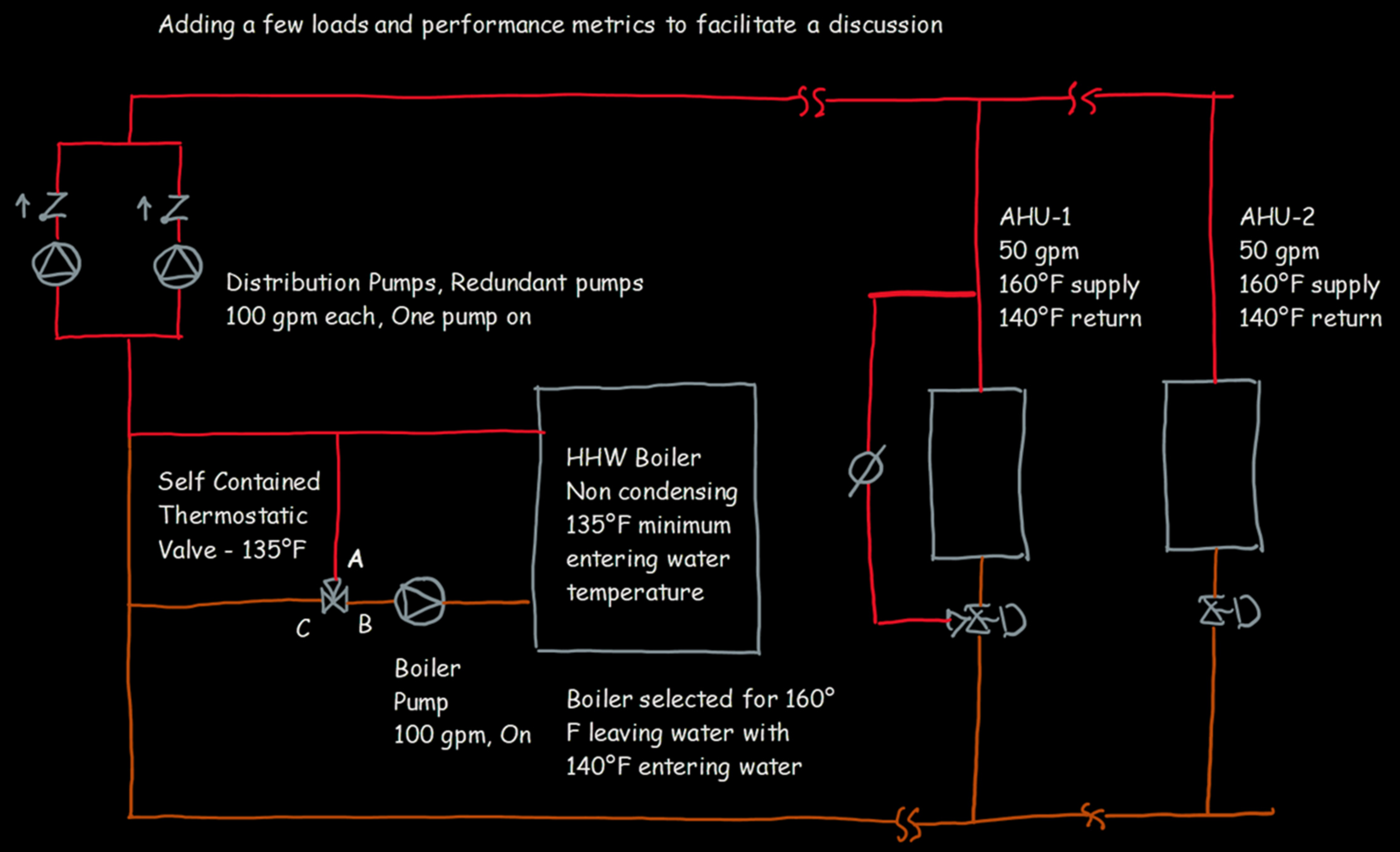
Adding a few loads and performance metrics to facilitate a discussion



The Answer

The assumptions behind the example include:

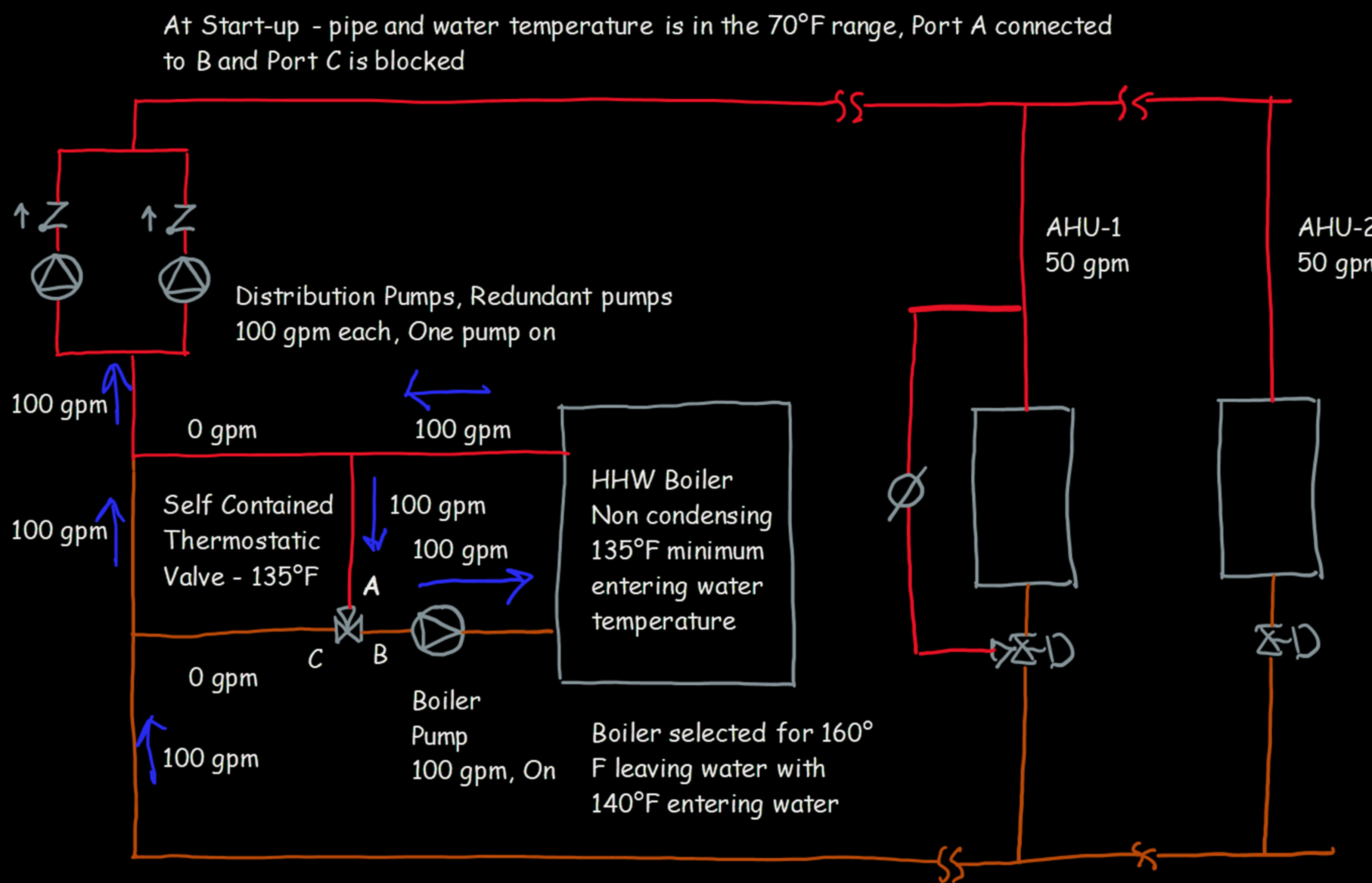
1. The piping network is relatively short and well insulated.
2. As a result of item 1, once the system is up to temperature, the parasitic losses from the system are minimal, thus the temperature reaching the loads will be the same as the temperature leaving the plant and vice versa on the return side.



The Answer

At start-up, since the boiler loop is isolated from the distribution loop by the thermostatic valve, the boiler pump only circulates water through the boiler.

Since the loop is cold relative to the boiler's design set point of 160°F, the boiler will start and go to full fire.

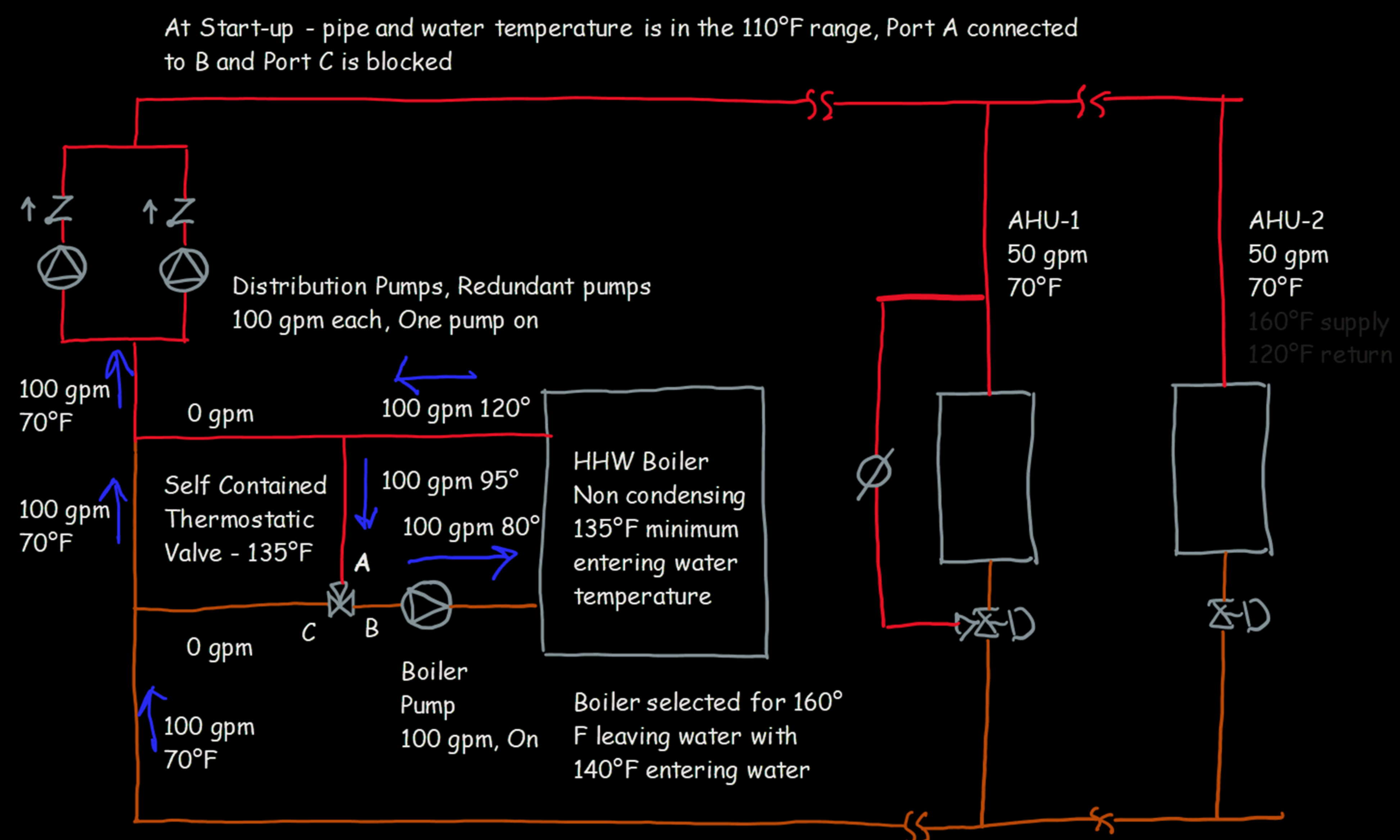


The Answer

Notice how the thermal mass of the boiler loop (the pipe, valves, pump, etc.) absorbs some of the energy added by the boiler.

In other words, even though the boiler raises the water temperature by 40°F when firing at full capacity, the 120°F water leaving the boiler is cooled down as it circulates through the boiler loop.

As a result, the loop temperature will tend to gradually rise vs. going up in 40°F incremental steps.



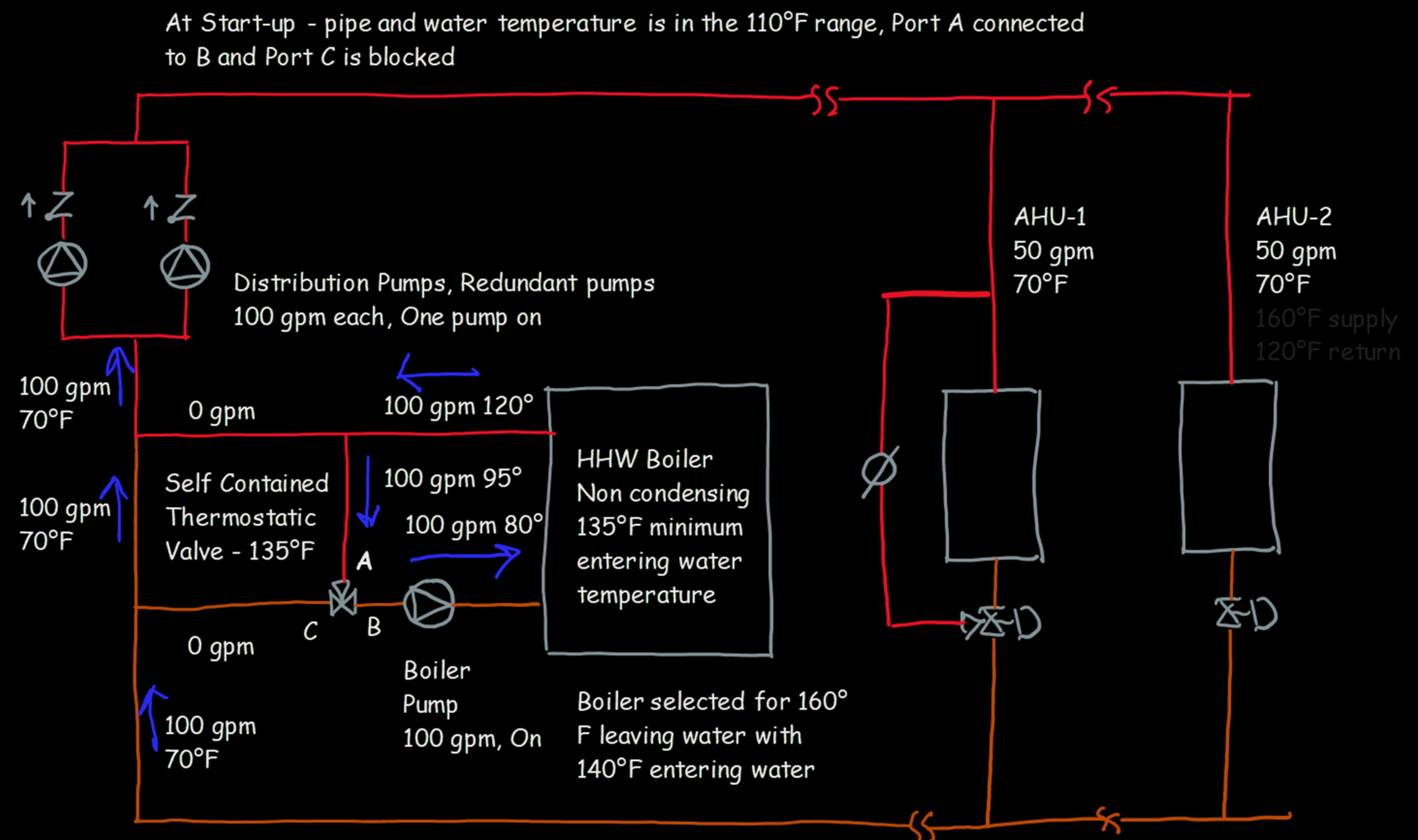
The Answer

Given the small volume in that loop, the loop will warm up fairly quickly.

The water in the distribution loop will remain at about the same temperature that it was at when the system was started if the AHUs have not been started yet.

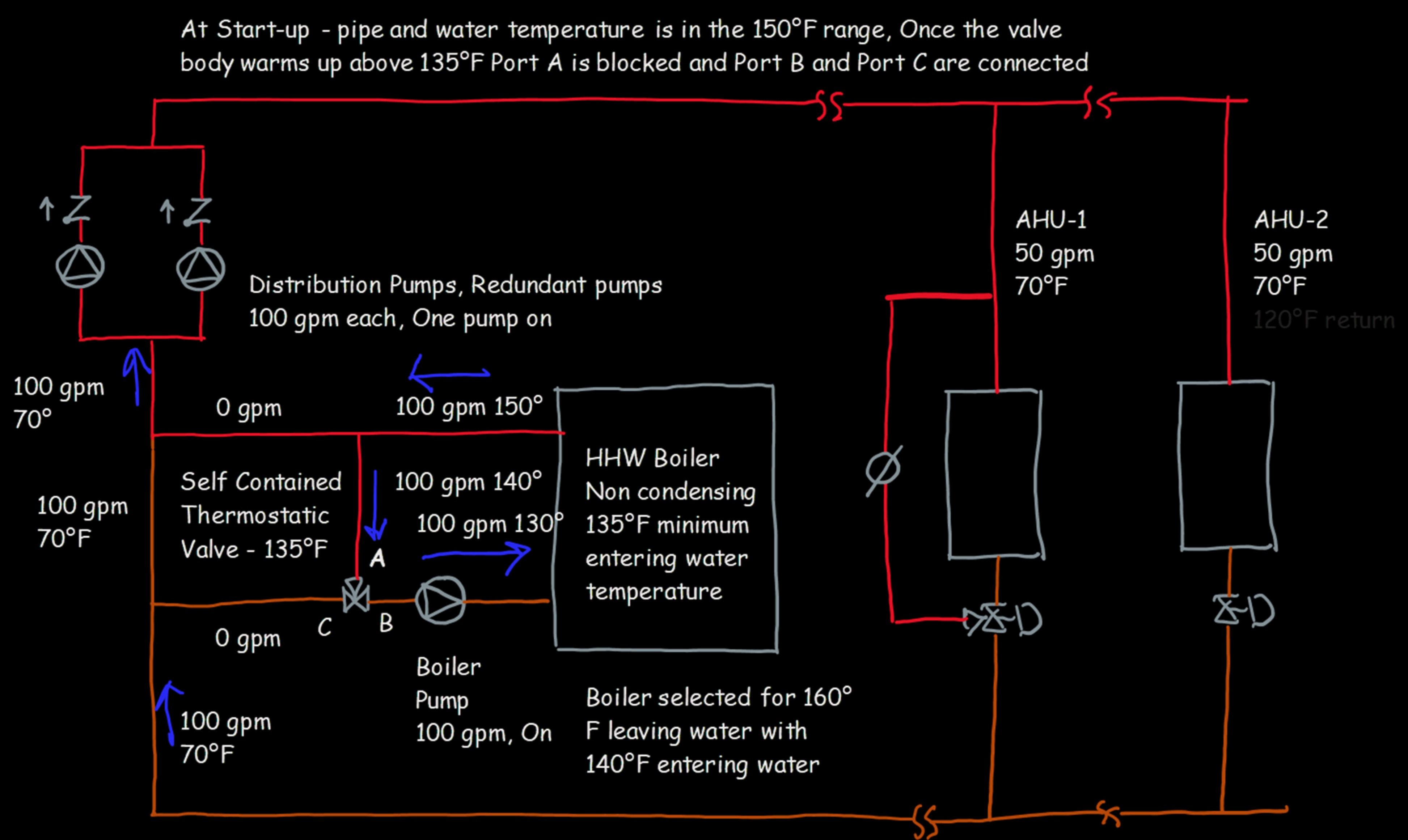
This is because the thermostatic valve is isolating the boiler loop from the distribution loop.

You could even delay the start of the distribution pumps until the boiler loop was up to temperature to save a bit of pump energy.



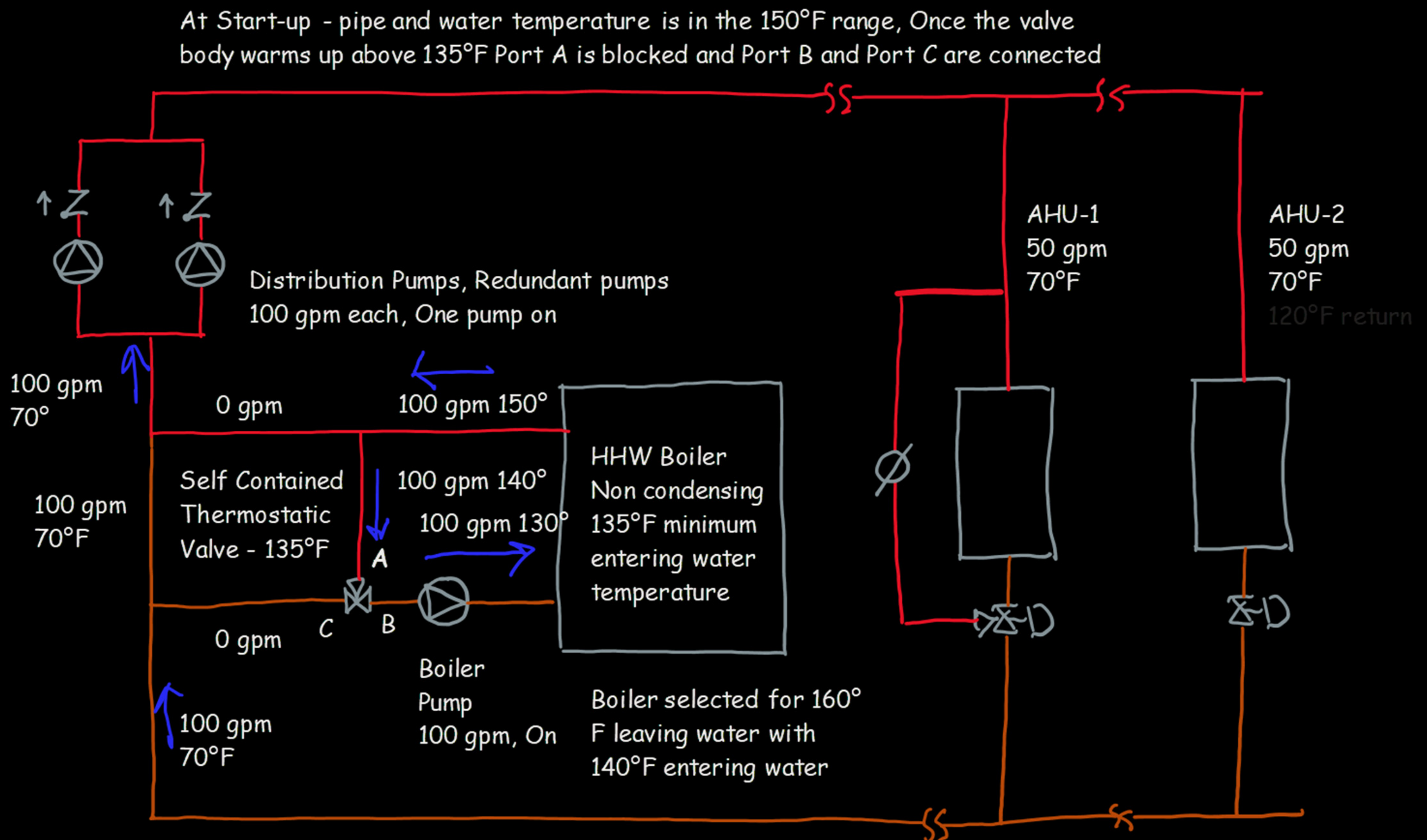
The Answer

But even eventually (and fairly quickly due to the relatively small amount of mass in the boiler loop), the boiler loop temperature will have warmed the thermostatic valve body up to its set point of 135°F.



The Answer

When the valve body reaches its set point, the wax inside the internal actuator changes state from a solid to a liquid. The change in state is also accompanied by a change in the volume of the wax*.



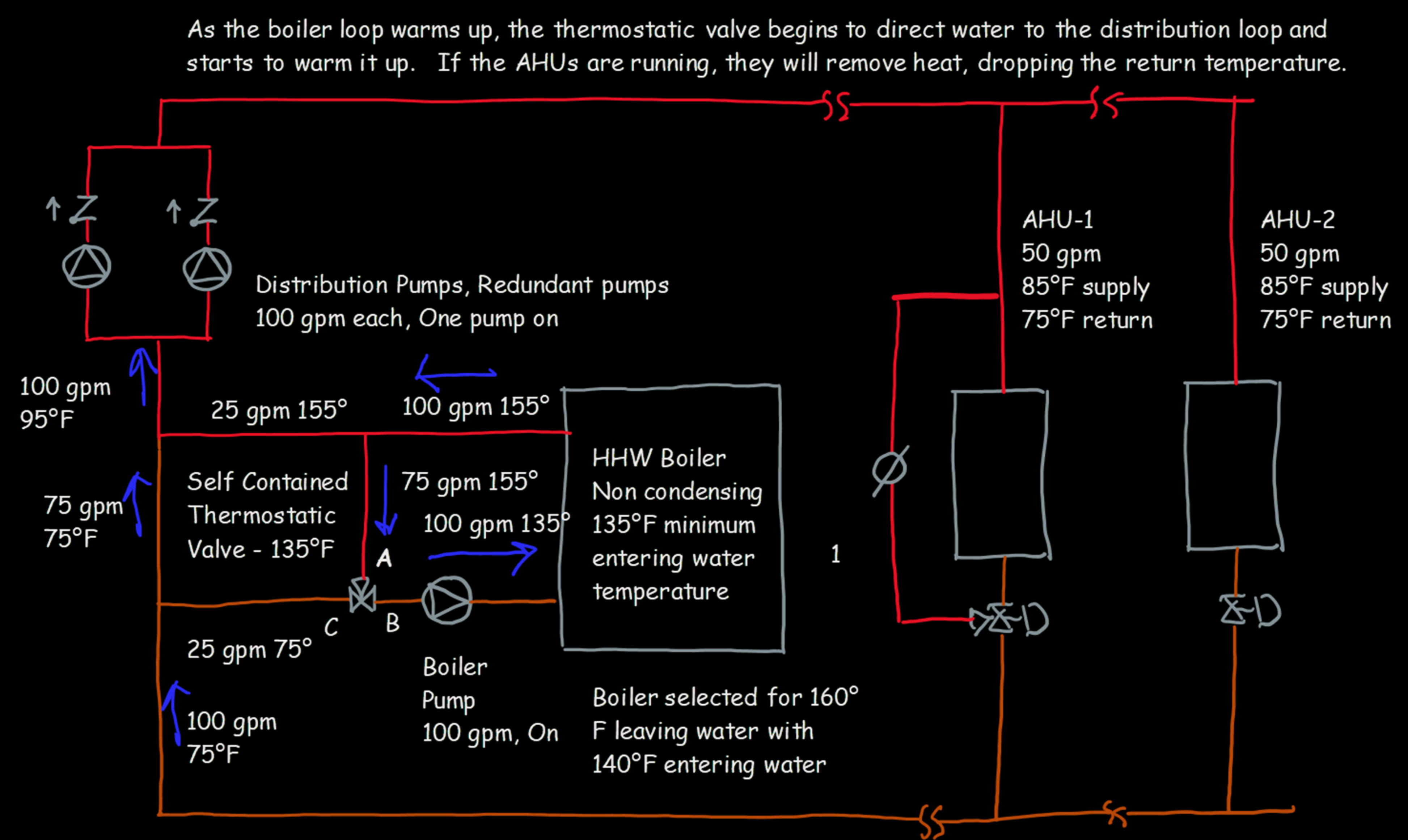
* *If you have ever made a candle, you have probably noticed this phenomenon. It is the reason that the top of the wax dips away from the wick and sides of the container as it cools (image courtesy of Pintrest)*

The Answer

The change in volume of the wax as it melts is used to move the actuating mechanism in the valve and it begins to close off Port A and open up Port B.

As a result, some cool water is blended into the boiler loop from the distribution loop and warm water is sent to the distribution loop and it begins to warm up.

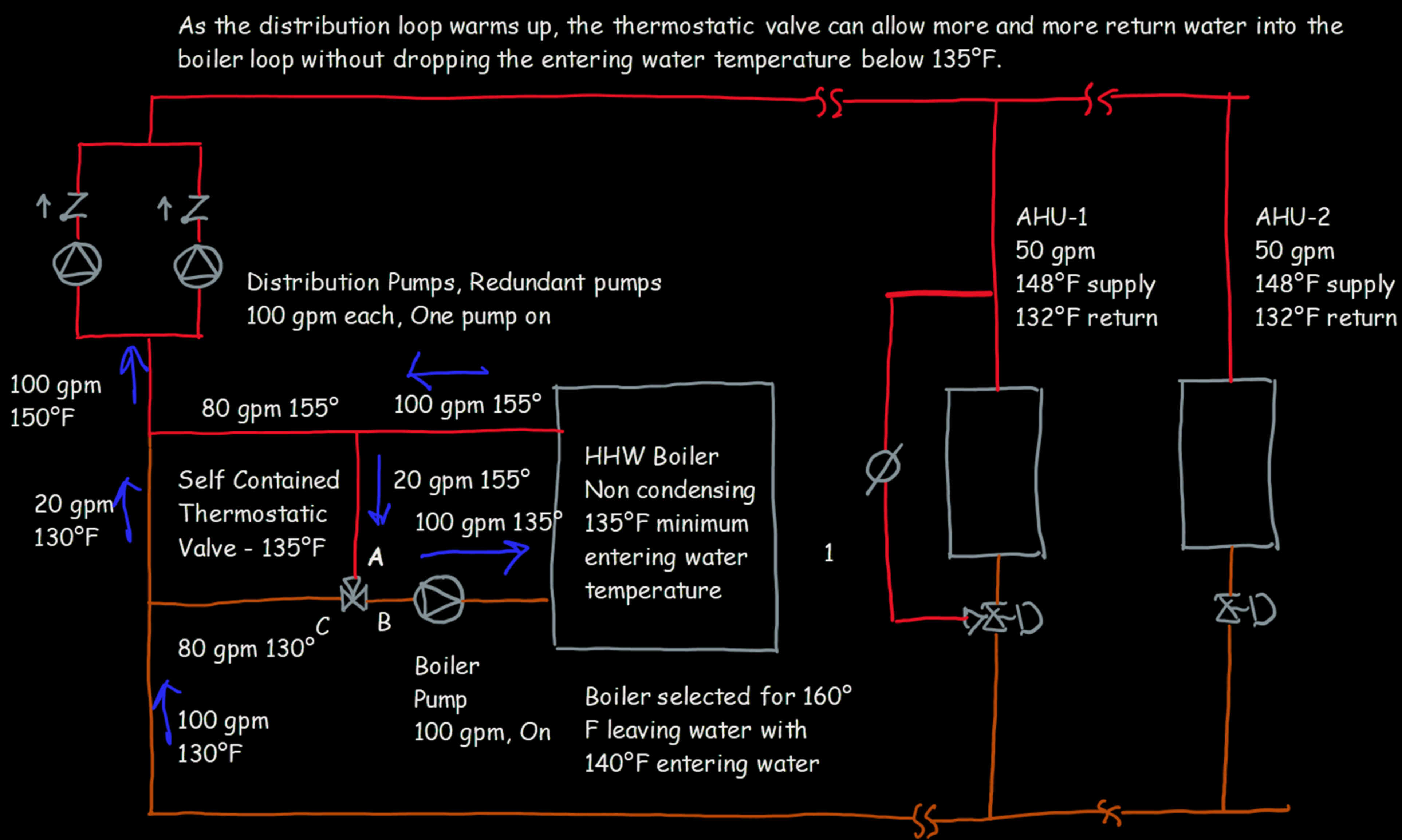
Note that the temperature of the water drops as it leaves the boiler loop and is pumped through the distribution loop because the water is warming up the previously cold piping.



The Answer

As the piping system warms up, the temperature loss associated with warming the piping up drops off, and warmer water reaches the loads. The warmer water allows the coils to transfer more heat to the air stream that they serve, which drops their leaving water temperature.

But the trend is for the system return water temperature to rise and the warmer return water allows more and more flow from the distribution loop to enter the boiler loop while still holding the 135°F thermostatic valve set point.

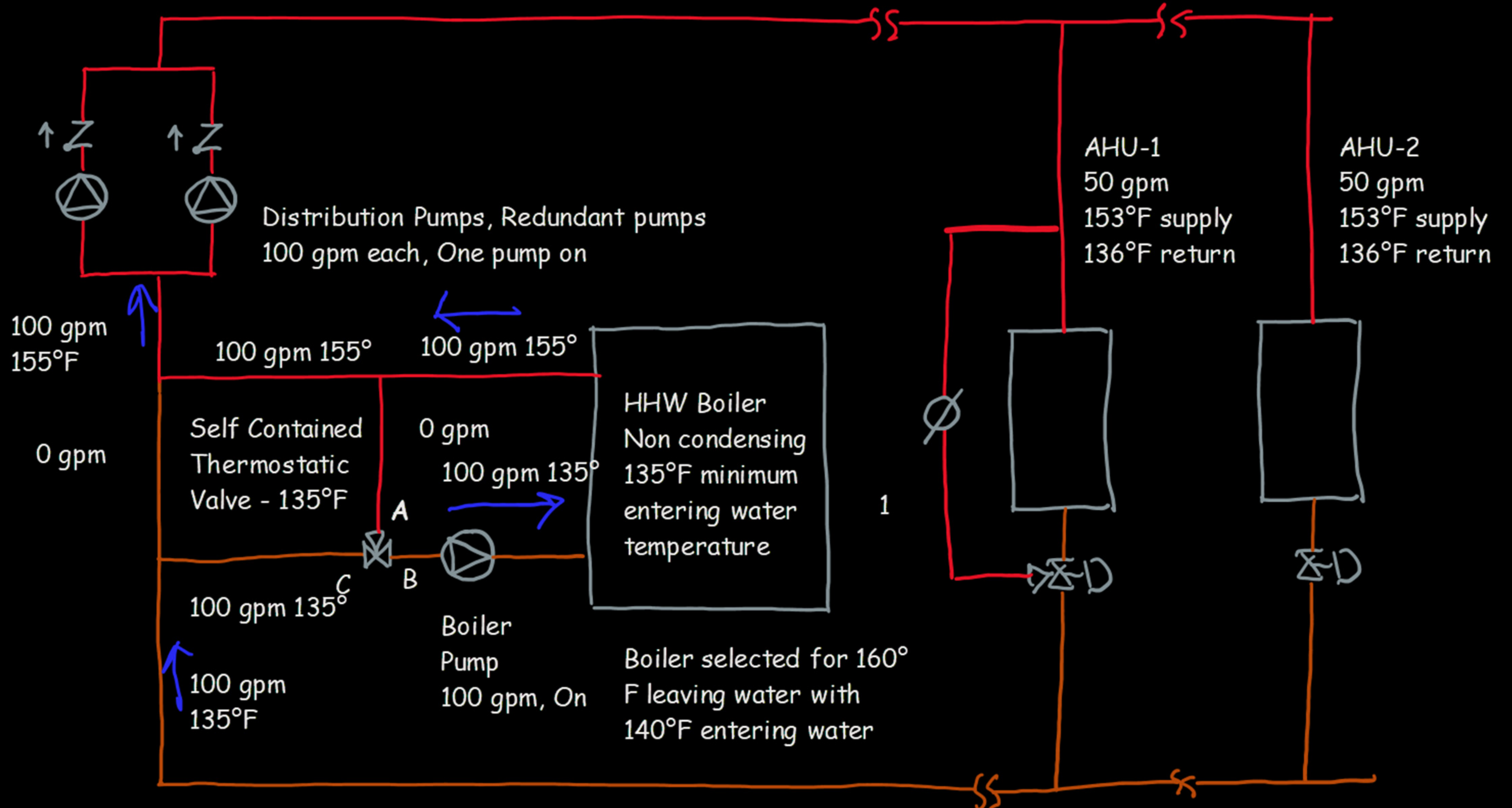


The Answer

Assuming the loads to do not exceed the boiler capacity, then eventually, the return water temperature will rise to 135°F.

When this happens, all of the water circulating in the distribution loop will be directed into the boiler loop because the thermostatic valve will completely shut off Port A and fully open Port B.

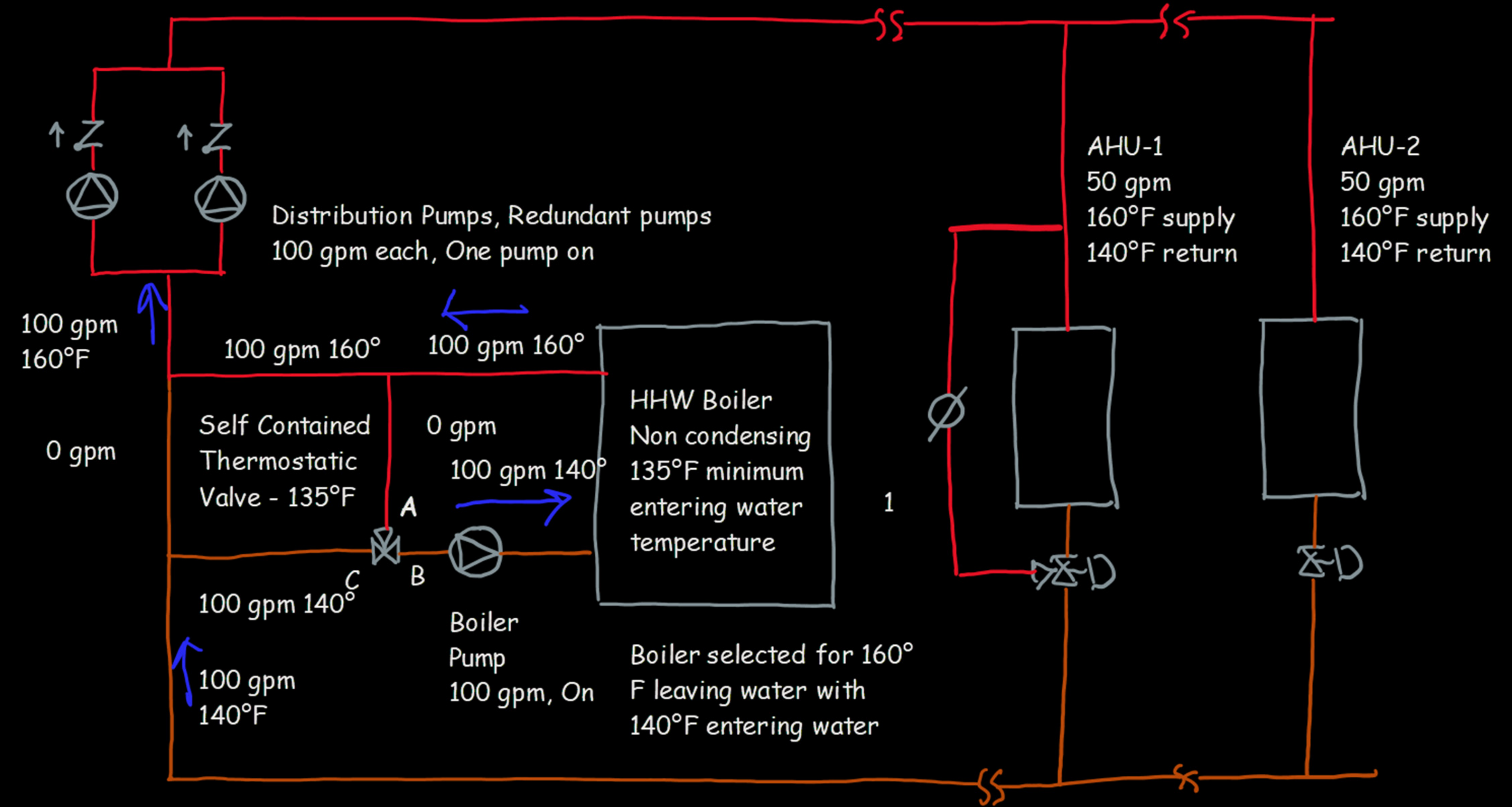
At some point, the thermostatic valve will fully close off Port A and fully open Port C. Thus, all of the distribution loop flow will be directed into the boiler.



The Answer

Assuming the loads to do not exceed the boiler capacity, then the boiler LWT will continue to rise and reach its design set point. And the piping system will warm up and the design supply water temperature will be delivered to the loads. (See assumptions)

If the demand from the loads is less than the boiler capacity, the supply temperature will rise to the boiler leaving water temperature set point and the system will stabilize at the design condition.



The Answer

If the load drops off, the flow rate in the distribution loop will drop and the return water temperature will rise.

This will result in:

1. Reverse flow in the decoupling bypass, and
2. An increase in the boiler entering water temperature.

As a result, the boiler will reduce it's firing rate (i.e. unload, to the extent possible given the nature of its control system).