Refrigeration Cycles vs. Steam Heating Systems

George R. Carey, Jr.
VP, Fluid Industrial Associates
gcarey@fiainc.com
𝕏@Ask_GCarey

Everyone involved in the heating and cooling industry, especially in the Northeast, has experienced a rapid increase in the popularity of Air Source Heat Pumps (ASHP). Without getting into all the reasons why, one interesting takeaway is that, when you understand how an ASHP can take heat out of the air and "pump" it into a home even when the outdoor temperature is 10°F, you can apply that to troubleshooting a steam system. As the Fall season begins and thermostats start calling for heat, existing older steam systems that may have received a new steam boiler will turn on. Or perhaps some renovation took place in a newly purchased home and radiators were relocated or changed. Whatever the reason, when you are tasked with solving a no-heat or noisy, banging steam system, remember the following;

- A steam system is filled with air any time the system is off; if you want heat, you have to get rid of all the air before the steam can get in and heat the radiation.

- A steam system operates *nothing* like a water system; when manufactured in the boiler, the steam desperately wants to turn back into water and will whenever it touches something cooler than itself. If you don't make enough, it will *never* reach the furthest radiators.

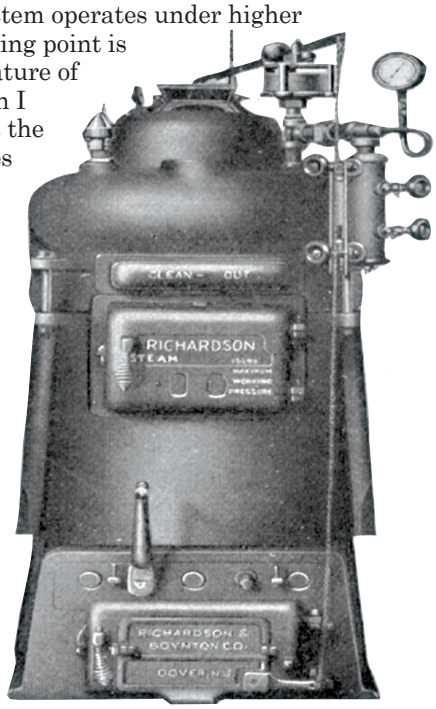
- Steam boilers today really aren't capable of producing dry steam internally, which is why manufacturers insist that you pipe the boiler according to their installation manuals.

- Steam boilers today are *very* different from the old boilers we are replacing. While some of those differences are good, unfortunately there are several that are not and may make some want to quit their job if those differences aren't being taken into account.

I have also been writing articles about Air to Water Heat Pumps; their compressors incorporate invertor technology which, in the compressor world, is state-of-the-art. The invertor basically allows the compressor to operate like a variable speed pump; the expansion valve can operate over a wide range of loads and with the continuing development of the refrigerants, ASHPs can extract heat from lower outdoor air temperatures than what they were previously capable of doing. However, at the end of the day, for heat pumps to work at all, it all comes down to the vapor compression refrigeration cycle.

What does this have to do with problematic steam systems? If you understand the vapor compression cycle and if you understand what a steam system is trying to accomplish, both systems have similar attributes. Here is what I mean:

To make steam, the boiler *has* to heat the water in the boiler up to the water's boiling point. What is the boiling point? It depends on what pressure the system is operating under. When a steam system operates under higher pressure, the water's boiling point is higher. Also, the temperature of the steam is hotter. When I say the boiler has to heat the water, there are two types of heat needed to make steam. Sensible heat is the type of heat that a thermometer can "sense." For example, when the boiler is operating at 2 psig, the boiler has to provide enough sensible BTUs to heat the water to 219°F. The other heat is known as latent heat. This is the amount of energy (BTUs) that is required to change the water's state from liquid to vapor. Why? Remember, we are dealing with a steam system. For it to work, you must change the water into vapor. Continuing with our example, the boiler would have to add an additional 966 BTUs of latent heat per pound of steam. That is five times greater than the amount of sensible BTUs that was needed to bring the water to a boil under 2 psig. When this 219°F steam travels out into the system and fills a radiator, it condenses back to water. The temperature of the water can be 219°F, but the radiator has received 966 BTUs that it uses to warm the room.



A very old steam boiler

When any medium goes through a phase change, it will either absorb or release a tremendous amount of energy; that is the parallel I was drawing between the vapor compression cycle and steam systems. In the compression cycle, instead of water, refrigerant is used, which has many favorable characteristics for the refrigeration process. It can operate under extreme temperature conditions (relative to what we consider "normal"), and it can change state from a liquid refrigerant to a vapor and then condense back to liquid, all while absorbing and releasing energy (heat) to where it's needed (heating application) or from where it is not wanted (air conditioning application). Of

course, there is no boiler in the refrigeration cycle. Instead, an evaporator is used to help change the refrigerant's phase and the compressor is used to increase the pressure on the vapor, which results in a high temperature gas. Before the vapor enters the compressor, it first flows across the evaporator as a cold liquid refrigerant. The volume and temperature of the cold liquid is controlled by an expansion valve. Outdoor air or some other substance (such as geothermal) flows across the other side of the evaporator. The cold liquid absorbs the heat from the outdoor air (or geothermal field) and changes its state into a low temperature vapor. To prevent damage to the compressor, it is critical that only vapor and not liquid enter the compressor. The low temperature vapor gets "compressed" into a high temperature gas that then flows across a heat exchanger. The cooler medium (return air from the ductwork or water from a hydronic system) flows across the other side of the exchanger. This cooler substance (air or water) absorbs the energy from the vapor, causing it to condense back to its liquid form. In the condensing process, a tremendous amount of energy is transferred.

When we take it back to our steam heating systems, the boiler is our evaporator and, to some extent, our compressor. Its job is to add enough sensible *and* latent BTUs so that the water is changed into steam (vapor). When the steam enters the radiator, its surface and surrounding air temperature is cooler than the vapor (steam), causing it to condense back to water (liquid). In doing so, it gives off a tremendous amount of energy (BTUs) to the space.

How does this analogy help solve or prevent steam system problems? Make sure the boiler is making good, *dry* steam; when it produces wet steam, the water in its liquid state "robs" the vapor of its latent BTUs. When this happens, the steam is condensing in the piping network and not where its needed… in the radiators!

• How do we make good *dry* steam? Make sure the new boiler is piped according to the manufacturer's installation instructions.

• A bouncing water line in the boiler can also make wet steam. If the water is moving in the gauge glass, it's an indicator that the water in the boiler is dirty. It needs to be skimmed to rid the boiler of any oils and debris that cause surface tension on the water, prohibiting the steam bubbles from making their way through the surface and out to the system.

• When a boiler is under-sized or under-fired, it can't produce enough steam to fill all of the radiators. The condensor side of the system (the radiators) is bigger than the evaporator side (the boiler). It is imperative that when you replace a steam boiler, you go upstairs and measure the amount of radiation in the building then size the replacement boiler to the connected load.

Whenever you are dealing with a steam system, it is vital that the boiler is making *dry* steam. If it isn't, don't waste your time chasing other symptoms or complaints; *always* start with *dry* steam.

If you have any questions or comments, e-mail me at *gcarey@fiainc.com*, call me at (800) 423-7187, or follow me on *X at @Ask_Gcarey*. **ICM**