Steam Systems Operate a Lot Like the Refrigeration Cycle...

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Steam systems with various problems have been coming at me fast and furious, even though it is still the summertime as I write this column. I have noticed though, with all of the jobs, there is one constant—the person wrestling with the problem really doesn't understand the nuances that a steam system brings to the table. These include:

• A steam system is filled with air anytime 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…the steam, when manufactured in the boiler, desperately wants to turn back into water and it will whenever it touches something cooler than itself. If you don't make enough steam, it will *never* reach the furthest radiators.

The boiling point of water actually depends on the pressure system it is in.

• Steam boilers today really cannot produce 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. Some of those differences are good; unfortunately, there are several that can be very challenging and could make someone want to quit his/her job if those differences haven't been taken into account!

In addition to looking at these problem steam jobs, I have also been writing stories about and designing hydronic systems that use *air-to-water heat pumps*. Many in the industry view these machines as state-of-the-art technology. Their compressors incorporate inverter technology, which in the "compressor world" is cutting edge. The inverter basically allows the compressor to operate like a variable speed pump and the expansion valve can operate over a wide range of loads, allowing the heat pump to extract more heat from lower outdoor air temperatures than was previously possible. At the end of the day, however—for any of these air conditioners and heat pumps to work at all—it comes down to the vapor compression refrigeration cycle.

Making steam

What does this have to do with a column about steam systems with problems? *If* you understand the vapor compression cycle and *if* you understand what a steam system is trying to accomplish, both systems have similar attributes. Read on to see 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, I mean that 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 two pounds per square inch gauge (psig), the boiler has to provide enough sensible British thermal units (BTUs) to heat the water to 219°F.

The other heat is known as **Latent heat**. This is the amount of energy (BTUs) 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 *have* to change the water into vapor.

Continuing with our example, the boiler would have to add an additional 966 BTUs of latent heat per pound (lb) of steam. That is five times greater than the amount of Sensible BTUs that was needed to bring the water to a boil under 2psig. 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 is used to warm the room.

The science of change

When any medium goes through a phase change, it will either absorb or release a *tremendous* amount of energy. This is how to draw a parallel between the vapor compression cycle and steam system.

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 (extreme relative to what we consider normal); it can change state and go from a liquid refrigerant to a vapor and then condense back to liquid. Of course all the while, it absorbs and releases energy (heat) to where it's needed (heating application), or from where it is not wanted (air conditioning application).

There is no boiler in the refrigeration cycle. Instead, an evaporator is used to help change the refrigerant's phase. 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) is flowing 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 *no* liquid enter the compressor. The low temperature vapor gets "compressed" into a high temperature gas that now 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 into 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.

Dry is good

How does this analogy help solve or prevent steam system problems? Make sure the boiler is making good, *dry* steam. When it makes 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 it's needed…in the radiators! Here's how to make good, *dry* steam:

In order to make dry steam, the water must be free of oil and debris.

- Make sure the new boiler is piped according to the manufacturer's installation instructions. Do what it says!

- A bouncing water line in the boiler can 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, go upstairs and measure the amount of radiation in the house (apartment, school, church, etc.). 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 FIA 1-800-423-7187 or follow me on Twitter at *@Ask_Gcarey*. **ICM**