How to size a replacement steam boiler—and why?

by George Carey

When you are asked to size a replacement steam boiler, the *last* thing you are concerned with is the heat loss of the house!

Huh? I know it sounds crazy, but it's true. If you were replacing a hot water boiler, you would calculate the heat loss and then select the correct boiler. But with steam, it is different. Steam is a gas and this gas carries the heat from the boiler out to the radiators where it is needed. If you don't produce enough gas (steam), the heat won't reach the radiators, and you'll end up with cold rooms and unhappy customers. You have to produce enough steam to fill the piping and all the radiators. This is because steam wants to turn back into water as quickly as it can, and when steam enters cold pipes and radiators, that is exactly what it does! So the idea is to produce enough steam to overcome the system's ability to condense it. When steam condenses, it releases a form of energy called "latent heat."

Steam is made up of two types of heat, or BTUs (British Thermal Units—a BTU is a measurement of heat). The first type is called sensible heat. This is the of amount of heat required to bring water to its boiling point. It can be "sensed" by a thermometer. At every pressure, there is a corresponding requirement of sensible heat to boil water (the higher the pressure, the greater the amount required of sensible heat).

The second type of heat is known as latent heat (the heat of evaporation). This is the amount of energy required to take the boiling water and change it into steam. A thermometer can't sense this energy, although it is VERY real. In fact, in a low pressure system (0-15 psig), the amount of latent heat is usually five times as much as the sensible heat per pound of steam. This is why steam is used for all kinds of process work as well as for heating systems. Steam can hold a tremendous amount of energy, while requiring no assistance to travel throughout the system.

When steam is manufactured in the boiler, it races out of the boiler into the piping system and towards the radiators. As it does, it encounters the cold pipes that cause the steam to condense back into water. During this condensing process, the steam gives back the latent heat it received in the boiler. In a steam heating system, this is what heats the radiator. It is not high pressure that heats the house, so there is no sense in turning up the pressuretrol. In fact, the lower the pressure, the greater the quantity of latent heat per pound of steam will be available. This is why people always say, "Turn the pressure down." (By the way, low pressure steam moves faster than higher pressure steam.)

The problem arises when the boiler can't produce enough steam to offset the system's ability to condense it. The steam condenses in the near-boiler piping, supply mains and maybe in some of the closer radiators. The thermostat never lets the burner shut off. No matter how much you turn the pressure up, you can't produce enough steam. One symptom I have consistently noticed is that the pressure gauge NEVER registers any pressure when the system is underfired. The boiler can't build any pressure because, as soon as any steam is produced, the system condenses it!

When you install a replacement steam boiler, it is important that it be sized to the connected load. Once you have picked the correct size and have installed it according to the manufacturer's specifications, make sure you also fire the burner to the connected load. If you don't, the results can be the same as an undersized boiler.

You have to realize that just because the boiler manufacturer says it's a steam boiler and supplies all the necessary trim, it doesn't make steam by magic. You have to input enough energy so that the boiler can offset the connected load's condensing ability. That means when the boiler is rated to a certain GPH, you have to use that firing rate. If you don't, the boiler won't be able to produce enough steam on those cold days. The steam won't be able to reach the furthest radiators because it's condensing in the pipes.

I recently had the chance to go out on one of these "problem" jobs. The complaint was that a couple of bedrooms in this big old house on the ocean just never seemed warm. The boiler had been replaced at the end of the summer. (New boilers are always a warning sign! They represent something that has changed in the system.) To add to the confusion, the homeowners were new to the house. They just purchased it in the fall. (That is another sign of a potential problem. They have no heating history of the house.)

After letting the boiler fire for 30 minutes, I noticed the pressure gauge didn't move. In fact, the water line on the gauge glass barely moved at all. This made me realize what might be going on. I had the service technician disconnect the union connection on one of the radiator traps and no steam came out. And this was after having the boiler run for 30 minutes.

The service technician then checked the burner nozzle. Sure enough! The boiler was rated to fire at 2.10 gph and inside the burner there was a 1.50 gph nozzle. When he changed it to the proper nozzle size, in 15 minutes all the radiators received enough steam for the first time this winter. He even went upstairs and opened a few of the union connections. There was steam billowing out of the outlet connections. Upon talking to the homeowner later on, I asked them about their oil consumption. This was the last piece of evidence we needed. Whenever a steam boiler is undersized or underfired, it consumes a lot of fuel. This is because the boiler never receives enough energy to produce the amount of steam required to fill all the radiators. Instead, the little amount of steam it produces condenses right back to water.

The same holds true regarding "overfiring" a steam boiler, especially in a one-pipe system. Years ago, a heating contractor would have calculated a heat loss and then selected the amount of

radiation to keep the building warm at design conditions. He would then have referenced a piping handbook to select the proper pipe size to support the installed radiation. And everything would have worked fine for the next 70-80 years.

If you install a boiler that is too big, or if you over-fire the boiler, you will have problems. Too much steam moving into an existing piping system will create velocity problems.

One-pipe systems are characterized by their namesake—*one pipe*! The supply riser that feeds each radiator with steam is also the same pipe that returns the condensate from the radiators. These pipes were sized based upon the amount of steam they could handle.

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When you install an oversized/over-fired steam boiler, too much steam will enter this piping network. The velocity will be too high, thus preventing condensate from draining back down. In fact, the steam will drive the suspended condensate up the riser, into the radiator (causing a sloshing sound) and eventually out of the radiator vents.

So remember, after sizing the boiler to the connected load; make sure you fire it at the required GPH.

If you have any questions or comments, please call me at 1-800-423-7187 or email me at gcarey@fiainc.com