FULL STEAM AHEAD

How to improve boiler or steam generator performance

A number of considerations go into determining boiler efficiency, including thermal efficiency, combustion efficiency and fuel-to-steam efficiency. To get the most out of your boilers or steam generators, you must compare apples to apples, look at the steaming rate and evaluate blow-down factor.

It will come as no surprise, but the cost-effective purchase of a new boiler or steam generator demands more than comparing price tags and installation costs. An informed evaluation calls for familiarity with terminology that may seem somewhat arcane to the non-engineer. To ensure an accurate comparison, a basic understanding of terms and the processes they describe is desirable, as well. When all factors are considered, the topic of boiler efficiency can be complex. A rudimentary knowledge of the related processes will enable you to make a realistic decision.

Let's start with an easy and obvious consideration—fuel cost. The annual cost of fuel can be two to three times the installed cost of the equipment. And it's an expense that will recur as long as the boiler lasts. As a result, a boiler that delivers demonstrable fuel efficiency can easily offset a difference in installed cost. There have been instances of fuel savings in the first year alone, which justified a difference in installed cost. Are you ready to enter the terminology jungle?

KEY FACTORS

A number of considerations go into determining boiler efficiency, including thermal efficiency, combustion efficiency and fuel-to-steam efficiency. You need to consider the following:

- **Thermal efficiency**: Surprisingly, of and by itself, this term is of little significance when comparing boilers or steam generators. Most often, it refers to the efficiency of the heat exchanger—a major component. The real significance of thermal efficiency lies in the heat exchanger's contribution to fuel-to-steam efficiency.

- **Combustion efficiency**: Combustion efficiency can be easily computed by using a combustion-gas analyzer, and is therefore used frequently for performance comparisons. What is it? Combustion efficiency describes the total heat released in combustion, minus the heat lost in the stack gases, divided by the total heat released. For example, if combustion releases 1,000 BTU's per hour, and 180 BTU's are lost in the stack, then combustion efficiency is 82 percent: \((1,000 - 180)/1,000 = 0.82\).
Fuel-to-steam efficiency: Many consider this measurement to be the most important. Fuel-to-steam efficiency refers to the energy that's converted to steam—the reason you're buying that boiler or steam generator in the first place. The computation is simple enough. Fuel-to-steam efficiency is combustion efficiency less the percentage of heat losses through radiation and convection. If, in the example above, 20 BTU's per hour are lost to radiation and convection, the loss is two percent: 

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\text{20 BTU's per hour} = \frac{20}{1,000} = 0.02
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Since we've determined that the combustion efficiency is 82 percent, the fuel-to-steam efficiency is 80 percent: 82 percent - two percent.

COMPARE APPLES TO APPLES

When comparing, it's important to know whether the efficiency measured is based on high heat value (HHV) or low heat value (LHV). In Canada and the U.S, boiler efficiencies are typically based on HHV. In Europe, they're based on LHV and result in a higher value. Both methods are perfectly acceptable. Just be sure that you're comparing apples with apples. The general relationship: for natural gas, efficiency based on LHV = efficiency based on HHV x 1.1; for diesel-fuel oil multiply by 1.06.

Just to complicate things a little, it should be noted that all these boiler-efficiency measurements assume operation at fixed conditions, such as 100-percent load and specified air and feedwater temperatures. Further, there are additional factors that affect an annual fuel bill, and may be greater than the difference of a point or two in equipment efficiency.

For example, certain design characteristics can contribute to fuel savings, including minimal exterior surface to reduce convective and radiant-heat loss. Operational factors that affect fuel savings include quick start-up, high steam quality (which can be measured) and reduced blow-down.

LOOK AT STEAMING RATE

The steaming rate is precisely what the name suggests—the rate at which a boiler produces steam. It's a measurement that's needed if you're going to purchase the right size boiler. Steaming rate is normally expressed as pounds per hour or kilograms per hour. The rate must be properly qualified, however, to obtain an accurate value. There are three terms used to do this:

From and at 212 degrees Fahrenheit (100 degrees Celsius): This is the term used most often when steaming-rate information is provided in literature. It's the rate for a boiler with feedwater at the inlet flange and steam at the outlet flange of 212 degrees Fahrenheit and 0 PSIG. For example, one boiler horsepower (BHP) is, by definition, equivalent to 34.5 pounds of steam per hour from and at 212 degrees Fahrenheit (100 degrees Celsius).

Gross steaming rate: This is the rate at which a boiler produces steam at the outlet flange based on application-specific feedwater conditions at the inlet flange and application-specific steam conditions. It usually differs from the "From and at ... rate." For example, an application may have feedwater at 190 degrees Fahrenheit and produce saturated steam at 100 PSIG.

Obviously, the inlet temperature here is less than 212 degrees Fahrenheit, and the outlet temperature greater. Heat needed to produce a pound of steam under these conditions is higher than that needed when inlet and outlet temperatures are 212 degrees Fahrenheit. The gross-steaming rate is frequently less than that: "From and at ... rate." It can be greater, however, if the feedwater receiver is a pressurized de-aerator that heats feedwater above 212 degrees Fahrenheit.

Net-steaming rate: This is the most important of the steaming rates because it represents the rate at which steam is produced for your plant or process. It differs from gross by taking into account the amount of steam needed to heat feedwater in the feedwater receiver. In brief, the net-steaming rate equals the gross minus the steaming rate to the feedwater receiver. As an example, take a 100-BHP boiler producing steam at 125 PSIG. In this case, the: "From and at ... rate" is 3,450 pounds per hour, but the net rate is only 2,874 pounds per hour, or 17 percent less.

EVALUATE BLOW-DOWN FACTOR

Blowing-down is the removal of boiler water that has a maximum acceptable level of total dissolved solids (TDS). The process is required periodically to maintain boiler efficiency, promote equipment life and reduce maintenance time and expenses. In a sense, however, blow-down also has a negative economic impact, simply because the water that's removed has been heated and chemically treated.

The amount of water that must be blown-down is contingent upon:

- The TDS level in the replacement (make-up) water. The higher the level—the more blow-down that's required;
- The amount of make-up water contrasted with the amount of condensate returned. The greater the amount of make-up—the greater the amount of blow-down;
- The maximum TDS level in the boiler water. The lower the level—the greater the amount of blow-down;
- The TDS in the blow-down water. The higher the TDS—the lower the amount of blow-down;
- The average load level for the boiler (measured in BHP or pounds of steam per hour).

Blow-down is a practical necessity, but the less the merrier since the process has an economic impact—the magnitude of which depends on factors, such as temperature of condensate and make-up water, steam pressure, cost of fuel, operating duration, boiler efficiency, cost of water and cost of blow-down water disposal.

There's no doubt about it—life would be simpler if choosing the proper boiler or steam generator were a matter of frequent-flyer miles. Non-engineers, however, don't need an encyclopedic knowledge to get the job done. If you do the homework and follow some of these basic steps—you're well on the way to improving boiler or steam generator performance.

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