Technologies

Comparing Condensing Boiler Efficiencies

Whether you are comparing the performance of different equipment or seeking to estimate your potential fuel savings, it is imperative to gain a basic understanding of how manufacturers perform efficiency tests and how test conditions differ from real-world operations. Unfortunately, efficiency ratings will generally not translate directly to fuel savings, because similar performance is rarely, if ever, consistently achieved in typical installations. The following material provides an overview of the standard test procedure and outlines key questions to ask as you design your overall heating system.

The Boiler Efficiency Test: ANSI Standard Z21.13

All gas-fired boiler manufacturers that publish an efficiency rating for equipment with capacities between 300,000 and 12,500,000 BTU base it on the American National Standards Institute (ANSI) – published efficiency test, Z21.13. The test involves operating the appliance over a specific period of time, measuring the temperatures of the inlet and outlet water, and calculating the energy absorbed by the water.

While the test itself is straightforward, it is the conditions under which the test is performed that prove most important. The test assumes:

- Full firing for 30-minutes prior to testing to “soak” the metal with heat
- Full firing at 100% capacity for the entire 30 minutes test period
- 80ºF feed water returning to the boiler

Those familiar with hydronic boiler installations will immediately notice that these conditions are not representative of most equipment installations. In fact, noncondensing equipment is not designed to accept return water under 140ºF and nonmodulating equipment will cycle to support loads that are less than full-BTU input. These differences, and their favorable impact on test results vs. real-world performance, are discussed below.

The Impact of the 30-Minute “Heat Soak”

The 30-minute heat soak period primes the surface area of the heat exchanger so that absolute heat transfer can be readily measured. The heat soak levels the playing field for manufacturers using different materials of construction and heat exchanger designs for the sake of testing; it assumes that the heat required to sustain this surface temperature stays constant in real-world applications.

Such an environment is possible to achieve only where the equipment runs continuously. In reality, any time a conventional unit cycles on/off or any time a boiler faults or is taken off-line, the internal temperature drops and the metal cools. Restarting the boiler requires a purge period that forces warm air out of the heat exchanger.

The Bottom Line: Some of your unit’s capacity will be required to initially “soak” the surface of the heat exchanger before the exchange of usable heat can begin. This diminishes real-world performance. Efficiency will suffer with each start or cycle your unit undergoes in your application. This loss can be minimized by employing modulating boilers that run at lower firing rates and by ensuring that your boiler has been appropriately sized (rather than “oversized”) to keep the units working.

The Impact of Continuous Firing at 100% of Capacity

Testing is performed with the boilers running at 100% firing for the duration of the test. Unfortunately, most boiler plants are oversized to provide adequate heat on a “design day” (a prediction of the coldest day of the year in a given climate zone) with extra capacity as a safety cushion. While such demand may exist a few days per year, the bulk of the heating season is characterized by mild weather that does not call upon the full resources of the boiler plant. Consequently, conventional boilers with 100% on/off or limited turndown firing capabilities resort to cycling to meet such “partload” conditions. Although they may deliver promised performance when on, it has been estimated that the temperature overshoot and cycling losses can contribute up to a 20%-30% reduction in overall efficiency over the course of normal operations.

Modulating boilers operate at lower firing rates to better meet actual demand. Firing may incrementally adjust over a wide firing range or may be fixed to one or two intervals. While this will reduce cycling and the associated energy loss, it does not ensure that low fire performance will equal the test score at a 100% firing rate. Interestingly, a well-designed heat exchanger can actually increase its performance at lower loads by allowing more time and greater surface area for heat transfer to take place. Several manufacturers of modulating equipment publish “part-load performance schedules” to pinpoint efficiency under part-fire conditions.

The Bottom Line: One hundred percent continuous firing is an unrealistic assumption for most real-world applications. Carefully consider the actual weather patterns in your climate zone when establishing your overall boiler plant capacity and setting up automated control schedules. Compare the range of modulation when evaluating equipment, and request part-load performance schedules to help accurately estimate efficiency.

The Impact of 80ºF Feed Water

The issue of 80ºF feed water needs special consideration because it has, by far, the greatest impact on published efficiency scores.

In its chapter on boilers, the ASHRAE Systems and Equipment Handbook published the curve shown at the right to characterize the normal efficiency profile common to all boilers (click on picture.) Efficiency increases as water temperature drops – with a dramatic jump at temperatures <130ºF. It is at this point (the dew point of flue gases) that boilers begin to condense – naturally extracting latent energy that is created during the combustion process. Effective condensing is capable of reclaiming as much as 12%-13% of the total energy used by a boiler.

However, unless a boiler is specifically designed for condensing applications, the appliance cannot accept such low-temperature return water in normal operation, due to the corrosive effect of the condensate. It is, in fact, a breach of many manufacturer warranties to install non-condensing equipment in applications that will supply return water below 140ºF. Nonetheless, all manufacturers are allowed to use 80ºF supply water, reaping the efficiency benefits of condensing, to comply with the ANSI efficiency test.

It is also important to recognize that return water temperature will also fluctuate under normal operating conditions, based on outlet temperature settings, environmental conditions, and the overall composition and performance of systemwide components (valves, terminal units, bypasses, etc.) However, by designing the overall system to take advantage of and preserve cooler water temperatures (i.e., designing a >20ºF temperature rise across the system) will help to maximize the performance of condensing boilers.

The Bottom Line: When employed in a heating system that promotes return water consistently <135°F, condensing boilers yield efficiencies that are far closer to those published than is conventional equipment.

A Superior Test Method

AERCO developed an efficiency test methodology that reflects how equipment operates in the field. This comprehensive series of tests, performed under realistic operating conditions, offers genuine value to engineers. Designers are enabled to accurately size systems, estimate operating costs, and set meaningful benchmarks to which field installations can be compared. A description of the test appeared in the December 2006 issue of ASHRAE Journal.