Beware of Exaggerated Claims and Uncertified "Manufacturers Ratings" Regarding Commercial Boiler "Efficiency"

For many years competent professional HVAC engineers have been aware of exaggerated or deceptive "efficiency" claims often made in boiler manufacturers' literature and press releases. Furthermore, unsuspecting consumers, municipal and utility authorities setting regulatory minimum efficiency levels and even federal "guideline" creators typically read the literature and accept the headline numbers they see in print as fact. Those numbers are then used to make cost/payback analyses, set efficiency minimum standards, or even try to force users toward specific and high cost boiler systems that seldom live up to their full theoretical expectations because of the application.

Up until now, the exaggeration of efficiency claims normally has fallen into three categories; steady state, seasonal and condensing part load. The typical methodologies to arrive at test results to support these numbers are as follows:

1. Steady State: The highest numbers are often the result of testing to nationally recognized standards tweaked to the maximum by optimizing all allowable tolerances to be in the manufacturers favor. The criterion for steady state testing and rating is currently in the process of being reviewed by AHRI.

2. Seasonal Efficiency: Claims about seasonal efficiency or "AFUE" for commercial boilers over 300 MBtuh are not based on any nationally recognized criterion. Current AFUE test standards have been developed for residential furnaces and boilers only. It can be assumed that if a manufacturer writes his own test criterion for commercial sizes and then tests to that, the results can be, at best, deceptively self serving. National test standards are being developed through ASHRAE, but are not yet published. For now manufacturers are free to set their own rules which best fit their design, and then publish the uncertified results.

3. Condensing Boilers: "Part load" efficiency is often applied to national standards by testing with extremely low return water temperatures (well under 100°F). This often achieves an optimum efficiency of 96%-99%. This result is prominently displayed in the literature preceded by the words "up to" and often accepted as the operational norm by unsuspecting consumers. In most hydronic heating systems, this "part load" occurs for a very small part of the season, if at all. The only reliable number to use for true selection criteria is the boilers' full input efficiency (which is often 4%-6% lower than the claimed "up to" value). The bulk of seasonal energy use occurs on colder days when full input is more applicable. It should also be remembered that any stated steady state efficiency over 88% is not achievable, according to the Laws of Physics, unless the return water is below the dew point temperature of the flue gases (typically 130°F or less) in the actual application.

All higher efficiency "spins" are driven by marketing needs, not engineering facts.

4. A New Tweak: Recently a new and particularly surprising "manufacturer's" steady state efficiency claim has surfaced. It clearly states with much fan fare, in press releases and literature, "guaranteed" "Minimum 90% Thermal Efficiency at 160°F Return with 20° Rise" with sub 30 PPM NOx emissions. The boiler industry has long recognized and accepted the fact that flue gases will not condense when return water is above 130°F, certainly not at 160°F. Since condensation does not occur at the return water temperatures specified, this manufacturer's claims seem to violate the Laws of Physics. They purport to achieve the "guaranteed minimum 90% thermal efficiency" by preheating the combustion air with heat from the flue gases.

There is a known technique for gaining some combustion efficiency by utilizing waste heat from exiting flue products to preheat the combustion air. This has been practiced in the Process Heating industry for over 100 years, although generally with exhaust temperatures in excess of 1000°F. Processes operating above 1600°F are generally good candidates, while preheated air is difficult to justify on processes operating below 1000°F.[1,2] In addition, preheating combustion air has been practiced with residential combi-boilers in Europe with concentric vents for many years.

The calculations that follow will show that it is impossible to gain the added efficiency necessary to attain their advertised "minimum 90% thermal efficiency at 160°F return water temperature" claims simply by preheating the combustion air from the energy contained in the flue gases.

The most efficient way to capture heat energy is to have it absorbed in the primary heat exchanger. It takes much more heat exchanger surface area in a secondary heat exchanger to absorb the same amount of energy in a smaller primary heat exchanger. As such, the boiler in question probably maximizes its primary heat exchanger heat transfer to the highest extent possible.

Since the flue products are transferring heat to the water in the heat exchanger, the flue products leaving the primary heat exchanger will always be hotter than the return water temperature. The flue products cannot transfer heat to water that is higher in temperature than they are. If we assume that the flue products exiting the primary heat exchanger are 20°F hotter than the return water temperature (maximized heat transfer in the primary heat exchanger), we will have 180°F flue products leaving the primary heat exchanger (certainly not the 1000°F necessary to cost justify the expense to preheat the combustion air) with 160°F return water temperature. With 180°F flue products and 8.34% CO_2 (30% excess air levels), the combustion efficiency based on the Laws of Physics is 87.2%. See Figure 1 below for a chart showing Combustion Efficiency vs. Flue Gas Temperature.[3]

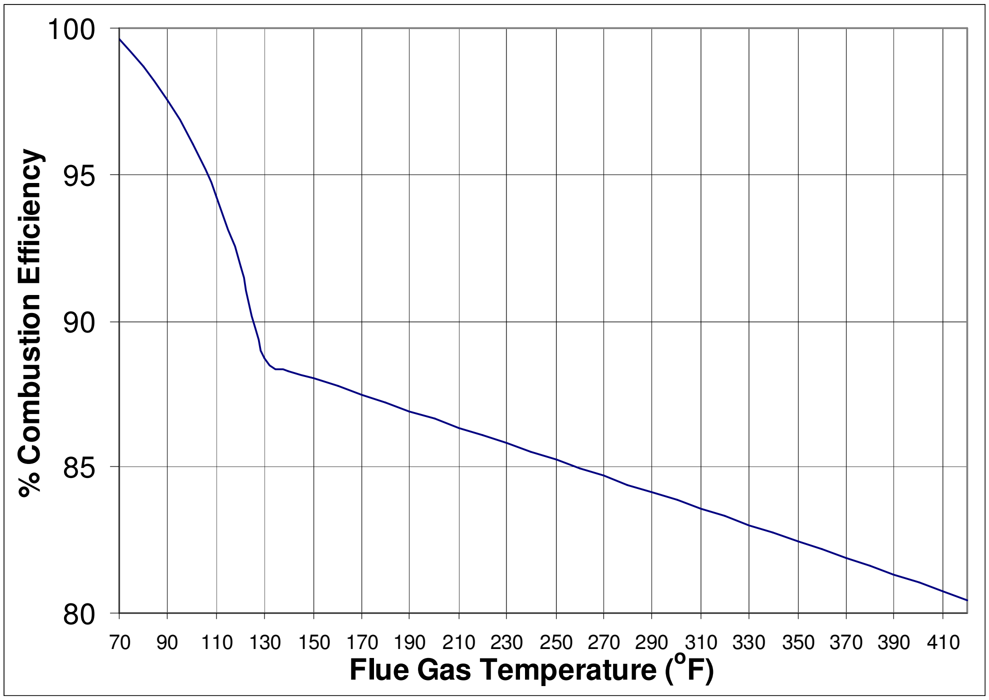

Figure 1 – Combustion Efficiency vs. Flue Gas Temperature Chart

In the HVAC industry, heating system designers historically utilize CFM of heated air in their design and sizing approach. They use the following formula to convert from CFM to Btuh:

CFM (ft^3/min) x 0.018 (Btu/°F·ft^3) x Delta T (°F) x 60 (min/hr) = Btu/hr (Btuh).

The 0.018 Btu/°F·ft^3 is the specific heat of air. Technical people who work in the HVAC industry are very familiar with this equation.

One nominally needs 10 cubic feet of air per cubic foot of natural gas to achieve stochiometric combustion. To ensure complete combustion, some excess air (usually 20% to 50%) is utilized. Lean combustion is commonly utilized in low NOx burners so we will assume 13 cubic feet of air for each cubic foot of natural gas (or for each 1000 Btu's of input) in this example.

If the combustion air is preheated 50°F (from nominally 70°F to 120°F) by utilizing waste heat that otherwise goes up the stack we will get:

13 x .018 x 50 = 11.7 Btu's for each 1000 Btu of input

Thus one could recover 11.7 Btu for each 1000 Btu of input which equates to 1.17% increase in combustion efficiency or, rounded up, 1.2%.

If we extract 1.2% more combustion efficiency from the flue products by preheating the combustion air we will have 87.2 + 1.2 = 88.4% combustion efficiency maximum. This is NOT “minimum 90% thermal efficiency at 160°F return”, regardless of where condensing occurs.

There is one important note to make at this point. Combustion Efficiency is a measure of the efficiency during the fuel burning process and is measured strictly by the percentage of O_2 or CO_2 in the flue gases and the temperature rise of said flue gases. Thermal Efficiency, on the other hand, is a measure of the energy transferred directly into the water. This means that jacket losses need to be taken into consideration and therefore, Thermal Efficiency is generally lower than Combustion Efficiency by 1 – 3%, sometimes more. As such, this manufacturer’s claims are even more exaggerated because their claims are based on Thermal Efficiency. If calculations show that preheating the combustion air cannot raise the Combustion Efficiency to 90%, it certainly can’t raise the Thermal Efficiency to a “minimum 90% thermal efficiency with 160°F return water”.

Thus there is no way, even by extracting heat from the exiting flue products to preheat the combustion air, that a Combustion Efficiency higher than 88.4% efficiency with 160°F return water temperature is achievable. The best they could do is 88.4% Combustion Efficiency and **they probably don’t reach that level in the real world anyways.**

There is one additional item to consider here. If the energy in the flue products were used to preheat the combustion air, the temperature of the flue products leaving the boiler would be reduced. Assuming a 100% conversion of energy from the flue gases to the combustion air (which isn’t possible), the 180°F flue gases leaving the primary heat exchanger would be reduced to approx. 130°F when leaving the boiler (according to Figure 1 – the maximum combustion efficiency at this point is 88.4%). With these low flue temperatures exiting the boiler, one would expect the manufacturer to certify the boiler with PVC or CPVC vent to reduce the cost of installation. However, the manufacturer states in their sample specification “the boiler will require a positive pressure AL29-4C stainless steel type metal flue”. Makes you wonder …..

Note that 87%-88% thermal efficiency is widely accepted as achievable at full input in several makes of copper fin-tube boilers. The potential 1%+ increase, if achieved, is hardly a breakthrough. This minimal improvement will very likely not withstand the scrutiny of a payback analysis when the considerable extra first cost and more than doubling of required floor space is properly considered. Also, like commercial boiler seasonal efficiency claims, this particular rating is not tested to any National Standard nor is it certified by any nationally recognized testing agency (such as CSA or UL). Consequently it’s just another “manufacturer’s rating”.

As always everyone should read between the lines and be aware of self-serving, non-certified claims. No one should depend on these claims for cost/payback analyses or minimum standards and regulations or buyers beware!

<u>Sources:</u>
[1] Energy Tips – Process Heating, Process Heating Tip Sheet #1 – November 2007, U.S. Department of Energy, Energy Efficiency and Renewable Energy, www1.eere.energy.gov/industry/bestpractices/pdfs/et_preheated.pdf

[2] Preheat Combustion Air to Improve Efficiency, EnergySC, South Carolina Energy Resource, www.energysc.org/downlaodables/preheat_combustion_air.pdf

[3] Data for chart obtained using FLOSS software developed by American Gas Association Research & Development Laboratory

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