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## Understanding Firetube Boiler Efficiency Ratings

Today's published boiler efficiency ratings are calculated by manufacturers using a 15% excess air level. The reason efficiency ratings are calculated using 15% excess air (or 3% O<sub>2</sub>) is that research has proven that 15% is the optimal amount of excess air to introduce into the boiler combustion process.

The terms "excess air" and "excess oxygen" correlate to each other and both can be used to define combustion. The percentage of excess air is the amount of air above the stoichiometric requirement for complete combustion. The excess oxygen is the amount of oxygen in the incoming air not used during combustion and is related to percentage excess air.

To have the most efficient combustion, the fuel-to-air ratio should be 1:1. This theoretical "perfect combustion" is called stoichiometric combustion, which produces no unused fuel or air. In practice, however, for safety and maintenance needs, additional air beyond the theoretical perfect ratio needs to be added to the combustion process, and this is referred to as excess air. With boiler combustion, if some excess air is not added to the combustion process, unburned fuel, soot, smoke and carbon monoxide exhaust will create additional emissions and surface fouling. From a safety standpoint, properly controlling excess air reduces flame instability and other boiler hazards.

Even though excess air is needed from a practical standpoint, too much excess air lowers boiler efficiency. It is essential to find a balance between providing the optimal amount of excess air to achieve ideal combustion and prevent combustion problems associated with too little excess air, while not providing too much excess air to reduce boiler efficiency.

While some boilers have been able to achieve 15% excess air at the top end of a boiler's firing range, the challenge presents itself at the lower end of the firing range, or below 50% of the boiler's maximum capacity. Most boiler and burner designs tend to have increasing excess air requirements as the firing rate of the boiler decreases, leading to reduced efficiency at the lower half of the entire firing range. To complicate matters, many boilers operate a large percentage of their online time at this lower end of the firing range. This is due to boilers that may have maximum capacities that are much larger than their current system requirements, or boilers that have a typical operational need below the peak requirements most of the time. Therefore, selecting a boiler that has low excess air throughout the firing range is critical.

It is also important to note that boiler/burner packages are tested in a lab setting under nearly perfect conditions. In reality, a boiler/burner combination typically requires a higher excess air level, which lowers its efficiency. For example, a boiler manufacturer may claim a boiler can achieve 80% efficiency, based on 15% excess air. However, the burner matched to the boiler may not be able to operate at 15% excess air; rather, it may need 50% excess air, and higher excess air reduces boiler efficiency by 1% to 2%.

Excess air is not the only variable to consider. Turndown and emissions controls are other important factors. If a boiler operator attempts to increase efficiencies by reducing the excess air level in a natural gas burner that was not designed to run at 15% excess air at low fire, CO emissions spike. Reducing the amount of combustion air results in an excess of unburned fuel, and unburned fuel is a form of CO. If a burner is guaranteed to operate at 15% excess air, check to ensure that the CO and NO<sub>x</sub> emissions levels are within a reasonable range.



When selecting a boiler, it is important to evaluate all three of these factors: excess air, emissions, and turndown. While some boilers may perform well on one or two of the parameters, it may be at the expense of the third.

It's a good rule of thumb to compare boiler efficiency ratings with actual excess air levels throughout the 10:1 turndown range. For gas-firing boilers, ask for efficiency charts from the manufacturer using actual excess air levels that are achievable in the field, not just in a lab setting. Otherwise, it is extremely difficult to accurately compare different types of boiler systems.

To learn more about boiler efficiency ratings, contact your local Cleaver-Brooks representatives or visit [cleaverbrooks.com](http://cleaverbrooks.com).