Uncovering the Myth of the Industry-Standard Boiler Efficiency Measurement

Theoretical Efficiency Is Not the Proper Gauge of Actual Efficiency

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Today's published boiler efficiency ratings are calculated by manufacturers using a 15% excess air level, regardless of a burner's actual ability to operate at that condition throughout the firing range during normal online operation. This "theoretical" boiler efficiency rating is inflated and typically unachievable outside of controlled lab conditions. To ensure that a boiler can meet its publicized efficiency level, it is mandatory to request and review the efficiency charts from the manufacturer that show the actual O2 levels achievable in the field, rather than the theoretical efficiencies. Otherwise, it is likely that a boiler's actual efficiency will be lower than expected, resulting in higher operating costs.

The reason efficiency ratings are often calculated using 15% excess air (or 3% O2) 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.

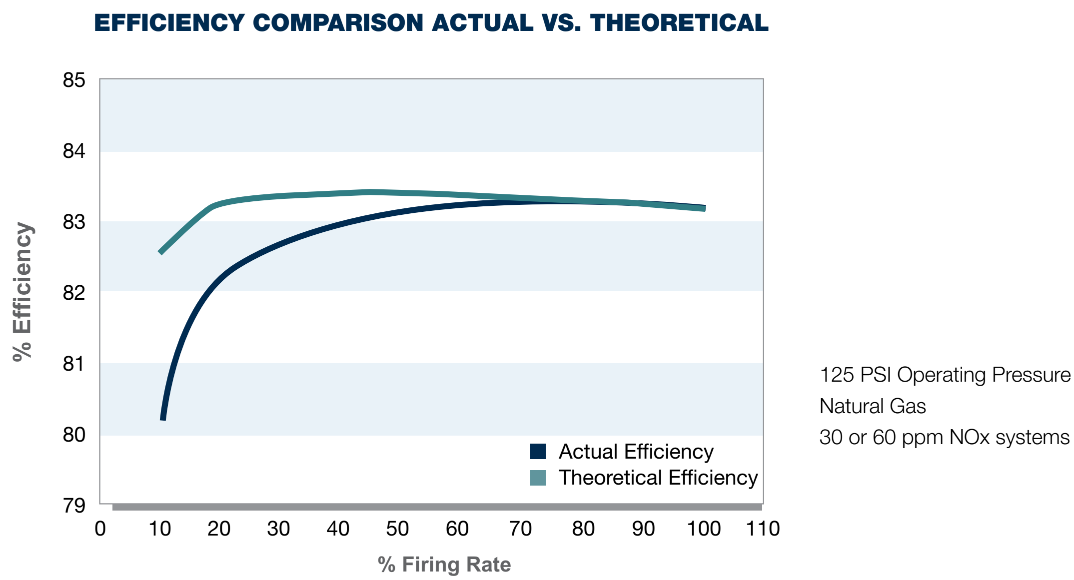
Even though excess air is needed from a practical standpoint, too much excess air lowers boiler efficiency. It is essential to find a balance between providing the optimal amount of excess air to achieve ideal combustion and prevent combustion problems associated with too little excess air, while not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

For example, at a firing rate of 25% to 30%, most burners require 30% excess air. At a 10% firing rate, 50% excess air typically is required. As excess air increases, boiler efficiency decreases. A boiler that requires 50% excess air at 10:1 turndown is 2% less efficient than a boiler that operates with 15% excess air at 10:1 turndown.

Graph 1 compares the theoretical and actual efficiency numbers. At mid- to high-fire, the two lines are close together. Below the 50% firing rate, the two lines separate and the spread expands, to the point that there is a 2% difference in efficiency at the minimum firing rate. Even if the boiler operates at 30% to 50% of its firing rate, efficiency is reduced by 0.5% to 1%. Most boilers operate between the 10% and 60% firing rate, which is why in-use efficiency often falls short of the manufacturer's stated boiler efficiency.

Graph 1

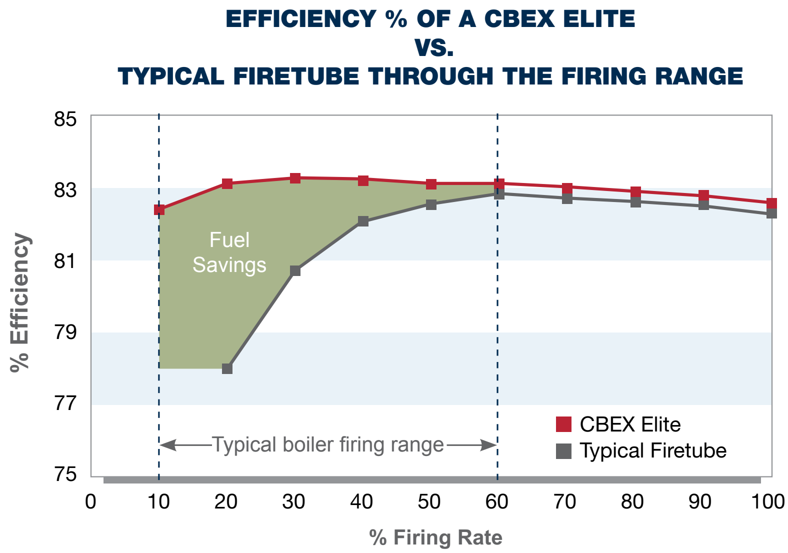


It is also important to note that boiler/burner packages are tested in a lab setting under nearly perfect conditions. In reality, a boiler/burner combination typically requires a higher excess air level, which lowers its efficiency. For example, a boiler manufacturer may claim a boiler can achieve 80% 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 NOx emissions levels are within a reasonable range.

Another performance parameter is combustion stability. Burners may require a higher amount of excess air to achieve stable and robust combustion.

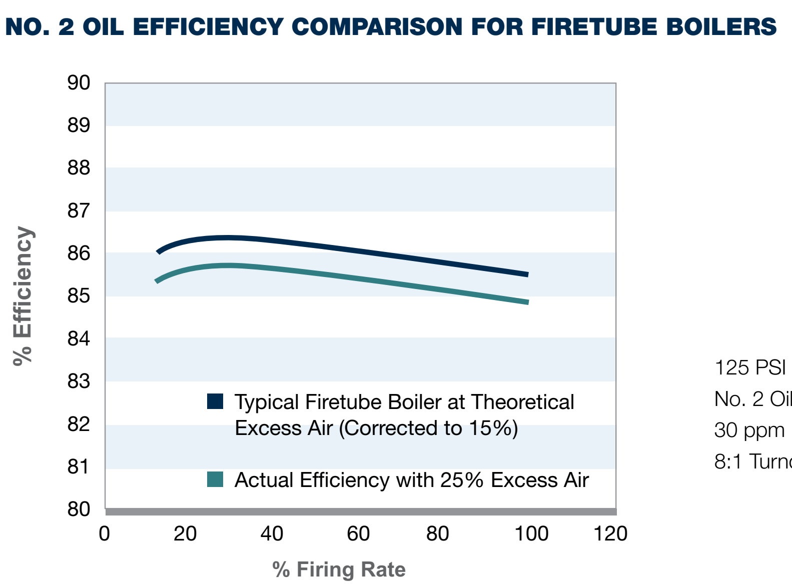
Boilers in the Cleaver-Brooks CBEX Elite line have integrated burners and controls. As shown in Graph 2, select models in this line guarantee 10:1 turndown with 15% excess air and less than 50 ppm CO and 30 ppm NOx while firing natural gas. When selecting a boiler, it is important to evaluate all three 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.



Graph 2

The standard excess air level for No. 2 oil differs from that of natural gas. Instead of 15% excess air being optimal, burning No. 2 oil requires 20% to 25% excess air. This is because oil requires more air than natural gas does to burn clean.

The theoretical vs. actual efficiency difference for No. 2 oil is depicted in Graph 3. Note that for No. 2 oil, the lines representing theoretical and actual efficiency are separated at all points throughout the firing range.



Graph 3

125 PSI Operating Pressure
No. 2 Oil
30 ppm NOx systems
8:1 Turndown

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 impossible to accurately compare different types of boiler systems.

While many boilers may tout a high-efficiency rating, the system may not be able to operate at the optimal setting of 15% excess air in the field through the complete firing range. The stated efficiency level is inaccurate and misleading. The truth is that very few burner designs actually can achieve 15% excess air at 10:1 turndown while maintaining low emissions across the full firing range of the boiler.

Cleaver-Brooks is the only manufacturer in the world that offers a completely integrated boiler, burner, and heat recovery system. Because its engineers have the ability to test and refine integrated components, they can align cutting-edge boiler and burner technology in the industry with the latest in advanced controls. Using state-of-the-art computer programs such as advanced CFD modeling enables the engineers to perform extremely complex calculations that advance design performance, optimizing the integration of core competencies.

Cleaver-Brooks is a leading provider of boiler room products and systems that is committed to providing efficient solutions to help its customers and the industry reduce energy usage, cost, and environmental impact. It has a dedicated alliance of representatives available for consultation, sales, maintenance, and aftermarket support.

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