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Flue Gas Analysis as a Boiler Diagnostic Tool

Overview, and Traditional Application

Combustion flue gas analysis has been used by Power Plant Operators for decades as a method of optimizing fuel/air ratio. By measuring the amount of excess oxygen and/or CO in the flue gases resulting from combustion, plant operators can operate at the best heat rate efficiency, lowest NOx, and generate the least amount of greenhouse gas. The theoretical ideal, or the stoichiometric point, is where all fuel is reacted with available oxygen in the combustion air, and no fuel or O2 is left over.

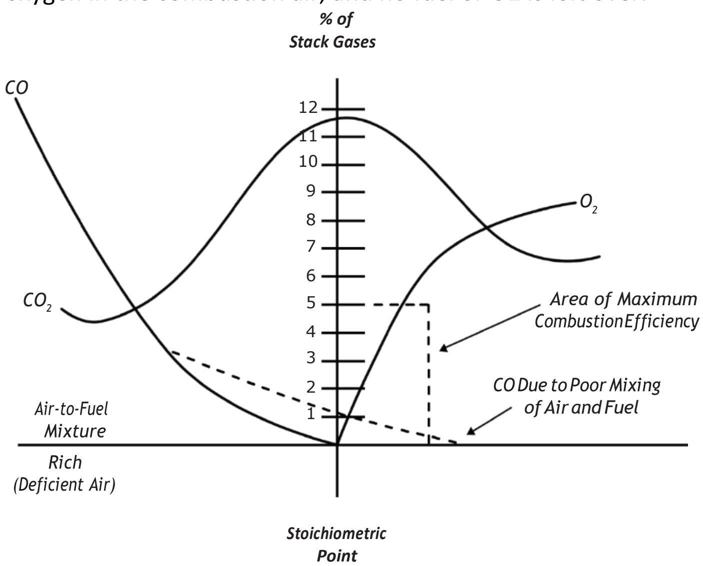

Figure 1 - Key flue gas measurements relating to ideal combustion stoichiometry.

Operating furnaces never attain this ideal, however, and the best operating point usually will result in 1–3 % excess air, and 0–200 PPM of CO. This optimum operating point is different for every boiler and varies for differing loads or firing rates. A higher firing rate induces greater turbulence through the burner(s), providing better mixing of fuel and air, and enabling operation with a lower excess O2 before unburned fuel (represented by CO) appears, or "breaks through".

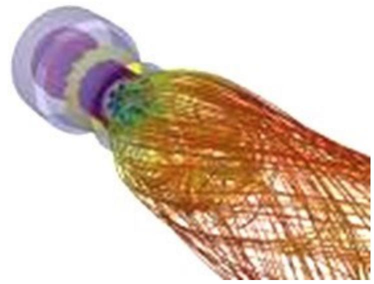

Figure 2 - CFD depiction of the turbulent mixing of fuel and air through a burner.

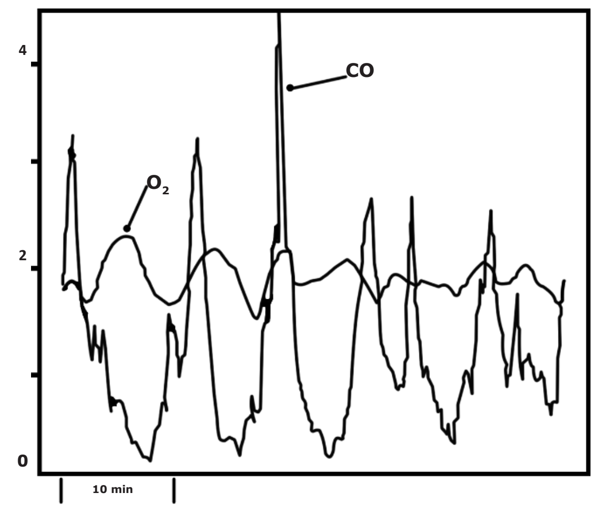

Figure 3 - DCS trend depicting the relationship of O_2 and CO indications at CO breakthrough point.

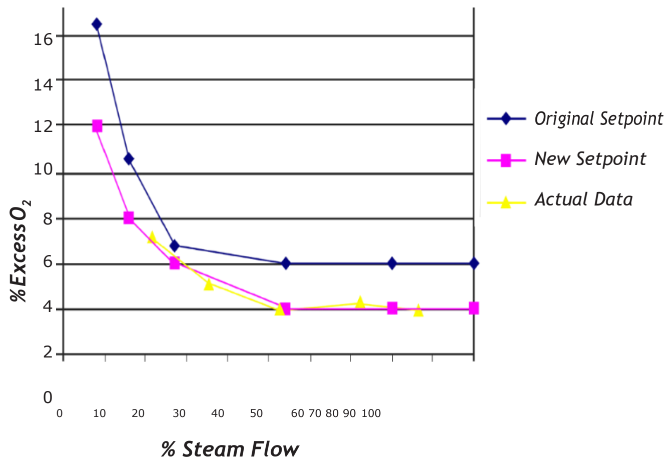

Figure 4 - a typical function generator depicting the optimum flue gas O_2 level at different steam flows (firing rates).

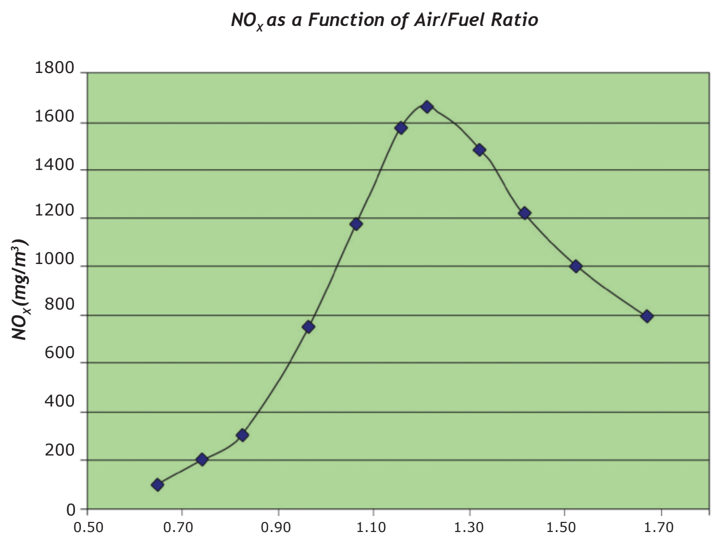

Figure 5 - NO_x as a function of flue gas excess O_2 Relationship of NO_x production.

This curve should be reestablished from time to time as burners wear, and other furnace conditions change over time. The curve for burners using natural gas and light oil fuels will tend to remain valid for long periods of time (years). Burners firing solid fuels such as coal, petroleum coke, or pelletized biofuels will experience more frequent pluggage and other degradation in the burners and fuel delivery systems and will benefit from more frequent re-establishment of this curve.

Large boiler operators will typically dynamically control oxygen to the optimal level via the distributed control system. Control of CO is more difficult, since target levels are usually in the PPM range, and making fan or damper adjustments small enough to control at these low levels is difficult. Many operators will make manual adjustments based upon the CO signal or use the measurement as a feed forward signal to adjust the O2 control setpoint upwards or downwards.

New Goals

The traditional goal of achieving best combustion efficiency is sometimes modified to accommodate two other goals:

1.Minimizing the thermal NOx produced through the burner. O2 levels and flame temperatures are key indicators to the production of NOx. One operating strategy to produce less NOx uses staged combustion, whereby a cooler fuel-rich combustion is established at the burner. Overfire air is then added higher in the furnace to complete the combustion. This results in less heat and oxygen passing through the burner, and less NOx produced. Advanced control strategies utilizing neural nets are often implemented to find the optimum air settings to minimize thermal NOx production.

2.Another NOx reduction strategy is flue gas recirculation, where a certain amount of flue gas is mixed with the normal air used for combustion. An O2 probe mounted after this mixing valve can be used to control final O2 going to the burner, resulting in a cooler flame that produces less NOx.

3.Slag prevention- Flux sensors provide good information about soot and slag buildup, but close attention to combustion analyzers can provide another indication of slag formation. Fly ash fusion temperatures are usually affected by the amount of excess O2 in the flue gases, and some operators run with an O2 setpoint that has been established to prevent slag.

Figure 6 - Slag formation on boiler tub