Continuous Boiler CO Monitoring for Combustion Optimization and Boiler Efficiency Improvement

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ABSTRACT

Boiler Efficiency has not always been a major concern for coal-fired power plants. Today's Power Industry has changed...coal is no longer "king". Inexpensive natural gas has put coal-fired power on the proverbial back burner. The ability to improve ones' place in the dispatch order is determined by operating cost and that means improving efficiency is key to being on line. Whether improving efficiency by manually tuning a boiler or by using advanced controls (Neural Networks), success comes from being able to reduce excess air. In order to accomplish this safely, it is critical to know that while reducing O2, CO does not increase dramatically. Accurately and reliably measuring CO on a coal-fired boiler has however been a challenge for the industry due to the hot, dirty, corrosive environment of the flue gas. This paper will focus on a continuous combustion monitoring system by EES (formerly Delta Measurement and Combustion Controls) that allows for accurate and reliable measurement of boiler CO and some successes associated with using these instruments.

INTRODUCTION

It has long been known that there is an ideal amount of excess air desired to operate a coal-fired boiler for optimum efficiency and emissions (see figure 1).

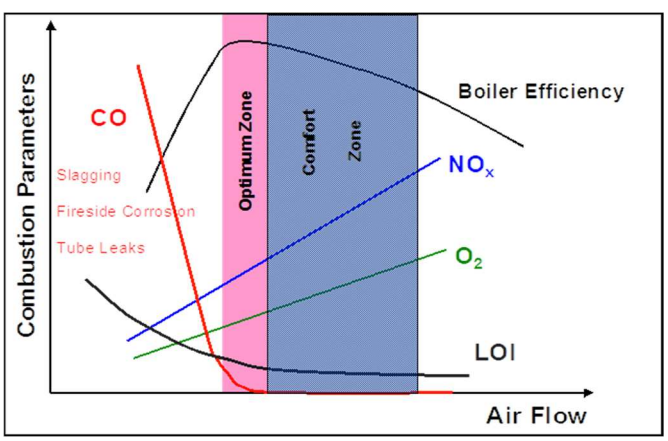

Figure 1 shows the desired (pink optimum zone) combustion. With air on the x-axis we see that too much air leads to high NOx and poor efficiency. Too little air leads to high LOI, CO, slagging/fouling and ultimately tube leaks.

To control to this optimum zone, O2 and CO measurements are critical.

Figure 1 – Optimum Combustion Zone

[1]In order to maintain optimum combustion, measurement and control of the excess air is critical. Traditionally, one of the problems with O2 measurement is the introduction of outside/tramp air. Most utility boilers today are balanced-draft boilers with FD fans and ID fans. As such, the boiler outlet duct as depicted in Figure 2 is under vacuum. Since most ductwork and expansion joints are somewhat old, they are subject to leaks due to corrosion, erosion and stress. This results in the addition of Air In-Leakage to these ducts. This air in-leakage can grossly affect the plant O2 readings leading to a false interpretation of excess air. This tramp air will however have only a minor effect on CO measurement. CO measurement is a better tool for optimum combustion control.

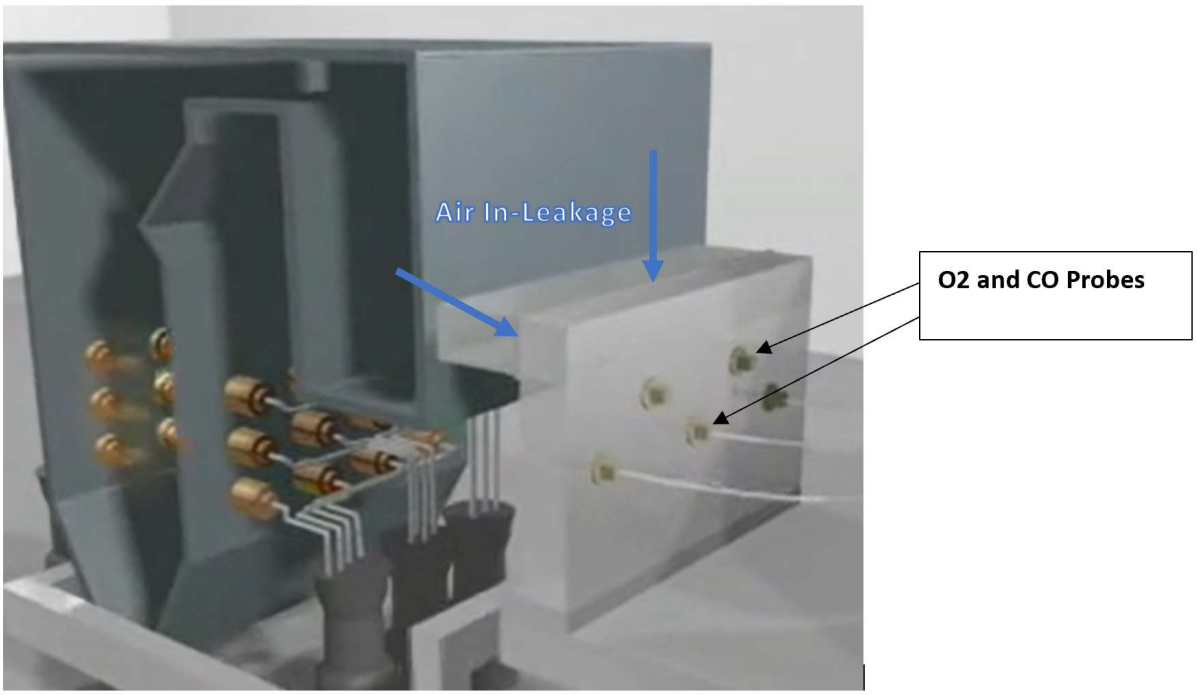

Figure 2 – Impacts of Parasitic Air on O2 Measurement

CO MEASUREMENT

Some of the benefits of CO Monitoring are:

- Continuously operate boiler in optimized combustion zone.
- Correct for O2 error due to in-furnace leakage.
- Various length probes can extract from areas conventional O2 probe cannot.
- Reduced boiler slagging.
- Improve SCR / SNCR Performance.
- Reduce fire side corrosion due to high CO.
- Increase boiler efficiency.
- Lower flue gas velocities through the furnace and precipitator.
- Conduct periodic boiler tuning, and for measuring additional combustion gasses.

Unfortunately, traditional methods for extracting flue gas from a particulate-laden ducts (dilution/extractive probes) have proven to have a high initial cost and extensive maintenance issues. Most of the maintenance issues revolve around the systems plugging with ash.

[1]The EES-Delta extractive monitoring system is unique because it was designed specifically for coal-fired boilers. The sampling point of the combustion monitoring system is a patented non-dilution extractive probe (*US Patent # 8,146,445*). The probe uses a combination of "slip stream effect" and "particle inertia" to extract a flue gas sample, *without* pulling significant ash into the sample lines. The patented probe uses a non-heated Teflon sample line which also resists plugging.

The components of the sample probe can be seen below in Figures 2 and 3. The featured components are the venturi inlet which accelerates the gas and ash particles as they enter the probe head so the ash does not get pulled into the instrument panel (as explained in figure 4), and the sintered filter which filters out any fine particulate that still may enter the probe.

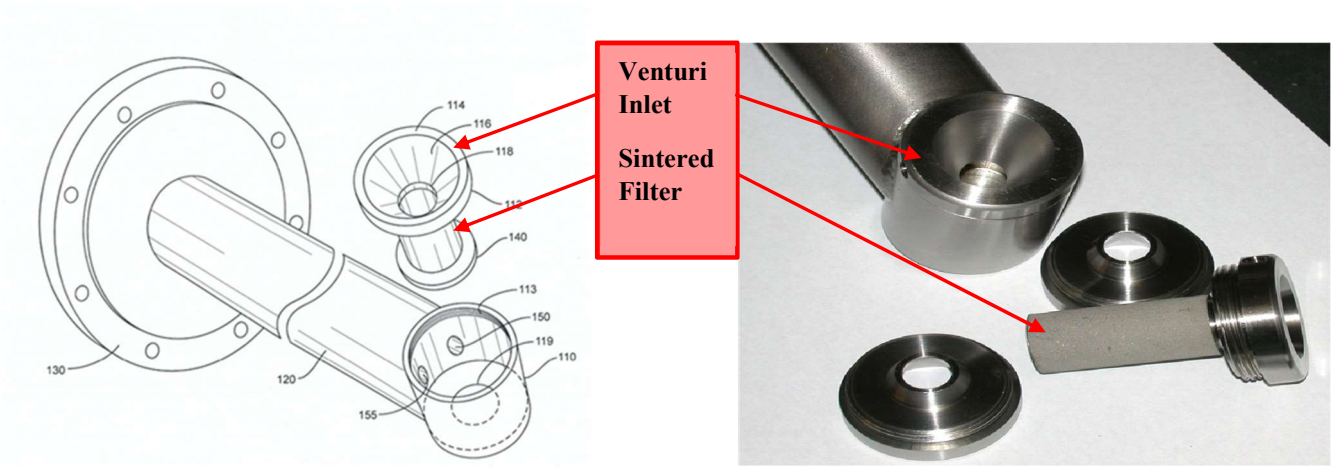

Figure 2 Figure 3

Figure 4 below shows how these components prevent ash from entering the system:

1) The flue gas enters the inlet venturi where the gas and ash particles are accelerated.
2) The gas sample enters the probe through an anulus on the downstream side of the probe head (vertical blue arrows), passes through a 0.5 micron sintered filter (in gold) and is then delivered through the sample line (horizontal blue arrows) to the analyzer.
3) The pump in the analyzer panel operates at a very low rate (0.5 l/m) to avoid pulling the solids (ash) that were accelerated through the probe venturi and the sintered filter prevents any fine particulate from entering the sample line.

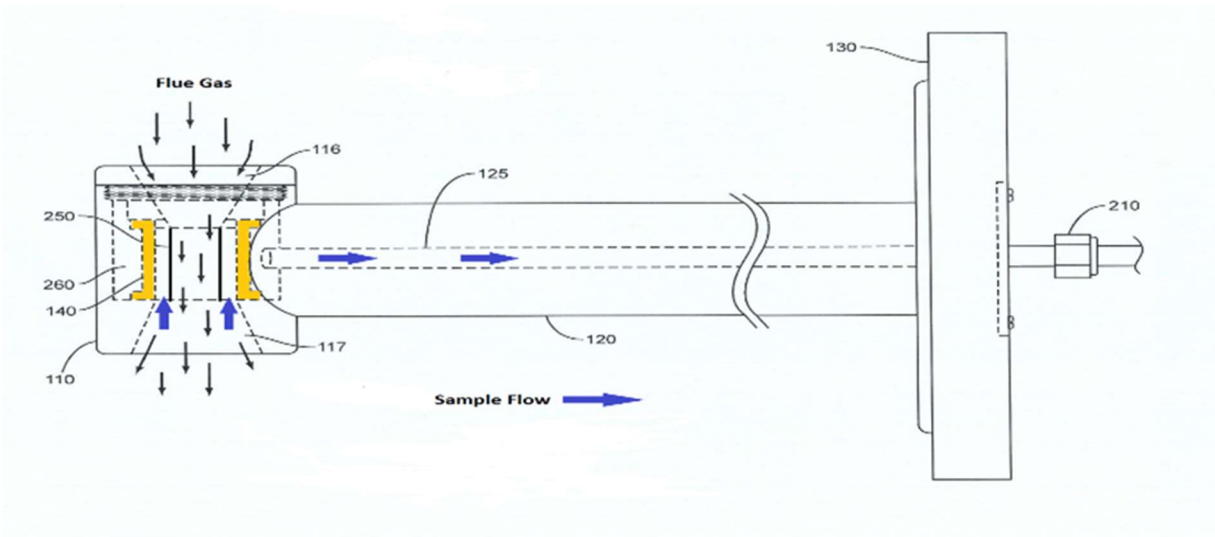

Figure 4 – Gas Extraction Process

One of the reasons previous CO measurement systems were prone to pluggage is that there was only one path back to the analyzers – the sample line. Because these did not have the above features, ash would enter the probe. Users were instructed to periodically purge the sample line(s) with instrument air. This has the effect of reversing the flow with clean air and blowing any ash and moisture that built up in the sample lines back into any filter that was on the probe head. The result is plugging of these systems in a short time.

As seen below in Figure 5, the EES-Delta system uses two flow paths: 1) the Sample Flow as detailed above and 2) a Purge Flow line. On a programmable interval, a valve in the instrument panel is initiated to allow purge air into a second line which cleans the sintered filter *with clean air*. Both lines become pressurized due to the resistance of the 0.5 micron filter and any debris (and moisture) that may have gotten into the sample line is blown out the bottom of the panel when a valve is opened.

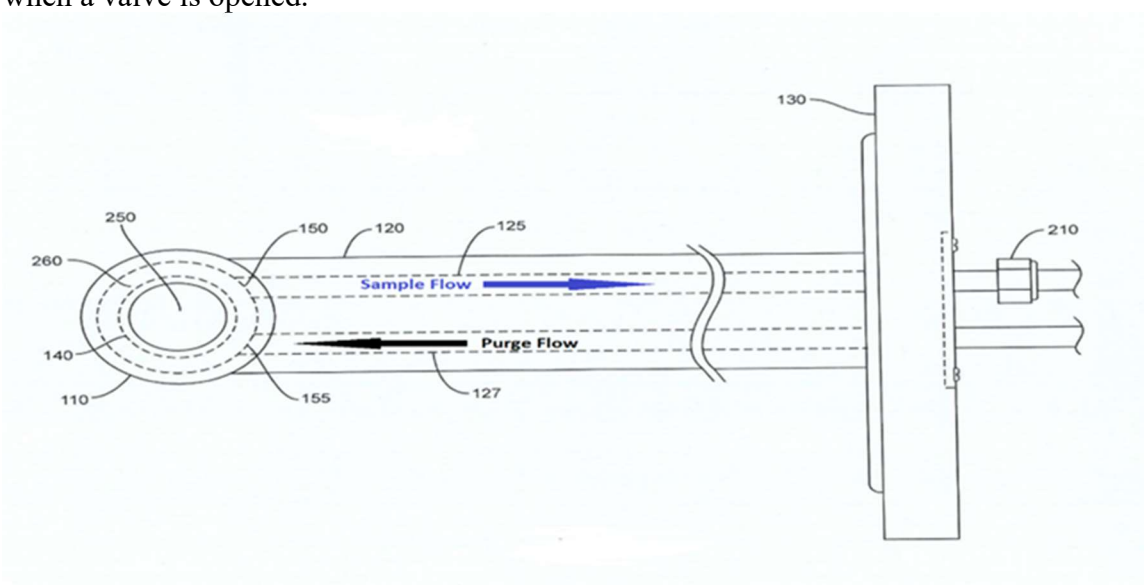

Figure 5 – Purge Air is Separate Path

Another advantage of this CO System design is that the EES-Delta probe is not limited in length like most O2 probes. This allows for gas sampling in more areas for attaining better representative samples of the flue gas.

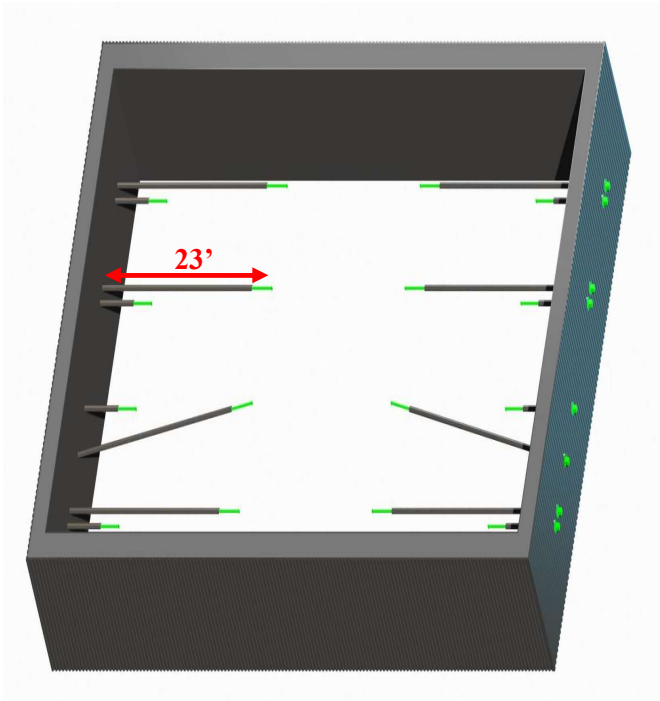

Figure 6 – Extended "Reach" of CO Probes

CO ANALYZER

The EES-Delta Analyzer can be configured to output CO or Combustibles. It is connected to the extraction probe with (2) Teflon tubes: one for the Sample Flow and the second for the Purge Flow.

Figure 7 shows a 4-Zone monitor, meaning there are four sample lines (and four purge lines) coming into the left side of the panel (Figure 7) from four different probes. The gas samples pass through a chiller where moisture drops out and then collects in the filters below it along with any residual debris. The lower left area is also where the purge along with the moisture collected in the filter(s) exits the analyzer.

The system uses non-dispersive infrared bench technology for measuring CO levels. To increase system accuracy without repetitive calibrations, the Delta system ZERO's the infrared bench every 30 minutes – note the IR Bench Zeroing valves circled. The IR benches (one per probe) are located in the large white panel within the enclosure. Also included in this panel are four zirconium oxide sensors to measure excess O2 which is displayed in red LED s along the top of this panel.

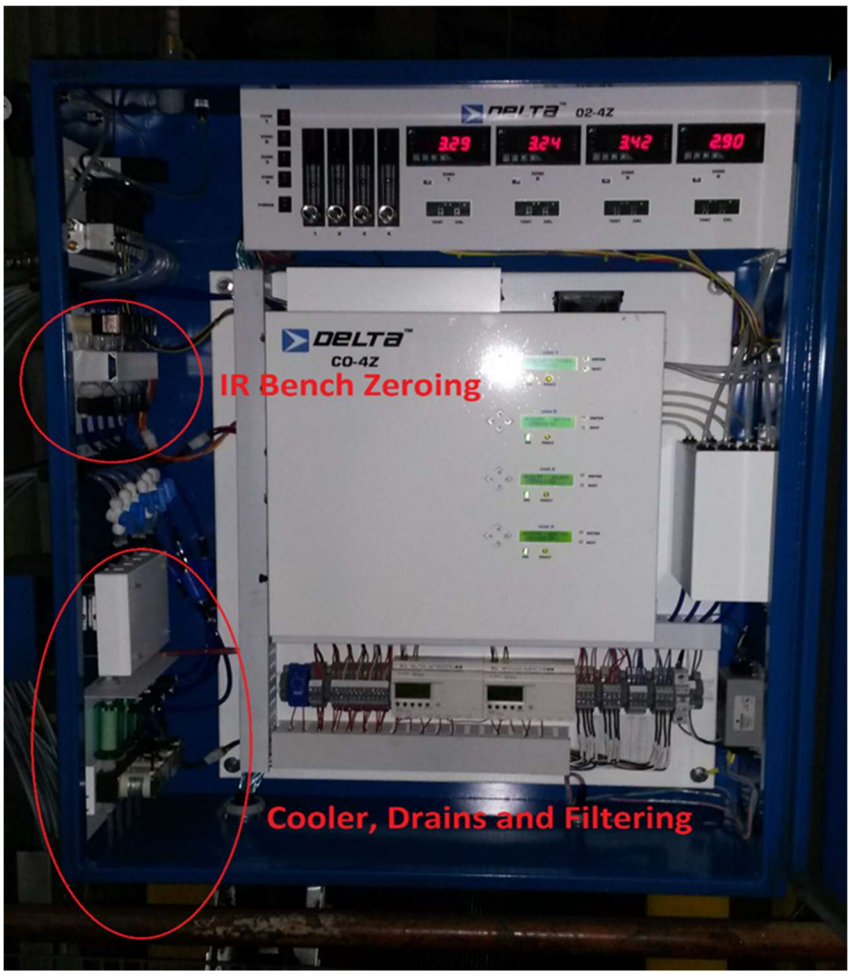

Figure 7 – CO Analyzer

Because of the IR Zeroing, intermittent calibration is NOT required. If, however it is desired to check the system calibration, the Sample Flow tubing on the side of the panel can be disconnected and a calibration gas can be connected as the inlet gas to the analyzer.

APPLICATIONS

[2]The first case study is Progress Energy (now Duke Energy) Crystal River Plant. This plant operates two 770 MW opposed wall-fired units. Both units have new OEM tuned burners. One (Unit 4) of the units also has Continuous Combustion Management (CCM) equipment that includes coal flow measurement and valves; burner airflow measurement; and a Delta CO Measurement Grid. During coal balancing (CCM Tuning- Figure 8) attempts to reduce O2 levels led to a CO increase. By having a 16-point grid we were able to locate areas of poor combustion and adjust air to improve the combustion.

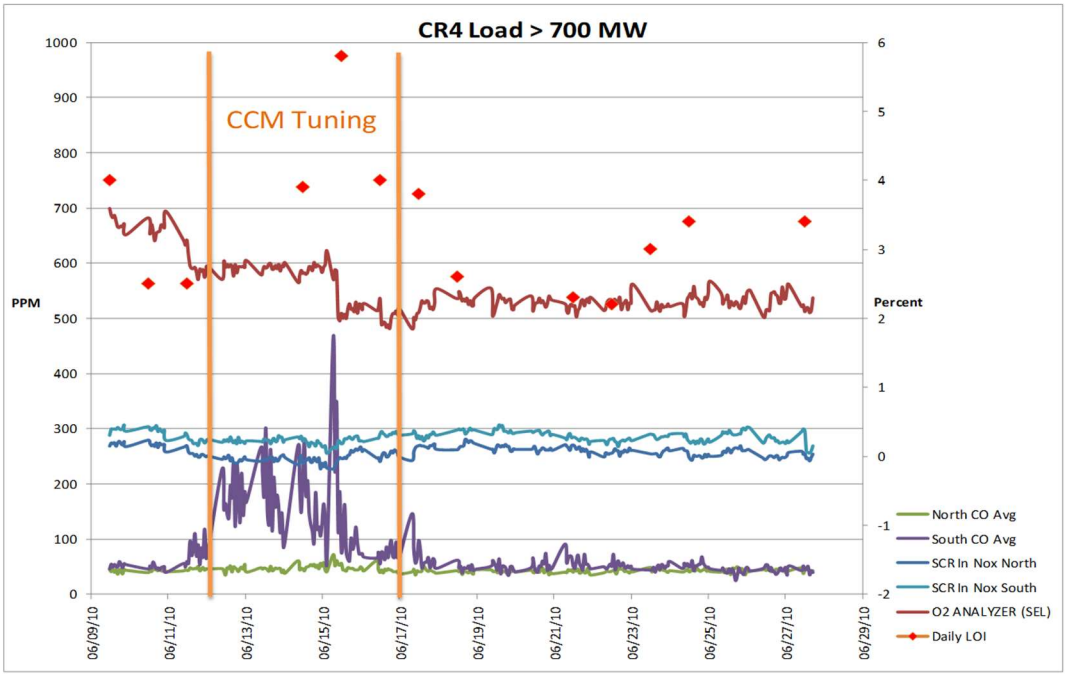

Figure 8 – Parameters During Combustion Tuning

Once CO was reduced a new O2 curve at the reduced levels was developed to attain improvements in efficiency, emissions and LOI as seen in Figures 9, 10 and 11 below.

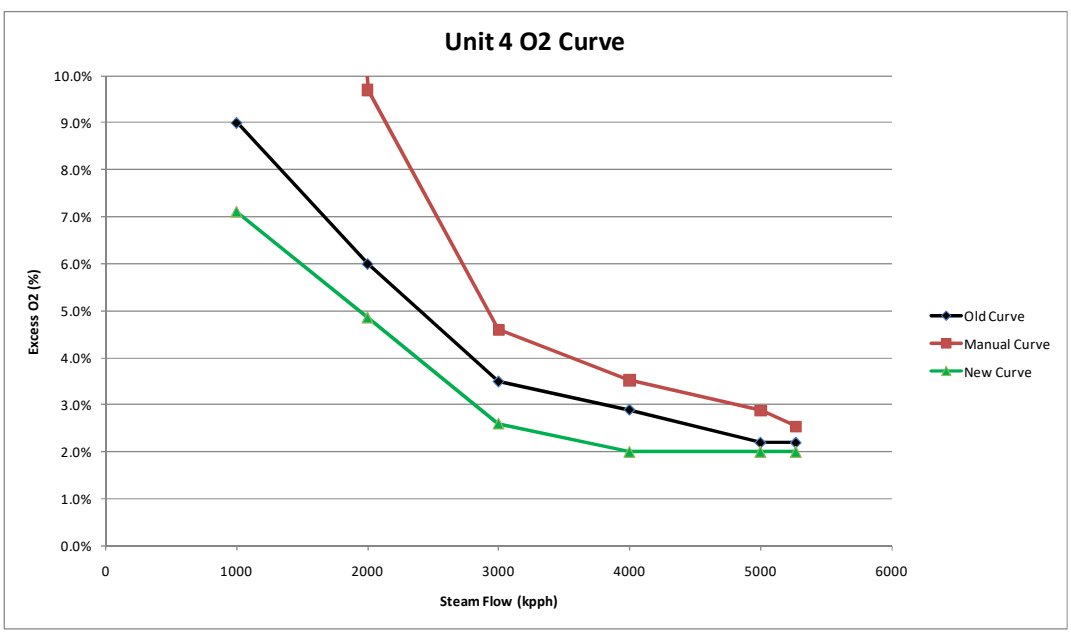

Figure 9 - New O2 Curve (green)

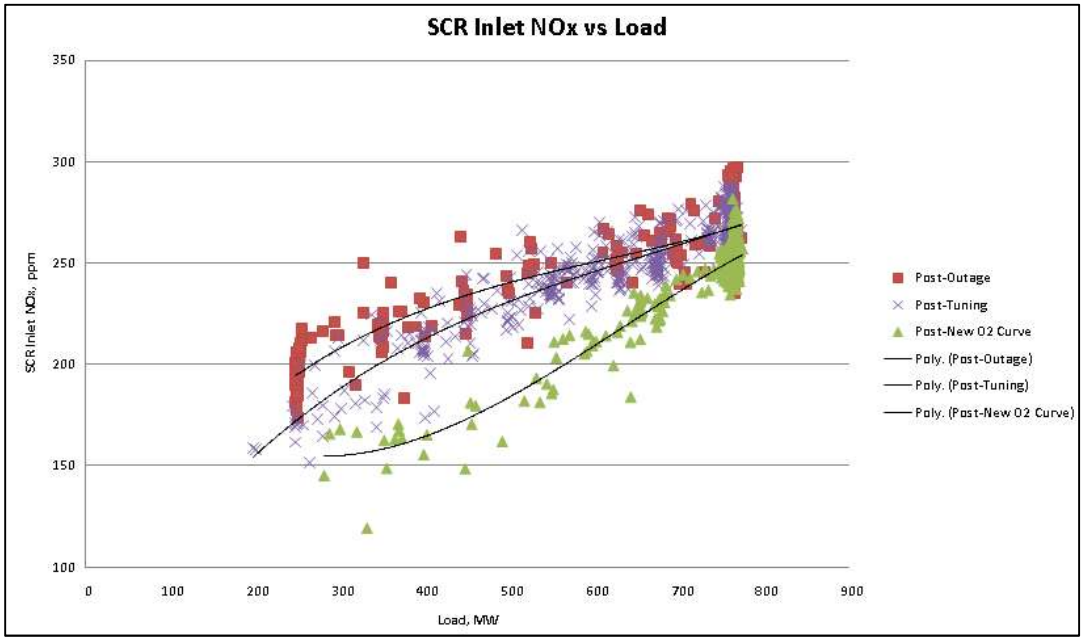

Figure 10 – NOx Improvement

PROJECT RESULTS

- Boiler Efficiency Increase = 0.5%
  - Annual fuel savings
- Combustion NOx Reduction
  - 7% at full load, 15-25% at part load
  - Annual Ammonia Reagent Usage Reduction
  - SCR Catalyst Life Extension
- Fan Auxiliary Power Savings

Figure 11 – Project Results

The second case study is an 8-Corner Tangentially Fired Boiler. Prior to installing the EES-Delta System, the plant had a single "stack" CO measurement device. This device was capable of alerting the plant to high CO conditions but was not able to identify *where* the CO was coming

from. By installing an 8-point grid across the backpass they were able to identify which corner the CO was coming from. Figures 12 depicts a time of elevated CO - one can see the "stack" CO (ID Fan Exit) shows some CO but the 8-point grid shows which corners the CO comes from. Figure 13 shows the boiler corners. This allowed the plant to go to the corners where CO was being formed and adjust air dampers to reduce the CO.

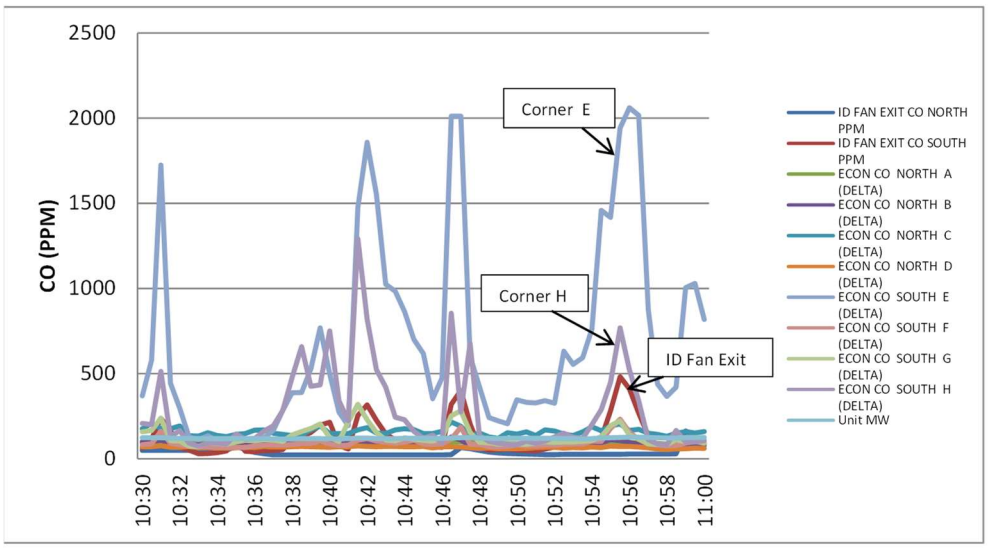

Figure 12 - Stack CO vs Corner CO

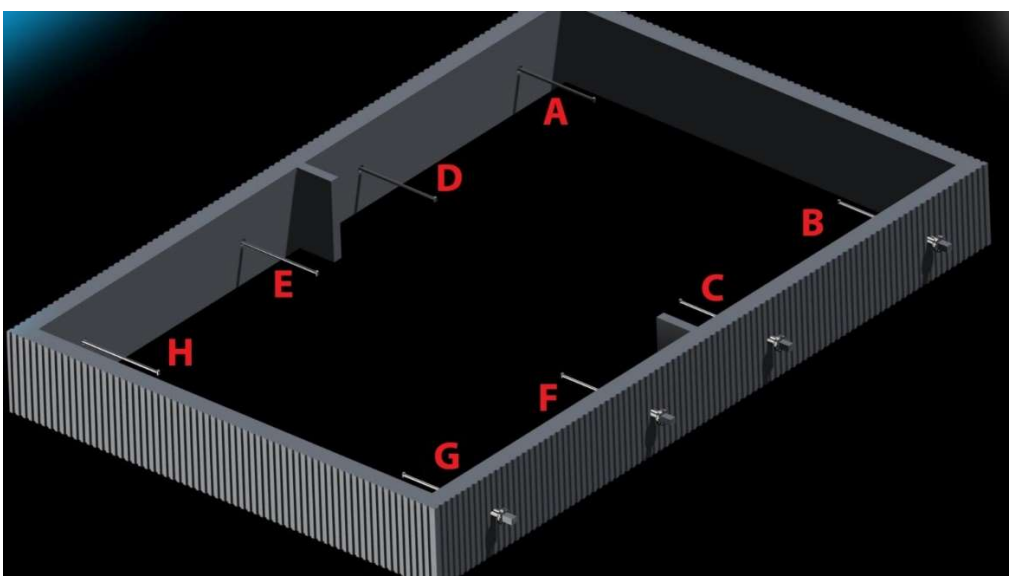

Figure 13 – Boiler Corners

The third case study is an example of another benefit of continuous CO measurement – diagnosing air preheater pluggage. In this case, the plant was experiencing intermittent (but cyclical) elevated CO. By evaluating the period of the cycling, Engineering was able to determine that a section of the air preheater was partially plugged and thus not introducing enough combustion air to the windboxes, starving some burners of air and creating CO.

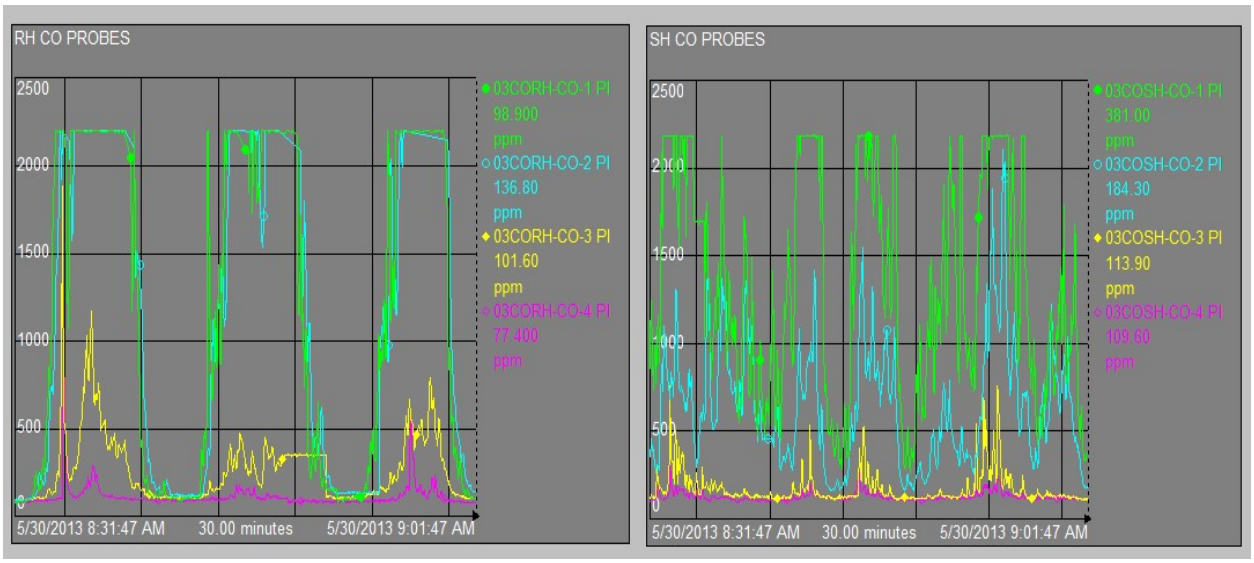

Figure 14 – Cycling CO Data Due to Preheater Pluggage

CONCLUSIONS

Improving combustion on utility boilers, especially coal-fired boilers, can be challenging. Knowing that changes made to pulverizers, pipe flows, burners, OFA and more are having a positive effect on combustion can be difficult. Having boiler excess O2 measurements alone may not tell you "the whole story". Plant O2 probes have maintenance problems; have length limits; are prone to error associated with duct leakage and more. Measuring CO in multiple locations "tells a more complete story" about combustion wellness. It also assists in locating areas of poor combustion, so they can be fixed. The system is useful for diagnosing a variety of combustion-related problems.

Using extractive probes that are not prone to maintenance problems, like plugging, is key to gaining confidence in your data so you can rely on it to balance, tune and ultimately improve efficiency and decrease emissions.

REFERENCES

[1]Boiler Optimization and MATS Compliance testing using an extractive Continuous Combustion Monitoring System by Nicholas Ferri, ISA POWID Symposium, 2015

[2] Combustion Optimization Through Air Flow and Coal Flow Balancing at Crystal River Unit 4, Joe Estrada, Strategic Engineer, Fuels & Power Optimization and Robert Sisson, Crystal River–Plant Engineer, Progress Energy Corp., Power Engineering Magazine April 2011