December 2009 Volume No.10

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Want to Generate More Power, Reduce Emissions and Improve Efficiency?

If so, let's address the #1 controllable stealth loss - Boiler Air In-Leakage

Stephen K. Storm, Executive Vice President of Storm Technologies, Inc.

Above: ID fan inlet housing hole (major source of air in-leakage)

In some of our past newsletter editions, we've talked about air heater performance, the firing system equipment and so forth. All of these topics are inter-related. However, in this issue I want to focus on air in-leakage or infiltration.

The problem with air infiltration

Balance draft steam generators over ten years of age can and often do experience high air in-leakage (or infiltration) throughout the boiler setting and sometimes upstream of the excess O_2 probes. It is not uncommon to find total leakage between the furnace exit and the economizer exit in the range of 10% to 15%. Such occurrences as this will result in indicated oxygen of 3% to 4% at the economizer exit and 0% at the furnace exit, which can lead to serious reliability issues (*especially with the units firing high sulfur fuels*). Some of the issues include secondary or delayed combustion in the upper furnace, overheated SH tube or RH tube circuits, decreased combustion efficiency, aggravation of coal-ash corrosion, tube thinning and elevated de-superheating spray flows. Air in-leakage upstream of the excess O_2 probes can also contribute to low steam temperatures due to the reduced mass gas flow over the super-heater and re-heater. However, the resulting high furnace exit gas temperatures in localized zones to maintain the required bulk furnace exit gas temperatures, combined with existence of a reducing atmosphere can lead to serious slagging issues and/or cinders from sintered ash deposits on the super-heater and re-heater tubes. These deposits then can contribute to air heater plugging. Increased cycle losses due to higher soot-blowing frequency can occur as a result of increased fouling and slagging of the heating surfaces. Higher boiler exit gas temperatures also lead to accelerated deterioration of air heater heating surface and possible degradation of precipitator performance. Not to mention the reduction in available induced draft (ID) fan capacity and subsequent de-rating of unit generation and availability.

Quite often in utility or industrial boilers, actual airflow measurement and control is often neglected and the "assumed" excess air at the furnace exit is determined by the accuracy and/or representation of the boiler exit O_2 probes. Too often, Storm Technologies validates O_2 probes that are found non-representative of the actual measurements when a representative grid of flue gas samples is collected. Because of this, it is most important to have proven, calibrated and repeatable online combustion airflow measurement systems. Yes, theoretically, excess oxygen can be an indicator of combustion airflow. However, our experience has shown that older units with high tramp air infiltration upstream of the O_2 probes corrupts the ability to accurately determine the true amount of excess air in the unit (*as tramp air in-leakage falsely represents excess air*).

Because of the importance of stoichiometry control and balancing of the combustion airflow, it's important to periodically measure combustion airflow as well as conduct system air in-leakage tests. This way, one can prove whether or not the measured values follow the theoretical air calculations. Going a step further, it is also pertinent that each combustion air flow path distributed to the burners is also uniform. Staged combustion and control of stochiometric firing ratios is important. However, "average stoichiometry" doesn't really matter if the unit is air rich on one side and fuel rich on the other. When discussing "representative" sampling, Storm Technologies, Inc. CEO, Dick Storm, likes to use an analogy stating, "If I put my left leg in a bucket full of dry ice and the other in a bucket of boiler water, on the average, I'd be comfortable." This is a great example because the boiler feels the same way and thus it was designed for design radiant heat absorption rates in the lower furnace, upper furnace as well as convective heat transfer in the back pass. In order to optimize a boiler's performance from a combustion standpoint, balancing the heat input and distribution begins with balancing the air and fuel flows within acceptable tolerances.

When conditions like this arise on a PC fired boiler and the substoichiometric zones are introduced with high in iron ash levels, increased particle sizing and increased carbon content on the water walls, slag propensity worsens and water-wall tube wastage is likely to accelerate. Again, these factors clearly illustrate the need for optimizing the air and fuel inputs.

Above: Heavy slag propensity on a furnace waterwalls. Note the “gold like” material. This is an example of a high concentration of iron deposition from the build up of coal ash.

Using an HVT Probe

The High Velocity Thermocouple (HVT) probe traverse has been without a doubt, the single most important test in diagnosing combustion related problems on a large utility furnace. On a utility boiler, as the load or output increases, radiant heat transfer decreases and convective heat transfer increases by design with an increase in boiler efficiency. Further, most boiler designs, tube spacing, tube surface areas and regional placement of surface area portions is based off a design furnace exit gas temperature for a given load. With that in mind, typically as load increases, furnace exit gas temperature increases as well. Considering this, periodic use of the HVT probe can be utilized to validate furnace exit gas temperature in relationship to the boilers design. The HVT probe, by design is intended to accurately measure flue gas temperature, but its greatest importance is the measurement of actual or “true” furnace exit, excess oxygen, carbon monoxide and NO_x profiles.

Above: Furnace Exit HVT Testing

Improving Boiler Reliability

If the combustion system is non-optimum, the furnace residence time within a furnace for carbon burn-out is reduced and this will correlate with higher boiler exit gas temperatures, likely over-heating some of the tube metal circuits. This in turn can induce such issues as tube exfoliation and solid particle erosion of the turbine blades, overheating of the carbon steel duct work and induced air in-leakage and tube alignment issues. To exacerbate the issues, the impacts of coal ash chemistry variation with high furnace exit gas temperatures and/or increased slag propensity will reduce heat transfer surface and/or create imbalances of the flue gas. This in turn will thermodynamically challenge the boilers capability to feed steam to the turbine at its design limits. Recently, I attended a United Dynamics Corporation (www.udc.net) training seminar on “Maximizing Reliability with Minimized Budgets,” and Dr. David N. French (Metallurgist) and the UDC instructors made numerous mentions about reducing the deposition of unburned carbon and iron sulfides in fuel rich regions to prevent aggressive conditions on a tube’s surface. Conditions that arise from a reducing environment (no oxygen present), high unburned carbon levels (due to incomplete combustion) and/or high heat flux zones can result in serious boiler reliability issues. This is not to mention overheating of the casing materials that enclose the boiler, expands and allows more air infiltration. The entire time I was listening to metallurgical challenges and how to conduct a reliability improvement program by optimizing the condition of the boiler components, I kept thinking about, “who’s doing the milling system evaluations, combustion airflow and burner tuning and then the periodic air in-leakage surveys to ensure that adequate oxygen is available? Obviously, we can spend the entire newsletter discussing comprehensive diagnostic testing techniques. However, I do want to focus on a practical approach to air in-leakage management. So, here is an approach to consider:

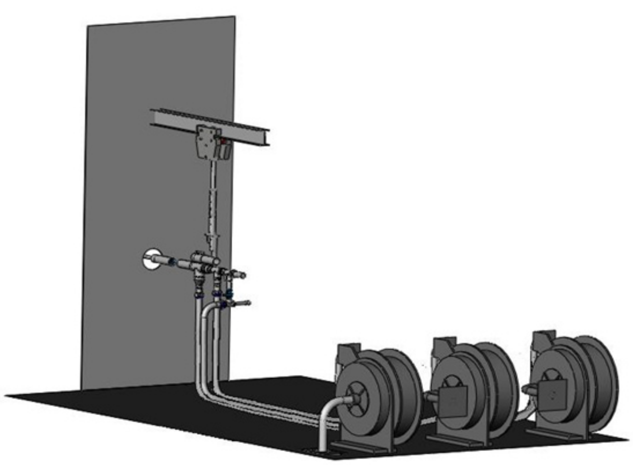
Managing Air In-Leakage

1. Periodically measure flue gas oxygen at the furnace exit with a water-cooled HVT probe to ensure the O_2 probes are representative and/or that adequate combustion airflow is being supplied to the burner belt.
2. Periodically measure total combustion airflow such that “theoretical” airflow and “actual” combustion airflow rates can be evaluated.
3. At full load operating conditions, representatively measure the flue gas oxygen levels at the boiler excess O_2 probe locations.
4. Continue testing under the same operating conditions and in a timely manner the O_2 rise from the APH inlet, APH outlet and then to the ID fan / stack inlet.
5. Post testing, conduct an external walk-down of the unit and report any obvious audible or exposed air in-leakage regions. Furthermore, smoke tests and/or infrared thermography can be used to identify zones of air in-leakage.

6. Use the previous data to plan upcoming outages accordingly and/or conduct online air in-leakage (as feasible) using such technologies as ISOMEMBRANE supplied by the North American Distributor – High Temperature Technologies (HTT). For more information on ISOMEMBRANE you can visit their website at www.isomembrane.com.)
7. During the very beginning of a planned outage, conduct a thorough air in-leakage inspection so that "air washed" areas can be inspected, reported and then repaired. Use ISOMEMBRANE and/or other proven solutions to correct the deficiencies.
8. During the outage, inspect and/or install multi-point flue gas sampling systems and/or any required testing ports to make pre and post outage testing easier. This is our "*work smarter, not harder*" approach. Although these sampling systems may be expensive up-front, these can be maintained, refurbished and extremely useful for boiler performance testing and tuning.
9. At the APH, conduct a thorough inspection and consider high performance air heater sealing solutions. Similarly, inspect all duct work upstream and downstream of the APH, all expansion joints, access doors, hoppers, dust collection system components, etc.
10. Prior to an outage completion, the performance inspection team should inspect the previously identified leakage path repairs.
11. Post outage: re-test, evaluate, tune and optimize performance to evaluate progress and attain results to validate the improvements.

Working Smarter, Not Harder

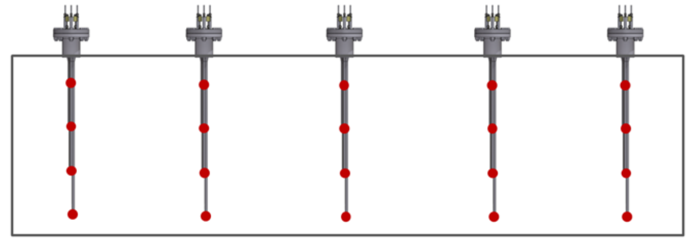
In an effort to minimize the manpower and effort required to conduct air in-leakage testing, previous newsletter editions have focused on Storm Technologies multi-point flue gas sampling systems. These systems are custom designed and built with an integrated in-line gas sampling grid for measuring flue gas constituents such as temperature, oxygen, CO and NO_x. It is also used as an in-line fly ash sampling "grid" system for collecting representative samples of fly ash for unburned carbon analyses.



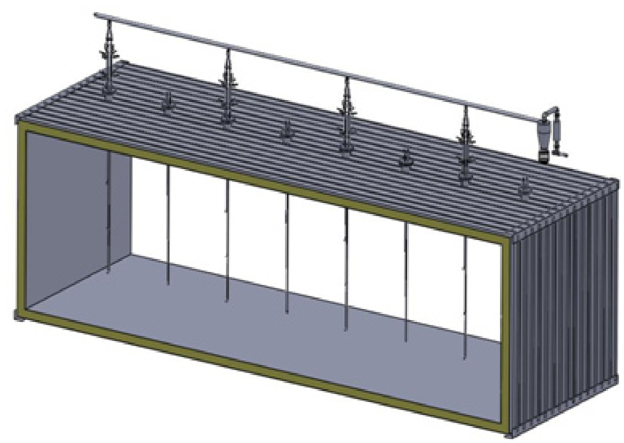
Above: Storm Technologies, Inc. - HVT Testing Assembly with a Customized Trolley.

The inter-relationships of total boiler performance must be considered when attempting to optimize combustion.

Below: Storm Technologies, Inc. - Multipoint Sampling Probes

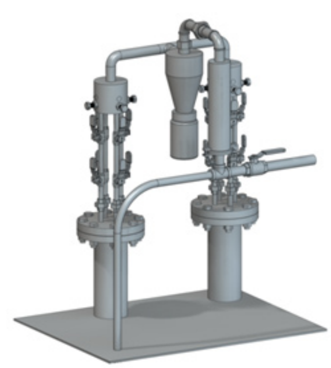


Unit load response, reliability and capacity are all related and therefore a successful approach must be comprehensive, taking into account boiler performance, mechanical adjustments, fuels, soot blowing, airflow measurement, actual in-furnace oxygen and other factors such as the fuel quality being fired. For boilers equipped with low NO_x burners, there are certain essentials that are a useful checklist. (www.stormeng.com/essentials). However, regardless of what fuel type you are burning, the fundamentals/essentials of airflow measurement and air in-leakage monitoring cannot be neglected. Non-compliance with the essentials will compromise the boiler's full potential. Too often, the evaluation of boiler design, burner design, OFA systems and/or fuel changes are solely based upon computational fluid dynamics (CFD) models and/or some other "engineering tool" model that evaluates conditional changes in design or the fuels fired. It should also be noted that with a model, there are many "assumed" variables and one often overlooked essential is reliable and representative measurements.



Above and Right: Storm Technologies, Inc. - Multipoint Emissions Sampling System

PATENT PENDING



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