STORM TECHNOLOGIES, INC. www.stormeng.com

IDENTIFYING AIR IN-LEAKAGE; THE #1 CONTROLLABLE STEALTH HEAT RATE PENALTY AND THE COST OF LETTING IT GO

Air in-leakage is a subject all power plant personnel have heard about but often gets overlooked. Due to typically developing over a long span of time, the negative effects of air in-leakage are often not observed until it is too late, resulting in unit derate, increased slagging, and increased dry gas losses. This short newsletter aims to dive into demystifying air in-leakage by giving you the tools to understand what air in-leakage is and where it typically occurs, how to find it, and the benefits of reducing air in-leakage.

So what is air in-leakage? Otherwise known as tramp air, air in-leakage can be viewed as any air that enters the boiler outside of the intended airflow provided by the forced draft fans. On a balanced draft boiler, Storm's experience is that any boiler over ten years of age is likely to experience increased leakage that negatively impacts unit performance. On any given unit, Storm generally believes there is around 500 Btu/kWh in achievable heat rate improvement. So why do we consider air in-leakage to be the largest stealth heat rate penalty? Out of the achievable 500 Btu/kWh improvement, 240 Btu/kWh can be attributed to air in-leakage in most cases, whether it is upstream or across the air pre-heaters.

In This Issue:

Up Coming Seminar

February 20-22, 2024
Orlando, Florida
Click here for more info

Storm Technologies, Inc.
PO Box 429
Albemarle, NC 28002

Phone: (704) 983-2040
Fax: (704) 982-9657
www.stormeng.com

Controllable Variable Quantities		
Reduction of Air In-Leakage (Before APH)	**Interrelated**	240 Btu/kWh
Reduction of Dry Gas Losses		
Reduction of Coal Rejects		40 Btu/kWh
Reduction of Air Heater Leakage		60 Btu/kWh
Reduction of Carbon in Ash		100 Btu/kWh
Reduction of De-Superheating Spray Water Flows		60 Btu/kWh
Achieved By:		
-Primary Airflow Optimization		
-Pulverizer Optimization and Improved Fuel Line Balance		
Total		**500 Btu/kWh**

Figure 1: Controllable Heat Rate Improvement

The effects of high air in-leakage are compounding, and depending on where the leakage occurs, different results (and the heat rate penalty) from the leakage can be observed. With that said, Storm generally breaks down where air in-leakage occurs into the following five categories.

1. Furnace
2. Penthouse & Convection Pass
3. Ductwork Before APH
4. Air Preheater
5. Ductwork After APH

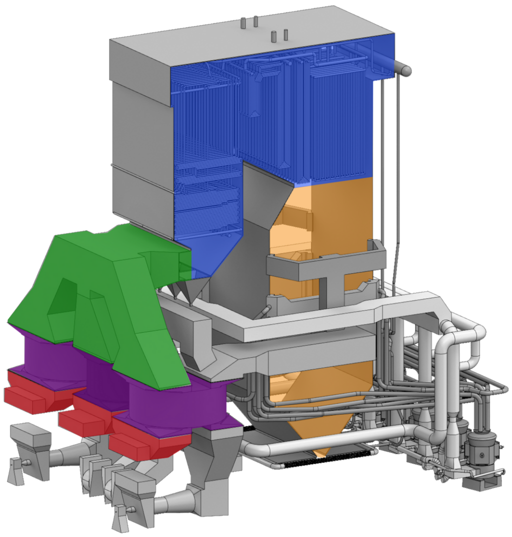


Figure 2: Air In-Leakage Locations

Leakage that occurs in the boiler can be difficult to measure, as it technically can be utilized for the combustion process. With that said, compared to the combustion air, tramp air in the boiler comes in at a much lower velocity and temperature, seeping up the boiler walls and never mixing with the fuel for combustion. At most plants, the oxygen probes are located at the economizer outlet. On an older boiler, Storm's experience is that it is not uncommon to find 10%-15% leakage between the boiler and economizer outlet. Leakage this high can show excess oxygen of 3%-4% at the economizer, however, due to leakage, the actual oxygen at the furnace exit can be close to 0%. When this occurs, secondary combustion is almost guaranteed. This leads to high furnace exit gas temperatures and increased slagging. As a result of higher temperatures and slagging, de-superheating spray flows and even worse reheat spray flows will increase, which are both heat rate penalties.

As mentioned previously, the negative effects of high air in-leakage are compounding. As a result of a reducing atmosphere in the furnace, temperatures and slagging will already be higher. With that said, depending on the fuel being used, the softening temperature of the ash can be 300°F to 400°F lower in a reducing atmosphere. Storm has seen many boilers slag up in one shift due to a reducing atmosphere; all while the unit appears to be operating with excess oxygen through observation of the oxygen probes.

Downstream of the oxygen probes, high air in-leakage can lead to increased degradation of the air heater heating surface as a result of the high exit gas temperatures and pluggage of the baskets as a result of increased gas side deposits from secondary combustion. Moving further downstream, air in-leakage can result in reduced precipitator performance due to increased gas velocities and elevated LOI's as well as reduced ID fan capacity; which most often results in a unit derate to maintain adequate excess oxygen. It should be noted that as you progress further downstream towards the ID fan, leakage is exacerbated by the progressive increase of the draft.

Now that we know what air in-leakage is and why it is bad for all-around unit performance, how is it detected and more importantly, how can it be found? While there are many published methods for finding air in-leakage, both with the unit online and offline, we will discuss what Storm has found to be the most effective over decades of experience.

With the unit online, Storm prefers to detect air in-leakage using the oxygen rise method. To do this, the excess oxygen is measured at various locations in the flue gas path. For this method, the more locations that can be measured, the better. Starting at the furnace exit, Storm utilizes our boiler testing equipment to measure the excess oxygen at each location. To do this effectively, an equally spaced testing grid is required to ensure that no oxygen stratifications, which are often found as a result of leakage, are missed. To determine the air in-leakage between each location measured, the equation to the right is used.

$$Leakage\ (\%) = \left(\frac{O_{2\ in} - O_{2\ Out}}{O_{2\ Out} - 20.9}\right) * 90$$

Using the oxygen rise method, Storm conducts annual leakage testing for many of our customers. The following graph shows the oxygen rise across multiple testing locations taken one year apart. As seen in the graph, the total leakage was slightly higher during the 2020 visit compared to the testing done the year prior.

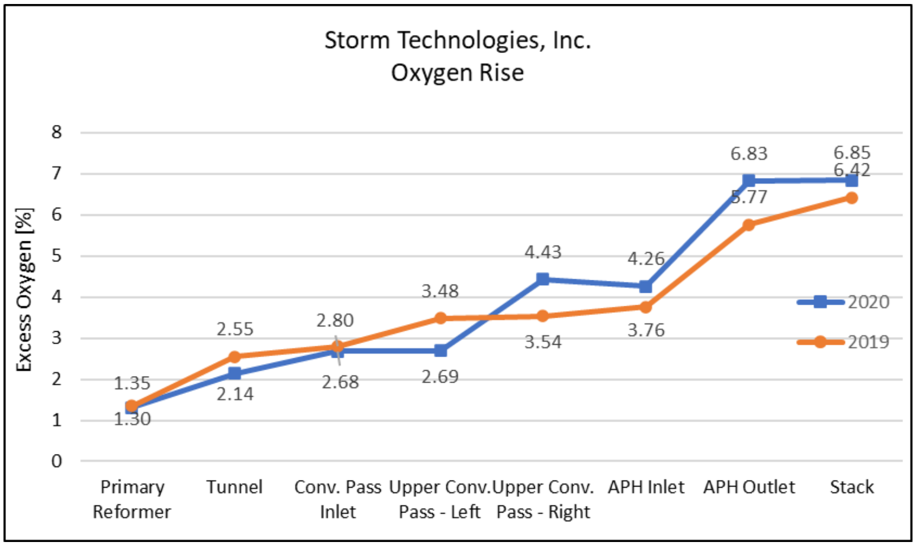


Figure 3: Oxygen rise across the system

Through annual leakage testing, our customers are able to use the test results to plan what areas need to be addressed during the next outage so that repairs can be made. While the oxygen rise method is good for determining what areas leakage is occurring in, testing in itself can not directly pinpoint the leakage. This is where Storm's preferred method of finding leakage offline is utilized. While not the easiest, Storm has found that the best method to pinpoint exact areas of leakage with the unit offline is to perform crawl-through inspections. Ideally, this should be done before any boiler washing occurs so that "washed out" areas of ash due to air in-leakage can be visually seen.

Figure 4: Internal Inspections Identifying Air In-Leakage

Case Study: Identifying and Quantifying the Cost of Leakage on a 1950s B&W Boiler

Storm was recently contacted by one of our customers requesting our testing services. While Storm's services were requested for several issues the plant was having, extensive slagging in certain sections of the boilers was of high concern. By measuring the flue gas constituents at the SH inlet and economizer outlet, the cause of the slagging was quickly determined. While completing testing at the SH Inlet, Storm measured areas of extremely low excess oxygen (below 2%) across all five units at this plant, all while the oxygen probes located in the economizer were showing adequate excess oxygen. By measuring the flue gas constituents at the economizer as well, Storm calculated the leakage between the SH inlet and economizer to be 11.33% to 17.54% across the five units. Having this high leakage upstream of the oxygen probes was causing the boilers to operate in a reducing atmosphere, which was leading to extensive slagging and forced outages. Due to the leakage found, the plant decided to derate several of the units to ensure an oxidizing environment was occurring in the furnace.

When completing boiler testing for our clients, we use the data gathered from flue gas analysis to create contour plots of the gas constituents, which aids us and our customers in observing areas of combustion deficiencies. The following plots show the excess oxygen measured at the SH inlet and economizer outlet on one of the five units at this plant.

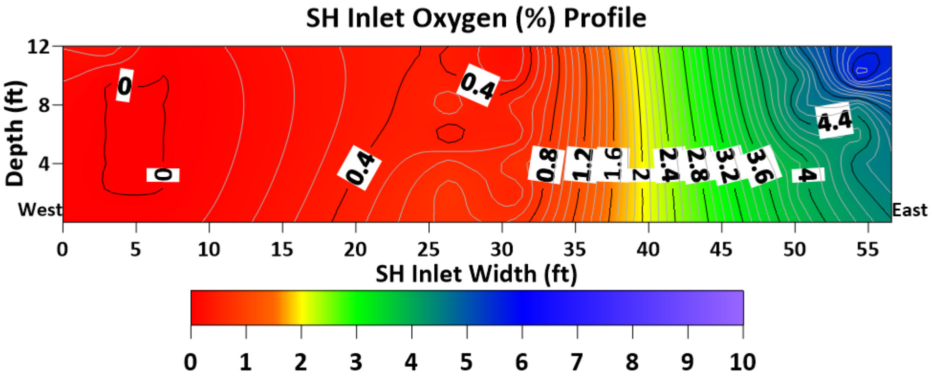


Figure 5: Superheater Inlet O2% profile

As shown in the previous contour plot, the oxygen was not well distributed in the furnace, with most of the boiler being below 1% excess oxygen. The following plots show the oxygen as measured at the same time downstream at the economizer.

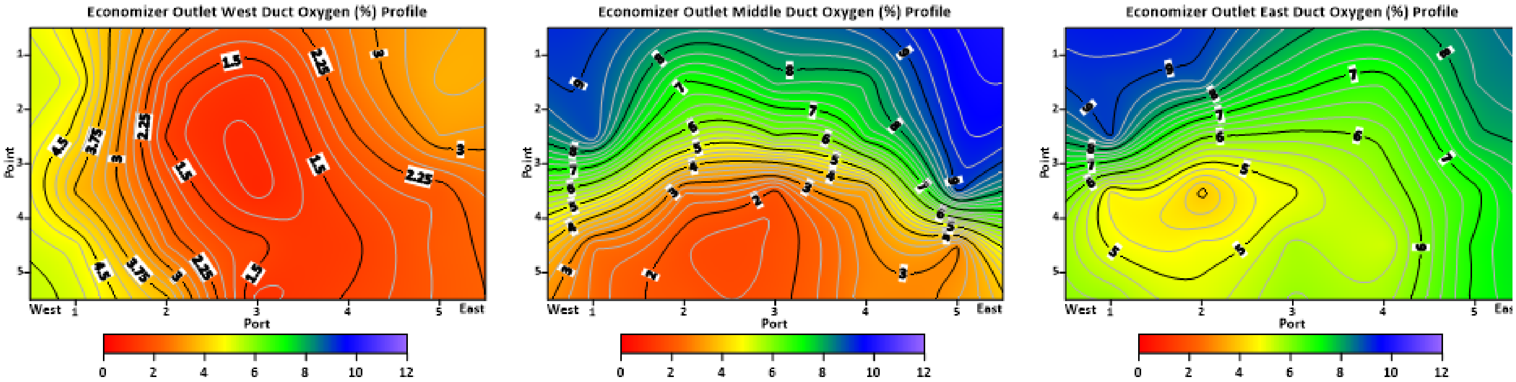
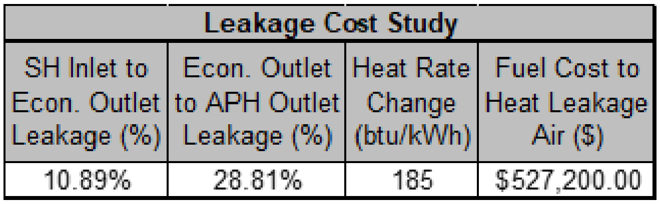


Figure 6: Economizer Outlet O2% profile

With no leakage, the oxygen profile at the economizer should look similar to the oxygen profile at the SH Inlet. This was not the case here. In the middle of the boiler, where Storm measured less than 1% oxygen, areas over 9% excess oxygen were measured at the Economizer. Furthermore, the oxygen was highly stratified at the economizer. From Storm's experience, this usually indicates a major leak just upstream of the test plane as the flue gas has not had time to mix with tramp air entering the flue gas stream.

Using the test results provided by Storm, the plant decided to go after the leakage. While it was known that high air in-leakage had been affecting the units for some time, the plant was not able to successfully track it down.

In addition to detecting the areas of air in-leakage, Storm reviewed what financial benefits would be obtained if the leakage was reduced. To do this, Storm analyzed the fuel cost to heat the additional air introduced to the boiler to the design air heater outlet temperatures. All other negative effects of leakage, which were previously discussed, were ignored. To come up with this fuel cost, it was assumed that the unit operated at a 60% capacity factor with a fuel cost of $2.5/MMBtu. Figure 7 shows the cost of increased fuel use alone due to leakage.



Leakage Cost Study

SH Inlet to Econ. Outlet Leakage (%)	Econ. Outlet to APH Outlet Leakage (%)	Heat Rate Change (btu/kWh)	Fuel Cost to Heat Leakage Air ($)
10.89%	28.81%	185	$527,200.00

Figure 7: Leakage Cost Study

As can be seen in the previous table, over $500,000 is being spent on additional fuel to bring the flue gas temperatures to design characteristics. In Storm's experience, this is the bare minimum cost of leakage, as increased wear on the boiler, poor combustion, and increased auxiliary power usage are not considered by this analysis.

Do you think your plant is experiencing high air in-leakage? If so, contact us today to review how leakage testing can be of benefit to your facility. Ultimately, we suggest completing leakage testing on an annual basis, as shown in one of the previous examples. This allows performance to be tracked year-over-year so that action can be taken before the unit is derated due to high leakage. Additionally, Storm has found that the frequent cycling in load due to chasing grid demand is causing leakage to increase at faster rates compared to past days of baseload operation. In today's competitive energy market, ensuring your boiler is not a victim of load-limiting air in-leakage is often a first step in total boiler optimization.

Respectfully,

Trey Autry

Trey Autry, P.E.
Storm Technologies, Inc.