STORM

Airflow Measurement

The Growing Importance of Accurate and Reliable Combustion Airflow Measurement

We have written volumes on this subject of airflow measurement and management. Most of it is available on our website, www.stormeng.com. This newsletter is a summary of "why" combustion airflow needs to be accurately measured and controlled. Basically there are six reasons.

1. In a pulverized coal furnace there is only one or two seconds of residence time before the products of combustion are quenched below the ignition point of carbon char (1,400°F).

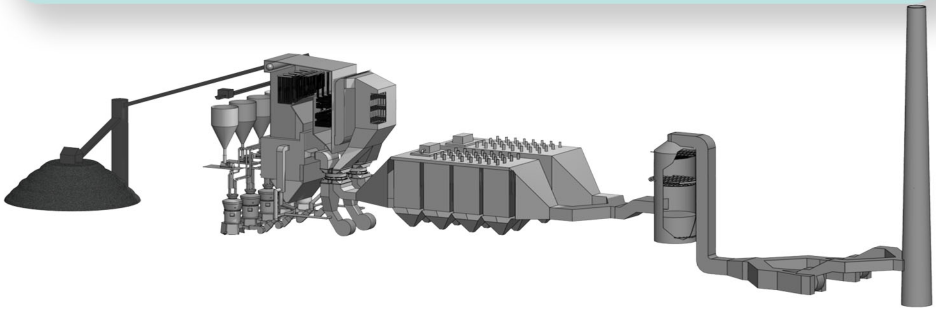
2. Even on CFB's which have much more residence time, the airflow proportioning is important for three reasons: 1) to minimize high NO_x generating zone, 2) reduce the high CO generating zones and 3) maximize sorbent efficency. Combustion airflow measurement to the various zones is important.

3. The ever more restrictive stack emission limits for CO, opacity, and NO_x make it imperative to achieve optimum furnace conditions. So that the air and fuel is admitted to the furnace in the optimum proportions so that the stack emissions are managed within acceptable limits.

4. Changed fuels often require changed airflow proportioning. For repeatable optimum performance, the measured flows are much more effective and reliable than damper position.

5. For optimum furnace performance, best boiler efficiency and repeatable steam temperatures airflow proportioning is a pre-requisite for best combustion practice. When the best heat rate is achieved, it is likely that the total airflow inputs are measured and controlled accurately and reliably.

6. For best reliability, especially with fuels that have high levels of sulfur, iron and chlorine, water wall wastage and superheater slagging avoidance has much to do with optimizing the airflows and fuel flows into the burner belt for a pulverized coal fueled boiler.



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Seven paths of total airflow are directed to the furnace.

1. Primary airflow to transport the coal in a pulverized coal fueled boiler or primary air to the bed of a CFB Boiler.
2. Secondary airflow to windbox or above the bed in a CFB.
3. Overfire air
4. Underfire air (Sometimes used in pulverized coal units)
5. Curtain air (Also sometimes used on PC units)
6. Air in-leakage or tramp air – A problem with all balanced draft boilers, unmeasured and usually not expected or accounted for.
7. Soot blower, observation doors and bottom ash water seal.

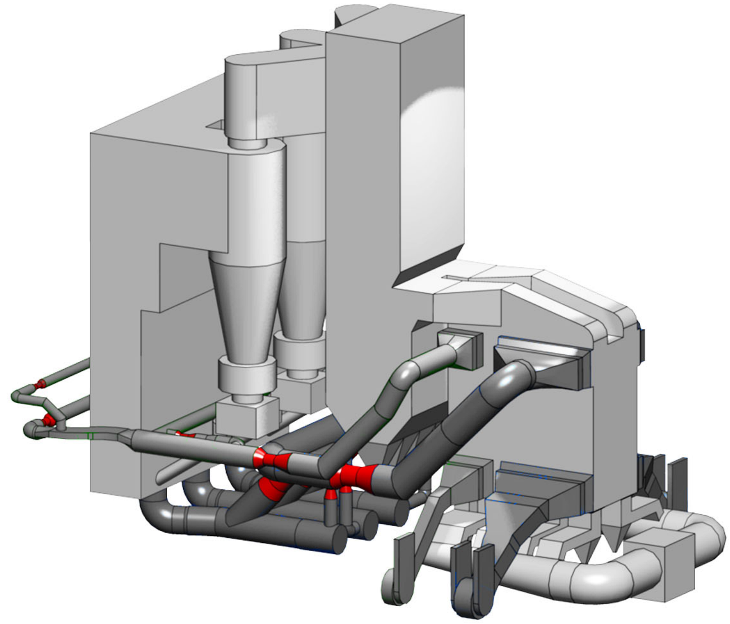


Figure 1
A typical CFB with some airflow measuring venturis shown in red

Case for Accurate and Reliable Airflow

Combustion optimization of coal, whether by pulverized coal firing, CFB's, stokers or IGTCC, is still based on providing the "exact" amount of combustion airflow to combust all of the carbon and hydrogen to CO_2 and H_2O. Interestingly, the "exact" amount of combustion air required for the combustion of all of the coals that we are familiar with, no matter which rank or classification is very similar. The varied coals fit into about a ±2.6% range. This is when the total combustion airflow is expressed in mass flows of total combustion air required per million Btu's input. For example, see Table No. 1

Table No. 1	HHV Btu's/#	#'s air required per million Btu's @ 120% theoretical air
Texas Lignite	~ 7,000	902
Wyoming Sub-Bituminous	~8,500	908
Pennsylvania High Volatile Bituminous "A"	~13,400	928
West Virginia Low Volatile Bituminous	~14,500	918
Colorado Anthracite	~13,650	944
Pennsylvania Anthracite	~11,800	949
Combustion Airflow Average in #'s of air per million Btu's		925

Table No. 1 is based on total combustion airflows. Advanced technology combustion for minimal NO_x, lowest unburned carbon in ash, minimal waterwall wastage and a myriad of other factors require careful measurement and control of the combustion airflows to the various points in the combustion process. This applies to all types of coal combustion furnaces. Take a CFB for example. The airflows typically have at least three main flow paths: grid flow or primary airflow, secondary airflow and overfire airflow.

Compounding the importance of measuring and controlling the combustion airflow to each furnace zone, is the network of ducting to distribute the combustion airflow to the full furnace width and depth. Please refer to the red venturis that are shown above on Figure 1 as an example and many of the smaller ducts are not shown on this view.

Similarly, the combustion airflows to a pulverized coal fired boiler with boosted overfire airflow is shown in the following Figures 2 and 3

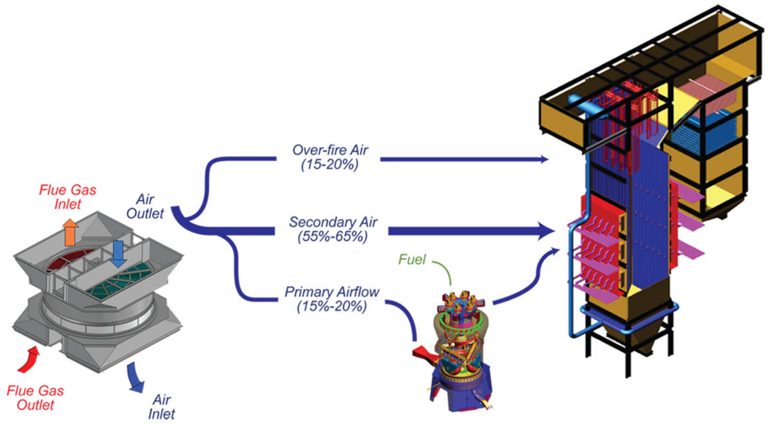


Figure 2

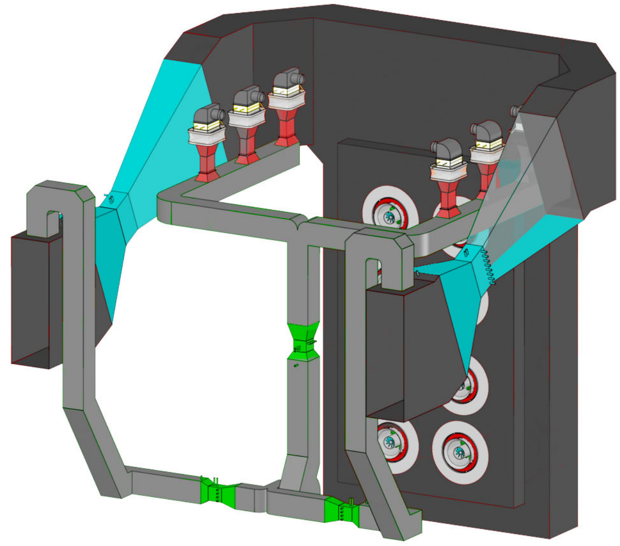
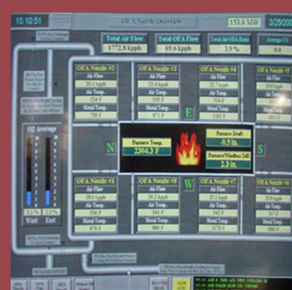
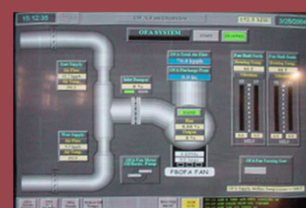


Figure 3

In using accurate and reliable flow elements, as shown in Figure 3, the transmitted flow signals can be displayed in the control room for the operators monitoring, awareness and fine tuning as shown.





The total airflow for complete combustion of various fuels may be the same, but where it is injected into the combustion process makes a huge difference in the quality of combustion. "Quality" of combustion here, refers to NO_X, flyash carbon content, slagging, fouling and sometimes SO_2 reaction rates, such as in CFB's.

Take the differences in PC firing of western PRB and eastern bituminous coals. Both work well with a primary air/fuel ratio of 1.8 lbs of air / lbs of fuel. The total combustion air required will be very similar. The proportions of primary airflow, secondary airflows and OFA flows however, are vastly different. Typical "as tuned" airflow proportions are:

	Secondary Air	Primary Air	OFA
Western PRB	51%	24%	25%
Eastern Bituminous	65%	15%	20%

The Point: THE ACCURACY OF COMBUSTION AIRFLOW MEASUREMENT AND CONTROL IS EXTREMELY CRUCIAL FOR OPTIMUM PERFORMANCE

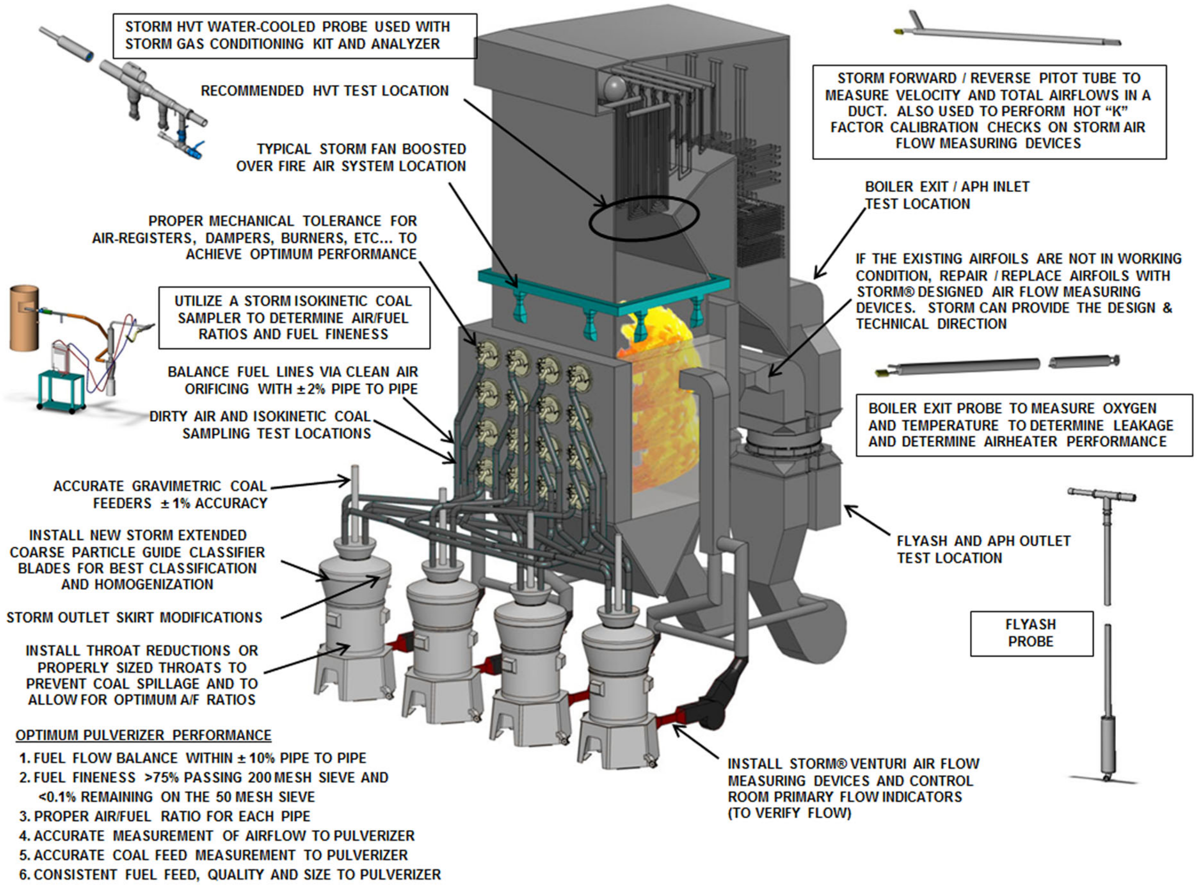


Figure 4

Figure 4 shows the inputs to the furnace and the special test equipment and test locations which are utilized to prescribe engineered solutions to airflow measurement/control and also fuel and ash measurement

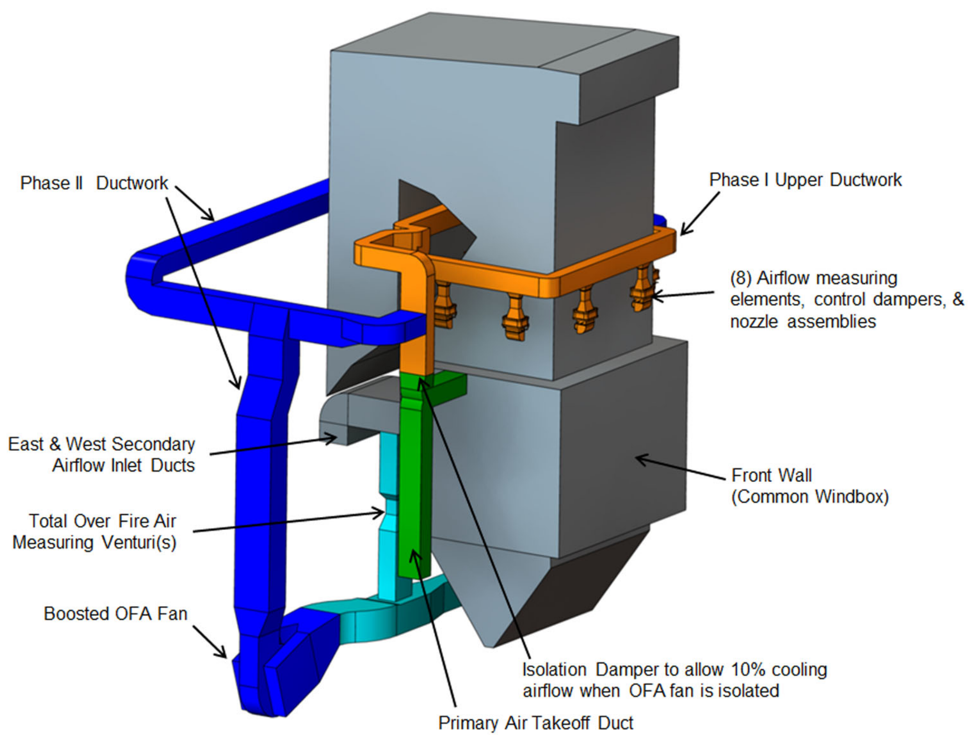


Figure 5

Figure 5 shows the application of flow nozzles and venturis for a fan boosted overfire air system. This particular FBOFA system was designed and installed on a fast track approach in two phases. The two phases of implementation were needed to fit the plant outage schedule, fan manufacturing lead time and stack NO_x emission limit regulations.

What is the preferred way to measure combustion airflow?

Figure 6

Depending on the location in the ductwork, a power plant quality venturi or flow nozzle is stongly preferred. In most cases the ductwork is rectangular but when possible a round venturi is preferred for the smoothest signal and the best pressure recovery. Averaging pitot tubes are economical, functional and can be accurate, depending on the airflow conditions. With averaging pitot tubes, we have found the key to repeatable and accurate pitot tube flow measurements is smooth laminar flow and the absence of fouling or plugging. This can be accomplished by careful flow straightening and increasing the velocity in the averaging pitot tube measurement plane. Then the hot “K” factor method should be used for calibration by a multi-point hand traverse, checked periodically to ensure proper calibration and proven repeatability. Averaging pitot tubes however, are prone to fouling and changing of the “K” factor when they become fouled with ash (see Figure 6). This is the main reason why Storm prefers power plant quality primary elements such as flow nozzles and venturis.

Hot “K” Calibrations

The important notation for hot “K” calibration is extremely important. Cold air, in our experience, does not fill the ductwork and flow with the same profiles as does hot air. In actual practice, the density of ambient air is about two times the density at operating conditions. This is what often causes what are called “K” factor shift from cold, to hot conditions. This is why Storm is adamant on hot “K” calibrations.

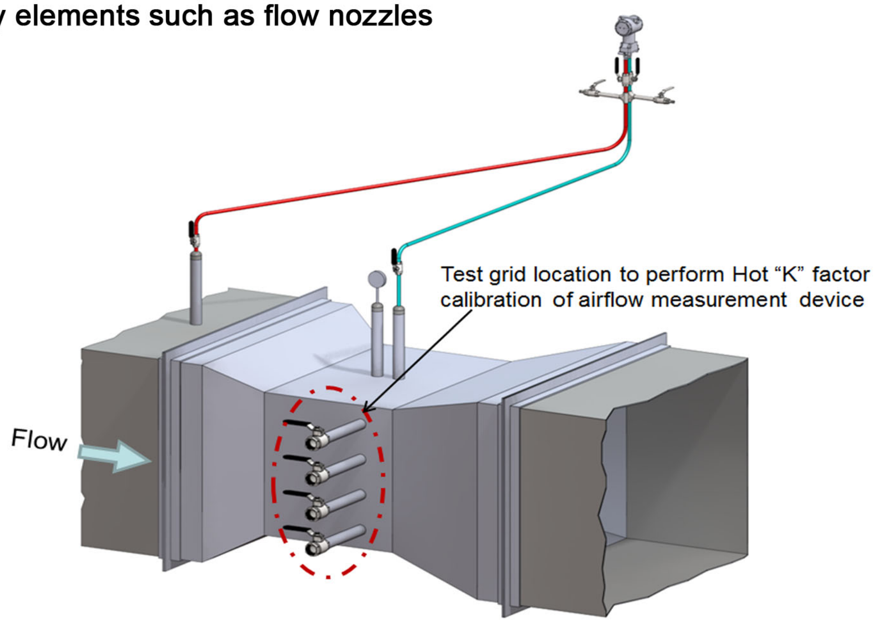


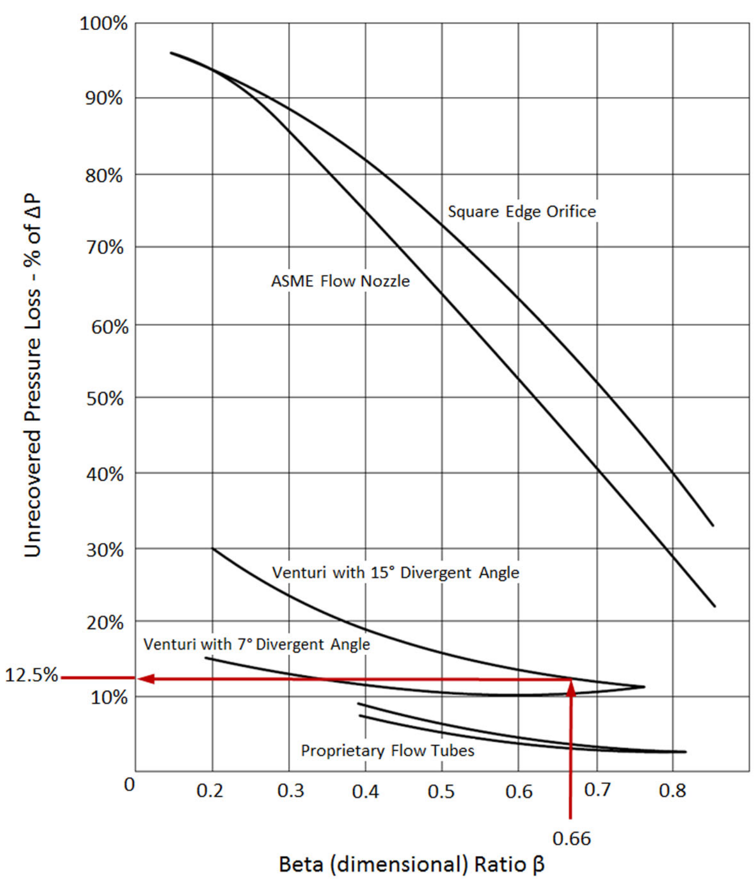
Figure 7

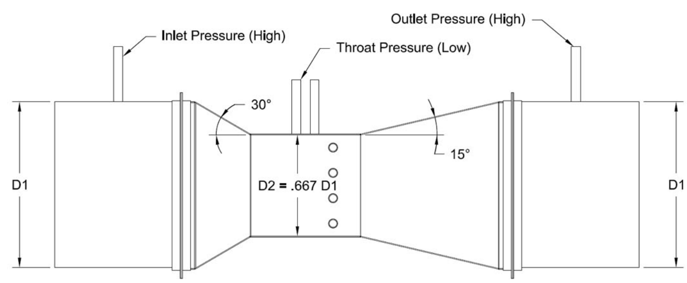
Averaging pitot tubes and airfoils can be leak tested, repaired, holes periodically cleaned by purge air and by careful continued maintenance, and periodically hot “K” calibrated to provide acceptable reliability and accuracy. However, the absolute best, most reliable approach to combustion airflow measurement is the venturi or flow nozzle. When properly applied/installed, and calibrated by the Storm hot “K” technique, the accuracy remains dependable. Sure, boiler ductwork puffs, plugged sensing lines, transmitter calibration errors or transmitted signal calibration/temperature compensation can create inaccuracies. Because of these real world actualities, Storm recommends periodic PM’s on venturis and flow nozzles. These PM’s include: leak checks, transmitter calibrations, sensing line purging and hot “K” calibration checks with a hand pitot tube (such as the Storm rugged forward-reverse pitot). Figure 7 shows typical venturi test ports for the hot “K” calibration process.

The “ULTIMATE” cure for troublesome airfoils or averaging pitot tube array flow elements.

Dispelling the Myth of High Unrecoverable Pressure Drop with Venturis

Venturis and flow nozzles do not have unreasonably high unrecovered pressure drop. The proponents of other primary elements usually emphasize the low pressure drop of their devices. We thought it would be well to remind our friends that the unrecovered pressure drop of a properly designed and built venturi is less than 25% of the maximum design flow ΔP. In other words, a venturi with a full load ΔP of 4” w.c. will recovermore than 75% of that ΔP, for a total maximum loss of about 1” w.c. Shown below is an example of unrecoverable pressure drop in a Storm designed venturi.





Typical Storm designed venturi with 15 degree divergent angle

Example:

Beta Ratio : 0.667 (D2/D1)

Calculated Differential Pressure : 4.0” w.c.

Unrecovered Pressure Loss : 0.50” w.c. (12.5% of DP)

Storm Case Studies of Unrecoverable Pressure Drop with Venturis

1. A case study of large venturis installed on the compartmentalized windbox of a 600MW B&W boiler follows: The original airfoil unrecovered pressure drop was 2” w.c. After removing the airfoils and installing the venturi sections, the unrecovered pressure drop was 1” w.c.

The accuracy and repeatability of the venturis are in the range of 1% as measured by a manual pitot tube traverse. This means, the total stack up of tolerances from the traversing, reading of the manometer, calculations, transmitter error and human factors all combined resulted in ± 1% agreement. We usually use a goal of ±3% from the manual traverse measurements to the transmitted signals. However, with reasonably straight ducts, calibration accuracy in the range of better than ±2% is possible.

Storm Case Studies of Unrecoverable Pressure Drop with Venturis

2. 750 MW Supercritical that had uncertain flow measurements an a history of slagging and high carbon in ash. Solution: Add circular flow nozzles to measure and control primary airflows. What was the cost in lost differential, zero net pressure loss. Why? Because before there was over 14 " water differential across the hot air dampers anyway. The lost 1" of unrecovered pressure drop was not lost and in fact was more than recovered by a lesser PA Duct set point when the sure flow measurement was attained.

Actually, we worked with a southern utility over a three year period and the system heat rate was reduced from about 10,700 Btu's/kWh to 9,700 Btu's/kWh. It was dramatic by installing flow nozzles, fixing air heater leakages, reducing flyash LOI, reducing slagging, etc. The basis of the improvements was to get the inputs right!

3. Similar, but smaller and more recent was a plant in southern Virginia. Originally, the primary air plenum pressure was set at 42" water column. After installing the Storm designed primary elements (in this case hybrid, flow nozzles and averaging pitot tubes) the load response was much improved and the plenum could be reduced to 38 " of water. A net saving of 4” of water in pressure loss.

4. A 360MW wall fired boiler was retrofitted with primary and secondary air measurement flow nozzles. These were central to the success in fuel flexibility, reliability, slagging reductions and maximizing capacity.

5. The first flow nozzles ever completed by Storm, were done about 1981 at an Arizona plant. These are still there and still have the same "K" Factors.

Power Plant Quality

Storm flow nozzles and venturis are "power plant quality" and have these advantages:

- Can be check calibrated on line by hand velocity traverse.
- The sensing lines (two, one HP one LP) rarely, if ever, plug. If they do, purge air or larger nozzle correct the problem. They are inherently resistant to flyash fouling.
- The “K” factors remain the same over time.
- The Storm experienced approach has designed, installed and proven calibration of flow nozzles in many installations where the textbooks say that flow nozzles or venturis cannot be used. We have been successful in applying our technology to solve difficult flow measuring challenges all around the world for many difficult fuels, ash and applications.
- The competition of thermal dispersion, averaging pitot tubes and other devices can work for a short time. But the robustness of the flow nozzles or venturi's have always been the best long term solution to difficult airflow measuring challenges.

Summary

The title we selected for this newsletter is "The Growing Importance of Accurate and Reliable Combustion Airflow Measurement". Why did we say "Growing Importance…"? To the right are eight reasons why.

Optimizing combustion airflows is about 30% of the 13 Essentials of combustion optimization for pulverized coal fueled boilers. As stated in the beginning of this newsletter, no matter what type of furnace design or type is utilized, the accurate and reliable control of combustion airflows is not an "optional" choice. It is **Essential!**

This would not be complete, unless we also mention the other 70% of the 13 Essentials, which are pulverizer fineness, fuel balance and fuel delivery related.

Storm Technologies, Inc., designs, calibrates, manufactures and technically directs the installation of accurate utility grade venturis and flow nozzles in difficult ductwork locations. Please call us when we may assist you in improving combustion!

Yours Truly,

Richard F. Storm, PE
CEO/Senior Consultant

1. Lower and lower furnace NO_x levels are sought.
2. Problems with "popcorn ash" plugging of SCR catalysts.
3. Fuel blends are more varied.
4. Fuel flexibilities are needed more now.
5. Fuels with lower fusion temperatures are being utilized.
6. Better heat rates have been good things to do for years, but have only recently been of mainstream importance when considering it is one of the few present technology ways of reducing CO_2 emissions.
7. Reliability is enhanced with more precise combustion airflow management.
8. Maximum load capability is often related to optimized furnace and combustion performance.

Disclaimer: These suggestions are offered in the spirit of sharing our favorable experiences over many years. Storm Technologies, Inc. does not accept responsibility for actions of others who may attempt to apply our suggestions without Storm Technologies' involvement.

Large Electric Utility Boiler Combustion and Performance Optimization Seminar

An interactive learning event for plant owners and managers who are exploring fuel strategies, operational strategies and enviromental compliance options.

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