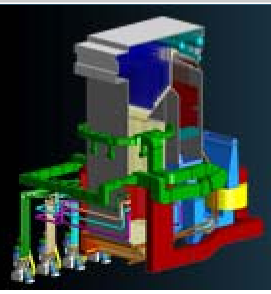

The Story Behind the STORM Fan Boosted Overfire Air System

Storm Technologies, Inc. June 8, 2010

Storm has designed and effectively implemented several fan boosted overfire air systems. The success has been very good. Results include NO_X reductions of over 40% and flyash carbon content reductions to 5 to 9% LOI with NO_X levels below 0.32 lbs/mmBtu, firing bituminous coal. Potentially, lower NO_X levels are likely with some additional tuning and minor pulverizer and burner changes. The success of the Storm Technologies, Inc. fan boosted overfire air system or FBOFA, as we call it, did not happen overnight. The success is attributed to an evolution of testing, experience and several applications on small boilers between 35,000 lbs/hour and 100,000 pounds per hour capacity. The successes are attributed primarily to four factors:

1. Sound design concepts
2. Co-operative partnerships with the owners
3. Applying a comprehensive approach to combustion optimization (applying the 13 essentials)
4. Great team efforts of performance preservation with the plant O&M team and Storm service engineers working together as partners in progress

All of of applications have proven to be highly successful Below is the story of that success.

The development came from five stages.

Stage 1 Testing observations of furnace stratifications

Stage 2 Concept of mixing the upper furnace products of combustion was applied to a small stoker fired boiler.

Stage 3 This concept was then applied to a larger bark fired boiler

Over-fire air without booster fans tends to flow into the furnace as shown in Figure 1. This is a fact that Dick Storm discovered years ago while being involved with hundreds of large utility boiler tests. This work was largely done before the Clean Air Act Amendment was enacted in the early 90s. During this period, required NO_X levels were in the range of 0.50 lbs/mmBtu to 0.70 lbs/mmBtu. Therefore, a certain amount of poor furnace mixing could be tolerated at these modest NO_X levels. The graph shown as Figure 2 depicts poor distribution of products of combustion on for a paper mill

Stage 4 Low NO_X concepts of completing combustion in the available residence time of large utility boilers was conceived and proposed

Stage 5 Getting the furnace inputs right and applying the high momentum fan boosted OFA system was designed and applied to utility scale pulverized coal and oil fired boilers.

Stage 1: Testing observations

Much of Storm's design is based on experience and testing of typical boilers. Back in the 70s and 80s, Dick Storm (Storm CEO and Senior Consultant) conducted considerably large utility boiler diagnostic testing and pioneered the large utility boiler comprehensive diagnostic test. Through this testing, which utilized water-cooled HVT probes at the furnace exit, he learned that the furnace exit gases are often highly stratified. This literally results in some furnace zones of 6% free oxygen, with a dozen ppm of CO and other zones of 4,000+ ppm CO with 0% oxygen. When burners are out of service, or low momentum overfire air is injected, it tends to penetrate short distances into the furnace and greatly exacerbates the stratifications of the products of combustion.

An example of this is shown in Figure 1.

a 500 MW coal fired utility boiler.

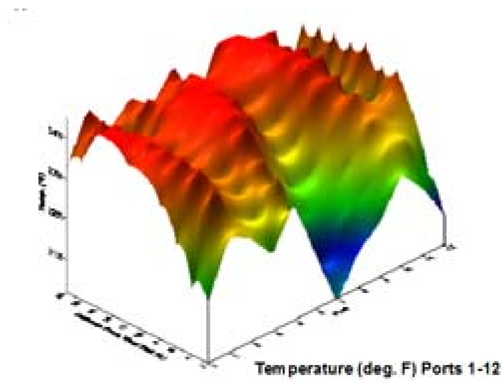

Figure 2 - Typical oxygen stratifications as ascertained by use of a water-cooled HVT probe.

These experiences were tantalizing. Aware of these extreme stratifications, we conceived the idea of high momentum overfire air and recirculated flue gas for enhanced mixing before the carbon char was quenched below the ignition point.

Stage 2: The First Field Trials

The first opportunity to design and install a high momentum overfire air/recirculated gas injection system was about 1982. One industrial customer had six coal stoker boilers that had a tendency to produce high opacity stack plumes. The problem was stratifications of airflow and uneven bed combustion on the stoker fired boiler. The experiences of our large utility boiler upper furnace stratifications were confirmed on these industrial sized boilers. A 3600-RPM fan was used for flue gas recirculation because of space limitations. By applying a common sense low velocity uptake to the fan suction (which is not shown on the diagram), satisfactory fan rotor life was achieved. These six systems remained in service for about twenty years, ultimately being written into the plant operating permit by the state's department of natural resources as "must run" when the boiler is operated.

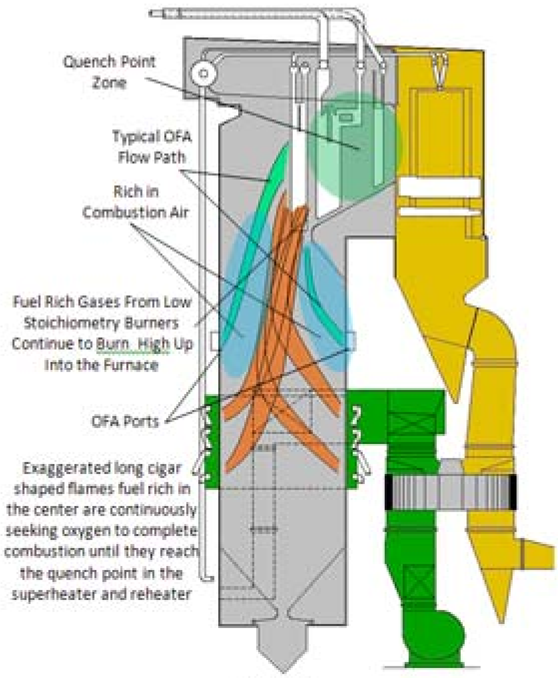

Figure 1

Our success is chronicled in:

Power Magazine

[AES Westover - October 2006]

ASME

[Georgia Power McIntosh - April 2005]

[AES Westover - May 2006]

This system is shown in Figure 3.

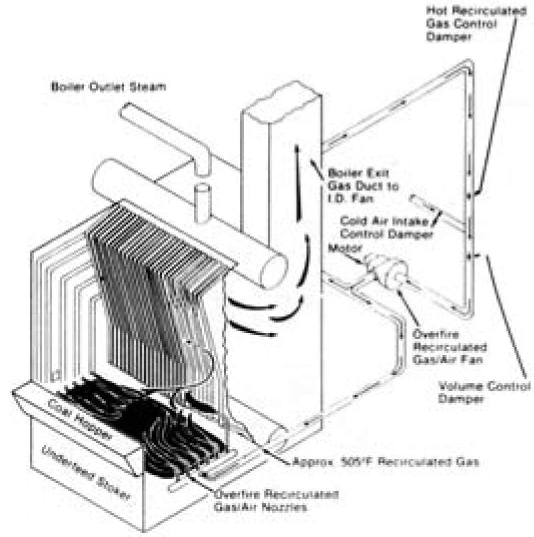

Figure 3

Stage 3: Larger Fan Boosted OFA System applied to a 75,000#/hr Bark boiler

Stage 3: Larger Fan Boosted OFA System applied to a 75,000 lbs/hr Bark boiler

This paper mill, located within the city limits of a major Florida city, had extreme opacity plumes when handling bark of varied moisture levels. An overfire air system was applied to the corners to promote high momentum swirling within the furnace. Again, a relatively small, 3600 RPM fan was used because of space limitations. The concept was proven and the boiler capacity was

Several years ago, we were given opportunities to apply **both** the fundamentals of getting the inputs right (the 13 essentials) and a fan boosted overfire air system. The STORM approach is intended to be comprehensive. Specifically, we mean, measure and control all airflows, optimize the pulverizers, balance the fuel lines and get the mechanical tolerances right. This approach was accomplished on a 90 MW coal fired boiler, as shown in Figure 4.

immediately increased to maximum. The bark-fuel, which cost almost nothing, produced steam that otherwise, would have to be generated in No. 6 oil fueled "power boilers," as the paper mill folks like to call them. Payback was in less than two months. This work was done in the early 80s; consequently by the time the Clean Air Act Amendment was passed, solid proof existed of what high momentum airflow and/or flue gas flows could do to increase combustion efficiently at the furnace exit area.

Stage 4: Early system concepts

During the late 1980s several design studies were made to apply high momentum overfire air systems to a number of large utility boilers.

Stage 5: Applying the fundamental of getting the inputs right and a fan boosted OFA system together. The combined success of "The 13 Essentials" and a high momentum OFA system.

Since the foundation of Storm Technologies, Inc., Dick Storm has recommended fan boosted OFA systems to specific customers as a viable option to improve combustion. Also, we strongly recommend adhering to the 13 essentials of combustion as closely as possible.

The results have been better than promised. Flyash LOI (carbon in ash) is in the range of 5-9%. The NO_X, on bituminous coal, was reduced about 50% from pre-outage levels.

The keys to success are:

1. Get the fundamentals right!
2. Manage and control all airflows.
3. Treat the entire boiler with a total and comprehensive systems approach: controls, soot blowing, operator training/awareness, pulverizer optimization, etc.
4. Great co-operation and a team effort by the designers, installing contractor, sub-contractors, maintenance personnel and plant management.

All four of the above are necessary! When properly applied, the next step is performance preservation. Again, teamwork will provide the ability to improve NO_X and increase efficiency gains.

Summary

The success of this installation allowed Storm the opportunity to prove the concept on a second unit for another utility. Please click the links to view the published results.

High momentum injection of overfire air and in some cases, flue gas, is a viable method to complete combustion within a boiler furnace and at the same time reduce NO_X. Furnace residence time is short, only one or two seconds. Therefore, completing the mixing of the products of combustion at the upper furnace provides an opportunity to vigorously and turbulently mix the air rich and fuel rich stratifications, while operating below the threshold temperature for thermal NO_X of about 2,804ºF. Whether an SCR is installed or not, this proposal is a valid and positive

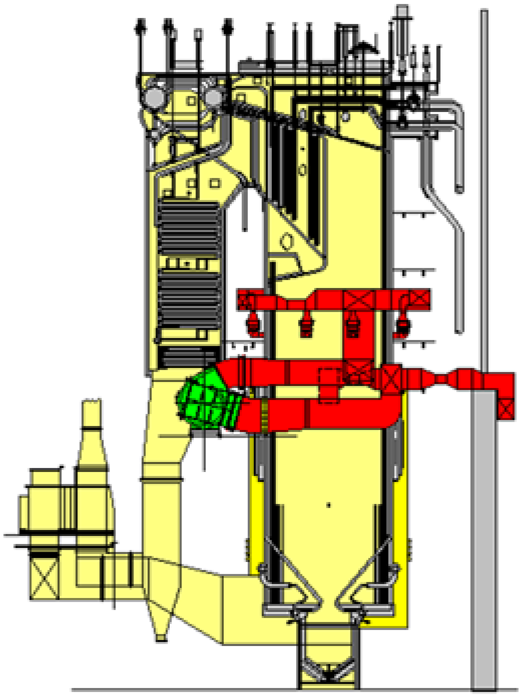

Figure 4

[Storm 13 Essentials of Optimum Combustion]

comprehensive systems approach to optimizing combustion. By comprehensive approach to combustion optimization, we mean addressing all factors, including:

- NO_X
- Slagging
- Flyash carbon content
- Waterwall wastage
- Heat rate
- SCR flue gas stratifications
- SCR cinder plugging
- SCR ammonia slip
- SCR catalyst life

STORM Technologies, Inc. remains enthusiastic about power production from our largest native source of energy, coal! Our strength is applying the fundamentals with our hard earned experience. We specialize in solving problems, whether they are slagging, NO_X, efficiency, hot tubes, capacity, reliability or pulverizer performance. The fan boosted overfire air system is one of our many success stories. We know that **RESULTS** count! Let us know how we can assist you.

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