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STORM TECHNOLOGIES, INC.
411 North Depot Street PO Box 429
Albemarle, NC 28002
Phone: 704/983-2040, Fax: 704/982-9657
www.stormeng.com

The STORM® Solid Fuel Injection System Approach to Excellence in Coal-Fueled Combustion

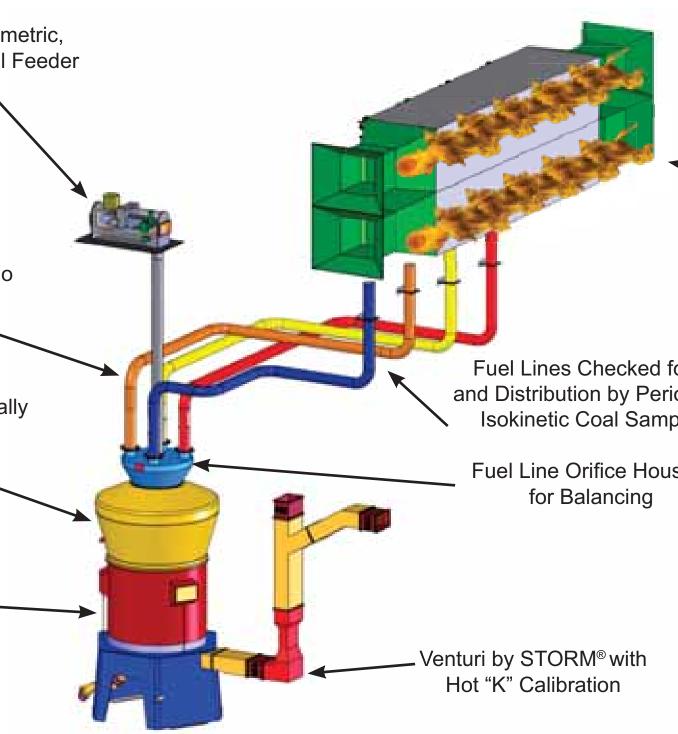

Figure 1

Importance of Teamwork:

One thing I have learned in the power plant performance optimization business is that performance optimization must be comprehensive. All working groups must be involved, including maintenance, operations, engineering and management.

Heat rate improvement is the one overlooked factor that can reduce a plant's carbon footprint. Personally, I do not believe man-made greenhouse gases are causing global warming, but the momentum of public opinion does (The reading list of people who know climate science are on the last page of the enclosed short essay titled, "Coal: Our National Treasure." I believe the true climate scientists, not the "conventional wisdom of junk science by consensus). So, the one thing we can and should do, is improve plant performance for the best possible heat rate. There is about 500-1,000 Btu's/kWh in heat rate improvement potential for the average plant.

When the 13 essentials and 22 O&M controllable variables are optimized, up to 500 Btu's/kWh has been proven to be achievable. Please see figure 2 for a 650MW coal plant where a concentrated effort was applied to "get the inputs right" and optimize combustion, including reducing air in-leakage and air heater leakage. Reducing air in-leakage and precisely proportioning combustion airflows are two of the largest O&M controllable variables on a large utility boiler. The typical opportunities are shown in Table 1.

Heat Rate Improvement Opportunities (Typical)

a. Reduce in-leakage
b. Reduce primary airflow
c. Reduce APH leakage
d. Optimize Pulverizer Performance

	Controllable Variable Qualities
Air in-leakage	**200 Btu/kWh**
Primary Airflow Optimization	**50 Btu/kWh**
Pulverizer Optimization and Improved Fuel Line Balance	100 Btu/kWh
Reducing Air Heater Leakage	**80 Btu/kWh**
Reduced Coal "Pyrites" Rejects	40 Btu/kWh
Reduced Carbon In Ash	50 Btu/kWh
Reduction of de-superheating spray water flows	50 Btu/kWh
Total	570 Btu/kWh

Table 1

Typical heat rate variation from a typical 650MW pulverized coal unit, designed and capable of achieving <10,000 Btu's/kWh.

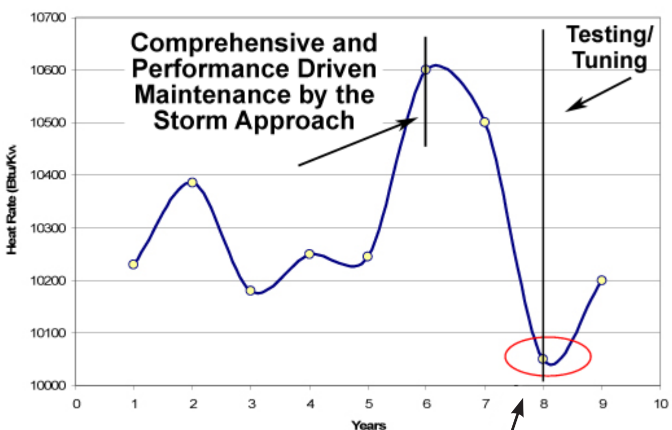

Figure 2

This is typical of potential heat rate improvement by focusing on the operations and maintenance variables, most of which are pulverizer, fuel line and combustion airflow related.

So, how can 500+ Btu's/kWh be improved? Not easily, but attainable providing that the entire plant team is all working together on a comprehensive approach of excellence in applying the "13 Essentials" and the "22 O&M Variables".

How Can Storm Participate and Help?

First: Perform a comprehensive diagnostic test series to identify quantifiable and economically justified opportunities.

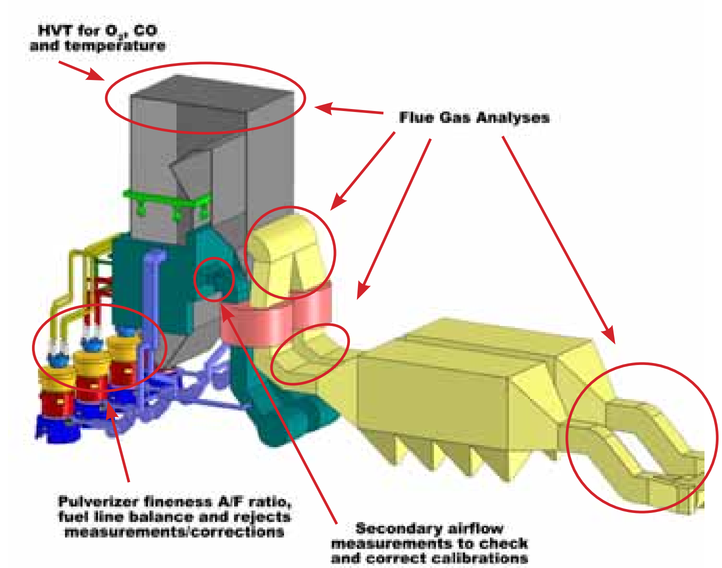

Figure 3

Second: Formulate an action plan for maintenance. We call this – "Performance Driven Maintenance". That means, quantify the opportunities and then make a prioritized list of opportunities for improvement. Use the available maintenance budget to correct the non-optimum conditions so that the greatest gain is obtained per available fund. Frequently overlooked opportunities are:

- Expansion joint air in-leakage
- High primary airflow
- Poor fuel fineness which contributes to slagging and fouling, also waterwall wastage
- Air heater leakage

(Figure 2 is an example)

Third: Use our resources to supplement yours. The STORM® fabrication shop and field services personnel are accustomed to tight outages, deadlines – and expediting shop fabricated components to achieve RESULTS.

Fourth: Following the outage repairs, perform testing and tuning for optimum performance.

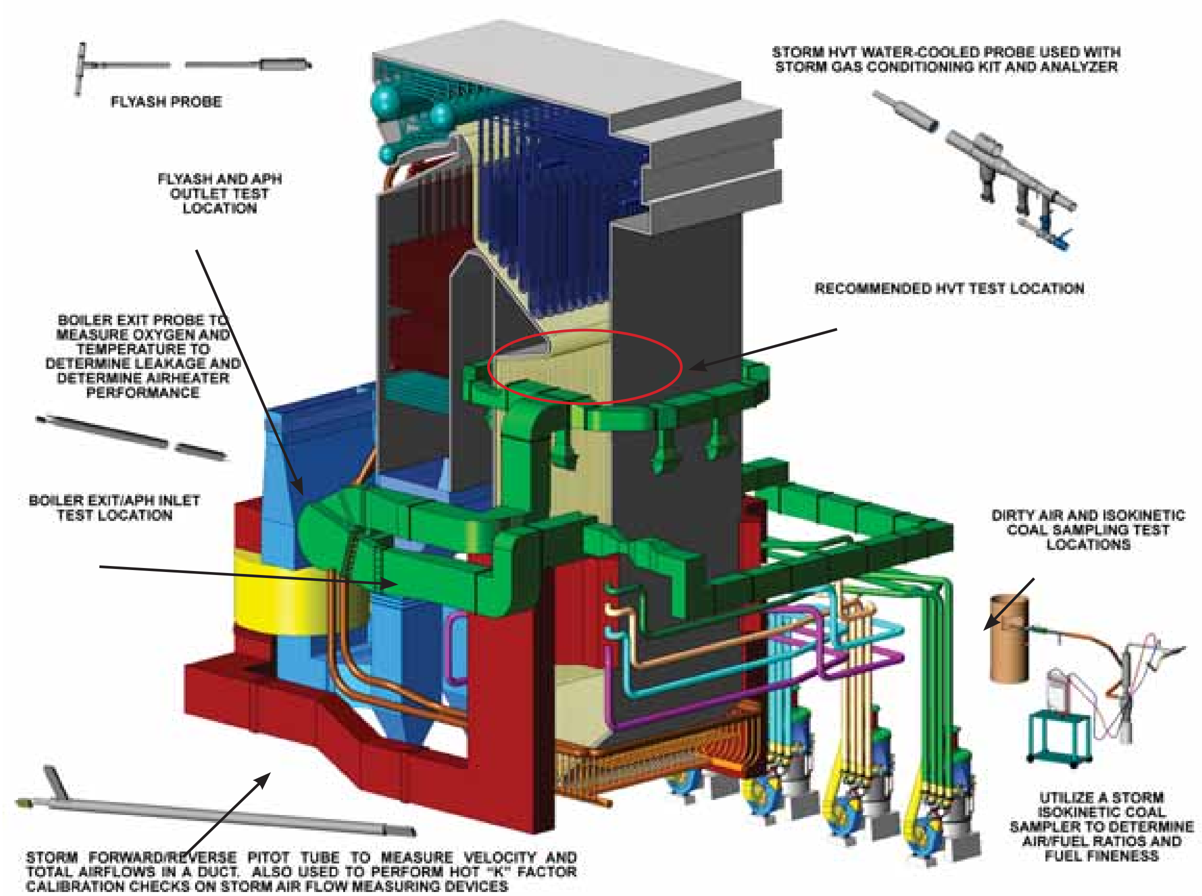

Figure 4

Storm has developed our own test equipment and techniques so that cost effective and results oriented performance improvements can be measured and gains verified.

Why Applying the 13 Essentials is Important

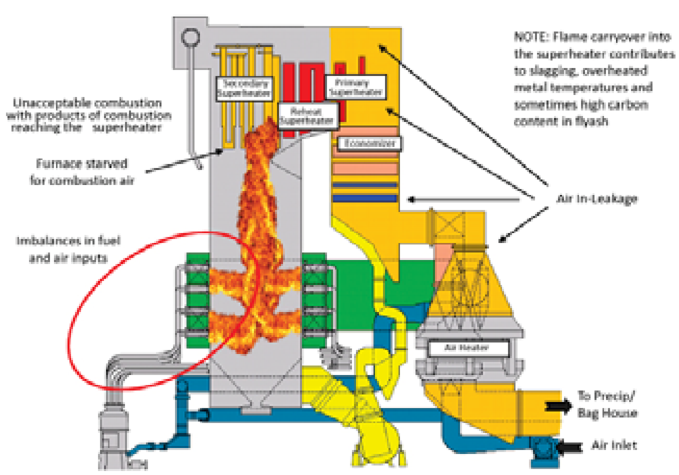

Figure 5

Summary:

Getting good combustion and performance from pulverized coal boilers need not be a mystery. Applying the Storm approach of measuring, quantifying and correcting the "inputs" to the furnace is a proven and results oriented technique.

Read over the 13 Essentials and you will notice most of the opportunities are with the primary airflow, pulverizers and fuel lines, about ¾ of the opportunities. This is not new, it has been our experience for many years.

The 13 Essentials and the 22 Boiler O&M Controllable Heat Rate Factors are listed on the next page for your perusal.

If you would like our assistance, kindly give us a call.

Sincerely,

[signature]

Richard F. "Dick" Storm

STORM®

Specialists in Combustion and Power

Thirteen Essentials of Optimum Combustion for Low NO_x Burners

1. Furnace exit must be oxidizing preferably, 3%.
2. Fuel lines balanced to each burner by "Clean Air" test ±2% or better.
3. Fuel lines balanced by "Dirty Air" test, using a Dirty Air Velocity Probe, to ±5% or better.
4. Fuel lines balanced in fuel flow to ±10% or better.
5. Fuel line fineness shall be 75% or more passing a 200 mesh screen. 50 mesh particles shall be less than 0.1%.
6. Primary airflow shall be accurately measured & controlled to ±3% accuracy.
7. Overfire air shall be accurately measured & controlled to ±3% accuracy.
8. Primary air/fuel ratio shall be accurately controlled when above minimum.
9. Fuel line minimum velocities shall be 3,300 fpm.
10. Mechanical tolerances of burners and dampers shall be ±1/4" or better.
11. Secondary air distribution to burners should be within ±5% to ±10%.
12. Fuel feed to the pulverizers should be smooth during load changes and measured and controlled as accurately as possible. Load cell equipped gravimetric feeders are preferred.
13. Fuel feed quality and size should be consistent. Consistent raw coal sizing of feed to pulverizers is a good start.

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22 Heat Rate Variables

1. Flyash Loss On Ignition (LOI)
2. Bottom ash carbon content
3. Boiler and ductwork air in-leakage
4. More precise primary airflow measurement and control, by reducing tempering air
5. Reducing pulverizer air in-leakage on suction fired mills
6. Pulverizer throat size and geometry optimization to reduce coal rejects and compliment operation at lower primary airflows
7. Secondary airflow measurement and control for more precise control of furnace stoichiometry, especially important for low NO_x operation
8. Reduction of extremely high upper furnace exit (FEGT) peak temperatures, which contribute to "Popcorn Ash" carryover to the SCR's and ApH's, High spray water flows, Boiler slagging and fouling, and high draft losses due to fouling. The high draft losses cause increased in-leakage, increased fan auxiliary power wastage and increased associated losses with the high spray water flows
9. High de-superheating spray water flow to the superheater
10. High de-superheating spray water flow to the reheater
11. High air heater leakage (note: Ljungstrom regenerative airheaters should and can be less than 9% leakage)
12. Auxiliary power consumption/optimization i.e., fan clearances, duct leakage, primary air system optimization, etc
13. Superheater outlet temperature
14. Reheater outlet temperature
15. Airheater outlet temperature
16. Airheater exit gas temperature, corrected to a "no leakage" basis, and brought to the optimum level
17. Burner "inputs" tuning for lowest possible excess oxygen at the boiler outlet and satisfactory NO_x and LOI. Applying the "Thirteen Essentials"
18. Boiler exit (economizer exit) gas temperatures ideally between 650°F to 750°F, with zero air in-leakage (no dilution!)
19. Cycle losses due to valve leak through – i.e. spray water valves, reheater drains to the condenser, superheater and re-heater drains and vents, and especially any low point drains to the condenser or to the hot well
20. "Soot blowing" Optimization – or smart soot blowing based on excellence in power plant operation. (Remember, soot blowing medium is a heat rate cost, whether compressed air or steam)
21. Feed water heater level controls and steam cycle attention to detail
22. Steam purity and the costly impact of turbine deposits on heat rate and capacity