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## Considering the Economics of Combustion Optimization

Dick Storm, PE, Senior Consultant, Storm Technologies, Inc.

Never in my four decades of working in the power generation business have I seen natural gas prices competitive with coal base load power generation plants, but we all saw it over the last couple of months. Of course, this could fool the policy makers that continue their war on coal to impose more and more restrictions and taxes on carbon, make mining coal more difficult and continue to make new coal plant permitting extremely arduous. As you can see in the table below, these estimates of operations with "as found" typical PRB and CAPP coals make the playing field for coal and natural gas fairly level. However, when you figure an estimated cost for carbon taxes, we are off the chart.

Economic Equivalents*	Units	Coal (PRB) Powder River Basin	Coal (CAPP) Central Appalachian	Baseload Gas
Base Fuel Cost	\$/mmBtu	\$0.63	\$2.08	\$4.00
Transportation Cost	\$/ton	\$45	\$10	-
Plant Heat Rate	Btu/kWh	10,000	10,000	7,000
Delivered Fuel Cost (pre-carbon)	\$/MWh	\$34	\$27	\$28
Delivered Fuel Cost (with \$20.00/ton carbon tax)	\$/MWh	\$54	\$47	\$39

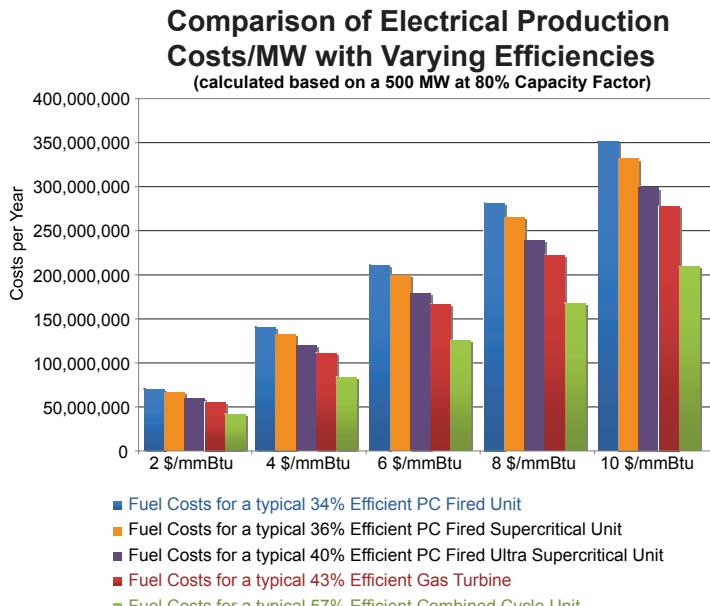
**Figure 1**

The poor public perceptions about coal are due in my opinion, to a virtual absence of effective presentation on the facts of why coal is good for America. The public is faced with an avalanche of advertisements on the promotion of the myth that renewable power can replace all traditional forms of American energy. Those of us involved in the industry know better. We cannot solve this problem of public perceptions of the virtues of using more coal to fuel America, but we can help to promote fine-tuning and operations and maintenance activities that can contribute to economical, reliable and clean combustion of coal.

Those of us involved in power and energy know the importance of coal for America's energy independence and national security. All of the above is well known so I will not dwell on the merits of coal energy. The topic of this message is using coal well at the best possible efficiency and being competitive with presently, low cost natural gas fuels. A strong argument for American coal is to prove that we use this resource wisely, cleanly and efficiently.

If you compare the various/majority of 500 MW electrical generating units operating at a consistent capacity factor,

the annual fuel consumption costs will vary with the thermal efficiency of the plant. Considering this, as you can see in the following example (Figure 2), if both gas and coal prices were equalized at \$4/mmBtu, the thermal efficiency plays a huge part on the fuel costs as well as the environmental impact. Considering this, we have recommended and agreed with others that there is indeed an industry need for repeal of New Source Review (NSR). By doing so, this would promote upgrades and modifications that would improve the efficiency of our operating plants and have a huge impact on reducing plant emissions.



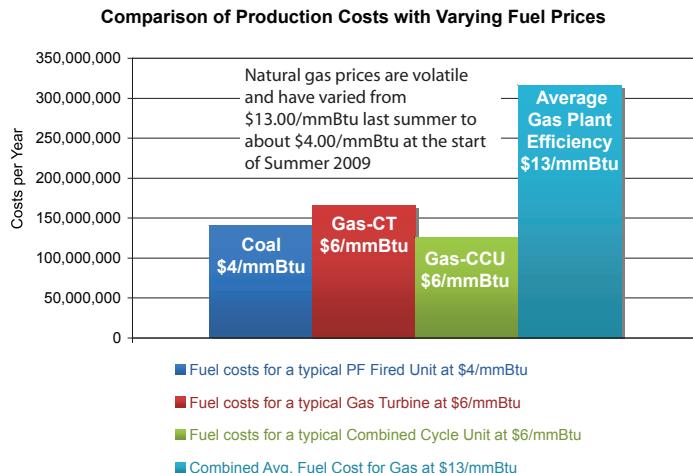
**Figure 2**

Considering the current economic situation, let's review seven reasons to work toward improving coal plant heat rates:

1. Firstly, because it is the right thing to do....
2. Promote national security by showing that we can continue to use domestic American coal in a responsible manner.
3. Keep economic prosperity by providing reasonable cost electricity to power American industry and keep American industries competitive with global suppliers of manufactured products
4. Environmental stewardship
5. How about profitability? Profits and Capitalism are not "Dirty Words" in our lexicon
6. The steps toward optimum heat rate operation usually

improve reliability, capacity factor, emissions and load response. (Such as applying the 13 Essentials of Optimum Combustion and/or utilizing Storm Technologies' APPLES program to its fullest potential)

- We must now compete with low cost and presently abundantly available shale gas. See Figure 3 that compares the electrical production costs for a typical 34% thermally efficient pulverized coal plant with a typical gas turbine and/or combined cycle unit.



**Figure 3**

No matter how advanced modern power systems have become or will become, they will always require the fundamentals to be applied in an effort to optimize plant performance. On a typical pulverized coal fired boiler, there is usually only 1 – 2 seconds of furnace residence time to complete combustion. Any carbon particles remaining within the flue gas at the furnace exit will be quenched on the tube surfaces within the convection pass once the temperature drops below 760°C (1400°F).

There are many common controllable plant performance opportunities within a PC fired unit. For review, let's discuss some of these:

- Coal spillage out of a vertical spindle coal mill is not only an efficiency factor, but mitigation often correlates with an operations adjusted increased primary airflow. The negative impact of high PA flow on combustion results in increased slagging, NO<sub>x</sub>, boiler losses and high temperatures in the superheater.
- Poor coal fineness mixed with high primary airflow reduces the amount of heat released in the lower furnace and increases the height of combustion within a furnace. This in turn, elevates the amount of secondary combustion and creates higher than designed furnace exit gas temperatures.
- Secondary combustion will indeed result with increased carbon carryover as well as sizing and quantity of the ash particles impinging the RH & SH. This will induce flyash erosion as well as high furnace exit gas temperatures. High FEGTs contribute to overheated tube circuits, slag, de-superheating spray flows and excessive soot blower operations that can become a serious reliability issue.
- On units 10 years old (or older), another common problem is tramp air in-leakage from the penthouse, convection pass and/or the air heaters. Air in-leakage introduces a number of issues such as incorrect excess

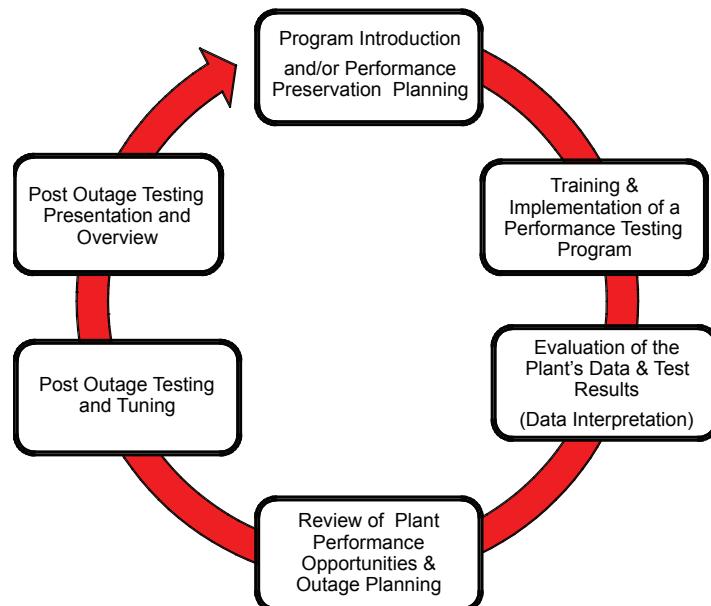
air measurement, creation of a reducing atmosphere in the furnace, accelerated tube metals corrosion, excessive mass flow across the precipitator, exhaustion of ID fan capacity and full load potential.

It is not unusual to have a boiler that meets design efficiency and a turbine that also meets design efficiency, yet the heat rate may be hundreds of Kcals (Btu/kWh) above optimum. We call these opportunities for heat rate and system efficiency improvement, "Stealth Losses." Storm Technologies has completed numerous assessments of stealth losses in the USA and some of the typical stealth losses identified are seen here. Based on the average, losses are commonly in the magnitude of 500 Btu/kWh. This is illustrated in Figure 4.

Controllable Variable Quantities		
Reduction of Air In-Leakage	Interrelated	240 Btu/kWh
Reduction of Dry Gas Loss		
Reduction of Coal "Pyrite" Rejects		40 Btu/kWh
Reduction of Air Heater Leakage		60 Btu/kWh
Reduced Carbon in Ash		100 Btu/kWh
Reduction of De-Superheating Spray Water Flows		60 Btu/kWh
Achieve by:		
- Primary Airflow Optimization		
- Pulverizer Optimization and Improvement		
- Fuel Line Balance		
Total		500 Btu/kWh

**Figure 4**

To become world class, one must first acknowledge understanding of your thermal plants and commit to a programmatic approach to optimization of performance. The APPLES (Annual Plant Performance Longevity Evaluation Service) approach has been proven successful. To introduce the program, allow me to review the six basic principles of this approach (See Figure 5).



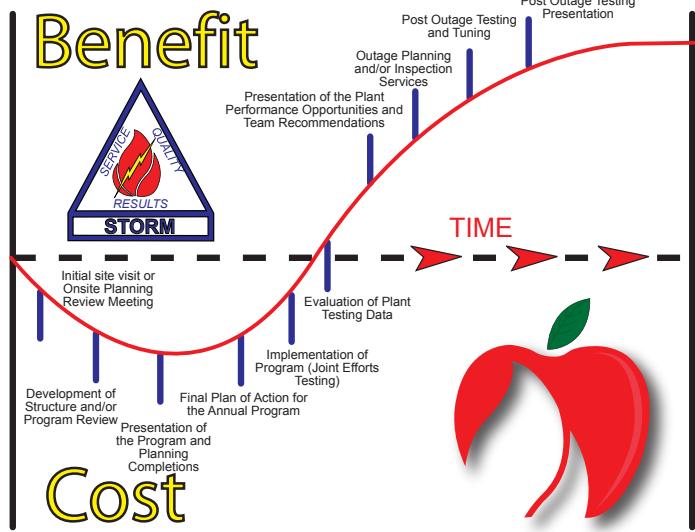
**Figure 5**

First, to suit each plant, the benefit of a program must be understood and designed. Secondly, the team must be trained and enthusiastically implement a performance testing program. This is in an effort to measure performance and be

able to interpret the testing data and evaluate the results. After that, the performance data is used to coordinate outage work. This is called **performance driven maintenance**. Then, after the outage, post outage testing must be completed to measure performance and conduct tuning and optimization of the plant's equipment. Upon completion of the post outage testing and tuning, the results are reviewed and testing starts over to preserve performance and/or continue the search for more stealth heat rate losses.

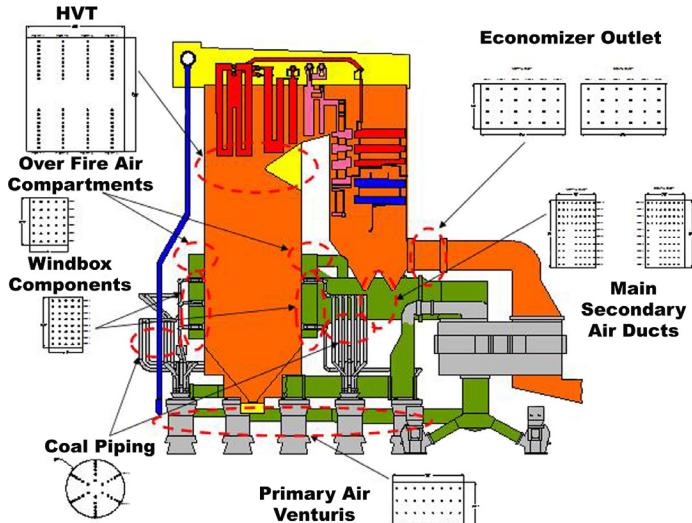
From a performance standpoint, the benefits always outweigh the costs of a performance driven program (to put this in perspective, refer to Figure 2). However, be assured that the results of improvements in reliability, load capacity, environmental performance and efficiency often result in a much greater payback upon implementation of a performance program. Keep in mind that world-class plants measure the stealth heat rate losses that are often hidden, yet are controllable.

### Annual Plant Performance Longevity Evaluation Service



**Figure 6**

One of the keys to a successful performance optimization program is to conduct periodic performance measurements through a representative sampling program. As you can



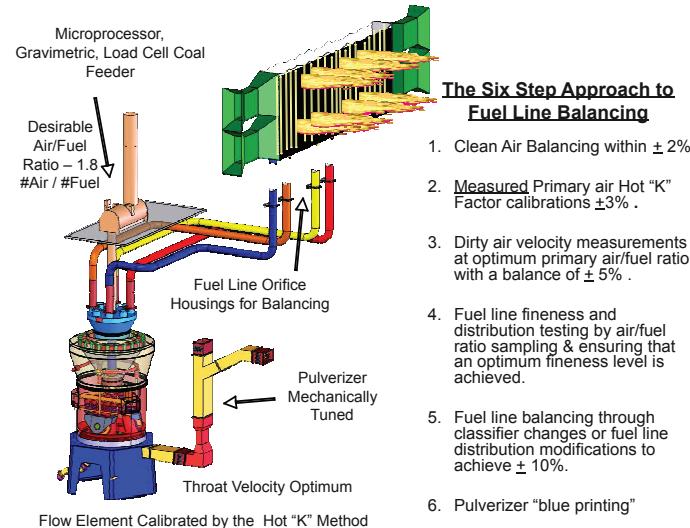
**Figure 7**

see in Figure 7, this illustration shows the traverse locations for representative measurement of the air and fuel "inputs" as well as the flue gas chemistry leaving the furnace. By taking periodic performance measurements, problems can be identified and as Ben Franklin once said, "a problem identified is a problem half solved." Stealth Losses are called that for a reason!

The repeated experience of Storm Technologies has validated that nearly 70% of the fundamental combustion problems identified in the industry (on PC fired boilers) are related to the pulverizers.

With that said, let's talk quickly about a six step approach to balancing fuel flow.

1. The first and fundamental principal to balancing fuel lines is to establish equal transport energy by clean air balancing within  $\pm 2\%$  to each one of the fuel lines.
2. Primary airflow must be accurately measured and controlled. Periodic calibration of the flow elements by the Storm hot "K" factor calibration method should be completed.
3. Dirty air velocity measurements at optimum primary air/fuel ratio with a balance of  $\pm 5\%$ .
4. Fuel line fineness and distribution testing by air/fuel ratio sampling and ensuring that an optimum fineness level is achieved is essential.
5. Fuel line balancing through classifier changes or fuel line distribution modifications to achieve  $\pm 10\%$  is the next step.
6. Fuel balance requires both classifier optimization and "Blueprinting" of the pulverizers (see Power Magazine March 2009, pages 60-63).



**Figure 8**

In an effort to validate "true" furnace excess air, the fuel and airflow inputs must be measurable. World-class combustion systems accurately measure all paths of combustion airflow to the furnace. This is a fundamental essential required to validate theoretical and/or assumed excess air as measured and trimmed by the excess oxygen probes.

As a part of the APPLES program, it is critical to incorporate "performance inspections" of the pulverizers, airflow systems, flue gas paths and/or condition of the performance monitoring equipment.

## Blueprint for Annual Plant Performance Longevity Evaluation Services

Item	Description	Outage Provisions
1.0	Pulverizer & Fuel Line Performance	Test Ports Must be Installed
1.1	Clean Airflow Balance	
1.2	Dirty Airflow Balance	
1.3	Fuel Flow Balance	
1.4	Air-Fuel Ratios	
1.5	Pulverized Coal Fineness	
2.0	Primary Airflow Calibration	
3.0	Secondary Airflow Distribution & Control	Accessibility & Testing Ports are Required
4.0	Excess O <sub>2</sub> Probe Measurement Accuracy	Multi-point test probes are Preferred
5.0	Furnace Exit Gas Temperature & Flue Gas Measurement	Water & Air Supply Hoses & Fittings will need to be prepared; Safe Test Platforms; Test Ports (test ports - bent tube openings with observation / test door assemblies)
6.0	Boiler Exit to Stack Flue Gas Measurements; Air Heater Performance; Boiler Efficiency & Total System Air In-Leakage Measurement	Accessibility & Testing Ports are Required
7.0	In-situ Flyash Sampling & Analyses for Sizing & unburned carbon	Accessibility & Testing Ports are Required; Multi-Point Emission Sampling Systems by STORM TECHNOLOGIES are suggested for ease of testing/daily measurements

**Figure 11**

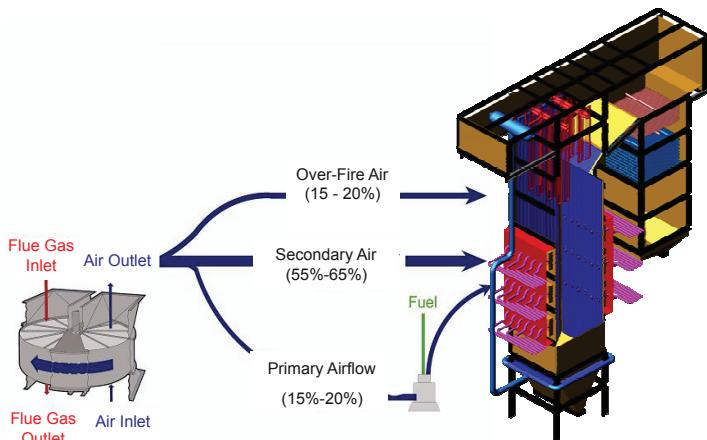
services you may need. Our reputation has been earned by achieving cost effective results. Let us use our resources to compliment yours.

Sincerely,

Richard F. Storm  
Senior Consultant/CEO  
Storm Technologies, Inc.

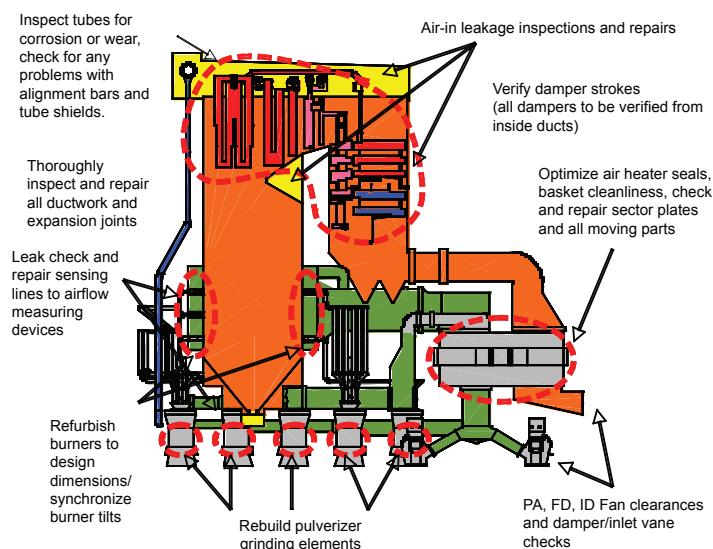
# FABRICATED SOLUTIONS

Fabricated Solutions (a division of Storm Technologies, Inc.) continues to be a leader and innovator among steel fabricators and machining services. We specialize in ASME code work, ductwork (new or replacement) and large diameter pipe in addition to our STORM performance components (i.e. pulverizer components, airflow management, etc.). Our fabrication shop is conveniently located within 35 miles of the greater Charlotte, NC area to serve large industrial and power generation needs regionally and nationally as well. Our shop is ready to support and meet the expedited needs of your plant and we look forward to the opportunity to work with your next fabrication/machining project. Our shop is proud to practice the Storm mantra – SERVICE – QUALITY – RESULTS!



**Figure 9**

When considering a comprehensive program, it should be understood that this is an opportunity to continue to utilize performance driven maintenance techniques to improve the plant's efficiency and overall reliability.



**Figure 10**

To illustrate a typical matrix of comprehensive testing locations for periodic measurement, Figure 11 illustrates the provisions required to ensure a successful APPLES program.

There are at least (5) expected outcomes for successful implementation of the fundamentals and the APPLES Program and these are as follows:

1. Improved Boiler Efficiency & Heat Rate Performance
2. Improved Load Capacity
3. Improved Reliability & Load Response
4. Improved Environmental Performance & Control of Emissions (Reduced NO<sub>x</sub>, Reduced CO<sub>2</sub> and Opacity Control).
5. Fuels flexibility to utilize various economically advantaged fuels.

Taking into consideration carbon taxes on our radar, we strongly recommend that you consider contacting STORM today for implementation of the APPLES Program and/or any optimization and efficiency parts, components and/or