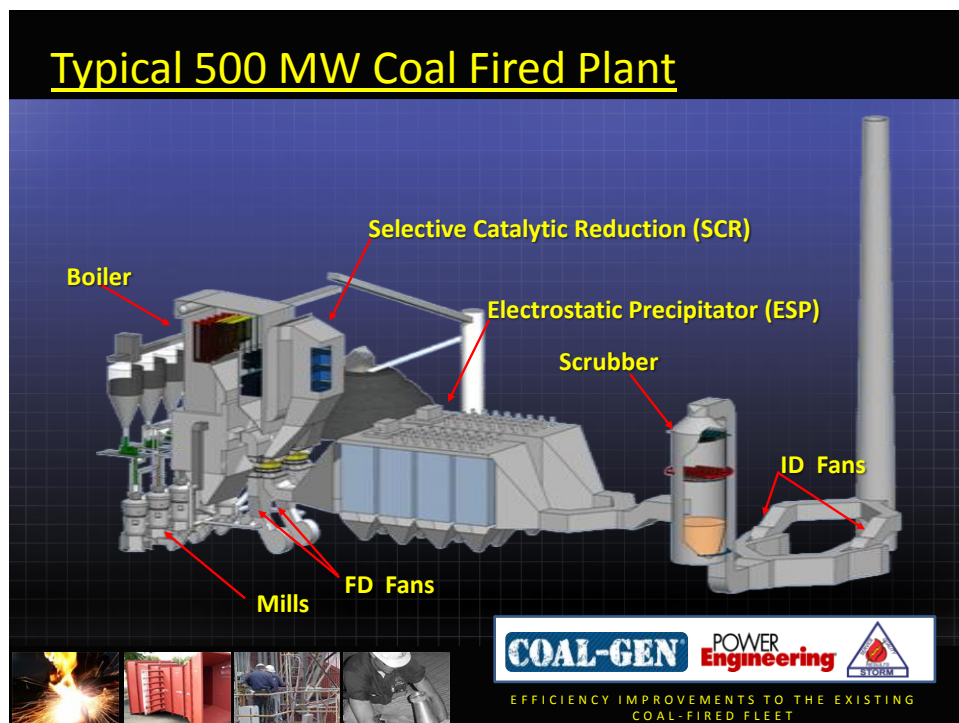


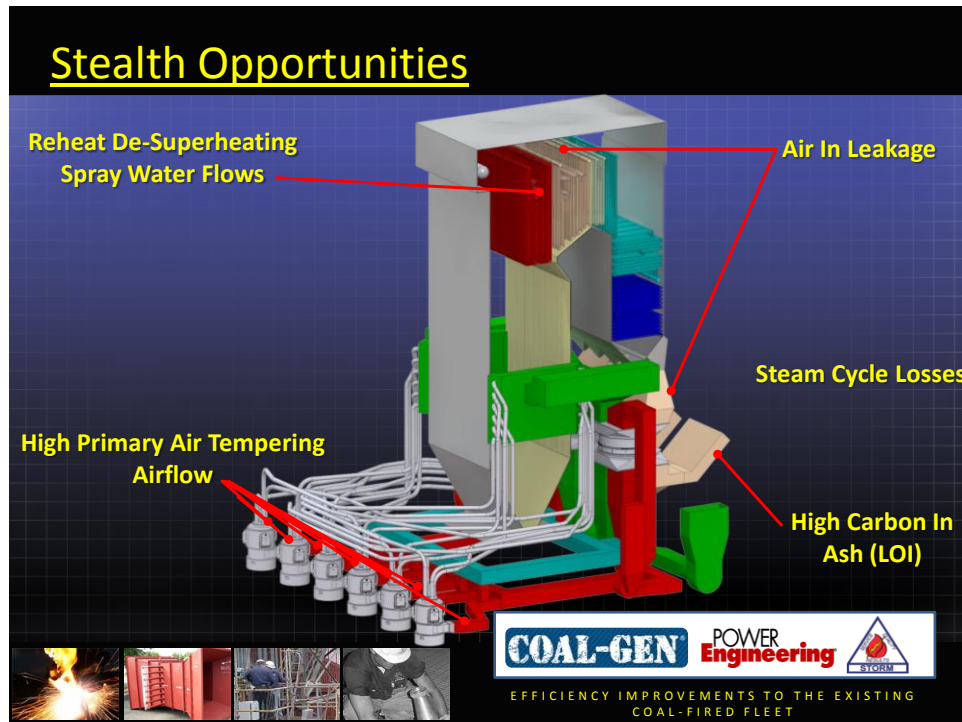
COAL – GEN PRESENTATION
Efficiency Improvements to the Existing Coal-Fueled Fleet
August 12, 2010
Richard F. Storm

The average pulverized coal units in America are about as old - as I have been involved as an adult engineer in this business – and that is over 40 years. Most of the existing coal fleet as Chris Nichols, Phil DiPietro ET al, have summarized in The NETL report prepared earlier this year, operate at an average efficiency of about 32.5% which is a heat rate of about 10,500 Btu's/kWh. The coal fleet, although old, has been pretty well maintained up to the last couple of years, but we are seeing the impact of cuts in operations and maintenance budgets and lack of investment in upgrades to more optimally maintain the existing fleet. Due to the threats of New Source Review (NSR) and anti-coal political correctness of top management, some of the coal fleet is operated at very good efficiency and some is simply mediocre in performance. The best, or top 5%, operate very good thermal efficiencies of about 37% efficiency and heat rates better than 9,500 Btu/kWh. Fair questions are why and what can be done to improve the thermal performance of the average existing coal fleet?



Most of the large units have been retrofitted with SCR's, scrubbers and upgraded electrostatic precipitators and/or bag houses. The focus of billions of dollars in investment has been applied to the back ends of the coal fleet - very responsible and the right things to do for clean coal plants. However, all of this equipment does nothing for thermal performance. It simply increases the parasitic auxiliary

power and in effect, reduces the net thermal efficiency of the plants. Let's look at some of the most common opportunities to improve thermal performance:



We call these stealth losses or stealth opportunities. The five most common correctable losses are:

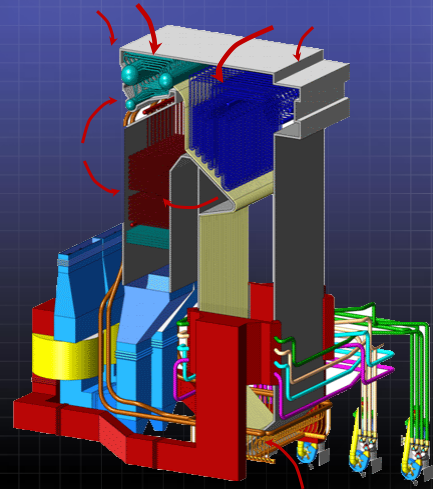
1. Air in-leakage
2. High furnace exit gas temperatures which causes high reheater, desuperheating spray water flows.
3. High primary airflows (especially harmful, is high tempering airflow that bypasses the airheaters)
4. High carbon in ash
5. Steam cycle losses

Other losses associated with a reducing atmosphere in the furnace are: slagging, fouling, increased soot-blowing, and increased fan power due to the fouling and plugging of the SH, SCR's, APH. The increased negative pressure, as a result of fouling, therefore increases air in-leakage. The increased draft losses further exacerbate losses of ID fan capacity and wastes auxiliary power.

The reducing atmosphere in the lower furnace, which is created by air in-leakage downstream of furnace exit, will also contribute to reliability problems such as water wall wastage.

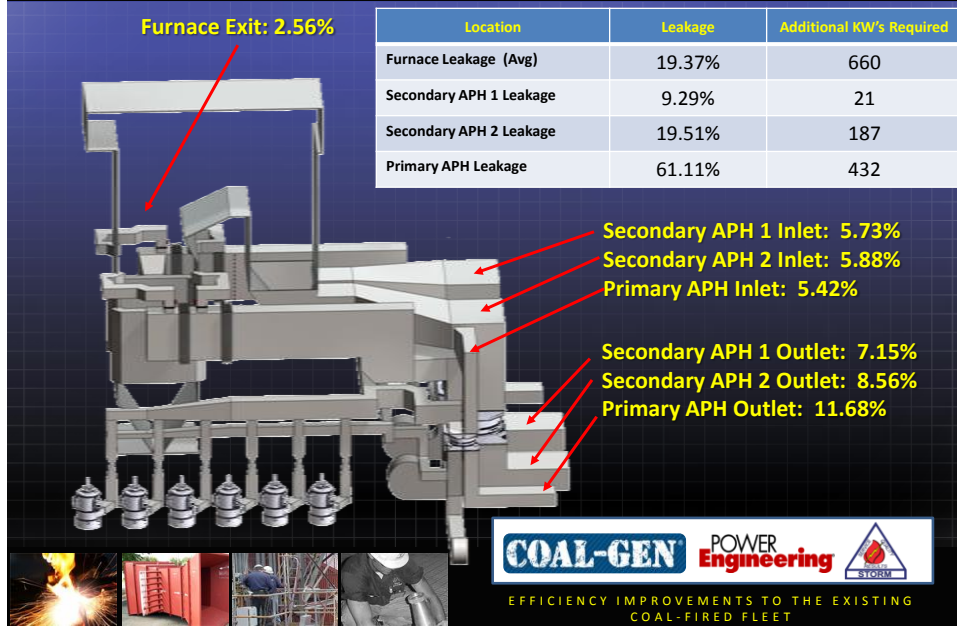
Air In-Leakage

- Penalties due to air in-leakage (up to 300 Btu's/kWh)
- PTC-4 does not take into account. Thus, we call them "Stealth Losses"
- In addition to the thermal penalty, artificially high oxygen readings can have serious performance impacts on good combustion
- Leak path between penthouse and air heater inlet gas
- Bottom ash hopper seals
- Air heater leakage and penalties



The number 1 problem in my experience, that is correctable, is air in-leakage of the convection pass. This stealth loss on 40+ year old boilers is almost a standard expectation for our test teams to find. Worse yet, if an ASME PTC 4.1 heat loss method efficiency test is run, the air in-leakage can be missed because the heat losses method of testing is based on calculating the efficiency losses per pound of as-fired fuel, based on flue gas chemistry and fuel analyses. All of the oxygen in the flue gas at the air heater inlet is "assumed" to have been admitted to the boiler through the burners. That is, when the heat loss method of calculating losses per pound of as-fired fuel is utilized.

Tracking Oxygen in the Boiler



I asked one of our engineers to look back on some past reports to get some actual numbers. This shows high leakage rates but really we have tested worse such as 600 mw units that have 35 year old Rothemuhle air heaters. Air heater leakage is mostly a fan power loss. But when the cold end of the air heater is maintained with additional heat from steam coil air heaters to keep the cold end above the acid dew point, then it becomes an efficiency loss equal to about 1% in efficiency for every 35°F of corrected to no leakage temperature at the APH exit.

An approximation of unit heat rate penalty for air in-leakage of up to 20% equivalent ambient air, is over 300 Btu's/kWh in heat rate penalty. Utility boilers built in the 1960's and 1970's were designed for zero air in-leakage and nearly no one ever expected the air in-leakage to reach double digit values.

How Can You Identify Air In-Leakage?

- Obtain good reliable, representative flue gas analyses and then calculate the X-ratio
- Perform oxygen rise testing from furnace to ID fans
- Monitor the stack CO₂ or O₂
- Combine the intelligence and conditions found of boiler inspections with test data, X-ratios and experience.

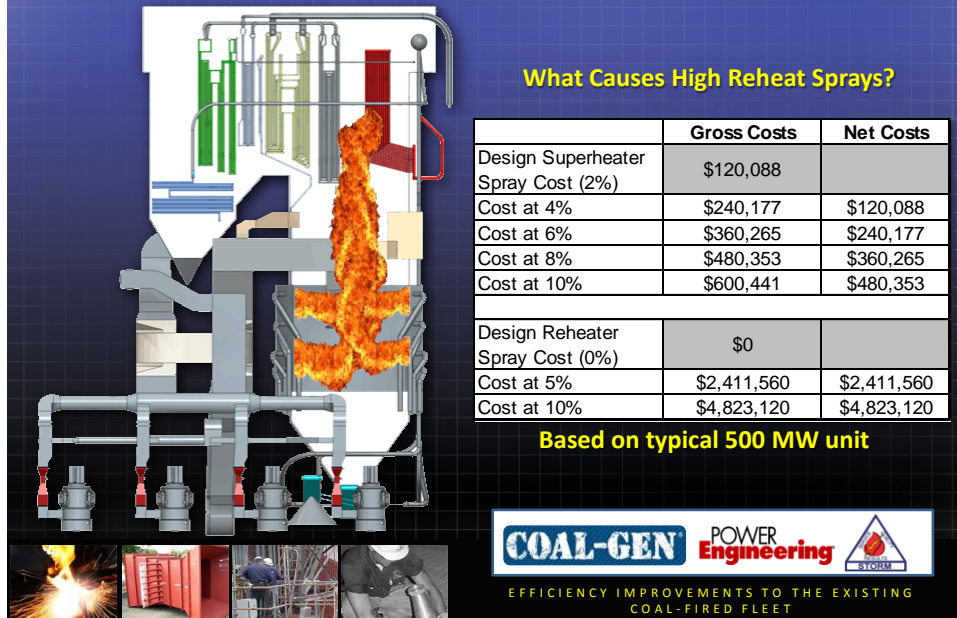


How Can You Identify Air In-Leakage?

Joe Nasal, Richard Des Jardins and their associates at General Physics have focused on monitoring “X” ratios. This is the ratio of flue gas to combustion air of the air heaters, one good method of identifying air in-leakage. However, representative and accurate instrumentation is required.

- The method we employ most is oxygen rise testing from the furnace to the ID fans.
- Monitor the stack CO₂ or O₂. In a perfect world of minimal leakage, the stack oxygen would be about 4.5-5%. In the real world, stack oxygen is often over 8%.
- Combine testing, operating data and internal inspections. Apply performance driven maintenance. Often we see performance engineers and maintenance engineers in different compartments or silos of responsibility, or mindset.

What Causes High Reheat Sprays?

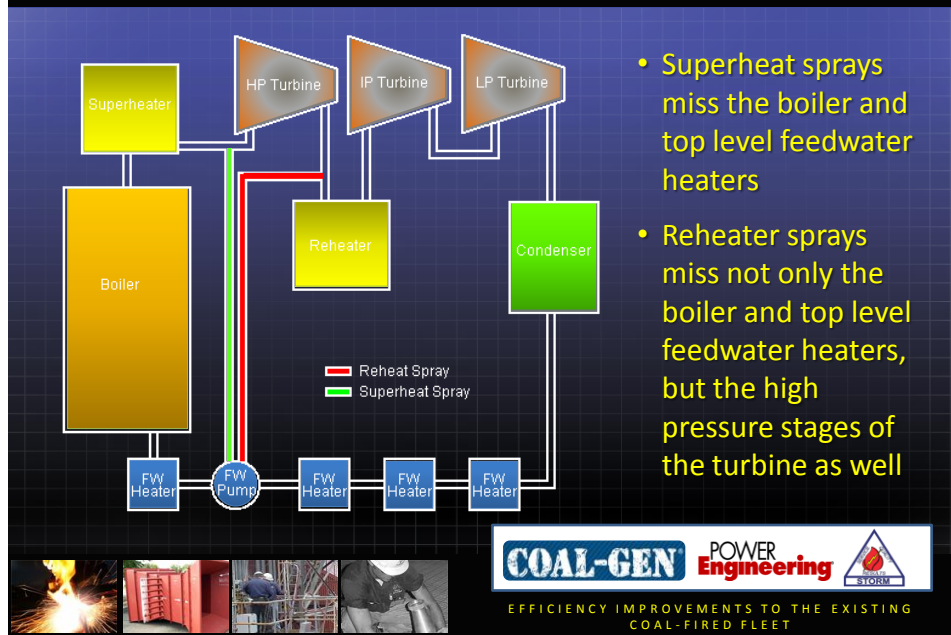


What about high RH sprays? What causes them? Basically 5 factors or a combination of these:

1. Low NO_x burners and secondary combustion
2. Insufficient furnace oxygen
3. Slagged furnace water walls
4. Fuel changes from the original design fuel
5. Non-optimized burner belt combustion

We have actually seen and tested non-optimal combustion, as illustrated in the slide above. Note the active flames entering the superheater. We have seen the difference between “optimized” (no flames in SH) and non-optimized (flame carryover into the SH) result in 1,000°F difference in flue gas temperatures with flame carryover. Truly, about 2,100°F with no flame carryover or 3,100°F with secondary combustion.

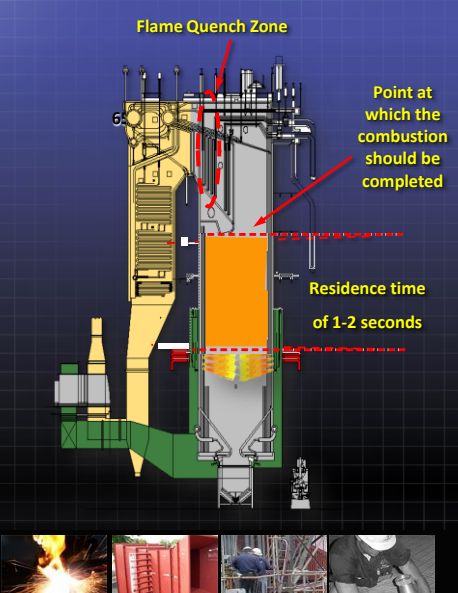
Typical Spray Paths



Why is RH spray harmful to efficiency? The feedwater simply bypasses the top FW heaters and the high pressure turbine. The portion of steam evaporation in the reheater on a pro-rated basis is like a steam cycle at 700psi throttle pressure. It is like regressing into 1920's power generation as Thomas Edison used steam in the early decades of the 20th century.

Reheat sprays, with much higher than design flue gas temperatures, can create an opportunity to generate peak power. If the plant is boiler feed pump limited, then reheat sprays are a way to increase output by increasing steam mass flow through the IP and LP turbines. This is an inefficient method of increasing turbine output.

High Carbon in Ash





Flame Quench Zone

Point at which the combustion should be completed

Residence time of 1-2 seconds

When flames carry over into the superheater, the tubes quench the flames causing the combustion of carbon to stop



COAL-GEN POWER Engineering 

EFFICIENCY IMPROVEMENTS TO THE EXISTING COAL-FIRED FLEET

High carbon in ash – basically – flame quenching in the SH and RH. It has consequences beyond the carbon losses (i.e. soot-blowing, cinders plugging SCR's + APH's, RH sprays, metals overheating).

“Good Combustion” LOI

- Benefits of good LOI
 - Improved heat rate
 - Indicative of “Optimum Combustion” (If LOI is good, so must combustion!)
 - Flyash utilization for concrete
 - Less sootblowing
 - Less cinders (popcorn ash to plug SCR and APH)



COAL-GEN POWER Engineering 

EFFICIENCY IMPROVEMENTS TO THE EXISTING COAL-FIRED FLEET

Good LOI: Heat rate, flyash utilization on concrete additive less sootblowing, less cycle losses, less cinders, less fouling.

High Carbon in Ash

- Example

- The worst measured LOI for a plant we have conducted business with was 35.88%
- This was an efficiency penalty of 4.71% (Higher than the dry gas loss)
- A simple classifier change brought the LOI and efficiency penalty down to 20.7% and 2.19% respectively.

Fuel Type	Good	Average	Poor
Eastern Bituminous	< 5%	8% - 12%	> 10%
Western (Lignite / PRB)	< 0.2%	0.2 – 0.7%	> 1%

- Typically only flyash LOI is measured, but it is important to account for potentially high bottom ash LOI as well.
- Bottom ash usually accounts for 5% to 20% of the total chemical ash remaining.



EFFICIENCY IMPROVEMENTS TO THE EXISTING COAL-FIRED FLEET

High carbon in ash: good combustion w/PRB 0.1-0.2% LOI, good combustion bituminous 3-5% LOI. It is hard to get good in furnace combustion for low NO_x and low LOI's also.

High Primary Air Flows and What it Means for Heat Rate

- Lower X-Ratios and gas side efficiencies are penalties of the dry gas loss

	Good	Average	Poor
Gas Side Efficiency	> 62%	52% - 58%	< 50%

- Usually contributes to long flames, higher furnace NO_x production and increased slagging of the upper furnace
- Wear is increased of coal piping and burner nozzles
- Increased slagging, increased sootblowing to clean SH and RH leads to increased cinder production which then creates air heater and SCR fouling, increased draft losses, increased fan power consumption and steam cycle losses for the increased soot blowing.



EFFICIENCY IMPROVEMENTS TO THE EXISTING COAL-FIRED FLEET

Another “Stealth Loss”

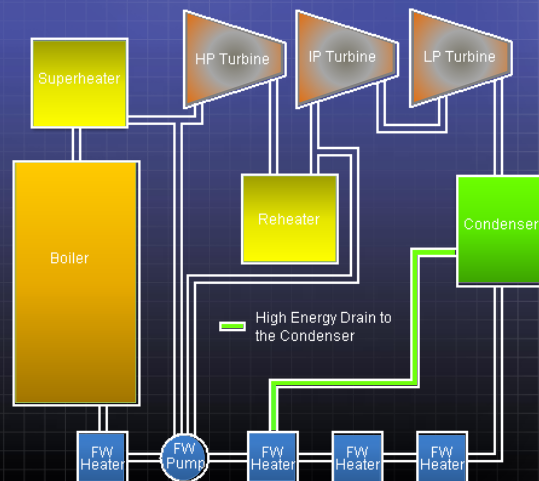
- Steam Cycle Losses
 - High Energy Drains. Valve leak-by
 - Feedwater Heater Emergency Drains
 - SH and RH high energy drains to blowdown tank or condenser should be checked regularly. Often 100+ Btu’s can be attributed to drain leakages. Especially Reheat drains to condenser



Cycle losses are real – high energy drains, valve leak-by

Steam Side Opportunity Example

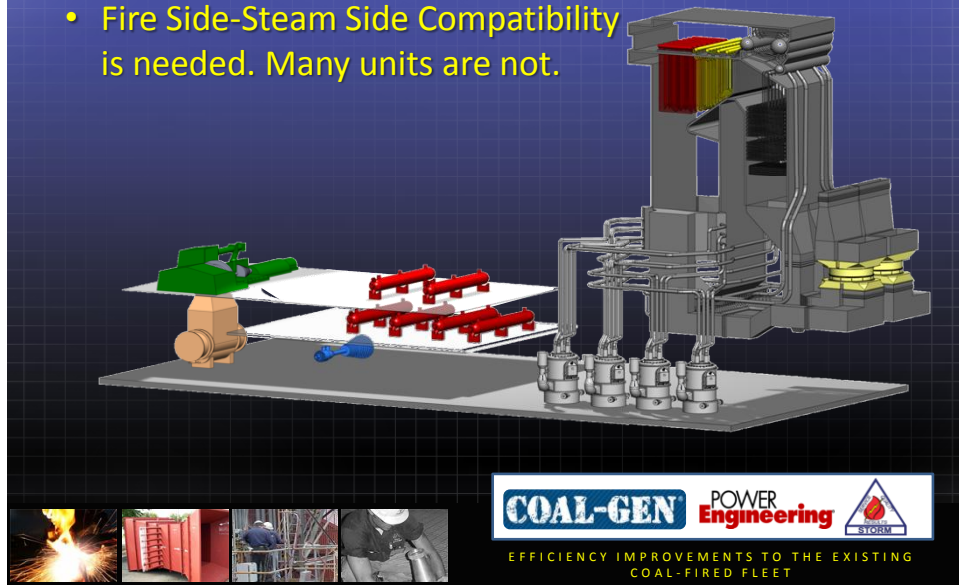
- Approximately 40MW oil electric utility plant limited on load.
- An emergency drain to the condenser was found to be open. When closed, it resulted in an immediate load increase of 3MW (Greater than 7% of total generation capacity!)



Example: On a small island power generating facility, a high level emergency drain to the condenser was found open. This oversight resulted in a loss of over 3MW of the 40MW capacity and a significant heat rate penalty.

How about NSR? Here are a few examples :

- Fire Side-Steam Side Compatibility is needed. Many units are not.



What are some impediments to do the right thing? As a consultant, I often look on, “as a fly on the wall” of high level decision makers, as they commit hundreds of millions of dollars to stack clean up apparatus, and deny a few million dollars that could improve the plant thermal performance. One rational reason for this as ridiculous as it seems, is the EPA and New Source Review. The same people who think that carbon endangers humanity are restricting improvements in thermal performance and the reductions in carbon dioxide by foolish and ill conceived laws. Not to mention that most large plants have SCR’s, sulfur scrubbers and basically most of the same stack flue gas clean up equipment as a new pulverized coal plant. Examples of some “good decisions that were not made” because of the NSR threat:

- Fire side steam side compatibility
- Add RH surface or S.H. surface
- New upgraded boiler feed pumps
- New air heaters to replace old and inefficient ones
- New and upgraded coal pulverizers for increased fineness and better fuel distribution
- New condensers and upgraded tubing
- New more efficient turbine rotors
- New and upgraded feedwater heaters

22 Controllable 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 / Reduced tempering airflow (which bypasses the airheaters)
5. Reducing pulverizer air in-leakage on suction mills
6. Pulverizer throat size and geometry optimization to reduce coal rejects and complement operation at lower primary airflows
7. Secondary airflow measurement and control for more precise control of furnace stoichiometry, especially important for low NOX 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 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 flows
9. High de-superheating spray flow to the superheater
10. High de-superheating spray flow to the reheater
11. High air heater leakage (note: Ljungstrom regenerative airheaters should and can be less than 9% leakage)



Operations and Maintenance Controllable Heat Rate Factors

Here, in the slide above and the next slide, are 22 - controllable at the boiler through best practices of performance driven maintenance. Amongst the operations and maintenance controllable factors are:

- Air in-leakage
- Flyash LOI
- FEGT (Furnace Exit Gas Temperature)
- S.H. and R.H. Sprays
- 13 Essentials to burner belt
- First identify the problems and then correct them!

22 Controllable Heat Rate Variables

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 NOX 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 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 hotwell
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



What can you do? Here are some suggestions:

- Train the O&M Staff in the basics of what can be gained by attention to small factors, such as airflow management, reducing air in-leakage and monitoring excess oxygen levels through the boiler and ductwork to the stack.
- Combine Performance Testing with Maintenance Planning, we call it “Performance Driven Maintenance”
- Convince management to push back on foolish NSR rules, get support from friends. NSR is a problem for improving efficiency of the fleet of old coal plants and serves no purpose anyway with most units that have been upgraded with stack clean up systems anyway.



What can you do?

1. Train the O&M Staff
2. Combine performance testing and maintenance planning, obvious but often overlooked, don't put performance & maintenance people in different silos
3. Educate your friends and the public on the importance of coal for America's future

4. Encourage your friends to write your congressmen and senators to push back on out of control radical environmental anti-coal laws and rules
5. Keep America strong – support Coal Power!

Thank you very much for your time and participation at this conference. I would like to acknowledge and say thank you to my associates who prepared the data and slides used for this presentation. The data is a result of nearly all of the Storm Technologies, Inc. team. The slides and data for this presentation were prepared by Nhia Ly and Stephen Hall.

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