STORM TECHNOLOGIES, INC
411 Depot Street, PO Box 429; Albemarle, NC 28002-0429
Phone: (704) 983-2040 • Fax: (704) 982-9657

July 8, 2015

Discussion of EPA 111 d
Improving Coal Plant Heat-Rates
By Dick Storm
RMEL Plant Management Meeting
Kansas City, Kansas

Introduction

The EPA released the Clean Power Plan in June 2014. As part of this rule they have included expected improvements in efficiency for the existing coal fleet. The expected improvements as written in the EPA documents is 4% by operational improvements and 6% with "Upgrades". My discussion today is to review both the "Operational" improvements and some ideas to consider for "Upgrading".

The USA coal fleet average heat-rate is in the range of 10,500 Btu's/kWh. The thermal efficiency of a 10,500 Btu/kWhr heat rate is 32.5%. The best supercritical plants such as Iatan #2 or Turk can achieve net heat rates in the range of 8,858 to 9,150 Btu's/kWhr (37.3% to 38.52% Thermal Efficiency). The average 2,400/1000/1000 degree F. plants with FGD and full environmental auxiliaries when tuned for optimum can achieve about 10,000 Btu/kWhr heat rate.

The margin between the "average coal plant" and a Net 10,000 Btu's/kWhr Heat-Rate is about 5%. The study by Sargent and Lundy and the EPA have therefore concluded that the improvement potential of 4% by operational changes is possible. I have published articles myself that show this to be true. The very large "But" is, today's normal operations are different than the conditions the plants were designed to operate. Most of the existing coal fleet was designed and built in the 1970's and 1980's for "Base Load" operations. Today we have "Must Run" renewables and nuclear plants. Then there is the inexpensively fueled, fast starting Combined Cycle natural gas plants that add even more competitive pressure for large coal Units.

Additionally there is changing electrical demand from an America that once was a strong manufacturing nation. Now a loss of much of the industrial base load for producing aluminum, copper and steel manufacture, combined with losses of other heavy manufacturing has reduced the 24/7 electricity demand. Much of this base electrical load demand for manufacturing has been lost to overseas competition. Especially manufacturing increases in China. The result is, electric load for a lot of utilities is now more commercial and residential demand. This compounds the challenges for operations to optimize "Best Heat-Rate" operations. Current more cyclic operation and lower capacity factor operations are normal. The capacity factors will become worse in the Fall and Spring as air-conditioning and heating requirements are lessened with mild weather. All of these factors combined, create an enormous problem of achieving a better average heat rate, because of the way that plants designed for base load operations are being operated at low loads and even cycled off on the weekends. All of these factors are beyond the scope of my expertise or influence; I just state the operations production and demand issues so that you know that I feel your pain.

Now, having addressed the systemic problems of achieving best heat rates and approaching design heat rate capability, let's move on to what we can do both by excellence in operations and maintenance improvements and by implementing upgrades to the existing plants. I will cover both.

Realizing that there are limits as described in the foregoing, due to the overall Grid operation, I believe the improvements in heat rate are about 2% potential, not 4%. If "Base Load" operation was to be a reality, yes we could find 4%. Throw out New Source Review and apply mechanical "Upgrades" and maybe even 6% improvements in heat rate could be realized.

My talk is about making the best of coal plant operations, in an environment that is not so friendly due to regulatory and competitive pressures.

The current situation is challenging, but there are some improvements that can be realized by applying excellence in Operations and Maintenance.

Today's Presentation:

Beyond The Plant Fence Coal Plant Heat-Rate "Challenges"

- Low Natural Gas Prices Creating a Gas First Dispatch which then causes….
- Low Capacity Factor Operation as a Result of Lower Cost Gas First and then "Must Run" Renewables and Nuclear Units
- Cycling which Creates Startup Losses
- Air Heater Fouling from Operation at Low Loads and Especially, Low Night Load Demand
- Low Steam Temperatures at Reduced Loads
- Slagging and Fouling from Burning the least cost fuels

411 North Depot Street
Albemarle, NC 28001
Office: 704.983.2040

EPA Document; Excerpt 111 (d)

1. BSER Factors Informing State Emission Rate Goals

(BSER = Best System Emission Reduction)

- The GHG Abatement Measures TSD describes the four categories of emission reduction measures (building blocks) used in determining the state emission rate goals. That document describes EPA's historic data review and analysis underlying each technology and informing EPA's assessment of its feasibility and cost-effectiveness as part of a BSER. The technology estimates determined through EPA's analysis and documented in the GHG Abatement Measures TSD are summarized below. These estimates are used in EPA's calculation of state emission rate goals, as described in this TSD.
- Heat Rate Improvement
  Proposed ----- 6% Heat-Rate (includes, **"Upgrades"** ?)
- Alternative -- 4% Heat- Rate (**"Operational"** Improvements)

411 North Depot Street
Albemarle, NC 28001
Office: 704.983.2040

The expectations for Heat-Rate improvement are 4% by O&M improvements and 6% by implementing “Upgrades”. I will discuss upgrades and New Source Review later in the presentation. So, where did the EPA get the idea that 4-6% Heat-Rate improvements are possible? Here are a couple explanations.

EXAMPLE OF RANGE OF “BEST HEAT-RATES” (EL&P)

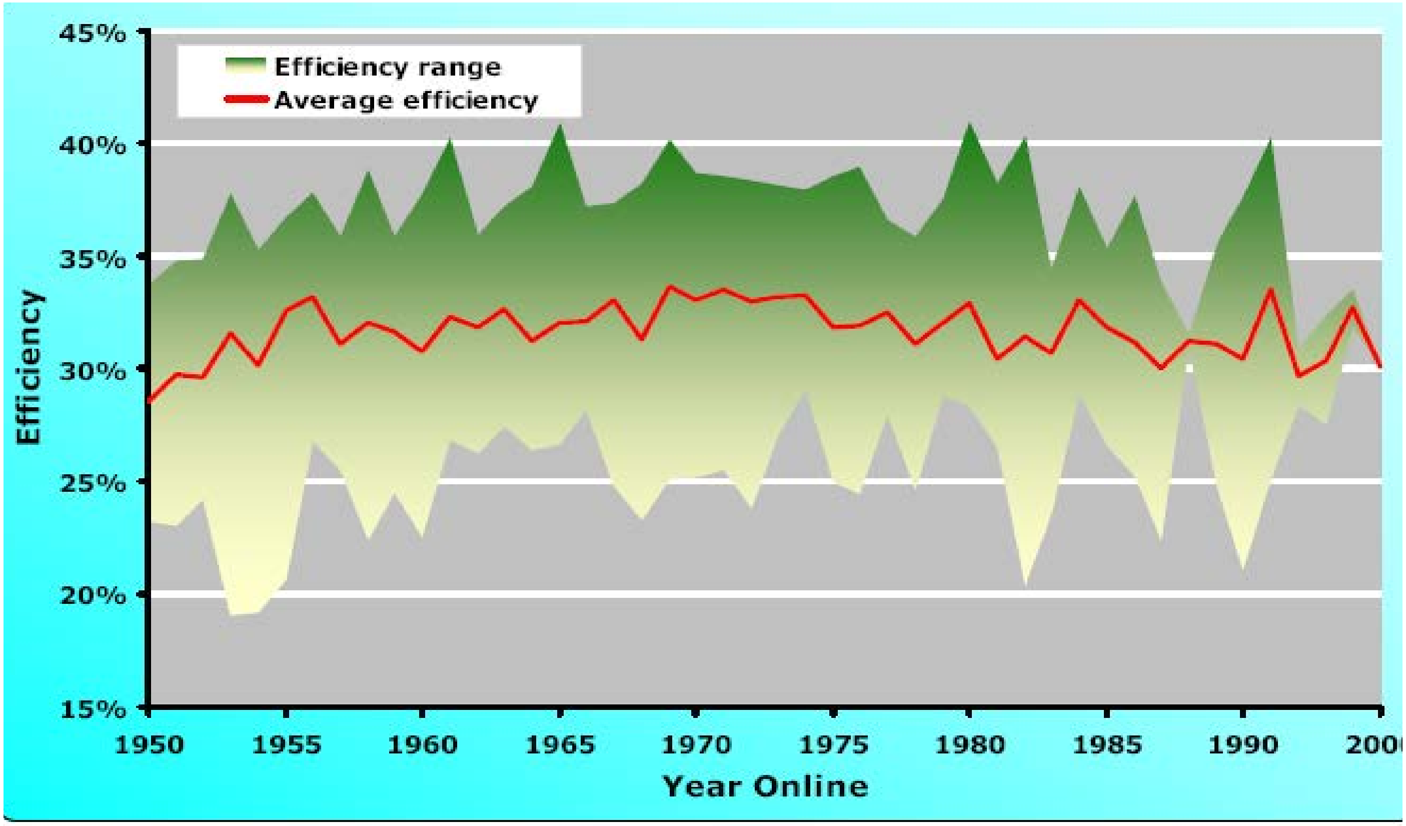
Table 3: Top 20 Coal Ranked by Heat Rate (2013)*

Rank	Owner/Operator	Plant	State	Capacity MW	Generation GWh	Capacity Factor	Fuel Consumption mmBtu	Heat Rate mmBtu/MWh	2012 Rank
1	AEP	John W. Turk Jr.	AR	609	3,846	72.1%	34,069,108	8.858	
2	First Reserve Corp.	Longview	WV	700	4,457	72.7%	40,623,185	9.115	1
3	Great Plains Energy	Iatan 2	MO	881	6,042	78.3%	55,152,398	9.128	
4	LS Power Group	Sandy Creek	TX	939	3,366	40.9%	30,806,238	9.151	
5	Duke Energy Corp.	Belews Creek	NC	2,270	12,536	63.0%	114,913,240	9.167	2
6	Duke Energy Corp.	Cliffside	NC	1,381	6,220	51.4%	57,064,445	9.174	
7	SCANA Corp.	Cope	SC	415	2,446	67.3%	22,481,012	9.192	4
8	Cleco Power LLC	Brame Energy Center	LA	628	4,042	73.5%	37,893,807	9.376	
9	Duke Energy Corp.	Marshall	NC	2,078	8,360	45.9%	79,052,567	9.456	7
10	NRG Energy Inc.	Keystone	PA	1,700	12,455	83.6%	117,876,401	9.464	8
11	WE Energies	Elm Road	WI	1,268	3,351	30.2%	32,085,709	9.576	
12	LADWP	Intermountain	UT	1,800	12,387	78.6%	119,400,452	9.639	
13	NRG Energy Inc.	Conemaugh	PA	1,700	11,760	79.0%	113,575,163	9.658	11
14	Duke Energy Corp.	W.H. Zimmer	OH	1,300	9,362	82.2%	91,014,788	9.722	
15	Xcel Energy Inc.	Valmont	CO	184	994	61.7%	9,669,147	9.724	18
16	SCANA Corp.	Williams	SC	610	3,344	62.6%	32,517,385	9.725	10
17	CPS Energy	J.K. Spruce	TX	1,340	7,536	64.2%	73,363,174	9.735	15
18	GenOn Energy	Avon Lake	OH	710	2,892	46.5%	28,221,235	9.757	9
19	Associated Electric Cooperative Inc.	New Madrid	MO	1,199	8,194	78.0%	80,128,109	9.779	
20	Southern Co.	Bowen	GA	3,232	12,037	42.5%	118,132,826	9.814	
				Total	**Total**	**Average**	**Total**	**Average**	
		Top 20 Heat Rates		24,944	135,627	63.7%	1,288,040,389	9.46	
		EIA Reporting		306,817	1,548,977	57.6%	16,130,063,115	10.41	

*Excludes cogenerating facilities

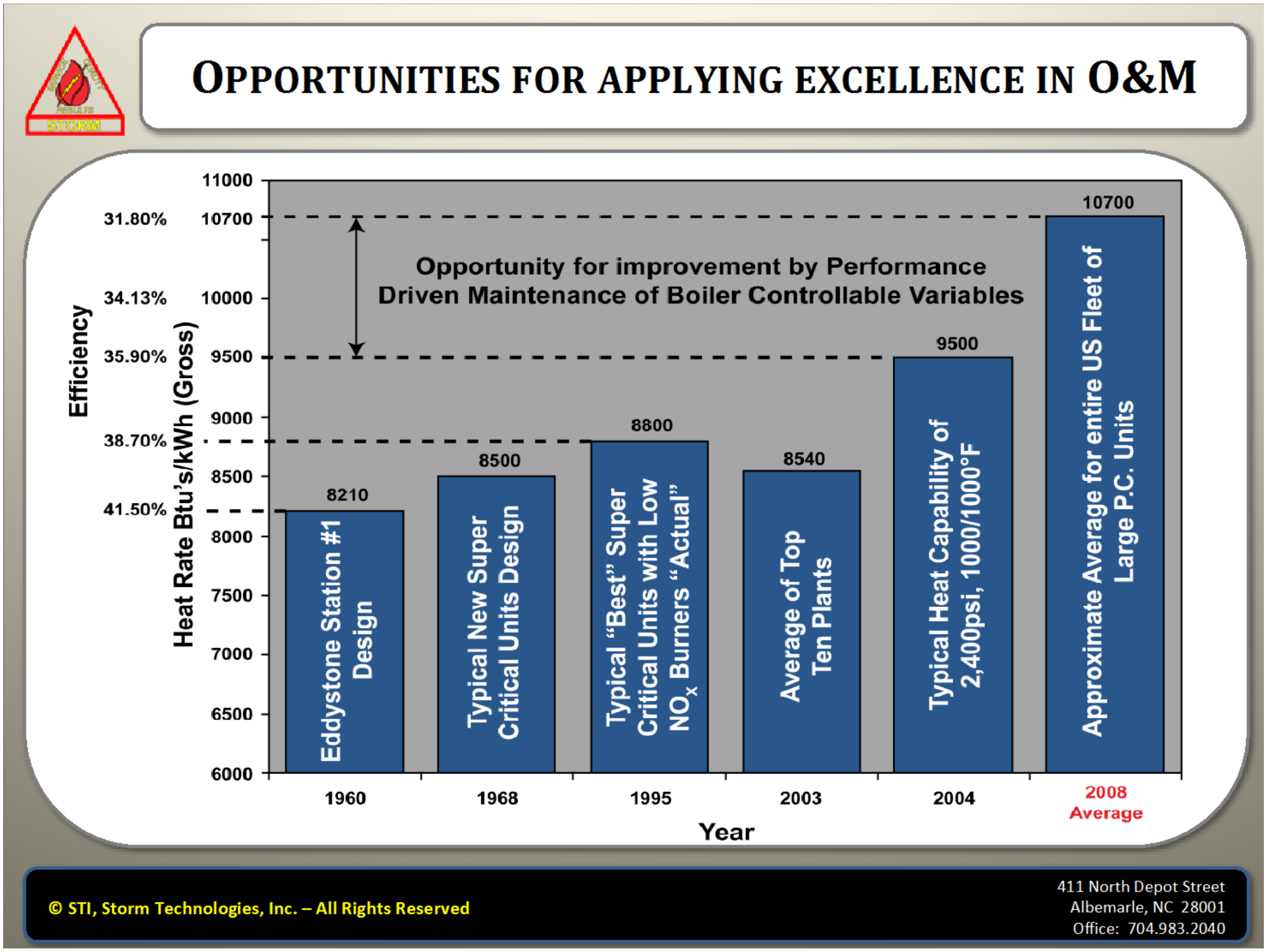
411 North Depot Street
Albemarle, NC 28001
Office: 704.983.2040

The above published “Best Heat-Rates” show very good potential when compared to the best of the best. However, at least two factors are not considered in this reasoning. One, most of the top 20 Unit’s listed above are supercritical units and are fairly new. Also, the load factor of these is higher than average. That is, at least for the year 2013 from which this data is taken.



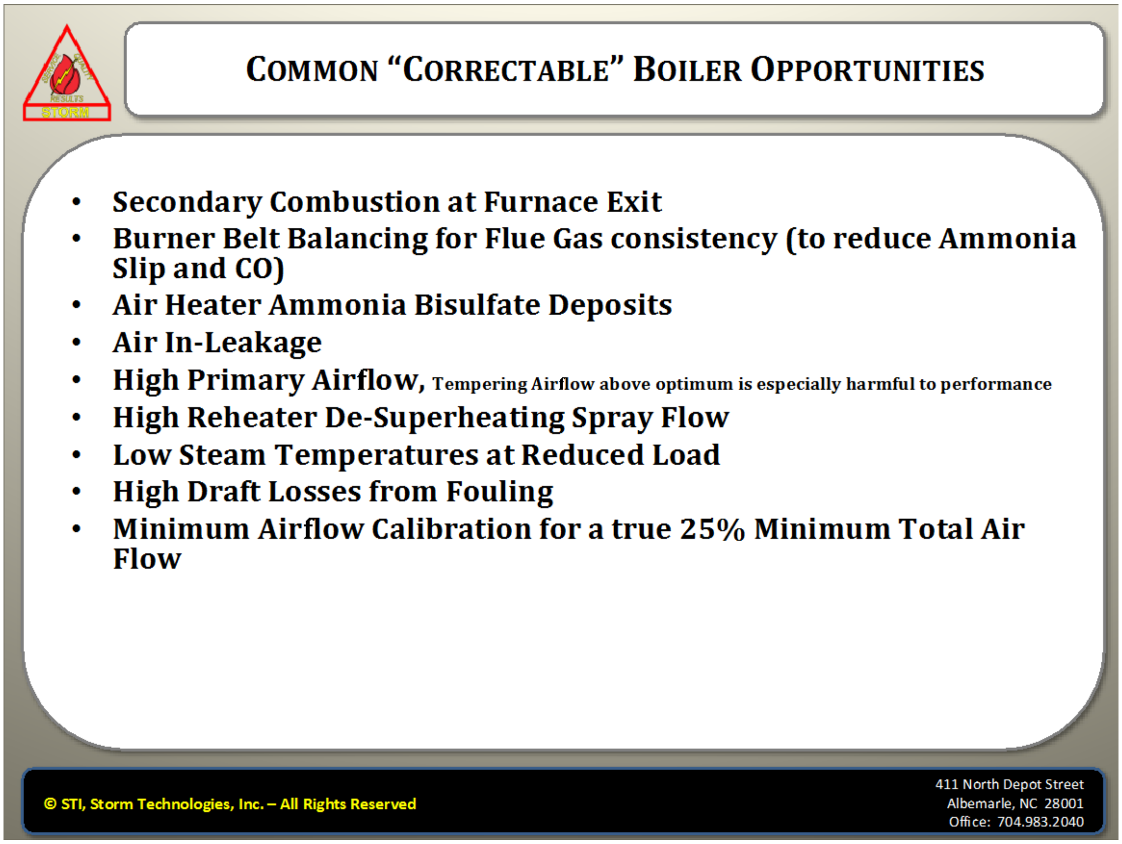
Then there is a study by the National Energy Technology Laboratories that prepared the graph above presenting the overall thermal efficiency range of the best and the worst heat rates from hundreds of coal plants across the USA. Again, the range of highest and lowest is significant and in the range of about 5+%.

An article in POWER Magazine that I co-authored with Dr. Bob Peltier referred to “Stealth Heat – Rate” factors. In that article, it was described that there is about 500-600 Btu’s/kWh heat rate improvement potential in most of the coal plants in America. At the time of the publication, the low cost natural gas, must run renewables and loss of industrial load were not significant factors and were not considered. So, the potential improvements in heat rate by excellence in O&M, was based on the premise of operating the plants at a reasonable capacity factor of say, 70% to show a good potential for improvement.

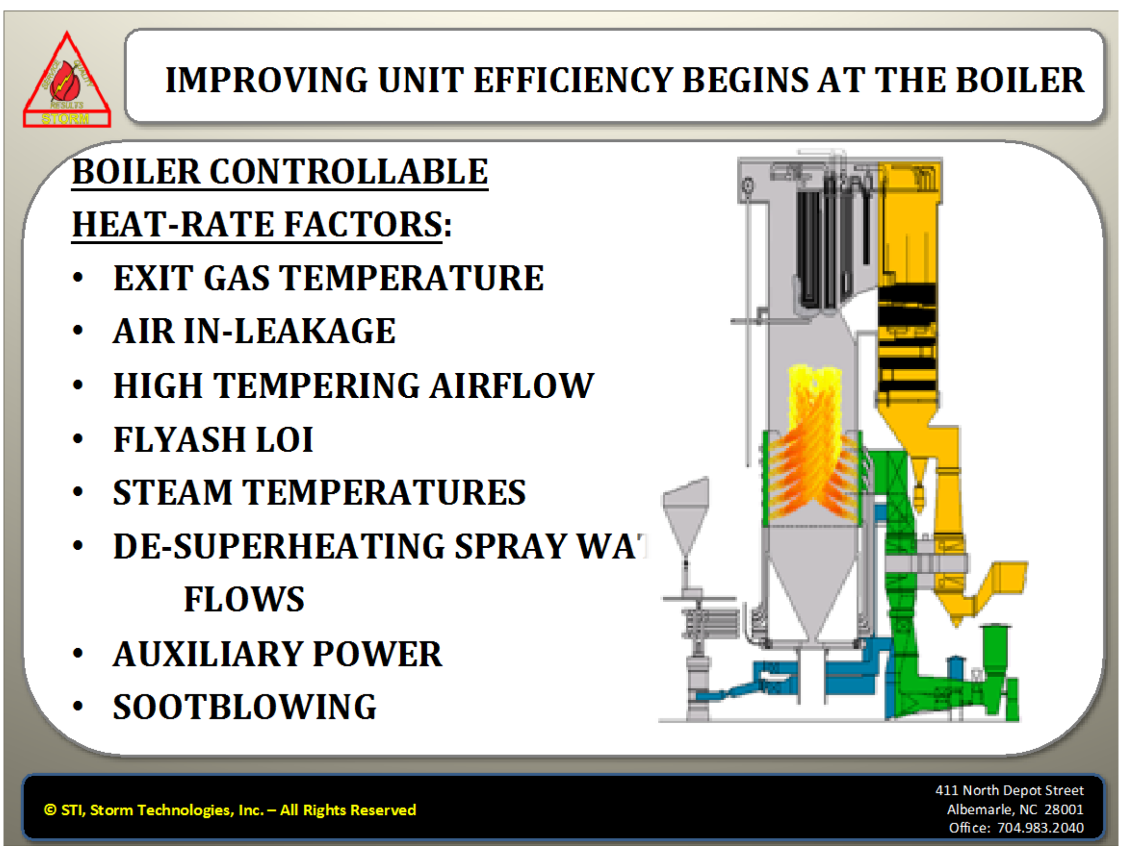


I should also mention that when this was published and the heat rate potential improvement of over 11% is shown, was before many backend environmental FGD and SCR equipment was added. These environmental retrofits significantly raise the parasitic auxiliary power. For 2400 psi/1000/1000 degree F. Units operating at a 70% or greater capacity factor, in my experience about 10,000 Btu's/kWhr is attainable.
Later in this presentation, I will show a case study which shows such an example.

One point I would like to make regarding achieving the "Best Possible" Heat-Rate. That point is, it needs to be a 100% Team effort by everyone on the O&M Team. In other words, a heat rate engineer cannot do it alone. It takes operators being vigilant 24/7. It takes maintenance staffs to support the best heat rate improvements when outage repairs are planned and implemented. It takes Instrumentation and management cooperation on such factors as primary airflow controls and details such as these. For example, the best load response of large coal unit can be achieved with high primary airflow. But, high primary airflow comes at a cost in heat rate penalty. Tuning of the boiler for the best heat rate may not be what the operators believe to be the optimum from a load response viewpoint. This is an example of working as a team makes a difference. Another example is maintenance practices for the longest wear of pulverizer components may not be conducive to best performance. Such as, achieving high coal fineness for best overall combustion efficiency.
Here are some common, correctable heat rate opportunities.



I am a boiler engineer, so you would expect me to address heat rate opportunities at the boiler. Here are some common examples.



"Stealth" O&M Corrections Potential for Best Heat-Rate, Coal Power Magazine, August 2013

Variable	Potential heat rate improvement (Btu/kWh)	Potential annual fuel savings
Boiler and ductwork ambient air in-leakage	300	$819,000
Dry gas loss at the air heater exit	100	$273,000
Primary airflow	75[a]	$204,750
Steam temperature	75	$204,750
De-superheater spray water flow	50	$136,500
Coal spillage	25	$68,250
Unburned carbon in flyash	25[a]	$68,250
Unburned carbon in bottom ash	25	$68,250
Slagging and fouling	25[a]	$68,250
Cycle losses	25	$68,250
All others, including sootblowing and auxiliary power factors	25	$68,250
Total	**750**	**$2,047,500**

Note: a. Interactions between variables will impact meeting this estimate.

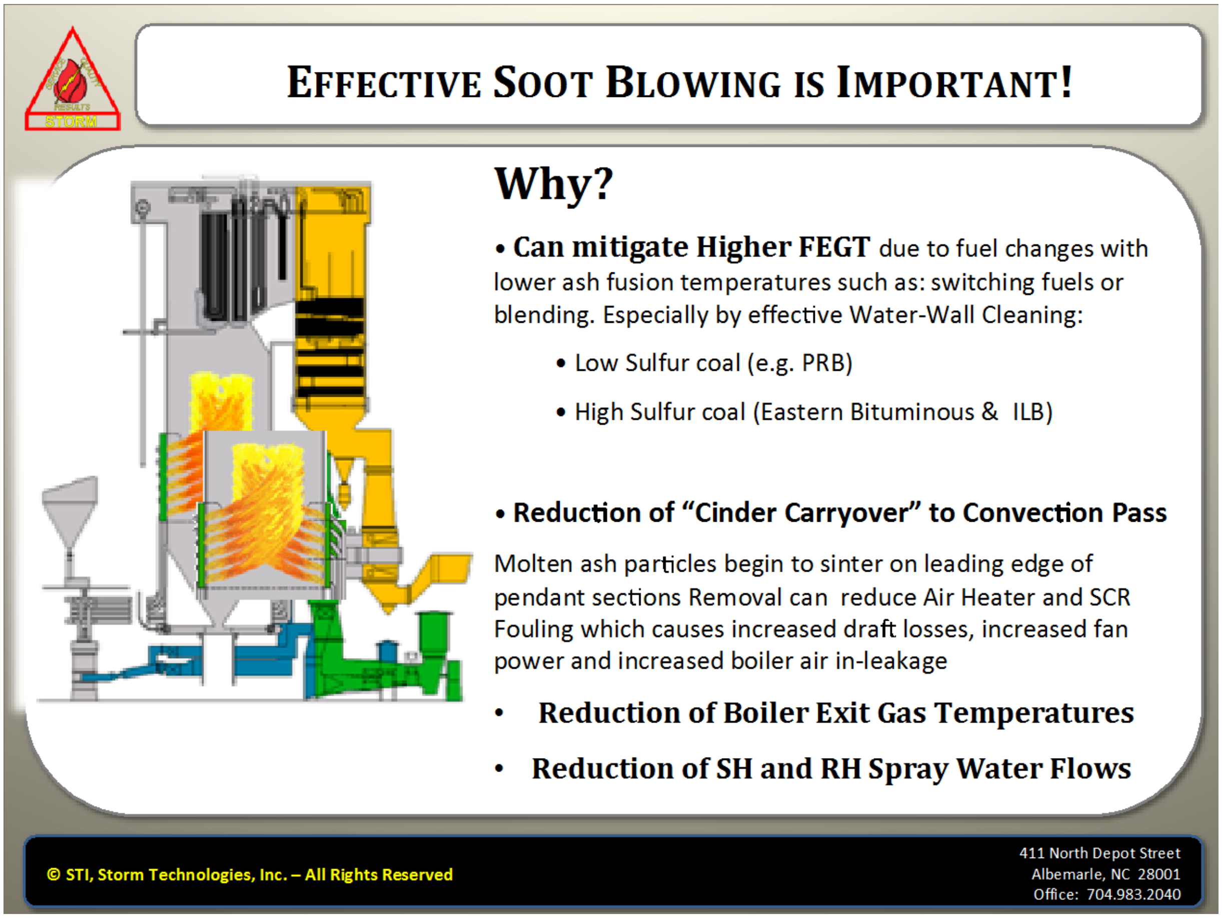
411 North Depot Street
Albemarle, NC 28001
Office: 704.983.2040

This list of potential heat rate improvements was published in POWER and Coal Power magazines. The net total improvements are up to 750 Btu's/kWhr. Of course, the fuel cost savings are significant as well as the CO_2 reductions. These are based on our experience at the time with a normal capacity factor operation. There were no thoughts of cycling or extreme low load operation.

Furnace Exit Secondary Combustion

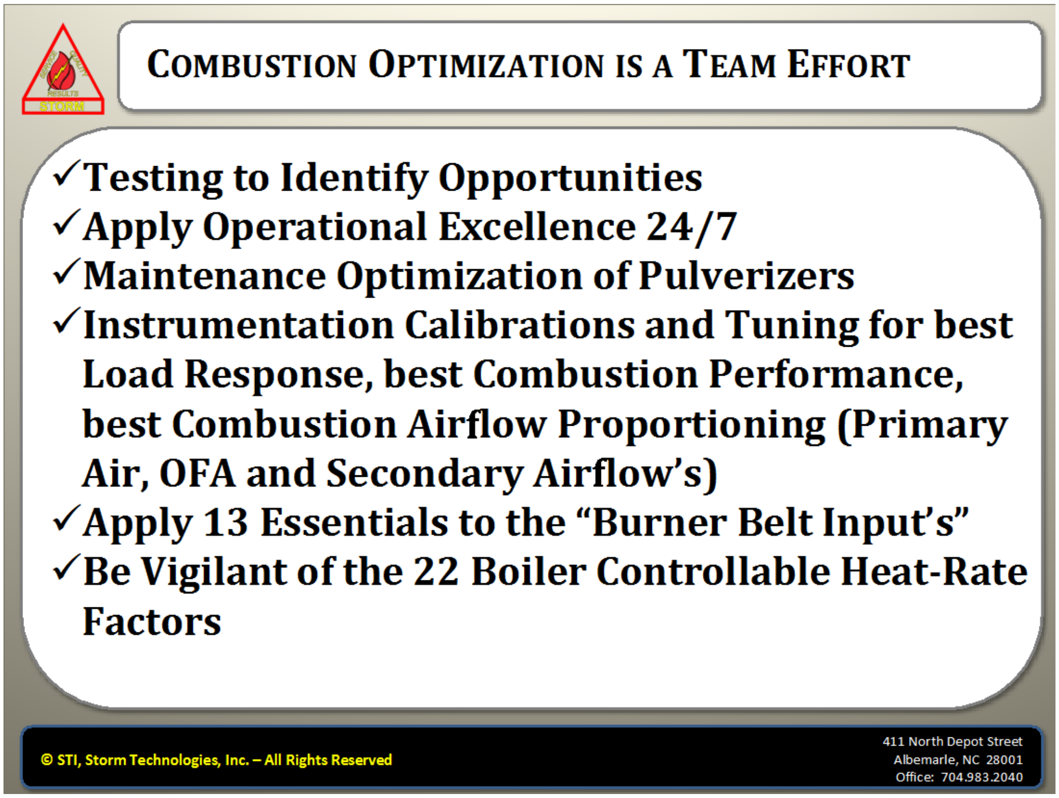
Secondary combustion creates at least ten issues. Most impact the heat rate:

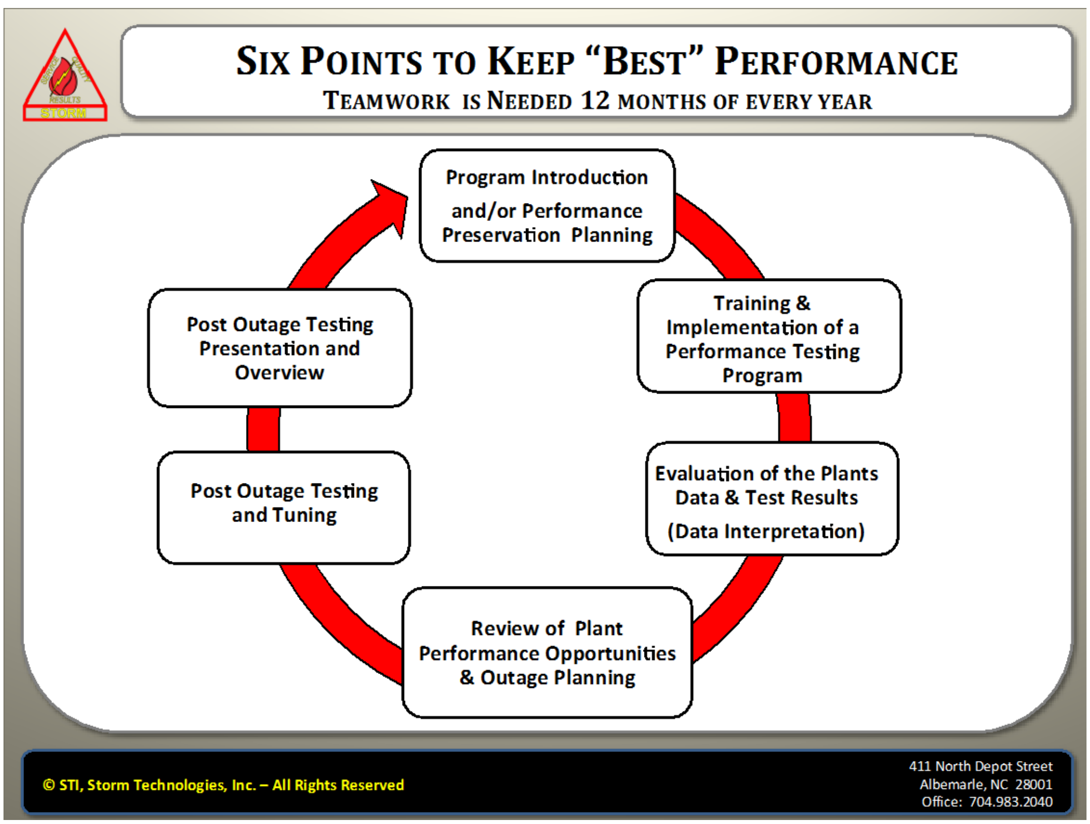
- Slagging and fouling
- Excessive sootblowing and the consequent steam cycle losses
- Cider carryover into the convection pass that contributes to SCR and air heater fouling
- Increased draft losses and the accompanying higher auxiliary power consumption
- Higher than optimum Superheater and Reheater Desuperheating spray water flows
- Increased auxiliary power consumption from the resulting draft losses
- More air in-leakage due to the higher negative pressures of the boiler ducts and convection pass.
- CO emissions
- Increased Ammonia or Urea injection into the SCR's which then create Ammonia slip and ABS deposits in the air heaters
- Reliability is harmed by the sootblower erosion of boiler tubing and also slagging and fouling



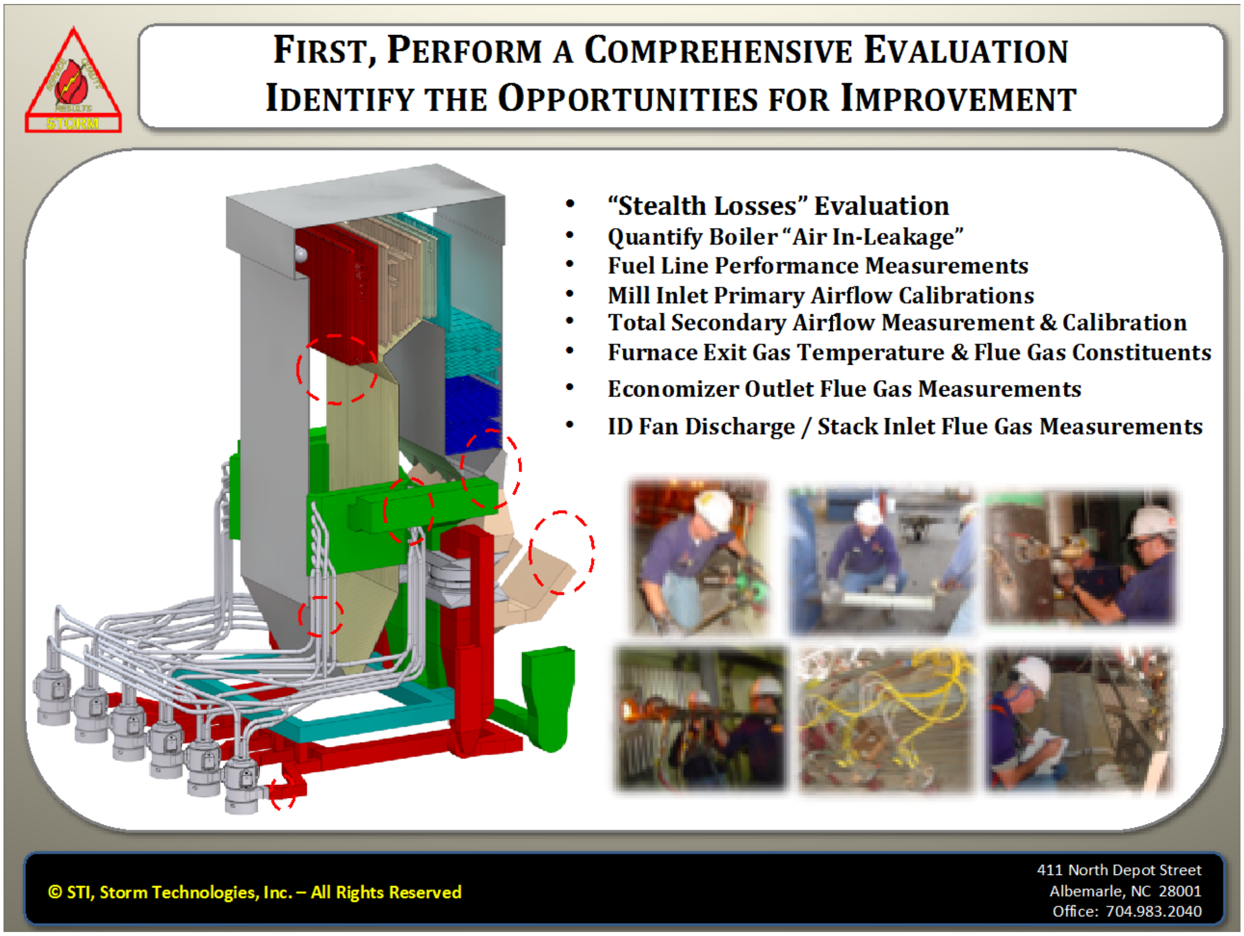
Sootblowing can be referred to as "Reactive" or "Preventive". For example, blowing the long retractable blowers to remove cinders and slag from the superheater is reactive. Cleaning the waterwalls to lower the FEGT (Furnace Exit Gas Temperature) is preventive. Also, waterwall blowers and water lances create less steam cycle heat losses than long retractable blowers. A long retractable sootblower in the high temperature zone of a furnace may use over 10,000 pounds of steam per hour. This loss of high-energy steam represents a significant heat rate penalty.

Keeping the furnace exit gas temperature in the range of 2,000-2,150°F rather than say, 2,700°F can make a huge difference in Unit performance and heat rate. I say this based on experience. We have seen a boiler when optimized, have a FEGT of about 2,150°F. When secondary combustion may be present the flue gases may be well over 3,000°F. It is not an exaggeration to state that the Furnace exit gas temperature peaks may be more than a 1,000 degrees F. above normal when secondary combustion is present.





Teamwork and continuous improvement is required to extract the optimum performance of a large coal plant. I will show a couple examples later of two plants that achieved "Best" then faded into mediocrity as victory was declared and the (employee) contributors to the success were promoted to other positions in the company. In my career I have seen this numerous times. The emphasis is applied to combustion optimization and improvements in operational vigilance and then after a year or two, operations then slides back to normal. Creating a culture of heat rate awareness is a challenge for management. This is especially true today with so many new competitive and regulatory "Dragons" to slay.



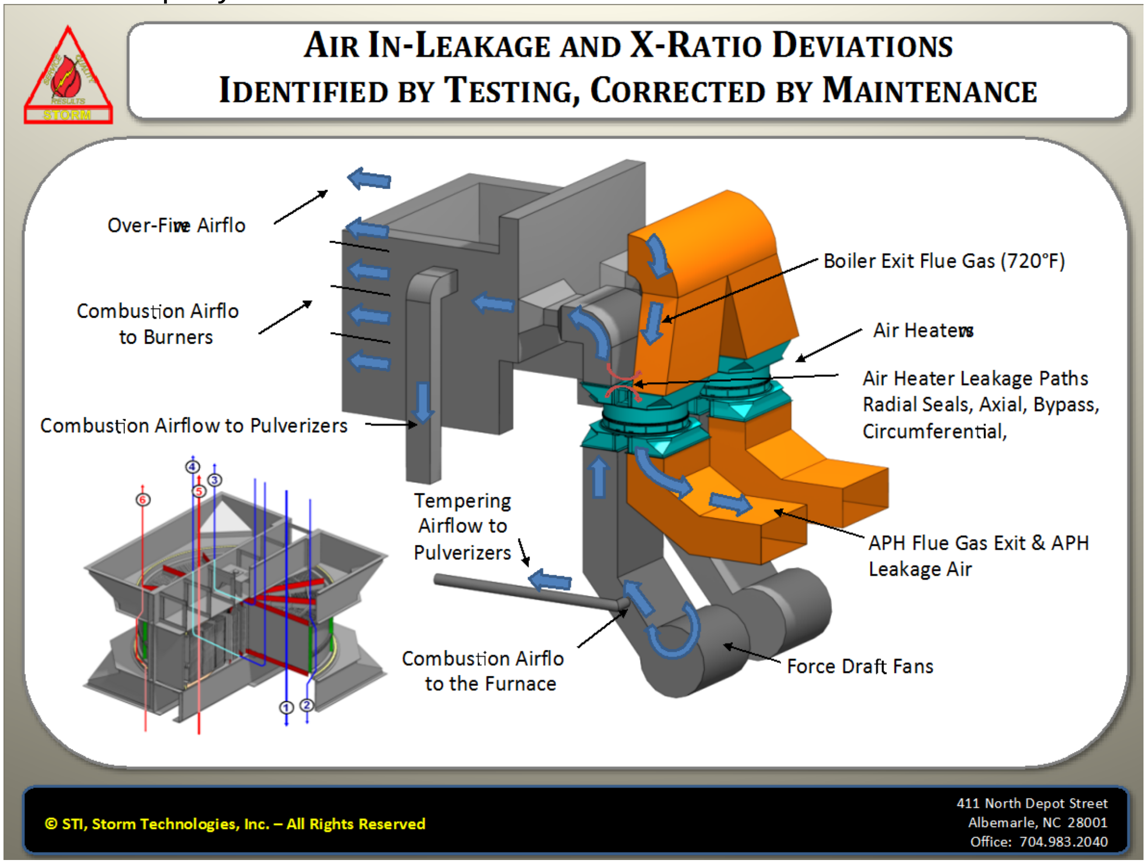
To correct what I refer to as "Stealth Heat Rate Variables," first they must be identified and quantified. Some of identification and quantification of opportunities can be done by accurate, permanently mounted sensors. However, more often than not, the opportunities for improvement must be identified by testing. The largest correctable losses that we have seen are air in-leakage and Burner Belt Optimization of the furnace inputs.

Applying the 13 Essentials is a great start. In 2012 I gave a presentation to RMEL and published a paper entitled, "First: Apply the Fundamentals". This is available on the Storm Technologies, Inc. web site at www.stormeng.com. I will not go over the materials I presented in 2012 considering our limited time today. If I do say so myself, the document has a lot of informative illustrations and details on testing and evaluating the Furnace Burner Belt "Inputs". If you are interested in improving boiler performance, I suggest downloading and studying that document. Of course, you can always call or email any of us at Storm if you have a question.

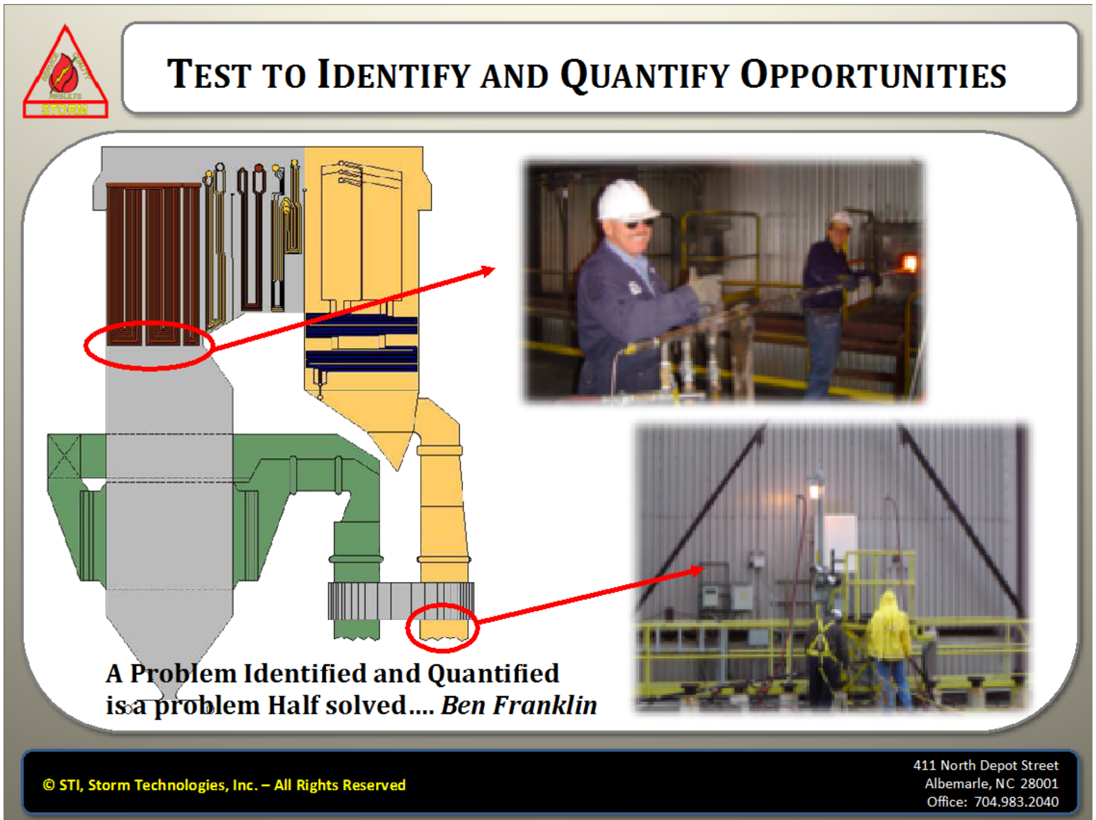
The permanent plant instrumentation can be helpful in providing guidance of the air heater "X-Ratio," and if oxygen sensors are representatively sampling ductwork flue gases, can provide oxygen rise from the Boiler exit to the stack.

Air in-leakage before the air preheaters is a large heat loss and even if an ASME, PTC-4.1 Boiler Efficiency test is run, the leakage will not be detected. Why? Because this test is based on the losses as calculated in percentage of efficiency losses per pound of "As-Fired Fuel" and based on complete flue gas analyses at the air heater inlet's and outlet's. Thus, any air in-leakage upstream of the air heater flue gas inlets, is "Assumed" to have come through the air heater(s) and burners.

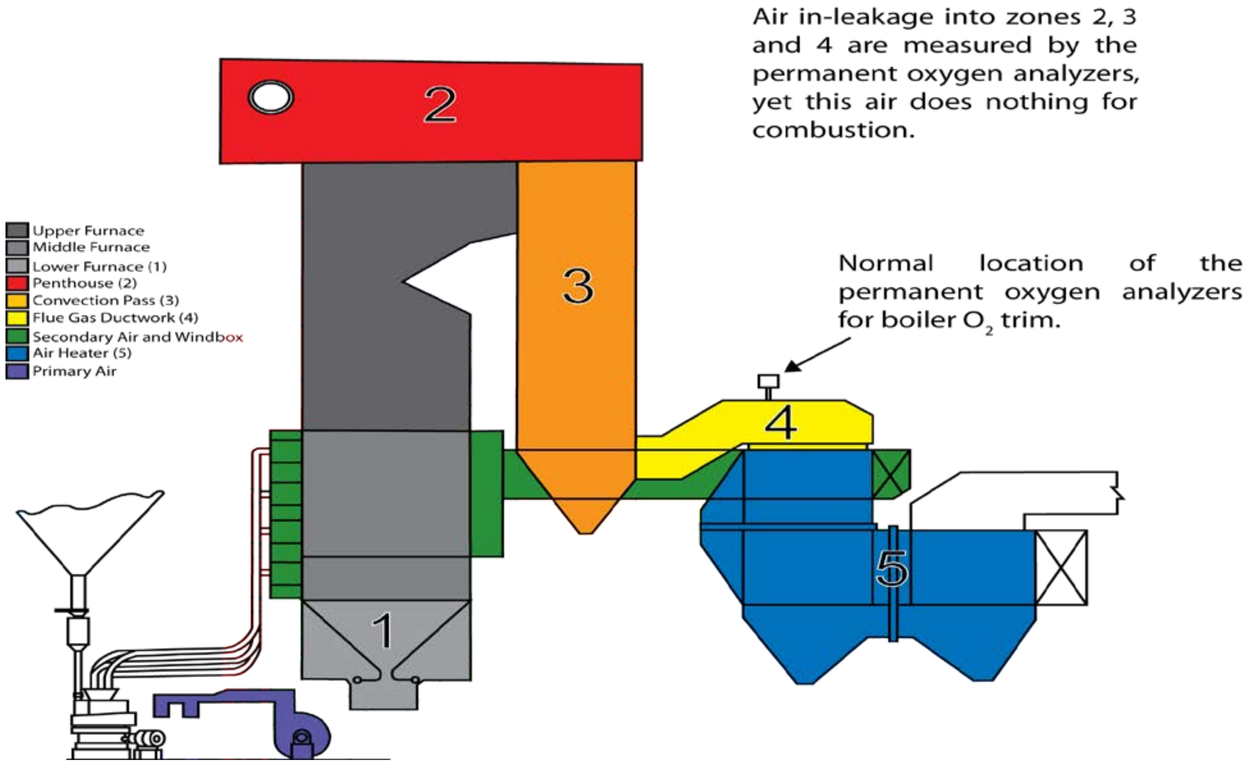
In our experience, it is a good idea to perform a "Comprehensive Boiler Diagnostic Test" at least twice per year.

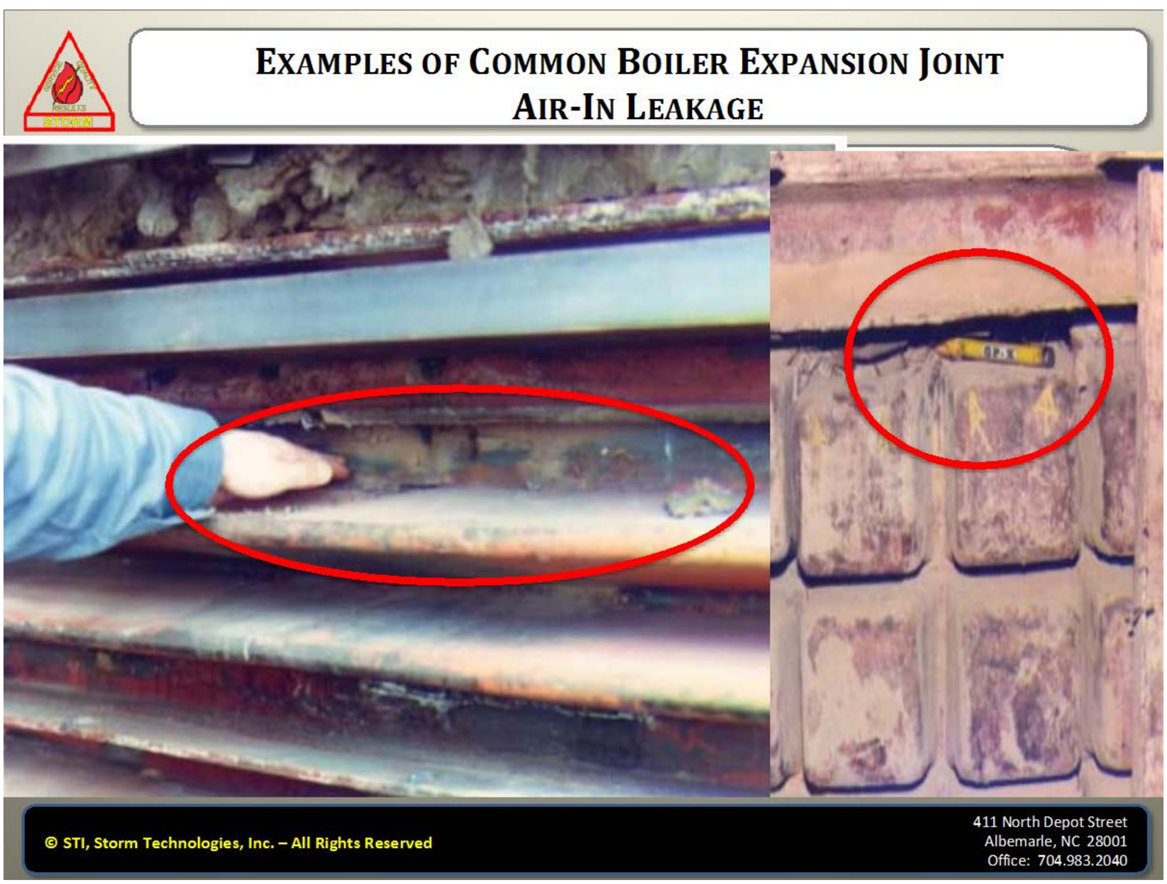


"To solve a problem, first it must be identified". (Ben Franklin). "If you can measure it, you can manage it". (Peter Drucker)



Stealth Heat Rate Loss No. 1: Air In-Leakage

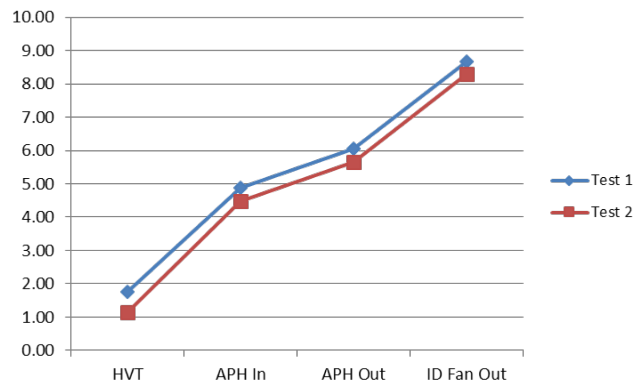


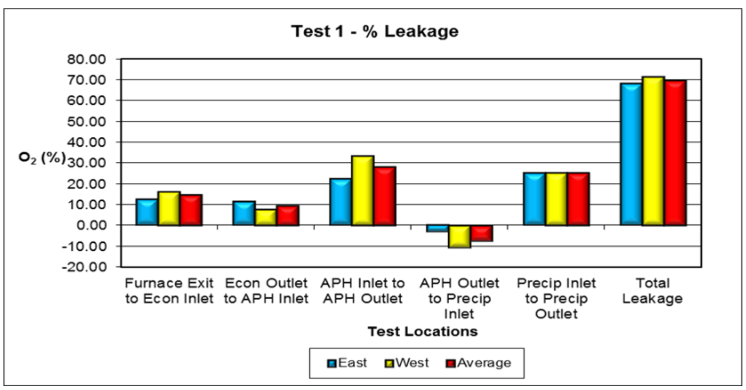


An example of an economizer outlet expansion joint leak. This is a 600 MW sized unit and the air in-leakage that flowed through this expansion joint was in the range of the equivalent of 15% of the total air-flow to the boiler. This would not be discoverable by performing an ASME PTC-4.1 test of flue gas analyses at the air heater inlets and exit flue gas ducts. In fact, we did

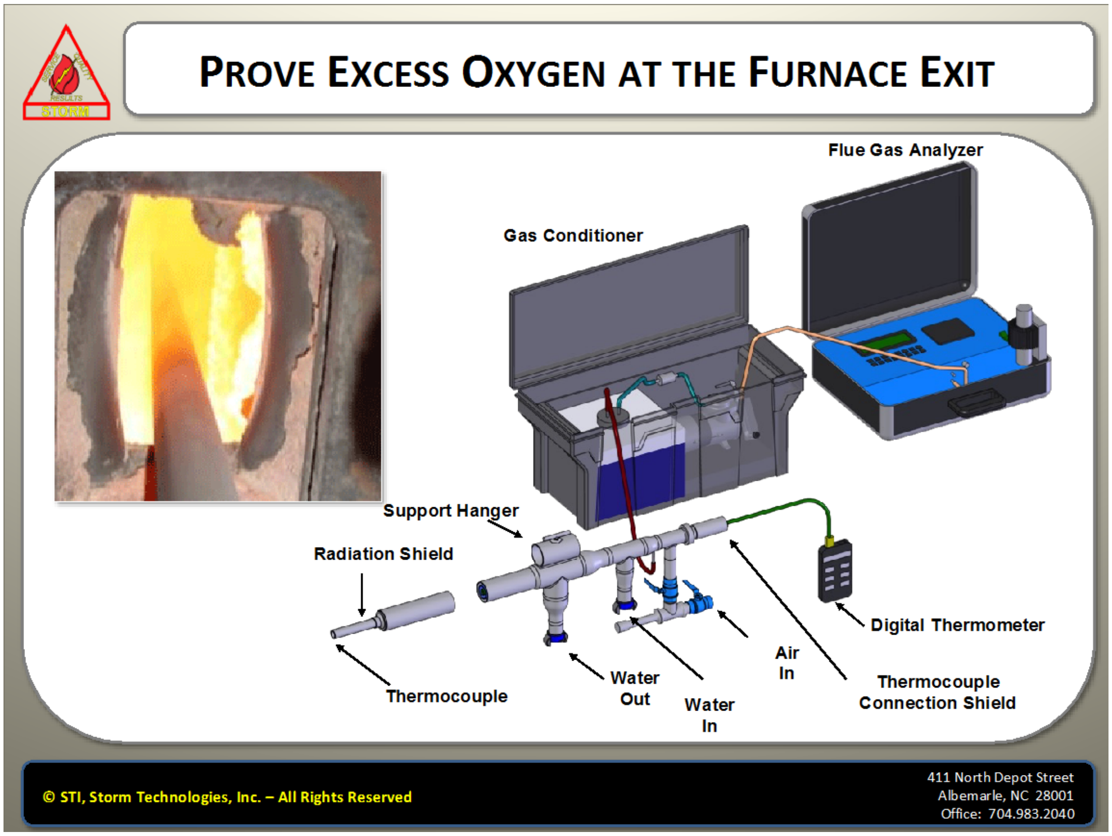
Case Study: Air In-Leakage

These examples show air in-leakage after the furnace exit. The ideal condition of no leakage would leave the O_2 percentage constant. Leaks in the system cause heat losses and thus decrease the system efficiency.





perform Air Heater inlet flue gas traverses and they were very uniformly mixed.

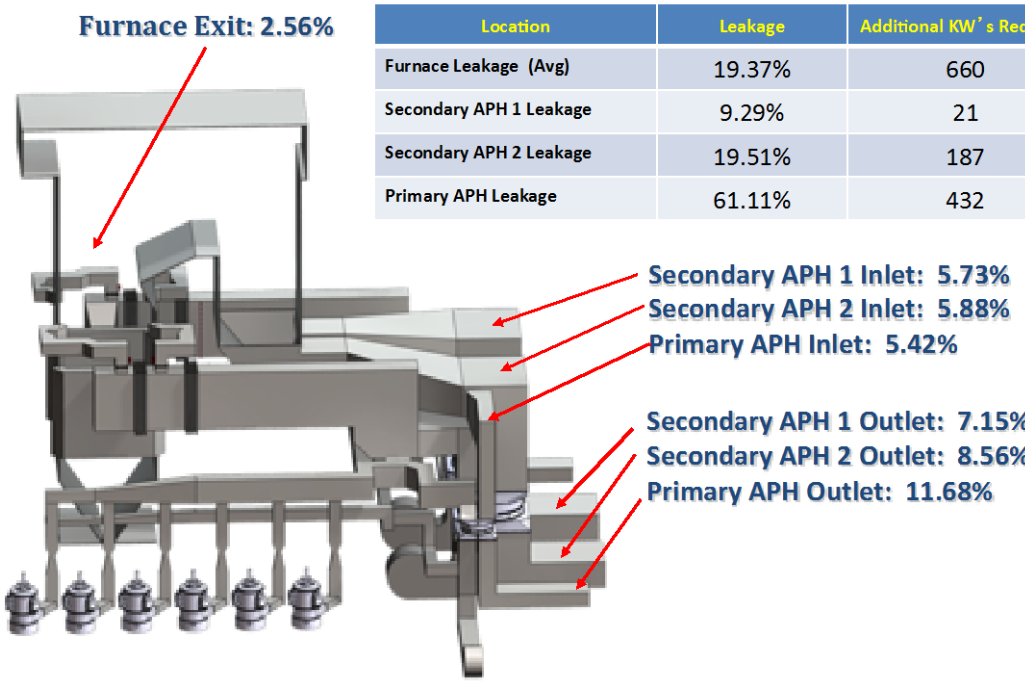


Measuring the Furnace Exit Flue Gas Oxygen is extremely important. The best way that we have found is to use water-cooled HVT Probes and a reliable flue gas analyzer.

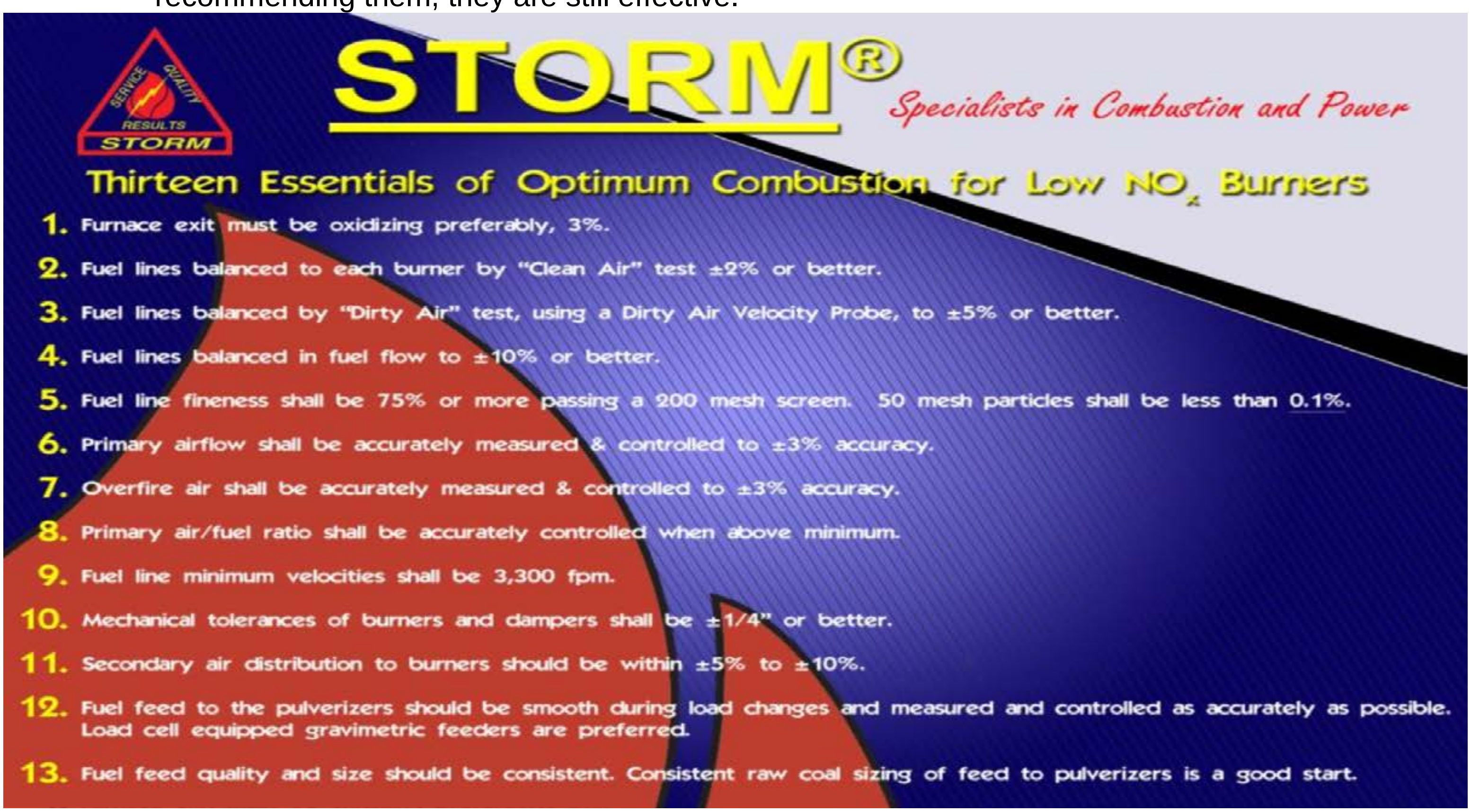
Air In-Leakage
Can be a Very Large "Stealth Loss"

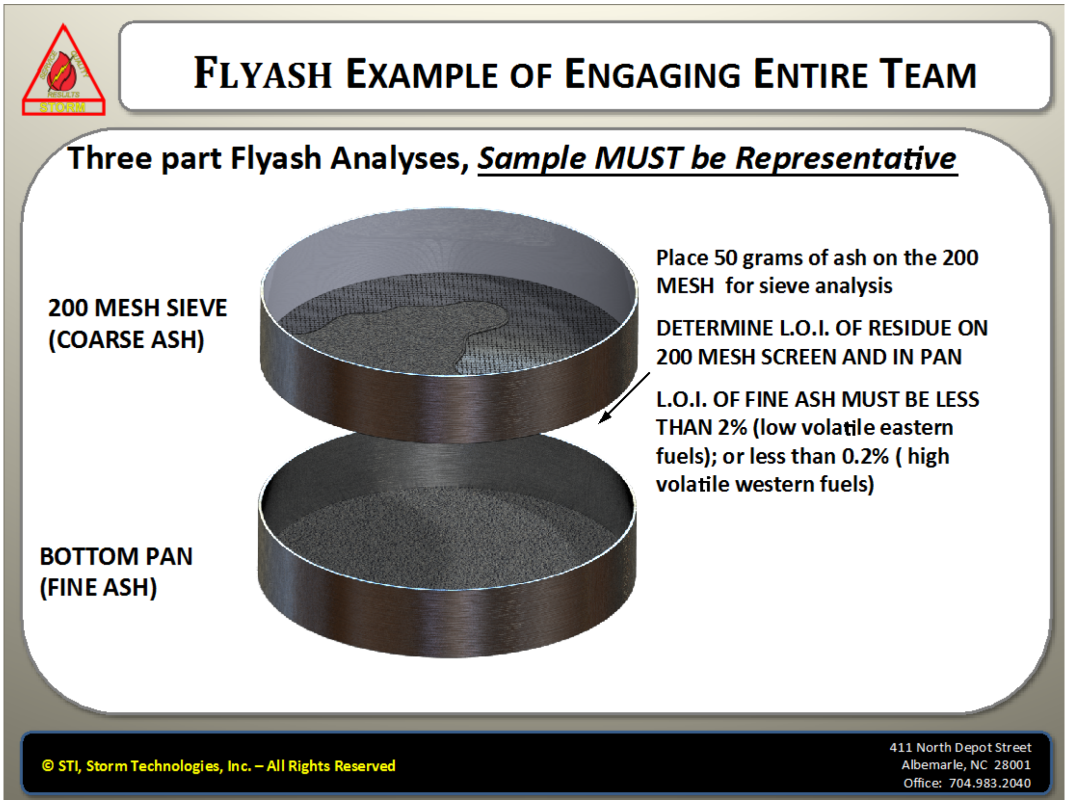
Tracking Oxygen in the Boiler

Location	Leakage	Additional KW's Required
Furnace Leakage (Avg)	19.37%	660
Secondary APH 1 Leakage	9.29%	21
Secondary APH 2 Leakage	19.51%	187
Primary APH Leakage	61.11%	432

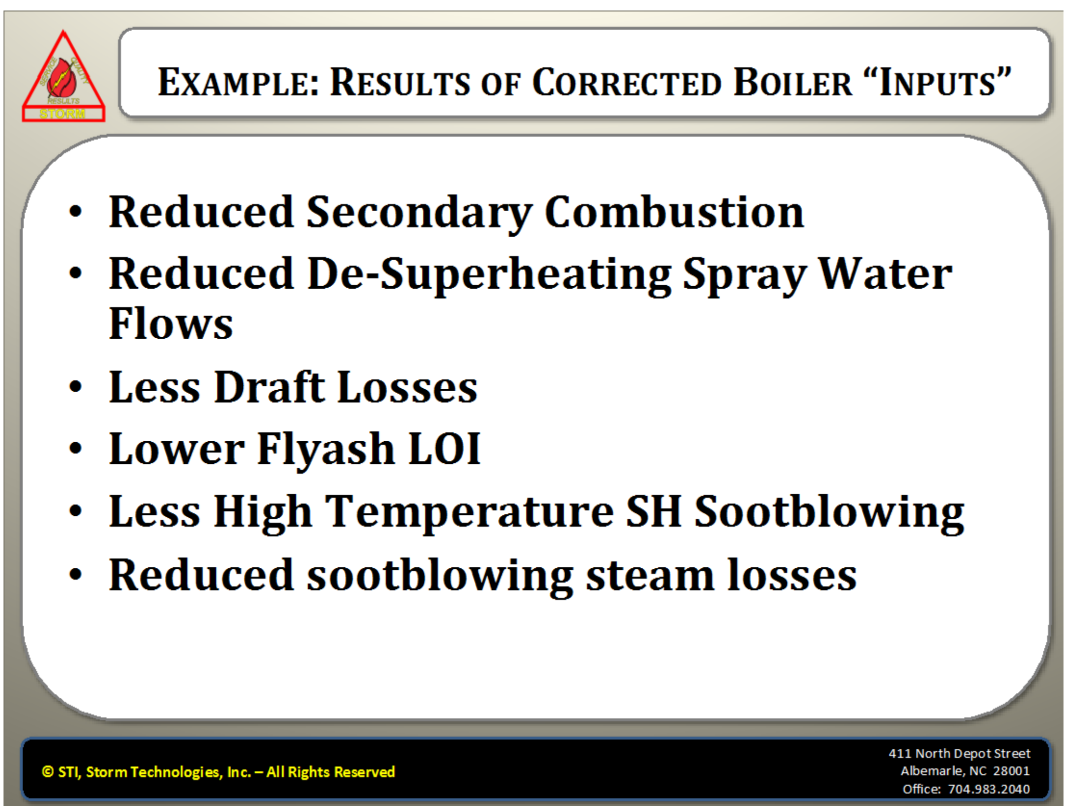


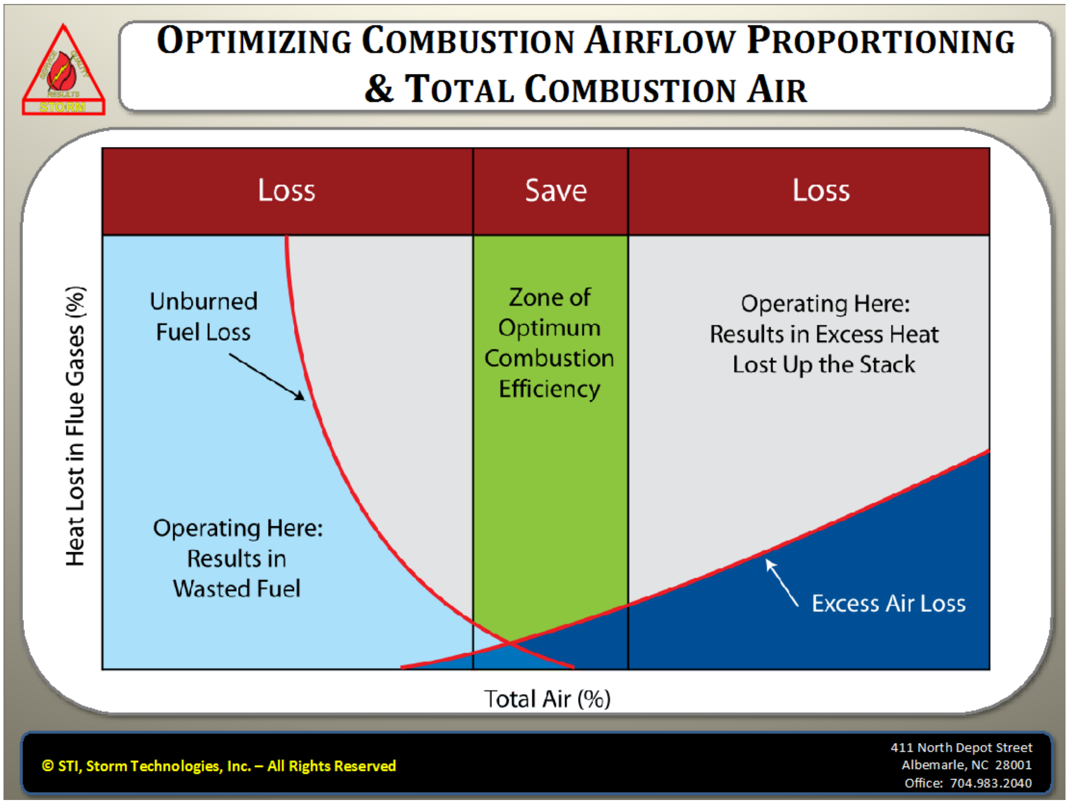
We take the 13 Essentials seriously and have to report to you, that after many years of recommending them, they are still effective.



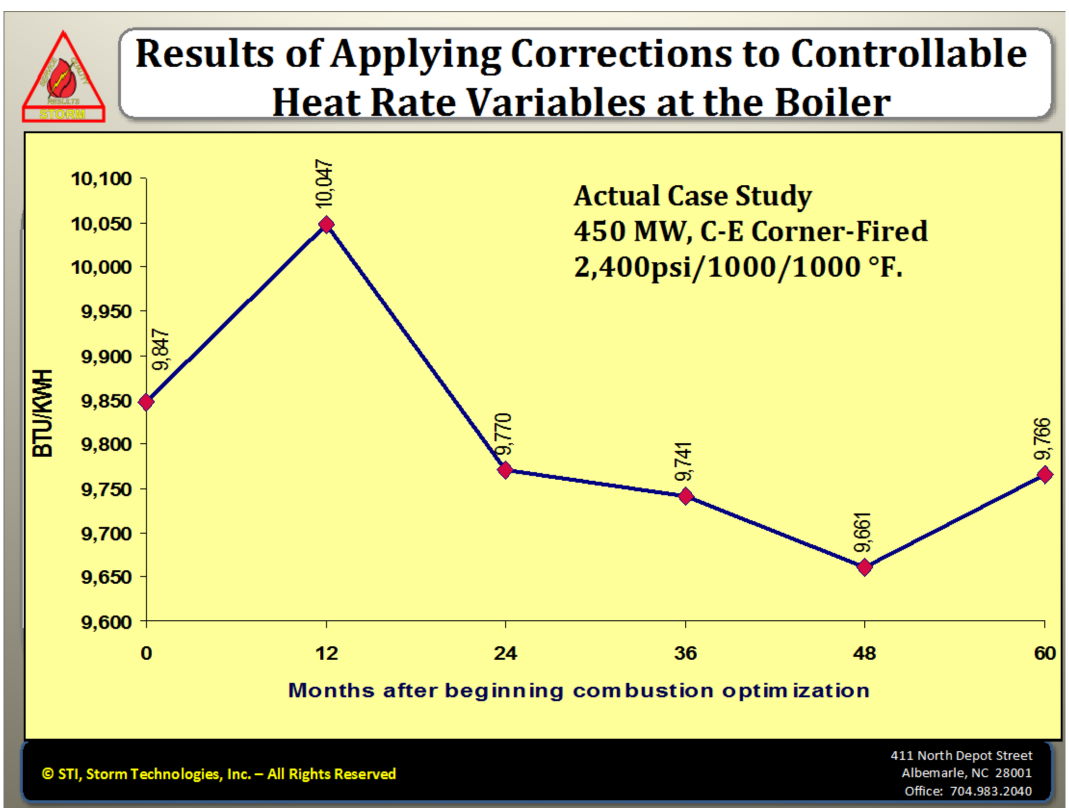


Here is a very informative test to “Referee” the Root Cause of higher than optimum flyash carbon content. By referee I mean, it determines whether the higher than desired carbon is ash is caused by insufficient oxygen in the furnace or if Coal Fineness is a significant part of the problem.

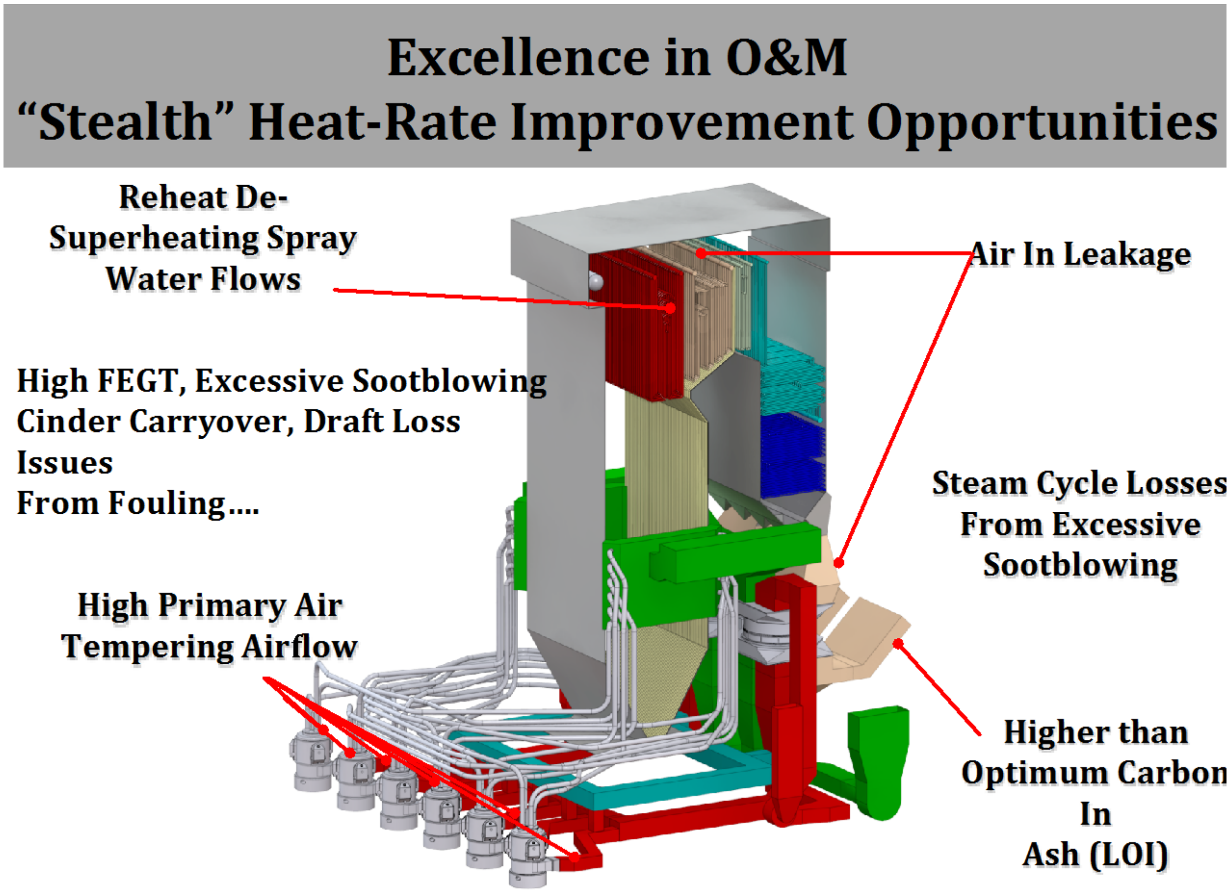




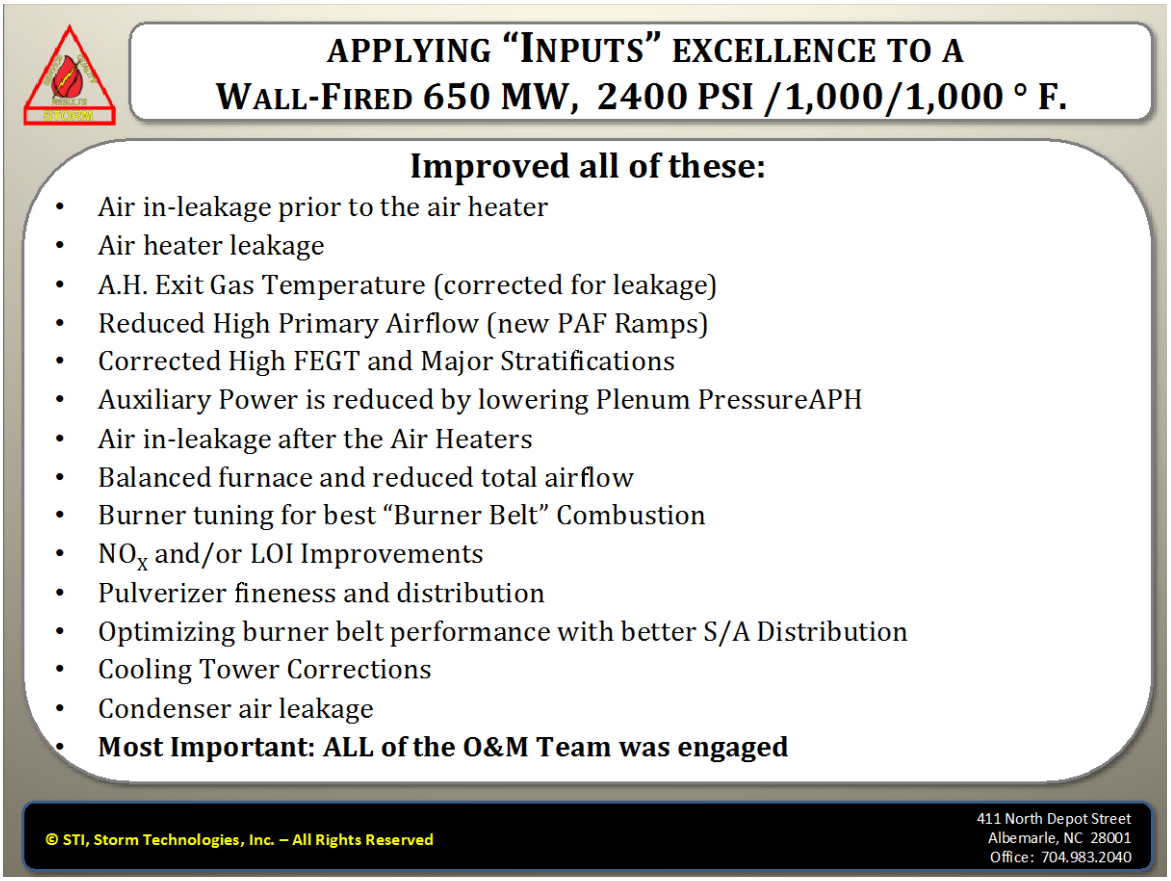
An example of a concentrated effort of applying the "Fundamentals" to the "Burner Belt Inputs" follows. First leakage was corrected. Then the mill fineness's, primary airflow's, secondary airflow balance and reduced excess air. All of these factors resulted together in an improved heat rate. The FEGT was reduced and then lower cost fuels could be utilized. This plus the



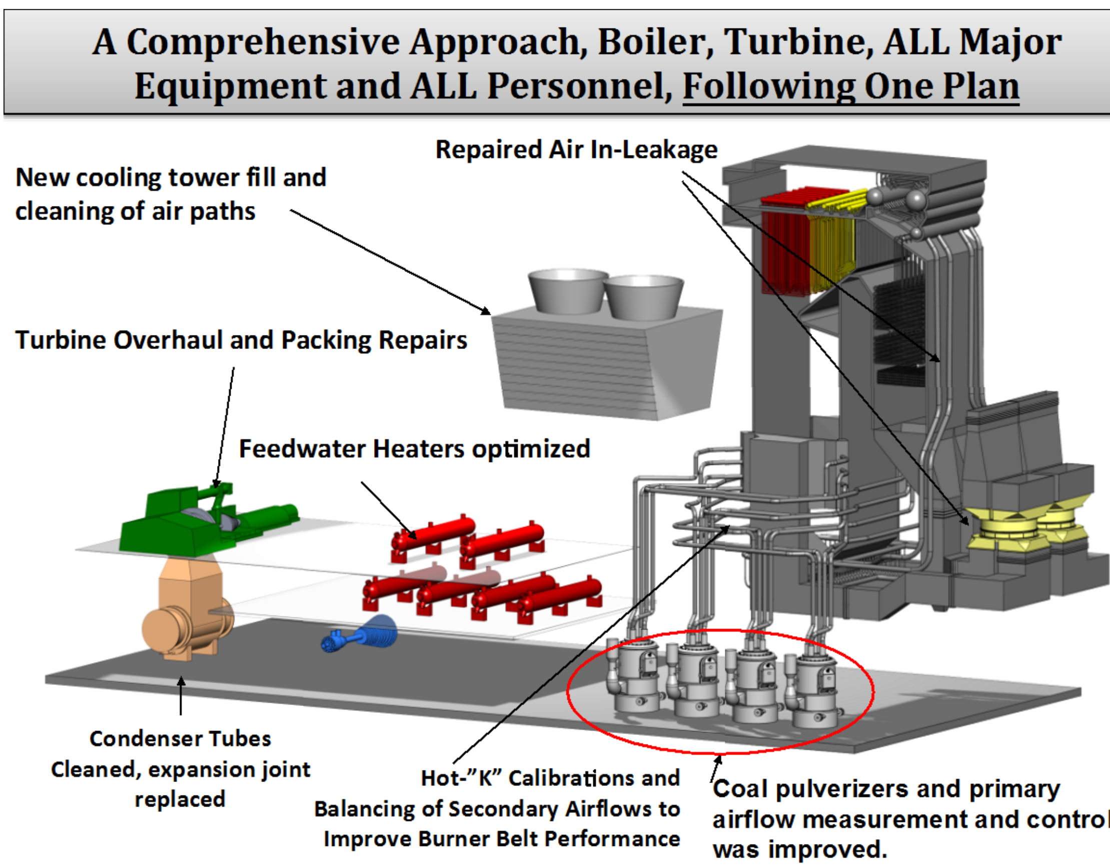
better heat-rate moved the Unit up several notches in the System Dispatch order.
This was before FGD and SCR installations and therefore the parasitic power was much lower. Nevertheless, it does show the Heat-Rate trend downward as better balance of air and fuel was admitted into the furnace. Many of the Unit Performance Factors are controlled at the Boiler, but may have nothing to do with boiler efficiency, such as De-Superheating spray water flows, steam temperatures, air in-leakage and tempering air quantities.

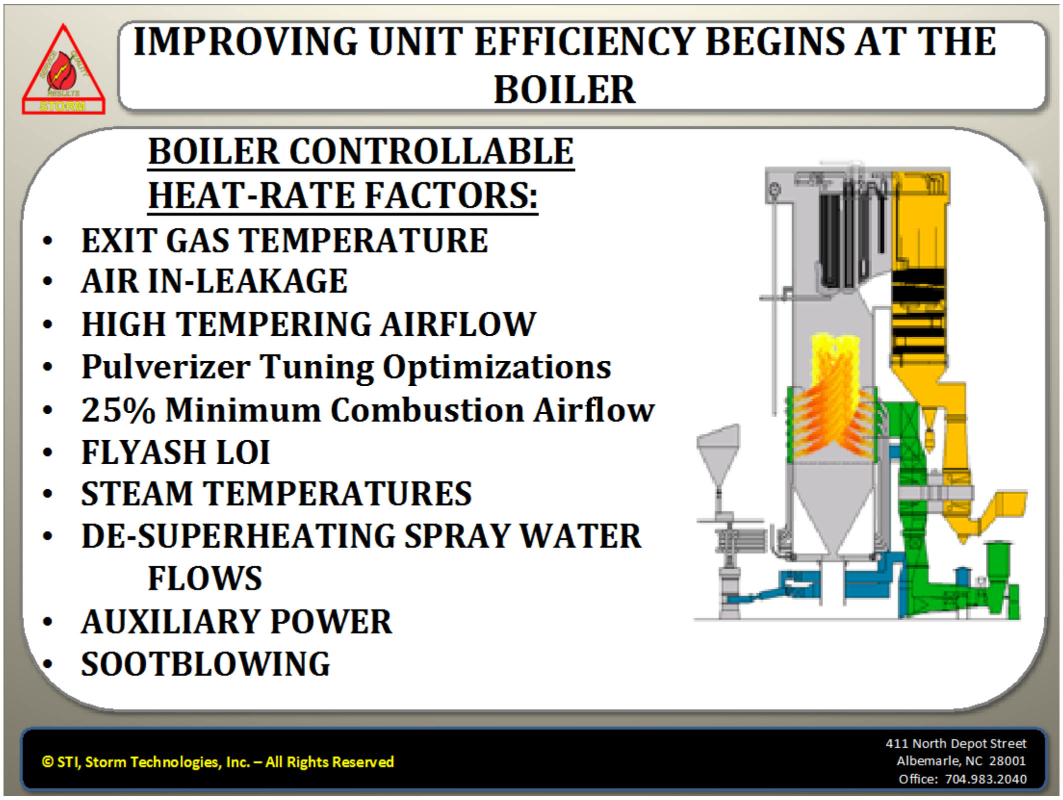


Great Teamwork was applied to another plant with a B&W Boiler. The key to the success of this program was truly, teamwork of all work groups functioning for the same goals.

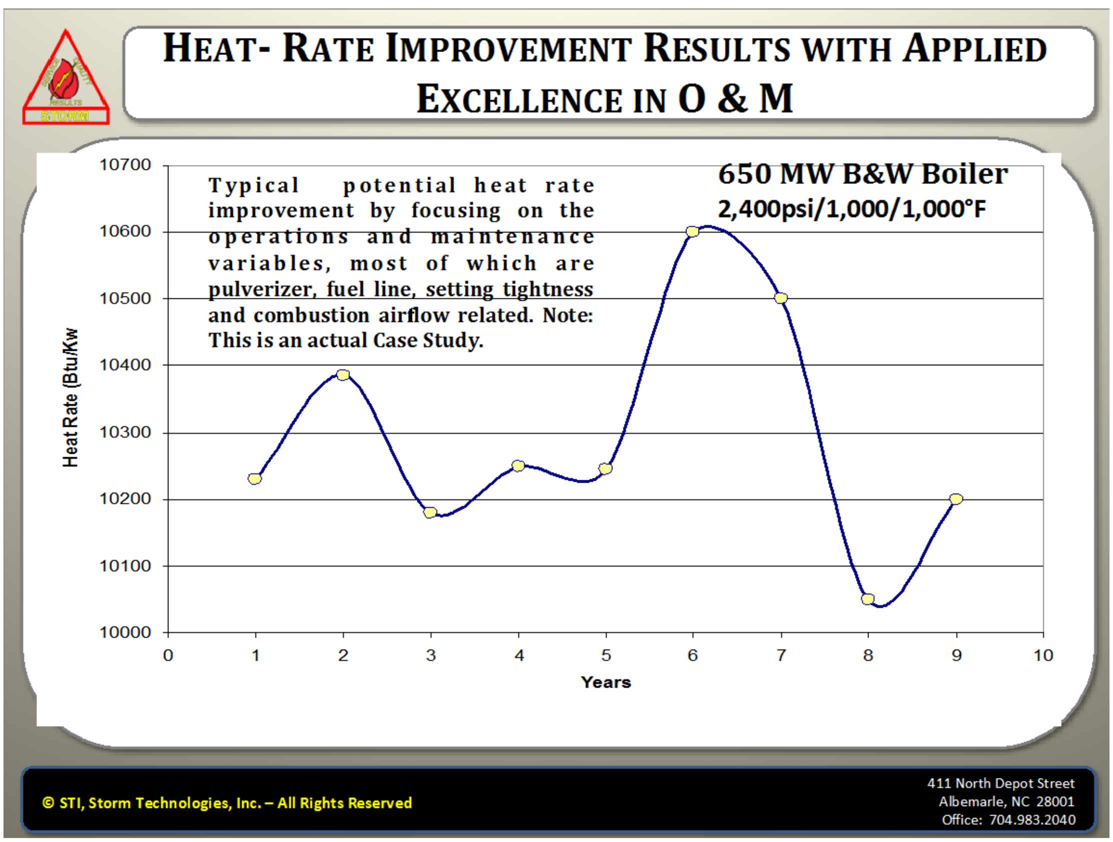


In this example, there were significant known deficiencies in the pre boiler cycle, the cooling tower and turbine issues. All of these were addressed during a major overhaul outage.

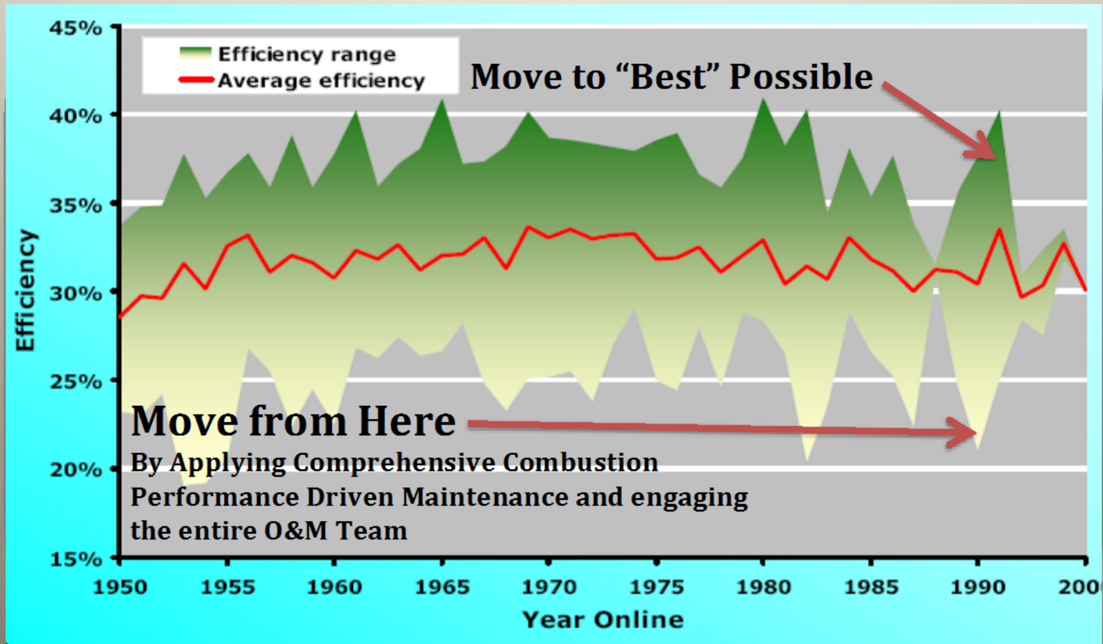




All factors were considered and all work groups cooperated to apply the 13 Essentials and to correct all possible Heat-Rate penalties. Including air in-leakage, high air heater leakage rates, high primary airflow's and poor fuel fineness. The result: A 400 Btu/kWhr Heat-Rate improvement.



Results of Applying Best Practices of Combustion Optimization Can Place Your Plant in Better Position



411 North Depot Street
Albemarle, NC 28001
Office: 704.983.2040

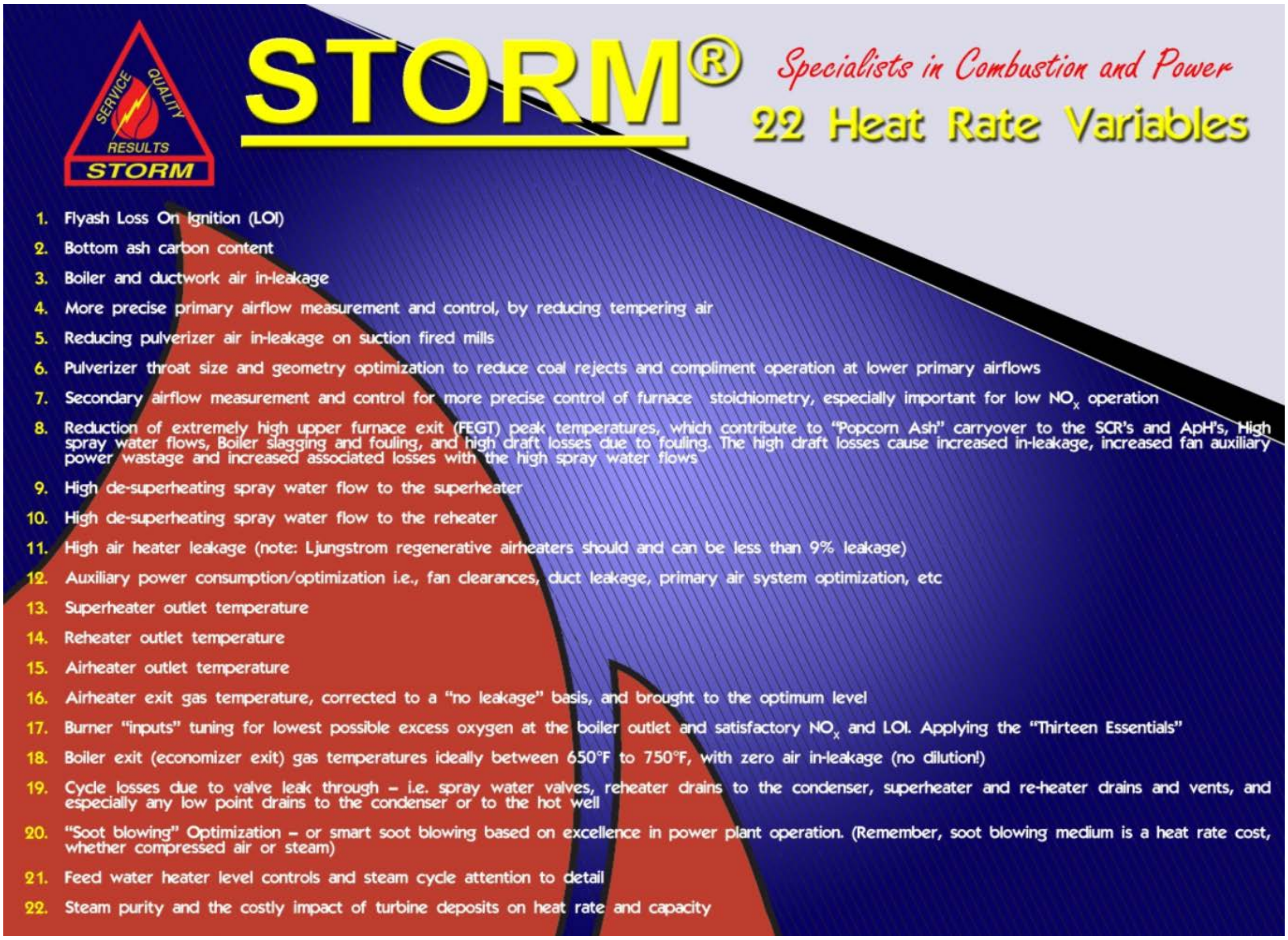
The Eight most common correctable losses are:

(in our experience)

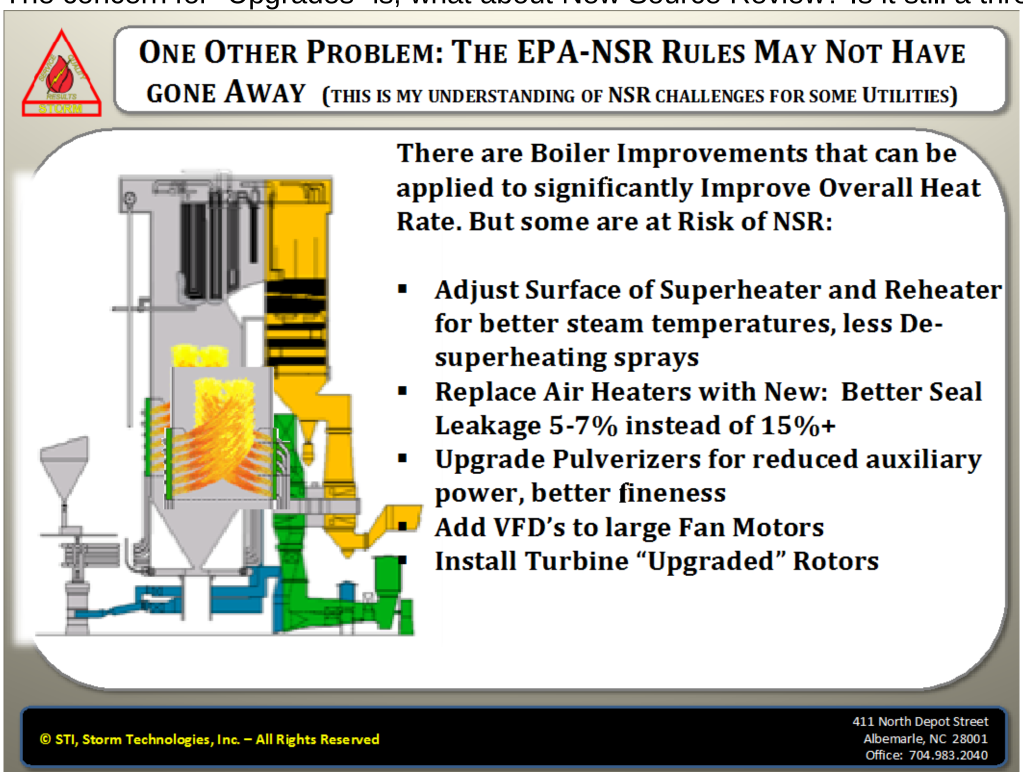
- **Boiler and Setting Air in-leakage**
- **High furnace exit gas temperatures which cause high Reheater and Superheater desuperheating spray water flows**
- **High Boiler Exit Gas and Airheater Exit Gas Temperatures**
- **High primary airflows** (especially harmful is high tempering airflow that bypasses the air heaters)
- **Higher than optimum carbon in ash** (Bottom ash and Flyash)
- **Steam cycle losses (especially those caused by high FEGT and excessive soot-blowing to mitigate slagging)**
- **Correct Burner Belt Fuel and Combustion Air Balance and Reduce CO and Ammonia Slip which contributes to Air Heater Fouling**
- **Air Heater Leakage and Non-Optimized Air Heater Exit Gas Temperature**

411 North Depot Street
Albemarle, NC 28001
Office: 704.983.2040

Here are eight common variables that when corrected/optimized, can make a significant difference.



The foregoing are my review of the "Operational" opportunities for improvement. As more Heat-Rate improvement may be sought after, then equipment changes and "Upgrades" come into consideration. The concern for "Upgrades" is, what about New Source Review? Is it still a threat?



Given that NSR is not a factor, then there are quite a few equipment upgrades that can be considered. Some may be considered maintenance and some may be considered upgrades. Unfortunately, some regulators make engineering decisions that should be simple, very complicated. Many projects for performance improvement have been shelved due to the threat of NSR.

Equipment "UPGRADES?"
Is NSR an Obstruction To "Best Performance"
(NSR=New Source Review)

"Upgrades" Is this still a "Dirty Word"

Imagine what the utility industry could do without NSR....
EPA References "Upgrades" in the Rule. Do they mean it? Can you Trust them?
Articles and Presentations on this topic were Published by Dick Storm in:

POWER Magazine, August 2009

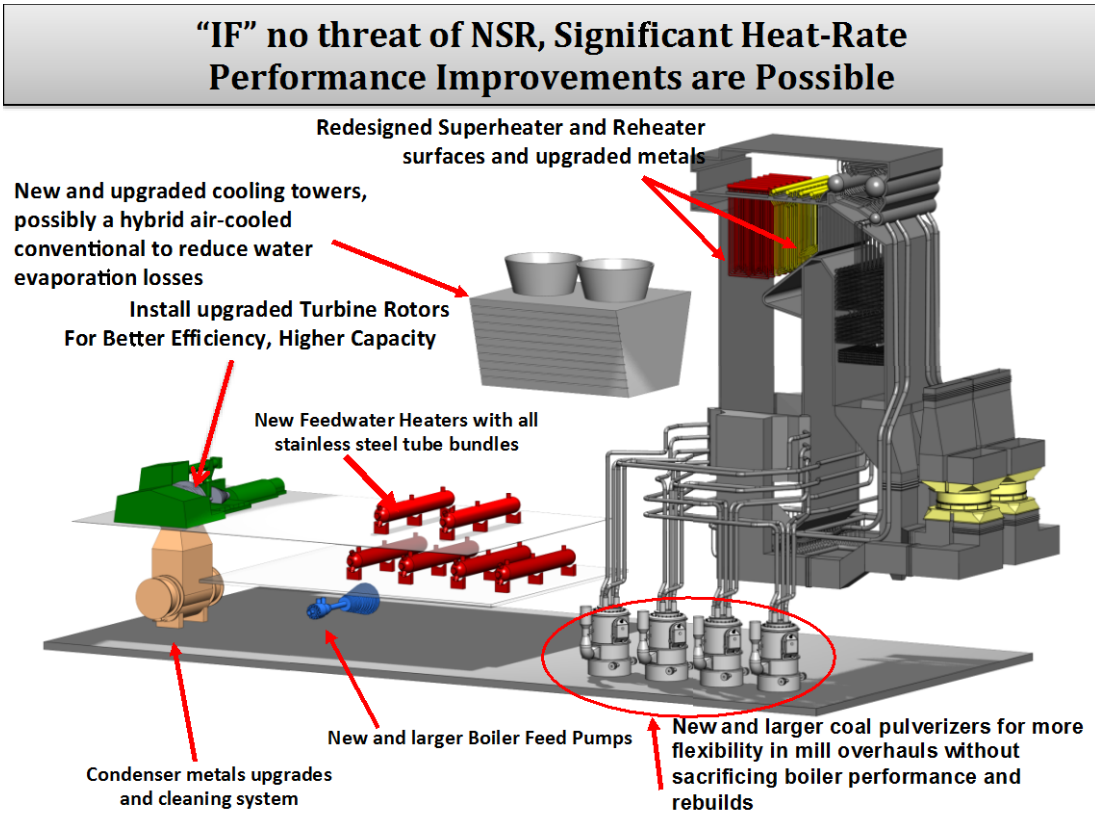
EPRI 2011, 2013 Heat-Rate Conference Presentations

ACC- American Coal Council

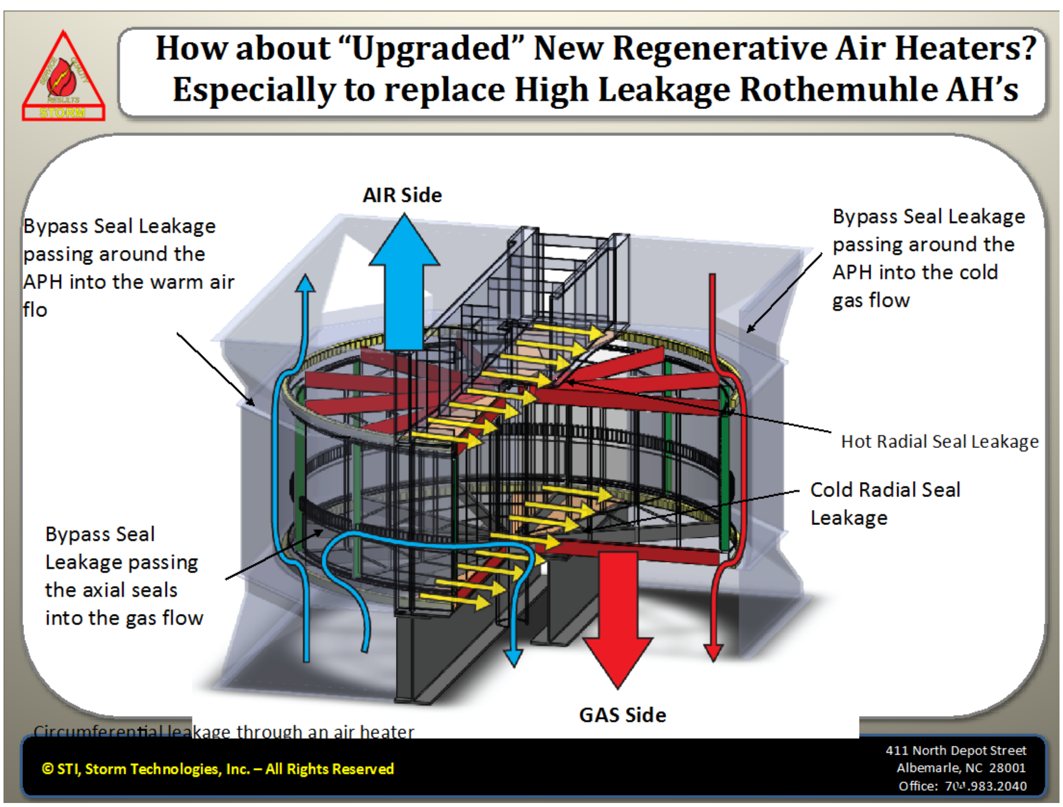
New Source Review is, in my understanding, still a threat.
Small changes to Boilers were considered "Upgrades" by some managers: Such as:

- Installing New and Larger Primary Air Fans for a Fuel Change to PRB Fuel
- Changing Superheater Surface to Optimize Heat Absorption of the SH and RH
- "Upgrading" SH and Reheater Alloys to Stainless Steel
- Changing troublesome Rothemuhle Air Heaters to "Upgraded" Current best Design Ljungstrom's to improve Leakage and Efficiency

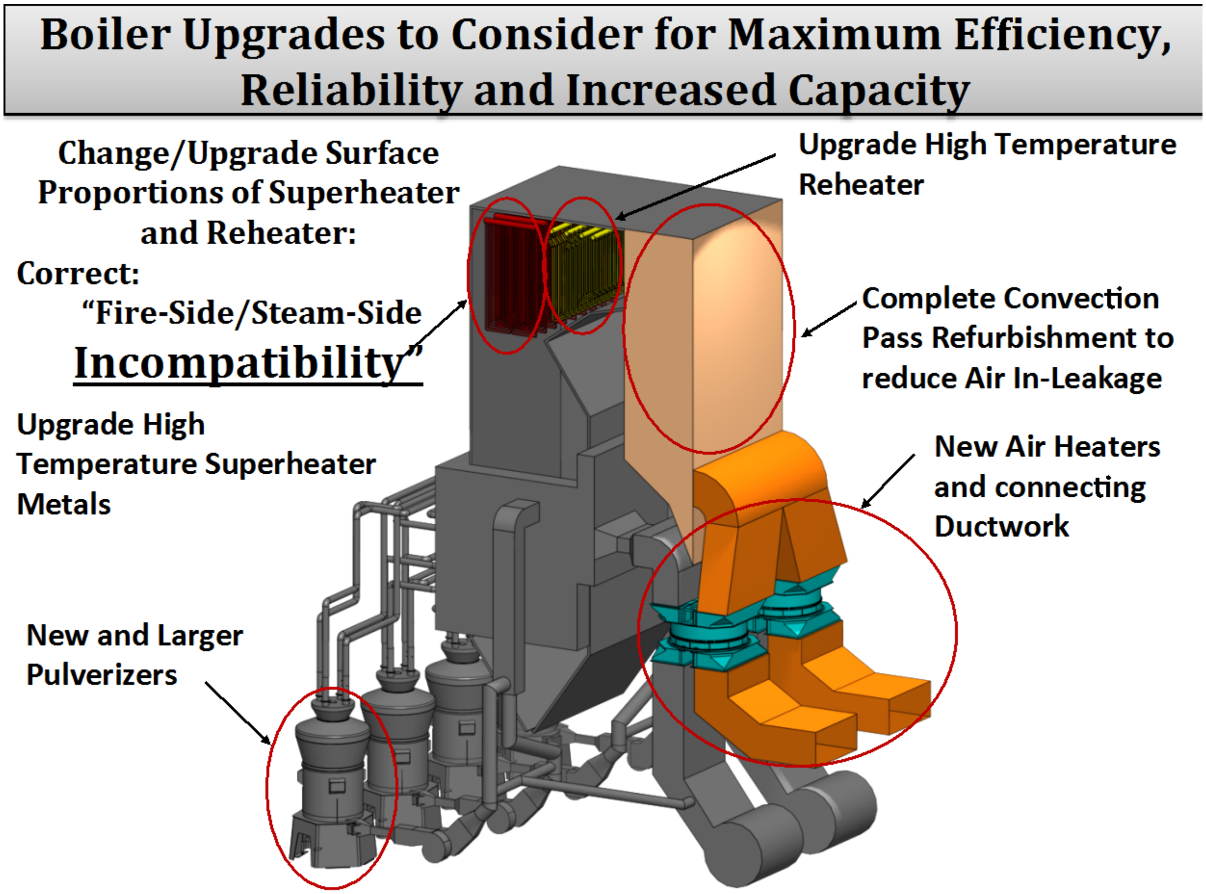
I have been involved with presentations regarding NSR, such as one of my references for this presentation. In my work I have seen Utilities sued for doing what all of us in this room would consider maintenance. Here are a few examples of Projects that could be implemented, cost effectively, were it not for the threat of NSR.



Here is a really good project that many plants could gain from. Upgrading the old regenerative air heaters to newer air heaters with less leakage and the best surface for the current fuels being fired. Some of you may have Rothemuhle Air heaters installed in the 1980's that looked at the time to be a good idea. Experience has turned out in favor of the Ljungstrom approach to Regenerative air heater design.



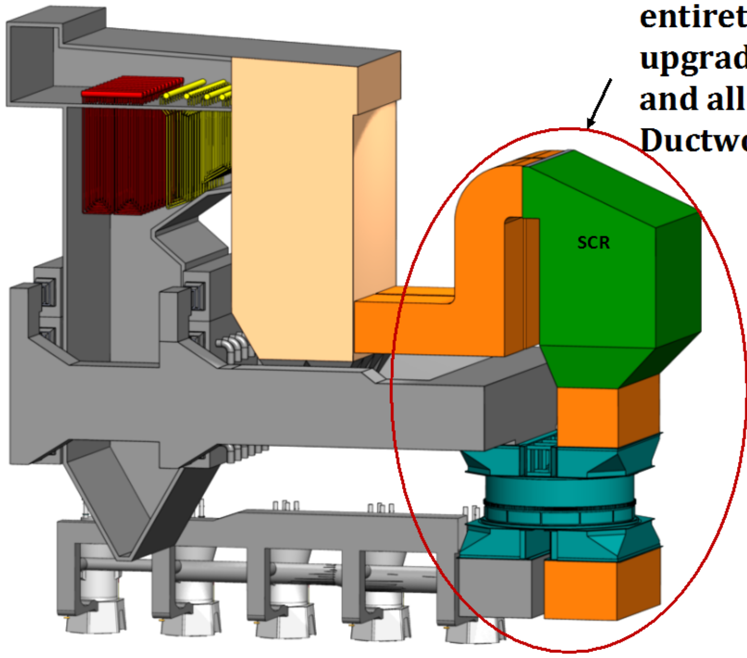
Then there is the issue of Surface incompatibility of the Fire-Side and the steam Sides.



We know of many boilers that should have surface adjustments as well as alloy upgrades of the Superheaters and the Reheaters. Why? Because, in some cases the FEGT needs to be raised above optimum of say, 2,150°F to as high as 2,400°F just to make 1,000°F steam temperatures. Tuning can be done to lower the FEGT, but when that is done, steam temperatures drop to the range of 900°F. Thus, a large thermodynamic penalty. The result of not upgrading the SH and RH surface is, that the boiler is operated with FEGT's several hundred degrees higher than optimum. From a slagging and fouling basis this requires nearly continuous blowing of the long retractable soot-blowers. Not only does it waste high-energy steam, but also the cinders that are removed from the SH and RH tubes contribute to fouling of the SCR and the air heater baskets. At other plants Reheater de-superheating sprays are continuous because the flue gas temperatures need to be higher than optimum because there is insufficient High Temperature Superheater surface.

The cinders blown off the SH and RH Pendants entrain into the flue gas stream and contribute to SCR and ApH plugging.

Boiler Improvement Potential for Heat Rate, Capacity and Reliability Improvement

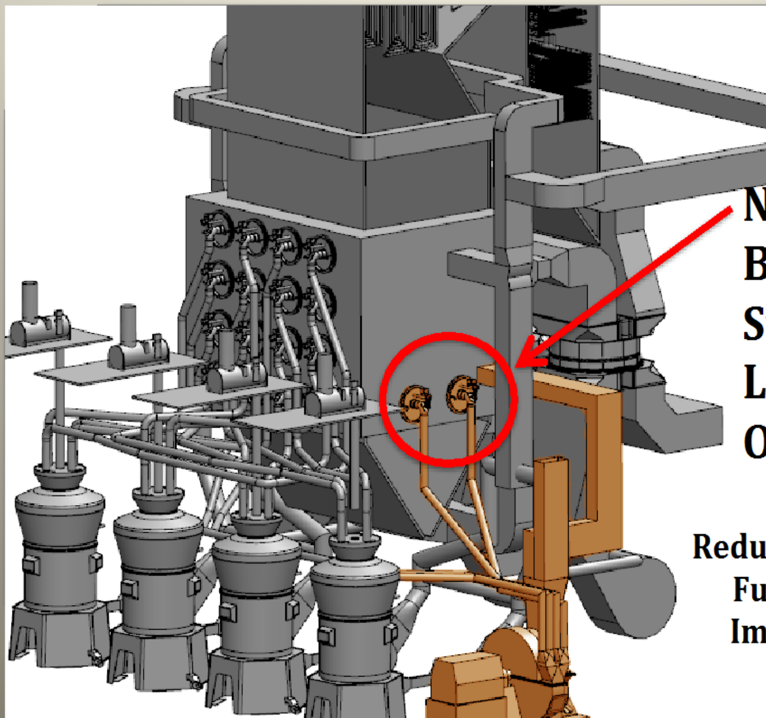


Replace the existing Air Heaters in their entirety with upgraded Air Heaters and all New Ductwork

Another example of upgrading the air heaters and ductwork at the back end of the boiler,
One plant we are aware has a hot electrostatic precipitator and extreme corrosion of the ductwork. If a package was done to renew the ductwork, replace the air heaters and upgrade the fan drives to VFD's, significant savings could be achieved.

This idea is one I thought up about thirty years ago. No one seemed interested then and I am not sure anyone is now. But, one issue we are seeing, is a lot of excessive ignition oil being burned for start-ups. This is not only a problem of fuel cost but if not burned cleanly, it also causes fouling of the electrostatic precipitators and opacity issues. Another challenge the industry is faced with today, is extreme low load turn down at nights and on the weekends. Taking a 500 MW Unit and operating them at very low loads of 150 MW or less. It is cases like this that I think installing auxiliary burners on the side walls with a separate windbox and measured and controlled airflow's, could make the low load operation cleaner and more efficient.

Install New Low Load, Retro-Fitted Sidewall Mounted Burners



New Low Load Burners for Startup and Low Load Operations

Reduce Startup Ignition Fuel Consumption
Improve Low Load "Turn Down"

411 North Depot Street
Albemarle, NC 28001
Office: 704.983.2040

Startup fuel savings could be realized as well.

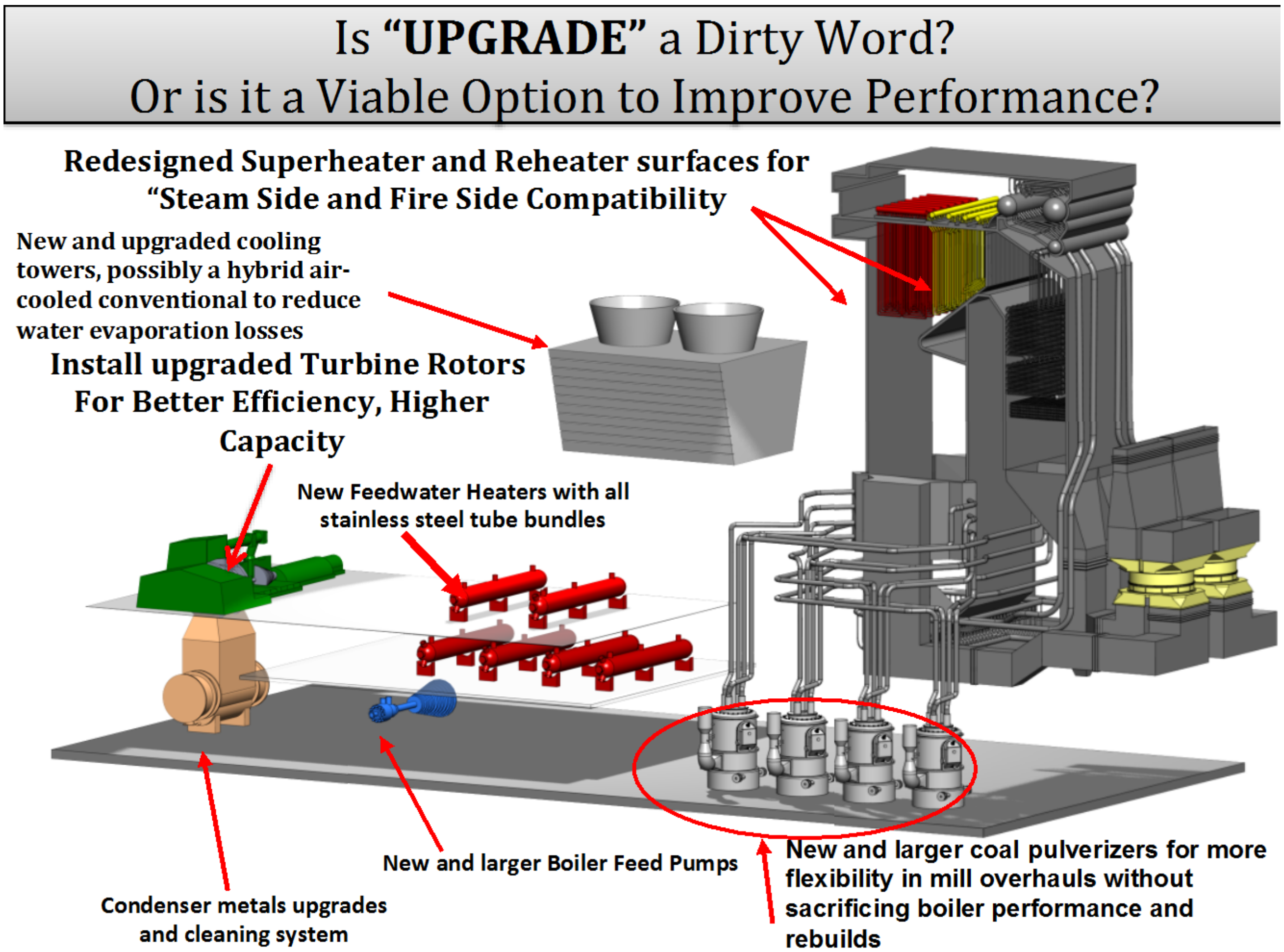
POWER Magazine, Feb. 2015 HR Improvements

"Upgrades" to Work Toward 6% Heat-Rate Improvement

Improvement	Range of heat rate benefit	Payback period
Improving combustion controls and monitoring	0.25%–1.00%	<1 year
Increased condenser cleaning and repair of air leaks	0.30%–2.00%	<1 year
Turbine seal improvements	0.50%–2.30%	1–3 years
Increased feedwater heater monitoring, maintenance, and repair	0.20%–1.00%	1–3 years
Air heater seal repair or upgrade	0.10%–0.50%	2–3 years
Preheating combustion air with waste heat	0.10%–0.30%	2–3 years
Increased cleaning of turbine deposits	0.25%–3.50%	2–4 years
Low-pressure turbine blade upgrade	1.00%–2.00%	2–4 years
Replacement of main fan motors with variable frequency drives	0.20%–0.50%	3–5 years

411 North Depot Street
Albemarle, NC 28001
Office: 704.983.2040

Una Nowling, PE another contributing editor to POWER Magazine, published this table of “Upgrades” to consider in the Feb. 2015 POWER Magazine. This gives another viewpoint of the potential for performance improvements of some of the ideas that I have offered as well as a few more.

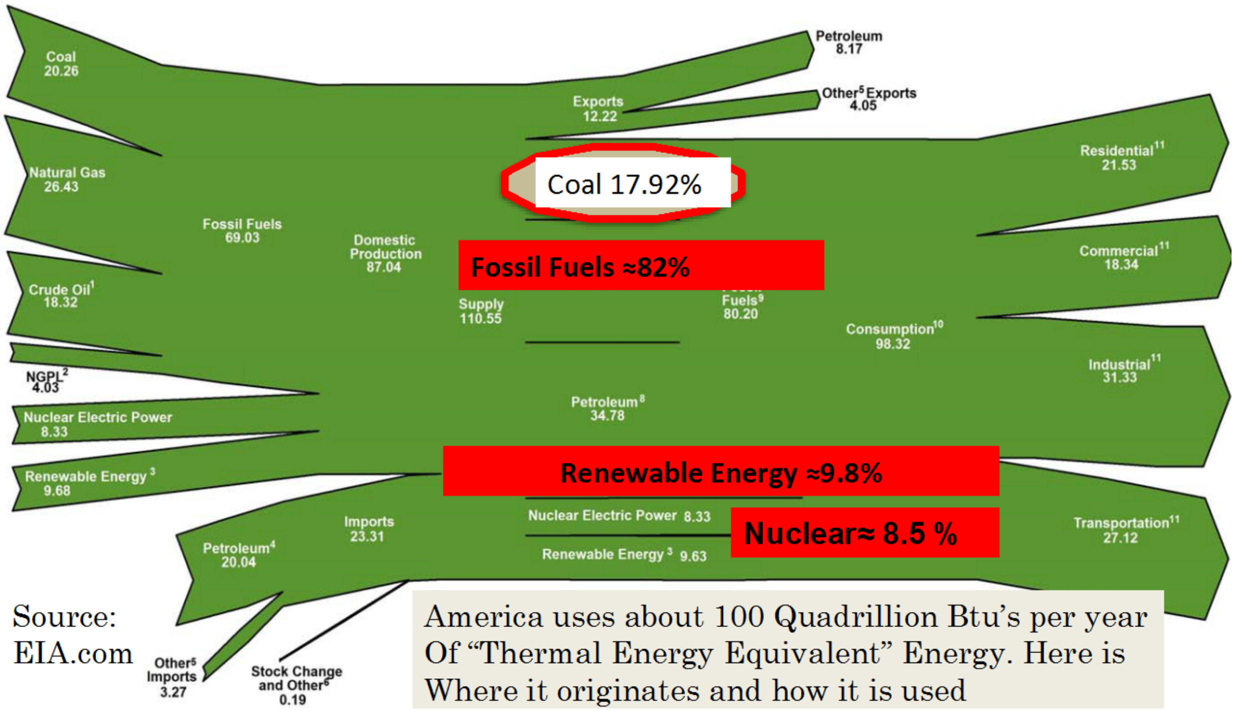


The bottom line, if I was one of you sitting in the audience, here is what I would be thinking: *“it is going to be very hard to find 4-6% improvements in heat-rate when all things are considered”.* Not the least of which is, operating at a lower capacity factor, cycling and having to take the demand variations when must-run renewable power surges on the Grid.
Yes, there are options that can improve heat rate. Both operational and mechanical upgrades. I have tried to provide a quick review of some of them and in the last slide, I have inserted a number of references for further research on the topic.

Let me close with my views on coal power and the importance of reliable, clean coal power to keep America strong. In my opinion, the EPA has over reached and is simply a tool that the current administration is using to wage a war on coal. We are in a minority and I estimate only two or three million energy engineers and operational and maintenance experienced persons in America. According to the Bureau of Labor statistics and some other references, there are only about 550,000 people employed by the electric utilities in the USA. Why am I deviating from the message of “Heat-Rate Improvement”? Well, I am doing so because, if we do not take the effort to explain the importance of coal fired power plants, then who will? Please bear with me and let me close with a couple slides that highlight the facts and importance of coal power plants to our country.

Just a Reminder, 90% of our Energy Comes from Traditional Sources, Including Coal

America's True Total Energy Supply & Demand

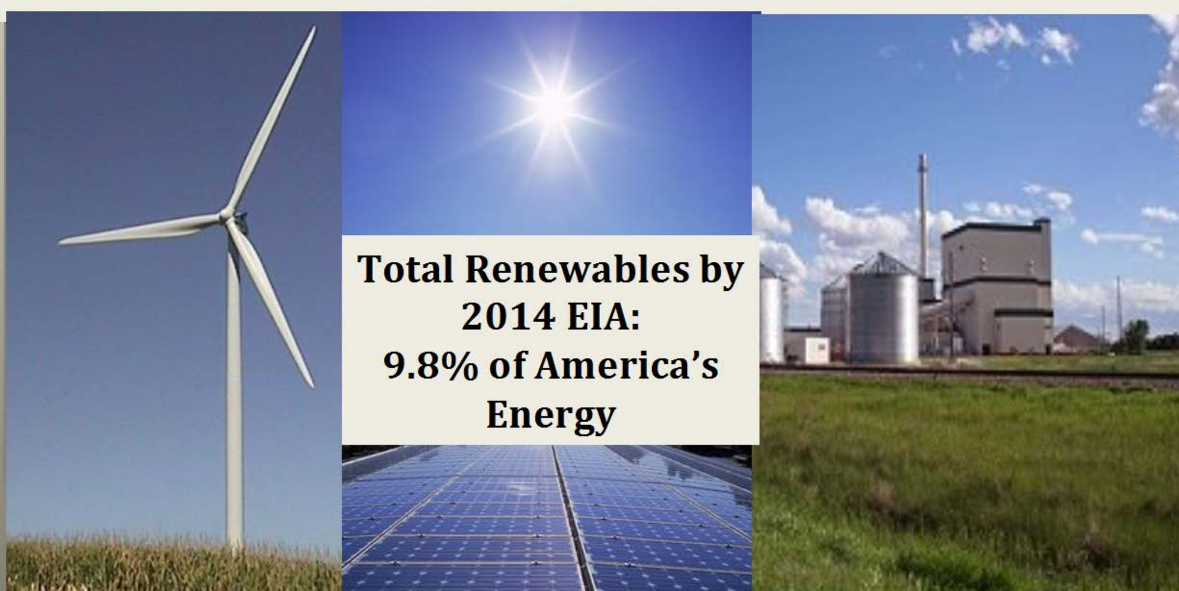


Source: EIA.com

America uses about 100 Quadrillion Btu's per year Of "Thermal Energy Equivalent" Energy. Here is Where it originates and how it is used

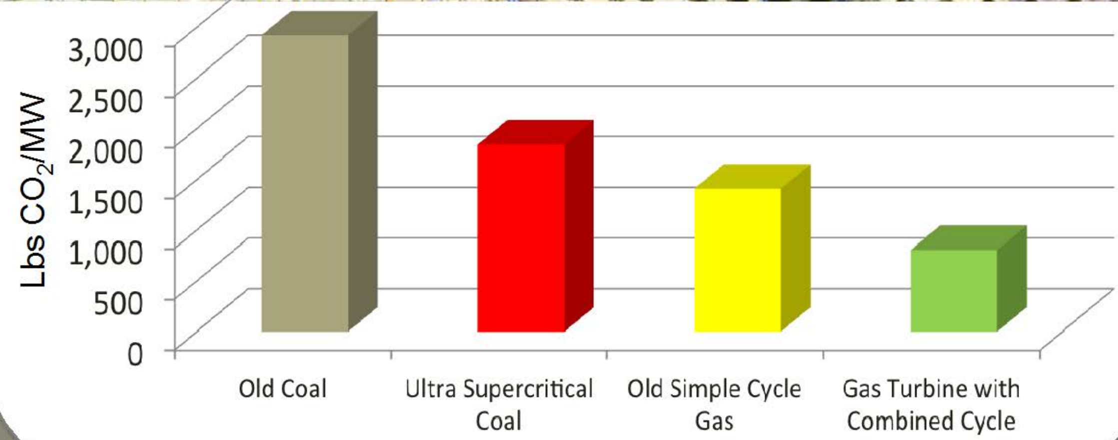
Popular Myth: Renewable Power CAN Power America

Coal remains the most reliable energy source for Bulk Power supply. We should use it well! NSR prevents doing plant improvements for best efficiency!



411 North Depot Street
Albemarle, NC 28001
Office: 704.983.2040

CO_2 Production per Megawatt



411 North Depot Street
Albemarle, NC 28001
Office: 704.983.2040

More New Plants Like Turk and Iatan #2 Should Please All Groups! Good for Reliable Power, Good for American Manufacturing and Good for the Environment

Modern USA Built Ultra Supercritical Boilers

High Thermal Efficiency and Low Emissions

- Turk plant shown at right has 39% efficiency. One of the most efficient and cleanest coal plants in the world.
- Operates at supercritical pressure and steam temp. of 1,100°F.
- High Temp and pressures enable more efficient operation of Rankine cycle.
- Increase in efficiency reduces fuel consumption, and thereby reduces emissions.

AEP's John W Turk Jr Plant, the first ultra-supercritical generating unit.

Source: www.aep.com - Supercritical Fact Sheet

References and Additional Information, FYI

- Available on the www.stormeng.com web site. Presentations and Technical papers by Storm Technologies, Inc. Staff
- RMEL, Management Group, June 2012; "One more Time: First Apply the Fundamentals" http://www.stormeng.com/technicalpapers.html
- EPRI, 2009 Heat-Rate Conference; "The Unintended Consequences of New Source review (NSR), Imagine What the Utility Industry could do without NSR", Dick Storm
- University of Kentucky, Coal Conference, 1990; "Pulverized Coal Boiler Optimization Through Fuel/Air Control Improvements, Barry Pulskamp, Pat McGowan and Dick Storm
- Power Magazine: July 2013, "How Stealth Combustion Losses Lower Plant Efficiency, Dick Storm http://www.powermag.com/how-stealth-combustion-losses-lower-plant-efficiency-part-1-the-problem/
- POWER Magazine, Nov. 2014, Coal-Fired Power Plant Heat-Rate Improvement Options, Part 1, Sam Korellis, EPRI
- Power Magazine, Dec. 2014, Coal-Fired Power Plant Heat-Rate Improvement Options, Part 2, Sam Korellis, EPRI
- POWER Magazine, Feb. 2015, Understanding Coal Power Plant Heat Rate and Efficiency, Una Nowling, PE, Univ. of Missouri and Black & Veatch
- "Coal-fired Power Plant Heat Rate Reductions", Sargent & Lundy SL-009597 Final Report (Project 12301-001), (January 2009), available at http://www.epa.gov/airmarkets/resource/docs/coalfird .pdf
- "Reducing CO2 Emissions by Improving the Efficiency of the Existing Coal-fired Power Plant Fleet", DOE/NETL-2008/1329, (July 2008), available at http://www.netl.doe.gov/energy- analyses/pubs/CFPP%20Efficiency-FINAL.pdf
- "Power Plant Performance Reporting and Improvement under the Provision of the Indian Energy Conservation Act – Output 1.1", Evonik/ VGB (2008), available at http://www.emt- india.net/PowerPlantComponent/Output1.1/Output1.1.pdf
- "Opportunities to Improve the Efficiency of Existing Coal-fired Power Plants, Workshop Report", NETL (July 2009), available at http:// www.netl.doe.gov/energy- analyses/pubs/NETL%20Power%20Plant%20Efficiency%20Workshop%20Report%20Final.pdf
- "Improving the Efficiency of Coal-fired Power Plants for Near Term Greenhouse Gas Emission Reductions", DOE/NETL-2010/1411 (April 2010), available at http://www.netl.doe.gov/energy- analyses/pubs/ImpCFPPGHGRdctns_0410.pdf
- "Power Generation from Coal - Measuring and Reporting Efficiency Performance and CO2 Emissions", OECD/IEA-CIAB (2010), available at http://www.iea.org/ciab/papers/power_generation_from_coal.pdf
- "Opportunities to Enhance Electric Energy Efficiency in the Production and Delivery of Electricity", EPRI Technical Report
- EPA Clean Power Plan website: http://www2.epa.gov/carbon-pollution-standards/clean-power-plan-proposed-rule-technical-documents
- Power Generation Changes since 2001, GAO (Government Accounting Office)
- http://www.gao.gov/assets/680/670545.pdf Report, May 2015:
- National Coal Council, "Value of the Existing Coal Fleet", May 2014; http://www.nationalcoalcouncil.org/page-NCC-Studies.html
- National Coal Council Existing Coal Fleet Study May 2014: http://www.nationalcoalcouncil.org/NEWS/NCCValueExistingCoalFleet.pdf

411 North Depot Street
Albemarle, NC 28001
Office: 704.983.2040

Thank you, I appreciate this opportunity to be with you. I hope that you have found the preceding presentation to be useful and informative. Let myself or any of my associates at Storm Technologies know when we may be of any assistance.

Yours very truly,

Richard F. (Dick) Storm, PE
Senior Consultant
Storm Technologies, Inc.
www.stormeng.com
Richard.storm@stormeng.com