STORM — SERVICE QUALITY RESULTS

# "Hot Topic"

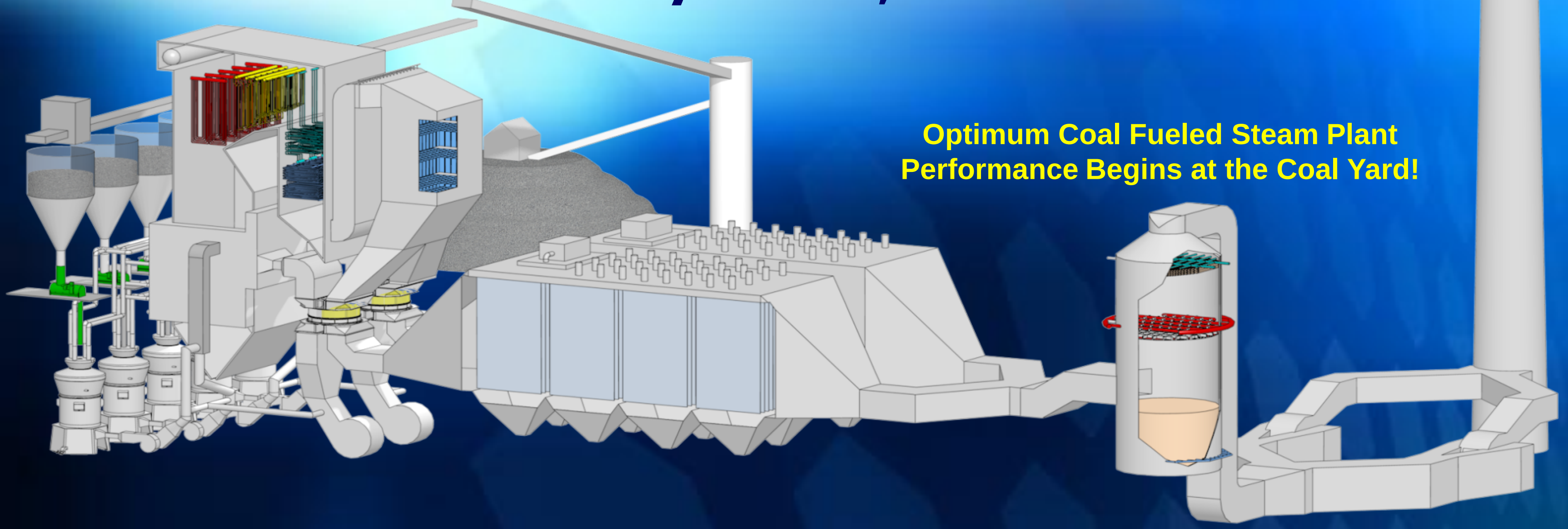
THE McILVAINE COMPANY

# Coal-Fired Boiler Optimization

## Improving Boiler Efficiency

## September 27, 2012

By Richard F. (Dick) Storm, PE, CEO
and Danny Storm, President



# Introduction

- Coal fleet has average 40 yrs.
- Investment to improve emissions.
  - SCR's (Selective Catalytic Reactors)
  - SNCR's (Selective Non-Catalytic Reduction)
  - FGD (Flue Gas Desulfurization)
  - Bag houses or ESP's
- 1960's coal fleet were designed for net heat rates well below 10,000Btu/kWhr.
- Net thermal efficiency designs in the range of over 38%.
- Today, the average old coal net plant heat rate remains about 33%.

- The opportunity for improvement for older coal plants is in the range of 600+ Btu's per kWh or cycle efficiency improvements of about 2%.

# A fair question: Where can opportunities to improve 600+ Btu's/kWh be found?

Here are some typical opportunities.

22 Operations and Maintenance Opportunities for Heat Rate Improvements.

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 air heaters)
5. Reducing pulverizer air in-leakage on suction 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 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 air heaters should and can be less than 9% leakage)

# A fair question: Where can opportunities to improve 600+ Btu's/kWh be found?

Here are some typical opportunities.

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

Twenty-two operations and maintenance controllable heat-rate factors. It has been our experience that the average power plant has at least 75% of these as "opportunities" for improvement.

# What is Heat Rate Improvement Worth?

The expected heat rate improvements of new air heaters and turbine rotors is about 2.4% when combined with a comprehensive combustion performance preservation program.

Typical 400-MW, 2,400-psi utility coal fired boiler

| Variable | Potential heat rate improvement (Btu/kWh) | Potential annual fuel savings |
|---|---|---|
| Boiler and ductwork ambient air in-leakage | 300 | $2,560,000 |
| Dry gas loss at the air heater exit | 100 | $853,333 |
| Primary airflow | 75 | $640,000 |
| Steam temperature | 75 | $640,000 |
| Desuperheater spray water flow | 50 | $426,667 |
| Coal spillage | 25 | $213,333 |
| Unburned carbon in flyash | 25 | $213,333 |
| Unburned carbon in bottom ash | 25 | $213,333 |
| Slagging and fouling | 25 | $213,333 |
| Cycle losses | 25 | $213,333 |
| All others, including soot blowing and auxiliary power factors | 25 | $213,333 |
| Total | 750 | $6,400,000 |

Based on $80.00/Ton of coal and 12,000Btu/lb of coal

Note: Interaction between variables and cost will impact meeting this estimate.

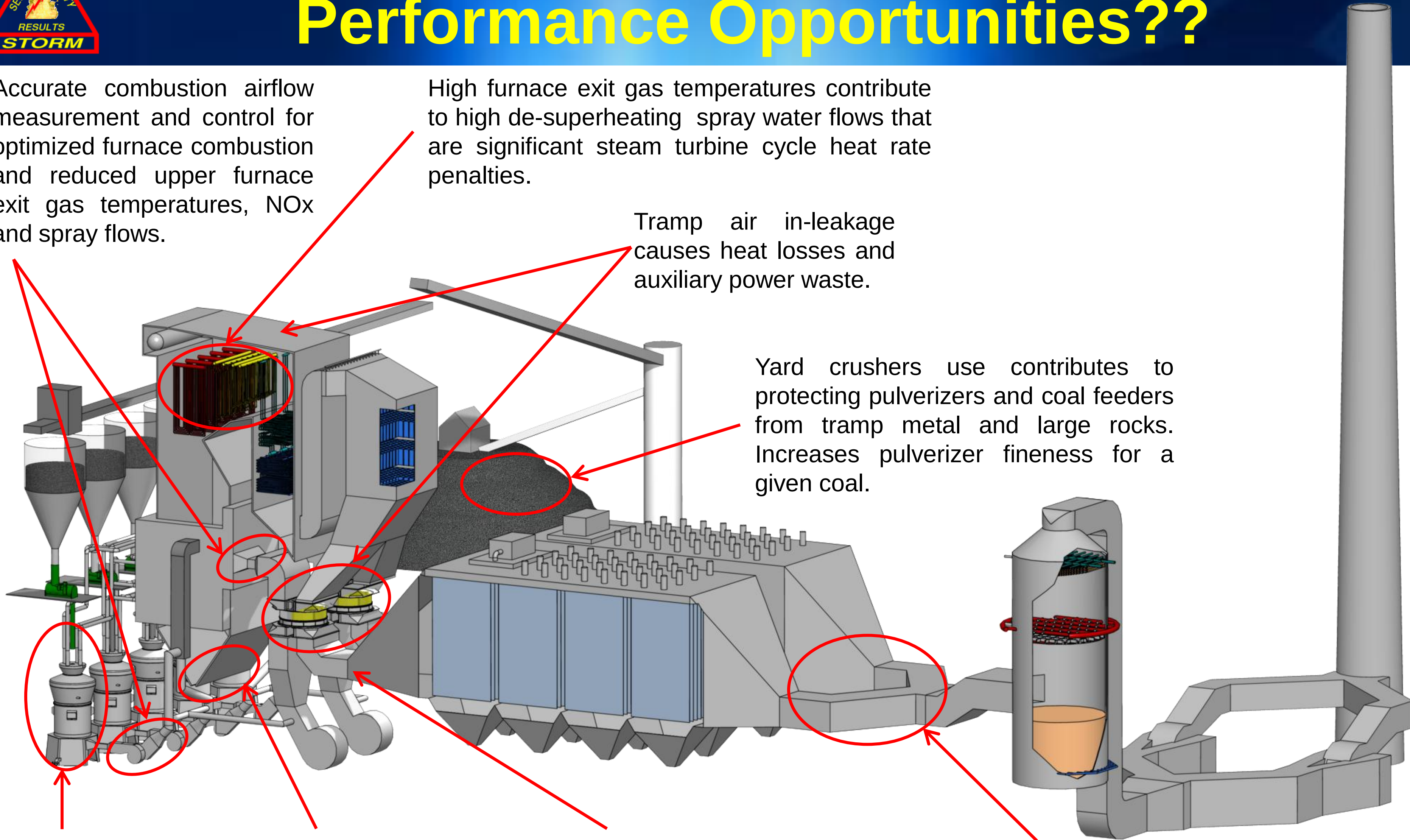
# Where are the Typical Plant Performance Opportunities??

Accurate combustion airflow measurement and control for optimized furnace combustion and reduced upper furnace exit gas temperatures, NOx and spray flows.

High furnace exit gas temperatures contribute to high de-superheating spray water flows that are significant steam turbine cycle heat rate penalties.

Tramp air in-leakage causes heat losses and auxiliary power waste.

Yard crushers use contributes to protecting pulverizers and coal feeders from tramp metal and large rocks. Increases pulverizer fineness for a given coal.



Coal spillage from pulverizer throats that are too large.

Bottom ash carbon content and bottom ash hopper air in-leakage.

Flyash carbon losses.

Air in-leakage after the APH contributes to wasted ID fan power and capacity.

# Total Performance Optimization Requires Three Components:

**First**: Apply the fundamentals

**Second**: Diagnostic testing to identify opportunities for improvement

**Third**: Operations – Maintenance – Engineering – Management all need to work on the same plan!  We call it:  **Performance Driven Maintenance**

## Fundamentals Including:

- Apply the 13 Essentials
- Apply the 22 Boiler Controllable Heat Rate Factors
- Implement Performance Preservation by using the Performance Driven Maintenance approach
- O&M Teamwork is absolutely essential

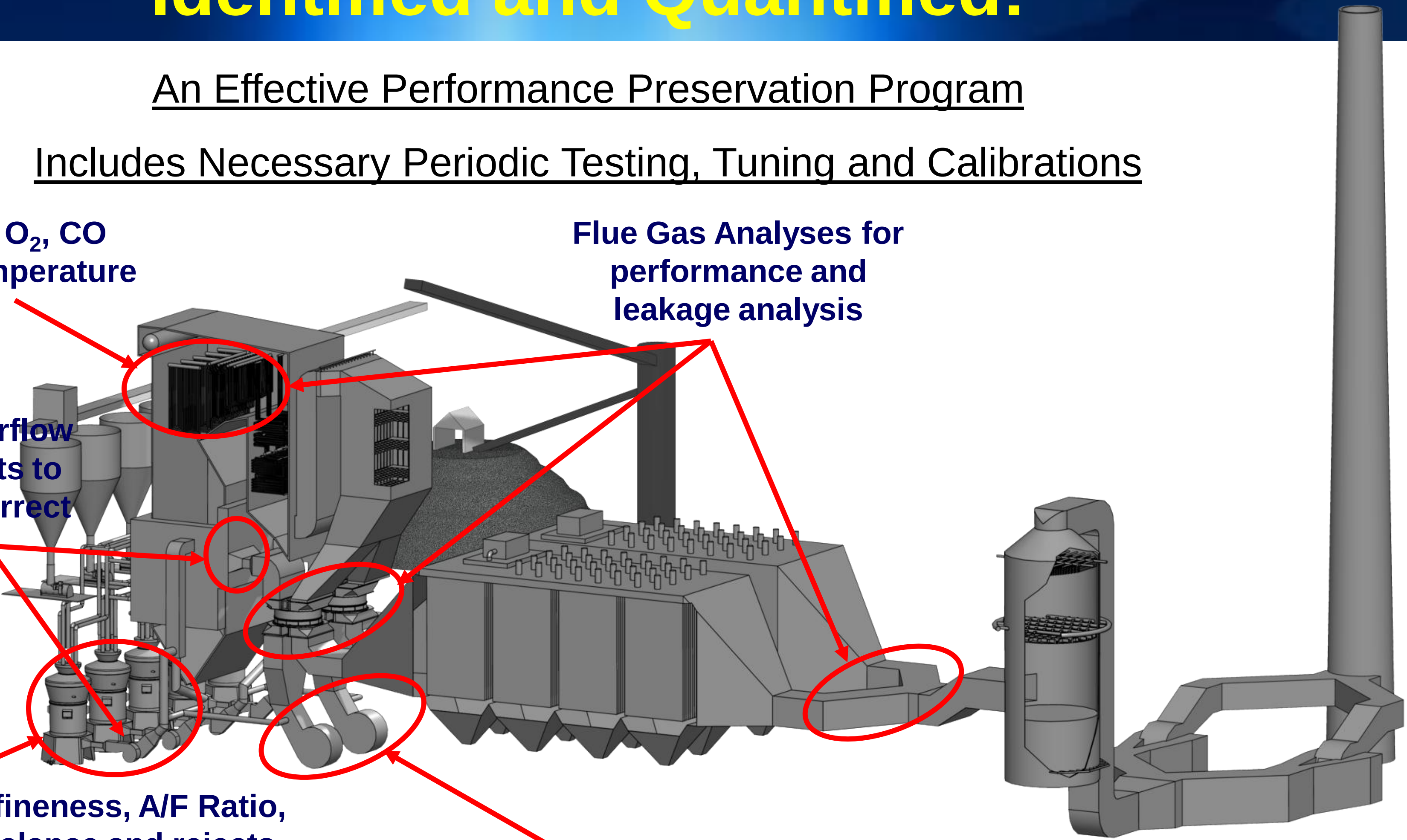
## Diagnostic Testing Including:

- Total Combustion Airflow Measurement and Control
- Optimized Pulverizers
- Optimized Maintenance of all Auxiliaries. Ex: Airheaters, Fans, Sootblowers, Controls
- Boiler and Overall Performance (HVT, Flyash, Leakage)

# To Correct a Problem – First is must be Identified and Quantified!

An Effective Performance Preservation Program

Includes Necessary Periodic Testing, Tuning and Calibrations




*"A problem identified is a problem half solved"*

**Ben Franklin**

# STORM®

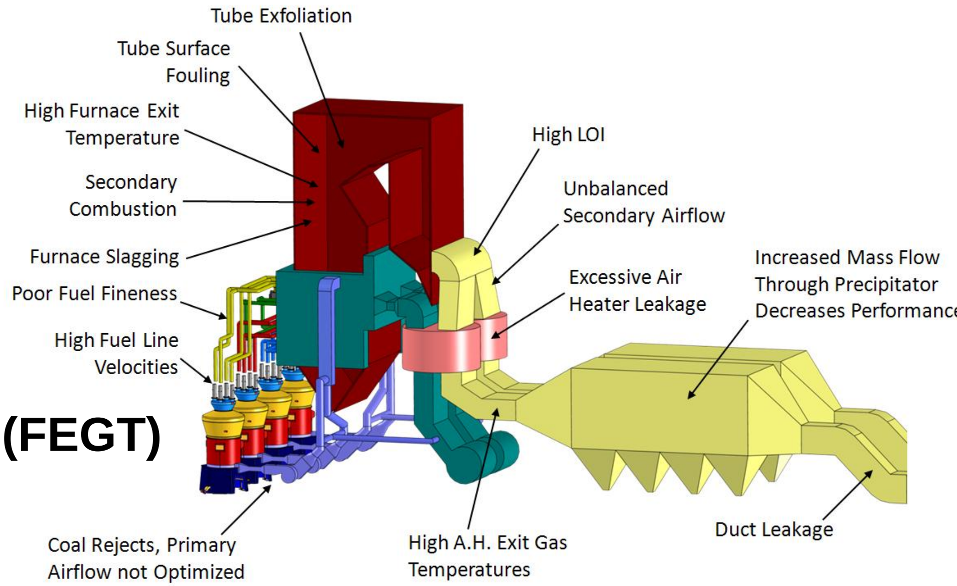
*Specialists in Combustion and Power*

## 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.

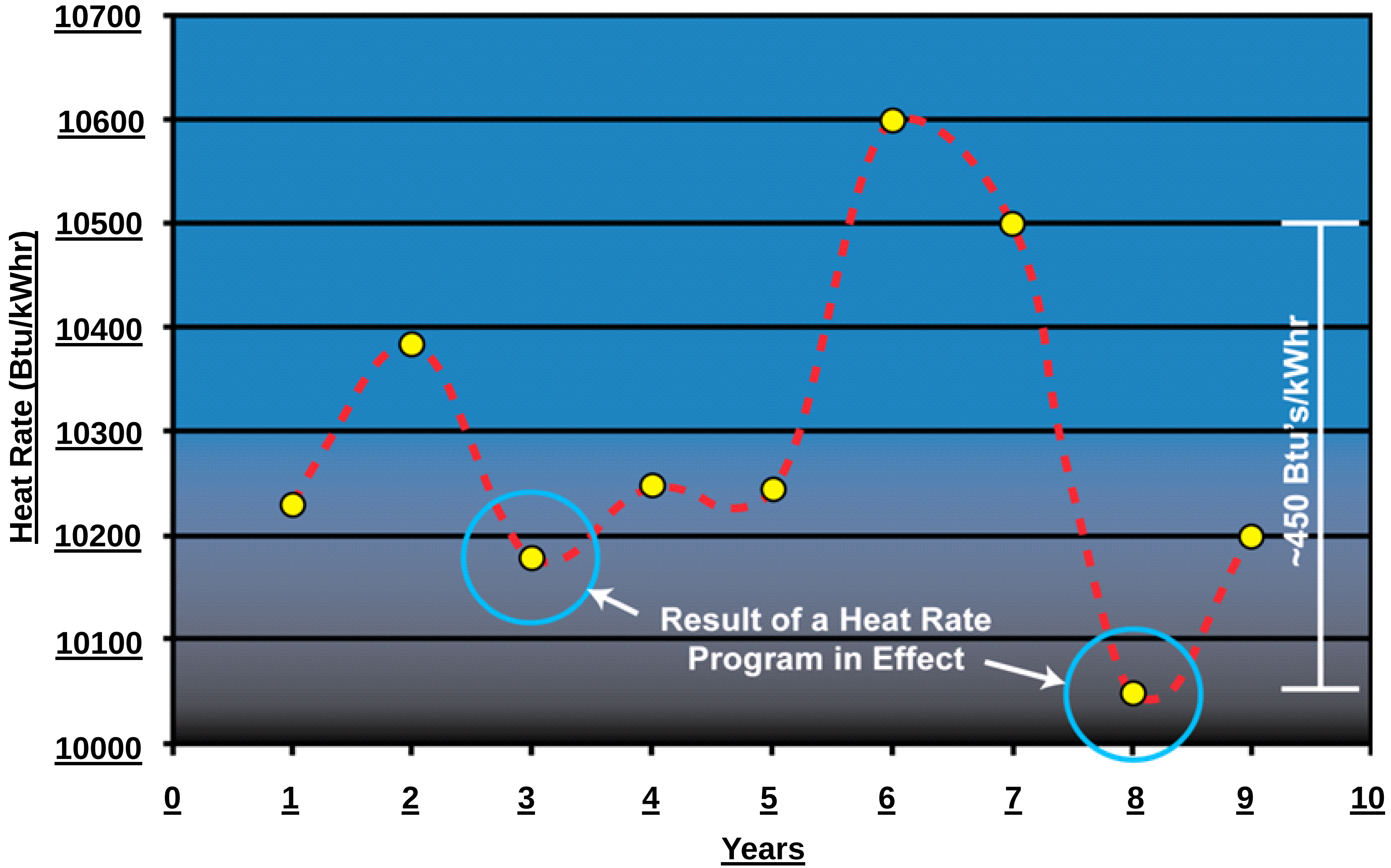
# Common "Correctable" Opportunities for Improvement:

1. Air in-leakage
2. High primary airflow's
3. Poor fuel fineness
4. Poor fuel distribution
5. High furnace exit gas temperatures (FEGT)
6. Unbalanced secondary airflows
7. Inaccurate overfire airflow measurement and control
8. Inaccurate primary and secondary airflow measurement and control
9. Slagging and fouling of the superheater and convection pass
10. Excessive air heater leakage
11. Excessive spray flows



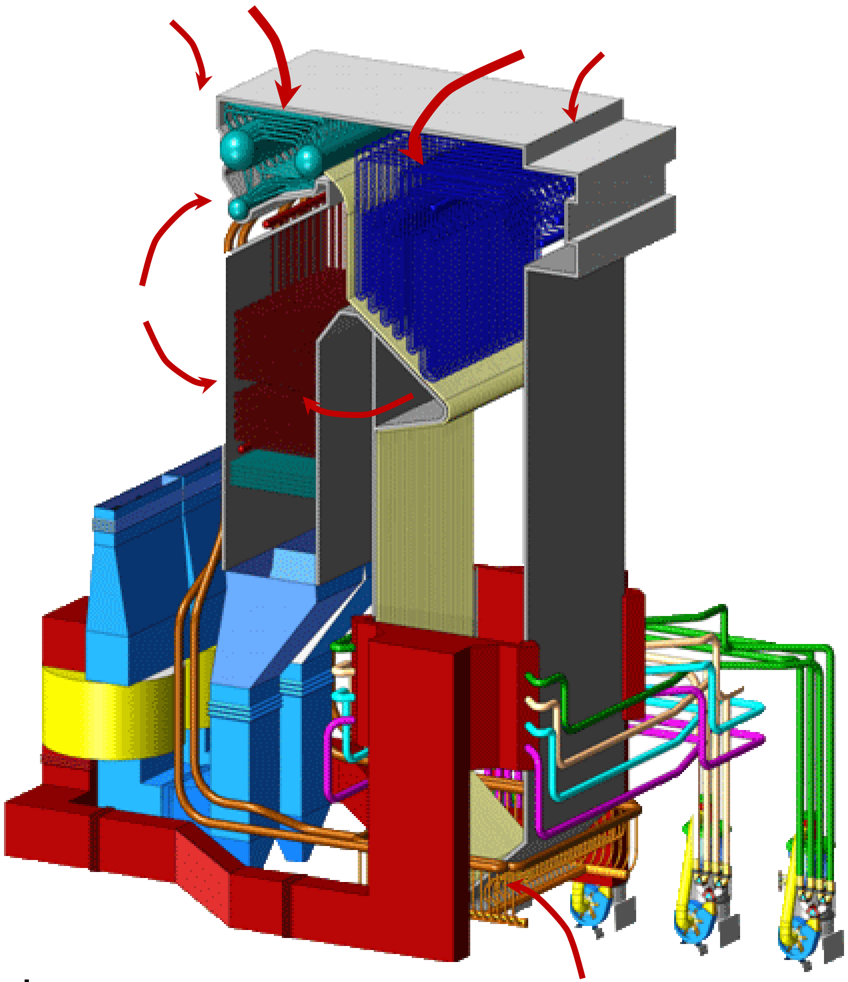
# Example Heat Rate Curve of What Can Be Accomplished By Applying The Basics

A 650MW – P.C. Fired, 2400psi, 1000°F/1000°F Unit



# 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
- The air that leaks into the boiler setting, Leak path between penthouse and air heater inlet gas is useless for combustion, it is simply “tramp air”
- Bottom ash hopper seals are another source of Air Heater Bypass air
- Traditional Concerns of Air heater leakage and the penalties of high Air Heater Leakage



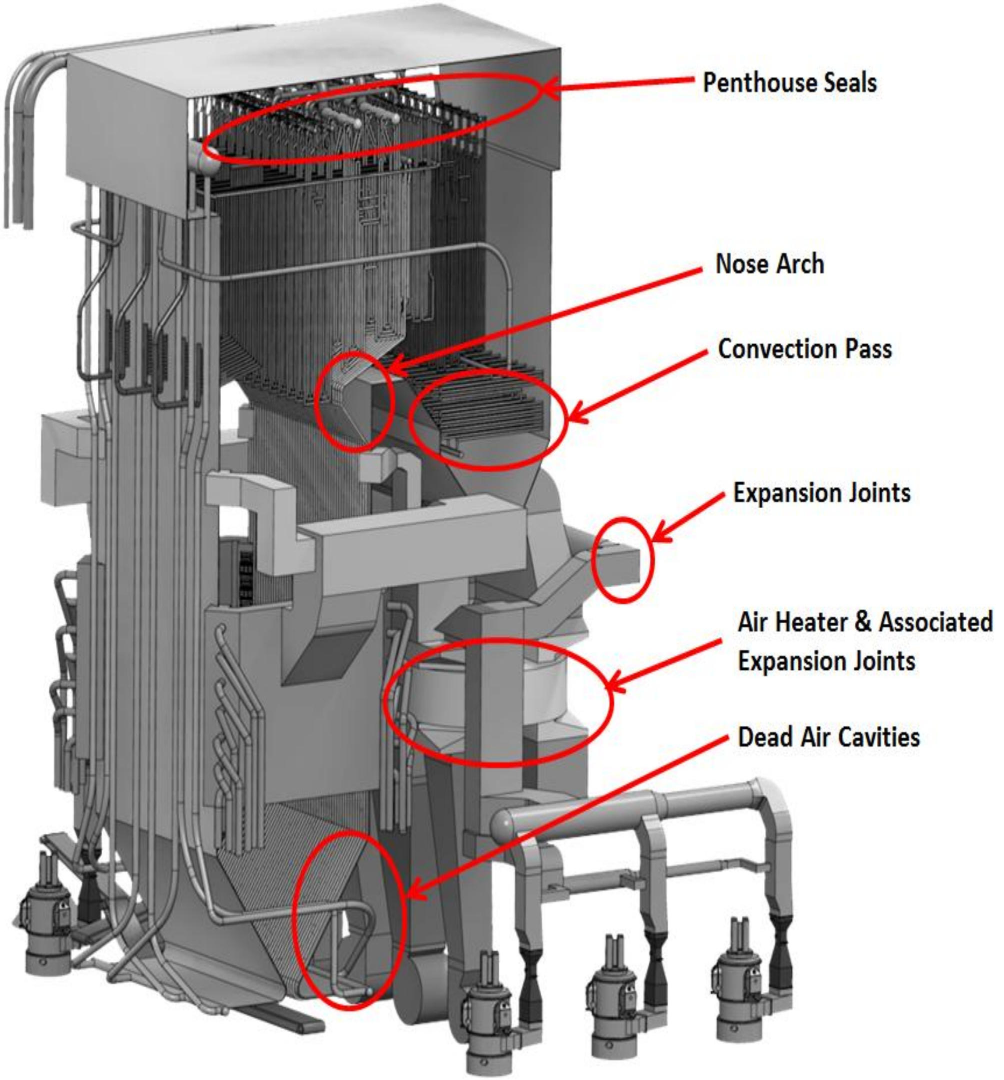
# Total Air In-Leakage

Completeness of combustion at the furnace exit requires approximately 850 pounds of air per million Btu's of fuel.

Tramp air does nothing for combustion but still requires fan power.

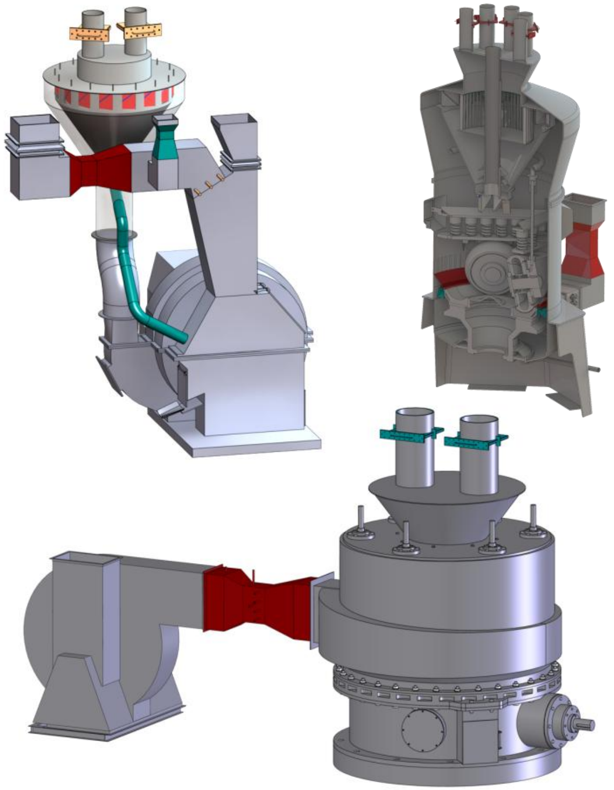
| Location | Leakage | Additional KW's Required |
|---|---|---|
| Furnace Leakage (Avg) | 19.37% | 660 |
| Secondary APH 1 Leakage | 9.29% | 21 |
| Secondary APH 2 Leakage | 19.51% | 187 |
| Primary APH Leakage | 61.11% | 432 |

*Actual test data.



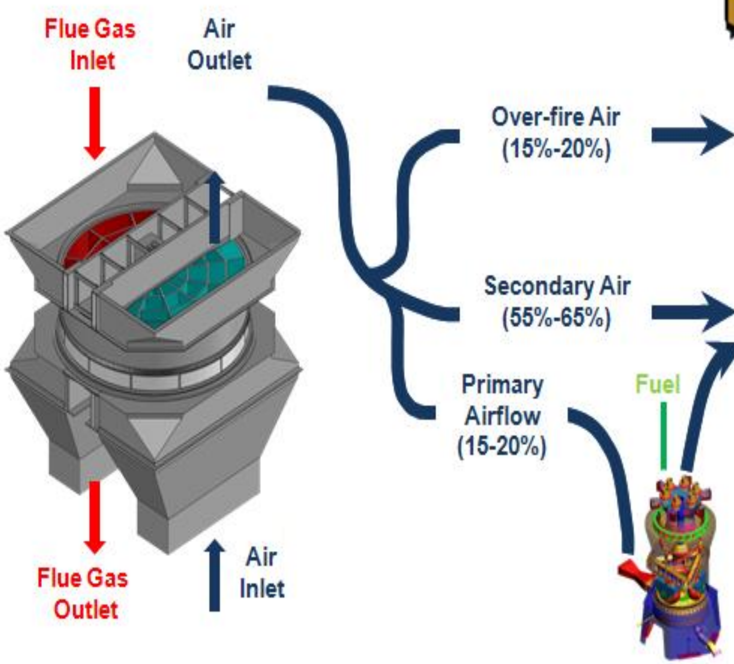
# Getting the Inputs to the Furnace Right is the First Step to Combustion Optimization!!

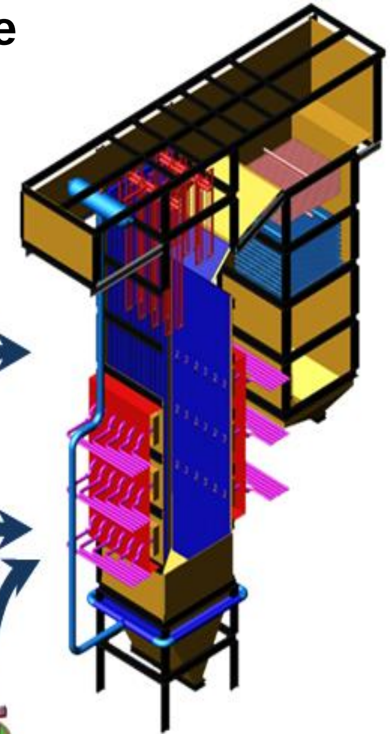
**The Total Combustion Optimization program requires the 13 Essentials and Including pulverizer performance optimization.**



**9 of the 3 Essentials are directly related to the pulverizer.**

**Comprehensive and Precise Control of all Combustion Airflows is Essential!**

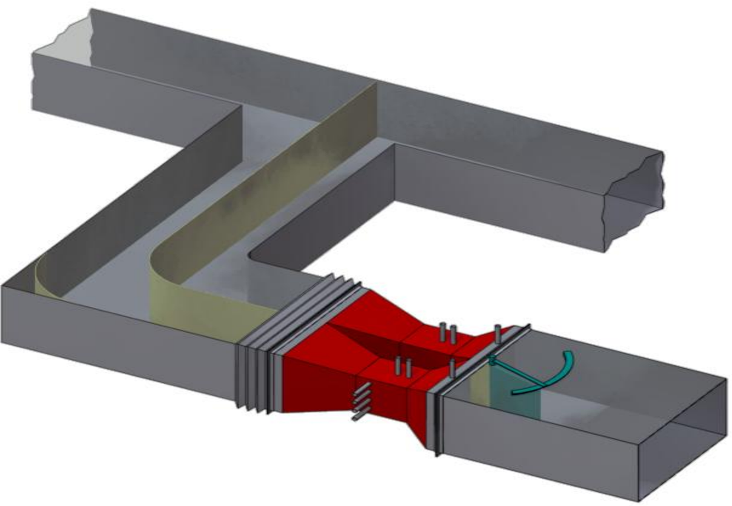


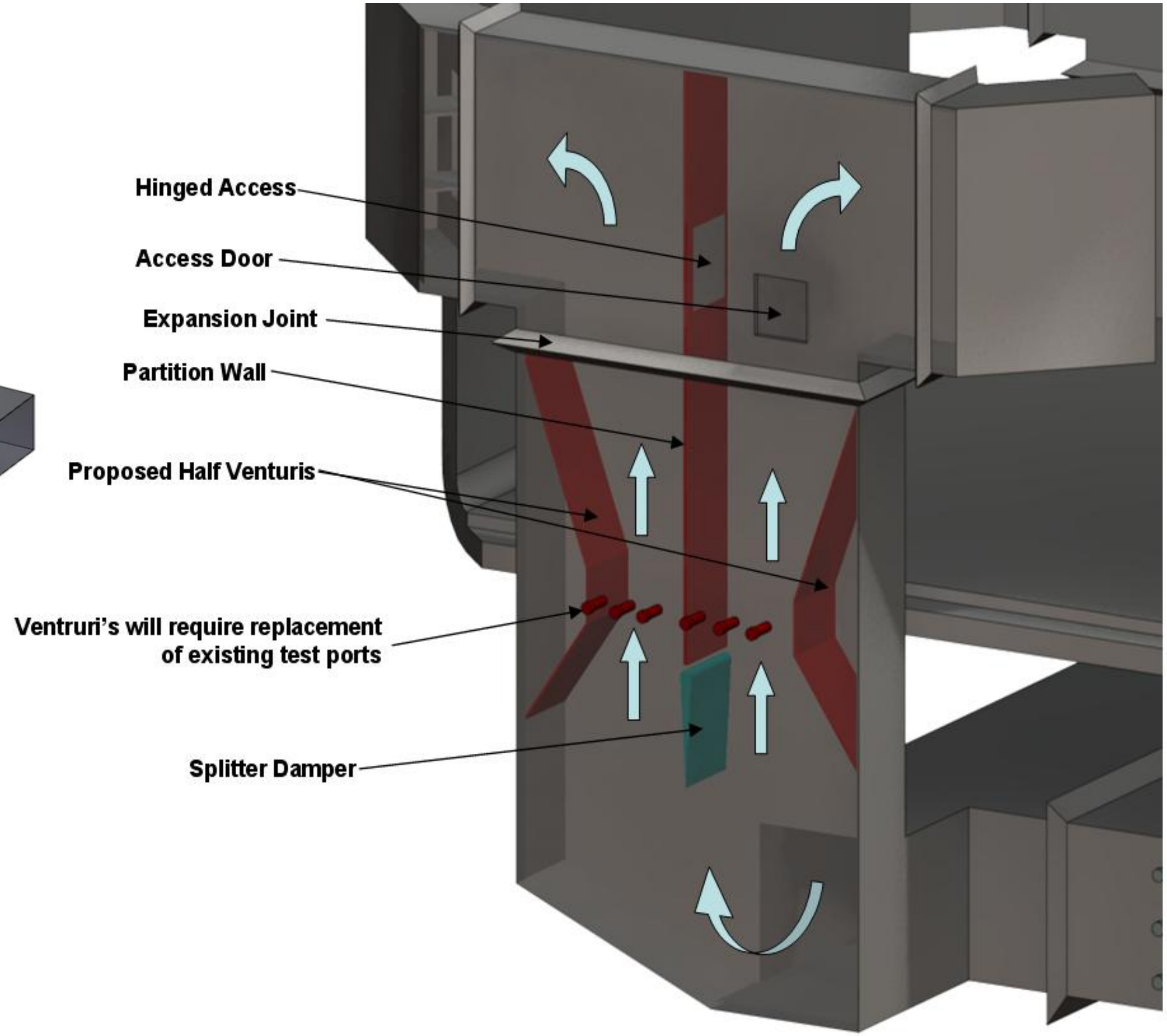
**The pulverizers and fuel lines comprise about 75% of the opportunities for improvement of a typical coal fueled steam plant**

# Combustion Airflow Measurement and Control Using Rugged, Reliable, Accurate Venturi's and Flow Nozzles

Implement the use of venturis sections for precise airflow



A complete airflow management system includes precise measurement of primary airflow and fuel line velocities




Benefits:

•Use of two sensing lines greatly reduces pluggage

•Increased accuracy/reliability of airflow measurement (  3%)

•Rugged design

•Low installation cost

•Provides optimum furnace conditions

•Improves control and reduction of $NO_X$

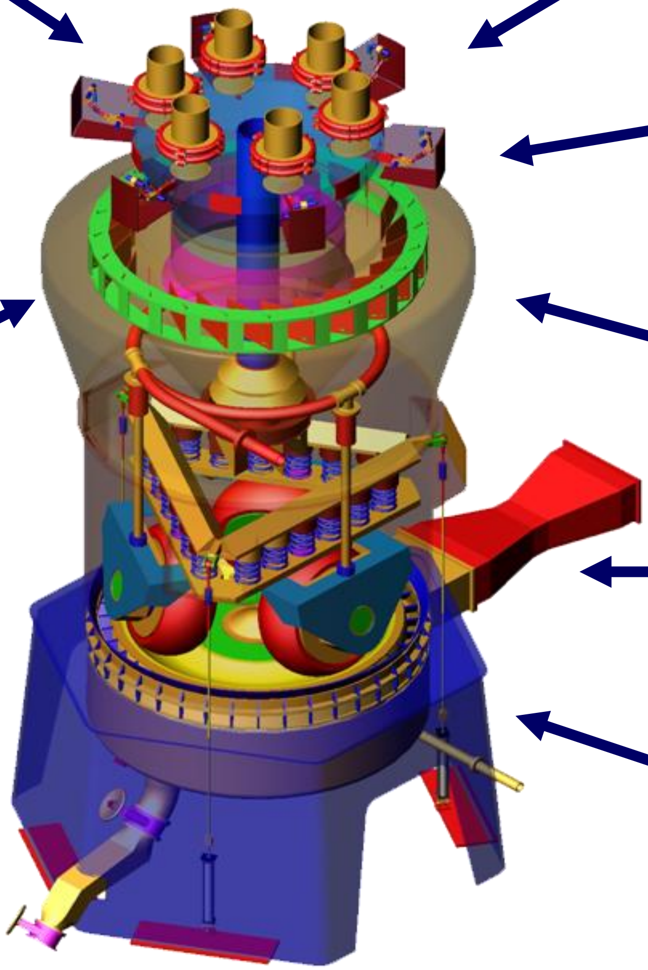
# Pulverizer Optimization Using Performance Driven Maintenance

**STOCK® Gravimetric Load Cell Coal Feeder Upgrades Installed**

**Clean Airflow Balanced within ±2%**

**Fuel lines balanced by "Dirty Air" test, using a Dirty Air Velocity Probe, within ±5% or better.**

**Fuel line fineness $\geq$75% passes a 200 mesh screen. Particles remaining on 50 mesh screen shall be < 0.1%.**



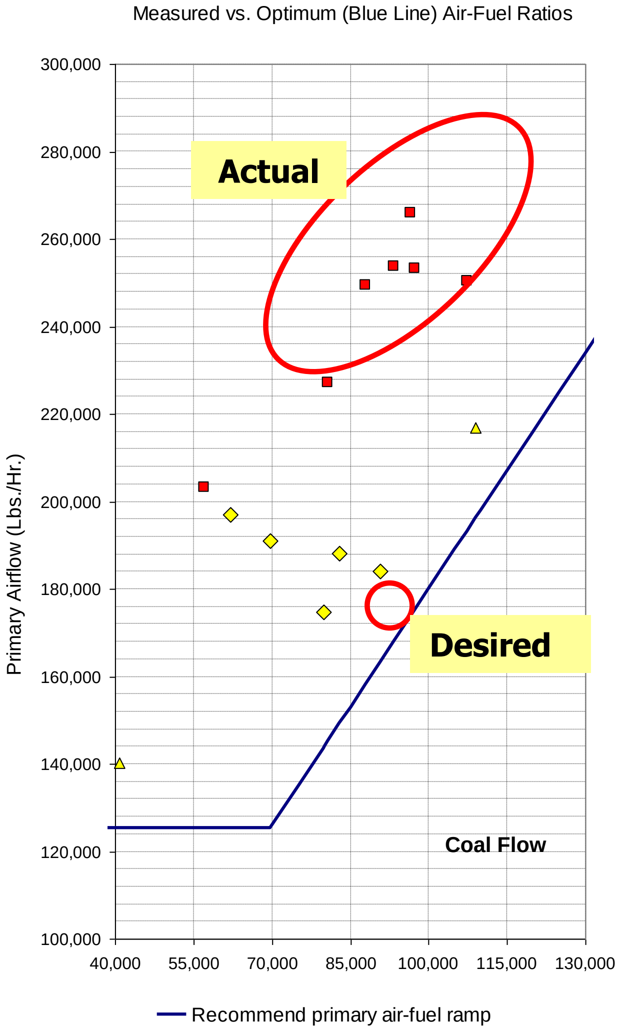
**Fuel lines balanced by fuel flows within ±10% or better**

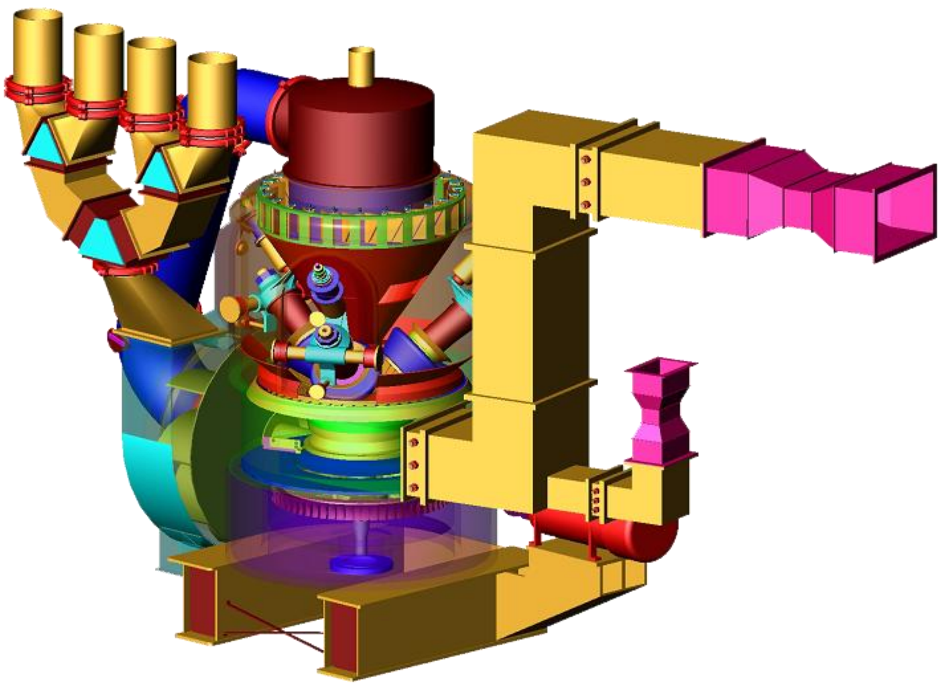
**Accurately Measure & Control Primary Airflow to within ±2% (Ctrl Vs. Measured)**

**STORM Throats & Deflectors optimized to reduce coal rejects and allow optimum air-fuel ratios to be maintained**

# Primary Air/Fuel Ratio Shall be Accurately Measured & Controlled

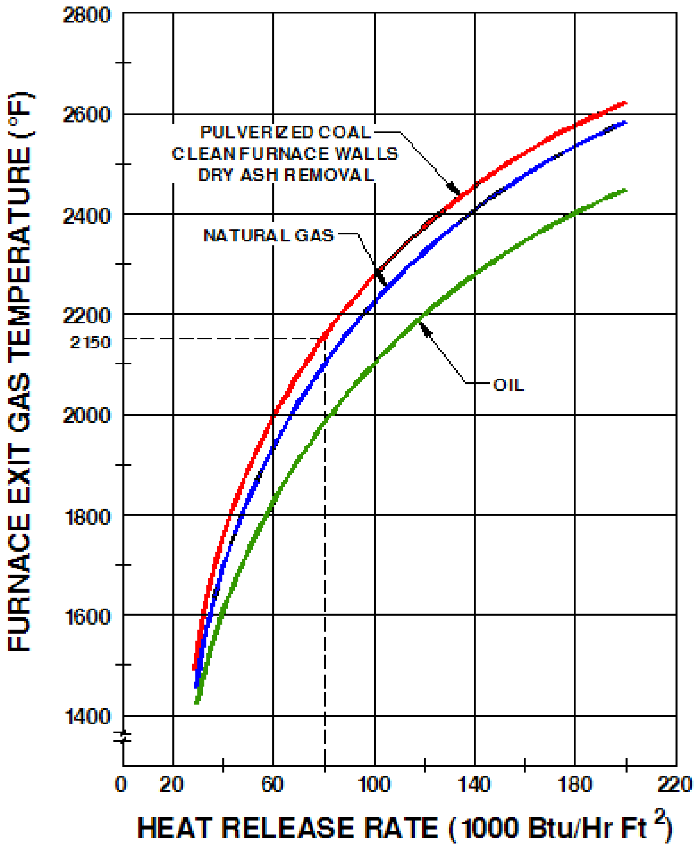
## Typical "As Found" Performance

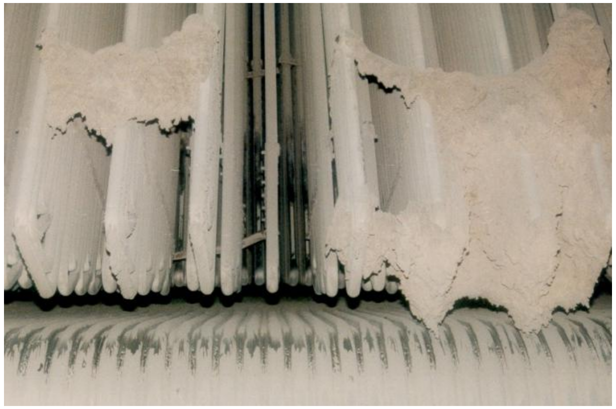


**High Tempering Airflow Bypasses the Air Heater and contributes to a less desirable "X" Ratio. Therefore, the mills must be optimized to insure that optimum performance is compatible with a desirable air-fuel ramp**

# Furnace Exit Gas Temperature (FEGT) Should Always be Below 2,250 F

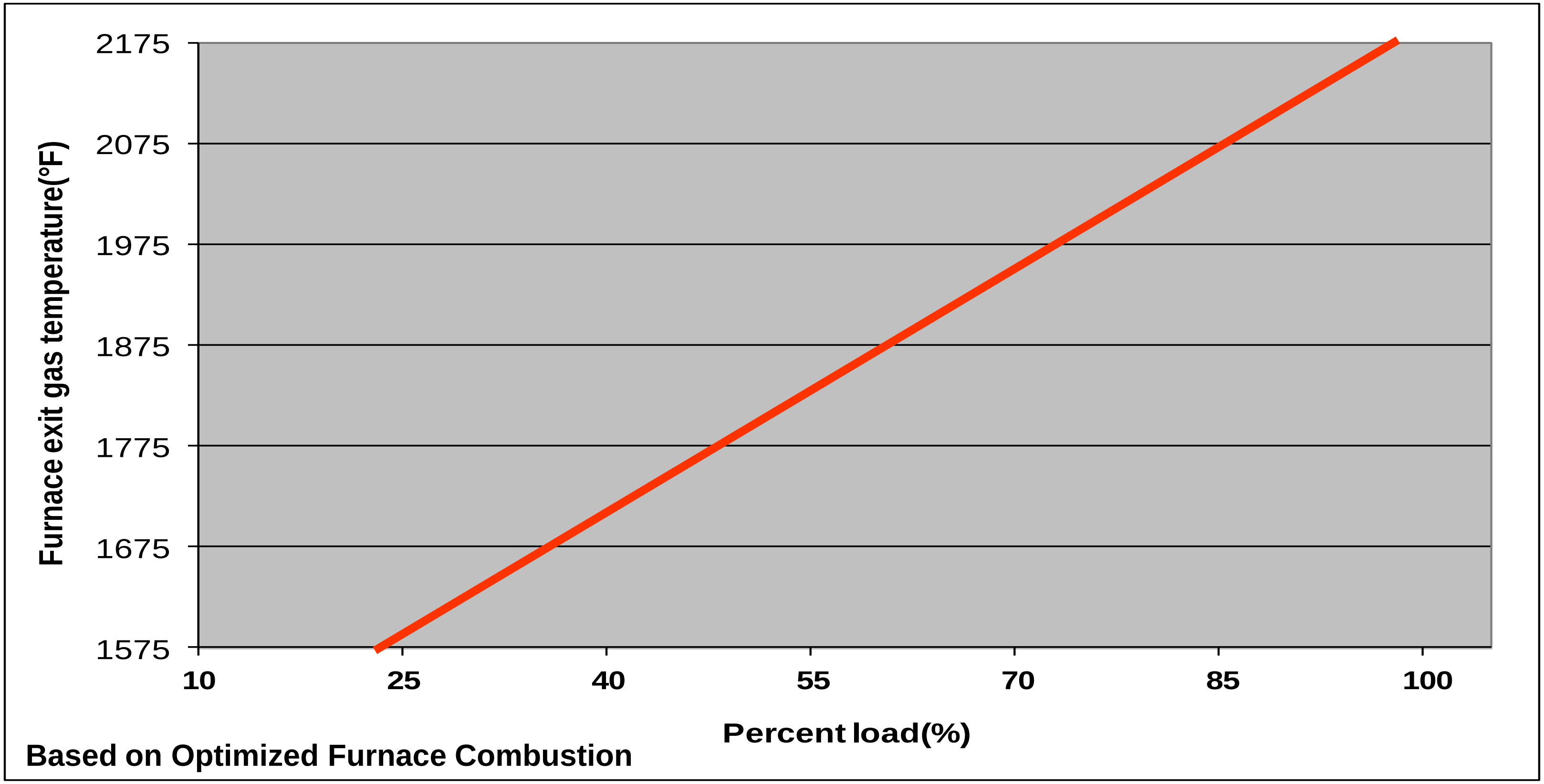


High furnace exit gas temperatures can contribute to overheated metals, such as these superheater alignment castings that only lasted 1 year due to greater than 2,500°F. furnace exit gas temperatures.

# Combustion Optimization in the burner belt is a pre-requisite for "BEST" heat rate performance

Optimum Furnace Exit Gas Temperature for a P.C. Boiler with 80,000 Btu/ft$^2$/hr Heat Release Rate



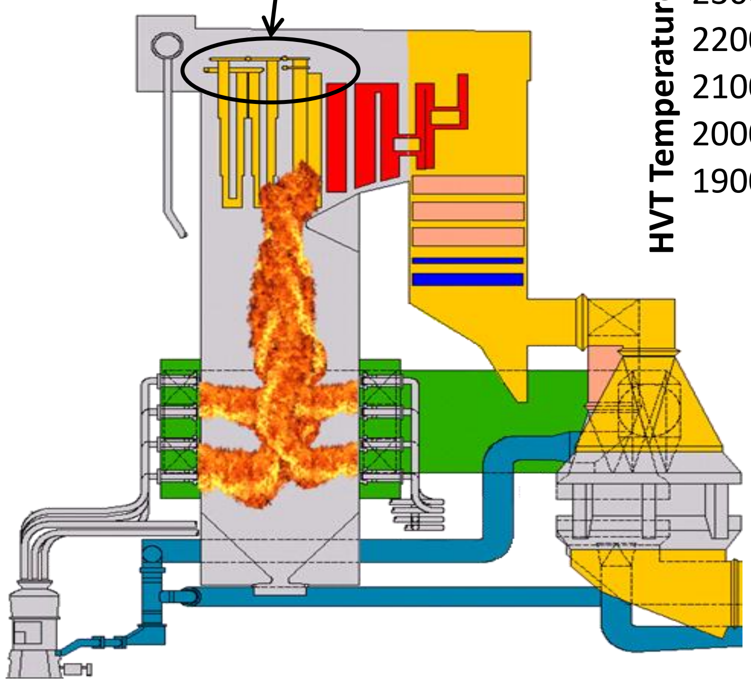

**The FEGT and the "PEAK" temperatures are reduced when the essentials of combustion are applied.**

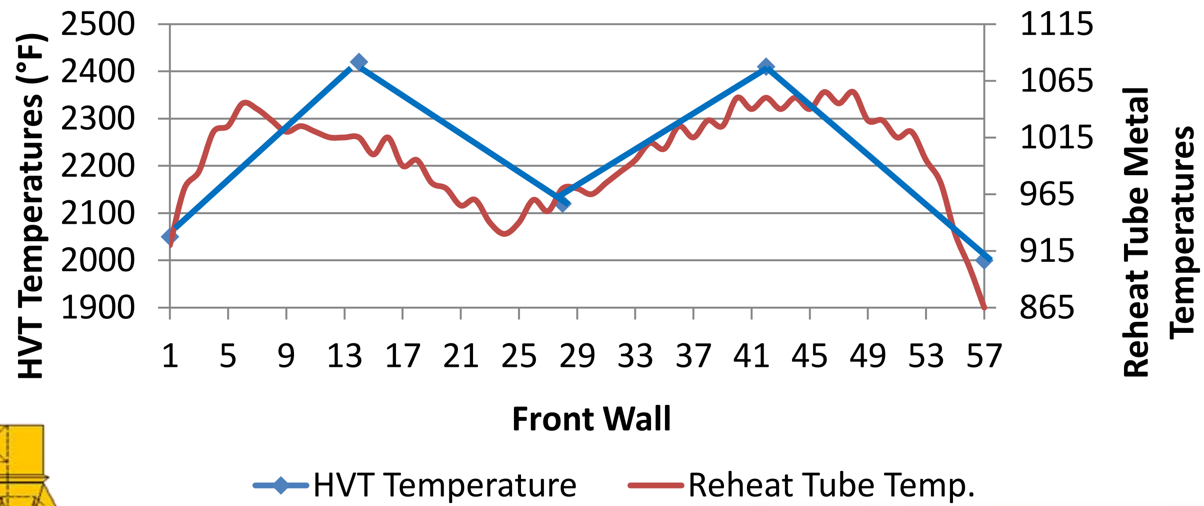
**The FEGT should be on the curve PROVIDING that the pulverizers, combustion airflows and burner belt performance is optimized.**

# High Flue Gas Temperature Peak Temperatures

**High flue gas temperature "peaks" and the corresponding peaks of individual tube temperatures. The point is, poor distribution of hot gas lanes, often correspond with overheated tube circuits.**

**Primary Super-Heat Tube Metal Thermocouple Location**





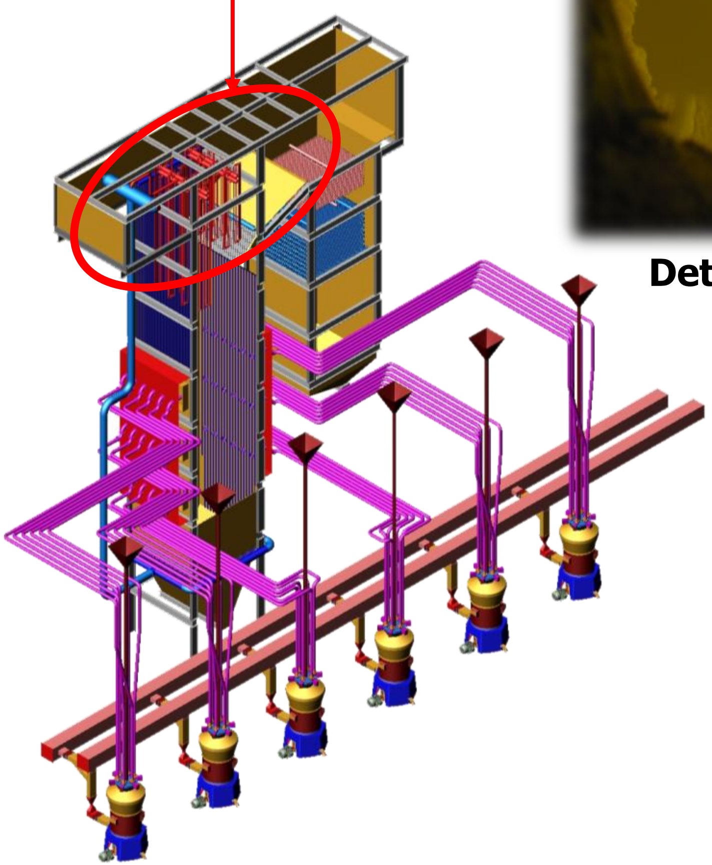


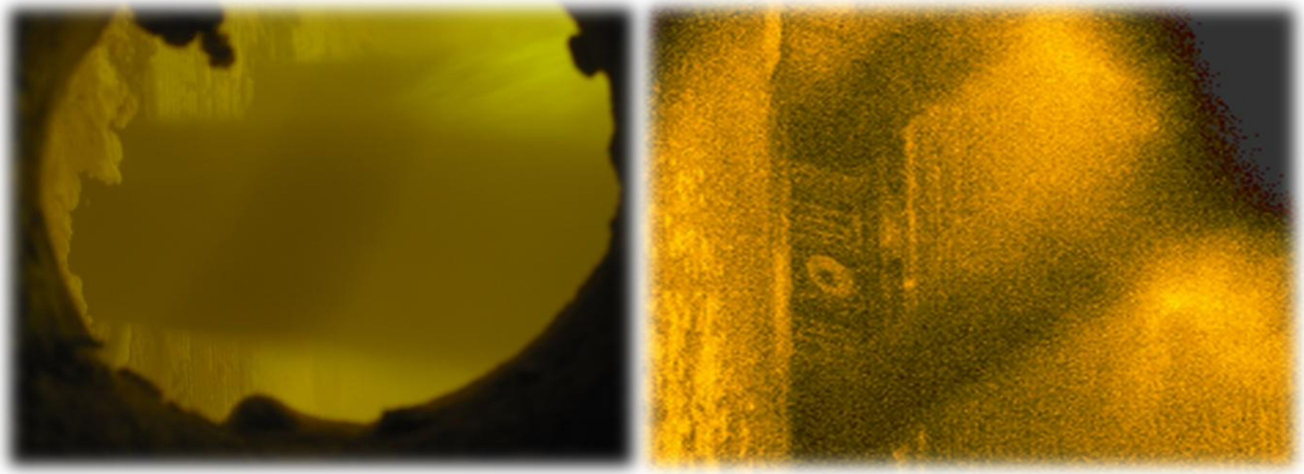
**Primary Super-Heat (PSH) Element Tube Metal Thermocouple Installation**

# Excessive De-superheating Spray Flows Negatively Effect Your Heat Rate

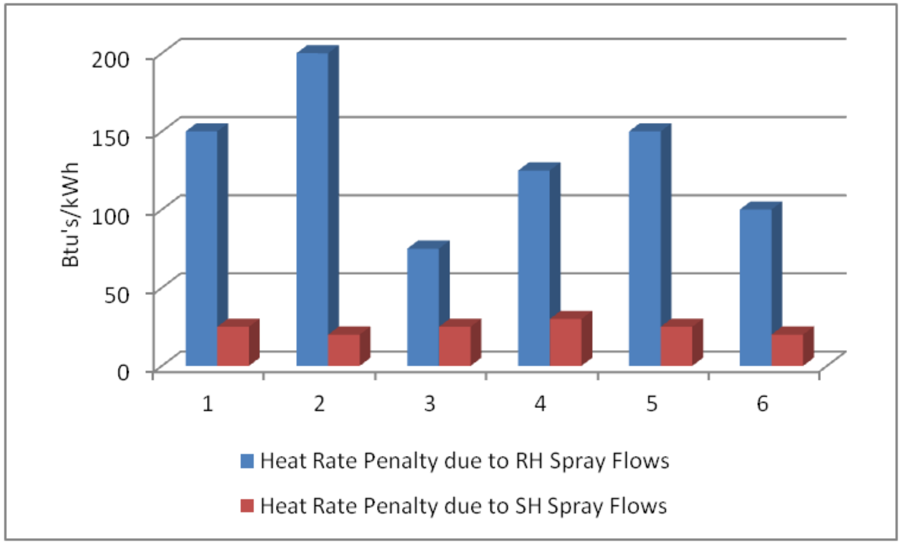
## High Spray Flows are also a symptom of high flue gas temperatures

**Too much heat absorption in the upper furnace will contribute to high desuperheating water spray flows.**



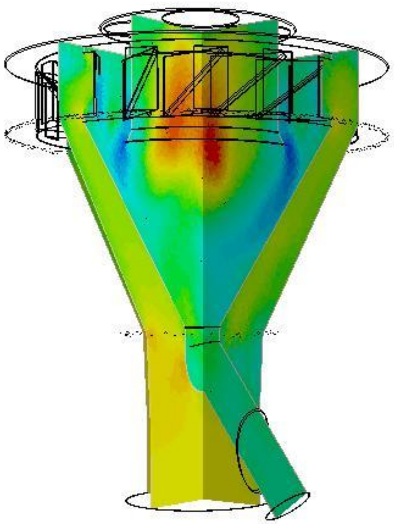


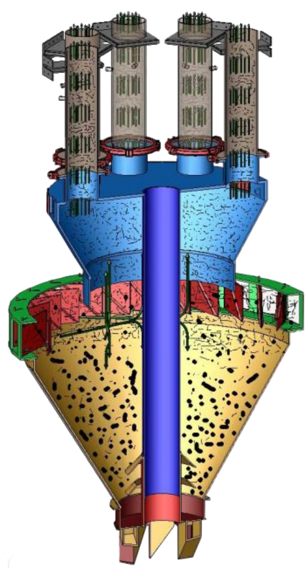
**Detached burner flames for a front wall and corner fired unit.**

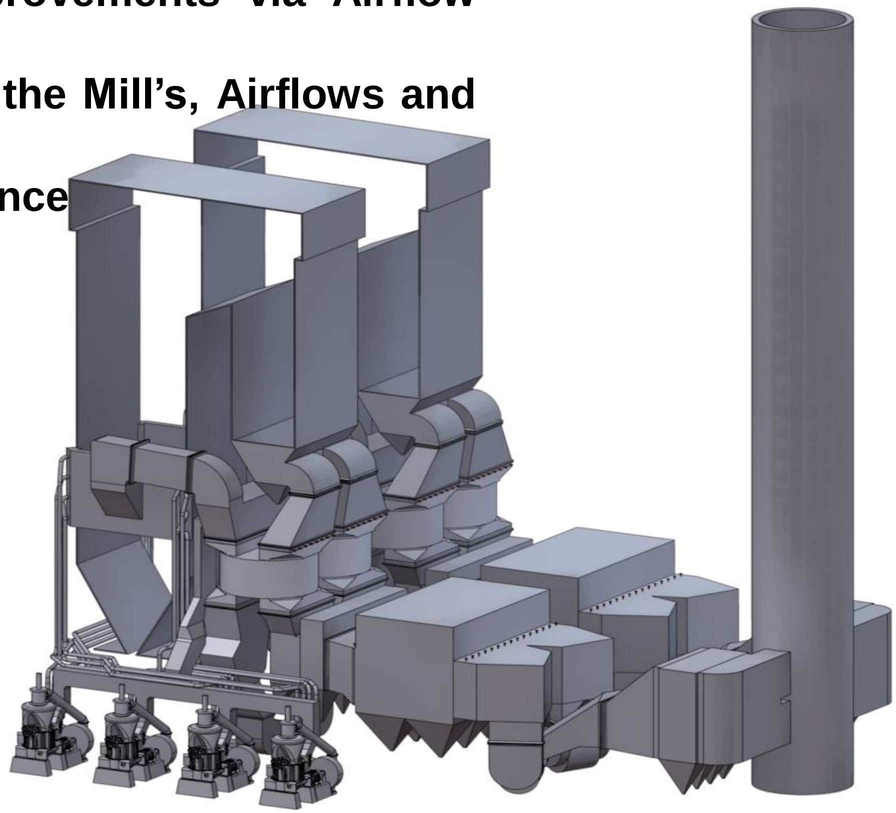


# The STORM approach to Combustion & Efficiency Improvements

- Testing to identify and quantify the opportunities.
- Internal inspections to implement repairs based on the priorities identified during testing
- Apply the 13 Essentials to all furnace Inputs and all ductwork leakage
- Test & Optimize mill performance as a first step
- Conduct Airflow Management & Improvements via Airflow measurement & calibrations.
- Perform Periodic Testing & Tuning of the Mill's, Airflows and Flue Gas Flow Path
- Perform Performance Driven Maintenance

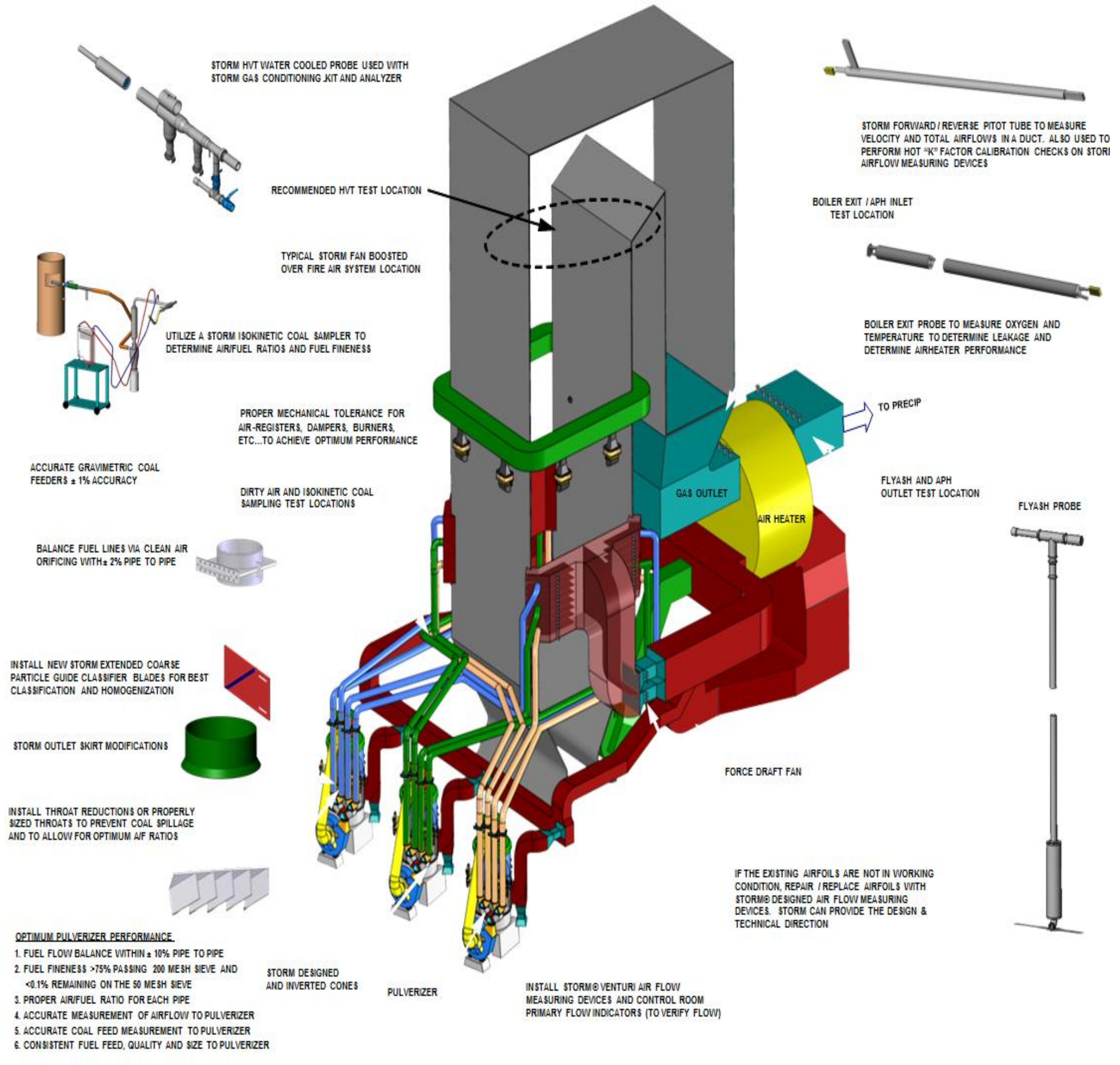




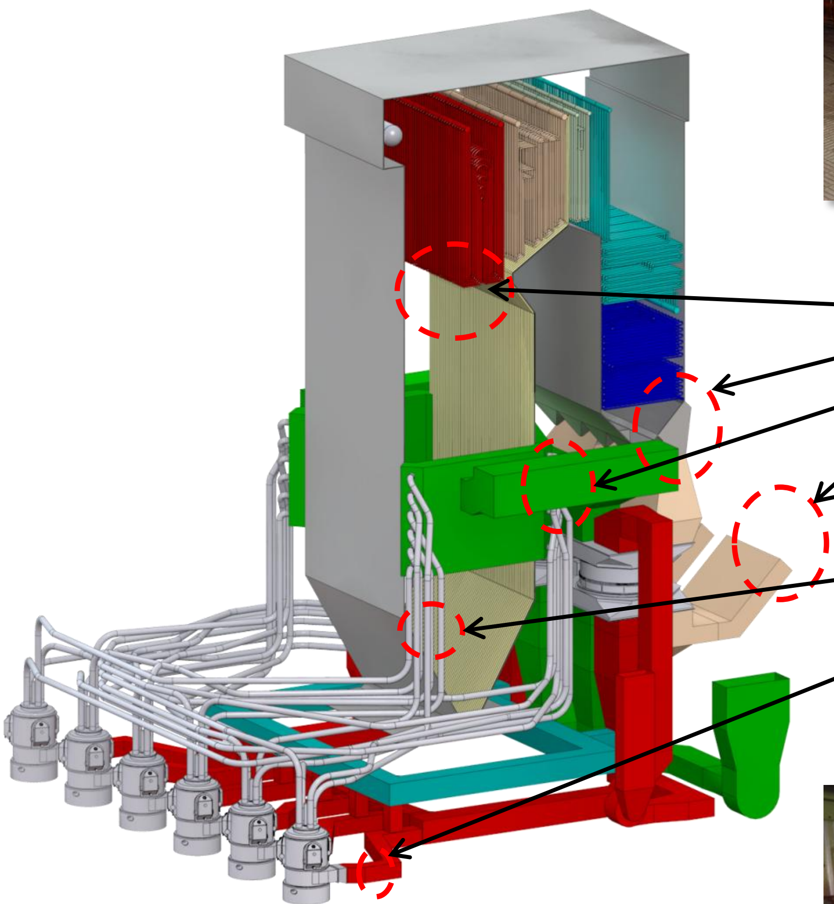


# Typical Opportunities Identified for Improvement as a result of diagnostic testing

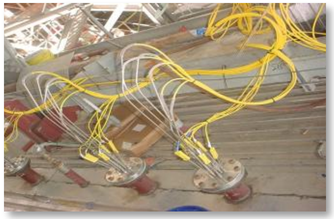
- Air in-leakage prior to the air heater
- Air heater leakage
- A.H. Exit Gas Temperature (corrected for leakage) higher than design
- High Primary Airflow
- High FEGT and Major Stratifications
- Auxiliary Power is excessive due to high APH differential and air in-leakage
- Unbalanced furnace requires higher total airflow
- Burner tuning issues
- $NO_X$ and/or LOI Improvements



# Comprehensive Evaluation and Application of the Basics by the Full Plant Team: Operations, Maintenance, Engineering and with Management Support



- **Furnace Exit Gas Temperature & Flue Gas Constituents**
- **Economizer Outlet Flue Gas Measurements**
- **Total Secondary Airflow Measurement & Calibration**
- **ID Fan Discharge / Stack Inlet Flue Gas Measurements**
- **“Stealth Loss” Evaluation, Optimization & Preservation**
- **Fuel Line Performance Measurements & Mill Optimization**
- **Mill Inlet Primary Airflow Calibration**



# Thank you very much.

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