Reinhold Environmental Ltd.

2010 NOx-Combustion Round Table & Expo Presentation

February 8 & 9, 2010 Chattanooga, TN

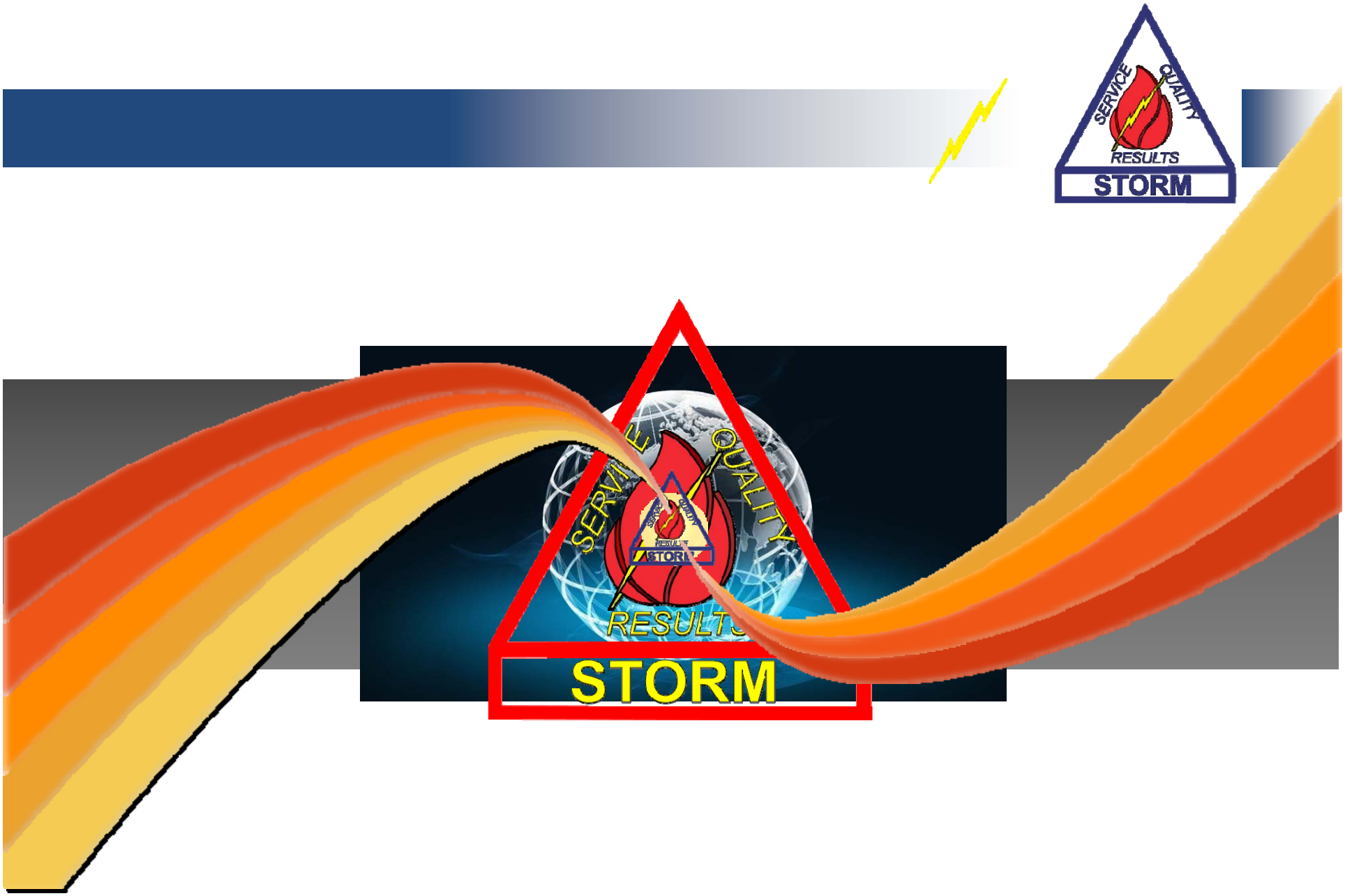
Combustion Optimization

Combustion Tuning, 101

Presented by, Stephen K. Storm
Storm Technologies, Inc.

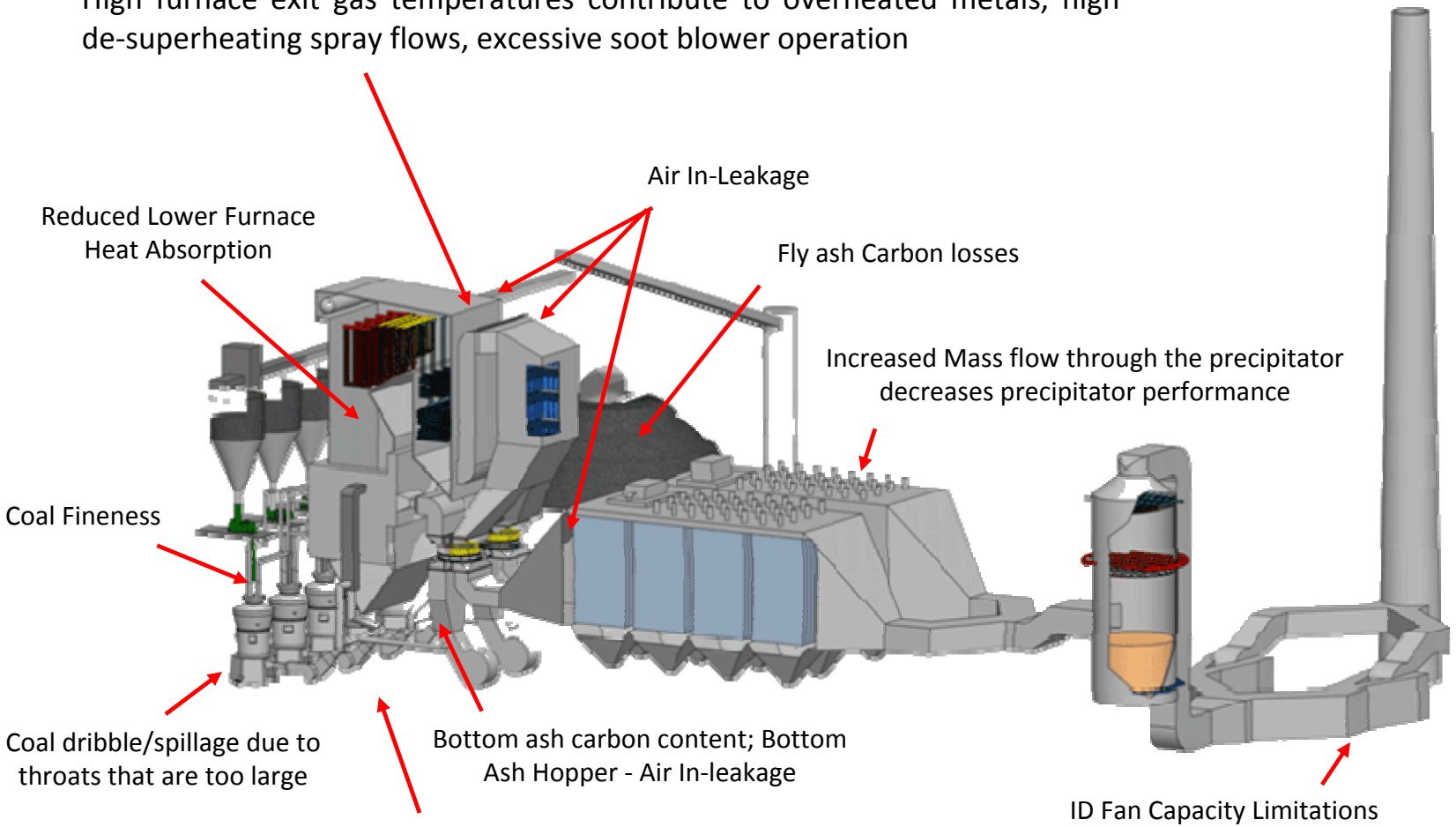
Reinhold Environmental, LTD
2010 NO_X-Combustion/PCUG Conference
Sponsored by TVA

The Chattanoogan Hotel
Chattanooga, TN USA



Typical Plant Performance Opportunities

High furnace exit gas temperatures contribute to overheated metals, high de-superheating spray flows, excessive soot blower operation



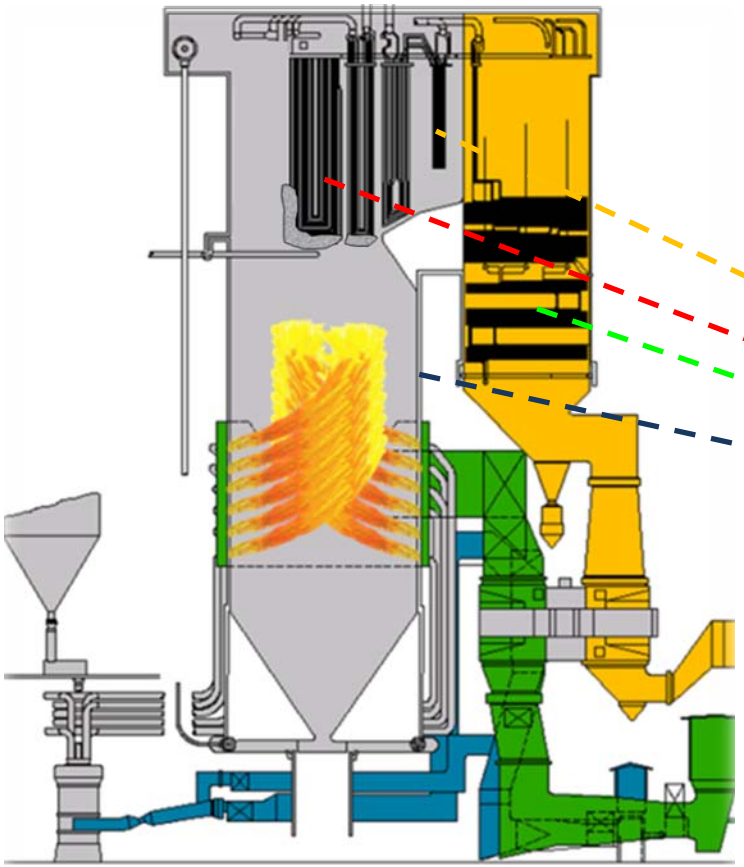
High primary airflows contribute to unnecessarily high dry gas losses. Also poor fuel distribution , poor coal fineness & load Control

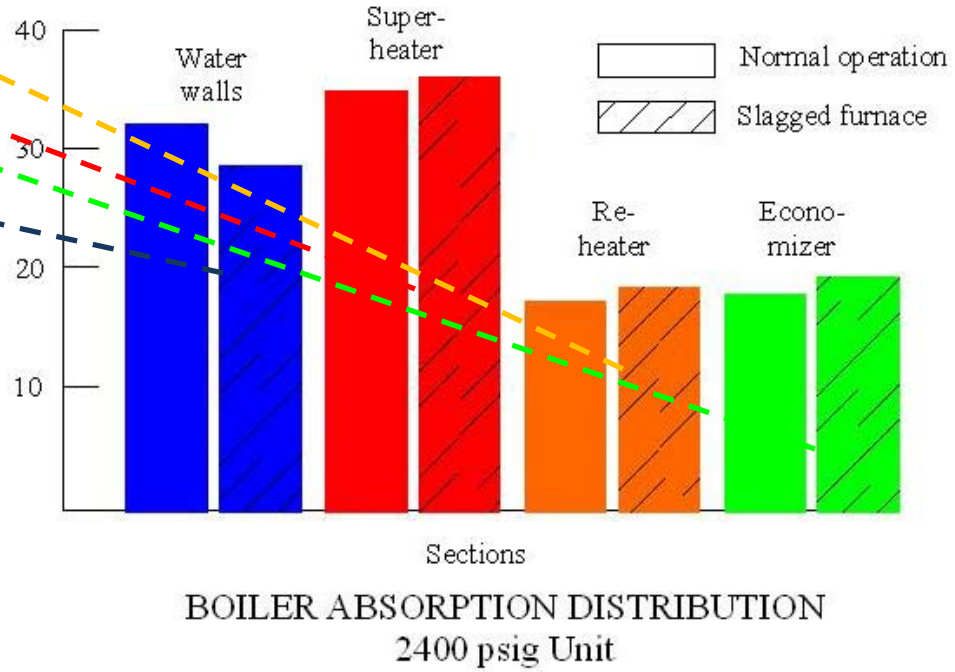
Furnace Exit Secondary Combustion

MOV 00243

Slag Propensity & Fouling Impacts on Tuning

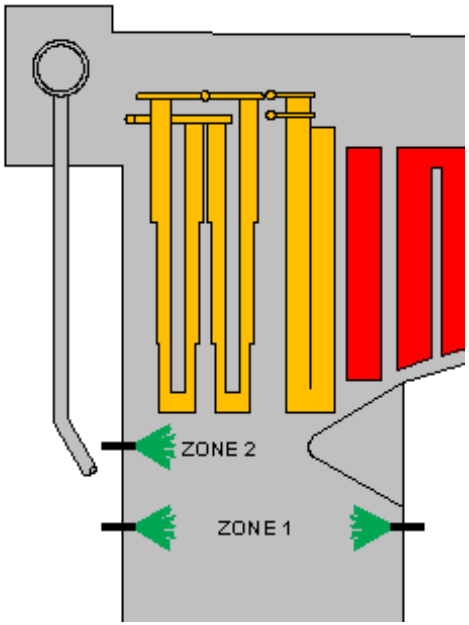
Slag & Fouling Impact on FEGT

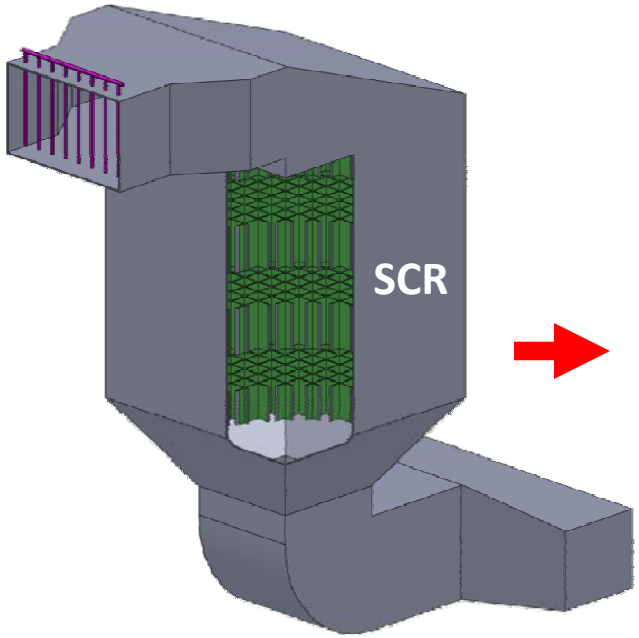


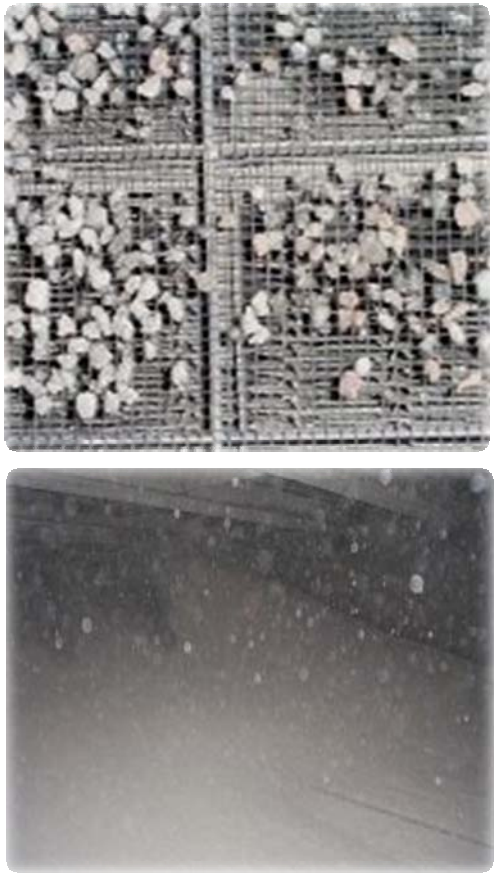


BOILER ABSORPTION DISTRIBUTION
2400 psig Unit

SNCR & SCR Performance Challenges



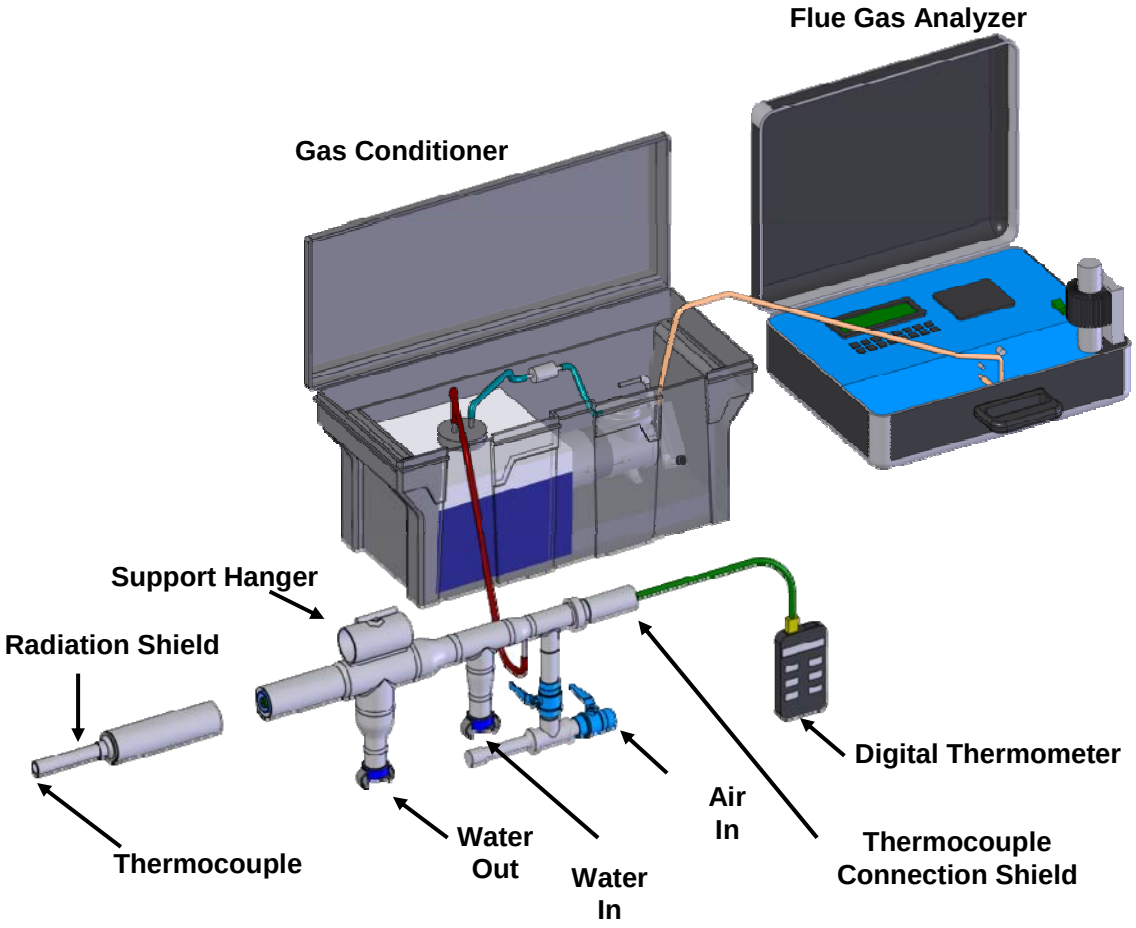




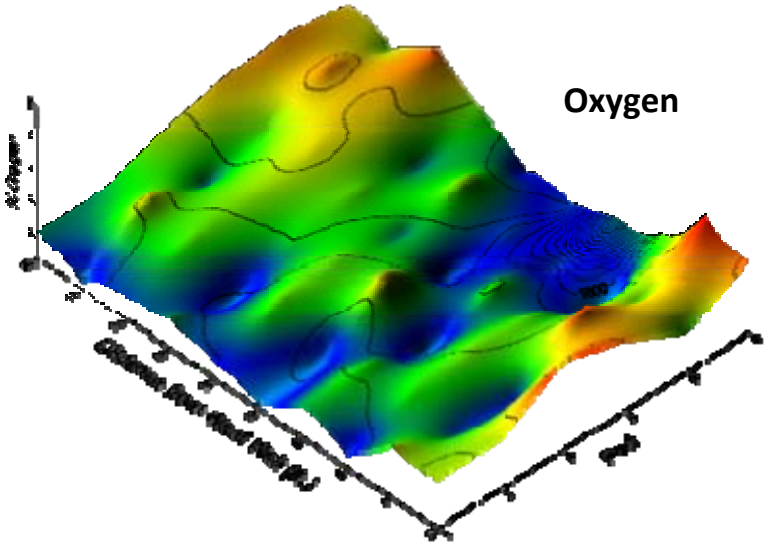
Optimized Furnace Combustion Reduces "Popcorn Ash" that tends to plug SCR catalysts

Ash build-up & plugging half of a catalyst due to popcorn ash

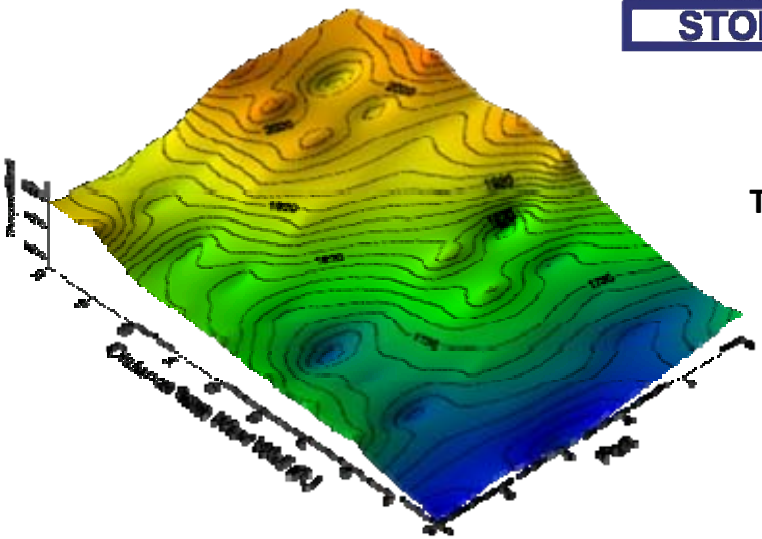
Furnace Exit HVT Testing



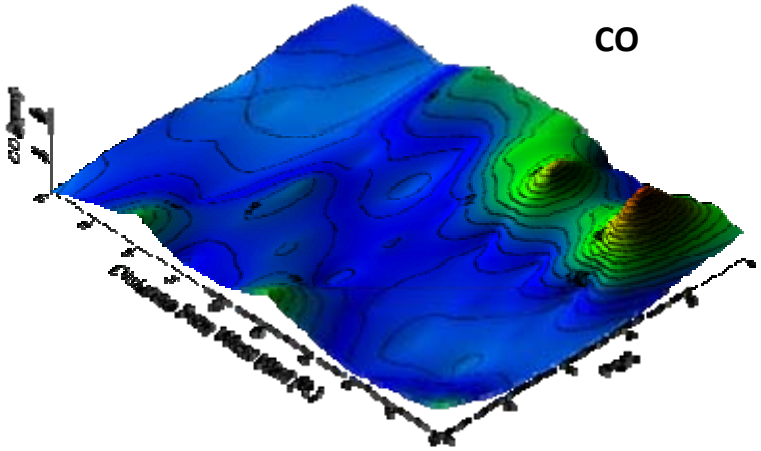
Flue Gas Measurements (Typical Imbalances)



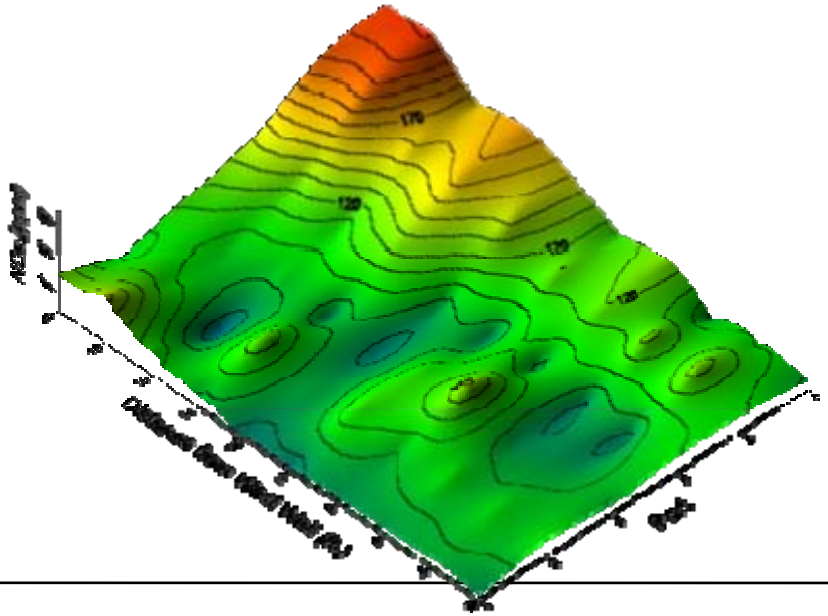
Oxygen



Temperature



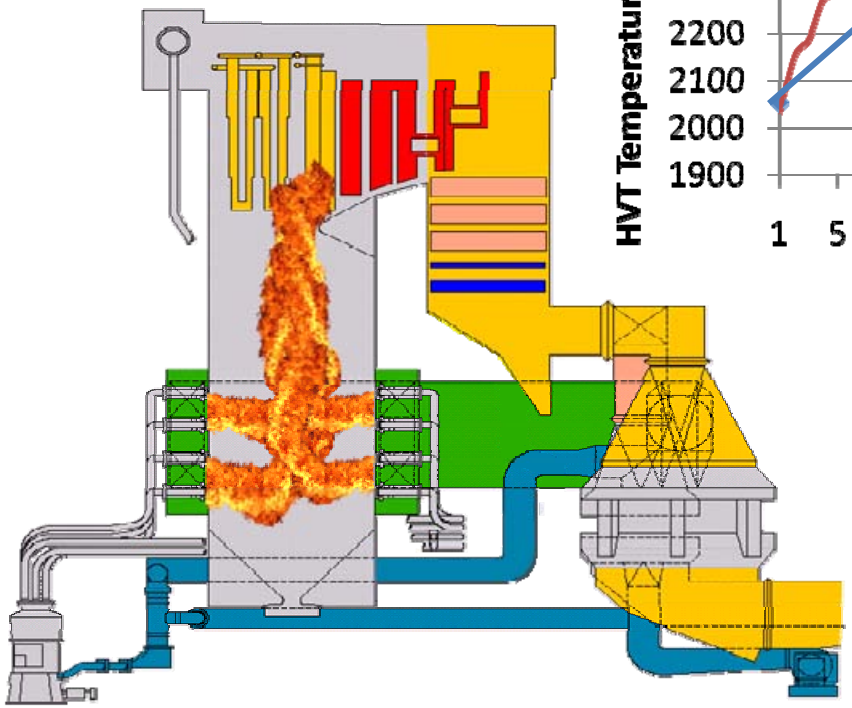
CO

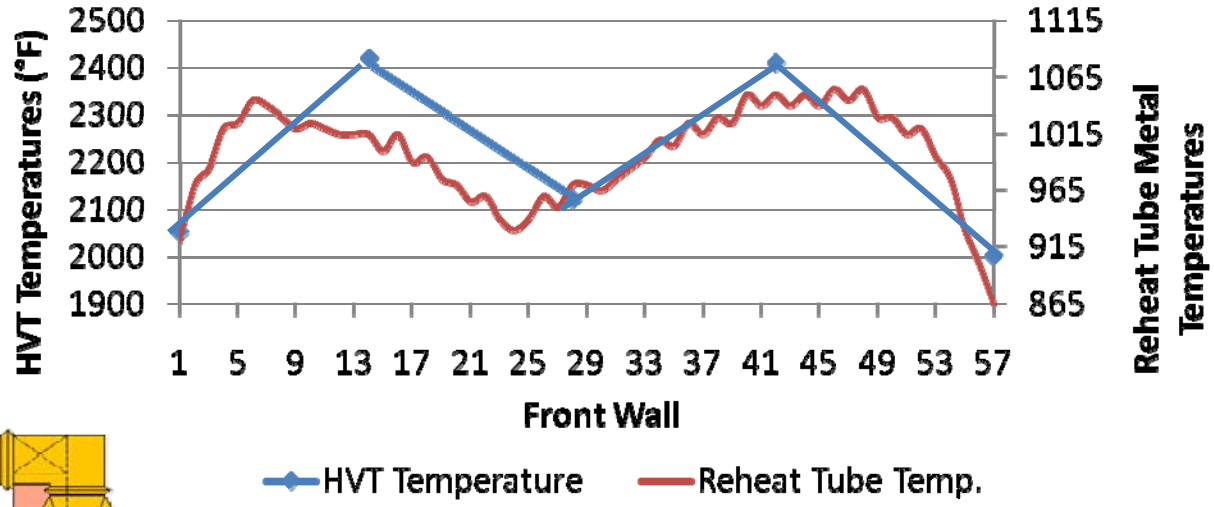


NO_X

High Flue Gas Temperature Peaks

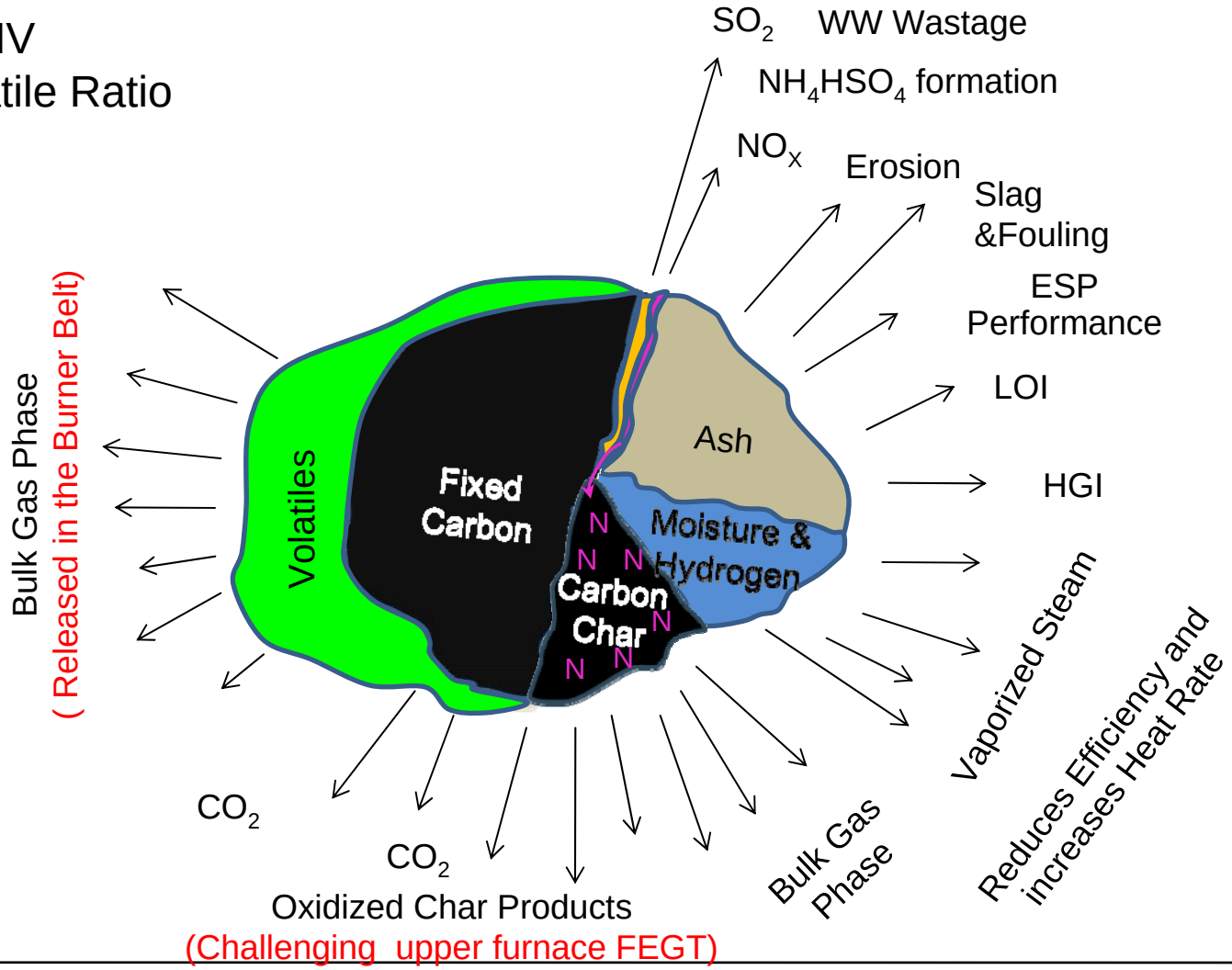
High flue gas temperature “peaks” and the corresponding peaks of individual tube temperatures. The point is, poor distribution of hot gas lanes, often correspond with overheated tube circuits.





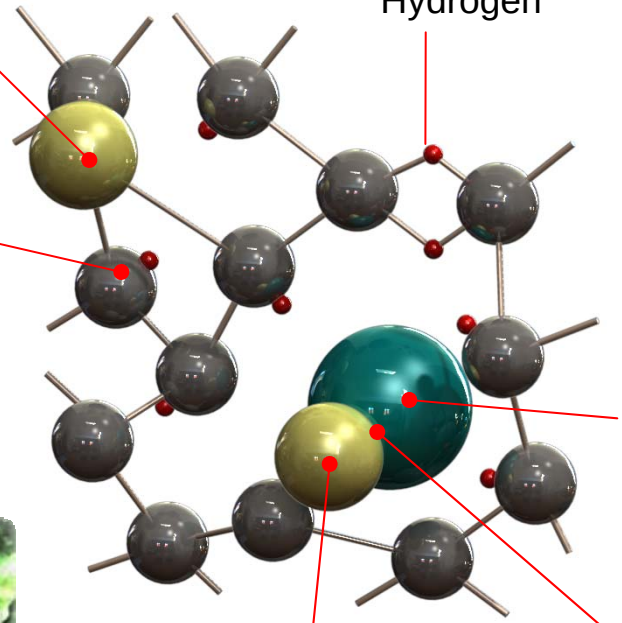
Fuel Factors that often Require Combustion Tuning

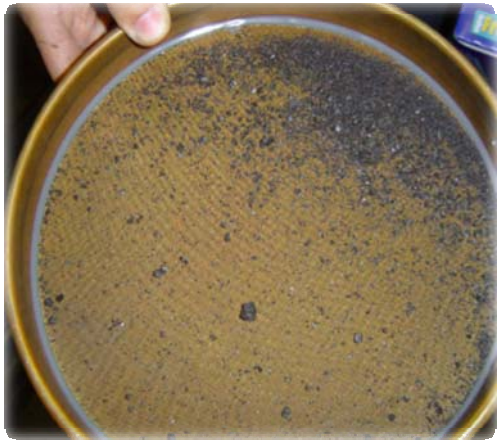
- Fuel HGI
- Fuel Moisture - HHV
- Fixed Carbon: Volatile Ratio
- Sulfur Content
- Nitrogen Content
- Ash Mineral Matter

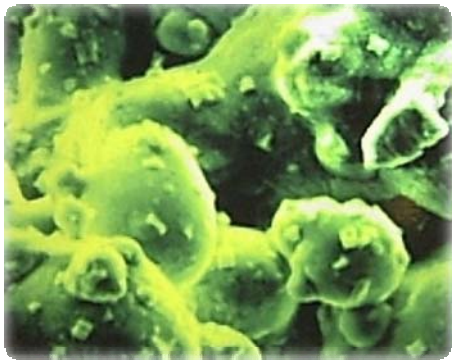


Challenges with High Sulfur Coal

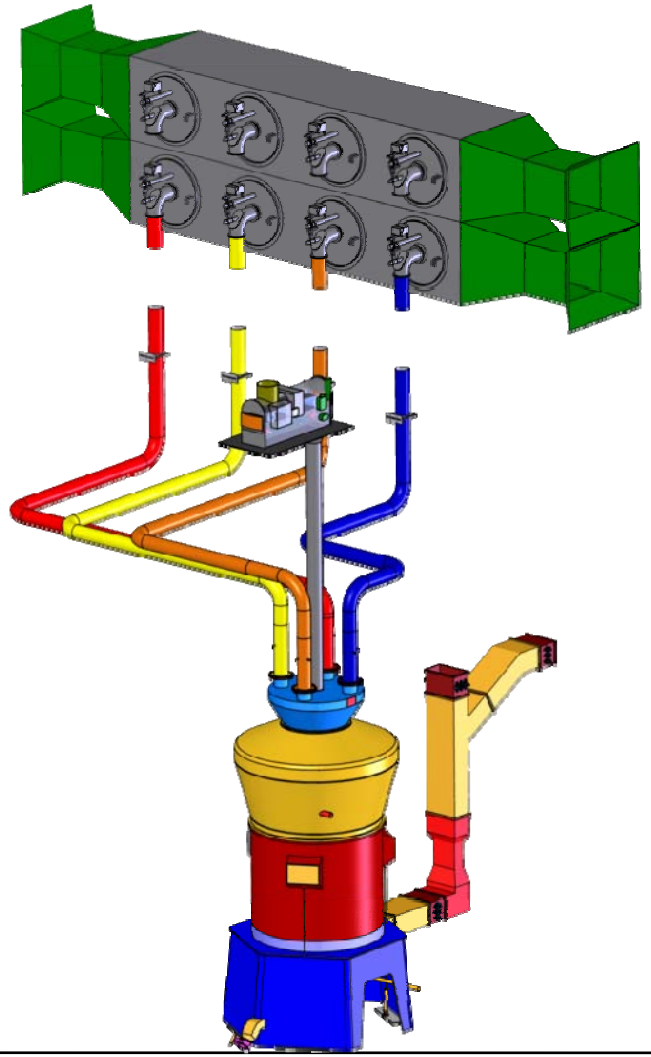
Chemically Bound
Sulfur & Carbon forms
"Organic Sulfur"

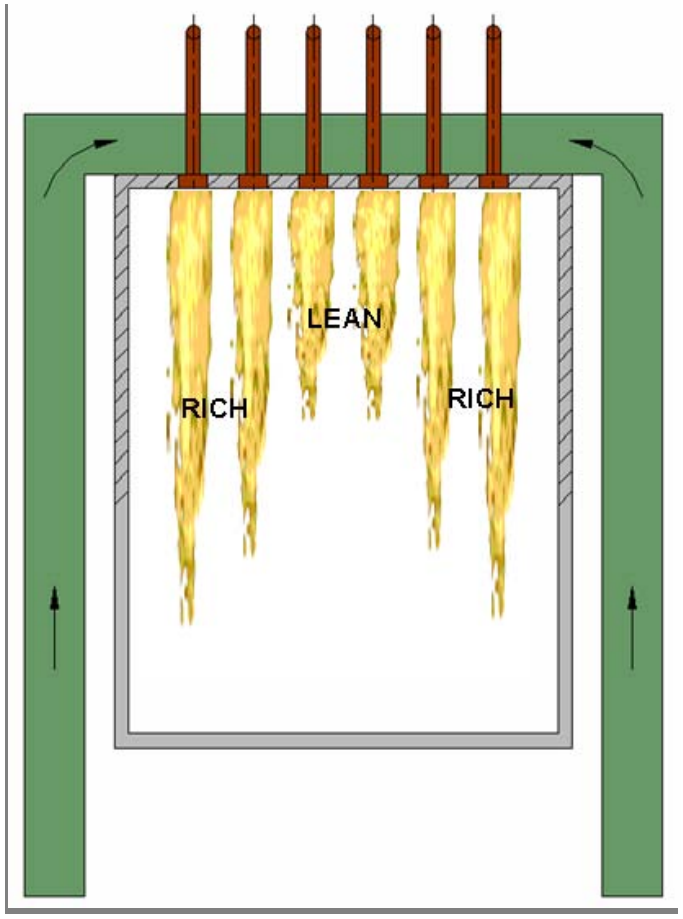




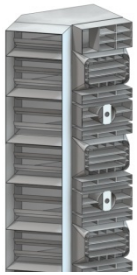


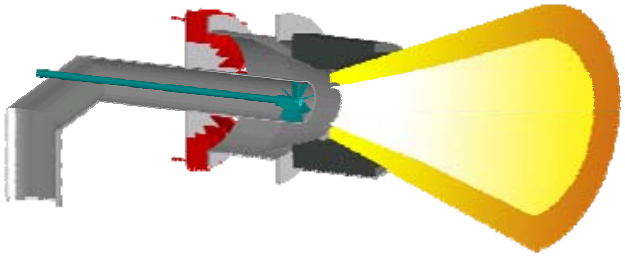
Both Fuel and Air Balancing Influence Combustion





The Evolution of Low NO_X Burners

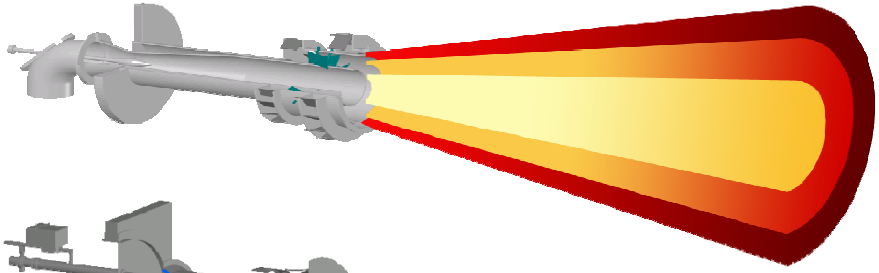




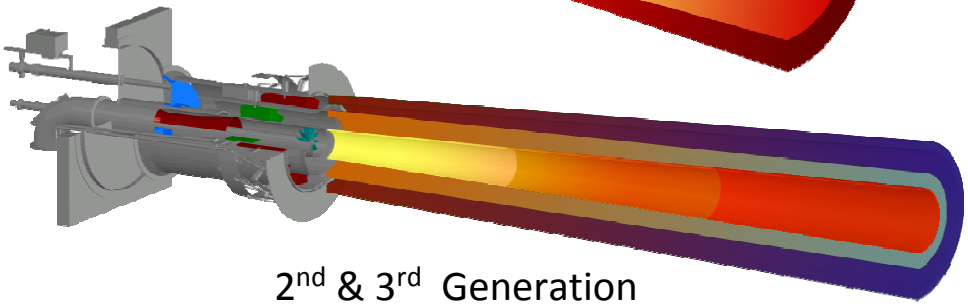
70's High Intensity Burner

Forgiving

First Generation Low NO_X Burner

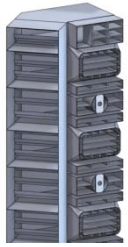


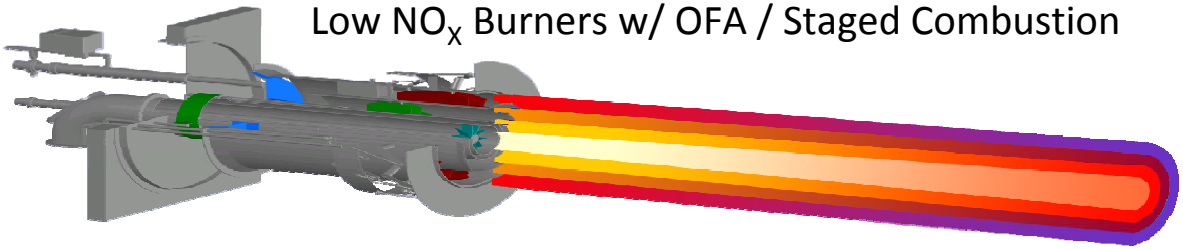
Sensitive



Unforgiving

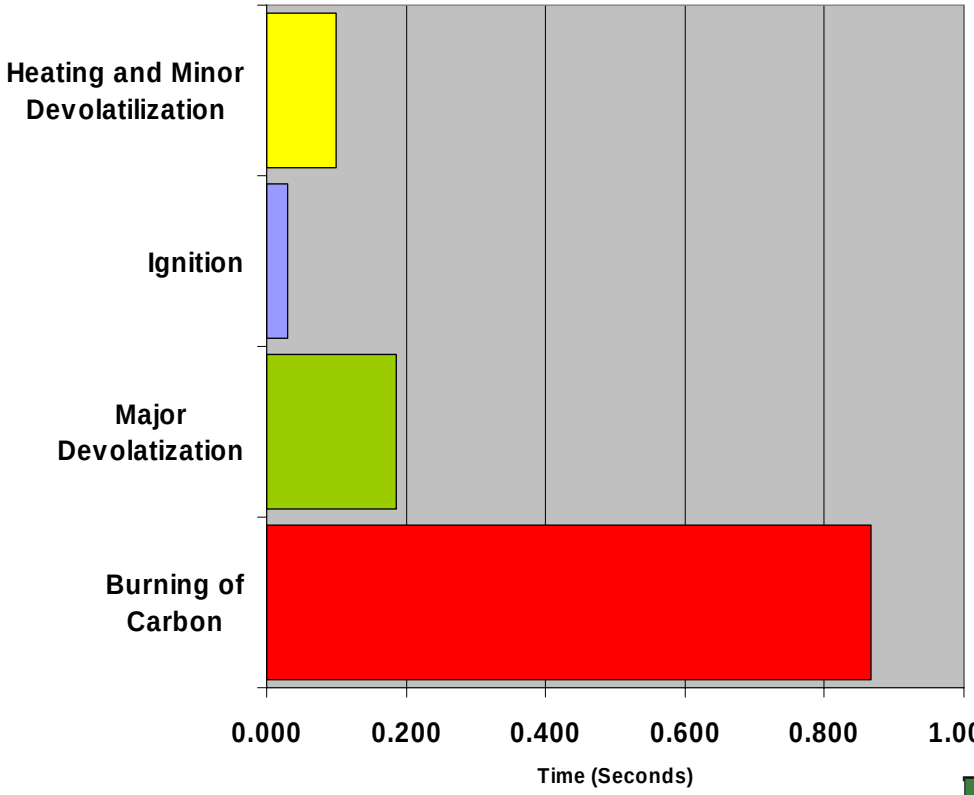
2^{nd} & 3^{rd} Generation
Low NO_X Burners w/ OFA / Staged Combustion

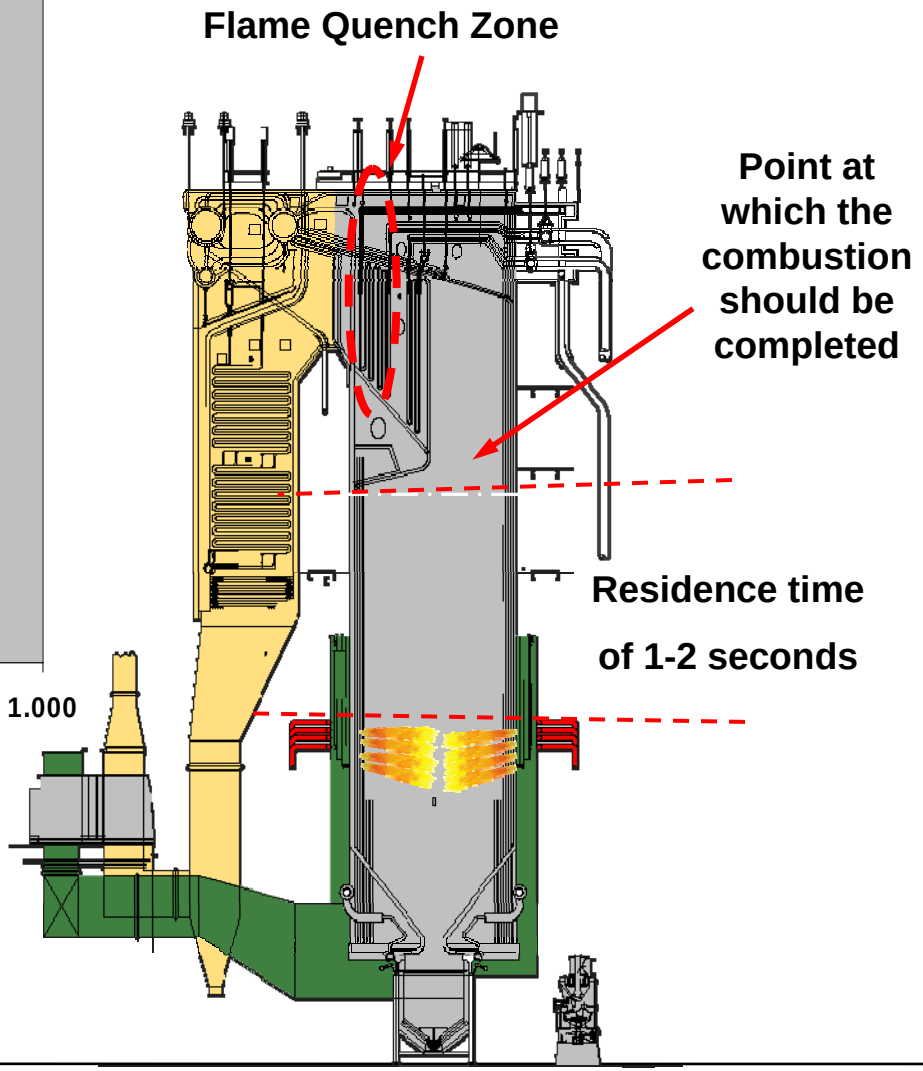




Challenging !

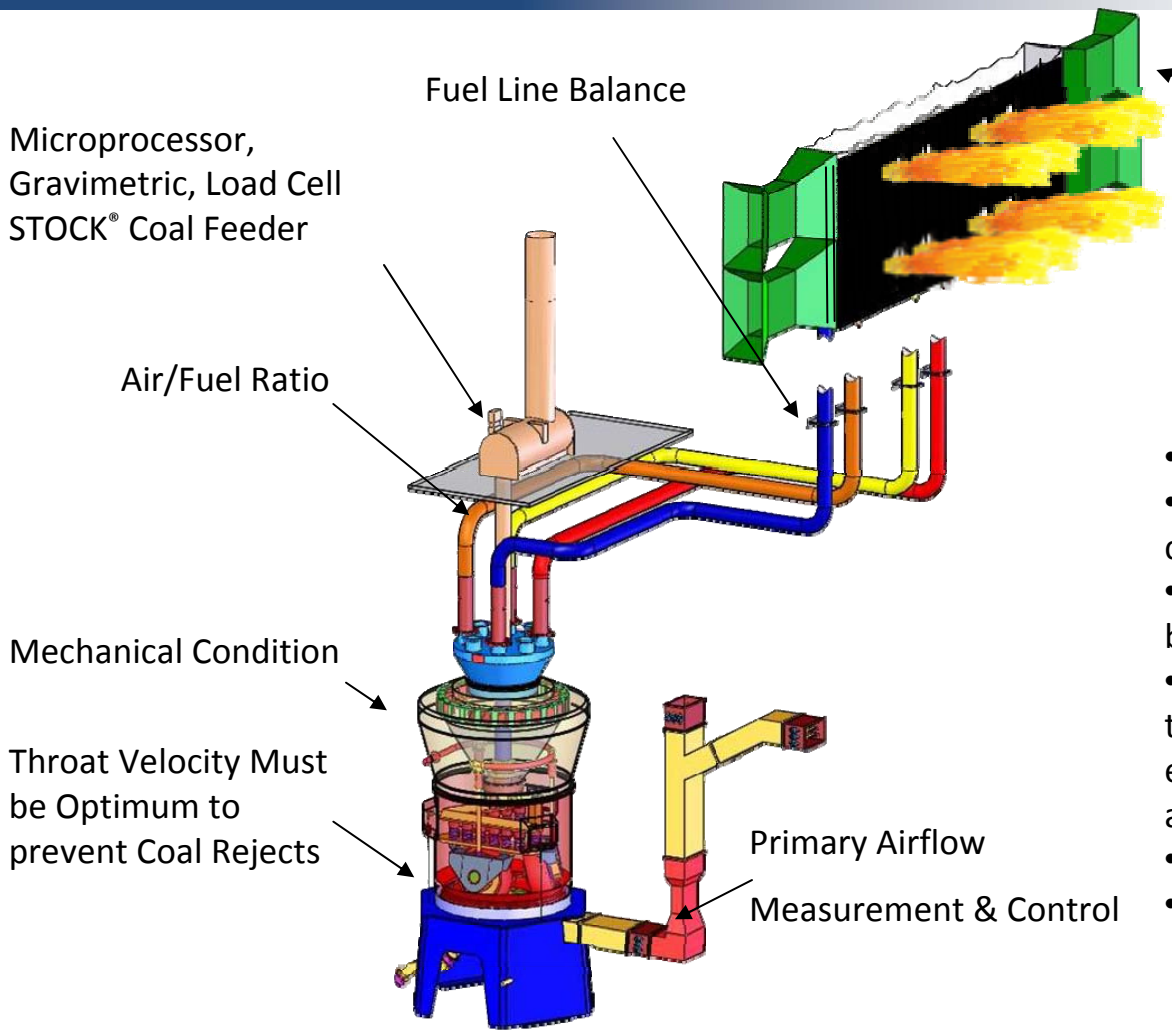
Furnace Residence Time / Carbon Burnout





This graph illustrates typical time requirements for combustion of coal. These times will vary with different coals & firing conditions but the combustion of carbon always requires the most time

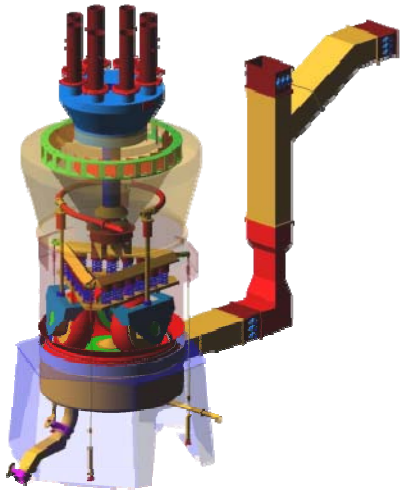
The STORM Solid Fuel Injection System Approach

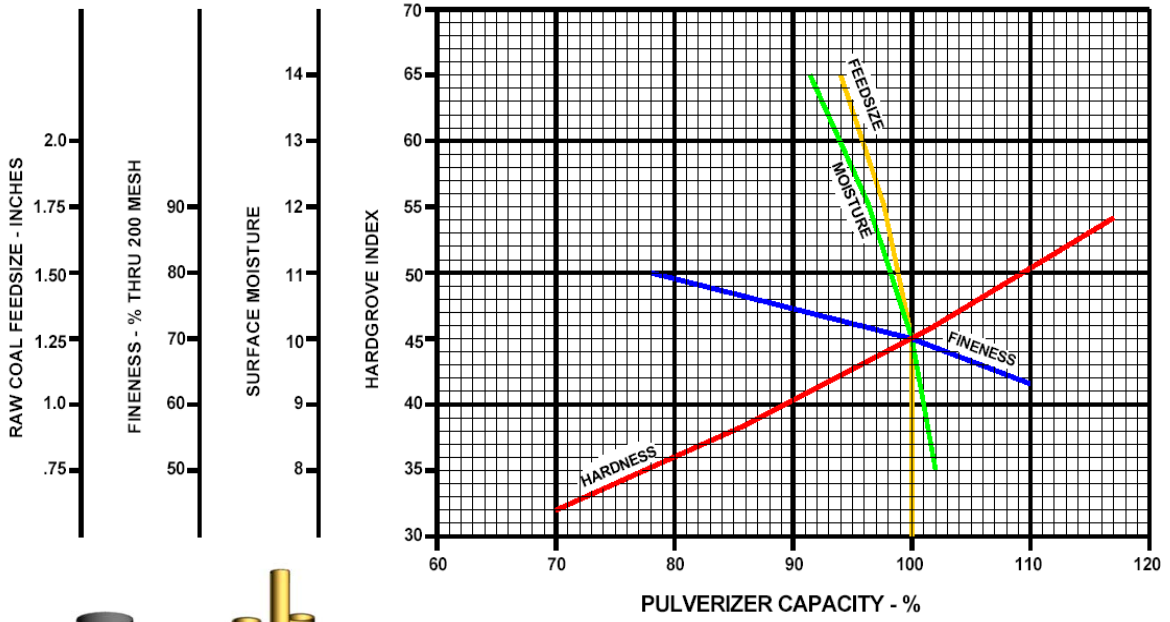


The Six Step Approach to Fuel Line Balancing

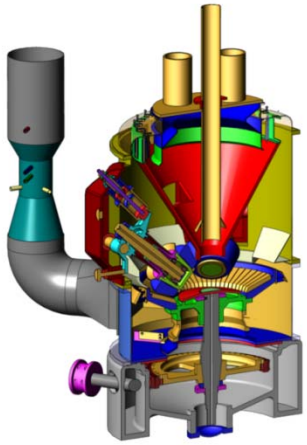
- Clean Air Balancing with ±2%
- Measured Primary air Hot "K" Factor calibration ± 3%
- Dirty air velocity measurements w/ balance of ± 5%.
- Fuel line fineness and distribution testing by air/fuel ratio sampling& ensuring optimum fineness level is achieved.
- Fuel line balance ± 10 %
- Pulverizer "blue printing"

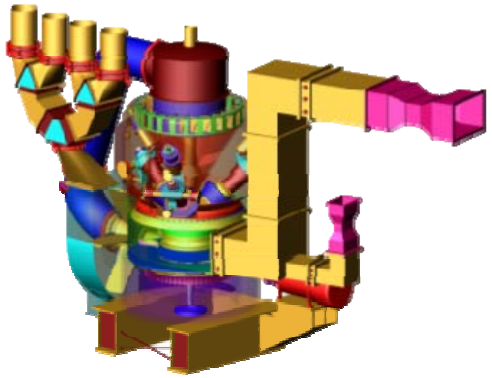
Coal Quality Impact on Mill Performance

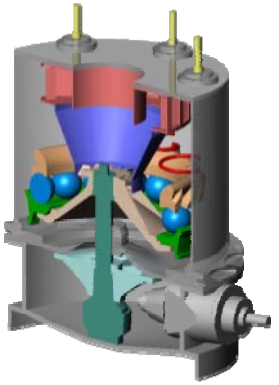




- Coal HGI & Moisture
- Coal Fineness
- Primary air flow
- Air & Fuel Ratio/Control
- Input Power
- Mill Outlet Temperature
- Pyrite/Coal Rejects
- Critical Mill Tolerances

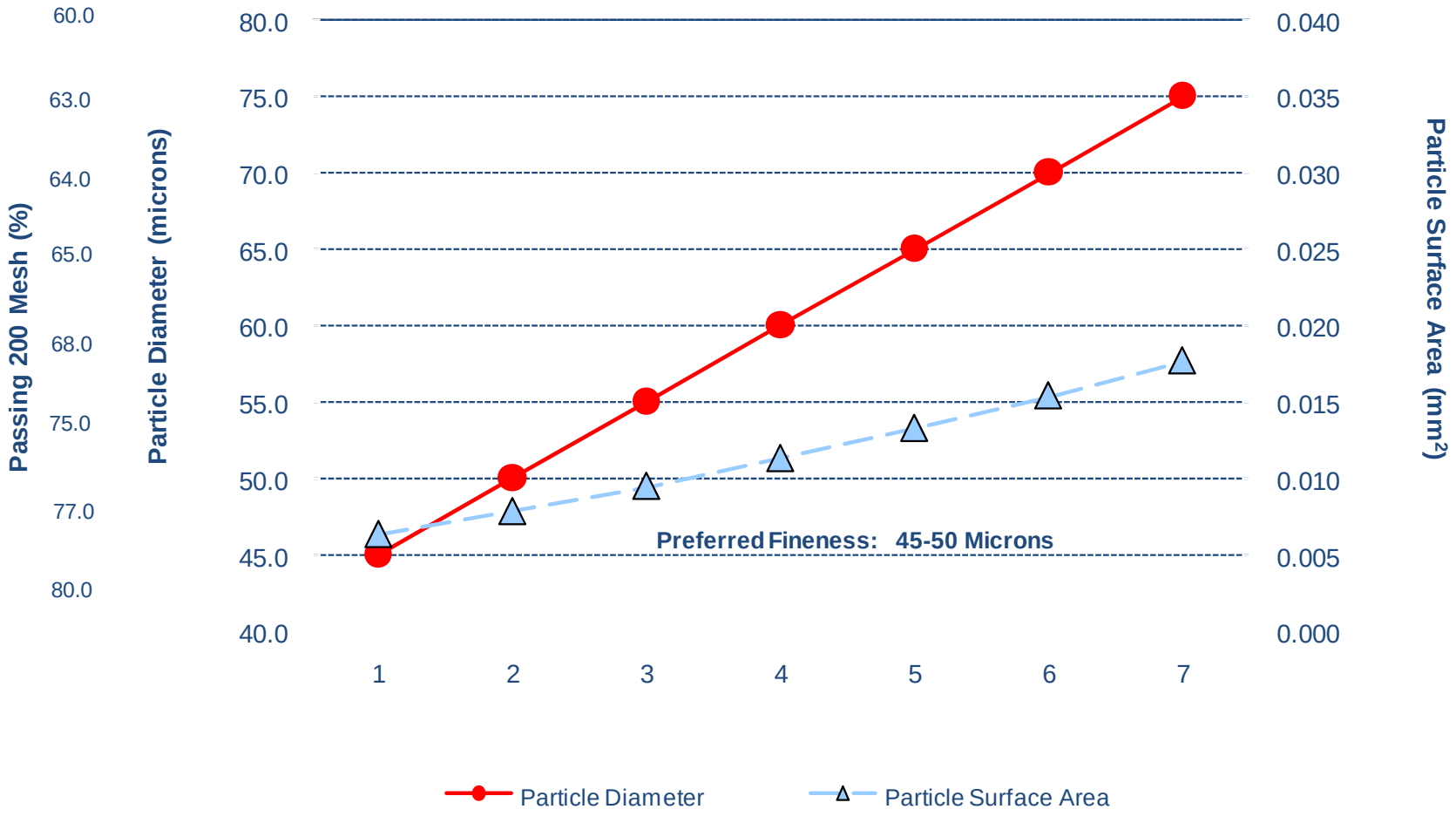




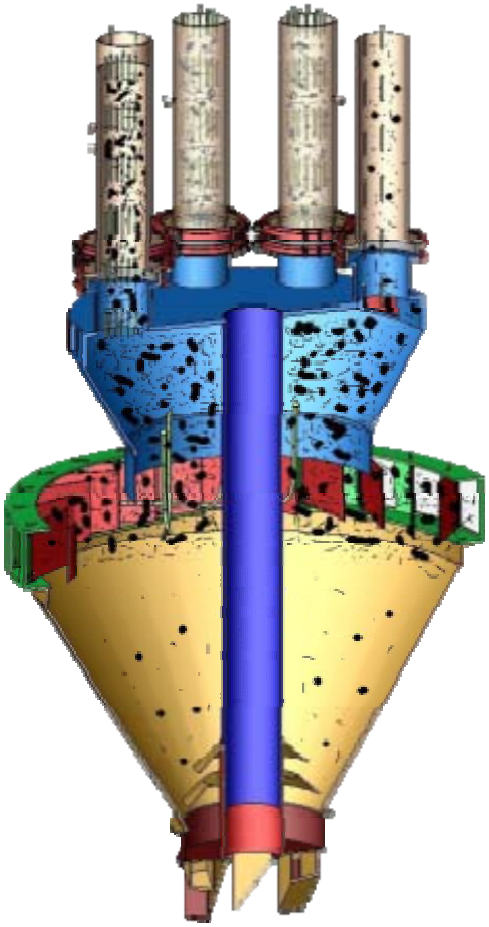


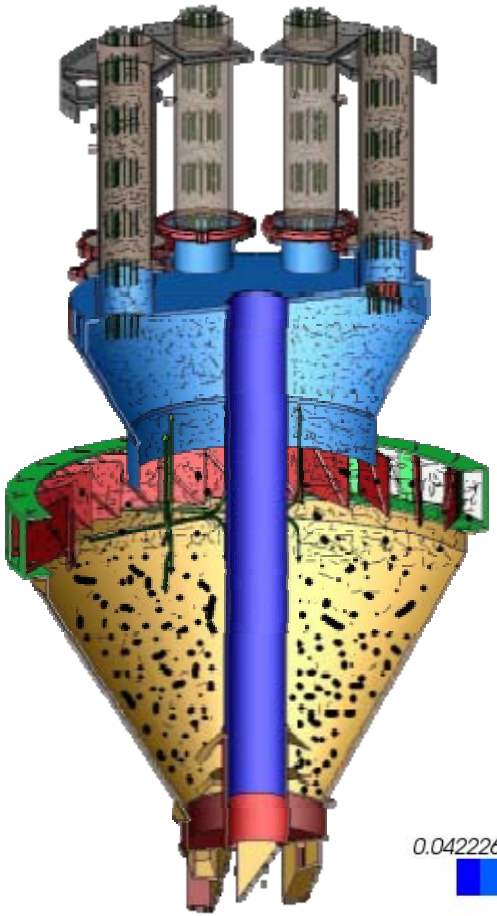
Average Collected Particle Size

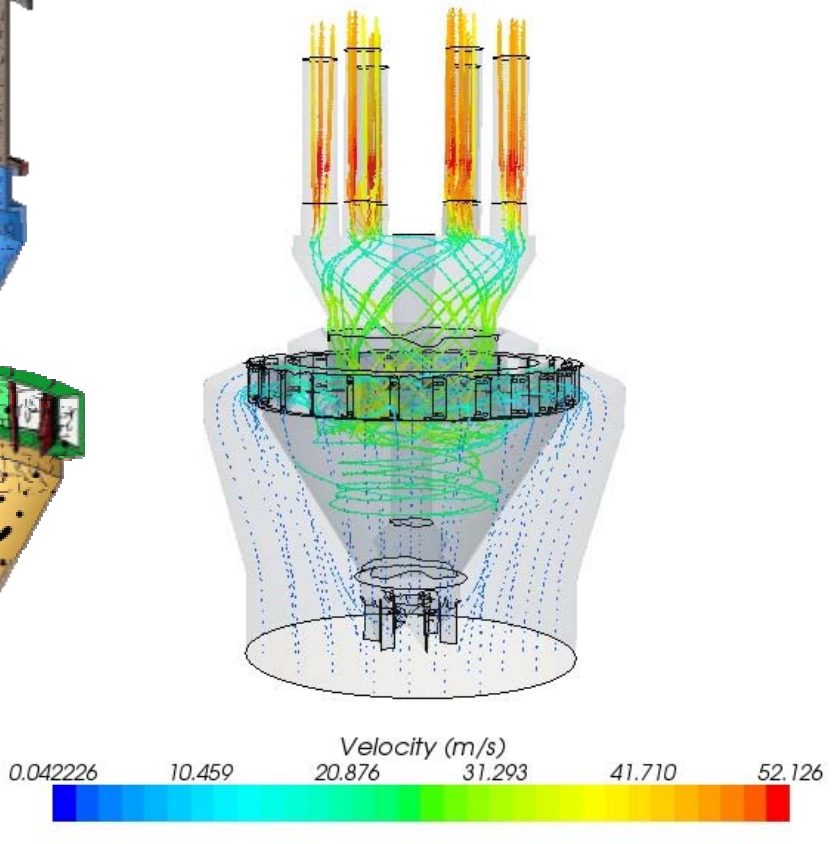
60% thru 200 mesh vs. 80% thru 200 mesh,
yields a 85.7% difference in the particle surface area (mm^2)



Classifier & Fuel Line Performance





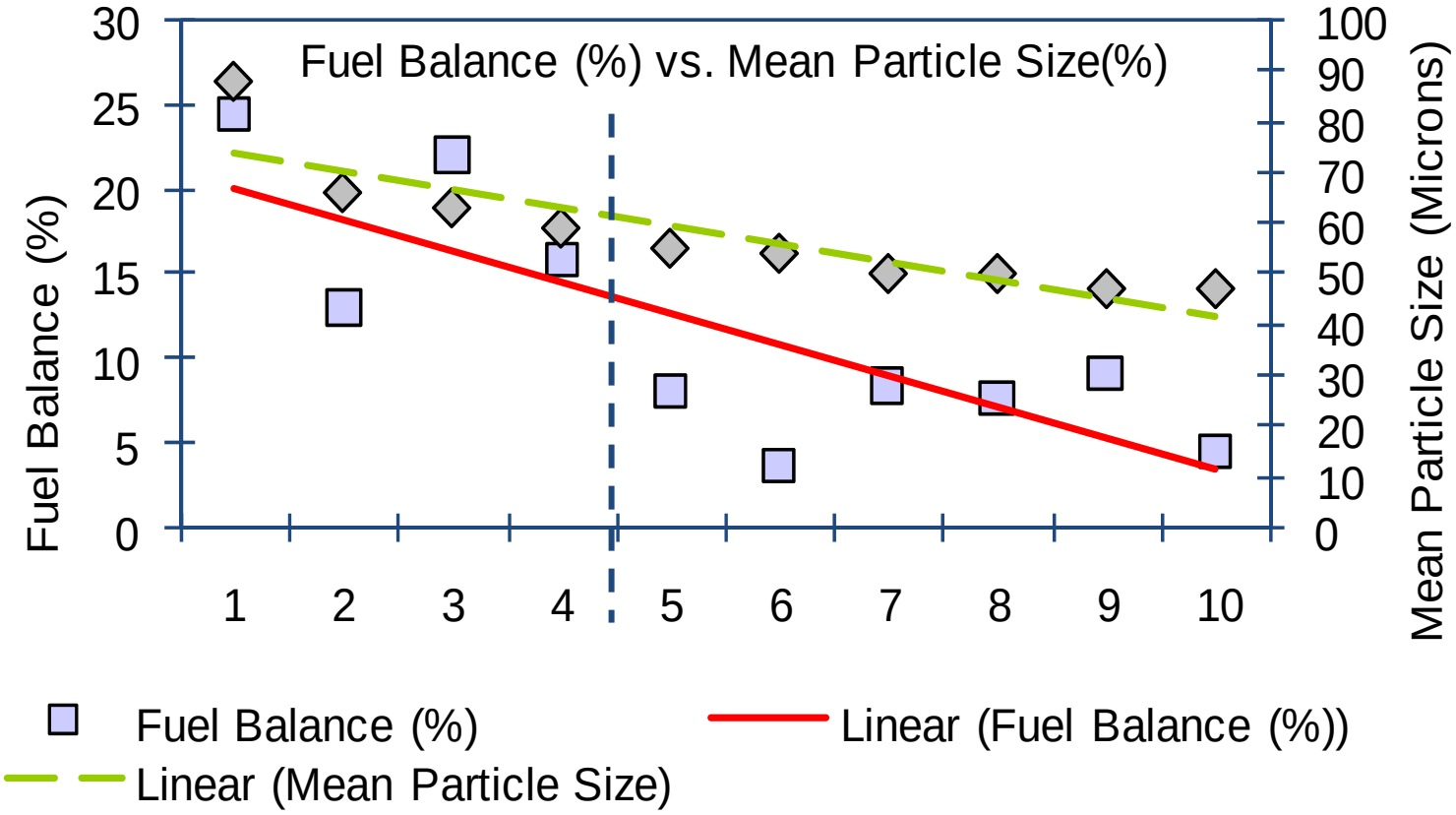


Poor Coal Fineness often yields poor distribution

Good Fineness Creates a homogenous & balanced mixture & will produce a more homogenous mixture if mechanical synchronization is optimum

Performance Testing Results

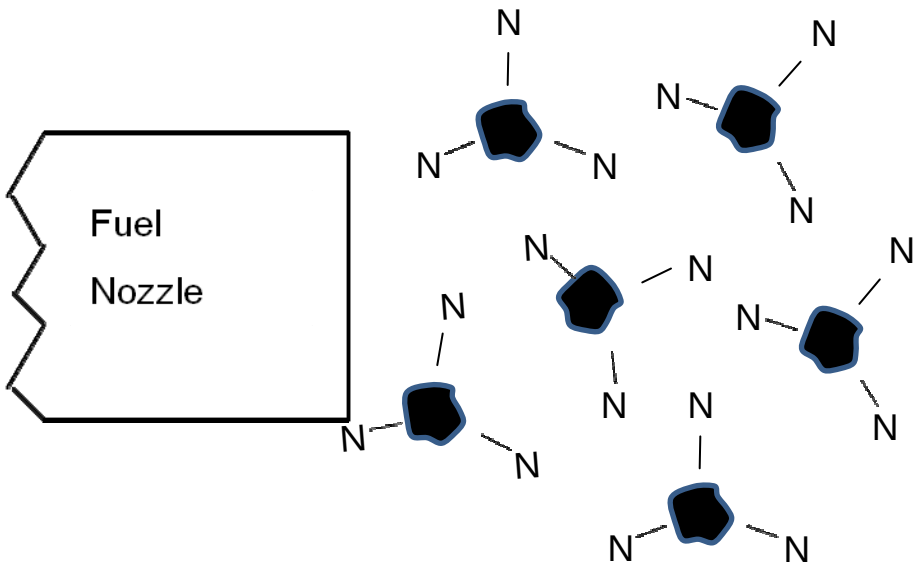
Note: Coal is 1,000 times more dense than air. The finer the product the better the distribution *(as finer coal acts more like a fluid or gas).*



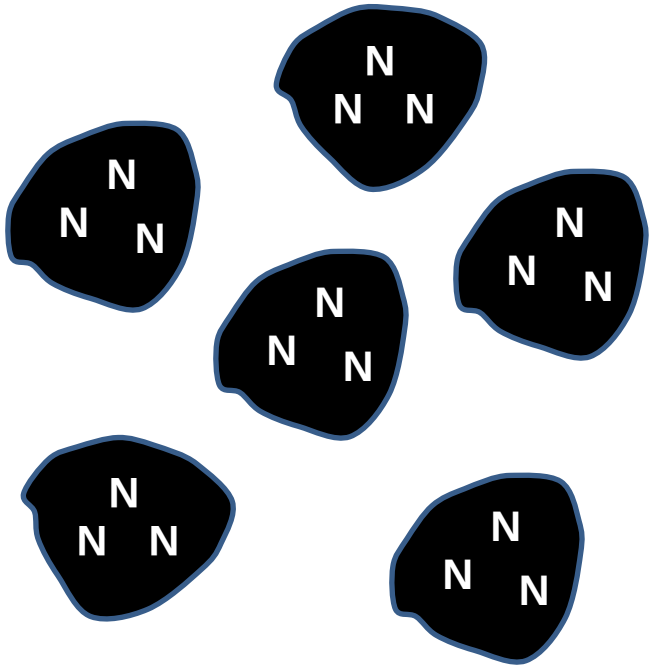
Fineness Relationship w/ NO_X

"Release of Fuel Bound Nitrogen in the De-Volatilization Zone"

Good Fineness



Poor Fineness



Stoichiometric or Theoretical Combustion

Stiochiometric or Theoretical Combustion is: The ideal combustion process during which a fuel is burned completely. A complete combustion is a process which burns all the carbon to (CO_2), all hydrogen (H) to (H_2O) and all sulfur (S) to (SO_2). If there are unburned components in the exhaust gas such as C, H_2, CO the combustion process is uncompleted.

The combustion process can be expressed as:

$$[C + H] + [O_2 + N_2] \quad \Rightarrow \quad [CO_2 + H_2O + N_2]$$

$$\text{Fuel} + \text{Air} \rightarrow \text{Combustion} \rightarrow CO_2 + \text{Water} + N_2 + \text{Heat}$$

Where:

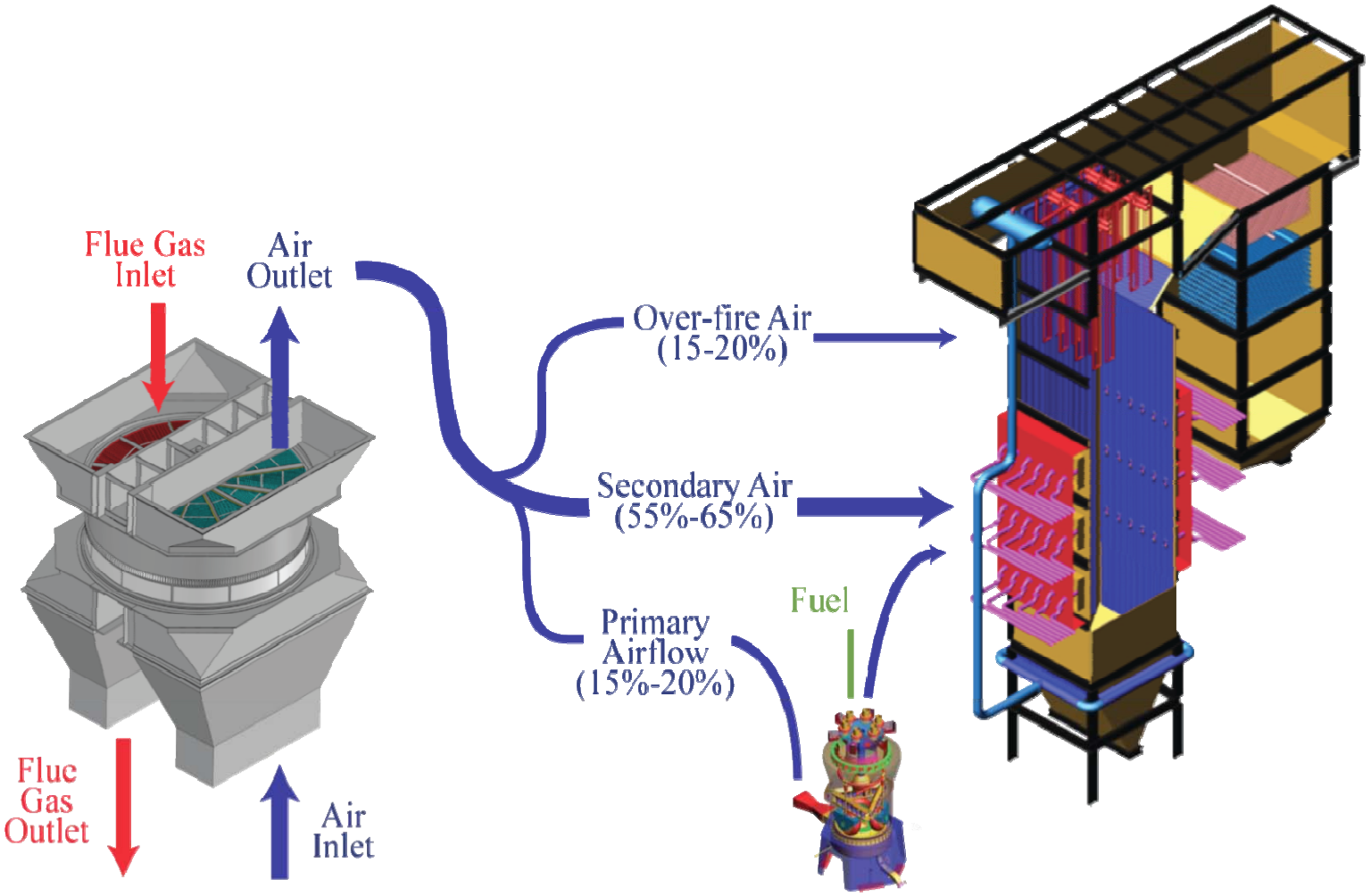
C = Carbon

H = Hydrogen

O = Oxygen

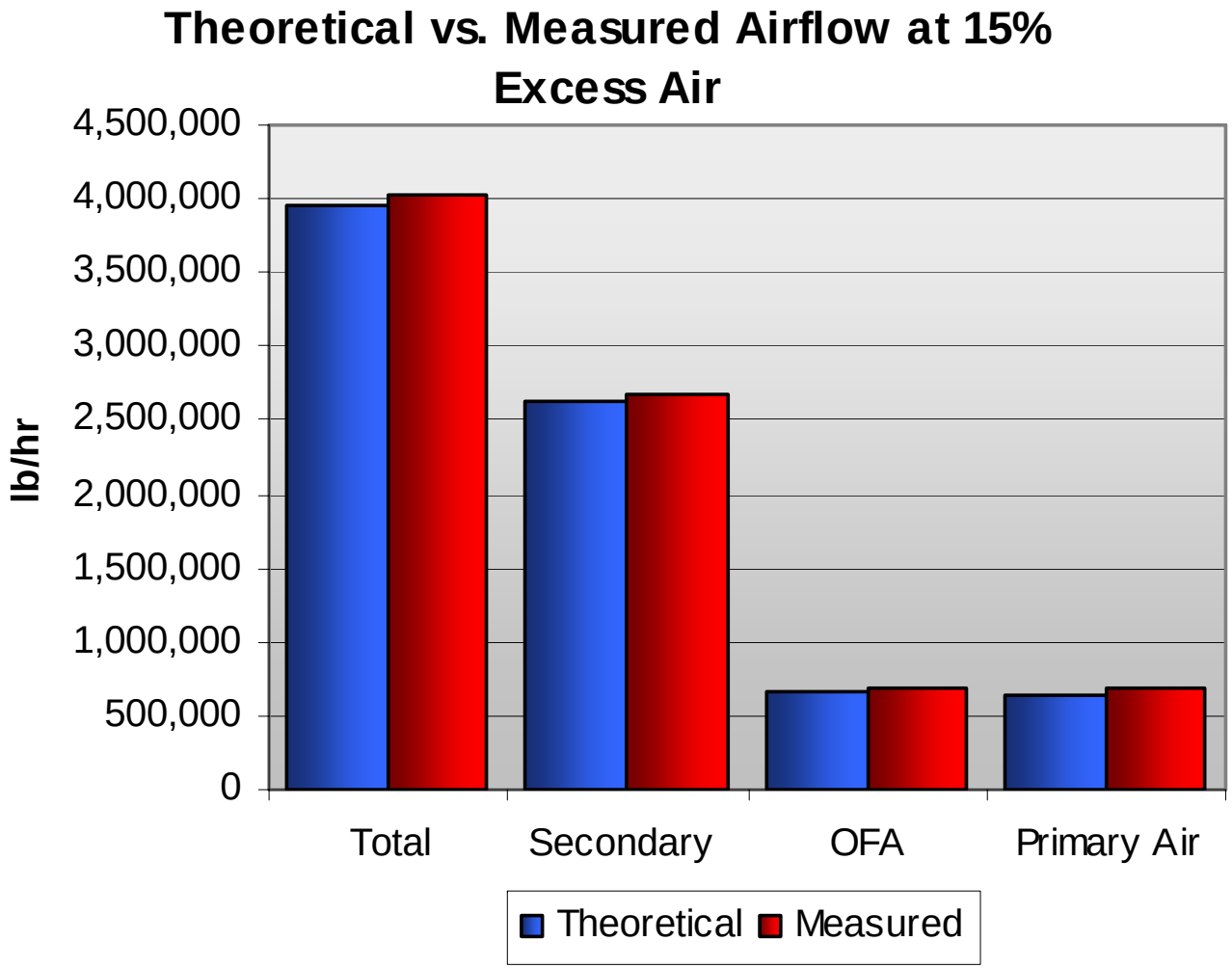
N = Nitrogen

Boiler Airflow Management

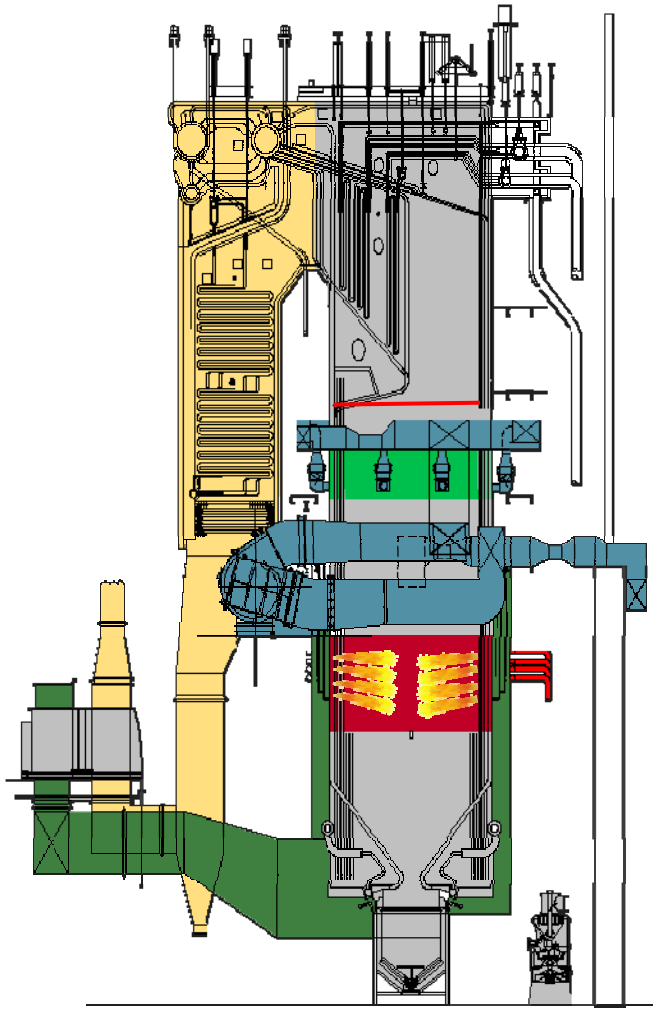


Theoretical vs. Measured Test Results

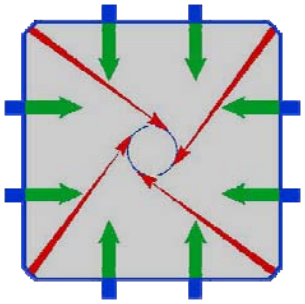
Example – 460MW Unit



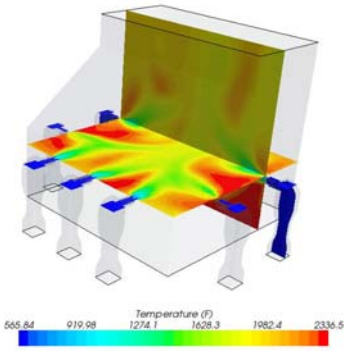
STORM Combustion Air Measurement System

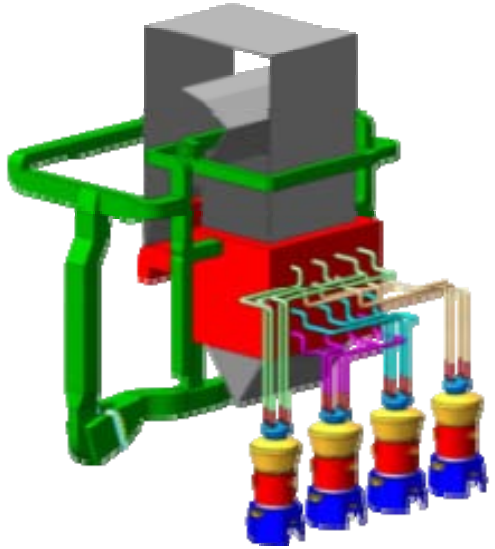


Controlled Burner Belt & Furnace Stoichiometry

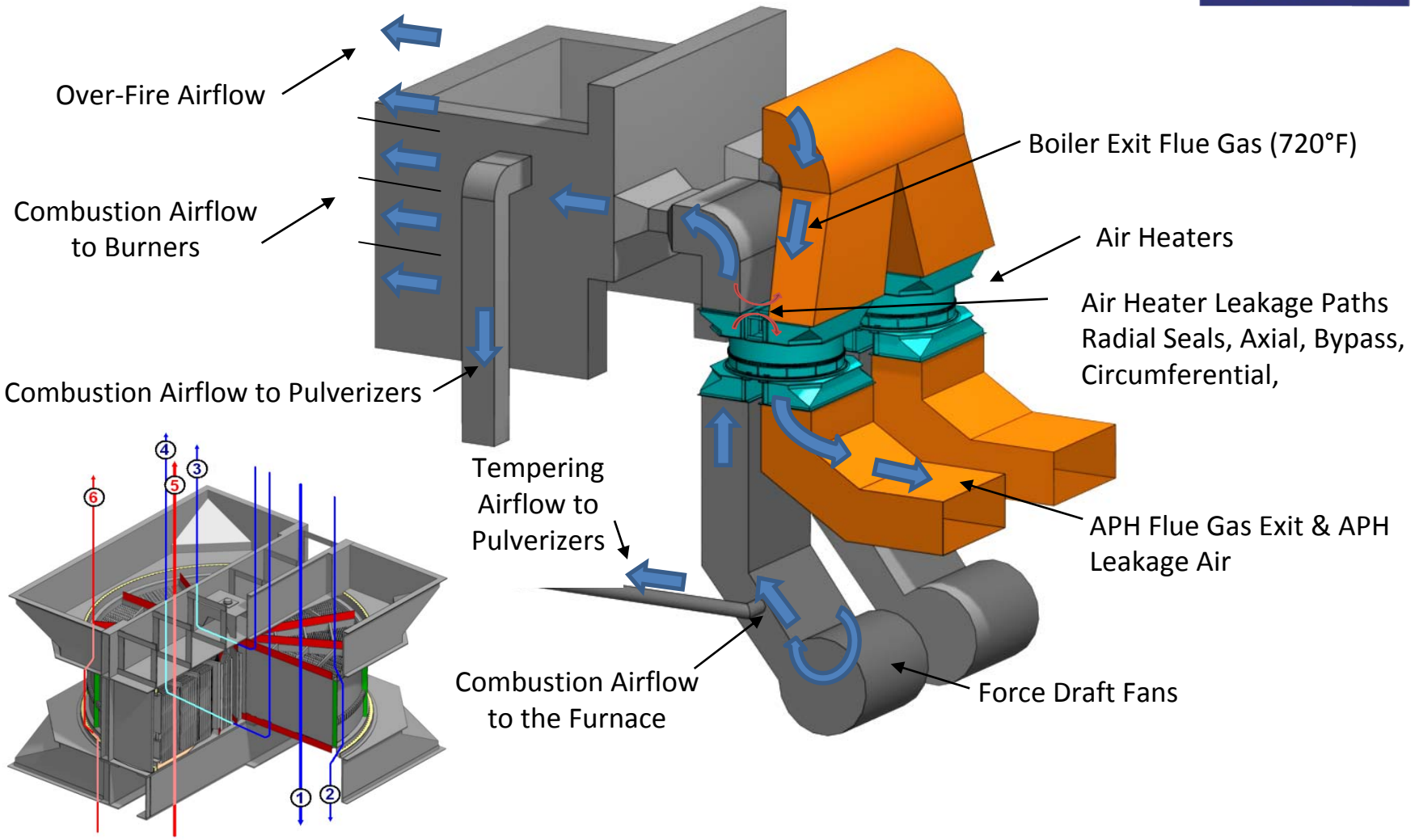


Airflow Control Stations should be designed such that all airflow paths are measured, controllable & most importantly ACCURATE. These flow rates should be periodically be measured for verification of accuracy.





Air In-Leakage and X-Ratio

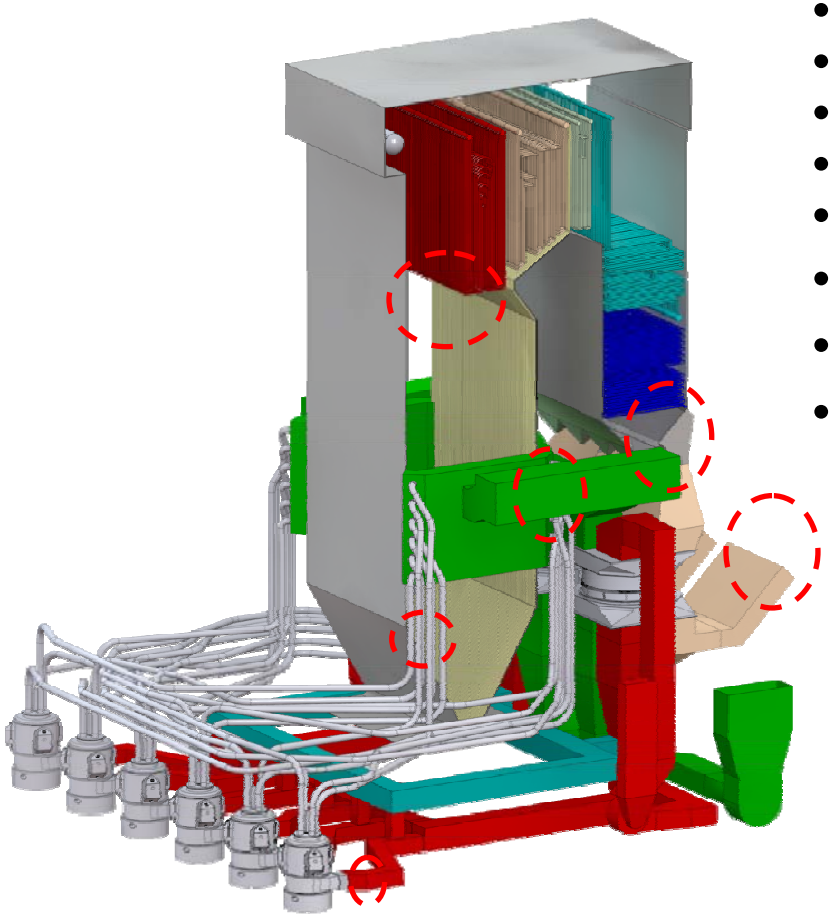


Uncontrolled Flow vs. Controlled Flow

Uncontrolled Flow
MOV 00052

Controlled Flow
MOV 00051

Comprehensive Evaluation



- Gross Turbine Cycle Heat Rate (GTCHR)
- Fuel Line Performance Measurements
- Mill Inlet Primary Airflow Calibrations
- Total Secondary Airflow Measurement & Calibration
- Furnace Exit Gas Temperature & Flue Gas Constituents
- Economizer Outlet Flue Gas Measurements
- ID Fan Discharge / Stack Inlet Flue Gas Measurements
- “Stealth Loss” Evaluation

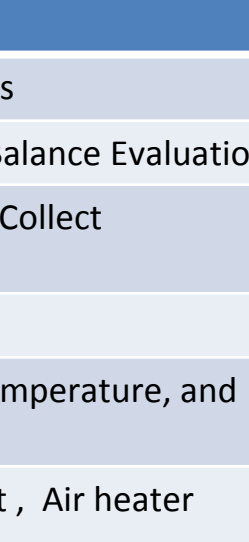


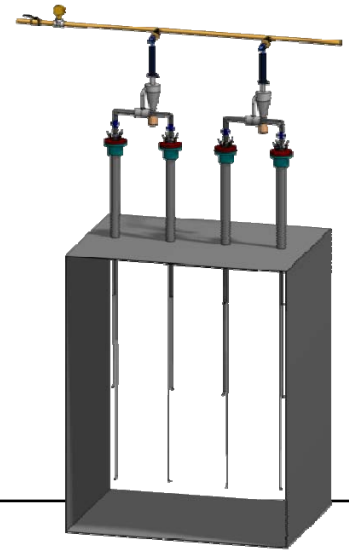



Performance Preservation Program

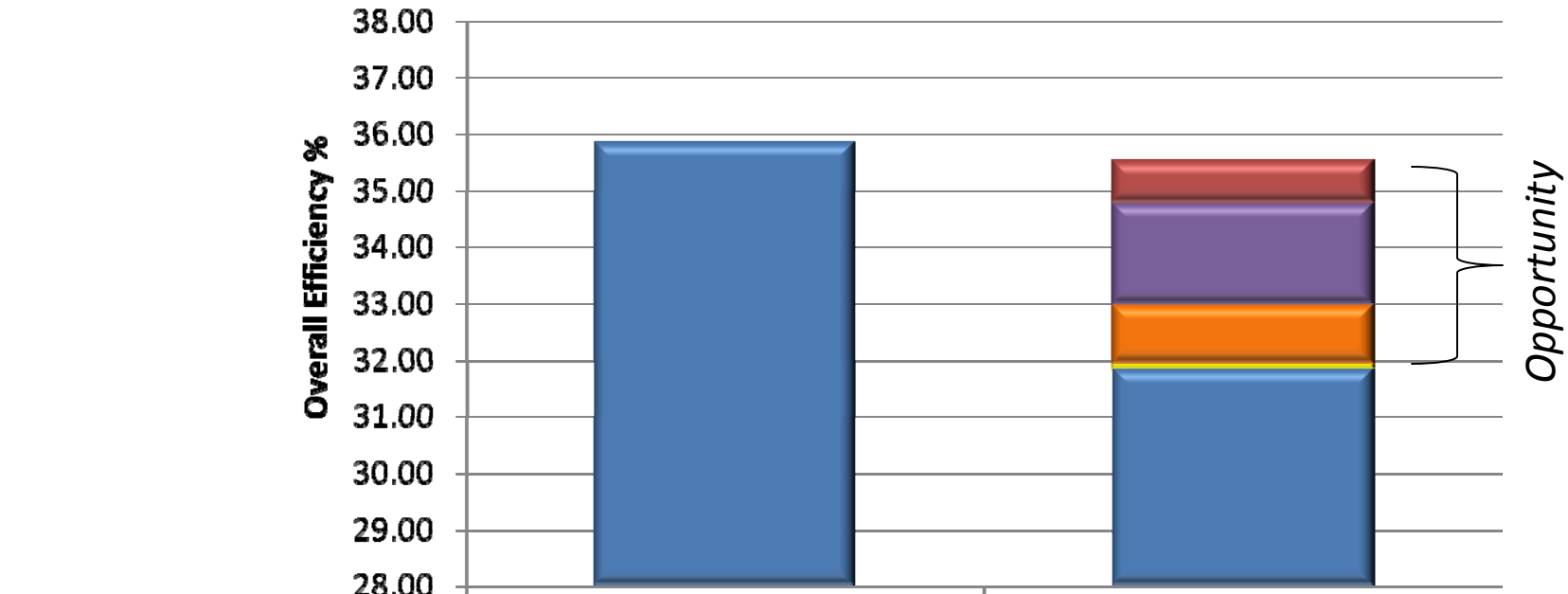
Testing Protocols & Evaluations

- Fuel Line Clean Airflow Testing, Balancing and Minimum Airflow Set-points
- Primary Airflow Measurements and Calibration Tests; Periodic Mill Heat Balance Evaluations
- Dirty Airflow and Isokinetic Coal Sampling to Evaluate Air-Fuel Ratios and Collect Representative Fuel Samples
- Secondary Airflow Measurements and Calibration Tests
- Furnace Exit HVT Traverses to Determination of actual flue gas oxygen, temperature, and carbon monoxide profiles
- Air In-Leakage Surveys(4 Major Regions) - Furnace exit, Economizer outlet , Air heater outlet, ID fan discharge
- Flue Gas Flow Measurement
- Boiler Efficiency & Heat Rate Evaluation
- Fly Ash Particle Size and Bottom Ash LOI Analyses
- Tuning and Optimization
- Fly-Ash and Bottom-Ash LOI Results
- Control Indications Evaluation
- Analytical Evaluation





Example - "As Measured" Efficiency Vs. Design



	Typical (Design)	As Fired
Boiler Opportunities		0.75
Turbine Opportunities		1.79
LOI and Rejects		1.04
Aux. ID Fan HP Opportunities		0.09
Design vs. Actual	35.83	31.85

Thermal Efficiency Deviation from Design ~ 4%

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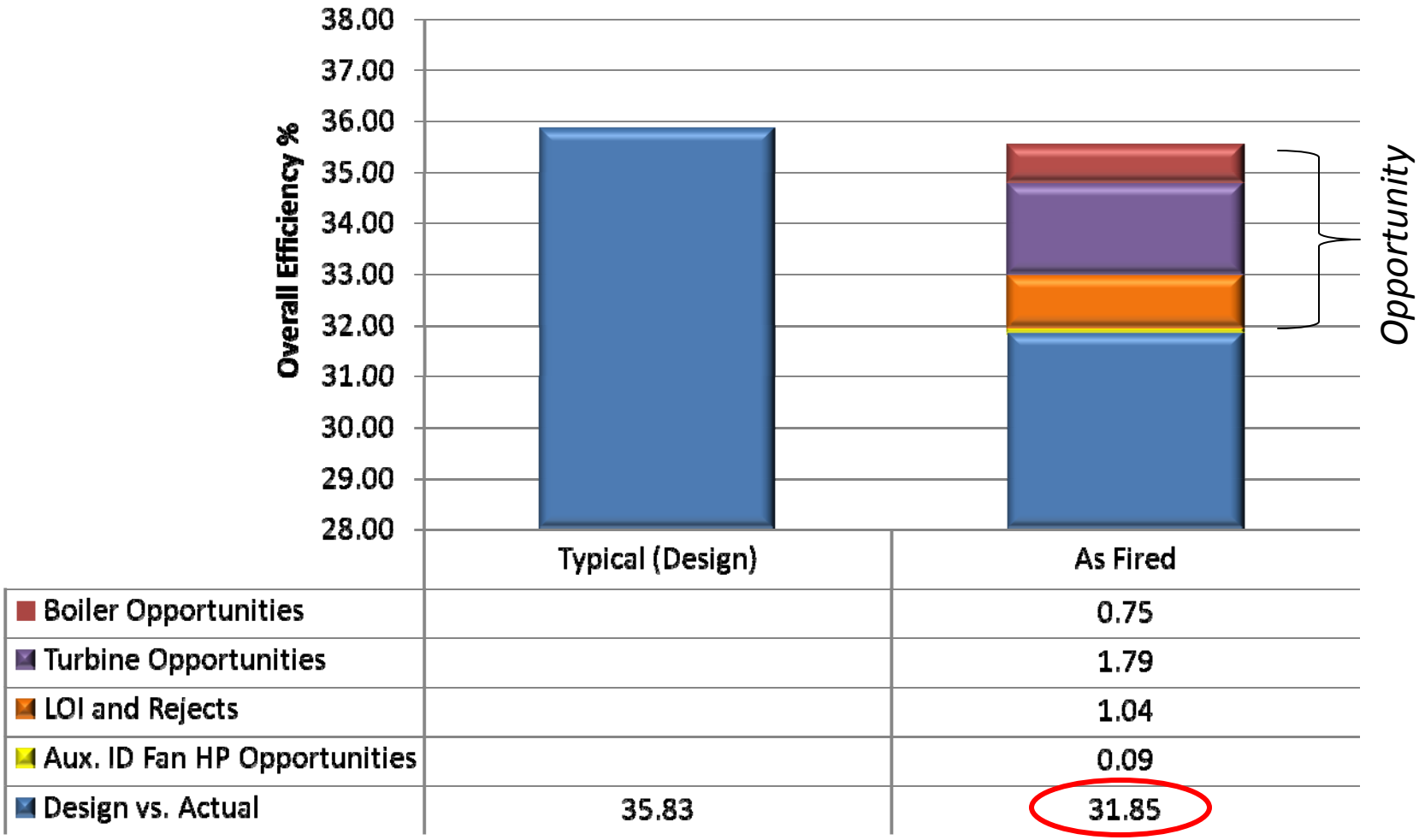

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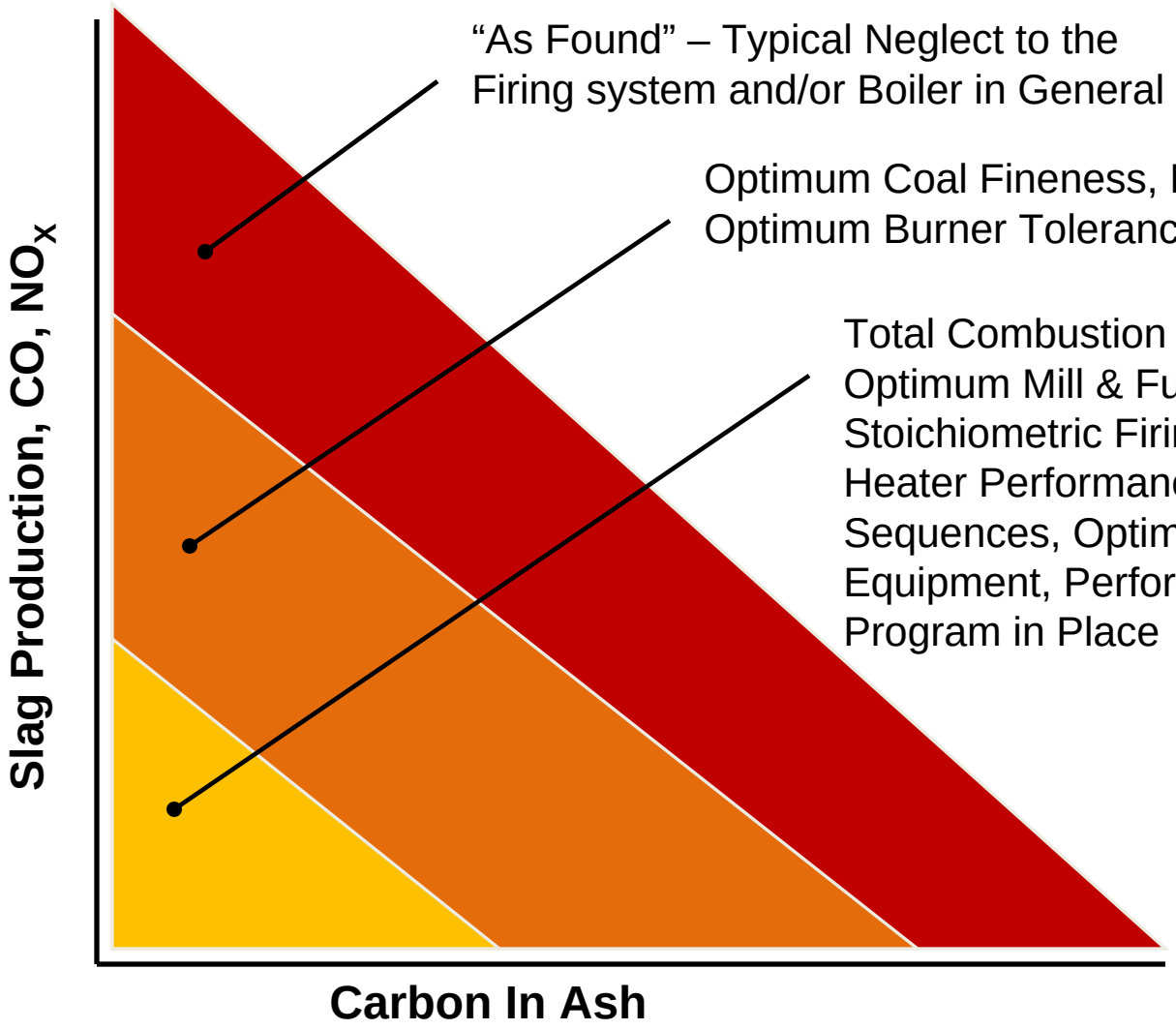
Performance Relationships

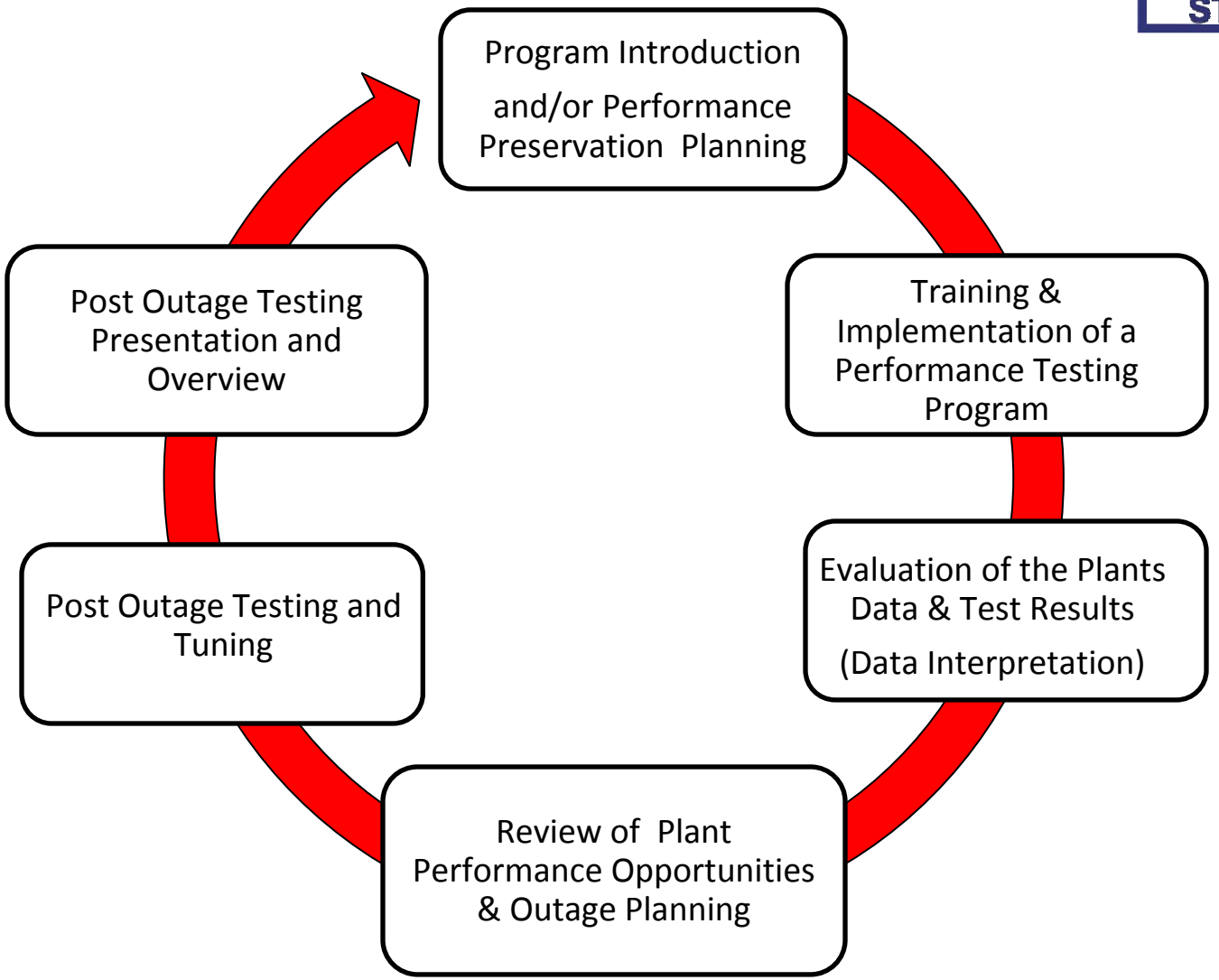


"As Found" – Typical Neglect to the Firing system and/or Boiler in General

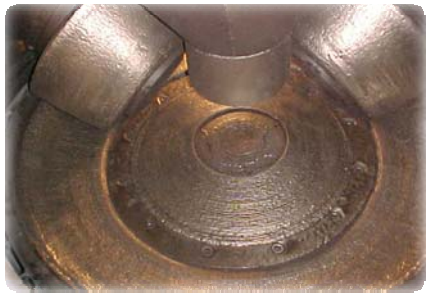
Optimum Coal Fineness, Balanced Fuel Lines, Optimum Burner Tolerances / Control

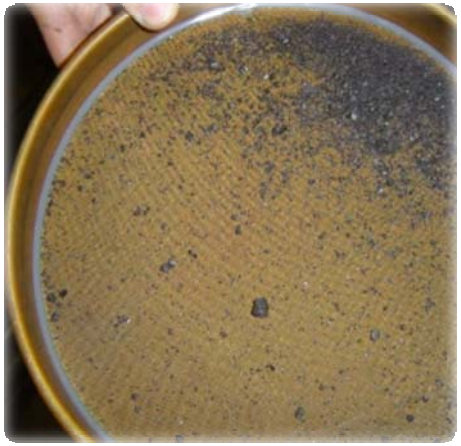
Total Combustion Optimization Program with Optimum Mill & Fuel Line Performance, Stoichiometric Firing Control, Optimized Air Heater Performance, Optimized Soot Blowing Sequences, Optimized Environmental Control Equipment, Performance Preservation Program in Place

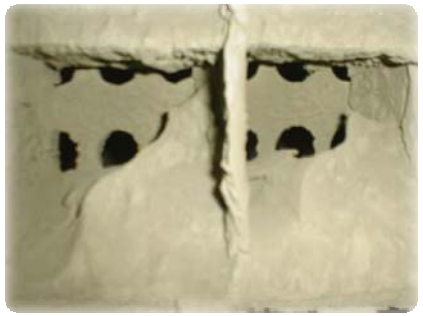
Performance Program Example (STI, APPLES)



Attention to Detail makes the Difference







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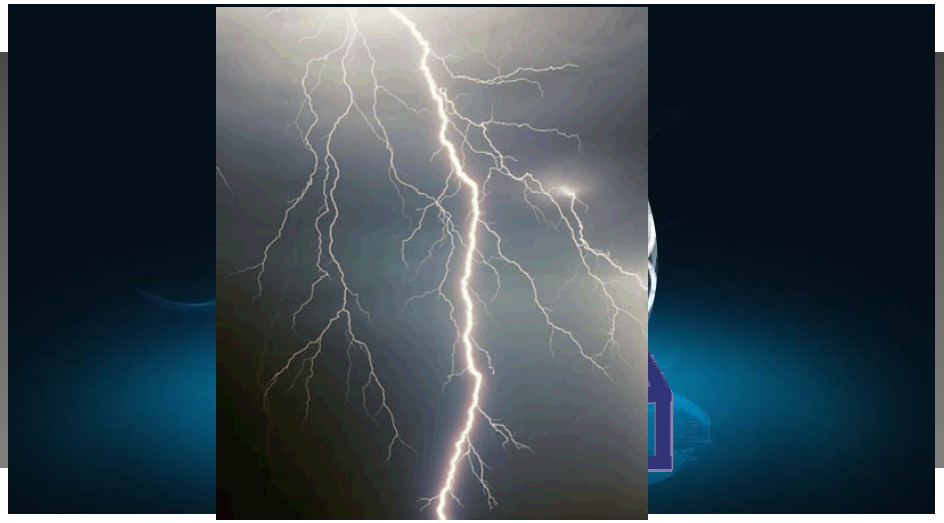

Whatever the need is, we stand behind our motto which is

Service, Quality and Results.