McIlvaine – *“Hot Topic Webinar”*

Here are some suggestions to consider

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Coal Plant Challenges Today

Coal Plant Generation Challenges are different today due to wind power & natural gas!

-Wind and other renewables plants are "must run" as nuclear are: With a declining 24/7 Industrial Base Load, coal plant minimum loads and response to a sudden demand increase are different.

Cost of Production for Fuel Component Only

Does not include maintenance cost, scrubber chemicals, operations labor, cost of Capital or any administrative or overhead costs. This is for fuel only, which is usually about 80% of the cost of power production

CCGT

- Heat Rate = 7,050 Btu/Kwh
- Fuel Cost = $2/MBtu
- Production Cost = $14.1/MWh

PC Boiler

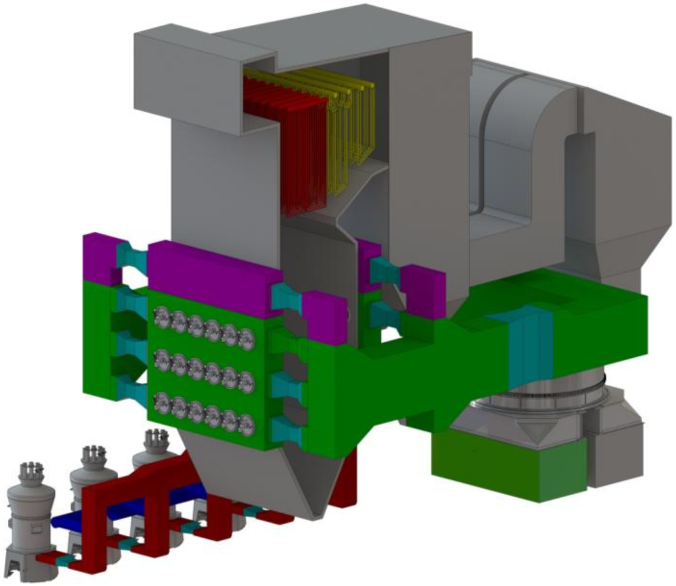
- Heat Rate = 9,500 Btu/Kwh
- Fuel Cost = $2.2/MBtu
- Production Cost = $20.9/MWh

The Challenges

- Keep Plants Reliable, they are needed in the Generation Portfolio
- Optimize Combustion and Overall Efficiency of Generation
- Improve Load Range and Load Responsiveness
- Reduce Fuel Costs and Optimize O&M Costs
- Compete, Supplement and Co-Exist with Natural Gas & All Other Fuels

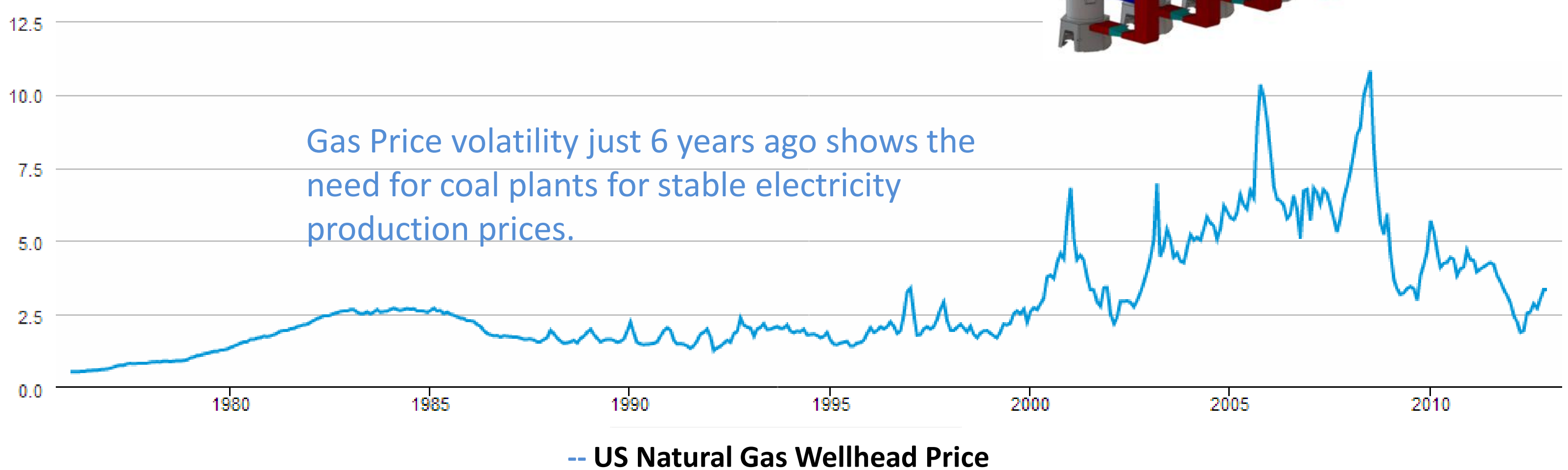
Storm's Experience

- Coal plants need greater turn down for low load operation in low demand periods.
- Coal plants need faster response from minimum to intermediate loads to back up sporadic renewable power.
- Low natural gas prices have caused plants to change fuels, blend fuels and co-fire with natural gas



U.S. Natural Gas Wellhead Price

Dollars per Thousand Cubic Feet



Always Apply the Fundamentals First!

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.

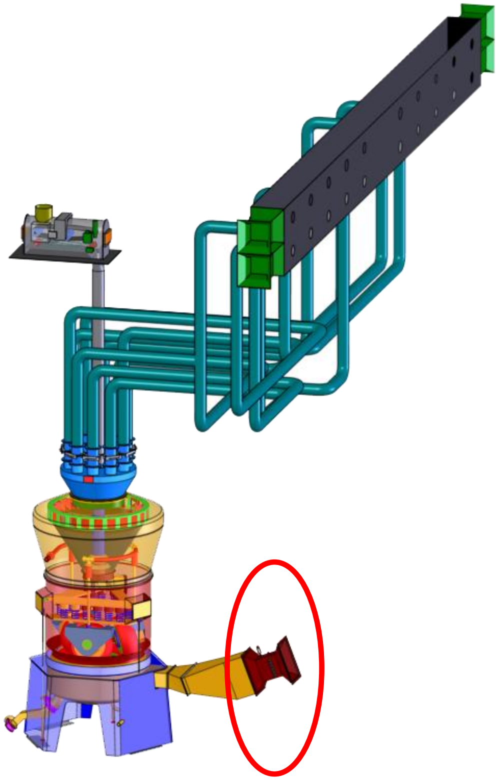
For Faster Response Time…

Accurate Airflow Management and Control is REQUIRED!

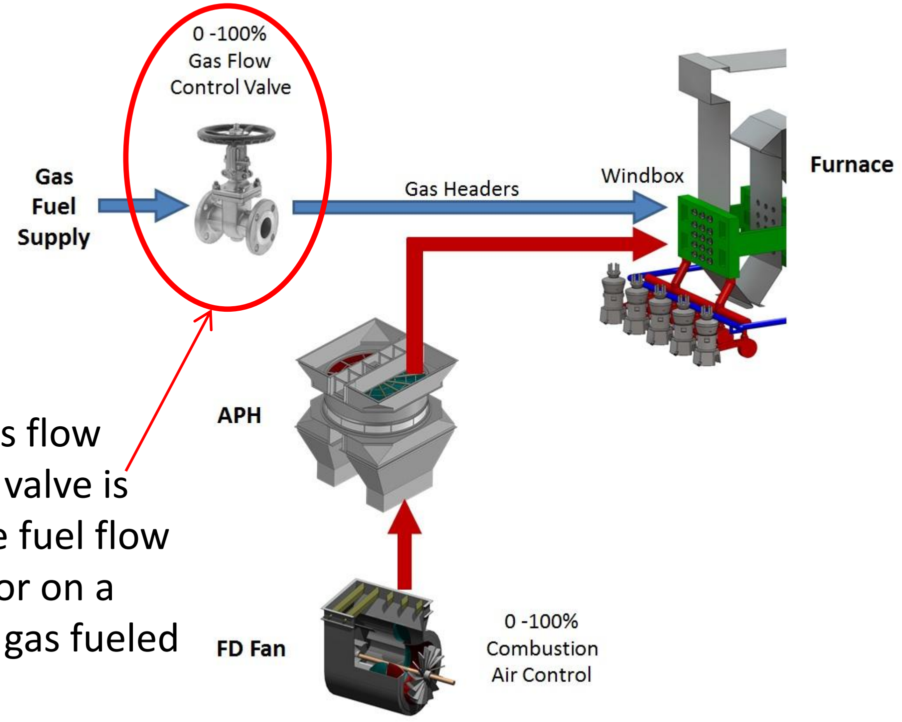
- **The solid fuel injection system approach (both fuel and air metered)**
- **Fuel fineness should be optimum**

Coal

•The Primary Air Damper and adequate changes in Primary Airflow are what transports the Coal from the pulverizer to the furnace.



Natural Gas

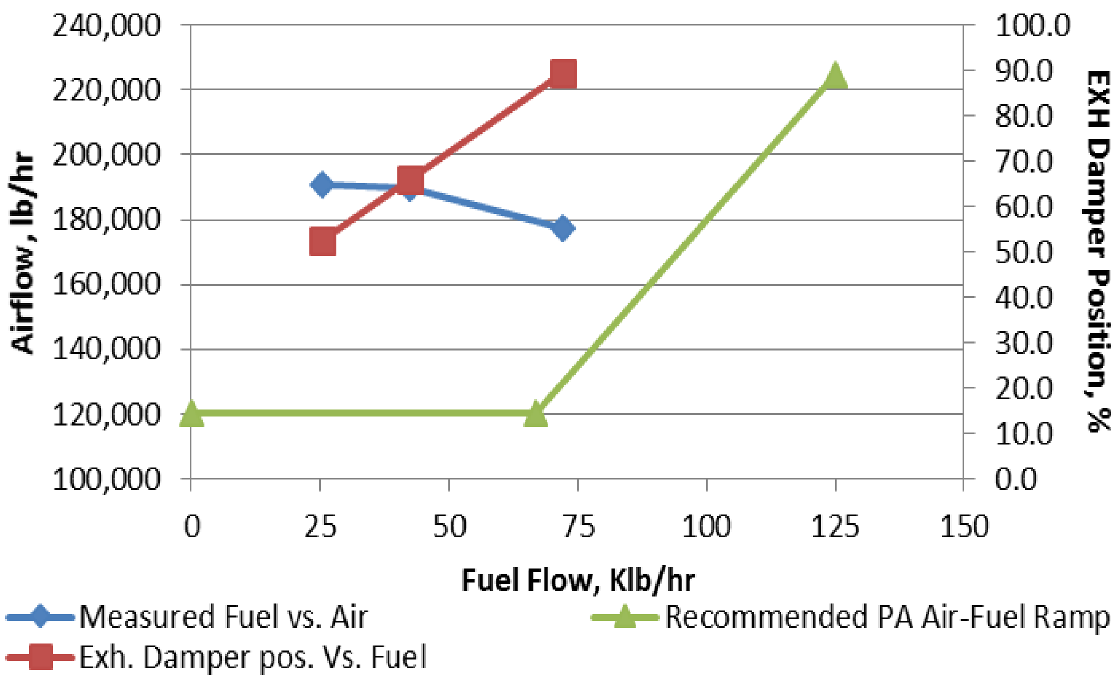


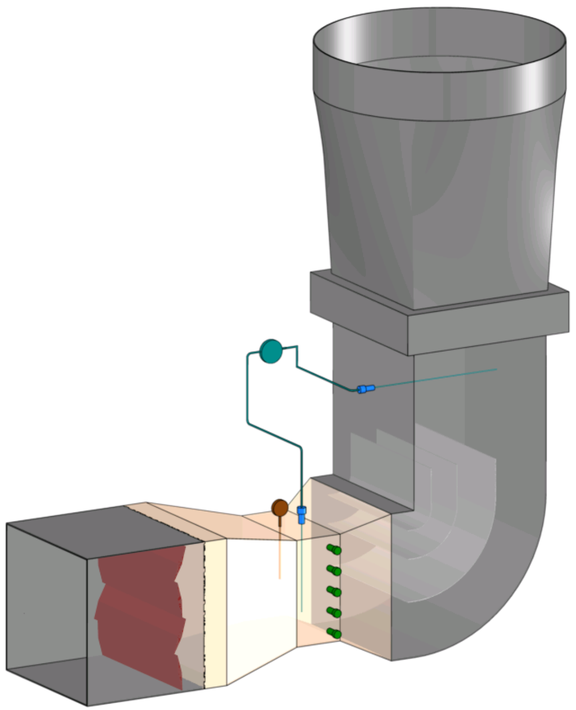
•The gas flow control valve is the sole fuel flow regulator on a natural gas fueled boiler

For Faster Response Time…

Accurate Airflow Management and Control is REQUIRED!

- **Primary air flow transports the fuel to the boiler, it <u>MUST</u> operate on the correct curve to achieve good load response while at constant load, then "kicked" up when the boiler master requires a sudden fuel increase.**

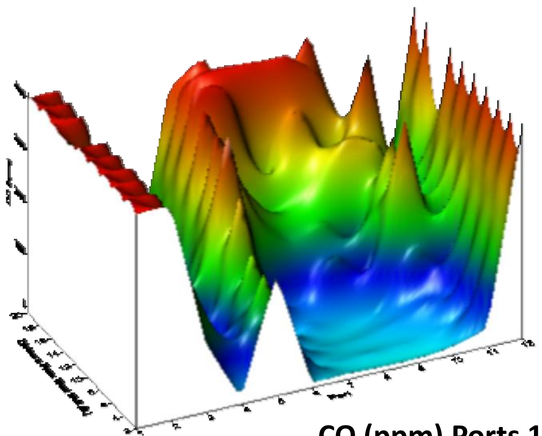




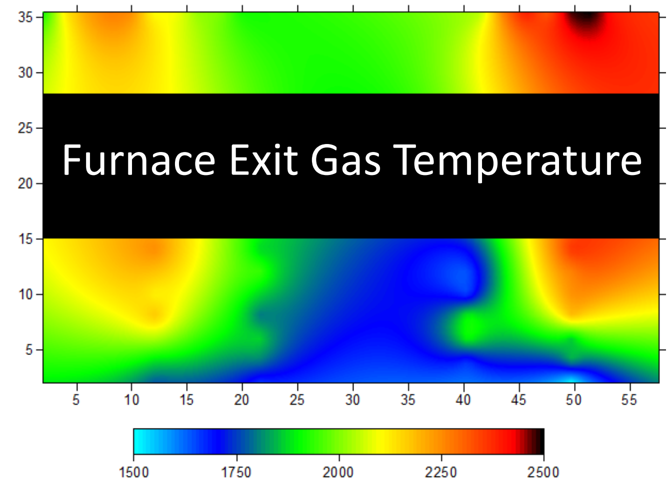
A Homogeneous Furnace Exit Flue Gas Matters

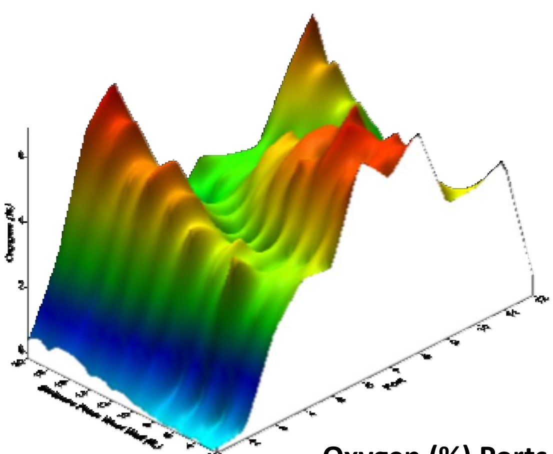
Again, Airflows MUST be Measured and Distributed Correctly

- **HVT Testing Should be Completed to Evaluate Excess Oxygen Levels at Low Load**

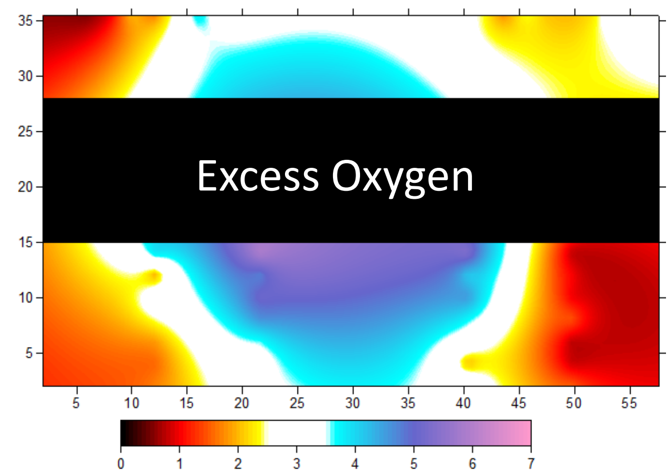


CO (ppm) Ports 1-12

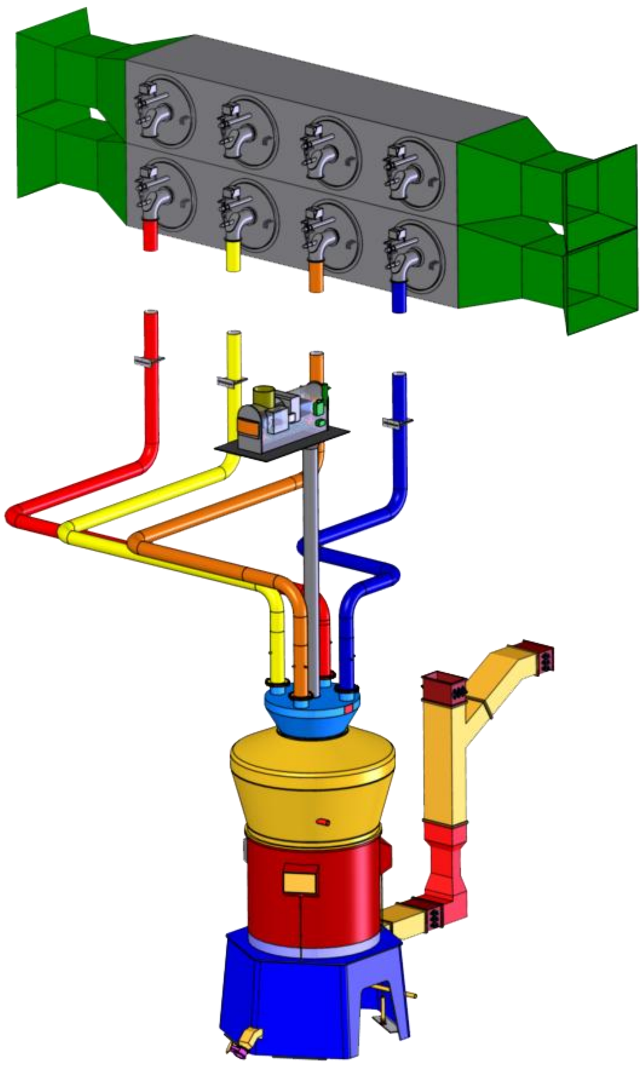


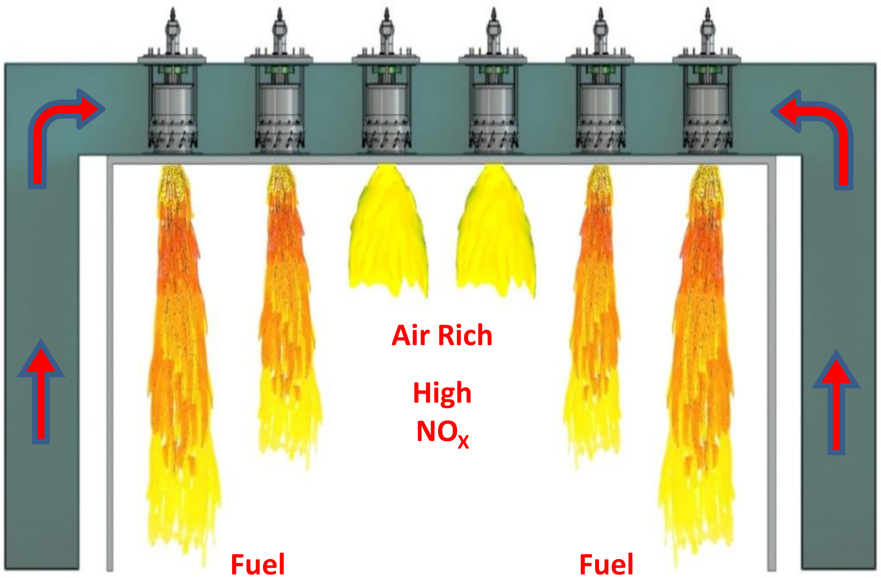


Oxygen (%) Ports 1-12



Both Fuel and Air Balancing Influence Combustion





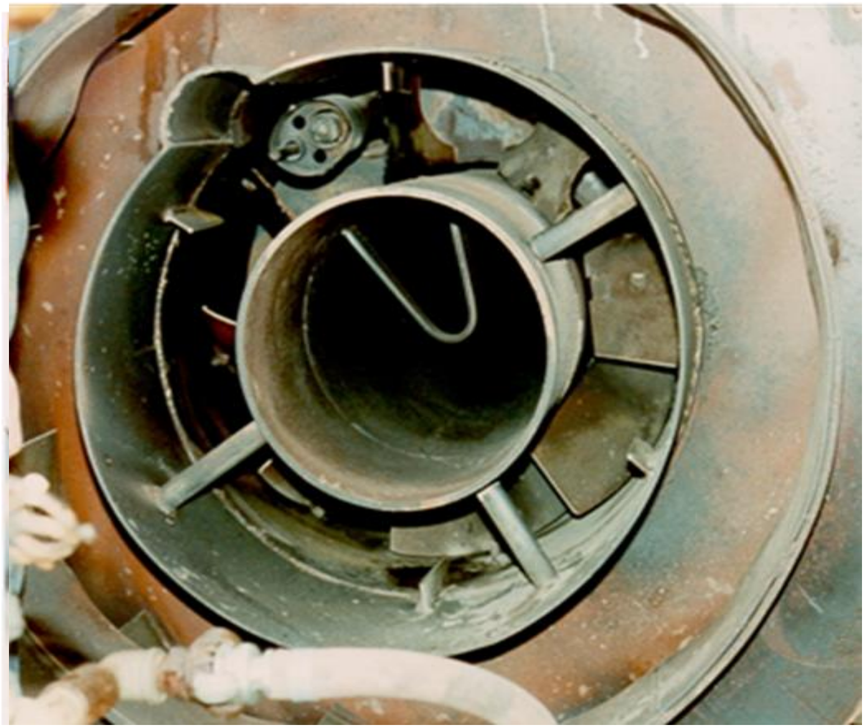
Often, burner air adjustments can be used to correct high CO in the upper furnace. But if fuel flow to individual burners is far above average, air sleeves or register adjustments cannot overcome the air/fuel imbalance.

Heat Warping from low load operation

Burner Cooling for burners out of service is still important!
If you have a spare mill, think of the burners!

Pre-Outage

Post-Outage



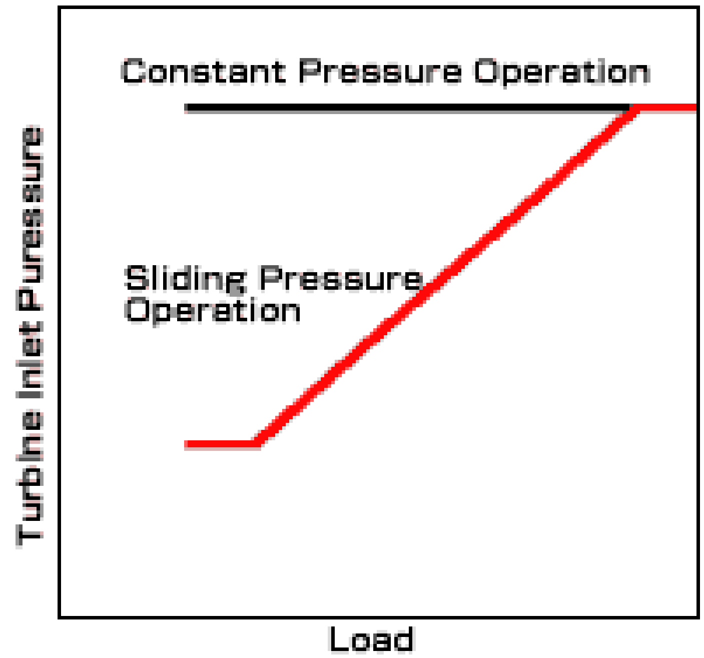
Burners can get destroyed while out of service

Or when coal contacts hot burner metal on a mill start-up

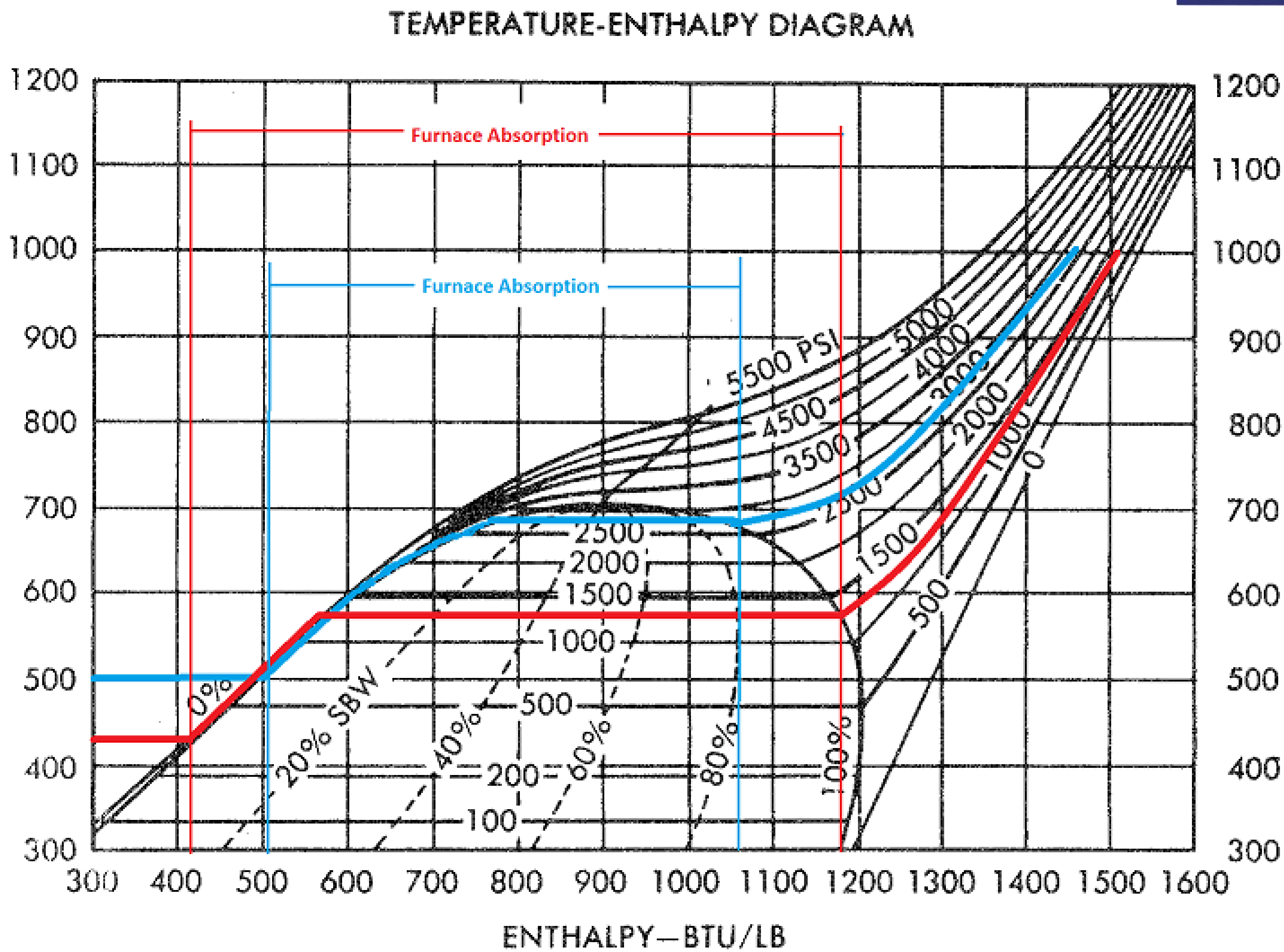
Sliding vs. Constant Pressure Operation

Sliding Pressure has a few basic effects on plant operation:

- At sustained low loads, sliding pressure permits higher steam temperatures.
- Better steam turbine efficiency because of higher steam temperatures.
- Rarely will it be beneficial for faster load response from lower load points!
- Sliding pressure assures better steam and metal temperatures for the steam turbine as long as load is held constant.
- Smooth steam temperature changes are important for turbine longevity.
- Sliding pressure usually harms load response from minimum loads



Why Steam Temperatures are Improved at Low Loads with Sliding Pressure



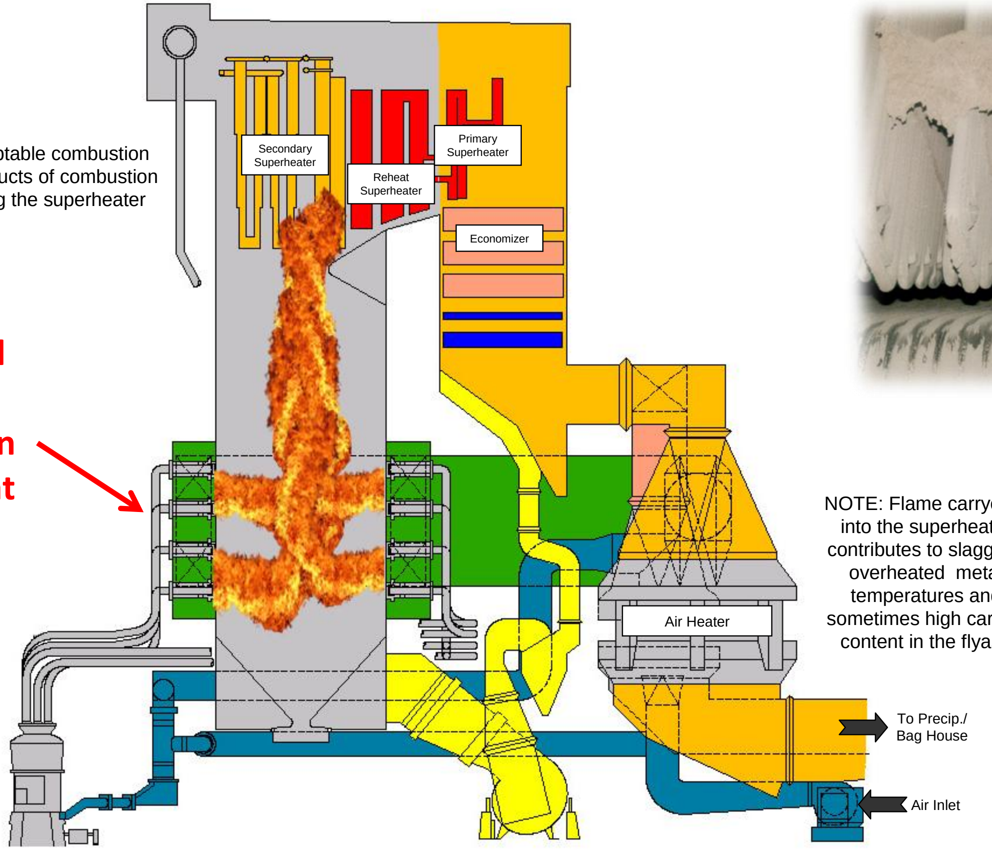
Fuel Switching, Blending & Co-firing

Low Natural Gas Prices have Forced Utilities to Reduce Fuel Costs to Remain Competitive

- **Boiler Conditions & Reliability are Affected if Care is Not Taken to Address the Inputs!**

Unacceptable combustion with products of combustion reaching the superheater

If co-firing w/ natural gas, the fuel and air must be in proportion for those burners that are being fired!

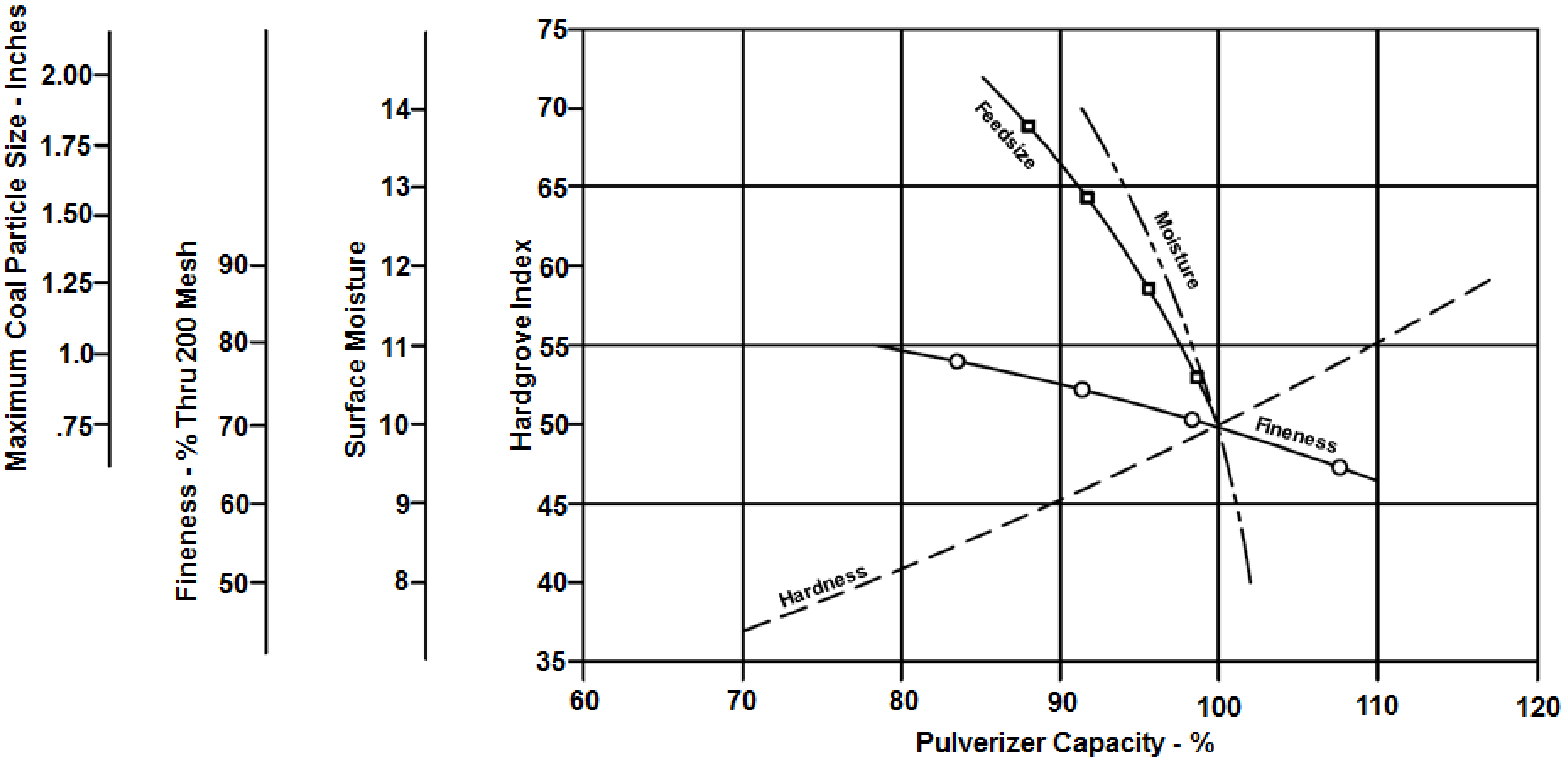


NOTE: Flame carryover into the superheater contributes to slagging, overheated metal temperatures and sometimes high carbon content in the flyash

Fuel Switching

Completely Changing Fuels Should be Taken Seriously!

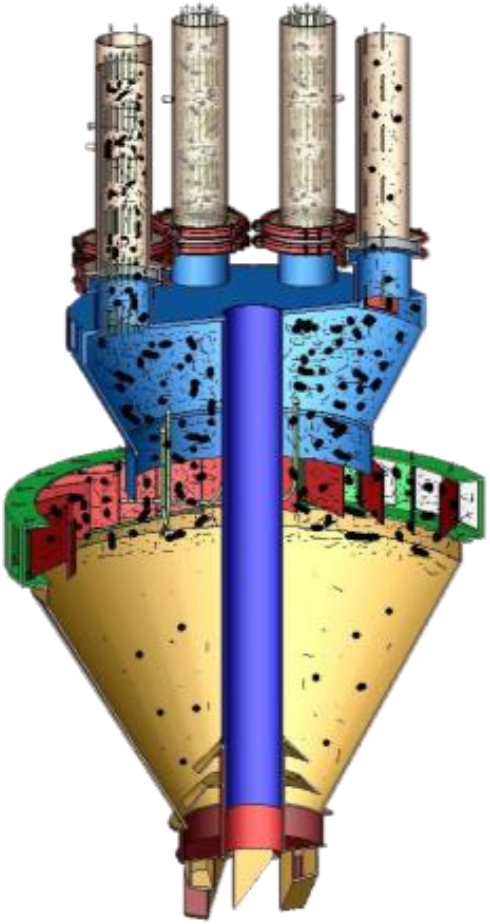
- **Pulverizer Performance Must Be Properly Evaluated and Optimized.**
- **HGI is just one factor!**

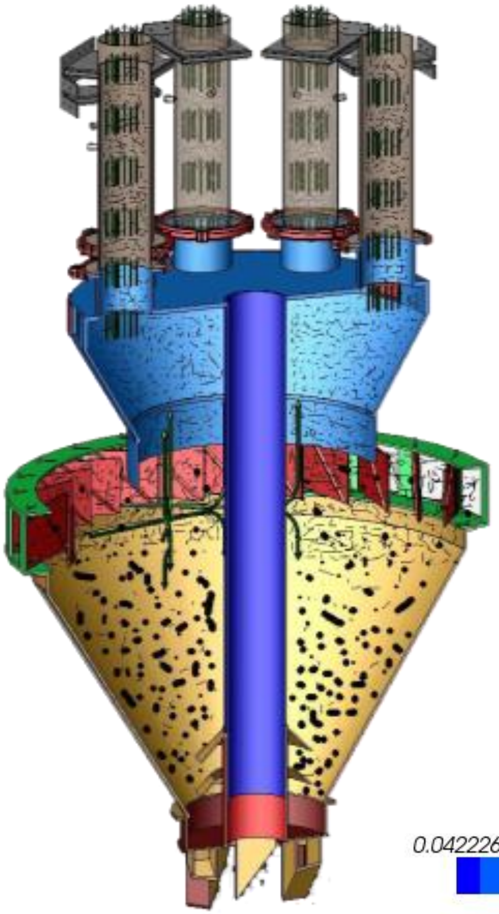


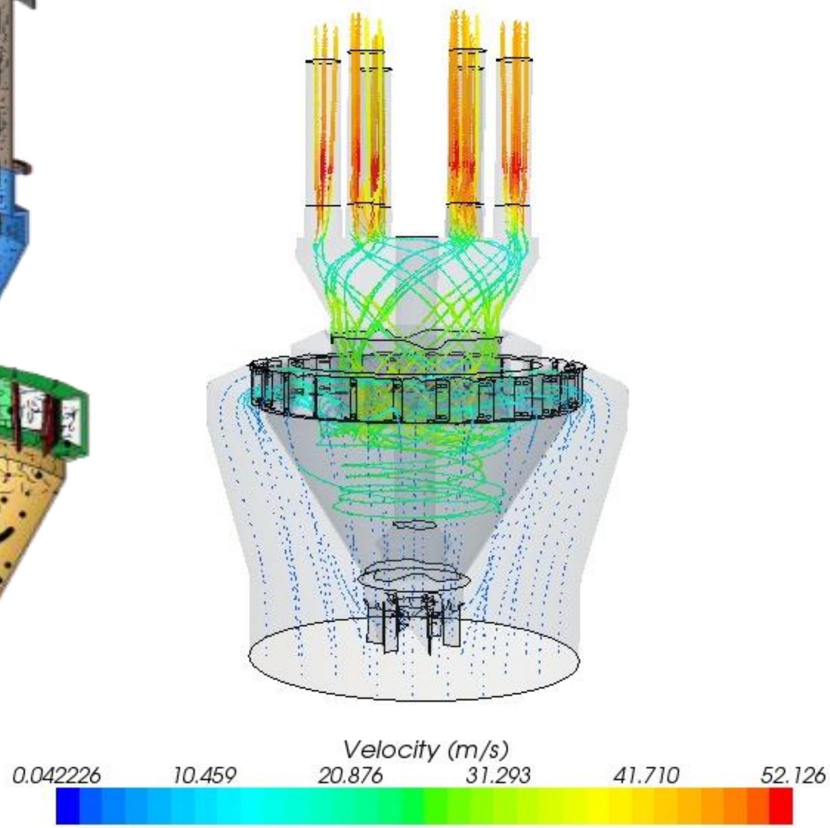
Key Factors Needed to Attain Optimum Pulverizer Performance

- Individual fuel lines balanced by "Clean Air" test to within ±2% deviation from the mean or better.
- Fuel lines balanced by "Dirty Air" test using a dirty air velocity probe, to ±5% deviation from the mean or better.
- Fuel line fineness shall be 75% or more passing a 200 mesh screen. Particles remaining on 50 mesh shall be less than 0.1%.
- Primary air flow accurately measured and controlled within ±2 – 3%.
- Pulverizer must be operating on proper air/fuel ramp
- Fuel line flows balanced to ±10% deviation from the mean or better.

Classifier & Fuel Line Performance







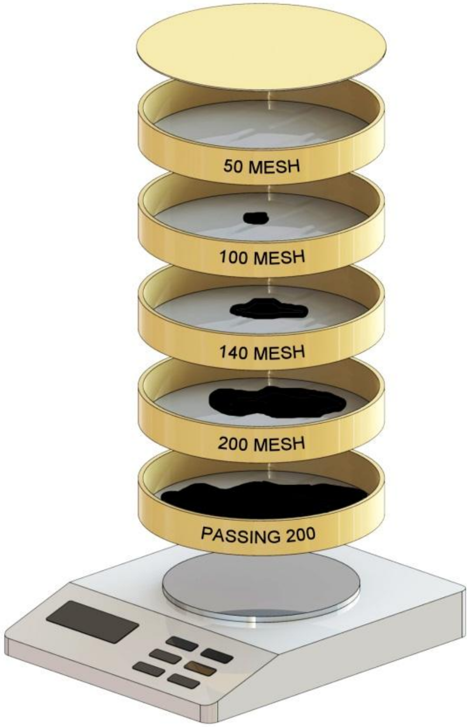
Poor Coal Fineness often yields poor distribution

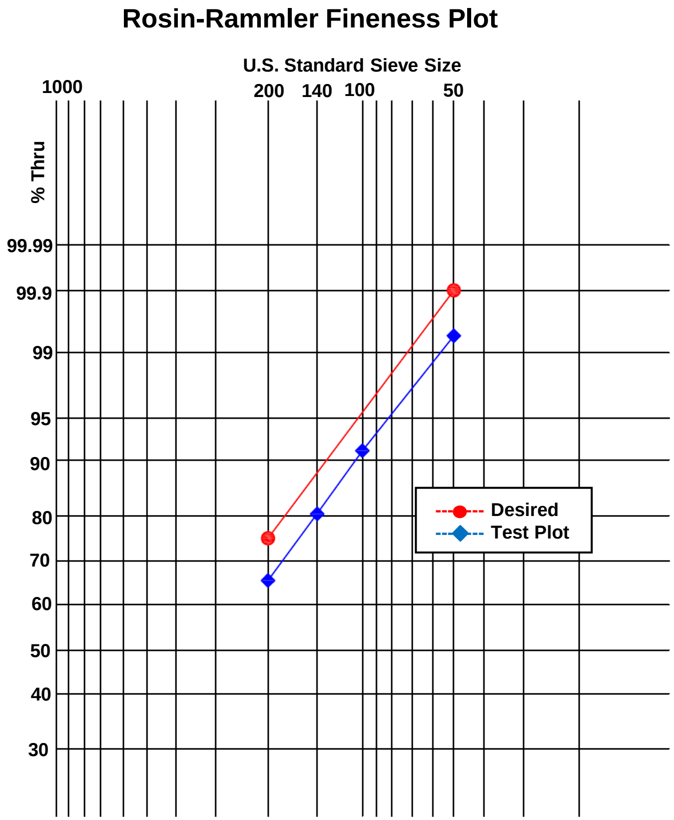
Good Fineness Creates a homogenous & balanced mixture & will produce a more homogenous mixture if mechanical synchronization is optimum and primary airflows repeatable.

Coal Fineness Analyses

Fuel line fineness shall be 75% or more passing a 200 mesh screen.

50 mesh particles shall be less than 0.1% on each of the fuel lines.



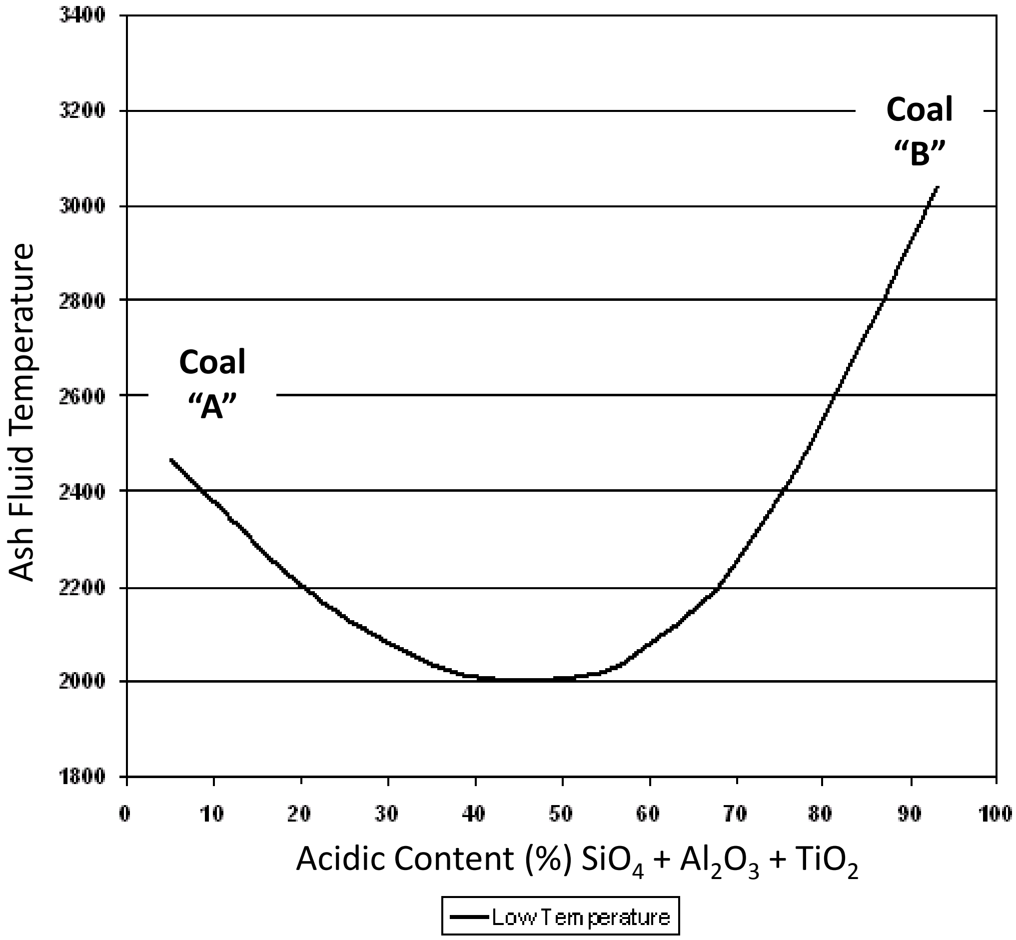


NOTE: Use 4 Sieves for best results!

Fuel Blending

Coal Ash Fusion Temperatures can Be Greatly Affected if the Wrong Blend eutectic of Fuels is Achieved!

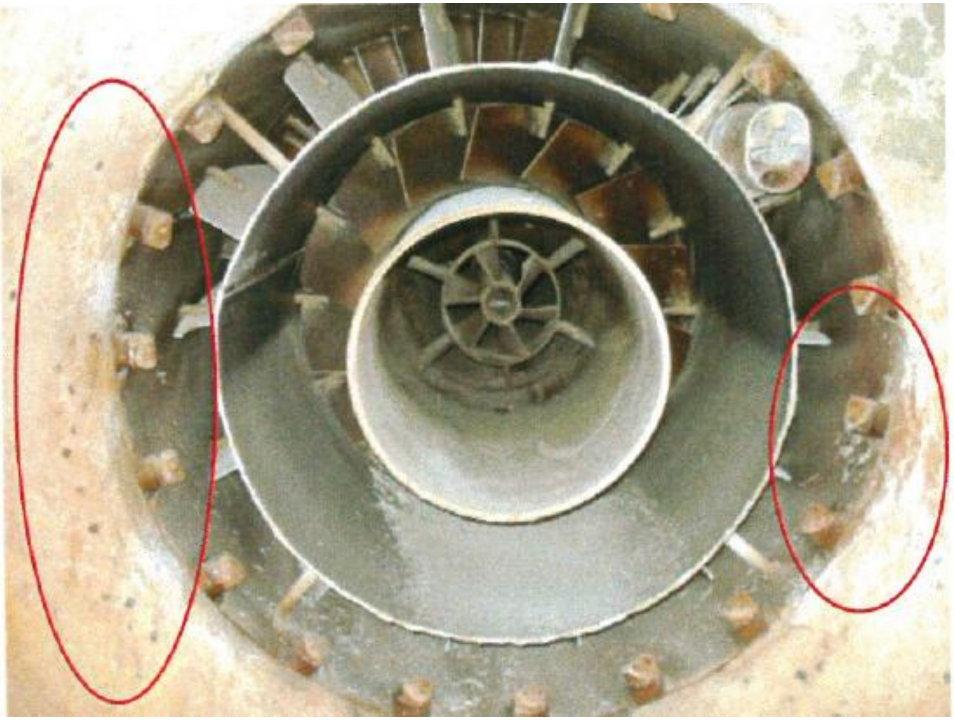
Melting temperatures of coal ash constituents	
FeO - FeS	1724 F
$FeO - Al_2O_3 - SiO_2$	1963 F
CaO - FeO	1967 F
$Na_2O - Al_2O_3 - 6SiO_2$	2012 F
$Na_2SO_4 - CaSO_4$	1675 F



Co-Firing With Natural Gas

Co-Firing Can Be Successful and Efficient

- **Combustion Air Flow to the Burners Must be Properly Metered to Ensure The Total Airflow is Correct for the Total Heat Input to the Burners, a compartmentalized windbox is helpful**
- **Heat Input to the Burners should Not Exceed Burner Design**

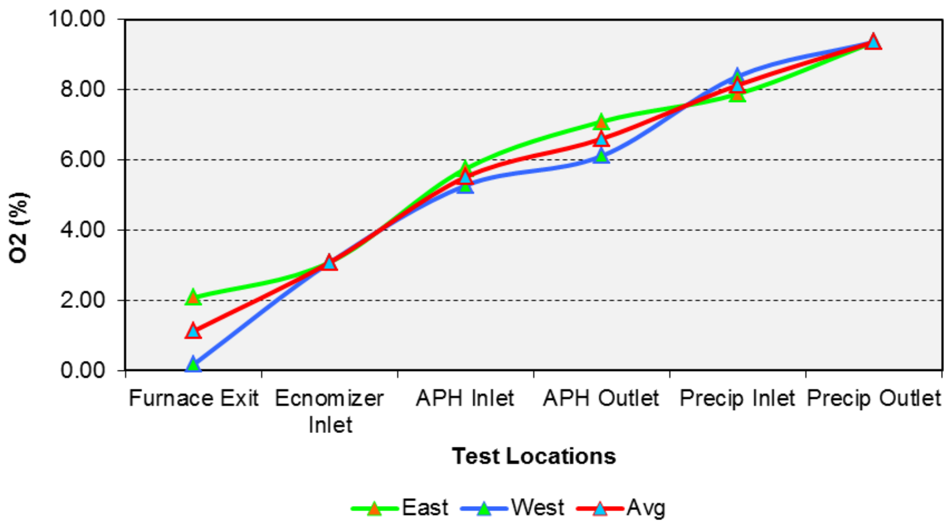


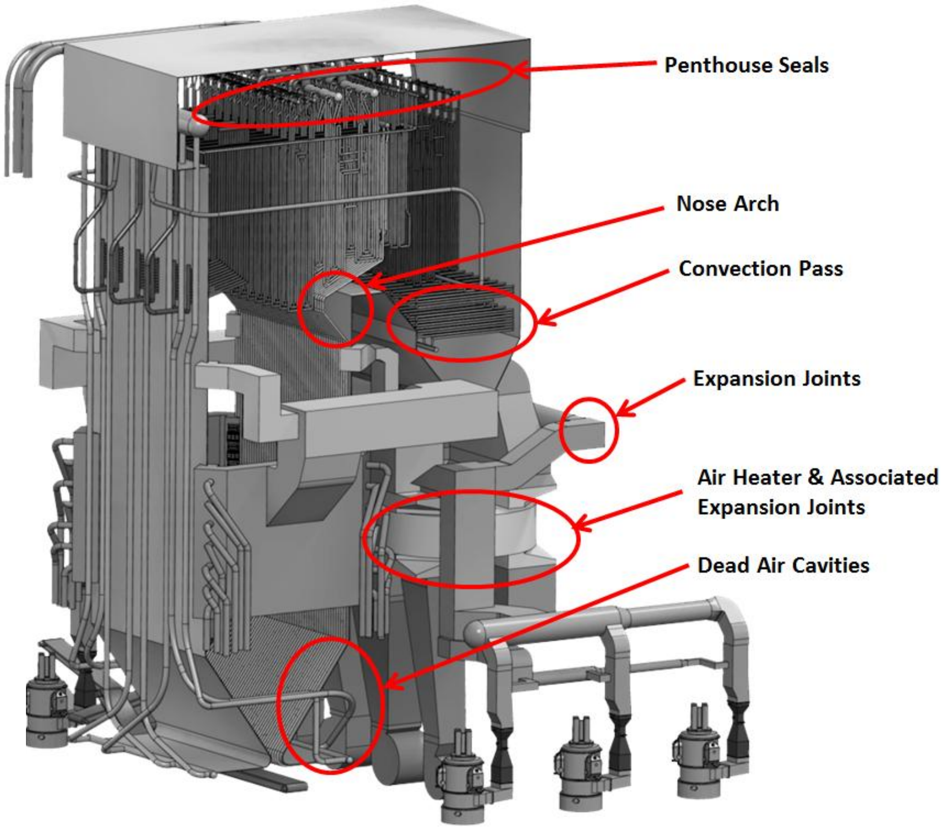
Burner Heat Input		
Coal Flow	lb/hr	84,850
Average Coal HHV	Btu/lb	12,056
Coal Heat Input	MMBtu/hr	1,023
Coal Heat Input per Burner	MMBtu/hr	170
Natural Gas Flow	kscfh	517
Natural Gas Btu (estimated)	Btu/cu. Ft	1,000
Natural Gas Heat Input	MMBtu/hr	517
Natural Gas Heat Input per Burner	MMBtu/hr	25
Landfill Gas Btu per Day	MMBtu	1,738
Landfill Gas Heat Input Per Burner	MMbtu/hr	18

Total Heat Input Per Burner w/ Nat. Gas	MMBtu/hr	195
Total Heat Input Per Burner w/ Nat. Gas and Landfill Gas	MMBtu/hr	213
Guarantee Burner Heat Input	MMBtu/hr	182.7

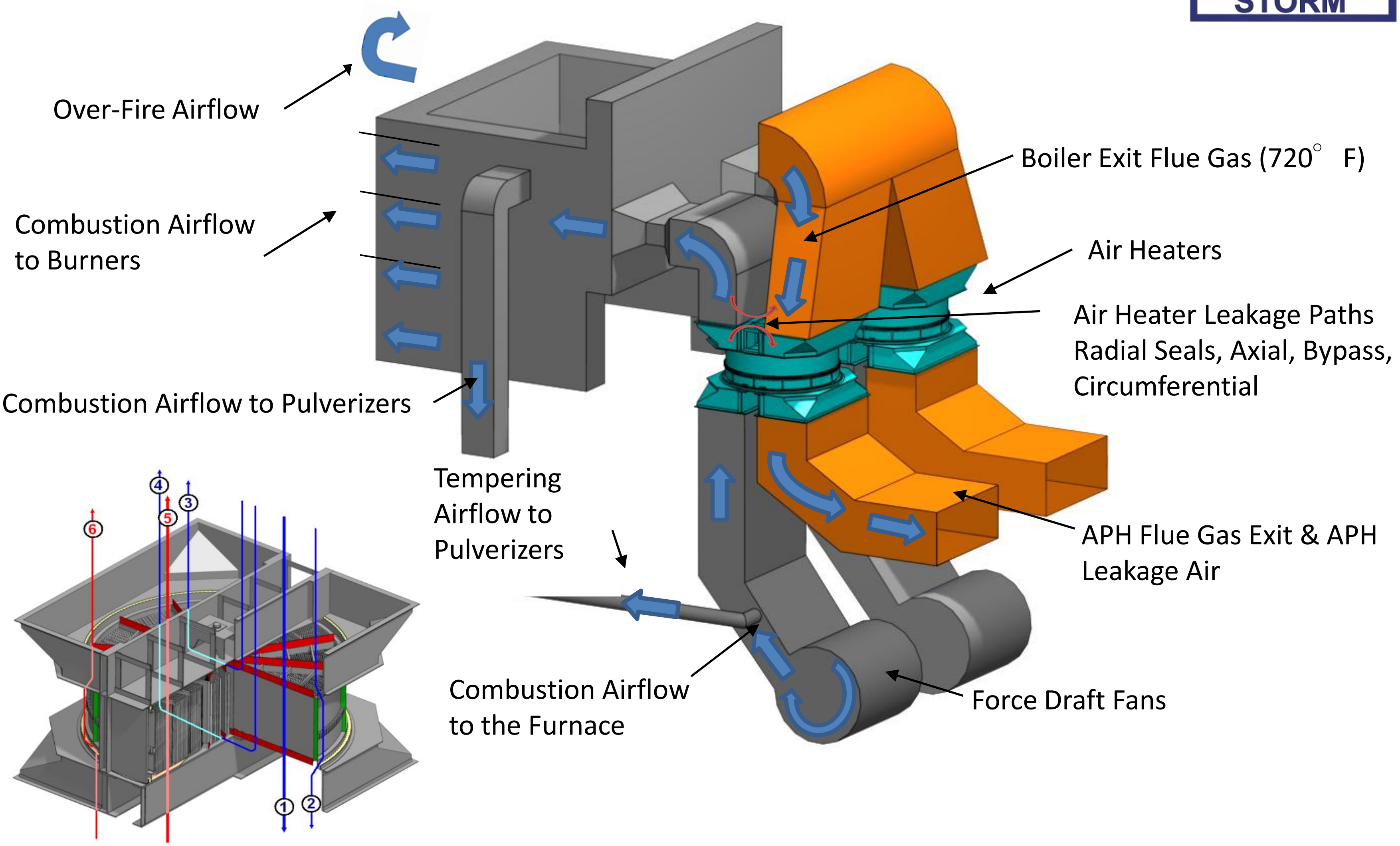
How Do We Quantify Air In Leakage?

- Oxygen rise from the furnace to the stack on a balanced draft boiler
  - Point by point traverses should be conducted
- Adverse affects:
  - Heat rate penalties
  - Increased auxiliary horsepower
  - Decreased combustion efficiency
  - Increased flue gas volume
  - Fan limitations
  - Reduced generation



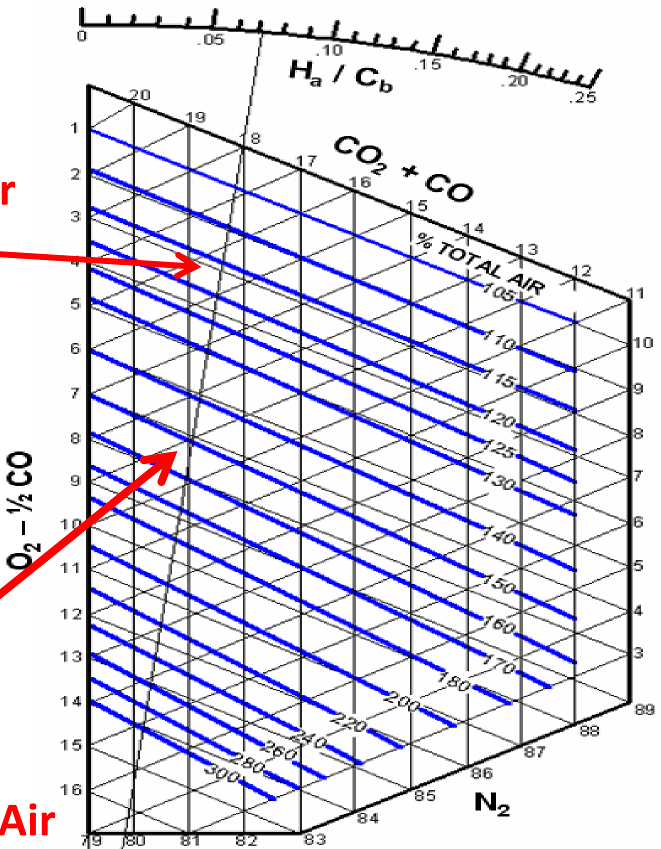


Air In-Leakage and X-Ratio



115% Theoretical Air
At Furnace

Volumetric Flue Gas Combustion Chart



Potentially, up to
150% Theoretical Air
At CEM's

$$\text{Unburned Loss \%} = \left(1 - \frac{H_a / C}{H_a / C_b}\right) \frac{C \times 14500}{\text{Btu / lb.}}$$

Where:

$\frac{H_a}{C_b}$ is from gas analysis

$\frac{H_a}{C}$ Btu / lb. is from coal analysis

- Excess Air
- Theoretical Combustion Air
- Stoichiometry

GENERAL DATA

S.F.	
A.F.	

FUEL ANALYSIS

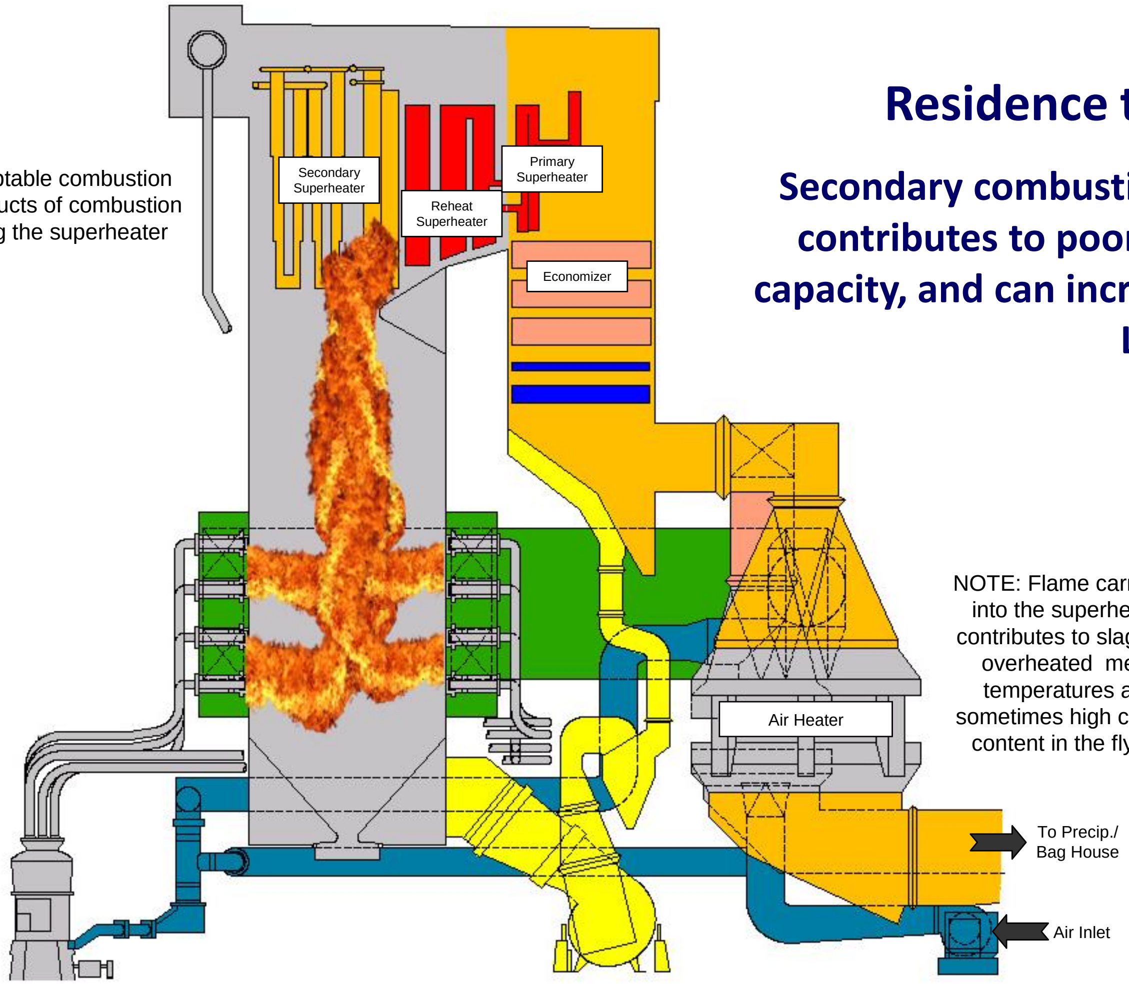
H	
O	
C	
Btu / lb.	
H_a / C	

"Low Hanging Fruit" Opportunities

- Airflow Measurement and Control
- Fix Leakage
- Mill Fineness
- Mill Fuel Distribution
- Burner Mechanical Tolerances

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

First! Apply The Essentials….



Unacceptable combustion with products of combustion reaching the superheater

NOTE: Flame carryover into the superheater contributes to slagging, overheated metal temperatures and sometimes high carbon content in the flyash

Residence time is FIXED!

Secondary combustion, as illustrated here, contributes to poor reliability, efficiency, capacity, and can increase NO_X, CO and flyash LOI.

Thank You!

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