Reinhold Environmental Ltd.

2009 NOx-Combustion Round Table & Expo Presentation

February 9 & 10, 2009, Cleveland, OH

Zonal™ Combustion Tuning Optimization

Reinhold Environmental
2009 NOx-Combustion Roundtable
February 9, 2009

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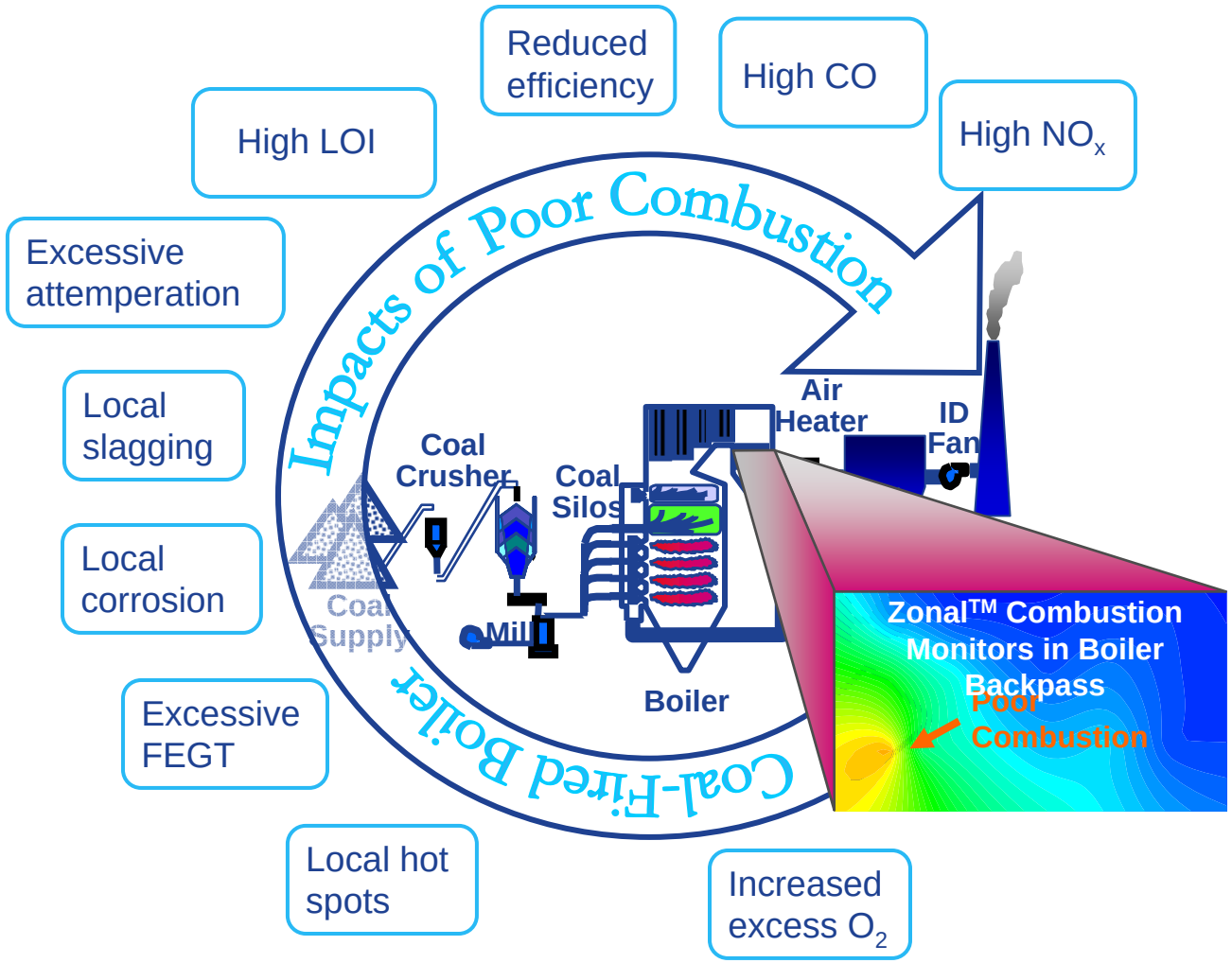
Workshop Agenda

- Impacts of Poor Combustion and Root Causes
- Principles of Good Combustion and Benefits
- Combustion Tuning Approaches
  - Overview
  - Coal Flow Balancing
  - Combustion Monitoring Systems
  - Combustion Optimization Software
  - Zonal Combustion Tuning Demonstration
- Conclusion
- Discussion

Impacts of Poor Combustion and Root Causes

Combustion Performance Issues

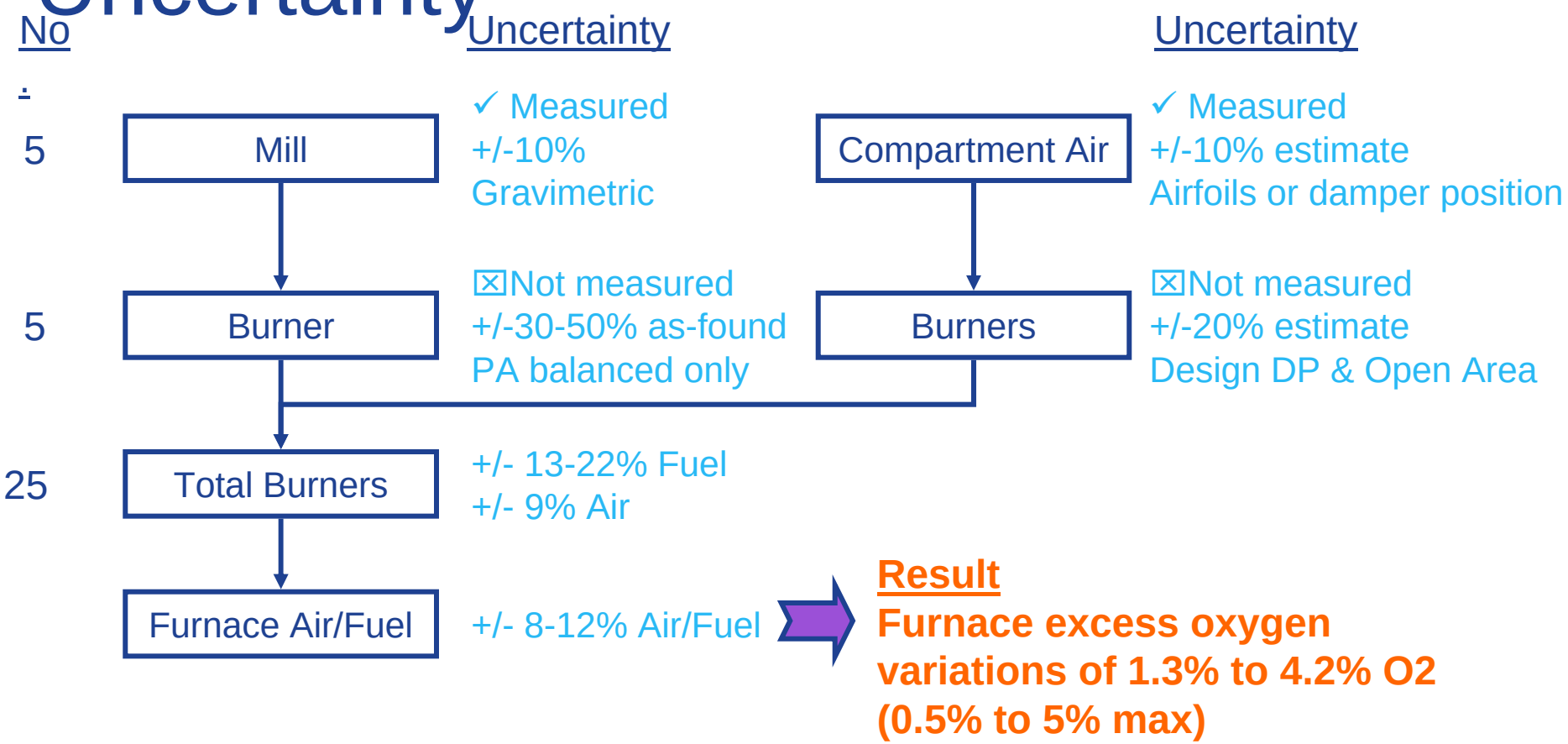


Root Causes of Poor Combustion:

- Burner Coal Flow Imbalanced
- Burner Air Imbalanced
- Poor Staged Combustion System
- Furnace mixing

Even Precise Burner Air and Fuel Supply Does Not Insure Uniform Air/Fuel Ratio in the Furnace

Quick "Six Sigma" Look at Uncertainty



Furnace Mixing is Not Perfect so there are Large Variations in Excess O_2

Illustration of Typically Coal Flow Distribution to Burners

Significant coal flow biases of over 30% are common

This unit routinely balancing PA flow with orifice plates

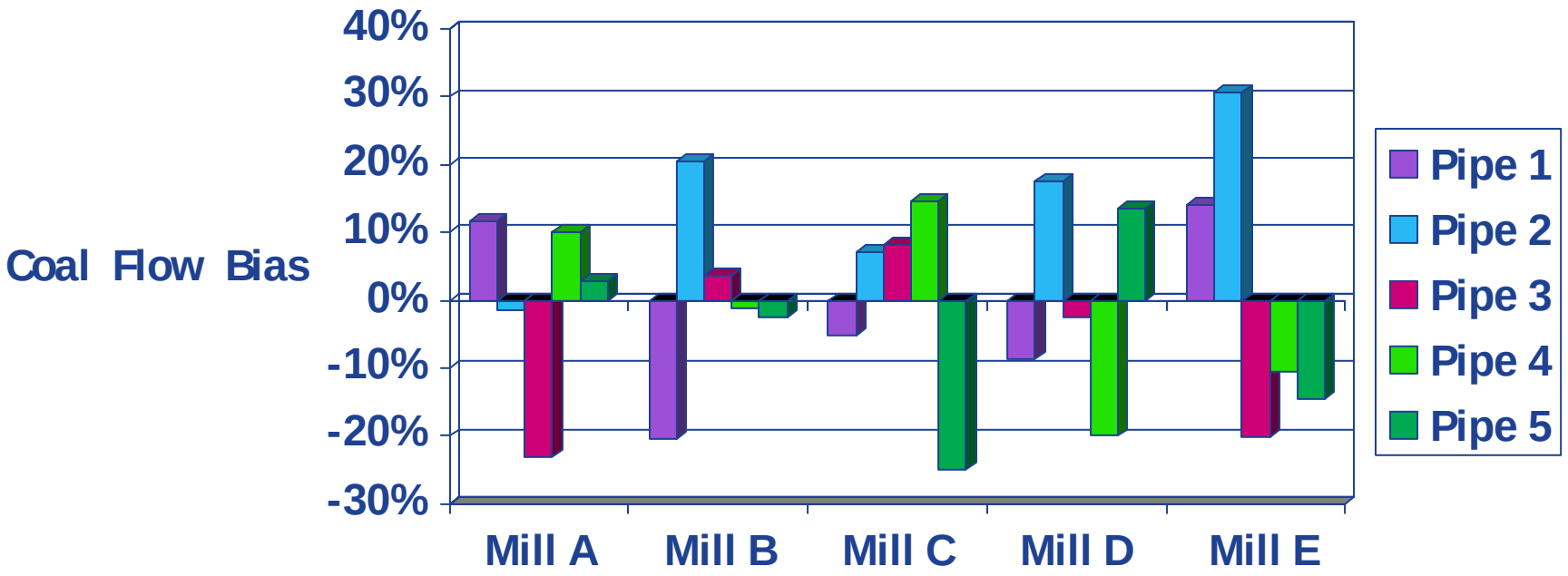
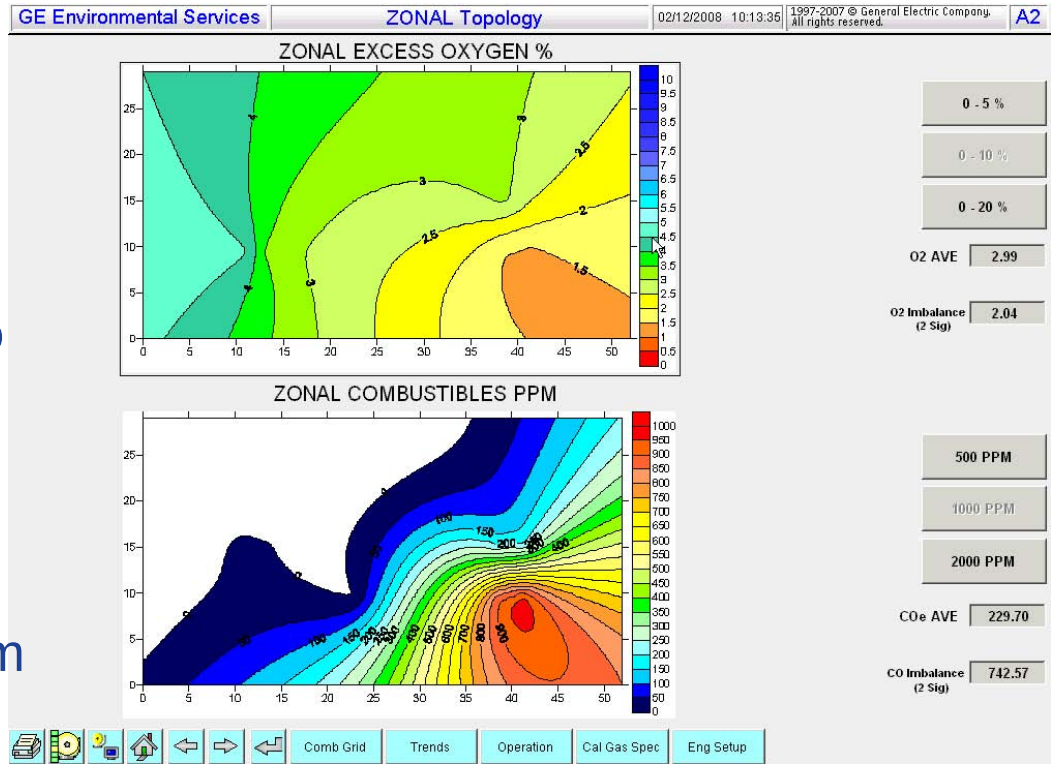


Illustration of Excess O_2 and Combustible Profiles from Furnace

- Western US
- 460 MW T-Fired
- 10 point Sensor Grid

O_2: 1.5 to 4.5%

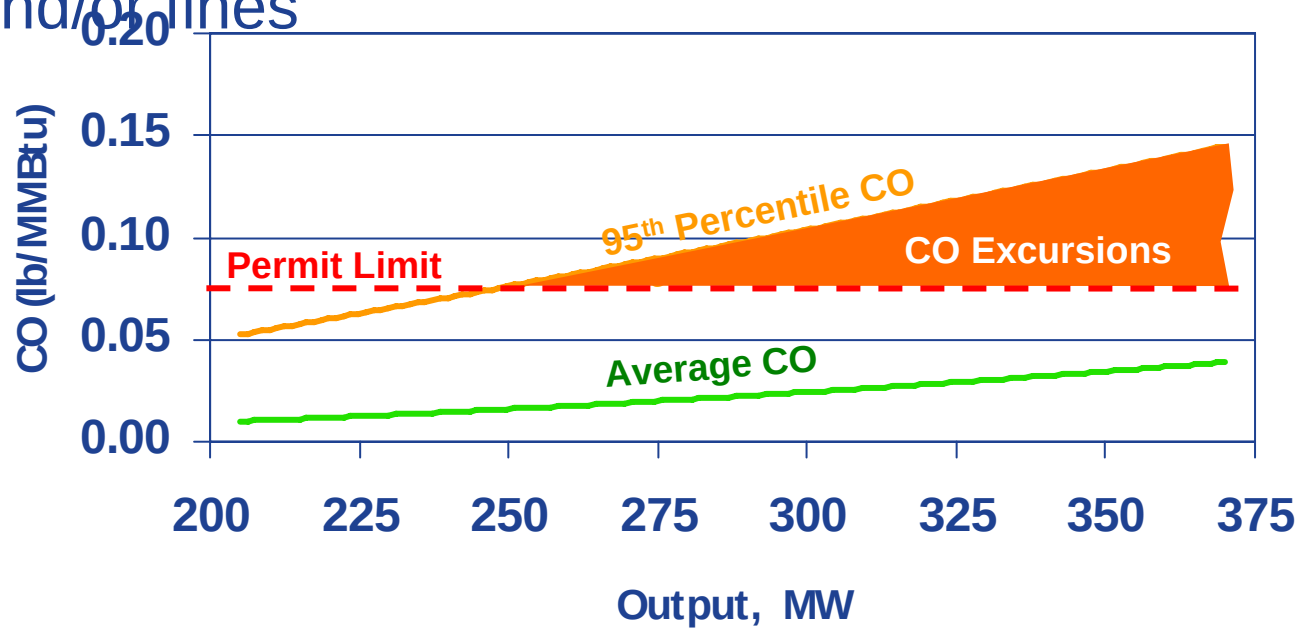
CO: 0 to 950 ppm



Combustion Issues may not be Detected by Stack CO

Historical Stack CO Emissions Variance by Load

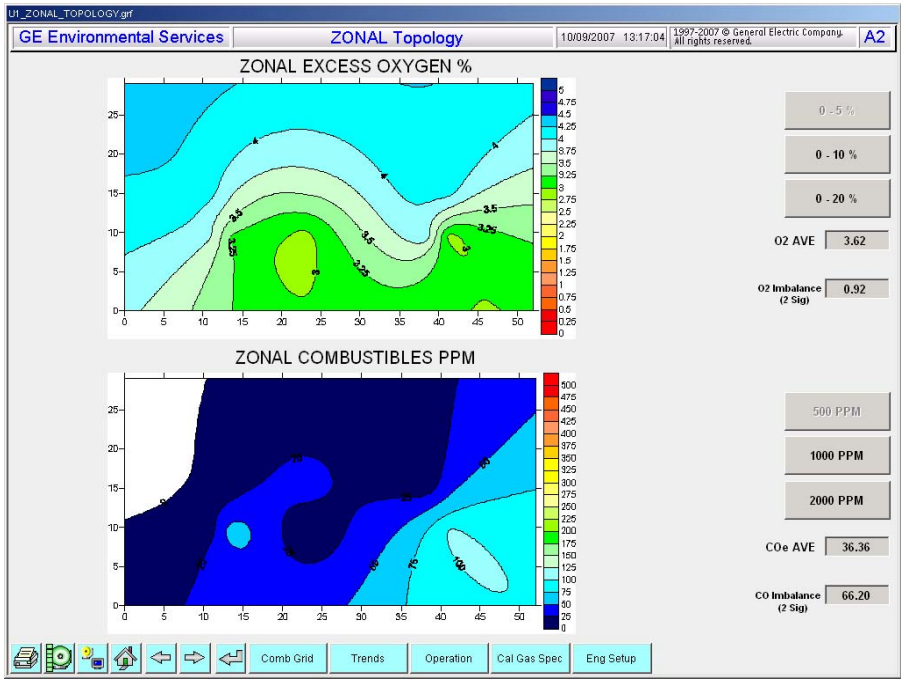
- Boilers subject to significant day-to-day combustion variance
  - Forced to operate below permit level in anticipation of variance that can lead to exceedances, lost output and/or fines



Operating Examples

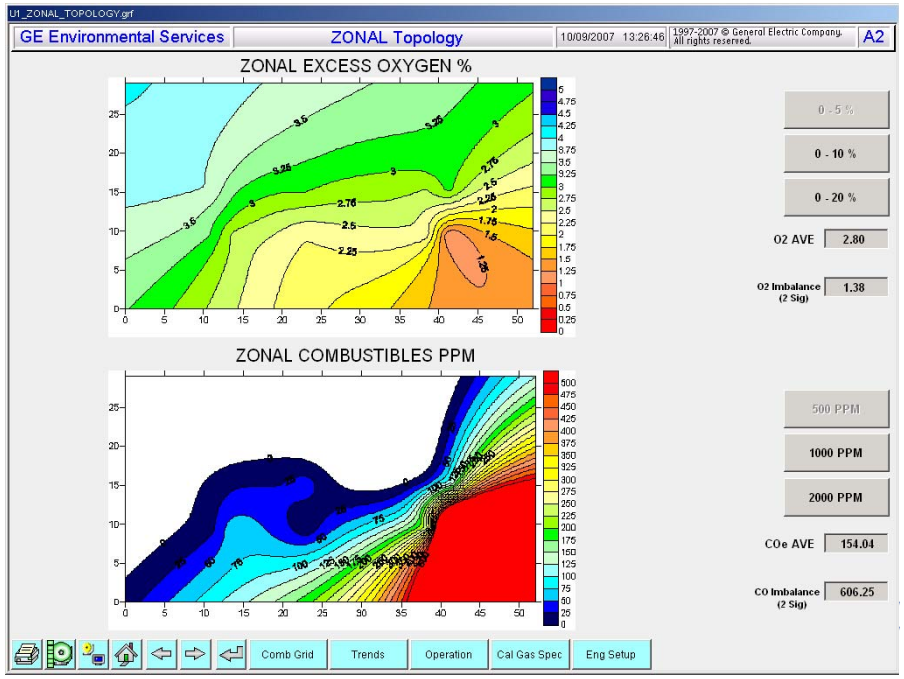
High Excess O2 Operation (3.6%)

- Higher NOx & FEGT, low efficiency
- Slagging potential due to temperature
- O2 imbalance about +/-1%



Target **Excess O2 Operation (3.0%)**

- Severe slagging potential due to fuel-rich conditions
- Average CO (Stack) low at 150 ppm
- Peak CO approaching 1,000 ppm
- O2 imbalance more severe at +/- 1.5%



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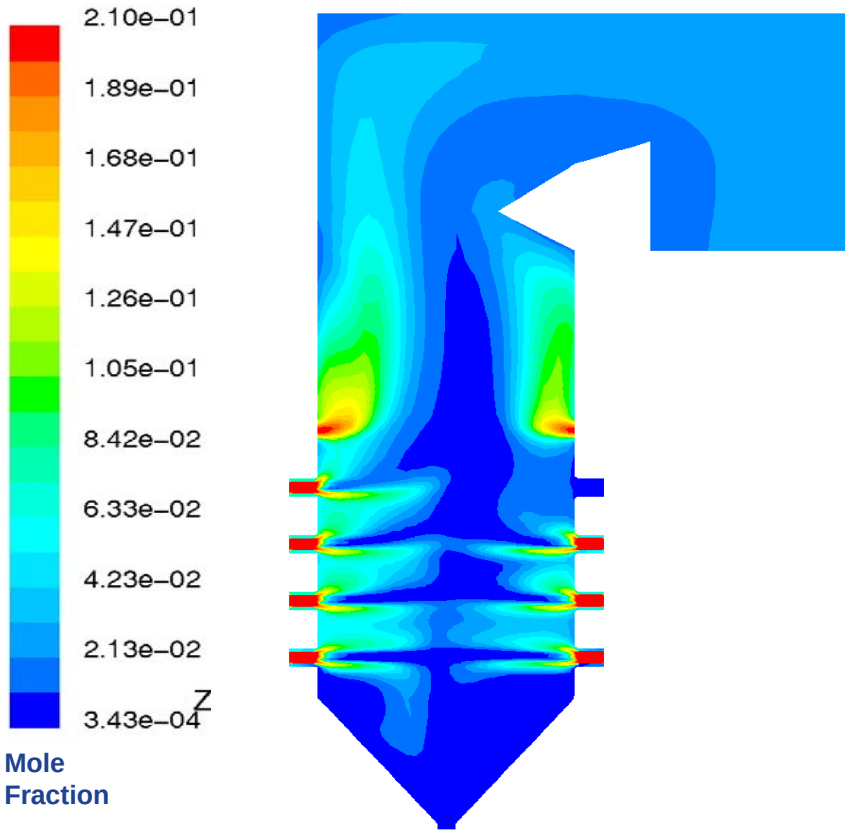
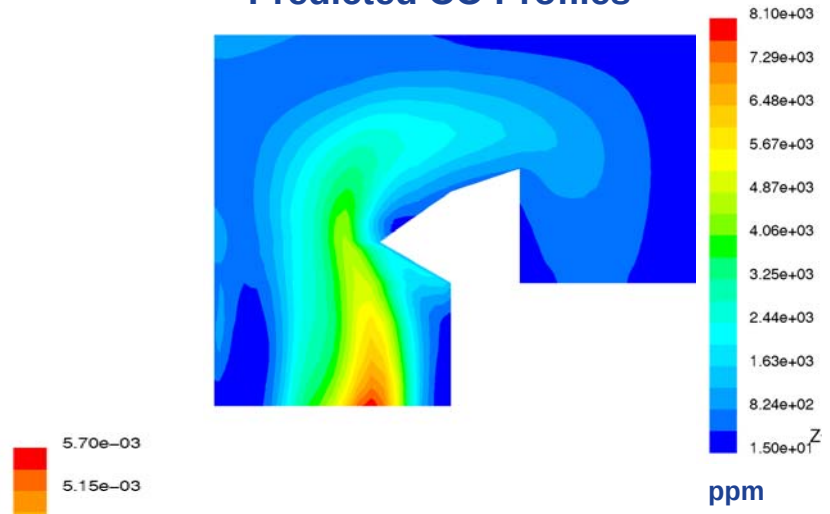
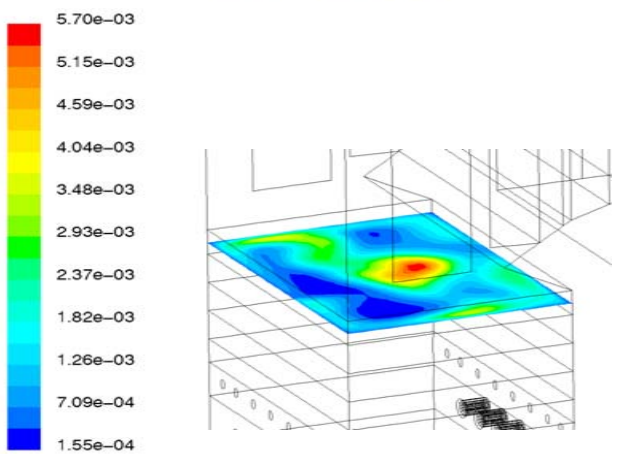
Example of Poor OFA Penetration Reducing Atmosphere Chimneys

Predicted Oxygen Profile



Predicted CO Profiles





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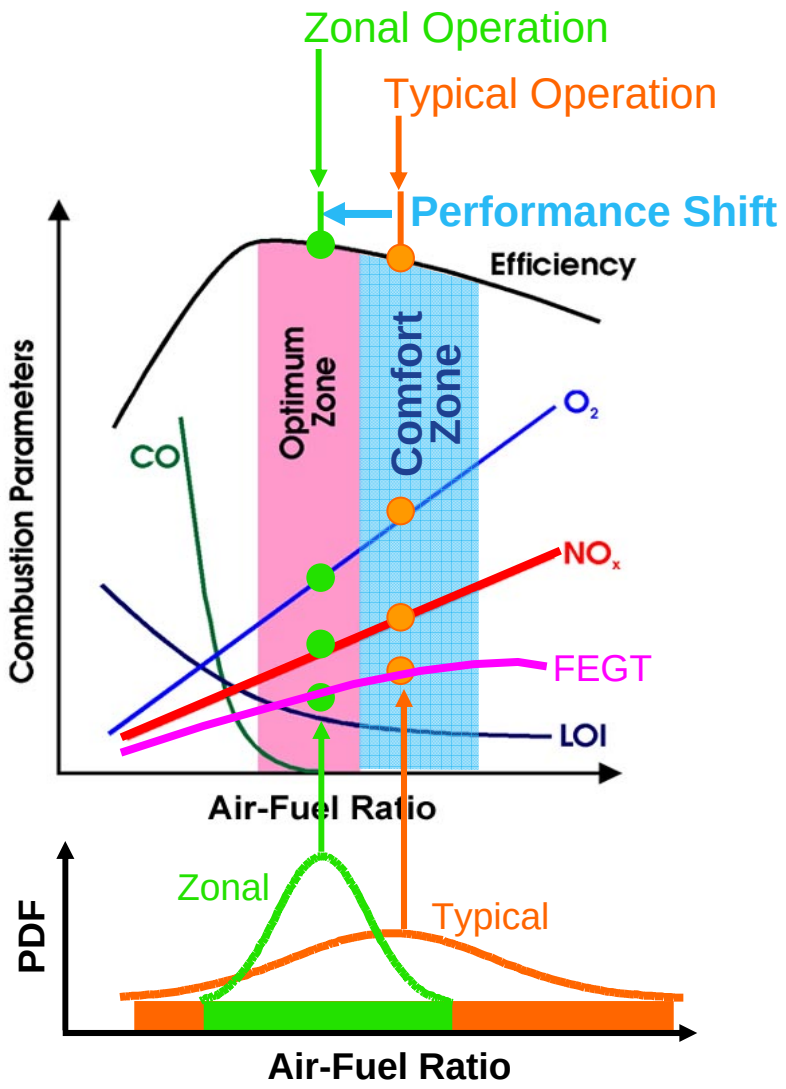
Principles of Good Combustion and Benefits

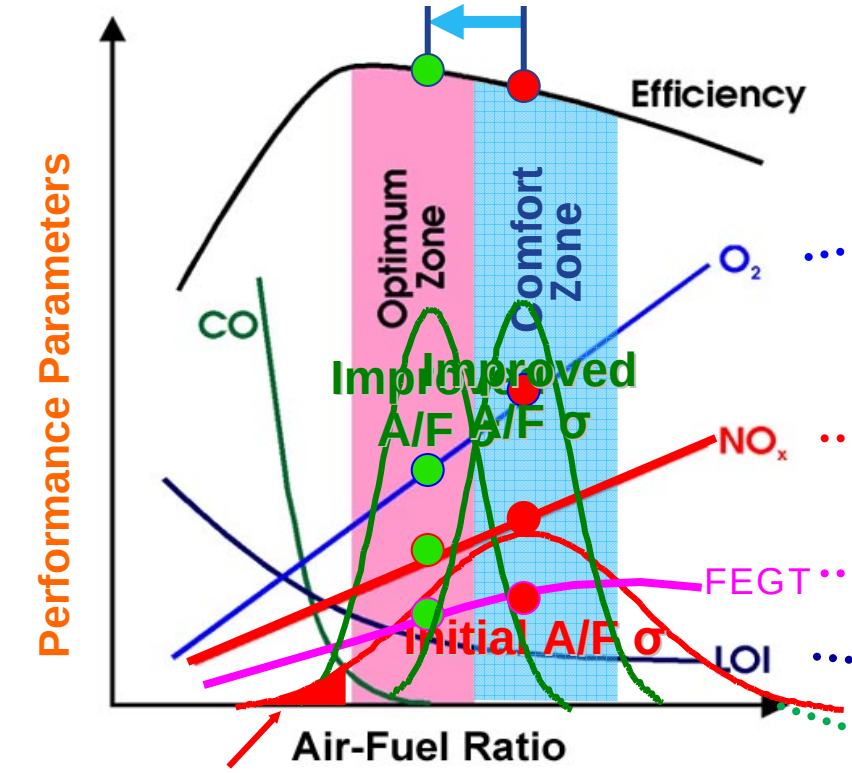
Combustion Tuning Fundamentals

Combustion and Boiler Performance Parameters versus Air-Fuel Ratio (Excess O2)

Hypothetical distribution of Air-Fuel Ratio uncertainty in the furnace:
- Orange is “as-found”
- Green is “tuned”



Principles of Zonal Combustion Tuning



Poorly combustion limits O_2 reduction

Fuel Savings & CO_2

Output, Throughput & Fan Power

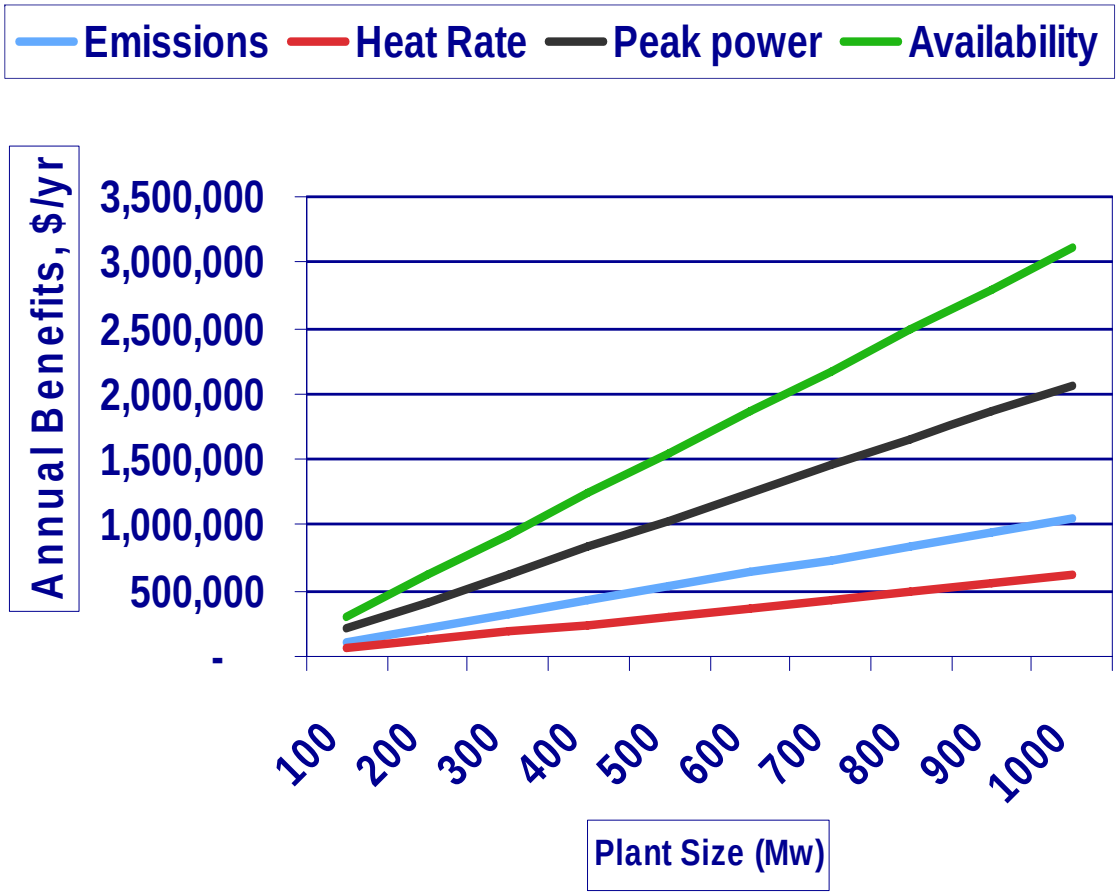
Credits & Compliance

Availability & Output

Ash Sales & Efficiency

Availability & CO compliance

Benefits of Maintaining Optimum Combustion



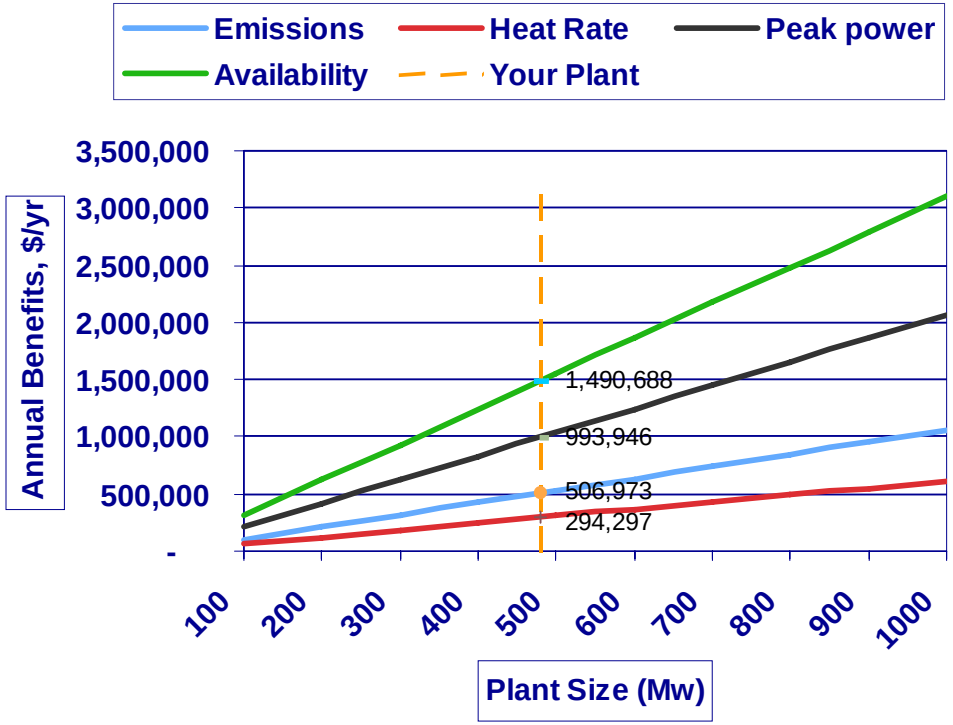
**Benefits and improvements are site-specific. Actual results may vary.*

Basic Benefits Calculations

Tool is available.

Leave me your business card or send email to neilwidmer@ge.com

- Input your parameters:
  - Heat Rate
  - NOx
  - Fuel Cost
  - Electricity Price
- Estimated your benefits:
  - Emission
  - Output
  - Heat Rate
  - Availability



Combustion Tuning Approaches Overview

Approaches to Combustion Optimization

Approach	Benefits	Challenges
Coal Balancing	Address largest uncertainty.	Coal/air mixing not uniform
More Plant O_2 Probes	Helps with burner tuning.	Air in-leakage. Difficult to trace to burners. Lack combustion.
Economizer CO/NOx Measurements	Effective for tuning boiler.	Time consuming. Imprecise due to changes in boiler conditions, air leakage
Combustion Measurements Grids	Immediate feed back. Allows improved tracing to burners.	Still requires operator to monitor and act on information.
Artificial Intelligence Software (Neural Net)	Optimize major assets like Total Air, Total OFA, Mill Bias, etc.	Requires model maintenance. Usually not applicable to burner tuning.
Combustion Tuning Advisor Software	Guides operator decisions. Captures operator knowledge.	Model built for specific operating modes.

Coal Flow Balancing

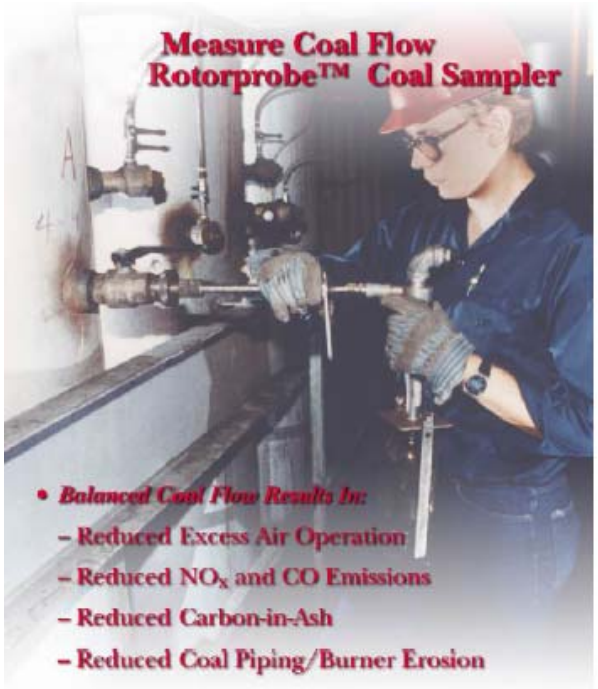
Coal Flow Balancing Approaches

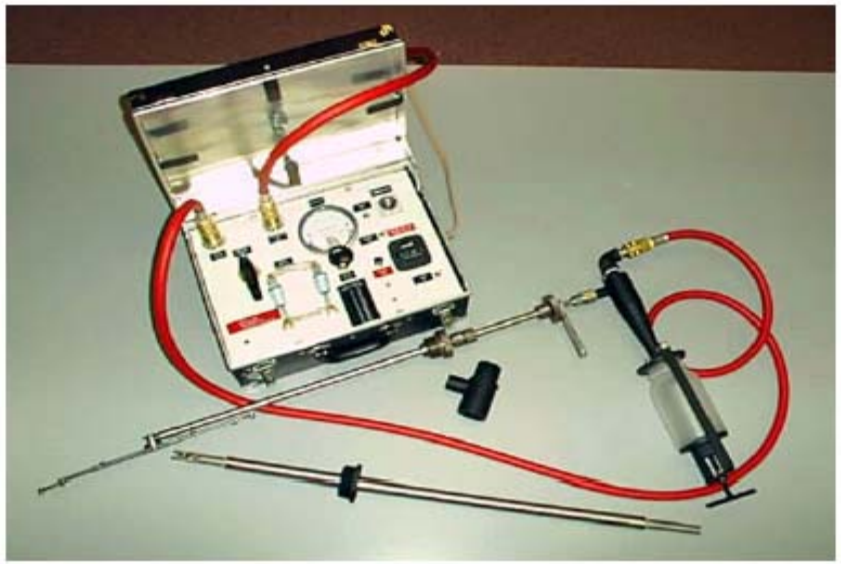
Approaches	Benefits	Challenges
PA Flow Balancing with Orifice Plates	Easiest, Lowest Cost	Coal flow usually remains imbalanced.
Burner Coal Flow Balancing	Addresses major source of uncertainty	Requires coal trimming damper investment
1) Manual Rotoprobe Measurement	Lowest cost coal measuring approach	Labor intensive
2) Continuous Coal Flow Measurement	Faster and safer than manual. Allows for tuning as conditions deteriorate.	Proven measurement techniques
3) Automated Coal Flow Dampers*	Faster and safer than manual adjustment.	
4) Coal Flow Balancing System	Automatic or 1-touch balancing. Biasing of fuel to burner.	

Rotoprobe™

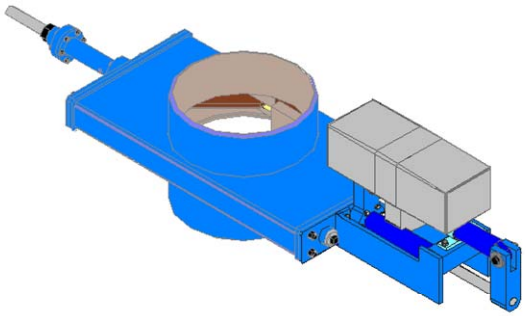
General Description

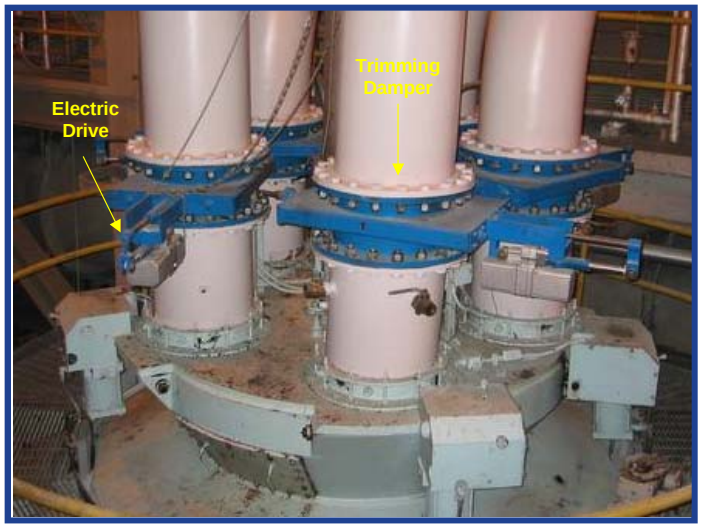
The Rotorprobe™ Pulverized Coal Sampling System implements International Standard Organization Method ISO 9931 for sampling pulverized coal in a primary air stream. The accurate samples obtained can be used to assess both the size and the relative mass flow of the coal in each burner pipe. When this information is used to balance coal flow to the burners and optimize coal mill settings, a wide variety of boiler operating problems can be prevented or eliminated.



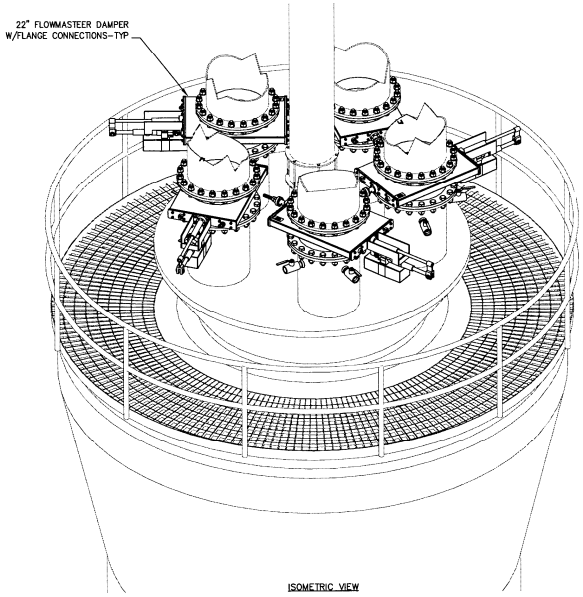


Coal Flow Dampers





Installation



Design

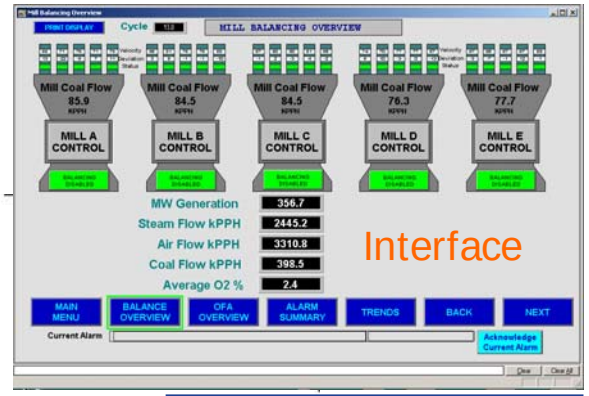
Burner Coal Flow Balancing System

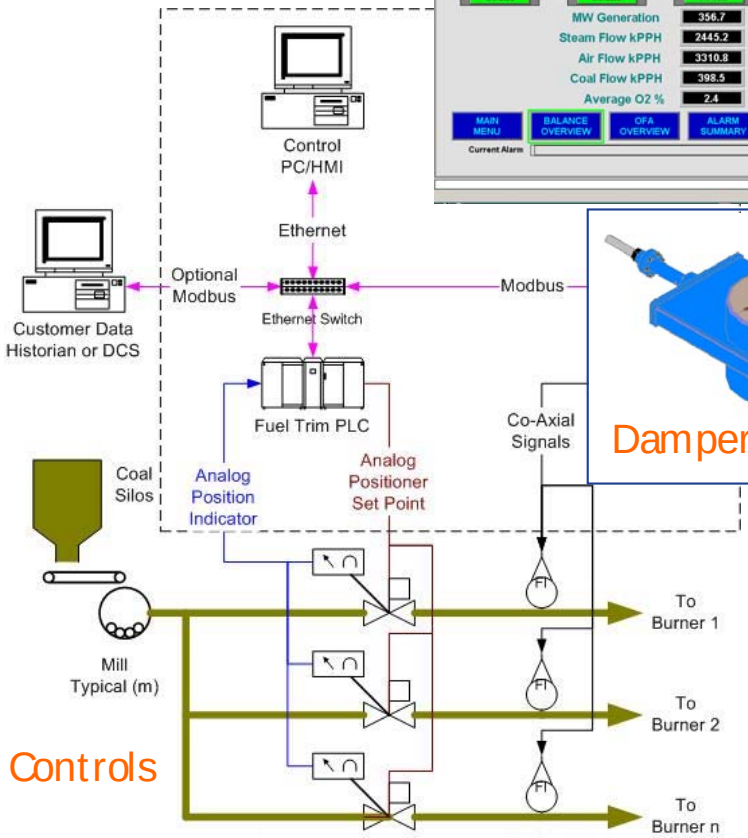
Scope Overview

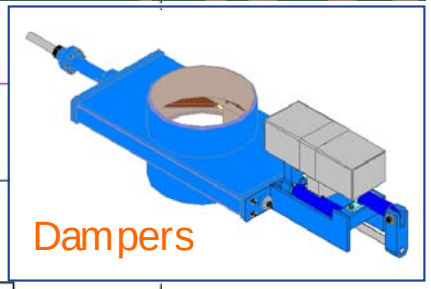
- Manual to automatic dampers
  - Field upgradeable
- Online or manual measurements
- Automatic and manual controls
- Operator interface

Applicable to:

- All coals
- Coal pipes 8 to 28 inches (NPS)
- Vertical up or horizontal flow
- Available head loss 3 inch H_2O

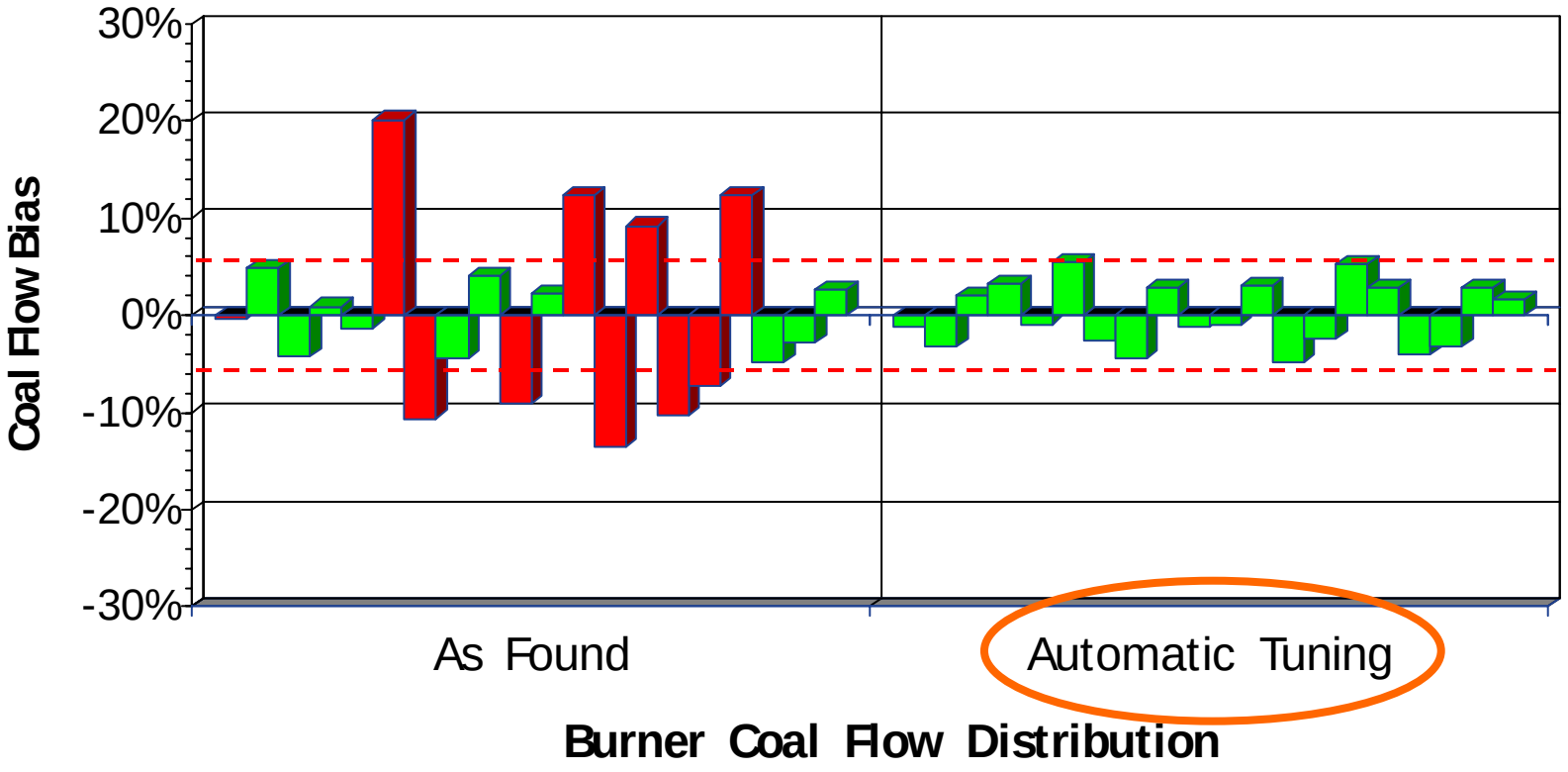




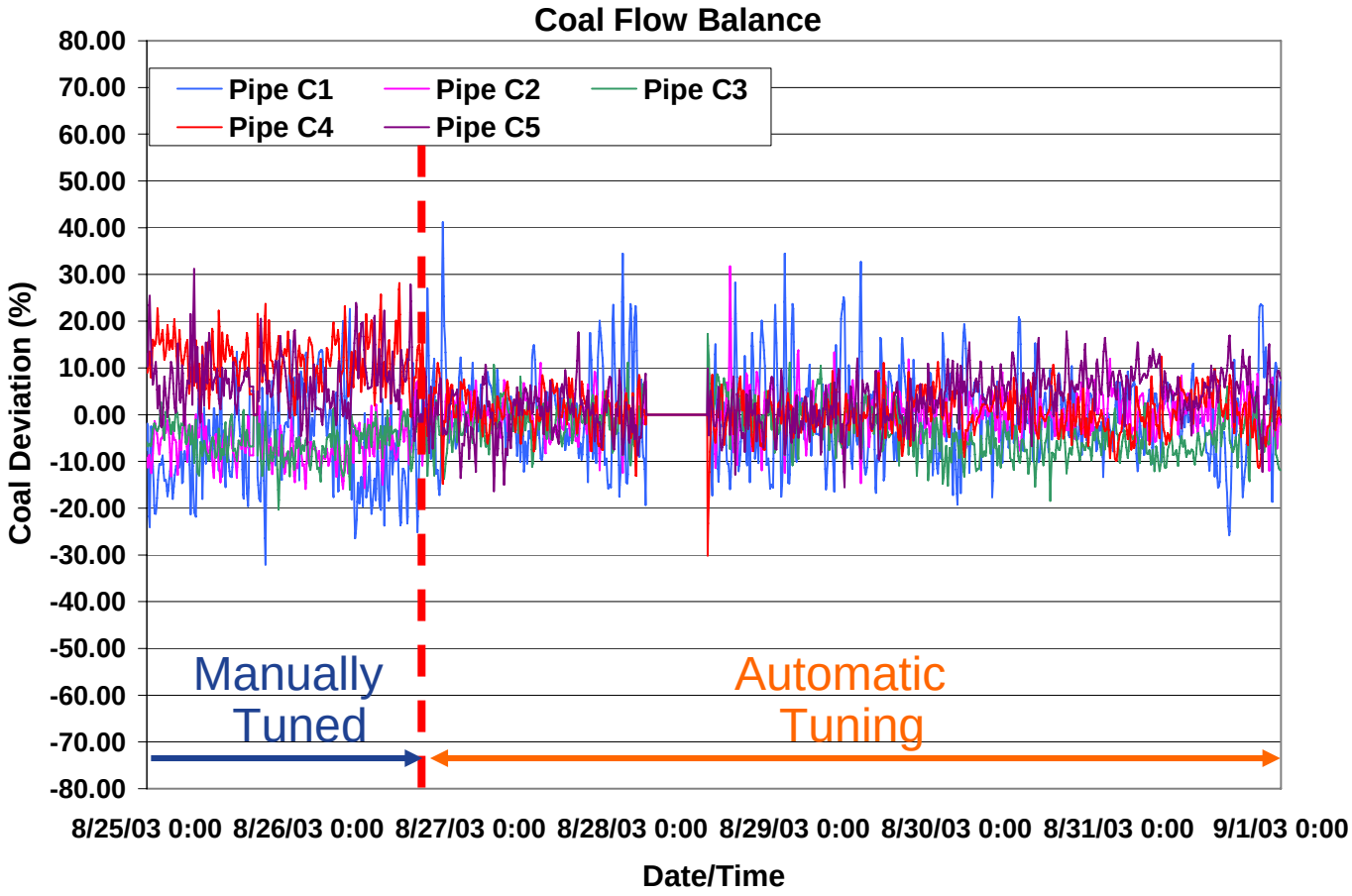


Automatic Burner Fuel Controls are Successful at Tightening Distribution

Application Data:



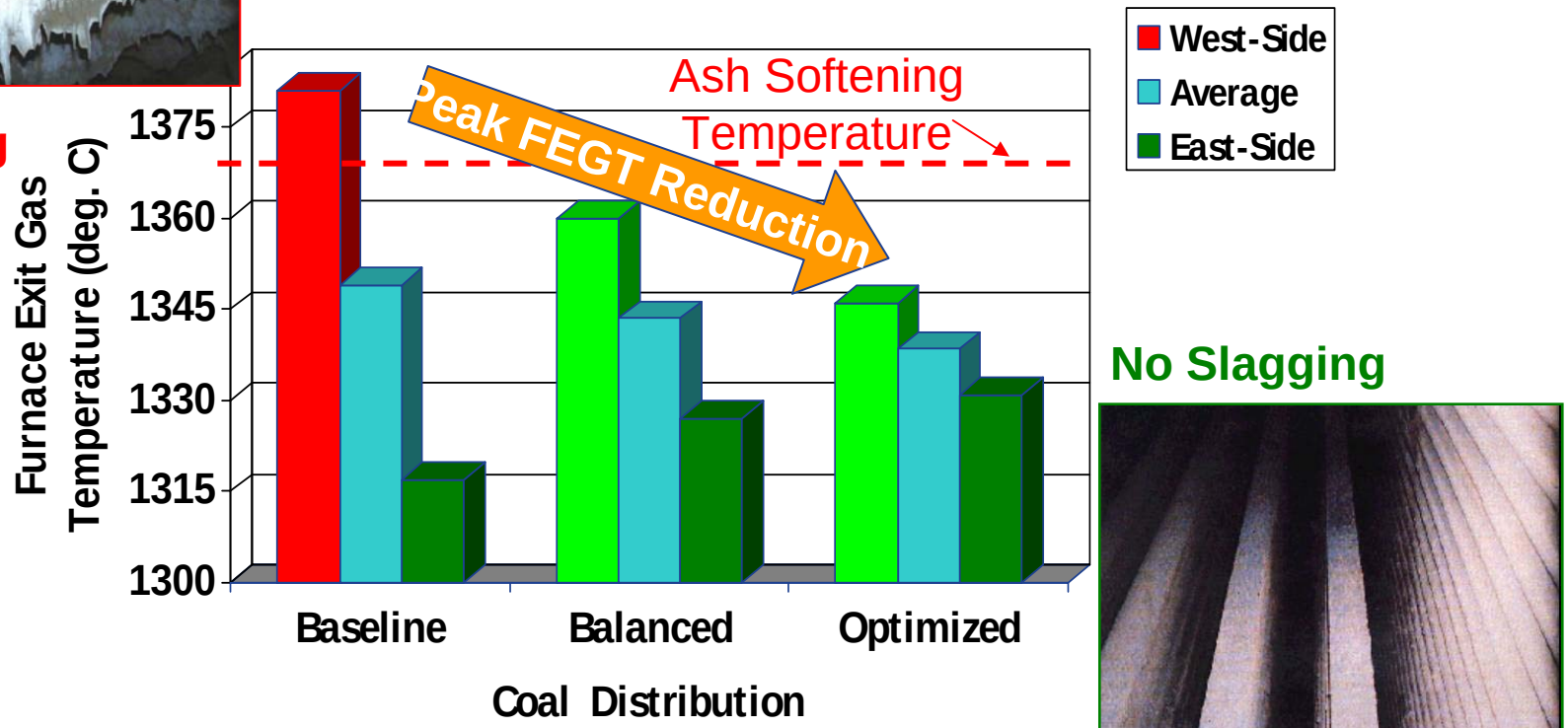
Automated System Maintains Burner Coal Balance



Biased Burner Coal Distribution Reduced Peak Temperatures

10 MWe Increase before Slagging Temperature Limit

Slagging



No Slagging

Combustion Monitoring Systems

Combustion Monitoring

Approaches	Benefits	Challenges
Combustion Monitor Feedback Tuning	Addresses actual A/F variance in furnace.	Harsh measurement environment. Tracing burners to sensors.
1) Manual Extractive CEMS-type Sampling	Traceable accuracy. Multiple species.	Often a 1-time service. Not suited to continuous and automated use. Inaccurate maps due slow sequential mapping.
2) Plant O2 Sensors	Fast. Excess O2 primarily.	Reliability of insitu sensors. Air inleakage. Poor tracing to burners. CO measurement not typically available.
3) Non-Intrusive (TDL)	“Cool” technology. Great promise. Non-intrusive. Multiple species.	500 ppm·CO detection limit. Multi-wall access. Peripheral hardware maintenance. Measurement validity. Path line data not intuitive for tuning.
4) Zonal Sensors (Close Coupled Extractive)	Fast and reliable. No pumps or condensable. Hot, wet O2 and CO.	

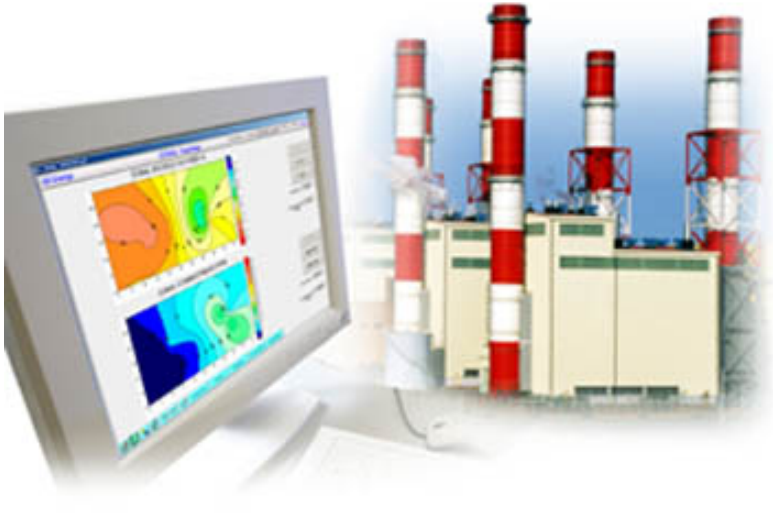
Zonal™ Combustion Monitoring System

Scope

- CO/O_2 analyzer grid
- Local analyzer interface panels
- Central controller located boiler side
- Remote operator interface over Ethernet
- Combustion topographical displays
- Start-up and operator training

Applicable to:

- Coal and Natural Gas fuels
  - – Distillate No. 2 startup
  - – Other fuels – consult GE
- All boilers … wall and tangential fired
- Sulfur, ash tolerant
- Located up to gas temperatures to 1500 °F (810 °C)



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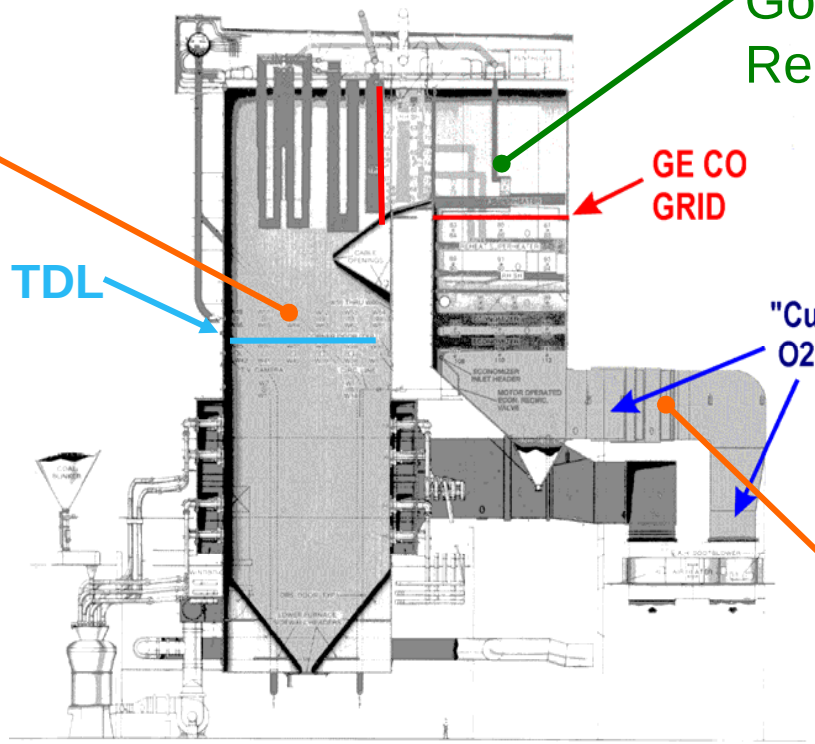
Combustion Monitoring Application

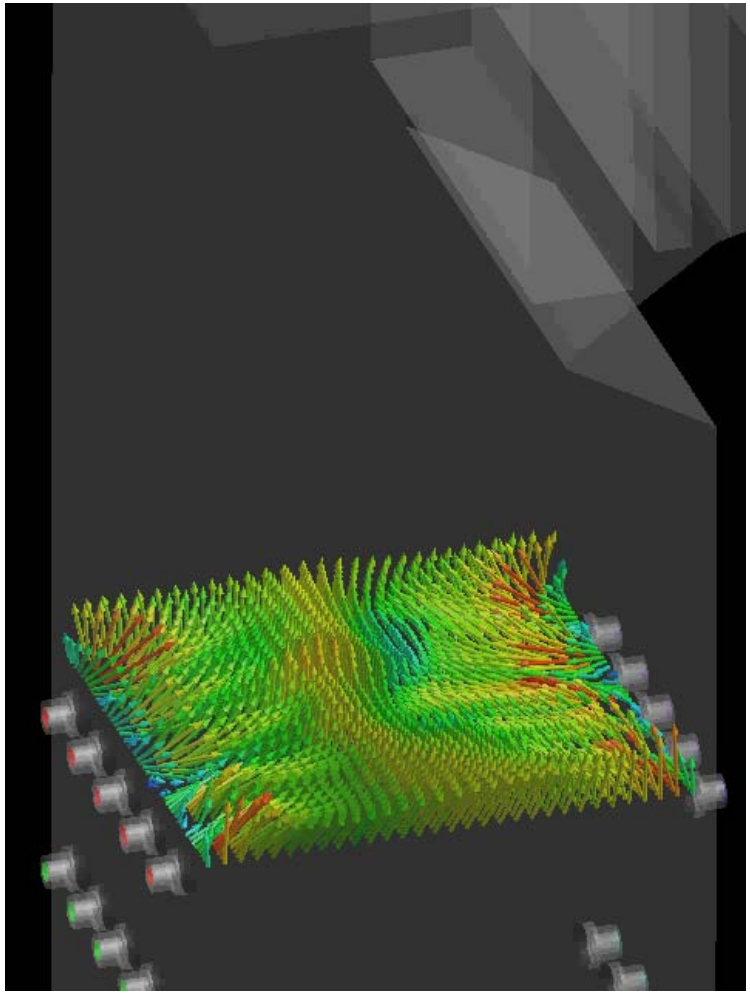
Incomplete combustion. Recirculation zones and non uniform flow.

Combustion completed. Good tracing to burners. Reduced air in-leakage.



Air in-leakage, non uniform flow and poor tracing to burners.

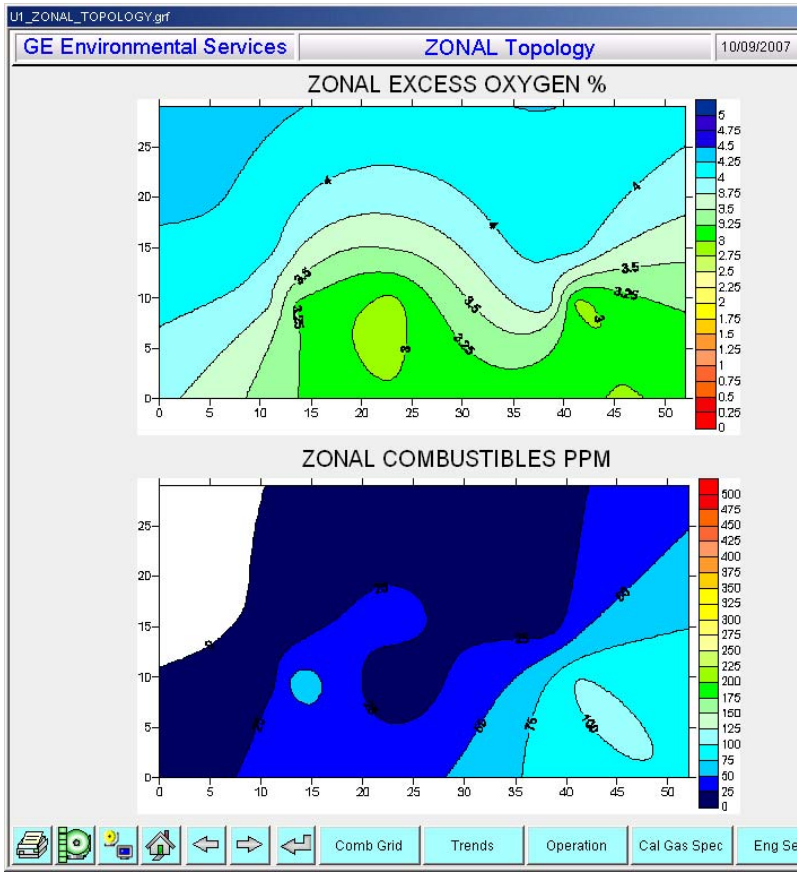
Incomplete combustion and non-uniform flow fields in the furnace



Zonal Combustion Monitoring

Benefits of Zonal Approach

- Post combustion
- Close to furnace
- Zonal data traces to burners
- Low air in-leakage
- Ease of installation
- Robust technology
- Accurate measurements
- Accurate point data



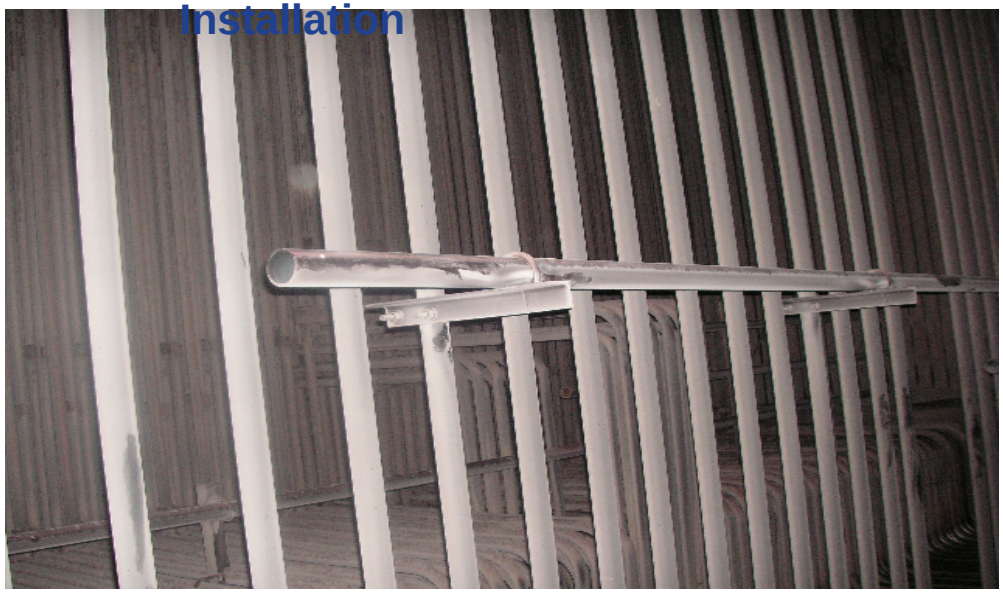
Local Boilerside Topographical Maps (Manual Tuning)

Zonal™ Grid Upper Backpass Installation

Membrane Opening

Port Installation

Probe Support Sleeve Installation



Combustion Optimization Software

Combustion Optimization Software

Approaches	Benefits	Challenges
O2 Trim Controllers (Common)	Effective at stabilizing O2 levels	Not a tuning system. Does not balance O2 or eliminate high average and peak CO.
O2 Trim with CO Constraint (Common)	Effective at minimizing O2 while maintaining low average CO.	Not a tuning system. Does not balance O2 or eliminate allow high peak CO zones.
Neural Network Optimizers	Effective at finding optimum in “noisy” data.	Not typically applied for burner tuning – requires historical data. Requires expert to build and maintain models.
Zonal Tuning Advisor	Built on first principle, empirical and tuning expertise.	

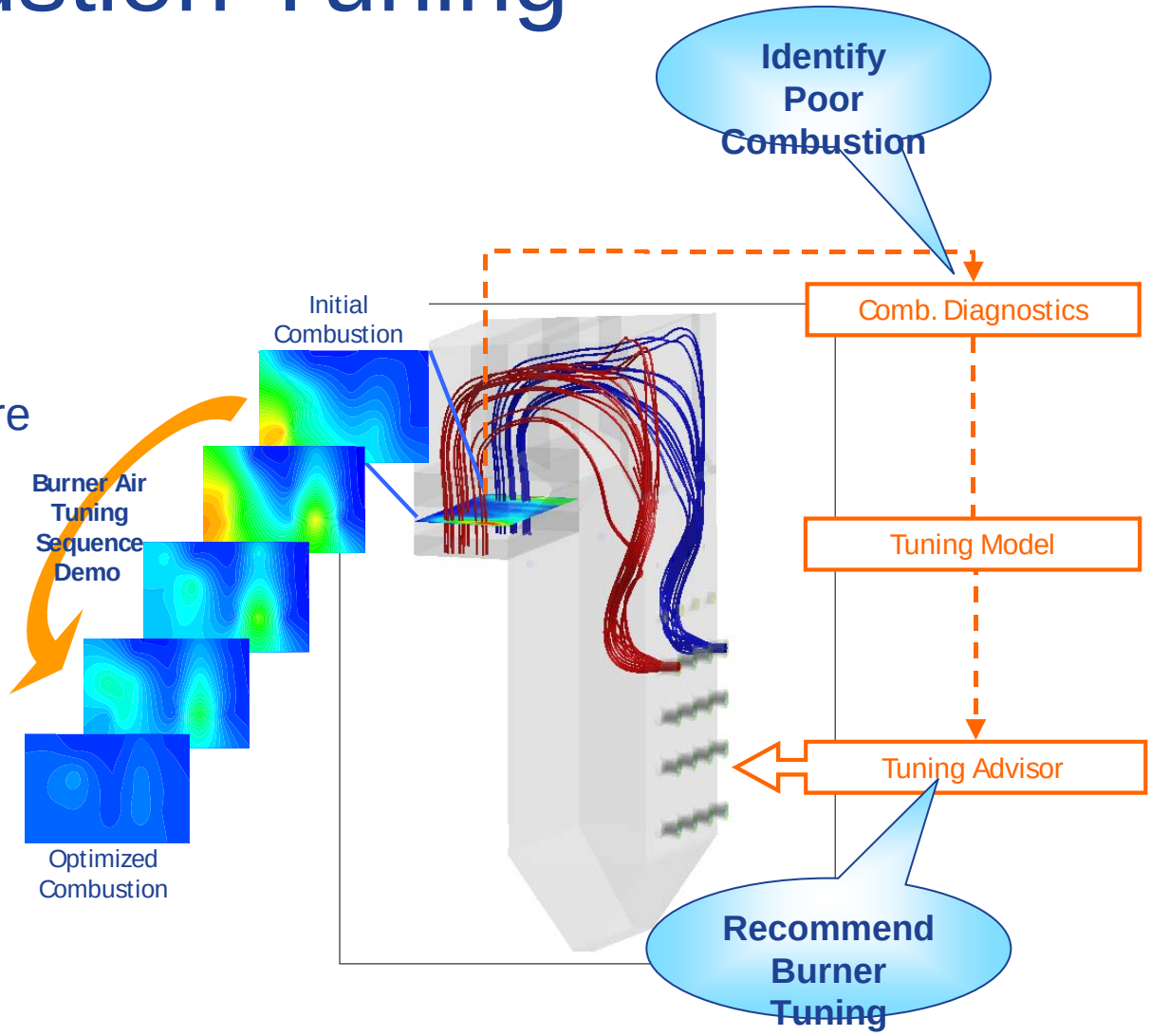
Zonal Combustion Tuning Advisor

Scope

- Combustion Monitoring System
- Combustion Tuning Software

Applicable to:

- Wall fired boilers
- Tangential fired



Zonal Combustion Tuning
How does Zonal work?

Integrated System

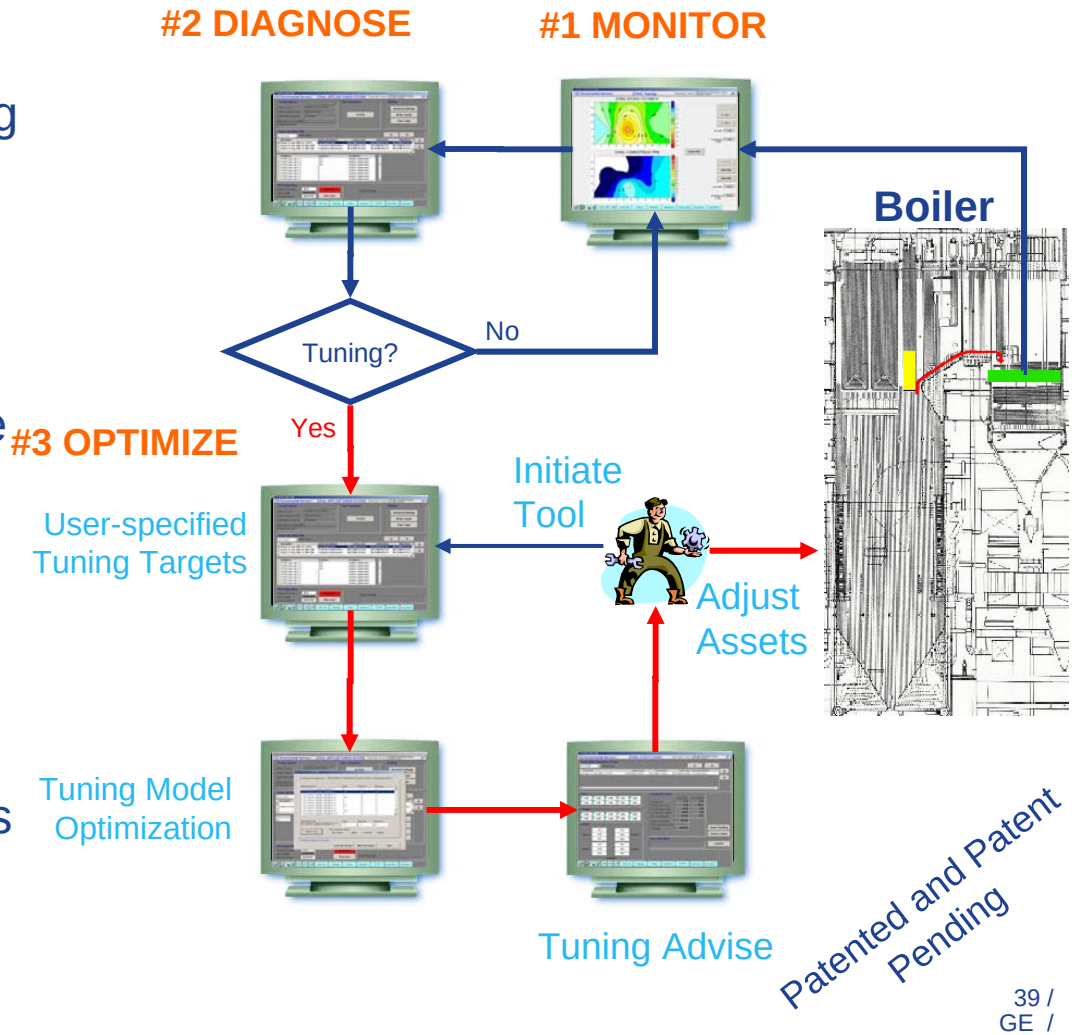
- Reliable combustion monitoring grid
- Combustion tuning expertise
- Operator-friendly advisor

3 Step process:

- Monitor – Diagnose – Optimize

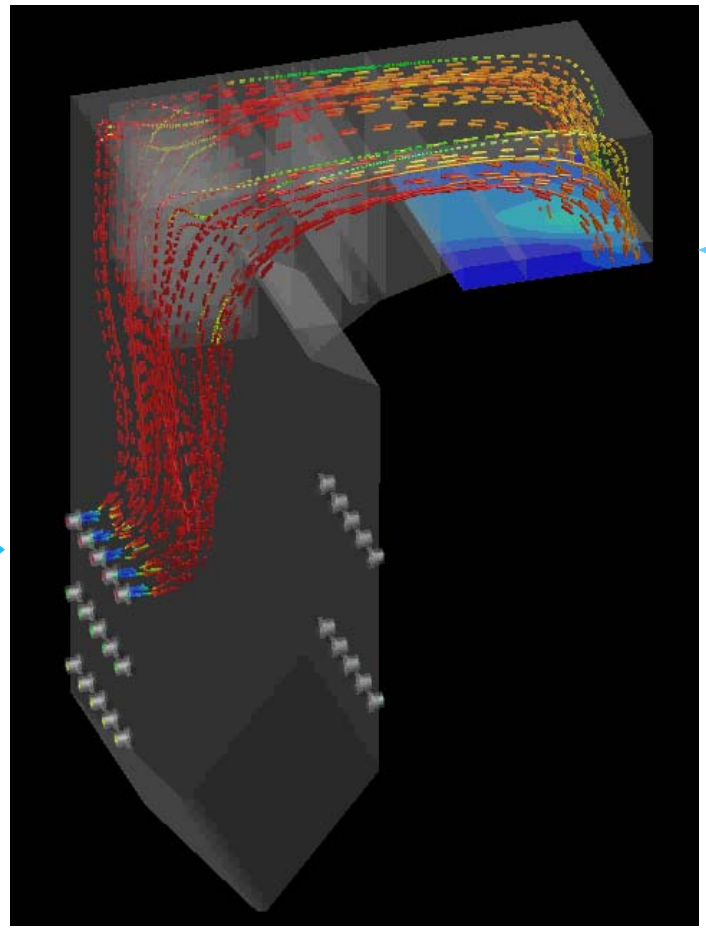
Built-in Innovations

- Intuitive display
- Tuning systems
- Slag mitigation method
- Hybrid neural-network
- … and various pending patents



Zonal™ Combustion Tuning Advisor Built on Predominant Fluid Structure

Predominant Burner Path Lines

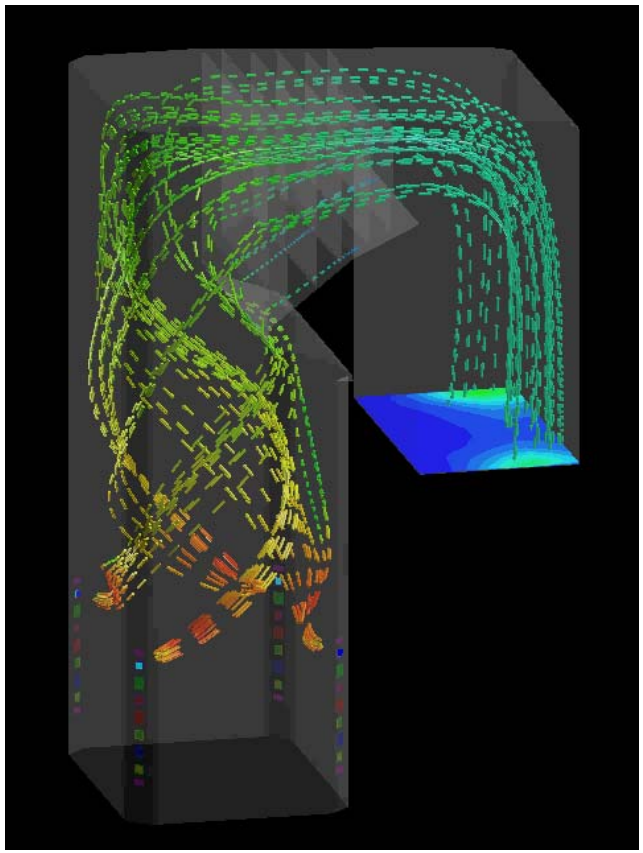


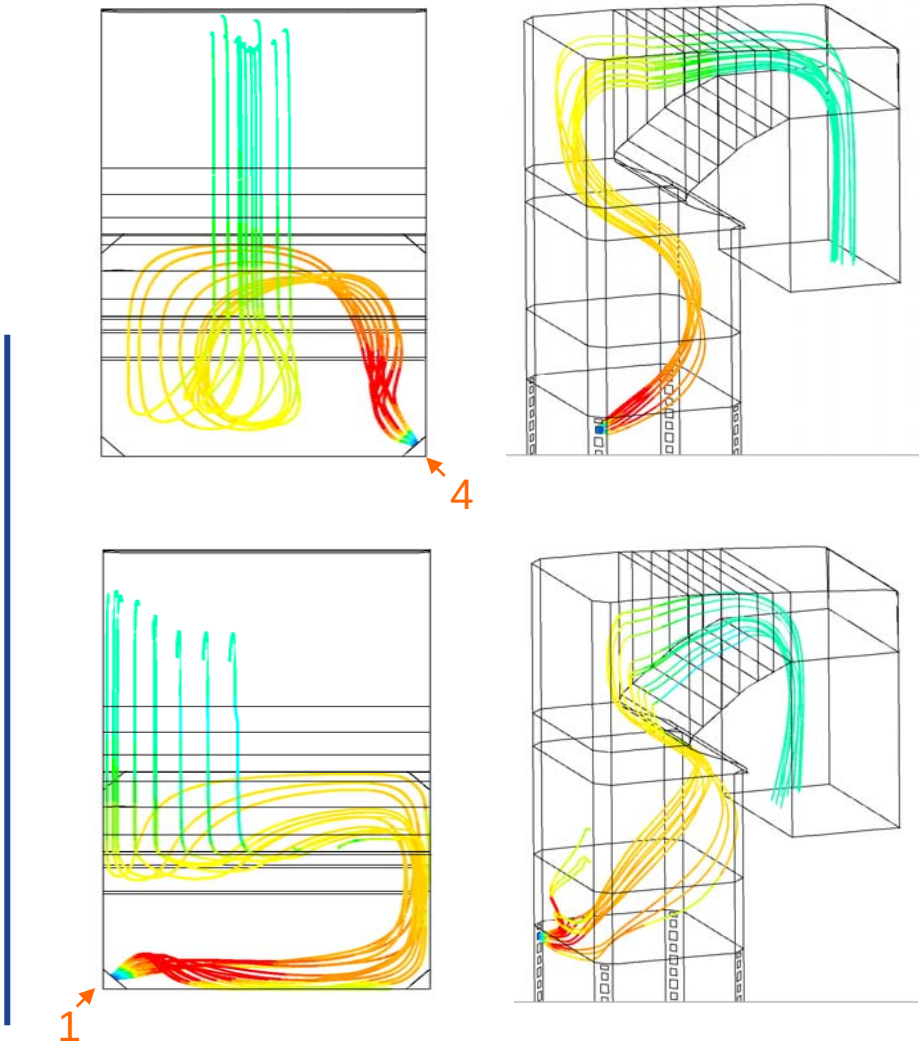
Combustion Monitoring

Burners/OFA

Burner-to-Sensor Models Capture Fluid Structure

T-Fired Fluid Stratification Suited to Zonal Tuning





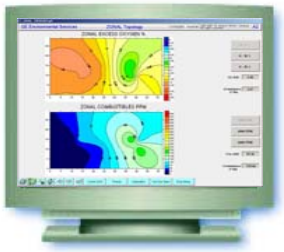
Zonal Combustion Tuning Installation

Plant
- Western US
- 460 MW T-fired boiler
- Western bituminous coal

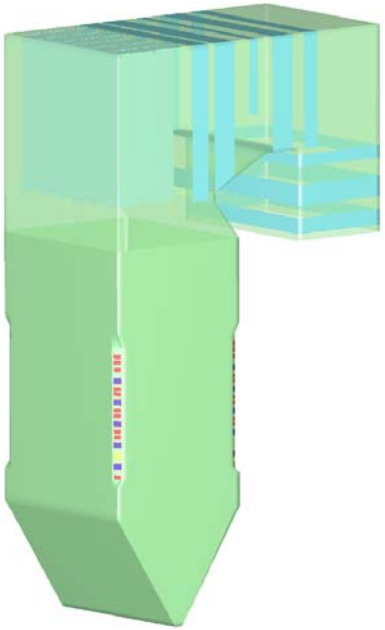
Zonal Project
- Zonal Monitor Grid
  - 2x5 sensor array
- Zonal Tuner
  - CCOFA yaw

Issues
- Frequent slagging events
- High excess O2 operation

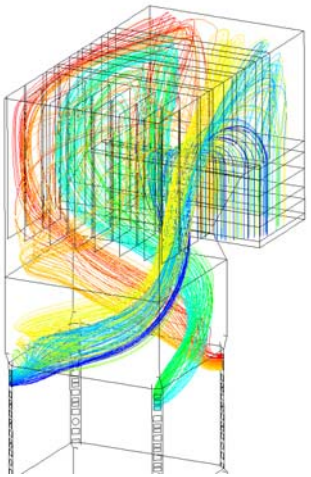
Zonal Grid & HMI



Boiler



CCOFA Path



CCOFA Yaw

Zonal Tuning Application

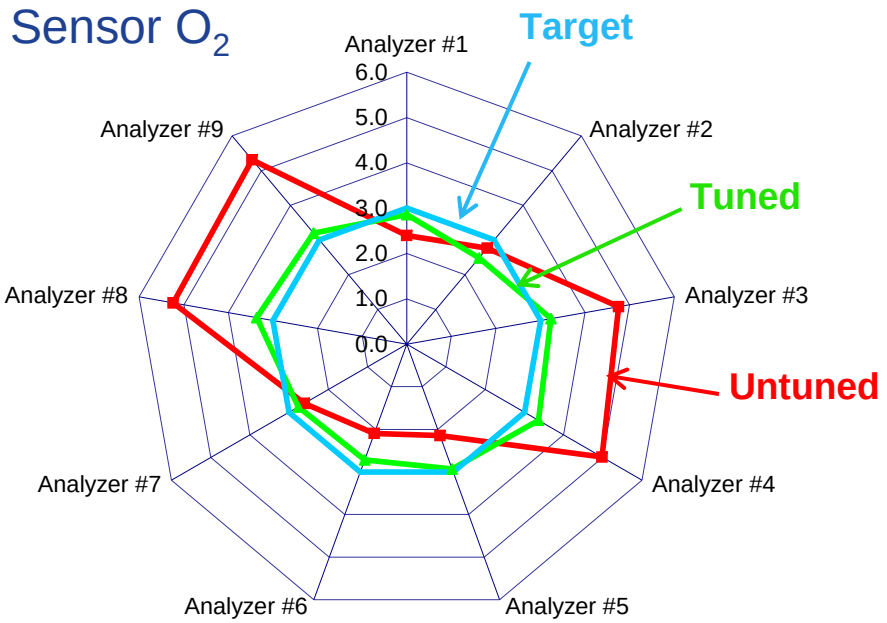
Initial O_2 imbalanced

Advised 1 step CCOFA adjustments

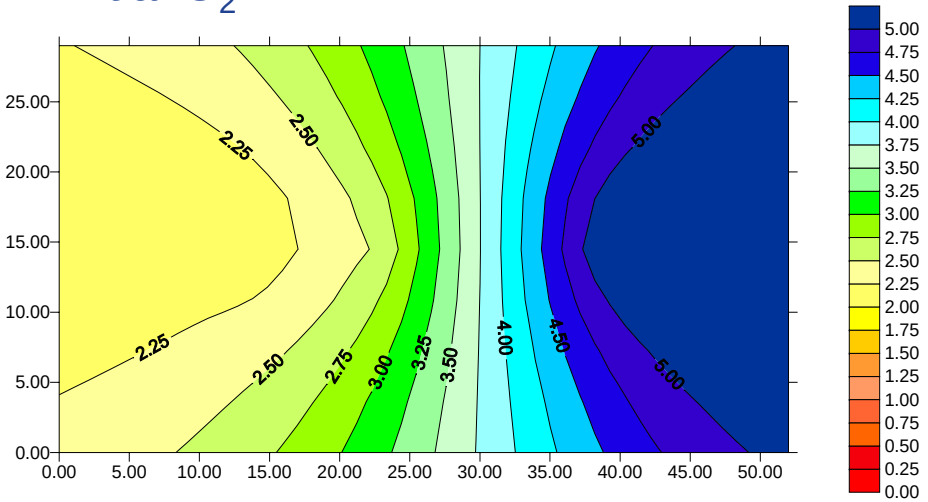
Final O_2 balanced

- Allowed maximum CCOFA
- Improved NOx

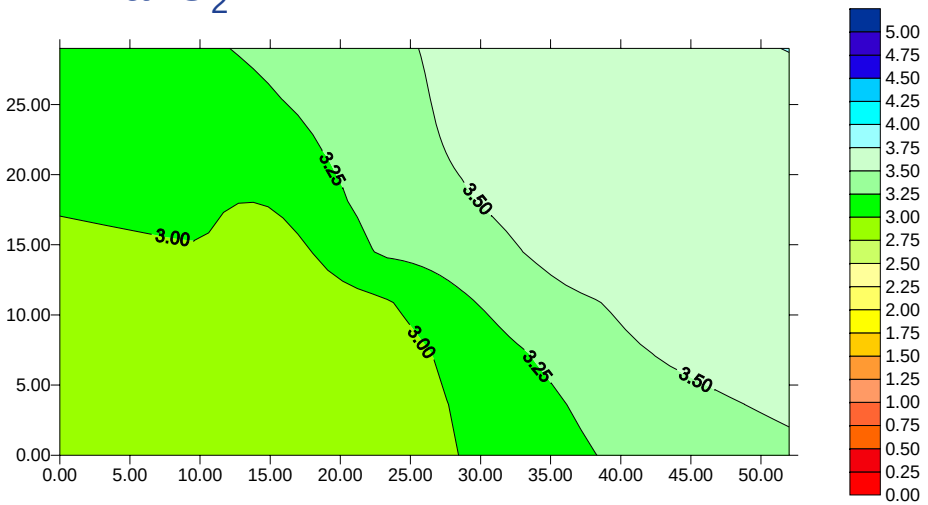
Sensor O_2



Initial O_2



Final O_2



Zonal Combustion Tuning Event

Step 1

Alert combustion imbalance and tuning recommended

- **Initial CO high** bottom-right zone

Step 2

Operator enters **Target O_2**

- Shift O_2 opposite corners

Step 3

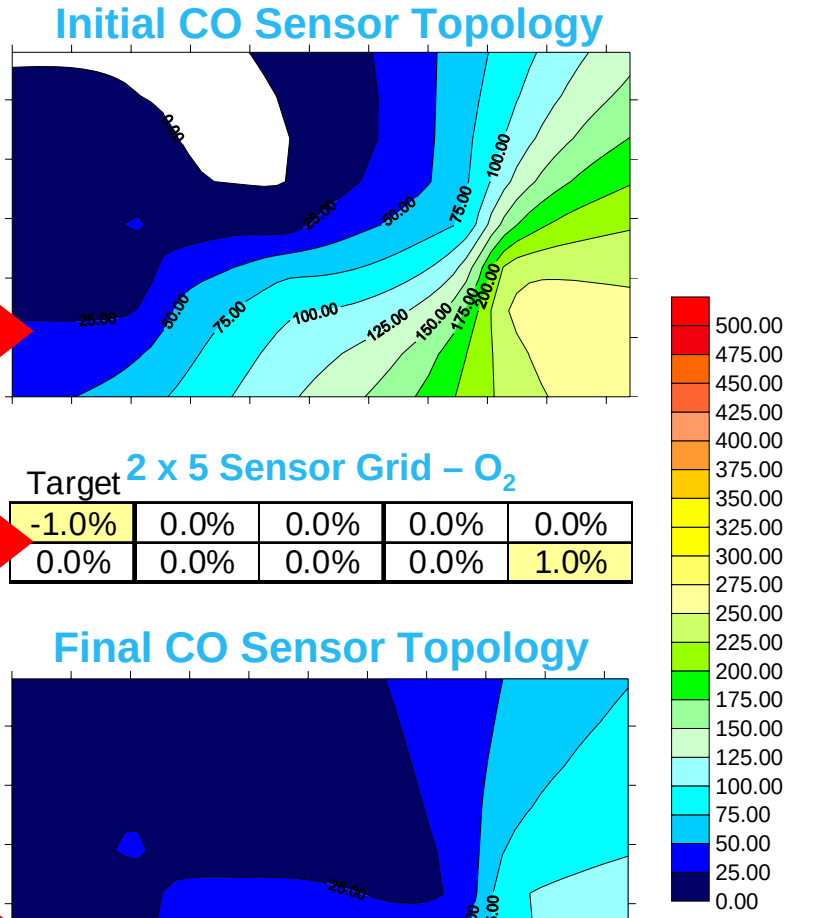
Model outputs CCOFA tuning recommendations

Step 4

Operator adjusts CCOFA.

- **Final CO Improves**
- **O_2 Changes**, increases by 1.6% in problematic bottom-right corner

Initial CO



Target O2

Target **2 x 5 Sensor Grid – O_2**

-1.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	1.0%

Final CO

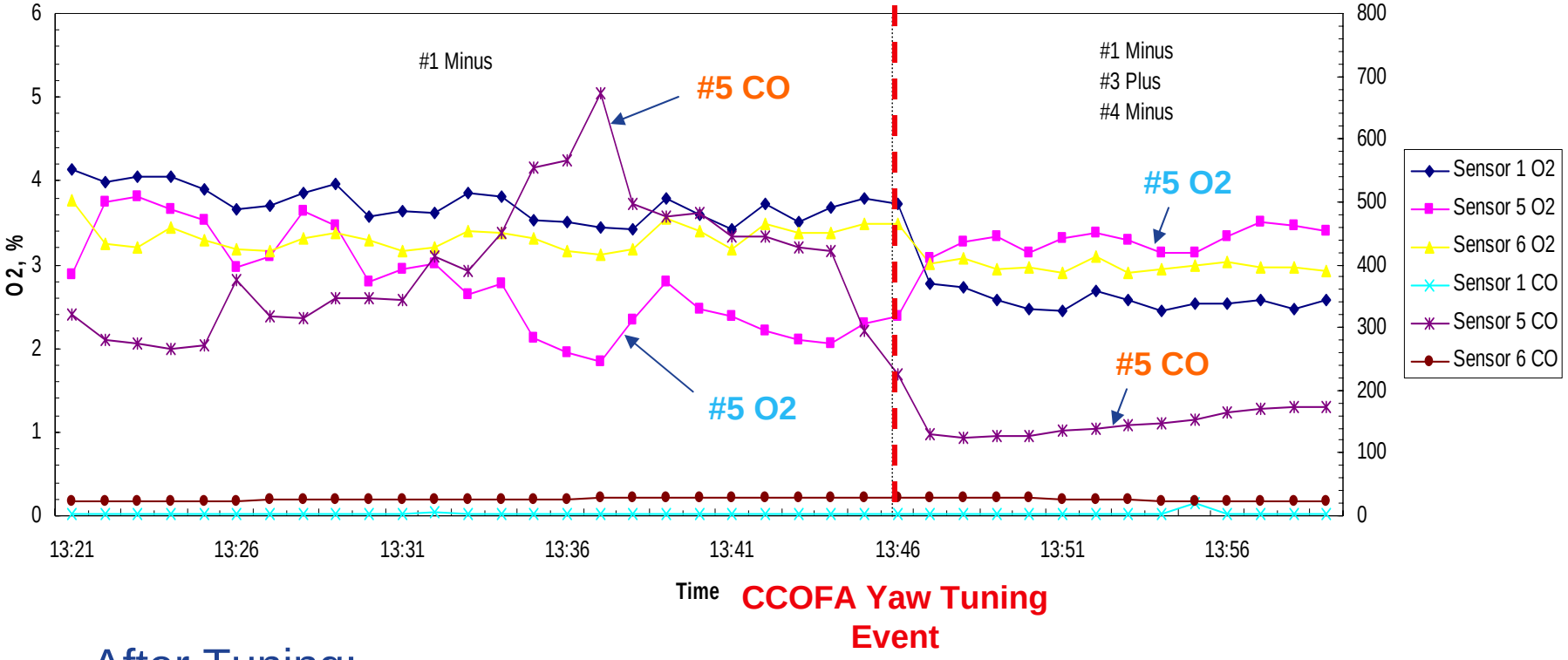
O_2 Changes

Actual **2 x 5 Sensor Grid – O_2**

-1.1%	-0.6%	0.0%	1.2%	1.3%
-0.6%	-0.2%	0.3%	1.1%	1.6%

imagination at work

Zonal Combustion Sensor Response



After Tuning:

- Right-side of boiler (Sensor 5) O2 increased and CO reduced.
- Left-side of boiler (Sensor 1, 6) O2 reduced, but CO remains low. (CO and O2 more stable.)

Conclusions

Compelling Reasons to Optimize

- Combustion systems are more complex
- Retiring operator pool – new operators benefit from improved tools
- Changing fuel sources – compliance coal, low cost coals, biomass co-firing future
- Aging fleet and increasing electricity demand
- Stricter CO and NOx regulations ... and Hg !!!
- Stiff penalties for emissions violations

Zonal Combustion Tuning Optimization Summary

Provide operators **Useful Information**

Monitor **End-Products** of Combustion

Monitor **Local Combustion Conditions**

Capture **Operator Expertise** in Tuning and Operations

Strive for **Predictable Performance** in:

- Emissions – CO, NOx, Opacity
- Availability – slagging, water wall wastage
- Output – Pressure drop, fan limits
- Heat Rate – Steam Gen, Attemperation, Heat Losses

Contact Information

Contact Information

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1-day Zonal Seminar

March 24, 2009

Evendale (Cincinnati)

For an invitation, send me your contact details

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Rotoprobe™

General Description

The Rotorprobe™ Pulverized Coal Sampling System implements International Standard Organization Method ISO 9931 for sampling pulverized coal in a primary air stream. The accurate samples obtained can be used to assess both the size and the relative mass flow of the coal in each burner pipe. When this information is used to balance coal flow to the burners and optimize coal mill settings, a wide variety of boiler operating problems can be prevented or eliminated.