Reinhold Environmental Ltd.

2009 NOx-Combustion Round Table & Expo Presentation

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Boiler Tuning With Flame Doctor

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babcock & wilcox power generation group

The Flame Doctor System

TECHNOLOGY OVERVIEW

Background and Motivation

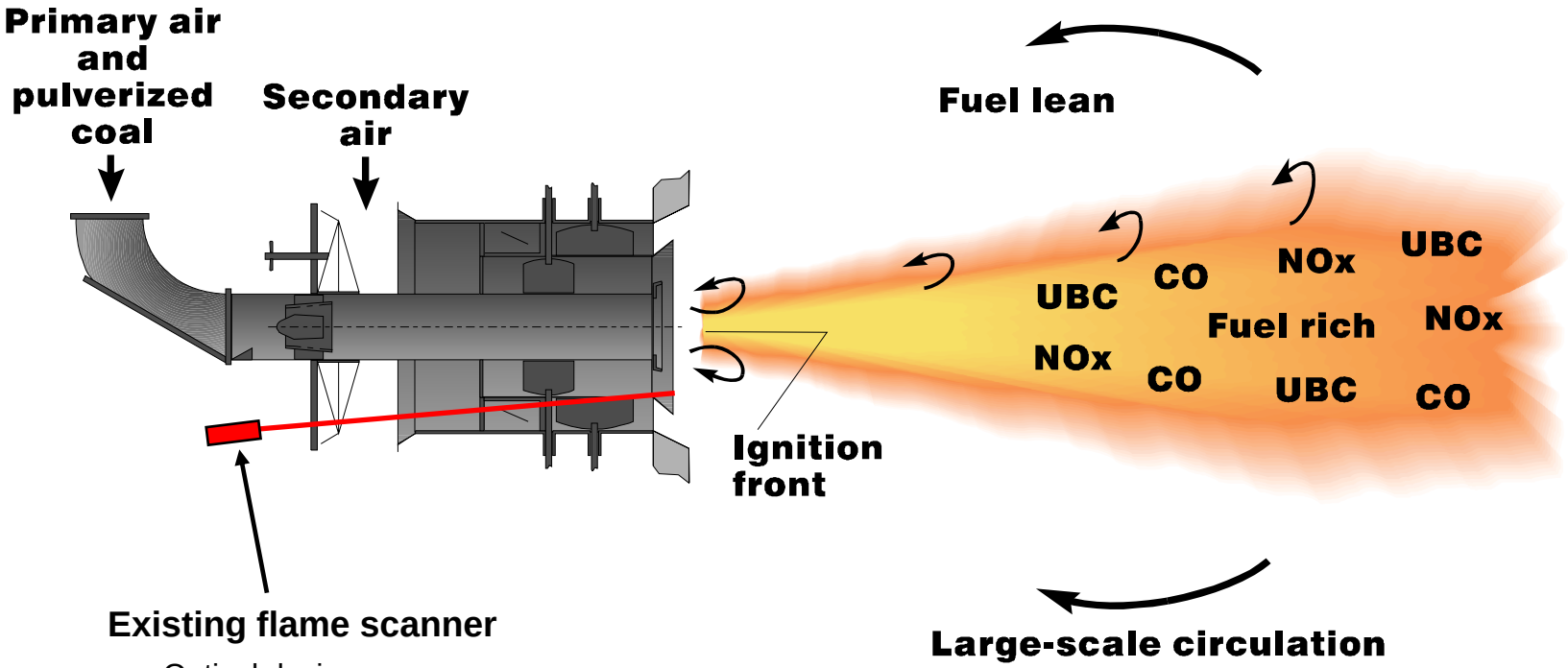
- Environmental and regulatory pressures drive operations
  - Lower emissions, more stable emissions
  - Changes in operating profile
  - Improved monitoring and control needed
- Traditional monitoring approaches
  - Measure inputs
    - Air flows to each burner (primary and secondary)
    - Coal flow to each burner
  - Measure outputs
    - CEMS systems
    - Gas emissions grids
- B&W chose to monitor actual combustion process
  - Initiated development in 1993
  - Teamed with Oak Ridge National Lab
  - EPRI sponsored development

Combustion Diagnostic Challenges

- Complex spatio-temporal dynamics
  - Turbulent air/fuel mixing, recirculation
  - Rapid heat-release
  - Inter-burner coupling
  - Perturbations from auxiliary equipment (i.e. feeders, pulverizers, fans, pneumatic conveyors)
  - Performance (i.e. emissions, efficiency) dominated by the stability shifts in highly nonlinear flame fronts
- Inadequate monitoring technology
  - Harsh environment, poor access
  - Existing sensors not designed for monitoring application
  - Traditional analysis techniques inadequate for complex dynamics

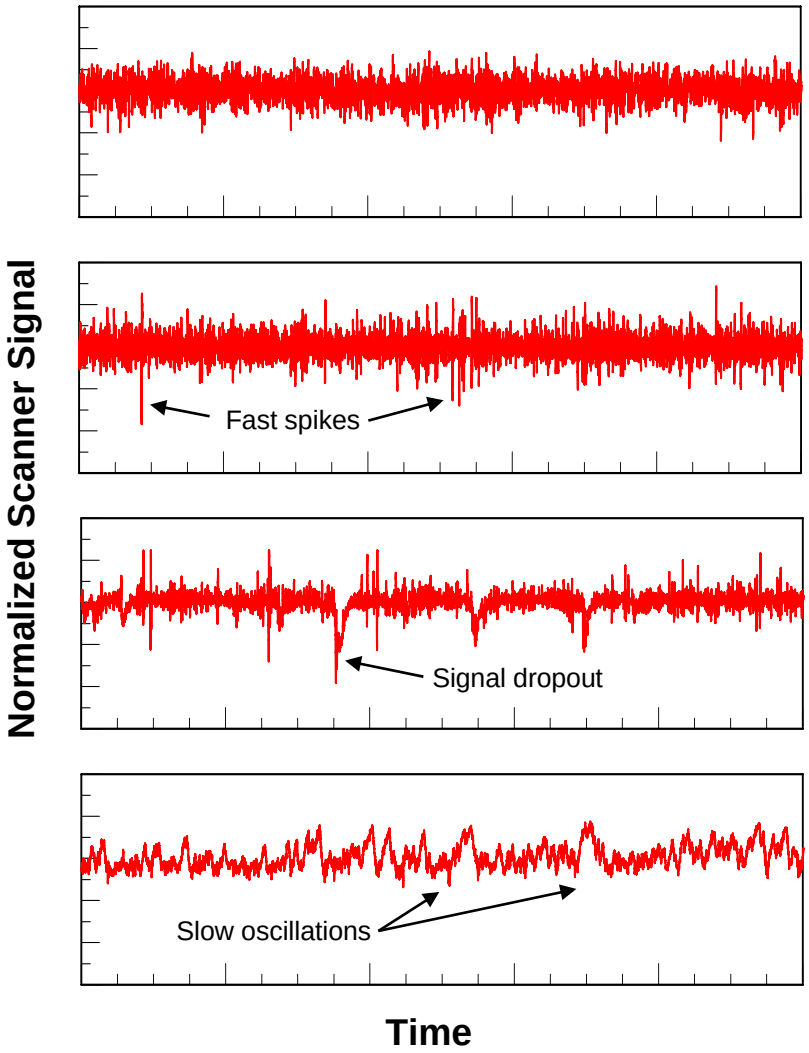
Undesirable Combustion Dynamics

Measuring Combustion Dynamics



- Optical device
- Converts flame flicker into electrical fluctuations
- Used for On/Off detection

Scanner Signals Reflect Dynamics



Stable Flame

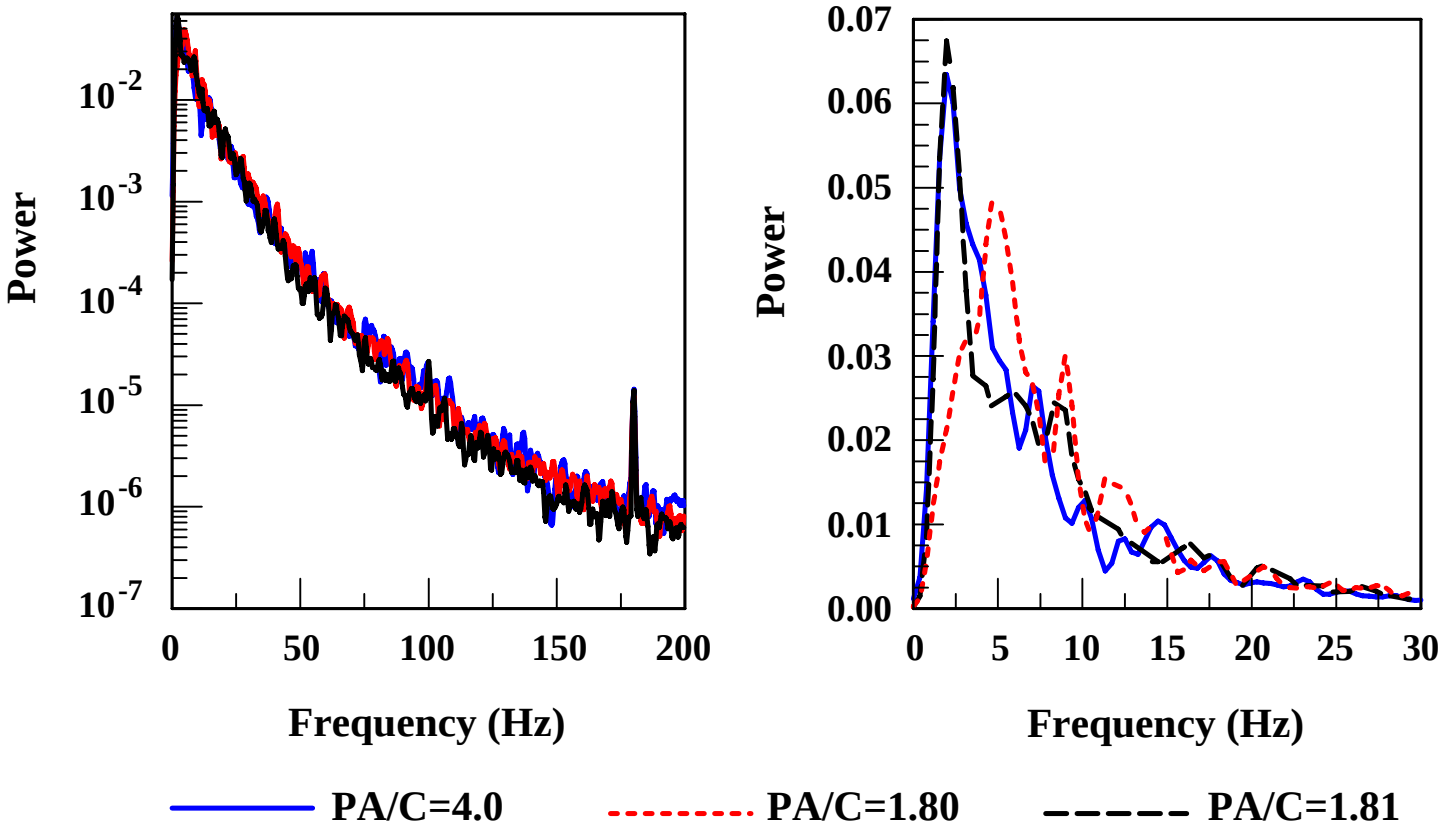
Slight Instability

More Severe Instability

Very Severe Instability

Traditional Linear Combustion Analysis

- Good for narrow, distinct frequencies
- Cannot detect nonlinearities
- Can be “fooled” by high levels of nonlinearity



Chaos Basics

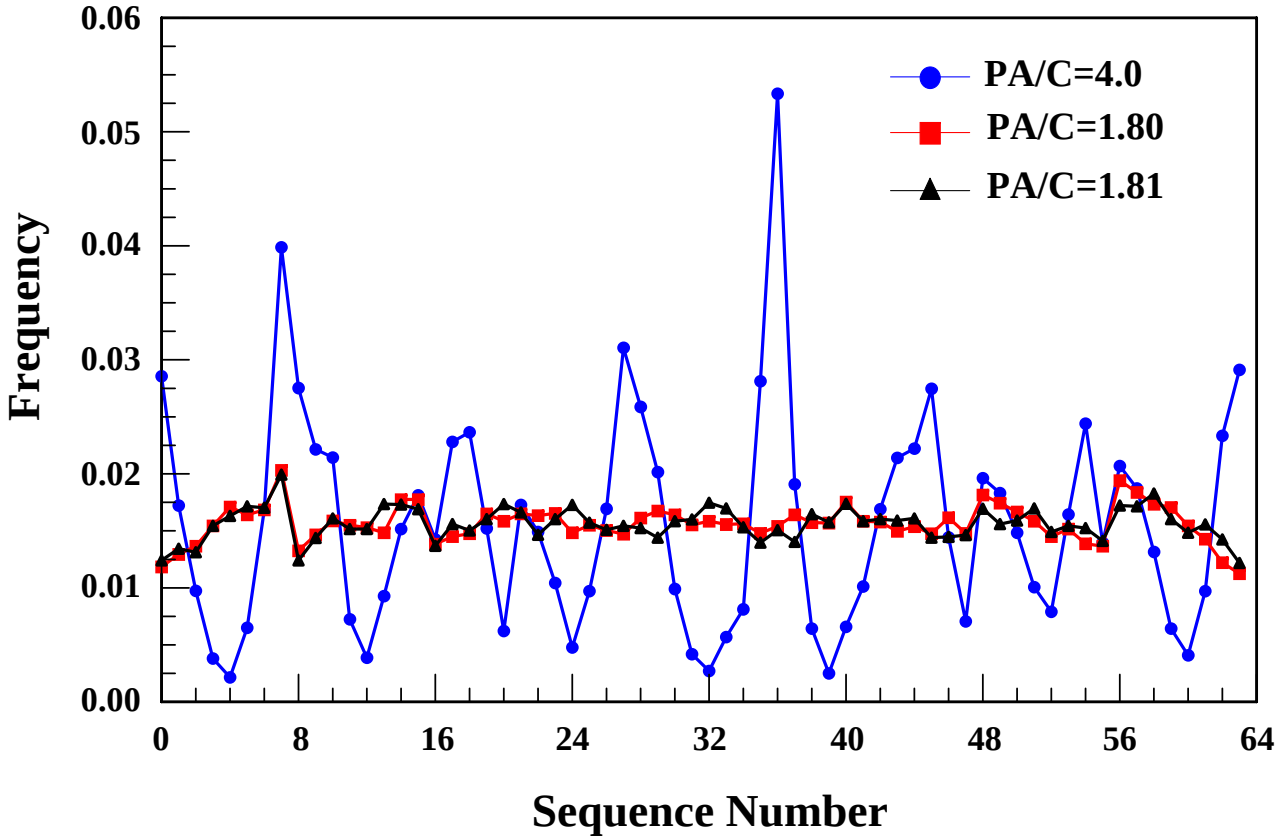
Chaotic behavior is "in between" traditional paradigms of linear (regular) and stochastic (noisy) behavior

Linear	Chaos	Stochastic
•Periodic •Predictable •Exact Solution •Stable •Small angle pendulum	•Aperiodic •Short-term predictable •Numerical solution •Unstable, bounded •Large angle pendulum	•No periods •Unpredictable •Monte-Carlo •? •Nuclear decay

- **Linear assumption misses nonlinear information**
- **Stochastic assumption misses temporal information**

Chaos Combustion Analysis

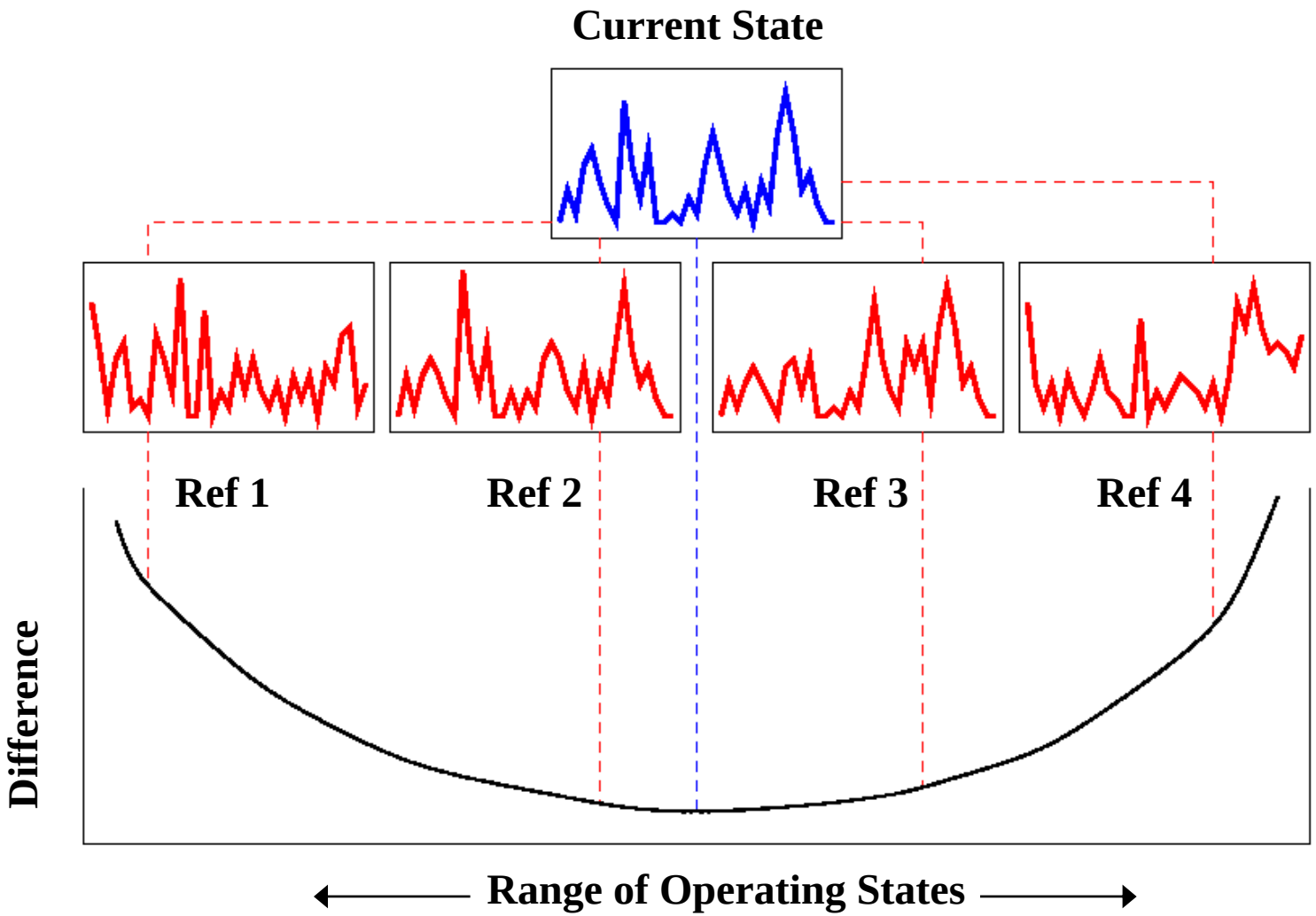
- Good for broad-band frequencies
- Detects nonlinear instabilities
- Provides repeatable, unique “signature”



Range of Analysis

- Traditional Analysis
  - Histograms
  - Standard statistics
    - Skewness
    - Kurtosis
  - Power spectral density (FFT)
- Nonlinear Analysis
  - Time asymmetry
  - Symbol sequence
  - Dimension analysis
  - Entropy
  - Nearest neighbor analysis
  - Phase-space trajectories

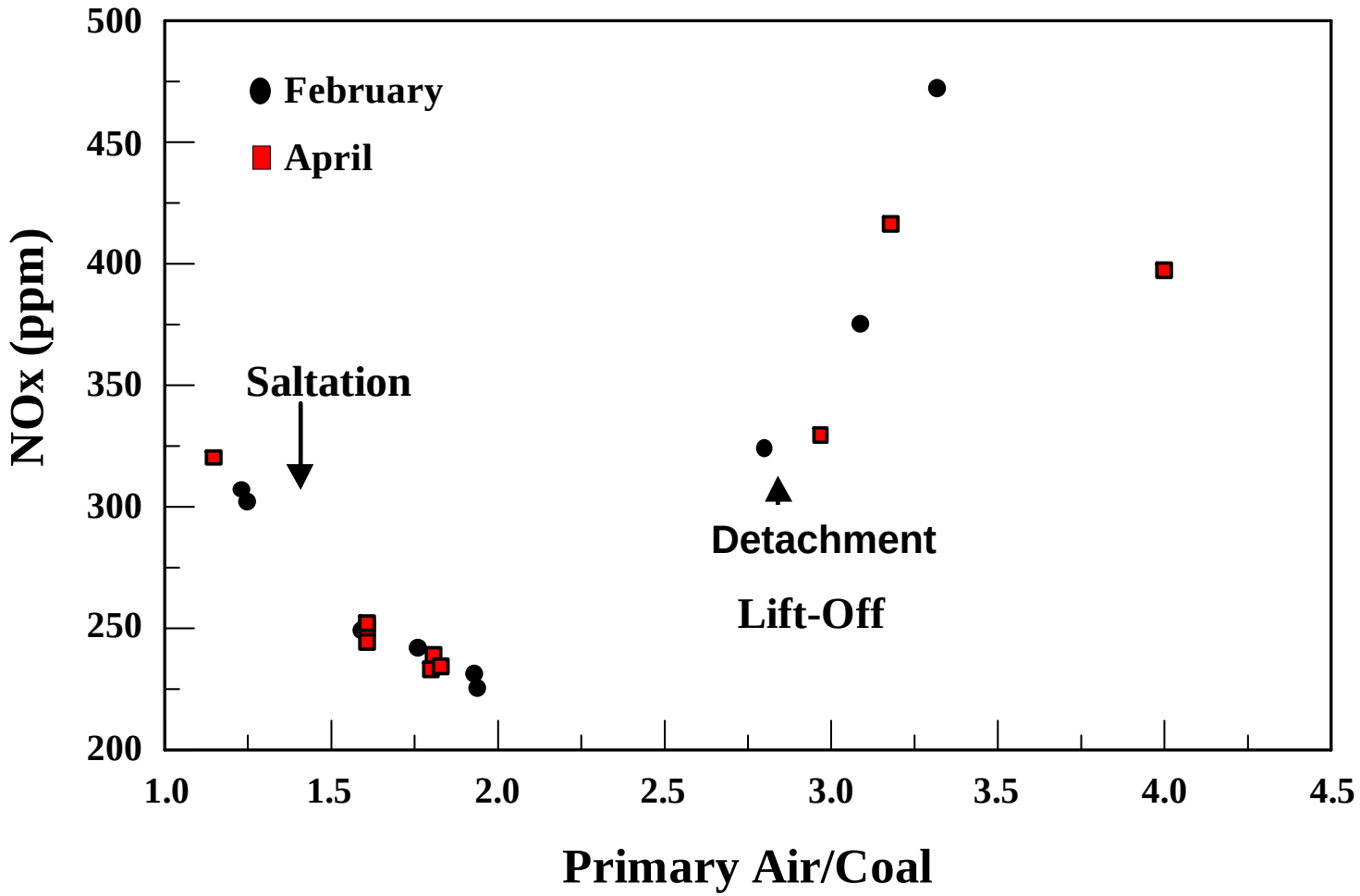
Knowledge-Based Flame Classification



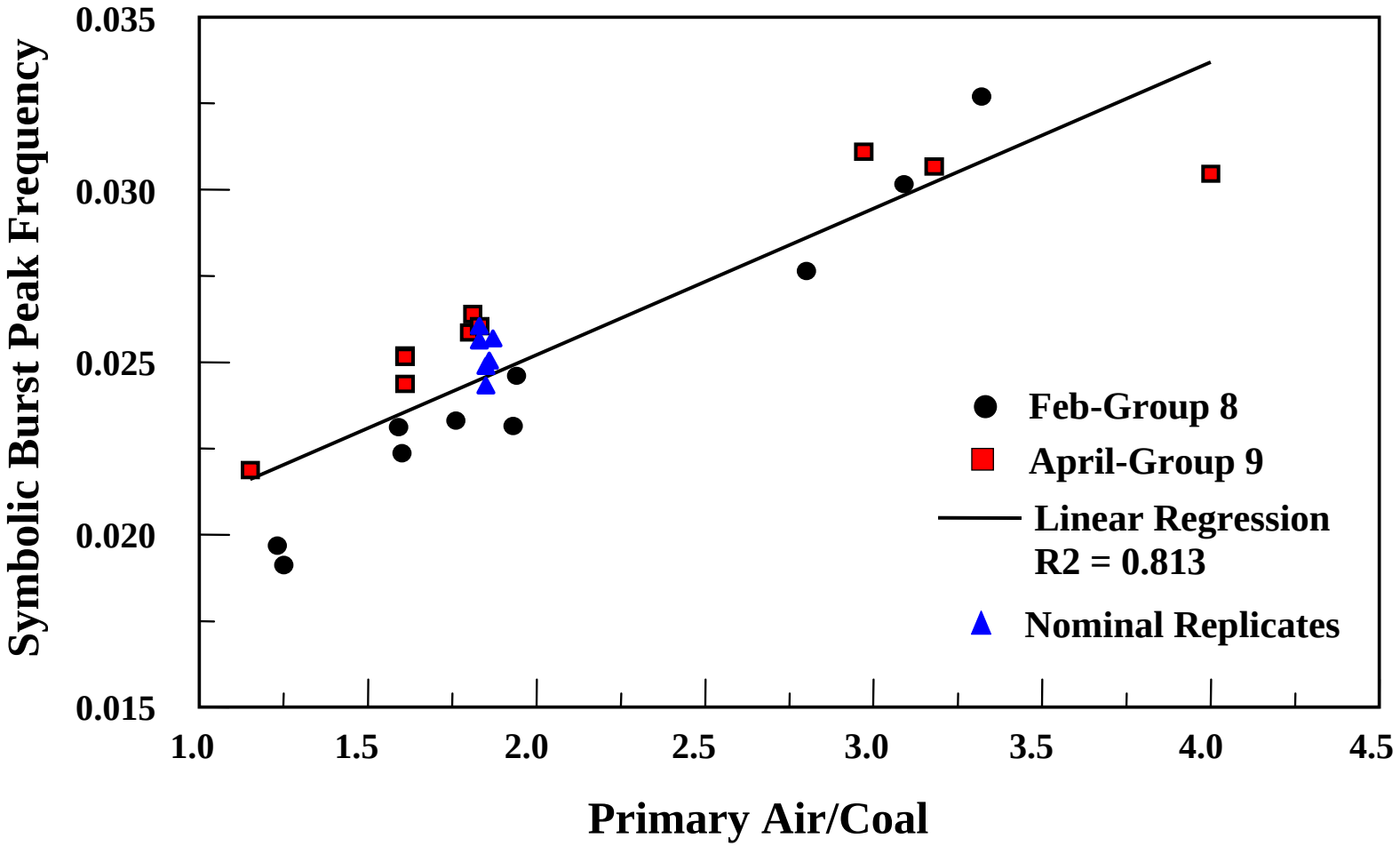
Flame Doctor Library System

- Holds example fingerprints (library entries)
  - Categorized into “flame states”
  - Unlimited number of flame state slots
- Provides starting number for flame rating
- Provides key to operator guidance
- Completely customizable
  - Add/Delete flame states
  - Add/Delete individual fingerprints
  - Move fingerprints between flame states
  - Change starting value for flame rating
- Managed with Library Manager Tool

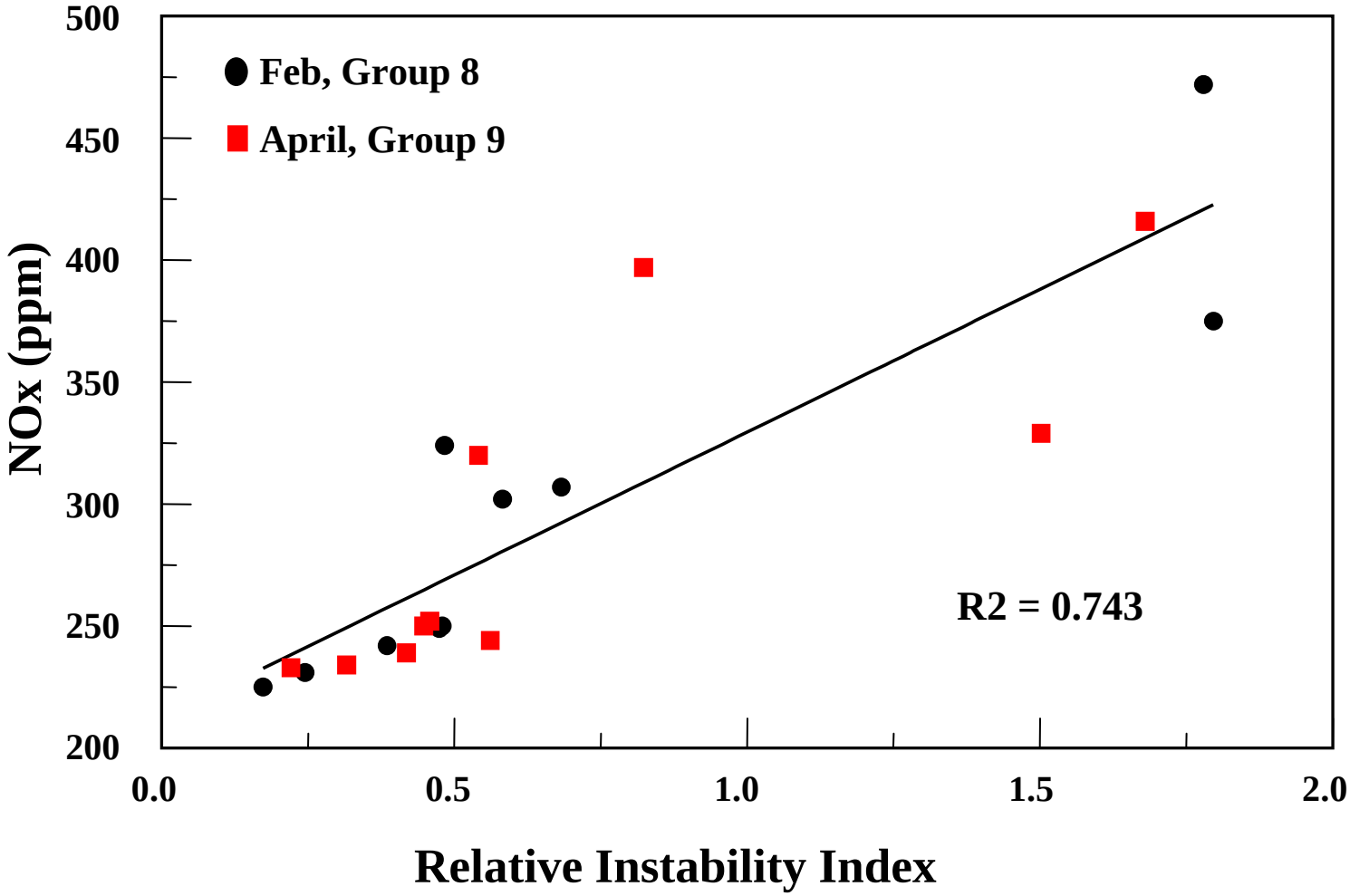
Emissions Track Burner Instabilities



Pilot-scale A/F Correlation



Pilot-scale NO_x Correlation



The Flame Doctor System

HARDWARE AND SOFTWARE

Flame Doctor Hardware

- Portable B&W Test System
  - 40 burner capability
  - Scanner friendly
    - High input impedance
    - Signal isolation
  - Multiple scanner connection options
    - Alligator clips
    - “J” clips
    - Spade ends
    - Bare ends
- Permanent Customer System
  - Variety of packaging options
  - Includes computer workstation

Flame Doctor Hardware Compatibility

Boilers/Burners

- B&W
- Alstom/CE
- Foster Wheeler
- Riley
- ABT (Siemens)
- ACT (FuelTech)
- Phoenix
- Mitsui Babcock

Good for wall-fired, cyclone-fired and turbo-fired units

Compatible Scanners

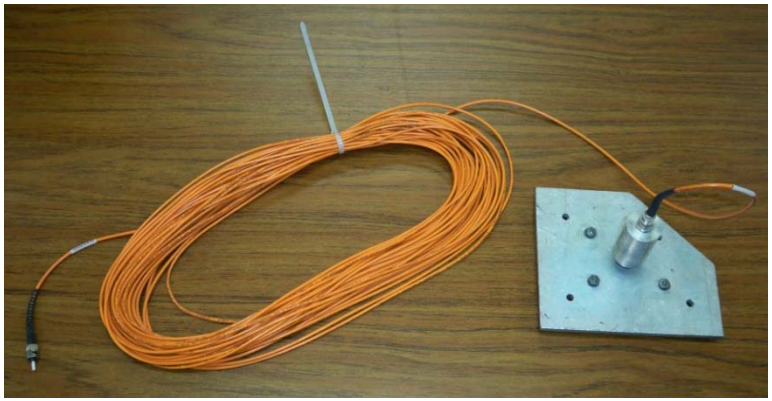
- Forney
- Coen
- Bailey/ABB
- FPS
  - Standard model
  - Special model
- Iris
  - Special model

Incompatible Scanners

- Iris
  - Standard model
- Fireye
- Detronics
- Durag
- Peabody

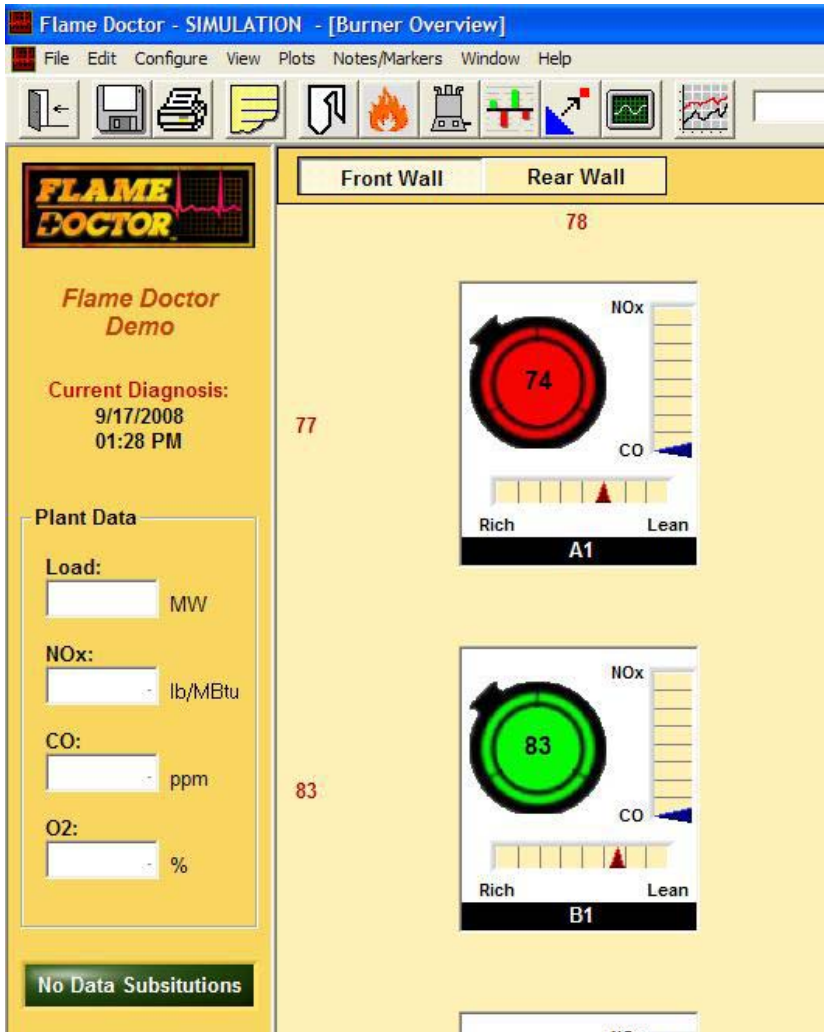
B&W Spyron System

- Application
  - Incompatible scanners
  - No scanners
- Features
  - Fiber optic system
  - Visible/IR wavelength ranges
  - Easy installation
  - Designed for Flame Doctor
- Mounting options
  - Magnetic plates
  - 3” nipple adaptor
  - Iris adaptor plate
  - Bailey adaptor plate



Flame Doctor Software

- Custom designed software
  - Built-in historian
  - Client/server architecture
  - OPC connectivity
- Available information
  - Burners
    - Absolute ratings (0-100)
    - Flame type identification
    - Root cause identification
    - Air/fuel index
    - CO/NO_x potential
  - Mills
    - Absolute ratings (0-100)
    - Relative rankings
    - Lean/rich alarming
    - Line-to-line balance



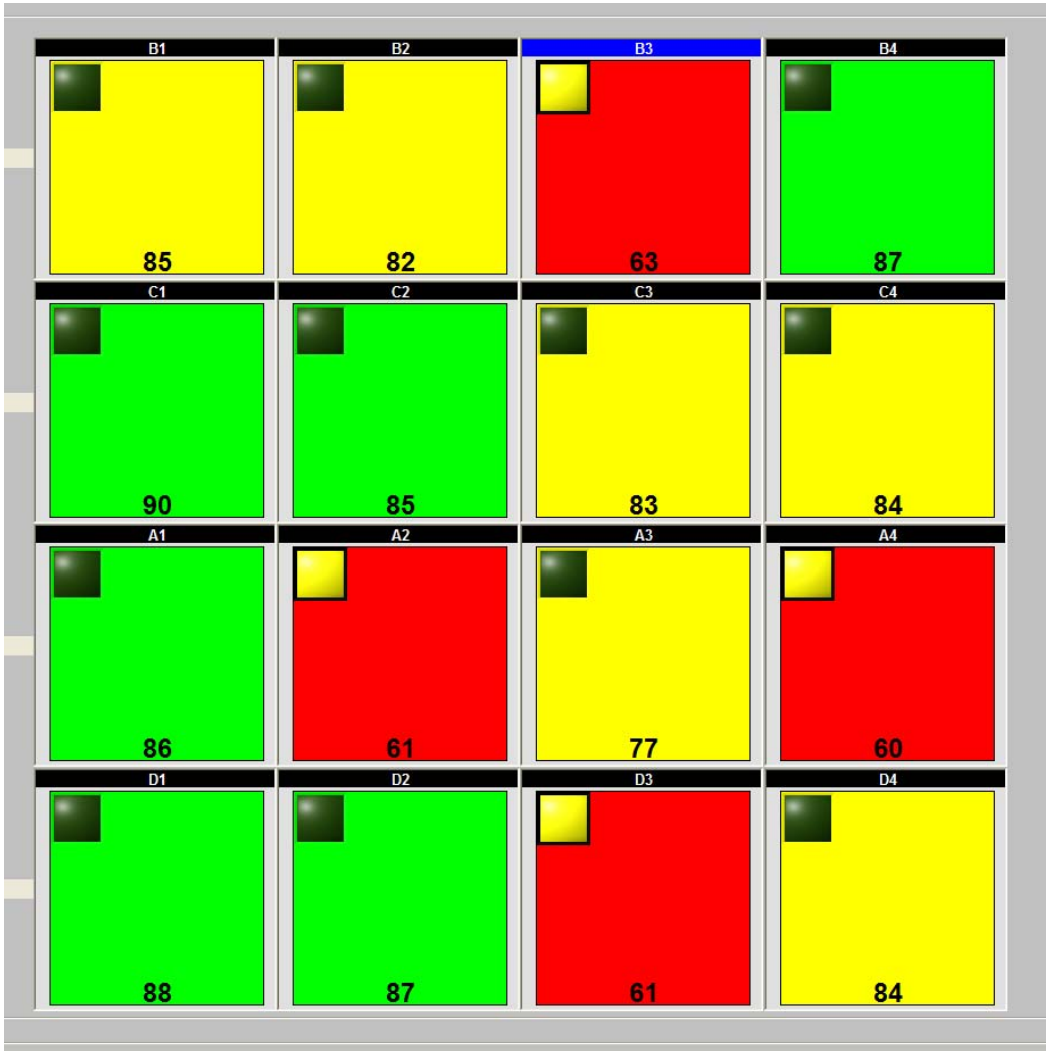
Case Study

BALANCE/REDUCE O_2

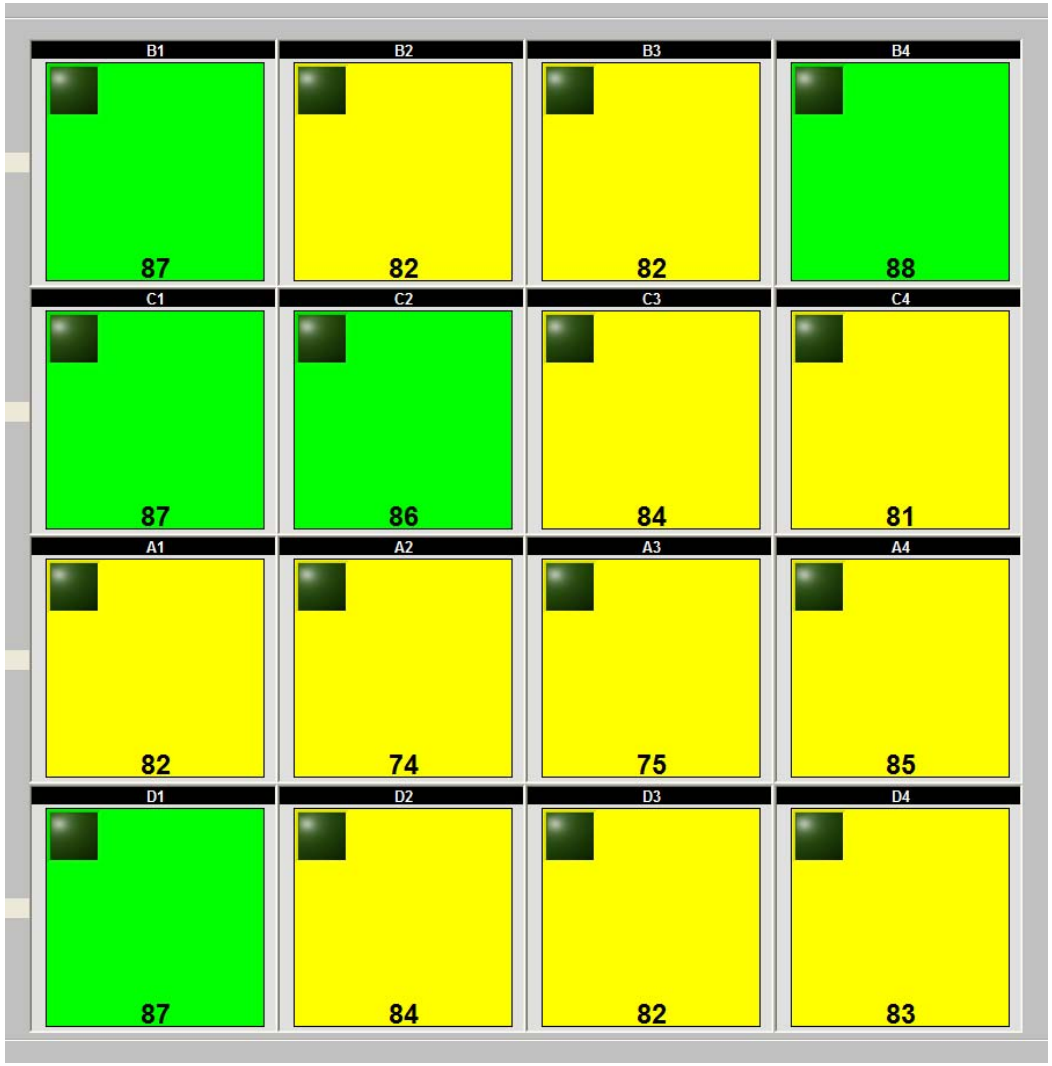
Project Description

- Goals
  - Primary: Balance/reduce O_2
  - Secondary: Reduce NO_x, Maintain sellable ash
- Boiler
  - 165 MW B&W radiant boiler
  - 16 B&W DRB-XCL burners
  - 4 B&W EL pulverizers
  - 4 Mitsubishi OFA ports
  - Western coal (not PRB)
  - Plant sells ash to local cement maker

As Found Combustion Performance



Tuned Combustion Performance



Tuning Results

- Balanced & reduced O_2: 3.5% to 2.8%
- Reduced NO_x: 0.23 lb/MBtu to 0.185 lb/MBtu
- Reduced CO: 1000+ ppm peak to 250 ppm peak
- Reduced LOI: 0.68% to 0.52% (burners only)
- Reduced LOI: 0.52% to 0.46% (burners+OFA+O2)

babcock & wilcox power generation group

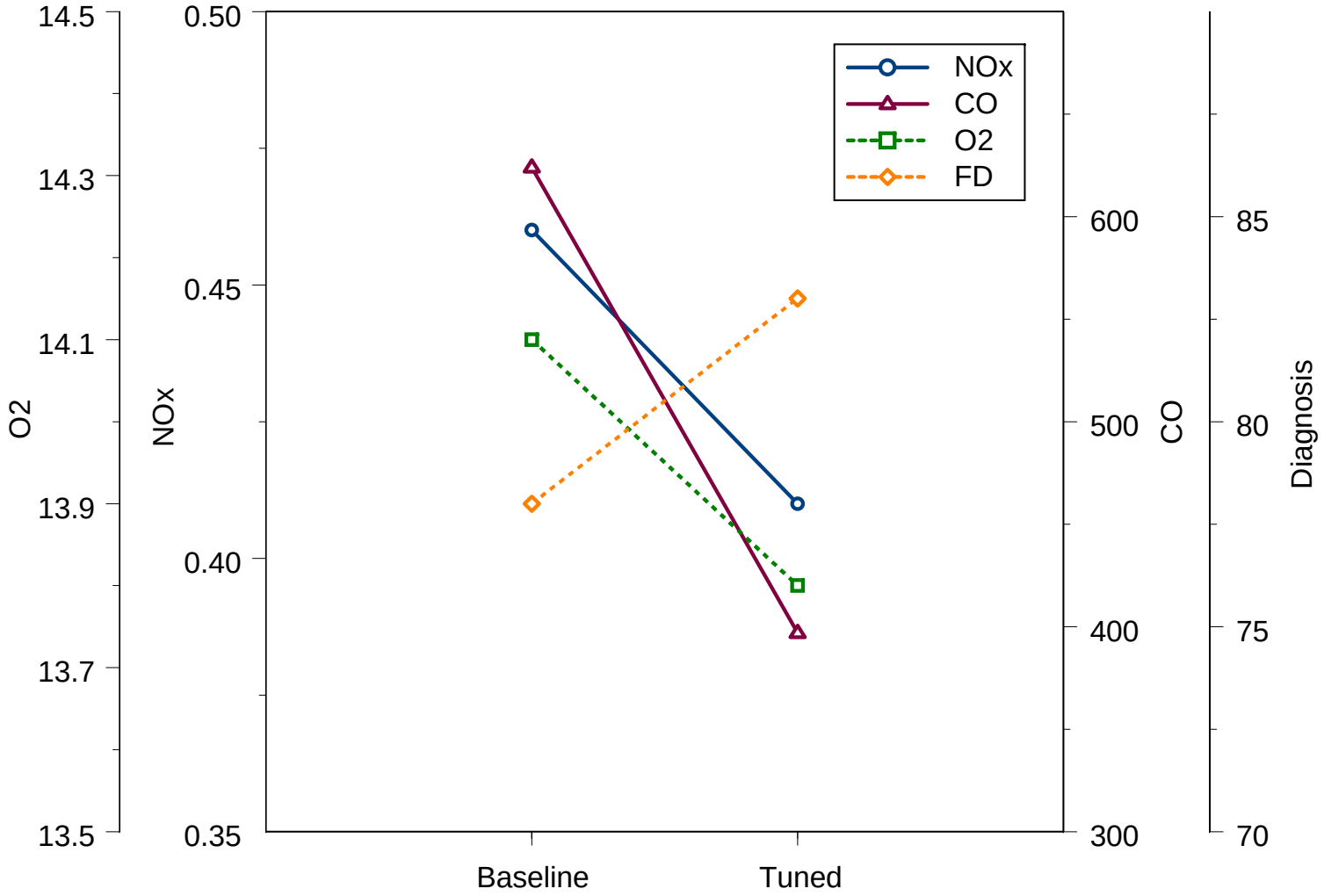
Case Study

REDUCE EMISSIONS AND IMPROVE FAN CAPACITY

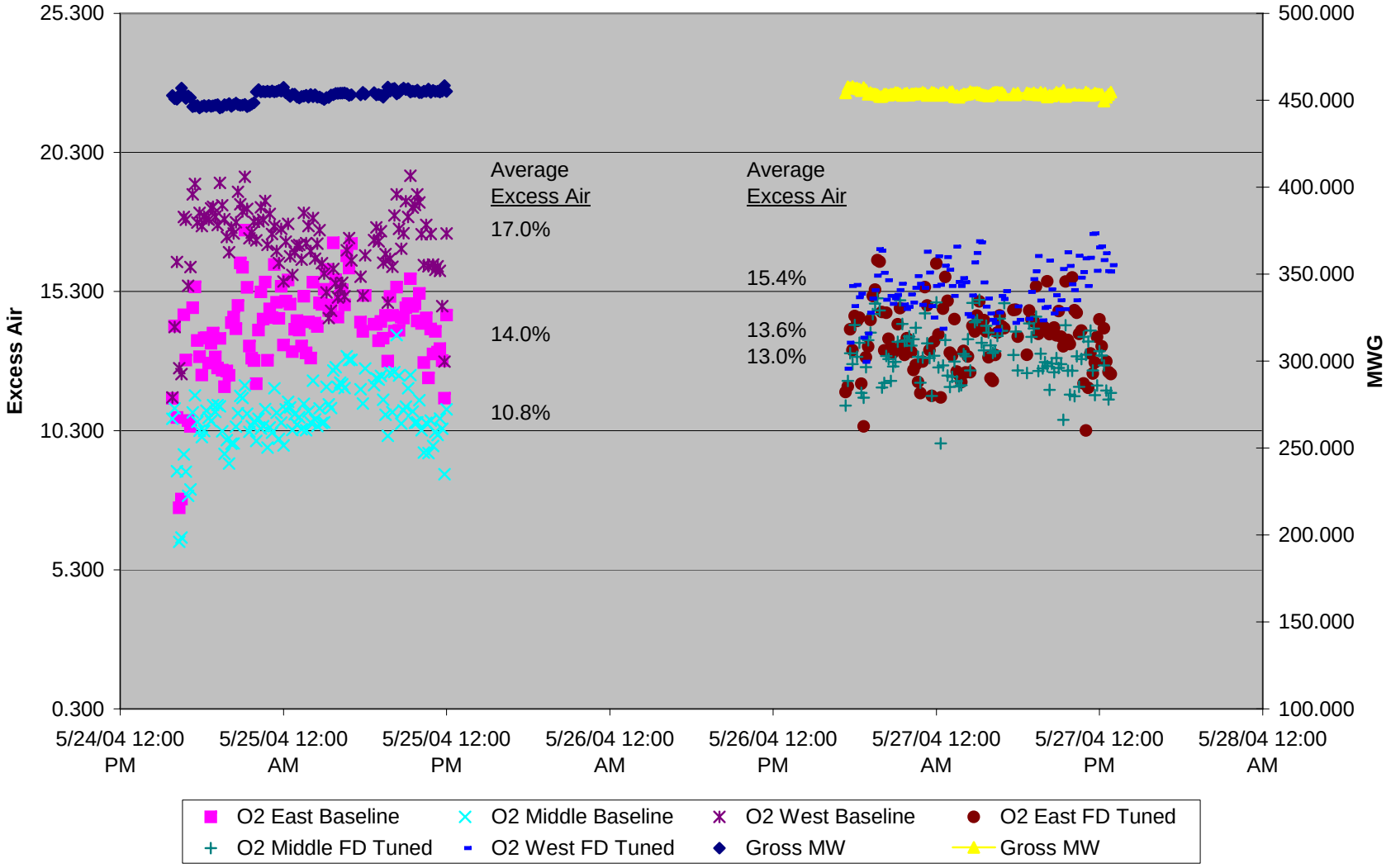
Project Description

- Goals
  - Primary: Reduce CO and NO_x emissions
  - Secondary: Improve FD fan capacity
- Boiler
  - 475 MW B&W universal pressure boiler
  - 30 Riley CCV low-NOx burners on 4 walls
  - 10 B&W EL-76 pulverizers
  - Open windbox
  - Tower design
    - Common SSH
    - 3 convection passes (front, middle, rear)
    - O_2 sensor in each pass
  - Eastern Bituminous coal

Boiler Tuning Results



Oxygen Balance Results



Repeat Tuning Results

- Balanced O_2: 7% Δ → 0.4% Δ
- Reduced NO_x: 0.39 lb/MBtu → 0.36 lb/MBtu
- Reduced CO: 621 ppm (avg) → 483 ppm (avg)

Case Study

FLAME IMPINGEMENT

Project Description

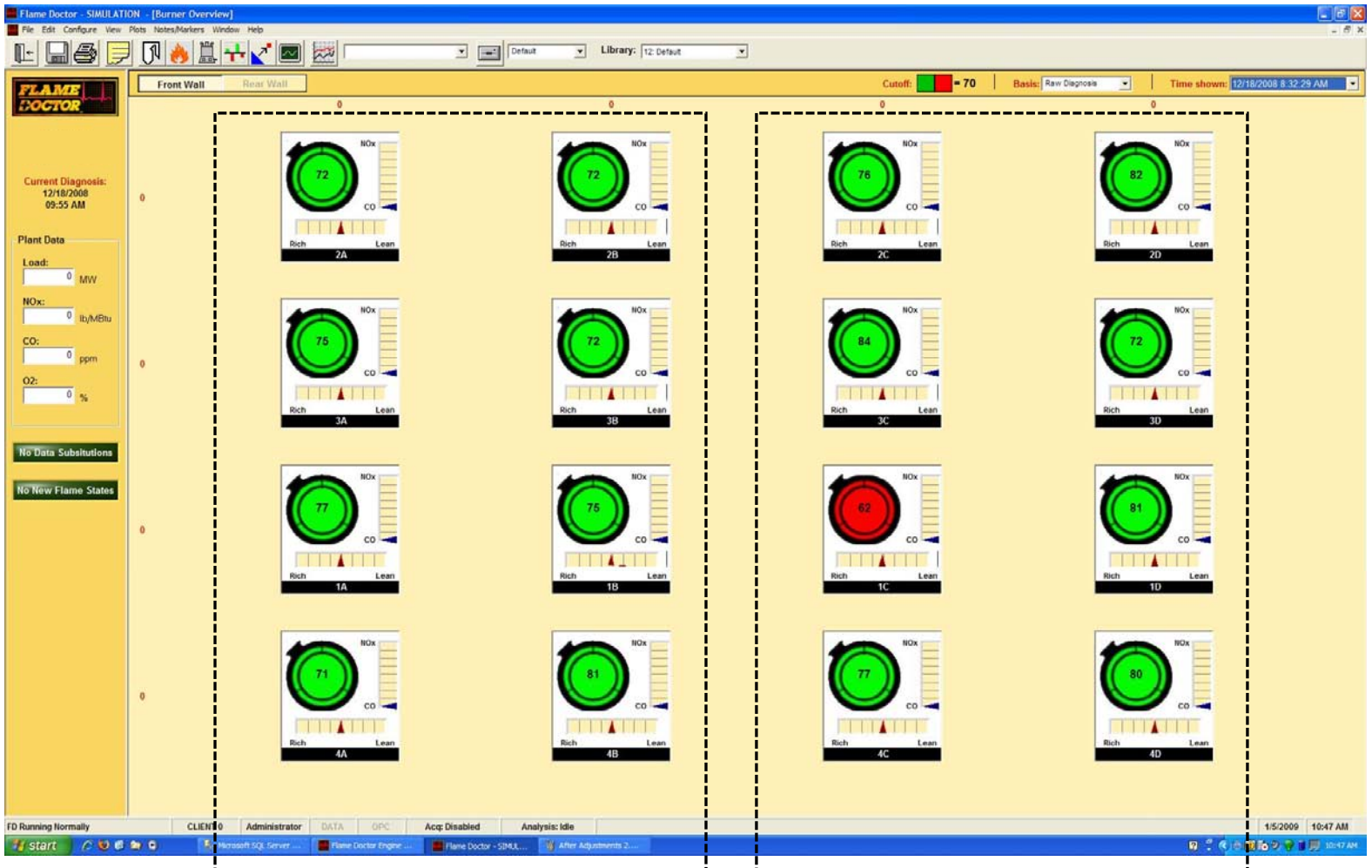
- Goal
  - Primary: Reduce flame impingement on rear wall
  - Secondary: Reduce CO and NO_x
- Boiler
  - 460 MW B&W radiant boiler
  - 30 B&W DRB burners
  - 5 B&W -89N roll wheel pulverizers
  - Compartmented windbox
  - Eastern Bituminous coal and SynFuel

As Found Combustion Condition

3.6% O_2

6.4% O_2

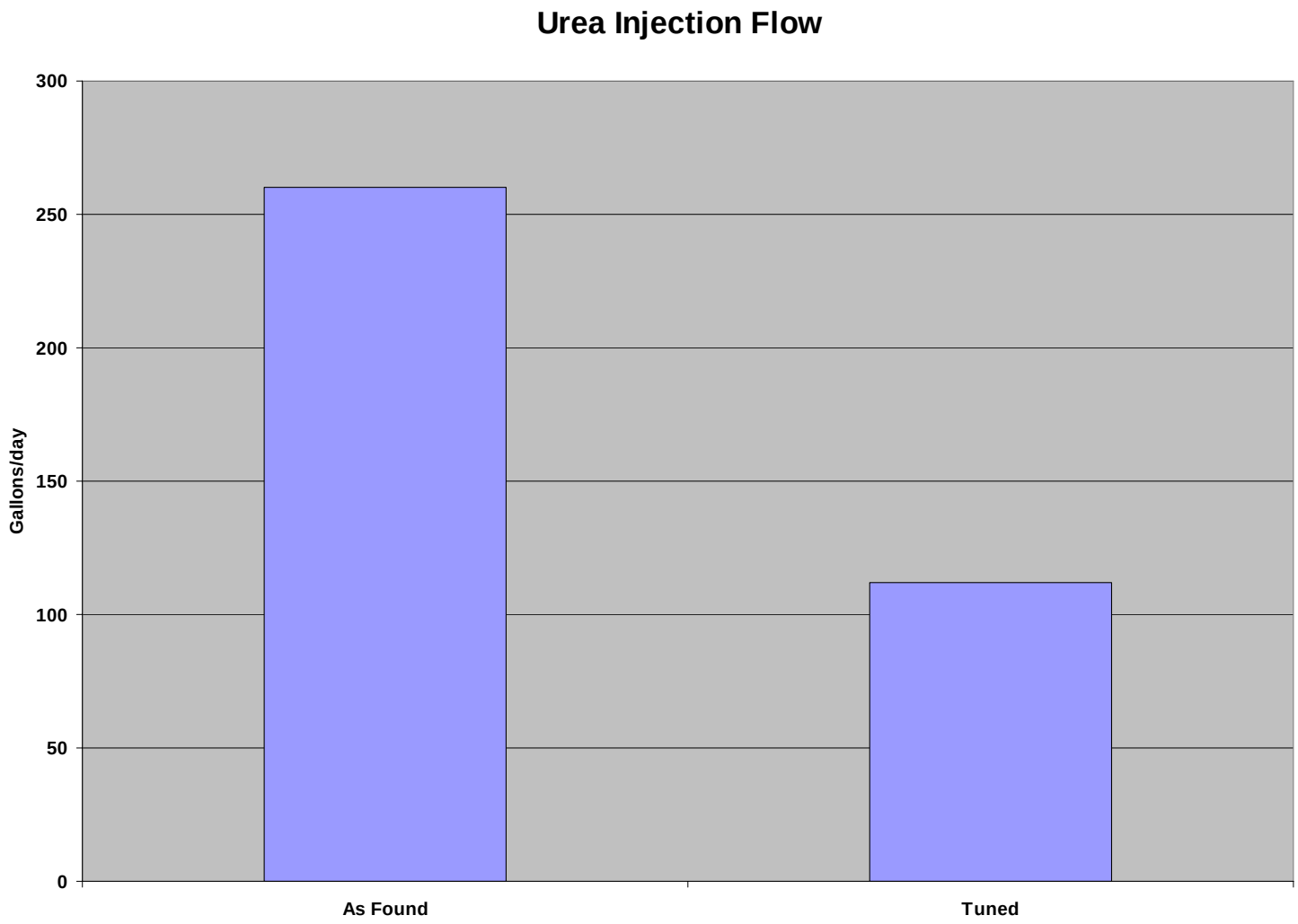
Tuned Combustion Condition



5.6% O_2

5.3% O_2

Additional Performance Results



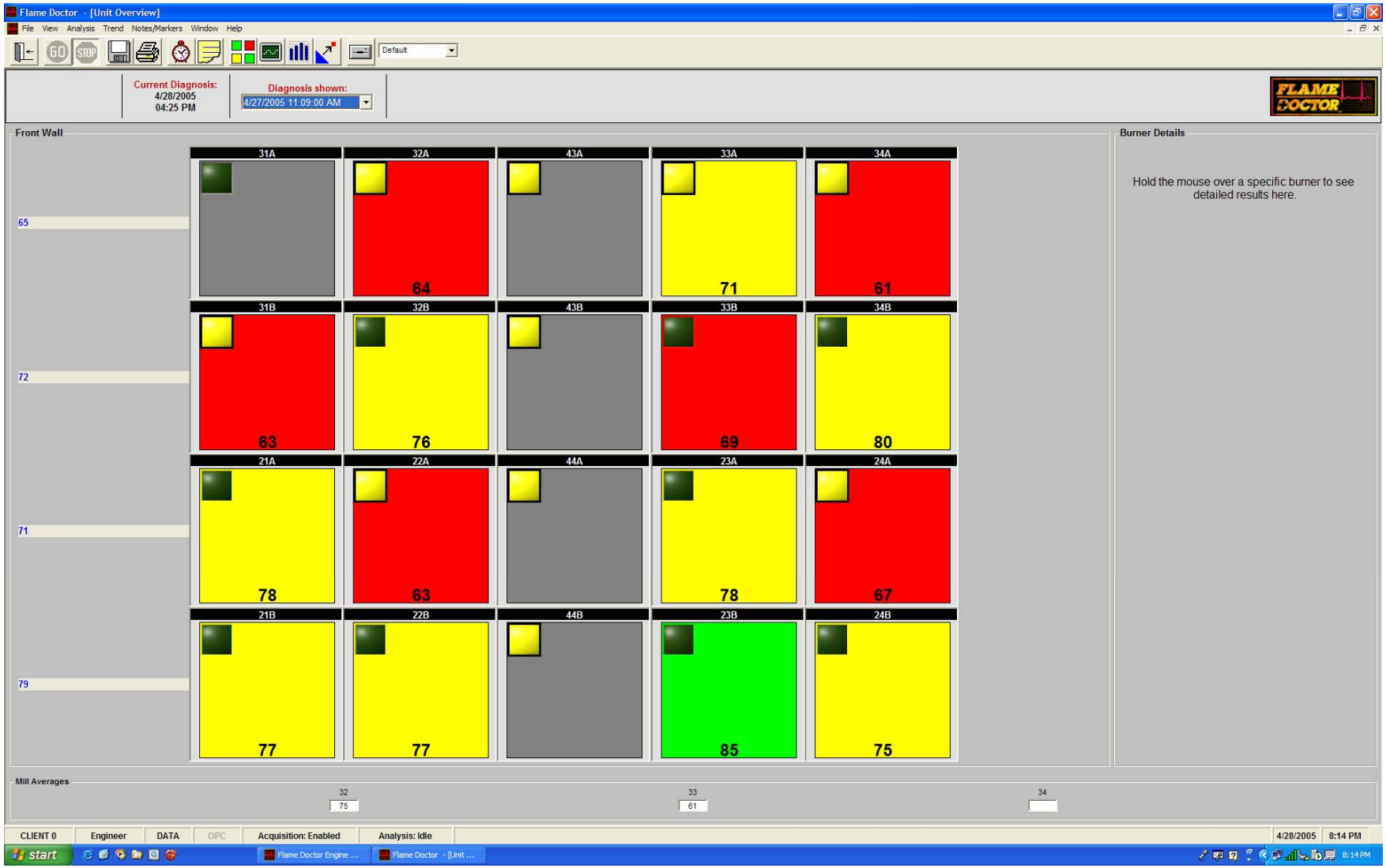
Case Study

PRE-OUTAGE INSPECTION

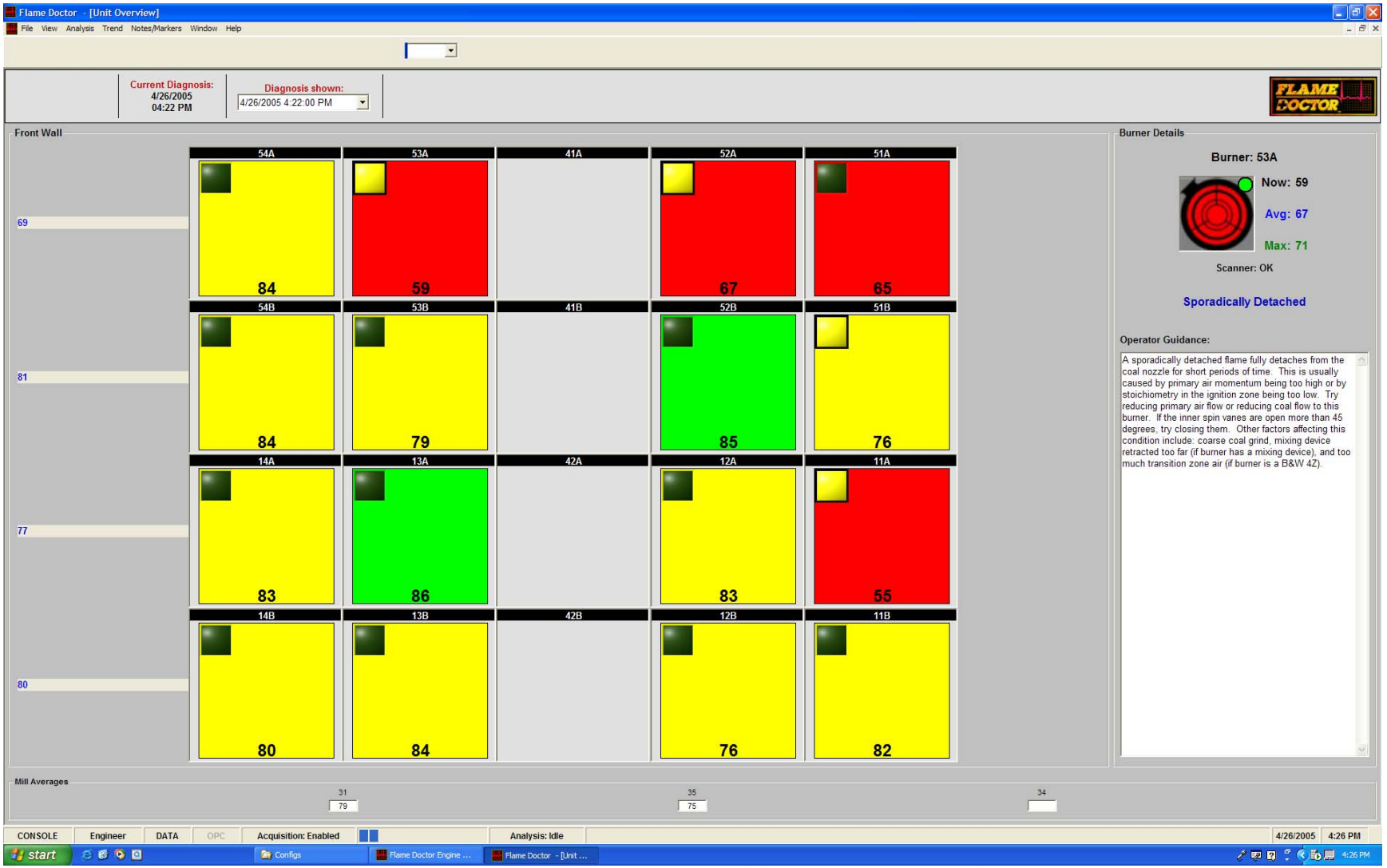
Project Description

- Goal
  - Identify problem burners for outage inspection
- Boiler
  - 650 MW B&W radiant boiler
  - 40 B&W DRB-XCL burners
  - 5 B&W -89N roll wheel pulverizers
  - 12 OFA ports
  - Compartmented windbox
  - Burn blend of 8 coals

As Found Performance – Front Wall

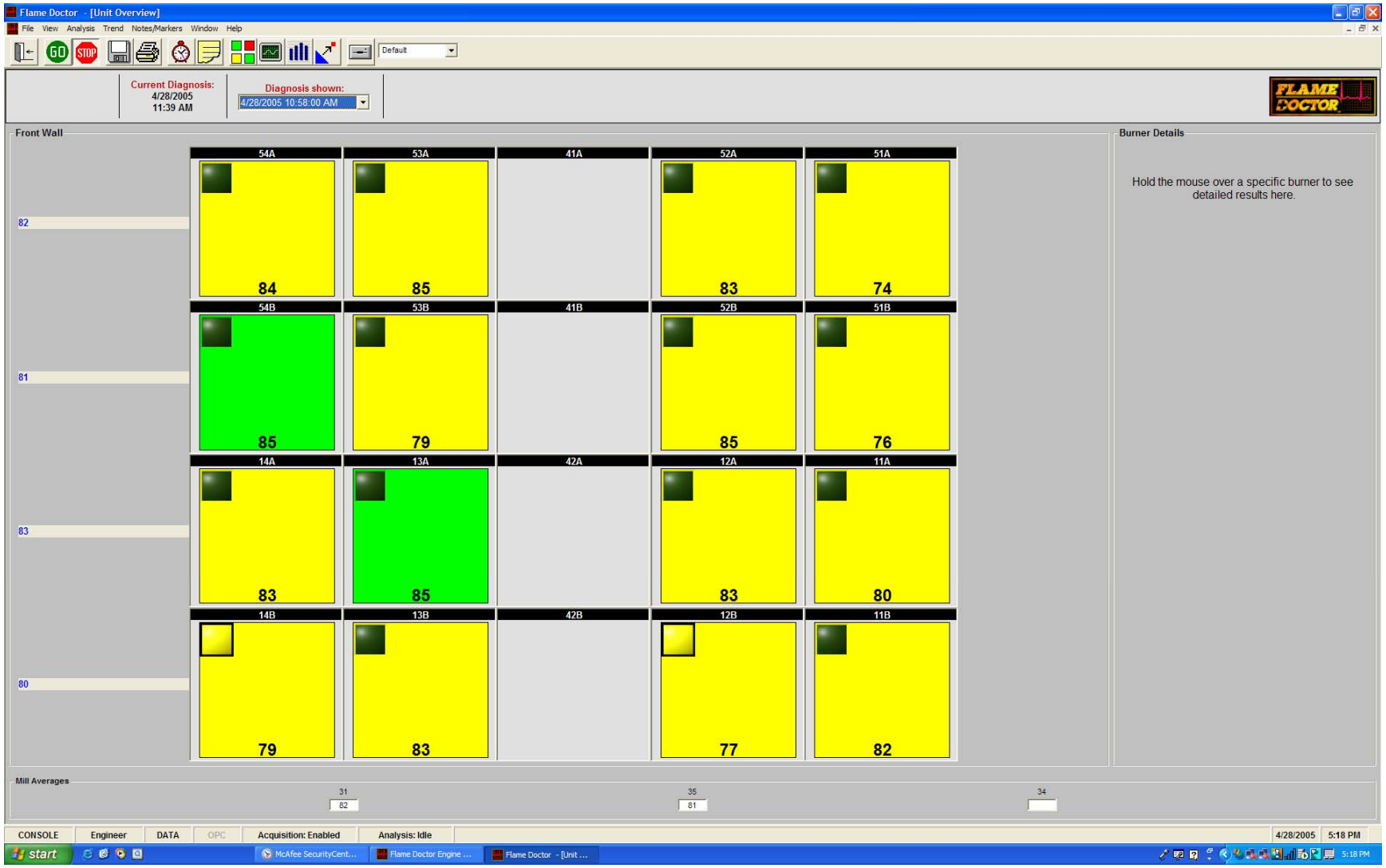


As Found Performance – Rear Wall



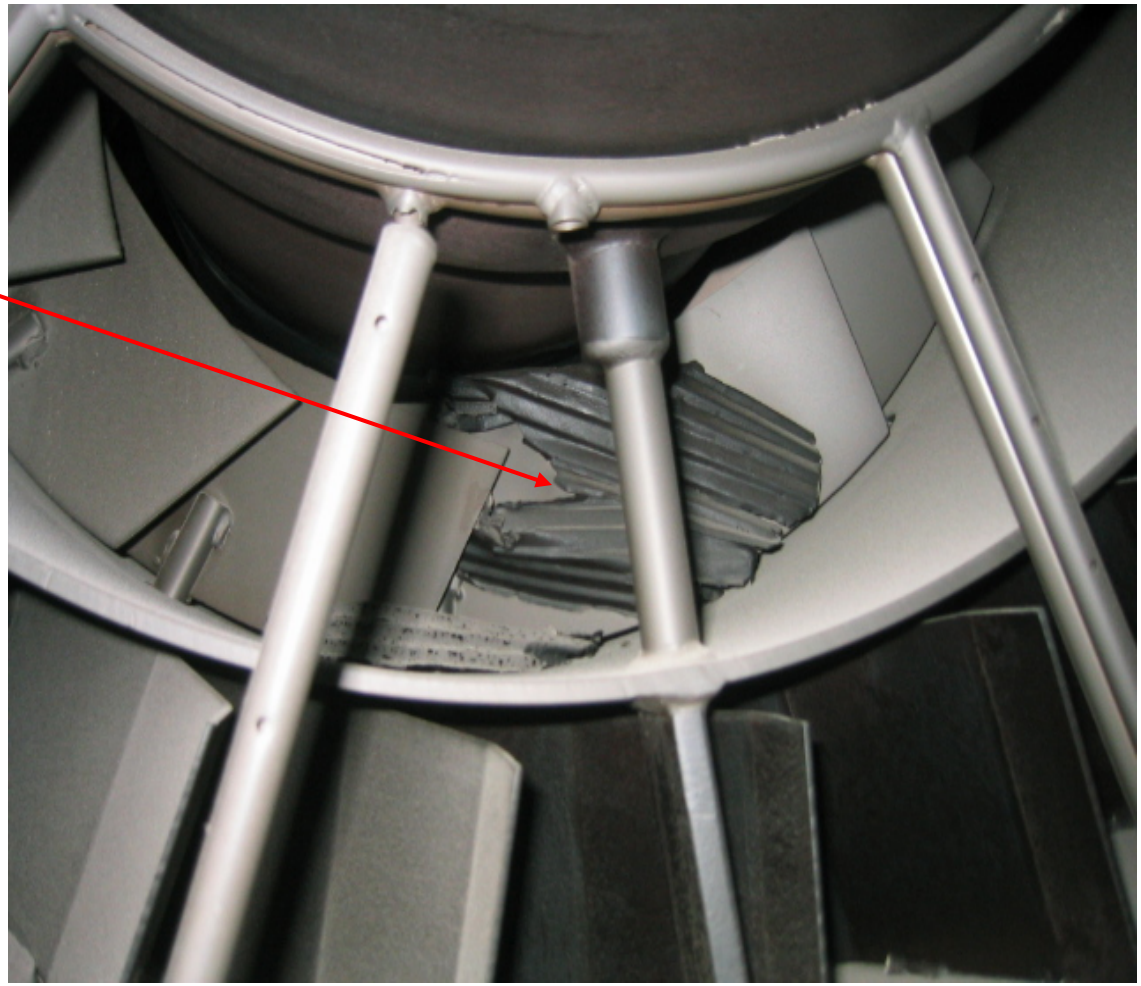
As Left Performance – Front Wall

As Left Performance – Rear Wall



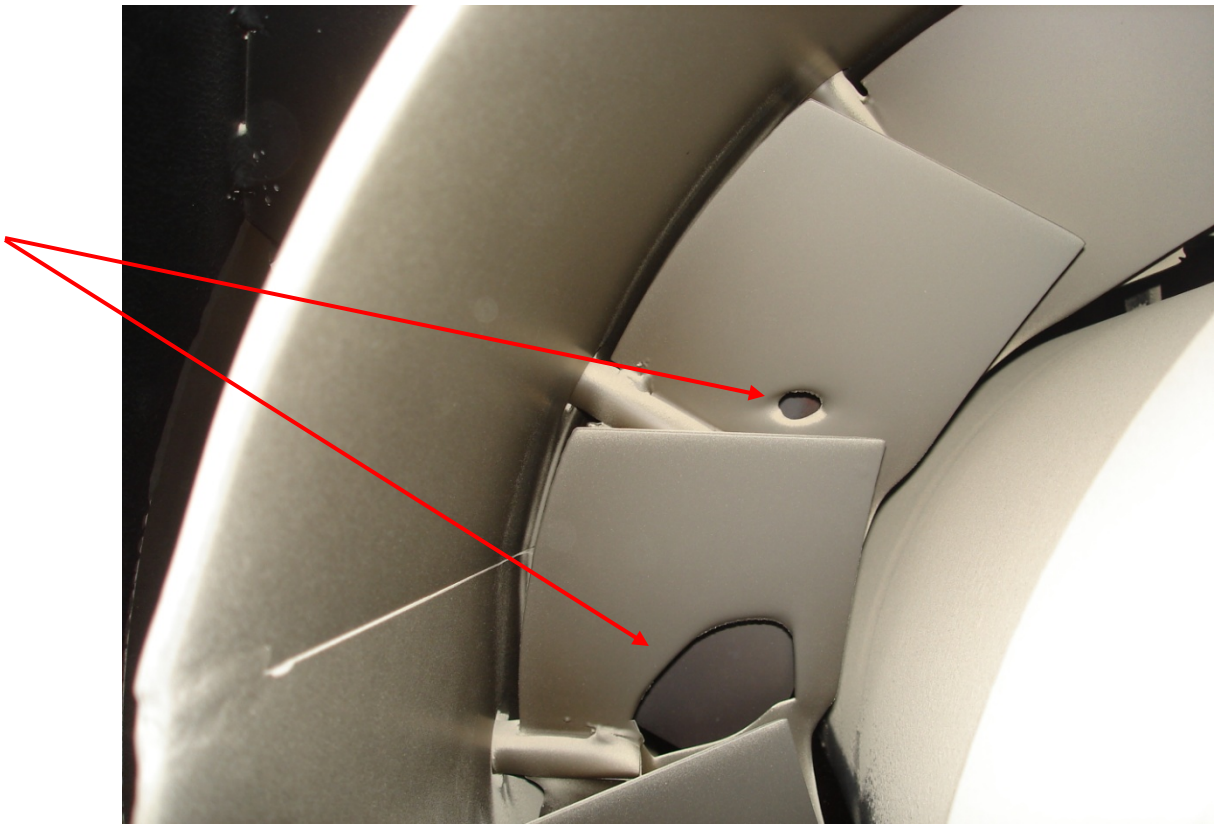
Outage Inspection Results

Air heater basket material lodged into the inner / outer spin vanes to the burners.



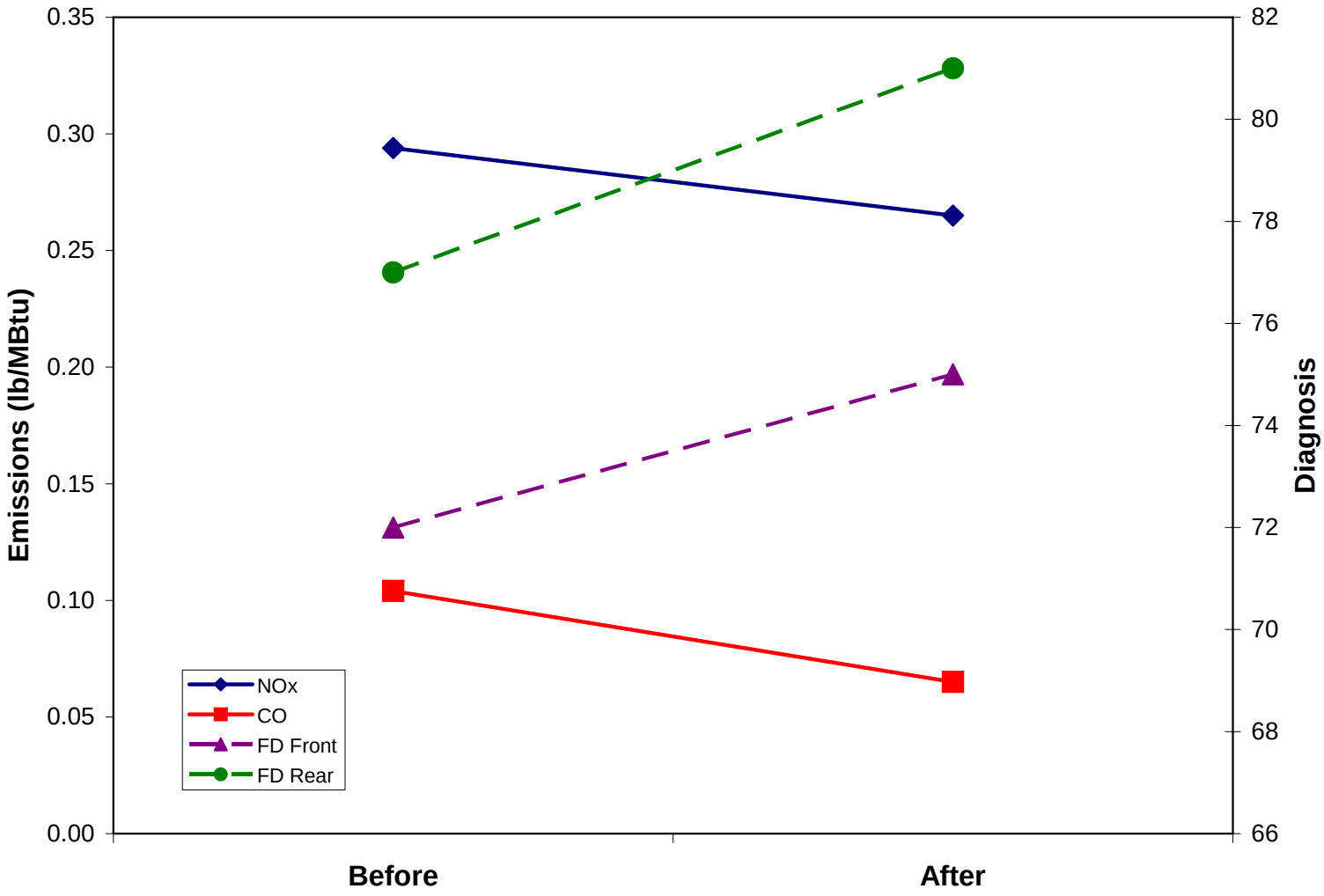
Outage Inspection Results

Burner inner spin vane erosion from the ash entering from the air heater.



Outage Inspection Results

Performance Improvement



Valuable Information

- Provides information to improve emissions
  - 10%-30% NO_x reduction
  - 50%-70% CO reduction
  - 50% LOI reduction (limited data)
  - Balance/reduce O_2
- Provides information on operational issues
  - Identify burner mechanical issues
  - Identify certain mill problems
  - Identify potential tube wastage conditions
  - Identify burner interactions

Questions?