Reinhold Environmental Ltd.

2009 NOx-Combustion Round Table & Expo Presentation

February 9 & 10, 2009, Cleveland, OH

Integrating In-Furnace Measurements with Combustion Optimization

Peter Spinney, Director of Market & Technology Assessment, NeuCo, Inc.
February 9, 2009
Reinhold Environmental NOx Roundtable

Outline

- CPS Energy J.T. Deely Power Plant
- CombustionOpt® Overview
- ZoloBOSS™ System
- Integration of Combustion Optimization with Spectroscopy Sensors at J.T. Deely
- Initial Findings
- Next Steps

CPS J.T. Deely Power Plant

- Owned and operated by CPS Energy
  - CPS 2nd largest municipally owned utility in the country
- J.T. Deely plant commissioned in 1977
- Two 446 MW Alstom-CE t-fired units w/Honeywell DCS
  - Unit 1 first in nation to integrate combustion optimization software with boiler optimization spectroscopy sensors

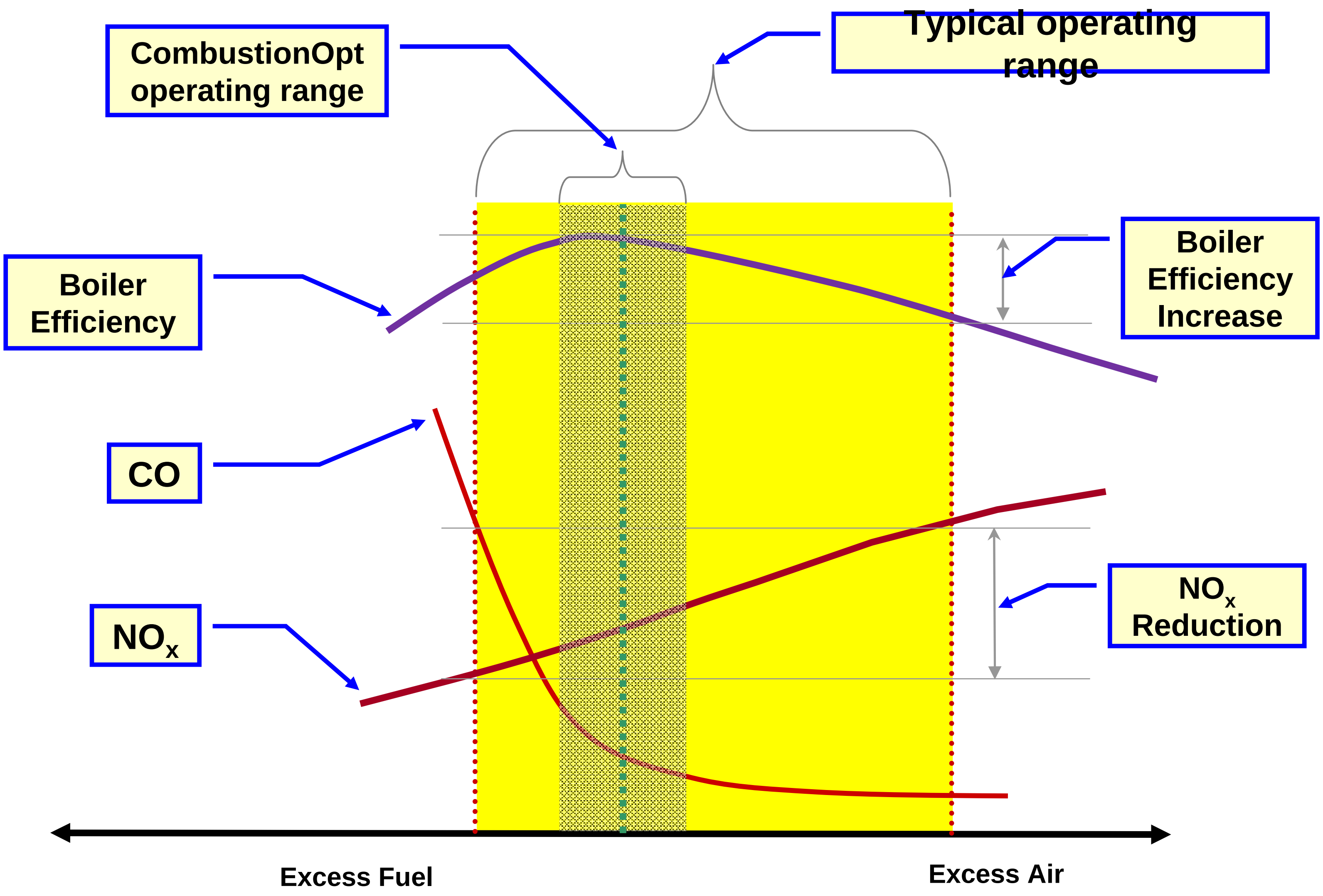
CPS J.T. Deely Power Plant

- 1998 CPS committed to voluntarily reduce NOx emissions by 15 to 20%
  - Smaller SCRs when needed
  - Lower associated capital and O&M costs.
- TCEQ and State Senate enacted NOx rules in 2000
- J.T. Deely success with in-furnace NOx reduction
- Combustion optimization installed on both units in 2004
- Multivariate predictive control (MPC) added in 2007
  - Explicit steam temperature control
  - Minimize attemperation sprays
  - Incremental heat rate and NOx reduction

CombustionOpt

- Provides real-time optimization & advanced control
- Utilizes 3 types of models:
  - Model-predictive control (MPC)
  - Neural networks with online learning
  - Engineering calculations
- Key goals for Deely
  - Minimize NOx (or control to a setpoint, depending on the season)
  - Maintain steam temperatures (average & side/side split)
  - Minimize sprays to reduce Heat Rate
  - Avoid plant constraints (high CO, damper positions, mill limits, etc.)

CombustionOpt Optimization



CombustionOpt operating range

Typical operating range

Boiler Efficiency

Boiler Efficiency Increase

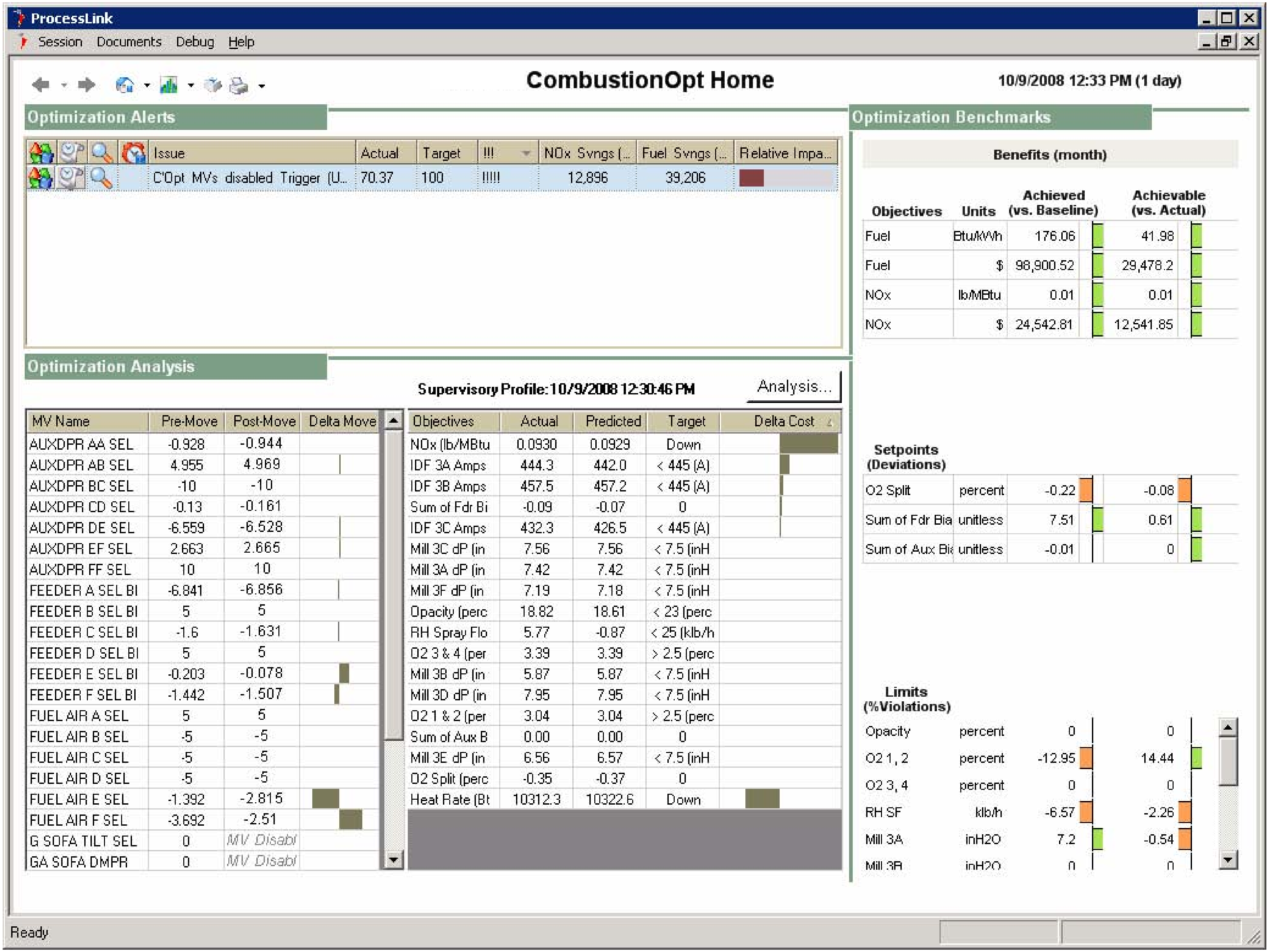
CO

NO_x

NO_x Reduction

Excess Fuel

Excess Air



CombustionOpt Home

10/9/2008 12:33 PM (1 day)

Optimization Alerts

Issue	Actual	Target	!!!	NOx Svngs (...	Fuel Svngs (...	Relative Impa...
C'Opt MVs disabled Trigger (U...	70.37	100	!!!!!	12,896	39,206	

Optimization Benchmarks

Benefits (month)

Objectives	Units	Achieved (vs. Baseline)	Achievable (vs. Actual)
Fuel	Btu/kWh	176.06	41.98
Fuel	$	98,900.52	29,478.2
NOx	lb/MBtu	0.01	0.01
NOx	$	24,542.81	12,541.85

Setpoints (Deviations)

O2 Split	percent	-0.22	-0.08
Sum of Fdr Bia	unitless	7.51	0.61
Sum of Aux Bi	unitless	-0.01	0

Limits (%Violations)

Opacity	percent	0	0
O2 1, 2	percent	-12.95	14.44
O2 3, 4	percent	0	0
RH SF	klb/h	-6.57	-2.26
Mill 3A	inH2O	7.2	-0.54
Mill 3B	inH2O	0	0

Optimization Analysis

Supervisory Profile: 10/9/2008 12:30:46 PM

MV Name	Pre-Move	Post-Move	Delta Move
AUXDPR AA SEL	-0.928	-0.944	
AUXDPR AB SEL	4.955	4.969	
AUXDPR BC SEL	-10	-10	
AUXDPR CD SEL	-0.13	-0.161	
AUXDPR DE SEL	-6.559	-6.528	
AUXDPR EF SEL	2.663	2.665	
AUXDPR FF SEL	10	10	
FEEDER A SEL BI	-6.841	-6.856	
FEEDER B SEL BI	5	5	
FEEDER C SEL BI	-1.6	-1.631	
FEEDER D SEL BI	5	5	
FEEDER E SEL BI	-0.203	-0.078	
FEEDER F SEL BI	-1.442	-1.507	
FUEL AIR A SEL	5	5	
FUEL AIR B SEL	-5	-5	
FUEL AIR C SEL	-5	-5	
FUEL AIR D SEL	-5	-5	
FUEL AIR E SEL	-1.392	-2.815	
FUEL AIR F SEL	-3.692	-2.51	
G SOFA TILT SEL	0	*MV Disabl*	
GA SOFA DMPR	0	*MV Disabl*	

Objectives	Actual	Predicted	Target	Delta Cost
NOx (lb/MBtu	0.0930	0.0929	Down	
IDF 3A Amps	444.3	442.0	< 445 (A)	
IDF 3B Amps	457.5	457.2	< 445 (A)	
Sum of Fdr Bi	-0.09	-0.07	0	
IDF 3C Amps	432.3	426.5	< 445 (A)	
Mill 3C dP (in	7.56	7.56	< 7.5 (inH	
Mill 3A dP (in	7.42	7.42	< 7.5 (inH	
Mill 3F dP (in	7.19	7.18	< 7.5 (inH	
Opacity (perc	18.82	18.61	< 23 (perc	
RH Spray Flo	5.77	-0.87	< 25 (klb/h	
O2 3 & 4 (per	3.39	3.39	> 2.5 (perc	
Mill 3B dP (in	5.87	5.87	< 7.5 (inH	
Mill 3D dP (in	7.95	7.95	< 7.5 (inH	
O2 1 & 2 (per	3.04	3.04	> 2.5 (perc	
Sum of Aux B	0.00	0.00	0	
Mill 3E dP (in	6.56	6.57	< 7.5 (inH	
O2 Split (perc	-0.35	-0.37	0	
Heat Rate (Bt	10312.3	10322.6	Down	

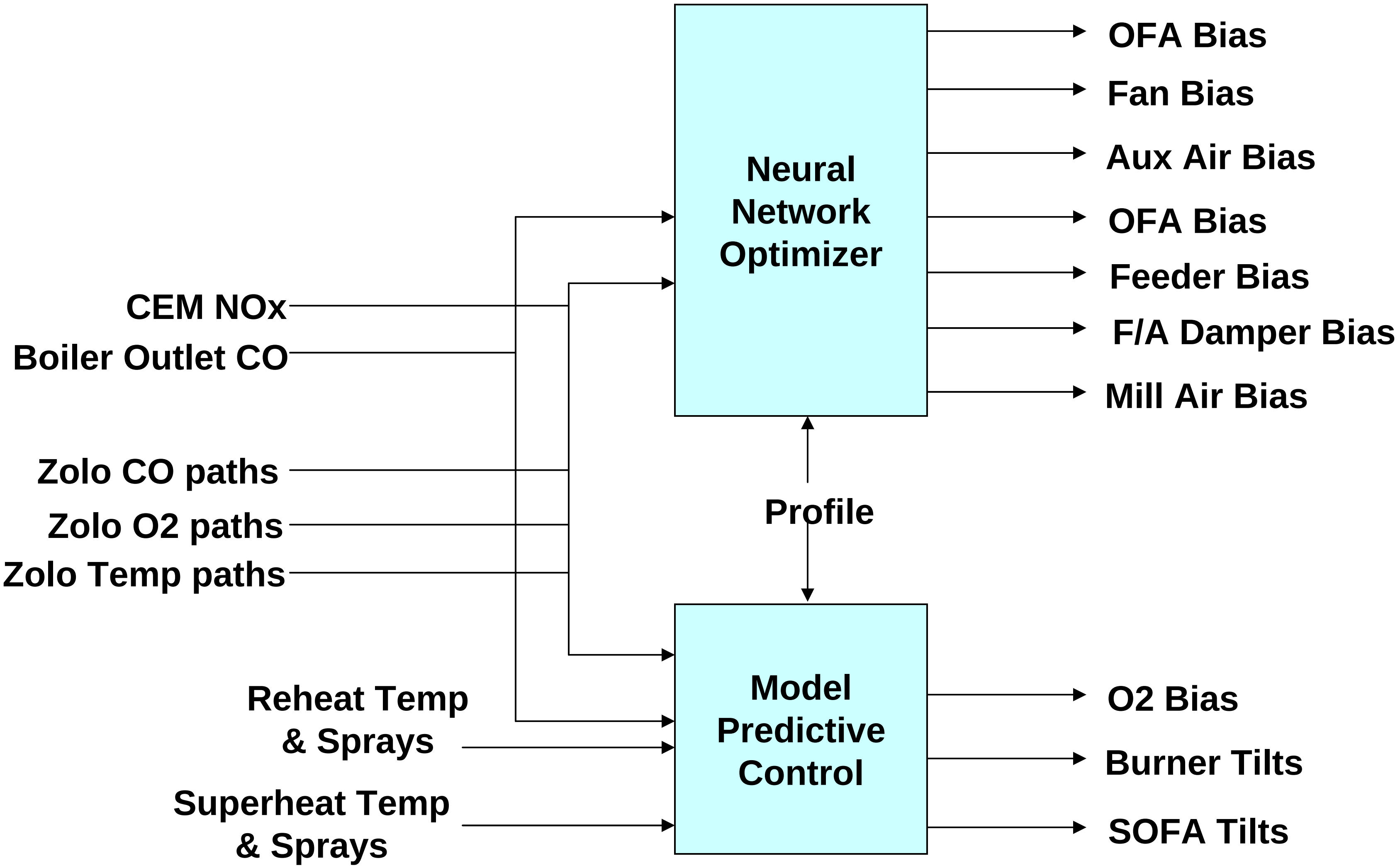
ZoloBOSS System

- Measures and maps multiple constituents directly in the furnace
- Tunable diode laser absorption spectroscopy
- Scans a laser in wavelength across the known absorption for a given constituent (i.e. CO)
  - Compares the amount of light absorbed by the constituent with the amount of light that traversed the boiler
- Up to 10,000 measurements per second
  - Each measurement has its own calibration for dust, ash, turbulence, and drift

CombustionOpt with ZoloBOSS at Deely

- CombustionOpt successfully used for several years
- Deely was the first site where MPC was integrated with neural, providing additional benefits
- Deely realizing between 0.12 and 0.13 lbs/mmbtu but had set a goal of 0.08 lb/mmbtu
- Motivations for adding ZoloBOSS
  - New unit at Spruce created additional NOx pressure
  - Increasing coal costs
  - Innovative culture and commitment to continuous improvement
  - Recognition that higher resolution measurements of key combustion indicators could provide additional performance gains

CombustionOpt w/ZoloBOSS at Deely 1



CEM NOx

Boiler Outlet CO

Zolo CO paths

Zolo O2 paths

Zolo Temp paths

Reheat Temp
& Sprays

Superheat Temp
& Sprays

Neural
Network
Optimizer

Profile

Model
Predictive
Control

OFA Bias

Fan Bias

Aux Air Bias

OFA Bias

Feeder Bias

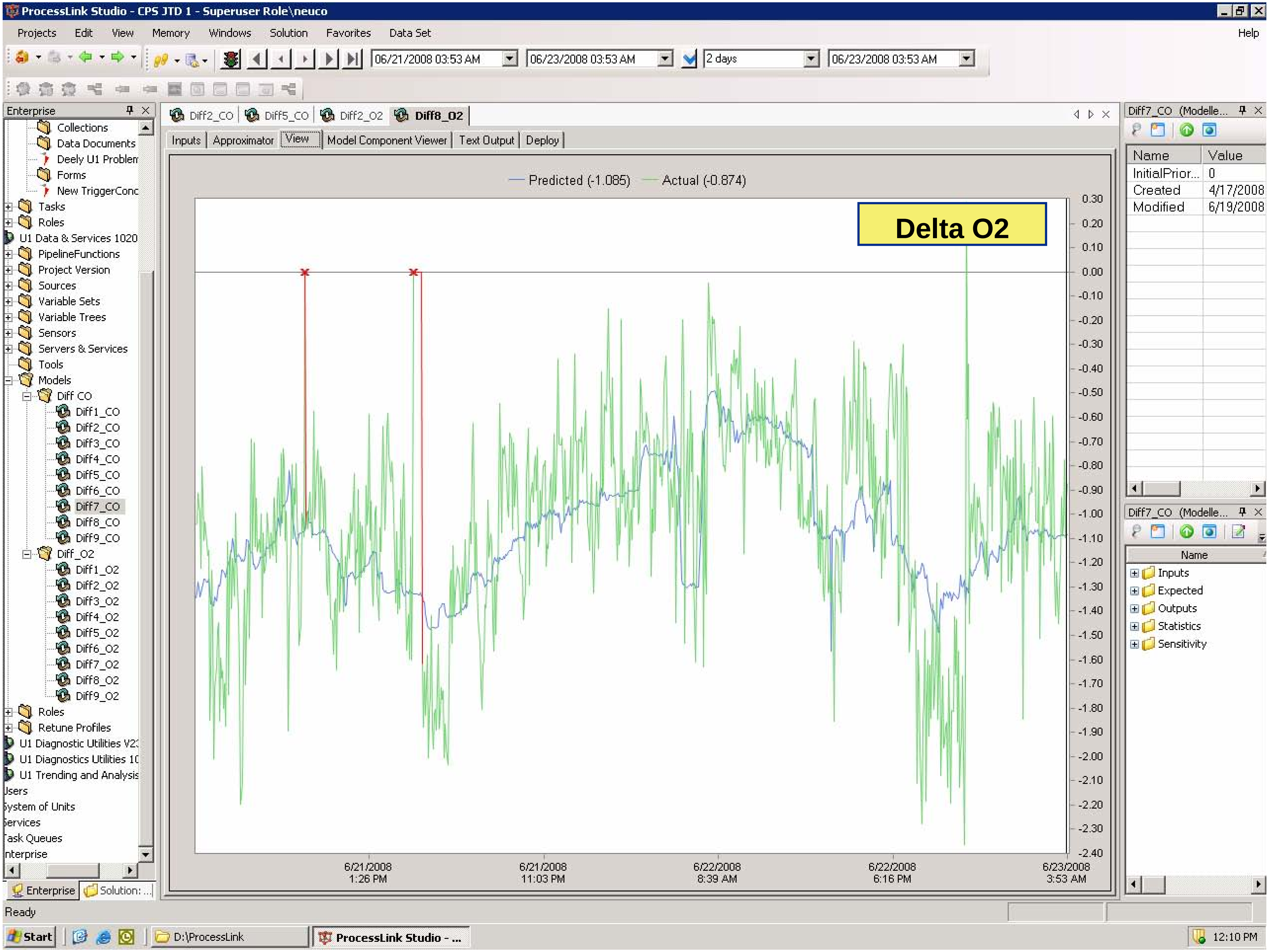
F/A Damper Bias

Mill Air Bias

O2 Bias

Burner Tilts

SOFA Tilts



Delta O2

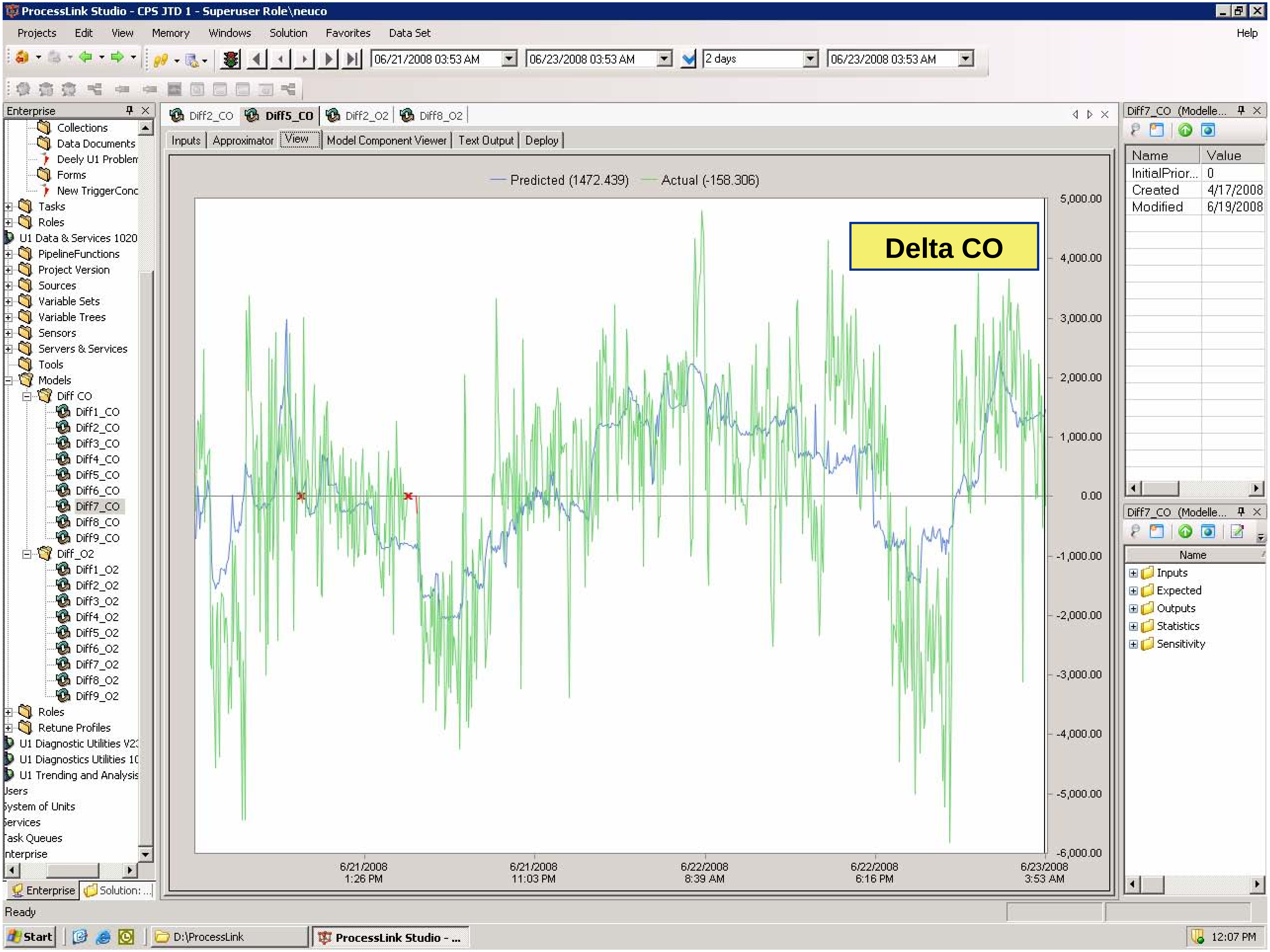
06/21/2008 03:53 AM

06/23/2008 03:53 AM

2 days

06/23/2008 03:53 AM

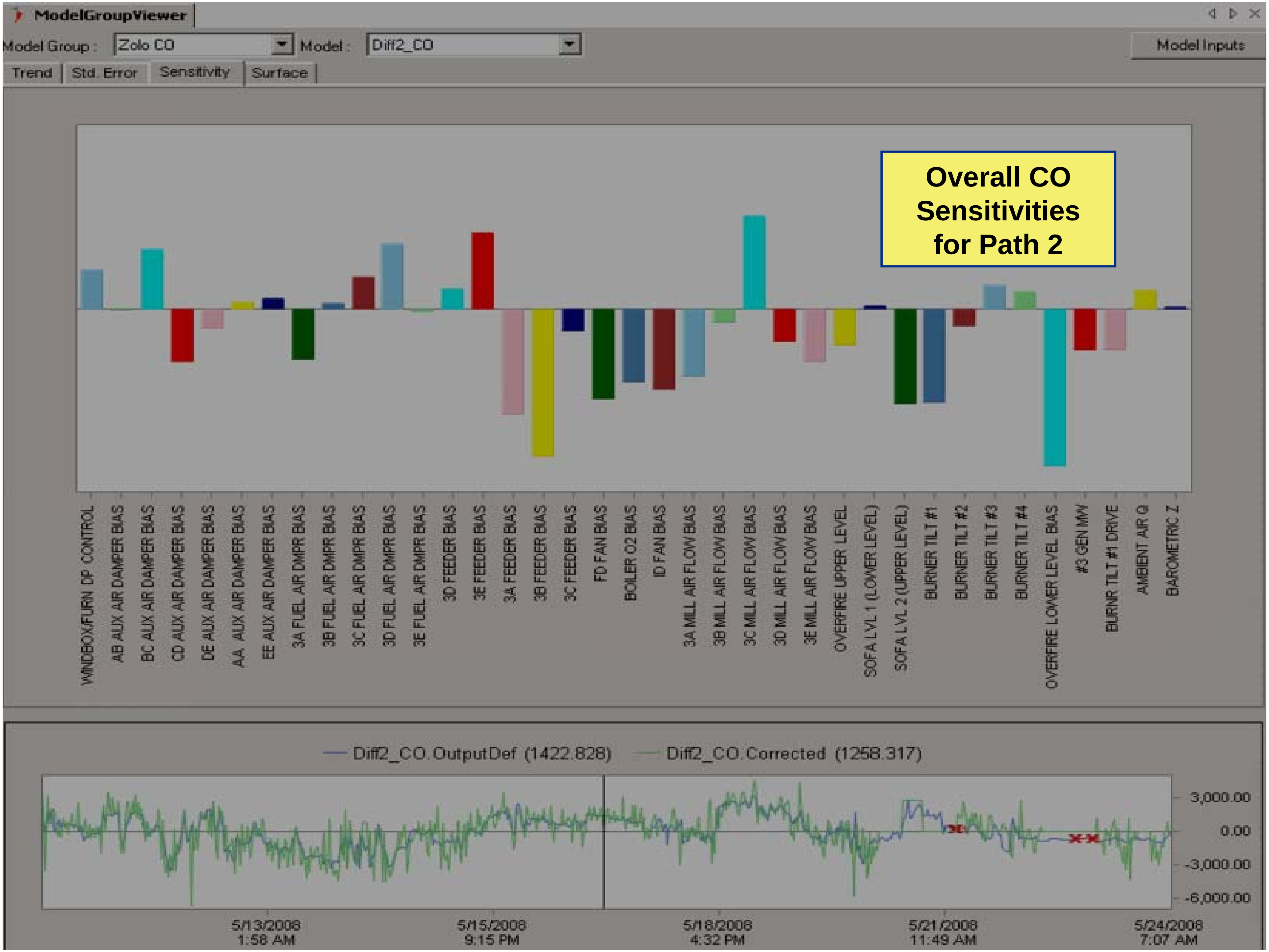
Name	Value
InitialPrior...	0
Created	4/17/2008
Modified	6/19/2008



06/21/2008 03:53 AM
06/23/2008 03:53 AM
2 days
06/23/2008 03:53 AM

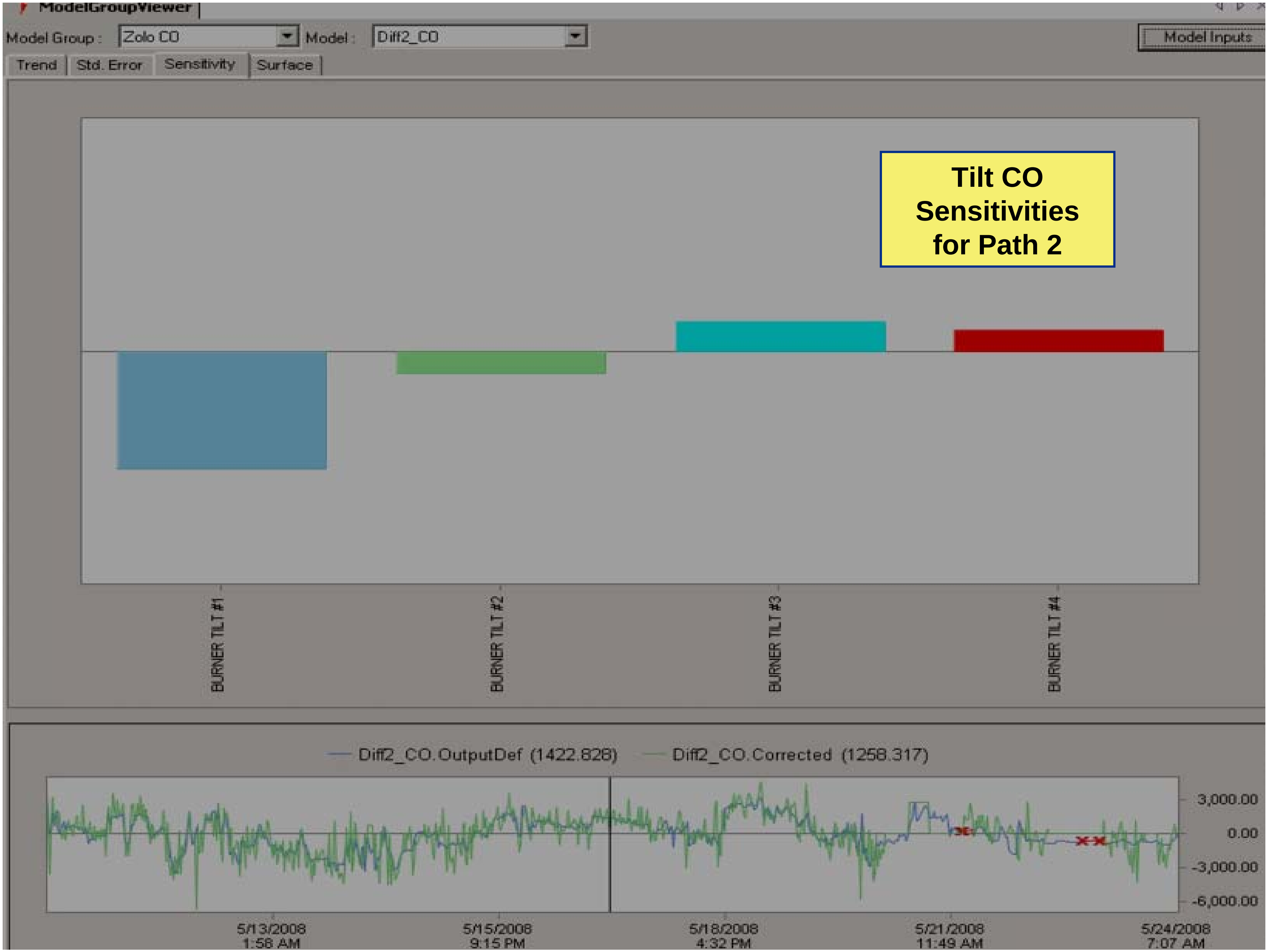
Delta CO

Name	Value
InitialPrior...	0
Created	4/17/2008
Modified	6/19/2008



Overall CO Sensitivities for Path 2

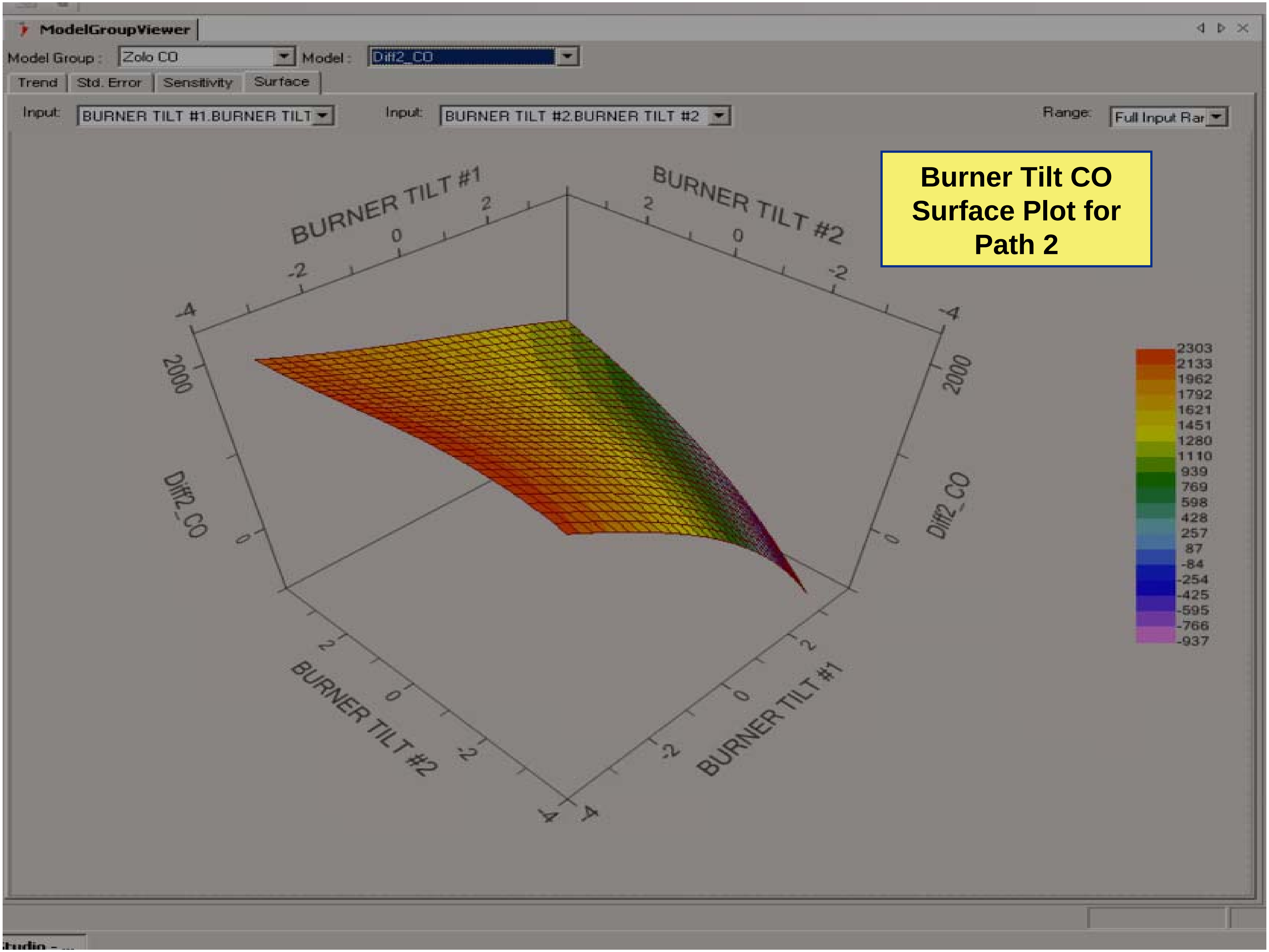
Tilt CO Sensitivities for Path 2



Model Group : Zolo CO

Model : Diff2_CO

Burner Tilt CO Surface Plot for Path 2



ModelGroupViewer

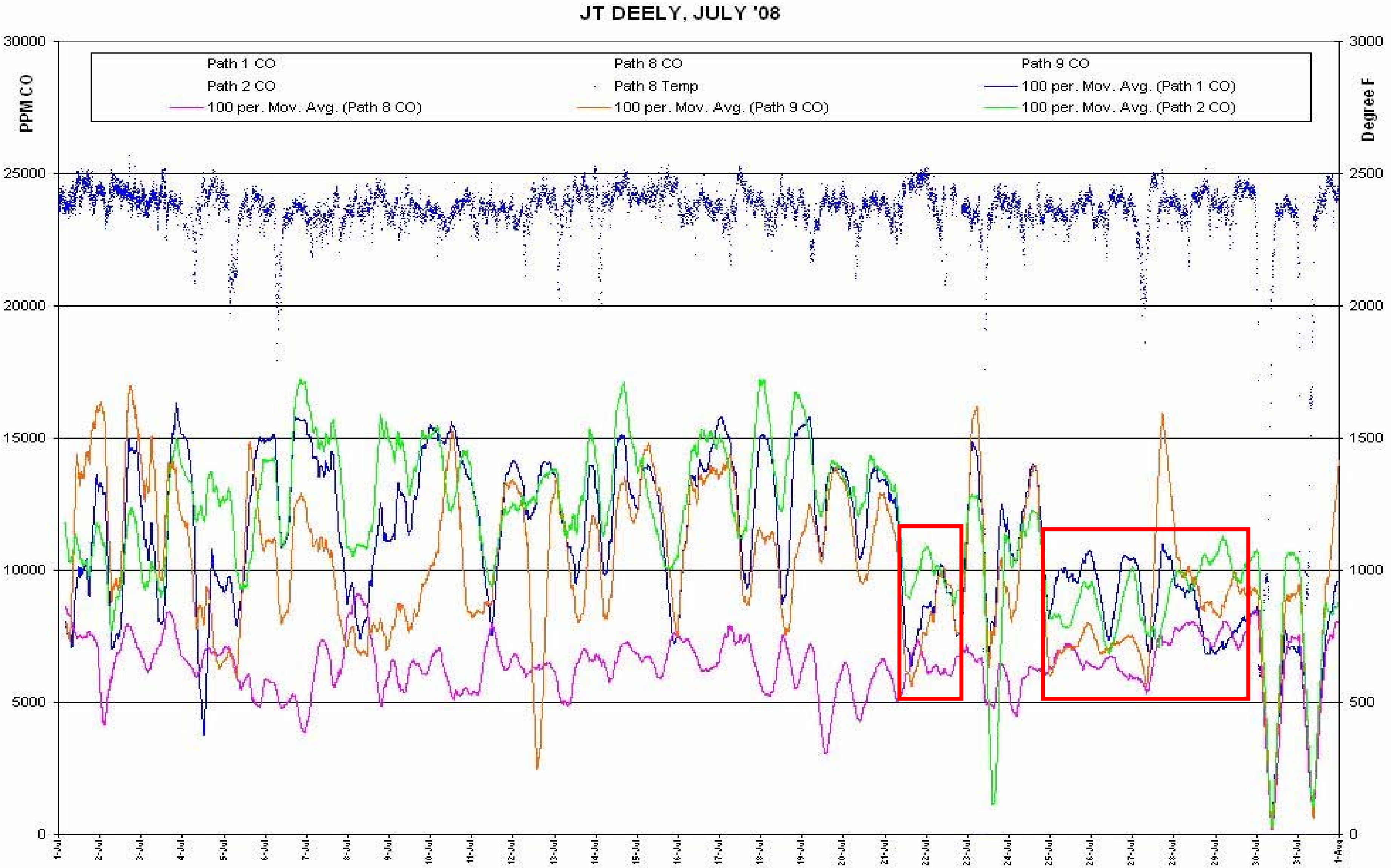
Model Group : Zolo CO

Model : Diff2_CO

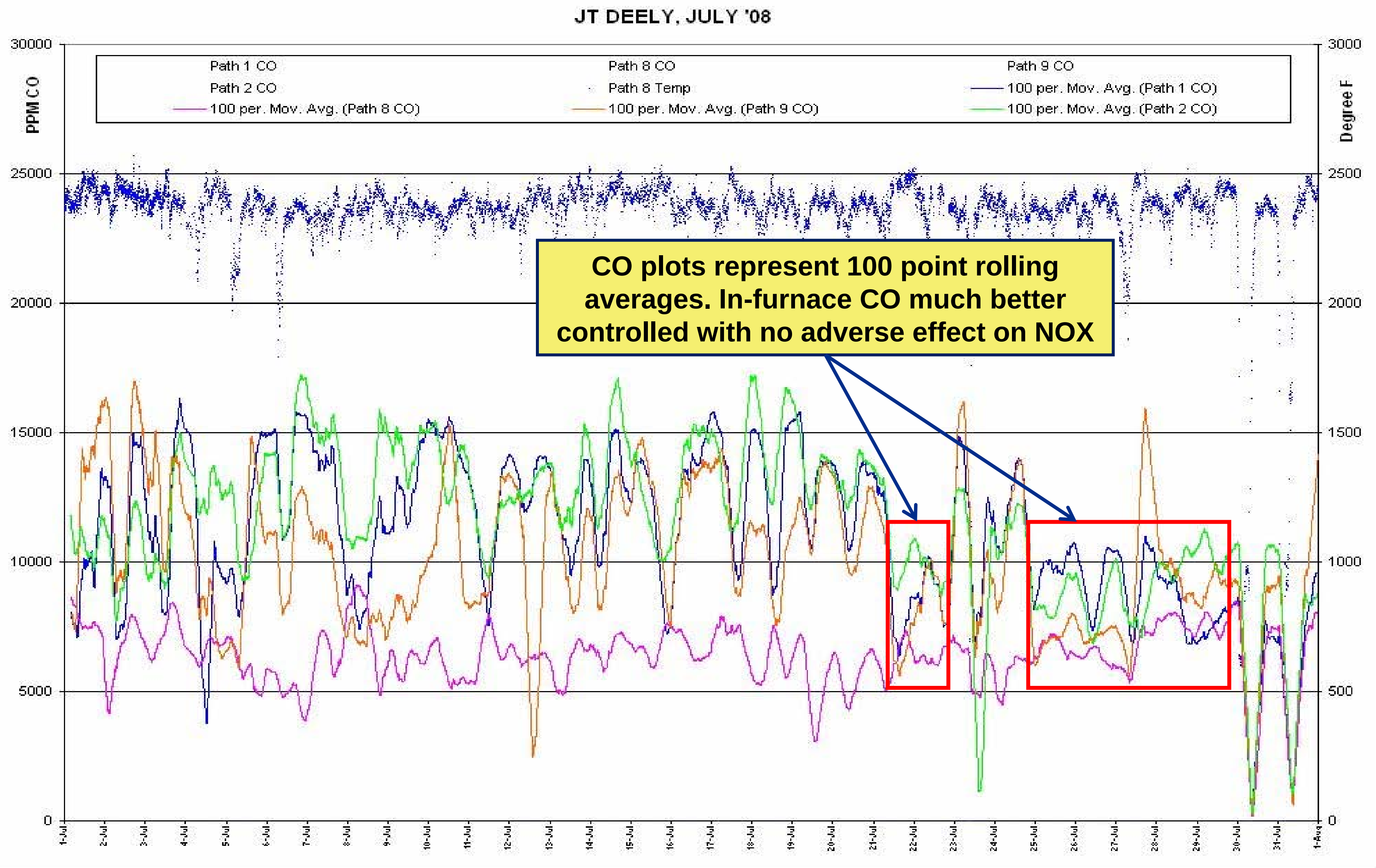
Input: BURNER TILT #1.BURNER TILT

Input: BURNER TILT #2.BURNER TILT #2

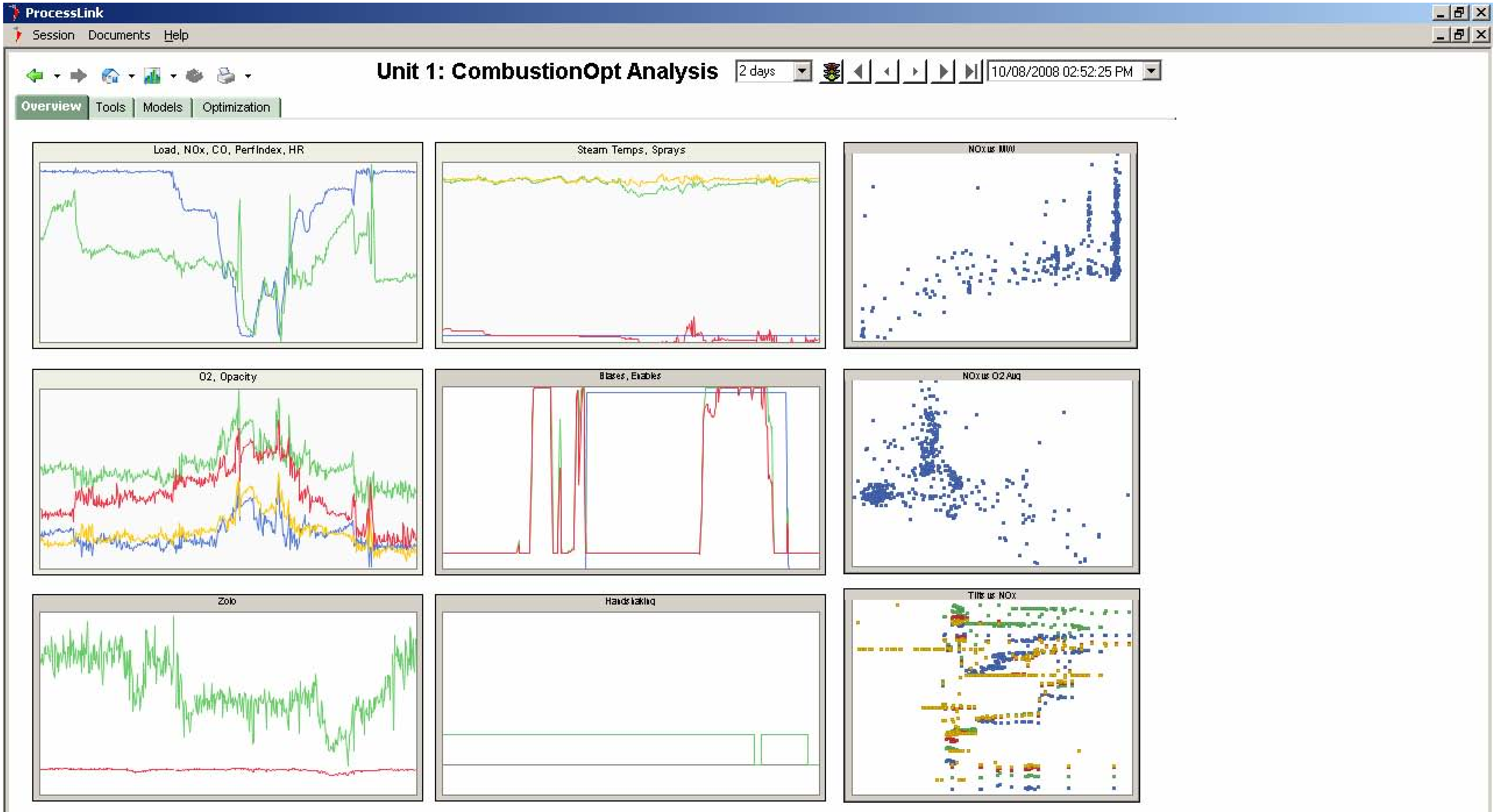
Range: Full Input Rar


JT DEELY, JULY '08
PPM CO
Degree F
Path 1 CO
Path 8 CO
Path 9 CO
Path 2 CO
Path 8 Temp
100 per. Mov. Avg. (Path 1 CO)
100 per. Mov. Avg. (Path 8 CO)
100 per. Mov. Avg. (Path 9 CO)
100 per. Mov. Avg. (Path 2 CO)
30000
25000
20000
15000
10000
5000
0
3000
2500
2000
1500
1000
500
0
1-Jul
2-Jul
3-Jul
4-Jul
5-Jul
6-Jul
7-Jul
8-Jul
9-Jul
10-Jul
11-Jul
12-Jul
13-Jul
14-Jul
15-Jul
16-Jul
17-Jul
18-Jul
19-Jul
20-Jul
21-Jul
22-Jul
23-Jul
24-Jul
25-Jul
26-Jul
27-Jul
28-Jul
29-Jul
30-Jul
31-Jul
1-Aug

Initial Experiments Controlling Zolo In-Furnace CO



CO plots represent 100 point rolling averages. In-furnace CO much better controlled with no adverse effect on NOX

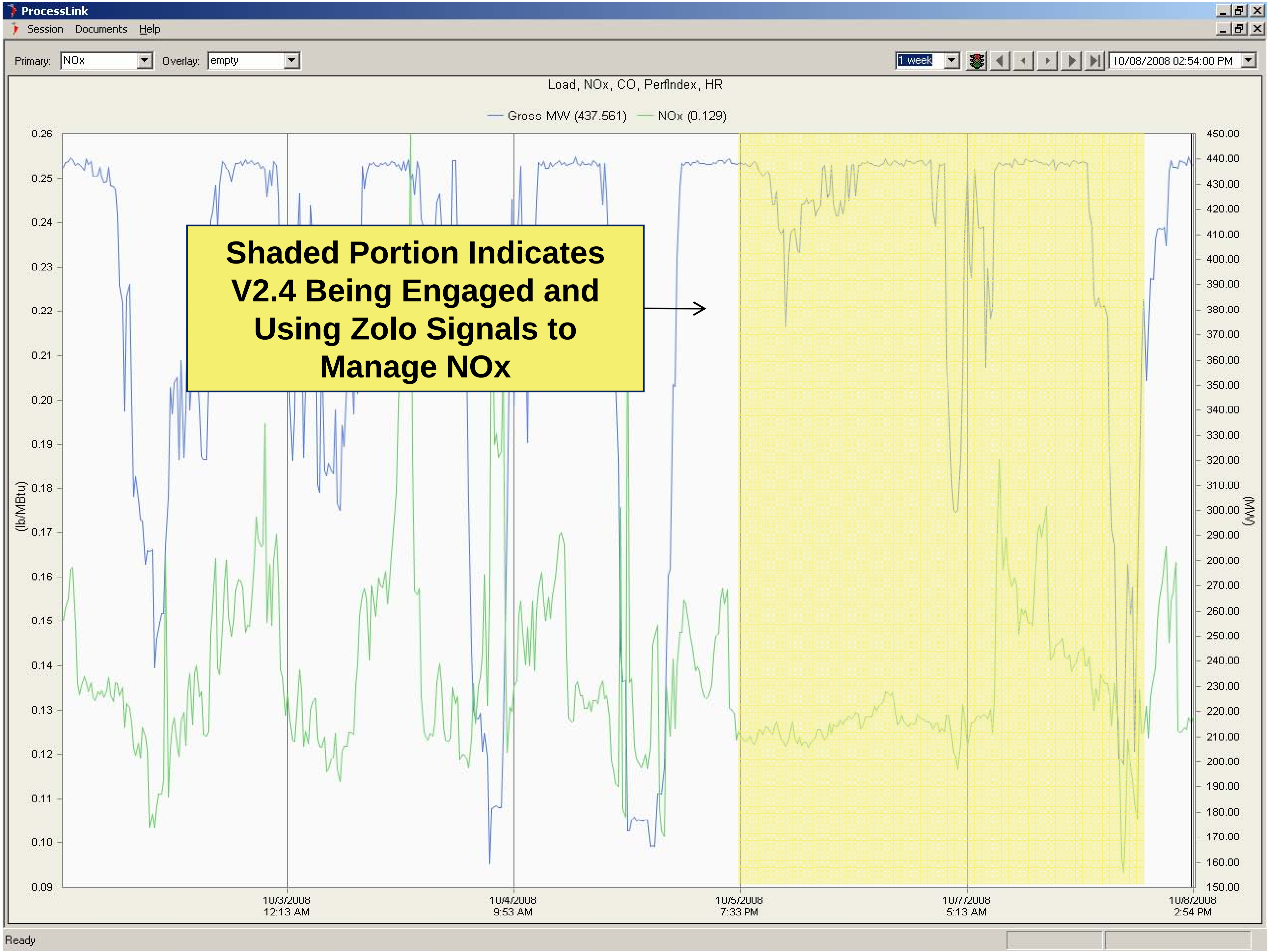


Unit 1: CombustionOpt Analysis

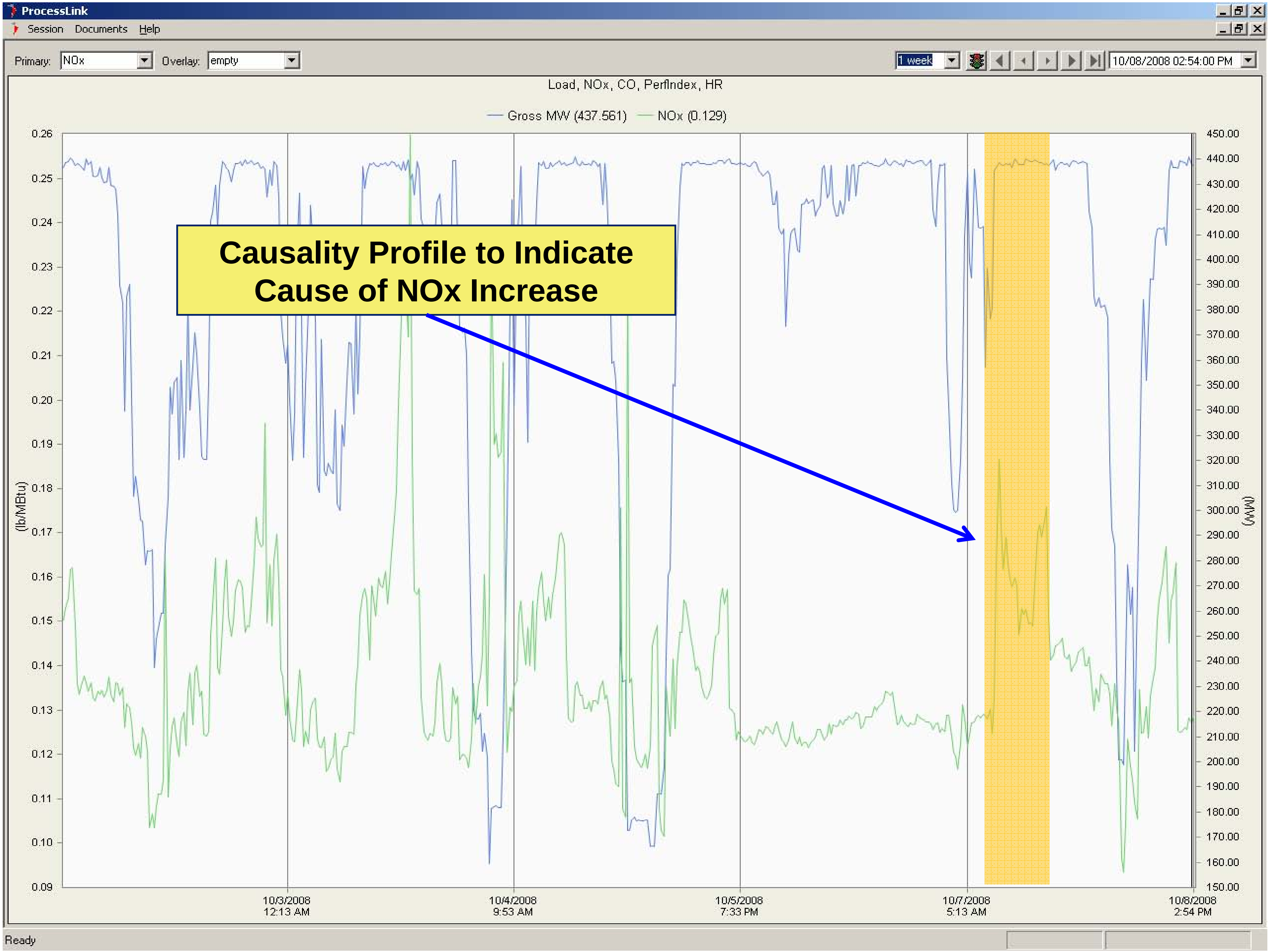
2 days

10/08/2008 02:52:25 PM

CombustionOpt Analysis Screen Shows Overall Unit Operating Parameters Over Selected Span (2 Days)



Shaded Portion Indicates V2.4 Being Engaged and Using Zolo Signals to Manage NOx



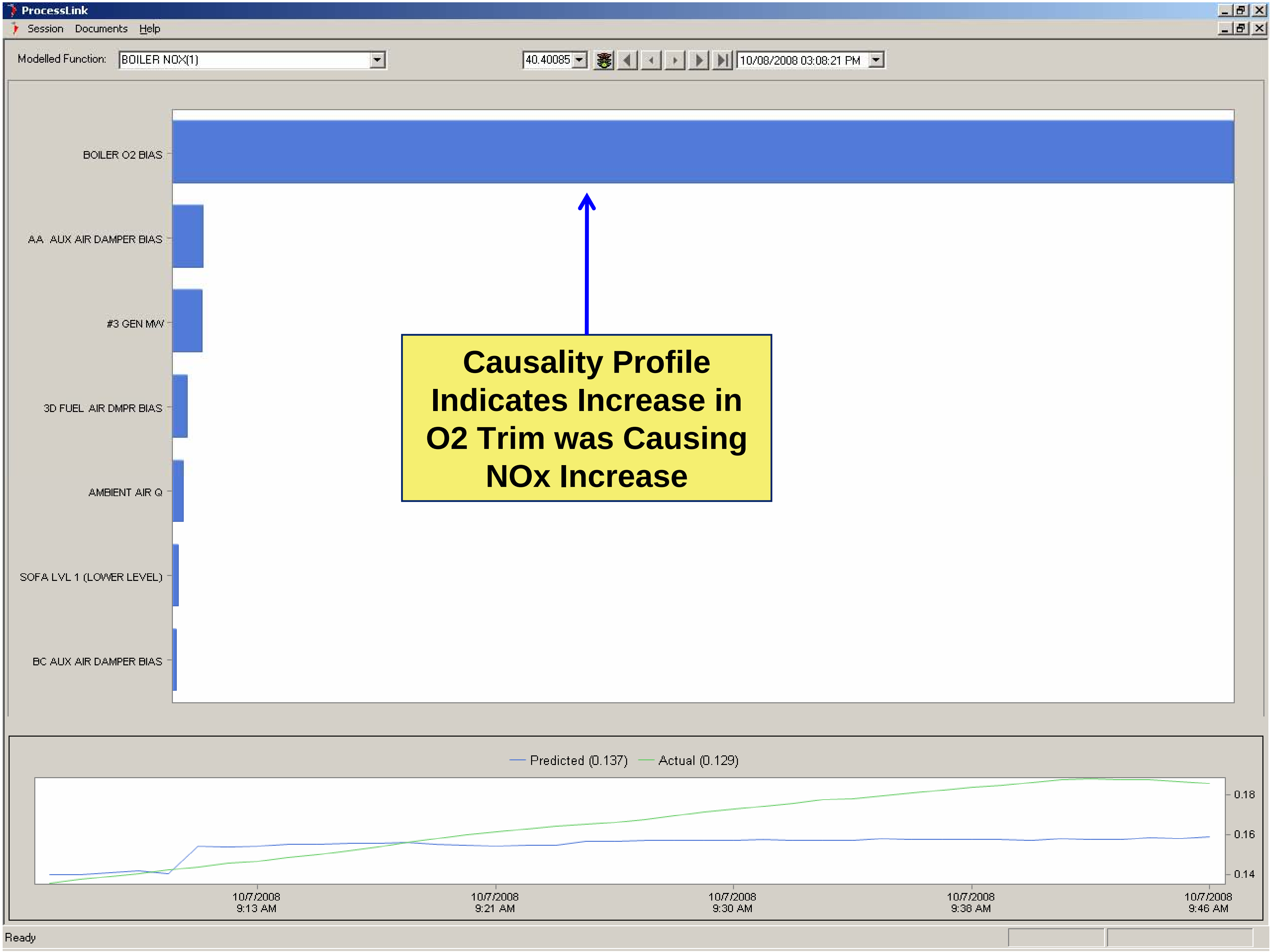
Primary: NOx

Overlay: empty

1 week

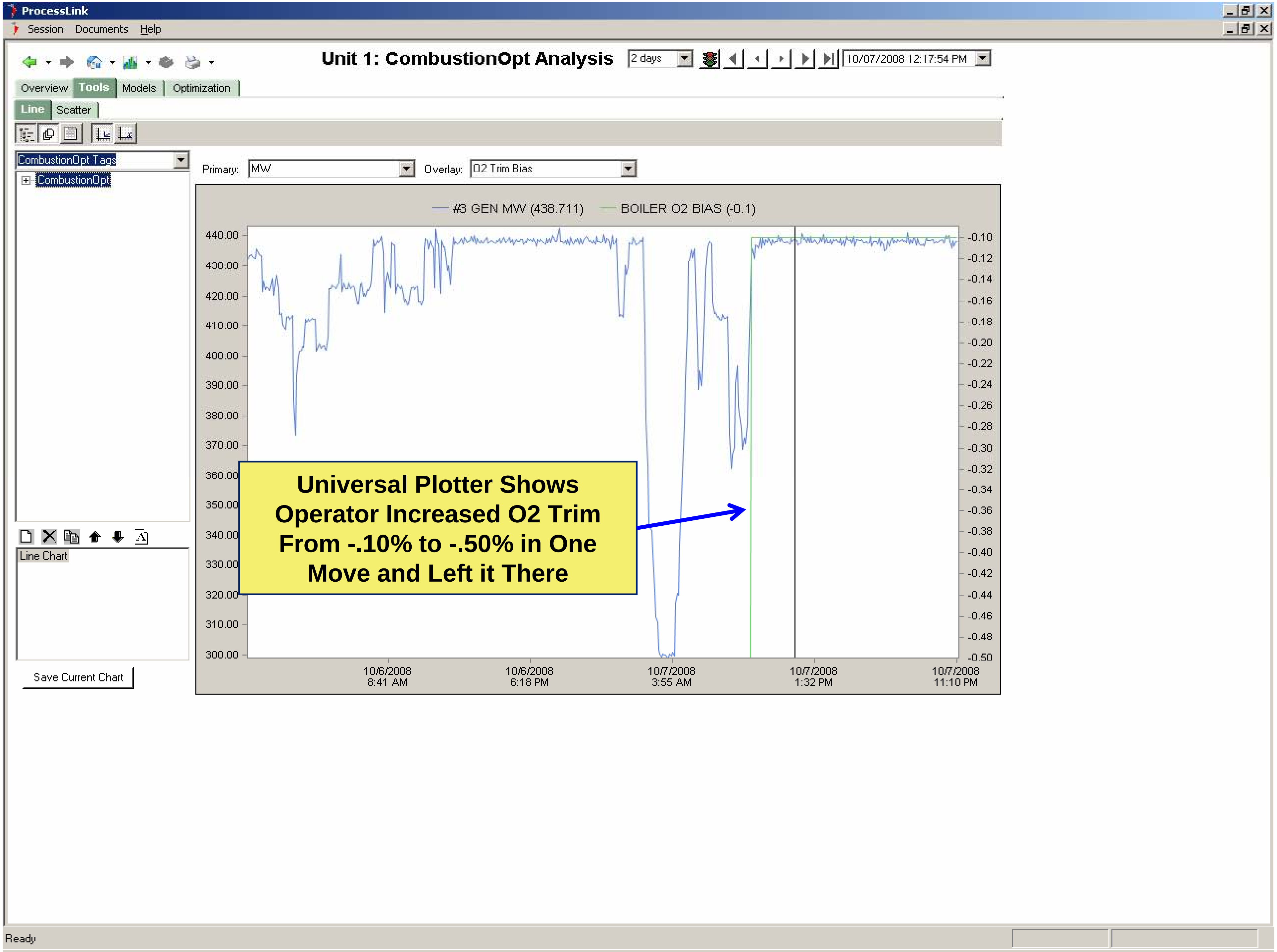
10/08/2008 02:54:00 PM

Causality Profile to Indicate Cause of NOx Increase



Modelled Function: BOILER NOX(1)

Causality Profile Indicates Increase in O2 Trim was Causing NOx Increase



Unit 1: CombustionOpt Analysis

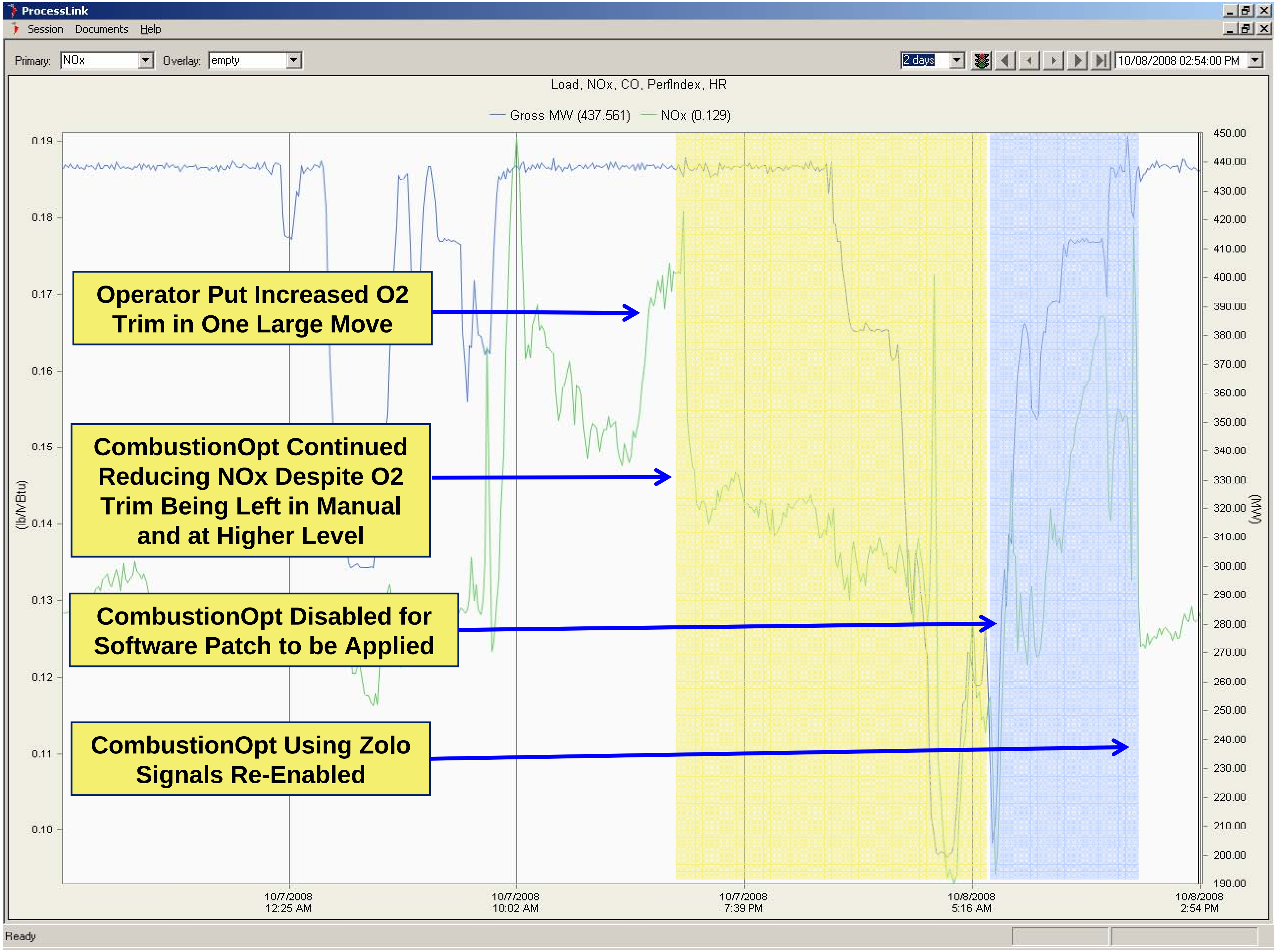
2 days

10/07/2008 12:17:54 PM

Primary: MW

Overlay: O2 Trim Bias

Universal Plotter Shows Operator Increased O2 Trim From -.10% to -.50% in One Move and Left it There

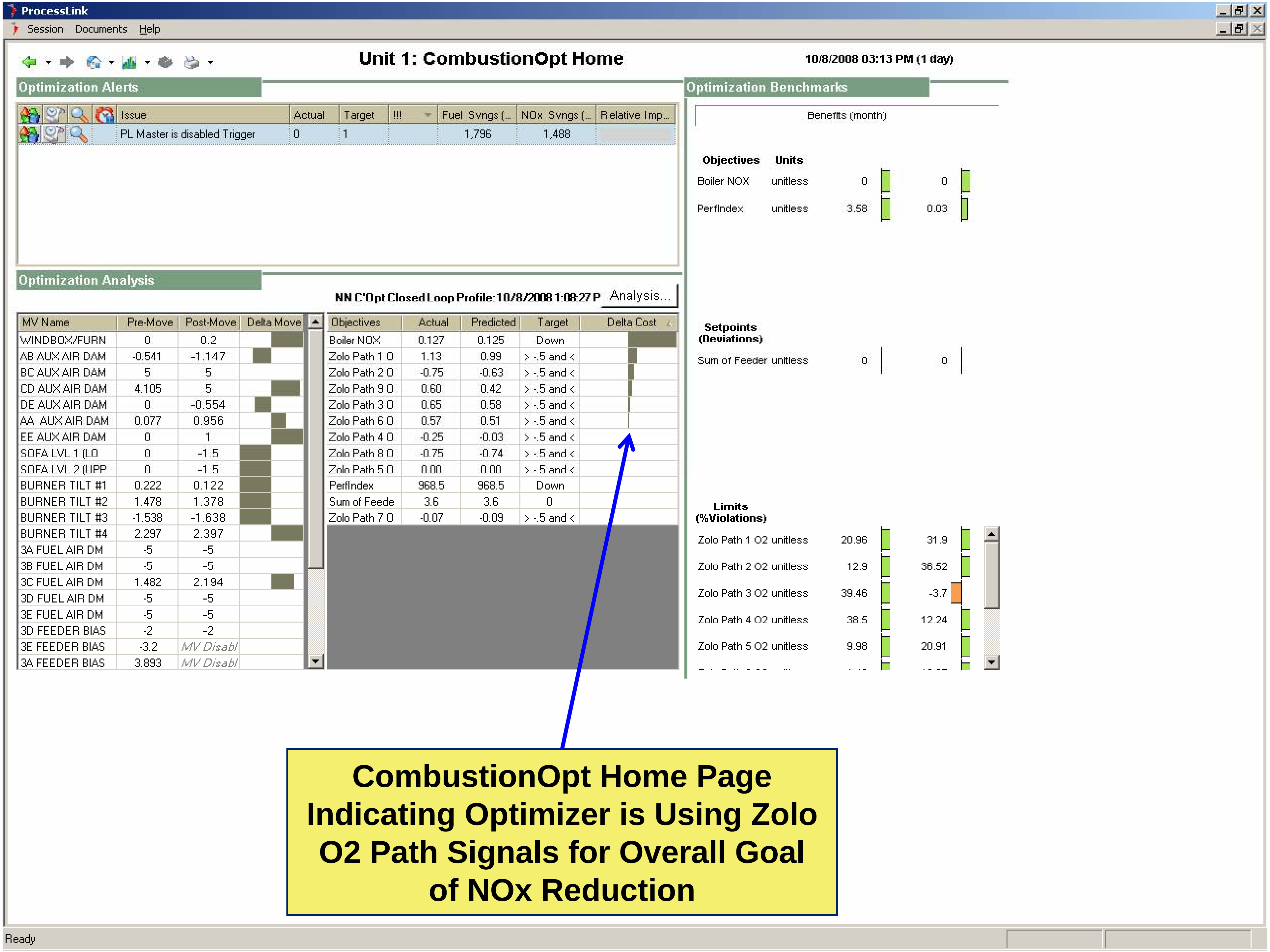


Operator Put Increased O2 Trim in One Large Move

CombustionOpt Continued Reducing NOx Despite O2 Trim Being Left in Manual and at Higher Level

CombustionOpt Disabled for Software Patch to be Applied

CombustionOpt Using Zolo Signals Re-Enabled



Unit 1: CombustionOpt Home

10/8/2008 03:13 PM (1 day)

Optimization Alerts

Issue	Actual	Target	!!!	Fuel Svngs (...	NOx Svngs (...	Relative Imp...
PL Master is disabled Trigger	0	1		1,796	1,488	

Optimization Analysis

NN C'Opt Closed Loop Profile:10/8/2008 1:08:27 P

MV Name	Pre-Move	Post-Move	Delta Move
WINDBOX/FURN	0	0.2	
AB AUX AIR DAM	-0.541	-1.147	
BC AUX AIR DAM	5	5	
CD AUX AIR DAM	4.105	5	
DE AUX AIR DAM	0	-0.554	
AA AUX AIR DAM	0.077	0.956	
EE AUX AIR DAM	0	1	
SOFA LVL 1 (LO	0	-1.5	
SOFA LVL 2 (UPP	0	-1.5	
BURNER TILT #1	0.222	0.122	
BURNER TILT #2	1.478	1.378	
BURNER TILT #3	-1.538	-1.638	
BURNER TILT #4	2.297	2.397	
3A FUEL AIR DM	-5	-5	
3B FUEL AIR DM	-5	-5	
3C FUEL AIR DM	1.482	2.194	
3D FUEL AIR DM	-5	-5	
3E FUEL AIR DM	-5	-5	
3D FEEDER BIAS	-2	-2	
3E FEEDER BIAS	-3.2	*MV Disabl*	
3A FEEDER BIAS	3.893	*MV Disabl*	

Objectives	Actual	Predicted	Target	Delta Cost
Boiler NOX	0.127	0.125	Down	
Zolo Path 1 O	1.13	0.99	> -.5 and <	
Zolo Path 2 O	-0.75	-0.63	> -.5 and <	
Zolo Path 9 O	0.60	0.42	> -.5 and <	
Zolo Path 3 O	0.65	0.58	> -.5 and <	
Zolo Path 6 O	0.57	0.51	> -.5 and <	
Zolo Path 4 O	-0.25	-0.03	> -.5 and <	
Zolo Path 8 O	-0.75	-0.74	> -.5 and <	
Zolo Path 5 O	0.00	0.00	> -.5 and <	
PerfIndex	968.5	968.5	Down	
Sum of Feede	3.6	3.6	0	
Zolo Path 7 O	-0.07	-0.09	> -.5 and <	

Optimization Benchmarks

Benefits (month)

Objectives	Units		
Boiler NOX	unitless	0	0
PerfIndex	unitless	3.58	0.03

Setpoints (Deviations)			
Sum of Feeder	unitless	0	0

Limits (%Violations)			
Zolo Path 1 O2	unitless	20.96	31.9
Zolo Path 2 O2	unitless	12.9	36.52
Zolo Path 3 O2	unitless	39.46	-3.7
Zolo Path 4 O2	unitless	38.5	12.24
Zolo Path 5 O2	unitless	9.98	20.91

Ready

CombustionOpt Home Page Indicating Optimizer is Using Zolo O2 Path Signals for Overall Goal of NOx Reduction

Initial Findings

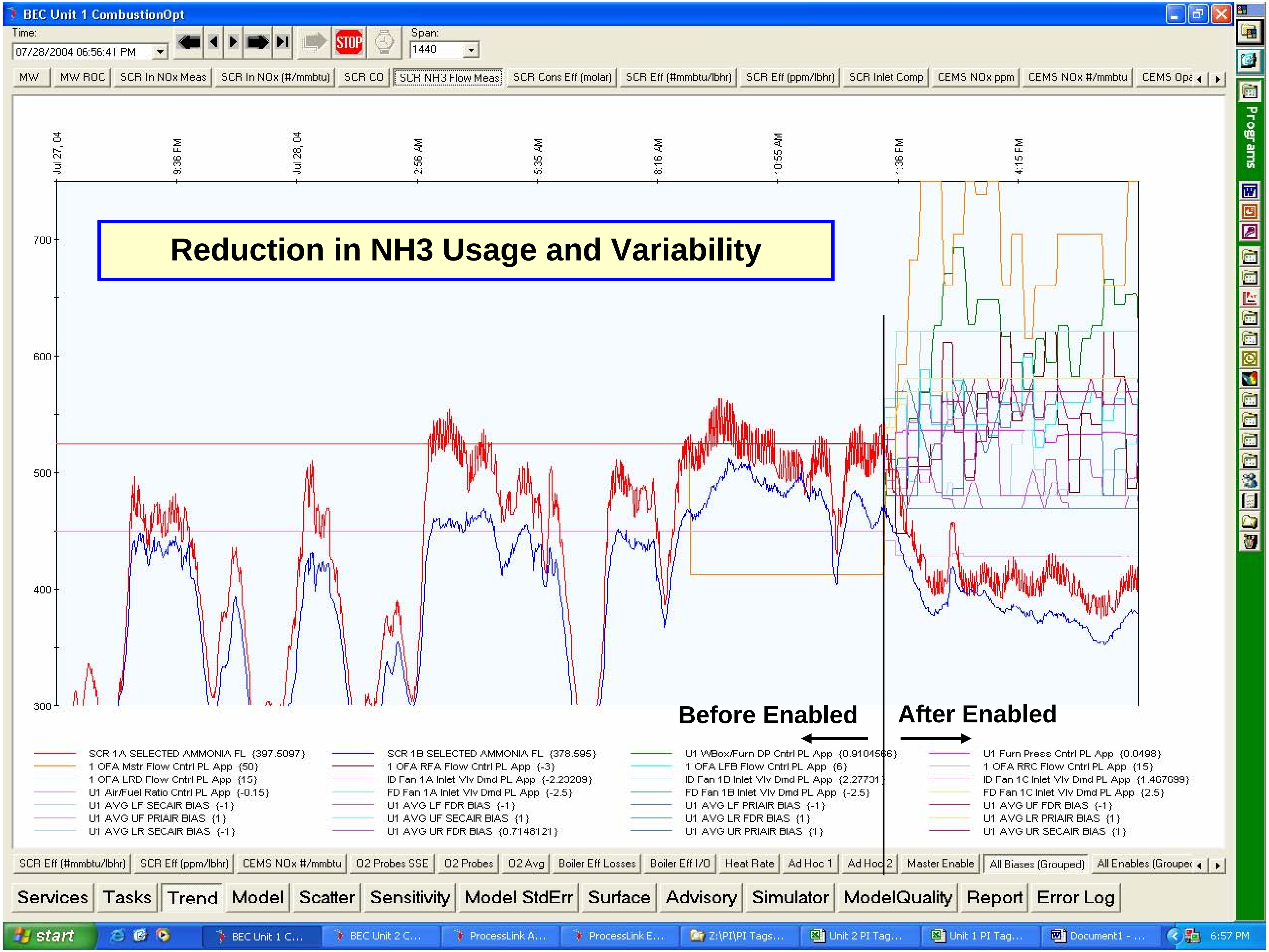
- ZoloBOSS signals are consistent with manual testing and CPS observations
- CombustionOpt able to accurately model ZoloBOSS signals
  - Individual sensors
  - Deviations across paths
- High model quality, in terms of both correlation and normalized mean squared error
- CombustionOpt able to minimize CO and O2 deviations within furnace and use better spatial resolution to better control NOx
- Inadvertent “On vs. Off” test demonstrated benefits

Next Steps

- Continue using Zolo models for optimization
- Employ validated models for optimization
  - Minimize deviation along and across paths
    - O2, CO, furnace temperatures
  - Minimum O2 and/or maximum CO constraints
- Observe impacts of additional inputs and objectives on overall unit performance
  - Incremental NOx and heat rate reduction
  - Tradeoffs between local and global objectives/constraints
- Tune Optimization Profile based on testing and observation
- Quantify initial benefits
- Examine prospects for individual aux air damper biasing

SCR/SNCR Systems & Optimization

- Reduce Reagent Usage
- Lengthen Maintenance Intervals
- Avoid Ammonia Slip
- Reduce risk of Ammonium Bisulfate & Sulfur Trioxide deposits
- Control “Blue-Plume” Excursions
- Better Manage Combustion Combustion syst

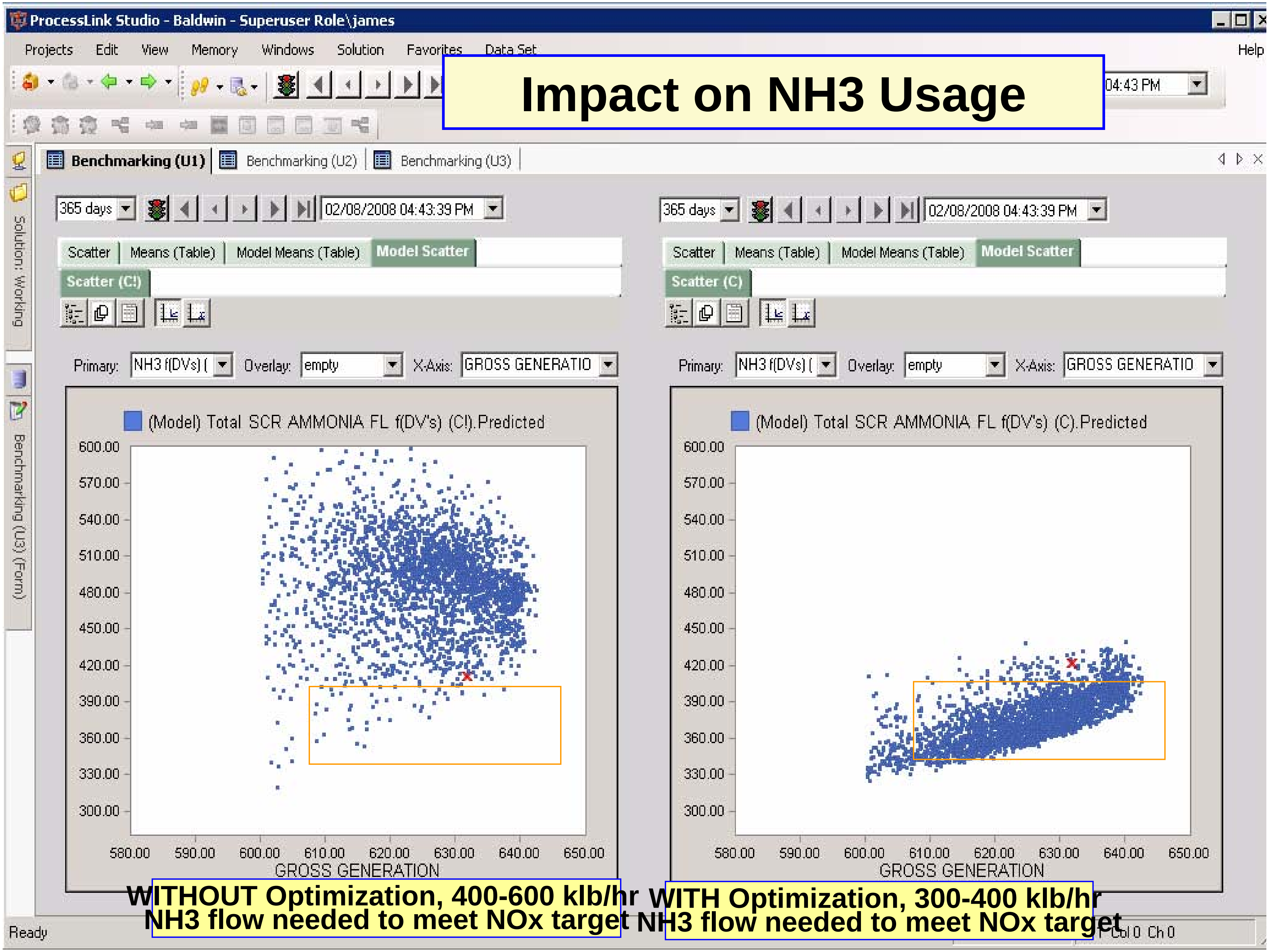


Reduction in NH3 Usage and Variability

Before Enabled ←

After Enabled →

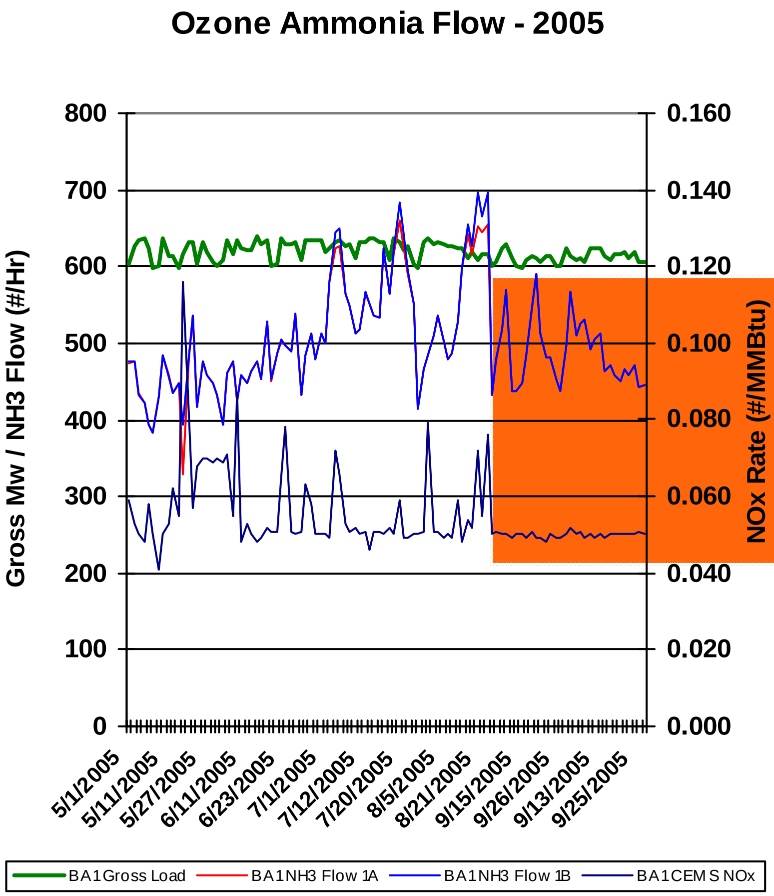
Impact on NH3 Usage



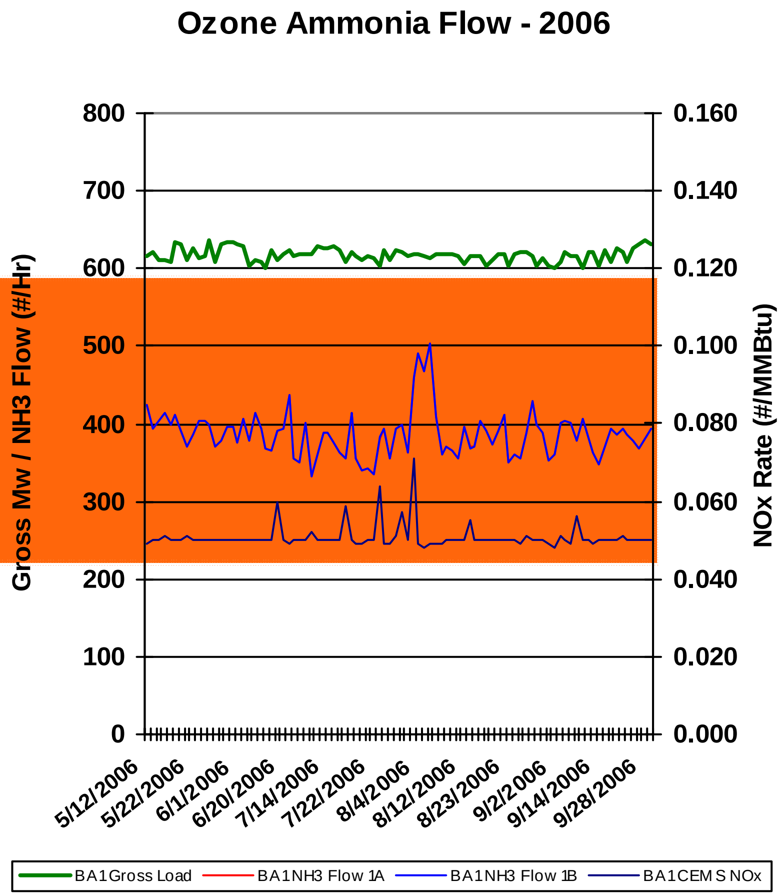
WITHOUT Optimization, 400-600 klb/hr NH3 flow needed to meet NOx target

WITH Optimization, 300-400 klb/hr NH3 flow needed to meet NOx target

Baldwin 1 – Full Load Comparison



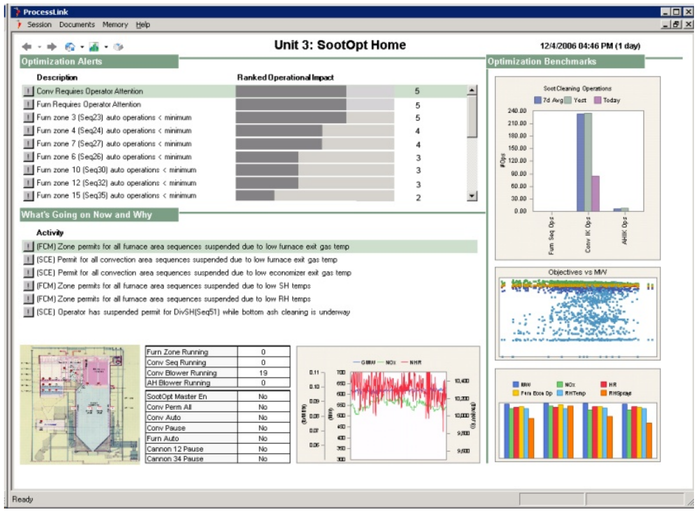
Ozone Ammonia Flow - 2005



Ozone Ammonia Flow - 2006

SootOpt

- **Context:**
  - Sootblowing controls rely on interval-based or operator-initiated cleaning actions, or when using “intelligent” sootblowing systems, rely on zone cleanliness set points, ignoring the fact that optimal heat transfer requires varying cleanliness over time and across zones
- **What SootOpt Does:**
  - Provides real-time closed-loop optimization of unit performance by manipulating all relevant sootblowing controls
- **Using:**
  - Expert systems, neural networks and model predictive control
- **To Achieve:**
  - Reliability, heat rate, steam temp and emissions improvements



Description	Ranked Operational Impact
Conv Requires Operator Attention	5
Furn Requires Operator Attention	5
Furn zone 3 (Seq23) auto operations < minimum	5
Furn zone 4 (Seq24) auto operations < minimum	4
Furn zone 7 (Seq27) auto operations < minimum	4
Furn zone 6 (Seq26) auto operations < minimum	3
Furn zone 10 (Seq30) auto operations < minimum	3
Furn zone 12 (Seq32) auto operations < minimum	3
Furn zone 15 (Seq35) auto operations < minimum	2

What's Going on Now and Why

Activity

- (FCM) Zone permits for all furnace area sequences suspended due to low furnace exit gas temp
- (SCE) Permit for all convection area sequences suspended due to low furnace exit gas temp
- (SCE) Permit for all convection area sequences suspended due to low economizer exit gas temp
- (FCM) Zone permits for all furnace area sequences suspended due to low SH temps
- (FCM) Zone permits for all furnace area sequences suspended due to low RH temps
- (SCE) Operator has suspended permit for DivSH(Seq51) while bottom ash cleaning is underway

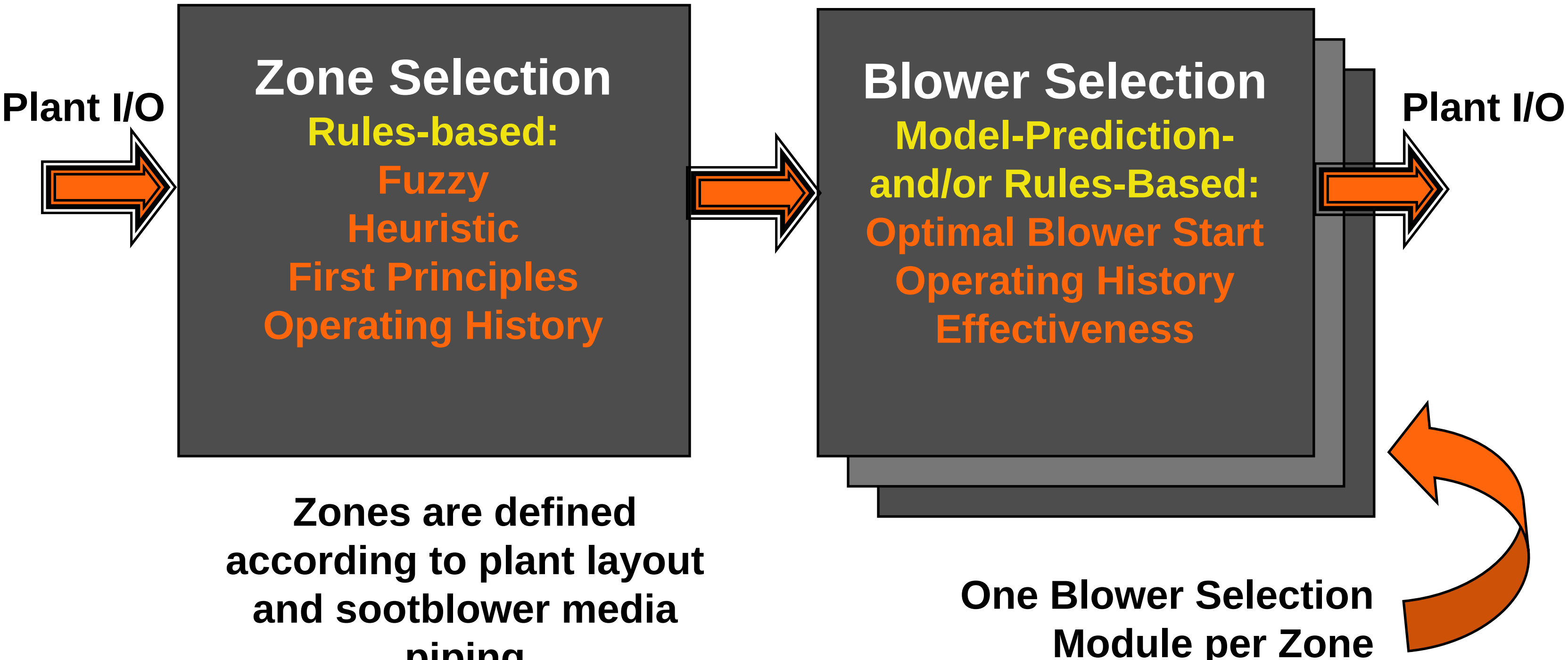
Furn Zone Running	0
Conv Seq Running	0
Conv Blower Running	19
AH Blower Running	0

SootOpt Master En	No
Conv Perm All	No
Conv Auto	No
Conv Pause	No
Furn Auto	No
Cannon 12 Pause	No
Cannon 34 Pause	No

Overview: What SootOpt does

- Improves heat rate
  - by improving heat transfer and heat transfer distribution
  - Be improving steam temperature control
  - by reducing use of attemperation spray and sootblowing media (steam, water, air)
- Improves availability
  - Reduced blowing reduces tube erosion and thermal fatigue
- Improves NOx control
  - through improved heat transfer, reduction of “hot spots”, and reduced firing intensity
- Reduces opacity violations
  - by using opacity data in decision-making
- Reduces operator workload and improves shift-to-shift consistency

Overview: How SootOpt Works



Plant I/O

Zone Selection

Rules-based:

Fuzzy

Heuristic

First Principles

Operating History

Blower Selection

Model-Prediction-and/or Rules-Based:

Optimal Blower Start

Operating History

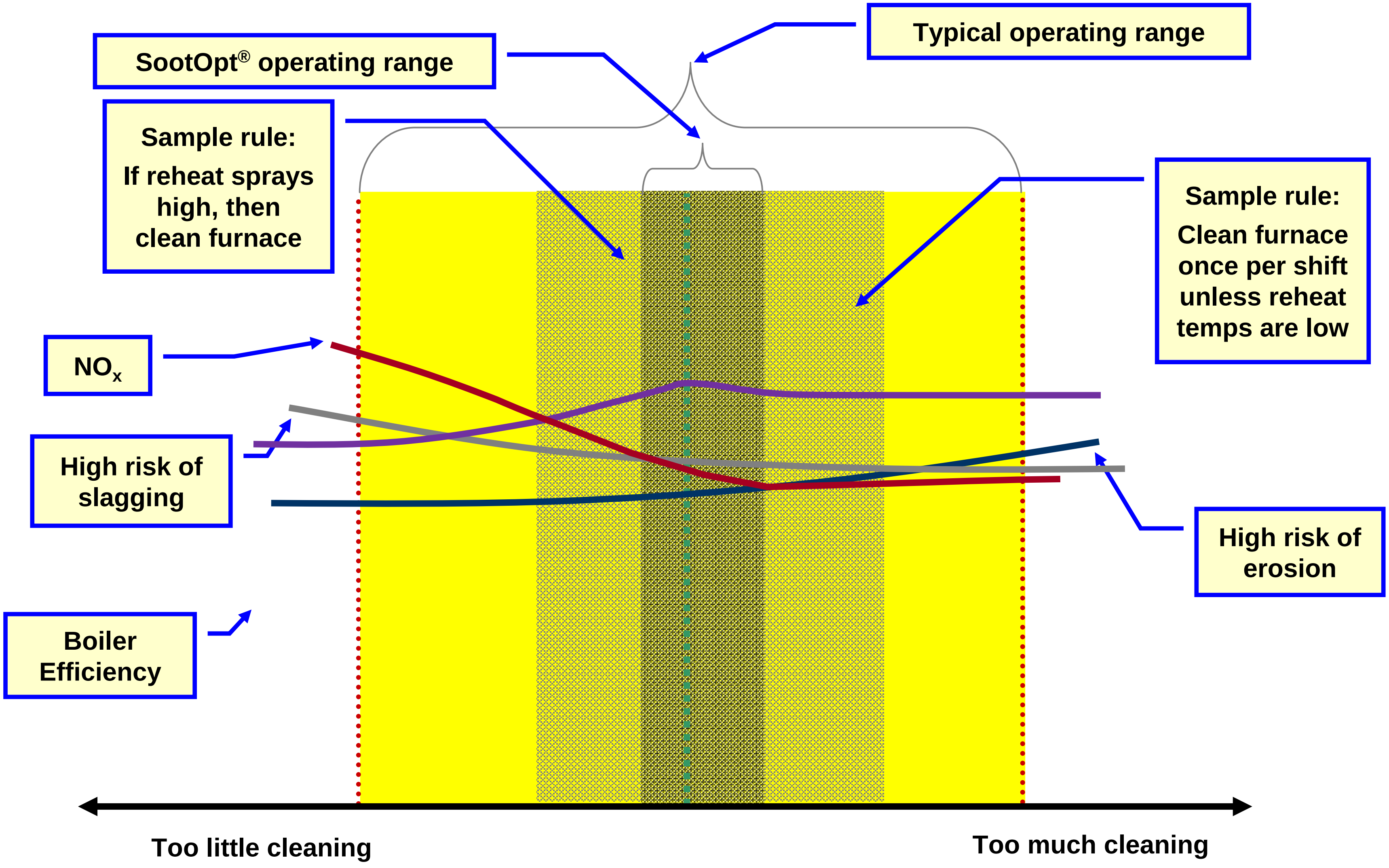
Effectiveness

Plant I/O

Zones are defined according to plant layout and sootblower media piping

One Blower Selection Module per Zone

Sootblower Optimization



Typical operating range

SootOpt® operating range

Sample rule:
If reheat sprays high, then clean furnace

Sample rule:
Clean furnace once per shift unless reheat temps are low

NO_x

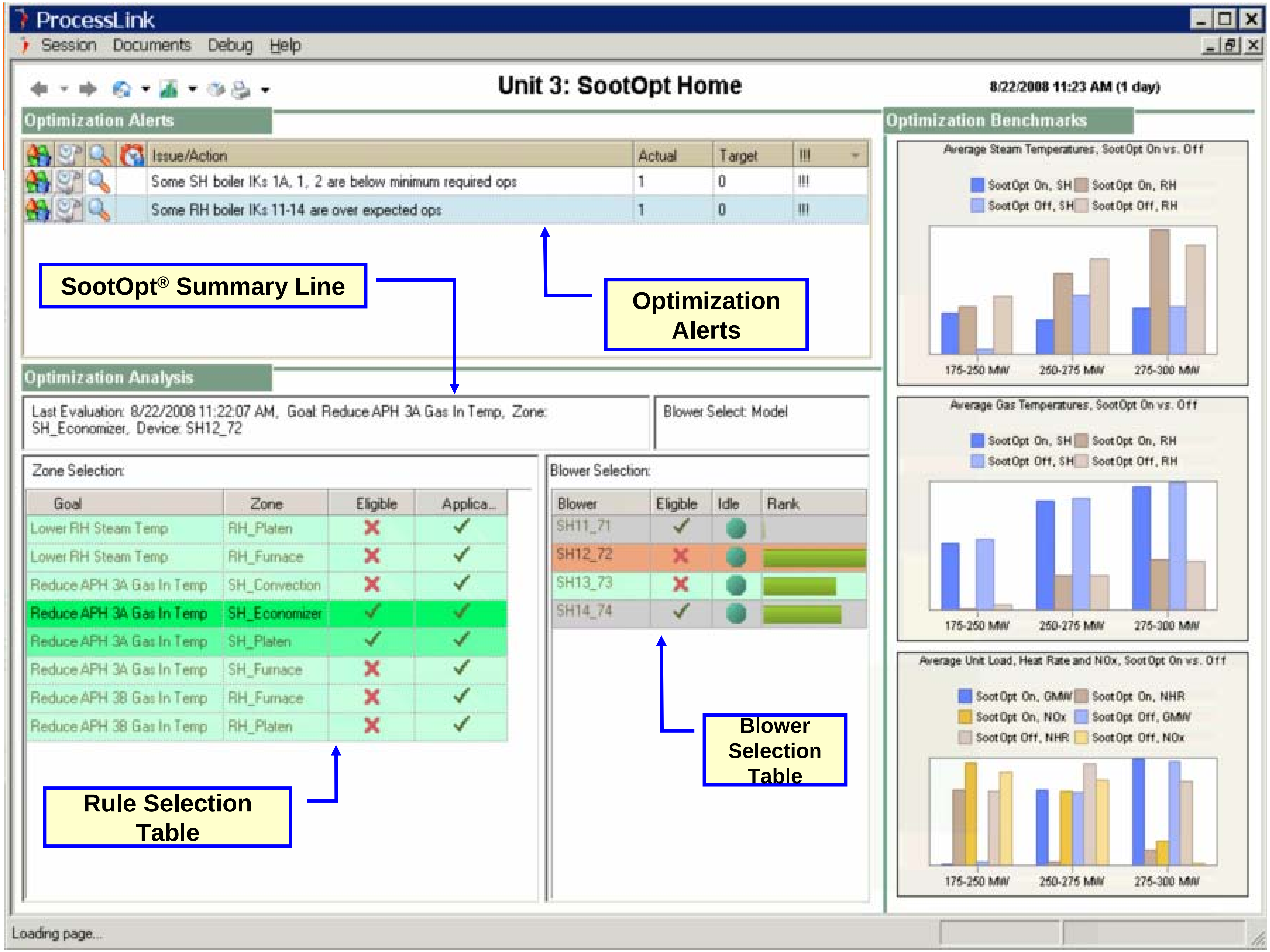
High risk of slagging

High risk of erosion

Boiler Efficiency

Too little cleaning

Too much cleaning



Unit 3: SootOpt Home

8/22/2008 11:23 AM (1 day)

Issue/Action	Actual	Target	!!!
Some SH boiler IKs 1A, 1, 2 are below minimum required ops	1	0	!!!
Some RH boiler IKs 11-14 are over expected ops	1	0	!!!

SootOpt® Summary Line

Optimization Alerts

Last Evaluation: 8/22/2008 11:22:07 AM, Goal: Reduce APH 3A Gas In Temp, Zone: SH_Economizer, Device: SH12_72

Blower Select: Model

Zone Selection:

Goal	Zone	Eligible	Applica...
Lower RH Steam Temp	RH_Platen	✗	✓
Lower RH Steam Temp	RH_Furnace	✗	✓
Reduce APH 3A Gas In Temp	SH_Convection	✗	✓
Reduce APH 3A Gas In Temp	SH_Economizer	✓	✓
Reduce APH 3A Gas In Temp	SH_Platen	✓	✓
Reduce APH 3A Gas In Temp	SH_Furnace	✗	✓
Reduce APH 3B Gas In Temp	RH_Furnace	✗	✓
Reduce APH 3B Gas In Temp	RH_Platen	✗	✓

Blower Selection:

Blower	Eligible	Idle	Rank
SH11_71	✓	●	
SH12_72	✗	●	🟩
SH13_73	✗	●	🟩
SH14_74	✓	●	🟩

Rule Selection Table

Blower Selection Table

Loading page...

Meramec APH Temps - SootOpt ON-OFF Comparison

Air Preheater 3A Gas Inlet Temperature Frequency Distribution and Percentage Change

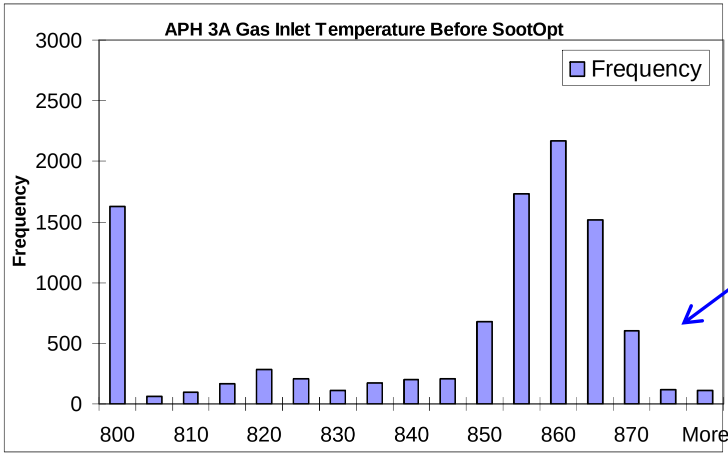
APH 3A Temp Ranges (DegF)	Before SootOpt Frequency	After SootOpt Frequency	% Change
800	1631	2685	-64.62
805	62	81	-30.65
810	99	48	51.52
815	167	66	60.48
820	281	58	79.36
825	205	50	75.61
830	109	67	38.53
835	173	49	71.68
840	198	81	59.09
845	206	427	-107.28
850	676	1213	-79.44
855	1732	2267	-30.89
860	2167	1674	22.75
865	1515	946	37.56
870	605	240	60.33
875	116	69	40.52
More	108	29	73.15

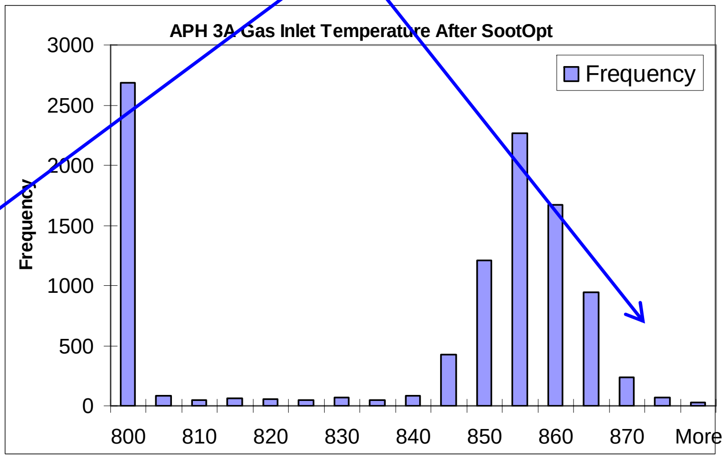
Notes

Positive % Change = decrease in occurrence frequency

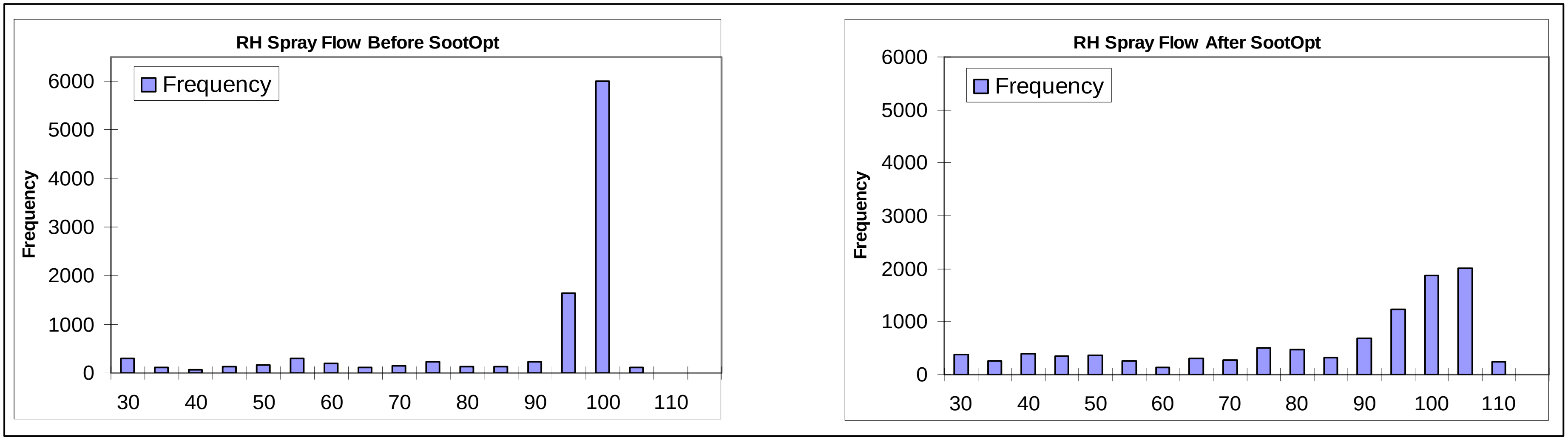
Negative % Change = increase in occurrence frequency

Better Control Over APH Inlet Temps is Providing 25 MW Capacity Increase





Meramec RH Sprays - SootOpt ON-OFF Comparison


RH Spray Flow Before SootOpt

RH Spray Flow After SootOpt

Summary of Meramec SootOpt Benefits

- Narrowed superheat and reheat steam temperature variability and moved closer to setpoint
- Simultaneously reduced attemperation sprays
- Reduced manually blowing of three lances in less than half
- No erosion-related tube leaks in at least *seven months*, relative to history of every 2-8 weeks
- Improved the operators' effectiveness:
  - Before, operators had to manually manage sootblowing
  - Now they operators spend very little time managing sootblowing.
  - “We just put in SootOpt and let it fly.”