

NPCC NO_x Workshop

Artificial Intelligence for Supervisory Control of Coal-Fired Electric Utility Boilers For NO_x Reduction and Heat Rate Improvement

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Pegasus Technologies



Leaders in Combustion Optimization for the Power Industry

Pegasus Technologies

- Headquarters in Ohio, USA
- Globally established
 - North America
 - Asia
 - Europe
- Experienced Staff for Power Market
 - Engineers: Combustion, Advanced Controls, IT

Pegasus Products

- **Optimization and Advanced Controls**
 - **Discovery N-Net - NeuSIGHT**
 - **MPC N-Net Control – Power Perfecter**
- **Performance and Sensors**
 - **Advanced Instrument Calibration Monitoring**
 - **Boiler Performance and Cleanliness**
 - **Virtual Carbon in Ash Sensor**
 - **Fuel Blending for units with reclaim tunnels**

Intelligent systems can be utilized to control the plant for

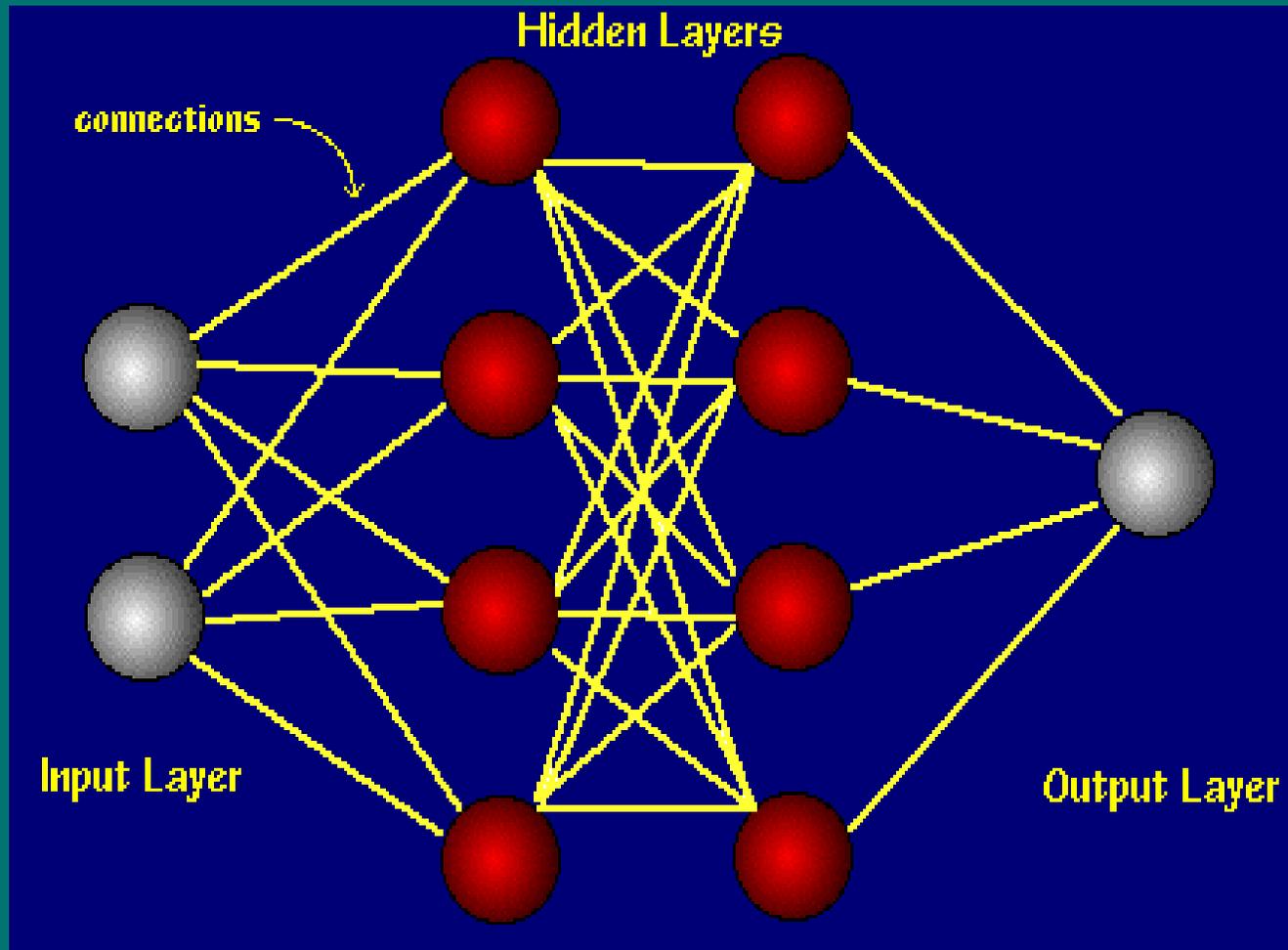
- **Reduced Coal Consumption**
- **Reduced Environmental Emissions (NO_x, SO₂, CO₂)**
- **Ash (C content, heat absorption, slag, fouling)**
- **Fuel (quality, blending)**
- **Reduction of Equipment Failures / Unplanned Outages**
- **Sootblower (sequencing, optimization)**
- **Optimum Benefit through Closed-Loop Operation**

Neural Networks

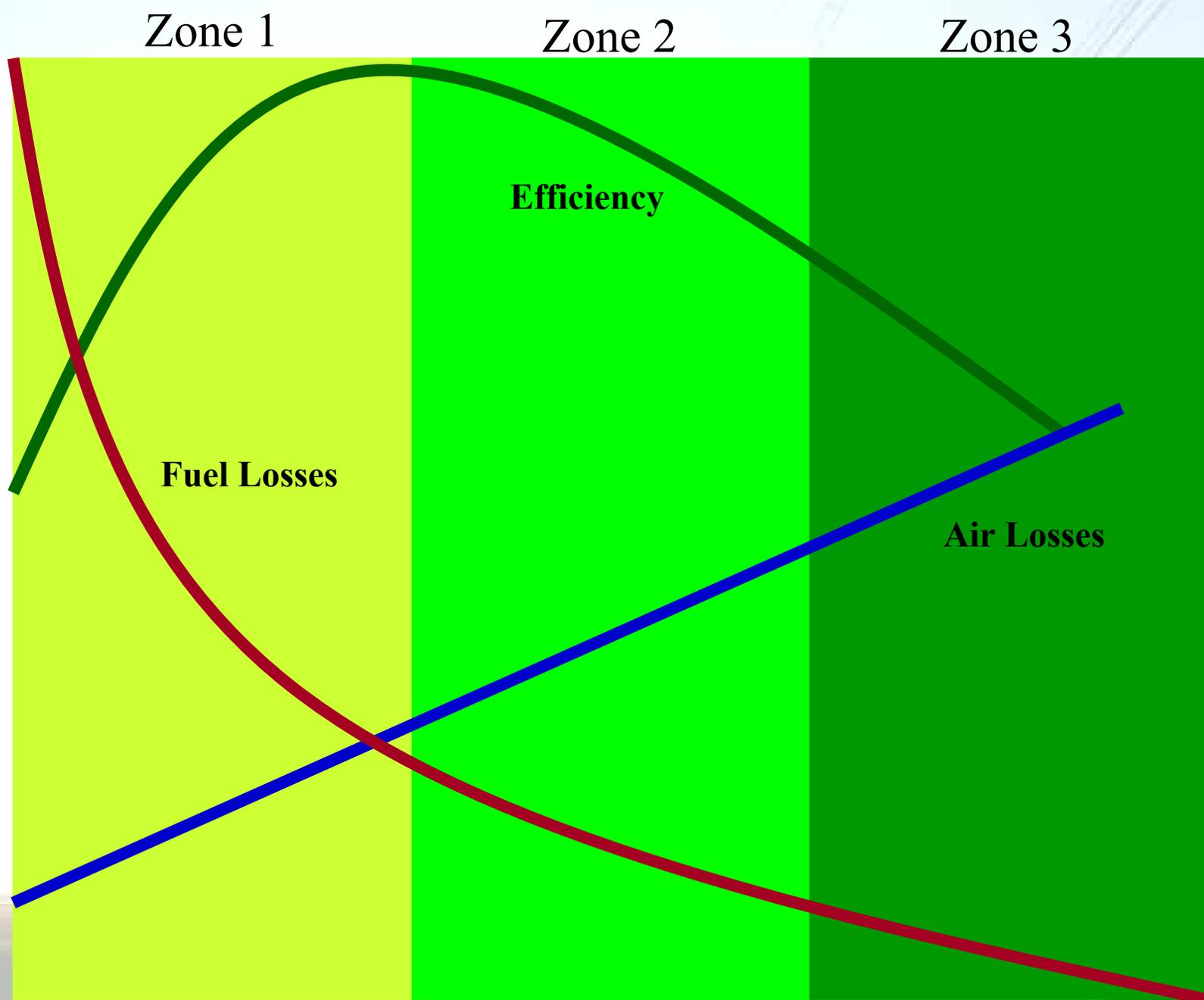
- Applied to Empirically Model Data
- Applied for Non-Linear Relationships
- Applied for Complex (multi-dimensional) relationships

Artificial Neural Networks

Neural Network



Combustion Optimization

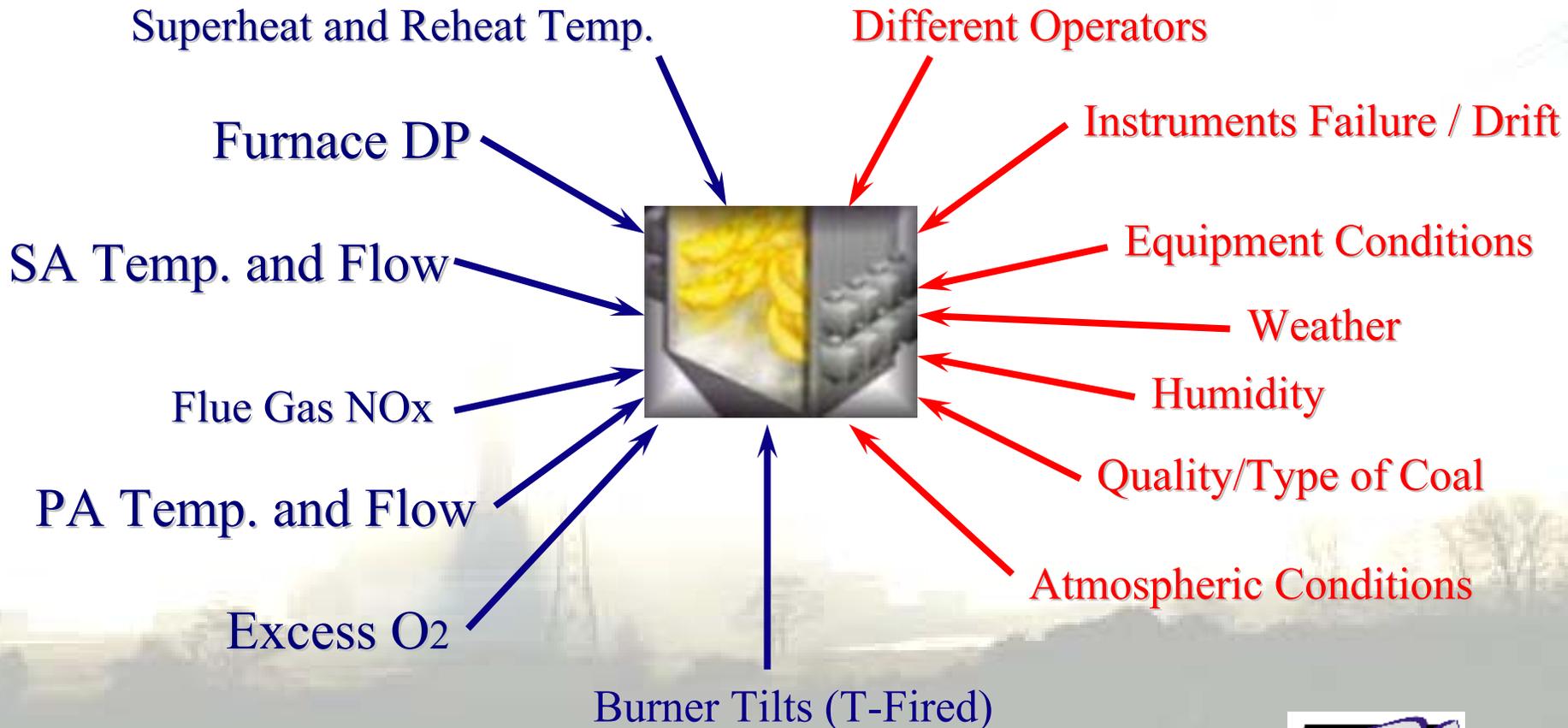


Combustion Optimization Challenge

- **To achieve the optimal combustion model - the system manages and analyzes up to 1500 or more inputs**
- **The system accurately models the complex interrelationships among 5-60 controllable parameters**
- **Optimization occurs within constraints of the operating environment**
- **The system responds to changing environmental and operational conditions**

Combustion Dynamics

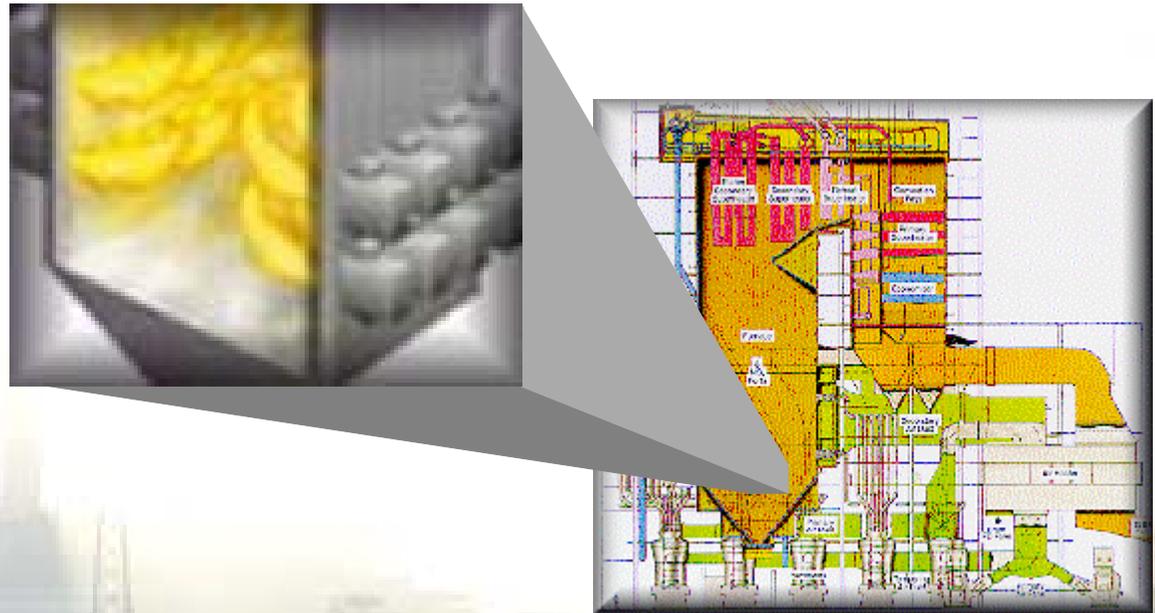
The Complex Relationships of Multiple Variables That Are Continuously Changing ... Dramatically Impact Combustion



Multiple Objectives

Combustion is Continuously Optimized Based On Changing Plant Conditions and your Unit Specific Operation Objectives...

NOx Output
Heat Rate
Capacity
Opacity
LOI



Objectives can be weighted for different seasonal operations.

Pegasus Solution for Dynamic Optimization

- Pegasus's Proven Dynamic Systems

- Data model and optimization is developed around a historical plant for predictive multi-variate control (1)
- Predictive technology is used to tighten control of combustion (1)
- Model optimizes combustion across all load ranges (1,2)
- Learns on its own new solutions for optimized results (1,2)
- Self-tuning insures optimization integrity during normal shifts (2)
- Global optimization for improved control of operating conditions (2)

- Note: Retraining still required for Major control or boiler modifications

1 = MPC dynamic control solution

2 = GESA dynamic search solution



Pegasus Closed-Loop



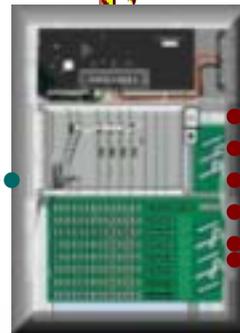
**Up to 1500 Current Inputs From DCS
Continuously Collected and Analyzed**

**Pegasus
Computer**

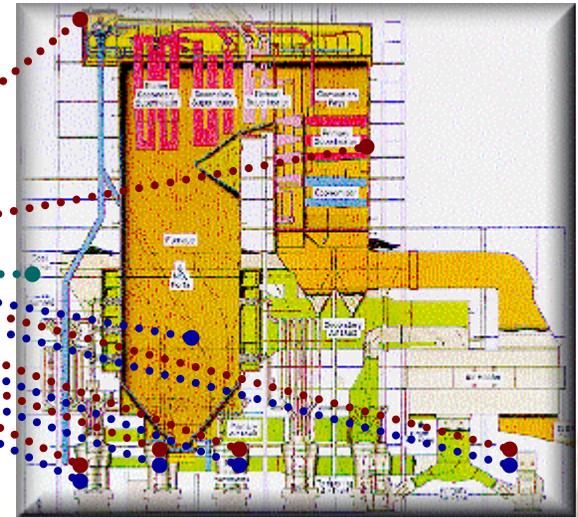
**5-60 Controllable Output Bias Settings
Automatically Sent To DCS as required**



**Control Room
Operator**

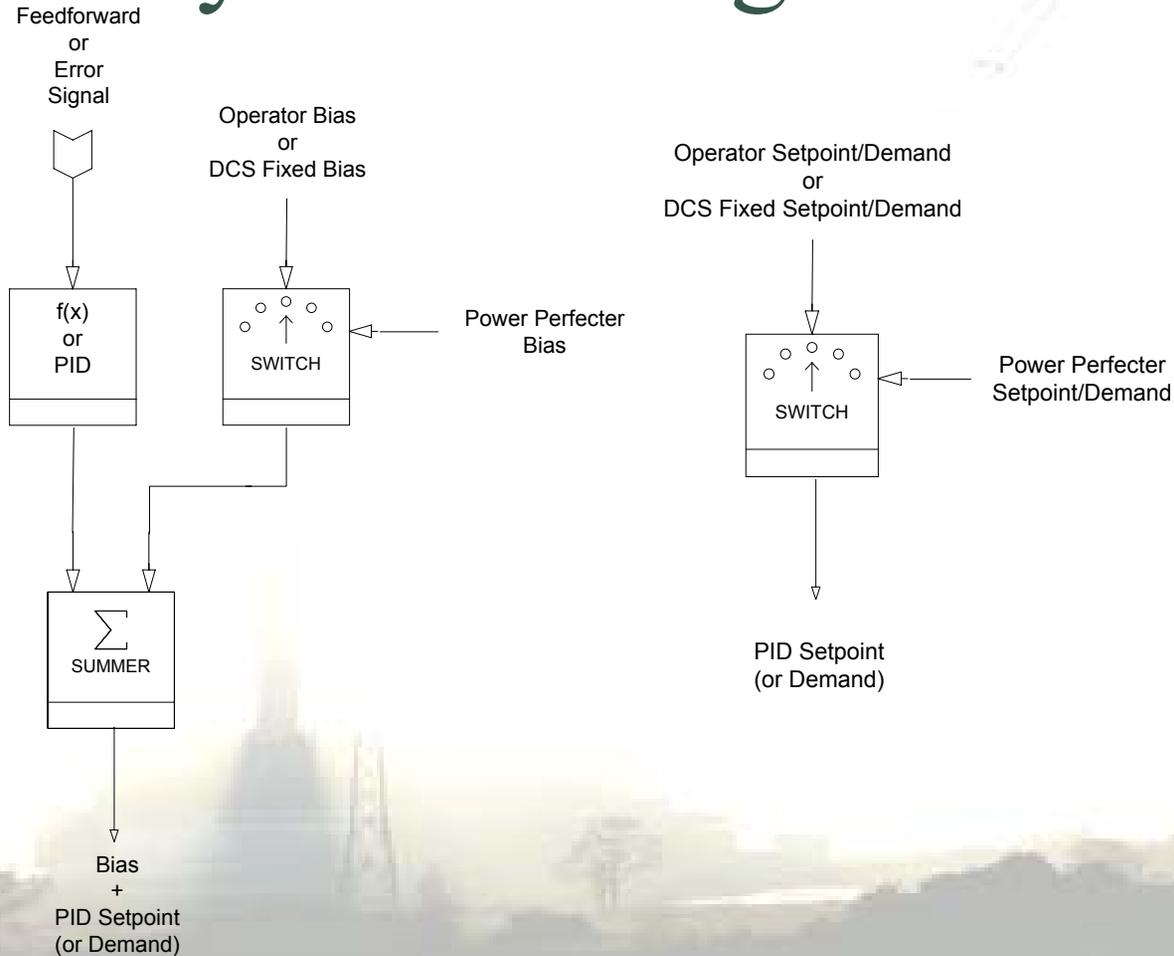


DCS



Field Sensors and Drives

Systems Integration



NeuSIGHT™ and Power Perfecter™

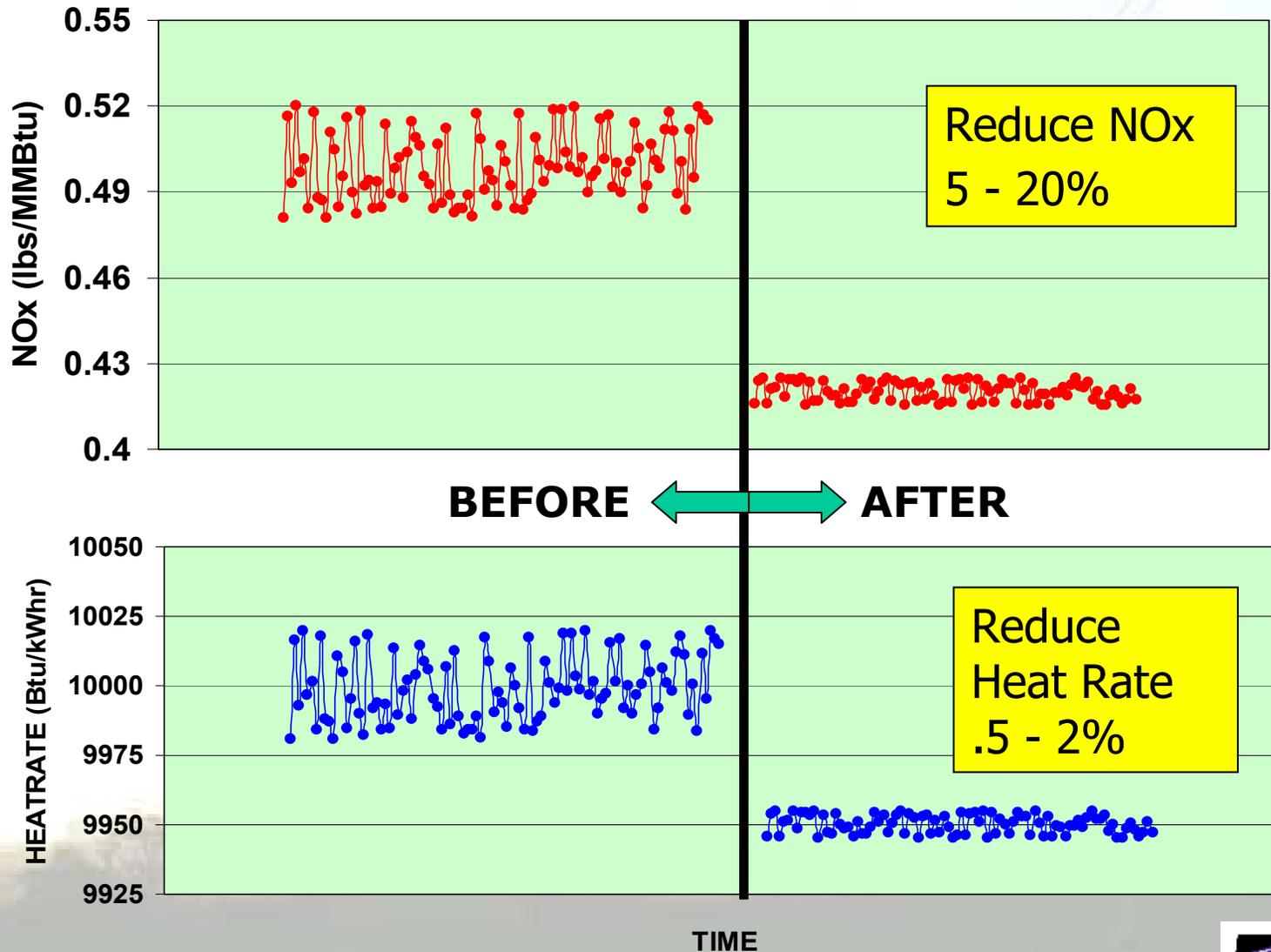
Products implemented as a supervisory control

1. It depends on DCS to do regulatory and coordination control
2. It works in separate Hardware
3. It does not handle or interfere with DCS's safety and interlock work.
4. It doesn't change DCS control Strategy and Philosophy.

Results

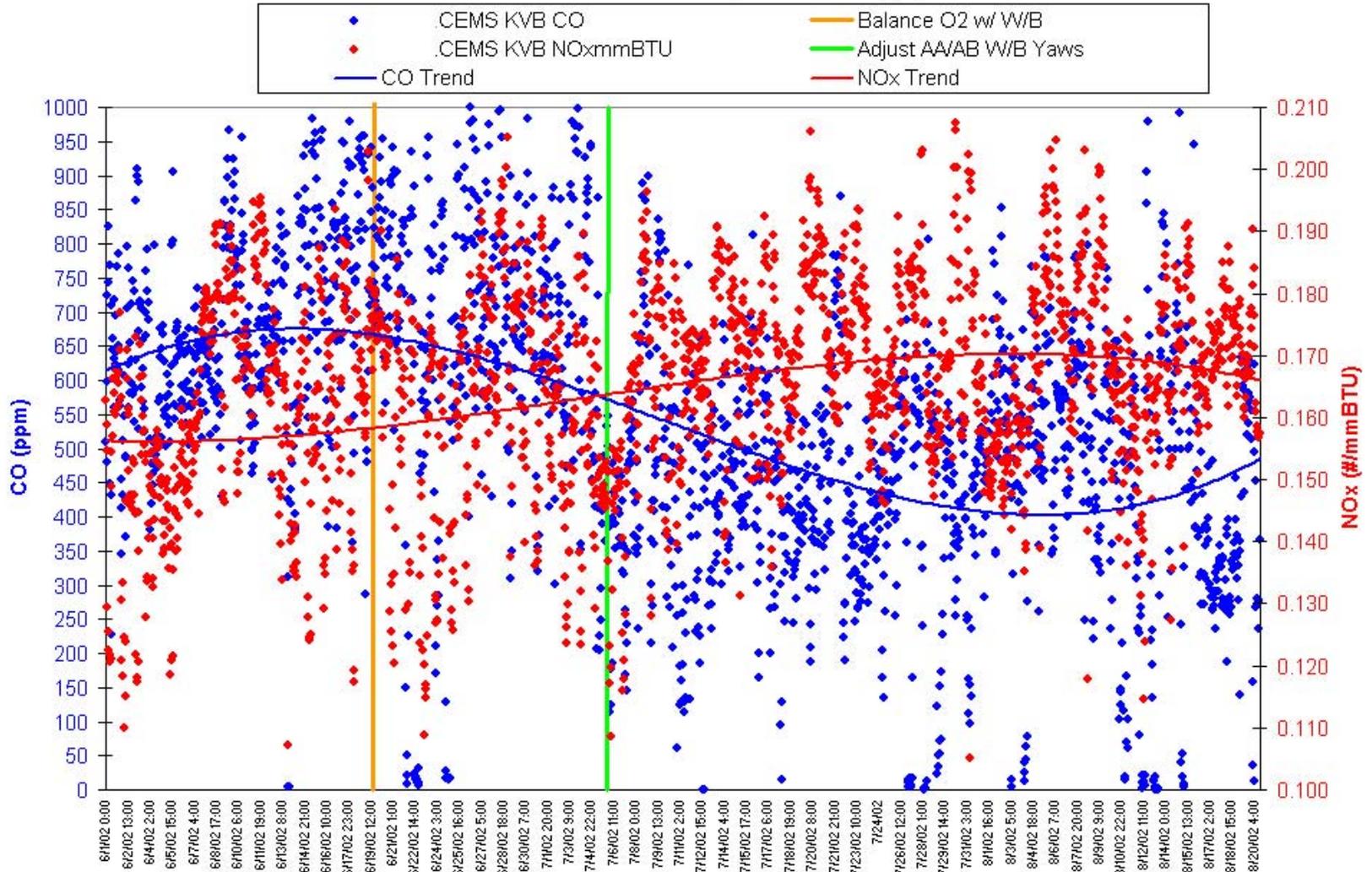


Boiler Optimization NOx & Heat Rate Control



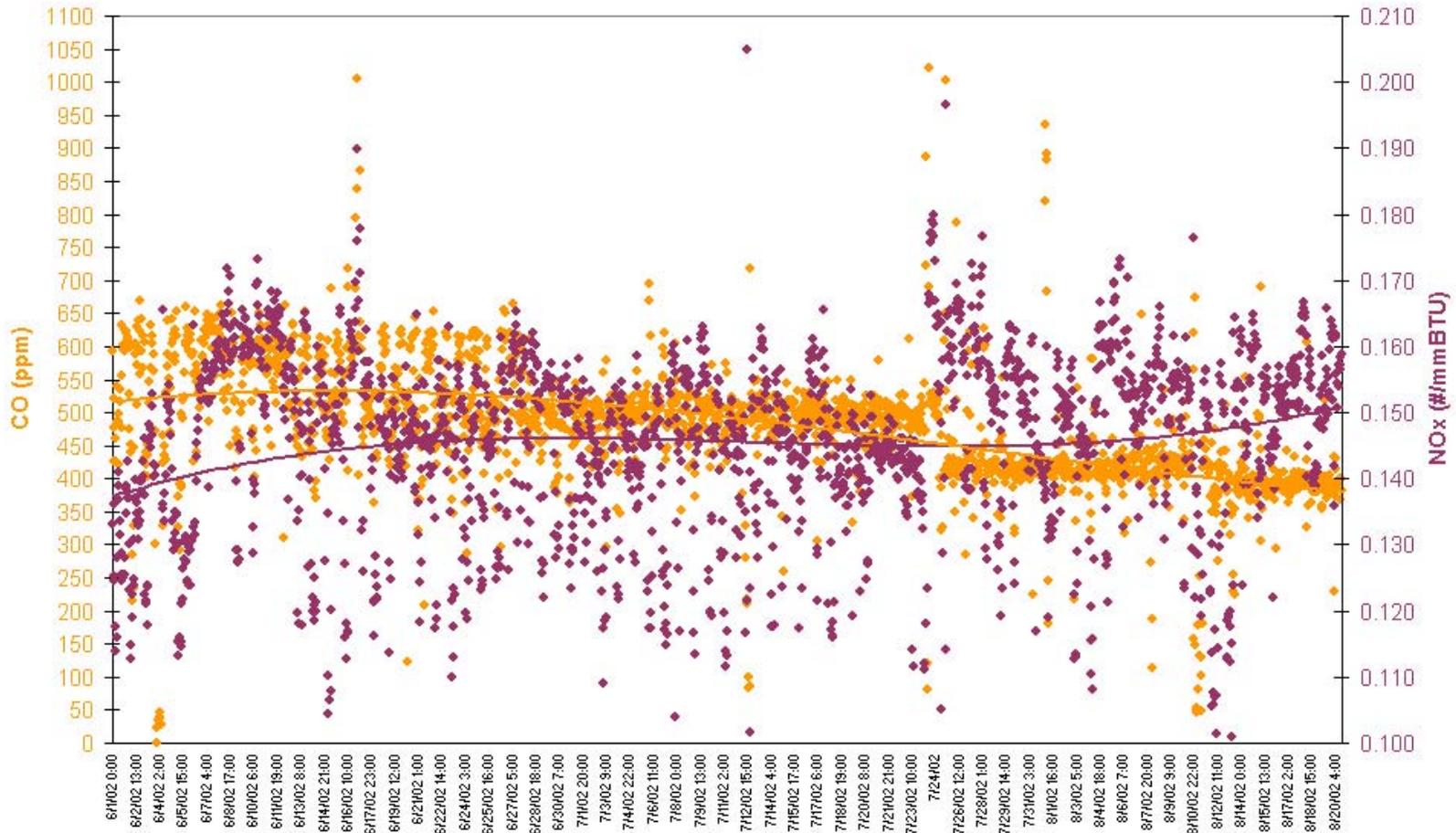
Texas Power Plant burning Lignite

Unit 2 CO & NOx (1 hour average)



Texas Power Plant burning Lignite

Unit 1 CO & NOx (1 hour average)



Results - Labadie

Boiler Information

- ◆ 625 MW CE tangentially fired boiler
- ◆ 6 mills
- ◆ PRB and Midwest Bituminous coals
- ◆ LNCFS Level 3 NO_x control with 2 levels of CCOFA and 5 levels of SOFA
- ◆ Bailey INFI-90 DCS

DCS used to control the auxiliary air, fuel air, and overfire air dampers.



NOX 0.092 HR 10196

WEIGHT FACTOR
41 1.0 HT R
42 10.0 NOX

PEGASUS MODE
RUN
Last Advice 8:45

GROUP TRANSFERS TO/FROM PEGASUS
51 ALL STATIONS
52 7 OVERFIRES
53 6 AUX AIRS
54 6 FUEL/AIRS

589 MW
Pegasus Overview
01 Heat Rate

SEC AIR DAMPERS	PEG	BIAS	CO	W/F	Δ	Y	PEG	BIAS	SP	PV	CO
A SOFA 5	89%	-11%	89%	4.2"			4.2"	-0.3"	4.2"	4.3"	53%
B SOFA 4	95%	-5%	95%	02	Z		2.2%		2.2%	2.2%	48%
C SOFA 3	87%	-13%	87%	55	11	A	88K	-8%	02PRB	92K	75%
D SOFA 2	95%	-5%	95%	12	B	A	102K	-7%		104K	87%
E SOFA 1	94%	-6%	94%	13	C	A	113K	0%		115K	93%
F CCOFA 2	34%	-40%	40%	14	D	A	PEGASUS	2%		116K	96%
G CCOFA 1	27%	17%	27%	15	E	A	THROTTLE	3%		115K	96%
H A F/A	38%	-7%	38%	16	F	A	ADVTC	2%		115K	96%
I AB AUX	69%	25%	69%	17	G	A	ADVTC	2%		115K	96%
J B F/A	43%	0%	43%	18	H	A	ADVTC	2%		115K	96%
K BC AUX	58%	0%	58%	19	I	A	ADVTC	2%		115K	96%
L BC OFF	0%	0%	0%	20	J	A	ADVTC	2%		115K	96%
M C F/A	47%	0%	47%	21	K	A	ADVTC	2%		115K	96%
N CD AUX	59%	33%	59%	22	L	A	ADVTC	2%		115K	96%
O CD OFF	0%	0%	0%	23	M	A	ADVTC	2%		115K	96%
P D F/A	36%	0%	36%	24	N	A	ADVTC	2%		115K	96%
Q DE AUX	74%	48%	75%	25	O	A	ADVTC	2%		115K	96%
R DE OFF	0%	0%	53%	26	P	A	ADVTC	2%		115K	96%
S E F/A	48%	3%	48%	27	Q	A	ADVTC	2%		115K	96%
T EF AUX	72%	46%	73%	28	R	A	ADVTC	2%		115K	96%
V EF OFF	0%	0%	53%	29	S	A	ADVTC	2%		115K	96%
W F F/A	54%	9%	54%	30	T	A	ADVTC	2%		115K	96%
X FF AUX	41%	-34%	41%	31	U	A	ADVTC	2%		115K	96%

Labadie allows the neural network model to control 29 system-optimizes the combustion process every 15 minutes (dampers, feeder speed, etc.)

1
K-4
P-1
CON
TUN
SHF

03-08:28 03-08:48
TILT-MAS
18 A -19
50 SW P -19
51 NW P -19
52 NE P -19
53 SE P -19
PEG ADVTC
SW-14 NE-15
NW-14 SE-14

SOFA TILTS
19 M -0
FUEL 91%
AIR 92%
MSPSI2394 P
AMB 55 F
SO2 0.53 #
CO2 11.4%
OPAC 6.6%
6MIN 8.1%



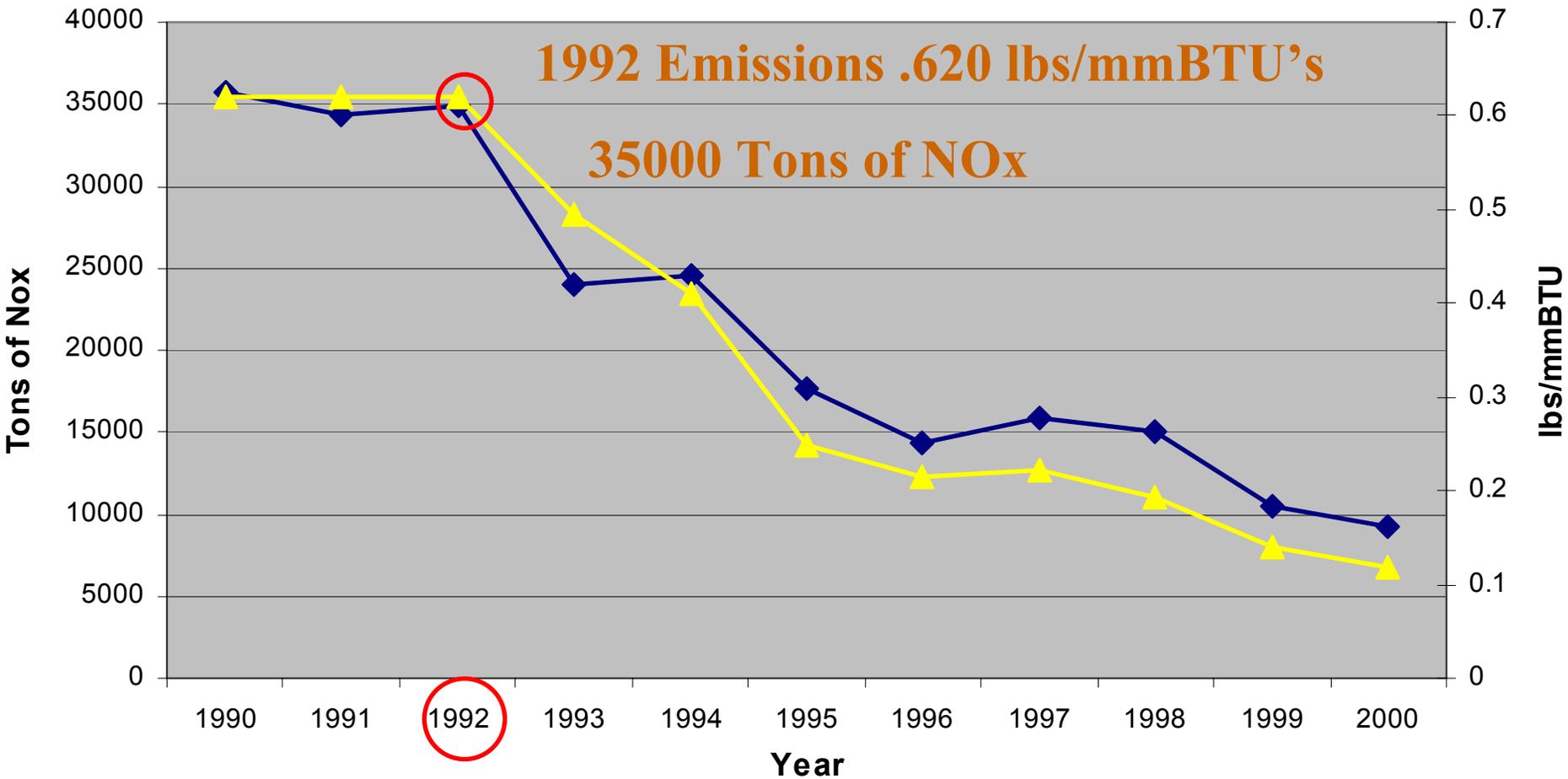
Results - Labadie

Results

- ◆ NO_x reduction over 30% below baseline levels that were achieved with CCOFA and SOFA
- ◆ Achieved compliance goals without requiring post-combustion controls
- ◆ Operated continuously over a wide range of coal compositions

Annual Mass & Avg Emissions

◆ Avg Nox
▲ Nox Tons



Power Results



"At our Conemaugh station we were able to sustain a **15% reduction** in NOx over an already low early reduction level, and improve our boiler efficiency by **almost 2%** over the results from our previous best tuned NOx efforts."

Frank Cabala, Operations Manager, Reliant Energy, Conemaugh Station



Combustion Optimization project at Yangliuqing in Tienjin, China

- 300MW W-fired unit, which is burning local Chinese coal
- 20% NO_x reduction
- Concurrent 0.7% heat rate improvement
- The North-East Electric R&D Institute performed the independent 3rd party testing
- Completed the project together with Huaneng Automation, Beijing, China

Success with wide range of Equipment Configurations

- ◆ Significant NO_x reductions achieved while maintaining or improving heat rate
- ◆ NO_x reductions after LNBS
- ◆ NO_x reductions after CCOFA and SOFA
- ◆ NO_x reductions with stringent CO constraint
- ◆ Operated over wide range of coal composition

Successful Applications Summary

- **The Pegasus neural network based system has been applied to:**
 - **100+ Closed Loop Control Sites Worldwide**
 - **capacity from 146 to 1300 MW**
 - **Tangential, cell, single wall, opposed wall, roof fired, cyclone boiler arrangements**

