2nd US-China NOx and SO2 Control Workshop

Foster Wheeler's Low-NOx Burners and SCR Technology

Pengzhi Jiang

Foster Wheeler

Topics

- NOx generating mechanism
- FW low-NOx burners
  - Arch-fired
  - Wall-fired
  - Tangential-fired
- ECT / CADM systems
- SCR

NOx Formation

- Thermal NOx

  High temperature reaction
- Prompt NOx

  Fast reaction between nitrogen, oxygen, and hydrocarbon radicals

  Lower temperature combustion
- Fuel NOx

  Important for oil & coal firing

NOx Control Philosophy

- Control of formation

    Using advanced combustion technology to reduce NOx formation

- Conversion after formation

    SCR or SNCR

Control of NOx Formation

----- Combustion Modification

- Thermal NOx

  Reduce flame peak temperature

- Prompt NOx

  Rapid mixing of fuel & air

- Fuel NOx

  Fuel / air staging

Conversion After NOx Formation
----- Post-Treatment

- SCR

  Temperature window: 230 ~ 600 C

  Boiler back-end

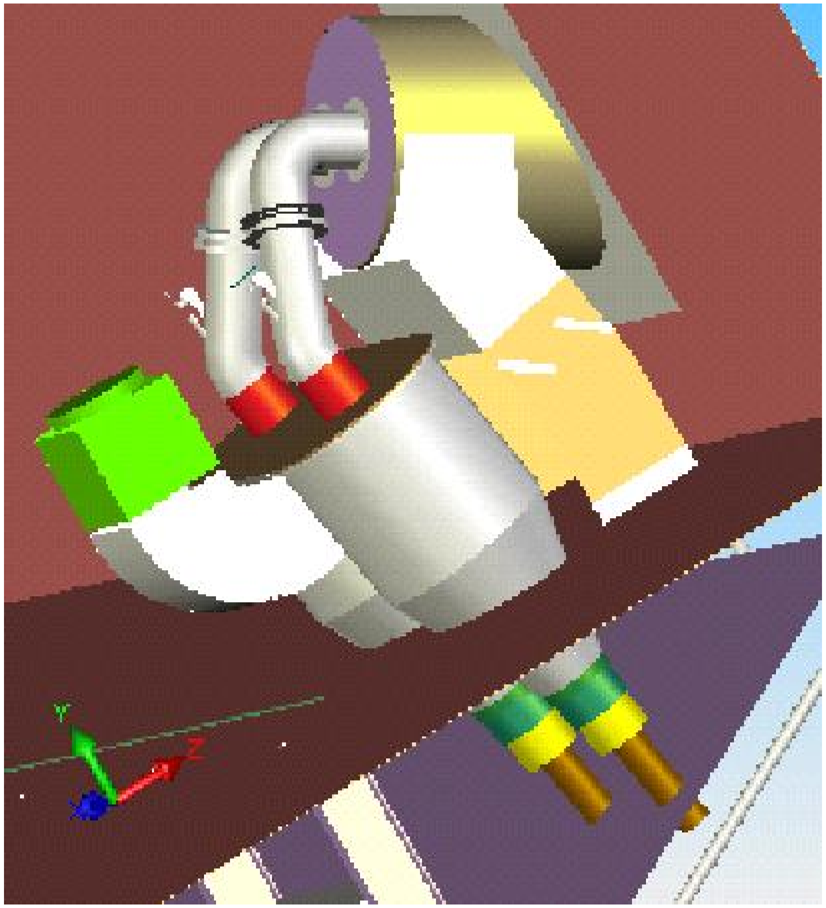
- SNCR

  Temperature window: 870 ~ 1100 C

  Boiler upper furnace and before backpass

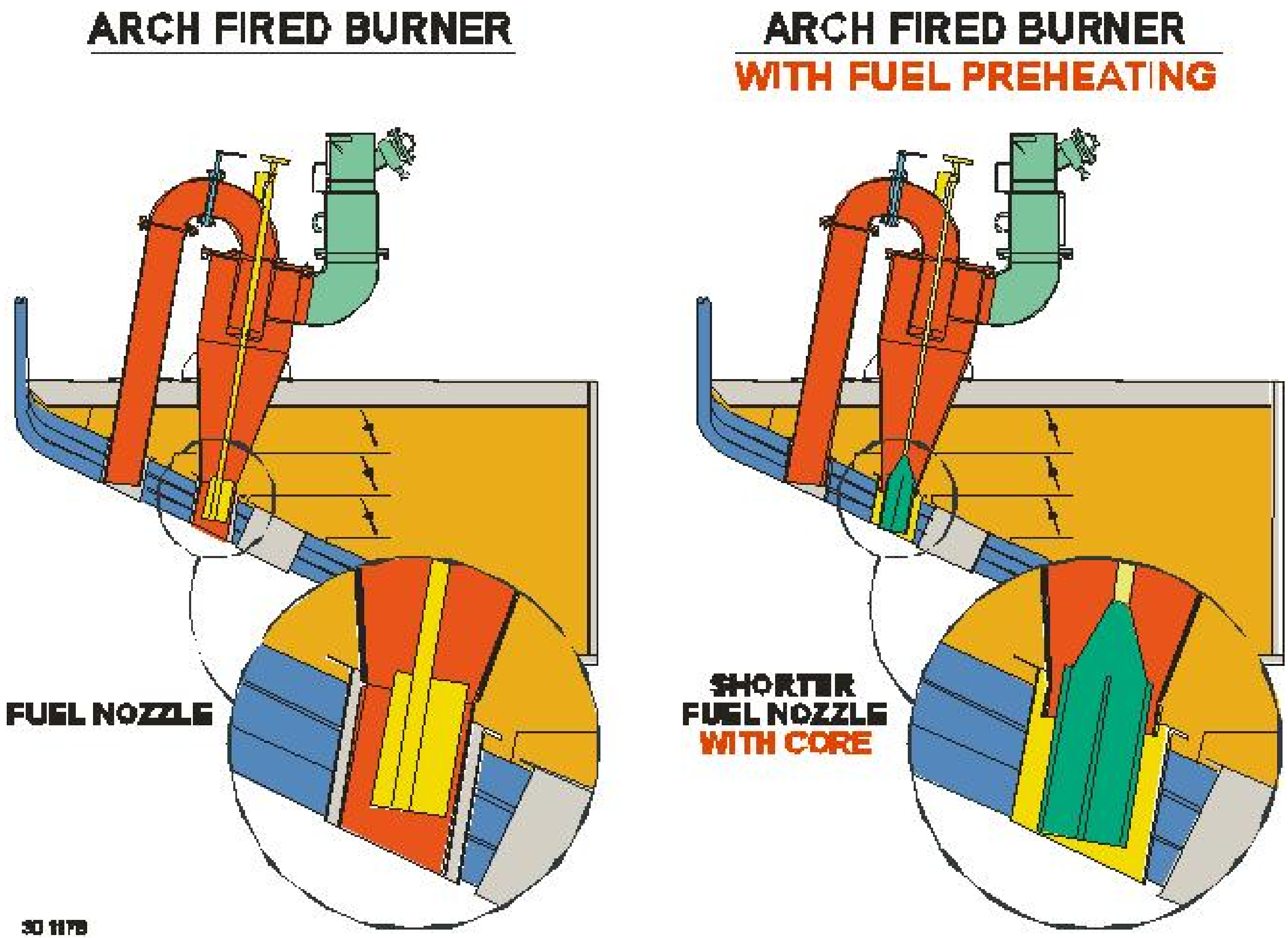
Foster Wheeler Arch-Fired Burner Technology

FW Cyclone Preheat Burner with Vent-To-OFA --- Arch-fired

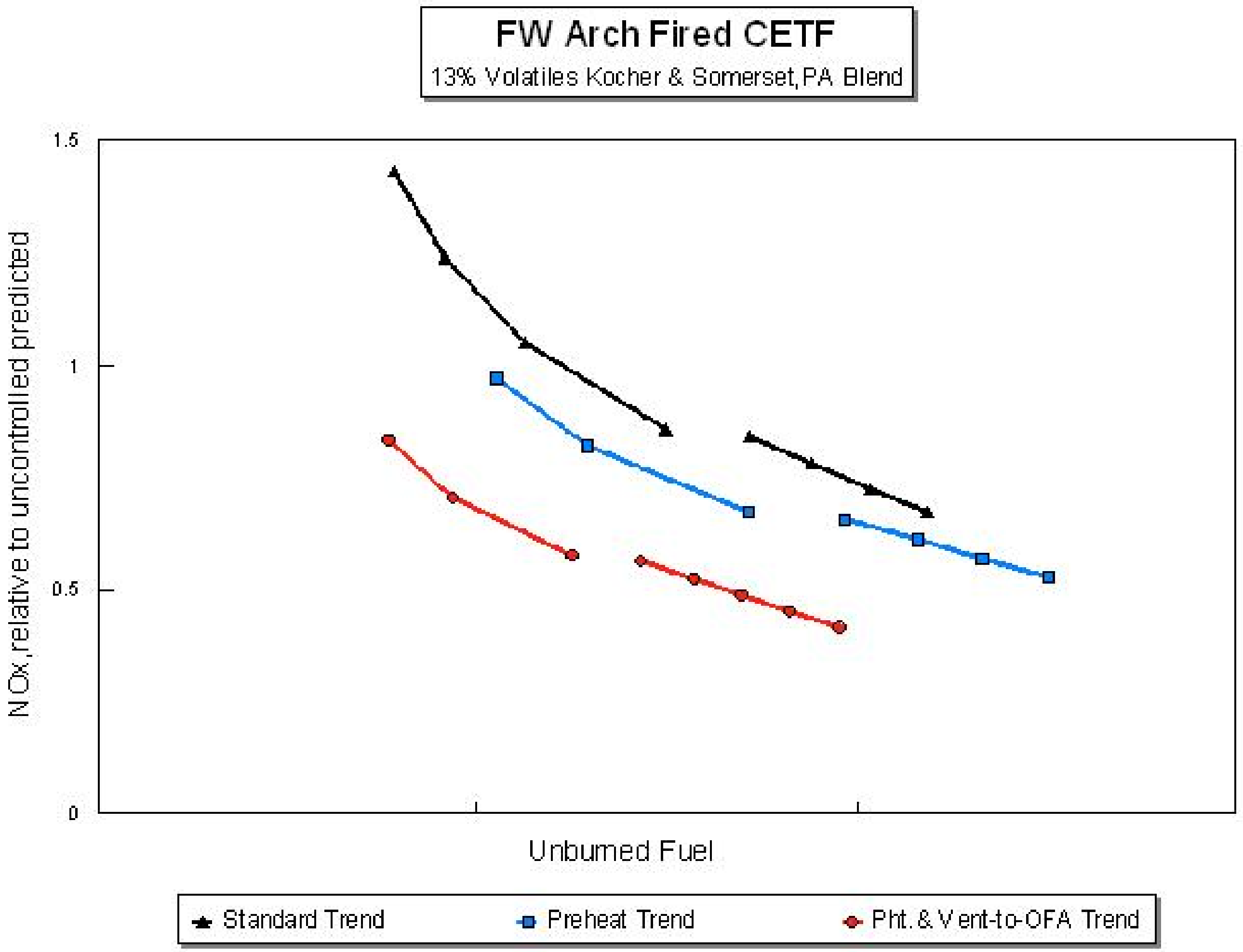


- Fuel preheat nozzle
- Cyclone burner vent-to-OFA

Fuel Preheat Nozzle



RESULTS: 22 MW_{th} Test Plant
NO_x vs. Unburned

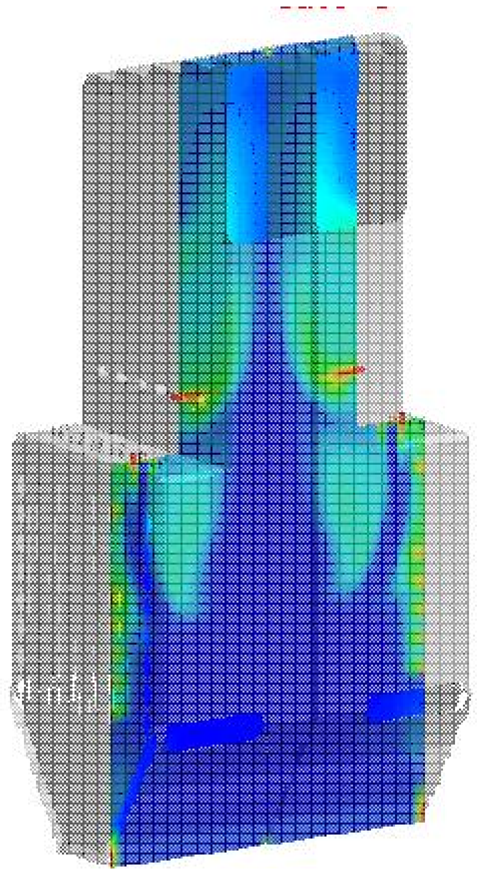


Reference: Sunbury 1 & 2

- **2 x 100 MW_e 2002 Retrofit**

- **NO_x with 7% VM Anthracite :**

  Initial ~ 1200 mg/Nm^3



Sunbury 1 & 2 Low NO_x Retrofit Major modifications examples

- Preheat Nozzle (overhead view with Core extracted) =>

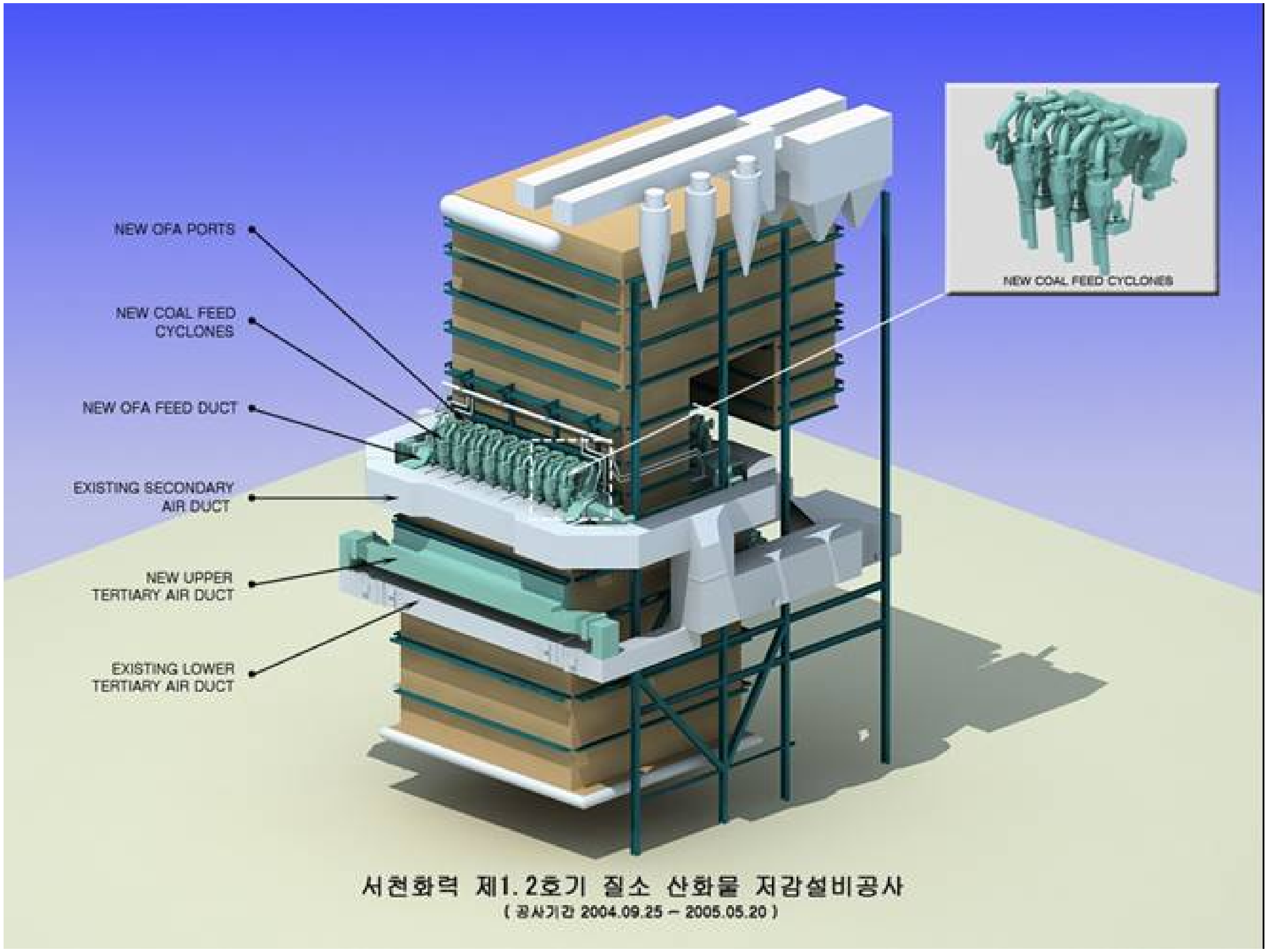
- OFA new ports =>

- Vents rerouting =>

Sunbury 1 & 2 Low NO_x Retrofit Major modifications examples

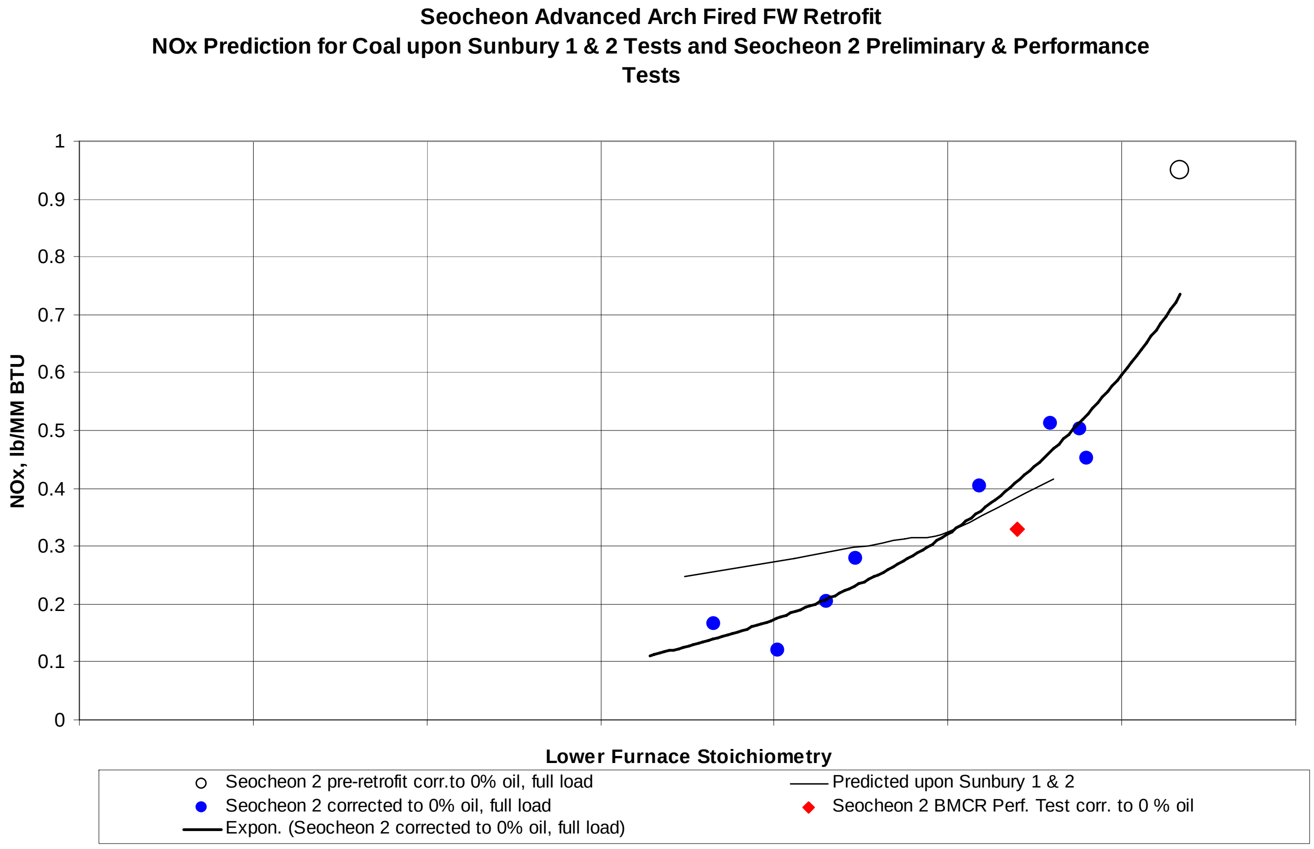
- 2 x 100 MW_e 2002 Retrofit
- NO_x with 7% VM Anthracite :
  - Initial ~ 1200 mg/Nm^3
  - Guaranteed ~ 510 mg/Nm^3
  - Min. Actual ~ 250 mg/Nm
- NOx with 18% VM Anthracite:
  - Min. Actual <200 mg/Nm

Seocheon 1 & 2 Modifications



Seocheon 1 & 2 Low NO_x Retrofit
Major modifications: New Cyclone Burners & Vent to OFA

Results: Seocheon 2 NO_x



Guaranteed NO_x ~ 0.43 lb/MM BTU (~510 mg/Nm^3) with this <5% VM coal.

Seocheon 1 & 2, Korea

- 2 x 200 MWe 2004/5 Retrofit
- OEM: Others
- NOx with <5% VM Anthracite :
  - Initial ~ 1000 mg/Nm3
  - Guaranteed ~ 510 mg/Nm3
  - Performance Test ~ 380 mg/Nm3
  - Min. Actual ~ 150 mg/Nm

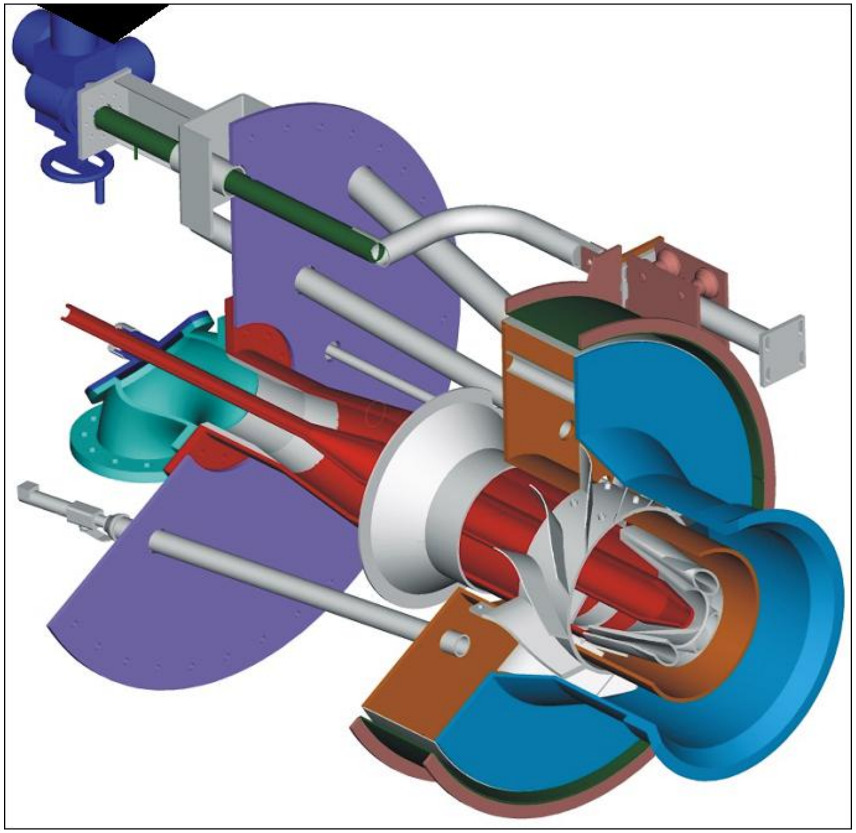
Wall-fired Burner

Vortex Series / Split Flame Burner

FOSTER WHEELER

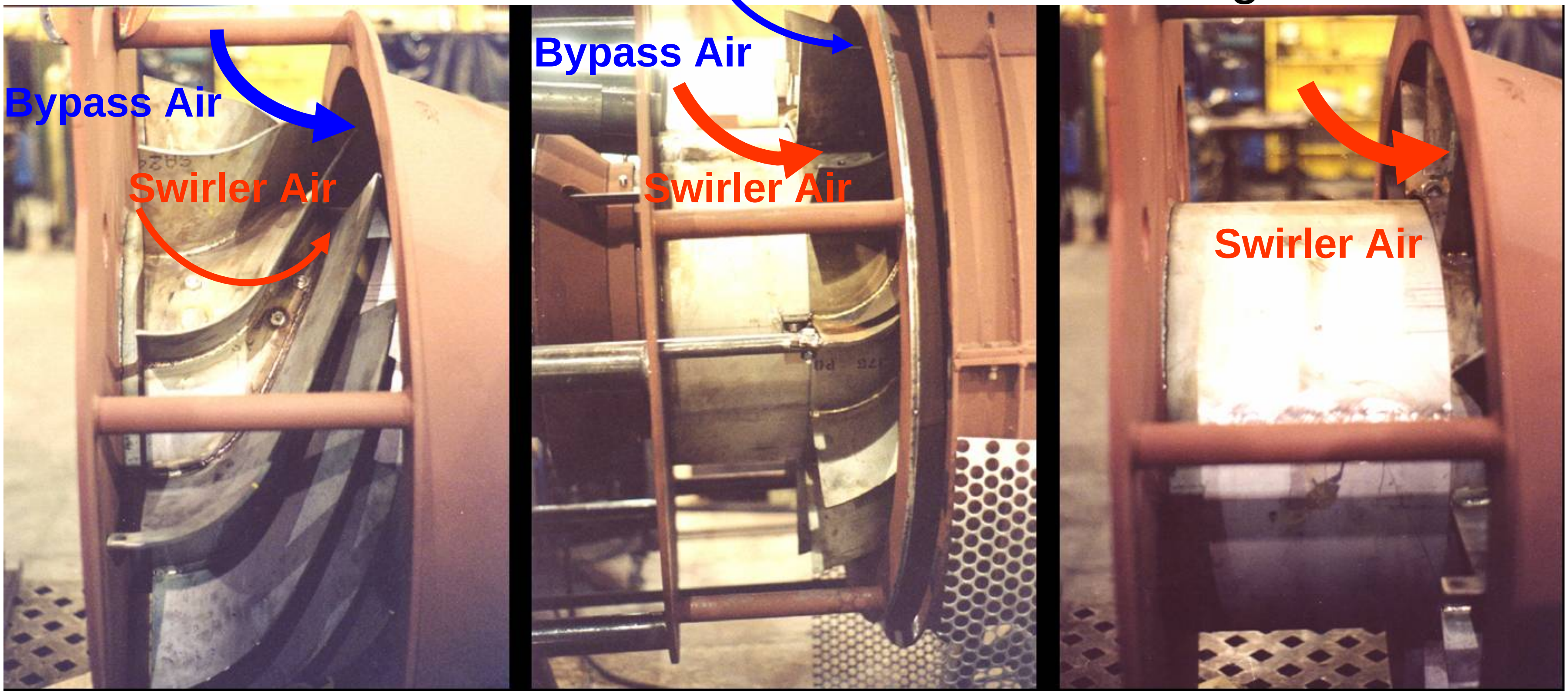
Wall-Fired VS/SF Low NOx Burner

- **More than 41,000 MW experience since 1979**
- **Entire Range of Fuels from Anthracite to Lignites**
- **50 to 300 MBtu/h**
- **Dual register for air staging**
- **Split Flame nozzle for improved ignition and fuel staging**
- **Co-firing of opportunity fuels**
- **Oil or gas guns**



Vortex Series Low NOx Burner Swirler Adjustment

Efficient Swirl Generation with ONE Moving Part



Fully Retracted Vanes - Minimum Swirl - High Bypass Flow	Partially Inserted Vanes - Moderate Swirl - Low Bypass Flow	Inserted Vanes - Maximum Swirl - No Bypass Flow

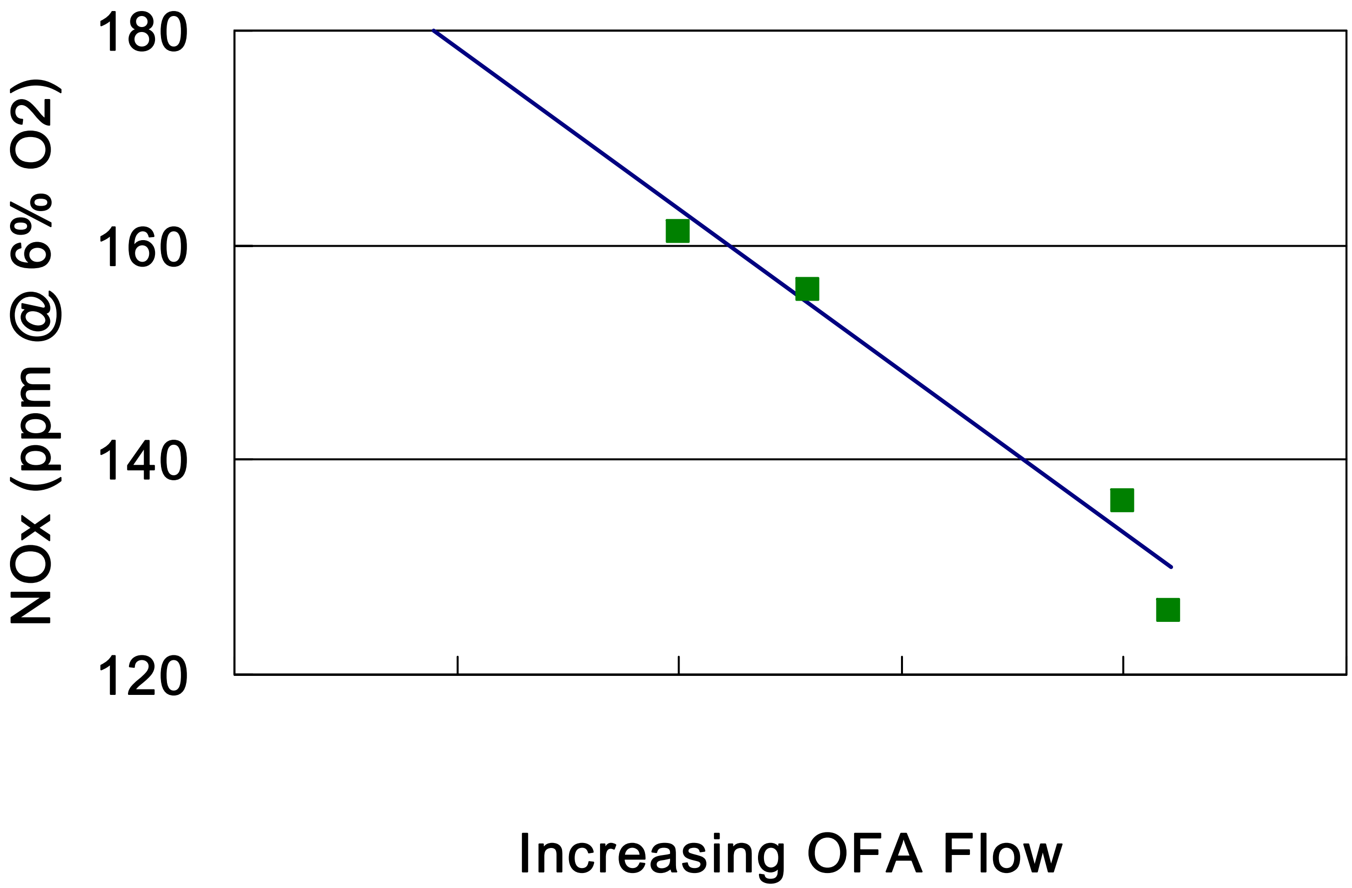
Benefits of the Split Flame Nozzle and Inner Barrel Sliding Tip

- Separates coal and primary air internally for NOx reduction
- Provides adjustable outlet velocity for better matching to register secondary air flow
- Replaces the coal impeller/spreader for better flame shaping capability

Retrofit Example: Wall-Fired

- Formosa Petrochemical Corporation
- 500 t/h, 130 ata, 541C boiler
- 8 front wall VS/SF burners with 2 columns & 4 rows
- OFA: 4 @ FW and 3 @ RW
- Bituminous coal from mainland China and Autralia (FC/VM = 2.0)

FPCC Retrofit Results



FPCC Retrofit Results

- NOx reduction of 75%

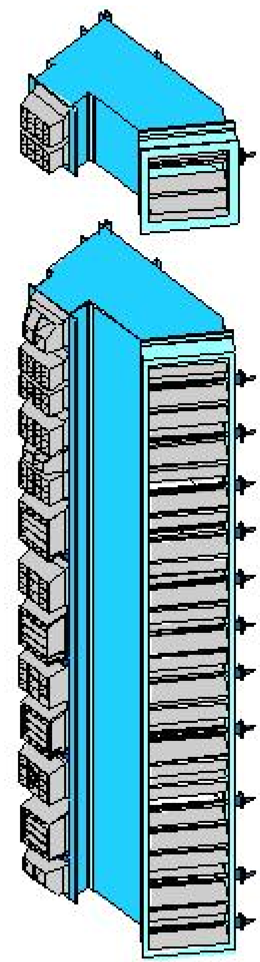
- NOx 126 ppm @ 6% O_2 achieved

TLN3 Burners and ECT / CADM

For Tangential Fired Boilers

FW TLN3 technology

	Utility	Unit	(MWg)	Line	Coal	System
1	MIRANT	Dickerson 1,2&3	190	2003-04	Bit	TLN3
2	Duke Energy	Riverbend 7	150	2004	Bit.	TLN3**
3	Allegheny Power	Albright	180	2003	Bit	TLN3**
4	DYNEGY	Hennipin	200	2003	PRB	TLN2
5	Duke Energy	Lee 2	100	2003	Bit.	TLN2
6	Duke Energy	Dan River 3	140	2003	Bit.	TLN2
7	Duke Energy	Allen 2	175	2003	Bit.	TLN3**
8	Duke Energy	Allen 5	280	2003	Bit.	TLN3**
9	CPS of San Antonio	Deely 1&2	405	2002	PRB	TLN3
10	Duke Energy	Riverbend 6	100	2003	Bit.	TLN3**
11	Duke Energy	Lee 1	100	2002	Bit.	TLN 2
12	Duke Energy	Riverbend 4	100	2002	Bit.	TLN3**
13	**Allegheny Power**	**Mitchell 33**	**300**	**2002**	**Bit.**	**TLN 3 w/ ECT & CADM**
14	Duke Energy	Riverbend 5	140	2003	Bit.	TLN3**
15	**TMPA**	**Gibbons Creek**	**430**	**2002**	**PRB**	**TLN 3 w/ ECT & CADM**
16	Dynergy	Wood River 4	100	2002	PRB	TLN 2
17	Dynergy	Wood River 5	370	2002	PRB	TLN 2
18	Duke Energy	Allen 3	280	2002	Bit.	TLN 3 **
19	Reliant Energy	Limestone 1	820	2001	LIG/PRB/Pet Coke	TLN 3 **
20	**AEP**	**Coleto Creek**	**550**	**2001**	**PRB/W. Bit**	**TLN 3 w/ ECT & CADM**
21	Tampa Electric	Big Bend 4	440	2001	Bit.	TLN1
22	Duke Energy	Lee 3	175	2001	Bit.	TLN 3 **
23	Duke Energy	Allen 1	175	2001	Bit.	TLN 3 **
24	Duke Energy	Allen 4	280	2000	Bit.	TLN 3 **
25	Carolina Power & Light	Sutton 1	100	2000	Bit.	TLN 2
26	Reliant Energy	Limestone 2	820	2000	LIG/PRB/Pet Coke	TLN 3
27	Allegheny Power	Fort Martin 1	500	2000	Bit.	TLN 2
28	CPA/UPA	Coal Creek 1	560	1999	LIG	TLN 3
29	CPA/UPA	Coal Creek 2	560	1998	LIG	TLN 3



TLN3 Advantages

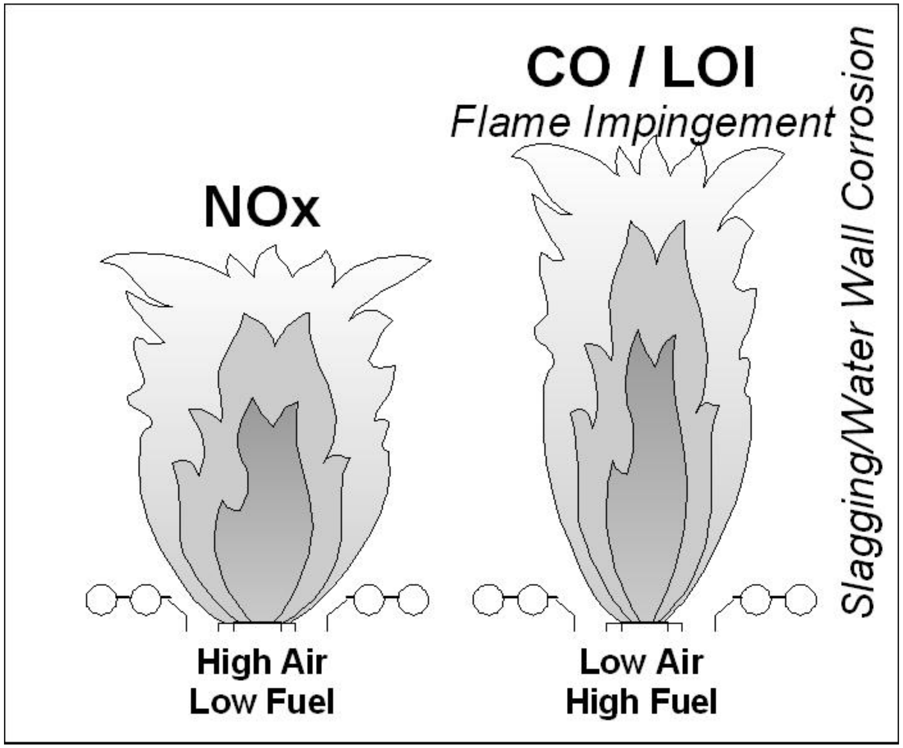
- Lower furnace stoichiometry control (LFSC)
- Vertical furnace air staging
- Air nozzle tips for fireball shaping

Air and Coal Flow Balancing

Air - coal imbalance at the burners causes either high NOx or high CO / LOI (UBC)

Benefits of Balanced Air and Coal at the Burners:

- Improve NOx emission
- Lower CO & LOI
- Lower slagging
- Margin to lower excess air
  - → lower NOx
  - → less aux power
  - → higher efficiency



Fuel and Air Metering Technologies...

ECT
Electric Charge
Transfer
Coal Flow
Measurement

CADM
Compartment Air
Distribution Monitoring

Electric Charge Transfer

The ECT system provides real time, on- line coal flow, particle velocity and coal fineness metering.

ECT measures the electric charges present in any two-phase flow application due to relative particle motion.

ECT Advantages

- Real-time and continuous coal flow distribution
- Coal flow velocity and particle fineness
- Not affected by coal type, moisture, ash content or coal roping
- Computer data processing and analysis
- Can be connected to plant DCS system

Over 20 ECT Installations

1998	Turku Energia	Finland	Wall Fired Boiler	Turku Station	6	2
1998	Helsinki Energia	Finland	200 MW Tangentially Fired Boiler	Salmisaari	16	4
1998	Helsinki Energia	Finland	150 MW Wall Fired Boiler	Hanasaari	3	1
1998	PP&L, Inc.	USA	120 MW Wall Fired Boiler	Martin's Creek Unit 1	6	1
1999	Powergen	UK	500 MW Tangentially Fired Boiler	Kingsnorth, Unit 3	8	1
1999	South Carolina Electric & Gas	USA	350 MW Wall Fired Boiler	Wateree Unit 2	24	6
1999	Mission Energy	UK	Wall Fired Boiler	Fiddlers Ferry	8	1
2000	Powergen	UK	500 MW Tangentially Fired Boiler	Kingsnorth, Unit 3	40	5
2000	PG&E Generating	USA	250 MW Wall Fired Boiler	Logan Station	12	2
2001	South Carolina Electric & Gas	USA	350 MW Wall Fired Boiler	Wateree Unit 1	24	6
2001	Scottish Power	UK	500 MW Wall Fired Boiler	Longannet 3	32	4
2001	ARF for TVA	USA	950 MW Tangentially Fired Boiler	Bull Run	8	1
2001	American Electric Power	USA	650 MW Tangentially Fired Boiler	Coleto Creek 1	24	6
2001	Western Kentucky Energy	USA	175 MW Wall Fired Boiler	Coleman 2	8	4
2001	CINERGY	USA	150 MW Wall Fired Boiler	Gallagher 4	18	3
2002	TMPA	USA	440 MW Tangentially Fired Boiler	Gibbons Creek	28	7
2002	TECO	USA	200 MW Riley Turbo Boilers	Big Bend 2	40	5
2002	Western Kentucky Energy	USA	500 MW Wall Fired Boiler	DB Wilson	25	5
2002	Allegheny Energy	USA	300 MW Tangentially Fired Boiler	Mitchell 33	40	5
2002	Western Kentucky Energy	USA	175 MW Wall Fired Boiler	Coleman 1	8	4

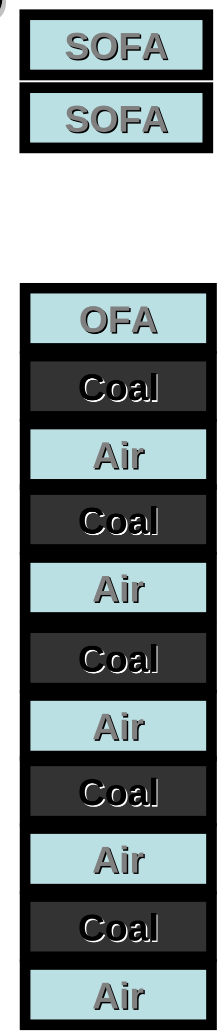
Purpose of Using CADM

- Measuring the air flow passing through each wind-box fuel, air and over-fire air compartment
- Control of air biasing based on ECT data
- Realize optimized combustion control

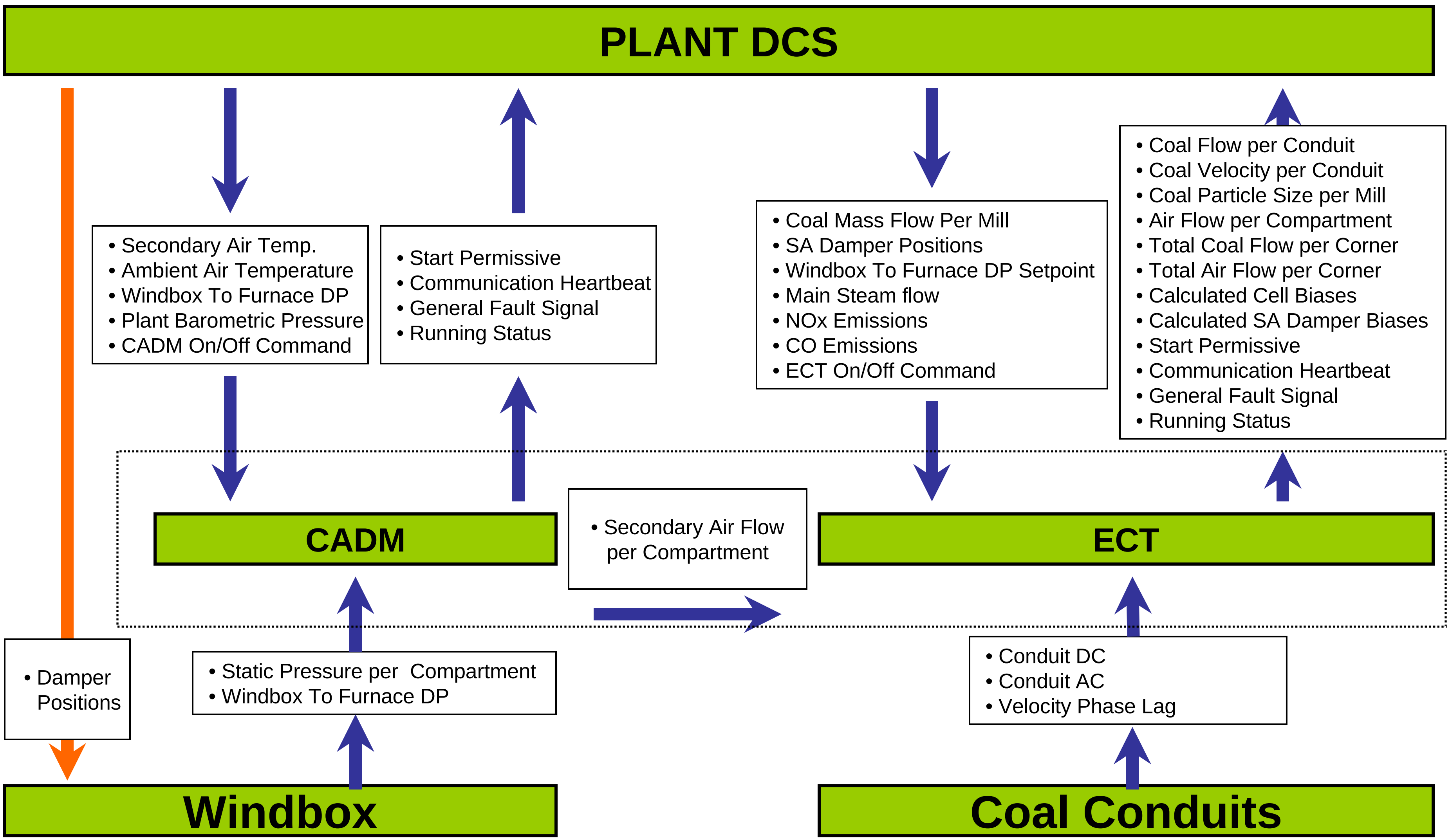
Compartment Air Distribution Monitoring

Tangential Fired Windbox Application

- % air distribution through every compartment
- secondary air velocity from every nozzle tip
- secondary air pressure in each compartment
- secondary air mass flow thru each compartment
- full trending & DCS interface



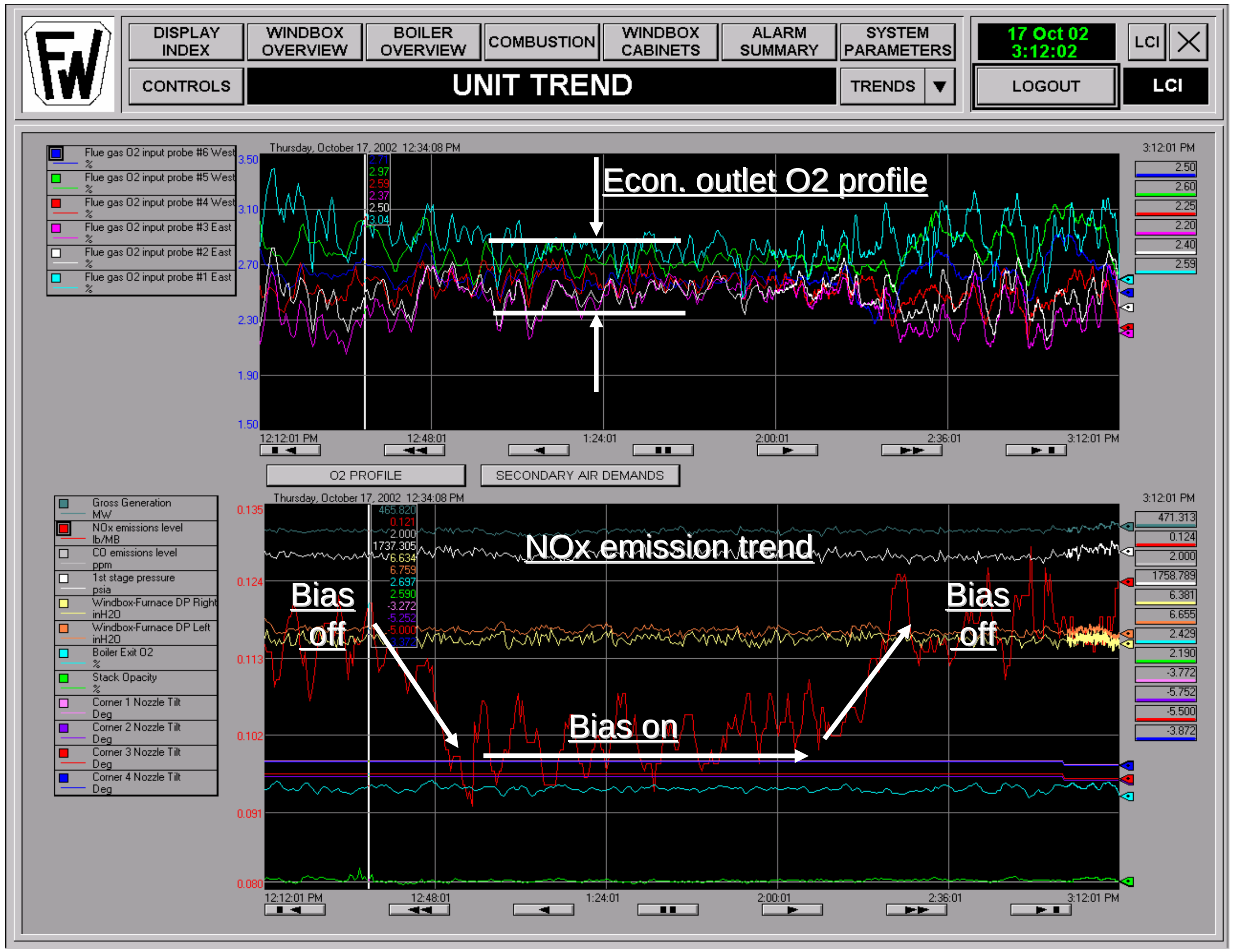
CADM / ECT Signal Flow Overview



“Fuel Injected” Results… 8 to15% NOx reduction

Source:

TMPA, Gibbons Creek
Unit: 480 MW T-fired
Coal: Codero Rojo PRB



TLN3 Reference Project

Texas Municipal Power Agency (TMPA)
Gibbons Creek unit, 2002

	Pre-retrofit	Post-retrofit
NOx	0.30-0.37 lb/MBtu	0.085 to 0.110 lb/MBtu
CO	0 to 900 ppm	less than 5 ppm
LOI	0.3%	0.1%

FW Low NOx Combustion References

Wall Firing

40645 MW Low NOx capacity since 1979

113 Low NOx Burner Applications

18 Vortex Series Low NOx Burner Jobs

55 Overfire Air Installations

Tangential Firing

10300 MW Low NOx capacity since 1992

35 TLN - Tangential Low NOx Systems

Advanced Technology

15 ECT Coal Flow Measurement Systems

3 CADM Air Flow Measurement Systems

FW NOx Post-Treatment Technology ----- SCR

FOSTER WHEELER'S PROVEN SCR TECNHOLOGY

- **FW is the most experienced US SCR supplier and one of the most experienced SCR suppliers in the world**
- **Originally FW's SCR technology was licensed from IHI (Ishikawajima-Harima Heavy Industries-Japan)**
- **Over 20 years experience. First SCR in 1982.**
- **FW was the first to design and install SCR on a Coal fired Unit in the USA in 1994.**
- **Over 100 Installations designed by FW for wide range of Fuels and Process Conditions.**

HOW DOES AN SCR WORK?

An SCR uses ammonia (NH_3) to convert NOx into harmless elemental nitrogen (N_2) and water vapor (H_20)

$$4\ NO + 4\ NH_3 + O_2 \xrightarrow{\text{(CATALYST)}} 4\ N_2 + 6\ H_2O$$

$$6\ NO_2 + 8\ NH_3 \xrightarrow{\text{(CATALYST)}} 7\ N_2 + 12\ H_2O$$

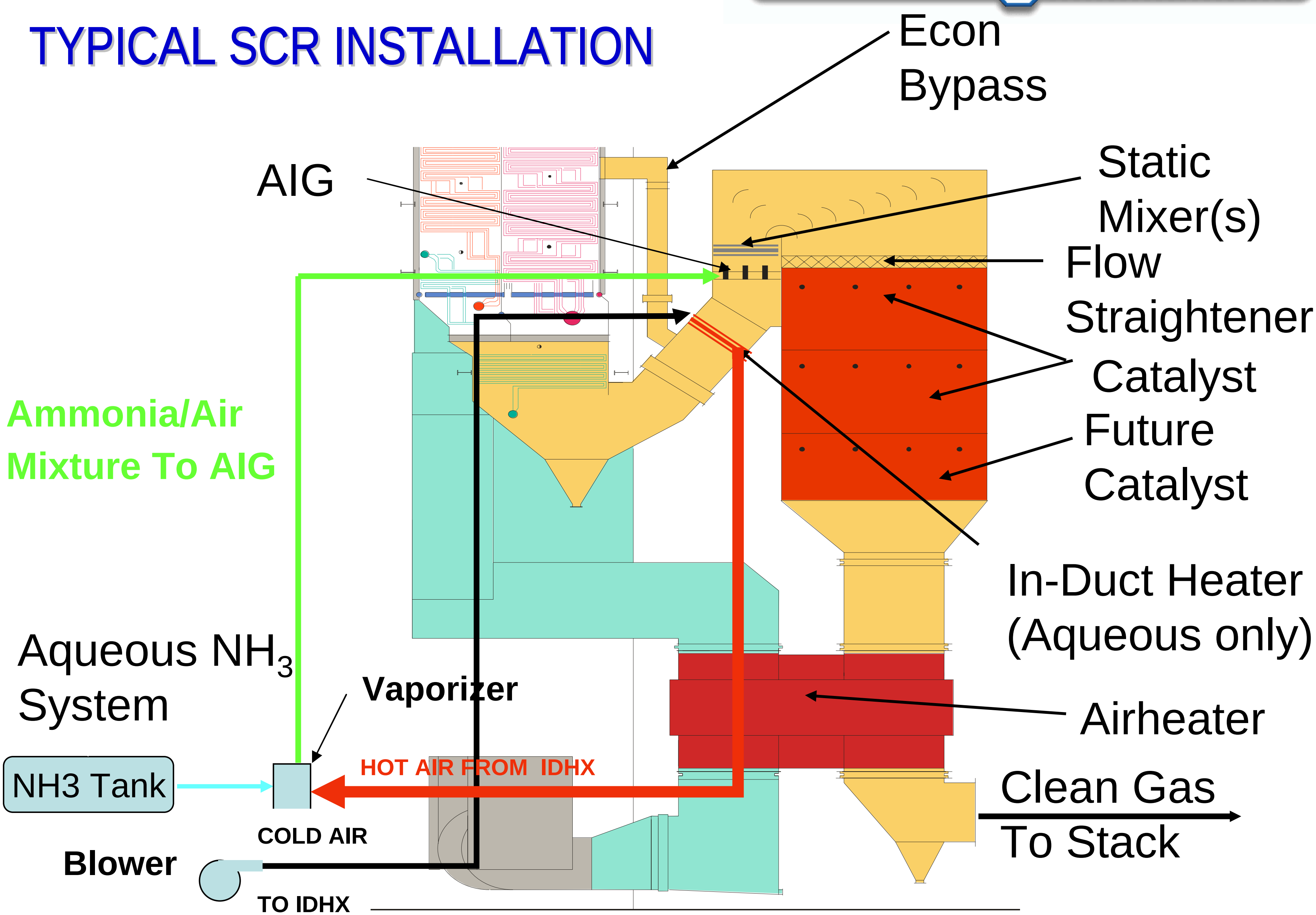
NOTE: THESE REACTIONS WILL PROCEED WITHOUT A CATALYST AT ~1500^{o}F (SNCR) BUT A CATALYST IS REQUIRED TO DRIVE THE REACTION AT 700^{o}F

THE LONGEST AND MOST COAL FIRED SCR EXPERIENCE IN THE US

UNIT	SIZE MW	START Mo/Yr	DeNOx %
Carney's Pt	2x130	Mar-94	63
Logan	225	Sep-94	63
Indiantown	330	Dec-95	50
CP&L Rox. 4	2x350	Jun-01	79
AES Cayuga	160	Jun-01	90
CP&L Rox. 1	385	Jun-02	84
CP&L Rox. 3	760	Jun-03	81
CP&L Mayo	2x350	Jun-04	79
Petersburg	460+540	Jun-04	90
Muskingum River	600	Apr-05	90

OVER 30 OPERATING YEARS OF COAL FIRED EXPERIENCE!

TYPICAL SCR INSTALLATION



FLOW MODELING

Flow modeling assures optimum SCR performance

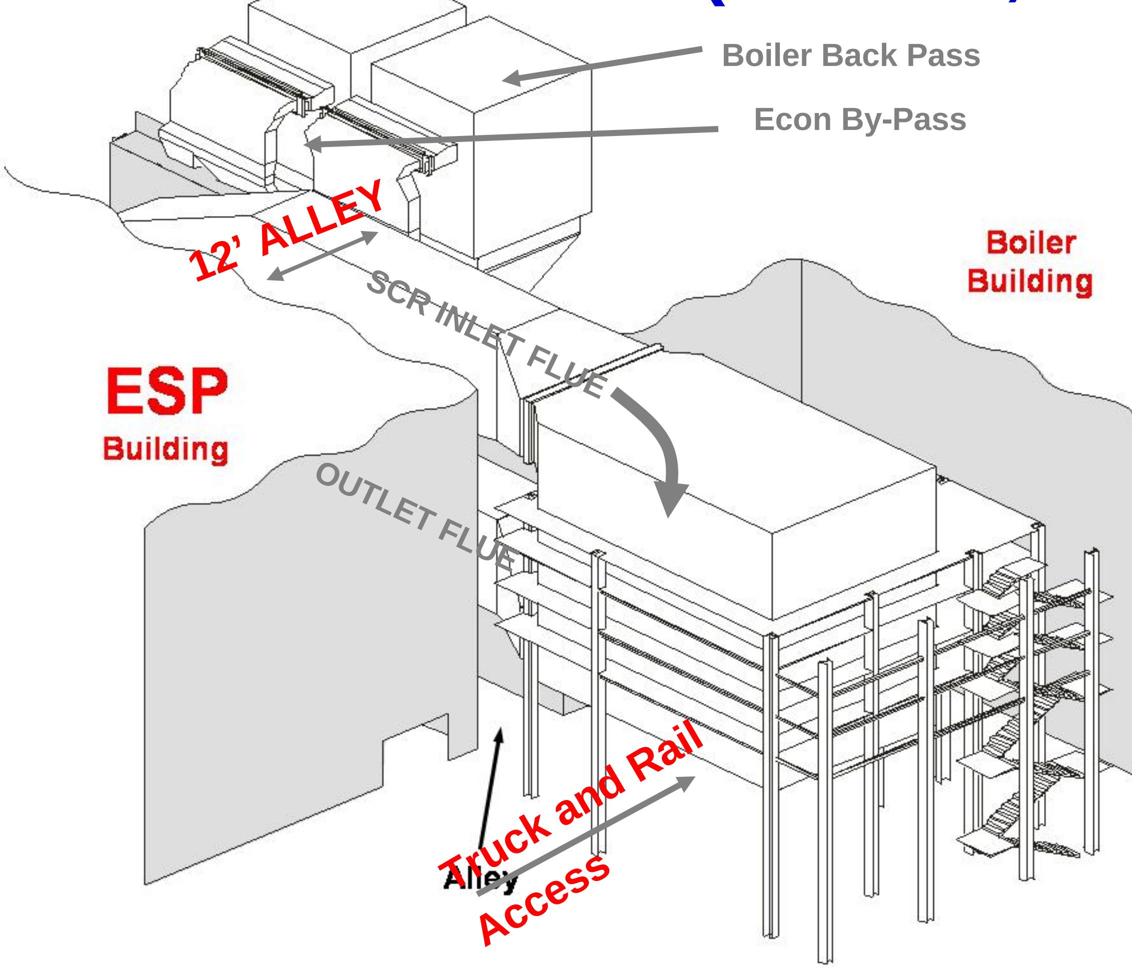
- **Optimize Turning vanes and flow distribution devices**
- **AIG and Mixer Design**
- **Ash layout (Even for low dust applications)**
- **Effects on Airheater and/or ESP performance**
- **Minimize Pressure Drop**

FW SCR TECHNOLOGY

- **FW Has Advanced "The State of the Art" in SCR technology**
  - In Duct Heat Exchanger for Aqueous NH3 Vaporization (US Patented 5296206)
  - Feed-forward/feed-back control logic (US Patent 5047220)
  - Simplified catalyst loading/unloading system
  - Integrated AIG/Mixer design
  - Lay-up system for catalyst protection
  - Economizer Bypass for low load operation
  - Proven FW Aqueous Ammonia Vaporizer design

PROVEN SUCCESS WITH COMPLEX RETROFIT PROJECTS

AES CAYUGA (160 MW, 90% Removal)



Summary

- FW's extenswive experiences on low NOx burner technologies:
  - → arch-fired
  - → wall-fired
  - → tangential-fired

Retrofit for low-NOx emissions on various types of boilers by any OEM.

Summary

- FW's high-tech ECT/CADM technology
  - Coal / air flow measurement
  - Optimized combustion control
  - Combined with FW's low-NOx burners for combustion system retrofit

Summary

- FW's proven SCR technology:

  - Post-Treatment: convert NOx to N2
  - Further reduce NOx emission after combustion modification

- Low NOx burners + SCR = solution for economically NOx abatement measure