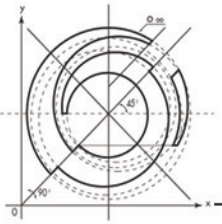
5 November 2003
Shenyang, China

NOx Compliance for Existing Tangentially Fired Boilers

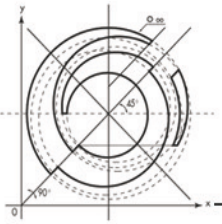
Zhang GaoZuo
Noël Bourquin

ALSTOM



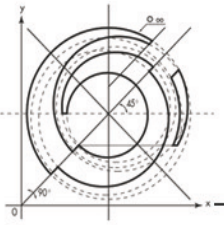
Agenda

- NOx Compliance Process
- NOx Reduction Options
- Background Information on NOx Formation
- Tangential Firing NOx Solutions
- ALSTOM NOx Experience



Objectives of NOx Compliance

- Meet Government Regulation's
- Minimize Financial Impact



Total Integrated NOx Compliance Strategy

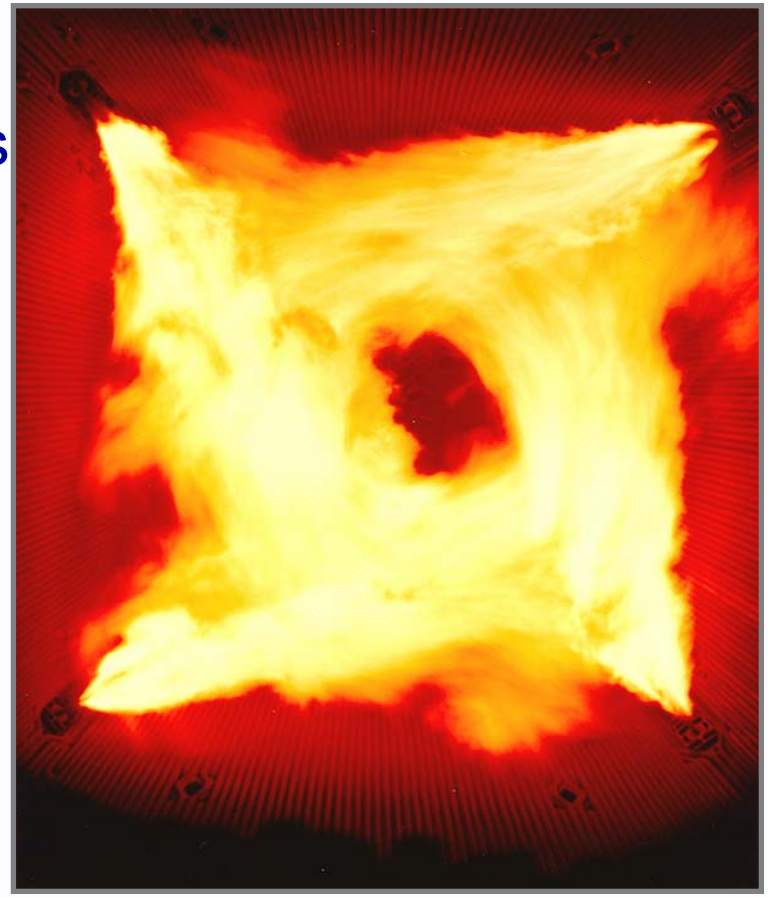
ALSTOM

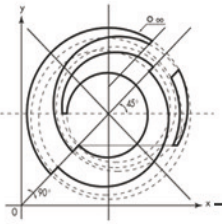
- Gather Input from all Boilers Within an Affected System
- Assess Boiler Conditions, Dispatch Requirements, Remaining Life, and Fuel Switching Options
- Evaluate all Potential NOx Reduction Options
- Determine Optimal Economic Solution

The optimum system solution may be a combination of some or all of the available NOx reduction options

NOx Reduction Options

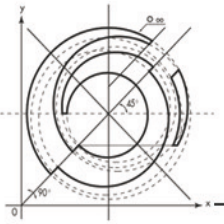
- Firing System Tuning and/or Existing Equipment Modifications
- Fuel Switching
- Firing System / Boiler Modifications Including:
  - Low NOx Burners
  - Overfire Air Systems
  - Reburn Systems
  - Pulverizer Modifications / Systems
  - Control System and/or Neural Network Upgrades
- SNCR Addition
- SCR Addition





Low NOx Design Criteria

- For retrofit Low NOx projects, the major design considerations are:
  - Fuel Characteristics
  - Original Boiler Design Parameters
  - Equipment Limitations
  - Boiler Integrity and Condition
  - Existing Boiler Performance
  - Available Space

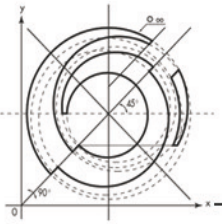


NOx Retrofit - Unit Upgrades and Improvements

ALSTOM

Unit Upgrades and Improvements can be Incorporated into a Low NOx Firing System Project

- Boiler Performance
  - Increase (or Reduce) SH / RH Steam Temperature
  - Correct Furnace Temperature Imbalances
  - Reduce Furnace Slagging / Pluggage Problems
  - Reduce Draft Loss with Redesigned Convective (SH, RH & Economizer) Elements
  - Increase Pulverizer Capacity
- Maintenance Problems
  - Replace Eroded / Corroded Waterwall Tubes with Chromized or Weld-Overlaid Tubing
  - Improve Access to High Maintenance Areas



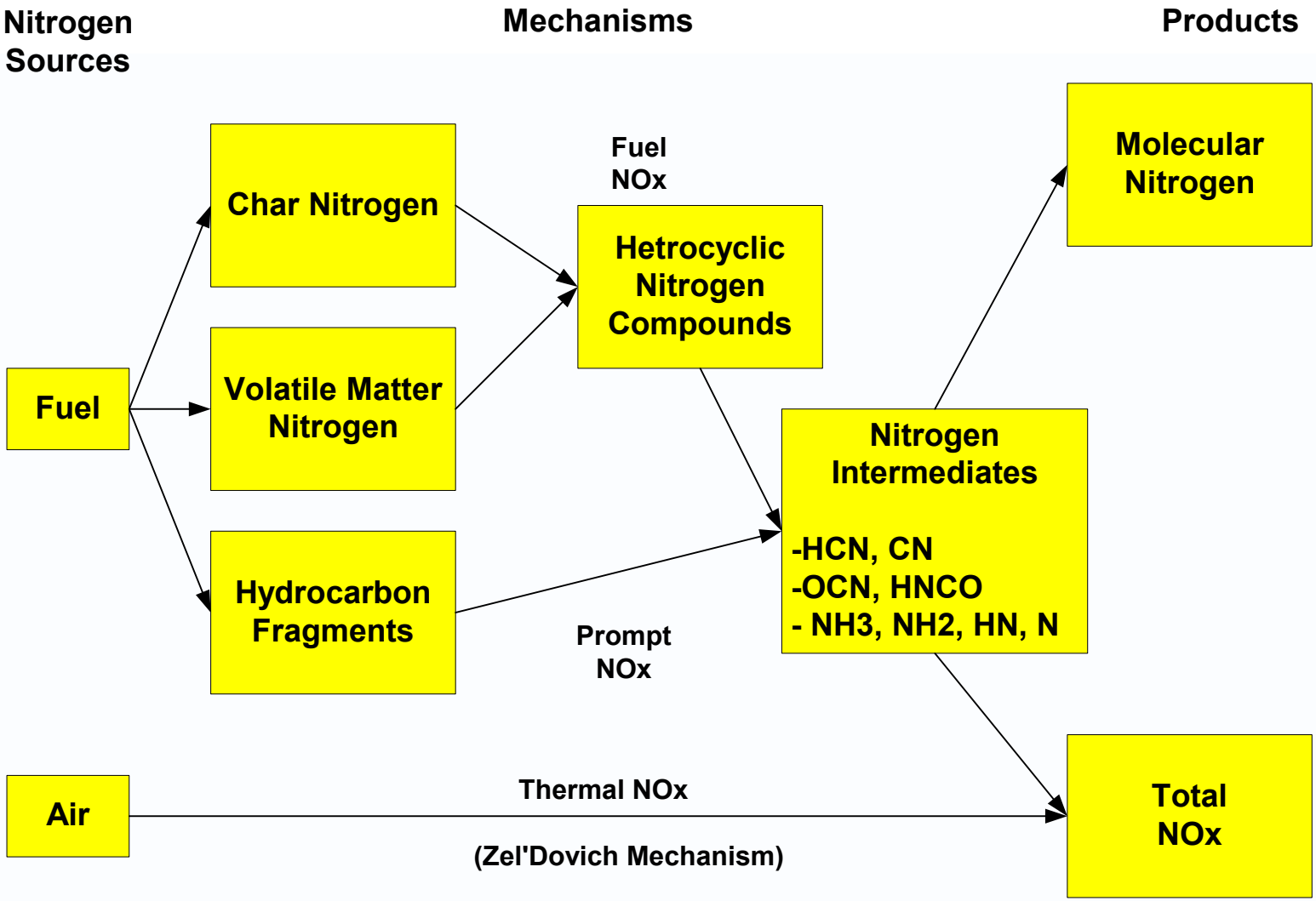
NOx Retrofit - Firing System Improvements

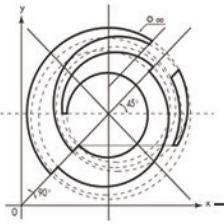
ALSTOM

New Equipment and Upgrades can be Incorporated into a Low NOx Firing System Project

- Fuel Transport System
  - Ceramic Orifices, Wear Resistant Piping & Elbows
  - Rockwell Coal Pipe Couplings
- Coal Compartments
  - Ceramic Lined Coal Nozzles
  - Wear Resistant Coal Tips
  - Various Material Options for Nozzle Tips
- Windbox Components
  - Tilt Upgrades
  - External Damper Bearing Assemblies
  - Air-Cooled Oil Guns
- Ignitor Upgrades

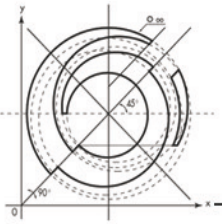
NOx Formation Mechanisms





Types of NOx

NOX Type:	Fuel NOx	Thermal NOx
Source:	Nox formed from Nitrogen in the Volitile Matter and Fixed Carbon in the Fuel	Nox formed from N2 in the Combustion Air.
Formation Sensitive to:	➢ Oxygen Availability ➢ Fuel Nitrogen Content ➢ Kinetics	➢ Furnace Temperature ➢ Oxygen Availability
Proportion	60 – 80%	20 – 40%



Basic NOx Reduction Strategies

ALSTOM

Staging of the Combustion Process

- **Vertically and Horizontally**
- **Fuel Rich / Air Lean Zones**
  - Minimize Air at Early Stages of Combustion (< Fuel NOx);
- **Fuel Lean / Air Rich Zones**
  - Minimize Gas Temperatures in Furnace (< Thermal NOx).

Concentric Firing System (CFS) Design Concept

ALSTOM

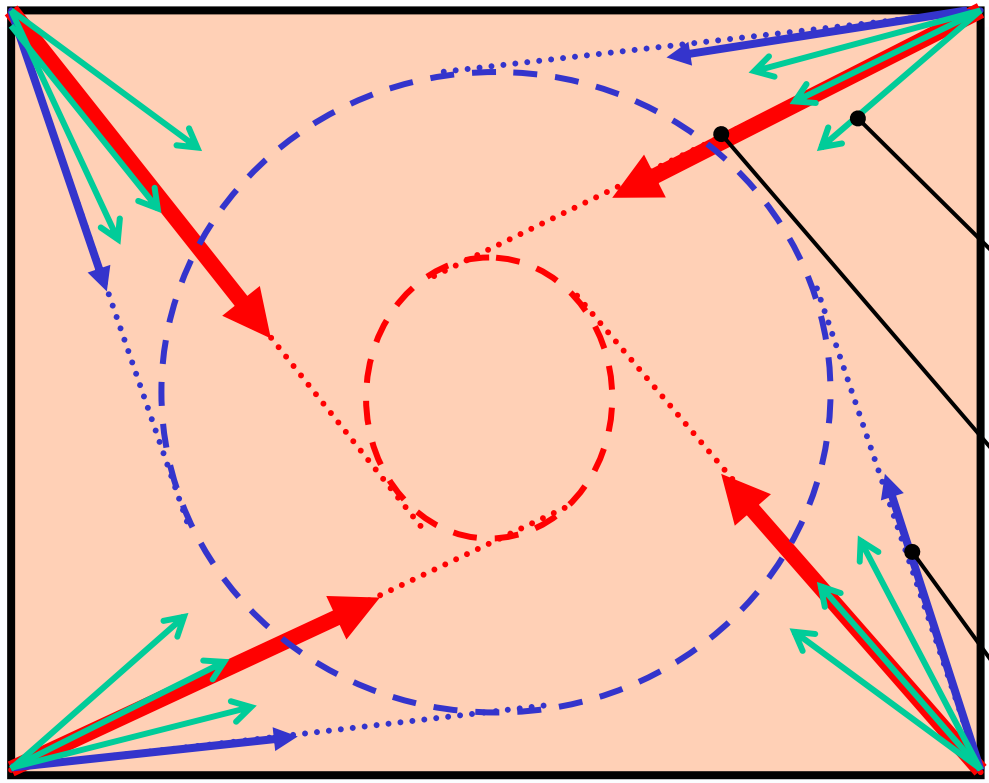
Creates an Oxidizing Near Wall Environment

Decreases Slagging / Increases Waterwall Heat Absorption

Promotes Oxidation of Sulfur Species for Reduced Waterwall Wastage

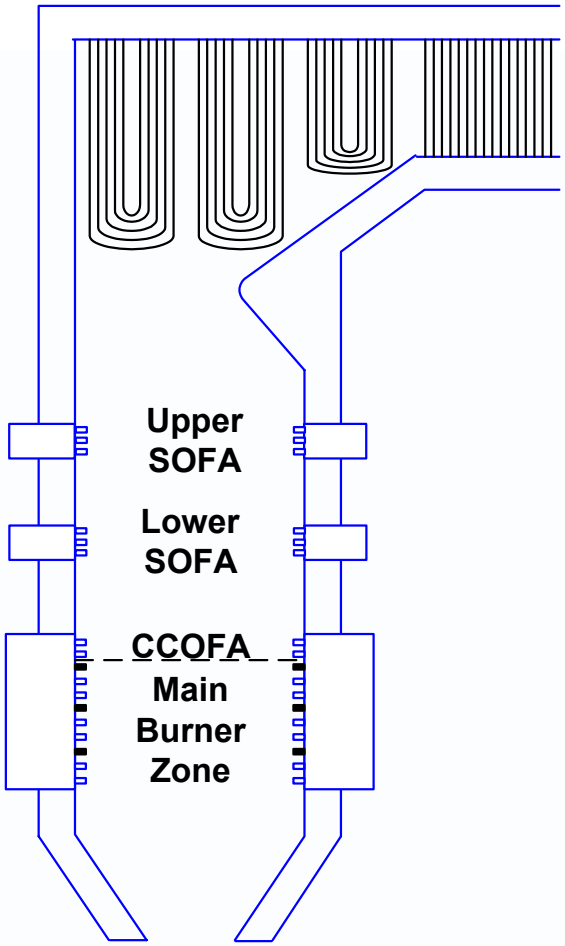
Increases Interaction of OFA and Gasses

Reduces CO and Unburned Carbon



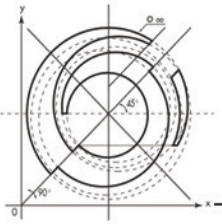
Plan View of Tangentially Fired Furnace

Vertical Staged Combustion for NOx Reduction



- Air-Staged Low NOx Firing Approach
- Utilizes a Flexible, Multi-point Air Injection Design
- Controls the Build-up of Lower Furnace Stoichiometry

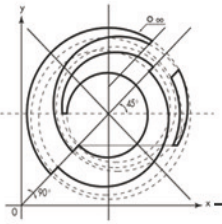
Provides for the Optimization of the Global Time - Temperature - Stoichiometry History for Minimum NOx and UBC



NOx Toolbox

ALSTOM

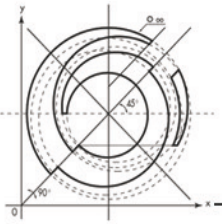
- **All ALSTOM Tangential Low NOx Firing Systems use, to varying degrees, the following three key elements:**
  - OverFire Air (CCOFA and / or SOFA)
  - Concentric Firing System (CFS) offset air
  - Specially designed coal nozzle tips



Family of T-Fired Low NOx Systems

ALSTOM

- LNCFS - P2
- LNCFS - Level I
- LNCFS - Level II
- LNCFS - Level III
- TFS2000R

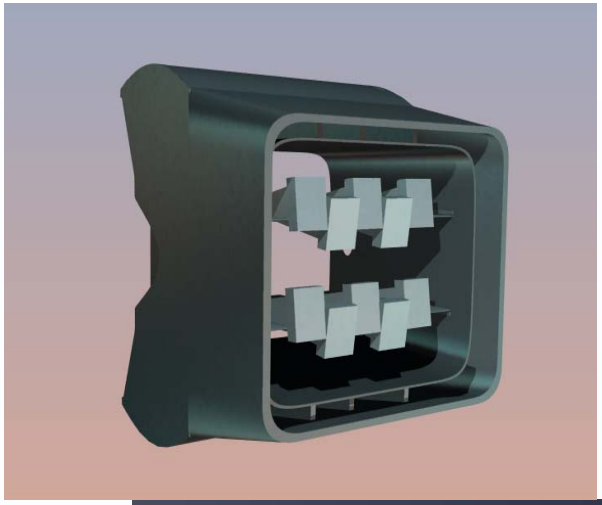


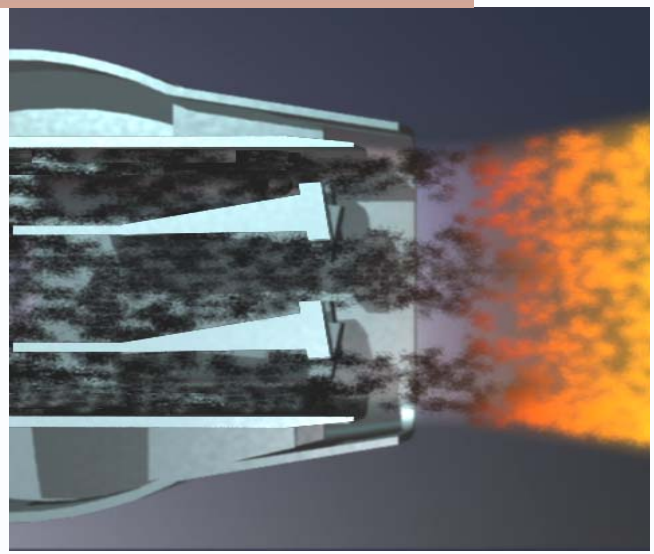
Low NOx Firing System Options

ALSTOM

EXISTING WINDBOX	LNCFS P2	LNCFS LEVEL I	LNCFS LEVEL II	LNCFS LEVEL III	TFS 2000 R
					SOFA
					SOFA
			SOFA	SOFA	SOFA
			SOFA	SOFA	SOFA
END AIR	VCCOFA	CCOFA	END AIR	CCOFA	CCOFA
COAL	P2 COAL	END AIR	P2 COAL	END AIR	END AIR
AUX AIR	CFS	P2 COAL	CFS	P2 COAL	P2 COAL
COAL	P2 COAL	P2 COAL	P2 COAL	P2 COAL	P2 COAL
AUX AIR	CFS	CFS	CFS	CFS	CFS
COAL	P2 COAL	P2 COAL	P2 COAL	P2 COAL	P2 COAL
AUX AIR	CFS	CFS	CFS	CFS	CFS
COAL	P2 COAL	P2 COAL	P2 COAL	P2 COAL	P2 COAL
END AIR	END AIR	END AIR	END AIR	END AIR	END AIR

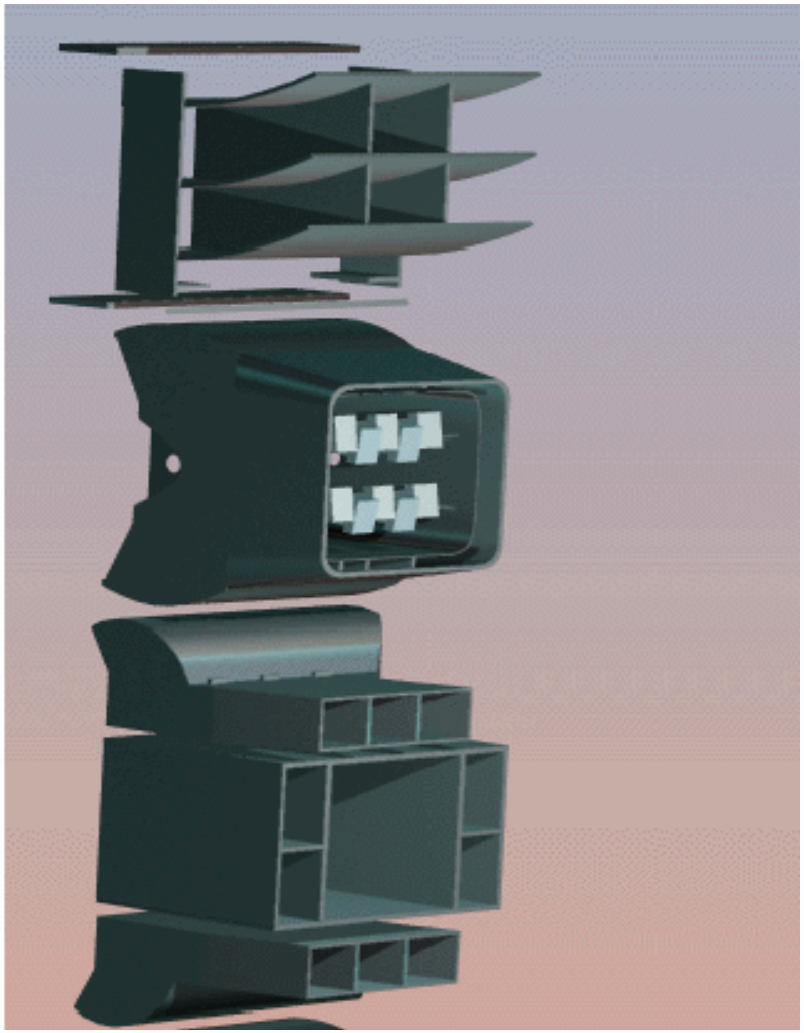
P2 Coal Nozzle Tip





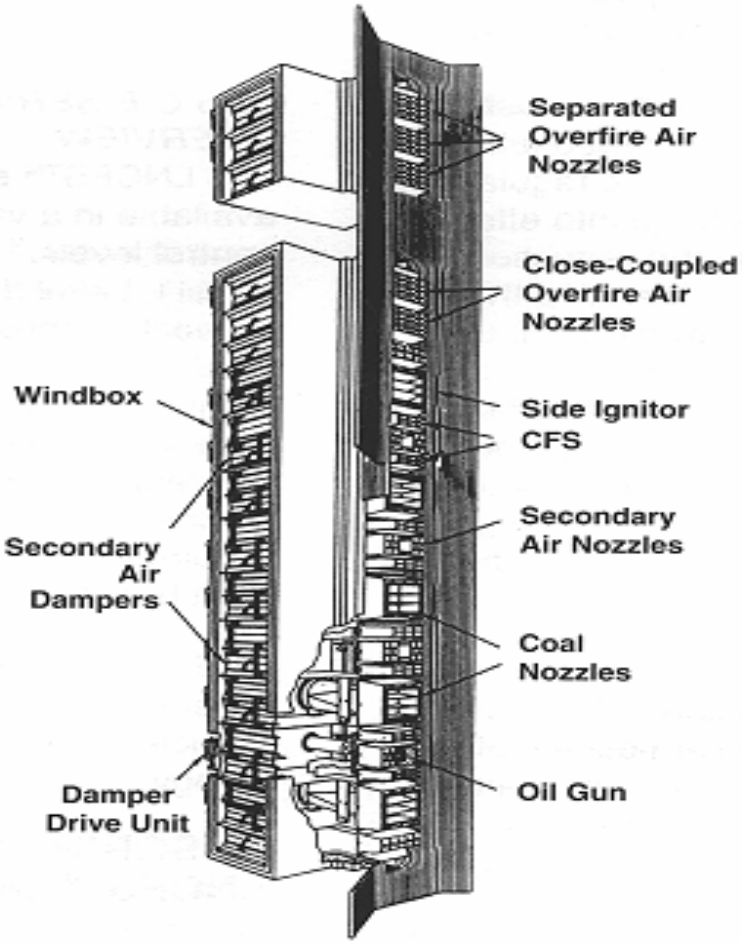
- Low NOx Extension of Proven Aerotip™ Design
- Utilizes Turbulence Generating Bluff Bodies to Increase Turbulent Mixing and Near Burner Ignition
- Bulbous Outer Shroud for Fuel Air Flow & Ignition Point Control
- Provides for Control Over the Local Stoichiometry of Combustion for Reduced NOx

LNCFS™ - P2 Firing System



- Integrated In-windbox Low NOx Firing System
  - Vaned Close Coupled Overfire Air (VCCOFA)
  - P2™ Coal Nozzle Tip
  - Concentric Firing System (CFS™)
- No Pressure Part Modifications
- Maximizes Use of Existing Firing System Equipment

LNCFS Levels I, II and III

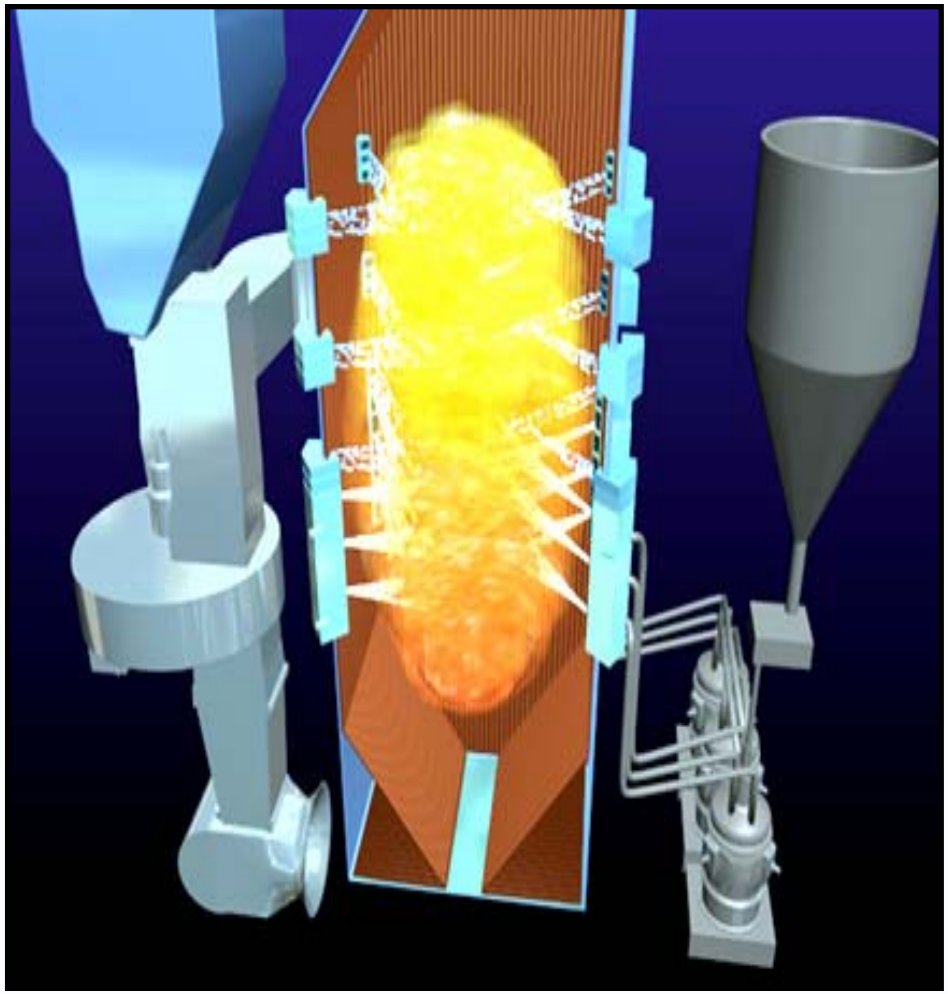


LNCFS ™ Level III

Low NOx Concentric Firing System (LNCFS™)

- Low NOx Coal Nozzle Tips
- Close Coupled Overfire Air (CCOFA) - Levels I & III
- Single-level Separated Overfire Air (SOFA) - Levels II & III
- Concentric Firing System (CFS™)

TFS 2000™R Firing System

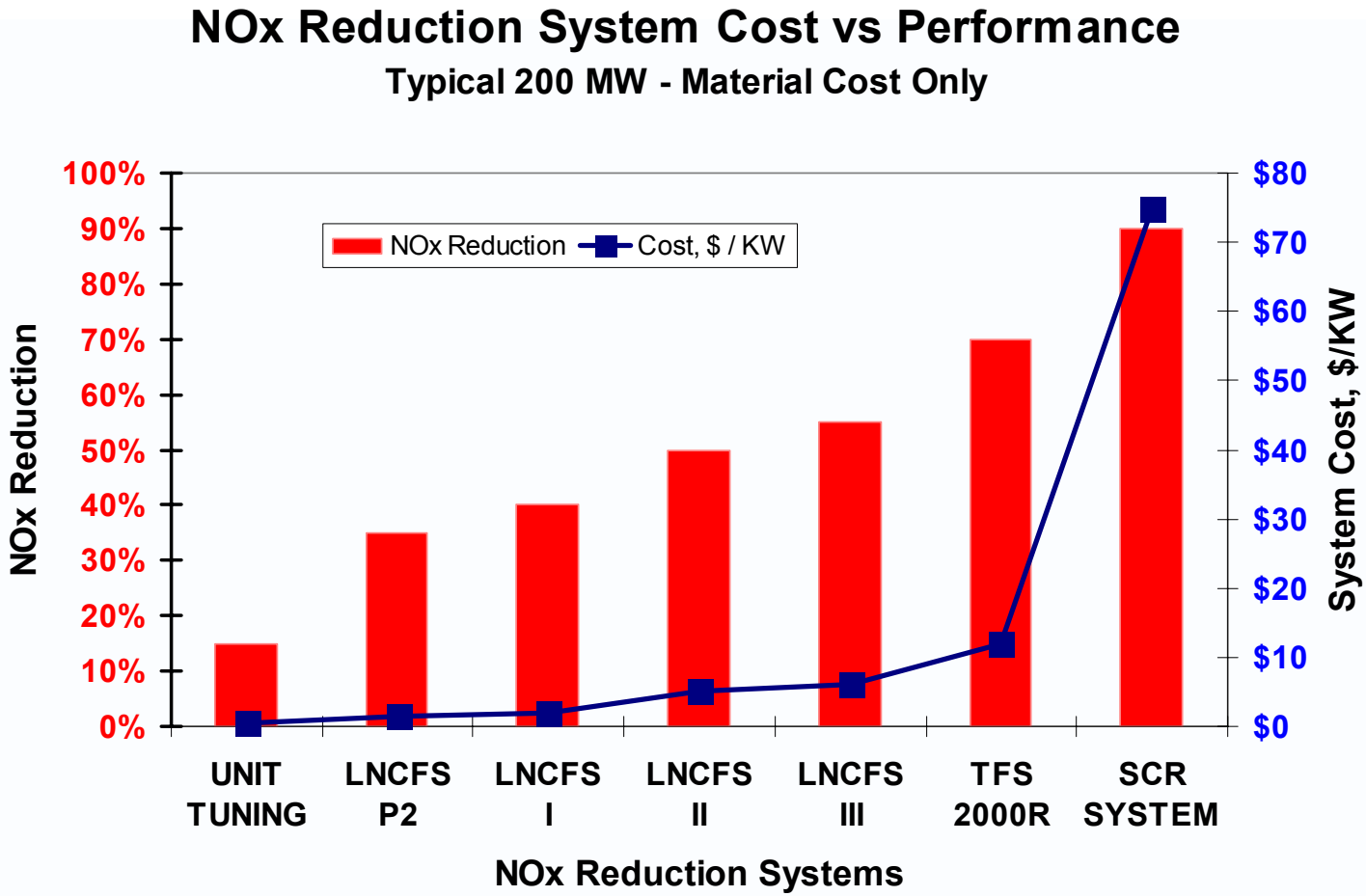


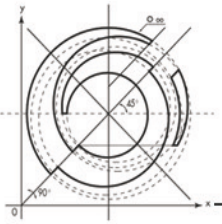
Integrated Low NOx Firing System

- P2™ Low NOx Coal Nozzle Tips
- Close Coupled Overfire Air (CCOFA)
- Multi-level Separated Overfire Air (SOFA)
- Concentric Firing System (CFS™)
- Dynamic™ Classifiers*

* Not required for sub-bituminous coals

NOx Reduction System Cost versus Performance



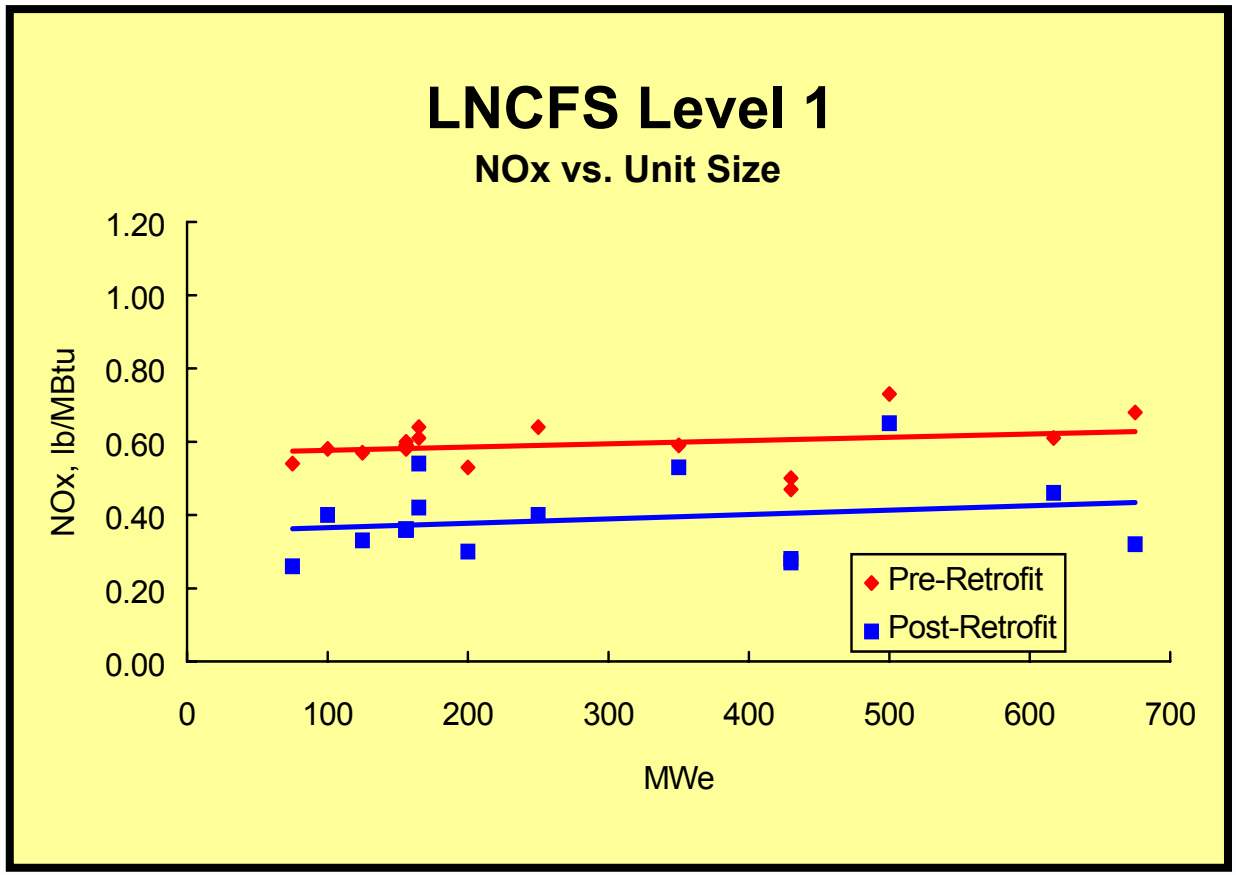


Recent Developments - Tangential Firing Technology

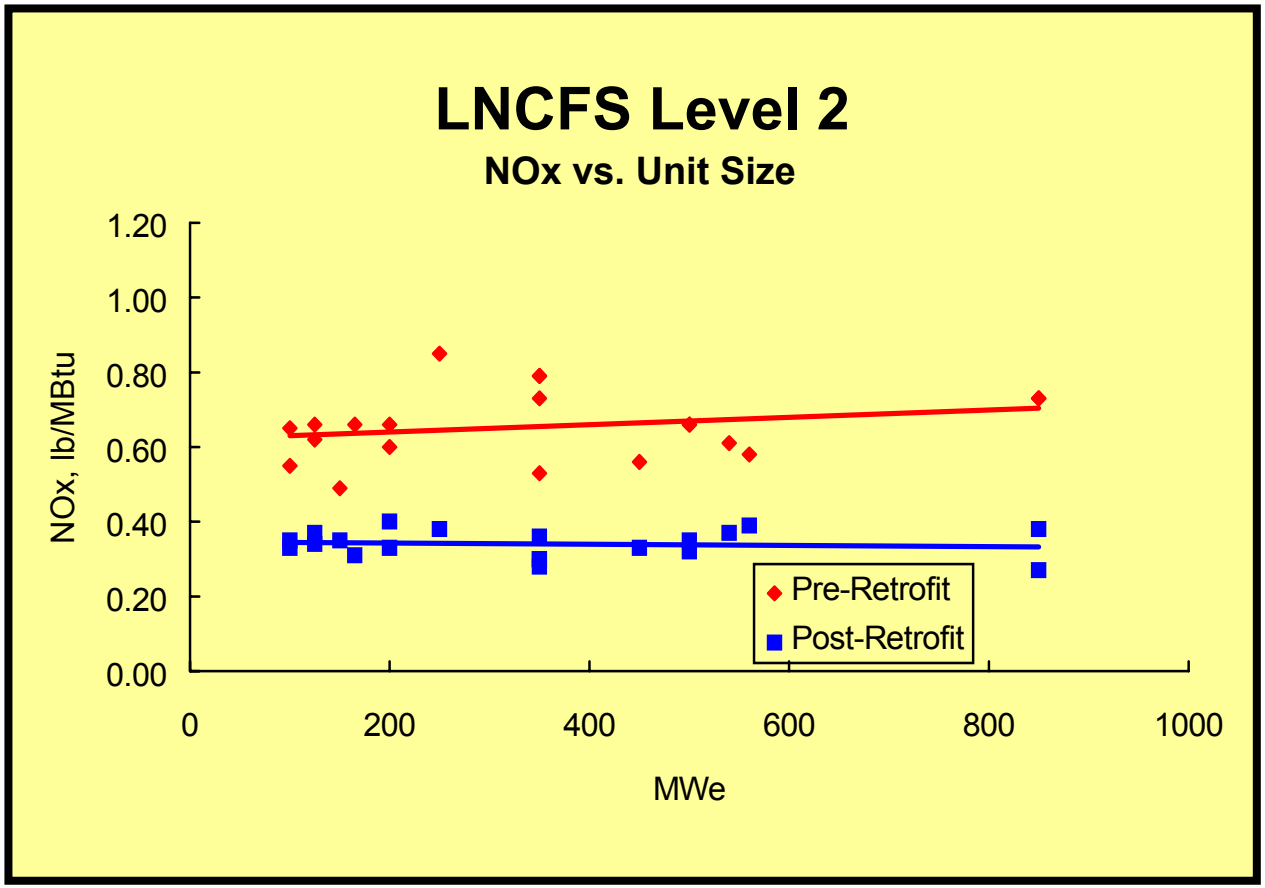
ALSTOM

- LNCFS P-2
  - 20% - 50% Reduction in NOx
  - < $1/kW for a 200 MW Unit
  - Nozzle Tip Replacement. No Modifications!
- TFS 2000R
  - < 0.26 lbs/MMBTU on E. Bit.
  - < 0.15 lbs/MMBTU with PRB and Indonesian Coals
  - * Experience as low as .10lbs/MMBTU
- DOE Ultra Low NOx results
  - < 0.23 lbs/MMBtu on M. Bit
  - < 0.13 lbs/MMBtu on PRB and Indonesian Coals

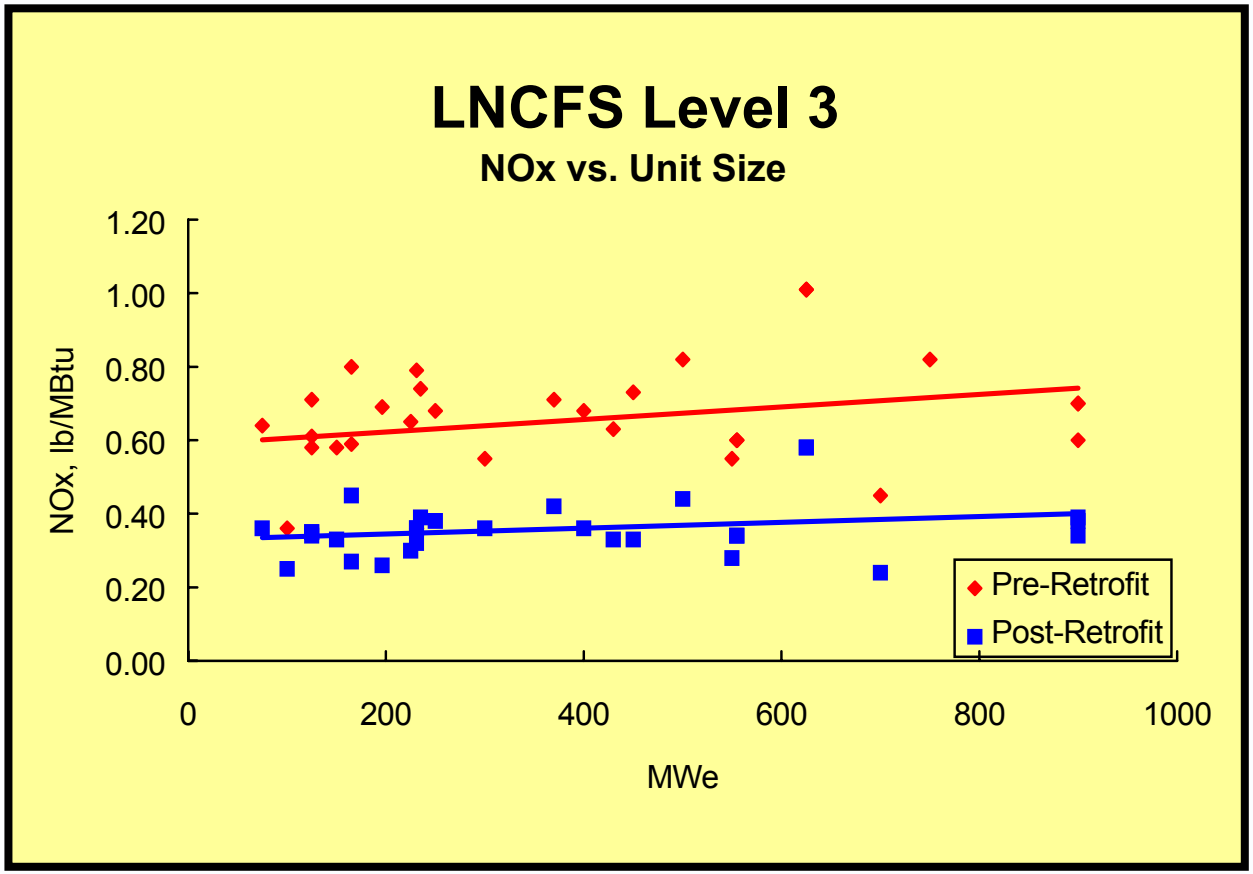
LNCFS™ Level I
NOx vs. Unit Size



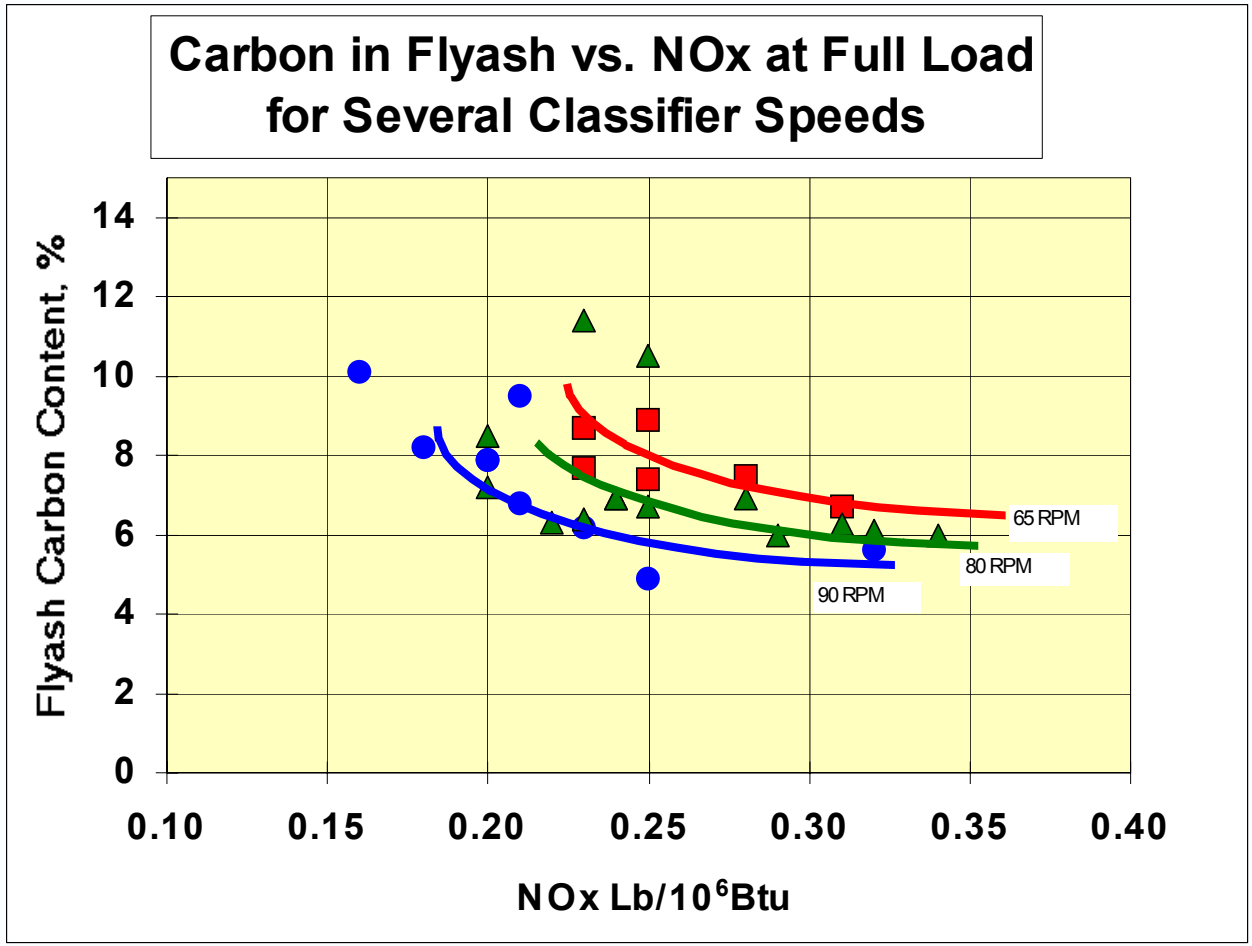
LNCFS™ Level II
NOx vs. Unit Size

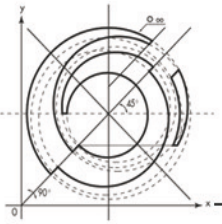


LNCFS™ Level III NOx vs. Unit Size



TFS2000™R - NOx and Unburned Carbon Results with an Eastern Bituminous Coal



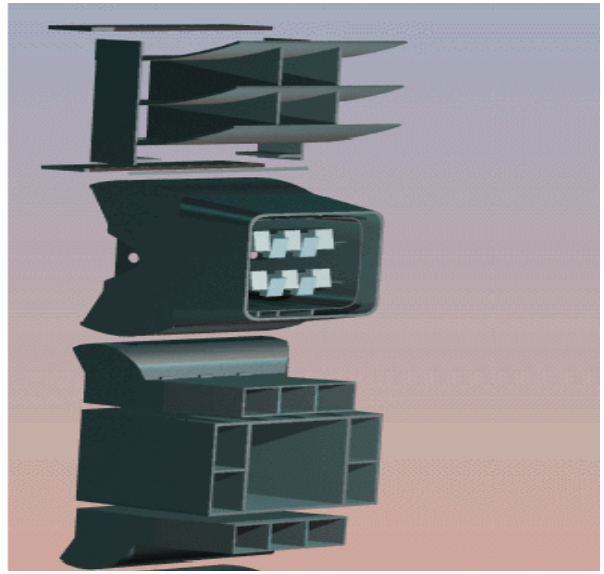


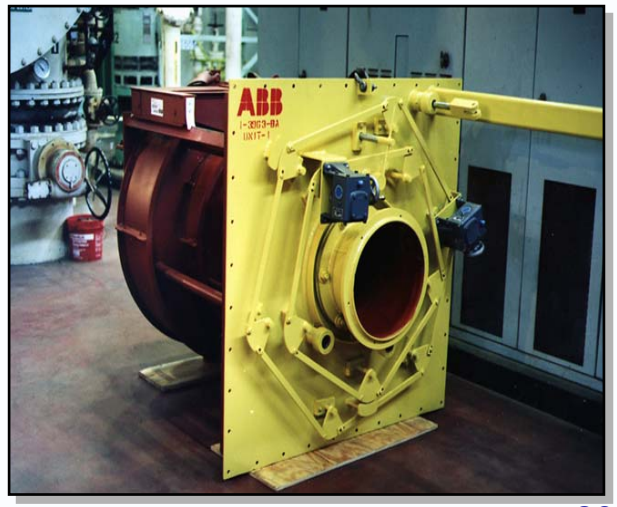
ALSTOM Power's Low NOx Experience

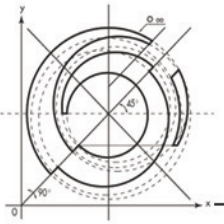
- Over 200 Units Modified with Low NOx Combustion Systems
- Over 180 Modified Units in Operation
- Patent Holders of LNCFS Technology
- Patent Holders of TFS2000^{TM}R
- Development of LNCFS-P2
- LNBFS Technology for Oil and Gas Low NOx
- Reburn Applications
- RSFC Burner

ALSTOM Power
In Furnace Low NOx Experience

Firing System	Units	Mw
LNCFS - P2	33	4,614
LNCFS Level I	49	13,126
LNCFS Level II	52	14,767
LNCFS Level III	52	23,957
TFS 2000 R	22	9,135
Cyclones OFA	2	508
Oil/Gas OFA	6	1,860
Other T fired	10	2,172
RSFC	24	2,600
TOTALS	**250**	**72,739**







ALSTOM Power
Low NOx Capabilities

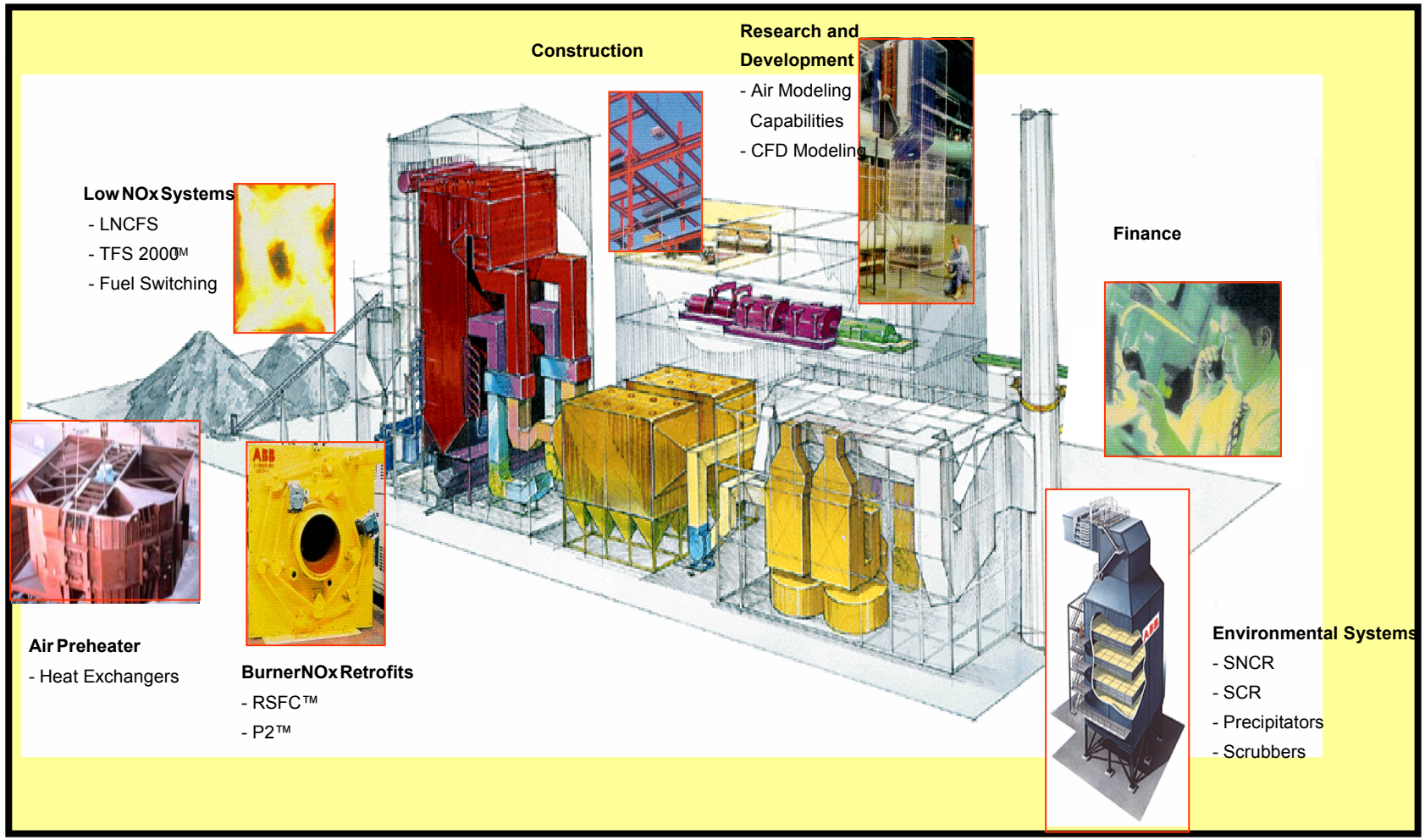
US EPA data for 2001 reveal that 19 of the 20 lowest emitting coal units use Alstom-supplied low NOx Firing systems

No	Unit	State	NOx	System	No	Unit	State	NOx	System
1	Polk 2000	FL	0.10	CGCC*	11	Baldwin 3	IL	0.14	TFS
2	Labadie 1 2000	MO	0.11	LNCFS	12	Parish 7	TX	0.14	TFS
3	Labadie 2	MO	0.11	LNCFS	13	Joppa 1	IL	0.15	LNCFS
4	Labadie 3	MO	0.11	LNCFS	14	Joppa 2	IL	0.15	LNCFS
5	Labadie 4	MO	0.11	LNCFS	15	Joppa 3	IL	0.15	LNCFS
6	Joliet 29 - 71	IL	0.12	TFS 2000	16	Joppa 4	IL	0.15	LNCFS
7	Joliet 29 - 72	IL	0.12	TFS 2000	17	Joppa 5	IL	0.15	LNCFS
8	Rush Island 2	MO	0.12	LNCFS	18	Joppa 6	IL	0.15	LNCFS
9	Waukeegan 8	IL	0.13	TFS 2000	19	Newton 1	IL	0.15	LNCFS
10	Rush Island 1	MO	0.13	LNCFS	20	Newton 2	IL	0.15	TFS2000

* Coal Gasification Combined Cycle demonstration unit

ALSTOM Power

ALSTOM



The Global Boiler Solutions Company


ALSTOM
www.alstom.com