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NOx Compliance for Existing Tangentially Fired Boilers

□有切向燃□□□NO_x的排放□□改造

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Agenda
目□

- **NO_x Compliance Process**
- **NO_x**排放□□工□
- **NO_x Reduction Options**
- **NO_x**□排方案
- **Background Information on NO_x Formation**
- **NO_x**形成基□知□
- **Tangential Firing NOx Solutions**
- 切向燃□□□**NO_x**的解□□法
- **ALSTOM NOx Experience**
- 阿尔斯通的去除**NO_x**□□

Objectives of NOx Compliance

NO_x□□目的

- **Meet Government Regulation's**
- □足政府的法□□定
- **Minimize Financial Impact**
- □□政支出的影□降□最低

Total Integrated NOx Compliance Strategy

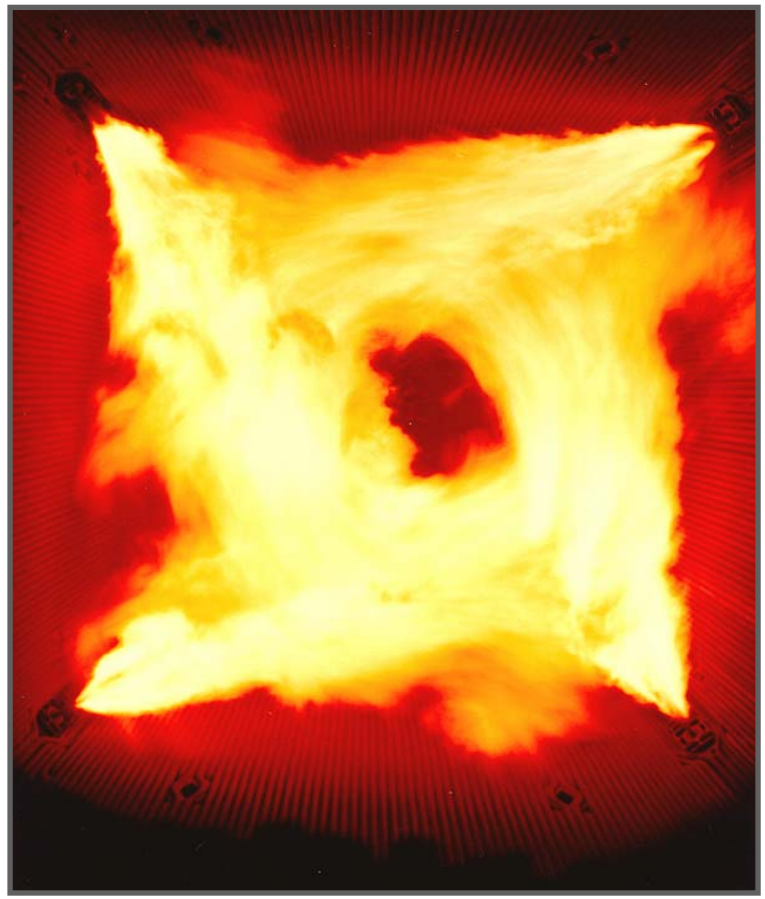
整体NO_x □□的□体□略

- **Gather Input from all Boilers Within an Affected System**
- 在一□起作用的系□□□集□自所有□□的□入□
- **Assess Boiler Conditions, Dispatch Requirements, Remaining Life, and Fuel Switching Options**
- □估□□□件，所需□排的要求，□□的使用□命，及可供□□的燃料
- **Evaluate all Potential NOx Reduction Options**
- □估各□可能□排NO_x 的方案
- **Determine Optimal Economic Solution**
- 确定最□□可行的解□□法
- **The optimum system solution may be a combination of some or all of the available NOx reduction options**
- 最佳的方法可能是一些或所有可利用的NO_x □排方案相□合的□果

NOx Reduction Options

NO_x □排□□方案

- **Firing System Tuning and/or Existing Equipment Modifications**
- 点火系□□整和/或□有□□改造
- **Fuel Switching**
- 燃料□□
- **Firing System / Boiler Modifications Including:**
- 燃□系□/□□的□整，包括：
  - **Low NOx Burners**
  - 低NO_x 燃□器
  - **Overfire Air Systems**
  - 燃□□系□
  - **Reburn Systems**
  - 再燃系□
  - **Pulverizer Modifications / Systems**
  - 磨煤机□整/系□
  - **Control System and/or Neural Network Upgrades**
  - 控制系□和/或神□□□升□
- **SNCR Addition**
- 增加SNCR
- **SCR Addition**
- 增加SCR



Low NOx Design Criteria

低NO_x □□□范

- **For retrofit Low NOx projects, the major design considerations are:**
- □于改造的低NO_x 工程□目，□□要考□的主要□□是
  - **Fuel Characteristics**
  - 燃料特性
  - **Original Boiler Design Parameters**
  - □□的原始□□□□
  - **Equipment Limitations**
  - □□的限制□件
  - **Boiler Integrity and Condition**
  - □□整体性及其□□□件
  - **Existing Boiler Performance**
  - □有□□的特点
  - **Available Space**
  - 可利用的空□

NOx Retrofit - Unit Upgrades and Improvements

低NO_x 改造-机□的升□和改□

Unit Upgrades and Improvements can be Incorporated into a Low NOx Firing System Project
在低NO_x 燃□系□工程中，可以合□□行机□的升□和改□

- **Boiler Performance**
- □□□行特征
  - **Increase (or Reduce) SH / RH Steam Temperature**
  - 增加（或降低）□□器/再□器蒸汽□度
  - **Correct Furnace Temperature Imbalances**
  - □整□□烟□偏差
  - **Reduce Furnace Slagging / Pluggage Problems**
  - □少□□□渣/堵灰□□
  - **Reduce Draft Loss with Redesigned Convective (SH, RH & Economizer) Elements**
  - 重新□□的□流受□面（□□器，再□器和省煤器）能□少通□□失
  - **Increase Pulverizer Capacity**
  - 提高磨煤机出力
- **Maintenance Problems**
- □修□□
  - **Replace Eroded / Corroded Waterwall Tubes with Chromized or Weld-Overlaid Tubing**
  - 用渗□或全覆盖□接管更□已侵□/腐□的水冷壁管
  - **Improve Access to High Maintenance Areas**
  - 改□高□修部位的通路

NO_x Retrofit - Firing System Improvements

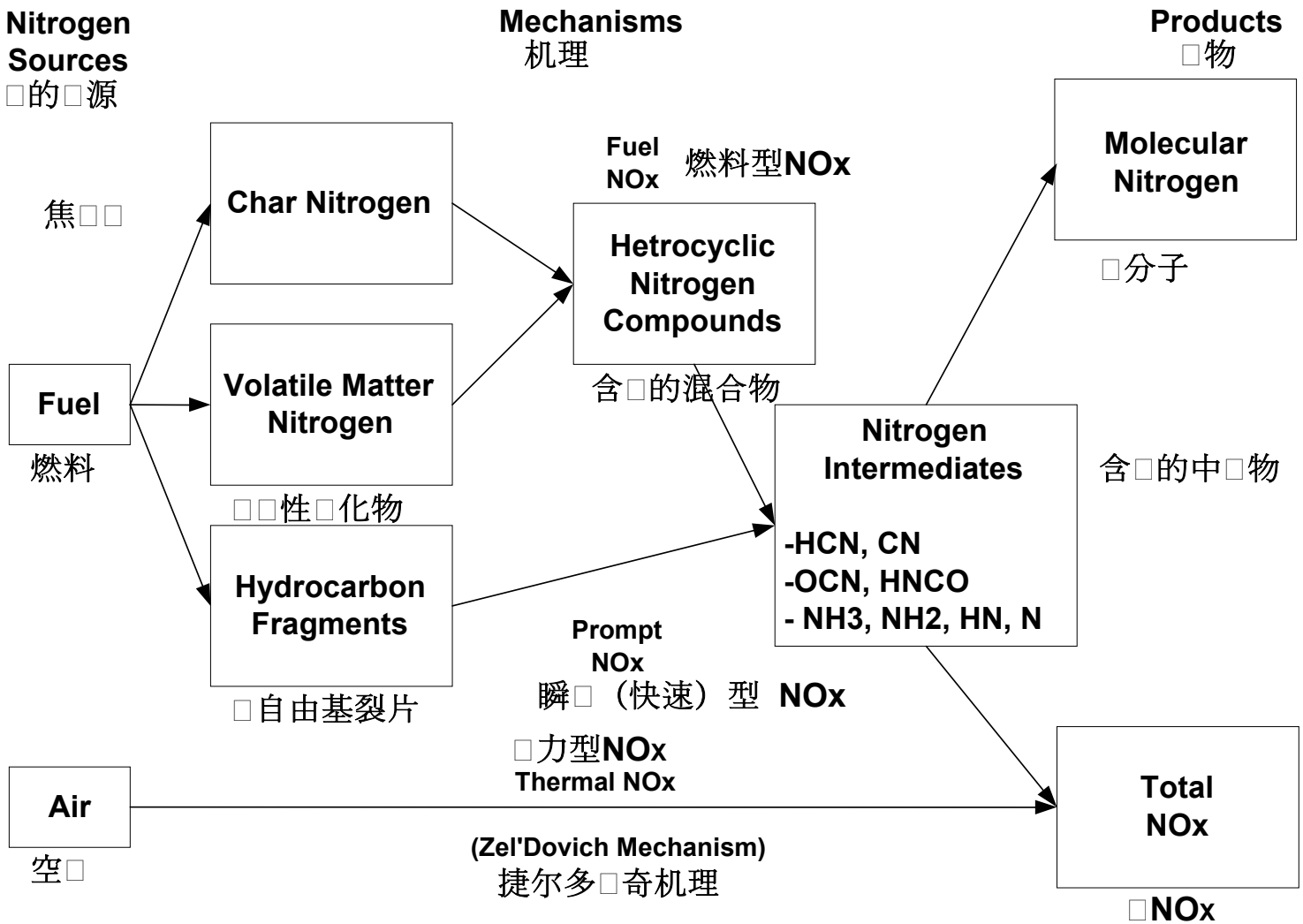
低NO_x 改造-燃□系□的改□

New Equipment and Upgrades can be Incorporated into a Low NOx Firing System Project
新□□和升□改造可以合□□低NO_x 燃□系□改造工程中

- **Fuel Transport System** 燃料□送系□
  - **Ceramic Orifices, Wear Resistant Piping & Elbows**
  - 陶瓷□流孔圈, □耐磨□里的管道和□□
  - **Rockwell Coal Pipe Couplings**
  - 振□落煤管的□接
- **Coal Compartments** 煤□
  - **Ceramic Lined Coal Nozzles**
  - □陶瓷的煤粉□嘴
  - **Wear Resistant Coal Tips**
  - 防磨粉□口
  - **Various Material Options for Nozzle Tips**
  - □□嘴□口的各□材料□□
- **Windbox Components** □箱部分
  - **Tilt Upgrades**
  - □□部分的升□
  - **External Damper Bearing Assemblies**
  - 外部□□□承的装配
  - **Air-Cooled Oil Guns**
  - □冷式油□
- **Ignitor Upgrades** 点火器升□

NOx Formation Mechanisms

NO_x 形成机理



Types of NOx

NO_X□型

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

Basic NOx Reduction Strategies

NO_X □排的基本策略

Staging of the Combustion Process

分□燃□工□

- **Vertically and Horizontally**
- 立式或□式
- **Fuel Rich / Air Lean Zones**
- 富燃料□/□□□
  - **Minimize Air at Early Stages of Combustion (< Fuel NO_x);**
  - 在燃□的□始□段用最小的空□量（降低燃料型NO_x）
- **Fuel Lean / Air Rich Zones**
- □燃料□/富□□
  - **Minimize Gas Temperatures in Furnace (< Thermal NOx).**
  - 降低□□□体的□度（降低□力型NO_x）

Concentric Firing System (CFS) Design Concept

同心式燃□系□（CFS）□□的□念

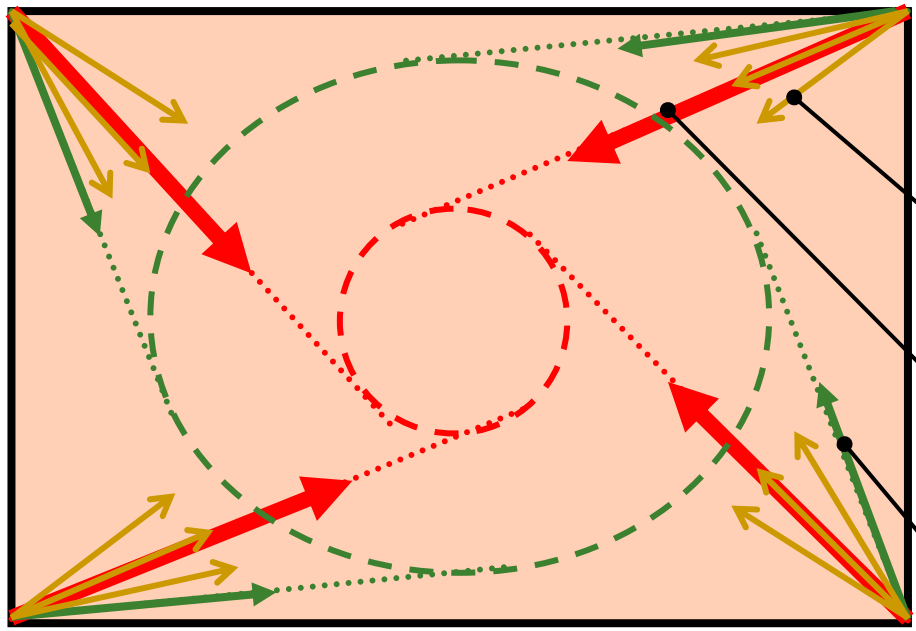
Creates an Oxidizing Near Wall Environment
□造了一□近壁□化的□境

Decreases Slagging / Increases Waterwall Heat Absorption
□少□渣/增加水冷壁的□吸收

Promotes Oxidation of Sulfur Species for Reduced Waterwall Wastage
提高硫化物的□化可以降低水冷壁的□耗

Increases Interaction of OFA and Gasses
增加燃□□（OFA）□烟□的相互作用

Reduces CO and Unburned Carbon
□少CO和未燃□



Plan View of Tangentially Fired Furnace

切向燃□□□的平面□

Overfire Air (Adjustable Yaw)

燃□□（偏□角度可□）

Primary Air, Fuel, & Secondary Air

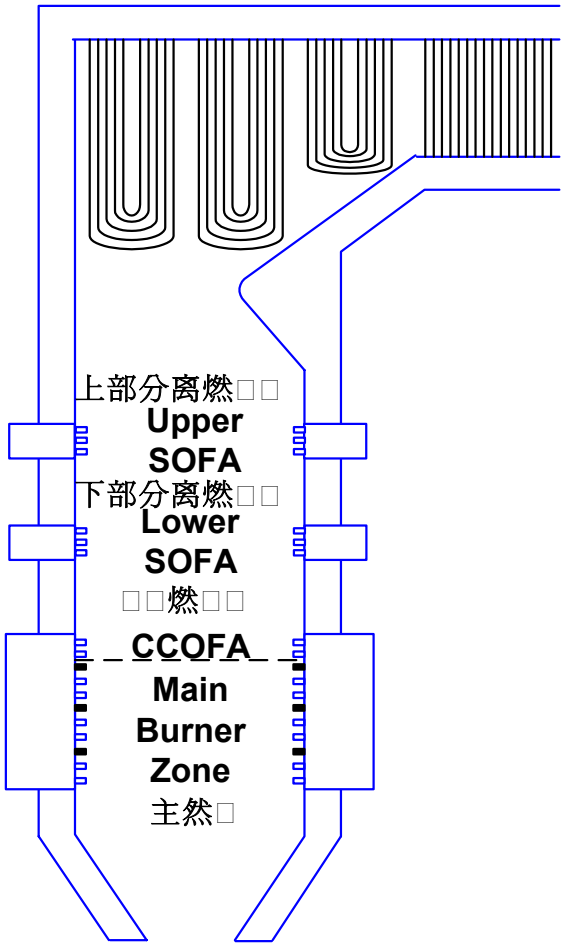
一次□燃料和二次□

CFS Offset Secondary Air

CFS偏移的二次□

Vertical Staged Combustion for NOx Reduction

立式分□燃□以□排NOx



Air-Staged Low NOx Firing Approach

空□分□的低**NOx**燃□方法

Utilizes a Flexible, Multi-point Air Injection Design

使用一□□活的，多点供□的□□

Controls the Build-up of Lower Furnace Stoichiometry

控制建立□低的□□化□□量比

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

□最小的**NOx**和未燃□□（**UBC**），提供□□-□度-化□□量比的□体□程

NOx Toolbox
降低NOx的方法

- **All ALSTOM Tangential Low NOx Firing Systems use, to varying degrees, the following three key elements:**
- 所有阿尔斯通的切向燃□低**NOx**系□都使用以下三□□□技□，适用不同的需要：
  - **OverFire Air (CCOFA and / or SOFA)**
  - 使用燃□□
  - **Concentric Firing System (CFS) offset air**
  - 加入偏置□的同心燃□系□
  - **Specially designed coal nozzle tips**
  - 使用特□□□的煤粉□嘴口

Family of T-Fired Low NOx Systems
系列的切向燃□低NOx系□

- **LNCFS - P2**
- 低**NOx**同心偏置□燃□系□**- P2**
- **LNCFS - Level I**
- 低**NOx**同心偏置□燃□系□**- I**
- **LNCFS - Level II**
- 低**NOx**同心偏置□燃□系□**- II**
- **LNCFS - Level III**
- 低**NOx**同心偏置□燃□系□**- III**
- **TFS2000R**
- 切向燃□（低**NOx** ）系□**2000R**

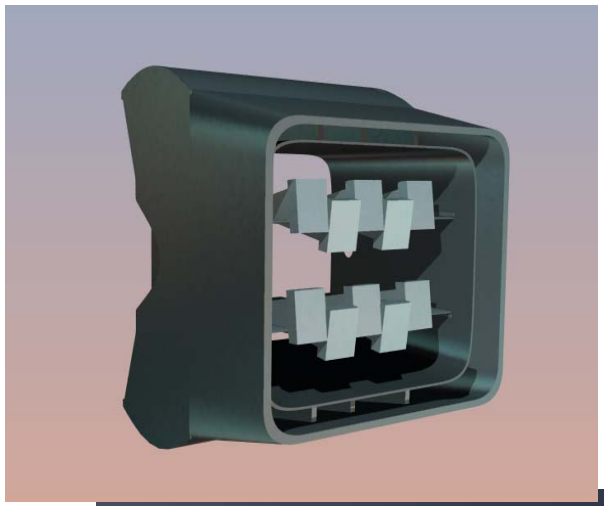
Low NOx Firing System Options

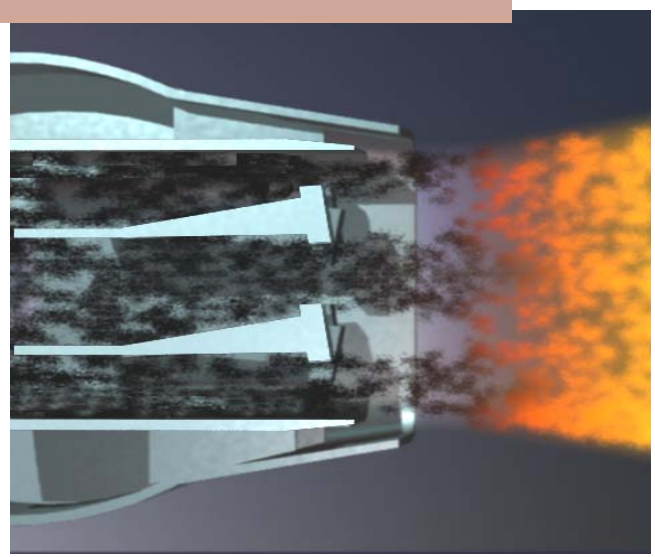
低NOx 燃□系□的□□方案

EXISTING WINDBOX Ö Ð Ä ç í	LNCFS P2	LNCFS LEVEL I	LNCFS LEVEL II	LNCFS LEVEL III	TFS 2000 R
					SOFA SOFA
			SOFA SOFA Ö À È¼ ¾ ç	SOFA SOFA	SOFA SOFA
END AIR ¶ ¾ ç	VCCOFA Ò ÆÕ½ Ö È¼ ¾ ç	CCOFA Õ½ Ö È¼ ¾ ç	END AIR	CCOFA	CCOFA
COAL Ò Î ç Û	P2 COAL	END AIR	P2 COAL	END AIR	END AIR
AUX AIR ¨ Ö ç £ ¶ Î ç ©	CFS í ä ÆÄ ç Ü í	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

P2煤粉□嘴

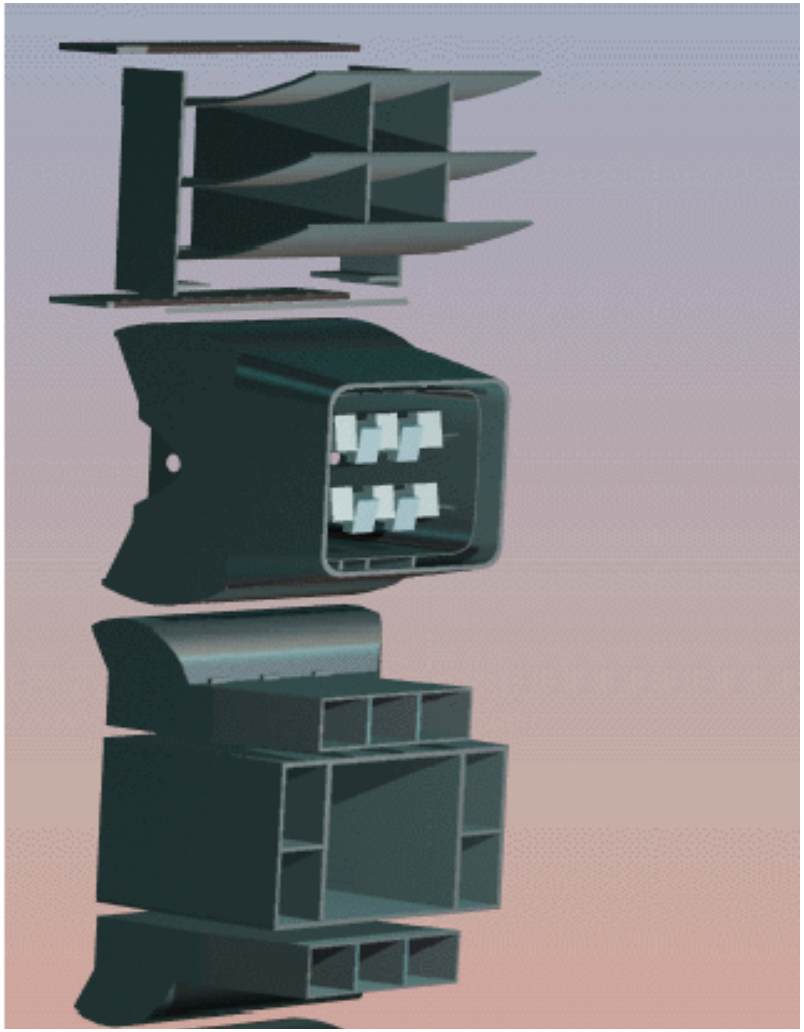




- **Low NOx Extension of Proven Aerotip™ Design**
- □□□的**Aerotip™** □□**-**低**NOx**技□的□展
- **Utilizes Turbulence Generating Bluff Bodies to Increase Turbulent Mixing and Near Burner Ignition**
- 使用湍流□体□生器，增加湍流混合□在近燃□器□着火
- **Bulbous Outer Shroud for Fuel Air Flow & Ignition Point Control**
- （火）球根部□的（高□烟□）覆盖，保□了□燃料**-**空□流（一次□粉）和着火点的控制
- **Provides for Control Over the Local Stoichiometry of Combustion for Reduced NOx**
- □了□少**NOx**排放，提供了在整□燃□的局部化□□量（理□空□量）的控制

LNCFS™ - P2 Firing System

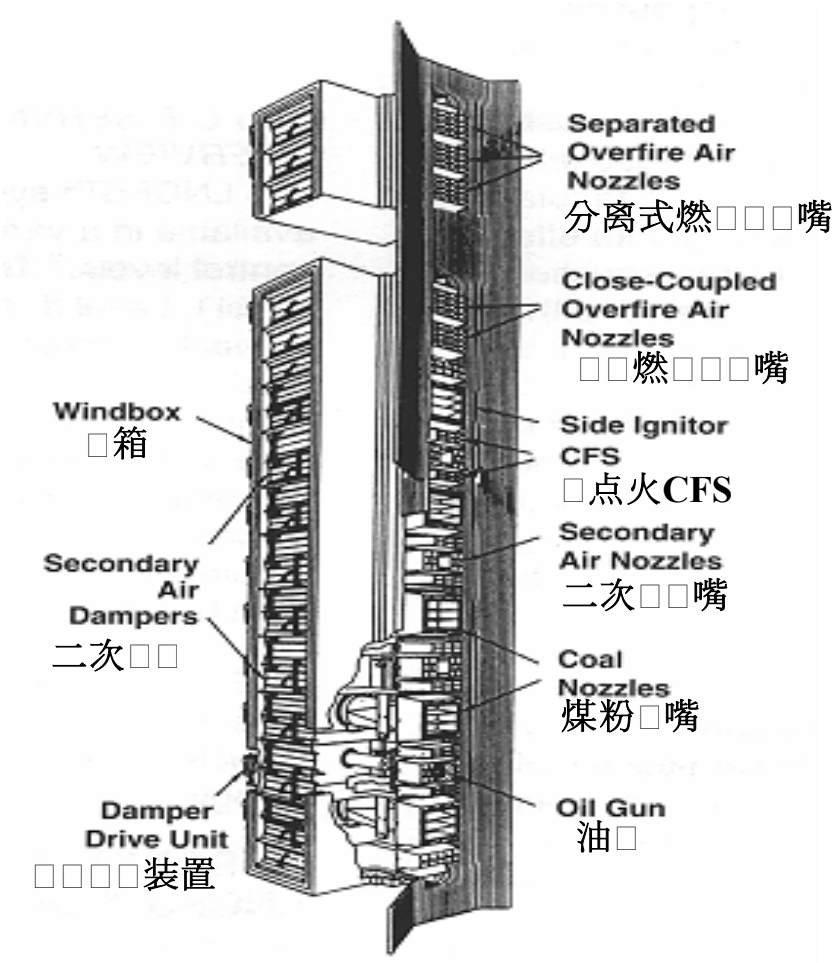
LNCFS™ - P2 燃□系□



- **Integrated In-windbox Low NOx Firing System**
- □箱□低**NOx** 燃□系□一体化
  - **Vaned Close Coupled Overfire Air (VCCOFA)**
  - 叶片□□燃□□（**VCCOFA**）
  - **P2™ Coal Nozzle Tip**
  - **P2™**煤粉□口
  - **Concentric Firing System (CFS™)**
  - 同心式燃□系□
- **No Pressure Part Modifications**
- 无□力部件的□整
- **Maximizes Use of Existing Firing System Equipment**
- □有燃□系□□□的最大利用

LNCFS Levels I, II and III

低NOx 同心燃□系□I, II 和 III



LNCFS ™ Level III

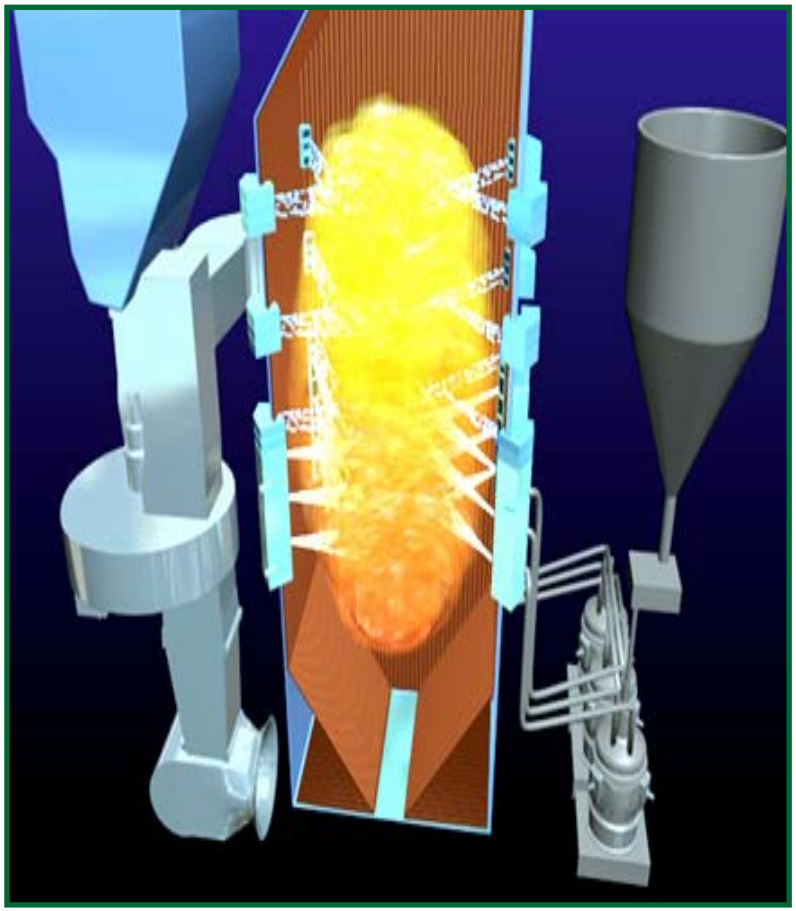
Low NOx Concentric Firing System (LNCFS™)

低NOx 同心式燃□系□

- **Low NOx Coal Nozzle Tips**
- 低NOx 煤粉□□
- **Close Coupled Overfire Air (CCOFA) - Levels I & III**
- □□燃□□（CCOFA）- Levels I 和 III
- **Single-level Separated Overfire Air (SOFA) - Levels II & III**
- □□分离燃□□ (SOFA) - Levels I 和 III
- **Concentric Firing System (CFS™)**
- 同心式燃□系□(CFS™)

TFS 2000™R Firing System

TFS 2000™R 燃□系□



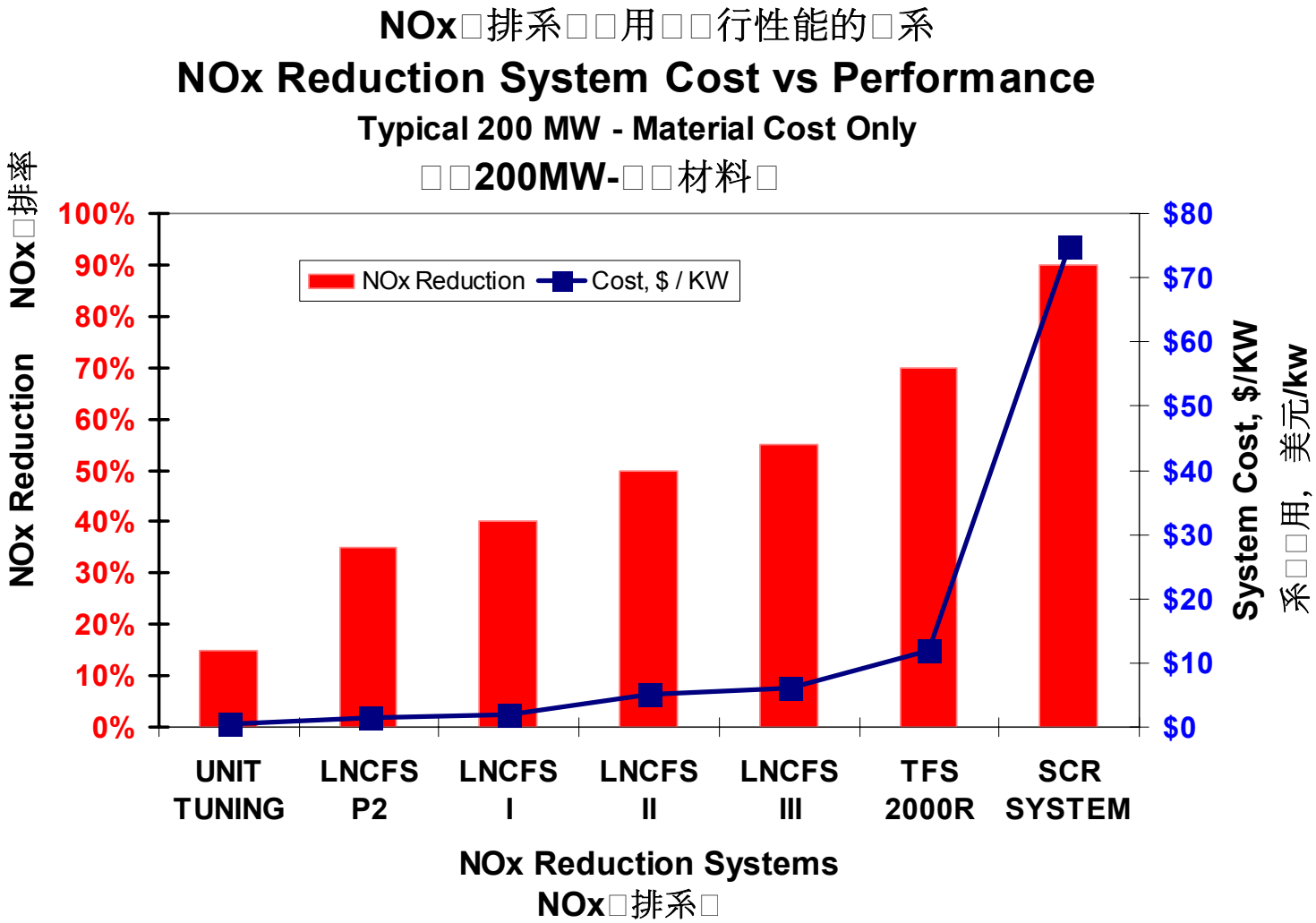
Integrated Low NOx Firing System

一体化的低**NOx** 燃□系□

- **P2™ Low NOx Coal Nozzle Tips**
- **P2™** 低**NOx**煤粉□口
- **Close Coupled Overfire Air (CCOFA)**
- 封□□接的燃□□**(CCOFA)**
- **Multi-level Separated Overfire Air (SOFA)**
- 多□分离燃□□**(SOFA)**
- **Concentric Firing System (CFS™)**
- 同心式燃□系□**(CFS™)**
- **Dynamic™ Classifiers***
- □□分离器
- **Not required for sub-bituminous coals**
- 不适用于劣□烟煤

NOx Reduction System Cost versus Performance

NOx□排系□□用□□行性能的□系

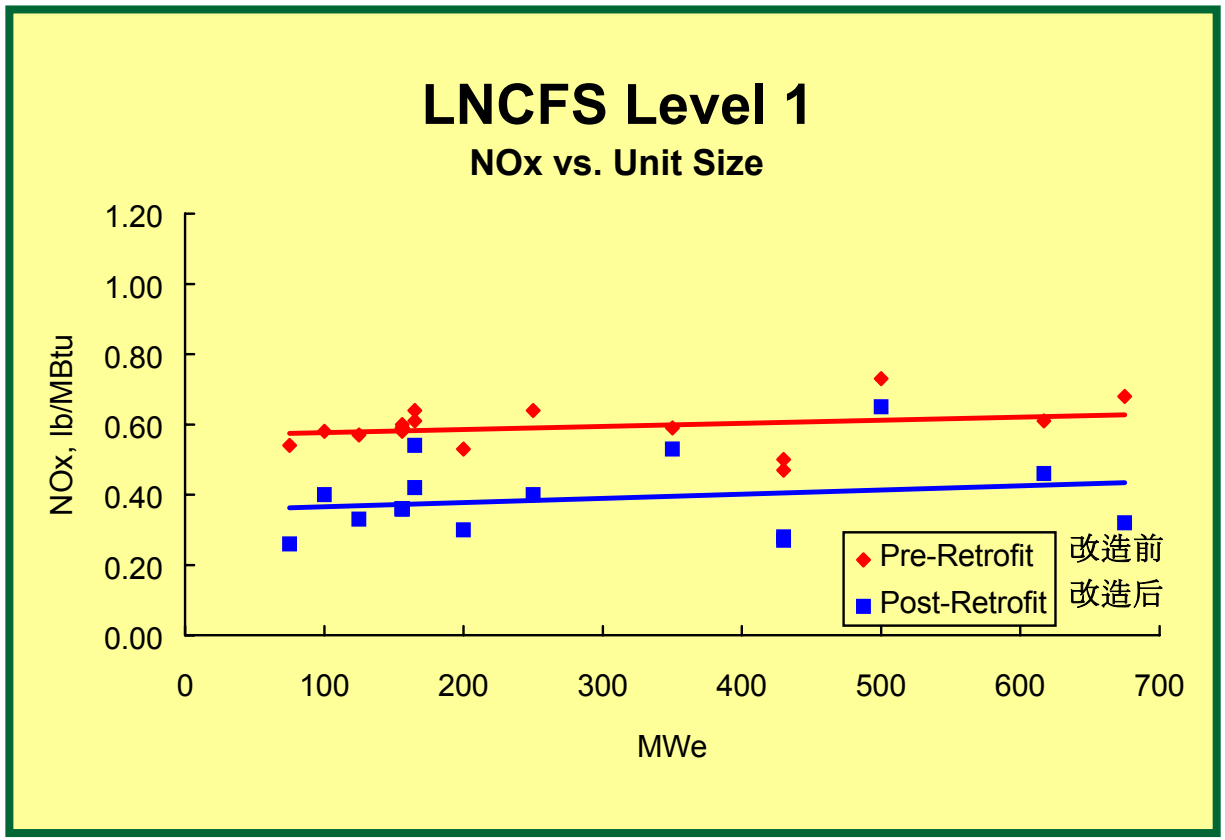


Recent Developments - Tangential Firing Technology
最近的□究□展-切向燃□技□

- **LNCFS P-2**
  - **20% - 50% Reduction in NOx**
  - **NOx□少20%-50%**
  - **< $1/kW for a 200 MW Unit**
  - **200MW机□低于$1/kW**
  - **Nozzle Tip Replacement. No Modifications!**
  - 更新□嘴口，不必改造
- **TFS 2000R**
  - **< 0.26 lbs/MMBTU on E. Bit.**
  - 使用□部烟煤□，低于 **0.26 lbs/MMBTU**
  - **< 0.15 lbs/MMBTU with PRB and Indonesian Coals**
  - 使用**PRB**和印尼煤□，低于**0.15 lbs/MMBTU**
  - *** Experience as low as .10lbs/MMBTU**
  - 有低于**0 .10lbs/MMBTU**的□□
- **DOE Ultra Low NOx results**
- **DOE**超低**NOx** □果
  - **< 0.23 lbs/MMBtu on M. Bit**
  - 使用中部烟煤，低于**0.23 lbs/MMBtu**
  - **< 0.13 lbs/MMBtu on PRB and Indonesian Coals**
  - 使用**PRB**和印尼煤□低于**0.13 lbs/MMBtu**

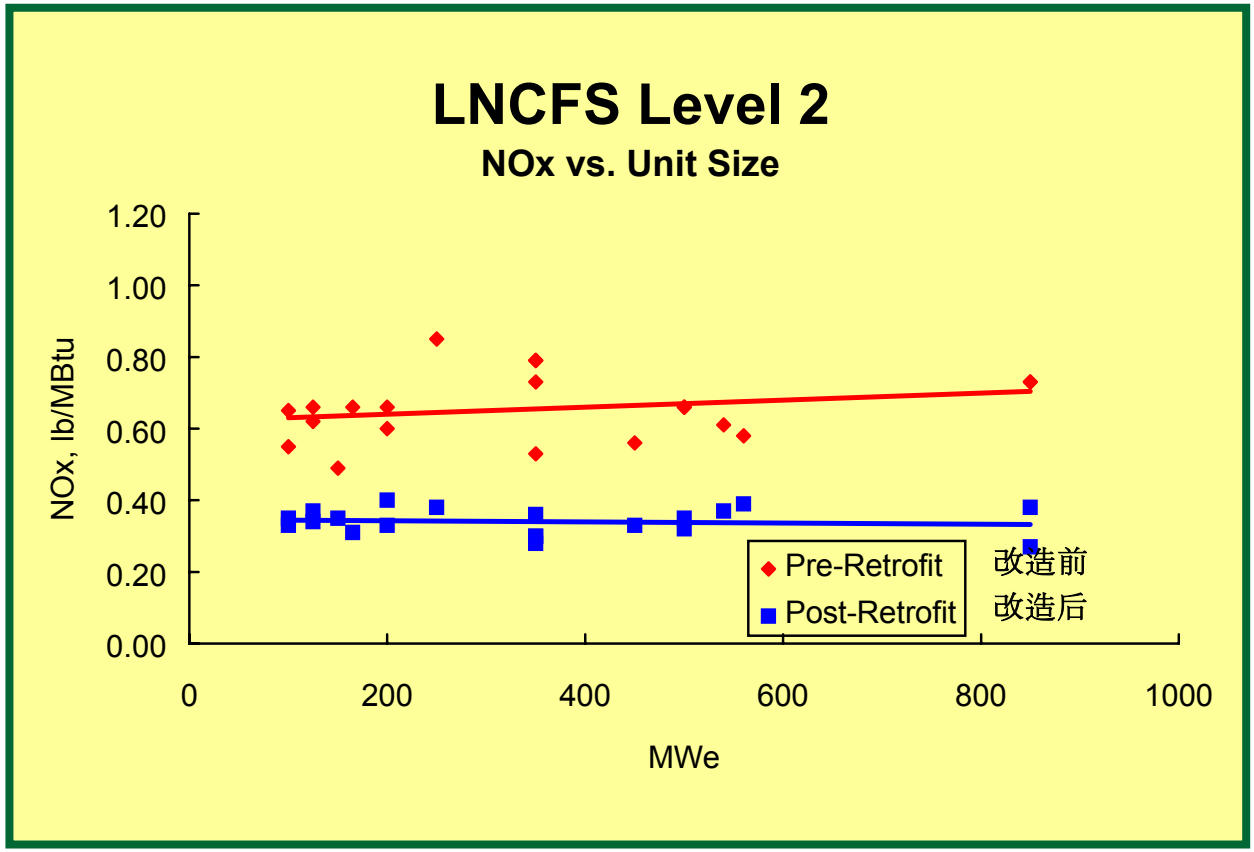
LNCFS™ Level I NOx vs. Unit Size LNCFS™ Level I的

NOx □□机□容量的□系（用LNCFS™ I 系□）



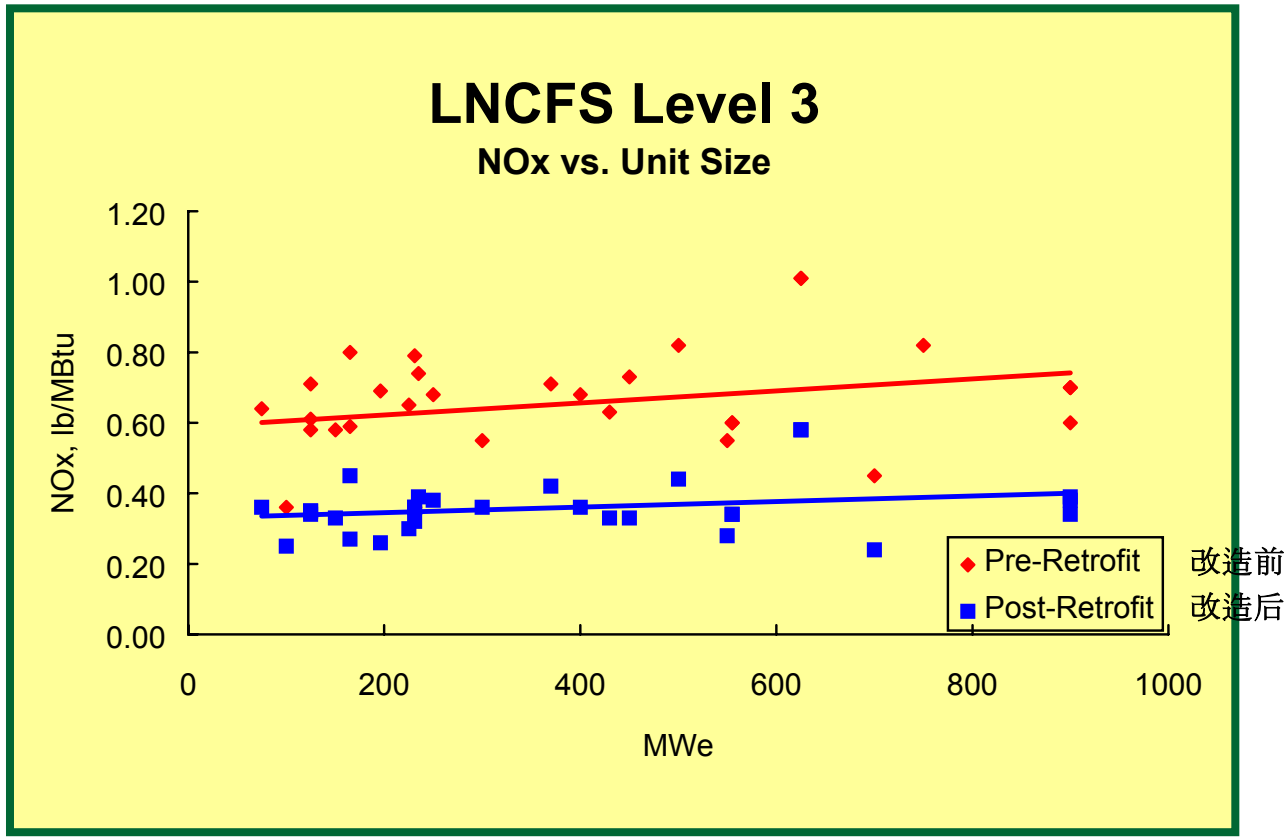
LNCFS™ Level II NOx vs. Unit Size LNCFS™ Level

II 的 NOx □□机□容量的□系（用LNCFS™ II 系□）



LNCFS™ Level III NOx vs. Unit Size

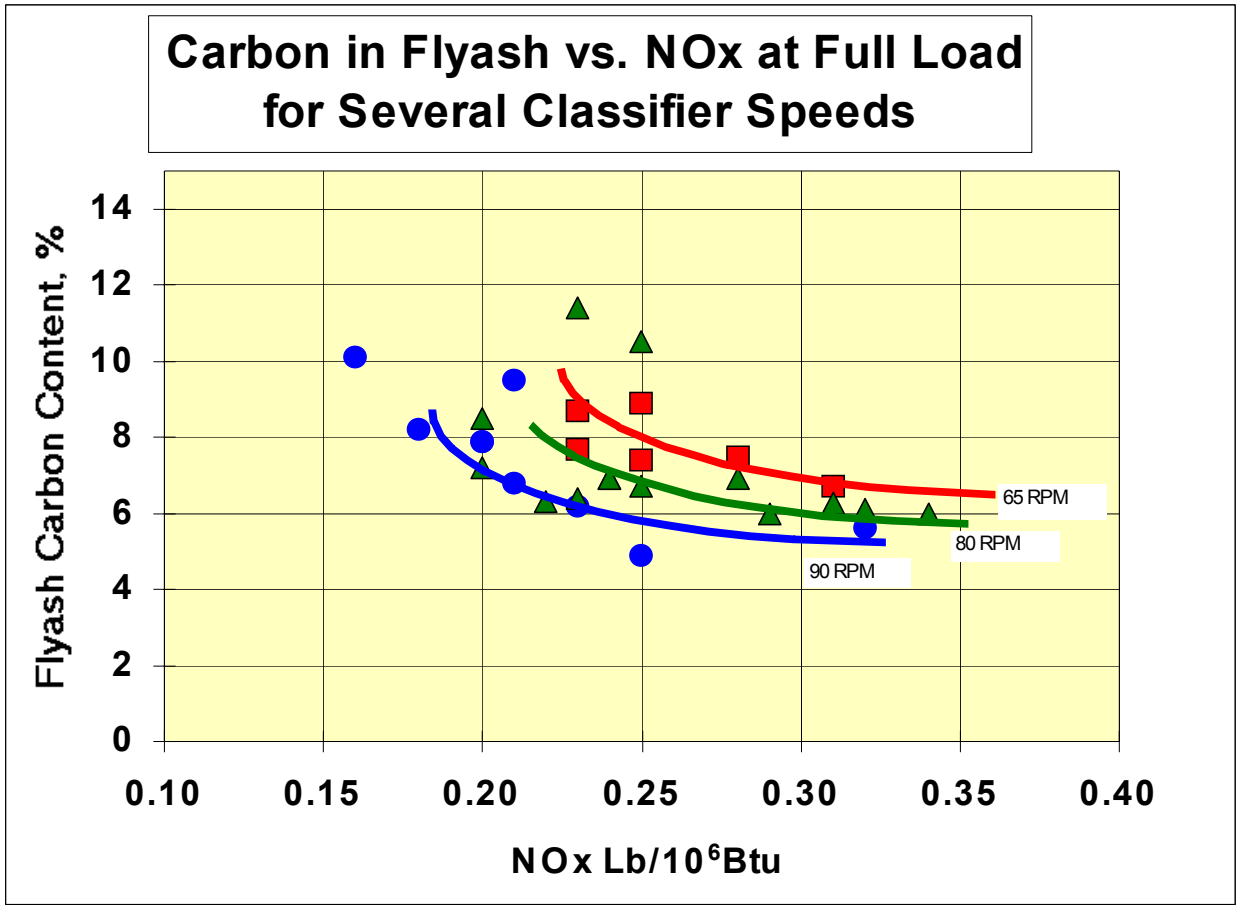
LNCFS™ Level III 的 NOx □□机□容量的□系（用LNCFS™ III 系□）



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

TFS2000™R 使用□□部烟煤的 NOx 和未□□的□行□果

□□荷□□□分离器不同□速下□灰含量和NOx □的□系



ALSTOM Power's Low NOx Experience

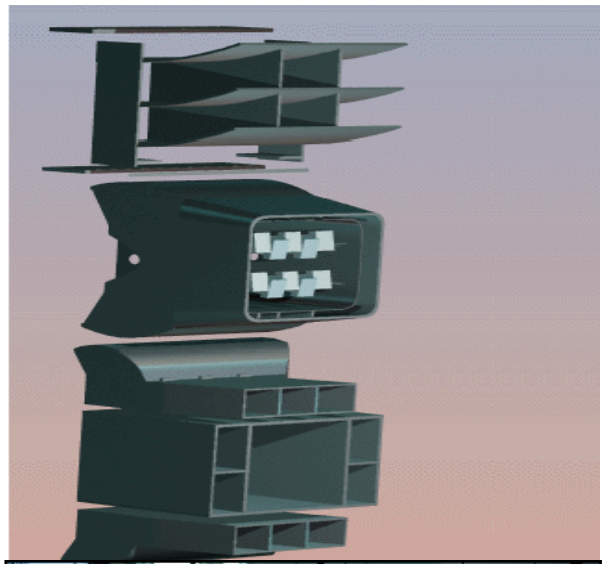
ALSTOM Power的低NOx 改造□□

- **Over 200 Units Modified with Low NOx Combustion Systems**
- 超□**200**套机□□行了低**NOx** 燃□系□改造
- **Over 180 Modified Units in Operation**
- 超□**180**套改造的机□投入□行
- **Patent Holders of LNCFS Technology**
- □**LNCFS**技□□□□利的持有者
- **Patent Holders of TFS2000^{TM}R**
- □**TFS2000^{TM}R**□□□利的持有者
- **Development of LNCFS-P2**
- □展了的**LNCFS-P2**技□
- **LNBFS Technology for Oil and Gas Low NOx**
- □燃油和燃□的低**NOx LNBFS**技□
- **Reburn Applications**
- 再燃技□的□用
- **RSFC Burner**
- **RSFC**燃□器

ALSTOM Power In Furnace Low NOx Experience

ALSTOM Power 在□□方面的低NOx 改造□□

燃□系□ Firing System	机□□ Units	容量 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

ALSTOM Power 低NOx 性能

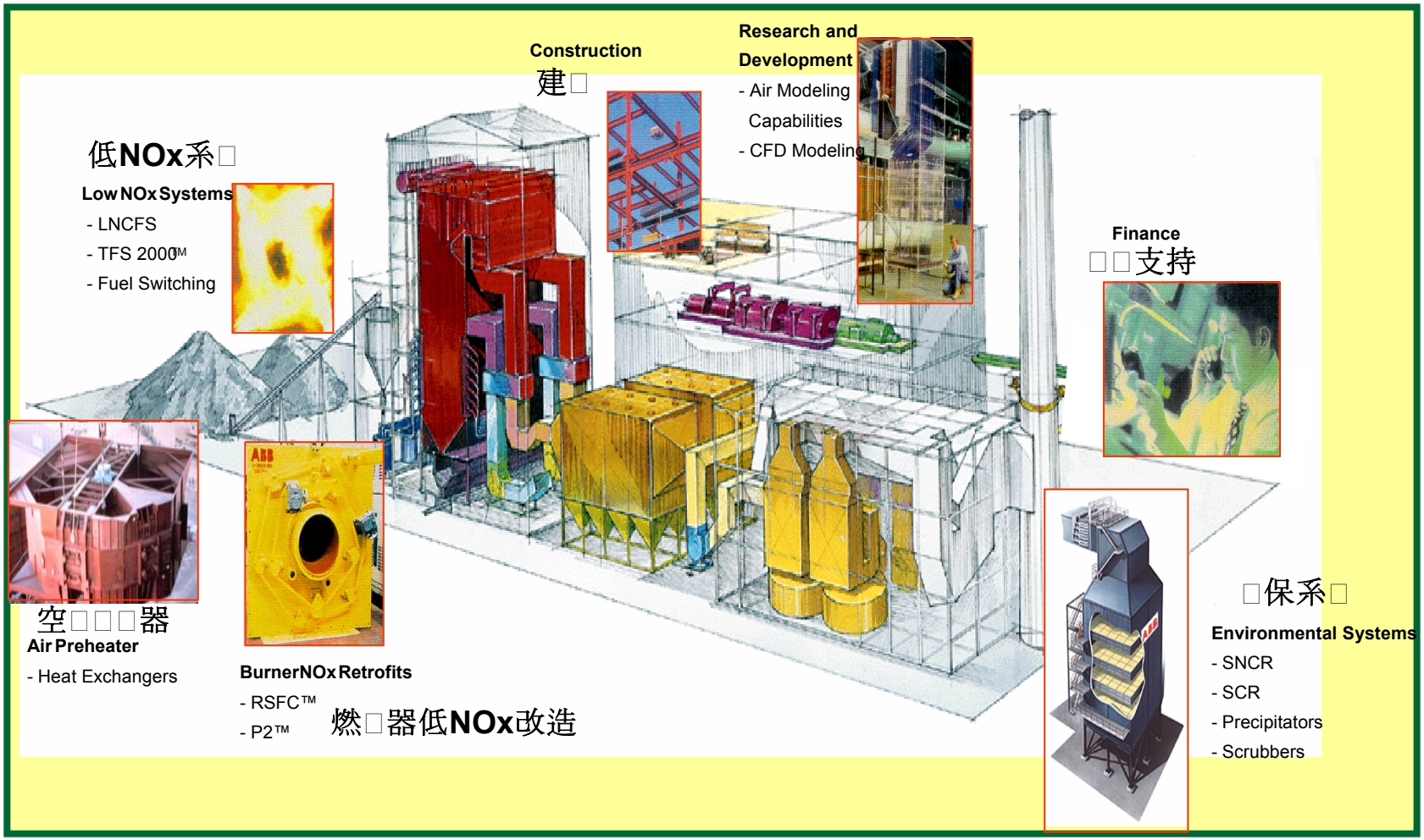
US EPA data for 2001 reveal that 19 of the 20 lowest emitting coal units use Alstom-supplied low NOx Firing systems

美□□保署2001公布的□据中，20□排放NOx 最低的燃煤机□中有19□使用了阿尔斯通提供的低NOx 燃□系□

序□ No	机□ Unit	州 State	NOx □ NOx	系□ System	序□ No	机□ Unit	州 State	NOx □ NOx	系□ System
1	Polk	FL	0.10	CGCC*	11	Baldwin 3	IL	0.14	TFS 2000
2	Labadie 1	MO	0.11	LNCFS	12	Parish 7	TX	0.14	TFS 2000
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**

*煤□化□合循□示范机□

ALSTOM Power

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