The Babcock & Wilcox Company

Generating Powerful Solutions℠

B&W / B&WBC
Low NOx Control Solution
美国巴威/北京巴威
NOx控制解决方案

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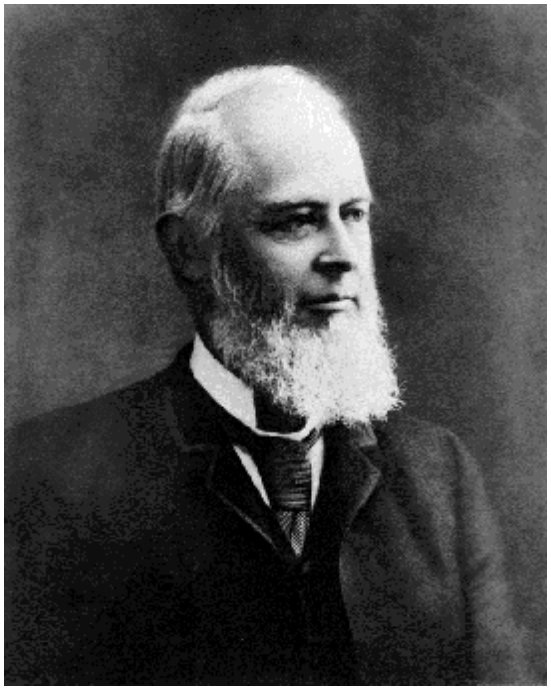
Who We Are



The original Babcock & Wilcox with more than 138 years experience in engineering, constructing and servicing steam generating systems. Over 138 years as a recognized leader in the steam generation industry.

138年蒸汽发生领域工程、建筑及服务等方面的广范实践与积累，使得B&W公司成为全球公认长期引领锅炉行业的先锋。

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Babcock & Wilcox 的世界第一

1867 World's first water tube boiler
第一台水管锅炉

1882 1st boilers for the first public utility
第一台电站锅炉

1929 1st Tomlinson recovery boiler
第一台Tomlinson余热锅炉

1930 1st welded boiler drum
第一台焊接锅炉汽包

1953 Components for world's first nuclear powered ship
世界第一艘核能源船只受压部件

1957 1st commercial supercritical boiler
第一台商业运营超临界锅炉

1972 Commercial operation of world's largest boiler (1300 MW)
全世界最大容量的锅炉投入商业运行

1987 1st coal-fired boiler with 607 days of continuous operation
第一台连续运行607天的燃煤锅炉

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Babcock & Wilcox Beijing Company 北京巴威

- 19 Year Joint Venture
  19年的合资企业
- Appr. 2000 Employees
  ~ 2000员工
- 4500 MW annual manufacturing capacity
  4500MW年制造能力
- 436,800 M^2 land area, 151,000 M^2 building area
  占地面积 436,800平方米，151,000平方米厂房及办工区
- 33,850 MW of large utility boilers experience-up to 600MW sub-critical and super-critical
  总量达33,850MW的大型电站锅炉的业绩
- 1000MW ultra-supercritical engineering and manufacturing capability
  具有设计制造1000MW等级超-超临界锅炉的能力

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Health and Environmental Effects of NO_X
NOx对环境和健康的影响

~ Acid Rain　*酸雨*

~ NOX＋Hydrocarbon ＋O2 ＋Sunlight ＋ Others

~ ***NOX＋碳氢化合物 ＋O2 ＋阳光 ＋ 其它***

- Atmospheric OZONE　低空臭氧
- Photochemical Smog　光化学烟雾

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NOx Formation　NOx的形成

NOx is formed by three mechanisms:

NOx形成的三种机理

- **Thermal oxidation of atmospheric nitrogen -- “thermal NOx”**
- 空气中的氮气在高温下氧化－热力型
- **Oxidation of nitrogen contained in the fuel -- “fuel NOx”**
- 燃料中的氮的氧化－燃料型
- **Reaction of atmospheric nitrogen with hydrocarbon fragments -- “prompt NOx”**
- 空气中的氮气同碳氢化合物共同作用－快速型

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Thermal NOx Formation *热力型NOx*

- **Temperature dependent reaction**
- 温度相关

- **NOx formation dependent on** 取决于
  - **Combustion process temperature**
  - 燃烧温度
  - **Available oxygen concentration**
  - 燃烧过程中氧的含量

- **Easily understood**
- 原理简单

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Fuel NOx Formation *燃料型NOx*

- **Complex process**
- 过程复杂

- **Formed by the direct oxidation of nitrogen contained in the fuel**
- 由燃料中的氮直接氧化而成

- **Represents a significant portion of NOx formed in coal and residual oil combustion**
- 此类ＮＯｘ在燃煤和燃油中占有很大的比重

- **Sensitive to early combustion process stoichiometry but not effected by local temperature**
- 对早期燃烧过程中的含氧量敏感，与就地温度相关性小。

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NOx Emissions Control　NOx的控制

- ***Low NOx Combustion*** *低氮燃烧*
  - **Operation** 运行调整
  - **OFA** 顶二次风
  - **Low NOx burners** 低氮燃烧器
  - **PC concentration** 煤粉浓缩
- ***Post combustion techniques*** *烟气脱除技术*
  - **Selective non-catalytic reduction (SNCR)**
  - 选择性非催化还原法
  - **Selective catalytic reduction (SCR)**
  - 选择性催化还原法

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Low NOx Control Selection
低氮控制技术的选择

B&W's Solution-Low NOx Combustion + SCR
B&W公司的解决方案—低氮燃烧+SCR

Low NOx Combustion

低氮燃烧

- Lowest cost 费用最低
- Limited efficiency 有限的效果

SCR

- Highest efficiency 高效率
- High cost 高费用
- Extensive Application 应用最广泛

SNCR

- Low cost 费用较低
- Low efficiency 效率低
- Control and reliability issue
- 控制和可靠性问题

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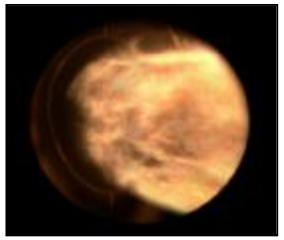
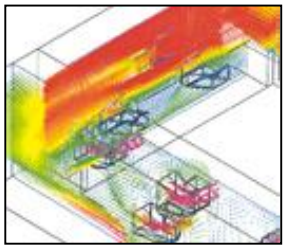
Combustion NO_X Control Innovation
低氮燃烧革新

- **B&W pioneered Low NO_X combustion equipment (OFA patent 1962)**
- **B&W公司是低氮燃烧技术的先驱(1962年即获得OFA技术专利)**



- **Advanced combustion technology for wall- and tangential-fired units**
- **先进的墙式和四角燃烧技术**

- **DRB-4Z™ ultra low NO_X burner available for bituminous and sub-bituminous coals**
- **DRB-4Z™超低NOx燃烧器，应用于烟煤和次烟煤**



- **Advanced CFD-assisted design OFA system further reduces NO_X on wall- and tangential-fired units.**
- **先进的数值模拟技术应用于降低NOx的排放**
- **Lower NO_X from the furnace leads to lower SCR costs**
- **低NOx燃烧技术降低了SCR的成本**

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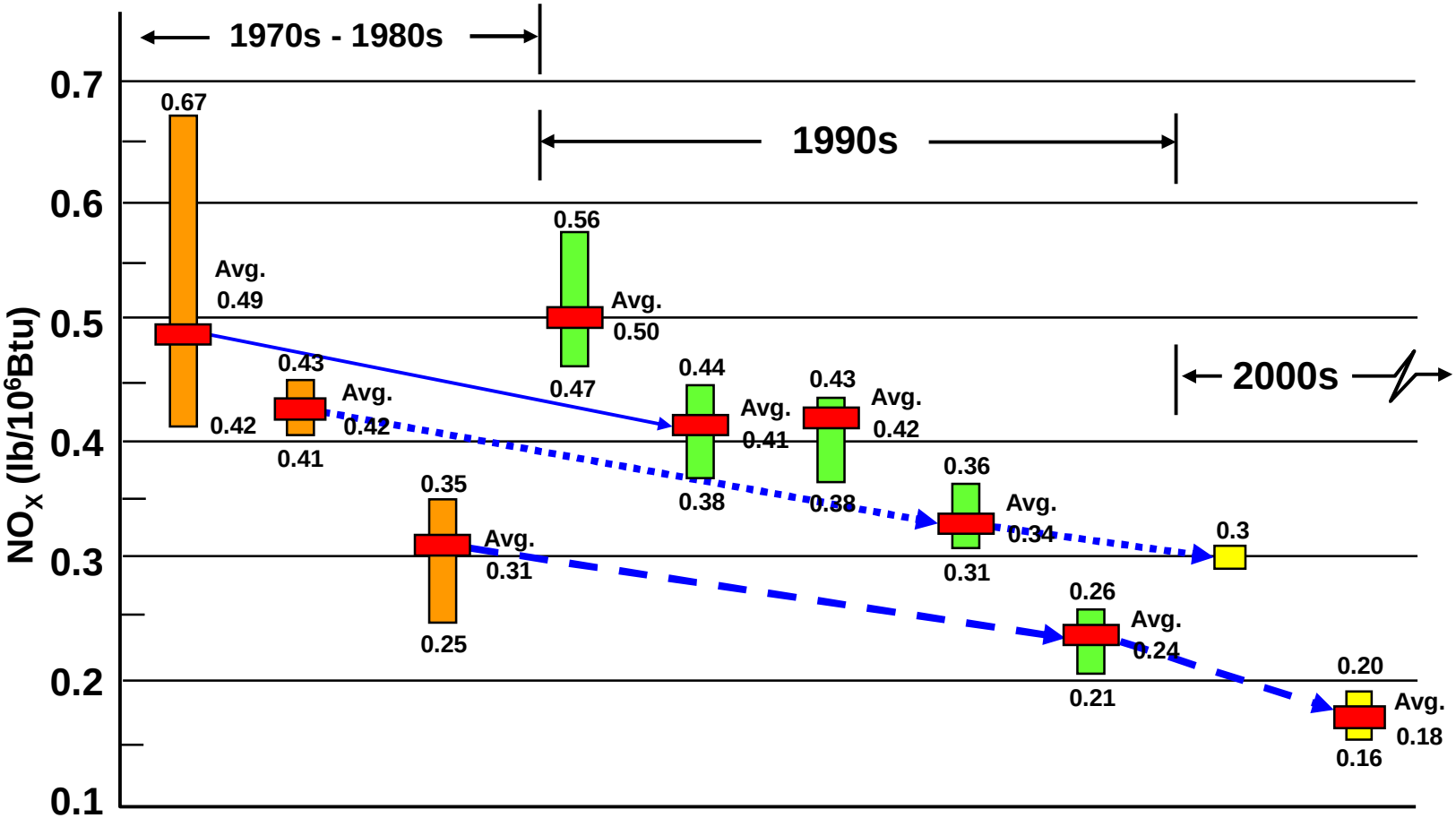
B&W Low NO_X Burner Advancements

B&W公司低氮燃烧的进展



	Bit DRB 9 Units (opposed)	Bit DRB + OFA 2 Units (opposed)	Sub-Bit DRB 14 Units (opposed)	Bit DRB-XCL 5 Units (Single)	Bit DRB-XCL 5 Units (Opposed)	Bit DRB-XCL + OFA 5 Units (Single)	Bit DRB-XCL + OFA 7 Units (Opposed)	Sub-Bit DRB-XCL + OFA 5 Units (Opposed)	Bit DRB-4Z + OFA 1 Units (opposed)	Sub-Bit DRB-4Z + OFA 4 Units (opposed)
Avg. MW	713	480	564	155	335	169	556	550	480	564

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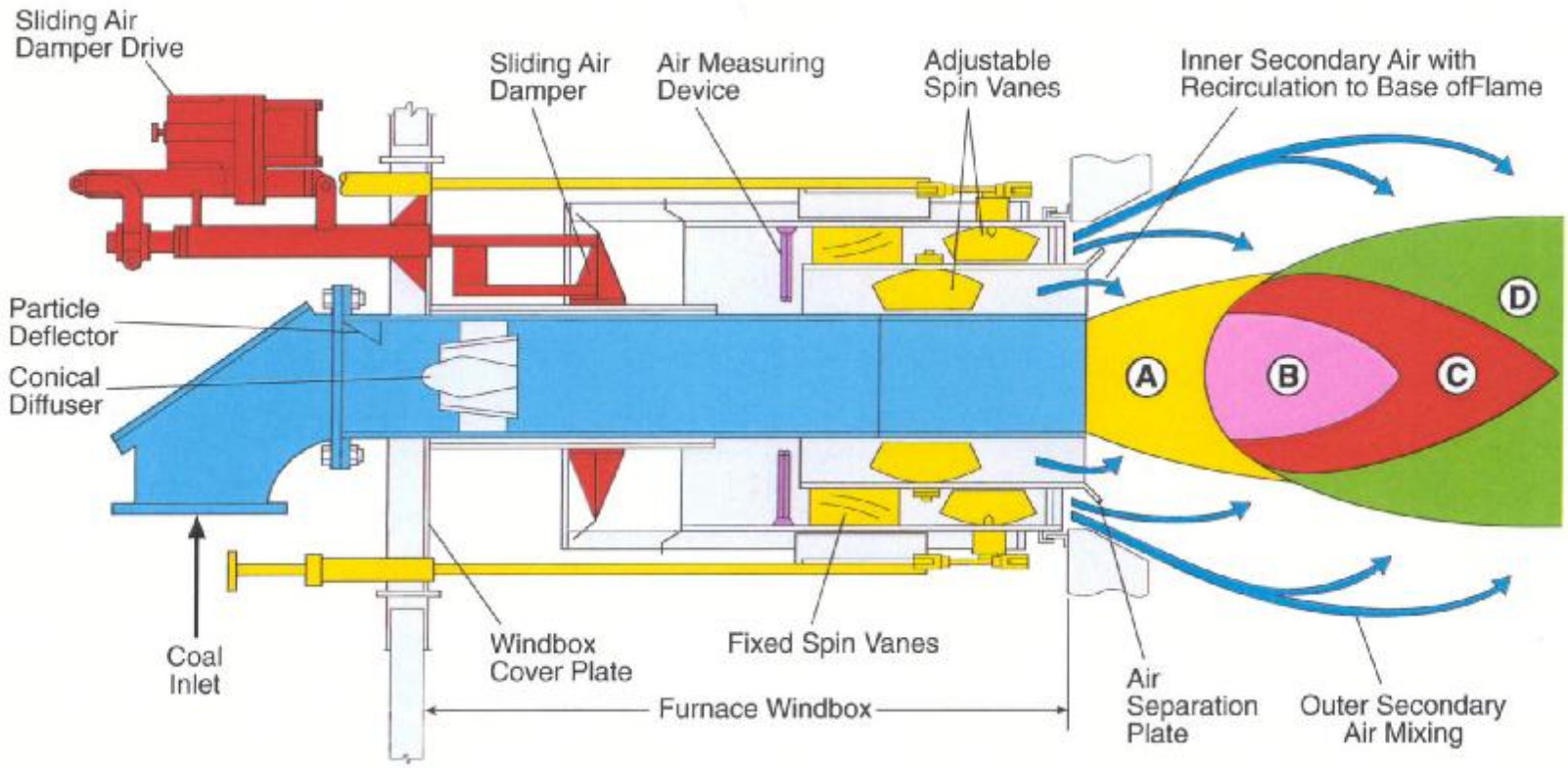
DRB-XCL® Burner (PC Fired) DRB-XCL® 低氮燃燒器



Ⓐ High temperature - fuel rich devolatilization zone
Ⓑ Production of reducing species zone
Ⓒ NOx decomposition zone
Ⓓ Char oxidizing zone

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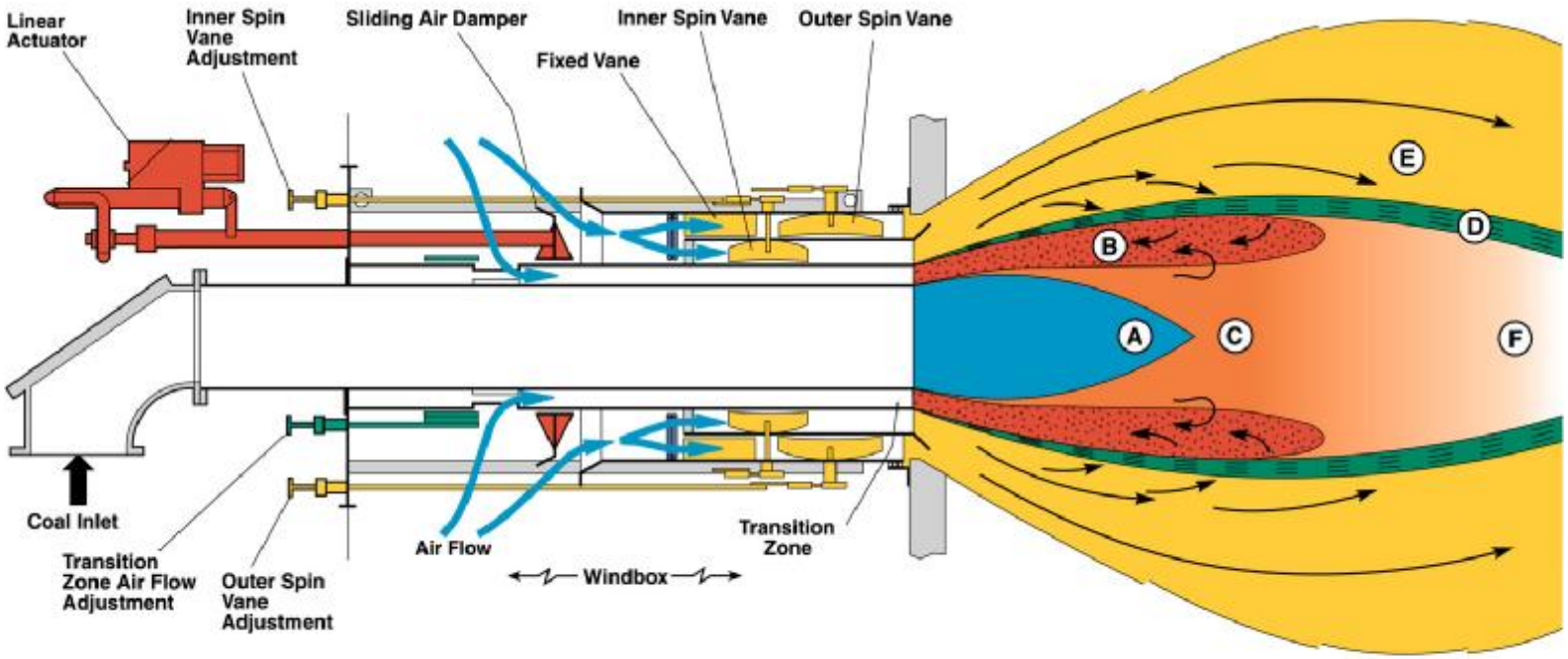
Low NO_X DRB-4Z™ Burner Combustion Zones
DRB-4Z™ 低氮燃烧器



A. Oxygen lean devolitilization
B. Recirculation of products
C. NOx reduction zone
D. High temperature flame sheet
E. Controlled mixing of secondary combustion air
F. Burnout zone

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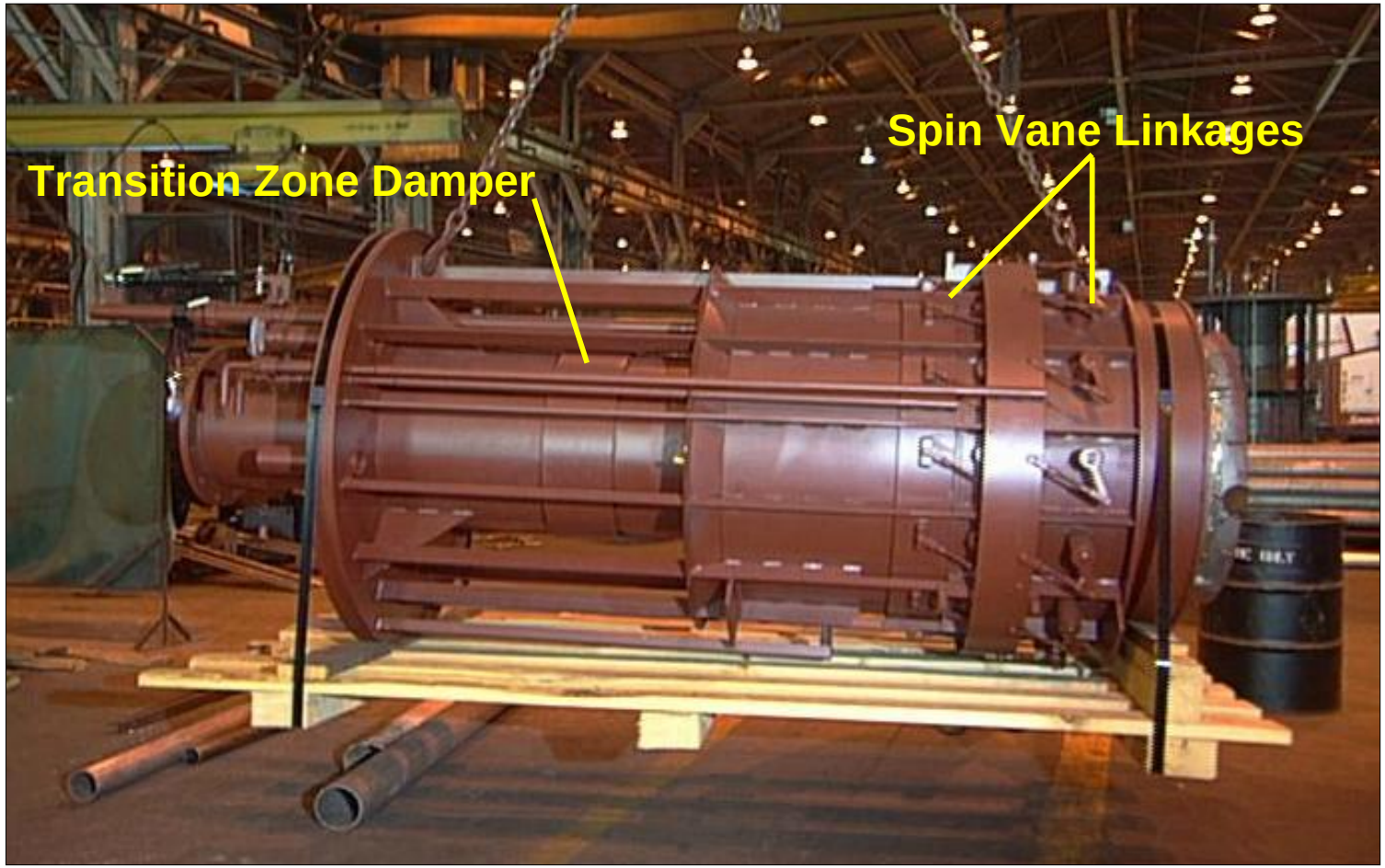
DRB-4Z™ Low NO_X Coal-Fired Burner
DRB-4Z™ 低氮煤粉燃烧器



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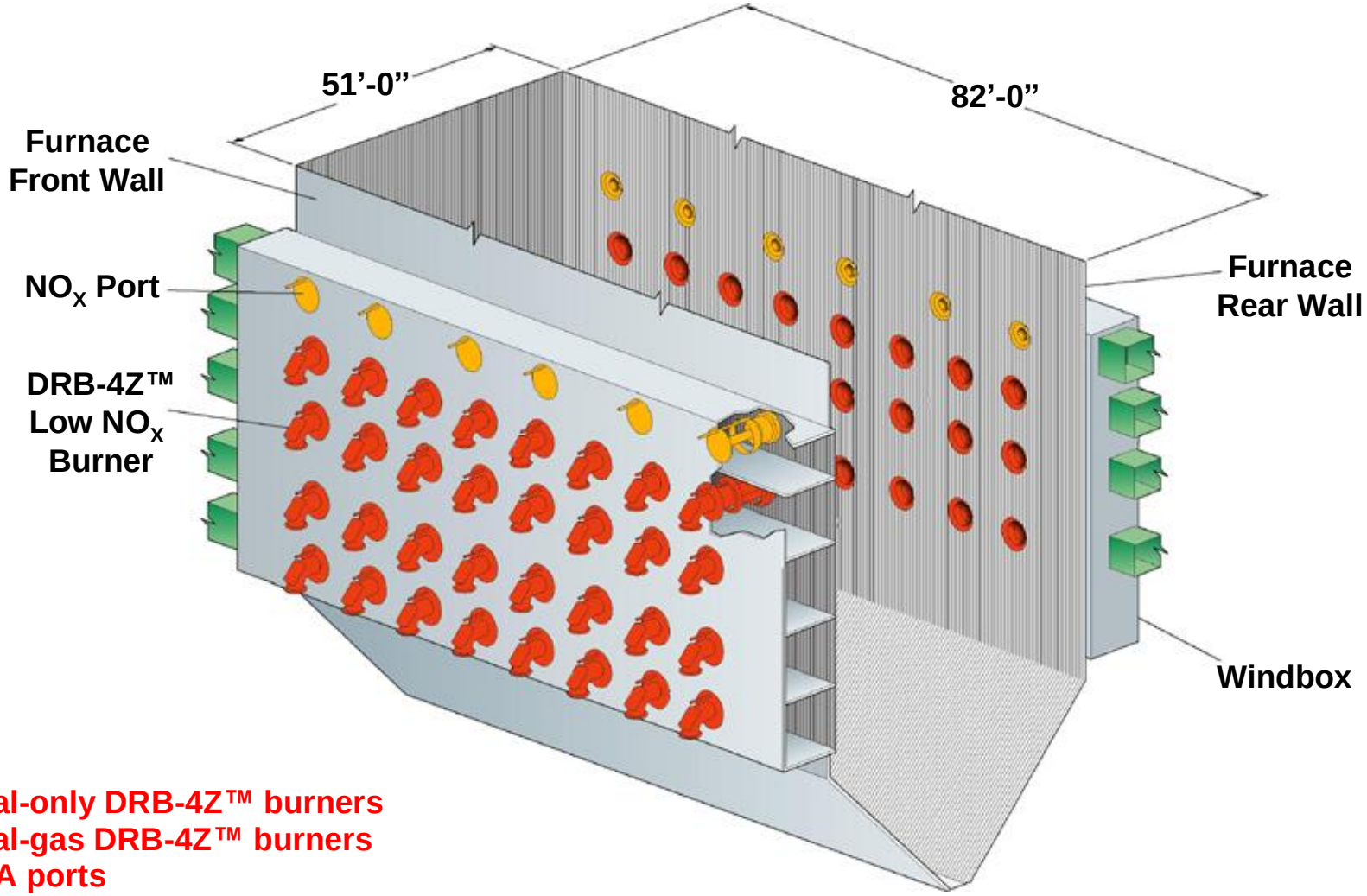
W.A. Parish Unit 6 - Retrofit Burner and OFA

W.A. Parish 6号机组 – 燃烧器和OFA改造



(16) Coal-only DRB-4Z™ burners
(40) Coal-gas DRB-4Z™ burners
(12) OFA ports
690 MW boiler unit

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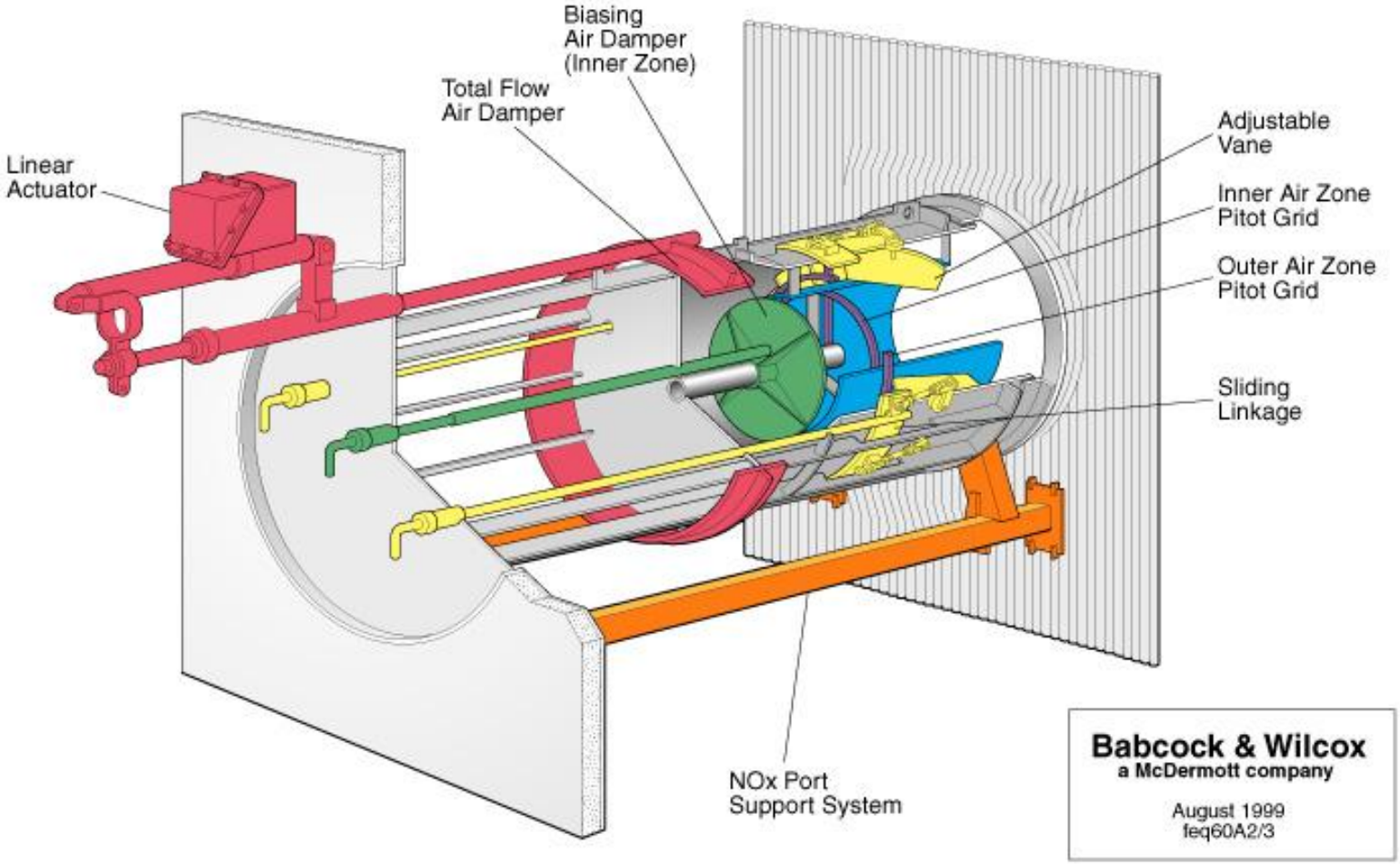
双通道可调低NOx喷口(OFA)

Dual Air Zone NO_x Port

with Total Air Flow Control



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Dual Air Zone OFA (NO_X) Port with Total Air Flow Control - W.A. Parish Unit 6

双通道可调低NOx喷口(OFA)

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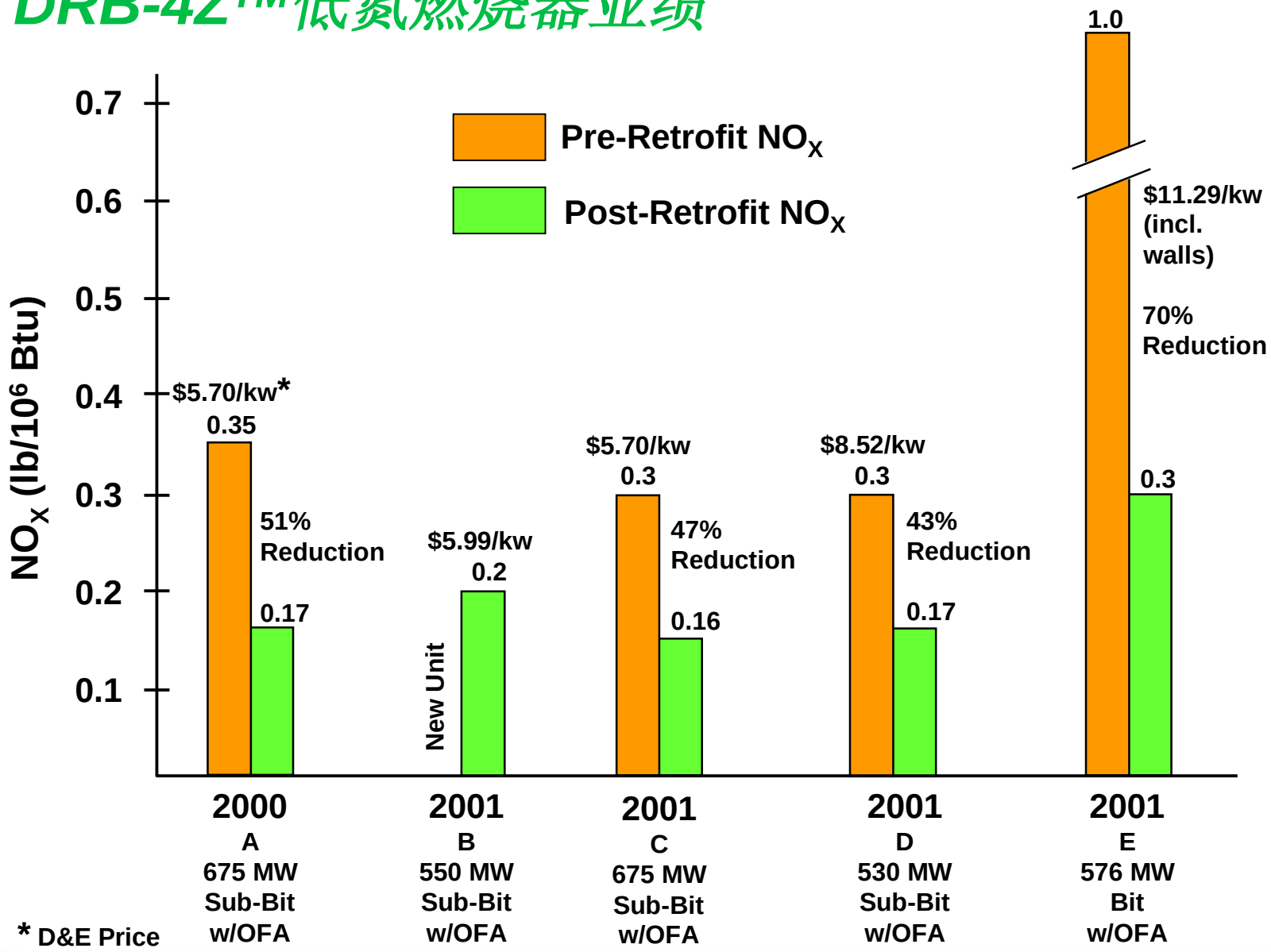
DRB-4Z™ Low NO_X Burner Experience

DRB-4Z™低氮燃烧器业绩



* D&E Price

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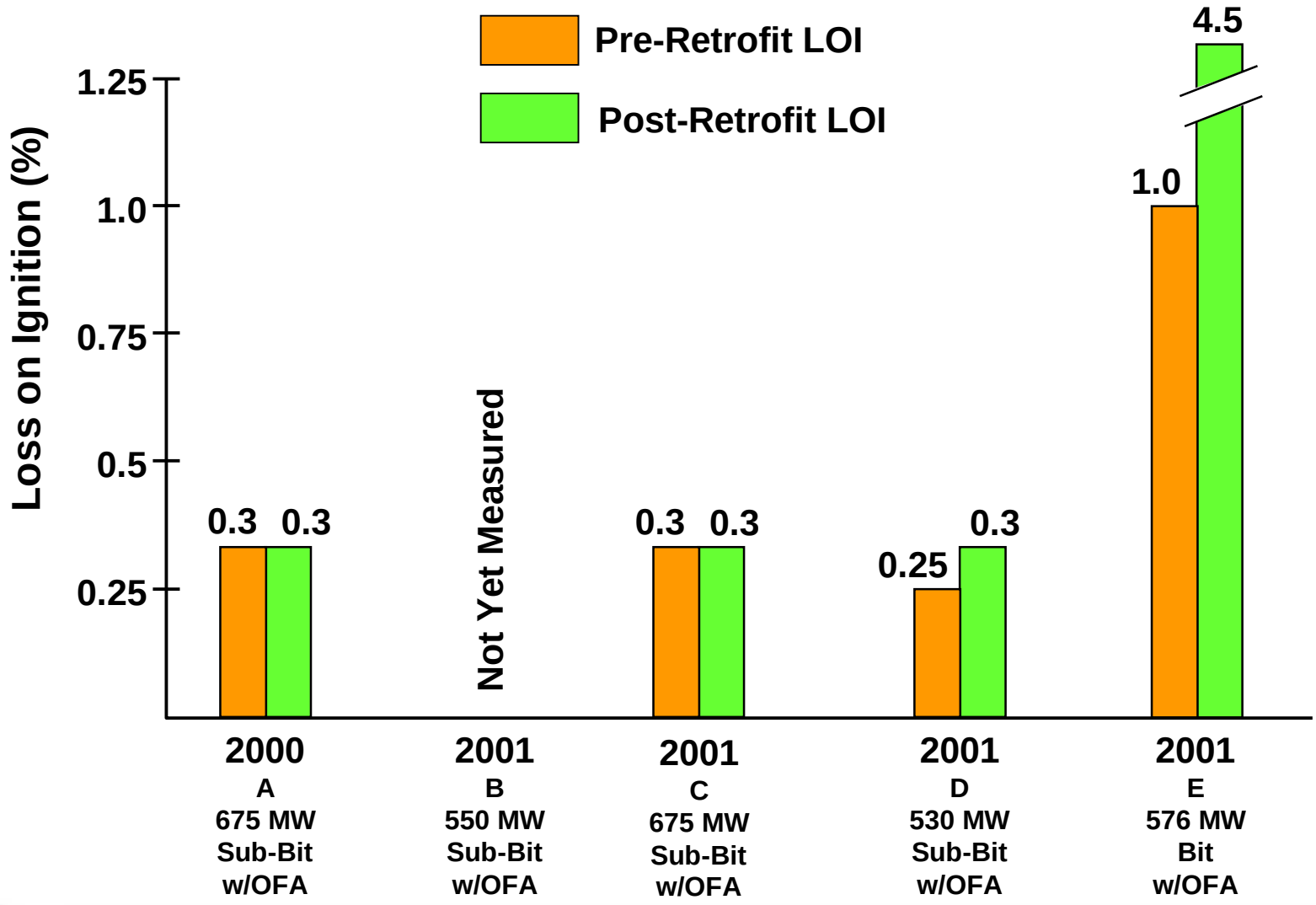
DRB-4Z™ Burner LOI Results
DRB-4Z™ 燃烧器 LOI 结果



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B&W SCR Experience
B&W　SCR 的发展

- 1982 Extensive SCR R&D
- 1982 全面展开ＳＣＲ的研发
- 1986 First SCR in operation
- 1986 第一台ＳＣＲ装置投运
- 1992 300ＭＷ SCR in operation
- 1992 300ＭＷ等级的SCR装置投运
- 1995 China’s First SCR in operation
- 1995 我国第一台ＳＣＲ装置投运
- 2003 900MW SCR in operation
- 2003 900MW等级的SCR装置投运
- Top SCR market share in North America
- 北美市场占有率第一

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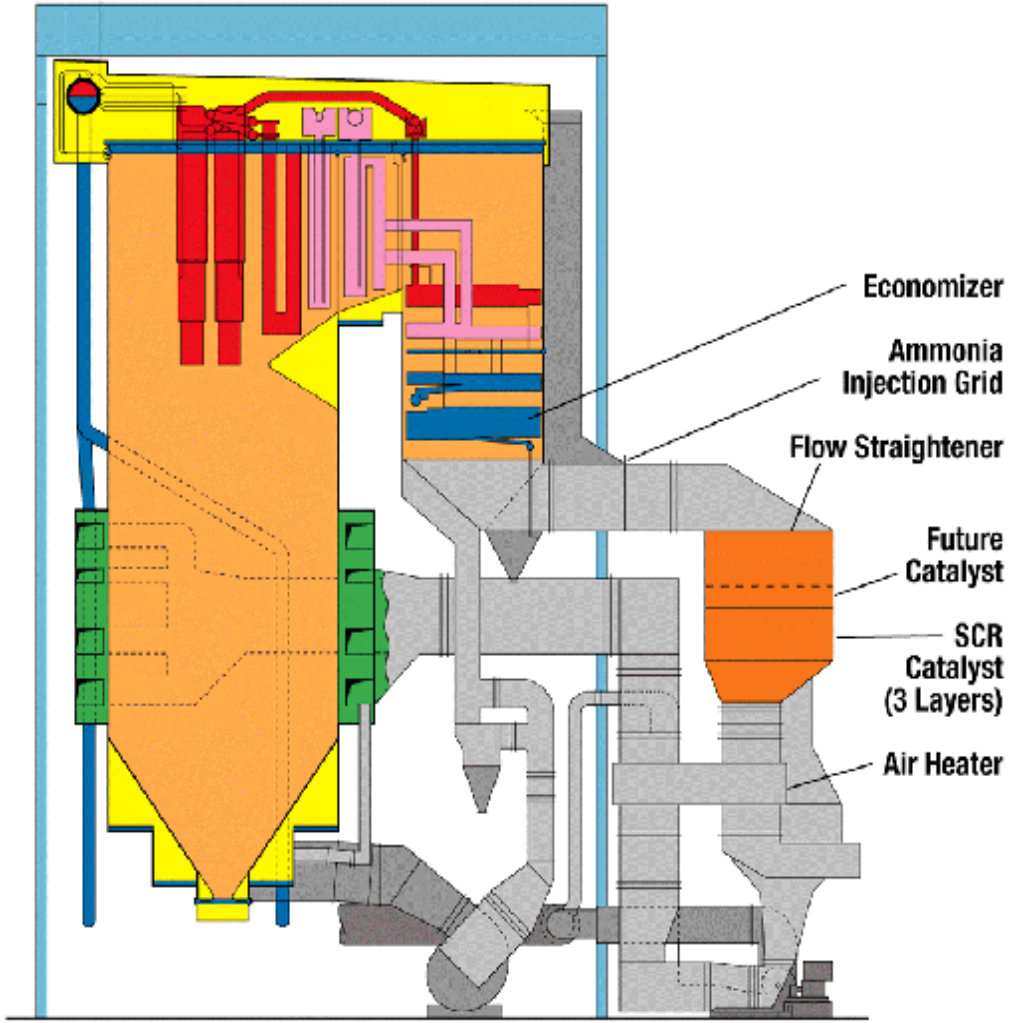
First SCR in China 我国最早的SCR

Taichun Power Plant台中电厂 5-8 Unit 4 x 550 MW



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What is Selective Catalytic Reduction (SCR)?
什么是选择性催化还原法？

- **A process for the control of Nitrogen Oxide emissions from stationary sources**
- *一种控制从固定源排放的氧化氮的方法*

- ***In the process, a catalyst facilitates a chemical reaction between NOx and ammonia to produce nitrogen and water***
- *在催化剂的促进下，**NOx**和氨发生化学反应，生成氮气和水*

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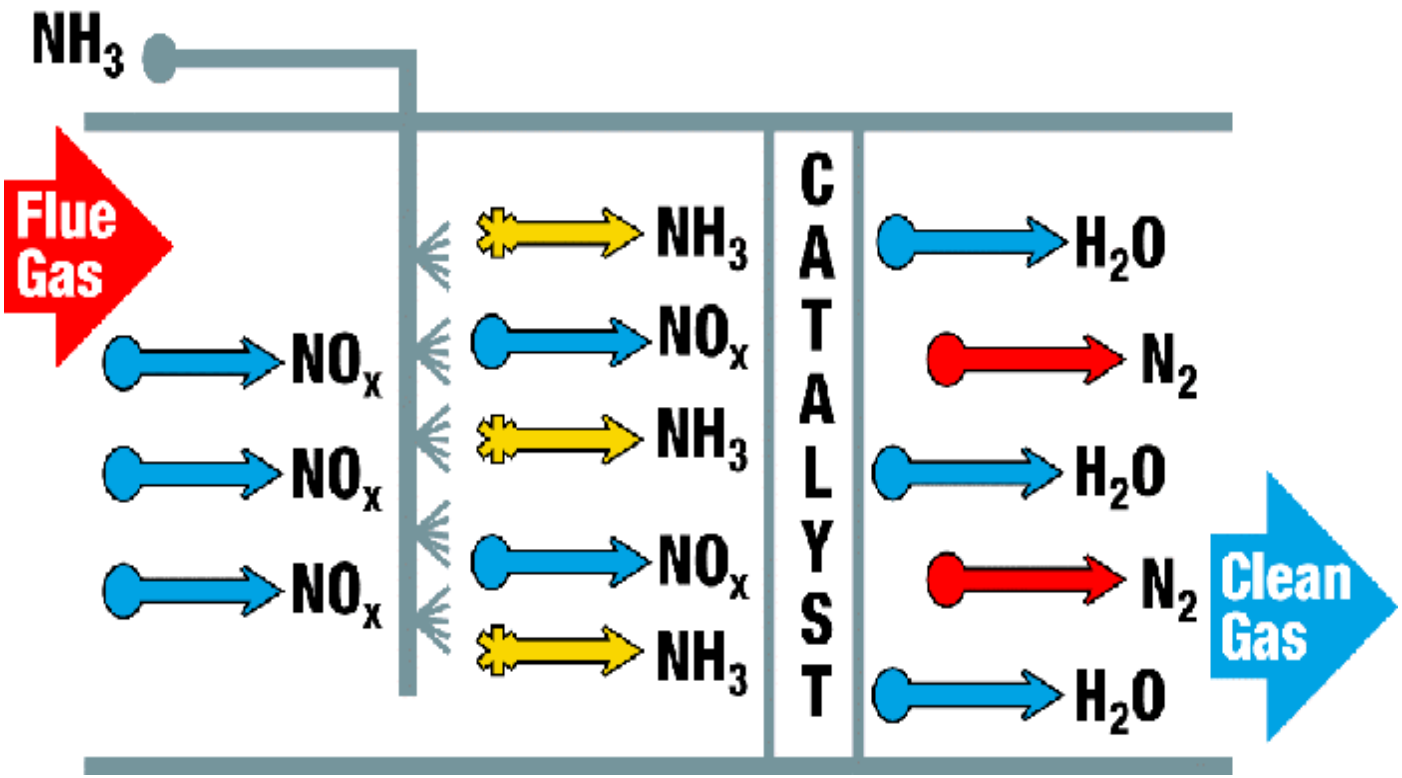
Principle of SCR NO_x Removal
SCR 的脱硝原理



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Fundamental Reactions
基本反应式

1. $4\ NO + 4\ NH_3 + O_2 = 4\ N_2 + 6\ H_2O$

2. $NO + NO_2 + 2\ NH_3 = 2\ N_2 + 3\ H_2O$

3. $6\ NO_2 + 8\ NH_3 = 7\ N_2 + 12\ H_2O$

Exothermic reactions
(but negligible temperature rise)
微放热反应，温升忽略不计

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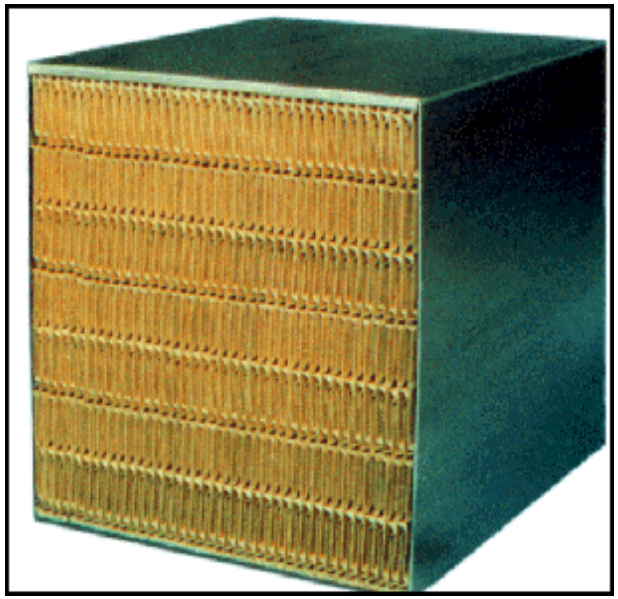
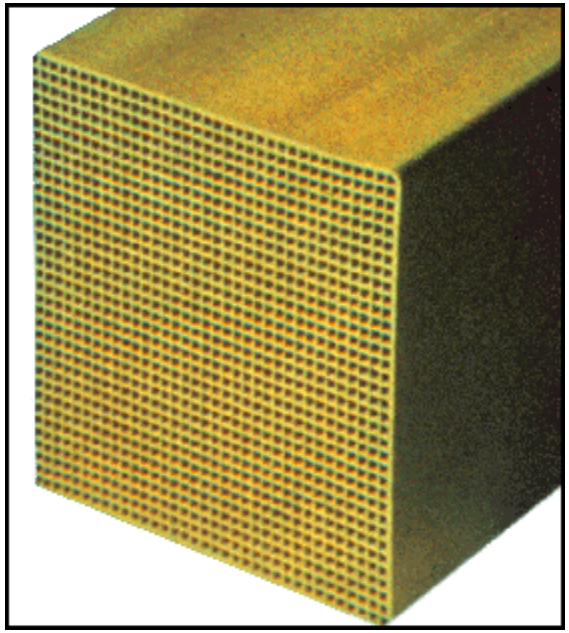
Catalyst Types *催化剂类型*

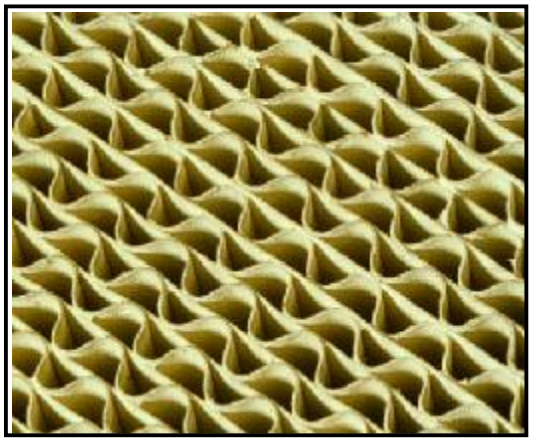
Plate

板式





Honeycomb 蜂窝式



Corrugated Plate 波纹板式

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Operating Principles 运行过程中原则性要点

- ***Operating temperature*** *运行温度*

  315－425 °C

- ***Reagent:*** *还原剂:*
  - **Anhydrous ammonia, aqueous ammonia, or ammonia derived from urea**

    纯氨， 氨水， 或尿素转化的氨

- ***Reagent consumption:*** *氨耗量:*
  - **1 mole per mole of NOx removed**

    每脱除1摩尔NOx消耗1摩尔的氨

- ***Velocities through the catalyst:***

  催化剂内内烟气的速度:
  - **Coal:19 – 21 ft/sec** 煤: **5.8 – 6.4 m/sec**
  - **Oil: 25 – 35 ft/sec** 油: **7.6 – 10.7 m/sec**
  - **Gas:30 – 40 ft/sec** 气: **9.1 – 12.2 m/sec**

- ***Uniform distribution of:*** *分布的均匀性:*
  - **Velocity** *烟气速度*
  - **Temperature** *烟气温度*
  - **NH_3/NOx** *烟气中的氨氮摩尔比*

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Technical Issues 技术要点

- ***Application*** *应用*
  - **System layout** 系统布置
    - **Gas flow path** 烟气通道
  - **Design for constructability**
    易安装的设计
    - **Modularization** 模块化设计
    - **Minimize construction costs**
      安装成本降到最低
- ***Performance*** *性能*
  - **Maintain design NOx removal rate**
  - 保持设计脱硝率
  - **Minimize ammonia slip**
    氨逃逸率降到最低
  - **Maximize catalyst life**
    延长催化剂的寿命
- ***System reliability*** *系统可靠性*
  - **Ammonia injection and mixing**
  - 氨的喷射和混合
  - **Popcorn ash** 爆米花状灰

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Zone Flow Control AIG 分区控制的喷氨栅格

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Typical Manifold Valve Station

流量分配阀门站

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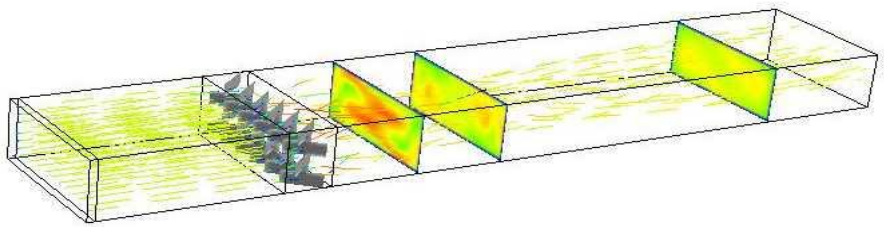
B&W Optimized Static Mixer
B&W优化设计的静态混合器

- **High efficiency, low slip mixer design**
- 高效率,低泄漏率的混合器设计
- **Field tuning time is significantly reduced: days/hours instead of weeks**
- 现场调试的时间大幅降低: 由几周缩短到几天甚至几小时



- **Excellent mixing to SCR inlet:**

  在**SCR**进口前达到很好的混合效果**:**
  - **efficient SCR operation** 高效的**SCR**运行
  - **ensures low slip** 确保低逃逸率

- **Designed specifically to work B&W's AIG**
- 为配合**B&W**的喷氨栅格**(AIG)**专门设计

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Popcorn Ash 爆米花状飞灰

- ***There have been a number of events in the industry in which the top layer of an SCR System have been plugged with Popcorn Ash***
- *业内发生了几起**SCR**系统催化剂顶层被爆米花状灰阻塞的事件*

- ***Popcorn ash is light, porous & irregularly shaped***
  爆米花状灰很轻, 多孔且形状不规则

- ***Often forms in the upper furnace or on the convective section of heat exchangers***
  常常在上炉膛或对流受热面形成

- ***Popcorn ash particles may reach a size of 10mm***
  *爆米花状飞灰粒径可达**10mm***

- ***Particles greater then 4 or 5mm have been know to cause catalyst plugging***
  *粒径大于**4** 或 **5mm** 就可造成催化剂阻塞*

- ***This blockage can cause:***
  阻塞会导致:
  - **Increases pressure drop** *烟气阻力增加*
  - **Decreased catalyst performance** *催化剂性能降低*
  - **Worst circumstances can force the SCR to be taken off line**
    *甚至可能导致**SCR**停运*

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B&W Popcorn Ash Experience
B&W 爆米花状灰处理的经验

- ***25 coal fired units***

  25 台燃煤机组
- ***9 units addressing popcorn ash***

  9 台机组报告爆米花状灰

- ***Coal 煤种***
  - **East. Bit./PRB**

    东部烟煤/PRB混煤
  - **Eastern Bituminous**

    东部烟煤

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B&W's Solution to Popcorn Ash
B&W的爆米花状灰的解决方案

- **Specially designed Deflector Plates (Batwings) to deflect the popcorn ash into the economizer hopper**

  专门设计了“偏转板”(Batwings) 使爆米花状灰进入省煤器灰斗

- **Specially designed Screens to trap the ash and also force into the economizer hopper**

  专门设计的筛式挡板用来收集灰并把它们送入省煤器灰斗

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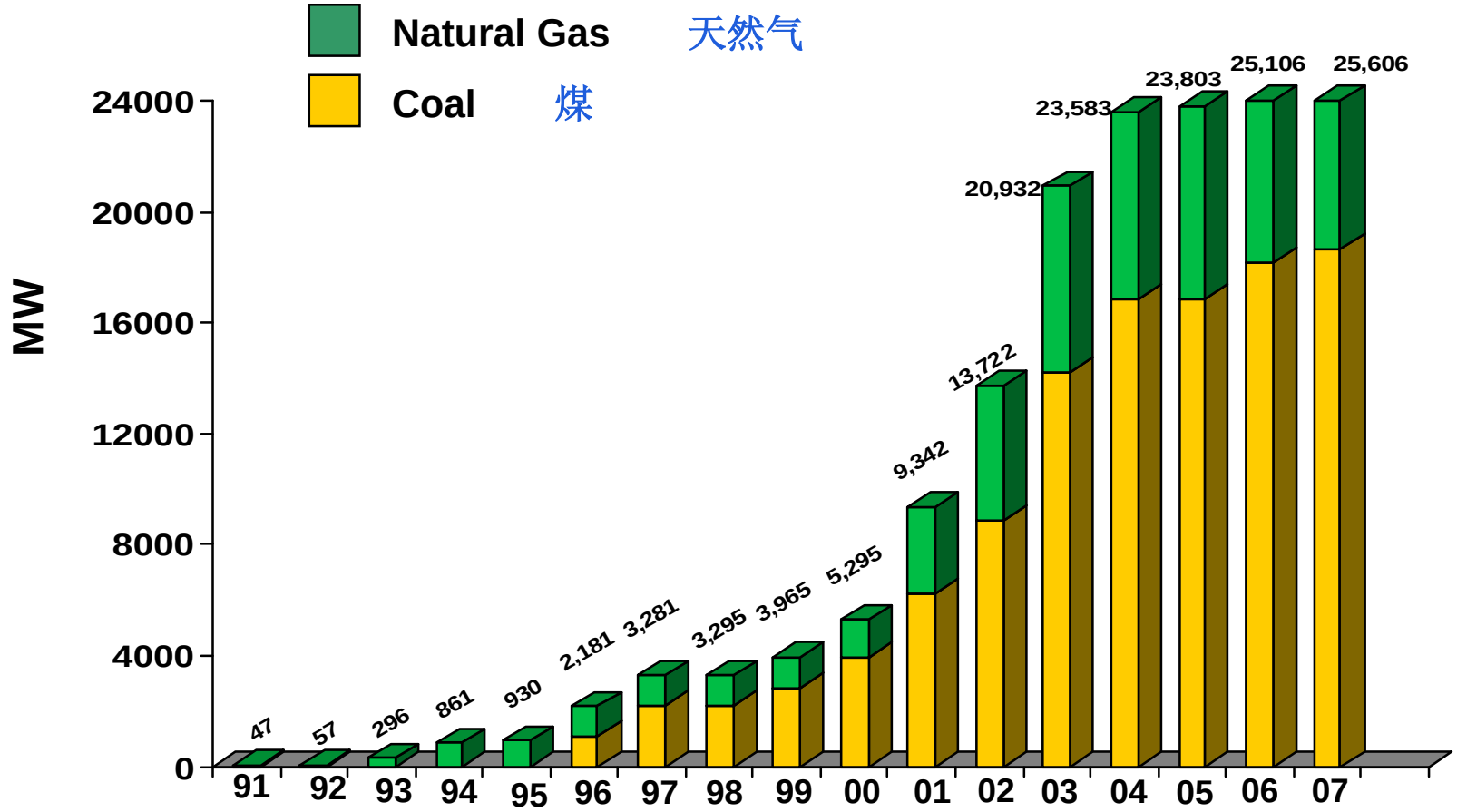
B&W Cumulative SCR Experience
Technology Supplier – Experience Leader
B&W SCR业绩—技术源头 –业绩领先



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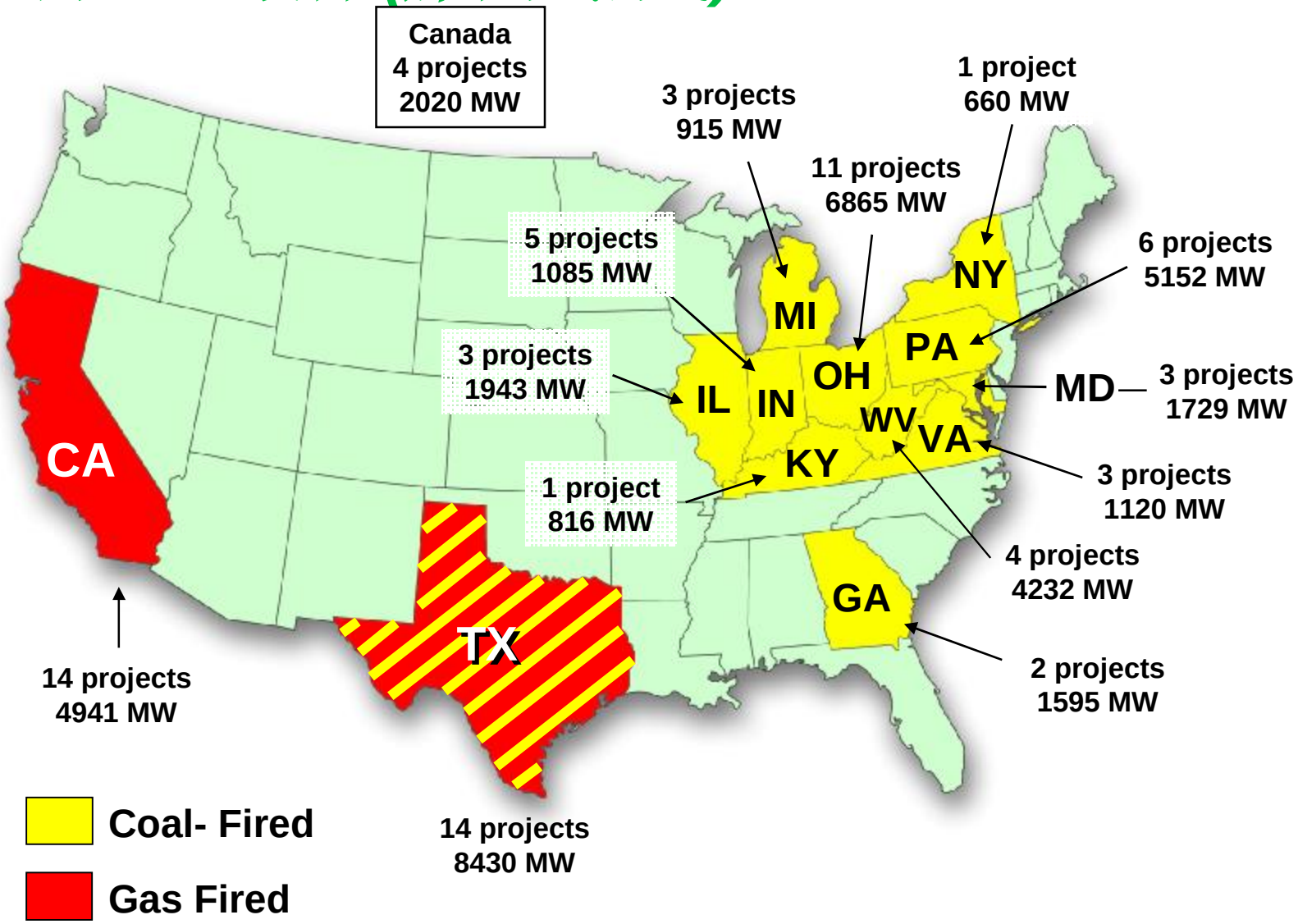
B&W SCR Projects (Coal and Gas-Fired)
B&W 的SCR 项目 (煤和天然气)



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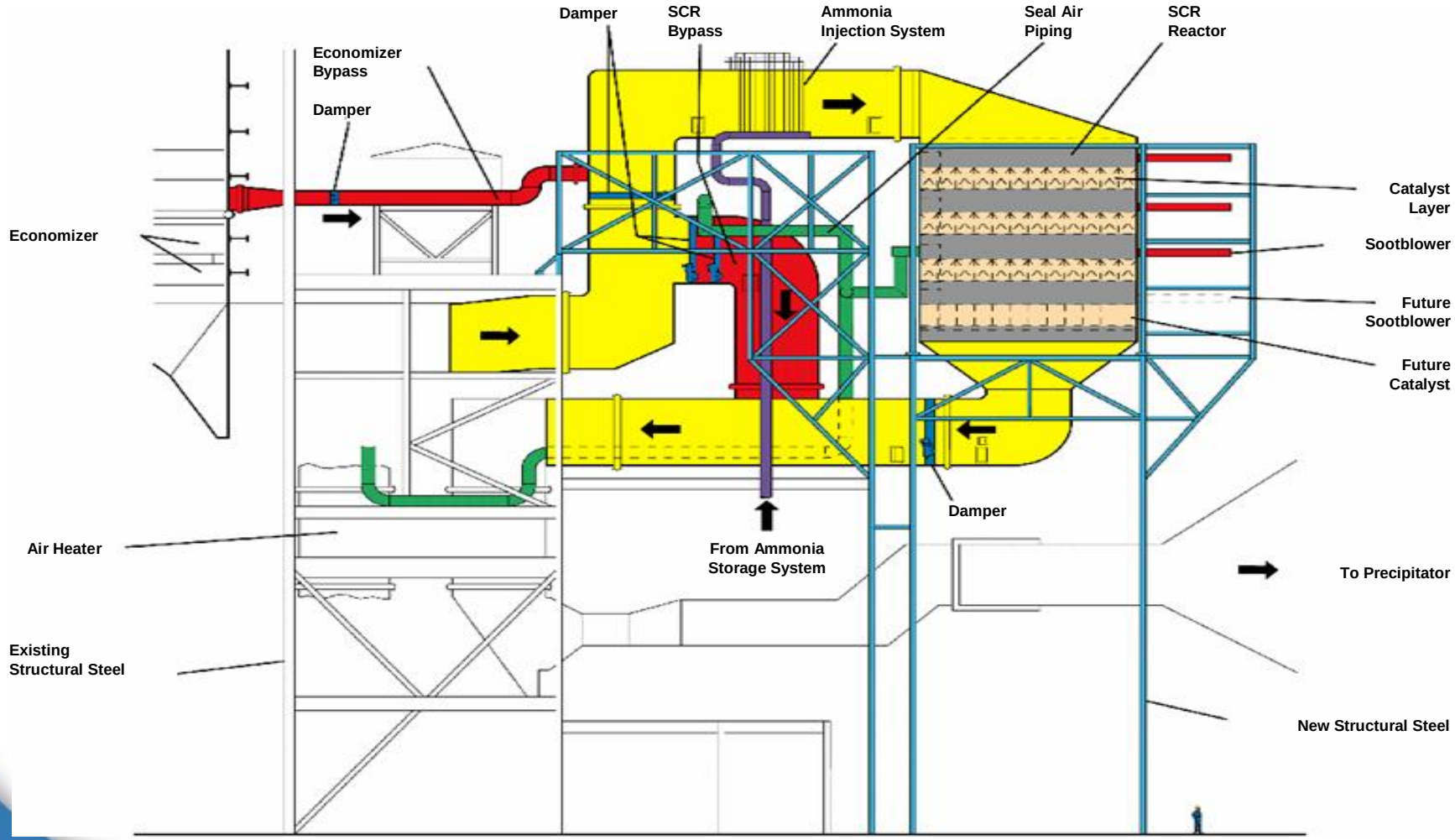
675 MW Coal Fired SCR System –AES Somerset
675 MW燃煤SCR系统 – AES Somerset



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B&W SCR Case History: Bruce Mansfield 1-3
B&W SCR 实例: Bruce Mansfield 电站 1-3号机组

- **Boiler OEM:** Foster Wheeler
  锅炉制造商: Foster Wheeler
- **Boiler MW:** 3 x 856; wall-fired
  锅炉 MW: 3 x 856; 墙式燃烧
- **Boiler Fuel:** Bituminous coal / pet coke
  锅炉燃料: 烟煤 / 石油焦
- **Inlet NOx:** 0.4 lb/10^6 Btu
  进口 NOx: 490 mg/Nm3
- **NOx Removal:** 90%
  NOx 脱除率: 90%
- **NH_3 system:** Aqueous
  NH3 系统: 氨水
- **Catalyst Mfg. & type:** Hitachi Plate;
  催化剂厂商和类型: 日立 板式;
- **Popcorn Ash:** Yes
- 爆米花状灰: 是
- **Startup dates:** Units 1&2 – April 2003,Unit 3 – April 2004
  投运时间: 1&2 号机组 – 2003年4月,3 号机组–2004年4月

First Energy

第一能源

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B&W SCR Case History: Chesterfield 6
B&W SCR实例: Chesterfield 6 号机组

- Boiler OEM: CE (Alstom)
- 锅炉制造商: CE (Alstom)
- Boiler MW: 650; corner-fired
  锅炉 MW: 650; 四角燃烧
- Boiler Fuel: coal
- 锅炉燃料: 煤
- Inlet NOx: 0.4 lb/10^6 Btu
- 进口 NOx: 490 mg/Nm3
- NOx Removal: 90%
- NOx 脱除率: 90%
- NH_3 system: Anhydrous
- NH3 系统: 无水氨
- Catalyst Mfg. & type: Cormetech honeycomb
- 催化剂 厂商. 和类型: Cormetech 蜂窝式
- Popcorn Ash: Yes
- 爆米花状灰: 是
- Startup date: April 2004
- 投运日期:2004年4月

弗吉尼亚电力公司

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B&W SCR Case History: Kincaid 1 & 2

B&W SCR Case History: Kincaid 1 & 2

- Boiler OEM: Babcock & Wilcox
- 锅炉制造商: Babcock & Wilcox
- Boiler MW: 2 x 600; cyclone-fired
- 锅炉 MW: 2 x 600; cyclone-fired
- Boiler Fuel: PRB
- 锅炉燃料: PRB
- Inlet NOx: 0.7 lb/10^6 Btu
- 进口 NOx: 860 mg/Nm^3
- NOx Removal: 90%
- NOx 脱除率: 90%
- NH_3 system: Anhydrous
- NH_3 系统: 无水氨
- Catalyst Mfg. & type: Cormetech honeycomb
- 催化剂 厂商和类型: Cormetech 蜂窝式
- Popcorn Ash: No
- 爆米花状 灰: 否
- Startup dates: Unit 1 – Dec. 2002; Unit 2 – July 2002;
- 投运日期: 1号机组 – 2002年12月; 2号机组 – 2002年7月;

Dominion Energy能源

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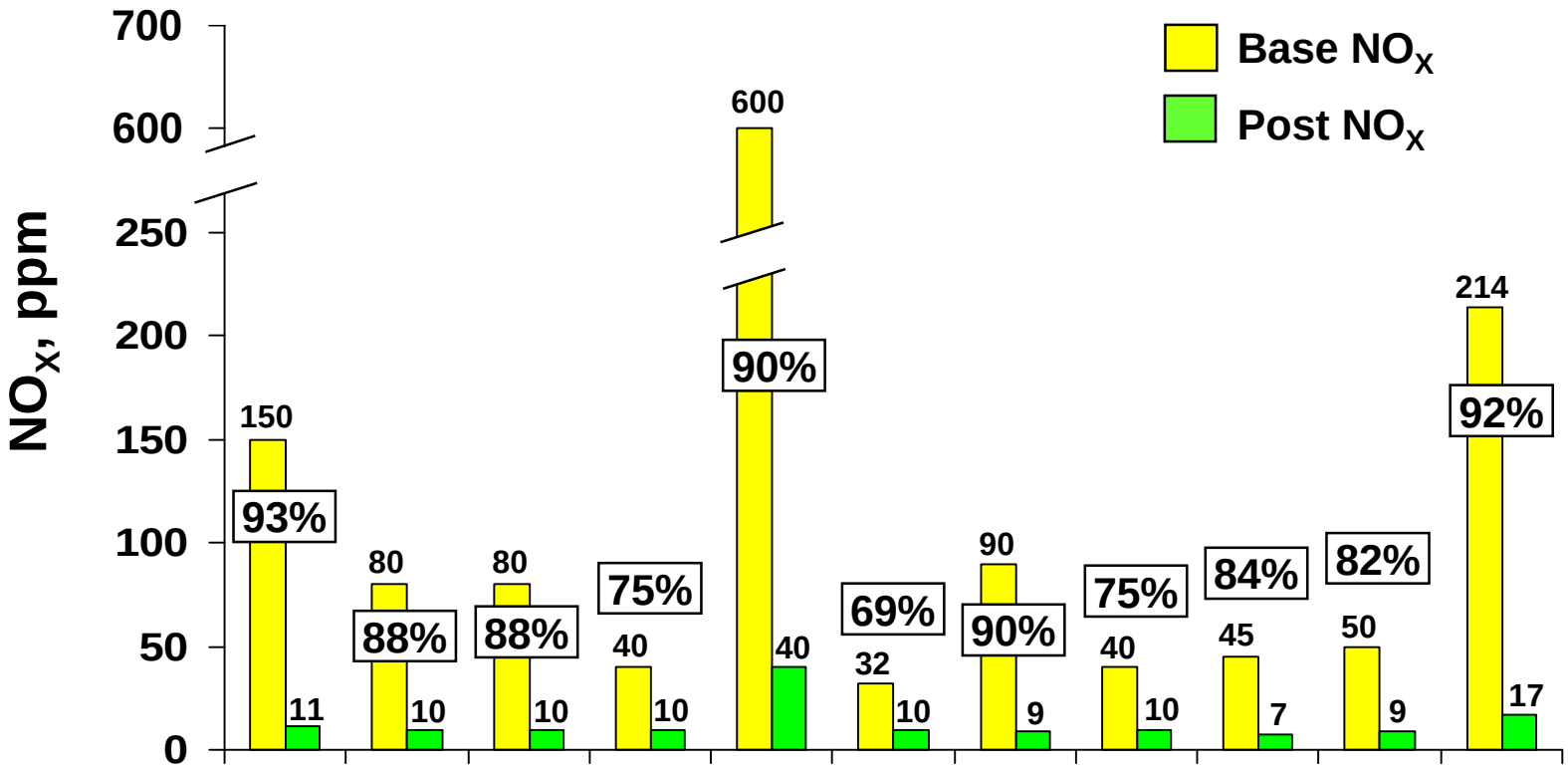
SCR Operating Results for Gas-Fired Units: Results = Guarantees

燃气机组　SCR运行结果=保证值



Unit	1	2	3	4	5	6	7	8	9	10	11
MW	40	812	812	326	82	359	320	326	345	323	270

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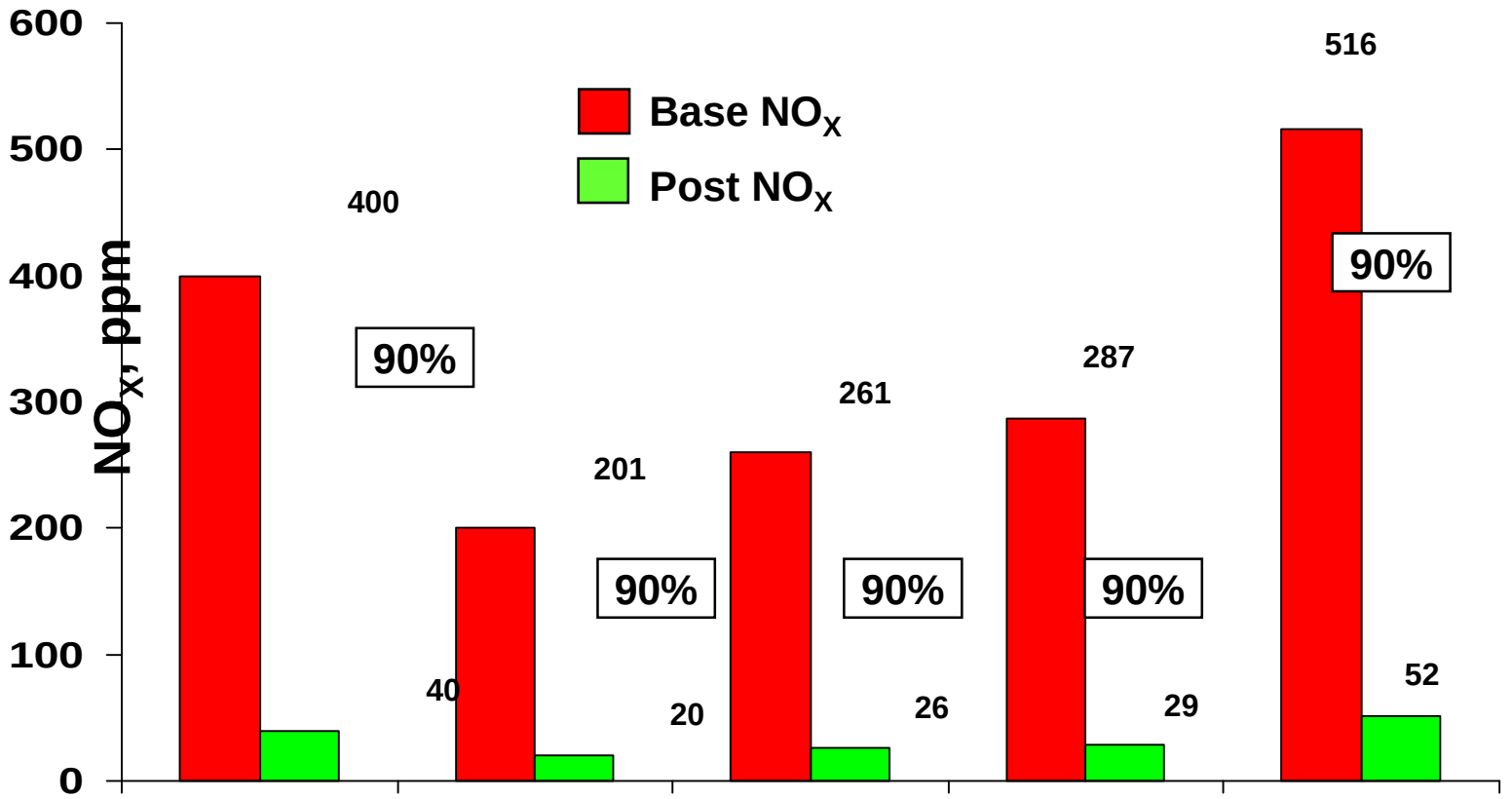
SCR Operating Results for Coal-Fired Units: Results = Guarantees

燃煤机组 SCR 运行结果＝保证值



Unit机组	A	B	D	E	F
MW	685	685	685	360	660

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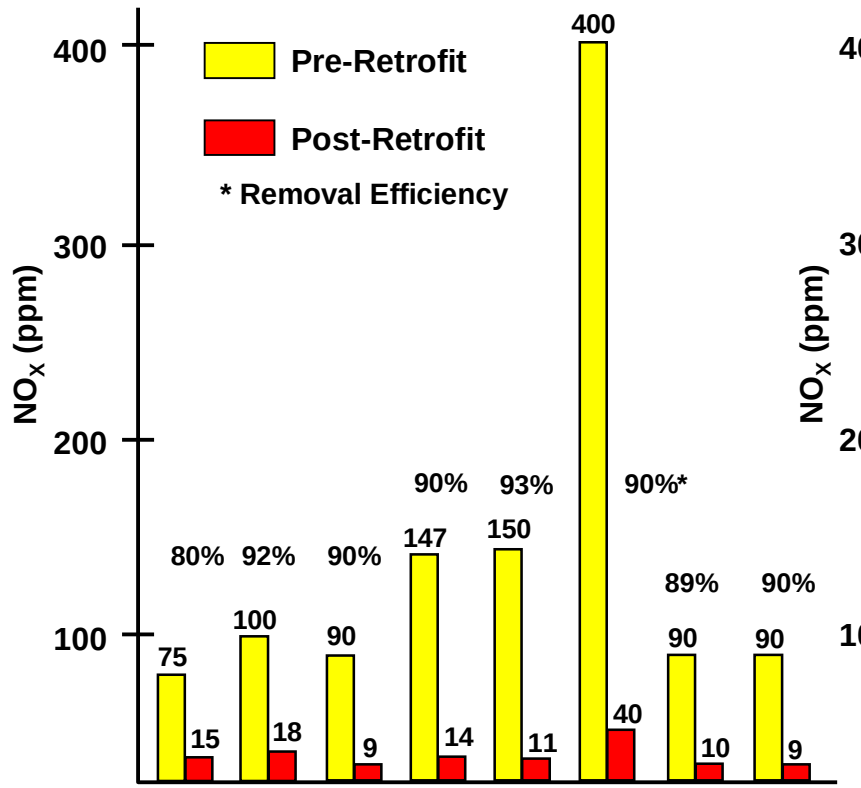
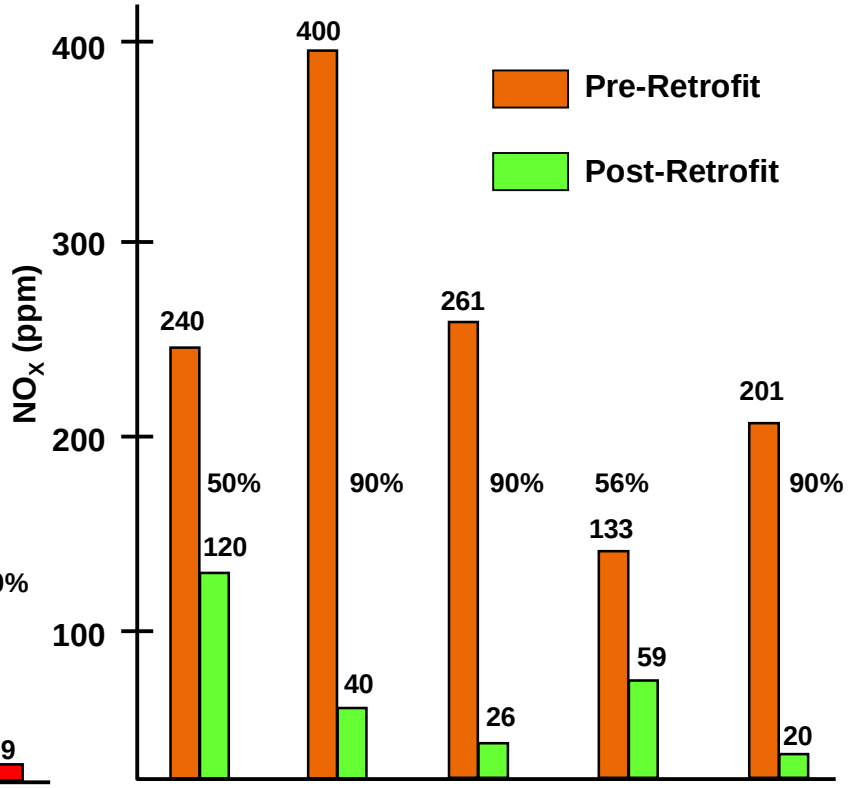
SCR Performance/Results Since 1986
SCR 性能/运行结果，始于1986

Natural Gas 天然气



Year	86	94	94	96	99	00	01	01
Plant	A	B	C	D	E	F	G	H
MW	42	230	335	151	40	80	750	335
OEM锅炉厂商	B&W	CE	CE	B&W	B&W	Riley	B&W	CE

Coal 煤



Year	96	99	01	01	01
Plant	I	J	K	L	M
MW	550	675	600	550	600
OEM	B&W (Int'l)	B&W	B&W	B&W	B&W

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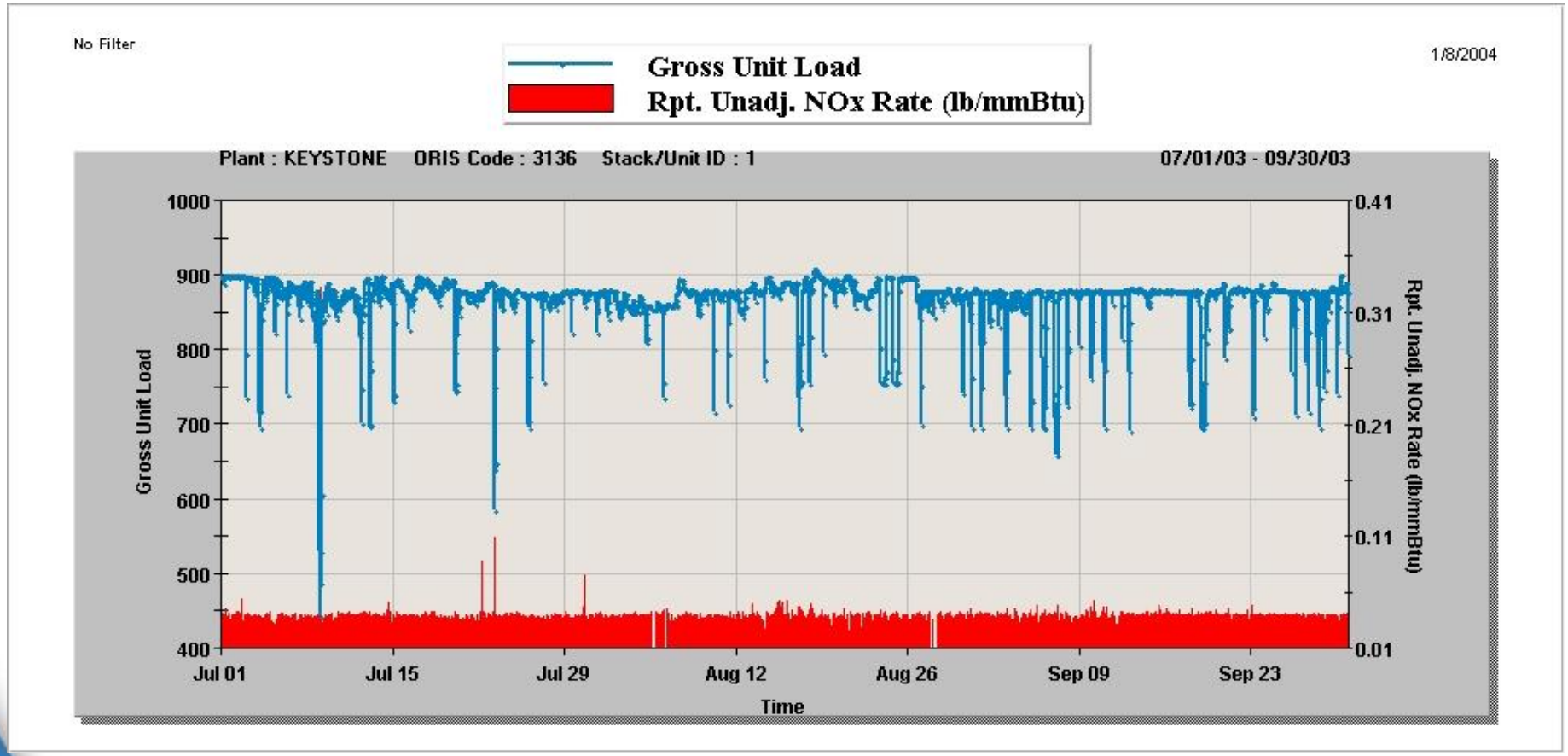
3rd Qtr. 2003 Operating Results－Keystone 1
2003年第3季度运行状态－Keystone 1号机组



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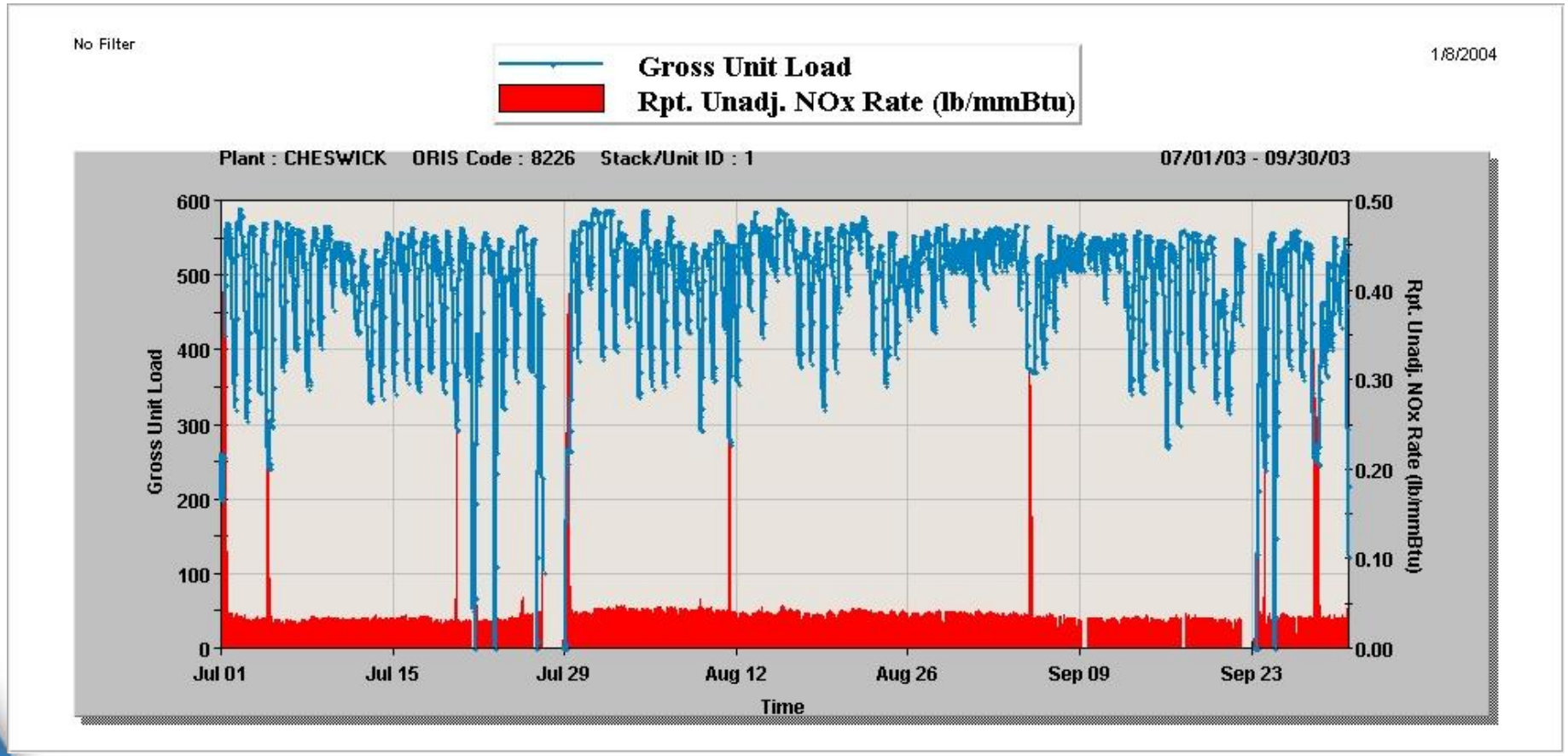
3rd Qtr. 2003 Operating Results-Cheswick

2003年第3季度运行状态-Cheswick



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Imperial Irrigation District
El Centro Generating Station
Unit 4 SCR

IMPERIAL IRRIGATION DISTRICT

OPERATING HEADQUARTERS • P O BOX 937 • IMPERIAL, CALIFORNIA 92251

August 2, 2000

Mr. James Kulig
Vice President and General Manager
B&W Service Company
P.O. Box 665
Barberton, OH 44203-0665

Subject: El Centro Generating Sta

Dear Mr. Kulig:

I would like to express my sincere appreciation for the [illegible] that B&W provided Imperial Irrigation District (IID). I typically do not write letters to vendors thanking them for products that they have provided [illegible] believe [illegible] case.

In late 1999, IID went out with a Request for [illegible] El Centro Generating Station Unit 4. In the specification, IID allowed as an option for the bidders to propose an alternate low NOx technology. [illegible] alternate low NOx technology, SCR. After [illegible] B&W's SCR system to solve the NOx problem on Unit 4.

Although IID's specification had adequate technical definition of a low NOx burner retrofit, it had very little technical definition (other than [illegible]) of a [illegible] other words, there was minimal language [illegible] a quality SCR system. IID entered into a contract with B&W in January 2000 with minimal technical definition, a very ambitious schedule and significant NOx reduction [illegible] pleased to write that B&W provided an SCR system that included all the items that IID would have specified had we known an SCR system would ultimately be installed. B&W met all contractual schedule dates and performance guarantees.

On behalf of IID, I would like to thank the many individuals within B&W that played a part in making this project's success. IID received what it requested and expected!

Sincerely,

Henryk A. Olstowski
General Superintendent
Power Generation

B&W = CUSTOMER SATISFACTION

B&W = 客户满意

“IID在2000年1月和B&W签订SCR的总包合同，其技术要求精练，工期要求严酷，脱硝率要求甚高。我很高兴写下这封信给B&W，感谢他们向我们提供了我们所有的要求。B&W满足了所有的合同中要求的工期和保证的性能。

谨代表IID，我要感谢B&W参与这个项目并做出贡献的的员工。IID采购到了自己要求以及希望的产品。

- Henryk A. Olstowski
电厂总指挥

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Reliant Energy
Cheswick Unit 1
B&W SCR Systems

PROJECT MANAGEMENT SKILL TRUST TEAM SUCCESS

项目管理技巧 – 信任 –团队成功

“从第一天起，贯穿整个的项目，**Tony Yagiela** 提供的项目管理服务是如此出色并超出我的预期。及时的沟通, 通力的合作, 有序的协调, 快速的反应, 强大的技术指导等等全部都超出了我的以前的经验。其中对我来说最为重要的是在项目伊始双方的信任就是如此的深入，我们完全采纳了项目组的理念。 这个团队，**Reliant, B&W,** 和 **Parsons,** 认为这个项目的成功比每个团队成员的成功更加重要，因为大家一致认为成功的项目必须建立在每个团队成员获得成功的基础上.

- Kevin P. Panzino, P.E.
项目工程师

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“Lessons Learned”经验和教训

- **Thorough planning results in cost-effective technology decisions**

  通过完善的计划和技术经济比较达到最佳效果

- **Each NOx reduction equipment package is a custom design**

  每一项脱硝设备包都是为用户定制设计的

- **An SCR system is not simply an “add-on”**

  一套**SCR**系统并非简单的加装在原有的系统上

- **Constructability reviews must begin “Day 1”**

  “第一天”就起施工为本的设计、管理理念

- **Short schedules mean trouble**
- 合理的工期。
- **A teamed approach can lead to success**

  团队合作是走向成功的重要条件

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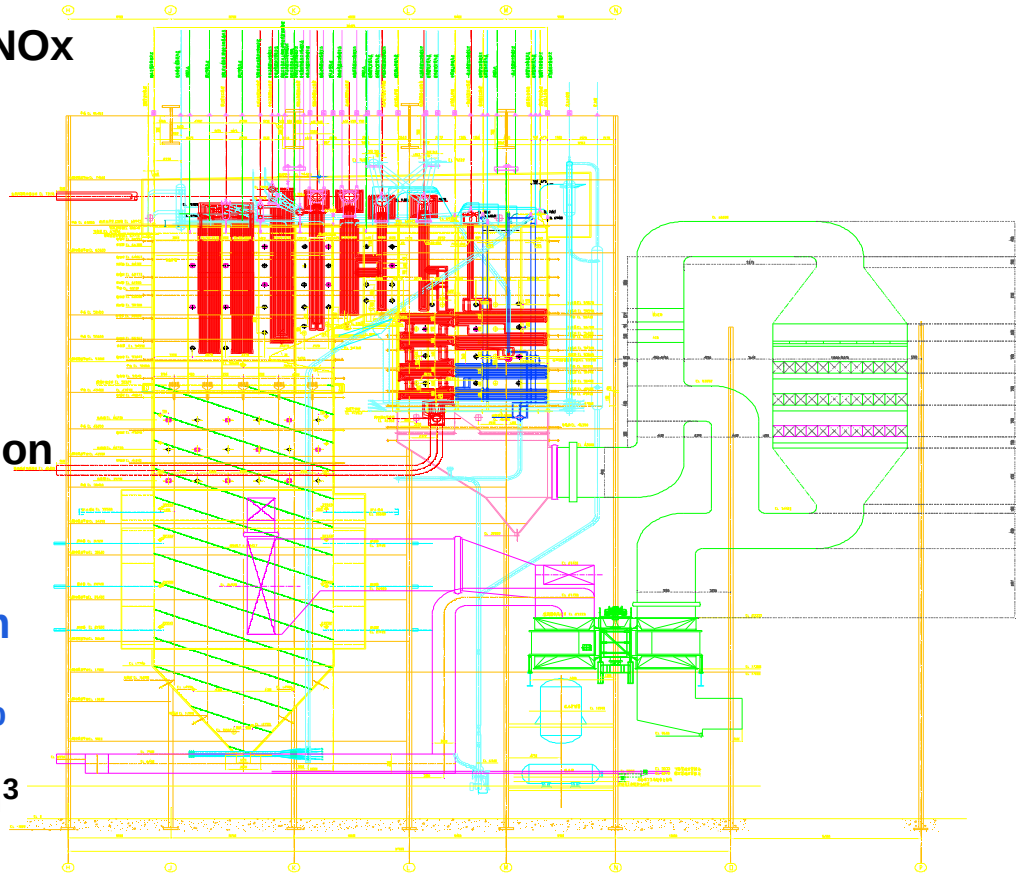
Low NOx Combustion + SCR B&WBC Project A
低氮燃烧+SCR方案 北京巴威 项目A

- **4Z Burner with less than 400mg/Nm^3 NOx Generation**
- **4Z燃烧器，生成的NOx低于400mg/Nm^3**
- **2+1 layer catalyst**
- **2+1层催化剂布置**
- **80%De-NOx 80mg/Nm3 NOx Emission**
- **80%脱硝效率 80mg/Nm3 NOx排放**
- **ammonia slip <3ppm 漏氨量小于3ppm**
- **SO2 oxidation <1% SO2氧化率小于1%**
- **Plate type Catalyst @6mm pitch 720m^3**
- **板式催化剂 节距6mm 体积720m^3**
- **2x85m3 AMM tank 两台85m3氨罐**



- **600MW Supercritical bit.**
- **600MW 超临界 烟煤**

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Why B&W?为什么选择巴威公司?

- **In-depth technology expertise (continued R&D efforts)**

  资深的技术专家(拥有持续不断的研发工作)

- **Integrate boiler operation with pollution control equipment**

  整合锅炉运行和污染控制设备的良好经验

- **Design for constructability (unparalleled construction expertise)**

  以施工为本的设计理念 (强大的施工实力)

- **Solid project track record**

  扎实的项目档案和跟踪制度

- **Organized for project success**

  专业、高效的项目团队

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