针对中国电力工业的OPTI-FLOW™ 高效低污染燃烧系统

OPTI-FLOW™ LOW NO_x COMBUSTION SYSTEM FOR CHINESE POWER INDUSTRY

Jeff Shan
Richard Conn
Joel Vatsky
Advanced Burner Technologies Corporation
271 Route 202/206
P.O. Box 410
Pluckemin, NJ 07978

Outline 内容安排

- ABT简介 Introduction for Advanced Burner Technologies (ABT)
- 中国电力工业新的挑战 Challenges for Chinese Power Industry
- ABT的产品 Equipment Supplied by ABT
  - » 燃烧器及其部件 Opti-Flow™ Burner and Components
  - » 燃烬风系统 Opti-Flow™ OFA
  - » 煤粉空气平衡系统 Coal Pipe Balancing and Secondary Air Balancing
  - » 防高温腐蚀系统Anti-corrosion System
- ABT业绩 Cases Study

简介 Introduction

- Advanced Burner Technologies (ABT) 已经在1000万千瓦机组容量的锅炉上安装了Opti-Flow TM 低 NOx 燃烧系统,单个机组容量从7万到95万千瓦。Over 10,000 MW of large utility boilers have been converted to the ABT Opti-Flow™ design. Unit range in size from 70 to 950 MW

- 改造内容包括：
  - » 磨煤机煤粉平衡系统, 动态分离器, 风箱改造 Coal and Air Balancing
  - » 高效低污染的燃烧器 Low NO_x Burners
  - » 燃尽风系统， Overfire Air and Anti-corrosion system
  - » 涉及墙式燃烧锅炉，四角切园燃烧锅炉 W-Fired, T-Fried Boilers

- 煤种涉及烟煤，次烟煤，褐煤等主要电力用煤和石油焦Diverse range of fuel firing experience including lignite, subbituminous, high S bituminous and petroleum coke/bituminous blends.

简介 Introduction

- ABT 的 Opti-Flow™ 低 NOx 燃烧系统特点 Features of ABT's **Opti-Flow ™** Low NOx Combustion System
  - » 降低氮氧化物 NOx control
  - » 提高燃烧效率 Combustion Efficiency Improvement
  - » 控制炉膛结渣 Slagging control
  - » 提高火焰稳定性和低负荷稳燃 Combustion Stability Improvement
  - » 平衡煤粉管道和二次风 Coal Pipe Balancing and Secondary Air Balancing
  - » 控制高硫份煤种水冷壁高温腐蚀 Corrosion Control

中国电力工业面临的挑战
Challenges for Chinese Power Industry

- 2003年7月颁布的《火电厂大气污染物排放标准》当电厂燃用挥发份高于10% 时，氮氧化物的排放应该低于450 mg/Nm3. From July 2003, NOx limit : 450mg/Nm3 （Vdaf≥10%）**Emission Control Cost 1.5% of Generation Cost and will cost 4.5% in 2005**

- 中国国情->控制氮氧化物的主要方式:燃烧设备的更新 Main Focus for NOx Control : Combustion System. Cheaper and More Benefits for Combustion and Slagging, Corrosion Control than SCR.

- 两个挑战：2 **Challenges**
  - » 提高已经安装了低氮氧化物燃烧器的锅炉性能 **Improve existing LNB**
  - » 降低非低NOx燃烧器的NOx排放。 **Retrofit Turbulent Burner**

中国电力用煤的煤质特性
Chinese Coal Property

- 低挥发份Low in Volatile Matter Content
- 高水份High Moisture
  - » 火焰稳定性Flame Stability
  - » 低负荷稳燃Unit Turndown
- 高灰份High Ash Contents
- 高硫份High Sulfur Contents
  - » 结渣Furnace Slagging
  - » 高温腐蚀Furnace Waterwall Corrosion
- ABT 对于上述煤质特性取得了很好的业绩ABT's Combustion System Yields Excellent Results with These Conditions

ABT全套解决方案 ABT Complete Solution for Chinese Power Industry

- 采用高性能的低**NOx** 燃烧器 **Utilize a Highly Effective Low NOx Burner**
- 减小燃烧器内部煤粉和空气的不均匀 **Minimize Fuel Imbalances within the Burner**
- 控制煤粉管道间以及不同燃烧器之间煤粉和空气的分布**Control Fuel and Air Distribution between Burners**
- 采用高效的燃尽风系统来降低**CO&LOI,**进而降低**NOx**。 **Use a Maximally Effective Overfire Air System to Minimize CO&LOI, Minimum NOx Can Not Be Attained Unless CO&LOI Are Minimized.**
- 采用独创的技术降低高温腐蚀 **Minimize Sidewall Corrosion with a Novel Anti-Corrosion System**

主要产品 Equipment Supplied by ABT

- 燃烧器及其部件
  - » Opti-Flow™ 燃料喷嘴：内部分级低NOx 燃料喷嘴。适用煤种包括褐煤，无烟煤，贫煤和石油焦煤粉混合物。**Opti-Flow™ Fuel Injector** Internal Staging LNB
  - » Opti-Flow™ 双调风系统：控制燃烧器内外二次风分配的设备。**Opti-Flow™ Dual Register**
- Opti-Flow™ 燃烬风系统：炉内分级降低NOx同时控制一氧化碳和未燃尽碳 **Opti-Flow™ OFA System** External Staging for Lower NOx
- ABT 防止高温腐蚀系统：针对燃用高硫煤的锅炉用空气保护水冷壁防止高温腐蚀的系统 **<u>ABT's Anti-Corrosion System</u>**
- 仓储均分器和ABT平衡阀：制粉系统的煤粉分布控制系统 **Tower Distributor™** and **Balancing Valve**

燃烧器及其部件

墙式燃烧和四角燃烧锅炉

Burner and Components

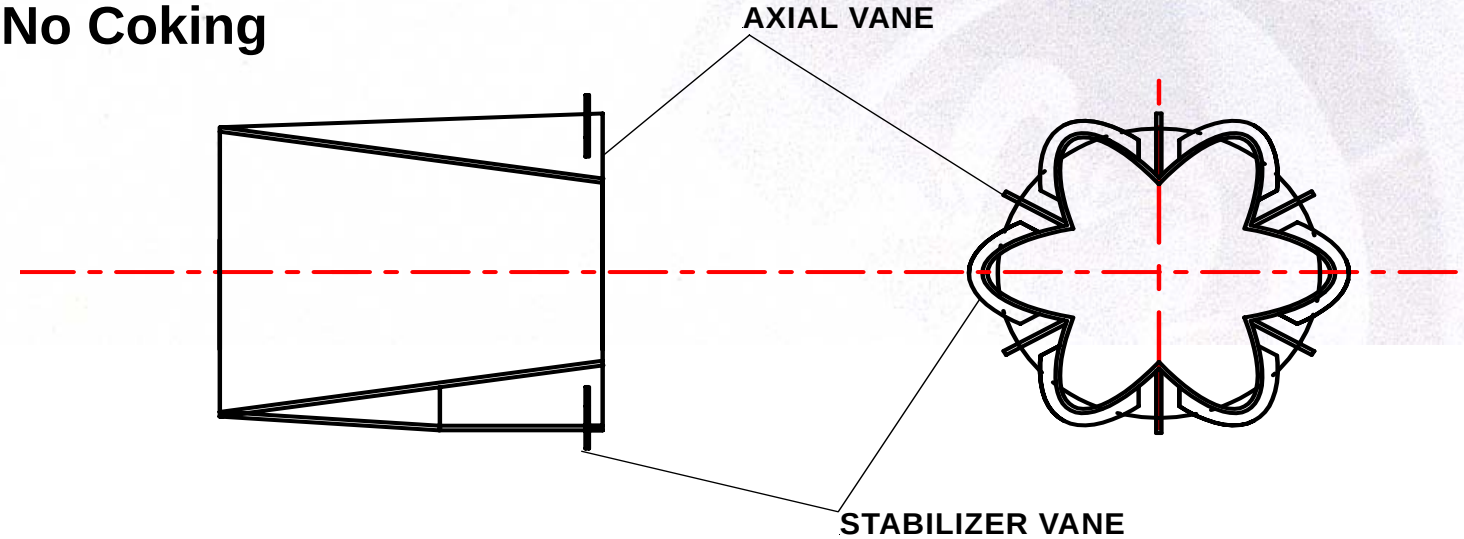
Wall-Fired and T-Fired Boiler

Opti-Flow™ 燃料喷嘴 Fuel Injector

- **OPTI-FLOW™低NOx燃烧器的核心部件Heart of the Opti-Flow™ Low NOx burner**
- 比其他同类的低**NOx**燃烧器降低**35%NOx**

  35% Lower NOx than the Conventional LNB Replaced by ABT
- 比常规的单调风湍流非低**NOx**燃烧器至少低**60%-70%**

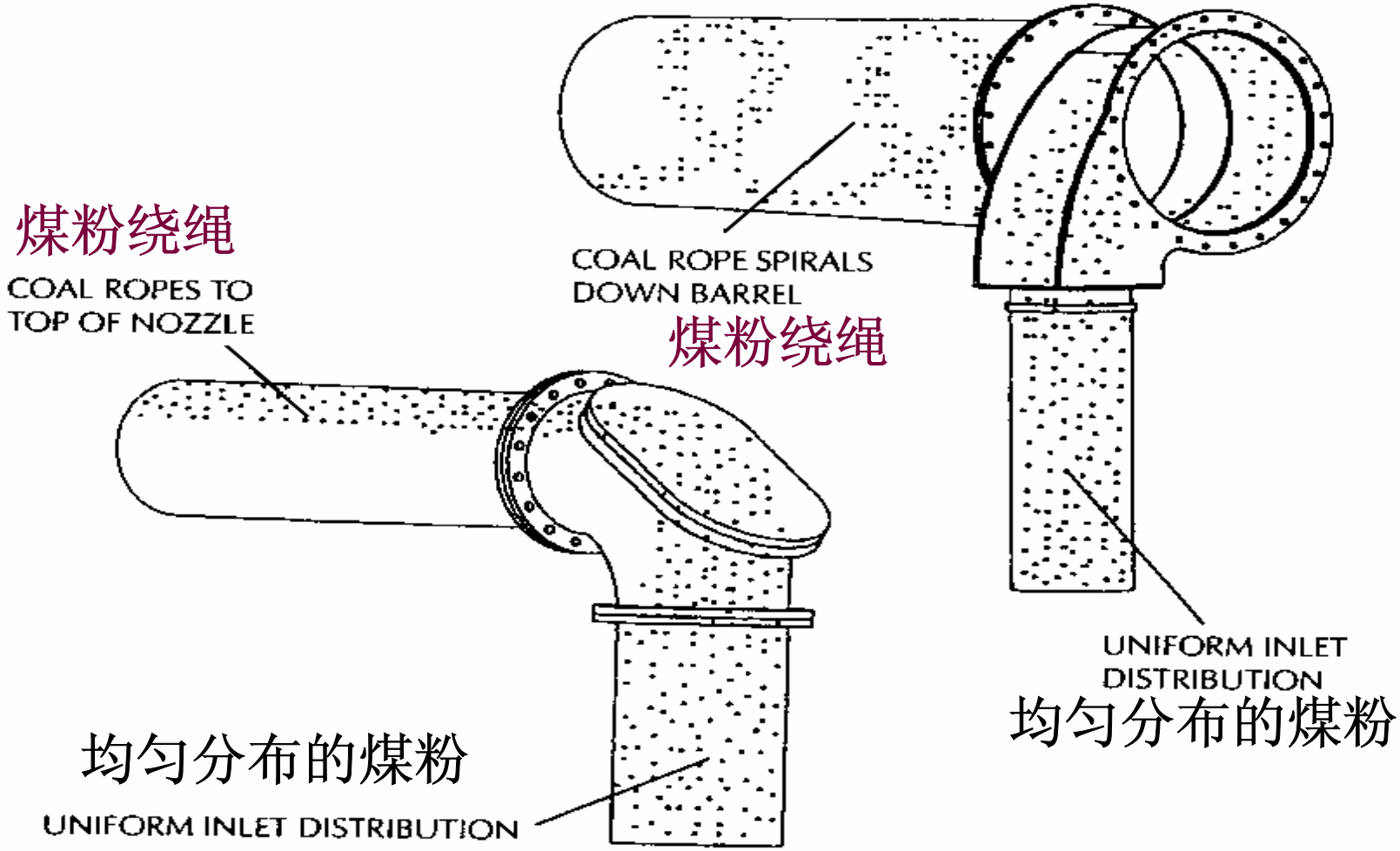
  At Least 60 to 70% below Turbulent Burner.
- 煤粉通道没有障碍物，不存在燃烧器结焦烧坏问题 **Open Nozzle, No Coking**



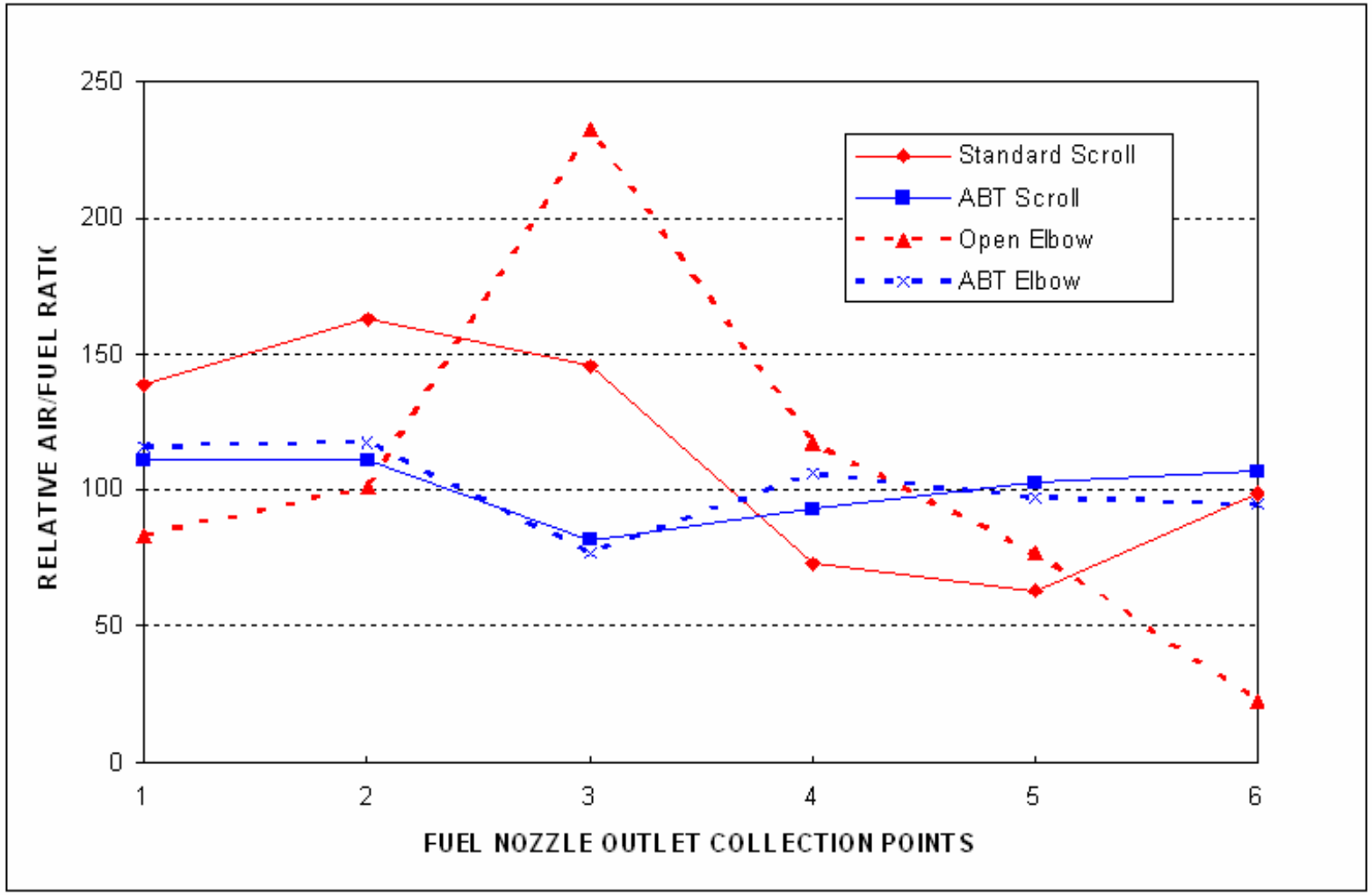
Opti-Flow™ 燃烧器的突出优点 Burner Features

- 燃烧器喷嘴周围近乎均匀的煤粉流分布可以同时显著地降低**NOx** 和未燃尽碳 **Uniform Fuel Distribution Around Burner Nozzle**
- 可调的高度稳定明亮的火焰 **Highly Stable Very Bright Flame**
- 喷嘴压降小，安装调整阀来控制煤粉流而不增加系统阻力 **Lower Pressure Drop**
- 可能保留现存的双调风系统 **May Keep Existing Dual Register**

煤粉绕绳现象 Coal Roping

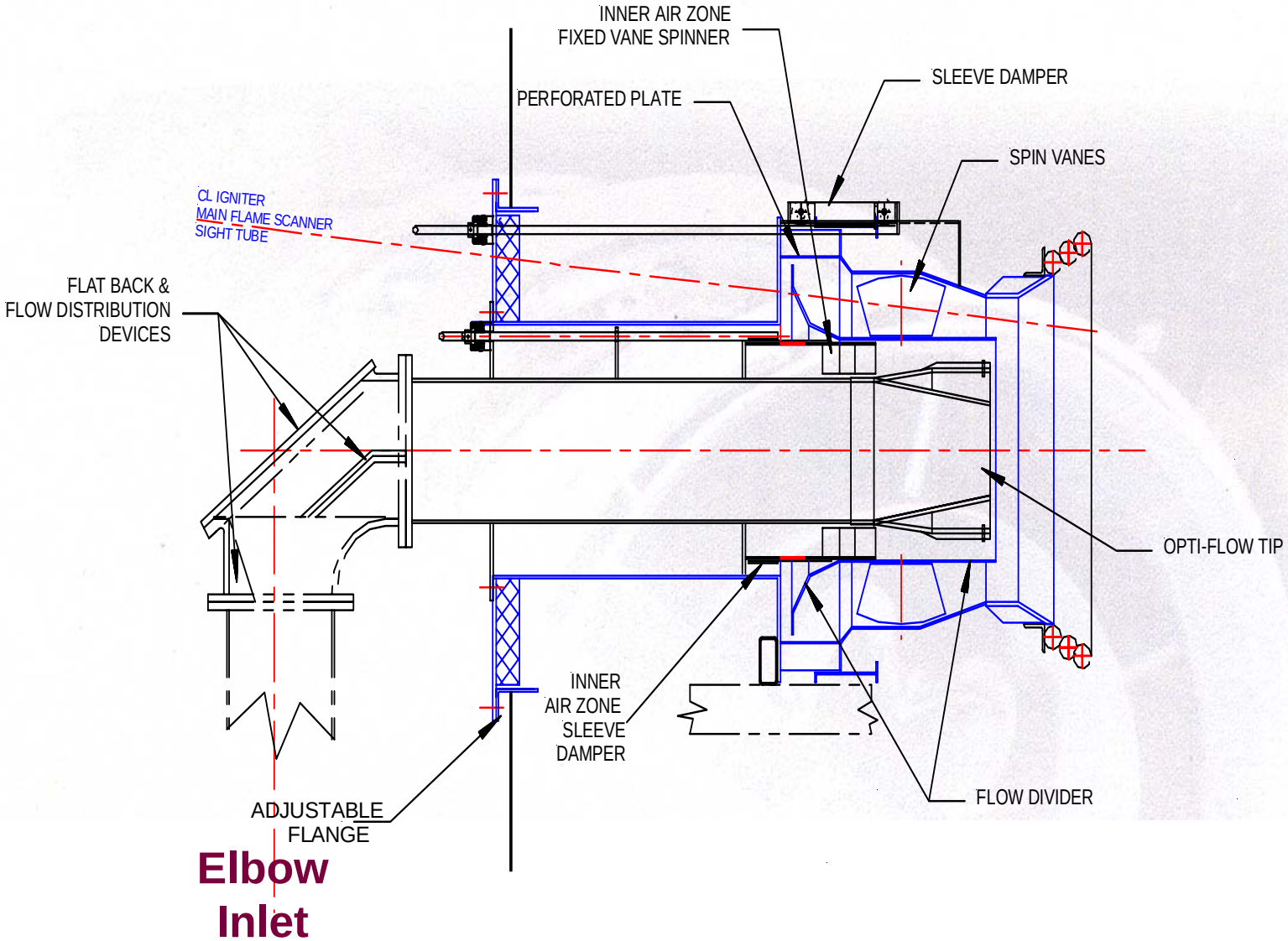


煤粉喷嘴出口不同测点处风煤比对照
Fuel Distribution for Scroll and Elbow



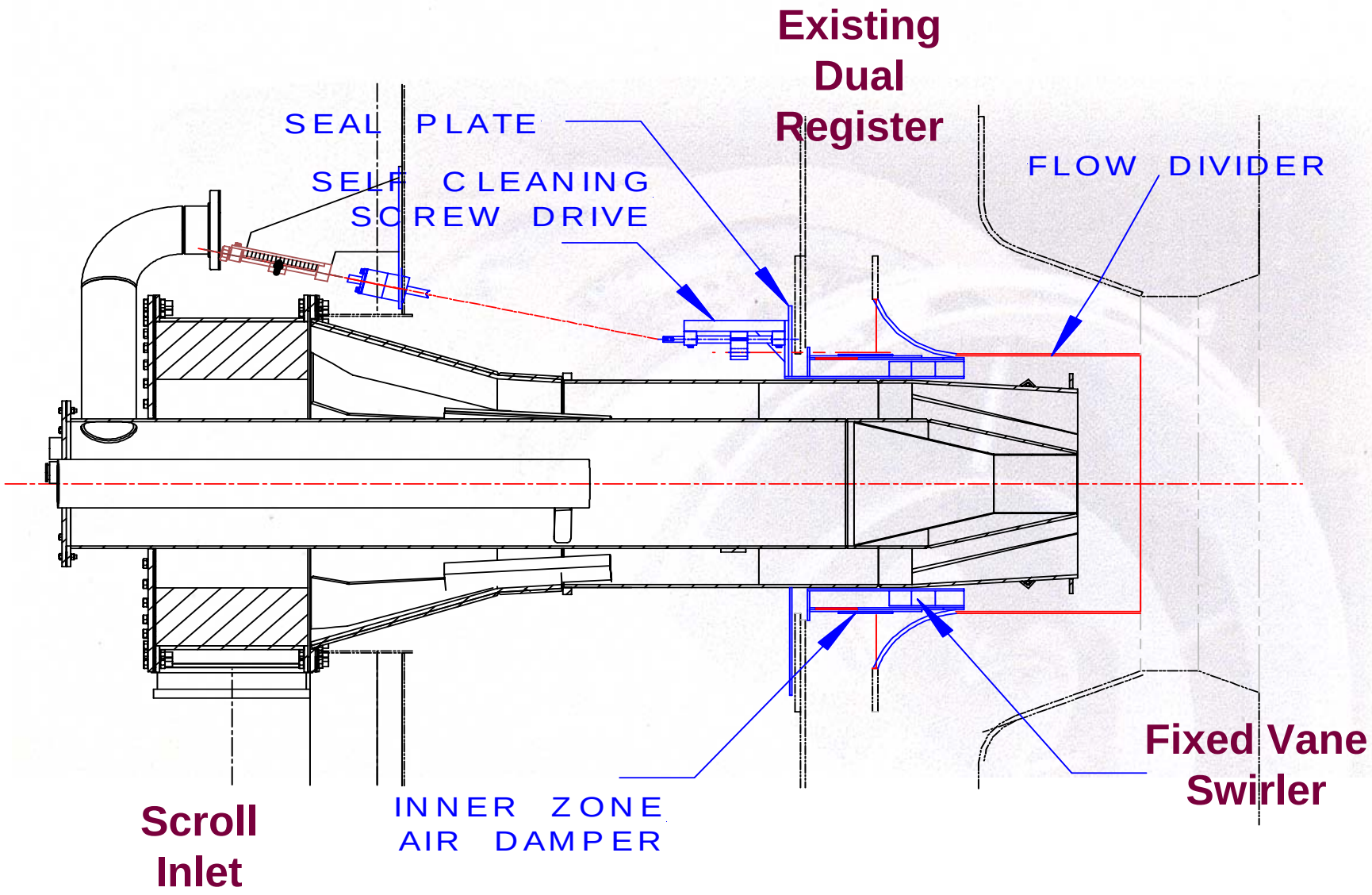
配有弯管的Opti-Flow™煤粉喷嘴和双调风系统草图

Opti-Flow™ Fuel Injector with Elbow and Dual Register

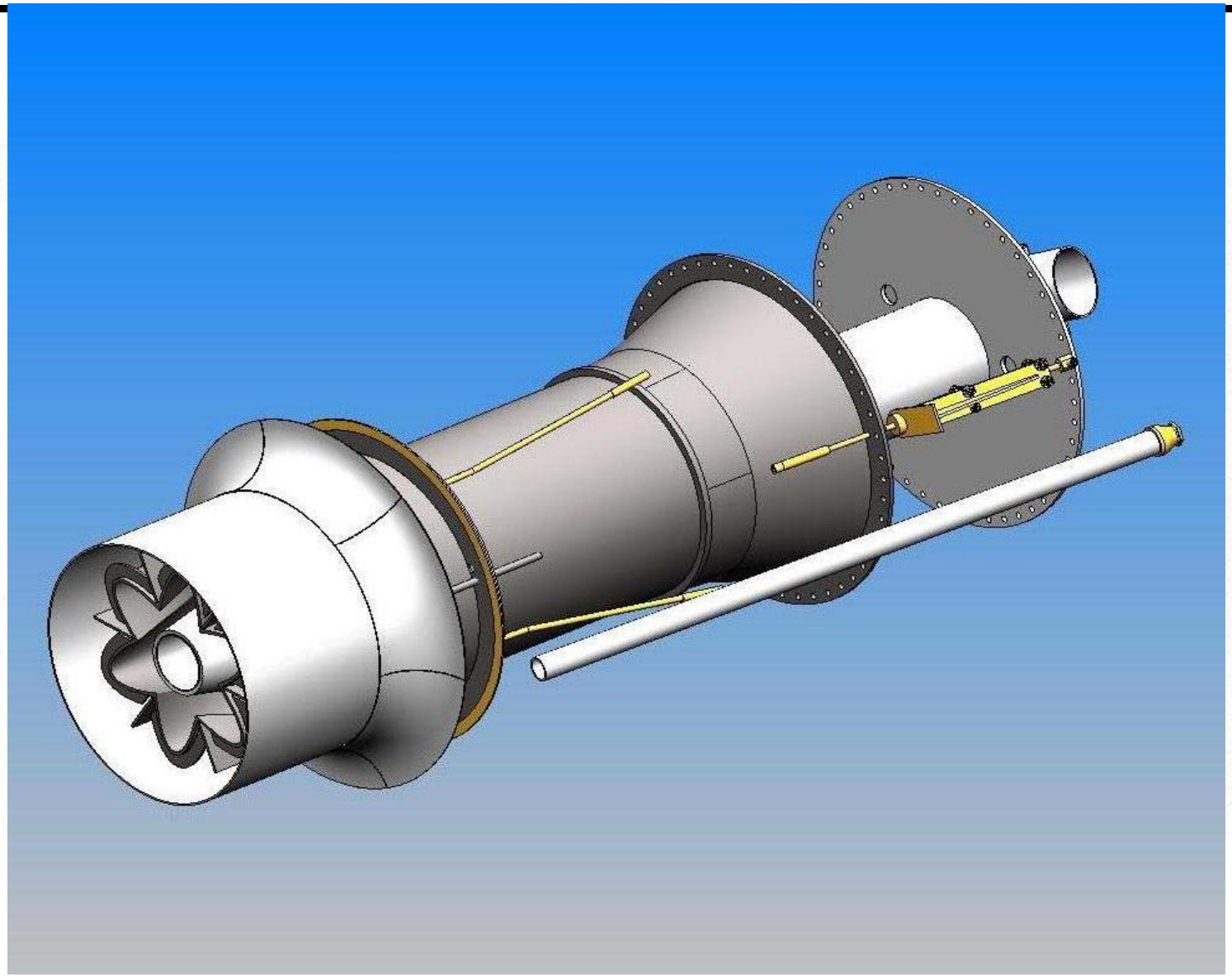


配有涡壳的Opti-Flow™煤粉喷嘴和双调风系统草图

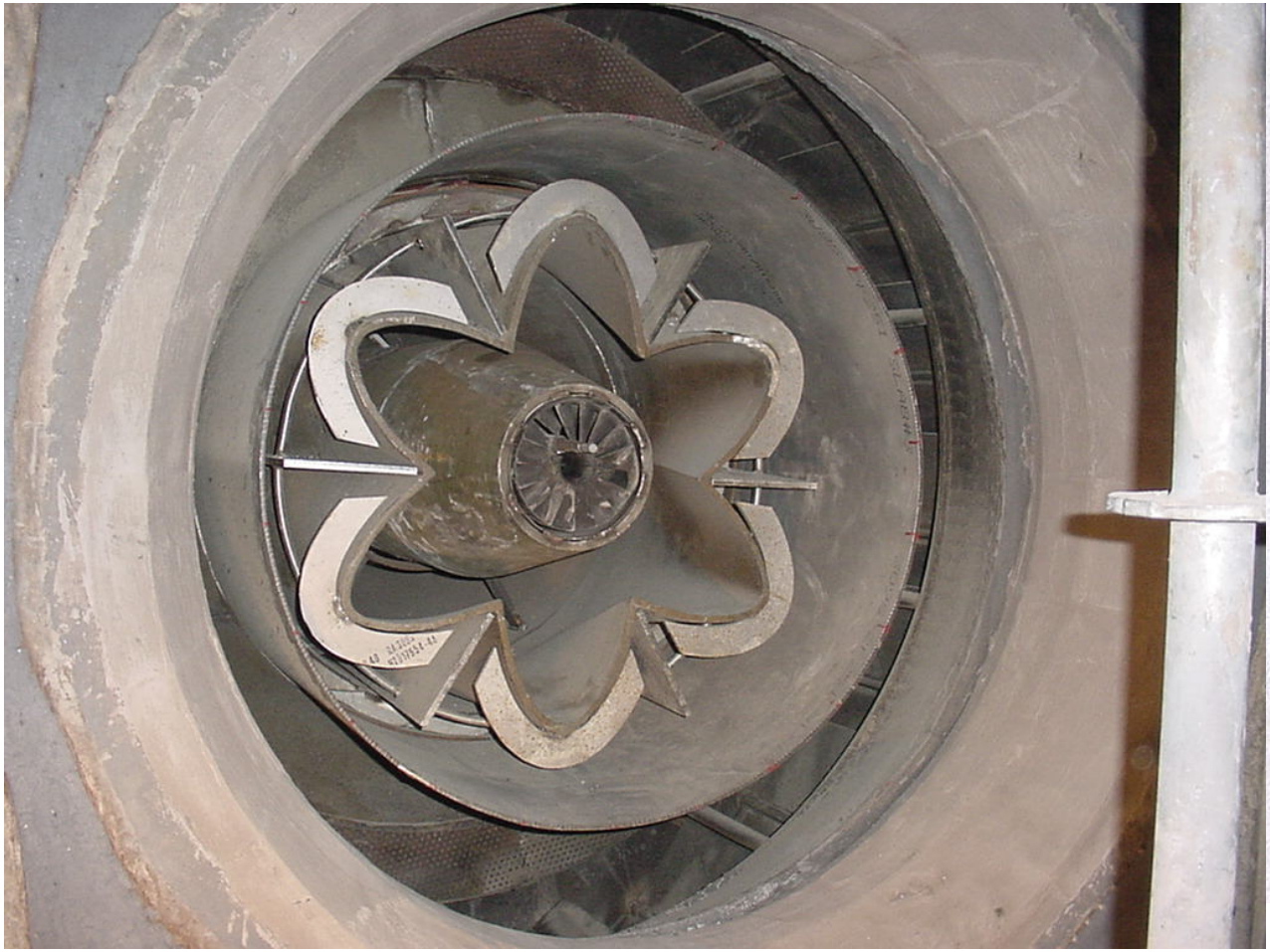
Opti-Flow™ Fuel Injector with Scroll and Dual Register



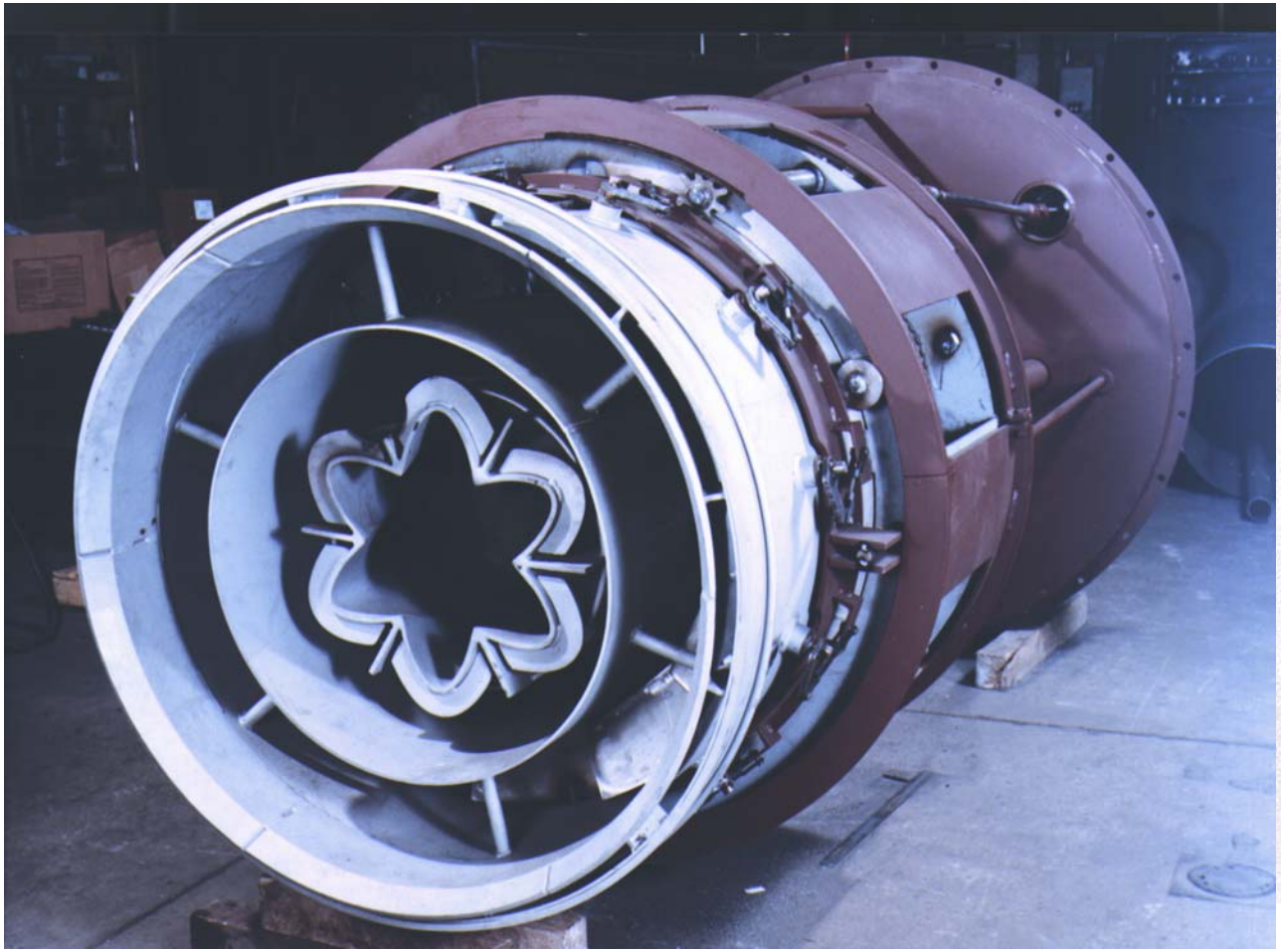
涡壳式Opti-Flow™煤粉喷嘴
Opti-Flow™ Fuel Injector



Scroll Burner with Center Igniter
安装在墙式锅炉上的中心点火涡壳燃烧器

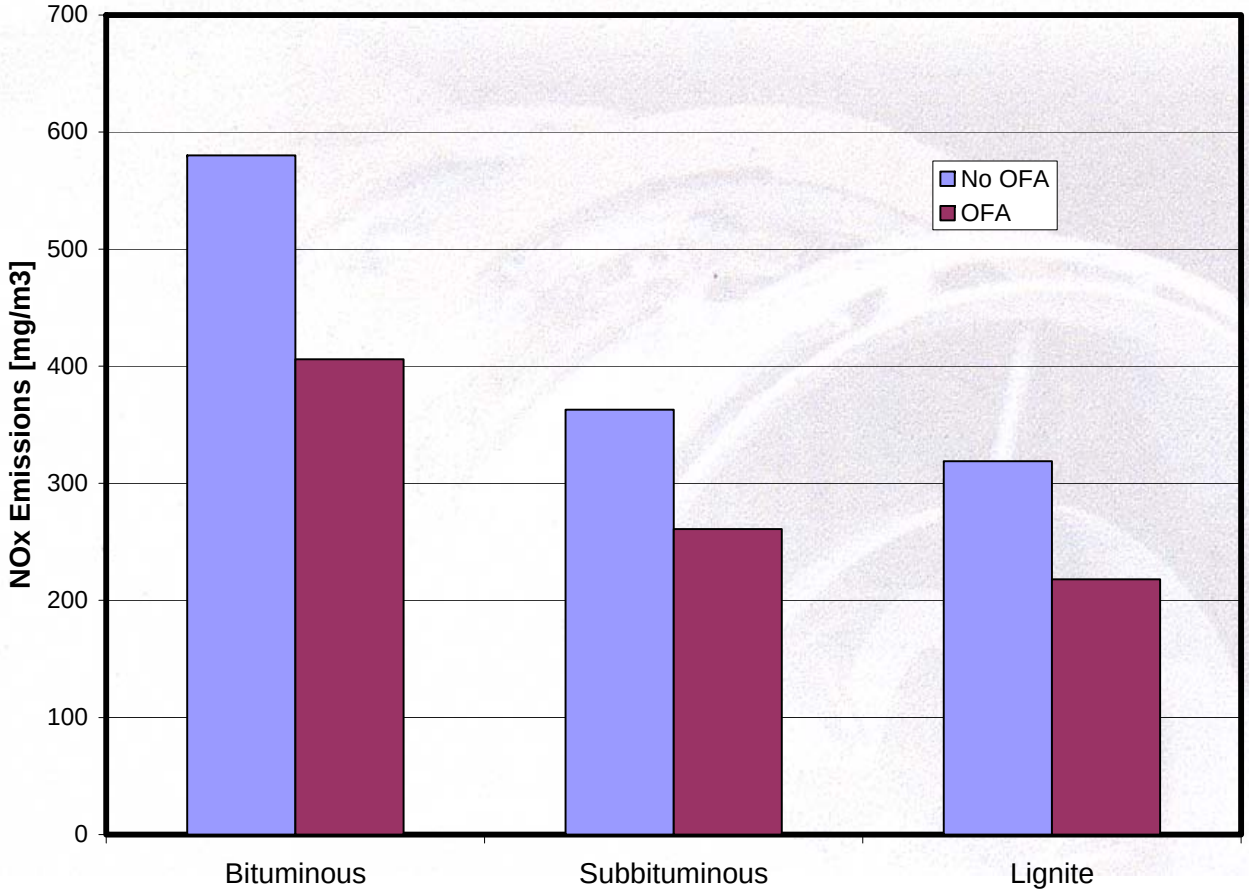


Burner with Side Igniter and Elbow Inlet 安装在墙式锅炉上的侧边点火弯管式燃烧器



NOx Emission with ABT Opti-Flow™ Burner

采用 ABT Opti-Flow™ 燃烧器后的NOx 排放



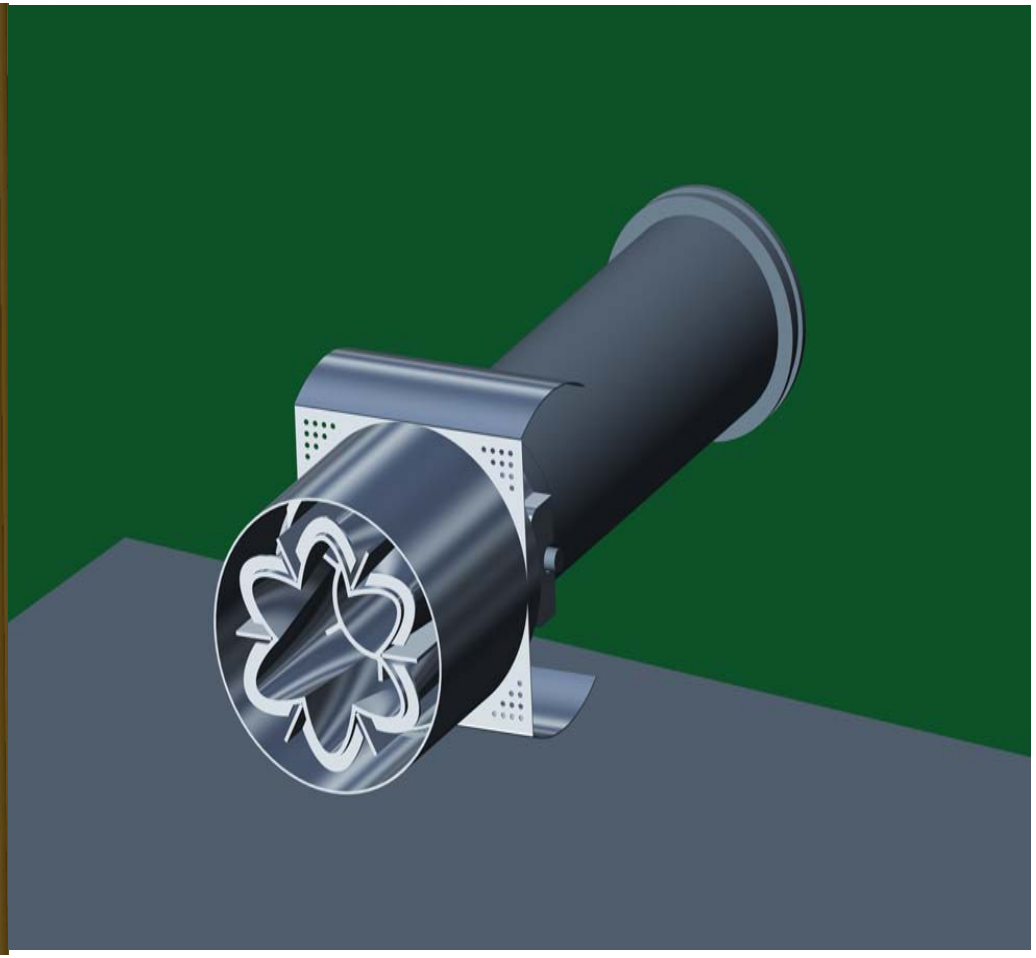
ABT Burner Flame at 55% Load Level
低负荷时火焰

20% Petroleum Coke and 80% Colombian Bituminous

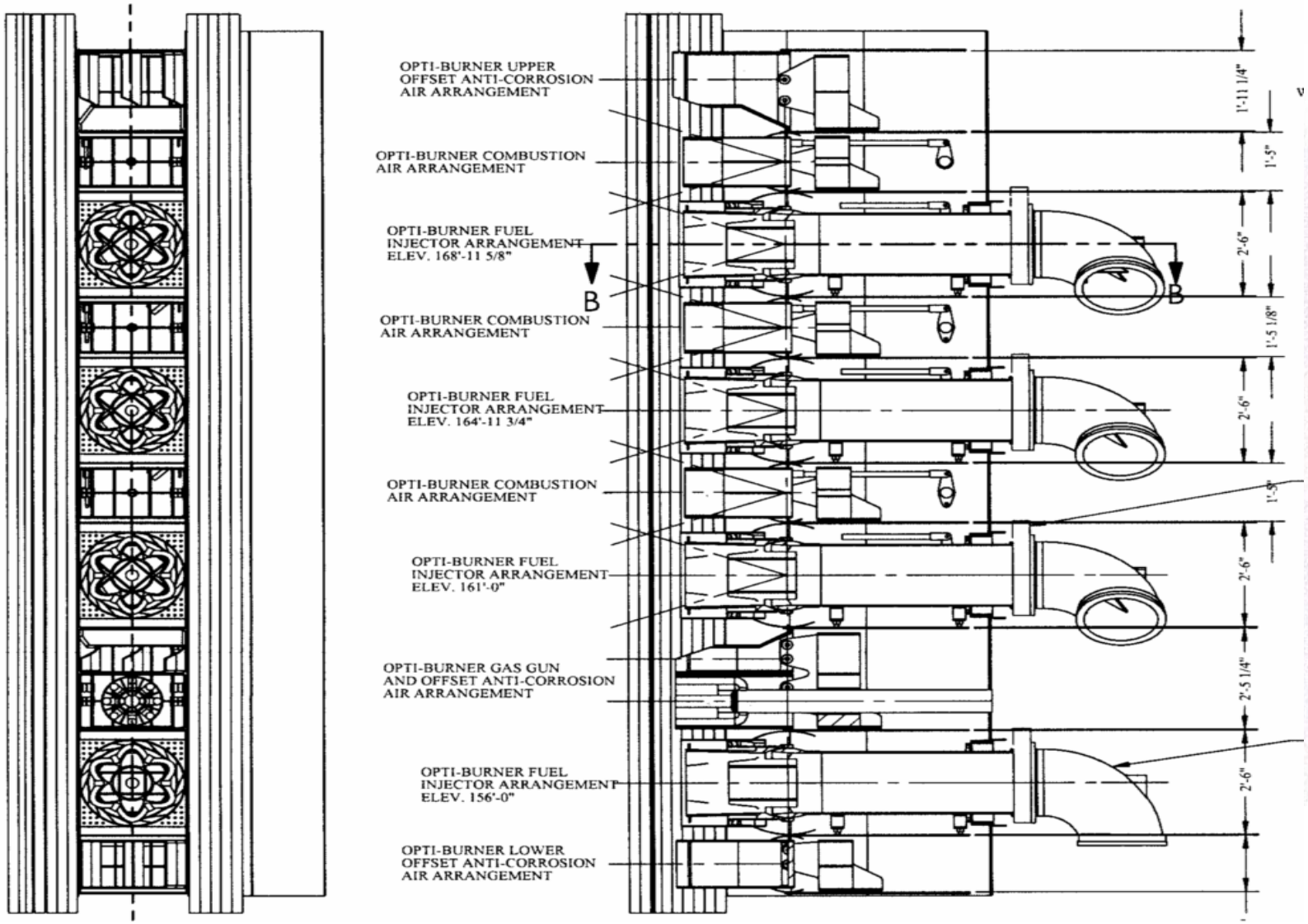
20%的石油焦和80%的烟煤

OEM Burner Full Load Flame
其他公司的燃烧器满负荷火焰

T-Fired Opti-Flow ™ 四角燃烧系统



Burner Drawing for 300MW T-Fired Boiler
30万千瓦四角切园锅炉的燃烧系统设计图纸



燃烬风系统

墙式燃烧和四角燃烧锅炉

OPTI-FLOW™ OFA System

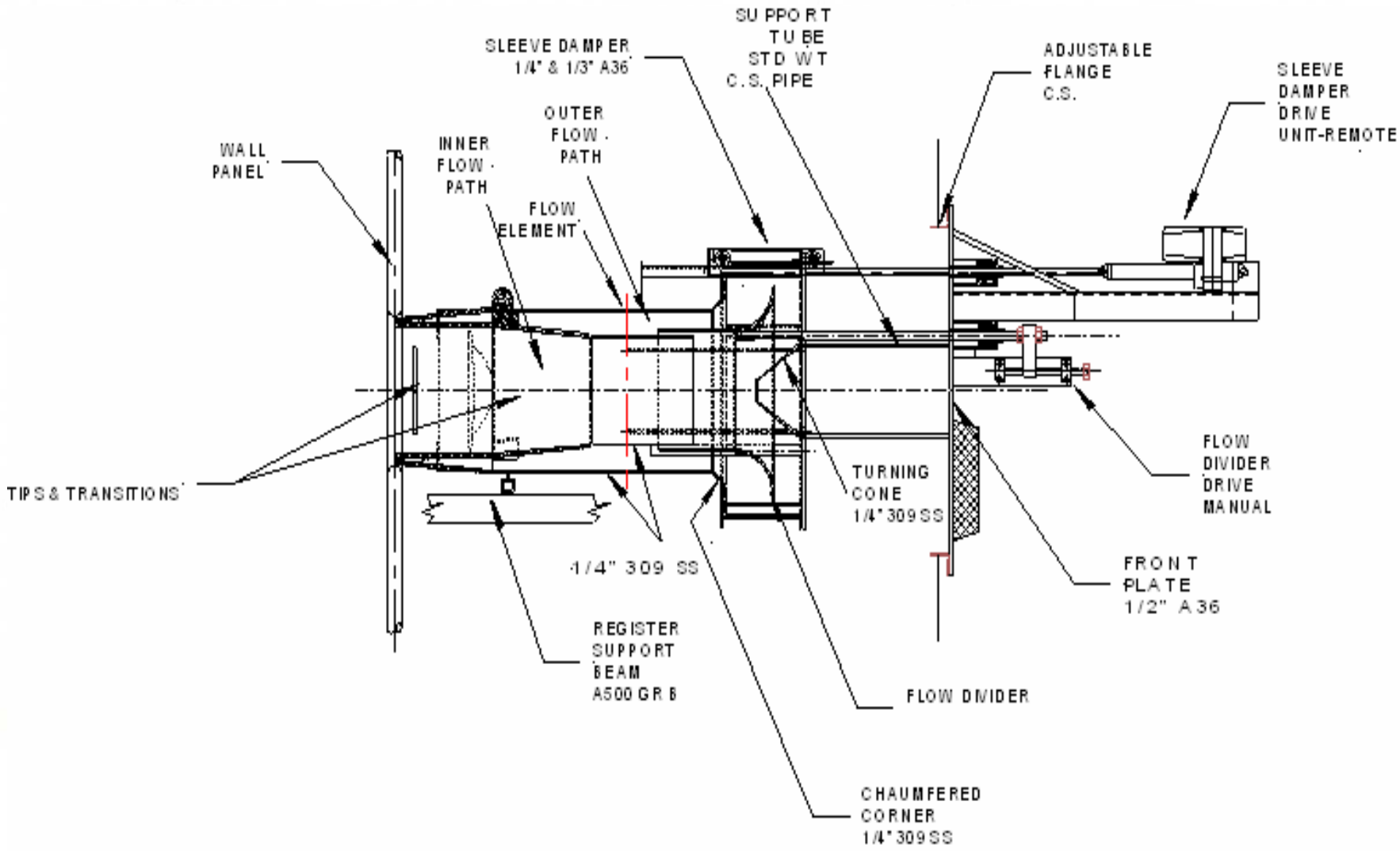
Wall-Fired and T-Fired Boiler

OPTI-FLOW™ OFA SYSTEM 燃烬风系统

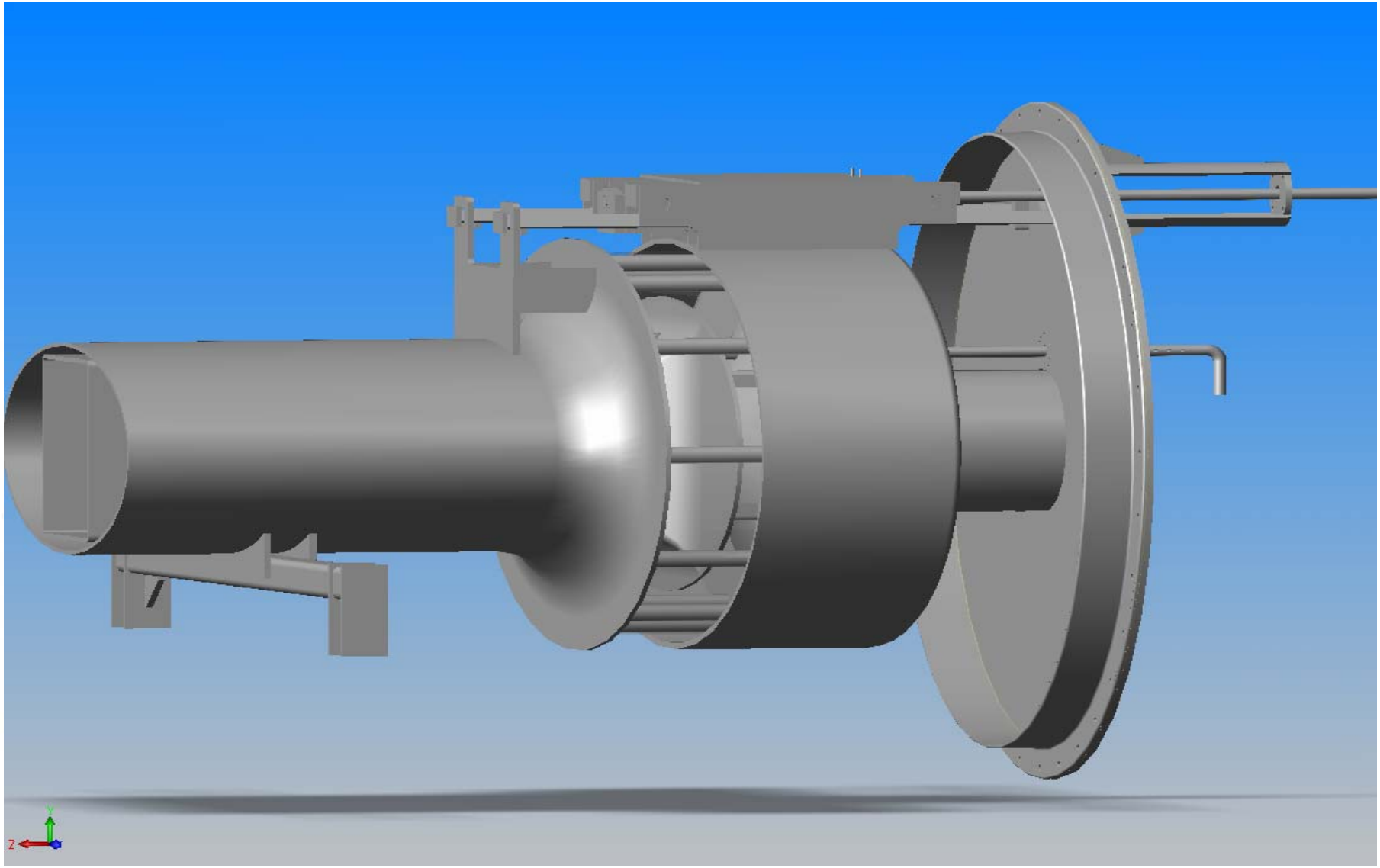
- Minimize Sub-Stoichiometric Burner Operation尽量减少燃烧器区域的低当量比燃烧
- Utilize Wing Ports to Blanket the Upper Furnace Sidewalls and Control CO 使用侧翼喷口产生氧化性气氛来保护炉膛上方侧墙
- Practical Optimize the Following:
  - » De-NO_x Zone Residence Time
  - » Residence Time in the Burnout Zone

  优化以下两个停留时间
  - » a) 燃烧器区域停留时间（从燃烧器的中心位置到燃烬风喷口）
  - » b) 燃烬区停留时间（从燃烬风喷口到炉膛折焰角)

OPTI-FLOW™ OFA 燃烬风系统



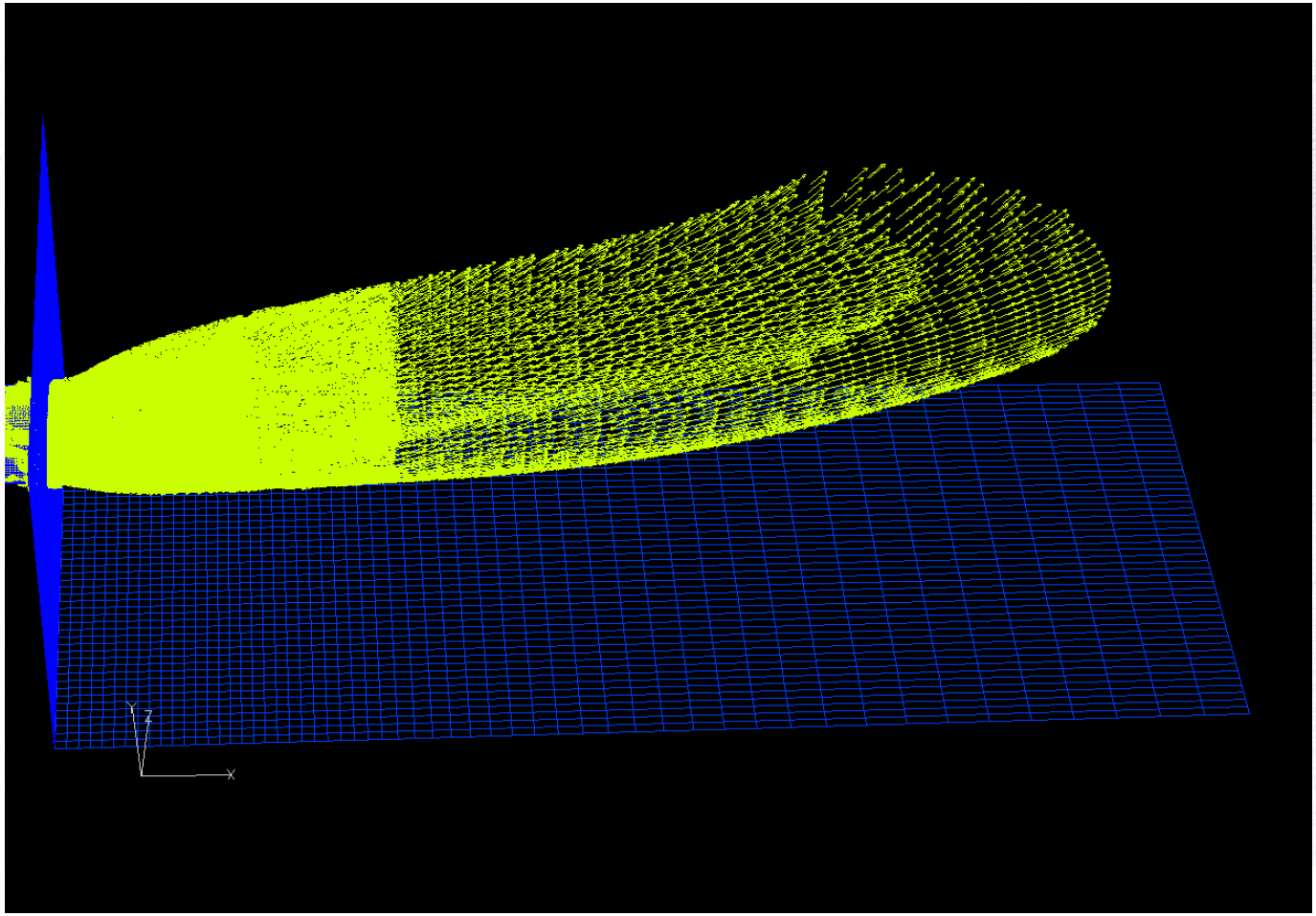
OPTI-FLOW™ OFA Aerodynamic Port
燃烬风系统



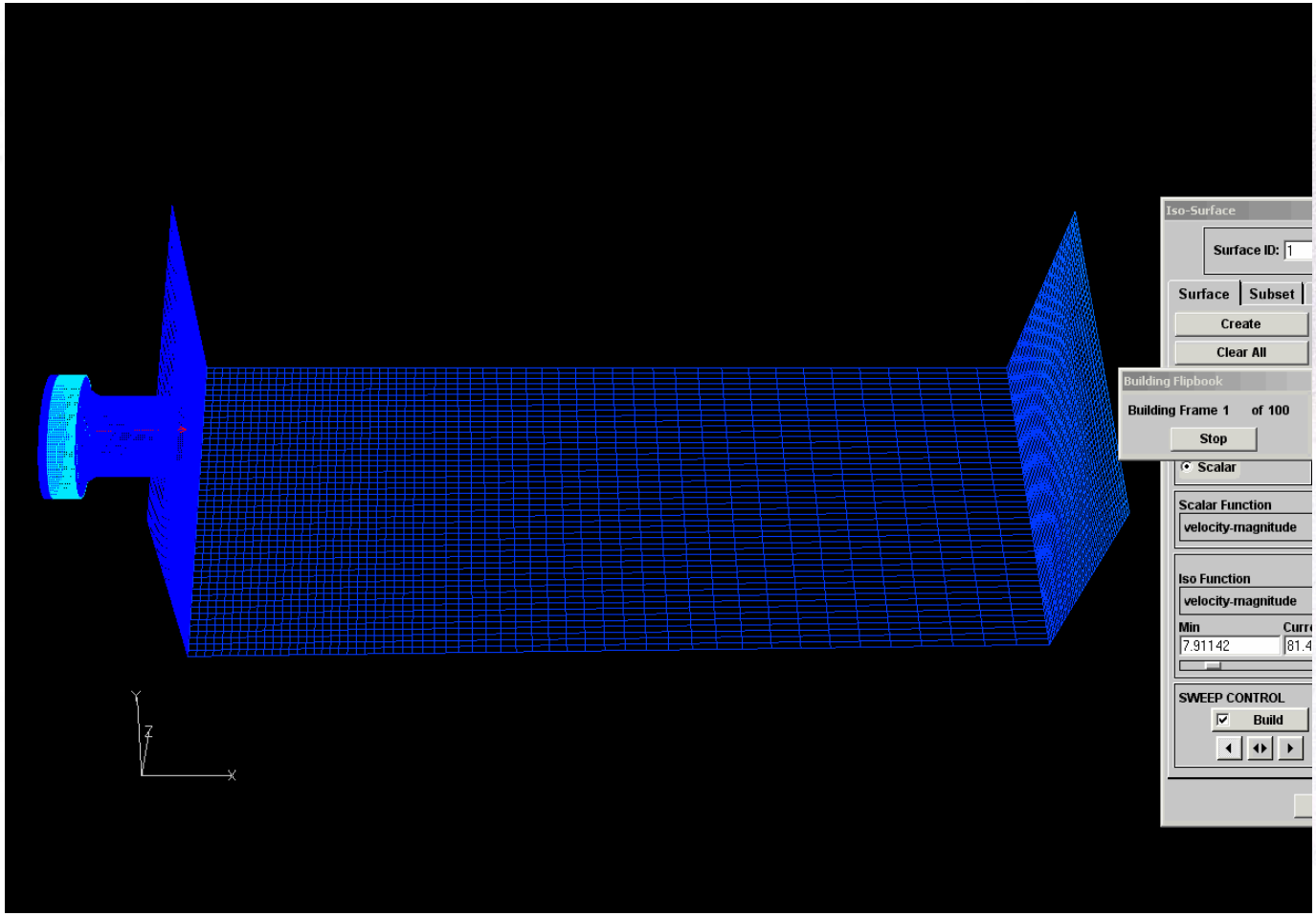
Features of OPTI-FLOW™ OFA Aerodynamic Port 燃烬风系统空气动力学喷口

- Dual Stage Design 双级喷口设计
  - » One Damper Controls Total Flow 一个挡板控制总流量
  - » One Damper Control Inner/Outer Ratio 一个挡板控制内外气流比
- No Swirl 没有旋流
- Deep Penetration 强大的穿透力
- Excellent Horizontal Mixing 充分的水平方向混合
- High Reliability Only 2 Moving Parts 高度可靠性，只有两个移动部件

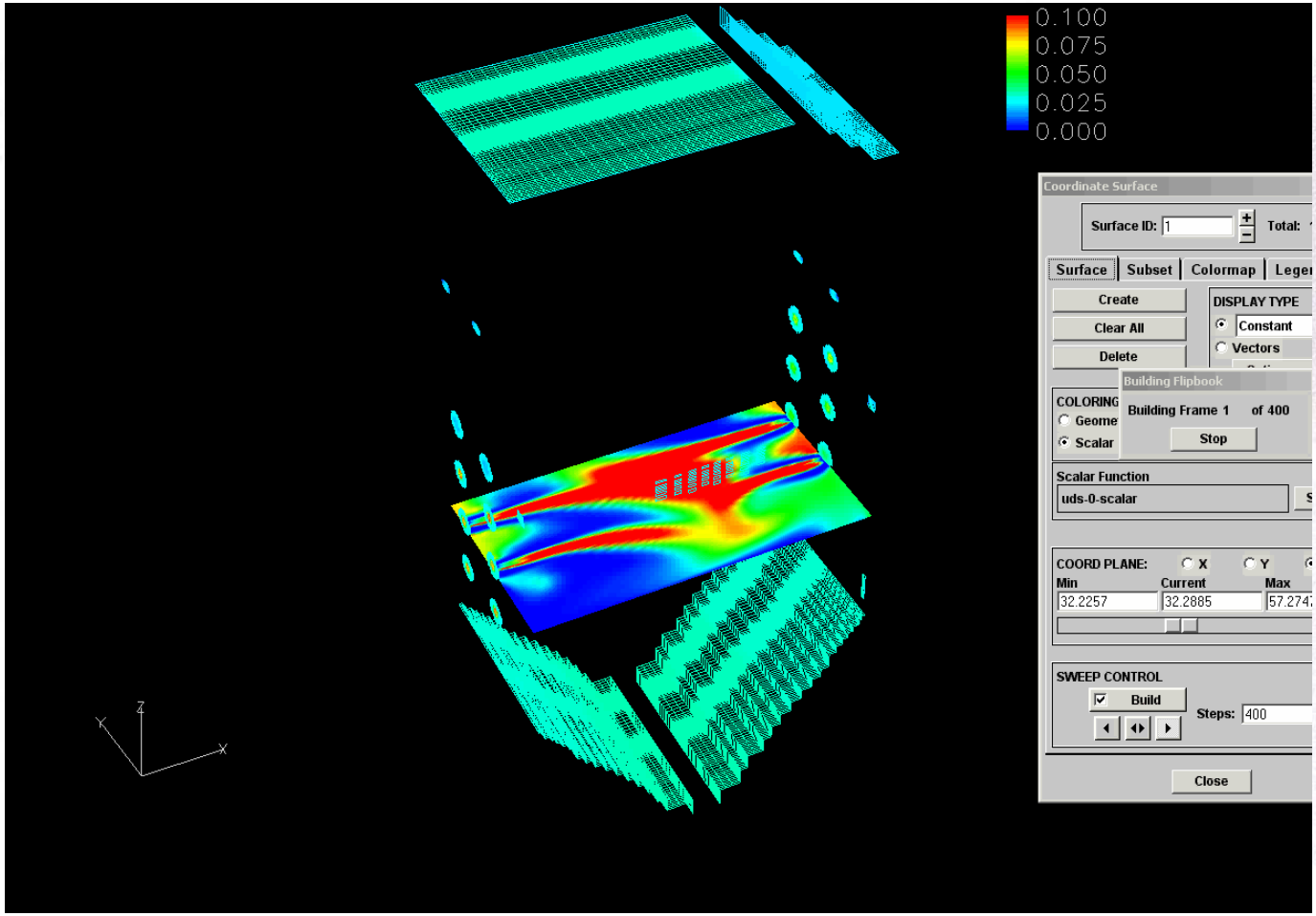
OPTI-FLOW™ OFA Aerodynamic Penetration
燃烬风空气动力学喷口的穿透效果



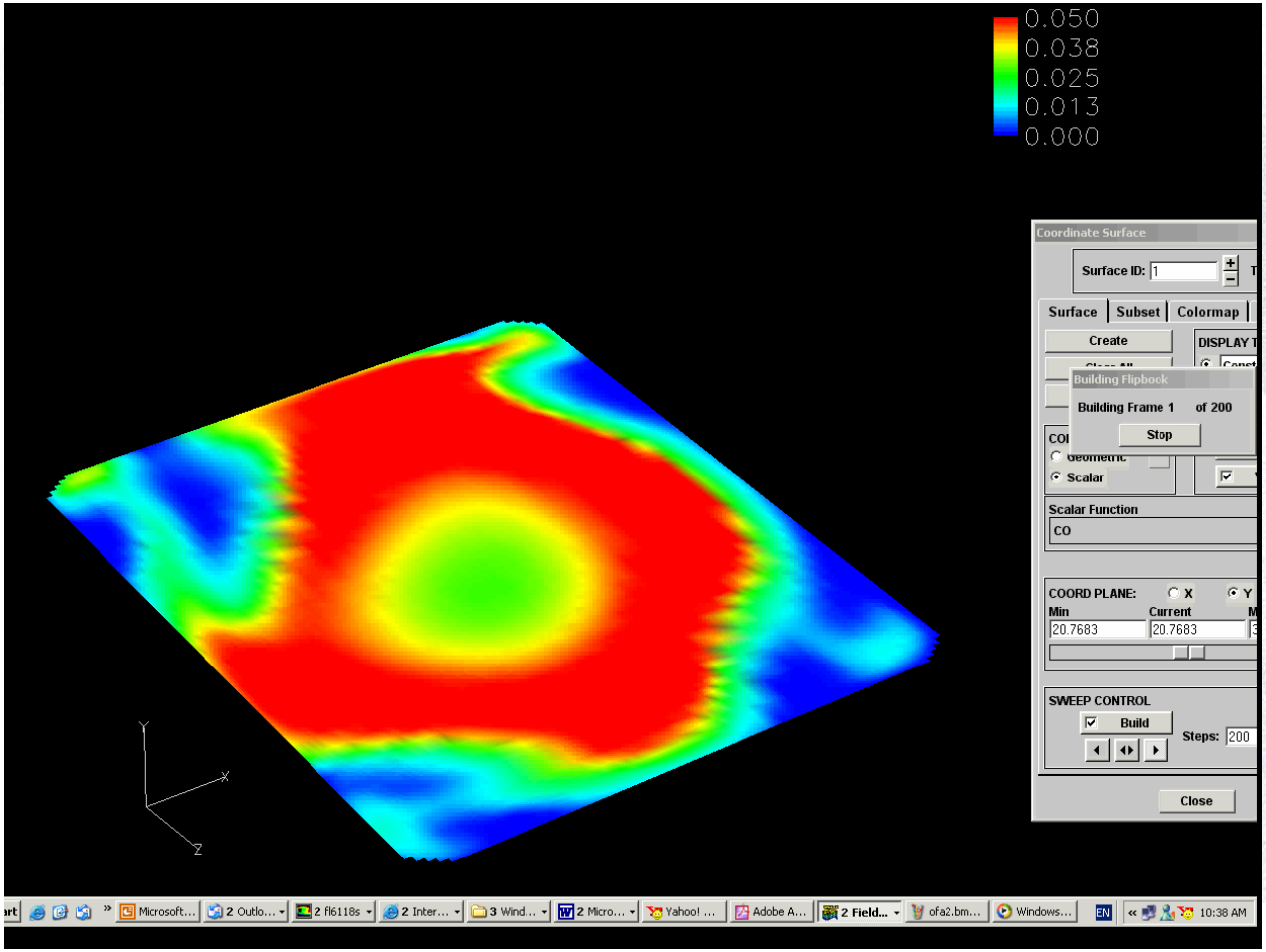
OPTI-FLOW™ OFA Penetration Animation 燃烬风的动画穿透效果



OPTI-FLOW™ OFA for Wall-Fired Boiler
墙式锅炉燃烬风系统的穿透效果



OFA's Effect on CO 燃烬风系统的穿透效果



OFA for 300 MW T-Fired Boiler

燃烧器之间的煤粉和空气的平衡

Fuel and Air Balancing between Burners

目的 Purpose:

- 控制煤粉管道间以及不同燃烧器之间煤粉和空气的分布
  Control Fuel and Air Distribution between Burners
- 降低氮氧化物和未燃烬炭
- **Control both NOx and Unburned Carbon**
- 消除煤粉富集区域（产生很高的一氧化碳和未燃尽炭）
- **Eliminate zones of very high coal flow (low stoichiometry) that generate high CO and UBC**
- 消除煤粉不足的区域（由于强氧化性气氛导致很高的氮氧化物） **Eliminate zones of very low coal flow (high stoichiometry, high excess air) that generate high NOx**
- 消除严重的烟气温度不平衡，解决高温过热器烟气偏差问题 **Eliminates severe gas temperature imbalances entering the super heater**

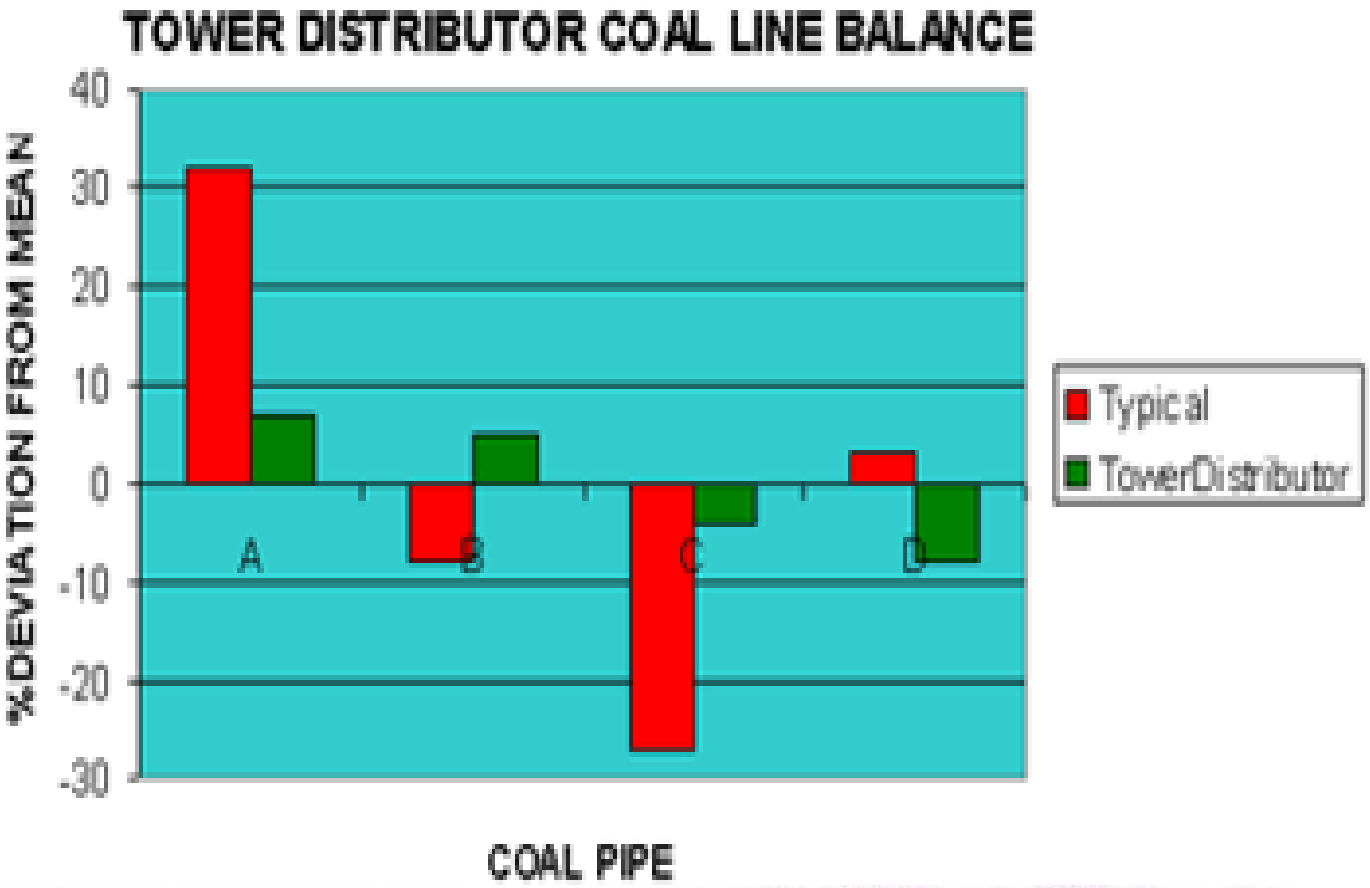
煤粉平衡 Coal Pipe Balancing

仓储均分器和平衡阀

Tower Distributor™ and **Balancing Valve**

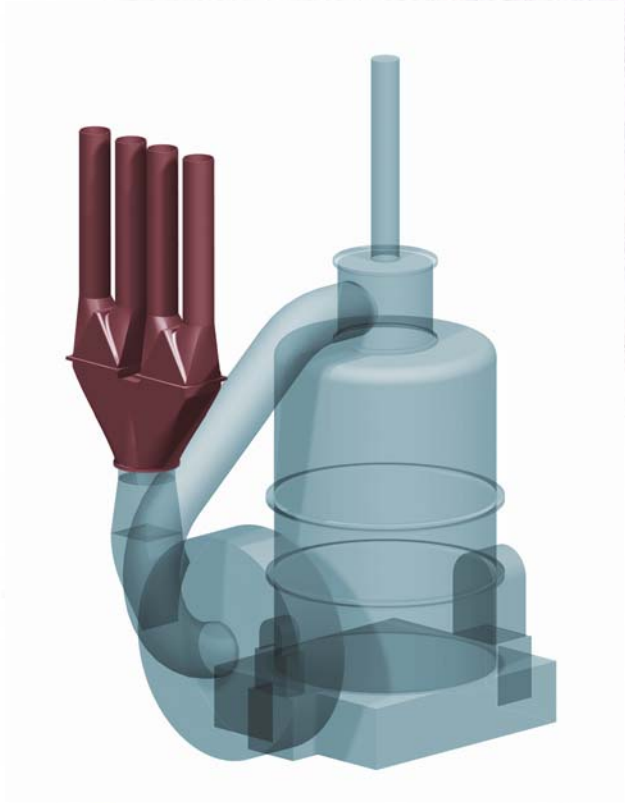
- 双端球磨 **Double-ended Ball (tube-type) mills**
- 乏气磨 **Exhauster mills**
- 多出口捶击磨 **Beater mills with multiple outlets**
- 垂直球磨和碗磨**Vertical ball and race mills**

Improved Coal Pipe Distributions with Tower Distributor™煤粉管道平衡系统

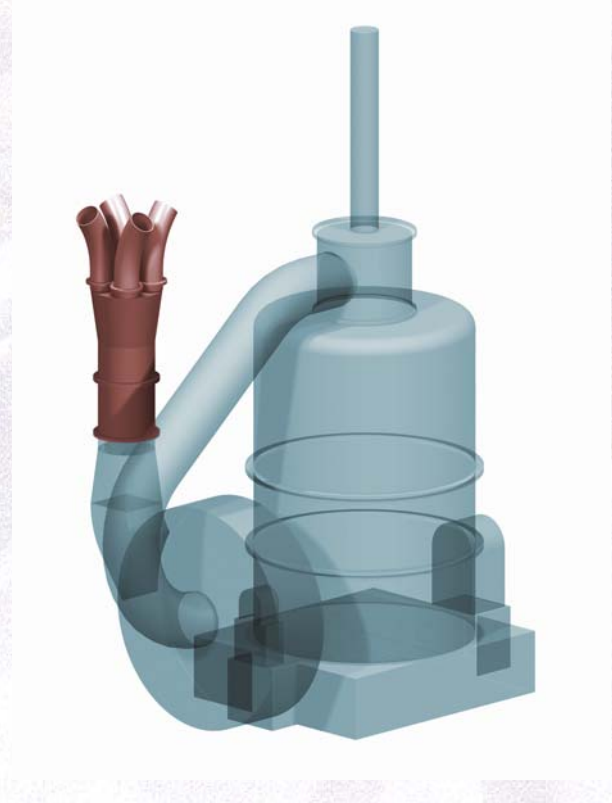


塔式分配器

Improved Coal Pipe Distributions with Tower Distributor™煤粉管道平衡系统

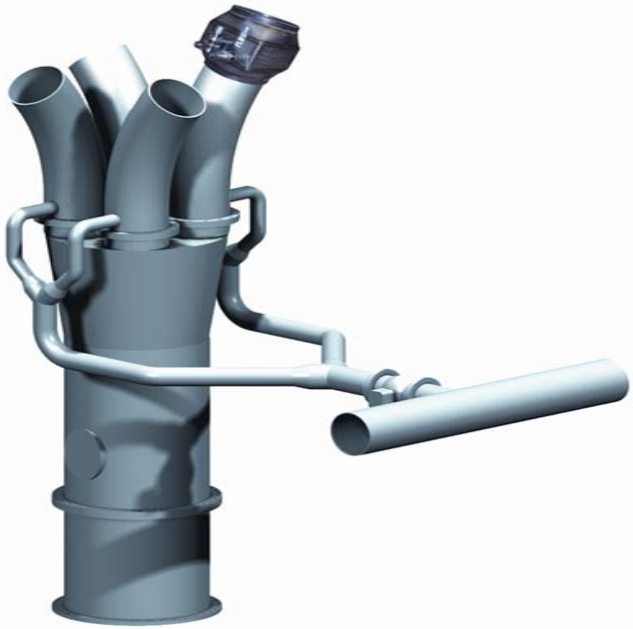


Standard Distributor
标准分配器



Tower Distributor
塔式分配器

Balancing Valve平衡阀

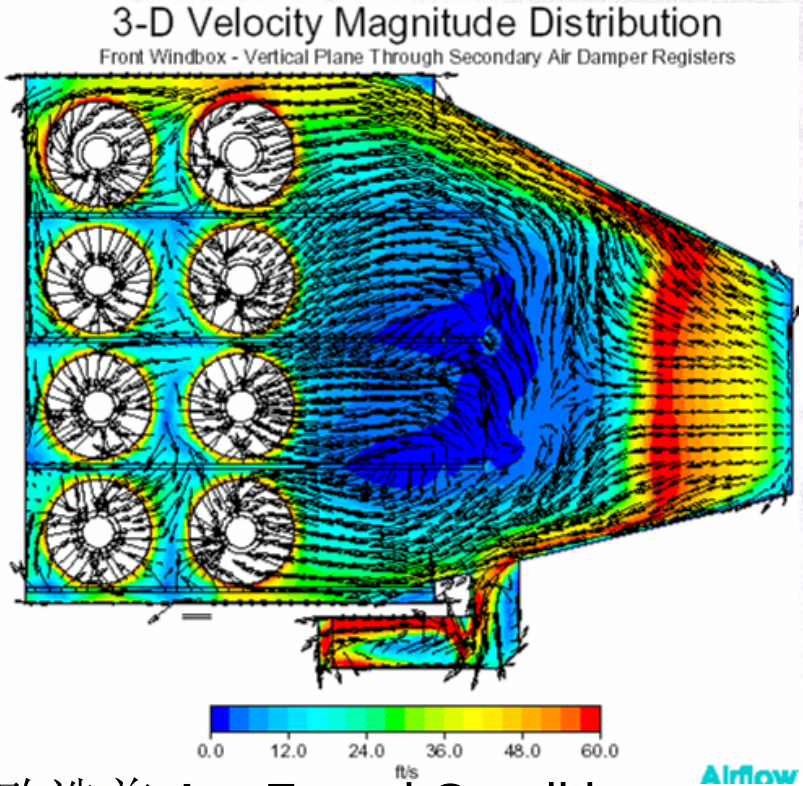


平衡阀的优点
Major Advantages for Balancing Valve

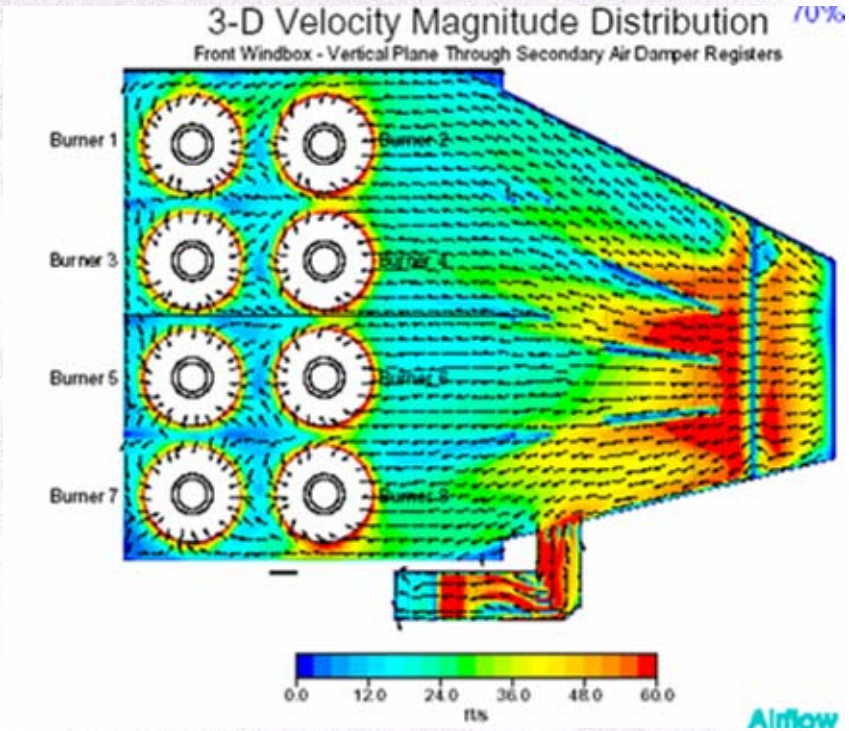
- Equalize Pressure between Coal Pipes from the Same Mill 均衡煤粉管道的压力
- 对于不能安装塔式分配器垂直正压磨最有效Most Useful with Vertical Pressurized Pulverizers where Tower Distributor Can Not Be Applied
- 安装灵活方便，可在线控制 Oriented in the Horizontal as well as the Vertical Direction without Forming Coal Piles Downstream
- 不存在煤粉回流区，避免磨损No Coal Eddies along the Pipe

70万千瓦机组风箱改造 700 MW Unit with 7 Mills and 28 Burners Windbox Modification

控制不同燃烧器之间二次风的分布
Improve Secondary Air Distribution



改造前 As- Found Condition



改造后ABT Remedy

圣约翰锅炉1&2机组风箱改造和升级燃烧器结果
St. Johns Retrofit Results #1 and #2 Unit

2 号机组示范工程 升级2 排 8个燃烧器，改造了风箱 Unit 2 : Initial Demonstration Two Rows of Burners (8) and Windbox Modifications

- 氮氧化物降低10% NO_x Reduction of 10 %
- 一氧化碳降低到100 ppm 以下 CO Lowered from >500 ppm to Less Than 100 ppm
- 未燃烬炭降低50% LOI Reduced by 50 %
- 燃烧效率提高大约1% Improved Combustion Results in ~1% Efficiency Gain.

随后1 号机组升级全部2 8个燃烧器，氮氧化物降低25%。Unit 1: All 28 Burners ABT NOx reduced ~25%

ADVANCED BURNER TECHNOLOGIES

ABT 防止高温腐蚀系统

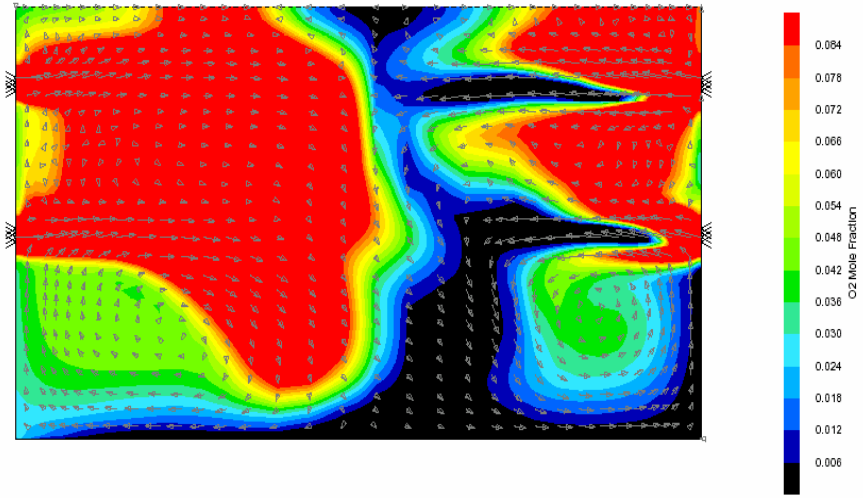
ABT's Anti-Corrosion System

目的 Purpose:产生氧化性气氛来保护炉墙

Blanket the Furnace Sidewalls with an Oxidizing Atmosphere to Prevent Corrosion and Slagging

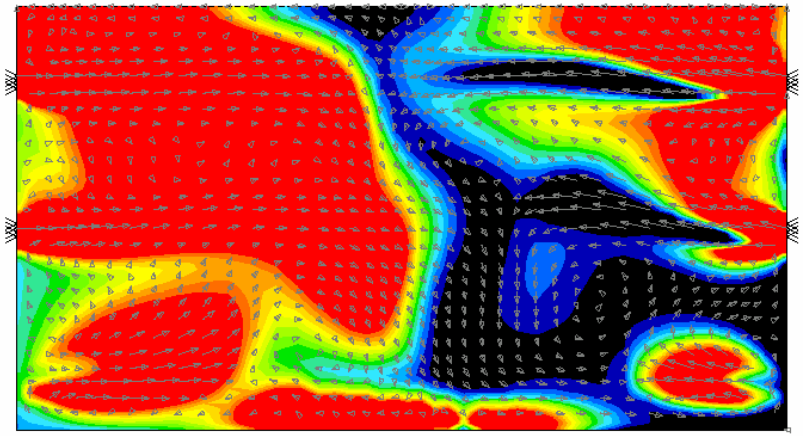
圣约翰锅炉的侧墙高温腐蚀区域CFD 模拟CFD

Model of St. Johns Furnace Sidewall in Corrosion Region



没有**ABT**防高温腐蚀喷口侧墙的氧量

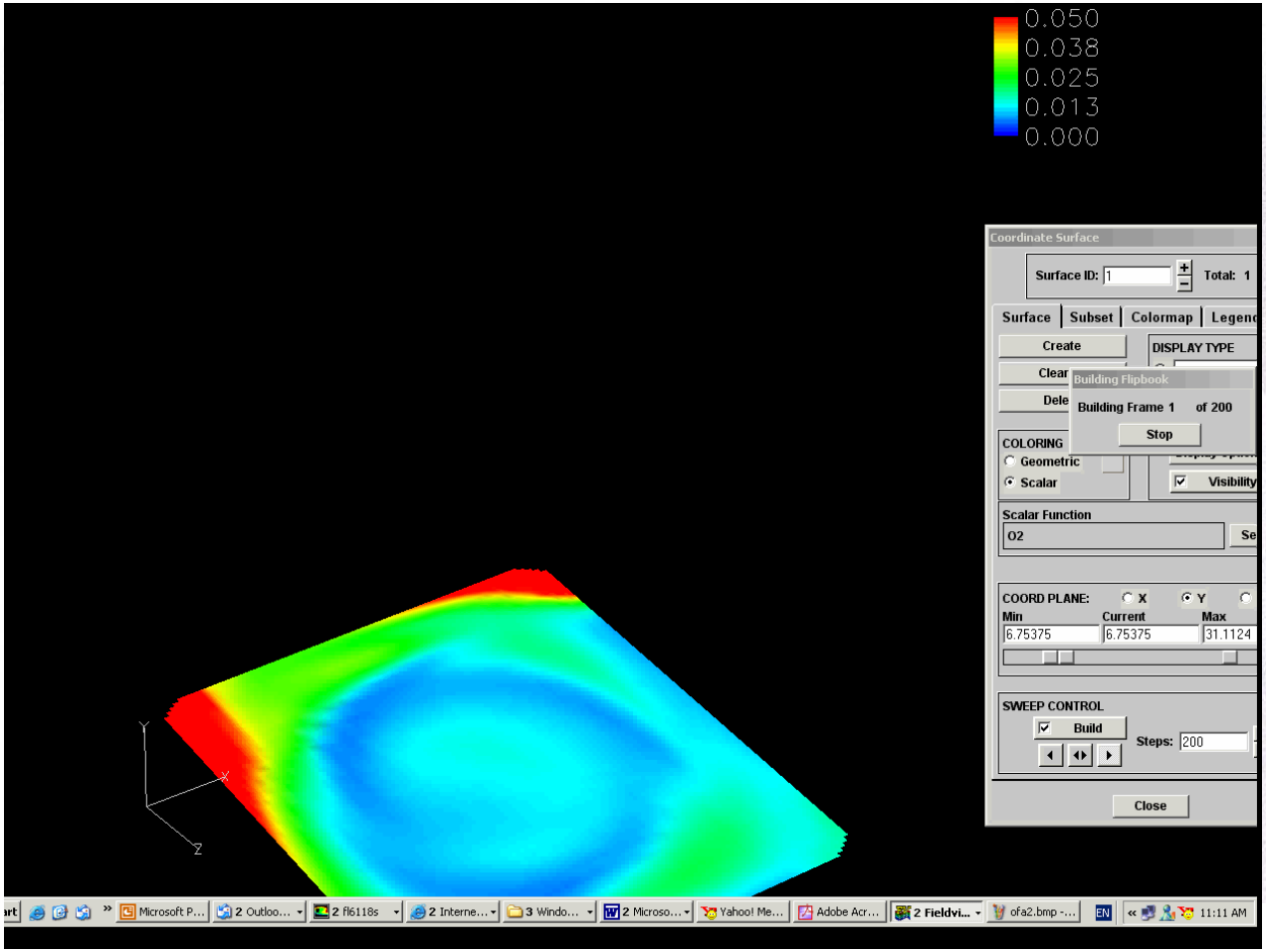
Sidewall O_2 without ABT Anti-Corrosion System



安装**ABT**防高温腐蚀喷口后的侧墙的氧量

Sidewall O_2 with ABT Anti-Corrosion System

防高温腐蚀技术 Anti Corrosion and Slagging for T-Fired Boiler

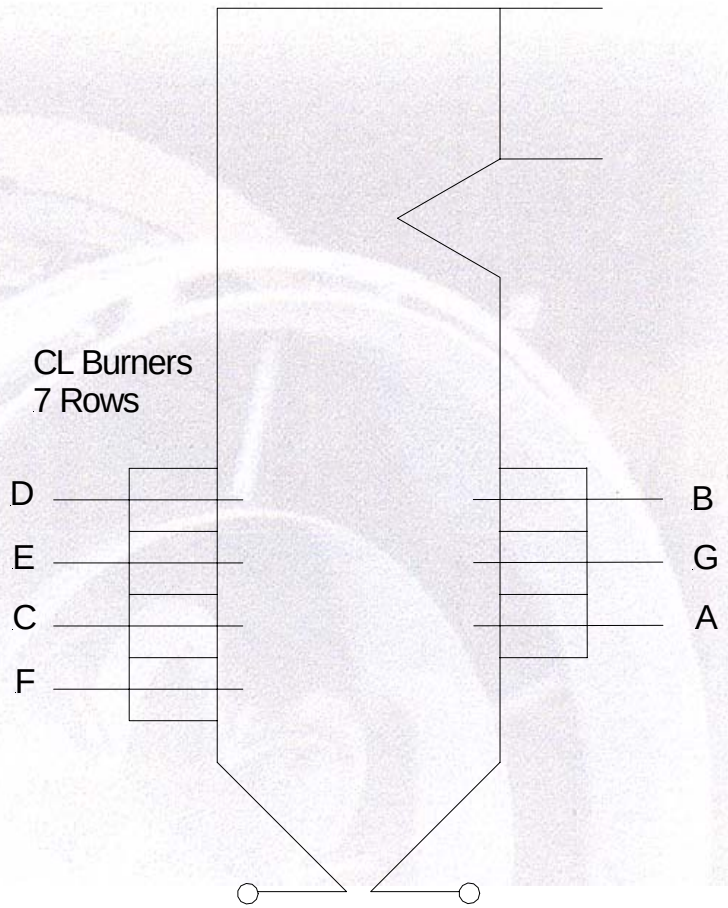


Clean Wall for 300 MW T-Fired Boiler (The Same Unit Shown Before)

与中国电厂相关 的业绩分析Case Studies
Relevant to the Chinese Power Industry

JEA 圣约翰 1#机组 28 Burners

- 20%的石油焦和80%的烟煤 20% Petroleum Coke and 80% Colombian Bituminous Coal
- 氮氧化物降低25%，安装燃烬风系统后可以降低到40% NOx reduced by over 25% for Unit 1, Expected 0.3 with OFA
- 一氧化碳大幅降低CO less than 10 ppm (300-500 ppm Before Retrofitting)
- 低负荷稳燃性能很好670 MW to 365 MW (46% turndown, Limited only by DCS. Lower Load is possible)
- 美国第一个掺燃石油焦的成功例子First to Demonstrate the Ability to Cofire petroleum coke in a wall-fired boiler and attain low NOx.
- 给国内提供了一种新的煤粉炉燃烧石油焦的途径，降低发电成本。Chinese Power Industry Can Cofire Petroleum Coke With ABT's Burner



中国典型煤种和**JEA** 圣约翰 煤种比较Comparison of Chinese Bituminous Coal with St. Johns Fuel Blend

Proximate Analysis, wt% (ar)	Chinese	St. Johns
Fixed Carbon	49.15	59.64
Volatile Matter	23.59	26.11
Ash	19.03	4.66
Moisture	8.22	9.59
Ultimate Analysis, wt% (ar)		
Carbon	61.38	71.40
Hydrogen	3.68	4.23
Oxygen	6.59	6.57
Nitrogen	0.71	1.42
Sulfur	0.38	2.13
HHV, kJ/kg (Btu/lb)	24,862 (10,700)	29,301 (12,600)
FC/VM Ratio	2.1	2.28
N, kg/GJ (lb/10^6 Btu)	0.32 (0.66)	0.54 (1.13)
NO_x Parameter: N x FC/VM	**0.67 (1.39)**	**1.23 (2.58)**

与中国电厂相关 的业绩分析Case Studies Relevant to the Chinese Power Industry

美国电力（AEP） 珀肯（Pirkey）一号机组

- 高水分和灰份的德克萨斯褐煤High Moisture and Ash Content Texas Lignite
- 低发热量Low Heating Value of 6500 Btu/lb (13,700 kJ/kg)
- ABT第二代弯管式燃烧器，极低的氮氧化物水平 0.15 lb/MMBtu (220 mg NOx/Nm3)
- 与中国的劣质煤相似，磨损问题得以解决 Erosion
- 火焰很稳定，明亮 Improved Flame Conditions and Excellent Turndown Capability
- 改造前喉部附近燃烧不稳定，在煤粉着火之前有1.8 – 2.4米的煤粉带 There was generally a 6 – 8 ft (1.8 – 2.4 m) coal skirt developed prior to initiation of combustion.
- 美国第一例成功改造燃用低劣褐煤的低NOx 燃烧器的案例 Highly Successful Retrofit by ABT at Pirkey is the First of Its Kind in the U.S.

燃烬风喷口关闭**OFA Ports Closed**

燃烬风喷口打开**OFA Ports Open**

与中国电厂相关 的业绩分析Case Studies Relevant to the Chinese Power Industry

肯塔基电力根特3 号和4号机组

Kentucky Utilities Ghent Units 3 and 4

- ABT的第一代蜗壳燃烧器
- 解决了侧墙结渣问题Solved Severe Side-Wall Slagging
- 解决了燃烧器喷口结渣问题Solved Severe Burner Eyebrows
- 解决了燃烧器内部结焦和烧毁的问题Solved Coal Layout and Coking
- 氮氧化物排放降低到300到350毫克 0.25 lb/10^6 Btu (300 mg/m3) with sub-bituminous，0.3 with bituminous coal

某电厂 1号，2号，3号机组 3X660MW

One Power Plant with 3 660MW units

- 煤种非常容易结渣, 煤种灰融点低，在燃烧器内容易炼焦并烧毁燃烧器 Highly Slagging Eastern Bituminous Coal
- 在没有燃烬风系统的情况下氮氧化物由880 mg/Nm3降到660mg/Nm3， NOx Reduced from 0.60 lb/MMBtu (880 mg/Nm3) to below 0.45 lb/MMBtu (660 mg/Nm3) without Overfire air.
- 未燃烬炭保持相同水平 Unburned Carbon Is Same.

ABT Experience 业绩

Project #	Coal	Burner Number	OEM Burner	Capacity MW
工程代号	煤种	燃烧器个数	原装燃烧器类型	机组容量 兆瓦
1	W.B.T西部烟煤	20	FW	440
2	E.B.T东部烟煤	24	FW	650
3	E.B.T东部烟煤	24	FW	650
4	E.B.T东部烟煤	24	FW	650
5	Sub B.T次烟煤	30	FW	700
6	E.B.T/Sub B.T东部烟煤/次烟煤	24	FW	540
7	E.B.T东部烟煤	24	FW	660
8	E.B.T/Sub B.T东部烟煤/次烟煤	24	FW	540
9	Sub B.T次烟煤	72	B&W	560
10	E.B.T东部烟煤	24	FW	660
11	E.B.T东部烟煤	8	B&W	70
12	E.B.T东部烟煤	8	B&W	70
13	Lignite褐煤	56	B&W	720
14	E.B.T东部烟煤	24	FW	660
15	Coal&Petr Coke烟煤和石油焦	28	FW	700
16	Coal&Petr Coke烟煤和石油焦	28	FW	700
17	E.B.T东部烟煤	16	CE (T-fired)	300
18	E.B.T东部烟煤	6	B&W	75
19	W.B.T西部烟煤	48	B&W	950

Summary 总结

- 磨煤机煤粉平衡系统，动态分离器，高效低污染的燃烧器，燃尽风系统，涉及墙式燃烧锅炉，四角切园燃烧锅炉，无烟煤燃烧锅炉等所有现存的系统。 ABT provides engineering for complete combustion system from the mills to the furnace: coal line balancing, windbox air distribution, burners, OFA and furnace sidewall anti-corrosion.
- 煤种涉及烟煤，褐煤等主要电力用煤和石油焦。 ABT Opti-Flow™ low NO_x burner has flexibility to burn difficult fuels including lignite and petroleum coke blends
- 自从1997年五月改造第一台锅炉以来，Advanced Burner Technologies 已经在1000万千瓦机组容量的锅炉上安装了自己的 Opti-Flow TM 低 NOx 燃烧系统 ABT has supplied low NO_x combustion equipment with proven results in over 10,000 MW of boiler capacity

Summary (Continued) 总结(续)

- **ABT 为中国提供全套的燃烧系统解决方案ABT Can Supply the Most Modern Combustion System for Chinese Power**
- 优化整个锅炉燃烧系统，包括风箱改造，煤粉和燃烧空气的平衡，优化锅炉运行参数，流体力学模拟，升级燃烧器和燃烬风系统 ABT Utilizes a System's Approach to Develop the Whole Combustion System.
  - 降低氮氧化物 **NOx control**
  - 降低**CO**和未燃烬炭**UBC,**消除水冷壁附近的**CO,**提高燃烧效率 **Combustion Efficiency Improvement, Elimination of CO along Furnace Sidewalls**
  - 控制炉膛结渣 **Slagging Control**
  - 提高火焰稳定性和低负荷稳燃 **Combustion Stability Improvement**
  - 控制高硫份煤种水冷壁高温腐蚀 **Corrosion Control**
  - 平衡煤粉管道 **Coal Pipe Balance**