Reinhold Environmental Ltd.

2010 NOx-Combustion Round Table & Expo Presentation

February 8 & 9, 2010   Chattanooga, TN

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SCR Design Advancements

Next generation SCR

William Medeiros

Riley Power Inc.

2010 NOx-Combustion Round Table

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What are the Drivers?

Regulation

- Ambient Levels (Measurement and Levels)
- Mercury
- Carbon Emission

Economics and Demographics

- Plant shutdowns – New Plants
- Carbon capture ready

Operation and Maintenance Costs

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What does this result in?

- **Different Fuels**
  - Biomass
- **Operating at Lower Operating Loads**
  - Low Load Requirements
  - Solar – Wind
- **Lower Emissions**
  - Combined Low NOx – SCRs
- **Shorter Payback Periods**
  - CO_2 emissions

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Biomass

- Large Particle Carry Over
  - Mechanical separator
  - Large particle ash screen
- Catalyst Poisons
  - Wide variety of fuels and fuel properties
  - Lower sulfur
  - Catalyst design and margins
    - Is it really going to happen and what does it mean to catalyst manufacturing volume?

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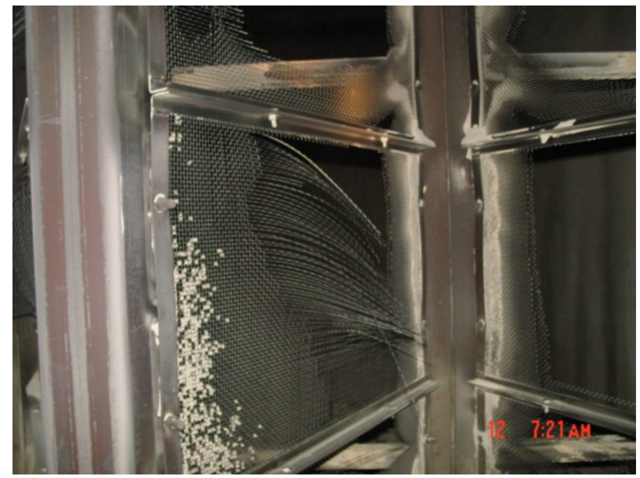
Large Particle Ash Design

- **LPA Properties**
  - **Size >4.0 mm**
  - **Density 0.7 to 1.25 g/cc**
  - **Sphericity 0.7 to 0.99**
  - **Coefficient of Restitution 0.15 to 0.2**



  - **Screen Design Important**
  - **Pluggage**
  - **Erosion**

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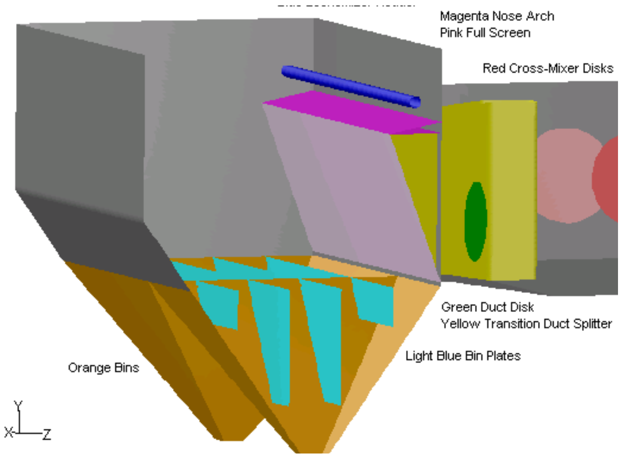
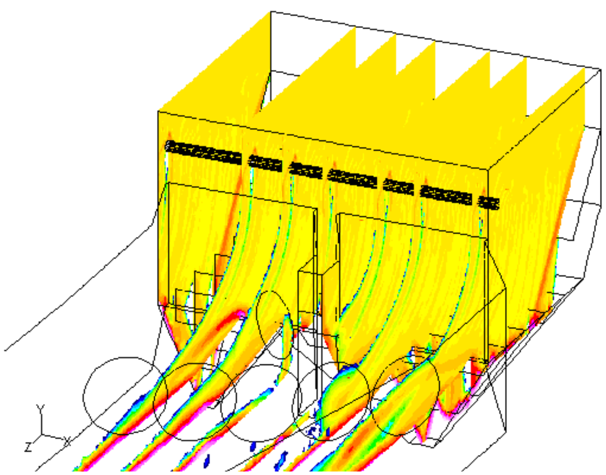
Large Particle Ash Design

- **Design and Modeling**
  - **CFD Modeling**
  - **Industry Coated Screens**
  - **Experience From Past**





  - **Soot Blowers**
  - **Low Velocity**
  - **Low Pressure Loss**

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Low Load Operation

- Present economic climate
- Dispatching to lower CO_2 source plants
- Air heater cold end temperature
- How to response?
  - Boiler Hardware Changes
    - Bypass Arrangements
  - Better Temperature Distribution
    - Additional Instrumentation
  - Transient Catalyst Performance
  - Additional Instrumentation
    - RTDs, ABS monitors, Slip

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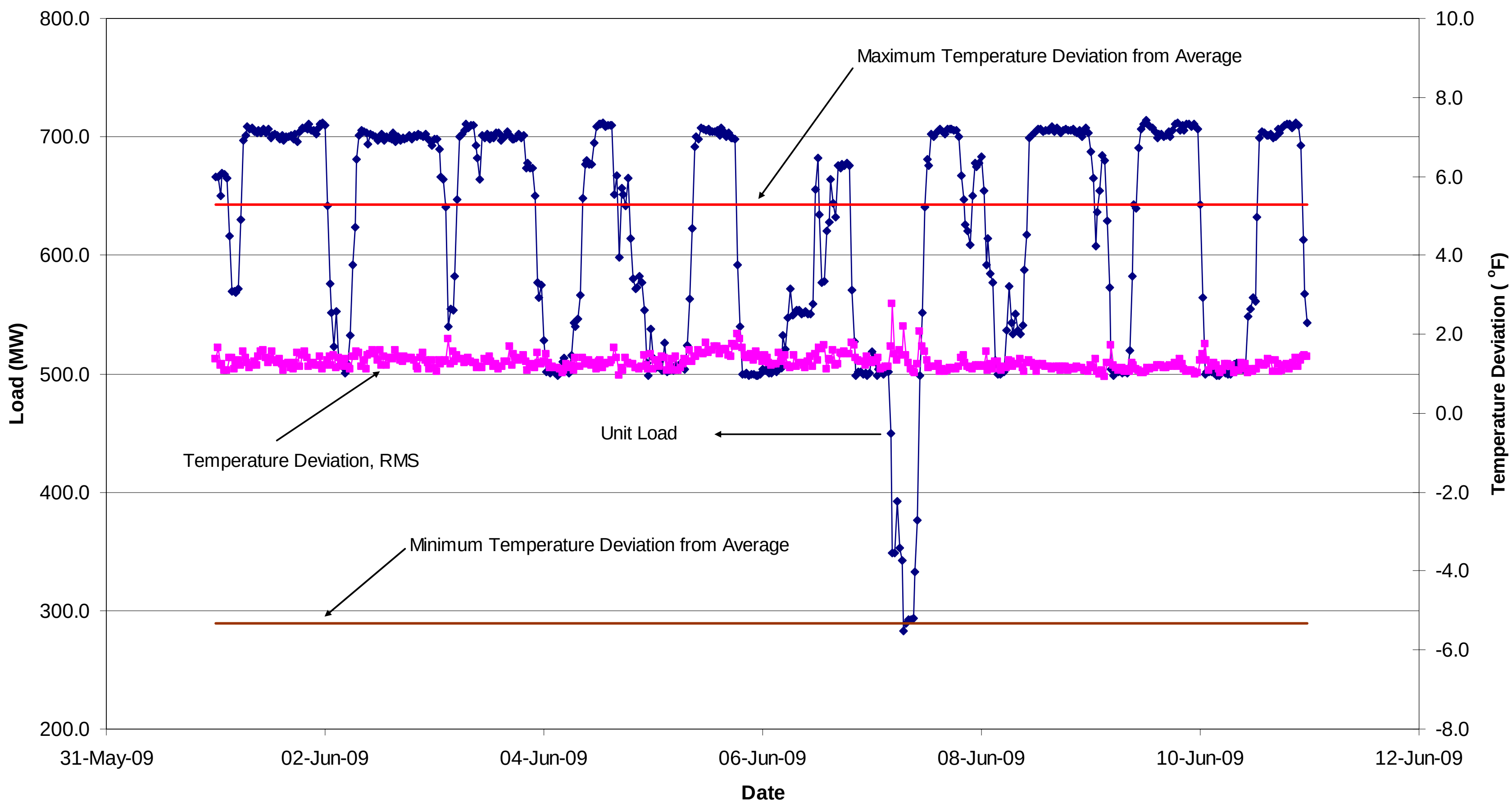
Temperature Distribution



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Lower Emissions

- Requirement > 95% Removal
  - Low NOx burners and SCR
  - More catalyst – More catalyst change outs
  - Catalyst Improvements
  - NH_3/NOx RMS < 1% to 2% *
    - Stable over the load range and fuels
  - Additional Manual Tuning - Automatic Control

* EPRI SCR Workshop, 2009

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Necessary input values of the MEA - Process

	PM [mg/Nm^3] grs/scf lb/MMBtu	NO_X as NO_2 [mg/Nm3] ppm lb/MMBtu	SO_X as SO_2 [mg/Nm^3] ppm lb/MMBtu
13. BImSchV (FRG 2004)	< 20 0.0012 0.0025	< 200 (solid fuel) 97.4 0.135	< 200 70 0.135
input values of the MEA - Process	< 15 0.00095 0.0020	< 10 (NO_2) 5 0.007	< 15 5 0.010

Daily average values for plants with thermal capacity of > 300 MW

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The 95% SCR

- More Catalyst Can Only Do So Much
  - If NO_x is not there to react, NH_3 will slip through = “Distribution Induced Slip”
- Higher Removals Through Better Mixing
  - The more uniform the NH_3/NO_x profile, the greater the catalyst performance and the lower the distribution induced slip
  - Maximum design NH_3/NO_x standard deviation to be 2 – 3 %
  - Current BPEI test data for NH_3/NO_x standard deviation are < 2%
    - Actual test results show 94.2% removal with NH_3/NO_x std. dev. of <2% yield undetectable slip for new catalyst.
    - (Based on catalyst design of 2 ppm slip – expected to be met)

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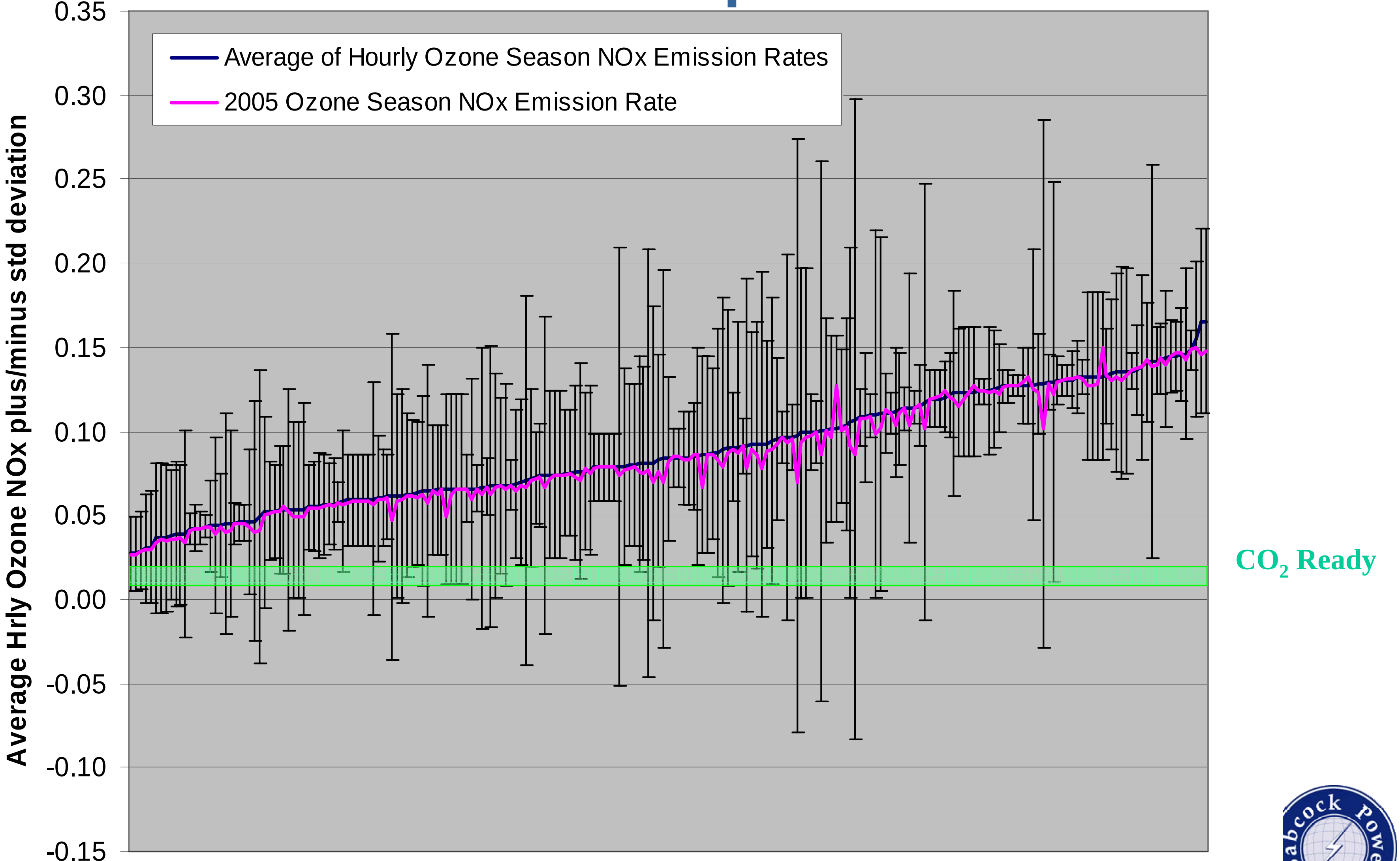
Industrial Experience



Performance History

Conference 2004

- 410 MW - NH_3/NOx RMS <1.6%-2.3%
- 520 MW - NH_3/NOx RMS<2.7%-3.4%
  - Low Load NH_3/NOx RMS<2.9% – 4.6%
- 530 MW - NH_3/NOx RMS<2.0%-3.7%
  - Low Load NH_3/NOx RMS<2.1% – 2.7%
- 520 MW - NH_3/NOx RMS<2.7%-3.4%

Conference 2003

- 590 MW - NH_3/NOx RMS< 3.0%

Conference 2008

- 650 MW - NH_3/NOx RMS< 1.0% – 0.8%
- 250 MW - NH_3/NOx RMS< 2.35%
  - Low Load NH_3/NOx RMS<2.9%

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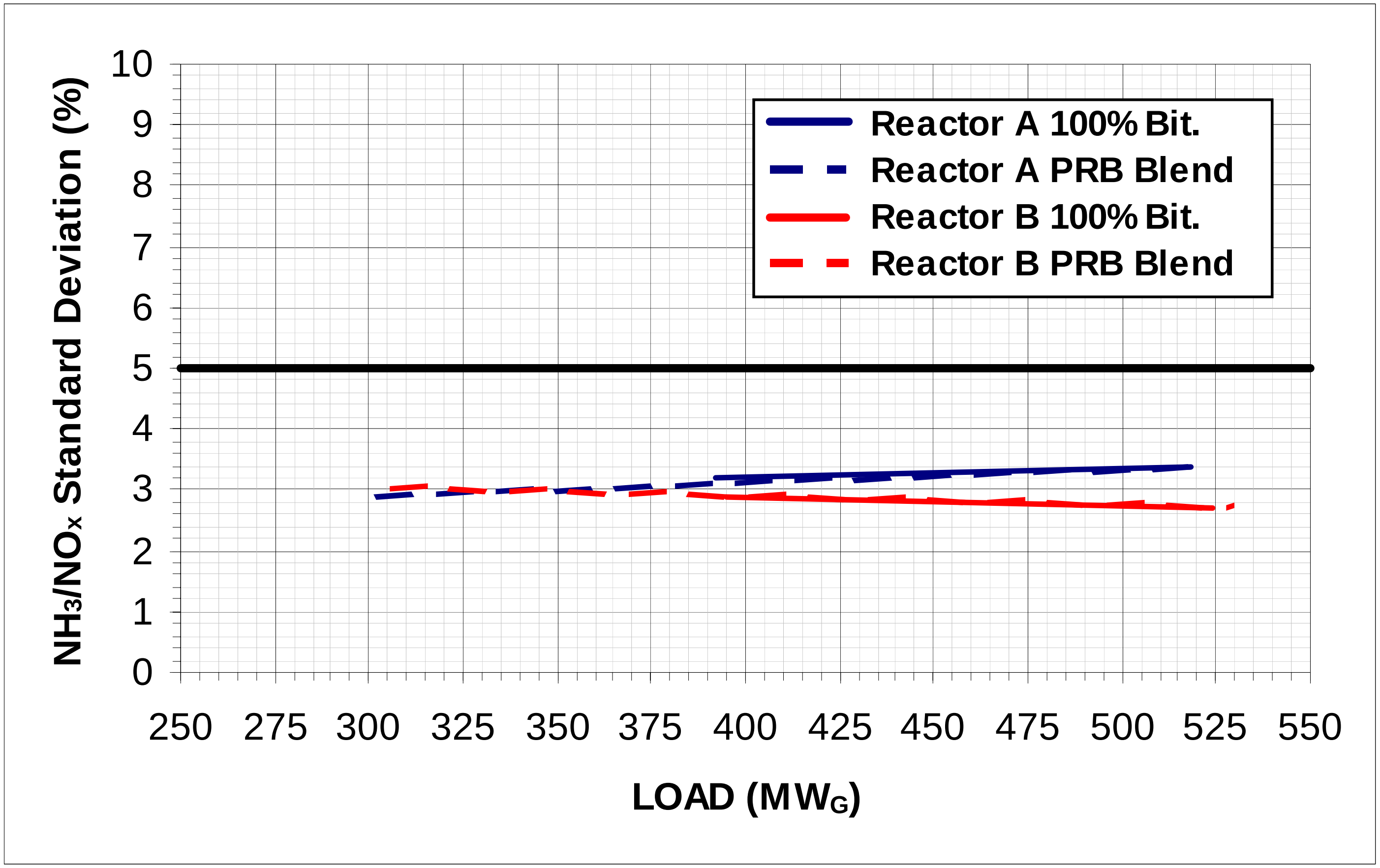
Performance Over the Load Range



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Manual Tuning For Higher Performance

- Start with consistent performance over the load and fuel range
- Ease of tuning with limited injection points
- Example Unit
  - 1200 MW Unit – 0.5 to 0.6 lbs/MBtu Inlet
  - >94% NOx Removal – 2007 OTAG
  - Ammonia Slip Monitoring

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Valve Influence Test and Optimization

- Constant ammonia flow
- Test each valve individually
- Plot results for each valve
- Create influence coefficient matrix
- Computer optimization program
  - Linear equations
  - Ammonia flow constraints
- Review and adjust valves

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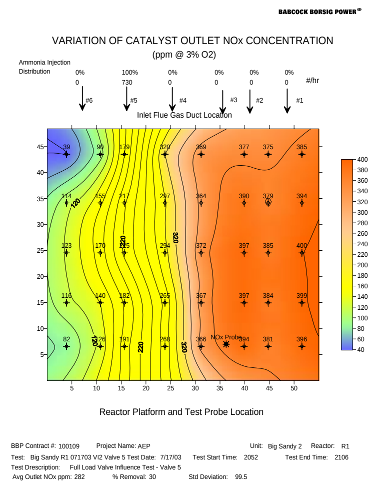
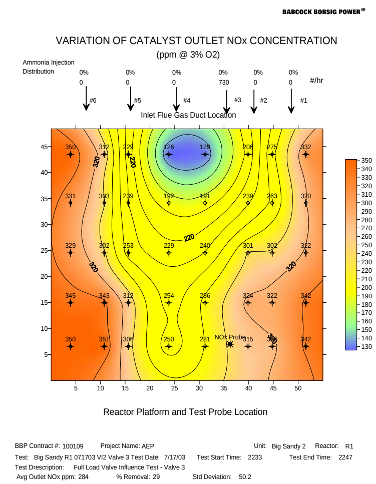
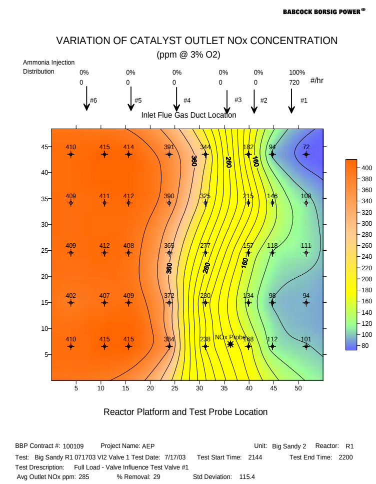
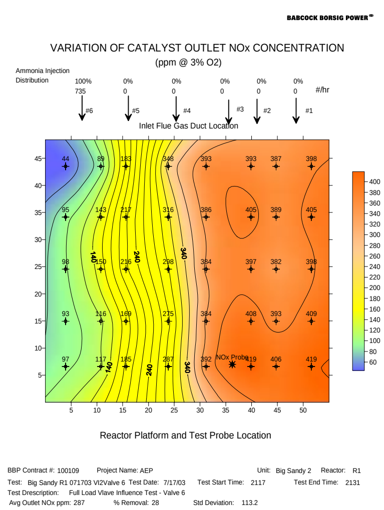
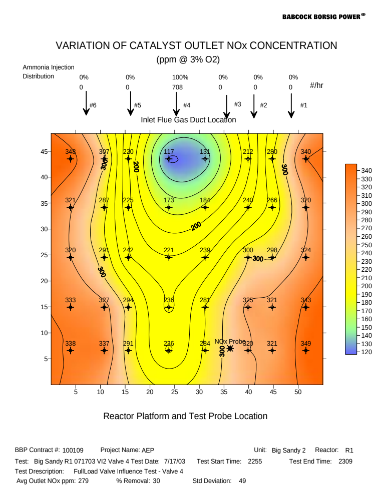
Injector Influence: Coal-Fired 400 MW SCR Reactor *

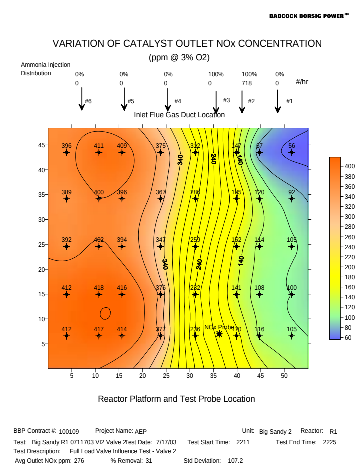












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* Benes & Erickson, Electric Power 2005

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Automatic Control - Example

- 180 MW Gas Fired Single Unit
- Poor ammonia flow control at non-design low injection rates
- Solution enhanced ammonia control
  - Limited number of NH3 injectors
  - Clearly defined influence fields

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Automatic Control - Example

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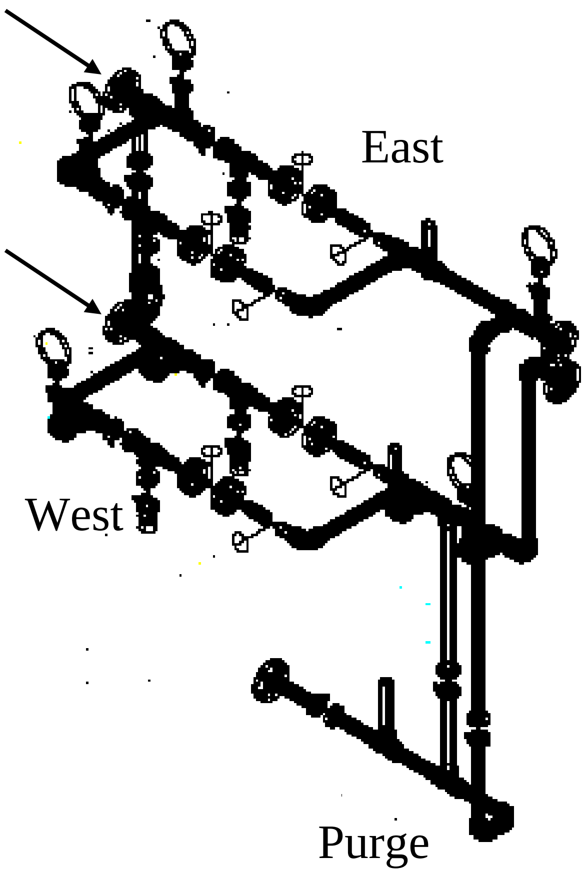
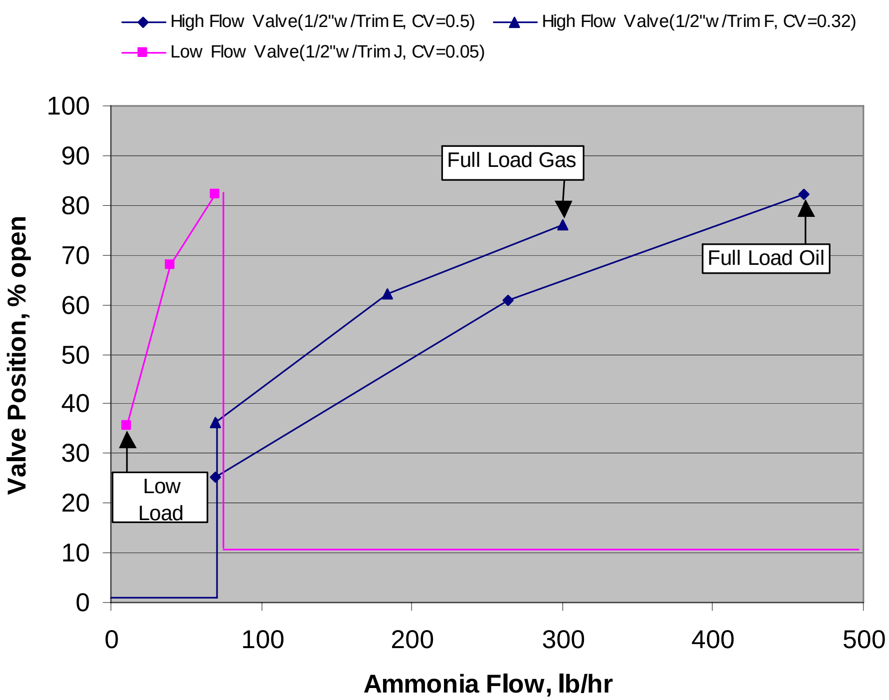
Ammonia Dual Range Flow Control





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Example: Self Tuning SCR

- 170 MW Gas Plant with Single Feed Forward/Feed Back Control
- Two Injection Points with Delta Wings
- Modified with Additional Outlet NOx Meter For Two Feed Back Loops
- Installed in Summer 2005
- Extended Time Between Injection Point ‘Tune Ups’

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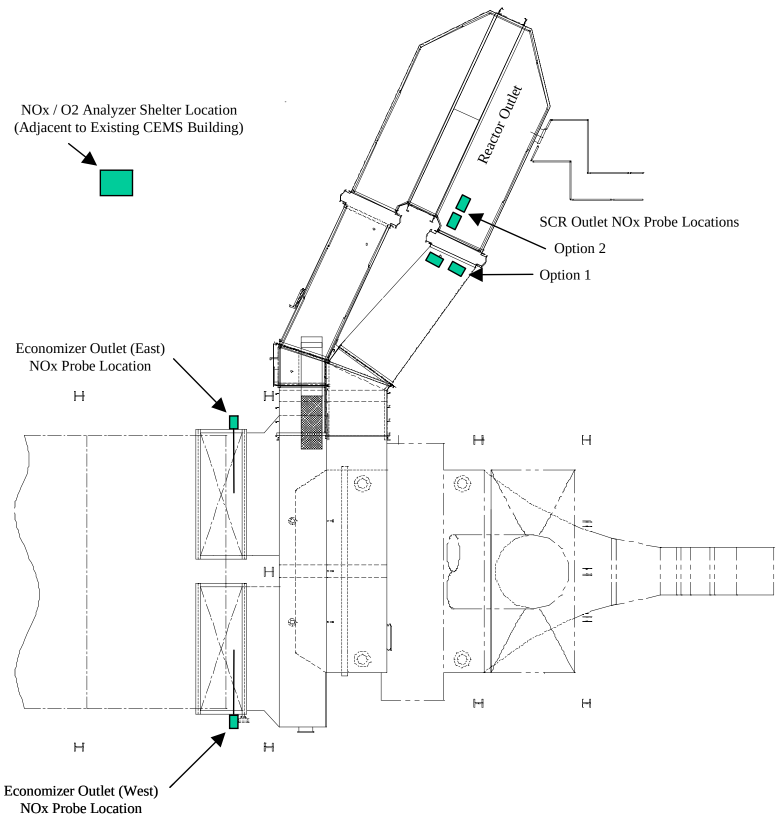
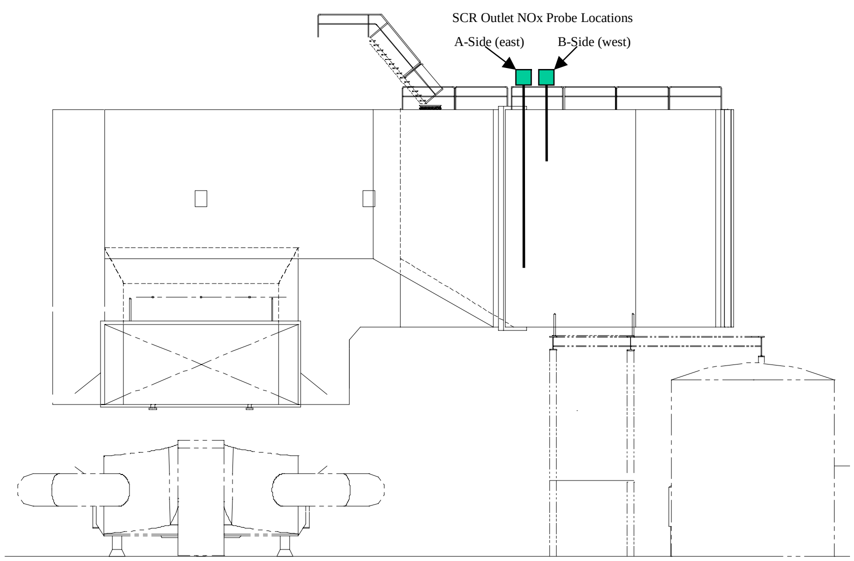
NOX Measurement





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THANK YOU !

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