Meeting Emissions Mandates
Case Studies on Fuel Flexibility
Applications

American Coal Council
Implementing Fuel Flexibility Strategies

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Addressing Fuel Flexibility

- Heat Rate and Unit Capacity
- Key Emissions Concerns
  - Air Toxics, such as SO3
  - Opacity
  - CO
  - NOx
- Operational Concerns
  - LOI and Fan Limitations
  - Furnace Slagging
  - Corrosion under Slag Deposits

A Complete Site Perspective

- Fuel Handling: Mills
- Combustion Systems: Burners
- Furnace Slag
- Tube Corrosion
- Fouling Deposits
- Heat Rate and Furnace Efficiency
- Unit Capacity: Fuel Heating Value
- Excess O2 / LOI
- NOx Control Systems: SNCR and SCR
- SO2 and SO3
Case Studies

- SO3 Control at Santee Cooper
  - Cross Station – Fuel Switch
- Blending at Colorado Springs Utilities
  - Colorado Coal and PRB
- Advanced SCR
  - Wind-box to Air-Heater NOx Control

All Solutions are based Fuel Tech’s Advanced Modeling Technologies

Fuel Tech Process Application

- Computational Fluid Dynamics
- Detailed Chemical Analysis
- Injection Model
**Fuel Tech Process Application**

- Combustion Optimization
- Low-NOx Burners / OFA Systems
  - Coal, Oil, Natural and Refinery Gases
- Targeted In Furnace Injection
  - Slag and Fouling Control
  - SO3 Abatement
- Air Pollution Control
  - NOx, SO2 and SO3, CO

**Santee Cooper Cross Station Units 1 & 2**

- Eastern Kentucky Bituminous coal
- Unit 1 - 600 MW opposed wall fired
  - Staged combustion low-NOx burners
  - Addition of an SCR in 2003
- Unit 2 – 600 MW T-fired
  - Close-coupled Over-Fired Air
  - Addition of an SCR in 2003
**SO$_3$ Related Opacity**

- Sulfuric acid mist emissions
- SO$_2$ to SO$_3$ conversion
  - Lowest-oxidation Rate Catalyst
  - Particularly problematic for Unit #2
- Increased with high iron in the ash
  - Oxidation in the furnace
- Regulatory pressure to control

**Fuel Tech Process Application**

- The Complete Site Perspective
  - Combustion Optimization Services
  - Furnace Slag and Efficiency Analysis
  - Performance of the SCR
    - NOx Reduction
    - SO$_2$ => SO$_3$ Oxidation
    - Ammonium Bisulfate Formation
  - Toxic Emissions – SO$_3$, H$_2$SO$_4$
Fuel Switching

• New Coal in 2004
  • Increased Iron Load
    • 1 lbs/10^6 BTU vs. 0.6 lbs/10^6 BTU
    • Boiler Design: 0.56 lbs/10^6 BTU
  • Decreased Ash Fusion Temperature
    • 2000-2100°F vs. 2300°F
    • Boiler Design: 2500°F

• Slag removal with explosives
• LPA forced SCR on-line cleaning

Project Objectives

• Reduce SO₃ related Opacity
• Reduce popcorn ash and SCR fouling
• Reduce the coal-related slag and fouling issues
• Increase fuel flexibility
**SO₃ Concentrations at High Load**

Unit #2 SO3 Concentrations at 580 MW

**SO₃-Related Opacity Controlled**

Untreated Opacity  TIFI Treated Opacity
**TIFI-mg reduced SO$_3$ and H$_2$SO$_4$**

- Lower Furnace Temperature
  - Decreased Oxidation Rate
- More Balanced Furnace
  - Reduced Excess Oxygen
- Reduced Slag and Iron Deposits
  - Less Catalytic Oxidation
- Direct Reaction with MgO
  - MgO + SO$_3$ => MgSO$_4$

**TIFI Case Study Conclusions**

- Allowed Fuel Blending
- Reduced SO$_3$ related opacity
- Reduced Total Toxic Release (TTR) by 20%
  - 35% reduction in H$_2$SO$_4$
- Reduced outage cleaning time more than 50%
- Increased MW capability by 44.5 MWe
- Increased boiler efficiency by 0.65%
Program Results at SC Cross

- Return on Investment
  - Greater than 4 : 1

- EUEC Conference Proceedings, Jan 2008
  - Santee Cooper: Davis, Toombs
  - Fuel Tech: Boyle, Hermanas, Benisvy, Schulz

Colorado Springs Utilities
Martin Drake Station

- Unit 7 - 142 MW Wall-Fired
- Colorado Coal and PRB Coal
  - Successful Blend at 10% PRB
- Issues with Higher PRB Blends
  - De-rates and Forced Outages
  - Blast Cleaning and Tube Leak Repairs

So What is the Problem?
**Coal Slagging Indices**

- **Colorado**
  - $\frac{Fe_2O_3}{(CaO+MgO)} = 0.86$ → Lignitic Ash
  - $R_s = \frac{(Max HT)+4(Min IT)}{5} = 2576$ → Low

- **PRB**
  - $\frac{Fe_2O_3}{(CaO+MgO)} = 0.24$ → Lignitic Ash
  - $R_s = \frac{(Max HT)+4(Min IT)}{5} = 2104$ → Very High

**Colorado Coal Ash Softening Isotherms**

- 2,670°F (Oxidizing)
- 2,595°F (Reducing)
**PRB Coal Ash Softening Isotherms**

- 2,200°F (Oxidizing)
- 2,120°F (Reducing)

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**TIFI Program Results at CSU**

- Drake Station, Unit 7, 142 MW Wall-Fired
- 5 Month Baseline: December 2007 – May 2008
  - Averaged 10% PRB Coal
- 5 Month TIFI Test: December 2008 – May 2009
  - PRB Blend Increased to 50% with TIFI
  - Waterwall and SH Absorptions Maintained
  - SH & RH Steam Temps Maintained at 1,005°F
  - Slag Shed Derates and Forced Outages on Same Pattern as Baseline Colorado Coal
  - 18% Increase in Oper Time Above 130 MW
TIFI Program Results at CSU

- Financial Analysis
  - Colorado Coal at $50/ton, Delivered
  - PRB Coal at $21/ton, Delivered
- Return on Investment
  - 420%

ASME 2010 Power Conference
- CSU: Towell, Martinez, Hightower, Maxey
- Fuel Tech: Snow, Gonzalez, Rians

ASCR - Advanced

- A Synergistic Layering of NOx Control
  - SCR Levels of NOx Control
  - Flexibility vs. Uncertainty
  - Improved Operation of all Components
  - Guaranteed Performance

- Does this introduce Risk?
### Combining NOx Reduction Technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Strength</th>
<th>Limitations</th>
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<tbody>
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<td>Low-NOx Burners</td>
<td>Low Capital and Operating</td>
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<td>Low Capital NOx Red%</td>
<td>NH3 Slip ABS</td>
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<tr>
<td>SCR</td>
<td>NOx Red% Low NH3 Slip</td>
<td>High Capital SO₃ Oxidation</td>
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### Retrofit Low-NOx Burner Installation

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### Moderate Combustion Modifications

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### Conservative SNCR application

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<td>Low Capital and Operating</td>
<td>Combustion, Corrosion, CO</td>
</tr>
<tr>
<td>SNCR</td>
<td>Low Capital NOx Red%</td>
<td>No NH3 Slip No ABS</td>
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<tr>
<td>SCR</td>
<td>NOx Red% Low NH3 Slip</td>
<td>High Capital SO₃ Oxidation</td>
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### Aggressive SNCR application

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<tr>
<td>Combustion Mods / OFA</td>
<td>Low Capital and Operating</td>
<td>Combustion, Corrosion, CO</td>
</tr>
<tr>
<td>SNCR</td>
<td>Low Capital &gt; Red%</td>
<td>NH3 Slip ABS</td>
</tr>
<tr>
<td>SCR</td>
<td>NOx Red%</td>
<td>High Capital SO₃ Oxidation</td>
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<tr>
<td></td>
<td>Low NH3 Slip</td>
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### In-Duct or Small SCR Space

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<td>Low Capital and Operating</td>
<td>Combustion, Corrosion, CO</td>
</tr>
<tr>
<td>SNCR</td>
<td>Low Capital &gt; Red%</td>
<td>NH3 is OK Feed to SCR</td>
</tr>
<tr>
<td>Small SCR</td>
<td>More Red%</td>
<td>Mod Capital, SO₃ and Cost</td>
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<tr>
<td></td>
<td>Low NH3 Slip</td>
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**Advanced SCR Application**

<table>
<thead>
<tr>
<th>Technology</th>
<th>Reduction</th>
<th>Total %</th>
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<tbody>
<tr>
<td>Low-NOx Burners</td>
<td>30%</td>
<td>30%</td>
</tr>
<tr>
<td>Combustion Mods / OFA</td>
<td>30%</td>
<td>51%</td>
</tr>
<tr>
<td>SNCR</td>
<td>30%</td>
<td>66%</td>
</tr>
<tr>
<td>Small SCR</td>
<td>45%</td>
<td>81%</td>
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Layered NOx Solutions

- Utilize Optimal Technology Suite
- Customized to Reduce Risks
- Balanced to Reduce Costs
  - Capital vs. Operation Costs
  - Variations in Fuel and Capacity
- Best Possible Performance
  - NOx Reduction
  - Secondary Impacts (BOP)

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