



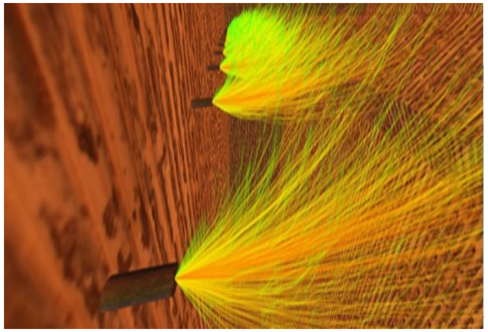

The Effects of Bio-Fuels and Other Alternative Fuels on SCR System Design and Performance

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AGENDA

- **Introduction**
- **Bio-Fuels**
- **Pet Coke**
- **Catalyst Poisons**
- **Operating Experience**
- **Design Considerations**

Fuel Tech Overview

Innovative Approaches to Enable Clean Efficient Energy

- Capital Projects for Multi-Pollutant Control
- Advanced Combustion Technologies with Low NO_x Burners and Over Fire Air Systems
- NO_x Reduction Systems including NO_xOUT® SNCR and HERT Systems
- NO_xOUT® CASCADE (Hybrid SNCR/ SCR) and NO_xOUT® ULTRA
- Flue Gas Conditioning Systems for Particulate Control – Outside US and Canada
- Sorbent Injecton for SO_2 Control

FUEL CHEM® Operating Programs

- Boiler Efficiency and Availability Improvements
- Slag and Corrosion Reduction
- Controls SO_3 Emissions and Addresses Related Issues
- CO_2 Reduction through Boiler Efficiency Improvements
- Targeted in Furnace Injection of Specialty Chemicals

Flow Modeling and SCR Catalyst Management Services

- Computational Flow Dynamics and Physical Modeling for Plant Systems
- SCR System Optimization and Catalyst Management Services

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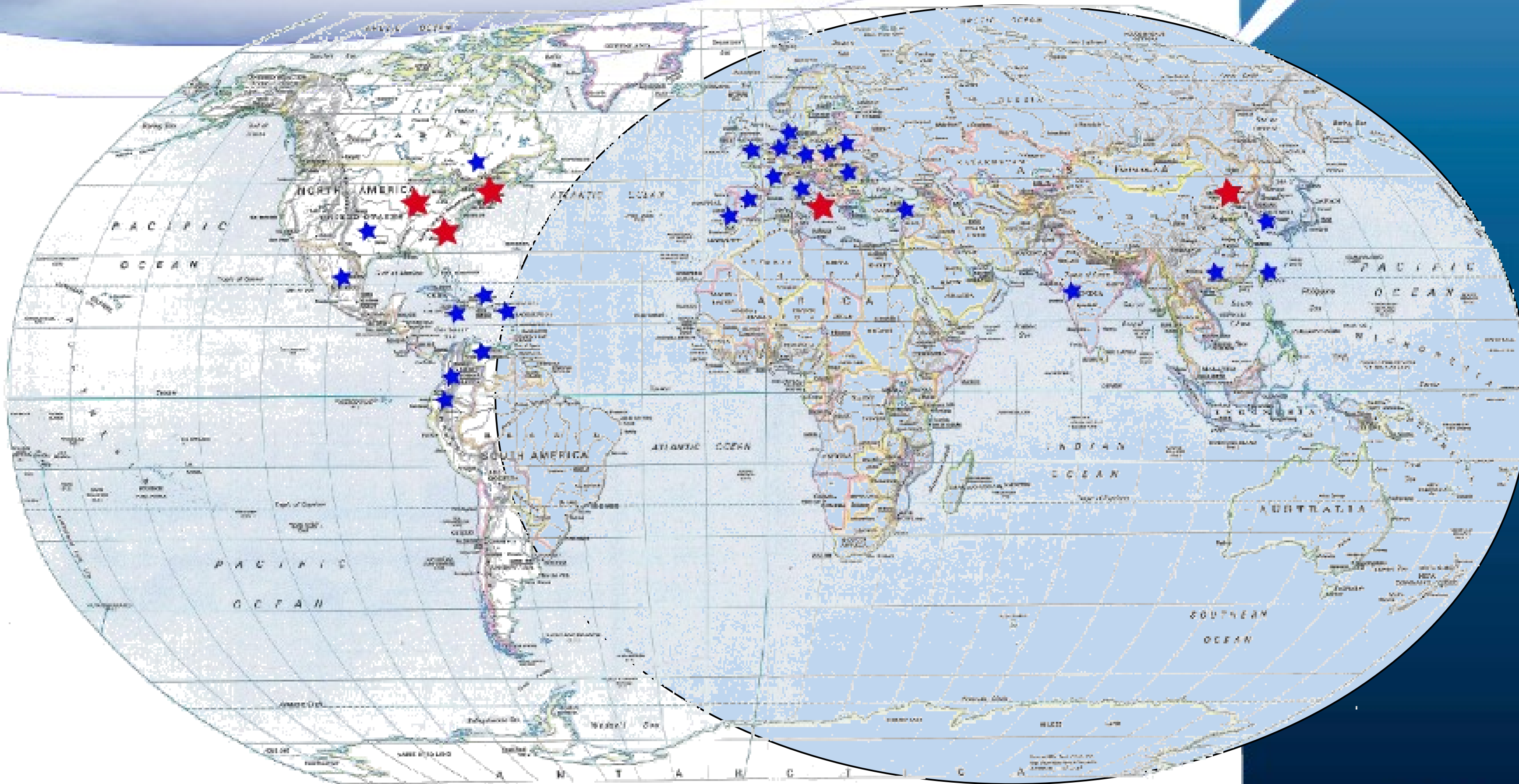
Global Presence



★ **Office Locations:** *Warrenville, IL; Stamford, CT; Hookset, NH; Durham, NC; Milan, Italy; Beijing, China*

★ **Countries where Fuel Tech does business:** *USA, Belgium, Canada, China, Columbia, Czech Republic, Denmark, Dominican Republic, Ecuador, France, Germany, India, Italy, Jamaica, Mexico, Poland, Portugal, Puerto Rico, Romania, South Korea, Spain, Taiwan, Turkey, United Kingdom, Venezuela*

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Why Co-Firing?

- Competitive Advantages
- Lower Fuel Costs
- Legislative Requirements
  - New England, Europe
  - GHG Reductions
  - Increase Green Power to Grid

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Types of Bio Fuels

- Wood (pellets, chips)
- Straw (bales, pellets)
- Miscanthus
- Oil Seeds
- Bagasse
- Palm Kernels
- Maize
- Oat Grains

Relevant Fuel & Ash Data

- Ash Content
- Potassium
- Sodium
- Phosphorus

Principal Deactivating Elements for SCR catalyst.

Bio-Mass Fuel Specifications

Whole tree chips (36% wt),
urban Tree waste (20% wt),
Site clearing (20% wt)
Understory (12% wt),
Sawdust (8% wt),
Bark (4% wt).

Ash Elemental Analysis (wt %)	Typical	Min	Max
SiO_2	24.4	8.8	56.7
Al_2O_3	3.8	1.5	8.4
TiO_2	0.2	0.01	0.5
Fe_2O_3	2.3	0.7	7.9
CaO	33.5	18.2	47.1
MgO	2.6	0.9	5.2
K_2O	14.9	2.2	25.7
Na_2O	0.3	0.05	0.7
P_2O_5	1.5	0.3	3
SO_3	1.5	0.6	2.4

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Bio-Mass Fuel Specifications

ASH ANALYSIS, Wt.%						
SiO_2 - Silicon dioxide	20.50	49.93	62.97	18.64	7.40	10.00
Al_2O_3 - Aluminium oxide	21.70	19.97	1.98	3.84	2.33	5.00
TiO_2 - Titanium oxide	0.80	0.98	0.26	0.27	0.12	0.20
Fe_2O_3 - Ferric oxide	26.70	16.93	2.02	7.19	1.05	4.00
CaO - Calcium oxide	**20.90**	**7.17**	**10.43**	**17.41**	**47.93**	**70.00**
MgO - Magnesium Oxide	**8.10**	**1.32**	**3.11**	**8.53**	**7.26**	**10.00**
K_2O - Potash oxide	**0.60**	**2.10**	**11.21**	**14.89**	**21.92**	**0.50**
Na_2O - Sodium oxide	**0.60**	**1.28**	**0.81**	**0.14**	**0.73**	**0.20**
SO_3 - Sulphite						
P_2O_5 - Phosphoric pentoxide	**0.10**	**0.34**	**4.19**	**28.23**	**7.07**	**0.10**

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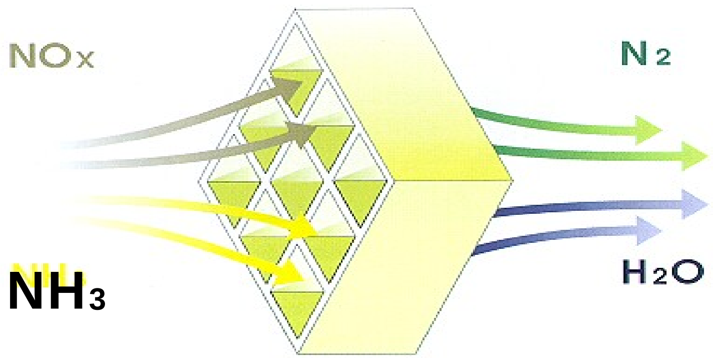
Relevant Fuel & Ash Data

- Limited Experience, Published Information
- Limits
  - One Catalyst Supplier
  - Potassium Oxide: <4%wt
  - Phosphorous Oxide: <3%wt
- Specific to Catalyst Supplier
- Dependent on Process Application
- High Variability due to Mix

SCR Process Chemistry



$$4NO + 4NH_3 + O_2 \xrightarrow[160 - 600℃]{\text{Catalyst}} 4N_2 + 6H_2O$$

$$2NO_2 + 4NH_3 + O_2 \xrightarrow[160 - 600℃]{\text{Catalyst}} 3N_2 + 6H_2O$$

$$NO + NO_2 + 2\ NH_3 \xrightarrow[160 - 600℃]{\text{Catalyst}} 2N_2 + 3H_2O$$

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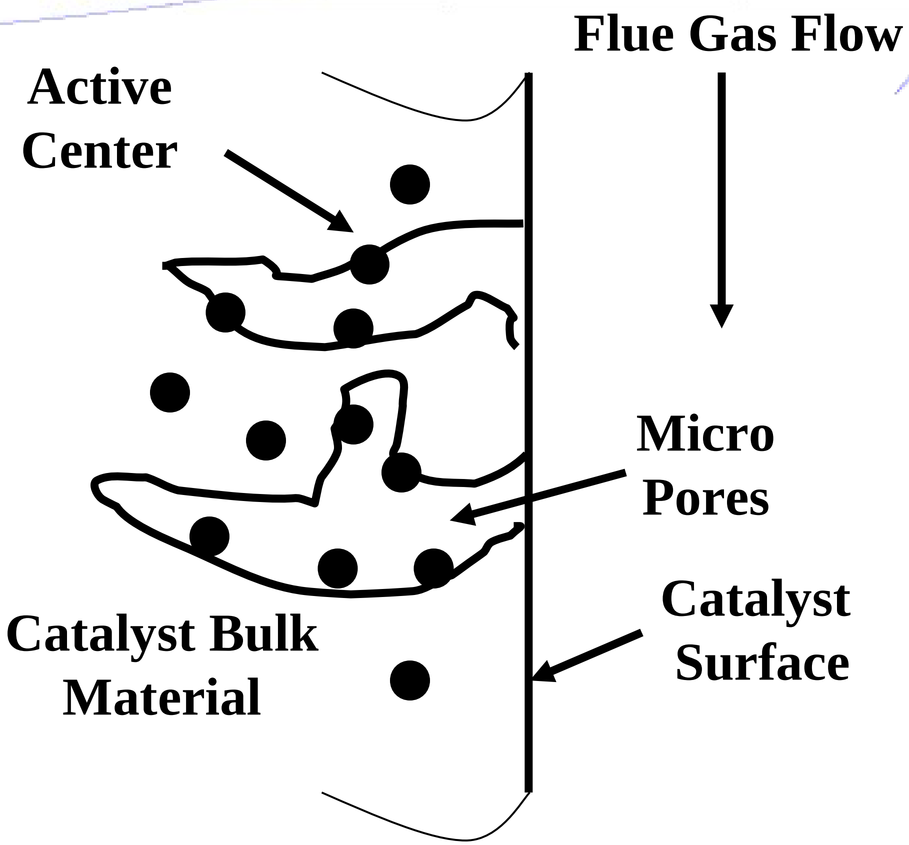
Catalyst Material

Potassium, Sodium, Phosphorous will leach into catalyst pores under certain operating conditions and poison active sites.



SCR Operating Experience

- 100% Bio Mass Fired Plants
  - Austria, Simmering
- Denmark
  - Amager (Tail End SCR)
- US
  - New England (High Dust, RSCR)

SCR Operating Experience

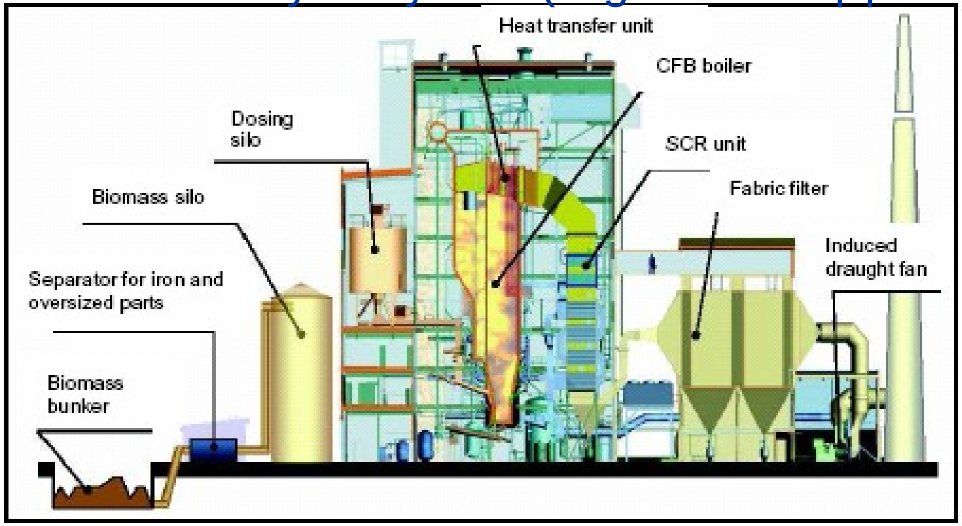
- 100% Bio Mass Fired Plants
  - Projected Catalyst Deactivation
    - ~50% over 16,000 hours
  - Europe:
    - Tail End SCR
    - Published information indicates SCR bypass is common for High Dust installations

SCR Operating Experience

- Co-Firing Bio Mass Fired Plants
  - Denmark
    - Avedore (Flue Gas from Bio Mass boiler untreated by SCR)
  - US
    - CWLP Springfield

Plant Simmering

- Plant Background
  - Location: Vienna, Austria
  - Austria's Largest Biomass CoGen Plant (CFB Boiler; 65.7 MW Capacity)
  - Fires Wood Chips From Forest Residues (100 mm size maximum)
  - SNCR and Catalyst Hybrid (High Dust Application)



Courtesy: CERAM Environmental

Plant Simmering

- Catalyst Design
  - Catalyst Supplied by Frauenthal (CERAM)
  - 41% NO_x Reduction; 5 ppmvd NH_3 Slip
  - 7.4 mm Pitch (20 x 20 cell)
    & 0.8 mm wall thickness
  - Design SO_2/SO_3 Oxidation Rate
    < 3.0% (NH_3 Off); Temp = 675 F
  - 6 x 2 Module Arrangement;
    1+1 Reactor

Courtesy: CERAM Environmental

Plant Simmering

- SCR Operations
  - Catalyst Exposed ≈ 17,000 hrs
  - Uses Steam Soot Blowers
  - Catalyst Heated Using Dry Air to 266 F

    Before Flue Gas First Enters Reactor
  - Catalyst Kept Warm & Dry
  - "Deactivation Rate as Expected"

Courtesy: CERAM Environmental

CWLP Dallman Unit 31

- Plant Background
  - B&W Cyclone (80 MW)
  - Design Coal – Illinois (3% Sulfur)
  - SCR High Dust; Operational 2003
- Co-Firing 5% Seed Corn in 2004-05
  - 52% P_2O_5 in Ash of Seed Corn
  - Equates to Adding ≈ 0.5% P_2O_5 To Coal
    - 0.6-1.5% Assuming 30/70 Split & All Phosphorous Converted to P_2O_5

Courtesy: CERAM Environmental

CWLP Dallman Unit 31

SCR Operations

- Layers 2 & 3 Exposed ≈ 17,000 hrs
- Operates ≥ 92% NO_x Reduction
- Uses Steam Soot Blowers
- Reactor Kept Warm & Dry During Non-Ozone Season

Courtesy: CERAM Environmental

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CWLP Dallman Unit 31

Effects of Biomass (Performance, Deactivation)

- Catalyst Deactivation Increased 2004-05 Due to Co-Firing Biomass in Unit 31
  - Test History Graph Showed 22% Unexpected Decrease in Relative Activity
  - Higher P_2O_5 Found in Bulk & Surface Chemical Analysis
- DeNOx Performance Still Achieved;

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Courtesy: CERAM Environmental

Design Considerations

- Define the Fuel Mix
- Reduce base NOx via Burners, OFA, FGR and SNCR to lessen catalyst impact
- Select Appropriate Catalyst Geometry
- Adhere to Specific Operating Requirements
  - Start Up & Shutdown Procedures
  - Catalyst Warming
  - Catalyst Cleaning
  - Chemical ash conditioning
  - Steam Sootblowing vs Acoustic
  - Off-line Precautions
- Conservative Catalyst Management
- Catalyst Cleaning

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Petroleum Coke

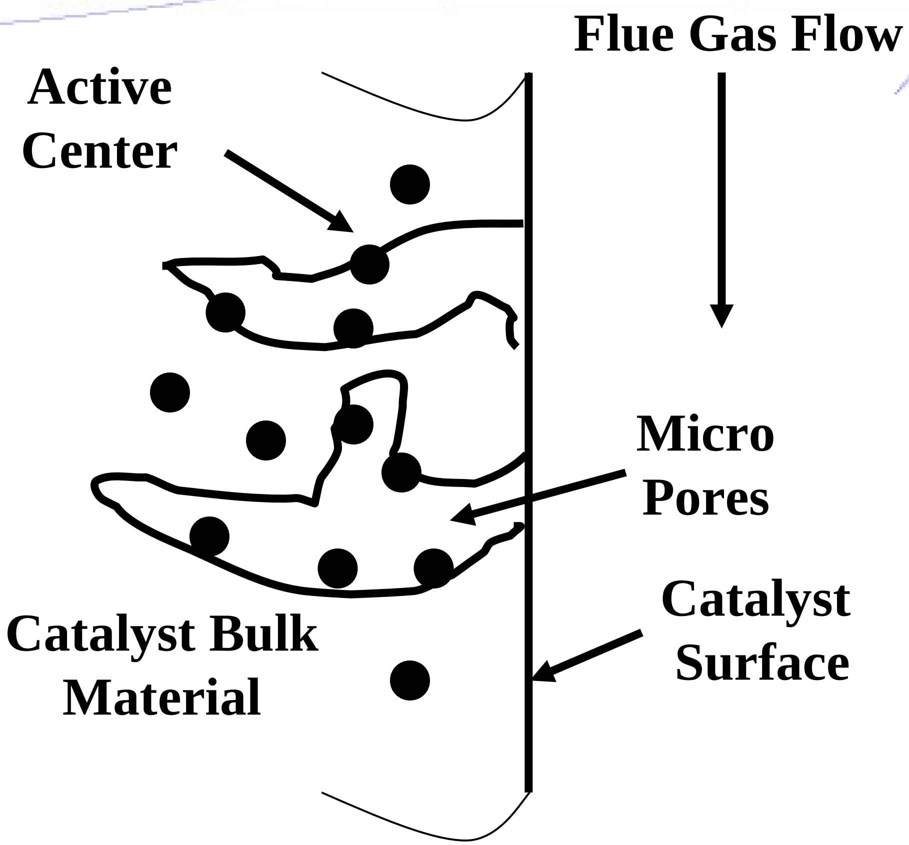
- **High Btu content**
- **Low ash**
- **High Sulfur**
- **High Vanadium**

Typical Analysis

- **Delayed Petroleum Coke Proximate Analysis (%)**
  - Fixed Carbon 83.92
  - VM 8.50
  - Ash 0.52
  - Moisture 7.06
- **Ultimate Analysis (%)**
  - Carbon 82.22
  - Hydrogen 3.35
  - Oxygen 0.00
  - Nitrogen 1.71
  - Sulfur 5.14
  - Ash 0.52
  - Moisture 7.06
- **HHV, Btu/ lb as rec'd** 14,200
- **Vanadium > 1000 ppmw**

Catalyst Material

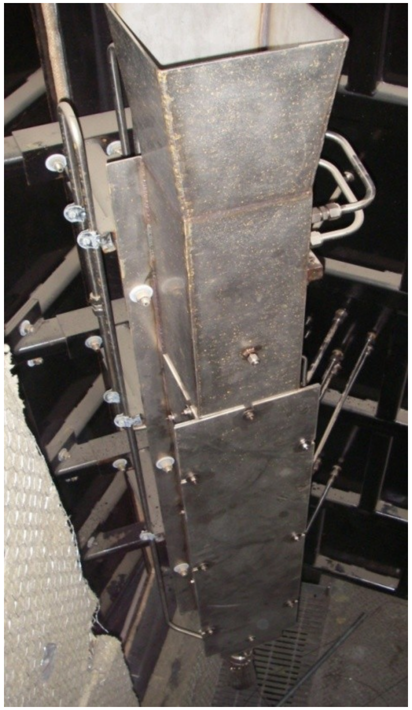
Vanadium in flue gas will adsorb onto catalyst surfaces.



Vanadium Deposition

- **Increase Catalyst Activity**
- **Increase Sulfur Oxidation Rates**
- **Changes to Long Term Catalyst Management Planning**
  - **Catalyst Cleaning**
  - **Catalyst Removal**

Catalyst Characterization

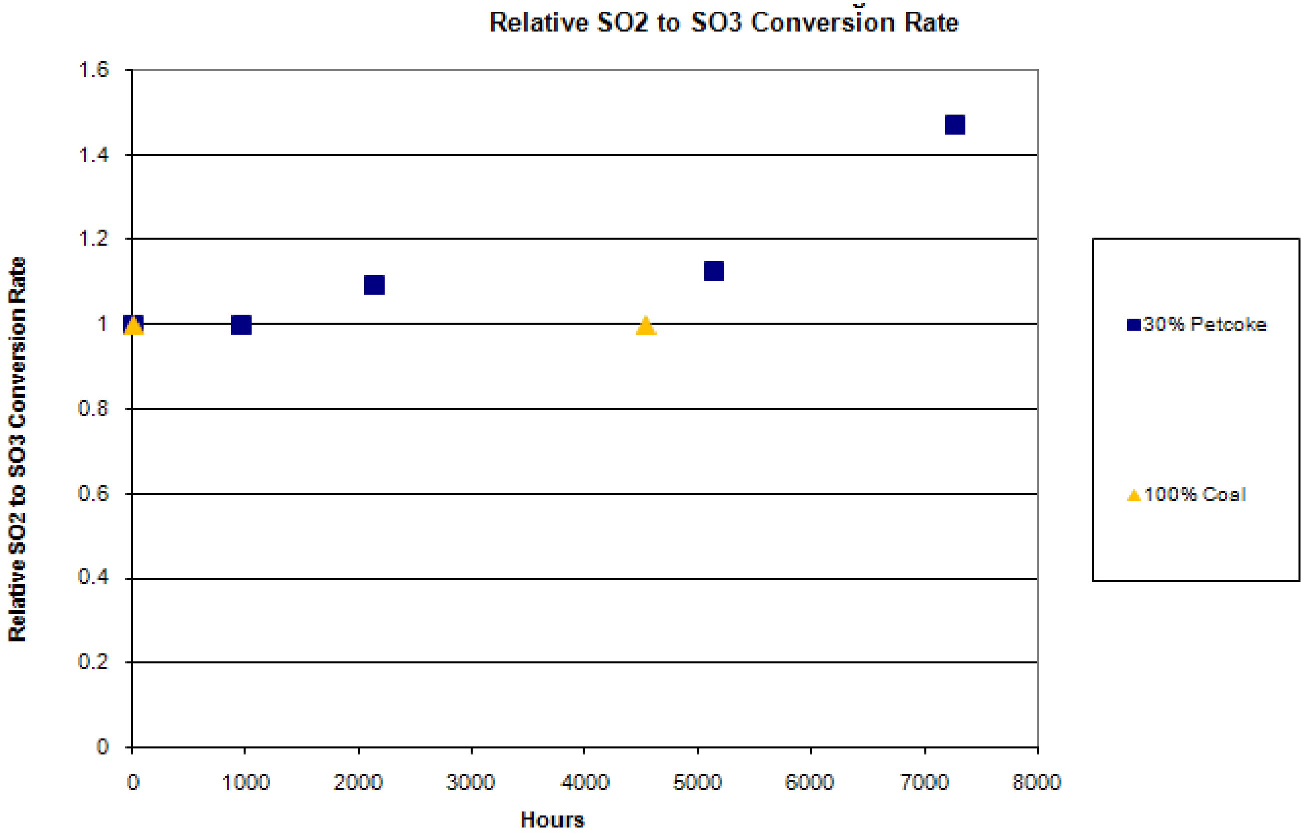


CoPilot® Test Reactor

CoPilot® In-Situ Catalyst Demonstration Testing

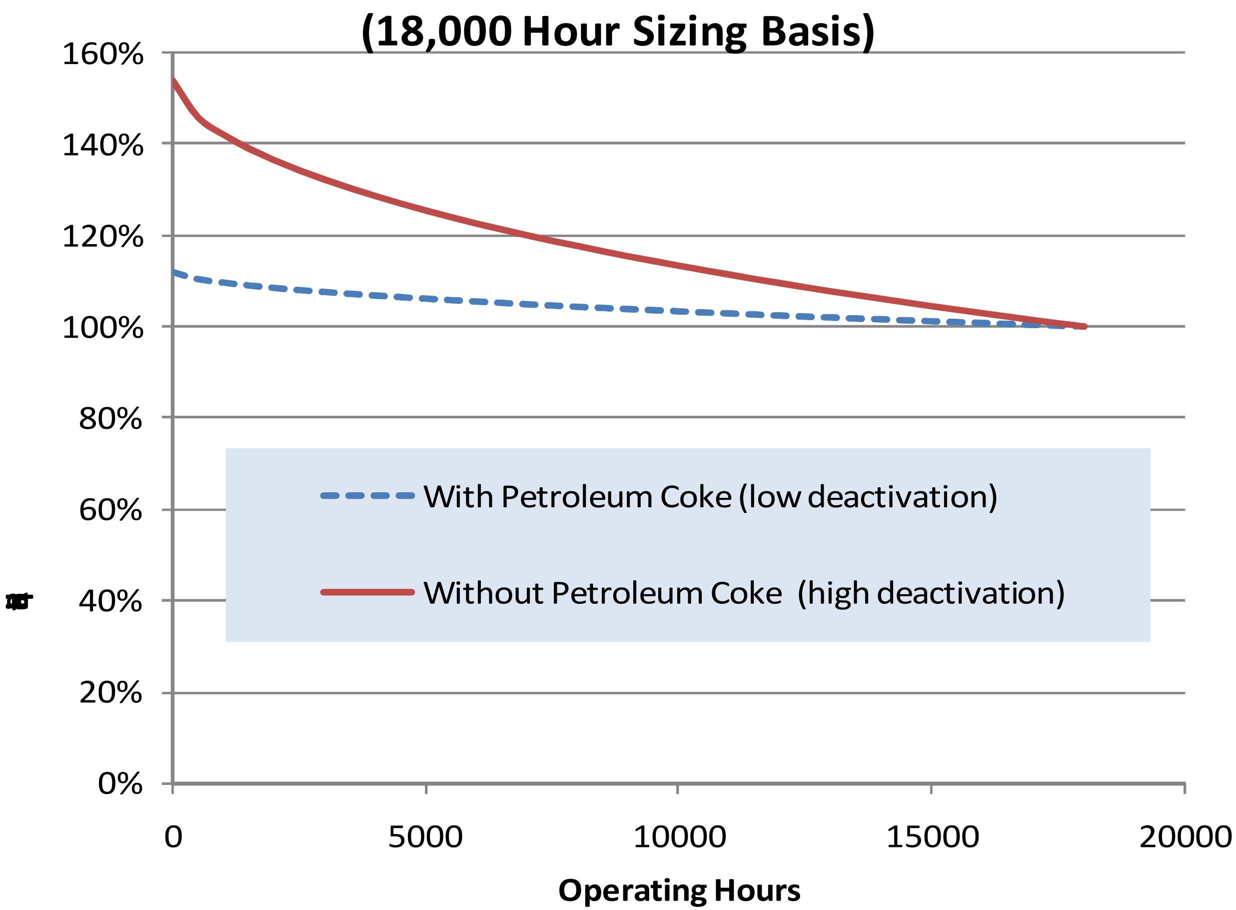
- Characterize SO_2 to SO_3 Conversion Rate Changes
- Characterize Catalyst Activity Changes

CoPilot® Test Results



Courtesy: CERAM Environmental

Catalyst Design



Courtesy: CERAM Environmental

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Design Considerations

- **Select Appropriate Catalyst Geometry & Oxidation Rate**
- **Adhere to Specific Operating Requirements**
  - **Start Up & Shutdown Procedures**
  - **Catalyst Warming**
  - **Catalyst Cleaning**
  - **Chemically Treat the Ash in the Furnace**
  - **Steam Sootblowing vs. Acoustic**
  - **Off-line Precautions**
- **Conservative Catalyst Management**
- **Catalyst Cleaning**
- **Possible SO_3 Mitigation Requirements**

Conclusions

- SCR is an applicable technology for controlling NOx emissions from co-fired units;
- Limited Operating Experience on bio-fuel units but growing;
- Fuel Mix and variability are very important design considerations.
- Balance of NOx reduction options ahead of catalyst will reduce impact on catalyst and improve management options

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Thank You!

Questions