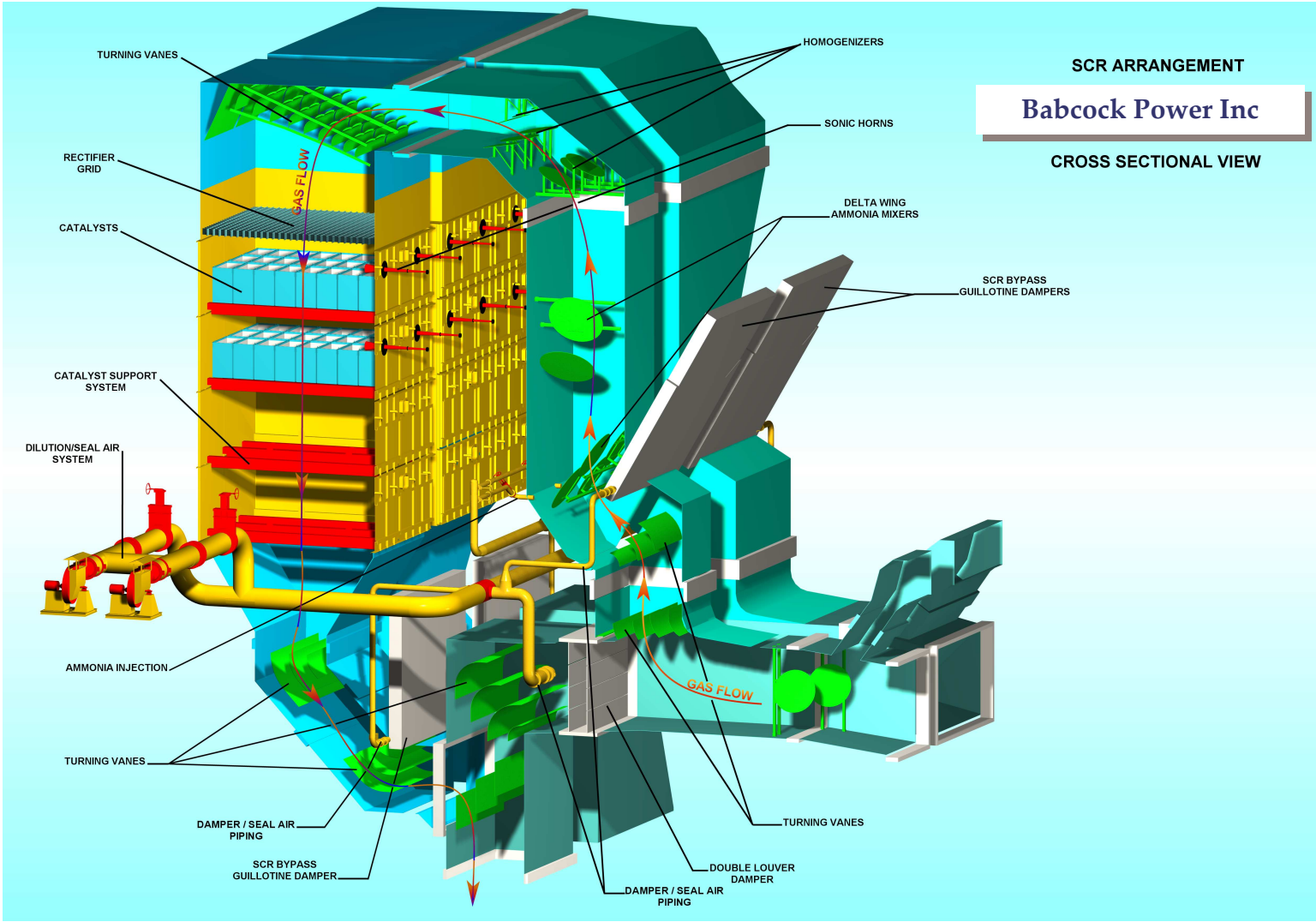
One Source…Many Solutions…One Purpose

Overview of SCR's

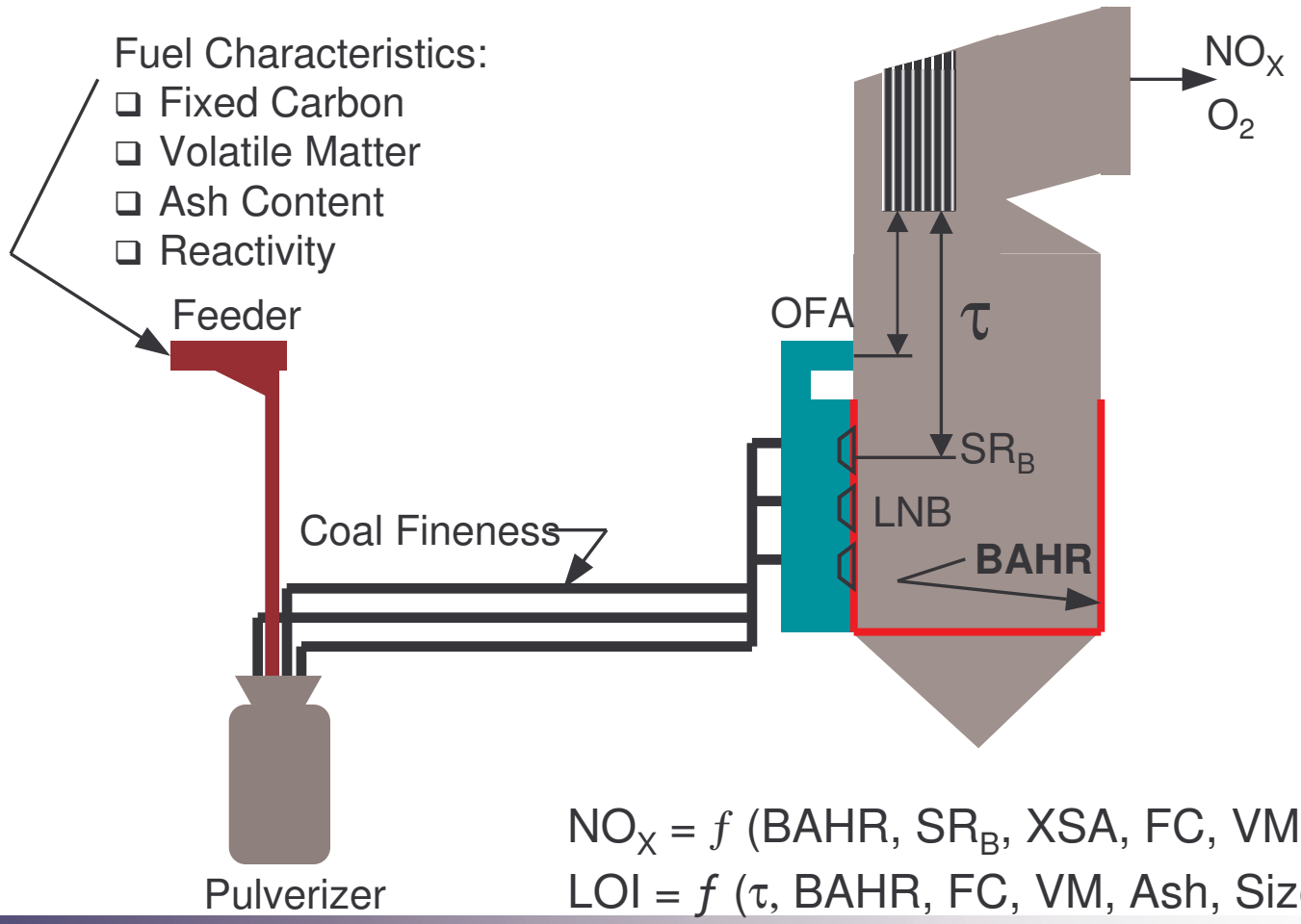
Clayton Erickson
Director
Process Engineering

Agenda
Overview of SCR Systems

- NO_x Formation
- Chemistry & Catalyst
- SCR Reactor and Ductwork
- Ammonia Storage and Supply
- Ammonia Injection and Flue Gas Mixing
- Controls and Instrumentation
- Testing and Commissioning


SCR ARRANGEMENT
Babcock Power Inc
CROSS SECTIONAL VIEW
TURNING VANES
HOMOGENIZERS
SONIC HORNS
RECTIFIER GRID
GAS FLOW
CATALYSTS
DELTA WING AMMONIA MIXERS
SCR BYPASS GUILLOTINE DAMPERS
CATALYST SUPPORT SYSTEM
DILUTION/SEAL AIR SYSTEM
AMMONIA INJECTION
GAS FLOW
TURNING VANES
DAMPER / SEAL AIR PIPING
SCR BYPASS GUILLOTINE DAMPER
TURNING VANES
DOUBLE LOUVER DAMPER
DAMPER / SEAL AIR PIPING

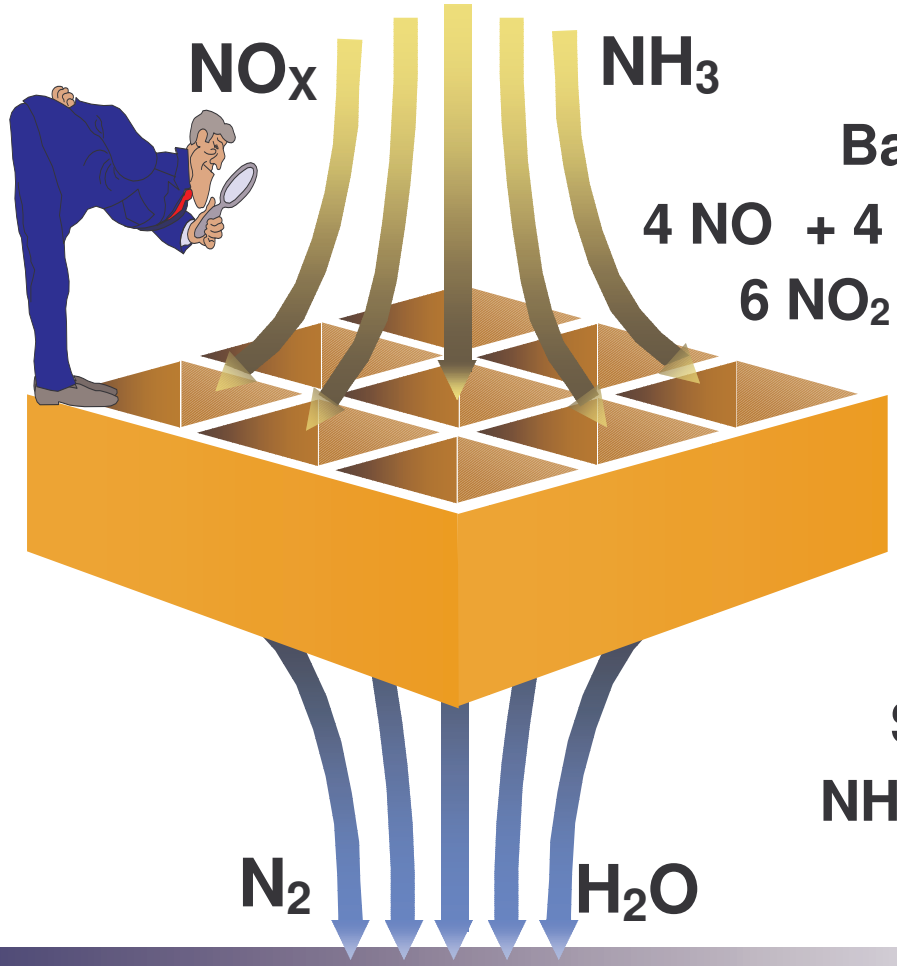
NO_X Formation



$NO_X = f$ (BAHR, SR_B, XSA, FC, VM, N, LNB)

LOI = f (τ, BAHR, FC, VM, Ash, Size, NO_X)

Chemistry & Catalyst



Basic reaction equations

$$4\ NO + 4\ NH_3 + O_2 \rightarrow 4\ N_2 + 6\ H_2O$$

$$6\ NO_2 + 8\ NH_3 \rightarrow 7\ N_2 + 12\ H_2O$$

Typical coal flue gas

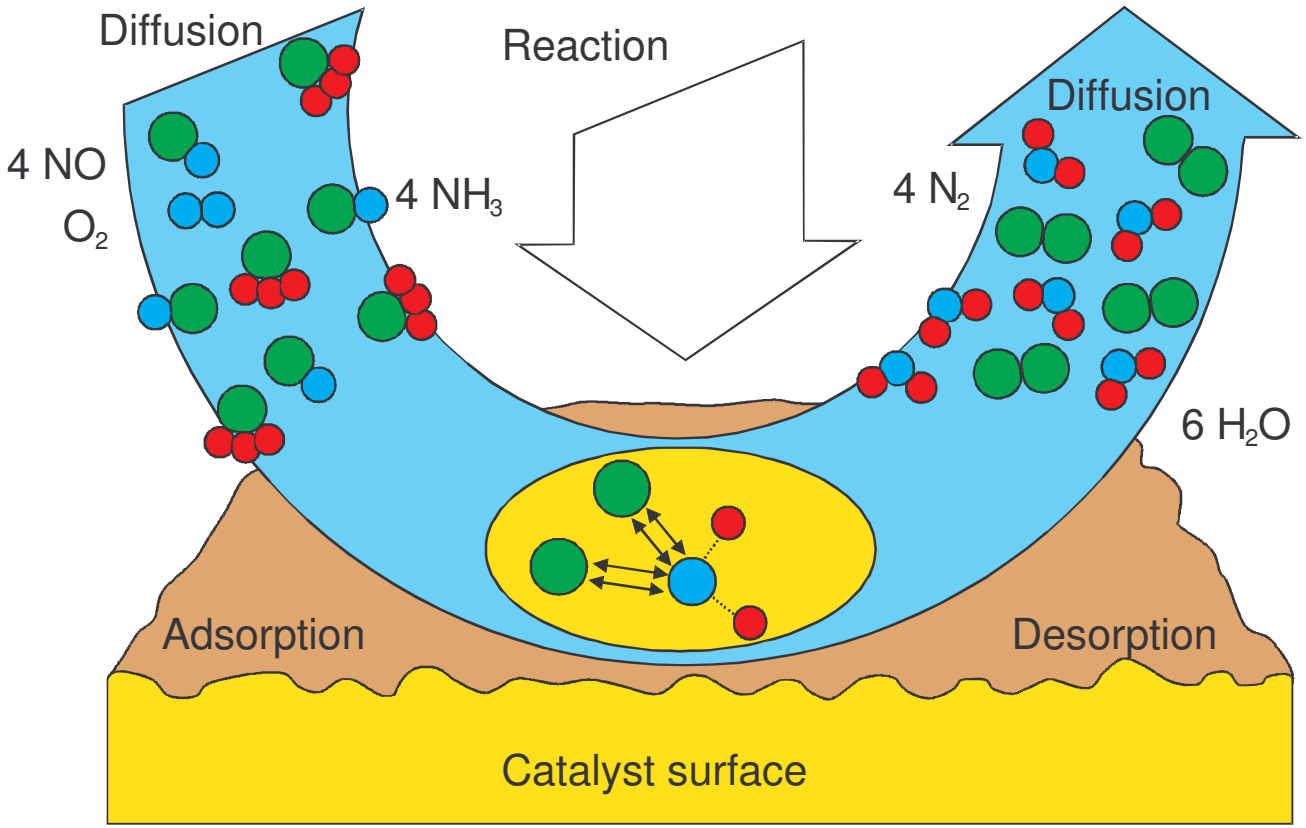
95% NO & 5% NO_2

Undesirable side reactions

$$SO_2 + 1/2\ O_2 \rightarrow SO_3$$

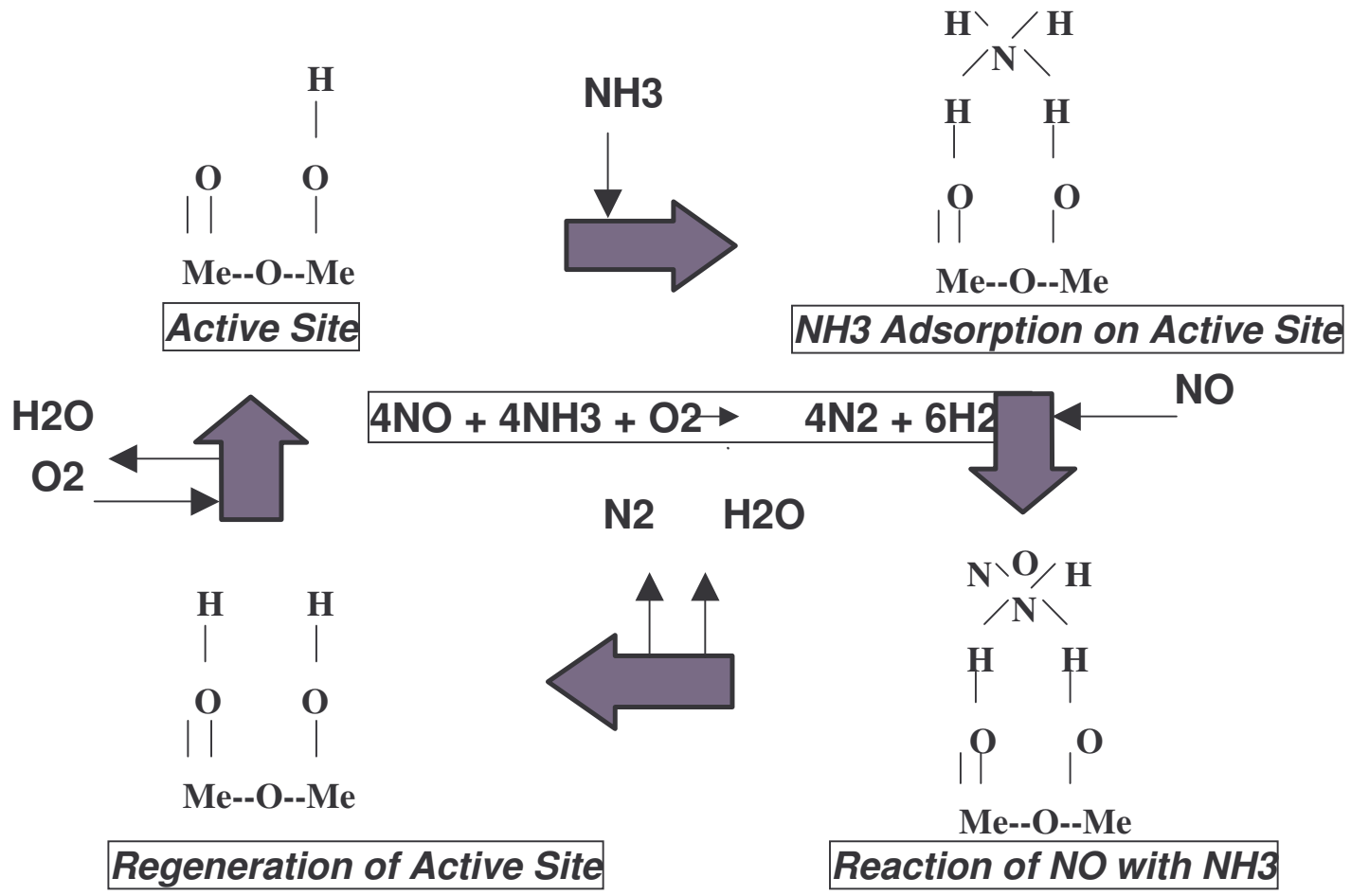
$$NH_3 + SO_3 + H_2O \rightarrow NH_4\ HSO_4$$

Chemistry & Catalyst



NO_x reactor occurs on catalyst surface

SCR Catalyst Surface Reactions

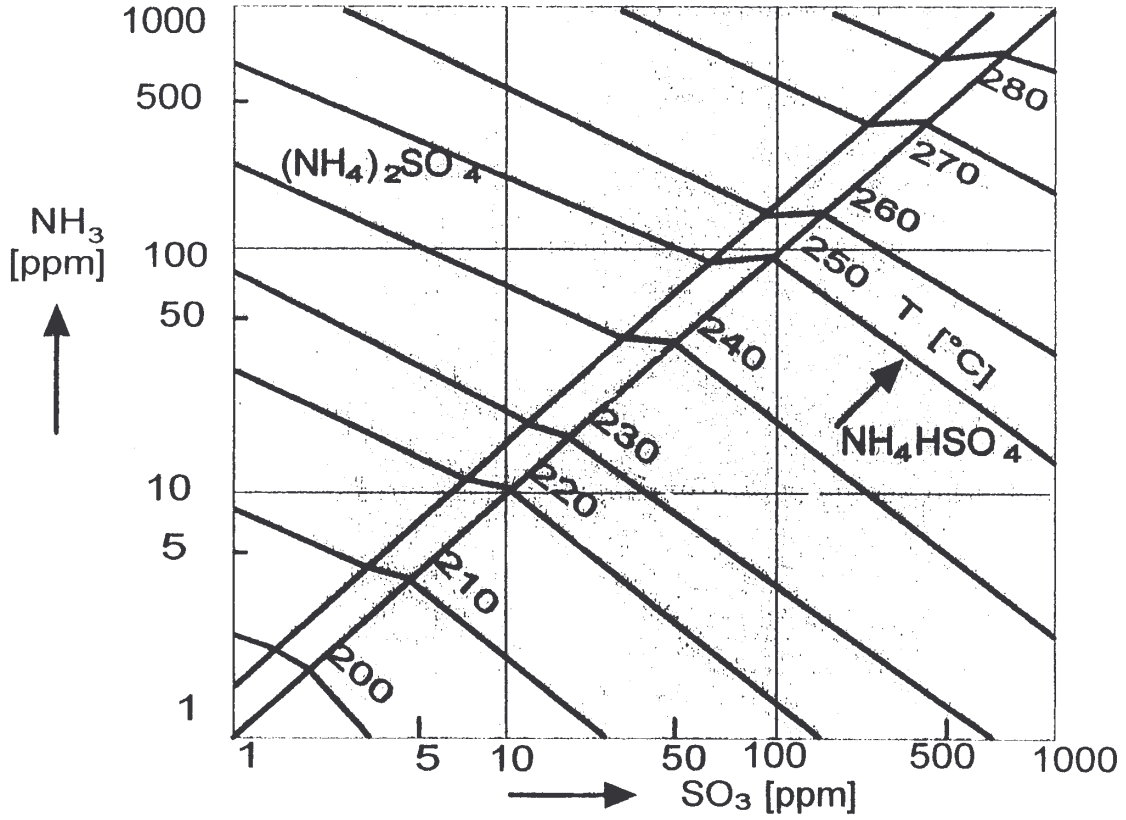


Chemistry & Catalyst

- SO_2 to SO_3 Conversion
  - Reaction occurs inside catalyst wall
  - Furnace conversion rates 0.1 to 1.5%
  - System component removal varies
  - Stack rule of thumb
    - 10 ppm H_2SO_4 Dry stack
    - 5 ppm H_2SO_4 Wet Stack

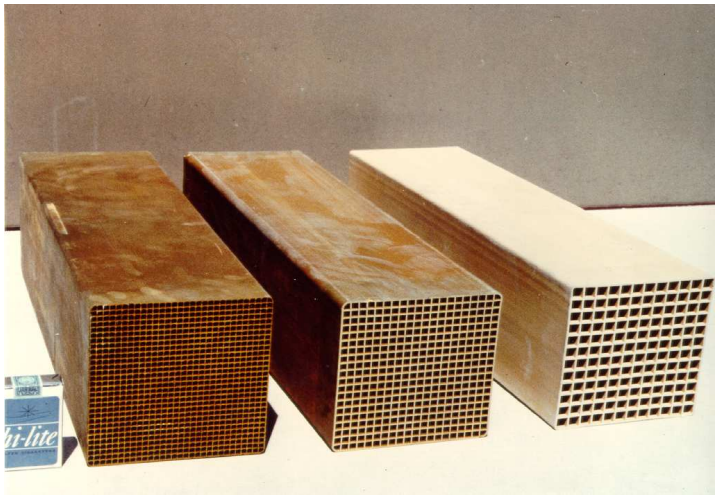
Minimum Catalyst Operating Temperature

- SCR inlet SO_3, NH_3 and H_2O
- Varies with fuel
- Catalyst pore size effects

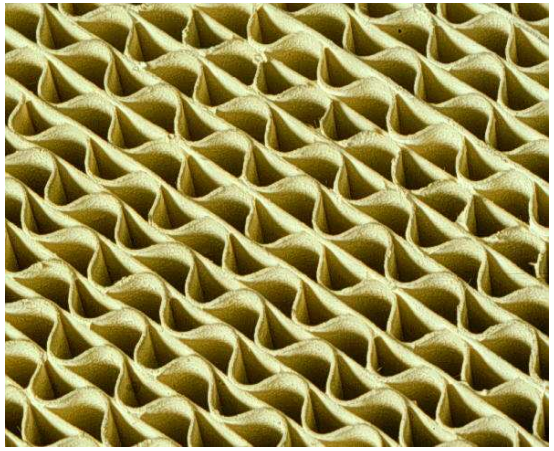


SCR Catalyst Types

- Honeycomb



- Plate



- Corrugated

Chemistry & Catalyst

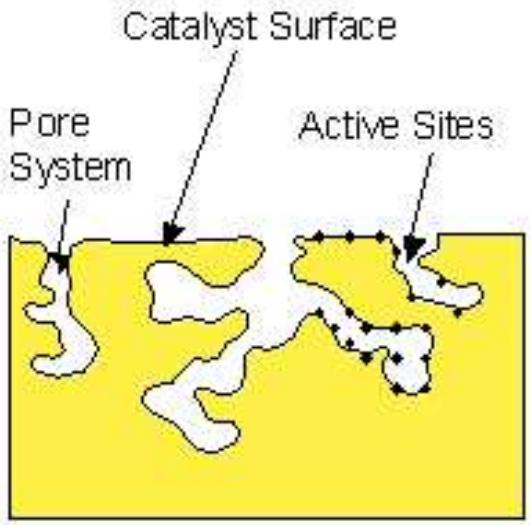
- Major Catalyst Deactivation Issue
  - Arsenic
  - CaO
  - Ash Content
  - Ammonia Bisulfate

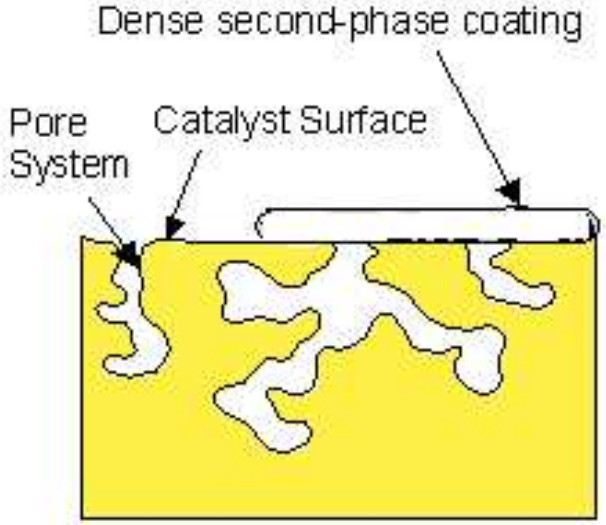
Chemistry & Catalyst

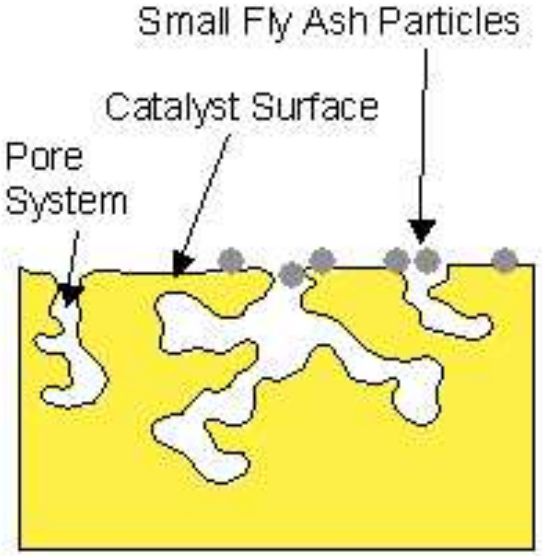
Poisoning:
Deactivation of active catalyst sites by chemical attack

Masking:
Macroscopic blockage of catalyst surface by dense second-phase coating

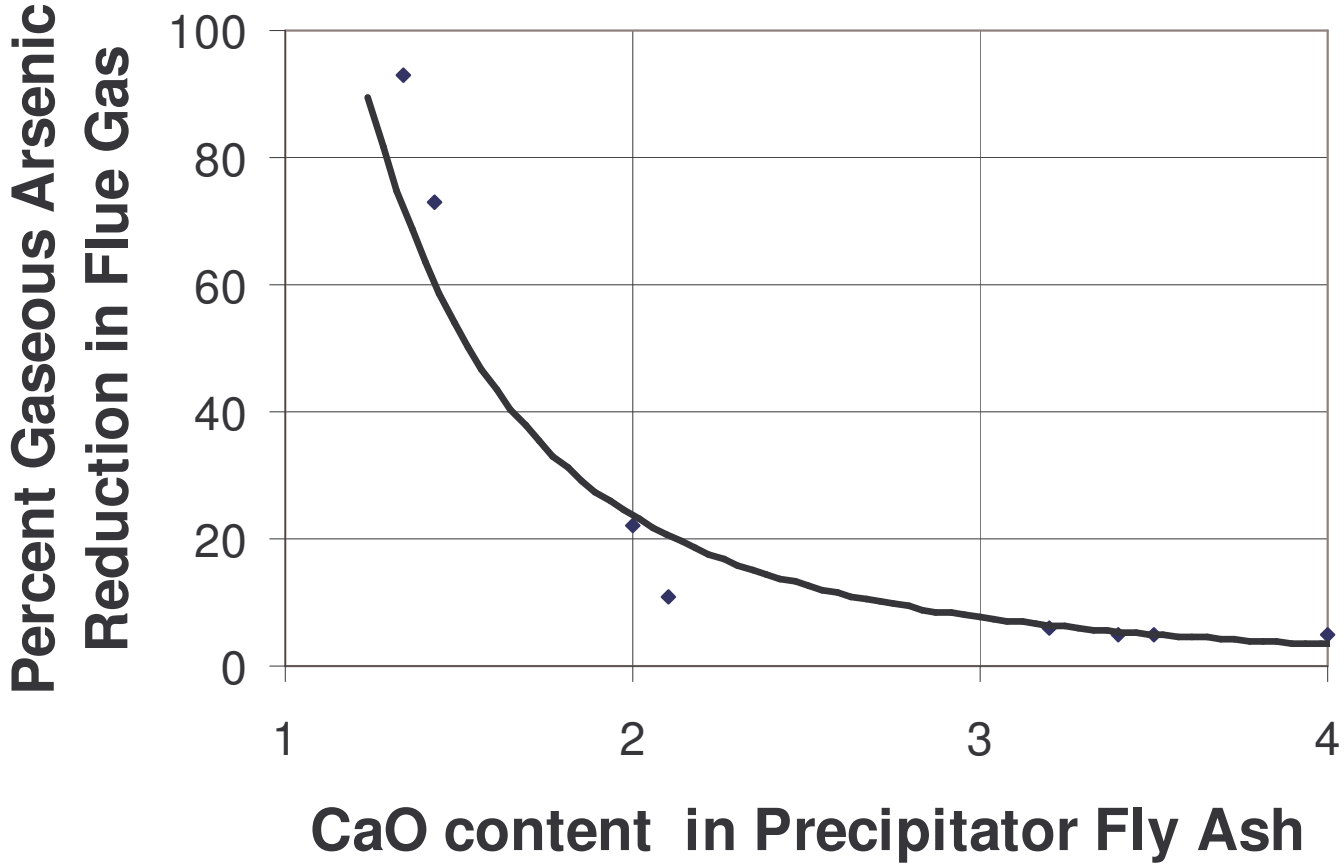
Plugging:
Microscopic blockage of catalyst pore system by small fly ash particles





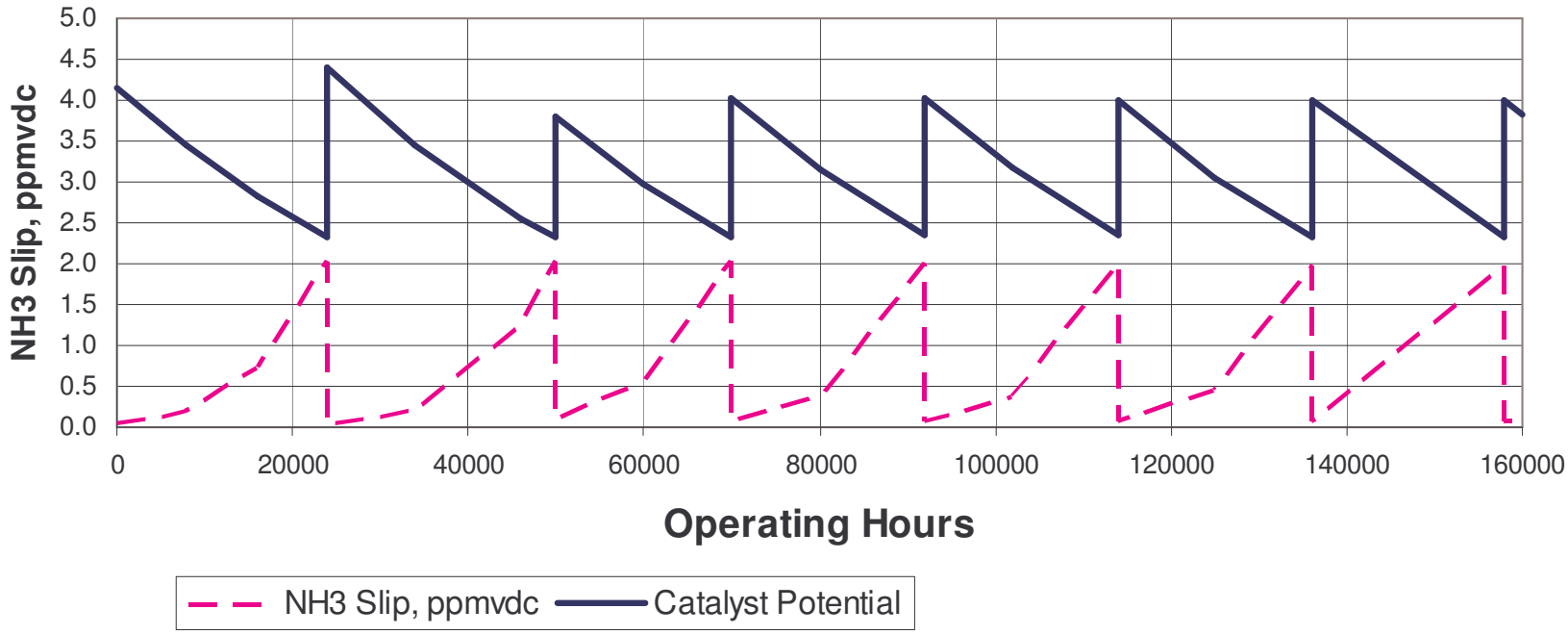


Control of Flue Gas Gaseous Arsenic



Catalyst Management Plan

2 Initial Layers + 1 Spare Layer

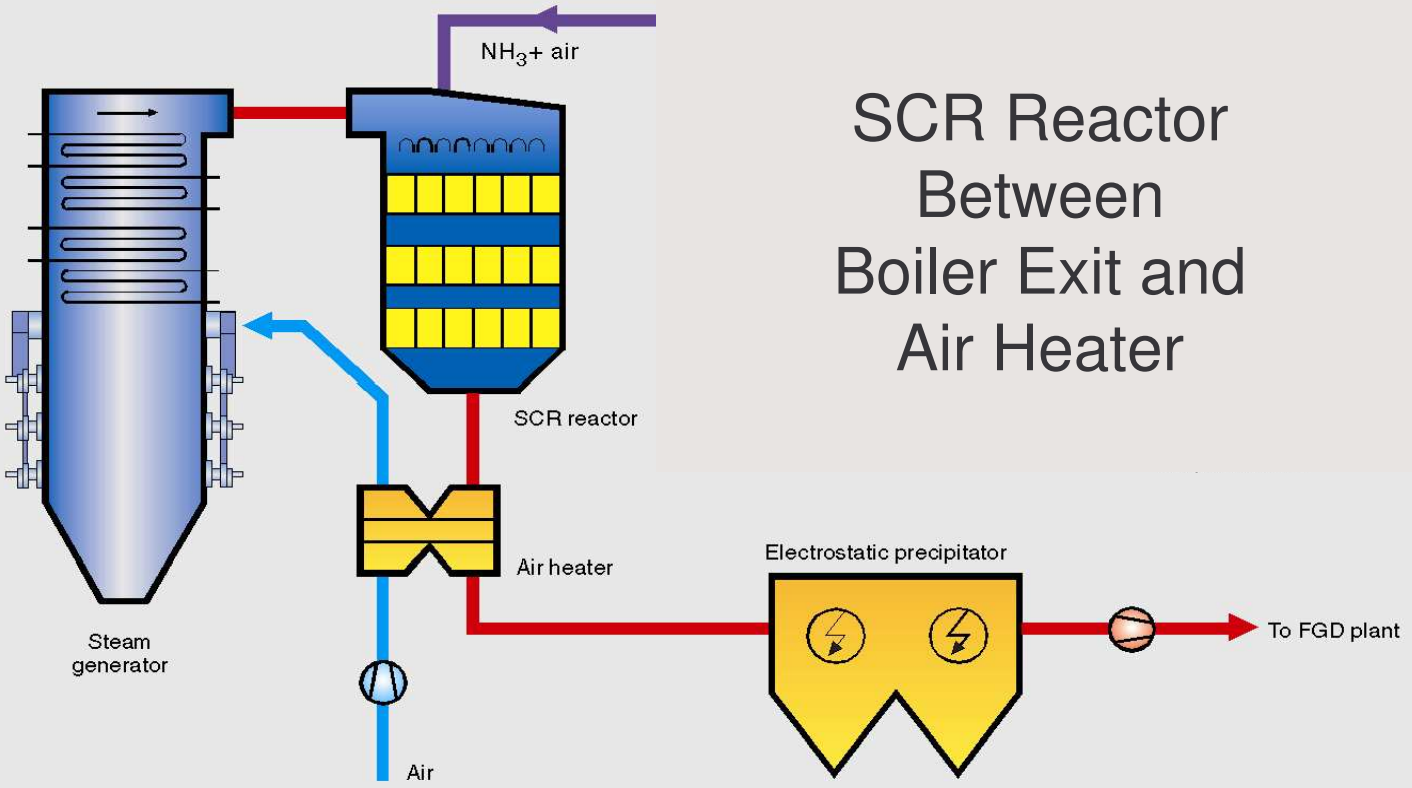


Catalyst Loading and Unloading

SCR Reactor and Ductwork

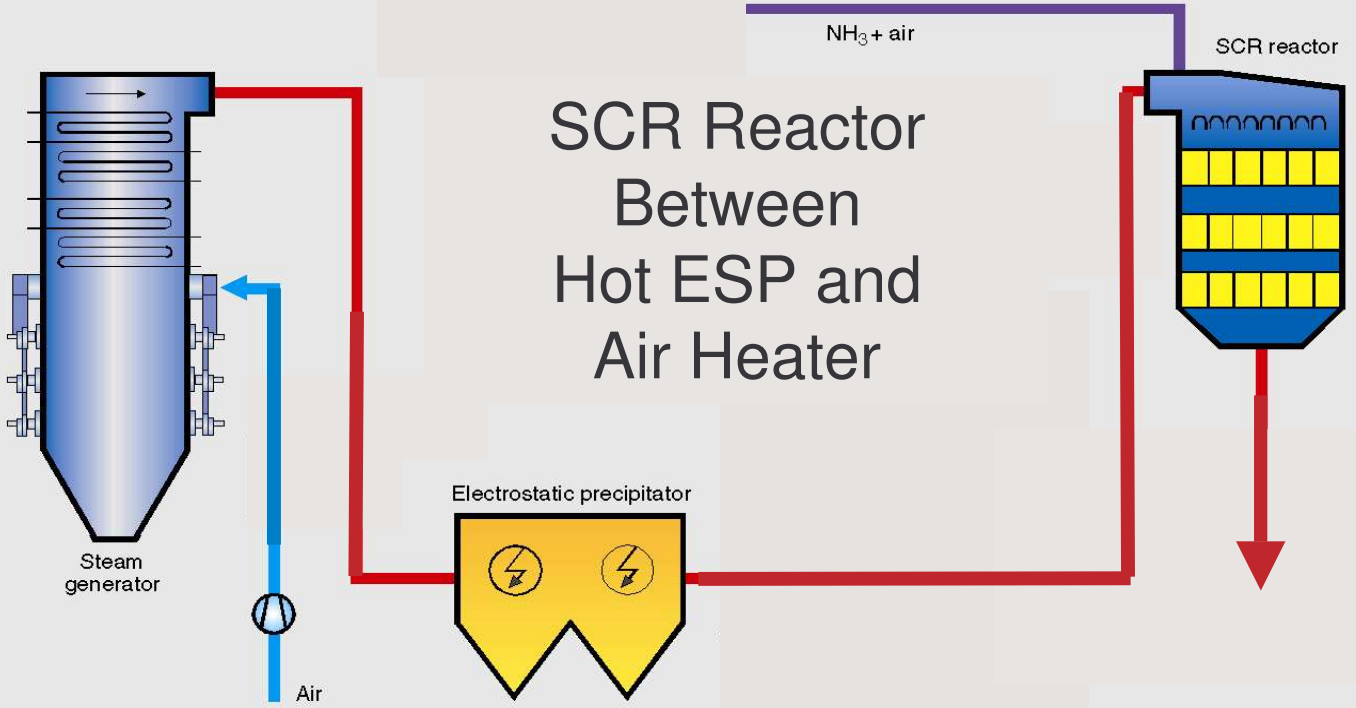
- SCR System Configurations
- Damper and SCR Bypass Configurations
- Low Load Temperature Control
- Catalyst Cleaning
- Large Particle Ash (Popcorn ash)

High Dust Arrangement

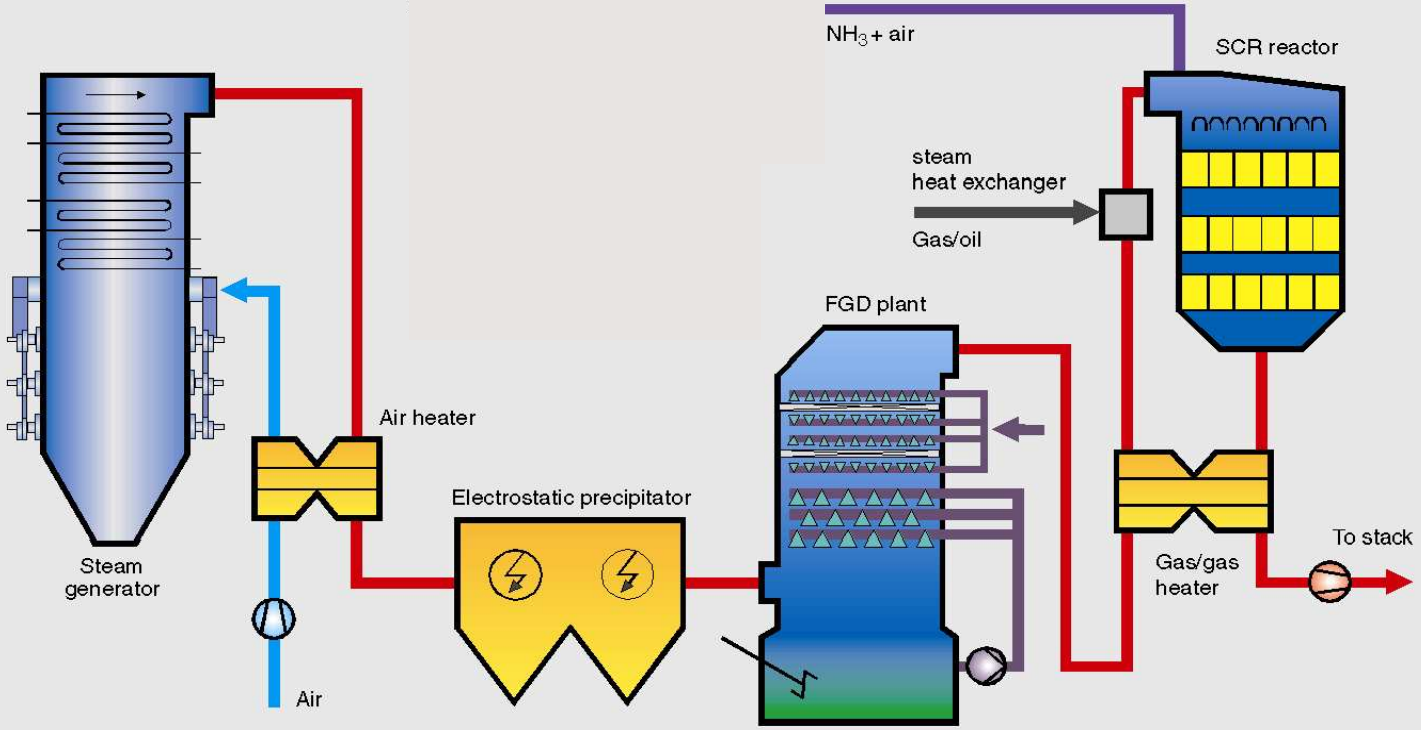


SCR Reactor Between Boiler Exit and Air Heater

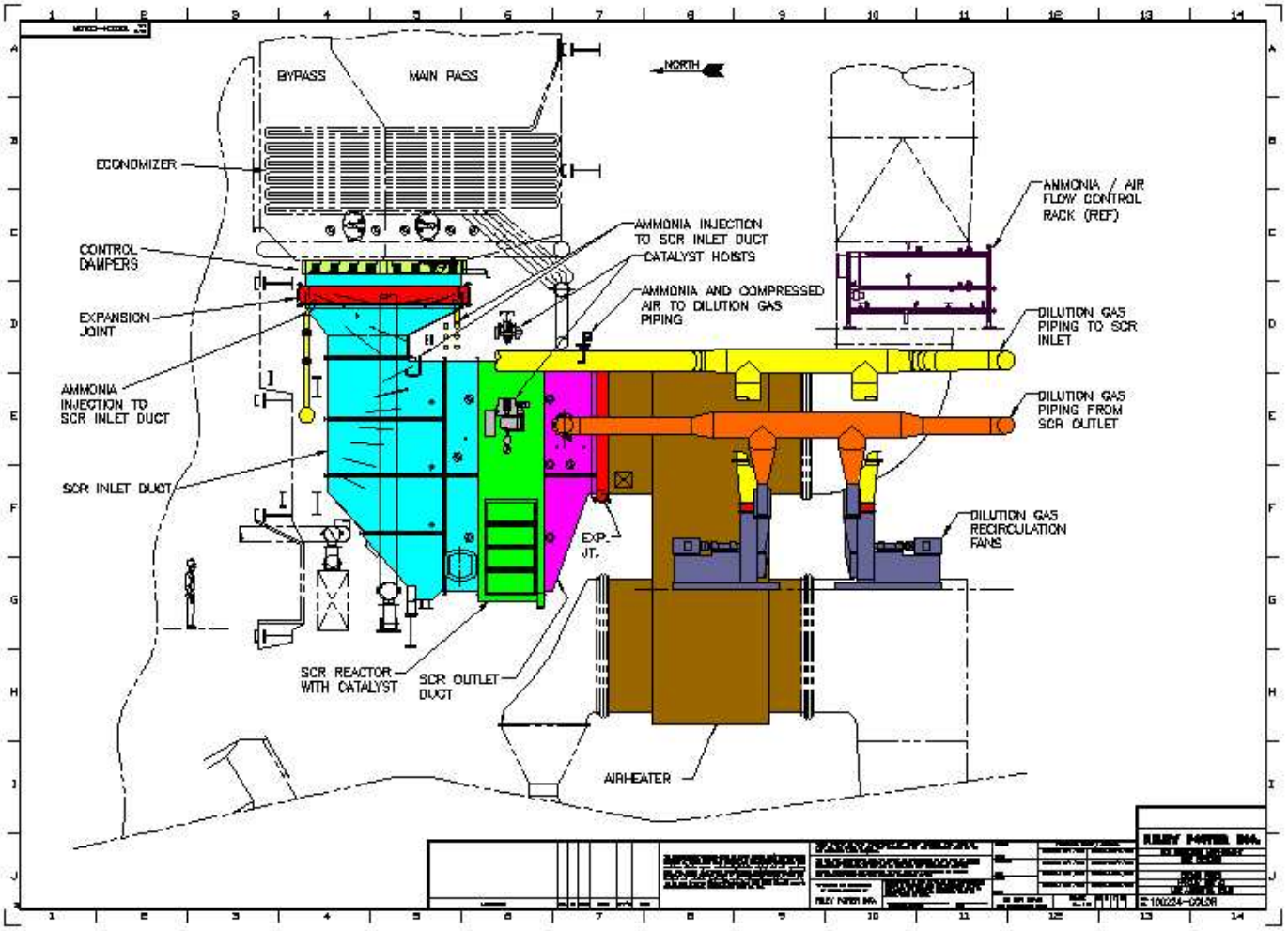
Low Dust Arrangement



Tail End Arrangement



In Duct SCR


BYPASS
MAIN PASS
NORTH
ECONOMIZER
CONTROL DAMPERS
EXPANSION JOINT
AMMONIA INJECTION TO SCR INLET DUCT
SCR INLET DUCT
AMMONIA INJECTION TO SCR INLET DUCT
CATALYST HOISTS
AMMONIA AND COMPRESSED AIR TO DILUTION GAS PIPING
AMMONIA / AIR FLOW CONTROL RACK (REF)
DILUTION GAS PIPING TO SCR INLET
DILUTION GAS PIPING FROM SCR OUTLET
DILUTION GAS RECIRCULATION FANS
EXP. JT.
SCR REACTOR WITH CATALYST
SCR OUTLET DUCT
AIRHEATER

SCR Reactor and Ductwork

- Full SCR bypass
  - Able to isolate reactor during operation and startup
  - No catalyst deactivation during non-ozone season
- Partial SCR bypass for startup
  - Able to isolate during startup only
- No SCR bypass or dampers

SCR Reactor and Ductwork

- Low Load Temperature Control
  - Flue gas economizer bypass
  - Economizer water side bypass
  - Split economizer
  - Feed water heater pegging

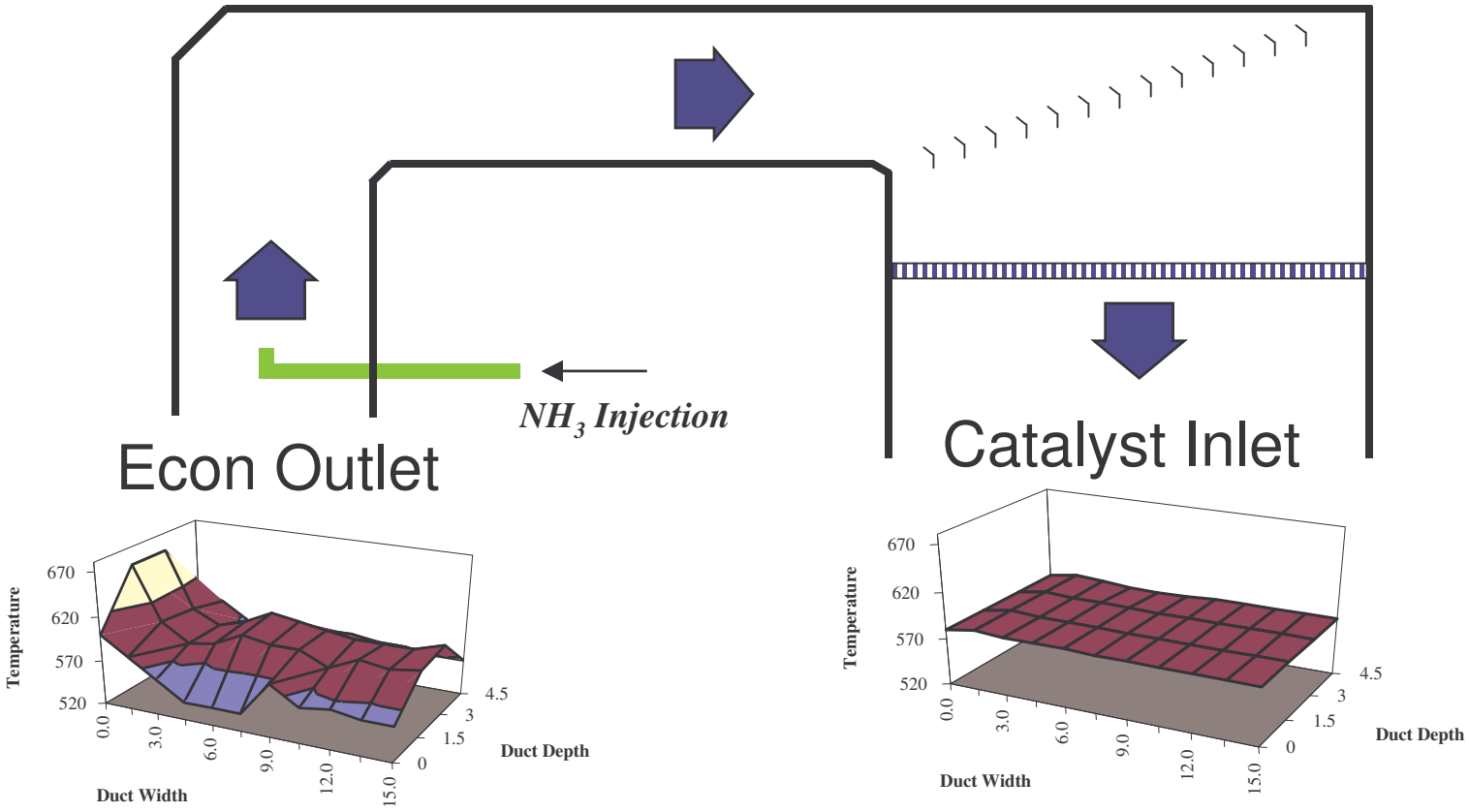
Ammonia Systems

- Anhydrous Ammonia
  - Hazardous chemical governed by codes
- Aqueous Ammonia
  - Concentration based codes, maybe changed in future
- Urea Based Ammonia
  - Safe storage, more equipment and complex

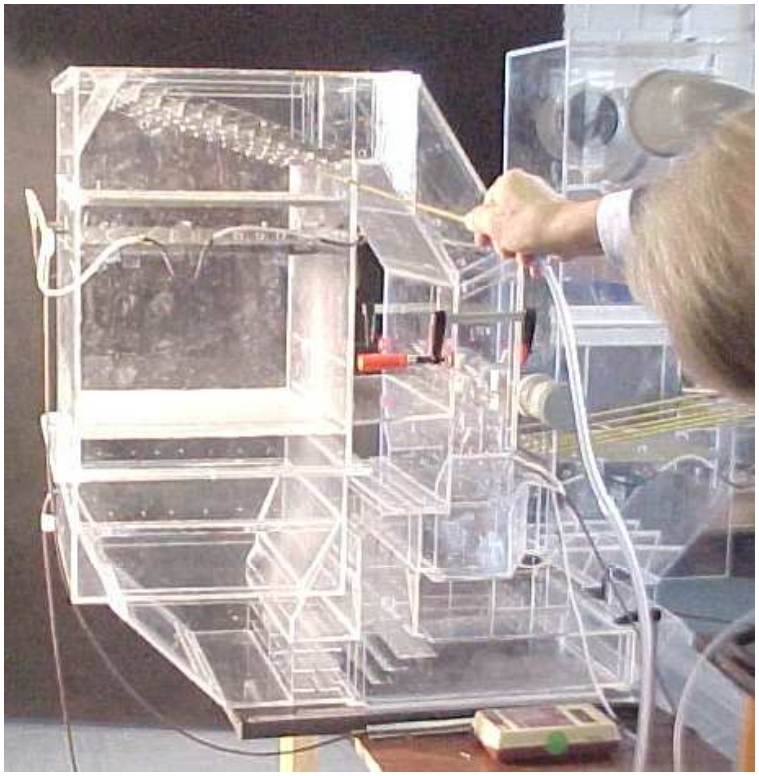
Ammonia Injection

- Anhydrous
  - Vaporizers
  - Direct Injection
  - Dilution air, 5% by Volume
- Aqueous
  - Vaporizers
  - Direct Injection
  - Dilution air, 5% by Volume
- Urea
  - Direct Injection
  - Dilution air, 5% by Volume

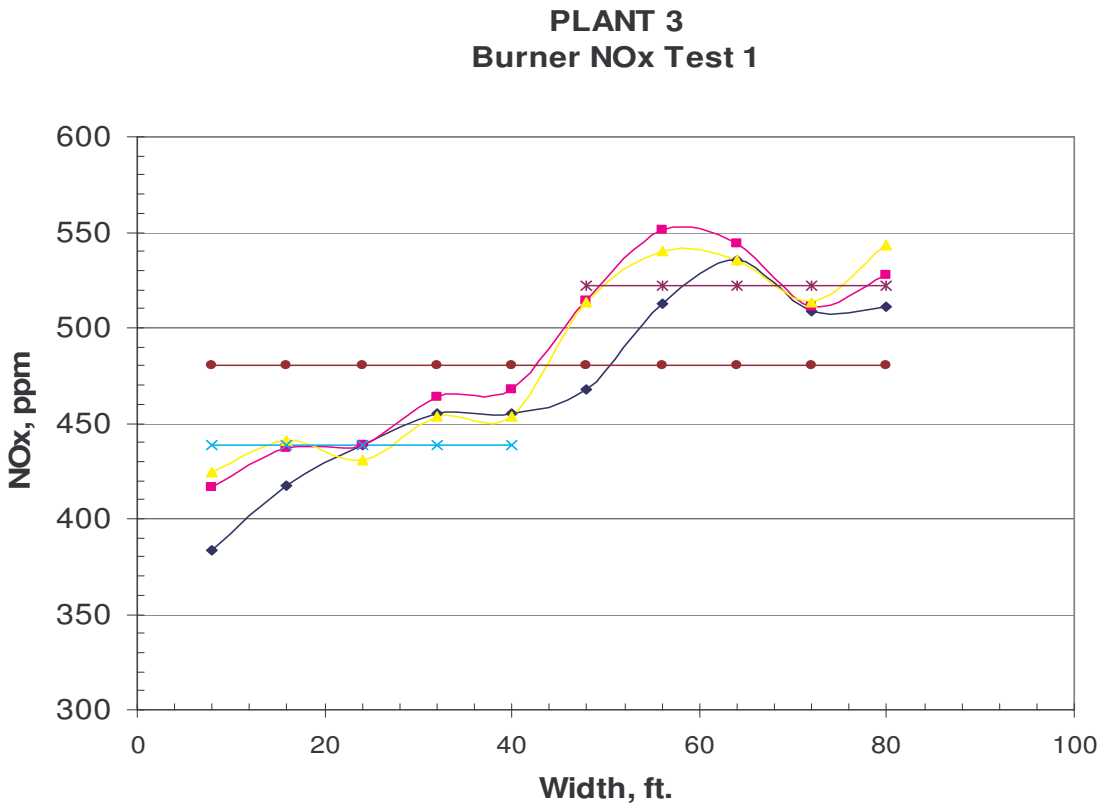
Ammonia Injection & Flue Gas Mixing



SCR Flow Models



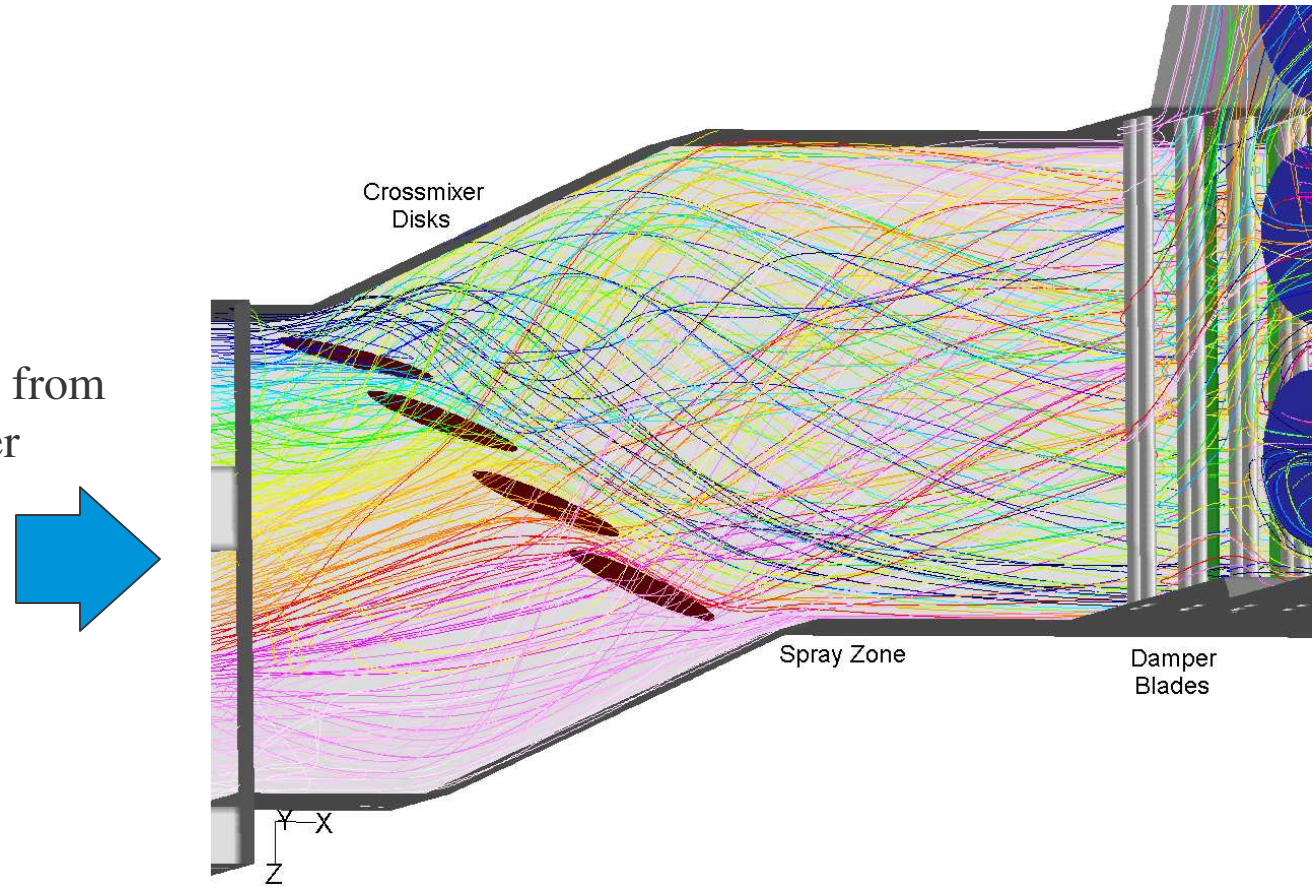
Ammonia Injection & Flue Gas Mixing



- Inlet variations of flue gas composition
- Load and burner group dependent
- Mix prior to ammonia injection

Mixing Prior to Ammonia Injection

Gas Flow from Boiler

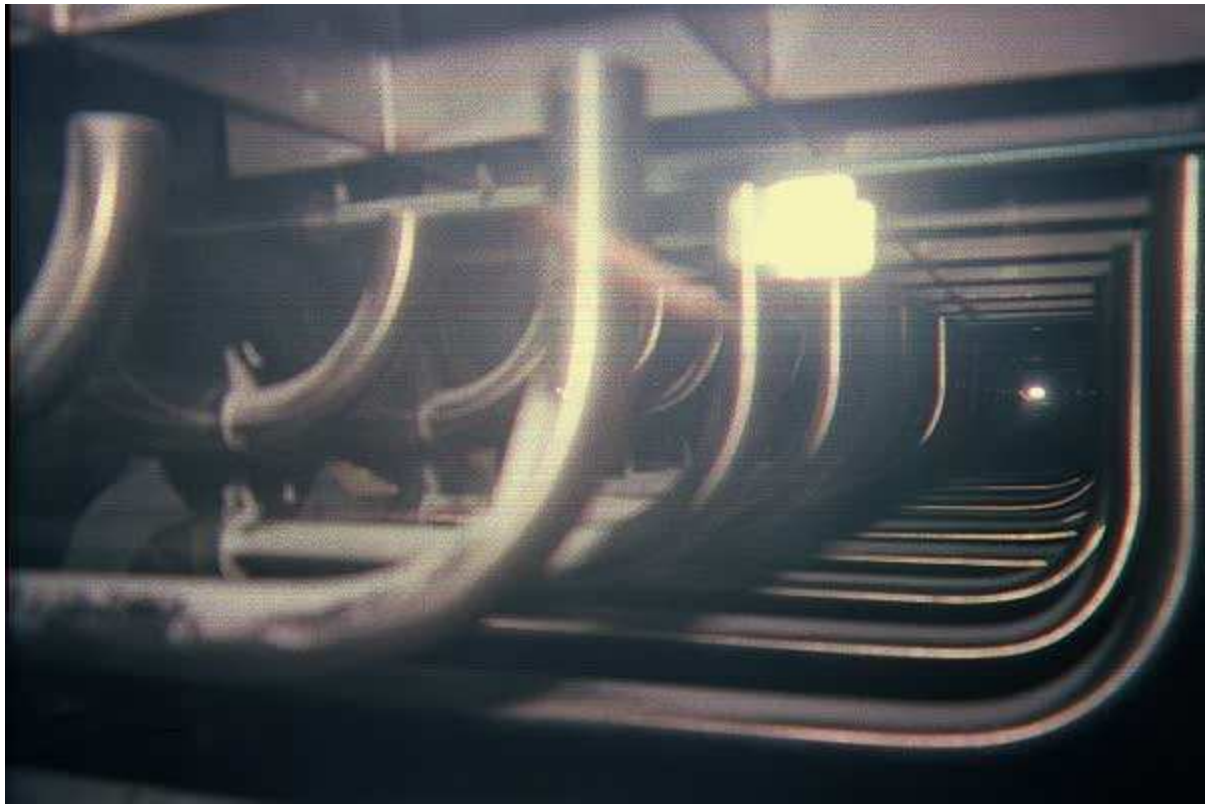


Static Mixers – Delta Wings

Delta Wing Ammonia Injection

Static Mixer

Static Mixer – Injection Grid

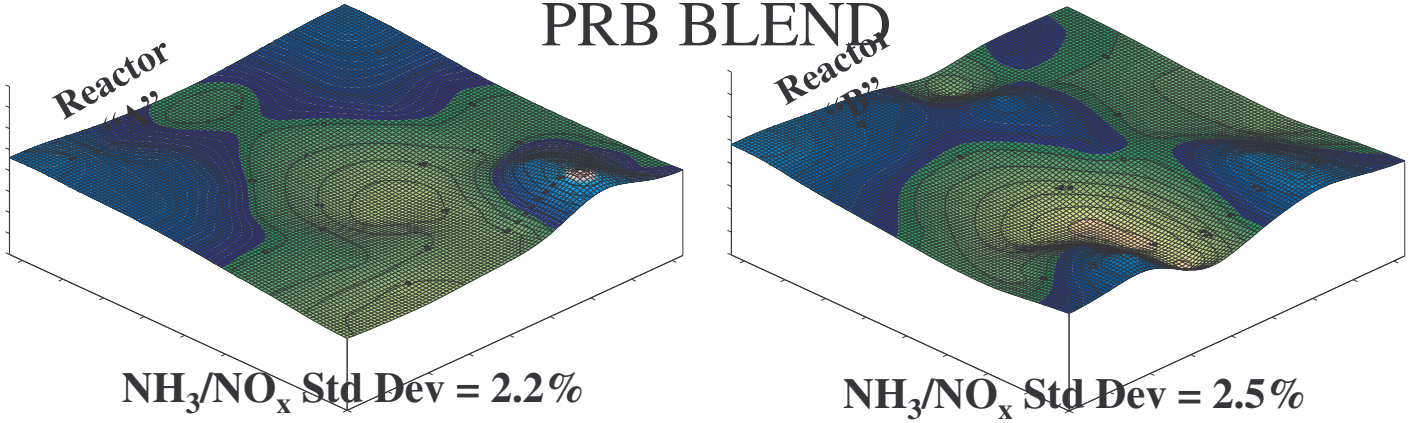


Ammonia Injection Control

- **Adjusted based on tesing**

Commissioning Results

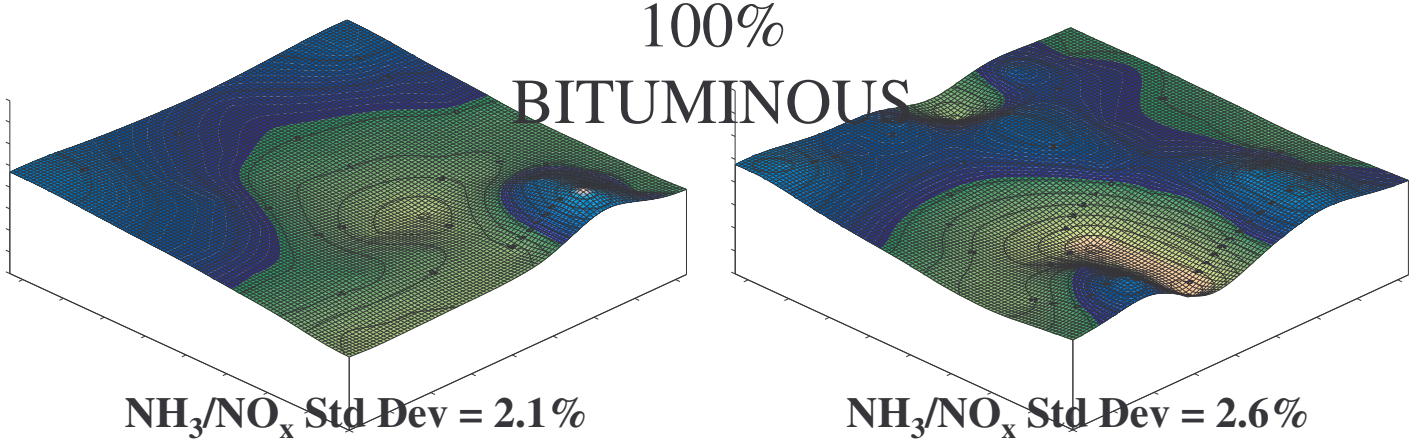
PRB BLEND



NH_3/NO_x Std Dev = 2.2%

NH_3/NO_x Std Dev = 2.5%

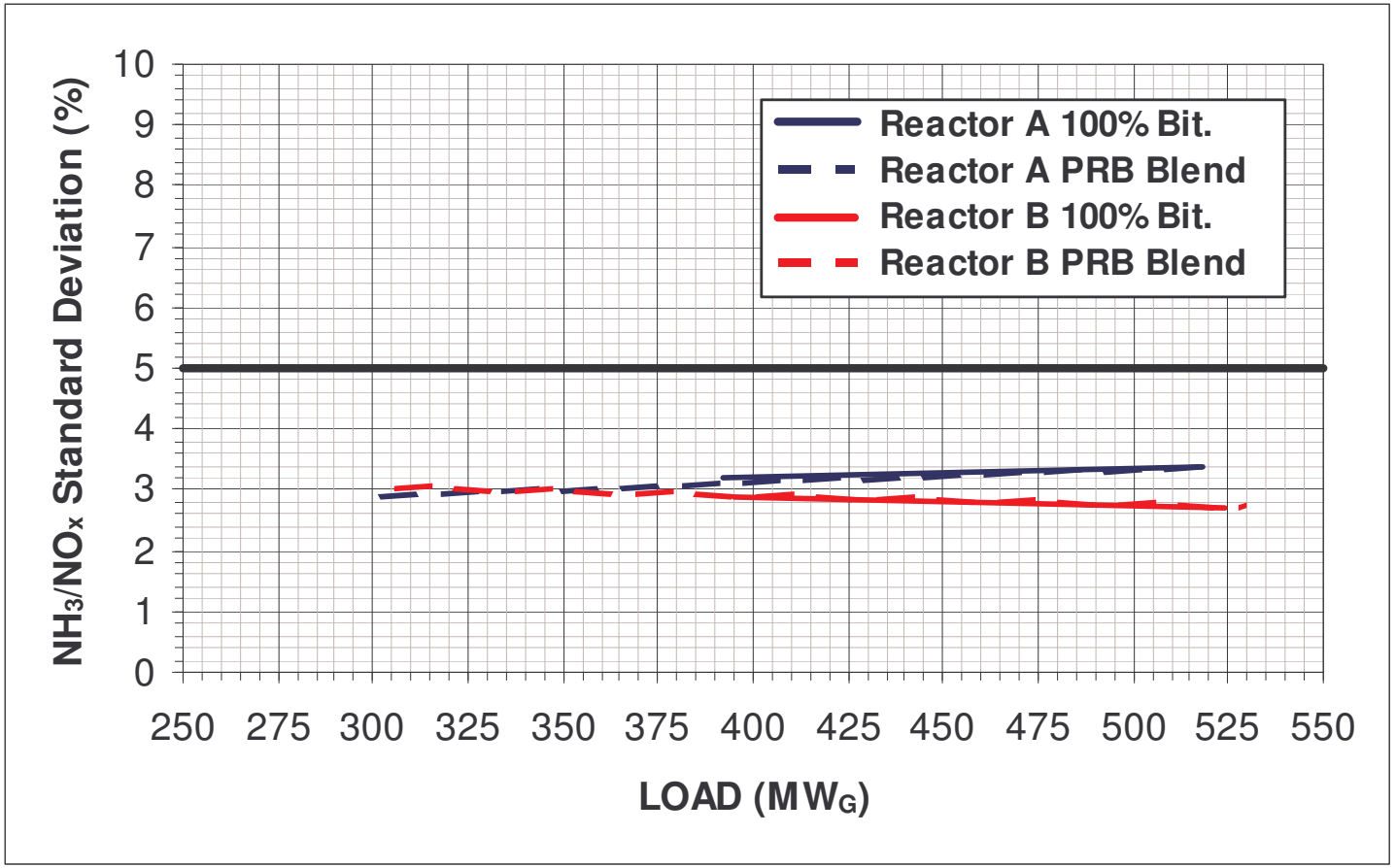
100% BITUMINOUS



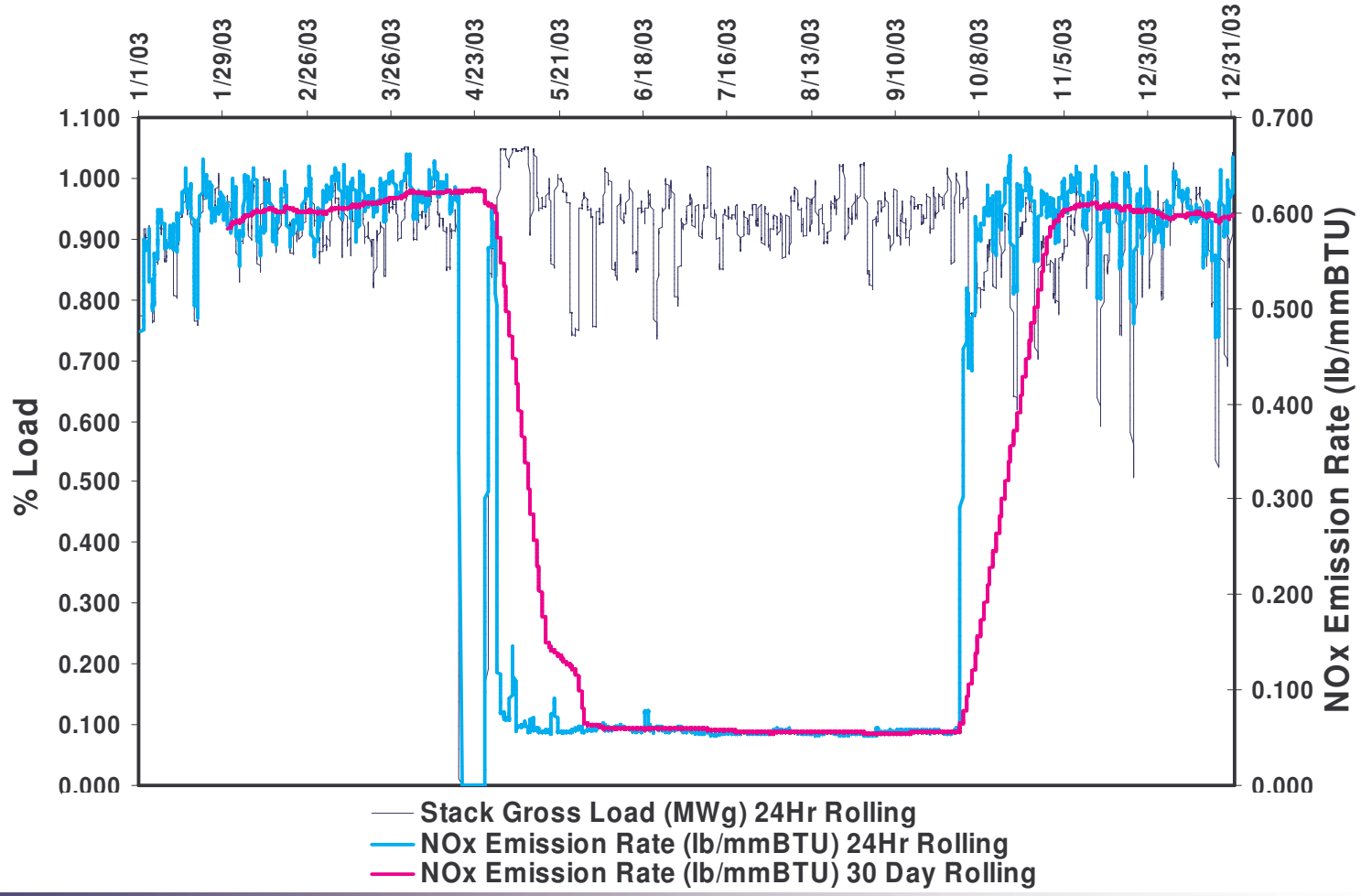
NH_3/NO_x Std Dev = 2.1%

NH_3/NO_x Std Dev = 2.6%

Commissioning Results



SCR System Performance



Questions

Thanks You