Selective Non-Catalytic Reduction: Overview

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WPCA/Duke NOx Seminar
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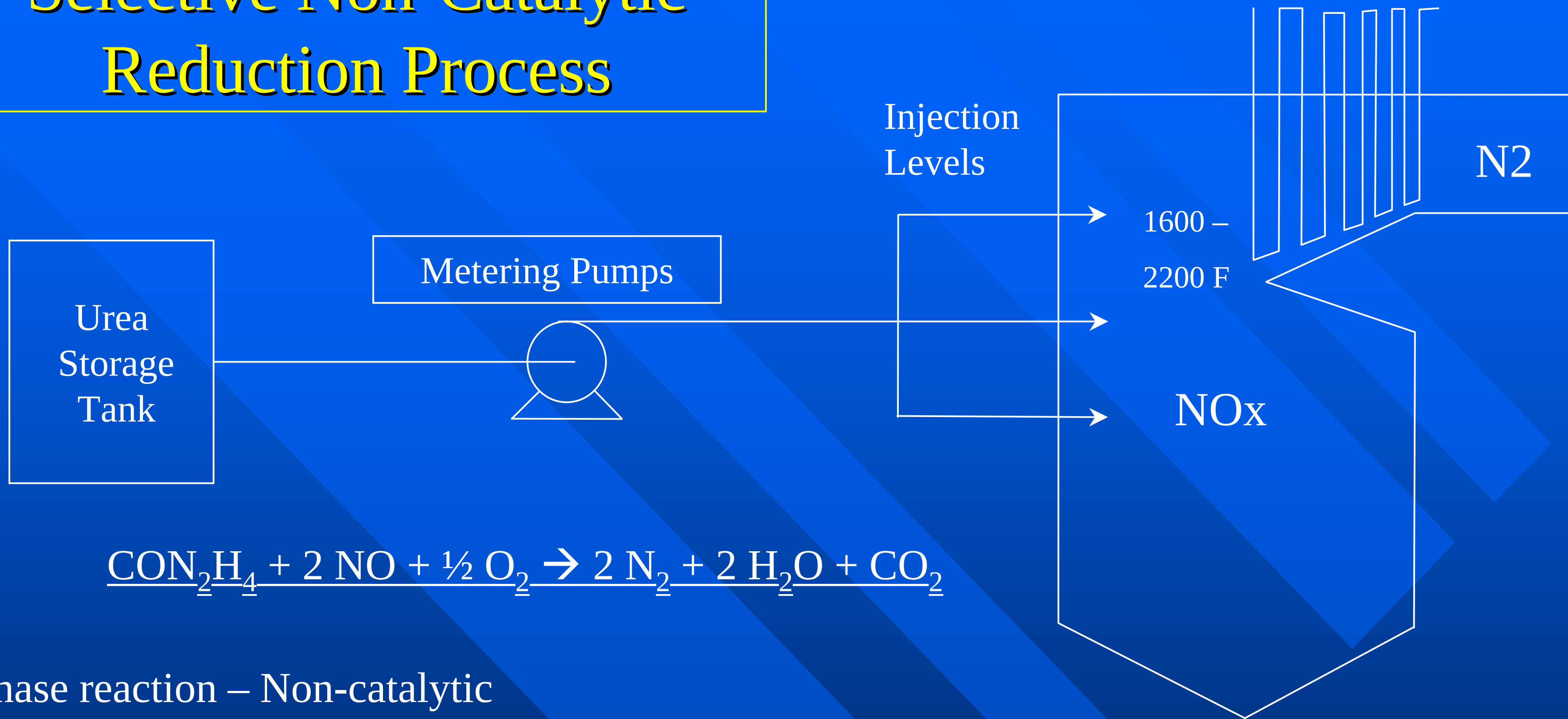
NOxOUT Process
Selective Non-Catalytic Reduction Process



$\underline{CON_2H_4 + 2\ NO + ½\ O_2 \rightarrow 2\ N_2 + 2\ H_2O + CO_2}$

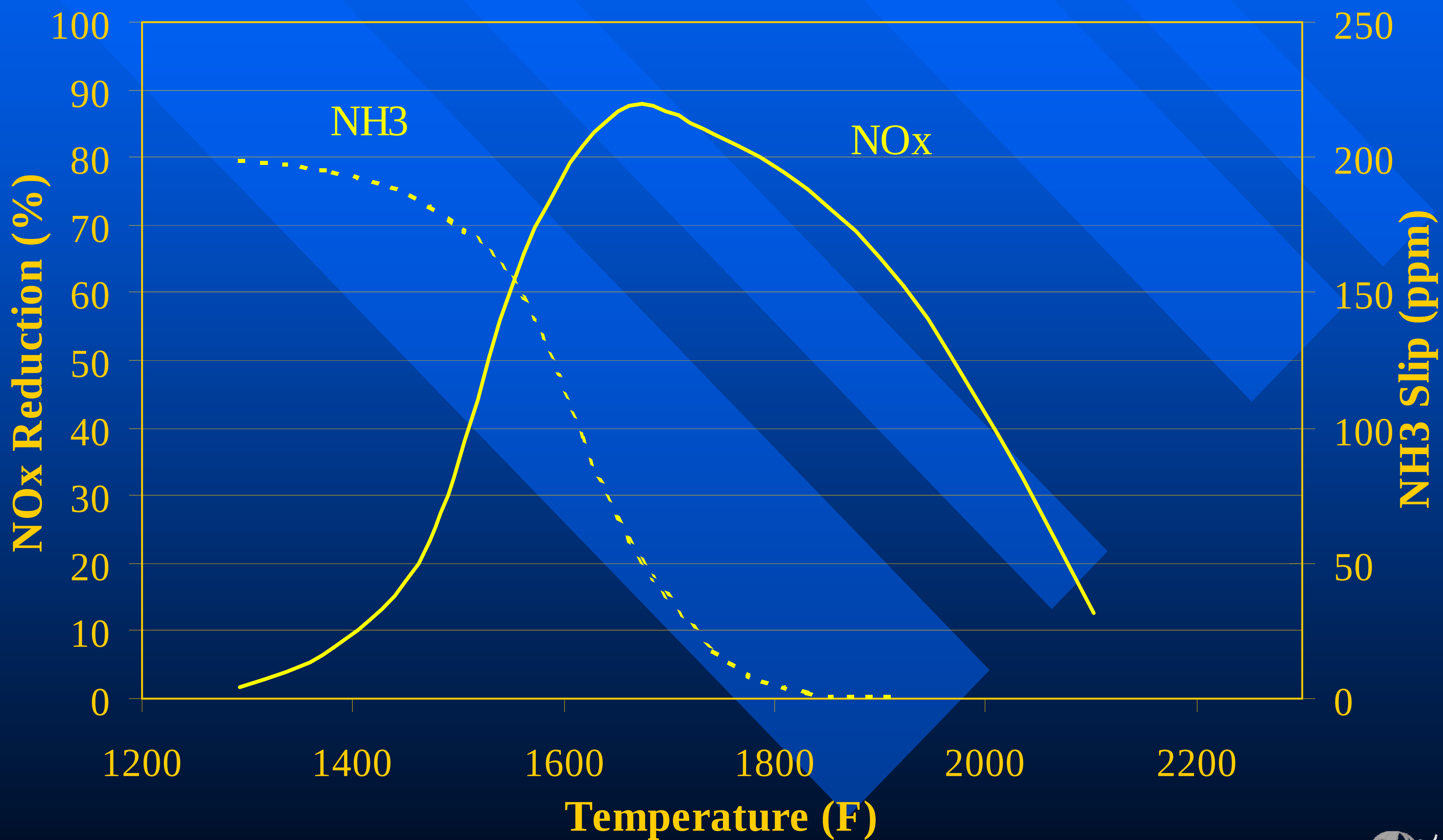
- Gas phase reaction – Non-catalytic
- Reactions occur in 1600 – 2200 F -- Post Combustion
- Reaction products are typical combustion products -- CO2, H2O, N2
- No solid residue
- Easily Installed
- Easily combinable with other NOx control technologies
- Low Capital Cost

Urea SNCR

- $CON_2H_4 + 2\ NO + ½\ O_2 \rightarrow 2\ N_2 + 2\ H_2O + CO_2$
  - Tycally applied under Oxidizing environment
  - Sensitive to temperature, CO, and residence time
  - Byproducts: NH_3 and CO
  - Safe reagent
- Reagent Distribution
  - Flue gas velocity, temperature, droplet trajectories, and reagent dispersion modeled using CFD
  - Field measurements of temperature and flue gas species
  - Multi level injection
  - Wall injectors and Multinozzle lances

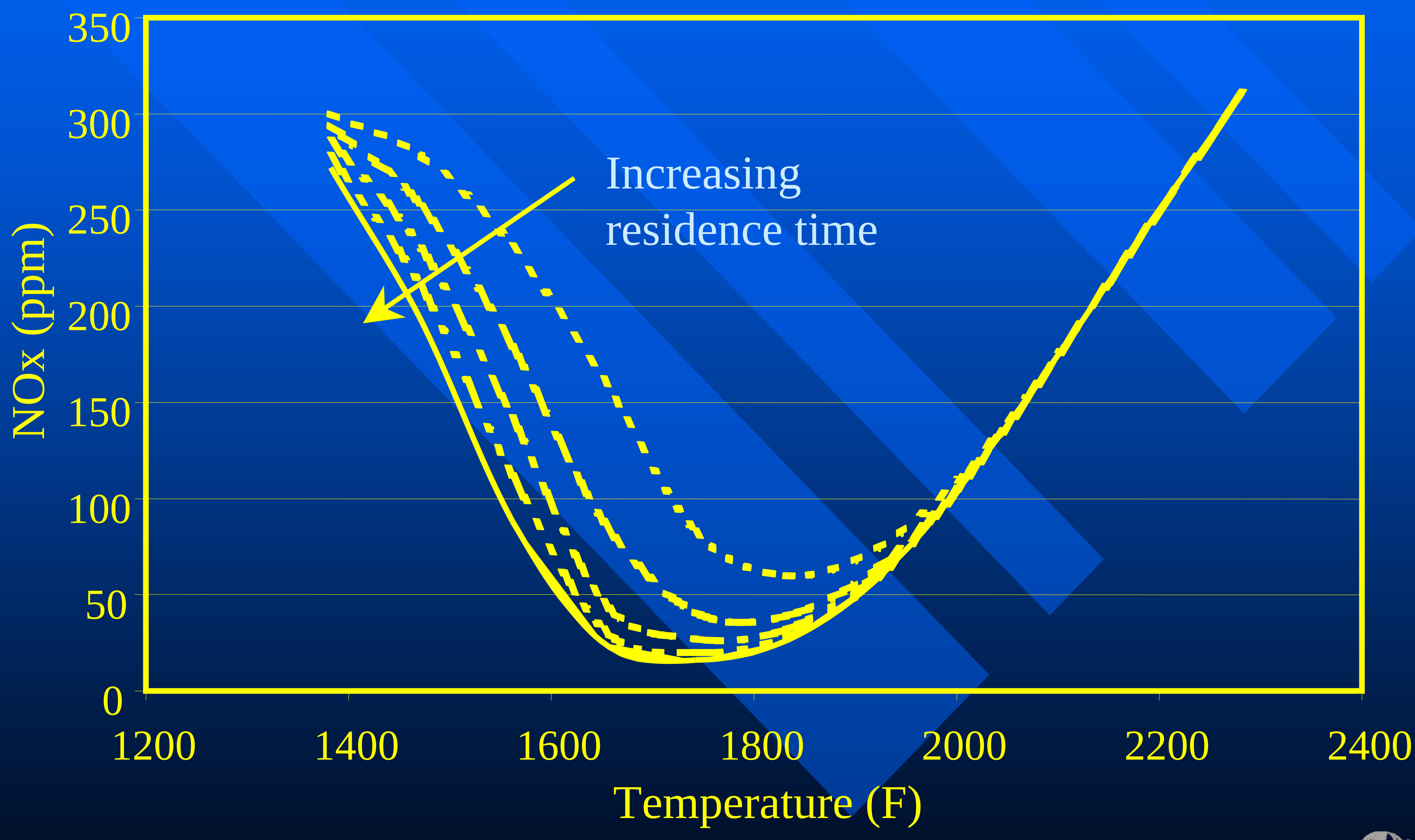
NOx reduction and NH3 Slip

chemical kinetic model



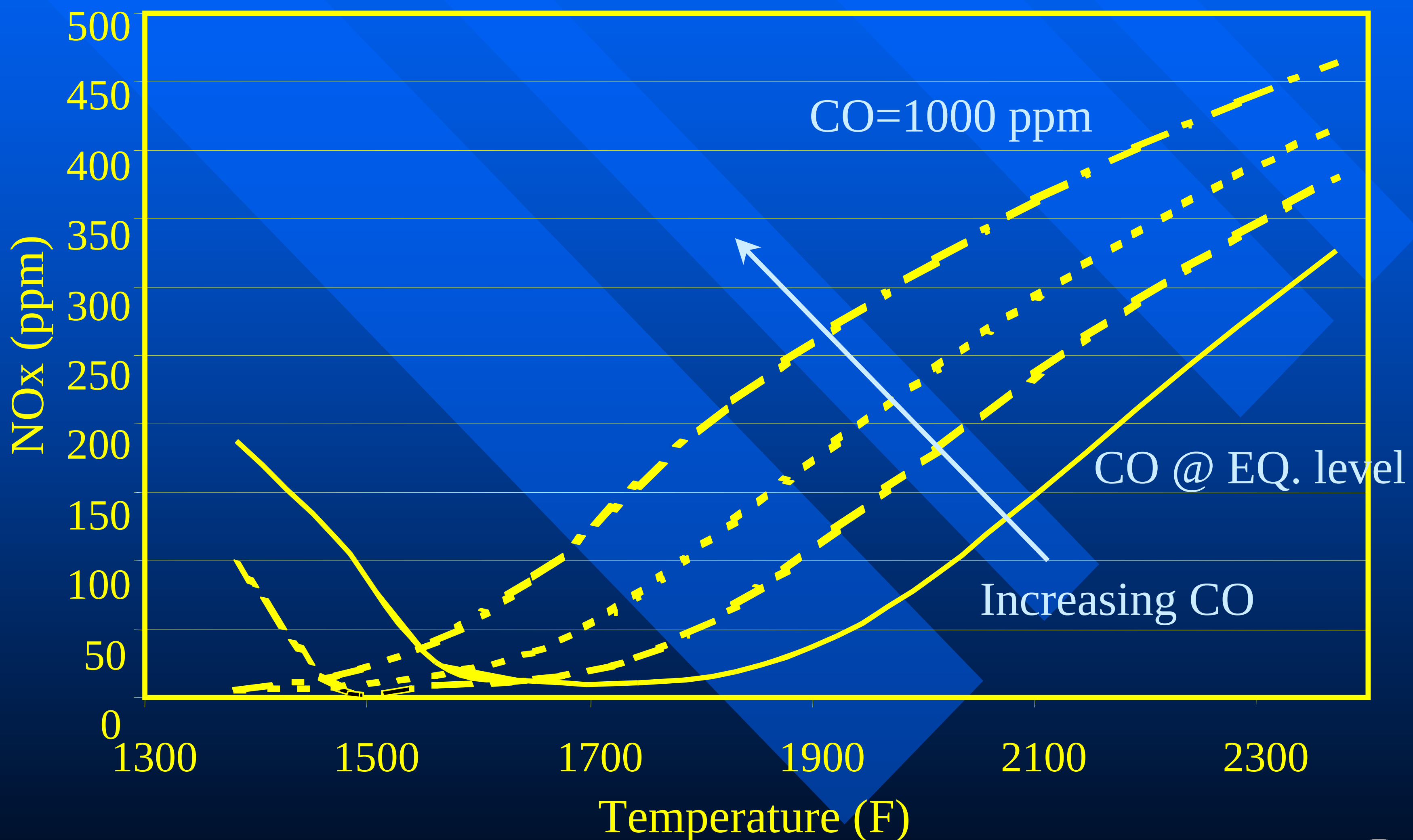
SNCR Temperature Window

chemical kinetic model



CO lowers SNCR Temperature Window

chemical kinetic model



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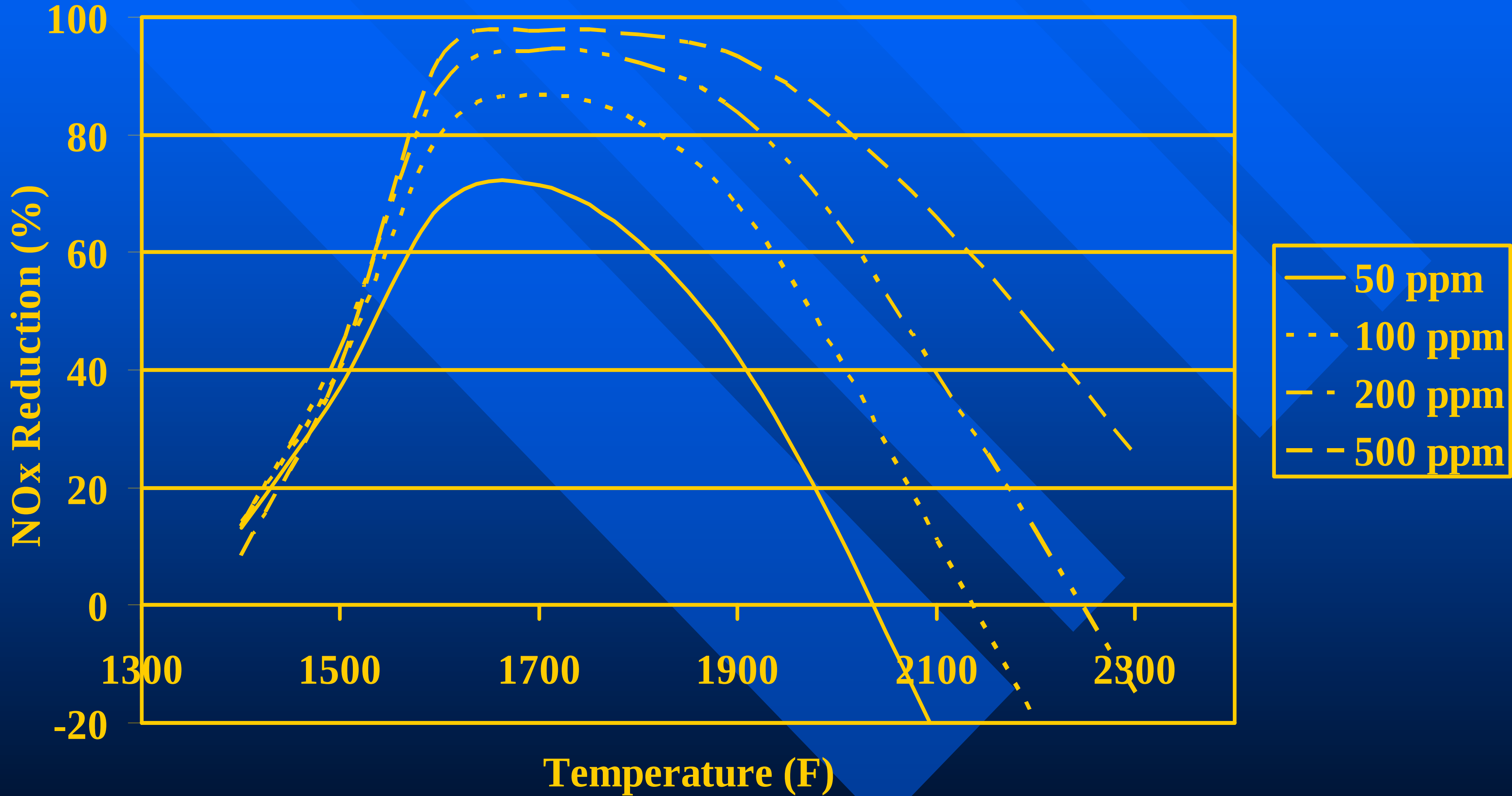
Effect of Baseline NOx on Reduction

Equilibrium CO, NSR = 2, t =1 sec



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Byproduct: NH_3 Slip

H2O + SO3	→	H2SO4
NH3 + SO3 + H2O	→	NH4HSO4 (l)
NH3 + NH4HSO4	→	(NH4)2SO4 (s)

- Formation temperature exists within the air heater
- Formation temperature increases with SO_3 and NH_3 concentration
- Higher temperature moves the deposition from cold to intermediate to hot baskets of the air heater.
- Ammonium salt deposition increases pressure drop across the air heater
- High fuel sulfur generates high SO_3 → must maintain low NH_3 slip

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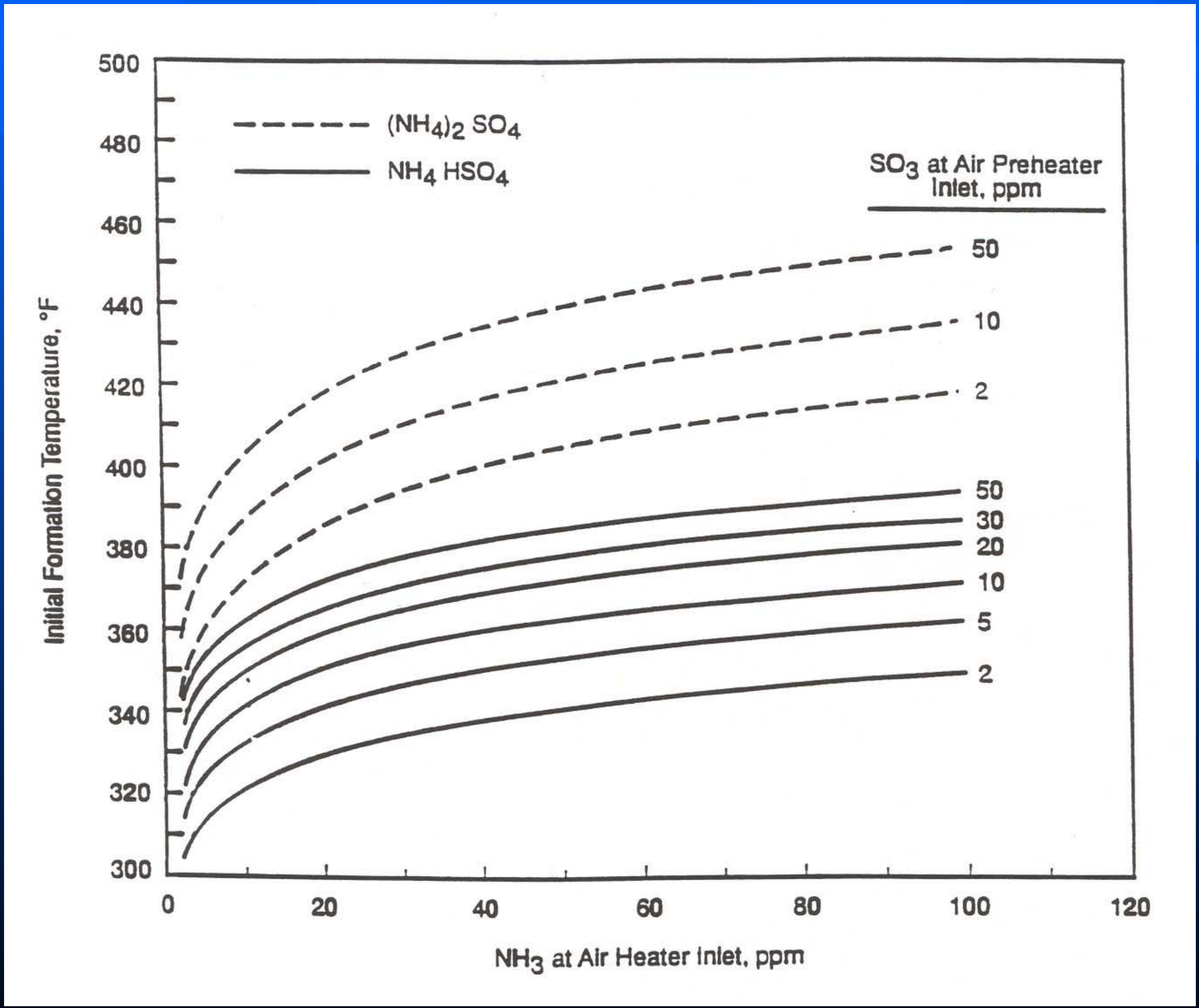
Formation Temperatures for Ammonium Sulfates



*AIR HEATER FOULING POTENTIAL**

- Deposition Number

$$= [NH_3][SO_3]\{T_f - T_{CE}\}$$

NH_3 : Ammonia Slip in ppm
SO_3 : Sulfur Trioxide in ppm
T_f : Formation Temperature of Ammonium Bisulfate in °C
T_{CE} : Metal Temperature at Air Heater Outlet in °C

> 5000~7000 – Fouling Potential Exists

* Based on EPA Report prepared by Radian Corporation, April, 1982

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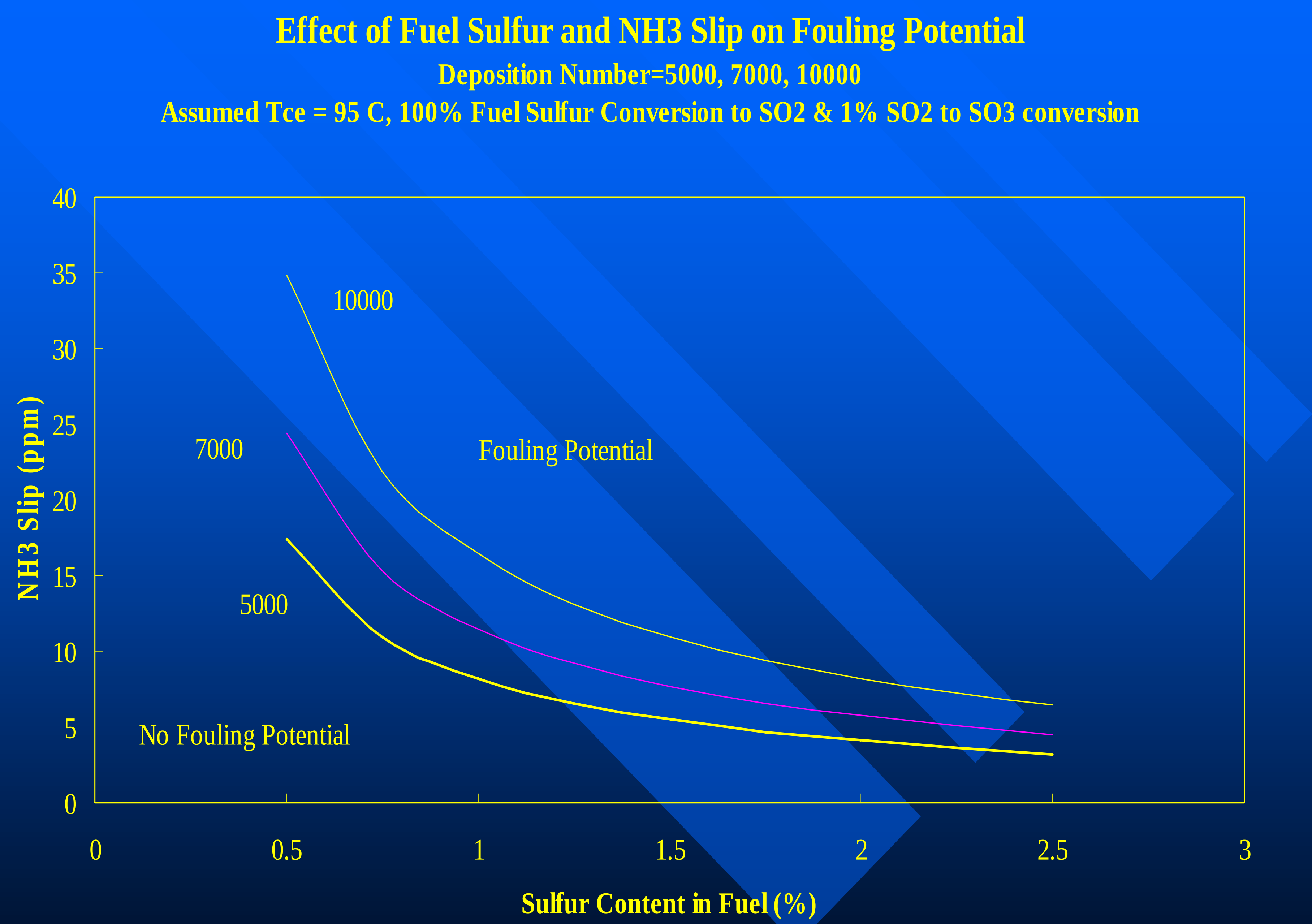
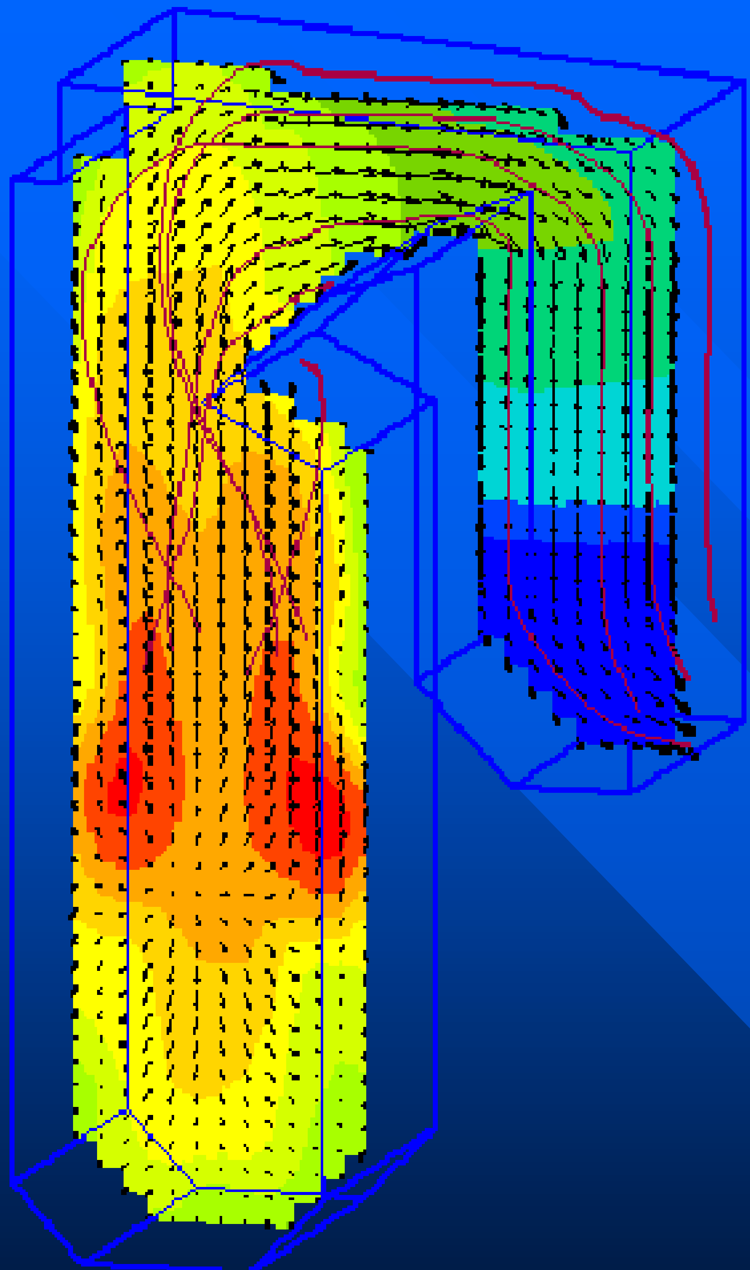

Effect of Fuel Sulfur and NH3 Slip on Fouling Potential
Deposition Number=5000, 7000, 10000
Assumed Tce = 95 C, 100% Fuel Sulfur Conversion to SO2 & 1% SO2 to SO3 conversion
NH3 Slip (ppm)
40
35
30
25
20
15
10
5
0
10000
7000
5000
Fouling Potential
No Fouling Potential
0
0.5
1
1.5
2
2.5
3
Sulfur Content in Fuel (%)

Computer Modeling of Furnace



Step 1: Define the Unit Geometry

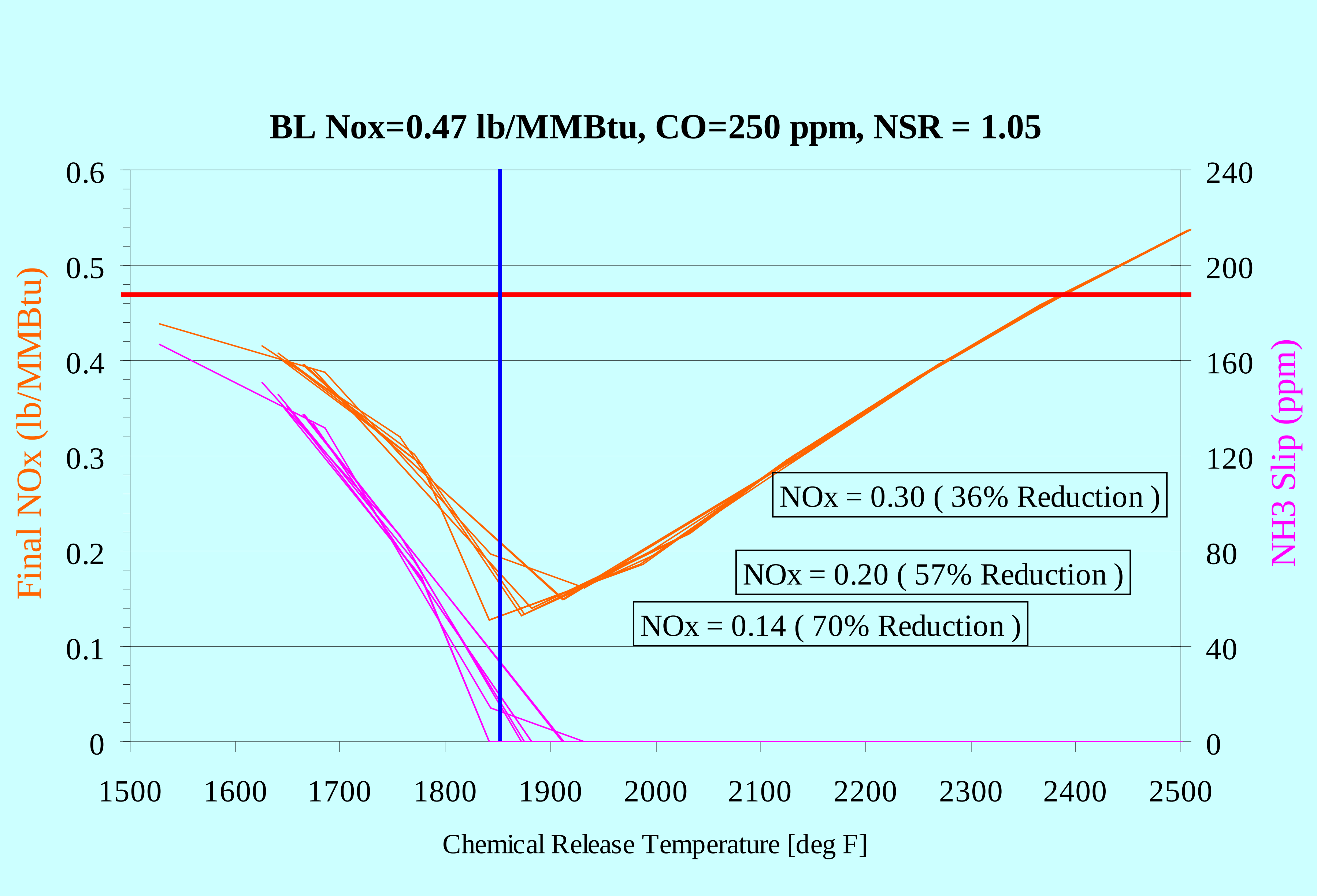
Step 2: Block Out Obstructed Cells and Faces

Step 3: Define Mass and Heat Sources

Step 4: Solve for Flue Gas Temperatures & Velocities

Step 5: Generate Temperature Versus Residence Time Data for CKM

Chemical Kinetics Model



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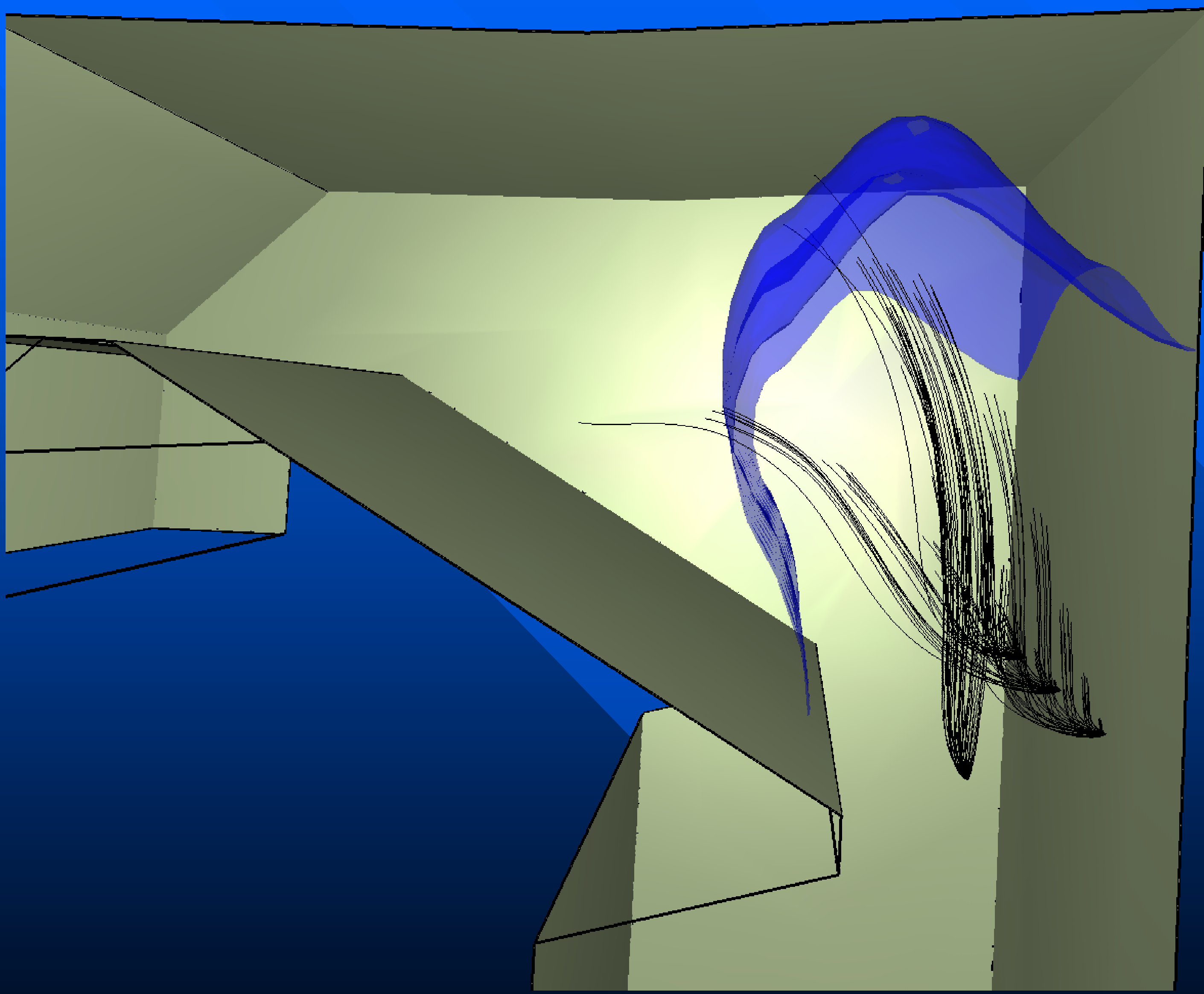
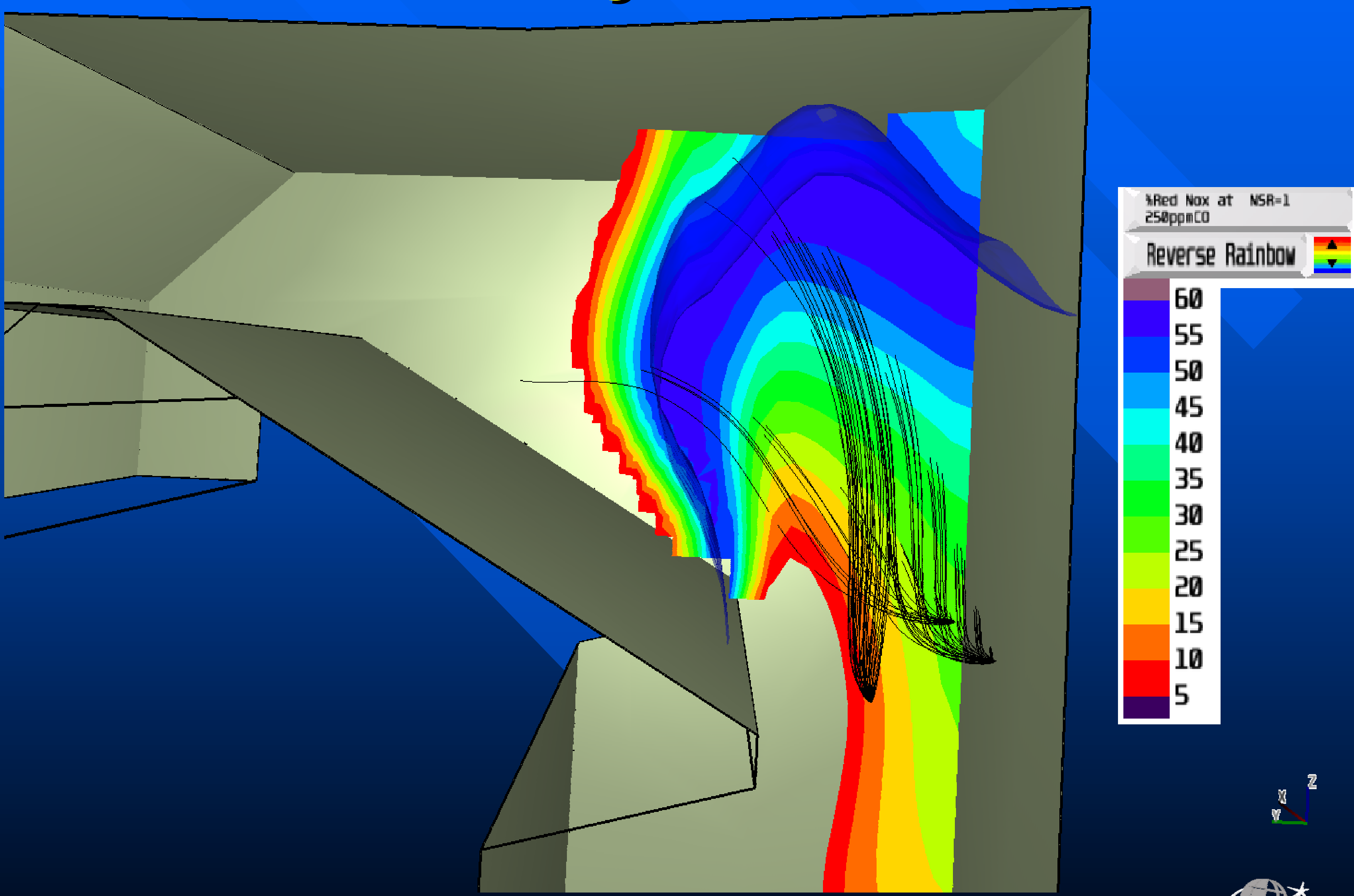
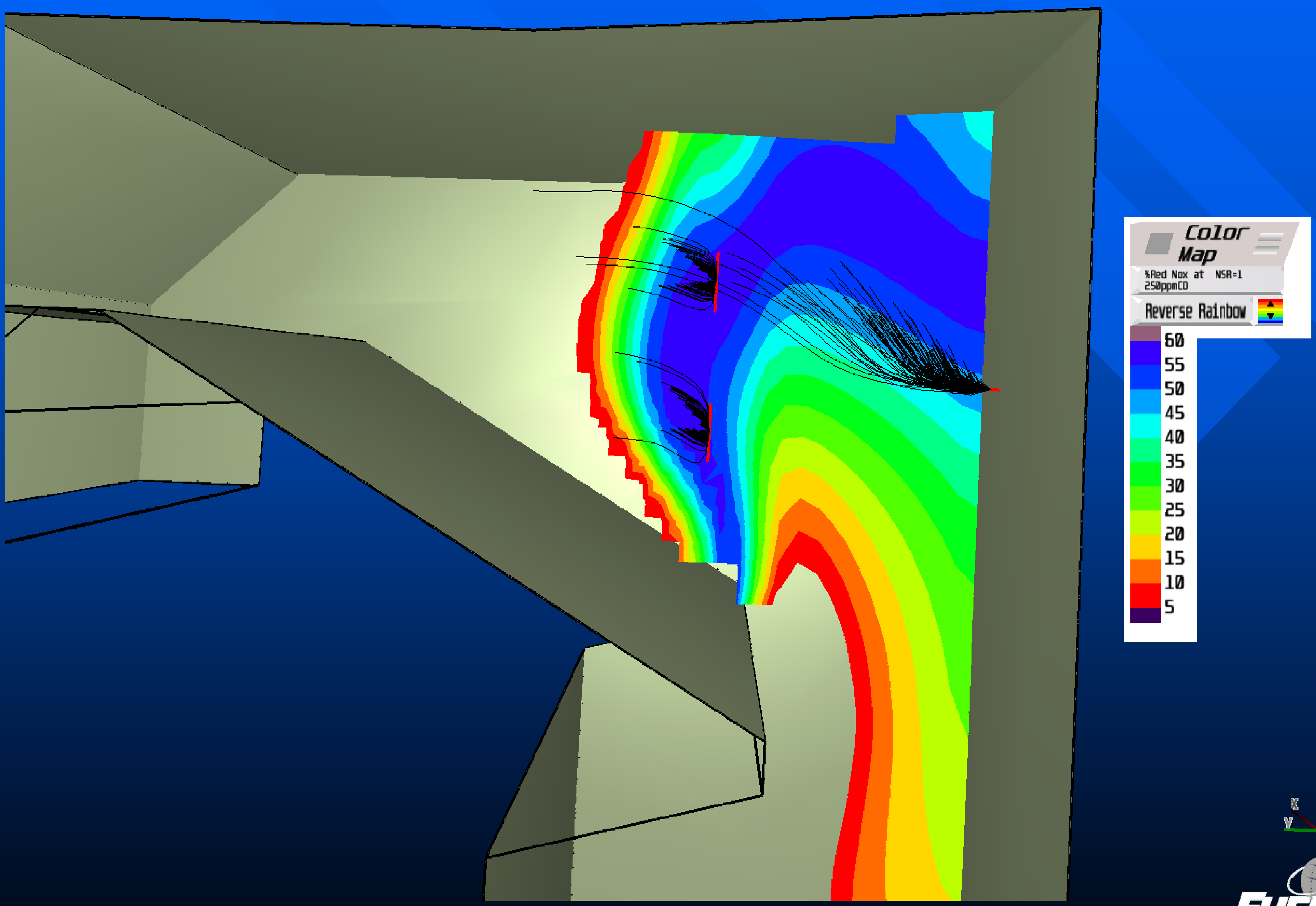
Low-Temperature Limit Surface



NOx Reduction Contour: Wall Injectors



NOx Reduction Contour: Wall Injectors and MNLs



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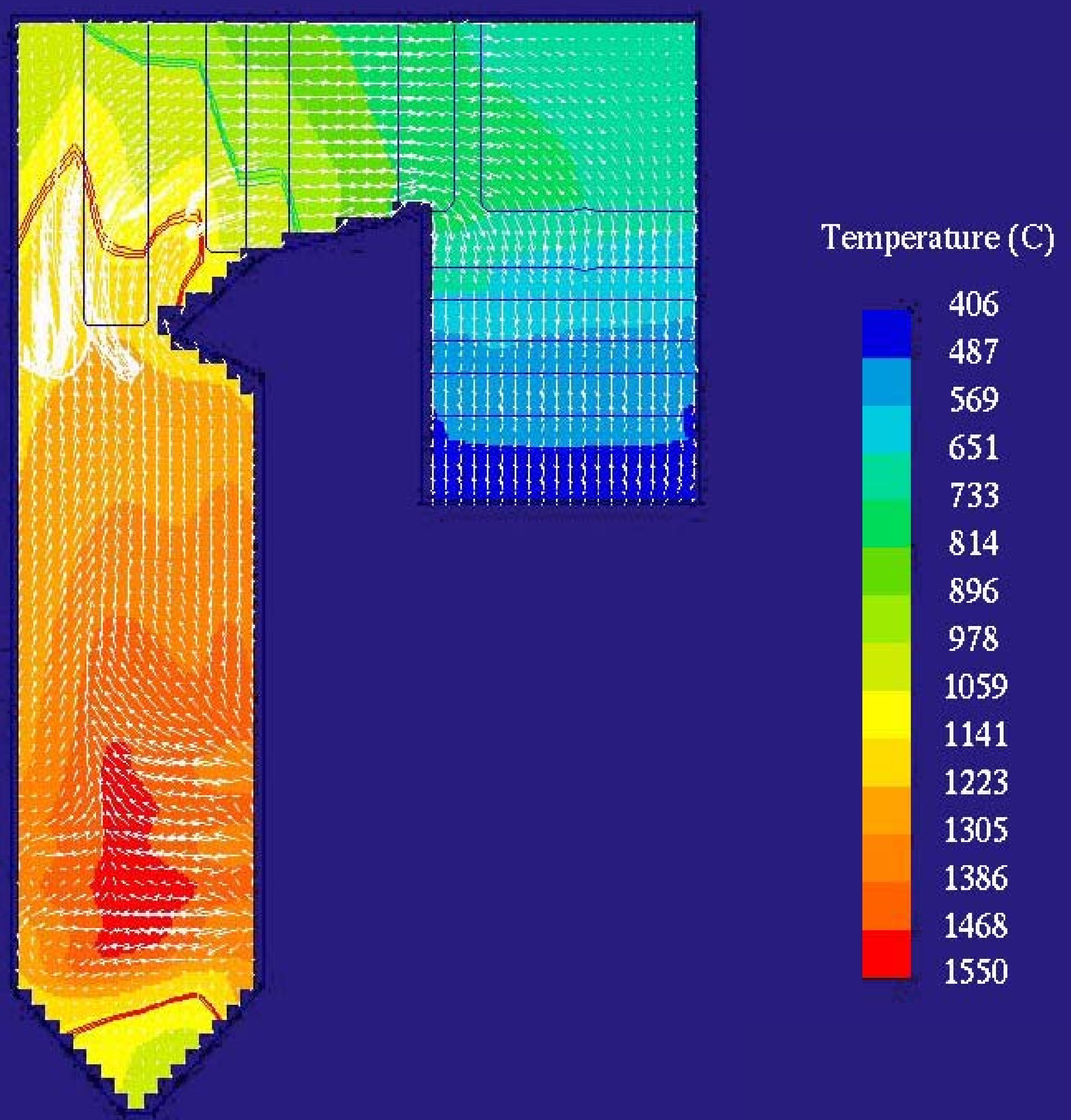
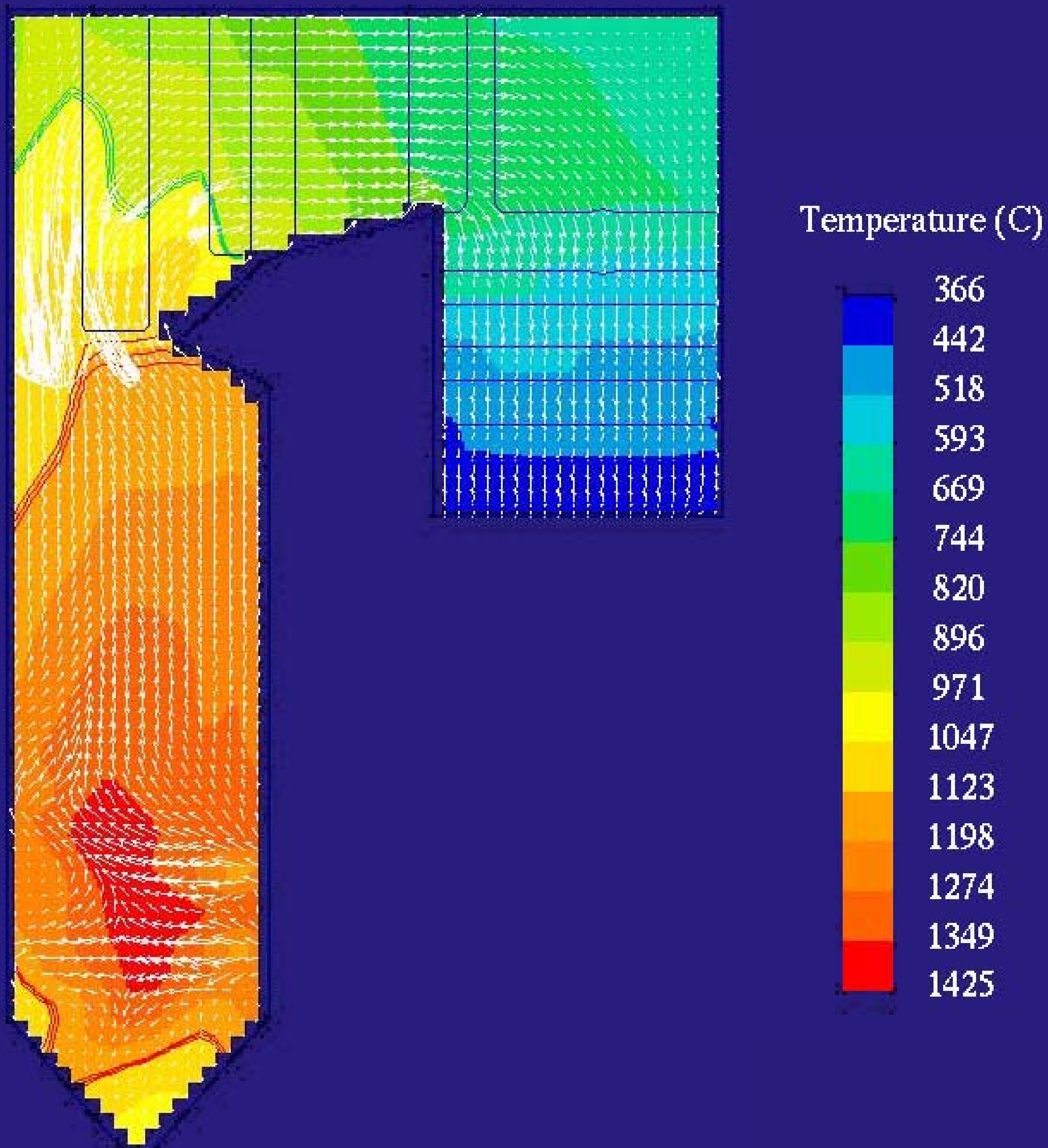
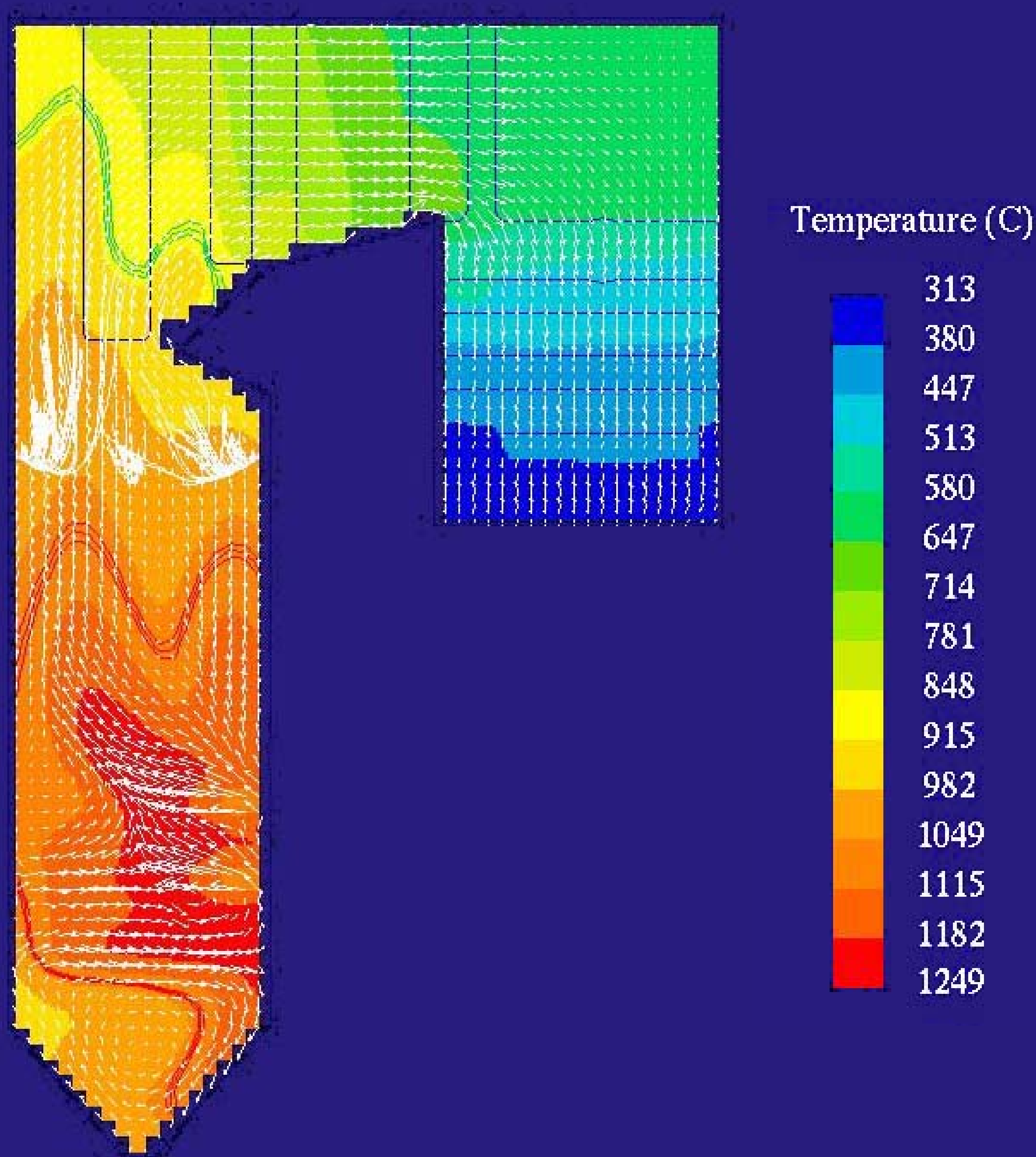
Furnace & Injection Modeling @ 100% MCR



Furnace & Injection Modeling @ 75% MCR



Furnace & Injection Modeling @ 50% MCR



SNCR Critical Process Parameters

- Residence Time
- Temperature
- Baseline NOx
- CO concentration in the injection region
- Fuel Sulfur
- Reagent distribution

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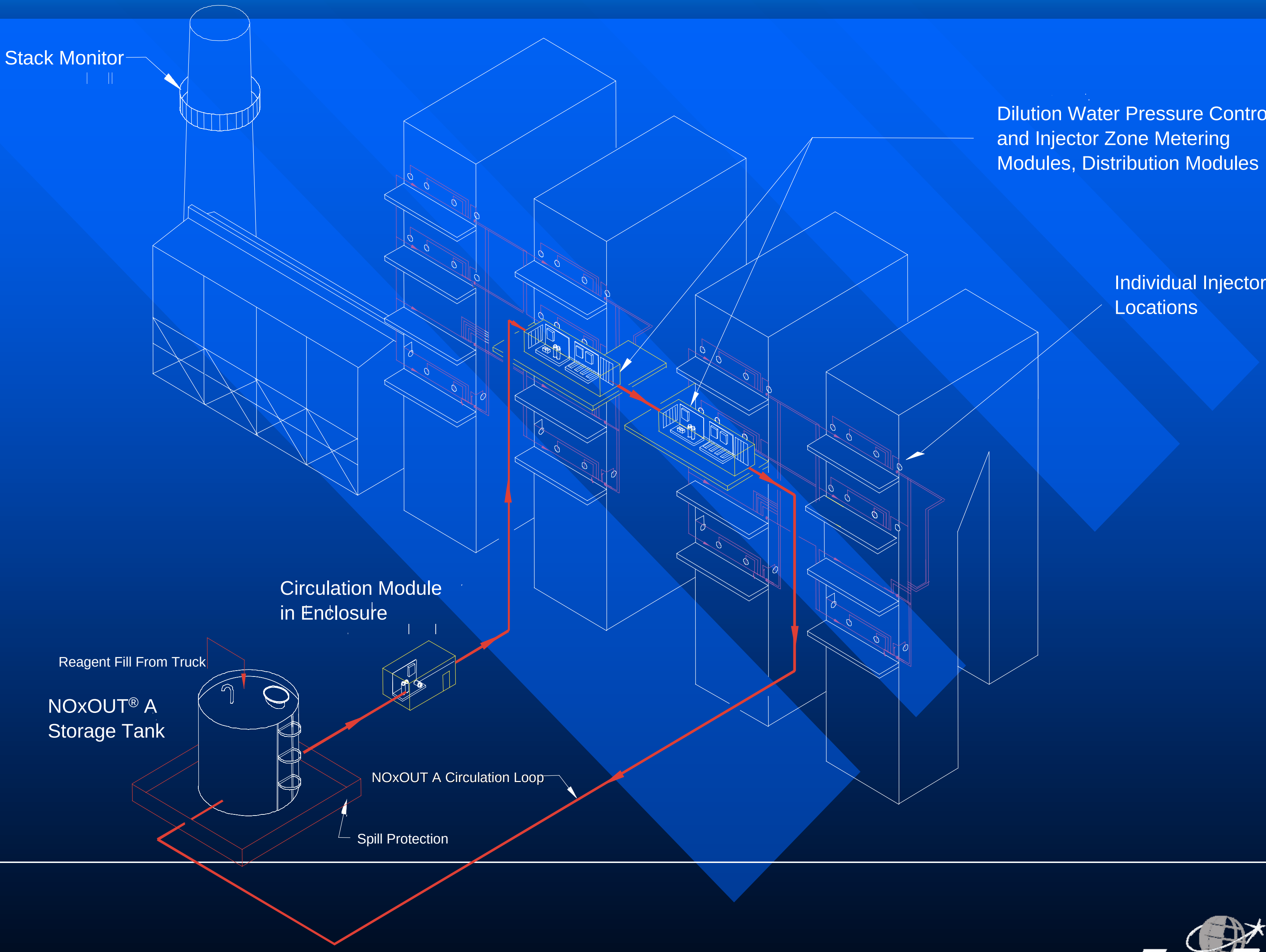
NOxOUT® SNCR PROCESS SCHEMATIC



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Urea Reagent Storage (2 × 25,000 gallon)

Urea Reagent Circulation Module

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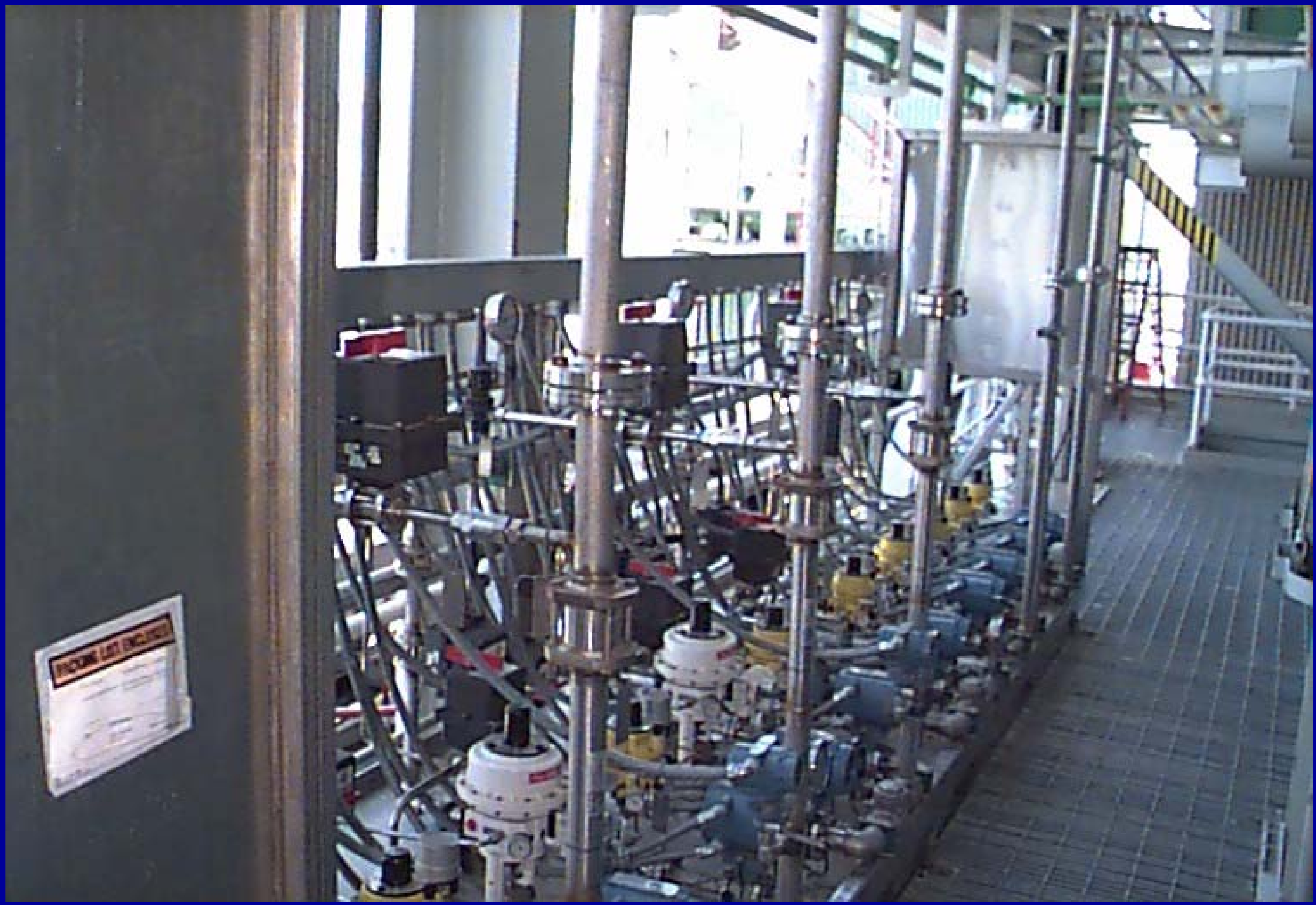
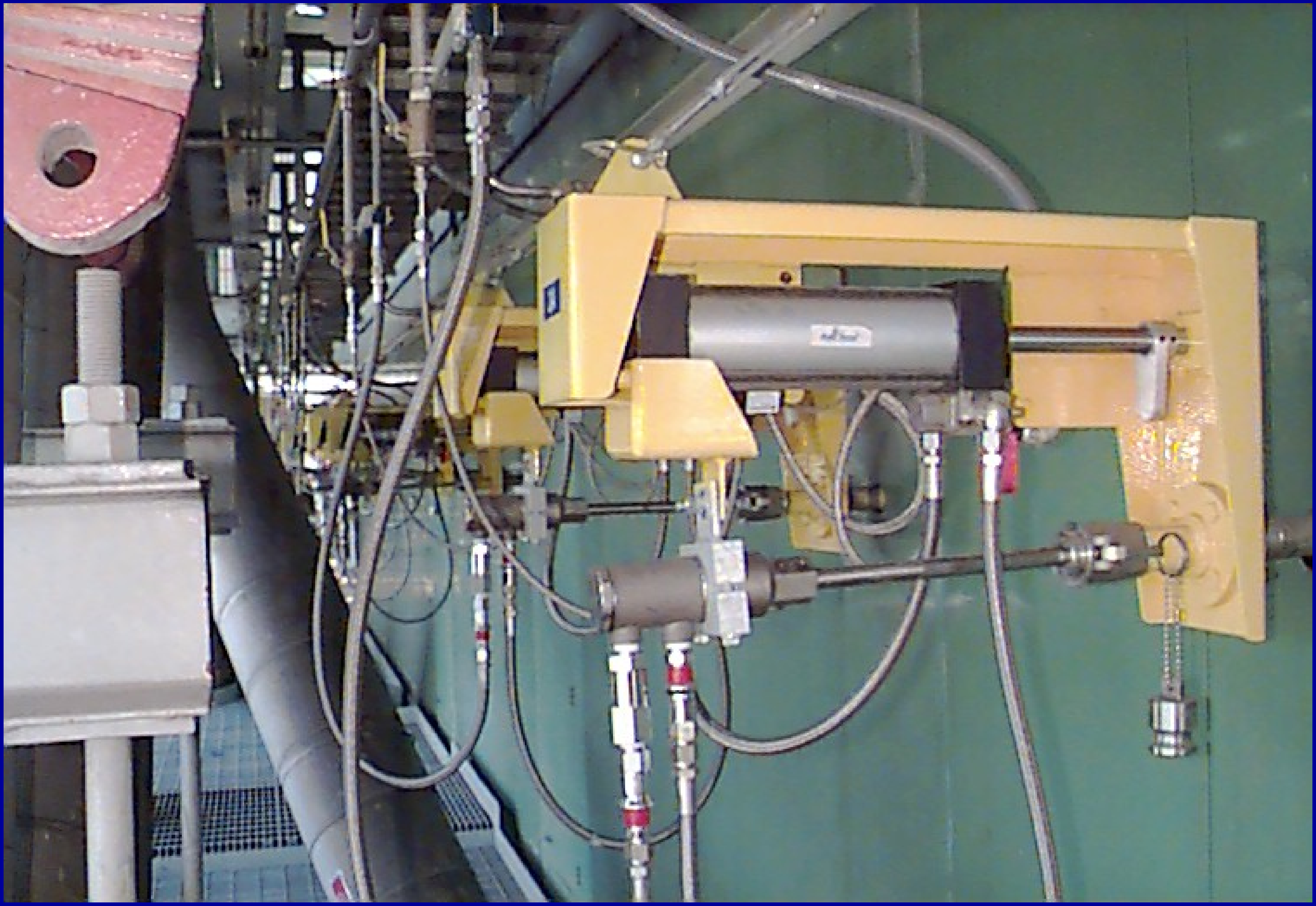
Urea Reagent Metering Module

Independent Zone Metering Module



Three-position Distribution Module

Urea Injector with Automatic Retract Mechanism



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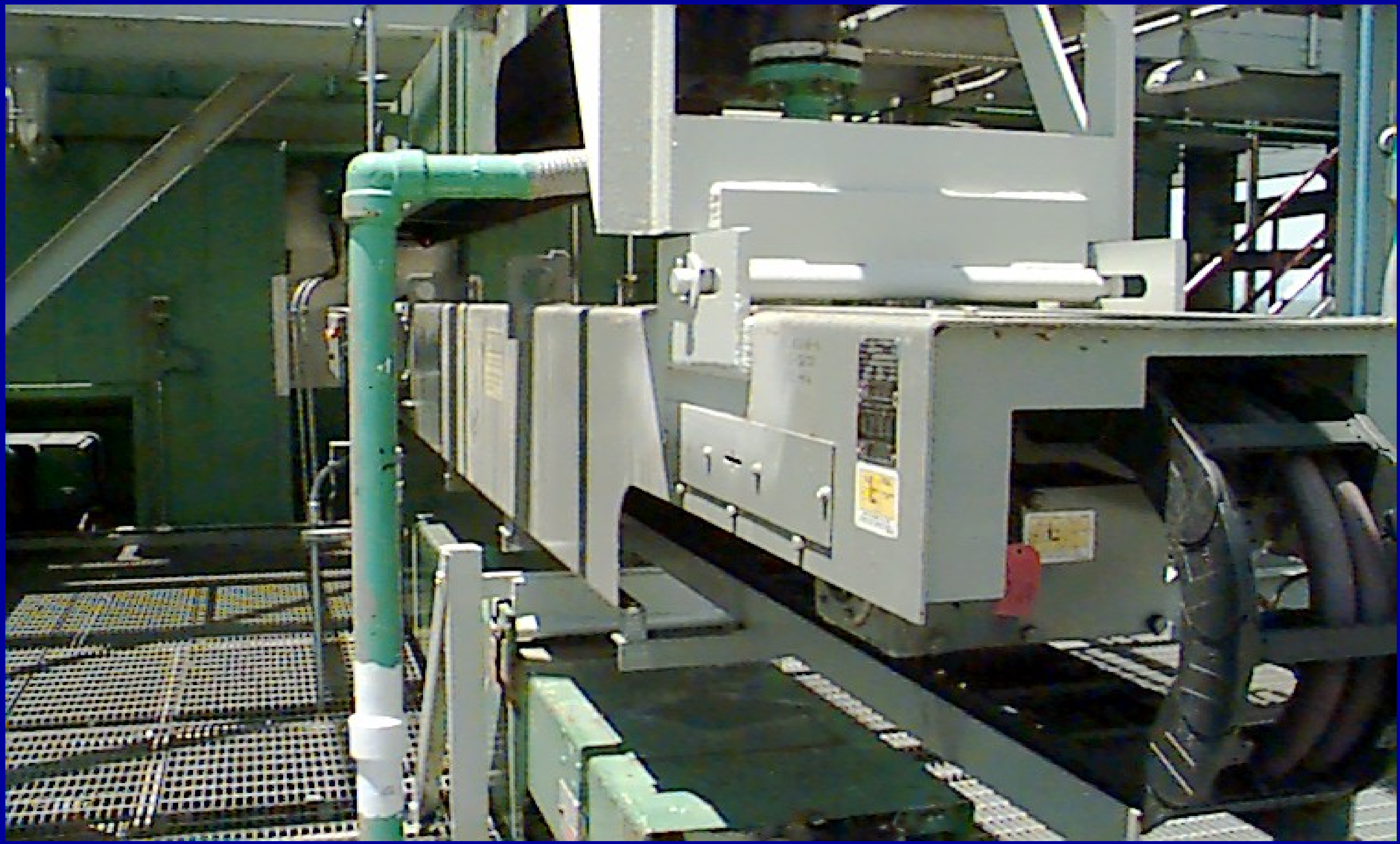
Multiple Nozzle Lance Retract Mechanism



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NOxOUT Process Control

A. Feedforward Control (Look-up Tables)
- Input Signals: Boiler Load and Fluegas Temperature
- Controlling Parameters:
  - » injection zone
  - » chemical flowrate
  - » atomizing air & dilution water pressures

B. Feedback Control (PID Controller)
- Input Signal: NOx CEM
- Controlling Parameter: Chemical Flowrate to each zone

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Utililty Boiler Experience Summary

- Unit Size: 50 ~ 620 MWe
- Fuel Sulfur: 0.2% ~ 3.8%
- Firing Type: T-fired, Cyclone, Front Wall fired (wet and dry bottom), front and rear wall fired, Cell fired
- Fuel: Coal (including PRB), Oil, Gas
- Majority were combined control technologies – LNB/OFA + SNCR
- ~50 Units

Non-Utility Experience

Boiler Types

Circulating Fluidized Bed

Bubbling Fluidized Bed

Stoker, Grate Fired

Incinerators

Industrial

Fuels

Coal – Bituminous and Sub-bituminous

Oil – #2 and #6

Natural Gas

Refinery Gases (High CO)

Municipal Solid Waste

Tire Derived Fuel

Wood

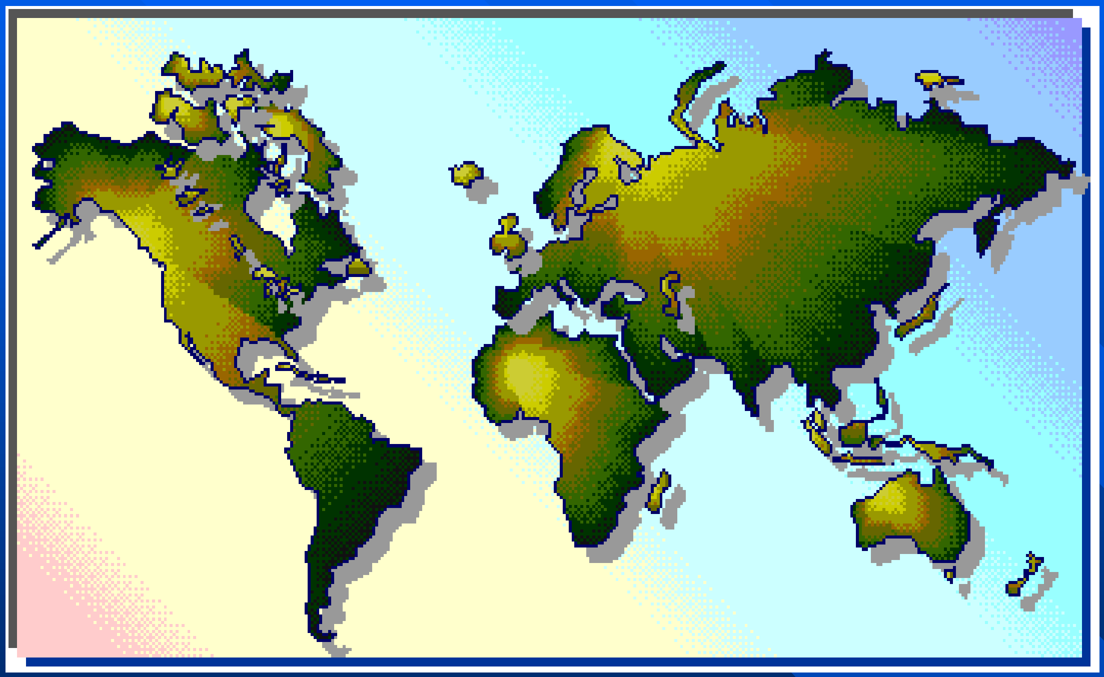
Sludge

General Industry Experience

- Electric Utilities
- Wood-fired IPPs / CoGen Plants
- TDF Plants
- Pulp & Paper
  - Grate-fired
  - Sludge Combustors
  - Recovery Boilers
  - Wellons Boilers
  - Cyclones

- Refinery Process Furnaces
  - CO Boilers
- Petrochemical Industry
- CoGeneration Package Boilers
- Municipal Solid Waste
- Process Units
- Cement Kilns

EXPERIENCE by GEOGRAPHY



- United States
- Czech Republic
- France
- England
- Portugal
- Germany
- Italy
- Poland
- Spain
- Sweden
- Switzerland
- Turkey
- Korea
- Taiwan

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