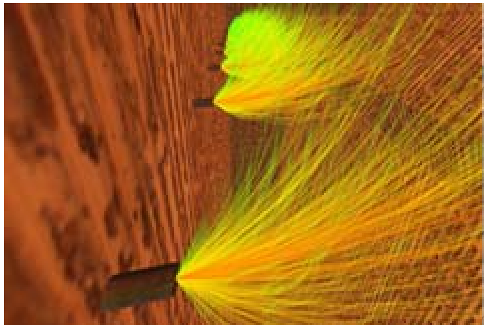
Reinhold Environmental Ltd.

2010 NOx-Combustion Round Table & Expo Presentation

February 8 & 9, 2010   Chattanooga, TN





2010 NO_x-Combustion/PCUG Conference

Hybrid In-Duct Advanced SCR Technologies

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Fuel Tech, Inc.
January 30, 2010

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Fuel Tech, Inc.
January 30, 2010

Agenda

- Fuel Tech Introduction
- Advanced SCR Basics
- ASCR Design
- Discussion

Fuel Tech Overview

- FUEL CHEM® Technology –
  - Slag and Corrosion Reduction with Efficiency Improvements
- NO_x Reduction Technologies
  - LNB / OFA
  - SNCR – “NOx-OUT® and HERT®”
  - Advanced SCR – the Right Combination of Technologies to Suit Individual Needs
- Services
  - Fluid Dynamics Modeling and Optimization Studies of APC Equipment
  - SCR Consulting and Catalyst Management Services

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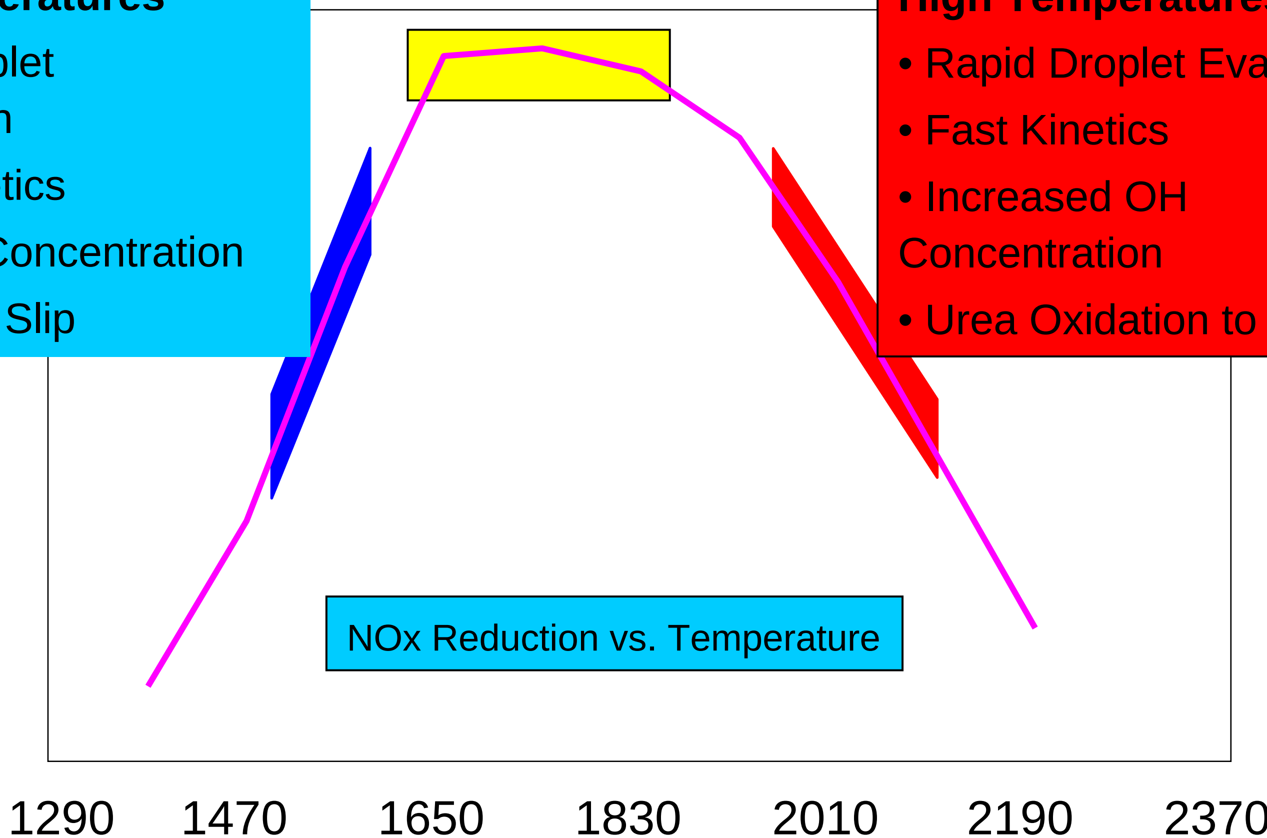
NO_x Reduction Technologies - SNCR

Low Temperatures

- Slow Droplet Evaporation
- Slow Kinetics
- Low OH Concentration
- Ammonia Slip

High Temperatures

- Rapid Droplet Evaporation
- Fast Kinetics
- Increased OH Concentration
- Urea Oxidation to NOx

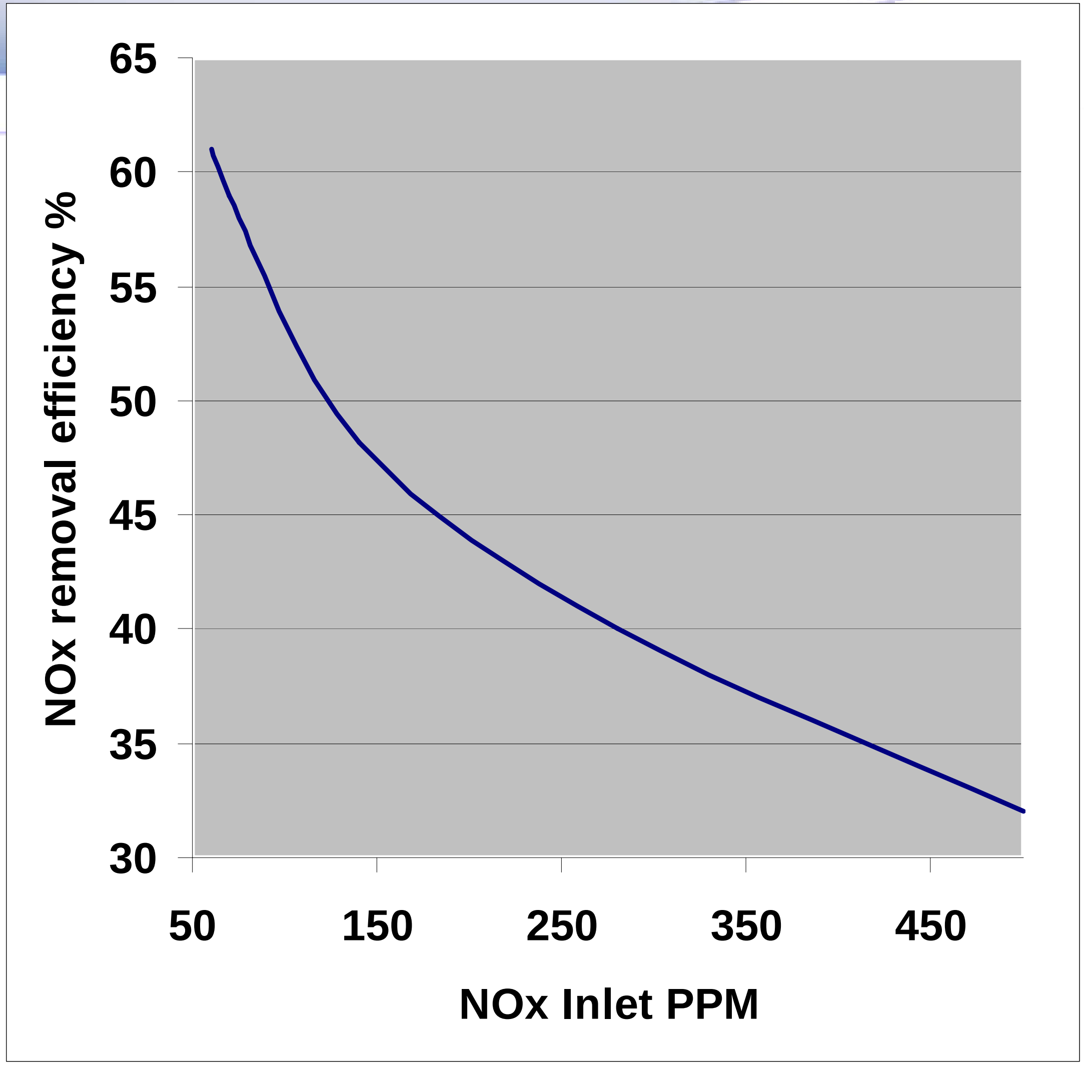


- 25-60% NO_x Reduction

NO_x Reduction Technology - ASCR

- Layered Technologies of LNB/OFA/SNCR/SCR as Needed
- Single Layer SCR Catalyst
  - No need to “Go to Ground”
- Ammonia Slip from SNCR Provides Reagent for Catalytic Reactions
- Or Additional AIG
- NOx Reduction Performance - 50-90%
- Lower Capital Cost compared to Full Scale SCR

NO_x Reduction Technology - ASCR



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ASCR/SCR Cost Comparison

- Capital Cost
  - Very Limited Steel Structure
  - Less Catalyst
  - Less Duct Work
- O&M Cost
  - More Catalyst Replacement
  - More Reagent Consumption in SNCR
  - Less Pressure Drop
- Lower Total Cost Except For Very High Capacity Factors
- Break-Even Point Site Limited

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Catalyst Consumption

- SCR For 600 MW Unit 85 % Reduction 20 Years Life
  - 600 m^3 Initial Loading
  - 200 m^3 Addition
  - 5 x 200 m^3 Exchange
  - Total Catalyst Demand 1,800 m^3
  - NPV $7,426,000
- ASCR For 600 MW Unit 85 % Reduction 20 Years Life
  - 200 m^3 Initial Loading
  - 9 x 200 m^3 Exchange
  - Total Catalyst Demand 2,200 m^3
  - NPV $7,787,000

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Reagent Consumption

- SNCR NSR 1.4 to 2 Depending On NO_x Removal Efficiency
- SNCR + Catalyst Has Higher Reagent Demand Than SCR
- LNB/OFA + SNCR + Catalyst Has Lower Reagent Demand Than SCR

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Pressure Drop

- ASCR Pressure Drop Is 4 To 6 iwg Lower Than SCR

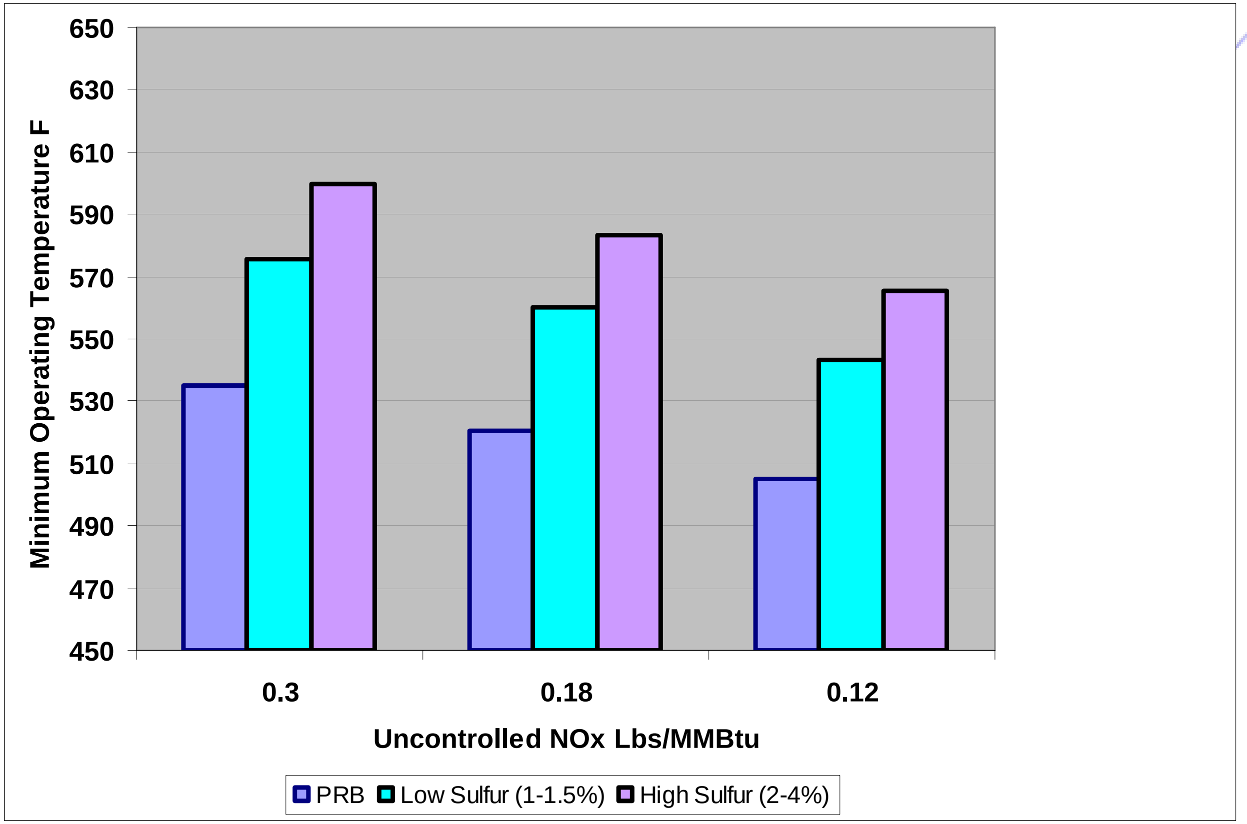
Reasons For Combination Of Technologies

- Lower Electricity Demand Due To Current Economical Situation
- Political Reason: Global Warming/ Renewable Energy
  - Example: UK plans For 25 % Electricity From Off-Shore Wind Farms By 2030
- Broader Operating Range Required
- Less Total Cost: Poland

ASCR Challenges

- Physical Space
- Outage Time
- Flow Distribution

ASCR Operating Range



China, Light and Power Castle Peak B Units 1-4

China, Light and Power Castle Peak B Units 1-4

- Four 685 MW Units
- “Two Shift” Operation
- BOFA/In-Duct Catalyst Retrofit
- More Than 50 % NO_x Reduction
- Potential For Higher Reduction With SNCR Retrofit
- Catalyst Face Design Velocity 25 fps
- OEM Doosan Babcock

China, Light and Power Castle Peak B Units 1-4

- Fuel Tech Scope
  - CFD
  - Experimental Model
  - AIG Design
  - Mixer Design
  - GSG Design
  - Ash Screen Design

China, Light and Power Castle Peak B Units 1-4

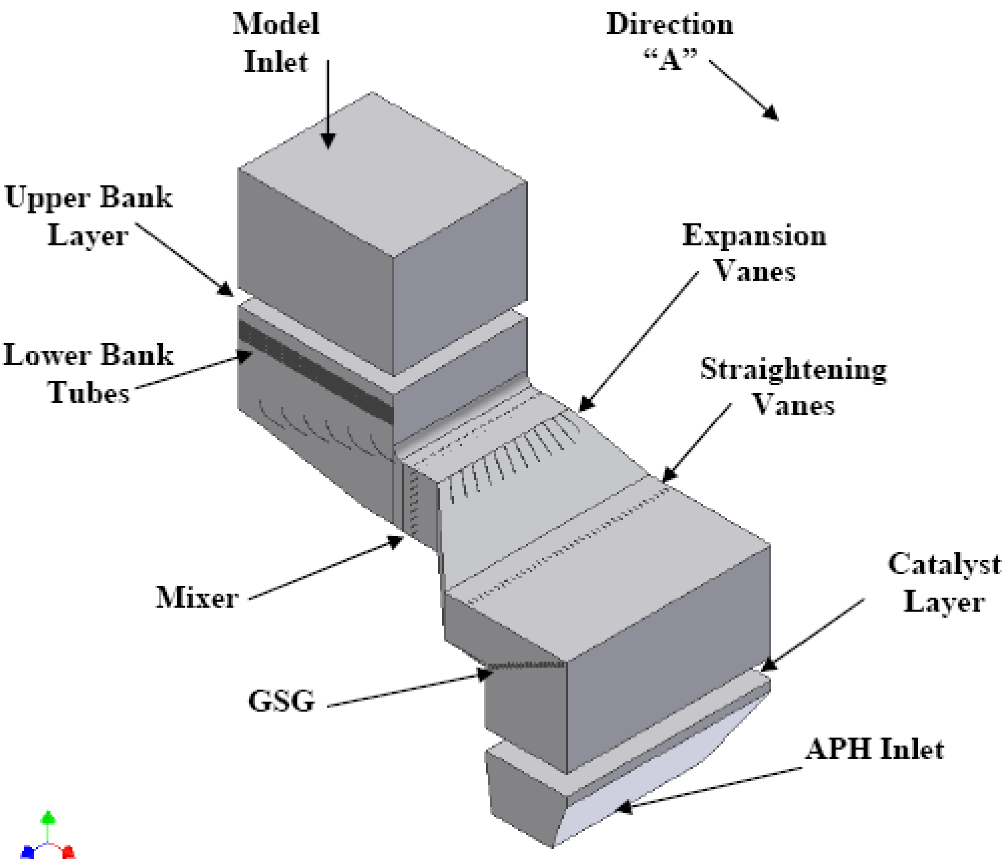


Figure 5: CFD model of Economizer to APH System

China, Light and Power
Castle Peak B Units 1-4

China, Light and Power Castle Peak B Units 1-4

	Goal	CFD				Experimental			
	+/- 10%	RMSE	+/- 10%	+/-15%	+/- 20%	RMSE	+/- 10%	+/-15%	+/- 20%
Velocity at Catalyst	100%	5.10%	96%	100%	100%	5.8%	94%	98%	100%

	Goal		CFD				Experimental			
	+/- 5%	+/- 10%	RMSE	+/- 5%	+/-10%	+/- 15%	RMSE	+/- 5%	+/-10%	+/- 15%
NH_3 at Catalyst	90%	100%	4.10%	85%	98%	100%	2.96%	90%	100%	100%
NH_3/NO_x Ratio at Catalyst	90%	100%	4.39%	83%	98%	100%				

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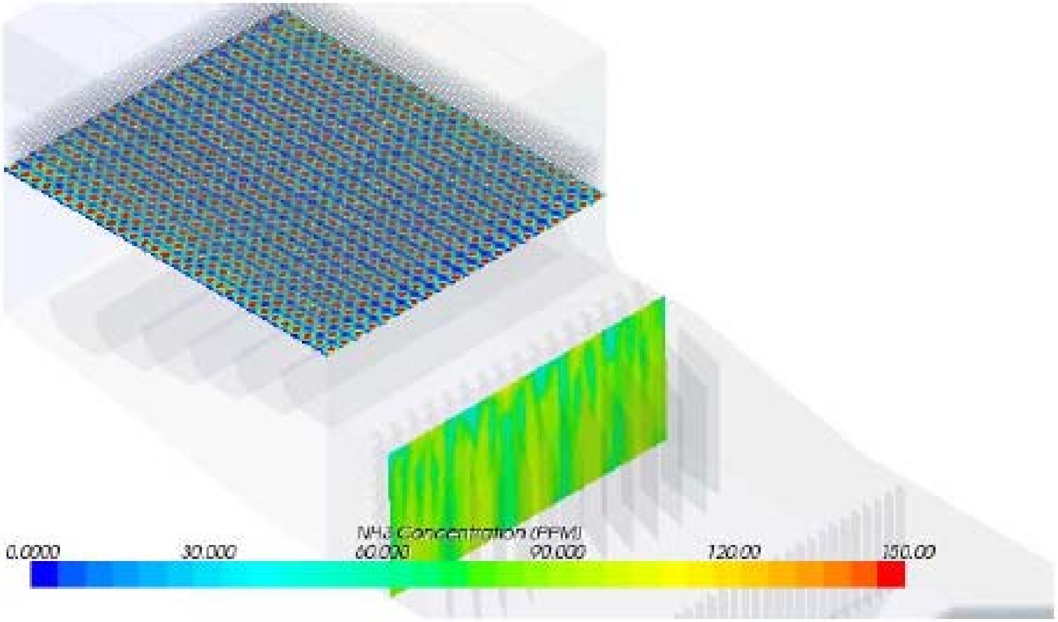
China, Light and Power Castle Peak B Units 1-4



China, Light and Power
Castle Peak B Units 1-4

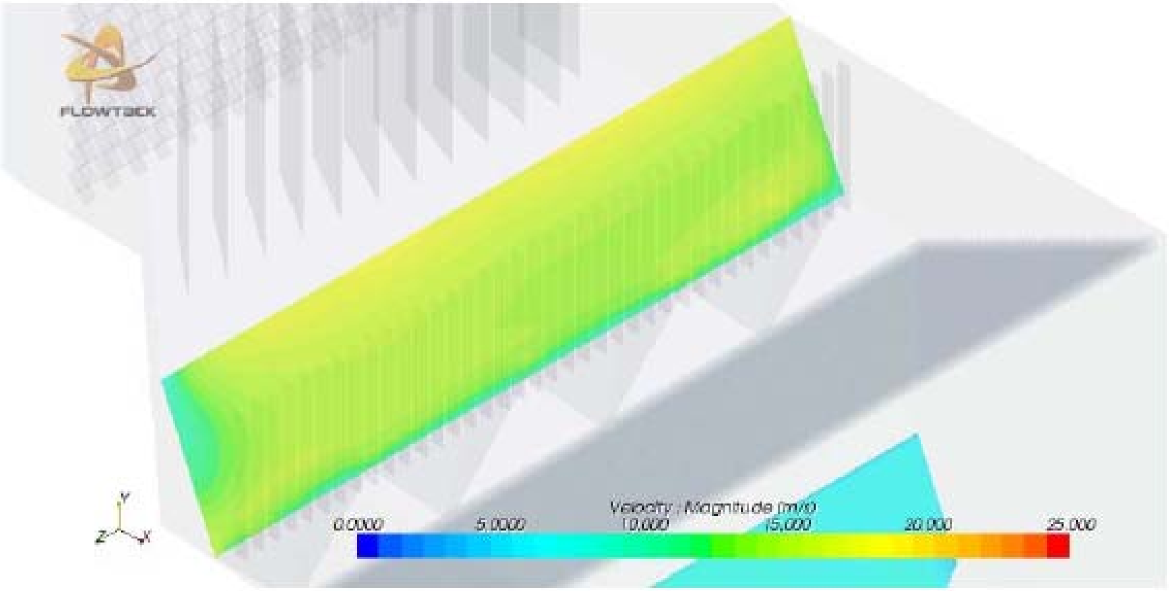
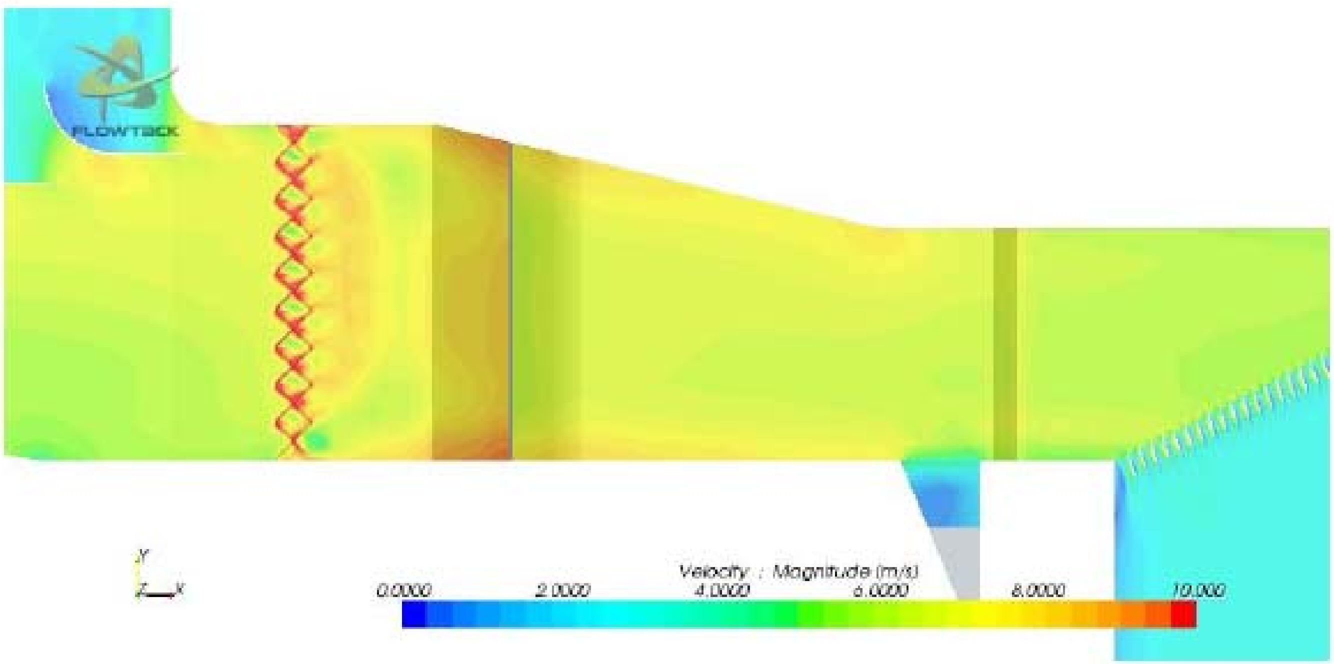


Figure 15: Full Load Velocities at Potential LPA Screen Location

China, Light and Power Castle Peak B Units 1-4



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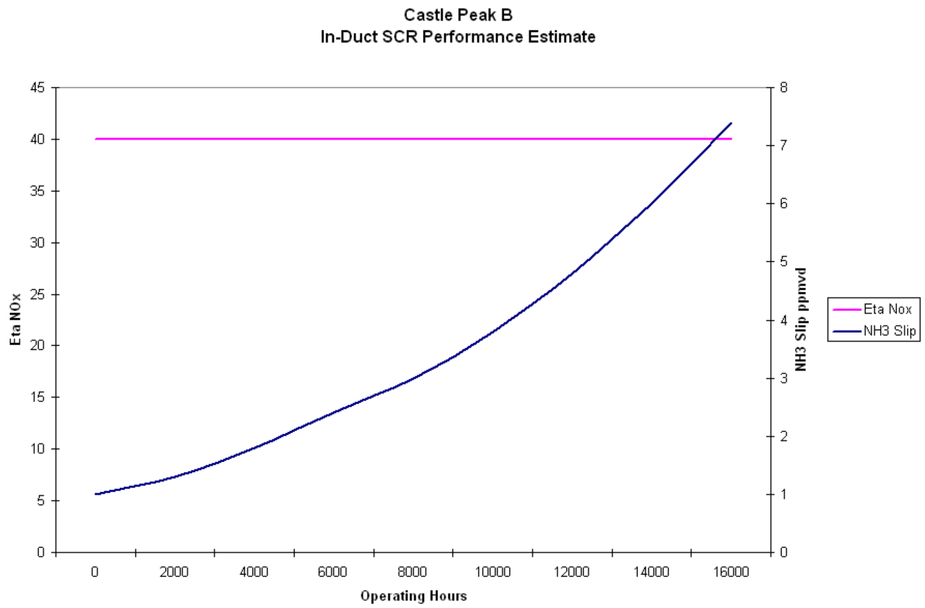
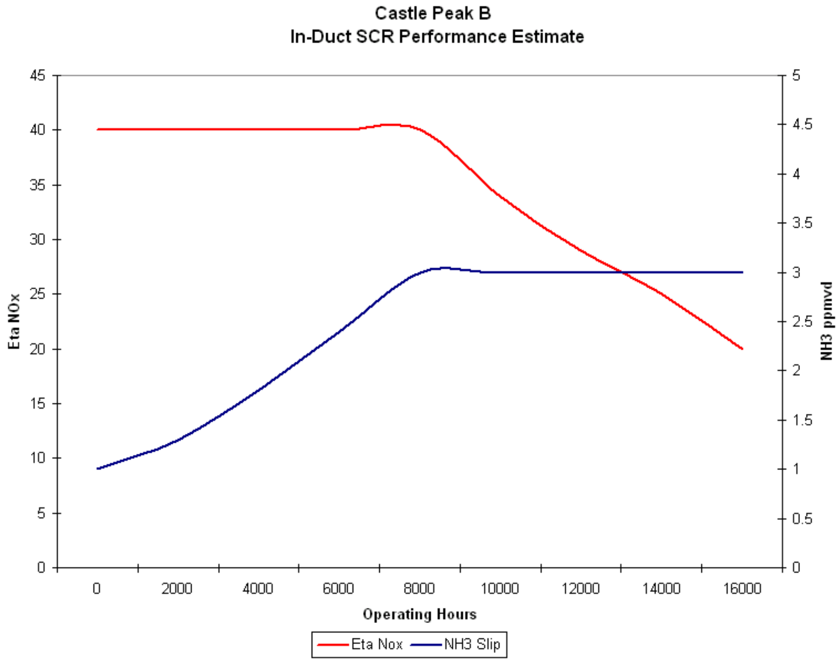
China, Light and Power Castle Peak B Units 1-4



China, Light and Power Castle Peak B Units 1-4

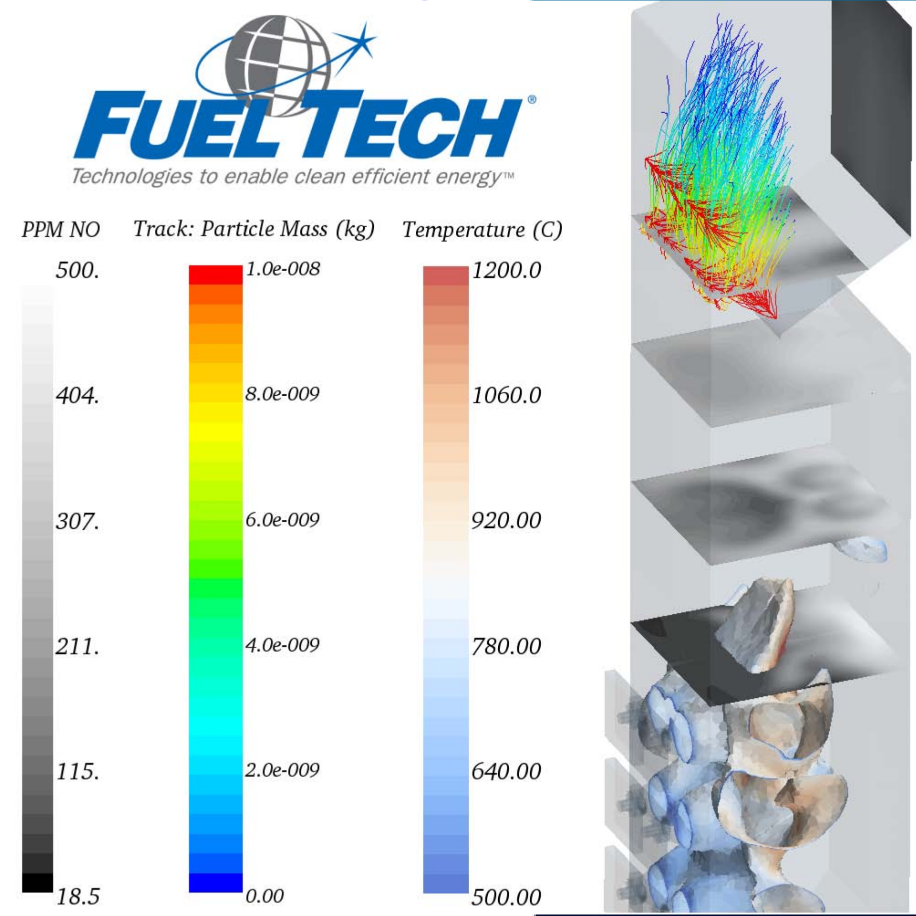


Current Status

- First Unit Is In Operation
- The Unit Passed The Performance Test
  - NO_x Reduction Guaranteed At Beginning of Life Time 40 %, Achieved 42 %
  - Ammonia Slip Guaranteed At Beginning of Life Time 3 PPM, Achieved 2.5 PPM

ASCR
CFD Study

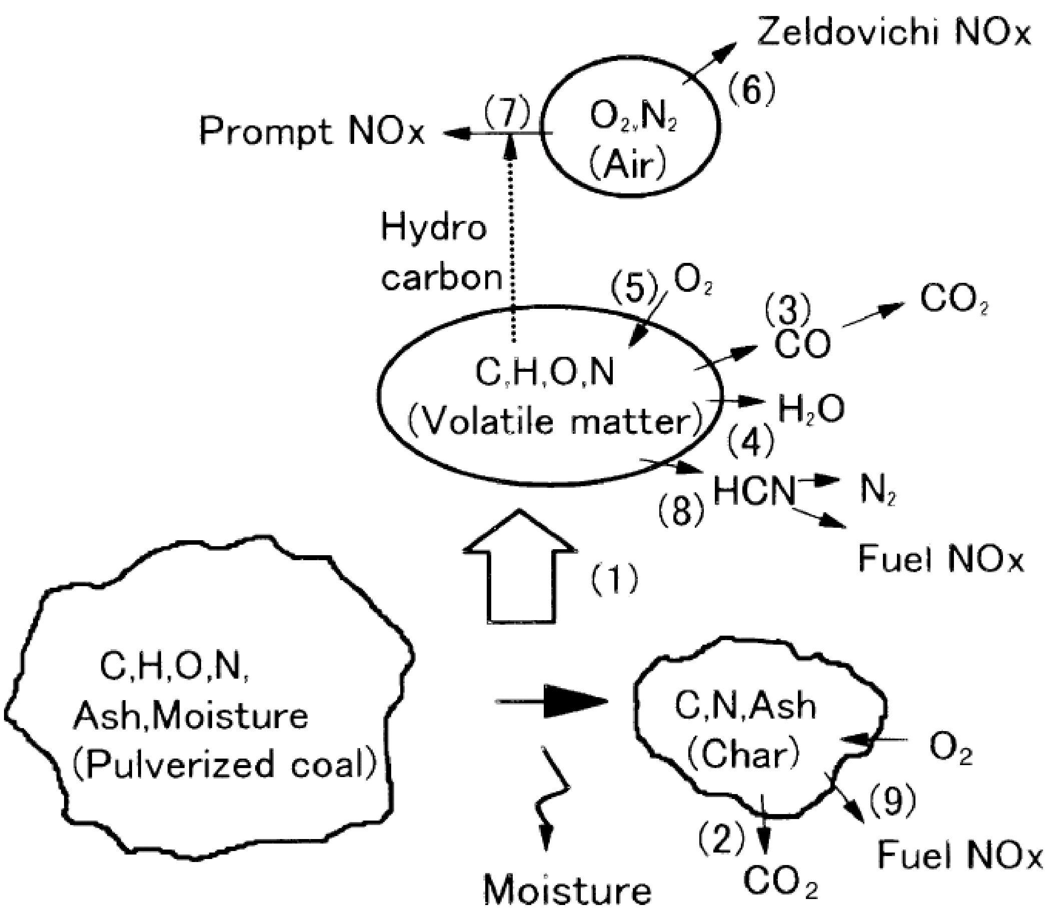
- Computational modeling necessary during design phase for any retrofit installation
- Provides proof of concept NOx reduction predictions
- Combustion Modifications + SNCR + SCR



Products of Combustion

Kurose et al.

- Coal



Products of Combustion

Zhou et al.

- Pyrolysis
  - Product are fuel dependent

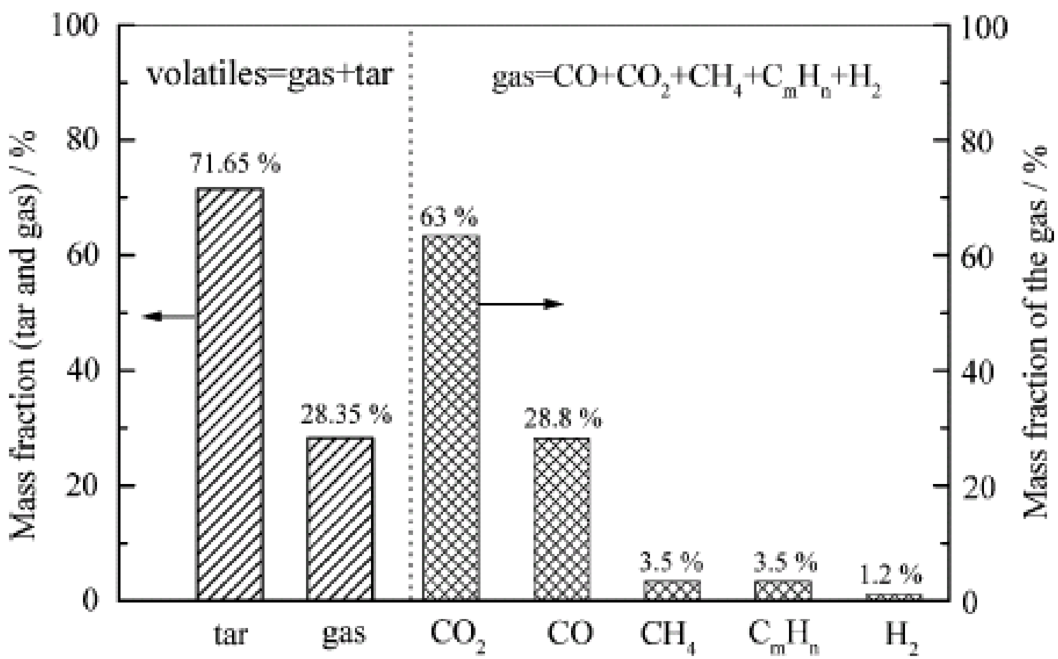


Fig. 2. Yields of pyrolysis products (dry basis).

Coal Combustion Modeling Basics

- Lagrangian particle tracking
- Drying by Clausius-Clapyeron
- Pyrolysis obeys Arrhenius rate and produces tar, light volatiles, char and ash per literature, per fuel
- Tar and light volatile oxidation per Arrhenius rates in literature
- Char combustion controlled by mixed gas film diffusion and chemical reaction
- Fuel N: Volatile HCN / Volatile NH3 / Char N per literature, per fuel
- Fuel and Char N oxidations controlled by Arrhenius rates, per reduced mechanism in literature
- +Zeldovich (Thermal) NOx

Plus NOx creation and destruction

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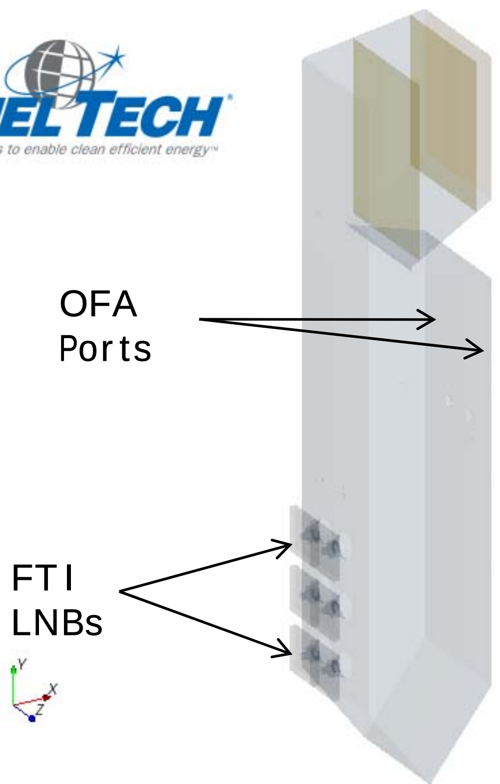
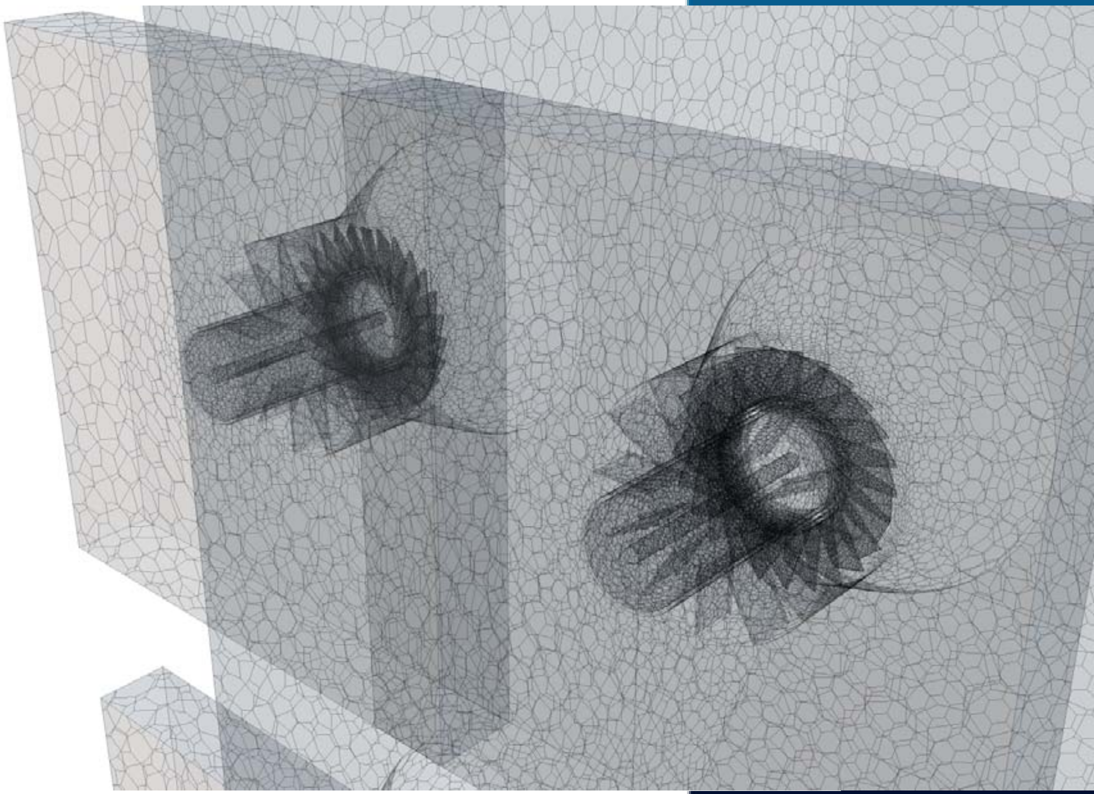
ASCR Test Case: Combustion Mods Design

- 32 MW, B&W front wall-fired unit with 6 burners
  - 29,334 lb/hr Coal; 372,187 lb/hr Air (14% excess)
  - Coal Heating Value: 11,291 BTU/lb
  - Primary/secondary/OFA splits
    - Primary: 63,510 lb/hr (17.1%)
    - Secondary: 234,239 lb/hr (62.9%)
    - OFA: 74,438 lb/hr (20%)
  - Baseline NOx: 0.42 lb/mmBTU
- ASCR Design
  - Combustion Mods: 21% removal (0.33 lb/mmBTU)
  - SNCR: 20% removal (0.26 lb/mmBTU)
  - SCR: 25% removal (0.195 lb/mmBTU)
  - Total: 53.5% removal

Boiler Geometry

>7 million computational cells





Baseline Case

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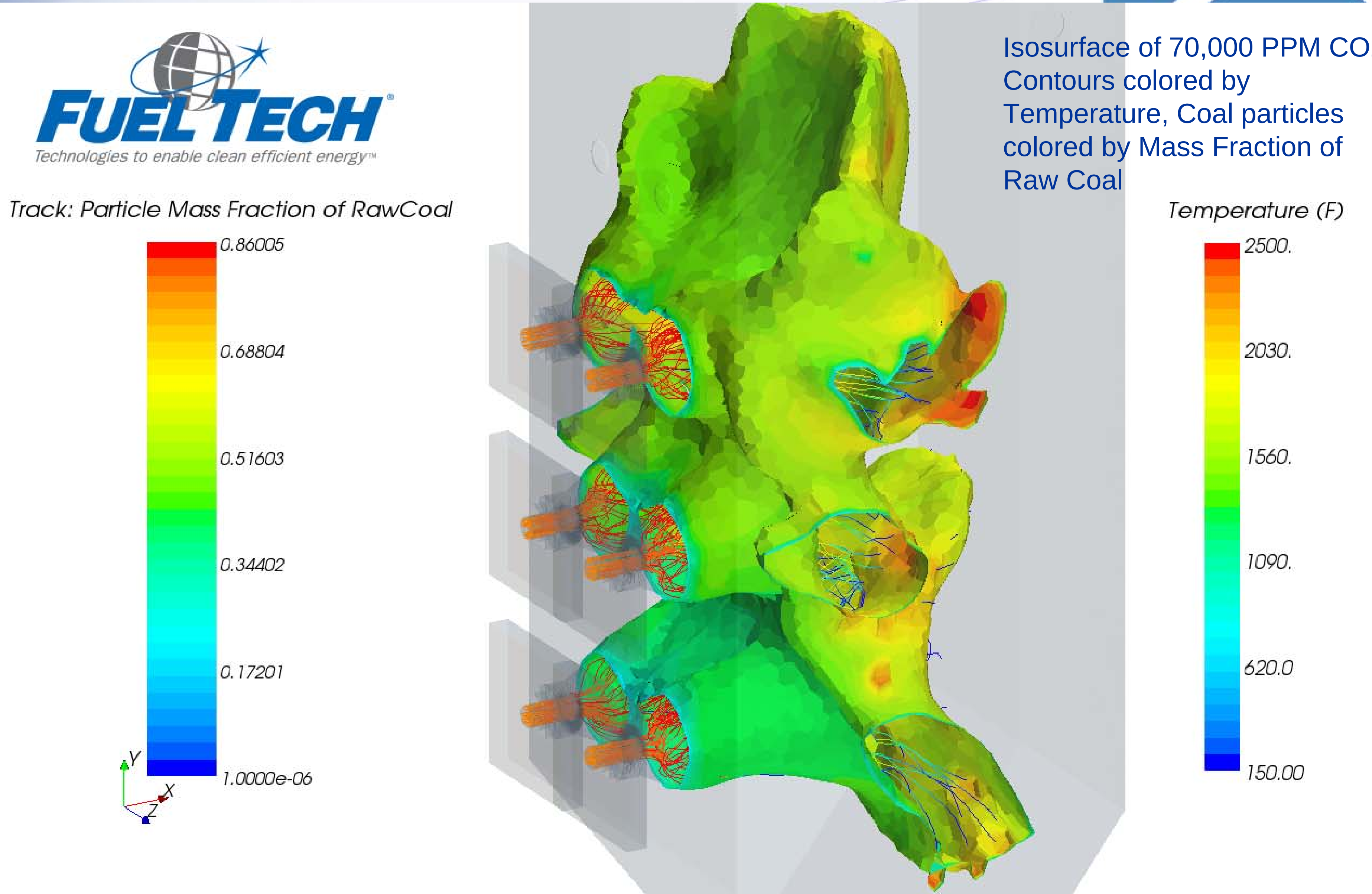
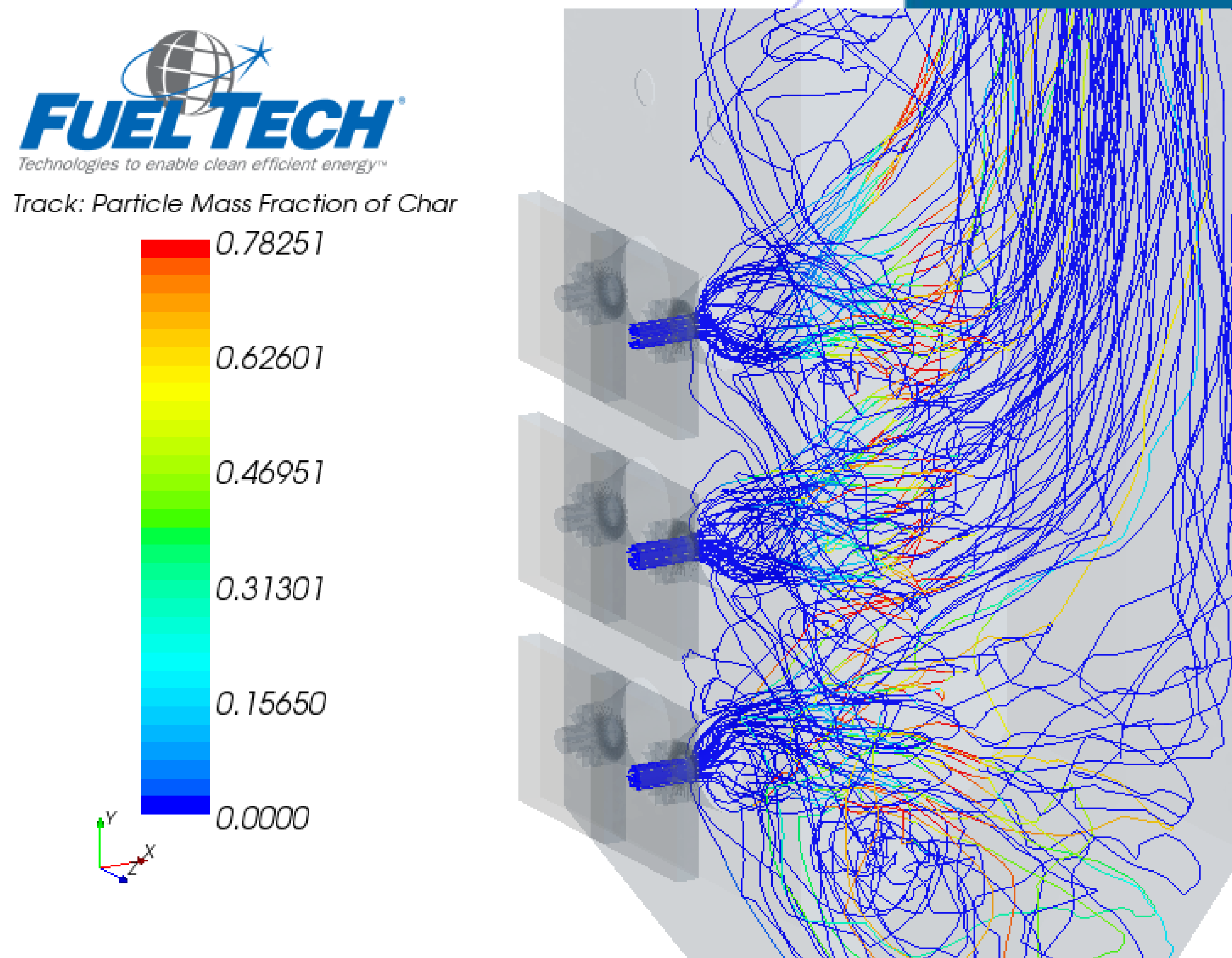
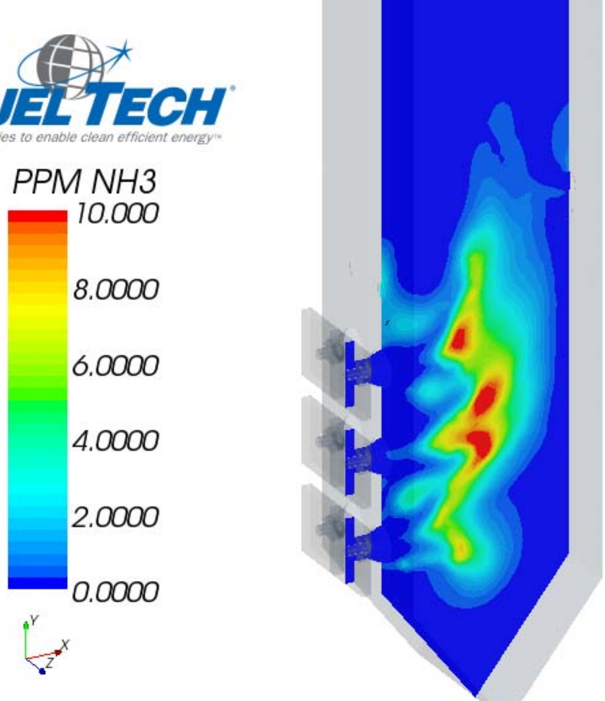


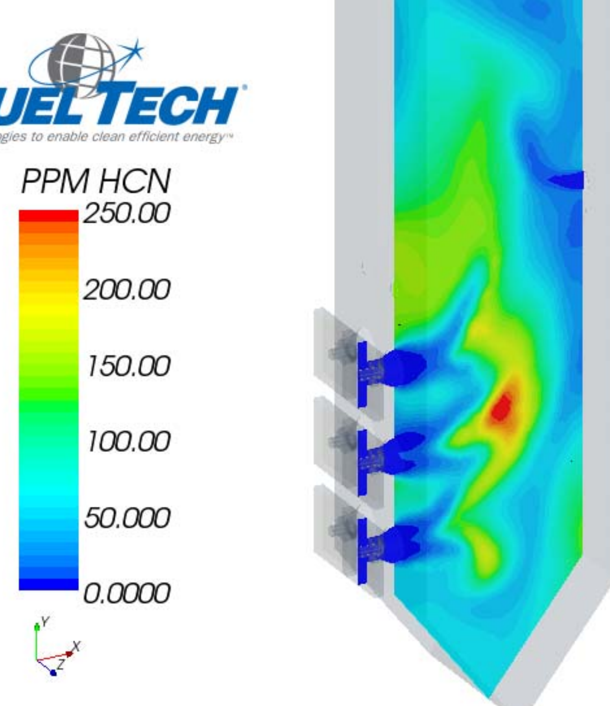
Isosurface of 70,000 PPM CO_2, Contours colored by Temperature, Coal particles colored by Mass Fraction of Raw Coal

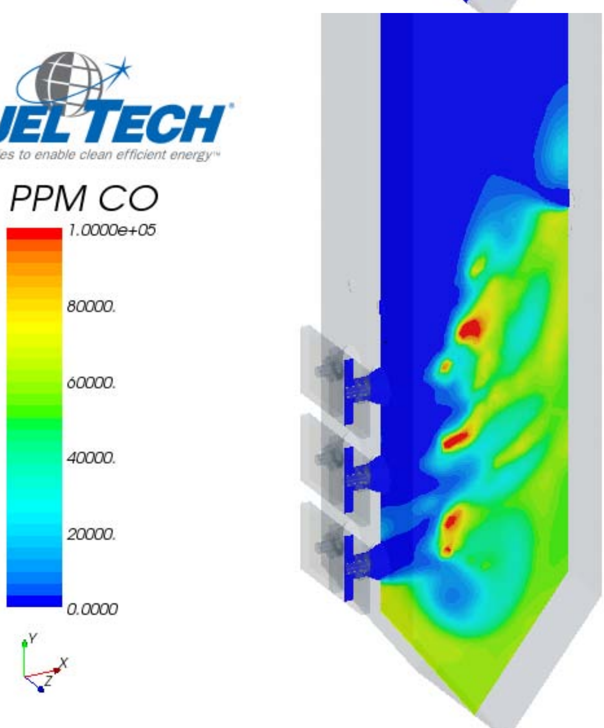
Baseline Case

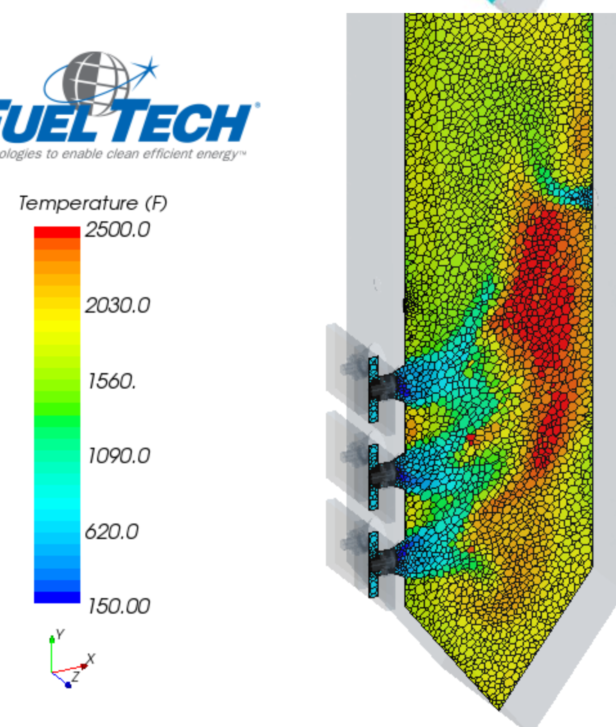
- Coal Particle Char Mass Fraction



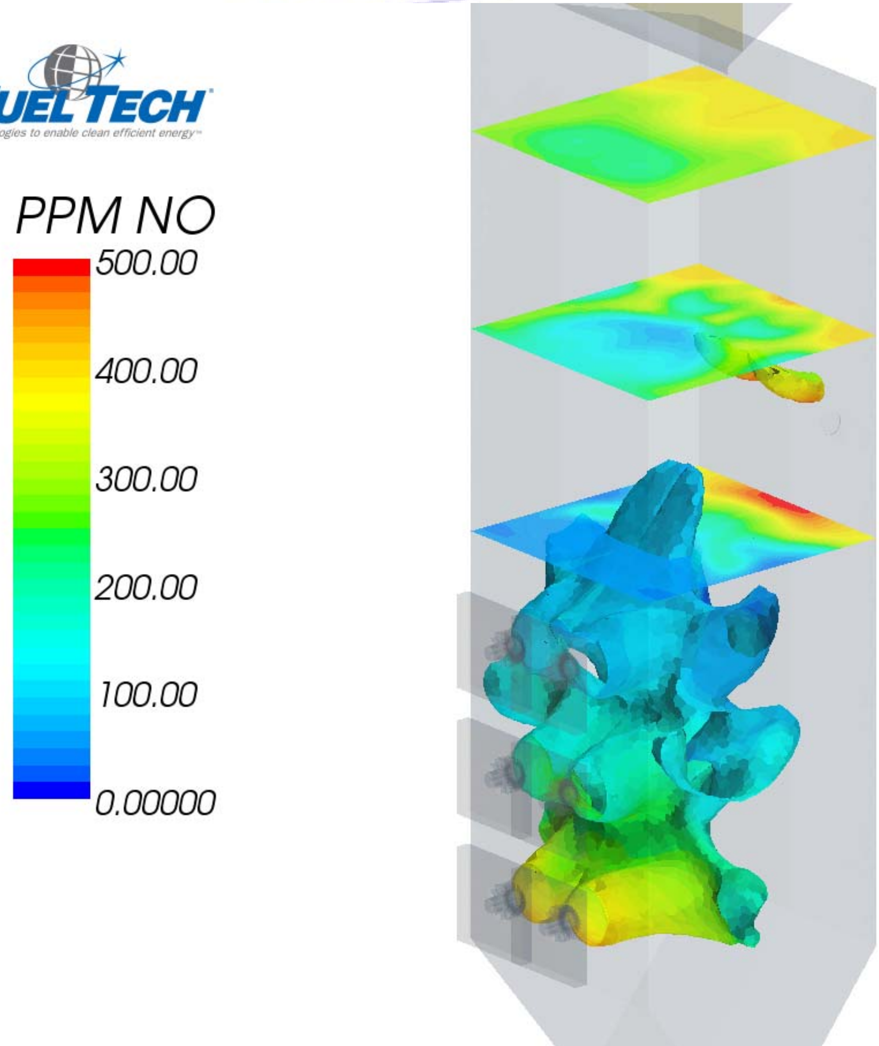

PPM NH3
10.000
8.0000
6.0000
4.0000
2.0000
0.0000


PPM HCN
250.00
200.00
150.00
100.00
50.000
0.0000


PPM CO
1.0000e+05
80000.
60000.
40000.
20000.
0.0000


Temperature (F)
2500.0
2030.0
1560.
1090.0
620.0
150.00

Combustion Mods



Combustion Mods Results

- Critical Stats
  - Temperature @ Nose: 1840 F
  - Avg. PPM CO @ Outlet: 64
  - Avg. PPM NO @ Outlet: 297
  - 21% NO Reduction

SNCR Design

- SNCR Design: 20% Reduction from 0.33 lb/mmBTU NOx to 0.26 lb/mmBTU
- 34 injectors
- NSR = 3.0 for initial simulation
- Equal flow to each injector (un-tuned) for initial simulation

SNCR Modeling Basics

- Lagrangian particle tracking
- Droplet evaporation by Clausius-Clapyeron
- NOx reduction and creation reactions obey Arrenhius type reaction rates, per literature and FTI rates

SNCR Results

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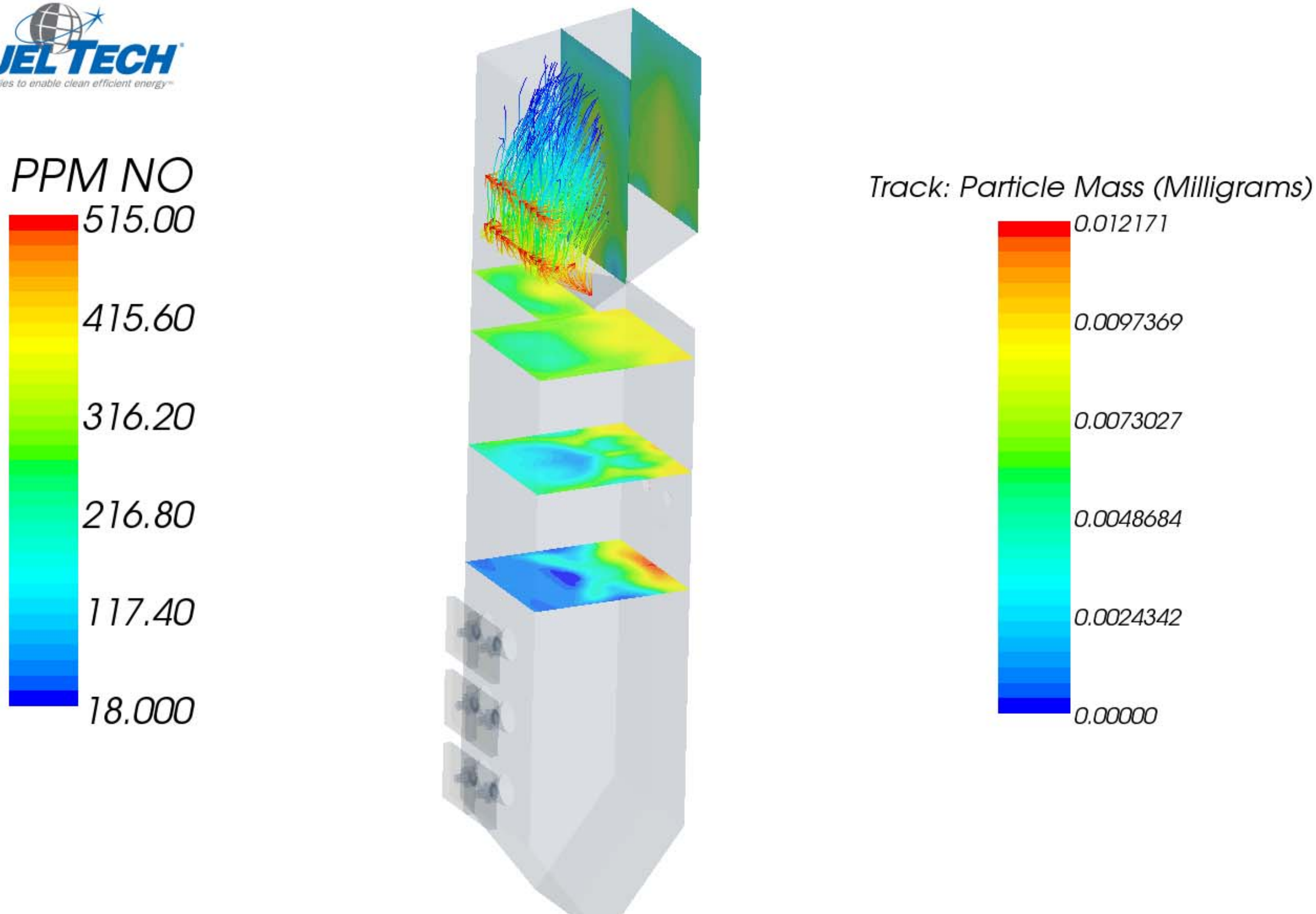

SNCR Results

- Critical Stats
  - Avg. PPM NO @ Nose: 297
  - Avg. PPM NO @ Superheater Outlet: 256
  - 14% NO Reduction

SCR Design

- 25% Removal from 0.26 lb/mmBTU to goal of 0.195 lb/mmBTU
- Single catalyst layer
- Mixer
- Ammonia Injection Grid (AIG)
- Graduated Straightening Grid (GSG)
- Goal: NH_3 slip to 2 ppm average leaving SCR

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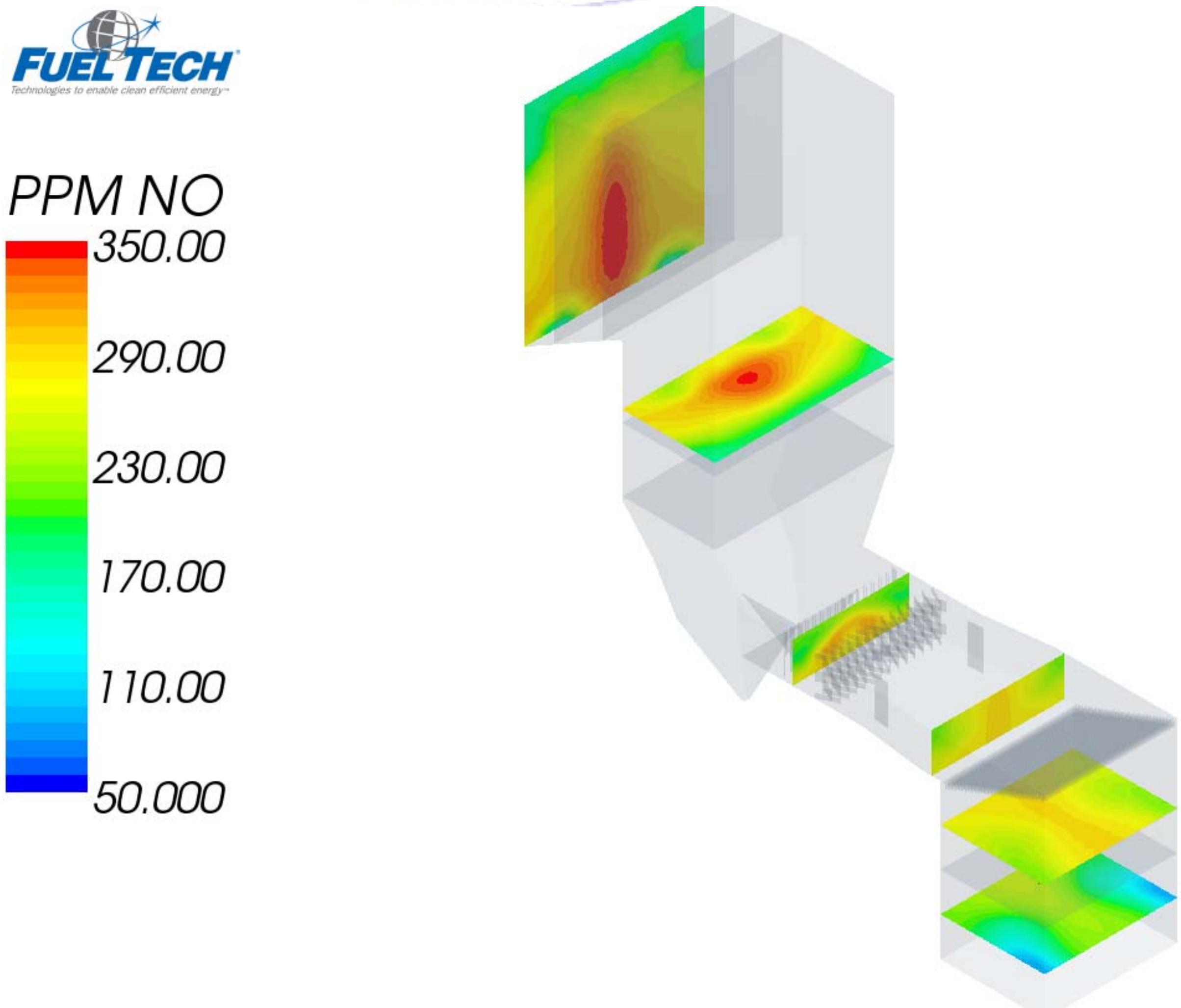
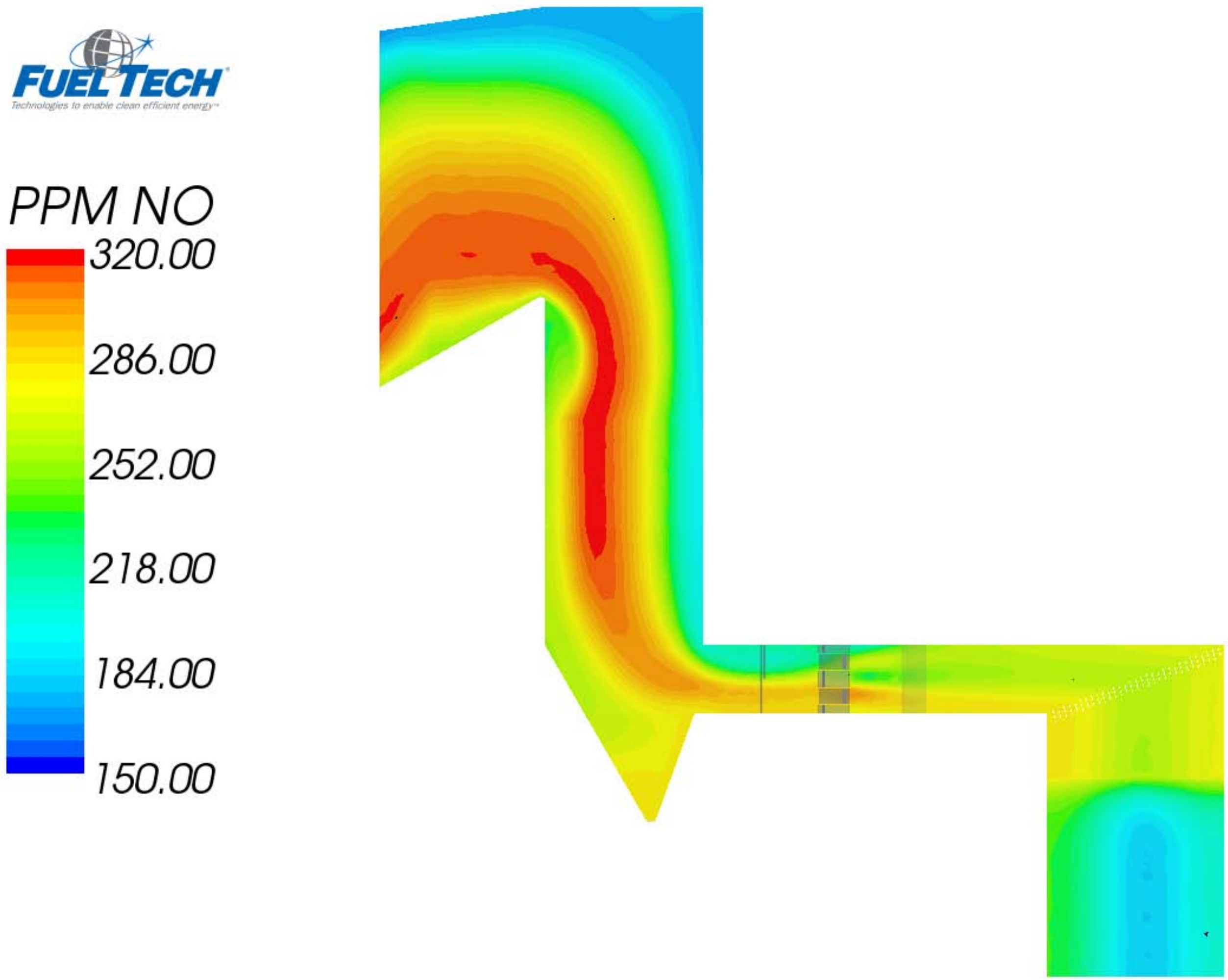
SCR Modeling Basics

- NOx reduction reaction obey Arrenhius type reaction rates, per literature and FTI rates

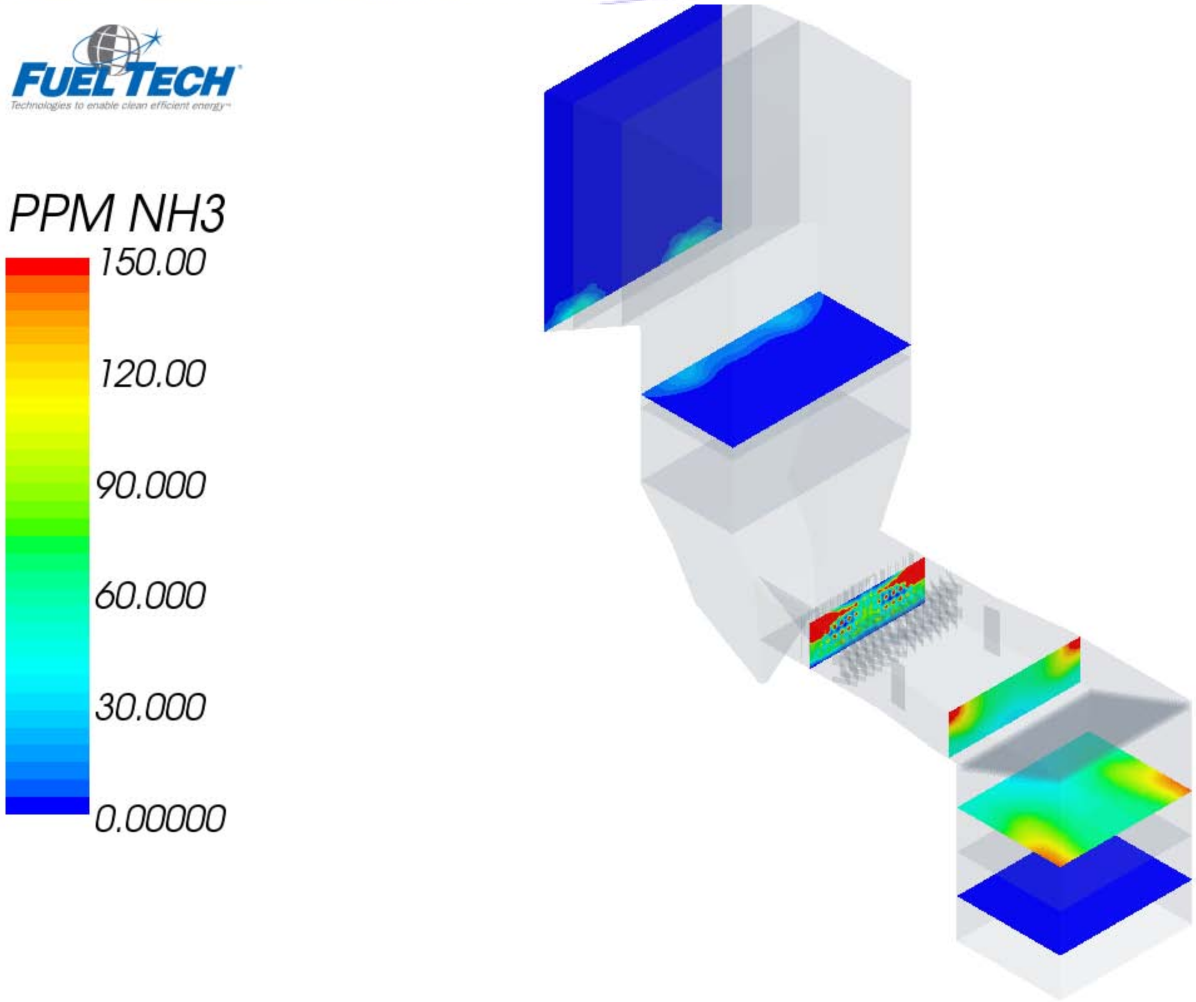
ASCR
Test Case



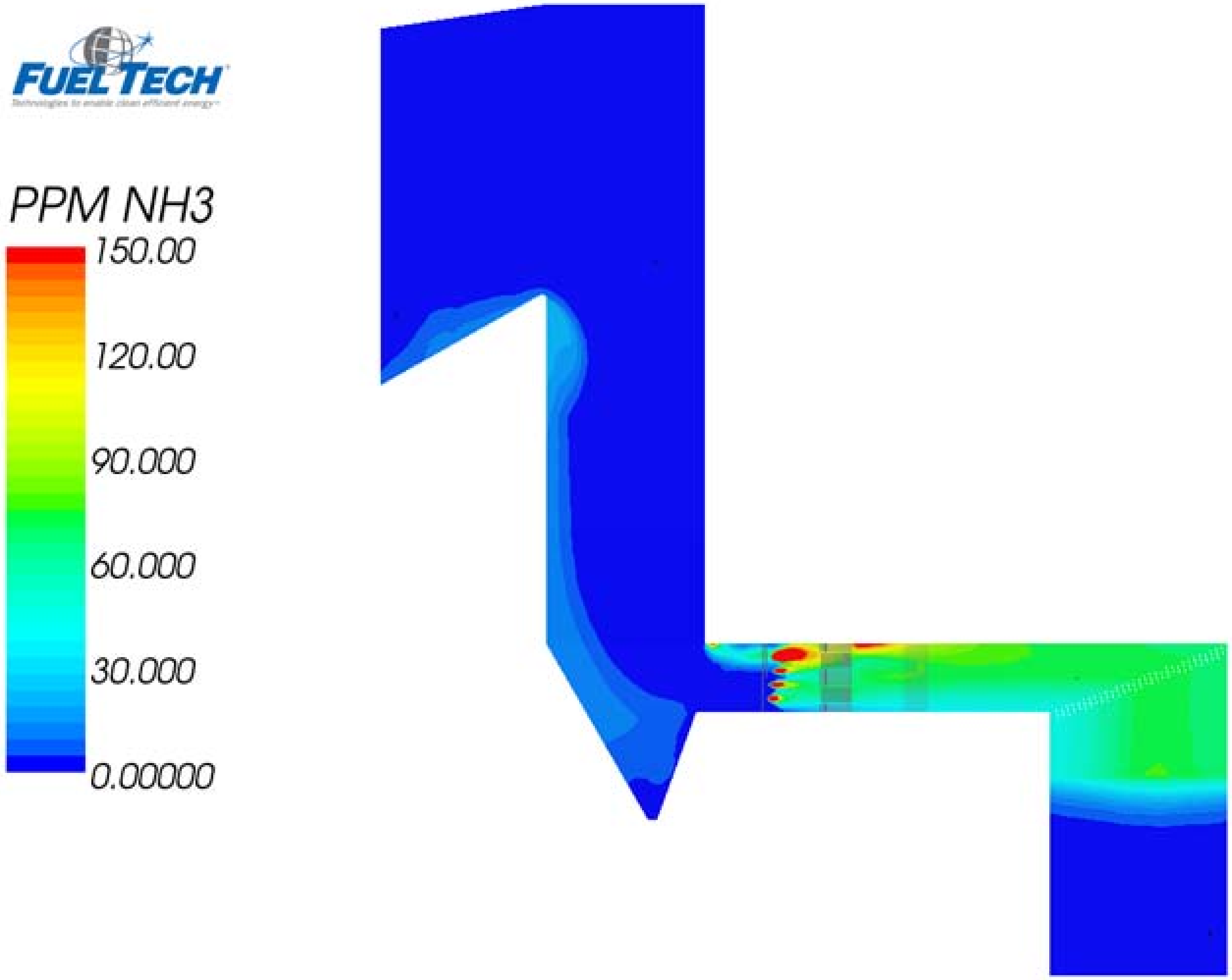
ASCR
Test Case



ASCR Test Case



ASCR Test Case



SCR Results

- Critical Stats
  - Avg. PPM NO @ SCR Inlet: 297
  - Avg. PPM NO @ SCR Outlet: 256
  - 24% NO Reduction

ASCR Test Case

- Baseline NO: 378 PPM (0.42 lb/mmBTU)
- NO At Furnace Nose: 297 PPM (.33 lb/mmBTU)
  - Combustion Mod Removal = 21%
- NO After SNCR Zone: 256 PPM (.285 lb/mmBTU)
  - SNCR Removal Efficiency: 14% (Un-tuned)
- NO Downstream Catalyst: 195 PPM (.217 lb/mmBTU)
  - Catalyst Removal Efficiency: 24% (Un-tuned)
- Total Removal = 48%
- NH3 Slip at Model Outlet: 1.5 PPM

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