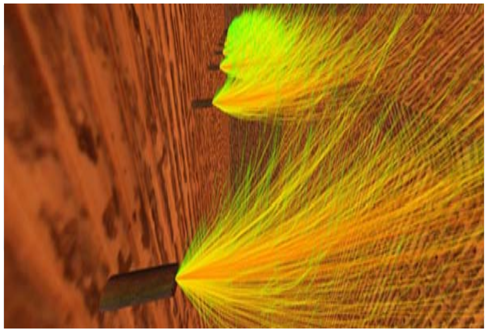
Reinhold Environmental Ltd.

2009 NOx-Combustion Round Table & Expo Presentation

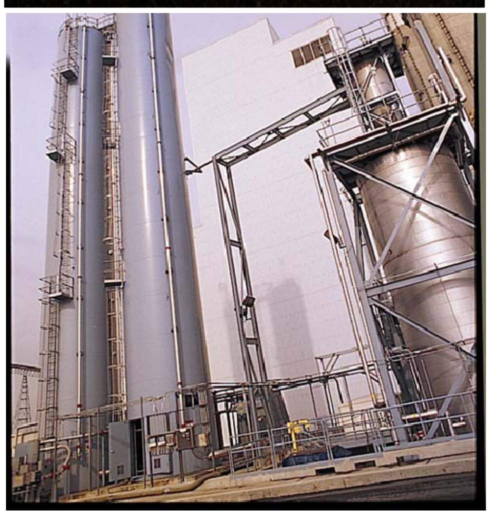
February 9 & 10, 2009, Cleveland, OH







Comprehensive NO_x Reduction in a Capital Constrained World



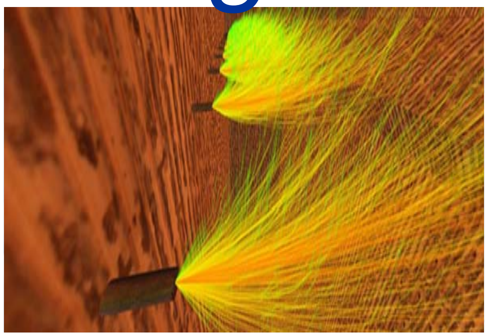
2009 NOx-Combustion Conference – Cleveland, OH

February 10, 2009





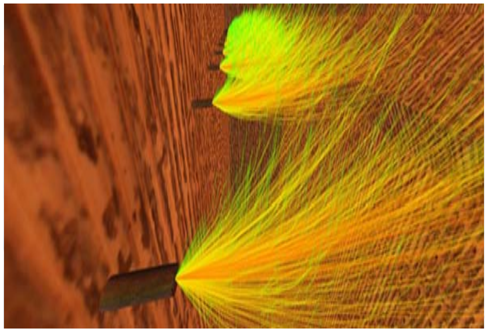
Agenda

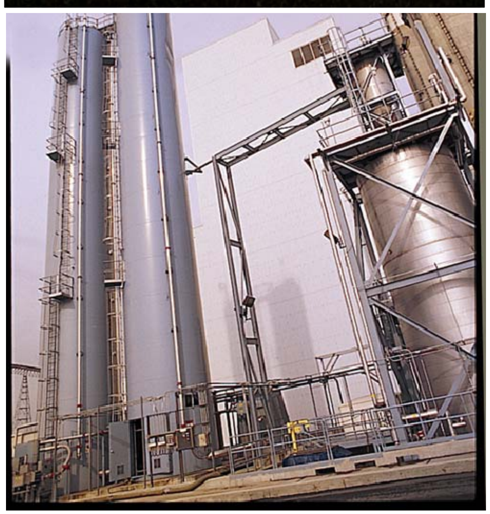


- Introduction
- Technologies
- Flow Optimization
- Economics



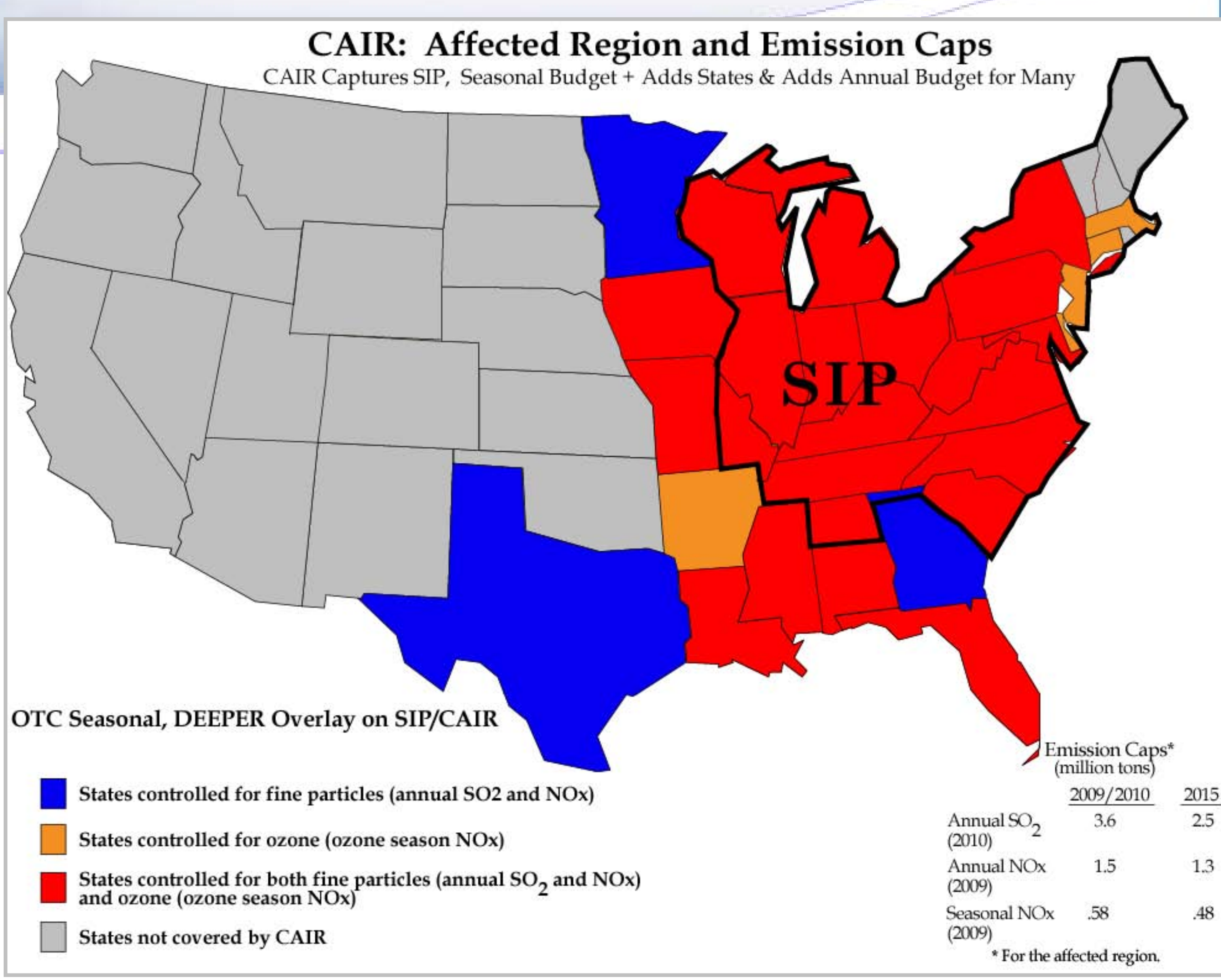




INTRODUCTION

CAIR Rule



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CAIR Rule Back in Play

- 2009 Clock is Ticking on Annual Ton Compliance
- Annual Tons >$3500/Ton
- Recent Values were >$5000/Ton
- Short Term Options for Compliance or to Generate Excess Allowances
  - Technology Costs Lower than Allowance Prices
- Less Capital Cost Available
- Smaller Units Less Accessible

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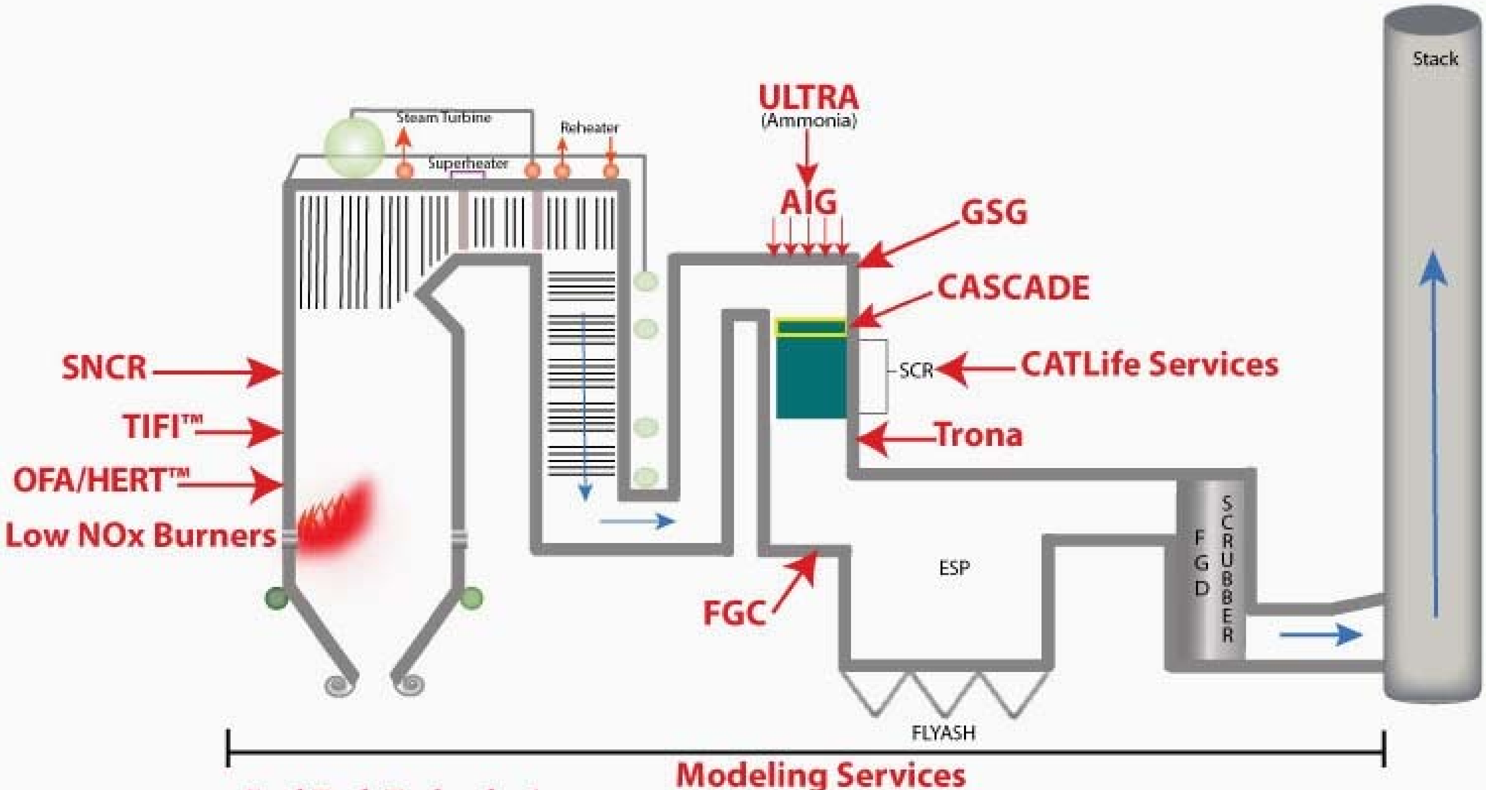
Fuel Tech APC Technology



Fuel Tech Technologies

AIG - Ammonia Injection Grid
CATLife Services - Catalyst Management Program
NOxOUT CASCADE® - SNCR + one Layer of Catalyst
FGC - Flue Gas Conditioning
GSG - Graduated Straightening Grid
HERT™ - High Energy Reagent Technology™
OFA - Over-Fire Air
SNCR - Selective Non-Catalytic Reduction
TIFI™ - Targeted In-Furnace Injection™
Trona - Sodium Compound used for SO_2 Control
NOxOUT ULTRA® - Fuel Tech Safe Ammonia Supply

Non Fuel Tech Supply

ESP - Electrostatic Precipitator for Particulate
FGD - Scrubber for SO_2
SCR - Selective Catalytic Reduction (full size)

Control Methods

NOx CONTROL METHOD	CAPITAL	EXPENSE	% REDUCTION
Low NOx Burners	Low	Minimal	20 - 70%
Staging OFA	Low	Minimal	30 - 50%
Optimization Software	Low	Minimal	10 - 20%
Reburn	Low-Moderate	High	10 - 50%
SNCR	Low-Moderate	Moderate	20 - 70%
SCR	High	Moderate	85 - 90%

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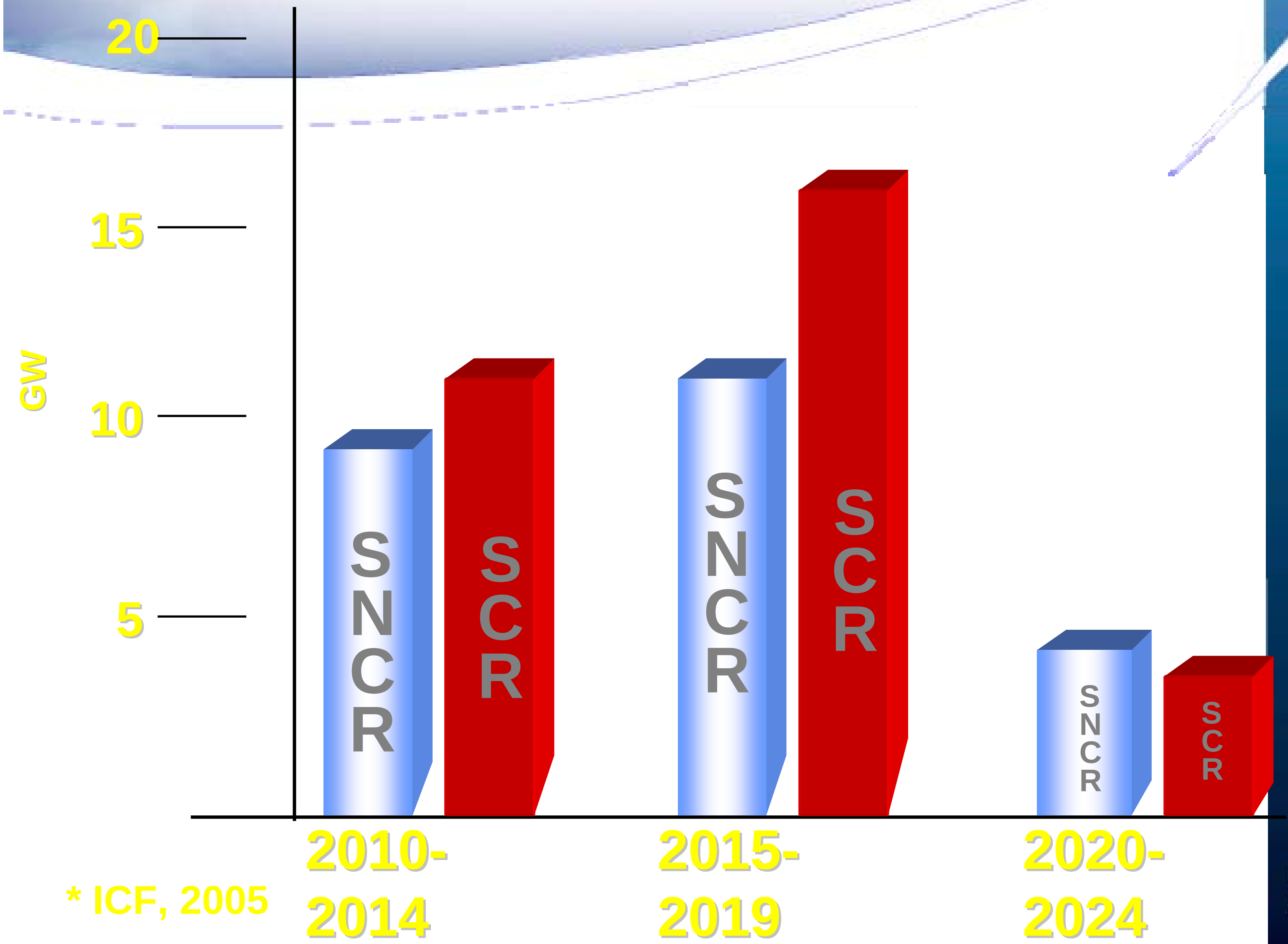
Technology Projections *



* ICF, 2005

Fuel Tech - Combined NOx Control Options

- New Options (ACT)
  - Burners/OFA/Combustion Modifications
  - SNCR
    - HERT™ Systems – Patented Technology
- SCR (FlowTack and Tackticks)
    - Expanded Expertise for NOxOUT Cascade (Hybrid SNCR/Compact SCR) Applications
    - Flow Optimization

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Technologies

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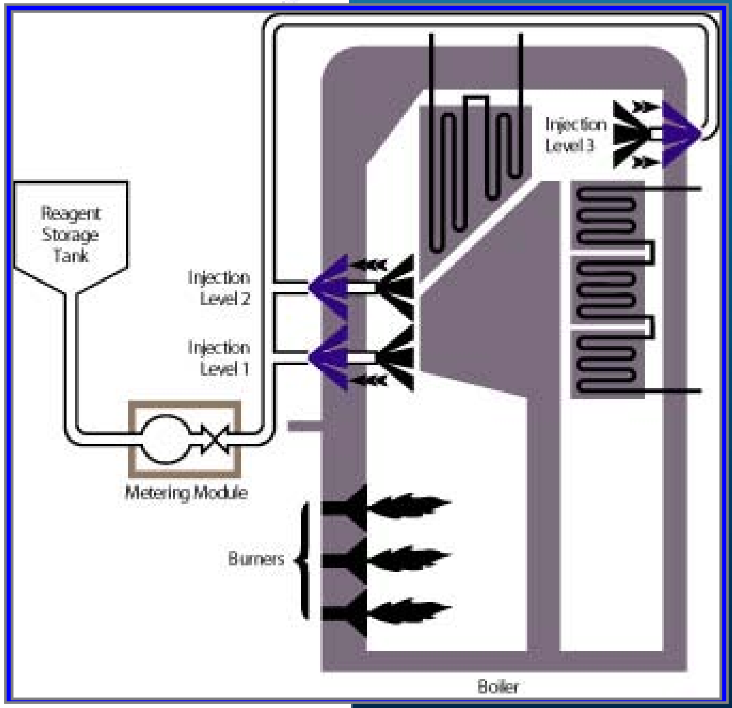
SNCR Technology Overview: HERT™ and NOxOUT® Systems

Selective Non-Catalytic Reduction

- In-furnace, Post-combustion NOx Control
- Injection of Urea in Upper Furnace:
  - Low Energy Droplets - NOxOUT
  - High Energy Droplets – HERT System
  - Controlled Distribution through Wall-mounted Injectors
  - Multiple Nozzle Lances for Large Furnaces with High Temperature, High Velocity Profile
- Process Reaction Temperature Range: 1600°F to 2200°F
- NOx Reduction – 25-50%



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HERT SNCR

- High Energy Reduction Technology (HERT)
  - Mechanically Atomized Urea Injection through OFA Ports (High Momentum Injectors) and Additional Levels of Injectors in Upper Furnace (Low Momentum Injectors)
  - Target 30+ Percent NOx Reduction with Low Slip
  - Recent Applications with Low Baseline Applications and Control Levels at or Below 0.100 lb/MMBtu

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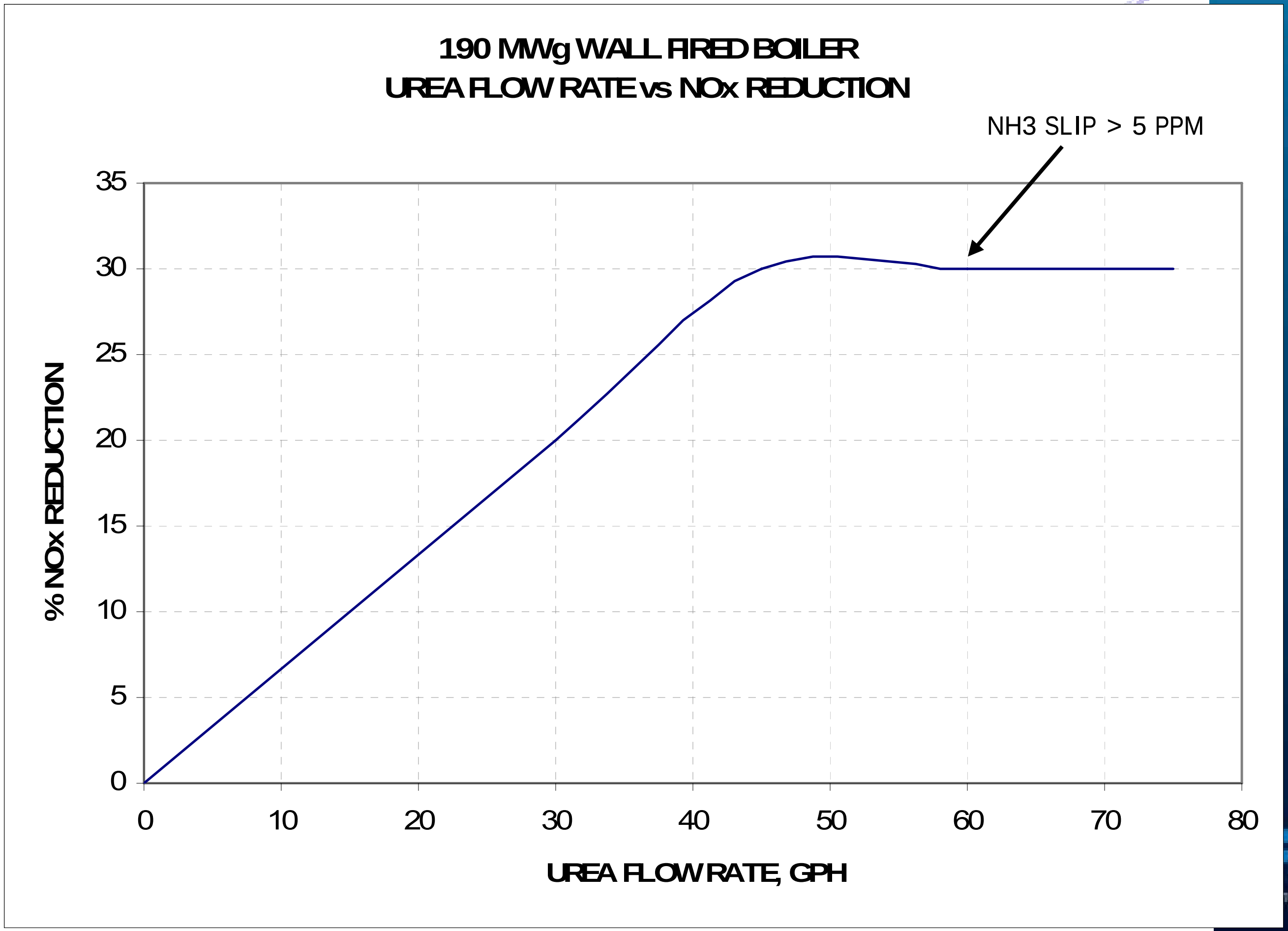
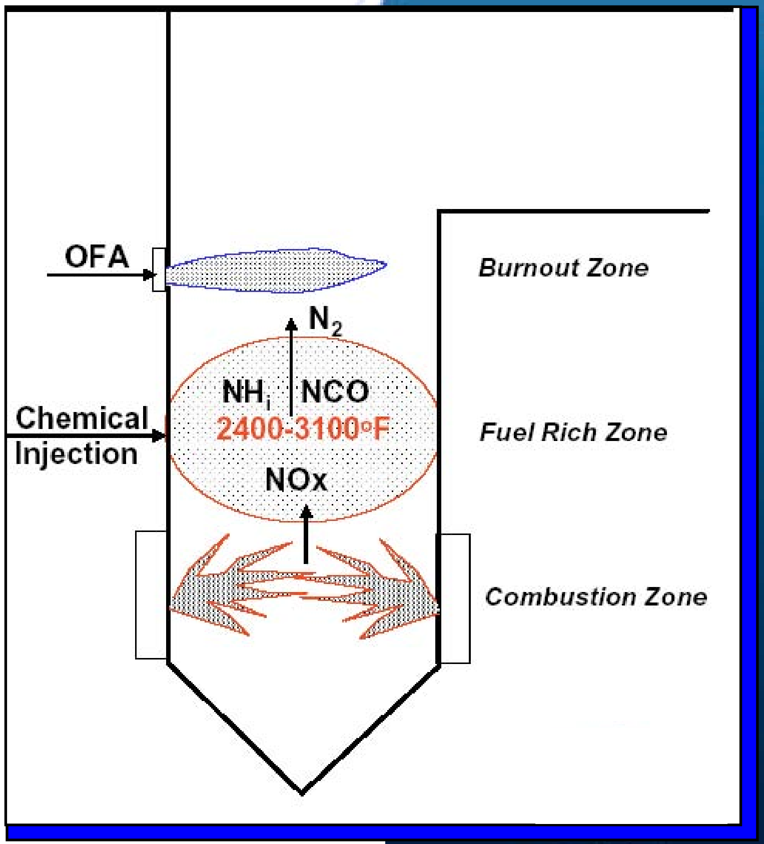
HERT SYSTEM REDUCTION POTENTIAL AND NH3 SLIP



Rich Reagent Injection (RRI) Technology Overview

- >55% NOx Reduction Combined with SNCR
- NOx Reduction in 30% Range with RRI Only– Primary Experience with Cyclone Boilers; Being Extended to Other Boiler Types
- Non-catalytic Reduction of NOx via Urea Injection in Sub-stoichiometric Conditions (SR: 0.85 to 0.95)
- No Reagent Slip Due to High Residence Time and Reagent Oxidation in the Burnout Zone
- Process Reaction Temperature Range: 2600°F to 3100°F
- Technology Licensed from REI



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Ozone Season Basis

NOx Control	NSR	Tons Removed	Total $/Ton
NOxOUT SNCR	0.67	283	2,608
NOxOUT SNCR	1.04	445	2,046
RRI	2.05	465	2,961
RRI	3.05	587	3,139
RRI	4.09	654	3,556
SNCR/RRI	2.97	843	2,794

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Annual Basis

NOx Control	NSR	Tons Removed	Total $/Ton
NOxOUT SNCR	0.67	680	1,753
NOxOUT SNCR	1.04	1,069	1,502
RRI	2.05	1,117	2,440
RRI	3.05	1,409	2,726
RRI	4.09	1,571	3,186
SNCR/RRI	2.97	2,024	2,507

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NOx Compliance Example

TVA Diversity of TVA Environmental Controls

Plant	Unit(s)	NO_x		SO_2	
		Combustion Controls	Post-Combustion Controls	Scrubber Online Date	Current Fuel
Allen	1-3	Staged Overfire Air	SCR (2002/2003)		West
Bull Run	1	Boiler Optimization	SCR (2004)	2009	CAP
Colbert	1-4	Low-NOx Burner			West
Colbert	5	Low-NOx Burner	SCR(2004)		West
Cumberland	1-2	Low-NOx Burner	SCR (2003/2004)	1994	ILB
Gallatin	1-4	Low-NOx Burner and Staged Overfire Air			West
John Sevier	1-4	Low-NOx Burner and Staged Overfire Air	U1 HERT (2007) U2-4 HERT (2009)	2012	CAP
Johnsonville	1,5-6	Boiler Optimization	U1 SNCR (2005) U5-6 SNCR (Future)		Blend
Johnsonville	2-4	Boiler Optimization	U2 HERT+OFA (2007) U3-4 HERT+OFA (Future)		Blend
Johnsonville	7-10	Low-NOx Burner			West

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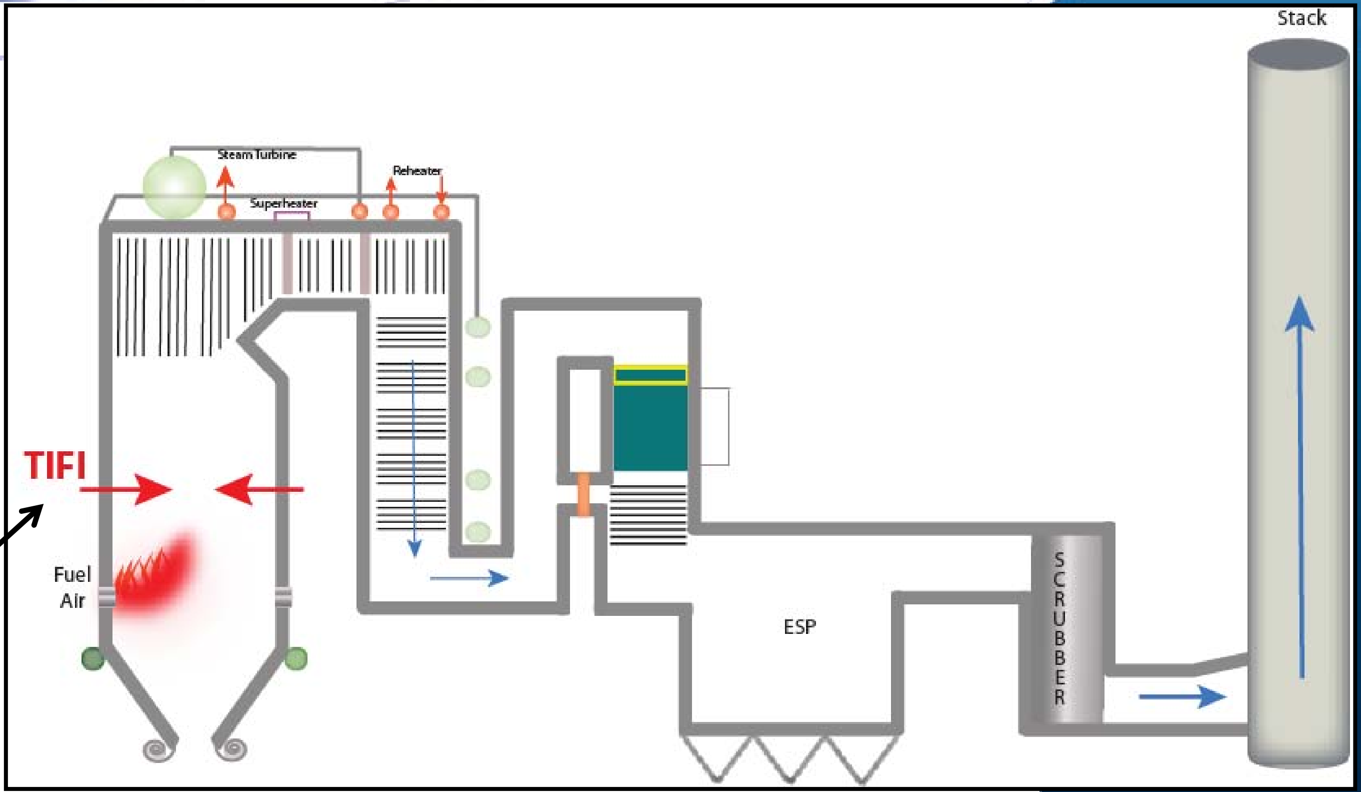
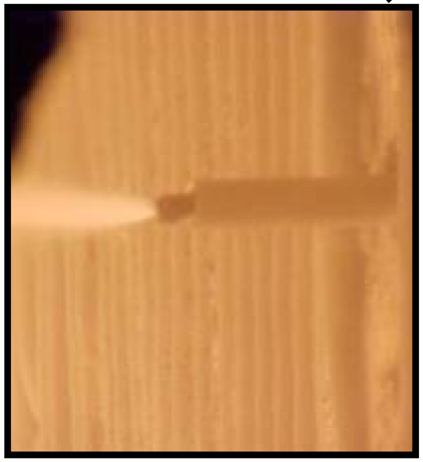
FUEL CHEM® TIFI Overview

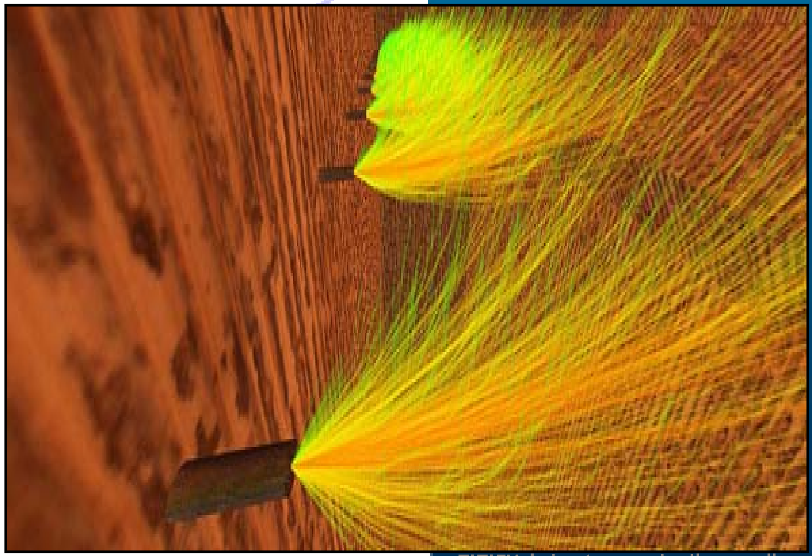


TIFI nozzle injecting Magnesium Hydroxide



TIFI™ Targeted In-Furnace Injection™ Program

- Patented process for the injection of chemicals using Computational Fluid Dynamic (CFD) modeling as the primary design method
- Critical Criteria
  - Furnace gas flows and temperatures
  - Chemical distribution, particle size and feed rate


TIFI™ Injector on boiler wall

FUEL CHEM®
Program Benefits

- Efficiency
  - Recovery of Derated MW
  - Heat Rate Improvement for Steam Production
  - Reduced Fan Power Requirements
  - Reduced Sootblowing
  - Reduced Operating O_2 Level
  - Reduced CO in Furnace and at the Stack
  - Increased Fuel Flexibility

- Availability and Reliability
  - Reduced Forced Outage Time
  - Reduced Derates
  - Increased Capacity and Boiler Availability
  - Reduced Outage Cleaning Times
  - Reduced Exit Gas Temperatures

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Stack Emissions Without TIFI™

- Heavy Blue Plume from Sulfur Trioxide (SO_3) and Sulfuric Acid (H_2SO_4) Mist
- Opacity Excursions
- Acid Fallout
- Air Preheater Corrosion and Fouling

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SO_3 Mitigation

- Other SO_3 Control Technologies
  - Control is a “Cost” to a utility
  - Impact on ash sales or can result in pluggage of air heater/ductwork
- TIFI delivers control of SO_3 generated in the furnace and from SCR operation
- SO_3 control delivered while generating positive return from other operational benefits

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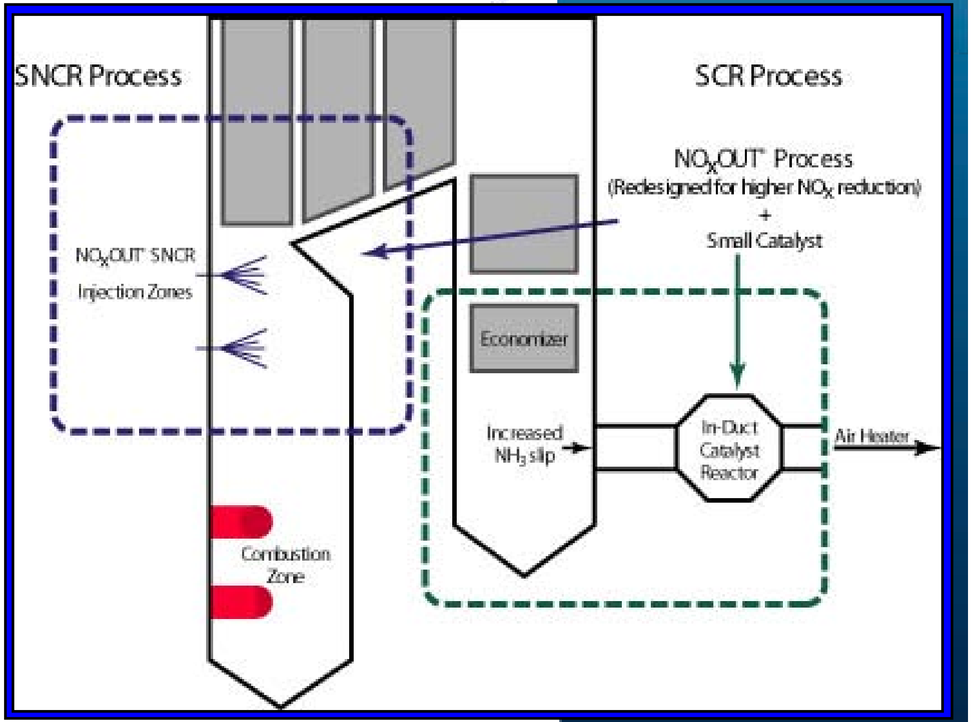
NOxOUT CASCADE® Technology Overview

- **Combined SNCR/SCR Process**
- **Single Layer SCR Catalyst – Reduced Volume or multiple layers**
- **Improved SNCR Chemical Utilization and Reduction Efficiency with Higher, Controlled Level of Ammonia Slip**
- **Ammonia Slip from SNCR Provides Reagent for Catalytic Reactions or Separate AIG**
- **Reductions in 50-70 Percent Range Typical, Capable of 80% Reduction**
- **Lower Capital Cost ($35 to $100 per kW) compared to Full Scale SCR ($80 to >$250/kW)**
- **Demonstrated Mercury Oxidation of >90% with Single Layer Catalyst for Capture with FGD System**



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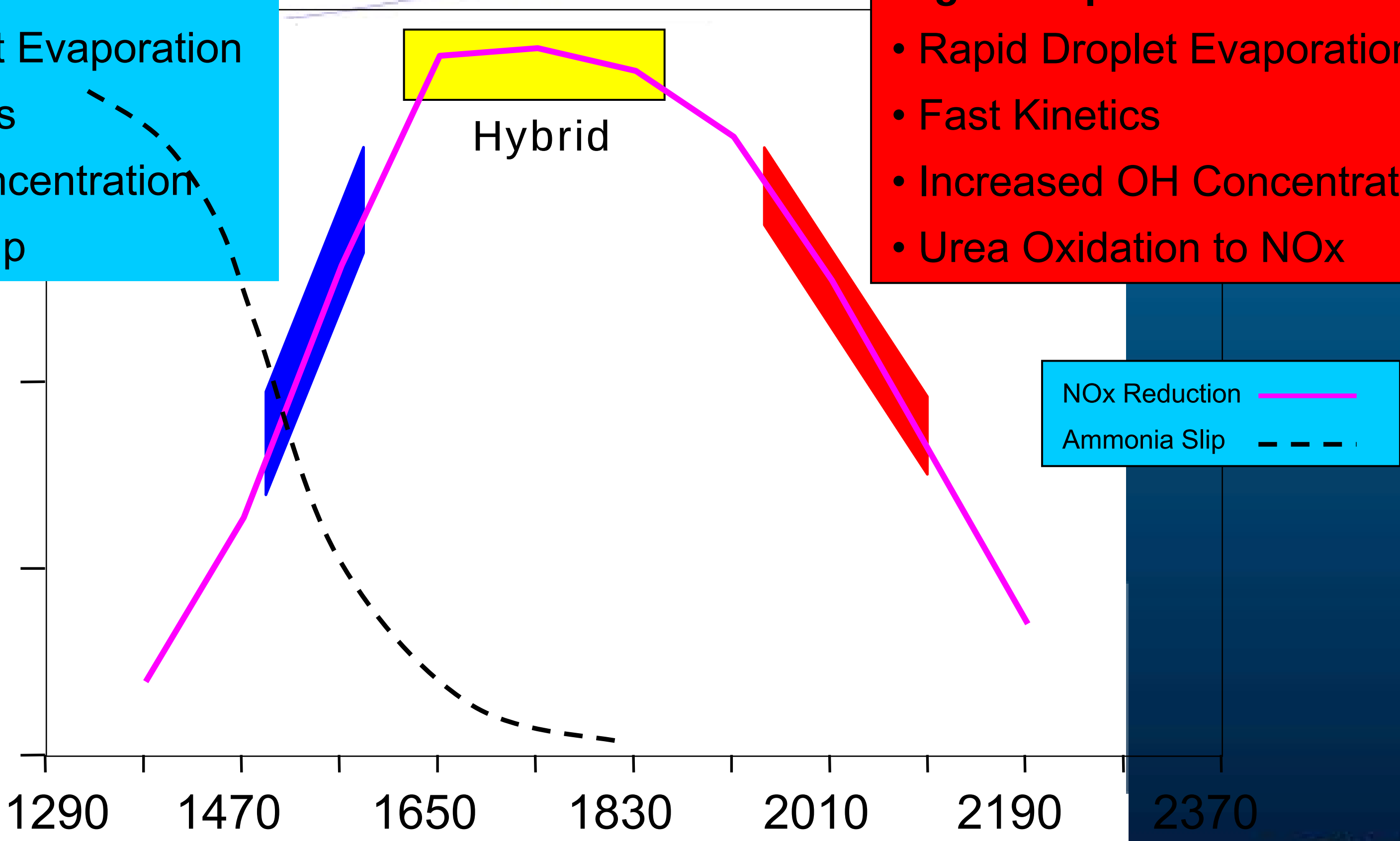
"Right Side of the Slope" Injection

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



CASCADE Results - 320MW Unit

Fuel	NOx Control System	NSR	SNCR Reduction	SNCR Utilization	SCR Reduction	Total Reduction	Overall Utilization
Coal	Standard SNCR	1.19	37.0%	31.1%	-	37.0%	31.1%
Coal	Hybrid	0.79	41.1%	59.2%	16.3%	50.7%	64.2%
Coal	Hybrid	1.15	36.9%	45.7%	54.2%	71.1%	61.8%
Gas	Hybrid	1.44	36.1%	38.6%	78.9%	86.5%	60.1%
Gas	Hybrid	1.56	39.0%	37.1%	83.6%	90.0%	57.7%

- Ammonia Slip at 10 ppm or less

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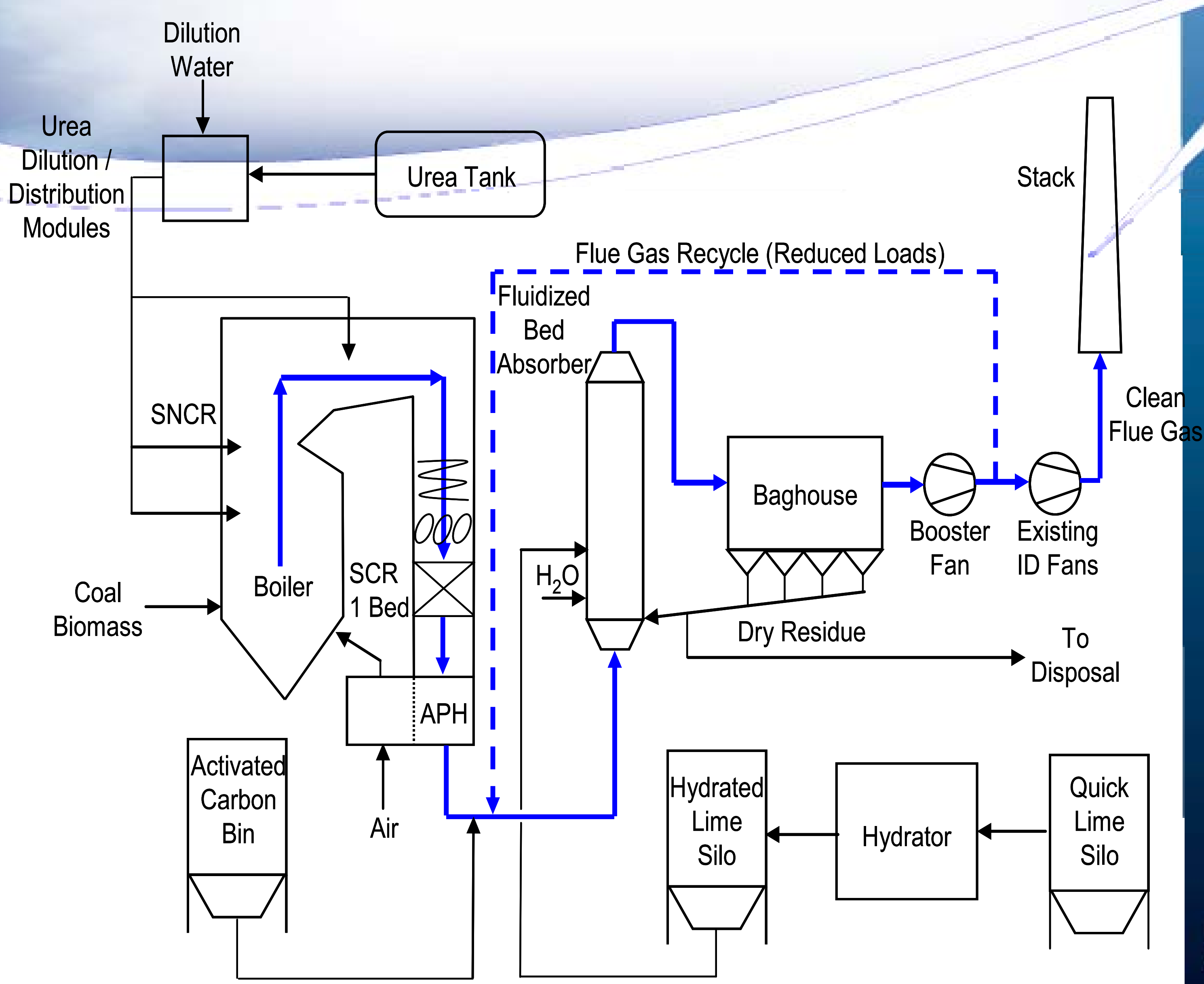
AES Greenidge Unit 4 (Boiler 6)

- Dresden, NY
- Commissioned in 1953
- 107 MW_e (EIA net winter capacity)
- Reheat unit
- Boiler:
  - Combustion Engineering tangentially-fired, balanced draft
  - 780,000 lb/h steam flow at 1465 psig and 1005 ^oF
- Fuel:
  - Eastern U.S. bituminous coal
  - Biomass (waste wood) – up to 10% heat input
- Existing emission controls:
  - Overfire air (natural gas reburn not in use)
  - ESP
  - No FGD – mid/high-sulfur coal to meet permit limit of 3.8 lb SO_2/mmBtu

Greenridge Process Flow Diagram



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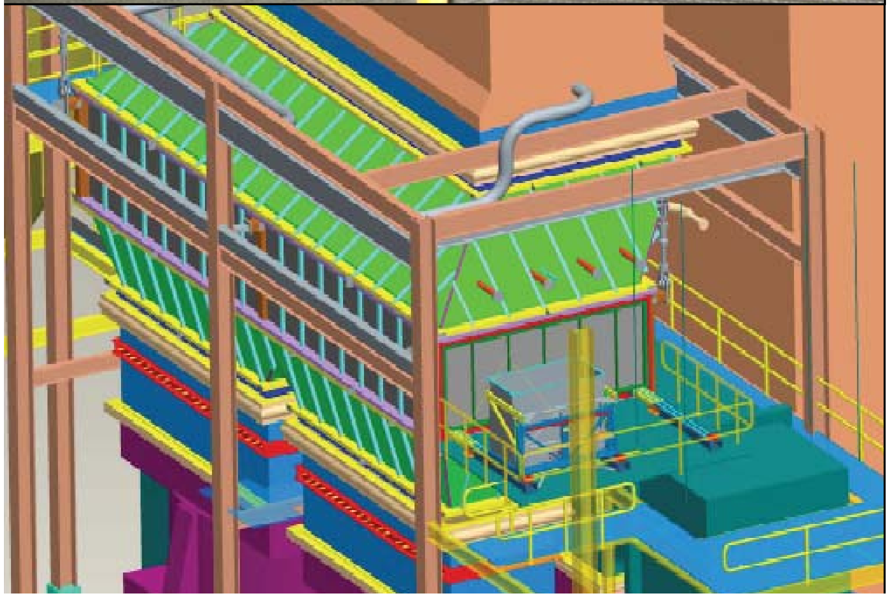
Greenridge Hybrid NO_x Control System



- Combustion Modifications
  - Low-NO_x burners, SOFA
  - Reduce NO_x to 0.25 lb/mmBtu
- SNCR
  - Three zones of urea injection
  - Provide NH_3 slip for SCR (NO_xOUT CASCADE®)
  - Reduce NO_x by ~ 42.5% (to 0.14 lb/mmBtu)
- SCR
  - Single catalyst bed (1.3 m)
  - Cross section = 45' x 14'
  - Fed by NH_3 slip from SNCR
  - Reduce NO_x by ≥ 30% (to ≤ 0.10 lb/mmBtu)

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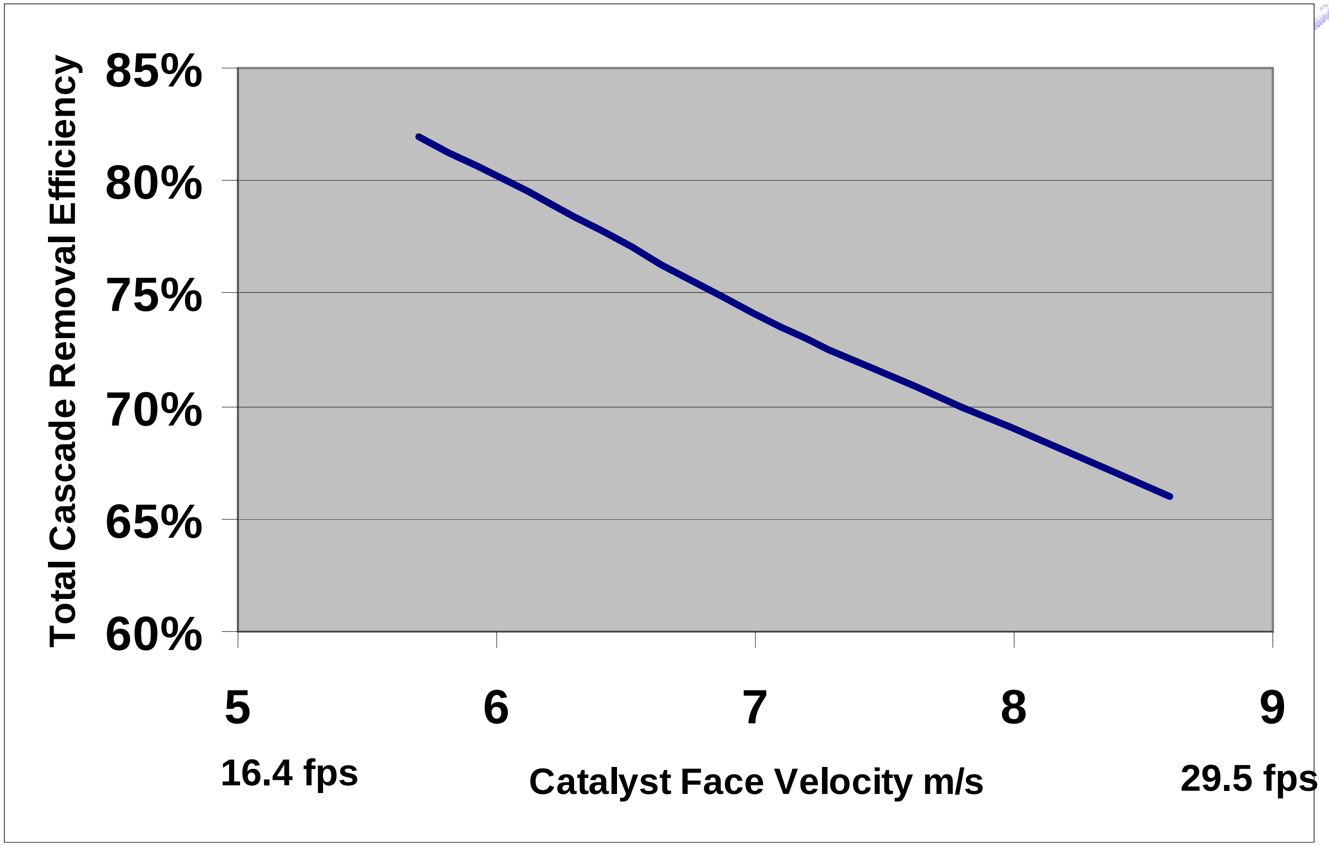
CASCADE Removal Efficiency vs. Velocity



CASCADE Evaluation

- Previous Graph Based on 50% SNCR Performance
- Ammonia slip from the SNCR process feeds the SCR Catalyst
- Can the SCR Catalyst Face Velocities be Achieved and get the Required SCR Performance?
- Use of Patent-Pending Graduated Straightening Grid (GSG)

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PERFORMANCE OF COMBINED TECHNOLOGIES

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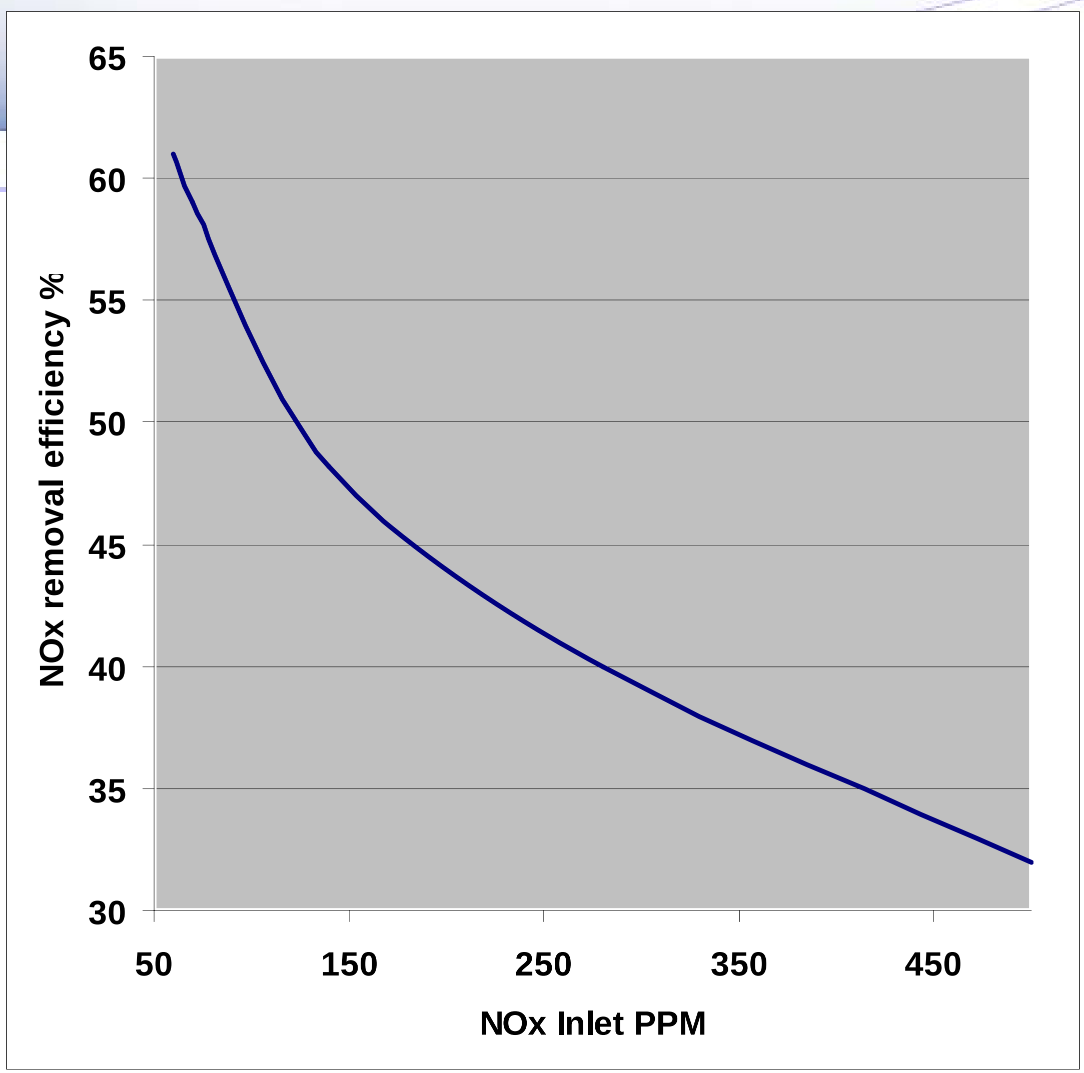
Catalyst Performan



Example Cascade Design Basis

- Total Removal Efficiency 75 %
- Inlet NO_x 0.4 Lbs/MMBTU
- Outlet NO_x 0.1 Lbs/MMBTU

NH_3/NO_x Distribution +/- 30%

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Example Cascade Results

• One Catalyst Layer	
• Catalyst Volume	185 m^3
• Catalyst Face Velocity	7.8 m/s 25.6 fps
• Catalyst Lifetime	8,000 TO 16,000 hours
• Ammonia Slip	2 PPM
• SNCR Removal Efficiency	50 %

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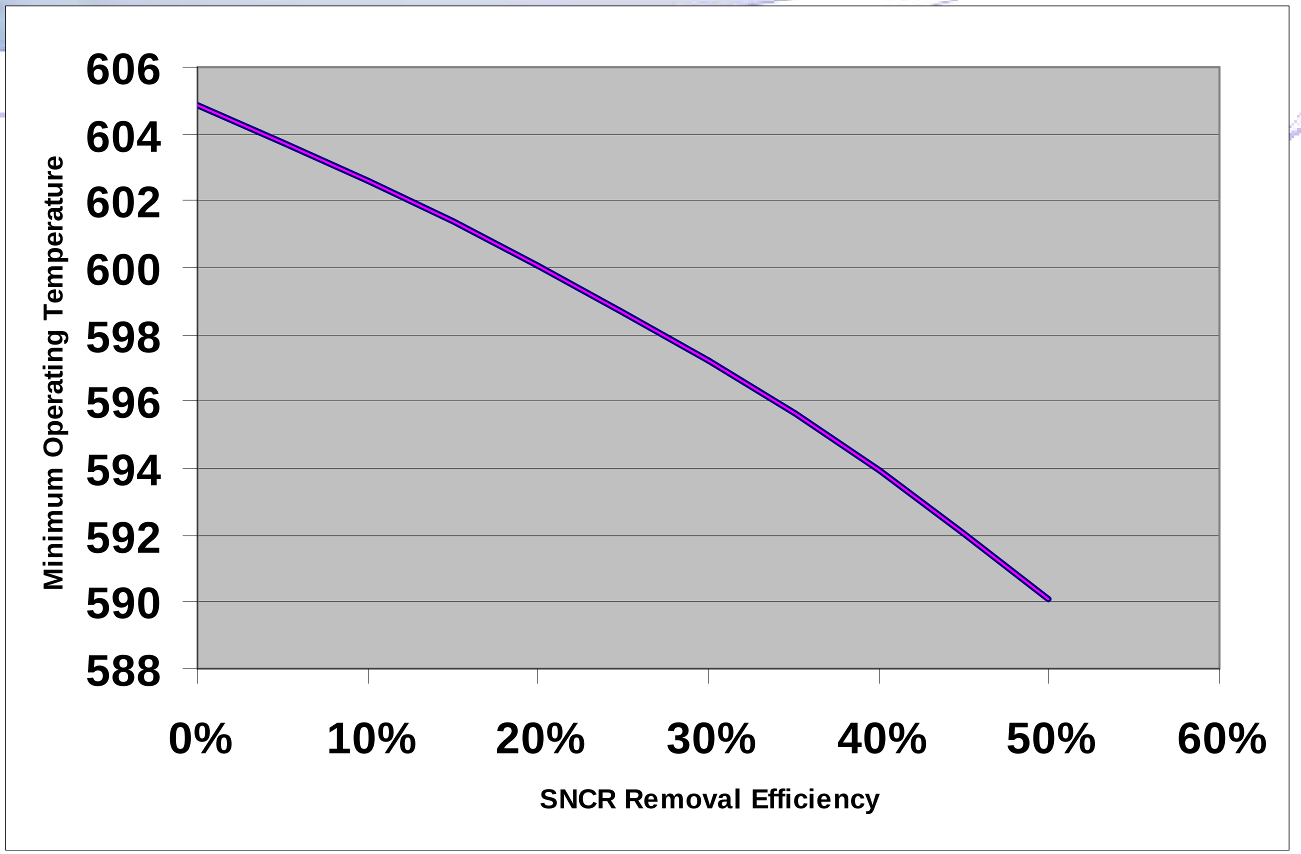
Operating Temperature

- The Minimum Operating Temperature of The Catalyst Depends On The Ammonia and SO_3 Concentrations In The Flue Gas Upstream of The Catalyst
- The Lower The Either One Is the Lower Is The Minimum Operating Temperature

Operating Temperature Example

- NO_x Inlet 0.4 Lbs/MMBTU
- NO_x Outlet 0.1 Lbs/MMBTU
- SO_3 Concentration 10 PPM
- SCR Minimum Operating Temperature 605 F

Operating Temperature Example



- NO_x Inlet 0.4 Lbs/MMBTU
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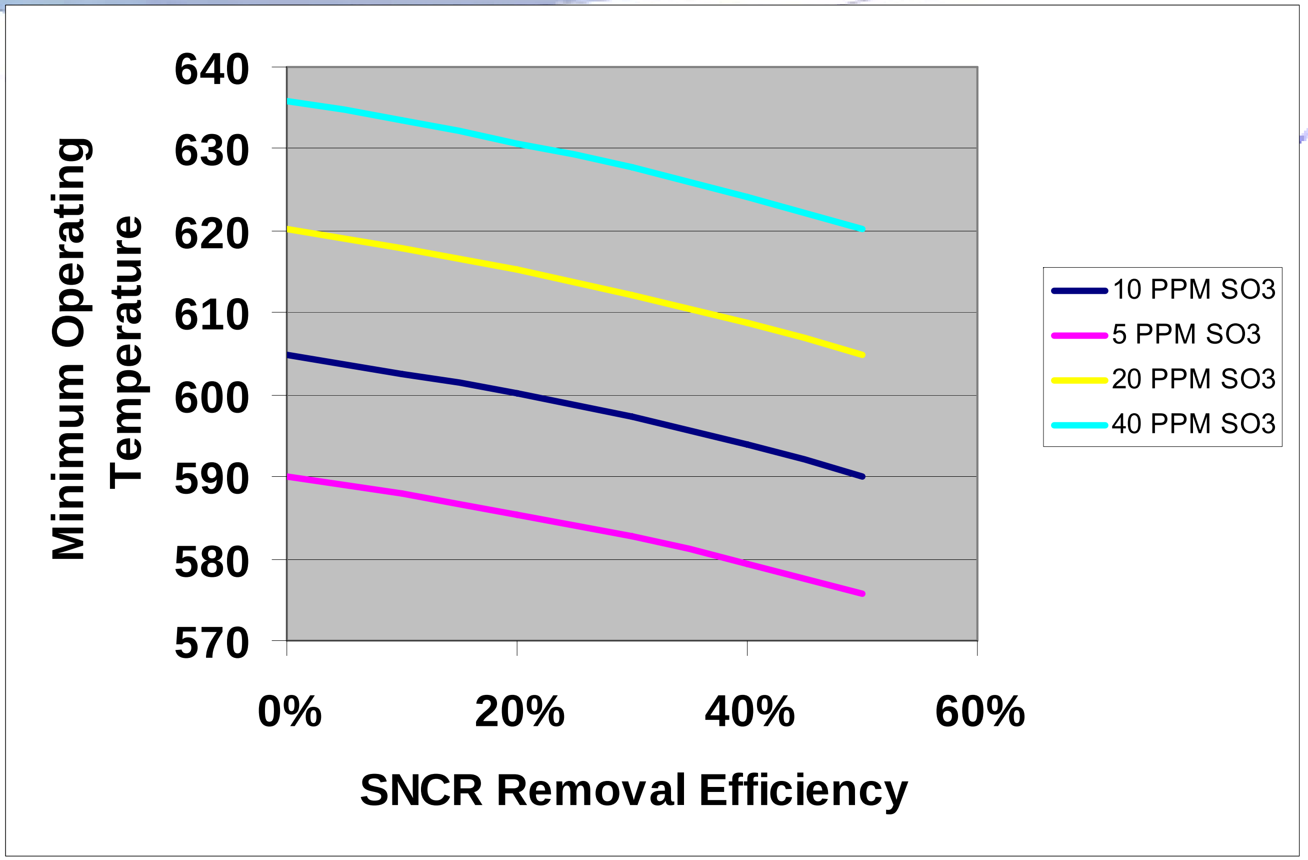
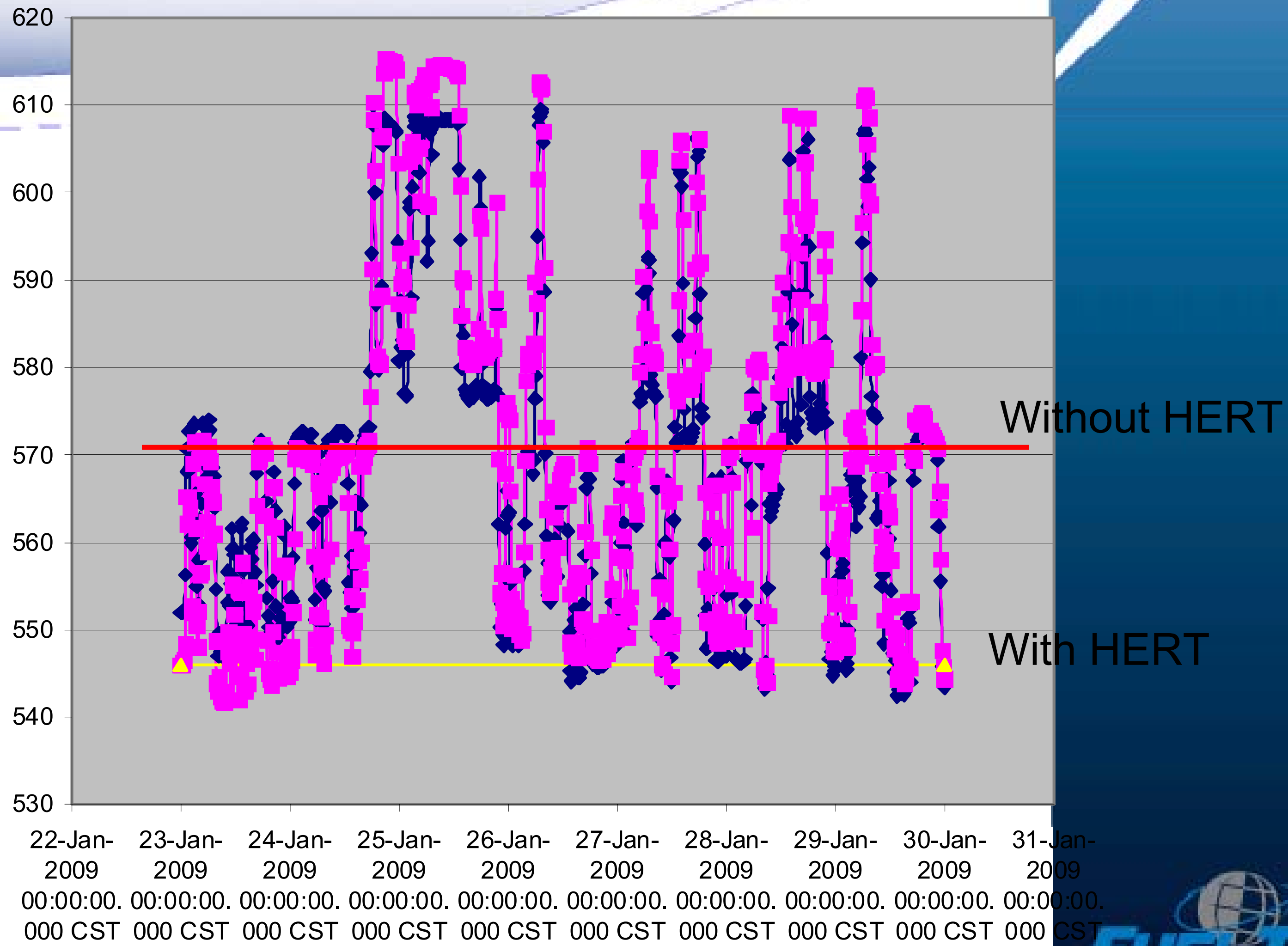
Minimum Operating Temperature

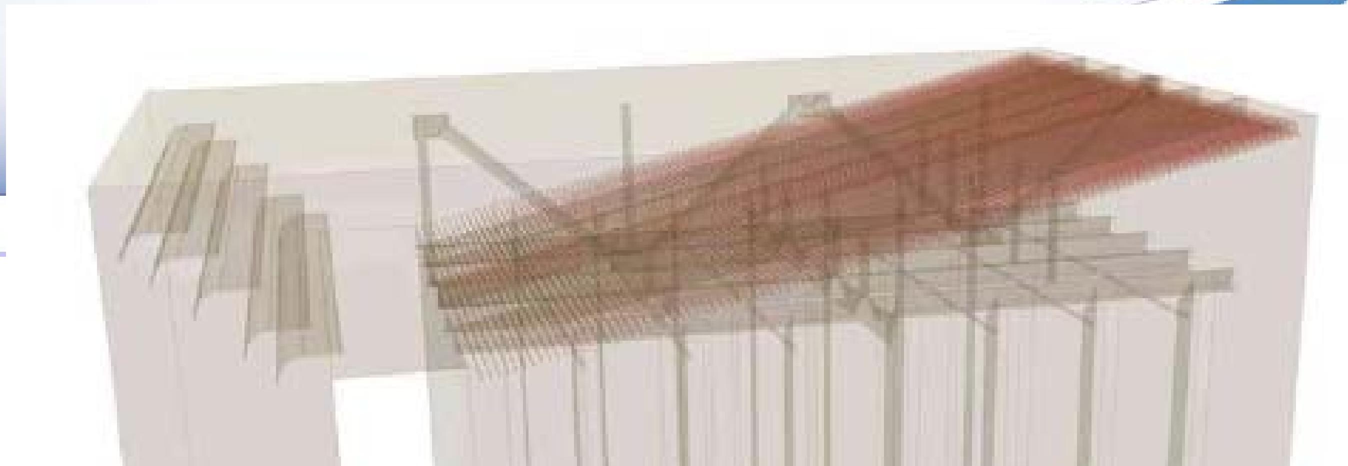


Minimum Operating Temperature



FLOW OPTIMIZATION

GSG Fluid Dynamics, Benefits



- Dramatically Improves Flue Gas Velocity Distribution without Increasing Cost, Complexity or Compromise on Performance
- Minimizes Angle at which Ash Particles Enter Catalyst, Near Perfectly Vertical Flow into Catalyst
- Innovative Design Allows for
  - Higher Flue Gas Velocity, Improved Operating and Financial Performance via Longer Catalyst Life and Reduce Downtime
  - Reduction in Time Required to Tune Ammonia Injection Grid
  - Higher Flue Gas Velocity Translates into Smaller Cross-section and Less Pressure Drop, Lower Capital

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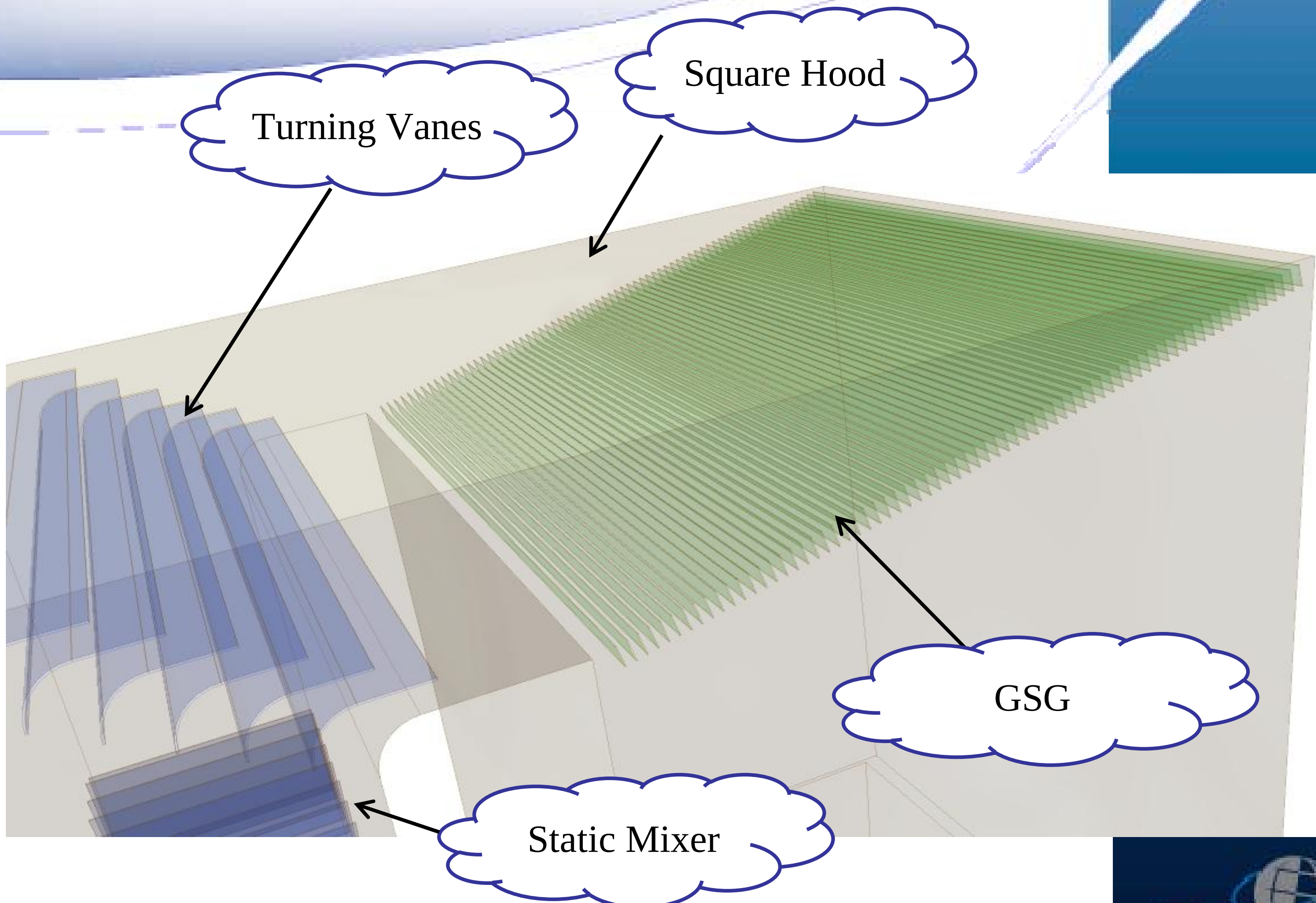
SCR Design – GSG Arrangement



Conventional Turning Vanes versus GSG

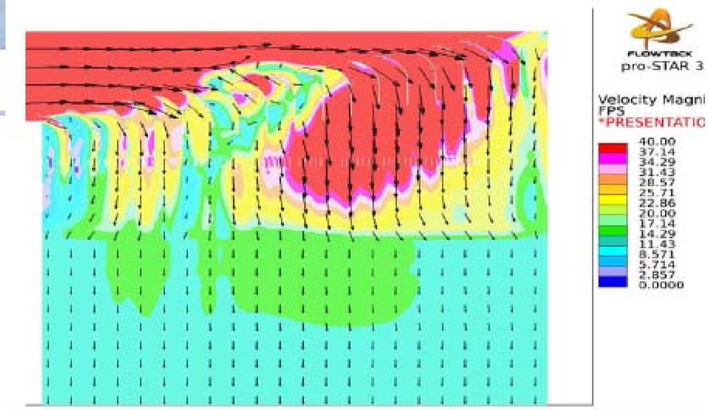


Figure 1: Standard Vanes SCR Velocity Profile (CFD results)

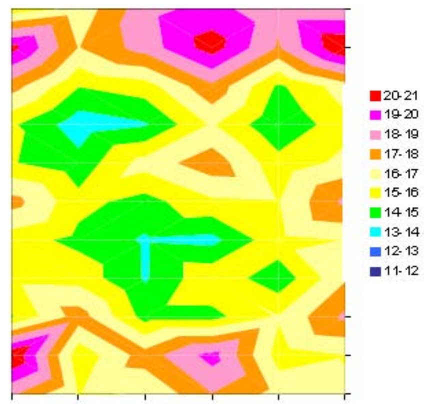


Figure 3: Velocities Measured at Catalyst Face with Traditional Vanes (Experimental Model)

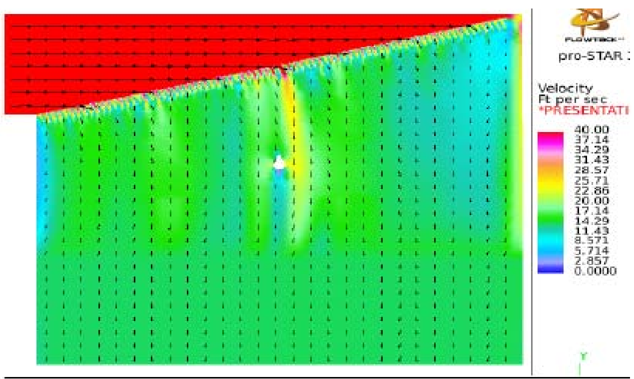


Figure 2: GSG SCR Velocity Profile (CFD results)

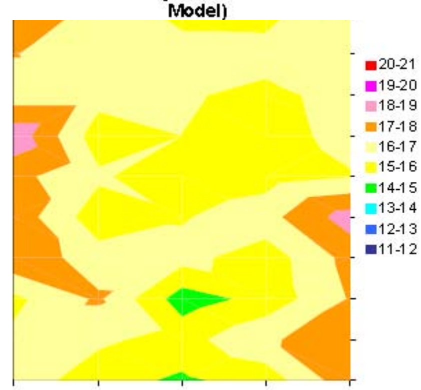


Figure 4: Velocities Measured at the Catalyst Face with GSG (Experimental Model)

Comparison of CFD and Experimental Model Velocity Profiles

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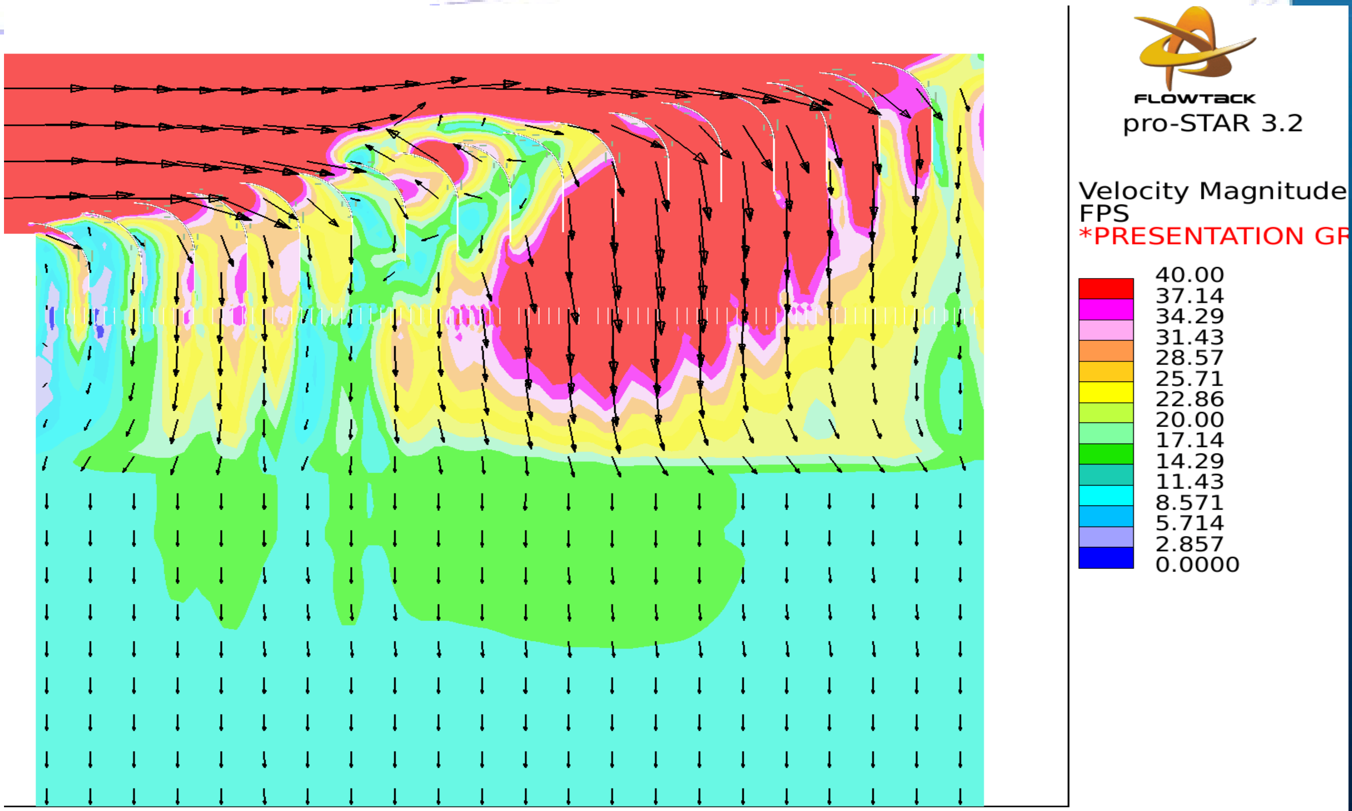
CFD FLOW PROFILE – NO GSG



Standard Vanes SCR Velocity Profile (CFD results)

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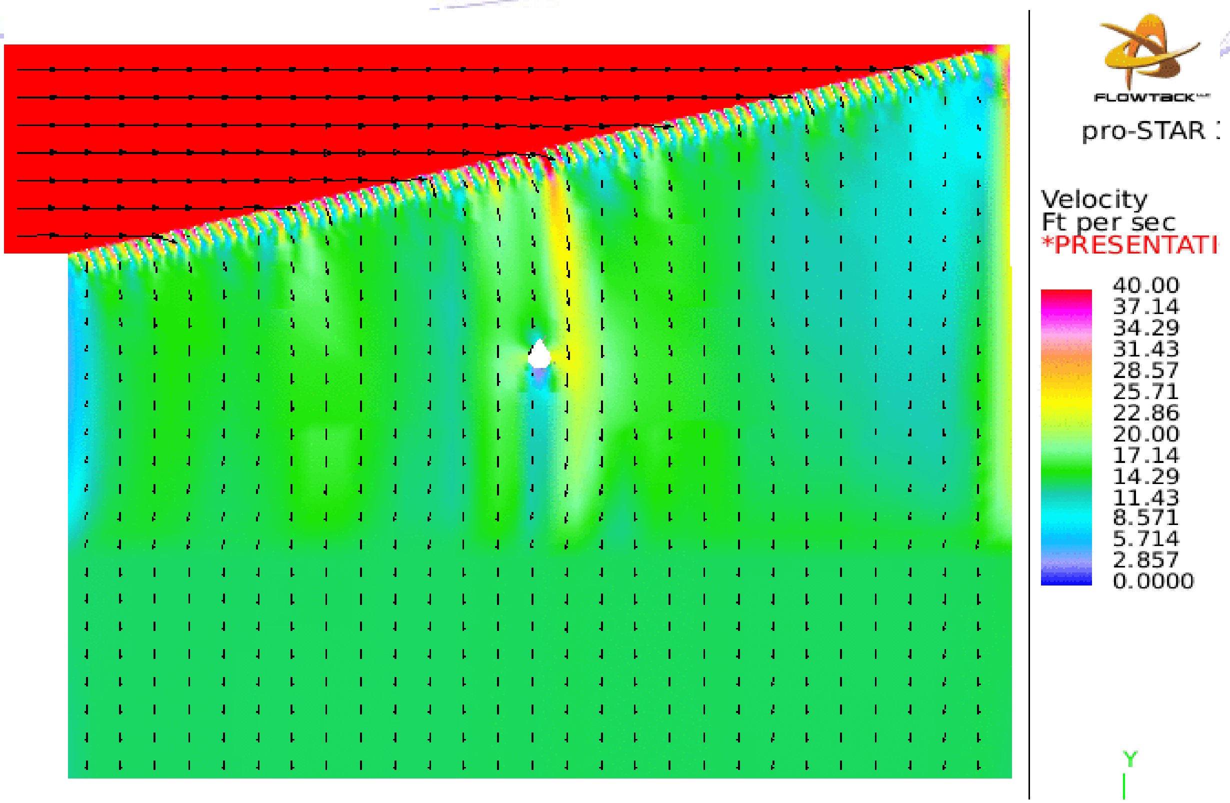
CFD RESULTS WITH GSG



GSG SCR Velocity Profile (CFD results)

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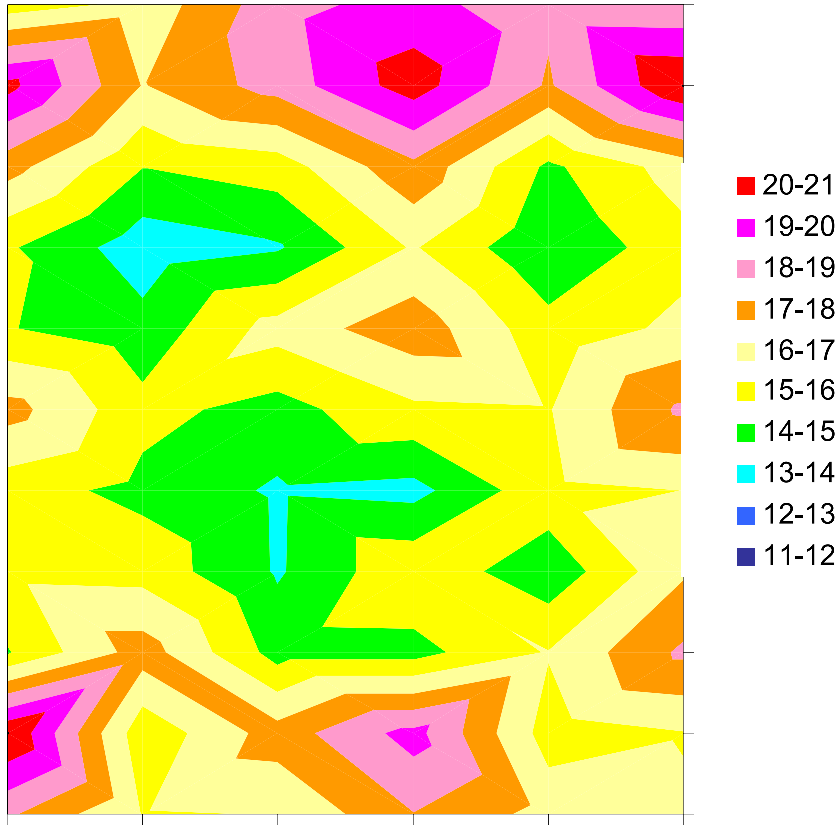
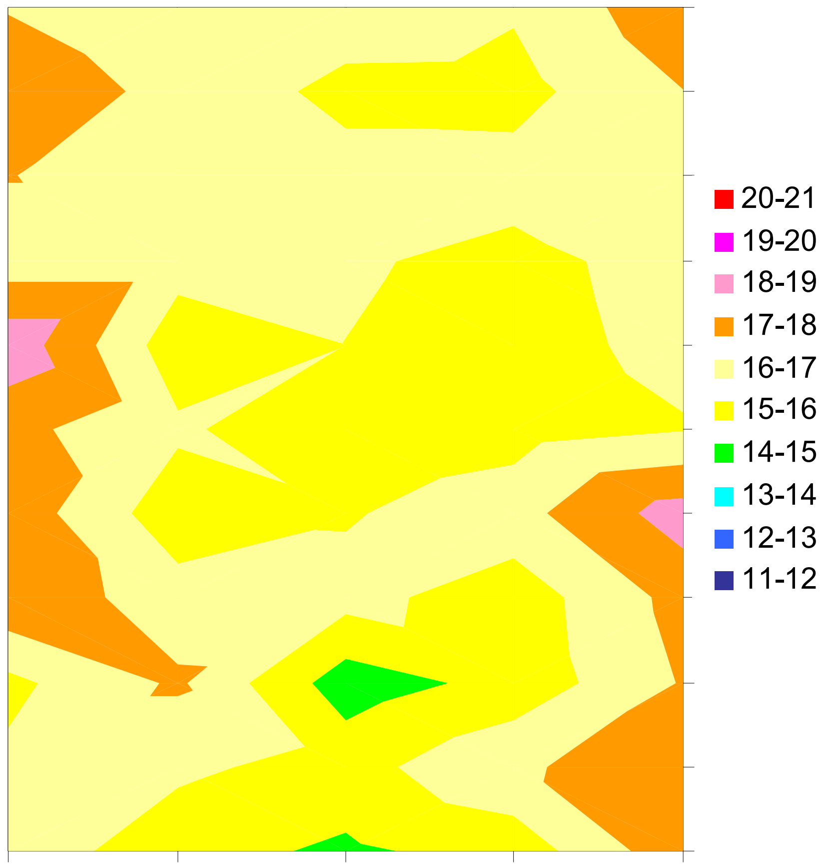
PHYSICAL FLOW MODEL - VANES



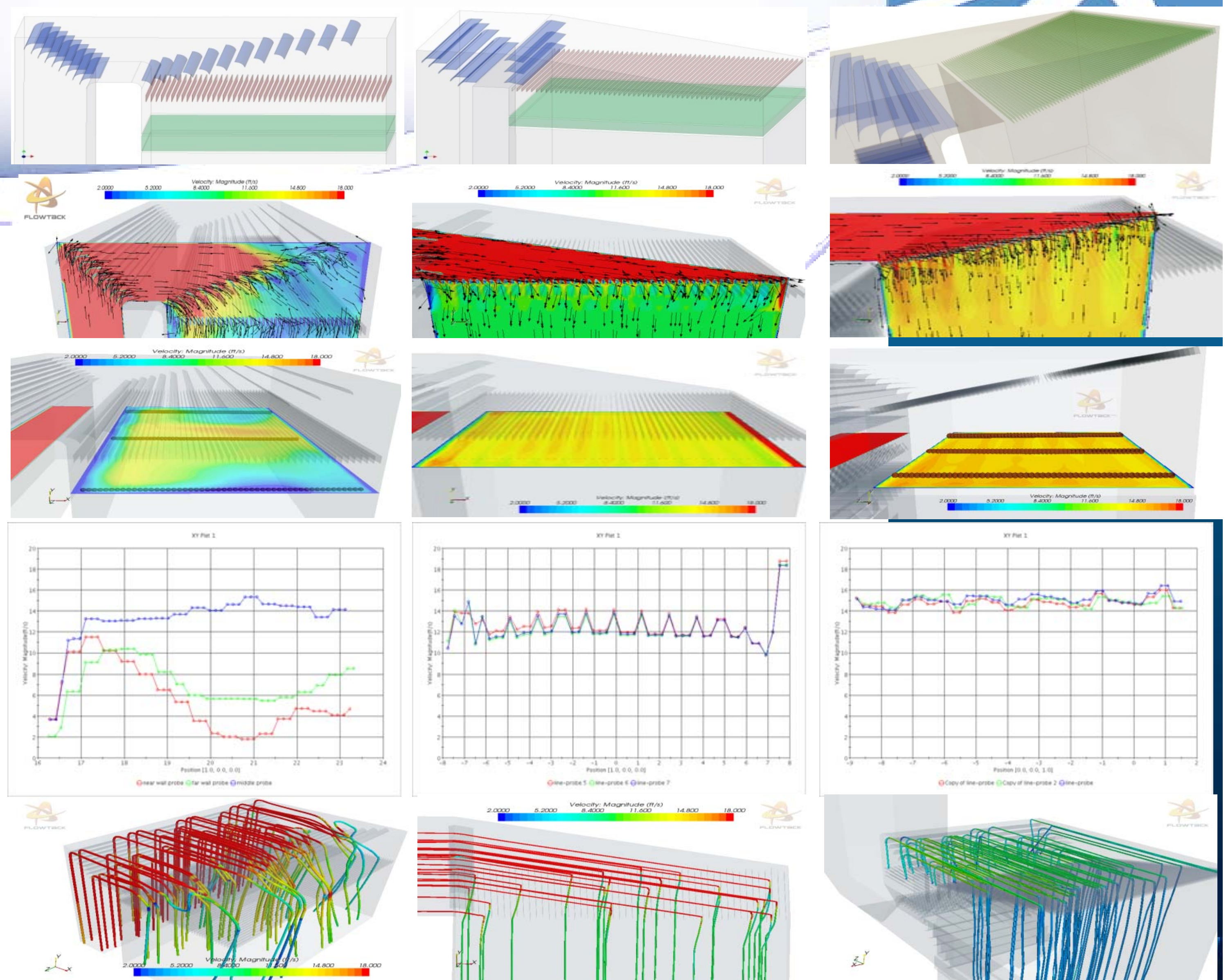
Velocities Measured at Catalyst Face with Traditional Vanes

PHYSICAL FLOW MODEL - GSG



Velocities Measured at the Catalyst Face with GSG

Side-by-Side



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Physical Model Summary

- Traditional Turning Vane Velocity Distribution at Catalyst Face Statistics
    - 62% of velocities within 10% of average
    - 93.9% of velocities within 20% of average
- GSG Velocity Distribution at Catalyst Face Statistics
    - 95% of velocities within 10% of average
    - 100% of velocities within 20% of average

Graduated Straightening Grid (GSG)

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Other Advantages

Applications

- All new units
- Existing units with operational problems
- Existing units where higher NO_x removal is desired

Other Advantages

- Lower total weight than either traditional arrangement
- Allows for reduction in height of reactor without the need for straightening grid and less space between crossover and 1st layer
- No horizontal surfaces for ash to buildup upon
- Improved flow distributions allow design limitations (average velocity) to be pushed (smaller reactors)

Cold Flow/Scale Modeling

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High Velocity Application

- Castle Peak
  - 4 x 680 MW
  - Catalyst Face Velocity >26 fps
  - Start Up of First SCR First Half 2009
  - OEM Doosan Babcock
- Fuel Tech Involvement
  - Urea Ultra System
  - CFD
  - Physical Model

GSG Field Results

- Saint John River Power Park
  - Units 1 and 2 - 670 MW each
- SCR Operation with GSG
  - January 2009 Startup
  - SCR System Performance of 0.05 vs. Guarantee of 0.06 lb/MMBtu

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Fuel Tech Scope

- CFD and Physical Modeling
- Mixer, AIG, GSG and LPA Screen Design
- Process Engineering and Start Up Support

SJRPP

SJRPP

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GSG Field Results

- SCR Test Results with GSG
  - Minor corrections to achieve final AIG tuning
  - AIG tuned in 9 hours

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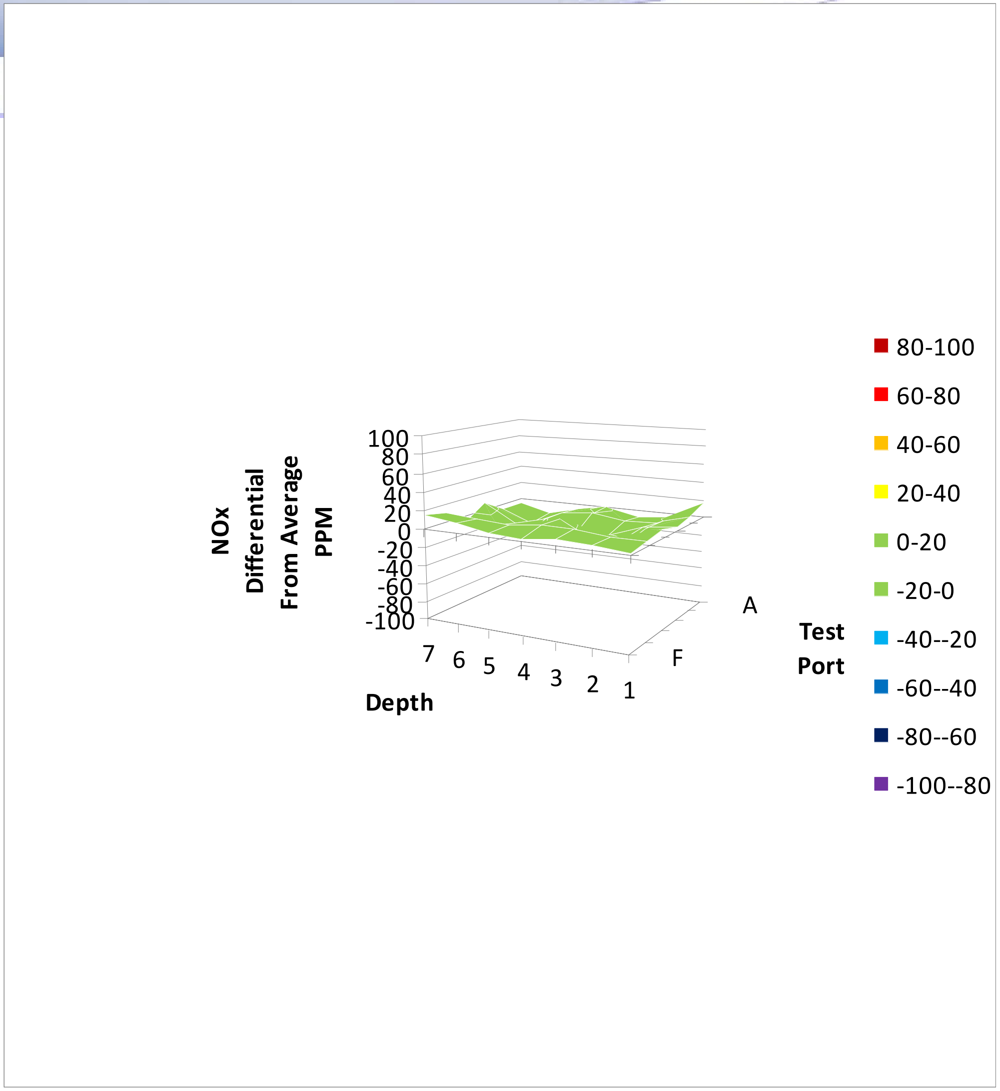
SJRPP Unit 2 Final AIG Tuning



Mixer

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Economics

All-In Capital Cost vs. NOx Reduction

• SCR	$90 - $300/KW		85 - 90%
• Burners	$5 - $10/KW		40 - 60%
• OFA	$10 - $20/KW		30 - 50 %
• SNCR	$10 - $20/KW		20 - 40%
•CASCADE	$35 - $75/KW	~~SO_3~~	60 - 80%
• BOFA+ CASCADE	$50 - $105/KW		85%+

Catalyst Replacement

- One Layer Design
  - – 8,000 to 16,000 hours Replacement
  - – Catalyst Exchange Strategy With Catalyst Rejuvenation
- 1 + 1 Layer Design
  - – Less Catalyst Consumption Compared to 2+1 or 3+1 Stand Alone SCR

Key Points - NO_x

- NO_x has significant benefits particularly for ozone non-attainment areas
- Because the NO_x Trading Programs depend on banking to a much lesser extent, emission reductions are mostly impacted by level of phase I cap and timing and are much less driven by perceptions about the future
- **Costs are likely to increase with short term fixes as companies favor short term solutions (e.g. switching to natural gas, potentially SNCR) with higher operating costs over more capital intensive solutions (e.g SCR) with higher capital costs, but lower overall costs**
- Because reductions and benefits are mostly driven by SO_2, EPA's analysis focused on SO_2 and excludes NOx reductions and benefits, including reductions in premature mortality associated with ozone.

- Source : US EPA Office of Air and Radiation – August 2008

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Conclusion

- The Combination of Technologies Can Provide High Performance, Low Cost Solutions in a Short Period of Time

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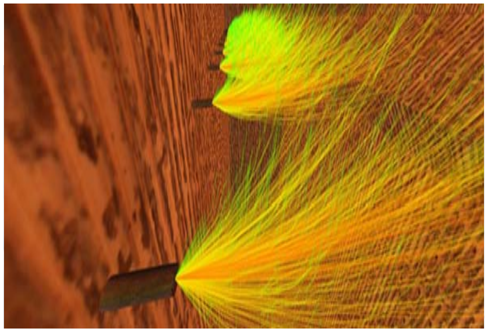

Questions