Reinhold Environmental Ltd.

2007 NOx Round Table & Expo Presentation

February 5-6, 2007 in Cincinnati, OH

Codan Development LLC

URS

"Influence of SO_3 Removal on SCR Design and Operation"

NO_x Workshop
Reinhold Environmental
February 5-6, 2007

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Presentation Outline

- Impacts Created by Presence of SO_3
- Benefits of Effective SO_3 Removal
- Requirements for SO_3 Technology
- SBS Injection™ Technology Description
- SBS Injection™ Development Programs

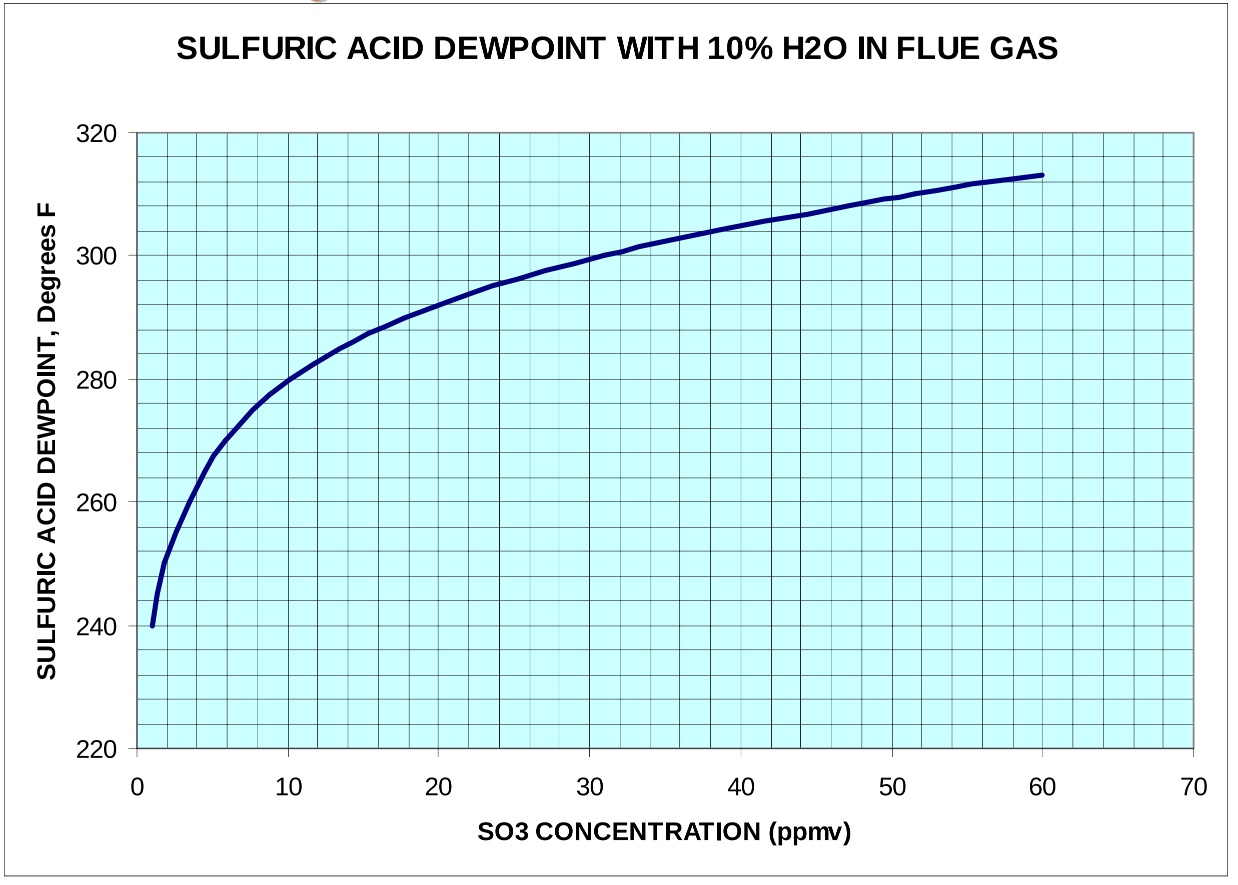
Impacts Created by Presence of SO_3

- Plume Opacity Issue: Coloration of Plume from Optical Light Scattering Effects of Sulfuric Acid Aerosol Particles

Sulfuric acid opacity can be visible when $SO_3 > 5$ppm

Impacts Created by Presence of SO_3

- Plume Effects: Opacity/Buoyancy
- Effect of SO_3 on Sulfuric Acid Dew Point



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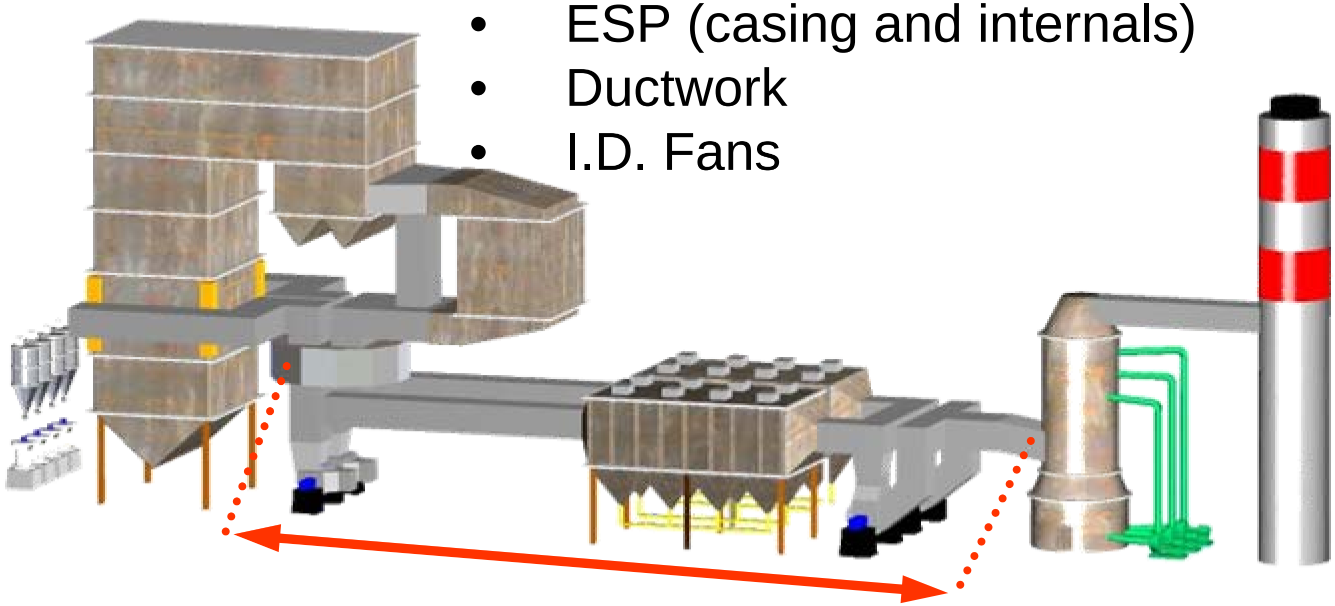
Increased SO_3: Acid Dew Point Implications

Increased Acid Corrosion of all Back-End Components

- Air heater cold-end baskets
- ESP (casing and internals)
- Ductwork
- I.D. Fans



Increasing Air Heater Outlet Temperature Negatively Affects Heat Rate
(Change of 35°F = 1% change in heat rate)

Impacts Created by Presence of SO_3

- Plume Effects
  - ✓ Opacity & buoyancy issues
- Acid Dew Point Effects
  - ✓ Corrosion and/or heat rate issues
- Reaction with Ammonia to Form ABS
  - ✓ Occurs as gas cools in air heater (350-420°F)
    - Plugging/pressure drop issues
    - NH3 slip criterion effects SCR design and operations
    - NH3 slip issue limits application of SNCR
  - ✓ Occurs within catalyst pores (530-630°F)

Impacts Created by Presence of SO_3

- Plume Effects: Opacity & Buoyancy Issues
- Acid Dew Point Effects: Corrosion/Heat Rate Issues
- Reaction with NH_3: Air Heater Fouling/SCR Implications
- Reaction with NH_3: SCR Catalyst Plugging/Deactivation
- Impacts on Use of Fabric Filters
  - ✓ Corrosion issue (casing/components/bags)
  - ✓ Effects on filter cake properties
    - Cake heavier, more sticky, more difficult to remove
    - Implications on cleaning frequency/pressure drop

Impacts Created by Presence of SO_3

- Plume Effects: Opacity & Buoyancy Issues
- Acid Dew Point Effects: Corrosion/Heat Rate Issues
- Reaction with NH_3: Air Heater Fouling/SCR Implications
- Reaction with NH_3: SCR Catalyst Plugging/Deactivation
- Negative Impacts on Use of Fabric Filters
- Adsorption on Fly Ash or Activated Carbon
  - ✓ By occupying these active adsorption sites, reduces ability of flyash/activated carbon to remove mercury

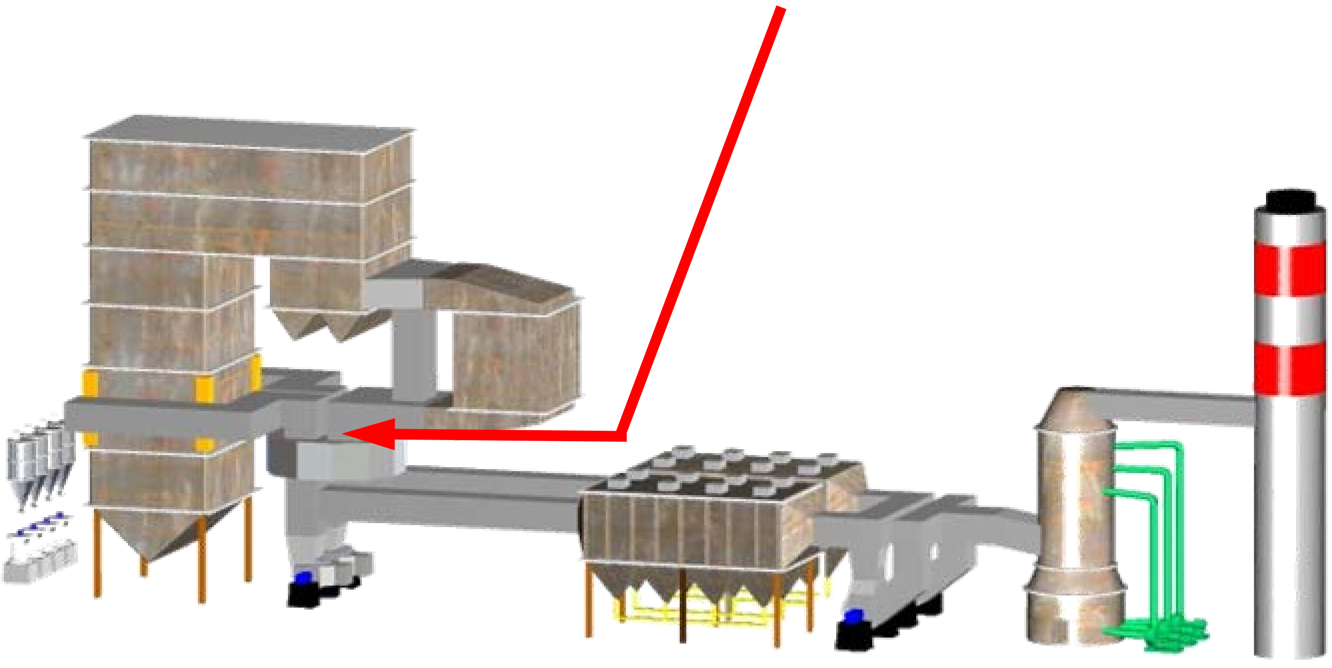
Impacts Created by Presence of SO_3

- Plume Effects: Opacity & Buoyancy Issues
- Acid Dew Point Issues: Corrosion/Heat Rate
- Reaction with NH_3: Air Heater/SCR Implications
- Limits SCR Minimum Temp/Affects Catalyst Life
- Negative Impacts on Use of Fabric Filters
- Reduces Hg Retention by Fly Ash/Activated Carbon.
- Improves ESP Particulate Removal Efficiency

"Effective SO_3 Removal"

Definition: Quick, Efficient Removal of SO_3

to Less than 3 ppm Entering Air Heater



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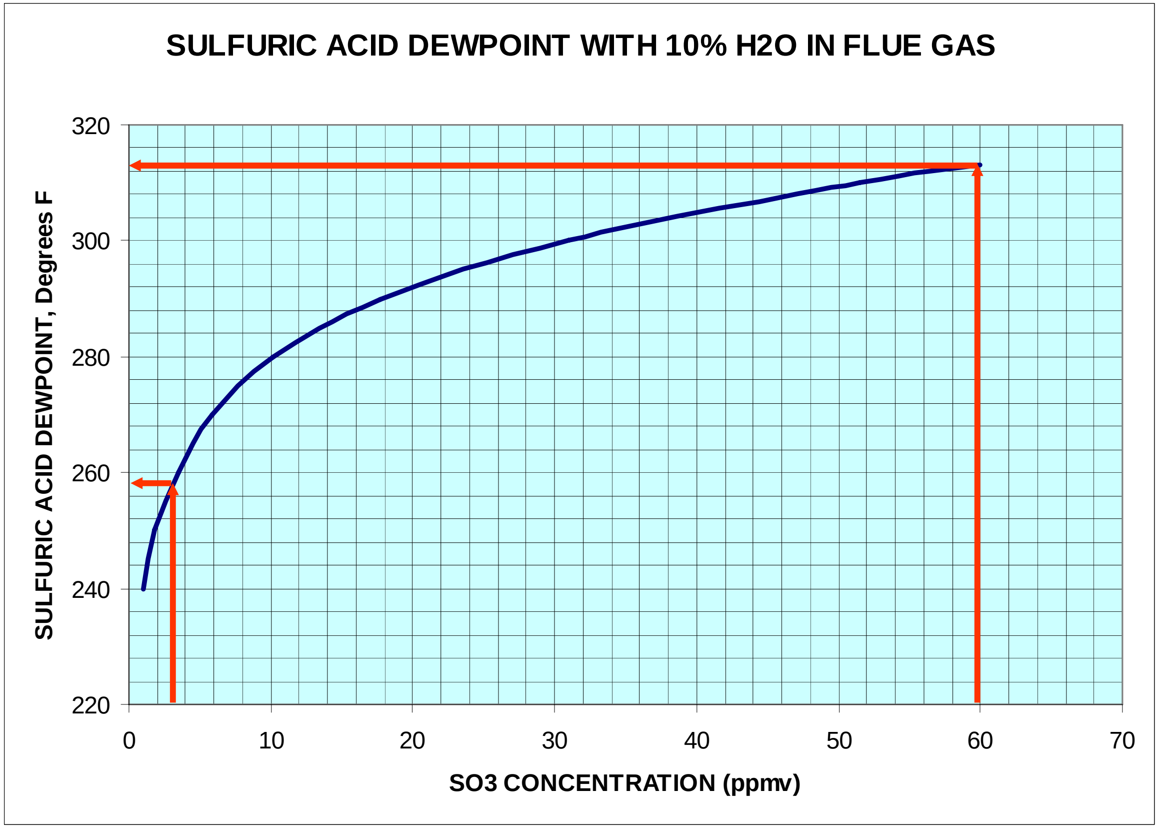
O&M Benefits of Effective SO_3 Removal

- Benefits from Reduced Acid Dew Point



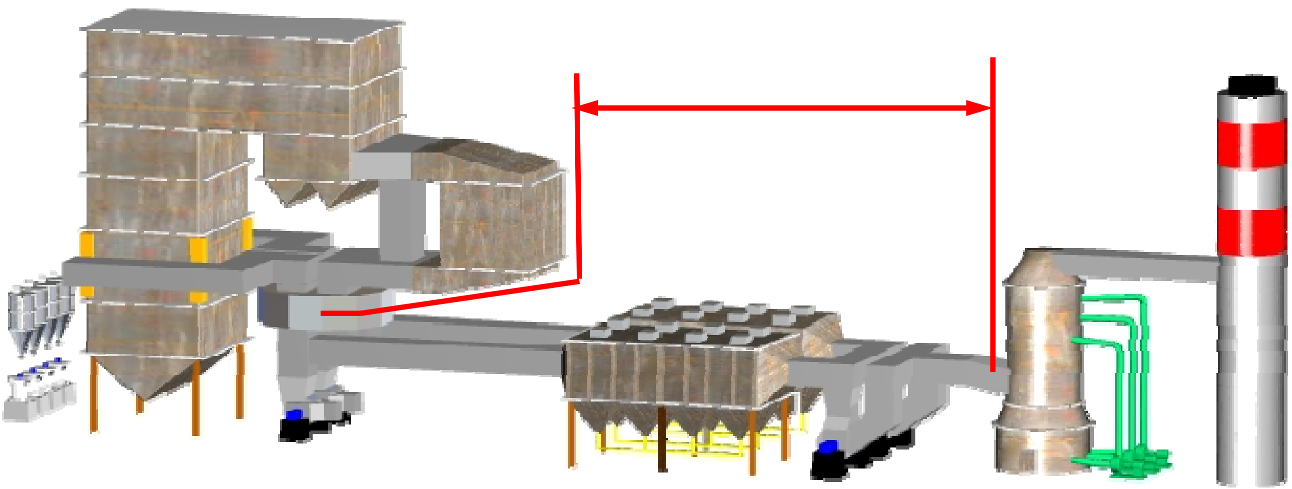
313°F @ 60 ppm

258°F @ 3 ppm

(at 10% H_2O)

O&M Benefits of Effective SO_3 Removal

- Benefits from Reduced Acid Dew Point
  - ✓ Reduced sulfuric acid corrosion for entire backend
    - Reduced dew point = lower potential for corrosion conditions
    - If conditions do occur, only 1/20 the amount of acid present
    - Could eliminate need for enamel coating of air heater cold end baskets



Value Site-Specific: Could Exceed $500k/yr

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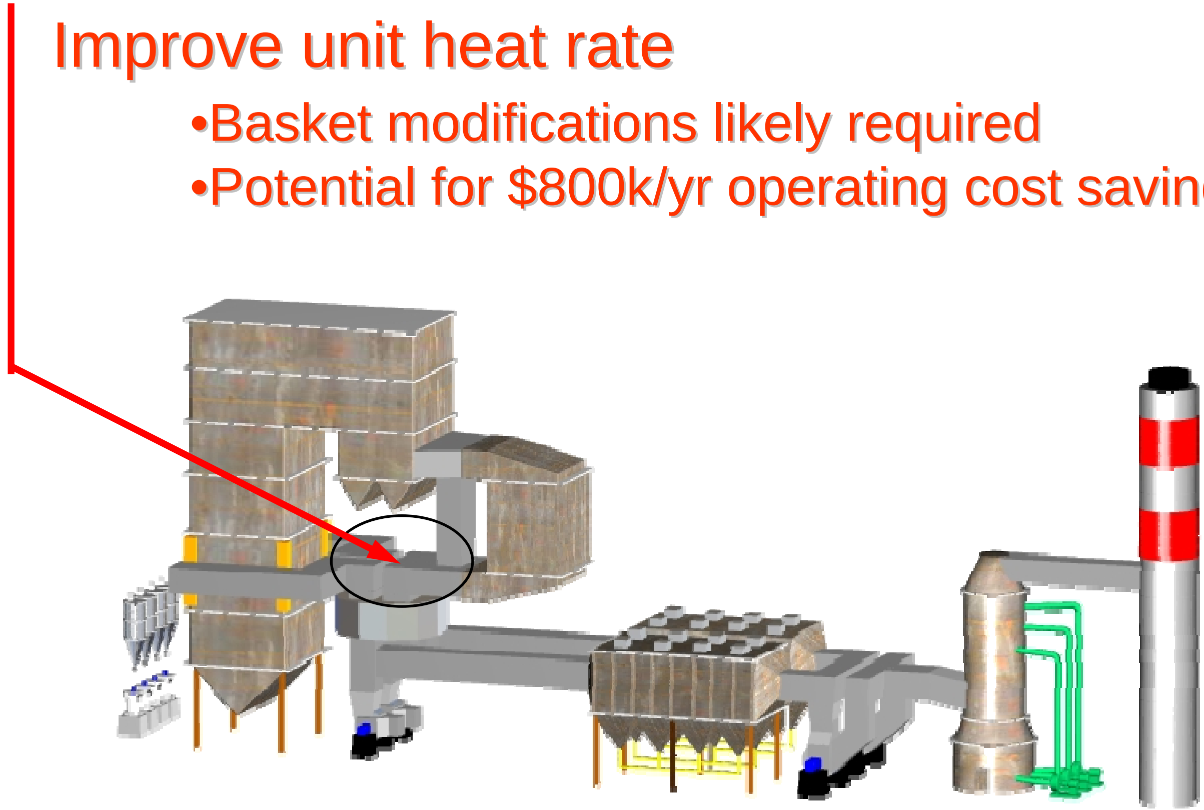
O&M Benefits of Effective SO_3 Removal

- Benefits from Reduced Acid Dew Point
  - ✓ Operate air heater at lower outlet gas temperature

Improve unit heat rate

- •Basket modifications likely required
- •Potential for $800k/yr operating cost savings for 500 MW unit



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O&M Benefits of Effective SO_3 Removal

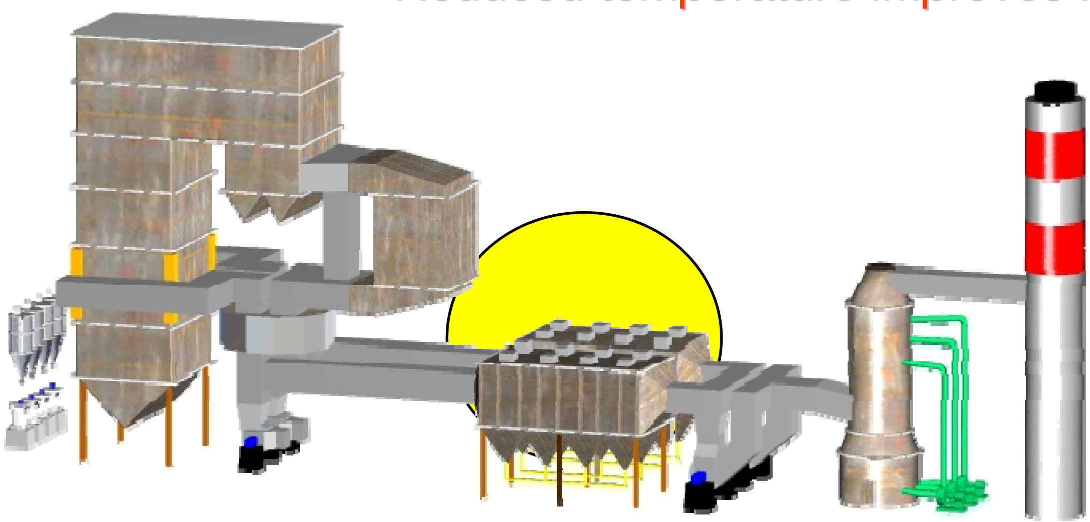
- Benefits from Reduced Acid Dew Point
  - ✓ Operate air heater at lower outlet gas temperature
    - Reduce gas volume (from 313F to 258F = ~7% decrease)

Reduced I.D. fan energy consumption

Increased ESP collection efficiency

-- Increased specific collection area (SCA)

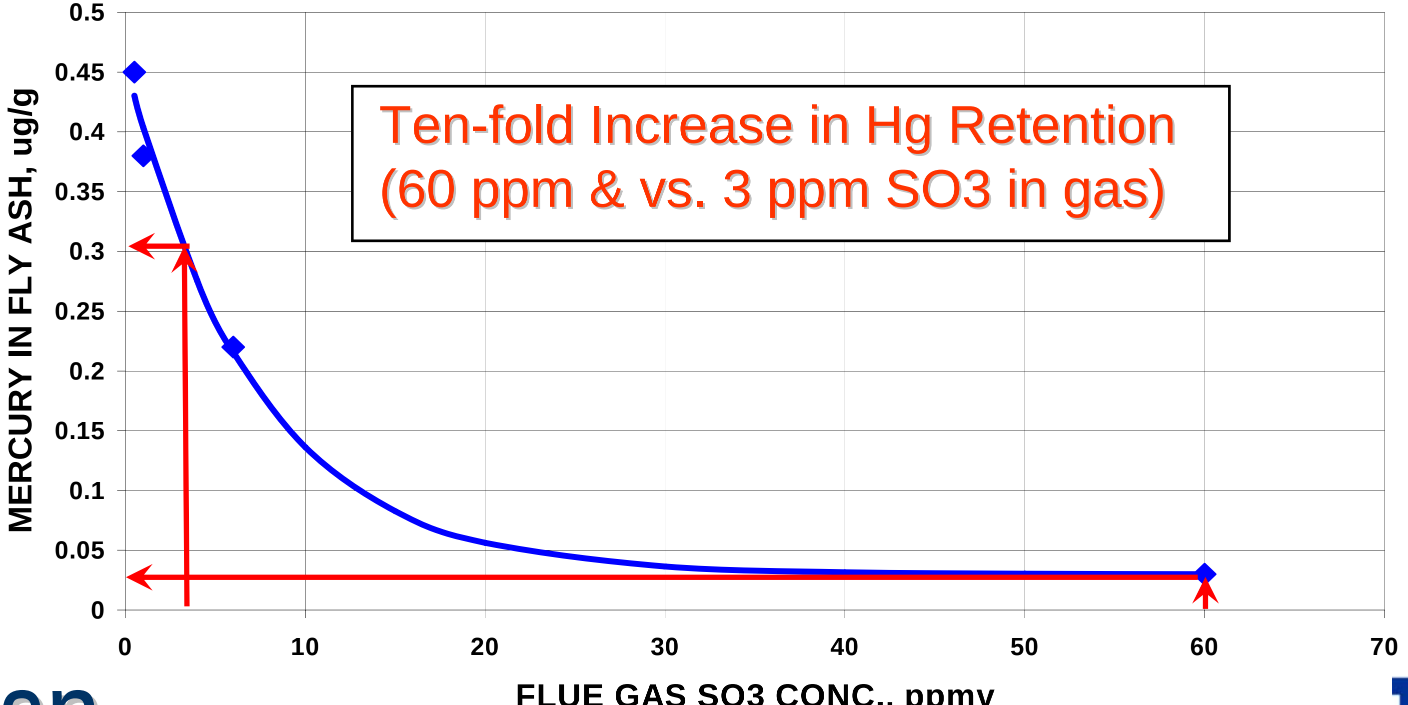
-- Reduced temperature improves fly ash resistivity



O&M Benefits of Effective SO_3 Removal

- With Respect to Mercury Control
  - ✓ Increase retention of mercury on native fly ash

EFFECT OF SO3 ON MERCURY COLLECTED WITH FLY ASH



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O&M Benefits of Effective SO_3 Removal

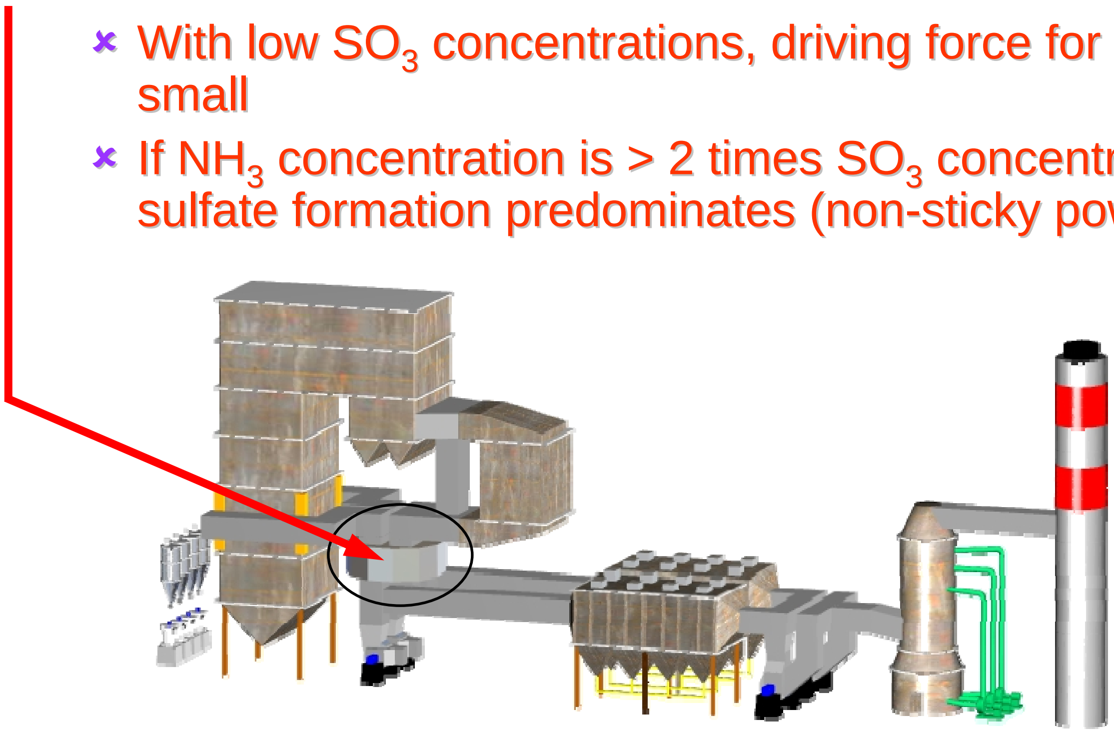
- With Respect to Mercury Control
  - ✓ Increase retention of Hg on native fly ash
  - ✓ Increase efficiency & improve economics of activated carbon injection (ACI) technology
    - In absence of SO_3, carbon will retain more mercury (removal efficiency increased, because carrying capacity increased)
    - Removal efficiency and carrying capacity both improved at lower temperatures – achievable with SO_3 removed.

O&M Benefits of Effective SO_3 Removal

- With Respect to Mercury Control
  - ✓ Increase retention of mercury on native flyash
  - ✓ Increase efficiency & improve economics of activated carbon injection (ACI) technology
    - In absence of SO_3, carbon will retain more mercury (both removal efficiency and carrying capacity increased)
    - Improved carrying capacity of carbon plus lower temperature improve mercury removal efficiency.
    - Could reduce amount of carbon required while increasing mercury removal

O&M Benefits of Effective SO_3 Removal

- Benefits of Limiting the Formation of Ammonium Bisulfate (ABS)
  - ✓ Minimize air heater ABS fouling issues
    - With low SO_3 concentrations, driving force for this reaction is small
    - If NH_3 concentration is > 2 times SO_3 concentration, ammonium sulfate formation predominates (non-sticky powder)



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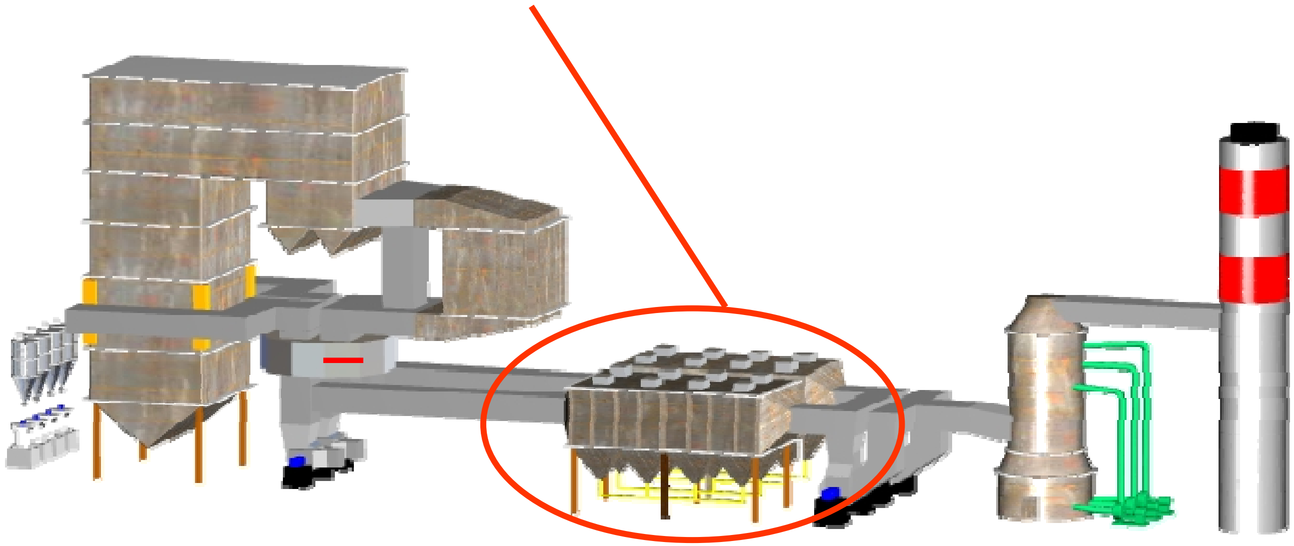
O&M Benefits of Effective SO_3 Removal

- ESP Particulate Removal Efficiency
  - ✓ Lower removal efficiency without condensed SO_3 on ash
  - ✓ Removal efficiency can be restored if sodium reagents are used for SO_3 removal



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Summary: SO_3 Impacts Eliminated

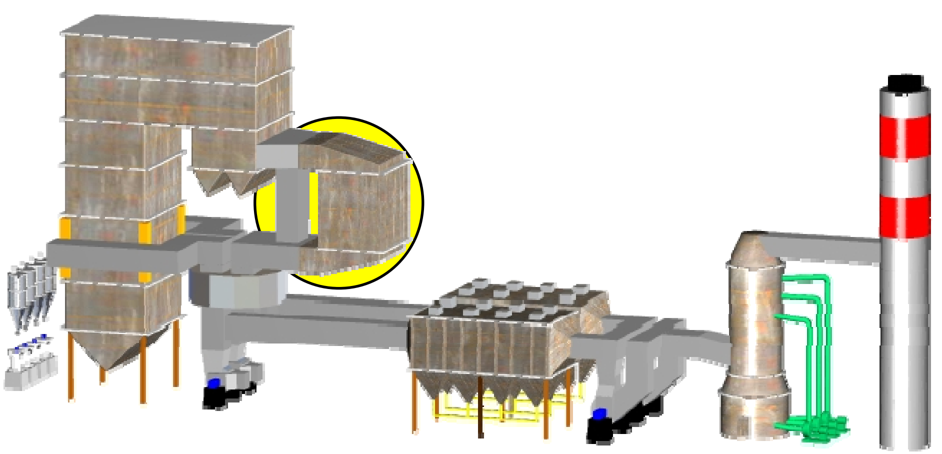
- Plume Effects: Opacity & Buoyancy Issues
- Acid Dew Point Issues: Corrosion/Heat Rate
- Reaction with NH_3: Air Heater/SCR Implications
- SCR Minimum Temp/Affects Catalyst Life
- Negative Impacts on Use of Fabric Filters
- Reduced Hg Retention by Fly Ash/Activated Carbon.
- ESP Particulate Removal Efficiency

SCR Improvement Opportunities

- Reducing the SO_3 Allows Ammonia Slip to be Raised without Air Heater Fouling
  - ✓ Limit ABS deposition in the air heater
  - ✓ Increased NO_x removal & credit generation
  - ✓ Optimized boiler operation (less staging needed)
  - ✓ Increased catalyst management options
  - ✓ Flexibility in NH_3 distribution equipment design
- Improve SCR Catalyst Design with Less Concern About SO_2 Oxidation
- Remove Combustion-Formed SO_3 Upstream of SCR

O&M Benefits of Effective SO_3 Removal

- Benefits from Raising SCR NH_3 Slip
  - ✓ Limit ABS deposition in the air heater
    - Maintaining 1 to 2 ppm maximum slip no longer critical
    - Raising slip modestly (4 – 6 ppm) provides design & operating flexibility



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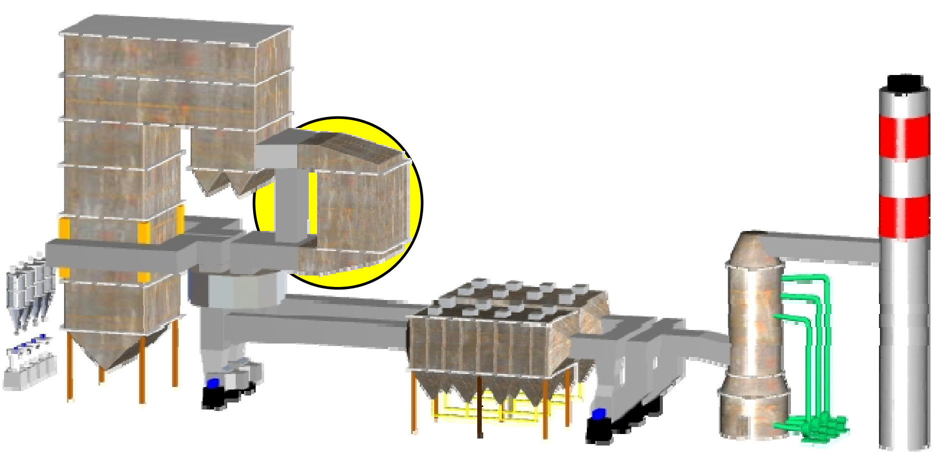
O&M Benefits of Effective SO_3 Removal

- Benefits from Raising SCR NH_3 Slip
  - ✓ Limit ABS deposition in the air heater
  - ✓ Increase NO_x removal efficiency & generate credits



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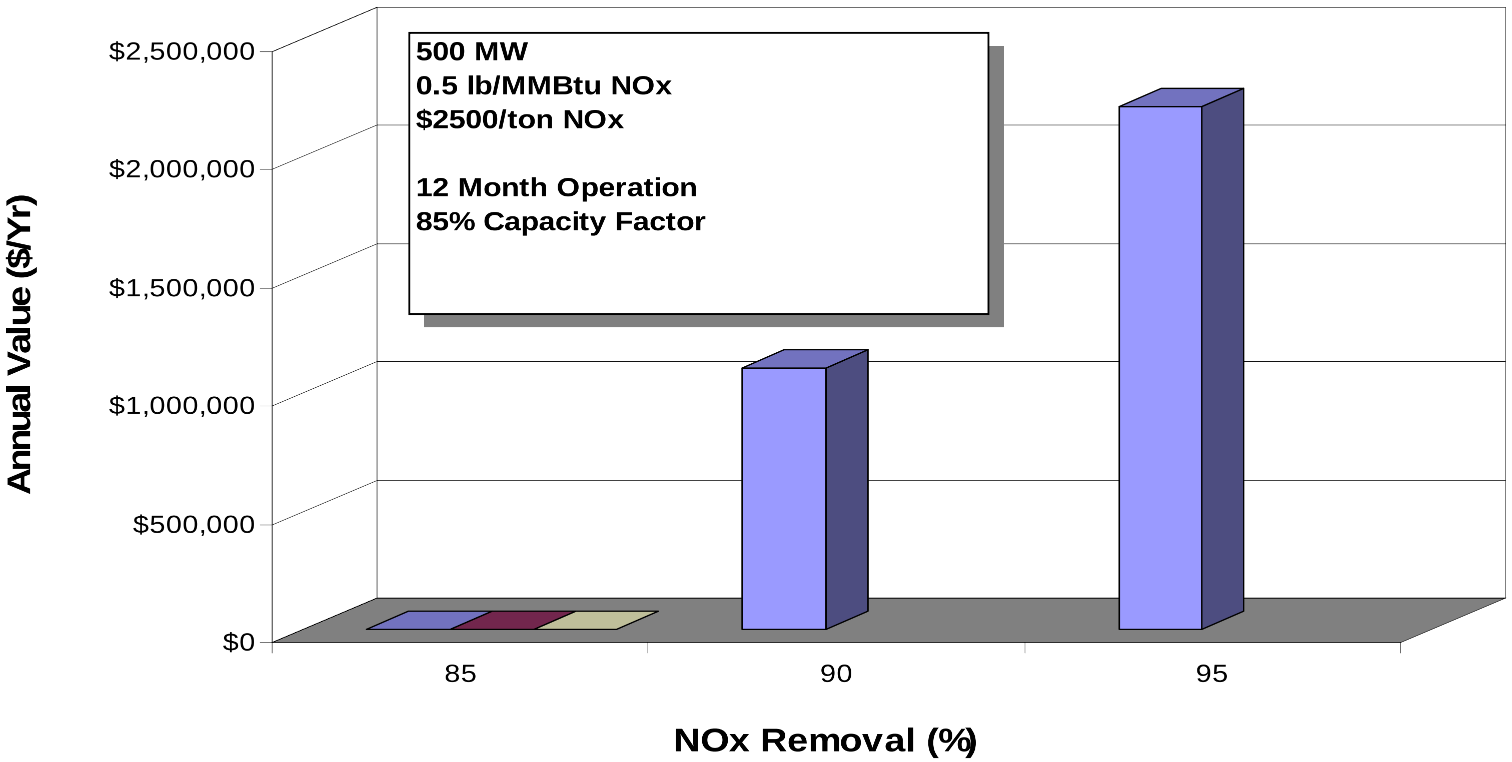
SCR Improvement Analysis – Removal



Incremental NO_x Removal Value =
~ $220k per 1% Improvement per Year

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From 2005 EPRI SCR Workshop Proceedings
"Availability of US SCR Fleet" by Clay Erickson

- "90% NO_x Removal Elusive"
- "Low NO_x Outlet Targets Offer Small Unforgiving Margins"
- Of the 130 units (70,170 MW) Analyzed:

NO_x Rem'l %	# of Units	% of Units	# of MWs	% of MWs
>90%	18	14	9,165	13
87 -90%	34	26	19,757	28
80 – 86%	44	34	26,205	37
70 – 80%	34	26	15,043	22

If NH_3 Slip could be increased (from 1-2 ppm to ~6 ppm) without Air Heater ABS Concerns

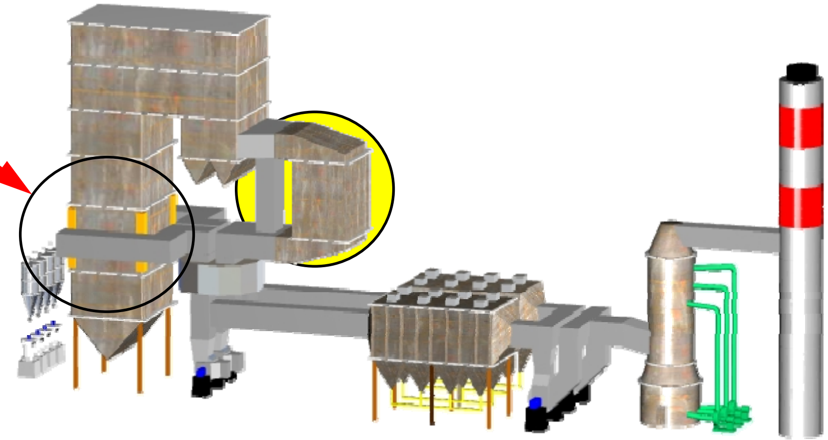
	Estimated Additional NO_x Removed
59% (~41,000 MW) could probably increase NO_x removal by 10% or more	~72,000 tons
An additional 28% (~20,000 MW) could probably increase NO_x removal by 5% or more	~18,000 tons
13% (~9000 MW) could probably increase NO_x removal by 2%	~3,000 tons

All units could achieve higher NO_x removal with greater margins

Increases achieved with no additional SCR capital expenses and a only small increase in operating costs (more NH_3)

O&M Benefits of Effective SO_3 Removal

- Benefits from Raising SCR NH_3 slip
  - ✓ Limit ABS deposition in the air heater
  - ✓ Increase SCR NO_x removal efficiency
  - ✓ Optimize boiler operation



Reduce low-NO_x combustion staging:
(Allow SCR to remove more NO_x)

Reduce fireside corrosion & tube leaks:
(Forced outage = $400k - $600k per occurrence)

Improve heat rate by reduction of unburned carbon:
(0.2% improvement > $100/yr benefit for a 500 MW unit)

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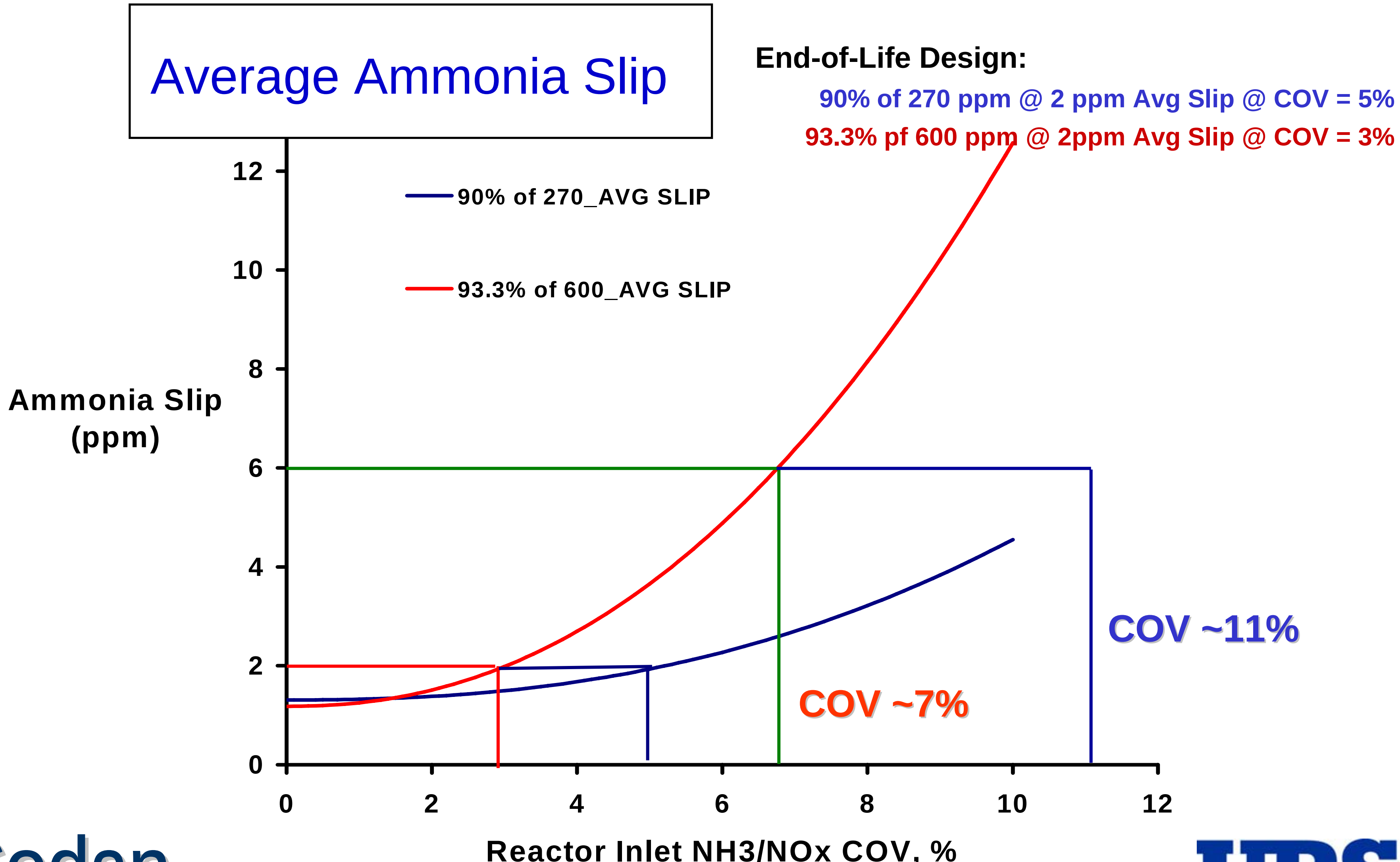
O&M Benefits of Effective SO_3 Removal

- Benefits from Raising SCR NH_3 slip
  - ✓ Limit ABS deposition in the air heater
  - ✓ Increase SCR NO_x removal efficiency
  - ✓ Optimize boiler operation
  - ✓ Increased catalyst management options
    - Increase NO_x removal efficiency at given catalyst activity
    - Fewer/less frequent catalyst replacements
    - Extend useful life of catalyst until next planned outage

O&M Benefits of Effective SO_3 Removal

- Benefits from Raising SCR NH_3 slip
  - ✓ Limit ABS deposition in the air heater
  - ✓ Increase SCR NO_x removal efficiency
  - ✓ Optimize boiler operation
  - ✓ Increased catalyst management options
  - ✓ Provide design flexibility with respect to NH_3:NO_x distribution
    - Higher NH_3/NO_x COV tolerable for given NO_x efficiency
    - Allows more flexibility in NH_3 distribution and mixing equipment design

"Uniformity Requirements and Challenges for Ultra-High SCR DeNOx System Design" by Kevin Rogers, B&W



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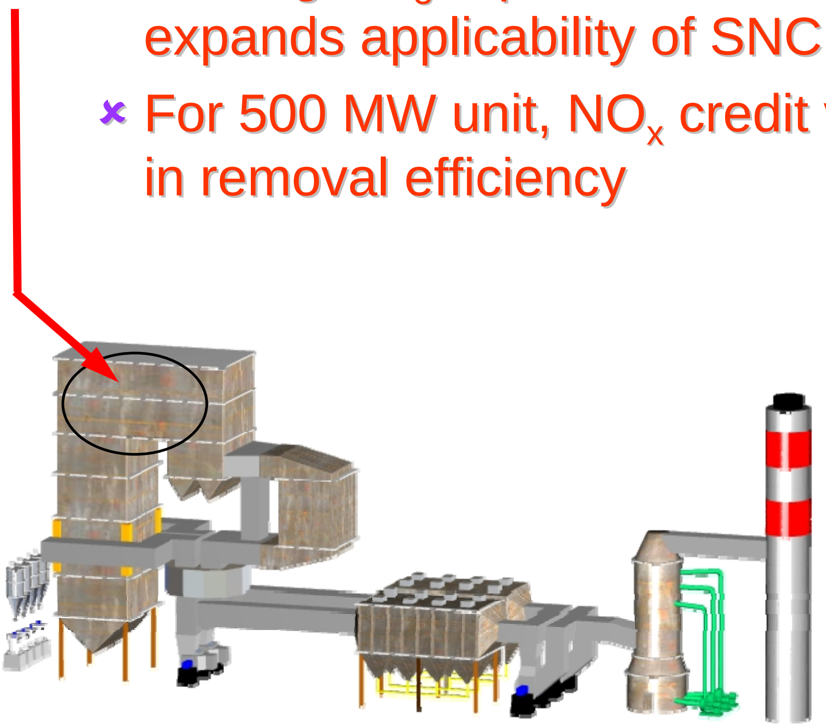
Optimize SCR Catalyst Formulation

- Treat SO_2 to SO_3 Oxidation as an Economic Variable
  - ✓ Consider using Higher Activity Catalysts (Higher V & Increased TiO_2 Support)
- SCR Design and O&M Options
  - ✓ For new SCR's: Lower catalyst volume or higher NO_x removal
  - ✓ For existing SCR's: Replacement with higher activity catalyst to improve NO_x removal efficiency or avoid additional layer
  - ✓ Decouple SO_2 oxidation and mercury oxidation
    - Facilitate development of high NO_x removal, high mercury oxidation catalysts
  - ✓ Synergy of high activity catalyst with increased NH_3 slip

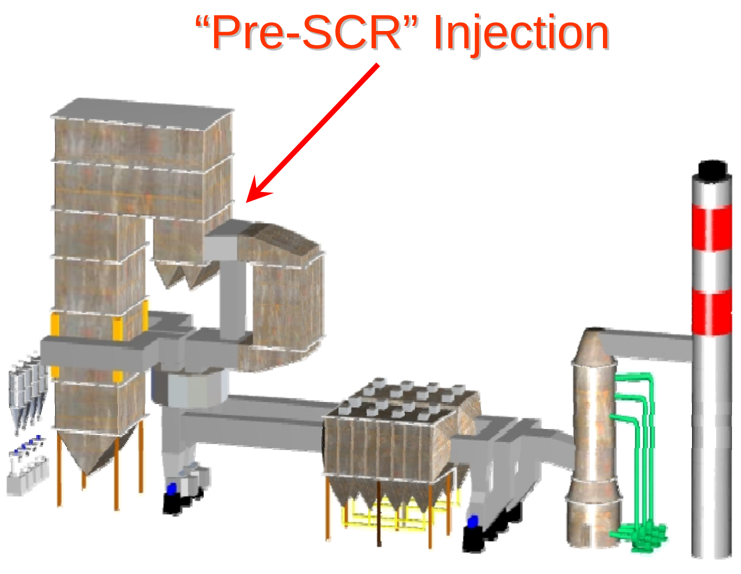
O&M Benefits of Effective SO_3 Removal

- Benefits from Raising NH_3 Slip
  - ✓ With respect to SNCR technology
    - Raising NH_3 slip increases NO_x removal efficiency and expands applicability of SNCR to higher sulfur coals
    - For 500 MW unit, NO_x credit value is ~$220k per % increase in removal efficiency



O&M Benefits of Effective SO_3 Removal

Remove Combustion-Formed SO_3 Upstream of the SCR



- ✓ Can allow lower Minimum Operating Temperature (MOT)
  - Reduce/eliminate formation of ABS within catalysts pores
  - Allow operation at lower loads without catalyst fouling
  - Reduced reliance on economizer bypass and associated maintenance & heat rate impacts
  - Reduced O&M costs

Requirements of SO_3 Control Technology

- Must Consistently Achieve High SO_3 Removal Efficiencies – Certainly >90%; Likely >95%
- Must Operate with Very High Reliability
- Must Not Negatively Impact Balance-of-Plant Operations
  - ✓ SCR (if technology used upstream of SCR)
  - ✓ Ductwork
  - ✓ Air heaters
  - ✓ ESP (must compensate for loss of "SO_3 conditioning")

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  - ✓ Air heaters
  - ✓ ESP (must compensate for loss of "SO_3 conditioning")
- Fate of Excess NH_3 Needs Resolution

Fate of Excess Ammonia

- Will the Ammonia Form an Ammonium Sulfate Particle and be Collected in ESP?
  - ✓ If unreacted SO_3 and NH_3 are present, they will react to form particles or condense on ash.
  - ✓ Without SO_3 present, NH_3 will most likely remain in gas phase with little being collected in the ESP

Fate of Excess Ammonia

- Will the Ammonia Form an Ammonium Sulfate Particle and be Collected in ESP?
- Will the Ammonia that Passes through the ESP be Absorbed in the FGD System?
  - ✓ Yes
  - ✓ NH_3 would provide cations that increase sulfite concentration for scrubbers with inhibited oxidation, which will enhance SO_2 removal efficiency.
  - ✓ NH_3 would cycle up and be washed out of the gypsum in LSFO scrubbers like chlorides.
  - ✓ FGD liquid blowdown or waste sludge treatment must account for NH_3.

Requirements of SO_3 Control Technology

- Must Consistently Achieve High SO_3 Removal Efficiencies – Certainly >90%; Likely >95%
- Must Operate with Very High Reliability
- No Negative Balance-of-Plant Impacts
  - ✓ SCR (if technology used upstream of the SCR)
  - ✓ Ductwork
  - ✓ Air heaters
  - ✓ ESP (must compensate for loss of "SO_3 conditioning")
  - ✓ Fate of Excess NH_3
- SO_3 Removal Efficiency and Point of Removal are Vital Parameters to Achieve Benefits

Potential Value of SO_3 Removal

- Benefits could be in the $5-10 M/yr Range for a 500 MW Unit
- Costs Involved for SO_3 Control – Both Capital and Operating Costs
- Benefits Involve Additional Costs: Air Heater Modifications & NH_3 Costs
- Potential Benefits Many Times the Costs

Presentation Outline

- Impacts Created by Presence of SO_3
- Benefits of Effective SO_3 Removal
- Requirements for SO_3 Technology
- SBS Injection™ Technology Description
  - ✓ Commercial installations
  - ✓ Opacity reduction
- SBS Injection™ Development Programs
  - ✓ Reagent testing
  - ✓ Mercury reduction
  - ✓ “Pre-SCR” reagent injection

Technology Description

- Injection of a Sodium Alkali Solution
- Injection Typically between SCR and ESP
  - ✓ Upstream or downstream of the air heater
- Solution is Flash Dried in Flue Gas
- Reaction between SO_3 and Dried Particles
- Dry Reaction Products Collected in ESP/FF
- High SO_3 Removal at Low Injection Rates

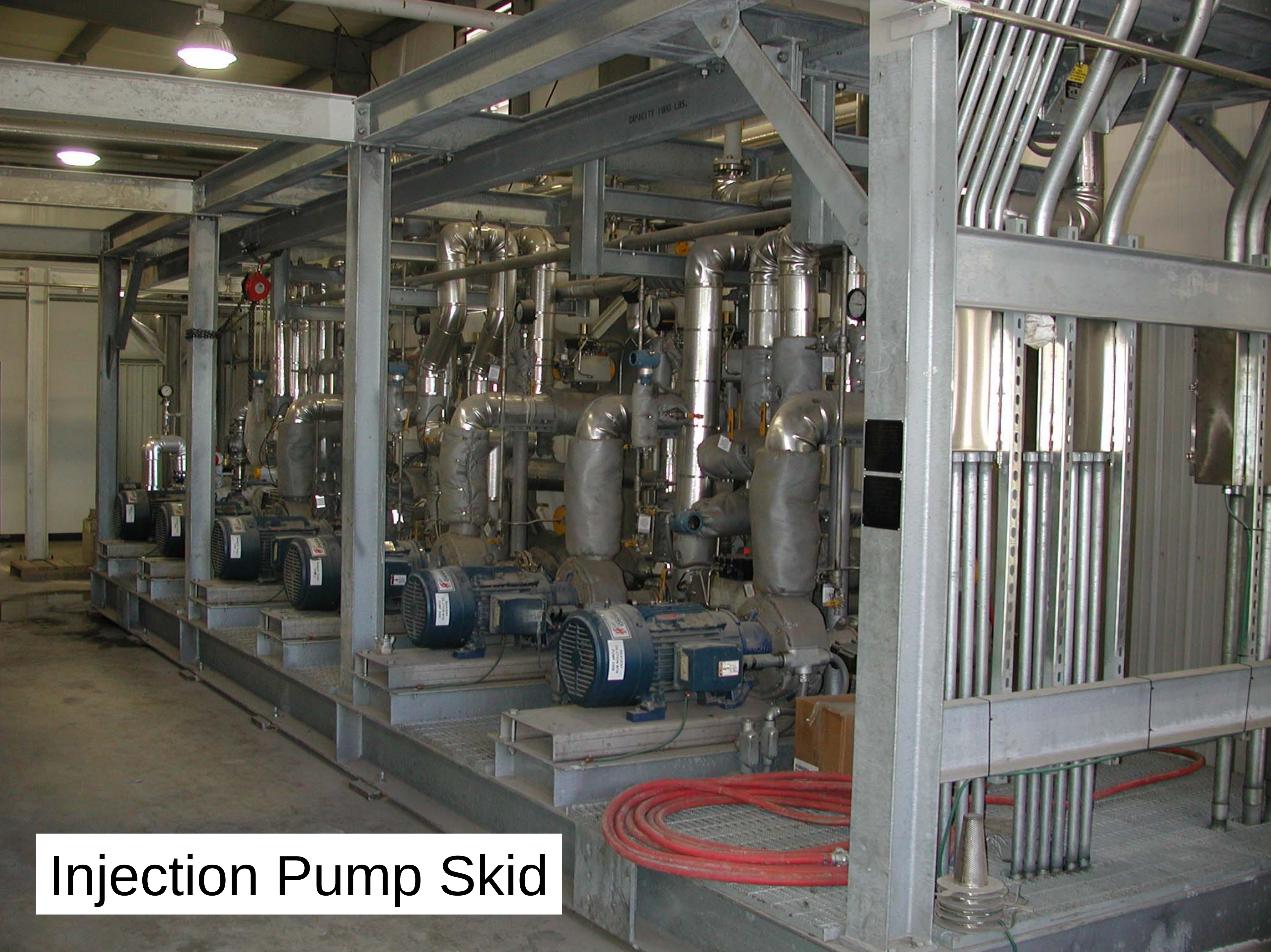
Commercial Installations

Utility	Plant	Location	MW	Design SO_3	Injection Location	Reagent	Operating Season	Startup Date
FirstEnergy	Mansfield 1-3	Shippingport, PA	3x860	80	Air Heater Inlet	Sodium Sulfite Solids	Year-round	March 2003
TVA	Widows Creek 7	Stevenson, AL	550	54	Air Heater Inlet	Sodium Sulfite Solution	Ozone	April 2003
NIPSCO	Bailly 8	Porter, IN	365	59	Air Heater Outlet	Sodium Carbonate Solution	Ozone	April 2004
Vectren	Culley 3	Newburgh, IN	287	48	Air Heater Inlet	Byproduct SBS Solution	Year-round	July 2004
PPL	Montour 1-2	Washingtonville, PA	2x765	42	Air Heater Outlet	Sodium Carbonate Solids	Ozone	Aug 2004
Cinergy	Gibson 1-5	E. Mt. Carmel, IN	5x650	110	Air Heater Outlet	Sodium Carbonate Solids	Ozone	May 2005

Over 8500 MW Installed and Operating

Duke Energy Gibson Generating Station


Reagent
Storage
Tanks and
Pump Bldg



Injection Pump Skid

Injection Metering Skids

Injection Lance System

Benefits of "Upstream" Injection

- Reduced AH Fouling
  - ✓ Reduced sulfuric acid & ABS deposition
- Improved Heat Rate
  - ✓ Lower air heater outlet temperature & fan power
- Enhanced SCR Performance
  - ✓ NO_x removal
  - ✓ Design & operating flexibility
  - ✓ Catalyst life & management strategy
- Enhanced Hg Removal
  - ✓ Lower flue gas temperature
  - ✓ Elimination of SO_3

Technology Development Activities

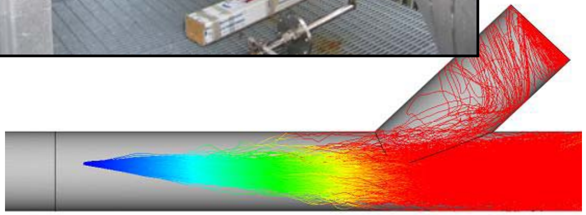
- Pilot Reagent Evaluation Test Program
- Pilot “Enhanced” Mercury Removal Test
- Pilot “Pre-SCR” SBS Injection Evaluation
- Pilot Baghouse Demonstration
- Single-Fluid Atomization Demonstration

Technology Development Activities

- Pilot Reagent Evaluation Test Program
- Pilot “Enhanced” Mercury Removal Test
- Pilot “Pre-SCR” SBS Injection Evaluation
- Pilot Baghouse Demonstration
- Single-Fluid Atomization Demonstration

Pilot Reagent Test Program Overview

- Evaluate Alternative Reagents at "Upstream" Injection Location
  - ✓ Sodium sulfite
  - ✓ Sodium carbonate
  - ✓ Sodium hydroxide
  - ✓ Sodium thiosulfate
  - ✓ Dissolved trona
- Southern Company Plant Crist Mercury Research Center (~5 MW)
- SO_3 Removal versus Residence Time & Molar Ratio
- Mercury Removal versus SO_3
- September/October 2006



Project Participants

- Indianapolis Power & Light
- FirstEnergy
- Hoosier Energy
- Southern Company/Gulf Power
- EPRI
- Southern Research Institute
- Southern Ionics
- Solvay

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Relative Reagent Costs

Reagent	Cost per Dry Ton, Delivered	Sodium Cost (Relative to Sodium Sulfite)
Sodium Sulfite	$350	1.00
Soda Ash	$225	0.54
Trona (T-200)	$150	0.52
Trona (T-50)	$125	0.45
Caustic	$350	0.63
Sodium Thiosulfate	$350	1.25

- Most of the Tested Reagents would Reduce Operating Costs Relative to Sodium Sulfite by ~1/2
- Costs would be Lower for Sodium Thiosulfate Provided from Waste or Byproduct Streams

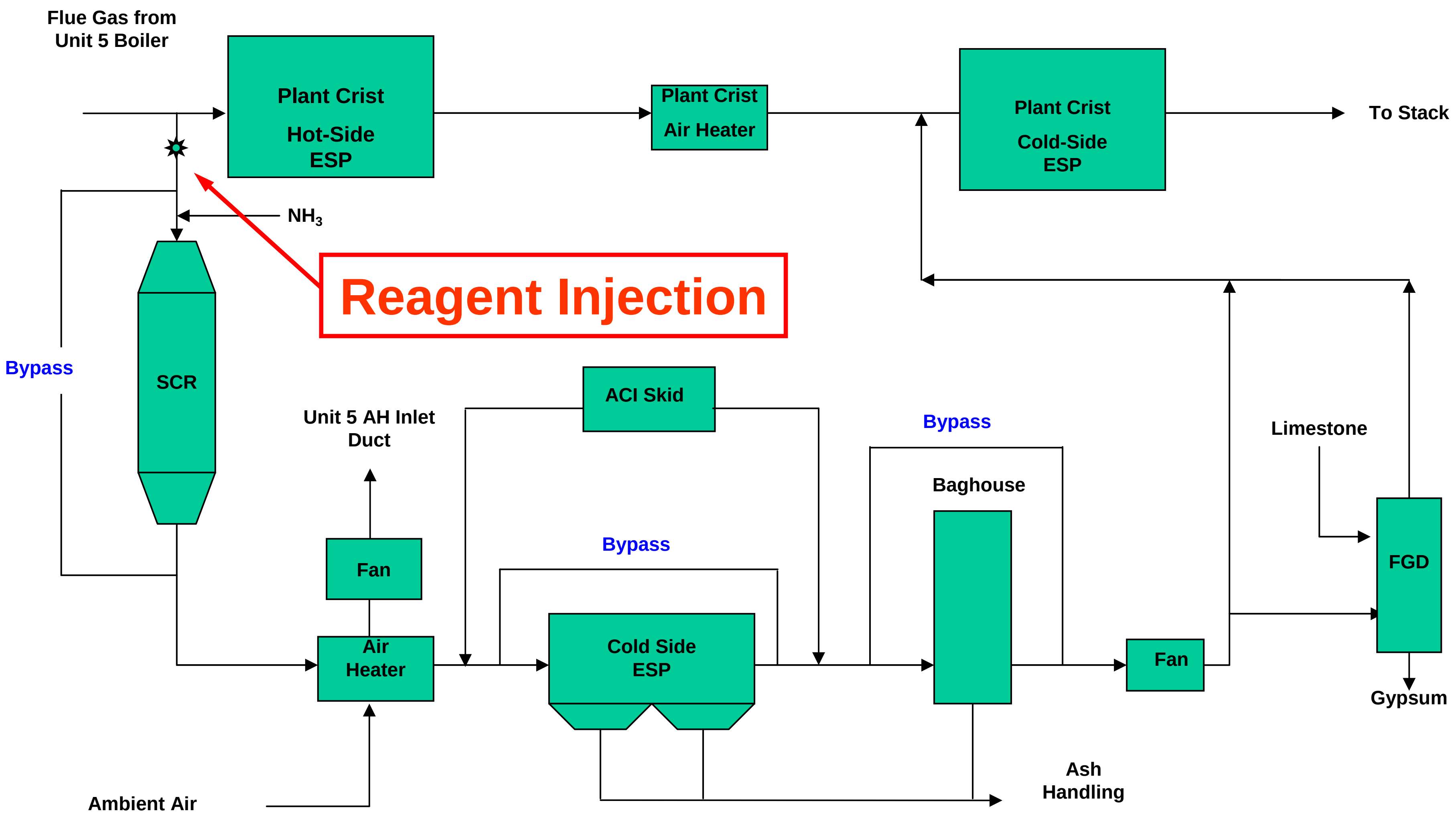
Pilot Reagent Test Program Objectives

- Quantify Performance of Sodium Carbonate (Soda Ash) and Other Potential Reagents for "Upstream" Injection
  - ✓ Increase the number of reagents that can provide "upstream" injection benefits
  - ✓ Develop lower-cost reagent alternatives to reduce operating costs
- Collect Performance Data to Improve Process Performance Estimates
- Evaluate Effect of Varying SO_3 Concentration on Mercury Removal with the Native Fly Ash

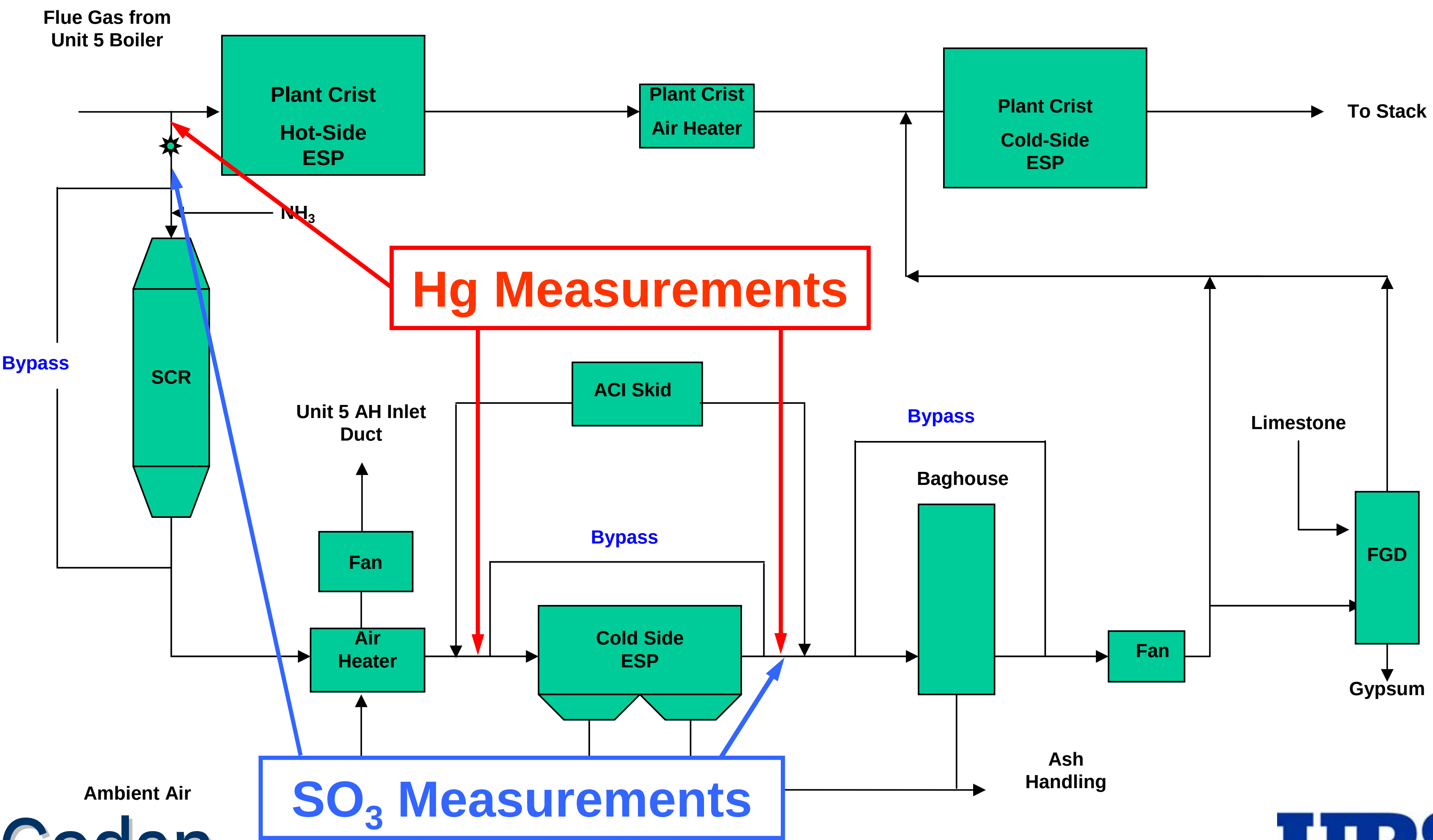
Project Appoach

- Testing Performed at the Mercury Research Center (MRC)
  - ✓ Unit 5 at Southern Company's Plant Crist
  - ✓ ~ 5 MW equivalent size
  - ✓ 0.5 to 1.0% sulfur coal
- Pilot Unit Equipped with SO_2/SO_3 Injection
  - ✓ Significant control over these species
- Single, Commercial-Size Injection Nozzle
  - ✓ Test ports for SO_3 with varying residence times downstream of the injection location (1 – 4 seconds)
  - ✓ Mercury measurements at MRC facility inlet and at EPS Inlet/Outlet

MRC Pilot Equipment Configuration



MRC Pilot Equipment Configuration



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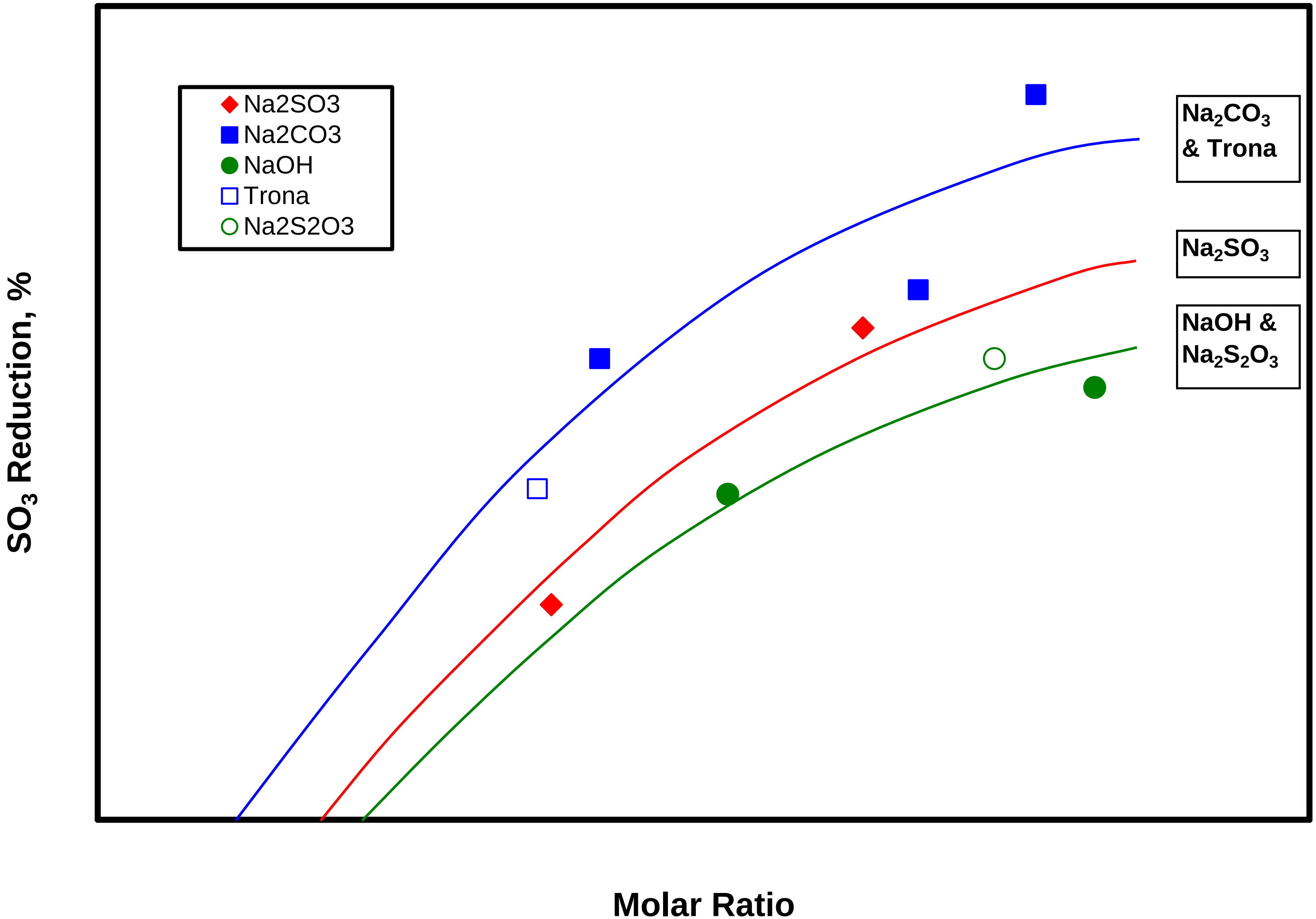
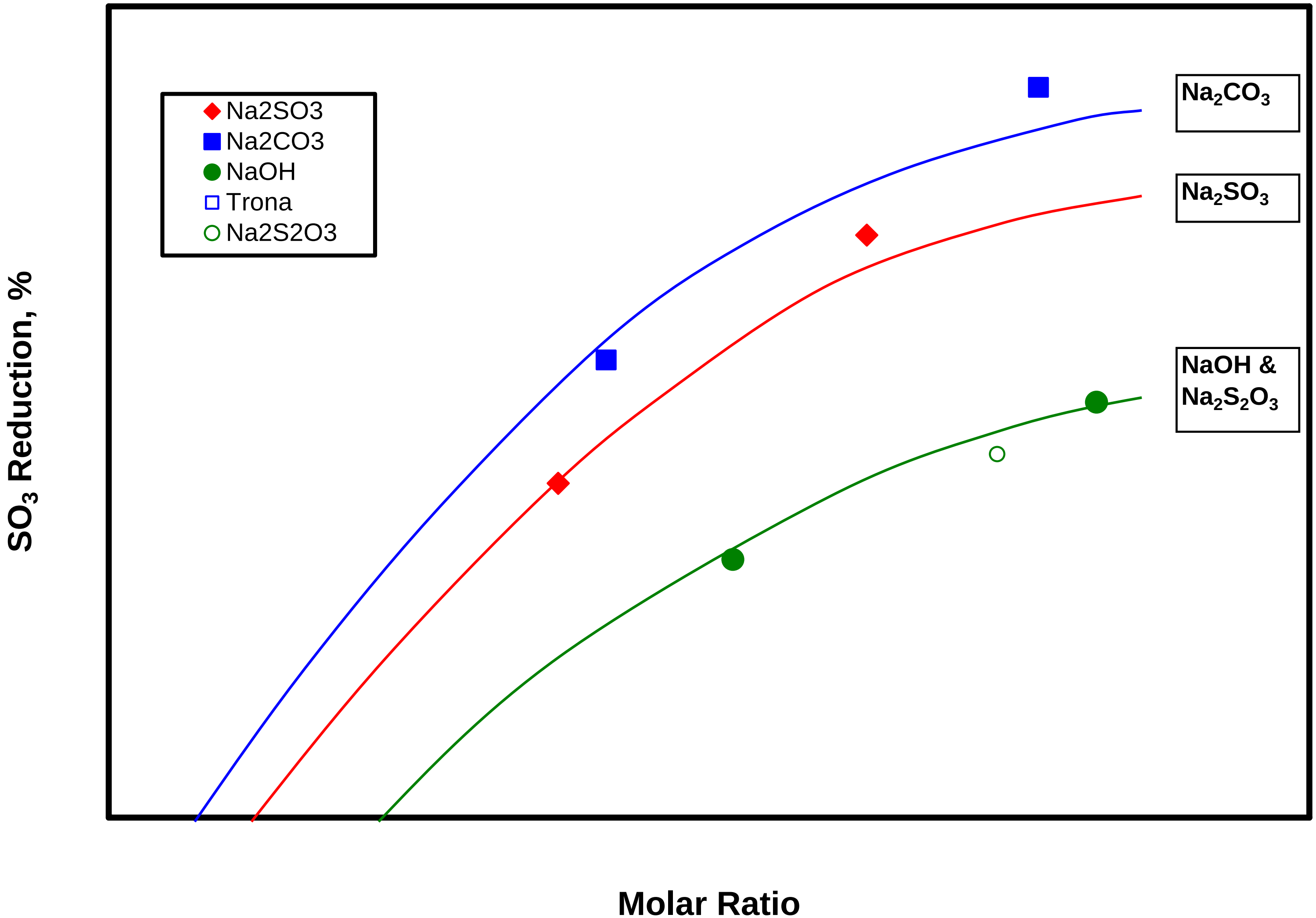
SO_3 Reduction vs Molar Ratio

(Residence Time = 1.0 Seconds)



SO_3 Reduction vs Molar Ratio

(Residence Time = 1.4 Seconds)



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Reagent Testing Results Summary

- All of the Tested Reagents were Effective in Removing SO_3
- SO_3 Removal Efficiencies with Soda Ash were As Good or Better than Sodium Sulfite
- "Upstream" Benefits can be Obtained with Lower Reagent Costs

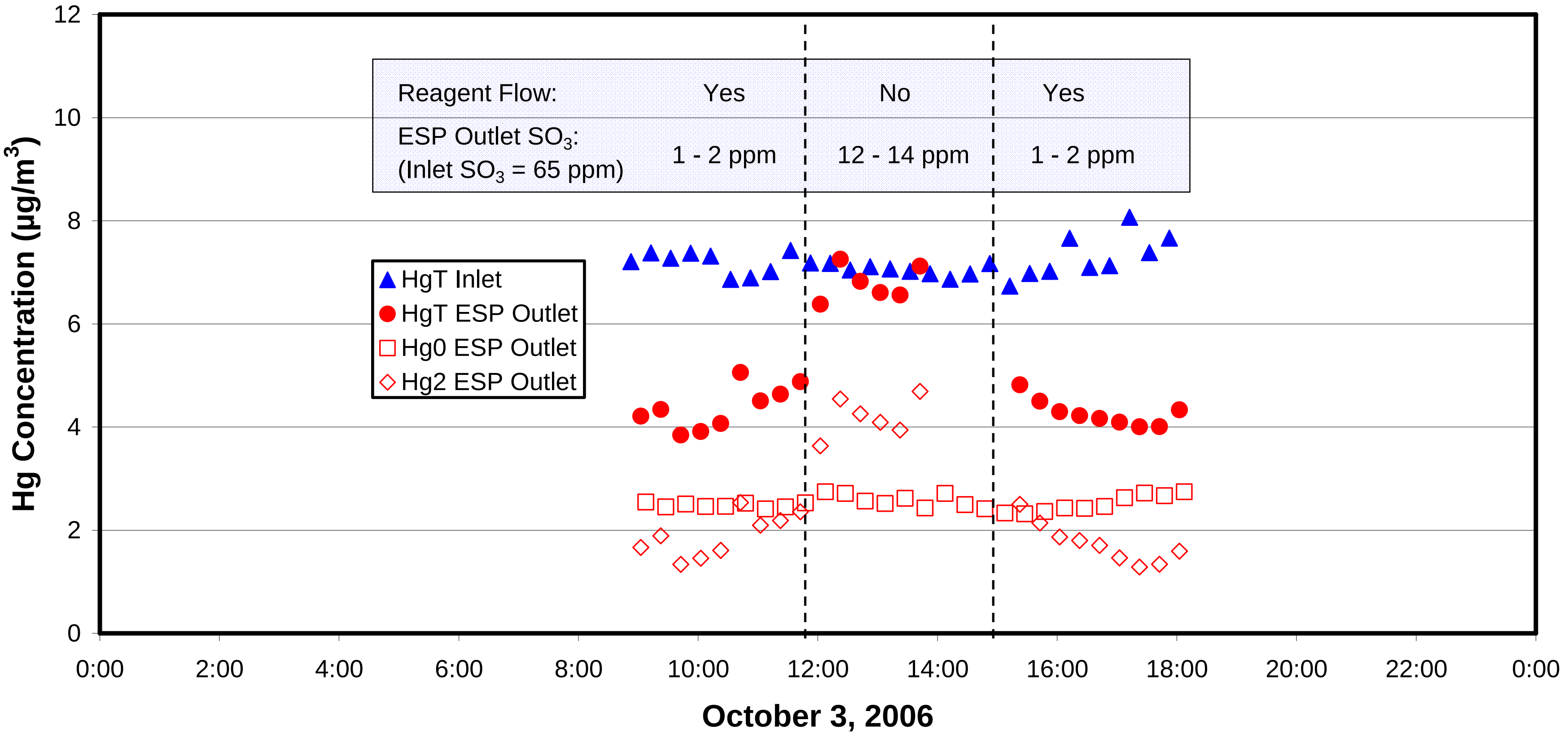
Mercury Removal Testing Approach

- Evaluate Impact of SO_3 on Hg Capture by Carbon in Ash
- Data Collected During & Between Reagent Tests
  - ✓Tests with/without SO_3 injection
  - ✓Tests with/without reagent injection
  - ✓Relatively short test periods (screening tests)
  - ✓Data collected for all five reagents

Mercury Removal Testing Data Collection

- Hg Concentration Data Collected by Southern Research for EPRI
  - ✓ Tekran Model 2375A Mercury Vapor Analyzer with a semi-continuous monitoring system
  - ✓ Measurements of total & elemental mercury
  - ✓ Measurements at MRC inlet & ESP Outlet
- Operating Conditions
  - ✓ LOI concentrations of 3 – 5% (SRI)
  - ✓ AH & ESP outlet temperatures of 300 & 285°F for all tests

Sample Mercury Removal Data (NaOH)



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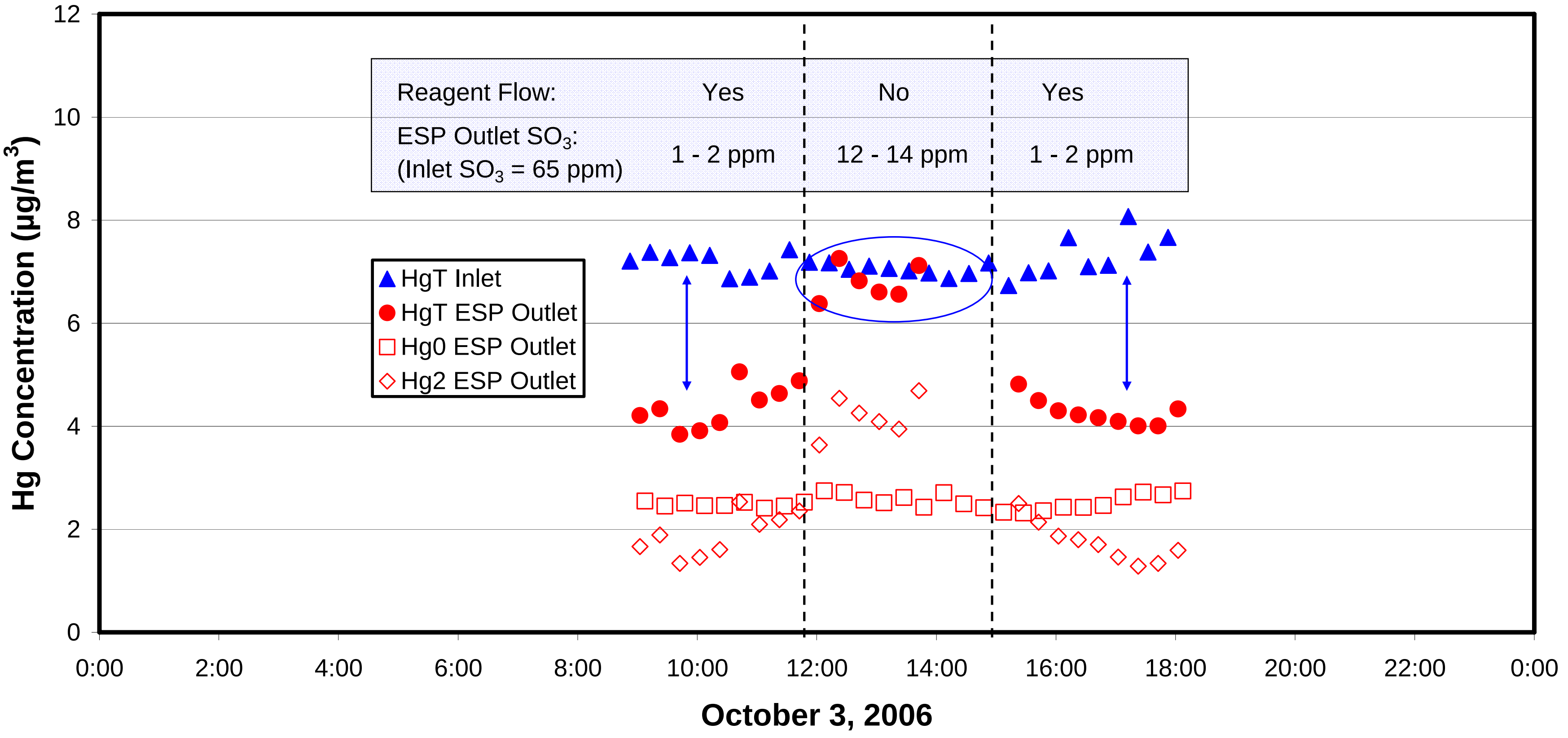
Sample Mercury Removal Data (NaOH)



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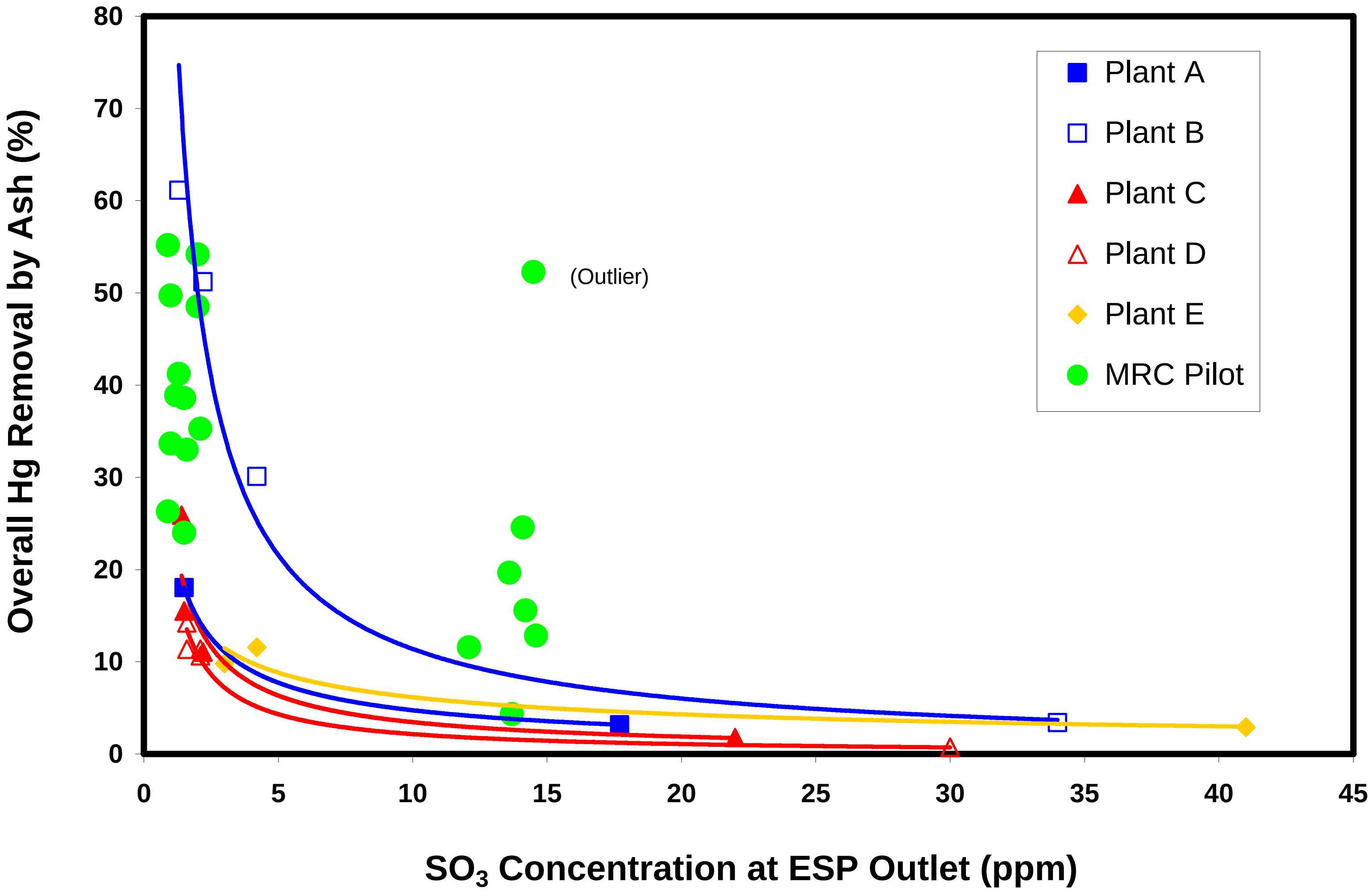
Comparison of Pilot and Commercial-Scale Results



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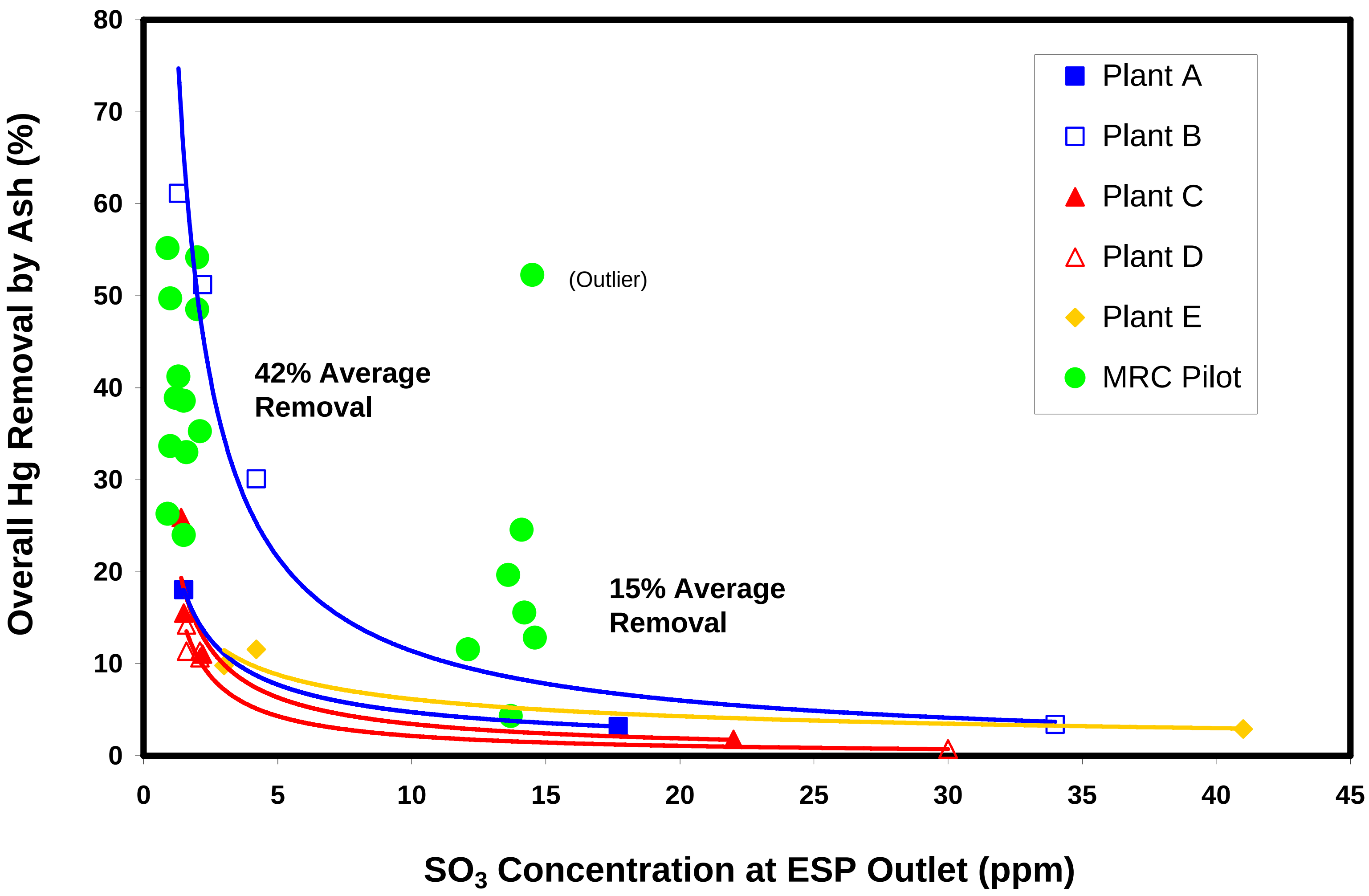

Overall Hg Removal by Ash (%)
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
35
40
45
SO3 Concentration at ESP Outlet (ppm)
Plant A
Plant B
Plant C
Plant D
Plant E
MRC Pilot
(Outlier)
42% Average Removal
15% Average Removal

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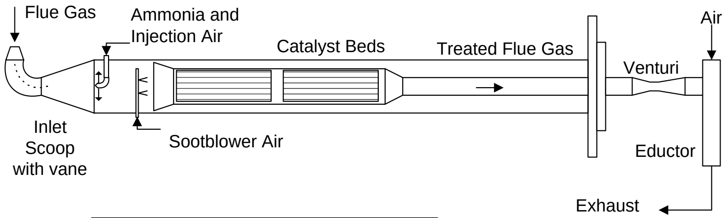
Conclusions

- Mercury Removal Efficiency was Affected by the SO_3 Concentration at the ESP Outlet
  - ✓ Mercury removal increased at lower SO_3 concentrations
- The Results Suggest that Oxidized Mercury was the Species that was Removed by the Fly Ash

“Pre-SCR” Injection Testing Overview

- Evaluate Impact of Catalyst Exposure to Sodium Reagents
- Host Site - FirstEnergy Mansfield
  - ✓ SBS system in operation
- Catalyst “Slip Stream” Mini-Reactor (FERCO)
- Short-Term Testing
  - ✓ Exposure to SBS (675°F)
  - ✓ Simulate lay-up conditions
- Catalyst Analysis
  - ✓ Bulk and surface sodium
  - ✓ Activity (relative)
- November 2006



Project Participants

- FirstEnergy
- Ameren
- Dayton Power & Light
- Duke Energy
- FERCo
- CERAM Environmental
- Cormetech

“Pre-SCR” Injection Testing Drivers

- Allow “Upstream” SBS Injection where Residence Time is Limited
  - ✓ Use residence time within the SCR itself
- Allow a Reduction in the Minimum Operating Temperature (MOT) of the SCR
  - ✓ MOT limited by ABS formation in the catalyst
  - ✓ Many utilities installing scrubbers and then switching to higher sulfur coals, which increases the MOT
  - ✓ Increasing the flue gas temperature can be expensive or impractical, even with economizer bypass
  - ✓ “Pre-SCR” injection could remove combustion-generated SO_3, allowing reduction in MOT

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“Pre-SCR” Injection Testing Objectives

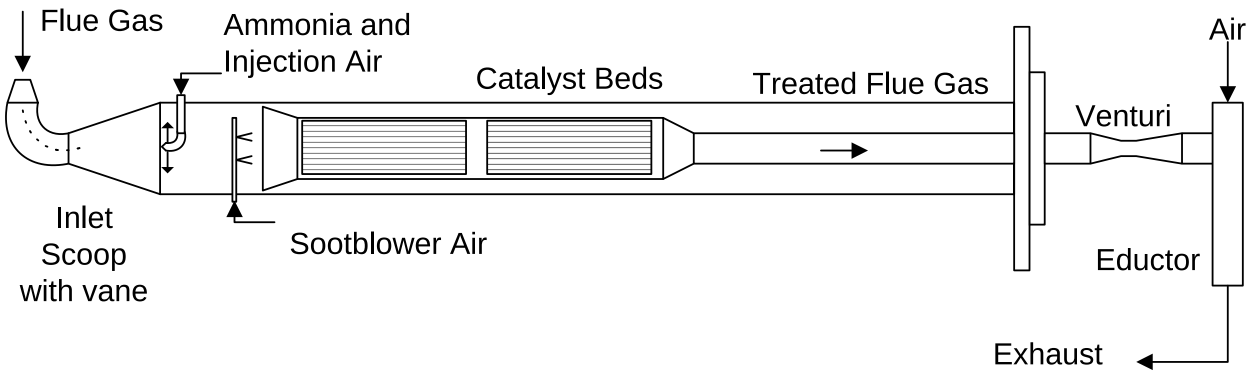
- Determine Feasibility & Impacts of Sodium Reagent Upstream of the SCR
  - ✓ Will normal, high-temperature operation of the SCR be affected by the sodium particulate?
  - ✓ Will SO_3 removal upstream of the SCR reduce the MOT?
  - ✓ What conditions or operating practices will be required during outages or lay-ups to protect the activity of the catalyst?

“Pre-SCR” Injection Testing Approach

- Phase I - Screening Tests
  - ✓ Short-term testing to determine feasibility
- Phase II - Longer-Term Testing
  - ✓ Quantify impacts of longer-term exposure on catalyst activity
- Phase III - Pilot and/or Full-Scale Testing
  - ✓ Demonstrate the Pre-SCR concept under actual operating conditions

"Pre-SCR" Injection Testing Approach

- Use FERCo Mini-Reactors to Expose Catalyst Samples to SBS-Containing Flue Gas

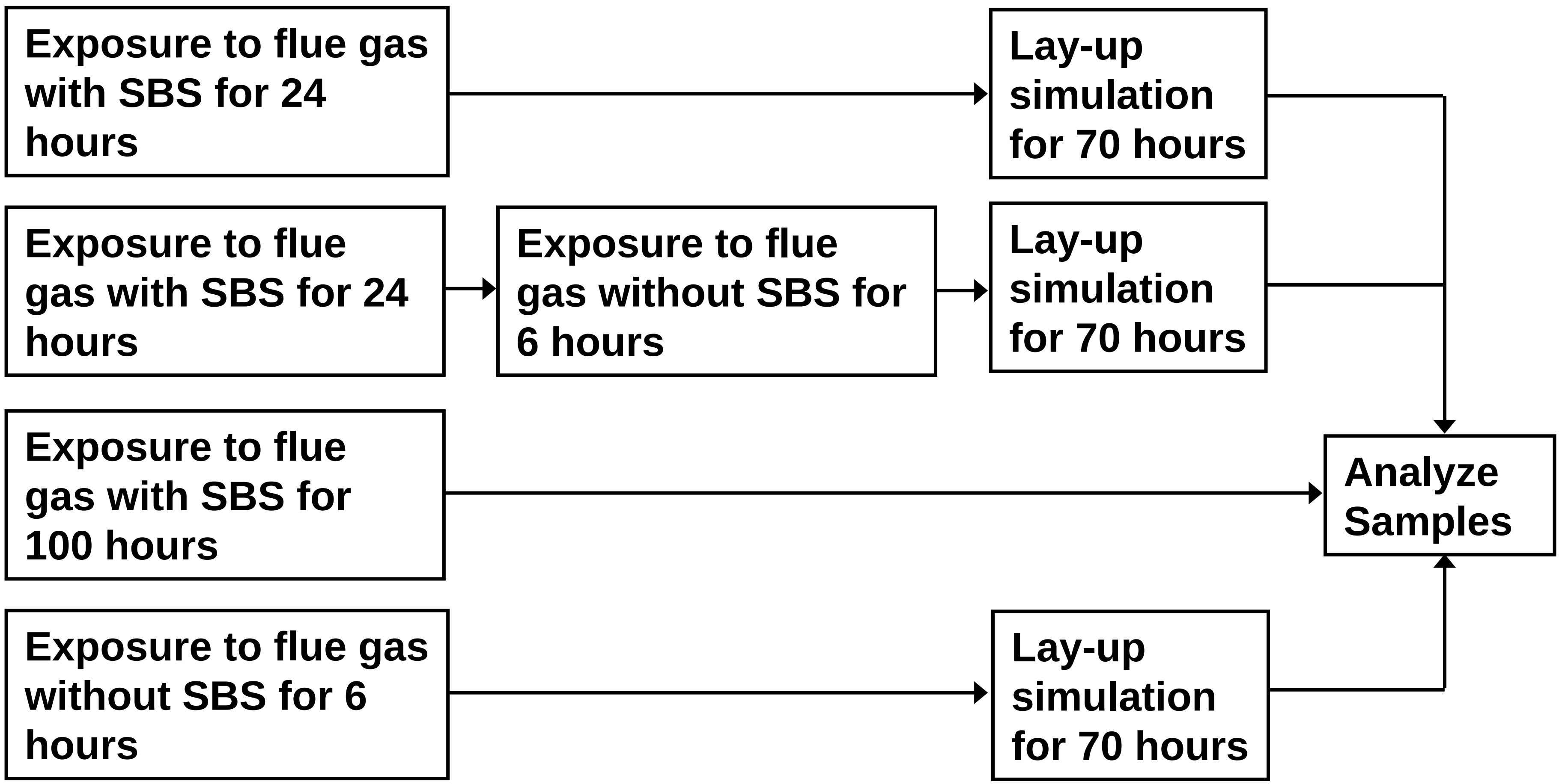


- Install the Equipment at FirstEnergy's Mansfield Station, which has SBS Injection
  - ✓ A horizontal installation was required (FERCo modified the equipment to accomplish this)

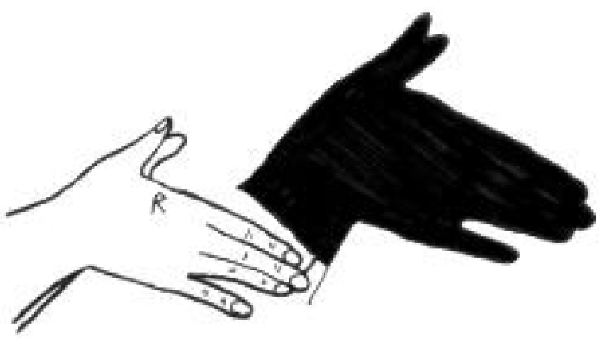
“Pre-SCR” Test Plan

- Exposure to Flue Gas
  - ✓ Duct Temperature of ~700°F
  - ✓ Gas Velocity Through Catalyst ~17 aft/s
- Exposure to “Lay-Up” Conditions
  - ✓ Air at 40°F above ambient (<20% RH)
  - ✓ Air at 10°F above ambient (ambient RH)
  - ✓ Humidified (saturated) ambient, then heated air to 10°F above ambient (about 80% RH)
- Analysis of Samples for Catalyst Activity & Bulk/Surface Sodium

“Pre-SCR” Test Plan



Just in Case There’s No Data !



Wait! We Do Have Some Results!

- One Catalyst Type Showed a Decline in Activity for Some Samples, the Other Type Did Not
- The Lay-Up Conditions used in the Testing Affected the Change in Activity
- It is Not Yet Clear if the Cause of the Activity Decline was the Sodium from the SBS Reagent or the Hostile Lay-Up Conditions
  - ✓ Samples not exposed to SBS also showed activity changes
- The "Scouring" Operating Procedure Did Not Seem to Provide Any Benefit
- Need to Examine Remaining Analytical Results

Additional Testing

- Conduct Phase II Longer-Term Testing
  - ✓Age catalyst 3 – 6 months
  - ✓Include NH_3 injection & monitor activity “in-situ”
  - ✓Evaluate ability to “control” SCR-generated SO_3
  - ✓Evaluate actual reduction in MOT (if possible)
  - ✓Use vertical reactor configuration