

Reinhold Environmental Ltd.



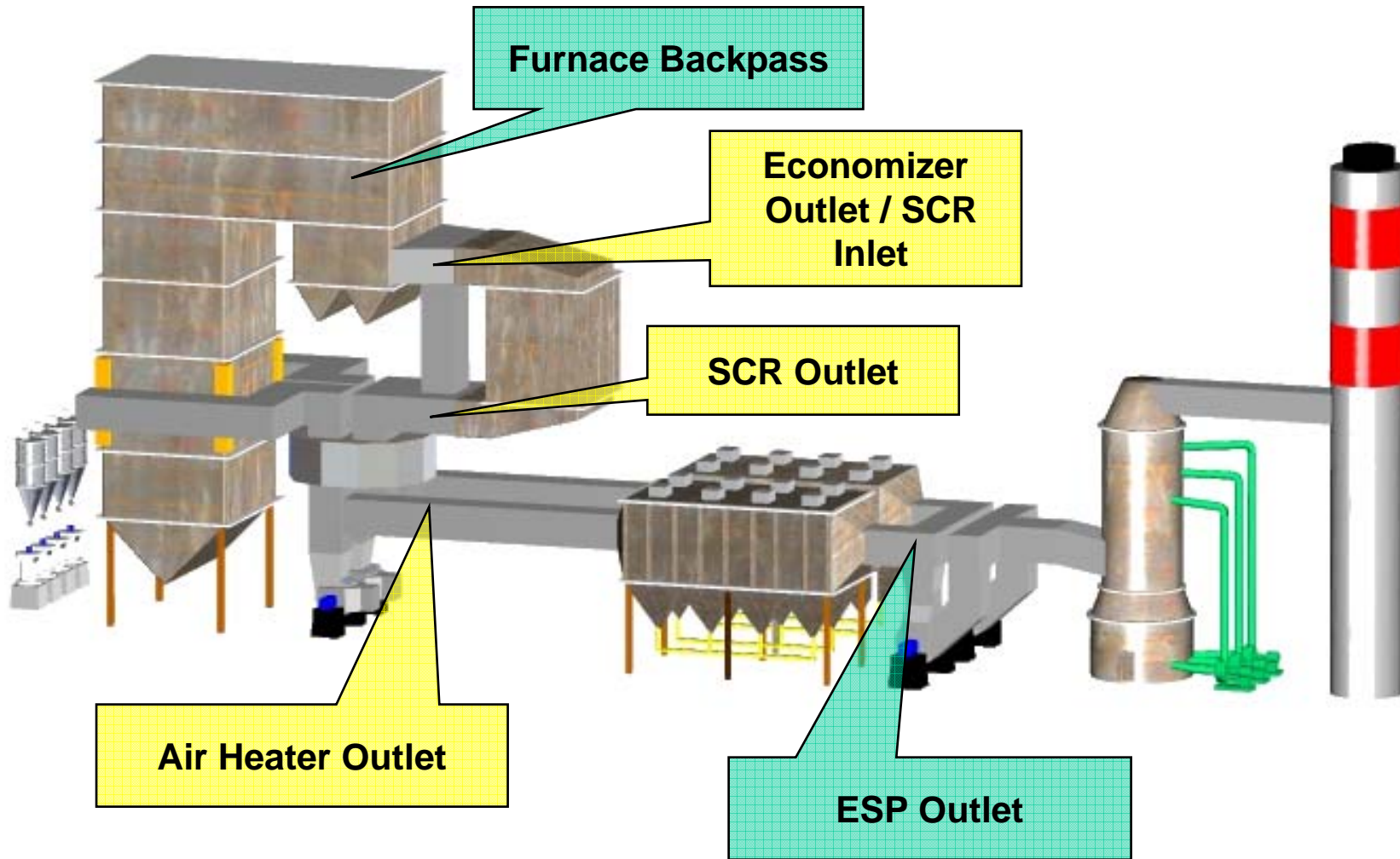
2008 NO_x-Combustion Round
Table & Expo Presentation

February 4-5, 2008 in Richmond, VA



Gibson May 2005 – SBS Injection

SBS Injection Locations



Commercial SBS 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	SCR Outlet	Byproduct SBS Solution	Year-round	July 2004
PPL	Montour 1-2	Washingtonville, PA	2x765	42	Air Heater Outlet	Sodium Carbonate Solids	Ozone	Aug 2004
Duke Energy	Gibson 1-5	E. Mt. Carmel, IN	5x650	110	Air Heater Outlet	Sodium Carbonate Solids	Ozone	May 2005
DP&L	Killen 2	Manchester, OH	635	34 / 36	Econ Outlet SCR Outlet	Sodium Carbonate Solids	Year-round	Aug 2007
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Almost 10,000 MW Installed (16 Units); 5,000 MW Planned

Technology Economics

- Capital Costs

- ✓ Reagent tank, injection skid, injection manifold, injection lances, compressors
- ✓ \$5–10/kW
- ✓ New design improvements may reduce capital costs

- Operating Costs

- ✓ Reagent, license fee, power, water
- ✓ < \$500/ton SO₃ removed

System Design Evolution

	Mansfield	Current	Future
Reagent	Sodium Sulfite	Soda Ash	
Reagent Unloading	Silo	Direct to Tank	
Reagent Prep	Batch Tank	Mixing Tee	
Storage Tank	Multiple	Single	
Solids Wetting Pump	Field Installed	Field Installed	Shop Fab Packaged Equipment Enclosure
Injection Pumps	Field Installed	Skid Mounted	
Dilution/Metering	Two Stage	Single Stage	
Process Control	DCS	PLC	
Electrical/MCC	Field Installed	Field Installed	
Injection Lance	1st Generation	5th Generation	New
Injection Nozzle	Dual Fluid	Dual Fluid	Single Fluid
Air Requirement	High	High	None
Lance Flow Indication	Rotometer	Flowmeter	Packaged Manifold



New Generation: SBS Injection vs W-ESP?

- Meets Sulfuric Acid Emission Limits
- Much Lower Capital Cost
- Improves Heat Rate
- Protects Air Heater
- Eliminates Corrosion
- Enhances SCR/SNCR Performance
- Enhances Hg Removal
- Reduces CO₂ Emissions

*Verbal Award for New
Coal-Fired Plant*

Presentation Outline

- Impacts Created by Presence of SO₃
- Benefits of Effective SO₃ Removal
- SBS Injection™ Technology Description
- SBS Injection™ Development Programs
 - ✓ Reagent testing
 - ✓ Mercury testing
 - ✓ “Pre-SCR” testing
- Case Study: Pre-SCR Applications on Full-Scale Boilers
- Summary

Technology Development Activities

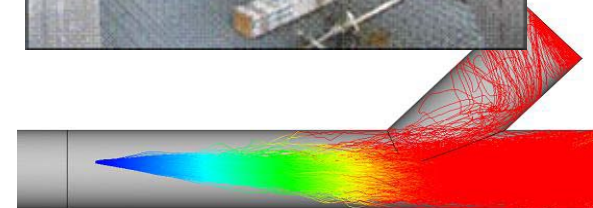
- Alternative Reagent Evaluation
- Mercury Co-Removal Testing
- “Pre-SCR” SBS Injection Evaluation
- SCR/SNCR Optimization Demonstration
- Pilot Baghouse Demonstration
- Single-Fluid, High-Pressure Injection
- Reagent Crystal Bed Storage Tank

Technology Development Activities

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Alternative Reagent Evaluation

- Evaluate Alternative Reagents Injected Upstream of APH
 - ✓ Sodium sulfite
 - ✓ Sodium carbonate
 - ✓ Sodium hydroxide
 - ✓ Sodium thiosulfate
 - ✓ Dissolved iron
- Pilot Testing at the Mercury Research Center (~5 MW)
- Sodium Carbonate was the Most Effective Reagent
- Sodium Carbonate Costs About Half as much as Sodium Sulfite



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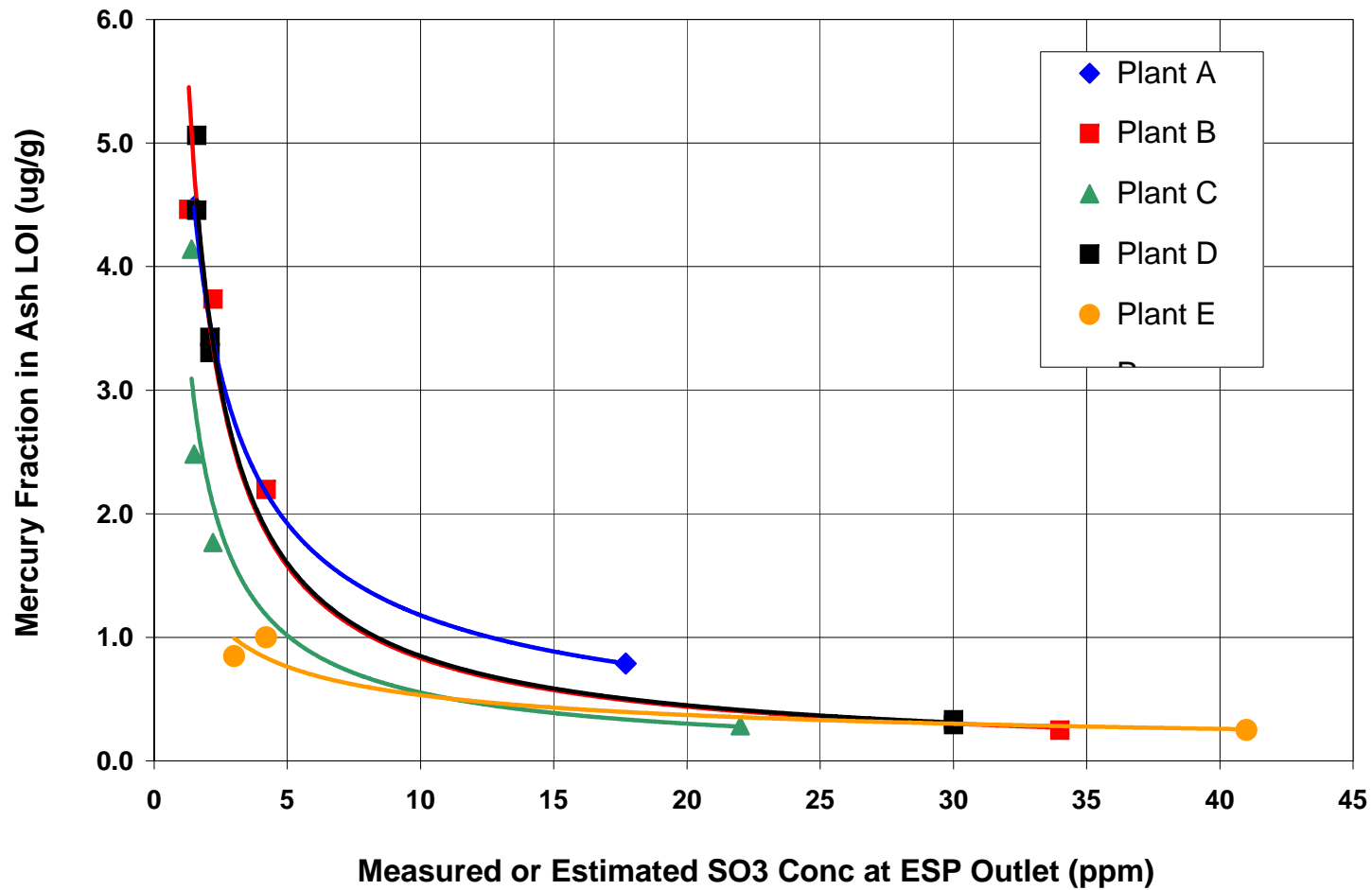
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Impact of SO₃ on Hg Capture in Ash

Mercury Removal By Carbon in Ash with SBS Injection



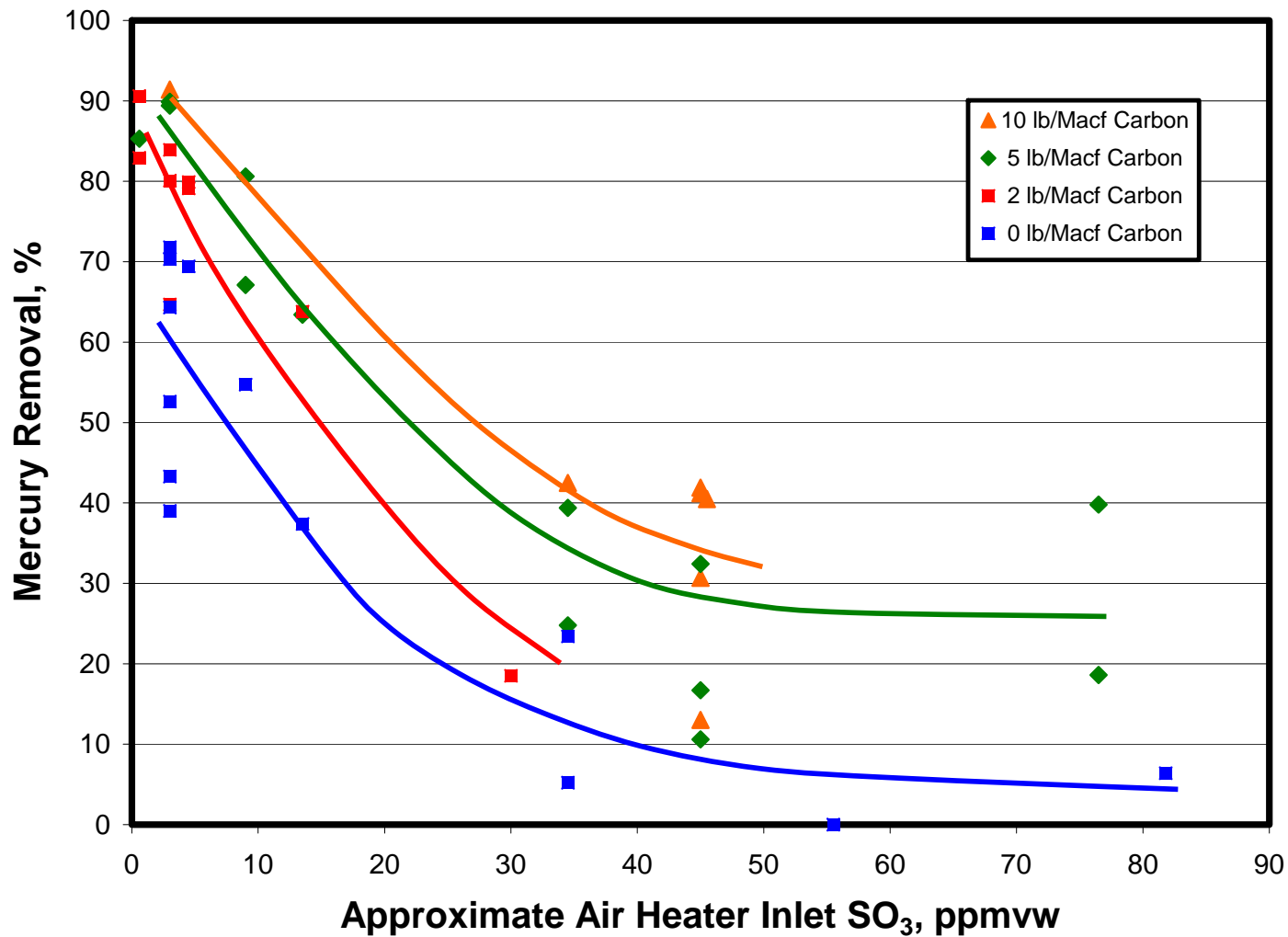
Mercury Research Center ACI Testing

- Purpose:
 - ✓ Quantify the Benefit of SO₃ Reduction on Mercury Co-Removal with Activated Carbon & Fly Ash
 - ✓ For SO₃, define how low is “low enough”
- Test Duration – 1 Week (March 2007)
- Funding:
 - ✓ EPRI funding of MRC costs with URS support for injection skid operation
 - ✓ Added SO₃ control to on-going EPRI testing with activated carbon

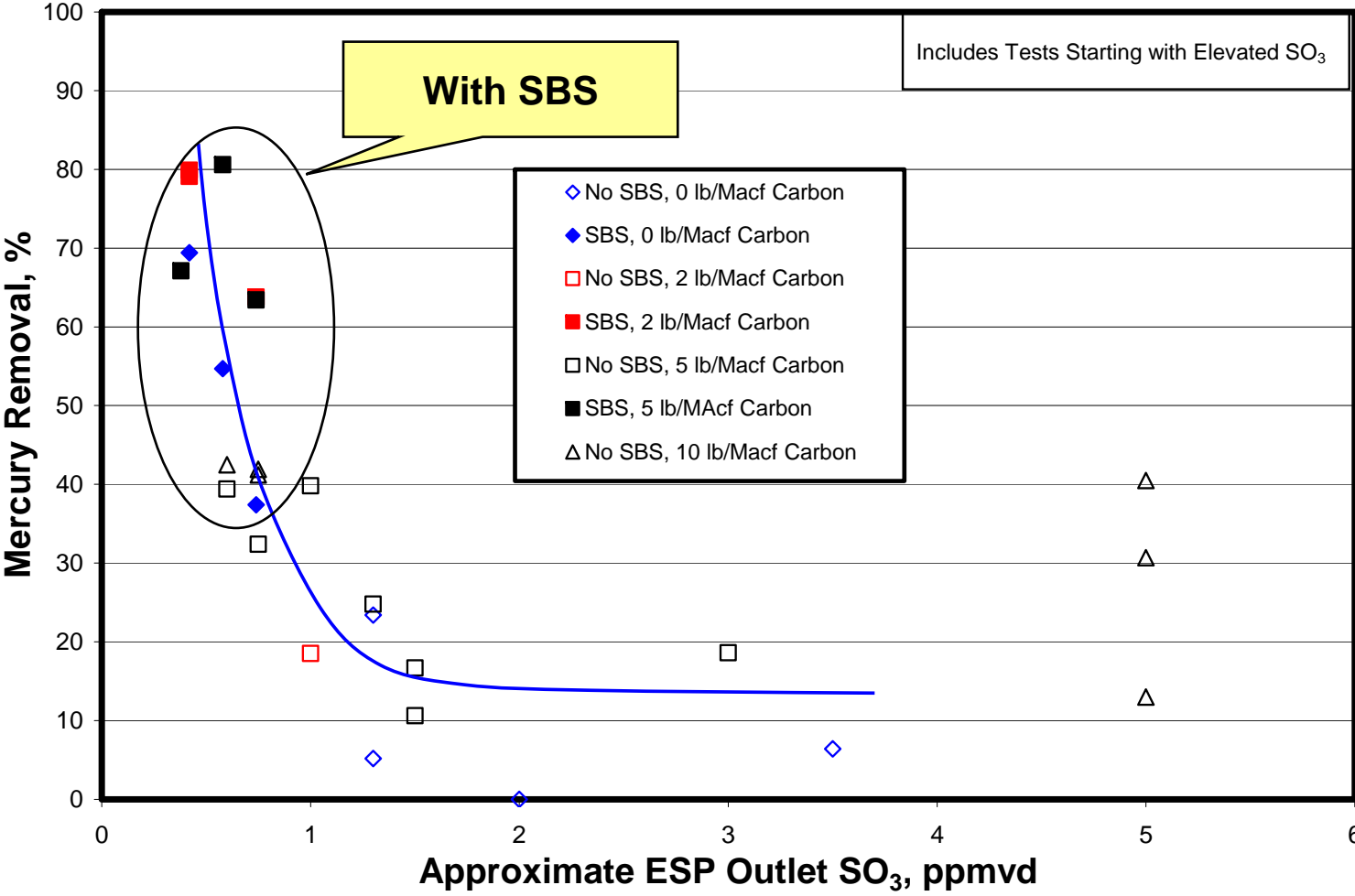
MRC Testing Approach

- Testing Performed w/wo SO₃ Injection
 - ✓ SO₃ Ranged from 3 to 80 ppm
- SO₃ Removed Upstream of the APH using SBS
 - ✓ Estimated SO₃ removal efficiencies of 70-80% at air heater inlet and 95+% at ESP outlet
- Carbon Injection Rates from 0 to 10 lb/Macf
 - ✓ Carbon injected at APH outlet upstream of ESP
- Mercury Measured at ESP Inlet & Outlet
- Results Correlated with Air Heater Inlet & ESP Outlet SO₃

“Incremental” Hg Removal vs APH Inlet SO₃



“Incremental” Hg Removal vs ESP Outlet SO₃



Hg Removal Cost Evaluation

SBS Injection	AC Rate (lb/mmacf)	Total Hg Removal (%)	Total Sorbent Cost (\$M/Yr)	Incremental Hg Control Cost (\$/lb Hg)
No	0	34	0	0
Yes	0	62	\$0.65	\$9,800
Yes	2	80	\$1.50	\$14,000
No	10	56	\$4.10	\$78,000

Basis: 500 MW, 90% CF, 10 ug/m3 Hg, 40 ppmv SO₃, \$240/ton Soda Ash, \$0.60/lb AC

MRC Testing Conclusions

- SO₃ Removal Alone, or Combined with ACI, can be a Cost-Effective Hg Control Strategy
- High SO₃ Removal Efficiencies are Necessary for Effective Hg Control
- SO₃ must be Removed Prior to the Point of AC Injection
- SO₃ Removal Upstream of the APH Provides Benefits in Addition to Mercury Removal

Technology Development Activities

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“Pre-SCR” Injection Concept & Benefits

- Inject SBS Reagent Upstream of the SCR
- Benefit #1 - Increase Residence Time for SO₃ Removal
 - ✓ Remove combustion- & SCR-generated SO₃
 - ✓ Higher removal efficiency & reduced reagent consumption
 - ✓ Realize benefits of removing SO₃ upstream of the air heater
- Benefit #2 - Reduce the Minimum Operating Temperature (MOT) of the SCR

“Pre-SCR” Injection Development Issues

- Determine Feasibility & Impacts of Sodium Reagent Upstream of the SCR
 - ✓ Will high-temperature performance of the SCR catalyst be affected by the sodium particulate?
 - ✓ What conditions or operating practices will be required during outages or lay-ups to protect catalyst activity?
 - ✓ Will SBS remove SO_3 generated by the SCR?
 - ✓ Are there any other BOP impacts such as changes in mercury oxidation or chloride removal?

“Pre-SCR” Injection Program Approach

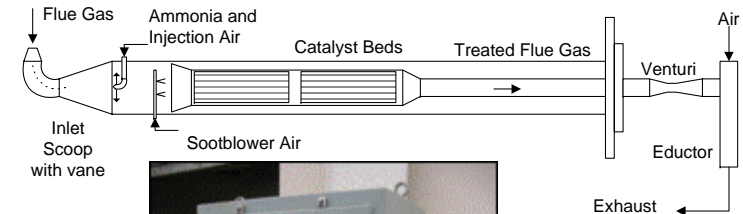
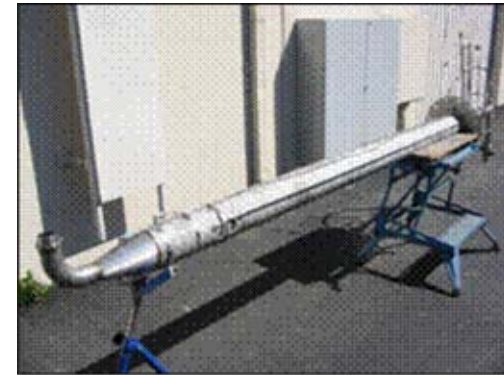
- Phase I - Screening Tests
 - ✓ Short-term exposure to SBS and near-ambient air
 - ✓ Testing completed in November 2006
- Phase II - Longer-Term Testing
 - ✓ Quantify impacts of longer-term exposure
 - ✓ Testing conducted from May through August, 2007 (2,000 hours of exposure)
- Phase III - Pilot and/or Full-Scale Testing
 - ✓ Demonstrate “Pre-SCR” concept with integrated process steps
 - ✓ MRC testing (one week) completed in December 2007

“Pre-SCR” Program Utility Participants

- FirstEnergy
- Ameren
- Dayton Power & Light
- Duke Energy
- Reliant Energy
- Southern Company

Phase I “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 (EPRI/FERCo)
 - ✓ Cormetech & Ceram catalyst
- Short-Term Testing
 - ✓ Exposure w/wo SBS (675°F)
 - ✓ Simulated lay-up conditions
- Catalyst Analyses
 - ✓ Bulk and surface sodium
 - ✓ Activity measurements
- November 2006



Phase I Conclusions

- **No Sodium Impacts Noted with Catalyst A**
 - ✓ No activity changes due to flue gas exposure
 - ✓ No activity changes with ambient air exposure at humidities from 20 to 80%
- **Activity Changes Observed for Catalyst B**
 - ✓ Activity declined after exposure to humid air
 - ✓ Declines occurred for all samples, including samples not exposed to sodium
- **Proceeded with Phase II Since No Impacts Tied to SBS**

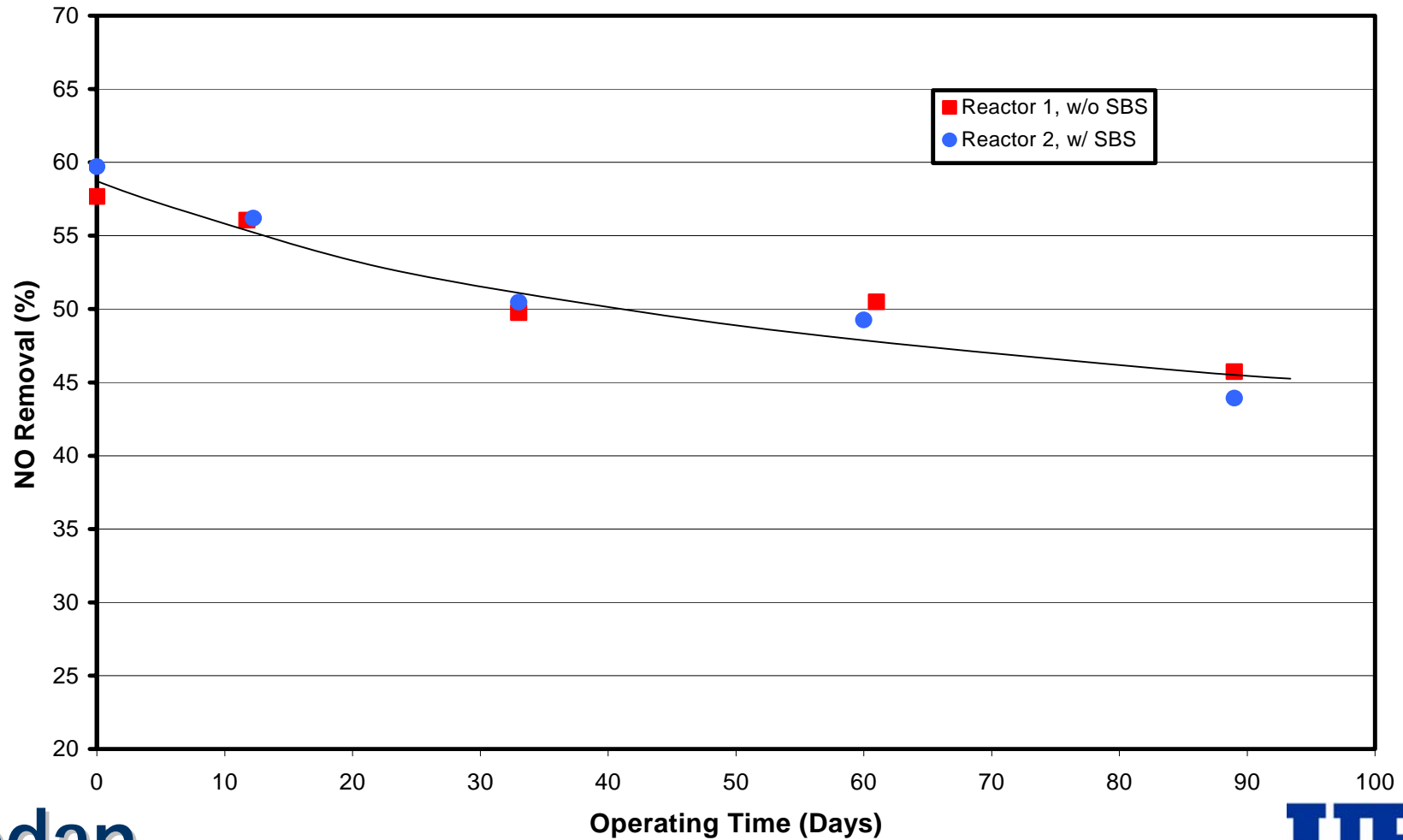
Phase II Longer-Term Testing

- Age Catalyst for 3 Months (May through August, 2007)
- Monitor Catalyst Activity Changes Over Time
 - ✓ Periodic NO removal measurements
 - ✓ Laboratory activity measurements by catalyst suppliers
- Testing at FirstEnergy's Mansfield Station
 - ✓ Catalyst reactors upstream/downstream of SBS injection point
- External Reactor with Vertical Gas Flow
- Collect Additional Information on the Effects of Lay-Up Conditions
 - ✓ Ambient air exposure periods at temperature differentials of approximately 15 and 40°F





Summary of NO Removal Measurements



Phase II Summary of Results

- Over 2,000 Hours of Flue Gas Exposure
 - ✓ Catalysts exposed to flue gas upstream & downstream of SBS
- NO Removal Measurements Showed No Effect of Sodium on Catalyst Activity
 - ✓ No impact of longer-term sodium exposure or subsequent ambient air exposure
 - ✓ A general decline in activity for all samples was noted
- Catalyst Supplier Measurements Confirmed No Impact of Sodium
 - ✓ Catalyst A: Ratio of $K_{\text{Sodium}}/K_{\text{No Sodium}} = 1.01$
 - ✓ Catalyst B: Ratio of $K_{\text{Sodium}}/K_{\text{No Sodium}} = 1.03$
 - ✓ Activity declines attributed to arsenic & phosphorous
 - ✓ Both suppliers noted increased sodium on catalyst surface

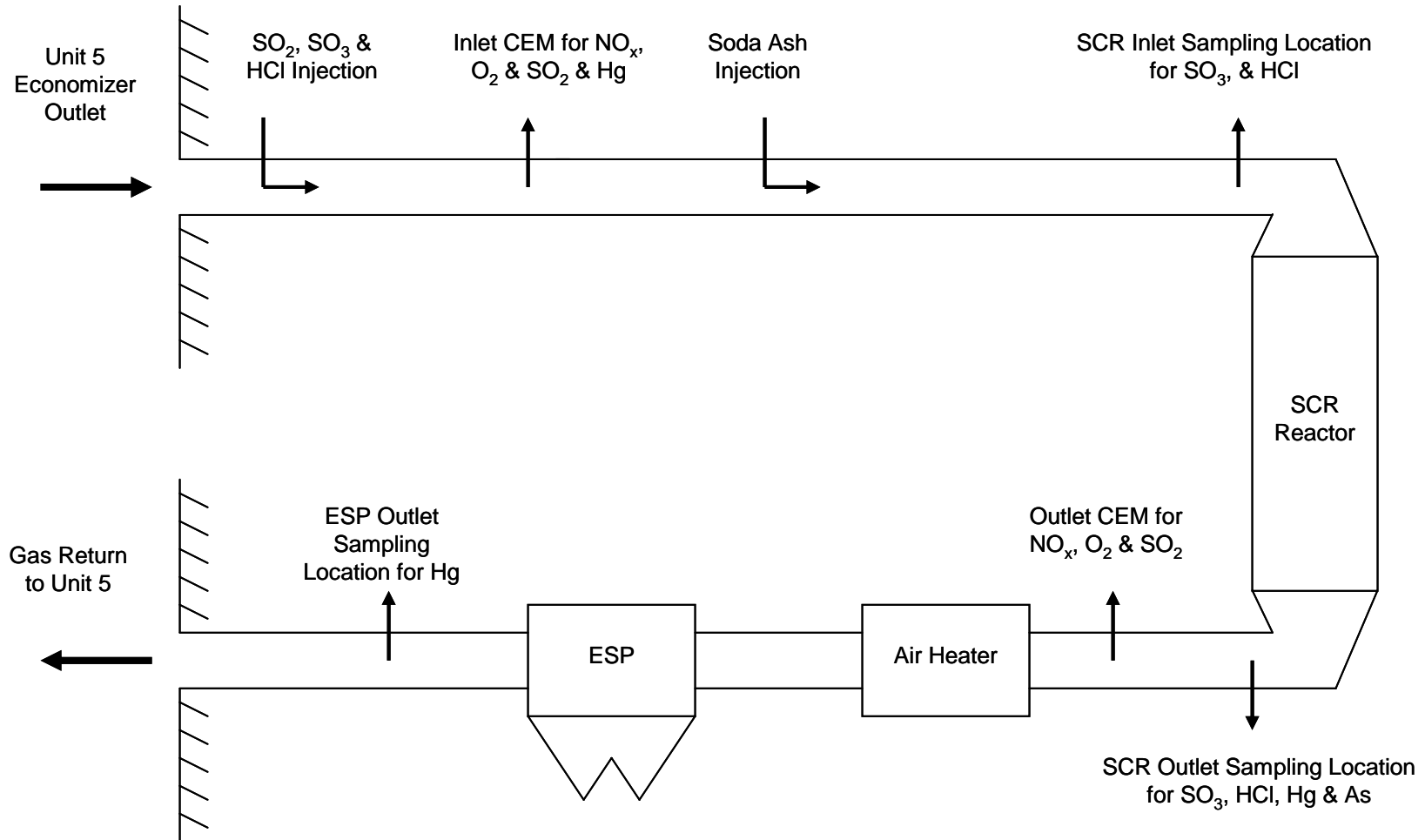
Phase II Recommendations

- Due to Sodium and Fly Ash on the Surface of the Catalyst, Utilities using the Pre-SCR Approach Should Protect the Catalyst to the Extent Possible during Outages
- Follow Catalyst Supplier Recommendations for Outage Procedures
- Consider More Aggressive Measures if Possible:
 - ✓ Shut off SBS prior to shutdowns and/or extend sootblowing
 - ✓ Elevate the SCR catalyst temperature during extended outages
 - ✓ Minimize contact between catalyst and ambient air
 - ✗ Minimize the time that reactor doors are open
 - ✗ Maintain heated air flow to minimize ambient air infiltration
 - ✗ Avoid periods of high relative humidity

Phase III Overview

- Integrated Assessment of Pre-SCR Approach
 - ✓ All process steps included with measurements to confirm impacts on key vapor-phase species
 - ✓ Demonstrate removal of SO₃ generated by the SCR
 - ✓ Demonstrate no significant interactions with HCl
 - ✗ Consumption of “excess” reagent
 - ✗ Reduction in mercury oxidation across the SCR
 - ✓ Ensure no impact of sodium on NO_x reduction or NH₃ slip
- Phase III Conducted at the MRC
 - ✓ One week of testing (December 2007)
 - ✓ Preliminary test results are available

Phase III Vapor-Phase Measurement Locations



Phase III Preliminary Results

- Modest Reductions in SCR-Generated SO_3
 - ✓ SO_3 concentrations were low (low “driving” force for removal)
 - ✓ Short residence time (0.3 sec) between catalyst and measurement location
- Minimal Removal of HCl
- No Impact on Hg Oxidation by SCR Catalyst
- No Apparent Impact on NO_x Removal of NH_3 Slip

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Pre-SCR Injection Case Studies

- DP&L Killen Unit 2
- DP&L Stuart Units 1-4



DP&L Killen Unit 2 - Overview

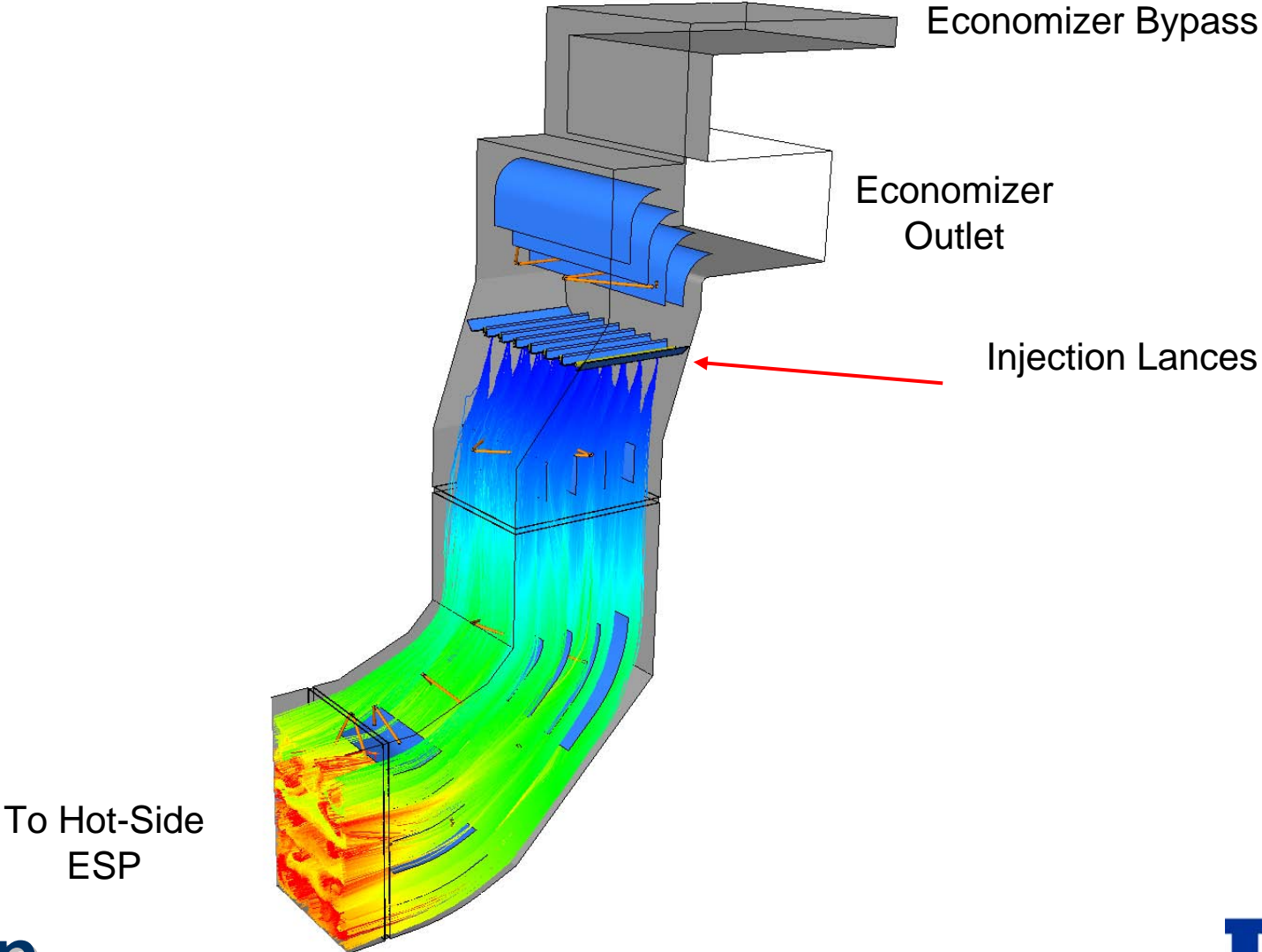
- 635 MW
- Hot-Side ESP
- Low-Dust SCR
 - ✓ Design NO_x reduction – 83%
- Rothmueller APH
- Chiyoda FGD
- Economizer Bypass
 - ✓ Bypass flow is limited
- Plant will be Increasing Coal Sulfur Levels
 - ✓ Transitioning from <2 lb/MMBtu to >6 lb/MMBtu



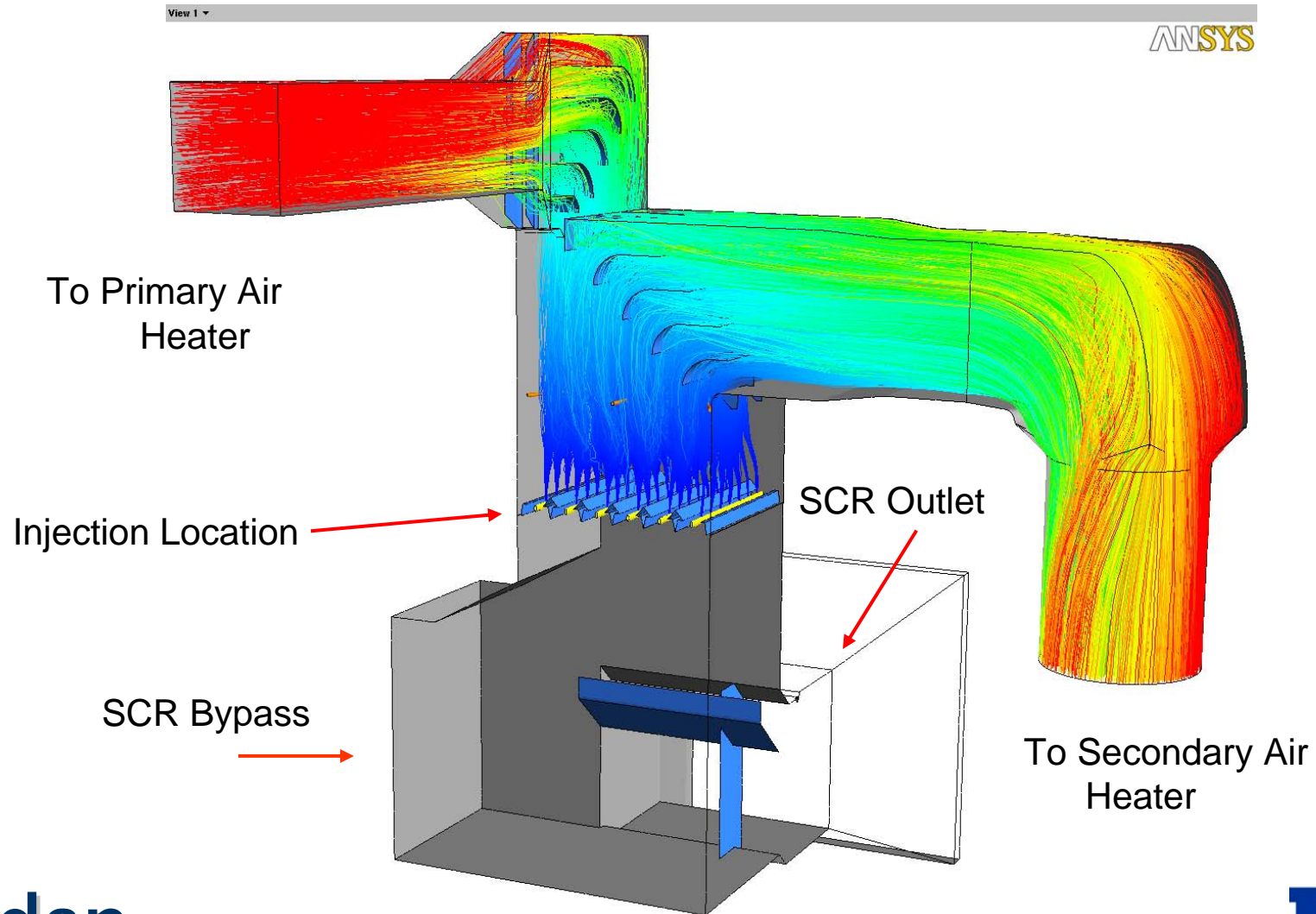
DP&L Killen Unit 2 – SBS Design

- Minimum Operating Temperature Constraints
 - ✓ SCR NO_x reduction limited at all conditions after switch to higher-sulfur coal
 - ✓ Evaluated SO₃ control, increased SCR temperature (duct burners) & boiler NO_x reduction (LNBS, OFA & SNCR)
 - ✓ Selected SO₃ control using SBS Injection™
- SBS Injection at Economizer Outlet and SCR Outlet
- Total Design SO₃: 70 ppm (Boiler + SCR)
- Initial System Operation in October 2007
 - ✓ SBS system not currently in operation (SCR not in service)
 - ✓ Year round operation of SBS/SCR by January 2009

Injection Location: Economizer Outlet



Injection Location: SCR Outlet



New SBS Design Features at Killen

- Shop-Fabricated Injection Skid
 - ✓ Self-Contained Enclosure
 - ✓ Electrical Gear (transformer, mcc, etc)
 - ✓ PLC Controller
- Shop-Fabricated Injection Manifolds
 - ✓ Atomization Air
 - ✓ Reagent Feed
 - ✓ Flush Water
 - ✓ Reagent Flow Indication
- Lance Extraction Assembly
 - ✓ Dedicated Monorail





DP&L Stuart Units 1 through 4 – Overview

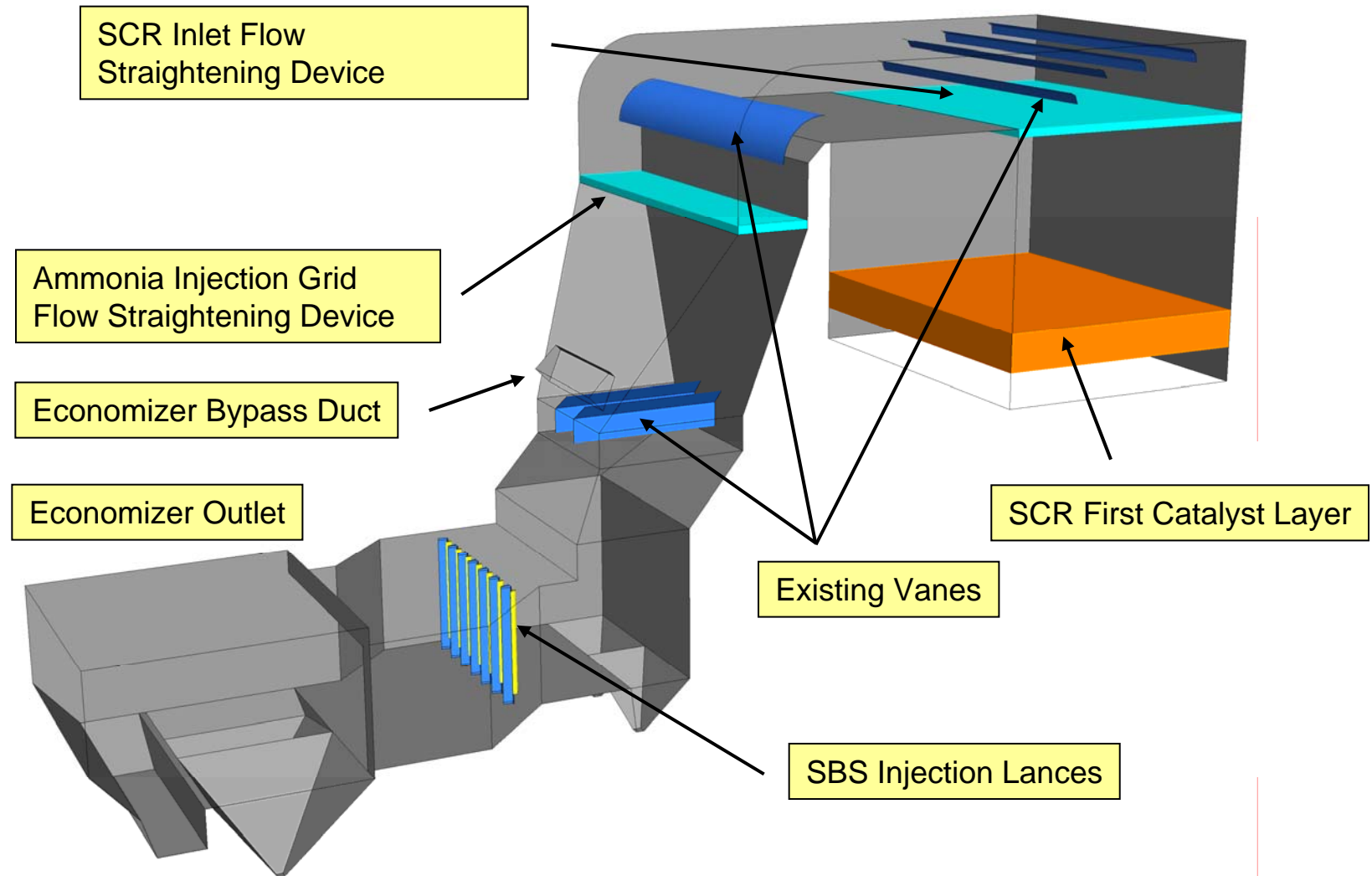
- Four Boilers (4 x 621 MW)
- Fuel Sulfur Level will Increase (Up to 5.5 lb/MMBtu)
- High-Dust SCR
 - ✓ Design NO_x reduction – 88%
 - ✓ SCR operation impacted at reduced load due to minimum operating temperature constraint
 - ✓ Year-round operation beginning January 2009
- Economizer Bypass
 - ✓ Operated at reduced loads to maintain SCR minimum operating temperature



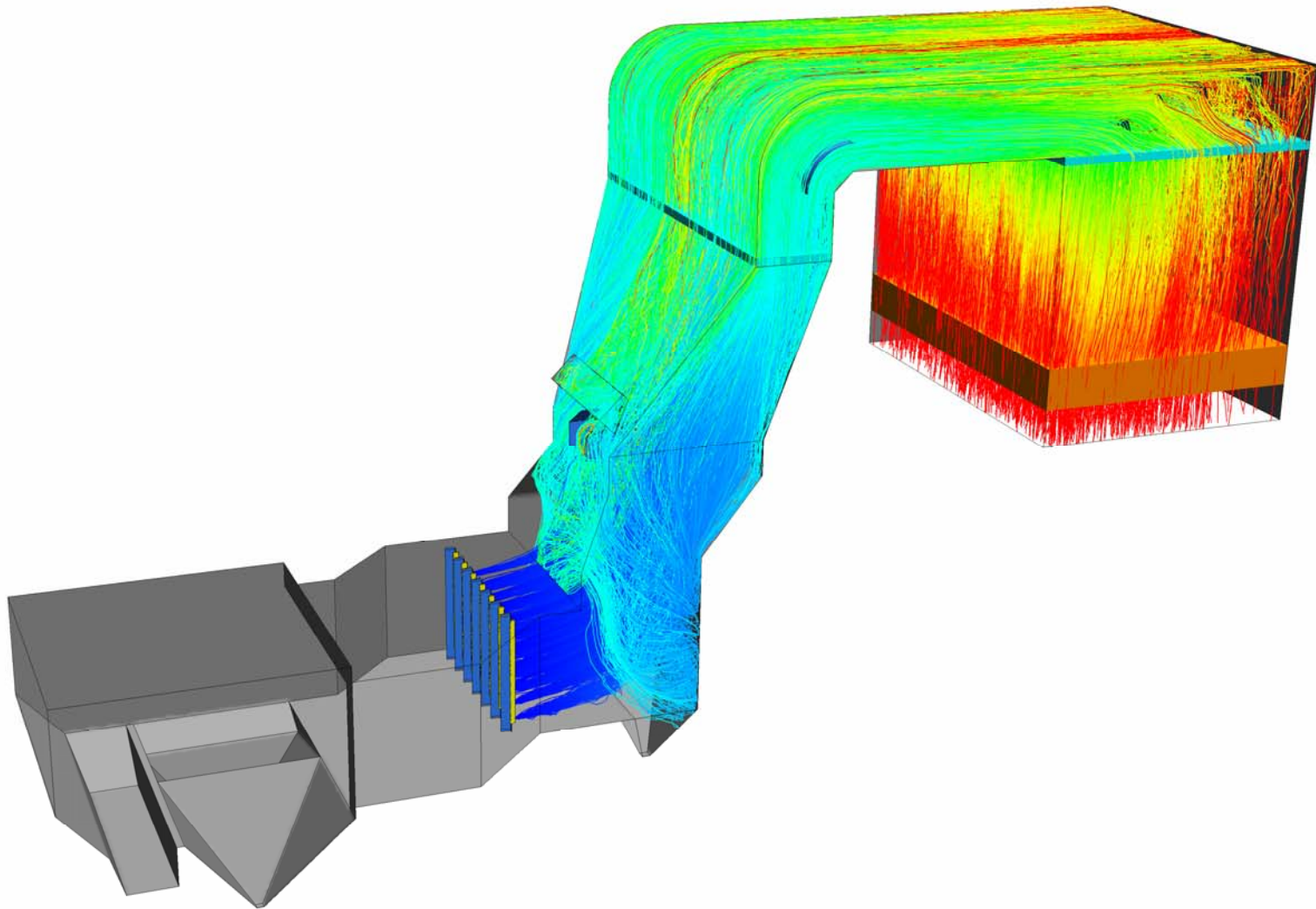
DP&L Stuart Units 1 through 4 – SBS Design

- Objectives
 - ✓ Retain high NO_x reduction efficiencies at lower loads after change to higher sulfur coal
 - ✓ Minimize APH fouling (SO₃/ABS)
 - ✓ Eliminate blue plume
- Current Approach is to Inject SBS at Economizer Outlet, Upstream of SCR, When SCR is in Operation
- Year Round Operation of SBS/SCR by January 2009
- Engineering Currently in Progress
- System Operation by Summer 2008

Injection Location: Economizer Outlet



Injection Location: Economizer Outlet



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Summary

- Visible Emissions will Continue to be a Significant Driver for the Application of SO₃ Control Processes
- “Secondary Benefits” will Drive the Future Application of SO₃ Controls as Utilities Recognize the Value of Removing SO₃
- Maximum Benefits are Obtained by Removing the SO₃ Upstream of the APH or SCR, and Using a High-Efficiency Control Process such as SBS

Summary

- For SCR's, SBS Offers Two Opportunities:
 - ✓ A reduction in MOT by reducing combustion-generated SO_3 and SO_3 produced by the catalyst
 - ✓ A modest increase in the ammonia slip, without APH plugging, which can be used to advantage in a variety of ways
- For SNCR's:
 - ✓ Increased NO_x removal efficiency without APH plugging
 - ✓ Wider application of SNCR to medium and higher-sulfur boilers

Summary

- Opportunities to Reduce Capital or Operating Costs:
 - ✓ Reduced downstream corrosion
 - ✓ Enhanced mercury removal
 - ✓ Improved heat rate with lower CO₂ emissions
 - ✓ Fuel flexibility
 - ✓ Alternative to W-ESP for New Boilers