

Reinhold Environmental Ltd.



2009 NOx-Combustion Round
Table & Expo Presentation

February 9 & 10, 2009, Cleveland, OH

Codan Development LLC



*“Pre-SCR SBS Injection at DP&L’s
Killen & Stuart Stations”*

8th Annual NO_x/PCUG Conference
February 9-12, 2009
Cleveland, Ohio



Agenda

- SBS Injection™ Technology Overview
- “Pre-SCR” Injection Concept & Benefits
- Summary of R&D Program Results
- Pre-SCR Applications at Killen & Stuart
 - System description & configuration
 - Performance testing results
 - Future operation & testing plans

SBS Technology Description

- **Patented Technology**
 - Owned by Codan Development, commercialized by URS
- **Reagent Injected via Dual-Fluid Nozzles**
 - Sodium-based solutions of soda ash or sodium sulfite
 - Droplets are flash dried to form a fine particulate
 - Particulate selectively reacts with SO_3
- **High SO_3 Removal Efficiency**
 - Injection lance & baffle design give full coverage across the duct
 - Optimum average particle size (5-7 μ)
- **Product Collected in ESP or Wet Scrubber**
 - Neutral to positive impact on ESP performance
 - 99%+ removal efficiencies in wet scrubber
- **Simple & Reliable Equipment Operation**
 - Routine preventative maintenance is essential



Vertical Injection
Lances in SCR
Outlet Duct



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	Year-round	March 2003
TVA	Widows Creek 7	Stevenson, AL	550	54	Air Heater Inlet	Sodium Sulfite	Ozone	April 2003
NIPSCO	Bailly 8	Porter, IN	365	59	Air Heater Outlet	Sodium Carbonate	Ozone	April 2004
Vectren	Culley 3	Newburgh, IN	287	48	SCR Outlet	Byproduct SBS	Year-round	July 2004
PPL	Montour 1-2	Washingtonville, PA	2x765	42	Air Heater Outlet	Sodium Carbonate	Ozone	Aug 2004
Duke Energy	Gibson 1-5	E. Mt. Carmel, IN	5x650	110	Air Heater Outlet	Sodium Carbonate	Ozone	May 2005
DP&L	Killen 2	Manchester, OH	635	34 / 36	Econ Outlet SCR Outlet	Sodium Carbonate	Year-round	Oct 2007
IP&L	Harding St 7	Indianapolis, IN	465	58	SCR Outlet	Sodium Carbonate	Year-round	Nov 2007
NIPSCO	Bailly 7	Porter, IN	180	59	SCR Outlet	Sodium Carbonate	Year-round	April 2008
DP&L	Stuart 1-4	Aberdeen, OH	4x620	90	Econ Outlet	Sodium Carbonate	Year-round	July 2008

12,500 MW Installed on 20 Boilers; ~ 3000 MW Planned



Gibson June 2004 – No Treatment

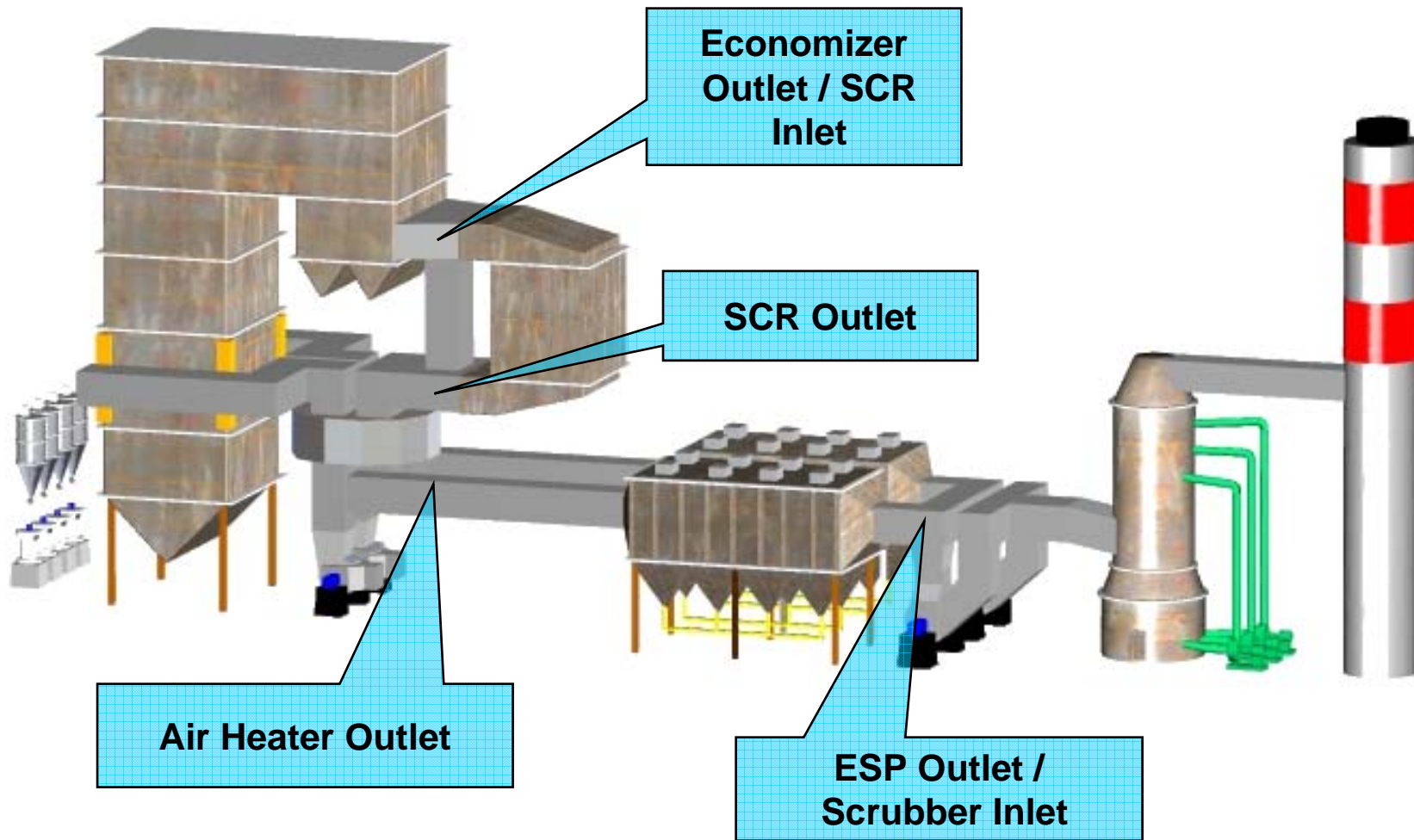


Gibson June 2005 – SBS Injection

Benefits of SO₃ Control

- Opacity Elimination
- Corrosion Reduction
- Co-Removal of Hg, HCl & Se with Fly Ash
- Enhanced Heat Recovery with CO₂ Reduction
- SCR/SNCR Operating Flexibility
 - Enhance NO_x removal
 - Extend catalyst life
 - Reduce the SCR Minimum Operating Temperature

SBS Injection Locations



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“Pre-SCR” Injection Benefits

- Benefit #1 - Increased Residence Time for SO₃ Removal
 - Increases SO₃ removal
 - Provides benefits associated with removing SO₃ upstream of AH if a suitable injection location is not available between the SCR & AH
- Benefit #2 - Reduced Minimum Operating Temperature (MOT) within the SCR

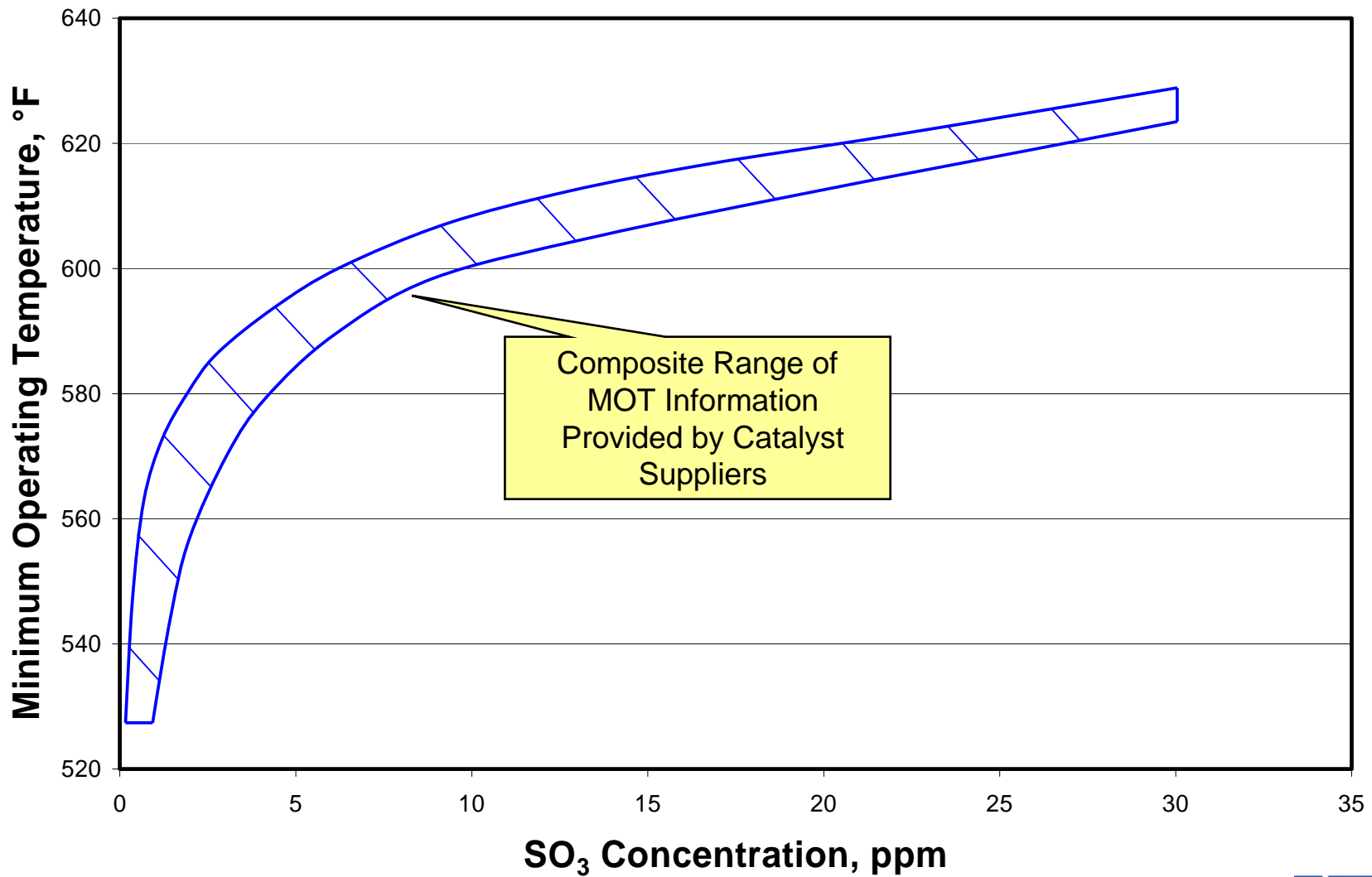
Impact of SO_3 on the SCR MOT

- SO_3 Reacts with NH_3 to form ABS
 - NH_3 concentrations are high within the SCR reactor
 - ABS condenses at higher temperatures within the catalyst pores due to capillary condensation
 - Prolonged operation with ABS formation will plug the catalyst
 - Catalyst suppliers specify an MOT that avoids catalyst deactivation

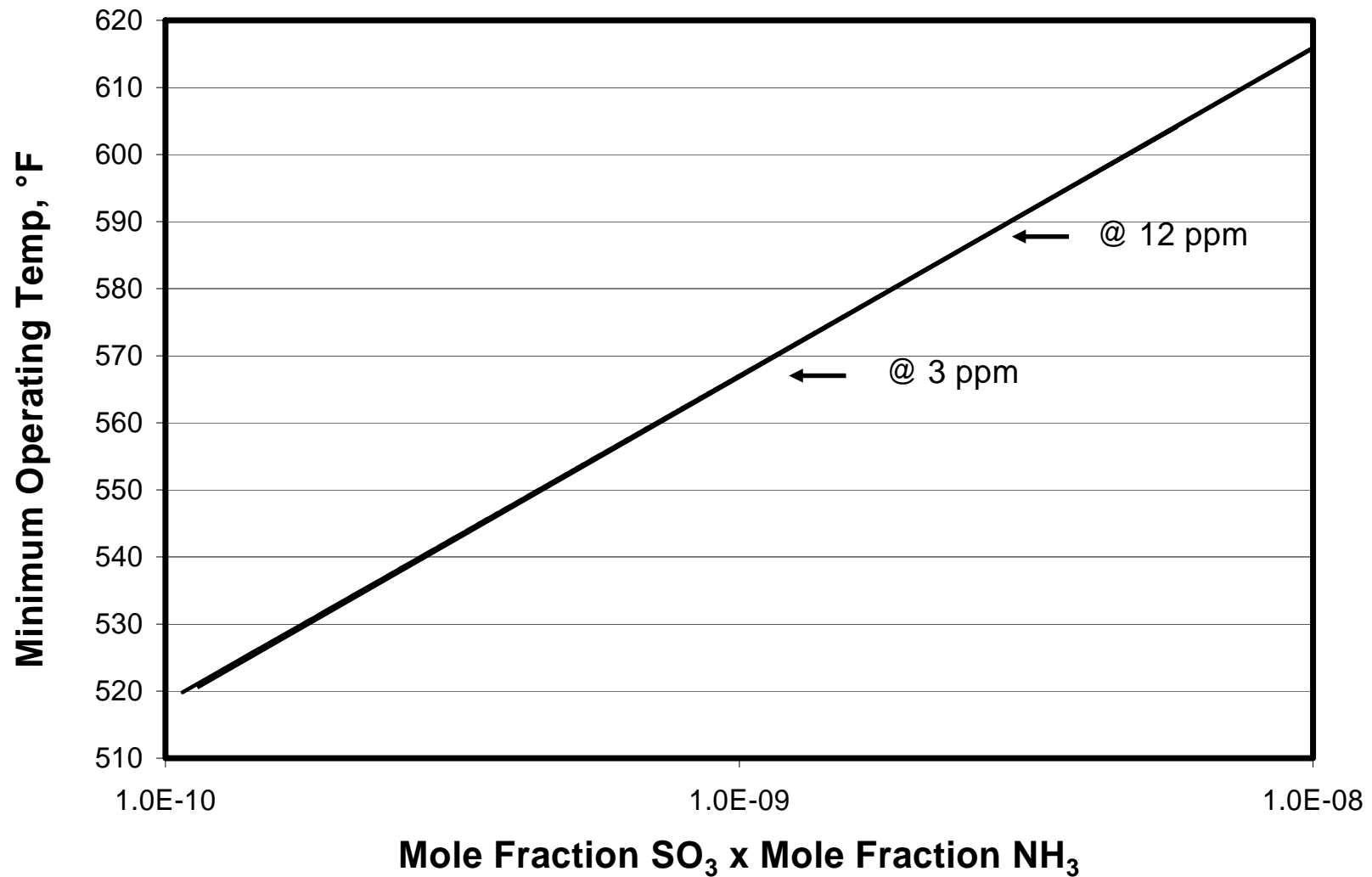
Impact of SO₃ on the SCR MOT

- MOT Management Strategies
 - Reduce or terminate ammonia flow
 - Raise the SCR temperature with economizer bypass, other economizer modifications or duct burners
 - Restrict lower-load operation
 - Fire lower-sulfur coals
 - “Burn off” condensed ABS
 - Remove SO₃ upstream of the SCR

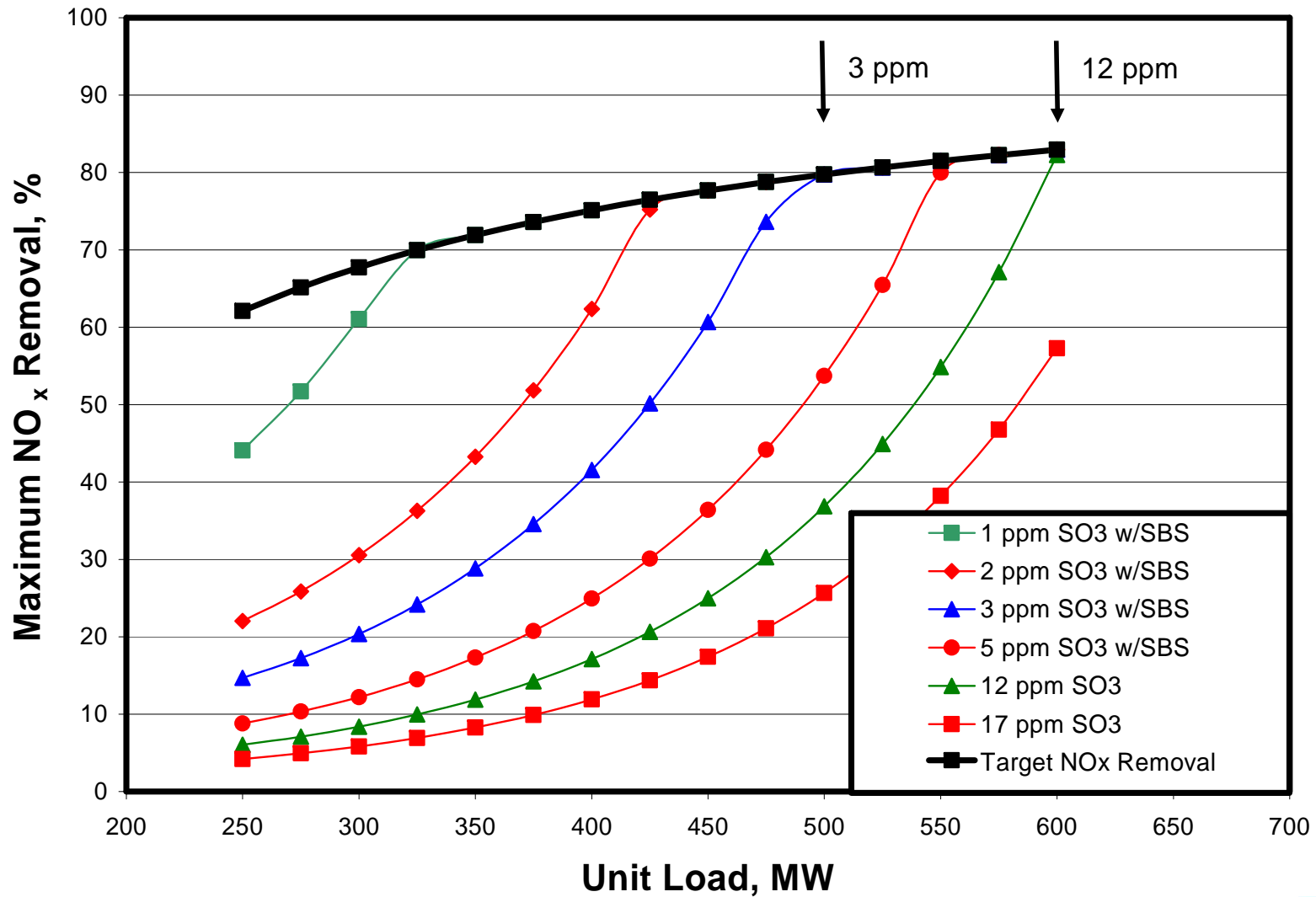
Minimum Operating Temperature versus SO₃



Example MOT Relationship

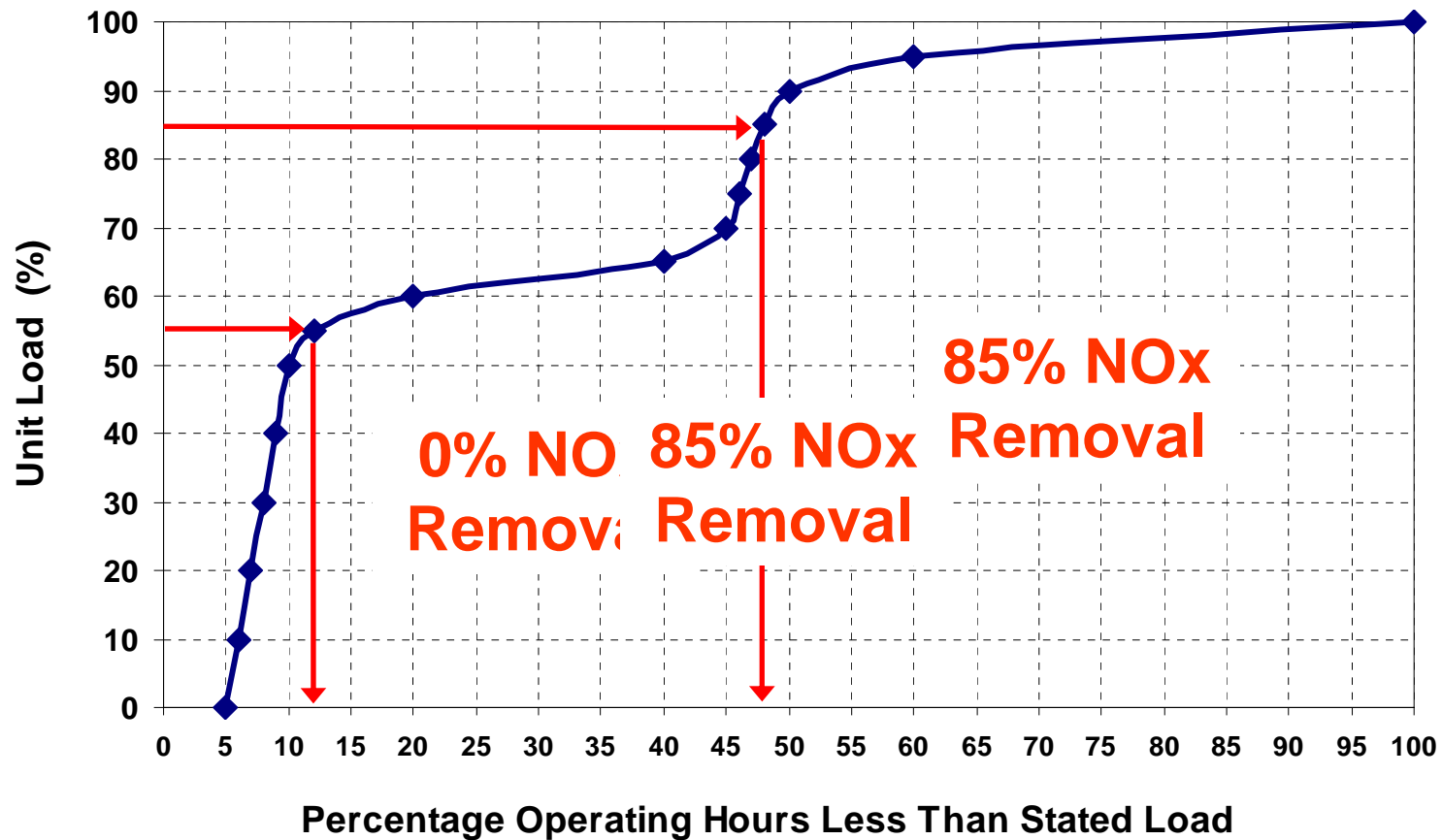


Example: MOT-limited NO_x Removal versus Load

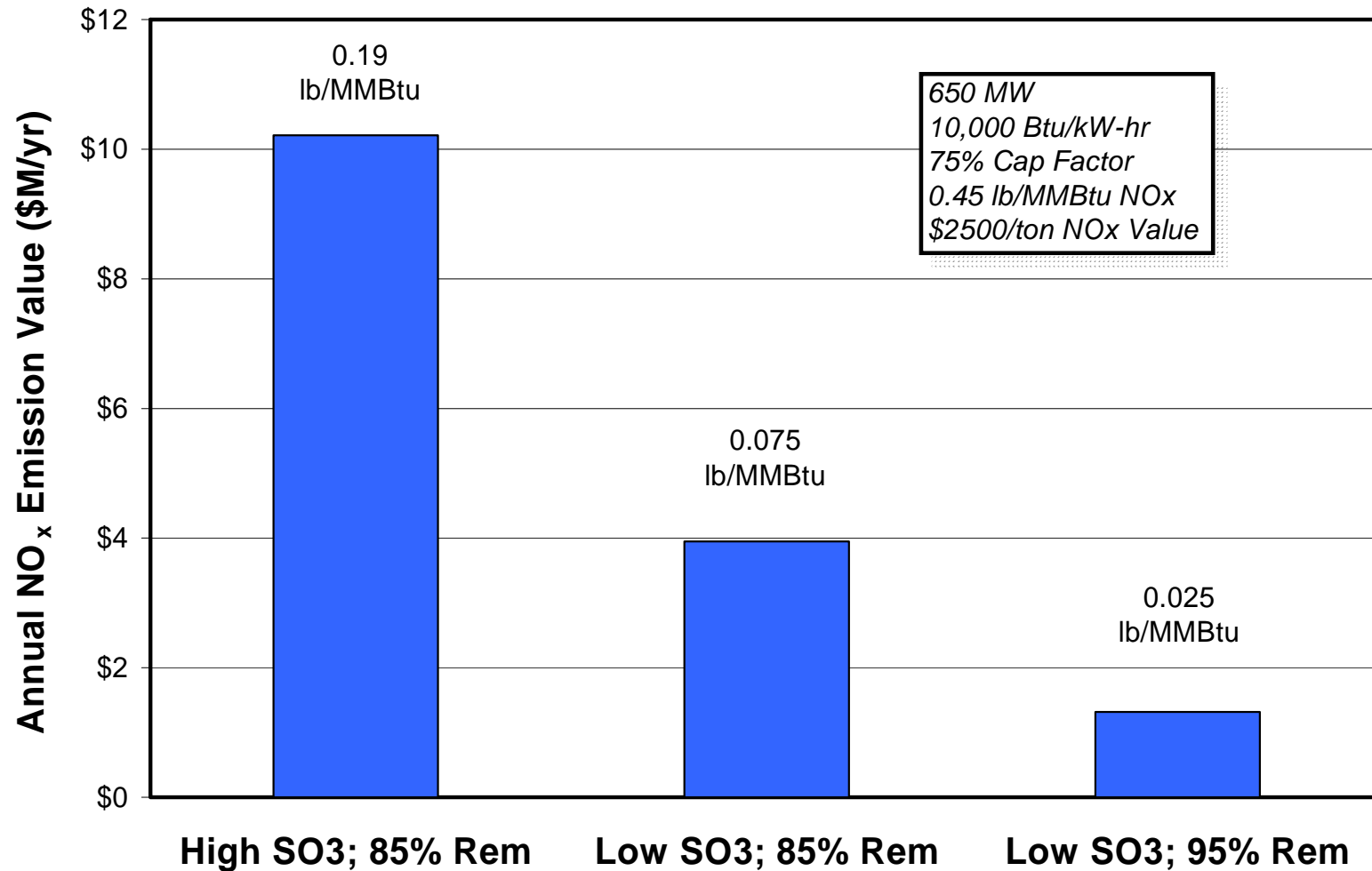


MOT Impact on Cycling Unit

Unit Load Profile



Net Impact on NO_x Emissions



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“Pre-SCR” Injection Development Issues

- Impacts of Sodium Injection Ahead of the SCR
 - Impact on SCR catalyst performance?
 - Requirements to protect catalyst activity?
 - Removal of SO_3 generated by the SCR?
 - BOP impacts such as changes in mercury oxidation or chloride removal?

Pre-SCR Research & Experience to Date

- Three-Phase Research Effort
 - Phase I – Short term catalyst exposure
 - Phase II – Longer-term exposure (2,000 hours)
 - Phase III – Pilot testing at the MRC to identify BOP issues

“Pre-SCR” Development Program

- Participating Utilities:
 - FirstEnergy
 - Ameren
 - Dayton Power & Light
 - Duke Energy
 - Reliant Energy
 - Southern Company
- Other Participants:
 - Ceram, Cormetech, FERCo

“Pre-SCR” Research Conclusions

- No Sodium-Related Impacts
 - Normal SCR operation (2,000 Hours)
 - Under simulated lay-up conditions
- Minimal Impacts of Ambient Air Exposure
 - Ambient air temperature heated by 15°F
- Sodium Accumulation Noted on Catalyst Surface
 - Critical to evaluate this at full-scale
 - Catalyst protection measures are recommended
- Modest Removal of the SCR-Generated SO₃
- No Other BOP Impacts were Identified

Pre-SCR Research & Experience to Date

- Commercial Applications at Killen & Stuart
 - Killen – Low-dust SCR, two injection locations
 - Stuart – High-dust SCR, injection upstream
- Commercial Application at a Midwest Utility
 - Injection upstream of high-dust SCR
 - System currently in startup

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DP&L Killen Unit 2

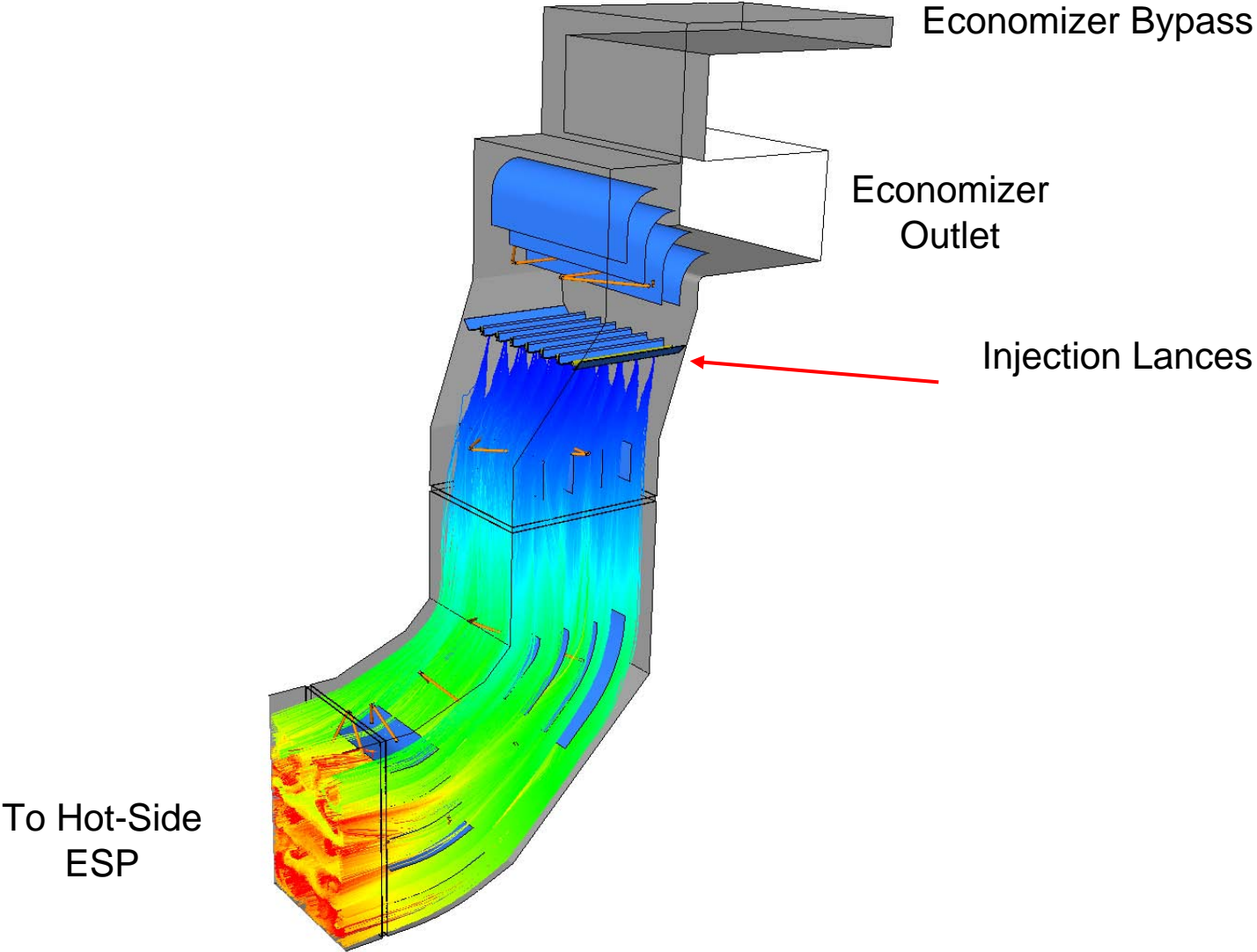
- Nominal 635 MW
- Hot-Side ESP
- Low-Dust SCR
- Rothmueller APH's
- Chiyoda FGD
- Economizer Bypass
 - Bypass flow is limited
- Plant will be Increasing Coal Sulfur Levels



DP&L Killen Unit 2 – SBS Design

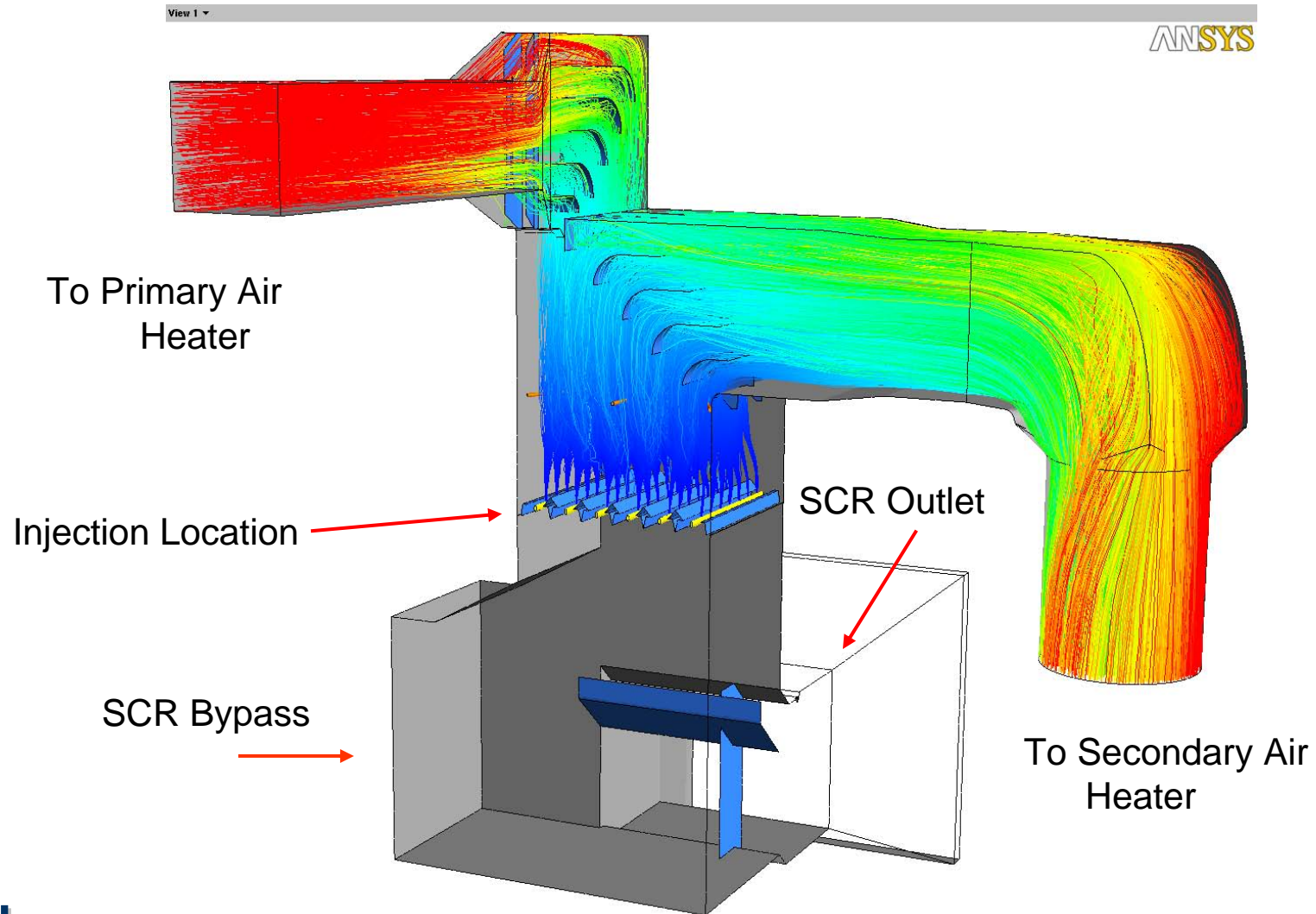
- Minimum Operating Temperature Constraints
 - NO_x reduction limited at all loads
- SBS Injection at Econ Outlet and SCR Outlet
- SBS in Operation through 2008 Ozone Season
 - Performance testing conducted in May 2008
 - Continuous injection at the economizer outlet
 - Periodic injection at the SCR outlet
- SCR & SBS Systems in Continuous Operation
 - Working through “cold weather” issues

Injection Location: Economizer Outlet





Injection Location: SCR Outlet



Performance Testing - Killen

● Key Results

- Lower-load boiler SO₂ conversion higher than expected
- Up to 75% SO₃ removal at SCR inlet (< 3 ppm)
- AH inlet SO₃ concentrations below 4 ppm
 - ✘ Breen probe indicated no condensable compounds present
 - ✘ Continued operation possible with low cold-end temperatures
 - ✘ Other secondary benefits should be possible

DP&L Stuart Units 1 - 4

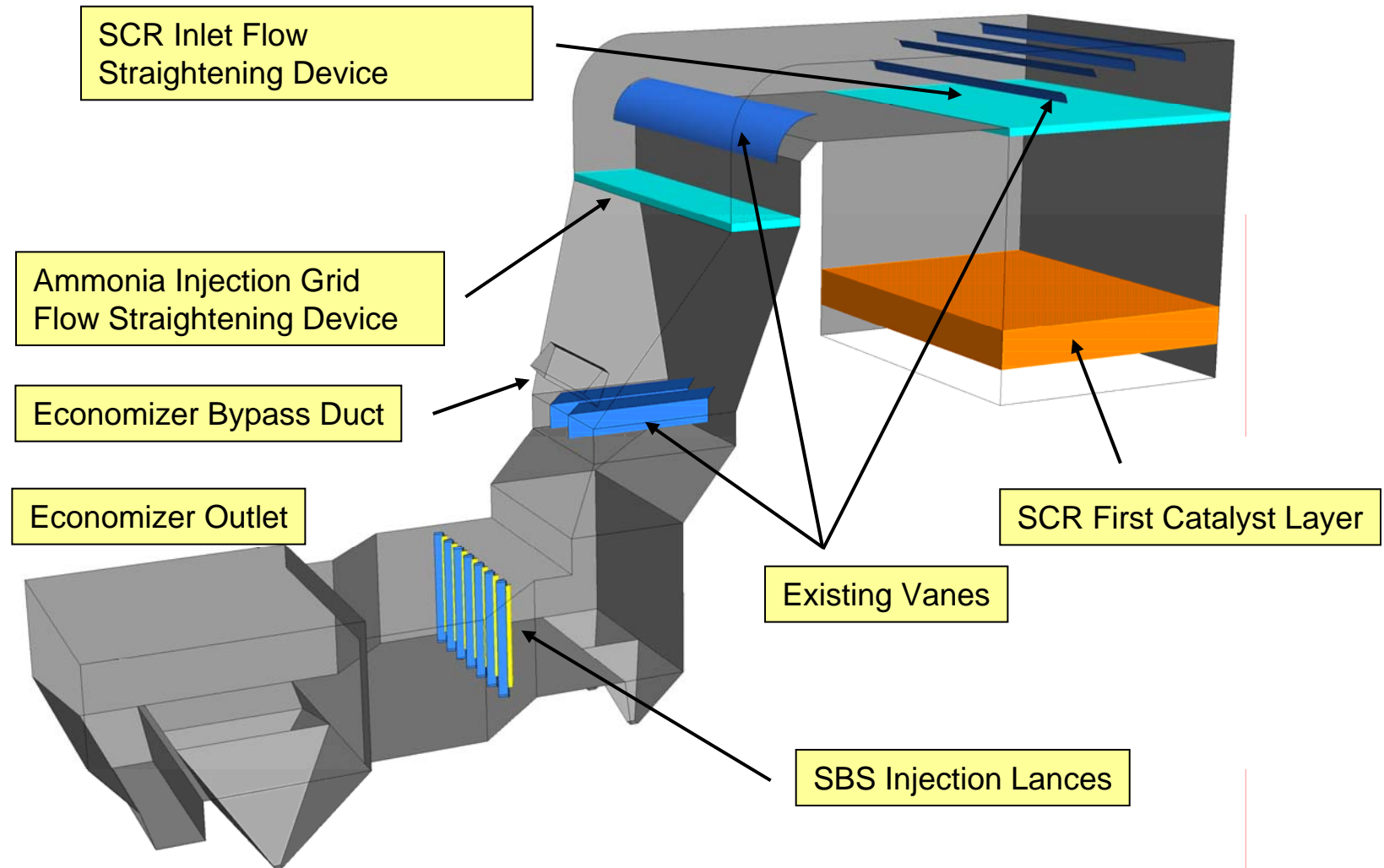
- Four Boilers (Nominal 621 MW Each)
- Fuel Sulfur Level will Increase
- High-Dust SCR
 - SCR operation impacted by MOT
 - Year-round SCR operation
- Economizer Bypass
 - Reliability is an issue
 - Currently open at all loads
 - Effectiveness is uncertain



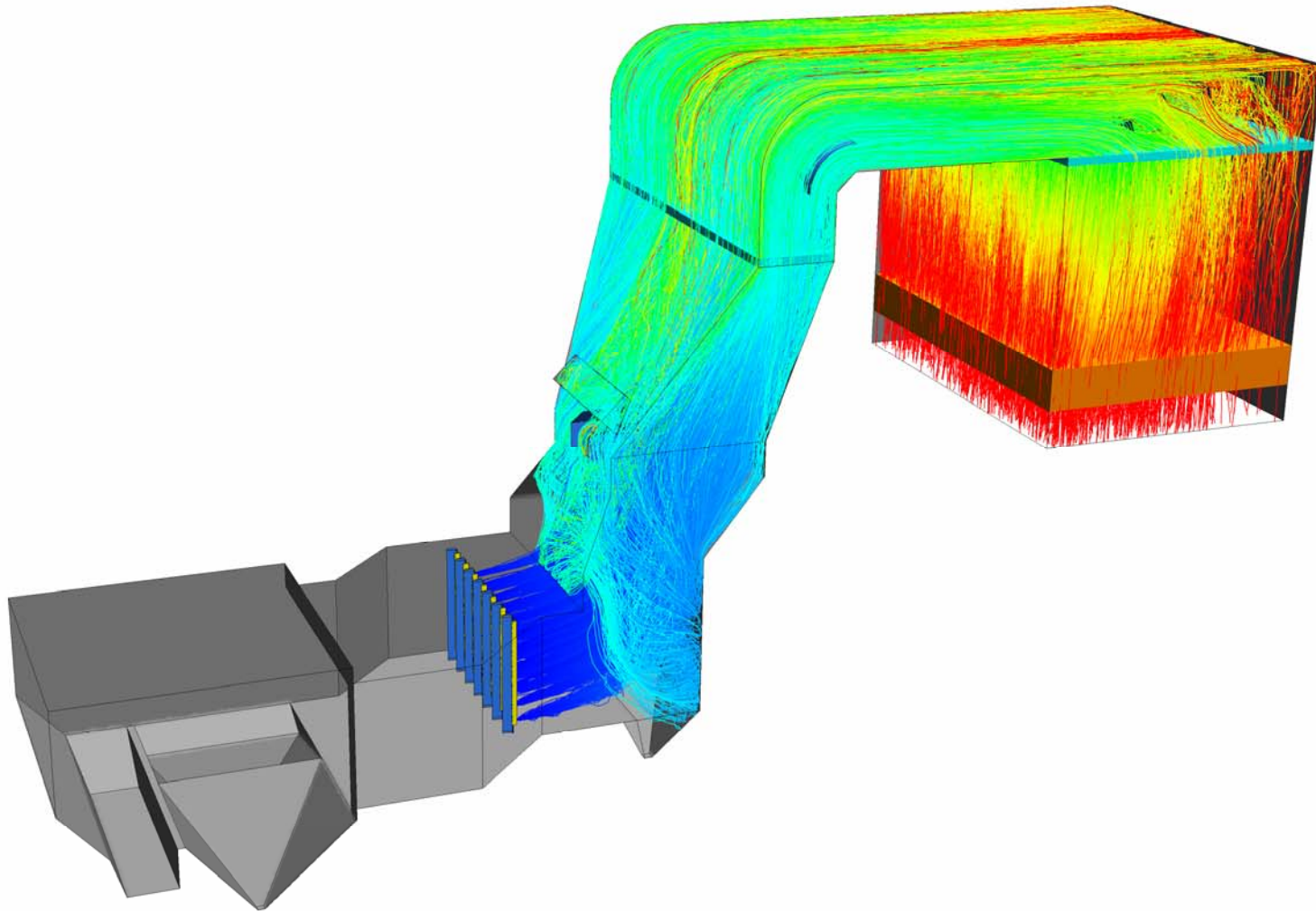
DP&L Stuart Units 1 – 4: SBS Design

- Primary Objectives
 - Retain ability to inject ammonia at lower loads
 - Allow use of higher-sulfur coal blends
- Inject SBS at Economizer Outlet
 - Treat both boiler- & SCR-generated SO₃
- SBS Start-Up Completed on All Four Units
 - Unit 4 operated ~3 weeks in September
 - SBS injection on all units in Nov/Dec 2008
 - Performance enhancement demonstration in progress

Injection Location: Economizer Outlet



Injection Location: Economizer Outlet



Performance Testing – Stuart

● Key Results

- Constant percentage SO₂ conversion in boiler
- 90% SO₃ removal at SCR inlet
 - ✖ SCR inlet SO₃ concentrations below 1 ppm
 - ✖ Elevated Na:SO₃ molar ratio promotes SO₃ removal
 - ✖ Allows compliance with Consent Decree NO_x reduction requirements over normal load range
- AH inlet SO₃ concentrations below 6 ppm
 - ✖ Should improve AH performance relative to no SBS

Future Operation & Planned Testing

- Stuart Performance Enhancement Demonstration
 - Pre-SCR strategy impacts all downstream equipment
 - Numerous operating variables including fuel sulfur, economizer bypass, SBS, Consent Decree, Wahlco, AH outlet temperature & ammonia slip
 - Demonstration objectives:
 - ✘ Identify optimum approach for SBS & other equipment
 - ✘ Demonstrate operating conditions that reduce costs

Catalyst Protection Issues

- Catalyst Protection Measures Under Consideration
- Strategies during Reactor Maintenance
 - Minimize ambient air intrusion into the reactor
 - Provide heating to slightly raise reactor temperature
- Strategies for SCR Start-Up
 - Increase the size of dilution air heaters to maintain catalyst temperature above the flue gas water dew point

Catalyst Protection Issues

- Catalyst Sampling & Testing
 - Measure catalyst activity & sodium level
 - Testing to evaluate impact of exposure to humid air
 - Results of October catalyst sampling not yet available
 - In-situ catalyst activity measurements
- No Current SCR Operating Problems at Either Station

Summary

- Pre-SCR Experience is being Accumulated at Killen & Stuart through Operation and Testing
- SO₃ Removals are Sufficient to Meet MOT Objectives
- Potential for Secondary Benefits will be Explored
 - Initial testing of elevated slip operation at Killen
 - Comprehensive demonstration testing at Stuart

Summary

- Catalyst Protection Measures are being Developed & Implemented at Both Plants
 - Catalyst testing results will help to quantify long-term catalyst performance and to define outage and startup requirements
 - No current SCR operating issues
- Pre-SCR Approach Beneficial for Other Plants
 - Conversion to higher-sulfur coals
 - MOT operating constraints at lower loads
 - Year-round operation with more cycling