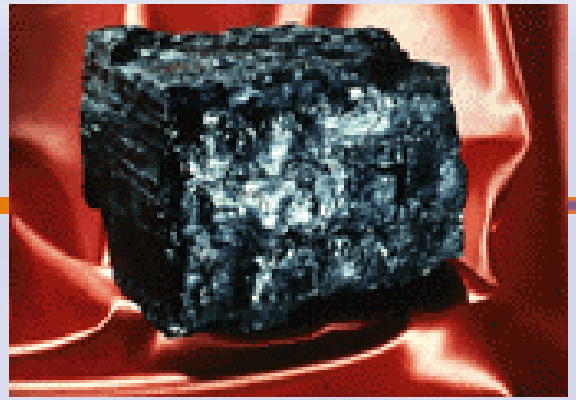
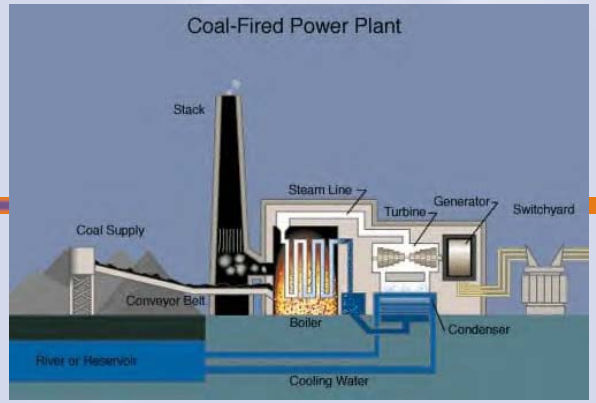
# REINHOLD ENVIRONMENTAL Ltd.

# 2012 NOx-Combustion Round Table & Expo Presentation

February 13-14, 2012, in Columbus, OH / Hosted by AEP




# *"Pre-SCR" $SO_3$ Mitigation*

Reinhold Conference
NOx Combustion Roundtable
February 14, 2012
Columbus, Ohio

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# Agenda

- Overview of $SO_3$ Generation
  - Method of Formation
  - Impact of $SO_3$
- Review of Available $SO_3$ Mitigation Technologies
- Challenges Associated With Pre-SCR Injection
  - Effect of Injected Sorbent on SCR Catalyst
  - Effect of Inlet $SO_3$ Concentration on Oxidation
- Experience of Pre-SCR Injection
  - Gibson Generating Station
    - System description & configuration
    - Implementation schedule & operating results
    - Performance testing results
  - Others



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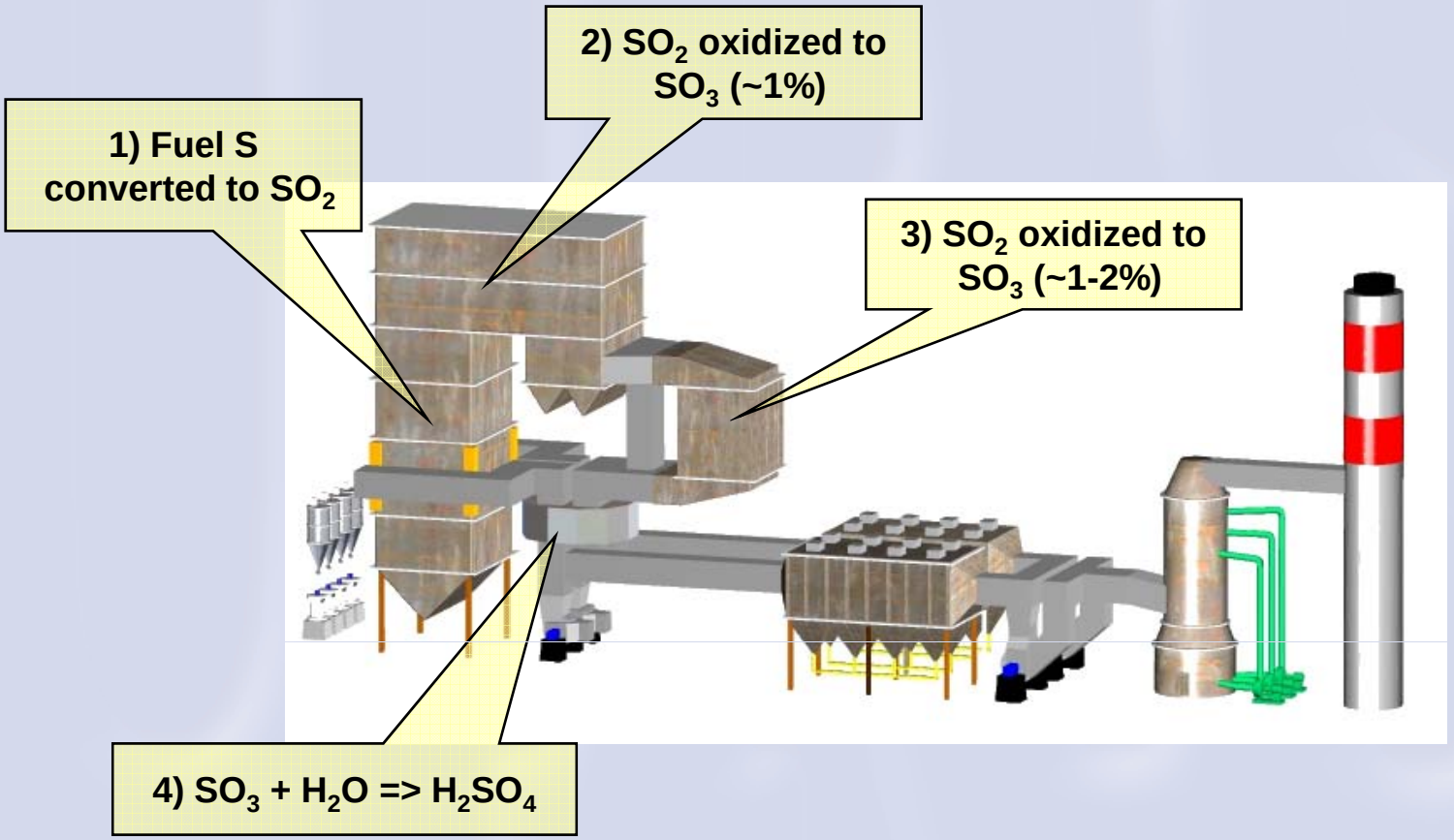
# Sulfuric Acid Formation



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# $SO_3$ Overview

- Factors That Increase $SO_2$ to $SO_3$ Oxidation
  - Various coal/oxygen stoichiometries
  - Presence of oxidizing catalyst in fuel (nickel, vanadium, etc…)
  - Combustion temperatures
  - Boiler configuration
  - Hi-oxidation catalyst



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# $SO_3$ Impacts

- Limited SCR Operation
  - SCR “Minimum Operating Temperature” (MOT) increases, resulting in decreased operating availability
  - $NH_3$ “slip” must be minimized to avoid ammonium bisulfate (ABS) deposition in AH. These lower $NH_3$ injection levels result in less $NO_x$ removal
- Increased Air Heater Fouling
  - Acid condensation on AH baskets and ABS fouling of AH
  - Heat rate & efficiency impacts – AH outlet temperature must be kept higher
  - More frequent outages required for AH cleaning
- Ductwork and Equipment Corrosion
  - Acid condenses in localized cold spots in ESPs, fans, ductwork, etc.
- Increased Stack Opacity (“Blue Plume”)
  - Aerosol formed in scrubber
- Limited Fuel Flexibility
  - Burning a higher sulfur coal worsens these impacts.



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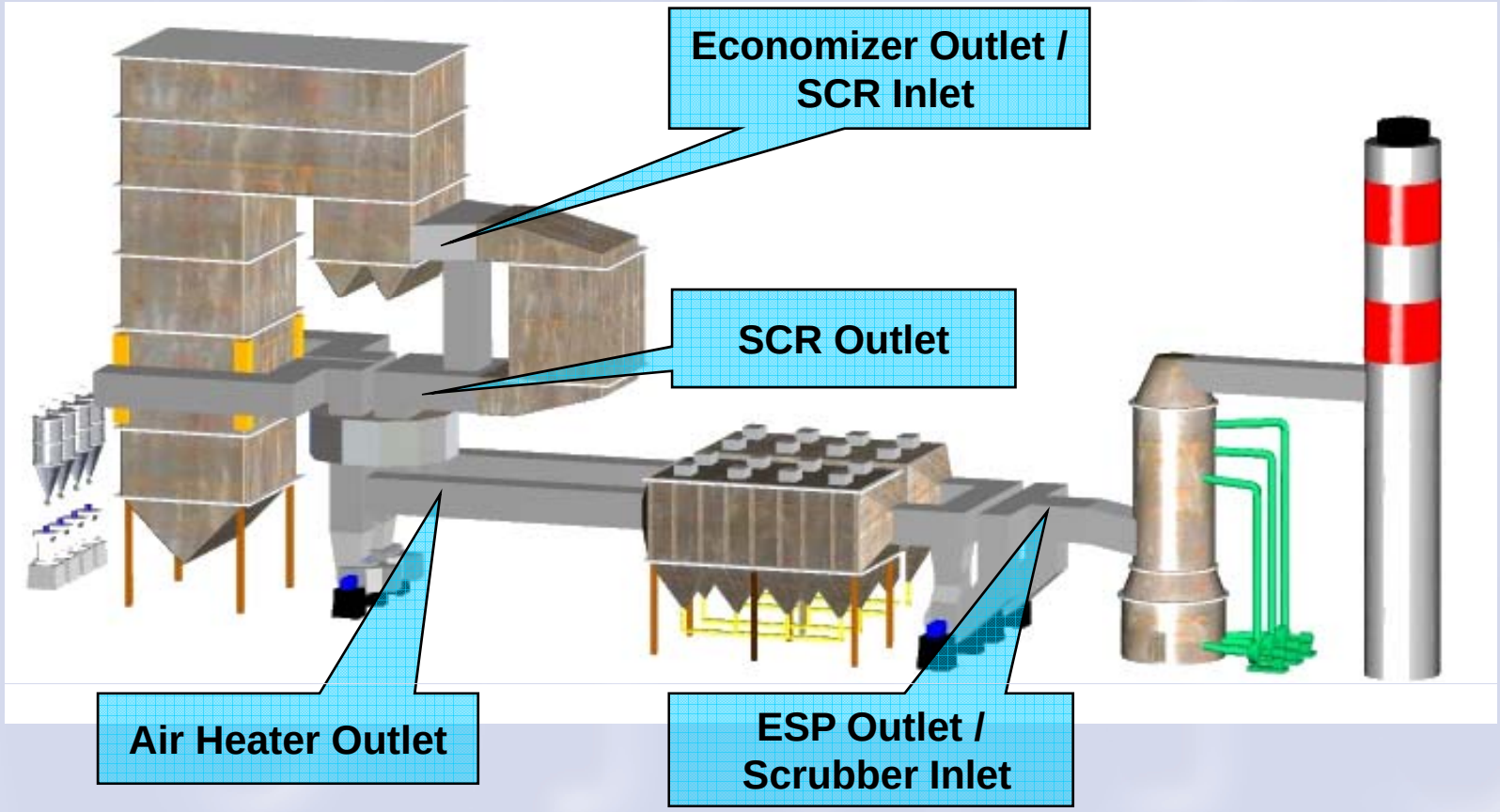
# $SO_3$ Mitigation Injection Locations




**Go Further Upstream to Maximize Benefits**



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# Available $SO_3$ Mitigation Technologies

| | SBS Injection | Mag Hydroxide | Hydrated Lime | Trona | Ammonia |
|---|---|---|---|---|---|
| **Typical Injection Location** | | | | | |
| ***Boiler*** | | √ | | | |
| ***Before SCR*** | √ | | | | |
| ***Before AH*** | √ | | | | |
| ***Before ESP*** | | | √ | √ | √ |
| ***Before FGD*** | | | √ | | |
| **Typical SO3 Removal** | **90 - 98%** | **50 - 90%** | **50 - 80%** | **70 - 90%** | **80 - 95%** |
| **Typical Injection NSR** | **1 - 1.5** | **2 - 4** | **3 - 5** | **2 - 3** | **1 - 2** |



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# SBS Injection™ Technology

***Features***

- Patented Technology
- Simple Solution Injection
- Sodium-Based Reagent
- Dual-Fluid Atomization
- Selective Reactions
- High $SO_3$ Removal
- Low Injection Rate
- Product Collected with Ash

***Benefits***

- Opacity Elimination
- Corrosion Reduction
- ESP Enhancement
- HCl and Se Removal
- Potential Heat Recovery
- SCR/SNCR Flexibility
- Hg Capture Enhancement
- $CO_2$ Reduction

***Maximum Benefits with "Upstream" Injection***



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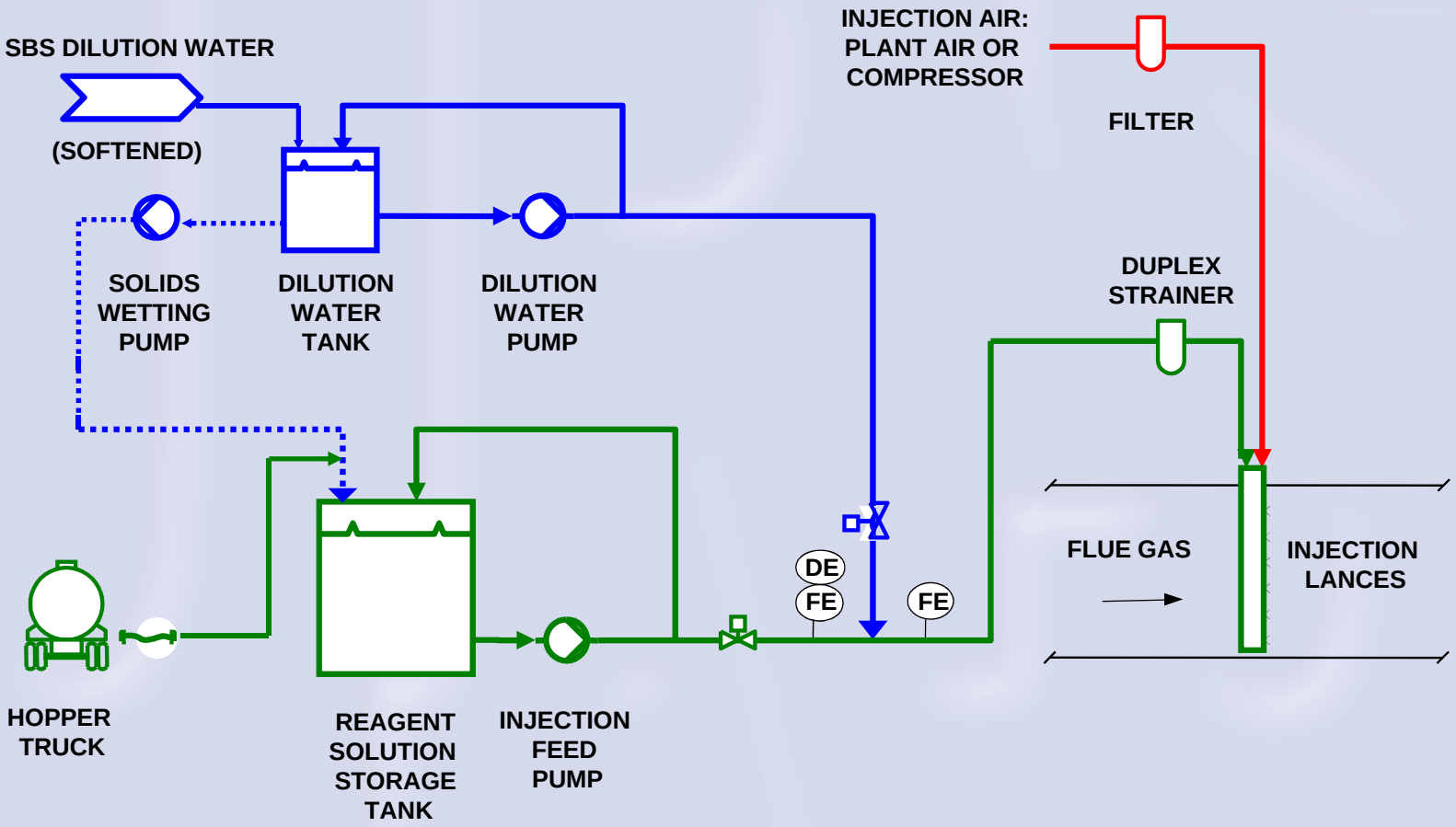
# Simplified SBS Flow Diagram



# SBS Applications

| Utility | Plant | State | MW | Design $SO_3$ | Injection Location | Reagent | Startup Date |
|---|---|---|---|---|---|---|---|
| **FirstEnergy** | Mansfield 1-3 | PA | 3 x 860 | 80 | Air Heater Inlet | Sodium Sulfite | 2003 |
| **TVA** | Widows Creek 7 | AL | 550 | 54 | Air Heater Inlet | Sodium Sulfite | 2003 |
| **NIPSCO** | Bailly 8 | IN | 365 | 59 | Air Heater Outlet | Sodium Carbonate | 2004 |
| **Vectren** | Culley 3 | IN | 287 | 48 | SCR Outlet | Sodium Carbonate | 2004 |
| **PPL** | Montour 1-2 | PA | 2 x 765 | 42 | Air Heater Outlet | Sodium Carbonate | 2004 |
| **Duke Energy** | Gibson 1-5 | IN | 5 x 650 | 110 | Air Heater Outlet | Sodium Carbonate | 2005 |
| **DP&L** | Killen 2 | OH | 635 | 34 / 36 | Econ Outlet / SCR Outlet | Sodium Carbonate | 2007 |
| **IP&L** | Harding St 7 | IN | 465 | 58 | SCR Outlet | Sodium Carbonate | 2007 |
| **NIPSCO** | Bailly 7 | IN | 180 | 59 | SCR Outlet | Sodium Carbonate | 2008 |
| **DP&L** | Stuart 1-4 | OH | 4 x 620 | 90 | SCR Inlet | Sodium Carbonate | 2008 |
| **Duke Energy** | Gibson 1-3, 5 | IN | 4 x 650 | 110 | SCR Inlet | Sodium Carbonate | 2009-2011 |
| **Allegheny Energy** | Pleasants 1-2 | WV | 2 x 700 | 74 | SCR Outlet | Sodium Carbonate | 2012 |
| **Hoosier Energy** | Merom 1-2 | IN | 2 x 540 | 100 | SCR Inlet | Sodium Carbonate | 2012 |

**14,800 MW Installed on 24 Boilers**



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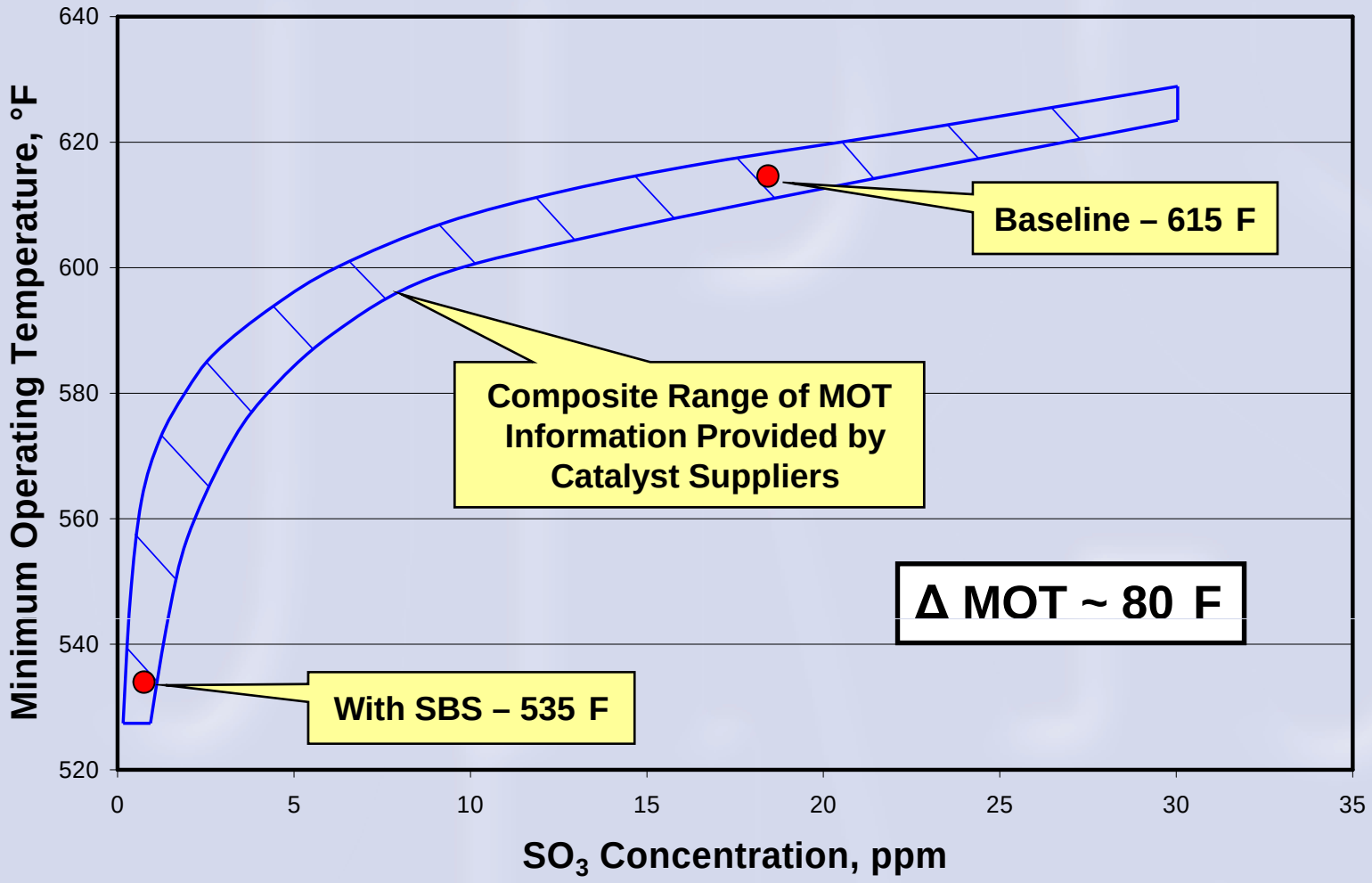
# SCR Min Op Temp vs $SO_3$



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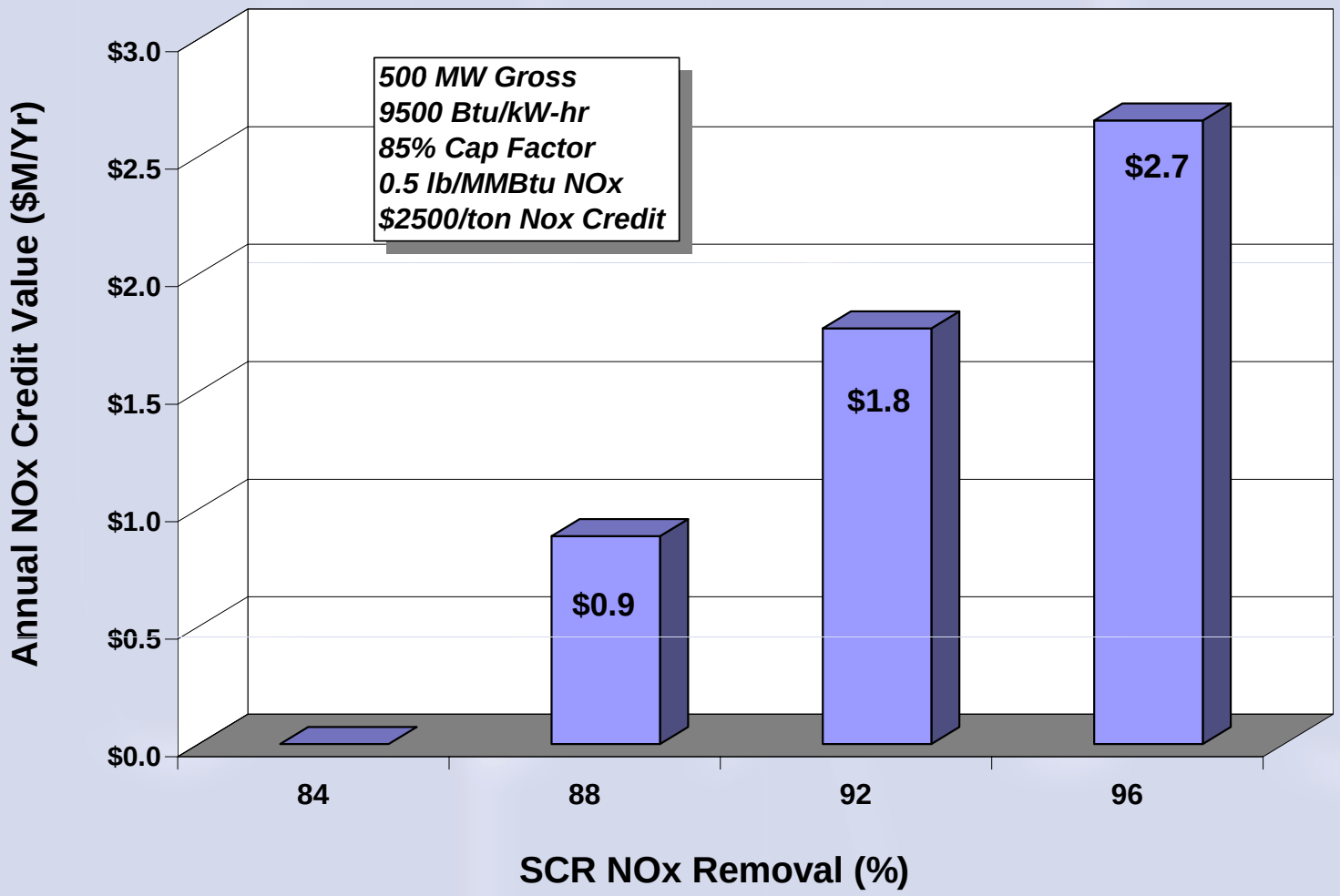
# Impact on NOx Removal



# Challenges With Pre-SCR Injection

- Effect of Sorbent on Catalyst Activation
- Effect of $SO_3$ concentration on catalyst's $SO_2$ to $SO_3$ oxidation characteristics



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# Challenges With Pre-SCR Injection

- Effect of Sorbent on Catalyst Activation
  - Some testing has been completed by URS and different utilities.
  - Results suggest that the addition of sorbent increases the importance of following catalyst vendors' outage/lay-up recommendations.
  - Additional testing required for long-term effect.
- Effect of $SO_3$ concentration on catalyst's $SO_2$ to $SO_3$ oxidation characteristics



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# Challenges With Pre-SCR Injection

- Effect of Sorbent on Catalyst Activation
- Effect of $SO_3$ concentration on catalyst's $SO_2$ to $SO_3$ oxidation characteristics
  - Catalyst vendor and contractor research showed:
    - $SO_2$ to $SO_3$ conversion decreases with higher $SO_3$ levels
    - Higher $SO_3$ levels increase NOx reduction
  - URS test results and experience suggest increased $SO_2$ to $SO_3$ oxidation across catalyst layers when inlet $SO_3$ levels are low



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# Practical Applications

- Gibson Generating Station
- Second Generating Station

# Gibson Units 1 through 5 – Overview

- Nominal 660 MW Boilers
- High Dust SCRs
  - 3 layers of catalyst
  - 85% design $NO_x$ removal efficiency
- Horizontal-Shaft Air Heaters
- Cold-Side ESP's
- Bituminous Coal
  - Sulfur levels range from 4-6 lb/MMBtu



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# Gibson SBS Injection™ System Design

- SBS Injection™ Installed on All 5 Gibson Units
  - Systems installed in May 2005 to mitigate blue plume
    - Reagent injected downstream of the air heaters
  - Now operated year-round with the SCR's
- Units 1, 2, 3, & 5 Converted to Pre-SCR
  - Benefits for Gibson:
    - Improved lance reliability with less duct deposition
    - Reduced condensables at air preheater inlet
    - Increased low-load flexibility (reduced MOT)
- Pre-SCR SBS Installation on Units 4
  - Tentatively planned for 2013



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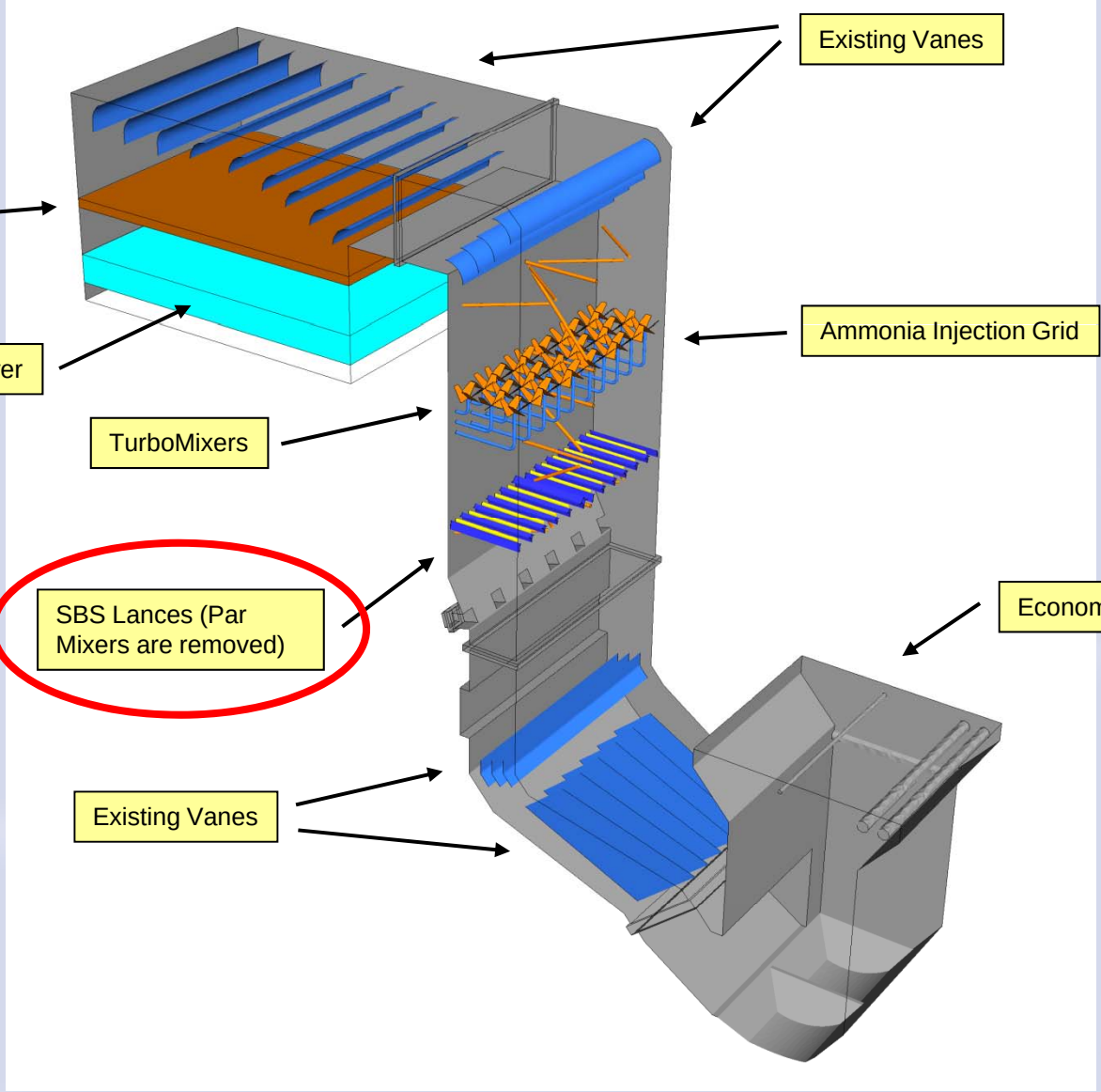
# “Pre-SCR” SBS Approach

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# Pre-SCR Conversion Observations

- Unit 5 Pre-SCR Injection Started March 2009
  - Have operated with single-duct injection since startup
  - No condensables after slight increase in reagent feed
  - Extremely high pre-SCR $SO_3$ removal



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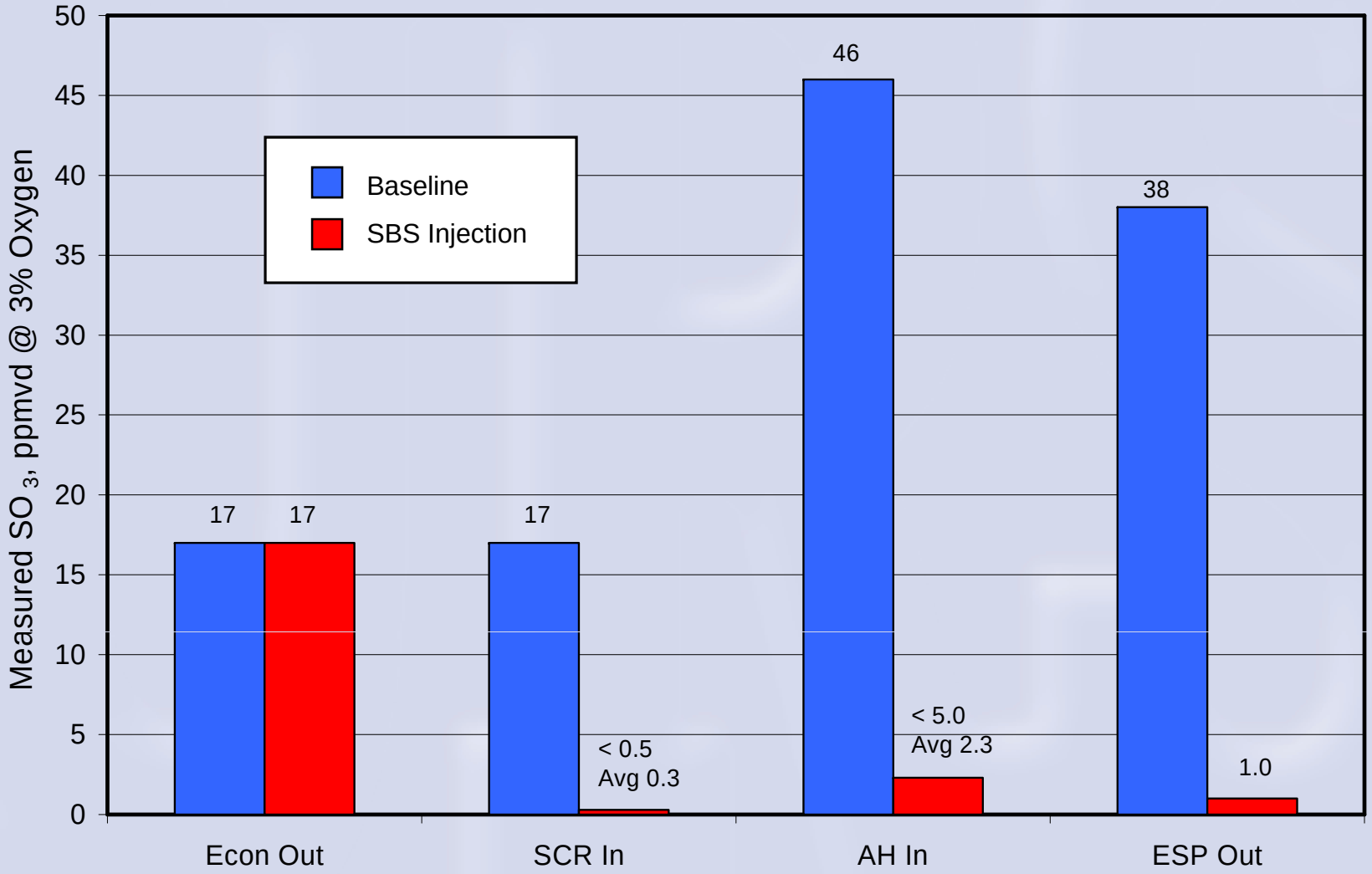
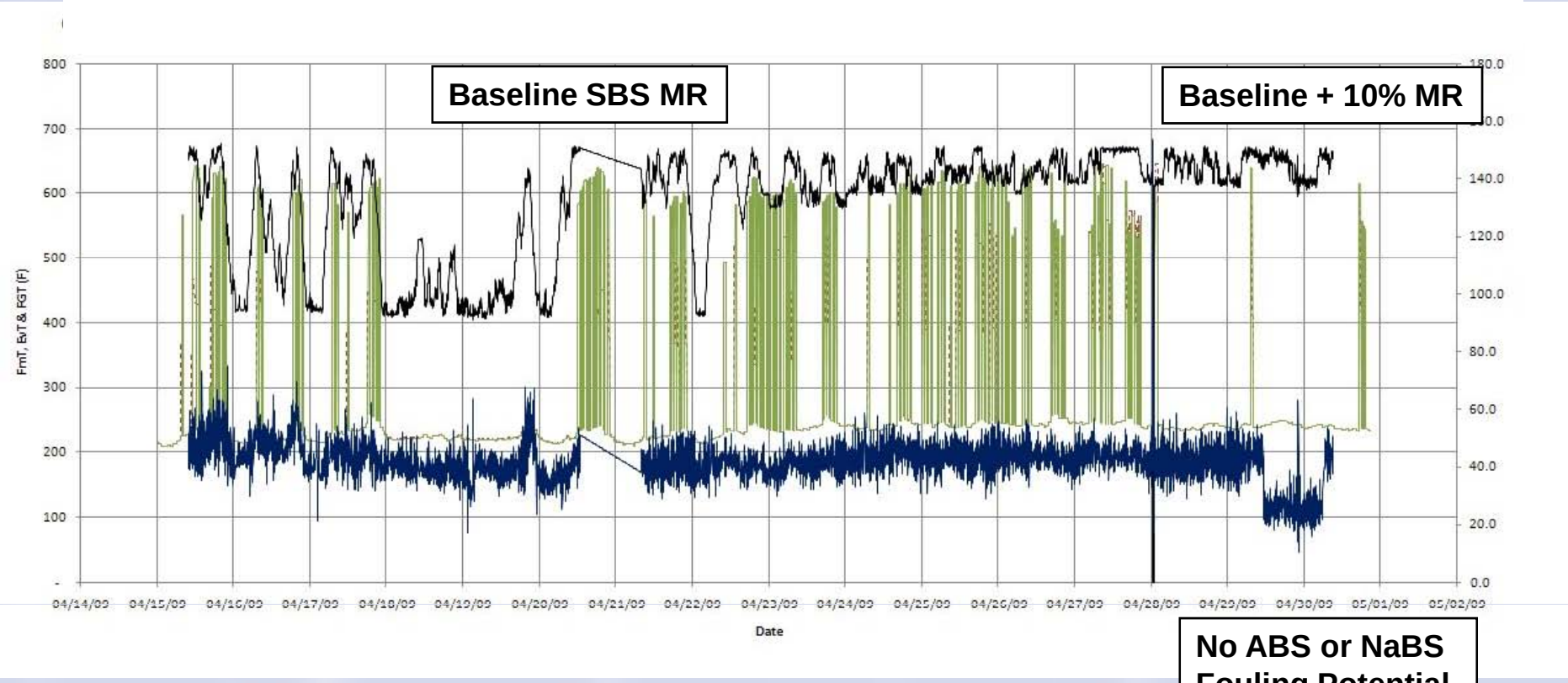
# 2009 Unit 5 Performance Test Results



# Unit 5, Duct B with SBS – 2009 Startup




***Black Trend = Unit Load (MW)***

***Green Trend = Evaporation Temperature, °F (NaBS Fouling Conditions)***

***Blue Trend = SCR $NO_x$ Out (ppm)***

# Pre-SCR Conversion Observations

- Catalyst change recently occurred on Unit 5
  - Recent catalyst replacement has increased overall $SO_2$ conversion from 1.9 to 3.1%
  - Now observe condensables at full load



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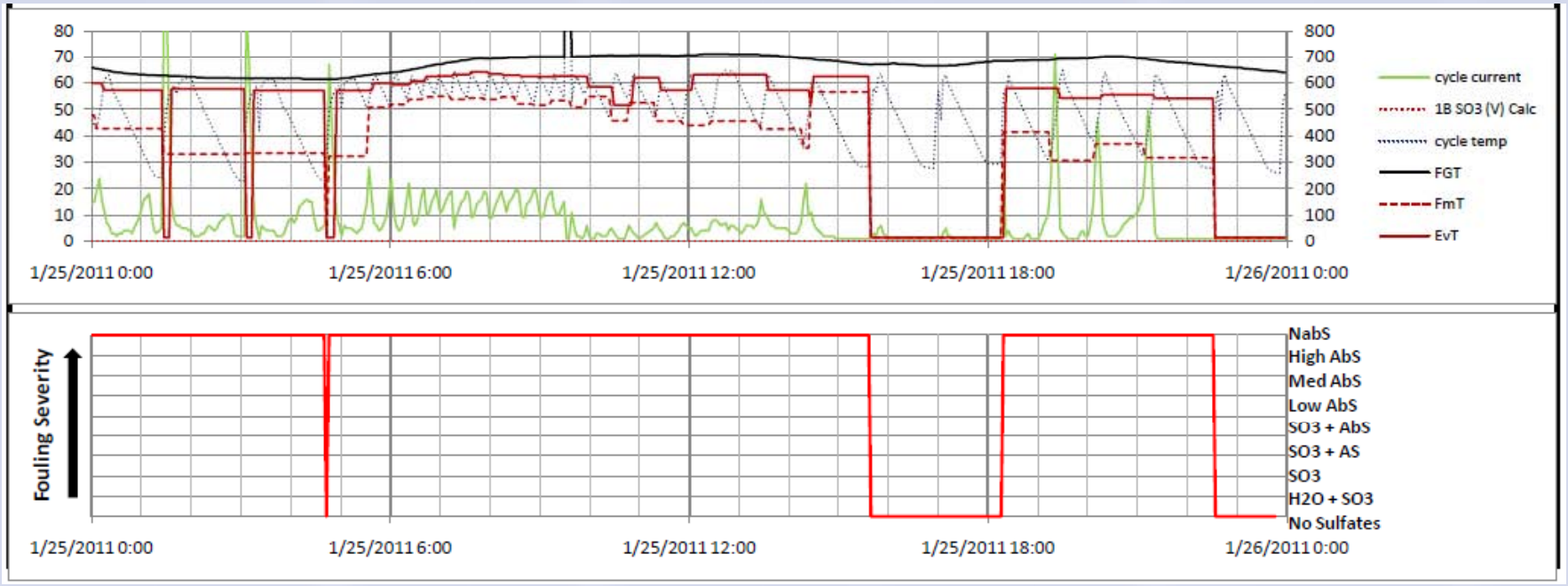
# Unit 5, Duct B with SBS – 2011 Startup




Results show condensables at full load following catalyst replacement

# Pre-SCR Conversion Observations

- Unit 1 Pre-SCR Injection Started December 2010
  - Have operated with single-duct injection since startup
  - Significant ABS detected on untreated duct
  - No condensables on treated duct
  - Have observed significant ESP plate buildup
  - Are presently testing dual-duct injection



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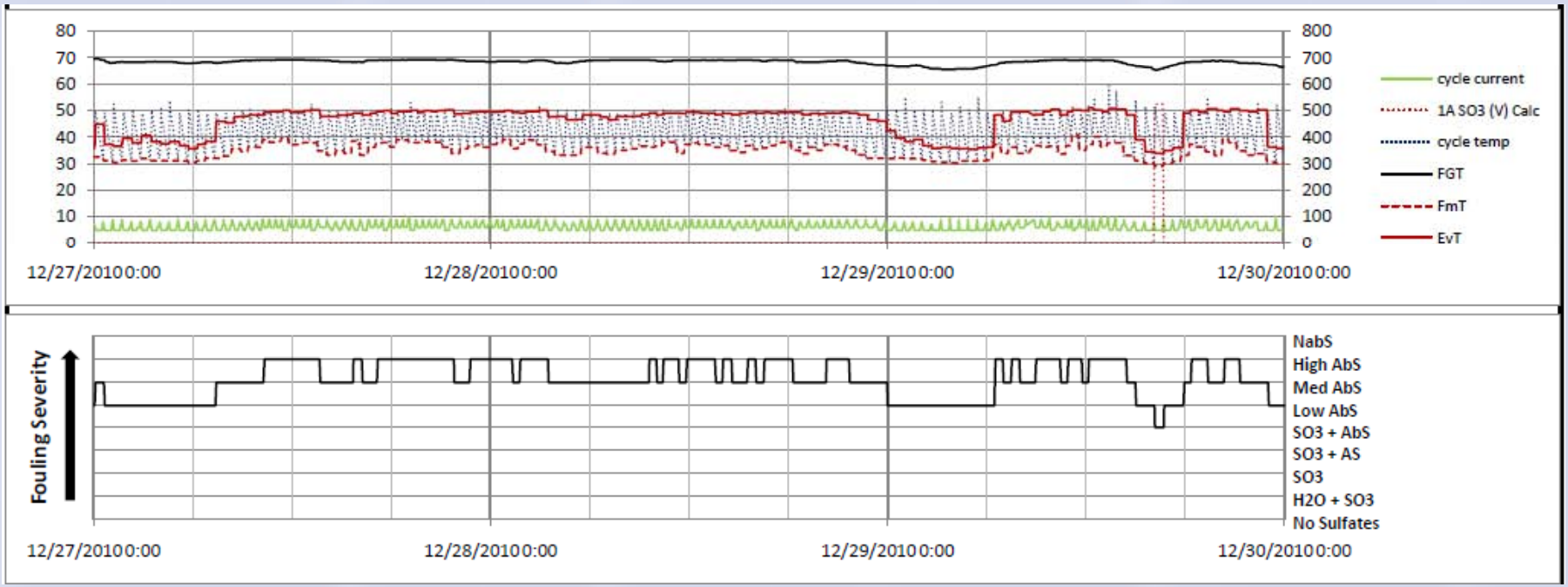
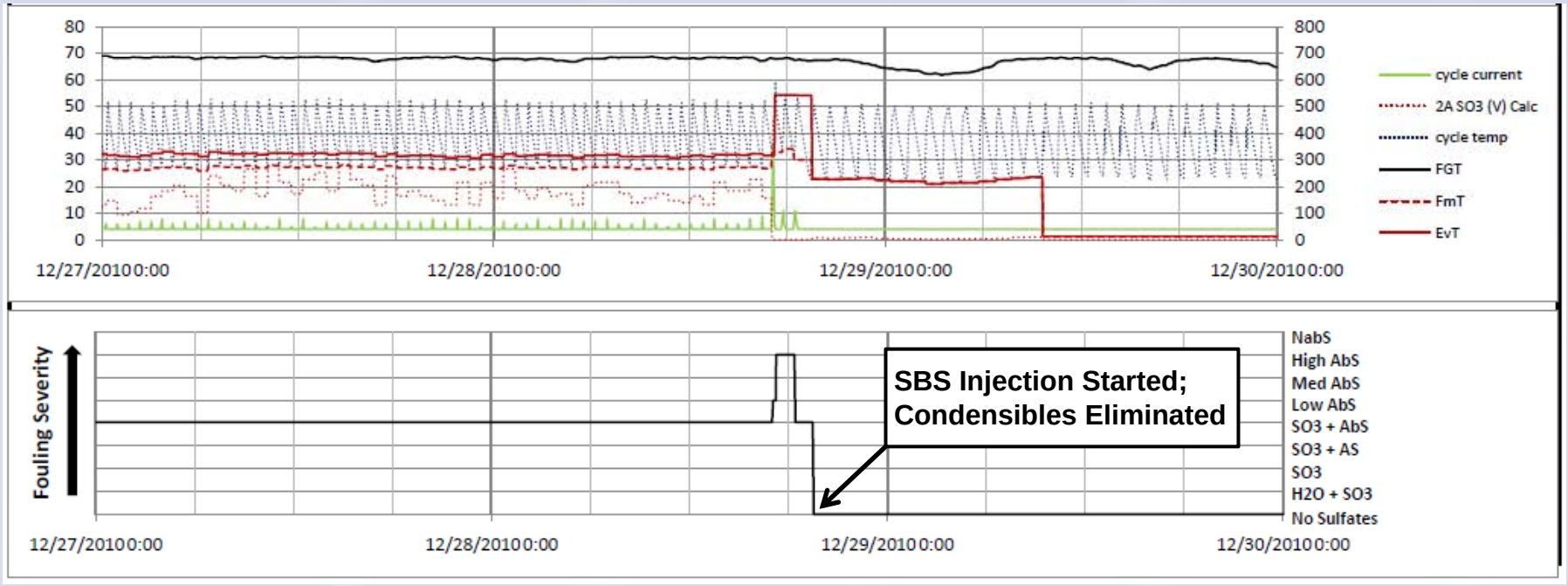
# Unit 1, Duct A – No SBS Injection



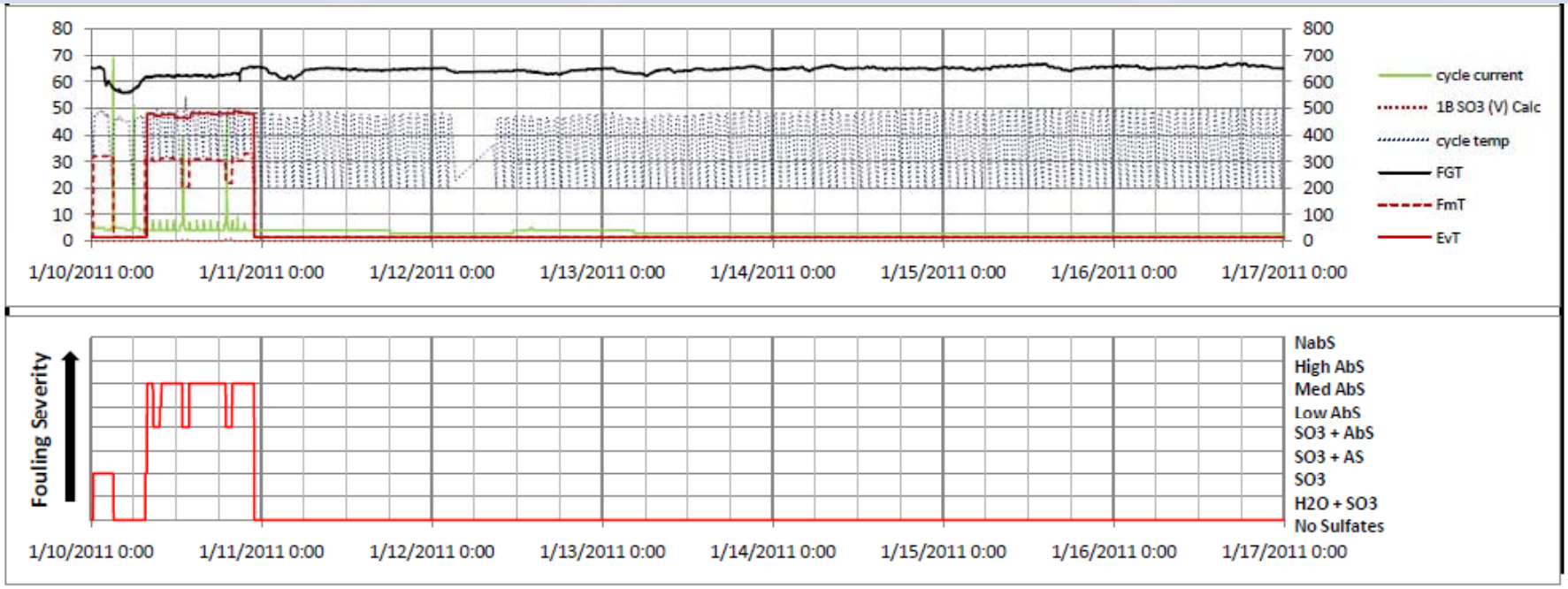

Results show significant ABS at air preheater inlet

# Unit 1, Duct B – During SBS Startup




Results show condensables eliminated with SBS in service

# Unit 1, Duct B – Second Startup




Results on treated duct show no condensables

# Pre-SCR Conversion Observations

- Unit 2 Pre-SCR Injection Started February 2011
  - Tested dual-duct injection for several weeks
  - Have operated primarily with single-duct injection
  - Some ABS detected on untreated duct
  - No condensables on treated duct or ducts
  - Minimal downstream deposition even with SCR bypass
  - Anticipate dual-duct injection starting in 2012



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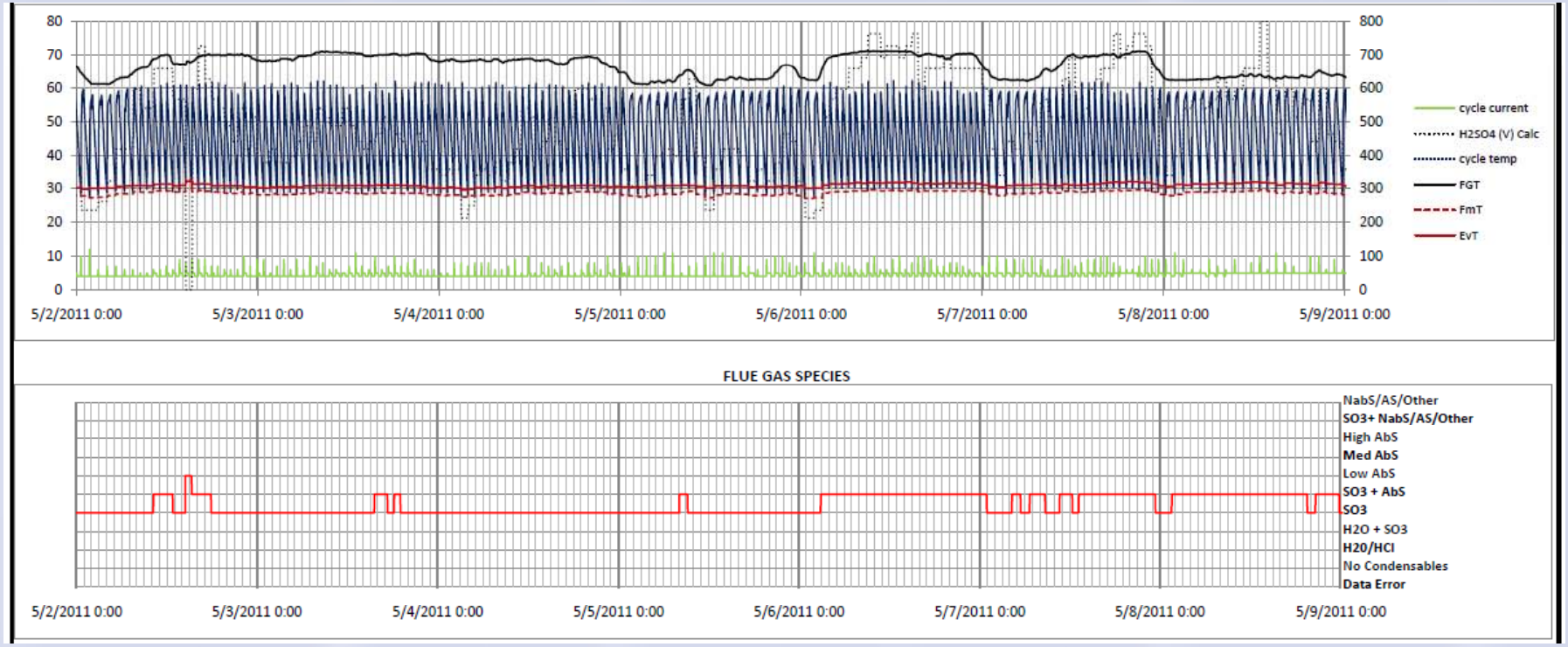
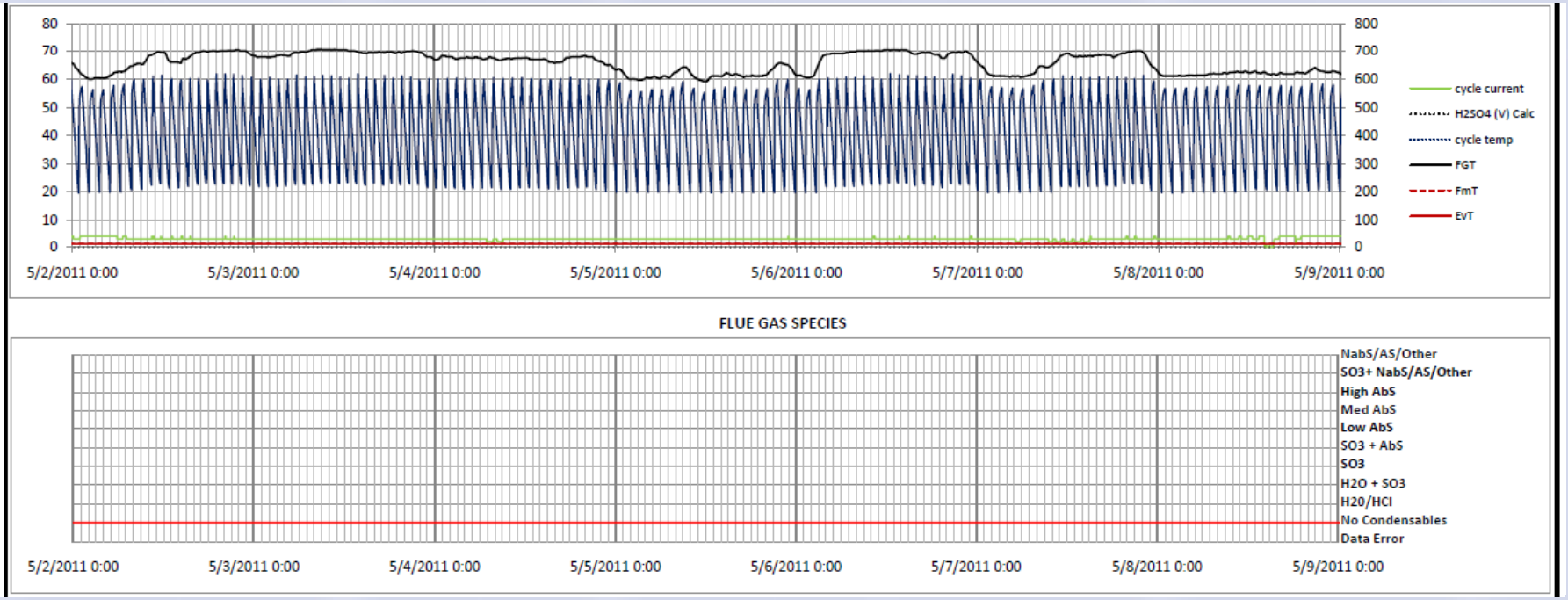
# Unit 2, Duct A – No SBS



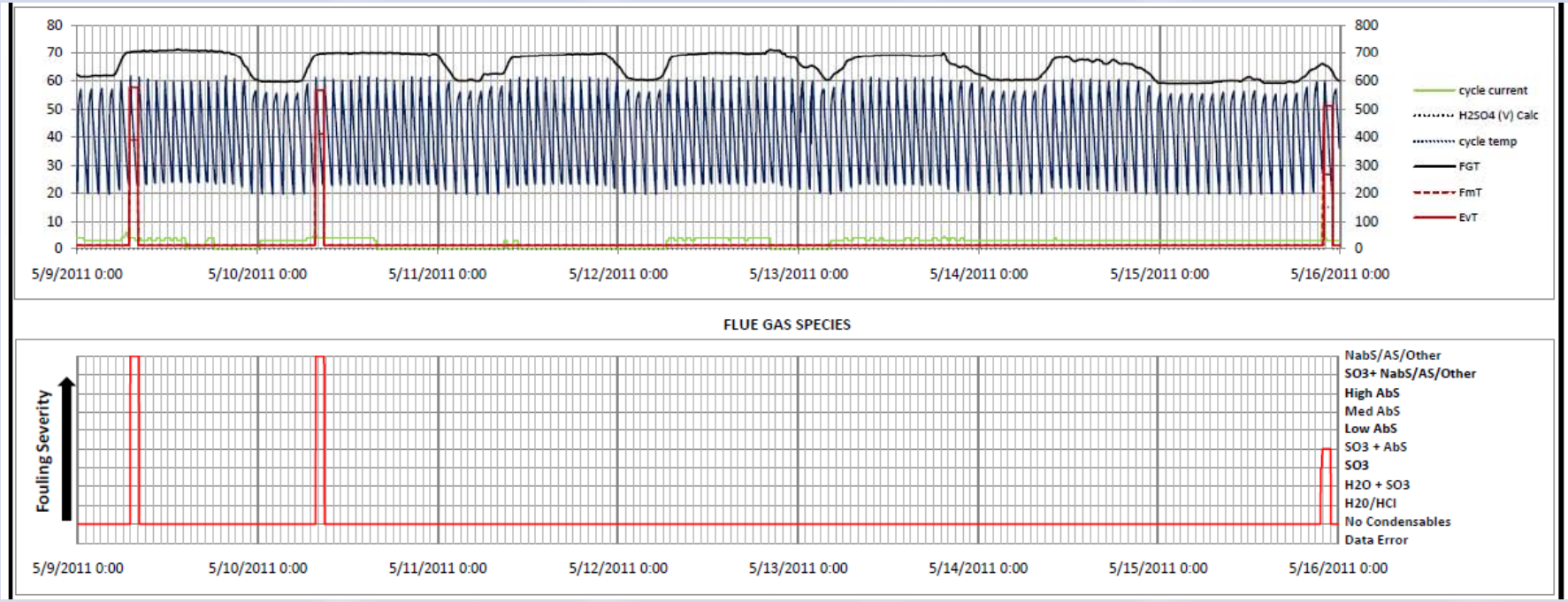

Results show presence of SO3 & ABS at air preheater inlet

# Unit 2, Duct B with SBS – 2011 Startup



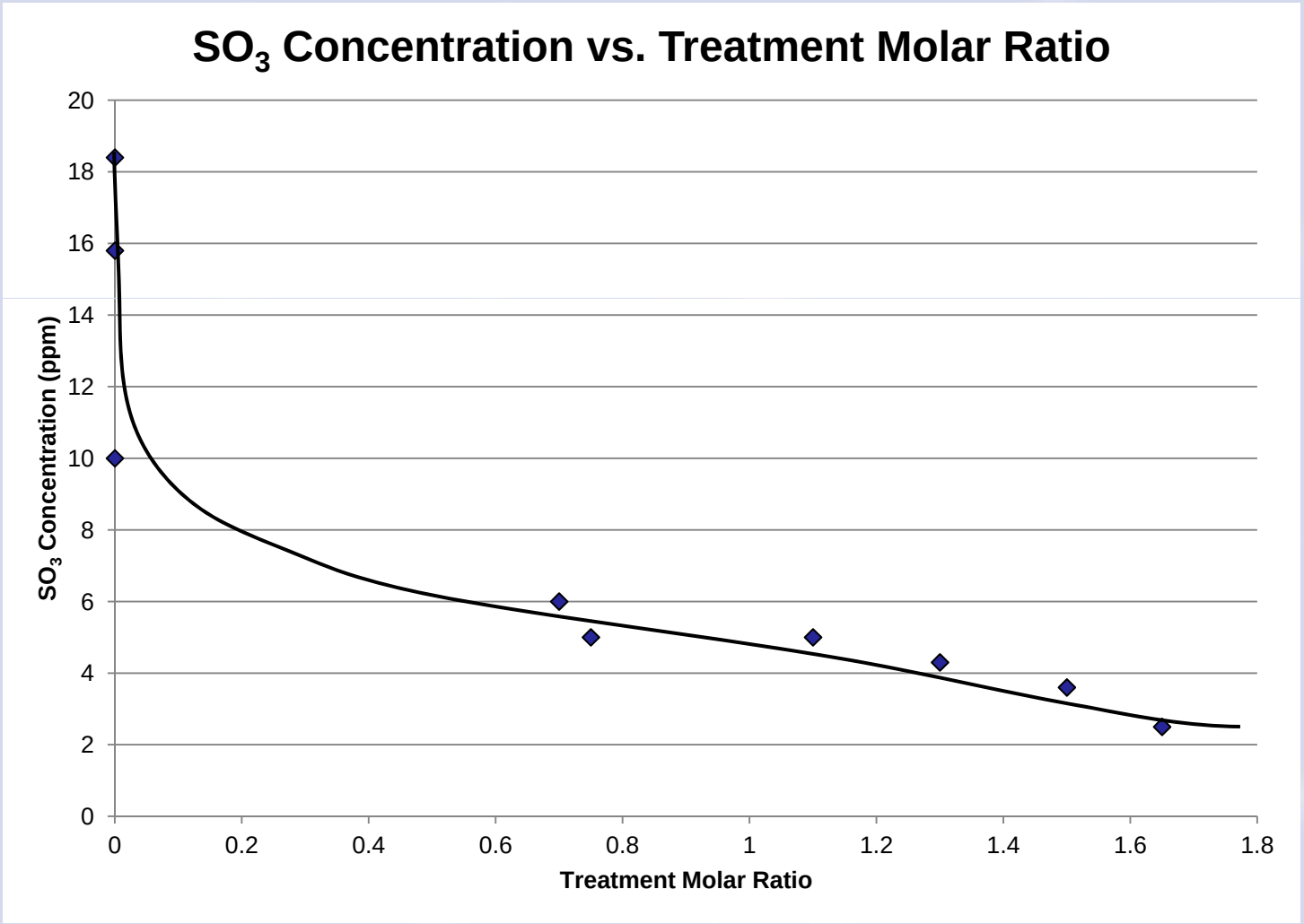

Results show no condensables at air preheater inlet

# Unit 2, Duct B with SBS – 2011 Startup




Some condensables may form on load pickup

# Second Generating Station Performance Data



# Summary of Pre-SCR SBS Operation

- $SO_3$ Adversely Impacts Plant Performance
  - Corrosion
  - AH fouling
  - Heat rate
  - $CO_2$ emissions
  - NOx removal
  - SCR Operational Limitations
  - Mercury capture
- Challenges with pre-SCR Injection Include:
  - Undetermined Potential Catalyst Impacts
  - Higher SO2 to SO3 oxidation across the SCR



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# Summary of Pre-SCR SBS Operation

- To Effectively Reduce SCR MOT and Maximize SCR Operational Flexibility, $SO_3$ Mitigation Must Reduce SCR Inlet $SO_3$ Levels to Very Low Levels (< 3 ppm)
- Pre-SCR SBS Injection has been Installed and Proven at Multiple Generating Stations:
  - Reduces Inlet $SO_3$ Levels to < 3 ppm
  - Reduces SCR Minimum Operating Temperatures
  - Allows Increased NOx Removal



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# Questions?

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**Injection Duct – Fall 2010; after 8 months of operation**