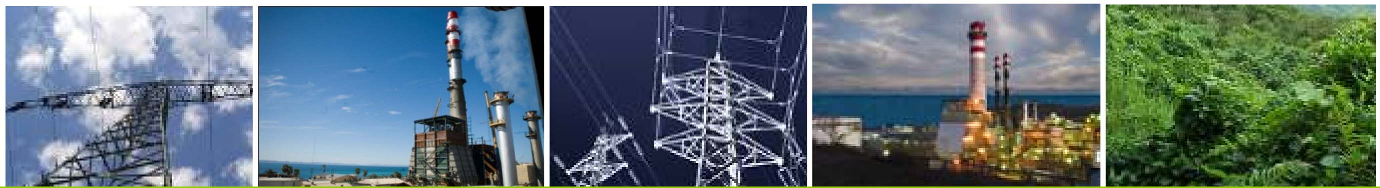
REINHOLD ENVIRONMENTAL Ltd.

2012 NOx-Combustion Round Table & Expo Presentation

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



Impact of SCR on Fuel Flexibility

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NO_x Combustion Round Table
February 14, 2012
Columbus, OH

Agenda

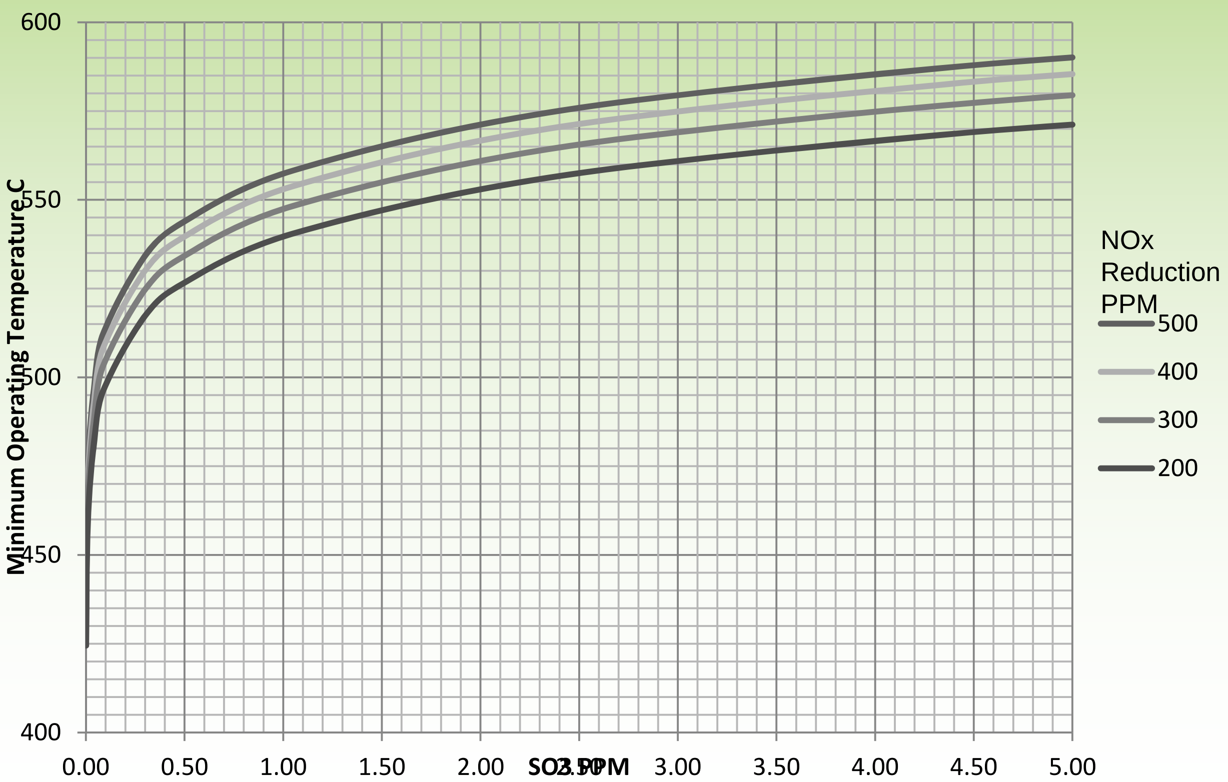
- Impact of catalyst technology on fuel flexibility
- Introduction of Targeted In Furnace Injection TIFI®
- Impact of TIFI® on boiler and SCR operation
- Other Benefits
- Conclusions

Impact of SCR on Boiler Operation and Fuel Flexibility

- **Minimum Operating Temperature MOT**
  - **Determined by ABS formation temperature (to protect catalyst from masking)**
  - **MOT may impose restrictions on unit minimum load, NOx removal efficiency (NH_3 injection rate) and fuel quality (Sulfur content)**
- **Downstream impacts of Ammonia Slip and SO_3**
  - **Fouling (delta-P), Corrosion, Byproduct Quality ($), Visible Emissions (Environmental)**
- **Catalyst poisons**
  - **Fuel flexibility and Catalyst life ($)**

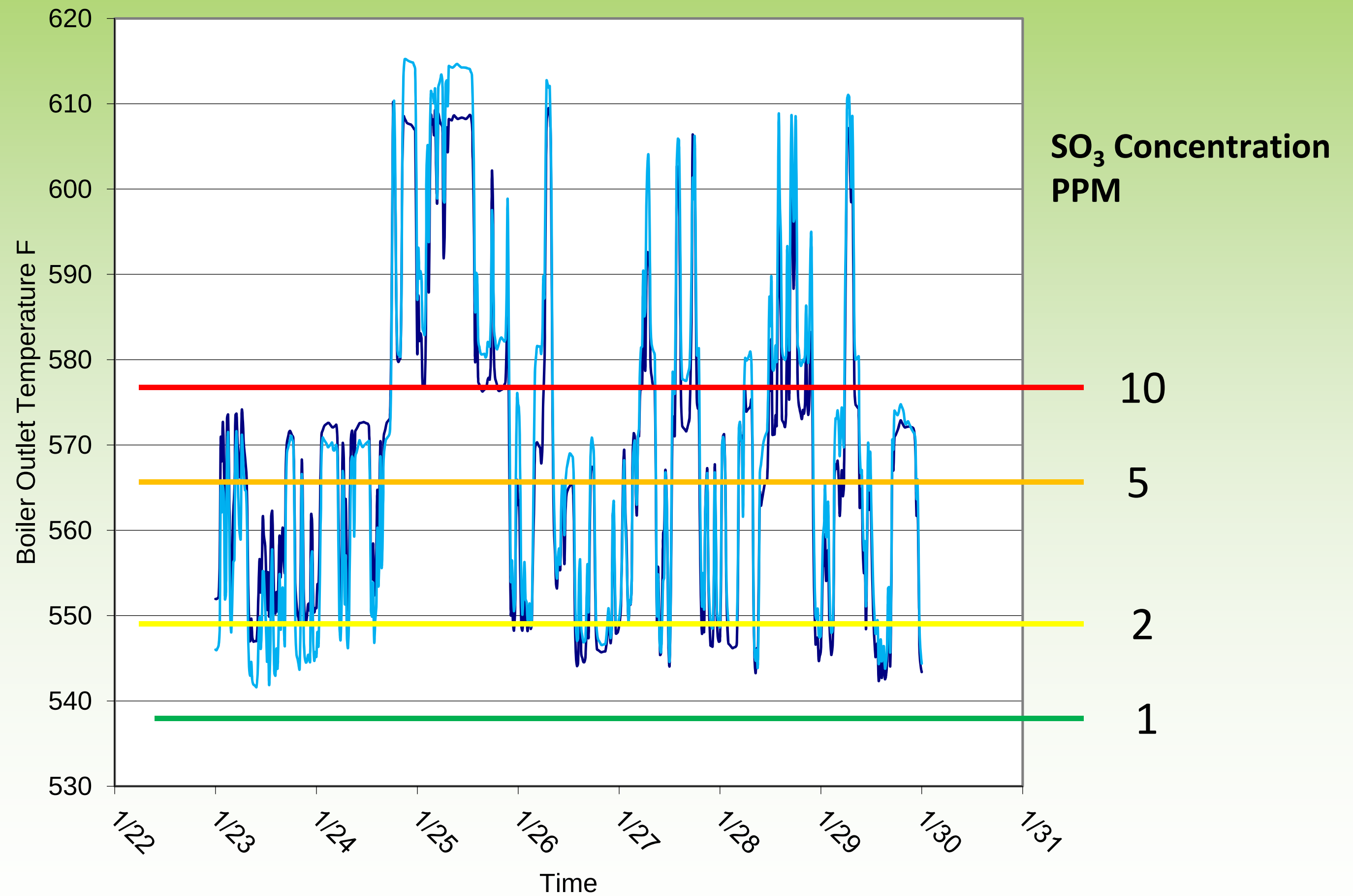
Minimum Operating Temperature

- **The MOT of the catalyst depends on the SO_3 and ammonia concentration in the flue gas**
- **The ammonia concentration is a function of the NO_x removal**



Impact of SO_3 on NO_x Reduction

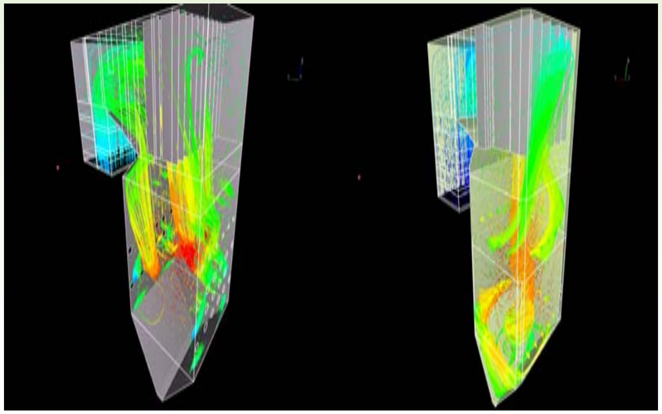
- **MOT impact at 200 PPM NO_x Reduction**



Lowering the Operating Temperature of the Catalyst

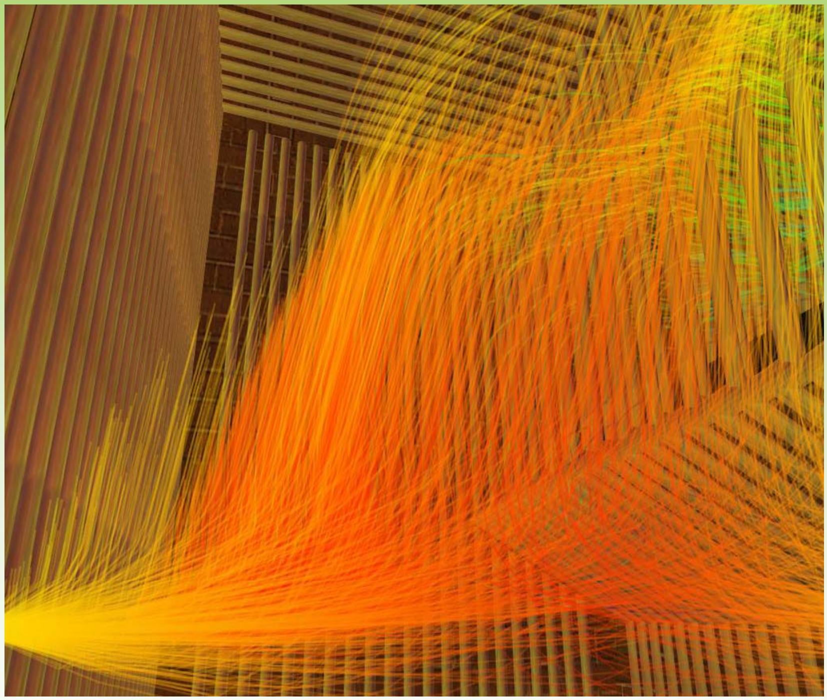
- **Restrict Fuel Sulfur/Supplemental Heating**

- **Reduce SO_3 in-furnace (before SCR)**



TIFI® Targeted In-Furnace Injection™

- **Highly reactive magnesium hydroxide $Mg(OH)_2$**
- **Patented process using Computational Fluid Dynamic Modeling**
- **Critical Design Criteria**
  - Furnace gas flows and temperatures
  - Chemical distribution, particle size and feed rate



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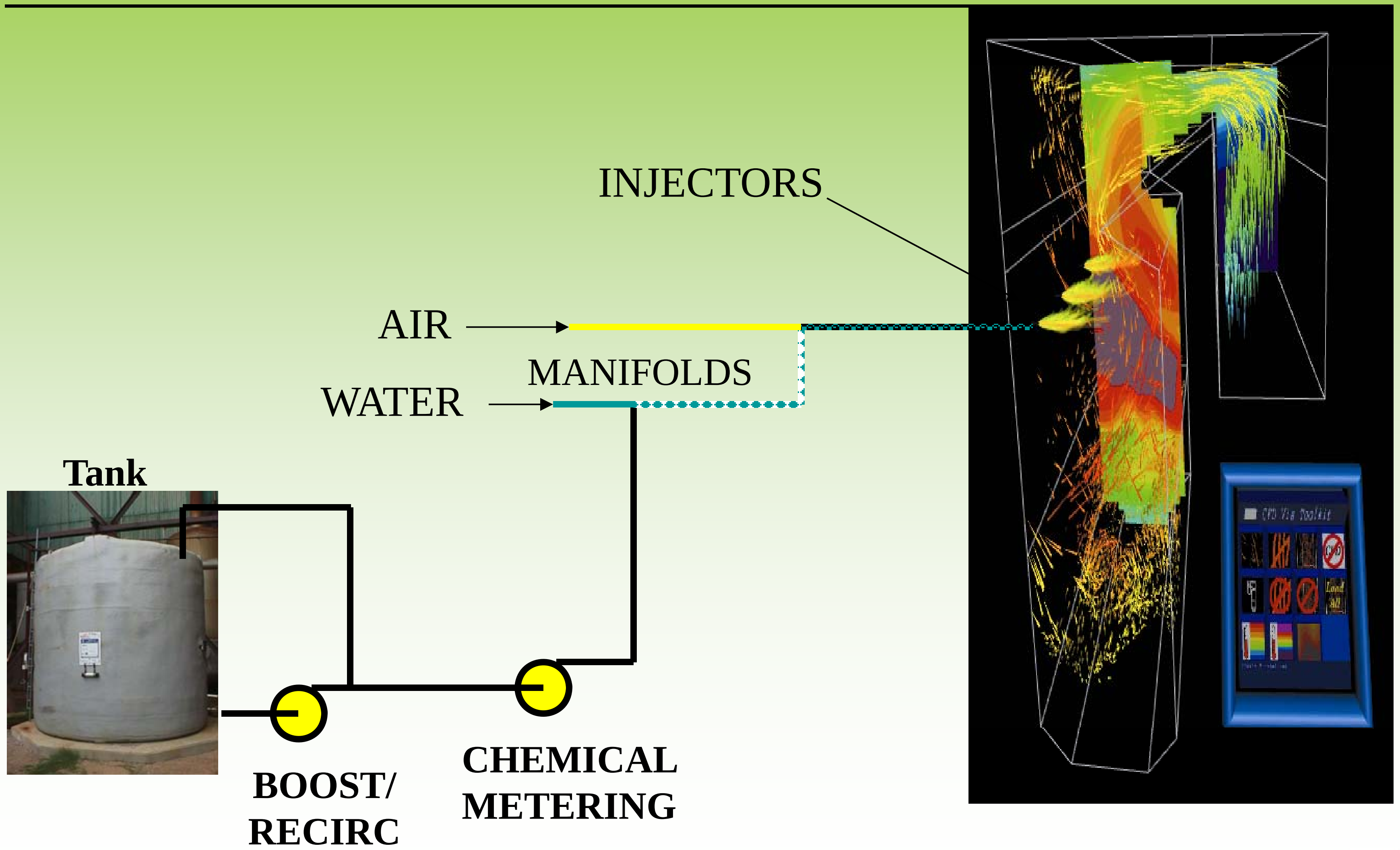
Technologies to enable clean efficient energy

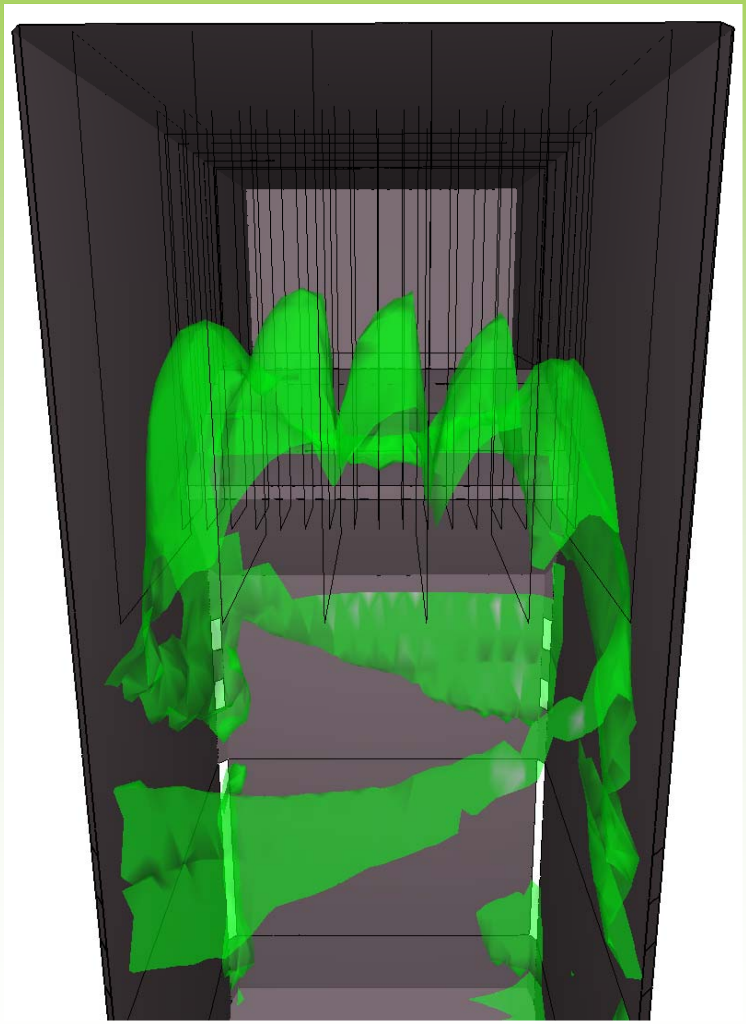
TIFI® Targeted In-Furnace Injection™

ANATOMY OF A TYPICAL INJECTION SYSTEM

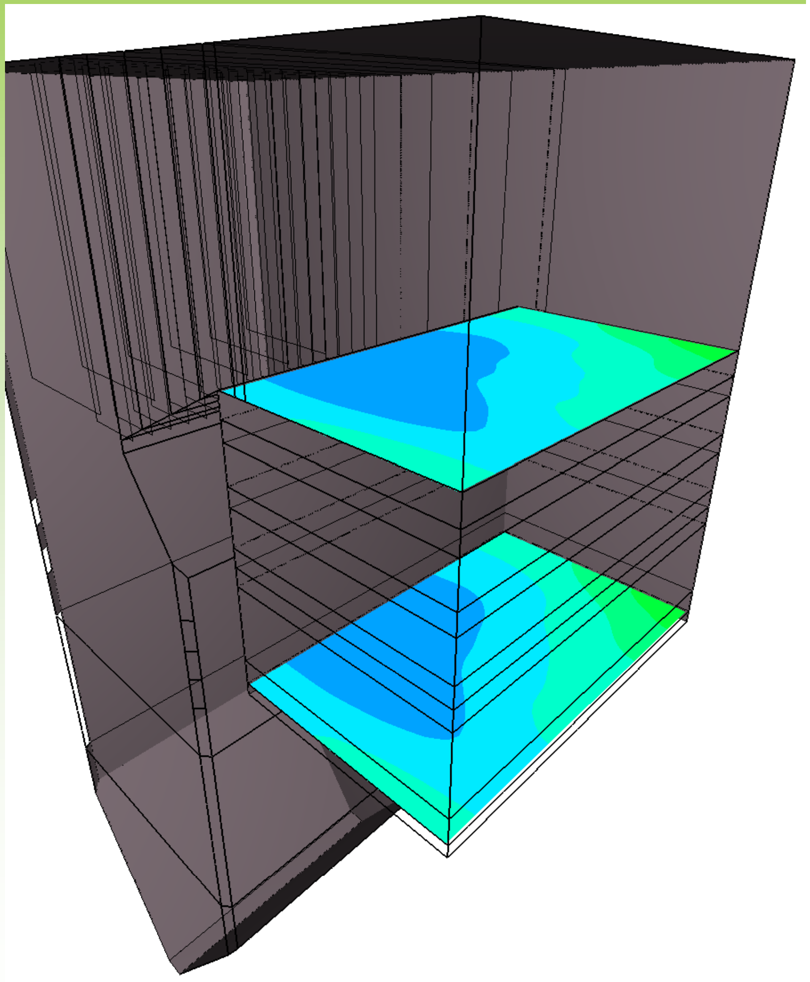


CFD Modeling of Injection Strategy includes both Furnace and Backend

TIFI Injection Model



SO_3 Distribution Map



Controlling Slag, Fouling, SO_3 & Ammonium Bisulfate (ABS)

Critical to Optimizing Catalyst Life, Costs, and Overall Unit Performance

TIFI reduces ABS, SO_3 and H_2SO_4

- **Lower Furnace Temperature**
  - Decreased SO_2 Oxidation Rate
- **More Balanced Furnace**
  - Reduced Excess Oxygen
- **Reduced Slag and Iron Deposits**
  - Less Catalytic Oxidation of SO_2
- **Direct Reaction with MgO**
  - $MgO + SO_3 \Rightarrow MgSO_4$
  - $MgO + NH_4HSO_4 \Rightarrow MgSO_4 + NH_3 + H_2O$

Case Studies

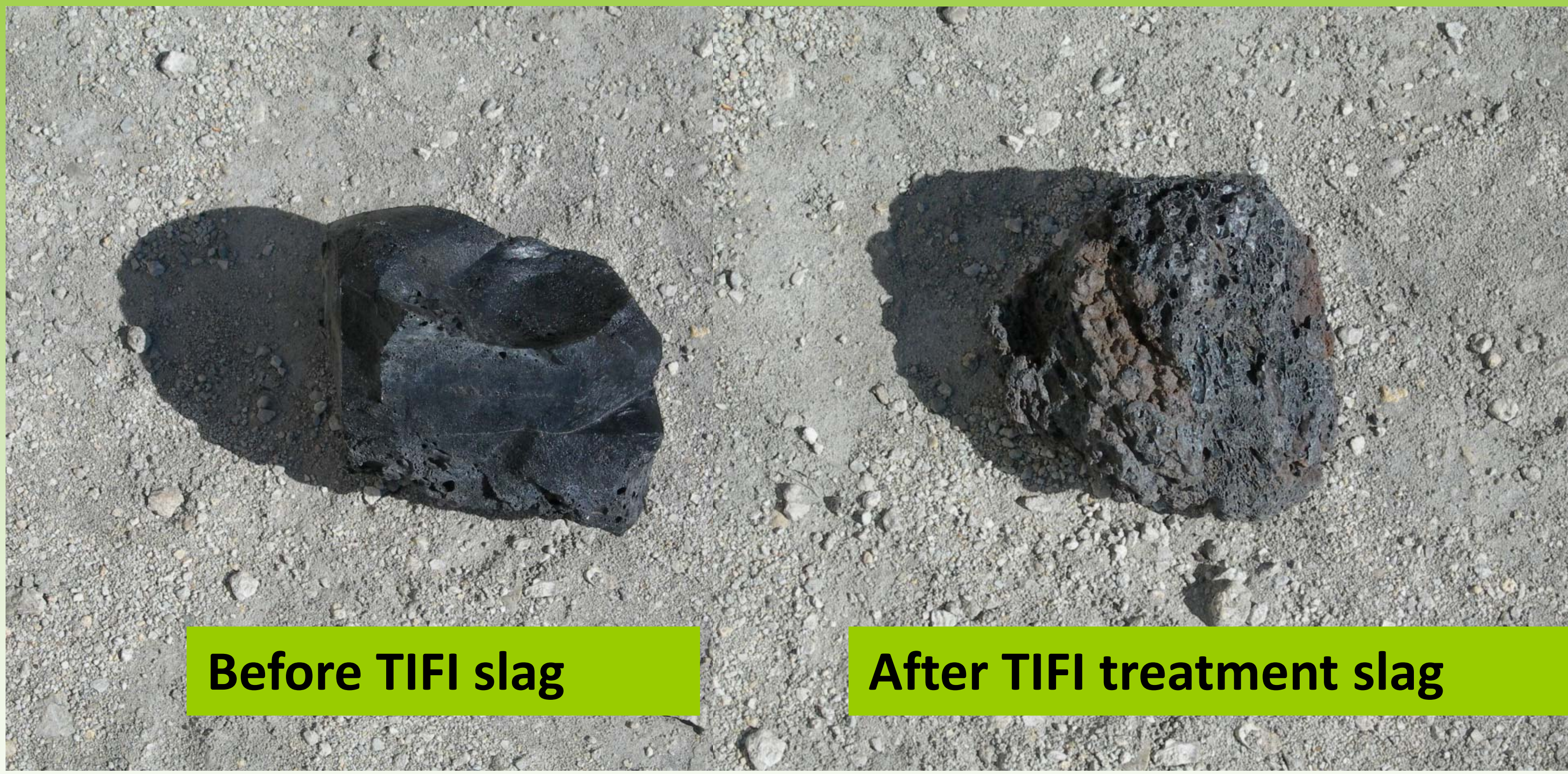
Demonstration of TIFI with SCR

Control of Hard Slag Formation

Typical Fuel Quality During This Study

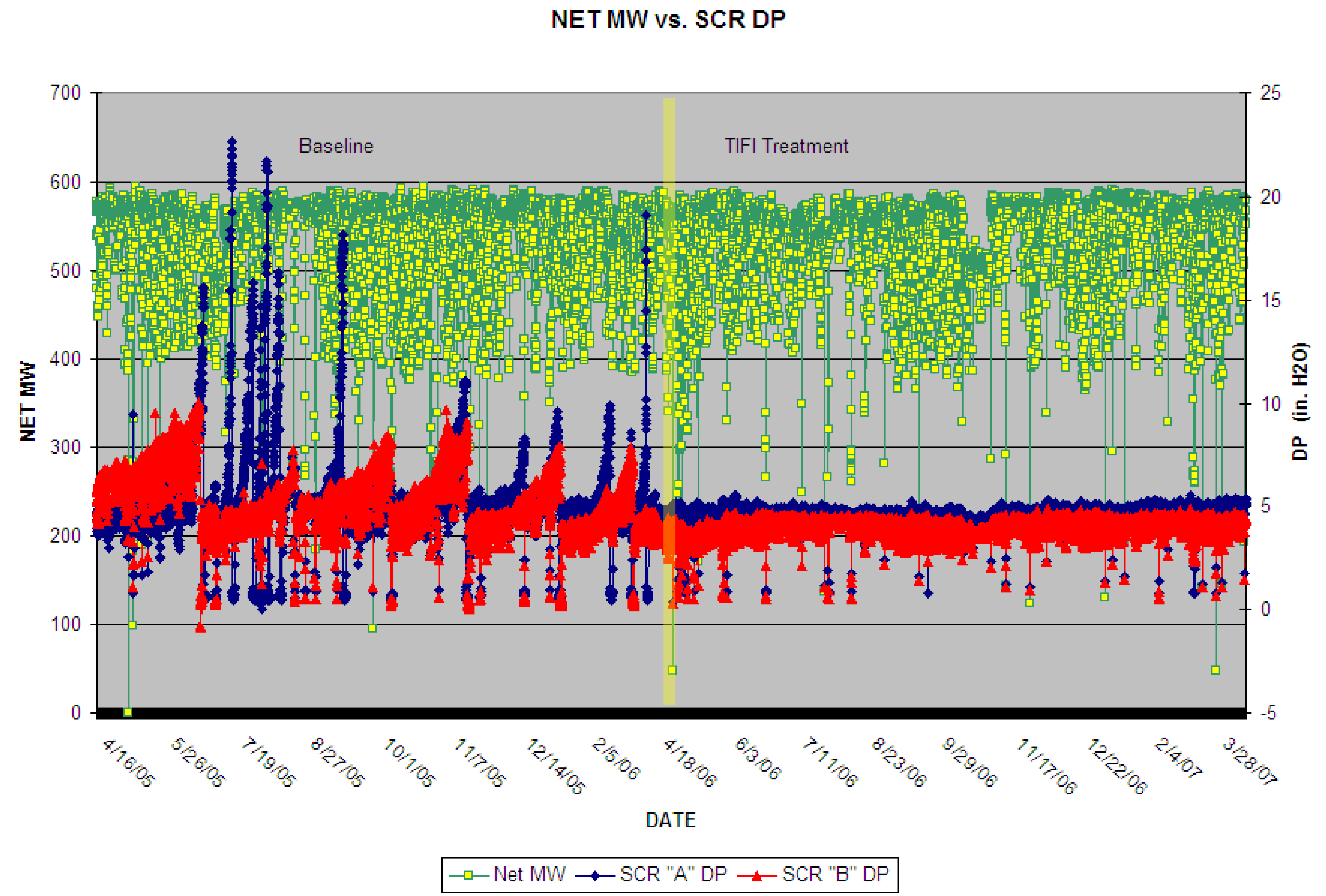
- **Sulfur**
  - U1 ≅ 3.3#/MMBTU
  - U3,U4 ≅ 4.5#/MMBTU
- **Iron**
  - U1 ≅ 23% Iron
  - U3,U4 ≅ 25% Iron

Control of Hard Slag Formation



- Treated slag material is more friable
  - More easily and thoroughly removed with existing soot blowing
  - Mitigates formation of Large Particle Ash/Popcorn Ash
  - Reduces build up of catalytic metals in the furnace

SCR Pressure Drop - Popcorn Ash



SO_3 Mitigation with TIFI

Inlet SCR Temperatures & Affect on SO_3

At 741°F there is 1% conversion of SO_2 to SO_3

At 760°F and 4% Excess O_2 – Additional 25% more SO_3

At 775°F and 4% excess O_2 – Additional 50% more SO_3

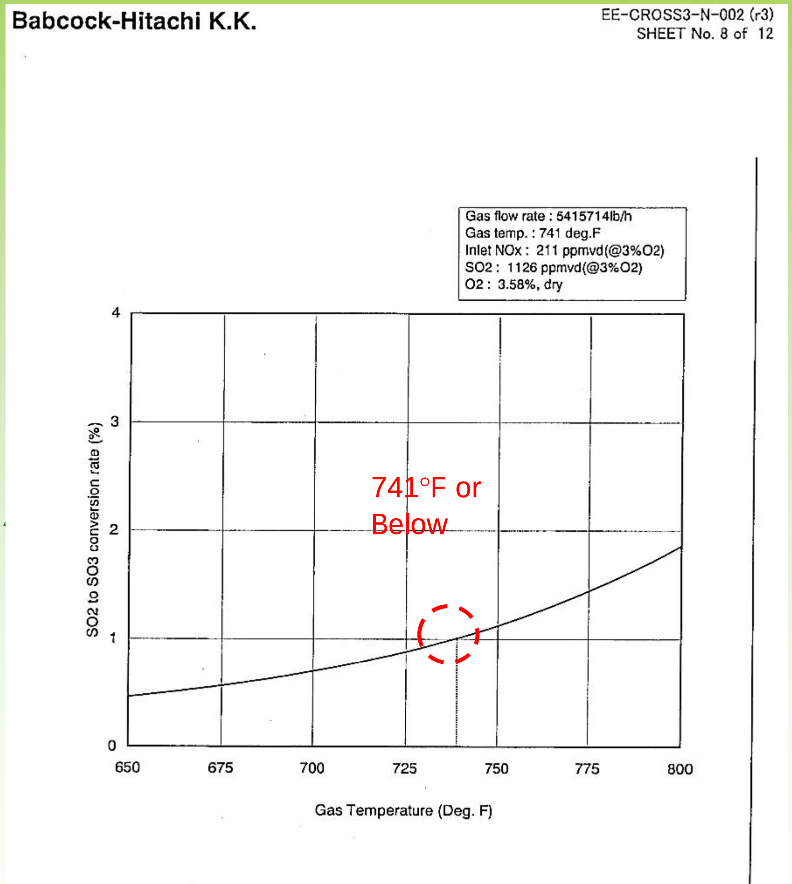
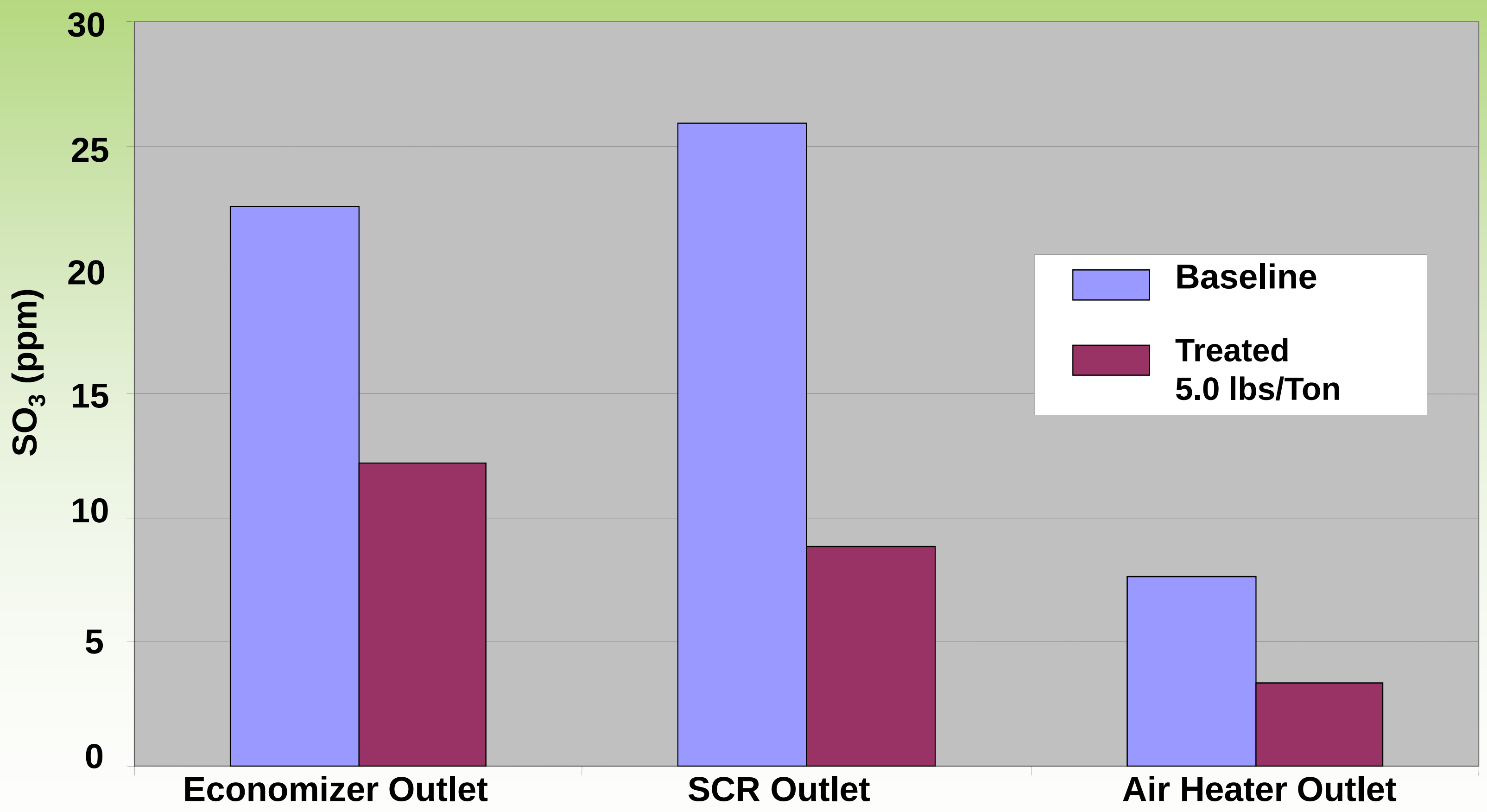


Fig. 7 SO2 to SO3 Conversion Rate VS. Gas Temperature in Base case

SO_3 Mitigation with TIFI



Managing Catalyst Life Cycle

- **As Catalyst activity becomes depleted, ammonia slip increases.**

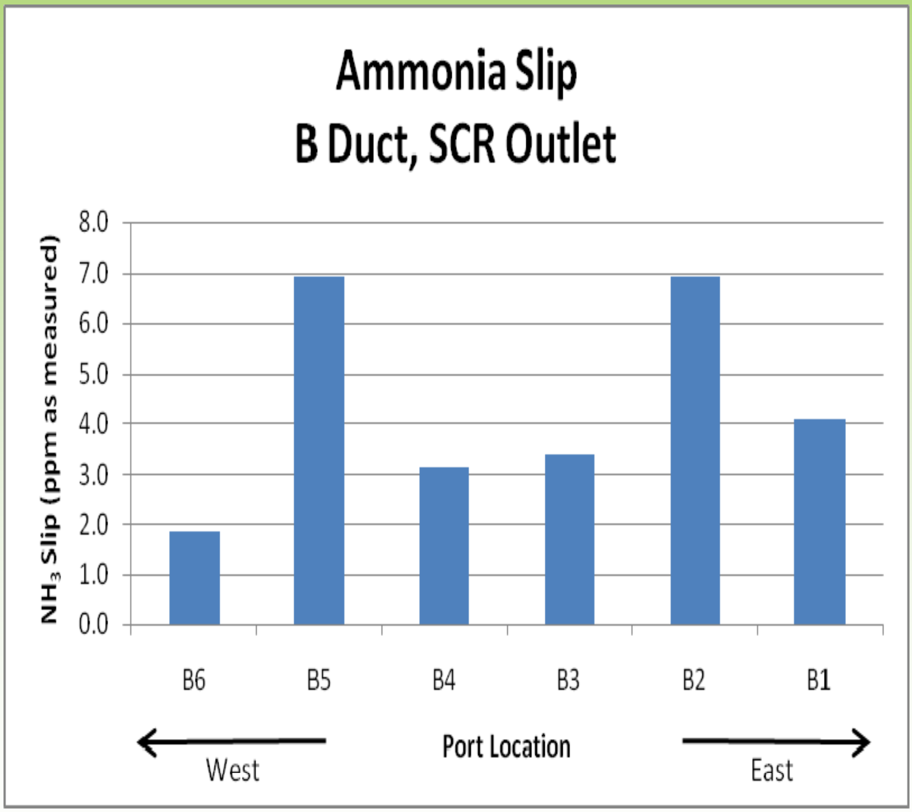
- **Ammonia slip in the presence of SO_3 will form ABS & influence Air Heater fouling**

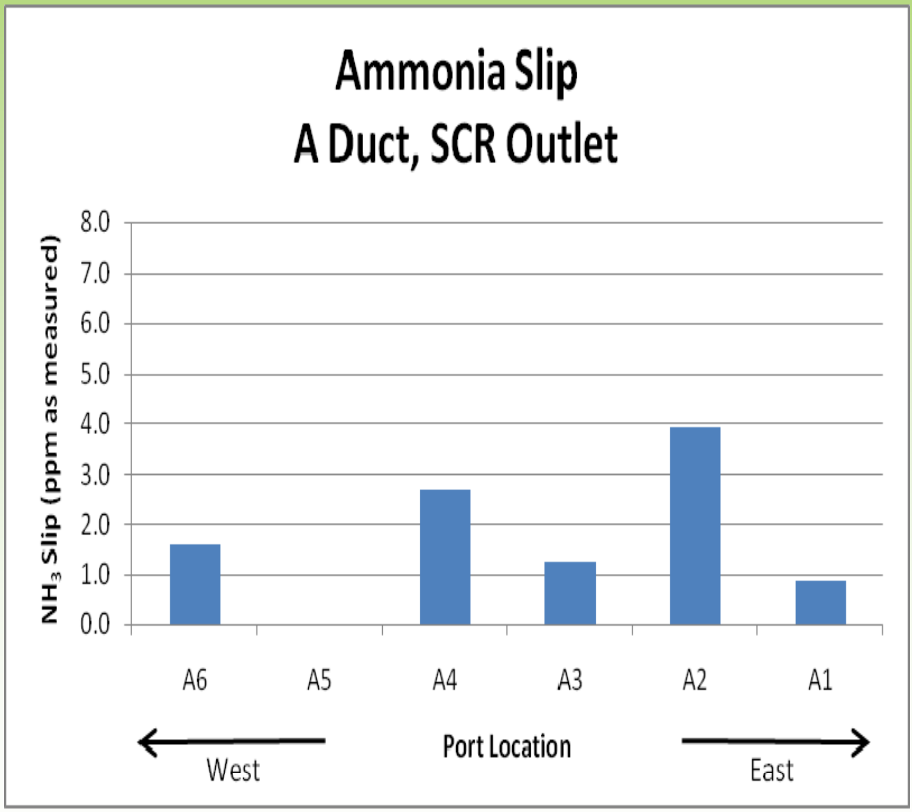
$$NH_3 + SO_3 + H_2O \longrightarrow NH_4HSO_4$$

- **Tolerance of ABS fouling = Effective Catalyst Life**

Unit 3 SCR Outlet Ammonia Slip

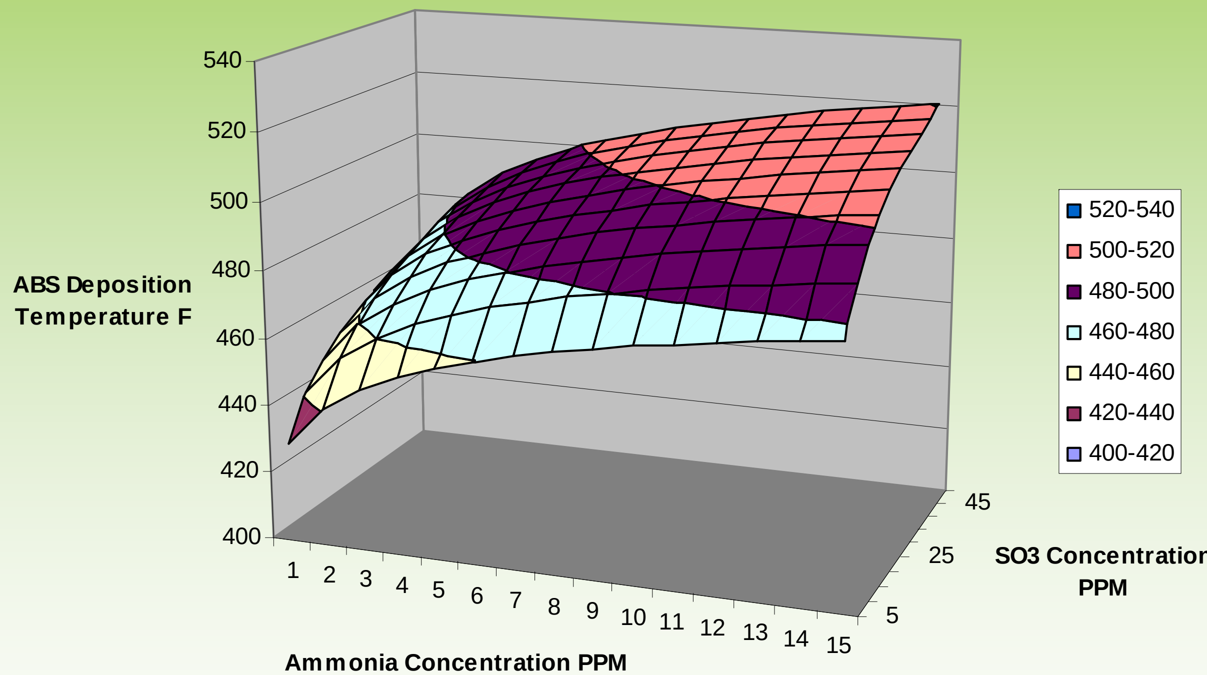
High Load





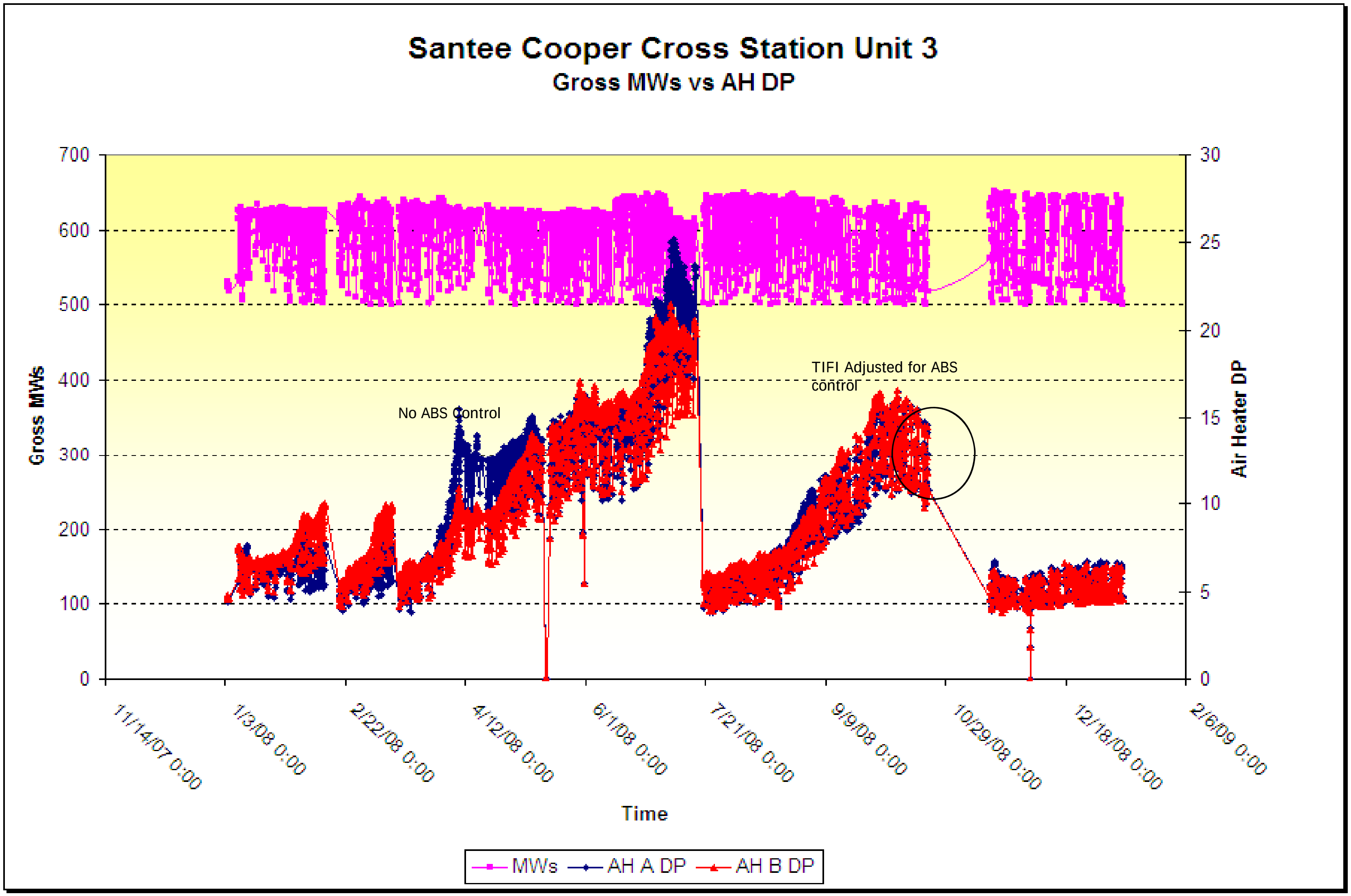
Managing Catalyst Life Cycle

- **The greater the ammonia slip & fuel sulfur concentration, the faster AH dP will Rise**

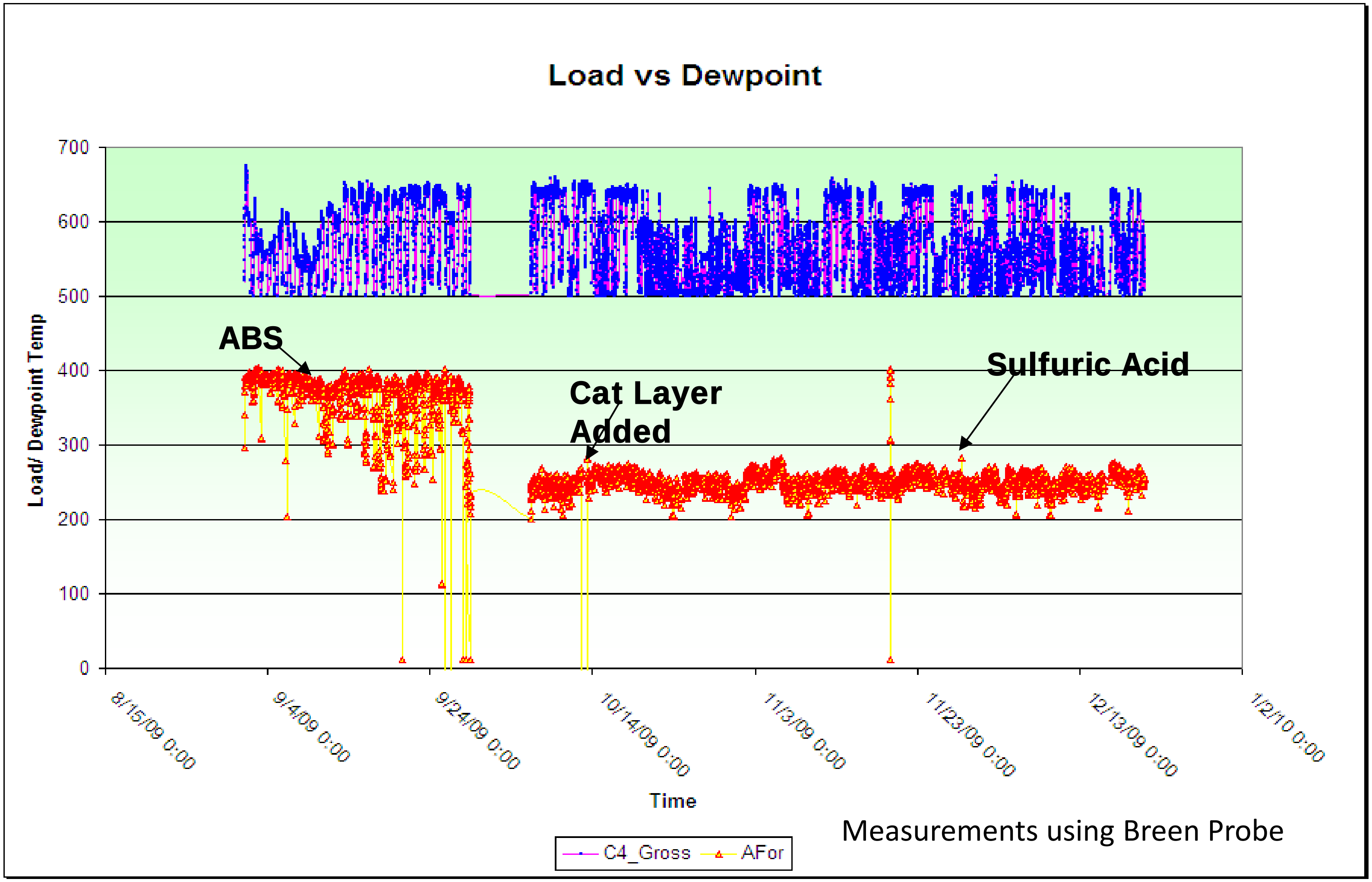


- **Typically becomes more significant with fuel sulfur content above 1.5%**

Initial ABS Control Demonstration

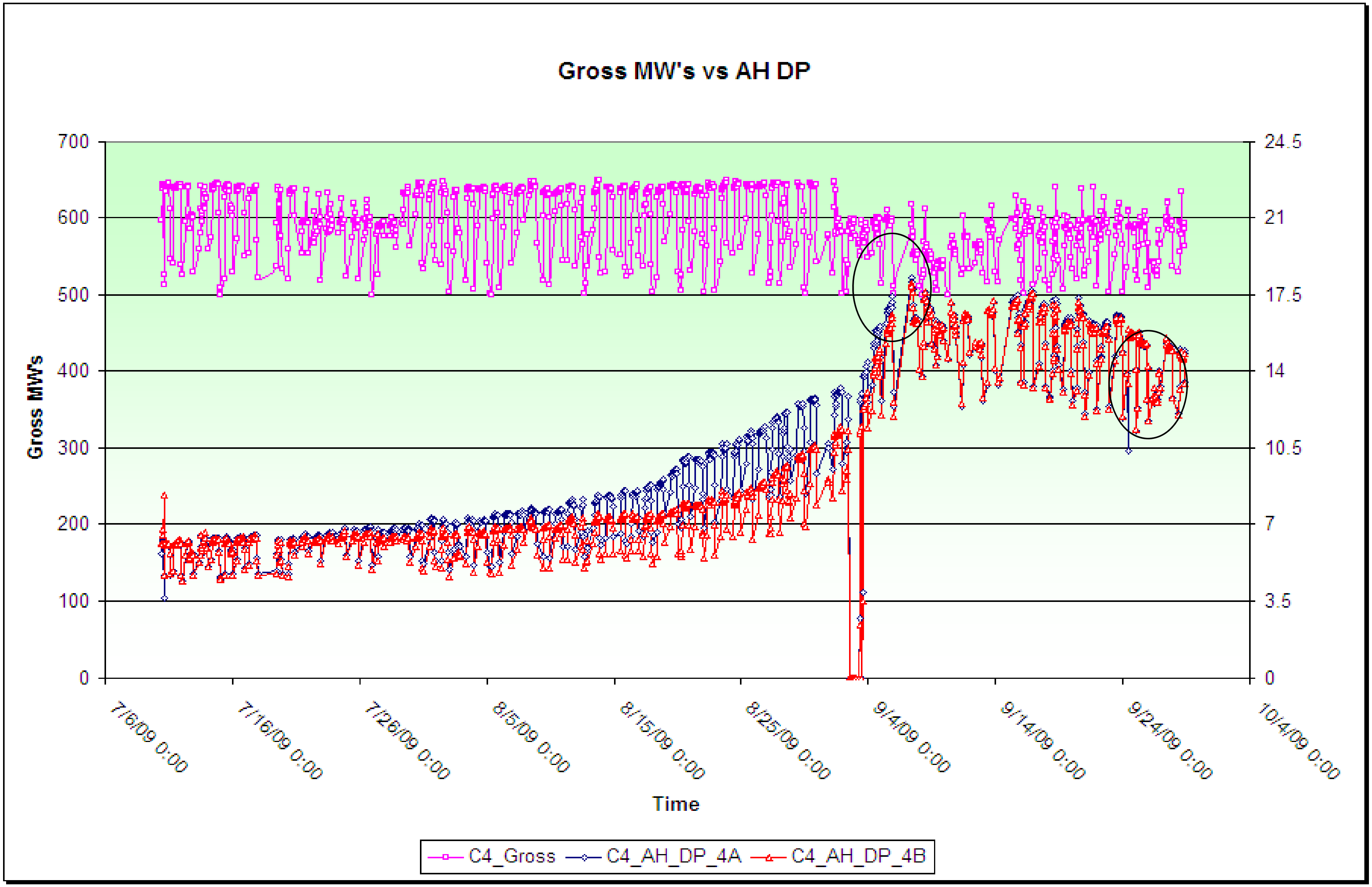


TIFI Clean up Of Air Heater

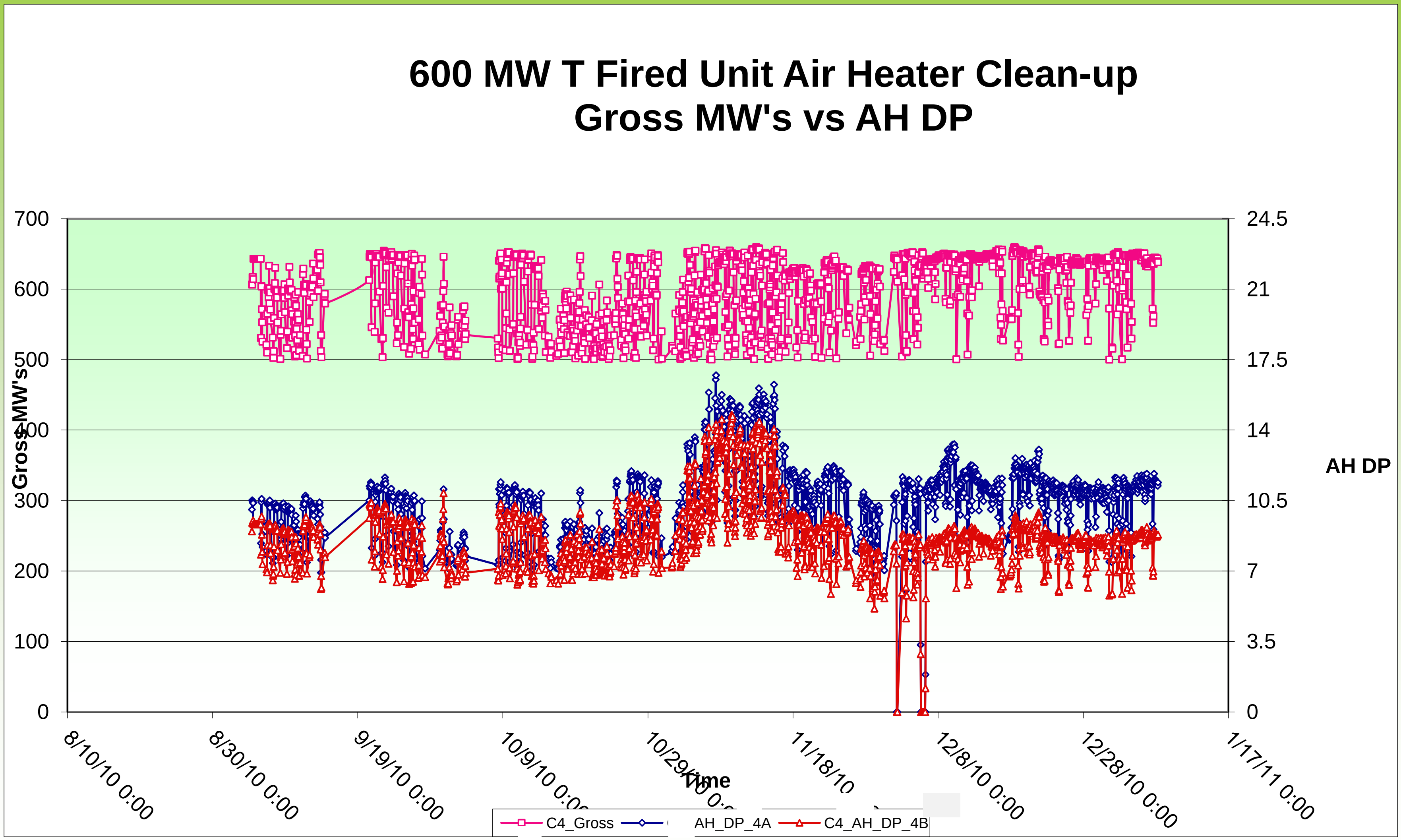


- TIFI virtually eliminates precipitation of ABS in the AH

AH dP Went Down from 17.8” to 14.7”



On Line Air Heater Clean-Up
No Shutdown - Maintained Full Load

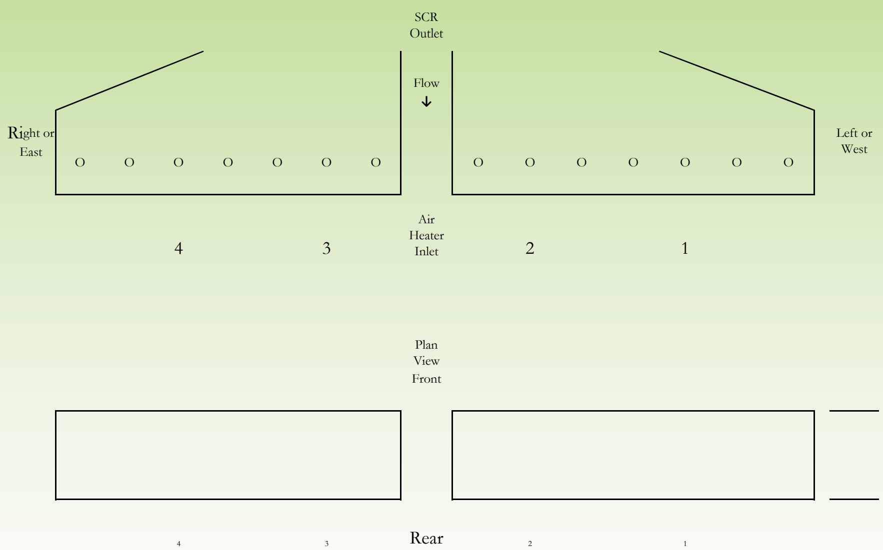


Catalyst Life Extension

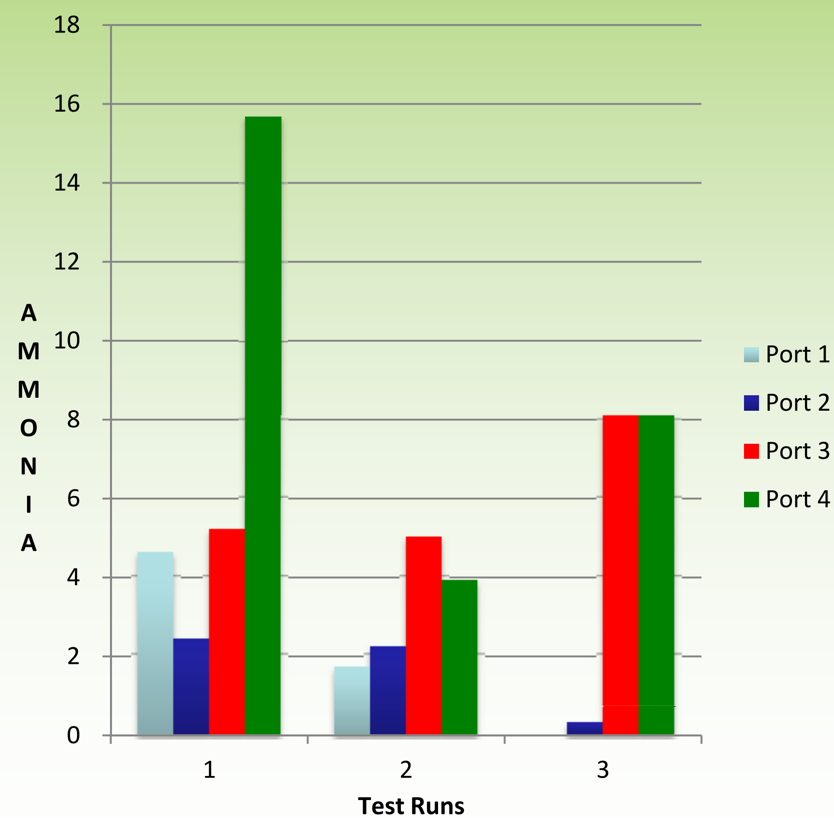
- **Catalyst OEM recommended Layer Removal April 2011**
- **Extended Performance with TIFI will allow one additional year of performance - 8000 Hours**
- **ABS Formation Controlled During Catalyst Degradation**

U1 Ammonia Slip

Test Location



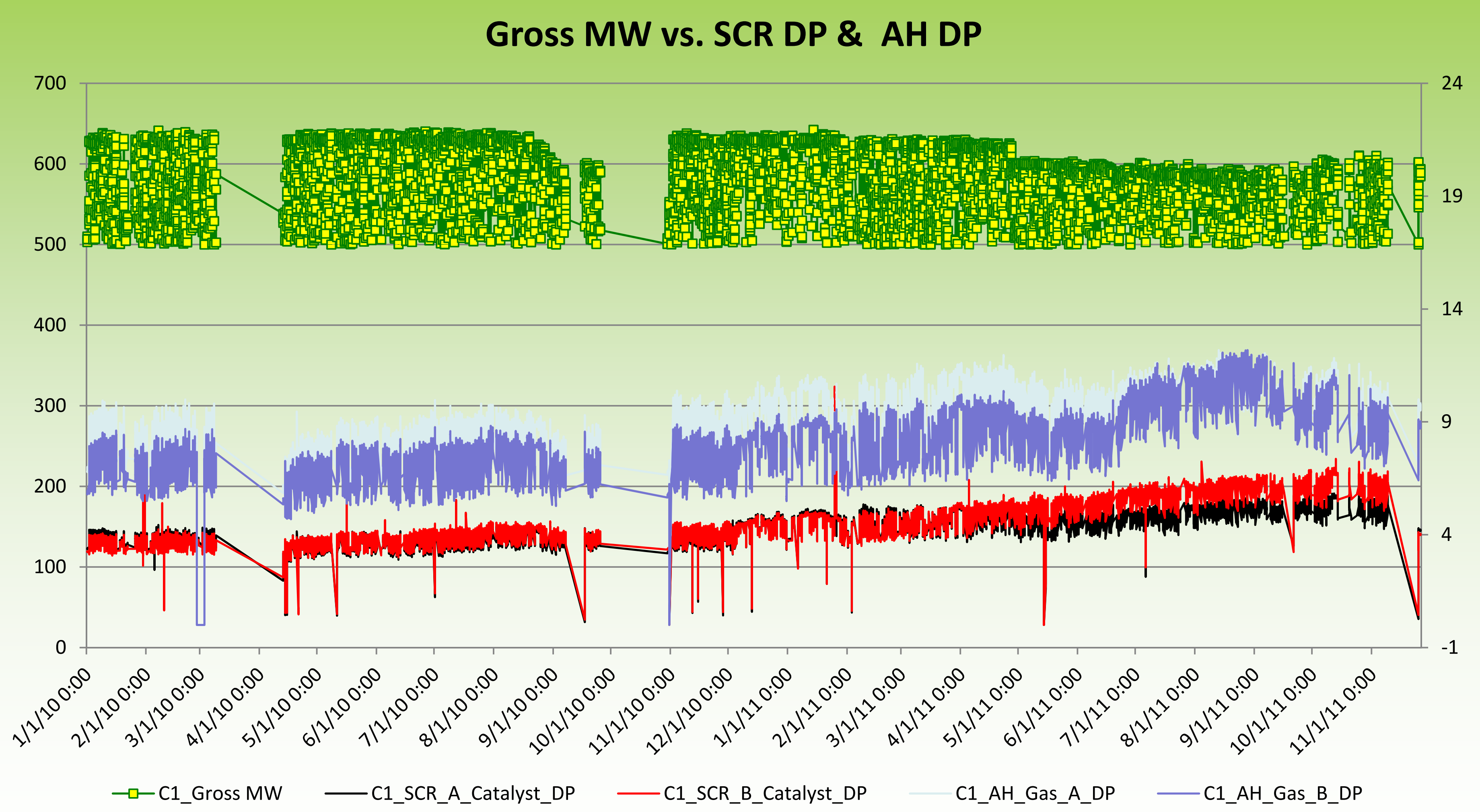
Full Load Ammonia Slip (ppm)



Ammonia in Fly Ash < 10 mg/kg

SCR dP and Air Heater dP controlled over 19 months

Ammonia Slip from 3-15 ppm Since June 2011



TIFI Successfully Controlled

Primarily:

- SO_3 mitigation for Opacity Control
- ABS Formation
- Slag and Furnace Fouling
- Large Particle Ash (LPA)/Popcorn Ash
- SCR Fouling & AH Fouling

- **Program Consistently Provided**
  - Fuel Flexibility
  - Unit Efficiency
  - Unit Capability

Arsenic Poisoning

Removal & Capture of Arsenic (As) – Quick Facts

- Pre-combustion conventional coal cleaning:
  - May be efficient if As_{pyr} is the dominant form
  - Cannot remove organic bound or micro mineral arsenic (shielded grains of As-bearing sulphides)

- Arsenic is captured from flue gas on active cation sites of the fly ash surface (e.g. Ca^{2+} and Mg^{2+}) by means of chemisorption
- Arsenic can be readily leached from acid (SiO2-rich) bituminous coal ashes but can be very difficult from alkali (CaO-rich) lignite ashes
- As_2O_3(g) condenses on the pore system of SCR catalyst

*** Gaseous arsenic is one of the predominant catalyst deactivation mechanisms in coal fired SCR applications in the US**

e·on Engineering

2010 NOx-Round Table, Chattanooga, TN
Workshop 25 - February 9, 2010

ppl

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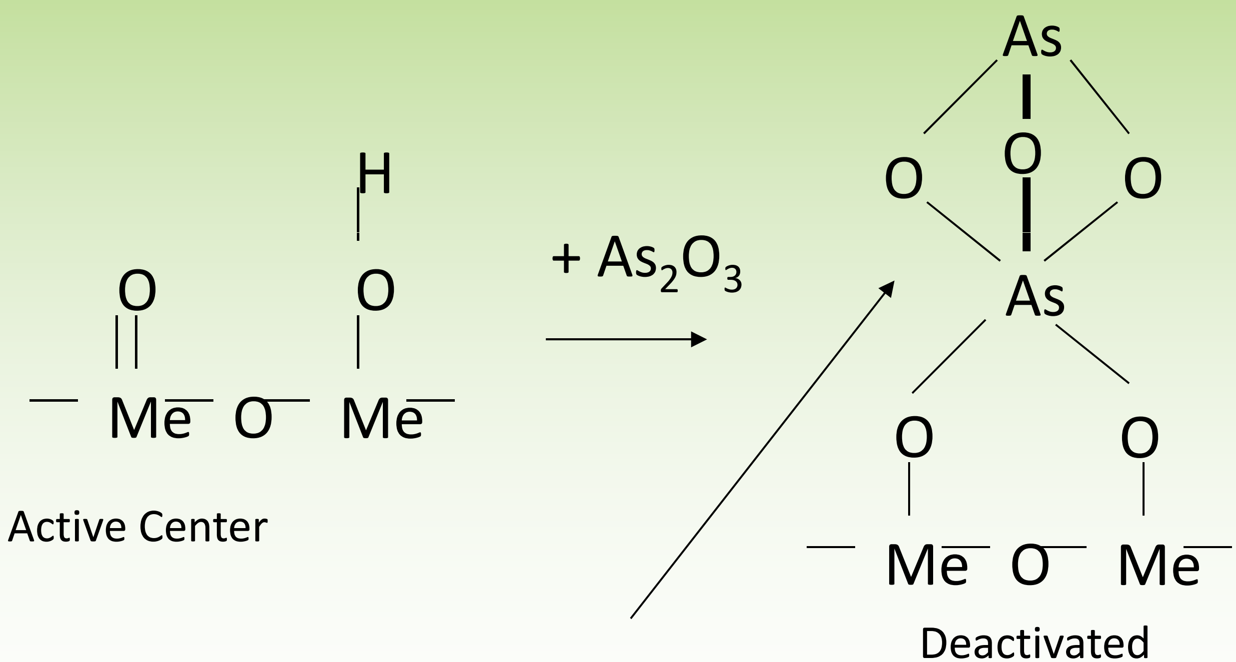
Arsenic Poisoning

Arsenic Poisoning

- **Arsenic Reduces the Activity of Catalyst Through Reaction With Vanadium**
- **Reaction Product is Permanent**
- **Vanadium Molecule is Not Available for NOx Reduction**



Only Permanent Bonds

Arsenic Mitigation

As described …Gaseous Arsenic is a predominant deactivation mechanism for SCR catalyst in coal fired applications AND…

Low concentration of alkaline metals in the fuel can exacerbate deactivation by Arsenic.

- TIFI provides alkaline metal (Mg) to mitigate

Higher flue gas temperatures can exacerbate deactivation by Arsenic.

- TIFI improves furnace heat recovery and allows lower MOT

Higher concentrations of SO_3 can exacerbate deactivation by Arsenic.

- TIFI effectively reduces SO_3

Conclusions

- **TIFI® Targeted In-Furnace Injection™ Successfully controlled slag, fouling, SO_3, & ABS**
- **Prevented ABS Formation, and removed ABS from a Fouled Air Heater**
- **Catalyst Life Significantly Extended by maintaining low SCR & AH dP**
- **Ammonia slip is managed - preventing need to buy new catalyst prematurely**
- **TIFI mitigates several contributors to catalyst deactivation by gaseous Arsenic**

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Technologies to enable clean efficient energy

Fuel Tech Inc (FTEK) – Please visit our Booth

NOx Reduction Technology Suite

- Advanced Combustion Technologies
  - Combustion Modifications: LNB, ULNB, FGR and OFA Systems
- Selective Non-Catalytic Reduction
  - RRI (Rich Reagent Injection)
  - NOxOUT® SNCR
  - HERT (High Energy Reagent Technology)
- Catalyst Technologies
  - Urea-based and NH3-based* SCR for Industrial Applications
  - NOxOUT CASCADE®: SNCR + SCR Hybrids
  - Advanced SCR Systems
  - NOxOUT ULTRA®: Thermal Decomposition of Urea
  - SCR Design and Application Consulting, Catalyst Mgmt Services

*Note: Recent development for small NH_3 flow SCRs under 10,000 pounds of reagent storage.