REINHOLD ENVIRONMENTAL Ltd.

2018 APC & Wastewater Round Table & Expo Presentation

July 23 & 24, 2018 in Lexington, KY / Hosted by East Kentucky Power Coop

DSI 501: Moving from Pollution Control to Cost Savings

MISSISSIPPI LIME

DISCOVERING WHAT'S POSSIBLE WITH CALCIUM

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Reinhold APC-Wastewater Conference

July 23, 2018

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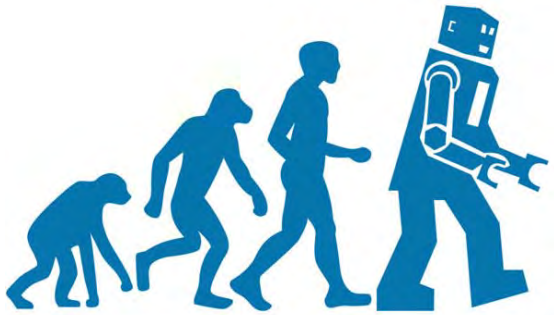
Discovering what's possible with calcium

The Evolution of Hydrated Lime DSI

- ✓ Entry-level hydrate
- ✓ Remove pollutant
- ✓ Basic conveying
- ✓ Poor utilization

- ✓ Enhanced hydrates
- ✓ Pre-APH injection
- ✓ Improved distribution
- ✓ Better conveying
- ✓ Improved utilization

- ✓ Targeted hydrates
- ✓ Pre-SCR to reduce MOT
- ✓ *Continually understand* flue gas
- ✓ Eliminate feed issues
- ✓ Expanded profile of pollutant control



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DSI Areas of Focus

- Conveying System
- Flue Gas Distribution
- Hydrated Lime Quality

Site Maintenance

Challenges

- Calcium carbonate scale formation

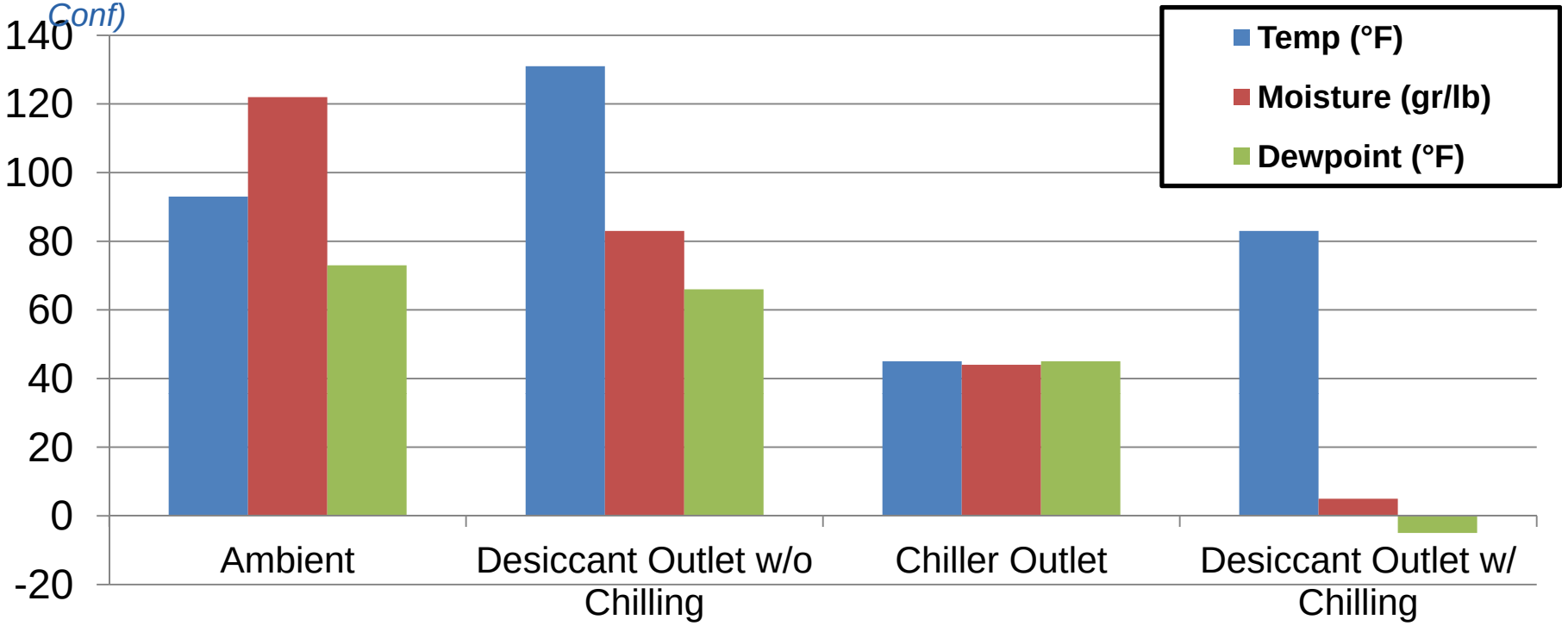
$$Ca(OH)_2 + CO_2 \xrightarrow[H_2O]{Heat} CaCO_3 + H_2O$$

Typically experience at first pipe bend or neck-down points

- Dry powder plugs
  - Conveying air velocity < Saltation velocity *(2400-2800 ft/min)*

Typically experience downstream of splitter

Conveying Air Quality *(Donner , Duke Energy; 2015 APC Conf)*



Pre-chill + desiccant dryer: very effective moisture removal

- Dewpoints near dry compressed air quality
- Greatly reduced possibility of “Condensation Event”

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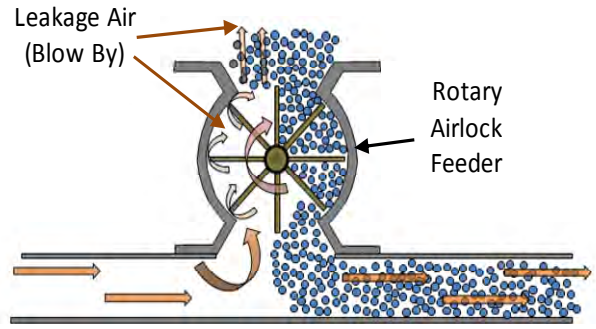
Leakage Air as a Result of Excessive Wear

Over time, valve body and rotor vanes develop wear

1. Abrasive
2. Erosive



Pickup Pan

Result: Reduction in conveying air velocity

1. Product deposits in conveying line
2. Gradual increase in conveying air pressure
3. Periodic spikes in conveying pressure

Scoring
Vane edge
Housing wall

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Equipment Advances - Dispersion

- More lances!
- Better lances or injectors
  - UCC Cobra Lances
  - Nol-tec Sorb-Tec injectors
- In-duct Mixers
  - Babcock Delta Wings
  - ADA-ES ADAir Mixers
- Benefits beyond using less sorbent

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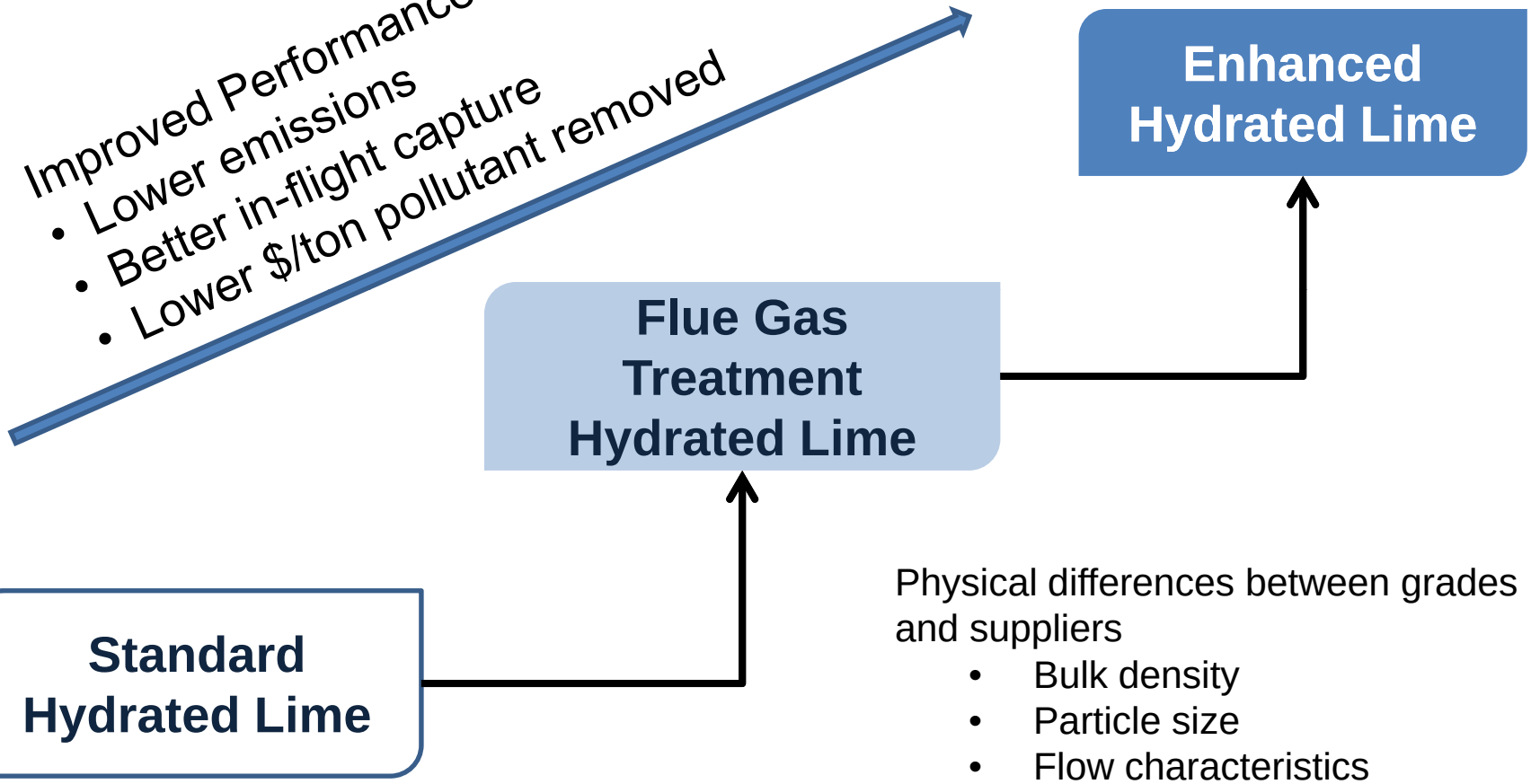
Hydrated Lime Advancements



Physical differences between grades and suppliers

- Bulk density
- Particle size
- Flow characteristics

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Enhanced Hydrate Benefits

Hydrate Performance Comparison

Property	Std hydrate	FGT grade	Enhanced grade
Utilization factor	1.15	1.00	0.70
Tons/year	11,500	10,000	7,000
Delta tons/yr	1,500	---	(3,000)
Delta trucks/yr	63	---	(125)
Estimated Ash tons/yr	17,250	15,000	10,500
Annual Ash Disposal cost*	$517,500	$450,000	$315,000

**at $30/ton*

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Sustained Operational Benefits

- Consistent and Reliable coverage of flue gas
- High Performing sorbent: in-flight capture
- Verification of operation

APH Benefits

Cleanliness

Operation

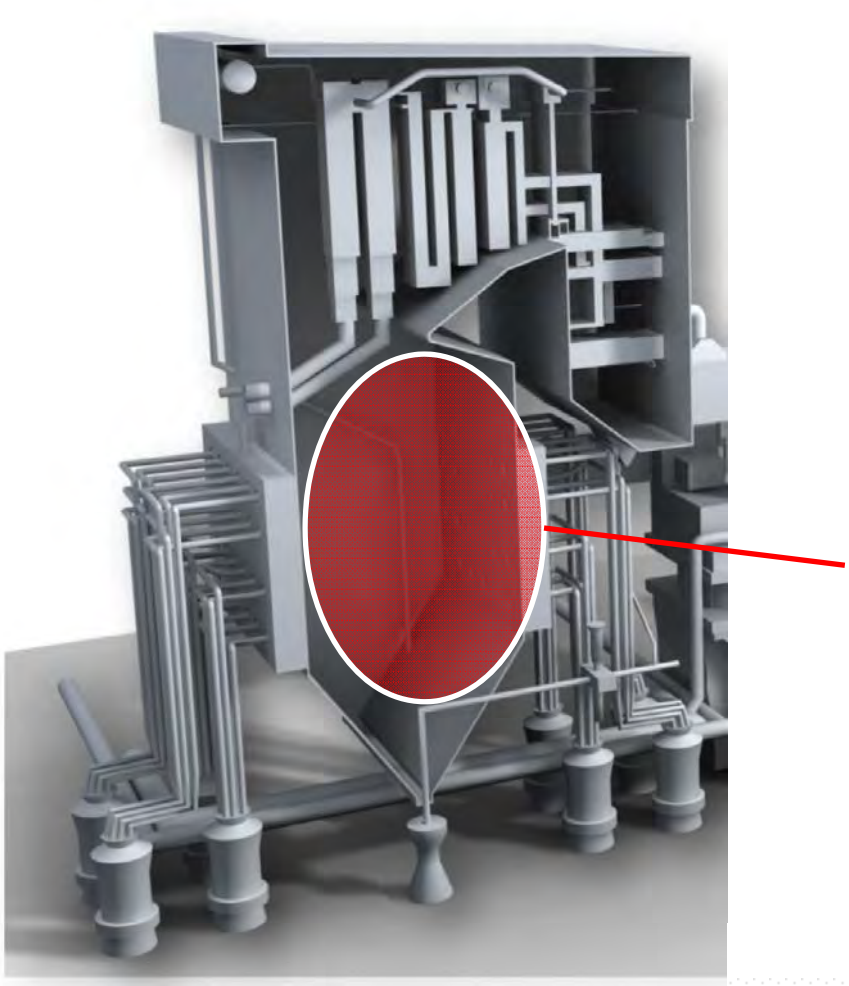
SCR Benefits

Minimum Operating Temperature

Acid Gas Generation

Furnace Impact

Furnace SO_2:SO_3 Conversion



Rule of Thumb is that 1% of the SO_2 will convert to SO_3

- **SO_2 is formed during combustion at the burner and in the fire ball.**
- **Some SO_3 is generated here, but SO_3 is an oxidized version of SO_2 and excess O_2 in the furnace is low**

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SO_2:SO_3 Furnace Conversion Factors

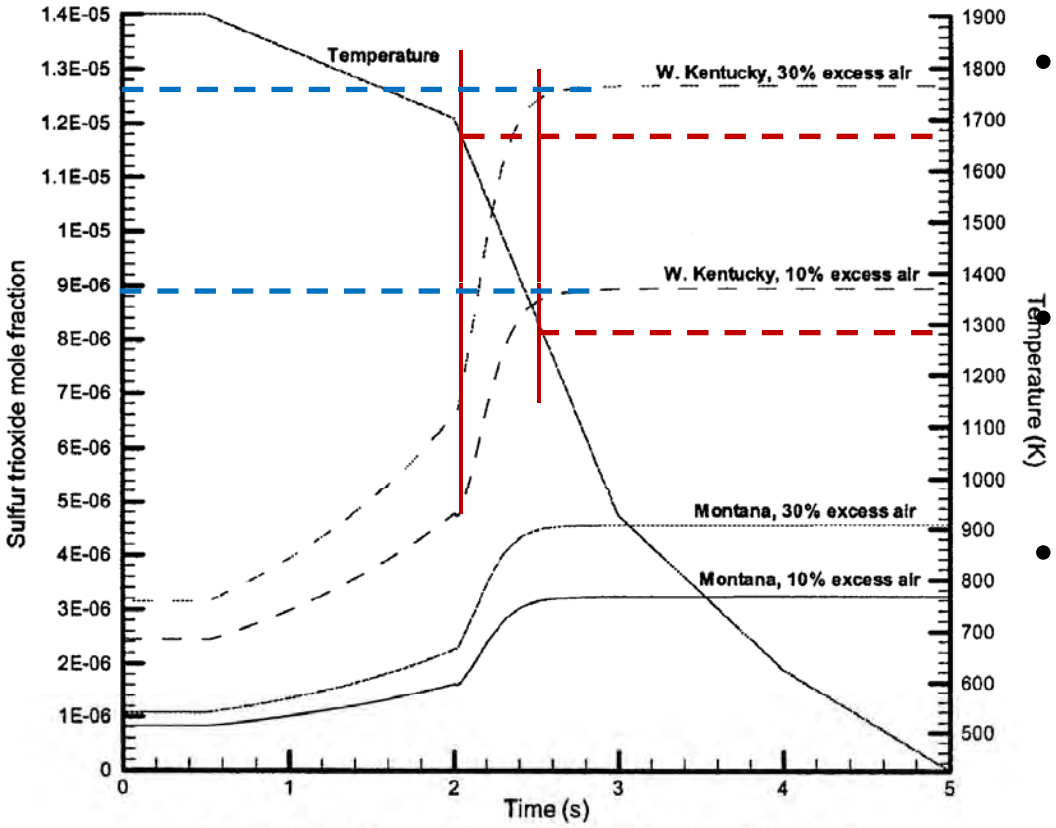

Figure 4a SO3 produced during coal combustion.

- **SO_2 Conversion is highly dependent on O_2 and temperature**
- **A change in O_2 from 2% to 5% can cause a 50% increase in SO_2**
- **Notice, though, that the conversion rate is temperature sensitive**

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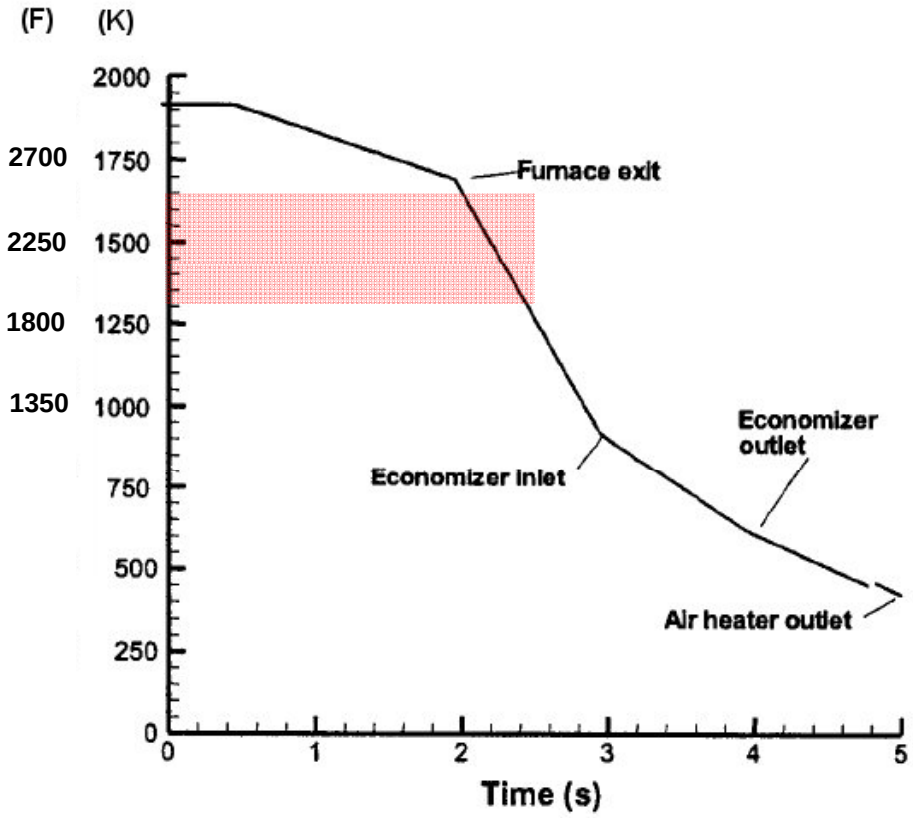
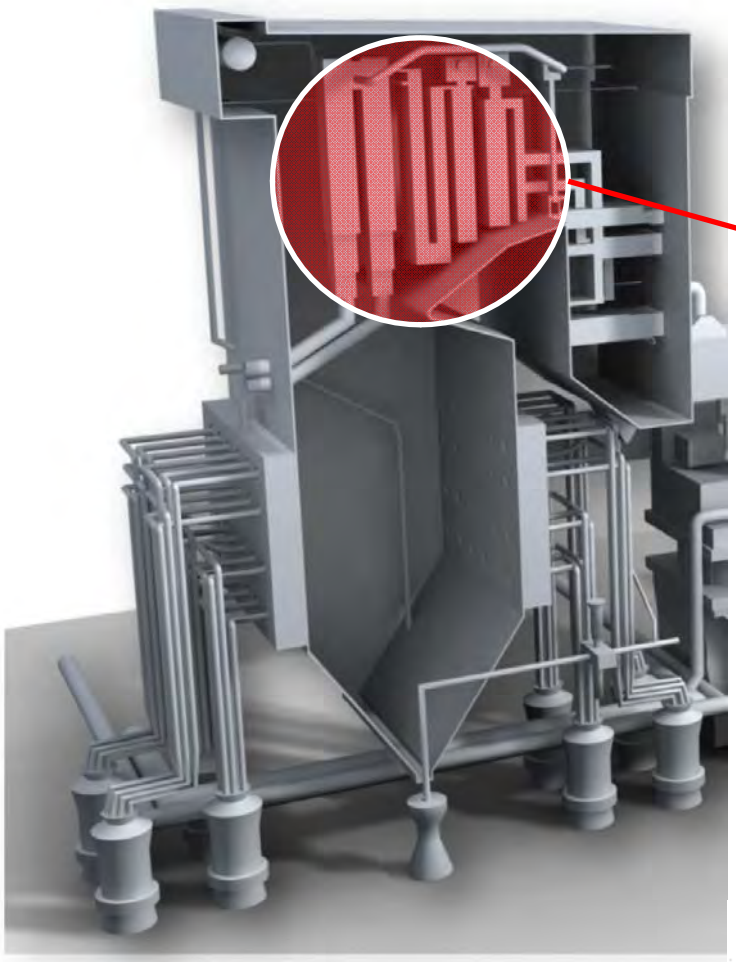
Understand the Temperature Point



Temperature-time history for a coal-fired power plant (from Senior et al., 1999)

SO_2:SO_3 Conversion Happens Here!



The bulk of Furnace SO_2:SO_3 conversion happens in the convective zone in the presence of iron, oxygen and suitable temperature

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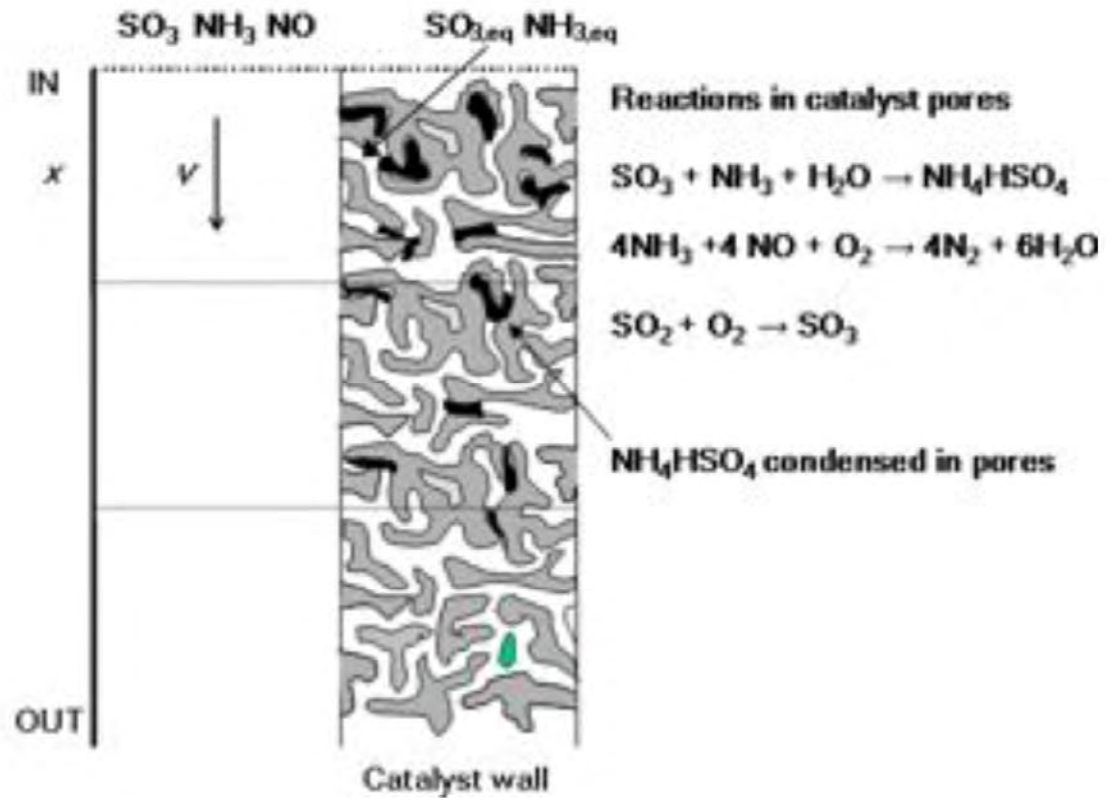
Acid Gas Generation

SCR Impact

The Catalyst Magic



- NH_3:NO reaction happens toward the pore inlet.
- SO_2:SO_3 reaction happens toward the pore depth

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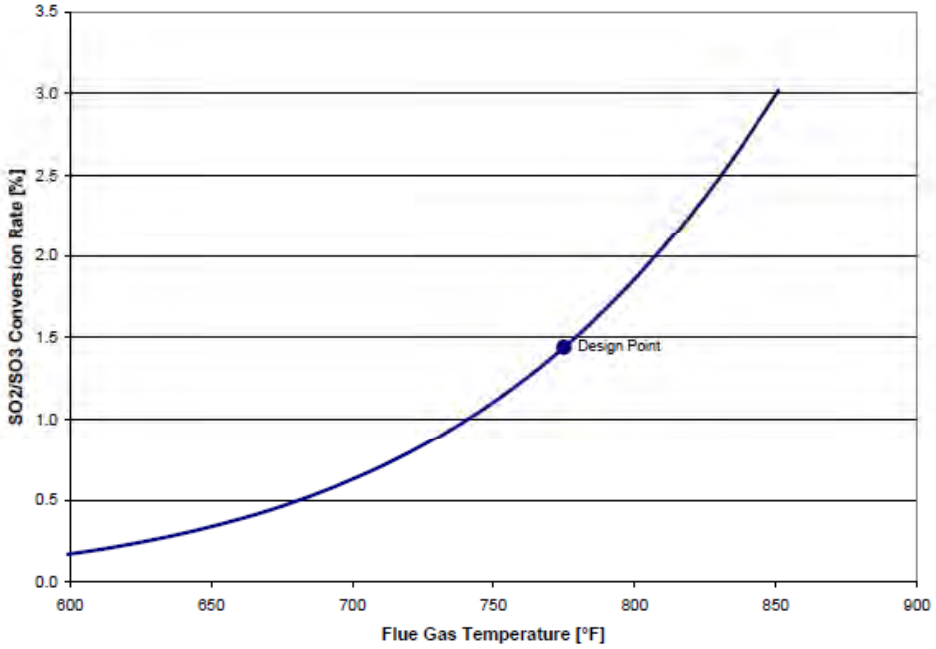
SO_2 Conversion Rate vs. Temperature

- **SO_2 Conversion Rate Increases Exponentially with Temperature**



If you do not know the temperature basis for your conversion rate, you do not know your conversion rate.

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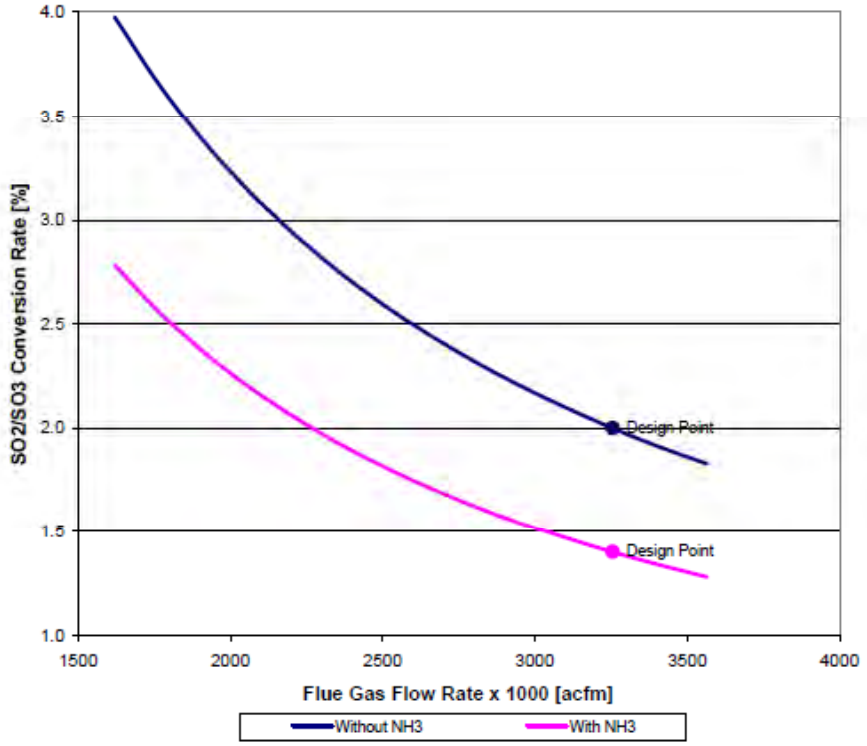
SO_2 Conversion vs. NH3/Gas Flow



- SO_2 Conversion increases without Ammonia present
- SO_2 Conversion increases with reduced gas flow

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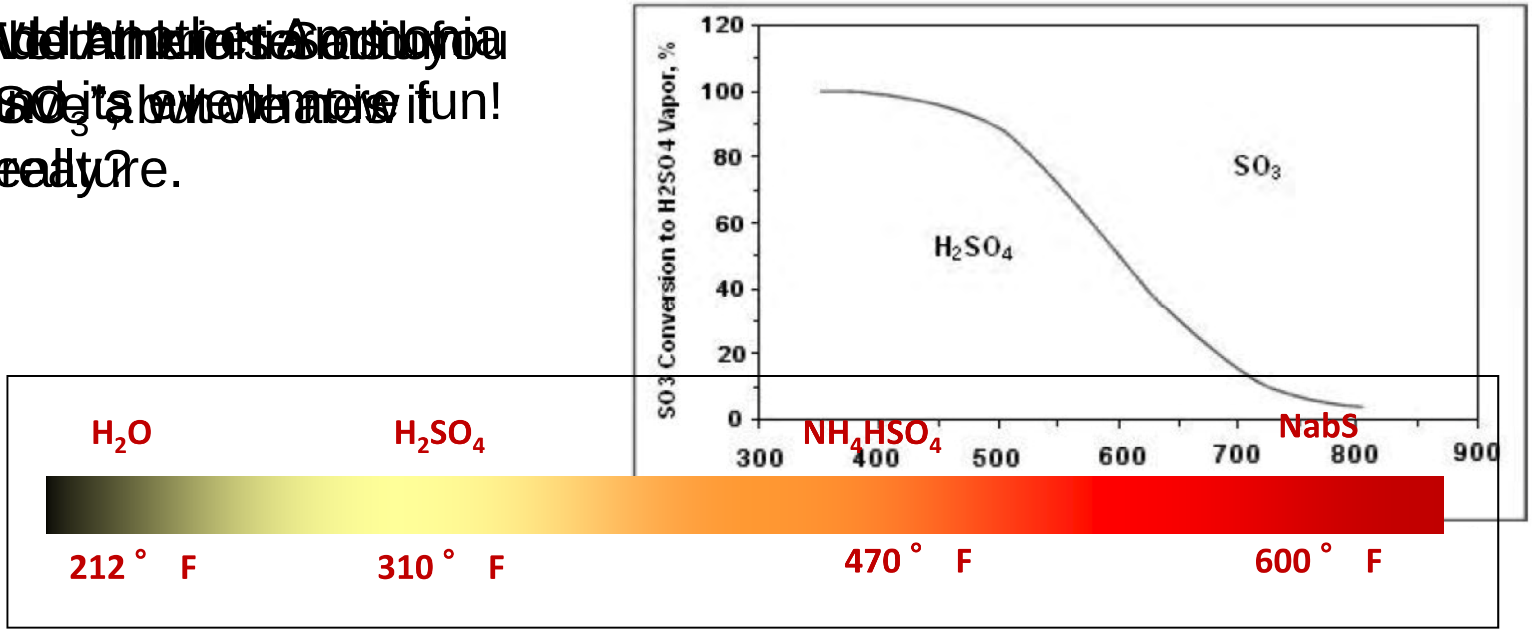
Minimizing SCR SO_3 Generation

To Control/Minimize SO_2 Conversion:

- **Minimize and Balance Furnace O_2**
- **Minimize SCR Inlet Gas Temperature**
- **Minimize Flue Gas Volume (Excess Air)**
- **Maximize NH_3 Flow but watch out for ABS**

What is “Acid Gas"

- Add Ammonia and it's even more fun! [illegible]



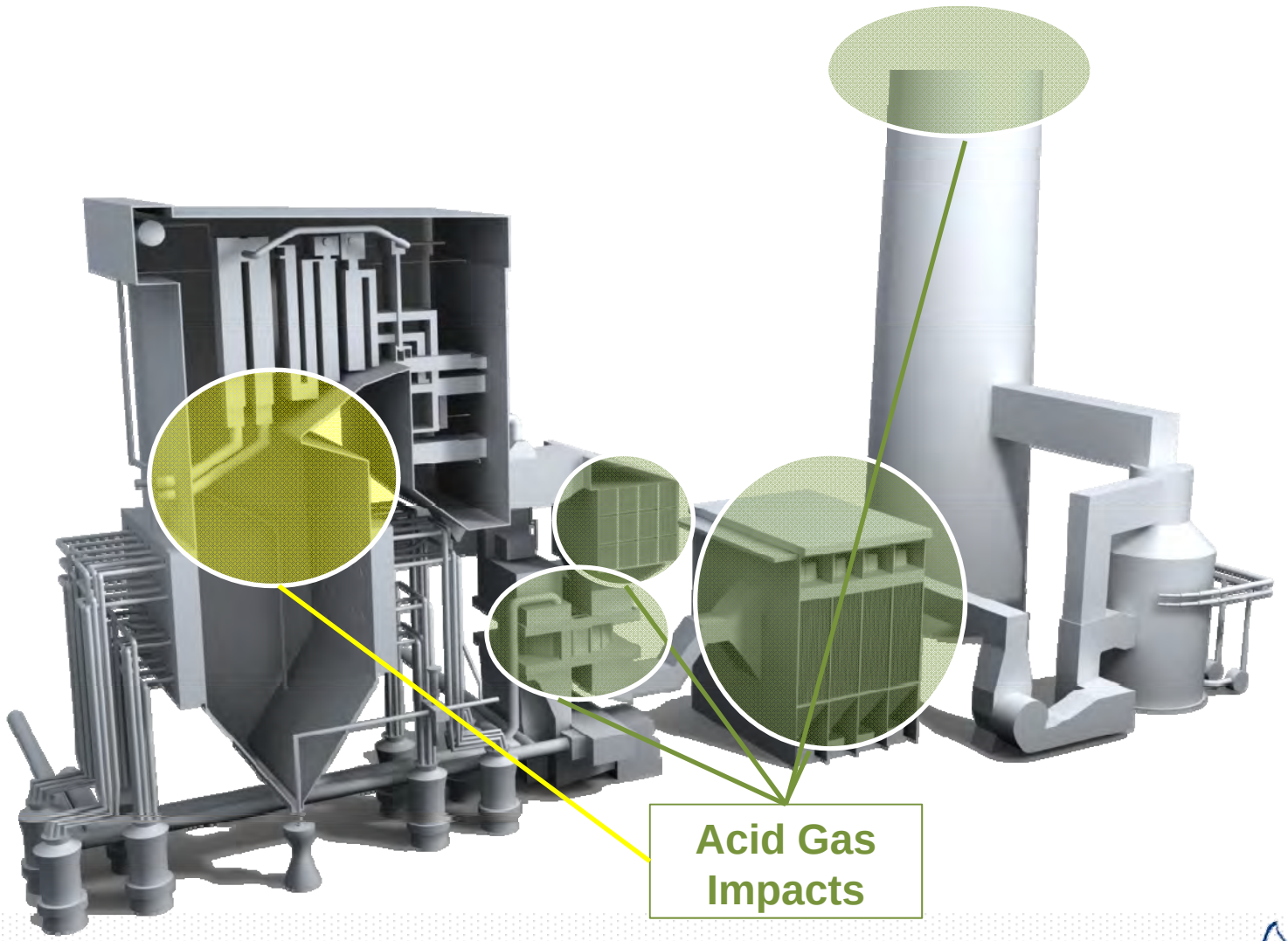
The same device measures condensables across the spectrum!

$SO_3 + H_2O \Rightarrow H_2SO_4$

$H_2SO_4 + NH_3 \Rightarrow (NH_4)HSO_4$

$H_2SO_4 + NH_3 \Rightarrow (NH_4)_2SO_4$

Acid Gas Impact Locations



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Acid Gas Impact

Legacy Impacts

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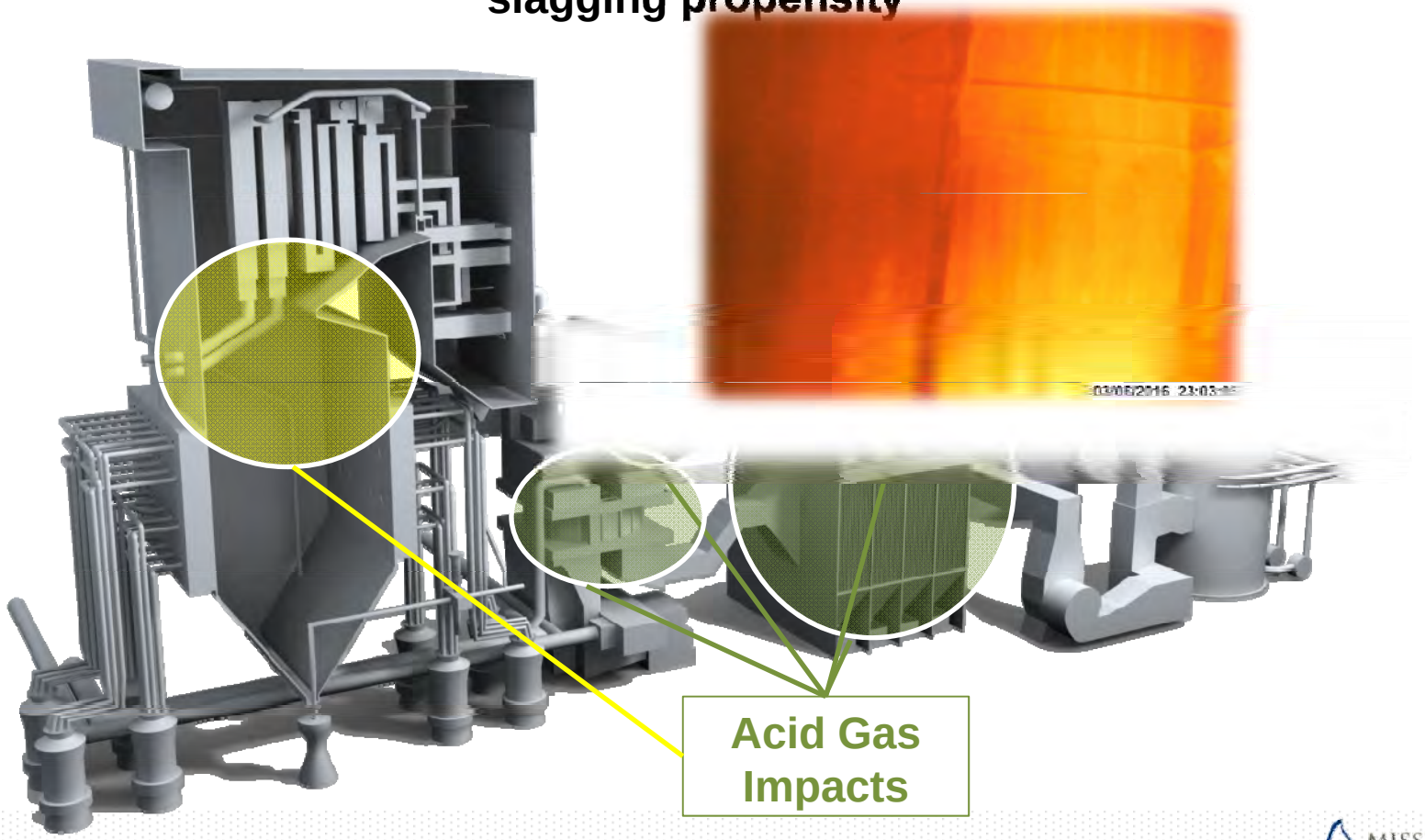
Acid Gas Impact Locations

Higher sulfur coals lead to higher acid gas and often higher upper furnace/superheat slagging propensity



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Acid Gas Impact Locations

Typical Acid Concentrations above 5 ppm will lead to a visible, or ”blue”, plume

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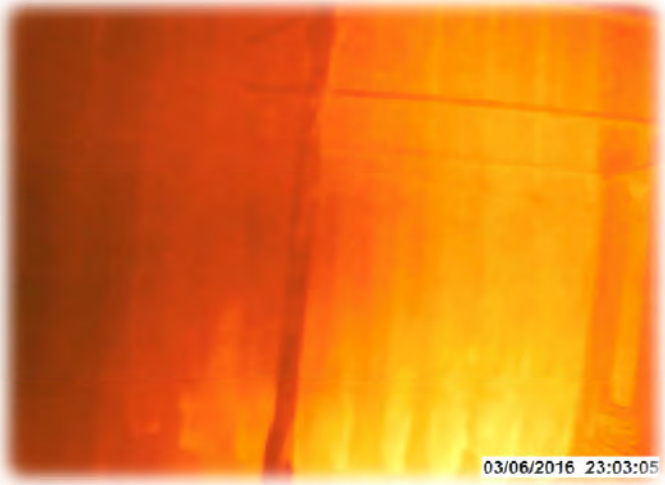
Important but Old News



While Boiler Fouling/Slagging and Stack Blue Plume are. Both significant impacts of higher sulfur coal, these effects have been covered, in depth by previous papers.

The balance of this talk will focus on Operational Impacts of Acid Gas that can be managed to improve overall plant heat rate and performance

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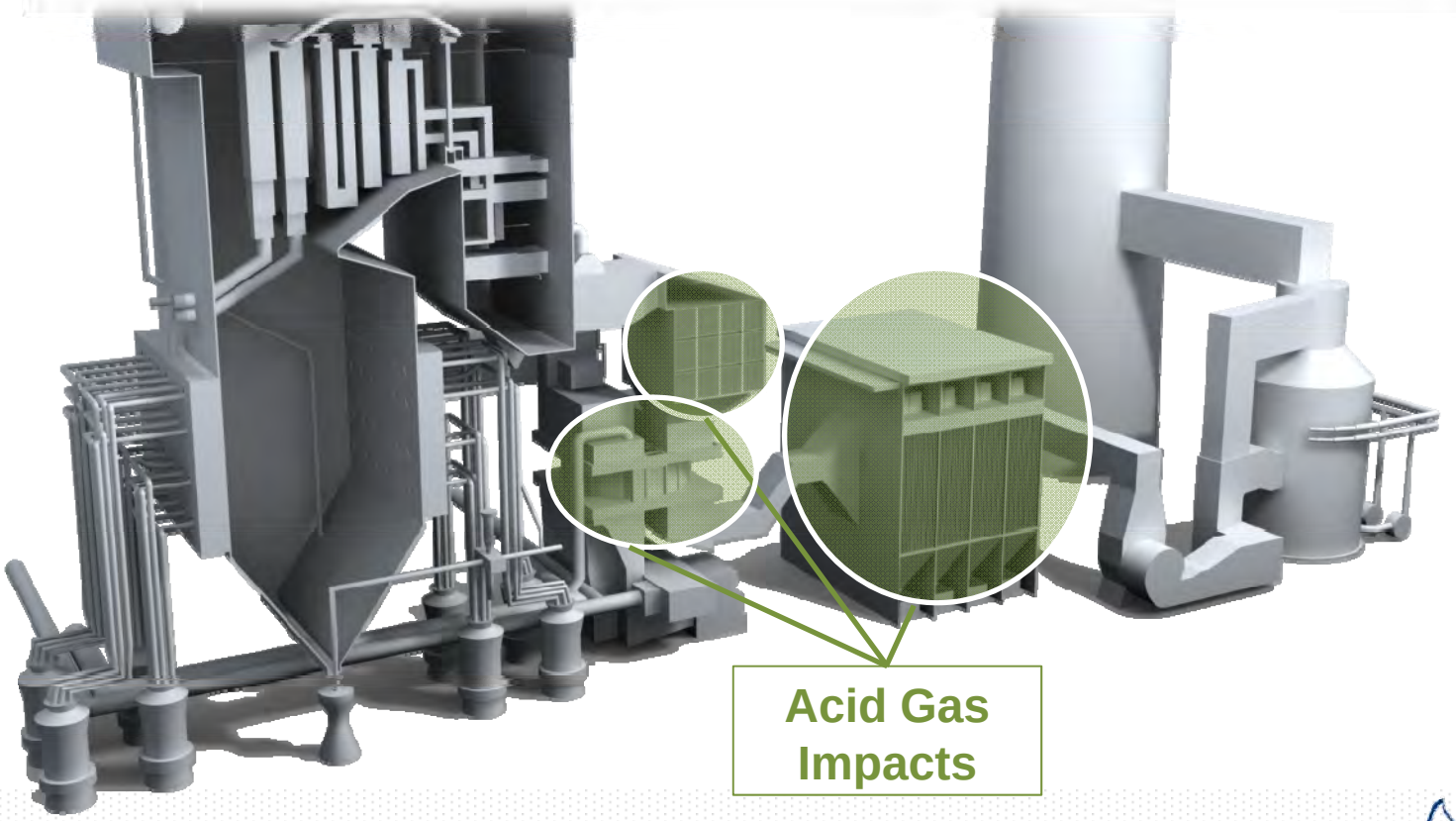
Acid Gas Impact

New Advancements

Acid Gas Impact Locations

Expansion of pre-AH Hydrated Lime Injection Work



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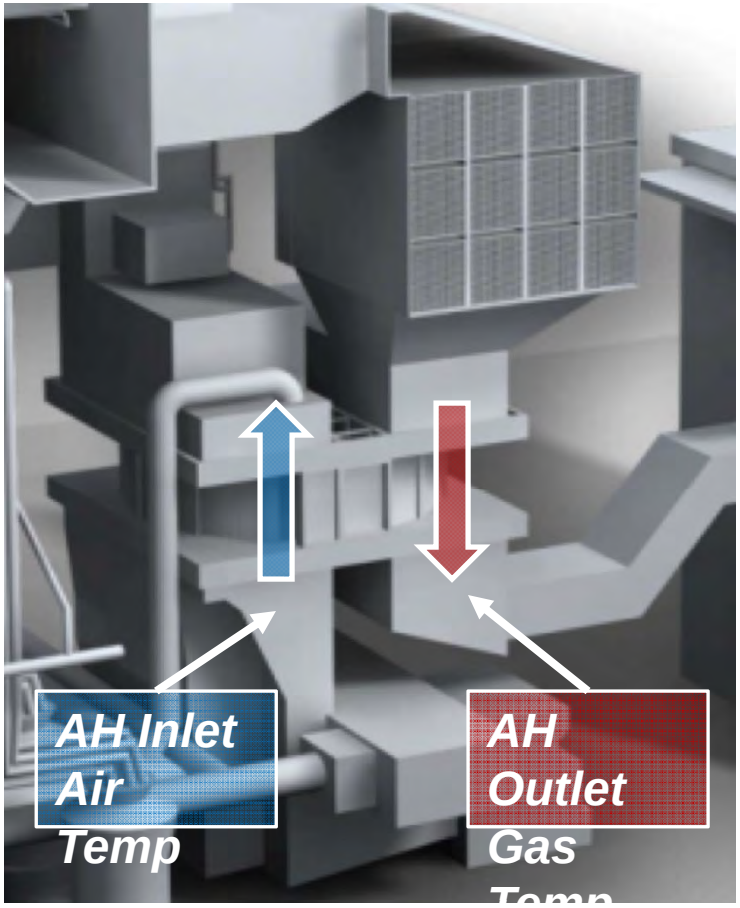
Air Heater – Steam Coil Impact



Why Preheat Inlet Air?

- Inlet air temp is adjusted via Steam Coils to maintain a desired AH Outlet gas temp
- Outlet gas temp is set to avoid condensable fouling
- ***It takes 0.24 BTU to raise 1 Lb of Inlet air by 1 degree*** F

Eliminating condensable material via hydrated lime injection eliminates the need for steam coils

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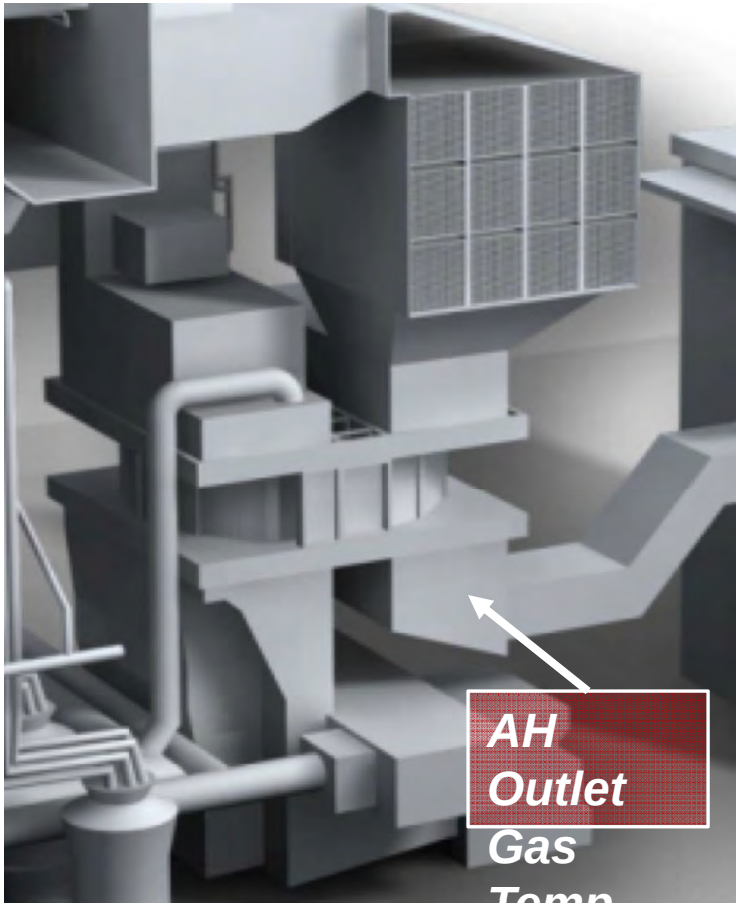
Air Heater – Outlet Gas Temp Impact



AH Outlet Gas Temp HR Impact

- After Steam Coil power is eliminated, every Lb of air at the AH outlet that is 1 degree higher than necessary is 0.24 BTU wasted
- It takes between 7 and 14 Lb of Air to Burn 1 Lb of Coal (on average)
- Allowing for 6% - 8% AH leakage impact, 30F of unneeded gas temp at the AH outlet requires 0.5% - 1% unneeded fuel input.
- ***This is 0.5% to 1% in Gross Heat Rate***

If Hydrated Lime eliminates AH Condensable Fouling, any process improvement that lowers the AH Outlet Gas temperature provides a permanent Heat Rate Improvement to the plant.

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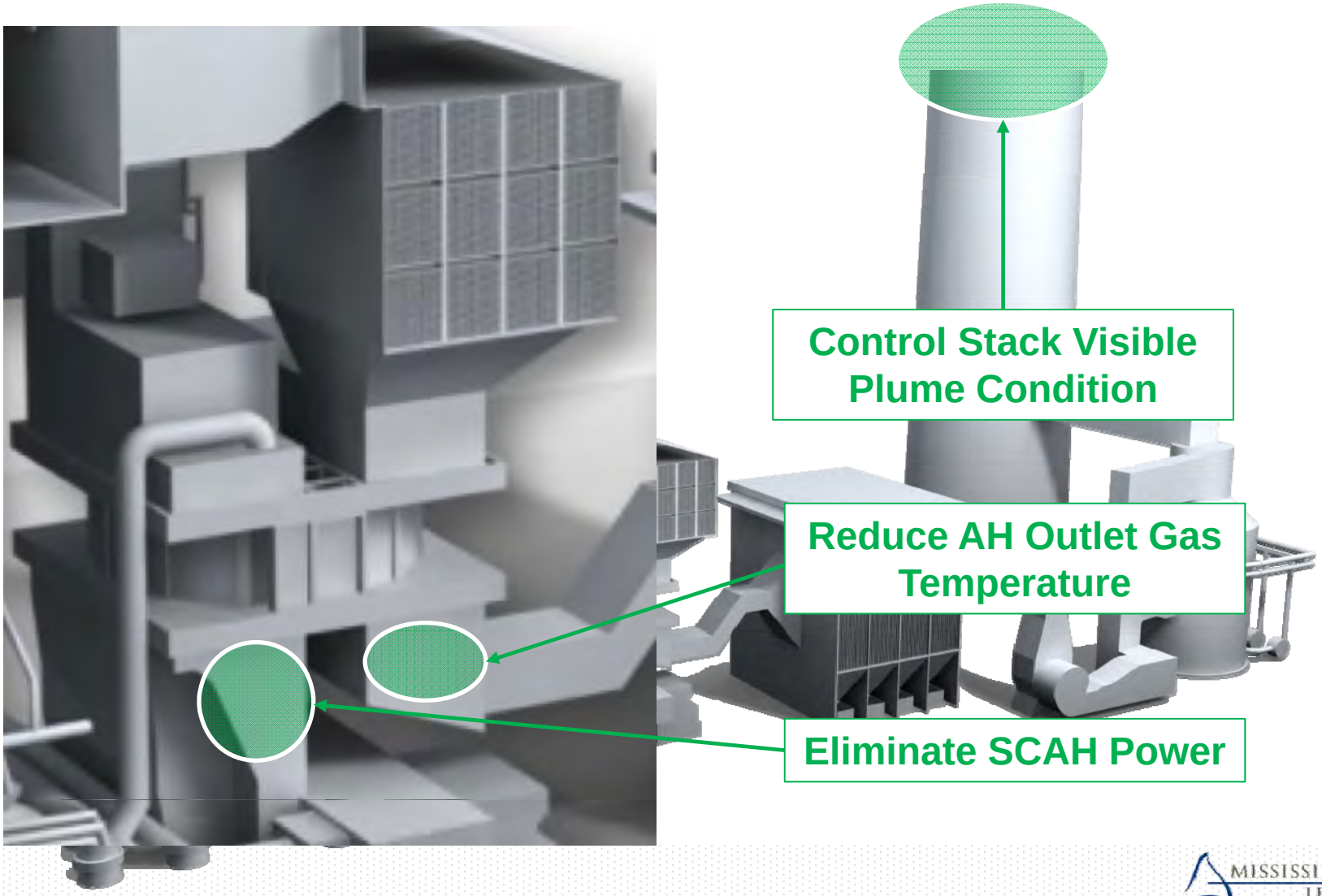
Quick Case Study - Goals



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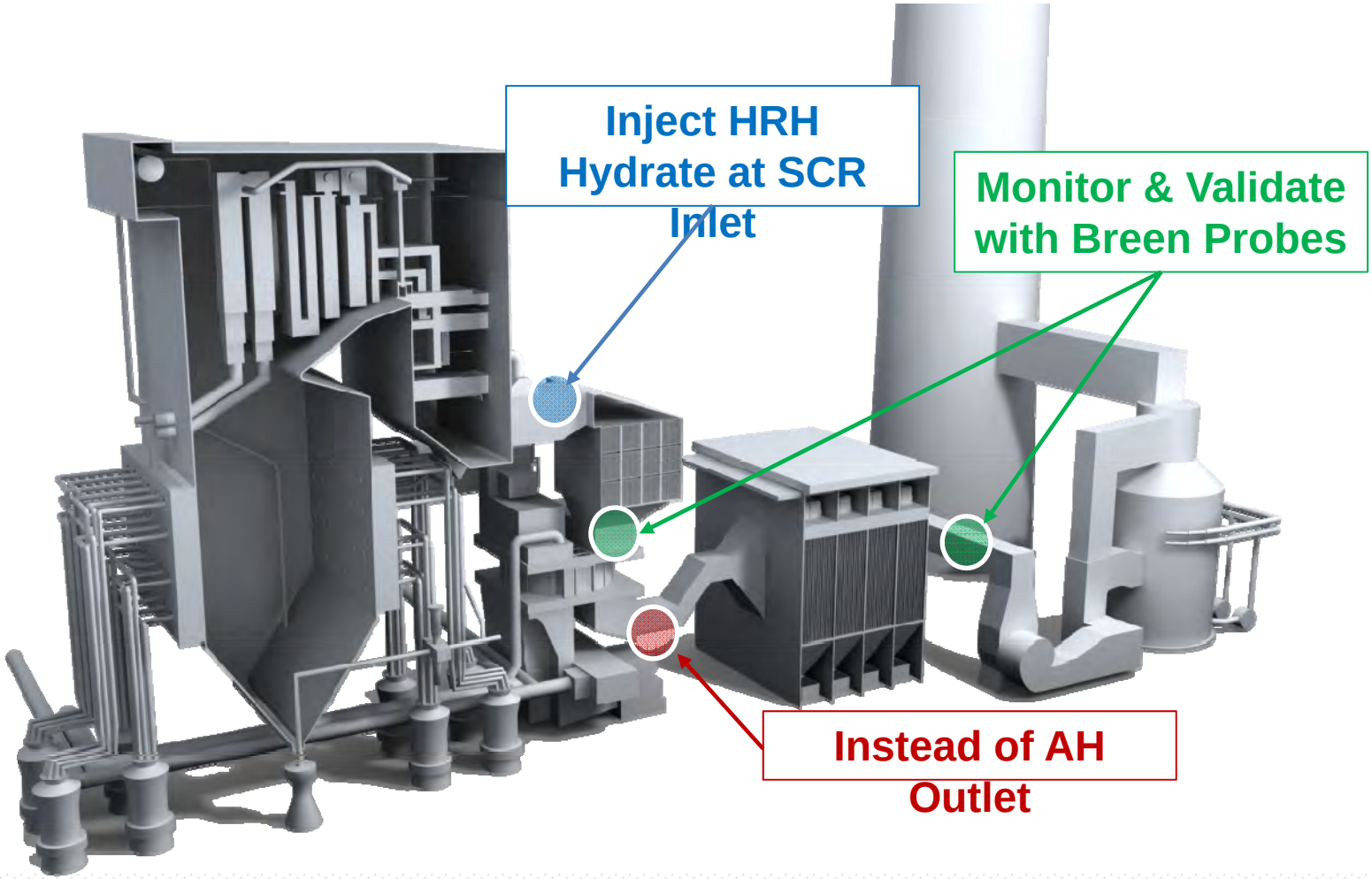
Project Implementation



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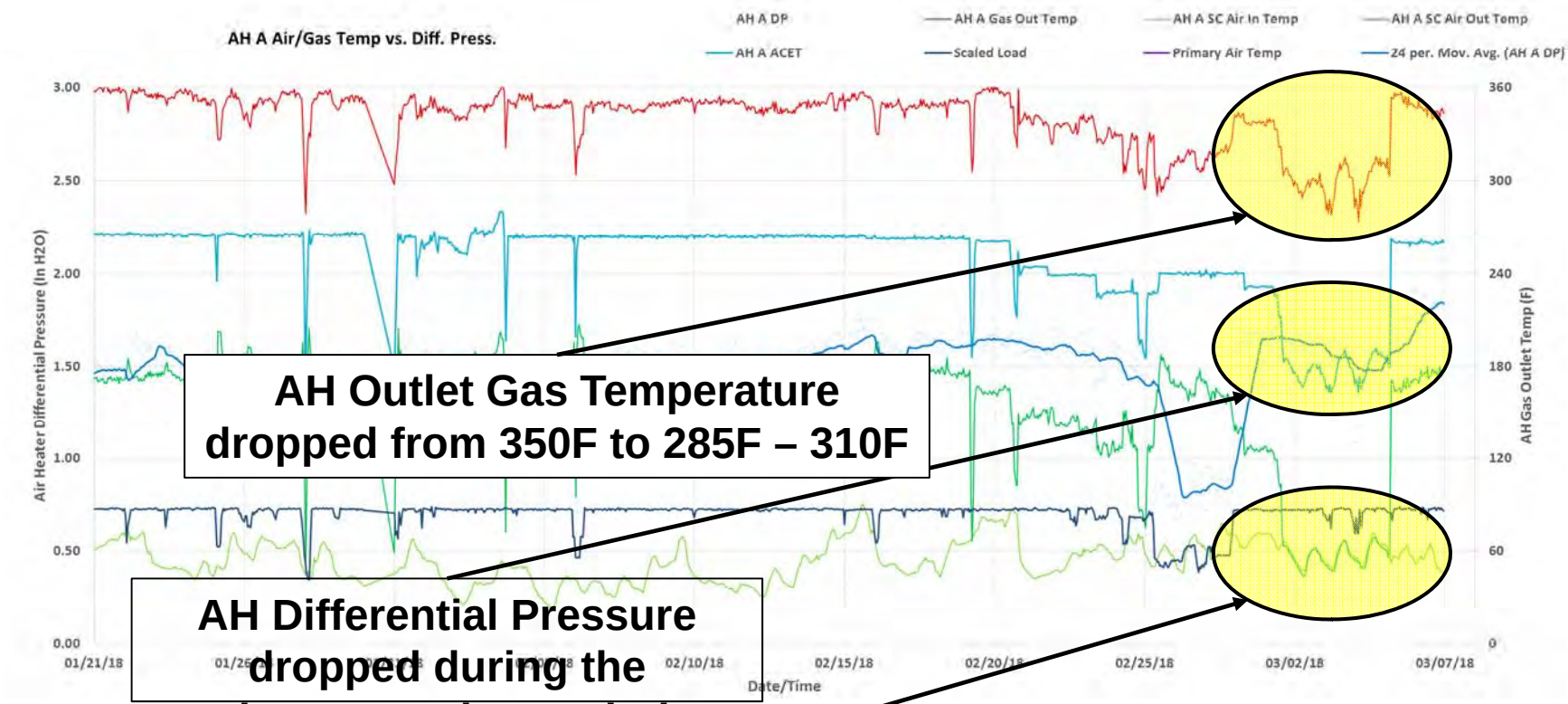
A Duct AH Temp vs. DP



AH Outlet Gas Temperature dropped from 350F to 285F – 310F

AH Differential Pressure dropped during the demonstration period

SCAH Power "OFF" from 3/3 – 3/5

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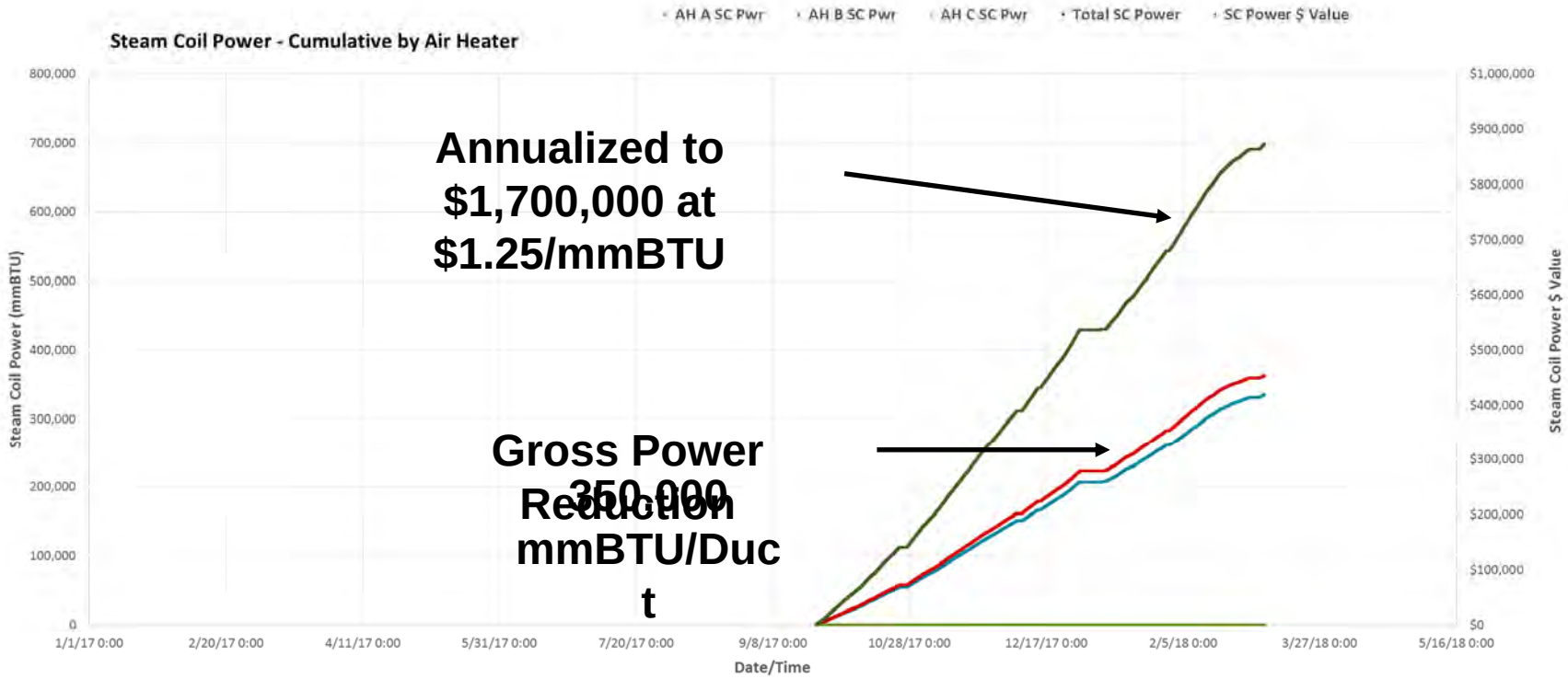
Steam Coil Power Impact



- Numbers shown reflect adjusted Air/Coal ratio from initial presentation (7 vs. 14) and assume $1.25mmBTU fuel cost
- Extrapolation of 5 month expense to 10 months projects annual savings form Steam Coil abatement in excess of $1.7 Million.

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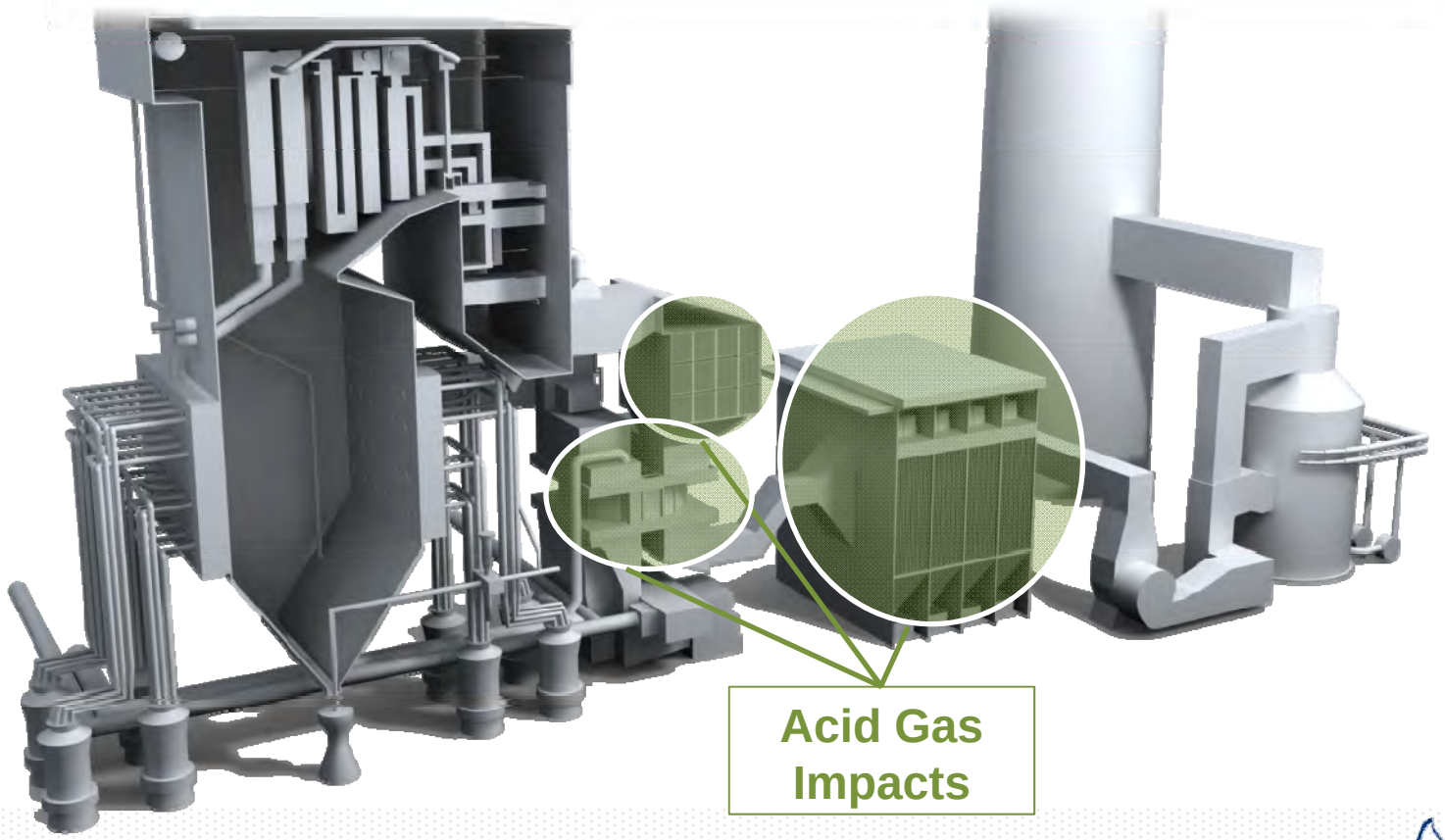
Acid Gas Impact Locations

Unit Turndown Improvement through MOT Reduction



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