REDEFINING CULTURAL PRACTICES
NATURAL GAS COFIRING CONSIDERATIONS

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DISCOVERING WHAT'S POSSIBLE WITH CALCIUM

October 2, 2019– WPCA/Spartanburg

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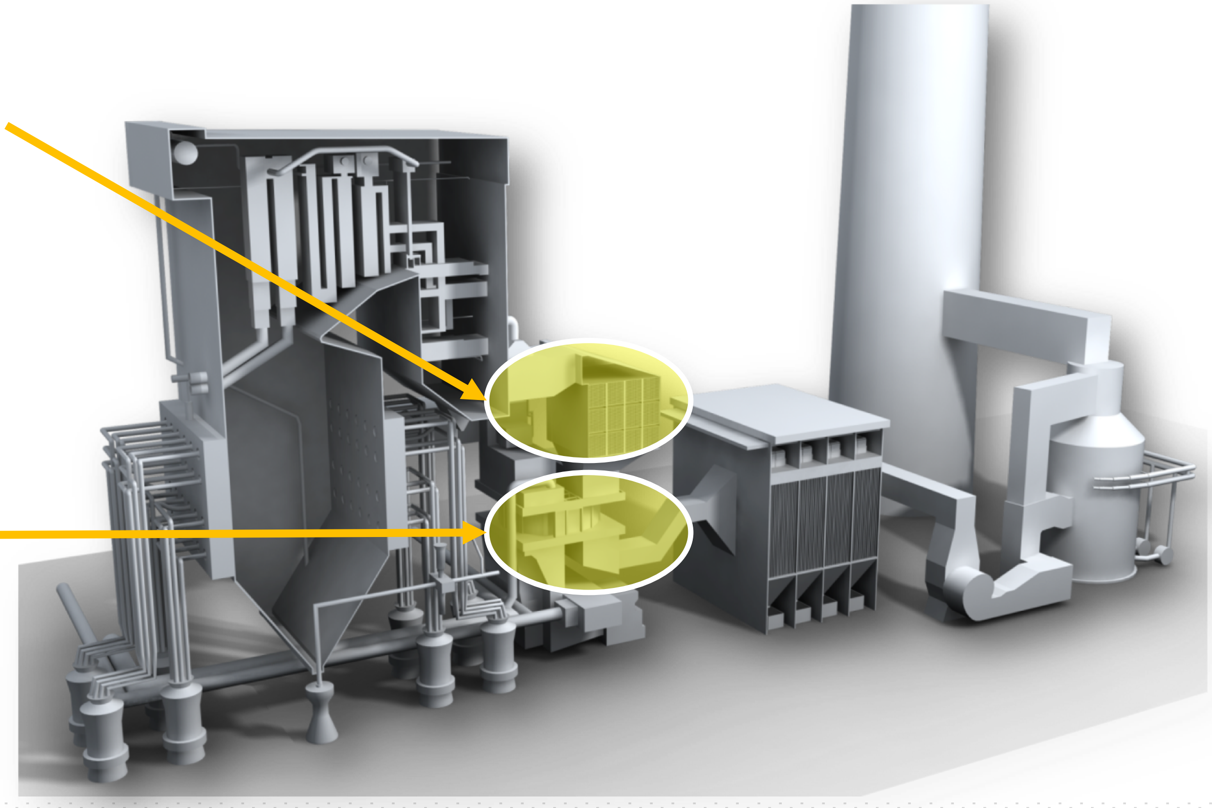
The Impact of DSI on Unit Flexibility

Let’s accept that DSI can eliminate SCR MOT constraints

Let’s also accept that DSI can eliminate air heater differential pressure issues without auxiliary heating from steam coils or bypass dampers



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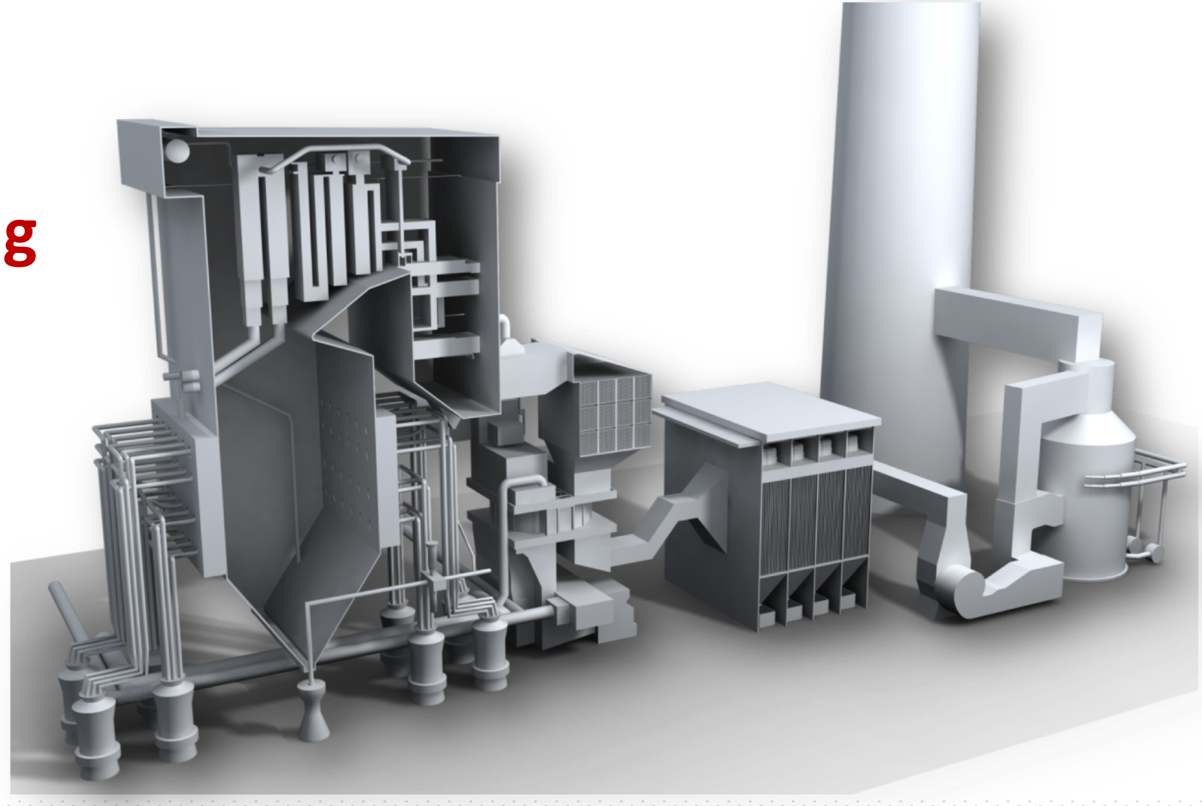
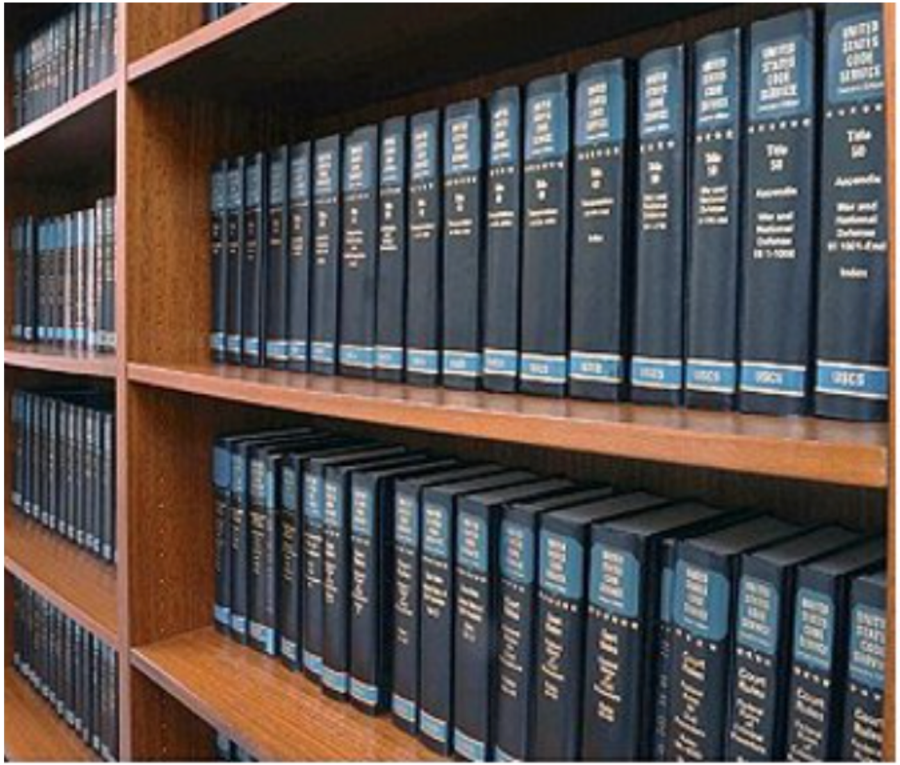
The Impact of DSI on Unit Flexibility

What is the impact of adding natural gas cofiring?



The ”Book” tells us How To Do It.



The “Book” was written to operate these units in a different time with completely different objectives.

To become more viable today, each plant must rewrite its book of operating practices

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Changing Plant Culture is a Deliberate Process

THE IMPACT OF NATURAL GAS COFIRING ON ACID GAS PARAMETERS

Flue Gas Constituents – 3.0% S/0% NG

Gas Percentage by Heat Input	0	%
Coal Percentage by Heat Input	100	%
TOTAL HEAT INPUT	5000	MMBTU/hr
SO_2 Conversion Rate	1.5	%
Furnace SO_2 Conversion Rate	0.7	%

Pre-SCR	Sulfuric Ac	16.9 ppm	
Post SCR	Sulfuric Ac	36.2 ppm	300

flue gas constituents			MOLES PER 100# FUEL	VOL % DRY	VOL % WET	MOLE WT. LB/MOLE	FLUE GAS LB/100# FUEL
CO2			5.284	14.960	13.629	44.010	**232.539**
SO2			0.094	0.265	0.241	64.065	**5.994**
O2			1.416	4.010	3.653	31.999	**45.321**
N2 (FUEL)			0.046	0.130	0.119	28.013	**1.290**
N2 (AIR)			28.479	80.634	73.458	28.161	**802.000**
H20			3.451		8.900	18.015	**62.163**
TOTAL DRY			35.319	100.000			**1087.143**
TOTAL WET			38.769		100.000		**1149.307**

key performance parameters			
MOLECULAR WEIGHT FLUE GAS (lb/mole)	**29.64**	HEAT INPUT (mmbtu/hr)	**5000.000**
H2O IN WET GAS (% by weight)	**5.41**	FUEL INPUT (lb/hr)	**397,172**
WET GAS WEIGHT (1,000 lb/hr)	**4564.73**	COMBUSTION AIR (lb/hr)	**4,201,674**
AIR FLOW WET (1,000 lb/hr)	**4201.67**	FLUE GAS (lb/hr)	**4,564,727**

Flue Gas Constituents – 3.0% S/50% NG

Gas Percentage by Heat Input	50	%
Coal Percentage by Heat Input	50	%
TOTAL HEAT INPUT	5000	MMBTU/hr
SO2 Conversion Rate	1.5	%
Furnace SO2 Conversion Rate	0.7	%

Pre-SCR	Sulfuric Ac	7.9 ppm	
Post SCR	Sulfuric Ac	17.0 ppm	295

flue gas constituents			MOLES PER 100# FUEL	VOL % DRY	VOL % WET	MOLE WT. LB/MOLE	FLUE GAS LB/100# FUEL
CO2			5.652	13.012	11.136	44.010	**248.732**
SO2			0.057	0.132	0.113	64.065	**3.682**
O2			2.514	5.788	4.954	31.999	**80.447**
N2 (FUEL)			0.065	0.151	0.129	28.013	**1.834**
N2 (AIR)			35.146	80.917	69.253	28.161	**989.738**
H20			7.315		14.415	18.015	**131.786**
TOTAL DRY			43.434	100.000			**1324.433**
TOTAL WET			50.750		100.000		**1456.219**

key performance parameters			
MOLECULAR WEIGHT FLUE GAS (lb/mole)	**28.69**	HEAT INPUT (mmbtu/hr)	**5000.000**
H2O IN WET GAS (% by weight)	**9.05**	FUEL INPUT (lb/hr)	**326,992**
WET GAS WEIGHT (1,000 lb/hr)	**4762.04**	COMBUSTION AIR (lb/hr)	**4,269,011**
AIR FLOW WET (1,000 lb/hr)	**4269.01**	FLUE GAS (lb/hr)	**4,762,040**

0

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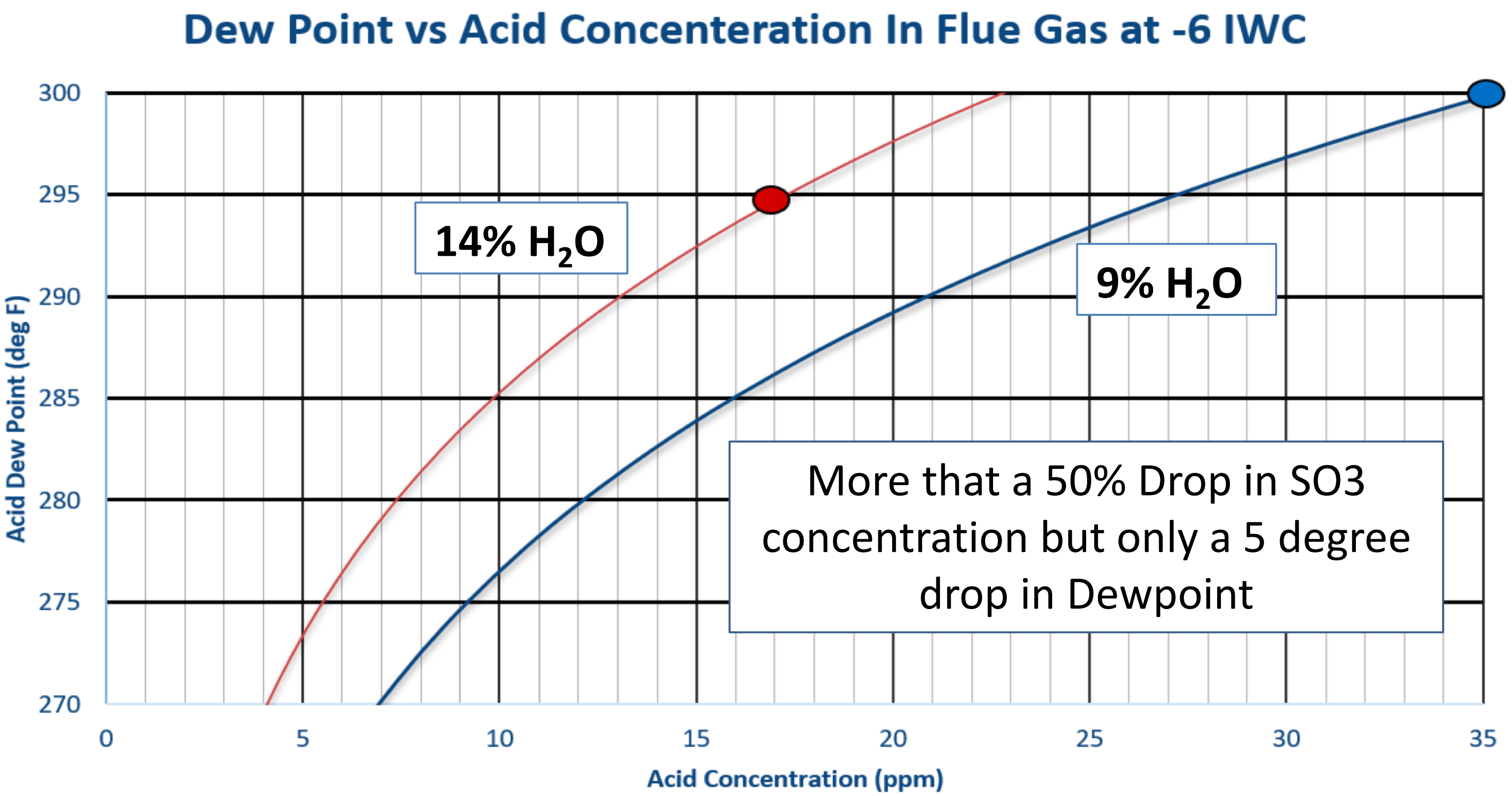
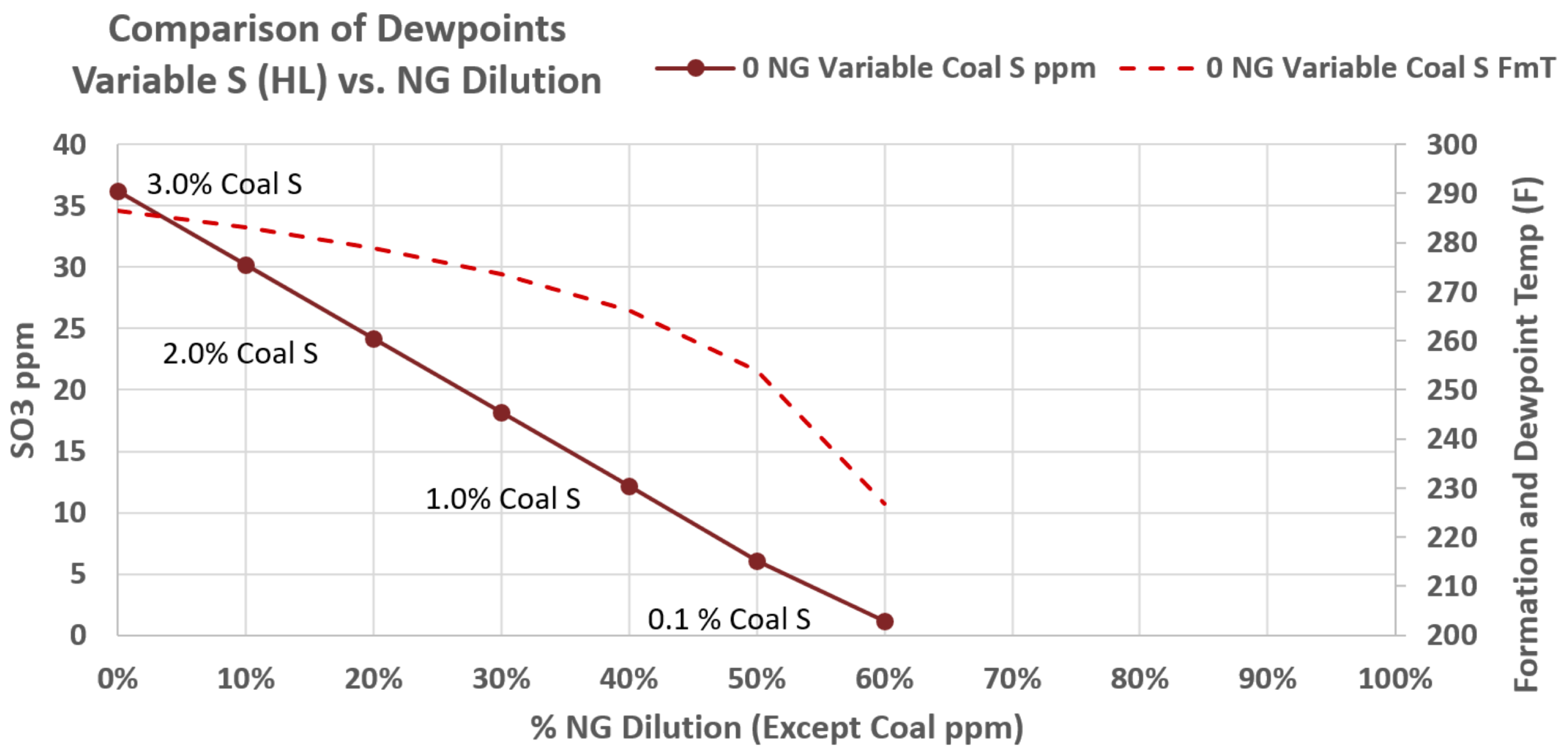
Acid Concentration vs. Dewpoint



0% NG SO_3 vs Dewpoint



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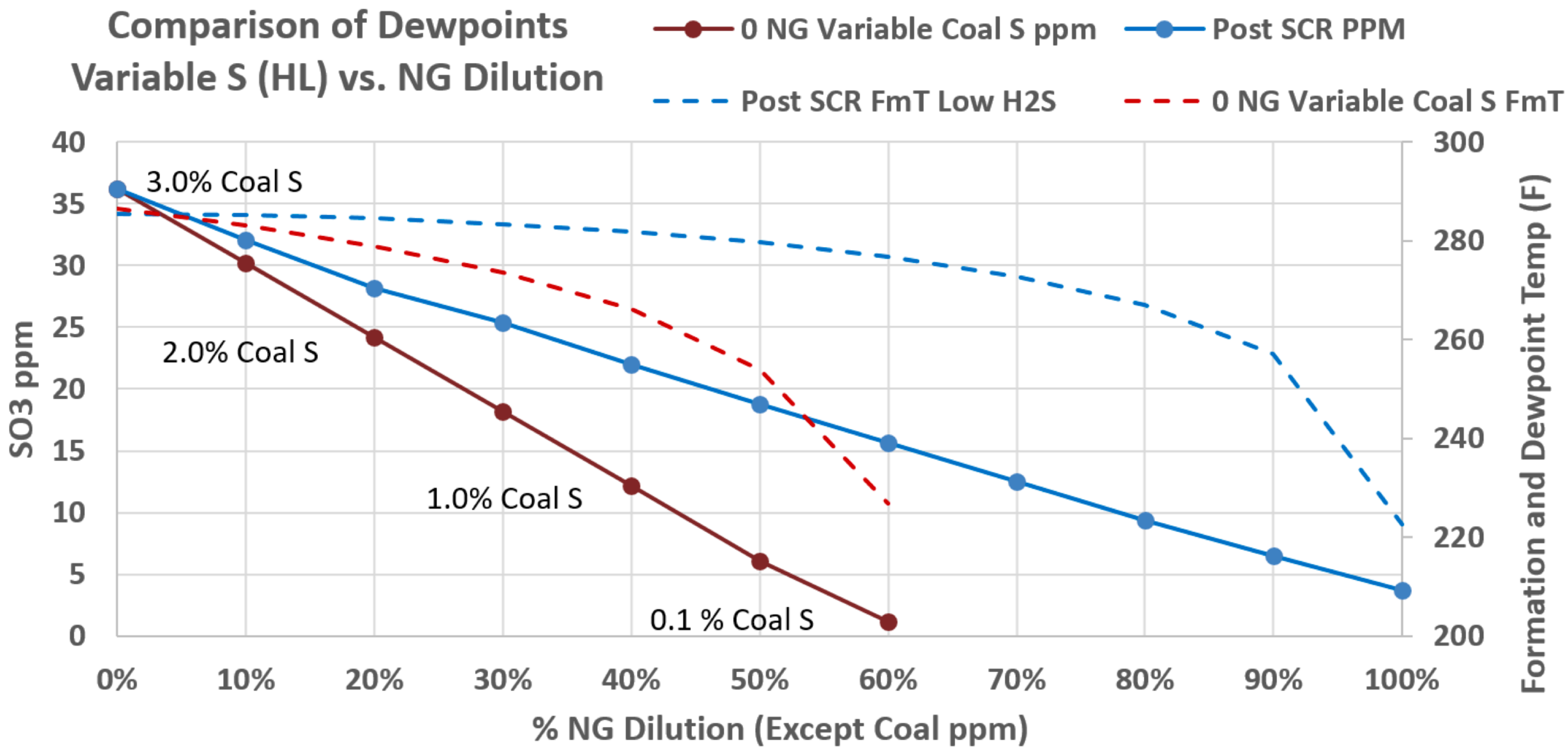
Combined 0%/50% NG SO_3 vs Dewpoint



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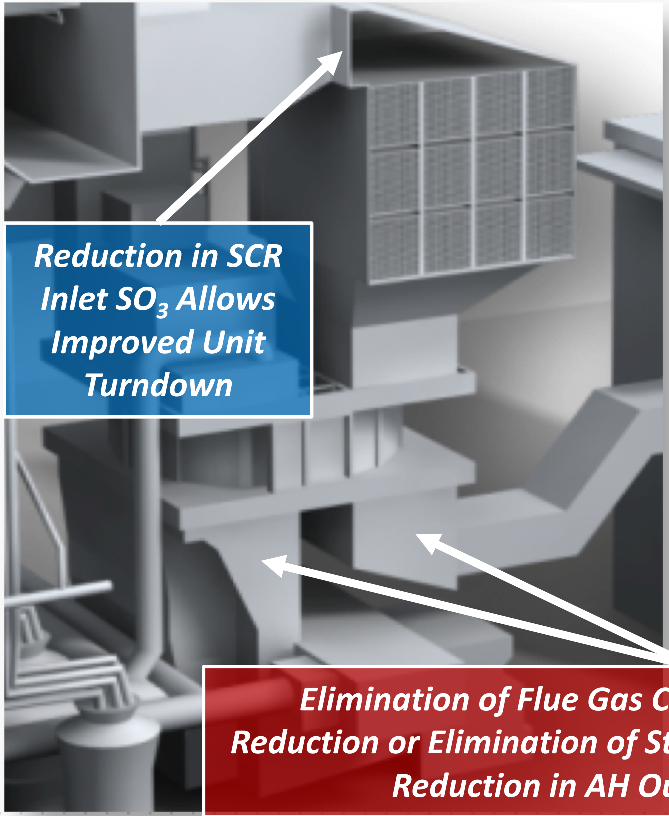
HOW DOES GAS COFIRING IMPACT THE CURRENT LOW LOAD PRACTICE

THE CURRENT WORKING MODEL FOR ACID MITIGATION PERFORMANCE IMPROVEMENTS

Major Sources of DSI Improvement

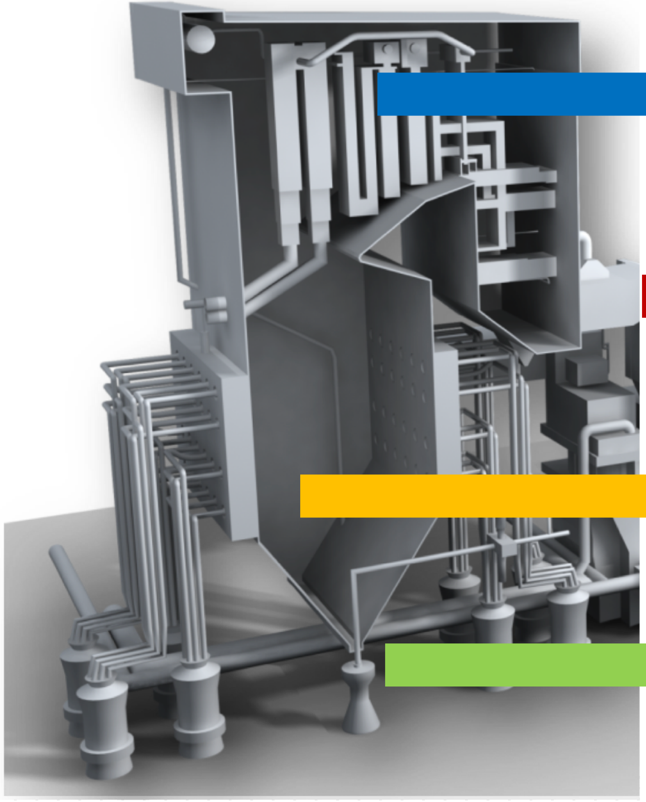


Unit Turndown and Steam/Glycol Heater Elimination can have huge impacts.

They might seem like separate objectives, but often they are linked to each other

WHAT DEFINES MINIMUM LOAD?

What Limits Unit Turndown?



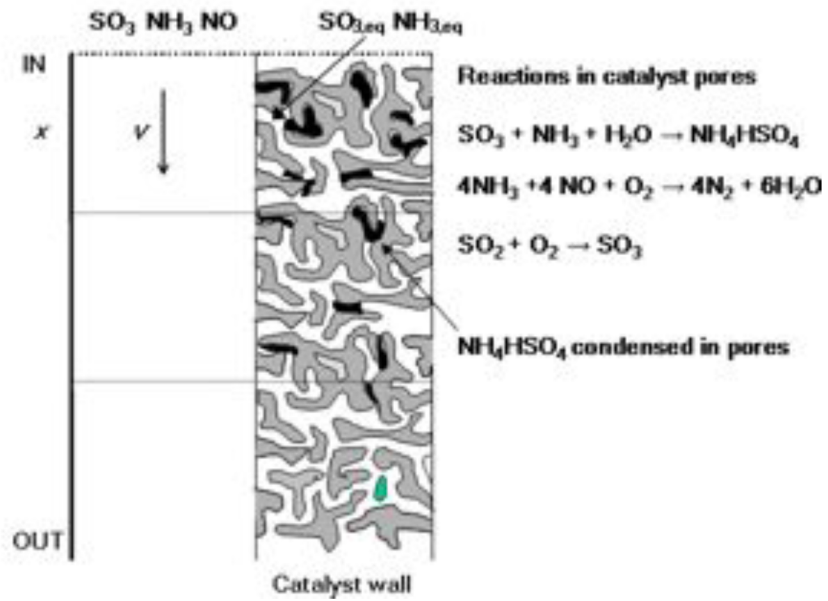
Main Steam Pressure

SCR Minimum Operating Temperature

Number of Mills in Service

Number of Feedwater Pumps in Service

What is Minimum Operating Temperature



- Depending on Catalyst Inlet SO_3 levels, it is probable that some portion of the ammonia introduced will interact with SO_3/H_2O and form an ammonia salt.
- While Ammonium Sulfate (AS) is the expected species due to stoichiometry, kinetics favor ABS before AS. Some ABS may condense, via capillary condensation, in the catalyst pores

- **Staying above the capillary dew point will avoid ABS condensation in the catalyst pores. Catalyst suppliers refer to this as staying above the Minimum Operating Temperature of MOT**

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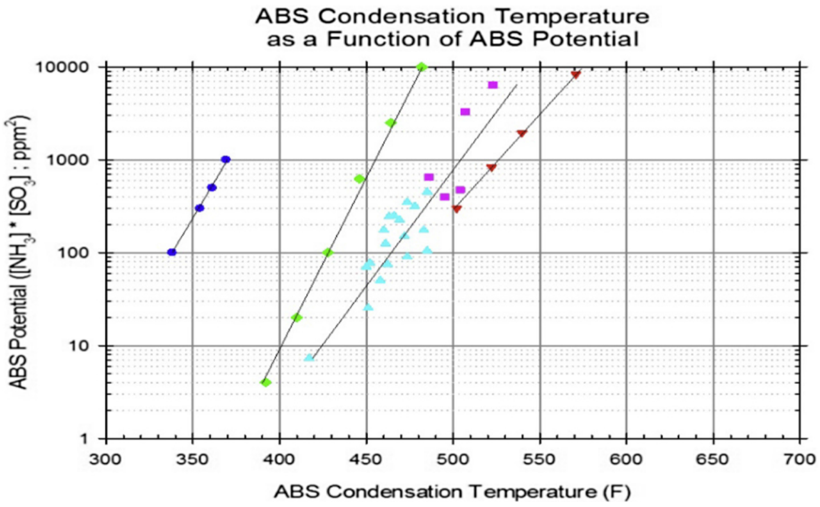
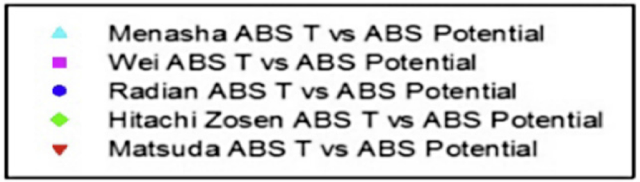
Identifying MOT – The Theoretical Bulk Dewpoint

L. Muzio et al. / Fuel 206 (2017) 180–189





The combined Wei/Menasha work can be defined by the formula below:

$$P_{NH3}(atm) * P_{SO3}(atm) = 2.97 * 10^{13} * e^{(-54{,}950/RT)}$$

- R is the universal gas constant (1.987 cal/K-mol)
- T is the flue gas temperature in degrees Kelvin (K)

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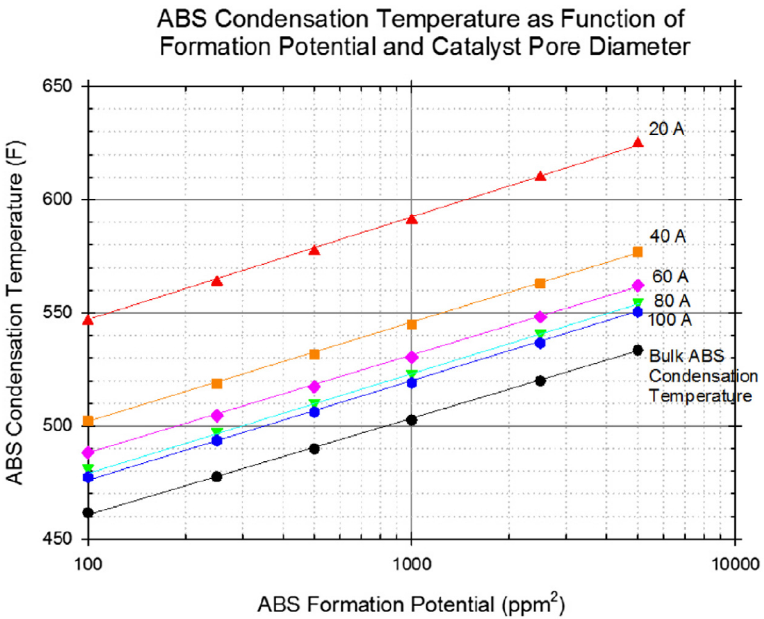
Identifying MOT – Allowance for Smaller Pore Size



- Simply put, Pore Size impacts the Dewpoint of ABS
- The smaller the pore size, the higher the capillary condensation temperature

Reference for this slide and the preceding slide:

Ammonium bisulfate formation and reduced load SCR operation

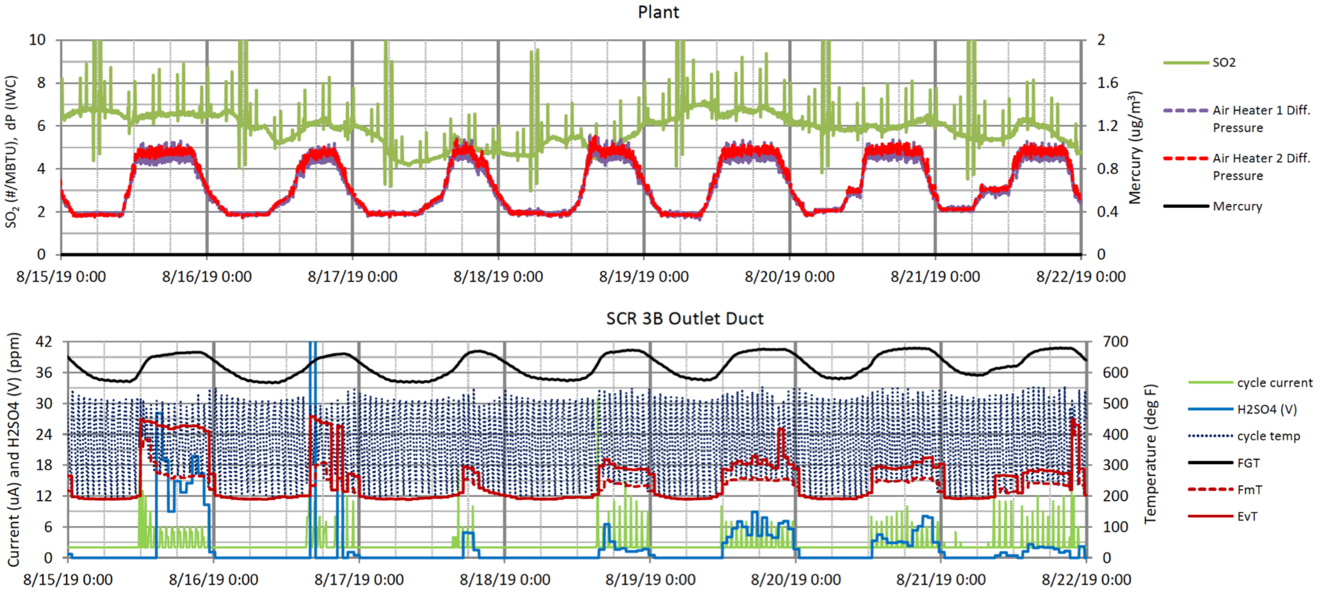
Lawrence Muzio [a], Sean Bogseth [a], Richard Himes [b], Yu-Chien Chien [c], Derek Dunn-Rankin [c,*]

[a] *Fossil Energy Research Corporation (FERCo), Laguna Hills, CA 92653, United States*
[b] *Electric Power Research Institute (EPRI), Palo Alto, CA 94304, United States*
[c] *Department of Mechanical and Aerospace Engineering, University of California, Irvine, CA 92697-3975, United States*

Real World Experience

- This is uncharted territory.
- EPRI does not believe that moisture in flue gas plays a significant role in the condensation temperature of ABS
- I am, personally, not sure of that position.
  - Whether ABS forms by concurrent combination of SO_3, NH_3 and H_2O, or
  - Whether ABS forms by SO_3 combining with H_2O to form Acid then combining with NH_3 to form ABS isn't known

Tale of Two Ducts – B Duct



- Spikes into ABS range reflect ABS burn-off during load ramp. Operation below MOT.
- Whether Gas Cofiring raises, or lowers, MOT in parallel with (or without) DSI injection pre-SCR remains to be explored

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MOVING BEYOND MOT

Moving Beyond MOT – How Many Mills?

- In our experience, the number of mills in service at the new minimum load becomes the next operational obstacle.
  - ***One plant is operating with 4 mills that go unstable at the desired new load***
  - ***Operations resists moving to 3 mills (which would inherently be more stable because they have always run with 4.***
  - ***But why not 3, why not 2, why not 1.***

When Natural Gas Cofiring is available the minimum number of operating mills can be controlled to fit.

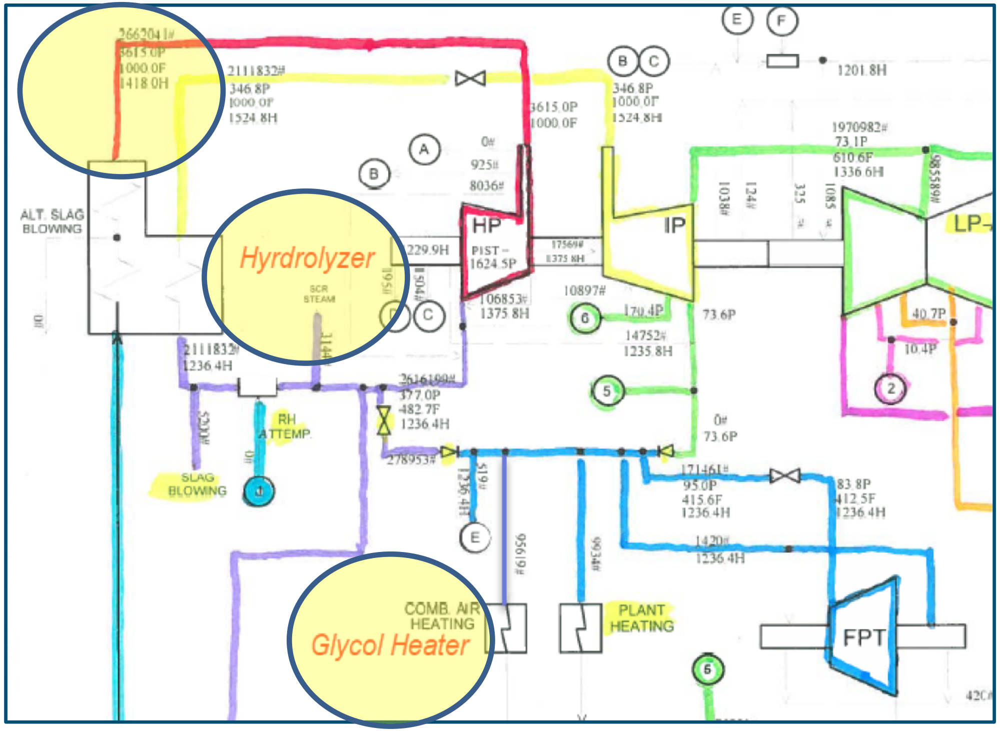
Moving Beyond That

- Main Steam Pressure can be alleviated with sliding pressure,

- Available steam to support Reheat Temperature is also an issue.
  - Balancing steam generation in the walls with higher upper furnace temperatures can be tricky.
  - Understanding the current vs. cofired use of Cold Reheat steam needs to be understood.
    - Steam/Glycol Coils
    - Sootblowing steam
    - Other uses

STEAM SOURCES & REQUIREMENTS AT REVISED MINIMUM LOAD

Another Real-World, non-Duke Example



At Low-Load Cold Reheat Steam Drives:

- **Glycol Coils for AH Outlet Gas Temperature Control**
- **Hydrolyzer for urea to ammonia gas conversion**
- **Reheat tube banks leading to IP and LP power generation**

Cold Reheat Conservation

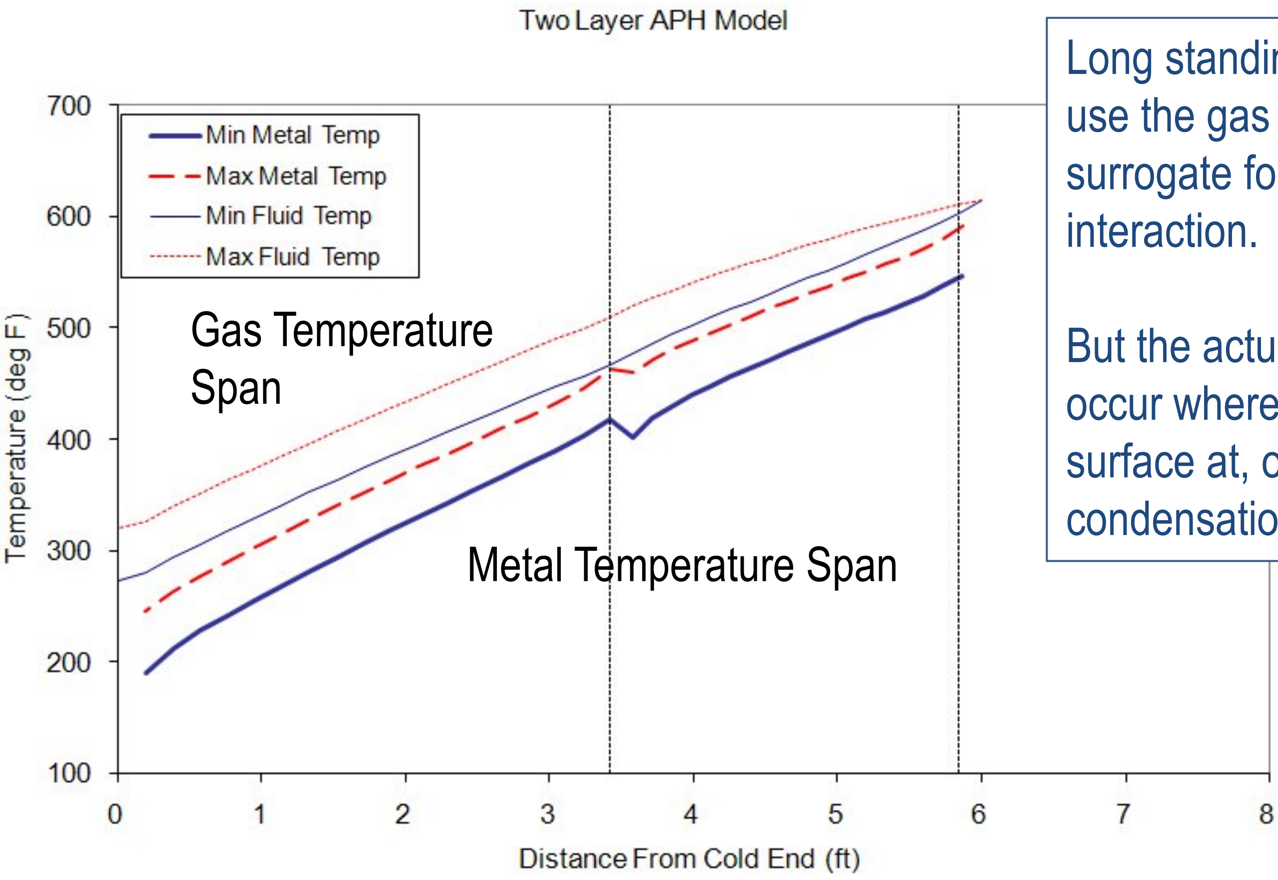
If too much Cold Reheat steam goes to the Glycol coils:

- There may be insufficient steam to provide ammonia vapor flow to the SCR, and/or
- There may be insufficient steam to absorb energy in the reheat tube banks. This, in turn, could lead to:
  - **High tube temperature problems, and/or**
  - **Unit Derates**

In Simple Terms, Eliminating the Glycol/Steam Coils could provide sufficient steam to operate at lower loads

ELIMINATION OF STEAM/GLYCOL COILS

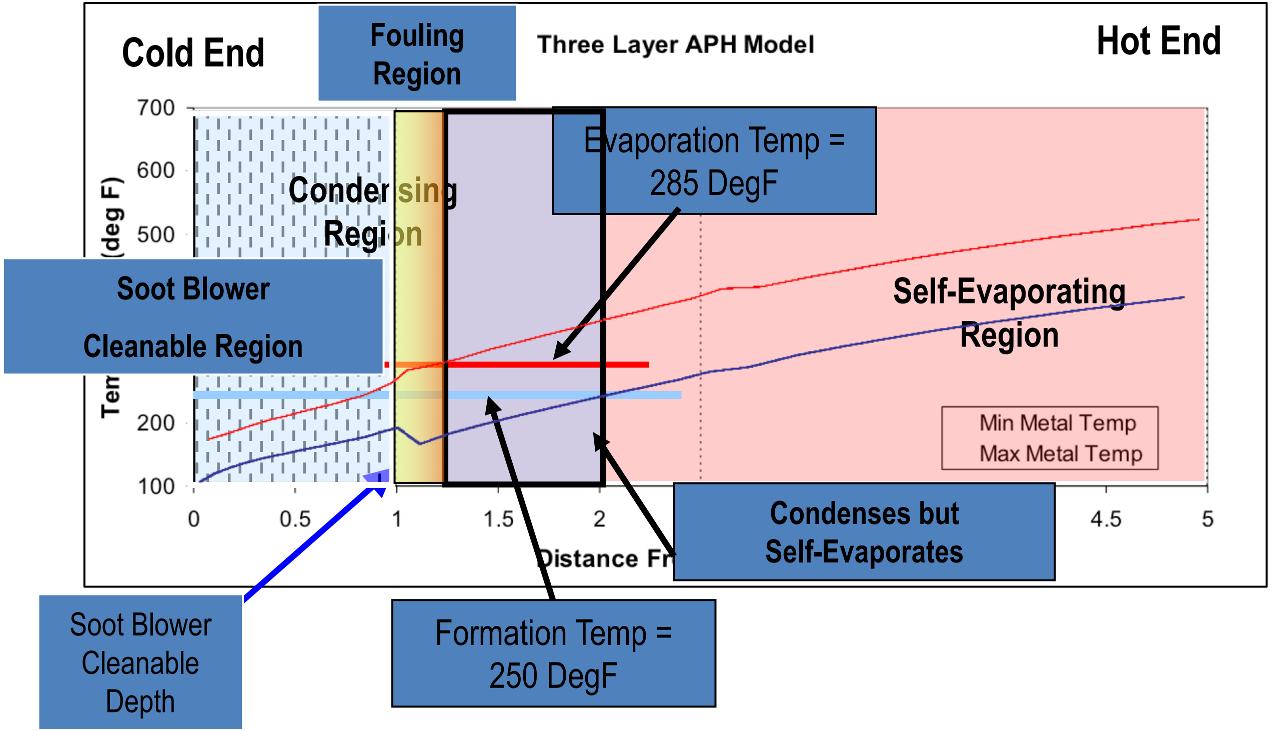
Air Heater Dynamics – the Basics



Long standing plant operations use the gas temperature as a surrogate for actual vapor/metal interaction.

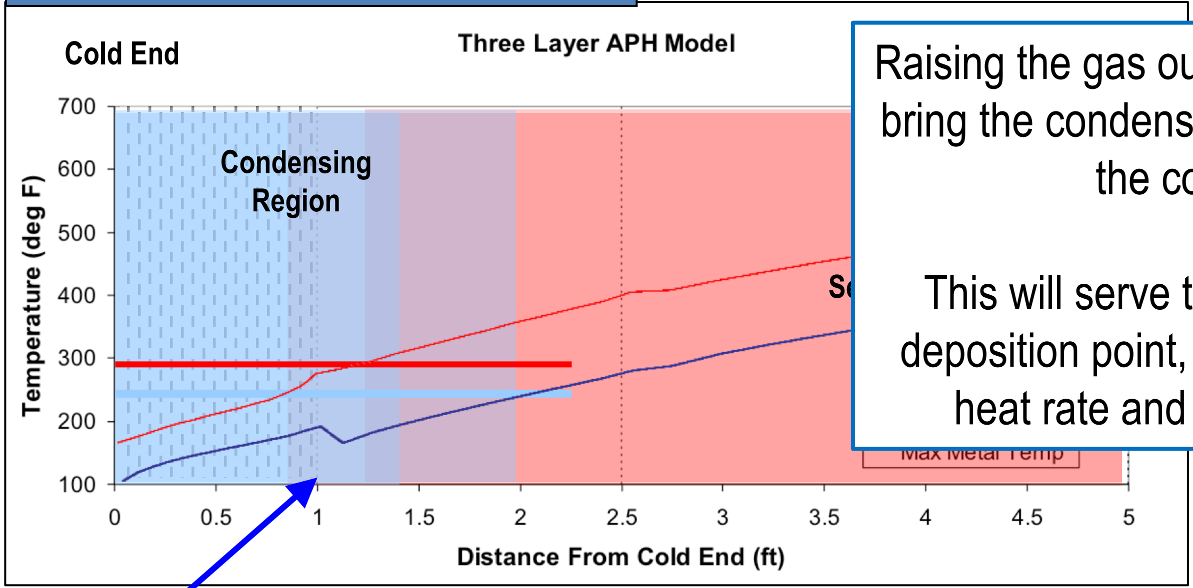
But the actual condensation will occur where the gas hits a metal surface at, or below, its bulk condensation temperature

AH Model and Deposition



What can you do?

Increase Average Cold End Temp



Raising the gas outlet temperature will bring the condensation point closer to the cold end.

This will serve to control the acid deposition point, but at a significant heat rate and steam use cost

Soot Blower Cleanable Depth

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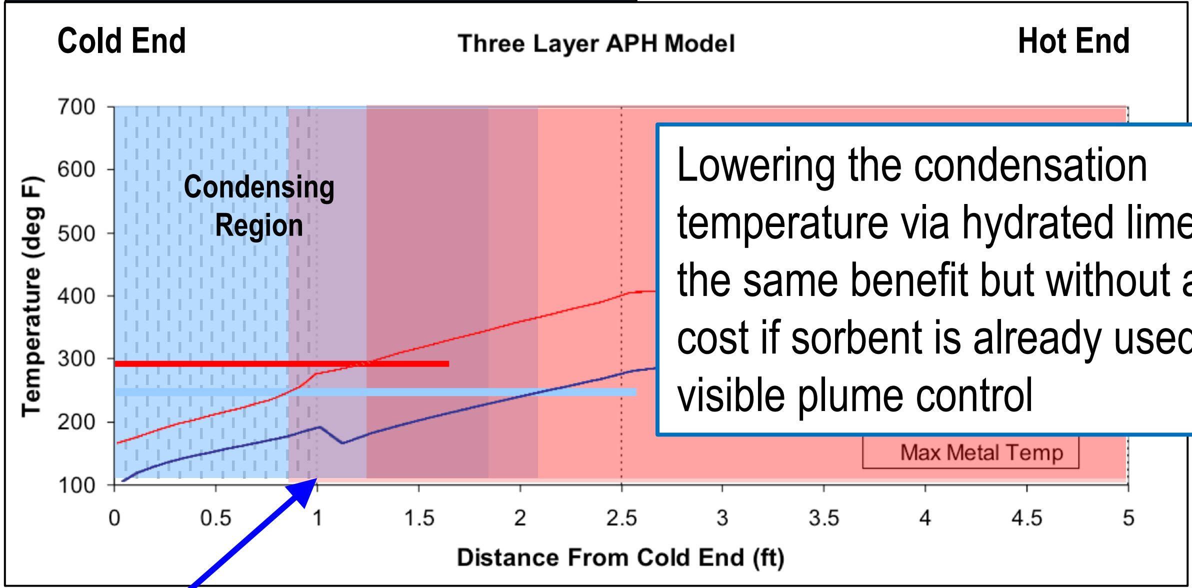
What can you do?

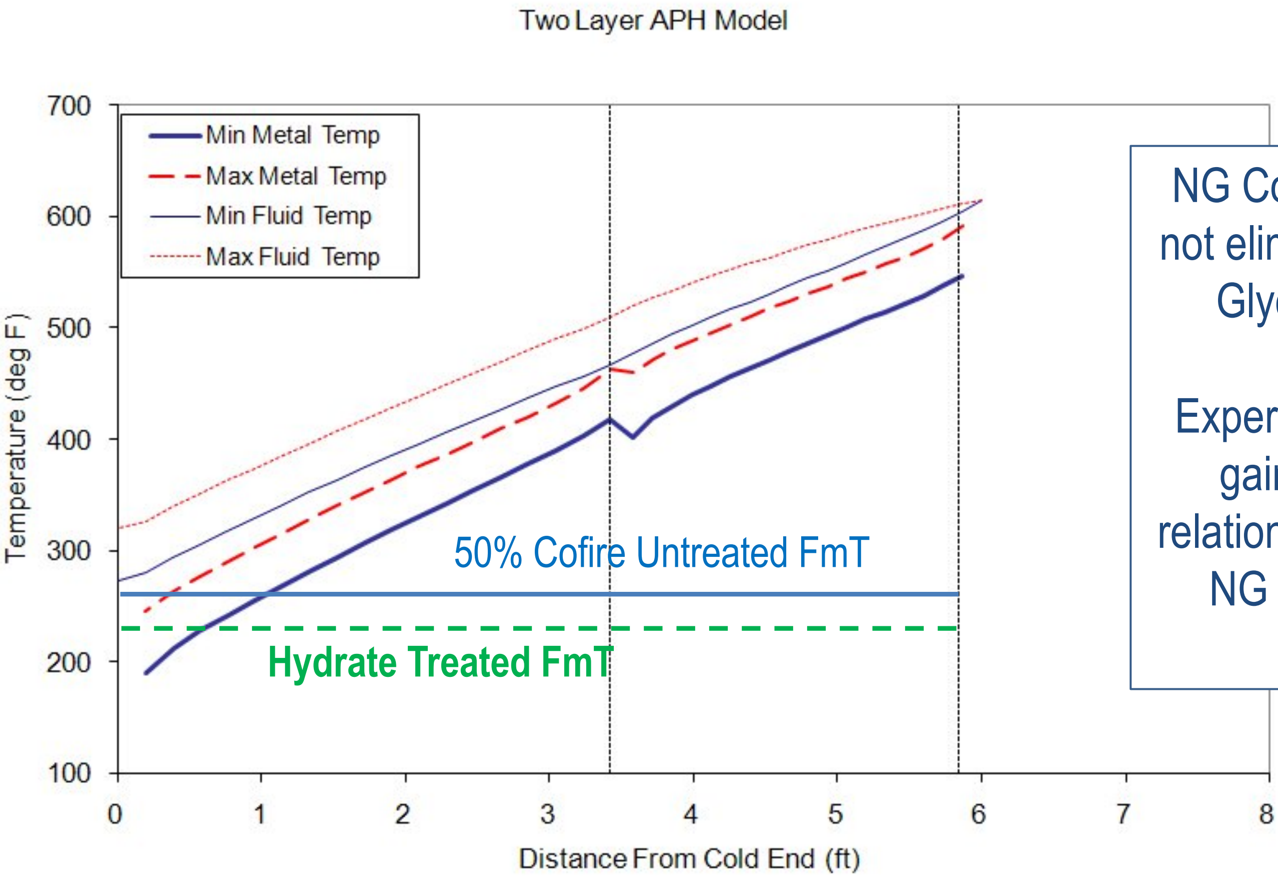
Reduce NH3 / SO_3



Lowering the condensation temperature via hydrated lime provides the same benefit but without additional cost if sorbent is already used for visible plume control

Soot Blower Cleanable Depth

Gas CoFiring Consideration



NG Cofiring, along, may not eliminate the need for Glycol/Steam Coils

Experience needs to be gained on the best relationship between DSI, NG and auxiliary air preheating

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SUMMARY & CONCLUSION

Summary

In the presence of current science on hydrated lime injection, distribution and performance:

1. ***SCR Minimum Operating Temperature can be eliminated as a plant operating constraint.***
   - ***Natural Gas Cofiring may, or may not impact that but the belief is it will not***
2. ***Air Heater outlet gas temperatures can follow the natural gas temperature patterns without the need for auxiliary heating***
   - ***Natural Gas CoFiring will lower the base SO3, but will increase the formation temperature.***
   - ***Some combination of reduced DSI and NG% needs to be explored***
3. ***Natural Gas Cofiring should provide benefits with regard to mill requirements***
   - ***An understanding of flame position and Steam generation vs SH/RH gas temperature must be developed***

But you MUST be Willing to Take the Leap!


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