

# Pre Heater Pluggage Issues

## 2006 NO<sub>x</sub> Round Table

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Charlotte

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# Agenda

- Introduction
- Air Heater Plugging Mechanism
  - Ammonium Bi Sulfate
  - SO<sub>3</sub> Condensation
- Impact on Non Enameled Surfaces
- ABS Impact on Different Air Heater Types
- Air Heater Cleaning
- Air Heater Retrofits
- Two Examples for SCR Design With Substitution of the Air Heater



# Acknowledgements

- Associated Electric Cooperative, Inc. AECl
- Burns & Mc Donnell
- Howden



# Introduction

## ➤ Tackticks, LLC

- SCR Consulting and Management
- Founded in 2001
- Located in Durham, NC

## ➤ FlowTack, LLC

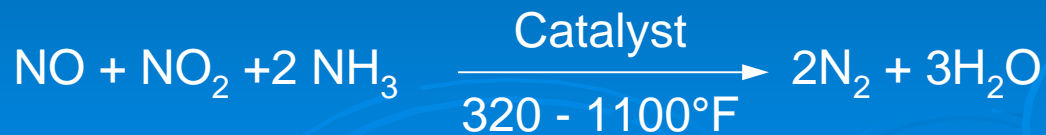
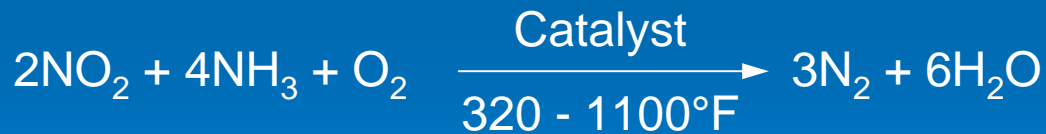
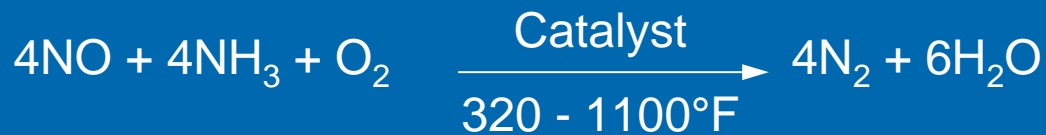
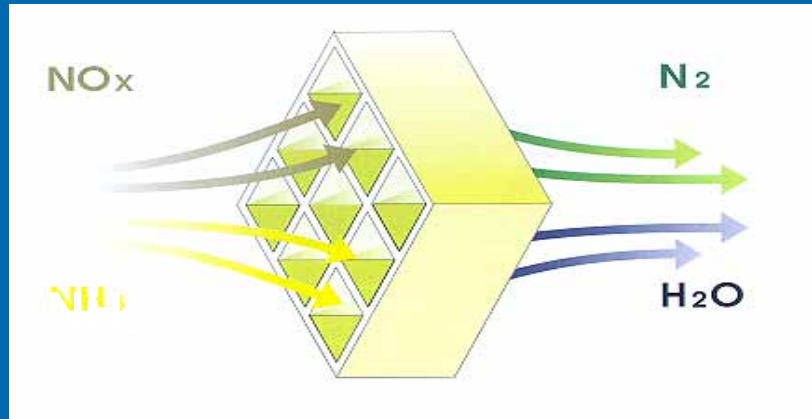
- CFD and Physical Models
- Founded in 2003
- Located in Durham, NC
- 50/50 Owned by Tackticks, LLC and Flowtech, Switzerland



# Air Heater Plugging Mechanism



# SCR Process Chemistry



# SCR System Process Reactions

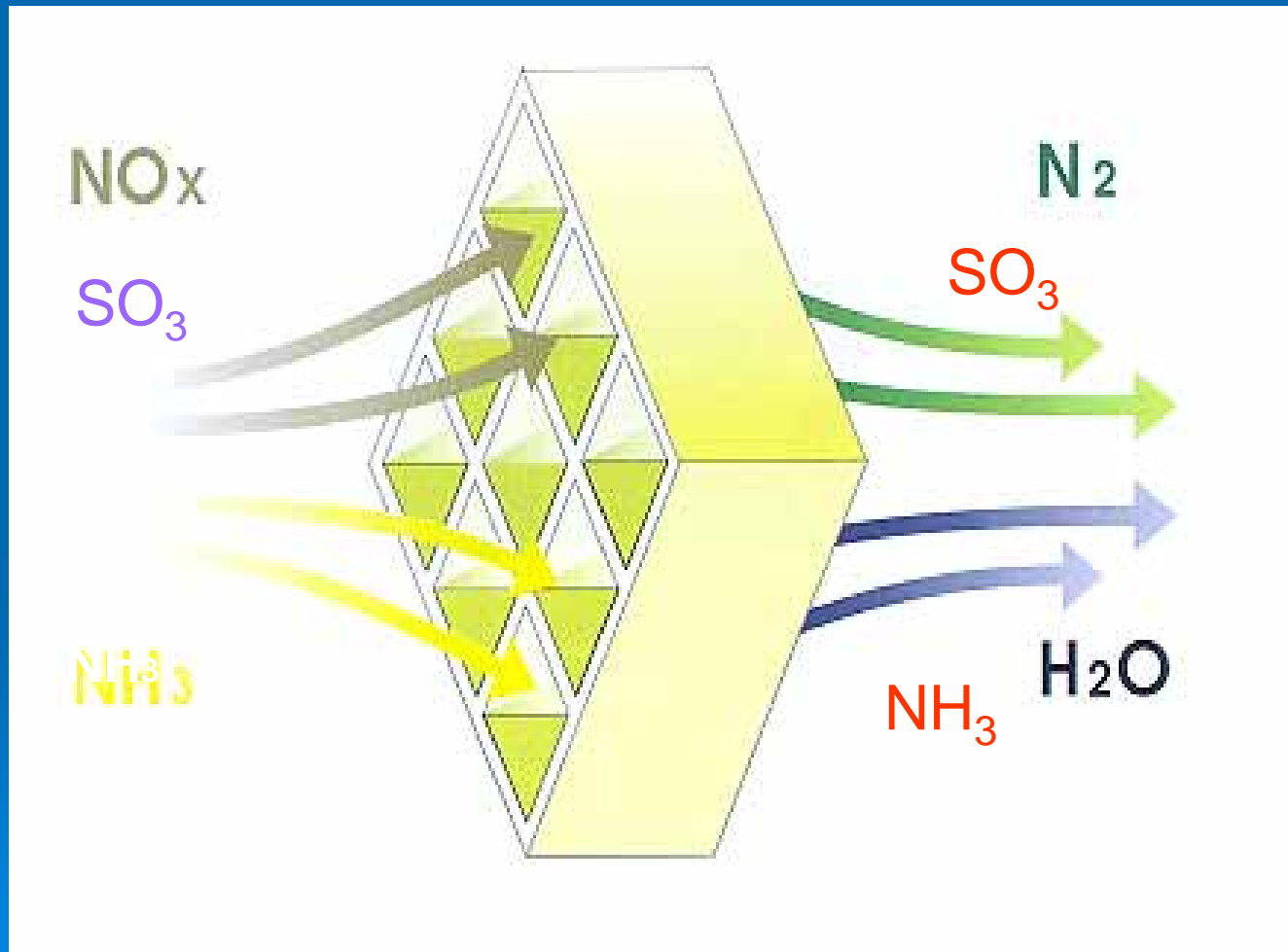
## Undesired Reactions/Implications:



- Ammonia Slip From Process Reacts With  $\text{SO}_3$  From the Boiler and the Catalyst to Form Ammonium Bisulfate
- Ammonium Bisulfate Can Precipitate at Intermediate Basket Levels of the Air Heater Leading to Plugging
- $\text{SO}_3$  Can Condense on the Cold End Layers



# Chemical Reactions On SCR Catalyst



# Air Heater Issues

## ➤ Ammonium Bi Sulfate Deposition

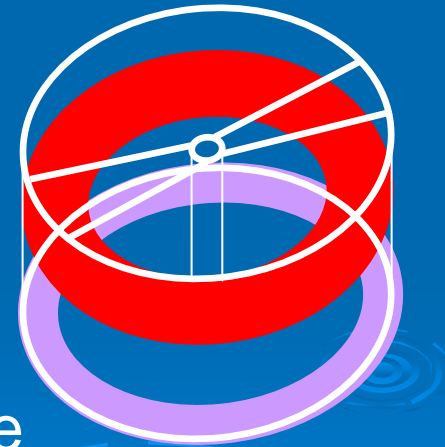
< 480 F

Temperature Range Depends on  $\text{SO}_3$  and  $\text{NH}_3$   
Concentration

## ➤ Cold End Plugging Due To Condensed Sulfuric Acid

< 280 F

Temperature Range Depends on  $\text{SO}_3$  and Moisture  
Concentration



# Characteristics of Ammonium Bi-Sulfate

- Ammonium bi-sulfate is a salt.
- It becomes a glue-like substance below its precipitation temperature.
- Because of this consistency, it can mask the catalyst, air heater elements and gas-gas heater elements.

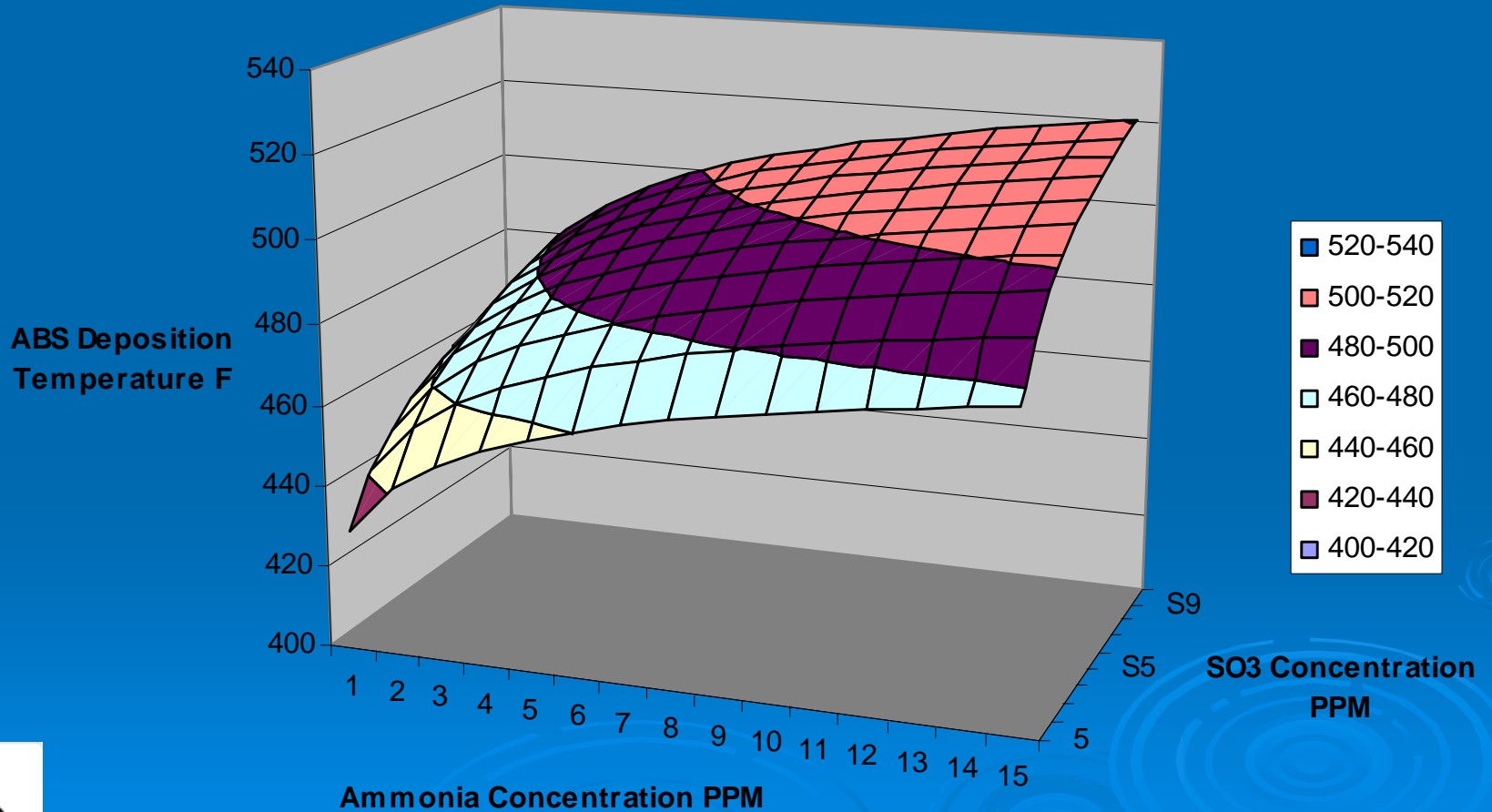


# Characteristics of Ammonium Bi-Sulfate

- Generally, the salt can be washed off with low pressure or high pressure water.
- The precipitation temperature is dependent upon the ammonium and sulfate concentrations.

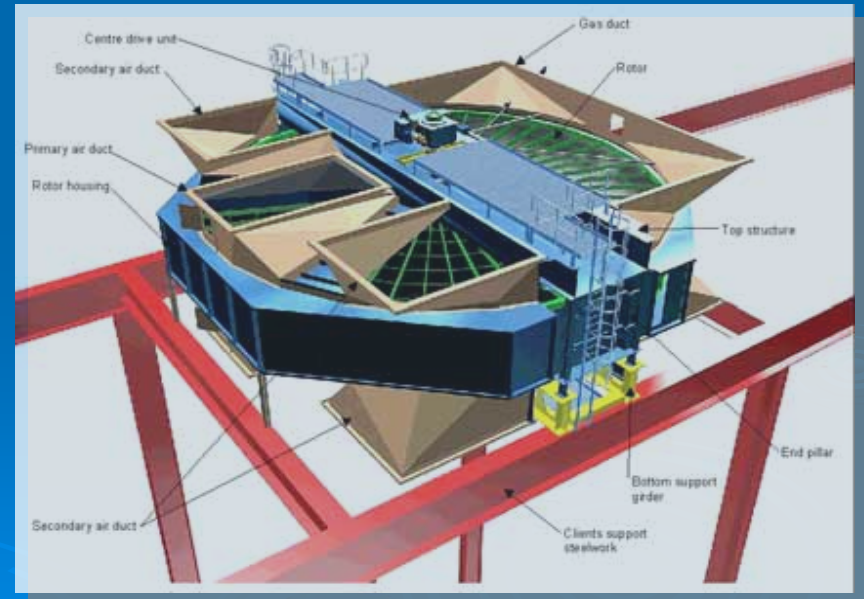


# Air Heater Issues

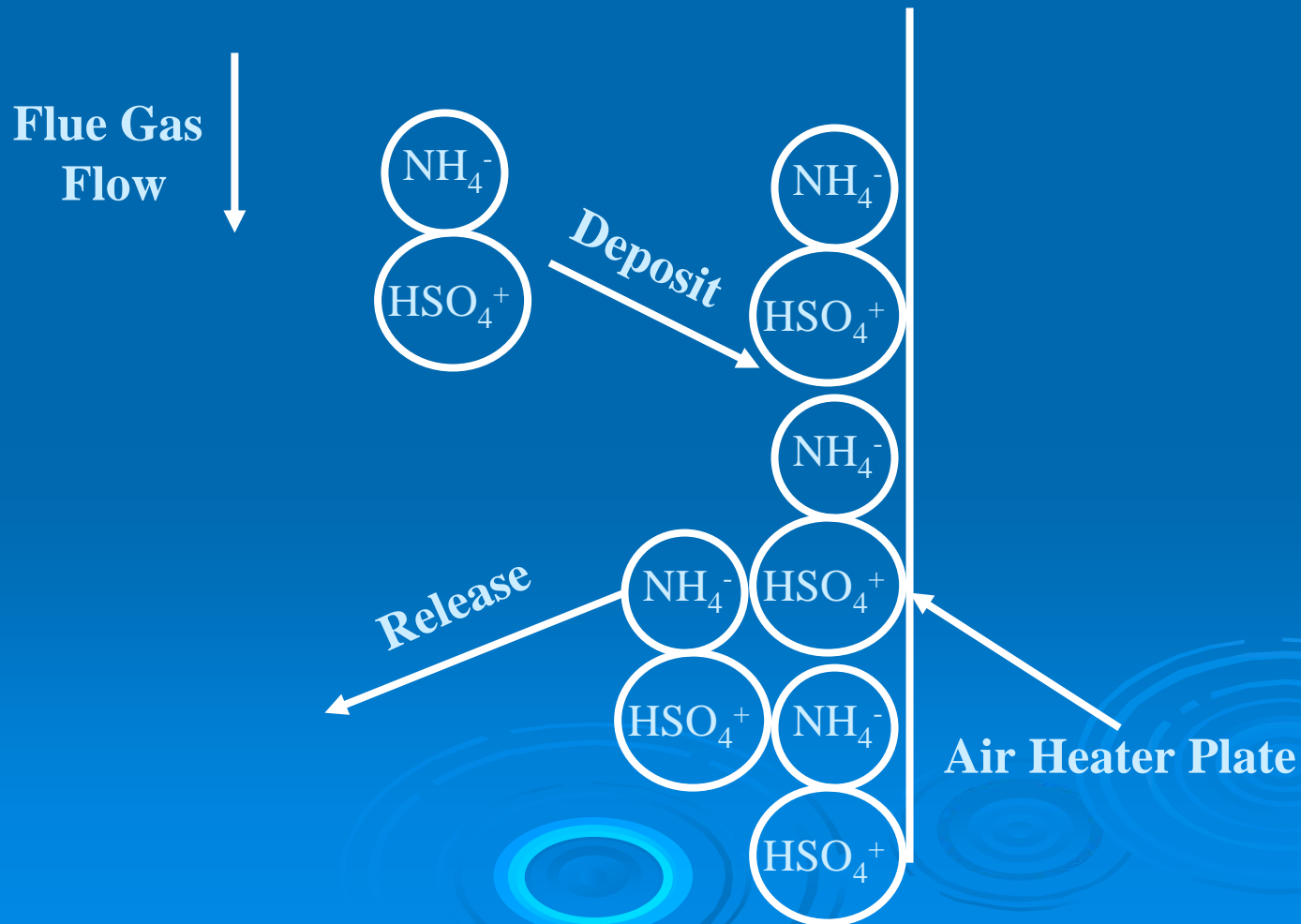


# Design Features of State of the Art Regenerative Air Heaters

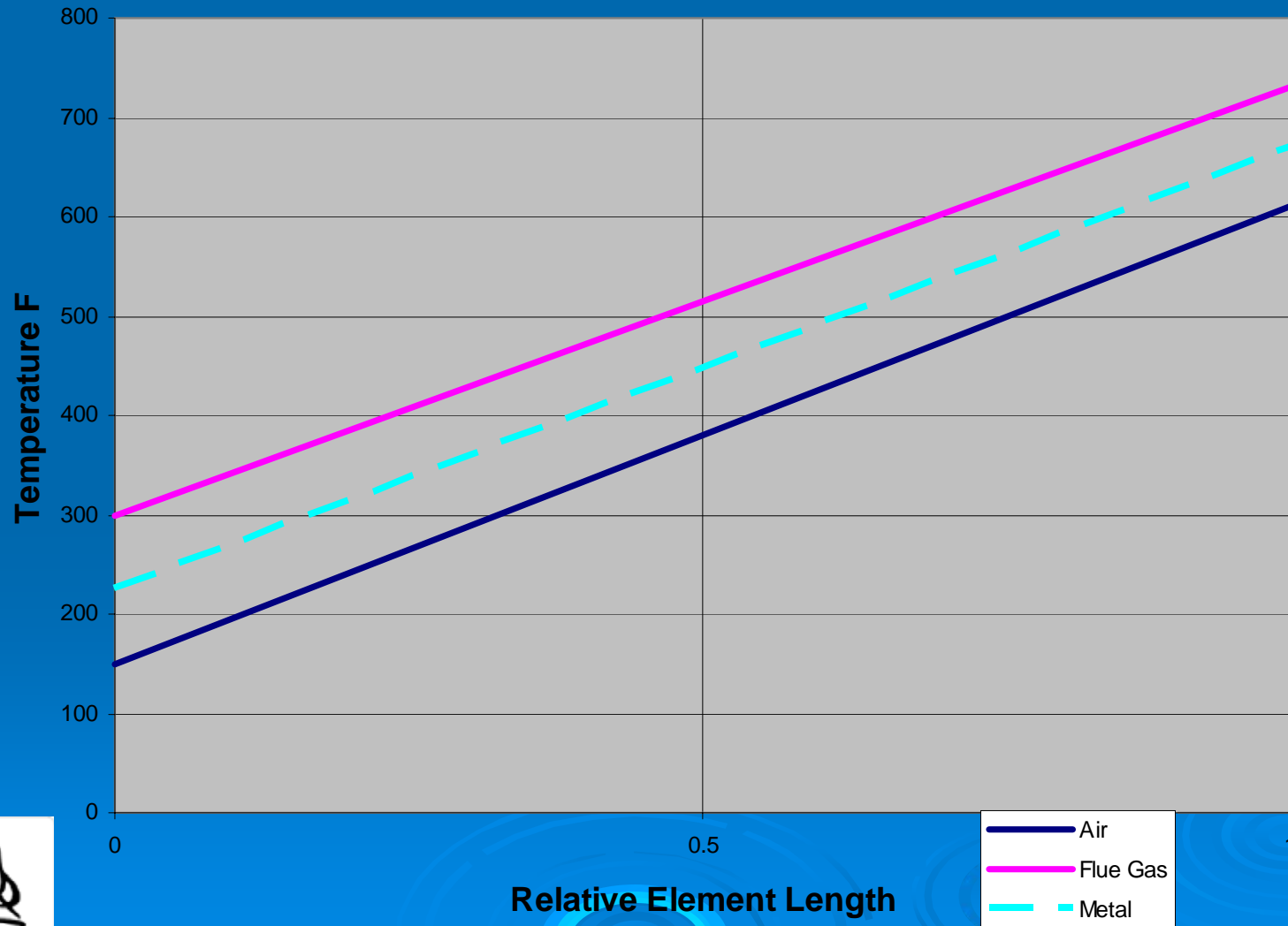
- Two Layer Design
- Enameled Cold End Baskets
- Double Sealing
- Cold End Soot Blowers



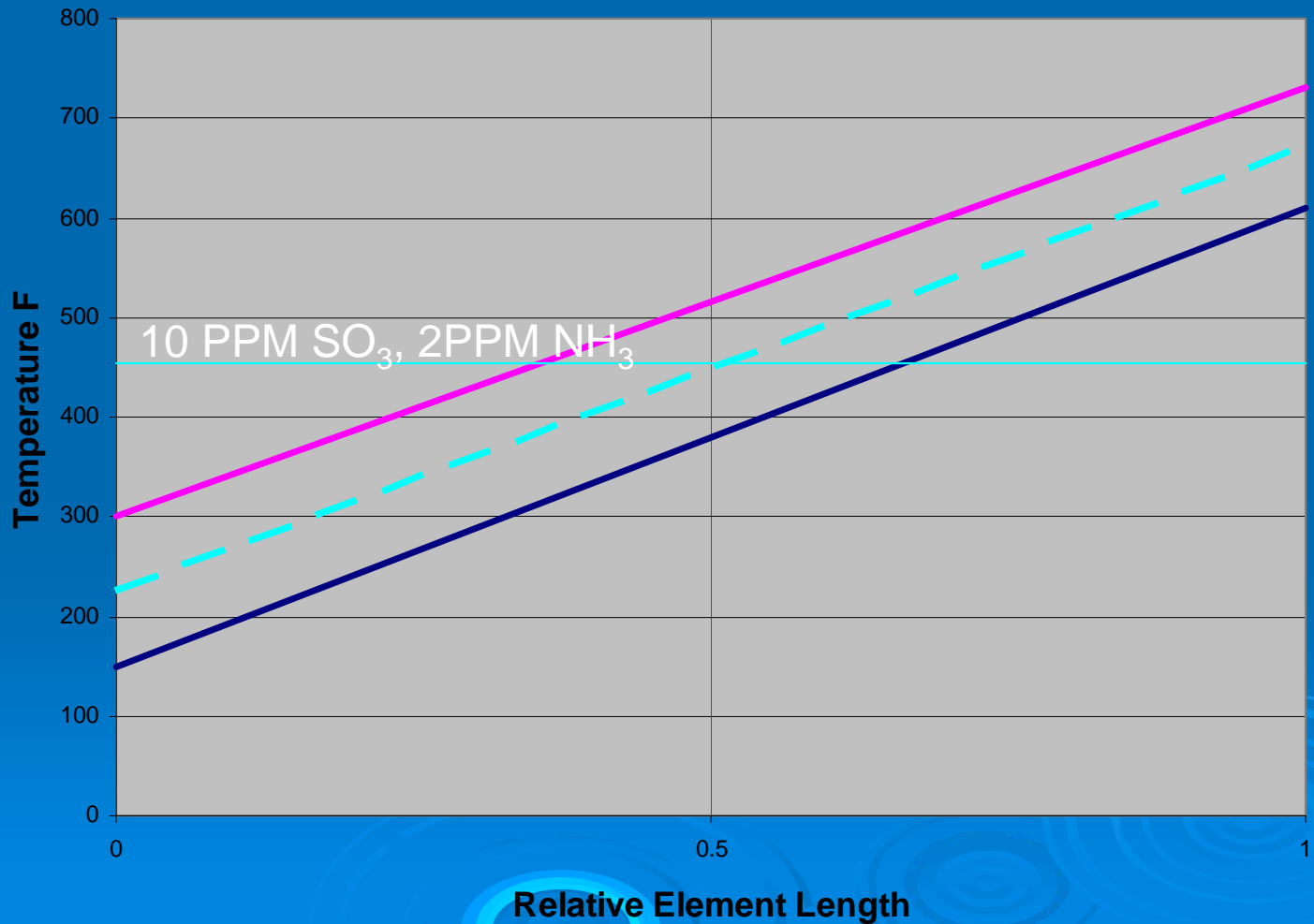
# ABS Deposition on Air Heater Difference of Concentrations



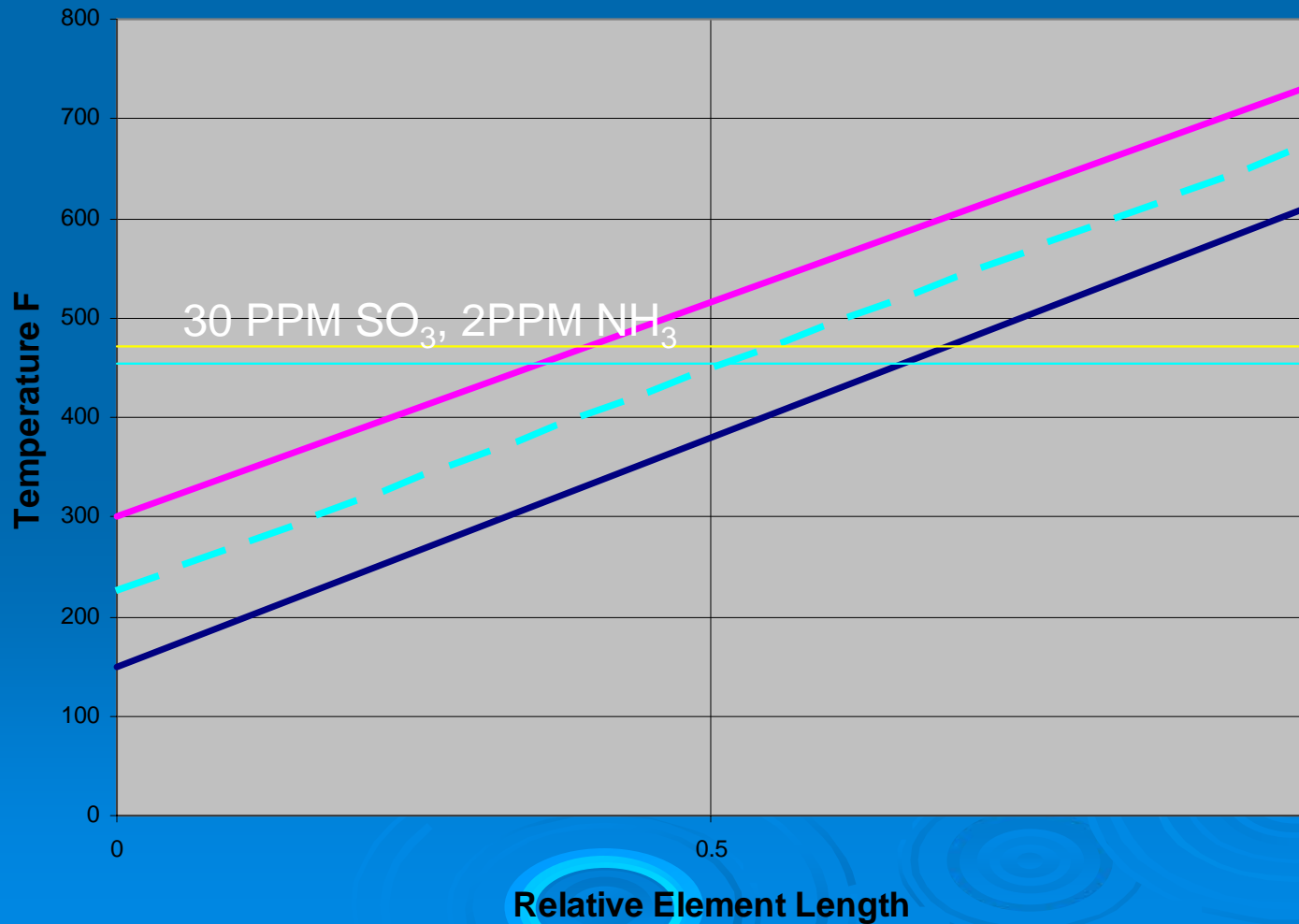
# Average Temperature Profile



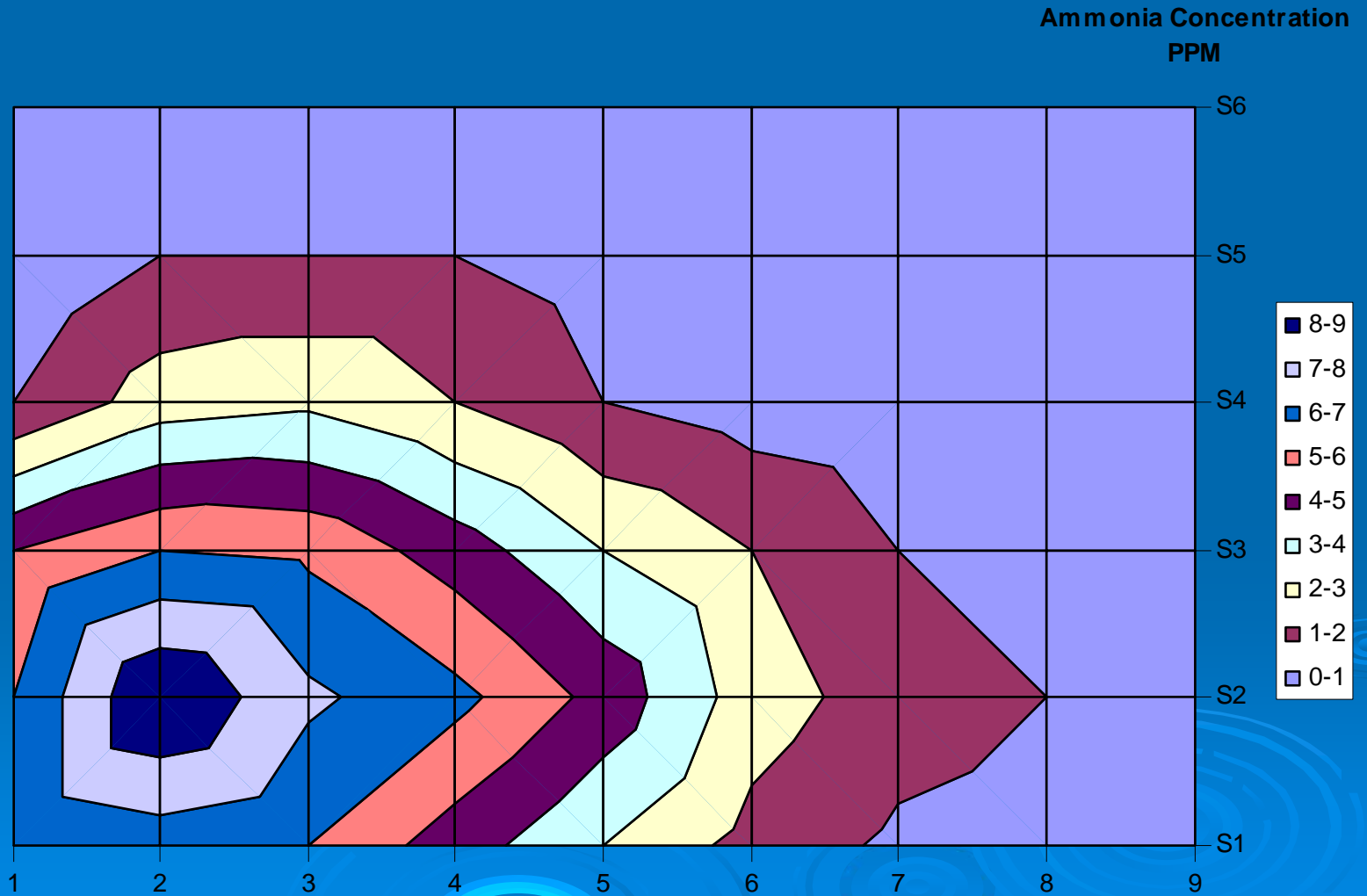
# Example 1



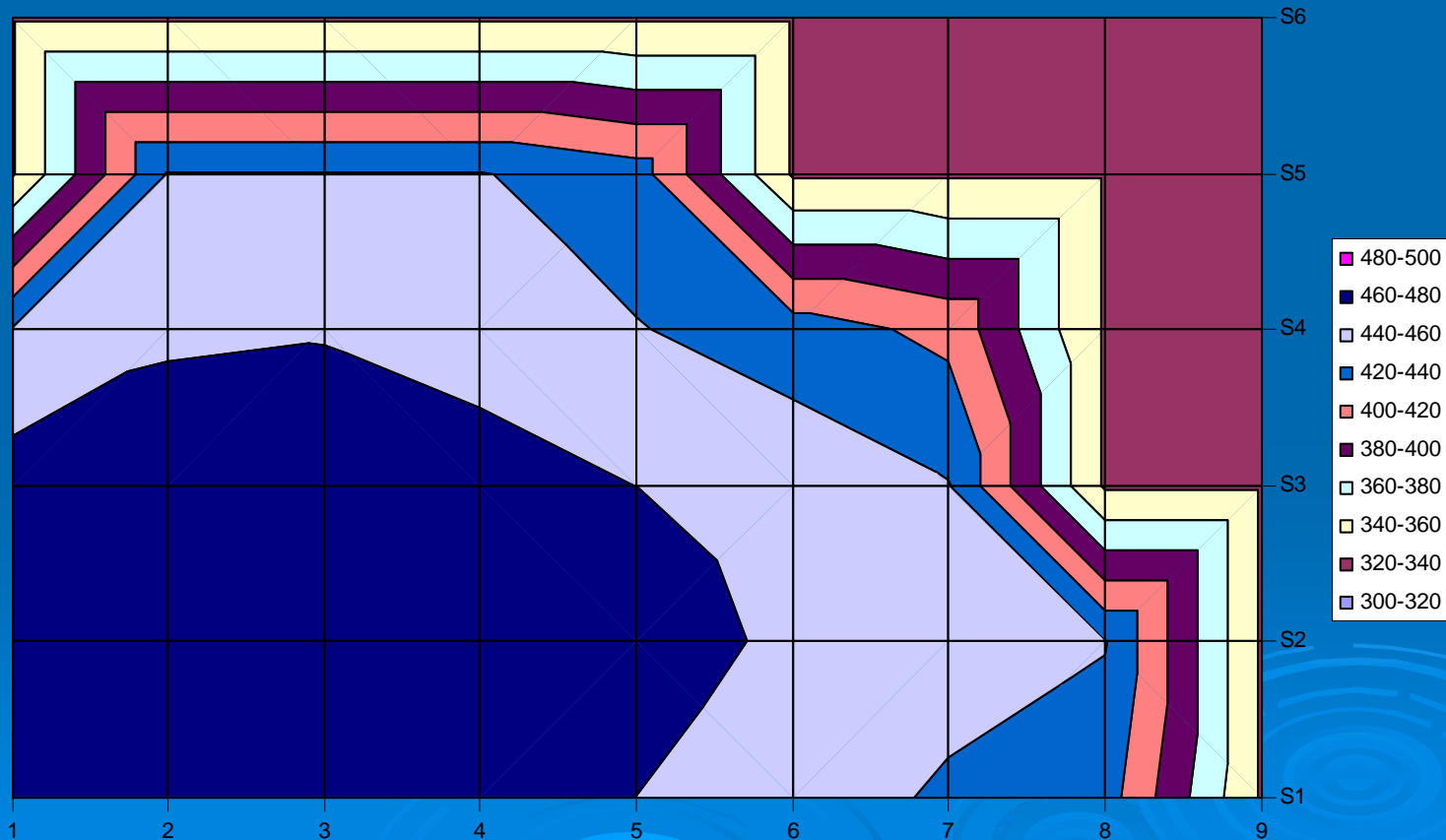
# Example 2



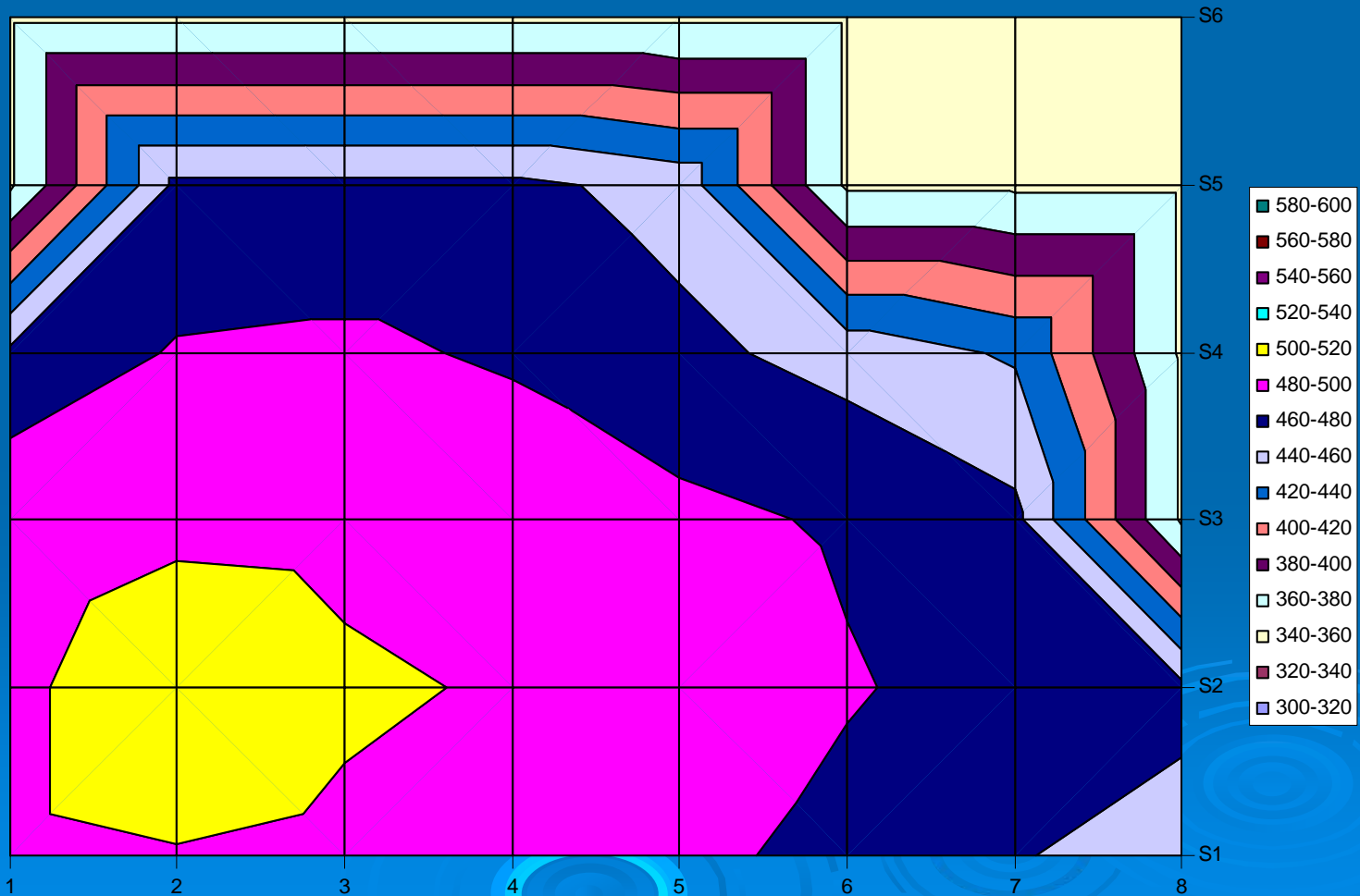
# Ammonia Distribution



# ABS Deposition Temperature (10 PPM SO<sub>3</sub>)



# ABS Deposition Temperature (40 PPM SO<sub>3</sub>)

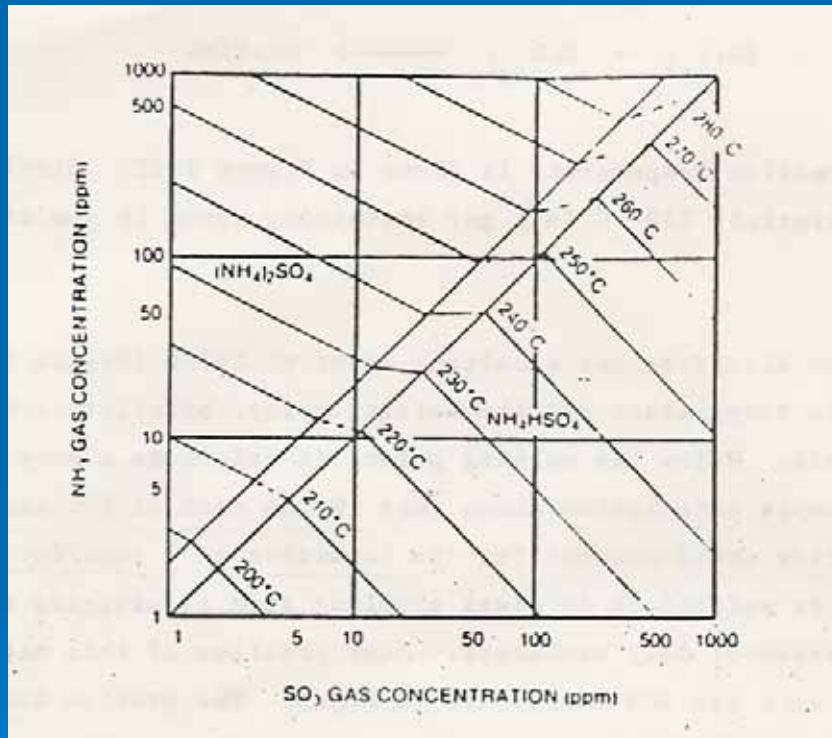


# Limitations of ABS Depositions

- Pressure Drop
- Weight of Deposits



# Ammonium Sulfates



- There Are More Than A Dozen Sulfates Formed From Ammonium, Sulfate, Iron And Alumina
- All of Them But The Ammonium Bi Sulfate Are in The Form of Particulate
- $\text{NH}_4\text{HSO}_4 + \text{NH}_3 \rightarrow (\text{NH}_4)_2\text{SO}_4$

Equilibrium Diagram

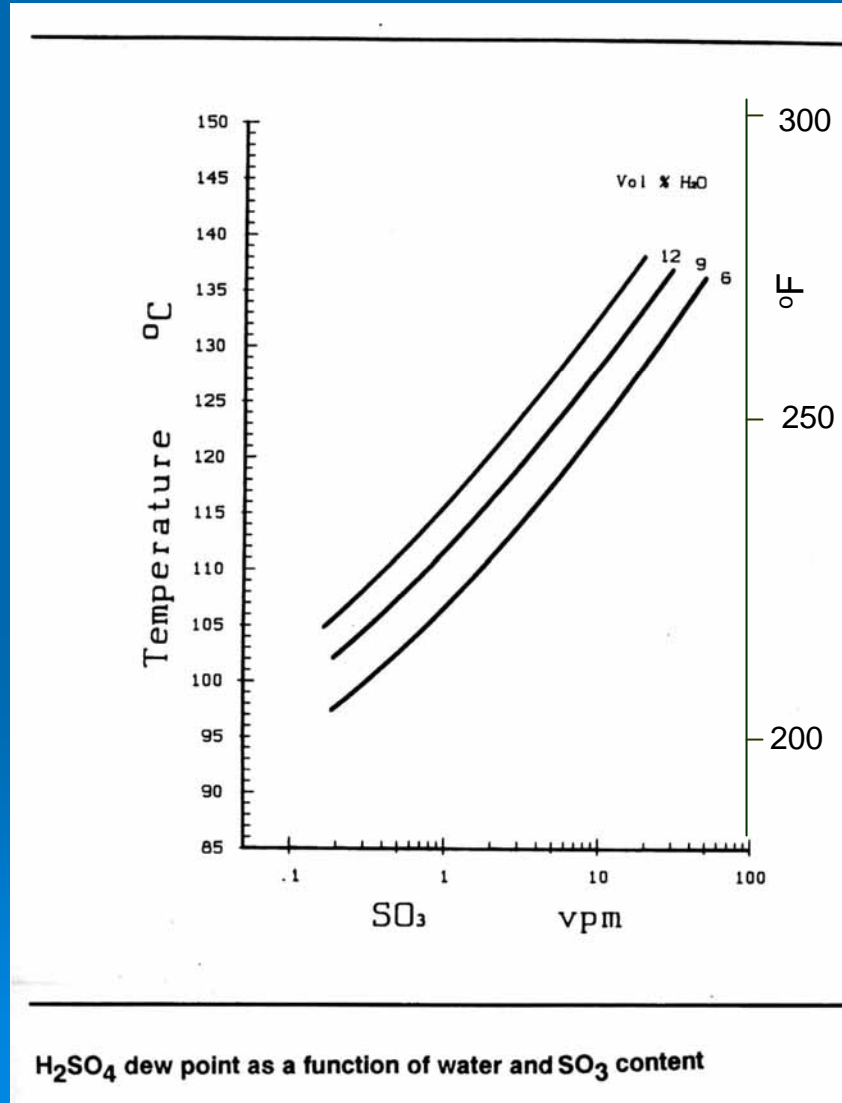


# ABS Summary

- Consequences Are Very Fuel Specific
- Thorough Design Review Is Important
- Pre Heat Coils Can Help to Keep ABS In Lower Layer



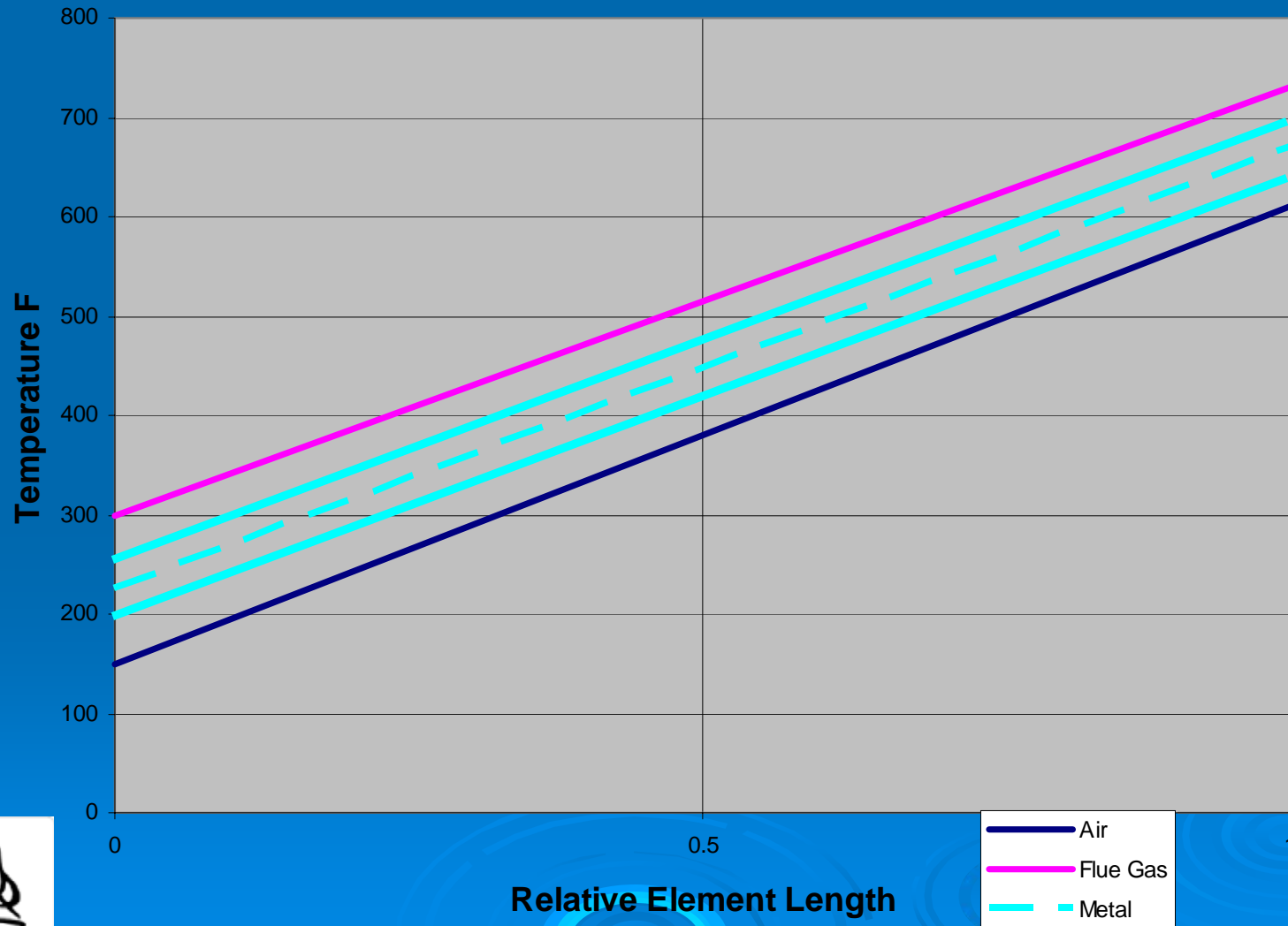
# Acid Dew Point



H<sub>2</sub>SO<sub>4</sub> dew point as a function of water and SO<sub>3</sub> content



# Average Temperature Profile



# Impact on Non Enameled Surfaces



# ABS and Iron Reactions

- $\text{Fe} + 4 \text{NH}_4\text{HSO}_4 \longrightarrow \text{NH}_4\text{FeH}(\text{SO}_4)_2 + (\text{NH}_4)_3\text{H}(\text{SO}_4)_2$
  - $\text{Fe} + 3 \text{NH}_4\text{HSO}_4 \longrightarrow (\text{NH}_4)_2\text{Fe}(\text{SO}_4)_2 + 3/2 \text{H}_2\text{O}$
  - $\text{Fe} + 2 \text{NH}_4\text{HSO}_4 \longrightarrow \text{NH}_4\text{Fe}(\text{SO}_4)_2 + \text{NH}_3 + 3/2 \text{H}_2\text{O}$
- Released Ammonia Reduces pH Value During Washing
  - Lowest Observed Was Well Below 1



# ABS Impact on Different Air Heater Types



# Types of Air Heaters

- Regenerative
  - Ljungstrom
    - Vertical Shaft
    - Horizontal Shaft
  - Rothemuehle
- Tubular Air Heaters
- Plate Type Air Heaters



# Air Heater Cleaning



# Air Heater Cleaning

- On-Line
- Off-Line

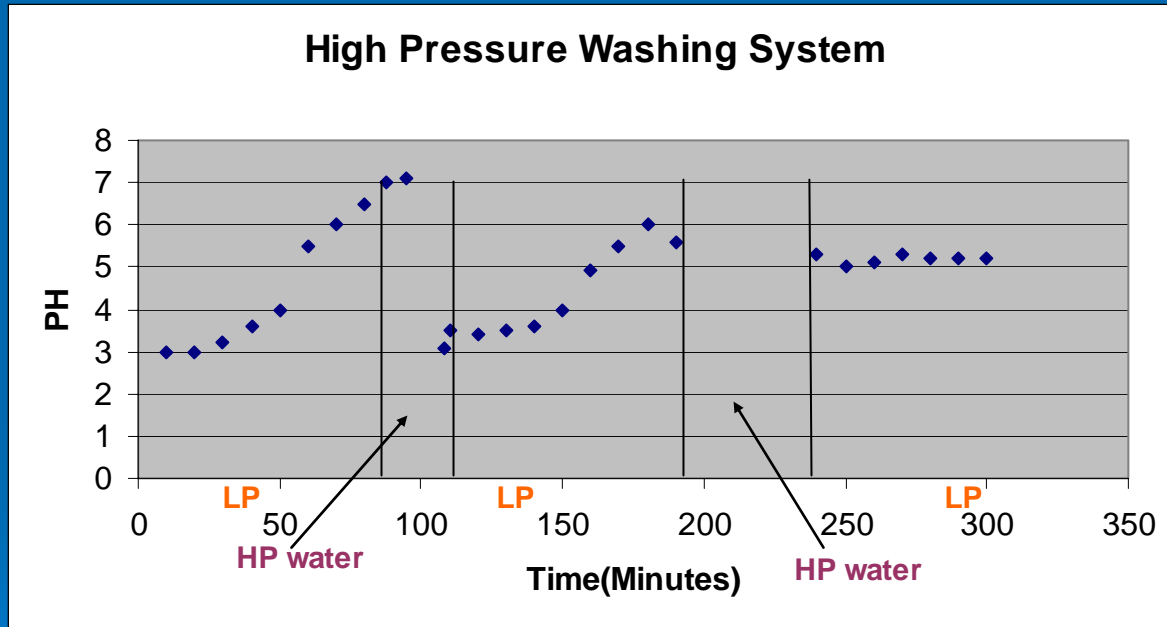


# On-Line Air Heater Cleaning

- Cold End Soot Blowers for  $\text{SO}_3$  Condensation
- Soot Blowers Have No Impact on ABS
- Turn Ammonia Injection Off. Helps, if
  - Plates Enameled
  - Dust Concentration Not Too High
  - No Alkaline Reaction Took Place



# Air Heater Washing Off-Line



# Air Heater Retrofit

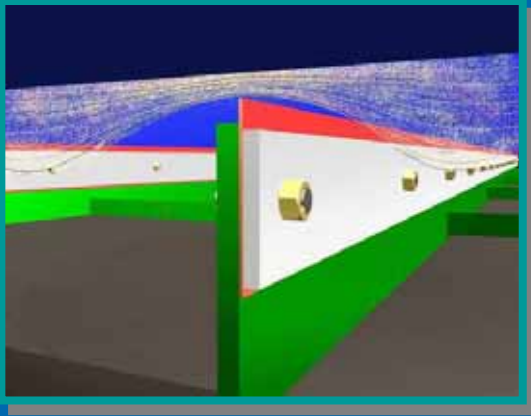


# Air Heater Retrofit for High Sulfur Units

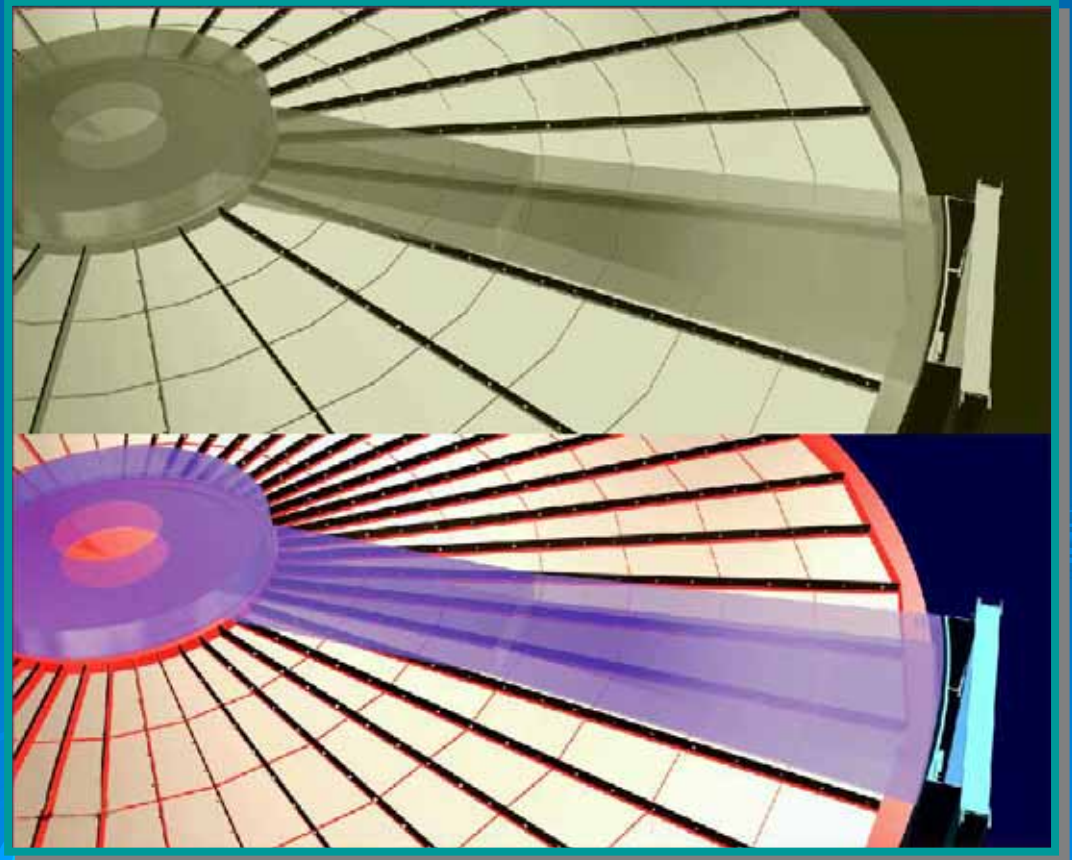
- Cold End Soot Blowers
- Enameled Baskets on Cold End
- Two Layer Design
- Wash Water Provisions
- Calcium Addition
- Disposal Provisions
- Air Pre Heat Coils



# Double sealing (Radial Seals)



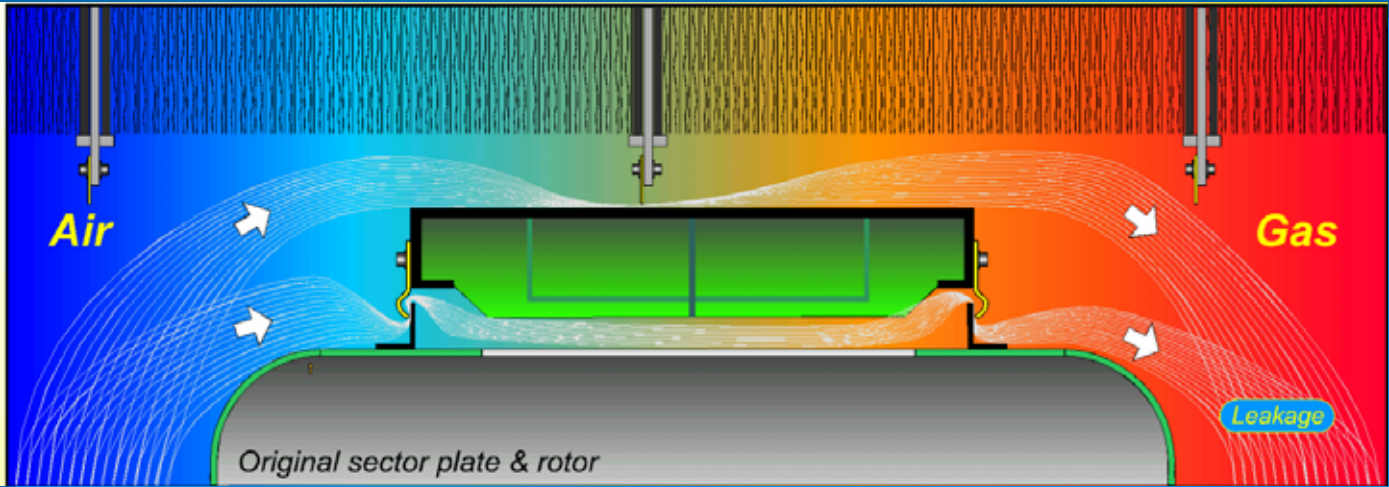
*old single sealing*



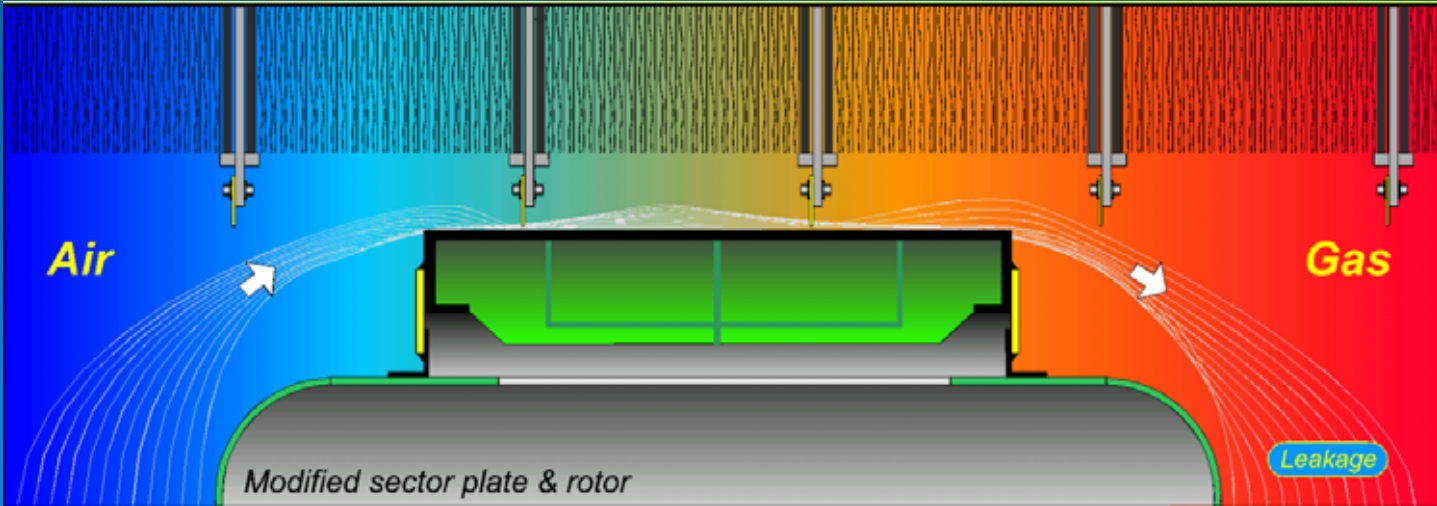
*new double sealing*



# Double Sealing & Fixed Sealing Plates



*Before*



*After*



# Combined Cleaning Device

- Combined soot blower/ HP wash device
- 6 nozzles
- Off-line washing
- On-line washing
- Fully retractable



# Two Examples of SCR Design With Substitution of the Air Heater



# Air Heater Replacement in New Madrid



- Tubular Air Heater replaced with an SCR “ready” Ljungstrom air heater. Exit gas temperatures reduced by approximately 70 degrees F.

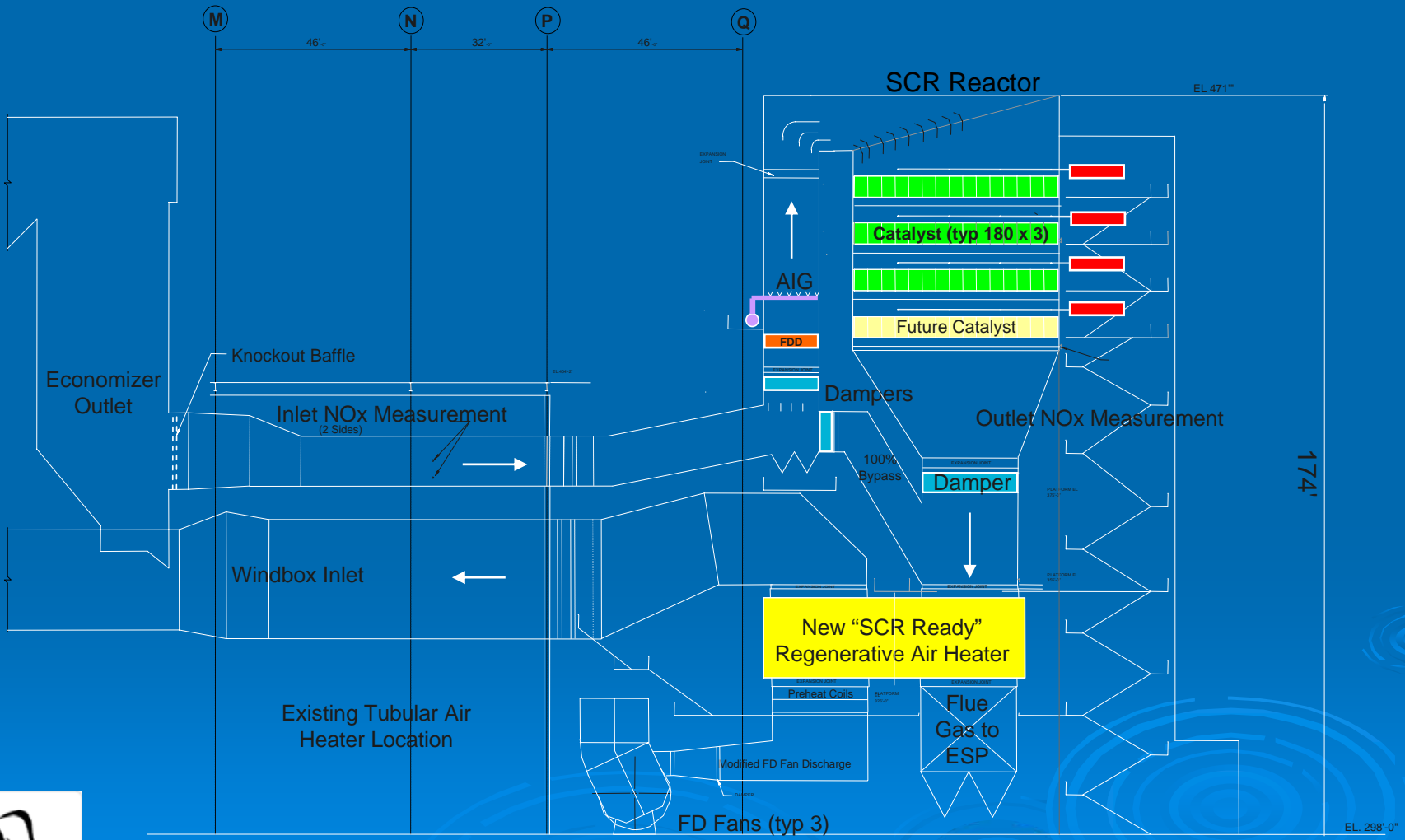


# Review of Plant

- Two 600 MW Units
- Brown Boveri turbine-generators
- B&W cyclone boilers, pressurized.
- Fuel is 100% Powder River Basin coal.
- Uncontrolled NOx emissions average  
...1.25 lbs NOx / MMBTU at 100% MCR.
- Plant is used for load control.



# New Madrid SCR Arrangement



# Catalyst Deactivation & Ammonia Slip

- The ammonia slip for the Unit 2 SCR is averaging 3.2 ppmv @ 93.7% NO<sub>x</sub> reduction with over 13,000 operating hours.
- The ammonia slip for the Unit 1 SCR is averaging 2.1 ppmv @ 93.5% NO<sub>x</sub> reduction with nearly 10,000 operating hours.
- What effects have been witnessed regarding NH<sub>3</sub> slip reacting with SO<sub>3</sub> to form ammonium bisulfate?



# Air Heater Concerns

- The possibility of the air heater plugging due to ammonium bisulfate formation is a concern.
  - The air heaters are equipped with enamel coated cold-end baskets to facilitate in air heater washing.
  - The PRB coal is low in sulfur content.
  - To date, the inspections of the air heaters during maintenance outages have not revealed any ammonium bisulfate deposits.



# New Madrid Results

- More Than 93% NO<sub>x</sub> Reduction
- Less Than 3 PPM Ammonia Slip
- Total Pressure Reduced By 2 I.W.G.



# Thomas Hill Unit 3 SCR Retrofit

- Project Consideration :
  - SCR Retrofit
  - New Tri Sector Air Heater



# Thomas Hill Unit 3 Overview

- 715 MW
- Balanced Draft
- Babcock & Wilcox PC Unit
- Existing Rothemuehle Air Heaters
- SCR Under Design by Burns & McDonnell



# Unit 3 Cost/Benefit Analysis

## Air Heater Replacement

- Opportunity for Improvement
  - Reduce leakage by  $2/3$
  - Reduce fan horsepower
  - Reduce pressure drop
  - Reduce forced outages
  - Reduce load limitations
  - Reduce construction outage time
  - Reduced maintenance
  - Use FD Fan Margin for Tuning of New LNB



# Unit 3 Cost/Benefit Analysis

## ➤ New Air Heater Capital Cost

\$4 M material new air heaters

\$4 M installation

\$0.2 M shipping

\$8.2 M

-\$4.5M old Air Heater rebuild costs

\$3.7M

-\$1.2M cost of 2 new 1700HP fans & Motors

**\$2.5 M for Air Heaters**



# Unit 3 Cost/Benefit Analysis

## ➤ Annual operating cost savings

\$0.8M HP reduction

\$ Reduced Outage Time

\$ Reduced forced outages

\$ Reduced load limitations

\$ Potential for ESP Rebuild w/no new fans



# Unit 3 Cost/Benefit Analysis

## ➤ Assumptions

- \$25/MWh replacement power cost
- Eliminate 2/3 of AH leakage
- New AH DP + SCR DP = existing AH DP
- \$0.95/mmBtu fuel cost
- 10,750 Btu/kWh Unit Heat Rate
- 80% CF, 3% inflation, 7% interest



# Conclusion

- ABS Formation Can Be Avoided
  - By Keeping The Ammonia Slip Under a Certain Level For the Specific Fuel
  - Maintain a Uniform  $\text{NO}_x$ ,  $\text{NH}_3$  Outlet Profile
- $\text{SO}_3$  Cold End Fouling Can Be Avoided By Proper Air Heater Design
- SCR Upgrade or Replacement is Very Site Specific for SCR Retrofits
- Recommended Upgrades for SCR Retrofit
  - Double Seals
  - Cold End Soot Blowers
- Investigate Air Heater Replacement

