"Benefits of Effective SO_3 Removal in Coal-Fired Power Plants: Beyond Opacity Control"

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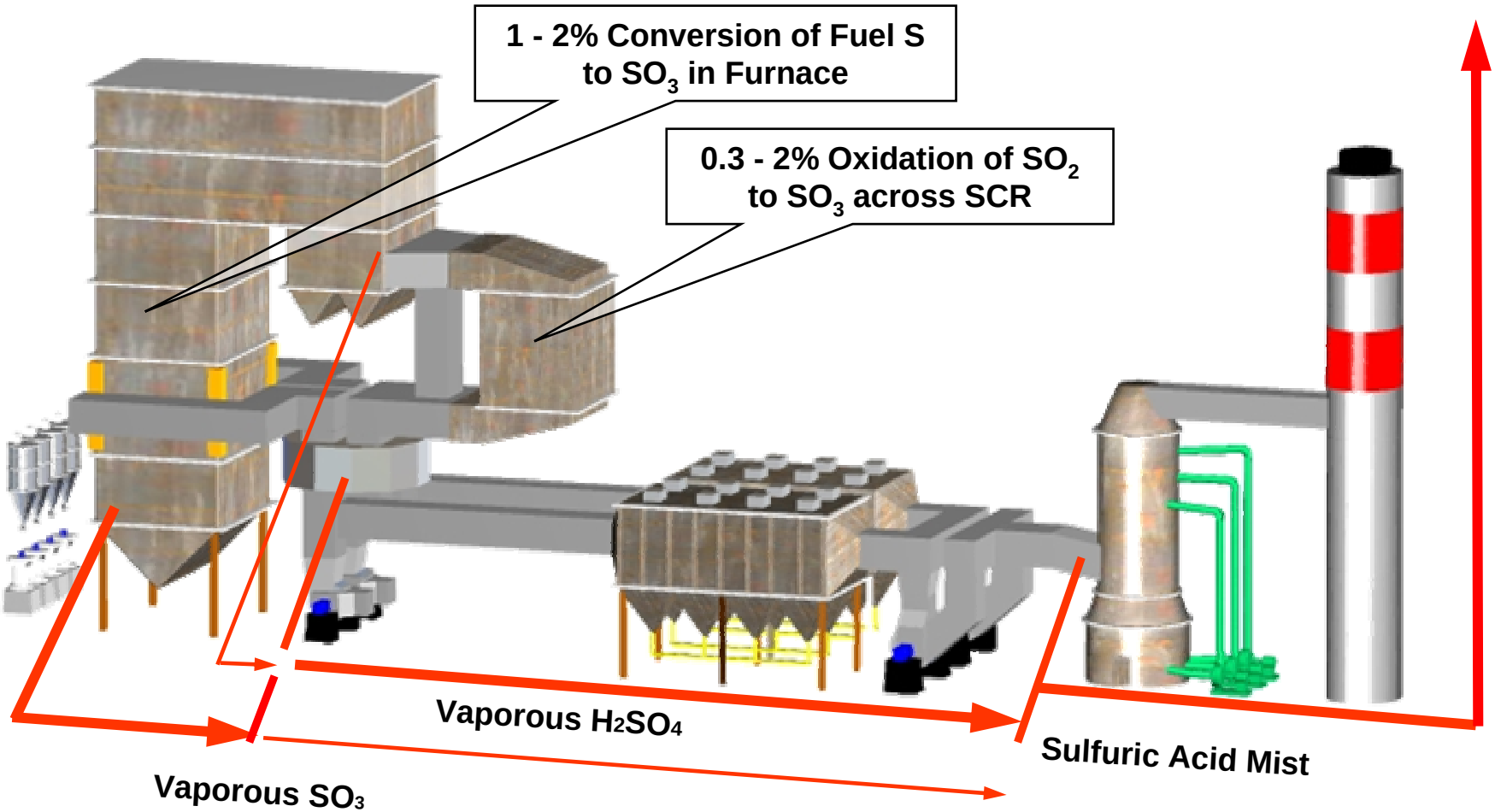
Presentation Outline

- Background Information
- Impacts Created by Presence of SO_3
- Benefits of Effective Removal of SO_3
- Requirements of SO_3 Removal Technology
- Summary

Generation of SO_3 and Physical Form



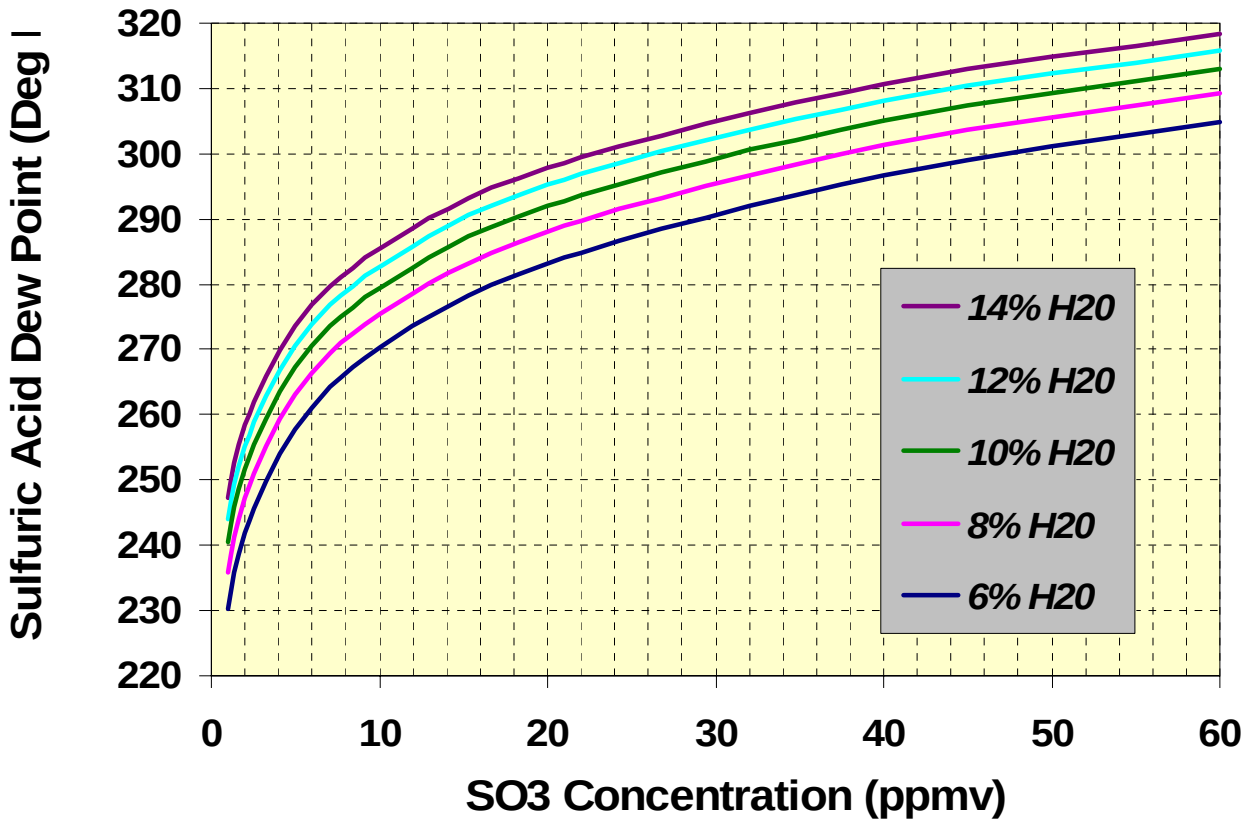
Impacts Created by Presence of SO_3

- Plume Opacity Issue: Coloration of plume from optical light scattering effects of sulfuric acid aerosol particles

Sulfuric acid opacity can be visible when SO_3 > 5ppm

Impacts Created by Presence of SO_3

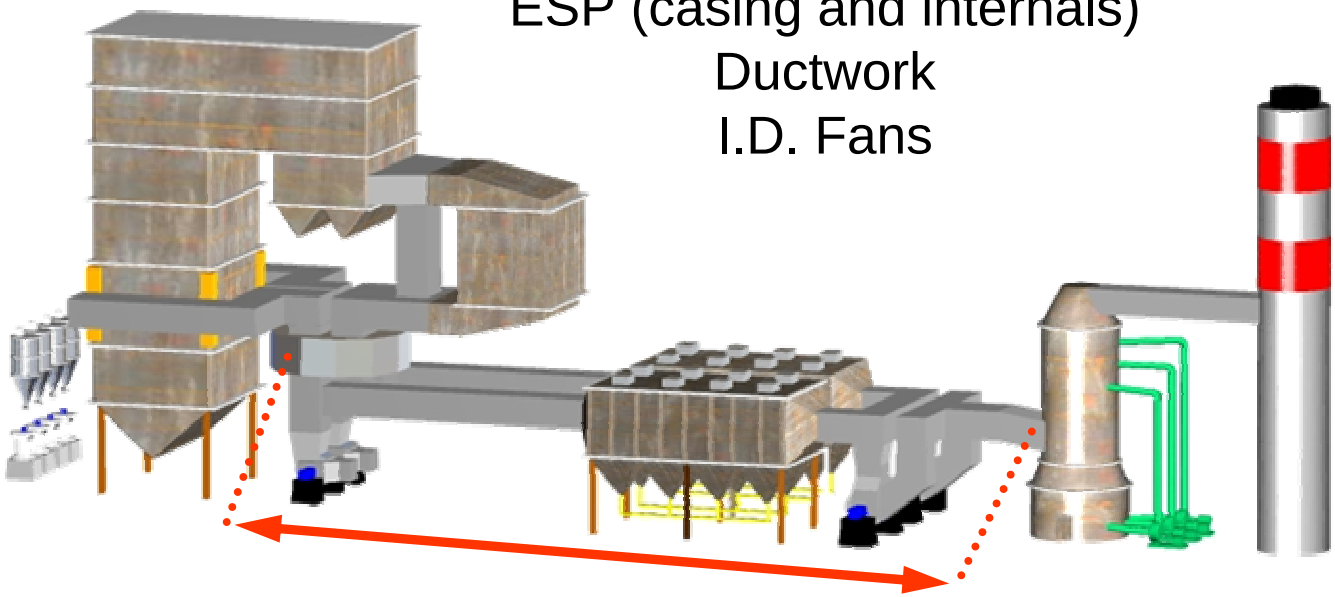
- Plume Opacity Effects
- Effect of SO_3 on Sulfuric Acid Dew Point



Increased SO_3: Acid Dew Point Implications

Increased Acid Corrosion of all Back-end Components

Air heater cold-end baskets
ESP (casing and internals)
Ductwork
I.D. Fans



Increasing air heater outlet temperature negatively affects heat rate
(Change of 35°F = 1% change in heat rate)

Impacts Created by Presence of SO_3

- Plume Opacity Effects
- Acid Dew Point Effects
  - ✓ Corrosion and/or Heat Rate Issues
- Reaction with Ammonia to form ABS
  - ✓ Occurs as gas cools in air heater
  - ✓ Can cause air heater fouling
  - ✓ Limiting factor in SCR design
  - ✓ Limiting factor in SCR operating flexibility

Impacts Created by Presence of SO_3

- Plume Opacity Effects
- Acid Dew Point Effects: Corrosion/Heat Rate Issues
- Reaction with NH_3: Air heater fouling/SCR Implications
- Deactivation of SCR Catalyst
  - ✓ SO_3 reacts with NH_3 to from ABS under catalytic conditions
  - ✓ At cooler temperatures (~570-620°F) and as a function of SO_3 concentration, ABS causes deactivation of catalyst through capillary condensation
  - ✓ SO_3 concentration at SCR inlet determines minimum operating temperature of SCR

Impacts Created by Presence of SO_3

- Plume Opacity Effects
- Acid Dew Point Effects: Corrosion/Heat Rate Issues
- Reaction with NH_3: Air heater fouling/SCR Implications
- Reaction with NH_3: SCR catalyst deactivation
- Impacts on use of fabric filters
  - ✓ Corrosion issue (casing/components/bags)
  - ✓ Effects on filter cake properties
    - × Cake heavier, more sticky, more difficult to remove
    - × Implications on cleaning frequency/pressure drop

Impacts Created by Presence of SO_3

- Plume Opacity Effects
- Acid Dew Point Effects: Corrosion/Heat Rate Issues
- Reaction with NH_3: Air heater fouling/SCR Implications
- Reaction with NH_3: SCR catalyst deactivation
- Negative impacts on use of fabric filters
- Adsorption on fly ash or activated carbon
  - ✓ By occupying these active adsorption sites, reduces ability of flyash/activated carbon to remove mercury

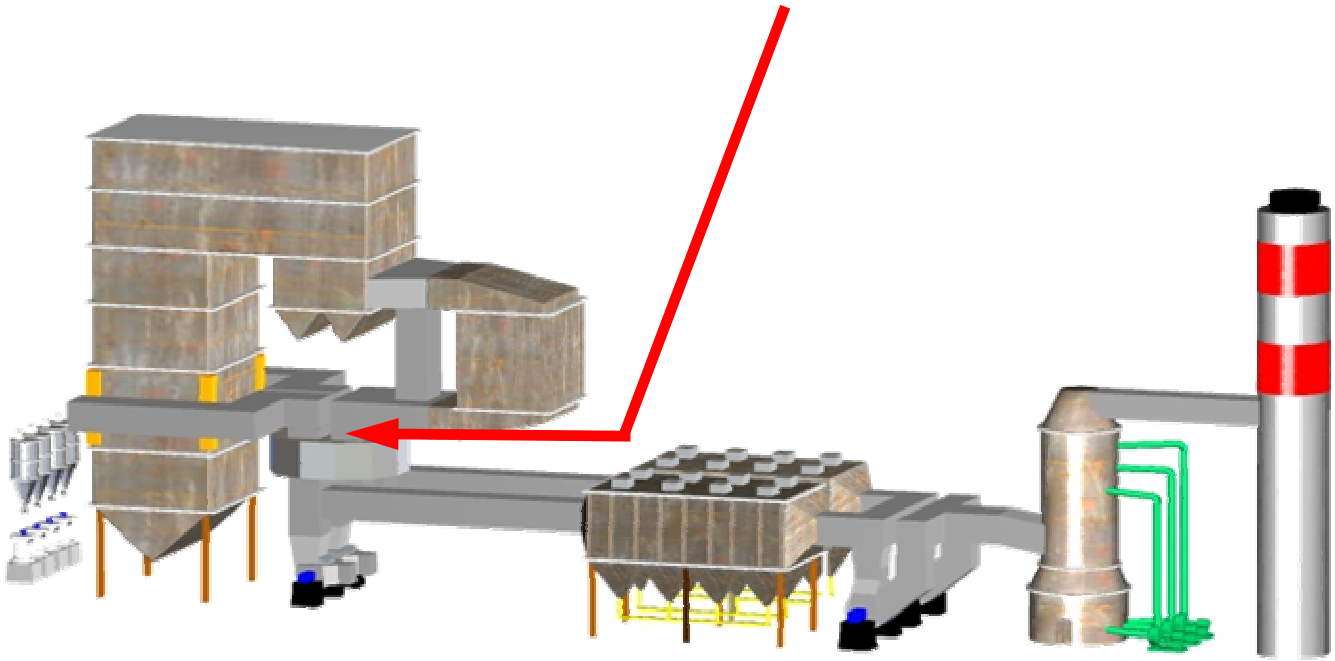
Impacts Created by Presence of SO_3

- Plume Opacity Effects
- Acid Dew Point Issues: Corrosion/Heat Rate
- Reaction with NH_3: Air heater/SCR implications
- Limits SCR minimum temp/affects catalyst life
- Negative impacts on use of fabric filters
- Reduces Hg retention by fly ash/activated carbon.
- Improves ESP particulate removal efficiency
  - ✓ Increases resistivity of fly ash, making collection more efficient

“Effective SO_3 Removal”

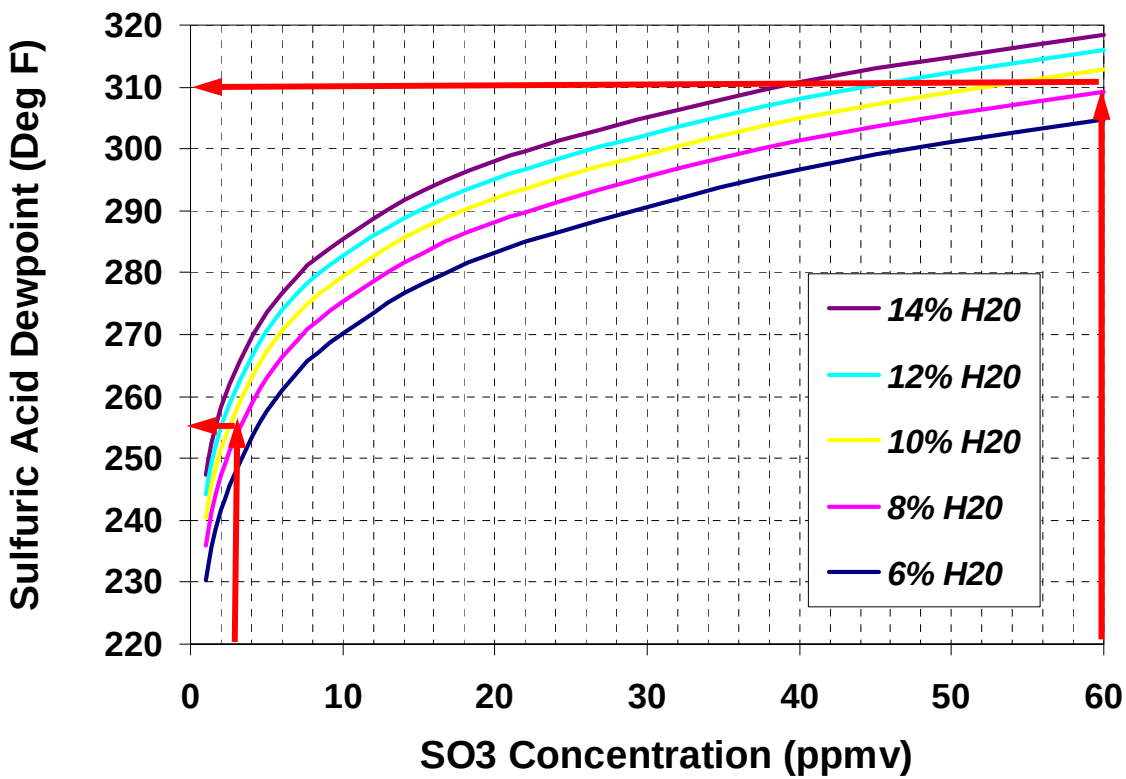
Quick, efficient removal of SO_3

Less than 3 ppm entering air heater



O&M Benefits of Effective SO_3 Removal

- Benefits from reduced acid dew point



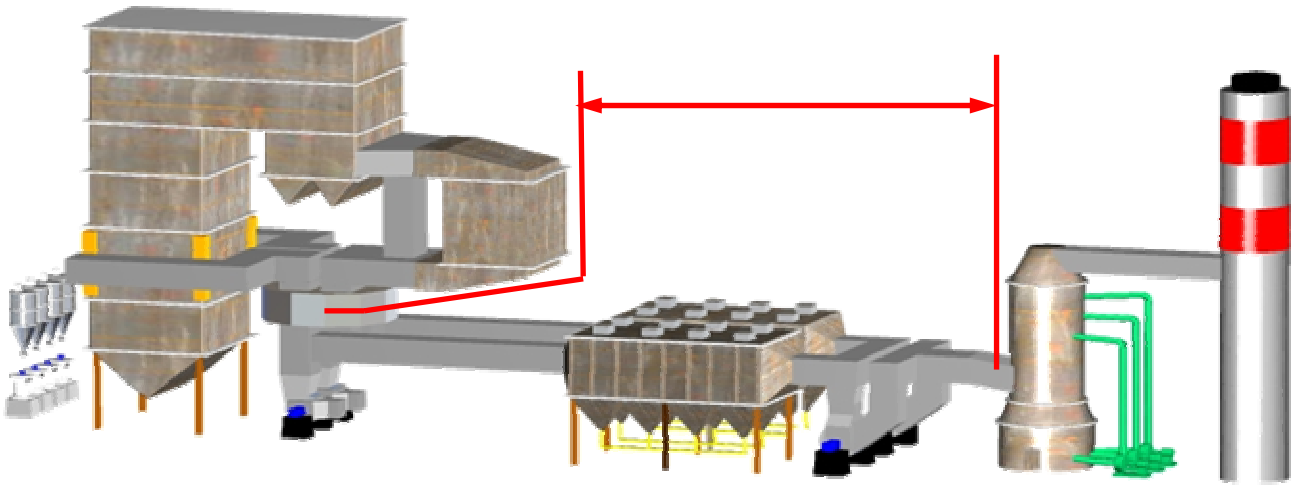
at 8% H_2O

310°F @ 60 ppm

255°F @ 3 ppm

O&M Benefits of Effective SO_3 Removal

- Benefits from reduced acid dew point
  - ✓ Reduced sulfuric acid corrosion for entire backend
    - Reduced dew point = lower potential for corrosion conditions
    - If conditions do occur, only 1/20 amount of acid present
    - Could eliminate need for enamel coating of air heater cold end baskets



Value site-specific: could easily exceed $500k/yr

O&M Benefits of Effective SO_3 Removal

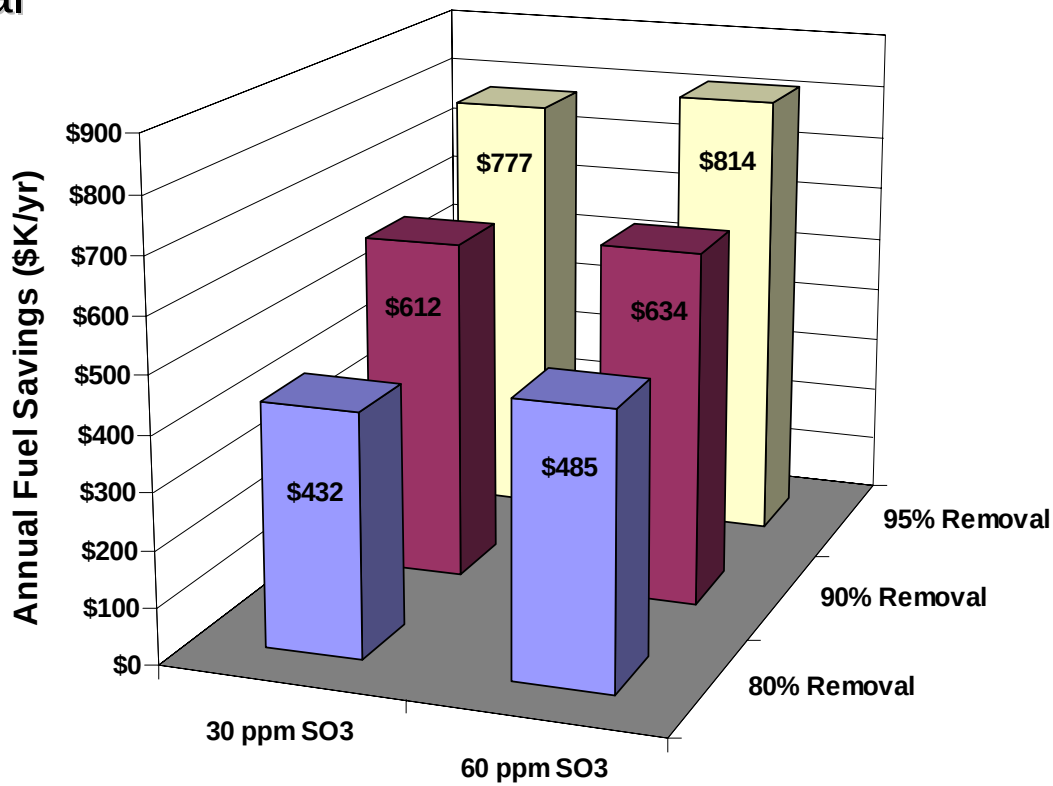
- Benefits from reduced acid dew point
  - ✓ Operate air heater at lower outlet gas temperature

Improve unit heat rate

Basket modifications may be required to achieve this.

Heat Rate Improvement Analysis

- Approach
  - ✓ Effective SO_3 removal
  - ✓ Lower dew point
  - ✓ Lower AH out temp
  - ✓ 35F ~ 1% efficiency
- Basis
  - ✓ 500 MW
  - ✓ 9500 Btu/KW-hr
  - ✓ $1.80/MMBtu
  - ✓ 80% Cap Factor

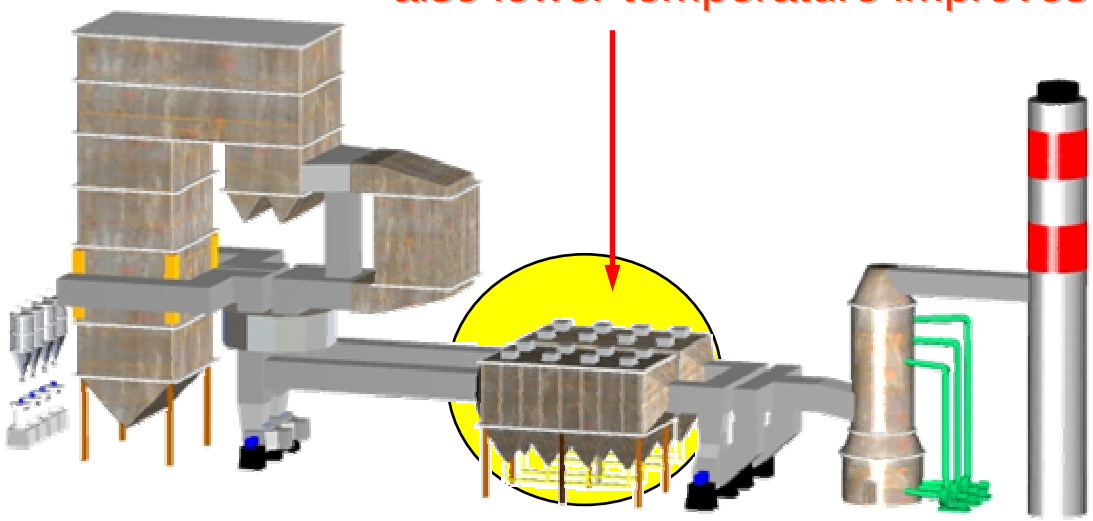


Fuel Savings > $750k/yr

O&M Benefits of Effective SO_3 Removal

- Benefits from reduced acid dew point
  - ✓ Operate air heater at lower outlet gas temperature
    - × Reduce gas volume (from 310F to 255F = ~7% decrease)

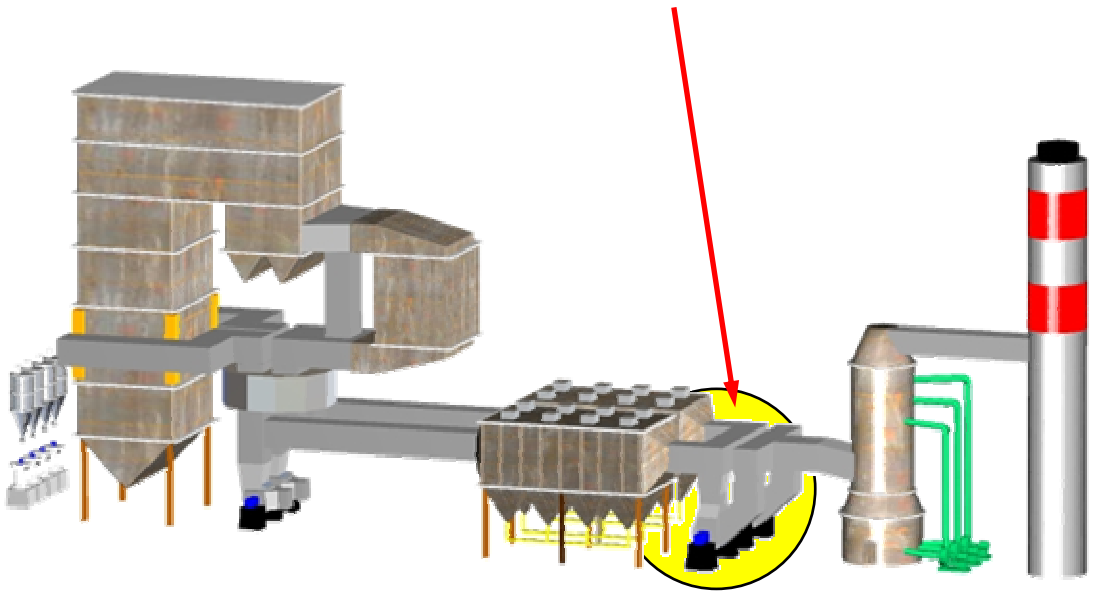
Increase ESP collection efficiency by:
-- increasing specific collection area (SCA)
-- also lower temperature improves fly ash resistivty



O&M Benefits of Effective SO_3 Removal

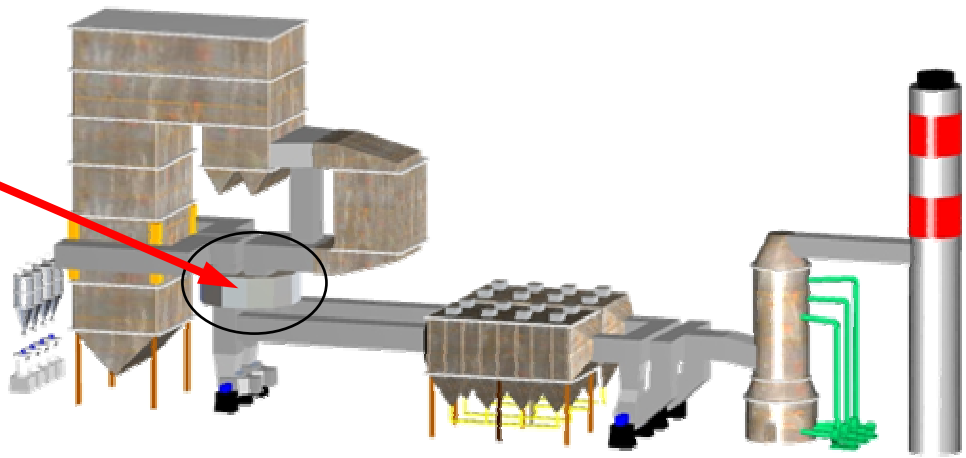
- Benefits from reduced acid dew point
  - ✓ Operate air heater at lower outlet gas temperature
    - × Reduce gas volume (from 310F to 255F = ~7% decrease)

Reduce I.D. fan energy consumption



O&M Benefits of Effective SO_3 Removal

- Benefits from eliminating formation of ammonium bisulfate (ABS) via NH_3:SO_3 reaction
  - ✓ Eliminate air heater ABS fouling issues
    - With low SO_3 concentrations, driving force for this reaction is small
    - If NH_3 concentration is > 2 times SO_3 concentration, ammonium sulfate formation is favored
    - Ammonium sulfate solids not an issue for air heater fouling



O&M Benefits of Effective SO_3 Removal

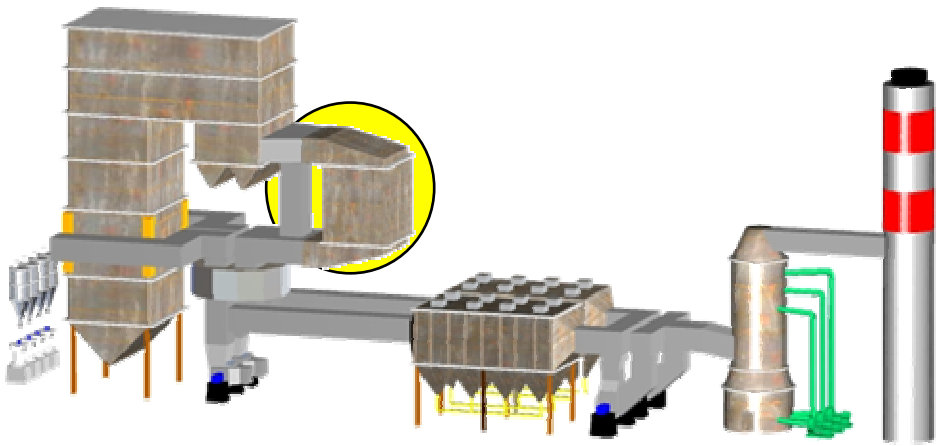
- Benefits from elimination of NH_3:SO_3 reaction

With respect to SCR:

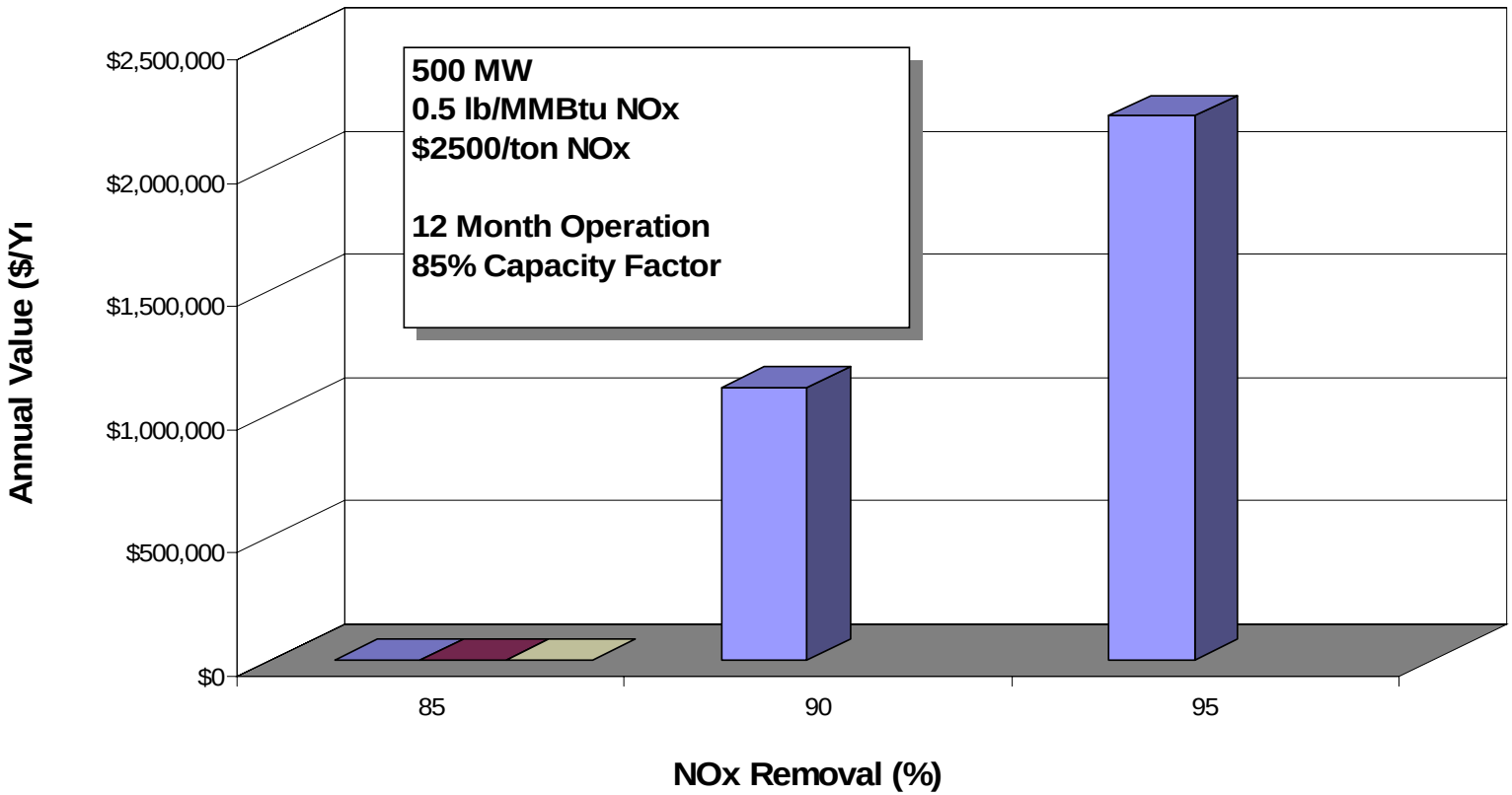
Maintaining 1 to 2 ppm max slip no longer critical

Increasing slip modestly (to ~4-6 ppm) provides operating flexibility

-- Improve NOx removal efficiency and generate saleable credits



SCR Improvement Analysis – Removal



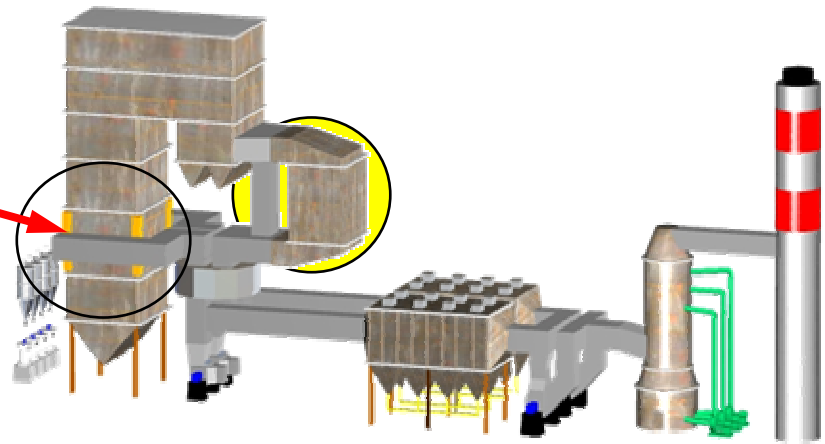
Incremental NOx Removal Value =
~ $220k per 1% Improvement per yr

O&M Benefits of Effective SO_3 Removal

- Benefits from Increasing SCR NH_3 slip

Improve NOx removal efficiency

-- Reduce Low-NOx combustion staging and allow SCR to remove add'l NOx



Improve heat rate by reduction of unburned carbon;
for 500 MW unit, 1% improvement > $500/yr benefit

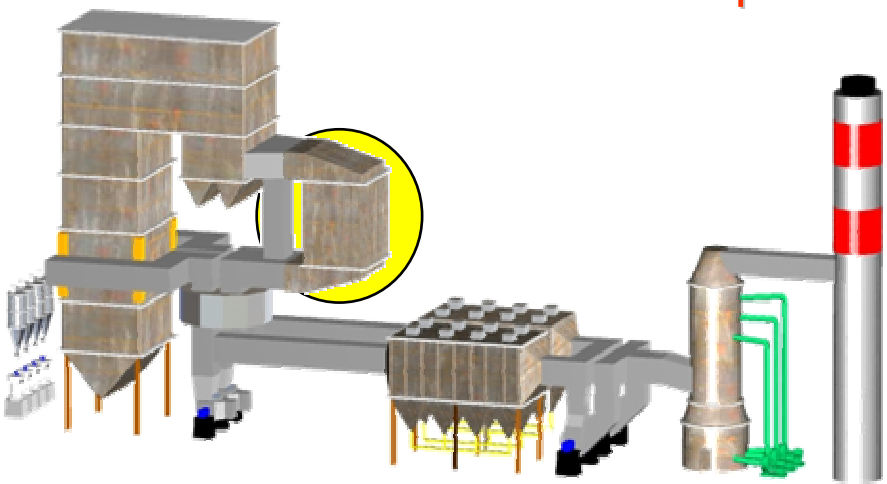
Reduce fireside corrosion, water wall losses & tube leak occurrences;
forced outage = $400k - $600k per occurrence

O&M Benefits of Effective SO_3 Removal

- Benefits from Increasing SCR NH_3 slip

Improve NOx removal efficiency
-- generate saleable NOx credits
-- improve heat rate via reduced combustion staging
-- reduce fireside corrosion via reduced combustion staging

Provide flexibility in catalyst management program
-- allow adequate NOx removal at lower catalyst activity
-- fewer catalyst replacements

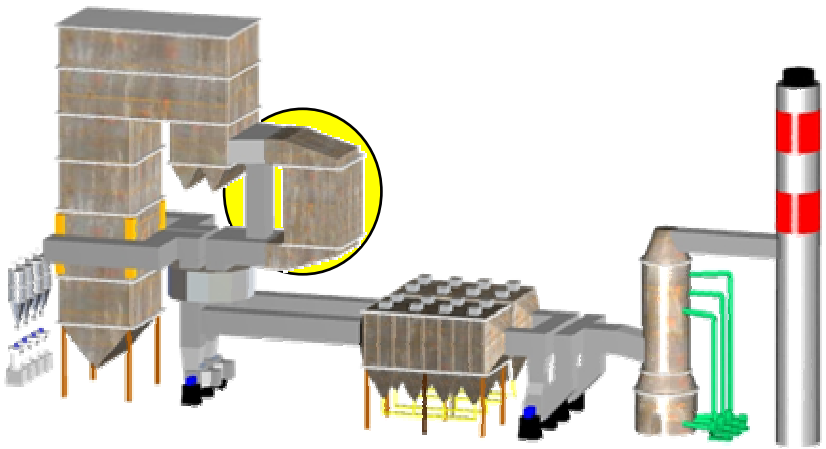


O&M Benefits of Effective SO_3 Removal

- Benefits from Increasing SCR NH_3 slip

Improve NOx removal efficiency
-- generate saleable NOx credits
-- improve heat rate via reduced combustion staging
-- reduce fireside corrosion via reduced combustion staging

Provide flexibility in catalyst management program
-- allow adequate NOx removal at lower catalyst activity
-- fewer catalyst replacements
-- extend catalyst useful life
until planned outage



O&M Benefits of Effective SO_3 Removal

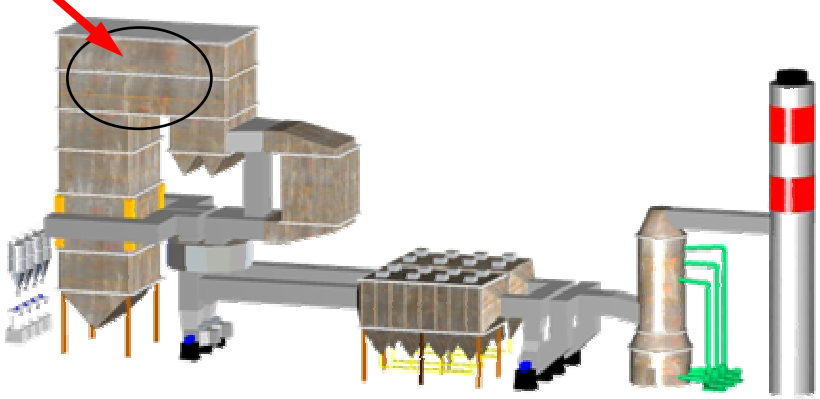
- For SCR catalyst, if SO_2 to SO_3 can be evaluated as an economic variable, then:
  - ✓ Use of high activity catalysts can be reconsidered
    - For new SCRs, less catalyst required or higher NOx removal designs possible
    - For existing SCRs, replacement with higher activity catalyst can improve NOx removal efficiency

O&M Benefits of Effective SO_3 Removal

- For SCR catalyst, if SO_2 to SO_3 can be evaluated as an economic variable then:
  - ✓ Use of catalysts with high NOx reduction capabilities can be reconsidered
  - ✓ Mercury and SO_2 oxidation and can be "decoupled"
    - × Catalysts which can achieve high NOx removal and very high Hg oxidation can be considered, with SO_2 oxidation as an economic factor, not an absolute constraint
    - × Valuable for high chloride coals where FGD capture of oxidized Hg important

O&M Benefits of Effective SO_3 Removal

- Benefits from eliminating formation of ammonium bisulfate (ABS) via NH_3:SO_3 reaction
  - ✓ With respect to SNCR technology
    - NH_3 slip and ABS issues limit NOx removal efficiency and applicability of technology to low sulfur coals
    - By eliminating SO_3, SNCR can achieve higher NOx removals and be applicable to higher sulfur coals



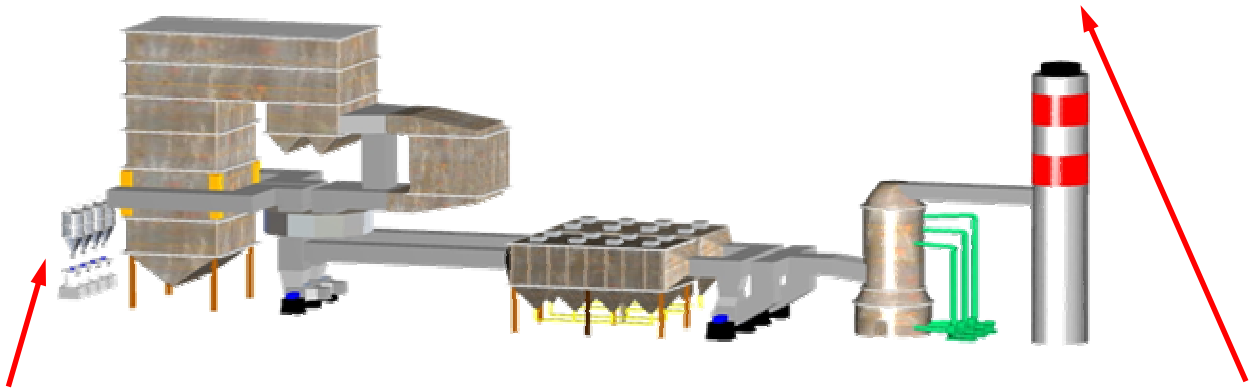
For 500 MW unit, NOx credit value is ~$220k per % increase per year

Capital cost for SNCR much less than for SCR

O&M Benefits of Effective SO_3 Removal

- If heat rate improvements are achieved, a reduction of carbon dioxide emissions results.

Utilities all face increasing pressure to reduce CO_2 emissions



1% less coal burned = 1% less CO_2 emitted

For a 500 MW unit burning a typical high S coal, at \$15/ton CO_2, (current trading value on European exchange), the value of 1% change in CO_2 emissions is ~ \$600k/yr

O&M Benefits of Effective SO_3 Removal

- With respect to Mercury Control

  Increase efficiency/improve economics of activated carbon injection (ACI) technology

  - ✓ In absence of SO_3, carbon will retain more mercury (both removal efficiency and carrying capacity increased)
  - ✓ Removal efficiency and carrying capacity both improved at lower temperatures – achievable with SO_3 removed.
  - ✓ Could significantly reduce amount of carbon required

    (reducing costs 20-40% may be possible)
  - ✓ Applicable for removal of elemental or ionic forms of mercury
  - ✓ Applicable to all types of coals

O&M Benefits of Effective SO_3 Removal

- Effective Removal of Combustion-formed SO_3 before the SCR
  - ✓ Reduce capillary condensation of ABS and catalyst deactivation
  - ✓ Can allow lower Minimum Operating Temperature
    - Allow operation at lower loads
    - May eliminate need for economizer bypass and associated capital and operating (maintenance & heat rate) impacts

Requirements of SO_3 Control Technology

- Must consistently achieve high SO_3 removal efficiencies – certainly >90%; likely >95%
- Must operate with very high reliability
- Must not negatively impact balance of plant operations
  - ✓ SCR (if technology used upstream)
  - ✓ Ductwork
  - ✓ Air heaters
  - ✓ ESP (must compensate for loss of "SO_3 conditioning"

Potential Value vs. Costs

- Benefits could approach or exceed $5 M/yr for a 500 MW unit
- Costs involved for SO_3 control – both capital and operating costs
- Achieving benefits may involve costs: air heater modifications; additional NH_3 costs
- Potential benefits likely many times the costs
- Very worthwhile goal to pursue for SO_3 control technology development