EFFECTS OF SO$_3$ and ABS on AIR HEATER PERFORMANCE

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Benefits of an Air Heater

• Accounts For ~10% - 15% Of a Unit’s Thermal Efficiency

• Reduces Fuel Cost By $10,000,000 Per Year on a 500 MW Unit
• ESTABLISHED STANDARD:

— A 10°F Increase In Gas Outlet Temperature Decreases Boiler Efficiency By 0.25%

— 10°F Increases Fuel Cost By $ 500,000+/Yr
GOAL:
Operate At Lowest Practical Gas Outlet Temperature

OBSTACLES:
Condensables
Effects of Gas Temperature on Equipment
Combustion Airflow Distribution & Control

- Over-Fire Air (15 - 20%)
- Secondary Air (55%-65%)
- Primary Airflow (15%-20%)
Poor Coal Fineness often yields poor distribution

Good Fineness Creates a homogenous & balanced mixture
Catalyst Fouling

1. Low Primary Air Temp or Flow
2. Open Mill Classifiers
3. Increase Coal Particle Size
4. Fireball Moves Upward
5. Increased FEGT
6. Popcorn Ash is Formed
7. Catalyst Fouls
8. NH3 Slip Increases
9. AH Fouls
10. Go to Step 1 - Repeat
The SCR Impacts the Air Heater

The Air Heater Impacts Combustion and APC Equipment

PLANT LAYOUT

BOILER

GREW

COMBUSTION

PULVERIZER

AIRHEATER

S.C.R.
SELECTIVE CATALIC REDUCTION

I.D. FANS

EMISSIONS

STACK

PRIMARY FD AIR FANS

SECONDARY

E.S.P.

ELECTROSTATIC PRECIPITATOR

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Inter-Relationships

- Combustion Performance
- APH performance
- Environmental Control Equipment
- Auxiliary Power Consumption
Electrostatic Precipitator (ESP) Challenges

**Air Heater Leakage:**
- Increased Gas Volume
- Reduced SCA
- Temperature and Flow Stratification
- Can Reduce Collection Efficiency Over 1%

**Air Heater Efficiency Deterioration:**
- May Result from ABS Plugging or Sorbent
- Increased Gas Temperature
- Increased Fly Ash Resistivity
- Increased Gas Volume
- Decreased SCA

*Air Heater Problems Shrink the Relative Size of an ESP*
Reducing Leakage Reduces ESP Emissions

A 10% Leakage Reduction =

- 10% Decrease in Flue Gas Volume
- 10% Increase in SCA
- Lower Gas Velocity Through ESP
- Decreased Particulate Emissions

![Graph showing emissions and gas flow]
Function of an Air Heater

• Extracts Waste Heat From Exhaust Gases
• Recycles That Heat to the Incoming Air

WARMED AIR 620°F  COOL AIR 100°F
HOT GAS 700°F  COOLED GAS 290°F
GAS TEMPERATURE PROFILE

350°F

330°F

~315°F

295°F

265°F
SO$_3$ EQUILIBRIUM

SO$_2$ + O + 😊 $\rightarrow$ SO$_3$ + 😊

SO$_3$ + O $\rightarrow$ SO$_2$ + O$_2$
Figure 6.1. Estimated SO$_3$/H$_2$SO$_4$ losses across combustion air preheaters versus average air preheater exit temperature for a temperature offset of 35 °F. The first value of each pair in the legend is the preheater inlet SO$_3$/H$_2$SO$_4$ concentration in ppm and the second value of the pair is the spread in exit gas temperature between the cold side and the hot side of the preheater exit.
SO$_3$ EXIT CONCENTRATION

Figure 6.2. Estimated air preheater exit SO$_3$/H$_2$SO$_4$ concentration versus average air preheater exit temperature for a temperature offset of 35 °F. The first value of each pair in the legend is the preheater inlet SO$_3$/H$_2$SO$_4$ concentration in ppm and the second value of the pair is the spread in exit gas temperature between the cold side and the hot side of the preheater exit.
SO$_3$ Vs. Sulfuric Acid Dew Point Temp.

Figure 10.6  Effects of rotor speed on the effectiveness and local metal temperatures at the cold air inlet end of a large rotary regenerator for a coal-fired steam power plant. (Karlsson and Holm, Ref. 2.)
Condensation Deposits

Cold End Rotor
ACID RESISTANT COATINGS

NEW
improved enamel
with better corrosion resistance

PICK YOUR CORROSIVE
Downstream Corrosion
EFFECT OF MOISTURE ON $\text{SO}_3$ REMOVAL
AH $\text{SO}_3$ REMOVAL-TEST VS MODEL

![Graph showing SO$_3$ Concentration vs Temperature (F)](image-url)
SO$_3$ Variation with Load and SO$_2$
SO₃ Affects ESP Efficiency (Resistivity)

Precipitator Efficiency vs. SO₃ for ESP of 325 SCA
SO$_3$ Exiting the Air Heater

SO$_3$ at AH Gas Inlet
Metal Temperature
Gas Temperature
Ash Quantity
Ash Alkalinity
PM 2.5
SO₃ - Central To Air Heater Limits

\[
\text{SO}_2 + \frac{1}{2} \text{O}_2 \leftrightarrow \text{SO}_3
\]

\[
\text{SO}_3 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{SO}_4
\]

\[
\text{H}_2\text{SO}_4 + \text{NH}_3 \leftrightarrow (\text{NH}_4)\text{HSO}_4
\]
Ammonia Slip Results in ABS Deposits in the Air Heater

ABS Deposits Degrade Air Heater Efficiency and Affect Downstream Air Pollution Control Equipment
ABS Formation Temperatures

NH₃*H₂SO₄, ppm^2 vs Temperature, F

- Matsuda et al
- Radian
- 30 ppm of NH₃
- 50 ppm of NH₃
- 75 ppm of NH₃
- 150 ppm of NH₃

Temperature, F: 250, 350, 450, 550, 650

SOLID
GAS
ABS Buildup at Precipitator Inlet
ABS Deposition Temperature

ABS Dewpoint

300°F TO 390°F

Max. Metal Temp.

Min. Metal Temp.

ABS Deposition Zone

Axial Displacement, Inches from Cold End

Cold End Layer

Intermediate Layer

Hot End Layer
“Clean” Air Heater Cold End
ABS Prevention

Measure ABS Formation Temperature
ABS Formation Temperatures (Probe)

Region of ammonium bisulfate (ABS) formation

Temperature (°F)

[\text{NH}_3] \times [\text{H}_2\text{SO}_4] \text{ (ppm)}
Breen Condensables System

• Predict the Formation of ABS vs. AS

• Predict the Location where ABS will Deposit

• Adjust the Ammonia Feed

• Change Air Heater Metal Temperature
Change Air Heater Metal Temperature

Bring ABS Deposits Closer to the Cold End

• Air Heater Bypass Duct
• Change Air Heater Rotational Speed
• Utilize Steam Coils

Must be Mindful of Downstream Limitations

– ESP Volume
– ESP Resistivity
– FF Bag Temperature
Breen Condensables System

• **Formation Temp**: The temperature at which material will first form

• **The Equilibrium Dew Point**

• **Evaporation Temp**: The temperature at which material will self-evaporate
Condensation Deposits

Cold End Rotor
Soot Blowers - Typical

**SWING ARM AH SOOT BLOWER**
Dynamic Speed Control (DySC)

- Sootblower logic is modified to allow the nozzle to be positioned as desired, and then left stationary

The Rotor Speed Coordinated With Nozzle Position To Provide Suitable Residence Time.
Penetration vs. Angular Velocity

Penetration Depth is greater here:

Than it is here:

Due to significant differences in angular velocity
Soot Blower Penetration vs. Tangential Velocity

Slow Speed, Full Penetration

Medium Speed, Partial Penetration

High Speed, Reduced Penetration
Angular Velocity/Sootblowing

Perimeter Angular Velocity Increases up to 10x

Outer = 75-150 ft/min

Inner = 15 ft/min
Dual Media Blower

On Or Off Line HP Water Wash With Dysc Angular Velocity Control
Bromine for Hg Oxidation

• Br₂ and/or HBr (Hydrogen Bromide)
• b.p. Br₂ = 137°F  HBr = -88°F
  • Oxidizes Mercury
  • Oxidizes Iron at 300°F+
• HBr + H₂O = Hydrobromic Acid (b.p. 280°F)

• Hydrobromic acid is stronger than HCl
BROMINE PAC PROBLEM?

RAPID CORROSION OF AIR HEATER ELEMENT

[Image of corroded air heater element]
HYDROBROMIC ACID (HBr) DEWPOINT

![Graph showing the dewpoint of hydrobromic acid (HBr) with different H2O concentrations.](image)
Br₂ GAS PHASE OXIDATION

![Graph showing corrosion loss at different temperatures with and without bromination.](chart.png)
PROTECTIVE OXIDE LAYER
BR₂ GAS PHASE OXIDATION

Metal

\[ \text{Fe} \]

Scale

\[ \text{FeBr}_2, \text{FeBr}_3 \]

\[ \text{Br}_2/\text{HBr} \]

Gas Phase

\[ \text{Fe}_2\text{O}_3 \rightarrow \text{Br}_2 \]
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