EFFECTS OF USING THE AIR HEATER FOR SO$_3$ REMOVAL

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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
Gas Outlet Temperature

- 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
The SCR Impacts the Air Heater

The Air Heater Impacts Combustion and APC Equipment

PLANT LAYOUT

BOILER

S.C.R.
SELECTIVE CATALytic REDUCTION

I.D. FANS

EMISSIONS

I.D. FANS

SCRUBBER

STACK

PULVERIZER

COMBUSTION

PRIMARY FD AIR FANS

SECONDARY
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
Function of an Air Heater

• Extracts Waste Heat From Exhaust Gases
• Recycles That Heat to the Incoming Air
SO$_3$ EQUILIBRIUM

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

SO$_3$ + O $\rightarrow$ SO$_2$ + O$_2$
SO$_3$ REMOVAL TEMPERATURES

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.
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.

Condensation Deposits

Cold End Rotor
COLD END CORROSION
ACID RESISTANT COATINGS

NEW

improved enamel with better corrosion resistance

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

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

Precipitator Efficiency vs. SO$_3$ 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
SO$_3$ - Central To Air Heater Limits

SO$_2$ + $\frac{1}{2}$ O$_2$ $\Leftrightarrow$ SO$_3$

SO$_3$ + H$_2$O $\Leftrightarrow$ H$_2$SO$_4$

H$_2$SO$_4$ + NH$_3$ $\Leftrightarrow$ (NH$_4$)HSO$_4$
SCR (Selective Catalytic Reduction)

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

\[ \text{NH}_3 \cdot \text{H}_2\text{SO}_4, \text{ ppm}^2 \]

Temperature, F

- Matsuda et al
- Radian
- 30 ppm of NH3
- 50 ppm of NH3
- 75 ppm of NH3
- 150 ppm of NH3
ABS Buildup at Precipitator Inlet
ABS Deposition Temperature

ABS

300°F TO 390°F

°F
“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
AbSensor – AbS/SO\textsubscript{3} System
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

- Inner = 15 ft/min
- Outer = 75-150 ft/min

5X ~ 10X FPM
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
HYDROBROMIC ACID (HBr) DEWPOINT

![Graph showing the dewpoint of hydrobromic acid (HBr) with various water contents (0.7%, 2%, 4%, and 7% H₂O) as a function of HBr content (ppmv). The graph illustrates how the temperature in °C changes with the HBr content.]
Br₂ GAS PHASE OXIDATION

Corrosion Loss, mm

80°F  150°F  300°F

Temperature

Brominated
Nonbrominated

EERC
PROTECTIVE OXIDE LAYER

WATER

OXIDE FILM

METAL

OXIDE-WATER INTERFACE

$\text{Fe}_2\text{O}_3$

$\text{Fe}_3\text{O}_4$

FeO

METAL-OXIDE INTERFACE

EERC
BR$_2$ GAS PHASE OXIDATION

Metal

Scale

Gas Phase

Fe

Br$_2$/HBr → FeBr$_2$ → FeBr$_3$ → Fe$_2$O$_3$ → Br$_2$
RAPID CORROSION OF AIR HEATER ELEMENT
EFFECTS OF SO$_3$ and ABS on AIR HEATER PERFORMANCE

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