Mercury and SO$_3$ Mitigation Issues for Scrubber Technology

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SO3 Behavior in Scrubbers – The Problem...

- SO3 converts to H2SO4 (Sulfuric Acid)
- Cool Wet Scrubber Promotes Fine Sulfuric Acid Particulate/Mist
- Fine Ash Particulate Offers Coalescing Surface
- Particle Size Appropriate for Refraction in Blue Visible Region (Blue Plume)
SO3 Conversion to Sulfuric Acid Vapor (8\% moisture)

SO₃ Conversion to Sulfuric Acid Vapor (8% moisture)

Formation of Condensed Sulfuric Acid

Effects of Fine Particulate and Sulfuric Acid on Opacity

Contributing Factors to Increased SO3

- Fuel Switching to High Sulfur Coals
- Installation of SCRs
- Boiler Operational Changes
**SO3 Mitigation Techniques**

- Alkali Addition to Furnace
- Alkali Injection after Furnace
- Ammonia Injection Prior to ESP
- Fuel Switching and Blending
- Wet ESPs
- Air Preheater Operational Changes
Alkali Addition to Furnace

Magnesium oxide or Limestone common reagents.

Added to furnace they adsorb or inhibit SO3 formation.

May be beneficial for SCR arsenic poisoning under some circumstances, but not fully evaluated.

Requires solids handling and may affect boiler operation/slagging, etc.
Alkali Injection After Furnace

Hydrated lime, limestone, MgO, Sodium Sulfite, Sodium Carbonate possible reagents.

May be used to prevent APH corrosion in addition to lowering SO3 at stack.

May affect ESP operation – loading will increase.

SCR may be affected – not clear.

Ash Characteristics may be changed.
**Fuel Switching and Blending**

Blends of Bituminous and Sub-Bituminous Coals may be very effective.

Synergistic effect of lowering overall SO2 and adsorbing/inhibiting SO3.

May not be practical for SO3 control alone.
Wet ESP

Wet ESPs are very good at capturing SO3.

Also good at removing fine particulate.

Very little industry presence.

APH Operation

Lowered outlet temperature provides better SO3 capture.

Increases potential for fouling and corrosion.

May be practical when SO3 “trim” is needed.

Very site specific
Mercury Control Using Scrubbers

Mercury 101

• Gas-phase mercury:
  – Elemental: $\text{Hg}^0$
  – Oxidized: $\text{Hg}^{+2}$ ($\text{HgCl}_2$, other species?)

• Particulate mercury
  – $\text{Hg}_p$
  – Mercury (adsorbed on particles)
Thermochemical Equilibrium Calculations

Mass Fraction

HgCl₂

HgO

Hg°

0 300 600 900 1200

Temperature, °C

Ref. Ravi K. Srivastava, National Risk Management Research Laboratory, Air, Pollution Prevention and Control Division Research Triangle Park, NC
Mercury Content in Various Coals

Ref. Ravi K. Srivastava, National Risk Management Research Laboratory, Air, Pollution Prevention and Control Division Research Triangle Park, NC
Chlorine Content in Various Coals

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Wet Scrubbers

• 90% Removal of Oxidized Mercury

• Very Low Removal of Elemental Mercury

• Possibility of Re-Emission due to conversion of oxidized to elemental Hg
Mercury Removal in Wet Scrubbers for Bituminous Coals

Low correlation of existing data; difficult to predict the mercury removal that will be achieved in a WFGD
Total Mercury Removal vs. Chlorine for Various Wet-Scrubbed Configurations

Reference: Behavior of Mercury in Air Pollution Control Devices on Coal-Fired Utility Boilers, Constance L. Senior, Reaction Engineering International, Salt Lake City, Utah 84101
Wet Scrubbers - Chlorine Effect on ESP/FGD Hg Capture

Reference: Constance Senior
Enhancing Capture of Hg in Wet Scrubbers:
Predicted Capacity for Scrubbers and SCR

Source: U.S. EPA – Clear Skies Initiative
Fate of Captured Mercury in Wet Scrubbers

Reference: Constance Senior
Effect of L/G Ratio on Hg Removal

Dry Scrubbers

- High Total Mercury Removal with High Chlorine

- Differences in Effectiveness Based on Particulate Control (ESP vs. FF)

- FF Alone May Perform Well in High Chlorine Environment

- Mercury Capture May be Inhibited by SDA with Low Chlorine Fuels Due to Loss of Chlorine via Scrubber
ICR SDA/FF Data

Source: ICR data

Reference: Constance Senior
ICR FF Data with and without SDA
(Open symbols are FF only)

Removal of Hg

-40%
-20%
0%
20%
40%
60%
80%
100%

Coal Cl, ug/g dry

- Bituminous
- Lignite
- Subbituminous

Mercury Removal in Dry Scrubbers
Total Mercury Removal vs. Chlorine for Dry Scrubber w/ Particulate Control

Reference: Behavior of Mercury in Air Pollution Control Devices on Coal-Fired Utility Boilers, Constance L. Senior, Reaction Engineering International, Salt Lake City, Utah 84101
Total Mercury Removal Rates vs. Coal Types and Controls

Hg Removal with Various FGD Systems

Comparison of Elemental Mercury in Stack for Scrubbed vs. Non-Scrubbed Units

Reference: Behavior of Mercury in Air Pollution Control Devices on Coal-Fired Utility Boilers, Constance L. Senior, Reaction Engineering International, Salt Lake City, Utah 84101