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Mercury and SO_3 Mitigation Issues for Scrubber Technology

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Southern Research Institute

WPCA/Ameren Particulate Seminar
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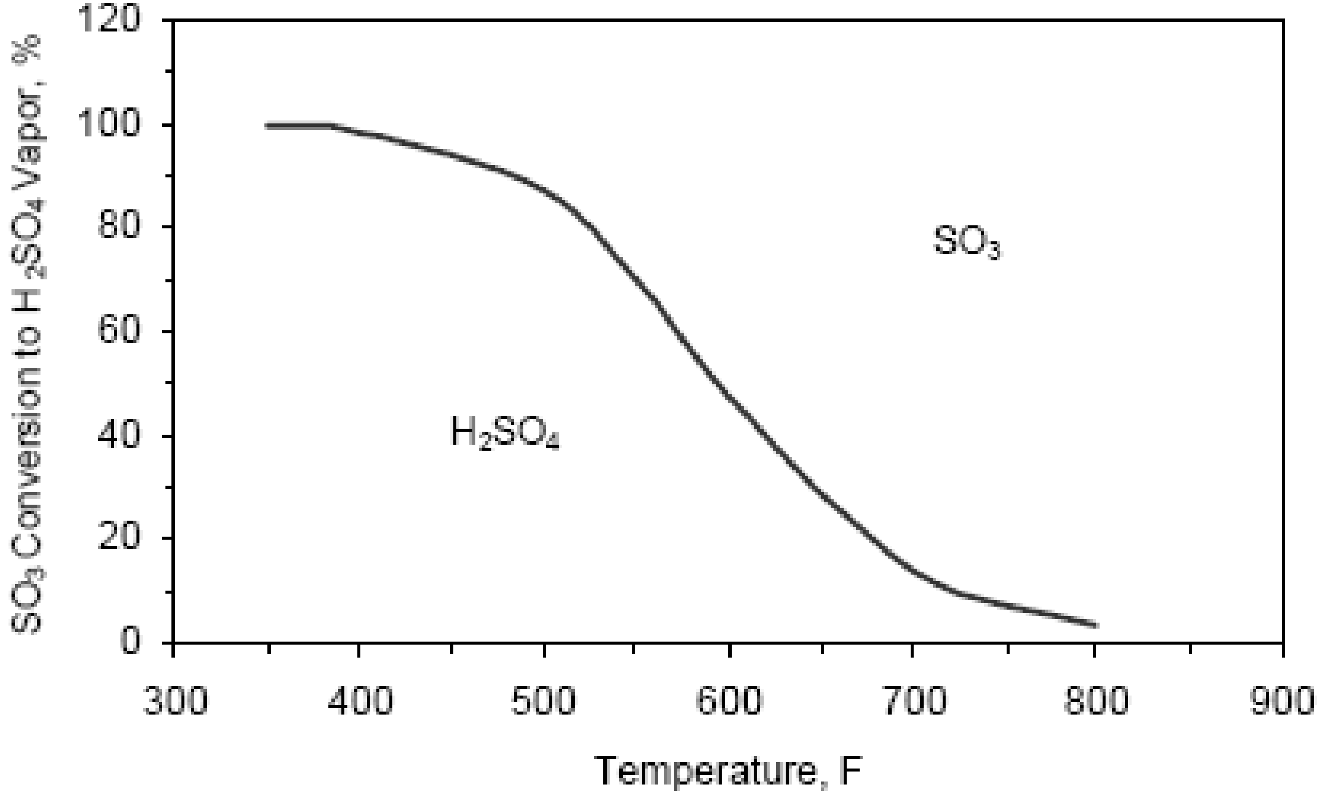
SO3 Behavior in Scrubbers – The Problem…

- **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)

Reference: Estimating Sulfuric Acid Aerosol Emissions from Coal-Fired Power Plants, R. Hardman, et. al.,U. S. Department of Energy-FETC Conference on Formation, Distribution, Impact, and Fate of Sulfur Trioxide in Utility Flue Gas Streams, March 1998

$$SO_3 + H_2O \leftrightarrow H_2SO_4$$

Table 5. SO_3 conversion to H_2SO_4 vapor at various flue gas temperatures

Temperature, °F	SO_3 converted to H_2SO_4 , %
800	3.85
700	14.30
600	47.54
550	70.54
500	87.50
400	98.86
350	99.74

SO3 Conversion to Sulfuric Acid Vapor (8% moisture)

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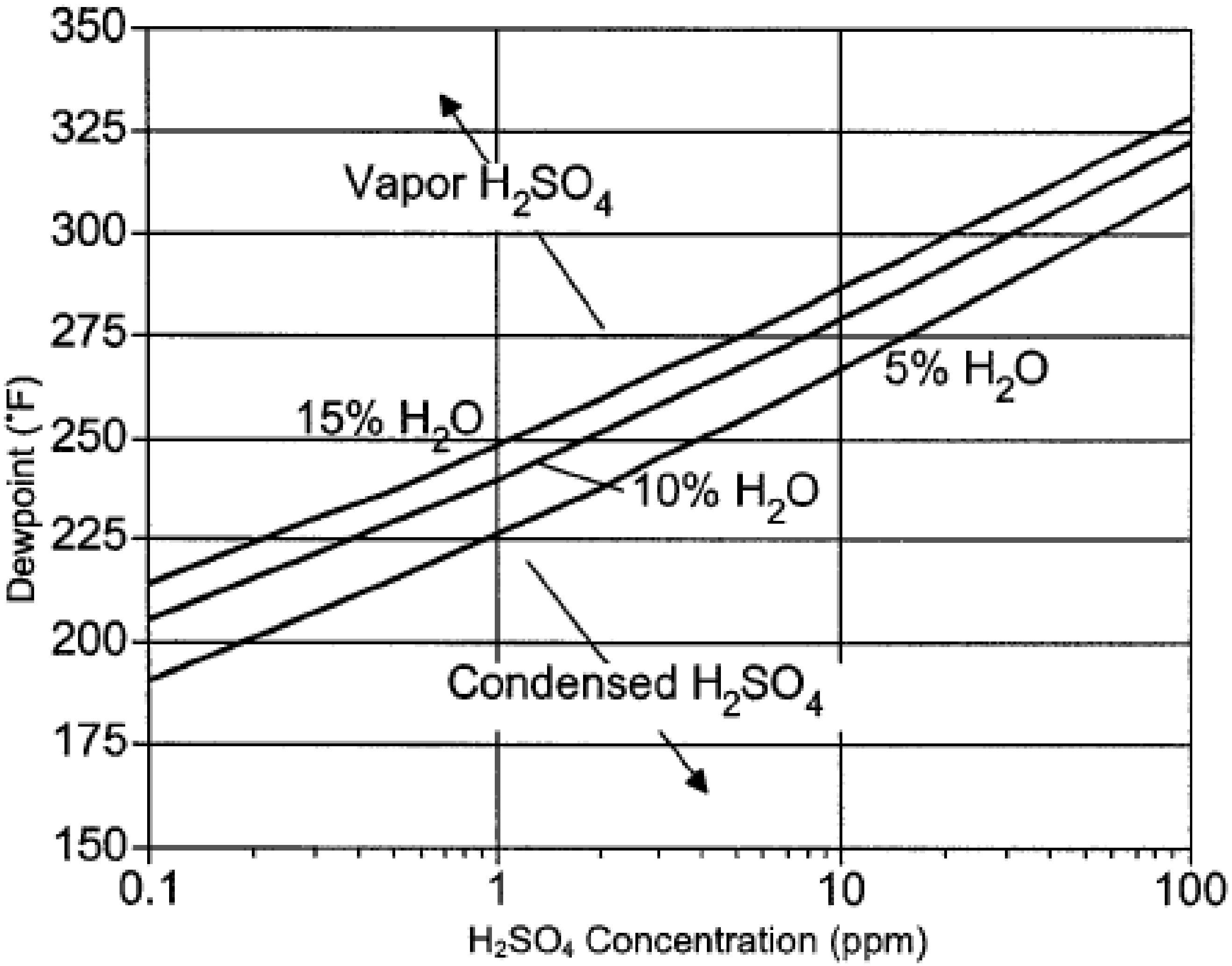
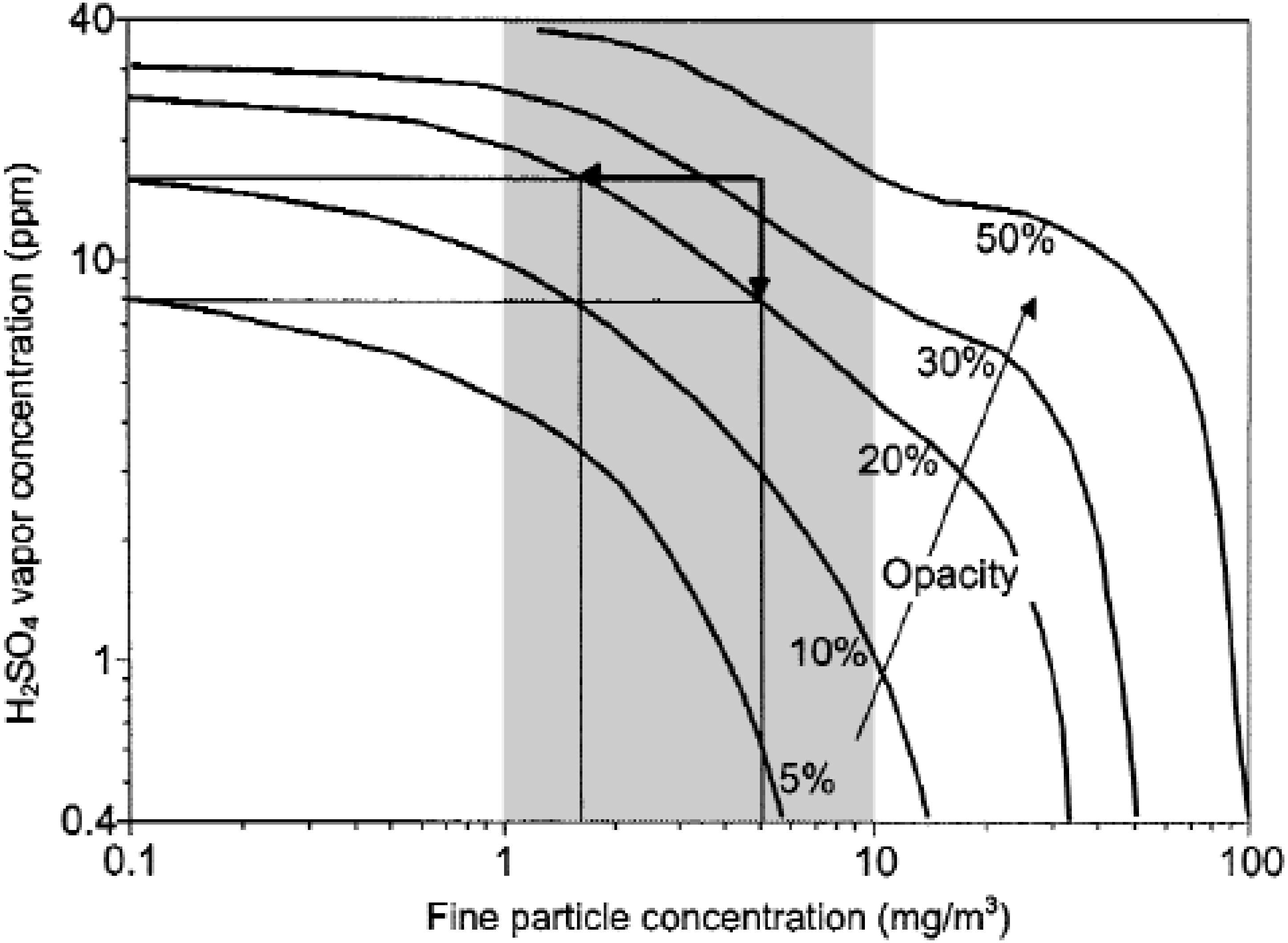


Formation of Condensed Sulfuric Acid

Reference . Emissions of Sulfur Trioxide From Coal-Fired Power Plants, R.K. Srivastava, et. al., Presented at POWER-GEN International 2002, December 10-12, 2002, Orlando, Florida



Effects of Fine Particulate and Sulfuric Acid on Opacity

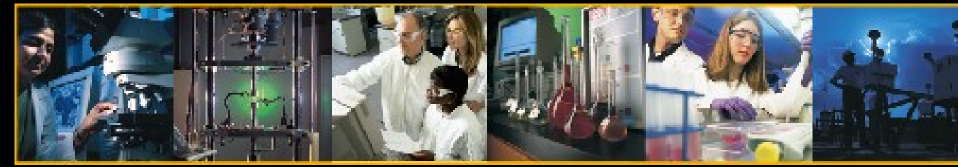
Reference . Emissions of Sulfur Trioxide From Coal-Fired Power Plants, R.K. Srivastava, et. al., Presented at POWER-GEN International 2002, December 10-12, 2002, Orlando, Florida

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 SO_3 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: Hg^0
  - Oxidized: Hg^{+2} ($HgCl_2$, other species?)
- Particulate mercury
  - Hg_p
  - Mercury (adsorbed on particles)

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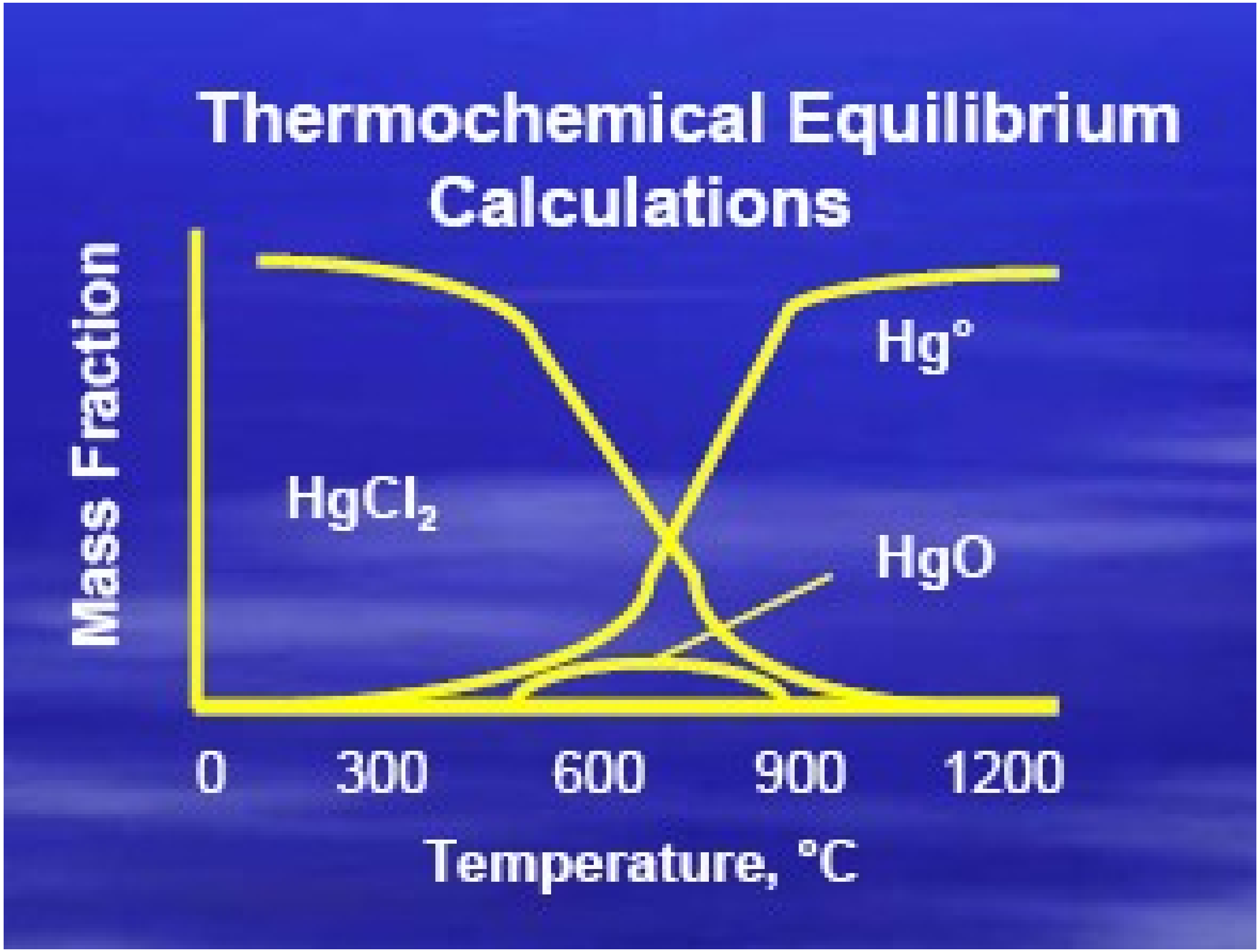
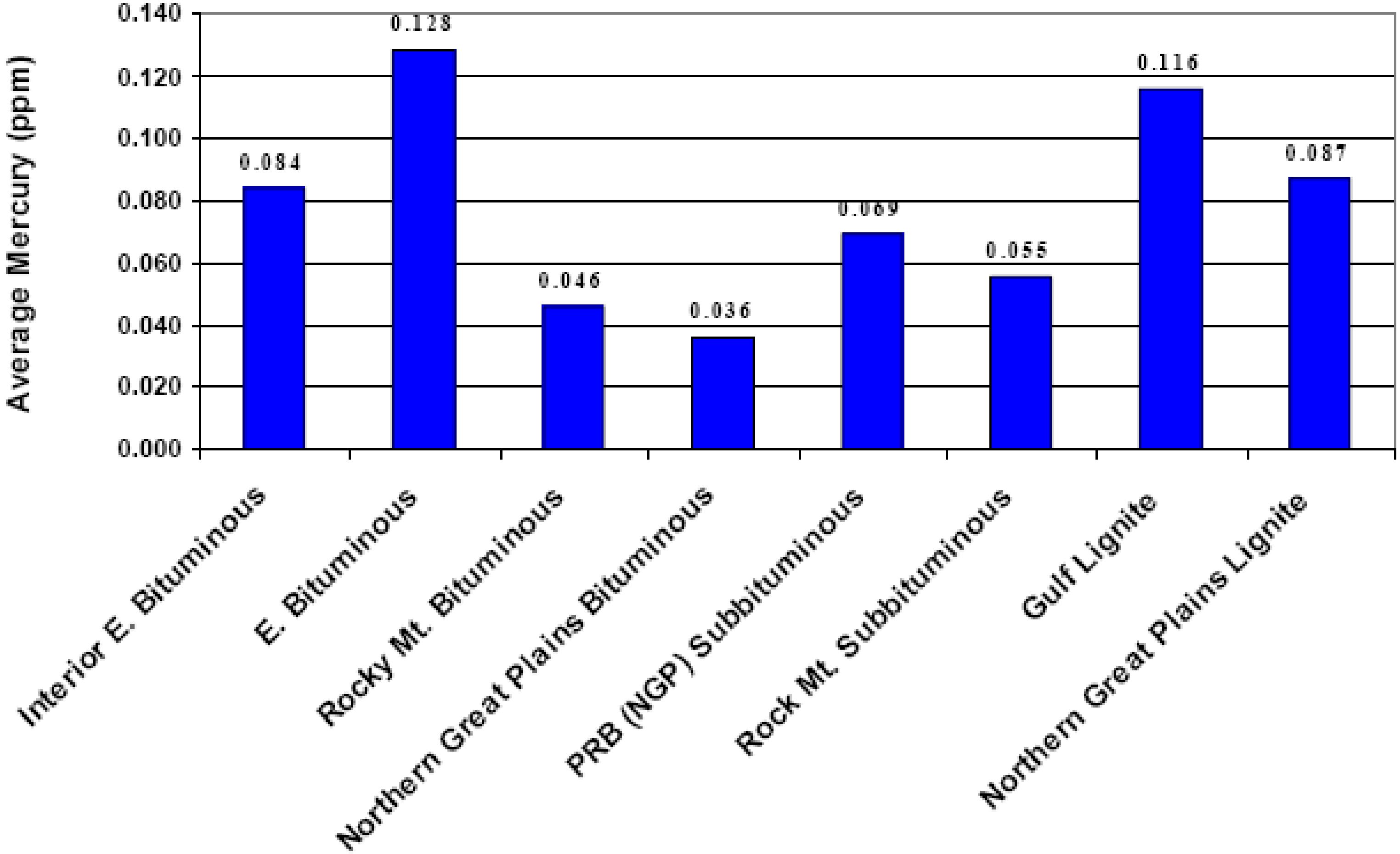
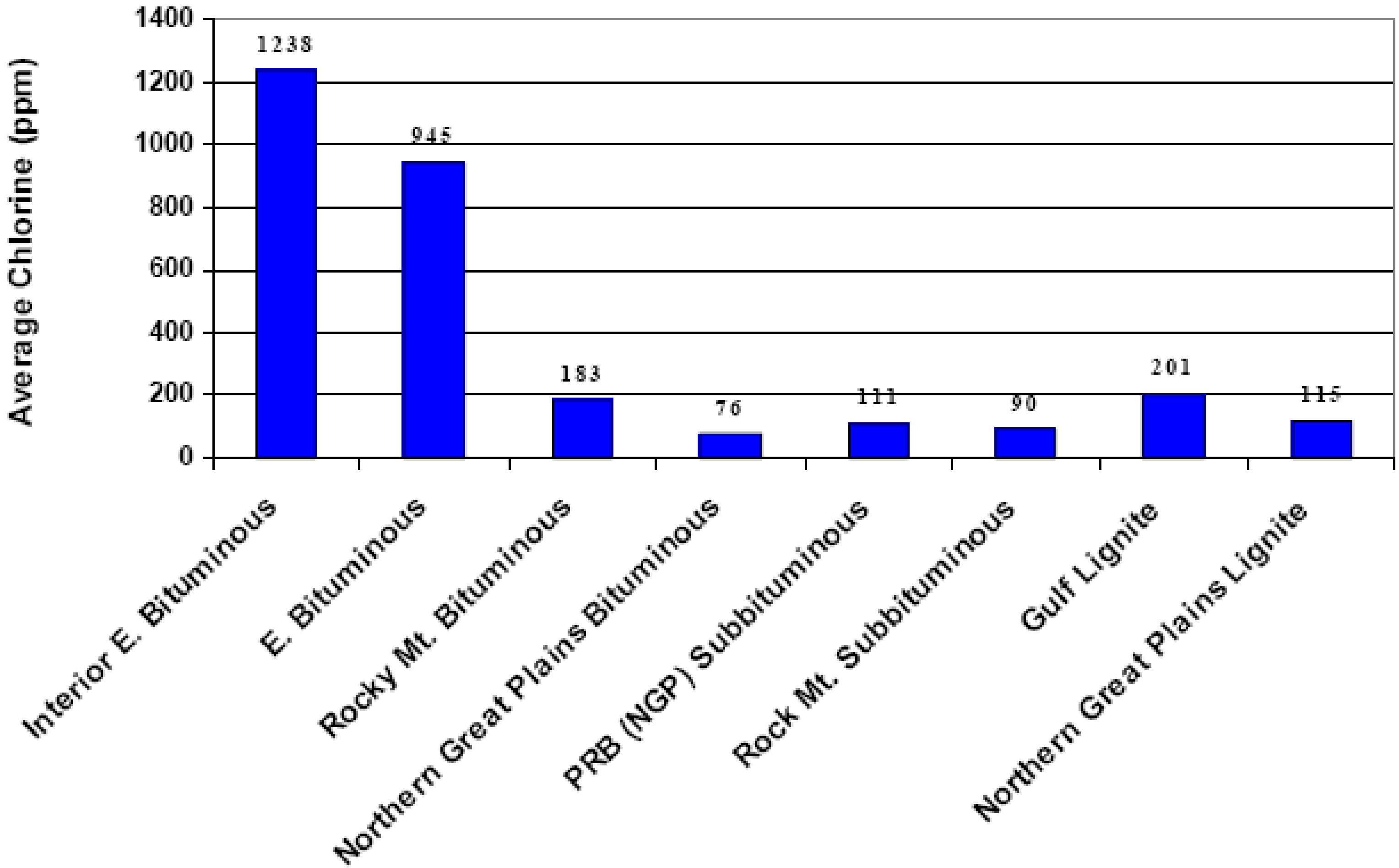


Ref. Ravi K. Srivastava, National Risk Management Research Laboratory, Air, Pollution Prevention and Control Division Research Triangle Park, NC



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

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

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

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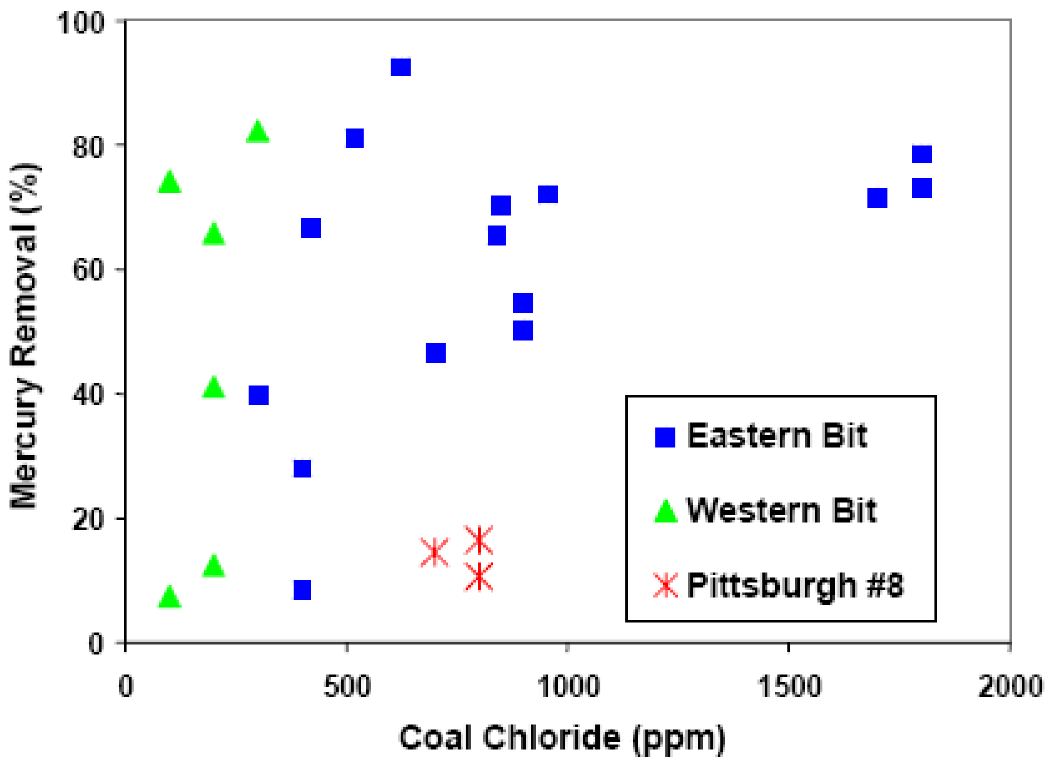
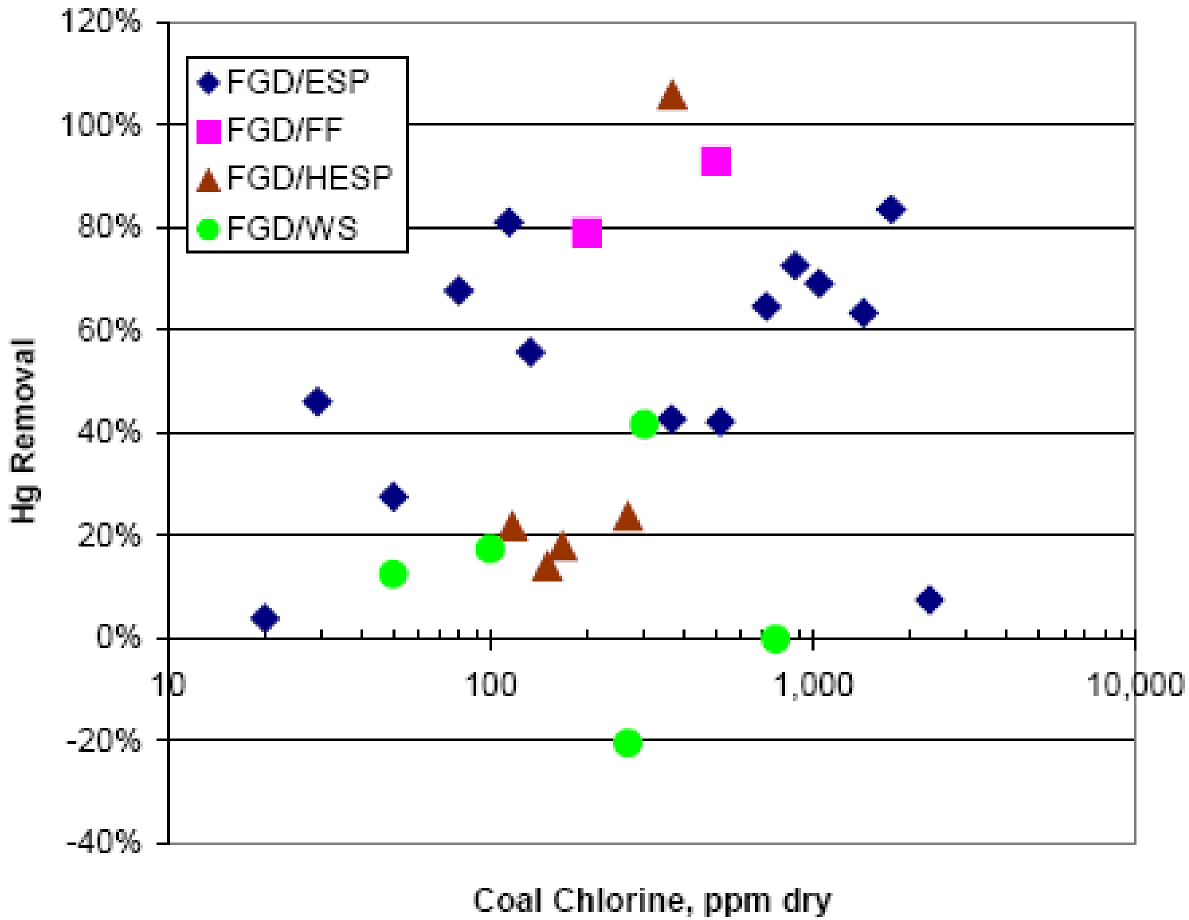
Northeast States for Coordinated Air Use Management

Mercury Removal in Wet Scrubbers for Bituminous Coals



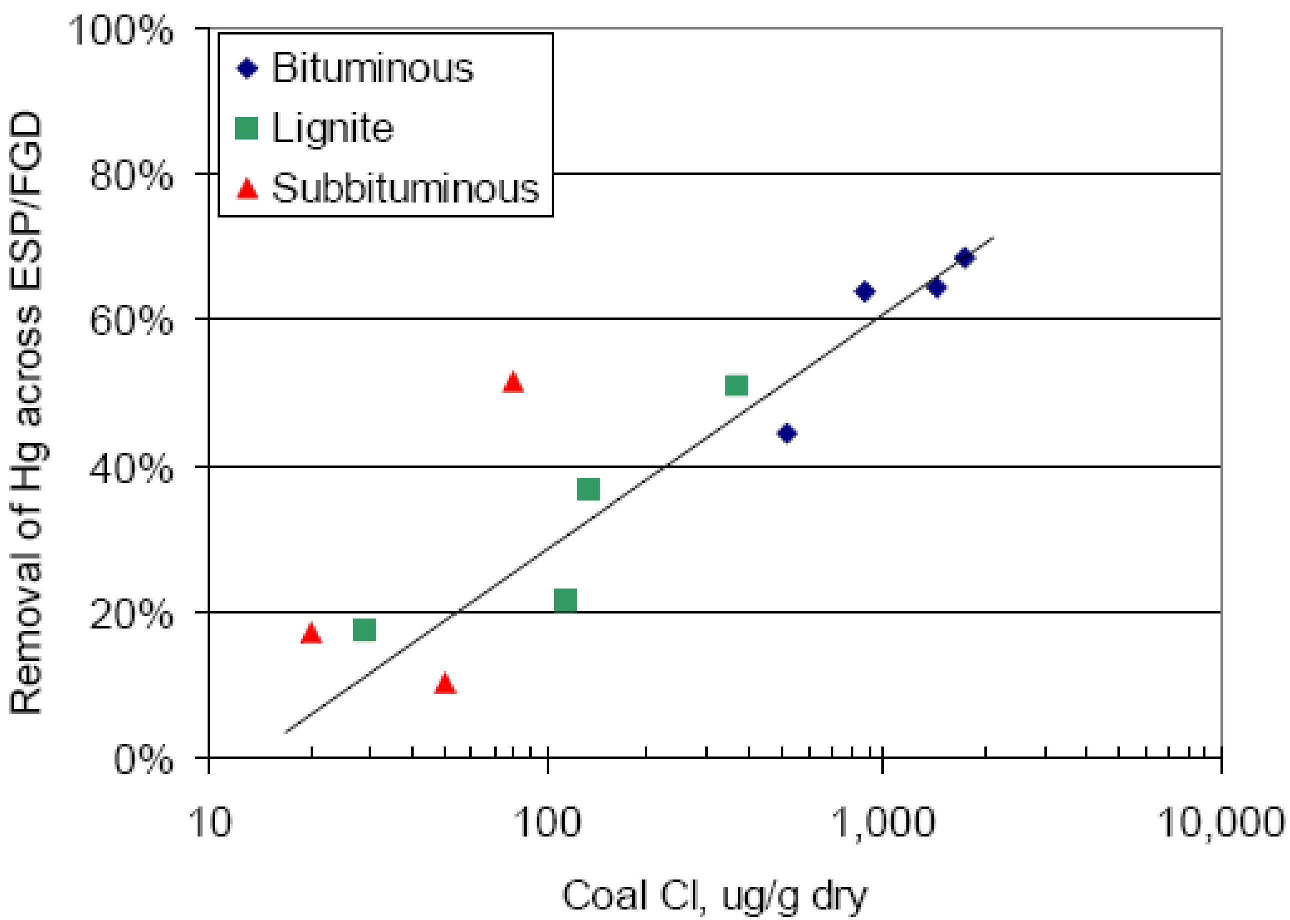
Low correlation of existing data; difficult to predict the mercury removal that will be achieved in a WFGD



<u>Total</u> 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

ICR ESP/FGD Data



Wet Scrubbers - Chlorine Effect on ESP/FGD Hg Capture

Reference: Constance Senior

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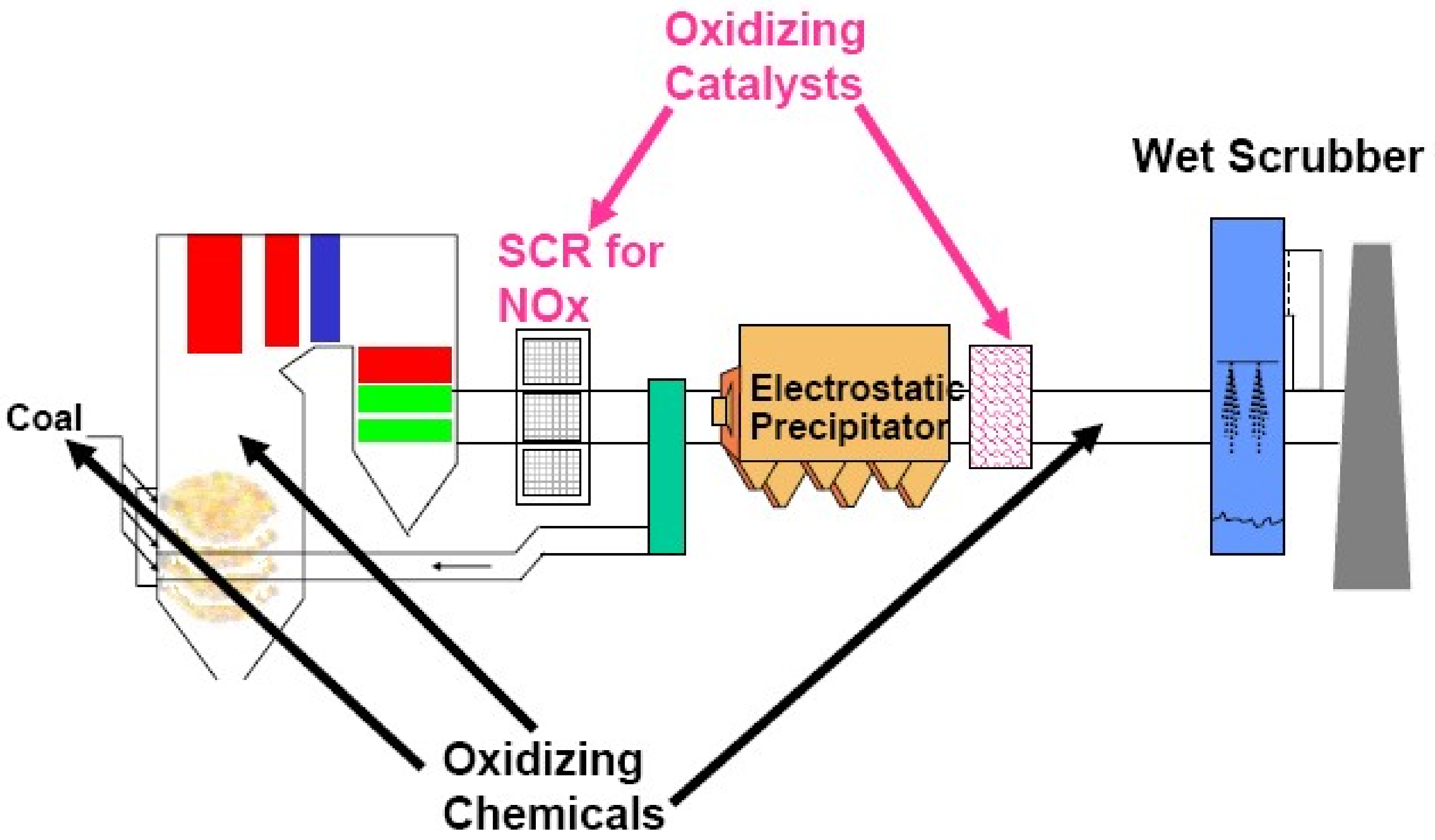
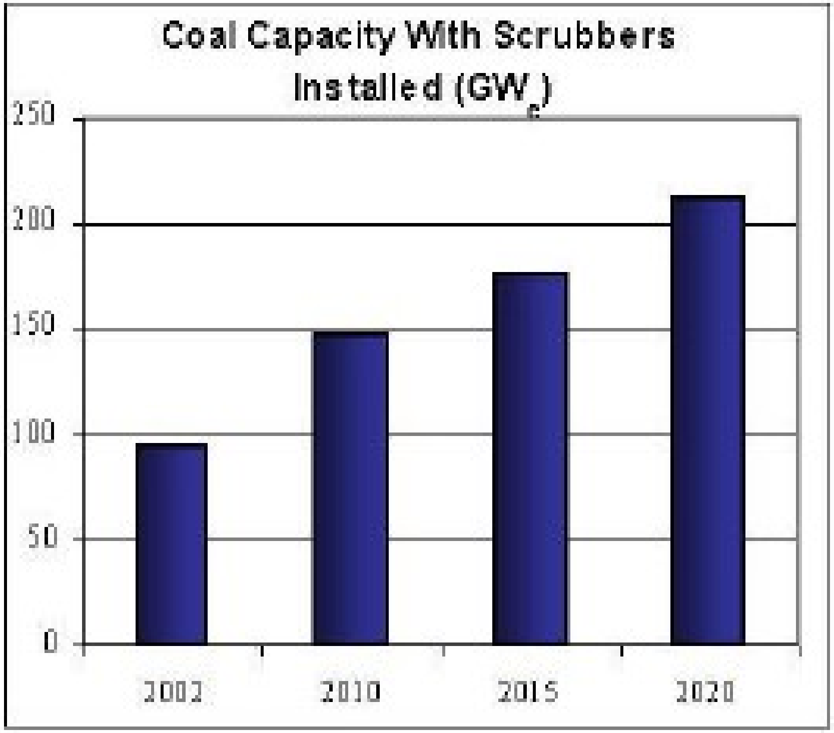
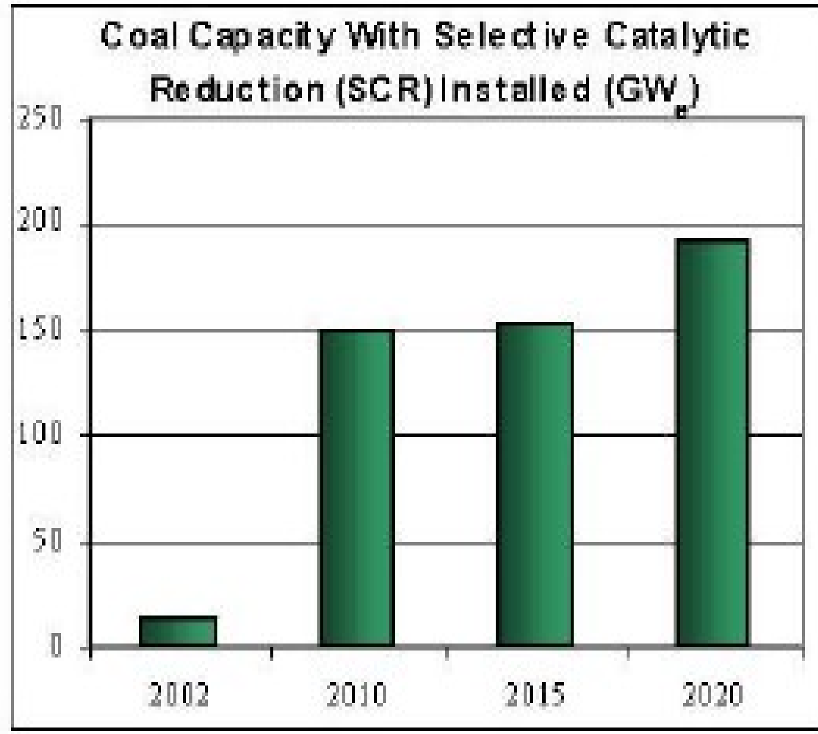
Northeast States for Coordinated Air Use Management

Enhancing Capture of Hg in Wet Scrubbers:







Note: Retrofit projections are EPA's analysis using IPM. "Controlled coal" includes one or more of the following: SCR, scrubbers, ACI, gas re-burn and SNCR.

Predicted Capacity for Scrubbers and SCR

Source: U.S. EPA – Clear Skies Initiative

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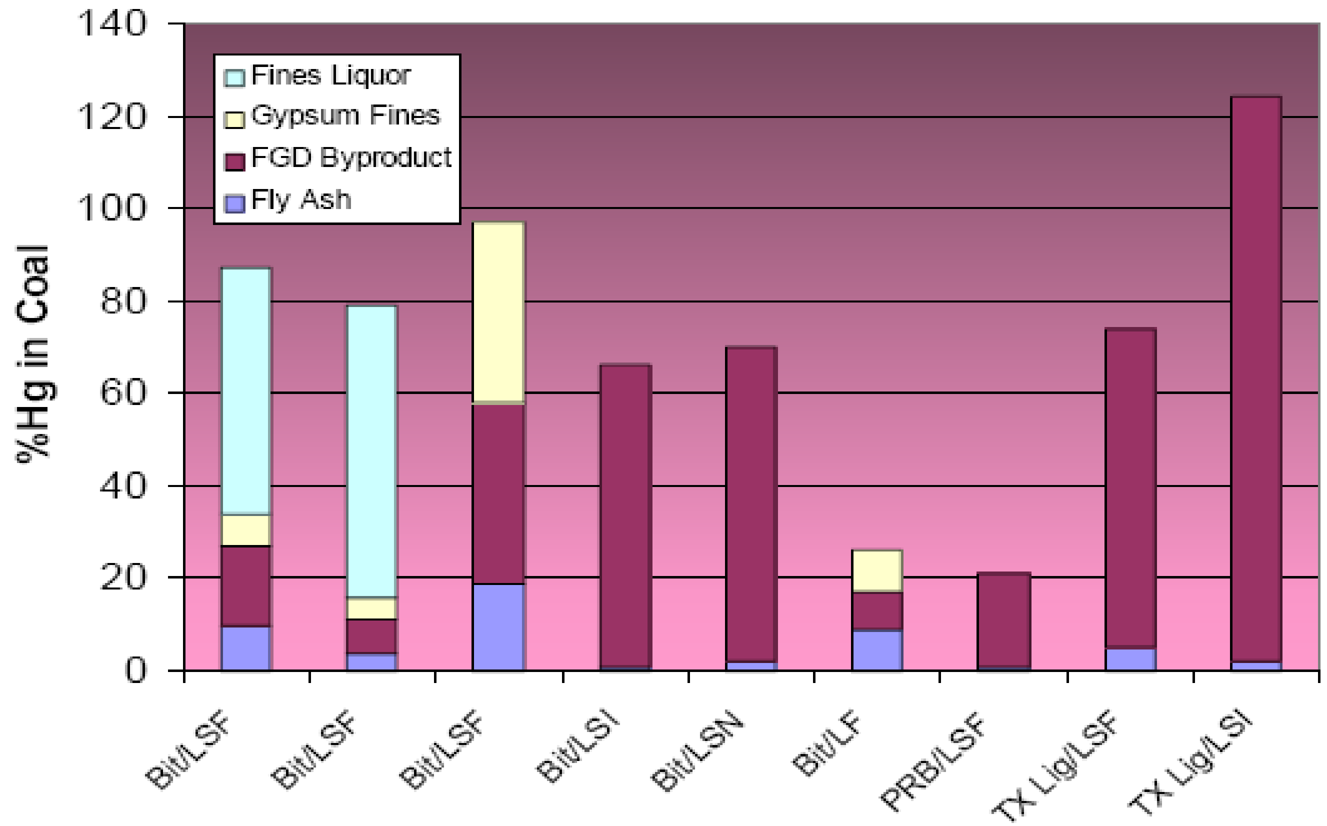
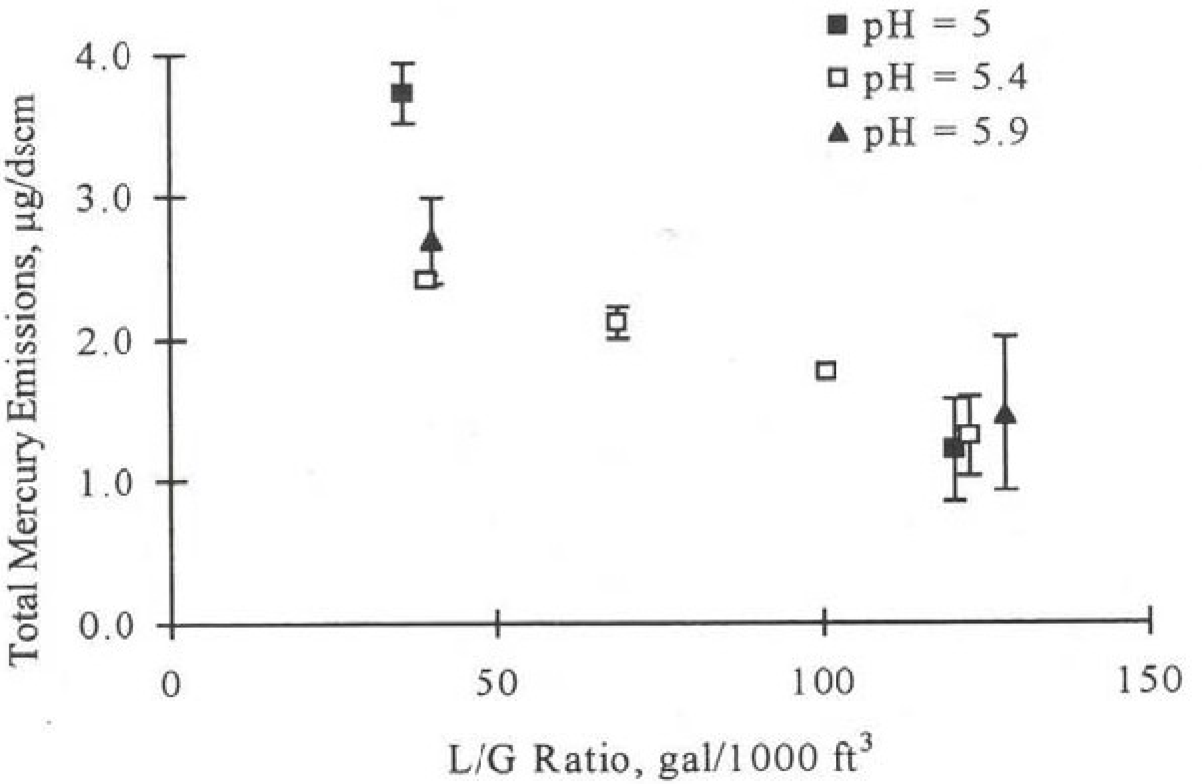


LSF = Limestone Forced Oxidation
LS = Lime Forced Oxidation
LSI - Limestone Inhibited Oxidation
LSN = Limestone Natural Oxidation

Fate of Captured Mercury in Wet Scrubbers

Reference: Constance Senior

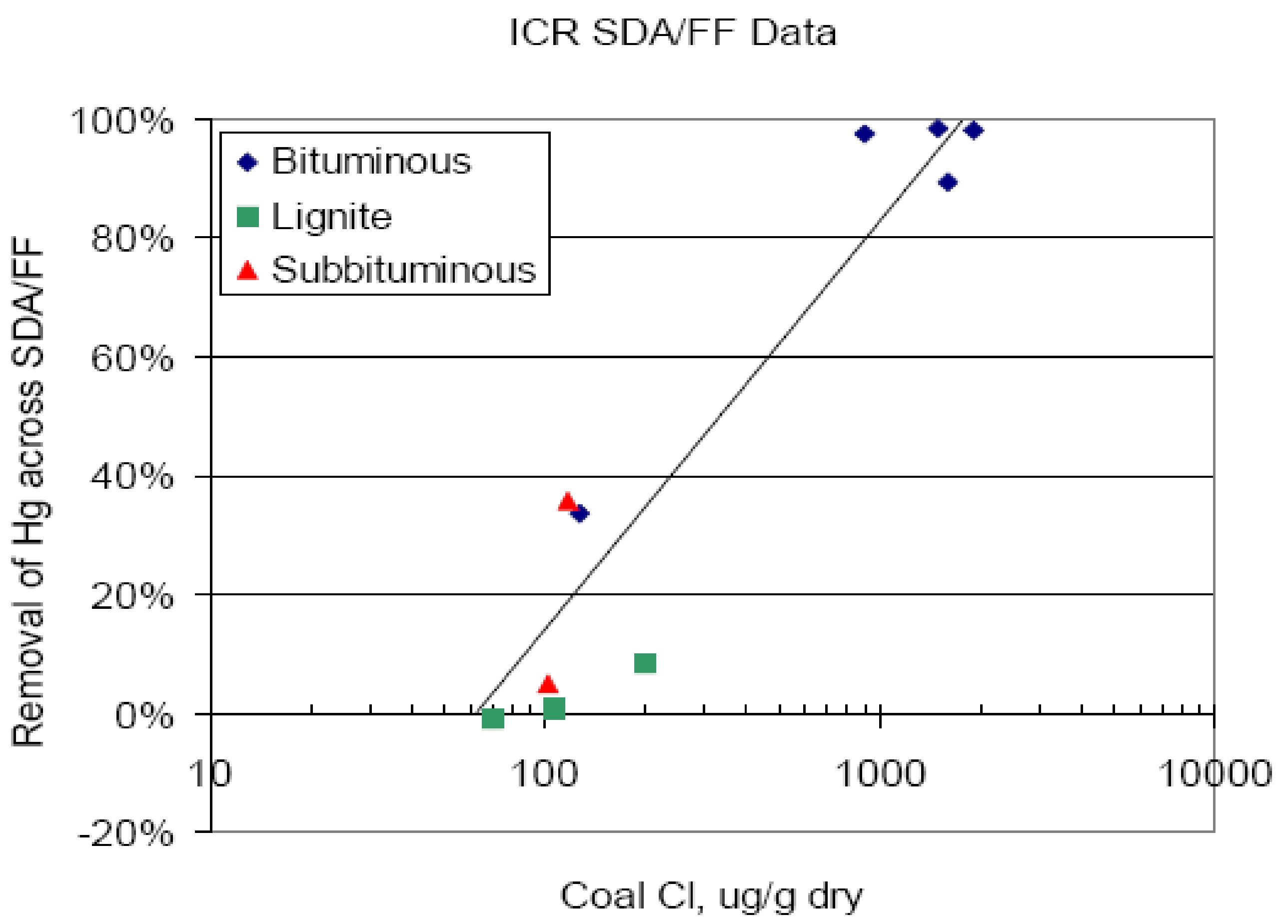


Effect of L/G Ratio on Hg Removal

Reference: Control of Mercury Emissions from Coal Fired Electric Utility Boilers: An Update, Air Pollution Prevention and Control Division National Risk Management Research Laboratory Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, NC, February 18, 2005

Dry Scrubbers

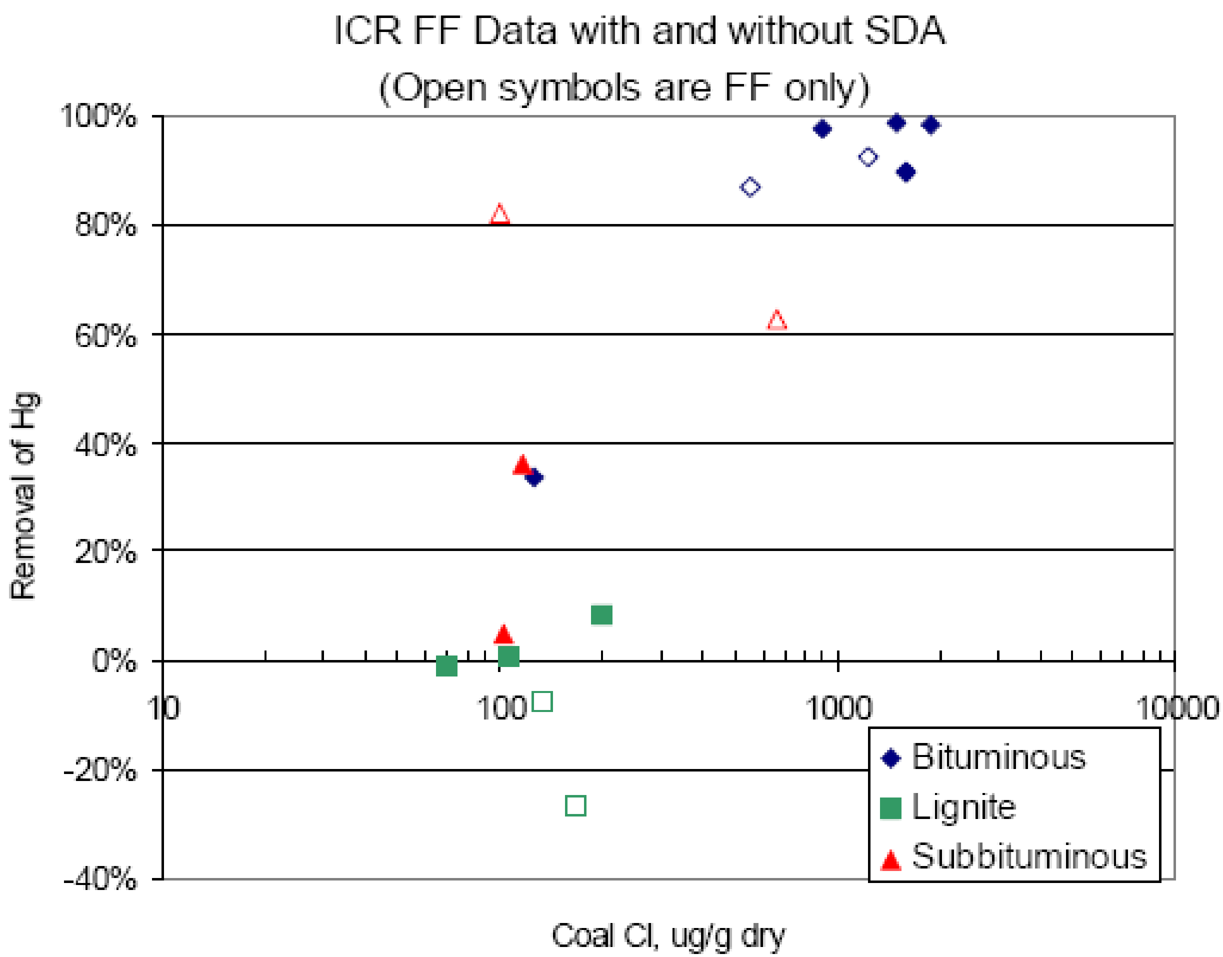
- High Total Mercury Removal with High Chlorine
- Differences in Effectiveness Based on Particulate Control (ESP vs. FF)
- FF Alone May Perform Well in High Chlorine Environment
- Mercury Capture May be Inhibited by SDA with Low Chlorine Fuels Due to Loss of Chlorine via Scrubber



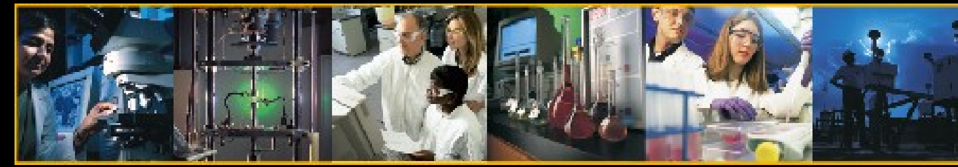
Source: ICR data

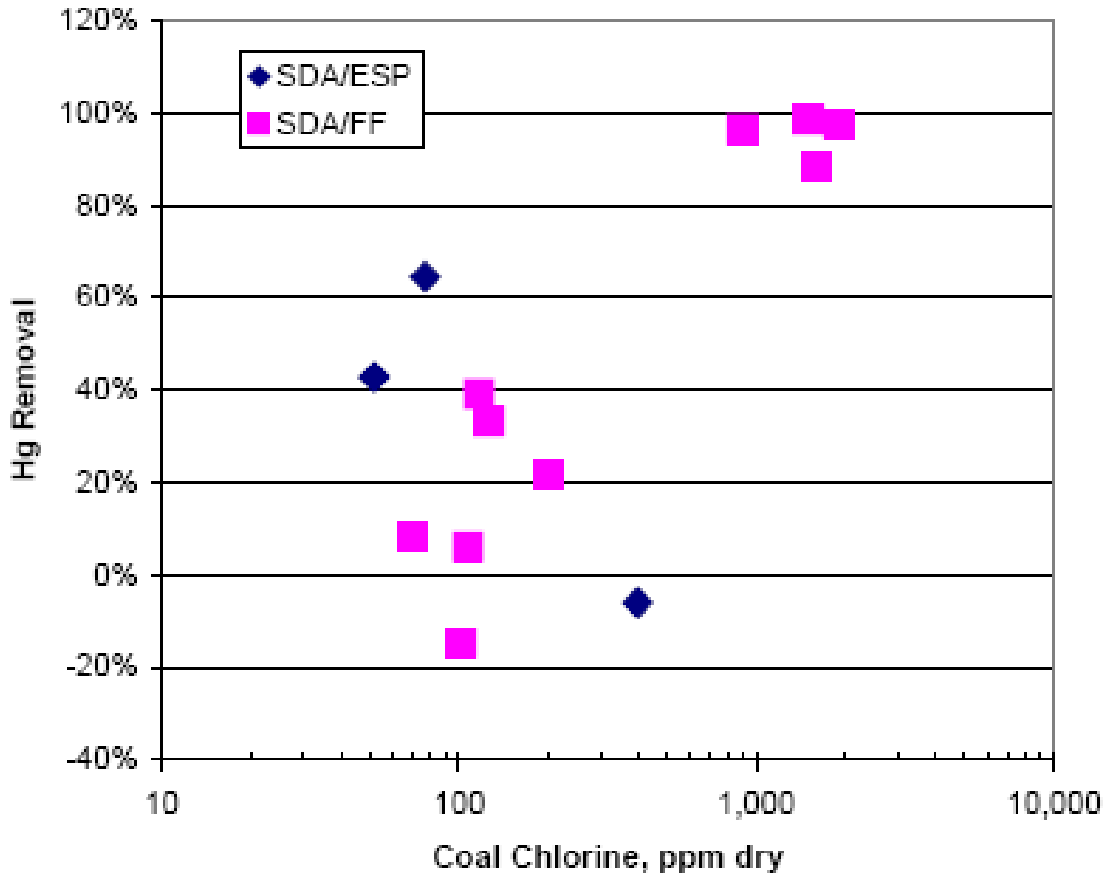
Mercury Removal in Dry Scrubbers

Reference: Constance Senior



Mercury Removal in Dry Scrubbers





<u>Total</u> 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

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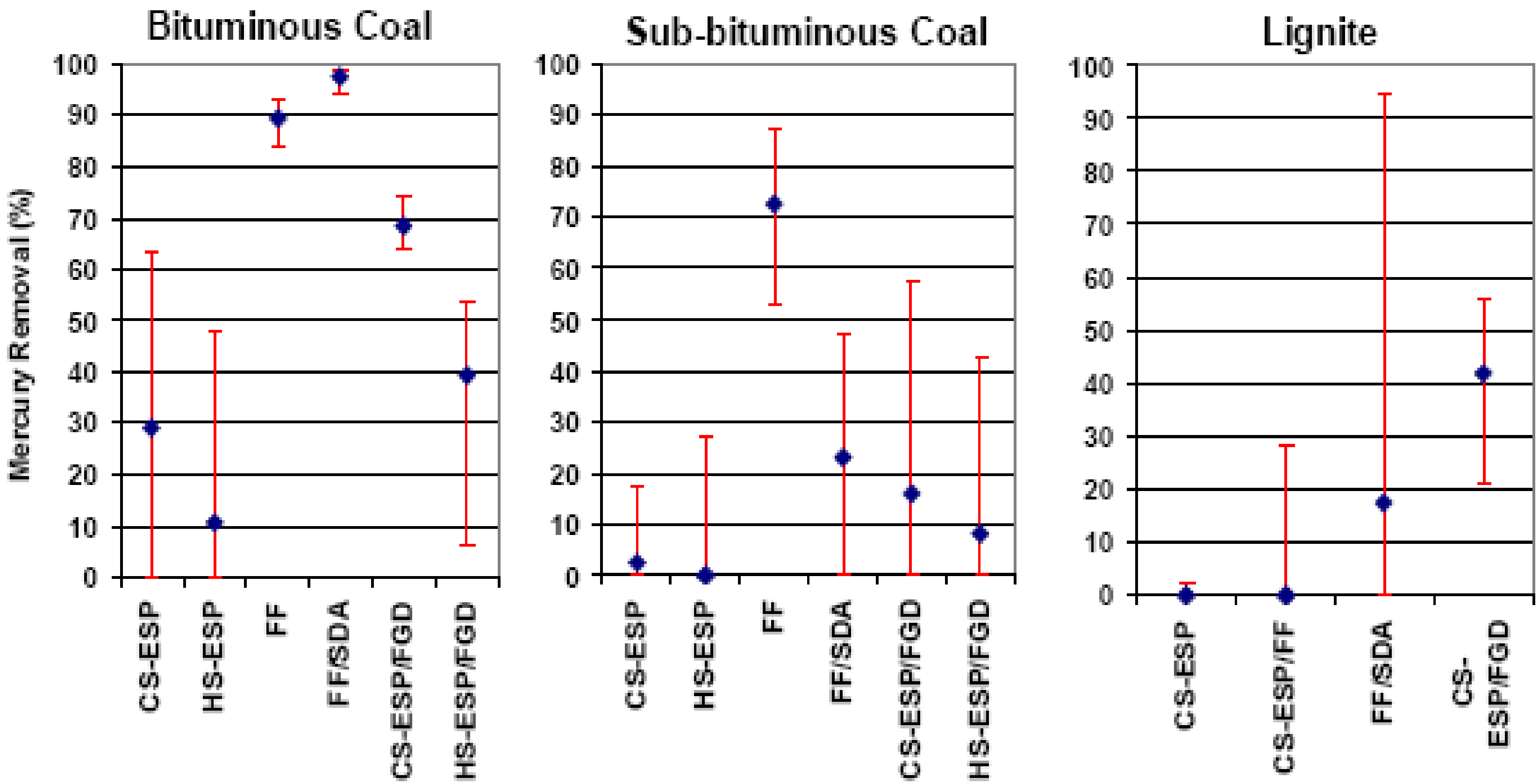

Total Mercury Removal Rates vs. Coal Types and Controls

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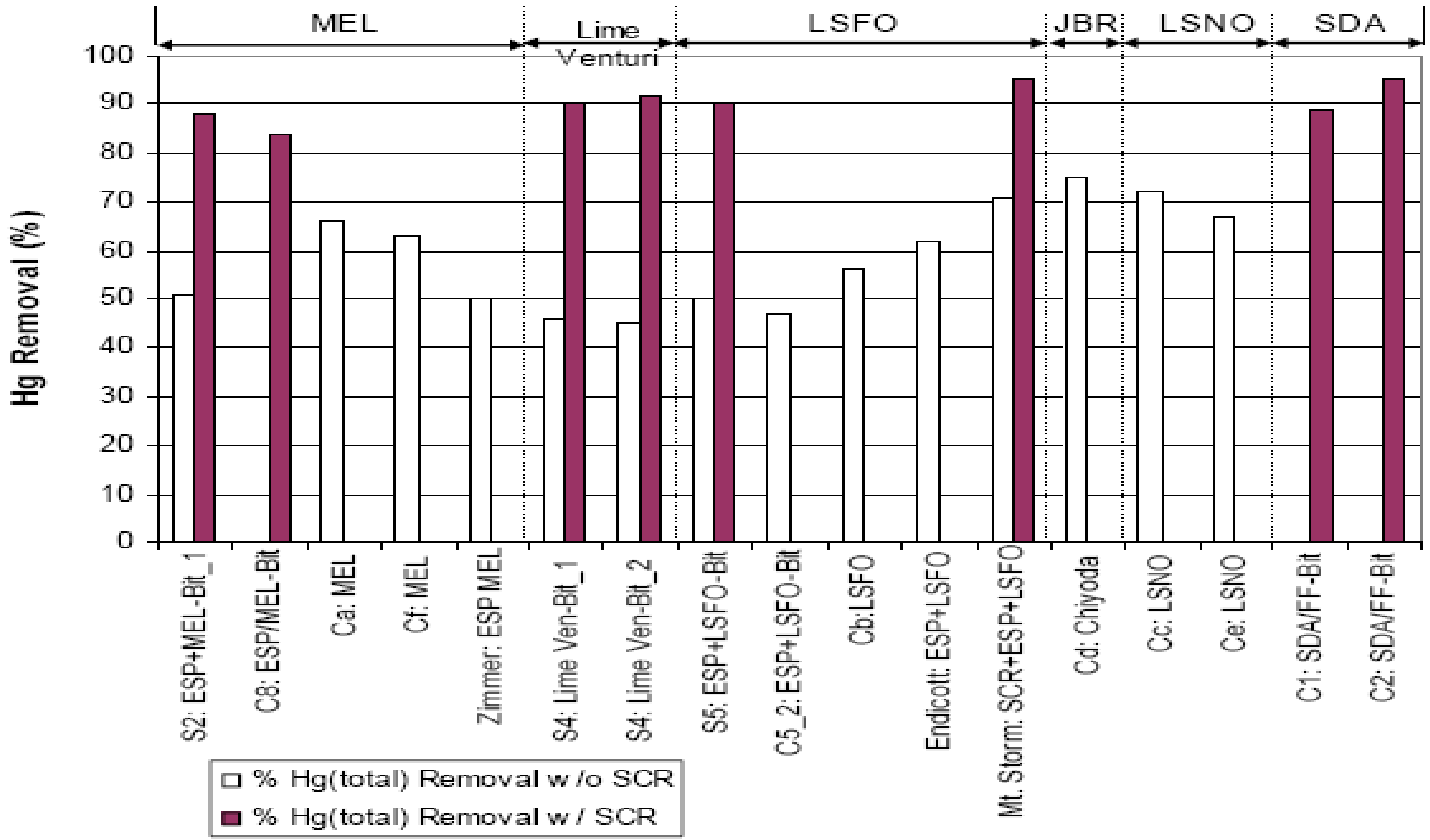
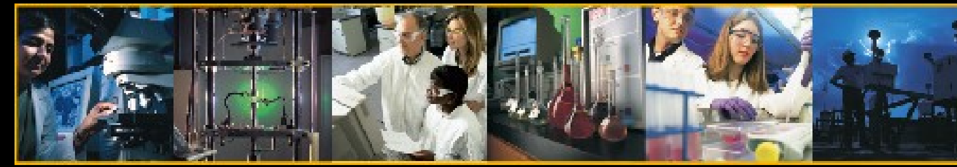
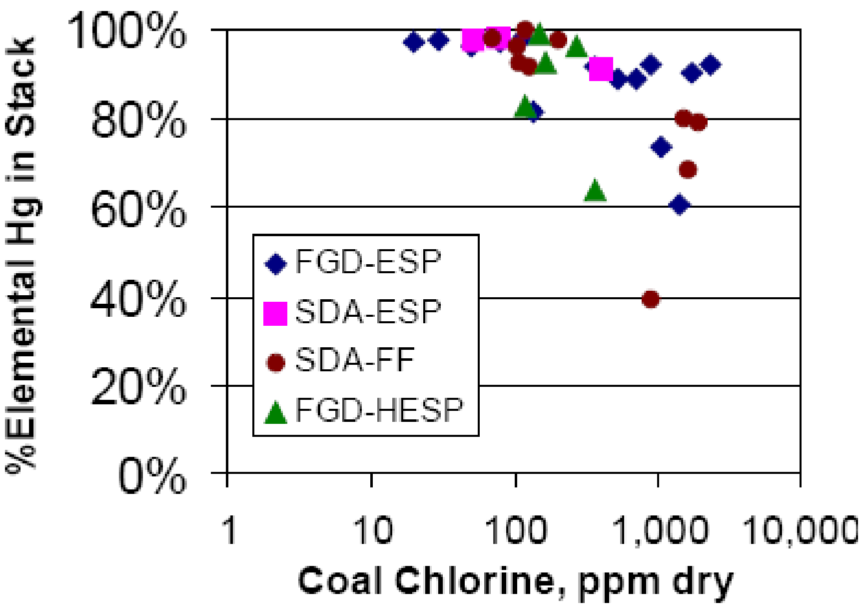


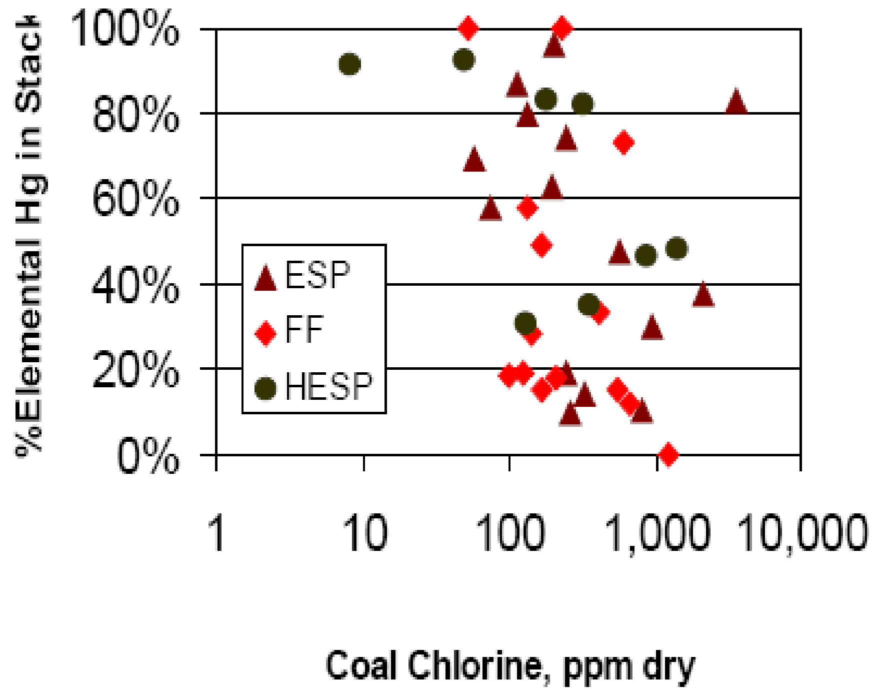
Hg Removal with Various FGD Systems

Reference: Control of Mercury Emissions from Coal Fired Electric Utility Boilers: An Update, Air Pollution Prevention and Control Division National Risk Management Research Laboratory Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, NC, February 18, 2005





(a) Scrubbers



(b) Particulate Control Devices

<u>Comparison of Elemental Mercury in Stack for Scrubbed vs. Non-Scrubbed Units</u>

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