



Mercury Emissions & Controls – Issues and Paths to Resolution

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Mercury “Basics”

- Mercury emission levels very low
 - ppb or lb/TBtu levels
 - ~250 lb/yr for 500 MW unit
- Generally a gas at ESP/fabric filter inlet
 - Elemental (metallic, Hg^0),
 - Ionic (oxidized, Hg^{+2}), or
 - Particulate (Hg^P)
- Typical speciation
 - Powder River Basin (PRB): 75-90% Hg^0
 - E. Bituminous: 60-90% Hg^{+2}
- Speciation affects controls and transport
- FGD captures only Hg^{+2}
 - Some captured Hg^{+2} may be converted to Hg^0 and re-emitted

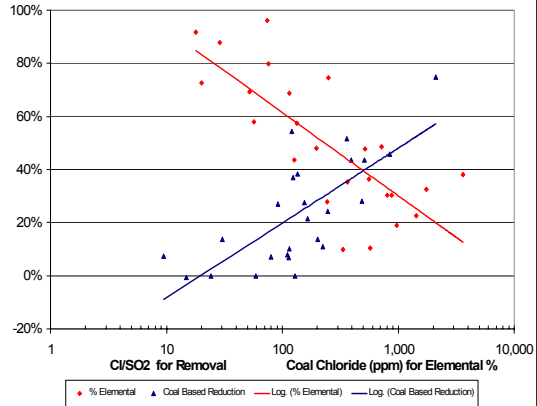
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Predictive Estimates, Models

- **Predictive correlations**
 - EPRI developed from the EPA Information Collection Request (ICR) data
 - Does not incorporate unburned carbon, LOI
- **2 first principle “models” being developed**
 - Homogeneous (without fly ash) – not sufficient
 - Heterogeneous (with fly ash) reactions must be included

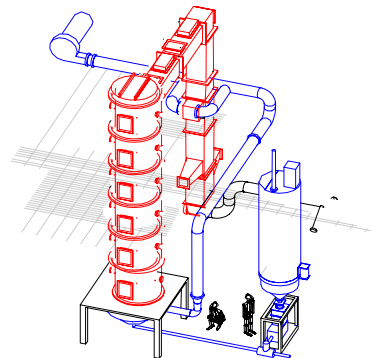


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Flue Gas Chemistry Mercury Speciation at Particulate Control Inlet

- **Questions remaining**
 - Reactions, rates esp. with unburned carbon, fly ash
 - Will models adequately predict?
 - Confidence levels; will plants just measure?
- **Solution path**
 - Pilot combustor studies
 - Modeling pilot and field data
 - Fundamental studies by EPA, et.al.
- **Roadmap**
 - Update EPRI correlations – '05
 - Heterogeneous model – 4Q'05
 - Further refinements as necessary



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How to Demonstrate Compliance?

- Draft “Mercury” Rule (12/03) offered 2 options:
 - CEMs – Continuous Emission Monitors
 - EPA Method 324, e.g. EPRI QuickSEM™
- 12 month rolling average
- CEMs
 - Near continuous data
 - Costs ~ \$100k capital
 - New, dry-based may be less labor-intensive. Stay tuned!
- QuickSEM™ (QSEM)
 - Time average – 1 week to 1 month
 - Costs ~ \$5-10k capital
 - Simple, low maintenance



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CEMs – Continuous Emission Monitors

- 13 Hg CEMs *Offered* commercially
 - EPA verification tests
 - Several passed accuracy test at an “easy” site (PRB coal)
 - Currently at 1st site with wet stack (E. Bituminous, FGD) – ultra-low Hg levels
- Sample conditioning is key issue
 - Wet chemistry used in past
 - Labor-intensive
 - Current tests with new, dry converters
 - Need challenge with range of flue gases



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EPRI QSEM



- Simple, low-cost, total mercury measurement
 - Activated carbon sorbent
 - Validated, EPA method
 - Included in proposed draft Hg rule
- Evaluated at 5 power plants
 - EPA CEMs Verification Tests
 - Passed accuracy test at the PRB power plant
 - Additional evaluations on-going
- Commercially available
 - Further refinements planned for wet stacks, flow control

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QSEM – EPA CEMs Verification Tests Relative Accuracy with Ontario Hydro Method

	All Runs (%)	Best 9 (%)
Site 1	53.9	4.8
Site 2*	9.5	1.6
Site 4 May	15.7	7.3
Site 4 July	19.7	11.3

* EPA pilot combustor

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Monitoring, Measurement

- Questions remaining
 - Will CEMs/QSEM work in all flue gas environments?
 - Ready in time?
 - Costs, maintenance
- Solution path
 - CEMs – follow EPA, vendor testing
 - QSEM - Field tests, and more!
 - Utilities encouraged to evaluate
 - Wet stacks
- Roadmap
 - Commercial QSEM – '03
 - Refinements – '04 and beyond
 - CEMs – progressing, when?



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SCR + FGD Co-benefits

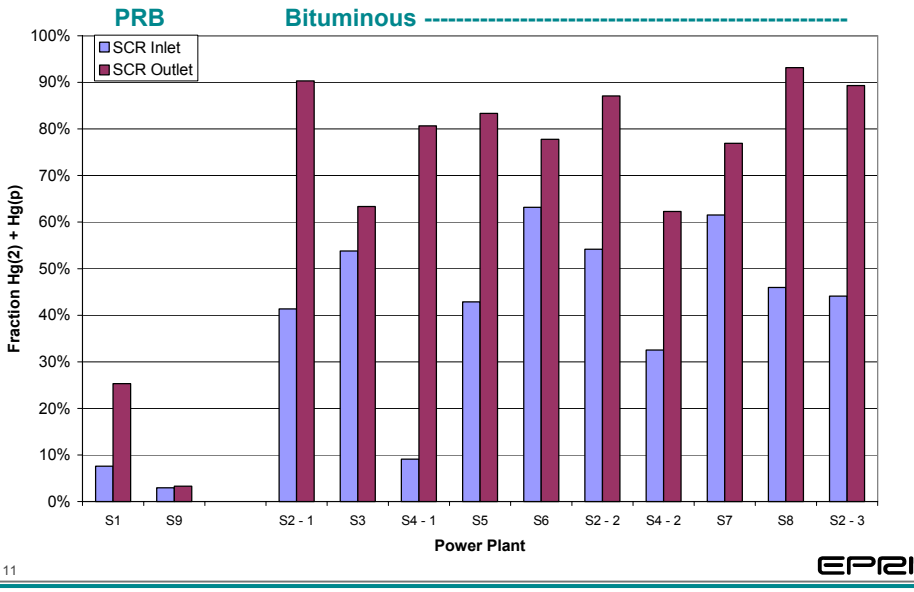
- SCR – Selective Catalytic Reduction: NO_x control
 - May oxidize Hg⁰ to Hg⁺²
- FGD – Flue Gas Desulfurization: SO₂ control
 - More efficient in capturing Hg⁺²
- Proposed “Transport” rule – more SCRs and FGDs
- Proposed “Mercury” rule – depends heavily on SCR + FGD cobenefits



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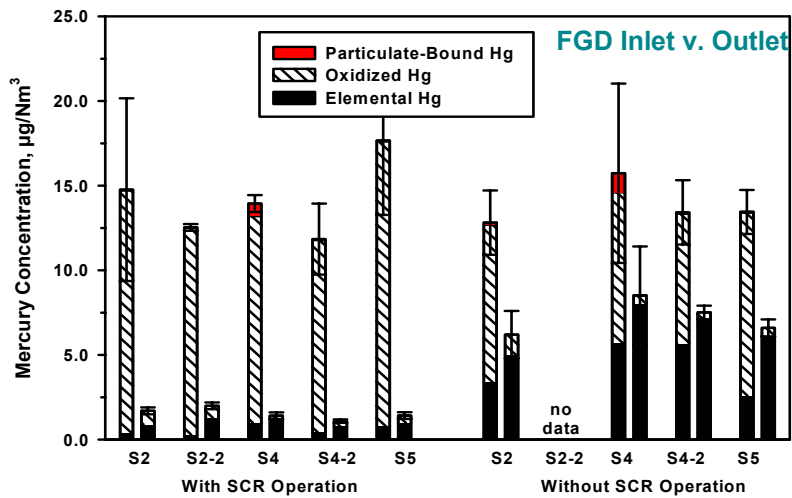
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Mercury Oxidation Across SCR Bituminous Coals – Likely, but Variable



SCR + FGD Cobenefits

Only 3 different FGDs tested; 2 Mg-Lime, 1 Venturi Scrubber



Co-benefits (SCR + FGD) – Bituminous Coal

- Questions remaining
 - Limestone, forced oxidation FGDs – will this design affect Hg removals?
 - PRB coals – are cobenefits possible?
 - Predicting SCR oxidation: variation with catalyst, flue gas, catalyst design
- Solution path
 - Field tests to include:
 - Limestone, forced oxidation FGDs
 - PRB coals, more bituminous
 - Pilot sidestream SCR, bench-scale tests – evaluate key parameters
- Roadmap
 - Preliminary SCR estimates – 1Q '05
 - Predictive model – 1Q'06
 - Refinements – as necessary



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Sorbent Injection – Prime Option for Plants Without FGD

- Sorbent injection is leading candidate
 - Activated carbon injection (ACI) best known
- % reduction depends on fuel
 - Lo-S Bit > high-S Bit > PRB/ND lignite
- All tests to date short-term
 - 1 long-term test underway
 - Others in 2004-6 under DOE program
 - 1-2 months
 - Multiple sites
- Substantial effort on lower cost or non-carbon sorbents



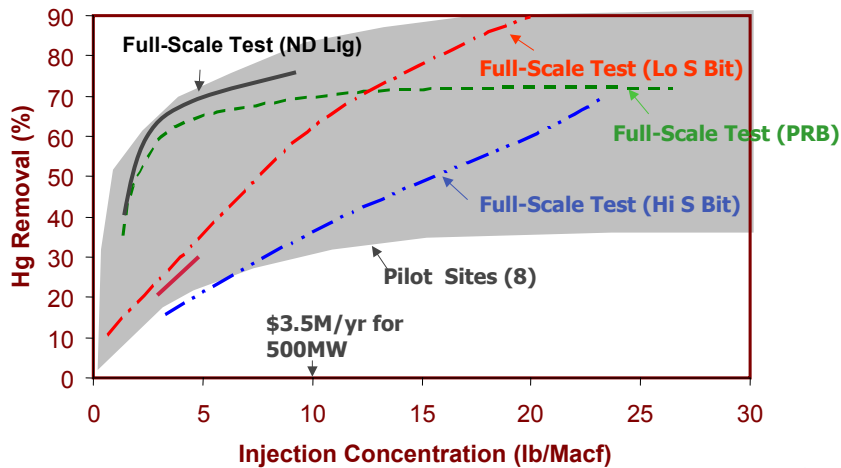
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Hg Removal by ACI w/ ESPs

-Which line is correct?

-Is each unique or representative of a category?

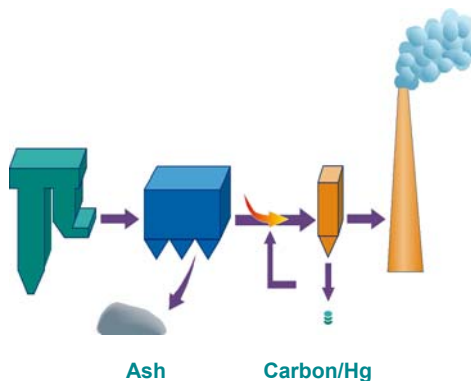


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Sorbent Injection (cont.)

TOXECON™ -- injection between ESP and polishing baghouse

- 80-90% removals appear possible
 - Much less sorbent than injection ahead of ESP
 - Recently started PRB pilot test
- No ash impacts
- \$45-55/kW projected
- Assumes real estate available
- Technology undergoing long-term test

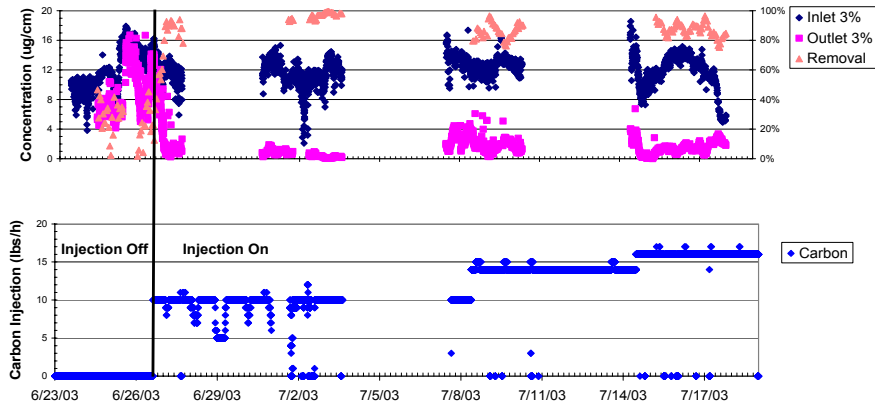


TOXECON™ II is alternative – injection into last ESP field

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Mercury Removal – 1 Month Trend



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Sorbent Injection (concl.)



- Questions remain:
 - Sustainable performance, costs, impacts for range of coals, combustion conditions (?), particulate controls (incl. hot ESP)
 - Capabilities of lower cost or non-carbon sorbents
 - Enhancement via chemical addition (W. fuels)
- Solution paths:
 - DOE, other field tests
 - Supporting lab, field pilot
- Roadmap:
 - DOE Round 1 tests - now to 3Q06
 - EPRI tests - now to 3Q05
 - New materials as offered

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Options for Low/Mod. Hg⁺⁺ & FGD

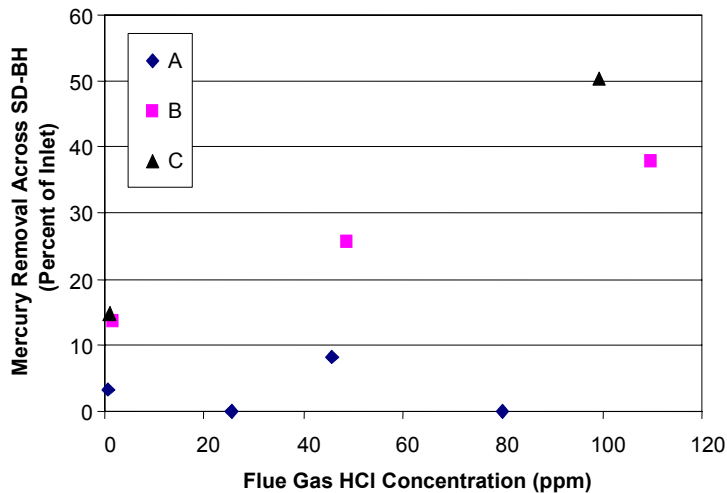


- Investigating oxidation catalysts (post-ESP) and chemical addition
 - Not all oxidized species captured
- Questions remain:
 - Catalyst performance, life, cost for range of fuels
 - What chemicals work, how much needed, differences with coal, boiler impacts, safety, costs
- Solution path:
 - DOE catalysts field pilot tests, full-scale designs
 - Full-scale injection tests, pilot combustor trials, modeling
- Roadmap:
 - Catalyst pilot 4Q06; full-scale TBD
 - Chemical additives 4Q06
 - Improvements will continue

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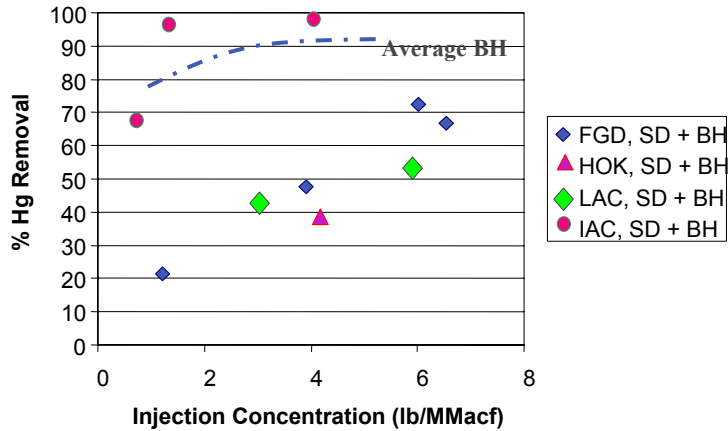
Impact of Different Salts on Hg Removal Across a SD-BH



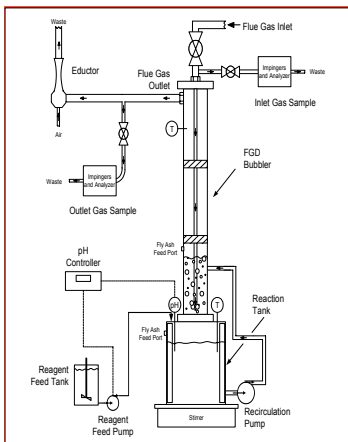
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SD-BH Reduces ACI Effectiveness for Low Chloride Western Coals



Capture/Fate of Mercury in FGD



- Questions on Hg chemistry in FGD:
 - Not all Hg⁺⁺ captured by FGD
 - Some captured Hg⁺⁺ emitted as Hg⁰
 - Chemistry causing above poorly understood
- Solution paths:
 - Field tests to seek patterns
 - Lab tests in representative pilot
- Roadmap:
 - 1-3 years

Pre-combustion Mercury Removal

- Moderate reduction option may open door to greater use of cleaned or “Hg-compliant” coal
- Question remains:
 - How much available
 - Safety, performance, deployment timeliness, fate of Hg with upgraded PRB, lignite
- Solution path:
 - Engineering evaluations
 - Possible test burns
- Roadmap
 - Uncertain; '05-'07 if evaluation positive and find host sites

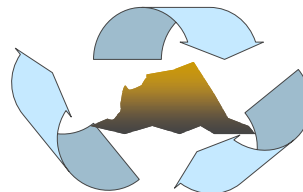


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Impacts of Controls on Combustion Product Use

- Mercury appears fixed in ash or gypsum in landfill
- General interest in using ash, gypsum to avoid landfill, gain other benefits
- Questions remain – fate of Hg when:
 - Ash used in high temperature applications
 - Gypsum calcined for wallboard
- Solution path:
 - Lab tests
 - Field test of gypsum plant
- Roadmap: 2-3 years



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Emerging Multi-Pollutant Controls – A Potential Option, But ...

- Many processes, a few leaders
- Often clever people involved; plenty of challenges
- Expect 10-25% savings over separate controls
 - Fertilizer market key to economics
- Commercial availability 3-5 years
 - Supportive legislation?
- EPRI seeking out, evaluating, testing

