Mercury Abatement in Power Generation -
Regulatory and Technical Status in the USA

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ALSTOM-Environmental Control Systems, Knoxville/TN, USA, exclusive licensee for North America

KNX™ Mercury Control Systems as trademark of ALSTOM Power Inc.

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Electric Power Research Institute, Palo Alto/CA, USA, research grant for demonstration test runs e.g. at the sites Monticello, Plant Miller

George R. Offen, Ramsay Chang

Southern Company Services, Inc. Birmingham/AL, USA, specific licensee for SC-utilities only

Larry S. Monroe, Mark S. Berry et. al
Example of EPRI project team on BCA in 2006
Bromine enhanced mercury abatement, invented by Prof. Vosteen in 2000

German Patent DE 10 233 173 granted 2005

US Patent 6 878 358 granted 2005

Canadian Patent 2 435 474 granted 2006

European Patent 1 386 655 granted 2008

Australian Patent 2 003 220 713 granted 2008

Patent applications pending in other countries
Agenda

- Introduction - Mercury Emissions from Coal
- US Regulatory Status 2008
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  - Activated Carbon Injection (ACI) - TOXECON™, TOXECON II™, Mer-Cure™ System
  - Boiler Chemical Additives (BCA) - Chlorides, Bromides (KNX™ Coal Additives)
  - Industrial Research / MACT
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- Outlook USA / Europe
- Acknowledgements
Mercury Emissions from Coal
in USA experienced as a growing threat

Eating Fish – Benefit, Risk, or Both?
Fuel
Hg, Cl
75 Tons Hg*

Stack Emissions
45 Tons Hg*
Hg⁰, HgCl₂

Bottom Ash & Fly Ash
Hg 30 tons Hg*

FGD Byproducts and Waste

* Values are for the entire US Market
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US coal fired power capacity

- 1300 units
- 500 plants
- 305 GW installed (mean unit size 230 MW)
- 1/3 of capacity has FGD
- 1/3 has or will have SCR based on existing plans
- Mercury from coal-firing is a political issue since late 1990’s
- Legal situation is complicated, and difficult to predict, actors:
  - Federal government, e.g. USEPA
  - States: 24 states have laws allowing more stringent limits than the federal limits. New plants permits with mercury rules.
  - Courts
  - Consent decrees
Clean Air Mercury Rule (CAMR) as proposed by US EPA on March 15th, 2005

Federal Law

- 2010: Hg Emissions Reduction to 38 tpy due to installation of more FGD and SCR, mainly in the East
- 2018: Hg Emissions reduction to 15 tpy
- Hg Emissions from new sources limited, depending on coal type (microg/MJ)

CAMR vacated by DC Court of Appeals on February 8th, 2008
EPA Regulations - actual considerations (2008)

- CAMR vacated on February 8th, 2008
- This puts an end to the (voluntary) cap-and-trade of Hg emission credits under CAMR
- Mercury again a Hazardous Air Pollutant (HAP) under Clean Air Interstate Rule (CAIR)
  --> Maximum Achievable Control Technologies (MACT) must be applied
- EPA will have to set an emission standard for every unit, independent of fuel, design, capacity
- Expected: > 90% Hg removal rate at all units
- Facility owners may be allowed to opt out of installing Hg CEMs
- States will likely still require Hg CEMs, but without emissions trading
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TOXECON™ Configuration

Presque Isle Power Plant

Coal

Hot Side Electrostatic Precipitator

APH

Fly Ash (99%)

Sorbent Injection

PJFF

Fly Ash (1%) + PAC
**TOXECON™ - 270 MW Demonstration**

- Presque Isle Power Plant, Marquette MI
  - Units 7-9
  - PRB Coal from Antelope and Spring Creek Mines

- $53.3M
  - $24.9M DOE
  - $28.5M We Energies

- 90% Hg Control
- 70% SO\textsubscript{2} Control
- 30% NO\textsubscript{X} Control
Economics – Cont.

- Capital Costs (2005$)
  - $34.4 million, 270 MW
  - $128/kw

- O&M Costs (estimate)
  - $0.81/MWH

- Hg Removal - 82 pounds/year
  - $11,000/lb – Variable
  - $62,000/lb – All In
„Technology commercially available“
Smoldering Filterbags, Hot Spots in 2 of 10 Chambers
Steve Derenne, DOE NETL Conference, Pittsburgh, Dec. 2006
Hot-Spot Problems shall be minimized today (2008)
Patented Mer-Cure™ system

Treated Sorbent

Hopper

Processor

Feeder

Air

Coal

Preheated Air

Air Heater

Particulate Collection Device

~250°F

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TXU Energy’s Monticello Steam Electric Station (793 MW)

Unit 3 tested in 2005  (DOE/EPRI Project on BCA)

50 % PRB coal and 50 % Tx-Lignite
Reduction of Baseline Elemental Mercury

Overview over all sites tested by EPRI in 2002 ... 2005 (chlorine) and respectively 2004 ... 2005 (bromine)
Alabama Power’s Plant Miller, 4 x 700 MW

Unit 4 tested 2006 (Phase I) and 2008 (Phase II)
Miller Measurement Locations
(October 2006)
CaBr$_2$ as 52 wt% solution was diluted with plant water into 2500 gal plastic holding tanks – 60 feet pumping distance up to the coal feeder deck level
Plant Miller in October 2006

Testing Results
Low Bromine Injection Test

0.5 – 1.0 ppmv HBr Concentration
Miller Average Elemental Mercury Concentrations
Measured During Each Bromide Injection Test (October 2006)
Hg Oxidation at Plant Miller - Modelling Prof. Vosteen:

SCR catalyst lowers the „Stop Temperature of Mercury Bromination“
Miller Phase II: Testings in March/April 2008 (SCR w/o NH₃) and June/July 2008 (SCR with NH₃)

Wet FGD-pilot (equivalent 2 MW)
Miller Phase II: Testing March/April 2008

25 ppm Br in the PRB coal  -  SCR w/o NH₃
Wet FGD-pilot (2 MW)

\[ \text{Hg}_{\text{total}} \text{- Measurements at WFGD-Pilot Inlet:} \]

\[ \text{Hg}_{\text{total}} \text{- Measurements at WFGD-Pilot Outlet:} \]

SCEM
Sorption Traps (Appendix K)
Ontario Hydro Method

Preliminary at WFGD-Pilot Outlet:

\[ \text{Hg}_{\text{total}} < 1 \mu g/dscm \text{ constantly} \]

(Data still to be cross-chequed)
KNX™ Coal Additive –
Addition on coal conveyor belt

Coal Conveyor (shown in black)

Injection Spray Header

KNX™ Additive Storage Tank

Metering Pump
KNX™ Coal Additive - drums and pumps in a full scale test
600 MWe, PRB coal, SCR/ESP/WFGD
315 t coal/h, 0.11 mg Hg/kg coal, SCR active year-around

> 95 % Total Removal
with 3,8 US gallons KNX per hour

March 31 until April 5, 2008
29 ppmw bromide per coal

Preliminary data

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Halogen Testing at Mercury Research Center

- Owned by Gulf Power
  - Plant Crist Unit 5
  - Operated by PCT Inc.

- 5MW Research Facility
  - Full Environmental Control Technology Suite

- EPRI - Halogen Injection Program
  - HCl, xBr, xCl
  - with & w/o SCR
  - 4 different catalyst types
  - Removal across WFGD

Gulf Power Mercury Research Center
Evaluating Bromine Fate & Balance-of-Plant (BOP) Impact

BOP

Advisory Committee (EPRI, Utilities, Experts)

Field Testing

Lead Coordinator (URS Corporation)

Literature Survey and update

Sample Acquisition

Laboratory Testing

Simulated Samples

Hg and Br measurements

Ash

Scrubber

Leaching

Ash Use

Liquid

Solid

Corrosion

Mercury Partitioning

Southern Company

EPR1
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Estimates for Plant Miller:

4 x 700 MW = 2,800 MW

12M dscm per hour

TOXECO\textsuperscript{TM}:

High Capital costs:

> $420M

High O&M Costs:

$8.4M per year for PAC,
$5.6M per year for bag replacement

22.4 MW auxiliary power

KNX\textsuperscript{TM} Technology:

Low Capital Costs:

little capital equipment, small footprint within the plant

Low O&M Costs:

$1.6M per year for CaBr_2
~ $5,000/lb Hg
(little or no impact on ash)
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Market US + Canada

> 90% mercury removal

Emissions < 1 μg Hg/dscm (goal)

Maximum Achievable Control Technology (MACT)

EPRI BOP Project (Br, Hg,...) etc.
EPRI MRC with Southern Company
EPRI site tests (e.g., PAC + KNX™)

Market EU

> 90% mercury removal?

New permits in NL, e.g.:
Emissions < 2.4 μg Hg/dscm
Emissions < 1 μg Hg/dscm

Best Available Technology (BAT)?

Industrial R&D?
VGB Project?
US coals have natural Br content of 0 - 100 ppm
Native Bromine in US coals
(Dr. Leif Lindau, ALSTOM POWER, in 2006)

- Subbituminous coals have very little: 0.5-5 ppmw in the coal
- Lignites have little: 1-10 ppmw
- Bituminous coals have more: 1-100 ppmw

- The industry has always lived with these coals, and no difference between high and low Br coals has been discerned...

- ...until now that Hg has become an issue:

- More than native Cl of some 1000 ppmw, native Br of only some tens of ppmw in the coal might be the crucial factor for mercury oxidation, as first advanced at AQIV Conference (Arlington, September 2003) by Prof. Vosteen of Germany
First two KNX™ Mercury Control Licenses issued in March 2008 for

Salt River Project's Coronado Station Units 1 & 2, AZ

(390 MW each, hot side ESP, WFGD with forced oxidation, fired with Western Bituminous Coal, 0.5 weight-% S)
First Industrial Demonstration in 2002 (2 x 5 days testing) 
diploma thesis of Michael Nolte 
PC-fired Wet Bottom Boiler (100 MW\textsubscript{therm}; 140,000 Nm\textsuperscript{3}/h dry) 
of CURRENTA GmbH & Co. OHG in Uerdingen (Germany), 
ESP, limestone based wet FGD, tail end DeNOx-SCR 

2002: Spiking with HBr, NaBr 

2008: Spiking with CaBr\textsubscript{2} (Dr. R. Krüger, DI D. Christoph)
May 2008:

KNX™ and PRAVO™
KNX™ and PRAVO™ - a perfect duo for mercury capture
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Carl Richardson
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Jennifer Paradis
Gary Blythe
John Currie
et al.
Thanks for Your attention

Questions?