Reinhold Environmental Ltd.

2008 NOx-Combustion Round Table & Expo Presentation

February 4-5, 2008 in Richmond, VA

Southern Company Bromine Injection Demonstration Results

Reinhold Environmental
NOx-Combustion Round Table

Mark S. Berry
Environmental Controls R&D Manager
February 5th 2008

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Demonstration Team

URS

Carl Richardson

Katherine Dombrowski

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Mark Berry / April Freeman Sibley

Eddie Borders / Shane McCray

EPRI

Ramsay Chang

VOSTEEN CONSULTING GMBH
Thermal Engineering and Environmental Protection

Professor Bernhard Vosteen

WS Hinton & Associates

Particulate Control Technologies

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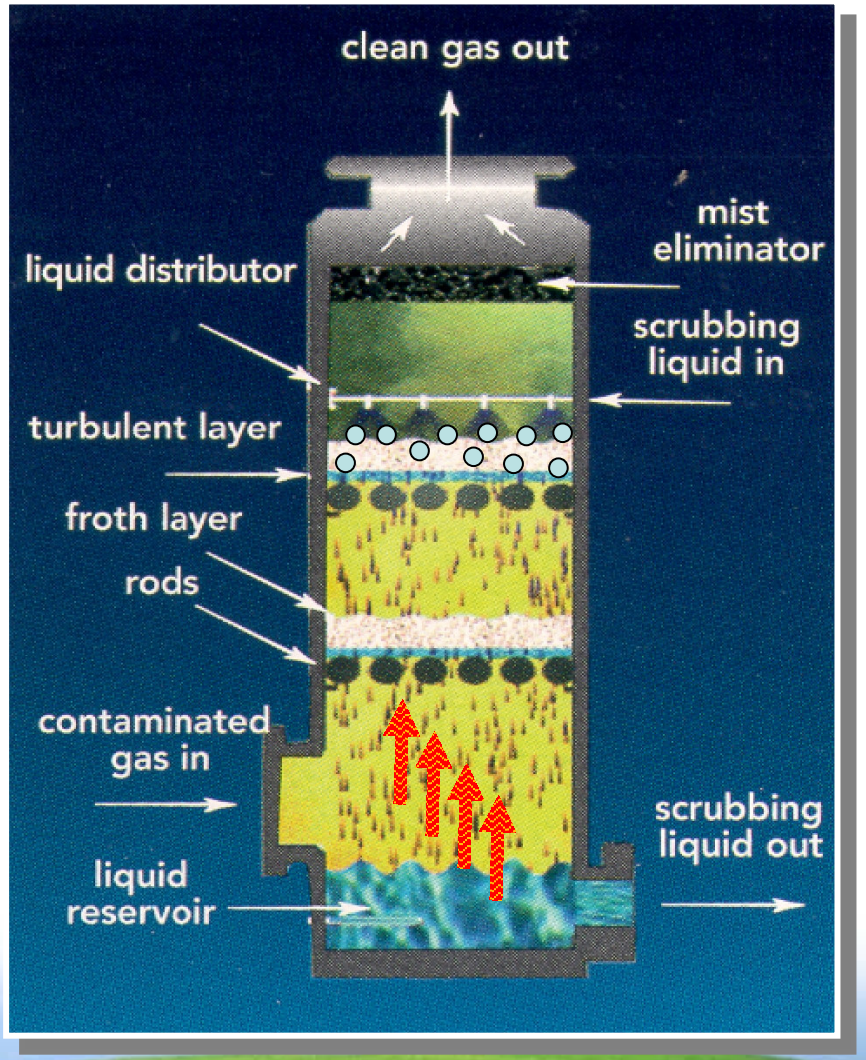
Types of Mercury

- **Oxidized Hg^{2+} (soluble)**
  caught with SO_2
- **Elemental Hg^0 (insoluble)**
  not captured
- Control methodologies
  - Co-Control in wet scrubbers
    - Hg^{2+} only
  - Activated Carbon Injection (ACI)
    - Hg^{2+} & Hg^0
    - ESP or Baghouse



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Financial Driver!

For a 500 MW unit

- TOXECON for Hg control (90% removal)
  - Capital cost: ($150 / kw - $200 / kw)
    - $75M to $100M
  - O&M costs
    - Activated carbon @ 200 pph: $1.50 M/yr material cost
    - Bag replacements (3 year life): $1.0M/yr
    - Fan and auxiliary power: 4 MW
- ACI into ESPs (50% - 70% removal)
  - @ 500 pph $3.75 M/yr
  - ESP Upgrades (NSR)
  - Loss of Flyash Sales

Clean Air Interstate Rule (CAIR)

- SCRs for NOx control already - in place
- WFGDs for SO_2 control - in place

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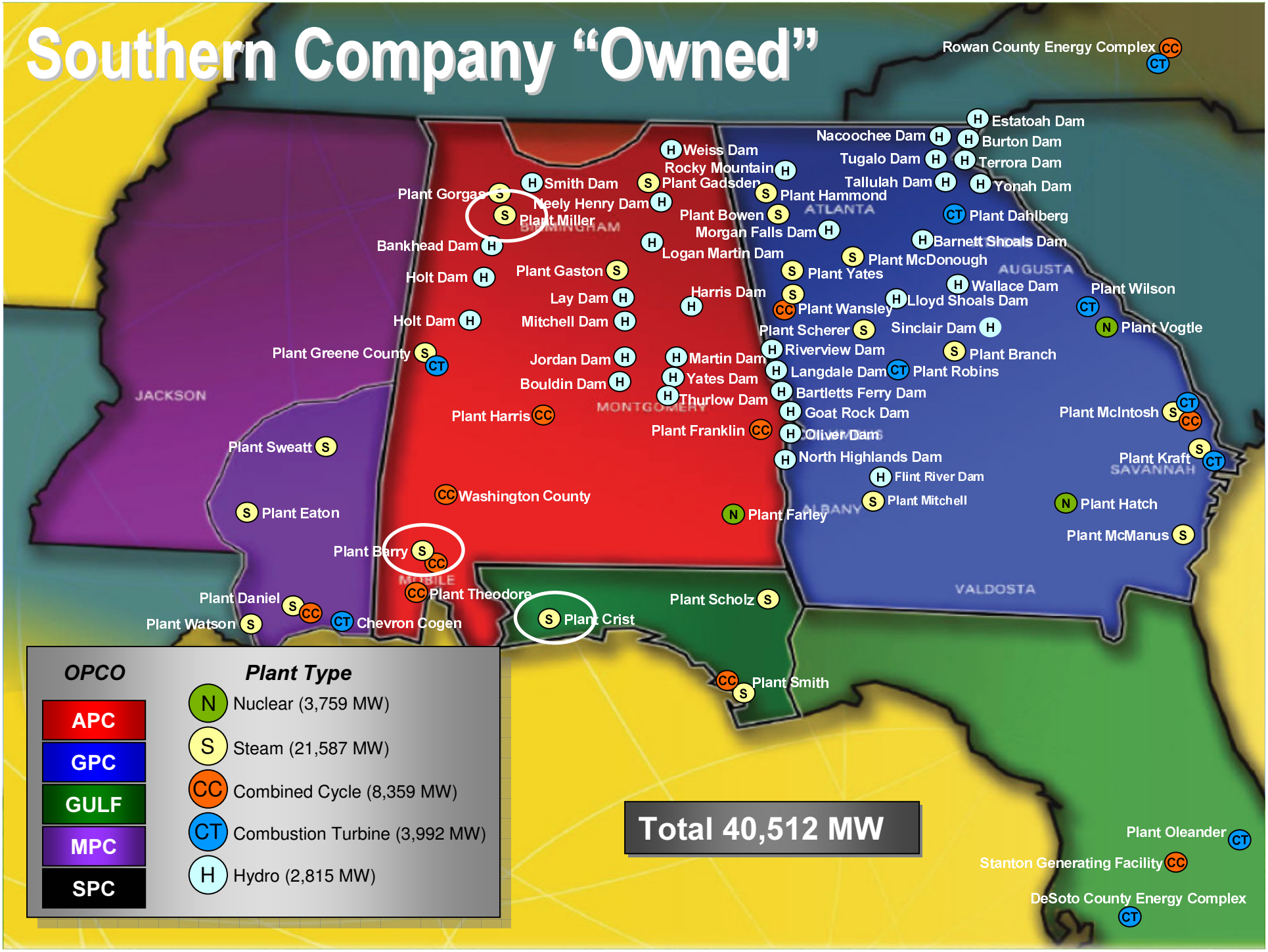
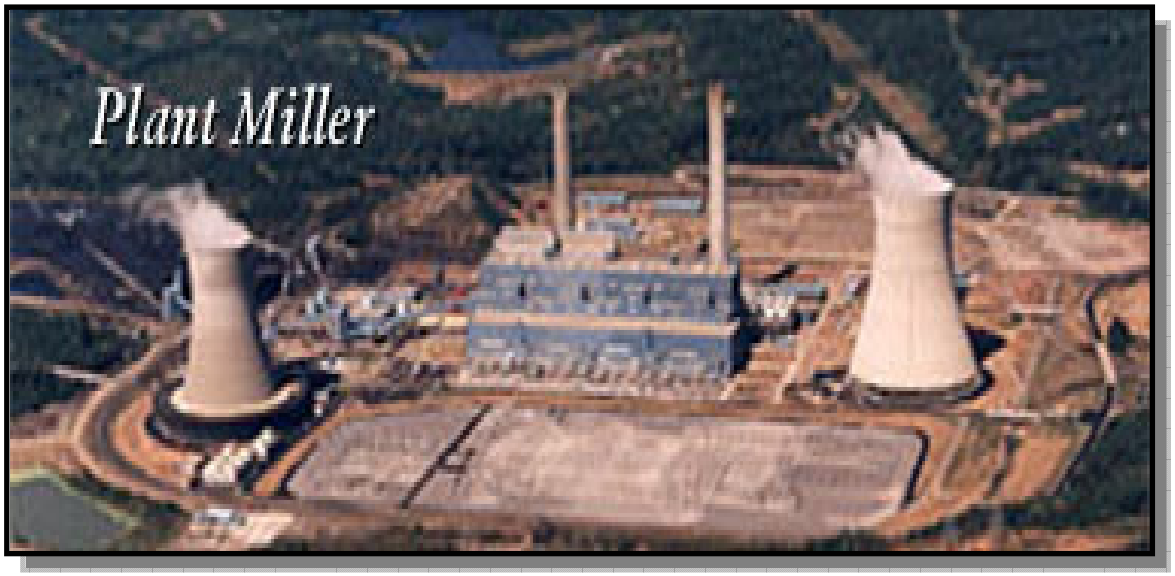

Southern Company "Owned"
Rowan County Energy Complex
Estatoah Dam
Nacoochee Dam
Burton Dam
Tugalo Dam
Terrora Dam
Weiss Dam
Rocky Mountain
Tallulah Dam
Yonah Dam
Smith Dam
Plant Gadsden
Plant Hammond
Plant Gorgas
Neely Henry Dam
Plant Miller
Plant Bowen
Plant Dahlberg
Morgan Falls Dam
Barnett Shoals Dam
Bankhead Dam
Logan Martin Dam
Plant McDonough
Plant Gaston
Plant Yates
Holt Dam
Wallace Dam
Plant Wilson
Lay Dam
Harris Dam
Lloyd Shoals Dam
Plant Wansley
Holt Dam
Mitchell Dam
Plant Scherer
Sinclair Dam
Plant Vogtle
Plant Greene County
Riverview Dam
Plant Branch
Jordan Dam
Martin Dam
Langdale Dam
Plant Robins
Bouldin Dam
Yates Dam
Bartletts Ferry Dam
Thurlow Dam
Plant Harris
Goat Rock Dam
Plant McIntosh
Plant Franklin
Oliver Dam
Plant Sweatt
North Highlands Dam
Plant Kraft
Flint River Dam
Washington County
Plant Mitchell
Plant Eaton
Plant Farley
Plant Hatch
Plant McManus
Plant Barry
Plant Theodore
Plant Daniel
Plant Scholz
Plant Watson
Chevron Cogen
Plant Crist
Plant Smith
OPCO
APC
GPC
GULF
MPC
SPC
Plant Type
Nuclear (3,759 MW)
Steam (21,587 MW)
Combined Cycle (8,359 MW)
Combustion Turbine (3,992 MW)
Hydro (2,815 MW)
Total 40,512 MW
Plant Oleander
Stanton Generating Facility
DeSoto County Energy Complex
ATLANTA
BIRMINGHAM
AUGUSTA
MONTGOMERY
JACKSON
MOBILE
ALBANY
SAVANNAH
VALDOSTA

Plant Miller Bromine Injection Testing

- 4 x 700 MW Units
- SCRs for DeNOx
- Advatech Scrubbers for SO_2 control (underway)
- CESPs for PM
- Phase I Testing
  - Oct. 2006
- Phase II Testing
  - Feb 2008



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Phase I Testing Summary

- Unit 4 Configuration During Test Program
  - Wall Fired Boiler
  - SCR with 90% DeNOx
  - 1100 SCA Cold-side ESPs
- Halogen injection
  - Br with coal (Vosteen Patent)
  - Inject chemical onto coal
  - GOAL: Measured the impact of Hg Oxidation at
    - Pre-SCR, Post SCR, ESP Inlet & ESP Outlet
  - Bromine Concentration Needed
  - Determine fate of Bromine

Parameter	Value
Fuel Parameter	**(dry basis, except where noted)**
Supplier	Cormetech
Catalyst Layers	3 + 1
Heating Value	11,899 Btu/lb
Structure	Honeycomb
Ash	5.5 wt.%
SCR Operating Temperature	720 F
Sulfur	0.3 wt.%
Moisture (as received)	30 wt.%
Design SO_2 to SO_3 conversion rate	2.67%
Mercury	0.068 ppm
NOx Reduction	90%
Chlorine	13 ppm
NH_3 slip	2 ppm
Bromine	5.8 ppm

SCR Reactor Information
PRB Coal

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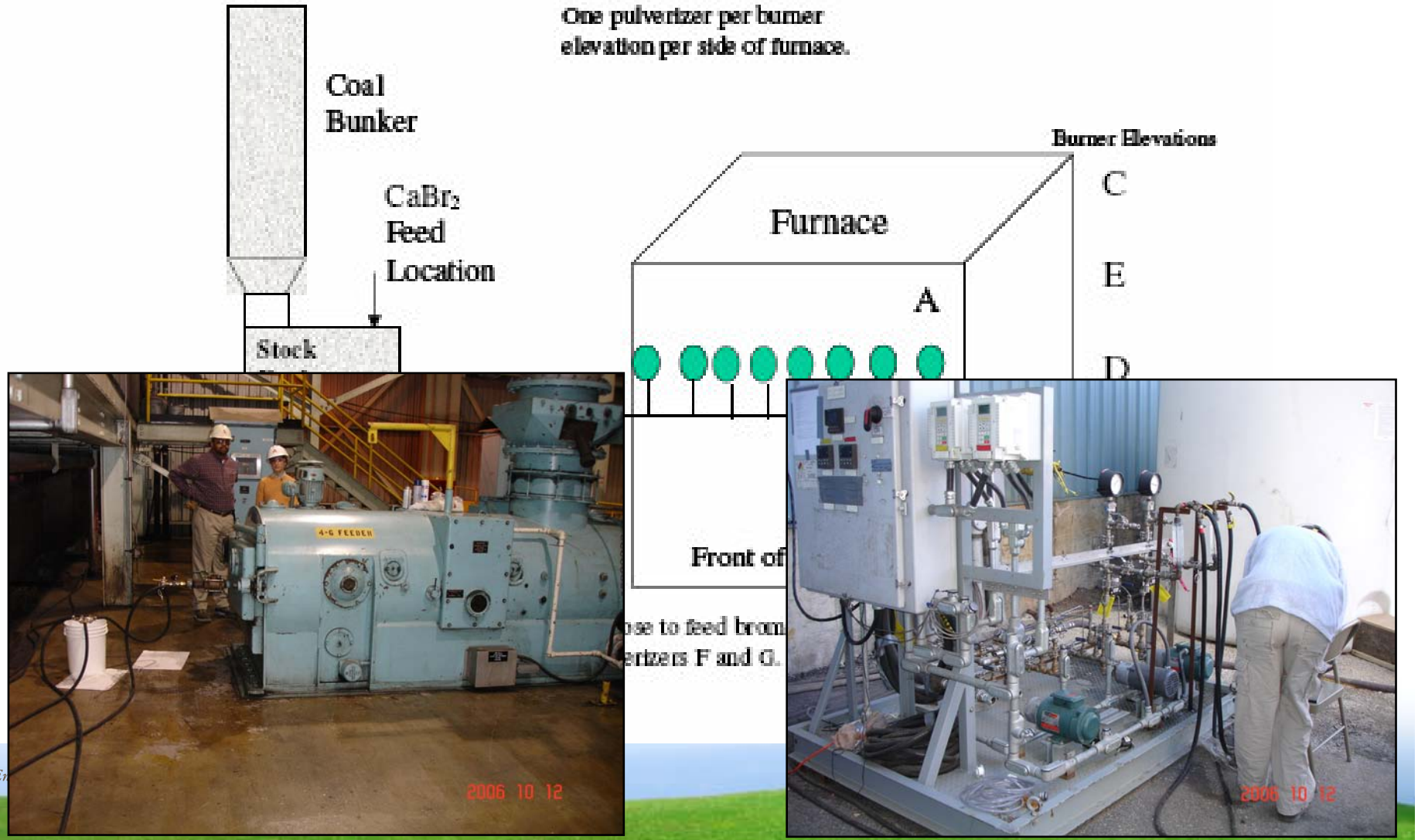
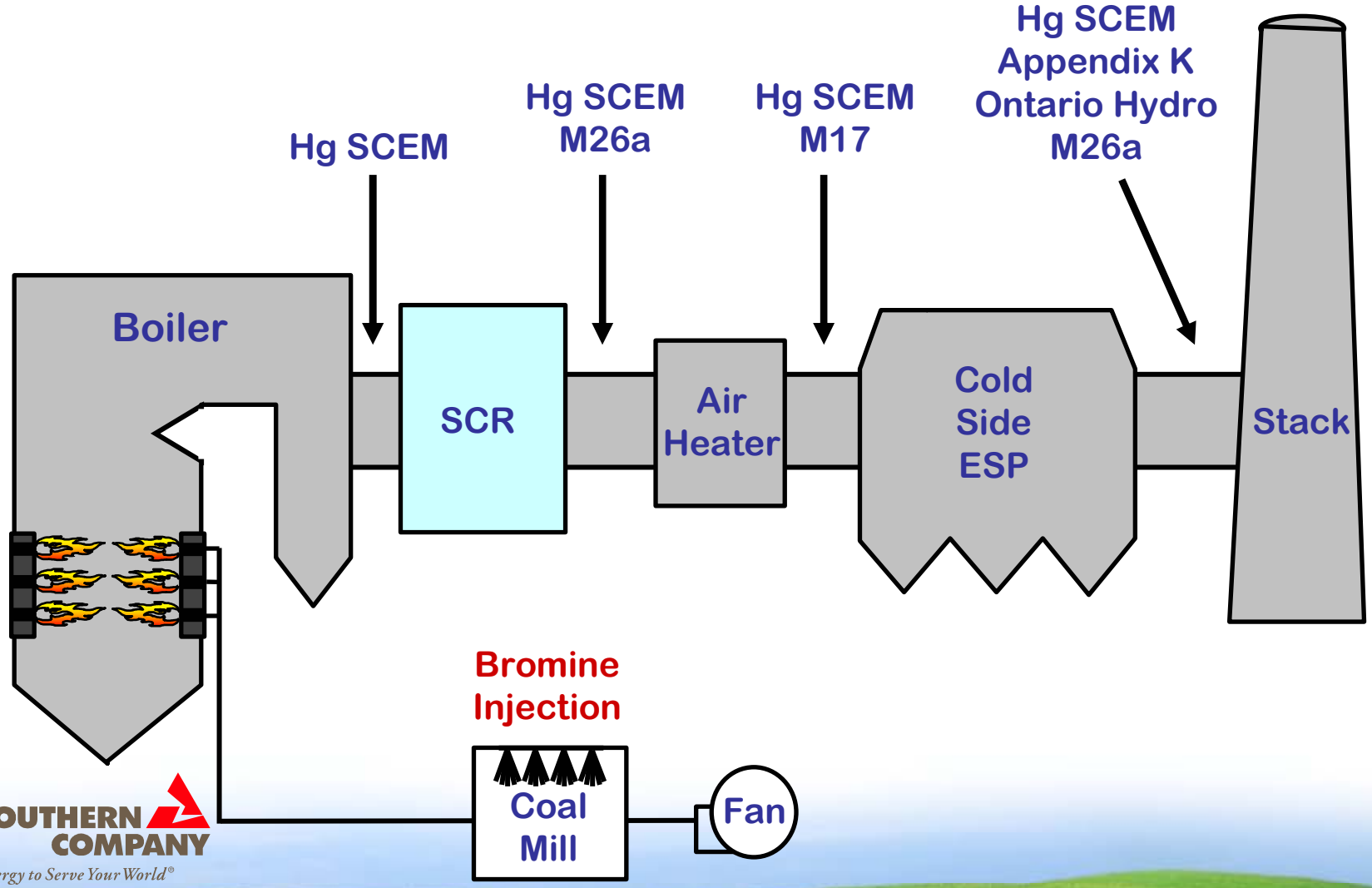
Method of Injection



Measurement Locations



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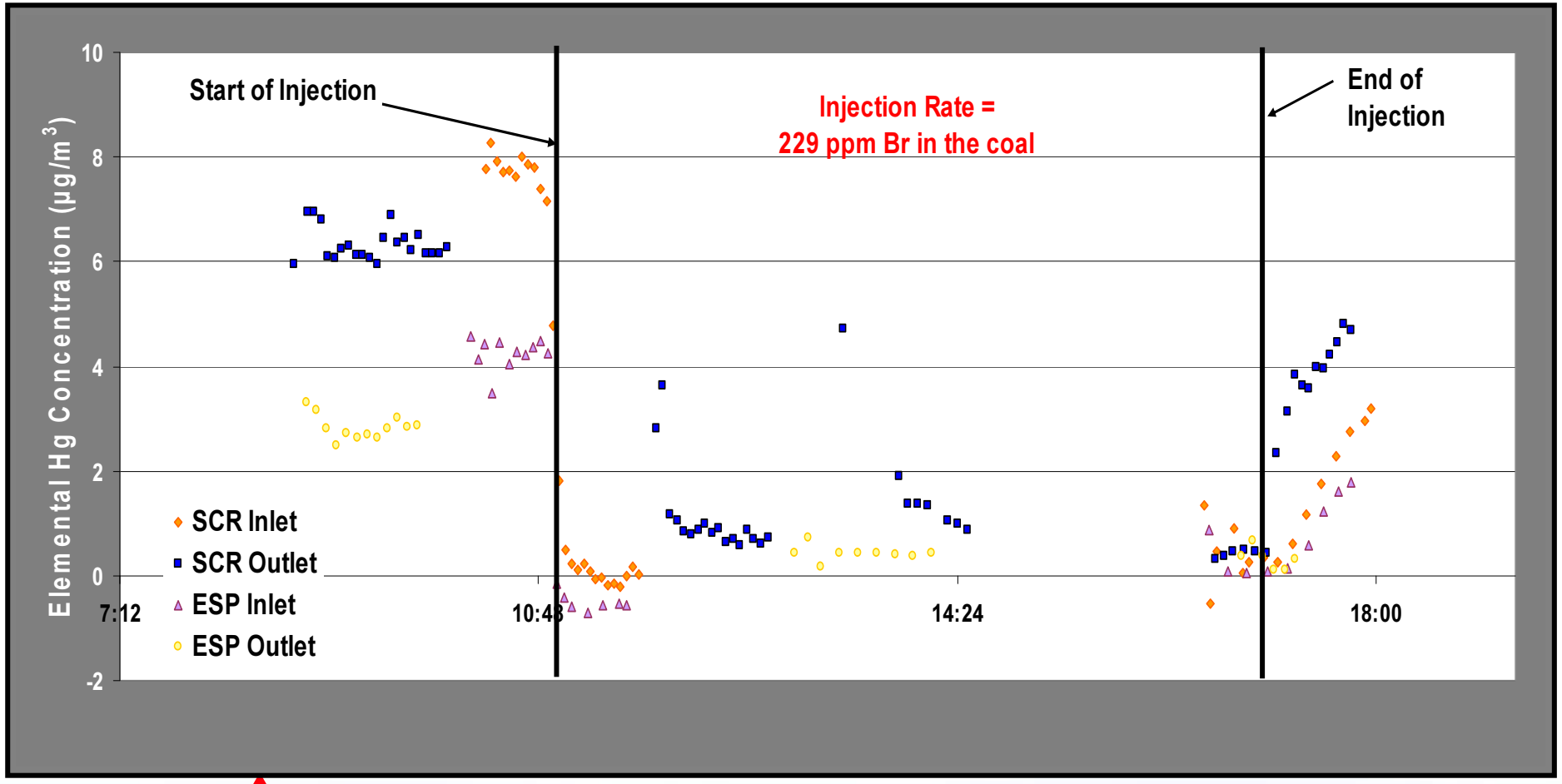
Testing Results
High Bromine Injection Test



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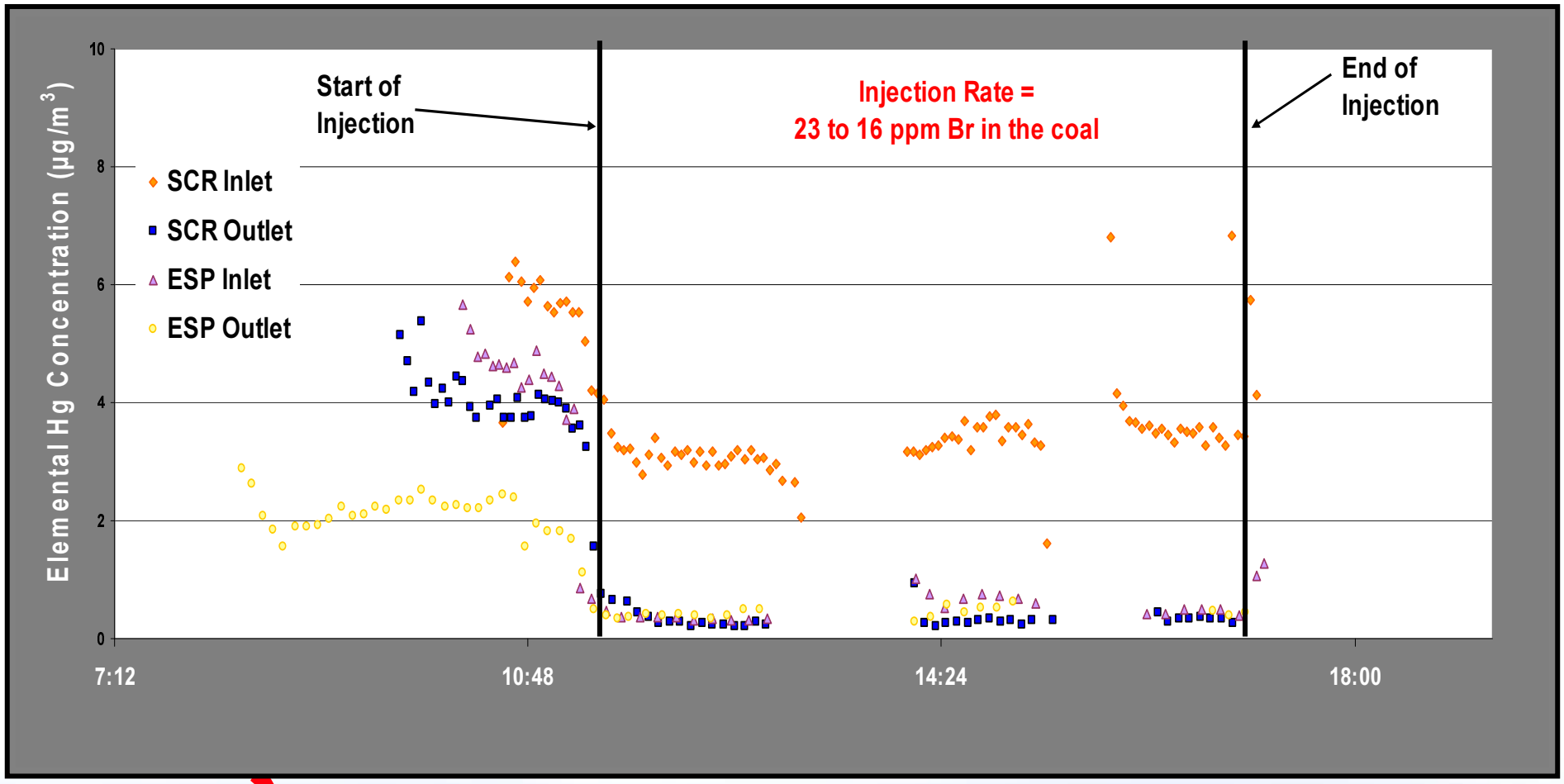
10 ppmv HBr Concentration

Testing Results
Low Bromine Injection Test



0.5 – 1.0 ppmv HBr Concentration

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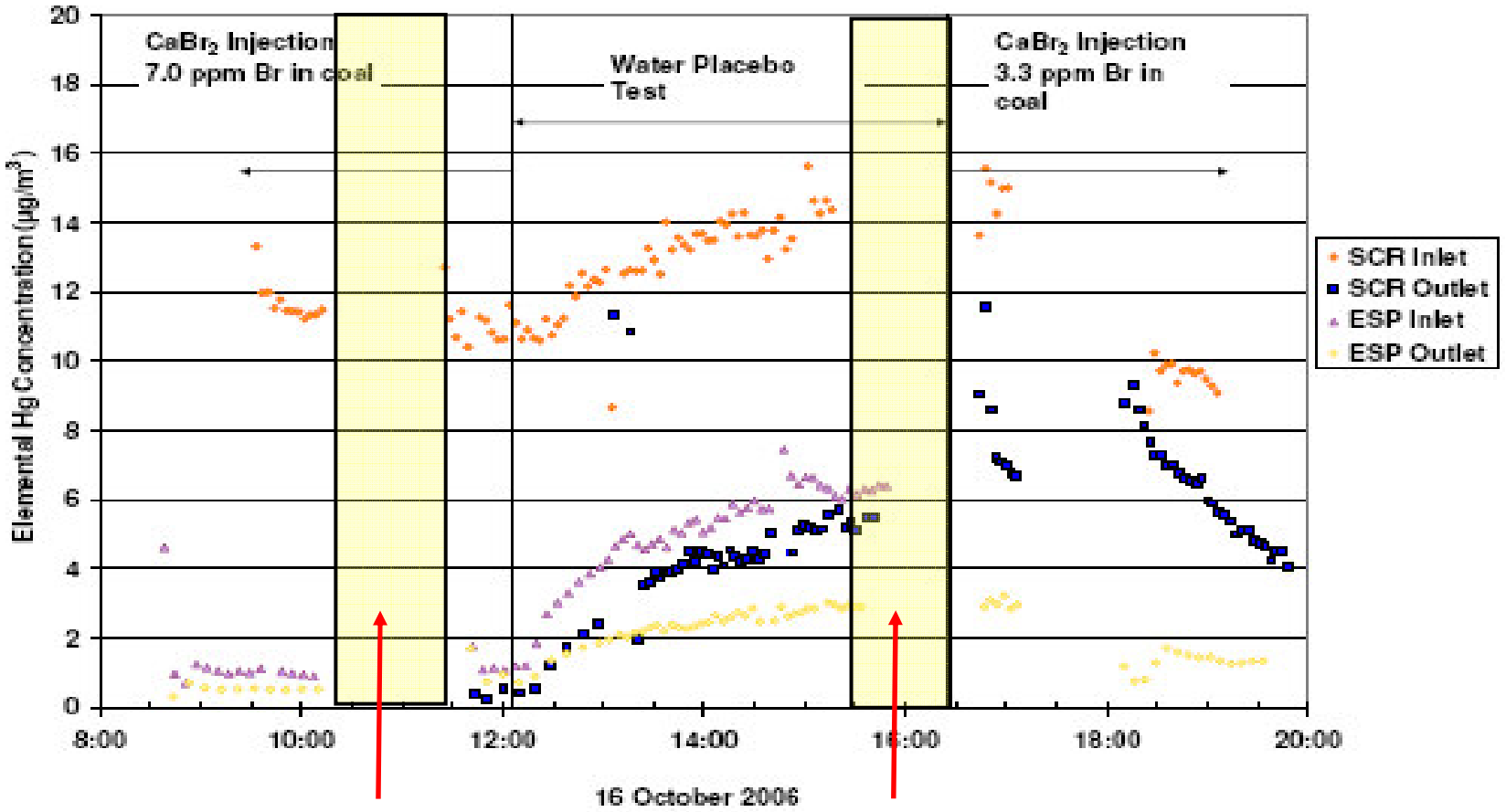
Water Placebo Test



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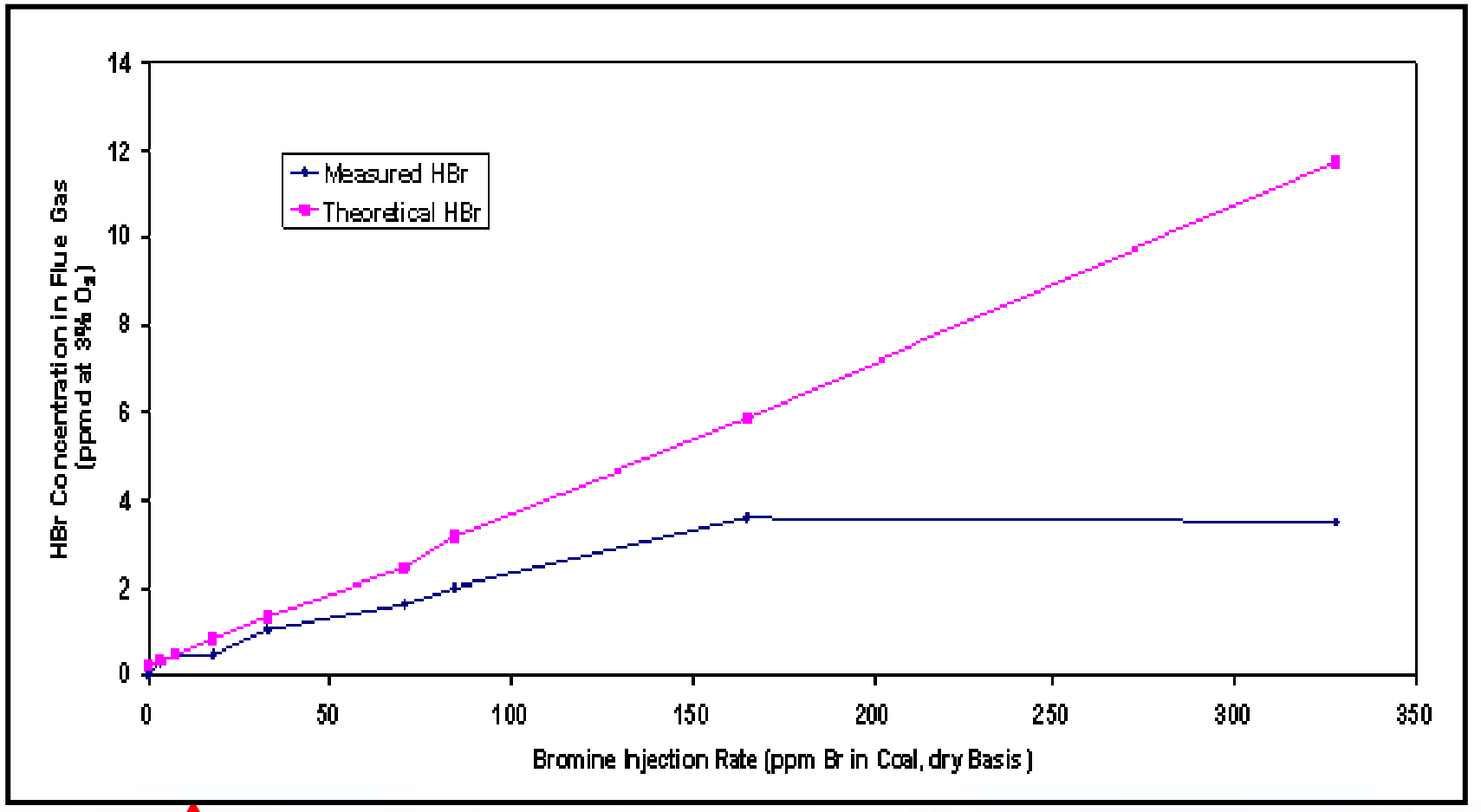
Where does the Br go?
M26 Results



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Br effects on Concrete

- 2006 Testing: Appeared that Br affected concrete 28 day strength
  - USA Ready Mix 4000 psi / 28 day design
  - All Class C ash sold at plant (1200 ton/day)

- Summer 2007 Lab Study showed no effect on concrete
  - Same USA Ready Mix Design

- **Research Program w/ Gallet & Associates**
- **Testing Series**
  - 3d, 7d, 14d, 28d & 56d strength testing
  - Set-time

Date	Br Injection Concentration (ppmv)	Br Ash Concentration (ppm)	Concrete Set Time	28 Day Concrete Strength (psi)	Baseline difference (%)
10/6	0	Not detected	315	5975	NA
10/10	10	43.5	300	4690	-21.5
10/11	5	4.0	315	5010	-16.2
10/12	2	4.8	270	4915	-17.7

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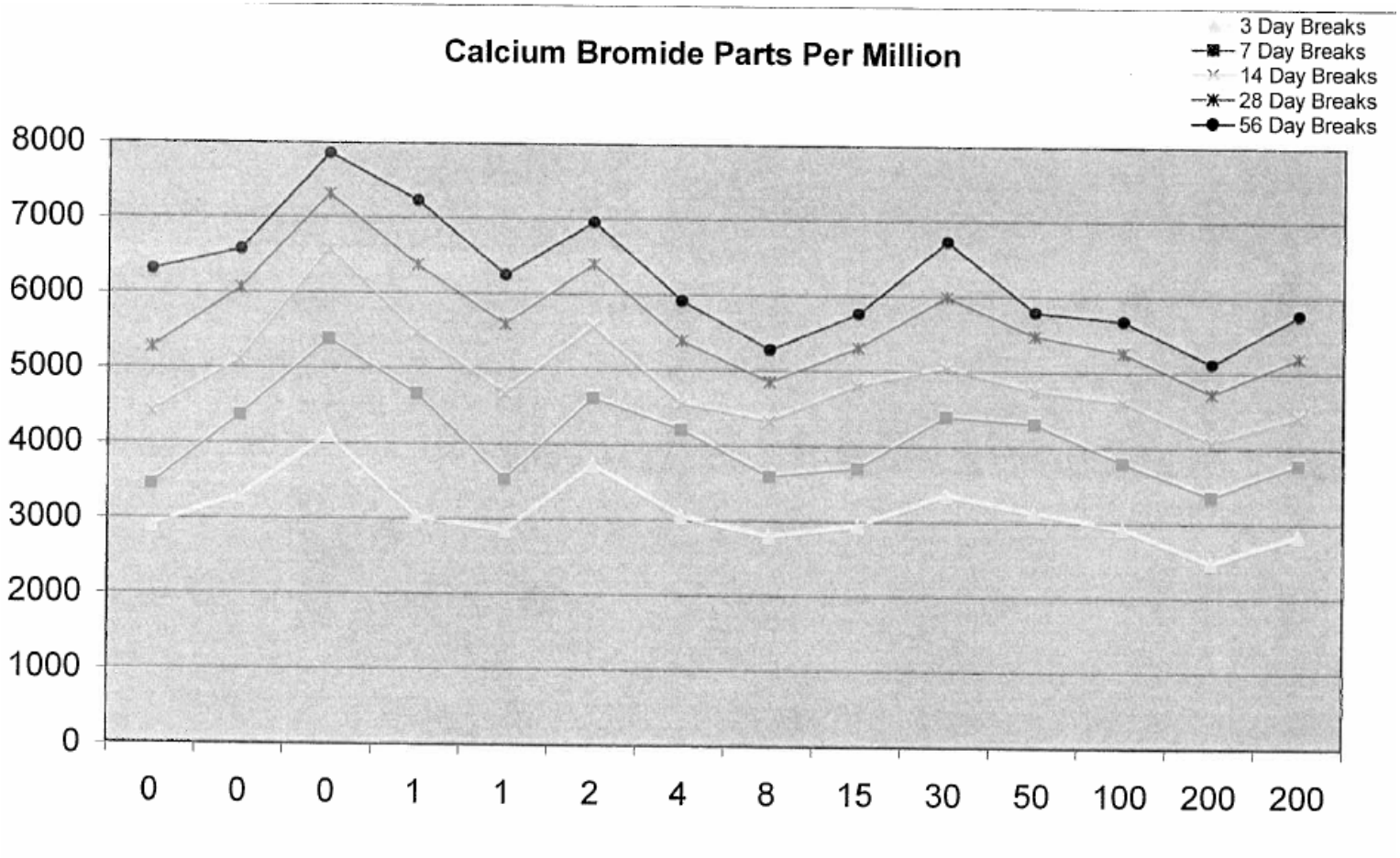
Simulated Bromine Injection Results



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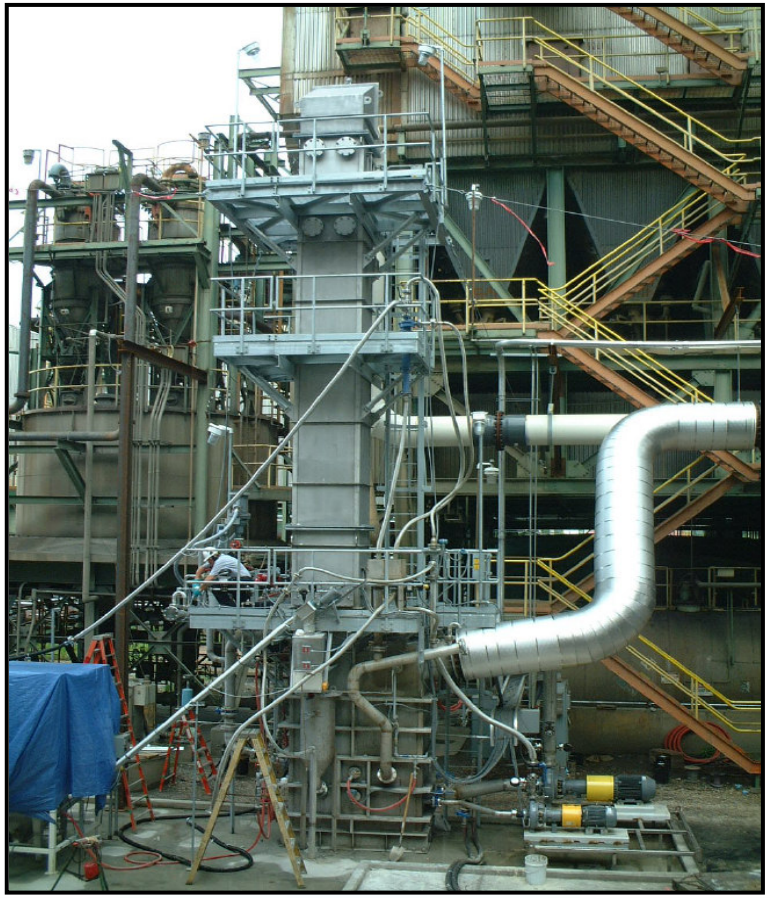
Miller Phase II Testing

- 6 week test program planned
- Mid February 2008 start date
- Key issues
  - Confirm earlier results with SCR
  - Determine oxidation results without SCR in service
  - Confirm Hg removal across pilot scale FGD
    - Investigate FGD chemistry (Hg, Br, Cl interactions)
  - Hg Partitioning (liquor / gypsum)
  - More ash / concrete admixture testing



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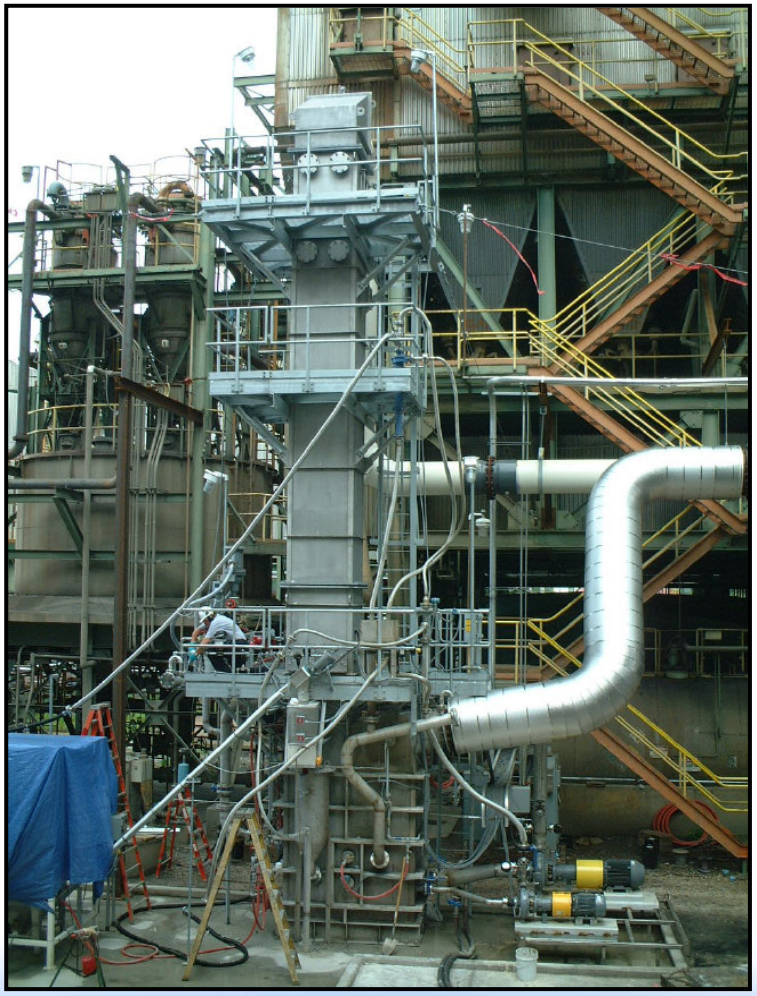
Plant Miller
Phase II Test Plan

Three Distinct Sections

- Parametric Testing with SCR-Off
  - Impact of the SCR on bromine usage rates
- Parametric Testing with SCR-On
  - Verify oxidation that was seen in 2006
  - Removal across pilot scrubber
- Steady State Testing with SCR On
  - Long-term oxidation / Hg removal performance
  - Hg re-emissions ???
  - Monitor scrubber chemistry (Hg, Br, Cl, etc…)
  - Concrete Testing with flyash + bromine
  - Gypsum Testing



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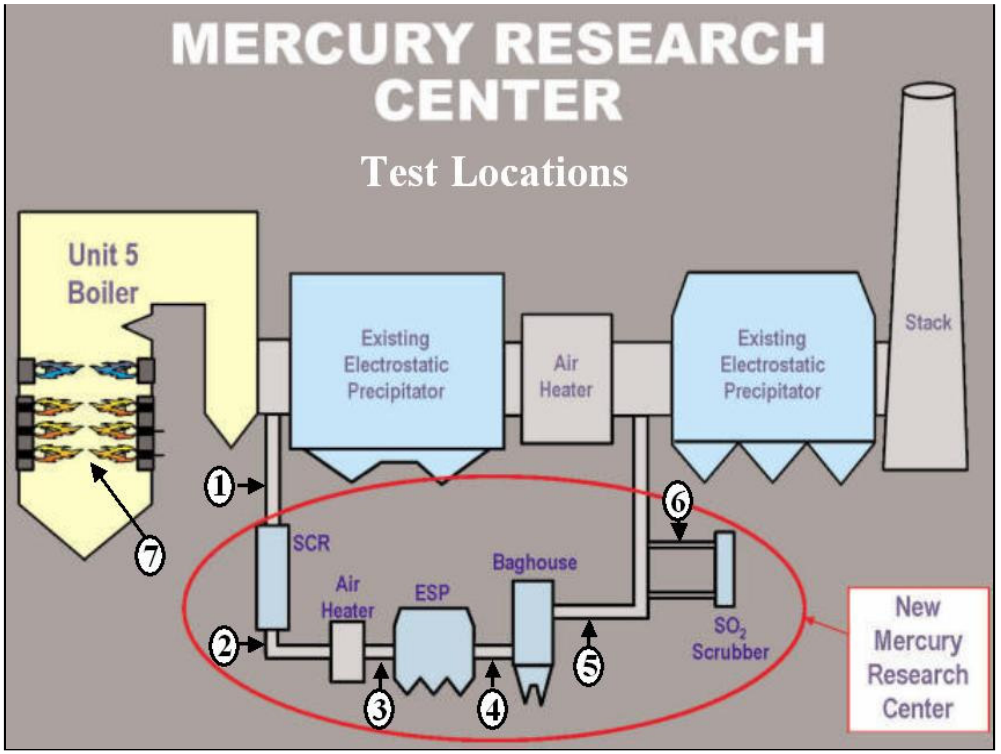
Halogen Testing at Mercury Research Center

- **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

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MRC Bromine Injection Study

- Test Conditions
  - With & without SCR in service
  - Various Concentrations of Bromine (0 – 100 ppm on the coal)
  - Flue Gas Temperature: 650 F to 700 F
  - Low Halogen Fuel (Colombian)
- Hg Measurements
  - SCR / Facility Inlet
  - SCR Outlet
  - ESP Inlet
  - ESP Outlet / WFGD Inlet
  - WFGD Outlet

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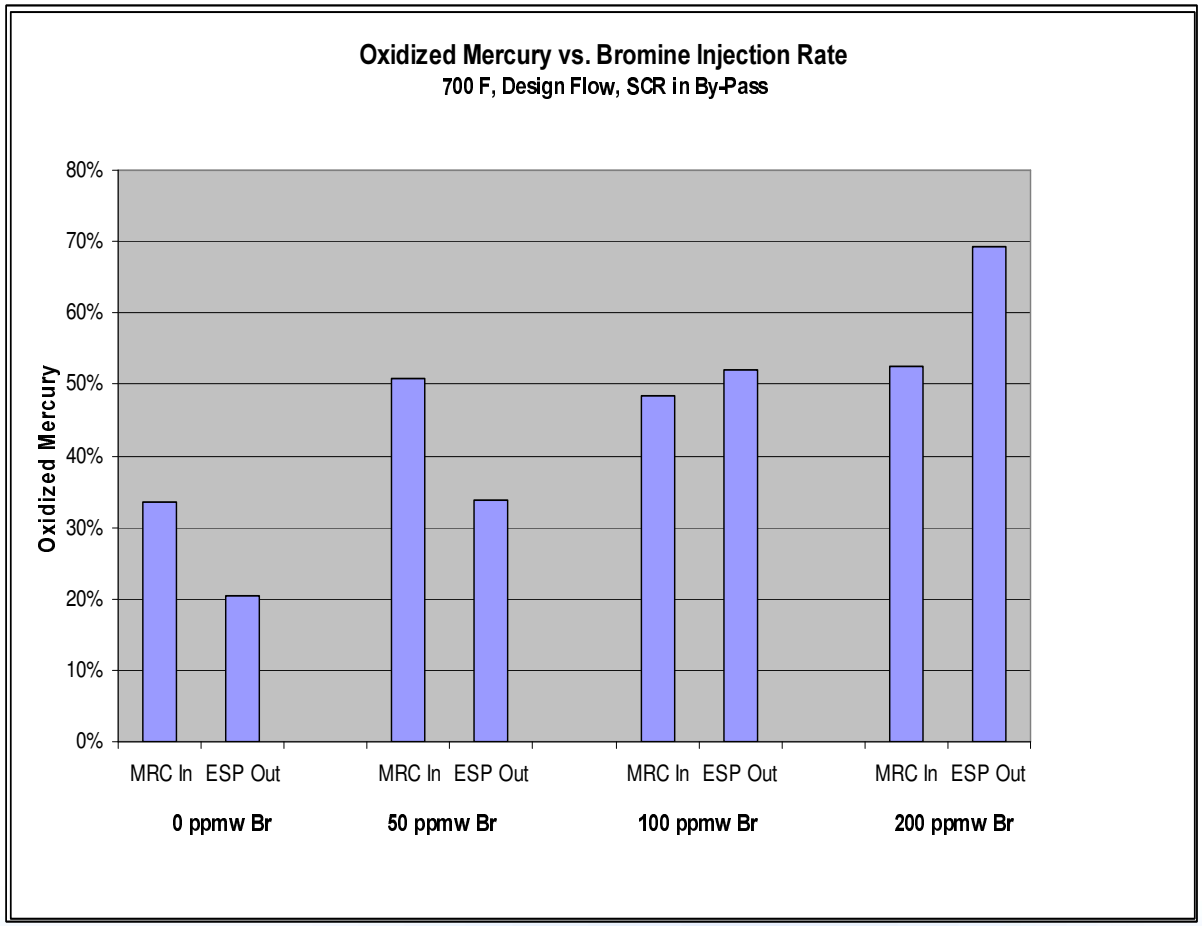
MRC Bromine Results

- Without SCR
- Colombian Coal
  - High native capture
  - Seen without bromine in other testing
- Large Conc. of Br needed for high oxidations



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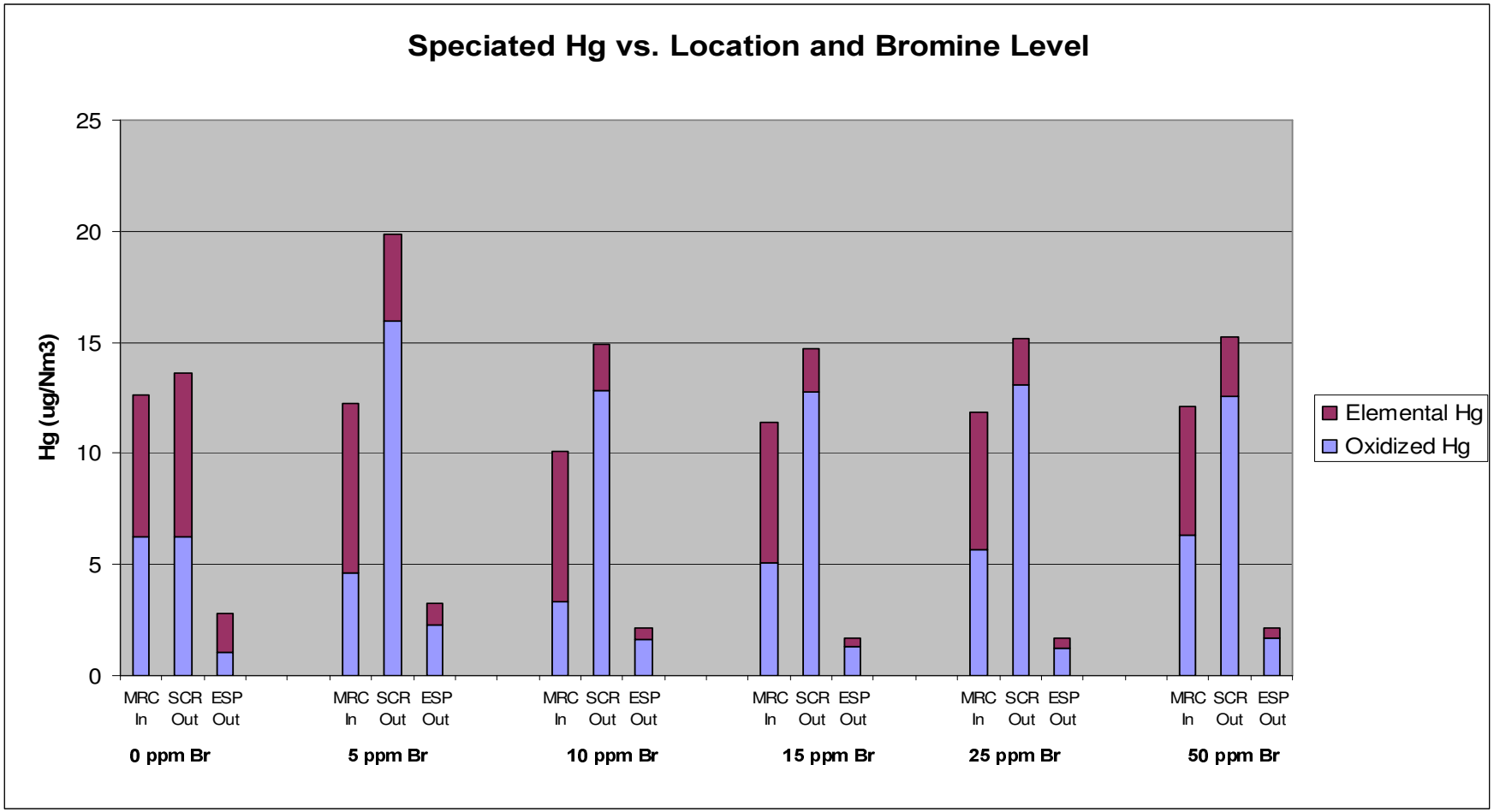
MRC Bromine Results



SCR in Service

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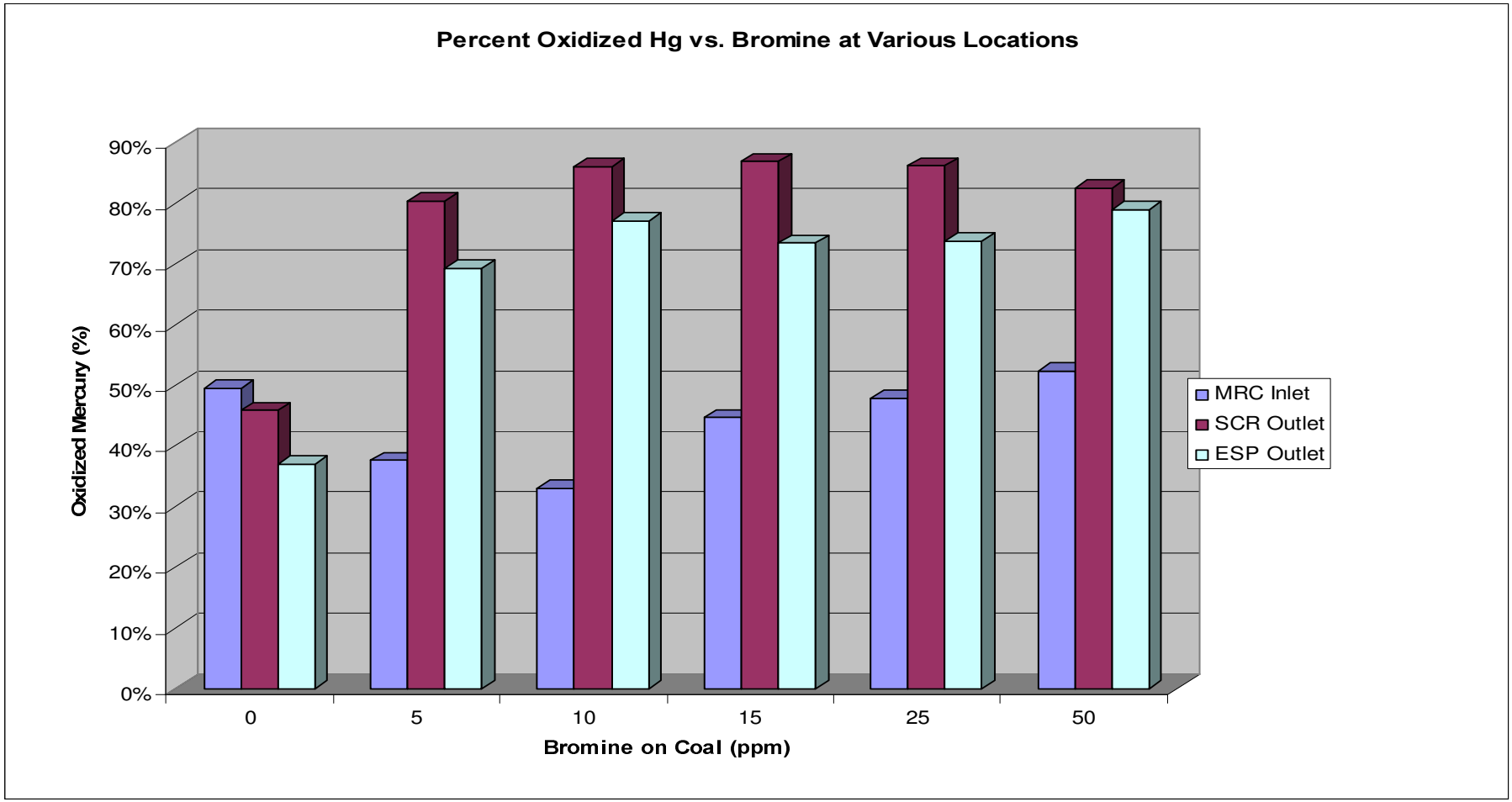
MRC Bromine Results



SCR in Service

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Southern Company
Bromine Injection Progress Report

- Mercury Research Center Testing
  - **One Catalyst test completed**
  - Tests with 3 Additional Catalyst Planned
  - Next test scheduled for 2nd quarter 2008

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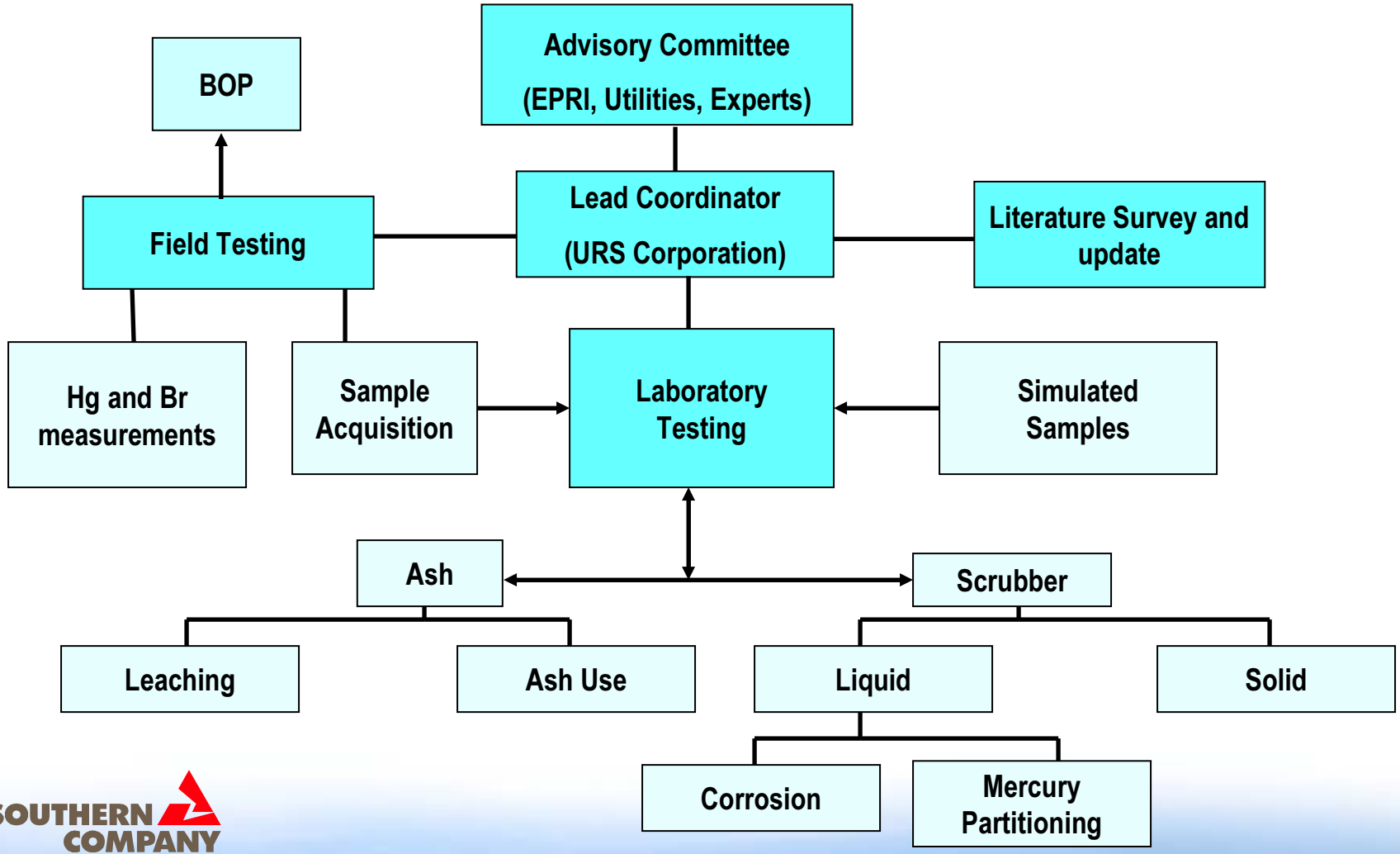
Evaluating Bromine Fate & Balance-of-Plant (BOP) Impact



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Questions

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The Dead Sea

- *The lowest elevation on earth on land (1,378 ft below sea level)*
- *With 30% salinity, it is 8.6 times saltier than the ocean*
- *Bromide ion (Br^-) concentration is the highest of all waters on Earth*
  - 140 times higher than in normal seawater
- *Evaporation basins are used to concentrate salt*
  - potash, bromine, caustic soda, sodium chloride, magnesium metal

High salinity creates buoyancy effect

Israel Chemicals Ltd

- 250,000 Metric tons/yr

Hg Measurement QA / QC

- In the presence of bromine focus on Hg^0
  - OH, S-CEM

Condition*	Date in 2006	Start Time	End Time	Ontario Hydro Results			SCEM Results – ESP Outlet			% RD	
				Total Hg (µg/Nm³)	Elem. Hg (µg/Nm³)	% Oxid.	Total Hg (µg/Nm³)	Elem. Hg (µg/Nm³)	% Oxid.	Total Hg	Elem. Hg
BL	10/06	10:25	12:25	9.5	4.2	56	8.6	3.5	60	-10%	-18%
BL	10/06	12:45	14:45	11.8	4.3	64	9.8	4.0	59	-19%	-7%
BL	10/06	15:02	17:02	11.9	4.0	67	10.1	3.4	67	-16%	-16%
BR	10/15	9:45	11:45	7.6	0.3	96	5.8	0.7	88	-27%	80%
BR	10/15	13:05	15:05	7.5	0.3	96	5.2	0.7	87	-36%	80%
BR	10/15	15:45	17.45	7.8	0.4	95	4.7	0.6	87	-50%	40%

* BL = baseline (no bromide injection); BR = calcium bromide injection at 18 ppm Br in coal

Near Detection limit of Measurement Techniques

Bias

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