REINHOLD ENVIRONMENTAL Ltd.

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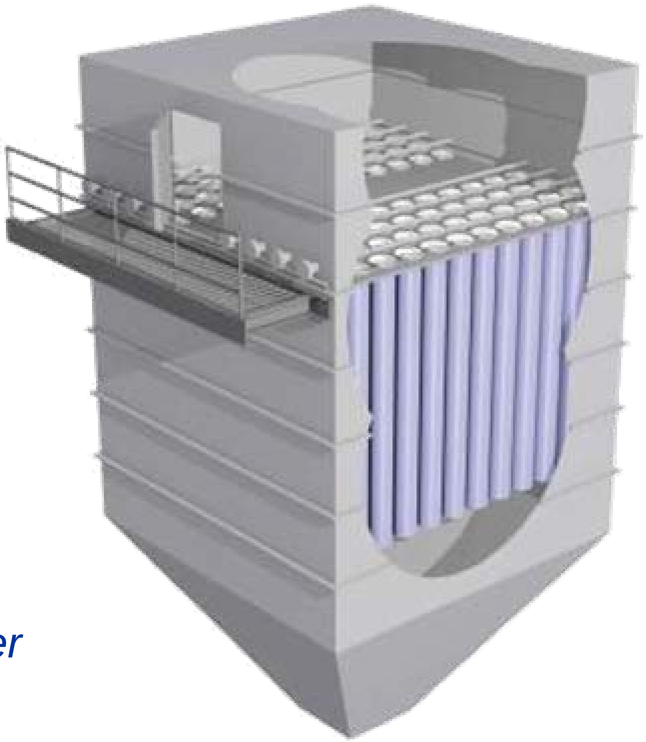
GE Energy Services

Enhanced Capture of Mercury using Novel Filter Design



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Background

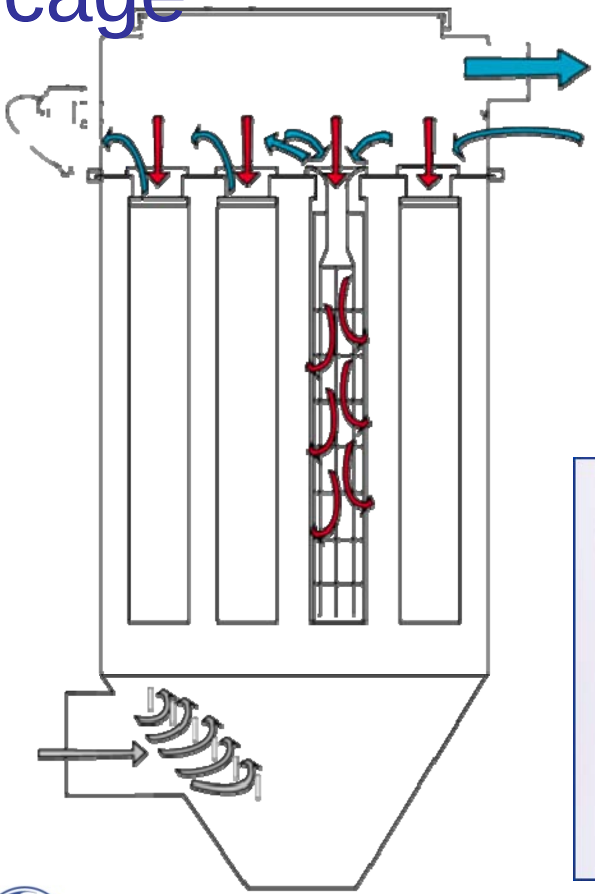
- Existing state regulations and pending Utility MACT are driving efforts to reduce mercury emissions from coal fired power plants
- The majority of existing coal fired power plants do not have FGD equipment
- For this reason, mercury control must occur as part of the PM removal process
- The objective of our activities is to minimize the need for sorbents or other material injected to facilitate mercury removal

Background

- When FGD is not present, powdered activated carbon is typically used to adsorb mercury
- This is an effective control method, but incurs significant operating costs and has associated maintenance issues
- When mercury control occurs as part of PM removal, field studies demonstrate that fabric filters more effectively utilize PAC compared to an ESP
- The focus of our investigation is to identify additional methods of improving fabric filter effectiveness

Conventional Fabric Filter

In a conventional pulse jet, the filter media is a smooth cylindrical section supported by a cage



Total cloth area is product of bag circumference and length

Pleated Filter Technology

In a **ThermoPleat®** element, conventional filter media is pleated, then placed around a perforated core.

The result is an increase in available filter surface by as much as 2 - 3 times over conv

Resulting in:

- Lower air to cloth ratio.
- Reduced differential pressure.
- Increased frequency between cycles
- Improved fine particle removal

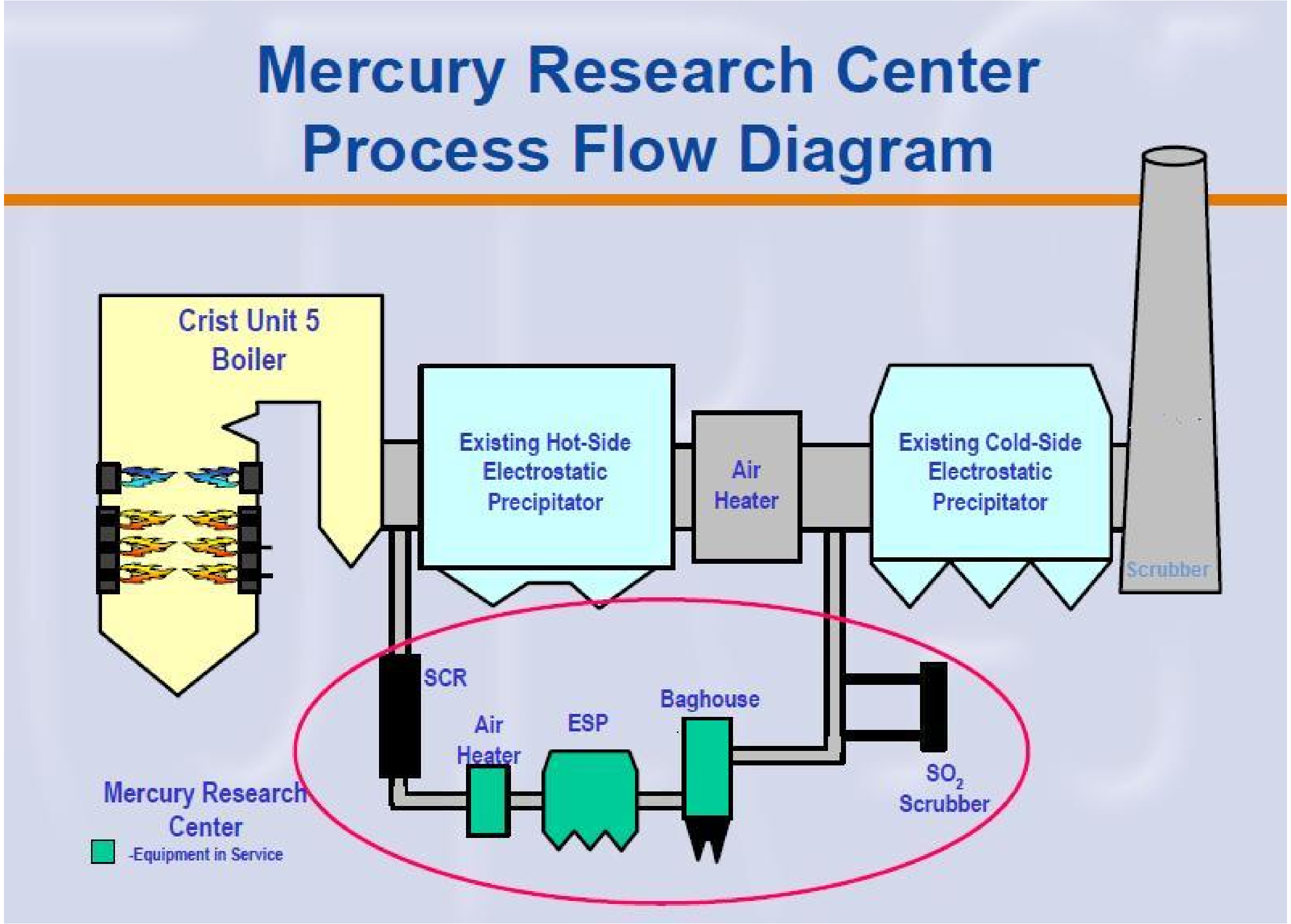
Mercury Testing Hypothesis

The ability of a pleated filter element to reduce air to cloth ratio results in enhanced capture of Mercury across the bag house

Why?

Increased cloth area results in longer interval between cleaning cycles, improves sorbent utilization

Test Facility



PCT, Inc. conducted testing for GE Energy in the MRC slipstream bag house located at Plant Crist

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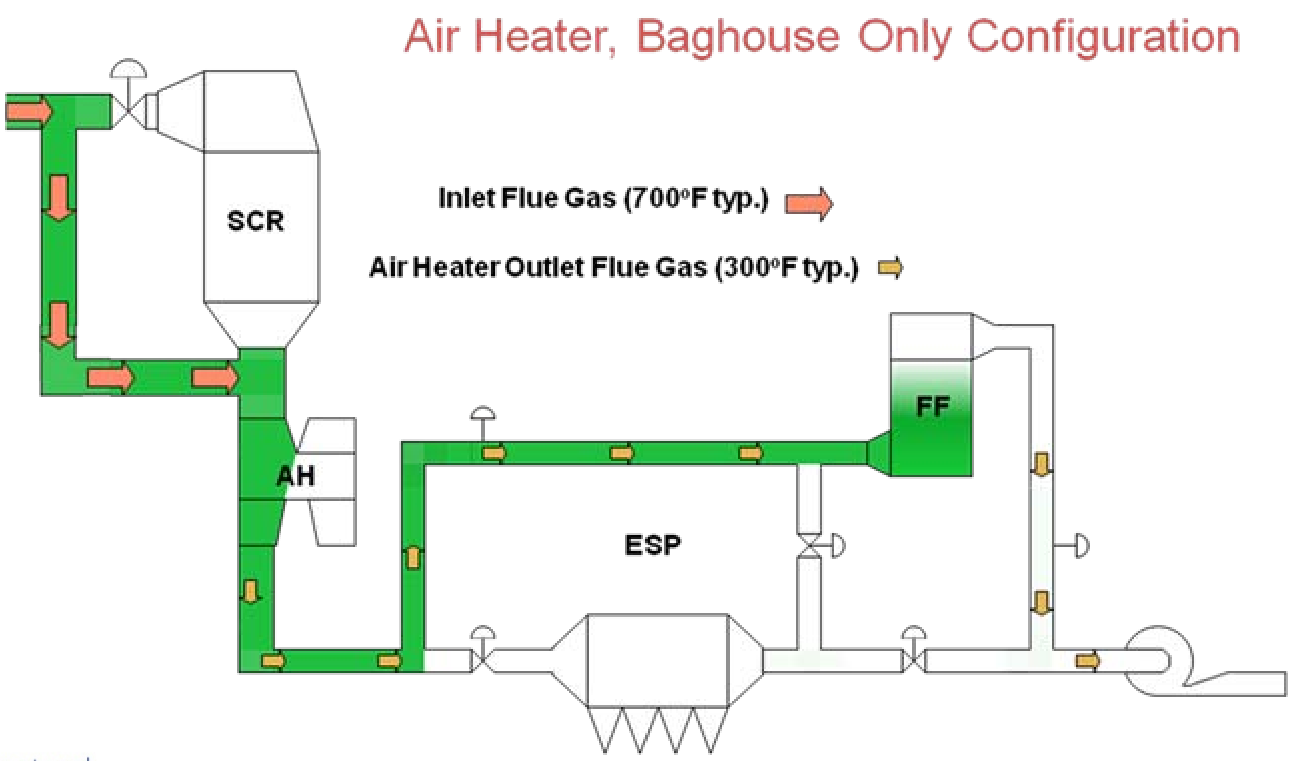
Test Facility

The MRC is a pollution control research facility located on a 5MW sidestream of Unit 5.

1. Facility can be operated in Bag house-only mode, ESP-only mode, or ESP + Bag house mode
2. SCR was kept offline for the entire duration of testing



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Filters Tested

1. Two-meter long Pleated Filter Elements (Thermopleat®) made from GE's proprietary QR811 media – a laminate based on PPS/P84 and expanded PTFE membrane

2. The pulse-jet Bag house had 82 Filter elements arranged in 9 rows

3. Cleaning can be based on pressure set points, or based on time

4. Pulse cleaning pressure of 55 psig, pulse time of 0.15 seconds, and time between pulses of 6 seconds.

Variables Studied

1. Flue gas flow rate – 14,000 acfm and 19,000 acfm
2. Different cleaning intervals
3. Varied flue gas temperatures at Bag house inlet
4. Activated carbon injection – 0.0, 0.3, 0.6, and 2.0 lbs/ MM Acf

Test Duration

Tests were conducted over a period of 10 days

A short period of “seasoning” of the bags took place from Sept 07 through September 12, 2010

Four days of parametric variable testing followed

Coal Characteristics

1. The coal combusted by plant during the test program was a blend of Drummond and Galatia coal.
2. The Drummond coal is a low sulfur sub bituminous of Columbian origin and the Galatia is a bituminous coal from the Central Illinois Basin.
3. The resultant blend is a low sulfur (0.75%) sub bituminous analog.

Additional Testing Background

- The average LOI of Fly Ash over the 10-day test period was 4.3%
- Initial testing occurred without injecting activated carbon
- The SCR was not in service for duration of test period
- The flue gas averaged ~1.3 ppm SO_3
- The gas averaged ~150 ppm Cl
- Typically 80% of the Hg entering FF is elemental

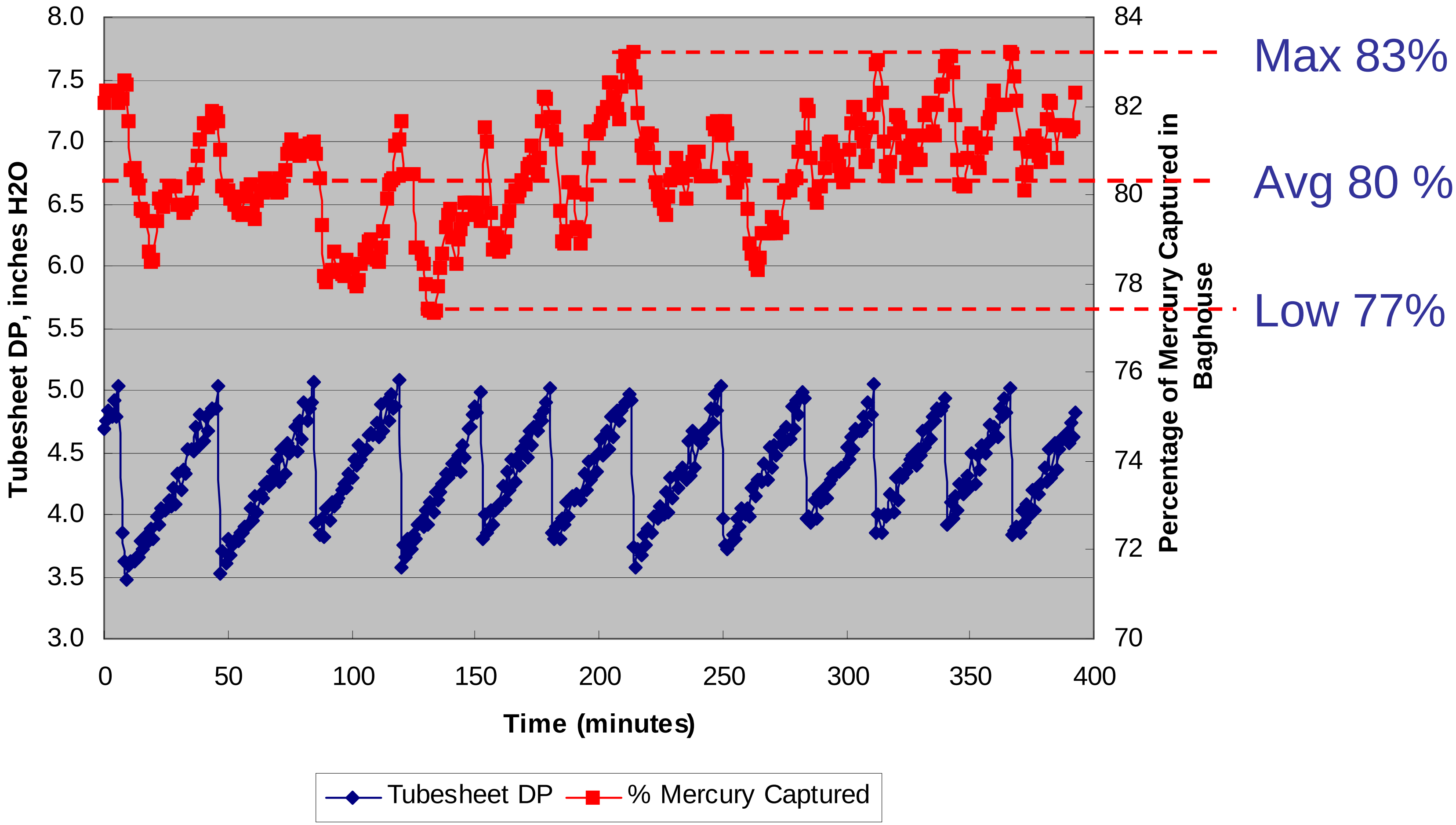
Mercury Measurements

Mercury analyzers were utilized to gather the data:

1. Thermo Fisher Scientific CEM mercury analyzer were used
2. A total of three analyzers gathered Hg data continuously
3. The analyzers provided total mercury levels as well as the speciation
4. Coal samples were also taken to provide supporting data

Impact of Cleaning Interval on Hg Reduction

Flow rate 14,000 acfm (air:cloth ratio of 3.7); Temperature 343^{o}F;
Cleaning in pressure mode with set points of 4" and 5" , no PAC



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Impact of Cleaning Interval on Hg Reduction

Flow rate 14,000 acfm (air:cloth ratio of 3.7); Temperature $343^{o}F$;
Cleaning in pressure mode with set points of 4” and 5” , no PAC

1. Average inlet Mercury of 10.3 $\mu g/m^3$; 80% Elemental, 20% Oxidized
2. Slight drop in Mercury capture immediately after cleaning cycle
3. Average inherent Mercury capture by pleated elements of 80.5%

Testing indicated high Hg removal efficiencies without injection of PAC

The level of Hg reduction observed was significantly higher than expected

Historical data indicates this fabric filter reduced Hg approximately 30% to 40% when conventional PPS filters were utilized

Additional tests indicated that the results may not relate to increased cleaning interval

What Other Factors?

- Impact of increased cleaning interval had less impact than expected

What Else is Happening?

- Additional testing was performed to characterize the impact of other factors on Hg removal

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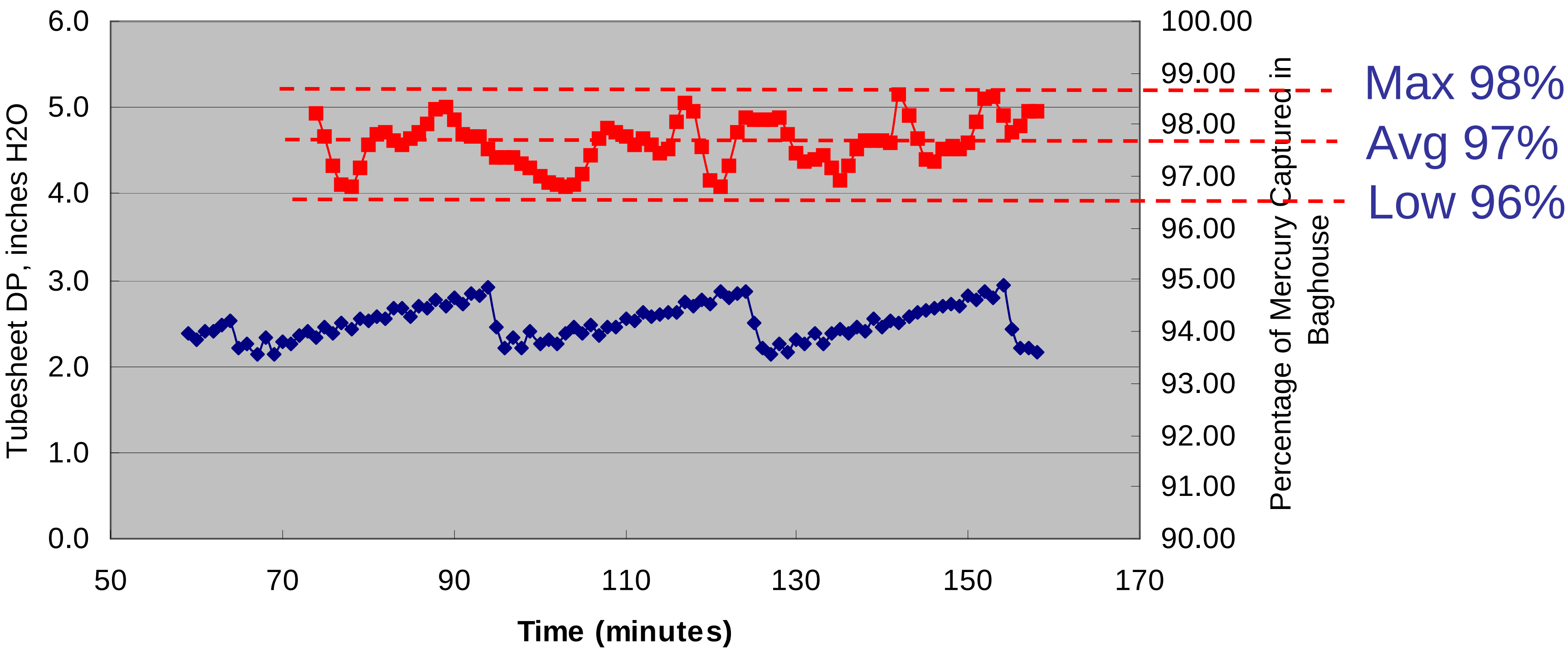
Impact of Temperature on Hg Reduction

Flue gas flow rate 14,000 acfm (air:cloth ratio of 3.7); Temperature 280ºF; *Cleaning in Time Mode every 30 minutes – Snapshot of data through 3 cleaning cycles, no PAC*

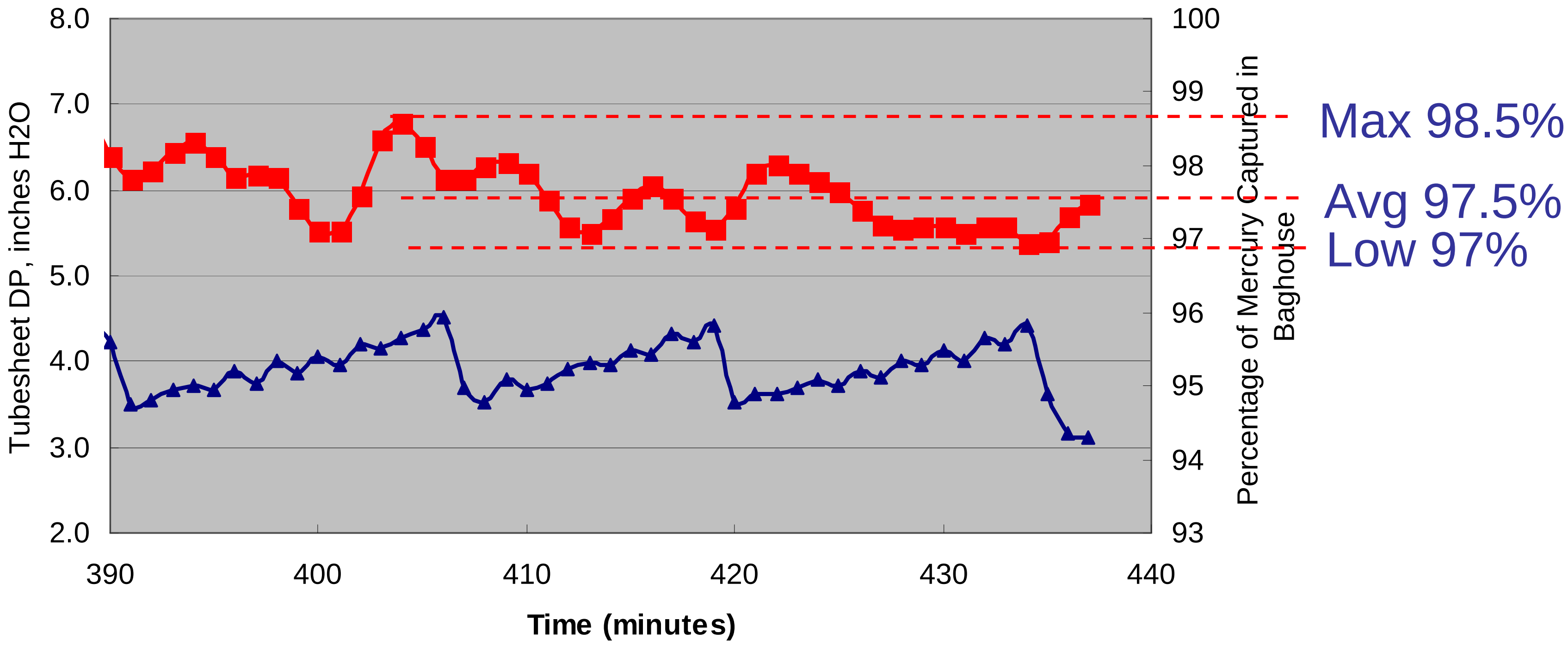


Not as clear a relationship between pulse cycle and reduction level

Gas temperature reduction improved average Hg removal from about 80% to about 97%

Impact of A/C Ratio on Hg Reduction

Flue gas flow rate 19,000 acfm (air:cloth ratio of 5.15); Temperature 280°F; *Cleaning in Time Mode every 15 minutes, no PAC*



Average Mercury capture of 97.5%

No measurable impact of increased A/C ratio

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Summary of Results

Multiple trials showed 85%+ removal levels without PAC

Test Number	Air-to-Cloth Ratio, fpm	Flue Gas Temperature (at BH entrance), dg F	Cleaning Mode	Time-average Percentage of Mercury Captured by Flyash in the baghouse, %
1	3.7	343	Based on differential Pressure Set-points (4" for clean and 5" for dirty)	80.5
2	3.7	343	Time-mode Cleaning, Every 30 minutes	77.0
3	3.7	343	Time-mode Cleaning, Every 60 minutes	78.5
4	5.15	343	Time-mode Cleaning, Every 8 minutes	90.3
5	5.15	343	Time-mode Cleaning, Every 15 minutes	91.0
6	3.7	280	Time-mode Cleaning, Every 30 minutes	98.0
7	3.7	280	Time-mode Cleaning, Every 60 minutes	98.0
8	5.15	280	Time-mode Cleaning, Every 8 minutes	97 – 98%
9	5.15	280	Time-mode Cleaning, Every 15 minutes	97 – 98%

Initial Summary

- Although test data showed the pulse cleaning interval to have an impact on total Hg removal, the magnitude of reduction measured was unexpected, even considering a period of stabilization prior to trial runs
- It was concluded that either:
  - The measured values are incorrect
  - Fly ash characteristics are biasing Hg reduction levels
  - An unexpected Hg removal mechanism is involved

We need further investigation

Are the Mercury Analyzers reading correctly?

The reduction levels achieved were questioned; are the CEMs accurate?

1. The flue gas duct was reconfigured to bypass the bag house. On bypassing the bag house, the outlet Mercury analyzer read within 2% of the inlet analyzer.

2. During steady state operation with bag house in service, Mercury samples were also collected with carbon traps. These carbon traps were sent to an outside test lab. The data from these carbon traps matched the inline Thermos data very closely

- Average of two traps 0.90 μg/m3 at 3% O2 (ran for 111 minutes)
- Average of Thermo Total Hg over the 111 minutes 0.88 μg/m3 at 3% O2

CEMs Hg values appear representative

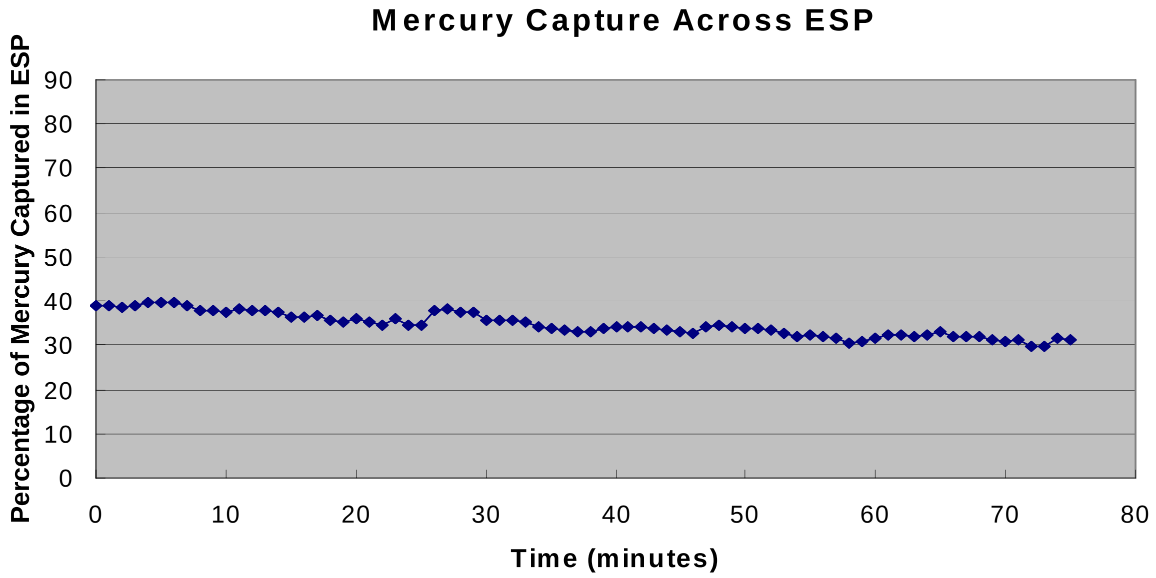
Is there something unusual about fly ash?

Potentially, unique conditions may have resulted in higher Hg removal than expected in the FF.

1. In order to verify this, Electrostatic precipitator (ESP) was brought inline.
2. Since amount of Mercury capture by ESP in a typical power plant is well documented, by collecting the baseline data with ESP, any unusual issues with this particular gas stream chemistry or fly ash composition can be ruled out
3. The four-field ESP was operated at the standard operating conditions (50KV on each field)

Mercury Capture in ESP

Flue gas flow rate 14,000 acfm. Temperature entering ESP of 340ºF.



1. Average inlet Mercury of 9.49 μg/m^3; 81% Elemental, 19% Oxidized
2. Average Mercury capture of around 30%. Some decline in performance as the temperature of plates was increasing

ESP mercury capture consistent with documented studies

Indication that FF performance is representative

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Conclusions

Considering test data and fly ash to be representative, the following conclusions were made:

1. Pleated elements with membrane produce very high rate of Mercury capture, compared to literature-reported values with traditional non-membrane round bags
2. This reduction occurred with high levels of elemental Hg present
3. Air to cloth ratio appears to have weak effect
4. Interval between cleaning does appear to have some effect (lengthening it increases the capture)
5. Temperature of flue gas has a strong effect
6. There appears to be something unique about pleated elements with membrane that is leading to high capture. The mechanism cannot be explained by cleaning interval, temperature, or air to cloth ratio alone.

In the proposed model, the membrane facilitates Mercury oxidation, and the pleat configuration facilitates capture of oxidized Mercury. Need to have both to maximize total capture.

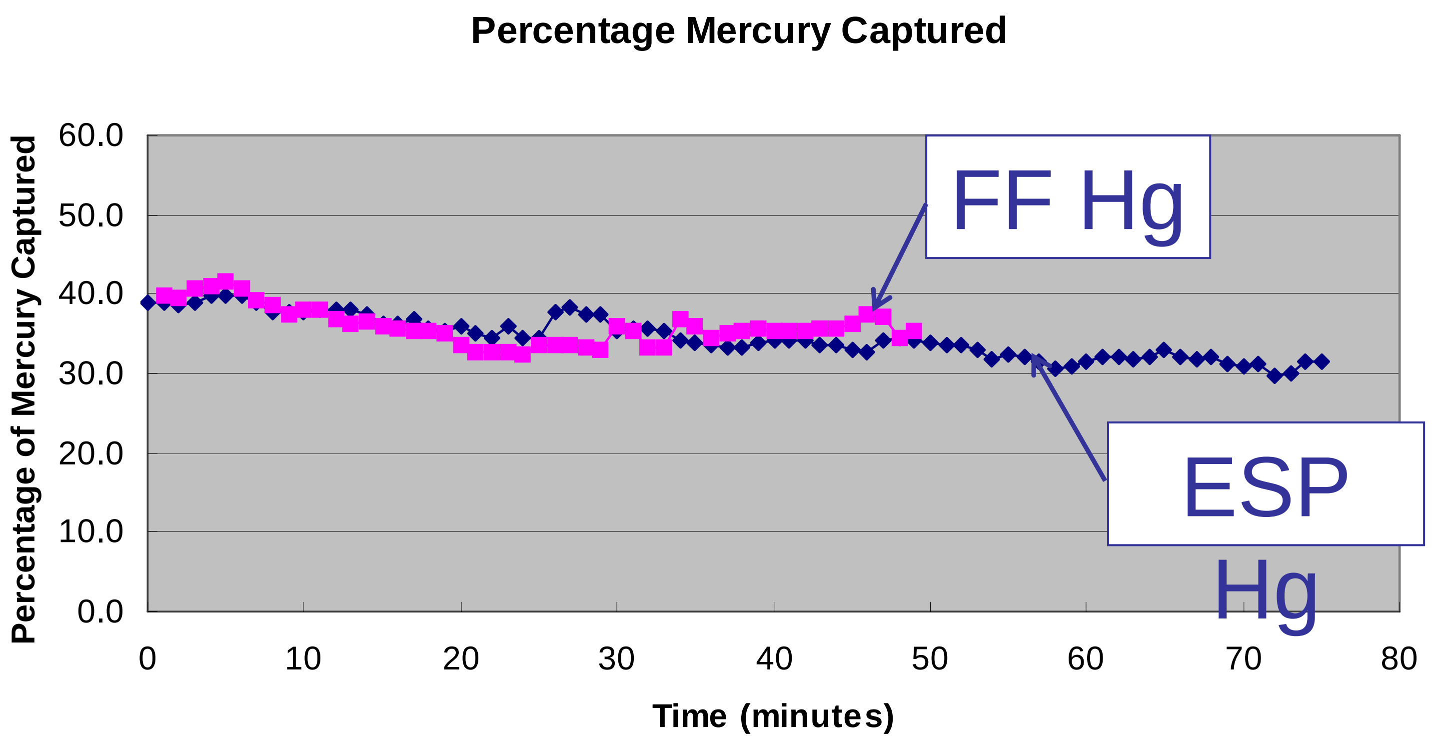
Effect of Removing Fly ash from equation

To evaluate the impact of fly ash loading on oxidation and Hg removal levels, the ESP was energized

1. ESP was operated at its standard conditions with all four fields operational.
2. At these conditions, this ESP is believed to remove 99.5%+ of the fly ash, per MRC (no opacity measurement available)
3. Hg removal efficiency and oxidation was measured for FF
4. Data on next slide

Effect of Flyash on Baghouse

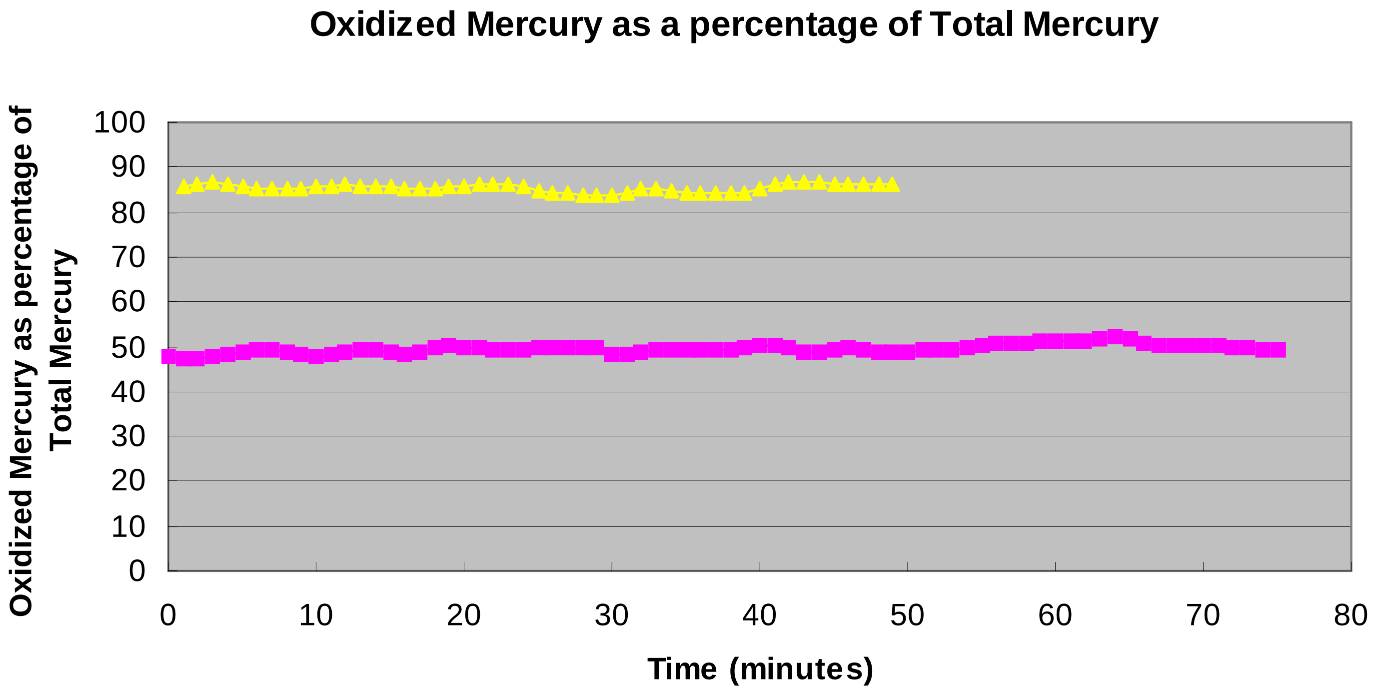
(Gas flow 14,000 acfm, 340ºF, cleaning every 30 minutes)



Test data shows no additional Mercury captured by the bag house when fly ash is removed from the flue gas

Adsorption sites have been eliminated

Hg Oxidation in Fabric Filter



FF Outlet +80% Oxidized

FF Inlet +50% Oxidized

Significant difference between inlet / outlet levels of oxidized Hg

Data shown with ESP in service

Hg oxidation is occurring in Fabric Filter at 340F

Hg Oxidation in Fabric Filter

1. Without fly ash in the flue gas stream, the HCl build-up on the membrane nodes and fibrils still occurs. This build up helps oxidize the elemental mercury to Chloride form. Experimental data shows that as well.

2. However, without any fly ash to capture this Mercuric Chloride, it would pass through the bag house as gas (at these concentrations dew point of Mercury in gas is below zero dg C)

Proposed Capture Mechanism

1. High Hg capture requires Membrane AND pleats in the filter element
2. Geometry of filter element provides turbulent mixing at pleat valley
3. High surface area of membrane (nodes and fibril structure on surface) provides collection surface for Hydrochloric acid (HCl) in the gas stream to collect on and to oxidize the elemental Mercury in flue gas to Mercuric Chloride.
4. With pleated elements, there is always some fly ash collected in the valleys that captures this Mercuric Chloride. This fly ash does not contribute to filter pressure drop, as it is not actually on the filtration surface, but located in close vicinity of filtration surface.
5. In case of round bags, there is very little fly ash that remains in vicinity of filtration surface (the cleaning pulse being directed at 90 degree angle from the bag would push out all the fly ash).

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Moving Forward

Objective is to gather additional test data to refine conclusions

- Install pleated filter elements in beta site and gather data
- Review impact of improved fine particle collection on Hg reduction
- Perform CFD analysis to define pleated element flow patterns
- Obtain additional conventional filter Hg removal data

Continued data gathering and analysis will provide better definition of the mechanisms at work

Thank You