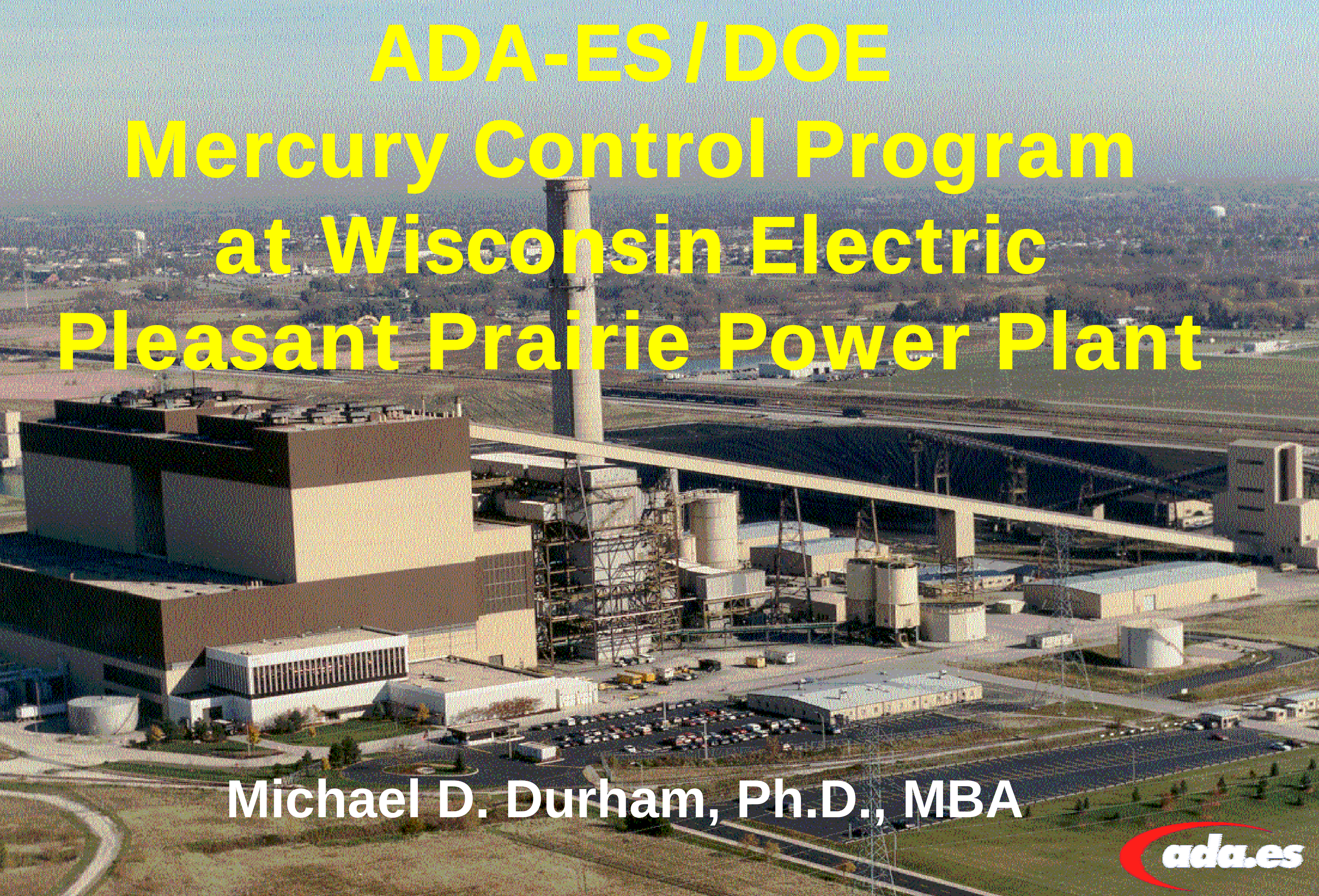
# ADA-ES / DOE
# Mercury Control Program at Wisconsin Electric Pleasant Prairie Power Plant



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# ADA-ES Hg Control Program

- Full-scale field testing of sorbent-based mercury control on non-scrubbed coal-fired boilers
- Primary funding from DOE National Energy Technology Laboratory (NETL)
- Cofunding provided by:
  - Wisconsin Electric
  - EPRI
  - Southern Company
  - PG&E NEG
  - Ontario Power Generation
  - TVA
  - First Energy
  - Kennecott Energy

# Key Partners

- Apogee Scientific
- EnviroCare
- Environmental Elements
- EPA
- GE Mostardi Platt
- UNDERC/Microbeam
- NORIT
- Reaction Engineering
- URS Radian

# WEPCO Pleasant Prairie

- Testing beginning mid-September and continuing through the end of the year
- PRB coal
- ESP only
- Spray cooling
- $SO_3$ conditioning system

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# Objective

- **Determine the cost and impacts of sorbent injection into the cold side ESP for mercury control.**
  - **Conduct tests on ¼ of Unit 2 gas stream (150 MW).**
  - **Evaluate mercury removal as a function of sorbent injection rate.**
  - **Evaluate impacts including ESP performance and ash marketability.**

# Key Features of PPPP Tests

- Burns coals from the Powder River Basin
- One ESP chamber can be treated in isolation. (1/4 of unit ~ 150 MW)
- Baseline mercury removal (1999) showed no removal of mercury by the ash.  High percentage of elemental mercury.
- Long duct runs provided good residence times for spray cooling and sorbent injection.
- Fly ash is currently sold as a valuable commodity. Impacts on ash re-use are important in determining the real costs of mercury control.

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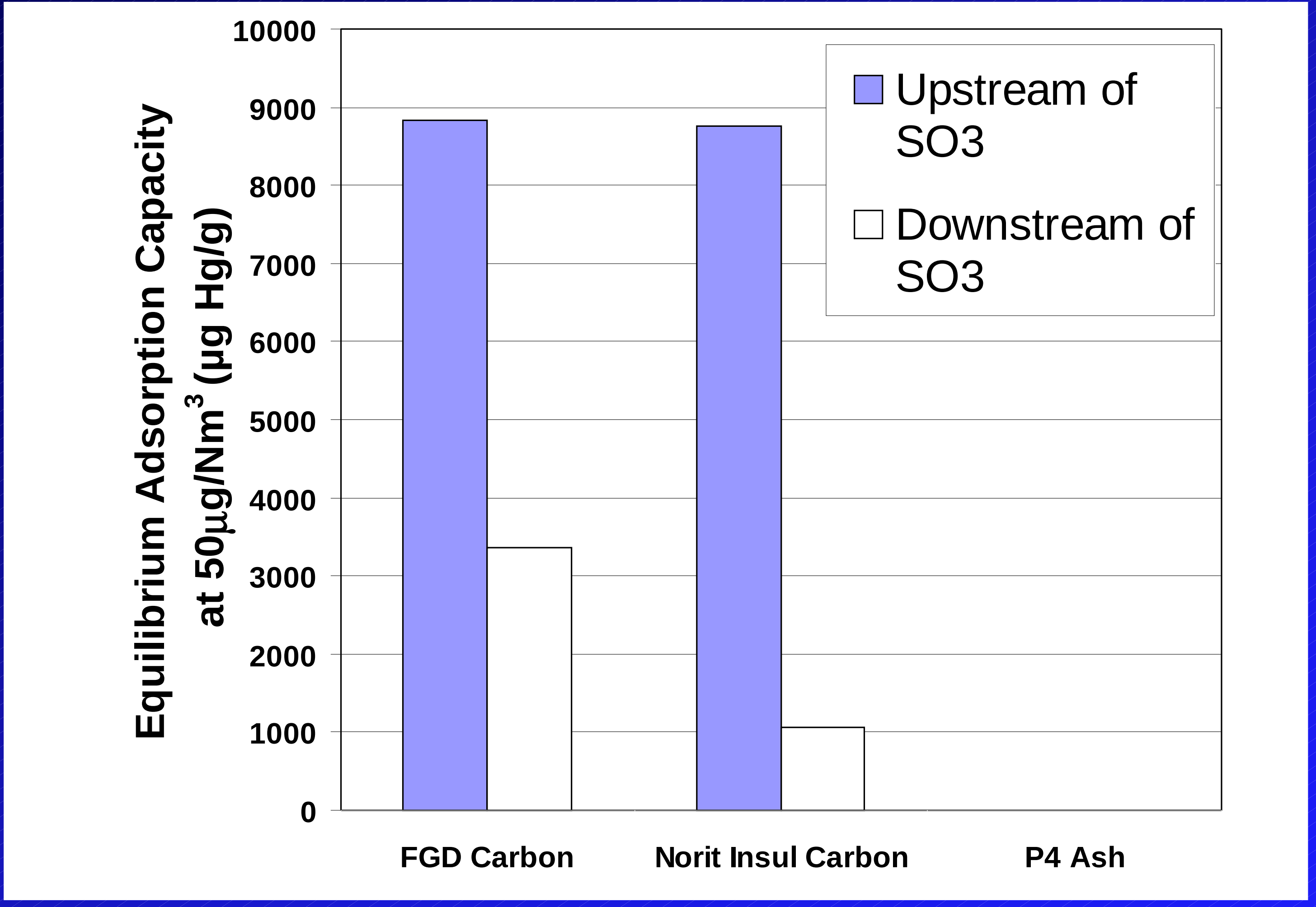
# Carbons Tested, Fixed Bed

| Carbon Name | Description |
|---|---|
| Norit Carbons | Various activations: Darco FGD, Insul, Darco hydrocarbon, FGD-M1161, FGD-M1182, GAC-830 |
| SAI-1<br>SAI-2 | Superior Absorbants Inc. carbons |
| Nuchar-1<br>Nuchar-DC | Westvaco carbons |
| SorbTech | Sorbent Technologies carbon |
| TDAC-L31 | ISGS experimental tire-derived carbon |
| IPAC-5 | ISGS experimental carbon |
| ACF cloth | ISGS fixed-structure sorbent - experimental |

# Equilibrium Adsorption Capacities at 250°F Upstream and Downstream of $SO_3$ Injection



# Conclusions, Fixed Bed

- Carbons are capable of achieving high mercury capacity in PPPP flue gas
- $SO_3$ appears to inhibit carbon adsorption; enhances fly ash adsorption.
  - Capacities are still high for carbon with $SO_3$ present
- Flue gas cooling should enhance Hg removal by carbon and fly ash
- Costs to process ash based sorbent prohibited consideration for full-scale tests

# Activated Carbon Storage and Feed System

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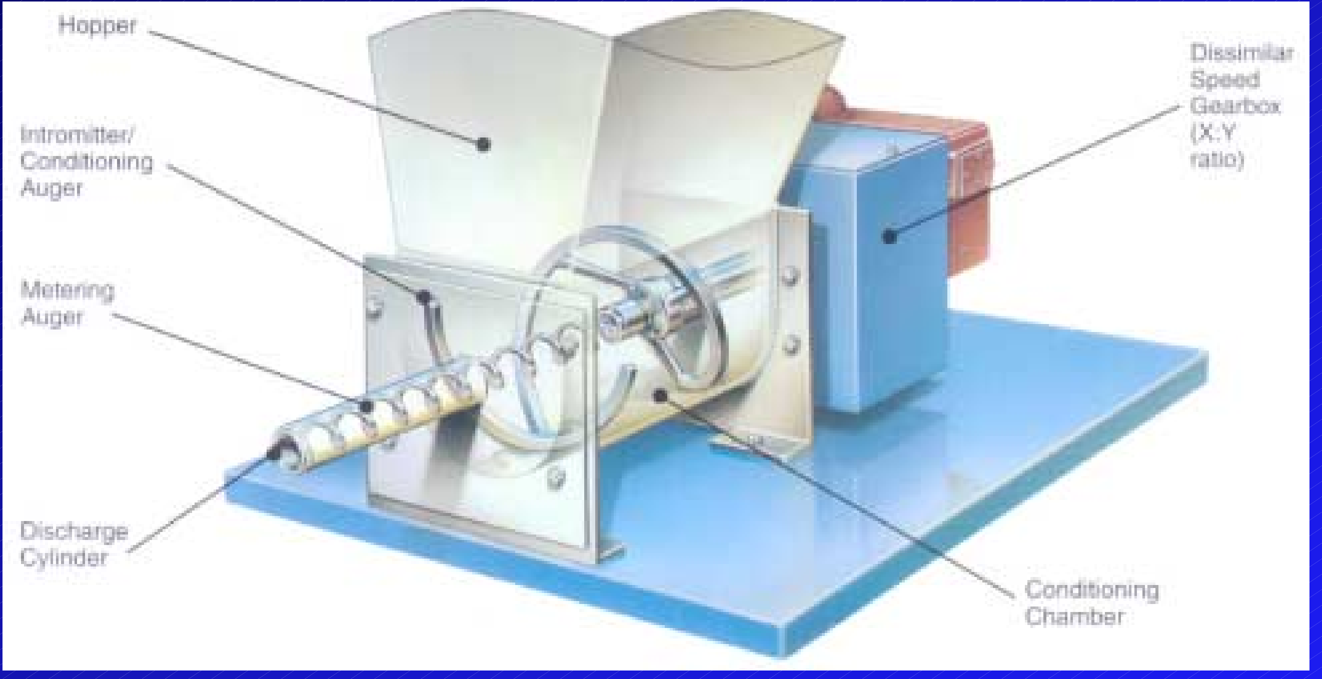

# Powdered Activated Carbon Delivery System


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# Powdered Activated Carbon Unloading


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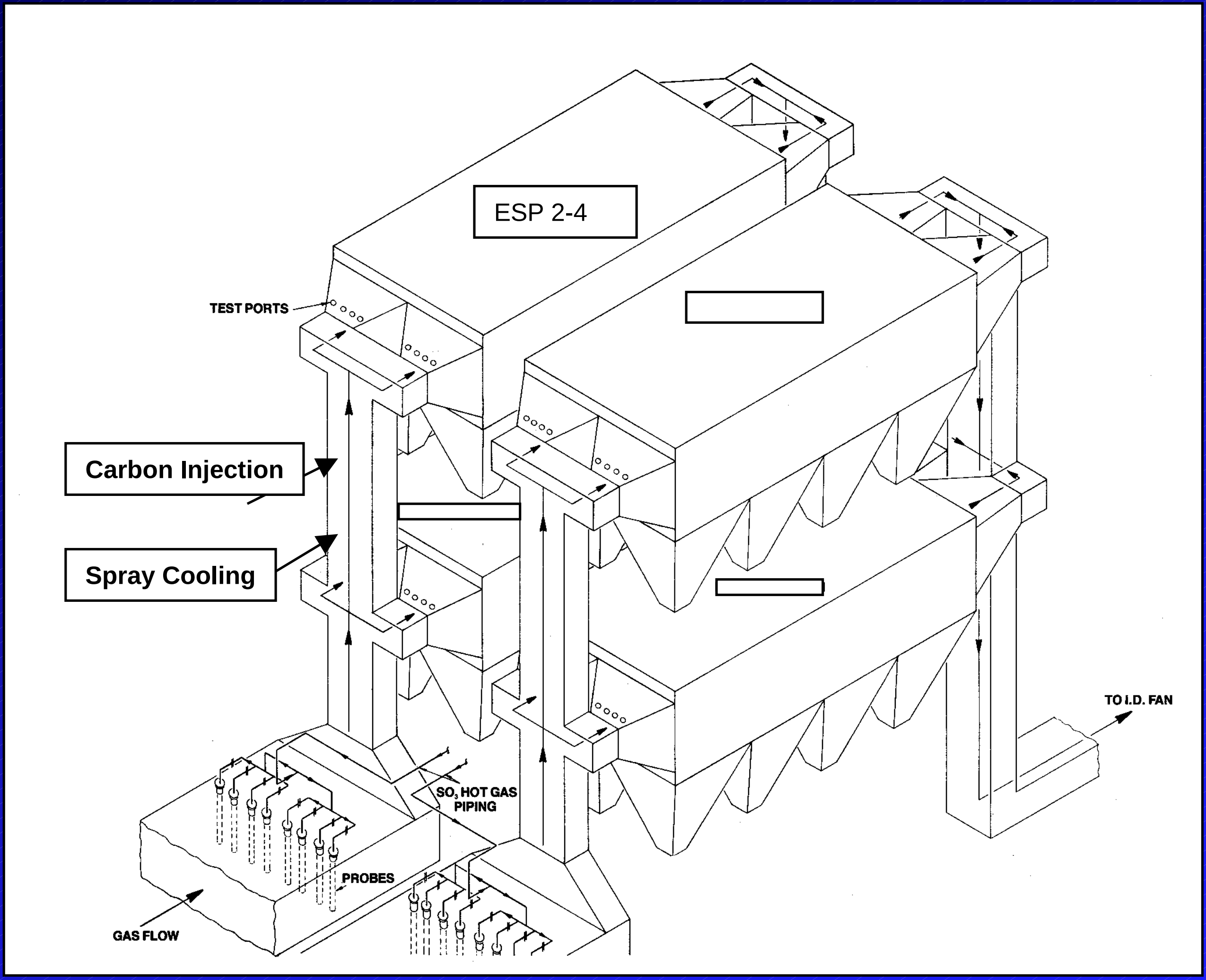
# ESP Configuration, PPPP



# Powdered Activated Carbon Injection System

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# Baseline Hg Measurements (μg/dscm)

| Location | Particle Bound | Oxidized, $Hg^{2+}$ | Elemental, $Hg^{0}$ | Total, Hg |
|---|---|---|---|---|
| Inlet ’99 | 0.16 | 2.29 | 6.21 | 8.65 |
| Outlet ’99 | 0.13 | 4.14 | 5.23 | 10.37 |
| Inlet ‘01 | 1.84 | 2.34 | 11.39 | 15.55 |
| Outlet ‘01 | 0.01 | 5.60 | 9.13 | 14.7 |

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# Carbons Used in Parametric Tests

| Carbon Description | Comments |
|---|---|
| Norit FGD<br>(18 microns) | Benchmark Sorbent |
| Ground FGD<br>(14 microns) | Effect of smaller size |
| FGL<br>(18 microns) | Effect of lower capacity<br>(lower cost) |
| Insul<br>(7 microns) | Effect of smaller size<br>Acid washed |

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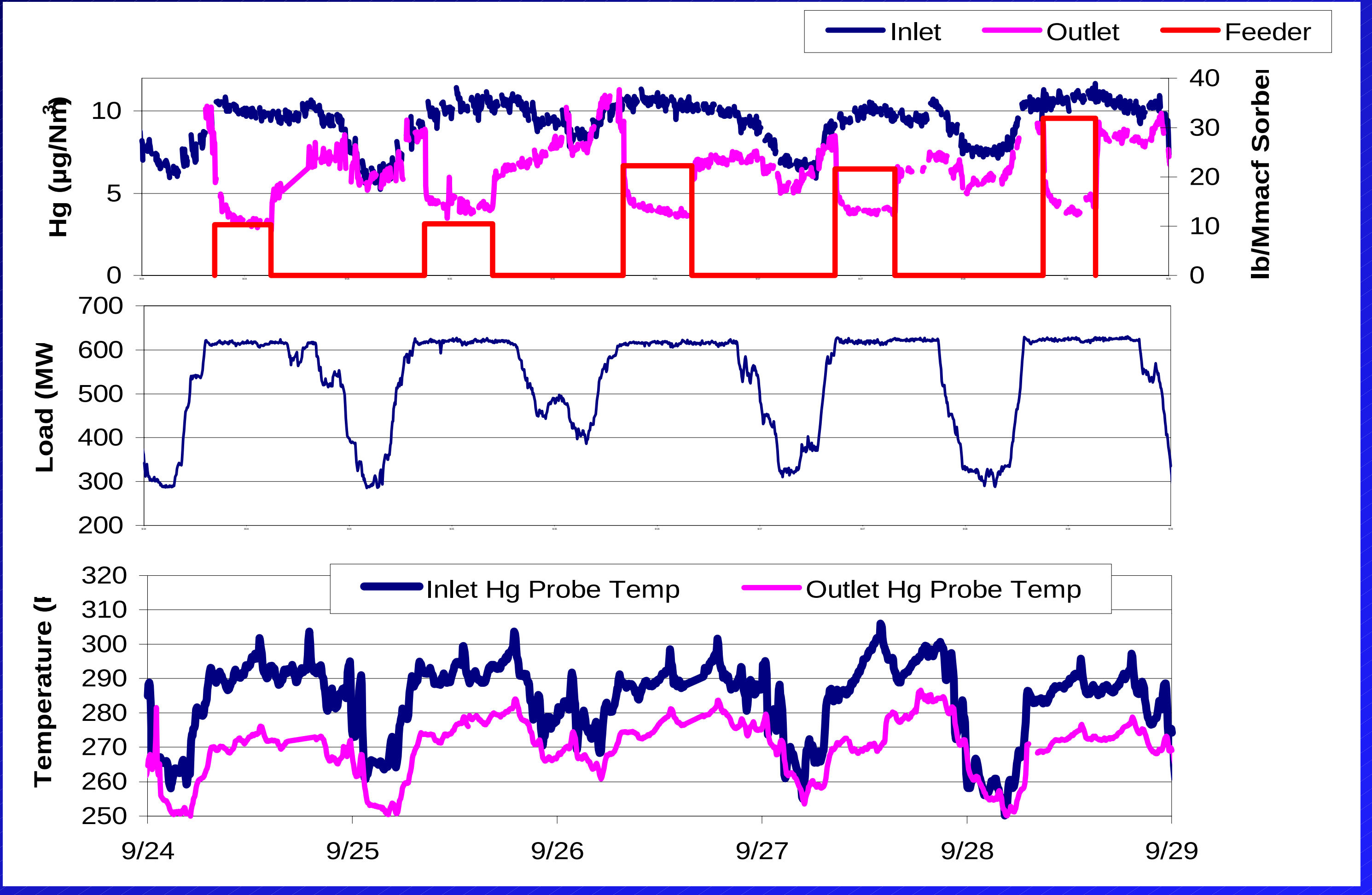
# Mercury Trends Week 1

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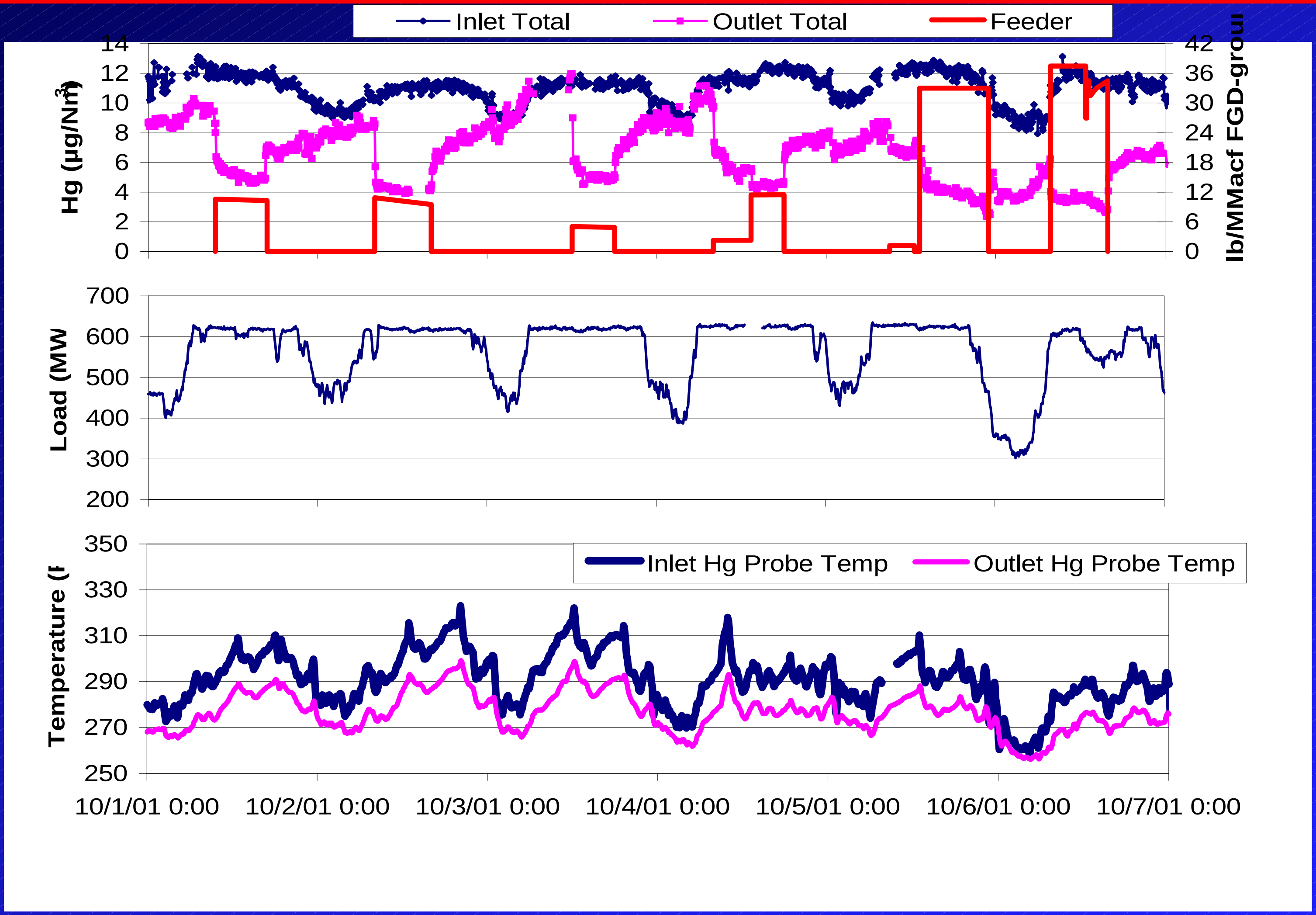
# Week 2 Parametric Tests (Ground FGD)

| Test ID (Day) | Carbon | Target Injection Rate | | Predicted Removal[a] /Actual Removal | Condition/Comments |
|---|---|---|---|---|---|
| | | lbs/Macf | lbs/hr[b] | % | |
| P-6: Standard Rate (Mon) | Fine[c] | 10 | 360 | 22/60 | Standard operating conditions |
| P-7: Standard Rate No $SO_3$ (Tues) | Fine[c] | 10 | 360 | 22/63 | $SO_3$ Off |
| P-8: Low Rate (Wed) | Fine[c] | 5 | 180 | 10/57 | Standard operating conditions |
| P-9: Lower Rate (Thurs) | Fine[c] | 2.2 | 80 | ?/51 | Standard operating conditions |
| P-10: Even Lower (Fri) | Fine[c] | 1.1 | 40 | ?/47 | Hg levels had not recovered |

a. Prediction from Meserole in-flight model with 1 sec residence time(1999)
b. Based on average flow of 600,000 acfm
c. Not able to get fine grind (14 microns), did not expect different performance from FGD

# Mercury Trends Week 2

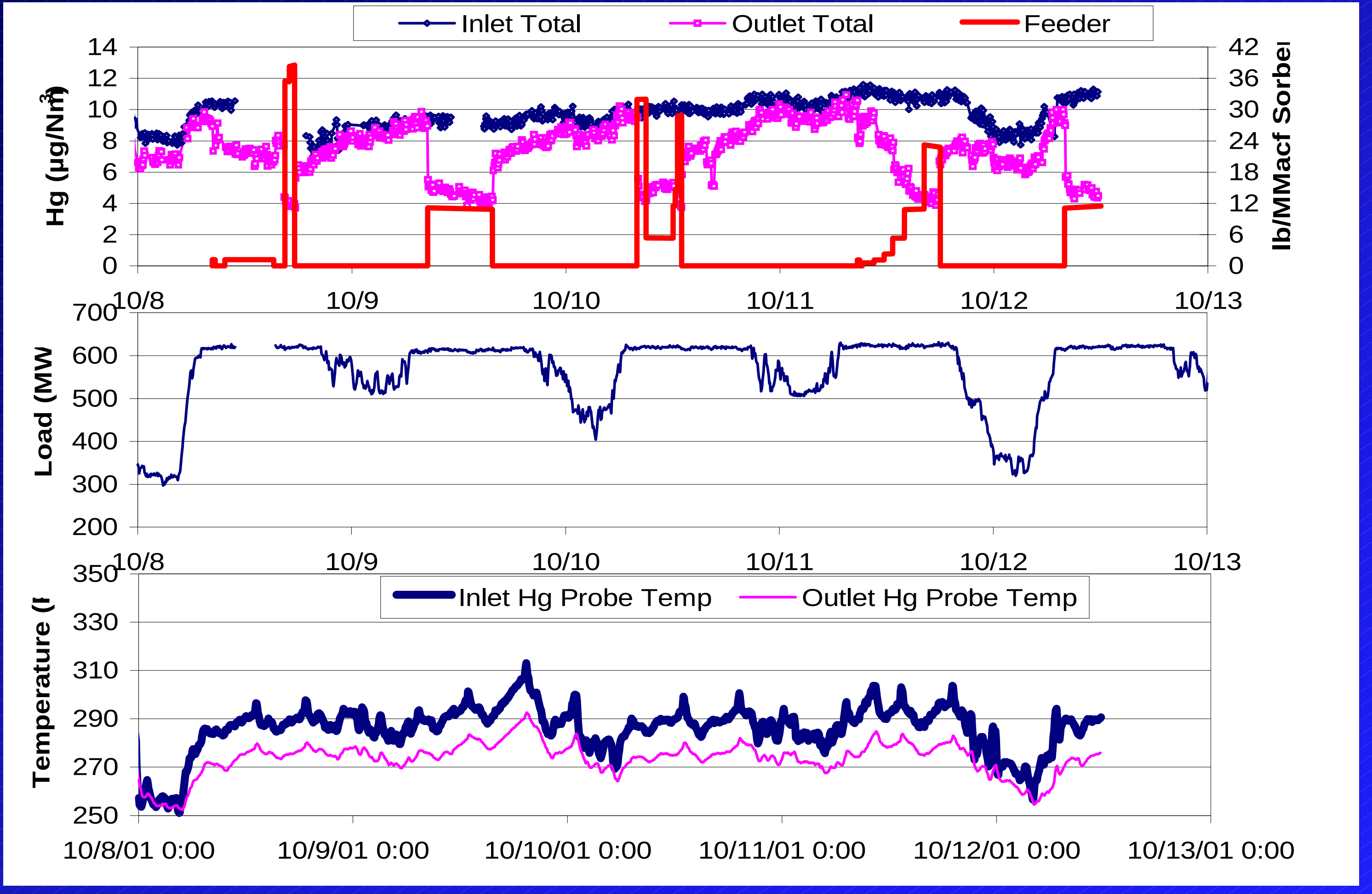


# Week 3 Parametric Tests (Ground FGD, FGL, Insul)

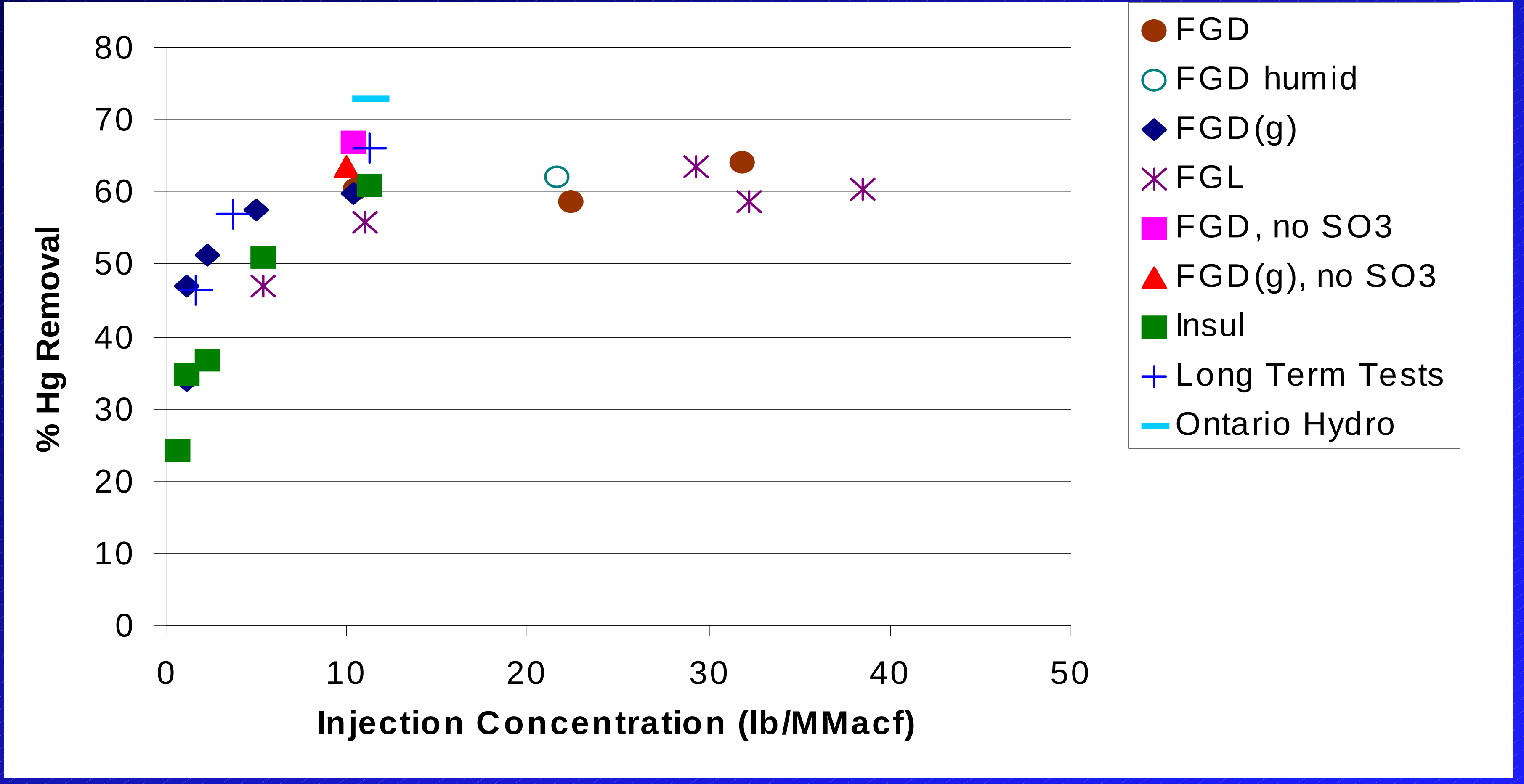
| Test ID (Day) | Carbon | Target Injection Rate | | Predicted Removal [a] /Actual Removal | Condition/Comments |
|---|---|---|---|---|---|
| | | lbs/Macf | lbs/hr [b] | % | |
| P-10a: Rerun P-10 (Mon) | Fine [c] | 1.1 | 40 | ?/36 | Standard operating conditions |
| P-11: Standard Rate (Tues) | FGL | 10 | 360 | 22/54 | Standard operating conditions |
| P-12: Low Rate (Wed) | FGL | 5 | 180 | 10/49 | Standard operating conditions |
| P-13: Lowest Rate (Thurs) | Insul | 0.5 | 20 | ?/47 | Standard Conditions Fill in performance curves |
| P-14: Low Rate (Thurs) | Insul | 1.0 | 36 | ?/47 | Standard Conditions Fill in performance curves |
| P-15: Low Rate (Thurs) | Insul | 2.0 | 72 | ?/47 | Standard Conditions Fill in performance curves |
| P-16: Low rate (Thurs) | Insul | 5.0 | 180 | ?/47 | Standard Conditions Fill in performance curves |
| P17: Standard Rate (Fri) | Insul | 10 | 360 | ?/60 | Compare to other carbons |

a. Prediction from Meserole in-flight model with 1 sec residence time(1999)
b. Based on average flow of 600,000 acfm
c. Not able to get fine grind (14 microns), did not expect different performance from FGD

# Mercury Trends Week 3



# Carbon Injection Performance on a PRB Coal with an ESP



# Parametric Test Conclusions

- Higher than expected removal observed at very low injection rates
- Hg removal improves rapidly with injection rates up to nominally 5 lbs/Mmacf
- Increase in performance minimal above 5 lbs/Mmacf
- No significant impact of $SO_3$ injection on Hg removal
- No improvement with spray cooling of 40 – 50$^{o}$F
- No significant difference between carbons
- Smaller sized sorbent did not improve performance
- Achieving 60 – 65% removal at lower than expected injection rates (insignificant increase in removal by injecting additional carbon)

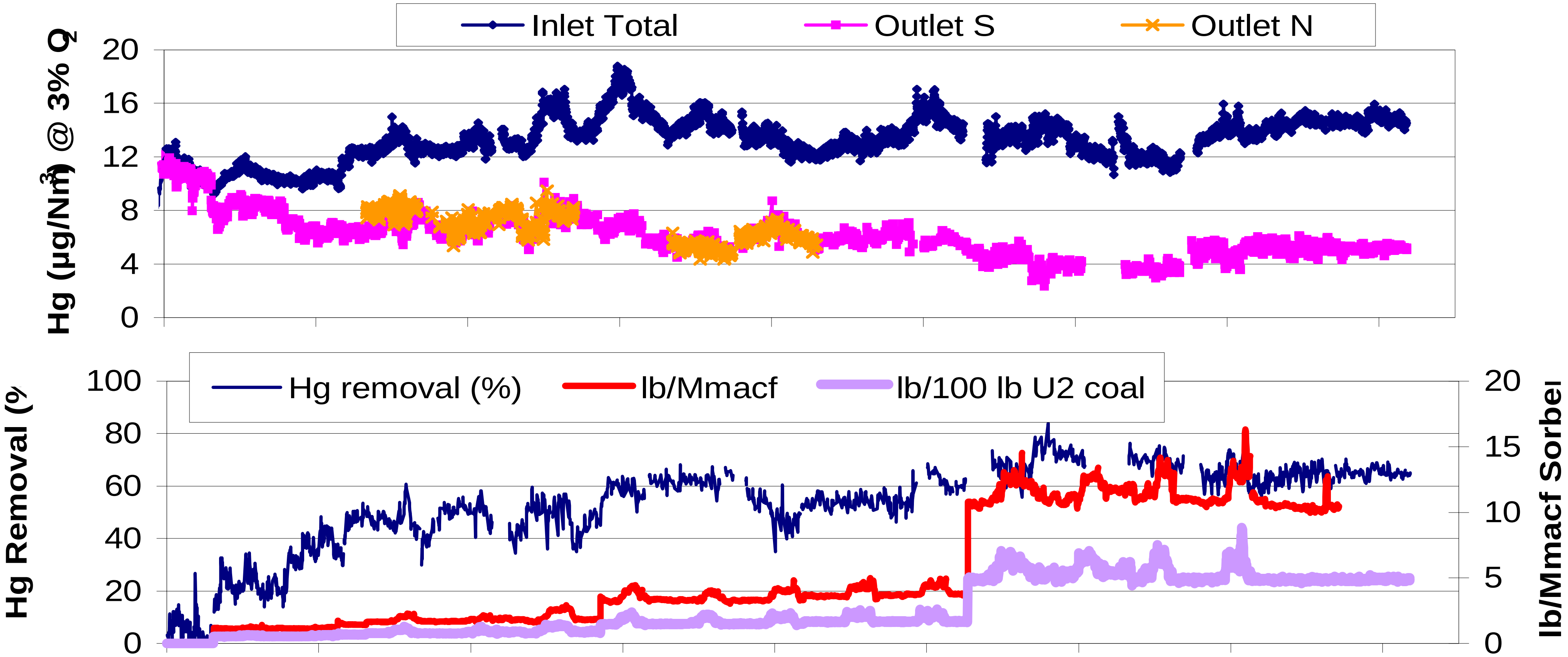
# Objectives of Long-Term Tests

- Choose target injection rate with highest removal
- Consider impact on ash
- Consider impact on ESP
- Evaluate several levels of mercury control

# Long Term Test Plan (5 days each)

- All tests conducted with Norit Americas Darco FGD
- Very Low Rate of 1 lb/MMacf
  - Minimize impact on ash
  - What is removal efficiency at very low rate?
- Low Rate of 3 lbs/Mmacf
  - Logarithmic “middle” point
  - Will removal efficiency increase with time?
- Highest Removal at 10 lbs/MMacf
  - Ontario Hydro Tests
  - Impact on ESP

# Long Term Trend Data



# Speciated Mercury During Long Term Tests (S-CEM)

| Injection Concentration | Inlet Hg (microgram/dncm) | | | Outlet Hg (microgram/dncm) | | |
|---|---|---|---|---|---|---|
| | $Hg^0$ | $Hg^{+2}$ | Total | $Hg^0$ | $Hg^{+2}$ | Total |
| 1 lb/Mmacf | 10.7 (89%) | 1.3 (11%) | 12.0 | 4.9 (72%) | 1.9 (28%) | 6.8 |
| 3 lb/Mmacf | 11.7 (84%) | 2.2 (16%) | 13.9 | 4.5 (75%) | 1.5 (25%) | 6.0 |
| 10 lb/Mmacf | 11.0 (81%) | 2.6 (19%) | 13.6 | 3.2 (72%) | 1.3 (28%) | 4.5 |

Note: Total and elemental mercury measured directly, oxidized mercury calculated from the difference.

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# Speciated Mercury Measured by S-CEM

| Species (microg/dncm) | 1 lb/Mmacf Inlet | 1 lb/Mmacf Outlet | 3 lb/Mmacf Inlet | 3 lb/Mmacf Outlet | 10 lb/Mmacf Inlet | 10 lb/Mmacf Outlet |
|---|---|---|---|---|---|---|
| Particulate | NA | NA | NA | NA | NA | NA |
| Elemental | 10.7 | 4.9 | 11.7 | 4.5 | 11.0 | 3.2 |
| Oxidized | 1.3 | 1.9 | 2.2 | 1.5 | 2.6 | 1.3 |
| Total | 12.0 | 6.8 | 13.9 | 6.0 | 13.6 | 4.5 |
| % Oxidized | 11 | 28 | 16 | 25 | 19 | 28 |

Note: Total and elemental mercury measured directly, oxidized mercury calculated from the difference.

# Speciated Mercury Measured by Ontario Hydro Method (10 lbs/MMacf)

Ontario Hydro Results Summary (microgram/dncm)

| | Baseline | | Long Term | |
|---|---|---|---|---|
| | Inlet | Outlet | Inlet | Outlet |
| Particulate | 1.97 | 0.01 | 0.98 | 0.00 |
| Elemental | 12.22 | 9.80 | 14.73 | 4.27 |
| Oxidized | 2.51 | 6.01 | 1.73 | 0.44 |
| Total | 16.71 | 15.82 | 17.44 | 4.71 |
| % Oxidized | 15.0% | 38.0% | 9.9% | 9.3% |

# Comparison of OH and S-CEM*, Long Term Tests (10 lbs/MMacf)

| Run Number | Run 1 | | Run 2 | | Run 3 | | Average | |
|---|---|---|---|---|---|---|---|---|
| Date | 11/12/2001 | | 11/13/2001 | | 11/13/2001 | | | |
| | S-CEM* | OH | S-CEM* | OH | S-CEM* | OH | S-CEM* | OH |
| Inlet (micrograms/dncm) | 13.5 | 15 | 13.7 | 18.3 | 14.3 | 19.1 | 13.8 | 17.4 |
| Outlet (micrograms/dncm) | 4.8 | 4.0 | 5.1 | 5.0 | 5.4 | 4.7 | 5.1 | 4.7 |
| Removal Efficiency (%) | 64.4% | 73.4% | 62.8% | 72.8% | 64.0% | 75.3% | 63.7% | 72.9% |

* S-CEM measures only gas phase mercury, average calculated over same time as OH tests

# Long Term Test Conclusions

- Hg removal efficiency of 40 - 50% obtained at 1 lb/Mmacf
- Hg removal efficiency of 50 - 60% obtained at 3 lb/Mmacf
- Hg removal efficiency of 60 - 70% obtained at 10 lb/Mmacf
- PAC injection reduced both elemental and oxidized mercury concentrations
- Fly ash could not be used for concrete with PAC present
- More development needed to fully assess and mitigate PAC effects on ash
- No detrimental impact on ESP performance
- On a PRB ash, if the gas temperature is below 300 ºF, it appears that additional cooling does not improve capture of mercury

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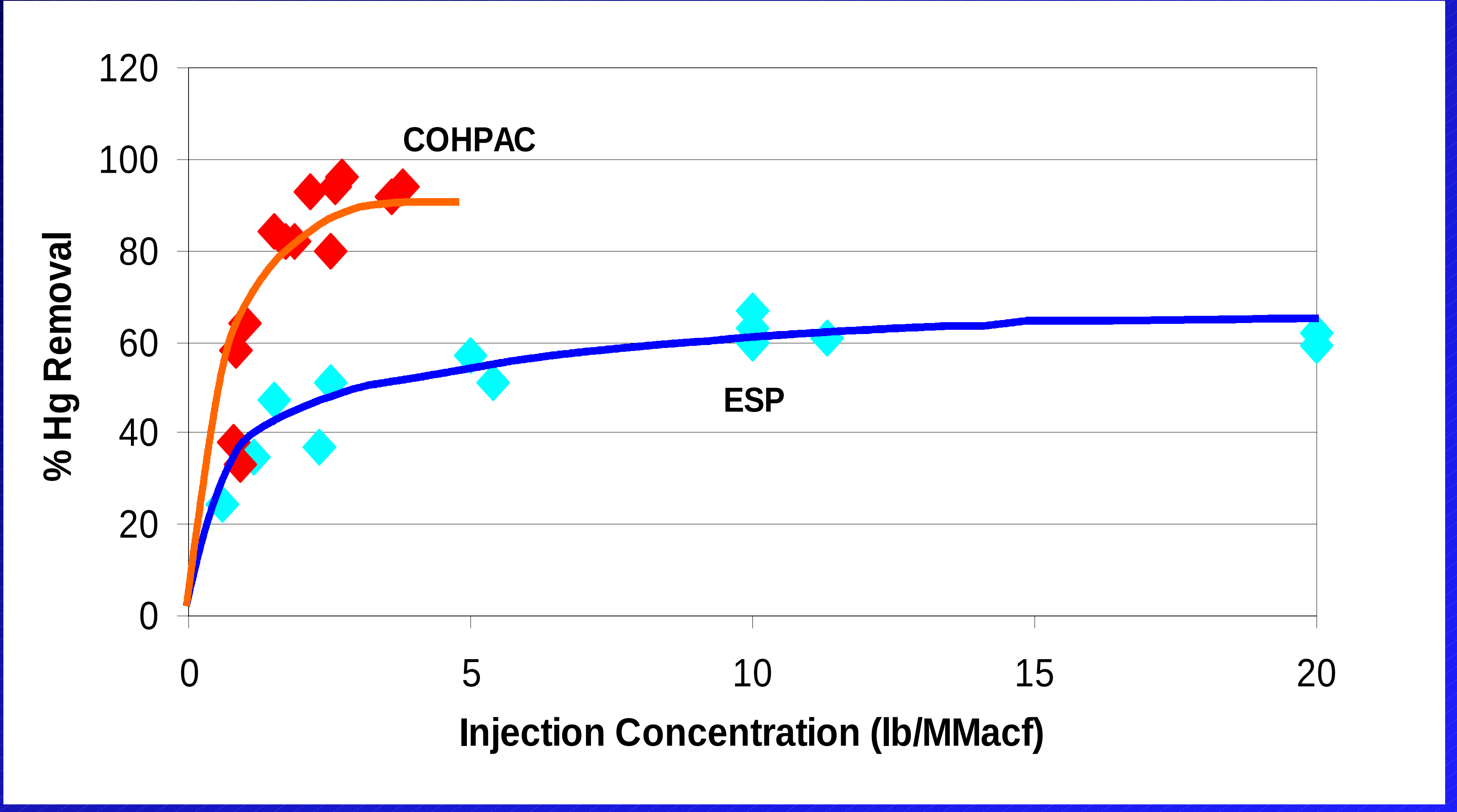
# Mercury Removal Trends for ESP and COHPAC

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