

# Pilot Testing of Mercury Oxidation Catalysts for Upstream of Wet FGD Systems



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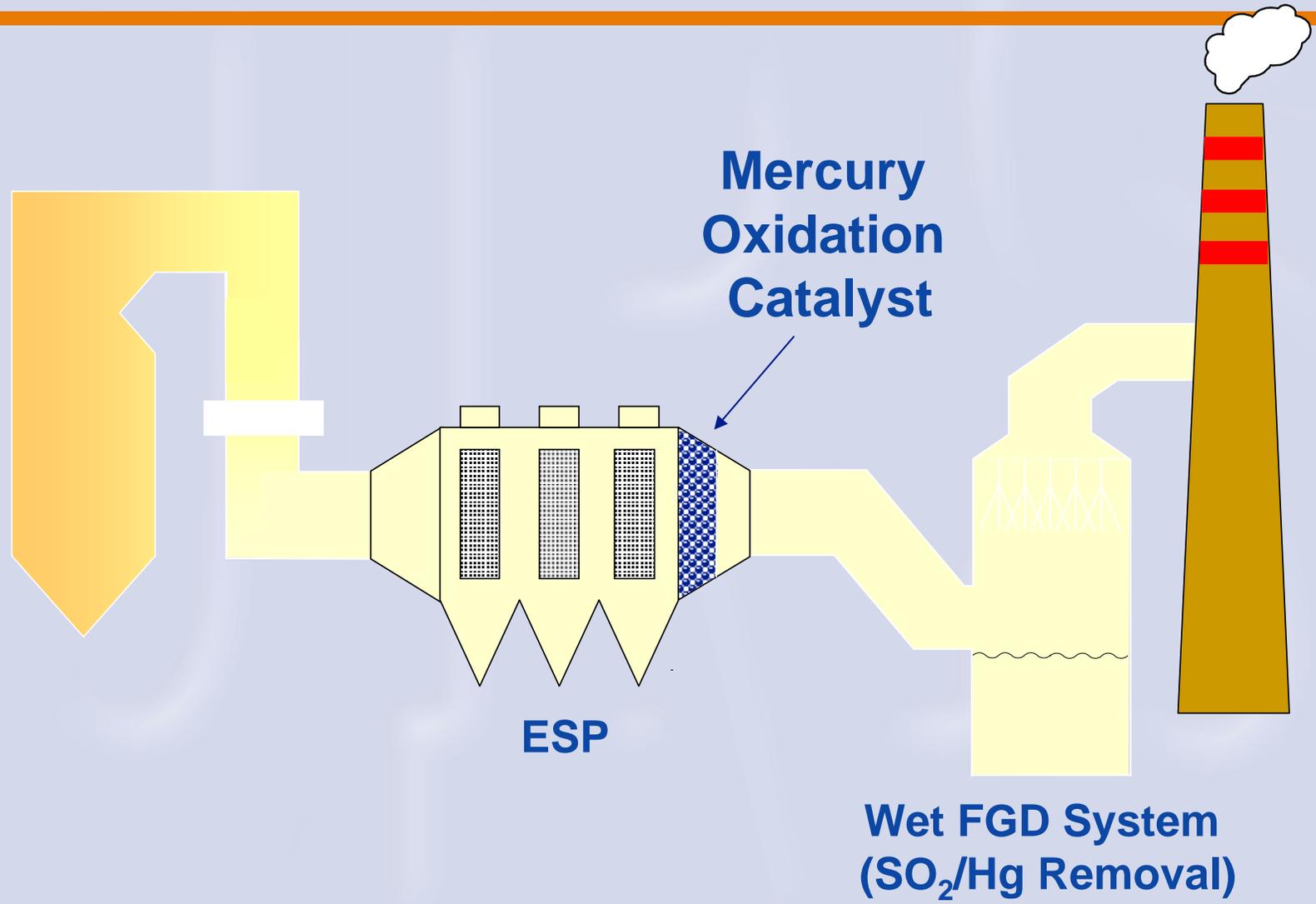


# Hg Control Technology Concept

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- Low temperature catalytic oxidation of Hg<sup>0</sup> in flue gas
- Increase Hg removal by wet FGD system

# Illustration of Process Concept



# Project Background

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- Development focused on fuel/plant configurations that produce higher Hg<sup>0</sup> percentages in flue gas
  - Project 41185: PRB and ND lignite
  - Project 41992: TX lignite/PRB and LSEB fuels
- Both projects conducting pilot-scale tests of honeycomb Hg<sup>0</sup> oxidation catalysts at two sites each
  - 4 catalysts tested in parallel (~2000 acfm each)
  - 14+ months automated operation at each site
  - ~Bimonthly catalyst activity measurements

# 41185 Project Pilot Testing

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- **Coal Creek pilot unit:**
  - Pilot unit started up October 02 (2 of 4 catalysts)
  - Long-term test completed June 04
  - Catalyst regeneration tests July, September 04
- **Spruce pilot unit:**
  - First 2 catalysts started up August 03
  - Restarted with 4 catalysts after station outage (Nov. 03)
  - Long-term test completed April 05
  - Catalyst regeneration tests April/May 05

# 41992 Project

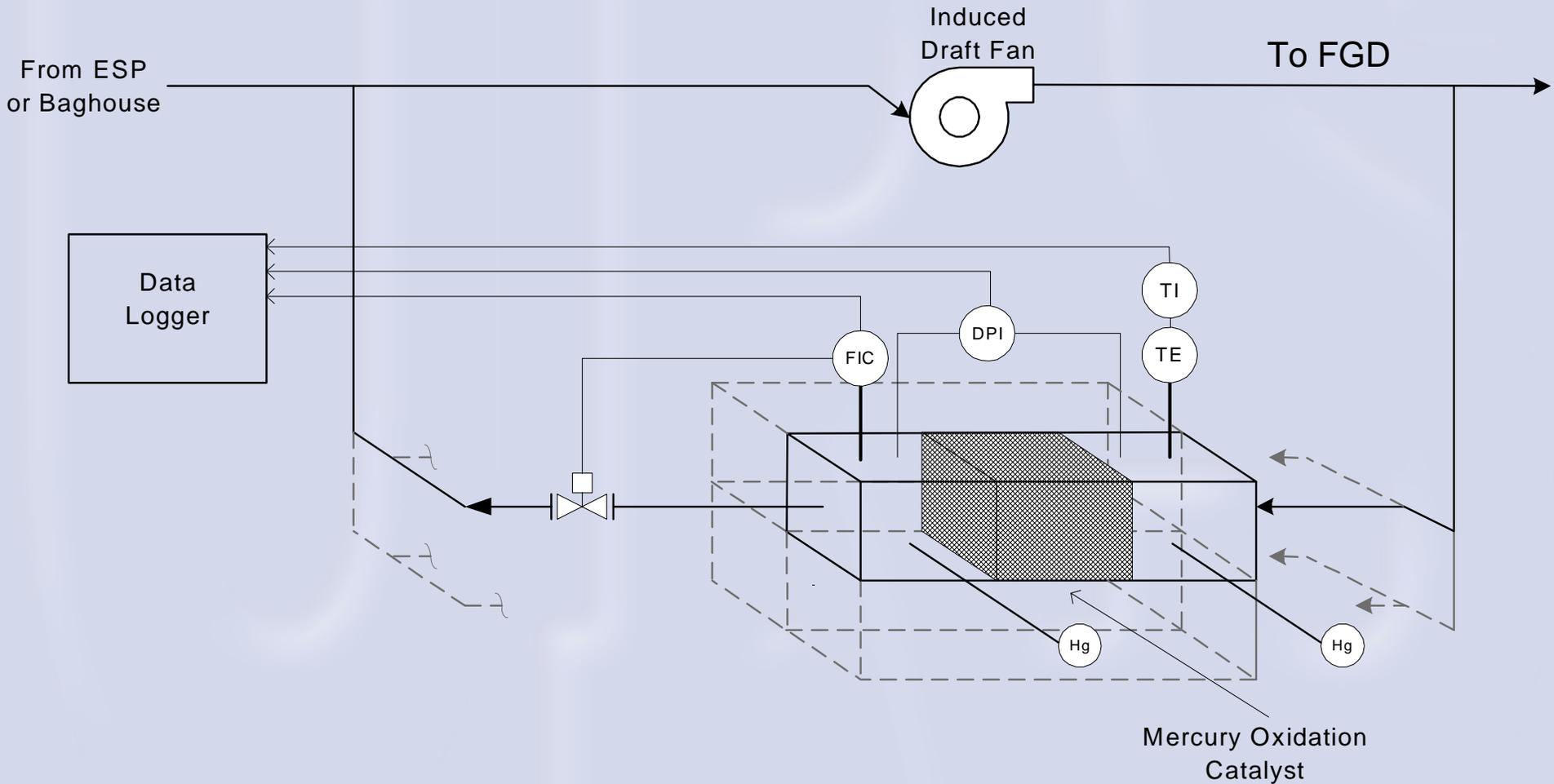
- **Existing pilot units used at 2 new sites**
  - TXU's Monticello Station (TX lignite/PRB, ESP, LSFO wet FGD) – began January 05
  - Southern Company's Plant Yates (low S Eastern bit., ESP, CT-121 wet FGD) – to begin August 05
- **Build and operate new wet FGD pilot unit downstream of oxidation catalysts**
  - 2000 acfm inlet flow rate to match one catalyst
  - Conduct short-term wet FGD tests at all 4 sites
  - Can test LSFO vs. Mg-lime chemistries

# Catalyst Types Tested

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- Metal-based
  - Palladium (Pd #1) – All sites
  - Ti/V (SCR) – Coal Creek, Spruce, Monticello
  - Gold (Au) – Spruce, Monticello, Yates
- Carbon-based
  - Experimental activated carbon (C #6) – Coal Creek, Spruce
- Fly-ash-based – Coal Creek only

# Catalyst Pilot Unit P&ID



# Hg Oxidation Catalyst Pilot Unit at Coal Creek Station (CCS)



# Catalyst Dimensions for CCS Pilot

<b>Catalyst</b>	<b>Cells per in.<sup>2</sup> (cpsi)</b>	<b>Cross Section (in. x in.)</b>	<b>Length (in.)</b>	<b>Area Velocity (sft/hr)</b>
Pd #1	64	30 x 30	9	49
C #6	80*	36 x 36	9	27
SBA #5	80*	36 x 36	9	27
SCR	46	35.4 x 35.4	19.7	14**

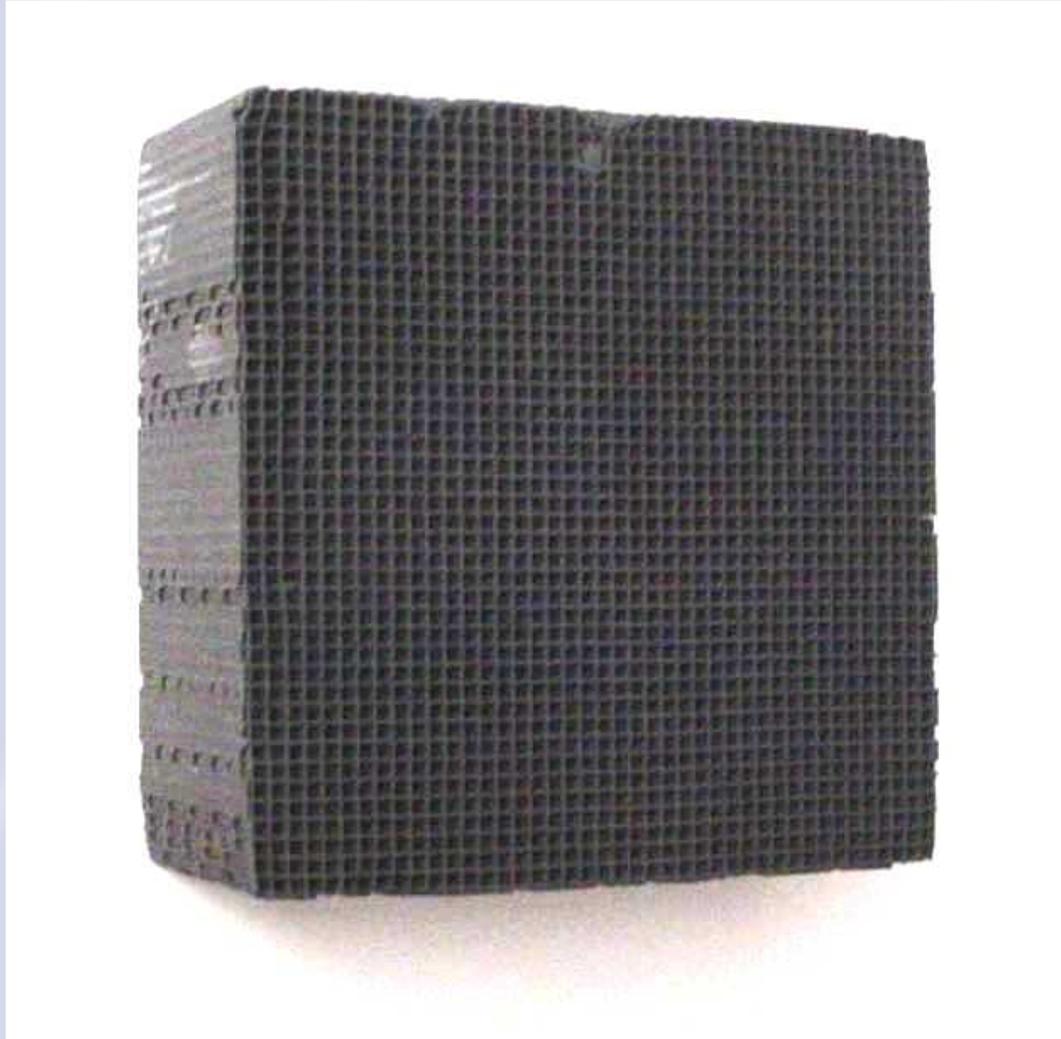
\*Die sized for 64 cpsi, cores shrank during drying

\*\*1500 acfm, other catalysts operate at 2000 acfm

# Example Catalyst Module (1 of 3)



# Close-up of One Catalyst Block



# Example Catalyst Installation



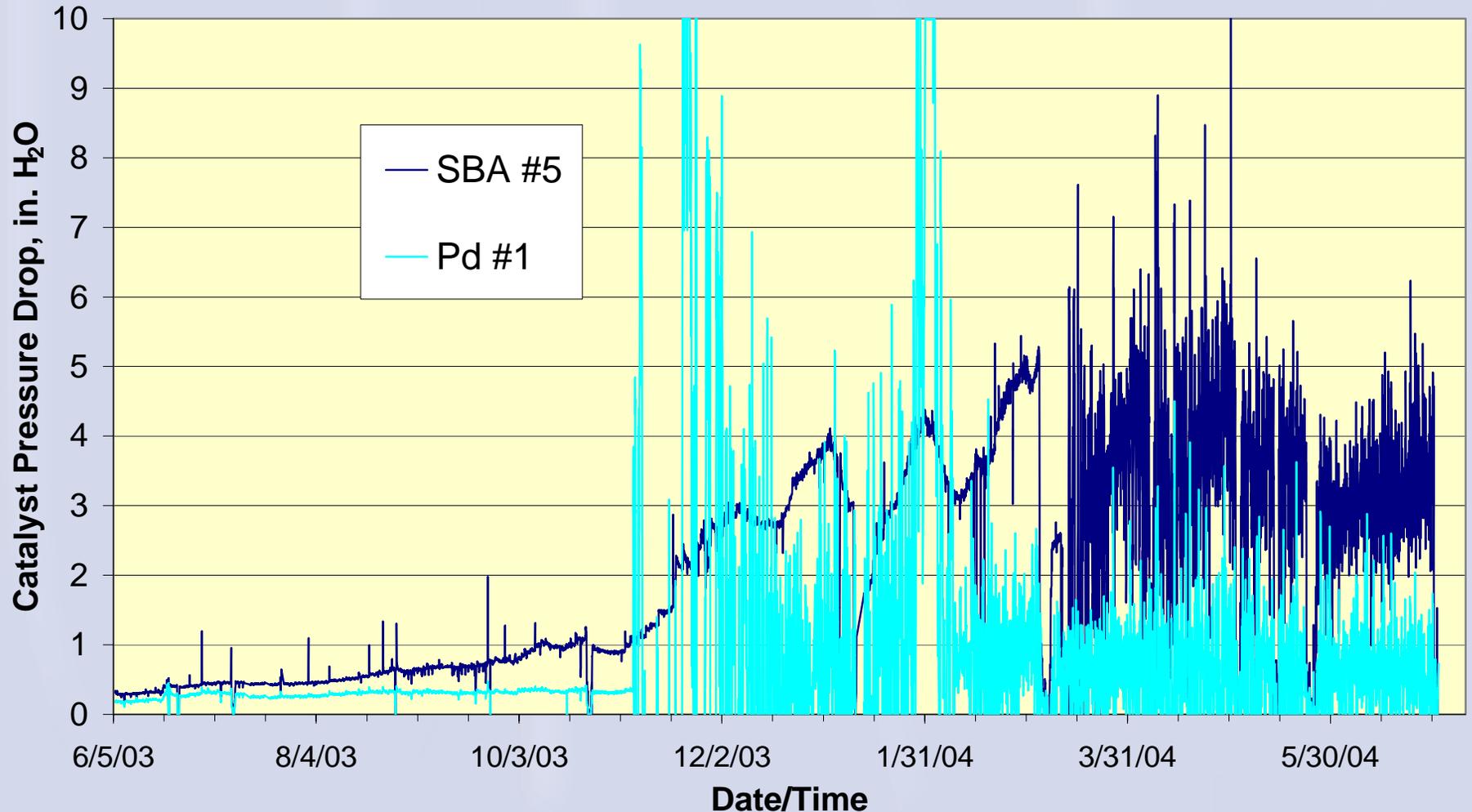
# Sonic Horn Installation on Pilot Unit



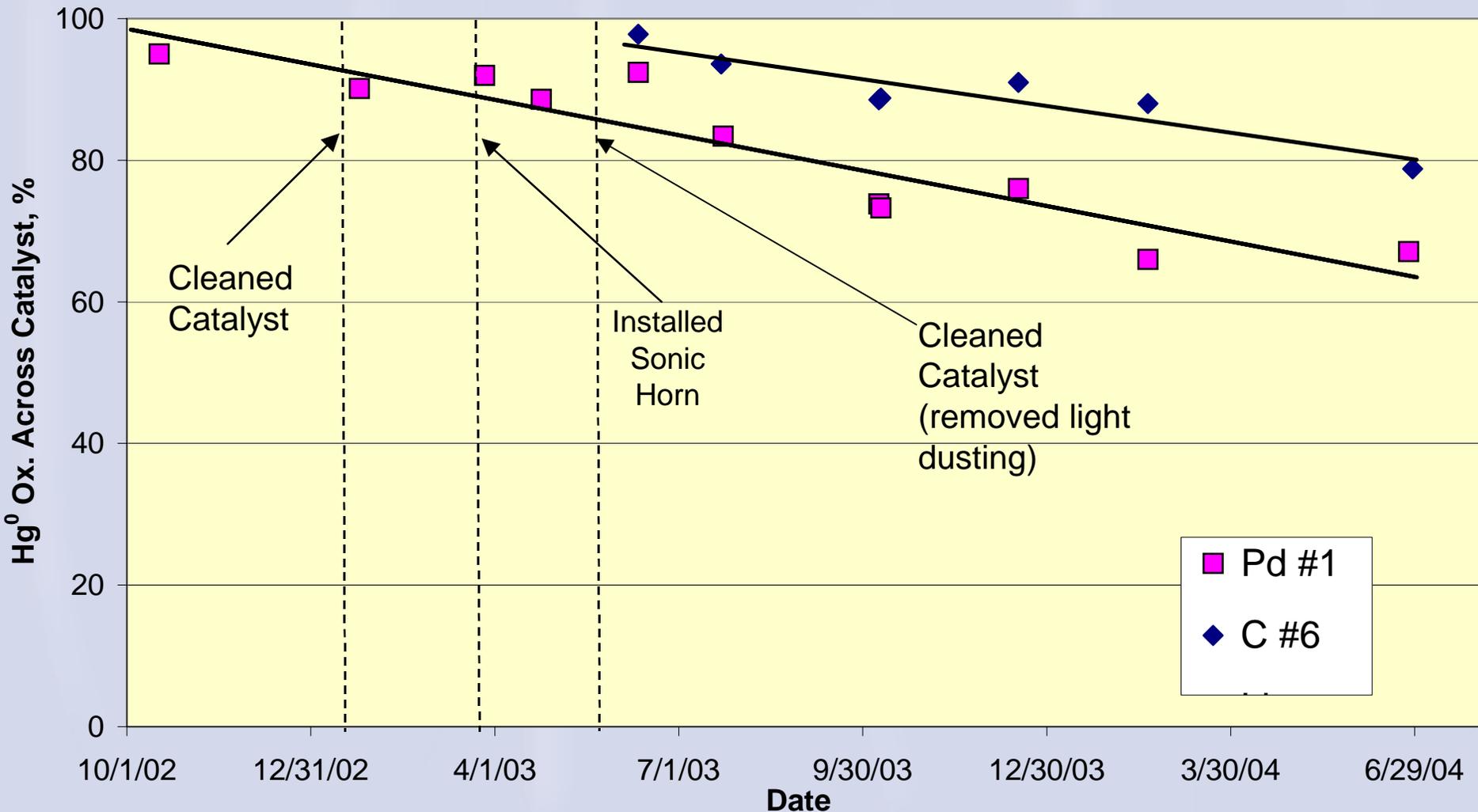
# Sonic Horn Locations



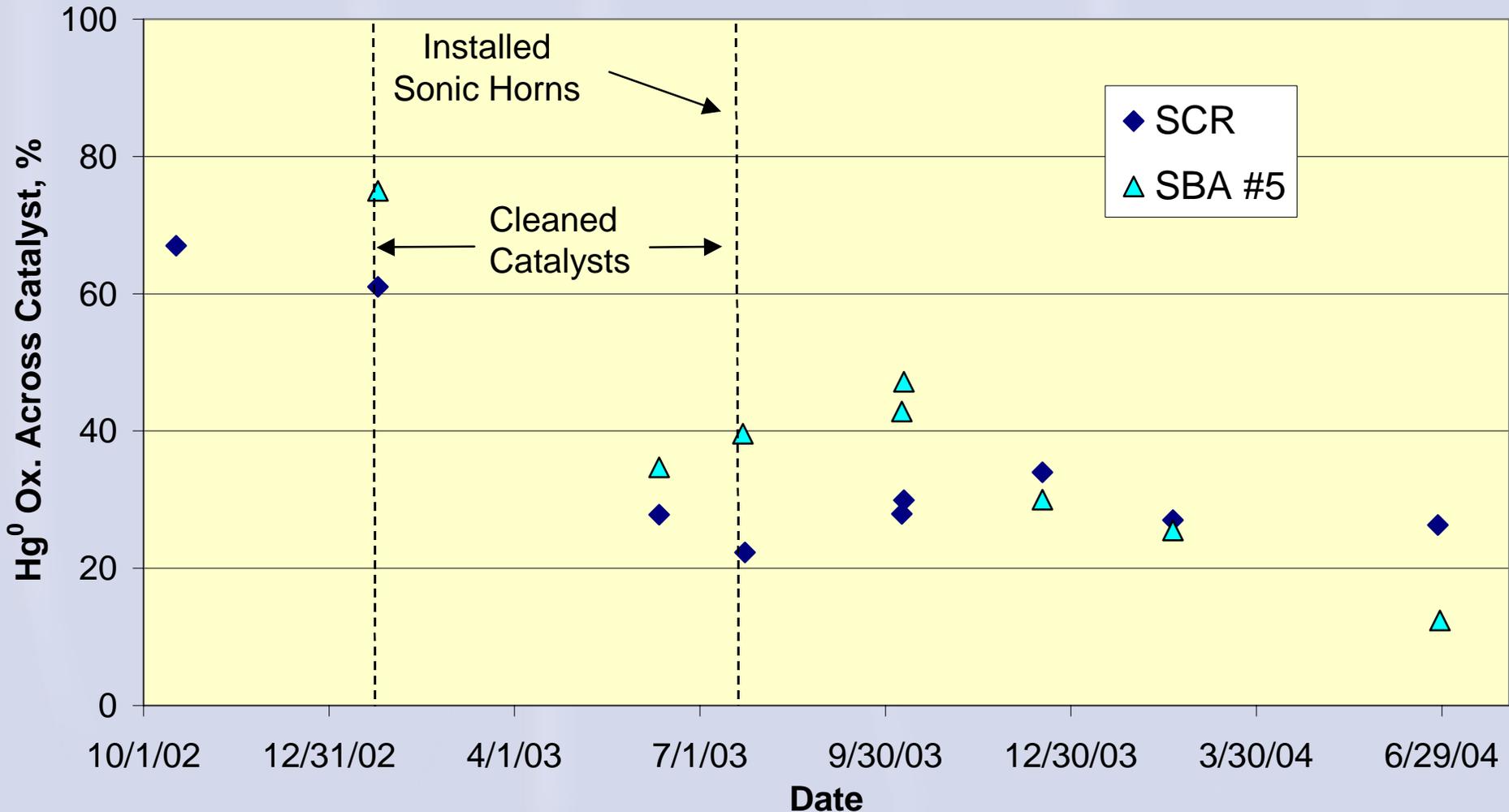
# Catalyst $\Delta P$ June 03 through June 04 (sonic horns in all 4 compartments)



# Catalyst Activity Trends over 20 Months at Coal Creek



# Catalyst Activity Trends over 20 Months at Coal Creek



# Coal Creek In Situ Catalyst Regeneration Tests

- Conducted on 3 of 4 catalysts, with 13-21 months previous flue gas operation
  - Pd #1 and SCR catalyst regenerated in July
  - C #6 regeneration delayed until September due to schedule constraints
  - Fly-ash-plugged SBA #5 modules had already been removed from chamber, no regeneration attempted
- Replaced sonic horn with 36 kW heater bolted to catalyst chamber inlet plenum
- Closed flue gas inlet to chamber, drew in ambient air through heater, heated to 600°F
- Ran regeneration overnight (280 acfm air rate, max. catalyst chamber outlet temperature 410-420°F)

# Catalyst Regeneration Test Results

- Pd and SCR catalysts showed improved Hg<sup>0</sup> oxidation activity, C #6 did not
- Results should be considered proof of concept only
  - Regeneration limited by heater size, and temperature limit of downstream control valves (450°F)
  - Not sure how uniformly heated air was distributed across catalyst face
  - Did not open compartments to clean any catalyst surface area covered with fly ash (i.e., not regenerable)

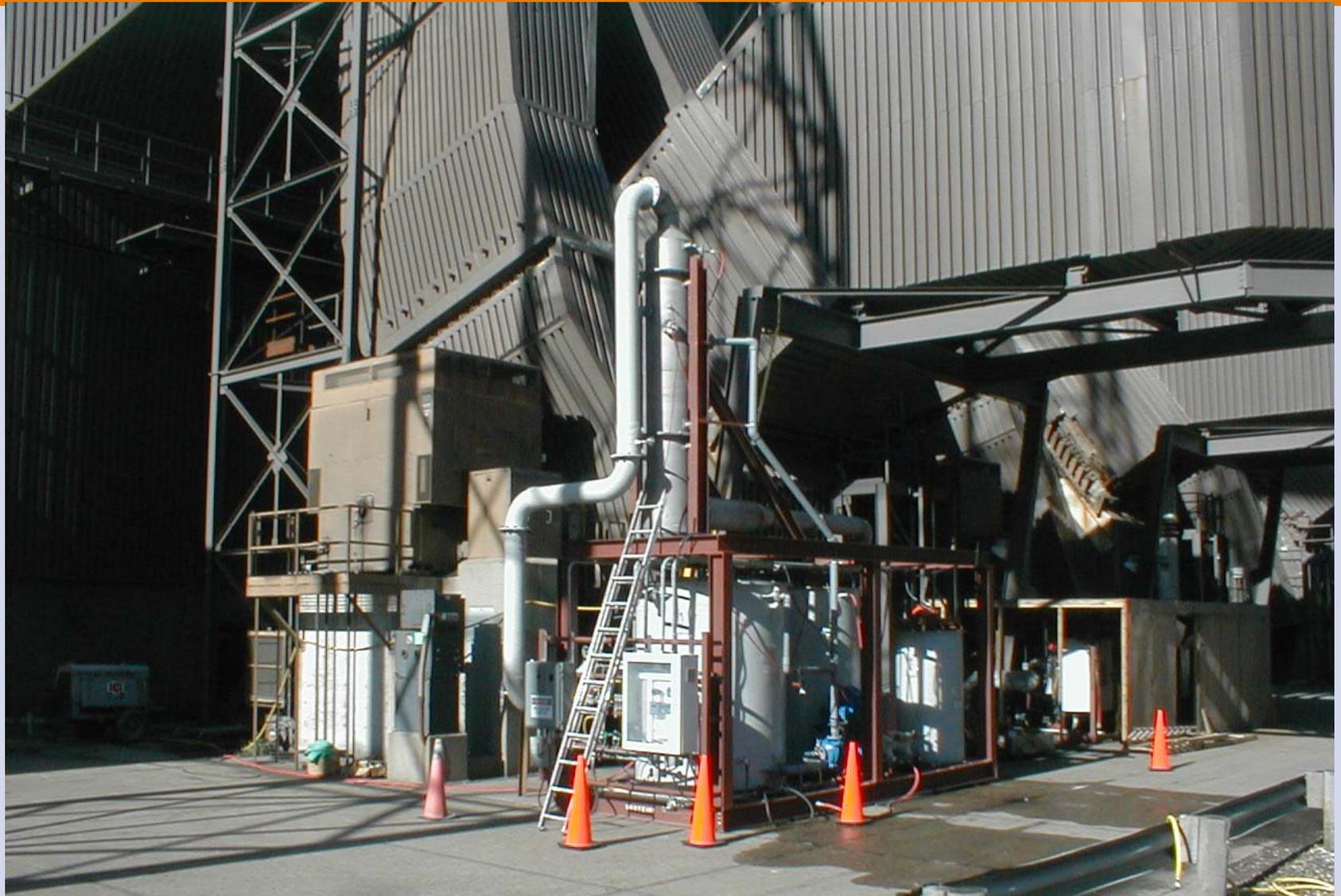
# Coal Creek Catalyst Regeneration Test Results

	Catalyst Activity, % Oxidation of Hg <sup>0</sup>			
Catalyst Type	Fresh Catalyst	End of Test (6/04)	Prior to Regeneration	After Regeneration
Pd #1	95 (10/02)	67	79 (7/04)	88 (7/04)
SCR	67 (10/02)	26	25 (7/04)	46 (7/04)
C #6	98 (6/03)	79	~53 (9/04)	48 (9/04)

# Pilot Wet FGD Design

- Alloy absorber, 24-in. diameter, tray contactor
- Adjust L/G to get desired mass transfer
- No dewatering –operates “open loop”
  - Use host site FGD liquor as makeup to get steady-state levels of soluble salts and trace metals
- Tests are short term (<1 to 3 reaction tank residence times)
  - Solids should approach steady state, liquor may not
  - Compromise between cost of testing and information derived

# DOE/EPRI/URS FGD Pilot Unit



# Coal Creek Pilot Wet FGD Tests

- Some test results are confounded by poor Hg recovery in SCEM sample from FGD outlet duct
  - Only results with “good” QC are presented here
- In spite of Hg recovery issues, all results show high percent capture of oxidized Hg
  - FGD outlet Hg is almost all Hg<sup>0</sup>
  - Indicates that Hg<sup>+2</sup> formed across catalysts is removed by wet scrubber
- Hg recovery issues make it difficult to quantify whether Hg re-emissions was occurring
  - All “good QC” results presented show some re-emissions
  - Subsequent tests use 2 analyzers to simultaneously sample FGD inlet/outlet

# Coal Creek Wet FGD Pilot Results – Pd #1 Catalyst, Mg-Lime Chemistry

	Total Hg	Hg <sup>0</sup>	Hg <sup>+2</sup>
Catalyst Inlet ( $\mu\text{g}/\text{Nm}^3$ )	16.9	10.5	6.46
FGD Inlet ( $\mu\text{g}/\text{Nm}^3$ )	14.0	2.23	11.8
FGD Outlet ( $\mu\text{g}/\text{Nm}^3$ )	4.98	4.56	0.42
FGD Hg Removal (%)	64	-104	96

# Coal Creek Wet FGD Pilot Results – Pd #1 Catalyst, LSFO Chemistry

	Total Hg	Hg <sup>0</sup>	Hg <sup>+2</sup>
Catalyst Inlet ( $\mu\text{g}/\text{Nm}^3$ )	18.0	11.9	6.1
FGD Inlet ( $\mu\text{g}/\text{Nm}^3$ )	17.4	2.71	14.7
FGD Outlet ( $\mu\text{g}/\text{Nm}^3$ )	3.73	3.76	-0.03
FGD Hg Removal (%)	79	-39	100

# Cost Estimates – Catalytic Oxidation vs. Conventional ACI

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- ND lignite flue gas
  - ACI performance based on Stanton Unit 1 data
  - Catalyst results based on Coal Creek pilot
- Assumed increase of 55% Hg capture compared to baseline removal
  - Minimum removal for oxidation catalyst case
  - Average removal for ACI
- Assumed 2-yr catalyst life
  - Sensitivity case considered 1 regeneration after 2 yrs

# Cost Estimates – Catalytic Oxidation vs. Conventional ACI

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- Best case for oxidation catalyst – plant with existing wet FGD that sells fly ash
  - Catalytic oxidation cost ~60% of ACI cost based on 2 yrs catalyst life
  - Little difference in cost between Pd and C #6
  - 1 regeneration cycle (Pd) improves to ~40% of ACI cost
- If plant does not sell ash – ACI and oxidation catalyst costs ~ equal with 2-yr catalyst life
  - 1 regeneration cycle improved to 60-70% of ACI

# Second Pilot Unit at Spruce Plant

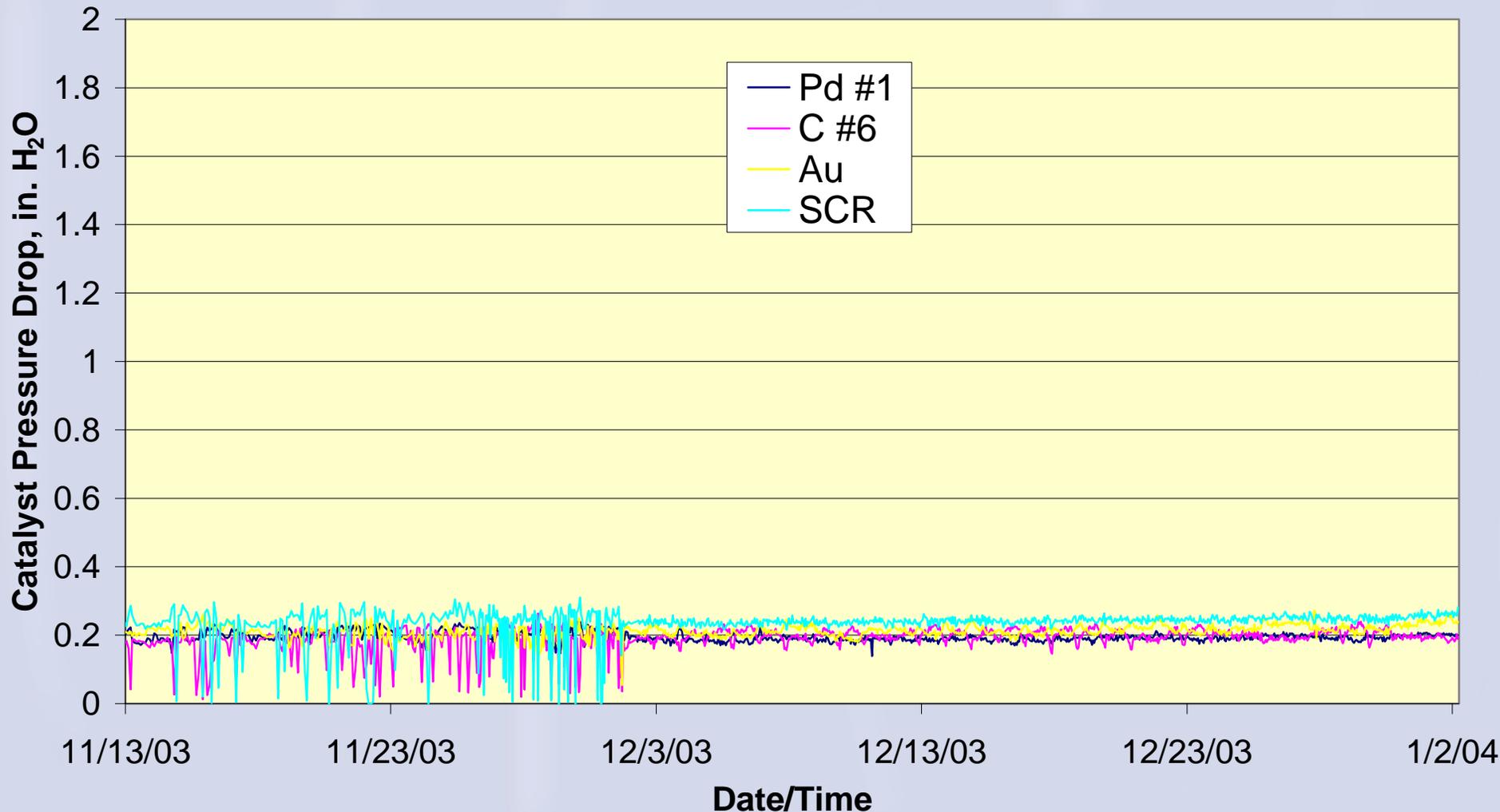


# Catalyst Dimensions for Spruce Pilot

<b>Catalyst</b>	<b>Cells per in.<sup>2</sup> (cpsi)</b>	<b>Cross Section (in. x in.)</b>	<b>Length (in.)</b>	<b>Area Velocity (sft/hr)</b>
Pd #1	64	30 x 30	9	49
Au	64	30 x 30	9	49
C #6	80*	36 x 36	9	27
SCR	46	35.4 x 35.4	29.5	13

\*Die sized for 64 cpsi, cores shrink during drying

# Catalyst Pressure Drop since 11/13 (no sonic horns in compartments)

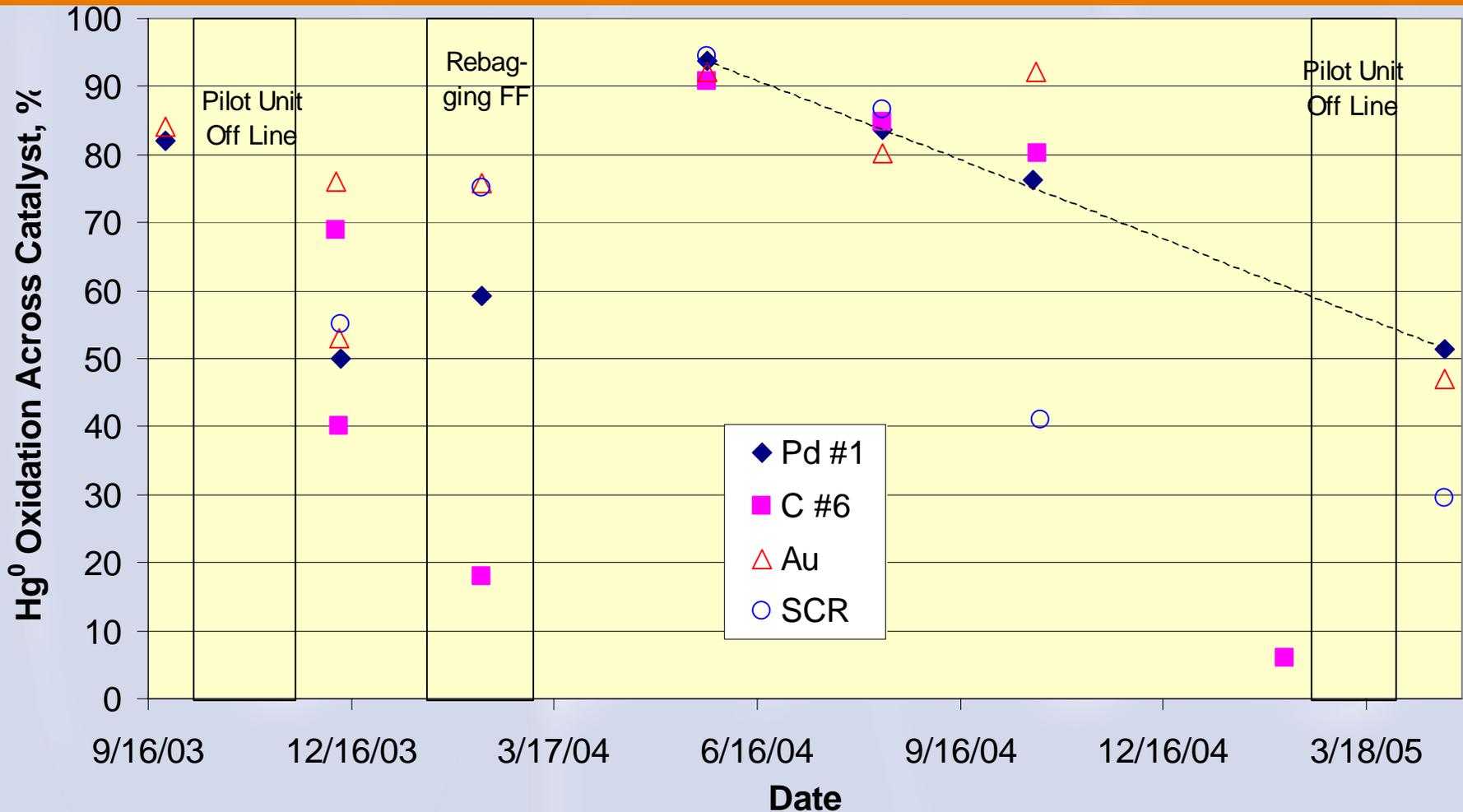


# Spruce End-of-Test Activity Results (April 2005)

Catalyst	Catalyst Inlet Hg <sup>0</sup> (μg/Nm <sup>3</sup> @ 3% O <sub>2</sub> )	Catalyst Outlet Hg <sup>0</sup> (μg/Nm <sup>3</sup> @3% O <sub>2</sub> )	Hg <sup>0</sup> Oxidation Across Catalyst (%)
Pd #1	1.32	0.64	51
C #6	1.26*	1.18*	6*
Au	1.48	0.78	47
SCR	0.80	0.56	29

\*February 2005 data

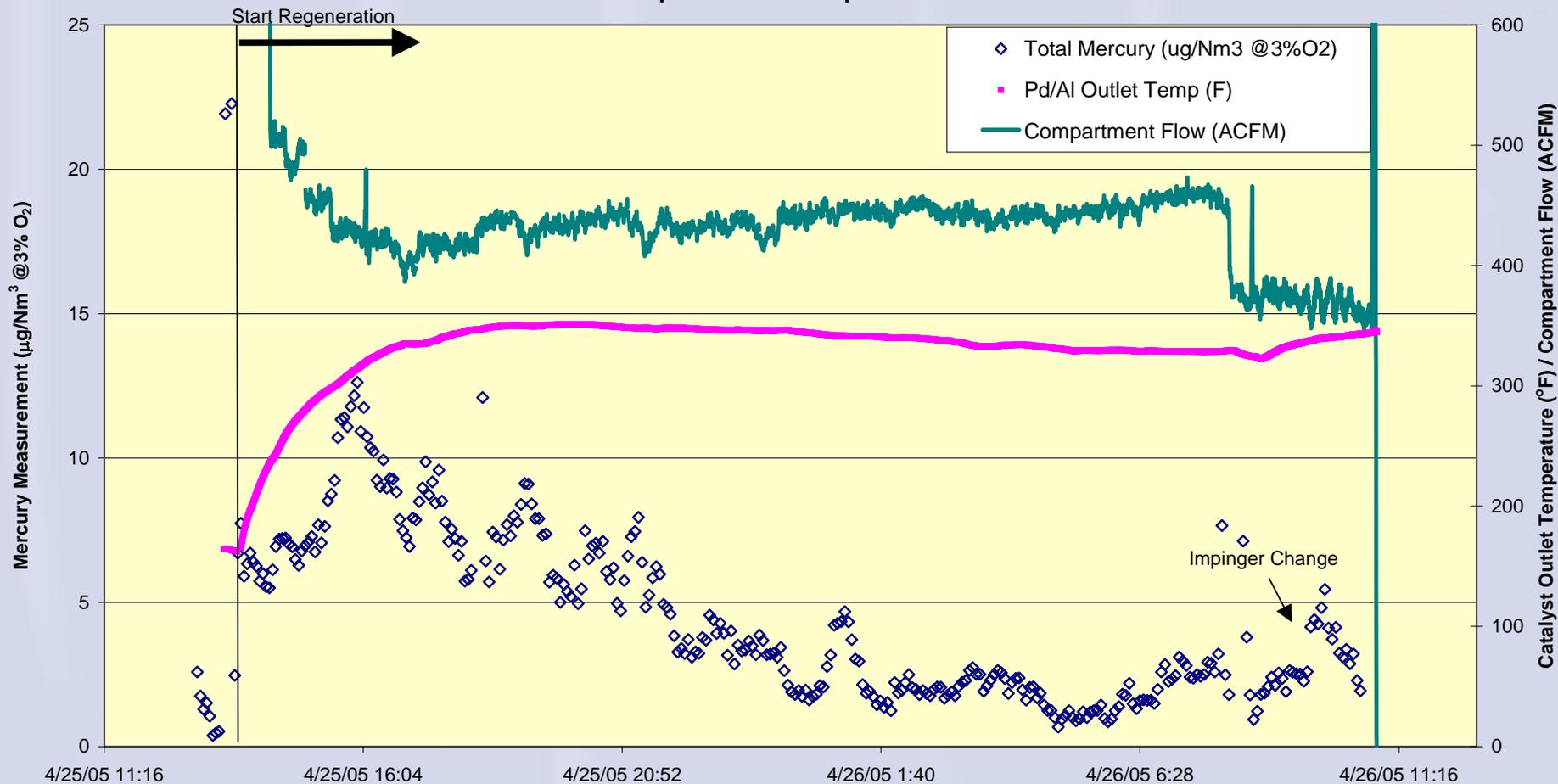
# Spruce Catalyst Activity Results



Pd #1 results are the only ones that show a linear loss of activity over the past year

# Example Spruce Catalyst Regeneration Test Trend Plot

Pd/Al Catalyst Regeneration  
Spruce Station - April 2005



# Spruce Catalyst Regeneration Results, April-May 2005

<b>Catalyst</b>	<b>Catalyst Inlet Hg<sup>0</sup> (<math>\mu\text{g}/\text{Nm}^3</math> @ 3% O<sub>2</sub>)</b>	<b>Catalyst Outlet Hg<sup>0</sup> (<math>\mu\text{g}/\text{Nm}^3</math> @ 3% O<sub>2</sub>)</b>	<b>Hg<sup>0</sup> Oxidation Across Catalyst (%)</b>	<b>Pre- Regen. Hg<sup>0</sup> Oxidation (%)</b>
Pd #1	1.17	0.19	84	51
C #6	0.94	0.41	56	6
Au	0.88	0.19	78	47
SCR	0.90	0.30	66	29

# FGD Pilot Unit at Spruce Plant



# Spruce Wet FGD Pilot Results – Baseline – No Catalyst

	Total Hg	Hg <sup>0</sup>	Hg <sup>+2</sup>
FGD Inlet ( $\mu\text{g}/\text{Nm}^3$ )	8.5	0.6	7.9
FGD Outlet ( $\mu\text{g}/\text{Nm}^3$ )	5.3	3.8	1.5
FGD Hg Removal (%)	38	-500	81

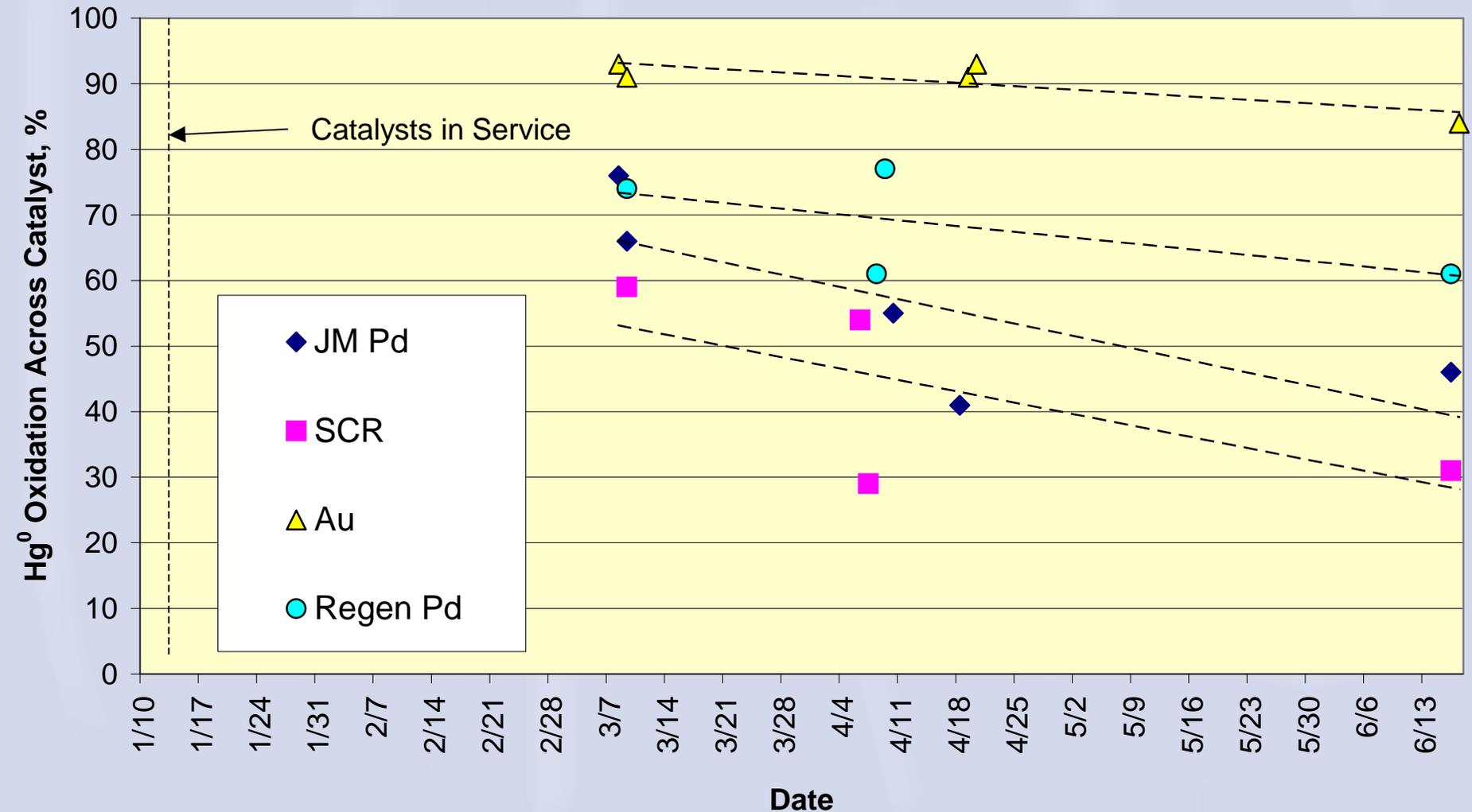
# Spruce Wet FGD Pilot Results – Au Catalyst, LSFO Chemistry

	Total Hg	Hg <sup>0</sup>	Hg <sup>+2</sup>
Catalyst Inlet ( $\mu\text{g}/\text{Nm}^3$ )	8.9	2.7	6.2
FGD Inlet ( $\mu\text{g}/\text{Nm}^3$ )	10.9	1.0	10.0
FGD Outlet ( $\mu\text{g}/\text{Nm}^3$ )	2.5	2.1	0.4
FGD Hg Removal (%)	77	-116	96

# 41992 Project – Monticello Pilot Catalysts

<b>Catalyst</b>	<b>Cross Section, in x in</b>	<b>Catalyst Depth</b>	<b>Cell Pitch, mm</b>	<b>Cells per Sq. In.</b>	<b>Area Velocity, std. ft/hr</b>
Gold (Sud-Chemie Prototech)	29.5 x 29.5	3 x 3 in.	3.2	64	52
Pd #1 (Johnson Matthey)	29.5 x 29.5	9 in.	3.2	64	52
Pd #1 (regenerated from CCS)	29.5 x 29.5	3 x 3 in.	3.2	64	52
SCR (Cormetech/MHI)	35.4 x 36.2	29.5 in.	3.3	58	38

# Monticello Catalyst Activity Data



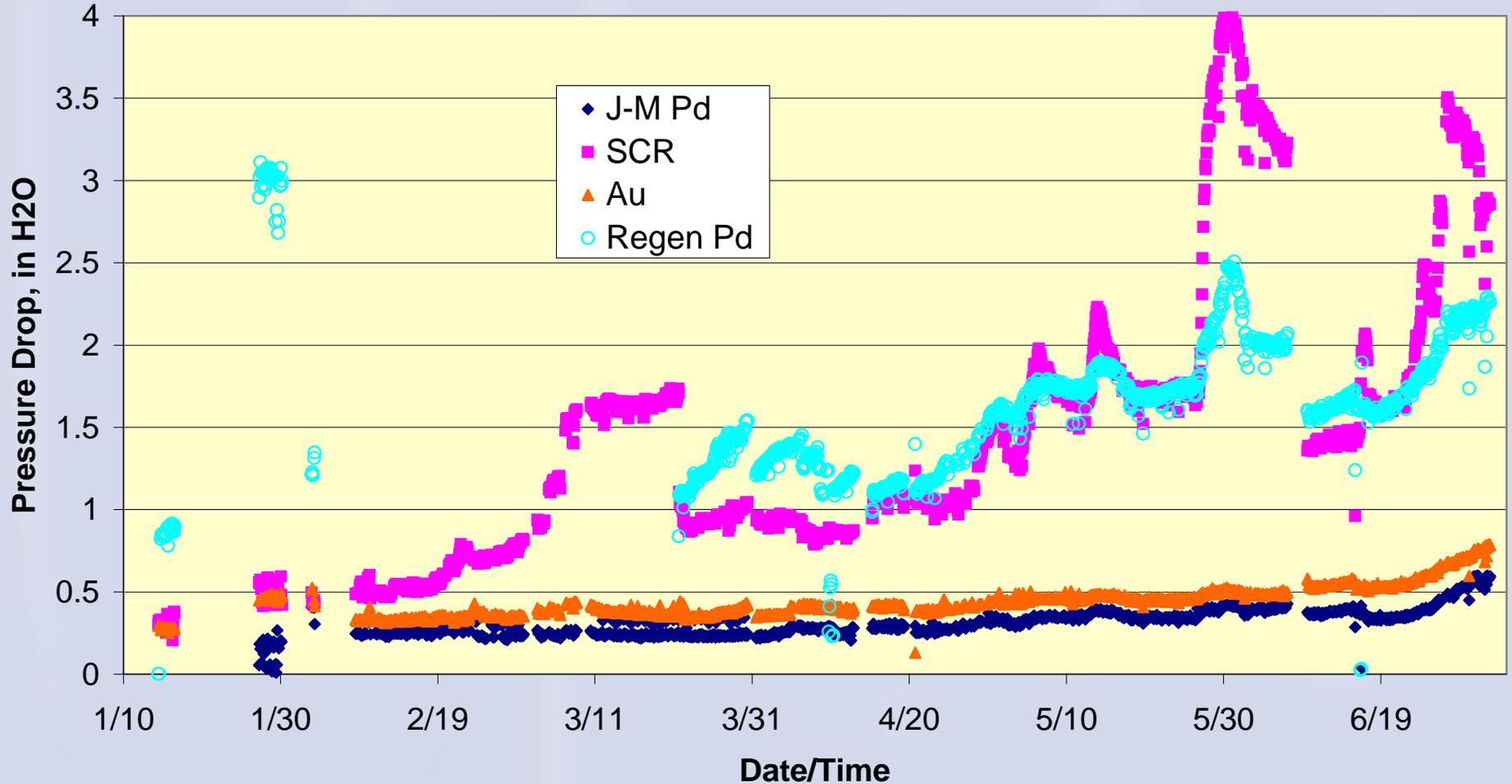
# Pilot Wet FGD at Monticello



# Pilot Wet FGD Data by SCEM

Catalyst	Catalyst Out/FGD Inlet Hg, $\mu\text{g}/\text{Nm}^3$ @ 3% O <sub>2</sub>		FGD Outlet Hg, $\mu\text{g}/\text{Nm}^3$ @ 3% O <sub>2</sub>		Total Hg Removal by FGD, %	Hg <sup>+2</sup> Removal by FGD, %	Hg <sup>0</sup> Removal by FGD, %
	Total Hg	Hg <sup>0</sup>	Total Hg	Hg <sup>0</sup>			
None	22.4	13.9	12.1	9.9	46	74	29
SCR	23.1	11.0	6.4	4.5	72	85	59
Regen. Pd	31.6	5.0	8.6	3.4	73	81	31
J-M Pd	28.8	7.9	4.6	2.4	84	89	70
Gold	31.7	1.5	7.7	2.1	76	81	-43

# Monticello Catalyst Pressure Drop Data



# Flue Gas Characterization Results

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- Ontario Hydro results do not always agree with Hg SCEM results
  - Inlet values agree reasonably well
  - OH often shows lower Hg<sup>0</sup> concentrations at catalyst outlets than Hg SCEM
    - Bias most apparent for SCR catalyst, JM Pd
  - Reason for bias remains unclear
    - Possible formation of alternate oxidized Hg form across catalysts?

# Conclusions

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- Sonic horns are required to keep horizontal gas flow catalysts clean downstream of ESPs
- Hg oxidized by catalysts removed by wet FGD at high efficiency, can be limited by re-emissions
- Catalysts can remain active up to 2 yrs
- Economics show possible lower cost than ACI
  - Economics best for plants with FGD that sell ash
  - Catalyst regeneration greatly improves economics
    - New EPRI project will optimize regeneration conditions
  - Low-cost carbon raw material catalyst no less expensive than precious metal catalysts