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

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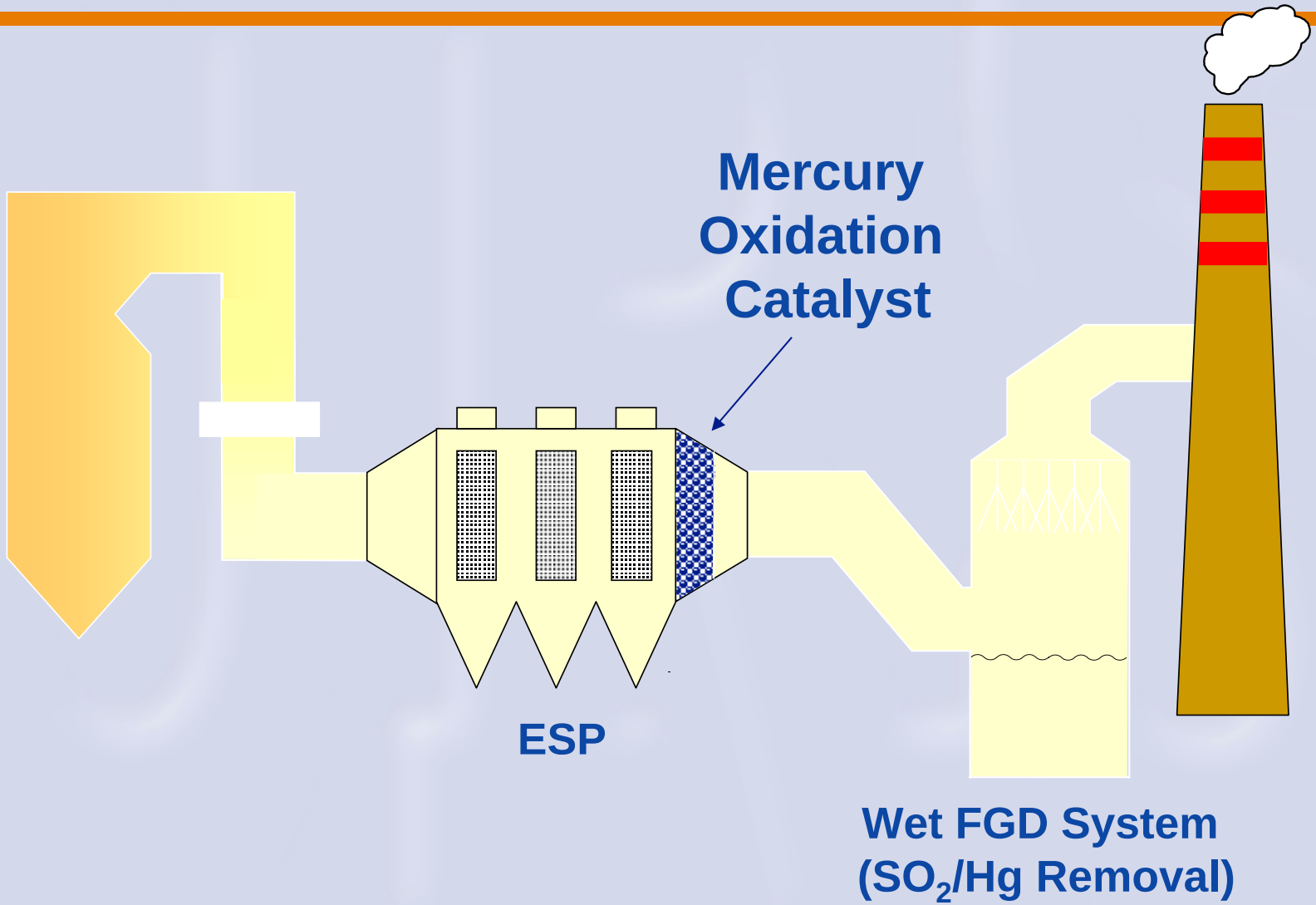
Illustration of Process Concept



Background

- Two DOE/EPRI projects are conducting pilot-scale tests of low-temp Hg^0 oxidation catalysts at four sites
  - 4 catalysts tested in parallel (~2000 acfm each)
  - 14+ months automated operation at each site
  - ~Bimonthly catalyst activity measurements

Test Locations – First Project

- GRE's Coal Creek (ND lignite, ESP/wet FGD)
  - Pilot unit started up October 02 (2 of 4 catalysts)
  - Long-term test completed June 04
  - Catalyst regeneration tests July, September 04
- CPS' Spruce (PRB, FF/wet FGD)
  - First 2 catalysts started up August 03
  - Long-term test completed April 05
  - Catalyst regeneration tests April/May 05

Second Project

- 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 September 05
- Built and are operating wet FGD pilot unit downstream of oxidation catalysts
  - 2000 acfm inlet flow rate to match one catalyst
  - Conducting short-term wet FGD tests at all 4 sites

Catalyst Types Tested

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

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

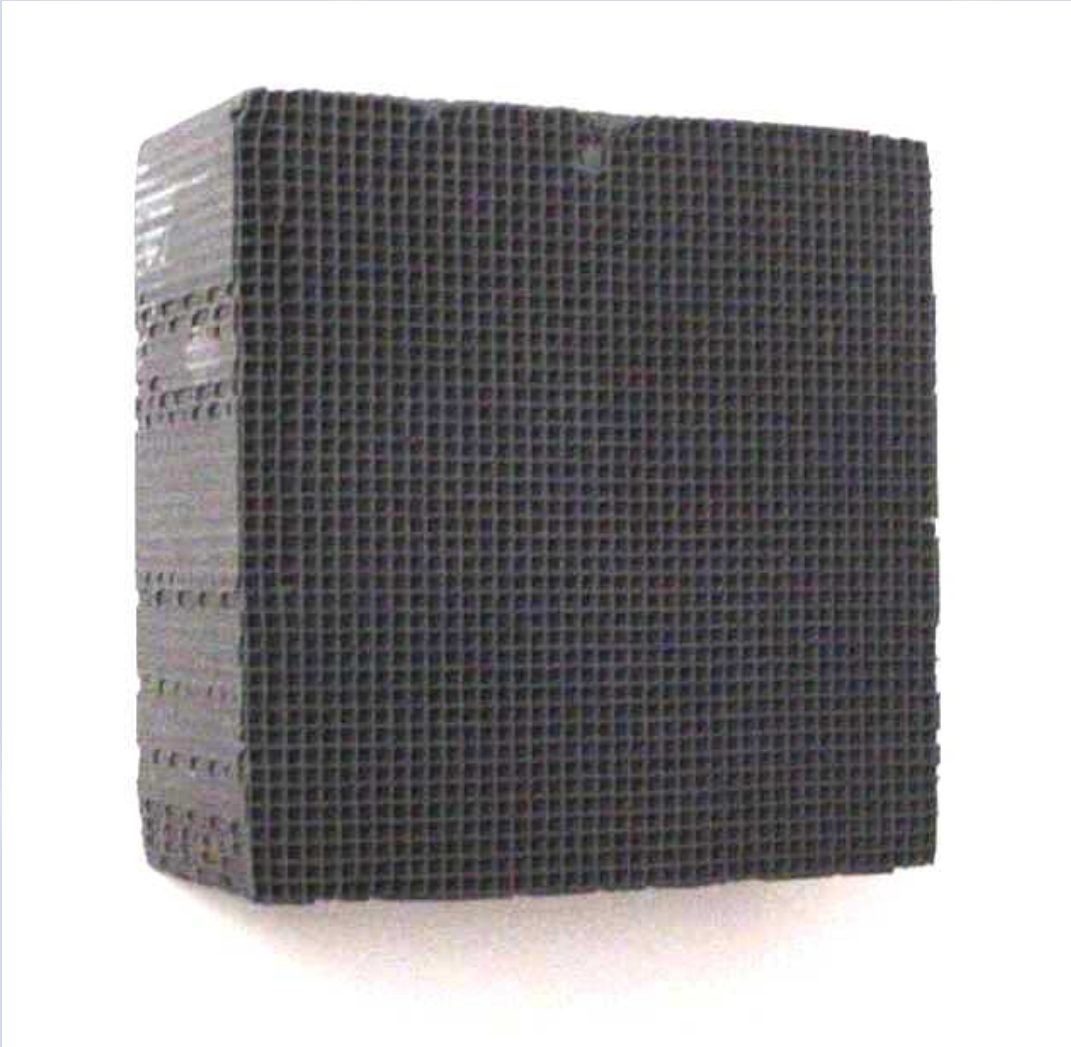
Catalyst Dimensions for CCS Pilot

Catalyst	Cells per $in.^2$ (cpsi)	Cross Section (in. x in.)	Length (in.)	Area Velocity (sft/hr)
Pd #1	64	30 x 30	9 (3 x 3)	50
C #6	80*	36 x 36	9 (3 x 3)	27
SBA #5	80*	36 x 36	9 (3 x 3)	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

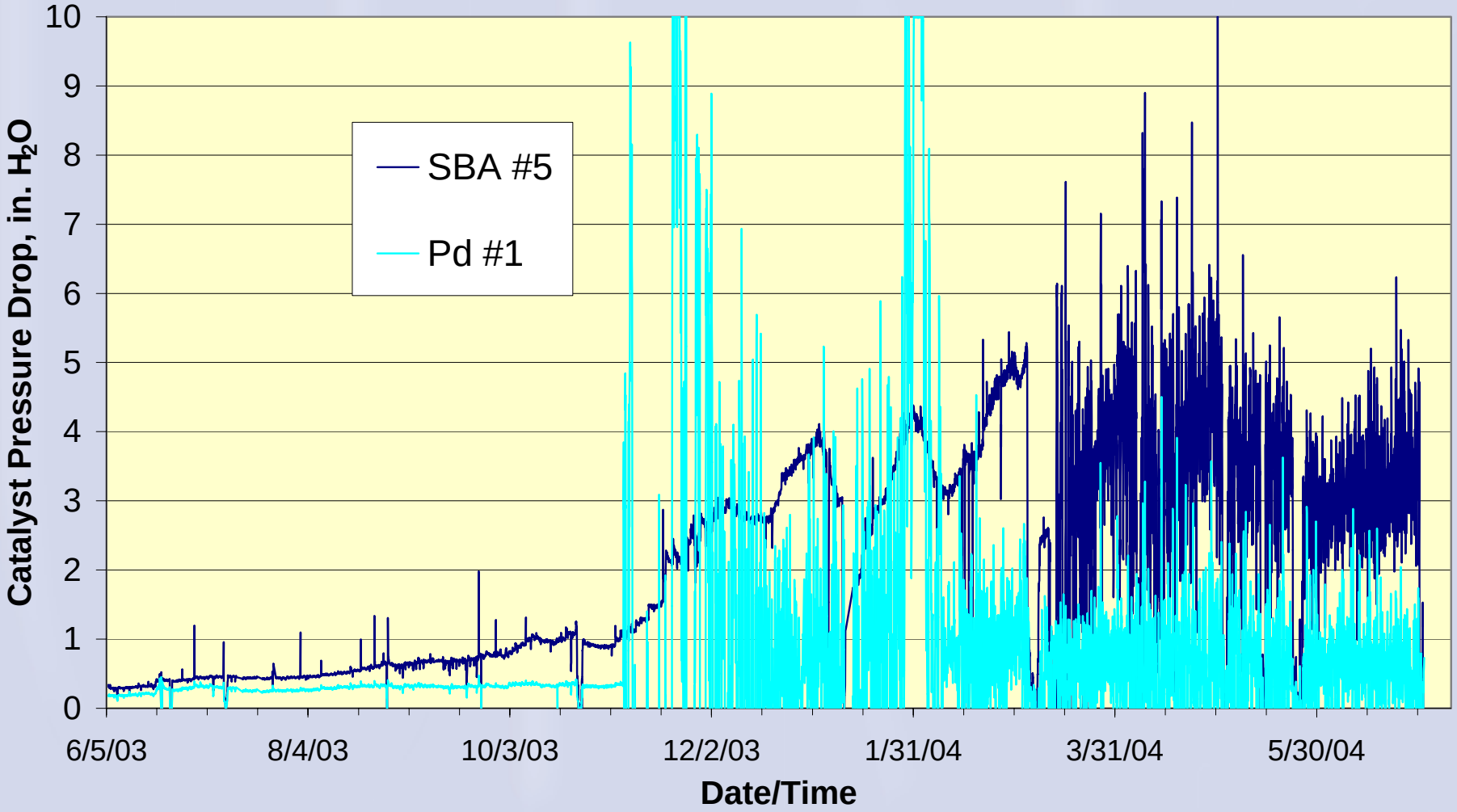
Close-up of One Catalyst Block



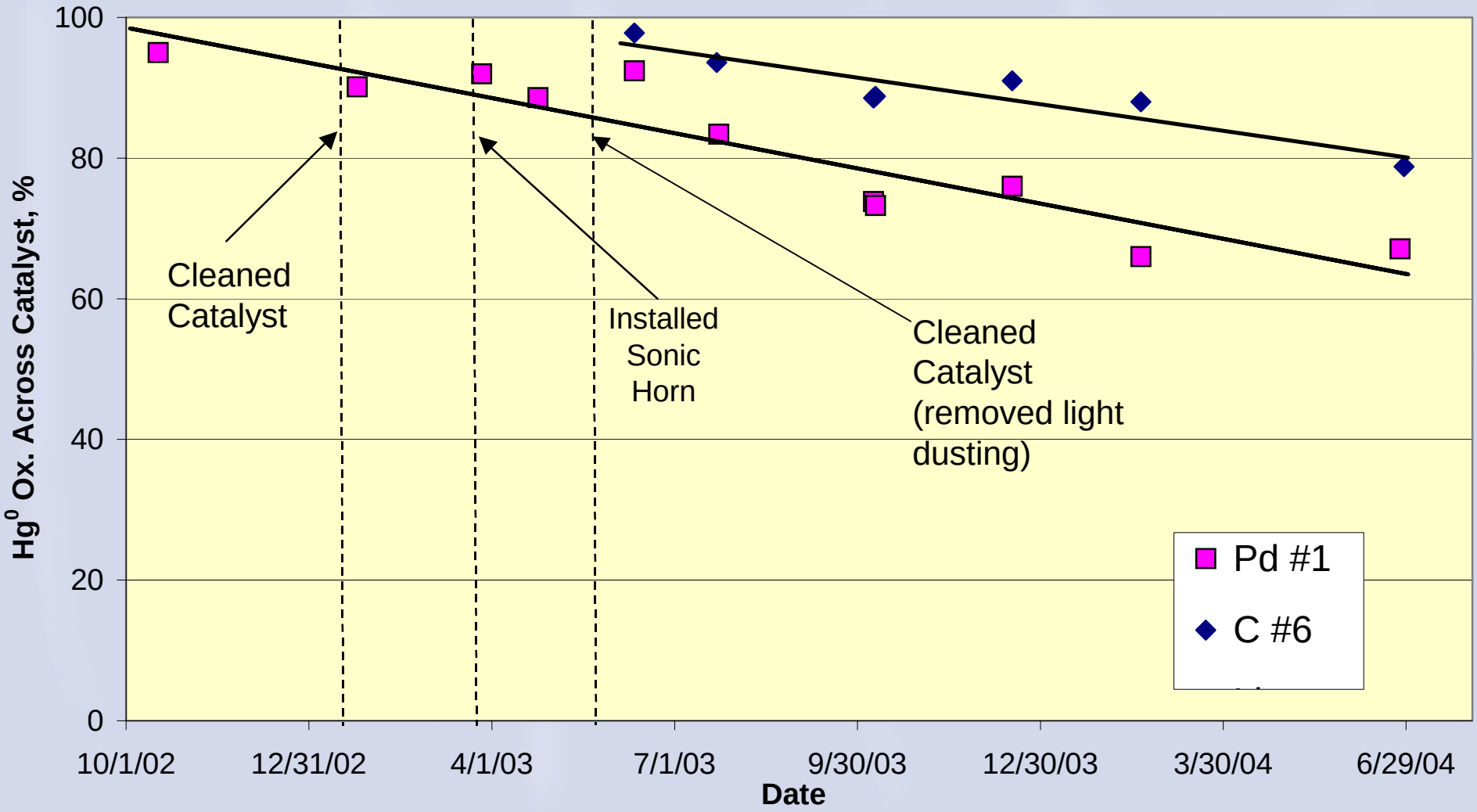
Example Catalyst Installation

Sonic Horn Installation on Pilot Unit

Catalyst ΔP since 6/03 – 6/04
(sonic horns in all compartments)



Catalyst Activity Trends over 20 Months at Coal Creek



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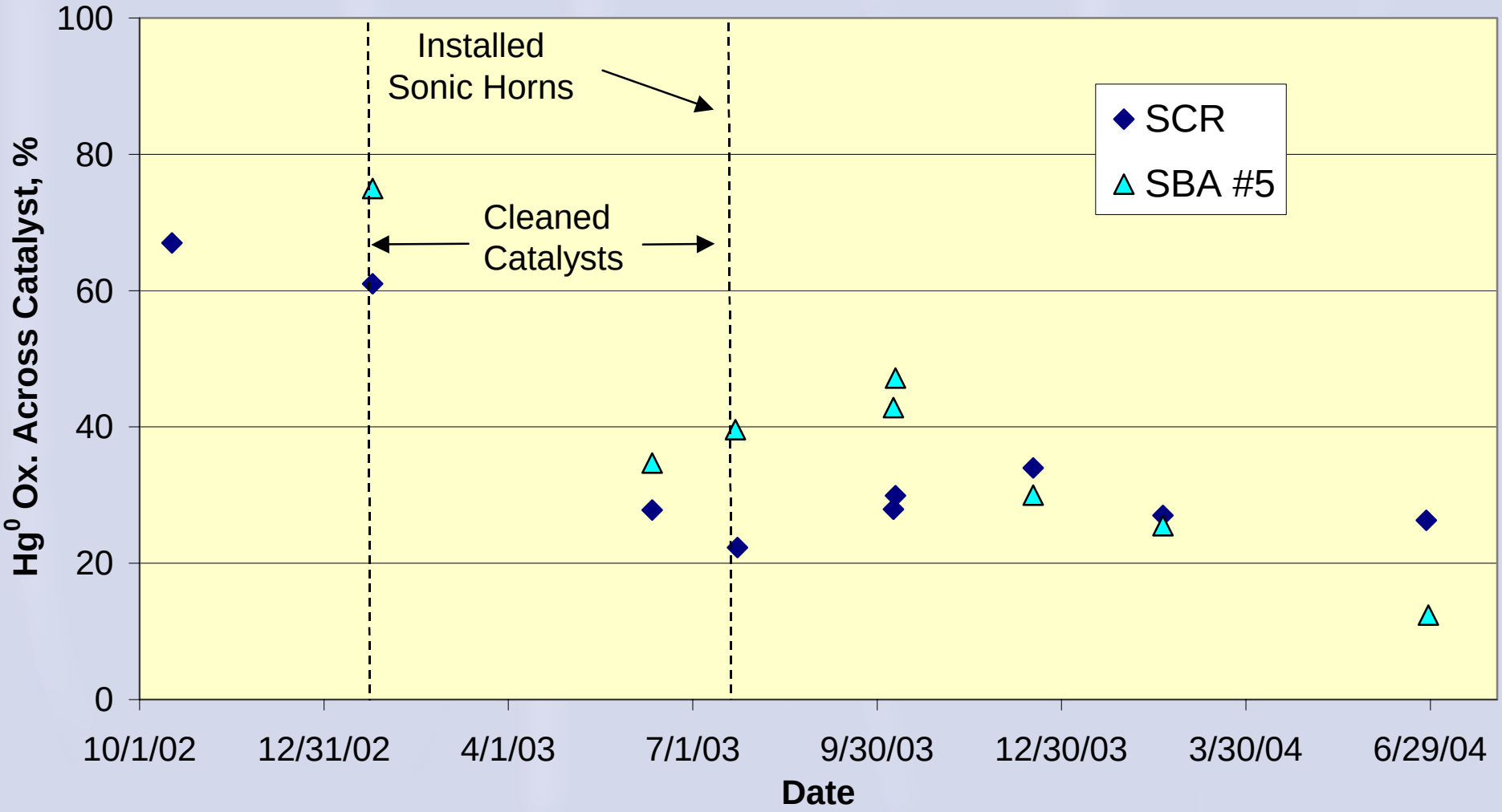


Coal Creek In Situ Catalyst Regeneration Tests

- Closed flue gas inlet to catalyst chamber, flowed heated air (600^{o}F) through catalyst
- Ran each regeneration overnight (280 acfm air rate, max. catalyst chamber outlet temperature 410-420^{o}F)

Coal Creek Catalyst Regeneration Test Results

	Catalyst Activity, % Oxidation of Hg^0		
Catalyst Type	**Fresh Catalyst**	**End of Long-term Test (6/04)**	**After Regeneration**
Pd #1	95	67	88
C #6	98	79	48

Catalyst Regeneration Test Results

- Results considered “proof of concept” only
  - Temperature, duration not optimized
  - Regeneration limited by heater size, and temperature limit of downstream control valves (450^{o}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)

FGD Pilot Unit at Coal Creek

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

	Total Hg	Hg^0	Hg^{+2}
Catalyst Inlet, μg/Nm³	18.0	11.9	6.1
FGD Inlet, μg/Nm³	17.4	2.71	14.7
FGD Outlet, μg/Nm³ [lb/Tbtu]	3.73 [2.5]	3.76	-0.03
FGD Hg Removal, %	79	-39	100

Cost Estimates – Catalytic Oxidation vs. Conventional ACI

- ND lignite flue gas
  - ACI performance based on Stanton Unit 1 data
  - Catalyst results based on Coal Creek pilot
- Assumed 55% Hg capture compared to baseline removal
  - Minimum removal for oxidation catalyst case
  - Average removal for ACI
- Assumed 2-yr catalyst life (replace every 2 yrs)
  - Sensitivity case considered 1 regeneration after 2 yrs – 4-yr catalyst life
  - Salvage value of spent Pd catalyst not considered

Cost Estimate Results – Catalytic Oxidation vs. Conventional ACI

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

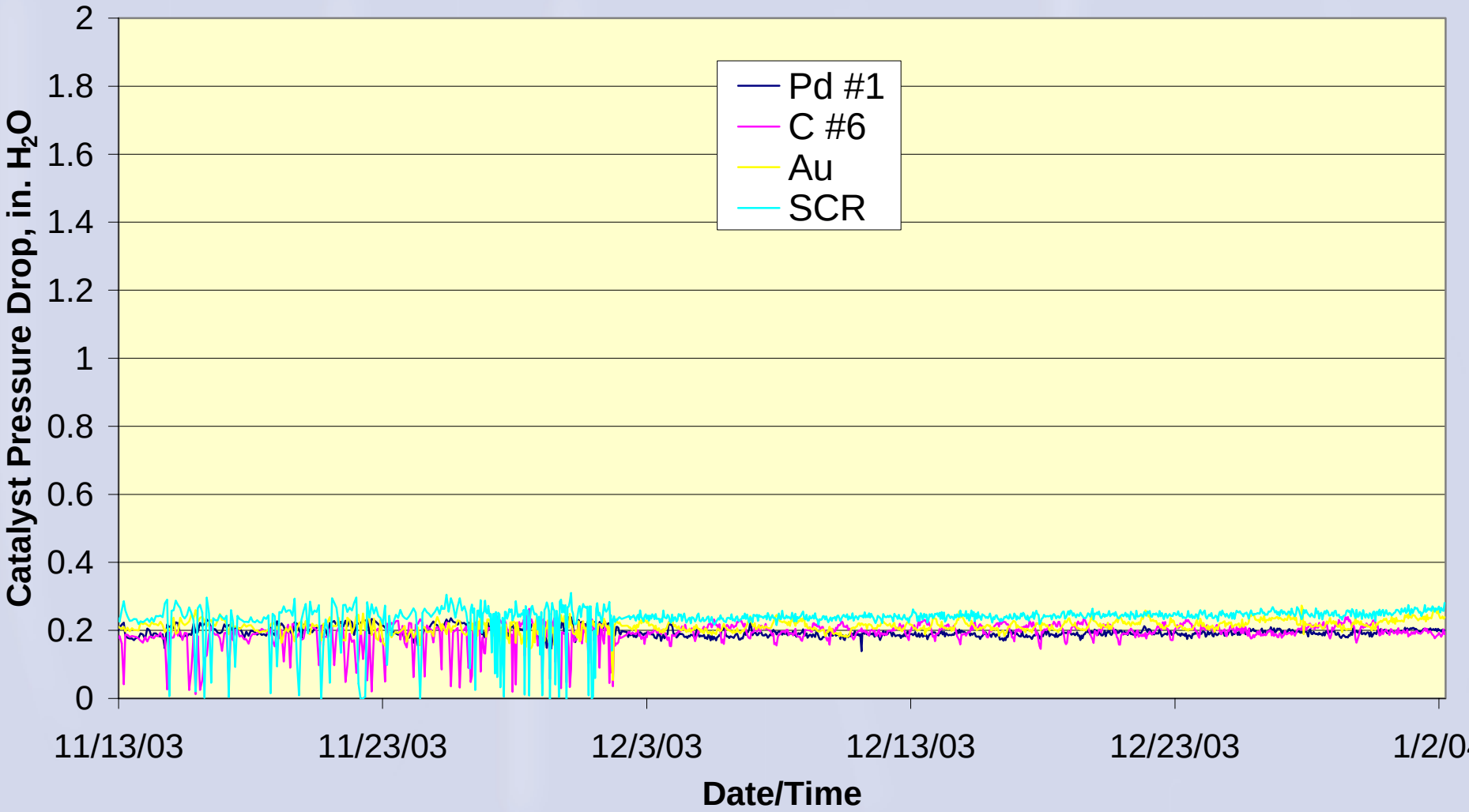
Second Pilot Unit at Spruce Plant

Catalyst Dimensions for Spruce Pilot

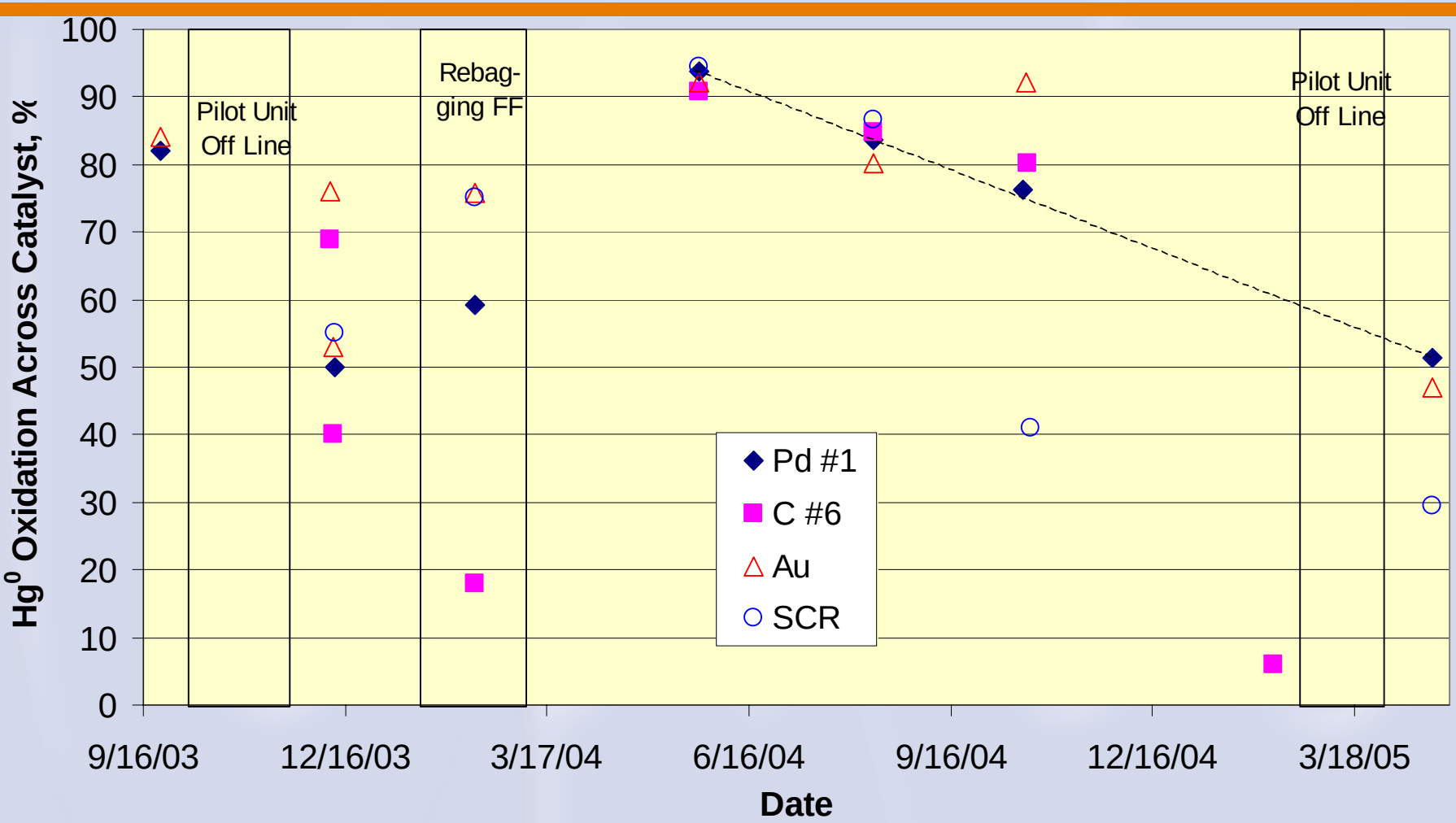
Catalyst	Cells per $in.^2$ (cpsi)	Cross Section (in. x in.)	Length (in.)	Area Velocity (sft/hr)
Pd #1	64	30 x 30	9 (3 x 3)	50
Au	64	30 x 30	9 (3 x 3)	50
C #6	80*	36 x 36	9 (3 x 3)	27
SCR	46	35.4 x 35.4	29.5	13

*Die sized for 64 cpsi, cores shrink during drying

Catalyst Pressure Drop at Spruce (no sonic horns in compartments, FF upstream)



Spruce Catalyst Activity Results



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

Spruce End-of-Test Activity Results (April 2005) – Very Low Inlet Hg^0

Catalyst	Catalyst Inlet Hg^0 ($\mu g/Nm^3$ @ 3% O_2)	Catalyst Outlet Hg^0 ($\mu g/Nm^3$ @3% O_2)	Hg^0 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

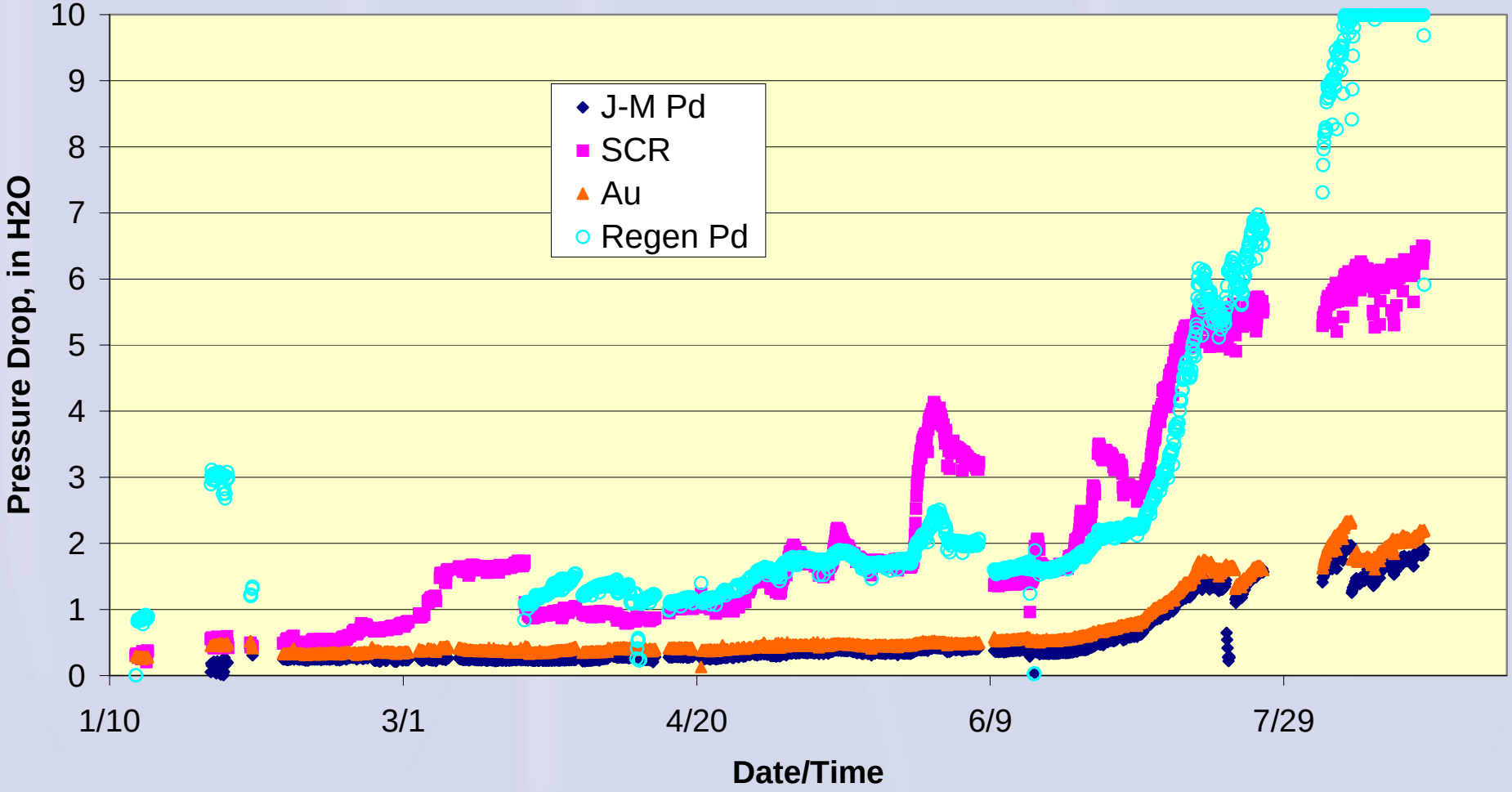
Spruce Catalyst Regeneration Results, April-May 2005

Catalyst	Pre-Regen. Hg^0 Oxidation (%)	Post Regen. Hg^0 Oxidation (%)	Hg^0 ($\mu g/Nm^3$ @ 3% O_2)	
			Catalyst Inlet	Catalyst Outlet
Pd #1	51	84	1.17	0.19
C #6	6	56	0.94	0.41
Au	47	78	0.88	0.19
SCR	29	66	0.90	0.30

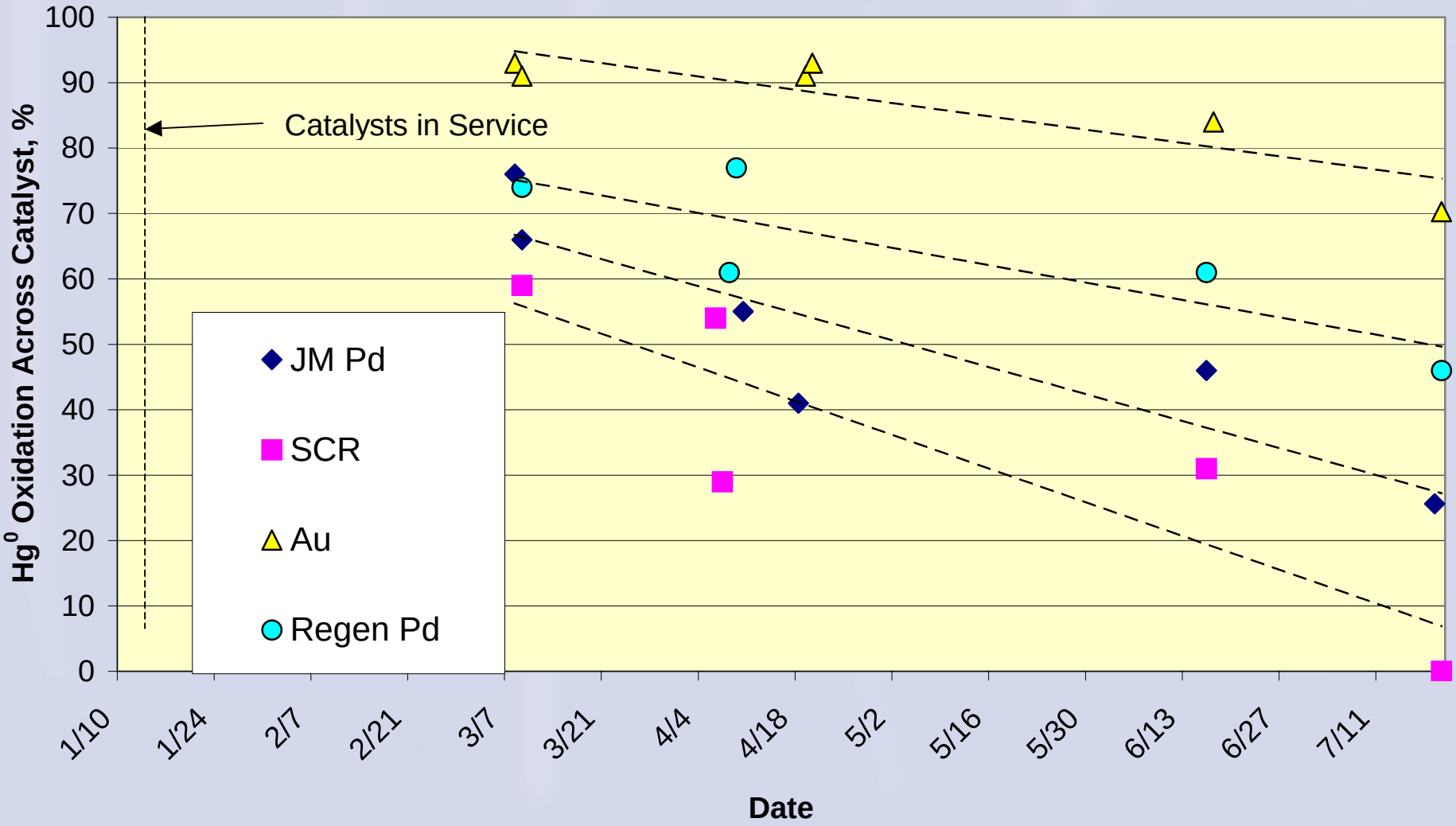
Monticello Pilot Unit (moved from CCS)

Catalyst	Cross Section, in x in	Catalyst Depth	Cell Pitch, mm	Cells per Sq. In.	Area Velocity, std. ft/hr
Gold (Sud-Chemie Prototech)	29.5 x 29.5	3 x 3 in.	3.2	64	50
Pd #1 (Johnson Matthey)	29.5 x 29.5	9 in.	3.2	64	50
Pd #1 (regenerated from CCS)	29.5 x 29.5	3 x 3 in.	3.2	64	50
SCR (Cormetech/MHI)	35.4 x 36.2	29.5 in.	3.3	58	12

Monticello Catalyst Pressure Drop Data



Monticello Catalyst Activity Data



Pilot Wet FGD at Monticello

Pilot Wet FGD Data by Ontario Hydro (April 05)

Catalyst	Hg^0 Oxid. Across Catalyst, %	Total Hg Removal by FGD, %	Hg^{+2} Removal by FGD, %	Hg^0 Removal by FGD, %	FGD Outlet Total Hg, lb/TBtu
None	-	36	94	5	10.7
SCR	78	87	94	14	2.4
Regen. Pd	79	67	92	-190	5.3
J-M Pd	83	79	97	-44	2.9
Gold	94	76	87	-190	4.7

Conclusions

- 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 to install than precious metal catalysts