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

Quarterly Technical Progress Report

January 1, 2003 – March 31, 2003

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ABSTRACT

This document summarizes progress on Cooperative Agreement DE-FC26-01NT41185, "Pilot Testing of Mercury Oxidation Catalysts for Upstream of Wet FGD Systems," during the time period January 1, 2003 through March 31, 2003. The objective of this project is to demonstrate at pilot scale the use of solid honeycomb catalysts to promote the oxidation of elemental mercury in the flue gas from coal combustion. The project is being funded by the U.S. DOE National Energy Technology Laboratory under Cooperative Agreement DE-FC26-01NT41185. EPRI, Great River Energy (GRE), and City Public Service (CPS) of San Antonio are project co-funders. URS Group is the prime contractor.

The mercury control process under development uses catalyst materials applied to honeycomb substrates to promote the oxidation of elemental mercury in the flue gas from coal-fired power plants that have wet lime or limestone flue gas desulfurization (FGD) systems. Oxidized mercury is removed in the wet FGD absorbers and co-precipitates with the byproducts from the FGD system. The current project is testing previously identified, effective catalyst materials at a larger, pilot scale and in a commercial form, to provide engineering data for future full-scale designs. The pilot-scale tests will continue for up to 14 months at each of two sites to provide longer-term catalyst life data.

This is the sixth full reporting period for the subject Cooperative Agreement. During this period, project efforts included continued operation of the pilot unit with three catalysts, conducting catalyst activity measurements, and procuring the fourth catalyst, all for the GRE Coal Creek pilot unit site. Laboratory efforts were also conducted to support catalyst selection for the second pilot unit site, at CPS' Spruce Plant. This technical progress report provides an update on these efforts.

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INTRODUCTION

This document is the quarterly Technical Progress Report for the project "Pilot Testing of Mercury Oxidation Catalysts for Upstream of Wet FGD Systems," for the time period January 1, 2003 through March 31, 2003. The objective of this project is to demonstrate at pilot scale the use of solid honeycomb catalysts to promote the oxidation of elemental mercury in the flue gas from coal combustion. The project is being funded by the U.S. DOE National Energy Technology Laboratory under Cooperative Agreement DE-FC26-01NT41185. EPRI, Great River Energy (GRE) and City Public Service (CPS) of San Antonio are project co-funders. URS Group is the prime contractor.

The mercury control process under development uses catalyst materials applied to honeycomb substrates to promote the oxidation of elemental mercury in the flue gas from coal-fired power plants that have wet lime or limestone flue gas desulfurization (FGD) systems. The oxidizing species are already present in the flue gas, and may include chlorine, hydrochloric acid (HCl) and/or other species. Oxidized mercury is removed in the wet FGD absorbers and co-precipitates with the byproducts from the FGD system. The objective of this project is to test previously identified effective catalyst materials at a larger scale and in a commercial form to provide engineering data for future full-scale designs. The pilot-scale tests will continue for up to 14 months at each of two sites to provide longer-term catalyst life data. After successful completion of the project, it is expected that sufficient full-scale test data will be available to design and implement demonstration-scale or commercial-scale installations of the catalytic mercury oxidation technology.

The two utility team members are providing co-funding, technical input, and host sites for testing. GRE is providing the first test site at their Coal Creek Station (CCS), which fires a North Dakota lignite; and CPS is providing the second site at their J.K. Spruce Plant, which fires a Powder River Basin (PRB) subbituminous coal. These two host sites each have existing wet FGD systems downstream of high-efficiency particulate control devices, an ESP at CCS and a reverse-gas fabric filter at Spruce**.**

The remainder of this report is divided into five sections: an Executive Summary followed by a section that describes Experimental procedures, then sections for Results and Discussion, Conclusions, and References.

EXECUTIVE SUMMARY

Summary of Progress

The current reporting period, January 1, 2003 through March 31, 2003, is the sixth full technical progress reporting period for the project. Efforts over the current reporting period included continued operation of the pilot unit with three of four mercury oxidation catalysts installed, conducting catalyst activity measurements, and procuring the fourth catalyst, all for the Coal Creek test site. A limited number of laboratory evaluations of catalyst materials were also conducted. Finally, a second pilot unit was completed with funding by EPRI during the quarter, and shipped to the second test site, CPS' Spruce Plant.

The first pilot unit is installed at the outlet of an induced draft fan and downstream of the cold-side electrostatic precipitator on Unit 1 at the Coal Creek Station (CCS). The SCR catalyst and the palladium-based catalyst (Pd #1) have been in operation since October 3, 2002. The third, subbituminous ash-based catalyst, SBA #5, was completed in November and installed in the pilot unit the first week in December. The fourth, Carbon #6 (C #6) catalyst, has not yet become available.

These three catalysts remained in operation for the entire quarter. Two catalyst activity trips were conducted, one in late January and one in late March. As described in the previous quarterly technical progress report[1], an increase in pressure drop with time has been seen across the three catalysts in service at CCS. This increase with time continued through January. During the catalyst activity measurement trip in late January, the catalyst compartments were opened and inspected. It was determined that the pressure drop increase and apparent loss of mercury oxidation activity measured in December were due to buildup of fly ash within the catalyst compartments. The catalysts and compartments were cleaned of fly ash at that time, and measurements showed that catalyst activity was restored by removing the fly ash. The three catalysts were left in service, with fly ash building up, through March. After some investigation, it was decided that a sonic horn might allow continued catalyst operation with no fly ash buildup. A horn was procured and installed on one compartment (Pd #1) in March. The pilot unit was left in operation with the horn in service in one compartment. In limited operation after the horn was installed (about two weeks) it appears to be effective in limiting the fly ash buildup, at least as measured by pressure drop. A follow up trip in April will determine the effectiveness of the horn at maintaining the activity of the Pd #1 catalyst.

Also during this reporting period, laboratory testing continued to support the selection and sizing of catalyst materials for pilot-scale evaluation at the second site, Spruce Plant. Testing was conducted on Pd #1, SBA #5, and a patented gold-based catalyst that is under consideration to be one of the four catalysts for testing there. Also during the quarter, a sample of the C #6 catalyst being prepared for the pilot unit at CCS was tested in the laboratory to confirm its activity for oxidation of elemental mercury in simulated flue gas.

One subcontract was completed during the current reporting period. A U.S.catalyst manufacturer completed the preparation of the C #6 catalyst and shipped the completed catalyst blocks to URS, where they will be modified for a leak-tight fit in the existing catalyst chamber at CCS.

Problems Encountered

There were no significant problems encountered during the reporting period other than the observed buildup of fly ash on the catalyst materials at CCS, with a corresponding reduction in catalyst activity while "dirty." This problem and efforts to resolve it are discussed in Section 4 of this report.

Plans for Next Reporting Period

The next reporting period covers the time period April 1 through June 30, 2003. Routine sampling trips will be conducted to evaluate catalyst activity at CCS. In April, catalyst activity measurements will be made on the Pd #1 catalyst to see if the sonic horn installed in March is effective at limiting fly ash buildup on catalyst surfaces and maintaining high catalyst activity. If so, three additional horns will be procured for installation on the other compartments and on a subsequent trip, fly ash buildup in the other three catalyst chambers will be cleaned out and the horns will be installed. At the same time, the fourth (C #6) catalyst will be installed in the currently empty chamber. Although the catalyst is already available, it will not be installed until the sonic horn is installed, assuming the horn proves effective with the Pd #1 catalyst. Once the C #6 catalyst has been installed and operated in flue gas long enough to achieve mercury adsorption equilibrium (approximately two weeks to one month), initial catalyst performance evaluation tests will be conducted. An intensive flue gas sampling trip is scheduled to occur after about seven months of pilot unit operation (~May 2003). However, the schedule for this trip will be adjusted as needed to ensure the trip does not occur until the fly ash buildup problems have been resolved and the C #6 catalyst has been installed and has reached mercury adsorption equilibrium.

One project team member, EPRI, has funded the construction of a second oxidation catalyst pilot unit, that will be used for testing at Site 2, CPS' Spruce Plant. The second pilot unit was shipped to Spruce in March. During the coming quarter, CPS will install the pilot unit, and startup of the pilot unit should commence near the end of the quarter. Catalyst selection and procurement activities will also occur during the quarter. The selection of catalysts for testing at Spruce has been held up pending resolution of the fly ash buildup problems at CCS, to see if increased catalyst pitch will be required as part of the solution. Also initial performance results for the C #6 catalyst at CCS are needed before any decisions can be made on which catalysts to test at Spruce.

Prospects for Future Progress

During the subsequent reporting period (July 1 through September 30, 2003) and continuing through calendar year 2003, the pilot unit is slated to remain in operation at CCS, and to be evaluated for elemental mercury oxidation activity through routine (~monthly) evaluation trips. A final intensive flue gas sampling trip will occur at the end of the 14-month long-term catalyst evaluation period at CCS (~December 2003). Pilot testing should be completed at CCS approximately at the end of calendar year 2003 or in the first quarter of 2004.

Catalyst testing should commence at the second site, CPS' Spruce Plant, early in the subsequent reporting period (July 1 through September 30, 2003). An initial intensive gas characterization effort for the Spruce Plant site should also occur during that quarter.

EXPERIMENTAL

The work described in this technical progress report was conducted using two different experimental apparatuses. One is an elemental mercury catalyst oxidation pilot unit (8000 acfm of flue gas treated) located at Great River Energy's CCS Station in North Dakota. The pilot unit has four separate compartments that allow four different catalysts to treat flue gas from downstream of the host plant's particulate control device and upstream of its flue gas desulfurization system. Details of the pilot unit design, construction, catalyst preparation and pilot unit operation have been discussed in previous quarterly technical progress reports[1, 2, 3, 4]. The activity of these catalysts is being determined by measuring the change in elemental mercury concentration across each catalysts, while ensuring that the total mercury concentrations do not change significantly across the catalyst. These measurements are primarily being conducted using a mercury semi-continuous emissions monitor (SCEM) developed with funding from EPRI. The analyzer has been described in a previous report[5]. Periodically, the analyzer results are being verified by conducting manual flue gas sampling efforts in parallel across each catalyst chamber by the Ontario Hydro method.

The second experimental apparatus is a bench-scale test unit that is used to evaluate the activity of candidate catalyst cores under simulated flue gas conditions. The testing is being conducted at simulation gas flow rates of approximately 1 to 2 nl/min. The simulation gases contain a mixture of compressed gases intended to approximate flue gas compositions at the pilot unit host sites. The simulation gases include nitrogen, oxygen, carbon dioxide, water vapor, sulfur dioxide, nitrogen oxides, hydrochloric acid, elemental mercury, and a small amount of mercuric chloride. As for the pilot units, an EPRI SCEM is used to measure catalyst activity for oxidizing elemental mercury in the simulation gases. The bench-scale catalyst oxidation test apparatus has also been previously described in quarterly technical progress reports[3, 4].

RESULTS AND DISCUSSION

This section provides details of technical results for the current reporting period (January 1, 2003 through March 31, 2003). The technical results presented include a discussion of the data from pilot operation at CCS, results of laboratory evaluations of catalyst materials, and a discussion of on-going pilot unit catalyst procurement efforts.

Pilot Unit Operation

As described in the previous quarterly reports, the pilot unit was started up with the SCR and Pd #1 catalysts the first week of October 2002. The other two catalysts (SBA #5 and C #6) were not yet available, so a decision was made to commence testing with only two of the four catalysts installed. The catalysts were left in service until the week of October 14, when initial catalyst activity measurements were made using the EPRI mercury semi-continuous emissions monitor, which has been described in earlier progress reports. The October results showed high activity for the Pd#1 catalyst, over 90% of elemental mercury across the catalyst, which is very near that expected based on previous laboratory and field testing with this material. The SCR catalyst results showed significantly lower oxidation percentages at the same flue gas flow rates, in the range of 60 to 70% oxidation of elemental mercury across the catalyst, which was lower performance than had been expected. Throughout this report, the elemental mercury oxidation percentages across catalysts are reported based on the drop in elemental mercury concentration across the catalyst, and do not just reflect the total flue gas mercury oxidation percentage at the catalyst outlet.

A second catalyst activity measurement trip was made the first week of December. The December results showed a marked decrease in activity for both catalysts. The percentage oxidation of elemental mercury across the Pd #1 dropped from greater than 90% in October to approximately 50 to 70% in December. The elemental mercury oxidation across the SCR catalyst dropped from 60 to 70% in October to 20 to 30% in December.

Several possible explanations for this apparent loss of activity were theorized in December. Follow-up testing in January determined the cause: the catalyst surfaces were becoming fouled due to a buildup of fly ash, in spite of the catalyst being installed downstream of a high-efficiency ESP. At the measured particulate loading of 0.004 gr/dscf in the pilot unit inlet gas, approximately one pound of fly ash passes through each catalyst chamber at 2000 acfm each day of operation. Just a small percentage of that fly ash accumulated within the catalyst chamber and on the honeycomb surfaces results in a significant accumulation of fly ash, and appears to account for the observed loss of activity.

First evidence of fly ash buildup was seen in the measured pressure drop across the catalyst chambers. When the two catalysts were put into service in October, the initial clean catalyst pressure drop across each chamber was less than 0.5 in. H_2O. By the end of December, the indicated pressure drop across the chambers had steadily increased, to about 1.5 in. H_2O across the SCR catalyst and over 3 in. H_2O across the Pd #1 catalyst. The third catalyst, SBA #5, also showed a dramatic increase in pressure drop over time since it was placed in service in early December. The pilot unit instrumentation was at the time scaled to read a maximum of 3 in. H_2O

pressure differential, hence the pressure drop data for the SBA #5 and Pd #1 catalysts were pegged at full scale at the end of the previous reporting period.

The next catalyst activity measurement trip occurred the week of January 20, 2003. The objective of that trip was to determine whether the apparent loss of activity continued with time, stabilized, or had reversed (i.e., improved activity compared to December results). Also, the catalyst pressure drop indications by the pilot unit instrumentation were verified and the instruments were re-scaled to read higher differential pressures (0 to 10 in. H_2O). The plan was that, if the activity of the catalysts was still well below the initial values and if the high pressure drop values were confirmed, the catalyst chambers would be opened to observe if fly ash buildup was present. If significant buildup was confirmed, an attempt would be made to clean the catalyst surfaces with dry compressed air.

The January results confirmed the elevated pressure drop readings across the catalyst modules, and showed lower catalyst activity for the SCR catalyst and Pd #1 than in October. Based on these results, the catalyst modules were shut down and opened for inspection. Each was found to have significant fly ash build up. The January trip also provided the first opportunity to measure the activity of the SBA #5 catalyst. However, it too was adversely affected by fly ash buildup.

Although the buildup was extensive, the fly ash remained dry and free flowing and was readily removed. The modules were cleaned by using compressed air to dislodge fly ash collected within the honeycomb passages and vacuuming out all loose fly ash. After cleaning all three catalyst-containing chambers, the pilot unit was put back in service. Physically cleaning the catalysts of fly ash buildup appears to have restored virtually all of their original activity. Figures 1 and 2 are photographs that show the surface of the Pd #1 catalyst before and after the cleanup.

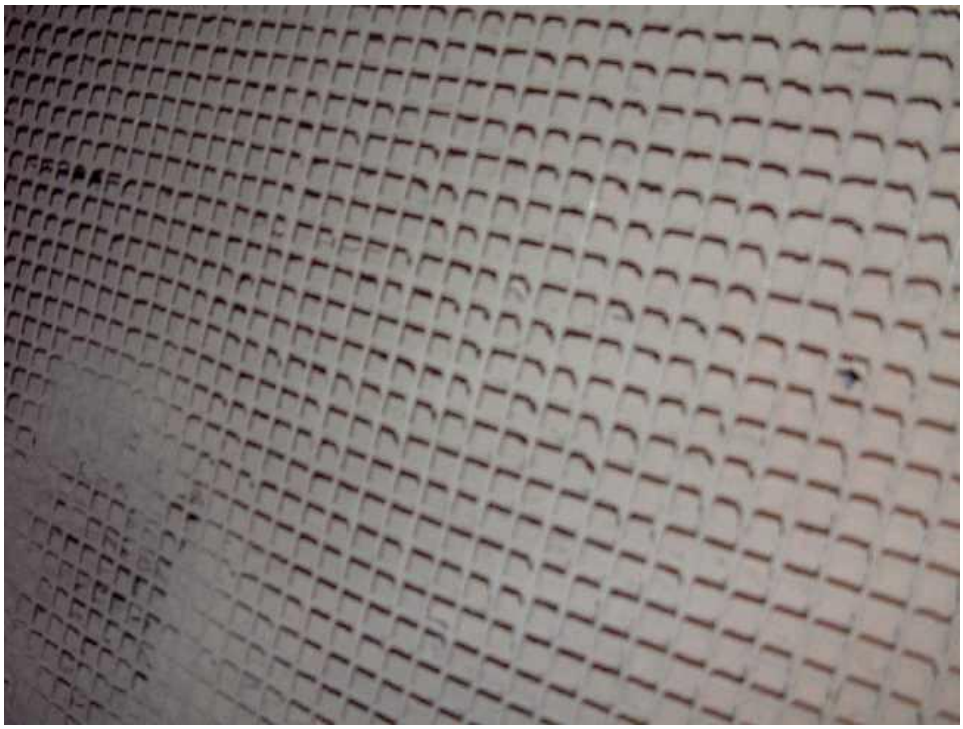

Figure 1. Fly Ash Buildup on the Pd #1 Catalyst Surface, January 2003

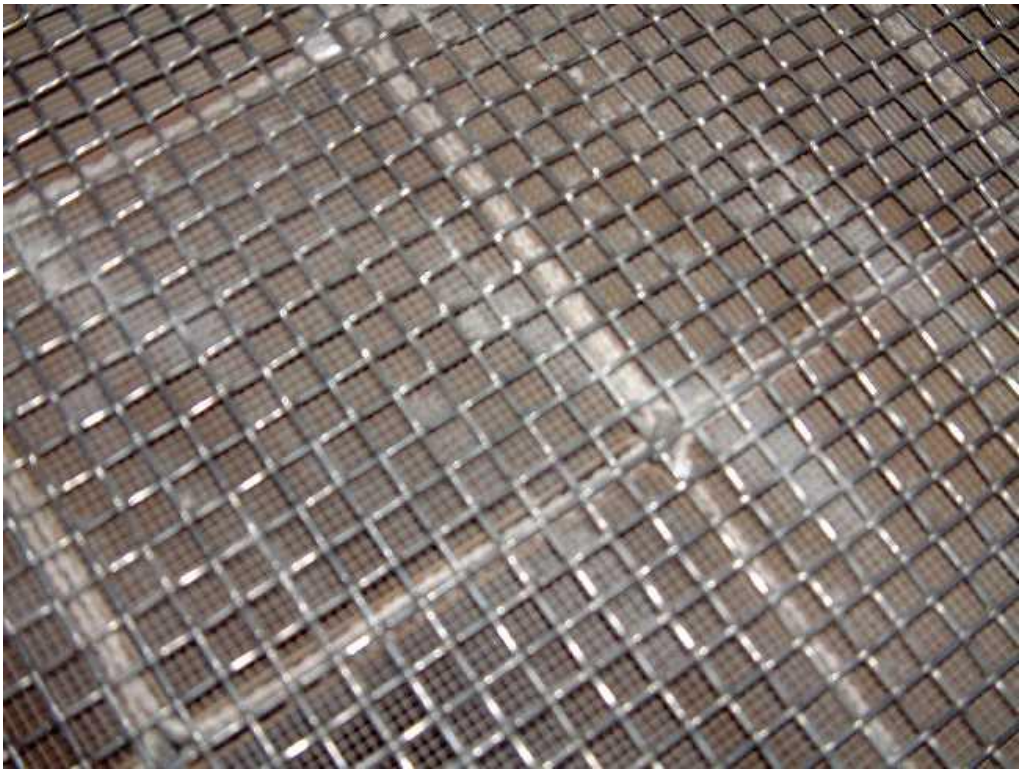

Figure 2. **Surface of the Pd #1 Catalyst after Fly Ash Cleanup, January 2003**

The January 2003 catalyst activity results from before and after cleaning are shown in Table 1. For comparison, results from the October and December measurement trips are also shown, where available. Note in the table that the January "pre-clean" values were equal to or actually a little better than the December measurements, which suggests the catalysts had reached a steady state blockage of catalyst surface area. Also note that the fly-ash-based catalyst was not as active as had been hoped (75% oxidation after cleaning), although its activity might have been a bit higher had measurement results been available sooner after it first went into service.

Table 1. Summary of Hg^0 Oxidation Catalyst Activity Results at CCS.

Catalyst (Flow Rate, acfm)	Hg^0 Oxidation across Catalyst (%)					
	October 17	December 3	January 22	January 24 (after cleaning)	March 27 (prior to cleaning)	March 27 (after cleaning)
SBA #5 (2000)	NA*	NA	59	75	14	NA
SCR (1500)	67	28	37	61	**4**	NA
Pd #1 (2000)	93	53	58	91	NA	92

*NA - No measurement results available for these dates

Based on these results, it was decided that some method of mechanical cleaning should be implemented on the pilot unit. Both air soot blowers and sonic horns were considered. After reviewing full-scale SCR experiences with on-line catalyst cleaning and talking to a number of soot blower and sonic horn vendors, it was decided that a sonic horn retrofit would be the easiest field retrofit at CCS and would have a good probability of success. A small horn produced by

Analytec Corporation of Pagosa Springs, Colorado appeared to be the best solution based on price, availability, and probability of success.

During the last week of March 2003, another site visit was made to CCS. The purpose of this trip was to install the sonic horn on the Pd #1 catalyst box and to measure the oxidation of mercury across each of the three installed catalysts. The sonic horn was installed to provide an occasional pulse of accoustic energy to the catalysts to dislodge any accumulated particulate matter. The sonic horn was installed on the top wall of the catalyst housing inlet transition, approximately 1.5 feet upstream of the first catalyst module. Installation was carried out by ICI, a contractor of GRE, and took approximately one day to complete. Electric wiring to the sonic horn control solenoid valve was performed by GRE employees. The horn is supplied by its own plant air line. It is programmed to sound for 10 seconds every half hour.

To install the sonic horn the catalyst housing was opened, allowing an opportunity to clean the Pd #1 catalyst modules. All three of the Pd #1 modules were coated with a thick layer of particulate matter as they had been in January. The modules were cleaned by blowing air through each honeycomb cell. Particulate matter had accumulated at the bottom of the catalyst housing box to a level of several inches. This material was removed by a vacuum cleaner.

The other two catalyst chambers were not cleaned during this trip. Once the Pd #1 catalyst modules were cleaned and the sonic horn was installed, the catalyst housing box was sealed and flue gas was directed through the box. Mercury oxidation measurements were made for each of the three installed catalysts, and for the fourth empty box (which served as a baseline oxidation value). The inlet flue gas had a baseline total mercury concentration of 10.98 μg Hg/Nm^3. The inlet elemental mercury was 6.59 μg Hg^0/Nm^3, therefore 40% of the inlet gas mercury was oxidized. The SBA #5 catalyst oxidized 14% of the inlet elemental mercury and the SCR catalyst oxidized 4% of the inlet elemental mercury. As mentioned above, neither the SBA #5 nor the SCR catalysts were cleaned. The cleaned Pd #1 catalyst oxidized 92% of the inlet elemental mercury, so, as in January, physically cleaning the fly ash from the catalyst appears to have restored its activity. These March results are included in Table 1. Due to technical difficulties with the mercury SCEM, mercury oxidation numbers prior to cleaning the Pd #1 catalyst were not successfully completed.

If effective, a horn will be installed on the other catalyst chambers. So far, the horn appears to be effective at controlling the pressure drop increases across the Pd #1 catalyst. Figure 3 illustrates the pilot unit pressure drop data for the three catalysts since placed in service in October 2002 (December 2002 for the SBA #5 catalyst). The data for Pd #1 (the lightest shaded line on the figure) show how the pressure drop was pegged at over 3 in. H_2O from early December 2002 through late January 2003. At that time, the pressure differential transducers were recalibrated, and the differential across the Pd #1 chamber was measured at 5.5 to 6.0 in. H_2O. Shortly thereafter, the pilot unit was taken off line and the catalyst was cleaned of fly ash. After the catalyst chamber was cleaned out and the pilot unit was put back into service, the signal from the pressure differential transucer on the Pd #1 catalyst was producing a noisy signal. However, on average the pressure drop across the Pd #1 catalyst increased to about 6 in. H_2O within three weeks of operation. After a host unit trip the pressure drop was reduced to about 4 in. H_2O, then quickly increased again until the pilot unit was brought off line in late March to clean the catalyst and install the sonic horn. Since coming on line after the horn was installed, the pilot unit has so

far operated about ten days (with a few days of host unit outage in the middle). Over that short period of operation the horn appears to be effective in limiting fly ash buildup. The pressure drop across the Pd #1 catalyst has not measurably increased, and remains less than 0.3 in. H_2O. A catalyst activity measurement trip will be conducted in late April to verify the low pressure drop across the Pd #1 catalyst and to determine whether the horn has also allowed the Pd #1 catalyst to remain at high activity for elemental mercury oxidation.

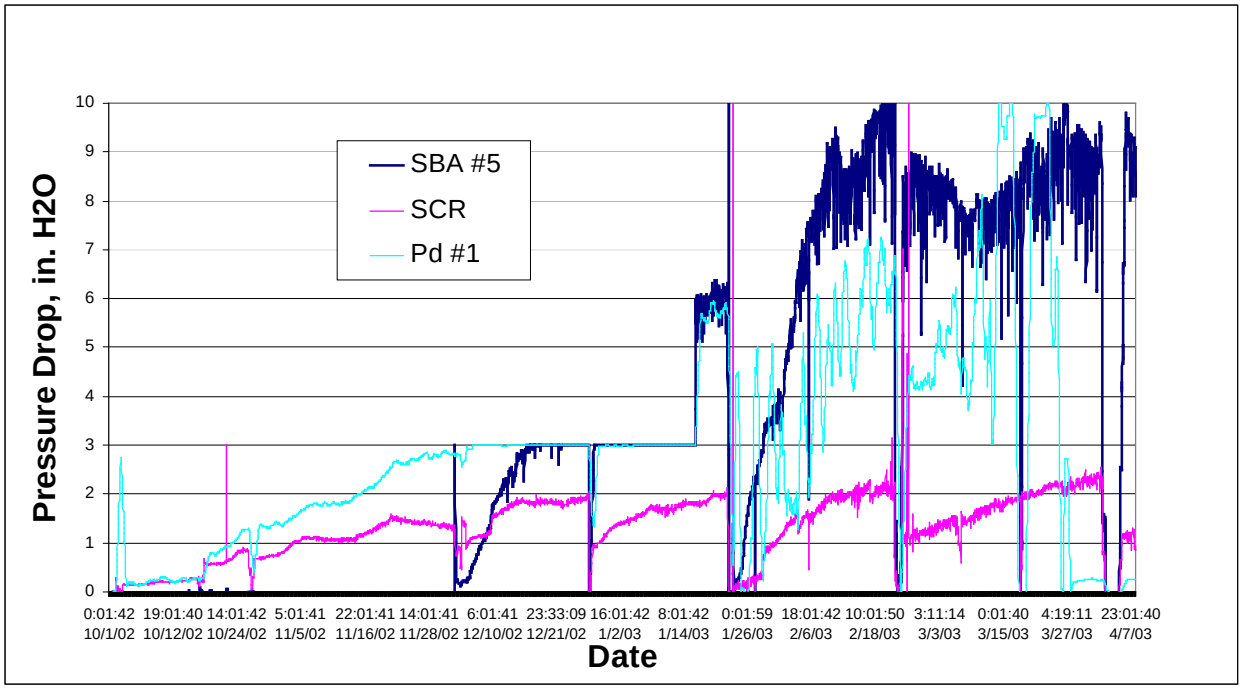

Figure 3. Pressure Drop Data for the Three Catalysts in Service at CCS.

These pressure drop results also suggest that a coarser catalyst pitch and higher superficial velocities through the catalyst chamber would help avoid fly ash buildup. Because the empty chambers were somewhat oversized to allow flexibility in the amount of catalyst that could be installed in each, the flue gas velocities through the empty portions are quite low. At 2000 acfm, the gas velocity is 3.1 ft/sec, and at 1500 acfm the velocity is only 2.3 ft/sec. Also, the reduced pressure drop and fly ash buildup for the SCR catalyst, which was installed as a single catalyst block, compared to that for the Pd #1 and SBA #5 suggests that a single catalyst layer rather than three individual layers would be a preferred configuration.

Laboratory Evaluation of Candidate Catalysts

Testing of catalyst cores in the laboratory for mercury oxidation activity continued during this quarter, under simulated PRB (Spruce) flue gas conditions. In previous technical progress reports for this project we reported scatter in laboratory results that appears to have been caused by an interference between some component in the sample gas exiting Pd #1 cores and the Tris-(hydroxymethyl)aminomethane (Tris) solution used to remove oxidized mercury from the sample gas. This apparent interference caused a high degree of variability in the measured

catalyst outlet elemental mercury concentrations, and thus caused much of the previous catalyst performance results for some sample cores to be suspect.

In the preceding quarter (October 1 through December 31, 2002), laboratory tests were conducted at simulated CCS and Spruce Plant flue gas conditions with current catalysts and with a new candidate catalyst material, gold. Gold has been patented by TVA as a flue gas elemental mercury oxidation catalyst.

The results of tests conducted at CCS conditions early in that quarter appeared to indicate that the gold catalyst compares favorably with Pd #1 for elemental mercury oxidation activity. However, late in the quarter, it was determined that the KCl impinger solutions were being depleted very rapidly during these laboratory runs. The result of this depletion is a low bias in the indicated elemental mercury concentration. Thus, there was concern that the favorable results for the gold catalyst from early in the quarter were biased by depleted KCl impinger solutions. The questionable results were not reported in the previous technical progress report.

Because of concern over depletion of the KCl impinger solutions, midway through the previous quarter the laboratory run procedures were modified so the performance of each catalyst core was measured both with fresh Tris and fresh KCl solutions. Good agreement between results with the two impinger solution types was taken as an indicator that potential biases with each solution type were avoided. If the results with the two impinger solution types did not agree well, the test was repeated.

This procedure has been used to evaluate candidate catalyst materials for the pilot testing to be conducted at Site 2, CPS' Spruce Plant, which fires PRB coal. Table 2 compares the simulation gas compositions for CCS versus Spruce Plant simulations.

Table 2. Gas Conditions for Host Site Simulations

Species	CCS Conditions	Spruce Conditions
SO_2 (ppm)	500	200
NO_x (ppm)	200	200
HCl (ppm)	6	6
O_2 (%)	5	5
CO_2 (%)	12	12
H_2O (%)	9	7
N_2 (%)	Balance	Balance
Temperature (^oF)	350	300

Table 3 summarizes the results of laboratory tests conducted in the current quarter under simulated Spruce Plant conditions. The first set of three results shown for the gold catalyst were considered suspect, because the results did not agree well between the Tris and KCl impinger trains. The gold tests were repeated and are shown as the second set of three results in Table 3. The second set tends to confirm the first set of results. Figure 4 shows the results of all of the catalyst testing conducted in the laboratory at simulated Spruce conditions, for Pd #1, SBA #5, and gold catalysts. Based on the high mercury oxidation percentage achieve with the gold

catalyst in the laboratory, it is likely that gold will be selected as one of the four catalysts for evaluation at Spruce Plant.

Table 3. Laboratory Simulation Results at Spruce Conditions from the Current Quarter (average results using KCl and Tris impingers for measuring elemental mercury concentrations)

Catalyst	Gas Flow Rate (l/min)	Inlet Hg^0 ($\mu g/Nm^3$)	Outlet Hg^0 ($\mu g/Nm^3$)	Hg^0 Oxidation (%)
Au 1x; 1" core	0.94	34.0	0.94*	97.2*
Au 1x; 1" core	1.3	12.4	0.61*	95.1*
Au 1x; 1" core	1.7	9.48	1.30*	86.3*
Au 1x; 1" core	0.97	37.5	1.88	95.0
Au 1x; 1" core	1.3	27.5	3.58	87.0
Au 1x; 1" core	1.7	18.4	1.71	90.7

*Value is suspect because of poor agreement between Tris and KCl impinger results

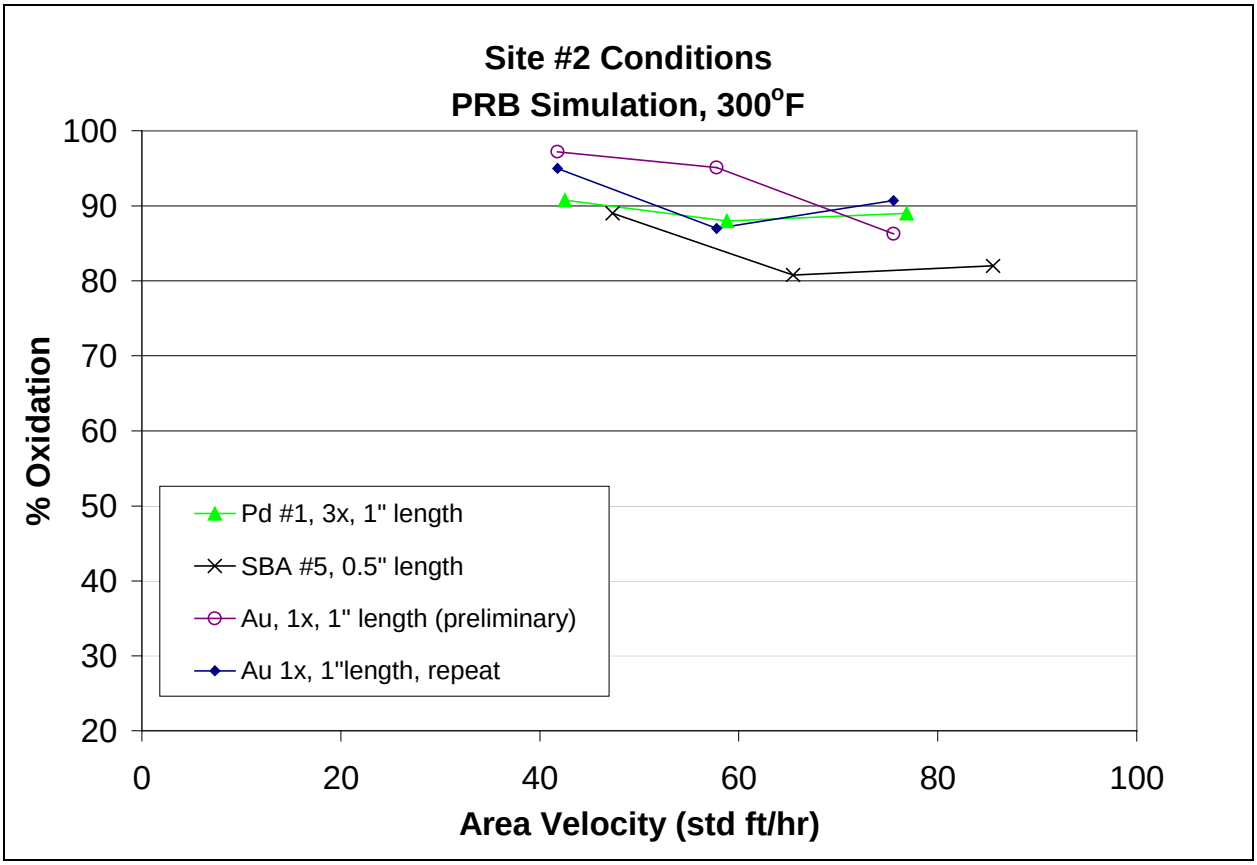

Figure 4. Effect of Area Velocity on Catalytic Oxidation of Mercury under Laboratory, Simulated Site 2 Conditions

One additional test series was conducted in the laboratory in March. The activity of a small amount of the C #6 catalyst was tested for activity in the laboratory before final firing of the entire quantity of catalyst blocks to be used in the pilot unit at CCS. The results of these tests are summarized in Table 4 and plotted in Figure 5. The plot also shows the original laboratory data for C #6 catalyst cores that were prepared by the catalyst vendor with laboratory equipment. The data for the laboratory-prepared catalyst cores (0.4-in. and 0.8-in. length) agree well with the results for the catalyst core prepared with commercial equipment (0.5-in. length) when plotted as a function of area velocity. All of the data points fall on roughly the same slope, considering test-to-test variations in results. Based on these results, the catalyst vendor proceeded with firing of the catalyst blocks to be used in the pilot unit at CCS.

Table 4. Laboratory Simulation Results at CCS Conditions (average results using KCl and Tris impingers for measuring elemental mercury concentrations)

Catalyst	Gas Flow Rate (l/min)	Inlet Hg^0 ($\mu g/Nm^3$)	Outlet Hg^0 ($\mu g/Nm^3$)	Hg^0 Oxidation (%)
C #6	0.69	47.9	7.6	84.1
C #6	1.0	33.1	8.8	73.3

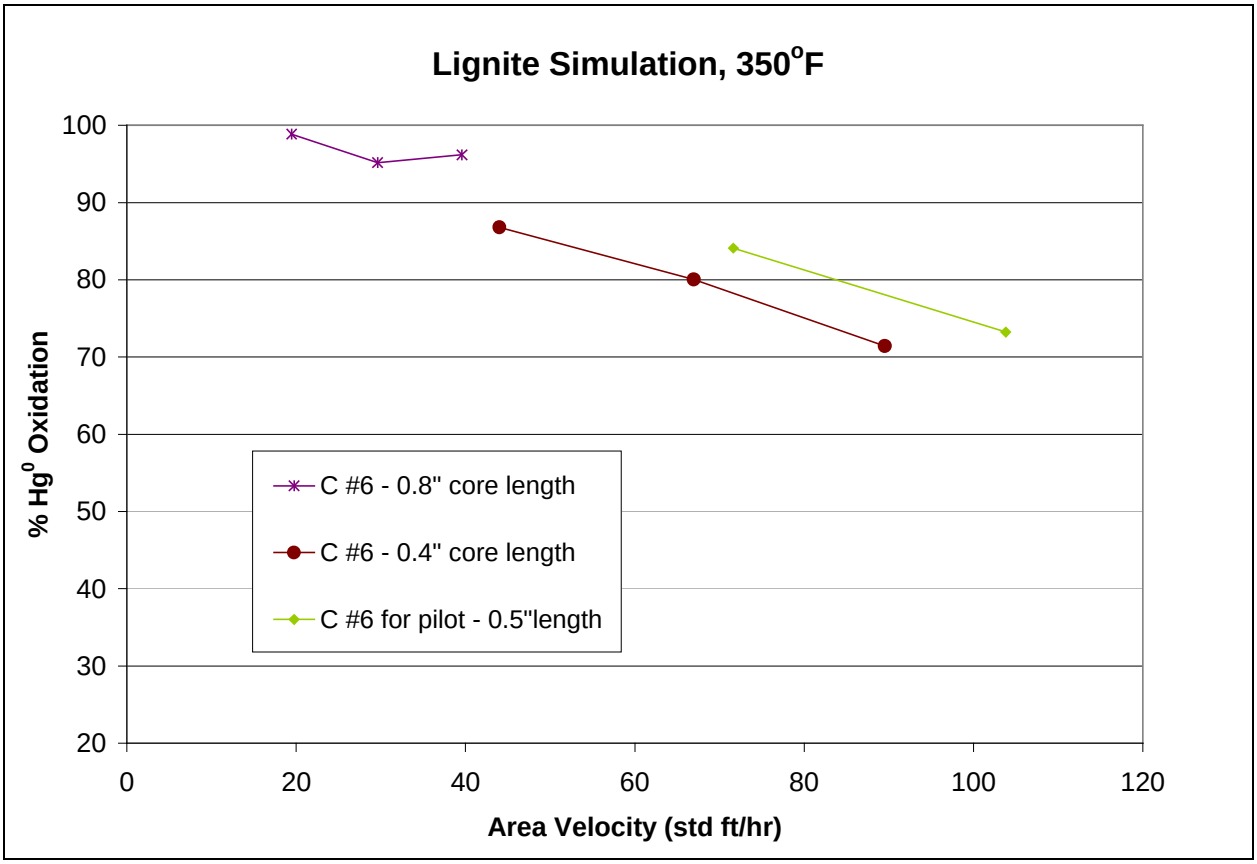

Figure 5. Effect of Area Velocity on Catalytic Oxidation of Mercury in the Laboratory under Simulated CCS Conditions for C #6 Catalyst Samples

Catalyst Supply

During the quarter, the C #6 catalyst was custom-prepared by a U.S.-based catalyst vendor, as extruded monoliths in an alumina substrate. In December a 300-lb lot of activated C #6 material, prepared by the Illinois State Geological Survey and MaxWell Engineering and Consulting, was ground to size for extrusion. The extrusion, drying, firing and canning of these catalyst blocks was completed by the end of the quarter, and the completed catalyst cans were received at URS at the end of March. The C #6 catalyst is planned to be installed in the pilot unit at CCS by the end of the next quarter, pending the results of efforts to retrofit on-line catalyst cleaning on the pilot unit to control the buildup of fly ash on catalyst surfaces.

CONCLUSION

In the initial six plus months of pilot unit operation, it has become apparent that the potential for adverse effects from the ash remaining in the flue gas downstream of a high-efficiency ESP was underestimated at the outset of the project. After two months of operation, the Pd #1 and SCR catalysts had seen a significant loss of activity for Hg^0 oxidation and a significant increase in pressure drop. Both of these effects were attributed to fly ash buildup within the catalyst chambers and within the flow channels of the catalyst honeycomb cells. Fortunately, the collected fly ash remained dry and free flowing, and was readily removed by blowing compressed air through the catalyst cells and vacuuming up loose fly ash. The Pd #1 catalyst recovered to greater than 90% oxidation, and the SCR catalyst recovered to greater than 60%, both near their originally measured Hg^0 oxidation percentages. The cleaned SBA #5 catalyst returned to 75% oxidation after cleaning, but there was no initial activity measurement available from prior to fly ash buildup for comparison.

Because of the observed ash accumulation on the catalysts at CCS, provisions are being made to help keep catalyst surfaces cleaner. Sonic horns and soot blowers are commonly used to clean catalysts in utility SCR applications for NO_X control, and may similarly be effective in this application. A trial application of a sonic horn was installed and on the Pd #1 catalyst chambers in late March, and appears to be effective in limiting fly ash build during operation to date. An air soot blower is also being considered as an alternative. Once an acceptable configuration is established, a similar arrangement will be installed on the other three chambers, and will also be installed on the pilot unit for the Spruce PRB site.

Laboratory results during the quarter showed that gold on alumina can be an effective elemental mercury oxidation catalyst, with activity results very similar to that of the Pd #1 catalyst at simulated Spruce Plant conditions. Although gold and palladium are both relatively expensive metals, the gold catalyst core tested had about one-third the metal loading of the Pd #1 core. This suggests that significantly less gold could be used to prepare catalyst honeycombs than would be required for palladium, with correspondingly lower catalyst costs. Gold should be considered for one of the four catalyst types to be evaluated at pilot scale at Spruce Plant.

Further laboratory testing during the quarter showed that a “test” block of the C #6 catalyst prepared by a U.S.-based catalyst manufacturer exhibited the expected activity towards oxidation of elemental mercury at simulated CCS flue gas conditions. These results meant that the catalyst manufacturer could proceed with preparation of the entire lot of catalyst for the CCS pilot unit. Successful preparation of the C #6 catalyst is important to the project because the C #6 material represents a low-cost catalyst that, if proved effective, could be produced for a substantially lower cost than palladium- or gold-based catalysts. The completed C #6 catalyst should be installed in the pilot unit in early June 2003.

REFERENCES

1. Blythe, Gary M. “Pilot Testing of Mercury Oxidation Catalysts for Upstream of Wet FGD Systems,” Quarterly Technical Progress Report, October 1, 2002 – December 31, 2002. Cooperative Agreement No. DE-FC26-01NT41185, URS Corporation, Austin, Texas 78729. January 2003.

2. Blythe, Gary M. “Pilot Testing of Mercury Oxidation Catalysts for Upstream of Wet FGD Systems,” Quarterly Technical Progress Report, July 1, 2002 – September 30, 2002. Cooperative Agreement No. DE-FC26-01NT41185, URS Corporation, Austin, Texas 78729. October 2002.

3. Blythe, Gary M. “Pilot Testing of Mercury Oxidation Catalysts for Upstream of Wet FGD Systems,” Quarterly Technical Progress Report, March 1, 2002 – June 30, 2002. Cooperative Agreement No. DE-FC26-01NT41185, URS Corporation, Austin, Texas 78729. July 2002.

4. Blythe, Gary M. “Pilot Testing of Mercury Oxidation Catalysts for Upstream of Wet FGD Systems,” Quarterly Technical Progress Report, January 1, 2002 – March 31, 2002. Cooperative Agreement No. DE-FC26-01NT41185, URS Corporation, Austin, Texas 78729. April 2002.

5. *Enhanced Control of Mercury by Wet Flue Gas Desulfurization Systems, Final Report, Phase II,* U.S. Department of Energy Cooperative Agreement Number DE-AC22-95PC95260, URS Corporation, Austin, Texas 78729. June 2001.