Investigation and Demonstration of Dry Carbon-Based Sorbent Injection for Mercury Control

Contract DE-AC22-95PC95256 DOE/PC/95256--T3

Quarterly Technical Report
April 1 - June 30, 1995

July 27, 1996

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Executive Summary

The overall objective this two phase program is to investigate the use of dry carbon-based sorbents for mercury control. This information is important to the utility industry in anticipation of pending regulations. During Phase I, a bench-scale field test device that can be configured as an electrostatic precipitator, a pulse-jet baghouse, or a reverse-gas baghouse has been designed and will be integrated with an existing pilot-scale facility at PSCo's Comanche Station. Up to three candidate sorbents will then be injected into the flue gas stream upstream of the test device to determine the mercury removal efficiency for each sorbent. During the Phase II effort, component integration for the most promising dry sorbent technology (technically and economically feasible) shall be tested at the 5000 acfm pilot-scale.

An extensive work plan has been developed for the project. Three sorbents will be selected for evaluation at the facility through investigation, presentation, and discussion among team members: PSCO, EPRI, ADA, and DOE. The selected sorbents will be tested in the five primary bench-scale configurations: pulse-jet baghouse, TOXECON, reverse-gas baghouse, electrostatic precipitator, and an ESP or fabric filter with no Comanche ash in the flue gas stream. In the EPRI TOXECON system, mercury sorbents will be injected downstream of a primary particulate control device, and collected in a pulse-jet baghouse operated at air-to-cloth ratios of 12 to 16 ft/min, thus separating the mercury and sorbent from the captured flyash. In

the no-ash configuration, an external flyash sample will be injected into a clean gas stream to investigate possible variations in sorbent effectiveness in the presence of different ashes. The use of an existing test facility, a versatile design for the test fixture, and installation of a continuous mercury analyzer will allow for the completion of this ambitious test plan.

The primary activity during the quarter was to complete fabrication and installation of the facility. Fabrication of the pilot was completed on April 15 and it was erected at Comanche on April 30. Controls and power connection were completed in April. The project was delayed by two weeks due to the use of the mercury CEM at another test site. An additional two week delay occurred due to problems startup problems with the CEM and electrical problems but the system is over 95% complete. Testing will begin the first week of July using the ESP configuration. At least two weeks of baseline testing will be completed before the first sorbent, FGD activated carbon, is injected into the duct.

Activities During Reporting Period

Task 1. Sorbent Selection

The objective of this task is to identify and select the most promising sorbents to be tested. The team of PSCO, ADA, and EPRI in consultation with DOE shall provide input and recommendations as to the sorbents that are showing the most promise from on-going research programs. Results from testing in EPRI laboratories have shown two promising sorbents in terms of effectiveness in removing mercury and cost. A third sorbent has not surfaced from those being tested in the laboratory. The third sorbent may be chosen for comparison solely for its ability to adsorb mercury and may not be an economically feasible choice for full-scale use. Identification of the third sorbent has been delayed until results are available from the FGD testing in the ESP configuration.

The two sorbents selected for testing are Darco FGD activated carbon and an experimental carbon identified as AC-1. Darco FGD is an activated carbon derived from lignite and is used to remove mercury in municipal solid waste (MSW) combustors in Europe and the United States. It has also been used in several utility mercury removal tests including previous tests at Comanche Station. Approximately 75 pounds of Darco FGD activated carbon has been acquired for sorbent testing at Comanche. The second sorbent selected by the team, AC-1, is an activated carbon prepared from a bituminous coal. Initial laboratory evaluations of AC-1 have shown promising results as compared to other carbon-based sorbents including FGD activated carbon. AC-1 was chosen for testing because of the promising technical results and it is projected that producing this sorbent will be less costly that producing FGD activated carbon. No other experimental carbon-based sorbents are currently as economical to produce and as effective at adsorbing mercury as AC-1. Nominally 40 pounds of this sorbent has been prepared for testing at Comanche Station.

Task 2. Design, Fabrication, and Installation of laboratory-scale test facility

A laboratory-scale particulate control module (PCM) that can be configured as an electrostatic precipitator, a pulse-jet baghouse, or a reverse-gas baghouse was installed at the existing pilot-scale facility at PSCo's Comanche Station in Pueblo, Colorado on April 30, 1996. The main structure is incorporated into an 8-foot by 10-foot tower that is 30-feet high. A photograph of the facility is shown in Figure 1.

Sorbents will be injected into an injection section upstream of the main particulate collection section. The injection section is a 12-inch diameter pipe with 4-inch ports at five locations along its 16-foot length. These port locations allow in-duct sorbent residence times from 0.75 to 1.5 seconds at typical operating conditions. Flue gas flows into the PCM through a heater assembly at the top of the unit, into the injection section and then into the lower portion of the main collection section. The outer housing of the collection section consists of a 28-inch diameter, 20-foot long pipe. Configuration specific components, such as ESP tubes, are installed within the main collection section. Components have been fabricated to configure the PCM as a wire-tube ESP, a pulse-jet fabric filter, or reverse-gas fabric filter.

An in-duct electrical resistance heater will be used to increase flue gas temperatures. Water cooled coils will be installed at this location to cool the gas when necessary. Skin heaters are also located on the outer housing of the injection section, the collection system, and on the hopper. These heaters will be controlled to set and maintain the temperature throughout the system.

A mast was installed on the tower to allow configuration changes in the PCM without the assistance of a crane. The boom on the mast will extend 25 feet above the tower. It is estimated that three people will be required for major configuration changes, such as from the electrostatic precipitator to the pulse-jet baghouse. This change includes removing the four 10-inch diameter gas passages, each 20-feet long. An in-duct heater is upstream of the injection section and can be accessed from the top platform.

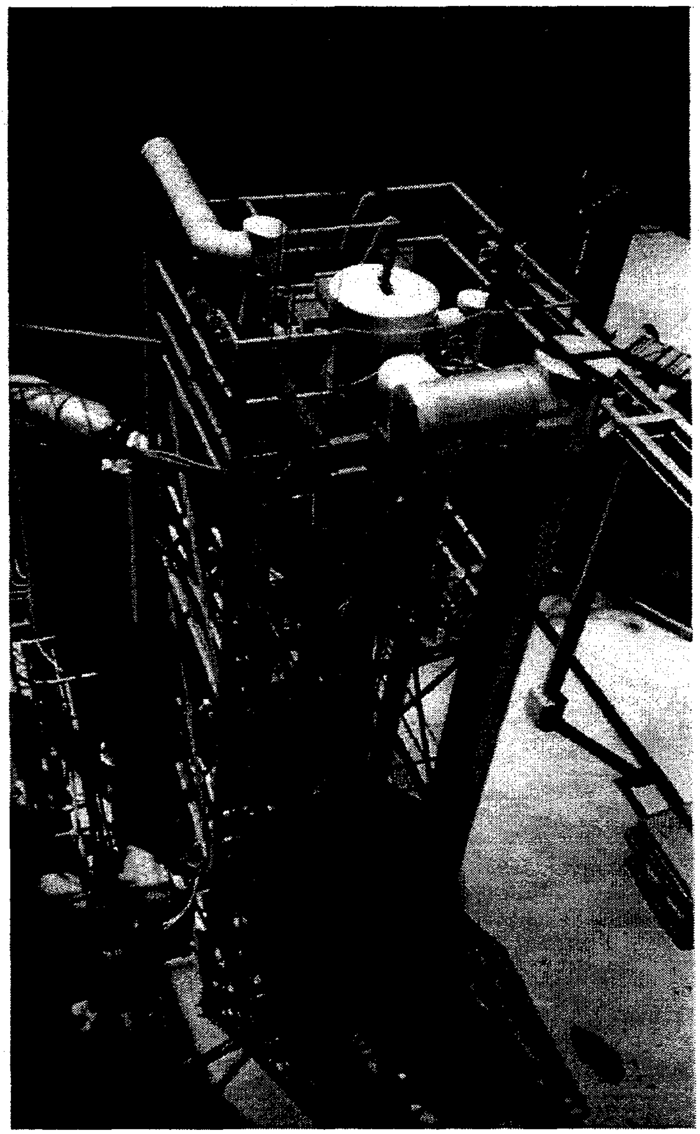

Figure 1. Photograph of PCM installed at Comanche Station

Control System

The control system is designed to allow manual or automatic operation of the pilot. The primary control elements for the pilot will be a Programmable Logic Controller (PLC) and an intelligent data-logger. Pneumatic actuators on several valves including the inlet, outlet, bypass, flow control, purge, and hopper isolation valves permit automatic flow control, off-line cleaning, and isolation of the pilot for shut-down. The control system is programmed to bring the pilot off-line, clean the bags or rap the plates, and purge the system for alarm trip conditions. Trip conditions include low boiler load and low duct temperature for all configurations and high duct temperature and high tubesheet pressure drop during the fabric filter tests. The bag cleaning or plate rapping sequence can be controlled automatically or manually at the control panel. Parameters which will be monitored and recorded include: gas temperatures, flowrate, pressures, boiler load, secondary voltage and current (ESP), cleaning/rapping frequency, pulse pressure or reverse gas flow (fabric filter), and mercury concentration. Dâta will be stored in time-stamped arrays for analysis and graphical presentation.

Fabrication of the control panel began in April. The panel was installed and checked out with the PCM in early June. Temperature controllers, pressure transducers, timers, PLC, data logger, and relays are located within the control box.

ESP Configuration

The PCM is configured as an ESP for the first test series. Four 10-inch diameter tubes are hung from a tubesheet installed at the top of the 28-inch diameter pipe. The 10-inch diameter tubes serve as the gas passages for the ESP. Four electrodes, one for each gas passage, are attached to a rigid frame and powered from a single transformer-rectifier (T/R) set.

The T/R set, provided by EPRI, was received during May and will be used during testing at Comanche. The T/R set is controlled by an automatic voltage controller (AVC) and will be set to simulate conditions in a full-scale wire-plate ESP. For this configuration, the T/R set will be operated in the 40 KV, 15 ma range. The AVC microprocessor was calibrated to assure accurate voltage and current readings. The T/R set is located at ground level, shown in the foreground of Figure 1 and power is brought to the electrodes through a shielded bus into the high voltage feedthrough insulators located near the top of the PCM.

Four 0.1 inch diameter electrodes were attached to a rigid frame which maintains one wire down the centerline of each tube. The lower frame is weighted to keep the wires straight and a pneumatic vibrator is attached for cleaning ash from the electrodes. The top frame is attached to the high voltage bus at the feedthrough insulators. The ESP was powered up on ambient air to determine the voltage and current characteristics of the arrangement and to verify proper alignment of all wires and tubes.

Task 3. Field Evaluations of Sorbents for Mercury Control

The facility was designed and fabricated to permit significant control over the operating conditions during evaluations. In addition to changing the particulate control configurations, the test plan identifies varying several operating parameters such as duct temperature, flue gas moisture content, in-duct sorbent residence time, and flue gas mercury concentration. Sorbent effectiveness will be evaluated for the temperature ranges: 1) 190-210 ^{o}F (expected cold weather baseline at Comanche), 2) 225-275 ^{o}F (expected warm weather baseline), and 3) 300-325 ^{o}F. Duct cooling will be achieved by two methods: 1) spray cooling with water (increased moisture content), and 2) cooling with a heat exchanger. The sorbent injection ports are located for in-duct sorbent residence times of 0.75 to 1.5 seconds to evaluate the effect of residence time on sorbent effectiveness.

Although most of the tests will be conducted at baseline mercury concentrations of nominally 7$\mu g/m^3$, plans include increasing the mercury concentration for a few tests. The baseline mercury concentration will be increased with diffusion vials of elemental mercury. The resulting inlet concentrations of elemental and speciated forms of mercury will be measured before the PCM without sorbent injection. This will account for any change in the form of the mercury after entering the system. A minimum of twelve manual EPA Method 29 samples are planned to provide comparison documentation with the mercury analyzer. Initial comparison tests will be conducted after the analyzer is fully checked out and fully operational.

Mercury Measurement

Mercury emissions will be measured using a continuous monitor developed by ADA Technologies during a DOE SBIR program. The system features a sensitive mercury detector that is based on ultraviolet absorption spectroscopy, a mercury species converter, and a calibration system. The "converter" is used to change speciated mercury compounds to elemental mercury. When the sample gas is passed through the converter, the total mercury content of the flue gas is measured. When the converter is bypassed, only elemental mercury is measured in the gas sample. The difference between the two measurements is the concentration of total speciated mercury. Thus, the monitor is capable of measuring total mercury, elemental mercury, and (by difference) the speciated mercury concentrations continuously in real time. The instrument is calibrated with permeation tubes to provide known and accurate concentrations of elemental mercury.

The mercury analyzer was checked out during this quarter in preparation for sorbent testing at Comanche. In the laboratory, the analyzer is capable of consistently detecting mercury to ± 0.5 μg/m^3. With a baseline mercury concentration of 7 μg/m^3 at Comanche, measuring to 1 μg/m^3 with sorbent injection would represent a mercury removal rate of ≥86%. Some temperature drift has also been experienced with the analyzer. This problem has not yet been solved and may cause some delays in testing as more temperature drift is expected in the field than is typically experienced in the laboratory.

The mercury analyzer arrived at Comanche on June 10. Due to delays in power availability, the analyzer was not operational until later in the month. Additional delays were experienced because the quartz cell that total mercury is measured through arrived at Comanche cracked. This crack was not identified until the analyzer was operational. Unfortunately, the spare total cell was also broken when it arrived on-site. The total cell was bypassed during initial analyzer check-out until the total cells could be repaired.

During the initial analyzer check-out, Comanche flue gas was routed from the outlet of the full-scale reverse gas baghouse through the PCM main bypass, into the fan and back into the Comanche ductwork upstream of the Comanche's baghouse. During these pre-test measurements, the Comanche baghouse was used as the main sample filter. Virtually particulate-free gas was passed through the analyzer's particulate filter and into the analyzer. Teflon hot lines carried flue gas from the PCM main bypass to the mercury analyzer. Teflon has been found to adsorb speciated forms of mercury for a period of time until the Teflon lines are conditioned. The analyzer was calibrated by passing a known concentration of elemental mercury directly into the analyzer. Calibration gas was then passed through the full length of Teflon hot-line and into the analyzer. The readings from the mercury analyzer were identical, indicating that elemental mercury was not adsorbed by the Teflon hot-line.

Sorbent will be injected into the duct via a screw feeder with an electronic control of feed rate. This permits changing the injection rate independent of gas flow. A feed hopper shall be used to store and supply sorbent to the feeder. Injection rate will be monitored continuously via an electronic signal to a data logger. This design has been previously tested in similar bench-scale systems.

Task 6. Management and Reporting

The contract with EPRI was approved on April 25. The start of testing at Comanche was delayed two weeks to accommodate analyzer use on another DOE project. An additional two delay occurred due to power problems but the system is over 95% and testing will begin in early July. All reports are current but PSCo has not begin billing the DOE. A paper was written and a poster was prepared for the PETC contractor's meeting in July. Pictures and a description of the facility at Comanche will be presented along with the projected test plan.

Activities Scheduled for Next Quarter (July 1 - September 30, 1996)

Task 1. Sorbent Selection

A third sorbent may be identified through testing at EPRI and DOE laboratories. However, unless a sorbent shows great promise, testing will focus on the Darco FGD activated carbon and the sorbent identified as AC-1.

Task 3. Field Evaluations of Sorbents for Mercury Control

Testing of the ESP configuration of the PCM will begin in early July. It is expected that carbon injection will begin at the end of the July after the baseline testing is complete. All testing with the ESP configuration will be completed in early September and the PCM will be reconfigured as a pulse-jet baghouse.

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Contract Concerns

The project is four weeks behind the original schedule. However, based upon the minimal time required to assemble the ESP hardware (tubesheet, ESP tubes, etc.), and the expectation that other configuration assemblies will require similar time expenditures, the delays realized thus far into the program will be recovered during configuration changeouts and minor changes to the test plan.

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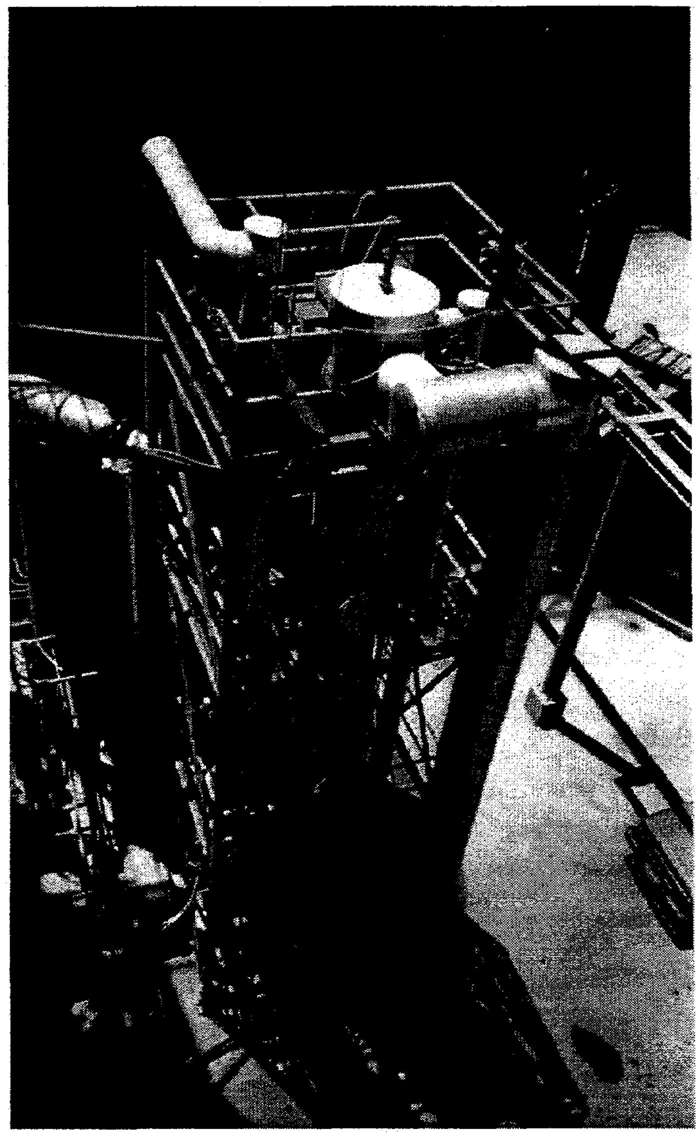

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