Re-injection of Flyash for Mercury Removal

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Introduction

Public Service Company of Colorado (PSCo) is under contract to the DOE to investigate the use of activated carbon as a potential mercury control sorbent in utility flue gas. Most of this project is being conducted by ADA Technologies in a pilot-scale test facility located at the Comanche Station of PSCo. In the course of demonstrating the use of activated carbon for removal of gas-phase mercury from utility boilers, ADA found it necessary to develop a unique sampling system to measure vapor-phase mercury. Fly ash present in the Comanche 2 duct was found to adsorb mercury, thus any sampling system with a filter created a type of "fixed bed" as ash accumulated. This ash layer removes mercury, making measurement of vapor-phase mercury difficult. This affinity for mercury is unusual, and has not been reported at other power plants. As part of the project, ADA has performed full-scale sampling for mercury at other PSCo generating plants. Several were found to have very low emissions of mercury. In these low-emission plants, vapor-phase mercury is captured on the ash, which is subsequently collected by ESPs and baghouses. Given these results, tests were conducted at the Comanche pilot to determine which PSCo fly ashes work well for mercury removal, and at what rates they must be injected. Concurrent lab testing is examining the fundamental ash properties which contribute to mercury capture.

Testing Procedure

In 1996 ADA designed and installed a 600 acfm pilot facility at PSCo's Comanche Generating Station. The unit extracts a 5000 acfm slipstream from the host unit's reverse-gas baghouse. From this stream, ADA diverts 600 acfm through the pilot. The pilot can be configured as an ESP (electrostatic precipitator), a pulse-jet baghouse, a reverse-gas baghouse, or a secondary polishing pulse-jet baghouse (patented by EPRI as TOXECON).

For ash re-injection testing, the pilot unit is set to run on clean flue gas (taken down stream of the host baghouse). For these tests the pilot was configured as a reverse gas baghouse. The gas is doped with mercury vapor to a mercury concentration of ~10µg/nm^3. This concentration is monitored at the inlet and outlet of the pilot using a mercury continuous emissions monitor (Perkin Elmer MERCEM). Sorbent ash is injected just down stream of the inlet sampling port. Any reduction in mercury concentration at the outlet is considered to be the removal of mercury due to adsorption by ash. The four fly ashes evaluated in the test matrix are from PSCo generating units Comanche 2, Cherokee 3, Arapahoe 1 and Arapahoe 4. Carbon concentration and LOI were measured for all candidate ashes.

Results

Tests were conducted on the candidate fly ashes over a four-week period. Results are summarized in Table 1. Comanche 2 ash demonstrated a moderate affinity for vapor phase mercury. The ash has enough capacity to remove most of the mercury in the Comanche flue gas, but seems to be nearly saturated (or no longer reactive) when collected by the baghouse. Re-injection showed only 10% removal, although removal increased to 31% after thermal desorption of mercury. Ash was injected at a rate of 1 grain/acf, loading that is typical for the pilot when operating on a slipstream extracted upstream of the Comanche baghouse. Comanche 2 LOI (Loss On Ignition) is typically 0.6%, a low value which makes the ash salable for PSCo.

Fly ash from Cherokee 3 showed good capacity for mercury adsorption. In full-scale measurements on the Cherokee 3 unit, mercury removal across the baghouse was found to be very high, ~98%. LOI for this fly ash is ~9%. Re-injection testing at the pilot demonstrated near complete removal (86%) at an ash injection rate of 0.33 grains/acf. This injection rate is significant compared to typical flue gas ash content, and would definitely impact the performance of most particle collectors.

Arapahoe 4 ash had very strong affinity for mercury under pilot conditions, although measured removal across the Arapahoe 4 baghouse was less than that seen at Cherokee 3 (82% vs. 98%). Re-injection at the pilot gave high removal (84%) at an injection rate of 0.13 grains/acf. This lower injection rate would still increase particulate loading to the current baghouse by ~10% at the Comanche station. LOI for this ash is ~14%. The observed trend is for high carbon ashes to adsorb more mercury. Separated ash carbon has been shown by other investigators to adsorb mercury under low temperature, high mercury vapor concentration bench scale conditions (Hwang et. al. “Utilization of Low NO_x Coal Combustion By-Products”).

Temperature has been shown to affect the sorption of mercury onto ashes and activated carbon, with lower temperatures favoring high mercury removal. ADA has performed several tests using spray cooling to enhance the sorptive activity of fly ash already present in the flue gas stream. In a test using flue gas from upstream of the Comanche 2 baghouse at 260°F, mercury removal due to collection on resident fly ash was 45%. When the flue gas temperature was lowered to 230°F by spray cooling, removal of mercury across the particle collector increased to 75%. Lower flue gas temperatures facilitated greater mercury removal across particle collectors for the Comanche fly ash.

Table 1

Ash	Temperature (°F)	Inj. Rate (grains/acf)	Carbon Content (%)	Hg Removal (%)
Comanche 2	280	1.13	0.42	10
Comanche 2 (desorbed)	280	1.21	0.26	31
Cherokee 3	320	0.33	7.6	86
Arapahoe 4	320	0.13	14.4	84
Activated Carbon	320	0.0075	(100)	88
Spray cooling	260 → 230	*	0.42	45 → 75

* Native ash concentration about 1 gr/acf, no additional sorbent injected.

Discussion

Two of the fly ashes tested, Cherokee 3 and Arapahoe 4, showed significant ability to control mercury emissions when injected at high rates. This was demonstrated in a flue gas slipstream at temperatures typical of utility ducts (280-320°F). High-LOI ashes appear to be more efficient sorbents.

ADA is currently conducting tests to determine which fractions of the ash are contributing to mercury capture. Carbon separation of the test ashes is being performed by several methods. Some high and low carbon fractions will be tested at the Comanche pilot. Separation based on size has also been performed in small quantities for bench scale evaluation (Bahco method). Twelve size fractions will be assayed for carbon content and mercury concentration. Fractions with greater levels of mercury will undergo further testing to determine their mercury capacities. If the high-carbon samples are also the high-mercury samples, the investigation will focus on confirming the contribution of carbon in the fly ash. Based on the results of these tests, ADA will identify separation methodologies that can enrich an ash in mercury sorbing constituents. Candidate techniques include screen sieving, air classification, and multiple carbon separation technologies. This work is designed to produce an ash product that is effective for mercury control at acceptably low injection rates. ADA plans a fundamental investigation of the chemical and physical ash properties that contribute to mercury adsorption. Tests will be conducted to determine the leachability, and long-term stability of mercury bound to fly ash. These factors will affect the disposability of the fly ash used as a mercury sorbent.