Full-Scale Evaluation of Mercury Control Technologies with PRB Coals

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ABSTRACT

Data indicate that plants firing Powder River Basin (PRB) coals achieve very low native mercury removal when configured with electrostatic precipitators (ESP) or spray dryer absorbers followed by fabric filters (SDA/FF). In addition, full-scale demonstrations show that the performance of non-chemically treated activated carbon may be limited in these applications.

ADA-ES, Inc., with support from DOE NETL, EPRI and industry partners, is conducting a mercury control demonstration at two units that fire PRB coal: Sunflower Electric's Holcomb Station, and AmerenUE's Meramec Station. Holcomb Station is a 360 MW unit and has a SDA and FF for emission control. Meramec Unit 2 is a 140 MW unit and has low NO_x burners and an ESP for emission control. This paper presents results showing that 1) blending PRB with bituminous coal, 2) injecting alternative sorbents specifically designed to operate in a halogen deficient flue gas, and 3) injecting chemical additives onto the coal are viable approaches for high levels of mercury control in these configurations.

INTRODUCTION

ADA-ES, Inc. is conducting a test program to obtain the necessary information to assess the feasibility and costs of controlling mercury from five plants with configurations that together represent over 80% of the existing coal-fired generation plants and potentially a significant portion of new plants. This program is being conducted under a cooperative agreement with the Department of Energy's National Energy Technology Laboratory (NETL), and is co-funded by EPRI and industry partners. Host sites that will be tested as part of this program are shown in Table 1. The field-testing portion of this program will be completed in 2005.

Table 1. Host Sites Participating in the Sorbent Injection Demonstration Project.

	Coal / Options	**APC**	**Capacity MW / Test Portion**	**Current Hg Removal (%)**
Sunflower Electric's **Holcomb Station**	PRB & Blend	SDA – Fabric Filter	360 / 180 and 360 / 360	0–13
AmerenUE's **Meramec Station**	PRB	ESP	140 / 70	15–30
American Electric Power's (AEP) **Conesville Station**	Bituminous Blend	ESP + Wet FGD	400 / 400	56
Detroit Edison's **Monroe Power Plant**	PRB/Bit Blend	SCR + ESP	785/196	NA
Missouri Basin Power Project's **Laramie River Station**	PRB	SDA – ESP	550/140	<20

BACKGROUND: MERCURY REMOVAL ON SUBBITUMINOUS COALS

Data collected in EPA's 1999 ICR program on mercury capture across existing emission control equipment (equipment designed to capture SO_2, NOx, and particulates) showed that the same emission control equipment at plants burning subbituminous/PRB coals captured lower amounts of mercury than plants burning bituminous coals (Sjostrom et al. (2002)). Some of these trends can be seen in Table 2.

Table 2. ICR Data Comparing Native Mercury Removal Efficiencies between Bituminous and Subbituminous Coals.

Controls	Average Removal Efficiency	
	Bituminous	**Subbituminous (PRB)**
Cold-Side Electrostatic Precipitator (ESP)	46%	16%
Fabric Filter (FF)	83%	72%
Spray Dryer Absorber and FF	98%	25%

The average mercury removal was 16% for plants burning PRB coal and with cold-side electrostatic precipitators (ESPs) (Sjostrom et al. (2002)). The mercury removal was 46% with same configuration and bituminous coal. Even more dramatic is the comparison for plants that have a spray dryer absorber (SDA) to capture sulfur dioxide and a fabric filter (FF) for particulate matter. On PRB coals, the FF, without a SDA, averaged 72% mercury capture. However, when a spray dryer was added to the configuration, the average mercury capture dropped to 25%. On bituminous coals, the average mercury removal in this configuration was 98%. This occurred in spite of the lower temperature associated with the spray dryer units. For FFs without SDAs, mercury collection is known to increase substantially when temperatures go below 260^{o}F (Lindau, 1983).

In 2001, sorbent-based mercury control technology was first applied to full-scale plants burning PRB coals. On units with ESPs it was discovered that while 50 to 70% mercury removal was achievable, there appeared to be a ceiling that prevented any higher levels of mercury removal (Durham et al., 2002). On the SDA-FF configuration, high levels of mercury control could be achieved, but only with significantly higher injection rates than needed for FF's alone (Sjostrom et al, (2002) and Bustard et al (2003)).

Because the overall SDA-FF mercury removal was low, it appeared that the spray dryer removed components from the flue gas that were critical to mercury removal by PRB fly ash collected in a FF. It was speculated that these components were halogens such as chlorine, bromine, and fluorine, which are also critical components for untreated activated carbon to be effective in removing elemental mercury based on fixed bed simulations and pilot-scale experiments. It was also speculated that this halogen deficiency was the causing the ceiling effect seen with activated carbon injection into ESPs filtering PRB ash.

RESULTS FROM FULL-SCALE MERCURY REMOVAL TESTING ON PRB COAL– SDA-FF CONFIGURATION

The first unit tested under this program was Sunflower Electric's 360-MW Holcomb Station (Sjostrom et.al., (2004)). Holcomb Station is located near Garden City, Kansas. The unit is a load-following sub-critical 360-MW pulverized coal opposed-fired Babcock & Wilcox Carolina-type radiant boiler designed to burn PRB coal. The existing unit is equipped with three SDA modules followed by two very low air/cloth ratio reverse air FFs, which is also the most likely air pollution control configuration for new units burning subbituminous coal. Holcomb primarily burns two different PRB coals, Jacobs Ranch and Black Thunder.

This test program was designed to provide a full-scale evaluation of new technologies that can overcome the limited mercury removal achievable at these sites. Each technology was based on supplementing certain halogens that are not available in sufficient quantities in these coals. The program was very successful in that three different technologies were found that have the potential to produce high levels (>80%) of mercury removal in this difficult application (Starns, et al. 2004). These technologies are:

1. Halogen Enhanced Activated Carbon: A proprietary product of NORIT Americas, DARCO FGD-E3, produced mercury removal in excess of 90%. (Note- DARCO FGD-E3 has been renamed to DARCO Hg-LH and DARCO FGD has been renamed to DARCO Hg.)

2. Coal Blending: By blending western bituminous coal with PRB coal, the mercury removal across the system increased to almost 80% even without injecting another sorbent. It is highly likely that firing a blend of Black Thunder and West Elk coals with ACI could result in greater than 90% mercury removal. Results with other coal blends must be evaluated.

3. Chemical Addition to the Coal: KNX, a proprietary chemical developed by Alstom Power, was found to enhance the performance of a standard activated carbon. Mercury removal of 86% was measured at a carbon feed rate of just 1.0 lb/MMacf.

Halogen Enhanced Activated Carbon

Short-term parametric tests showed that NORIT's halogen-treated sorbent DARCO FGD-E3 outperformed the non-treated sorbent DARCO FGD. These sorbents were injected upstream of the SDA. Based on these results, DARCO FGD-E3 was selected and used for a four week, continuous test. Figure 1 presents data collected during the four-week test. The results show that very high levels of mercury removal were obtained, average of 93%, at an injection rate of 1.2 lb/MMacf. During this test period mercury emissions averaged 0.8 lb/TBtu.

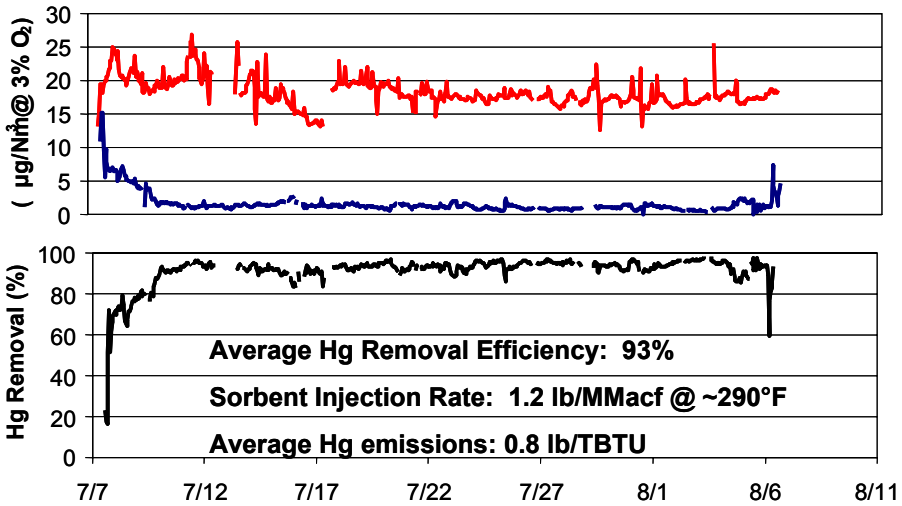

Figure 1. Results of Four Weeks of Injecting NORIT's DARCO FGD Upstream of a Spray Dryer/Fabric Filter on PRB Coal.

Coal Blending

One week of coal blending tests were conducted at Holcomb. The baseline PRB coal was from the Jacobs Ranch mine. During blending tests, PRB coal from the Black Thunder mine was co-fired with western bituminous coal from the West Elk mine. Two different blend ratios of Black Thunder and West Elk were evaluated. The vapor-phase mercury removal during the first blend test was an average of 50% compared to no removal with 100% Jacobs Ranch PRB during this test period. The removal across the SDA-FF during the second blend test increased to 76% (81% based upon M324 samples). These results are summarized in Figure 4.

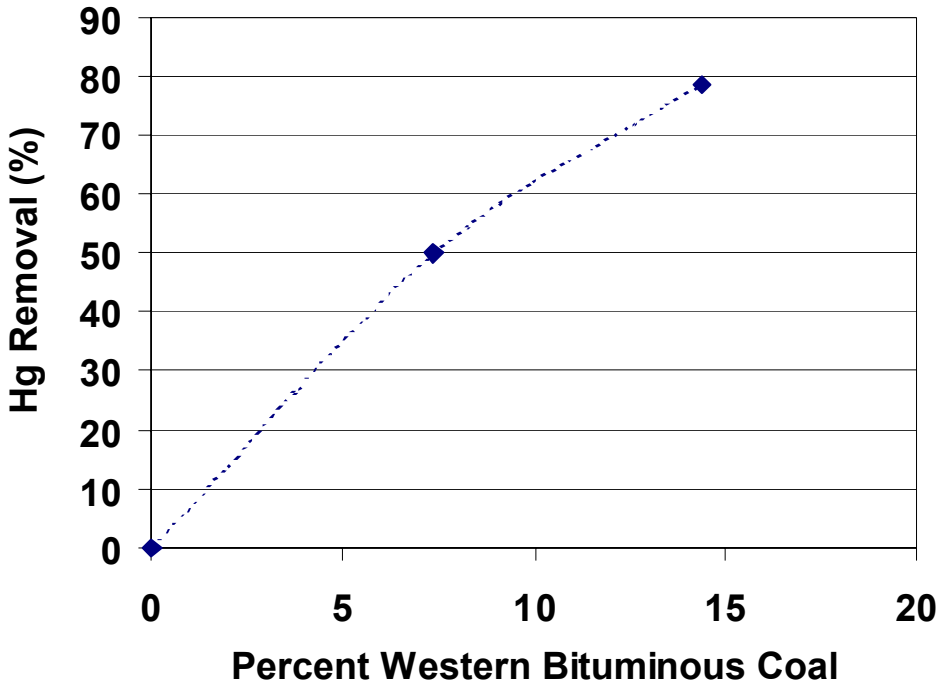

Figure 2. Summary of Coal Blending Tests Conducted at Sunflower Electric's Holcomb Station, 2004.

Coal Additive With/Without Sorbent Injection

Another option for introducing halogens is by adding it to the coal. The additive tested at this site was KNX, a proprietary Alstom Power mercury control technology. KNX was applied to the coal at the crusher house prior to entering the transfer house and coalbunkers.

During this period of testing, the unit was burning coal from the Jacobs Ranch mine. At normal operating conditions this coal yielded a total vapor-phase mercury concentration of 18 to 22 $\mu g/Nm^3$ at the outlet of the air preheater with 70 to 90% in the elemental form. During the chemical additive tests, the fraction of elemental mercury at the air preheater outlet decreased to 20 to 30%. Although the fraction of oxidized mercury increased substantially, no increase in mercury removal was measured across the SDA or across the SDA-FF. This suggests that either

the KNX addition resulted in a sampling artifact that biased the elemental mercury measurement of the mercury monitor, or the SDA-FF was reducing oxidized mercury back to the elemental form.

The final day of coal additive testing included the injection of the DARCO FGD sorbent at the SDA inlet location. The sorbent injection concentration at the inlet to the SDA was 1.1 lb/MMacf, while the chemical additive flowrate was held steady. Combining the coal additive and the non-treated activated carbon showed a total mercury capture across the system of 86%, compared to 54% with DARCO FGD alone (no KNX). These data, plotted in Figure 3, clearly indicate that there was improved performance of DARCO FGD when halogens were added.

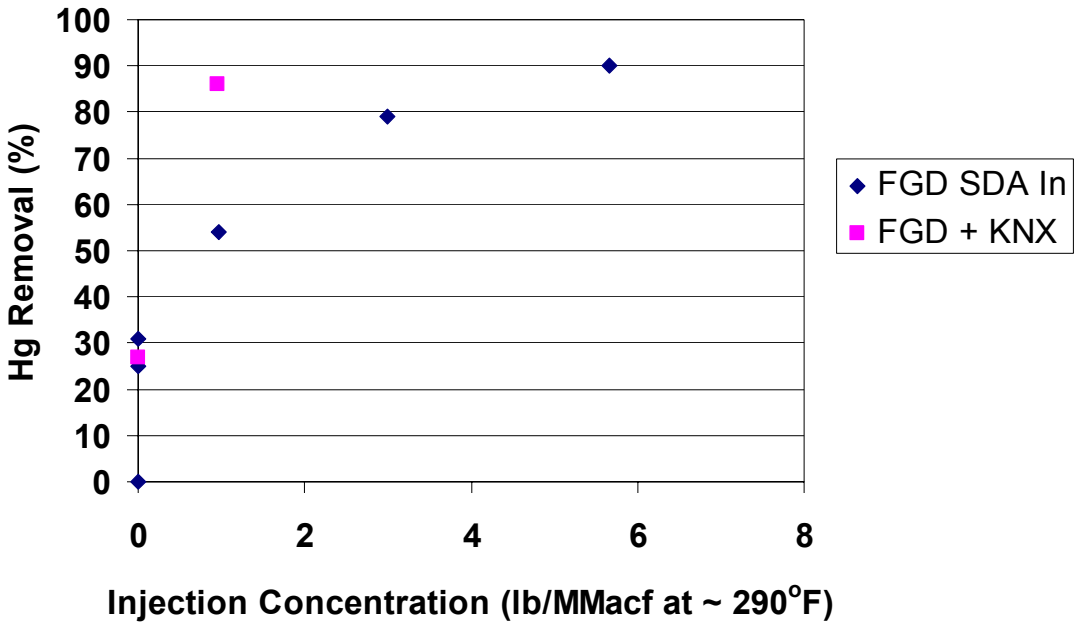

Figure 3. Impact of the Coal Additive (Alstom's KNX) on Mercury Removal With and Without Injection of Non-Chemically Treated Activated Carbon (DARCO FGD).

In addition to the Holcomb tests, URS conducted a DOE/NETL sponsored program at the Great River Energy's Stanton Station Unit 10 (Machalek, et al., 2004). This unit fires North Dakota lignite, which has similar coal characteristics as PRB coals (Sjostrom et al., (2002)), and has the identical configuration of a spray dryer/baghouse as Holcomb. During this test program two halogenated sorbents were tested, NORIT's DARCO FGD-E3 and Sorbent Technologies B-PAC. Mercury removal levels greater than 90% were achieved at an injection rate of 1.5 lb/MMacf with both of these sorbents. Figure 4 is a plot of data from both Holcomb and Stanton showing results for halogenated sorbents and the Alstom KNX process compared to results with standard, untreated activated carbons.

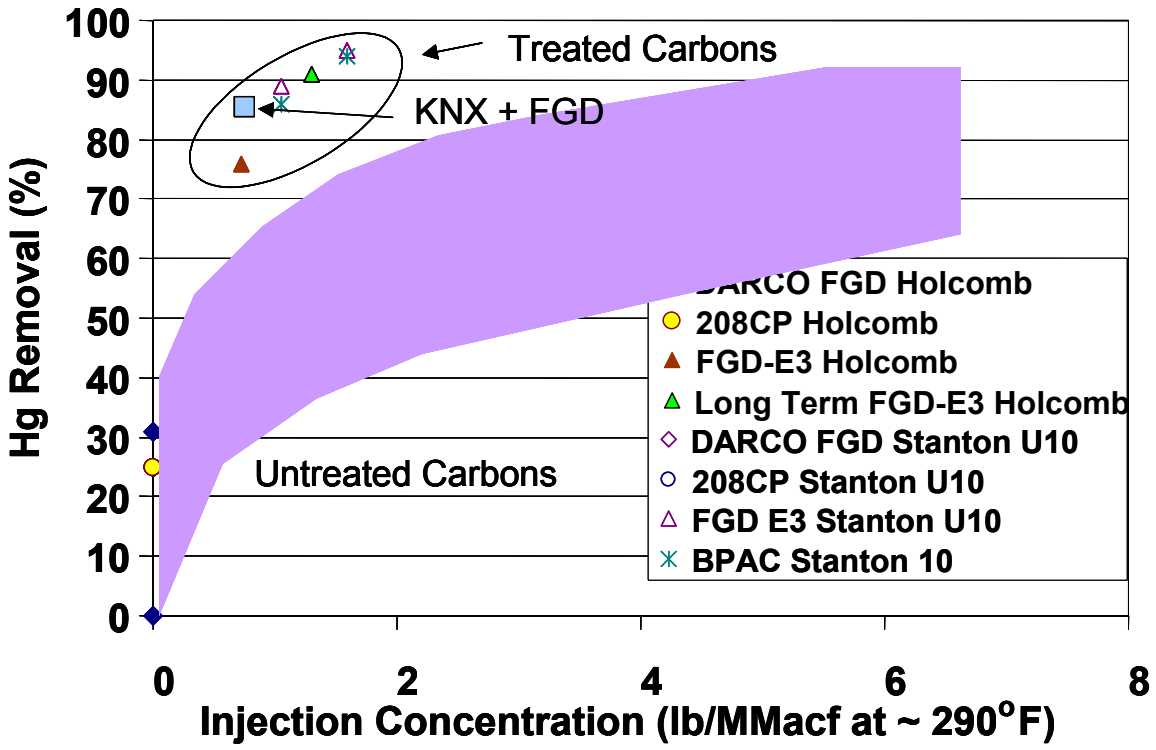

Figure 4. Performance of Halogen Enhancements on Units with Spray Dryer/Fabric Filters Burning Subbituminous and Lignite Coals.

RESULTS FROM FULL-SCALE MERCURY REMOVAL TESTING ON PRB COAL – COLD-SIDE ESP

Following the success of the halogenated sorbents on the SDA-FF, the next test site was AmerenUE's Meramec Unit 2, located south of St. Louis Missouri. Meramec Unit 2 is 140 MWs and fires 100% PRB coal obtained from several different mines. The unit is equipped with cold-side ESPs for particulate control (Starns et al. 2004). This configuration represents the majority of existing plants that burn subbituminous coals.

Halogen Enhanced Activated Carbon

During this program, the performance of NORIT's standard carbon, DARCO FGD, was compared to the halogenated version, DARCO FGD-E3, in short-term, parametric tests. The results are shown in Figure 5. With the standard carbon, the "ceiling effect" is observed in that a maximum removal of about 70% mercury removal is achieved at a feed rate of 3 to 5 lb/MMacf. No additional mercury removal was obtained even if the carbon feed rate was double and tripled. In contrast, DARCO FGD-E3 overcomes this effect and greater than 90% mercury removal is achieved at a feed rate of 3 lb/MMacf (Starns et al, 2004).

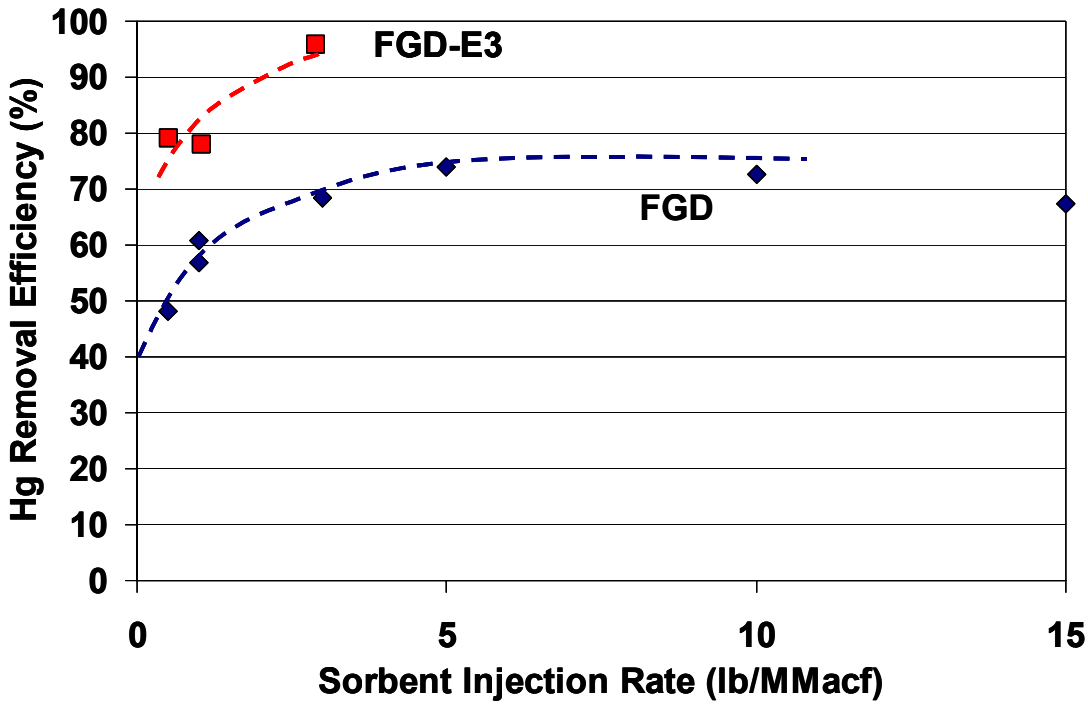

Figure 5. Mercury Removal on PRB Coal with NORIT's Halogenated Activated Carbon DARCO FGD-E3 Injected Upstream of a Cold-Side ESP.

In a longer-term test, DARCO FGD-E3 was continuously injected over a 30-day period. A trend graph showing mercury concentrations at the inlet and outlet of the ESP during long-term testing is presented in Figure 6. During this test period the average mercury removal was 93%, with an average outlet emission of 0.44 lb/TBtu (Sjostrom, 2005).

Coal Additive With/Without Sorbent Injection

Similar to the tests with the SDA-FF at Holcomb, it was of interest to see the effect of a coal additive on native mercury removal and if the coal additive enhanced performance of an untreated activated carbon. In one of the parametric test series, Alstom's KNX material was evaluated. With KNX, removal ranged from 57 to 64% compared to 22 to 34% with no KNX. No boiler operational changes were made during this time. These data suggest the KNX alone can enhance the effectiveness of native fly ash containing LOI.

During one day of KNX injection with DARCO FGD the maximum vapor-phase mercury removal was 87% at an injection concentration of 5 lb/MMacf, compared to 73% in the absence of KNX.

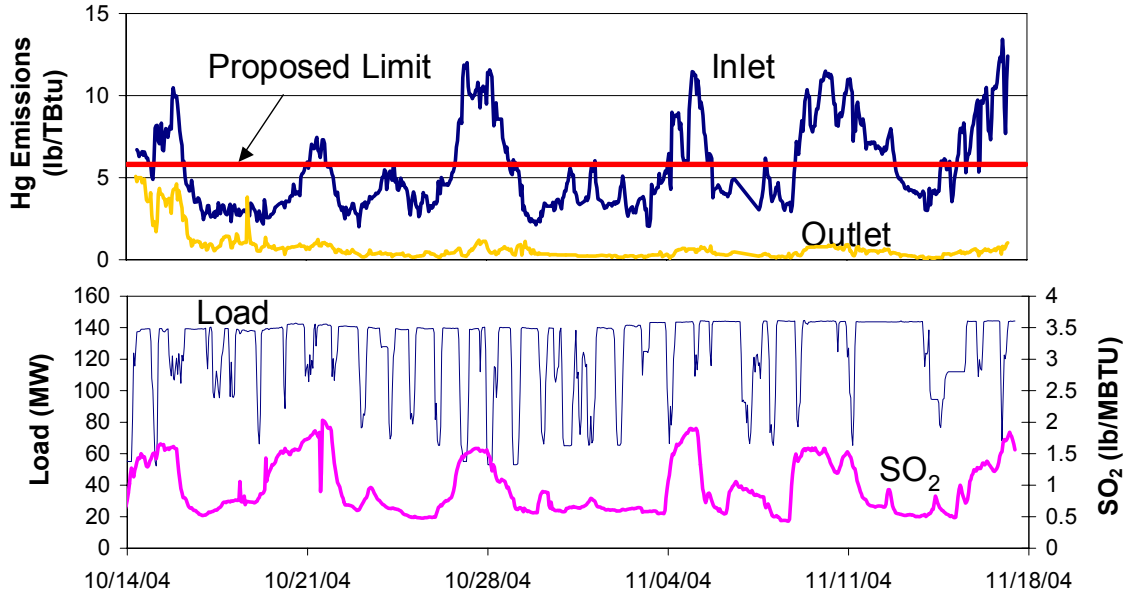

Figure 6. Mercury and SO_2 Trends During Long-Term Activated Carbon Testing at AmerenUE's Meramec Unit 2.

CONCLUSIONS

Power plants that burn PRB coal represent a challenging application for controlling mercury emissions. Several new technologies were developed to overcome the limited mercury removal achievable at these sites. Each technology was based on supplementing certain halogens that are not available in sufficient quantities in these coals. Full-scale tests of these new technologies were conducted at two sites. Options evaluated included coal blending, introduction of additives onto the coal, and sorbent injection with chemically treated activated carbons. General conclusions and observations from these tests include:

- **Coal Blending**
  - Up to 80% mercury removal was achieved during short-term tests with a SDA-FF
  - Additional tests are required to confirm this result
- **Coal Additives**
  - >80% removal was achieved at Meramec with an ESP without carbon injection *(plant configuration and high LOI may have contributed to removal)*
  - Carbon injection was required in addition to coal additives at Holcomb for high removal in the SDA-FF configuration

- **Treated Activated Carbon Injection**
  - High removal (>90%) achieved in 30-day tests in SDA-FF and ESP configurations
  - No adverse balance-of-plant impacts were noted at either site
- **Other Balance-of-Plant Concerns**
  - Historical data suggest that no measurable mercury will leach from collected ash. Tests are underway on the ash/sorbent mix collected during the 30-day DARCO FGD-E3 injection tests at Holcomb and Meramec to determine if either mercury or bromine leach from the samples. DARCO FGD-E3 is a bromine-treated activated carbon.
  - Flue-gas bromine measurements were made at Holcomb and Meramec during long-term testing of DARCO FGD-E3. No levels of bromine in excess of those expected for plants firing PRB coals were measured.
  - Trace amounts of activated carbon can be detrimental to ash quality for cement use. Options to protect ash for sales include TOXECON™ and TOXECON II™. TOXECON II™ tests are scheduled to begin this fall on a separate DOE contract.

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