ANALYSIS OF KEY PARAMETERS IMPACTING MERCURY CONTROL ON COAL-FIRED BOILERS

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ABSTRACT

As part of an ongoing NETL program, full-scale and bench-scale carbon injection test results from NETL and EPRI programs will be integrated with ICR and other available data to expand the understanding of mercury control options for different particulate control devices and coals. An initial analysis of these data showed factors that influence mercury removal in the absence of sorbent injection include coal type, temperature, LOI, sulfur and chlorine concentrations, and particulate control device (PCD) (S. Sjostrom, Bustard, Durham, Chang, "Mercury Removal Trends in Full-Scale ESPs and Fabric Filters." Presented at the "A&WMA Specialty Conference on Mercury Emissions: Fate, Effects and Control," Chicago, IL, August 21 –23, 2001.). Further analysis will include predicted mercury removal performance with activated carbon, the impact of operation variables such as temperature and LOI, and the implication of other flue gas components on mercury capture.

This paper presents an updated analysis of mercury removal trends with and without activated carbon injection, and addresses the low mercury removal configurations of western coals with spray dryers and lignite coal applications.

INTRODUCTION

In anticipation of pending regulations, a great deal of information has been collected and research conducted to characterize the emission and control of mercury compounds from the combustion of coal. Much of this research was funded by the Department of Energy, EPRI, and the EPA. Injection of dry sorbents such as powdered activated carbon (PAC) into the flue gas and further collection of the sorbent by conventional particulate control devices (electrostatic precipitators (ESPs) and fabric filters) represent the most mature and cost-effective retrofit control technology for utilities, particularly those burning low-rank fuels.

All of the work prior to 2000 has been conducted using bench-scale and pilot experiments. Although these reduced-scale programs provide valuable insight into many important issues, they cannot fully account for impacts of additional control technology on plant-wide equipment. Seven full-scale evaluations of PAC injection for mercury control were conducted in 2001 and 2002. Three of these tests were conducted on units burning low-rank coals (two PRB sites and one lignite site), three on plants burning low sulfur bituminous coals, and one on a plant burning high sulfur bituminous coal. Data from each of these have been presented. Of the seven tests, four were evaluations funded under a DOE/NETL cooperative agreement with ADA-ES and included two evaluations of sorbent injection upstream of cold-side ESPs on plants burning low sulfur coals, sorbent injection upstream of an ESP on a unit burning subbituminous Powder River Basin (PRB) coal[1], and sorbent injection upstream of a COHPAC fabric filter on a unit burning low sulfur bituminous coal[2]. The other three tests were EPRI-sponsored evaluations. One was co-funded by Great River Energy for a demonstration of the effectiveness of PAC injection upstream of a spray dryer-fabric filter on a plant burning North Dakota lignite[3]. Another EPRI test was co-funded by Minnesota Power and Xcel Energy to demonstrate PAC injection upstream of a particulate scrubber on a plant burning PRB coal[4]. The third EPRI test was co-funded by the Illinois Clean Coal Institute to demonstrate mercury control using injected sorbents on a plant burning high sulfur bituminous coal with an ESP for particulate control.

This paper presents a summary of the range of mercury concentration and mercury speciation measured for coal-fired units in the United States, the natural mercury removal measured across a variety of control devices, and mercury control trends experienced during full-scale demonstrations of PAC injection during field demonstrations in the past few years.

BACKGROUND: MERCURY IN COAL AND FLUE GAS SPECIATION

During 1999, the EPA conducted an Information Collection Request (ICR) program in which approximately 40,000 samples of coal were analyzed to determine the concentration of mercury and chlorine (Phase II effort). This program provides a great deal of information about the variability of these compounds in the various coals being burned to produce power in the U.S. This information is available on the EPA website[5].

In addition to analyses of delivered coal, the ICR program also provided an opportunity to perform measurements of mercury speciation in flue gas to determine the capture of mercury by existing air pollution control equipment. Eighty-four different plants were selected for testing to provide enough data to cover a range of boiler designs, coal types, and air pollution control (APC) equipment. Measurements have also been made at several additional sites, including the seven PAC demonstration sites, since the ICR through EPRI and DOE funding.

Coal Characteristics

The range of mercury concentrations measured from the Phase II ICR coal samples is presented in Figure 1 for low-rank (Texas lignite, Montana/North Dakota lignite, and subbituminous) and bituminous (Western and other) coals. The mercury distribution varies among the five classifications of coal. As shown, the mercury concentration in over 40% of the Texas lignite samples was greater than 10 lb/TBtu, as compared to less than 30% for the northern lignite samples (North Dakota and Montana), 10% for the subbituminous samples, 2% for the Western subbituminous samples, and 26% for the other bituminous samples (Eastern and Midwestern U.S., South American, etc.). As a category, the Western bituminous coals have the lowest average mercury content.

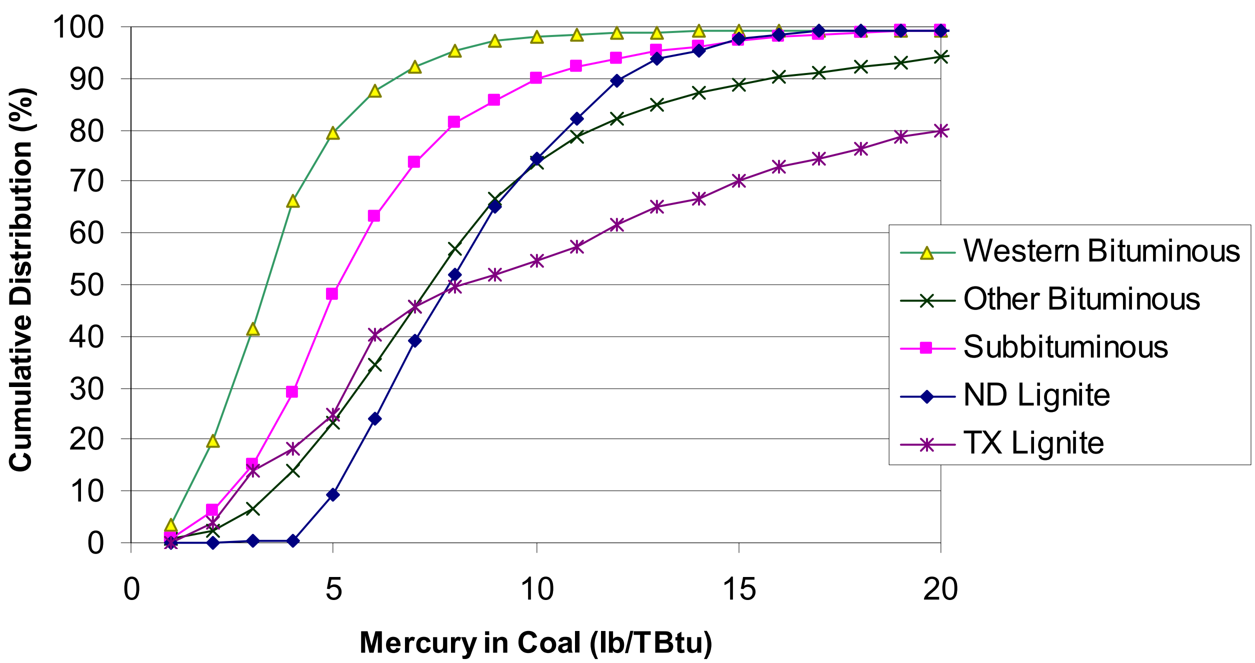

Figure 1. Range of Mercury Concentrations From Phase II ICR Database

Chlorine concentrations were also measured in the coal samples. Coal chlorine contributes to the fraction of oxidized mercury measured in the flue gas. A frequency distribution of the chlorine concentration is presented in Figure 2. The graph suggests the lignite samples contain more chlorine than the subbituminous samples. However, this conclusion may be misleading. Chlorine was below detection limits in 34% of the lignite samples. Of these, 9% were recorded as 200 ppm, and 25% were recorded as 100 ppm, depending upon the chlorine detection limit at the laboratory. For subbituminous coals, chlorine was below detection level in 46% of the samples. Of these, 13% were recorded as 100 ppm, and 33% recorded as 50 ppm. Because the detection limits for the laboratories analyzing the subbituminous coals were typically lower than for the lignite samples, and the samples with no measured mercury were recorded as the detection limit, the actual variation between the low-rank coal classifications is difficult to determine. The chlorine content of the Western bituminous coals closely resembles the content of the low-rank coals. Figure 2 clearly shows that the coal category "Other Bituminous" has significantly higher chlorine than the other categories.

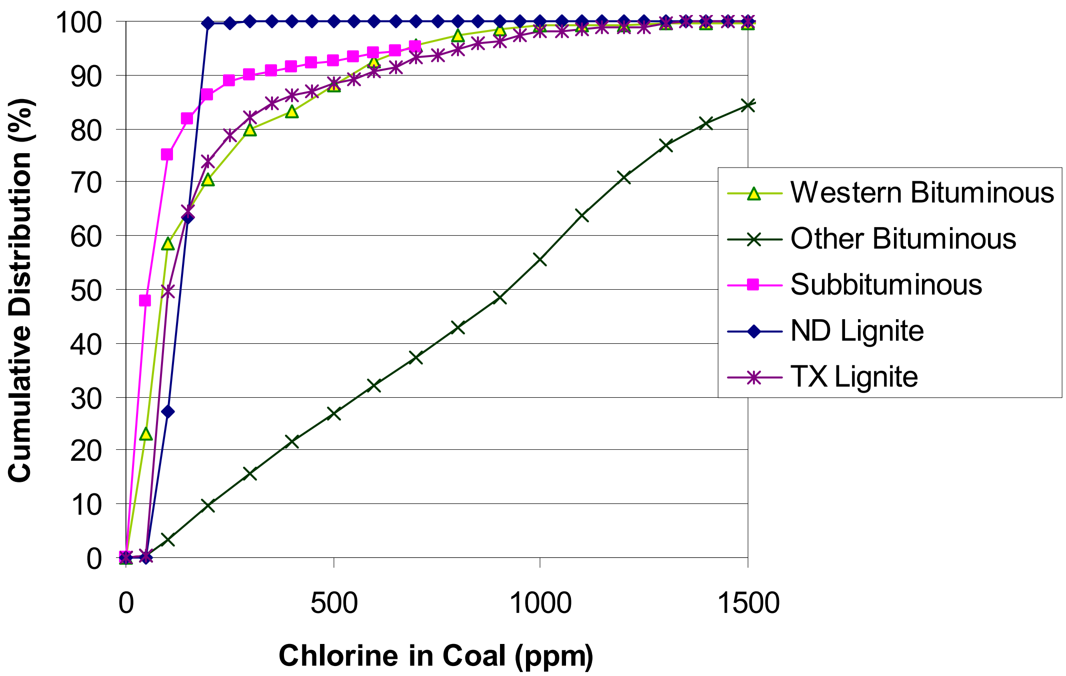

Figure 2. Frequency Distribution of Chlorine Concentrations from Phase II ICR Database

Sulfur concentrations in the coal for the five coal categories are presented in Figure 3. As would be expected, the Western bituminous and low-rank coals have the lowest sulfur levels. North Dakota lignite coals typically have lower sulfur levels than Texas lignite coals. The non-western bituminous coals have the highest average sulfur contents.

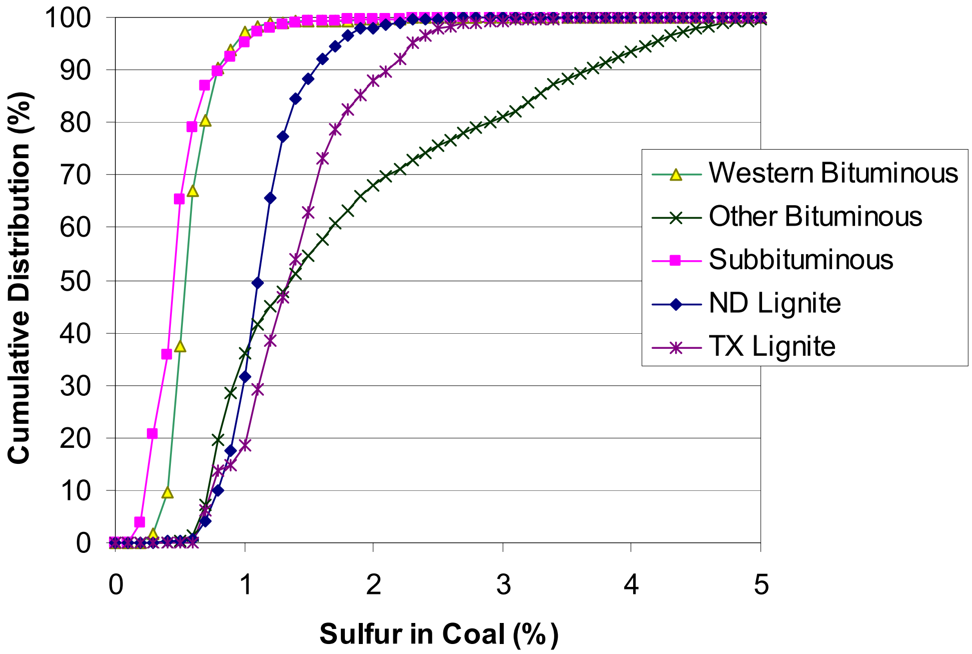

Figure 3. Cumulative Frequency Distribution of Sulfur Concentrations from Phase II ICR Database

Flue Gas Characteristics

Flue gas mercury measurements were made at 80 units during the ICR effort: 27 units burning subbituminous coal, 7 plants burning northern lignite coals, 5 plants burning Texas lignite coals, 4 plants burning Western bituminous coals, 23 plants burning bituminous coals, and 14 plants burning either a blend of fuels or waste. Other data are available through DOE and EPRI programs.

The mercury concentration and speciation can affect the amount of mercury collected in a control device. The flue gas data also suggest identifiable trends associated with the coal categories identified. Of the plants burning low-rank fuels, the units burning Texas lignite demonstrated the largest fraction (20-80%) of oxidized mercury measured at the inlet of the particulate control device, with none of the five units with more than 80% elemental. The fraction of elemental mercury measured at the western bituminous plants tracks fairly well with distribution measured at the Texas lignite plants. Recall from Figure 2 that the chlorine content in these coals is also very similar. Of the plants burning subbituminous coals, only 38% demonstrated more than 80% elemental mercury. Of the plants burning northern lignite coals, 75% demonstrated more than 80% elemental mercury. More than 50% of plants burning non-western bituminous coal demonstrated less than 30% elemental mercury in the flue gas at the inlet of the particulate collector. These data are presented in Figure 4.

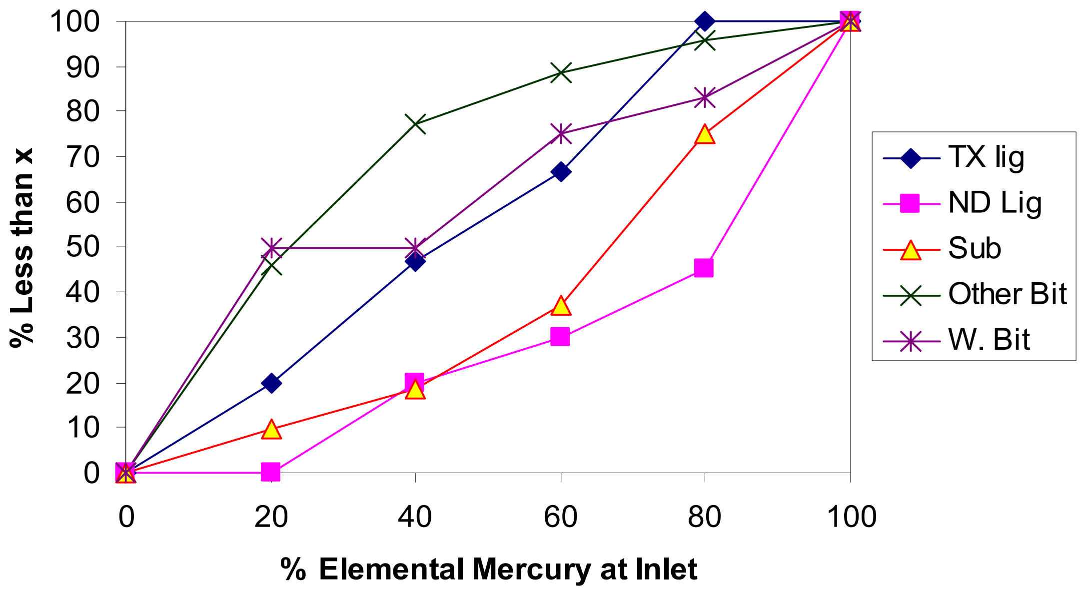

Figure 4. Distribution of Elemental Vapor-Phase Mercury at the Inlet to the Particulate Collector for Plants Included in the 1999 ICR

The mercury concentration measured at the plants burning the five classifications of coals also varied, as shown in Figure 5. The plants burning Texas lignite coals demonstrated the highest mercury concentrations at the inlet to the particulate collector. This follows the high coal mercury concentrations presented in Figure 1. The flue gas mercury concentration from plants burning northern lignite coals is similar to that measured at plants burning subbituminous and other bituminous coals. The plants burning western bituminous coals demonstrated the lowest flue gas mercury concentrations at the inlet to the particulate collector, which tracks well with the low mercury concentrations measured in the western bituminous coals.

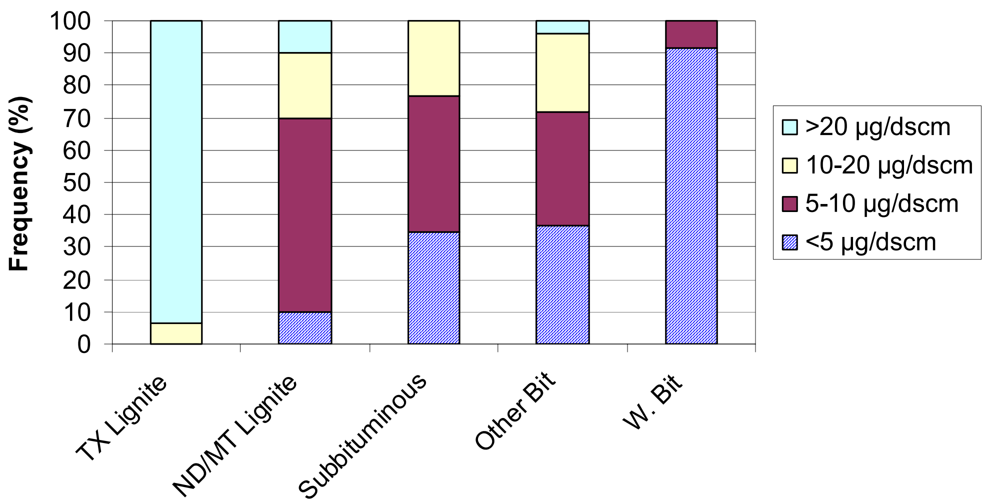

Figure 5. Range of Total Mercury Measured at the Inlet to the Particulate Collector for ICR Test Sites

Another critical factor for mercury removal in ESPs and fabric filters is the temperature of the flue gas. Laboratory testing has demonstrated that the capacity of fly ash samples for mercury decreases with increasing temperature. The temperature at the outlet of the air preheater is typically higher for plants burning lignite coals than for plants burning subbituminous or bituminous coals. Based upon data collected during the ICR stack measurements, the average temperature for the plants burning subbituminous coals was less than 300^{o}F. The average temperature for plants burning northern lignite coals was near 350^{o}F and over 350^{o}F for plants burning Texas lignite coals.

Mercury Removal in Existing Air Pollution Control Equipment

Because of the constantly evolving air pollution control regulations, there is a wide variety of air pollution control (APC) configurations found at existing power plants in the U.S. Figure 6 shows the distribution of APC configurations for coal-fired power plants. Most of these plants utilize a cold-side electrostatic precipitator for particulate control. Results from the ICR effort and subsequent DOE/NETL testing suggest that the native mercury removal for plants with cold-side ESPs burning lignite or subbituminous coals, the mercury removal is poor. The maximum removal by an ESP measured during the ICR effort was 28% on a plant burning a subbituminous coal and 7% on a plant burning North Dakota lignite coal. For plants with ESPs burning bituminous coals, the mercury removal is highly variable (35% average removal, 88% maximum removal during ICR tests). In general, higher removal may be expected at plants with high LOI carbon in the ash. The LOI is often a few percent for plants burning bituminous coals, and this, coupled with larger portions of oxidized mercury, may account for the higher average and maximum mercury removal demonstrated for these units.

Adding a polishing fabric filter downstream of an ESP (EPRI's COHPAC technology) did not significantly improve the mercury removal effectiveness of the system because the presence of particulate matter is necessary for mercury removal across a baghouse. In general, the particulate loading to COHPAC fabric filters does not provide enough active material to capture the vapor-phase mercury.

The next most prominent particulate control device is hot-side ESPs. Due to the high temperatures, very low mercury removal is expected for any coal type in this configuration.

Fabric filters that are not downstream of spray dryers offer the highest native mercury removal potential of any particulate control device. This is the third most common particulate control device for units burning subbituminous coals, and the most common control device for units burning Western bituminous coals. On average, the plants participating in the ICR effort that burned subbituminous coals demonstrated 70% mercury removal and plants burning bituminous coals demonstrated 84% mercury removal. The plants burning lignite coal demonstrated insignificant mercury removal. The low mercury removal measured at the lignite site is likely due to the high fabric filter operating temperature (average 358^{o}F), which is typical at plants burning lignite coal. High operating temperatures inhibit mercury removal by the fly ash.

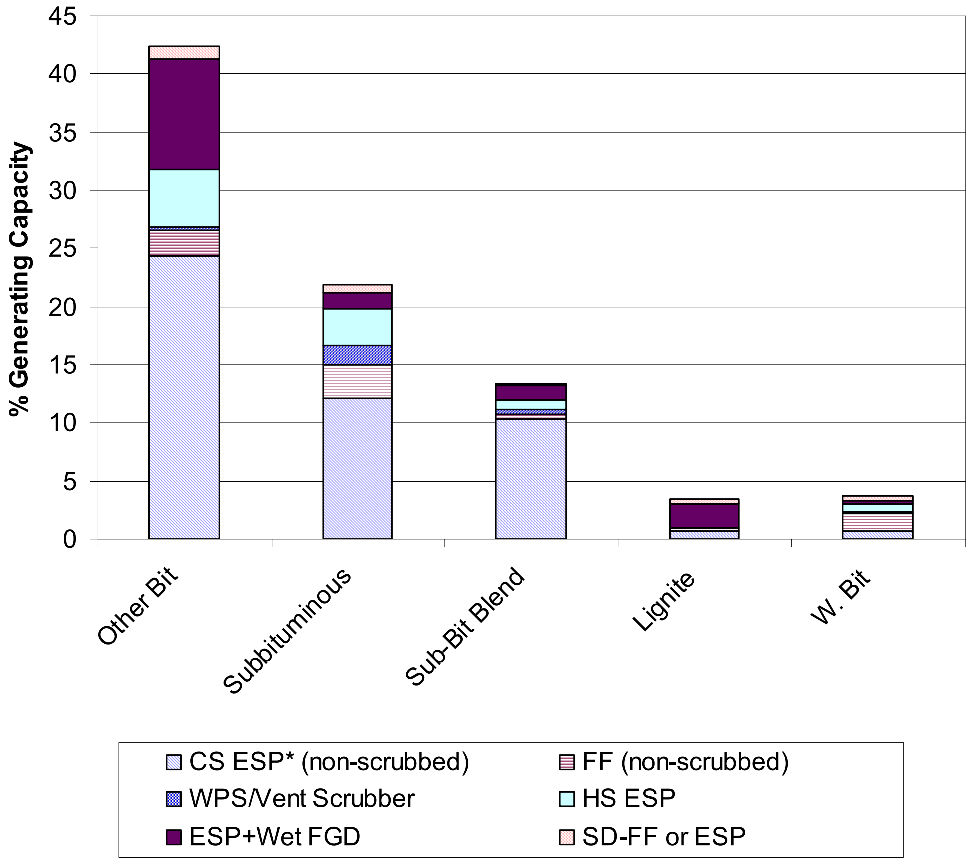

Figure 6. Distribution of Control Devices

When a spray dryer was installed upstream of a fabric filter, the average mercury capture for plants burning subbituminous coals dropped to 25%. Sjostrom et al. reviewed data from 20 units using fabric filters as either the primary or polishing particulate control device to evaluate the native removal across a fabric filter[7]. The clearest trend indicates that for subbituminous coal, the mercury removal on plants with spray dryers was lower than for the three plants without spray dryers (~5-39% vs. ~55-82%). This occurred in spite of the lower temperature of the fabric filter associated with the spray dryer units. Because the overall SD-FF removal on plants burning low-rank fuels is low, it appears that the spray dryer removes components from the flue gas that are critical to mercury removal by subbituminous fly ash collected in a fabric filter. It is believed that this component is a compound such as HCl or HF, which is also a critical component for untreated activated carbon to be effective in removing elemental mercury.

For plants burning bituminous coals, the average mercury removal when a spray dryer was included in the configuration was 98%. This improved performance likely indicates two conditions: 1) the spray dryer was effective in removing oxidized mercury and 2) enough HCl or other components were present downstream of the spray dryer for the ash to continue removing mercury while on the fabric.

The second most common combined control configuration for plants burning bituminous coals, and the predominant control configuration used on plants burning Texas lignite coals, is an ESP followed by a wet scrubber. This configuration has the potential to remove a significant fraction of the oxidized mercury in the flue gas. Flue gas measurements during the ICR effort indicate that sites burning Texas lignite coals may contain 20 to 80% oxidized mercury. Two units burning Texas lignite coal with wet scrubbers were included in the ICR stack tests. These results indicate 64 to 97% effectiveness removing the oxidized fraction of the mercury. As expected, an insignificant change in the elemental fraction was noted. The overall mercury removal at these two sites was 28 to 61%. The mercury removal at sites burning northern lignite coals and subbituminous coals would be expected to be lower than at sites burning Texas lignite coals because of the lower fraction of oxidized mercury expected in the flue gas. The removal at sites burning bituminous coals with wet scrubbers indicated some additional removal within the scrubber, as would be expected with flue gas containing oxidized mercury. The overall removal at sites with hot-side ESPs was lower than at sites with cold-side ESPs (44% as compared to 73% on average) because the hot-side ESPs did not contribute to the overall removal. At sites burning bituminous coals with wet scrubbers located downstream of fabric filters, the mercury removal was similar to plants with stand-alone fabric filters.

Another particulate control device that is a poor-performing mercury control device is the wet particulate scrubber. ICR data on plants burning subbituminous coals using wet venturi scrubbers suggest that elemental mercury will pass through the scrubber. Data from sites burning bituminous coals suggest that oxidized mercury can be captured in a wet scrubber, however some data indicate that captured mercury may be reduced by the scrubber chemistry and reemitted as elemental mercury. The net mercury removal in either case is insignificant.

Evaluations are currently being conducted to determine the influence of Selective Catalytic Reduction (SCR) units for NO_x control on the fraction of oxidized mercury. The impact of this control device on mercury removal is not included in this analysis.

IMPROVING MERCURY REMOVAL USING SORBENT INJECTION

In 2001 and 2002, DOE/NETL and EPRI sponsored several full-scale demonstrations of powdered activated carbon injection (PAC). The configurations are summarized in Table 1 and results presented below.

Sorbents

PAC with the appropriate characteristics for mercury control is commercially available from several U.S. suppliers. There have also been opportunities to test innovative sorbents in these full-scale tests if the sorbents pass bench-scale and cost screening criteria. However, full-scale evaluations require large quantities of sorbents for testing in comparison with lab- and pilot-scale experiments. Thus the benchmark sorbent, DARCO FGD produced by NORIT Americas, Inc., is tested at each site for comparison purposes.

Table 1. Full-Scale PAC Injection Unit Descriptions.

Unit	Size / Tested Size	Coal	Particulate Control
Salem Harbor	88 MW/ 42 MW	LS-Bit	Cold-side ESP
Brayton Point	250 MW/ 125 MW	LS-Bit	Cold-side ESP
Abbott Power Plant	11 MW/ 11 MW	HS-Bit	Cold-side ESP + WFGD
Pleasant Prairie Unit 2	600 MW / 150 MW	PRB	Cold-side ESP
Gaston Steam Station	270 MW/ 135 MW	LS-Bit	Hot-side ESP + COHPAC
Laskin Energy Center Unit 2	55 MW / 55 MW	PRB	Wet particulate scrubber
Stanton Station Unit 10	60 MW / 60 MW	ND Lignite	Spray dryer / fabric filter

Cold-Side ESP

As mentioned previously, this is the most common particulate control configuration, representing about 50% of the generating capacity in the United States. Full-scale PAC injection tests for mercury control have been conducted at two low-sulfur bituminous sites, one high sulfur bituminous site, and at one PRB site.

Results from We Energies Pleasant Prairie Power Plant, which burns a PRB coal, have been reported in detail[1]. These results are summarized in Figure 7. Baseline mercury removal at the PRB sites was negligible and no additional removal above 70% was observed, even as the injection concentration was increased above 10 lb/MMacf. At 1 lb/MMacf, a relatively low injection concentration, 40-50% removal of mercury was measured (this was confirmed in a five-day test). Above this injection rate returns rapidly diminished. A similar limited removal trend was observed during EPRI slipstream tests on sites burning PRB coals[6]. This behavior is likely a function of the coal and resulting mercury speciation and flue gas constituents.

An important lesson from the Pleasant Prairie PAC tests is that fly ash, which is usually a high-quality marketable ash, was rendered unusable for concrete applications as screened by the foam test. However, the byproduct did meet the criteria under TCLP and SGLP testing as a nonhazardous waste for disposal.

Tests were conducted on three sites burning bituminous coals. At one of these sites (Salem Harbor) the baseline removal was over 90% and it was difficult to assess the effectiveness of PAC injection. The other two test sites were Brayton Point, which burns a low sulfur Eastern bituminous coal, and Abbott Power Plant, which burns a high sulfur Illinois coal. PAC performance at these two sites was significantly different. Performance comparisons of the two bituminous tests with the PRB test are presented in Figure 7. The mercury removal at the PRB site was the highest at low injection concentrations (< 5 lb/MMacf), but achieved a maximum mercury removal of nearly 70%. The low sulfur bituminous site demonstrated lower initial removal but the removal steadily increased to 90% at the highest injection concentration tested (20 lb/MMacf). The high sulfur flue gas appeared to impair the performance of the PAC. It is possible that the sulfur is competing for active sites on the activated carbon.

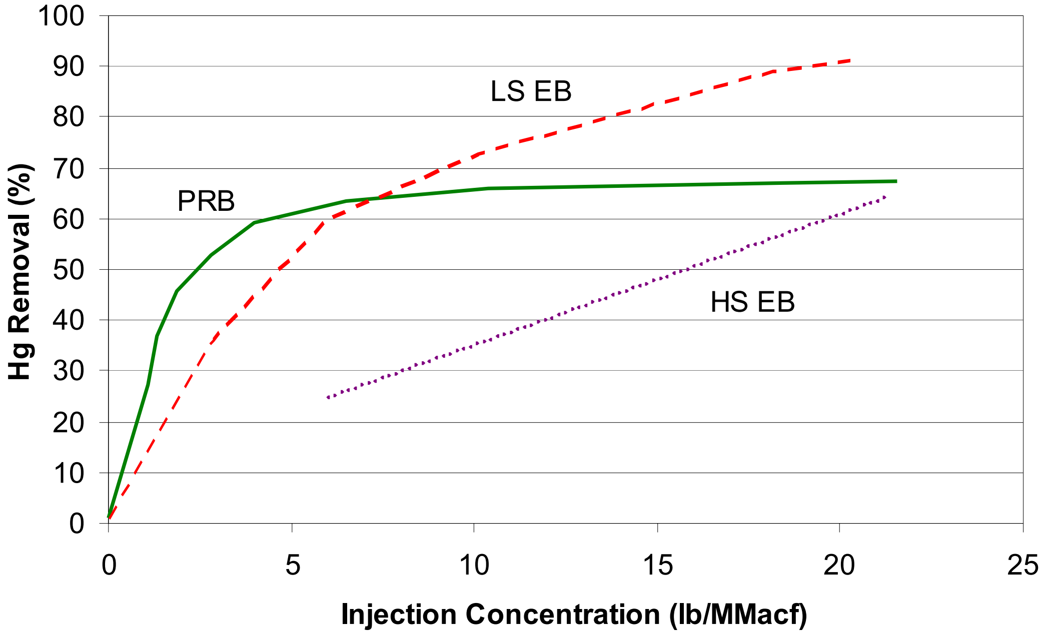

Figure 7. Comparison of Mercury Removal Performance with PAC

COHPAC or TOXECON

Adding a pulse jet fabric filter downstream of an ESP and injecting sorbent into the fabric filter for mercury control may be a viable option for plants burning low-rank fuels. This configuration is EPRI's TOXECON technology. The fabric filter for this application is larger than a typical COHPAC installation to accommodate the additional particulate matter. This is an attractive option to separate the injected carbon from otherwise saleable fly ash, and to reduce the carbon required for mercury control.

Although no full-scale TOXECON units have been installed, full-scale evaluations of activated carbon injection into Southern Company's Gaston Steam Station (low sulfur bituminous coal) suggest that this option may be a viable alternative for mercury control on units with ESPs. EPRI has conducted PRB coal slipstream tests using a 10 acfm unit (PoCT system) at Pleasant Prairie and the results were comparable to those measured at Gaston as shown in Figure 8. The results also indicate that the performance of the activated carbon is not influenced by temperatures from 260 to 350^{o}F at Pleasant Prairie[1].

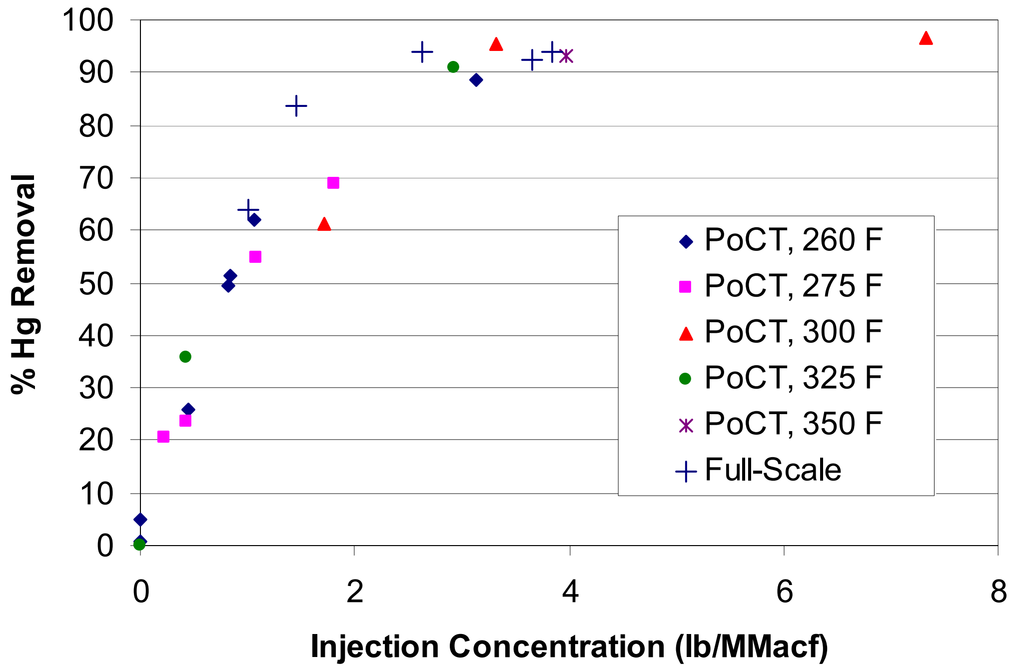

Figure 8. Comparison of Pleasant Prairie PoCT and Gaston COHPAC Results

Wet Particulate Scrubber

Mercury control tests were conducted on Unit 2 at the Laskin Energy Center firing a PRB coal located in Aurora, MN. Downstream of the air preheater, flue gas passes through a Krebs Engineers Elbair two-stage, high–pressure, water spray wet particulate scrubber (WPS). The Krebs WPS also provides approximately 45% reduction of SO_2. Results from these have been reported elsewhere[4].

Baseline tests at Laskin showed 10-40% (typically 20%) mercury removal efficiency in the absence of sorbent. Both chemically treated and untreated sorbents were evaluated at Laskin. Overall, the untreated sorbents demonstrated poor effectiveness (< 15% mercury removal due to PAC) at injection concentrations up to 12 lb/MMacf. The activated carbon treated with iodine demonstrated improved mercury removal performance over the untreated carbons, achieving 54% mercury removal across the scrubber at the highest injection concentration tested (11 lb/MMacf).

Spray Dryer-Fabric filter

GRE's Stanton Generating Station is located in Stanton, ND. Mercury control testing at Stanton Station was performed on Unit 10, and results have been reported in detail elsewhere[3]. Unit 10 consists of a 60 MW Combustion Engineering PC-tangential-fired boiler retrofitted with low-NO_x burners that fire North Dakota lignite coal. Downstream of the air preheater, flue gas passes a triple-wheel pebble lime spray dryer followed by a reverse-gas fabric filter with sonic horn cleaning.

Baseline removal at Stanton is negligible. The mercury removal measured across the SD-FF resulting from injecting different concentrations of Norit FGD activated carbon and an iodine-treated carbon is shown in Figure 9. The maximum mercury removal measured for the FGD carbon during the parametric tests was less than 70% removal at an injection concentration of 5 lb/MMacf. The results from the iodine-impregnated carbon injection were significantly better, achieving 66% removal at 0.4 lb/MMacf, and 96% removal at an injection rate of 0.7 lb/MMacf. These results were from very short-term tests and longer-term tests should be repeated to verify performance and assure no balance-of-plant issues are associated with injecting iodated carbon. This improved performance with a chemically treated sorbent is further indication that the spray dryer removes a component critical to the effective performance of untreated activated carbon.

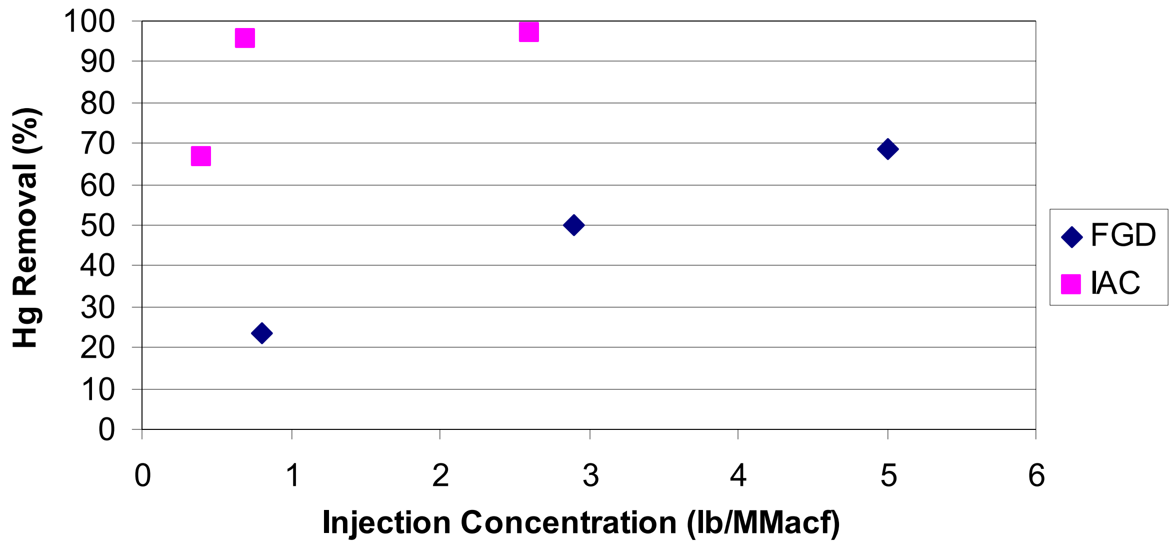

Figure 9. Mercury Removal Measured Across the Spray Dryer and Fabric Filter at Stanton Station During Parametric Testing *(Injection concentration calculated at SD inlet temperature)*

CONCLUSIONS

Limited data are available to assess the variability of mercury emissions and control options for coal-fired power plants. However, based upon data from the EPA ICR effort and data from pilot and full-scale studies sponsored by DOE/NETL and EPRI, several general trends can be identified. These include:

- The subbituminous coals and ND/MT lignites produce very similar concentrations of mercury, dominated by the elemental species.
- Non-western bituminous coals have the highest fraction of oxidized mercury.
- The Texas lignites appear somewhat different than the other low-rank fuels in that they produce a larger percentage of oxidized mercury.
- Baseline or “native” mercury removal in non-western coal-fired units with cold-side ESPs is highly variable, ranging from 1 to 98%. The LOI, temperature and fraction of oxidized mercury coupled with the air pollution control device are all contributors to this variation in removal.
- Baseline mercury removal in low-rank coal-fired units is low for all configurations except a stand-alone baghouse (no spray dryer; not COHPAC) on units burning subbituminous coals. For these units, an average of 70% removal is achieved in baseline measurements. This configuration applies to about 10% of the units firing subbituminous coals.
- Plants that burn Texas or ND/MT lignites operate at higher flue gas temperatures than plants burning subbituminous coals. This explains the lower natural capture measured at lignite plants. It also produces a more difficult environment for sorbents such as activated carbon to capture mercury.
- Cold-side ESPs are installed on >50% of plants burning low-rank coals. The natural mercury removal across cold-side ESPs is fairly low for all units evaluated. Untreated activated carbon can be injected upstream of the ESP to remove up to 70% of the incoming mercury. Treated sorbents or a TOXECON configuration may be required for higher mercury removal.
- Cold-side ESPs are installed in nearly 80% of plants burning non-western bituminous coals. The natural mercury removal ranges from 8 to 88%. Untreated activated carbon can be injected upstream of the ESP to remove >70% of the incoming mercury for plants burning low sulfur coals. High sulfur levels appear to be detrimental to mercury removal by fly ash and activated carbon.
- The TOXECON configuration offers an option for ESP users to control mercury and not compromise the quality of their fly ash.
- Significant (>50%) mercury removal may not be practical with sorbent injection alone for wet particulate scrubbers.

REFERENCES

1. Starns, T., C.J. Bustard, M.D. Durham, C. Lindsey, C. Martin, R. Schlager, B. Donnelly, S. Sjostrom, P. Harrington, S. Haythornthwaite, R. Johnson, E. Morris, R. Chang and S. Renninger (2002). *"Full-Scale Test of Mercury Control with Sorbent Injection and an ESP at Wisconsin Electric's Pleasant Prairie Power Plan."* 95th A&WMA Annual Meeting, Session AE-1, Baltimore, MD, June 23-27.
2. Bustard, J., et al (2001). *"Full-Scale Evaluation of Mercury Control with Sorbent Injection and COHPAC at Alabama Power E.C. Gaston."* Presented at the "A&WMA Specialty Conference on Mercury Emissions: Fate, Effects and Control," Chicago, IL, August 21 –23.
3. Sjostrom, S., T. Ebner, R. Slye, R. Chang, M. Strohfus, J. Pelerine, S. Smokey (2002). *"Full-Scale Evaluation of Mercury Control at Great River Energy's Stanton Generating Station Using Injected Sorbents and a Spray Dryer/Baghouse."* Presented at the Air Quality III Conference, Session A3b.
4. Sjostrom, S., R. Chang, T. Hagley, A. Rudek and J. Skelton, T.Ebner and R. Slye (2003). *"Full-Scale Evaluation Of Mercury Control Across A Wet Particulate Scrubber."* Presented at the Combined Power Plant Air Pollutant Control Symposium, May 19-22.
5. EPA website, www.epa.gov/ttn/atw/combust/utiltox/utoxpg.html.
6. Sjostrom, S., Bustard, J., M. Durham, and R. Chang (2002). *"Mercury Removal Trends and Options for Coal-Fired Power Plants with Full-Scale ESPs and Fabric Filters."* Nineteenth Annual International Pittsburgh Coal Conference, Pittsburgh, PA, September 23-27.
7. Senior, C.; J. Bustard, K. Baldrey, T. Starns, and M. Durham (2003). *"Leaching Studies of Fly Ash from Full-Scale Demonstration of Sorbent Injection for Mercury Control on Coal-Fired Power Plants."* The Mega Meeting: Power Plant Air Pollution Control Symposium, Washington, D.C., May 19-22.