

CONTROL OF MERCURY EMISSIONS FROM COAL COMBUSTORS

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ABSTRACT

Injection of activated carbon sorbents has been shown in laboratory and field situations to control total mercury (Hg) emissions from municipal waste combustors (MWCs). Efforts are currently underway to extend this experience to control emissions of Hg from coal-based power units. However, to achieve high removal of Hg (approximately 90 percent) from flue gas, the activated carbon to Hg ratio (by weight) has been found to be significantly higher in coal-based units than in MWCs. In order to optimize Hg removal for coal-based units, we performed bench-scale experiments to study capture of three species of Hg: elemental (Hg^0), mercuric chloride (HgCl_2), and mercuric oxide (HgO) by different activated carbon sorbents at temperatures (100 and 140 °C) and Hg concentrations (~ 1 ppb Hg) representative of applications in coal combustors. This paper also reports a comparison of these results with our earlier investigations of Hg control under MWC conditions.

INTRODUCTION

The Environmental Protection Agency (EPA) "mercury" report to Congress¹ cites the largest emitters of mercury (Hg) as coal-fired utilities, medical waste incinerators (MWIs), municipal waste combustors (MWCs), chlor-alkali plants, copper and lead smelters, and cement manufacturers. These sources account for 90 to 100 percent of anthropogenic Hg emissions. All the sources listed above, except the coal-fired utilities, are subject to intended, proposed, or existing regulations. The EPA "mercury" report suggests the likelihood of utility boilers' being listed under Section 112 of the Clean Air Act Amendments (CAAA)². This will enable EPA to identify Hg emitting utility boilers and promulgate technology-based pollution control requirements.

There are several methods of Hg control either being used or tested in waste incineration plants (MWIs and MWCs). These include a variety of chemical, adsorption, and absorption techniques³. Primarily, dry sorbent injection (DSI) followed by a fabric filter (FF), a spray dryer (SD) followed by a FF, and wet scrubbing have been tested to determine Hg control. A database is available^{4,5,6} on the levels of Hg control achieved in field tests employing these techniques.

Apart from field tests, laboratory work has also been conducted by investigators^{7,8,9,10} to study Hg capture by solid sorbents in MWCs. All tests show that existing flue gas desulfurization units (SD/FF and wet scrubber systems) with the addition of DSI lead to consistently high (> 90 percent) Hg removal in MWCs.

The concentration of total Hg found in the flue gas of a coal-fired utility is typically at least an order of magnitude lower than that found in a MWC flue gas. Moreover, the flue gas composition [in particular, hydrogen chloride (HCl) concentration] of a coal-fired unit differs from that of a MWC unit which may lead to the existence of different proportions of the species of Hg [that is, the fractions of elemental mercury (Hg^0), mercuric chloride (HgCl_2), and mercuric oxide (HgO) -- the three species that exist at equilibrium¹⁰ in the flue gas]. Because of these factors -- mainly concentration and speciation of Hg -- there is uncertainty in extending the technology for MWC Hg capture to Hg control in coal-fired utilities.

Existing flue gas cleaning devices -- particulate and sulfur dioxide (SO_2) removal -- have shown varying levels of Hg control¹¹⁻¹⁹. Hg control achieved through various particulate and flue gas desulfurization devices is summarized in Table 1. To resolve uncertainties regarding emissions, the Pittsburgh Energy Technology Center (PETC) of the Department of Energy (DOE) has initiated a program to characterize toxic emissions from coal-fired electric utilities. Table 2 lists the capture of Hg in four of the eight power stations that are to be assessed in the DOE program. The results shown in Tables 1 and 2 suggest the need for additional control processes in coal-fired utilities to consistently achieve high (> 90 percent) Hg removal.

Duct injection of activated carbon has been proposed as an additional process for achieving high levels of Hg removal in coal-fired utilities. This relatively simple add-on technology has been tested by investigators^{11,16,20} in pilot-scale units.

In the pilot-plant studies of Felsvang et al.¹⁶, injection of activated carbon achieved Hg removals greater than 90 percent. The high removals reported by Felsvang were for each of two types of coals. However, to achieve 90 percent Hg removal by injection of activated carbon in each case, the required amounts of activated carbon differed by a factor of five. This was thought to be due to differences in Hg speciation in the flue gas. This conclusion would be contrary to the tests of Chang et al.¹¹ which showed no dependence of Hg removal on Hg species.

Chang et al.'s¹¹ slipstream study concluded that injection of activated carbon before a FF is capable of removing Hg. The results suggested a dependence on the flue gas temperature and the amount of activated carbon used in determining the fraction of Hg removed. For temperatures around 120 °C, they reported a carbon:Hg weight ratio of 3,000:1 for high Hg removal. Pilot plant studies conducted at the University of North Dakota's Energy and Environmental Research Center (UNDEERC)¹² employing different coals, however, showed lower Hg removal (60 percent) with activated carbon injection at a similar carbon:Hg weight ratio.

At a carbon:Hg ratio of 3000:1 and an activated carbon cost of \$ 1.125/kg, our estimates indicate that the material cost would be \$ 500,000 per year for a 500 MW power plant. Chang et al.¹¹ report an annual cost of carbon injection of \$ 100,000 - \$ 1 million for Hg control in a 500 MW

plant. These estimates can vary depending on equipment, installation, and disposal costs. The significant additional costs associated with Hg removal in coal-fired utilities emphasize the need for process optimization.

The factors found to influence Hg removal in the field studies were coal type (leading to different Hg speciation), activated carbon injection rate or method (or both) and type, and flue gas temperature. Bench-scale studies are convenient in order to study the individual effects of these parameters on Hg capture in a controlled environment. Most of the bench-scale efforts have been directed at studying Hg control in MWC situations (that is, relatively higher concentration of Hg)⁷⁻¹⁰. Livengood et al.²¹ have studied Hg capture in bench-scale absorbers in nitrogen (N₂)/air, but, their studies were limited to Hg⁰. Moreover, the Hg⁰ concentration in their experiments was approximately 5-11 ppb, compared to approximately 1 ppb total Hg for most coal-fired utilities. Morency²² studied bench-scale Hg capture in simulated flue gas to quantify Hg⁰ and HgCl₂ capture by activated carbons. Here, too, the inlet Hg concentration was much higher (roughly 13 ppb) than found typically in coal flue gas. Hg capture observed at the higher concentrations may not be the same at lower Hg concentrations due to the non-linear effect of concentration on mass transport and sorption kinetics. Also, the HgCl₂ in Morency's study was produced by reacting Hg⁰ with HCl which produced very small quantities of HgCl₂ (5-10 percent of total). This may lead to errors in quantifying the separate capture of each species of Hg by activated carbons.

In this paper, we have studied the capture of low concentration Hg⁰ (less than 2 ppb) and HgCl₂ (approximately 1 ppb) by two types of activated carbons. The experiments were conducted with only a single Hg species present in the gas stream in order to obtain information on the capture of each individual species of Hg. The capture of the two Hg species was studied at two temperatures -- 100 and 140 °C. In addition, capture of HgO by the two activated carbons and hydrated lime [Ca(OH)₂] has been studied in this investigation. Finally, a comparison is made between low concentration Hg control (coal-fired utility) and high concentration Hg control (MWC situation) results obtained in our earlier studies⁷⁻¹⁰.

SORBENTS

Two types of activated carbons, namely PC-100 and FGD (manufactured by American Norit Company, Inc.), were used in this study as in previous field studies²³. PC-100 is bituminous-coal-based activated carbon, and FGD is derived from lignite. Both the carbons are thermally activated. PC-100 has a BET surface area of 964 m²/g compared to 547 m²/g for FGD. The mass median diameters (obtained by gravity sedimentation) for PC-100 and FGD were 17.55 and 6.80 μm, respectively. The details of their physical characteristics, including the pore size distributions, are given in an earlier study⁸. Apart from the two activated carbons, reagent grade Ca(OH)₂ was used in this study to compare its capture of HgO with the two activated carbons. The Ca(OH)₂ sample has a BET surface area of 13 m²/g.

EXPERIMENTAL PROCEDURES

Hg⁰

Figure 1 shows the schematic of the bench-scale apparatus used to study capture of Hg^0 by PC-100 and FGD. The apparatus has been used to study Hg^0 capture by sorbents in earlier studies⁷. Unlike the previous studies, the concentration of Hg^0 used in this study (~ 1 ppb) was very near the detection limit of the online Hg analyzer (Ametek, Model 400). The Hg analyzer was used to provide only an estimate of the Hg^0 concentration in the gas stream. Since online analysis of Hg^0 was not possible, the samples were directly analyzed for total Hg. Therefore, all experiments were conducted in batches (differing in time of exposure of sorbent to Hg^0).

The reactor (see Figure 1) was typically loaded with 100 mg of fresh test carbon in stage 1 followed by two stages of fresh PC-100 (100 mg each) as breakthrough traps (stages 2 and 3). The three stages [i.e., the test (either PC-100 or FGD) and the two sections of PC-100] were separated by glass wool.

After establishing a Hg^0 baseline (based on a reading from the online analyzer), the gas stream was passed through the reactor where the activated carbons (maintained at a set temperature) capture Hg^0 for 8 to 24 h as indicated in Figure 3. The experimental procedure (i.e., positioning of valves) has been described earlier^{7,8}. At the end of the fixed duration, the Hg^0 stream was diverted away from the activated carbons. The three stages were then separately analyzed using x-ray fluorescence (XRF) for total Hg. Two tests were run for a single datum.

The percentage Hg^0 capture by PC-100 or FGD after exposure to Hg^0 for time t , ϕ_t was calculated as:

$$\phi_t = [\alpha_1 / (\alpha_1 + \alpha_2 + \alpha_3)] * 100 \quad (1)$$

where α_1 , α_2 , and α_3 are the total Hg measured (ppmw using XRF) in each of the three sequential reactor stages (see Figure 1). In all of our experiments, the fraction of total Hg capture in stage 3, $\alpha_3 / (\alpha_1 + \alpha_2 + \alpha_3)$, was less than 0.1, indicating little, if any, Hg^0 breakthrough.

HgCl₂/HgO

The schematic (Figure 2) of the experimental setup for studying HgCl_2 or HgO capture is similar to that for Hg^0 capture. HgCl_2 or HgO powder was placed in a diffusion vial in the furnace (generator) to provide the source for the two Hg compounds. N_2 is the carrier gas for both HgCl_2 and HgO .

Unlike the online Hg^0 analyzer which provided a rough estimate of the Hg^0 concentration in the gas stream, there is no such instrument for the HgCl_2 or HgO setup. Therefore, trial runs established the necessary furnace temperatures to produce the desired concentrations of either HgCl_2 or HgO . The measurement of the HgCl_2 or HgO concentration in the gas stream proceeded by analyzing for total Hg in each stage of the sorbent bed. The fraction of HgCl_2 or HgO captured by the sorbents is obtained as described earlier [from Equation (1)].

ANALYSIS OF Hg SPECIES IN FGD, PC-100, AND $\text{Ca}(\text{OH})_2$

XRF was employed to quantitatively determine total Hg captured in each of the three stages. Standards were prepared for each sorbent type [the two activated carbons and $\text{Ca}(\text{OH})_2$] by doping with known concentrations of Hg solution. The XRF machine (Siemens, Model SRS303) was calibrated for each sorbent in the 0-9 and 0-50 ppm range using these standards. A linear correlation for each sorbent was obtained in both ranges. The strength of the XRF signals obtained from the analysis of sorbents from our experiments was matched with these correlations to obtain the Hg species concentration in the solid samples.

The accuracy of XRF calibration was verified by comparing with the results of the online analyzer (for Hg^0). Here, a single stage of PC-100 (100 mg) was loaded in the reactor and exposed to 30 ppb of Hg^0 . Integration of the signal from the online analyzer gave an estimate of the Hg in PC-100. The sample was then unloaded from the reactor and analyzed employing XRF. A very close match was seen between the two methods of analysis, indicating the reliability of the XRF technique to measure Hg in samples. Periodically, samples used for calibrating the XRF machine were also analyzed through cold vapor atomic absorption (CVAA) as a further measure of data quality. Results from the CVAA analysis showed that the samples used for calibrating the XRF machine were within 10 percent of the XRF value.

RESULTS AND DISCUSSION

Hg⁰ Capture

Figure 3 shows the capture of 2 ppb Hg^0 (in N_2 gas) by 100 mg of PC-100 and FGD at 100 and 140 °C. The face velocity is 5.5 m/min (18 ft/min) and the bed depth is roughly 0.3 cm.

It can be seen from Figure 3 that PC-100 captures a higher percentage of incoming Hg^0 compared to FGD at both temperatures. PC-100 captures 80-90 percent of incoming Hg^0 up to an exposure time of 24 h. On the other hand, FGD captures 30-50 percent of incoming Hg^0 at 100 °C and 10-30 percent of incoming Hg^0 at 140 °C. Qualitatively, similar results were obtained when PC-100 and FGD were exposed to 30 ppb Hg^0 during MWC studies⁹.

The capture of Hg^0 by PC-100 does not seem to be affected by temperature; whereas, the capture of Hg^0 by FGD is lower at 140 than at 100 °C. A similar trend in Hg^0 sorption with temperature was seen for FGD when exposed to 30 ppb Hg^0 in N_2 ⁹. This is perhaps indicative of a physisorptive mechanism of Hg^0 capture by FGD.

Despite the long exposure periods (24 h), the amount of Hg^0 captured per gram of PC-100 or FGD is far lower than in our earlier study⁹. For example, after 24 h of exposure, the amount of Hg^0 (mg) per gram of PC-100 is 0.06 (in this study) compared to 0.2 mg/g of PC-100⁹ after only 4 h of exposure. This is because the inlet Hg^0 concentration in the current study is lower by a factor of 15. The lower Hg^0 concentration in this study is representative of conditions in a coal flue gas and the higher concentrations in our earlier study⁹, that of conditions in a MWC. Hence, it is very likely that activated carbon would be highly under-utilized with respect to its potential of Hg^0 capture in a coal-fired unit.

A high utilization of the activated carbon with respect to its potential for Hg^0 capture is critical for an economical Hg removal process. Unlike the high HCl concentrations present in a MWC flue gas, the level of HCl is lower in a coal flue gas. This possibly accounts for higher Hg^0 levels in the latter¹⁰. Therefore, high capture of Hg^0 becomes important in a coal-fired utility. High capture of Hg^0 with the least amount of activated carbon (thereby increasing the utilization of the activated carbon) would reduce operating costs.

The carbon/ Hg^0 exposure time is equal to the time between cleaning the particulate collection devices. This time is controlled by the solids handling capacity (or pressure drop) of the device. By injecting activated carbon in pulses downstream of the particulate collection device (and upstream of a secondary collection device for carbon), the time that the carbon particle is exposed to Hg^0 can be substantially increased. Hence, the amount of Hg^0 in the carbon particle would be higher, thereby reducing the material cost. Moreover, this process would allow for regeneration of the spent activated carbon as the secondary particulate collection device traps only the carbon.

HgCl₂ Capture

Hg speciation of MWC flue gas has shown Hg to exist in the oxidized form (Hg^{++}), although the exact distribution of the different Hg^{++} species is unclear. However, our equilibrium studies¹⁰ have indicated that presence of minor quantities of HCl in the flue gas leads to a significant fraction as HgCl_2 .

Figure 4 shows the capture of HgCl_2 by PC-100 and FGD at 100 and 140 °C. The concentration of HgCl_2 in the gas stream varied from 0.4 to 0.7 ppb. The experimental conditions (i.e., face velocity, bed depth, sorbent amount) were the same as those for studying Hg^0 capture by these sorbents.

Similar to Hg^0 capture results (see Figure 3), PC-100 captures a higher percentage of incoming HgCl_2 than FGD at each temperature. This behavior is in agreement with our earlier studies involving high concentration (30 ppb) HgCl_2 ¹⁰. In the earlier study¹⁰, we had seen that both PC-100 and FGD captured a higher fraction of HgCl_2 at 100 °C than at 140 °C. This is also in agreement with our current findings for PC-100 at the low concentrations. However, FGD seems to capture higher amounts of HgCl_2 at 140 °C. The percentage of HgCl_2 captured by PC-100 is around 55-65 percent at 100 °C and around 45 percent at 140 °C for the various exposure times tested (see Figure 4). In our earlier study¹⁰, the percentage of HgCl_2 captured by PC-100 was 90-95 percent and 75-95 percent at 100 and 140 °C, respectively, for similar exposure periods. That is, smaller fractions of HgCl_2 are captured by PC-100 when exposed to lower concentrations of HgCl_2 . The same conclusion is drawn for FGD from a comparison with our earlier results¹⁰. Two factors that could possibly cause a non-linear sorption behavior (with respect to HgCl_2 concentration) in FGD and PC-100 are intraparticle mass transport and the sorption isotherm.

Our calculations show that exposure of 100 mg of PC-100 to 0.5 ppb of HgCl_2 for a duration of 24 h results in approximately 0.0135 mg HgCl_2 / g of PC-100 (based on 70 percent capture of incoming HgCl_2 at 100 °C). From our past study¹⁰, we found that 100 mg of PC-100 captures

0.17 mg of HgCl_2 . That is, similar to the results with Hg^0 capture, activated carbon would be highly under-utilized with respect to its potential for HgCl_2 capture. In order to effectively utilize activated carbon's Hg capture potential, longer exposure times to Hg are desirable. This can be achieved as explained in the section on Hg^0 capture by providing a secondary collection unit solely for activated carbon.

HgO Capture

The two main species of Hg that exist in equilibrium in a flue gas are Hg^0 and HgCl_2 . A third, but not significant species (according to equilibrium predictions at 600-800 °C), is HgO . There has been no reported data in the literature on HgO capture by dry sorbent injection.

Figure 5 shows the capture of HgO (1 ppb in N_2) by 100 mg of FGD at 100 and 140 °C. The data show that roughly 35-45 percent of the incoming HgO is captured by FGD. This value is approximately the same as that seen for capture of Hg^0 and HgCl_2 by FGD at the two temperatures. Unlike the capture of Hg^0 and HgCl_2 by FGD, however, the capture of HgO appears to be insensitive to temperature between 100 and 140 °C.

The temperature of the furnace (HgCl_2/HgO generator) encasing the diffusion vial (see Figure 2) is the controlling factor in determining the concentration of HgCl_2 or HgO in the gas stream. Higher furnace temperatures were required to generate HgO than HgCl_2 for identical amounts of each species in the vapor phase. This is indicative of HgO having a lower volatility than HgCl_2 . However, the lower volatility of HgO did not result in higher capture (compared to the other two Hg species) by FGD. Our earlier studies⁹ showed that certain active sites in carbons are responsible for Hg^0 capture. Also, the affinity between HgCl_2 and activated carbon is probably due to an acid/base interaction¹⁰. Here, HgCl_2 is acidic in nature and, depending on the manufacturing process, activated carbon can be basic in character. HgO , however, is reported to be an extremely weak base when dissolved in water²⁴. The same percentage of capture of HgO as HgCl_2 despite HgO 's lower volatility may be explained by a weaker interaction between HgO and FGD.

$\text{Ca}(\text{OH})_2$ has been shown to capture high fractions of incoming HgCl_2 ¹⁰. The reason for the high capture is postulated to be an acid/base reaction. Figure 6 shows the capture of 10 ppb of incoming HgO by reagent grade $\text{Ca}(\text{OH})_2$ (the same material used in our earlier study). Roughly 5-20 percent of incoming HgO is captured. The fraction of HgCl_2 captured by $\text{Ca}(\text{OH})_2$ on the other hand is much higher (45-90 percent)¹⁰. This is in agreement with the postulate of a weaker interaction of HgO with the sorbents.

A comparison of the percentage of incoming HgO captured by PC-100, FGD, and reagent grade $\text{Ca}(\text{OH})_2$ at 100 and 140 °C can be seen in Figure 6. Here, the concentration of HgO is 10 ppb in N_2 . Similar to the results seen for HgCl_2 capture, PC-100 exhibits the highest reactivity followed by FGD. However, unlike the HgCl_2 capture results, PC-100's and FGD's performance is not significantly affected by temperature. This is in agreement with the results shown in Figure 5 (1 ppb of HgO).

SUMMARY AND CONCLUDING REMARKS

Two types of activated carbons -- PC-100 and FGD -- were tested for capture of low concentration (around 1 ppb) of Hg^0 and HgCl_2 . The two sorbents' potential for capture of the two Hg species was tested at two temperatures -- 100 and 140 °C. Experiments were also conducted to determine capture of HgO (1 ppb) by FGD. Finally, a comparison of the capture of HgO (approximately 10 ppb) by FGD, PC-100, and $\text{Ca}(\text{OH})_2$ was carried out.

In general, it was found that all sorbents [the two activated carbons and $\text{Ca}(\text{OH})_2$] capture higher amounts of each species of Hg at the lower temperature. The same behavior was observed in our earlier study^{9,10} with higher concentrations of Hg^0 and HgCl_2 . This is indicative of a physisorptive mechanism.

Results from the study on higher Hg^0 and HgCl_2 concentration capture¹⁰ by FGD and PC-100 showed that HgCl_2 was captured with greater ease than Hg^0 . This, however, was not the case in the current study. PC-100 was found to capture a higher fraction of the incoming Hg^0 than HgCl_2 at both temperatures. Also, FGD was found to capture similar fractions of Hg^0 and HgCl_2 .

A comparison with our earlier study¹⁰ showed that the fractional capture of incoming HgCl_2 was lower in this study (at the lower concentration). The reason for lower HgCl_2 (1 ppb case; current study) capture by PC-100 and FGD is perhaps the non-linear behavior of HgCl_2 capture by the activated carbons. Assuming linear dependence of external mass transfer on HgCl_2 capture, the possible cause could be non-linear dependence of intraparticle mass transport or sorption kinetics on HgCl_2 concentration.

A higher capture of Hg (mg Hg^0 or HgCl_2 per g of activated carbon) was seen in our earlier studies compared to the current studies. The amount of Hg^0 or HgCl_2 after only 4 h of exposure to 30 ppb of Hg was greater by an order of magnitude compared to the amount of Hg in activated carbons after 24 h of exposure at the lower concentration. This implies that employing the same procedure (injection of activated carbon before a particulate collection device) would require a larger activated carbon:Hg ratio in a coal-fired unit compared to MWC operation. The sorbent and, therefore, operating costs are bound to be higher in a coal-fired utility for identical Hg percentage removal. Activated carbon injected in a coal-fired flue gas can capture more Hg if left exposed to the flue gas until the carbon becomes saturated with Hg. In current practice, the time of exposure may be limited by the particulate collection device's solids handling capacity (pressure drop). Longer exposure time for carbon may therefore be achieved by injecting the particles after the main particulate collection device, but before a secondary particulate collection device (primarily for activated carbon).

Studies on capture of solely HgO (1 ppb) were conducted for the first time in this study. Similar capture as Hg^0 and HgCl_2 was found for FGD at the two temperatures. Experiments were also conducted to study HgO capture (10 ppb) by PC-100, FGD, and $\text{Ca}(\text{OH})_2$. At the higher HgO concentration, it was found that the fraction of HgO captured by FGD and $\text{Ca}(\text{OH})_2$ was lower than HgCl_2 captured¹⁰. The capture of HgCl_2 is postulated to be an acid/base reaction, with the three sorbents possessing basic properties. HgO is classified as a weak base in water and, hence,

the solid bases do not have the same capture mechanism for HgO as HgCl₂.

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TABLE 1. MERCURY CONTROL BY EXISTING DEVICES FOR PARTICULATE AND SULFUR DIOXIDE CONTROL

Control Device	Temperature °C	% Hg (Total) Captured	Reference No. /Cited By
Fabric Filter (FF)	96	50	11, Chang et al., 1993
"	99	33	"
"	107	27	"
"	121	20-80	12, Miller et al., 1994
"	135	10-60	"
"	204	8-30	"
Electrostatic Precipitator (ESP)	NA	26-40	13, Wesnor, 1995
Wet Scrubber (WS)	NA	94-98	14, Noblett et al., 1995
"	NA	30-95	19, Tomita et al., 1987
"	NA	10-90	PISCES database
"	NA	36	13, Wesnor, 1995
Hot ESP	NA	0	13, Wesnor, 1995
ESP and WS	NA	10-70 (avg 50)	18, Meij, 1991
"	NA	60 in Germany	"
"	NA	75 in Sweden	"
Spray Dryer (SD) and ESP	NA	88	17, Huang et al., 1991
	NA	57-79	15, Felsvang et al., 1992
SD and FF	NA	5-25 (low Cl coal)	16, Felsvang et al., 1993
"	NA	45-96 (high Cl coal)	"

TABLE 2. MERCURY CAPTURE AT FOUR OF THE EIGHT POWER PLANTS COMMISSIONED TO BE CHARACTERIZED BY DOE/PETC

Power Plant	Power (MW)	Control Device	% Hg (Total) Captured
Yates Unit No. 1 (Georgia Power Co.)	100	ESP and WS	50
Clay Boswell Energy Center Unit No. 2 (Minnesota Power Co.)	61	FF	70
Baldwin Power Stations Unit No. 2 (Illinois Power Co.)	565-575	ESP	25
Springville Generation System (Tuscon Electric Power Co.)	360	3 SD and 2 FF	15 across FF 25 across whole

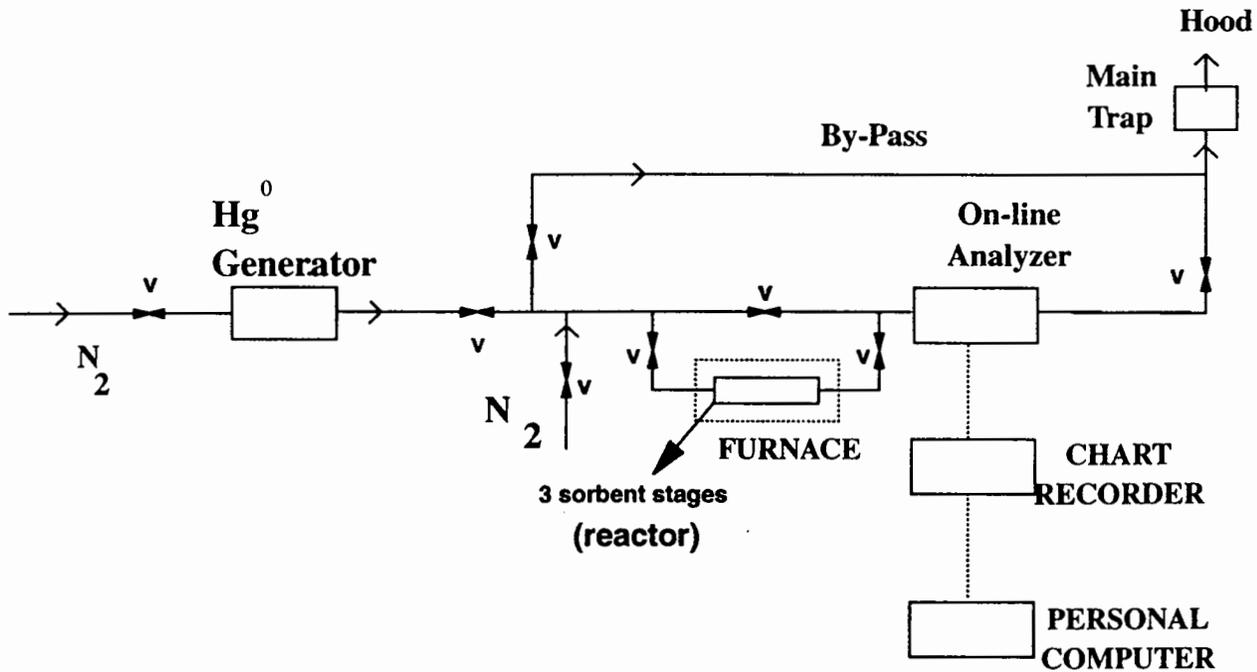


Figure 1. Schematic diagram of bench-scale apparatus used for Hg^0 sorption studies (v: valve).

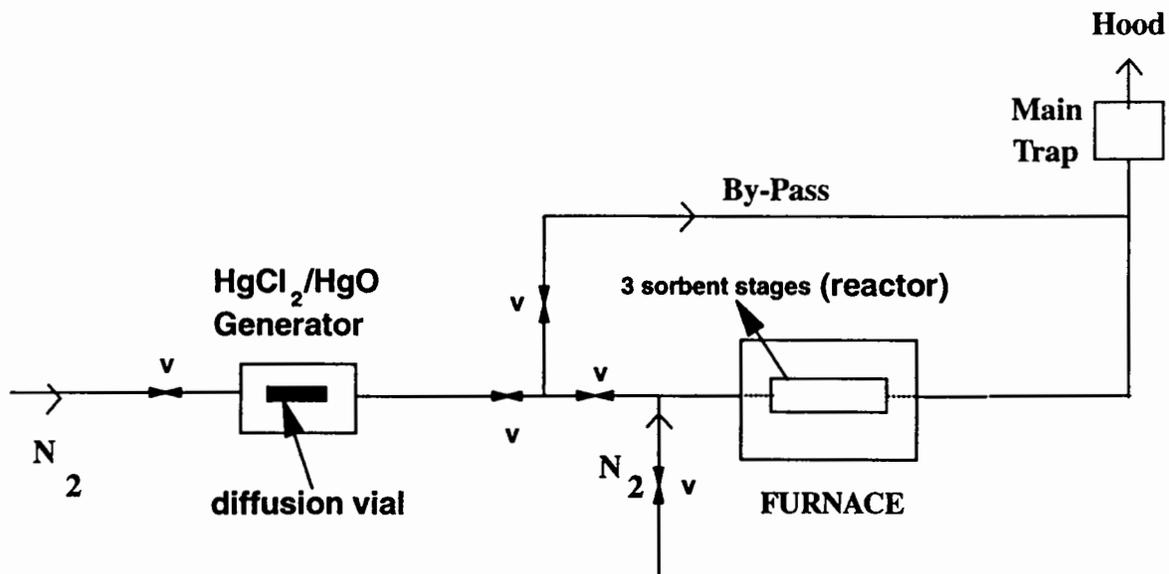


Figure 2. Schematic diagram of bench-scale apparatus to study HgO or HgCl_2 sorption (v: valve).

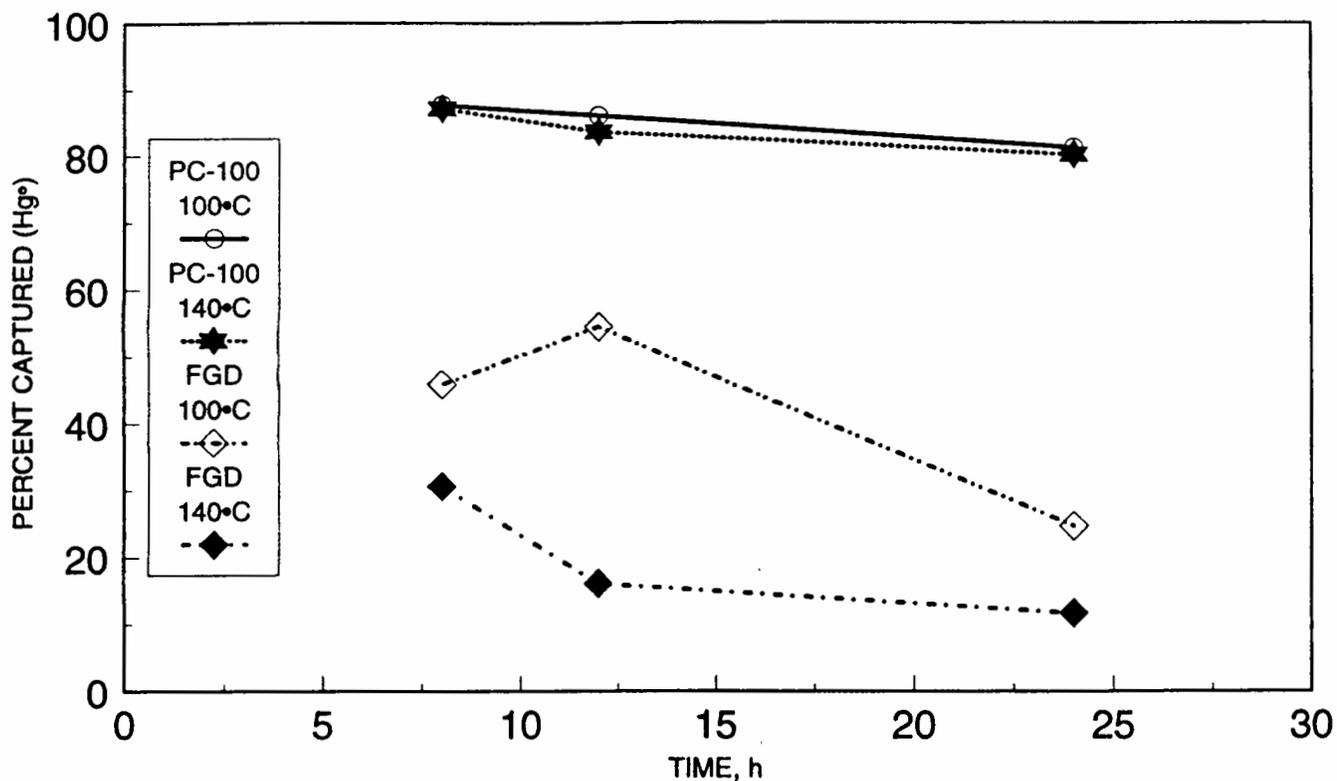


Figure 3. Capture of low concentration Hg⁰ (2 ppb) by PC-100 and FGD at 100 and 140°C.

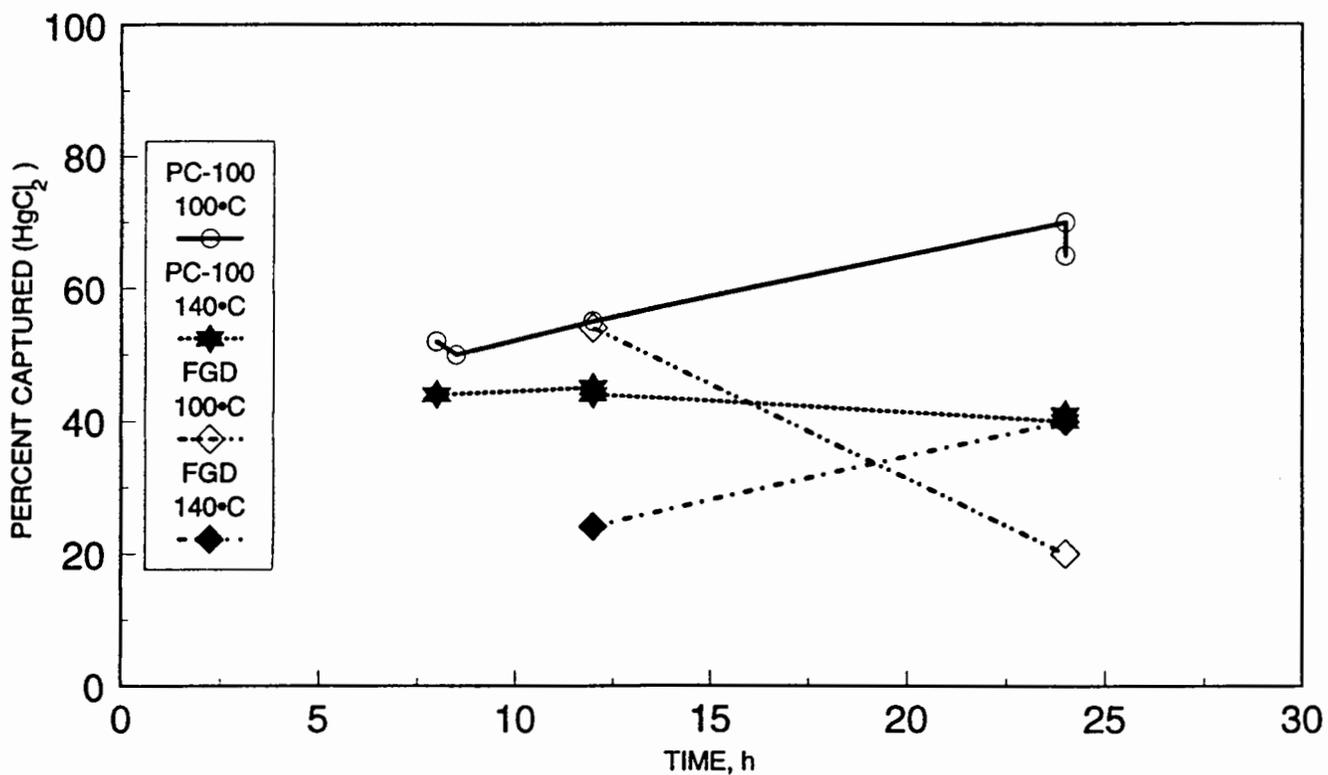


Figure 4. Capture of low concentration HgCl₂ (0.4-0.7 ppb) by PC-100 and FGD at 100 and 140°C.

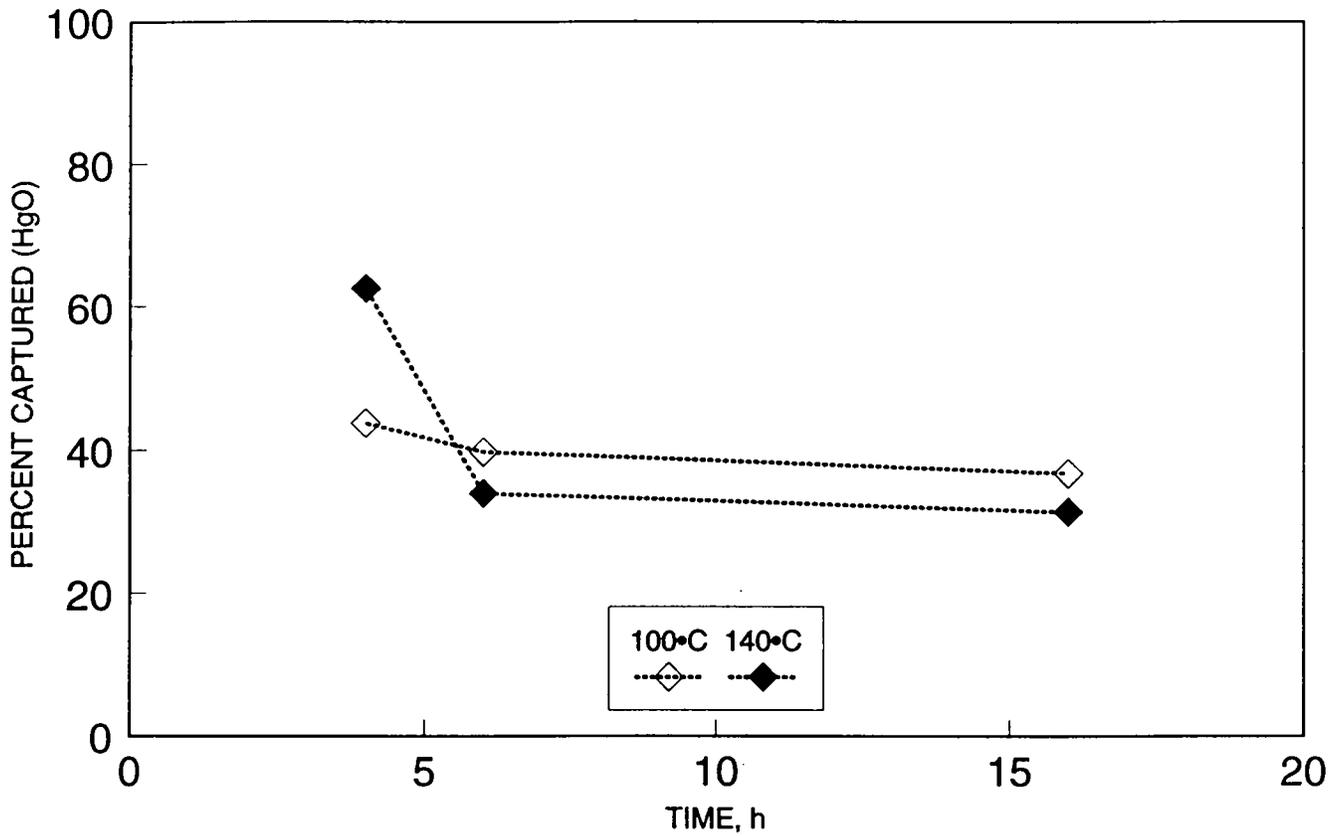


Figure 5. Capture of low concentration HgO (1 ppb) by FGD at 100 and 140° C.

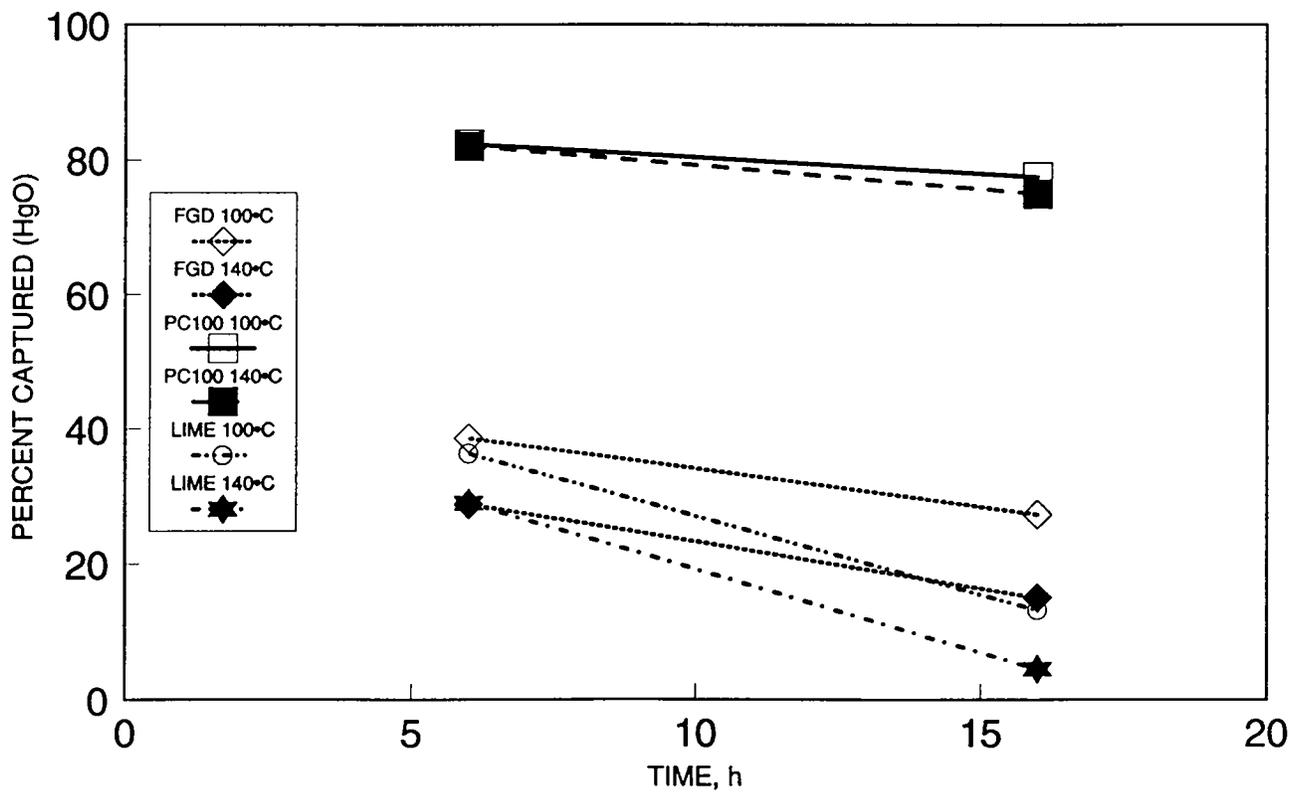


Figure 6. Capture of HgO (10 ppb) by PC-100, FGD, and Ca(OH)₂ at 100 and 140° C.

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16. ABSTRACT The paper reports results of bench-scale tests to determine the effects of injecting activated carbon sorbents to control total mercury (Hg) emissions from coal-based power units. To optimize the Hg removal, the experiments included the capture of elemental Hg, mercuric chloride, and mercuric oxide by different activated carbon sorbents at temperatures (100 and 140 C) and Hg concentrations (approximately 1 ppb Hg) representative of applications in coal combustors. The paper also reports a comparison of these results with earlier investigations of Hg control under Municipal waste combustion conditions.			
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