PILOT-SCALE PRODUCTION AND TESTING OF AN ILLINOIS COAL-DERIVED ACTIVATED CARBON FOR MERCURY REMOVAL

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Introduction

A carbon development study is in progress at the Illinois State Geological Survey (ISGS) and the University of Illinois (Urbana-Champaign) to develop low-cost, high reactivity coal-based sorbents for removal of trace amounts of vapor phase mercury (<10 ppb) from coal combustion flue gas. The results from an initial mass transfer analysis [1] showed that mercury transfer from the bulk flue gas to the external surface of carbon particles plays the dominant role in determining C/Hg ratio of the injection process. Intraparticle diffusion was found not to be important.

Guided by the these studies, several gram-sized quantities of Illinois coal-derived activated carbon (ICDAC) samples with desired properties were prepared in a 5-cm ID fluidized-bed reactor (FBR). The elemental and ionic mercury reactivities and capacities of the samples were comparable to a commonly used commercial product. In this paper the results of pilot-scale production and mercury removal testing of an ICDAC are presented.

Experimental

ISGS engineers worked with Svedala Industries (Oak Creek, WI) to prepare about 100 pounds of activated carbon from an Illinois coal in a batch, 46-cm ID FBR. The properties of the pilot-scale ACs were comparable to those prepared in the 5-cm ID FBR.

The mercury removal performance of the Illinois coal-derived activated carbon (ICDAC) and a commercial carbon were determined in a 500 scfm (0.25 MWe) pilot plant at CONSOL. The pilot plant can simulate flue gas conditions downstream of the air preheater in a coal fired utility power plant. The flue gas mercury concentration studied (10-15 $\mu g/m^3$) is typical of utility flue gas concentration. Mercury removals were evaluated in the flue gas duct, which provides a gas residence time of approximately 2 sec, and in the baghouse, where the solids retention times can be as high as 30 min. Common test conditions were: flue gas flow, 350 scfm; flue gas wet bulb temperature, 121-128 °F; flue gas composition, 1000 ppmv dry SO_2, 10 vol% dry O_2, and 10 vol% dry CO_2. All tests were conducted with a fly ash obtained from a coal-fired utility boiler firing an eastern bituminous coal. The fly ash feed rate was 10-11 lb/hr (solids loading of 3.2-3.7 gm/scf). Mercury removal was determined from the mercury feed rate, the solids (carbon and fly ash) feed rate, and mercury analysis of the feed and recovered solids (by combustion followed by cold vapor atomic absorption spectroscopy). Except where noted, all mercury removal results discussed in this paper include mercury removal by the carbon sorbent and the fly ash.

Results and Discussion

The ICDAC samples tested, identified as AC-F and AC-C, had mass median particle sizes of 5 and 8 μm, respectively. The commercial activated carbon, produced by Norit America Inc. (FGD), had a mass median particle size of 15 μm. Table 1 shows selected properties of the activated carbons.

At all test conditions studied, both ICDAC samples were as effective as the commercial activated carbon, and in many cases were significantly more effective. As shown in Figure 1, the effect of mercury species on removal at a carbon/mercury (C/Hg) weight ratio of 3,000 and 225 °F flue gas temperature was small. System removals of Hg° and $HgCl_2$ with AC-F were 52 and 47%, respectively. Removals with the Norit FGD were 44% with both mercury species. Figure 2 shows system mercury removals at flue gas temperatures of 275 and 325 °F and a 10,000 C/Hg weight ratio. At both conditions, AC-C and AC-F achieved significantly higher mercury removals than the Norit FGD carbon. With AC-F, Hg°removal was 77% and $HgCl_2$ removals were 64 to 69%. With the Norit FGD carbon, Hg° removals were 53% to 57% and $HgCl_2$ removals were 34 to 44%. Hg° and $HgCl_2$ removals at 275 °F with AC-C were about 84%. The data shown in Figure 2 do not demonstrate a pronounced effect on Hg° removal as flue gas temperature rose from 275 to 325 °F. $HgCl_2$ removal with AC-F and Norit FGD carbon decreased with increasing temperature. The absolute changes however, were small.

Test results from injecting fly ash alone at 275 °F showed Hg° and $HgCl_2$ removals of 9 (Hg°) and 15 ($HgCl_2$) duct and 31 (Hg°) and 23 ($HgCl_2$) system (duct+baghouse), and 8 (Hg°) and 15 ($HgCl_2$) duct and 25 (Hg°) and 33 ($HgCl_2$) system at 325 °F. If the fly ash mercury removal is assumed to be constant, then the incremental removal due to the activated carbon can be estimated by subtracting the fly ash contributions from the combined carbon plus fly ash

mercury removal tests.. AC-F Hg° system removal at flue gas temperatures of 275 and 325 °F and at 10,000 C/Hg weigh ratio were 46 and 52%, respectively, compared to 22 and 32% with the Norit FGD carbon. AC-F $HgCl_2$ system removals at these conditions were 46 and 31%, compared to Norit FGD removals of 21 and 1%, respectively. AC-C Hg° and $HgCl_2$ system removals at 275 °F were 53 and 60%, respectively. Duct mercury removals were low with both AC-F (7%(Hg°) and 2% ($HgCl_2$)) and FGD carbon (3% (Hg°) and 3% ($HgCl_2$)). AC-C duct removals were somewhat higher, 15% (Hg°) to 21% ($HgCl_2$).

The pilot plant duct provide a 2 s residence time. As shown in Figures 1 and 3, mercury removal in the duct is limited by bulk gas mass transfer. For most tests, the duct mercury removal was between 9 and 19%, and was independent of carbon type, carbon feed rate, temperature, or mercury species. This has been observed in previous activated carbon pilot-plant studies [2]. AC-C showed a somewhat higher in-duct $HgCl_2$ removal (36%), Figure 3. Reducing the mass median particle size of the carbons from 13-24 μm in the previous work [2] to as low as 5μm. in this work (Table 1) did not significantly increase mercury removal in the duct.

Conclusions

More than 100 pounds of activated carbon were produced from an Illinois coal in a pilot-scale FBR. This pilot production showed little difficulty with the scaling-up of the process. The results from pilot-scale mercury tests showed ICDAC has mercury removal capacity comparable or higher than a commercial carbon. Production costs of the ICDAC have been estimated to be considerably lower than those of commercial activated carbons. The ICDAC has also been tested in two utility demonstration sites (slip-stream). Results from these tests will be presented in future publications.

References

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Acknowledgment

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Table1. Select properties of activated carbon samples.

	AC-F	AC-C	FGD
Ash, dry wt%	24.7	18.6	33.1
MMD, m.	5.2	8.0	15.2
Surface area, m^2/g	671	688	546

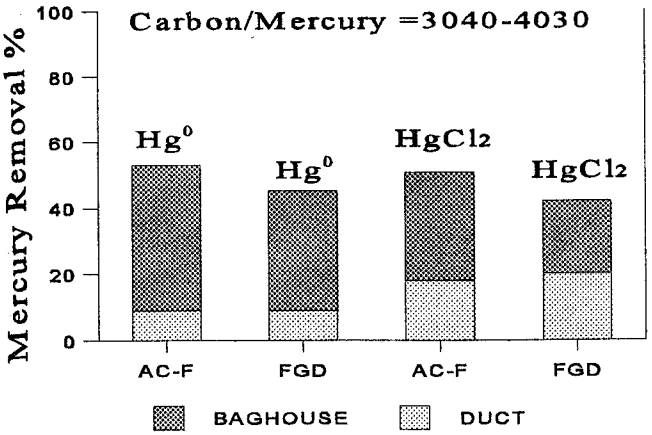

Figure 1. Effect of Contact Time on Mercury Removal at 225°F and 3000 C/Hg Weight Ratio.

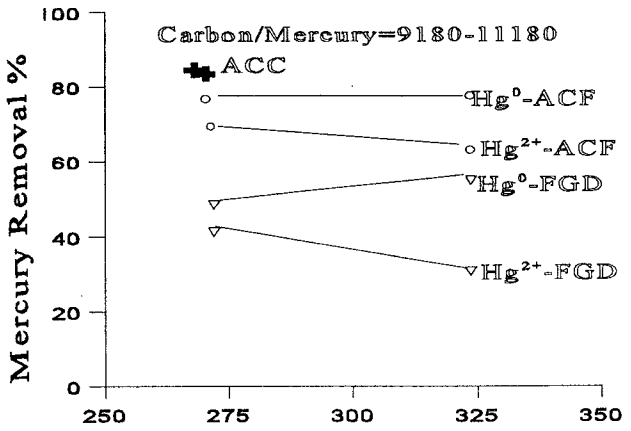

Figure 2. Effect of Temperature on System Mercury Removal at 275°F, 325 °F and 10,000 C/Hg Weight Ratio.

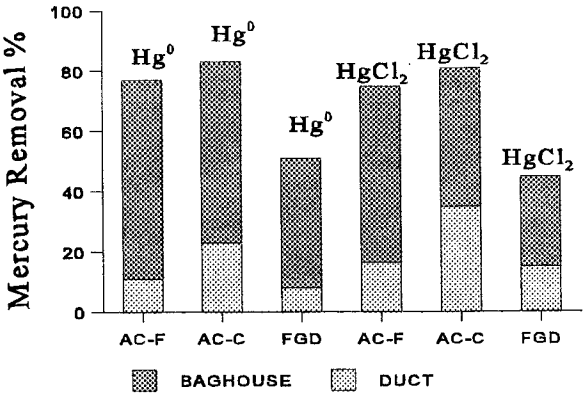

Figure 3. Effect of Contact Time on Mercury Removal at 275°F and 10,000 C/Hg Weight Ratio.