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ALKALI METAL VAPOR REMOVAL FROM PRESSURIZED FLUIDIZED-BED COMBUSTOR FLUE GAS

Annual Report, October 1979—September 1980

by

Irving Johnson, W. M. Swift,
and S. H. D. Lee

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Printed in the United States of America
Available from
National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

NTIS price codes
Printed copy: A03
Microfiche copy: A01

Distribution Category:
Coal Conversion and Utilization--
Direct Combustion of Coal
(UC-90e)

ANL/CEN/FE-80-16

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue
Argonne, Illinois 60439

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Chemical Engineering Division

October 1980

Prepared for the
U. S. Department of Energy
under Contract No. W-31-109-Eng-38
and the
U. S. Environmental Protection Agency
under Agreement IAG-D5-E681

Previous reports in this series

ANL/CEN/FE-80-4	October-December 1979
ANL/CEN/FE-80-5	January-March 1980
ANL/CEN/FE-80-6	April-June 1980

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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October 1979-September 1980

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ABSTRACT

In the application of pressurized fluidized-bed combustion (PFBC) to the generation of electricity, hot corrosion of the gas turbine (downstream from the combustor) by alkali metal compounds is a potential problem. The objective of this investigation is to develop a method for the removal of gaseous alkali metal compounds from the high-pressure high-temperature gas from a PFBC before the gas enters the gas turbine. The use of a granular bed filter, with either diatomaceous earth or activated bauxite as the bed material, is under study. Breakthrough data are reported on the sorption of gaseous NaCl by activated bauxite. Results are reported for the regeneration of activated bauxite using water leaching and a thermal swing method.

SUMMARY

Removal of Alkali Compounds from the Hot Flue Gas

In the potential application of pressurized fluidized-bed combustion of coal (PFBC) for power generation, corrosion of the turbine blades (in the downstream gas turbine) due to the presence of alkali metal compounds in the hot PFBC flue gas appears to be a problem. The objective of this task is to develop an effective sorbent for use in a hot, granular fixed-bed filter to remove alkali metal compounds from the hot flue gas before it is expanded through a gas turbine.

Earlier experiments identified activated bauxite and diatomaceous earth as effective sorbents at high temperature and atmospheric pressure for removing NaCl, KCl, and K_2SO_4 vapors from a simulated flue gas. Alkali sorption characterization of these two sorbents in a pressurized system has been started, using a pressurized alkali sorption test unit which is described in this report. The experimental results obtained from testing diatomaceous earth at 800°C and 9 atm indicated that 90% NaCl vapor removal from a simulated flue gas containing approximately 3 ppmV NaCl vapor was achieved with a 5-in.-thick bed operated for 25 h onstream time.

Preliminary pressure drop measurements across fixed beds of diatomaceous earth and activated bauxite were also made in the pressurized alkali sorption test unit, using a differential pressure transducer. Results show that, as expected, pressure drop increases with (1) increasing superficial gas velocity, (2) increasing bed depth, and (3) increasing system pressure.

A sectioned-bed technique has been developed to obtain alkali breakthrough data for a sorbent without direct analysis of the alkali vapor concentration in the simulated flue gas. The technique is described and illustrated in this report; activated bauxite was tested as a sorbent for removing NaCl vapor from flue gas at 800°C and atmospheric pressure. Test results show that operation of a 5-in.-thick activated bauxite bed for an onstream time of 4 h gave an average 0.1% breakthrough (or 99.9% NaCl vapor sorption efficiency).

Regeneration of activated bauxite has been investigated by (1) water-leaching and (2) thermal-swing processes. The regenerability of activated bauxite by water-leaching has been demonstrated in two cyclic experiments--a ten-cycle experiment of NaCl-vapor sorption and water-leaching regeneration and a five-cycle experiment of KCl-vapor sorption and water-leaching regeneration. It was concluded from these cyclic experiments that activated bauxite can be easily and effectively regenerated by a simple water-leaching process.

Studies to measure the rate of leaching showed that, on the average, 75% of the adsorbed NaCl was leached in the first five minutes of leaching and that this amount increased to 85% for one-hour leaching. The maximum leaching rate of the adsorbed NaCl was found to occur during the first five minutes of leaching. After that, the rate rapidly decreased and approached a constant value. The leaching rate also increased with increasing number of water-leaching regeneration cycles.

In experiments employing a thermal swing in the bed temperature to effect regeneration of sorbent, 40% of the adsorbed NaCl was desorbed in three hours when the bed temperature of 800°C was increased 45° to 845°C in N_2 purging gas. The extent of desorption was not significantly affected by increasing the thermal swing to 85°C.

INTRODUCTION

In the application of pressurized fluidized-bed combustion of coal to power generation, corrosion of the turbine blades (downstream from the combustor) due to attack by alkali metal compounds in the hot flue gas is a potential problem. This problem can be eliminated by reducing the concentration of alkali metal compounds in the hot flue gas to a level which can be tolerated by a gas turbine. A way to accomplish this would be to use a hot fixed-bed sorbent filter to remove the alkali metal compounds from the hot flue gas before it is expanded into the turbine. The objective of this task is to develop an effective sorbent and to obtain the necessary characteristic sorption parameters for the design of a hot fixed-bed sorbent filter.

Among the six commercial products screened in this work, diatomaceous earth and activated bauxite have been identified to be very effective in removing NaCl, KCl, and K_2SO_4 vapors from hot simulated flue gas of PFBC.[1] Also, activated bauxite has been found to be easily and effectively regenerated by a simple water-leaching process.[2] The studies completed were conducted under atmospheric pressure. To permit testing of both diatomaceous earth and activated bauxite for alkali-vapor removal under pressurized conditions, a high-pressure alkali-vapor sorption test unit has been set up during this reporting period. The initial experimental results of testing these two sorbents using this test unit are presented.

In order to obtain sorbent breakthrough data without direct analysis of the alkali vapor concentration in the simulated PFBC flue gas, a sectioned-bed technique has been developed. The development of the sectioned-bed technique is presented. Results are also reported on continuing studies to investigate (1) the regeneration of activated bauxite by both water-leaching and thermal swing methods, and (2) water-leaching regeneration kinetics.

I. TESTS OF DIATOMACEOUS EARTH AND ACTIVATED BAUXITE IN A PRESSURIZED SYSTEM

In earlier completed studies, diatomaceous earth and activated bauxite were tested under atmospheric pressure for their alkali vapor sorption performance. In the potential application of these sorbents in a granular fixed-bed filter, the filter will be operated at about 10-atm pressure; therefore, the sorption behavior of these two sorbents in a pressurized system needs to be characterized.

A. Description of Pressurized Alkali-Vapor Sorption Test Unit

This unit (Fig. 1) is designed so that tests to characterize sorbents for alkali removal from hot gas streams can be carried out at 900°C (or lower) and 10 atm (or lower). A detailed description of this test unit was presented in a previous quarterly report (ANL/CEN/FE-80-4). In this test unit, a known amount of pure alkali metal compound (such as NaCl and KCl) contained in a platinum sample pan is heated and vaporized inside a pure Al_2O_3 tube that is heated by a clam-shell type tubular resistance furnace. Preheated simulated flue gas of PFBC carries vaporized alkali metal compound downstream through (1) a bed of the sorbent to be tested and (2) a cold trap. The cold trap is used to condense alkali metal compound vapor not removed in the sorbent bed. Downstream from the cold trap, a glass-wool filter backing up the cold trap captures the alkali metal compound condensate. Minor modification of the equipment to improve the control and safety of the unit was described in a subsequent quarterly report (ANL/CEN/FE-80-6).

B. Sodium Chloride-Vapor Sorption Tests for Diatomaceous Earth

The performance of the test unit was checked out during two experiments made to test diatomaceous earth for NaCl-vapor capture at 800°C and 5-atm absolute pressure, using a simulated flue gas containing 16% CO_2, 3% O_2, approximately 7 ppm NaCl vapor, and the balance N_2. Very good NaCl material balances were obtained for the two shakedown experiments. Results obtained from these two runs (ANL/CEN/FE-80-4) show that diatomaceous earth is as effective in capturing NaCl vapor from flue gas at 5 atm as at atmospheric pressure.

Four additional experiments were made to test diatomaceous earth for the sorption of NaCl vapor as a function of experimental duration (7, 16, 20, and 25 h). In these experiments, a 5-in.-thick bed of sorbent was divided into five equal sections, using platinum gauze dividers. The tests were performed at a bed temperature of 800°C, a system pressure of 9 atm absolute, and a superficial gas velocity of 30 cm/s. The volumetric composition of the simulated flue gas was 5.1% O_2, 18.2% CO_2, 3.3% H_2O, and the balance N_2. To prevent corrosion of the test system, there was no SO_2 in the simulated PFBC flue gas. A measurement of the temperature profile along the axis of the sorbent bed, and NaCl material balances for these four tests, were reported and discussed in detail in an earlier report (ANL/CEN/FE-80-6).

The temperature profile measurement shows that with the center of the sorbent bed at about 800°C, the temperature of the entire 5-in.-thick bed can be controlled within 12°C. The upstream end of the bed is on the low side of

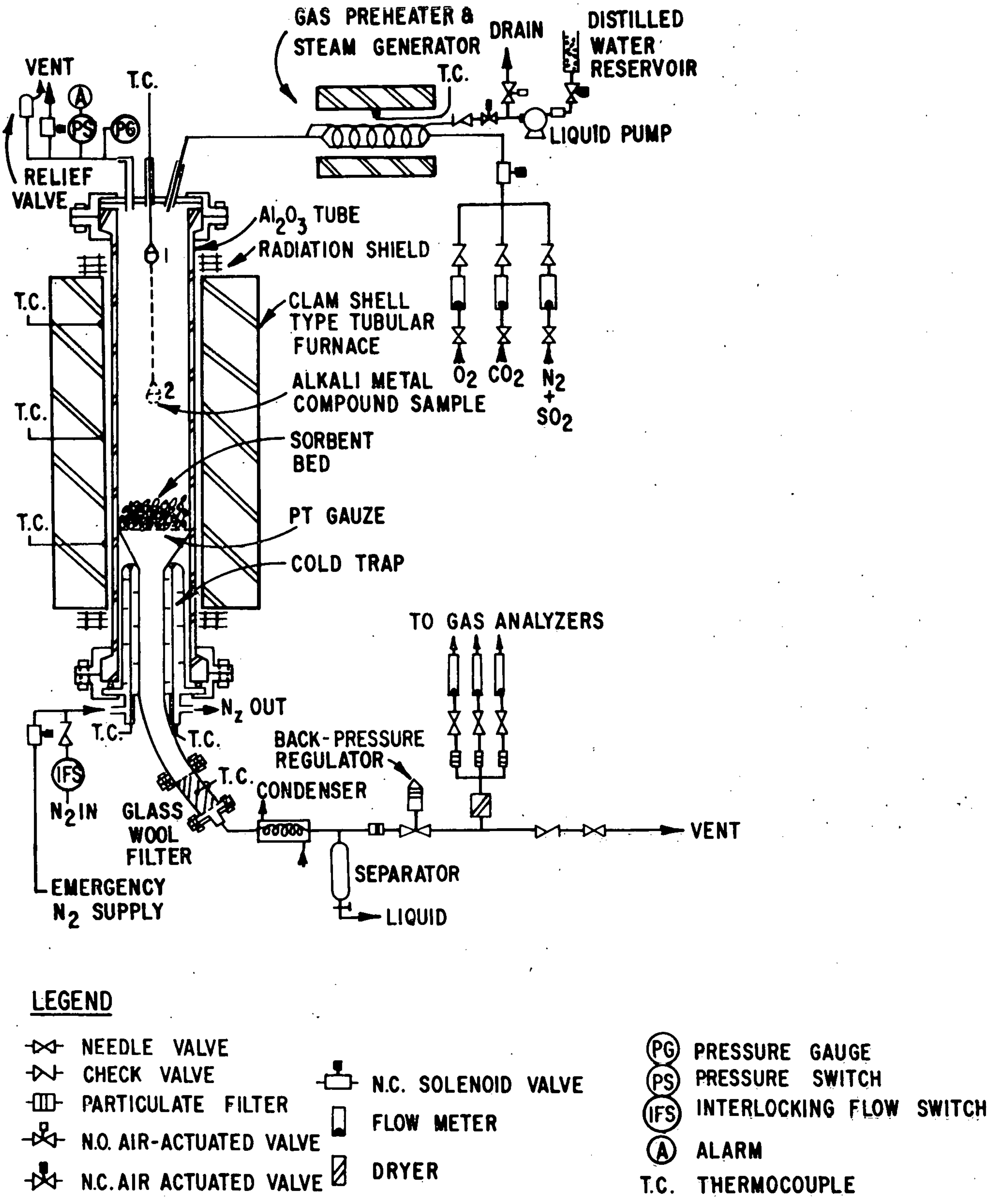

Fig. 1. Schematic of Pressurized Alkali-Vapor Sorption Test Unit

the average bed temperature; the downstream end of the bed is on the high side of the temperature.

In the four tests completed, an excursion from experimental conditions was observed in three of the experiments due to unexpected decreases in gas flow to the sorption test unit during the tests. The results obtained from the successfully completed experiment indicate that (on the average over the duration of the experiment), 90% NaCl vapor removal from a simulated flue gas containing approximately 3 ppmV NaCl vapor was achieved with a 5-in.-thick bed operated for 25 h onstream time at 800°C and 9 atm.

C. Preliminary Tests for Pressure Drop Measurement

Measurements of pressure drop across fixed beds of diatomaceous earth and activated bauxite were obtained as functions of system pressure, superficial gas velocity, and bed depth. The sorbent was packed inside the Al_2O_3 sorption tube of the sorption test unit, and the pressure drop was measured by using a differential pressure transducer.

For this series of pressure drop experiments, measurements were made using a fixed bed of -8 +10 mesh sorbent particles at approximately 800°C and hot simulated PFBC flue gas. The volumetric composition of the flue gas was 3% O_2, 16% CO_2, 5% H_2O, and the balance N_2. In this study, pressure drops were measured at system pressures of 5, 8, and 10 atm absolute pressure, superficial gas velocities of 10, 15, 21, and 27.5 cm/s for diatomaceous earth and 15, 21, and 27.5 cm/s for activated bauxite, and sorbent bed thickness of 5, 8, and 10 in. for diatomaceous earth and 5, 8, and 12 in. for activated bauxite.

Results of these pressure drop measurements were given in a previous quarterly report (ANL/CEN/FE-80-5). Results show that, as expected, pressure drop increases with (1) increasing superficial gas velocity, (2) increasing bed thickness, and (3) increasing system pressure. When the superficial gas velocity increases from 15 to 27.5 cm/s at a system pressure of 10 atm, the pressure drop across the diatomaceous earth bed increases from 0.38 to 0.94 in. of water per in. of bed. For the same change, the pressure drop across the activated bauxite bed increases from 0.47 to 0.90 in. of water per in. of bed.

II. DEVELOPMENT OF SECTIONED-BED TECHNIQUE FOR MEASURING SORPTION PERFORMANCE PARAMETERS

Breakthrough data for the sorbents under investigation would provide useful information for the design of a fixed-granular-bed filter, using the sorbent as the filter medium. Breakthrough data could be easily obtained if direct measurement of the alkali concentration in the effluent flue gas from the sorption test equipment were possible. However, no analytical method is available for directly measuring the alkali concentration in the flue gas; therefore, an alternative technique is needed to obtain breakthrough data for both diatomaceous earth and activated bauxite. A sectioned-bed technique has been developed and is illustrated in the following by a series of experiments using activated bauxite as a sorbent for removing NaCl vapor from simulated flue gas.

In this technique, a bed of activated bauxite was divided into equal sections (thicknesses) by using platinum gauze dividers. Tests were made for the sorption of NaCl vapor transported in a hot simulated flue gas of PFBC as a function of experiment duration. At the end of each test, the sorbent in each section was separately collected and analyzed for sodium content. From these analyses, the amount of NaCl vapor captured in each section of the bed can be obtained. By dividing this amount by the total amount of NaCl vapor transported to the bed, the average percent NaCl vapor capture for each section is obtained. Then, the average cumulative percent NaCl vapor captured and the average percent breakthrough can be calculated as a function of bed depth and experiment duration.

As an illustration of this technique, the activated bauxite (-8 +10 mesh) bed (5-in. thick) was divided into five sections and tested at 800°C and atmospheric pressure for experiment durations (or onstream time) of 3, 5, and 8 h. The superficial gas velocity was 66 cm/s, and the gas hourly space velocity (based on the entire 5-in. bed) was 18,600 h^{-1} (or a contact time of 0.2 s between the flue gas and the entire bed). The results of this series of experiments, presented and discussed in detail in an earlier quarterly report (ANL/CEN/FE-80-5), are summarized in Fig. 2.

Figure 2 shows the average percent NaCl breakthrough data for activated bauxite as a function of experiment duration for each bed depth (or GHSV). Percent breakthrough is defined here as the amount of NaCl vapor passing through the bed and is expressed as a percentage of the total NaCl vapor transported to the sorbent bed. The breakthrough data presented in Fig. 2 establishes a relationship for the onstream time (or experiment duration) and bed depth (or GHSV) required to achieve a specific average breakthrough of NaCl vapor through the bed. By extrapolating the curves in Fig. 2 to 0% breakthrough, a series of curves can be derived for this relationship, as shown in Fig. 3. This graph indicates that a 5-in.-thick activated bauxite bed could be operated for an onstream time of only 4 h if an average 0.1% breakthrough (or 99.9% NaCl-vapor sorption efficiency) was not to be exceeded, could be operated for 5 h if breakthrough was to be limited to 1%, and so on. It must be noted that the relationship shown in Fig. 3 apply only for the specific sorption conditions used for the test series--sorbent bed temperature of 800°C, system pressure of one atmosphere, superficial gas velocity of 66 cm/s, and

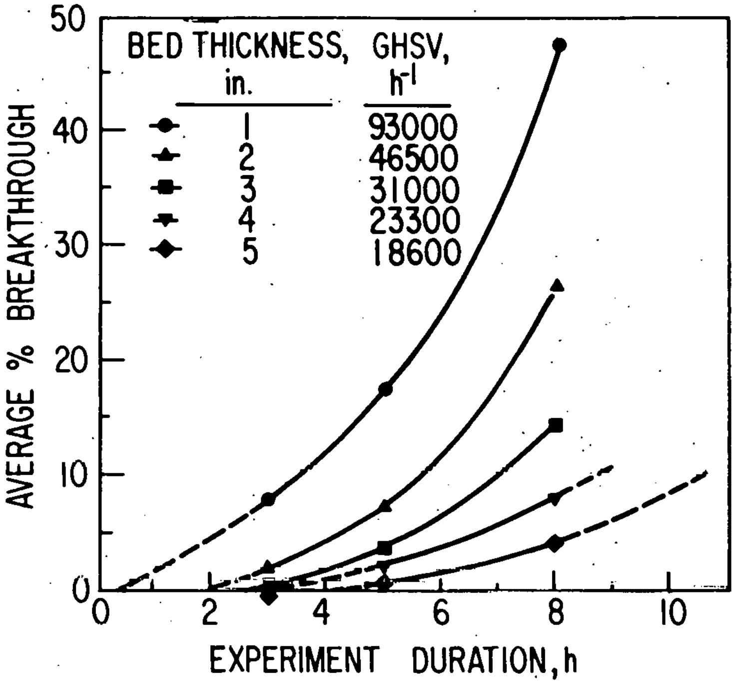

Fig. 2. NaCl Breakthrough Data for Activated Bauxite

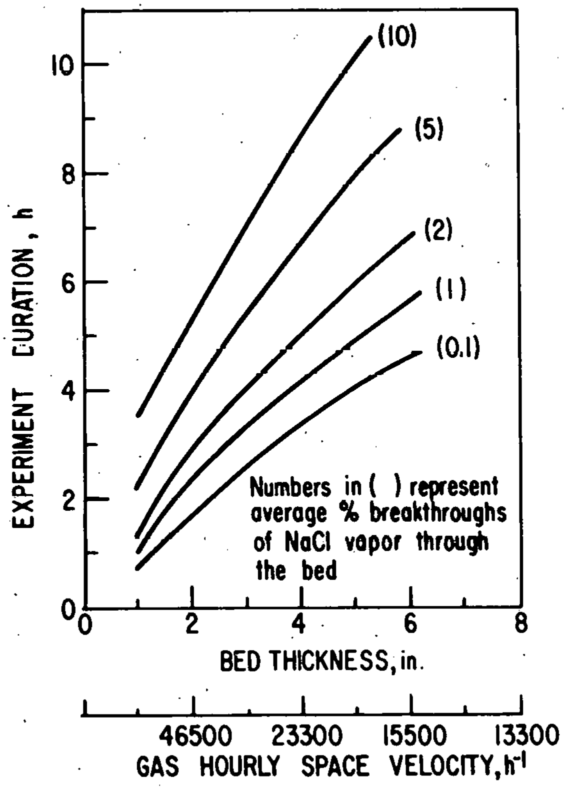

Fig. 3.

Relationship of Experiment Duration and Bed Depth (or GHSV) to Average Percent NaCl Breakthrough for Activated Bauxite

NaCl vapor concentration of approximately 35 ppm in the flue gas. Relationships of this type for various sorption conditions, especially for a high-pressure system (approximately 10 atm) and low alkali vapor concentration (approximately 10 ppm), are needed for the design of a large-scale granular-bed filter. Work to obtain these relationships will be continued.

III. REGENERATION OF ACTIVATED BAUXITE

NaCl-vapor-adsorbed activated bauxite has been found to be easily and effectively regenerated by use of a simple water-leaching process.[2] Regeneration of the sorbent not only provides a possible economic benefit to the alkali-removal process, but also eliminates the spent sorbent disposal problem. Studies on the regeneration of activated bauxite have been continued (1) to investigate the water-leaching regenerability of activated bauxite that has adsorbed KCl vapors, (2) to obtain a better understanding of the water-leaching kinetics of NaCl-vapor-adsorbed activated bauxite, and (3) to evaluate the "thermal swing" method as an alternative regeneration process for activated bauxite.

A. Water-Leaching Regeneration

The regenerability of activated bauxite has been demonstrated by a 10-cycle experiment of NaCl-vapor sorption and water-leaching regeneration.[2] The regenerability of activated bauxite by a water-leaching process was further investigated in a five-cycle experiment of KCl-vapor sorption and water-leaching regeneration. The sorption tests for this series of experiments were carried out in the laboratory-scale, batch-unit combustor system[3] at 800°C and atmospheric pressure, using a simulated dry flue gas of PFBC. The flue gas had a volumetric composition of 3% O_2, 16% CO_2, about 300 ppm SO_2, about 180 ppm H_2O, about 35 ppm KCl vapor, and the balance N_2. The superficial gas velocity of the flue gas passing through the sorbent bed was 66 cm/s, and the gas hourly space velocity was 18,600 h^{-1}. At the end of each sorption test, the sorbent was leached with distilled water, separated from liquid by filtration with a filter paper, dried in a muffle furnace, and finally sieved with a 10-mesh screen to remove fines. Make-up sorbent was added to replace the fines removed by screening, and the next sorption test was initiated.

Experimental results for this cyclic test were presented previously (ANL/CEN/FE-80-4). The KCl vapor removal efficiency as a function of regeneration cycle is summarized in Fig. 4. To allow comparison, results of the previous 10-cycle cyclic test with NaCl are also included. As shown in Fig. 4, both fresh and regenerated activated bauxite very effectively captured 98% (on the average) of either NaCl vapor or KCl vapor in the flue gas. The quantity of fresh activated bauxite make-up added to the regenerated activated bauxite represented less than 3% by weight of the total quantity of sorbent bed (50 g). The alkali vapor removal efficiencies observed for the regenerated activated bauxite were consistently very high (similar to that for fresh activated bauxite), indicating that the sorption capability of regenerated activated bauxite is unaffected by the number of sorption-regeneration cycles.

It is concluded from Fig. 4 that activated bauxite can be effectively regenerated by a simple water-leaching process and that regenerated activated bauxite behaves as effectively as fresh activated bauxite in capturing NaCl and KCl vapors from flue gas.

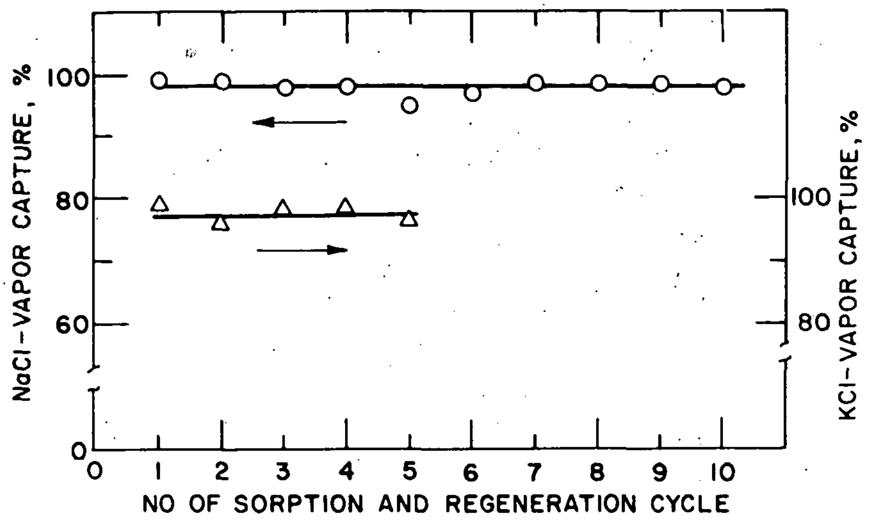

Fig. 4. NaCl- and KCl-Vapor Sorption by Fresh Activated Bauxite and by Activated Bauxite Regenerated by Water Leaching as a Function of Sorption-Regeneration Cycle

B. Rate of Water-Leaching

This study has two objectives. The first is to obtain information on the rate of NaCl leaching by water from NaCl-adsorbed activated bauxite. The second objective is to produce regenerated activated bauxite samples which will be characterized for their alkali sorption behavior using the pressurized sorption test unit. In this water-leaching kinetics study, activated bauxite was cyclically tested for NaCl vapor sorption and water-leaching regeneration for seven cycles. The procedure for the cyclic experiments is shown and explained in Fig. 5. The NaCl-vapor sorption experiments were carried out using the laboratory-scale, batch fixed-bed combustor.[3] Experimental results from these cyclic tests have been presented in an earlier report (ANL/CEN/FE-80-6).

Figures 6 and 7 summarize the results of these cyclic tests. Figure 6 is a plot of the percent NaCl leached as a function of leaching duration in minutes. The values plotted in this figure represent the average values for the percentages of NaCl leached in the corresponding cycles of experiments HGC-88 and HGC-89. As shown in this figure, the data points are somewhat scattered. This is believed to be due to difficulty in dividing NaCl-adsorbed activated bauxite sample into equally homogeneous portions for leaching. Despite the scatter in the data, Fig. 6 shows that the maximum leaching rate of the adsorbed NaCl from the activated bauxite occurs during the first five minutes of leaching. After that, the leaching rate quickly decreases and approaches a very low constant value.

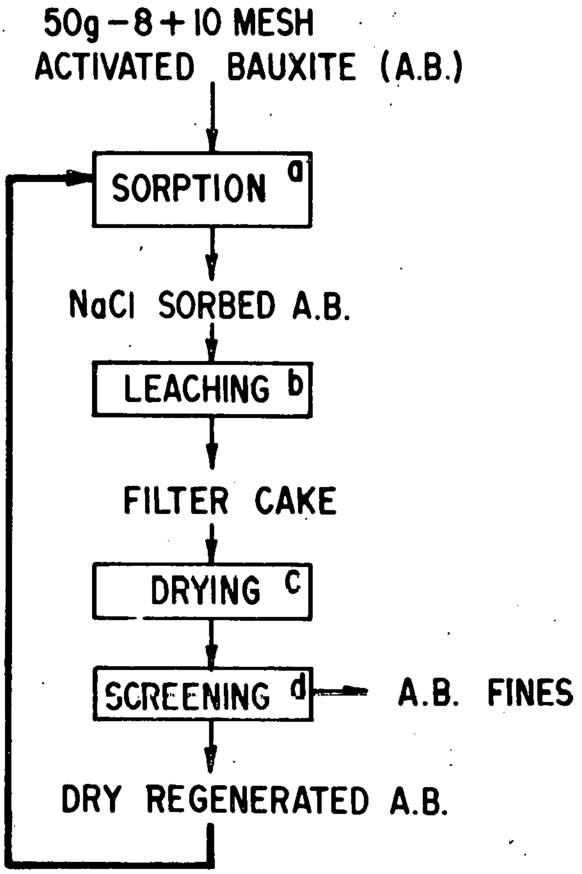

Fig. 5. Flowsheet Showing NaCl-Vapor Sorption Step and Water-Leaching Regeneration Step for Activated Bauxite

a. Sorption experiment conditions: 800°C at atmospheric pressure in a simulated dry flue gas of PFBC containing 3% O_2, 16% CO_2, 300 ppm SO_2, and the balance N_2; superficial gas velocity = 66 cm/s; GHSV $\cong$ 18,600 h^{-1} or contact time of 0.2 s); experiment duration = 6 h.

b. Leaching conditions: leached with distilled water in a beaker at gently boiling temperature (about 95°C).

c. Drying conditions: 400°C for 1 h in an air flow.

d. Sieved with 10-mesh screen to discard fines.

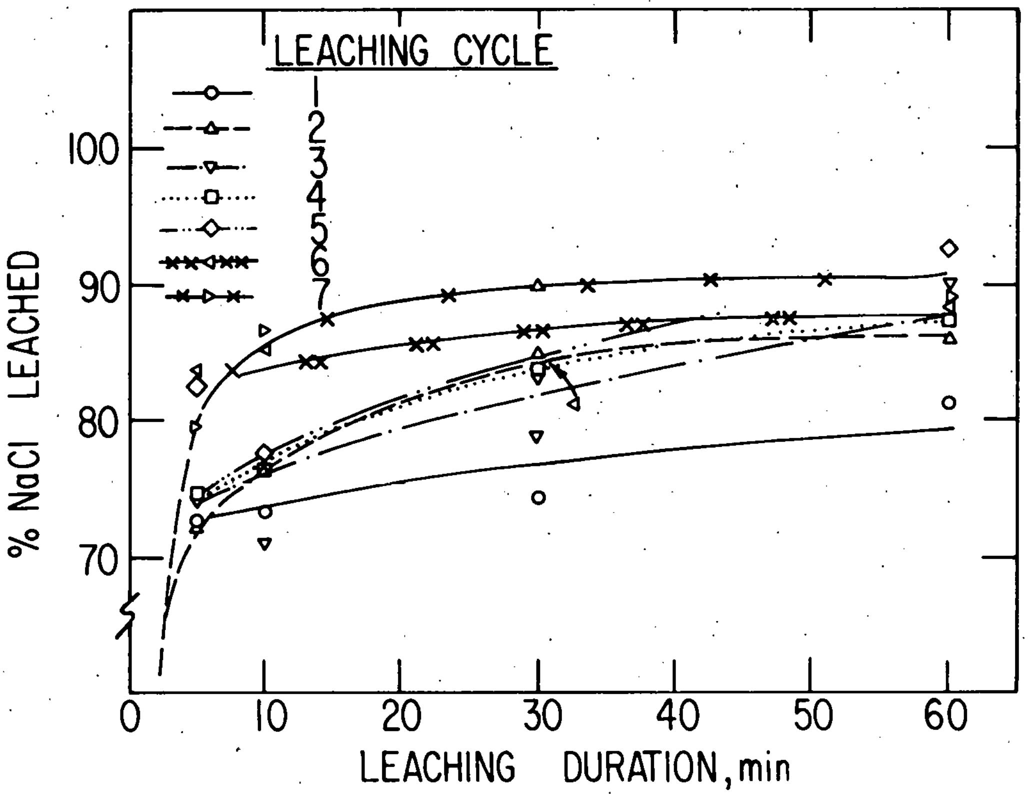

Fig. 6. Quantity of Leachable NaCl Leached as a Function of Leaching Duration. Each point represents the average of an Exp. HGC-89 value.

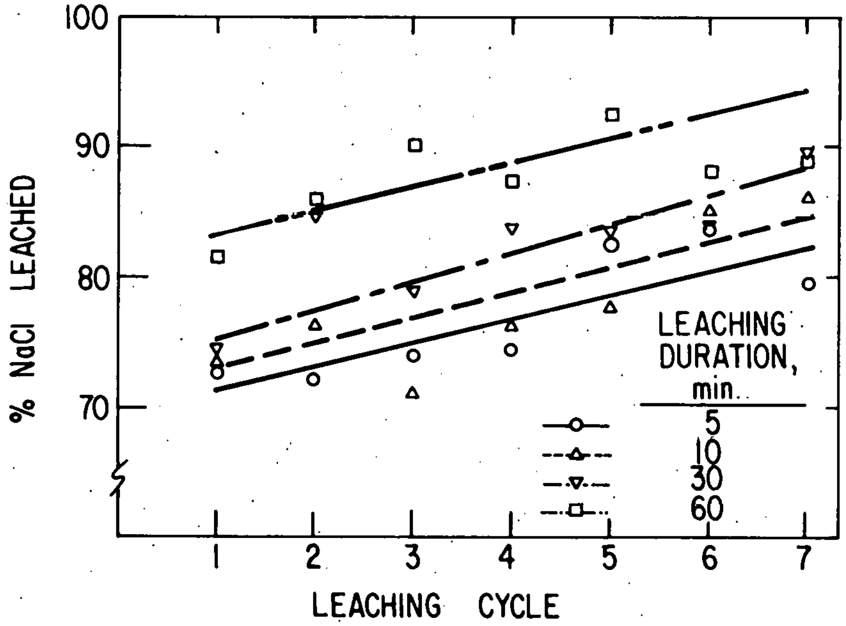

Fig. 7. Amount of Leachable NaCl Leached from NaCl-Adsorbed Activated Bauxite as a Function of Leaching Cycle

Figure 6 also shows that the rate of leaching increases at later leaching cycles. This is further illustrated in Fig. 7, a plot of the average percentages of NaCl leached from experiments HGC-88 and HGC-89 as a function of leaching cycle. It is evident from Fig. 7 that for each experimental level of leaching duration, the percent NaCl leached increased in each subsequent leaching regeneration cycle. On the average, 75% of the adsorbed NaCl was leached in the first five minutes of leaching, and this amount increased to approximately 85% for one-hour leaching.

As explained in a previous report (ANL/CEN/FE-80-6), the reactions of NaCl vapor with both SiO_2 and clay minerals (present as impurities in activated bauxite) tend to open up the structure of activated bauxite, i.e., to increase the average pore size of the activated bauxite and create more fine pores. The increase in pore size reduced the resistance to water diffusion into the pores and thus to extraction of the adsorbed NaCl molecules. Consequently, rate of leaching increases at later leaching regeneration cycles, as observed in Fig. 7.

It is concluded from this series of cyclic experiments that the maximum leaching rate of the adsorbed NaCl from activated bauxite occurs during the first five minutes of leaching. Following the first five minutes of leaching, the rate rapidly decreases and approaches a very low constant value. The leaching rate also increases with an increasing number of water-leaching regeneration cycles.

C. Thermal Swing Method of Activated Bauxite Regeneration

Activated bauxite has been shown to capture alkali chloride vapors by two mechanisms: chemical reactions and physical adsorption.[1] It has also been found that with repeated utilization of the sorbent over several cycles of alkali-sorption and water leaching regeneration, the physical adsorption mechanism gradually comes to play a dominant role in capturing alkali chloride vapors. The general characteristics of a physical adsorption process allow the regeneration of activated bauxite by a "thermal swing" of the bed temperature as an alternative to water-leaching. The objective of this study is to evaluate the thermal swing method as a regeneration process for activated bauxite.

Regenerated activated bauxite that had been subjected to more than ten cycles of alkali chloride vapor sorption and water-leaching regeneration was used in these thermal swing studies. This was to minimize the role of chemical reaction during alkali sorption by the sorbent. The experiments (RAB series) were conducted in the pressurized sorption test unit described in Section A of this report. In these studies, the amount of NaCl vapor that can be adsorbed by activated bauxite under specific sorption conditions (Table 1) was first measured. This measurement was obtained by Soxhlet-extracting the sorbent (after the sorption test) for 15 h, using water as an extracting medium. The same batch of activated bauxite sorbent (after Soxhlet extraction) was then tested in a separate run for NaCl vapor sorption under the same sorption conditions, as well as for subsequent desorption of the adsorbed NaCl at a higher bed temperature. At the end of a test, the sorbent was again Soxhlet-extracted for 15 h and the amount of the adsorbed NaCl was measured.

Table 1. Experimental Conditions for RAB Series Experiments

	Sorption Stage	Desorption Stage
Sorbent Bed Temperature, °C	800	845; 885
System Pressure, psig	12-15	18-25
Sorbent Bed Thickness, cm	5.08 (2 in.)	5.08 (2 in.)
Simulated Flue Gas Composition, %		
O_2	4	0
CO_2	16	0
N_2	Balance	100
Superficial Gas Velocity, cm/s	21	20
Gas Hourly Space Velocity, h^{-1} (Contact Time, s)	14600 (0.25)	14000 (0.26)

In these studies, desorption of the bed was started in situ immediately after the sorption stage. The experimental procedures for switching from the sorption stage to the desorption stage are as follows: (1) flow of simulated flue gas is stopped, (2) the NaCl sample pan is raised to the cool section of the reactor to prevent further vaporization of NaCl, (3) the sorbent bed temperature is increased to a selected value, and finally (4) a nitrogen sweeping gas is introduced. The desorption conditions are given in Table 1.

During experimental handling of the sorbent, sorbent fines were produced; therefore, some regenerated sorbent (generally less than 2% by weight of the regenerated activated bauxite) was added to make up the bed for the subsequent test. For the desorption stage, it took 10 min to heat the bed from 800°C to the desorption bed temperature of 845°C and 20 min for heating to 885°C.

Table 2 presents material balances for the five RAB-series tests completed. In this table, the amount of NaCl extracted from the sorbent [row (3) in the table] represents the amount of NaCl physically adsorbed by activated bauxite sorbent. The difference [row (5)] between the amount of NaCl transported to the bed [row (1)] and the sum of the total NaCl collected [row (4)] represents the amount of NaCl retained in activated bauxite as water-insoluble compounds. The clay minerals present as impurities in activated bauxite are responsible for the NaCl retention.

In Table 2, it is seen that in experiment RAB-2, 13.0 mg NaCl was physically adsorbed per gram of sorbent. In experiment RAB-4, the sorbent was subjected to sorption conditions similar to those in experiment No. RAB-2 (except for slightly higher system pressure and lower NaCl vapor concentration in the flue gas) followed by 1 h desorption of NaCl from the bed at 845°C under nitrogen sweeping gas. In experiment RAB-4, 12.4 mg NaCl was adsorbed

Table 2. NaCl Material Balances for RAB Series of Experiments (25 g of Sorbent was Tested for NaCl Vapor Sorption at 800°C for 8 h)

	RAB-2	RAB-4	RAB-6	RAB-7	RAB-8
System Pressure, psig	12	18	25	25	25
Desorption Bed Temperature, °C	--	845	845	--	885
Desorption Duration, h	--	1	3	--	3
Avg. NaCl Vapor Conc. in Flue Gas, ppmV	101	86	98	99	89
INPUT					
(1) NaCl Transported to the Bed, mg	485	455	578	581	522
OUTPUT					
(2) NaCl Captured by					
(a) Cold Trap, mg	76	95	238	109	238
(b) Glass-Wool Filter, mg	24	19	46	25	31
(3) NaCl Extracted from Sorbent, mg	324	309	244	408	230
(4) Sum, mg	424	413	528	542	499
(5) Difference [(1)-(4)], mg	61	32	50	39	22
(6) NaCl Adsorbed, mg NaCl/g sorbent [(3)/25]	13.0	12.4	9.8	16.3	9.2

per gram of sorbent. Also, the amount of NaCl captured by the cold trap and the the glass-wool filter slightly increased. These results indicate that the adsorbed NaCl vapor possibly desorbed during the desorption stage.

To further investigate NaCl desorption at high temperature, experiments RAB-6 and -7 were conducted at the same sorption conditions, except that the bed of experiment RAB-6 was further desorbed at 845°C for 3 h. Results in Table 2 show that at the higher temperature, the amount of NaCl physically adsorbed per gram of sorbent decreased from 16.3 mg to 9.8 mg, indicating desorption of 40% of the adsorbed NaCl. This desorption phenomenon was further supported by the capture on the cold trap and the glass-wool filter of an amount of NaCl corresponding to that desorbed from the sorbent.

Based on the results of experiments RAB-6 and -7, the rate of NaCl desorption caused by an upward thermal swing in the bed temperature of 45°C is relatively low--only 40% of the adsorbed NaCl was desorbed in 3 h. To investigate how the magnitude of the temperature swing affects the desorption rate, experiment No. RAB-8 was conducted at a desorption bed temperature of 885°C. Table 2 shows that the extent of desorption was not significantly affected by increasing the thermal swing to 85°C.

Theoretically, in a physical adsorption process, the adsorbate should desorb from the adsorbent at a higher sorbent bed temperature than that at which the adsorbate is adsorbed; therefore, the results of experiment No. RAB-6 and -7 provide additional evidence for the conclusion made previously that part of the NaCl is physically adsorbed by activated bauxite.

D. Future Work

Experimental studies will be continued to test activated bauxite in a pressurized system. The technical data base to be obtained is required for the design of large-scale granular-bed filters in which activated bauxite as the filter medium would remove gaseous alkali metal compounds from hot flue gas. Alkali sorption isotherm and alkali breakthrough data will be obtained in the first phase of this work. Next, the effects of pressure and the moisture content of the flue gas on the alkali vapor sorption performance of the sorbent will be investigated. Studies of the water-leaching of activated bauxite will also be continued to investigate the effects on the leaching rate of (1) adsorbed alkali loading on activated bauxite, (2) leaching temperature, and (3) the quantity of leaching medium.

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