Project Title: ALKALI EMISSION AND CONTROL IN PRESSURIZED CIRCULATING FLUIDIZED BED COMBUSTORS

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ABSTRACT

The objective of this research program is to predict the vapor phase alkali concentration in Illinois coal-fired pressurized fluidized bed combustors. Alkali release (Na and K) during combustion of three Illinois coals was evaluated in API's atmospheric circulating fluidized bed combustor. These coals were the Rend Lake mine coal, Crown II coal, and Arch coal. The sorbent was Iowa Industrial Lime No.1.

The results indicated that the Na concentration in the flue gases were 49±5, 47±6, and 44±6 ppbW (62±6, 60±7, 56±7 ppbv) for Rend Lake, Crown II, and Arch coals, respectively. The vapor phase K concentration was low (<10 ppbW) for all three coals. Illinois Rend Lake coal was selected to study the control of alkali emission with two getter materials, emathlite and kaolin. The time averaged sodium vapor concentration was measured to be 19±3 and 23±4 ppbW, indicating 61 and 55% reductions in vapor phase Na emission for tests with emathlite and kaolin, respectively.

The theoretical equilibrium calculations were performed in the temperature range from 1290°F to 1830°F at two system pressure values; 14.5 and 174 psia. At a combustion temperature of 1600°F, the equilibrium concentrations of Na were calculated to be 922, 130, and 170 ppbv for Rend Lake, Crown II, and Arch coals, respectively. The measured values of 62, 60, and 56 ppbv are all substantially lower than the theoretical values. The theoretical calculations showed that when the pressure increases from 14.5 psia to 174 psia, the equilibrium concentrations of both Na and K are decreased by a factor of 20. If this ratio holds true, the alkali emissions from a PCFB combustors should be on the order of a few ppb. The effectiveness of alkali getters in controlling alkali emission in a CFB combustor has been demonstrated and quantified. Further studies on optimization of alkali getter addition will be helpful in designing an improved combined cycle system.

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EXECUTIVE SUMMARY

During the combustion of coal, some alkali species such as sodium and potassium volatilize and disperse throughout the gas stream. The release of sodium and potassium is difficult to control since the combustion temperature range is fixed. The species can condense on cooler surfaces such as heat exchangers and/or gas turbine components.

Condensed alkalis support the build-up of ash particles and reduce the effectiveness of heat exchange surfaces by adding more resistance to heat flow or corroding the metals in contact, such as the turbine blades. In advanced energy conversion systems, the absorption of the vapor phase alkali by a "getter" can reduce this harmful effect. Reduced vapor phase alkalis ensure long life of the turbine components.

Earlier studies have been conducted in bench-scale test rigs to quantify the level of alkalis in bubbling fluidized bed systems. However, no extensive alkali measurement has been conducted in circulating fluidized bed combustors burning Illinois coals. The reliability of vapor phase alkali level measurements done in the early eighties and before appear to be questionable. Argonne National Laboratory (ANL) has developed a method that gives an improved accuracy of the measurement data. This method has been used in the current program.

The objective of this research program is to predict the vapor phase alkali concentration in Illinois coal-fired pressurized fluidized bed combustors. First, alkali release during combustion of three Illinois coals in an atmospheric circulating fluidized bed combustor was evaluated. After evaluating the coal that released the highest alkali concentration, this coal was selected to study the control of its alkali emission by in-situ alkali capture in the bed with two getter materials. Finally, based on theoretical equilibrium concentrations, the vapor phase alkali concentration in pressurized fluidized bed combustors was predicted.

Ahlstrom Pyropower's bench-scale atmospheric circulating fluidized bed (CFB) combustor facility was used to measure the alkali release during combustion of three Illinois coals. These coals were the Rend Lake mine coal, Crown II coal, and Arch coal. The sorbent selected for the study was Iowa Industrial Lime No.1, which is the sorbent selected for the Des Moines Energy Center-1 project planned under the U.S. DOE's Clean Coal Technology III program. Illinois No.6 coal is one of the design fuels for the same project.

The alkalis, namely sodium and potassium, were measured using ANL's state-of-the-art alkali measurement system. In this system, the activated bauxite based alkali sorber bed was used
to measure vapor phase alkalis from the flue gas samples extracted during the combustion of three Illinois coals.

Three week-long tests were conducted with all coals at 870°C. The measurement results indicated that the sodium concentration in the flue gases were 49±5, 47±6, and 44±6 ppbW (62±6, 60±7, 56±7 ppbv) for Rend Lake coal, Crown II coal, and Arch coal, respectively. The vapor phase potassium concentration in the ACFBC flue gas was low (<10 ppb) for all three coals.

After evaluating the coal that released the highest alkali concentration, Illinois Rend Lake coal was selected to study the control of its alkali emission by in-situ alkali capture in the bed with getter materials. Two promising getter materials were tested with this coal. These were the emathlite and kaolin. Coal was pre-mixed with the getter material at weight ratio of coal to getter material of 10.

The time averaged sodium vapor concentration in the ACFBC flue gas was measured to be 19±3 and 23±4 ppbW for tests with emathlite and kaolin getter materials, respectively. These values are compared with 49±5 ppbW for the test under the same test conditions but without getter material, indicating the 61 and 55% reduction in sodium-vapor emission as a result of in-situ gettering of sodium by emathlite and kaolin, respectively. The time averaged vapor phase potassium concentration in the ACFBC flue gas was determined to be significantly lower than sodium - 8±2 and 5±1 ppbW for tests with emathlite and kaolin, respectively.

The equilibrium calculations were performed in the temperature range from 1290°F to 1830°F at two system pressure values - 14.5 and 174 psia. Then, the total Na and K were calculated from the compounds which contained Na and K species in equilibrium at each temperature and pressure.

The highest vapor phase Na and K concentrations in flue gas was calculated for the Rend Lake coal. The Arch coal and Crown II coal gave lower values for the flue gas concentrations of Na and K. It is noted that as the system temperature increases, the Na and K in the flue gas also increase for all three coals, but the alkali concentration decreases with increasing pressure.

At a combustion temperature of 1600°F, the equilibrium concentrations of Na are calculated to be 922, 130, and 170 ppbv for Rend Lake coal, Crown II coal, and Arch coal, respectively. When these values are compared with the measured values of 62, 60, and 56 ppbv (49, 47, and 44 ppbw), it is seen that the measured values are all lower than the theoretical values. This is as expected since the theoretical values represent the maximum concentrations that can possibly exist in equilibrium under conditions specified. Based on the
Theoretical maximum, the fraction of the measured Na in flue gases are 7, 46, and 33% for the Rend Lake, Crown II, and Arch coals, respectively.

The equilibrium calculations show that at a higher pressure of 174 psia, the alkali concentrations in flue gas are many times lower than those of the atmospheric pressure. When the pressure increases to 174 psia, the equilibrium concentrations of both Na and K are decreased by a factor of 20.

It is also noted that the ratio of observed to predicted values are not the same for all three coals. This observation indicates that the release of Na varies with the type of coal. Although the acid soluble Na is the highest in Crown II coal, the measured vapor phase Na in flue gas is higher in Rend Lake coal test. This may be due to the larger amount of chlorine present in Rend Lake coal.

The effectiveness of alkali getters in controlling alkali emission in a CFB combustor has been demonstrated and quantified. Further studies on optimization of alkali getter addition will be helpful in designing an improved combined cycle system.