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Project Summary

Performance and Modeling of a Hot Potassium Carbonate Acid Gas Removal System in Treating Coal Gas

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Aqueous solutions of potassium carbonate, with and without an amine additive, were used as the acid gas removal solvent in the Coal Gasification/Gas Cleaning Test Facility at North Carolina State University. The acid gas removal system consisted of a packed absorption column, one or more flash tanks for intermediate pressure reduction, and a packed stripping column operated with a reboiler. The removal of CO_2, H_2S, COS, and other species from the crude coal gas was studied, and data on the distribution of these gases in regeneration exit streams were obtained. Operating conditions for the selective removal of sulfur species were also examined.

A system model for chemical solvents was developed and incorporated into a simulation program. The model was based on the mass transfer rate of a key component, CO_2, with the assumption that non-key reactive components affect the equilibrium of the key component, but not its mass transfer rate. The absorption and stripping of non-key components were assumed to be controlled by equilibrium between the gas and liquid phases in these columns. An isothermal flash model for chemical solvents was also developed and included in the program.

The agreement between program predictions and pilot plant data was quite good, supporting the validity of the model. Program simulations are shown to provide insights into the effects of changes in process variables on system operation.

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

As gasification processes have developed in the U.S., it has become apparent that improved technology in gas cleaning is needed to meet current environmental standards. As part of a program to develop this technology, the U.S. EPA sponsored a Coal Gasification/Gas Cleaning Test Facility at North Carolina State University. The final gas cleanup in this facility is accomplished by an acid gas removal system (AGRS) in which a solvent is circulated through a packed absorption column for removal of acid gases from the coal gas Several flash tanks and a packed stripping column are used for regeneration of the solvent. A process that removes CO_2 and H_2S from a gas stream is referred to as an AGRS due to the acidic nature of these species.

All previous work at the facility has employed refrigerated methanol as the acid gas removal solvent. The experimental work described in this report employed an aqueous solution as potassium carbonate, K_2CO_3, as the AGRS solvent. This process is referred to as the hot potassium carbonate process since absorption and regeneration units are typically operated at elevated temperatures. The primary difference between this solvent and methanol is that K_2CO_3 removes the acid gases by a chemical reaction, and is thus classified as a chemical solvent, while methanol physically absorbs the acid gases, and is thus termed a physical solvent. Another important difference is the solubility of organic compounds in the two solvents. Hydrocarbons (e.g., methane, benzene, and large cyclic compounds) are essentially insoluble in the aqueous solution of K_2CO_3, and will thus remain in the product gas stream. Such compounds are, however, highly soluble in methanol, and they are absorbed and ultimately distributed in all gas streams leaving the regeneration units. These hydrocarbons are important for their energy values, and many are also considered environmentally hazardous.

Major Objectives

The present work had two primary objectives: (1) to evaluate the performance of aqueous solutions of hot K_2CO_3 in conditioning gases produced from coal, and (2) to develop a model that could be used in the design or simulation of packed adiabatic absorbers and strippers that use hot K_2CO_3 to condition gases produced from coal. An experimental program was conceived and executed to satisfy the first objective directly and to assist with the second. Several operational variables were purposefully manipulated to examine the effect on removal of CO_2, H_2S, and COS from the gas exiting the absorber. The model developed to describe adiabatic absorption and stripping was incorporated into a system model that consisted of an absorber, a flash tank, and a stripper, and a computational procedure was developed to predict system performance.

Conclusions

As a result of the experimental and modeling efforts, several conclusions regarding the use of K_2CO_3 can be drawn:

1. The model developed in this study predicted gas flow rates and compositions that were in close agreement with measured values.

2. Heat effects with the hot K_2CO_3 process are less than with most other acid gas removal solvents. Calculations assuming isothermal absorption, flash tank, and stripping operations give accurate results.

3. CO_2 removal ranged from 38.1 to 98.4% at the conditions examined, and was, in general, highly sensitive to AGRS operating conditions and solvent composition. The effect of H_2S and other coal gas species on the mass transfer rate of CO_2 appeared to be small.

4. The absorption of CO_2 was found to be insensitive to solvent compositon when the absorption of CO_2 was controlled by equilibrium between the gas and liquid phases at the top of the absorber column.

5. The absorption of CO_2 was found to be highly dependent on solvent regeneration.

6. The regeneration of CO_2 accomplished by flashing was negligible at the conditions examined.

7. H_2S removal ranged from 97.3 to 100% at the conditions examined and was found to be insensitive to solvent composition. The absorption of H_2S was found to be controlled primarily by equilibrium between the gas and liquid phases at the top of the absorption column.

8. COS removal ranged from 20.0 to 95.8% at the conditions examined and appeared to be a function primarily of absorber temperature.

9. H_2S and COS may be selectively removed with AGRS operating conditions that include low K_2CO_3 concentrations, low absorber pressures, and high absorber temperatures.

10. The absorption of coal gas species that do not participate in a reaction in the solvent was found to be insensitive to solvent composition at the conditions examined. The absorption of these species was found to be controlled by equilibrium between the gas and liquid phases at the bottom of the absorber column.

11. An amine additive, commonly used to increase the mass transfer rate of CO_2, appeared to have no significant effect on the fates of other coal gas species. This additive appeared to increase the absorption of CO_2 slightly when such absorption was controlled by equilibrium between the gas and liquid phases in the absorption column.

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The complete report, entitled "Performance and Modeling of a Hot Potassium Carbonate Acid Gas Removal System in Treating Coal Gas," (Order No. PB 88-131 297/AS; Cost: $19.95) will be available only from:
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