PROJECT facts

U.S. Department of Energy
Office of Fossil Energy
National Energy Technology Laboratory

Carbon Sequestration

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NETL

Carbon Dioxide Capture by Absorption with Potassium Carbonate

Background

Although alkanolamine solvents, such as monoethanolamine (MEA) and solvent blends have been developed as commercially-viable options for the absorption of carbon dioxide (CO_2) from waste gases, natural gas, and hydrogen streams, further process improvements are required to cost-effectively capture CO_2 from power plant flue gas. The promotion of potassium carbonate (K_2CO_3) with amines appears to be a particularly effective way to improve overall solvent performance. K_2CO_3 in solution with catalytic amounts of piperazine (PZ) has been shown to exhibit a fast absorption rate, comparable to 30 wt% MEA. Equilibrium characteristics are also favorable, and the heat of absorption (10-15 kcal/mol CO_2) is significantly lower than that for aqueous amine systems. Studies also indicate that PZ has a significant rate of reaction advantage over other amines as additives.

Description

The University of Texas at Austin will investigate an improved process for CO_2 capture by alkanolamine absorption/stripping that uses an alternative solvent, aqueous K_2CO_3 promoted by PZ. If successful, this process would use less energy for CO_2 capture than the conventional MEA scrubbing process. An improved capture system would mean a relative improvement in overall plant efficiency.

The project will include the development of models to predict performance of absorption/stripping of CO_2 using the improved solvent and performing a pilot plant (see figure) study to validate the process models and to define the range of feasible process operations. As part of the pilot plant study, a test with MEA will be conducted as a baseline to compare CO_2 absorption and stripping performance with tests using the K_2CO_3/PZ solvent. Researchers will also investigate key issues such as solvent degradation, solvent reclamation, and corrosion as well as alternative stripper configurations.

Pilot Plant at the University of Texas

Primary Project Goal

The primary goal of this work is to improve the process for CO_2 capture by alkanolamine absorption/stripping by developing an alternative solvent, aqueous K_2CO_3 promoted by PZ.

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Objectives

- To improve the process for CO_2 capture by developing aqueous K_2CO_3 promoted by PZ as an alternative solvent to MEA.
- To develop a system model based on data from bench-scale operations.
- To perform pilot-scale experiments to validate the process model and define the range of feasible process operations.
- To optimize process variables, such as operating temperature, solvent rate, stripper pressure, and other parameters.
- To quantify the effectiveness of the promoter.

Benefits

The major benefit of this project would be the ability to decrease the energy requirement for CO_2 capture from fuel gas or flue gas streams. Should CO_2 capture and sequestration become necessary, an improved capture process would significantly improve overall plant efficiency. The capital and operating costs for CO_2 capture could also be reduced.

Accomplishments

- Three solvents (7 molal (m) MEA, 5 m K_2CO_3/2.5 m PZ, and 6.4 m K_2CO_3/1.6 m PZ) were evaluated in four pilot-scale testing campaigns with three different absorber packings (two structured and one random).
    - To achieve equivalent absorber performance, 5 m K_2CO_3/2.5 m PZ requires two times less packing than 7 m MEA and three times less packing than 6.4 m K_2CO_3/1.6 m PZ.
    - The effective wetted area of two structured packings, Flexipak AQ Style 20 (213 m^2/m^3 dry area) and Flexipak 1Y (410 m^2/m^3), is 50 to 60 percent and 80 percent of that measured by CO_2 absorption from air by 0.1 N and NaOH, respectively.
- A rate-based model of absorber performance was developed in AspenPlus® with the RateSep™ block. This model was used to interpret pilot plant data and to predict performance at design conditions with and without intercooling.
    - The effective working capacity of 4 m K_2CO_3/4 m PZ is about 60 percent greater than 7 m MEA, and the heats of absorption are nearly equivalent.
    - The rate of CO_2 absorption in 4 m K_2CO_3/4 m PZ is 20 to 50 percent faster than in 7 m MEA.
    - Absorber intercooling is effective at enhancing system performance when the temperature bulge is in the middle or lower end of the column, at moderate liquid-to-gas ratios, and typically with higher capacity solvents.
- Three stripper models were developed: one in Aspen Custom Modeler (ACM) based on equilibrium stages, a rate-based model in ACM, and an equilibrium model in AspenPlus®. These models were used to estimate and compare energy requirements of alternative solvents and process configurations.
    - The double matrix stripper configuration is effective and produces some of the CO_2 at higher pressure.
- Studies of solvent loss, degradation, and reclamation have been completed.
    - PZ loaded with CO_2 shows less than 3 percent loss of PZ when heated at 135 °C for 8 weeks, compared to 60 percent loss of 11 m MEA at the same conditions.
    - The rate of oxidative degradation for PZ is low in the absence of dissolved copper.

PARTNER

University of Texas at Austin

PROJECT DURATION

07/09/2002 to 08/31/2007

COST

Total Project Value
$2,262,325

DOE/Non-DOE Share
$1,565,275 / $697,050

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