NETL

the ENERGY lab

PROJECT FACTS

Existing Plants, Emissions & Capture

Advanced Low Energy Enzyme Catalyzed Solvent for CO_2 Capture

Background

The mission of the U.S. Department of Energy/National Energy Technology Laboratory (DOE/NETL) Existing Plants, Emissions, & Capture (EPEC) Research & Development (R&D) Program is to develop innovative environmental control technologies to enable full use of the nation's vast coal reserves, while at the same time allowing the current fleet of coal-fired power plants to comply with existing and emerging environmental regulations. The EPEC R&D Program portfolio of post- and oxy-combustion carbon dioxide (CO_2) emissions control technologies and CO_2 compression is focused on advancing technological options for the existing fleet of coal-fired power plants in the event of carbon constraints.

Pulverized coal (PC) plants burn coal in air to produce steam and comprise 99 percent of all coal-fired power plants in the United States. CO_2 is exhausted in the flue gas at atmospheric pressure and a concentration of 10–15 percent by volume. Post-combustion separation and capture of CO_2 is a challenging application due to the low pressure and dilute concentration of CO_2 in the waste stream, trace impurities in the flue gas that affect removal processes, and the parasitic energy cost associated with the capture and compression of CO_2. Chemical solvents can be used to capture CO_2 from flue gas by absorbing it into a liquid carrier. Although this method is used commercially to remove CO_2 from industrial gases, it has not been applied to the removal of large volumes of gas as in coal-fired power plant flue gas due to significant cost and efficiency penalties.

Project Description

Akermin, Inc., in partnership with Battelle Memorial Institute, will demonstrate at a bench-scale level the ability to capture 90 percent of CO_2 from simulated flue gas using a solvent system with significantly lower regeneration energy than commercial monoethanolamine (MEA) and with comparable reaction rates. Akermin will continue development of their patent-pending enzyme immobilization and stabilization technology that enables the use of enzyme-catalyzed carbonate solvent systems for carbon capture that potentially can meet DOE goals of achieving 90 percent CO_2 removal with no more than 35 percent increase in cost of electricity (COE). Although carbonate solvent systems have been used for CO_2 removal in high-pressure applications such as natural gas sweetening, they have not been considered practical for flue gas carbon capture due to kinetic limitations and pressure requirements. In this project, high reaction rates are achieved through the use of an immobilized enzyme, carbonic anhydrase (CA), to catalyze the hydration reaction of CO_2. Potassium carbonate (K_2CO_3) will be used as the benchmark system and alternative solvents will also be evaluated. Key to achieving an economical system utilizing enzyme catalysis is the effective catalytic lifetime of the enzyme under the harsh conditions associated with flue gas treatment. Akermin will utilize their micellar polymer structure to provide sufficient enzyme stabilization and immobilization, allowing for economically viable enzyme lifetimes.

CONTACTS

Jared P. Ciferno
Technology Manager
Existing Plants, Emissions & Capture
National Energy Technology Laboratory
626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
412-386-5862
jared.ciferno@netl.doe.gov

Andrew Jones
Project Manager
National Energy Technology Laboratory
626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
412-386-5531
andrew.jones@netl.doe.gov

John Reardon
Principal Investigator
Akermin, Inc.
4633 World Parkway Circle
St. Louis, MO 63134-3115
314-824-1966
reardonj@akermin.com

PARTNERS

Battelle Memorial Institute

PERFORMANCE PERIOD

Start Date	**End Date**
10/01/2010	09/30/2012

COST

Total Project Value
$2,906,759

DOE/Non-DOE Share
$2,255,407 / $651,352

U.S. DEPARTMENT OF ENERGY

The bench-scale testing will be used to establish the optimal immobilization polymer and enzyme loadings required to achieve carbon capture rates anticipated to be greater than an order of magnitude increase over the rate of a K_2CO_3-based system. Aspen Plus® process modeling will be performed by Battelle to demonstrate how to scale-up the process for integration into an existing coal-fired power plant while meeting DOE's goal of a less than 35 percent increase in the COE.

Akermin's Closed-Loop Reactor for Carbon Capture Testing

Goals

Project goals are to demonstrate, at a bench-scale level, the catalyzed carbonate solvent system with the ability to cost-effectively capture up to 90 percent of CO_2 from a simulated flue gas; achieve high reaction rates using the immobilized enzyme; demonstrate enzyme life in excess of six months; evaluate the impact of coal-fired flue gas impurities on the solvent; and to model how such a system would scale up for cost-effective integration into an existing coal-fired power plant.

Objectives

Four developmental objectives have been set to achieve the project goals: (1) identification of a preferred enzyme, (2) optimization of immobilization polymer/enzyme system, (3) definition of operating limits through analysis of lab reactor data for CO_2 absorption and modeling, and (4) scale-up of the current laboratory-scale unit to a bench-scale unit capable of processing up to 500 standard liters per minute (equivalent to a 5 kWe power plant) using simulated gas streams or interfacing directly to a commercial slipstream.

Planned Activities

- The CA enzyme will be down-selected based on stability studies. Several known strains of naturally occurring CA enzyme will be evaluated to determine the best candidate for a commercial carbon capture system.
- Enzyme retention, thermal stability, and percent activity retention will be evaluated and quantified for optimization of the polymer matrix. The micellar polymer will be down-selected to one preferred and one alternative for the lab reactor evaluation and eventual scale-up.
- A full Aspen Plus® supercritical pulverized coal power plant model will be prepared of a K_2CO_3 system to estimate differences in operating cost between the baseline (MEA) and alternative processes: un-catalyzed alternative solvent (several types), and CA-catalyzed alternative solvent (several types).
- Initial laboratory tests will be carried out to evaluate the capture rate of the enzymatic system in a small scale batch reactor and laboratory absorber at varying temperatures and pressures to create the most energy efficient system while maintaining or exceeding current achievable CO_2 capture rates.
- A laboratory-scale unit will be commissioned to evaluate the steam requirement of the reboiler, the system sensitivity to impurities such as SO_2, and the varying inlet conditions of flue gas (temperature and pressure specifically). The CO_2 concentration in the inlet gas will be varied to determine kinetic rates of the system along with the enzyme loadings.
- A bench-scale unit capable of treating a simulated flue gas stream at flow rates up to 500 standard liters per minute will be designed that will best demonstrate the efficacy of the system for carbon capture, and will incorporate features to allow for integration into a slipstream from an existing coal-fired facility.
- The bench-scale unit will be constructed and tested with simulated flue gas streams to verify performance goals.

Accomplishments

- Kick-off Meeting conducted on 10/29/2010.
- Greater than 80 percent physical enzyme retention was demonstrated in a bench-scale flow system.
- Design, installation, and startup of a laboratory-scale semi-batch reactor system for kinetic studies were completed.
- Kinetic studies were initiated with 17 percent by weight K_2CO_3 using 65 percent pure bovine carbonic anhydrase (bCA II) at 30 °C with no anti-foaming agents.
- Akermin began to transition from bCA II to an engineered strain of CA for future immobilization development efforts.

Benefits

The Akermin low energy, enzyme-catalyzed solvent system may provide a CO_2 capture method that rivals the CO_2 conversion rate of an MEA system but with significantly lower cost. The enzyme system incorporates many of the existing features of commercial MEA systems; however, the lower regeneration energy achieved by the use of a carbonate solvent coupled with the unique micellar polymer enzyme immobilization technology will potentially enable this system to achieve the DOE cost and performance goals. Additionally, the Akermin CO_2 capture process will be applicable to both retrofit and new-build opportunities, with a smaller footprint than an equivalent MEA-based capture system due to the lower heat requirement for solvent regeneration.