the ENERGY lab

PROJECT FACTS

Carbon Capture

Bench-Scale Process for Low-Cost Carbon Dioxide (CO_2) Capture Using a Phase-Changing Absorbent

Background

The mission of the U.S. Department of Energy Office of Fossil Energy's (DOE FE) Carbon Capture Research & Development (R&D) Program, implemented through the National Energy Technology Laboratory (NETL), is to develop innovative carbon dioxide (CO_2) emissions control technologies for fossil fuel-based power plants. The Carbon Capture R&D Program portfolio of pre- and post-combustion CO_2 emissions control technologies and related CO_2 compression is focused on advancing technological options for new and existing power plants to enable cost-effective CO_2 capture for beneficial use or storage of CO_2 and ensure that the United States will continue to have access to safe, reliable, and affordable energy from fossil fuels. The DOE FE/NETL goal is to demonstrate second-generation technologies that can capture 90 percent of the CO_2 at less than $40 per metric ton (tonne) in the 2020–2025 timeframe. DOE is also committed to extend R&D support to even more advanced transformational carbon capture technologies that will increase the competitiveness of fossil based energy systems beyond 2035.

Post-combustion CO_2 capture technologies are applicable to conventional pulverized coal (PC)-fired power plants, where the fuel is burned with air in a boiler to produce steam that drives a turbine generator system to produce electricity. The 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 from PC-fired plants is a challenging application due to the low driving force resulting from 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. Carbon capture technologies developed by the DOE program may also be applied to natural gas power plants after addressing the R&D challenges associated with the relatively low concentration of CO_2 (typically 3-4 percent) in the flue gas of natural gas plants. Phase-changing solvents have been identified as innovative absorbents for post-combustion capture of CO_2.

Project Description

General Electric Global Research (GEGR) will develop and test a novel bench-scale aminosilicone-based phase-change process for post-combustion CO_2 capture. GEGR will utilize the phase-changing solvent (GAP-0) tested under a previous Advanced Research Projects Agency-Energy (ARPA-E)-funded project. The GAP-0 solvent was proven to readily form a solid in the presence of CO_2 in a thermally reversible reaction with no apparent degradation to the absorbent. An innovative process design was required to accommodate the unique conditions of the phase-changing absorbent capture method and a laboratory-scale continuous process was developed in the ARPA-E project.

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PROJECT DURATION

Start Date	End Date
01/01/2014	12/31/2016

COST

Total Project Value
$2,999,951

DOE/Non-DOE Share
$2,399,961/$599,990

PROJECT NUMBER

FE0013687

The process disperses the liquid absorbent into the absorber as fine droplets for rapid reaction with CO_2 to form a dry, conveyable solid. Bench-scale testing and analysis of an improved version of this novel process will show its feasibility and scalability. In this project, a phase-changing solvent-based, bench-scale CO_2 capture system (Figure 1) will be constructed, integrating an absorber unit, a solids transfer operation, and a CO_2 desorber into a continuous system and will include recycle of the absorbent through all of the unit operations.

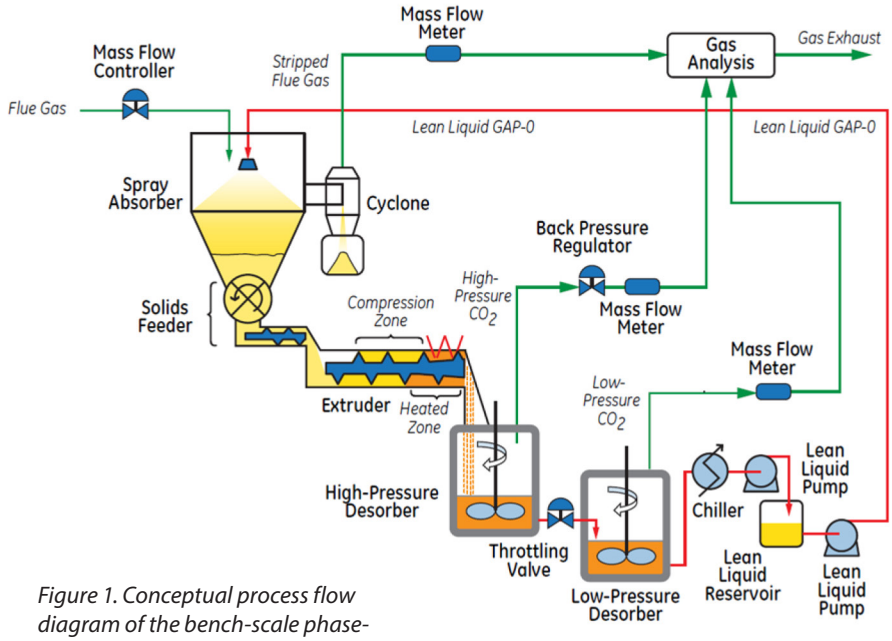

Figure 1. Conceptual process flow diagram of the bench-scale phase-changing CO_2 capture. system

Data obtained from the bench-scale testing will be used to determine process scalability and includes mass transfer parameters, kinetic parameters, heat transfer parameters, solvent stability, effects of flue gas contaminants, and recommended operating conditions. Other supplementary property data required to evaluate feasibility, such as absorption/desorption isotherms and solvent regeneration energy, will be determined during laboratory testing. The manufacturability of the solvent will be analyzed in consultation with silicone suppliers and a manufacturing cost will be estimated. The solvent manufacturing cost, bench-scale engineering data, and laboratory property data will be used to complete the techno-economic assessment and develop a scale-up strategy. The innovative phase-changing solvent-based CO_2 capture process is expected to show improved energy efficiency and reduced costs compared to a monoethanolamine system. The technology can be used in new construction or retrofitted to existing PC power plants.

Primary Project Goal

The project goal is to design and optimize a continuous bench-scale process for a phase-changing CO_2-capture solvent and establish scalability and potential for cost-effective post-combustion CO_2 capture from coal-fired power plants. The novel process is anticipated to help DOE meet its goal of demonstrating second-generation technologies that can capture 90 percent of the CO_2 at less than $40 per tonne in the 2020–2025 timeframe.

Objectives

Project objectives are to generate preliminary process and cost models; design and build a bench-scale system; perform bench-scale testing on unit operations; perform an environmental, health, and safety (EH&S) risk assessment; perform continuous bench-scale system testing; and complete techno-economic and scale-up analyses.

Planned Activities

- Design, construct, and operate a spray reactor where the novel solvent is atomized and reacted with CO_2 to form a powder.
- Design, construct, and operate an extruder-like system for dry-solids transport that will also incorporate a segment allowing total or partial desorption of CO_2 within the extruder.
- Design, construct, and operate a high-pressure reactor that will serve as a desorption polishing step and/or reservoir for regenerated liquid solvent.
- Conduct continuous, steady-state bench-scale tests of the integrated system with simulated flue gas to determine its performance under a variety of conditions.
- Complete techno-economic and EH&S analyses based on bench-scale data.

Accomplishments

Project awarded in September 2013.

Benefits

Validation of a bench-scale process using an aminosilicone-based solvent for CO_2 capture will establish scalability and technical and economic feasibility of using a phase-changing CO_2 capture absorbent for post-combustion capture in coal-fired power plants. This will enable a practical technology path to later development at larger scales and, ultimately, commercialization of the CO_2 capture process.