Sorbent Based Post-Combustion CO$_2$ Slipstream Testing
Project # DE-FE0012870

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2014 NETL CO$_2$ Capture Technology Meeting
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Project Overview

DoE Project DE-FE0012870

Funding - Total Project $5,880,378

- DOE: $4,704,509
- Cost Share: $1,175,868

Project Dates

- April 1, 2014 to December 31, 2017
Technology Background & Approach
TDA’s Approach

- TDA Research has developed:
  - A solid alkalized alumina adsorbent, and
  - An CO₂ capture process designed around this process

![Image of adsorbent material]

Diagram:

- Adsorber
- Regenerator
- Flue gas
  - 1 atm, ~130 to 180°C
- Low CO₂ flue gas
- Regeneration outlet With CO₂
- Sorbent circulation
- Low Pressure Steam
TDA’s Post Combustion CO$_2$ Capture

- **Process advantages:**
  - An inexpensive, durable sorbent
  - Regenerates with low pressure steam
  - Operates at near isothermal conditions
  - Does not require heat recovery from solids
  - Extremely low heat of adsorption
  - Uses counter-current operation to:
    - Maximize capture efficiency
    - Maximize sorbent loading
Process Design

- Multiple Fixed Bed Contactor
  - Provides counter-flow contact between the solids and gases
- Beds cycle between adsorption and regeneration functions
- Gas flows in series across regeneration beds
- Multiple fixed beds are flexible and can allow demonstration of multiple process design configuration.

This slipstream project builds on previous DoE funded research

Contract #DE-NT0005497
Continuous Operation

- Demonstrated continuous CO$_2$ capture in 8 bed bench-scale unit in field testing with coal gas at Western Research Institute
- Slipstream project builds on previous DoE funded research
  - Contract #DE-NT0005497
Slipstream Testing

- **Project Goal:** Demonstrate TDA’s sorbent technology under realistic conditions at 0.5 MW_e (~10 tpd) scale to collected data necessary for scale up to next level plant.

- Design, construction, and operation of slipstream test unit to capture CO_2 from flue gas at the National Carbon Capture Center (NCCC)
Project Scope
Project Schedule

• Budget Period 1: Design
  • April 2014 to June 2015

• Budget Period 2: Construction & Installation
  • July 2015 to Sept 2016

• Budget Period 3: Operation
  • Oct 2016 to Dec 2017
Budget Period 1
## Budget Period 1 Schedule

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Budget Period 1 Tasks

- **Task 1: Project Management**
- **Task 2: Preliminary Techno-Economic Analysis**
  - Based on integration with a nominal 550 MW_e greenfield supercritical plant
- **Task 3. Pilot Plant Design Optimization and Basis Design**
  - Process experiments to finalize process design
  - Basic process specification and design
- **Task 4. Pilot Plant Detailed Design and Engineering**
  - Design a 0.5 MW_e pilot plant to capture 10 tons per day of CO_2,
  - Perform an initial Environmental, Health and Safety (EH&S) study
  - Hazard Review with NCCC
- **Task 5. Determine Slipstream Unit Construction Cost**
  - Develop a firm cost estimate for the slipstream unit
Preliminary Techno-Economic Analysis

- Integration with greenfield supercritical 550 MW coal fired power plant
  - Cost and Performance Baseline for Fossil Energy Plants (Black 2010) Case 12
  - Analysis will follow DoE guidelines

- Work being performed by University of California at Irvine (UCI)
Economic Analysis

- Total of four cases will be studied as part of the TEA
  - Baseline Case 1 run initially
  - Three additional cases will be evaluated for optimization
- TEA economic analysis is underway
**Slip Unit Design Data**

- Collect experimental data needed to design pilot plant unit
- Characterize breakthrough performance and pressure drop considerations
  - Evaluate different pellets sizes
- Conduct process optimization in bench-scale unit to determine optimum flow/cycling logic for pilot plant
Effect of Pellet Size

- Breakthrough curves measured for two different sized pellets
  - Maintained same space velocity
- No loss in performance with 1/8” pellet size compared to 1/16” pellets
**CO₂ Product Purity**

- Evaluated of composition of regeneration product gas
  - Measured by GC
- Average CO₂ out meets 95% purity standard
Kinetic Studies

• Performance as a function of space velocity
  • Future studies to evaluate regeneration and adsorption side separately
Process Design Optimization

• Underway to modify existing bench-scale unit to mimic design to be constructed
• New system will have additional dedicated beds for purge between adsorption and regeneration steps
• Collect data to evaluate trade-off of adding beds and performance recycles/purge steps
Slipstream Unit Test System

- Adsorption, regeneration and purge beds
- Each stage operates for a full cycle
  - Current unit has some stages operating for a fraction of a cycle
Slipstream Unit Design

- 0.5 MW<sub>e</sub> Skid mounted system
- Adsorber/Regeneration Contractor is a multiple fixed bed unit
  - Beds switch between adsorption, regeneration, purge operations
- Sorbent is regenerated by steam
- Adsorber/Regenerator operates near isothermal (adiabatically) at 140 to 160°C with about 17 psia steam
- Operation pressure is near atmospheric pressure
- Slipstream unit includes adsorber/regeneration beds, heat exchangers, blower
Pilot Plant Engineering Design

• Budget Period 1 will determine cost to construct Slipstream Unit
  • Final Process Flow Diagram, General Arrangement Sketch, Elevation Sketch

• Hazard analysis to be conducted per NCCC requirements

• Estimated CO$_2$ delivery conditions: pressure, temperature, flow rate, and gas composition

• Startup, steady-state operation, and shut-down procedures

• Sorbent disposal plan
  • to be disposed of by NCCC
Budget Periods 2 & 3
Budget Period 2 Tasks

Budget Period 2  July 2015 to Sept 2016

- Scale-up production of the sorbent
- QA/QC testing of sorbent at TDA
- Fabricate the sorbent bed vessels for the pilot plant and other modules
- Finalize Test Plan
  - Operating conditions and key parameter parametric conditions selected
  - Operator training
- Integrate the unit at the NCCC.

6. Sorbent Production Scale-up and Assurance

- Scale-up production of the sorbent to 5 tons
- Sorbent production will be coordinated with industry partner Clariant, formerly Sud Chemie, can produce sorbent
- Sorbent is alkalized alumina - not exotic material
- Sorbent QA/QC testing at TDA in bench-scale unit
- Sorbent will be tested under proposed test conditions
- Evaluation of optimum steady state conditions

7. Procurement and Fabrication of

- Fabricate the adsorber/regeneration sorbent vessels for the pilot plant
- Procure/fabricate of heat exchangers and blower skid mounted units
Budget Period 3 Tasks

Budget Period 3  Oct 2016 to Dec 2017

• Demonstrate this process in slipstream testing at the NCCC under both parametric and steady state conditions using coal derived flue gas.
• Update the Techno-Economic Analysis and finalize the EH&S assessment.
• Data from the pilot plant test will be used to develop recommendations for the next level of scale up.
Summary

• Slipstream testing will assess and demonstrate technical viability of this CO$_2$ capture approach
• 0.5 MW slipstream testing at NCCC
• Technical Experimental work in progress to design optimal slipstream unit
• Initial TEA in in progress
TDA Research Inc.
Privately Owned/Began operations in 1987
80 Full-time technical staff
Located just west of Denver, CO