Sorbent Based Post-Combustion CO₂ Slipstream Testing
Project # DE-FE0012870

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2015 NETL CO₂ Capture Technology Meeting
June 25, 2015
Project Objectives

• The objective is to develop a new post-combustion capture technology that captures CO$_2$ at less than $40$ per tonne (DOE’s near term cost target)

• Demonstrate TDA’s sorbent technology under realistic conditions at the 0.5 MW$_e$ (~10 tpd) scale to collect data necessary for scale up to the next level plant

• Major Project Tasks
  • Design, construction, and operation of slipstream test unit to capture CO$_2$ from flue gas at the National Carbon Capture Center (NCCC)

• Successful project completion will move the technology along the commercialization road map towards slipstream demonstrations and multi MW installations by 2020-2025

National Carbon Capture Center
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 May 31, 2018

- Budget Period 1: Optimization & Design
  - $1,542,398
- Budget Period 2: Construction & Installation
  - $2,946,991
- Budget Period 3: Operation
  - $1,390,989
Technology Background & Approach
TDA’s Approach

TDA Research has developed:

• A solid alkalized alumina adsorbent, and
• A CO₂ capture process designed around this process

TDA CO₂ Capture on Supercritical 550 MW plant

• Moving bed had expensive conveyors, although the beds would be smaller
• New multiple fixed bed design
  • Low cost construction
  • Simple bed design
  • Eliminates power lost to moving sorbent
• Lower overall cost that moving bed
Sorbent-based
Post Combustion CO₂ Capture

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

- **Patents filed July 2014**
  - Pending U.S. and PCT applications

Heat of adsorption ranges from 3 kcal/mole at higher CO₂ concentrations of 10-14%, to 10.3 kcal/mole at CO₂ concentrations of 1-5%
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 configurations
- Slipstream unit is being designed as multiple fixed bed unit
Earlier Demonstration Testing at Western Research Institute

- Slipstream project builds on previous DoE funded research
  - Contract #DE-NT0005497
- Demonstrated continuous CO$_2$ capture in 8 bed bench-scale unit in field testing with coal flue gas at Western Research Institute (Laramie, WY)
Project Scope
Project Schedule

• **Budget Period 1: Optimization & Design**
  • April 2014 to November 2015

• **Budget Period 2: Construction & Installation**
  • December 2015 to Feb 2017

• **Budget Period 3: Operation**
  • March 2017 to May 2018
Major Project Tasks

• **Preliminary Techno-Economic Analysis**
  • Based on integration with a nominal 550 MW_e greenfield supercritical plant, Case 12

• **Pilot Plant Design Optimization and Basis Design**
  • Process experiments to finalize process design
  • Basic process specification and design

• **Pilot Plant Detailed Design and Engineering**
  • Design a 0.5 MW_e pilot plant to capture 10 tons per day of CO_2,
  • Hazard Review with NCCC and Initial Environmental, Health and Safety (EH&S) study

• **Scale-up production of the sorbent**
  • QA/QC testing of sorbent at TDA

• **Fabricate slip stream unit and install at NCCC**

• **Demonstrate this process in slipstream testing**
  • Under parametric and steady state conditions

• **Update the Techno-Economic Analysis and finalize the EH&S assessment**
Budget Period 1
Progress to Date

- Project kick-off meeting held at DoE on May 2014
- Several improved process designs developed
  - New bench-scale unit constructed for optimization testing which mimics slipstream unit
  - Several generations of changes have been made as part of optimization
  - Reconstruction of bench-scale apparatus for optimization experiments delayed project schedule.
- Engineering and design of 0.5 MW slip stream unit started
  - Design presented to NCCC for discussion on requirements and logistics
  - Multiple fixed beds design reactor design and layout developed
  - PFD and P&IDs prepared
- Preliminary Hazard Review with NCCC completed May 2015
- EH&S report to be completed June 2015
Process Design Optimization

- Multiple Fixed Bed Contactor
  - Provides counter-flow contact between the solids and gases
- Beds cycle between adsorption and regeneration functions
- Gas flows in parallel through adsorption beds and in series across regeneration beds
Features & Benefits of 12 Bed Design

- Previous TDA bench-scale apparatus had 8 beds and limited ability to simulate recycle options
- New 12 bed apparatus is redesigned for improved performance and better simulation of slip stream unit & commercial system

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<tr>
<th>Feature</th>
<th>Advantage</th>
<th>Benefit</th>
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<tr>
<td>12 beds (vs. 8 beds)</td>
<td>Additional regeneration stages</td>
<td>• Additional stripping for same steam usage</td>
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<td>• Trade-off of adding more beds to be assessed</td>
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<td>Steam saver recycle with controlled flow and timing</td>
<td>Steam in wet flue effluent recycled back to regeneration side to rehydrate bed can be optimized in controlled manner</td>
<td>• Steam usage decreased</td>
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<td>• Steam saver can now be tuned for maximize benefit</td>
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<td>Adsorption Breakthrough recycle</td>
<td>Effluent flue in last adsorption bed recycle back to feed to keep capture up</td>
<td>• This recycle option was not available in previous bench-scale apparatus</td>
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- TDA is collecting data to evaluate optimized process conditions and performance of recycles/purge steps
Slipstream Unit at NCCC

- 0.5 MW_e Skid mounted system
- Adsorber/Regeneration Contractor is a multiple fixed bed unit
- Sorbent is regenerated by steam
- Adsorber/Regenerator operates near isothermal (adiabatically) at 120 to 140°C with about 17 psia steam
- Operation pressure is near atmospheric pressure

System to be located at NCCC Pilot Bay #3 47” x30”
Pilot-scale Unit Design

- Engineering design of 0.5 MW of skid mounted slip stream unit with multiple fixed beds (5000 lb/hr flue gas)
- Pilot System includes 4 units
  - Adsorber/Regeneration Contractor
    - 12 Beds switch between adsorption, regeneration, purge operations
  - Support unit (heat exchanger, blower, flow metering, exhaust cooler)
    - Blowers to increase pressure of flue which is provided to the unit from NCCC with virtually no pressure head
    - Steam and resistive heat exchangers to heat flue gas up to the operating temperature and control (fine tune) the regeneration steam temperature
    - Flow metering to measure flue gas and steam flow rates
    - Cooling water heat exchangers to cool exhaust gases to less than 60°C to make it compatible with NCCC exhaust vent system.
  - Instrument/control unit
    - Gas analyzers and control system units

- Engineering issues being addressed related to bed design, flow distribution, valves & manifolding to minimize pressure drop, transportation/weight of units
- SolidWorks models complete on contactor unit
Slipstream Unit Reactor Design

- Beds are cylindrical reactors with carbon steel flanges.
- Top flange is removable to fill sorbent.
- A main 3 way ball valve is the central piece of each valve assembly with a number of 2 way ball valves for each gas stream.
- All valves are pneumatically actuated.

Manifolding & valves to control multiple operation on each bed
Slipstream Unit Bed Design

- A 4.5” high plenum above and below the sorbent bed for flow distribution.
- A grated plate/screen is secured at the bottom of the plenum to keep the sorbent in place.
- CFD modeling with the Solids Works flow simulation program on adsorption and regeneration flow distribution.

Flow distribution simulation through reactors
Slipstream Unit Bed Design

- SolidWorks models of the reactors and piping developed
- Sorbents beds are arranged in two rows on two skid mounted units
- 12 beds in internally insulated box, entire trailer at operating temperature, removable panels for maintenance/repair
Budget Periods 2 & 3
Budget Period 2

BP 2 Tasks   December 2015 to February 2017

- 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
Budget Period 3 Tasks

Budget Period 3  March 2017 to May 2018

- 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

• Process design optimization is focused on the flow pattern of the gases (which is controlled by the programming of the system) through the multiple fixed bed system
• We have moved forward with hardware design even as we continue to push of the optimization of the system
• Initial process flow diagrams and P&IDs of the slipstream system have been prepared
• We have completed initial Process Hazard Analysis with NCCC
• We have nearly completed preliminary Environmental, Health and Safety (EH&S) review
• We will complete final process optimization and economic analysis
• By end of Budget Period 1 we will complete engineering design, HAZOP review and submit design package to DoE
TDA Research Inc.
Privately Owned/Began operations in 1987
80 Full-time technical staff
Located just west of Denver, CO
Acknowledgements

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