

DEVELOPMENT OF A DRY SORBENT-BASED POST-COMBUSTION CO₂ CAPTURE TECHNOLOGY FOR RETROFIT IN EXISTING POWER PLANTS

primary project goals

Research Triangle Institute (RTI) developed and tested a carbon dioxide (CO₂) capture process that utilizes a dry sodium carbonate (Na₂CO₃) sorbent that is based on the reaction of Na₂CO₃ with CO₂ and water vapor present in the flue gas from a coal-fired power plant.

technical goals

- Determine the optimal process configuration for the dry carbonate process.
- Construct and demonstrate a bench-scale CO₂ capture process using Na₂CO₃.
- Construct and demonstrate a pilot-scale, dry carbonate process that captures 0.9 tonnes of CO₂/day (1 ton of CO₂/day).
- Demonstrate the long-term chemical and mechanical stability of the sorbent.
- Update the economic analyses of the CO₂ sorbent capture process.
- Develop a commercialization plan for instituting the CO₂ capture process.

technical content

In an effort to develop a pre-pilot scale facility, RTI has been collecting data needed for designing, constructing, and operating the dry sorbent-based capture unit. RTI has designed and constructed a bench-scale heat transfer evaluation unit, shown in Figure 1, which is used to experimentally determine realistic gas and solid circulation rates and overall heat transfer coefficients for new reactor designs. A schematic diagram of the process is shown in Figure 1.

technology maturity:

Bench-Scale/Small Pilot-Scale

project focus:

A Dry Sorbent-Based Post Combustion CO₂ Capture

participant:

RTI International

project number:

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performance period:

3/7/07 – 12/31/09

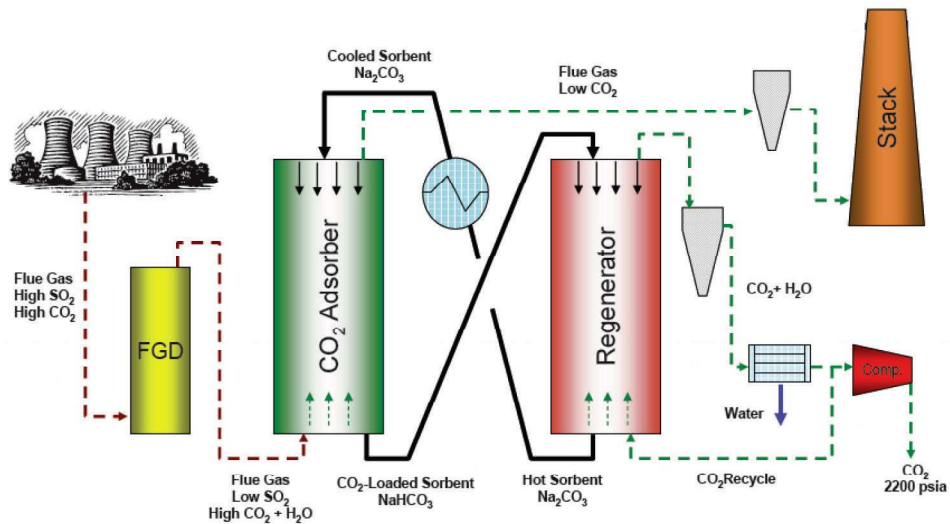


Figure 1: Schematic Diagram of CO₂ Capture Process

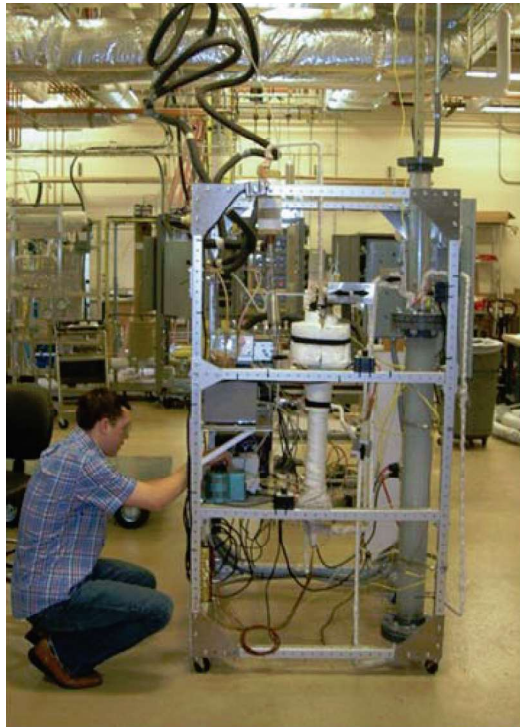


Figure 2: Lab-Scale CO₂ Absorption Reactor Skid

Pilot-scale testing will be performed on a slipstream from the air-blown gasifier at the National Carbon Capture Center (NCCC) in Wilsonville, Alabama. SRI has designed a pilot-scale, continuous, integrated test system. The equipment is being procured and will be assembled. The pilot-scale test will emphasize stability of integrated operation. The effects of trace contaminants will be observed, as the pilot tests will use a gas stream from an operating gasifier that has undergone minimum cleanup and will contain trace contaminants.

The CO₂ capture unit is located after the wet flue gas desulfurization (FGD) unit. The Na₂CO₃ sorbent reacts with the CO₂ and water (H₂O) located in the gas stream through a cyclic temperature swing cycle by adsorbing the CO₂ and H₂O at 60°C and releasing the constituents at 120°C during the sorbent regenerating stage. Considering the high exothermic heat of absorption (3.08 MJ/kg), significant cooling fluid is required to maintain the adsorption temperature at the desired value.

Utilizing the information gathered from the bench-scale unit, as well as the lab-scale unit shown in Figure 2, RTI has developed engineered sorbents that exhibit improved CO₂ capture rate and physical characteristics (e.g., attrition resistance, fluidizability, and density) over the supported (multi-layer) sorbents. These improvements will have a significant impact on a commercial, dry carbonate system by lowering the solids handling requirements and minimizing the heating and cooling duties in a commercial process. A long-term, multi-cycle testing of these sorbents to demonstrate chemical stability has been undertaken. Initial results indicate that the engineered sorbents are highly stable in the presence of contaminants such as hydrochloric acid (HCl), nitrous oxides (NO_x), H₂O, and oxygen (O₂). While sulfur dioxide (SO₂) forms irreversible chemical bonds to the sorbent, it is considered a minor issue, considering the rate of attrition is generally greater than the rate of deactivation due to SO₂.

TABLE 1: PHYSICAL PROPERTIES OF SODIUM CARBONATE SORBENTS

Property	Value
Bulk Density	1.0 – 1.1 g/mL
Average Particulate Size	65 – 75 μm
Surface Area	100 – 120 m ² /g
Physical Strength (A)	0.77
Na ₂ CO ₃ Strength	10 – 40 wt%
Heat of Absorption	3.08 MJ/kg
Regeneration Energy	3.08 MJ/kg

The heat transfer experiments will be conducted in a fluidized bed contactor, as shown in Figure 2. The conveyors (one heated, the other cooled) will be used to move the Na₂CO₃ through the fluidized bed to introduce a simulated flue gas (from coal or natural gas) to the sorbent. The instrument is used to analyze the adsorption effectiveness and the attrition rate of the Na₂CO₃ sorbent. Data from the fluidized bed will be used to validate and develop the computational fluid dynamic (CFD) model called MFIx.

Some physical properties of the sorbent are provided in Table 1.

As seen in the aforementioned table, the theoretical maximum CO₂ loading for the sorbent is ≈40 wt%. While RTI has achieved loading as high as 30 wt%, it requires a cycle time much greater than would be practical. Allowing only 30 minutes per cycle phase results in loading capacities of ≈20 to 25 percent.

technology advantages

- Lower capital and operating costs for CO₂ removal.
- Sorbent is inexpensive and easy to acquire (≈\$200/ton).
- Sorbent is non-hazardous, non-toxic, and does not produce hazardous waste.

R&D challenges

- Circulation of solids may be problematic.
- The reaction of Na₂CO₃ with H₂O is highly exothermic and requires effective heat transfer.
- Removal of CO₂ requires equimolar amounts of H₂O.
- Irreversible reactions of Na₂CO₃ with SO₂ and HCl during process conditions.
- Raw Na₂CO₃ is not a physically strong material, leading to high attrition rates.
- Raw Na₂CO₃ agglomerates upon contact with condensed H₂O.

results to date/accomplishments

- Constructed a heat transfer evaluation system used to evaluate the hydrodynamics and heat transfer characteristics of the reactor designs.
- Constructed a packed-bed reactor system to demonstrate sorbent stability over many adsorption and regeneration cycles and provide insight into reaction kinetics.
- Validated the operation of a bench-scale, coupled cold-flow system and collected data on gas-solid contactor bed height control, range of operability, sorbent bed densities, bed void volumes, and fluidization characteristics.
- Measured the heat transfer limitations of the existing screw conveyor system and determined that the screw conveyors cannot be used for sorbent regeneration in a 1-ton/day CO₂ capture pre-pilot system.
- Developed updated process simulations for the new dry carbonate process design using ASPEN Plus.

next steps

This project ended on December 31, 2009. The final report was completed in April 2010.

available reports/technical papers/presentations

Development of a Dry Sorbent-Based Post Combustion CO₂ Capture Technology for Retrofit in Existing Power Plants – Final Report – April 2010.

Nelson, T., et al., “Development of a Dry Sorbent-Based Post Combustion CO₂ Capture Technology Retrofit in Existing Power Plants,” presented at the Annual NETL CO₂ Capture Technology for Existing Plants R&D Meeting, Pittsburgh, Pennsylvania, March 2009. <http://www.netl.doe.gov/publications/proceedings/09/CO2/pdfs/43089%20RTI%20sorbent%20%28Nelson%29%20mar09.pdf>.

The Dry Carbonate Process: Carbon Dioxide Recovery from Power Plant Flue Gas, 7th Annual Conference on Carbon Capture and Sequestration in Pittsburgh, Pennsylvania, May 2008.

The Dry Carbonate Sorbent Technology for CO₂ Removal from Flue Gas of Existing Coal-Fired Power Plants – Power Plant Air Pollutant Control “Mega” Symposium in Baltimore, Maryland, August 2008.

Development of a Dry Sorbent-Based Post Combustion CO₂ Capture Technology for Retrofit in Existing Power Plants Fact Sheet, April 2008.

Carbon Dioxide Capture from Flue Gas Using Dry Regenerable Sorbents, Topical Report, November 2004.