Process for CO_2 Capture from Low-Concentration Sources

primary project goal

InnoSepra LLC has developed a low-cost capture process using structured sorbents to remove carbon dioxide (CO_2) from low-concentration feed streams. The project demonstrated the technical and economic feasibility of using structured sorbents for CO_2 capture in InnoSepra's novel adsorption-based process through lab testing, process modeling and simulation, and a detailed techno-economic analysis (TEA). Physical sorbents in their structured form have significantly lower pressure drop, require less parasitic power and plot area, and have a lower overall capital cost compared to their particulate counterparts. Laboratory tests indicated that these physical sorbents can remove moisture and concentrate CO_2 from low-concentration sources at a very high efficiency and require low parasitic power.

technical goals

- Fabricate adsorption test modules for CO_2 and moisture adsorption.
- Complete semi-bench-scale testing for moisture removal.
- Complete lab- and semi-bench-scale testing for CO_2 adsorption.
- Perform an engineering design for CO_2 enrichment of the residue stream for a 550-megawatt-electric (MWe) power plant.
- Prepare a TEA for a feed plant of 1 million standard cubic feet per minute (scfm).

technical content

InnoSepra developed a process, as shown in the schematic in Figure 1, using structured sorbents to capture CO_2 from low-concentration sources, which minimizes the pressure drop for the very high flows associated with the low-concentration sources. For a dry residue stream, a single-stage process is utilized to remove CO_2 with the structured sorbents. To treat a wet residue stream, a two-stage process is employed. Moisture is removed in the first stage in a rapid cycle adsorption process. The CO_2 adsorption occurs in the second stage, using the structured sorbents in an adsorption process. This stage produces a CO_2-enriched stream containing 10–15% CO_2 after regeneration, which can be fed to a new or an existing post-combustion CO_2 capture system. The structured sorbents used in this process have very high capacities at low-CO_2 concentrations and can be regenerated to produce the CO_2-enriched stream, achieving a CO_2 enrichment by a factor of five to 10.

Phase I focused on lab-scale evaluation of prototype adsorbents using low-CO_2 concentration simulated feed gas. Phase II included fabrication of test modules and evaluation of the structured sorbents for moisture removal and CO_2 adsorption capacity. Test unit modules were evaluated in two different configurations: a rotating-bed configuration and a fixed-bed configuration. Test results inform parameters needed for an engineering design of a full-scale plant and for a TEA.

program area:
Point Source Carbon Capture

ending scale:
Laboratory Scale

application:
Post Combustion Power Generation PSC

key technology:
Sorbents

project focus:
Structured Sorbent-Based Process for Low CO_2 Concentration Sources

participant:
InnoSepra LLC

project number:
SC0015114

predecessor projects:
N/A

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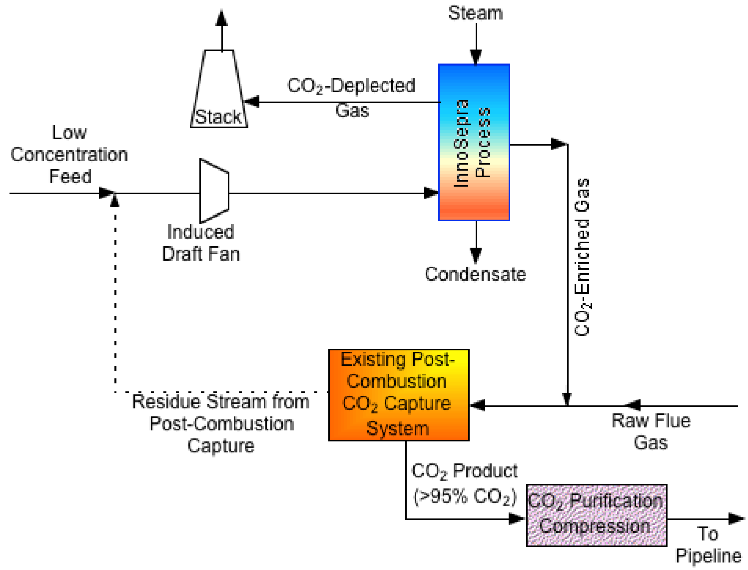

Figure 1: InnoSepra capture process.

technology advantages

The structured sorbents have:

- A very high surface area-to-volume ratio and a lower heat requirement for regeneration compared to amine-based absorption using structured packing.
- Are not subject to fluidization constraints or attrition concerns.
- Very low pressure drops, typically 1/5–1/10th of particulate adsorbents.
- Very small effective particle size (less than 80 μm) that provides very short mass transfer zones.
- Ability to process significantly higher flows for a given bed volume compared to particulate adsorbents, which is particularly beneficial for low-concentration source CO_2 capture where flow rates can be much higher.
- Ability to be fabricated using virtually any commercially available adsorbent.

R&D challenges

- Assuring sufficient moisture removal to enable significantly higher CO_2 capacity for the sorbent in the CO_2 adsorption stage.
- Validating the process model with test results.

status

Process economic evaluation based on the experimental data, process modeling, and scale-up studies indicated that the structured sorbents can cost-effectively concentrate CO_2 from a stream containing 1–1.5% CO_2 (typical of a residue stream after 90% CO_2 capture from a supercritical pulverized coal post-combustion capture process) by a factor of 10 or more. The CO_2 enrichment cost depends on the moisture content of the residue stream. If the residue stream is moisture-saturated (such as that from an amine-based capture process), the enrichment cost is about $55/tonne. If the residue stream is nearly dry (such as that from InnoSepra's adsorption-based post-combustion CO_2 capture process), the enrichment cost is about $37/tonne. The original project milestones, both in terms of process performance and the CO_2 capture cost, were significantly exceeded during the execution of this project. The current CO_2 enrichment costs of $37–55/tonne are significantly better than a cost of $350/tonne for the amine-based process for low-concentration streams. If the enriched CO_2 stream is mixed with the feed to a post-combustion CO_2 capture process, cost-effective capture of 98–99% of CO_2 is possible. The results from this project are also applicable to CO_2 capture from a natural gas combined cycle (NGCC) plant and may eventually allow CO_2 capture from air at a cost of $110–150/tonne. If the captured CO_2 is used for enhanced oil recovery (EOR), it can potentially address, depending on the oil price, a CO_2-EOR market worth more than $100 billion without the need for climate legislation. EOR can also store up to 30 gigatons (equivalent to emissions from 140 gigawatts of coal-based power generation for 35 years) of CO_2 in oil fields, significantly reducing the carbon footprint of coal-based power generation and oil production.

available reports/technical papers/presentations

Jain, R. "Process for CO_2 Capture from Low Concentration Streams," Final Technical Report, August 2018. *https://www.osti.gov/biblio/1577323-process-co2-capture-from-low-concentration-sources*.

Jain, R. "Process for CO_2 Capture from Low Concentration Streams," presented at the 2018 NETL CO_2 Capture Technology Project Review Meeting, Pittsburgh, PA, August 2018. *https://netl.doe.gov/sites/default/files/netl-file/R-Jain-InnoSepra-Low-Concentration-Capture.pdf*