Chevron Natural Gas Carbon Capture Technology Testing Project

primary project goal

Chevron, partnering with Svante Inc., Electricore Inc., Kiewit Engineering Group Inc., Kiewit Power Constructors, and Offshore Technical Services, is validating the transformational VeloxoTherm™ solid sorbent carbon capture technology at engineering scale under indicative natural gas flue gas conditions and continuous long-term operation at Chevron's Kern River Oil Field. The VeloxoTherm technology uses proprietary novel CALgary Framework-20 (CALF-20) metal-organic framework (MOF) sorbent materials and is comprised of a rotary adsorption machine for rapid-cycle thermal swing adsorption (RC-TSA) using structured adsorbent beds. The team is designing, constructing, and testing an engineering-scale plant of approximately 25 tonnes per day (TPD) under steady-state conditions at varying flue gas carbon dioxide (CO_2) concentrations (4–14%) using a once-through-steam-generator (OTSG). Chevron is also conducting a techno-economic analysis (TEA) on the VeloxoTherm technology integrated into a full-scale natural gas combined cycle (NGCC) power plant, as well as a comprehensive gap analysis.

technical goals

- Successfully complete the design, construction, commissioning, and long-term testing of an engineering-scale plant of approximately 25 TPD under steady-state conditions.
- Conduct a TEA on the Svante RC-TSA technology as integrated into a nominal 550-megawatt (MW) (net) natural gas power plant.
- Conduct a comprehensive gap analysis addressing the current stage of development of the Svante technology for NGCC application, and summarize the research, development, and demonstration requirements to close any of the gaps to approach achievement of the U.S. Department of Energy's (DOE) Carbon Capture Program performance goal of CO_2 capture with 95% CO_2 purity at a cost of \$30/tonne of CO_2 captured by 2030.
- Complete a Technology Maturation Plan (TMP) and Environment, Health, and Safety (EH&S) Risk Assessment.

technical content

The VeloxoTherm process developed by Svante is comprised of an RC-TSA process that uses a patented architecture of structured adsorbent beds (SABs) and a novel process design and embodiment to capture CO_2 from industrial and natural gas-fired flue gas streams. SABs possess unique physical and transport properties that serve to greatly improve the performance of gas separation, enabling fast cycle times and small equipment sizes that deliver attractive capture economics. Figure 1 shows the Rotary Adsorption Machine (RAM) design at the core of the technology. Svante uses solid adsorbents that have very high surface-to-volume ratios, instead of liquid chemicals (amines or potassium hydroxide), to capture CO_2. A new class of advanced sorbent materials, CALF-20, has been developed by Svante and lab-tested under DOE Cooperative Agreement No. DE-FE0031732 and field-tested in Q3-2020 at a cement plant in Vancouver, Canada.

program area:
Point Source Carbon Capture

ending scale:
Small Pilot

application:
Post-Combustion Power Generation PSC

key technology:
Sorbents

project focus:
Metal-Organic Framework-Based Sorbent

participant:
Chevron

project number:
FE0031944

predecessor projects:
N/A

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Electricore Inc.; Svante Inc.; Kiewit Engineering Group Inc.; Kiewit Power Constructors; Offshore Technical Services

start date:
10.01.2020

percent complete:
75%

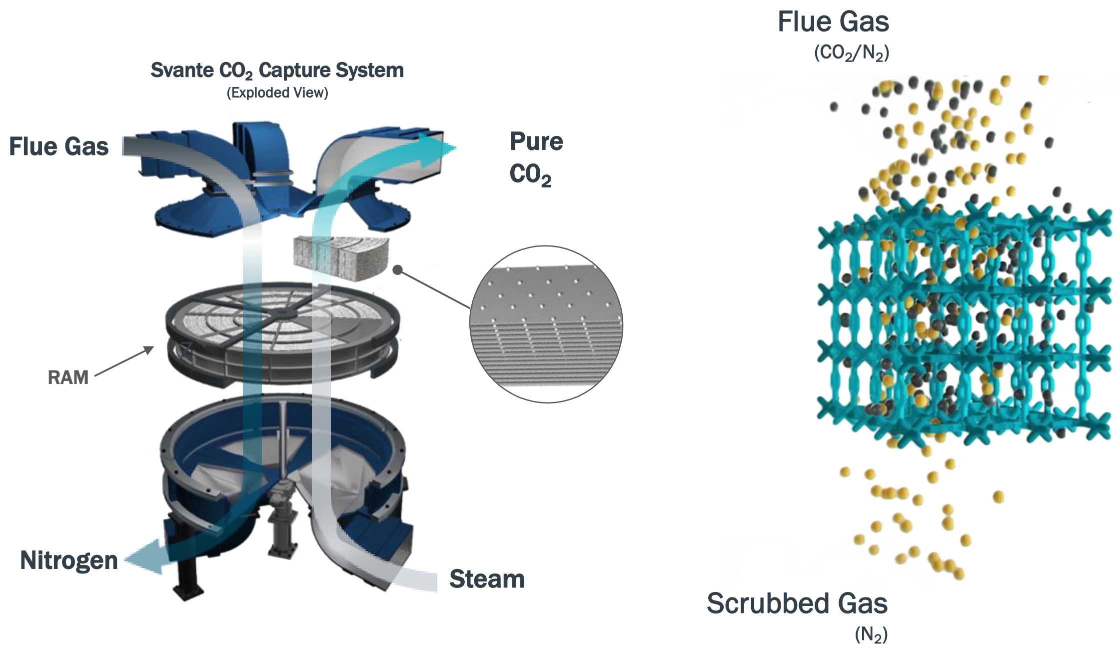

Figure 1: VeloxoTherm™ Rotary Adsorption Machine.

The sorbent material exhibits unique resistance to sulfur oxide (SO_X), nitrogen oxide (NO_X), and oxygen impurities, as well as moisture swing. Utilizing CALF-20 eliminates the need for a site nitrogen generator that is required on an amine-doped silica sorbent plant to protect the adsorbent from oxidation during conditioning steps. The VeloxoTherm process has been scaled-up to 30 TPD of CO_2 and is undergoing demonstration with flue gas derived from natural gas combustion at Cenovus in Canada using a first-generation sorbent material of amine-doped silica. In this proposed project, the team plans to leverage the design and learnings from the Cenovus 30-TPD project to improve the performance and flexibility of a second-of-a-kind (SOAK) engineering-scale plant (400 Series) using CALF-20 MOF sorbent material.

The test program will be performed at a feed CO_2 concentration of approximately 8% (10.5% dry basis) for normal steady-state operations, with flexibility to gather data and test equipment at a wide operating range of 4–14% CO_2 in the feed by employing an air-mixing and CO_2 product recycling system. The CO_2 product specification will be 95% (versus 85% in the Cenovus unit), meeting existing CO_2 pipeline specifications. To achieve this product purity and process flexibility, a reflux step will be added to the RAM and balance of plant (BOP).

TABLE 1: SORBENT PROCESS PARAMETERS

Sorbent	Units	Current R&D Value	Target R&D Value
True Density @ STP	kg/m^3	350-380	350-380
Bulk Density	kg/m^3	NA	NA
Average Particle Diameter	mm	0.31-0.35	0.31-0.35
Particle Void Fraction	m^3/m^3	NA	NA
Packing Density	m^2/m^3	2300-2500	2300-2500
Solid Heat Capacity @ STP	kJ/kg-K	1.4-1.6	1.4-1.6
Thermal Conductivity	W/(m-K)	0.25-0.35	0.25-0.35
Manufacturing Cost for Sorbent	$/kg	30-35	20-25
Adsorption			
Pressure	bar	1-1.1	1-1.1
Temperature	°C	50	50
Equilibrium Loading (20% CO_2)	g mol CO_2/kg	1.7-1.9	1.7-1.9
Heat of Adsorption	kJ/mol CO_2	35-38	35-38
Desorption			

Pressure	bar	0.8-1.0		0.8-1.0
Temperature	°C	120-140		120-140
Equilibrium CO_2 Loading (20% CO2)	g mol CO_2/kg	0.3-0.4		0.3-0.4
Heat of Desorption	kJ/mol CO_2	35-38		35-38
Proposed Module Design				
Flow Arrangement/Operation	—	Rapid cycle rotary valves moving bed		
CO_2 Recovery, Purity, and Pressure	% / % / bar	90-95	95	150

Definitions:

STP – Standard Temperature and Pressure (15°C, 1 atm).

Sorbent – Adsorbate-free (i.e., CO_2-free) and dry material as used in adsorption/desorption cycle.

Manufacturing Cost for Sorbent – "Current" is market price of material, if applicable; "Target" is estimated manufacturing cost for new materials, or the estimated cost of bulk manufacturing for existing materials.

Adsorption – The conditions of interest for adsorption are those that prevail at maximum sorbent loading, These may be assumed to be 1 atm total flue-gas pressure (corresponding to a CO_2 partial pressure of 0.13 bar) and 40°C.

Desorption – The conditions of interest for desorption are those that prevail at minimum sorbent loading. Operating pressure and temperature for the desorber/stripper are process-dependent.

Pressure – The pressure of CO_2 in equilibrium with the sorbent. If the vapor phase is pure CO_2, this is the total pressure; if it is a mixture of gases, this is the partial pressure of CO_2.

Packing Density – Ratio of the laminated sorbent composite sheet area/filter bed volume.

Equilibrium Loading – The basis for CO_2 loadings is mass of dry sorbent measured with 20% CO_2 in N_2 mixture without moisture.

Flow Arrangement/Operation – Gas-solid module designs include fixed, fluidized, and moving bed, which result in either *continuous*, *cyclic*, or *semi-regenerative* operation.

Other Parameter Descriptions:

Chemical/Physical Sorbent Mechanism – Physisorption.

Sorbent Contaminant Resistance – High oxidation resistance below 50 parts per million (ppm) SO_X and NO_X.

Sorbent Attrition and Thermal/Hydrothermal Stability – Very stable under direct steam regeneration.

Flue Gas Pretreatment Requirements – Conventional Direct Contact Cooler (DCC).

Sorbent Make-Up Requirements – A three- to five-year lifetime without bed replacement.

Waste Streams Generated – No chemicals in depleted N_2 and typical cooling water blow-down.

TABLE 2: CARBON CAPTURE ECONOMICS

Economic Values	Units	Current R&D Value	Target R&D Value
Cost of Carbon Captured	\$/tonne CO_2	50	30
Cost of Carbon Avoided	\$/tonne CO_2	Site specific	Site specific
Capital Expenditures	\$/TPD	70,000 to 80,000	60,000 to 70,000
Operating Expenditures	\$/tonnes CO_2	26 - 28	20-23
Cost of Electricity	\$/tonnes CO_2	12-18	12-18

Definitions:

Cost of Carbon Captured – Projected cost of capture per mass of CO_2 captured under expected operating conditions.

Cost of Carbon Avoided – Projected cost of capture per mass of CO_2 avoided is site specific depending on the source of electricity and steam.

Capital Expenditures – Projected capital expenditures in dollars per tonne per day of capacity.

Operating Expenditures – Projected operating expenditures in dollars per unit of tonne of CO_2 produced including filter bed replacement and compression cost.

Cost of Electricity – Projected cost of electricity per unit of tonne of CO_2 produced for a range of price of electricity of 3.5 to 6 cents per kWh.

Scale of Validation of Technology Used in TEA – The technology numbers were validated for use in the TEA from pilot-scale data.

technology advantages

- Svante's technology has the potential to enable a 50% reduction in capital costs compared to first-generation approaches.
- Novel technology replaces large chemical solvent towers (conventional approach) with a single piece of compact equipment, significantly reducing capital expenses (CAPEX).
- Advanced sorbent material exhibits sharper temperature and pressure swing absorption and desorption, which allows for lower energy loads and faster kinetic rates.
- The proprietary material also exhibits unique resistance to SO_X and NO_X, oxygen impurities, and moisture swings.

R&D challenges

- Engineering-scale testing and analysis.

status

Chevron, through its partnership with Svante, completed the Preliminary TEA Summary Report in response to a request for a Class IV TEA of a retrofit package to capture CO_2 from existing NGCC power plant facilities. The project also completed a general process flow diagram identifying all major process equipment for the power plant, including CO_2 capture and compression systems, separation vessels, heat exchangers, pumps, compressors, etc. Chevron's partner Svante upgraded the Rotary Seal Validation Testing (RSVS) for design validation of key parameters that cannot be replicated on the smaller material seal test station. The RSVS upgrade, including design, procurement, assembly, programming, and commissioning, was completed. The RSVS has been upfitted with a new gearbox to enable operation at expected rotational speed, along with true-size seal segments and counterface parts similar to actual RAM seal parts for design validation. A 50-day RSVS was completed. The project also demonstrated sorbent scale-up production required for project execution. Additional and complementary tests conducted at Svante confirm material properties, sorbent characterization, and slurry processability into coated laminates are meeting current specifications developed from Svante internal synthesized materials.

available reports/technical papers/presentations

Justin Freeman, "Chevron Natural Gas Carbon Capture Technology Testing Project," Project kickoff meeting presentation, Pittsburgh, PA, April 2021. *http://www.netl.doe.gov/projects/plp-download.aspx?id=11026&filename=Chevron+Natural+Gas+Carbon+Capture+Technology+Testing+Project.pdf*.

Justin Freeman, "Chevron Natural Gas Carbon Capture Technology Testing Project," Budget Period 1 Project Review meeting presentation, Pittsburgh, PA, July 2021. *http://www.netl.doe.gov/projects/plp-download.aspx?id=11028&filename=Chevron+Natural+Gas+Carbon+Capture+Technology+Testing+Project.pdf*.

Justin Freeman, "Chevron Natural Gas Carbon Capture Technology Testing Project," NETL Carbon Management Research Project Review Meeting, Pittsburgh, PA, August 2021. *https://netl.doe.gov/sites/default/files/netl-file/21CMOG_PSC_Freeman.pdf*