ROTA-CAP™: An Intensified Carbon Capture System Using Rotating Packed Beds

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Outline

• Project Overview
• Technology Background
• Technical Approach Discussion
• Progress and Current Status
• Summary
Project Overview
ROTA-CAP™ – An Intensified Carbon Capture System Using Rotating Packed Beds

• Sponsor

• Funding: $2,784,222 DOE ($743,000 co-funding)

• Objective: The objective of this project is to develop and validate a transformational carbon capture technology—ROTA-CAP™

• Design, construct, test and model novel rotating packed bed (RPB) absorbers and regenerators

• Assess the performance of the integrated hardware and solvent under a range of operating conditions

• Test with simulated flue gas at GTI Energy

• Long term test with real flue gas at the National Carbon Capture Center (NCCC)
ROTA-CAP™ uses compact rotating packed bed (RPB) absorbers and regenerators for contacting flue gas with an advanced solvent such as Carbon Clean’s CDRMax ® for carbon capture.
Technology Background
• GTI Energy and its predecessor institutions GRI and IGT has experience on RPB process technology for natural gas dehydration and bulk acid gas removal process design and operation.

• GTI Energy Engineering Team reviewed mechanical requirements of the RPB sizing submitted by Carbon Clean.

• GTI Energy prepared initial RPB design concept, mechanical design of RPBs for construction and worked with our fabricator as well as in house construction team to build the test skid.

• Packing for RPB’s are provided by Montz Engineered Column Systems, Germany.
Technical Approach
Test Plan and Key Experimental Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotational Speed</td>
<td>100–500 RPM</td>
</tr>
<tr>
<td>Absorber Liquid/Gas ratio</td>
<td>0.5–5.0 kg/m³</td>
</tr>
<tr>
<td>Solvent Circulation Rate</td>
<td>30–150 kg/h</td>
</tr>
<tr>
<td>Solvent Concentration &amp; Viscosity</td>
<td>35–70 wt.% &amp; 5–80 cP</td>
</tr>
<tr>
<td>Regenerator Operating Pressure &amp; Temperature</td>
<td>0.0–1.0 bar(g) &amp; 100–130°C</td>
</tr>
<tr>
<td>Flue gas composition</td>
<td>Synthetic - Natural gas-fired - Coal-fired</td>
</tr>
</tbody>
</table>

- 50kWe (1000kg/day CO₂ removal) scale integrated carbon capture skid
- Design, construct, test and model novel rotating packed bed (RPB) absorbers and regenerators
- Assess the performance of the integrated hardware and solvent under a range of operating conditions
- Test with simulated flue gas at GTI Energy
- Long term test with real flue gas at the National Carbon Capture Center (NCCC)
ROTA-CAP™ – Bench Scale Test Skid

Integrated (RPB absorber and RPB regenerator), Continuous, Bench-scale, 1 TPD test skid at GTI

GTI Conceptual design and 3D skid layout

Operational ROTA-CAP™ skid at GTI
Progress and Current Status
ROTA-CAP™ has two stages of absorber RPB and one regenerator RPB with a separate reboiler.
Test Skid Construction at GTI Energy

3D Layout of the ROTA-CAP™ Test Skid

RPB Delivery to GTI

Absorber RPB’s and Flue Gas Piping
Experimental Development Unit

- 1 ton CO₂ per day removal capacity
- Skid size is 20 feet x 8 feet x 8 feet (NOT OPTIMIZED)
- RPB diameter is about 1 meter
ROTA-CAP™ – Transportation from GTI to NCCC

Shipping Preparation

ROTA-CAP™ Skid Leaving GTI Energy

Arrival at NCCC
ROTA-CAP™ – Test Results
ROTA-CAP™ – Parametric Testing at GTI Energy

• Key Variables:
  • Absorber and Regenerator RPMs
  • CO₂ Concentration and Circulation rate
  • Regenerator Operation

Total lab operation:
About 400 hours

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range Tested at GTI Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂ Inlet Concentration</td>
<td>2.12 to 13.2%</td>
</tr>
<tr>
<td>Solvent Circulation Rate</td>
<td>0.5-1.8 GPM</td>
</tr>
<tr>
<td>Absorber and Regenerator Speed</td>
<td>Up to 600 RPM</td>
</tr>
<tr>
<td>Solvent Concentration</td>
<td>40% to 60% solvent</td>
</tr>
<tr>
<td>Gas Flow Rate</td>
<td>100 to 400 lb/hr</td>
</tr>
</tbody>
</table>
ROTA-CAP™ – GTI Energy Test Data

- Startup stabilization takes less than 1 hour after a set point change.
- Steady state within 2 hours.
- After regenerator optimization capture rate improved (dark blue data)
ROTA-CAP™ – SSTU Tests at NCCC (Fall 2021)

- Solvent concentration levels between 35% and 55%
- Fuel gas CO₂ concentration:
  - Coal Flue Gas at 11.9%
  - NG Flue Gas at 4.4%
  - NG Flue Gas at 10.1%
- L/G range between 1 and 4

**Preliminary Review:**

- Conventional column is unable to sustain stable operation above 55% concentration.
- Removal efficiency is similar in ROTA-CAP™ to the much larger conventional column.
- Lean loading impacted ROTA-CAP™ at lower L/G ratios when compared to the conventional column.
- Focus on ROTA-CAP™ regeneration optimization.
ROTA-CAP™ – Field Testing at NCCC

Five test campaigns:

1. October – November 2021
   - NCCC Boiler: NG flue gas (parametric)
   - Over 120 hours

2. March 2022
   - NCCC Boiler: NG Flue gas
   - Over 150 hours

3. Late April – May 2022
   - Power Plant: Coal Flue Gas
   - Over 200 hours

4. June 2022
   - Power Plant: Coal and Coal + NG Flue Gas
   - Over 450 hours

5. August 2022
   - Power Plant: Coal and Coal + NG Flue Gas
   - About 360 hours

Total field operation: >1200 hours

Total power plant flue gas operation: >1000 hours
Long Term Testing at NCCC

Test Campaign 2:

• Feed gas was from NCCC’s NG boiler. Feed gas is diluted with air or augmented with CO₂.

• Achieved 93% removal efficiency under all conditions.

• The CO₂ product is consistently about 95% purity.

• The skid reaches steady state operation in about 2 hours.
Long Term Testing at NCCC

Test Campaign 3:

- **Power Plant Feed:** Coal
- **Operation Hours:** 195
- **Removal Efficiency:** >90%
- **Solvent Concentration:** 35-40%

Test Campaign 4:

- **Power Plant Feed:** Coal + NG
- **Operation Hours:** 455
- **Removal Efficiency:** >95%
- **Solvent Concentration:** 45-50%
Capture Efficiency as a function of L/G:

- Collective data from Test Campaigns 3, 4 and 5
- Process simulation model solutions are in the indicated area.
ROTA-CAP™ – Future Development
ROTA-CAP™ – Future Projects and Scale Up Plan

Evaluating different industrial emission sources:
- Steel
- Concrete
- Petrochemical

Process simulation and preliminary TEA's prepared for:
- 2.5 TPD scale industrial emission application
- 5 TPD and 10 TPD NGCC application

Commercial unit size expected at 10,100 and 300 TPD
Summary:

- ROTA-CAP™: A compact and more versatile process compared to other next generation CO₂ capture technologies
- First RPB absorber AND RPB regenerator integrated, continuous, bench-scale CO₂ capture skid
- Successful power plant flue gas operation for more than 1,000 hours
- RPB reactors are agnostic to the solvent used
- Challenges of scale up from bench-scale to commercial scale; likely limited to modular design approach

Next Step:

Bench-scale to Pilot-scale
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