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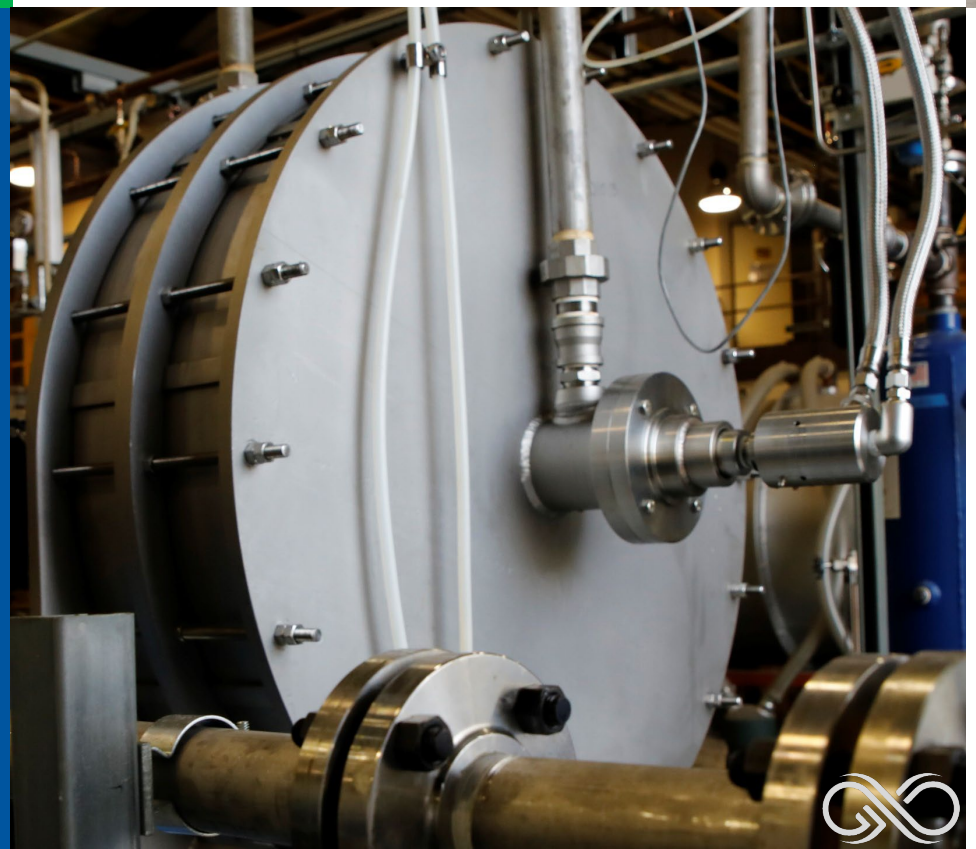

# ROTA-CAP™: An Intensified Carbon Capture System Using Rotating Packed Beds

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U.S. Department of Energy
National Energy Technology Laboratory
Carbon Management Project Review Meeting
August 15-19, 2022

DOE Contract No. DE-FE0031630

# 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

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- Sponsor



**DE-FE0031630**

- 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™

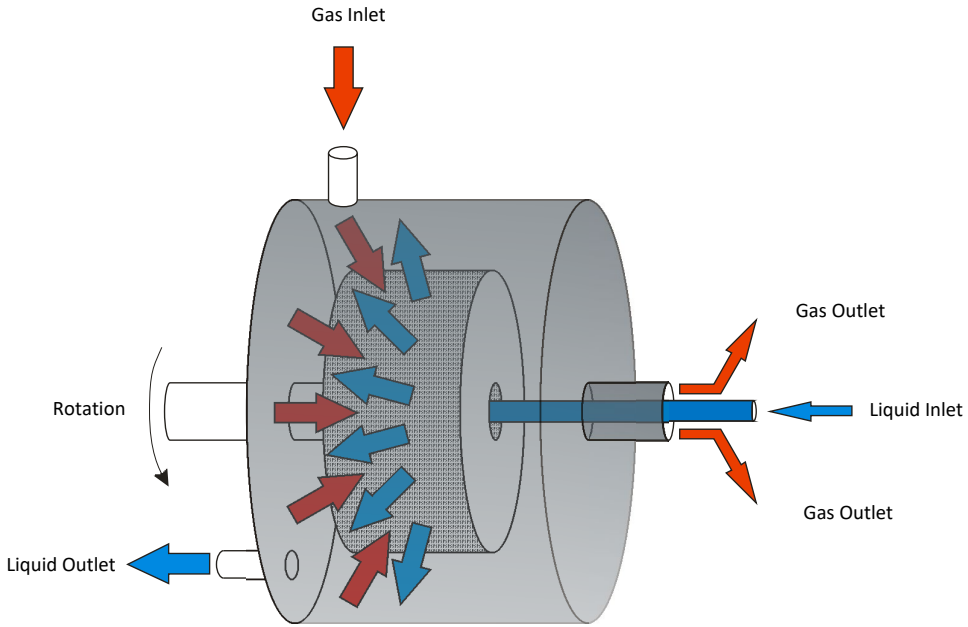
  - BP1: 10/1/2018 – 3/31/2021  BP2: 4/1/2021 – 12/31/2022

# ROTA-CAP™ – DOE/NETL Project Objectives and Members

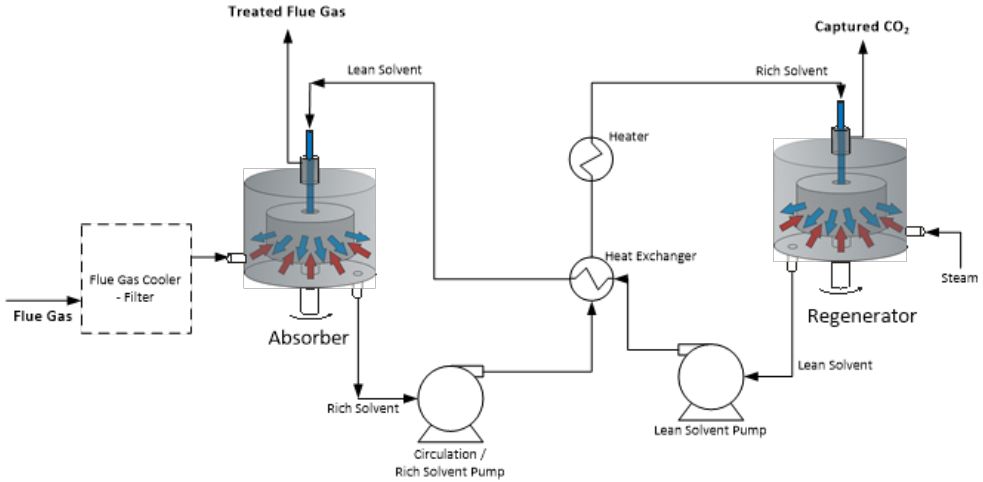
- Design, construct, test and model novel rotating packed bed (RPB) absorbers and regenerators
- Assess the performance of the integrated hardware and solvent under a range of operating conditions
- Test with simulated flue gas at GTI Energy
- Long term test with real flue gas at the National Carbon Capture Center (NCCC)

# ROTA-CAP™ – Process Intensification (PI)

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




**COUNTER CURRENT CONTACT**




Simplified ROTA-CAP™ flow diagram

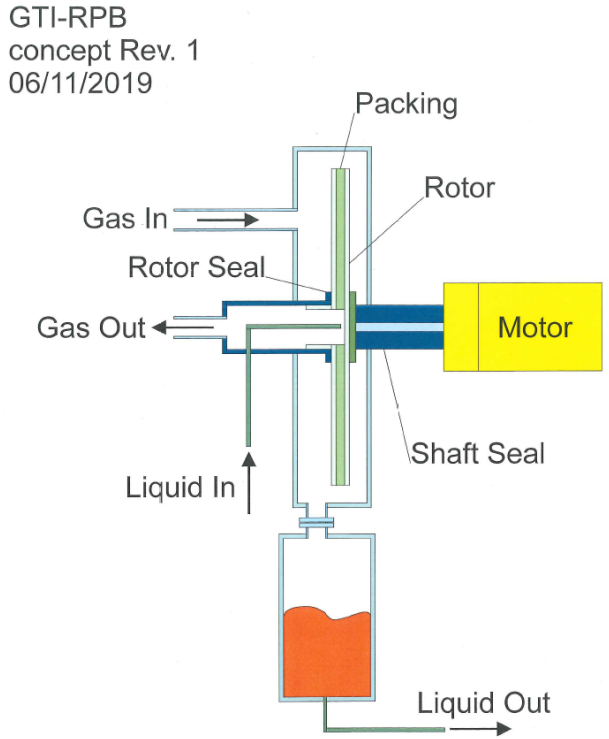
ROTA-CAP™ Absorber and Regenerator RPBs

# Technology Background

# ROTA-CAP™ – Rotating Packed Bed Design

- 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.

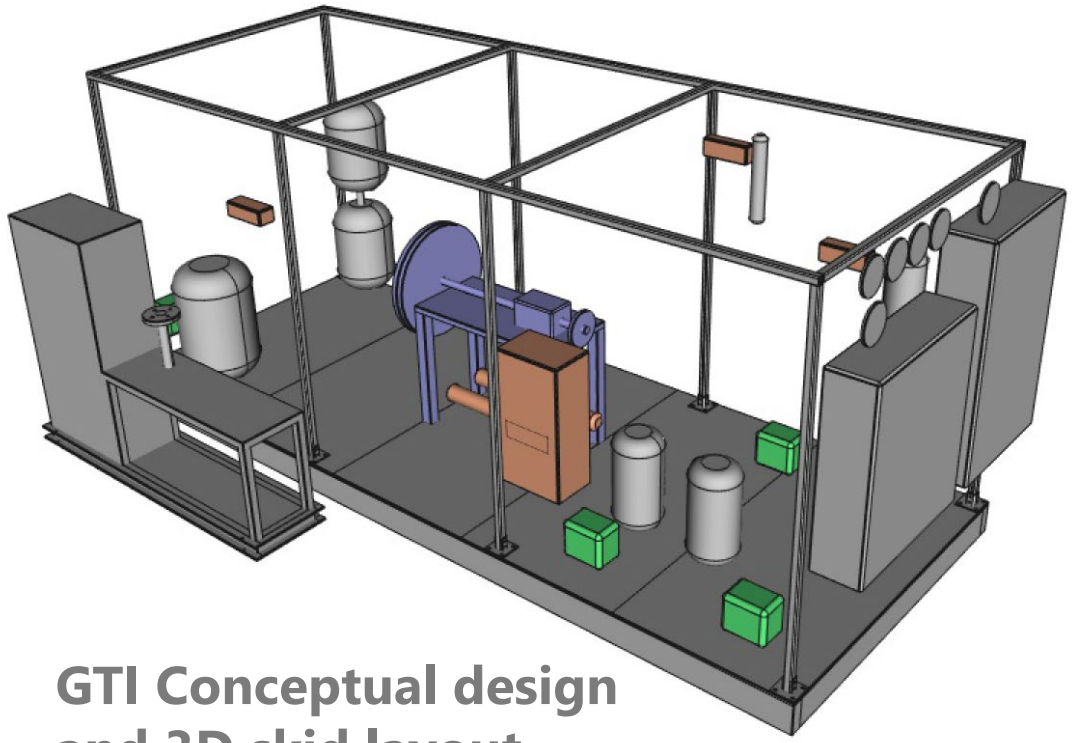
# Technical Approach

# Test Plan and Key Experimental Parameters

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

- 50kWe (1000kg/day $CO_2$ 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

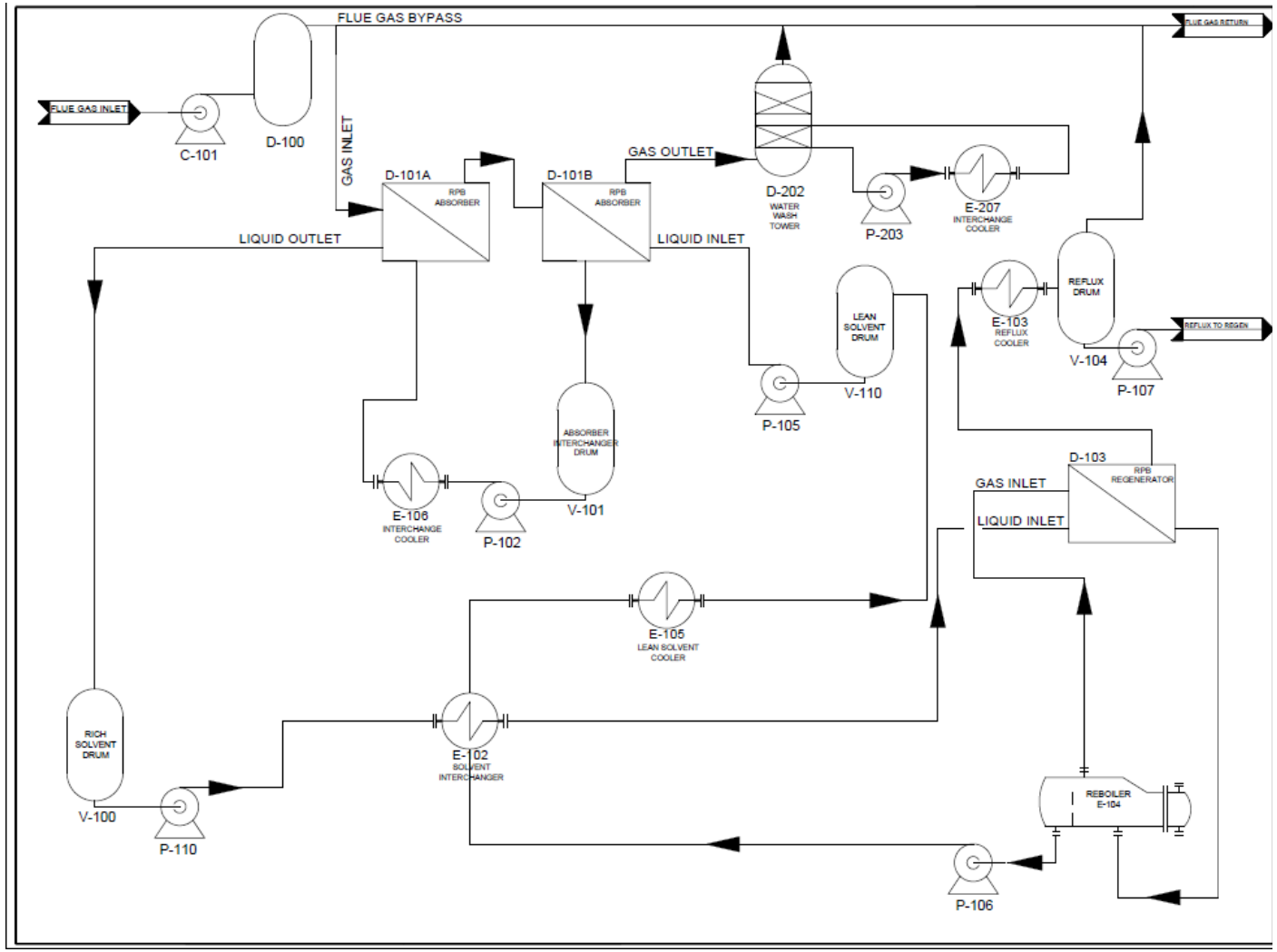


**GTI Conceptual design and 3D skid layout**

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

# Progress and Current Status

# ROTA-CAP™ Process Flow Diagram (PFD)

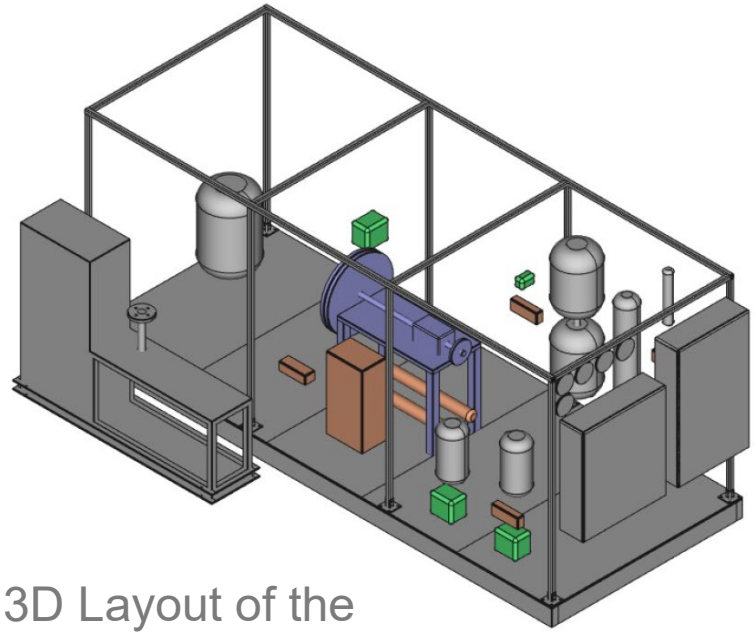



Simplified

ROTA-CAP™ PFD

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$^{tm}$ Test Skid

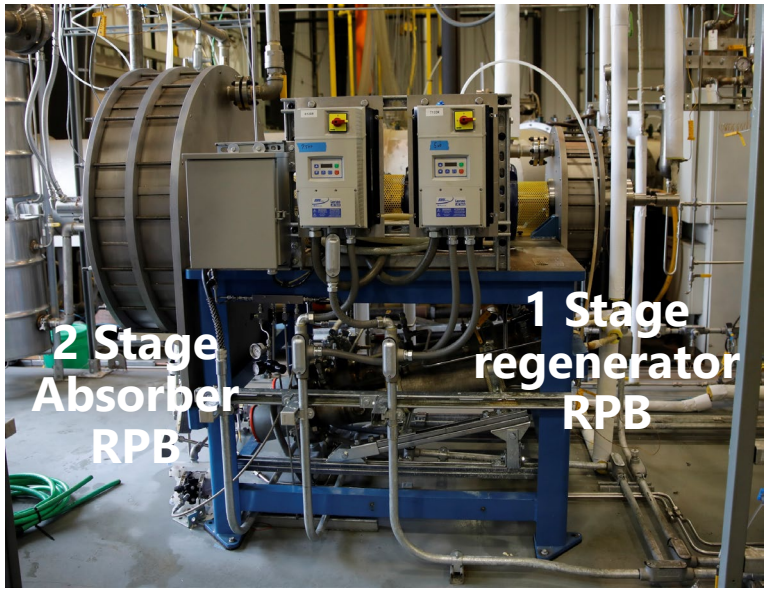
RPB Delivery to GTI

Absorber RPB's and Flue Gas Piping

# ROTA-CAP™ – Test Unit at GTI Energy

## Experimental Development Unit

- 1 ton $CO_2$ 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



# ROTA-CAP™ – Test Results

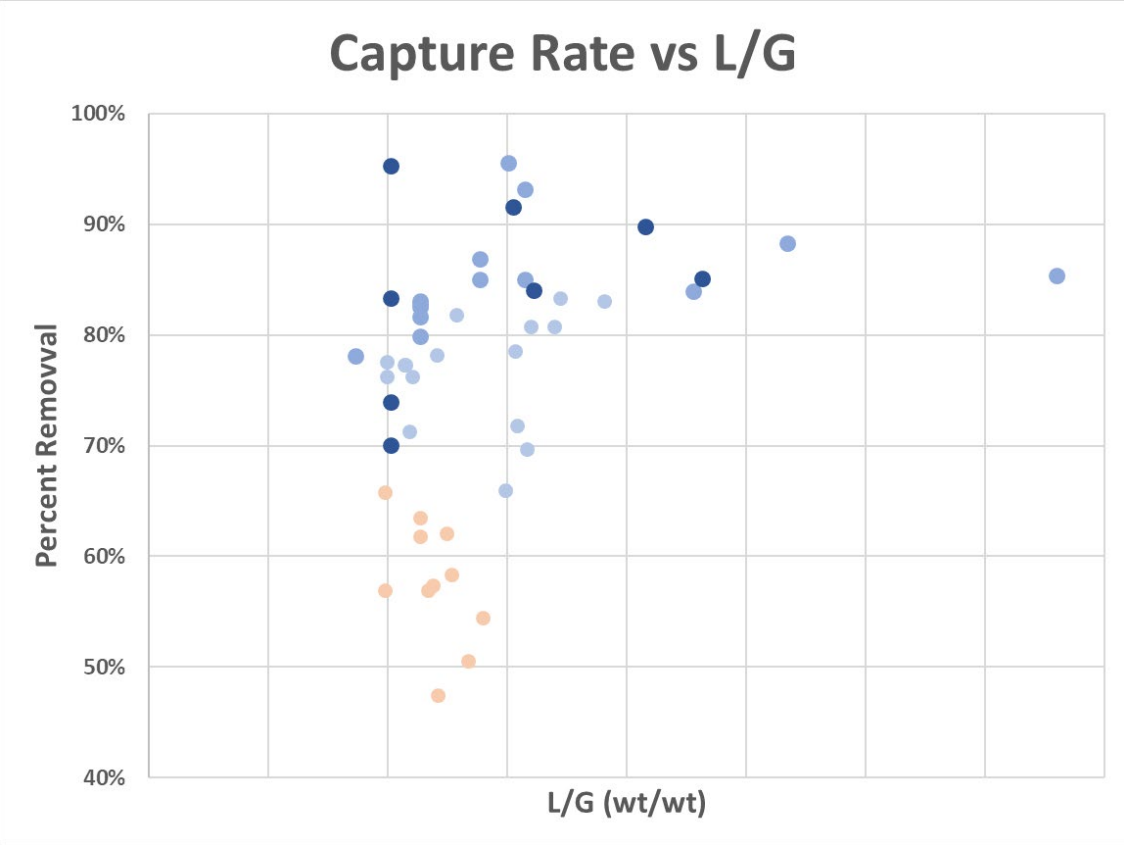
# ROTA-CAP™ – Parametric Testing at GTI Energy

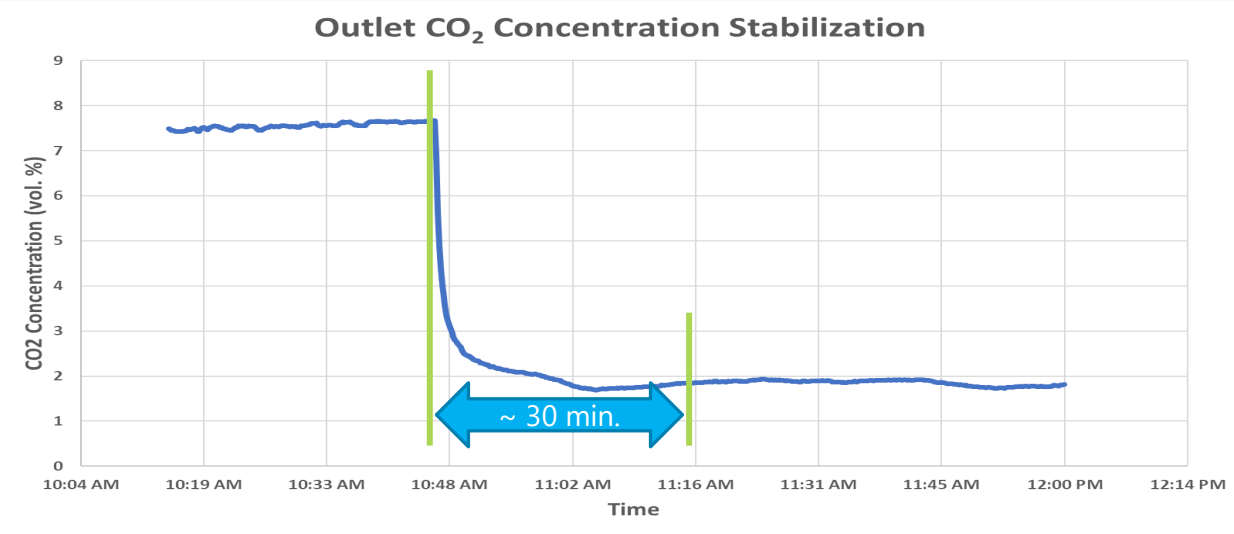
- Key Variables:
  - Absorber and Regenerator RPMs
  - $CO_2$ Concentration and Circulation rate
  - Regenerator Operation

**Total lab operation:**
About 400 hours

| Parameter | Range Tested at GTI Energy |
|---|---|
| $CO_2$ Inlet Concentration | 2.12 to 13.2% |
| Solvent Circulation Rate | 0.5-1.8 GPM |
| Absorber and Regenerator Speed | Up to 600 RPM |
| Solvent Concentration | 40% to 60% solvent |
| Gas Flow Rate | 100 to 400 lb/hr |

# 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 $CO_2$ 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

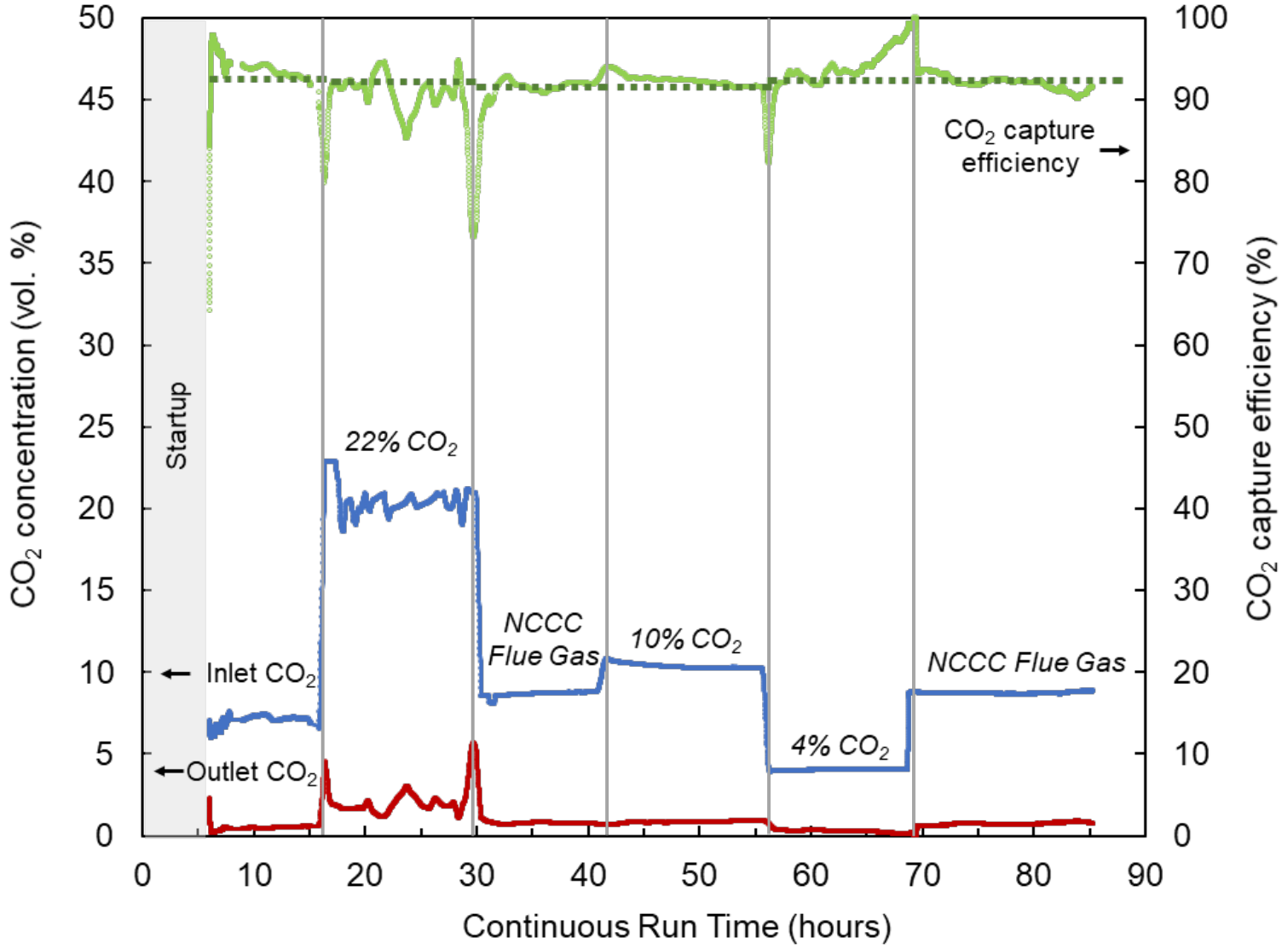
**Total power plant flue gas operation:**

>1000 hours

# Long Term Testing at NCCC

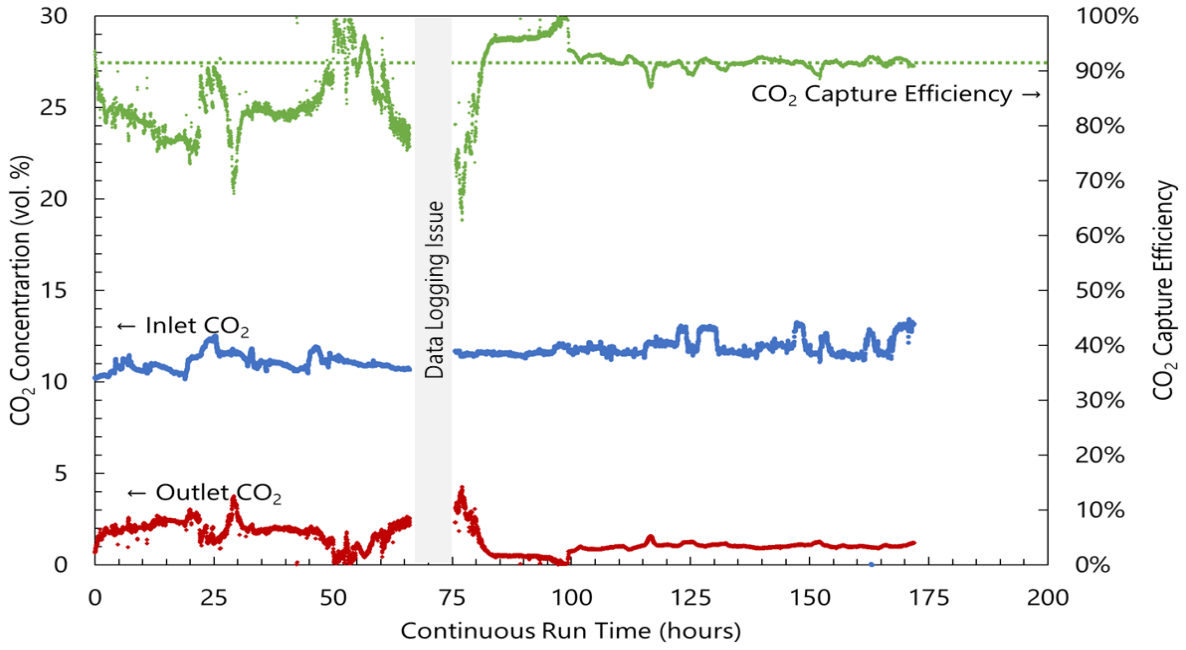
## Test Campaign 2:

- Feed gas was from NCCC's NG boiler. Feed gas is diluted with air or augmented with $CO_2$.
- Achieved 93% removal efficiency under all conditions.
- The $CO_2$ product is consistently about 95% purity.
- The skid reaches steady state operation in about 2 hours.

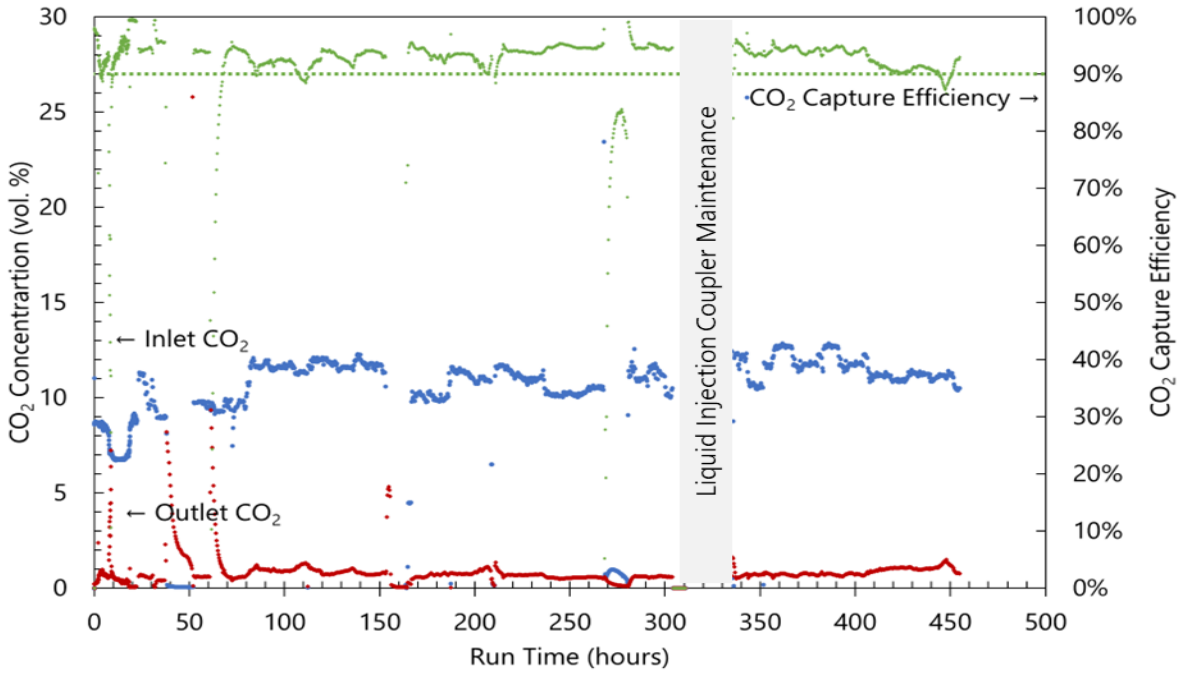


# Long Term Testing at NCCC

## Test Campaign 3:




## Test Campaign 4:

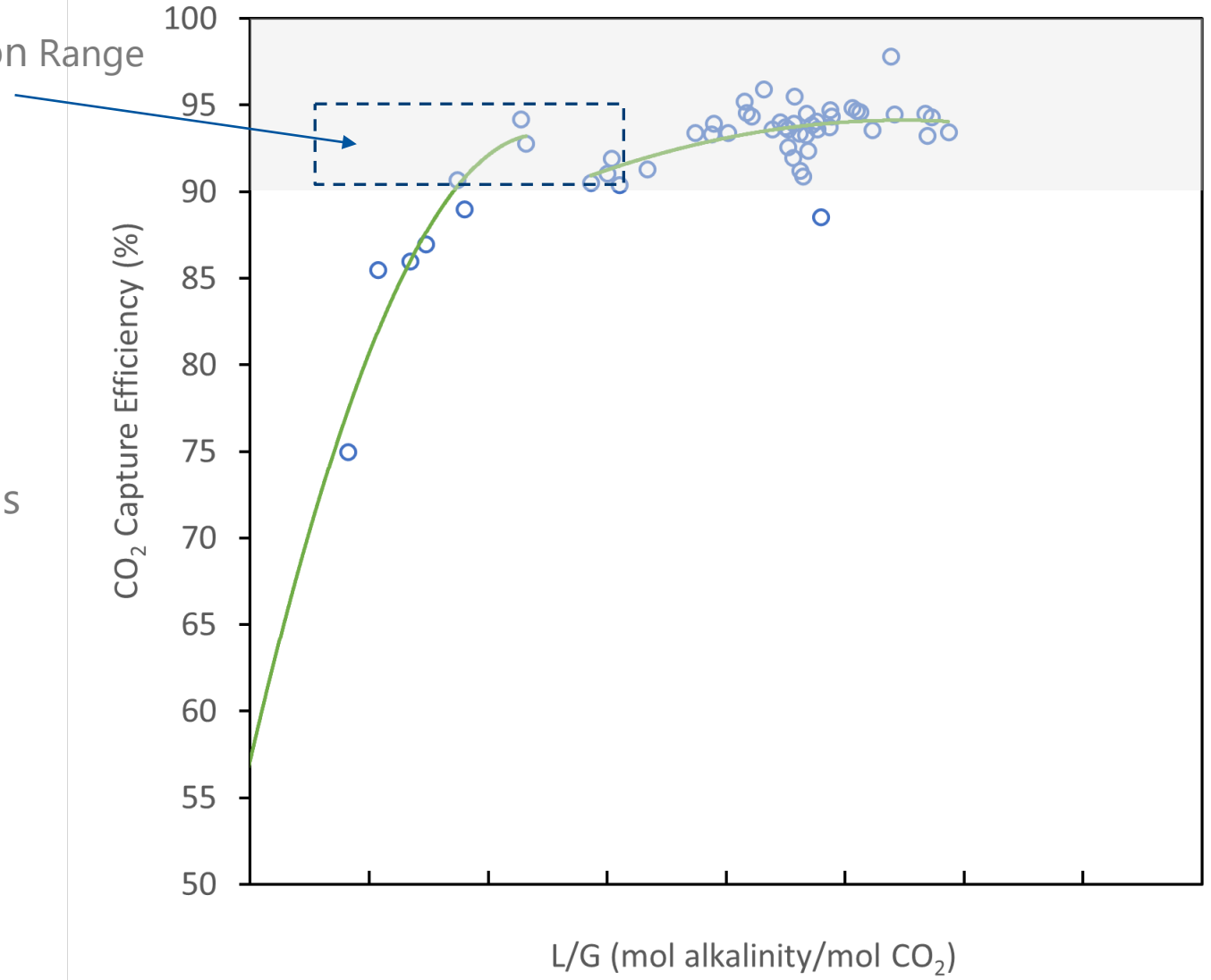



| | Test Campaign 3 | Test Campaign 4 |
|---|---|---|
| Power Plant Feed: | Coal | Coal + NG |
| Operation Hours: | 195 | 455 |
| Removal Efficiency: | >90% | >95% |
| Solvent Concentration: | 35-40% | 45-50% |

# Removal Performance PRELIMINARY

## 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

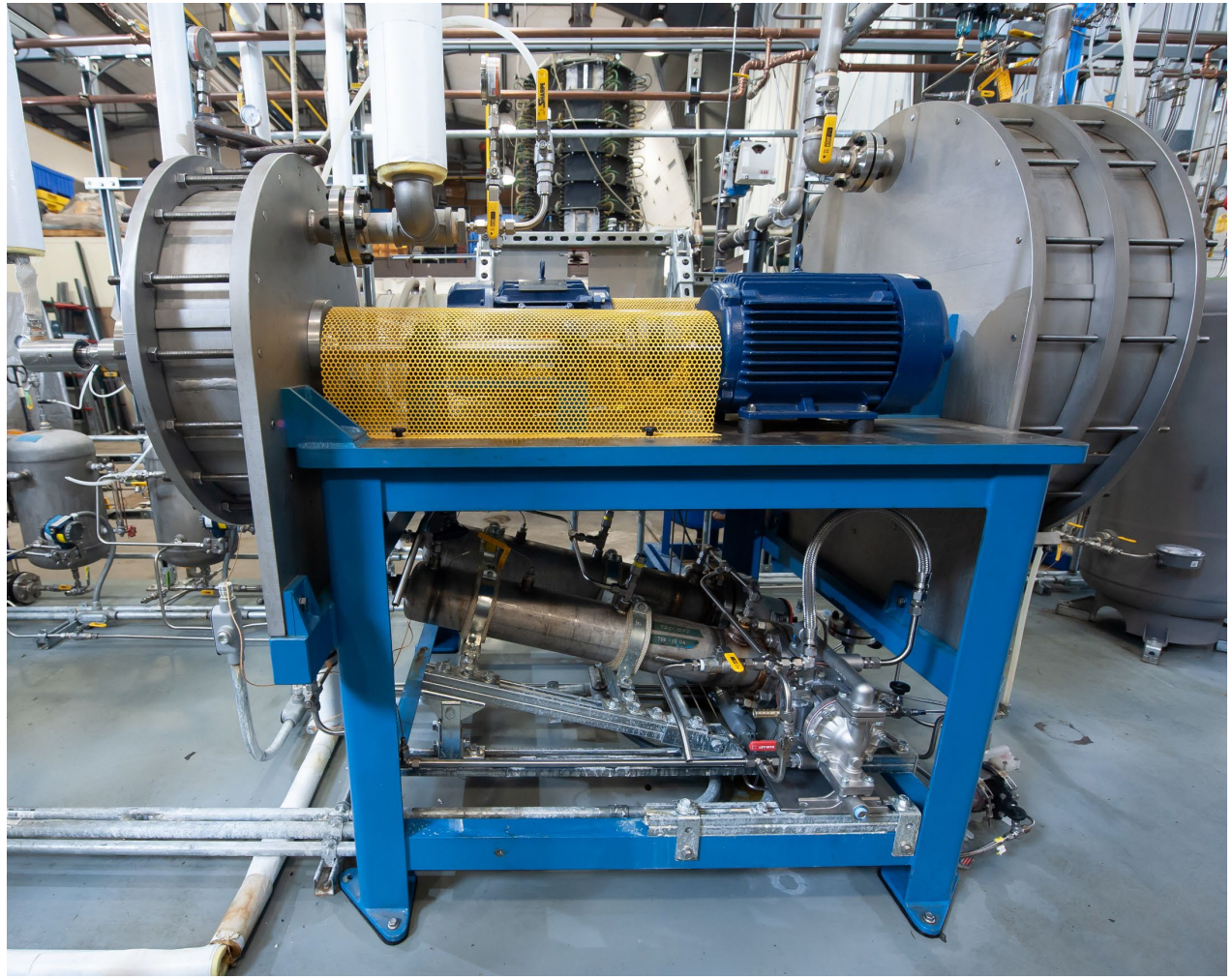
Evaluating different industrial emission sources:

- Steel
- Concrete
- Petrochemical

Process simulation and preliminary TEA's prepared for:

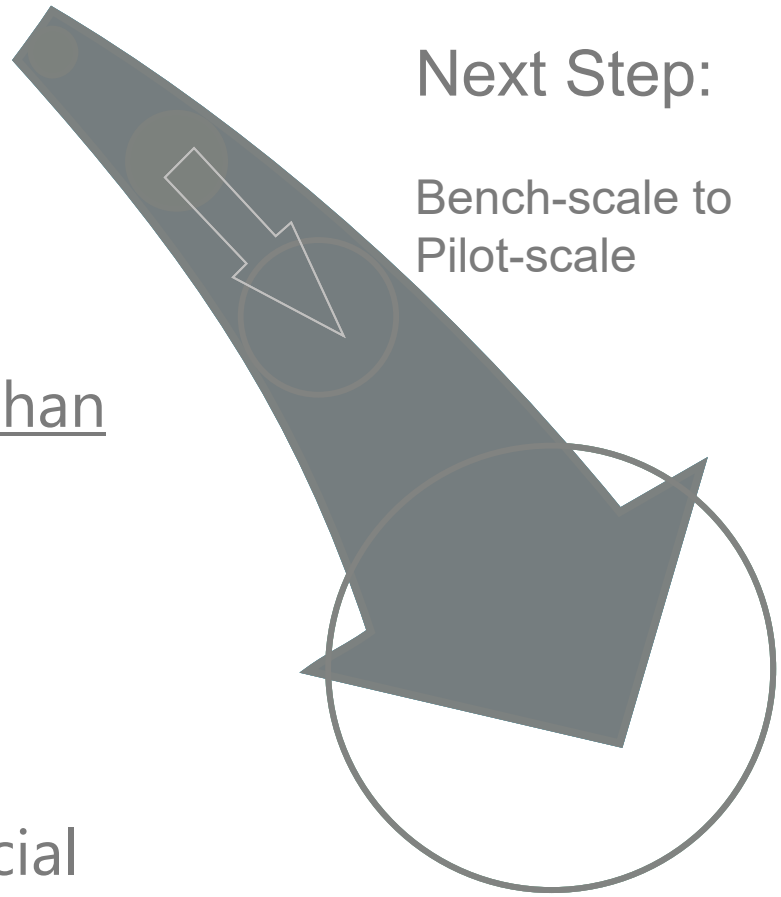
- 2.5 TPD scale industrial emission application
- 5 TPD and 10 TPD NGCC application

Commercial unit size expected at 10,100 and 300 TPD



# Summary:

- ROTA-CAP™ : A compact and more versatile process compared to other next generation $CO_2$ capture technologies
- First RPB absorber AND RPB regenerator integrated, continuous, bench-scale $CO_2$ 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



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- NCCC Team

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