“Rapid Design and Testing of Novel Gas-Liquid Contacting Devices for Post-Combustion CO_2 Capture via 3D Printing”
Modular Adaptive Packing (MAP)

DE-FE0031530 – NETL Project Review Meeting Pittsburgh

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Agenda

- Background
- Project Overview
- Technical Approach

BACKGROUND

Results from SBIR Phase I & SBIR Phase II - DE-SC0012056

ION's CO_2 Capture Technology Development

ION is developing its technology by leveraging existing research facilities

2010

ION Engineering Lab-pilot

0.01 MWe, $4M

Boulder, CO, USA

2012

Univ. of N. Dakota EERC

0.1 MWe, $2M

Grand Forks, ND, USA

2015

National Carbon Capture Center

0.5 MWe, $10M

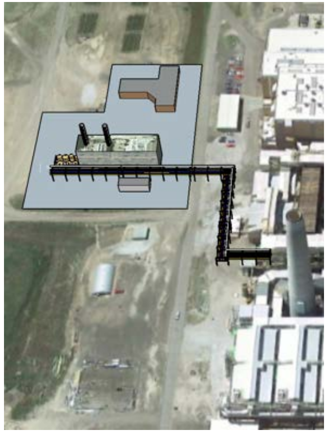
Wilsonville, AL, USA

2016 - 2017

CO_2 Technology Centre Mongstad

12 MWe, $15M

Mongstad, Norway



2018 - 2019

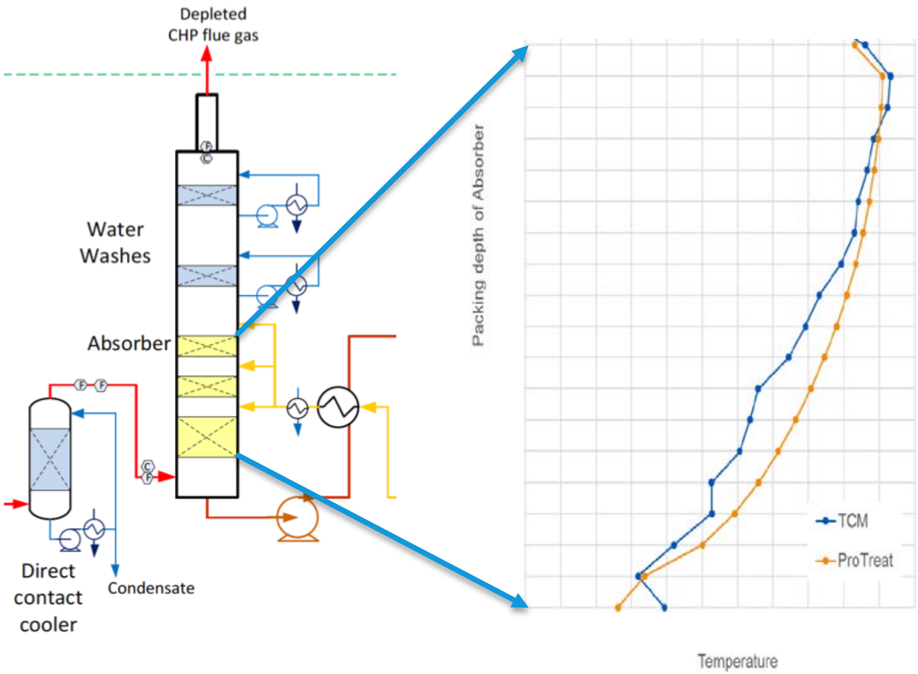
Design & Costing Commercial Retrofit

300 MWe

Sutherland, NE, USA

Background

High Temperature Bulge for Fast, Low Heat Capacity Solvents



Source: Thimsen et al., GHGT-12, 2014

ION Campaign at TCM (2016-17)

- Testing operating window was limited by absorber materials (T_{max})
- Additionally, temperature bulge affects emissions and degradation reactions
- Hence, can we incorporate in-situ cooling throughout the absorber column?

Background

“Rapid Design and Testing of Novel Gas-Liquid Contacting Devices for Post-Combustion CO_2 Capture via 3D Printing”

ION has initiated the development of an innovative internal absorber design including distributor, mass transfer, heat exchange and collectors through additive fabrication techniques

The application of 3-D printing is to significantly reduce the cost of such columns

- Accelerates the design cycles of gas-liquid contacting devices
  - Design process is entirely software-based
  - Devices are parametrically engineered
  - Rapid and flexible feedback loop between design, fabrication and testing that can only be provided through 3-D printing will more quickly advance the performance and lower the costs of novel gas-liquid contacting devices for CO_2 capture.
- Minimizes manufacturing costs

Background

SBIR Phase I Results

- A dual function mass and heat transfer packing media was developed
- Optimization based on multi-physics including:
    - mass transfer
    - heat transfer (focus point in Phases I and II)
    - pressure drop
- Printed the devices in plastic and characterized packing

Background

SBIR Phase II Results

- Created framework to test our current and future models & design
  - Extensible
  - Scalable
- Added CFD and heat transfer properties to the multi-physics model
- Manufactured both engineering plastic and metal prototypes
  - Engineering plastic prototypes were created to test for overall fit, to check for design flaws and to check potential for commercialization
  - Metal prototypes were printed, installed in ION's CO_2 capture lab pilot and conducted a preliminary evaluation in contact with solvent and simulated flue gas

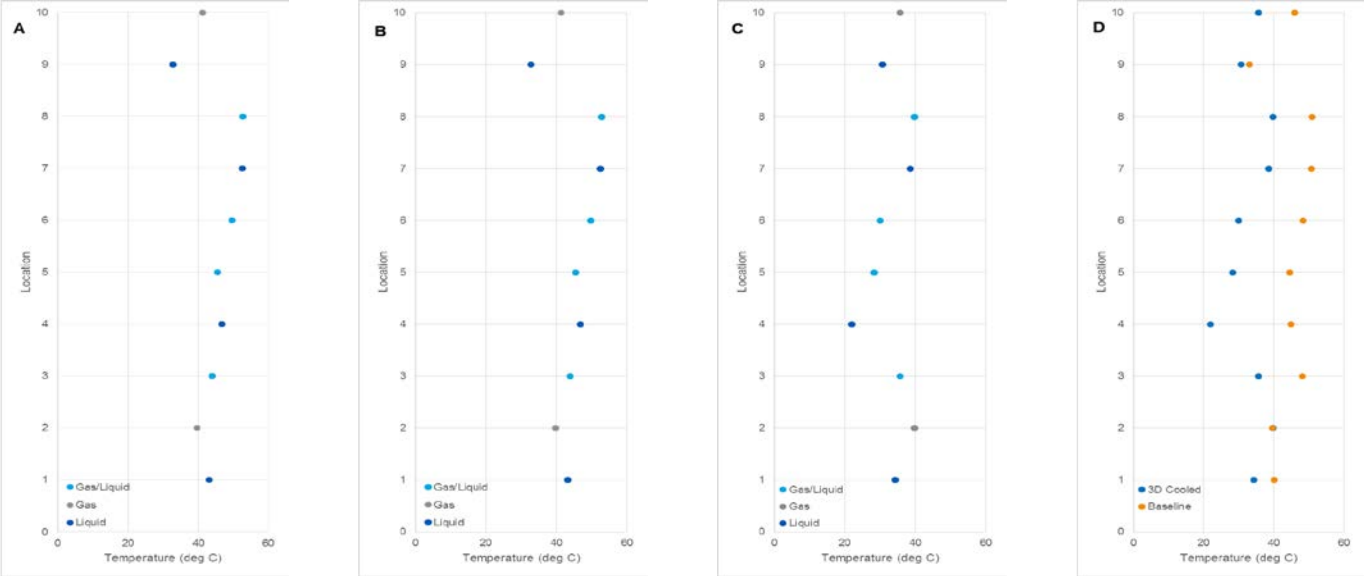
Background

SBIR Phase II Results – Proof-of-Principle

- Benchmarking our device with commercially available packing
    - Sulzer Mellapak™ 350X was used (3” diameter)
    - evaluated under the same process conditions
    - benchmarking cases run without internal or external cooling
- Performance of the MAP was evaluated in several ways
    - lean and rich solvent CO_2 loadings were measured by Total Inorganic Carbon (TIC) for mass transfer
    - absorber column temperature profile was measured
    - pressure drop across the packing was measured both for individual beds and as a column
    - with the ION MAP, active cooling packed beds were tested as well as w/o active cooling

Background

SBIR Phase II Results – Proof-of-Principle



Plots of absorber temperature profiles for ***(A)*** *baseline packing,* ***(B)*** *printed packing uncooled,* ***(C)*** *printed packing cooled,* ***(D)*** *comparison of baseline and cooled packing. The lean solvent feed is at location* ***9*** *and the flue gas inlet is at location* ***2****; these are controlled temperatures.*

PROJECT OVERVIEW

Project Overview

DE-FE0031530

- SBIR Phase III
  - Prior project: DE-SC0012056
- Project Period of Performance: Jan 2018 – Jan 2020
- $2.6M DOE-NETL project funding

- Overall Project Objective:

  Develop a 3D-printed Modular Adaptive Packing (MAP) with internal heating or cooling capabilities. Once a finalized design is complete, packing performance will be characterized in a modified Packing Characterization Rig.

Technical Approach

Overall Project

Budget Period 1

Jan 2018 – Jan 2019

- Task 1: Project Management
- Task 2: MAP Design & Plastic Prototype Manufacture
- Task 3: Packing Characterization Test Preparation
- Task 4: MAP Metal Module Printing

Budget Period Continuation

Success Criteria:

1. Successful Printing of MAP modules in titanium
2. Packing characterization rig modifications complete

Budget Period 2

Jan 2019 – Jan 2020

- Task 1: Project Management
- Task 5: Packing Characterization
- Task 6: Results & Final System Analysis

Technical Approach

Overall Project – Success Criteria

- Success Criteria for Budget Periods
  - Budget Period 1
    1. Successful printing of MAP modules in titanium
    2. Packing characterization rig modifications complete
  - Budget Period 2
    1. Completion of packing characterization as outlined in test plan
    2. Concept evaluation report completed

Project Participants & Roles

Funding

Commercial Packing Supplier & Engineering Support

Process Simulation & Design

3D Printing & Design Support

MAP Module CFD Model Development

Project Schedule

MAP Phase III Project Schedule		Budget Period 1													Budget Period 2							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
		Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19
Task 1	**Project Management**	D1		M1		M2				M3		D2	M4		D3 M5	D4		M6				D5
Task 2	**MAP Design**																					
	2.1 Design basis																					
	2.1 Parametric design delivered to ANSYS																					
	2.1 ANSYS module developed to model physics, fluid dynamics, etc.																					
	2.2 ION optimizes ANSYS model with different parameters																					
	2.2 Prototype prints/evaluation																					
	2.3 Fittings designed																					
	2.4 Detailed analysis of prototype prints																					
	2.4 Final design chosen																					
Task 3	**Host Site / Packing Characterization Test Preparations**																					
	3.1 Modfications identified for test rig																					
	3.2 Procurement / construction of modifications																					
	3.3 Test plan development																					
	3.4 Baseline packing characterization utilizing commercial packing																					
Task 4	**MAP Metal Printing**																					
	4.1 Metal module printing commences																					
	4.2 First metal module inspected for quality control prior to remaining modules being printed																					
	4.3 Second metal module printed - quality control testing																					
	4.4 Remaining modules printed																					
	4.4 Delivered to test facility																					
Task 5	**Packing Characterization Testing**																					
	5.1 Installation & Commissioning of MAP Modules																					
	5.2 Characterization of MAP Modules																					
	5.3 Decommissioning of MAP Modules																					
Task 6	**Evaluation & Reporting**																					
	6.1 Process modeling & simulations																					
	6.2 Data analysis & concept evaluation																					
	6.3 Final reporting																					

Project Overview

Deliverables & Milestones

ION ENGINEERING

Deliverables

#	Corresponding Task/Subtask	Title/Description
D1	1.0	Project Management Plan – BP1
D2	2.4	Test internals final design (report)
D3	3.3	Initial test plan
D4	1.0	Project Management Plan – BP2
D5	6.2	Concept evaluation (report)

Milestones

#	Task	Milestone Title / Description	Original Completion Date
M0	1.6	Project Management Plan	04/30/18 V1.1 (On-Going)
M1	2.1	Basis of Design Finalized	04/19/18
M2	2.8	MAP module design finalized	9/30/18
M3	4.4	MAP prints completed	12/15/18
M4	5.1	MAP modules installed & commissioned	2/15/19
M5	5.2	Packing characterization completed	5/31/19

DE-FE0031530 – SBIR PHASE III

Project Overview & Objectives

Phase III: Objectives

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- Improve upon SBIR Phase II MAP design modelling tool
    - Incorporate pressure drop, heat and mass transfer, and fluid dynamics
    - Parametric model
    - Scale-up to larger diameter column from SBIR Phase II

Phase III: Objectives

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- Print MAP design modules & characterize
  - 3D print prototypes
    - Engineering Plastic for mechanical fitting and to check for errors
    - Titanium for packing characterization
  - Baseline characterization rig with commercially available packing
  - Modify packing characterization rig to accept MAP prototypes
  - Characterize ION MAP
- Evaluate economic benefits with ProTreat® simulation model

TECHNICAL APPROACH

Technical Approach

ANSYS, ProTreat®, Commercial Assessment

- Improve MAP design in collaboration with ANSYS
- Improve reaction and mass transfer equations and code
  - Improve of heat transfer equations and code
  - Scale model to use more computational power to handle increased complexity
- Modify and validate process models
- Analysis of readiness for commercial scale

Technical Approach

Packing Characterization

- Testing includes measurements of:
  - Pressure drop over the height of the packing as a function of gas- and liquid load and viscosity
  - Packed bed liquid hold-up will be mapped over a broad range of column gas and liquid loads
  - Determination of effective surface area of the packings as a function of gas and liquid load will be performed by reactive experiments with CO_2 and sodium hydroxide solutions in the column
  - These tests are performed with water, sodium hydroxide and air/CO_2

Acknowledgement and Disclaimer

Acknowledgement

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