"Rapid Design and Testing of Novel Gas-Liquid Contacting Devices for Post-Combustion CO₂ Capture via 3D Printing" Modular Adaptive Packing (MAP)

DE-FE0031530 - NETL Project Review Meeting Webinar

Principal Investigator: Technical Lead: Project Manager: Significant Contributors:

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Project Overview

- Overall Project Objectives:
 - Design, Manufacture, Characterize, and Model a structured-packing with *in-situ* cooling by using 3D printing techniques to tailor precise packing geometries
- Project Budget:
 - DOE-NETL: \$2,599,521
 - ION & Partners: \$699,837
- Project Results
 - MAP modules were successfully fabricated at 10-inch diameter and 12-inch height stacked to create a packed column
 - MAP modules showed higher pressure drop and lower effective area than standard structured packing to accommodate intracooling channels
 - MAP intracooling significantly outperforms both adiabatic and intercooled absorbers despite lower hydraulic and mass transfer performance

Technology Background *High Temperature Bulge for Fast, Low Heat Capacity Solvents*



Depleted CHP flue gas Water depth Washes Packing Absorber -TCM -ProTreat Direct Condensate contact cooler Temperature

ION Campaign at TCM (2016-17)

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

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

Technology 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 costs 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 advance more quickly the performance and lower the costs of novel gas-liquid contacting devices for CO₂ capture

Project Scope (Budget Period 2)



- Fabricate MAP characterization rig
- Baseline Mellapak 250Y
 - Hydraulics, Effective Area
- Characterize MAP
 - Hydraulics, Effective Area, Cooling
- Utilize data for modeling *in situ* absorber intracooling with MAP

	MAP Phase III Project Schedule							Budget Period 2										
								31		32		3	3					
		Ар	r-20	May-	20	Jun	-20	Jul	-20	Aug	1-20	Sep	-20					
Task 1	Project Management	D3	D4			M4				M5			D5					
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																	
			Overall Task Timing															
		Subtask Timing																

Characterization Rig







Characterization Results: Hydraulics





Characterization Results: Effective Area





ProTreat® Modeling of MAP Intracooling





- 25 m of Total Packing; 22 m Diameter
- 10 m of MP250Y on Top and Bottom
- 5 m of MAP in Middle Section
 - Hydraulics of MP452Y
 - Effective Area = 35% MP452Y
 - 10 sections of 0.5 m height; distributed cooling
- FG Inlet: 82,600 kmol/hr, 40 °C,12.6 vol% CO₂
- Lean: 30 wt% MEA, 40 °C, 0.24-0.35 mol CO₂/mol MEA
- Vary cooling and solve MEA flow for 90±0.2% capture
- Determine effect on MEA Capacity, Pressure drop, and
 Temperature profiles

Capacity Increase with MAP Intracooling





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MAP Intracooling for MEA: Temperature Profiles





Column Temperature (°C)

Intracooling vs. Intercooling





MAP Project and Commercial Development



- Future Project Work
 - Measure Intracooling Channel Hydraulics (Expected flow of 3-6 lpm per module with minimal backpressure)
 - Measure Intracooling Channel Heat Transfer (Designed for full intracooling duty when scaled up and using typical cooling water conditions)
- Path to Commercialization
 - Further study of integrated distributors
 - Cooling water manifold design at scale
 - Cost reductions and size increase of 3D printing technology
 - Possible application for stripper intraheating

Project Summary and Results



- Largest 3D-printed packed column fabricated and characterized
 - 10 inch O.D., 12 foot packed height column
 - Hydraulically characterized with air/water and air/water/glycerin; higher pressure drop to accommodate intracooling channels
 - Effective area characterized with air/NaOH; excellent results consistent with full wetting at applicable liquid flow rates
- Absorber modeling with direct experimental results
 - Intracooling most important when mass transfer pinch occurs at temperature bulge
 - Intracooling away from mass transfer pinch limits maximum temperature, but decreases MEA capacity and increases pressure drop
 - Despite hydraulic and mass transfer limitation, intracooling outperforms intercooling

Acknowledgement and Disclaimer



Acknowledgement

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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	2	13	14	15	16	17	18	1	9	20 2	21	22	23	24	25	26	27	28	29	j
		Jan-18	Feb-1	8 14	er-18	Apr-18	May -18	Jun-1	نىر 8	-18 A	Nug-18	Sep-18	Od-18	Nov-18	B Dec-	-18 J	kan-19	Feb-19	Mar-19	Apr-19	Mary-1	Jun-E	ەد (-19 A	kug-19 Se	p-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20	Mar-20	Ap-19	May-1	19
Task 1	Project Management	D1				M1				M2				MB	3										D2		D3 M4		D4		MS			C	05
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																															T			
	5.2 Characterization of MAP Modules																																		
	5.3 Decommissioning of MAP Modules																																		
Task 6	Evaluation & Reporting																																		
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1	6.3 Final reporting																																		

Project Overview Deliverables & Milestones



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	Revised Completion Date	Actual Completion Date
M1	1	Project Management Plan	2/19/18	N/A	4/30/18 (V1.1) (On-Going)
M2	1	Kickoff Meeting	4/19/18	N/A	7/19/18
М3	2	MAP module design finalized	9/30/18	N/A	11/20/18* (Redesign Q1 2019)
M4	4	MAP prints completed	12/15/18	10/31/19	
M5	5	MAP modules installed & commissioned	2/15/19	2/15/20	
M6	5	Packing characterization completed	5/31/19	3/31/20	

MAP Intracooling for MEA





Column Temperature (°C)

MAP Intracooling for MEA





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