ION
CLEAN ENERGY

“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 Webinar

Principal Investigator: Erik Meuleman, Ph.D.
Technical Lead: Nathan Fine
Project Manager: Tyler Silverman
Significant Contributors: Greg Staab

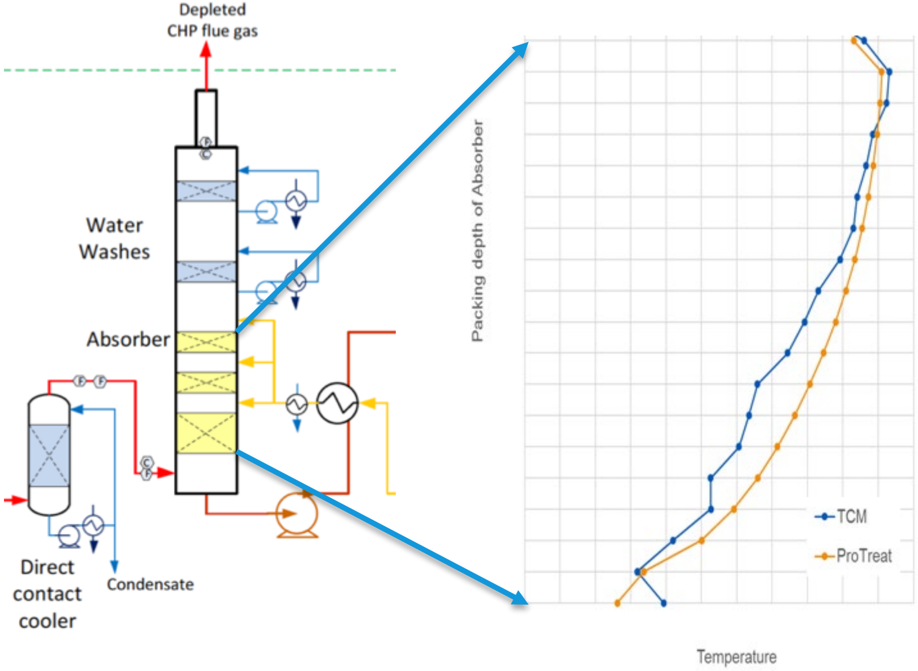
October 5-7, 2020

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



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 solvent capacity, emissions, and degradation
- Hence, how can we incorporate in-situ cooling throughout the absorber column?

Technology Background

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

ION CLEAN ENERGY

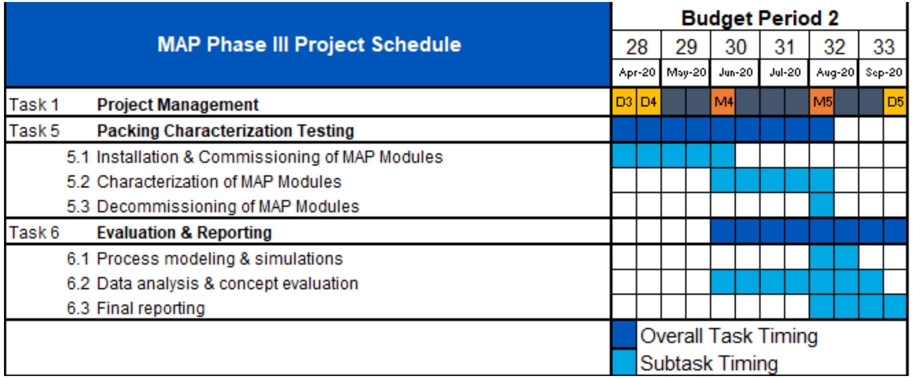
ION has initiated the development of an innovative internal absorber design including distributor, mass transfer, heat exchange and collectors through additive fabrication techniques

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 CO_2 capture

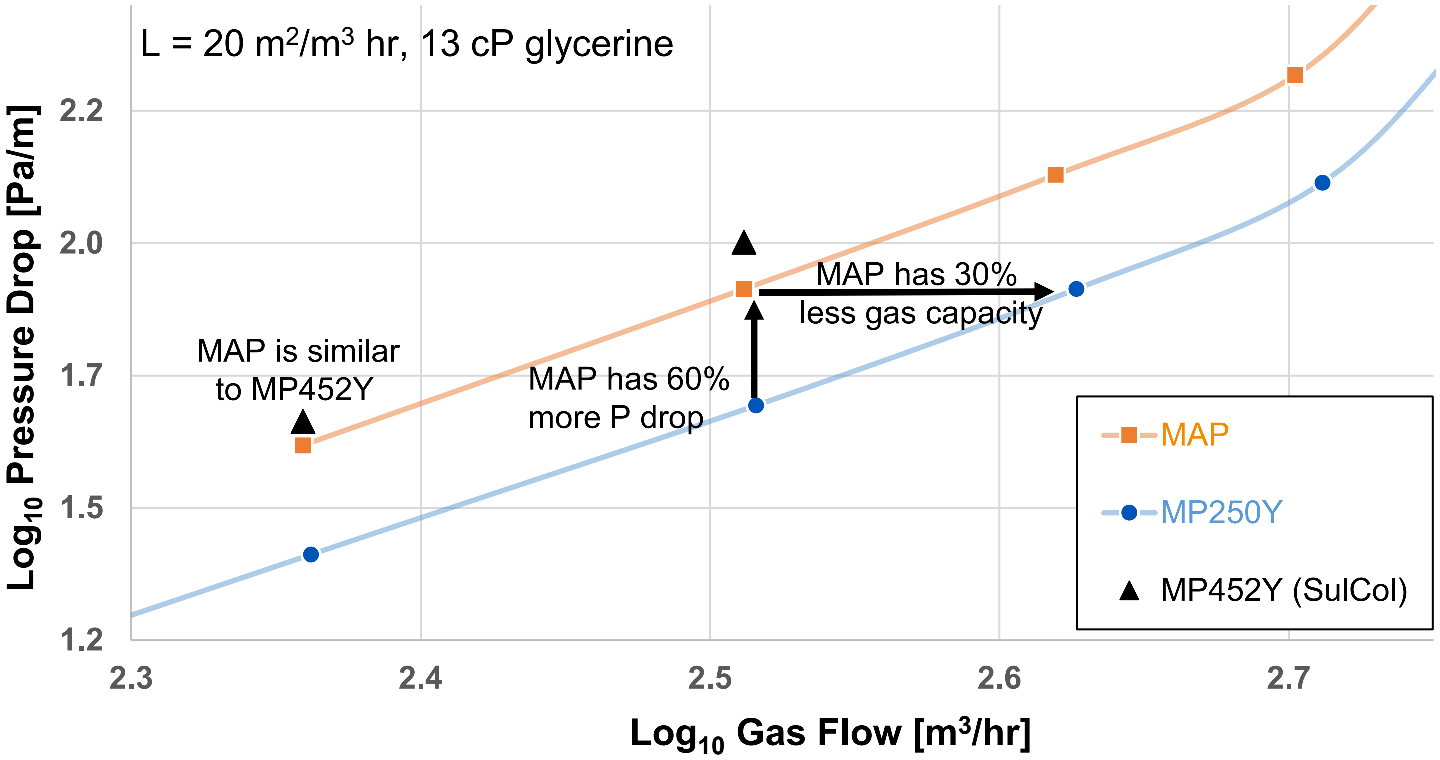
Project Scope (Budget Period 2)

- 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

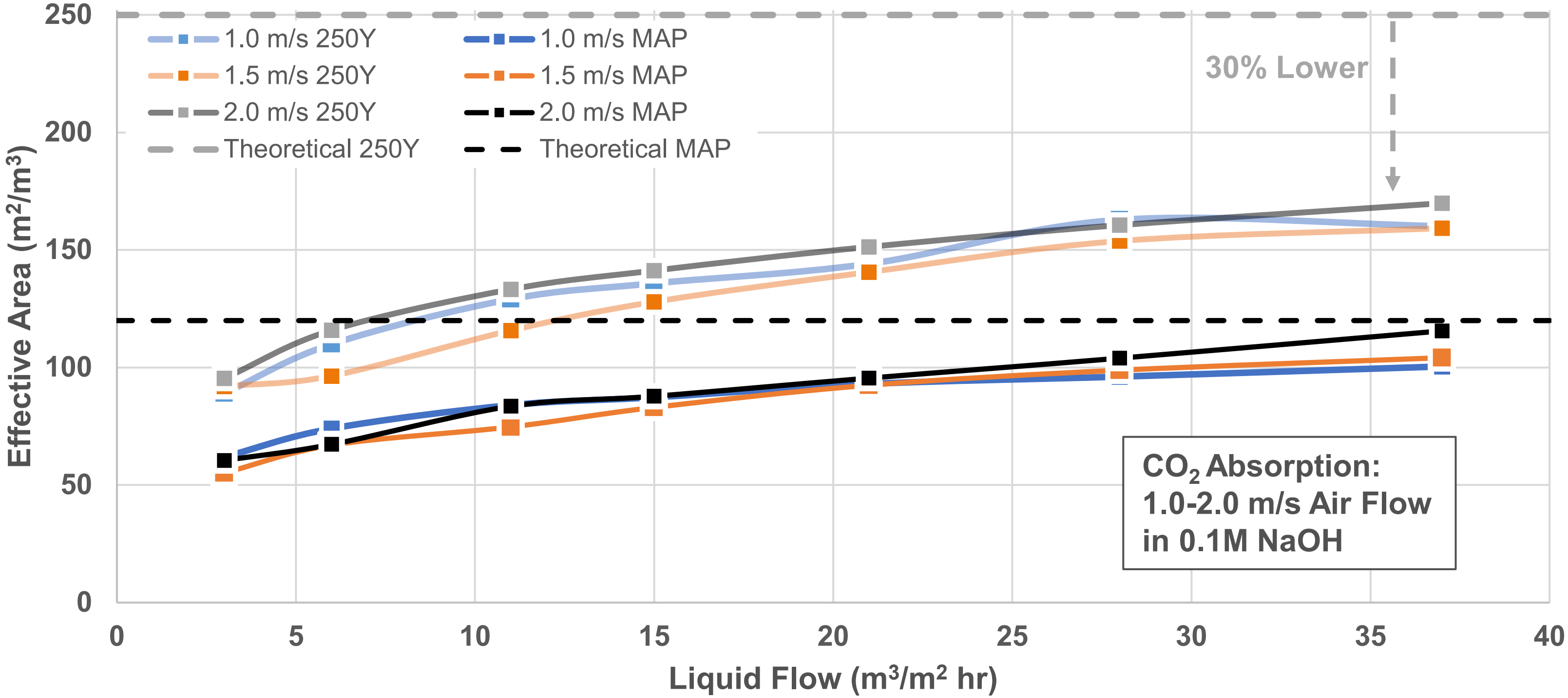


Characterization Rig

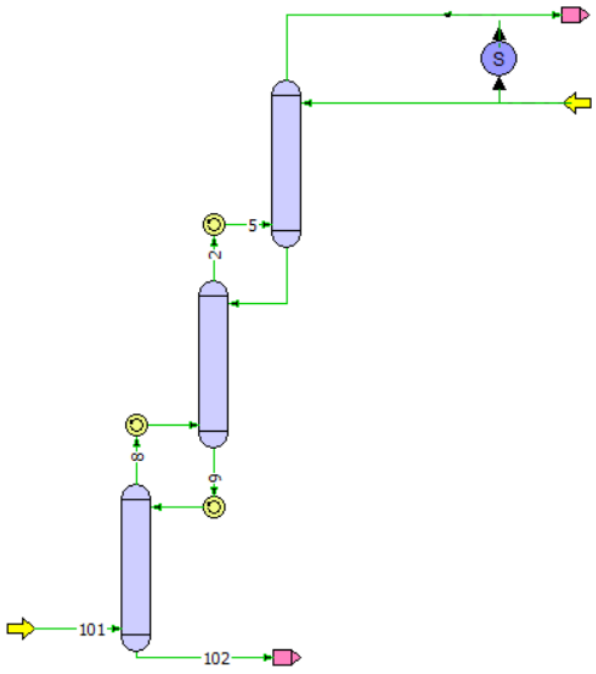
Characterization Results: Hydraulics



Characterization Results: Effective Area

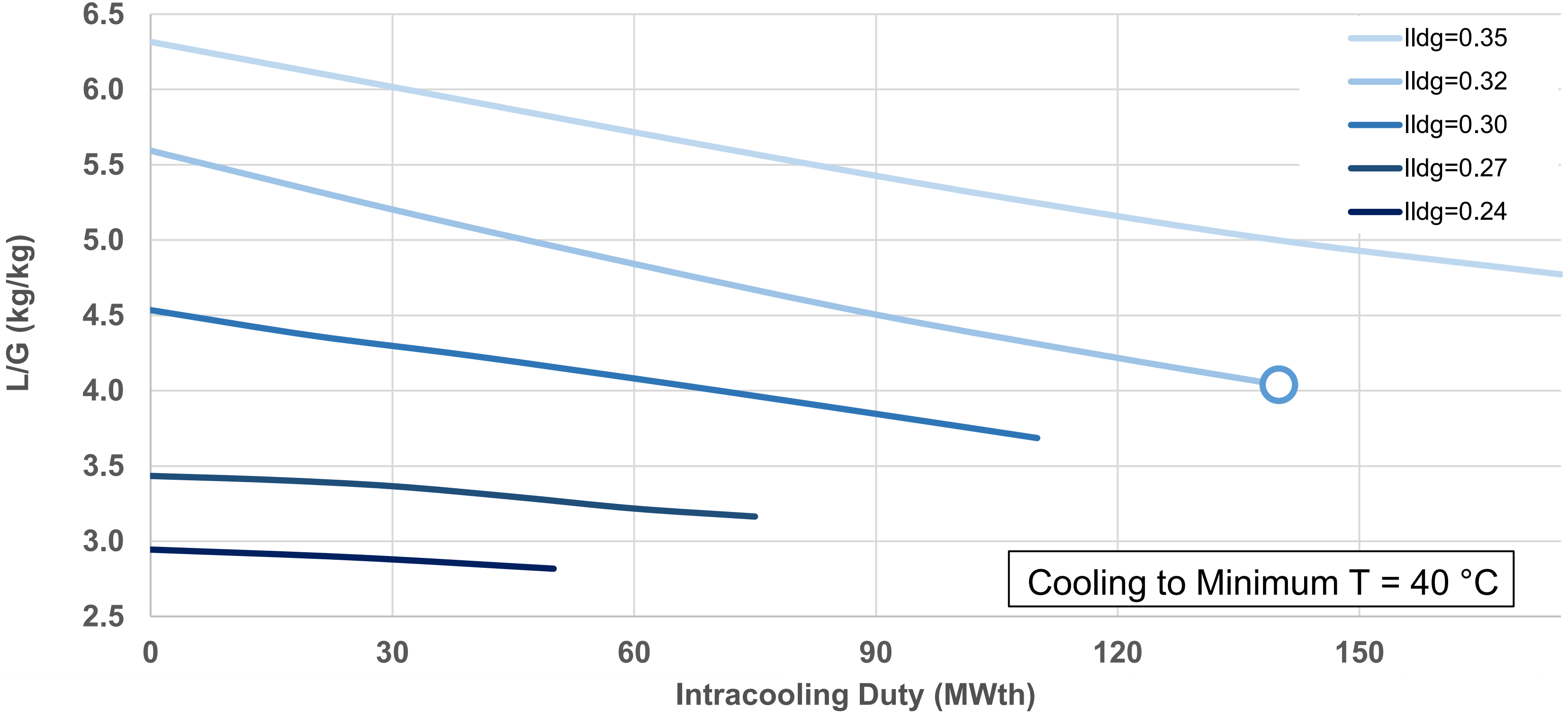


ProTreat® Modeling of MAP Intracooling



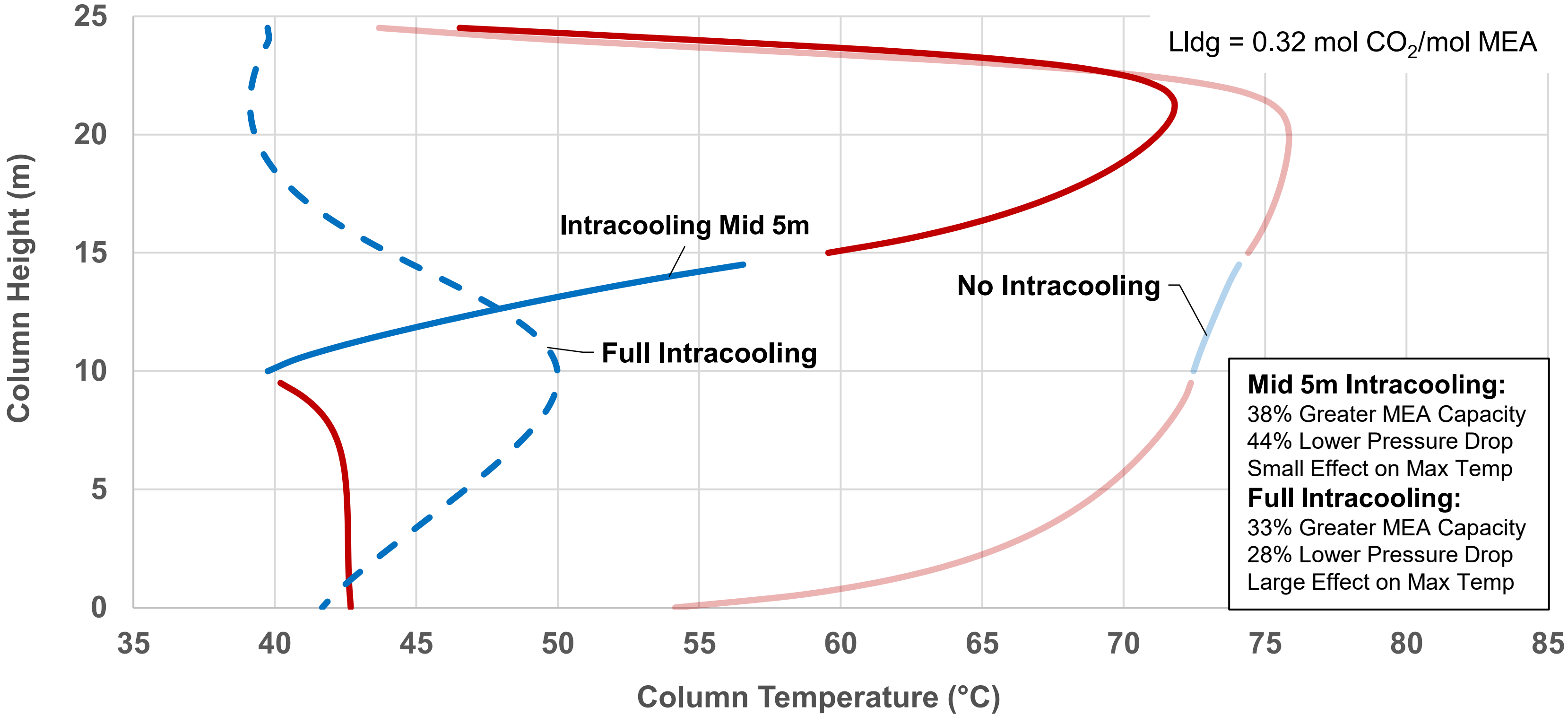
- 25 m of Total Packing; 22 m Diameter
- 10 m of MP250Y on Top and Bottom
- 5 m of MAP in Middle Section
  - Hydraulics of MP452Y
  - Effective Area = 35% MP452Y
  - 10 sections of 0.5 m height; distributed cooling
- FG Inlet: 82,600 kmol/hr, 40 °C,12.6 vol% CO_2
- Lean: 30 wt% MEA, 40 °C, 0.24-0.35 mol CO_2/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



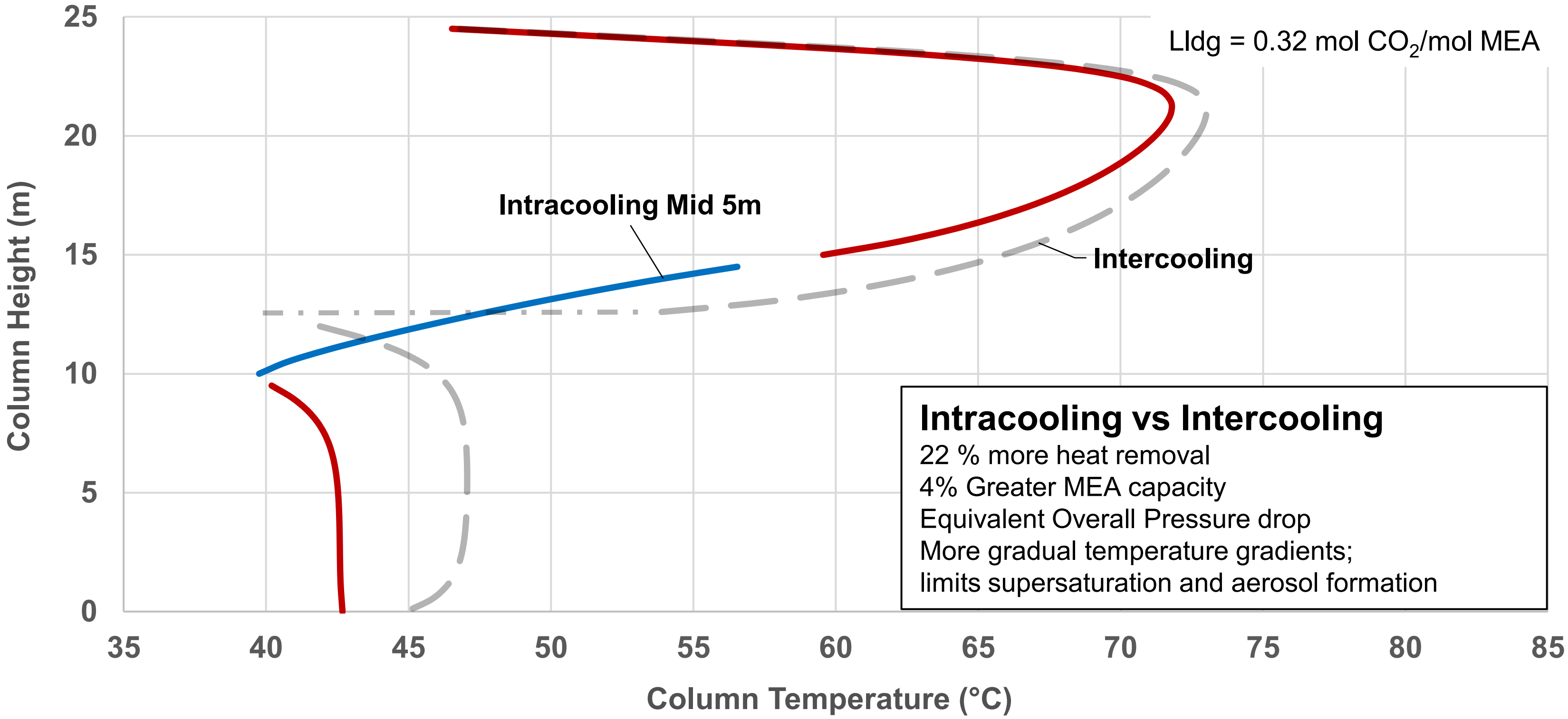
MAP Intracooling for MEA: Temperature Profiles

ION CLEAN ENERGY



Mid 5m Intracooling:
38% Greater MEA Capacity
44% Lower Pressure Drop
Small Effect on Max Temp
Full Intracooling:
33% Greater MEA Capacity
28% Lower Pressure Drop
Large Effect on Max Temp

Intracooling vs. Intercooling



Intracooling vs Intercooling

22 % more heat removal
4% Greater MEA capacity
Equivalent Overall Pressure drop
More gradual temperature gradients;
limits supersaturation and aerosol formation

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

This material is based upon work supported by the Department of Energy National Energy Technology Laboratory under cooperative award number DE-FE0031530.

Disclaimer

ION CLEAN ENERGY

ION Team:
Nathan Fine, Greg Staab, Tyler Silverman, Erik Meuleman, Buz Brown, Jennifer Atcheson

Department of Energy:
Katy Daniels, Steve Mascaro, Lynn Brickett, José Figueroa, Bethan Young, Jeff Kooser

THANKS

NATIONAL ENERGY TECHNOLOGY LABORATORY

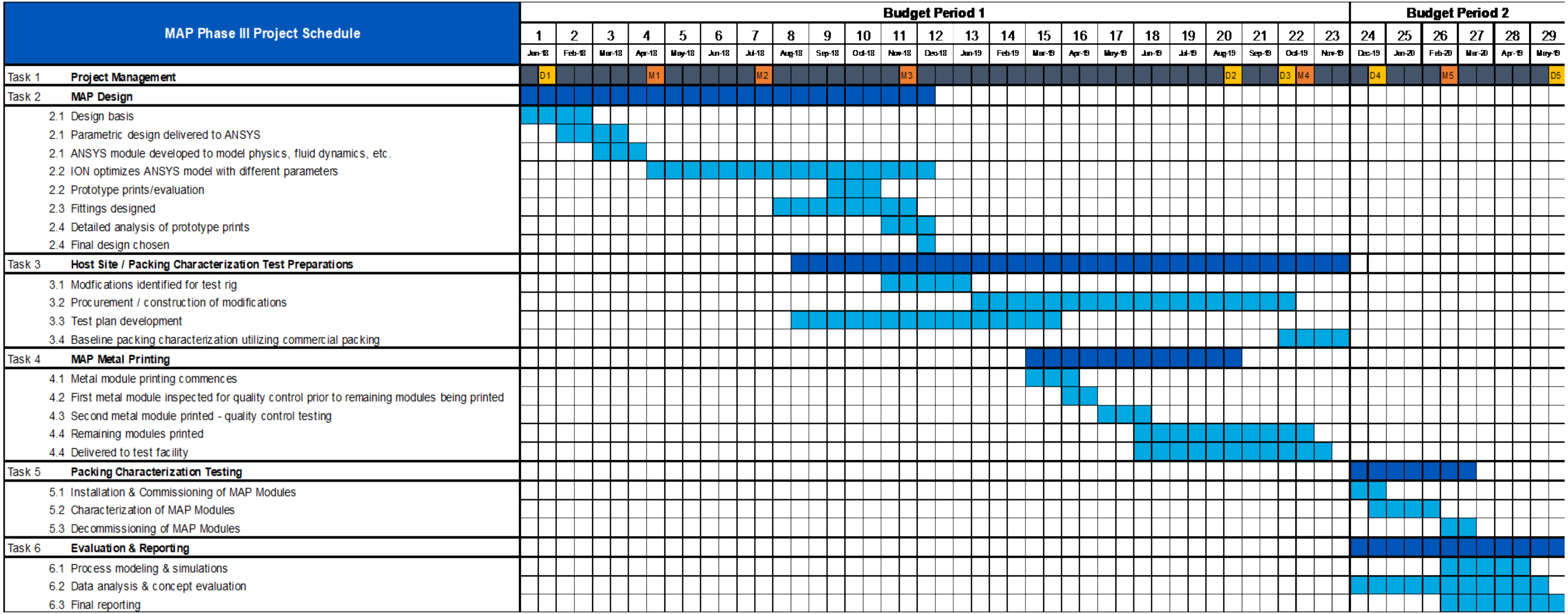
3D SYSTEMS

ANSYS

SULZER

Project Schedule

ION
CLEAN ENERGY



Project Overview

Deliverables & Milestones

ION CLEAN ENERGY

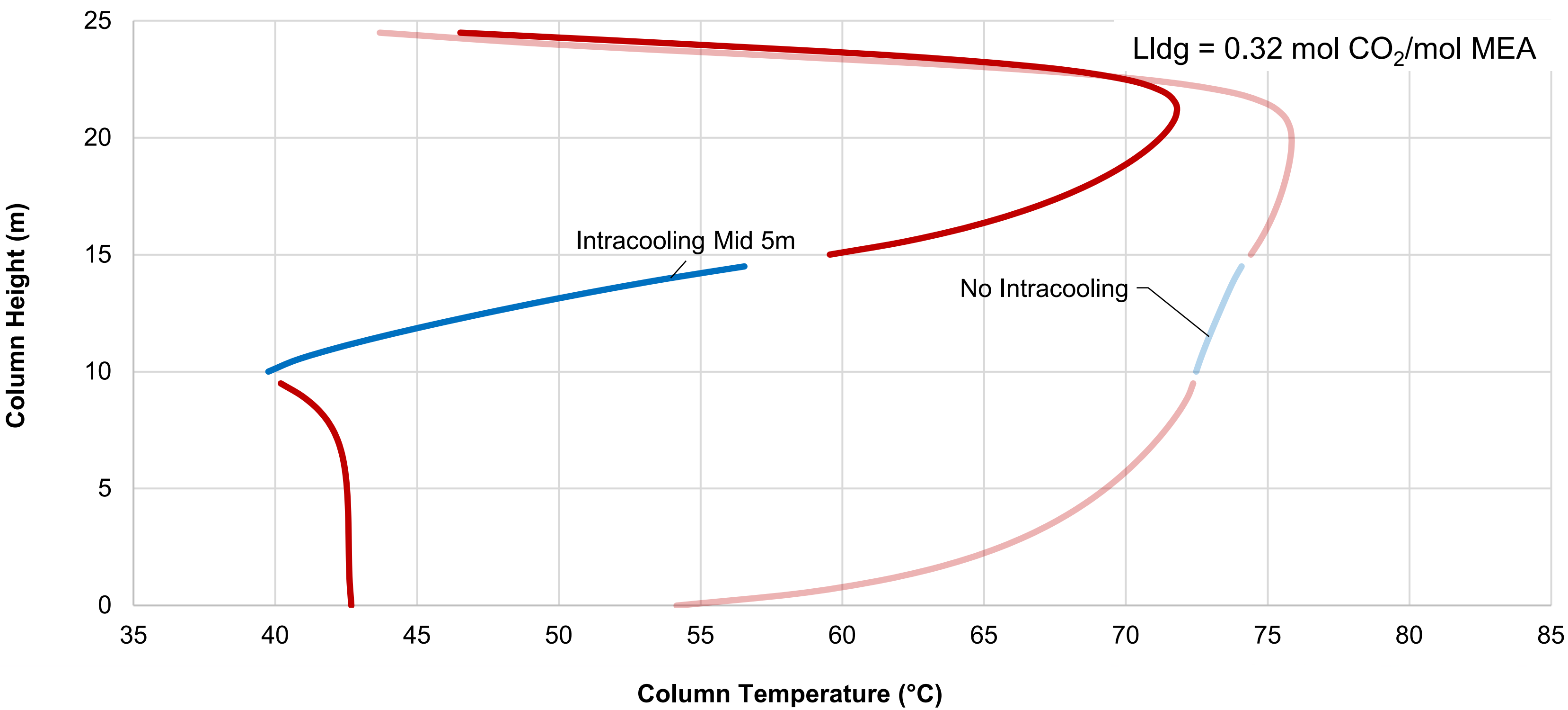
Deliverables

#	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
M3	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



MAP Intracooling for MEA