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Advancing Post-Combustion CO_2 Capture through Increased Mass Transfer and Lower Degradation

Project Number: DE-FE0031661

Performing Organization: University of Kentucky CAER

Principal Investigator: Jesse Thompson

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National Energy Technology Laboratory
Carbon Management and Natural Gas & Oil Research Project Review Meeting
Virtual Meetings, August 2 through August 31, 2021

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Project Overview

- Funded as part of the Novel and Enabling CO_2 Capture Technologies
- Project consists of three primary area: (1) development of novel 3-D printed polymeric absorber packing; (2) modifying solvent physical properties to increase solvent wetting; (3) developing an effective process to decompose nitrosamines from waterwash systems

- **Project Period:** 10/1/2018 - 9/30/2021 (3 years)
    - NCTE being executed;
- **Funding**: Federal - $2.9M; CS - $725K; Total - $3.6M

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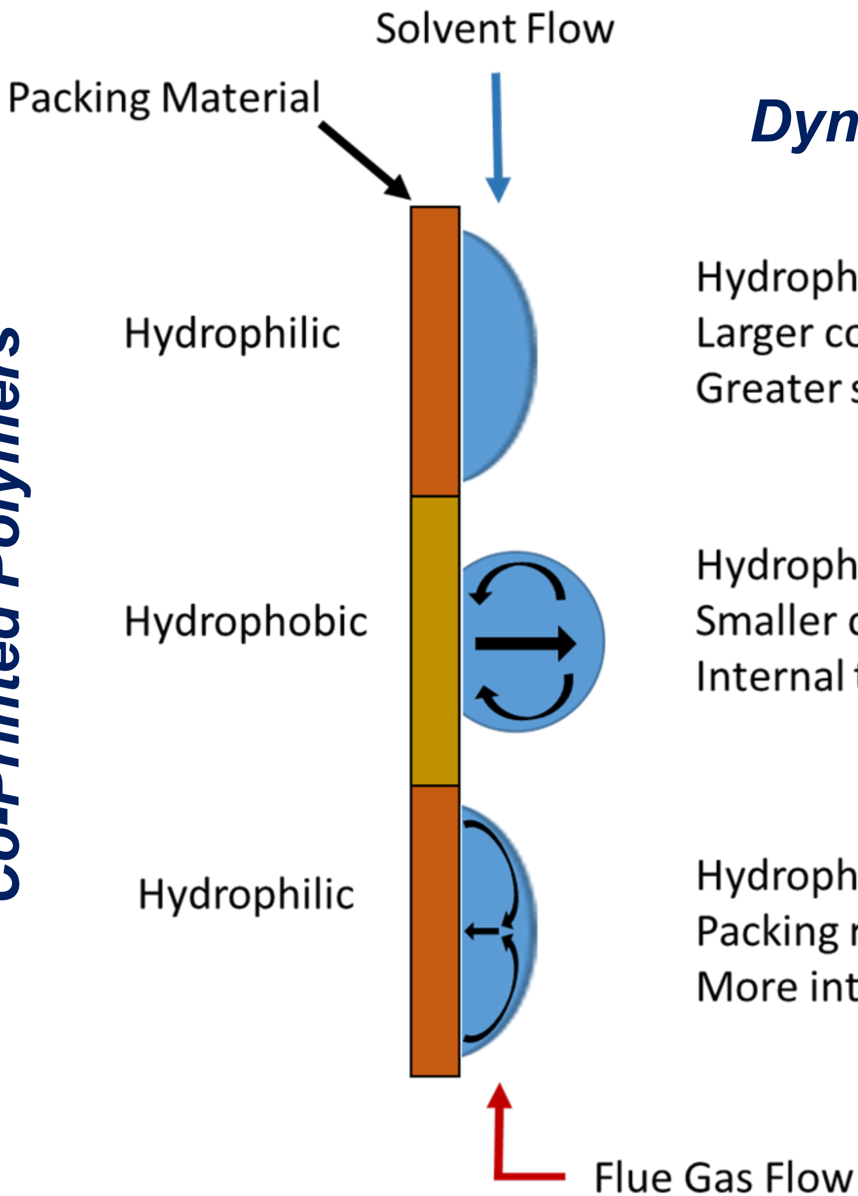
Project Objectives

Developing process enhancements/technologies that can be broadly applied to amine-based post-combustion CO_2 capture systems:

1. Hydrophobic/hydrophilic patterned packing to increase solvent turbulence and CO_2 mass transfer
2. Correlation of solvent physical properties, specifically those related to increasing CO_2 mass transfer, with wettability on absorber packing surfaces
3. Nitrosamine decomposition using electrochemical treatment within the waterwash

Technology Background – Dynamic Packing

Co-Printed Polymers



Dynamic Packing with 3D Printing

Hydrophilic-hydrophilic interaction
Larger contact angle
Greater surface contact

Hydrophilic-hydrophobic interaction
Smaller contact angle
Internal turbulence from solvent drawing up

Hydrophilic-hydrophilic
Packing re-wetting
More internal turbulence and mixing

Contact angle on Packing Surface

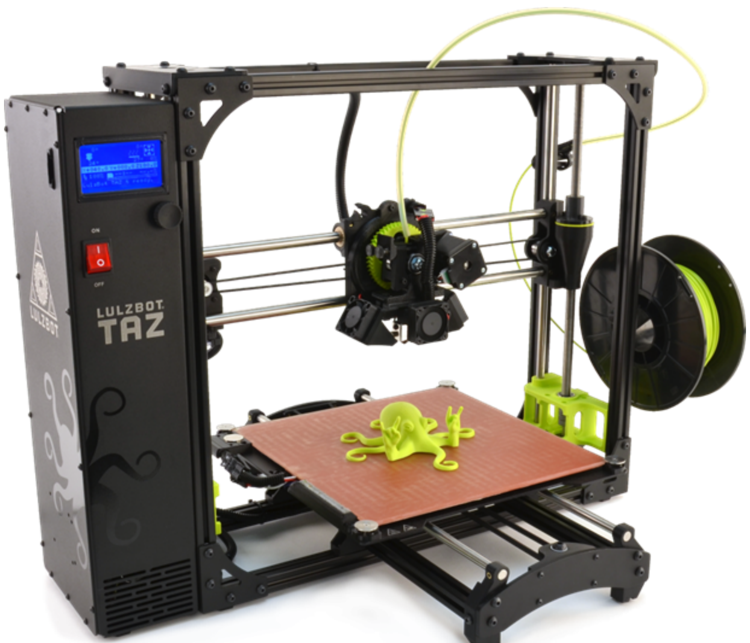
Polymers that can used for 3D Printing

High Density
Polystryene (HDPS)

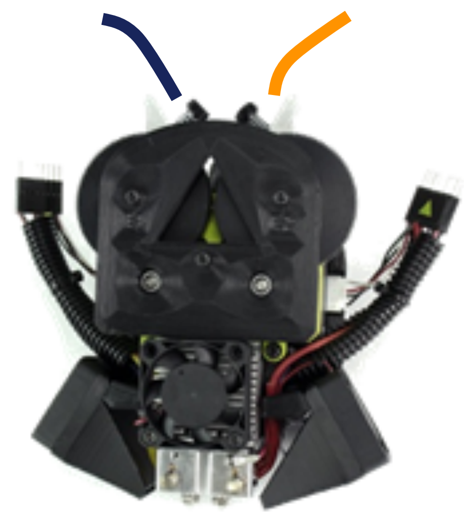
Acrylonitrile butadiene
styrene (ABS)

Nylon

Polylactic Acid (PLA)



Dual-head printer



Co-Printed Polymers

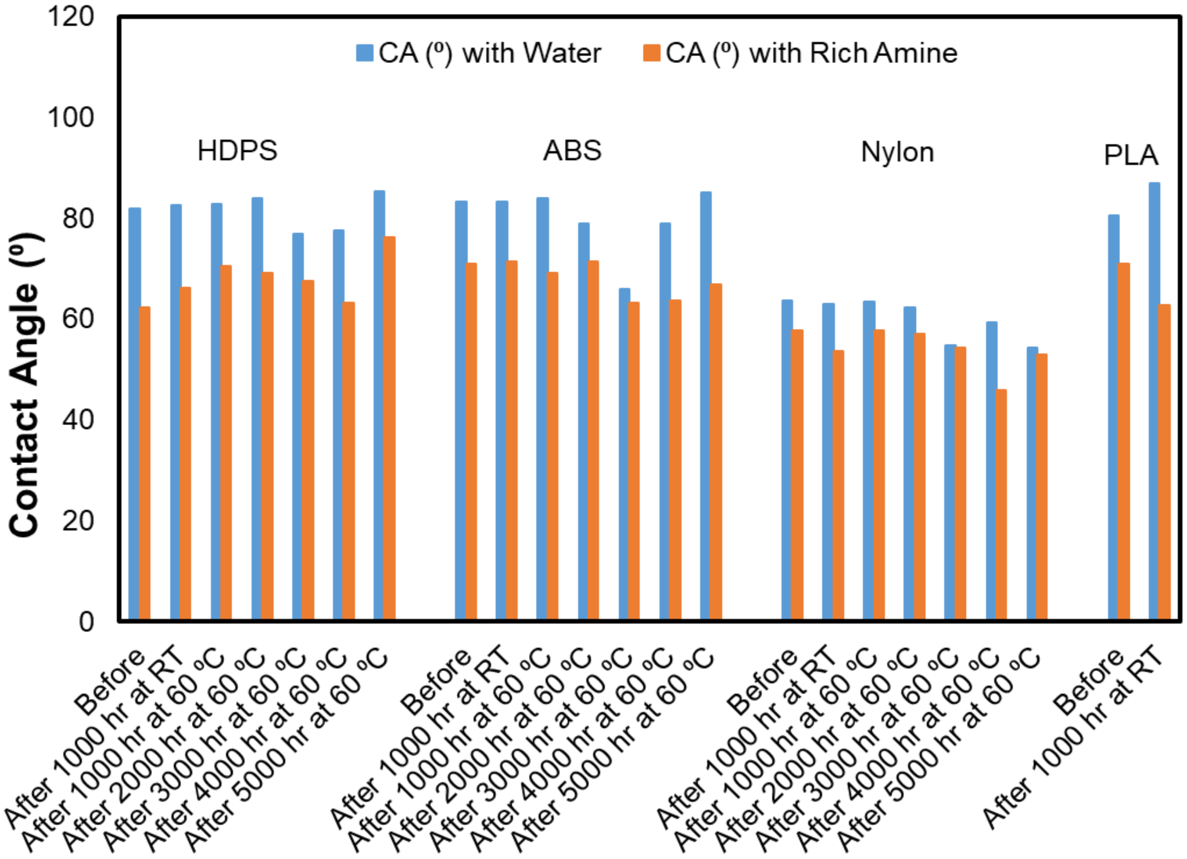
Polymer stability when exposed to amine solvents

HDPS

ABS

Nylon

PLA



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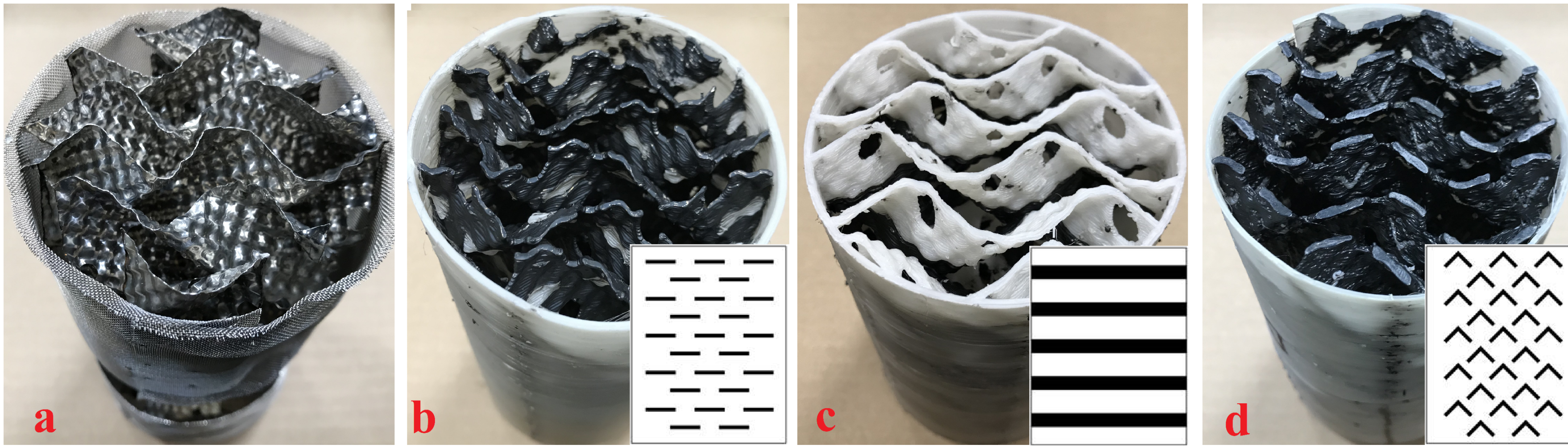
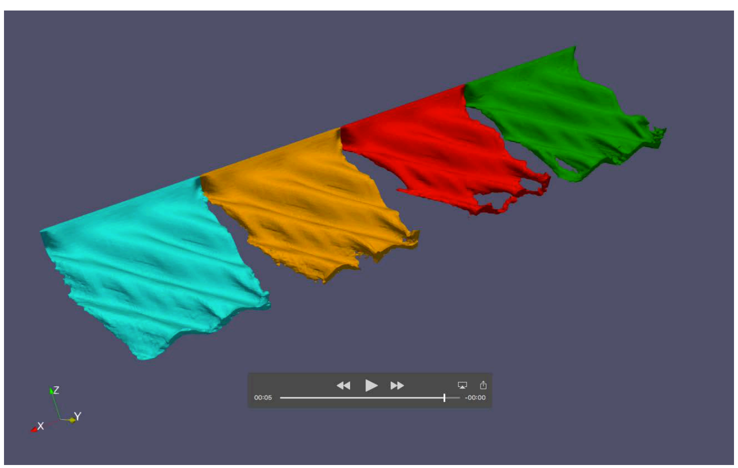
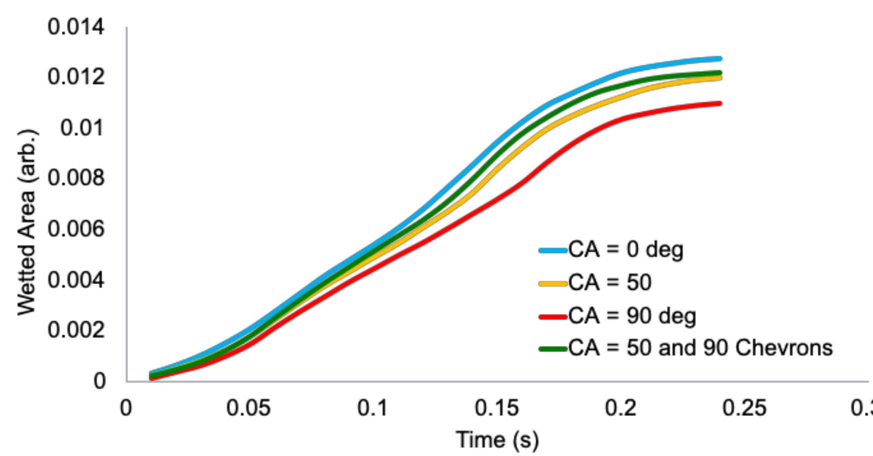
Bench Testing – Packing Design and Fabrication



a: Mellapak 250Y steel packing; b: DP-1 packing; c: DP-2 packing; d: DP-3 packing.





CFD modeling using the OpenFoam software

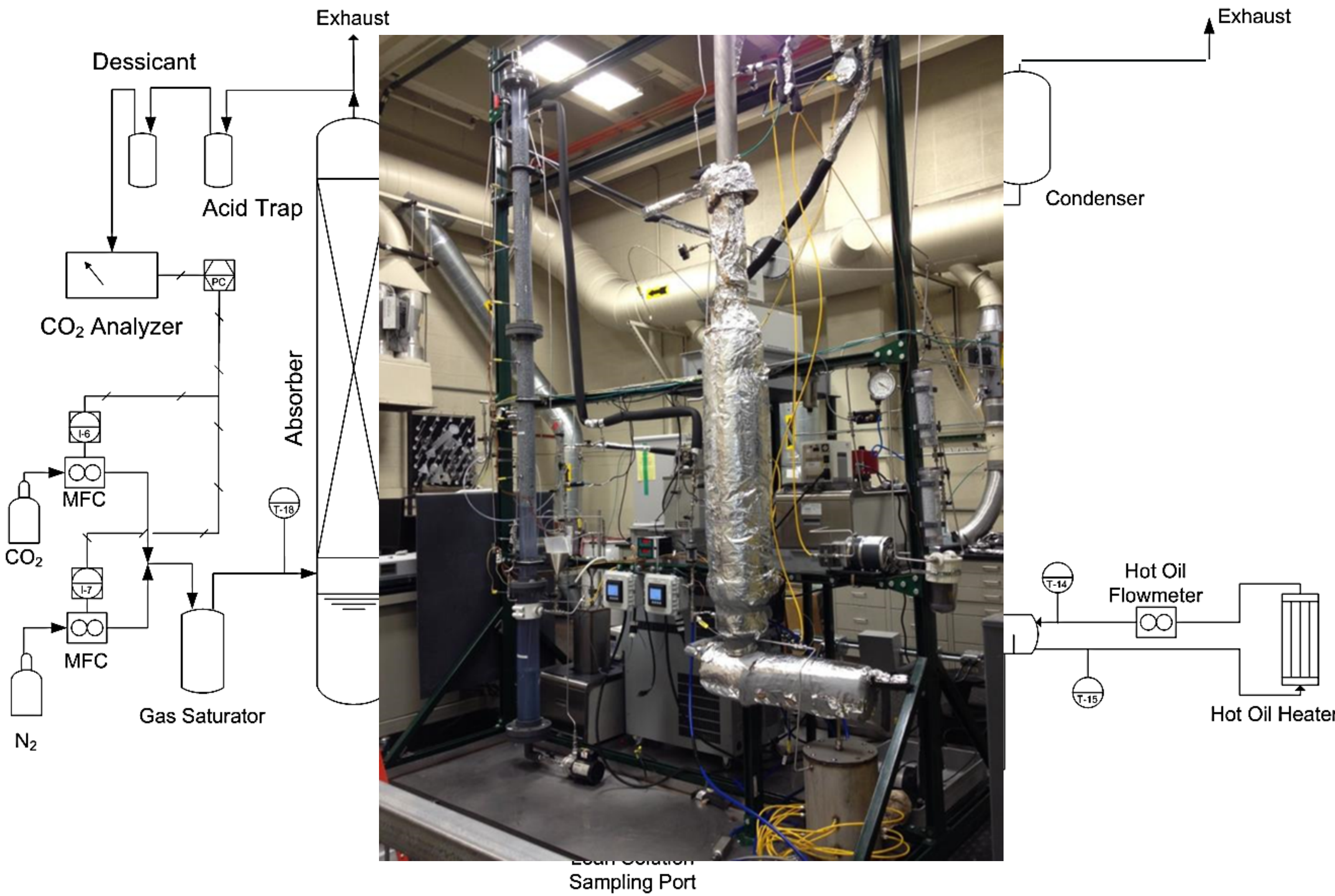
Bench Testing : Long-term

BP2: Fabrication of 3" diameter Dynamic Packing and installation into our small-bench CCS followed by 500 hour of long-term integrated solvent/packing testing

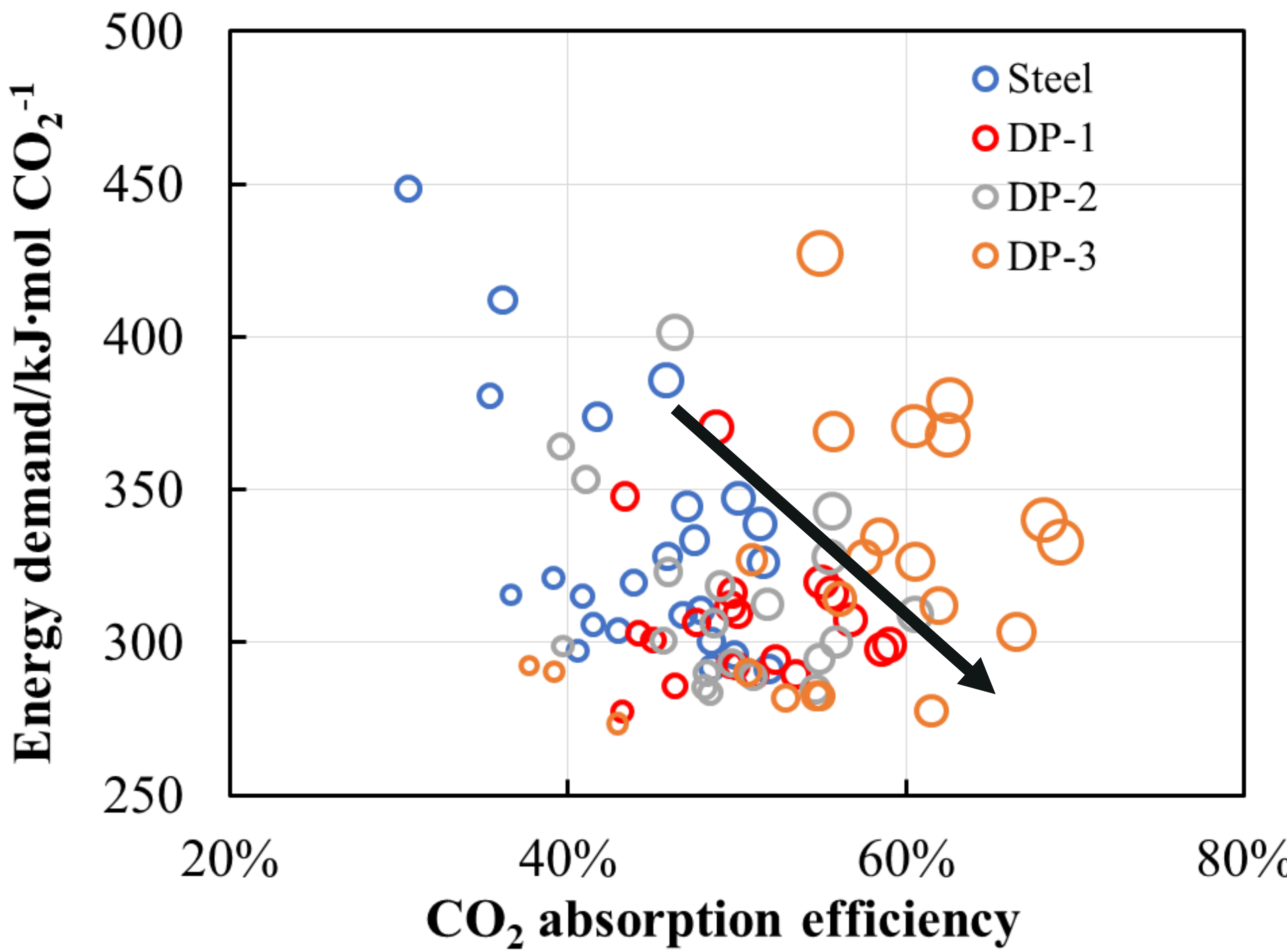
Primary goals for long-term testing are: (1) evaluate packing stability including contact angle and physical changes, and (2) assess the impact of solvent degradation on the packing and the impact of the packing on solvent degradation

Bench Testing

UK CAER's 3" Integrated Bench CO_2 Capture System w/ Simulated FG



Bench Testing - Parametric

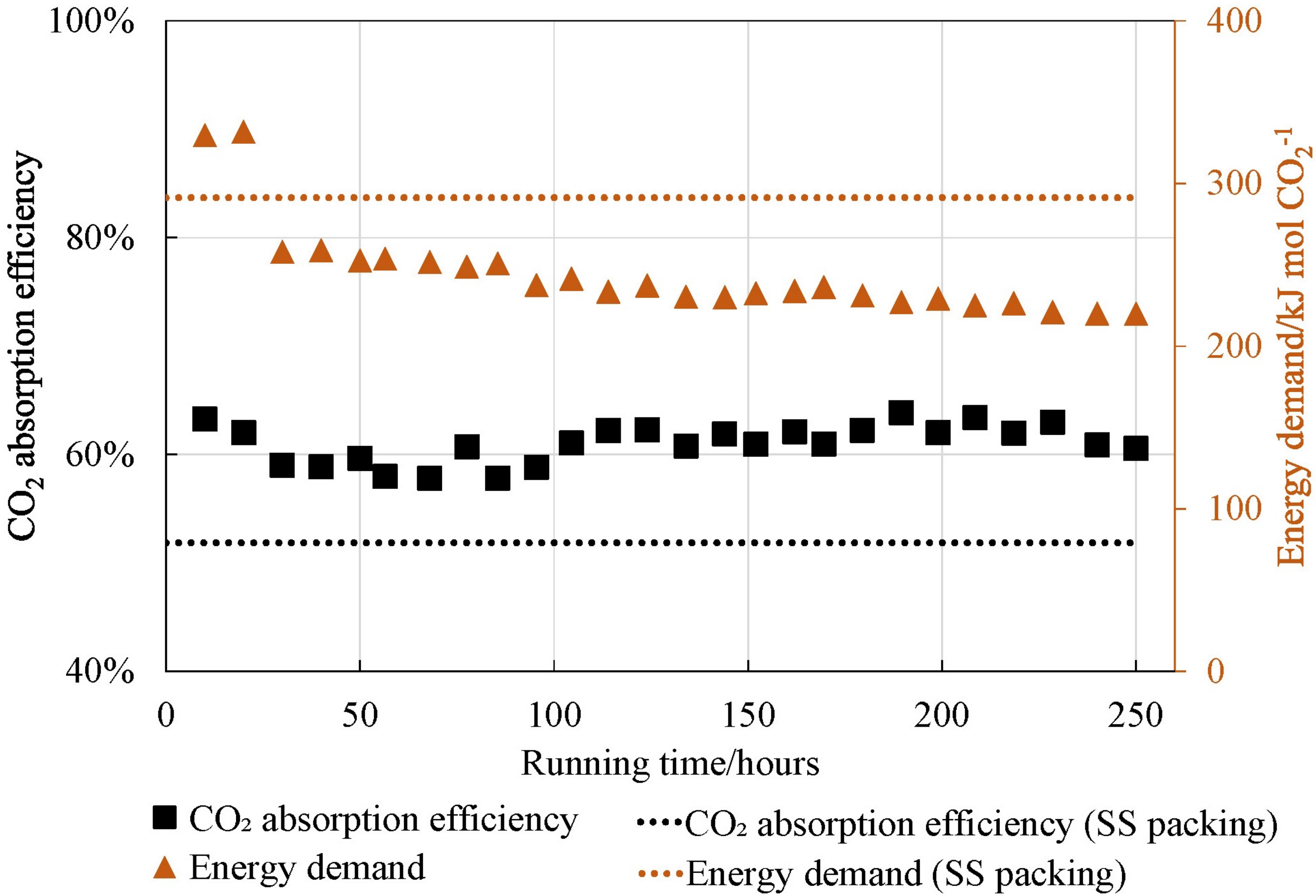


Variables	Range
Inlet CO_2	14%
L/G (Kg/Kg)	1.7, 2.6, 3.5
Stripper Pressure (kPa)	110-180
Stripper Temp (ºC)	105-120

DP packing with enhanced solvent achieved an average increase in CO_2 absorption efficiency of 22.7% and a 20.0% decrease in energy penalty compared to reference steel packing during parametric testing

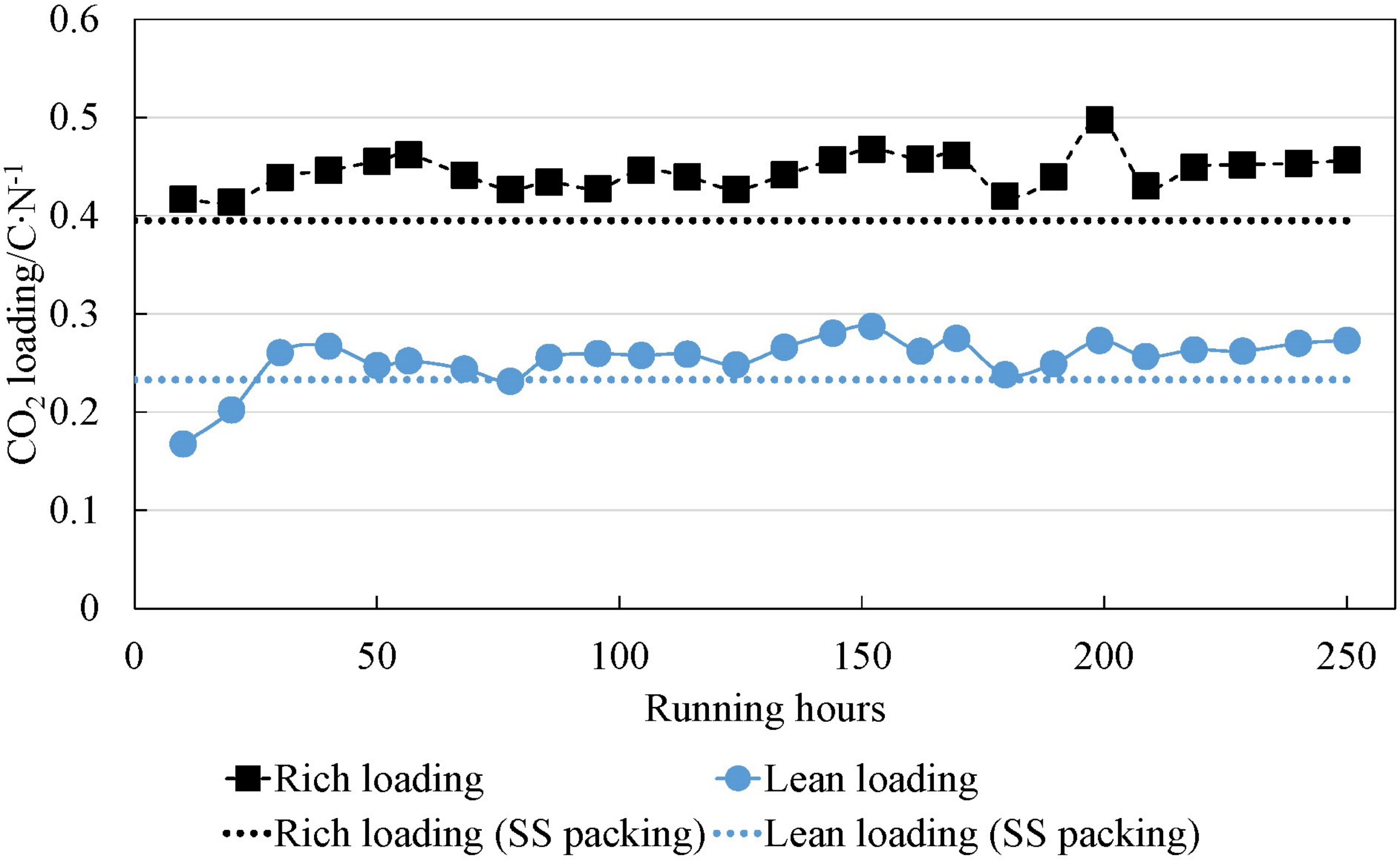
Bench Testing : Long-term

Initial long-term testing achieved a 17.3% increase in CO_2 capture efficiency and a 18.6% decrease in energy penalty



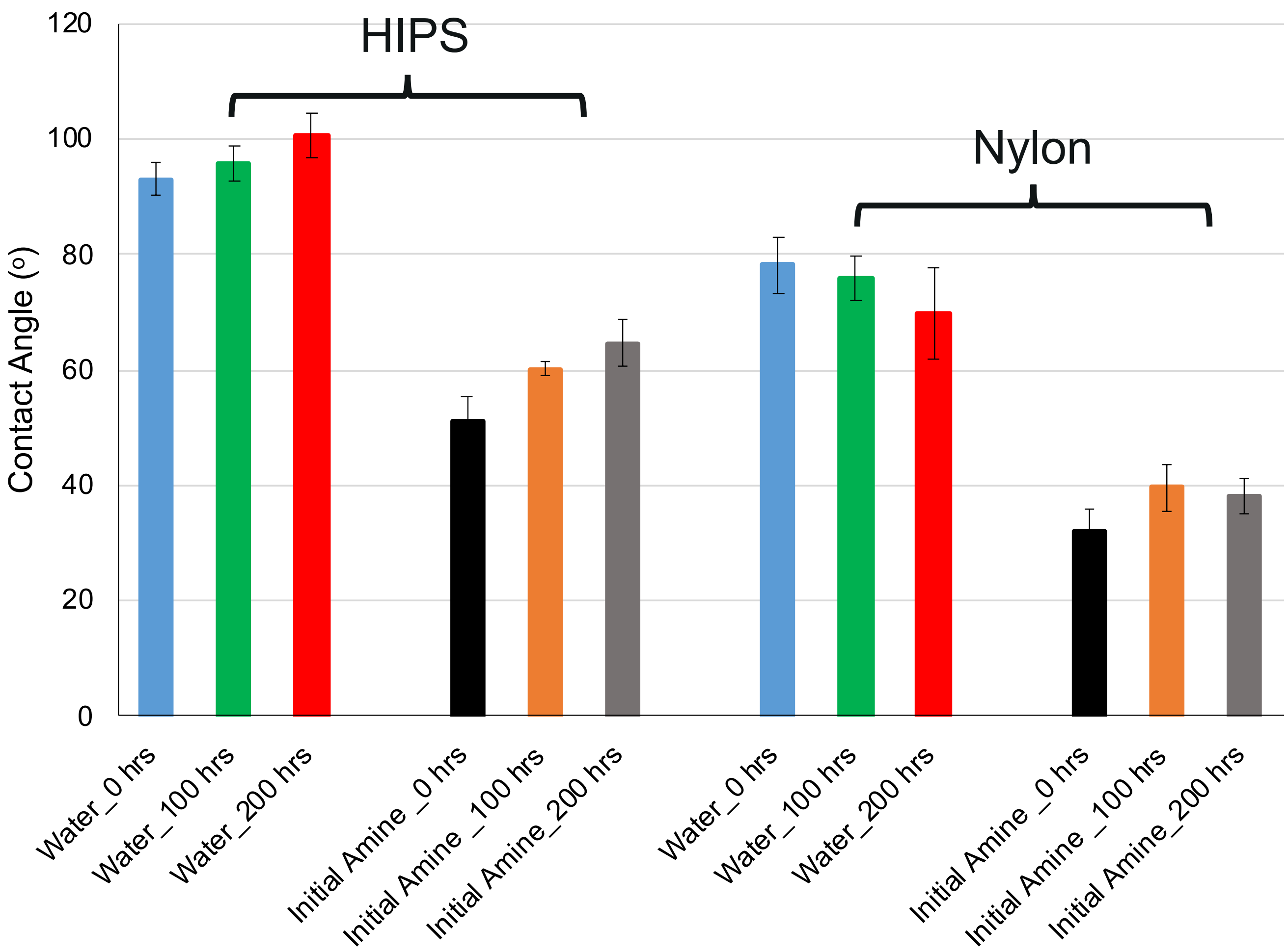
Bench Testing : Long-term

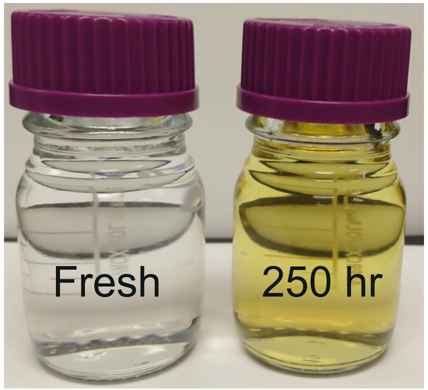
DP packing turbulence contributes to increased CO_2 mass transfer with a 13% increase in rich CO_2-loading compared to baseline steel packing



Bench Testing – Long-term

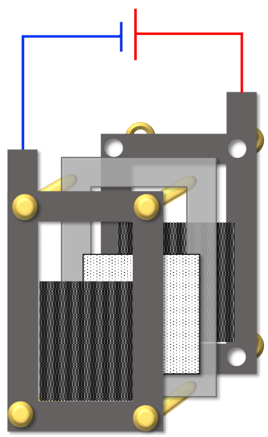
- HIPS and Nylon polymers are generally stable during long-term CO_2-loaded amine exposure at absorber temperatures
- No solvent degradation through interaction with polymers

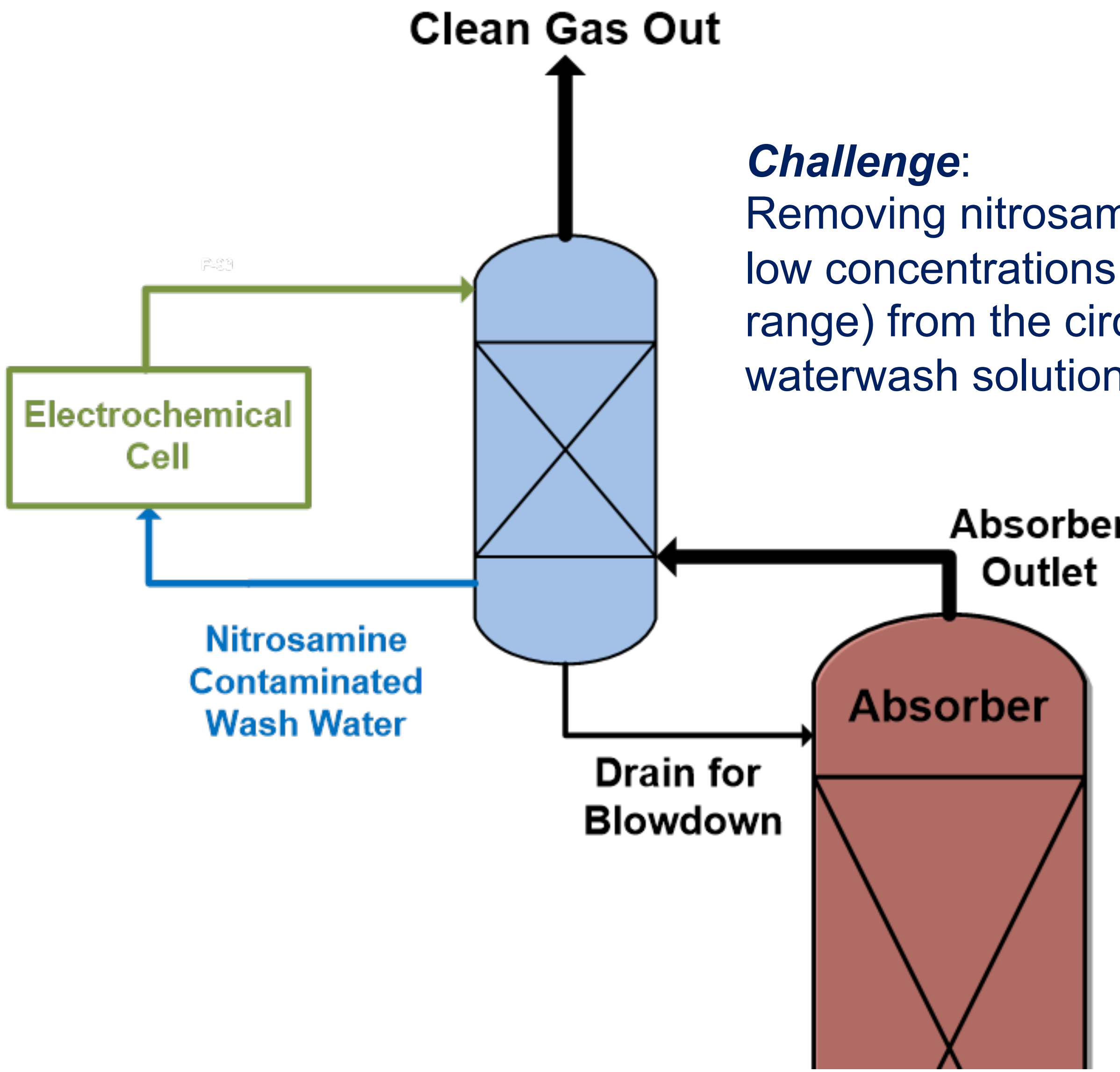




No observed leaching of colorants from HIPS or Nylon through 200 hrs

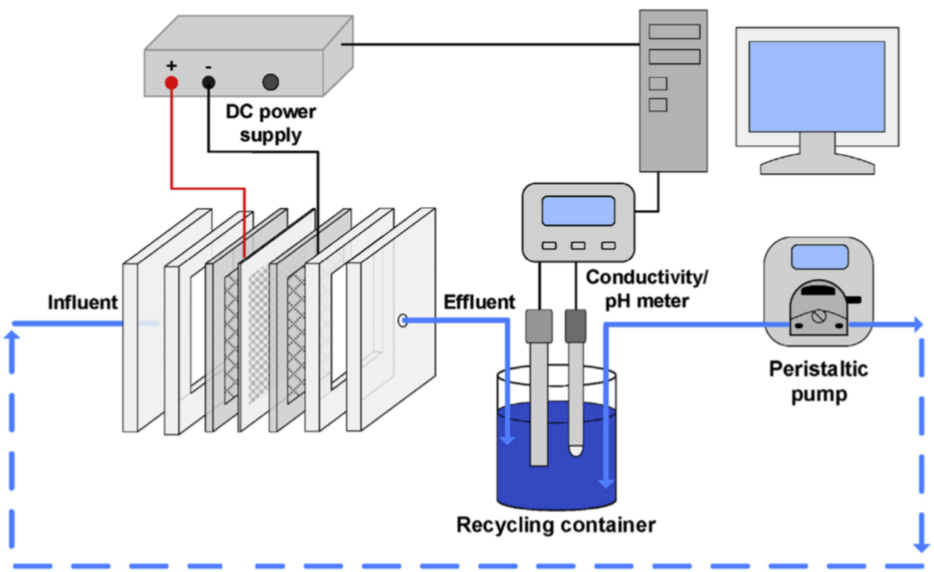
Current Progress – Nitrosamine Mitigation





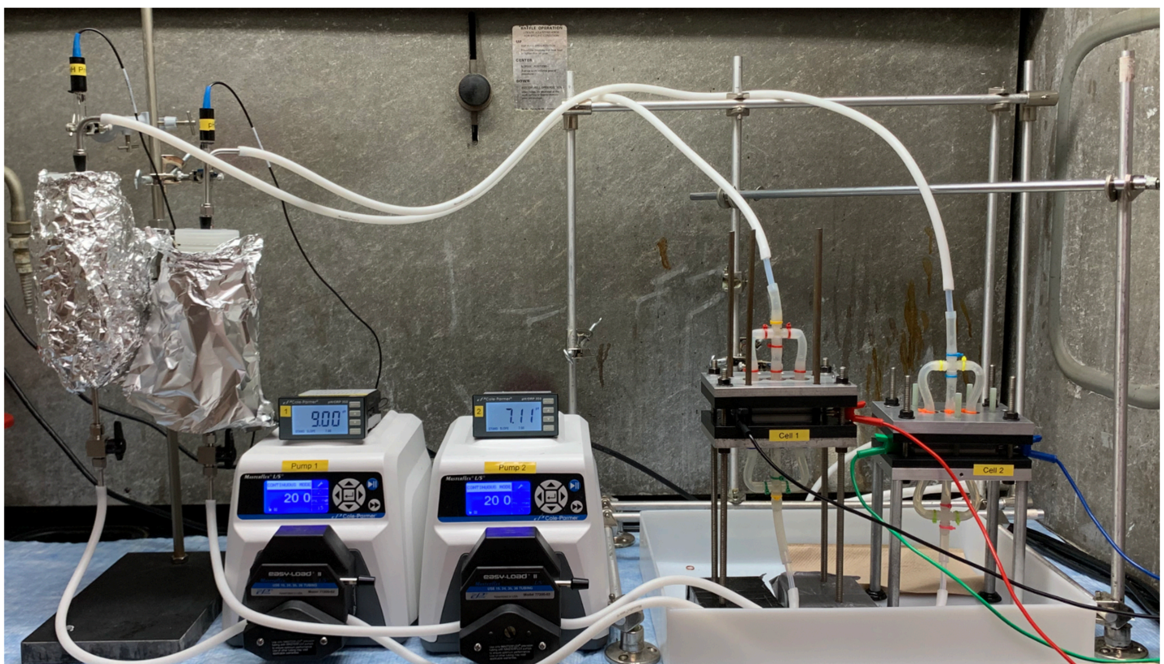
Challenge:
Removing nitrosamines at very low concentrations (ppb - ppm range) from the circulating waterwash solution

Current Progress – Nitrosamine Mitigation



Development tasks:

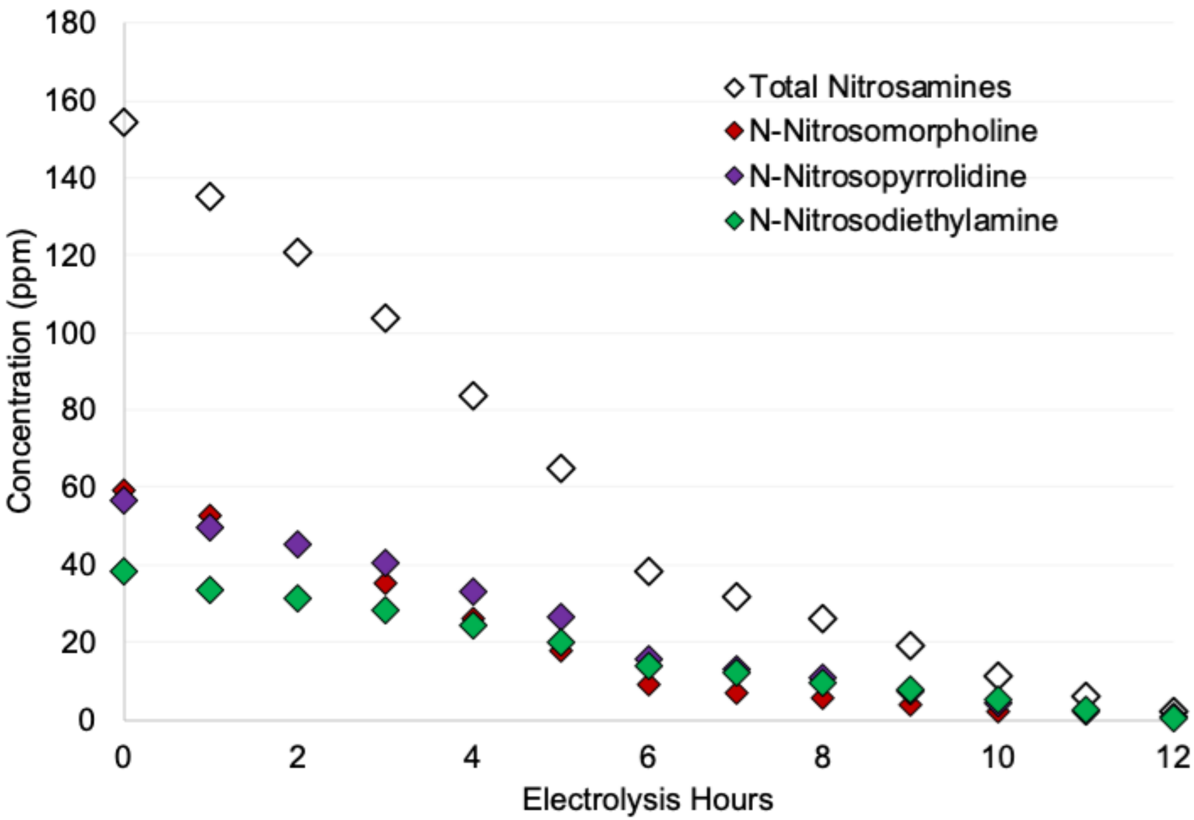
- Fabrication of flow-through electrochemical cell
- Optimize nitrosamine removal and efficiency
- Test using authentic waterwash collected at our 0.7 MWe Small Pilot CCS



Key properties:

- Flow-through design for constant treatment
- Ability to decompose a variety of nitrosamines
- Does not degrade amines in WW
- Small footprint and energy usage

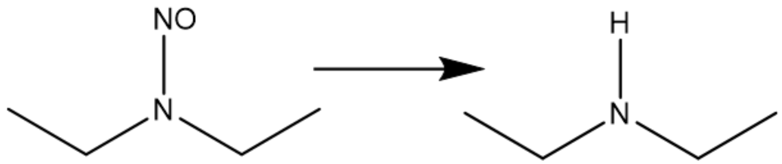
Current Progress – Nitrosamine Mitigation



Operating Conditions	
Electrodes (A + C)	Carbon Xerogel (CX)
Flow Rate	20 mL/min
Simulated Water Wash	1 wt% MEA
Applied Current	25 mA

Target: > 60% removal of nitrosamines and 20% efficiency

Achievement: >95% nitrosamine removal (below LOD) at >25% efficiency



Primary byproduct is regeneration of the parent amine with minimal amine decomposition

Success Criteria

Decision Point	Date	Success Criteria
Completion of BP1	3/31/2020	1. Production of a 3" sections of dynamic packing 2. Dynamic packing to achieve the target 20% mass transfer enhancement 3. A completed test matrix plan for the dynamic packing and solvent test campaign 4. Production of an electrochemical cell capable of being decomposing nitrosamines below the target value of 60% removal
Project Completion	9/30/2021	1. A stable operation with average of 20-30% less energy consumption compared to MEA reference 2. Completed high level technical and economic analysis of the proposed process concepts

Project Schedule – Budget Period 2

			FY2020		FY2021			
Task Number and Name	Start	End	Q3	Q4	Q1	Q2	Q3	Q4
1. Project Management and Planning	10/1/18	9/30/21						
1.1 Task management and execution	10/1/18	9/30/21						
1.2 Update PMP	10/1/18	9/30/21						
1.3 Briefings and Reports	10/1/18	9/30/21						
7. Nitrosamine Cell	10/1/18	6/30/21						
7.2 Testing of cell	4/1/19	6/30/21						
Cell efficiency > 20%		6/30/21					★	
8. Integrated Testing	4/1/20	9/30/21						
8.1 Additive Solvent testing	4/1/20	5/30/20						
8.2 Parametric Testing	6/1/20	11/30/20						
8.3 Long-term Testing	12/1/20	9/30/21						
8.4 Degradation and Aerosols	12/1/20	9/30/21						
Integrated testing 10% C/N increase, 10% liquid circulation decrease		9/31/21						★
9. Technical and Economic Assessment	7/1/21	9/30/21						
Issue TEA report		9/30/21						★

<u>Budget Period 2 Summary (before NCTE)</u>:

1. Integration and long-term testing (500 hour) of packing material and enhanced solvent using bench CO_2 capture unit
2. Conduct high-level TEA of enabling technologies

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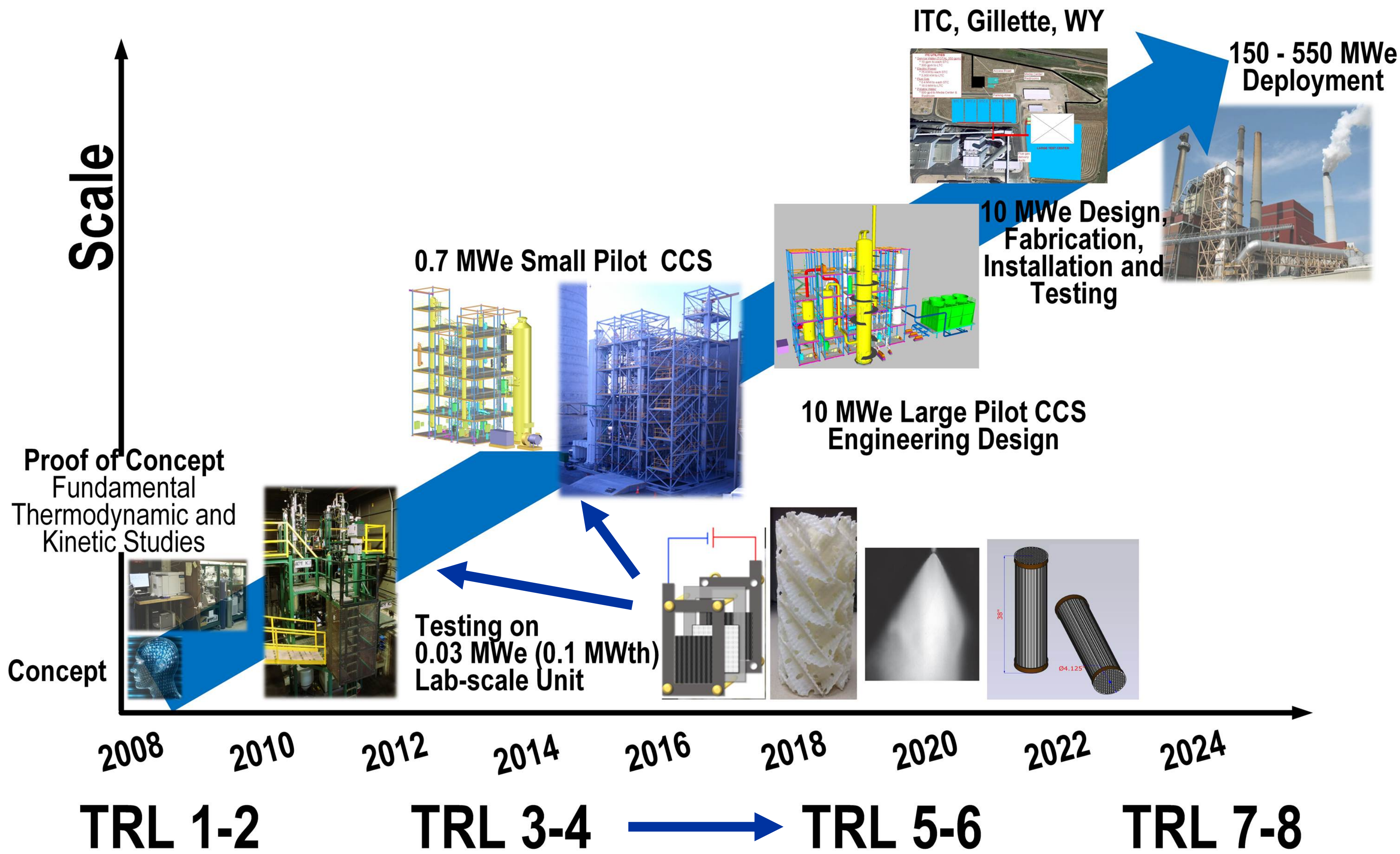
Key Knowledge Gained

- Dynamic polymer packing is a promising lower-cost alternative for CO_2 capture absorbers
- Amine solvent physical properties can be modified through the addition of additives to decrease surface tension and increase wettability on packing surfaces
- Nitrosamine decomposition can be achieved using an electrochemical treatment process.

Next Steps – Technology Development

Enabling technologies have met/surpassed performance targets and are ready to scale-up



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