DOE-ARRA Geologic Sequestration Training and Research 2011 Yearly Review Meeting

Project DE-FE0002196

Title: Efficient Regeneration of Physical and Chemical Solvents for CO2 Capture

University of North Dakota

Presenter: Dr. Brian Tande, Dept. of Chem. Eng.

February 25, 2011

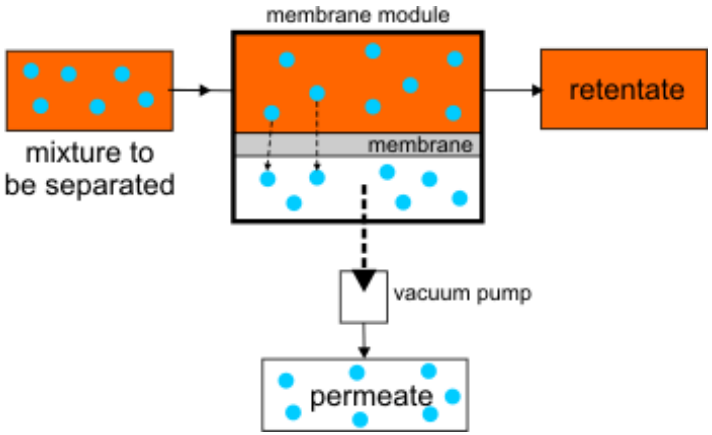
Project Participants

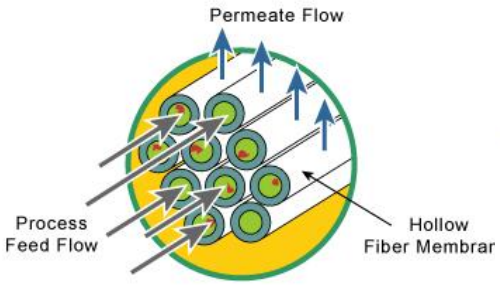
- Principal Investigators
  - Brian Tande,
    - Ph.D. U of Delaware
  - Wayne Seames,
    - Ph.D. U of Arizona
  - Steve Benson,
    - Ph.D. Penn State U

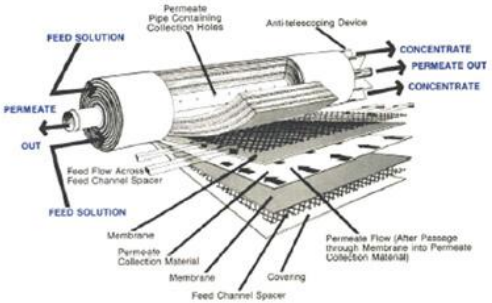
- Graduate Students
  - Xuefei Zhang,
    - M.S. U of Maine
  - Willie Wells,
    - B.S. San Jose State U

Introduction

- **Goal: reduce the cost of CO_2 capture by increasing the energy efficiency of the solvent regeneration process.**
- **Specifically, we aim to develop and evaluate membrane materials that more efficiently regenerate CO_2 solvents using pervaporation and membrane contactors.**







- **Increased interfacial surface area →Smaller equipment, lower capital cost**
  - Packed and trayed columns: ~30-300 m^2/m^3
  - Membrane modules: 300- 6000 m^2/m^3
- **Less energy consumed -** Greater surface area may mean lower temperatures needed
- **Less amine degradation –** Degradation is very minor below 110°
- **Wider operating range -** No physical limitations, such as flooding found in traditional columns

Project Objectives

1. Design and construct test apparatus to evaluate membranes
2. Assess the capability of the membranes in the test apparatus
3. Conduct a commercial feasibility study based on the test results
4. Engage and train students in the CO2 capture technologies

Project Funding

- Total Project Cost: $300,000
- DOE Share: $300,000
- Non-DOE Cost Share: $0
- Cost Share Provider: N/A

Highlights of Project to Date

- Test system has been built and validated.

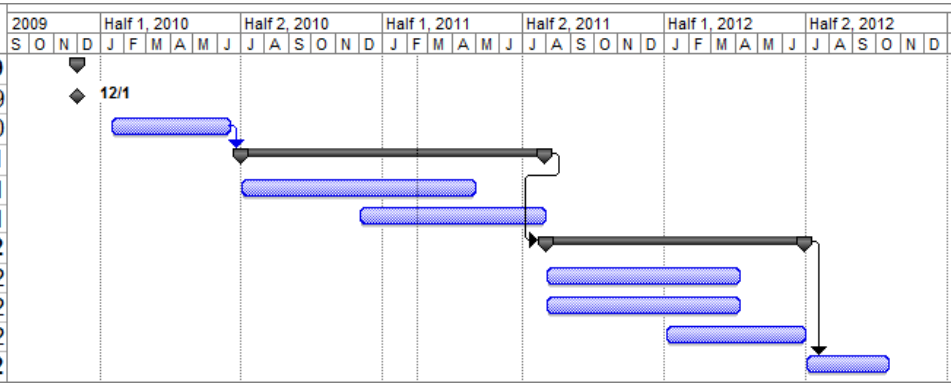
- Membrane testing is in progress
  - Encouraging early results with porous membranes
  - As much as 40% of CO_2 recovered from MEA in single pass

Tasks – Overview

Task No.	Task Description	Task Duration	Task Funding
1	Project Management and Planning	12/01/2009 – 11/30/2012	$29,068
2	Test System Fabrication and Validation	1/15/2010-6/30/2010	$54,062
3	Baseline material testing for CO_2 permeability and selectivity.	7/1/2010-7/31/2011	$96,455
4	Parametric study for promising membrane materials	8/1/2011-6/30/2012	$82,785
5	Commercial Feasibility Analysis	7/1/2012-10/15/2012	$37,630

Project Schedule

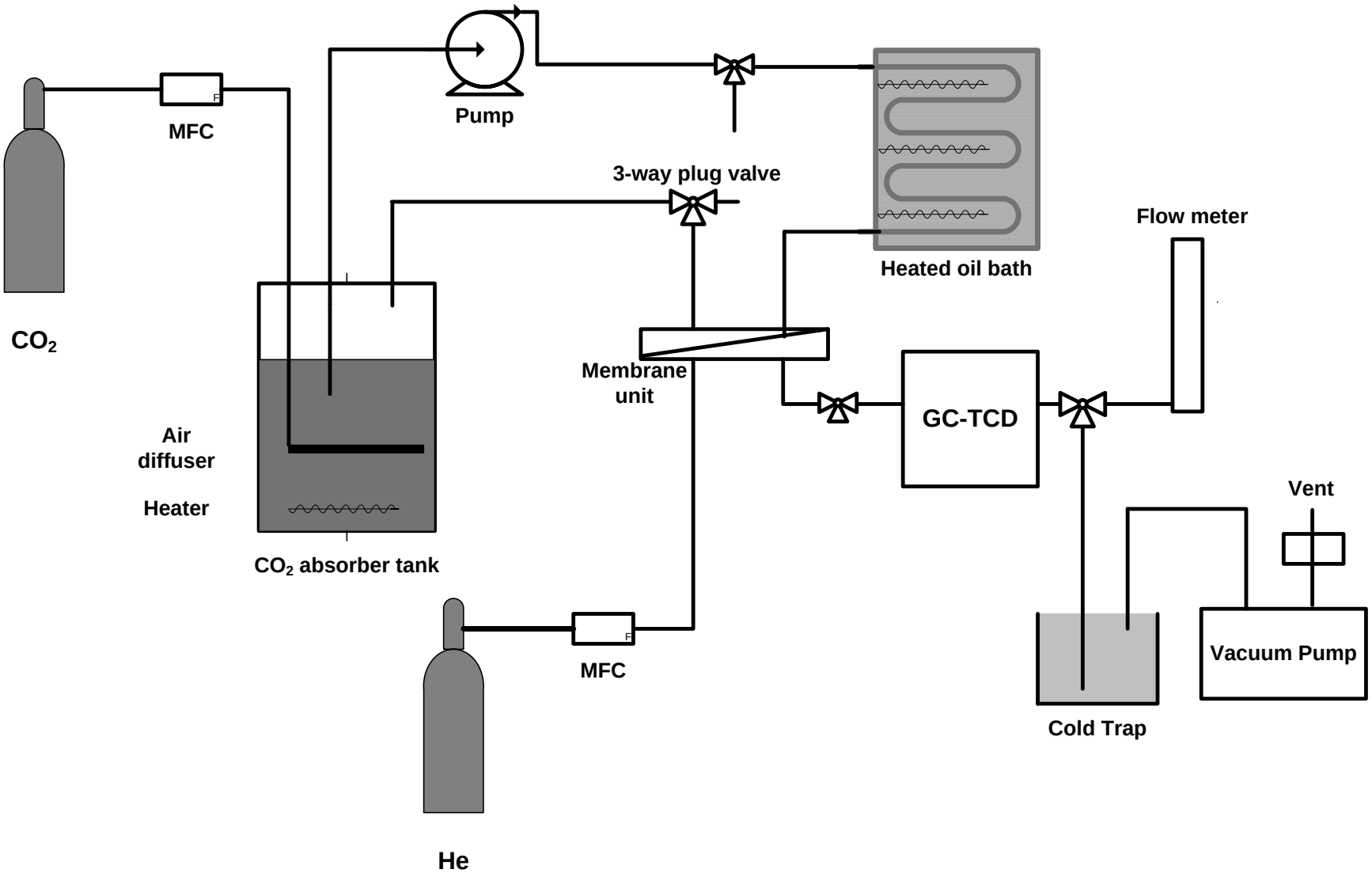
ID	Task Name	Start	Finish
1	**1. Project Management and Planning**	**Tue 12/1/09**	**Tue 12/1/09**
2	Project Start	Tue 12/1/09	Tue 12/1/09
3	**2. Test System Fabrication and Validation**	Fri 1/15/10	Tue 6/15/10
4	**3. Baseline material testing for CO2 permeability**	**Thu 7/1/10**	**Fri 7/29/11**
5	3.1 Composite membrane screening	Thu 7/1/10	Fri 4/29/11
6	3.2 Porous membrane contactor screening	Wed 12/1/10	Fri 7/29/11
7	**4.Parametric study for promising materials**	**Mon 8/1/11**	**Fri 6/29/12**
8	4.1 Composite membranes	Mon 8/1/11	Thu 4/5/12
9	4.2 Porous membranes	Mon 8/1/11	Thu 4/5/12
10	4.3 Model Syngas Tests	Mon 1/2/12	Fri 6/29/12
11	**5. Commercial Feasibility Analysis**	**Mon 7/2/12**	**Mon 10/15/12**



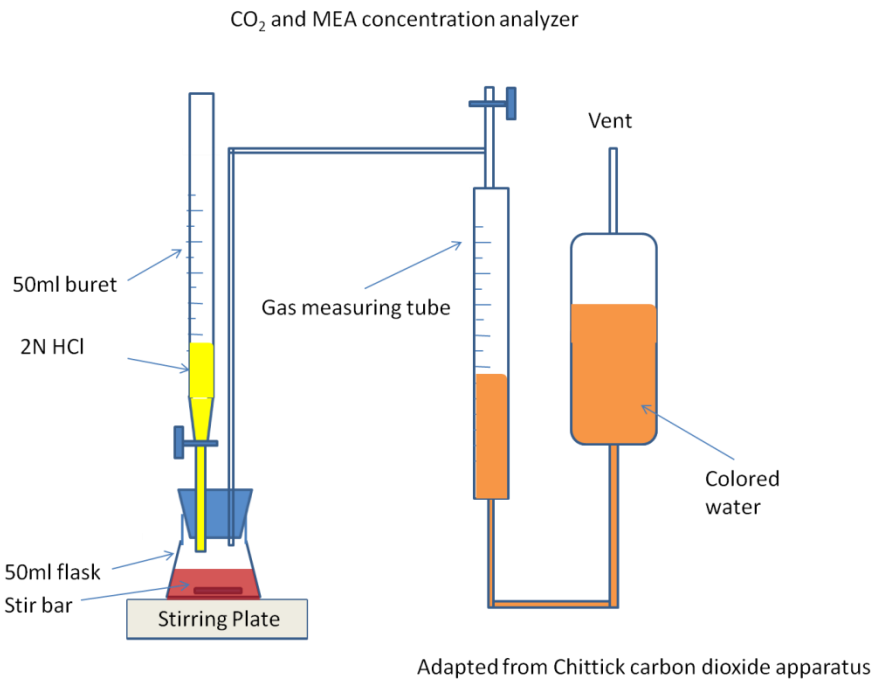
Discussion – Task 2

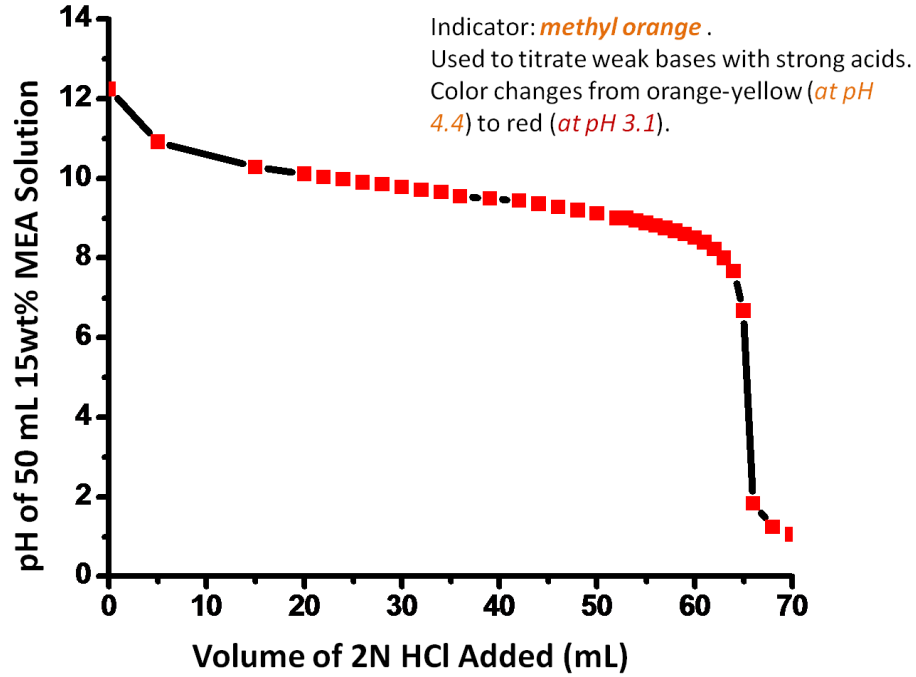
- Test System Fabrication and Testing
  - Rather than separate batch and continuous systems, only one system has been built
- Responsible parties
  - Xuefei Zhang, Brian Tande
- Task Status (100% complete, though improvements will be made over time)

Schematic of Test System



Measuring CO_2 Loading in Solvent





Volume of displaced water in the gas measuring tube (ml)

HCl titrant volume (ml)

$$\alpha = \frac{moles(CO_2)}{moles(MEA)} = \frac{\left[\frac{(V_{gas} - V_{HCl})(P)(273K)}{(760mmHg)(T)(22.4L/mol)}\right]}{C_1 V_1}$$

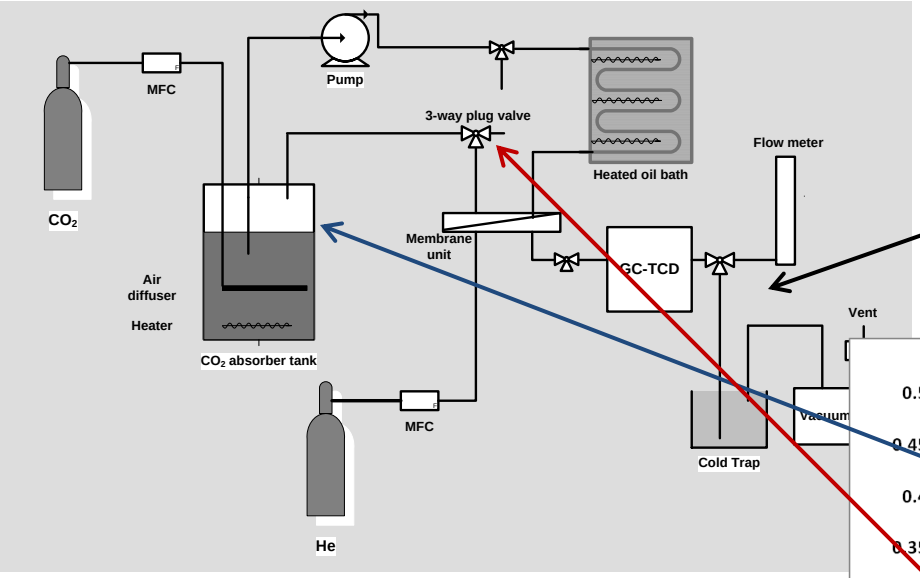
CO_2 loading

Amine solution concentration

Amine sample volume(ml)

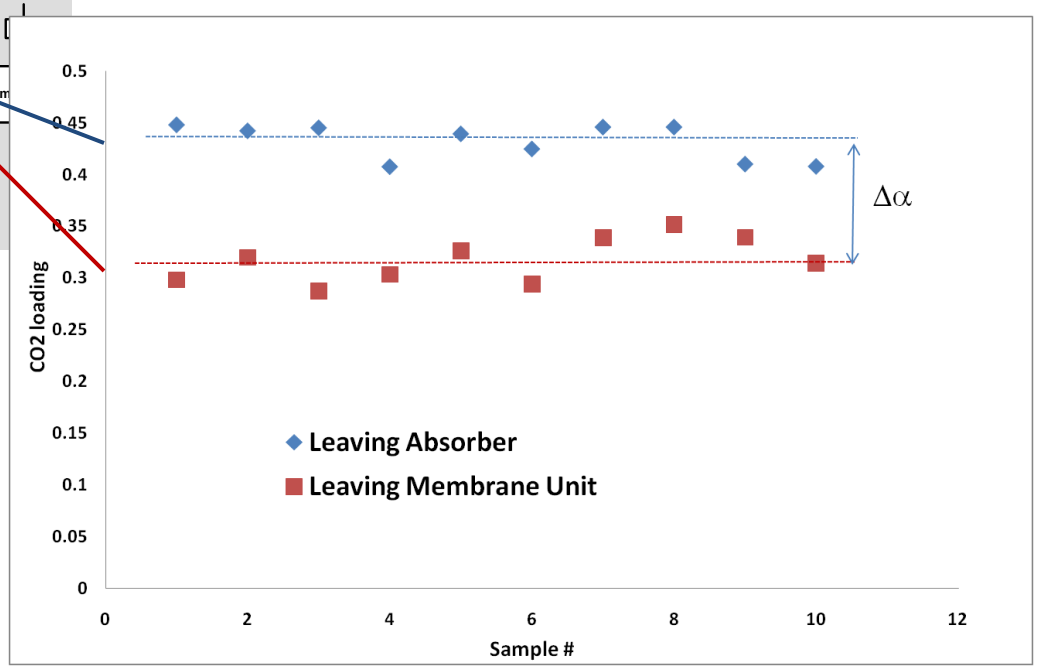
L. Ji, S.J. Miksche, L.M. Rimpf and G.A. Farthing, CO_2 Chemical Solvent Screening, 8th Annual Conference on Carbon Capture and Sequestration – DOE/NETL, Pittsburgh, Pennsylvania, U.S.A., May 4-7, 2009

Test procedure



Samples of sweep gas analyzed with GC

Liquid samples collected leaving absorber and membrane



<u>CO_2 Mass Balance:</u>

(Moles CO_2 leaving absorber) – (moles CO_2 leaving membrane unit) =Moles of CO_2 in sweep gas

Discussion – Task 3

- Baseline material testing for CO_2 permeability and selectivity
  - Membrane contactor screening
  - Composite membrane screening
- Responsible parties
  - Xuefei Zhang, Willie Wells, Brian Tande
- Task Status (10% complete)

Discussion – Task 3

Status of Membrane Contactor Experiments

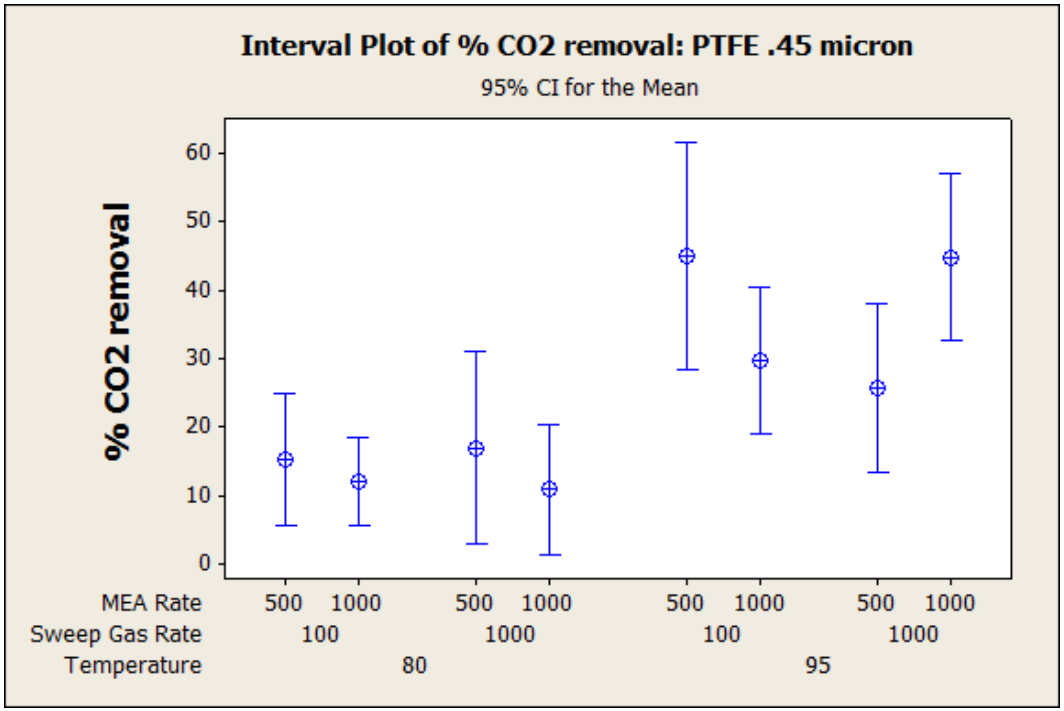
Sample	Status
PTFE (.45, 1.2 μm)	Samples tested, performed well
Cellulose Acetate (.8 μm)	Samples tested, substantial leakage
Nylon, hydrophobic (.45 μm)	Samples tested, performed well
Polyester (.4 μm)	Not yet tested
Polypropylene (.45 μm)	Not yet tested
Polyethersulfone (.45 μm)	Not yet tested
PVDF (.45 μm)	Not yet tested

Task 3 Sample Data

.45 micron PTFE Membrane

Screening DOE:

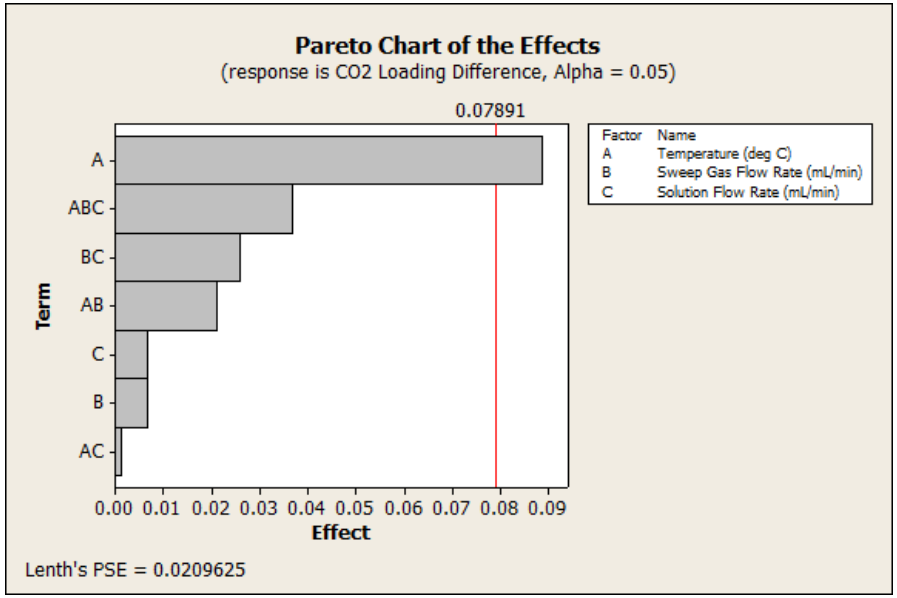
	Low	High
Temperature (°C)	80	95
Liquid Flow Rate (ml/min)	500	1000
Gas Flow Rate (ml/min)	100	1000

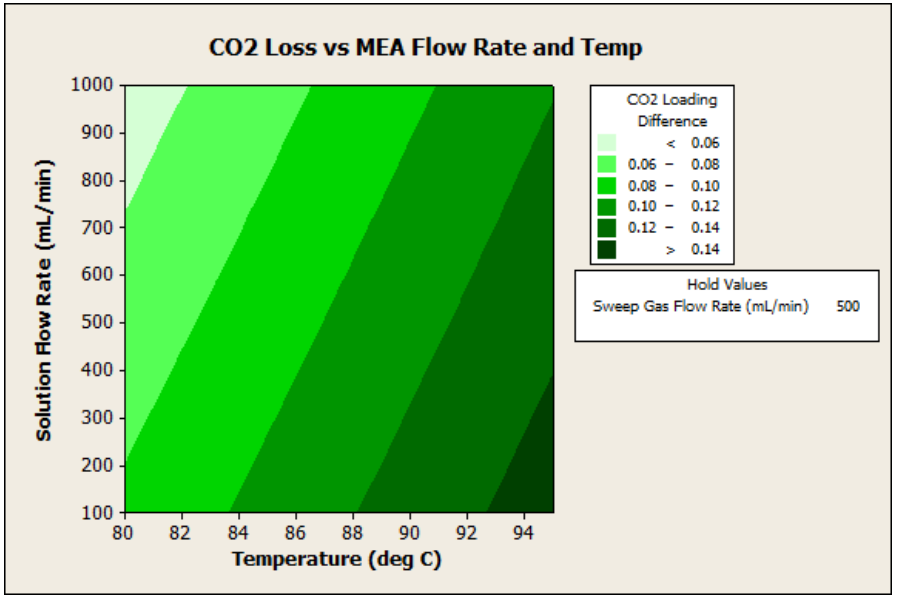


Significant difference with temperature increase, but large variability in measurements

Task 3 Sample Data

.45 micron PTFE Membrane





Discussion – Task 3

- Major accomplishments
  - Proof of concept with porous membranes
  - As much as 40% of CO_2 recovered from MEA
- Major issues/problems
  - Delays due to instrument problems
  - Currently only MEA loading measurements are being done- GC will be upgraded to allow us to close the mass balance

Discussion – Task 4

- Parametric study for promising membrane materials
  - Promising membranes and solvents from Task 3 will be studied in more detail under various conditions (solvent flow rate, sweep gas rate, pressure, temperature).
  - Long term performance will be evaluated with a model syngas -minor and trace components typical of a gasification syngas.

- Responsible parties
  - Xuefei Zhang, Brian Tande, Steve Benson

- Task Status
  - not yet started, due to begin in late summer

Discussion – Task 5

- Commercial Feasibility Analysis
  - Use permeability, selectivity, and operating parameters to design a large scale process and asses its economic feasibility
  - The design will include
    - Process Flow Diagram, major and minor equipment design
    - Operating and capital cost estimates
    - Economic analysis – NPV, DCFROR
- Responsible parties
  - Wayne Seames, Undergraduate student
- Task Status
  - not yet started

Project Milestones

(HQ milestones)

Milestone	Planned Completion Date	Actual Completion Date
HQ Milestone: Project Kick-off Meeting	03/31/10	03/25/10
HQ Milestone: Educational Program Instituted	06/30/10	01/11/10
HQ Milestone: Semi-Annual Progress Report	09/30/10	07/30/10
HQ Milestone: Yearly Review Meeting	03/31/11	02/25/11
HQ Milestone: Yearly Review Meeting	03/30/12	

Project Milestones

Milestone	Planned Completion Date	Actual Completion Date
Test system fabrication complete	6/13/10	6/30/10
Composite membrane screening completed	4/29/11	
Porous membrane screening completed	7/29/11	
Composite membrane parametric study completed	4/5/12	
Porous membrane parametric study completed	4/5/12	
Model syngas study completed	6/30/12	
Commercial feasibility analysis completed	10/15/12	

Anticipated Efforts for the Coming Year

- Continue membrane screening evaluations through the summer, then begin detailed parametric study
- Make improvements to test system as needed
  - Work to reduce measurement variability, close mass balance
  - Install inline pH meter to speed up analysis
- Hire full time engineer to replace M.S. student

PI Contact Information

- If you have any questions or would be interested in collaboration please contact
- briantande@mail.und.edu