Design and Assembly of Pilot-Scale Membrane Filtration System

Cyrus Flynn, Jared Maraist

Faculty Sponsor: Dr. Trevor Carlisle

PROJECT GOALS

Design and implement a pilot-scale membrane separation system, complete with a standard operating procedure and a lab assignment ready for immediate use in CHE 334.

BACKGROUND

Membrane separation processes are commonly used industrial unit operations, yet there are currently no membrane concepts included in the CHE curriculum. In this lab project, students will characterize the performance of a polydimethylsiloxane (PDMS) membrane.

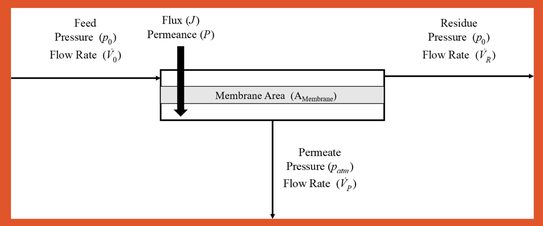

Figure 1 *- A conceptual representation of a typical gas separation module. Gas is fed to the membrane housing where it then permeates through the membrane, with the remaining gas being swept out in the residue stream*

KEY PARAMETERS

- Flux (J) - Permeate gas flowing through the membrane per unit area
- Permeance (P) - The ability of a gas to penetrate the membrane, computed by normalizing the flux by the pressure differential across the membrane
- Selectivity (α) - A measure of the membrane's ability to permeate one gas relative to another, defined as the ratio of pure gas permeances.

Students will examine these parameters for nitrogen, carbon dioxide, helium, and a CO_2-N_2 gas mixture.

Oregon State University

CHE 334 LAB PROCEDURE

- The filtration experiments will be done over the course of a single 3-hour lab period
- Students will familiarize themselves with the use of gas cylinders, two-stage pressure regulators, and soap-film bubble flow meters
- Students will be expected to create the following plots:
  - Pure gas flux versus feed pressure for N_2, CO_2, and He
  - Pure gas permeance versus feed pressure for N_2, CO_2, and He
  - Permeate CO_2 concentration versus pressure ratio (feed/permeate pressure) for a mixture of CO_2 and N_2 gas
- Students will also be expected to calculate an "ideal selectivity" from N_2 and CO_2 permeances for comparison with mixed gas experiments

OUR SYSTEM

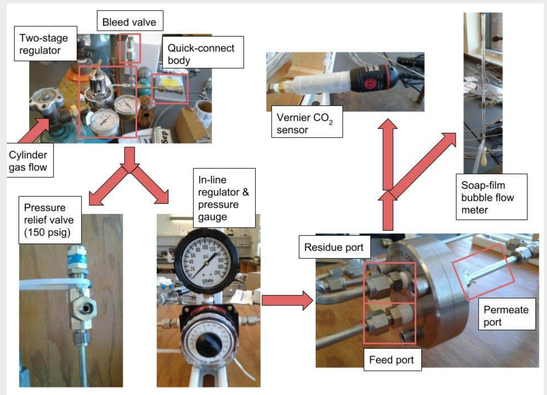

Figure 2 *- A pictorial representation of how gas flows through the system. Gas is fed from the cylinder, with the pressure limited by a two-stage regulator. The cylinder assembly is connected to the filtration system via a quick-connect system. The gas flows to an in-line regulator, where the pressure can be finely controlled for each experiment. A pressure relief valve, with a set pressure of 150 PSIG, is positioned before the regulator to prevent damage to the system. The gas then enters the membrane housing. Residue gas may be vented out the back port if desired. Permeate gas goes to the bubble flow meter for volume measurements, or the valve can be opened to send mixed gas to the CO_2 sensor for composition measurements.*

EXPERIMENTAL RESULTS

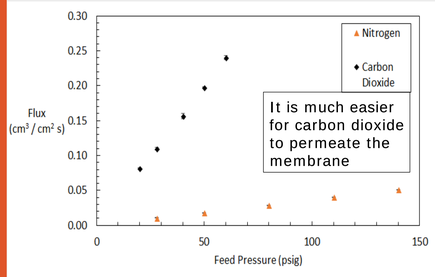

Figure 3 *- This graph shows flux through the membrane versus the feed pressure. The black diamonds represent carbon dioxide and the orange triangles represent nitrogen. The error bars shown represent the standard deviation of 9 samples. The data shows that the flux of carbon dioxide increases much more rapidly and at much lower pressure than the flux of nitrogen.*

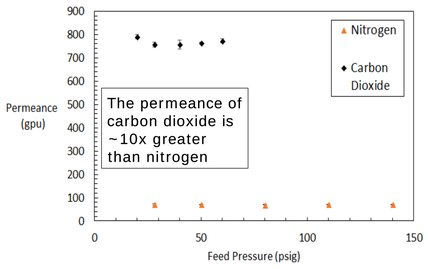

Figure 4 *- This graph shows permeance versus the feed pressure. The black diamonds represent carbon dioxide and the orange triangles represent nitrogen. The error bars shown represent the standard deviation of 9 samples. This graph shows that the permeance of carbon dioxide is much higher than nitrogen for this PDMS membrane, which corresponds to a selectivity of approximately 11.*

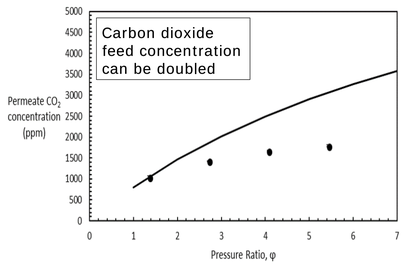

Figure 5 *- This graph shows the carbon dioxide concentration of the permeate stream versus the feed pressure. The error bars shown represent the standard deviation of 3 samples. The black line represents a theoretical prediction. The feed carbon dioxide concentration is 800 ppm, and this concentration can be doubled in the permeate stream at higher feed pressures.*

DISCUSSION

Our initial data shows that our membrane is selective, and can provide significant enrichment in the permeate stream. This is good because it means that our membrane will not need to be changed in the future for students to perform the same experiments.

CONCLUSIONS

Average CO_2 Permeance: 768 ∓ 14 gpu

Average N_2 Permeance: 71.2 ∓ 1 gpu

This gives an ideal CO_2 / N_2 selectivity (α) of 10.8 ∓ 0.2

CHALLENGES

- Cutting the membrane was a significant challenge. We needed to cut a circle with a ~47mm diameter using a combination of scissors and a knife.

Figure 6 *- Cutting from the roll of PDMS membrane provided to us by the kind folks at Membrane Technology and Research, Inc.*

FUTURE WORK

- Conclusion of pure gas testing:

  Helium gas will be tested for comparison with pure nitrogen and carbon dioxide permeances.

- Installation of a better purging system around the membrane housing:

  Purging the system by running nitrogen through the membrane is relatively slow due to low permeance.

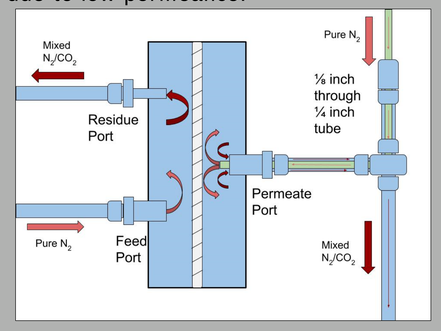

Figure 7 *- A conceptual diagram of the purging system the team plans to implement. During the purging process, nitrogen is diverted to the permeate side of the membrane housing via a one-eighth inch tube through the inside of the port. This will quickly displace CO_2 in the membrane housing, which is pushed out through the outer tube of the permeate port. Purging times are reduced from several minutes to a matter of seconds.*

- Permanent system installation on a Unistrut frame.
- Finalization of the operating procedure and lab assignment for students.

ACKNOWLEDGEMENTS

- Dr. Trevor Carlisle for project guidance and advice
- John Cochran and Andy Brickman for technical assistance and advice
- Dr. Phil Harding for advice and support of the project