Sequential Design of Experiments in Support of Membrane-based Carbon Capture Pilots

Glenn Lipscomb (Toledo), Abby Nachtsheim (LANL), Charles Tong (LLNL), Phan Nguyen (LLNL), Katherine Hornbostel (Pitt)

Motivation

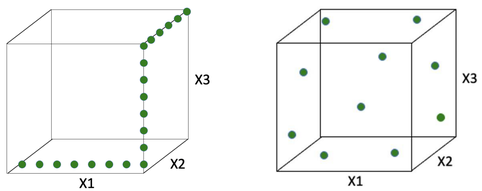
Maximize information obtained from expensive, time-consuming, large-scale carbon capture pilots.

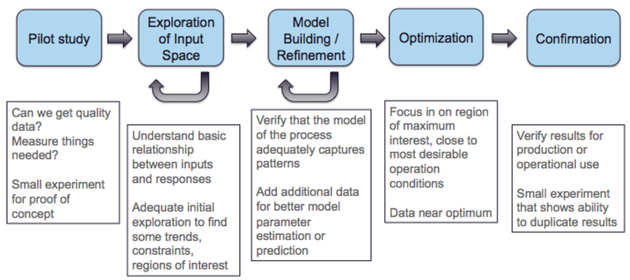
- MTR: CO2 Capture from Coal Flue Gas
  TCM, Mongstad, Norway
- NETL: CO2 Capture from Steel Blast Furnace
  US Steel, Braddock, PA
- OSU: CO2 Capture from Cement Gas
  Holcim, Holly Hill, SC
- OSU: CO2 Capture from NGCC Flue Gas
  ITC, Gillette, WY

https://www.facebook.com/WyomingITC/
https://www.holcim.us/sites/us/files/2022-03/HOLLY_HILL_Fact_Sheet_March2022_HR.pdf
https://www.osti.gov/servlets/purl/2371810; https://en.wikipedia.org/wiki/Edgar_Thomson_Steel_Works

Sequential Design of Experiments (SDOE)

Instead of one factor at a time experimentation, use experimental sequence to optimally estimate process model parameters and identify interactions.

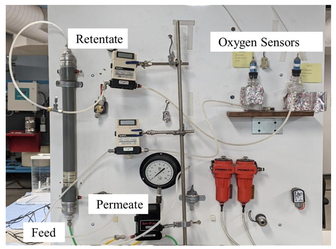




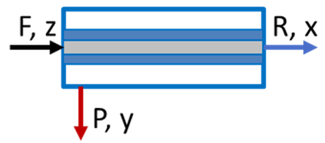
Commercial N2 Hollow Fiber Membrane Module

Experimental plan
Inputs:
Feed Flow rate, Pressure, Temperature

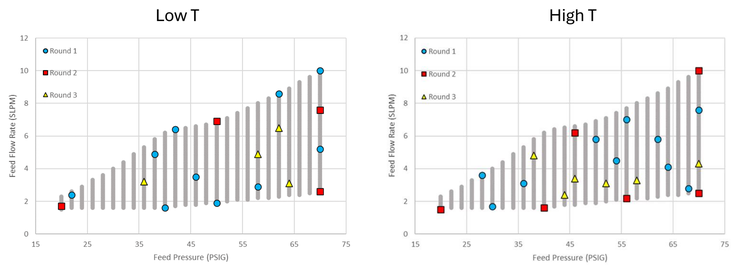
Outputs:
R – Retentate flow
P – Permeate flow
XO2 – Retentate O2 concentration
YO2 – Permeate O2 concentration
$\hat{R}$ = R/membrane area



Parameters:
EaR(N2) – Activation energy of nitrogen
EaR(O2) – Activation energy of oxygen
ID_StDev – Standard deviation of inner diameter
P0(N2) – Permeance pre-exponential of nitrogen
P0(O2) – Permeance pre-exponential of oxygen

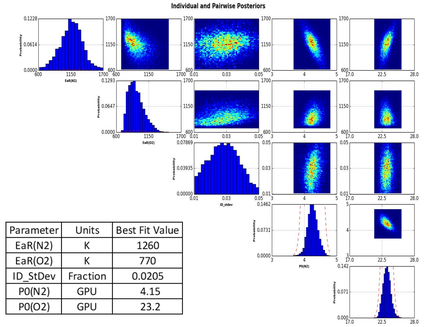


Three experimental rounds



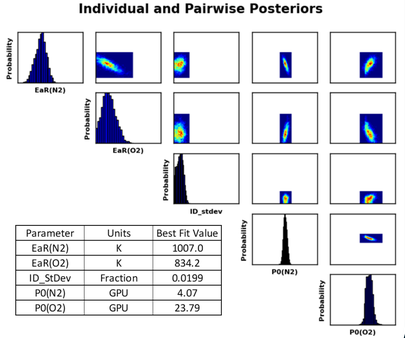
Posterior parameter estimates

First Round



Parameter	Units	Best Fit Value
EaR(N2)	K	1260
EaR(O2)	K	770
ID_StDev	Fraction	0.0205
P0(N2)	GPU	4.15
P0(O2)	GPU	23.2

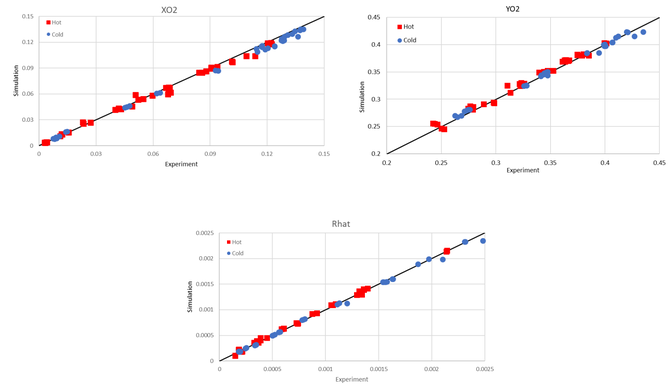
Second Round



Parameter	Units	Best Fit Value
EaR(N2)	K	1007.0
EaR(O2)	K	834.2
ID_StDev	Fraction	0.0199
P0(N2)	GPU	4.07
P0(O2)	GPU	23.79

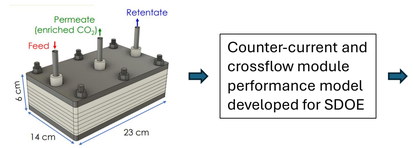
Commercial N2 Hollow Fiber Membrane Module

Output parity plots

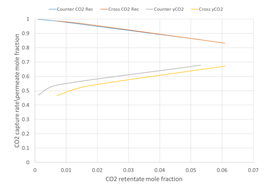


Current Status

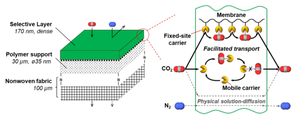
NETL:



Counter-current and crossflow module performance model developed for SDOE



OSU:



Incorporate facilitated transport mechanism in counter-current and crossflow module performance models

https://www.nationalcarboncapturecenter.com/wp-content/uploads/2023/08/OSU-Field-Test-Report-4-12-23_revised-5-1-23.pdf

Summary and Conclusions

- SDOE offers the potential to maximize the information obtained from pilot campaigns
- Demonstrated potential with commercial N2 module
- CCSI2 tools used to develop process models and optimally obtain model parameter estimates.

Contact: Glenn Lipscomb, glenn.lipscomb@utoledo.edu

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