Membrane Separation Technology

Discussion of Critical Process Design Variables

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Outline

1. Why use membranes
2. Types of membranes
3. Disadvantages of using membranes
4. Process Schemes
5. Design considerations

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Advantages of Membrane Separation

Current SotA methods for carbon capture , primarily liquid solvents, are operationally intensive processes generating large quantities of waste streams and capable of releasing chemicals harmful to health and the environment

- Mechanical Separation
- Small Footprint
- Modular
- Mobile
- Low HSE impact
- Lower Capital Cost
- Minor Maintenance Requirements
- Separation Not Dependent on Phase Change
- Primary/Secondary Containment Not Required

Compared to a traditional amine gas contactor, membranes have ~40% less initial capital cost and >25% shorter lead time for the carbon capture generated by a 6MWe emission source

Footprint Comparison Between Membranes and Liquid Solvent

https://www.nationalcarboncapturecenter.com/

https://www.dmt-cgs.com/project/big-run-landfill-rng/

NCCC 1 MWe PTSU	Ashland, KY Big Run Landfill Renewable Natural Gas Plant
Treats 1 MWe emission source (~2000 scfm)	Treats ~4000 scfm landfill Gas
13% vol CO2	Combination of PSA and Membranes to separate and remove CO2
110-240F @2 psig	
1500-2000 gal solvent inventory	

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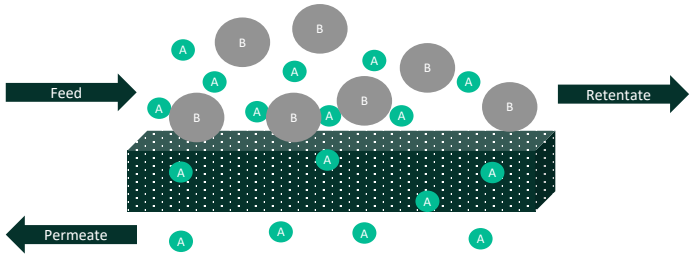
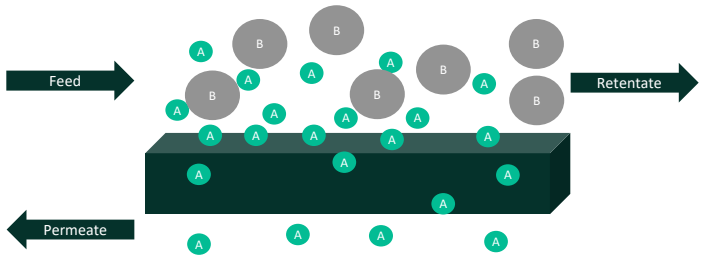
Types of Membranes

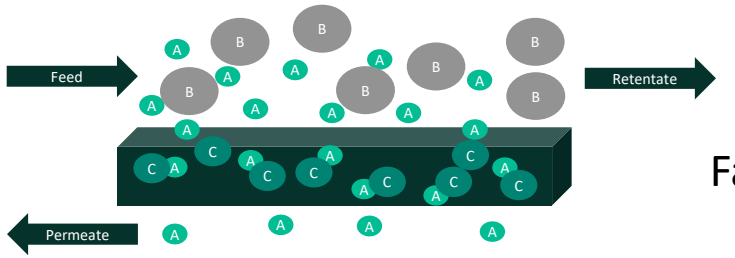
Separation Method



Kinetic Diameter



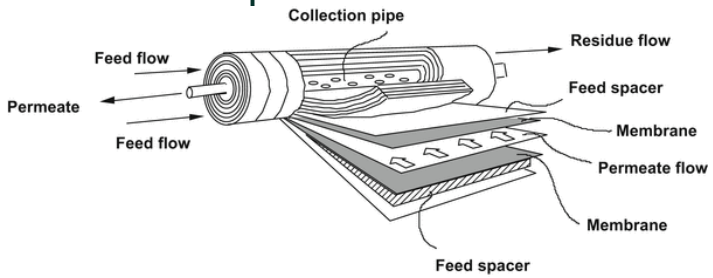
Surface Diffusion
(*physisorption)



Facilitated Transport
(*chemisorption)

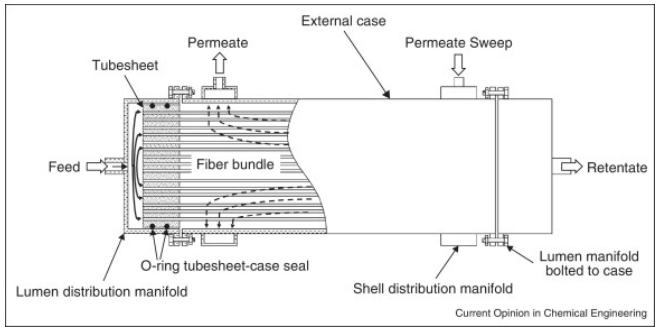
Construction Type

Spiral Wound



Balster J. (2013) Spiral Wound Membrane Module. In: Drioli E., Giorno L. (eds) Encyclopedia of Membranes. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-40872-4_1586-1

Hollow Fiber



Che Mat, et. al., Hollow fiber membrane modules, Current Opinion in Chemical Engineering,Volume 4,2014,Pages 18-24,ISSN 2211-3398

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Disadvantages of Using Membranes

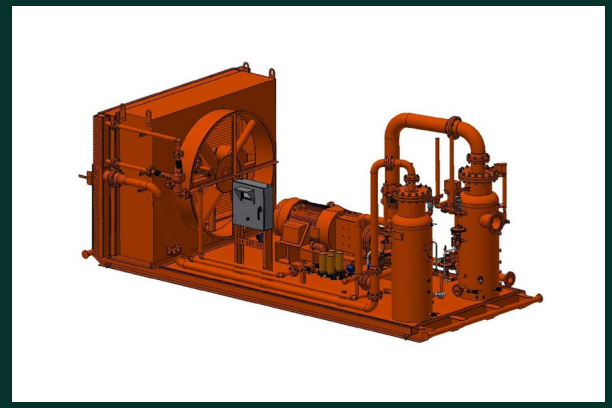
Typically, commercially available membranes require an elevated pressure ratio across the feed and permeate streams which increase operating expenses considerably

- Typically Require Elevated Feed Pressure
- Recycle Costs
- Limited Number of Stages
- Product Purity Achievable
- Membrane Poisoning
- Membrane Fouling
- Lower Feed Temperature Requirements
- Flowrate Scaling Wall

Compared to a traditional amine gas separation, membranes have ~25% increased operating costs which corresponds to >25% increase in $/ton for the carbon capture generated by a 6MWe emission source

Examples of PreFeed/Interstage Compressors

https://gracoair.com/compressor-rental-fleet/



https://flogistix.com/atmospheric-solutions/equipment/fx20/

Centrifugal Booster Compressor	Oil-Flooded Rotary Screw
500 hp	300 hp
CO2/N2 Mixtures	Produced gas
150 psig	350 psig

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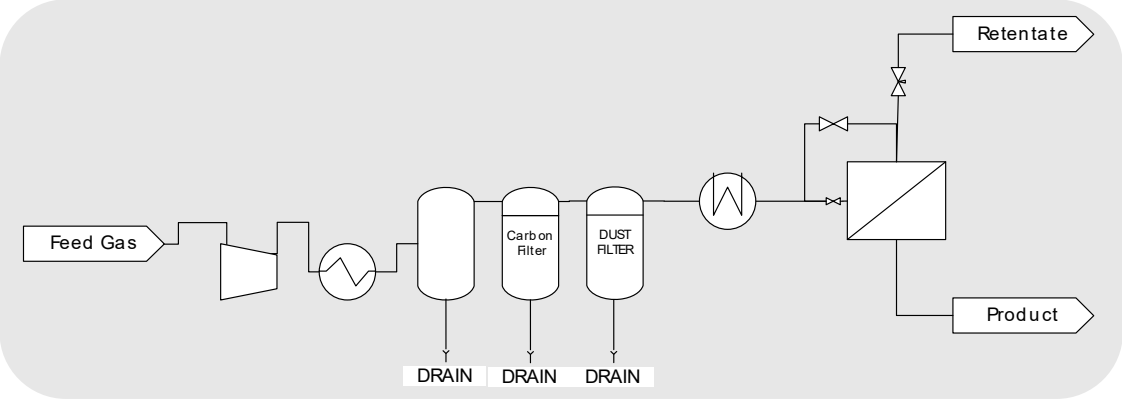
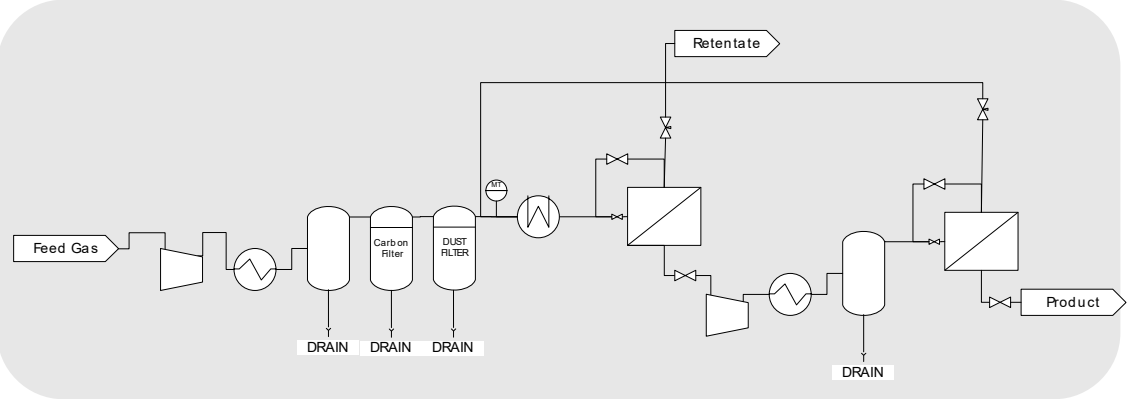
Process Scheme

Design Drivers

- Required Product Purity
- Required Product Flowrate
- Energy Costs
- Feed Gas Composition
- Membrane Performance
- Process Integration
- Downstream Considerations

Sample PFDs





Single Stage

Decreased Cost
- Single Feed Compressor
- Zero Recycle
- Fewer Membrane Cannisters

Increased Product Stream
- Decreased Purity
- Increased Flow

Two-Stage

Higher Cost
- Minimum of Two Compressors
- Recycle Dependent on Purity
- At least 30%+ Membrane Cannisters

Increased Product Purity
- Increased Purity
- Decreased Flow

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Membrane Separation – Design & Cost Implications

Performance Requirements

- Product Purity
- Dehydration Requirements
- Pressure Ratio Requirements
- Feed Concentration
- Lifespan
- Temperature Requirements
- Cooling Requirements

Site Considerations

- Vibration Mitigation Requirements
- Proximity of Water
- Power Source
- Water Disposal
- Availability of Instrument Air
- Emission Regulations

Cost Drivers

- Compression Needs
  - Electric or Gas Drives for Compressors
- Recycle Rates
- Contaminant Removal
- Membrane Replacement Schedule
- Materials of Construction
- Control Scheme (T, Flow, Gas Sampling)
- MAWP
- Maximum Allowable Water Content
- Fin/Fan or Evaporative Coolers
- Civil Requirements
  - Crush & Run
  - Earth Compaction
  - Helical Piles
  - Skidding
  - Concrete Pad
- Water Sourcing
  - Pipeline
  - Truck
  - Water Well
  - Local Water Board Requirements
- Proximity of Water Treatment
  - Collection & Transport
- Power Availibility
  - GenSet
  - Grid
  - Microgrid
- Is Complete IA subsystem required
  - Compressor
  - Dehydrator
- Exhaust Requirements
  - Blower with Stack
  - Plume Study Requirements
  - DEQ Permit Requirements

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