Low-Pressure Membrane Contactors for Carbon Dioxide Capture
DE-FE0007553

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NETL CO₂ Capture Technology Meeting
Wednesday, July 10, 2013
Membrane Technology and Research

MTR designs, manufactures, and sells membrane systems for industrial gas separations

- 70 Employees
- 2012 Sales: $25 million
**Project Overview**

- **Award name:** Low-pressure Membrane Contactors for CO$_2$ Capture
- **Project period:** 10/1/11 to 9/30/14
- **Funding:** $3.0 million DOE; $1.0 million MTR
- **DOE program manager:** Mike Mosser
- **Participants:** MTR, University of Toledo
- **Project scope:** Develop compact large membrane area (> 500 m$^2$), low pressure drop plate-frame sweep module for CO$_2$ capture application
- **Project plan:** The key project work organized by budget period is as follows:
  - BP1: Construct prototype laboratory modules (20m$^2$), select components, develop fabrication technology.
  - BP2: Scale up production to 1m x 1m pilot scale modules (100m$^2$), demonstrate with lab test system that modules meet CO$_2$ separation performance and pressure drop targets.
  - BP3: Scale up to full scale module (> 500 m$^2$), show modules meet all performance targets. Be ready to test at NCCC.
The MTR Membrane Contactor

A Way of Generating an Affordable (Partial) Pressure Difference

A separation is performed at a minimal energy cost
A Coal Power Plant

- Coal
- Boiler
- Steam turbine
- Flue gas (~12% CO₂)
- Air

Diagram showing the flow of coal, air, steam, and flue gas in a coal power plant.
A Membrane CO₂ Pre-Concentrator

Steam turbine → 20% CO₂ → Selective membrane recycle → 12% CO₂, 18% O₂ → Coal

20% CO₂ purge → Nitrogen purge 2% CO₂
MTR’s Membrane Solution

500 MW\textsubscript{e} plant requires one million m\textsuperscript{2} of membrane
The Issues and Solutions

Membrane module area and cost are not an issue

- Skid packing density
- Manifolding
- Footprint
- A sweep process
- Needs low pressure drop

\[\text{Large area modules, compact skids}\]
\[\text{Needs wide, straight channels on both sides of the membrane}\]
Membrane Module Designs in Current Use

- **Capillary Fibers**
  - Diagram showing feed flow, permeate, and residue.

- **Hollow Fine Fibers**
  - Diagram showing vessel, concentric layers, and product water.

- **Spiral-Wound Modules**
  - Diagram showing membrane, feed spacer, feed flow, and residue flow.

- **Plate-and-Frame Modules**
  - Diagram showing product manifold, feed gas passed through shell, and septa stacked.
Packing Density for Different Membrane Module Configurations

- **Hollow Fiber**
- **Spiral Wound**
- **Plate and Frame**

**CO₂ Capture Application Range**
Two Membrane Contactor Designs

**Countercurrent**
- Most efficient
- Difficult to make

**Cross-flow**
- Uses 40% more membrane area
- Easier to make
Progress to Date

- **Year 1**
  - Footprint: 1ft x 2 ft
  - Modules: 20 m²

- **Year 2**
  - Footprint: 1m x 1m
  - Modules: 100 m²
Our Concept

A single 100 m² module element

50 Module elements connected to make a 5000 m² module
Membrane Module and Test System

Feed Direction
Sweep Direction

Membrane Contactor with Vessel

Test System
Partial Countercurrent Design

- Symmetrical sweep spacer
- Stagnant
- Feed 10% CO₂, 2 bar
- Sweep 0% CO₂, 1 bar

Needs 30% more membrane compared to countercurrent
Partial Countercurrent Design

Needs 18% more membrane compared to countercurrent

Asymmetrical sweep spacer

Stagnant

Feed 10% CO₂, 2 bar

Sweep 0% CO₂, 1 bar
Our Plans

- Refine module fabrication techniques
- Improve module flow design
- Develop multi-element modules (3~5 elements)
- Test modules at NCCC (2014)
Combination Process May Be the Way to Go

Series Hybrid Case

- Double the CO₂ concentration
- 50% removal required

Parallel Hybrid Case

- Double the CO₂ concentration
- Half the flow
- 95% removal required