the Energy to Lead

Nanoporous PEEK® Hollow Fiber-based Gas/Liquid Membrane Contactors for Sour Gas Treating

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Introduction

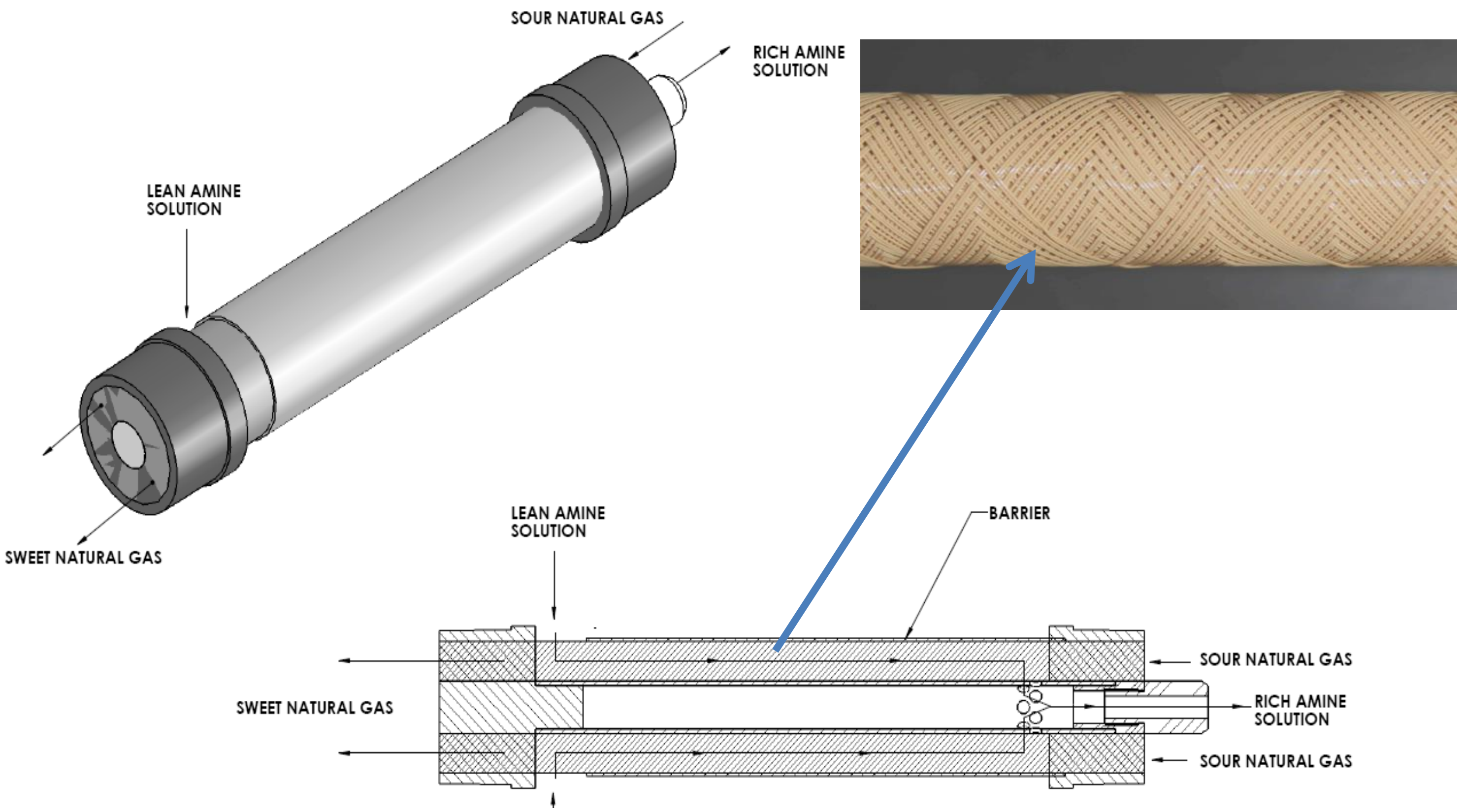
> GTI and PoroGen Inc. have teamed to develop a hollow fiber membrane contactor (HFMC) technology as absorber and regenerator stages for CO_2 removal from natural gas to achieve pipeline and LNG specifications

> We have carried out lab-scale tests of high-pressure absorption and lower-pressure regeneration

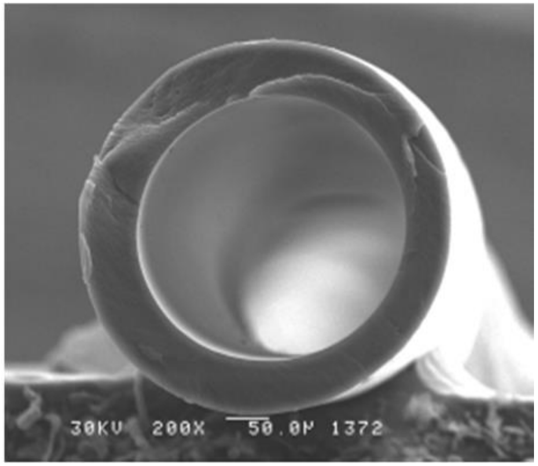
> Advantages for the technology are:

- lower weight,
- smaller size systems,
- insensitivity to motion for offshore operations,
- no flooding,
- high turndown ratio, and
- modularity and shop fabrication for any capacity.

Technology Features



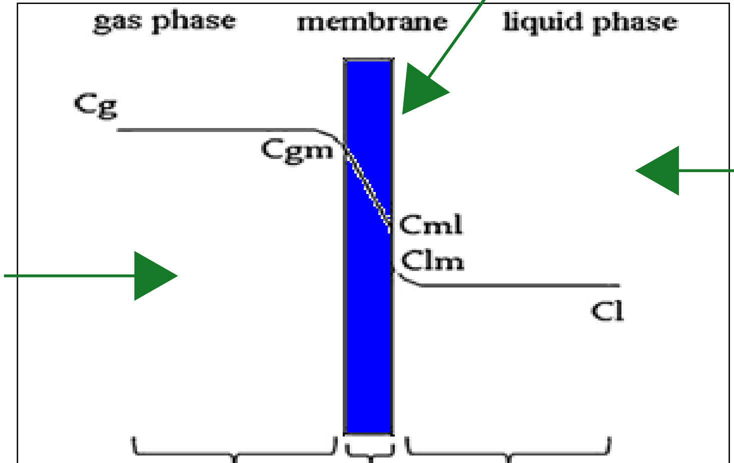
Hollow Fiber Function



Nanoporous PEEK® fiber wall

Shell side

Bore side



$$\frac{1}{K_G} = \frac{1}{k_g} + \frac{1}{k_m} + \frac{H_{adim}}{E \cdot k_l}$$

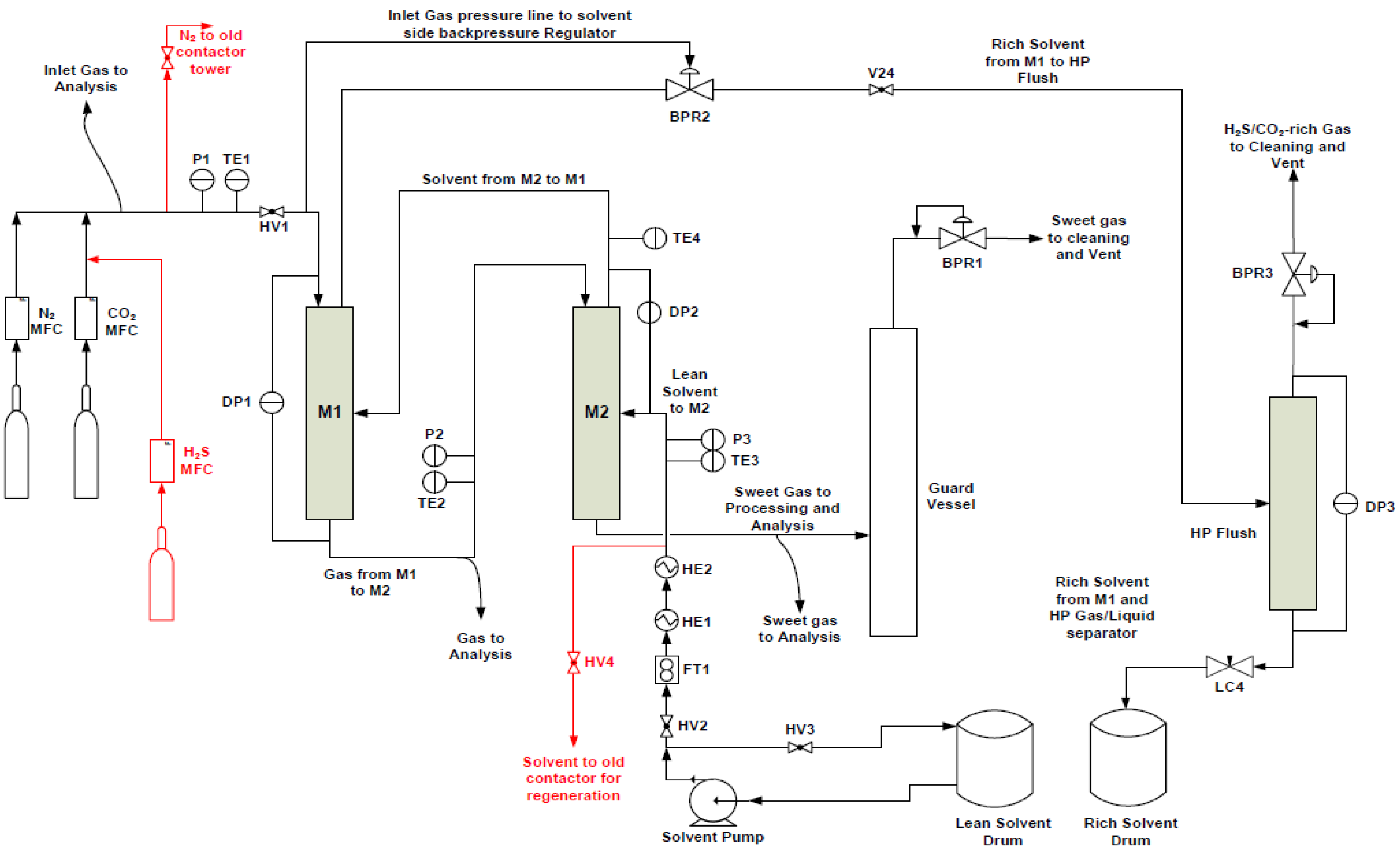
Mass Transfer Performance

Comparison to other technologies

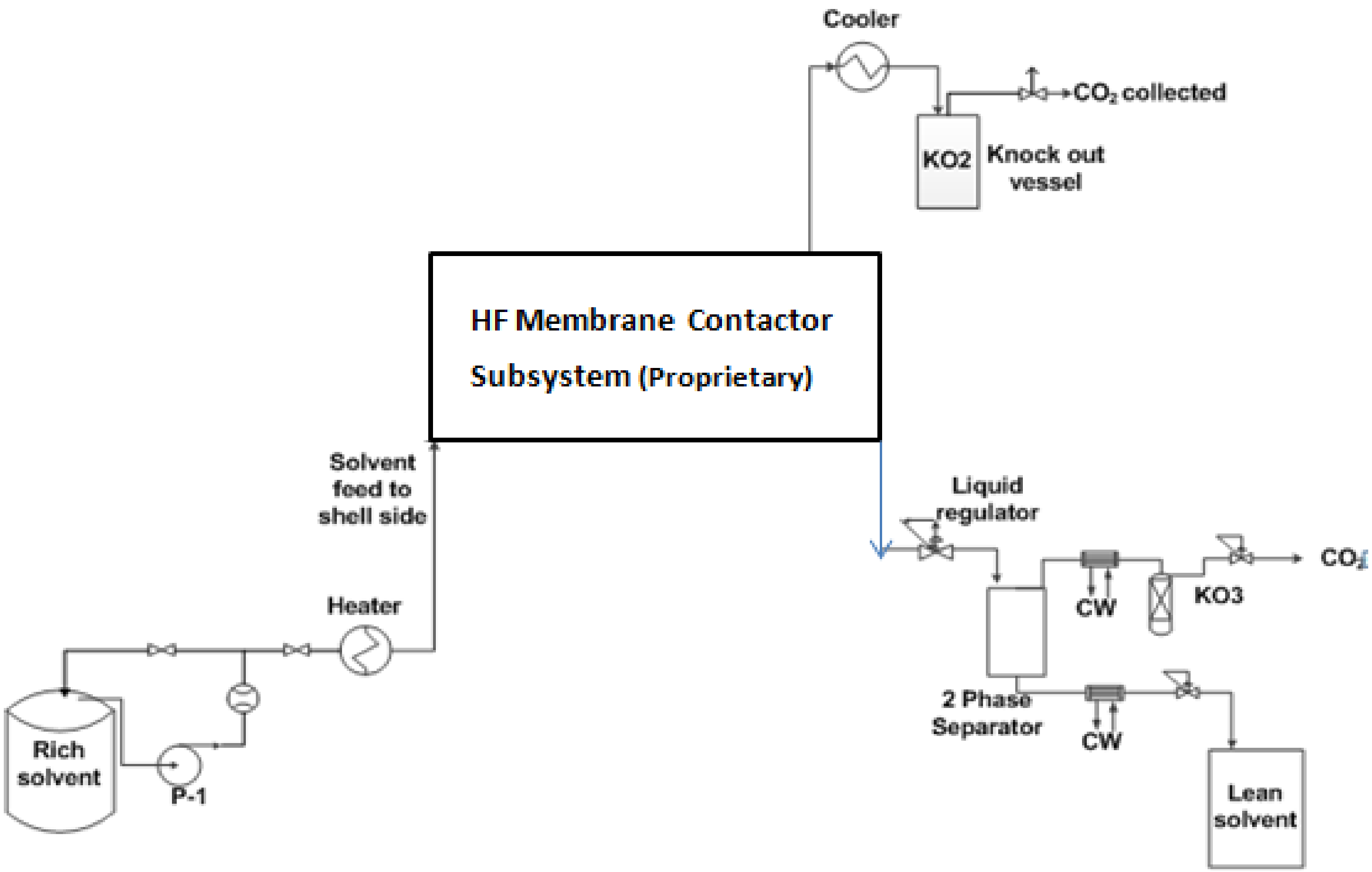
Gas-liquid Contactor	Specific Surface Area, (m^2/m^3)	Volumetric Mass Transfer Coefficient, $(sec)^{-1}$
Packed Column (Countercurrent)	10 – 350	0.0004 – 0.07
Bubble Column (Agitated)	100 – 2,000	0.003 – 0.04
Spray Column	10 – 400	0.0007 – 0.075
Membrane Contactor	**100 – 7,000**	**0.3 – 4.0**

ABSORPTION SECTION

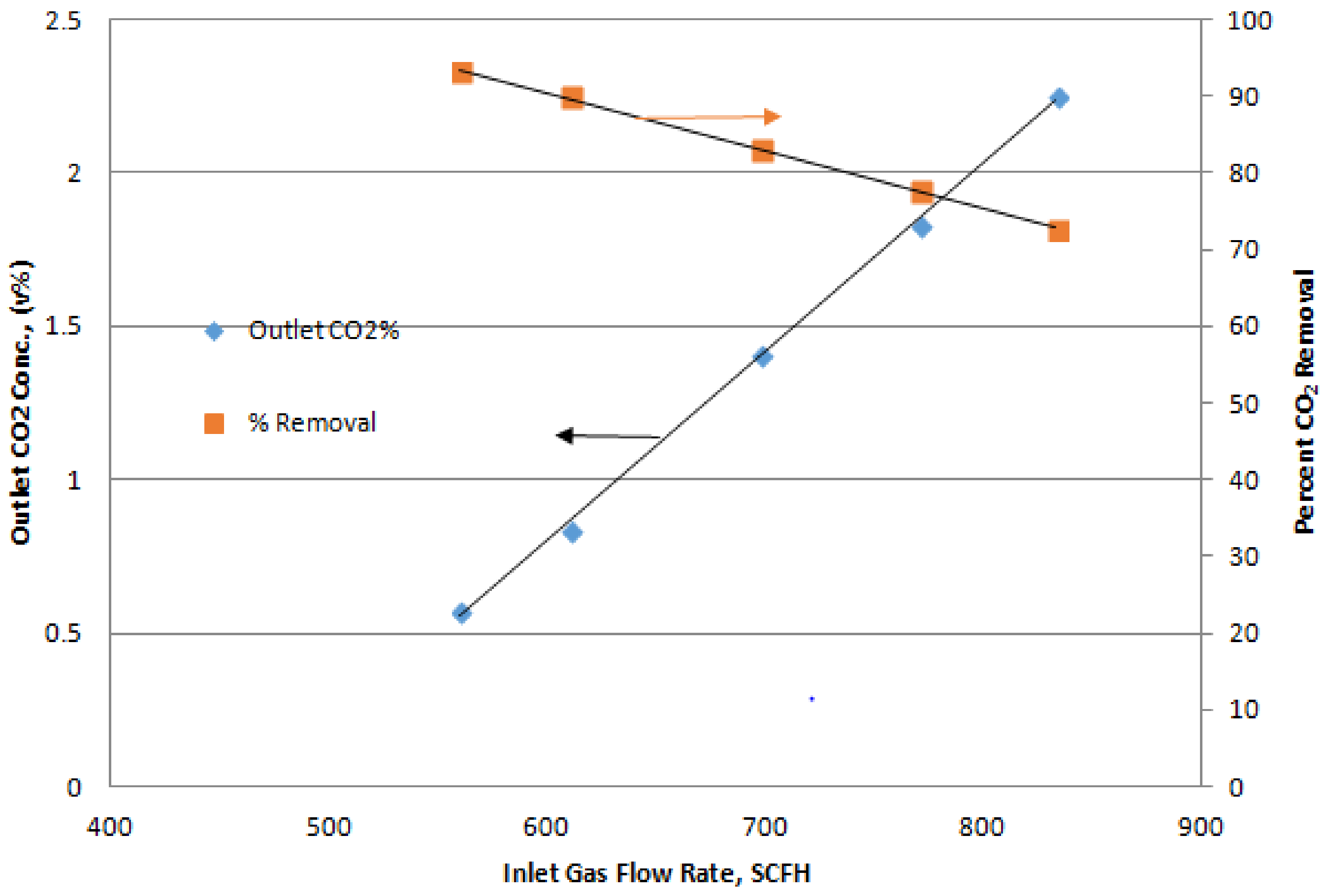
Laboratory Rig Flow Schematic



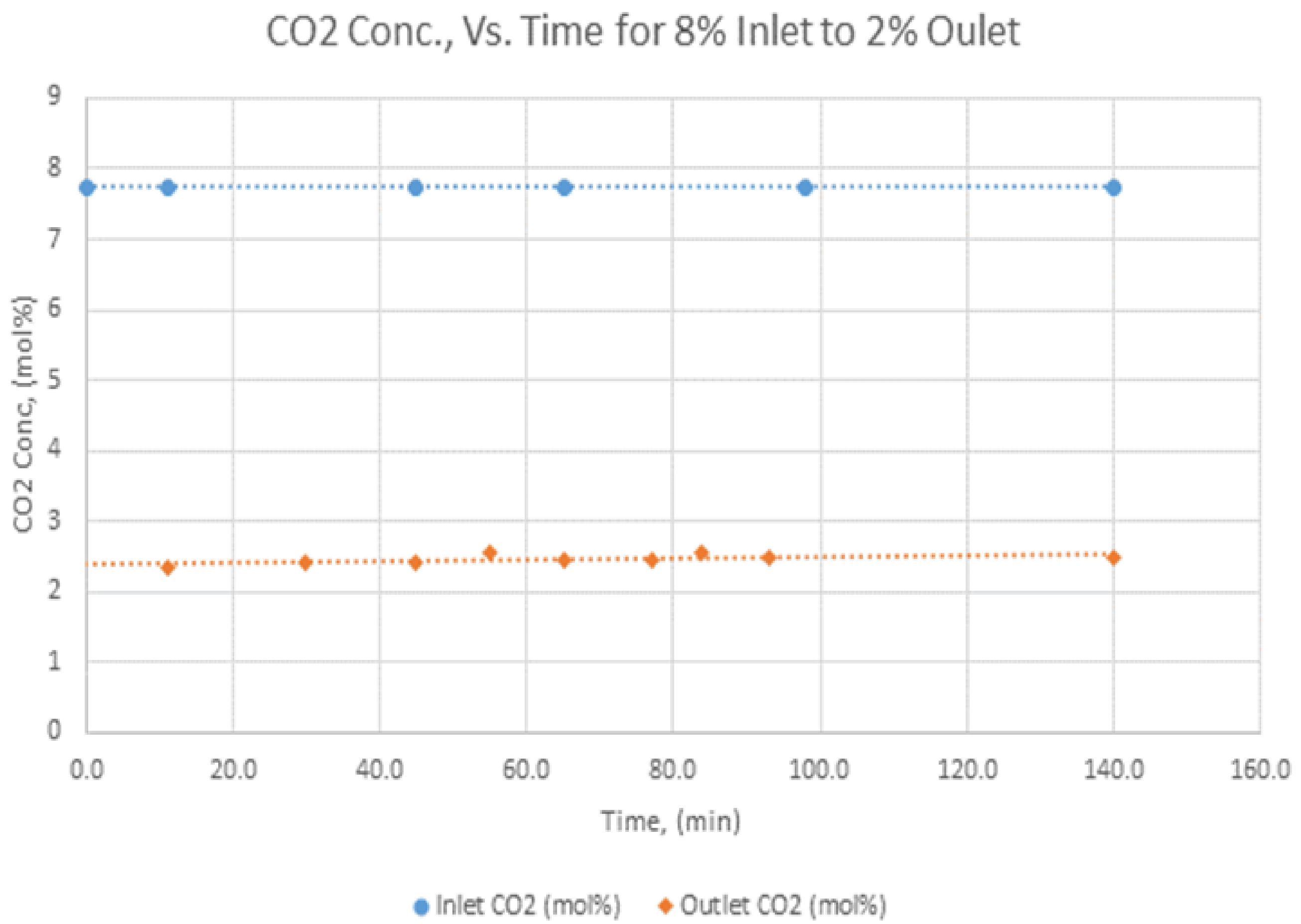
Laboratory Rig Flow Schematic



Absorber Performance



Achieving Pipeline Specs



Pipeline CO_2 Specifications (~2 vol%)

> Liquid flow rate affects exit CO_2 concentration: higher liquid rate = lower CO_2 concentration

> Pipeline specifications achieved in tests with single membrane module

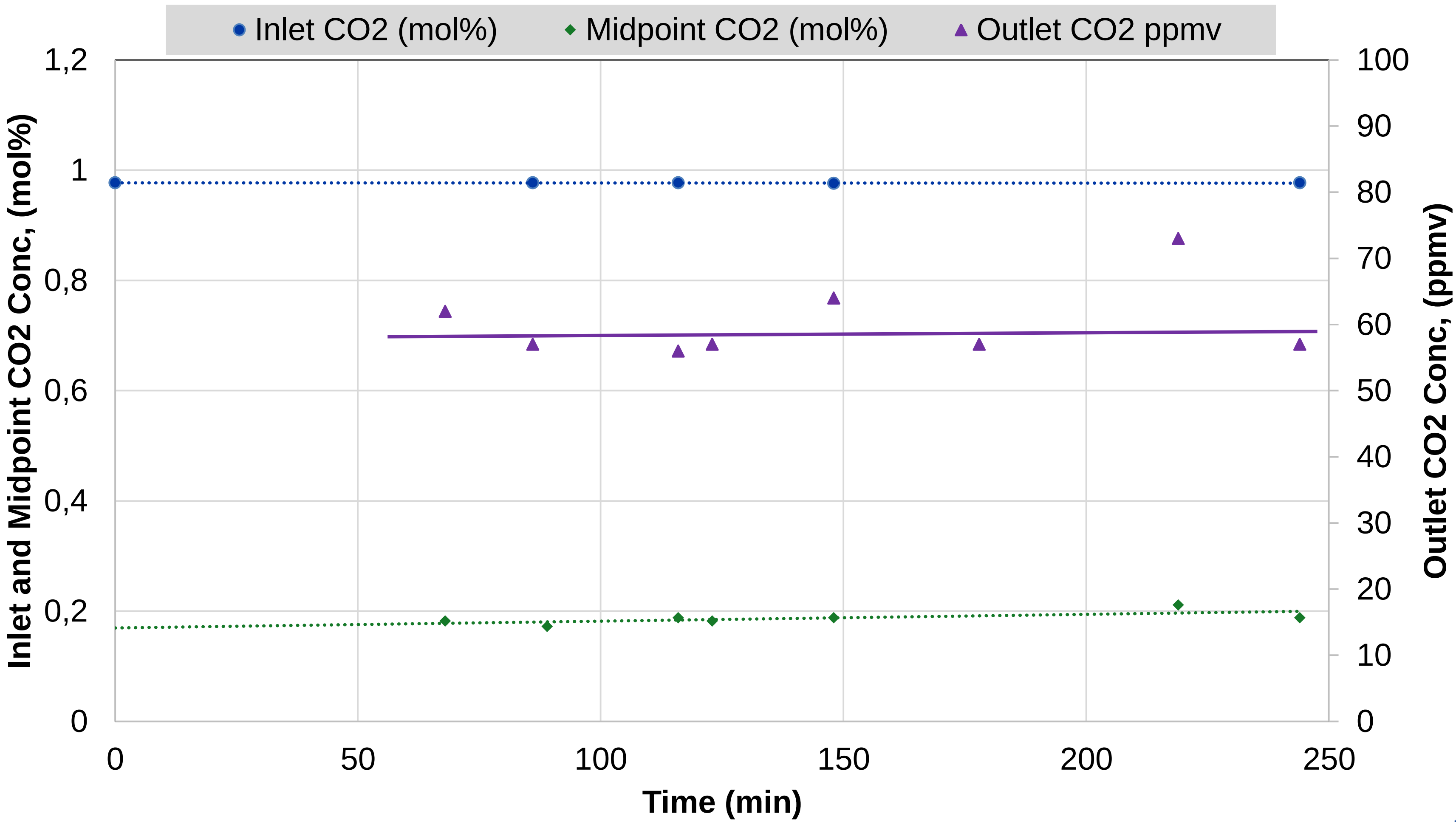
> Module parameters:

- Nominal 2 in. diameter module, 2,000 GPU, ~7,000 cm^2 outside fiber area, ~1,200 fibers
- K_G = 825 – 1150 mol/(m^3·hr·Kpa), or 0.5 - 0.7 s^{-1}

> Test conditions:

- 40 wt% (incl. 8 wt% piperazine) aMDEA at
- 950 psia, 24 °C
- non-integrated (no regenerator, once-through solvent)
- 1.6 ℓ/min solvent rate, 800 SCFH feed gas rate

Achieving LNG Specs

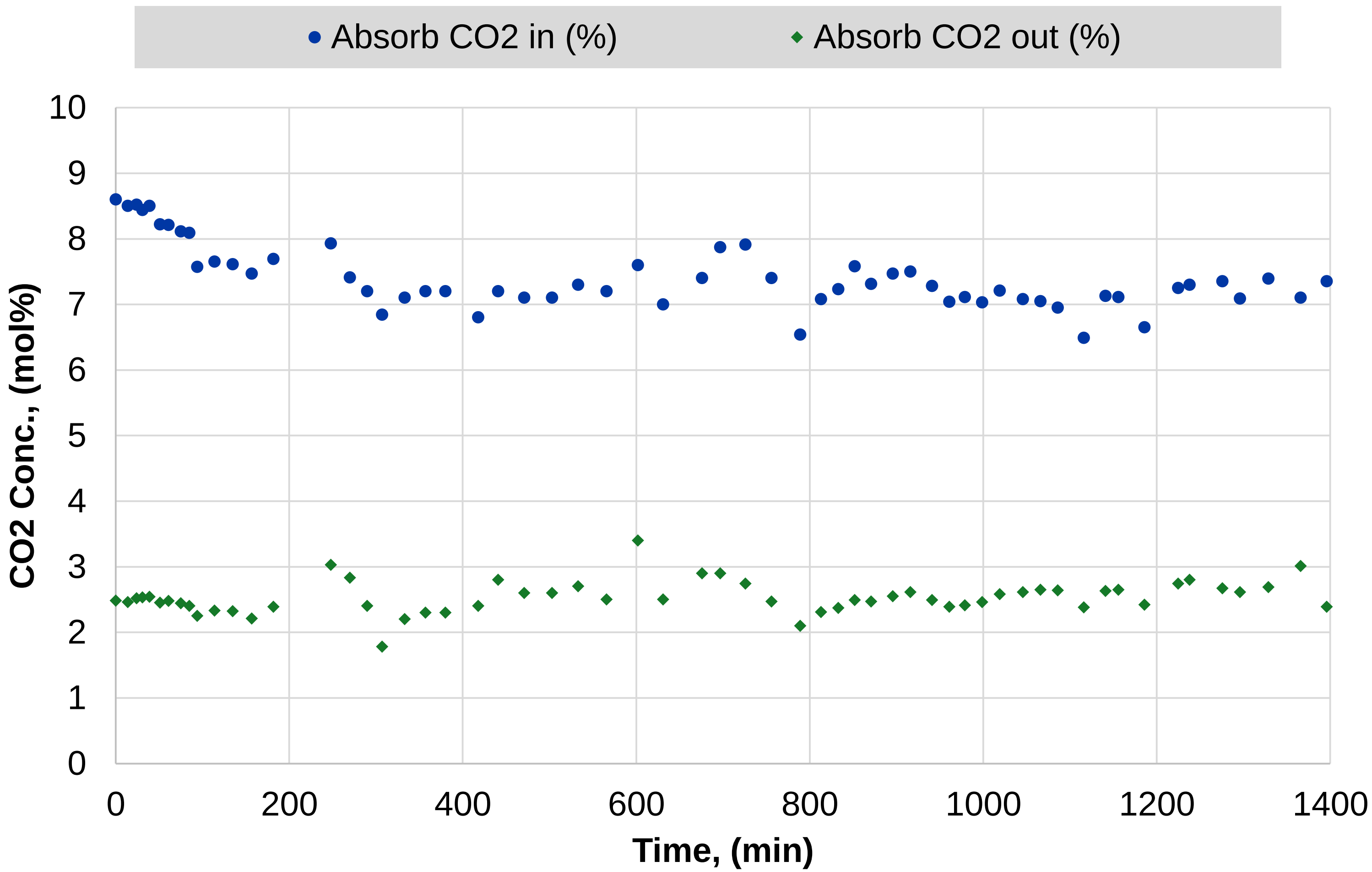


ABSORBER PERFORMANCE

LNG Specs

- Feed gas at 1% CO_2, very lean aMDEA solvent used
  - First-stage membrane would be used to reduce feed to 1-2 vol% CO_2, as shown separately
- Less than 60 ppmv CO_2 specification on outlet reached
  - We have demonstrated in other tests that lowering gas flow slightly will achieve <50 ppmv CO_2
- Excursion at ~220 min. deliberate – returned to previous level when conditions were returned to original value

Integrated Test (~8 vol% CO_2 to ~2 vol% CO_2)



Integrated Test

- Membrane contactor in both absorber and regenerator stages
- Regenerator used directly to produce the lean solvent to the absorber
  - Lean solvent ~0.1 wt% CO_2 or 0.0064 mol CO_2/mol amine
  - 23 solvent turnovers
- After startup adjustments, results stable over ~24 hr. test
- Outlet tracks inlet concentrations
- Slightly lower gas flow in test will likely produce <2 vol% CO_2 in outlet
  - When CO_2 in inlet was below 7% outlet approached 2%

ABSORBER PERFORMANCE

Effect of H_2S

> Test was performed for conditions meeting LNG specs
  - Feed Gas at 1 vol% CO_2 and 950 psig, 71 °F

> 26 ppmv CO_2 at 297 SCFH and 45 ppmv CO_2 at 520 SCFH, aMDEA flow at 0.35 ℓ/min

> Spiked H_2S at different levels:
  - With 250 ppmv spike, H_2S was below detection limit of 0.1 ppmv in exit gas
  - With 500 ppmv spike, H_2S was ~4 ppmv in exit gas
  - CO_2 was unchanged

Next Steps

> Continued laboratory and field testing
  - Improve model to better understand process at a fundamental level
  - Get more operating time, data
  - Optimize membrane configurations

> Obtain commercialization partner
  - Provide engineering support, sales support

> Scale-up efforts
  - Larger module fabrication
  - Skid package design with pre-treatment

Next Steps (continued)

> Pilot Plant Test Objectives

- Test nominal 8 in. diameter, 1,000 ft^2 modules – 10X scale up
- Determine pretreatment requirements
- Develop startup and shutdown protocols and best practices for operating procedures
- Confirm membrane durability, performance life through continuous, longer-term testing

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Conclusions

> Promising R&D results
  - High mass transfer rates confirmed for HFMC
    - Up to an order of magnitude greater than packed columns
  - Absorption and regeneration schemes tested successfully

> Path going forward identified
  - JIP supported by 6 major oil and gas companies
    - Next phase solicitation being evaluated
  - Progressing discussions with engineering partners for commercialization
  - DOE slipstream testing at National Carbon Capture Center (NCCC)

Acknowledgements

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