Motivation

• Reduce CO₂ capture costs
• Flue gas units will dwarf acid gas treaters
• Precise sizing requires accurate mass transfer data
• No existing data for aged solvents
• Packing requires rate-based modeling
• Significant energy savings in the regenerator
Aqueous Amine Absorption

ABSORBER

20 x 80 ft
2 psig
Treated Flue Gas
Wet Gas Scrubber
Make-Up Water
Disposal

Cooling Water

STRIPPER
12 x 60 ft
40 psig
Air Fin Cooler
Reflex Pump
Reboiler
Condensate

COMPRESSOR TRAIN

High Pressure Drop
Large Diameters
Large Heights
Modeling

High Energy
CO2

Solvent Optimization
Solvent Make Up

MEA Pump

Large Diameters
Large Heights
Corrosion Modeling

Solvent Circulation Rate

High Energy

High Pressure Drop
Large Diameters
High Power Consumption
Make-Up Water

Large Size
High Power Consumption

ConocoPhillips
Capture Costs

**CapEx**
- 40-50% (Absorber)
- 25-30% (Regenerator & Circulation System)

**OpEx**
- 69-75% (Pre-treatment & Compression)
- 24-28% (Regenerator & Circulation System)
- 1-3% (Absorber)
Wetted-Wall Column

• Gas-liquid contactor
• Well defined surface area
Mass Transfer with Chemical Reaction

The diagram illustrates the components involved in mass transfer with chemical reaction, including:

- **Bulk Gas**
- **Diffusion Film**
- **Reaction Film**
- **Contacting Surface**
- **Bulk Liquid**

The equations and formulas related to the process are:

\[
N_{CO_2} = K_G (\Delta P)
\]

\[
\frac{1}{K_G} = \frac{1}{k_g} + \frac{1}{k_l}
\]

Where:
- \(N_{CO_2}\) is the amount of CO\(_2\)
- \(K_G\) is the mass transfer coefficient
- \(\Delta P\) is the pressure drop
- \(k_g\) is the gas-side mass transfer coefficient
- \(k_l\) is the liquid-side mass transfer coefficient

The diagram also shows the partial pressures at different locations:

- \(P_{CO_2,b}\) in the bulk gas
- \(P_{CO_2,i}\) in the gas film
- \(P^*_{CO_2}\) across the contacting surface

These pressures are used to calculate the mass transfer rates and understand the process dynamics.
Experimental Technique

\[ K_g = \frac{\text{flux}}{\text{driving force}} \]

\[ k_l = \left( \frac{1}{K_g} - \frac{1}{k_g} \right)^{-1} \]
Gas Film Calibration and Benchmark

\[
Sh = C \left( Re \, Sc \, \frac{d}{h} \right)^\alpha
\]

\[
k_g = 1.4 \left[ \frac{D_{CO_2}}{RTd} \right] \left[ \frac{d^2 u}{D_{CO_2}h} \right]^{0.44}
\]

**k_l (mol/sm²Pa)**

<table>
<thead>
<tr>
<th>Concentration</th>
<th>COP</th>
<th>Published*</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 wt% MEA, 0.351 loading</td>
<td>1.8 x 10⁻⁶ ± 6.6 x 10⁻⁸</td>
<td>1.7 x 10⁻⁶</td>
</tr>
<tr>
<td>30 wt% MEA, 0.496 loading</td>
<td>4.1 x 10⁻⁷ ± 7.6 x 10⁻⁸</td>
<td>3.8 x 10⁻⁷</td>
</tr>
<tr>
<td>14 wt% PZ, 0.352 loading</td>
<td>1.2 x 10⁻⁶ ± 1.1 x 10⁻⁶</td>
<td>1.4 x 10⁻⁶</td>
</tr>
</tbody>
</table>

Aged Solvents

- Most designs based on fresh solvents
- Effect of degradation components unknown

\[
\begin{align*}
  k_l \text{ fresh (mol/s m}^2 \text{ Pa)} & \quad k_l \text{ aged (mol/s m}^2 \text{ Pa)} \\
  3.7 \times 10^{-6} & \quad 3.1 \times 10^{-6}
\end{align*}
\]
Modeling Results

- Non-equilibrium, Aspen Hysys model

- Model compares favorably to literature (30 wt.% MEA)

<table>
<thead>
<tr>
<th></th>
<th>COP</th>
<th>Published</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂ Capture (%)</td>
<td>90.1</td>
<td>90.1</td>
</tr>
<tr>
<td>Regen. Energy (MJ/kg CO₂)</td>
<td>13.8</td>
<td>15.9</td>
</tr>
<tr>
<td>Solvent Circulation (L/s)</td>
<td>2638.9</td>
<td>2639.4</td>
</tr>
<tr>
<td>Absorber Packing Height (m)</td>
<td>15.0</td>
<td>15.0</td>
</tr>
<tr>
<td>Regenerator Packing Height (m)</td>
<td>10.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Lean CO₂ Loading (mol CO₂/mol alk.)</td>
<td>0.28</td>
<td>0.25</td>
</tr>
<tr>
<td>Rich CO₂ Loading (mol CO₂/mol alk.)</td>
<td>0.48</td>
<td>0.46</td>
</tr>
</tbody>
</table>

Conclusions and Future Work

• Accurate experimental data required for proper design of CO₂ capture systems

• Kinetic information of aged systems needed to predict real performance

• Incorporate kinetic data into rate-based models
Acknowledgements

• Luminant Carbon Management Program

• Scott McArthur (COP)

• Jim Finley and Dennis Sprague
Questions?