Evolution of a Concept for Regional Gathering/Processing of CO$_2$ Flood Recycle Streams

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Status of EOR Reinjection/Processing

• Currently you are “on your own” when processing CO₂ EOR flood produced gas
• Limited regional gathering and processing options exist
• Most fields have their own equipment on site
Potential Regional Gathering/Processing

• Thesis:
  – Regional gathering/processing of produced gas from CO₂ EOR floods is feasible and potentially the best choice for field development

• *This is to be accomplished by:*
  – *In-field use of membranes and reinjection of CO₂ followed by,*
  – *Dense phase gathering of enriched gas to a,*
  – *Central plant with high recovery of all products.*
Put yourself in the shoes a company planning to develop a CO$_2$ flood

- Once you evaluated the field and have procured CO$_2$,
- And figured how to separate the oil and water from the produced gas,
- You need to do something with the gas.
- Of course. It will be reinjected.
- But Wait!
- The engineering firm informs you that 12% to 20% of the liquids are about to be reinjected along with the gas.
- “No problem” smiles the process engineer. “Just …”
“Install a CO$_2$ Processing Plant”

– One could be forgiven for thinking that this is a refinery
– Another look at reinjection vs. processing is needed
Reinjection vs. Processing

• Reinjection:
  – It is the simplest means of handling CO₂ flood produced gas
  – But there is no recovery of products
  – Many operators reinject gas rather than process it

• Processing (with reinjection)
  – Complex, high cost, high opex, high energy
  – Natural gas recovery and deeper NGL recoveries cost more
Option 1 - Reinjection

Line thicknesses are proportional to flow rate
Option 2 – Gathering and Processing

- Reservoir
- Produced Gas
- Central Field Facilities
- Reinjected Gas
- Gathered Gas
- Processing Plant

Line thicknesses are proportional to flow rate
Future Option - Membrane Enrichment, Gathering, and Processing

Line thicknesses are proportional to flow rate
Reinjection

- Inlet: 100 MMSCFD; 90% CO$_2$
- Power: 16,100 hp

135 psig

Inlet Comp. 8100 hp

Dehydration

Reinjection Compression 8000 hp

2050 psig
Membrane Enrichment

- Inlet: 100 MMSCFD
- Power: 24,100 hp
Membrane Skid

- One skid with 42 tubes is shown
- 100 MMSCFD facility would use three skids
Membrane Enrichment Facility

- Facility with four skids of membrane tubes
## Recoveries – 100 MMSCFD

<table>
<thead>
<tr>
<th>Produced Gas</th>
<th>Re-injection</th>
<th>Gas Gathered to Plant</th>
<th>Pipeline Gas</th>
<th>Recovery gpm</th>
<th>NGL bbl/d</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2</td>
<td>90.0%</td>
<td>97.4%</td>
<td>52.3%</td>
<td>9%</td>
<td></td>
</tr>
<tr>
<td>H2S</td>
<td>0.5%</td>
<td>0.5%</td>
<td>0.3%</td>
<td>11%</td>
<td></td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0.4%</td>
<td>0.1%</td>
<td>1.7%</td>
<td>75%</td>
<td></td>
</tr>
<tr>
<td>Methane</td>
<td>4.7%</td>
<td>1.6%</td>
<td>20.5%</td>
<td>72%</td>
<td></td>
</tr>
<tr>
<td>Ethane</td>
<td>1.9%</td>
<td>0.3%</td>
<td>10.0%</td>
<td>86%</td>
<td>2.68</td>
</tr>
<tr>
<td>Propane</td>
<td>1.1%</td>
<td>0.1%</td>
<td>6.2%</td>
<td>91%</td>
<td>1.72</td>
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<tr>
<td>Butanes</td>
<td>0.7%</td>
<td>0.0%</td>
<td>4.2%</td>
<td>98%</td>
<td>1.34</td>
</tr>
<tr>
<td>Pentanes+</td>
<td>0.8%</td>
<td>0.0%</td>
<td>4.7%</td>
<td>99%</td>
<td>1.88</td>
</tr>
<tr>
<td>Totals</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>16%</td>
<td>7.62</td>
</tr>
</tbody>
</table>

**BTU/cuft**
- Total: 2650
- Fuel Gas MDTKH/D: 3.38

**Plant Recovery of Ethane**: 70%
Pipeline Impacts of Enriching Gas

• Gathering 50 miles from a 100 MMSCFD field at 67 deg F requires the following:
  – No enrichment:
    • 20” gathering line at 740 psig, 9.6 #/cuft
    • 10” CO₂ return line at 2000 psig, 57.1 #/cuft
  – Enrichment:
    • 10” gathering line at 740 psig, 9.5 #/cuft
    • 6” gathering line at 2000 psig, 36.0 #/cuft
      – Single phase gathering (no slug catcher)
Dense Phase Gathering Preferred

Gathering System Operating Envelope

Enriched Gas Phase Envelope
Other Benefits

• Reservoir: Removal of light ends minimizes MMP
• Pipeline: Increase capacity through use of pumps
• Plant –
  – Lower CO₂ concentration into plant:
    • Recovery of ethane will be greater
    • Flares will not require added fuel
  – Reduced flow rate results in:
    • Smaller equipment including vessels and columns
    • Reduced pump and compression power
    • Lower heating and cooling duties
  – Dense phase saves refrigeration due to inlet JT
Implementation of Enriched Gathering and Processing

• Opportunities from existing fields that are currently reinjecting produced gas

• Greater opportunities come from a potential renaissance of CO₂ EOR
  – Drivers include:
    • High oil prices
    • Low gas prices
    • Development of further CO₂ sources
Thank You!

• Acknowledgement
  – ProSep:
    • Provided membrane performance calculations
    • Pictures of membranes