Natural Gas Conditioning Using Membranes

By

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Membrane Separation Mechanism

Permeability = Diffusivity * Solubility
\( P \) \( D \) \( S \)

Membrane Selectivity

\[ \frac{P_1}{P_2} = \frac{D_1 \cdot S_1}{D_2 \cdot S_2} \]

MTR's Rubbery Membranes Reject Methane and preferentially permeate the heavy hydrocarbons.
## Glassy v/s Rubbery Membranes

### Glassy Membranes

<table>
<thead>
<tr>
<th>Fast Gas</th>
<th>Slow Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>Nitrogen</td>
</tr>
<tr>
<td>H₂O</td>
<td>CO₂</td>
</tr>
</tbody>
</table>

### Rubbery Membranes

<table>
<thead>
<tr>
<th>Fast Gas</th>
<th>Slow Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hexane</td>
<td>Ethane</td>
</tr>
<tr>
<td>H₂O</td>
<td>Propane</td>
</tr>
</tbody>
</table>
Membrane System Installations

Gas/Gas Separation Systems

- $\text{H}_2/\text{N}_2$, $\text{CH}_4$ ~ 200 Units
- $\text{O}_2/\text{N}_2$ ~ 5,000 Units
- $\text{CO}_2/\text{CH}_4$ ~ 200 Units

Vapor/Gas Separation Systems

- VOC/Air
- Hydrocarbon/$\text{N}_2$, $\text{CH}_4$ ~ 100 Units
MTR’s Composite Membrane

Polymeric Selective Layer

Microporous Support

Support Fabric

Separating Layer

Layers for Mechanical Support
MTR Spiral Wound Cartridge

Module housing

Feed flow

Residue flow

Permeate flow

Residue flow

Spacer

Membrane

Spacer

Permeate flow after passing through membrane
NGL Separation Skid

Flow Capacity
Max: 8 MMSCFD
Operated: 2.5-3.0 MMSCFD

Pressure rating
Max: 1250 psig
Operated: 475 psig

Temperature
Max: 135°F
Operated: 100-125°F
Field Data - Feed/Permeate Flow rates

Location: Chevron’s Lost Hills Station, CA

Feed pressure: 450 psig
Avg. Feed Flow : 2.8 MMSCFD
Avg. Permeate Flow : 0.6 MMSCFD
Field data - Percent Removal Rates

<table>
<thead>
<tr>
<th>Component</th>
<th>Average % Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propanes</td>
<td>55.7</td>
</tr>
<tr>
<td>Butanes</td>
<td>61.0</td>
</tr>
<tr>
<td>Pentanes</td>
<td>68.1</td>
</tr>
<tr>
<td>Hexanes</td>
<td>74.0</td>
</tr>
<tr>
<td>Octanes</td>
<td>91.4</td>
</tr>
</tbody>
</table>
NGL Separation and Recovery Applications

- Well-head Gas Dewpoint Control
- Associated Gas Liquids Recovery
- Engine and Turbine Fuel Gas Conditioning
- Propane Refrigeration Plant Debottleneck
CNG Conditioning for Vehicular Use

- Current CARB Specifications
  - Ethane < 6 mol-%
  - Propane+ < 3 mol-%

- “Hot Gas” issue in some California counties
- Internal combustion gas engines have to be derated if knocking occurs. Poor gas quality is usually the problem.
# Gas Composition Range

<table>
<thead>
<tr>
<th>Stream Type (Nominal)</th>
<th>Concept 1 (Nominal)</th>
<th>Concept 2 (Ethane Rich)</th>
<th>Concept 3 (Propane Rich)</th>
<th>Concept 4 (Ethane And Propane Rich)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (°F)</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>Pressure (psia)</td>
<td>614.7</td>
<td>614.7</td>
<td>614.7</td>
<td>614.7</td>
</tr>
<tr>
<td>Total std V scfm</td>
<td>333.96</td>
<td>336.69</td>
<td>335.13</td>
<td>337.96</td>
</tr>
<tr>
<td>Component mole %</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxygen</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0.36</td>
<td>0.35</td>
<td>0.357</td>
<td>0.347</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>2.19</td>
<td>2.13</td>
<td>2.173</td>
<td>2.114</td>
</tr>
<tr>
<td>Methane</td>
<td>86.468</td>
<td>84.113</td>
<td>85.783</td>
<td>83.464</td>
</tr>
<tr>
<td>Ethane</td>
<td>6.149</td>
<td>8.705</td>
<td>6.1</td>
<td>8.638</td>
</tr>
<tr>
<td>i-Butane</td>
<td>0.34</td>
<td>0.331</td>
<td>0.337</td>
<td>0.328</td>
</tr>
<tr>
<td>n-Butane</td>
<td>0.71</td>
<td>0.691</td>
<td>0.704</td>
<td>0.685</td>
</tr>
<tr>
<td>i-Pentane</td>
<td>0.14</td>
<td>0.136</td>
<td>0.139</td>
<td>0.135</td>
</tr>
<tr>
<td>n-Pentane</td>
<td>0.11</td>
<td>0.107</td>
<td>0.109</td>
<td>0.106</td>
</tr>
<tr>
<td>N-Hexane</td>
<td>0.07</td>
<td>0.068</td>
<td>0.069</td>
<td>0.068</td>
</tr>
<tr>
<td>Water</td>
<td>0.014</td>
<td>0.014</td>
<td>0.014</td>
<td>0.014</td>
</tr>
</tbody>
</table>
### Expected Membrane Performance

<table>
<thead>
<tr>
<th></th>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
<th>Value 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>C&lt;sub&gt;2&lt;/sub&gt; Content of Conditioned Gas (mol-%)</td>
<td>4.1</td>
<td>5.86</td>
<td>4.09</td>
<td>5.83</td>
</tr>
<tr>
<td>C&lt;sub&gt;3+&lt;/sub&gt; Content of Conditioned Gas (mol-%)</td>
<td>2.19</td>
<td>2.13</td>
<td>2.55</td>
<td>2.50</td>
</tr>
<tr>
<td>Feed Gas Volume (scfm)</td>
<td>333</td>
<td>336</td>
<td>335</td>
<td>338</td>
</tr>
<tr>
<td>Product Gas Volume (scfm)</td>
<td>250</td>
<td>250</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>System Budgetary Price (US $)</td>
<td>55,000</td>
<td>55,000</td>
<td>55,000</td>
<td>55,000</td>
</tr>
</tbody>
</table>

Meets CARB CNG Specs
Typical Fuel Conditioning Skid-mounted Unit

Designed for Offshore Installation

Main System Components

   Membrane Modules/Housings
   Filter Separator/Coalescer
   Inlet and Discharge Valves

System Dimensions: 6 ft (W) x 8 ft (L) x 8 ft (H)

Location: Nigeria

Flow Capacity: 2.5 MMSCFD
Pressure rating 550 psig
Operating pressure: 220 psig

Feed hydrocarbon dewpoint: 82°F
Conditioned Gas Dewpoint: 20°F
Wellhead Gas Conditioning

C$_3$+ enriched gas

Raw Natural Gas

Current Refrig. System

Compressor

Membrane System

Stabilizer

250 psia
6 MMSCFD

10562 gpd
NGL

To Gas Pipeline
Meets CARB Specification

C$_3$+ Hydrocarbons are Reduced to meet CARB Specification

Approximate Price of VaporSep System: $500,000-1,000,000
Advantages of Membrane Systems

- Simple passive system
- High on-stream factor (typically > 98%)
- Minimal or no operator attention
- Small footprint, low weight (Platform Applications)
- Ambient temperature operation in many applications
- Large turndown ratio
- Low maintenance
- Lower capital and operating costs
Summary

Wide range of applications in the *Oil, Gas and Refining Industries*

**Gas:** Fuel gas conditioning, NG dewpointing, Natural Gas Dehydration.

**Oil:** Associated gas processing, Vapor recovery from storage tanks and transportation.

**Refining:** LPG/Fuel gas, Hydrotreater/Hydrocracker Purge, Refinery gas plant, Hydrogen recovery.