New Membrane Applications in Gas Processing

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Membrane Separation Mechanism

Permeability = Diffusivity * Solubility

\[
\text{Permeability} = \frac{P_1}{(D_1 \cdot S_1)} = \frac{P_2}{(D_2 \cdot S_2)}
\]

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

Feed flow

Feed flow

Permeate flow after passing through membrane

Spacer

Membrane

Spacer

Residue flow

Permeate flow

Residue flow
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 rate: 2.8 MMSCFD
Avg. Permeate Flow rate: 0.6 MMSCFD
Field data - Percent Removal Rates

<table>
<thead>
<tr>
<th>Date</th>
<th>Propanes</th>
<th>Butanes</th>
<th>Pentanes</th>
<th>Hexanes</th>
<th>Octanes</th>
</tr>
</thead>
<tbody>
<tr>
<td>11/16/97</td>
<td>55.7</td>
<td>61.0</td>
<td>68.1</td>
<td>74.0</td>
<td>91.4</td>
</tr>
<tr>
<td>1/5/98</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2/24/98</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4/15/98</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6/4/98</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/24/98</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Field Data - Hydrocarbon Dewpoints

- Feed Gas Temperature °F
- Dewpoint of Feed Gas °F
- Dewpoint of Conditioned Gas °F

Graph showing data points and trend lines for different conditions over dates from 8/8/97 to 7/24/98.
NGL Separation and Recovery Applications

- Well-head Gas Dewpoint Control
- Associated Gas Liquids Recovery
- Engine and Turbine Fuel Gas Conditioning
- Propane Refrigeration Plant Debottleneck
- Re-injection Gas Liquids Recovery
- Flare Gas Liquids Recovery/Conditioning
- Vapor Recovery from Storage Tank Losses
Wellhead Dewpoint Control

Value of NGL (@ $14/bbl): $1.2 Million/yr

Both Hydrocarbon and Water Dewpoint Reduced in one process
Price of VaporSep System: $750,000-850,000
## Economic Comparison – Dewpoint Control

<table>
<thead>
<tr>
<th>Process</th>
<th>Installed Cost (MM$)</th>
<th>Processing Cost ($/inlet Mscf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propane Refrigeration</td>
<td>1.6</td>
<td>0.165</td>
</tr>
<tr>
<td>Membrane</td>
<td>1.1</td>
<td>0.098</td>
</tr>
</tbody>
</table>

Basis: 10 MMSCFD Plant/Lean Gas (3.9 GPM, 1185 Btu/SCF)

Propane Refrigeration Cost: Purvin and Gertz, June 1999, Private Study
Platform Associated Gas Treatment

Increased Oil Production: 870 Barrels/day
Value of Additional Oil Recovered (@ $10/bbl): $3.0 Million/yr
Additional Power required: 470 hp

Price of VaporSep System: $1 - 1.25 Million
Fuel Gas Conditioning - Gas Engine Example

Membrane System Price: $150,000

<table>
<thead>
<tr>
<th>Process Conditions</th>
<th>Membrane Feed</th>
<th>Conditioned Fuel Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (°F)</td>
<td>95</td>
<td>51</td>
</tr>
<tr>
<td>Pressure (psia)</td>
<td>955</td>
<td>945</td>
</tr>
<tr>
<td>Flow Rates (MMscfd)</td>
<td>0.95</td>
<td>0.5</td>
</tr>
<tr>
<td>Octane Number</td>
<td>113.7</td>
<td>116</td>
</tr>
<tr>
<td>Hydrocarbon Dewpoint (°F)</td>
<td>95</td>
<td>37</td>
</tr>
</tbody>
</table>
Fuel Gas Conditioning - Gas Turbine Case

Fuel Gas Flow Rate (MMSCFD) : 6.1
Feed Temperature (°F) : 120
Conditioned Fuel Dewpoint(°F) : 76
NGL Recovered (gpd) : 15,000
Value of Recovered NGL (US $) : 500,000
Membrane System Price (US $) : 400,000 – 600,000
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
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.