Membrane Systems for Nitrogen Rejection

By

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Membrane Separation Mechanism

Permeability = Diffusivity * Solubility

\[
(P) = (D) \cdot (S)
\]

Membrane Selectivity

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

MTR’s Rubbery Membranes Reject Nitrogen and permeate hydrocarbon components
Glassy v/s Rubbery Membranes

**Glassy Membranes**

- **Fast Gas**
  - Hydrogen
  - Nitrogen
  - Methane
  - Propane
  - H₂O
  - CO₂

- **Slow Gas**
  - Hexane

**Rubbery Membranes**

- **Fast Gas**
  - Hexane
  - Ethane
  - Methane
  - Nitrogen
  - Hydrogen
  - Propane
  - CO₂

- **Slow Gas**
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

- Selective layer
- Microporous layer
- Support web
Field Test Unit Process Diagram

- High pressure, N₂ rich natural gas
- N₂ rich stream
- Methane permeable membrane
- Condensed C₃+ liquids/Water
- J-T Valve
- Methane rich stream
Nitrogen Rejection Test System

**Flow Capacity**
- Max: 0.2 MMSCFD
- Operated: 0.1-0.2 MMSCFD

**Pressure rating**
- Max: 1250 psig
- Operated: 400-600 psig

**Temperature**
- Max: 135°F
- Operated: 15-50°F
# Field Test – Inlet Gas Composition

<table>
<thead>
<tr>
<th>Component</th>
<th>Composition (mole%)</th>
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<tbody>
<tr>
<td>Methane</td>
<td>75.0</td>
</tr>
<tr>
<td>Ethane</td>
<td>2.8</td>
</tr>
<tr>
<td>Propane</td>
<td>1.0</td>
</tr>
<tr>
<td>Butane</td>
<td>0.4</td>
</tr>
<tr>
<td>Pentane and heavier</td>
<td>0.1</td>
</tr>
<tr>
<td>Water</td>
<td>1.7</td>
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<tr>
<td>Nitrogen</td>
<td>19.0</td>
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</tbody>
</table>
Comparison of Lab and Field Data

Methane-Nitrogen Selectivity

Feed Temperature, °F

CH$_4$-N$_2$ Selectivity

field data from module  lab data from stamp
Nitrogen Rejection – Application Envelope

- Inlet Nitrogen Content between 4 and 20 vol-%
- Inlet flow rate between 0.1 – 20 MMSCFD
- Discharge N₂ specification between 4 and 8 vol-%
- Upgrading to Pipeline acceptability
- Upgrading fuel gas to meet BTU-Value for Burning
- Hydrocarbon Removal for Nitrogen Re-injection
Case 1: Inlet $N_2$ Content = 8 mol%

Two step process produces pipeline quality gas and fuel gas for process use.

Product gas compressor may be required to boost pressure to pipeline pressure.
Case 2: Inlet N\textsubscript{2} Content = 15 mol%
## Economic Analysis

- Processing Costs about 0.25 to 0.5 $/MCF are very favorable
- Membrane system are flexible and can be used for various sites and inlet gas compositions
- Ideal for remote continuous operation without operator attention
- Well suited for low flow rate applications

### Parameter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Configuration 1</th>
<th>Configuration 2</th>
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<tbody>
<tr>
<td>Process Characteristics</td>
<td></td>
<td></td>
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<tr>
<td>N₂ in feed (%)</td>
<td>8</td>
<td>15</td>
</tr>
<tr>
<td>Feed flow rate (MMSCFD)</td>
<td>10</td>
<td>10</td>
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<tr>
<td>N₂ in product gas</td>
<td>4</td>
<td>4</td>
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<tr>
<td>Methane recovery (%)</td>
<td>86</td>
<td>86</td>
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<tr>
<td>Methane in fuel gas (%)</td>
<td>87</td>
<td>75</td>
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<tr>
<td>Methane in waste gas (%)</td>
<td>50</td>
<td>35</td>
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<tr>
<td>Product gas flow rate (MMSCFD)</td>
<td>8.2</td>
<td>7.6</td>
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<tr>
<td>Power Requirements</td>
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<td></td>
</tr>
<tr>
<td>Power required (Hp)</td>
<td>750</td>
<td>2,000</td>
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<tr>
<td>Capital and Operating Costs</td>
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<td></td>
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<tr>
<td>Equipment cost ($000)</td>
<td>1,300</td>
<td>3,500</td>
</tr>
<tr>
<td>Processing cost ($/1000 scf)</td>
<td>0.27</td>
<td>0.56</td>
</tr>
</tbody>
</table>
Similar Applications – Fuel Gas Conditioning for Gas Engines and Turbines

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
- Large turndown ratio
- Low maintenance
- Lower capital and operating costs
Other applications in the Oil & Gas Industries for MTR’s Reverse-Selective membranes

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

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