UOP Separex™ Membrane Technology

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Agenda

- Membrane Technology Overview
- Pretreatment Options
- Flow Scheme Options
- Commercial Experience
Regions of Use for Acid Gas Technologies

Partial pressure of acid gas in feed, psia

Partial pressure of acid gas in product, psia

Separex™ Membrane
What Is a Membrane?

A *semi-permeable film of various*:

- **Materials**: Cellulose Acetate (CA), Polyimide (PI), Polyamide, Polysulfone, Silicone
- **Types**: Asymmetric or Composite
- **Construction**: Spiral-Wound or Hollow Fiber
Asymmetric Membranes

- Single polymer
- Thin selective layer
- Porous support layer
Composite Membrane Structure

Composite Membranes

- Two or more polymers
- Thin layer of highly optimized polymer
- Mounted on an asymmetrical structure
- Highly tailored properties at low cost
Membrane Elements - Spiral Wound
Spiral Wound Membrane Element and Tube
Separax Membranes

• Not A Filtration Process
• Solution-Diffusion Based Separation Process
  – Components dissolve into membrane surface and diffuse through it
  – More soluble components permeate quicker

Membranes are characterized by permeability (flux) and selectivity
Driving Force

A pressure differential across the membrane

High Pressure (Feed)  \(P_{\text{CO}_2}\)  Low Pressure (Permeate)  \(P_{\text{CO}_2}\)
Separex Membranes
Regions of Use

- **Flow Rates**: Economical only for > 5 MMSCFD
- **Feed Pressure**: Up to ~ 2,000 psiA (138 barA)
- **Permeate Pressure**: Typically below ~50 psiA (3.5 barA)
- \( \Delta p \) (Feed \( \rightarrow \) Permeate): 1,500 psi max (100 barA)
- **Feed Temperature**: 60 to 150°F (16 to 65°C)
Agenda

• Membrane Technology Overview
• **Pretreatment Options**
• Flow Scheme Options
• Commercial Experience
Pretreatment Design Considerations

- Feed Composition
  - CO$_2$ Content or Percentage of CO$_2$ Removal
  - Heavy Hydrocarbons
- Feed Contaminants
  - Compressor Oils
  - Well Additives
  - Pipeline Corrosion Inhibitors

All Membranes Require Some Form of Pretreatment
Standard Pretreatment

- Removes feed contaminants such as lube oil and corrosion inhibitor
- It is not meant for removal of heavy HC tail as in very rich feed gas
Enhanced UOP MemGuard™ Pretreatment

- Regenerable adsorbent unit replaces the non-regenerative absorbent bed
- Provides efficient dew point depression
- Can deal with varying levels of feed gas contaminants

**Diagram:**
- Feed → Filter Coalescer → MemGuard™ Regenerable Adsorbent System → Particle Filter → Membrane
- MemGuard™ Regenerable Adsorbent System is connected to the heater.
MemGuard Flow Scheme

1. Feed
2. Filter Coalescer
3. Adsorbing Bed(s)
4. Particle Filter
5. Regen Gas Blower
6. Regen Heater
7. Regen Gas Cooler
8. Regen Gas Separator
9. Regenerating Bed
10. Liquids
11. Clean Gas
MemGuard System Performance

Hydrocarbon Content, ppm

- Pretreatment Feed Gas
- Pretreatment Discharge Gas

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Benefits of MemGuard System

- Selectively removes heavy HC tail and hence can provide efficient dew point depression
- MemGuard™ product gas is bone dry which allows use of carbon steel metallurgy
- If permeate gas is to be sequestrated, additional dehydration is typically not required
Agenda

• Membrane Technology Overview
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• Flow Scheme Options
• Commercial Experience
Flow Scheme Options

1 Stage

2 Stage

Pre-Membrane

Hybrid
Flow Schemes

- No moving parts
- Simple, reliable operation
- Low hydrocarbon recovery

- Allows greater CO₂ removal
- High hydrocarbon recovery
- Requires recycle compressor

- Feed with high CO₂
- Intermediate hydrocarbon recovery
- Reduced compression
Hybrid

- Debottleneck existing plants or reduce Amine unit size
- Allows high CO₂ removal, low ppm of CO₂ & H₂S as in LNG production
- Can minimizes capital and operating costs
Effect of CO₂ Removal

- **Relative Area Requirement**
  - One Stage System
  - Multistage System

- **% CO₂ Removed**
- **% Hydrocarbon Recovery (1 Stage)**

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Effect of Number of Stages

Hydrocarbon Retention

Two Stage

One Stage

Percentage CO₂ Removal
Effect of Feed Pressure on Performance

![Graph showing the relationship between feed pressure and relative area or losses.](image)

- **Hydrocarbon Losses**
- **Membrane Area**

Feed Pressure, psia

Relative Area or Losses

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Effect of Permeate Pressure on Performance

Permeate Pressure, psia

Relative Area or Losses

Membrane Area

Hydrocarbon Losses

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Effect of Feed Temperature on Performance

- Relative Area or Losses
  - Hydrocarbon Losses
  - Membrane Area

Operating Temperature, °F

- 70
- 90
- 110
- 130
- 150
- 170

Relative Area or Losses

- 0.5
- 0.7
- 0.9
- 1.1
- 1.3
- 1.6
Agenda

- Membrane Technology Overview
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- Commercial Experience
Separex Membranes: A Proven Technology

- World-Scale Processing Plants Delivered as Modular Packaged Equipment
- Advanced Pretreatment Demonstrated to Improve Element Life
- Off-shore Experience
Large Separex Membrane Projects

Ease of Operation – Remote Plants

<table>
<thead>
<tr>
<th>Location</th>
<th>MMSCFD</th>
<th>CO₂ Inlet</th>
<th>CO₂ Outlet</th>
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<tbody>
<tr>
<td>Nigeria</td>
<td>200</td>
<td>7%</td>
<td>2%</td>
</tr>
<tr>
<td>Pakistan</td>
<td>550+450</td>
<td>6.5%</td>
<td>2%</td>
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<td>Pakistan</td>
<td>240</td>
<td>12%</td>
<td>3%</td>
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<td>Mexico</td>
<td>120</td>
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<tr>
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<td>32</td>
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<tr>
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<td>107</td>
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<td>218</td>
<td>6.8%</td>
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<tr>
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<td>3%</td>
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<tr>
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<td>20%</td>
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<td>8%</td>
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<tr>
<td>Thailand</td>
<td>163</td>
<td>17%</td>
<td>5%</td>
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* Offshore

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<td>Tunisia*</td>
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Pakistan II Overall Layout
Pakistan II MemGuard System
Egypt I Plant Layout
## Recent Project Offshore

**Hydrocarbon Recovery:** 95%

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Feed</th>
<th>Product</th>
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<tbody>
<tr>
<td>Flow, MMSCFD</td>
<td>630</td>
<td>350</td>
</tr>
<tr>
<td>$\text{CO}_2$, mol%</td>
<td>44.5</td>
<td>&lt;8.0</td>
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<tr>
<td>Mercury, $\mu$/Sm$^3$</td>
<td>40 max</td>
<td>&lt; 5</td>
</tr>
<tr>
<td>Water, lb/MMSCFD</td>
<td>Saturated</td>
<td>&lt; 5</td>
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*Table showing feed and product values for recent offshore project.*
SE Asia Platform I
Optimized Layout & Packing Density
Installed SE Asia MemGuard System
Opinion of our Customers

Membrane Technology – A Success Story in Gas-Processing

Sour Gas Development: a History, Technological Challenge and Success

Membrane technology has to be considered one of the promising future options for gas processing, probably also for H₂S.

Oil & Gas Journal / July 14, 2008

Changing feed conditions push Egyptian gas plant to upgrade CO₂ membrane system

Membrane system

The membrane system at the Salam gas plant had been started up in July 1999 (Fig. 3) and has operated successfully and without major upsets or membrane replacement. It includes two membrane stages. Each stage...

COST EFFECTIVE NATURAL GAS CONDITIONING:
TWELVE YEARS EXPERIENCE OF MEMBRANE SYSTEM OPERATION

Jeff Cook
Quick Silver Resource, Inc.
Fort Worth, Texas, USA

William Echt
UOP LLC, a Honeywell Company
Des Plaines, Illinois, USA
Separex Technology Summary

- Modular supply advantages
  - High degree of shop fabrication
  - Minimized installation time & cost
- Phased in expansion for future capacity or CO₂ increase
- Weight and space efficiency
- Easy to start-up, operate, turndown and shutdown
- High reliability and on-stream time
  - Low maintenance requirements
- Lowest processing cost (~ $ 0.09/MSCF)
- Membranes are excellent dehydrators
- Advanced pretreatment and materials
- Membranes operate in gas phase (no flammable liquids, refrigerants or chemicals)
- Meets API-521 RP for system inventory blowdown during ESD
Separex Technology Summary

- **Synergies with other UOP technologies with one system wide performance warranty**
- **Unparallel capabilities**
  - UOP manufactures its own membranes
  - Membrane and Pretreatment development program
  - Supply of continually improved membranes
- **Extensive commercial experience**
- **Long-term proven commitment**
  - Ongoing operational support
  - Remote process monitoring