Nitrogen-Rejecting Membranes to Increase Gas Heating Value and Recover Pipeline Natural Gas: A Simple Wellhead Process Approach

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Outline

- Application – Recapturing CH$_4$ from Blow down of Nitrogen-Foam Fractured Horizontal and Vertical Wells.
- Novel Composite Membranes
- Why a Membrane Process for this Application?
- Process Designs and Economics
- Conclusions
High Rate Nitrogen-Rich Blowdown Operation in Nitrogen-Foam Fractured Horizontal Wells
High Rate Nitrogen-Rich Blowdown Operation in Nitrogen-Foam Fractured Horizontal Wells
A membrane can separate components of a gas mixture due to differential permeation rates across a non-porous polymer film resulting in a differential pressure driving force.

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 versus Rubbery Membranes

**Glassy Membranes**

- Fast Gas
  - Hydrogen
  - Nitrogen
  - Ethane
  - Hexane
  - Methane
  - Propane
  - $\text{CO}_2$
  - Hydrogen
  - $\text{CO}_2$
  - Nitrogen
  - Methane
  - Propane
  - Hexane

**Rubbery Membranes (MTR Technology)**

- Fast Gas
  - Hexane
  - Ethane
  - Methane
  - Nitrogen
  - Hydrogen
  - $\text{CO}_2$
  - Propane
  - Hydrogen
  - $\text{CO}_2$
  - Nitrogen
  - Methane
  - Ethane
  - Hexane
Membrane System Installations
Membranes are a Mature Separation Technology

Gas/Gas Separation Systems

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

Vapor/Gas Separation Systems (MTR’S Reference Base)

- Hydrocarbon/\text{N}_2, \text{CH}_4 \sim 100 \text{ Units}$
MTR Membrane in Spiral Wound Cartridges

Module housing

Feed flow

Residue flow

Permeate flow

Spacer

Membrane

Spacer

Permeate flow after passing through membrane

Selective layer

Microporous layer

Support web

*Not to scale
Typical Commercial Skid-Mounted Unit

Twin Bottoms Membrane System
Design Flow Rate: 0.2 MMSCFD

NTE Membrane System
Design Flow Rate: 1.0 MMSCFD
Proven Long-Term Separation Efficiency
(400 years Cumulative Operating Experience with Silicone Rubber Membrane)
15% inlet nitrogen content
< 4 mol% product nitrogen content
Btu enhancement from 830 to 970 Btu/scf

Feed gas flow rate: 0.500 MMSCFD
Feed gas nitrogen content: 15 mol%
Pipeline gas nitrogen content: 4 mol%
Annual net revenue: $US 600,000
Annual operating expenses: $US 165,000
Simple payback period: 9 months
Membrane system price: $US 350,000
Process Scheme for High Nitrogen Feed Gas from Horizontal Wells

12-30 mol% nitrogen in inlet gas
< 4 mol% nitrogen in product gas
Btu enhancement from 783 to 890 Btu/scf

Feed gas flow rate: 3.5 MMSCFD
Feed gas nitrogen content: 31 mol%
Pipeline gas nitrogen content: 10 mol%
Annual net revenue: $US 3.5 million
Annual operating expenses: $US 515,000
Simple payback period: 6 months
Membrane system price: $US 620,000 - 720,000
Nitrogen Rejection – Application Envelope

- Inlet nitrogen content between 4 and 30 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 heating value for burning
- Hydrocarbon removal for nitrogen re-injection
- Mobile units can be manufactured easily
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
- Units are mobile. No foundation required. Level gravel or soil is adequate for membrane skid.
Other Oil & Gas Applications

Other Applications in the Oil & Gas Industries for MTR’s Reverse-Selective Membranes

Gas:
- Fuel gas conditioning
- NG Dew point Control
- NGL recovery
- Natural gas dehydration.

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