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

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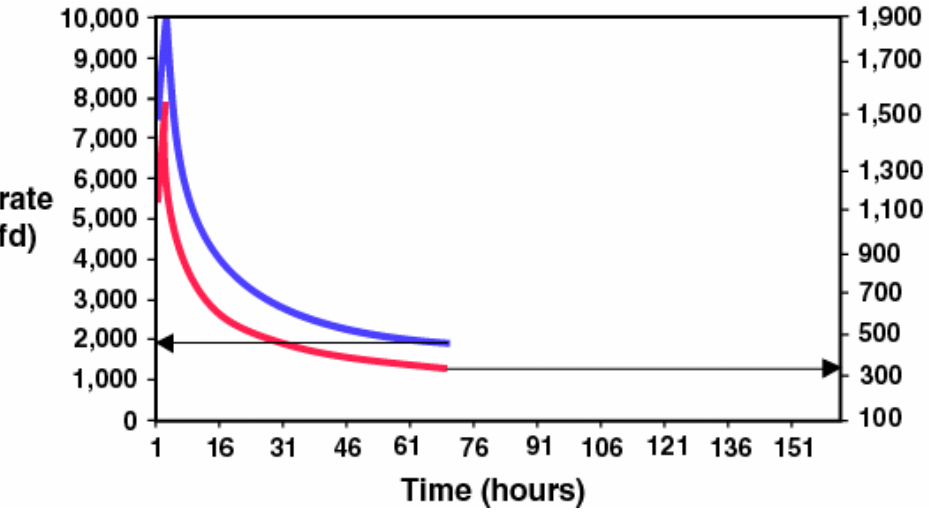
Outline

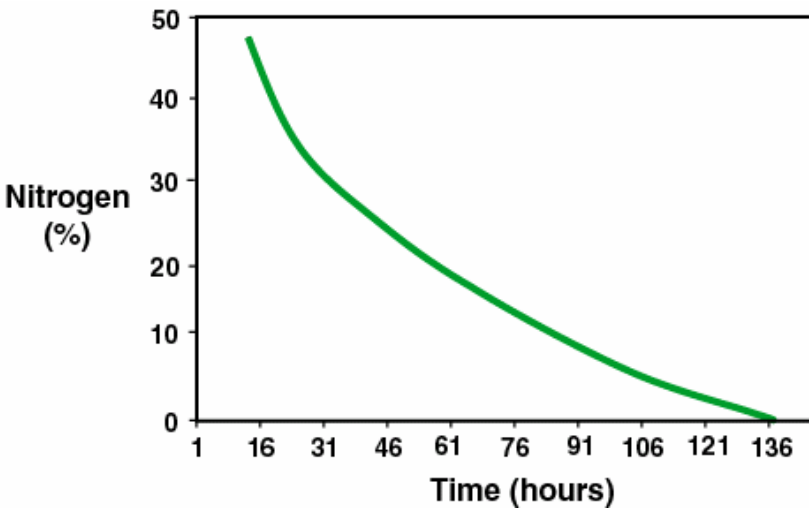
- **Application –**

  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





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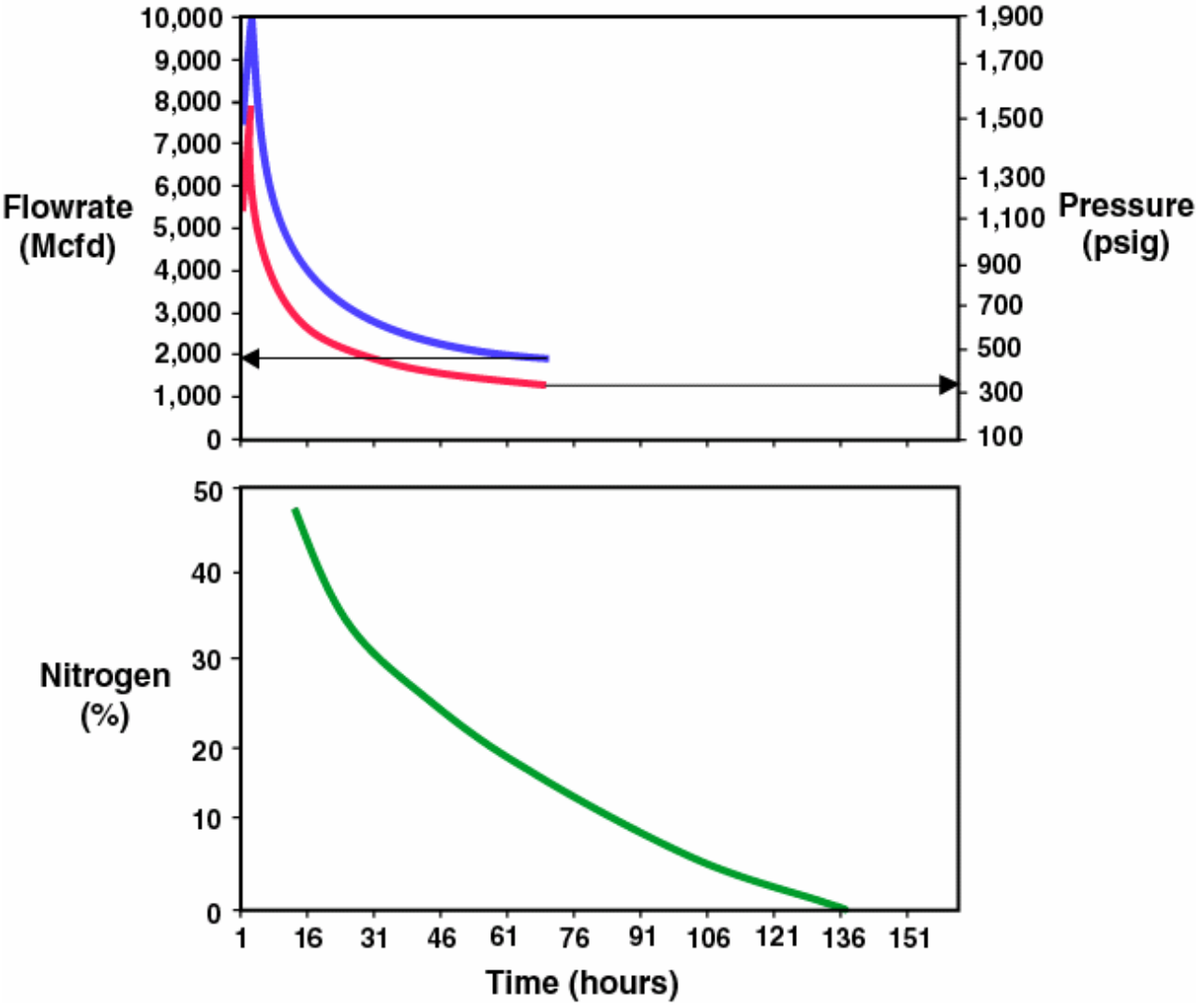
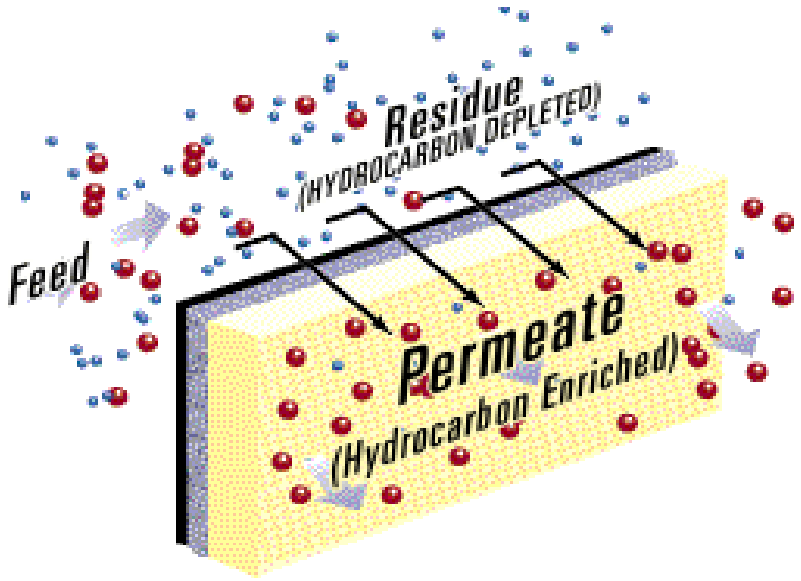


Membrane Separation Mechanism



MTR's Rubbery Membranes Reject Nitrogen and Permeate Hydrocarbon Components

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.

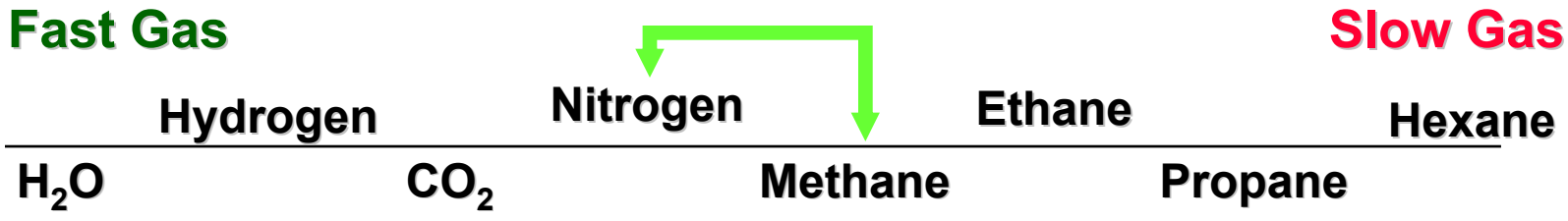
Permeability = Diffusivity * Solubil
(P) (D) (S)

Membrane Selectivity

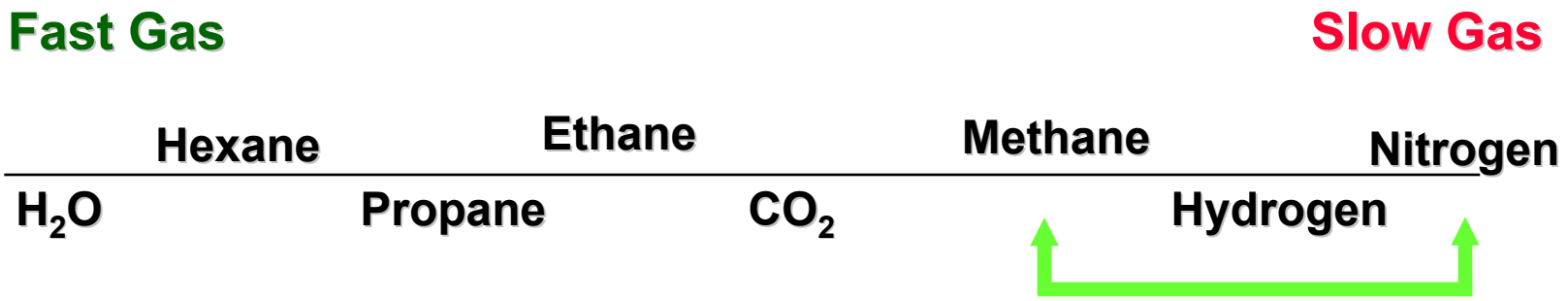
$$\frac{P_1}{P_2} = \frac{D_1}{D_2} \cdot \frac{S_1}{S_2}$$

Glassy versus Rubbery Membranes

Glassy Membranes



Rubbery Membranes (MTR Technology)



Membrane System Installations
Membranes are a Mature Separation Technology

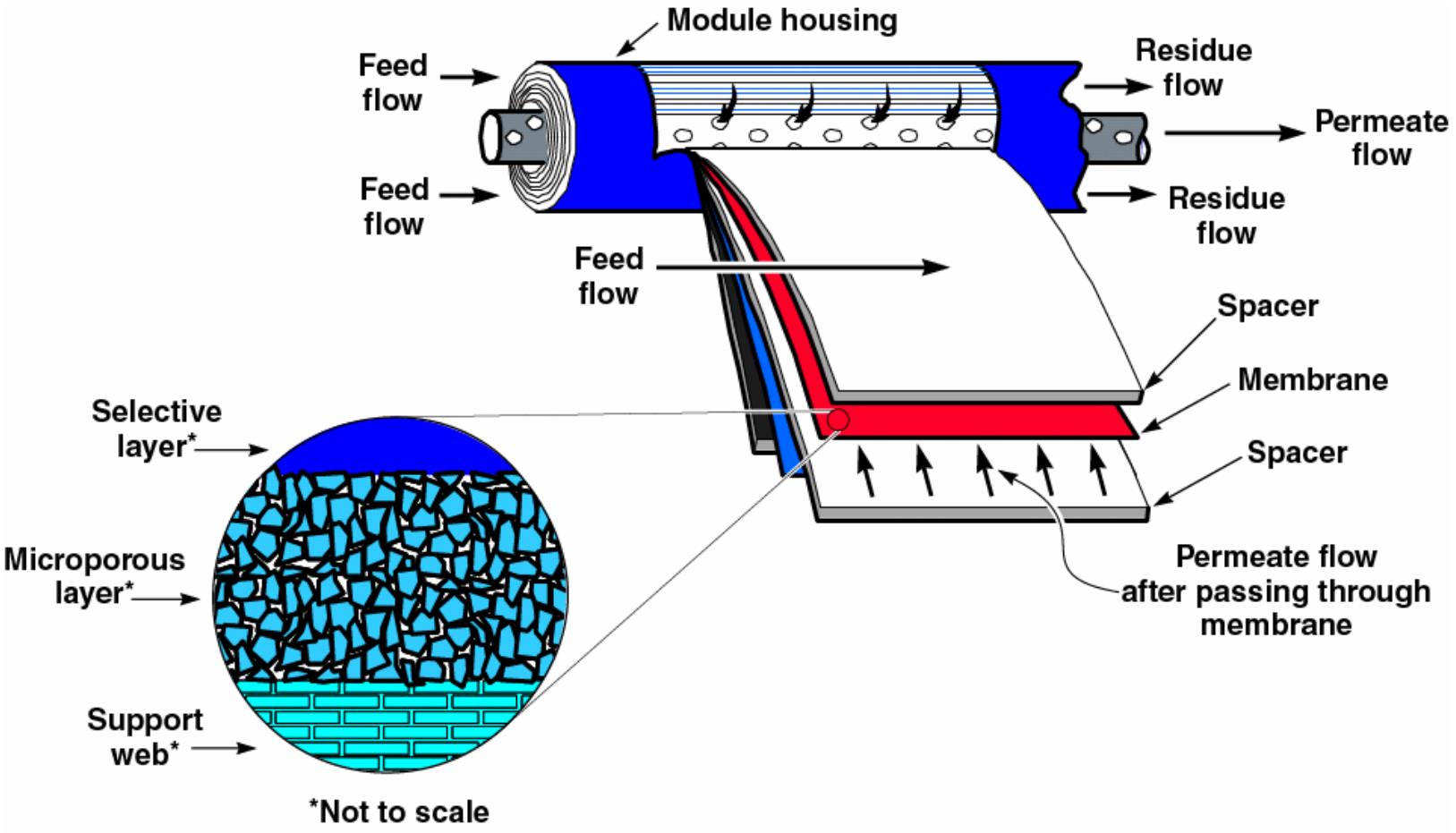
Gas/Gas Separation Systems

H_2/N_2, CH_4	~ 200 Units
O_2/N_2	~ 5,000 Units
CO_2/CH_4	~ 200 Units

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

Hydrocarbon/N_2, CH_4	~ 100 Units

MTR Membrane in Spiral Wound Cartridges

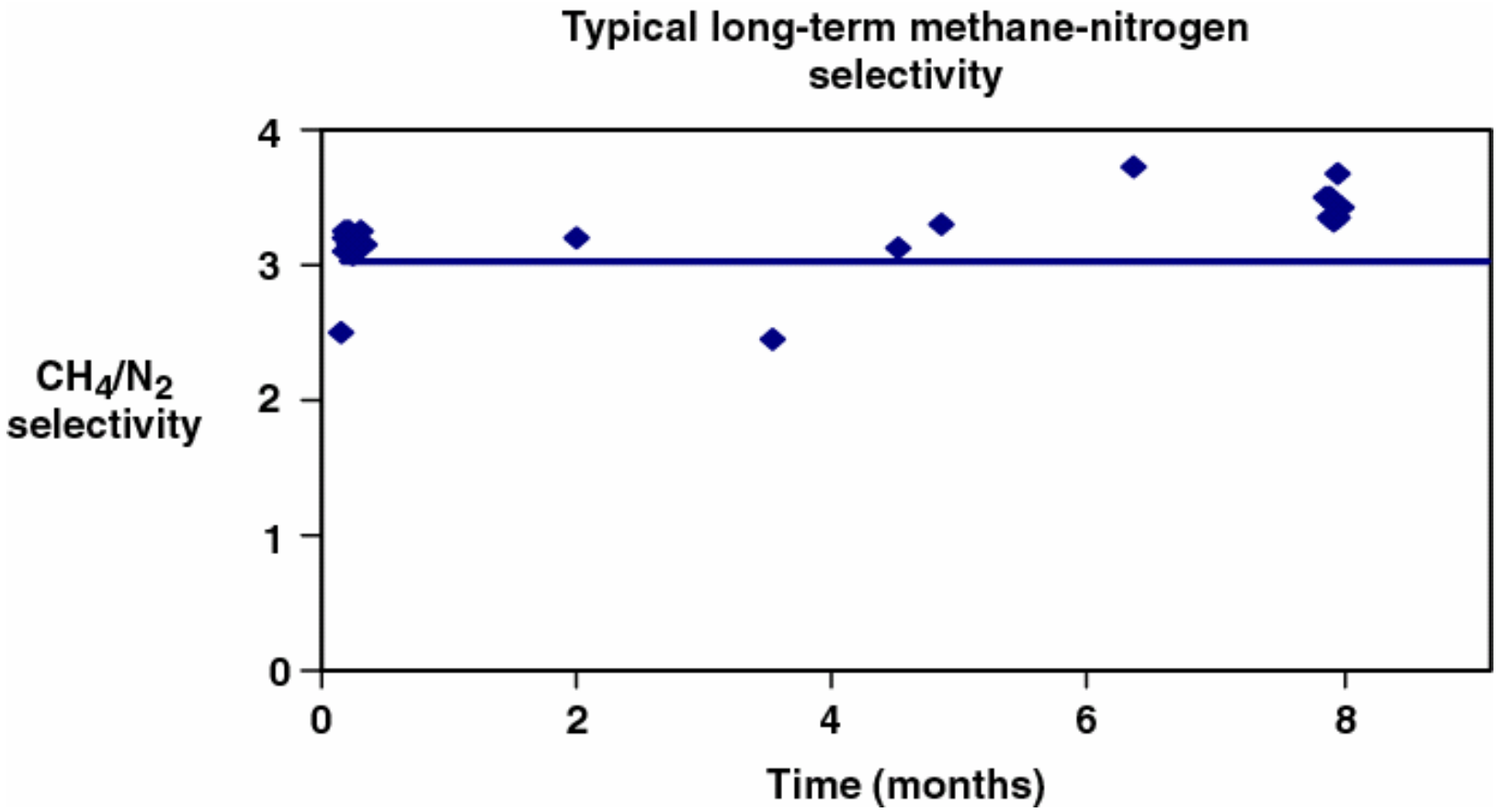


Typical Commercial Skid-Mounted Unit

Twin Bottoms Membrane System
Design Flow Rate-0.2 MMSCFD

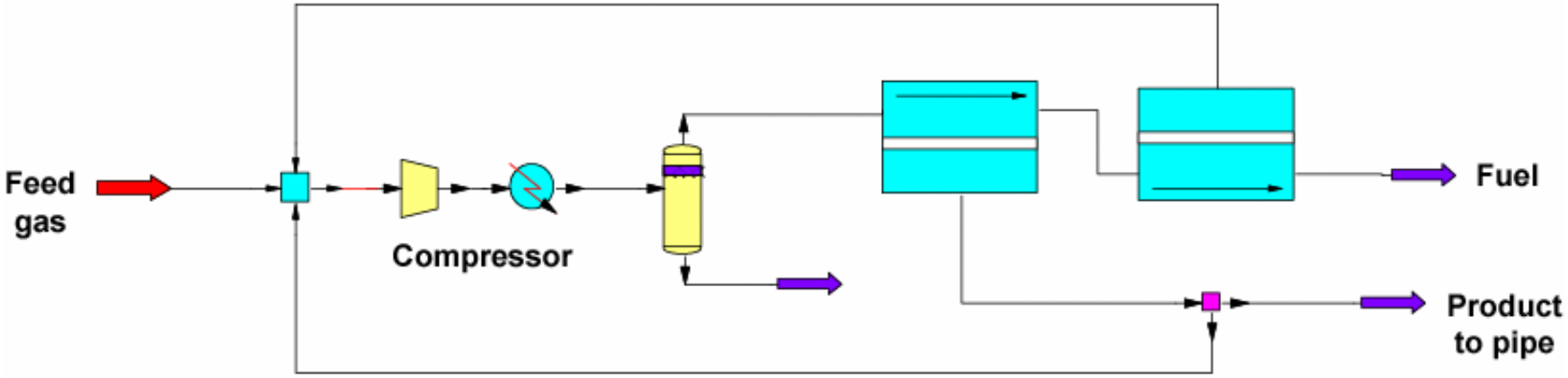
NTE Membrane System
Design Flow Rate-1.0 MMSCFD

Proven Long-Term Separation Efficiency
(400 years Cumulative Operating Experience with Silicone Rubber Membrane)



Process Flow Diagram for Vertical Wells

15% inlet nitrogen content
< 4 mol% product nitrogen content
Btu enhancement from 830 to 970 Btu/scf

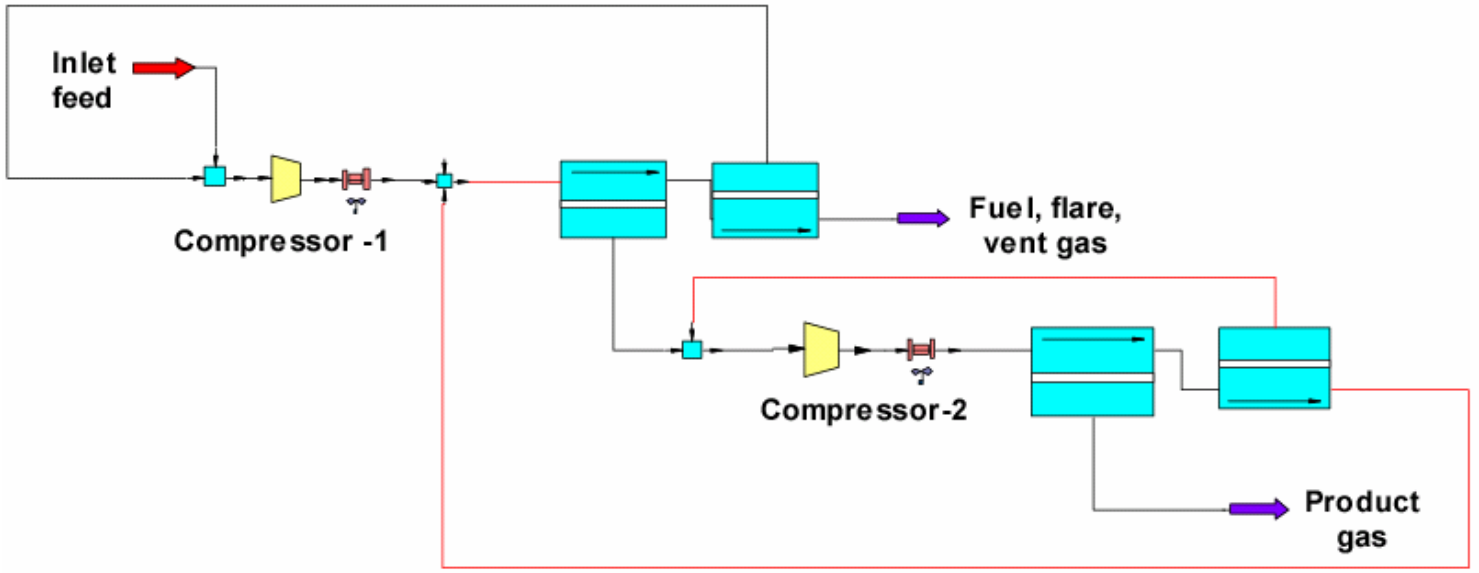


Product recycle to allow for change in inlet composition

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 N_2 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.