

Only Raw Sour Gas Available for Engine Fuel? Proven Membrane Process Cleans Gas for Engines

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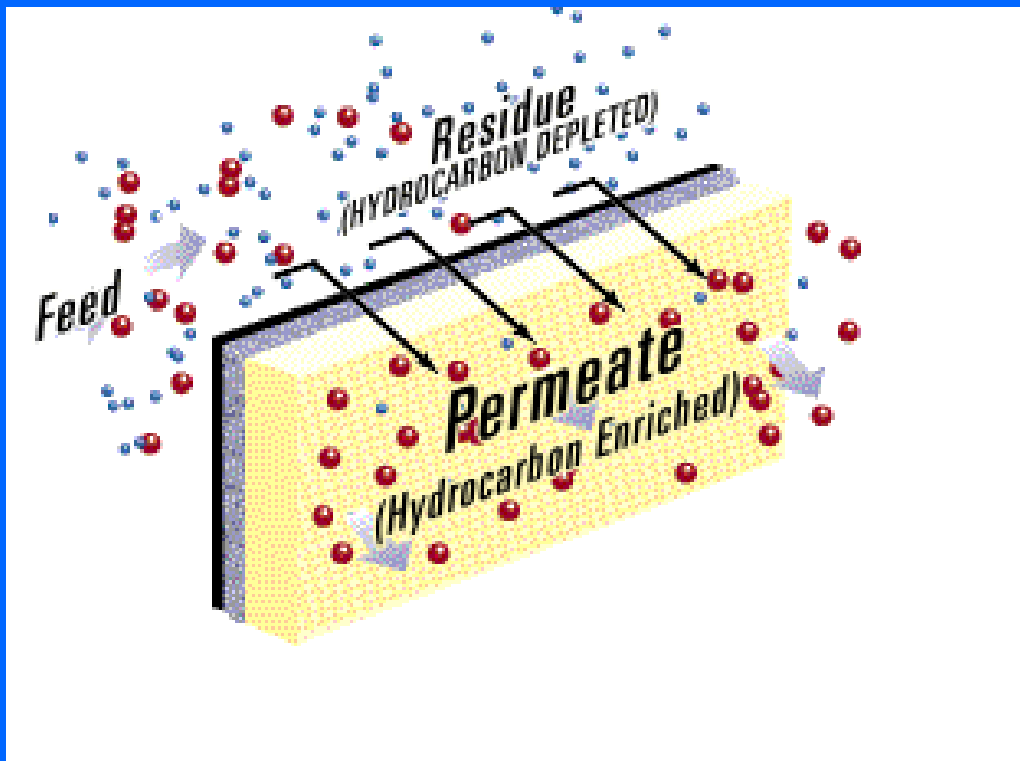
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Membrane Separation Mechanism



$$\text{Permeability} = \text{Diffusivity} * \text{Solubility}$$

(P) (D) (S)

Membrane Selectivity

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

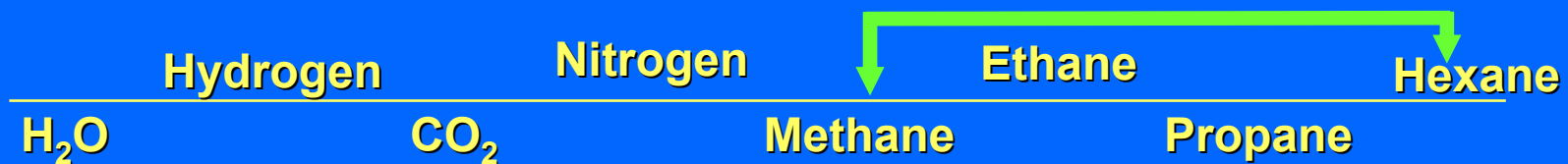
Rubbery Membranes Reject Lighter Gases such as N_2 , CH_4 and H_2 and Permeate Heavier Hydrocarbon Components

Glassy v/s Rubbery Membranes

Glassy Membranes

Fast Gas

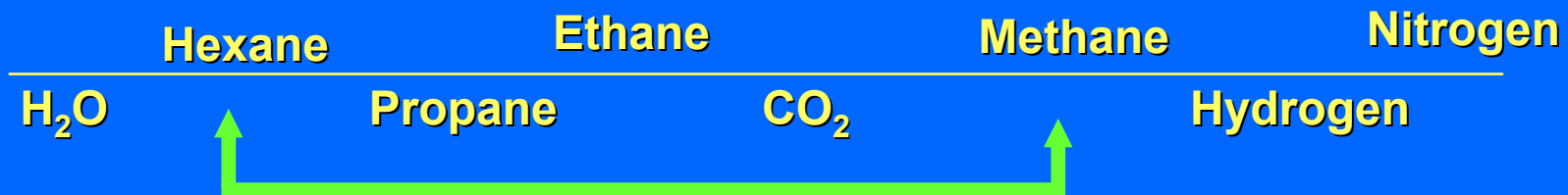
Slow Gas



Rubbery Membranes

Fast Gas

Slow Gas



Membrane System Installations Increasing References and Application Envelopes

Gas/Gas Separation Systems

H_2/N_2 , CH_4

~ 250 Units

O_2/N_2

~ 5,000 Units

CO_2/CH_4

~ 250 Units

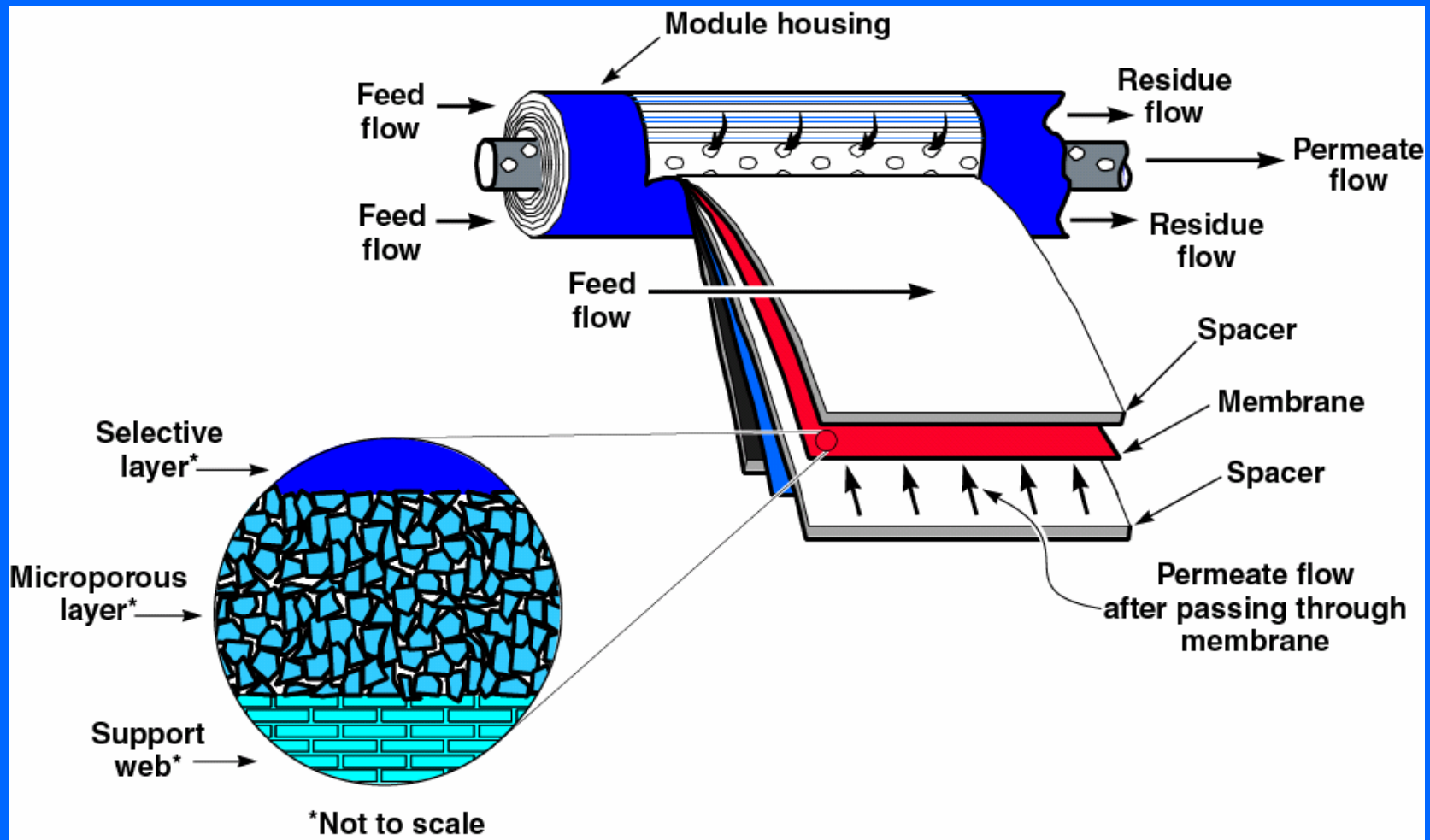
**Glassy
Membranes**

Vapor/Gas Separation Systems

Hydrocarbon/ N_2 , CH_4 ~ 125 Units

**Rubbery
Membranes**

Membrane Structure and Packaging

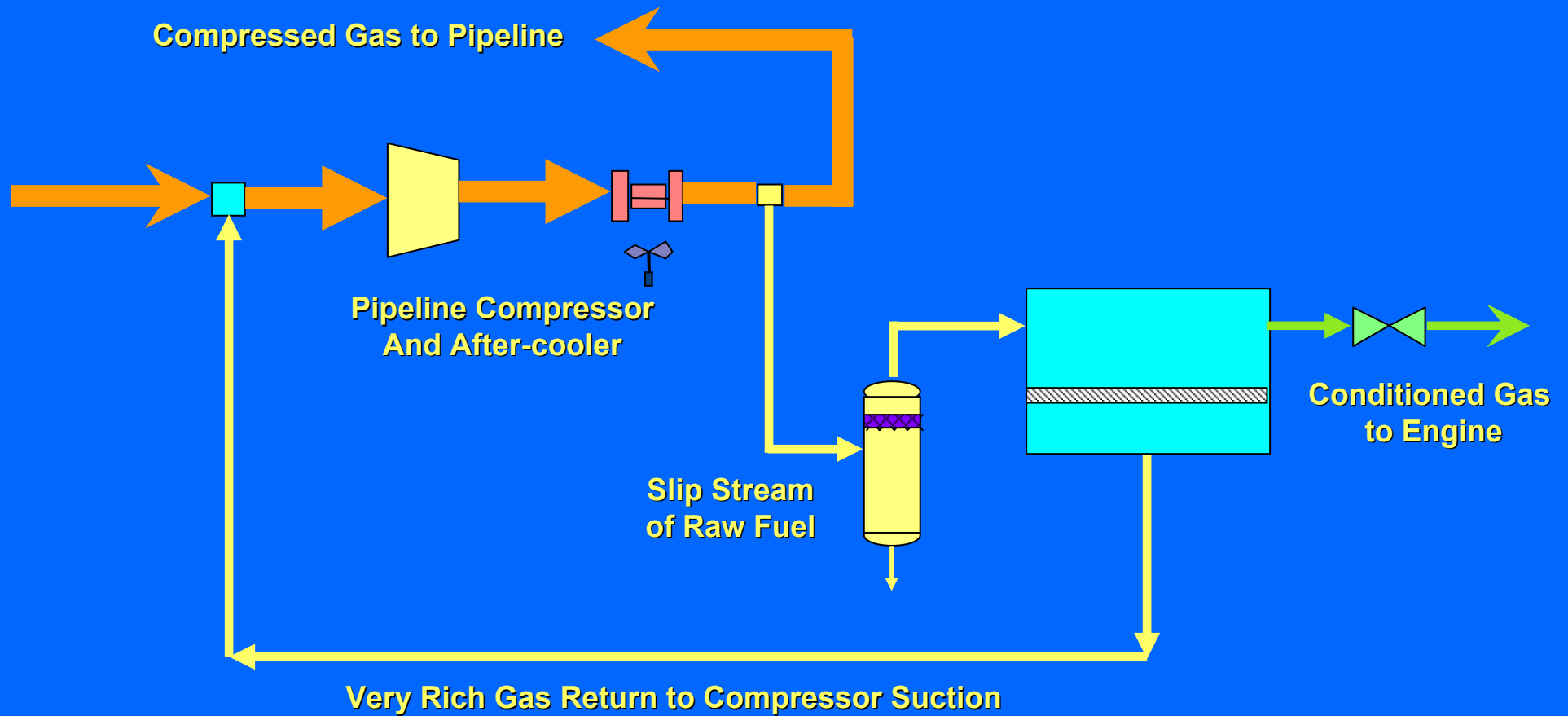


Fuel Gas Conditioning Remote Site Considerations

- Increasingly Natural Gas Production is Coming for Remote Locations
- Raw Gas in Gathering Systems Requires Compression
- Fuel Choices are Limited – Diesel or Raw Gas
- Diesel represents cost, transportation logistics, storage and other issues
- Poor Quality Raw Gas Results in Deration of Available Power to Compressors and Gensets
- Derated Compressors or Gensets = Loss in Production Volumes and Equipment Shutdowns
- A Simple Process Technology Which Operates Without Attention and Consumables Is Required

Reverse-Selective Membranes Have Been Now Proven to Meet These Requirements

How Does The Process Work ?



Selected Field Experience Data

Membrane FGCU's

- Kakap-H Remote Platform
Star Energy, Indonesia
- Sour Gas Processing - H₂S Reduction in Fuel Gas
Dominion Exploration, British Columbia, Canada
- 3 Engine Gen-set on Petrojarl - I (FPSO)
Statoil (PGS) – North Sea
- Gas Conditioning for 500 MW Power Plant Turbines
El Paso Gas/UEG, Curitiba, Brazil
- Superior and Waukesha Engines Fuel Gas Conditioning
Sid Richardson, New Mexico (2 Units)

Kakap-H Remote Platform Star Energy, Indonesia

Components	Gas Compositions	
	Feed Gas (mol%)	Conditioned Fuel Gas (mol %)
Propane	4.60	1.48
i-Butane	1.97	0.52
<i>n</i> -Butane	1.53	0.30
Pentanes	1.74	0.28
Hexane	1.05	0.126
C ₆₊	0.91	0.078
Balance Methane and Ethane		
Total C₃₊ Hydrocarbons	11.76	2.78
METHANE NUMBER	<u>16</u>	<u>71</u>

Acknowledgement: Data Provided by Mr. Zikri Syah, Star Energy

Kakap-H Remote Platform Star Energy, Indonesia



Sour Gas Processing - H₂S Reduction in Fuel Gas British Columbia, Canada

Gas Stream Component	Feed Gas (mol %)	Conditioned Gas (mol %)
Hydrogen Sulfide	0.34	0.004
Propane	2.72	0.624
i-Butane	0.37	0.049
<i>n</i> -Butane	0.67	0.088
i-Pentane	0.18	0.018
<i>n</i> -Pentane	0.19	0.019
Hexane	0.16	0.010
C ₆₊	0.14	0.008
Total C₃₊ Hydrocarbons	4.43	0.82
H₂S Content	<u>3400 ppm</u>	<u>40 ppm</u>

Acknowledgement: Data Provided by Mr. Brett Kimpton, Dominion Exploration

Sour Gas Processing - H₂S Reduction in Fuel Gas British Columbia, Canada



3 Engine GenSet on Petrojarl - I (FPSO) Statoil (PGS/Wartsila) – North Sea

Stream Name	Inlet Feed (Mol-%)	Conditioned Fuel Gas (Mol-%)
Methane	72.94	86.95
Ethane	9.73	5.68
Propane	8.51	3.18
Butanes	5.05	1.10
Pentanes	1.63	0.30
Carbon Dioxide	0.40	0.25
Nitrogen	1.22	2.49
N-Hexane	0.52	0.06
Methane Number	<u>32</u>	<u>65</u>
Pressure (bar)	13.8	10.3
Volume (MMSCFD)	5.5	1.8

3 Engine Gen-set on Petrojarl - I (FPSO) Statoil (PGS/Wartsila) – North Sea



Gas Conditioning for 500 MW Power Plant Turbines

El Paso Gas/UEG, Curitiba, Brazil

Component	Gas Compositions	
	Feed Gas (mol %)	Conditioned Fuel Gas (mol %)
Propane	2.000	1.489
C ₄₊	0.785	0.449
Pressure (psig)	700-900	
Flow Rate (MMSCFD)	120 MMSCFD	

Gas Conditioning for 500 MW Power Plant Turbines El Paso Gas/UEG, Curitiba, Brazil



Superior and Waukesha Engines Fuel Gas Conditioning Sid Richardson, New Mexico (2 Units)

Stream Name	Inlet Feed (mol-%)	Guaranteed Conditioned Fuel Gas (mol-%)	Actual Inlet Feed (mol-%)	Actual Conditioned Fuel Gas (mol-%)
Methane	73.3	81.99	69.58	81.19
Ethane	10.89	6.93	11.23	6.89
Propane	6.00	2.63	6.53	2.35
Butanes	2.55	0.56	2.53	0.66
Pentanes	1.07	0.2	0.77	0.16
Carbon Dioxide	1.63	0.85	4.67	3.07
Nitrogen	3.71	6.69	4.05	5.41
N-Hexane	0.83	0.126	0.37	0.07
Methane Number	39	67	44.4	68

Acknowledgement: Data Provided by Gary McCoy, Sid Richardson, Dallas, TX

Superior and Waukesha Engines Fuel Gas Conditioning Sid Richardson, New Mexico (2 Units)



Where Can These Membrane Skids be Used Right Now?

- **Remote Compressor Stations Currently Derated Due to Raw Fuel – Elimination of Engine Derate will Immediately Increase Gas Production/Transportation Volumes**
- **Sour Gas Production Sites without access to clean gas - Elimination of Diesel or Expensive solvent systems. Especially Suitable to Colder Climates**
- **Derated GenSet Due to Fuel Quality – Elimination of Derate will allow additional power generation for production activities**
- **Offshore Platforms – Reduced Power Generation or Compressor Utilization due to poor fuel gas would be eliminated resulting in higher volume gas and oil production**

Other Opportunities for Reverse Selective Membranes

- ◆ **Fuel Gas Conditioning to Increase BTU Value by Reducing N₂ and CO₂**
- ◆ **Direct Wellhead Nitrogen Removal from Natural Gas**
- ◆ **Direct Wellhead CO₂ Removal From Natural Gas**

Summary

- Reverse Selective Membranes Have Been Successfully Proven in Well head Natural Gas Conditioning Applications
- More than 100 combined Installations of these membranes Worldwide in Petrochemicals and Oil/Gas Industries.
- Standardized Fuel Gas Conditioning Units Designed for Unattended Operation Reduce Deployment Time and Cost
- Immediate Production Boost and Additional Revenue Generation in Gas Gathering is Possible in Many Locations Currently Operating Under Derated Conditions.