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

By

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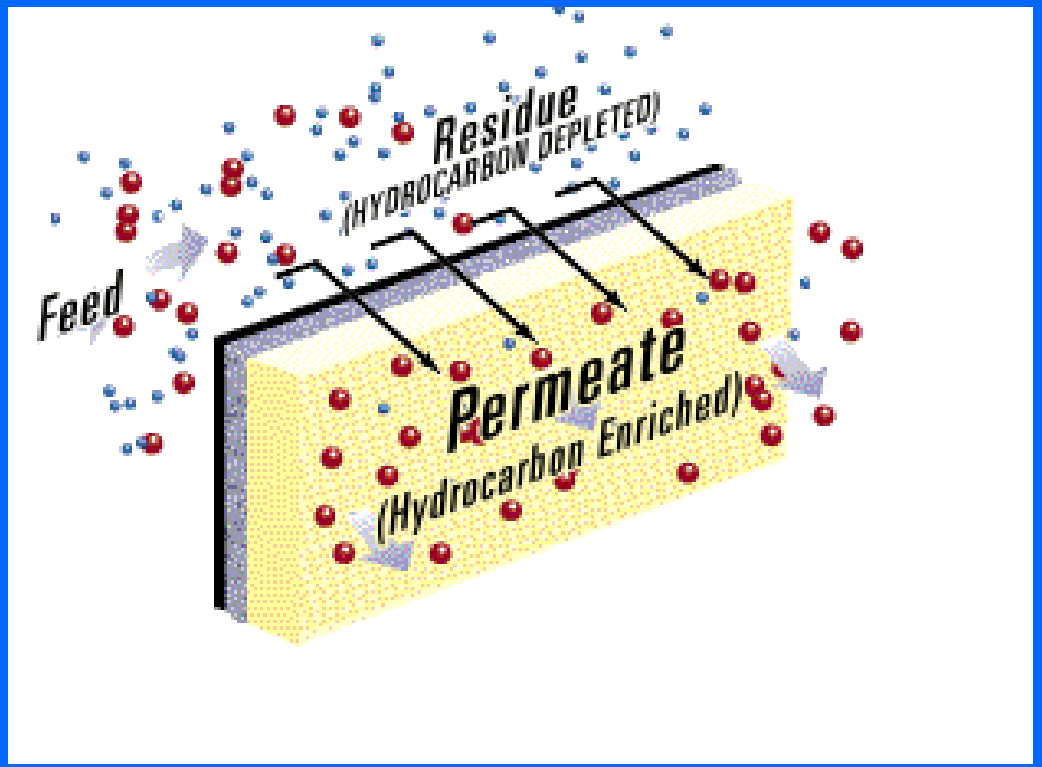
Membrane Separation Mechanism



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

Membrane Selectivity

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

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

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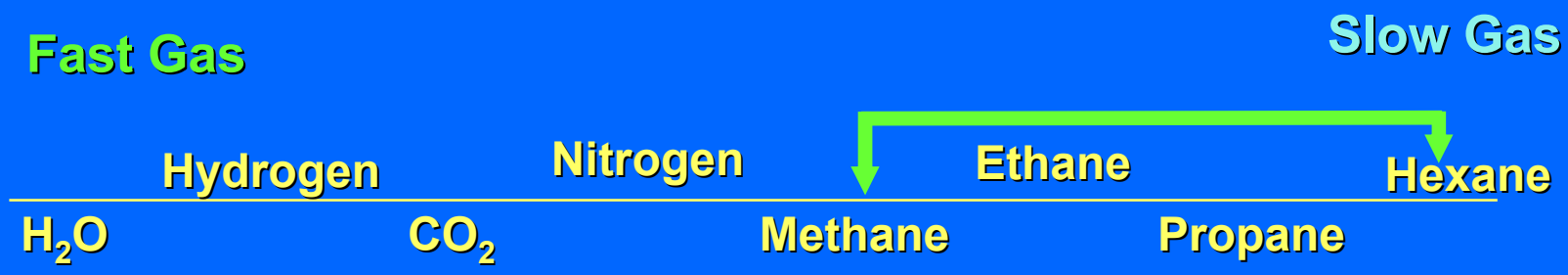
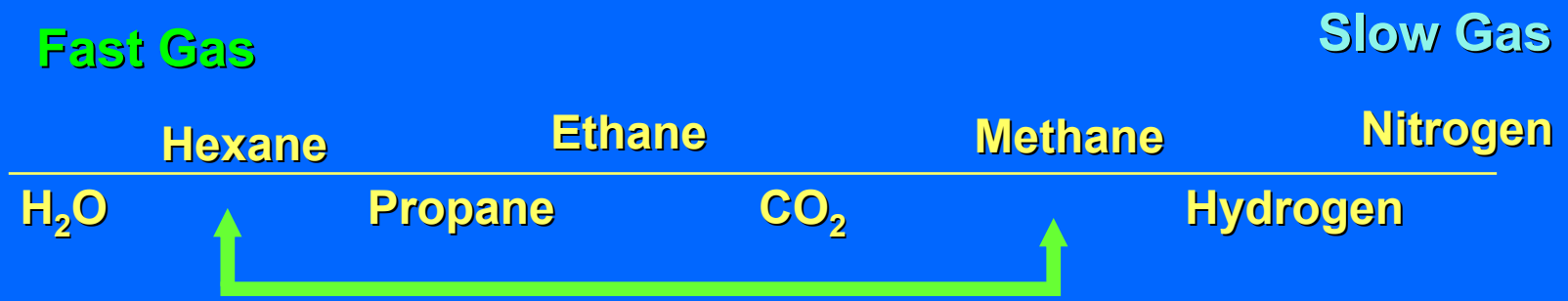
Glassy v/s Rubbery Membranes

Glassy Membranes



Rubbery Membranes



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Membrane System Installations
Increasing References and Application Envelopes

Gas/Gas Separation Systems

H_2/N_2, CH_4	~ 250 Units	**Glassy Membranes**
O_2/N_2	~ 5,000 Units	
CO_2/CH_4	~ 250 Units	

Vapor/Gas Separation Systems

Hydrocarbon/N_2. CH_4	~ 125 Units	**Rubbery Membranes**

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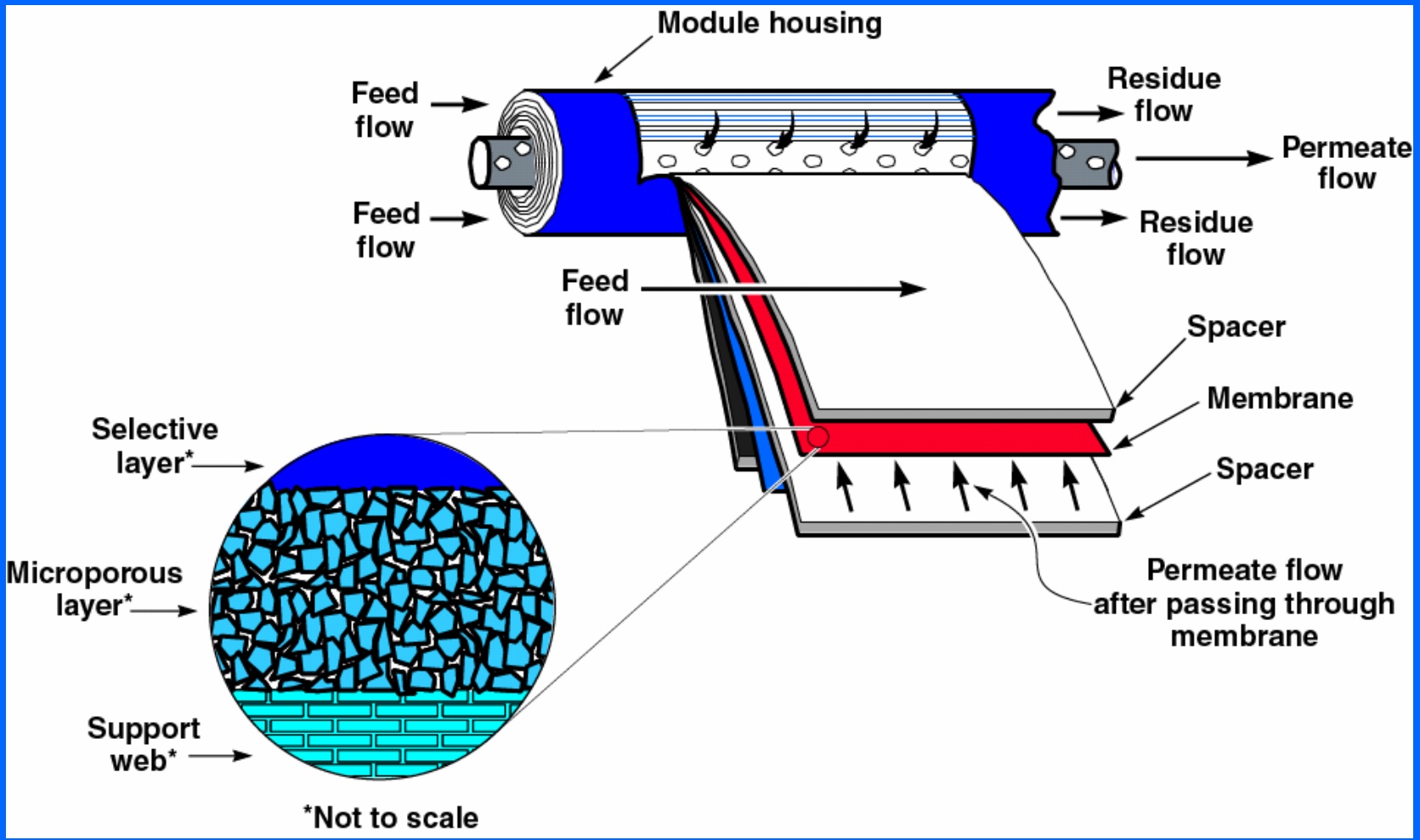
Membrane Structure and Packaging



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

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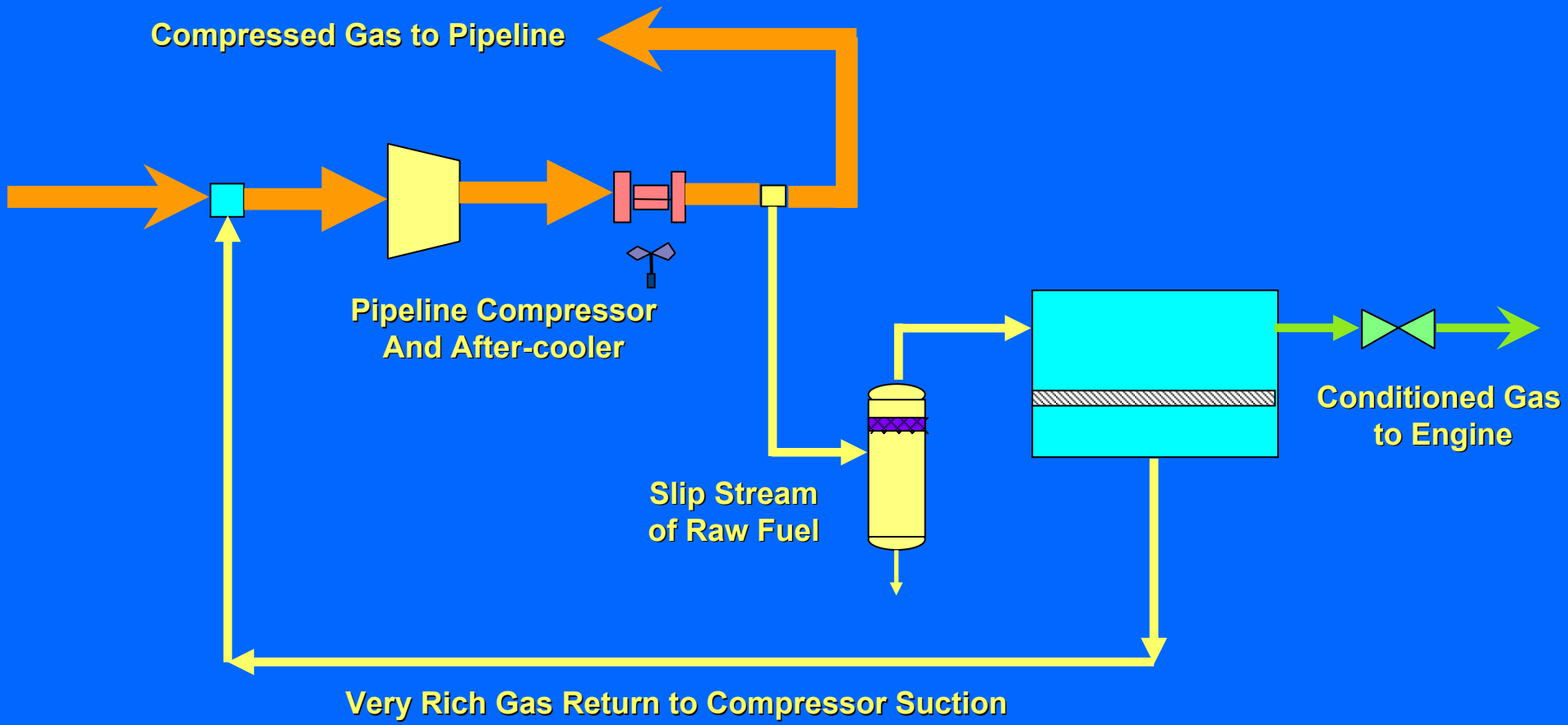
How Does The Process Work ?



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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)

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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
n-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 C_{3+} Hydrocarbons	**11.76**	**2.78**
METHANE NUMBER	**16**	**71**

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

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Kakap-H Remote Platform
Star Energy, Indonesia

Sour Gas Processing - H_2S 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
n-Butane	0.67	0.088
i-Pentane	0.18	0.018
n-Pentane	0.19	0.019
Hexane	0.16	0.010
C_{6+}	0.14	0.008
Total C_{3+} Hydrocarbons	**4.43**	**0.82**
H_2S Content	**3400 ppm**	**40 ppm**

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

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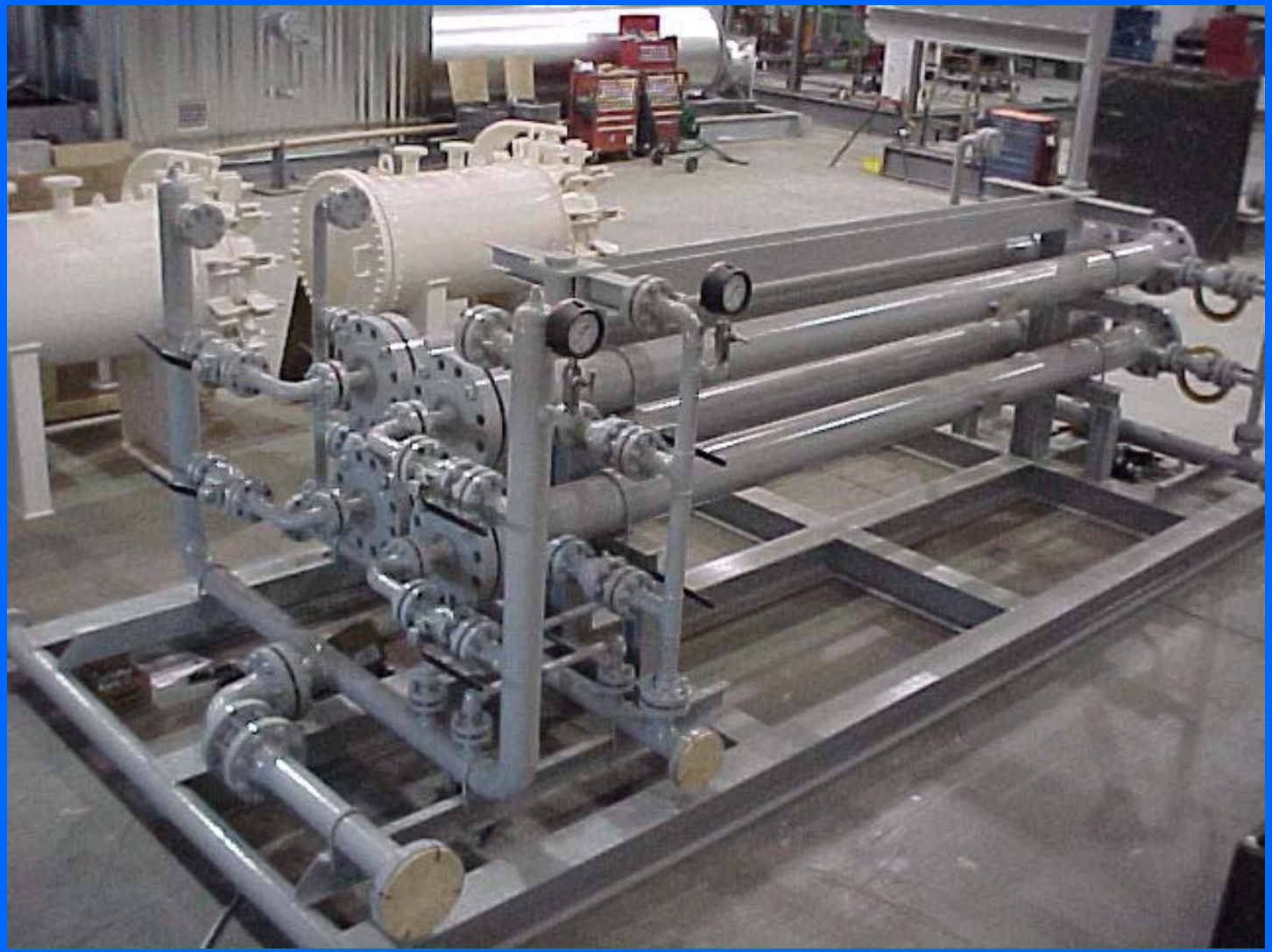
Sour Gas Processing - H_2S Reduction in Fuel Gas
British Columbia, Canada



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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	**32**	**65**
Pressure (bar)	13.8	10.3
Volume (MMSCFD)	5.5	1.8

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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**	

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

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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

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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**

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Other Opportunities for Reverse Selective Membranes

- **Fuel Gas Conditioning to Increase BTU Value by Reducing N_2 and CO_2**
- **Direct Wellhead Nitrogen Removal from Natural Gas**
- **Direct Wellhead CO_2 Removal From Natural Gas**

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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.

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