UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

TRIMMING RESIDUE CO_2 WITH MEMBRANE TECHNOLOGY

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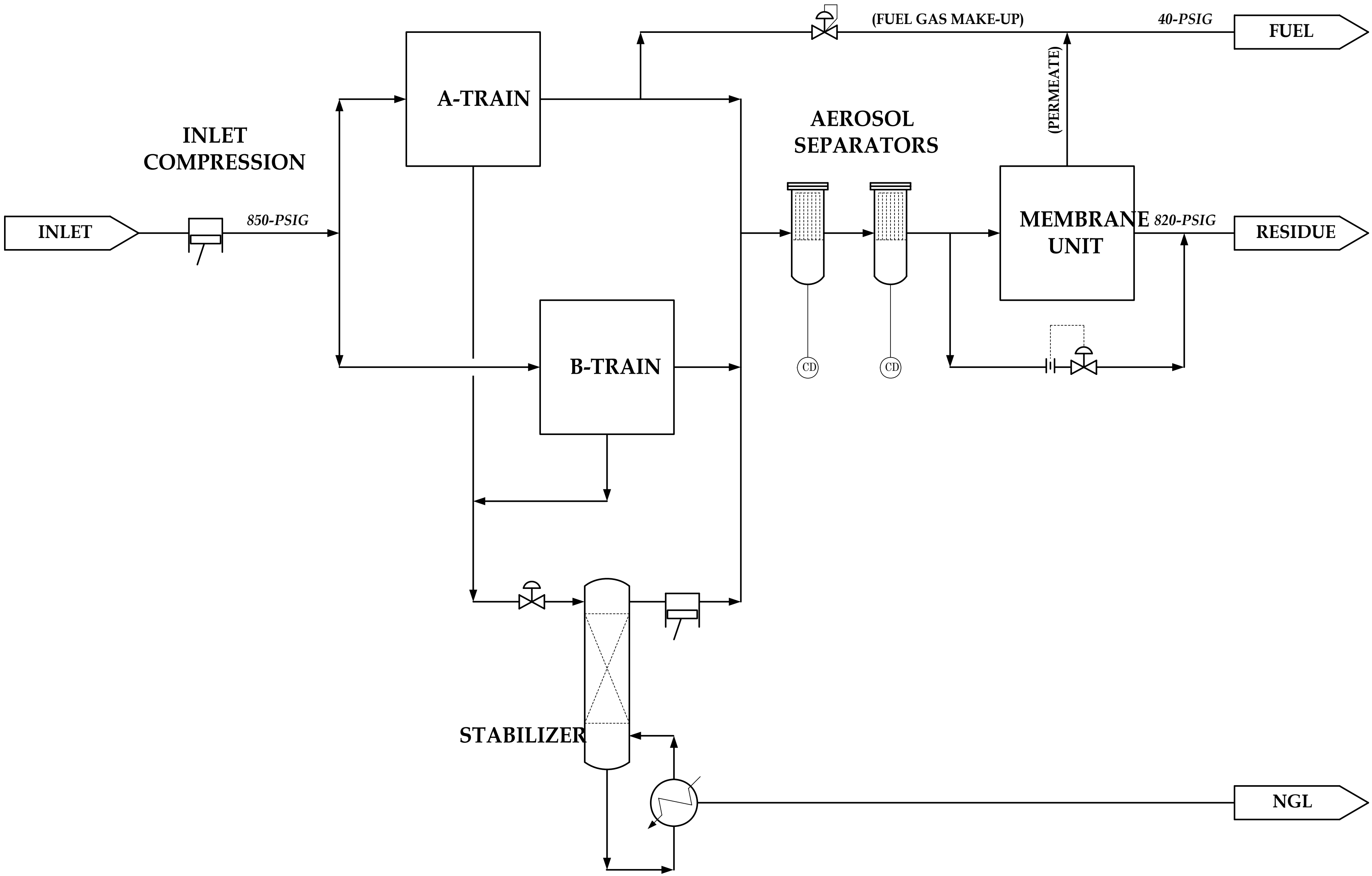
- Lew Mologne, Kvaerner Process Systems, USA
- John Holland, Industrial Distributors, Inc.

INTRO

- The Problem (*Opportunity*)
- The Hunt for the Best Answer
- The Solution

DEFS Mewbourn Plant

- Weld County Colorado
- 60 -70 MMscfd Inlet Gas Rate
- 2 Refrigerated JT Trains
- EG Dehydration
- DJ Basin/Wattenberg Gas


(FUEL GAS MAKE-UP)
40-PSIG
FUEL
A-TRAIN
AEROSOL
SEPARATORS
(PERMEATE)
INLET
COMPRESSION
INLET
850-PSIG
MEMBRANE
UNIT
820-PSIG
RESIDUE
CD
CD
B-TRAIN
STABILIZER
NGL

The Problem

- Residue Sales Gas Exceeding 3 Mole % CO_2
- 6 Month Deadline to Remedy
- Minimize Capital and Operating Costs

Possible Solutions

- Amine Treating
- Blending
- Deep Liquids Recovery
- Membrane Separation

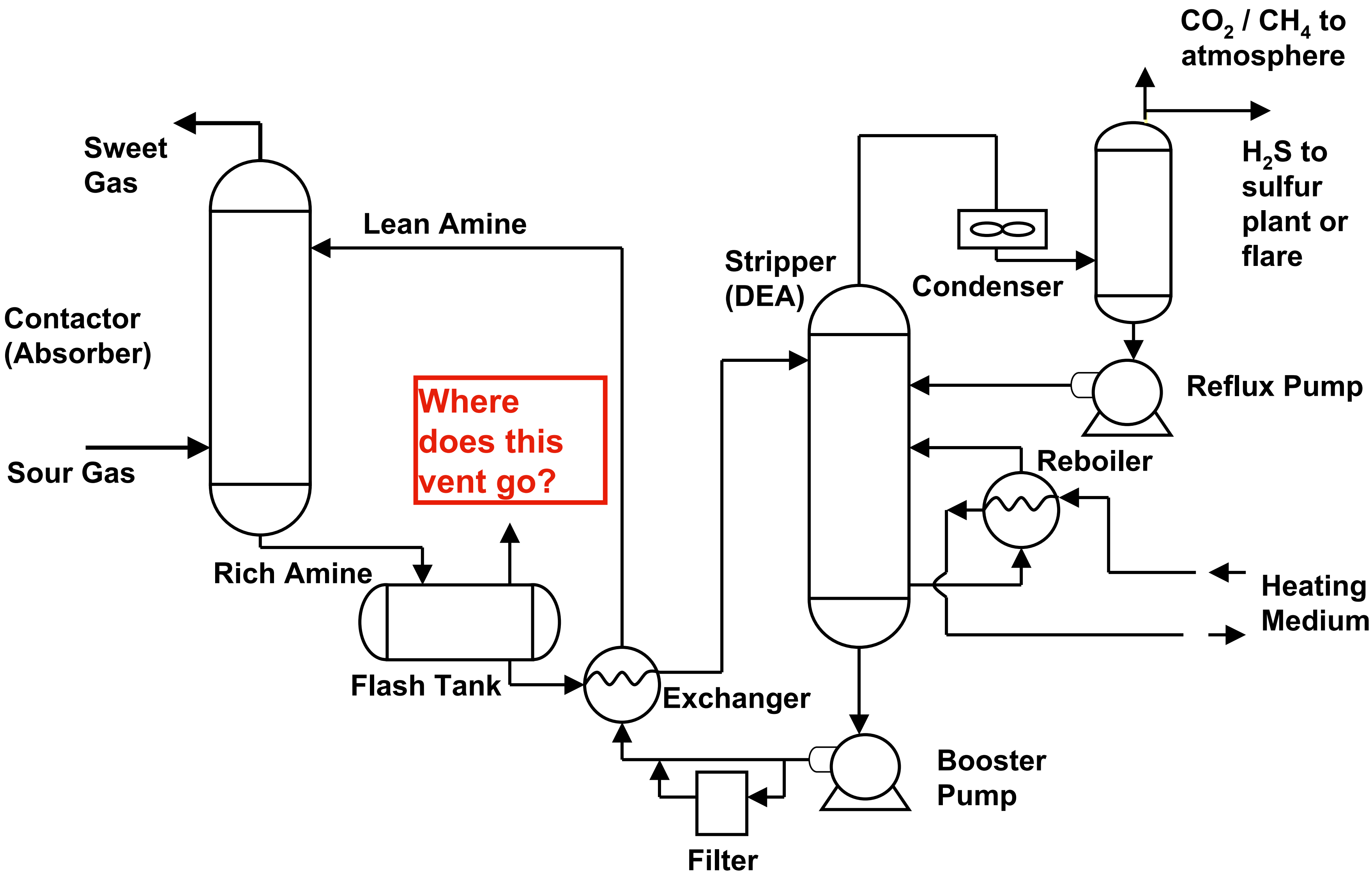
Amine Treating

- Tried and True
- Capital Cost
- Operating Cost
- Complexity

Amine Treating

- Control of Treating Target
- Permitting
- Waste Streams
- DEA, MDEA, Blends

Typical Amine Process



HYDROCARBON SOLUBILITY IN AMINE

- Flash Tank 85 – 90% Hydrocarbon
  - TOX
  - Fuel
  - Recycle/Re-process
  - Flare
  - Vent to atmosphere

HYDROCARBON SOLUBILITY IN AMINE

- Stripper/Still 0.1% – 0.3% Hydrocarbon
  - TOX
  - SRU
  - Further processing
  - Flare
  - Vent to atmosphere

Blending

- Dilution of CO_2
- Sweet Gas Not Conveniently Available
- Costs to Lay Pipe for Supply

Deep Liquids Recovery

- Incremental Refrigeration
- Cryogenic Expansion
- NGL Infrastructure
- Defers Treating to Liquid Sales
- Costs

Membrane Separation

- Technology Step Out for DEFS
- Capital Cost
- Operating Cost
- Simplicity
- Project Schedule

Membrane Separation

- Control of Treating Target
- Permitting
- No Waste Streams
- Cellulose Acetate, Hollow Fiber, …

Membrane Application Drivers

- Water “Dry” Feed
- Hydrocarbon “Dry” Feed
- High Pressure Feed
- Low Pressure Permeate
- Temperature Control

Membrane Design Objectives

- Trim CO_2 to Under 3.0 Mole %
- Consume all Permeate as Fuel
- Ensure Flexibility to Meet Target

Gas Compositions (Mole%)

Plant Inlet		Membrane Feed		Membrane Residue		Blended Residue	
C_1	82.3	C_1	82.37	C_1	82.69	C_1	83.0
C_2	11.9	C_2	11.53	C_2	11.96	C_2	11.06
C_3	2.2	C_3	2.22	C_3	2.34	C_3	2.29
C_4's	0.4	C_4's	0.46	C_4's	0.47	C_4's	0.46
C_5's	0.03	C_5's	0.00	C_5's	0.04	C_5's	0.05
C_6^+	0.006	C_6^+	0.00	C_6^+	0.06	C_6^+	0.01
CO_2	2.9	CO_2	3.13	CO_2	2.16	CO_2	2.85
N_2	0.28	N_2	0.29	N_2	0.29	N_2	0.28

Feed Pretreatment

- Solids
- Aerosols
- Free Liquids
- BTEX & Other Aromatics

Membranes

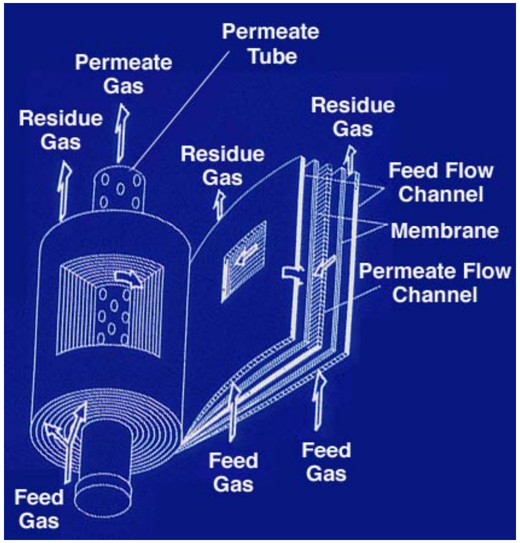
- Grace – KPS USA
- Spiral Wound Cellulose Acetate
- 16 Tubes
- 4 Banks
- 4 Tubes per Bank
- 7 Membrane Modules per Tube

Membrane Modules

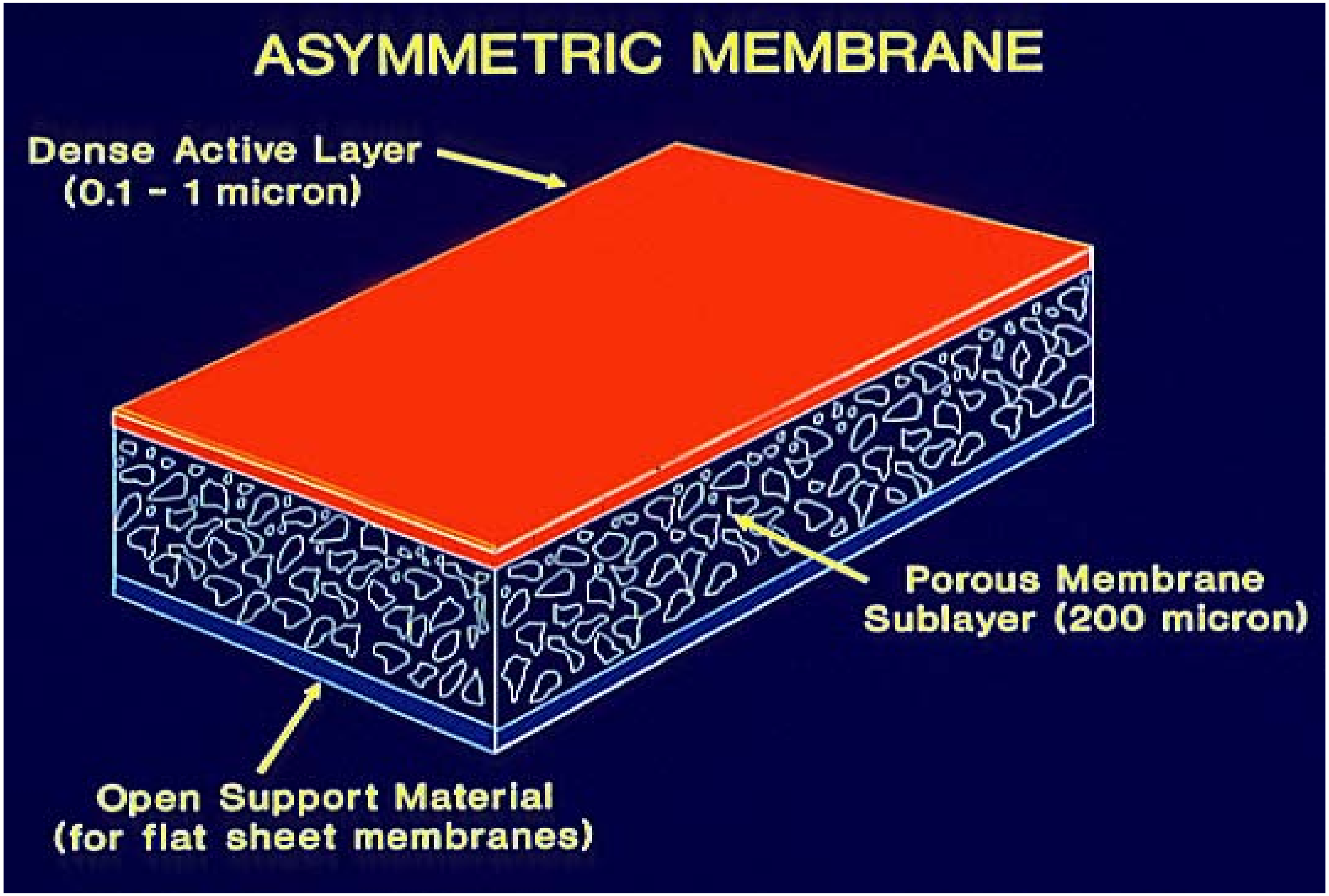
- 8.26” I.D. x 10” Pipe Tubes
- 42” Long Modules/Sections
- Spiral Wound
- About 45 pounds per Module

Grace Cellulose Acetate Spiral Wound Module

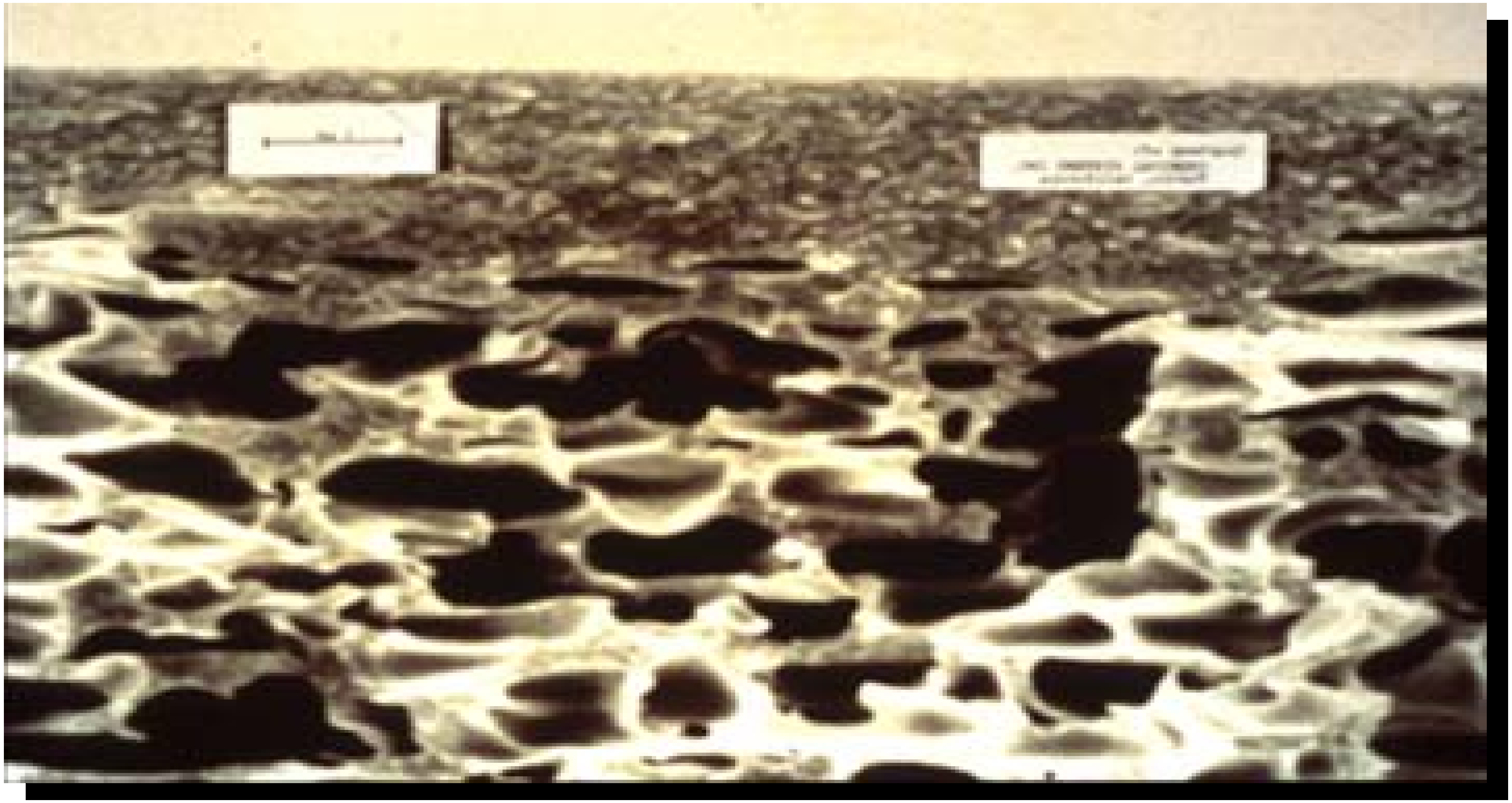
- Manufactured By Grace Since 1984
- Used In Over 220 Natural Gas Applications
- Robust Design – 1800 PSI Differential Pressure
- Light Weight/Easy To Handle – 8.25” (Diameter) x 42” (Long) - < 45 Lbs.



Flat Sheet Cellulose Acetate Membrane



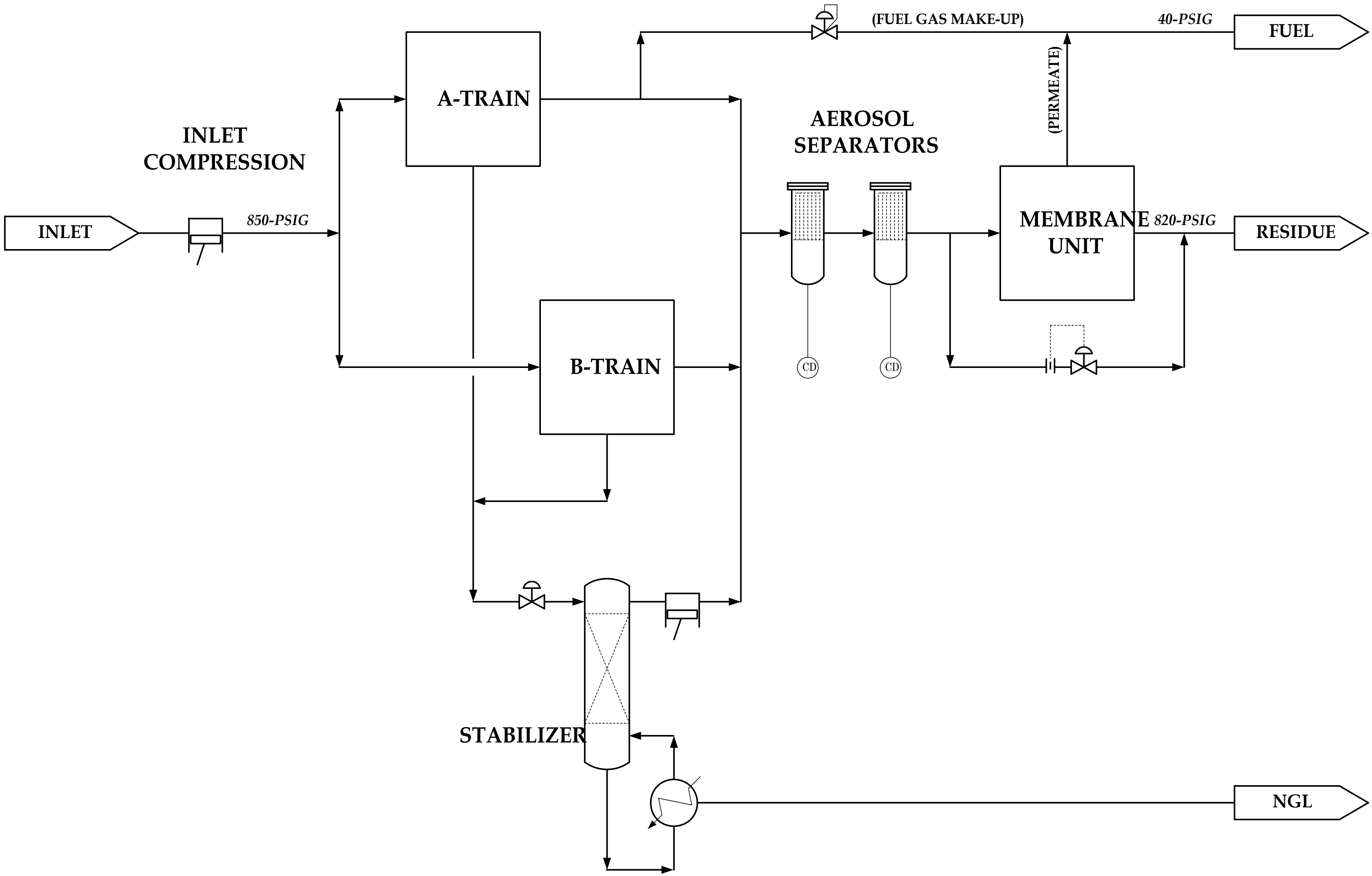
Flat Sheet Cellulose Acetate Membrane



The photo above is an electron microscopic image of a typical flat sheet membrane.

Initial Membrane Loading

- 84 Membrane Modules
- 21 Modules per Bank
- 50% of Area in Service
- 2 Banks on Line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STABILIZER
NGL


500LBS MAX
AKER KVÆRNER
ROAD CLOSED

Permeate – Fuel Blend (Mole%)

Permeate		Blended Fuel	
C_1	77.27	C_1	76.7
C_2	6.70	C_2	11.89
C_3	0.85	C_3	2.09
C_4's	0.17	C_4's	0.32
C_5's	0.00	C_5's	0.03
C_6^+	0.00	C_6^+	0.06
CO_2	14.68	CO_2	8.71
N_2	0.33	N_2	0.20

Fuel Requirements

- Engine Performance
- Lower Btu – Higher Flow
- Emissions Performance
- “Contaminant” Content
- Air Fuel Ratio Controllers
- Variability

Residue Sales Quality

- CO_2 on Spec (<3%)
- Wobbe on Spec
- Btu on Spec
- S.G. on Spec
- Less Water
- Less H_2S

Conclusion

- Cost Effective
- Rapid Deployment
- Flexible
- Simple
- No Waste
- Easy to Redeploy

Q & A

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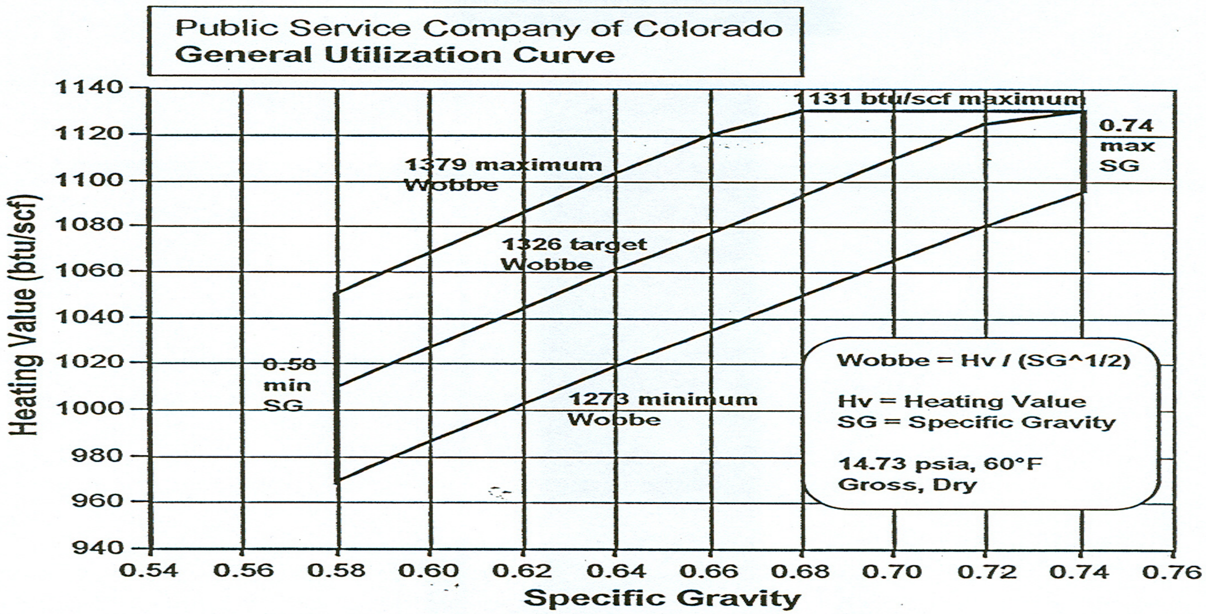
Effective Date Of Agreement: 2/15/99
Effective Date of Exhibit: 7/15/99

EXHIBIT "C-2"

GAS UTILIZATION CURVES

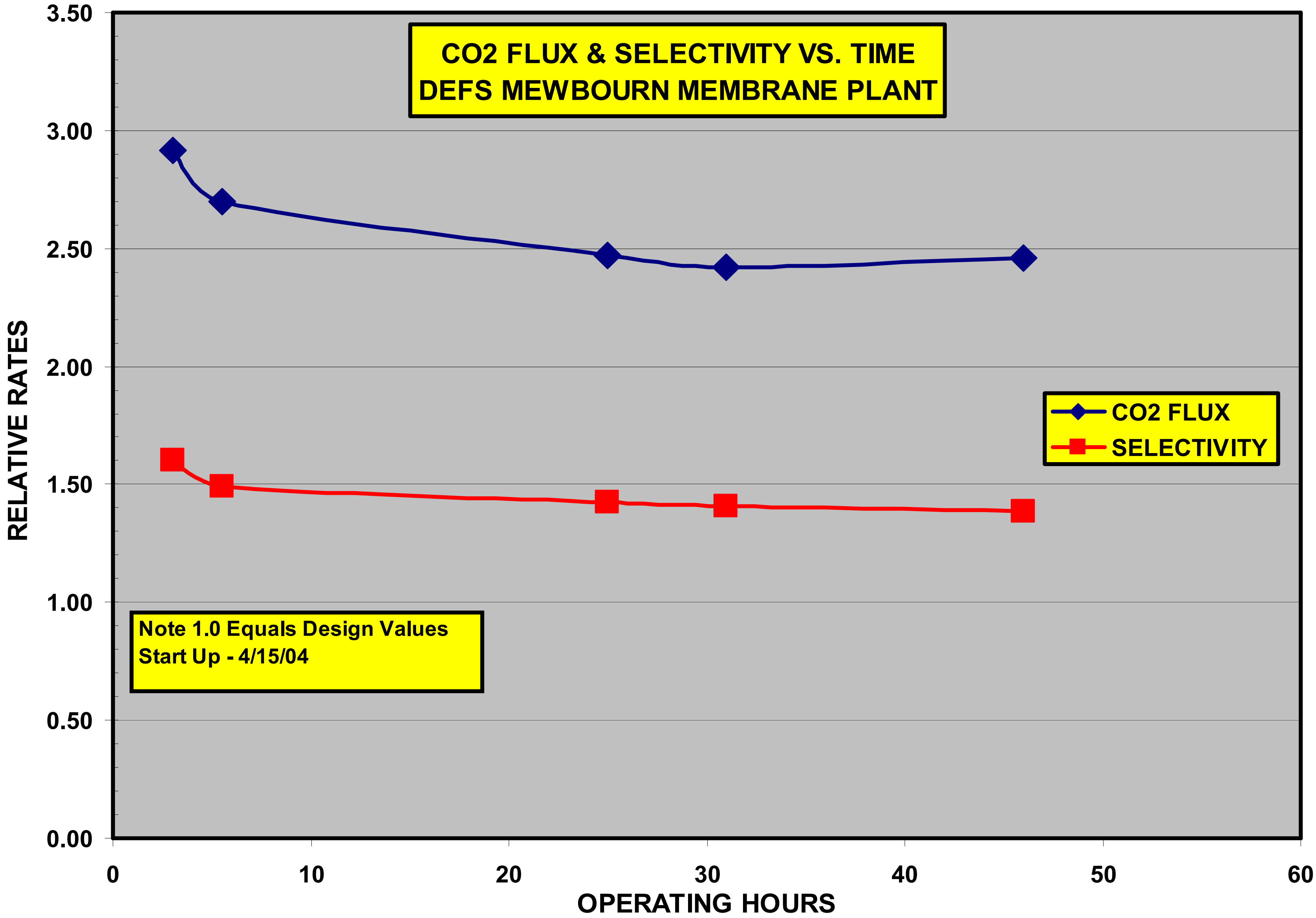
General Utilization Curve



The Utilization Curve is a general representation of the natural gas quality that is acceptable from a utilization standpoint. However, the gas composition must be known to determine if a supply is acceptable and can be interchanged with supplies in Company's system. Company reserves the right in all instances to evaluate gas composition to determine system compatibility and to refuse any gas that is unacceptable from a utilization basis.

CA Spiral Wound Membrane Loading

KPS US – DEFS Mewbourn Membrane Plant



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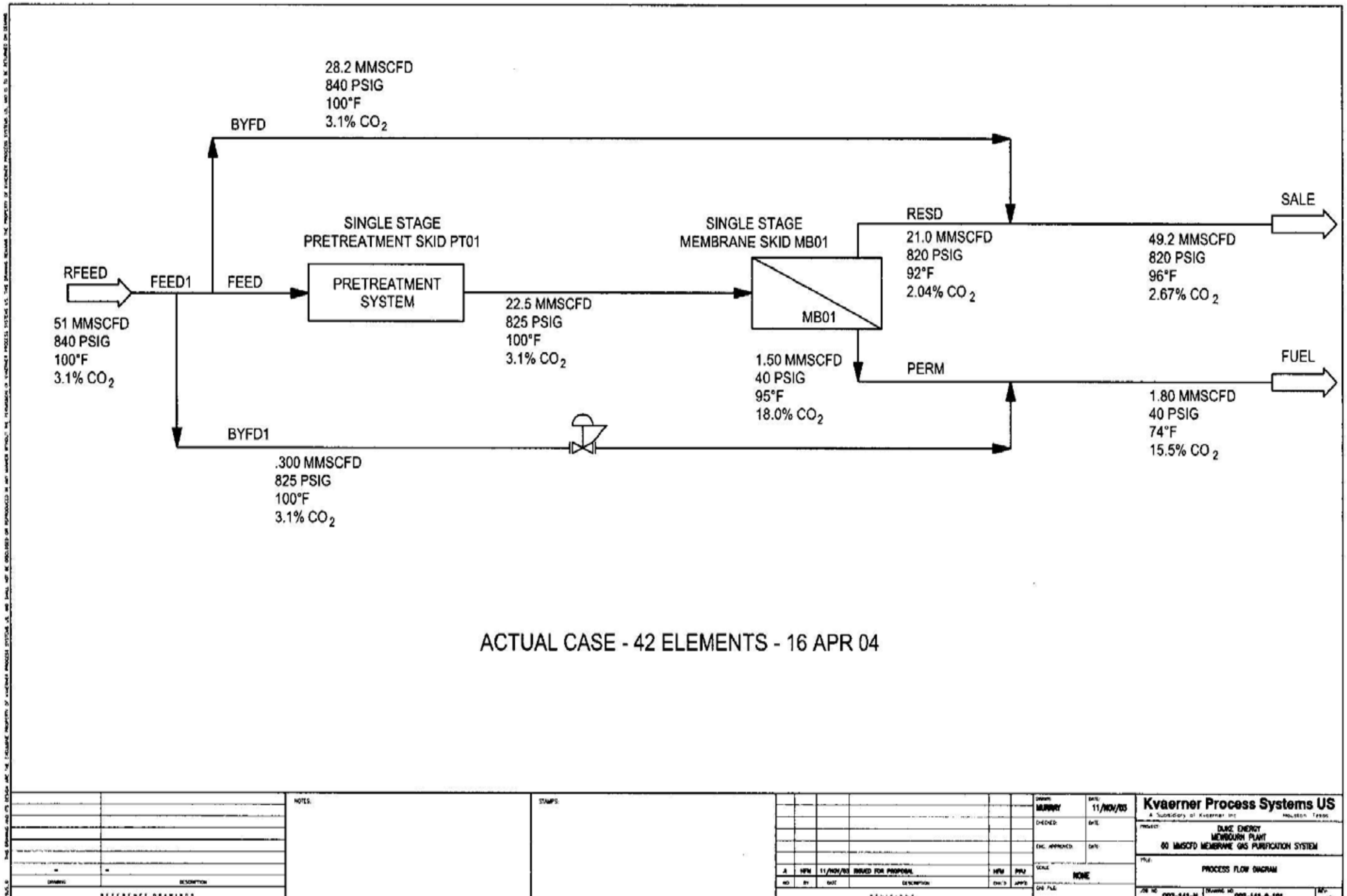

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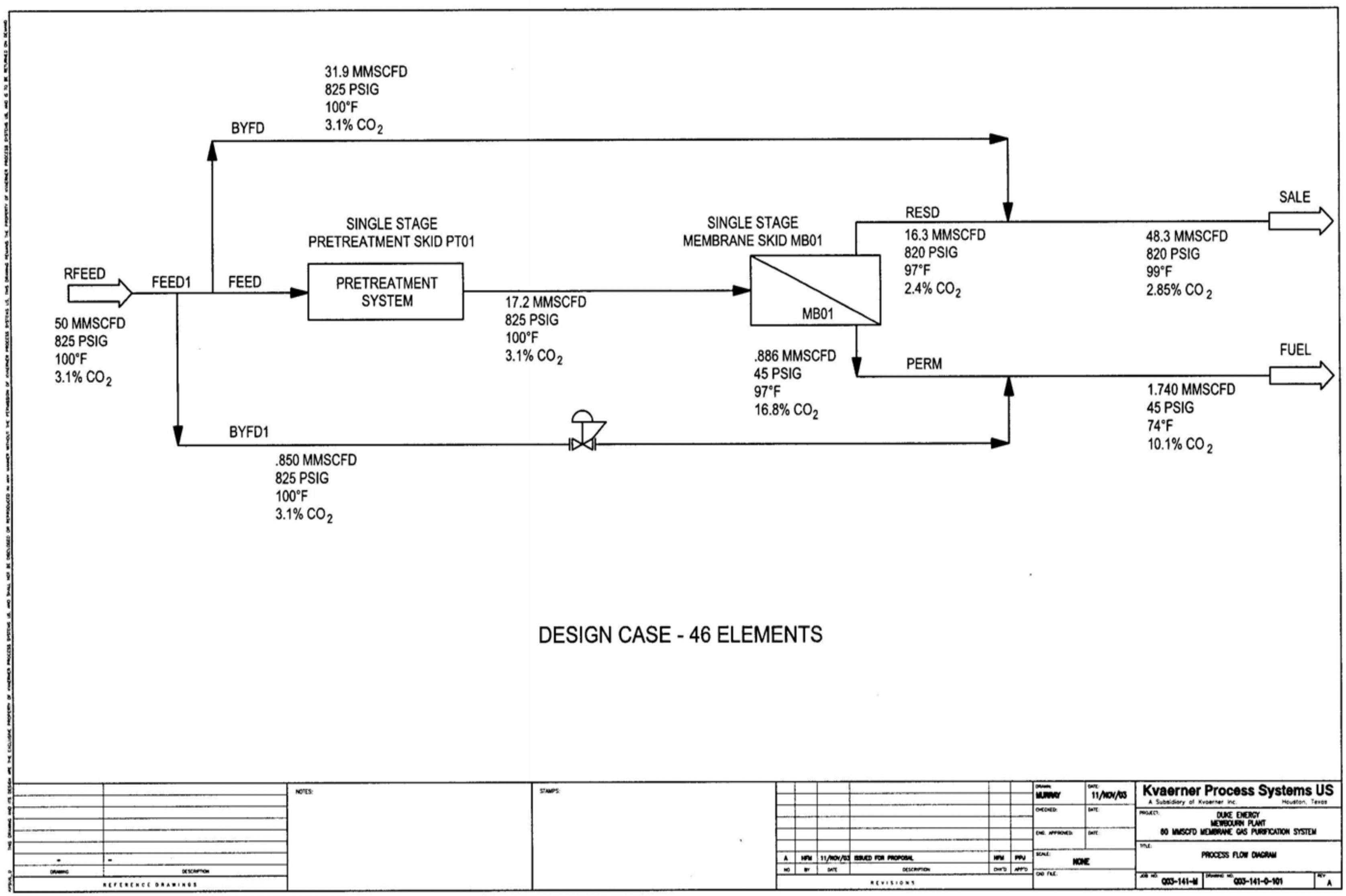
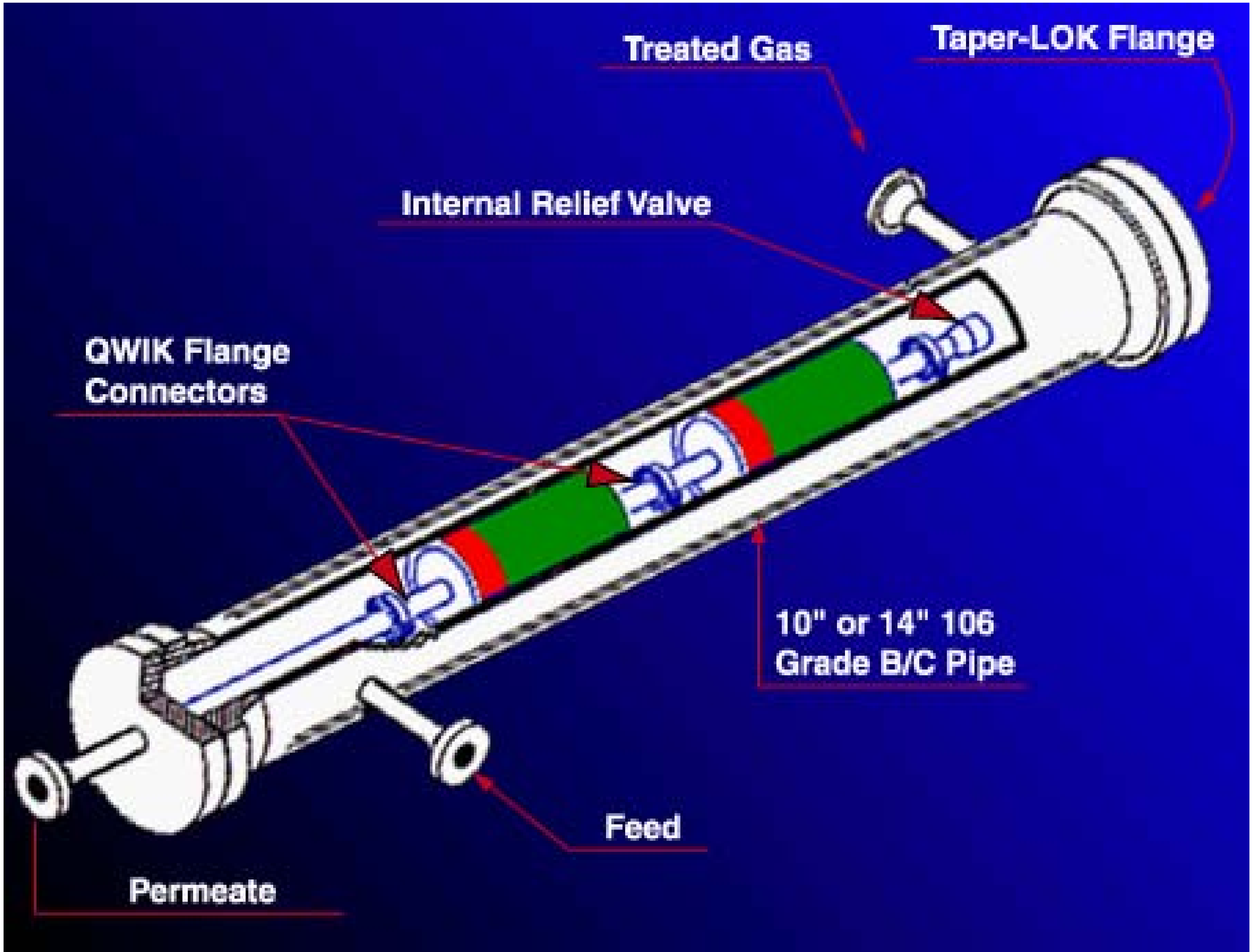
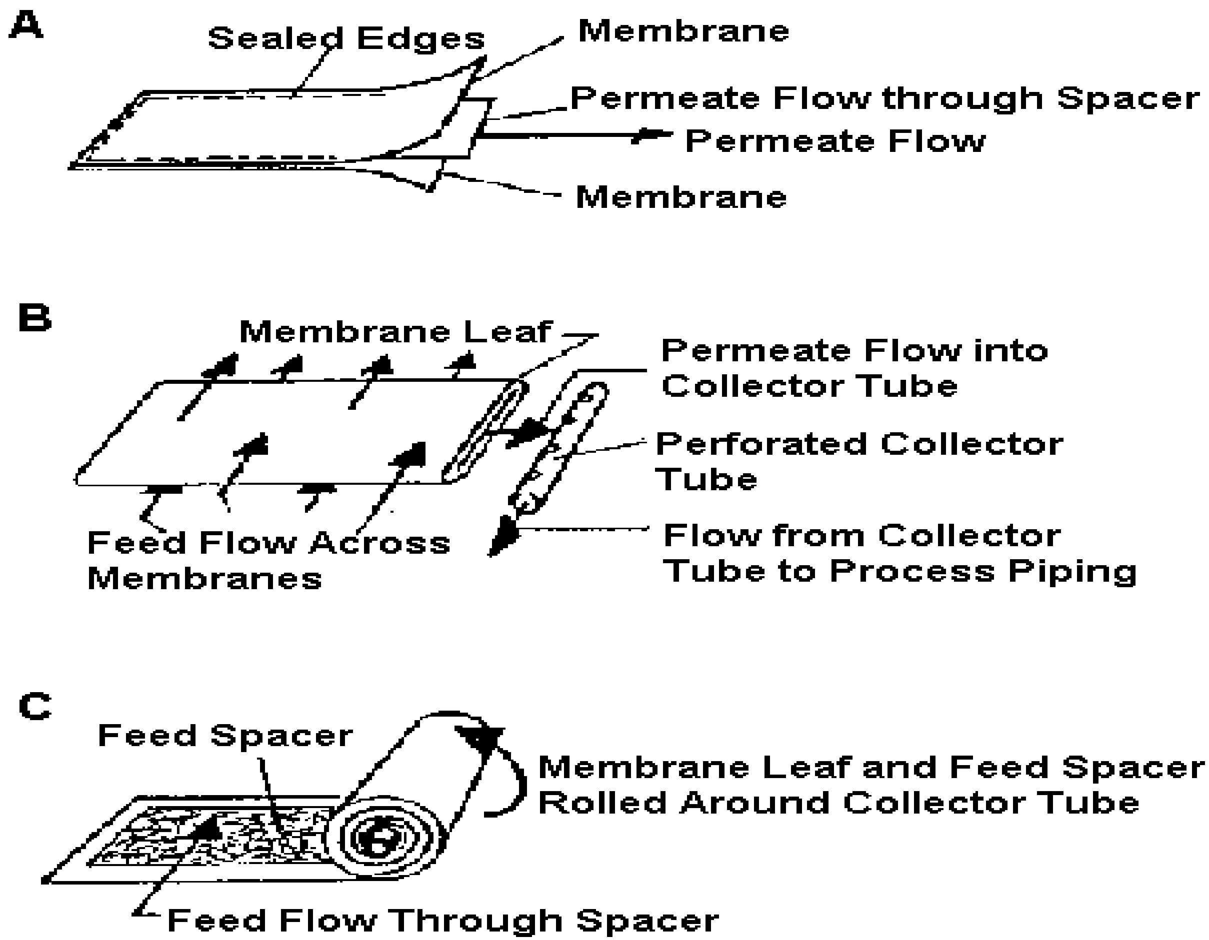


CA Spiral Wound Membrane Housing Design



Grace Spiral Wound Membrane Construction



Grace Spiral Wound Membrane Construction

GRACE Cellulose Acetate
Spiral Wound Membrane