HIGH PERFORMANCE CONTAMINANT RESISTANT MEMBRANES MINIMIZE PRETREATMENT AND IMPROVE CO_2 REMOVAL ECONOMICS

Kaaeid A. Lokhandwala and Ankur Jariwala
Membrane Technology and Research, Inc. (MTR)

Michael G. Malsam
Randall Gas Technologies
A Division of ABB Lummus Global (ABB)

MTR

Outline

- ABB–Randall Gas Technologies/MTR Alliance
- Composite Membranes
  - Materials selection flexibility
  - Improved stability and fouling resistance
- Carbon Dioxide Separation
  - Increasing the Range of Applications
  - Membrane Design aspects for Producer Success in Gas Field Applications
  - Design Issues to Consider in Membrane Process Design

MTR

ABB–Randall Gas Technologies and MTR

Alliance in the Area of Natural Gas Processing

- Randall Gas Technologies
  - A division of ABB Lummus Global (ABB), An international EPC company
  - A gas processing technology and engineering company
  - Vast Experience in Gas Processing Plant Design and Engineering
- Membrane Technology and Research, Inc. (MTR)
  - A supplier of membrane gas separation systems
  - A leader in membrane and membrane process development
  - Commercialized several types of membranes addressing various separations such as remote gas conditioning, H_2S separation, N_2/CH_4 separation.

MTR

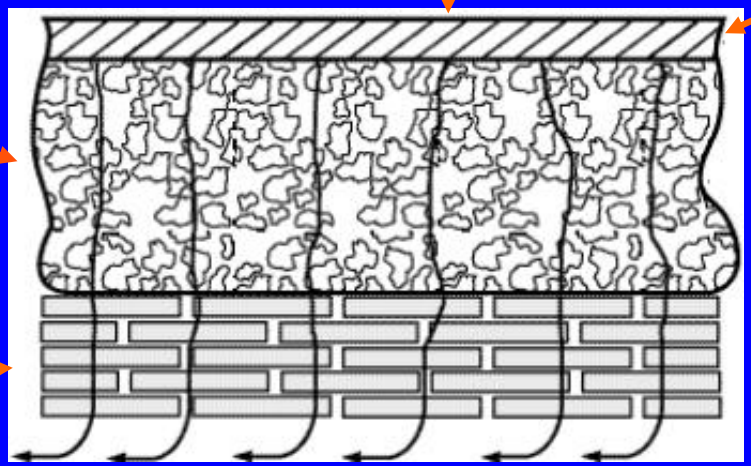
Composite Membranes

Flexibility in Membrane Design and Manufacturability

Nonporous Coated Selective Layer

Microporous Support Layer

Support Fabric



Composite Membrane

Desired Properties

- High permeability
- High selectivity
- Chemical resistance

Desired Properties

- No mass transfer resistance
- Mechanical strength
- Chemical resistance

MTR

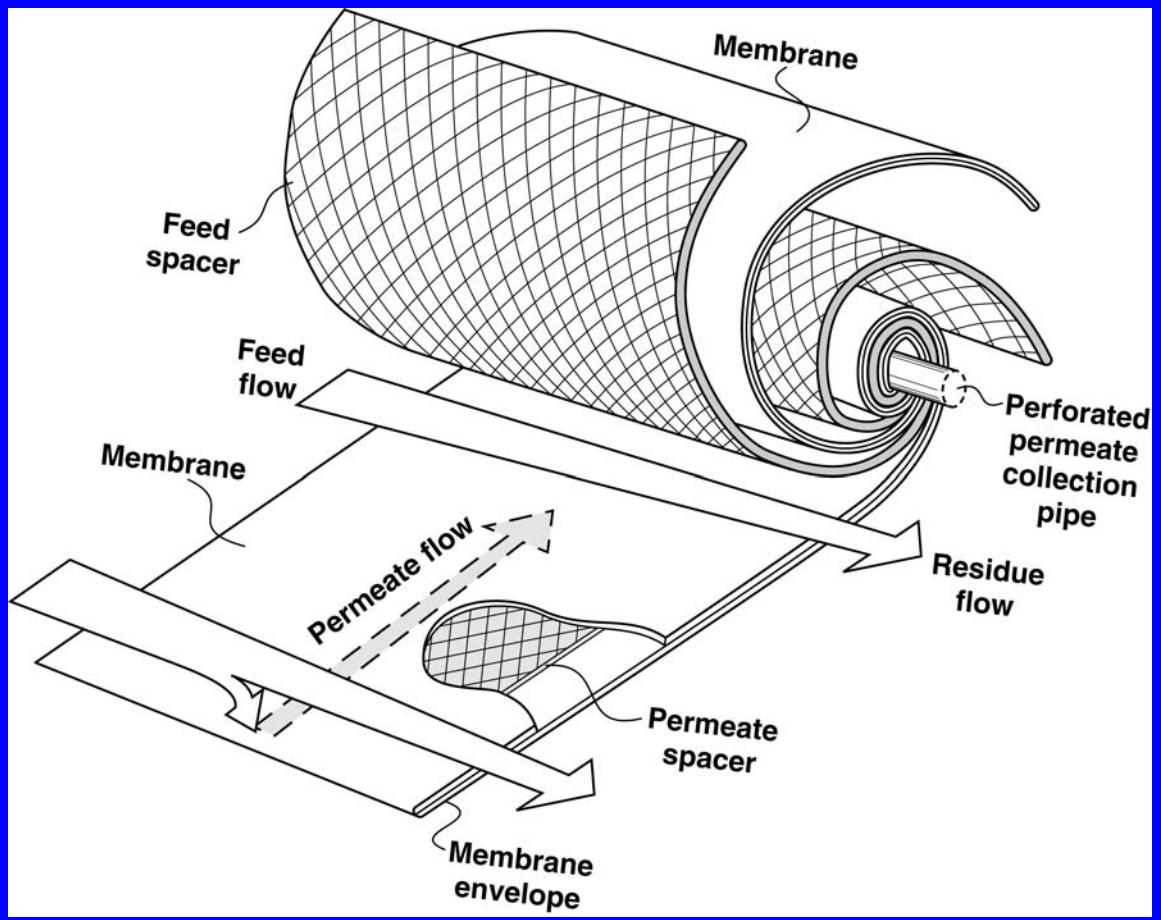
Membranes Packaging

Spiral-Wound Modules

Each module contains

20 to 50 m^2 of membrane

Area



MTR

Possibility of Membrane Fouling
Process Design Concern

Potential Foulants in Natural Gas

- Mercury
- Salt
- Asphaltenes
- Waxes
- Water
- Compressor Oil
- Lubes and Additives
- Mercaptans
- Oxygen
- Aromatics
- Glycols
- Methanol
- Amines
- Sulfur

MTR

CO_2 Separation

US Market Applications

MTR

CO_2 Separation
US Market Applications

- MTR/ABB have combined with Dominion Field Services to market treating services for high-CO_2 natural gas. Allowing producers to bring additional gas to market.

- The approach has been to develop a complete standardized process and equipment solution including inlet piping, compression, and pretreatment to provide a one-stop solution for independent producers.

- This has been accomplished by focusing on several key process and engineering aspects which are discussed below in more detail.

MTR

Design Aspects
Limited Pretreatment

- Pretreatment consists of
  - using filter/separators and
  - managing temperatures to control hydrocarbon dew point.
- The gas from the recycle compressor requires only a filter/separator to remove lube oil and trace contaminates. However, investment in a small sacrificial carbon guard bed could be economically justified by the extra protection provided.
- The feed is conditioned to remove water, thus avoiding free water formation that would cause corrosion.
- For gases rich in heavy hydrocarbons, the feed is also superheated in a field heater to avoid hydrocarbon condensation

MTR

Design Aspects

Wide Range Of Applicability

- These standard CO_2 membrane skids are designed for contract CO_2 treating on the U.S. Gulf Coast by Dominion Field Services
- The membrane treatment solution designed to be operationally more flexible and have a higher net gas recovery compared to amine-based alternatives.
- Typical CO_2 treatment ranges from 3-11 mol% CO_2, and from 2-10 MMSCFD flow.
- The membrane system is designed for wide turndown. Nominal performance for the larger model standard skid is 7 MMSCFD of feed containing 7 percent CO_2, with 2 percent CO_2 in the sales product.
- A wide range of NGL content is accommodated. The feed can be very lean coal seam type gas or associated gas with a few gal/1000scf NGL.

MTR

Design Aspects
High Btu Recovery

- Minimal gas shrinkage, high Btu recovery was a prime objective in the CO_2 process development we are describing. Gas shrinkage comes from compressor fuel requirements and methane lost in the CO_2 vent.

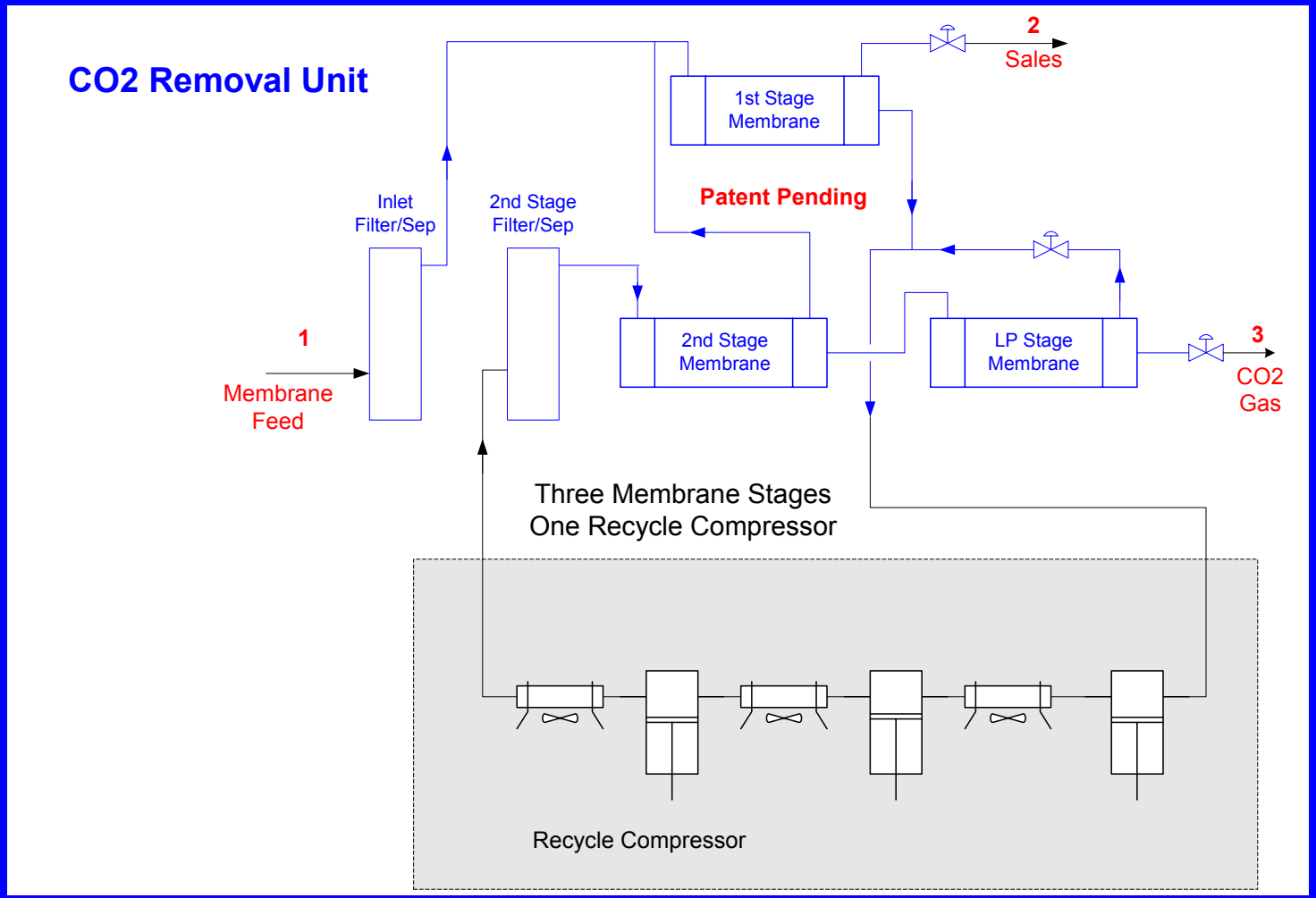
- In order to compete with amine units, gas shrinkage must be small. Historically, gas shrinkage of membrane systems was competitive at higher CO_2 concentrations, but suffered particularly high methane losses with 3-11 percent CO_2 in the feed.

- MTR/ABB's new patent pending process has three membrane stages for high recovery mated with a single standard three-stage reciprocating compressor typically found in gathering systems.

- For many applications, gas shrinkage is less than 2 percent of the inlet gas.

MTR

Process Flow Diagram
3 Stage Membrane Process



Design Aspects
Scope Of Facility

- The skid was designed with minimal field construction in mind.
- The membrane system and filter separator are supplied as skid mounted systems.
- The system includes a complete PLC-based control system.
- It only takes a few hours to unload and set the skid mounted equipment.
- No equipment requires foundations. Normally, soil is compacted and equipment is placed on pads topped with gravel.
- The relatively light and small equipment is easily transported and unloaded on-site. The membrane skid is similar in size to the direct fired reboiler used on a comparable amine system.

MTR

Design Aspects
Minimized skids – Rapid Deployment

- A typical installation has
  - the membrane skid
  - the membrane filter/separator skid
  - a skid mounted recycle compressor
  - a skid for auxiliary equipment
  - a portable building.

- Dominion is building an inventory of membrane units and other equipment for rapid deployment. This allows the producer to begin production ASAP. It also makes the project schedule for installing this membrane solution very competitive with the reinstallation of an existing amine system.

MTR

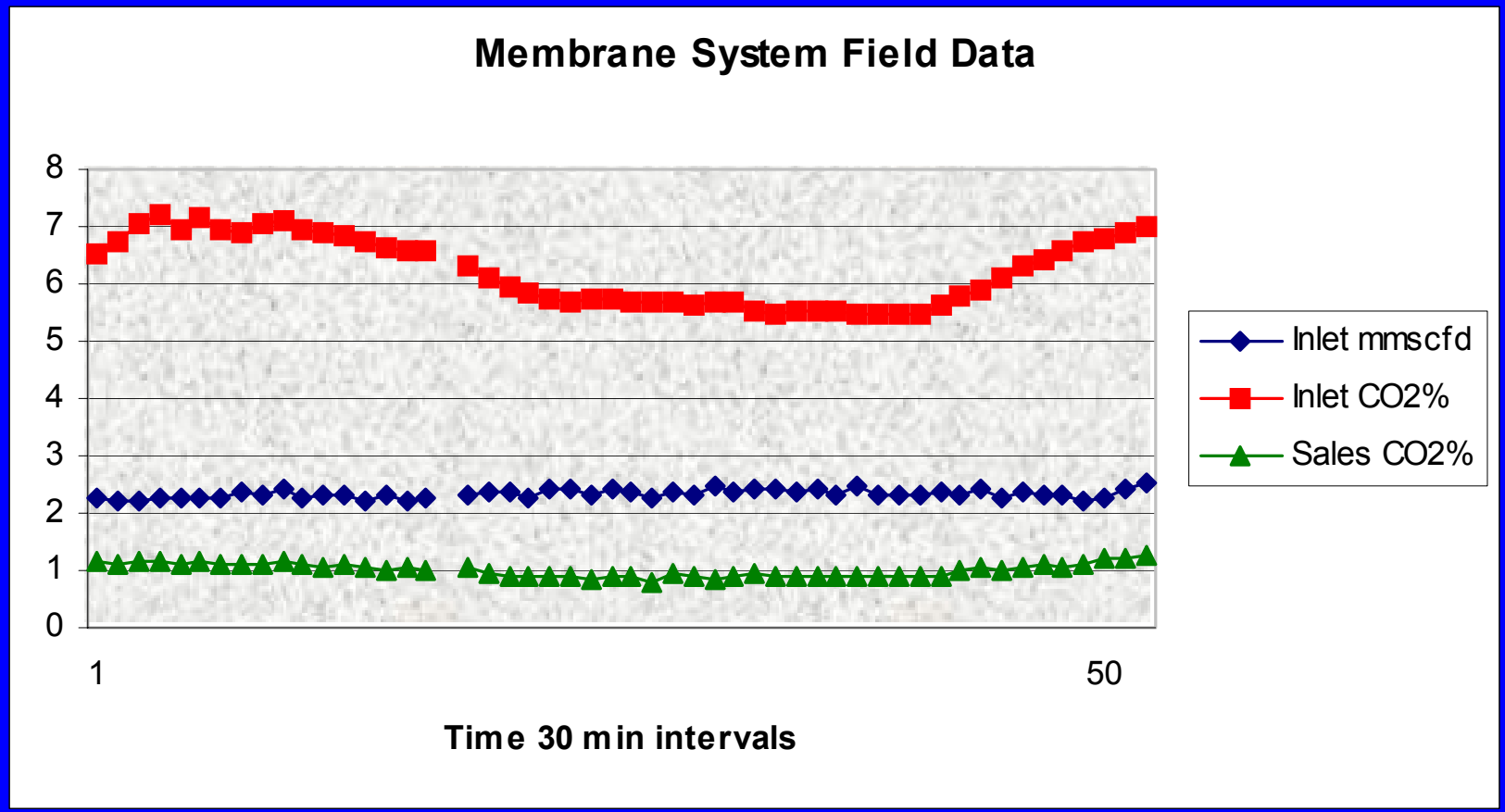
Startup and Performance Tests
Dominion E&P – Sheridan, Texas

- Dominion's Alverstone unit near Sheridan, Texas, has been in operation since April 2006.
- Alverstone unit was designed for a feed pressure of 975 psig and 5.125 mol-% CO_2
- Start-up conditions were a feed of 6.4 mol-% CO_2 at 710 psig. Initially, the membrane skid was only half loaded because available gas volumes were low.
- The membrane unit lowered the CO_2 in the sales gas stream to 1.83 mol-% during the performance test.
- The vent stream averaged 78.4 mol-% CO_2; this allowed 98.8 % retention of the membrane inlet Btu value in the sales gas stream.

MTR

Performance Data – Site Variability

Dominion E&P – Sheridan, Texas



Potential Design Issues To Consider – 1

- ***Dew Point Management***
  - Before proceeding with a project, information regarding gas temperature, pressure and detailed gas composition should be known.
  - Typically, 30 degrees of super heat is applied to the gas before being processed through the membranes.
  - The membrane itself is tolerant of NGL liquids, but continuous two-phase flow must be avoided. Crossing over into the dew point region has been observed in the field.
  - The presence of liquids reduces mass transfer. When proper temperature is restored, the membrane dries out in a few minutes and performance fully recovers.

MTR

Potential Design Issues To Consider - 2

- ***Safe Purging***
  - A system must be safely purged to remove air before start-up.
  - Reverse pressurization on the membrane modules during purging can cause severe mechanical damage to membrane modules. Attention to details during design and operation of the unit are necessary.
  - The membrane include a PLC program to assist the operator during purging.
  - The PLC provides instructions and opens and closes automated valves during purging.

MTR

Potential Design Issues To Consider – 3

- ***Safe Shutdown***
  - A safe and systematic shutdown of the membrane system is performed by the PLC.
  - The system is isolated and blown down on shutdown.
  - The membrane system includes special blow-down valves designed to prevent condensation of NGLs that can occur during shutdown.

MTR

Potential Design Issues To Consider – 4

- ***Automated Operation***
  - The membrane system is controlled from the PLC screen.
  - The PLC screen has a graphical user interface for easy operation.
  - Start-up and normal operation of the unit can be achieved without opening or closing any manual isolation valves on the membrane skid.
  - The PLC system has been successfully interfaced with a SCADA system for remote monitoring.

- ***Startup Time***
  - Routine start-up of the membrane system can be achieved in a few minutes.
  - Membranes reach steady state quickly.
  - The PLC helps automate start-up, providing instructions to the operator and automatically ramping set points during start-up.
  - A single operator can start the unit. If auxiliary equipment is ready for service, startups typically take only 15-30 minutes.

MTR

Potential Design Issues To Consider – 5

- ***Pretreatment***
  - Although the membranes for this system are engineered to be tolerant of contaminants, gross contaminants should be avoided.
  - A good upstream operation to remove dirt, oil, TEG etc. helps protect the membrane system.
  - The filter coalescer elements before the membrane unit are “last line of defense.” The filter coalescer used in this project removes several quarts a day of lube oil from the recycle gas stream. The filter coalescer on the inlet stream is downstream of a TEG unit.

- ***Upstream Environment***
  - The membrane system needs to be able to tolerate changes in the upstream environment.
  - Frequent changes in gas volume composition and availability are possible due to normal field operations. The automation of the membrane unit keeps it online through most changes in field conditions.
  - The ability to easily restart is a benefit when gas flow is discontinued due to field compression or well problems.

MTR

Summary/Conclusions

- To enable natural gas producers to monetize high-CO_2 gas in the US Gulf Coast, MTR/ABB and DFS have combined to lease a completely packaged membrane solution for acid gas reduction in natural gas.

- Robust membranes that require a minimal amount of pretreatment, using standardized skids and very high Btu recovery processes, have been developed and demonstrated commercially.

- Newer membranes, more predictable designs that are operator friendly, and easy adapted to field conditions, will allow the range of membrane applications to significantly increase.

MTR

Thank You!

Membrane Technology and Research, Inc. (MTR)

1360 Willow Road, Menlo Park, CA 94025

Telephone: 650-328-2228 Fax: 650-328-6580

Website: www.mtrinc.com

and

Randall Gas Technologies

A Division of Lummus Process Technology

ABB Lummus Global

3010 Briarpark, Houston, TX 77042

Telephone: 713-821-4100 Fax: 713-821-3538

Website: www.abb.com\lummus

MTR