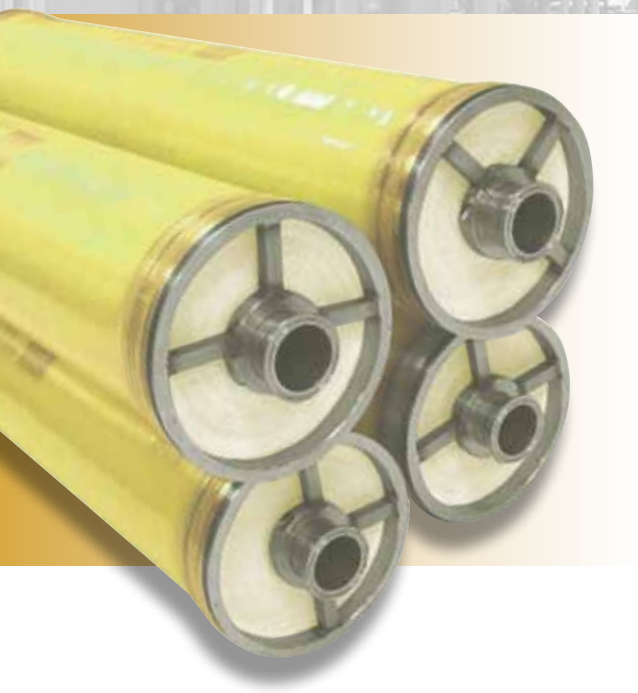


FUEL GAS CONDITIONING

FuelSep™

(REMOVE H_2S, C_{3+}, CO_2, N_2, H_2O)

- **Upgrades raw gas to premium quality fuel gas**
- **Generates quality fuel gas right at the point of use — no trucked in diesel required**
- **Premium fuel quality increases engine and turbine life, eliminates de-rate, and brings emissions into compliance**
- **Avoids downtime due to unscheduled shutdowns**
- **Increases NGL recovery downstream**

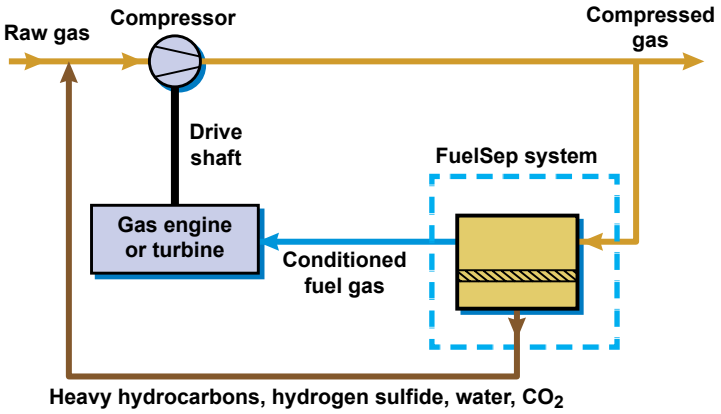
"Conditioning fuel gas using FuelSep™ minimizes costly unscheduled downtime — a smart and simple solution."

MTR Membrane Technology & Research

Problem

Raw gas often cannot be used to fuel the gas engines or gas turbines driving pipeline compressors due to poor quality. Significant concentrations of H_2S and/or C_{3+} causes corrosion and carbon build-up in the gas engine. CO_2 and nitrogen lowers the BTU value. Any of these impurities can compromise engine operation, increase downtime or at a minimum put emissions out of compliance. Their presence in the raw gas can even render the gas unusable as fuel so expensive diesel has to be trucked in.

Membrane Solution



MTR's FuelSep™ systems purify raw gas sidestreams to premium quality fuel gas. MTR membranes easily remove H_2S, C_{3+}, CO_2, N_2 and water from fuel gas at moderate pressure. Because these impurities are taken out of the fuel gas and returned to the compressor suction, there are no effluent streams to be disposed of. Any C_{3+} removed from the fuel gas goes back into the main gas stream, so all NGL in the raw gas stream is available for downstream recovery, if desired.

These units have no moving parts, are simple to install and operate unattended. Many units are operating worldwide.

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FUEL GAS CONDITIONING

FuelSep™

FuelSep® unit operating in Texas

Benefits

- Removes heavy components such as C_{3+} to clean up fuel gas
- Removes significant portions of acid gases such as H_2S and CO_2 that will reduce acid formation in the turbine or engine exhaust and reduce emissions
- Increases reliability of gas engines and turbines
- Operates at ambient conditions with no external heating required to prevent hydrate formation
- Eliminates need to de-rate gas engine
- Decreases maintenance costs and reduces unscheduled downtime
- Contains no moving parts, simple to operate and maintain
- Reduces NMHC emissions
- Retains all valuable NGL in pipeline

System Performance

Gas Turbine Unit

- Feed flow rate: 5 to 15 MMscfd
- Raw feed C_{3+} content: 4 to 20 vol%
- Raw feed dew point: 80°F to 120°F
- Conditioned gas dew point: 40°F to 60°F
- C_{3+} removal: greater than 70%
- Unit dimensions and weight: 20 ft (L) x 6 ft (W) x 10 ft (H), 12,000 lb

Gas Engine Unit

- Feed flow rate: 0.5 to 5 MMscfd
- Raw feed Btu value: 1100 to 1500 Btu/scf
- Conditioned fuel gas Btu value: 1000 to 1100 Btu/scf
- Feed dew point: 80°F to 120°F
- Conditioned gas dew point: 40°F to 60°F
- C_{3+} removal: greater than 70%
- Unit dimensions and weight: 20 ft (L) x 6 ft (W) x 10 ft (H), 12,000 lb

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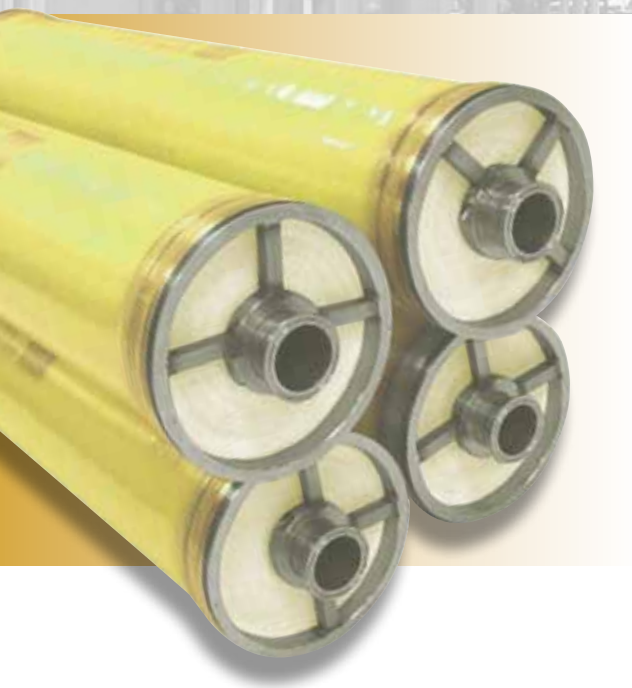

MTR Membranes for CO_2 Removal

Orion™, Z-Top™, Pegasus™, Polaris™

MTR's diverse membrane portfolio offers high-efficiency and cost-effective acid gas separation solutions, tailored to minimize operating costs and boost production capacities.

Company Background

Membrane Technology and Research, Inc. (MTR) is a worldwide recognized leader in the development and production of membranes and membrane-based solutions for gas processing and treating applications in the natural gas, petrochemical and refinery process industries.

MTR has designed, engineered, fabricated, and commissioned over 300 membrane separation plants for a variety of applications for both onshore and offshore locations worldwide. MTR's state-of-the-art membrane systems are based on proprietary polymeric materials specifically designed & engineered to perform efficiently in hydrocabon-rich environments, and deliver improved productivity to the end-client .

Membranes and modules are manufactured in the company's manufacturing facility in California, USA. Skids are designed and engineered in-house, fabricated by outside contractors, and shipped as complete units to customer sites. MTR has the demonstrated experience and facilities to deliver customized turnkey solutions engineered to fit the application and the industry.

- **"Made in USA" Membranes**
- **> 300 field installations in various applications**
- **> 160 Patents on membranes/process development**
- **> 30 years of proven history and commercial success in membrane applications & operation experience**
- **60,000 square feet of R&D, manufacturing and office space**
- **Advanced R&D and world-class engineering design teams**
- **Expertise:**
  - **-Complete engineering package for commercial systems**
  - **-Construction by fabricators in US, Europe & Asia**
  - **-Commissioning & start-up support**

MTR MEMBRANE TECHNOLOGY & RESEARCH

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MTR Main Product Lines

MTR supplied N_2 removal system operating in California

Natural Gas

- **Fuel Gas Conditioning -** Upgrading fuel gas by removal of heavy hydrocarbons, CO_2, H_2S & water
- **CO_2 Removal -** Pipeline gas, EOR applications, Biogas
- **N_2 Removal -** Pipeline gas, Offshore platform BTU enrichment, Fuel gas conditioning
- **HC/Water Dew-point Reduction -** Pipeline gas quality
- **Biogas Treatment -** Upgrade quality of gas generated from landfills and bio-digesters
- **Flare Gas Recovery -** LPG and NGL production

MTR supplied LPG recovery system operating in USA

Refinery

- **Hydrogen Purification -** from refinery waste gases and reactor purges
- **LPG & H_2 Recovery -** from refinery fuel/flare gas streams
- **Hydrogen & CO_2 Separations -** in syngas production processes for ratio adjustment.
- **Hydrogen Recovery -** from Ammonia and Methanol plant purge gas

MTR supplied propylene recovery system operating in Middle East

Petrochemicals

- **Propylene Recovery -** from resin degassing vents in polypropylene production
- **Ethylene Recovery -** from resin bin off-gas & reactor column vents in polyethylene production
- **Ethylene Oxide Production -** Recovery of ethylene feedstock from EO reactor purges
- **Fuel Gas Recovery -** Recovery of valuable fuel gas from purge bin offgas
- **Vinyl Chloride & Vinyl Acetate Monomer Recovery -** from reactor purges in PVC and VAM plants.

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MTR CO_2 Membranes Product Portfolio

MTR has supplied several complete commercial membrane plants for removal of CO_2 from natural gas. Various membrane types (size-selective and solubility-selective) and packaging configurations (spiral-wound/hollow-fiber) have been utilized for these plants. Combination of different membrane types and configurations is utilized to either reduce the CO_2 content only, or to remove both CO_2 and heavy hydrocarbons simultaneously and minimize pre-treatment requirements, or any other client-specific requirements.

A comprehensive membrane product line allows MTR to tailor-design a solution to best fit any client-specific needs. MTR's diverse membrane portfolio will assist clients in increasing production capacities and product recoveries, and minimizing operating costs.

Applications - CO_2 Removal

- **Pipeline Natural Gas:** Remove CO_2 & H_2S from natural gas to meet pipeline specs.
- **Enhanced Oil Recovery:** Recover CO_2 from EOR floods & re-inject to improve oil recovery.
- **Biogas Upgrading:** Remove CO_2 and water vapor from landfills & biodigesters to meet pipeline specs.
- **Fuel Gas Conditioning:** Condition the quality of fuel gas for compressor engines, turbines, and power gen-sets.

Operating Range

MTR commercial membrane systems have been demonstrated to perform and adapt to a wide range of field processing conditions. Commercial systems have been operating at feed gas conditions with CO_2 content ranging from 2% to 95%, between 300 and up to 1600 psig pressure.

Product Name	Operating Characteristics	Performance Benefits
Orion™	3 versions available: • High capacity • High selectivity • Balanced productivity & selectivity	• Various options available to meet specific client needs to maximize product recoveries, increase profits and minimize capital outlay • Ideal for debottlenecking existing units and increasing product gas throughput • Drop-in replacement for all existing types of spiral-wound elements
Z-Top™	• High selectivity and balanced capacity	• Increased hydrocarbon recovery leading to higher profits • Lower feed gas & OPEX requiremnets to meet the same product specifications for existing units • Hollow fiber configuration - various sizes and pressure ratings available
Pegasus™	• High capacity and balanced selectivity	• Ideal for bulk removal of CO_2 • Robust against water vapor and aromatics exposure
Polaris™	• High capacity & balanced selectivity • Polar-solubility selective membranes	• Highly robust membranes with minimal pre-treatment

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Orion™ Membrane Product Features

MTR has several years of commercial experience in successful installation of Z-Top™, Pegasus™, Polaris™ and Orion™ membrane types for CO_2 separation in various applications. Orion™ membranes possess some unique characteristics, including **"condensation-mode"** operation-ability, indicated in the below section. Orion™ membranes' robust chemistry & unique packaging characteristics are specifically designed for drop-in replacement of existing spiral-wound membrane modules, resulting in improved productivity & significant savings in operating costs for the end user.

Benefits of Orion™ Membranes

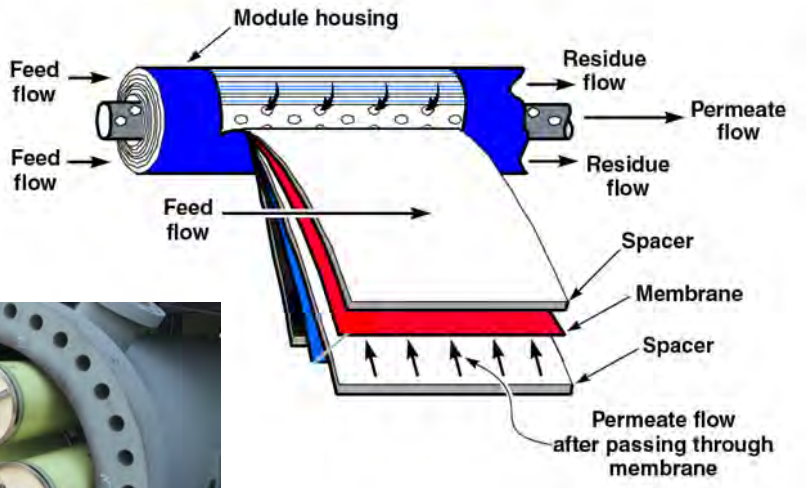
- Robust membrane chemistry leads to superior performance. In some operating ranges, the Orion™ membrane will even outmatch the performance of existing competitors' CO_2 membranes.
- 'Plug-n-Play' drop-in replacement for all existing CO_2 removal plants where spiral-wound membranes are being used. Seamlessly fits into the existing hardware & vessels.
- Proven field-performance operating in **"condensation-mode"** with liquid generation inside membranes.
- High packaging-density compared to currently available membranes in market - Significant reductions in capital and membrane replacement operating costs.

Enhanced reliability and improved membrane life-time, combined with the high packaging-density feature of this state-of-the-art Orion™ membrane, has enabled MTR to become the technology of choice for CO_2 removal applications.

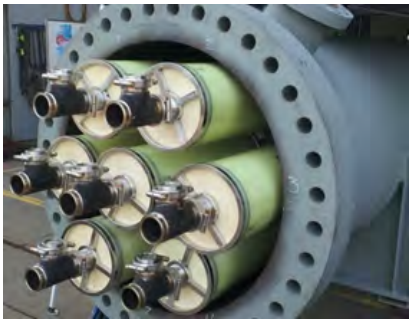
- **Advanced high packing-density membranes for lower operating costs & enhanced reliability**
- **Very low hydrocarbon losses**
- **Compact footprint, lower installation costs**
- **Robust membrane chemistry**
- **Simple, rugged, skid-mounted construction for quick installation**
- **Quick automated startup takes minutes from cold start to steady state**
- **Tolerates a wide range of inlet feed conditions**
- **Excellent turndown capability**
- **Very high availability factor**

Membrane Configuration

Spiral-wound membranes and spacer materials are wound around a perforated central collection pipe. Multiple modules in series are installed inside a tubular pressure vessel.



Spiral-wound type membrane module configuration



Multi-vessel membrane bundle installation in Europe

MTR MEMBRANE TECHNOLOGY & RESEARCH

Field Installations - CO_2 Removal

Alabama & Texas Units

- Feed flow-rate: 2-20 MMscfd
- Feed CO_2 content: 10-40%
- Product CO_2 content: 2%
- Hydrocarbon recovery: > 95%

Offshore FPSO - Far East

- Feed flow-rate: 20 MMscfd
- Feed CO_2 content: 60%
- Product CO_2 content: 40%
- Bulk CO_2 Removal - Turbine Fuel Gas Conditioning

Colorado, USA Installation

- Feed flow-rate: 15 MMscfd
- Feed CO_2 content: 4%
- Product CO_2 content: 2%
- Hydrocarbon recovery: > 95%

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Field Installations - CO_2 Removal

EOR Application - Permian Basin, USA

- Large Enhanced Oil Recovery (EOR) Application for CO_2 enrichment
- Operating in **"condensation-mode"** with gas/liquid phase feed
- Feed CO_2 content: 95% - Product CO_2 content: >98%

Offshore Application - Asia

- Large Offshore Application for CO_2 removal
- Wide range of inlet feed CO_2 content & flow-rate conditions

For more information

For more information on MTR's membrane technology and services provided, please contact your MTR representative or visit us online at www.mtrinc.com

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