Advanced Prism® Membrane Systems
For Cost Effective Gas Separations
Advanced Prism®
Membrane Systems
For Cost Effective Gas Separations

Air Products is a world leader in the supply of gas separation systems and industrial gases. Air Products offers gas separation systems based on cryogenic, adsorption and membrane technologies. Over the last 50 years, Air Products has supplied over 2500 industrial gas plants, owning and operating over 250 of them. This wealth of experience means that for any application, Air Products will be able to recommend the most cost effective and efficient solution for your gas separation requirements.

PRISM® separator membrane technology offers a unique combination of capabilities among gas separation techniques.

**Benefits Include:**
- Ease of operation
- Unrivalled experience
- Demonstrated membrane life
- Excellent on-stream time
- High recovery
- Tolerance of fluctuating feed conditions
- Unaffected by particulates
- Resistance to many chemical contaminants
- Fast start-up/shutdown
- Easily adaptable to changing requirements
- Minimal installation time & expense
- Negligible operator attention
- Minimal maintenance
- Minimal utilities
- Quick delivery
- Small space requirement

PRISM® Separators are operating around the world, recovering and purifying gases for:
- Refinery process streams
- Petrochemical process streams
- Natural gas applications
- Nitrogen production
- Air and gas dehydration

These are some of the 230+ PRISM® separator systems installed for process gas separation since 1977.
EASE OF OPERATION

PRISM® separators require virtually no adjustments, no maintenance, no operator attention. One operator summed it up by saying, “It’s like operating a piece of pipe”.

EXCELLENT ON-STREAM TIME

The ability of PRISM® separators to maintain proper operation under varying process conditions and to tolerate various contaminants results in excellent on-stream time. In most applications, on-stream time is equal to feed availability.

HIGH RECOVERY

Hydrogen, CO₂, or hydrocarbon recoveries of 80-95%+ can be obtained for most applications. Recoveries in the range of 95% can be expected in ammonia purge recovery applications.

OPERATES UNDER FLUCTUATING FEED CONDITIONS

PRISM® separators produce a relatively constant quantity of permeate gas, even when the system feed stream experiences fluctuations in pressure, flow rate or concentration. When exposed to fluctuating feed purity and pressure, the separators operate efficiently while dampening fluctuations in both the permeate and retentate product streams.

FAST START-UP/SHUTDOWN

Start-up and shutdown are simple and rapid. Recovery begins immediately after gas is fed to the system. No cool down or preconditioning is required.

DEMONSTRATED MEMBRANE LIFE

PRISM® separators have been operating in a wide variety of services - some since 1977. Over 2,000 years of field experience have proved that long membrane life can be expected.

OPERATING FLEXIBILITY

PRISM® separators offer unique operating flexibility when planned or unexpected process changes occur. Increased capacity requirements can be handled by the simple addition of more separators. Some turndown is accommodated automatically. Additional turndown is accomplished by valving off the appropriate number of separators to maintain desired recovery and purity values. Multiple takeoffs from the permeate manifold are possible if streams of different purities and flow rates are required. Also, because the separator system is skid mounted, it can easily be moved to different plant locations, should needs change.

MINIMAL INSTALLATION TIME AND EXPENSE

The systems are skid mounted to minimise field installation time and expense and to reduce potential construction errors. Site preparation is minimal, requiring only a simple concrete support pad and installation of appropriate process and utility lines. Tie ins to the pre assembled system usually require no special shutdown.

MINIMAL MAINTENANCE

PRISM® separators are virtually maintenance-free when properly installed and operated within design conditions. The separators contain no moving parts to monitor, repair, or replace. If pre treatment or compression is required, typical maintenance should be expected for these portions of the system.

MINIMAL UTILITIES REQUIRED

Utility consumption is normally limited to instrument air and steam or water for temperature control. Additional utilities would be required only for those applications where specialised feed gas pre treatment is required.

SMALL SPACE REQUIREMENTS

Because of the simplicity and compact size of the skid mounted system, it can be easily fitted into small or crowded plant areas.

QUICK DELIVERY

A delivery time of 6 to 12 months after order entry means quick payout of your investment.
The first PRISM® SEPARATORS were installed in an oxo-synthesis gas stream in Texas, USA. The system adjusts the ratio of carbon monoxide to hydrogen to meet the stoichiometric requirements of a continuous process reaction.

The amount of hydrogen removed from the gas stream can be varied to meet specific process requirements. PRISM® SEPARATORS have operated in this plant without additional energy usage since March, 1977.

This two stage PRISM® SEPARATORS system recovers hydrogen from an ammonia purge stream in Louisiana, USA. The system recycles 90% pure hydrogen to the process synthesis loop. A water scrubber is used for pre-treatment to reduce feed stream ammonia concentration. The system has operated successfully since September, 1979.

This PRISM® SEPARATORS system upgrades a portion of a naphtha hydrotreater off gas stream for use as makeup hydrogen to a hydrocracker in California, USA. This system was designed to produce high purity hydrogen (>97%) over a wide range of system feed quantities and feed purities.

Since start-up in June 1980, the PRISM® SEPARATORS system has met or exceeded all design expectations and has been essentially maintenance free. On-stream time has equalled feed stream availability.
**PRISM® Separators** are extremely well suited to CO₂ applications because of their ability to accommodate fluctuations in feed gas composition and flow rate with minimal adjustment of operating variables. The system is configured to provide for easy adjustment for large variations in gas compositions and flows. CO₂ removal capacity can be readily brought on stream or taken off-line as required.

**PRISM® Separators** can be used effectively in several process schemes. For bulk removal, the separators can be used as a topping unit to recover a portion of the produced CO₂ while maintaining a constant CO₂ molar flow rate to existing gas processing facilities downstream. This allows for maximum utilisation of existing plant equipment and has proven, favourable economics. Using the separators to reduce retentate CO₂ content to 8-10% is also practical for many gas processing applications.

In this instance a recycle stream is often used to increase hydrocarbon recovery. Site specific economics may favour reducing the residual CO₂ content below 8%. Any remaining CO₂ can be removed, if necessary, by conventional polishing techniques.

Each system is designed and configured to meet the projected casing head gas compositions and flows. Operating pressure, temperature, and CO₂ return pressure are selected to minimise overall compression requirements and to limit pre treatment to air cooling, liquid knockout, and reheating. Energy for reheating is obtained from compression of the casing head gas.

**CO₂ Recovery From Associated Gas**

**PRISM® Separators** recover CO₂ that dilutes the hydrocarbons in the casing head gas after CO₂ breakthrough. The typical system will recover 90% to 95% of the CO₂ at purities ranging from 90 to 97%. This recovered CO₂ can be combined with additional CO₂ for re-injection.

**Simplified Pre-Treatment**

In most CO₂ applications, heavier hydrocarbons must either be removed initially or the membrane operating temperature be maintained high enough (65-100°C) to prevent their condensation. These hydrocarbon liquids cause decreased membrane flux rates. A major advantage of **PRISM® Separators** is their ability to operate at temperatures over 95°C. This capability provides protection against condensation problems and greatly reduces the need for elaborate pre-treatment of the casing head gas.
HYDROGEN RECOVERY FROM AMMONIA PURGE GAS

PRISM® SEPARATORS operating in ammonia purge recovery systems can recover up to 95% of the available hydrogen. This recovered hydrogen can be made available at purities in excess of 98% either for recycle to synthesis loop or for use in other processes.

Where the hydrogen is recycled to the ammonia plant, it can be used to increase production or, if extra ammonia capacity is not required, the natural gas feed to the reformer can be reduced, thus saving energy.

A third alternative is to use PRISM® SEPARATORS for a combination of incremental production and natural gas savings. The retentate gas from the hydrogen recovery system is returned to the primary reformer as fuel.

The system also recovers essentially all of the ammonia in the purge gas stream as an aqueous solution, or as anhydrous ammonia by incorporating a distillation package.

This PRISM® SEPARATORS system was the first to be installed on an ammonia plant in 1978. The typical system includes a high pressure water scrubber to recover ammonia presently lost in the purge; concentrations of aqueous ammonia are normally in the region of 15-20% NH₃, but can be higher if required. Recovery of 99.9%+ of the ammonia virtually eliminates all NOₓ emissions due to combustion of purge ammonia.

The scrubbed gas is then processed in a series of PRISM® SEPARATORS to recover up to 95% of the hydrogen at high purity. Water and ammonia do not affect the operation of the system.

Normal fluctuations in ammonia plant operating conditions can easily be tolerated. For larger changes, the separator system can be adjusted to work in harmony with the operating conditions of the plant by simply valving off or valving on separators. For example, after a catalyst change, the system can be adjusted to handle the smaller purge flow rate by valving off some separators.

A further advantage PRISM® SEPARATORS is the ability to handle the purge gases from several ammonia plants on the same site. Several such systems have been sold. In this case, the flexibility over an extremely wide range of flows can be used to adjust performance when some of the plants are shut down. Should plant capacity increase or another ammonia plant be built, the existing system can be easily expanded by simply adding more separators.
ARGON RECOVERY

When an ammonia plant operator intends to recover argon as well as hydrogen from the purge gas, the retentate argon rich stream from the PRISM® SEPARATORS makes an ideal feed for a cryogenic argon recovery unit. This combination yields extremely attractive economics and lower power requirement than when other hydrogen recovery systems are used.

HYDROGEN FROM METHANOL PURGE

Low pressure systems are designed to recover 60% of the hydrogen and 40% of the carbon oxides in the feed. Systems for high pressure synthesis loops are capable of recovering 90% of the hydrogen and 60% of the carbon oxides for return to the synthesis loop. The hydrogen recovery system includes a water scrubber to recover methanol presently lost in the purge. The system can be easily adjusted to meet fluctuating conditions of the methanol plant. Recovered hydrogen is recycled to the synthesis loop to increase methanol production. When extra production is not desired, energy savings can be realised by maintaining constant methanol production and reducing hydrocarbon feed to the reformer.

CO/H₂ SYNTHESIS GAS RATIO ADJUSTMENT

PRISM® SEPARATORS are used in oxo-alcohol synthesis gas streams to adjust the ratio of CO to H₂ to satisfy the stoichiometric requirement of the continuous process. The process is elegant because the synthesis gas is produced at essentially feed gas pressure without the need for external compression. The amounts of CO recovered and H₂ rejected can easily be fine-tuned to meet specific process requirements. The system can also be simply controlled to automatically compensate for feed purity variations and product flow rates.

The first system of this type was installed early in 1977. This was also the first commercial application of PRISM® SEPARATORS.

CARBON MONOXIDE PURIFICATION

PRISM® SEPARATORS are used for the purification of carbon monoxide from feed streams containing hydrogen. In this type of application the retentate product stream is made available at high pressure and the system removes water vapour as well as hydrogen, thus making a feed stock suitable for direct use in many processes.

A typical system recovers 85% of the available carbon monoxide at purities of 85-95% from a feed containing 50% carbon monoxide, without any additional energy requirement. Higher purities and recoveries will be obtained if some additional compression power is used.

HYDROGENATION PURGE RECOVERY

PRISM® SEPARATORS are used to recover hydrogen from hydrogenation purge streams. Recovered hydrogen may be recycled to the hydrogenation process or utilised elsewhere in the plant. The system’s flexibility permits it to operate properly under widely fluctuating purge flow rates. Other hydrogen recovery systems have been known to perform inadequately under similar fluctuating conditions. These systems have been designed to recover about 80% of the hydrogen at 99% purity from purge streams which contain up to 85% hydrogen purity. Higher recoveries are more common where purity requirements are less stringent.

OTHER APPLICATIONS

PRISM® SEPARATORS are being used on the purge gas of a pressure swing adsorption (PSA) system to improve overall recovery. One petrochemical complex is using PRISM® SEPARATORS to recover 97%+ hydrogen from ammonia synthesis feed gas streams for use elsewhere in the plant. Another system is recovering high purity hydrogen from an ethylamine purge gas stream. Petrochemical producers around the world are using these unique membrane systems to add flexibility to their operations.
HYDROGEN RECOVERY FROM PURGE GAS

With PRISM® Separators, purge gas streams from hydrotreaters can be upgraded to hydrogen purities of 92% to 98% at recoveries of 85% to 95%.

Even catalytic cracker tail gas streams containing 10 to 30% hydrogen can be upgraded to 70 to 90% purity with a single stage separation or up to 98% with a two stage system.

INERT REJECTION FROM-recycle LOOPS

One approach that improves hydrotreater or hydrocracker performance is to recover high purity hydrogen from the purge for use as incremental make-up. Another approach is to reject inerts from the recycle loop. By rejecting inerts as they form in the reactor, PRISM® Separators can produce higher loop purity, higher than using pure hydrogen for makeup.

Inerts rejection capability allows the operator to adjust the hydrotreater to a wider range of feed and product specifications, without concern for hydrogen losses.

The PRISM® Separators in this system recover high purity hydrogen from a naphtha hydrotreater offgas stream for use as make-up hydrogen to a hydrocracker. Since its June, 1980 start up, this system has met all design expectations and has been essentially maintenance free.

FINE TUNING HYDROGEN CASCADES

PRISM® Separators can extend hydrotreater catalyst life by improving the hydrogen partial pressure in the feed. They can increase feed purity to permit increased throughput or severity in an existing hydrotreater. They can allow the installation of a new hydrotreater by recovering hydrogen from low purity fuel streams. Or they can skim a small amount of hydrogen from catalytic reformer offgas; the remaining catalytic reformer offgas remains near its initial hydrogen purity for use in other hydroprocesses.

OIL REFINERY APPLICATIONS OF PRISM® SEPARATORS

Debottlenecking can easily be done by PRISM® Separators to recover high-purity hydrogen from the feed. With the hydrogen removed, more hydrocarbons can be fed to the hydrogen plant which results in increased hydrogen production.
The retentate gas exits PRISM® SEPARATORS with essentially no loss of pressure. With its hydrogen removed, it is a high pressure, high heating value fuel gas with many uses. It can be used as hydrogen plant feed or fuel. It can also be fed to a high-pressure fuel header, sold as pipeline gas or fed to an LPG plant.

Refinery gas streams are frequently rich in C₂-C₄ components, which can be recovered by a turboexpansion or chilling system. Placed just before the turboexpander or chilling system PRISM® SEPARATORS can recover valuable hydrogen and improve LPG recovery.

PRISM® SEPARATORS FOR REFINERIES ARE SIMPLE AND FLEXIBLE

- 95+ % recovery available
- Requires minimal operator attention
- Easily adaptable to different feed streams as slates change
- Up to 98% purity available
- Low maintenance
- Skid mounted systems are quick, easy and inexpensive to install
- Accommodates 20% variations in feed flow and purity without attention
- Virtually unlimited turndown
- Customised performance
- Easily expanded to increase recovery
- Smooth, surge-free output
- Water, normal levels of hydrocarbons and aromatics, H₂S, CO₂ and NH₃ present no operational problems
- Fast delivery
Prism® Separators operate on the principle of selective gas permeation. Every gas entering the Prism® Separator has a characteristic permeation rate that is a function of its ability to dissolve in, diffuse through and dissolve out of the hollow fiber membrane. In fact, the permeation rate is the product of the solubility and diffusivity rates of the gas in the membrane.

Prism® Separators utilise these relative permeation rates to selectively separate a “fast” gas, such as hydrogen, from the “slow” gas components, such as methane, in a process gas stream. Relative rates of permeation for some common gases are shown in the table on this page. The driving force for gas separation is the difference between the partial pressure of each stream component on either side of the hollow fibre membrane.

The Prism® Separator consists of a compact bundle of hollow fibres which are sealed at one end and open at the other. The open ended fibres are held in a tube sheet. The bundle is contained within a coded pressure vessel. The pressurised feed gas enters at the side inlet of Prism® Separator and flows up through the Prism® Separator on the outside of the fibres (shell side). The fast gases selectively permeate through the membrane into the inside of the hollow fibres (tube side) which is at lower pressure. The permeate stream is collected in a manifold at the lower end of Prism® Separator. The retentate gas exits through the upper end of the Prism® Separator at essentially the same pressure as the entering feed gas.

Each Prism® Separator employs hundreds of thousands of these small diameter hollow fibres to provide the maximum separation surface in a compact, easily handled module. To obtain the desired performance, an appropriate number Prism® Separators, arranged in series, parallel or cascade, are assembled into a skid mounted system.

Prism® Separators function simply; there are no moving parts and therefore no mechanical maintenance problems. The system is controlled by pressure or flow adjustment of the feed or retentate gas streams. The systems are supplied completely instrumented and will operate unattended.

| H₂O, H₂, He | CO₂ | O₂, Ar, CO, N₂ |
| “Fast” | | “Slow” |

Relative Permeation Rates
PRISM® SEPARATORS are ideally suited for hydrogen recovery from petroleum refinery hydrosprocessing streams, including hydrocracking and severe hydrosulfurization.

PRISM® SEPARATORS are also used for hydrogen recovery from synthesis process purge streams such as ammonia and methanol purges. Methanol and other oxo-alcohol processes also PRISM® SEPARATORS to remove hydrogen from synthesis gas for ratio adjustment. PRISM® SEPARATORS can also separate carbon dioxide from methane in enhanced oil recovery or in natural gas upgrading applications.

PRISM® SEPARATORS are also being used to separate air into a nitrogen rich inert gas stream and an oxygen rich stream as well as dehydration of compressed air and gas streams.

PRISM® SEPARATOR systems typically produce 90% to 98% purity and, in some cases, as high as 99.9% purity. Product purity is dependent upon feed purity, available differential partial pressure and desired recovery level.

PRISM® SEPARATORS require little pre-treatment. Minimum pre treatment for clean gas streams is superheating of the gas to drive the gas away from saturation and raise the membrane operating temperature.

Water can be accepted at any level up to saturation without any pre treatment. The system can accept particulates in suspension without any filtration. The presence of any liquid droplets requires mist elimination. Heavier liquid loading requires the use of a liquid knock out vessel.
Please send me an estimate of the cost and performance of Prism® separators for the application described below.

Note: If more than one stream is to be considered, please machine copy this form and complete the information requested for each stream.

**Feed Stream Data**
Source of feed _____________________________________________________________________________
Flow Rate _____________________________
Pressure ______________________________
Temperature ___________________________
Feed Composition _______________________

**Desired Results**
Key Component _________________________ Pressure ______________________________________
Recovery ______________________________ Purity ______________________________________

If a trade-off between purity and recovery is necessary, which is more important?

☐ Purity  ☐ Recovery

**Use/Special Requirements for the Residual Gas**

NAME: _______________________________________
TITLE: _______________________________________
COMPANY: ___________________________________
ADDRESS: ___________________________________
CITY: _______________________________________
COUNTRY: ___________________________________
TELEPHONE: _________________________________
FAX: _______________________________________
EMAIL: _____________________________________

**Plant Location:**

**Prism® is a registered trademark of Permea, Inc., a subsidiary of Air Products and Chemicals, Inc.**
FIND OUT MORE!

For over fifty years, Air Products has been helping customers increase the performance of their operations through innovative gas supply and applications technology. With sales of 4.9 billion and more than 16,700 employees in over 30 countries, the company is ranked among the top 200 U.S. industrial companies.

AIR PRODUCTS’ CORPORATE HEADQUARTERS LOCATED IN ALLENTOWN, PENNSYLVANIA

AIR PRODUCTS’ EUROPEAN HEADQUARTERS LOCATED IN THE UNITED KINGDOM

AIR PRODUCTS & CHEMICALS, Inc.
Permea Division
11444 Lackland Road
St Louis, Missouri 63146
U.S.A.
Tel 314-995-3300
Fax 314-995-3500

Air Products Japan, Inc.
Kamishita Bldg. 11F Shuwa 2
3-18-19, Toranomon, Minato-ku
Tokyo 105,
JAPAN
Tel 813-3432-7043
Fax 813-3432-7052

Permea (China) LTD
Nanjiao
Yantai
Shandong
PRC
Tel 86-535-6730921
Fax 86-535-6730723

Air Products A/S
Lumbeckeien 49
4602 Kristiansand S.
NORWAY
Tel 47-380-12455
Fax 47-380-11113

Air Products S.A.
Chausseau de Wavre 1789
B-1160 Brussels
BELGIUM
Tel 32-2-674-9581
Fax 32-2-674-9584

Prisma® is a registered trademark of Permea, Inc., a subsidiary of Air Products and Chemicals, Inc.