

Biogas upgrading cycle options for two-, three-, and four-stage systems



GENERATING A CLEANER FUTURE

Air Products Membrane Solutions Biogas Cycle Offerings

Introduction

Air Products Membrane Solutions collaborates with our global customer base to supply membrane modules for use in two-, three-, and four-stage membrane systems, with an emphasis placed on delivering customer-focused support and solutions for their projects. We understand that not every system is the same and, through our technical expertise and innovative, proprietary membrane designs, we continue to drive excellence across the biogas upgrading spectrum.

Two-Stage Biogas Upgrading

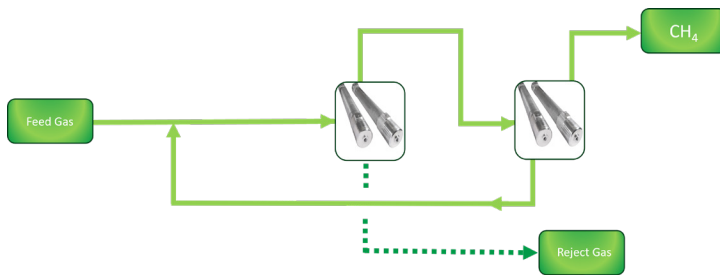
Background

In cases where biogas system end-users are serving applications that accept 93-98% methane recovery, two-stage membrane systems provide a simple, compact solution that offers both flexible design options and capital savings.

Solution

Air Products Membrane Solutions can support a simple and cost-effective system design that is ideal for 93-98% methane recovery, while still achieving <1 mol% CO₂ in the final biomethane product. In these cases, two-stage systems can be economically advantageous, while also presenting an option for future system expansion to three- or four-stage designs, with proper planning.

Air Products has successfully supported multiple installations of two-stage biogas systems globally. For example, one specific installation in India operates at 15 barg, achieving 97% CH₄ recovery, with flexibility to meet <3 mol% CO₂ CNG for restaurant cooking and <1 mol% CO₂ CNG for vehicle fueling, depending on what the end use will be.



Comparison

A comparison of two-stage systems is shown in Table 1 below, for a raw biogas stream containing 60 mol% CH₄ and 40 mol% CO₂ operating at 20°C and an inlet pressure of 16 barg.

Table 1: Two-Stage Solutions for Various Methane Recovery and CO₂ in Product

	97% CH ₄ Recovery 99 mol% CH ₄	97% CH ₄ Recovery 98 mol% CH ₄	98% CH ₄ Recovery 99 mol% CH ₄	98% CH ₄ Recovery 98 mol% CH ₄
Relative Membrane Quantity†	100%	88%	111%	94%
Power Consumption (kW/Nm ³ /hr of raw gas)	0.23	0.22	0.27	0.26

* Performance is based on the constant variables listed above for temperature, pressure, and composition

† Relative membrane quantity is compared to the green column

Air Products Membrane Solutions offers membrane modules for a range of two-stage solutions, tailored for those who need a system that is compact and affordable, while still offering flexibility in methane purity and recovery.

Three-Stage Biogas Upgrading

Background

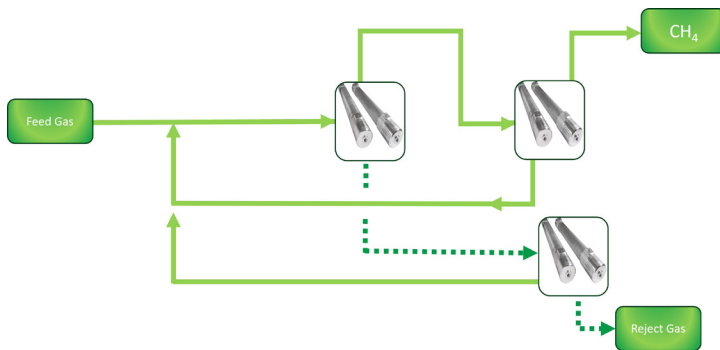
For biogas system end-users who need to achieve 98-99.5% CH₄ recovery with <1 mol% CO₂ in the final biomethane product, three-stage biogas upgrading systems are an ideal, efficient option thanks to the third membrane stage, which enables greater methane recovery. While there are many variations of three-stage systems that meet different specifications and regulatory requirements, configuring a system to meet project-specific needs is essential to maximizing performance.

Solution

Air Products Membrane Solutions specializes in supporting biogas upgrading systems that deliver results, through close collaboration with our partners. Three-stage cycles reduce capital and operational expenses, and our applications team delivers deep technical insight to maximize efficiency.

In one recent reference, Air Products Membrane Solutions successfully completed a three-stage project with an OEM customer in Europe to meet the typical grid injection requirements. With operating pressure of ~17 barg, Air Products Membrane Solutions membranes achieve 99.5% CH₄ recovery and 1.25 mol% CO₂ in the product with ~55% recycle. This is just one of over 200 of our success stories in the biogas upgrading space.

A three-stage system can be further enhanced through adding additional equipment, such as vacuum pumps or blowers, resulting in reduced recycle. An extra benefit to utilizing a blower leads to reduced membrane module quantity, saving in capital expenses.



Comparison

Table 2 below shows a comparison between a basic three-stage design and designs that include an additional vacuum pump or blower. This example raw biogas stream contains 60 mol% CH₄ and 40 mol% CO₂ operating at 20°C and an inlet pressure of 16 barg, targeting 99.5% CH₄ recovery and 98.75 mol% CH₄ in the product gas.

Table 2: Three-Stage Solutions with Equipment Variations*

	Basic Three-Stage Design	Three-Stage Design with Vacuum Pump on Vent	Three-Stage Design with Interstage Blower
Relative Membrane Quantity†	100%	97%	71%
Power Consumption (kW/Nm ³ /hr of raw gas)	0.23	0.21	0.22

* Performance is based on the constant variables listed above for temperature, pressure, recovery, and composition

† Relative membrane quantity is compared to the green column

By utilizing additional equipment, Air Products Membrane Solutions is able to maximize system performance, while still supporting an economically favorable design.

For applications that require low levels of CO₂ in the product, such as bio-LNG producers who need <50ppm CO₂ in their gas streams, Air Products has successfully developed and implemented a specialized membrane separator, PRISM® GreenSep LNG, and an associated, proprietary cycle that eliminates the need for intermediate purification technologies, such as amine scrubbing or TSA.

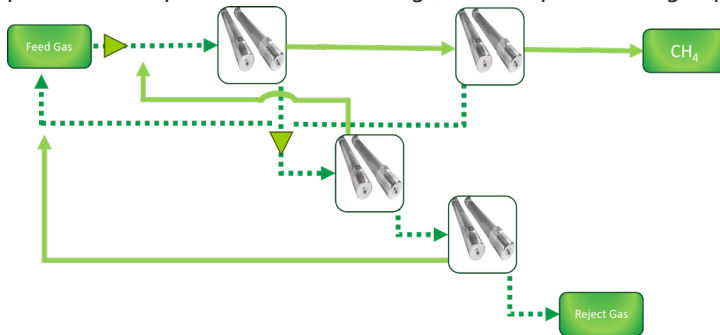
Four-Stage Biogas Upgrading

Background

With increased global focus on reducing greenhouse gases (GHG), certain regions are looking at more stringent emission laws to combat impact on the climate. With biogas upgrading emissions primarily being methane and carbon dioxide, reducing methane loss is essential to minimizing emissions and maximizing profit.

Solution

For ultra-high methane recovery of 99.7%-99.9% and 99 mol% CH₄ in the product stream, Air Products Membrane Solutions has developed a proprietary, four-stage, two compressor system design that minimizes power consumption, while recovering >99.7% of methane. Not only does the second compressor design enable higher methane recovery, it results in lower total power consumption versus a three-stage, one compressor design operating at the same recovery.



Comparison

For a raw biogas stream containing 60 mol% CH₄ and 40 mol% CO₂ operating at 20°C, targeting 99.8% CH₄ recovery and 98.75 mol% CH₄ in the product gas, Table 3 below shows a comparison between a basic three-stage design, Air Products' proprietary four-stage one compressor design at two different pressures, and Air Products' proprietary four-stage two-compressor design.

Table 3: Four-Stage Solutions with Condition and Equipment Variations*

	Three-Stage Design 14 barg	Four-Stage Design with One Compressor 14 barg	Four-Stage Design with One Compressor 16 barg	Four-Stage Design with Two Compressors 14 and 15 barg
Relative Membrane Quantity†	100%	109%	100%	116%
Power Consumption (kW/Nm ³ /hr of raw gas)	0.28	0.28	0.28	0.23

* Performance is based on the constant variables listed above for temperature, recovery, and composition

† Relative membrane quantity is compared to the green column

While comparing a three-stage design to a four-stage design at the same pressure, the relative membrane quantity increases; however, with a slight increase in pressure, the relative membrane quantity and power consumption are equivalent to a three-stage design for high recovery. This allows for the choice between favorable capital expense versus operational expense. If lower operational expense is the goal, then a four-stage two compressor system design can significantly lower power consumption.

Conclusion

Air Products Membrane Solutions has a vast amount of experience supporting biogas operations worldwide. With over 200 system references across two-, three- and four-stage system designs, our experience and technical insight make us your ideal partner in optimizing your biogas systems. Contact us to learn more.