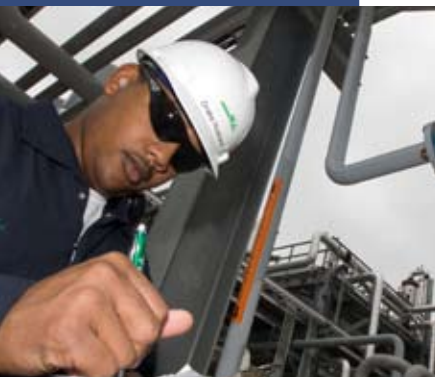


Increased Production Through Enhanced Oil Recovery (EOR) Nitrogen Injection and Nitrogen Rejection



Enhanced recovery projects have grown in importance as world energy prices have risen and new production technologies have been developed. Air Products' industrial gases are being used to significantly increase recoverable hydrocarbon reserves.

Our Enhanced Recovery technology spans the production of high-purity nitrogen for applications such as pressure maintenance, miscible displacements, and recovery of natural gas liquids (NGL). Nitrogen rejection plants have further utility in Btu upgrading for sales gas.

Air Products has successfully supplied multiple nitrogen injection and nitrogen rejection projects and continues to be at the forefront of developing enhanced recovery techniques involving non-hydrocarbon gases.

Nitrogen Injection

Nitrogen gas, produced on-site by cryogenic air separation, has replaced hydrocarbon gas injection in many enhanced oil and gas recovery applications.



An Air Products/Cryolinfra nitrogen plant servicing the Jujo-Tecominoacan oil field in Mexico. The plant provides Pemex Exploration and Production pure nitrogen gas at a pressure of 4,300 psig for enhanced oil and gas recovery. The nitrogen injection process has benefited the customer by increasing their daily oil production more than 200% and natural gas production by more than 400%.

Air Products pioneered the on-site supply of pure cryogenic nitrogen gas for enhanced oil and gas recovery in 1977 and is a leading supplier of nitrogen to the global oil industry for such applications.

Major applications

The injection of high-pressure pure nitrogen gas has been selected for the following applications to increase oil production:

- Miscible displacement of oil
- Gas cap displacement
- Cycling rich gas reservoirs
- Immiscible displacement of oil
- Pushing carbon dioxide miscible fronts

Miscible displacement of oil

In many deep reservoirs containing light crude, nitrogen achieves multiple contact miscibility with oil, dramatically increasing recovery in the swept zone. Nitrogen has been selected over carbon dioxide for many of these applications.

Gas cap displacement

Nitrogen injection is being used to replace the gas cap over an oil column, allowing immediate production and sale of gas while maintaining the reservoir pressure needed to maximize production from the oil column.



Cycling rich gas reservoirs

The injection of nitrogen maintains the reservoir pressure needed to maximize natural gas liquids and condensate recovery, eliminates the need to buy makeup gas, and allows immediate sale of produced gas.

Immiscible displacement of oil/pressure maintenance

Nitrogen is being used to augment gravity drainage in dipping reservoirs, to maintain pressure in solution gas drive reservoirs, and to form secondary gas caps in attic oil formations.

Pushing carbon dioxide miscible fronts

In reservoirs where carbon dioxide must be used to achieve miscibility, lower-cost nitrogen can be used to push a slug of more expensive carbon dioxide.

Advantages of Nitrogen Injection

Although the reservoir engineering and the design of each nitrogen injection project are unique, nitrogen is being chosen for five primary reasons:

- Nitrogen is economical.
- Nitrogen is readily available and can be generated and injected wherever, whenever and in whatever quantities are needed.
- Nitrogen is environmentally friendly, completely inert, and remains inert in the presence of water.
- Nitrogen can be removed economically from a sales gas stream if necessary to increase Btu content.
- Nitrogen gas is less compressible than either carbon dioxide or natural gas, so less is required.

Nitrogen Rejection

In addition to a nitrogen generation facility, some projects need the capability to separate the nitrogen from the field gas for Btu upgrading. As nitrogen is injected, it may break through in increasing quantities into the produced gas, lowering Btu content. The rejected nitrogen stream can be reinjected if desired.

Air Products is uniquely qualified to solve your nitrogen rejection problems. We have commissioned eleven plants since 1984 for natural gas processing to reject nitrogen, with and without helium recovery steps. We are the only supplier to have built all four NRU cycles: 1) single high pressure; 2) double column; 3) triple column with CO₂ scrub; 4) dual column.

Air Products' technology has been used to treat natural gas streams since 1958 as part of the U.S. government Helium Conservation program. We designed and built plants as large as 500 MMSCFD to recover helium and reject nitrogen from natural gas streams with constant nitrogen composition.

In enhanced recovery applications, the nitrogen content of the field gas can increase over the life of the project. Air Products has developed process technology to design distillation columns and heat exchangers to handle wide ranges for the N₂ content in the NRU feed gas.

Each nitrogen rejection unit must be designed for the specific requirements of the application. Air Products has the capability to fully integrate the nitrogen rejection unit with pretreatment equipment and other gas processing units, whether for a new facility or for modification of an existing facility. Many factors must be considered in determining the optimum design for each requirement.

Figure 1

Nitrogen Injection Process Flow Diagram

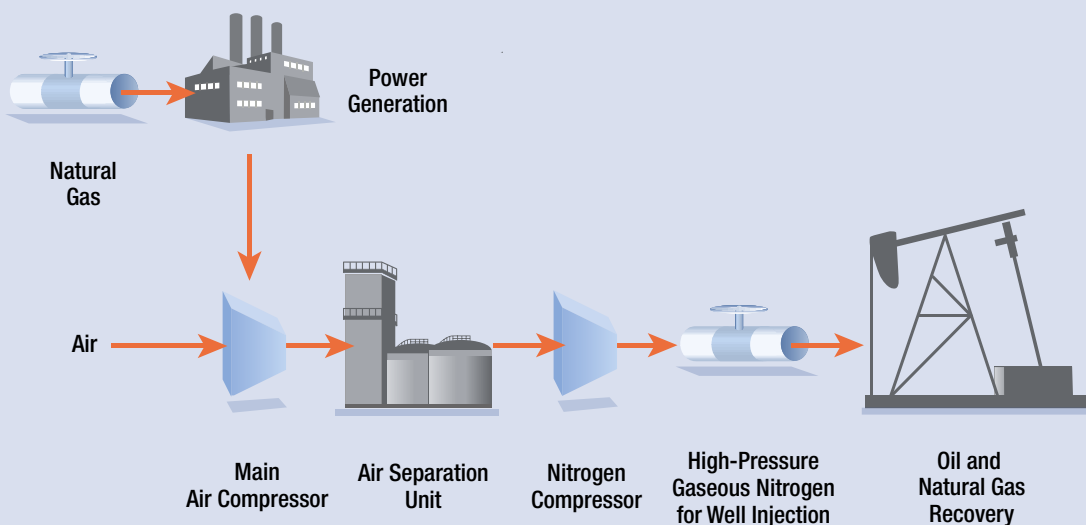
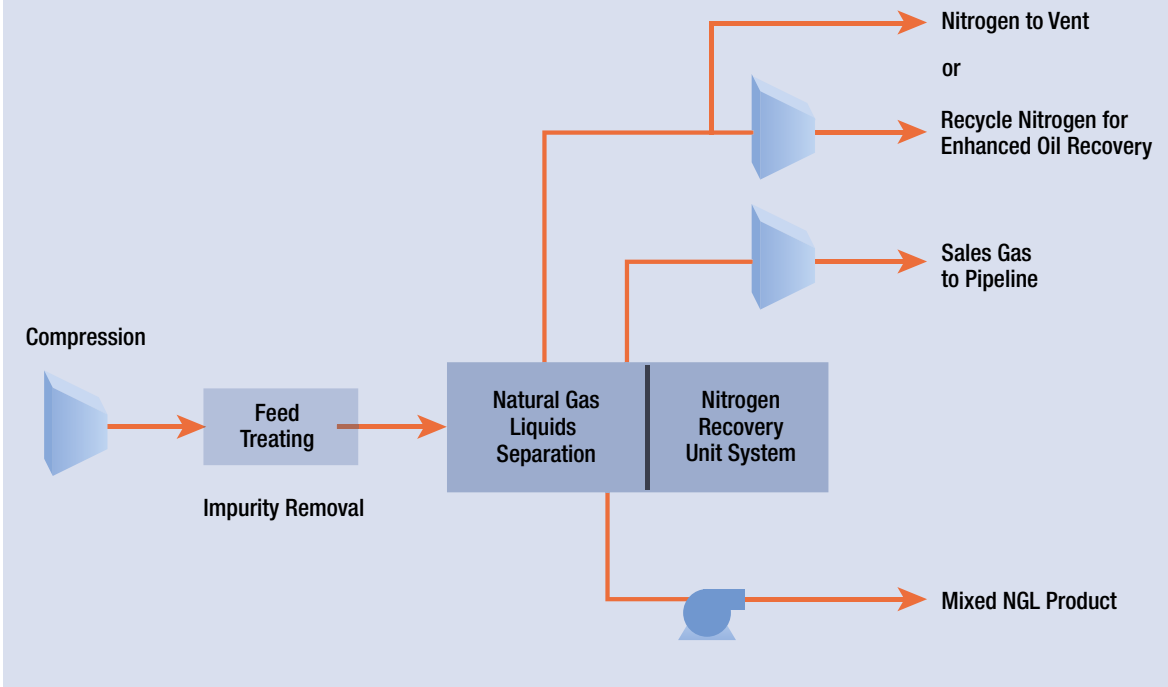


Figure 2

Nitrogen Recovery Unit Process Flow Diagram



This general flow diagram shows the nitrogen recovery unit (NRU) process blocks that can be modified to best meet customers' needs. The plant makes your hydrocarbons salable. Removed nitrogen can be vented or recycled for enhanced oil recovery. Air Products has the NRU to meet your needs.

Supply Options

Air Products can supply your EOR technology needs based on the specific requirements of your project. Nitrogen can be supplied from an Air Products owned and operated facility on a price-per-MCF basis. This relieves you of capital investment and operational risk and responsibility. We can also design and build a turnkey facility to meet your needs.

Air Products' nitrogen rejection facilities are specifically designed for each project. Since these units are an integral part of other gas processing facilities, they are frequently owned and operated as part of the field facilities. These units also can be owned and operated by Air Products.

About Air Products

Air Products serves customers in industrial, energy, technology and healthcare markets worldwide with a unique portfolio of atmospheric gases, process and specialty gases, performance materials and equipment services. Founded in 1940, Air Products has built leading positions in key growth markets such as semiconductor materials, refinery hydrogen, home healthcare services, natural gas liquefaction, and advanced coatings and adhesives. The company is recognized for its innovative culture, operational excellence and commitment to safety and the environment. Air Products has annual revenues of over \$10 billion, operations in over 40 countries, and 21,000 employees around the globe.



Located in western Wyoming, this nitrogen rejection unit processed up to 300 MMSCFD of EOR field gas for N₂ rejection and sales gas upgrading.

For Additional Information

The Americas

Air Products and Chemicals, Inc.
7201 Hamilton Boulevard
Allentown, PA 18195-1501
Tel 800-654-4567
Fax 800-272-4449
E-mail info@airproducts.com

Europe

Air Products PLC
Hersham Place
Molesey Road
Walton-on-Thames
Surrey KT12 4RZ
England
Tel +44 1270 614114
Fax +44 1932 258502

Asia

Air Products and Chemicals (China)
Investment Co. Ltd.
East Wing, Floor 1
Building #88, Lane 887
Zu Chongzhi Rd.
Zhangjiang Hi-Tech Park
Shanghai, 201203
P.R. China
Tel +86 21 38962103
Fax +86 21 50809831
Email ASUChina@airproducts.com



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www.airproducts.com