

Nitrogen Generation
and Nitrogen Rejection.

Enhanced Oil Recovery.



Introduction.

Enhanced oil recovery (EOR) includes methods for increasing the amount of oil, condensate and associated natural gas recovered from hydrocarbon reservoirs. Following primary oil recovery, the majority of the original oil remains in the reservoir. In a framework of increasing global oil demand and regional natural gas shortages, unlocking remaining hydrocarbons is becoming evermore of a priority.

Linde supports the economic recovery of oil, condensate and natural gas through its leading position as a supplier of industrial gases as well as supplier of cryogenic air separation plants for nitrogen generation. Furthermore, Linde provides cryogenic process technologies, equipment and plants to reject nitrogen from natural gas streams associated with the production of oil and condensate, the so called nitrogen rejection unit (NRU).

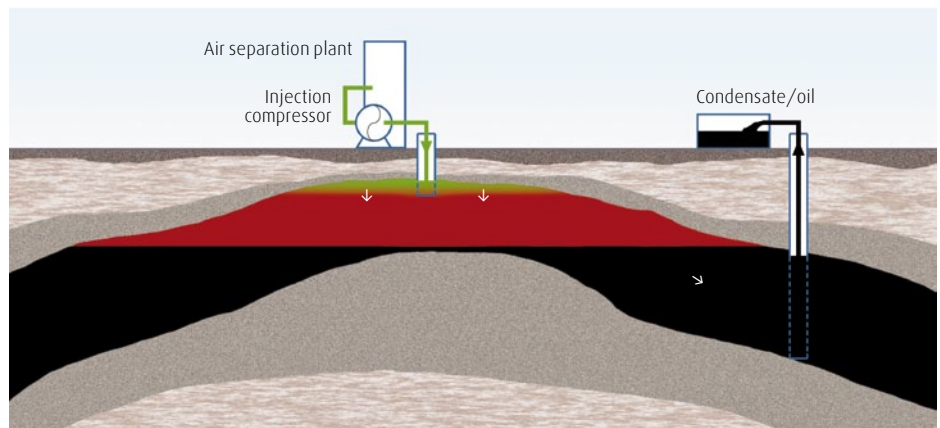
Nitrogen injection.

Use of Nitrogen is a promising application for EOR. While the specifics of each reservoir dictate which EOR-methods have the greatest potential for recovering additional hydrocarbons, high purity nitrogen has properties which make it the ideal gas for certain situations. Nitrogen's low compressibility means that less energy is required to inject it into high pressure reservoirs. Nitrogen is inert, non-corrosive and readily available at any location. These properties make Nitrogen advantageous where field material costs, degradation and availability of alternative gases are a concern. As a non-toxic, non-greenhouse gas, Nitrogen also is an environmentally favourable choice.

Nitrogen can be used for the following enhanced oil recovery applications:

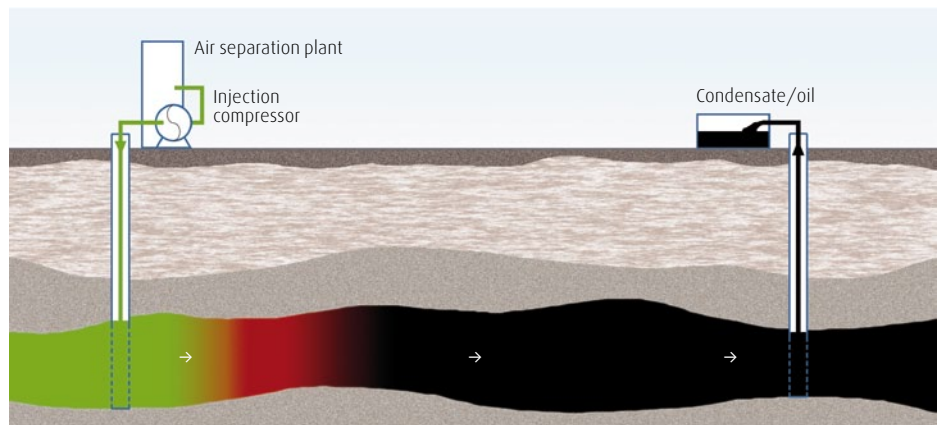
Gas cap displacement

Nitrogen is used to replace the gas cap of a reservoir. As such, the reservoir pressure is maintained while allowing the production of oil and associated gas to continue.



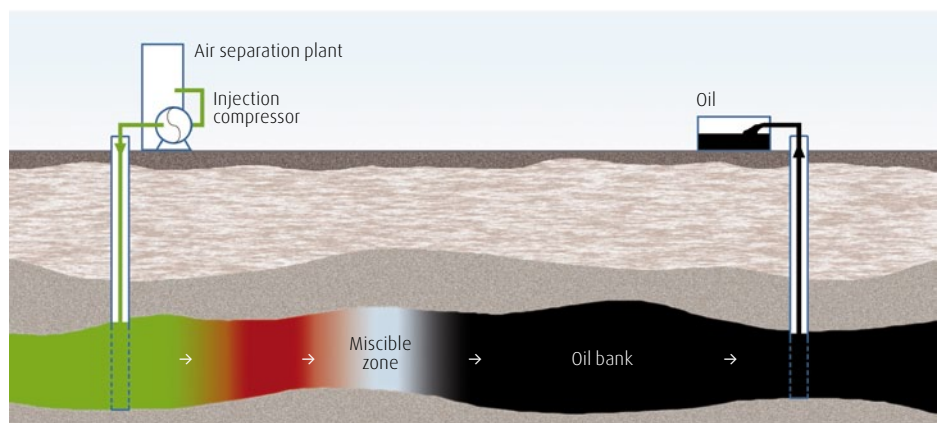
Pressure maintenance

Nitrogen is injected into the oil- or condensate bearing stratum under high pressure. This pressure pushes the oil or condensate towards the production well.



Miscible displacement of oil

Nitrogen is injected to form a miscible zone, where light hydrocarbons form a mixture with nitrogen which dissolves in the oil. This miscible zone allows a coherent drive of the oil front.





Air separation plant in Ras Laffan, Qatar

Air separation/nitrogen generation.

The Linde Group – with its Linde Gas Division – is a world leader in the industrial gases market offering a wide range of tonnage compressed and liquefied industrial gases to a large variety of industries. We are an important and reliable partner to many industries to whose operations Linde's continuous and timely supply of high quality industrial gases is essential. The Linde Group owns and operates more than 300 air separation plants of significant size worldwide. In addition Linde – with its Linde Engineering Division – is a pioneer in the air separation industry and has built more than 2,800 cryogenic air separation plants in more than 80 countries for the production of oxygen, nitrogen, argon and other rare gases, including the world's largest air separation complex in Ras Laffan, Qatar with a capacity of more than 30,000 tons per day of oxygen supplied by eight equal trains.

Enhanced Oil Recovery (EOR) with the use of nitrogen requires very significant quantities of pure high pressure nitrogen in the vicinity of the reservoir. Linde's cryogenic air separation technology with a nitrogen production capacity of

more than 10,000 tons per unit is often the most economical and in many cases the only feasible choice. Linde engineered, built, owns and operates the world's largest nitrogen generation complex supplying one of the world's largest oil fields named Cantarell located in the Gulf of Mexico with 55,000 tons per day of high pressure nitrogen for EOR (see cover page). Likewise in

Mirfa, Abu Dhabi Linde currently is in the process of executing another large nitrogen generation complex with a capacity of more than 18,000 tons per day of nitrogen for EOR. This facility will be owned and operated jointly with the client. Both projects clearly demonstrate Linde's unique set of capabilities and extensive experience in the area of nitrogen generation for EOR.



Nitrogen generation complex in Mirfa, Abu Dhabi

Nitrogen rejection unit (NRU).

Nitrogen in non-associated or associated natural gas often is a natural phenomenon and can be tolerated within limits. However, natural gas pipeline operators need to control nitrogen content to meet heating value and Wobbe index requirements governed by downstream applications, such as burners or gas turbines. In case significant natural gas volumes require treatment, cryogenic nitrogen rejection technology is the most economical choice and, in some cases, the only feasible option. Similarly, nitrogen in the feed gas to LNG plants poses a challenge as it accumulates in the end flash gas and requires that nitrogen is rejected prior to using the flash gas in gas turbines or fuel systems. While in both aforementioned applications nitrogen content often is stable, nitrogen content in associated natural gas may increase during the lifetime of a reservoir and fluctuate significantly some time after nitrogen injection has commenced as part of a EOR-scheme.

With over 125 years of experience with cryogenic process technologies, manufacturing of key cryogenic process equipment and expertise as an EPC contractor, Linde is in a position to work closely with its clients to develop customized nitrogen rejection units.

The Linde portfolio for nitrogen rejection includes single and double column processes, complemented by pre-separation columns and closed or open recycles as the case may be. Furthermore the process and equipment design can be tailored to accommodate an increasing nitrogen content, part load requirements and nitrogen fluctuations which can occur in complex gas well networks.

Linde also is a leading provider of natural gas pre-treatment technology and gas separation plants which are often required upstream of a nitrogen rejection unit. This experience in natural gas processing puts Linde in an exceptional position to provide integrated, robust and energy-efficient solutions for every application along the entire natural gas process chain. The growing importance of reducing greenhouse gas emissions has led Linde to pay special attention to minimize methane in vent gas during the design of nitrogen rejection units. As a result of such efforts, Linde's nitrogen rejection units in Hammerfest, Norway and Karratha, Australia are best in class with regard to methane emissions.



↓ NRU integrated in an LNG plant in Hammerfest, Norway

NRU module for an LNG plant in Karratha, Australia ↑





Nitrogen rejection unit and helium production unit
in Skikda, Algeria

Services.

General

The Engineering Division has extensive experience in executing large complex multi-national turnkey projects particularly for large petrochemical and LNG plants (e.g. Hammerfest LNG plant: 1.6 million engineering hours, 9 construction sites, 120 suppliers, 19 main subcontractors). The Engineering Division is the only company that has comprehensive experience in the execution of turnkey contracts for air separation plants in China and in the Middle East.

Basic engineering

Process design and optimization with advanced process simulation software OPTISIM (developed by Linde). The process design incorporates features of numerous in-house patents. Design of plant operation and control using Linde's 125 years of plant operation experience.

Detail engineering

Mechanical design using 3D CAD software to establish a complete model of the plant. Specification of the electrical equipment and design of the power supply networks with specific exper-

tise in large drives (up to 60 MW). Specification of control system hardware from well-known international automation companies. Programming of control functions using pre-engineered and pre-tested basic control functions. Implementation of advanced control functions (automatic load change, automatic start-up, automatic product adaptation) using the Linde advanced process control system.

Project management

Project managers with senior-level experience of complex multi-national/multi-partner projects. Advanced tools and methods for project control (scheduling, cost control). Reliable tools, methods and procedures for global sourcing and material logistics.

Construction

Extensive experience with turnkey projects for large plants (including Middle East and China). Methods and experience in controlling complex pre-fabrication and construction activities as well as material flow.

Commissioning and training

Skilled experienced commissioning teams ensure smooth start-up and handover of the plant to the customer. Remote support for the commissioning team on site by specialists of every discipline (e.g. process, control, machinery) makes the whole Linde expertise available on site. Extensive safety procedures and safety training ensure safe commissioning and operation of the plant.

After sales service

Prompt response to any customer request by qualified specialists. Global remote on-site support to optimize operation and minimize plant downtimes. Plant optimization services to improve plant efficiency. Remote support for the on-site commissioning team by specialists of every discipline (e.g. process, control, machinery) giving access to the total Linde expertise. Linde's safety procedures and safety training ensuring safe plant commissioning and operation.

Collaborate. Innovate. Deliver.

Linde's Engineering Division is a leading player in the international plant engineering business. Across the globe, we have delivered more than 4,000 plants and cover every step in the design, project management and construction of turnkey industrial facilities. Our proven process and technology know-how plays an indispensable role in the success of our customers across multiple industries – from crude oil, natural gas extraction and refining to chemical and metal processing.

At Linde, we value trusted, lasting business relationships with our customers. We listen carefully and collaborate closely with you to meet your needs. This connection inspires us to develop innovative process technologies and equipment at our high-tech R&D centres, labs and pilot plants – designed in close collaboration with our strategic partners and delivered with passion by our employees working in more than 100 countries worldwide.

From the desert to the Arctic, from small- to world-scale, from standardised to customised builds, our specialists develop plant solutions that operate reliably and cost-effectively under all conditions. You can always rely on us to deliver the solutions and services that best fit your needs – anywhere in the world.

Discover how we can contribute to your success at www.linde-engineering.com

Get in touch with our natural gas plant team:

Phone: +49 89 7445-3434, e-mail: naturalgas@linde-le.com

Core competencies at a glance

Plant engineering

- Air separation plants
- LNG and natural gas processing plants
- Petrochemical plants
- Hydrogen and synthesis gas plants
- Adsorption plants
- Cryogenic plants
- Carbon capture and utilisation plants
- Furnaces, fired heaters, incinerators

Component manufacturing

- Coldboxes and modules
- Coil-wound heat exchangers
- Plate-fin heat exchangers
- Cryogenic columns
- Cryogenic storage tanks
- Liquefied helium tanks and containers
- Air-heated vaporisers
- Water bath vaporisers
- Spiral-welded aluminium pipes

Services

- Revamps and plant modifications
- Plant relocations
- Spare parts
- Operational support, troubleshooting and immediate repairs
- Long-term service contracts
- Expert reviews for plants, operations and spare part inventory
- Operator training