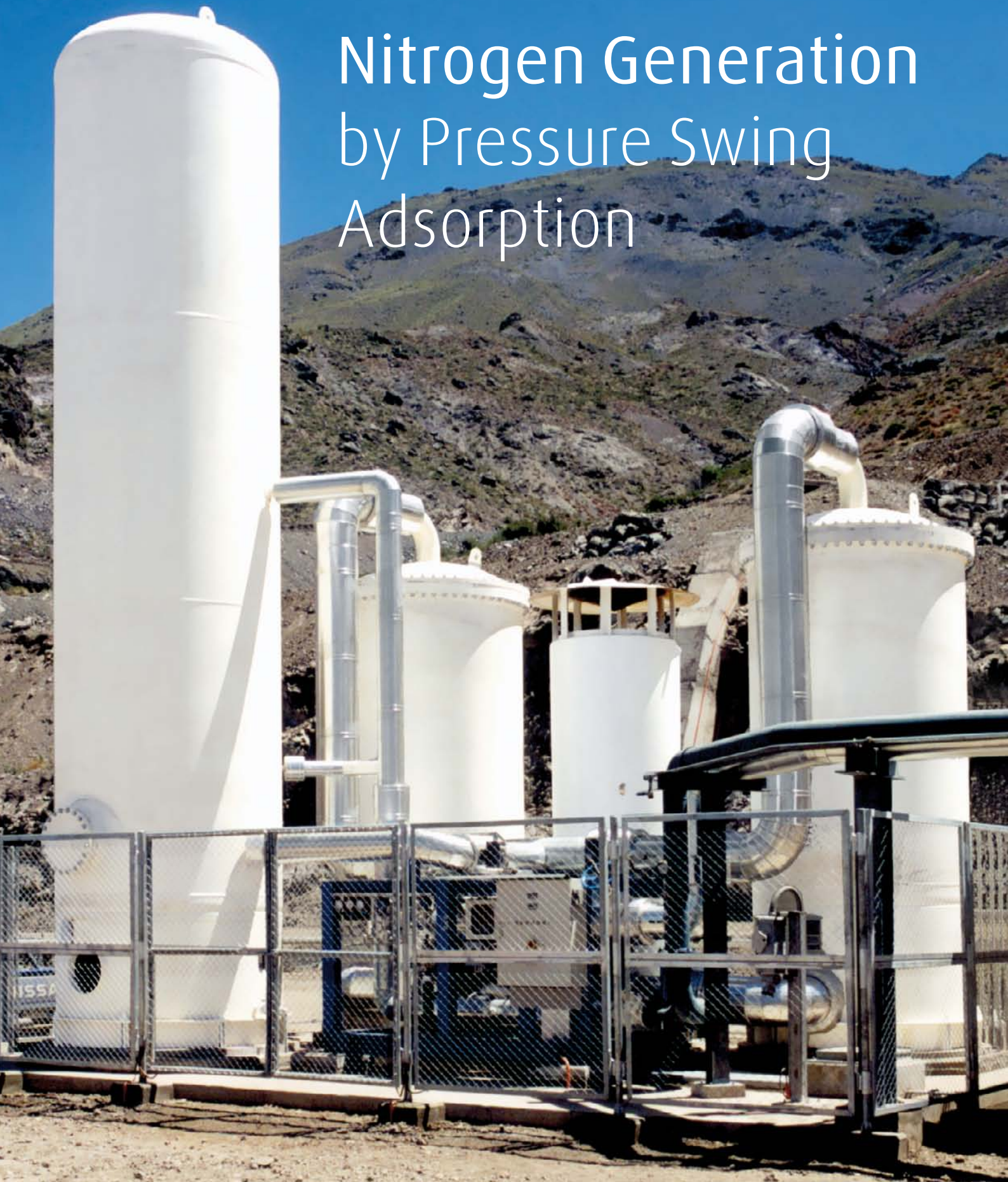


THE LINDE GROUP

Linde

Nitrogen Generation by Pressure Swing Adsorption



Introduction.

The experience

The use of the Pressure Swing Adsorption (PSA) process has seen tremendously growth during the last decades mainly due to its simplicity and low operating costs. Major applications have been the recovery of high purity hydrogen, methane and carbon dioxide as well as the generation of nitrogen and oxygen. In addition, it has gained significance for the bulk removal of carbon dioxide from direct reduction top-gases.

Linde as the world leader in adsorption technology has designed and supplied more than 500 PSA plants - including the world's largest units and units with highest availability.

The Linde nitrogen PSA generators

The Linde nitrogen PSA generators are designed for onstream applications, where there is need for clean, dry nitrogen of high purity for inerting, blanketing and purging.

The capacities of the Linde nitrogen PSA generators range from small plants with product requirements of only several Nm³/h, up to large-scale plants with several thousand Nm³/h nitrogen product flows.

Depending on client needs, the PSA plant can be designed for nitrogen product purity in the range of a few percent oxygen content or with oxygen content in the ppmv level.

Linde N₂-PSA systems are available in two plant series:

- The G-series, fully standardized with a range of 26 capacity types.
- The A-series, a tailored modular plant series that features highest capacities and purities. This series can be supplied to the needs of customer's specifications.

The nitrogen product is normally delivered between 4 barg to 9 barg (60 psig to 130 psig). In case a higher product pressure is required a downstream nitrogen compressor will be applied.

Linde's PSA systems have proven to be successful in cases where performance, flexibility, availability and reliability are the determining factors. High quality and easy accessibility to all components minimize and facilitate maintenance to the maximum extent.

The process.

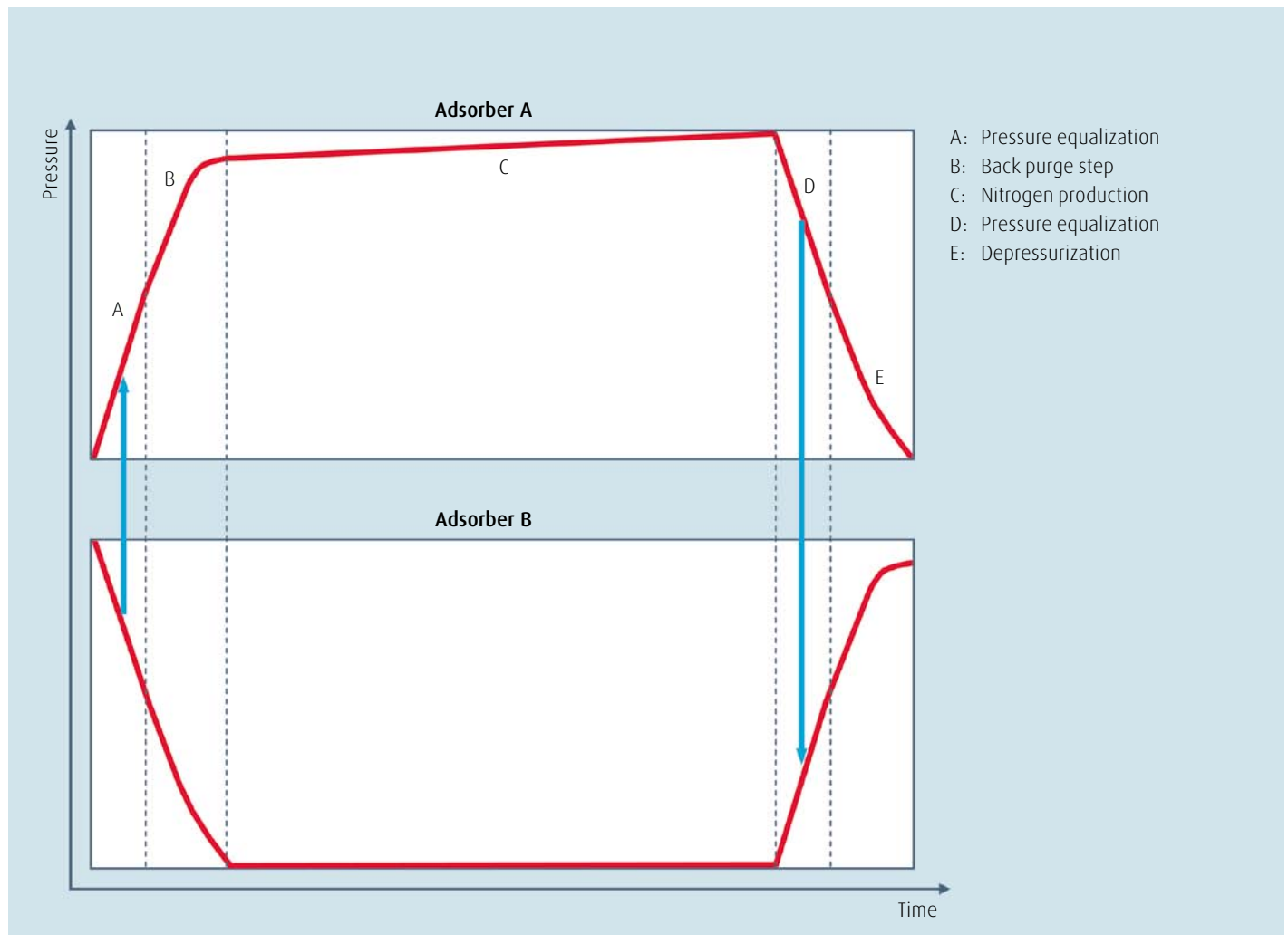
The separation of nitrogen and oxygen from air takes place in an adsorber vessel filled with carbon molecular sieve.

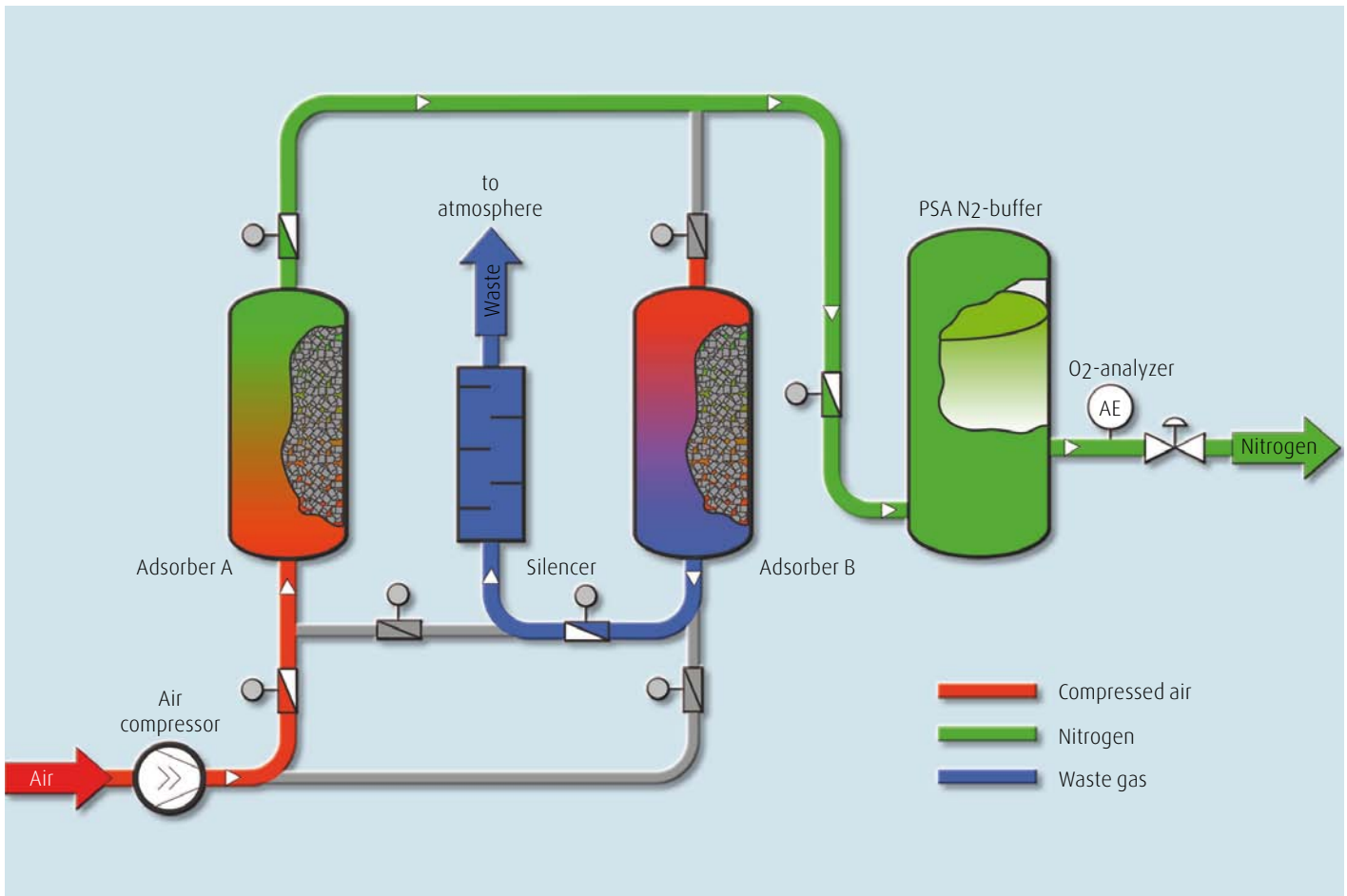
This is based on the fact of faster kinetic diffusion of oxygen molecules into the pore structure of the carbon molecular sieve than for nitrogen molecules.



Pressure time diagram for nitrogen PSA process

Carbon molecular sieve





Typical process flow diagram of a Linde nitrogen PSA plant

PSA process cycle

The PSA process cycle consists of two key mechanisms:

- Pressurisation/adsorption
- Depressurisation/desorption

Compressed air alternately pressurises each of two identical adsorber beds. Beginning at a point in the cycle where one adsorber bed (A) is being pressurised and the other adsorber bed (B) is undergoing depressurisation, the description of the PSA process cycle is as follows:

As compressed air enters adsorber bed A, moisture, oxygen, and carbon dioxide are adsorbed. After operating pressure is reached, nitrogen

product flows from adsorber bed A into a nitrogen product receiver prior to entering the product piping. Simultaneously, adsorber bed B is depressurised to atmospheric pressure.

Upon completion of nitrogen production from adsorber bed A, an equalisation step occurs. Adsorber bed B (atmospheric pressure) is pressurised to an intermediate pressure as the gas remaining in adsorber bed A (at operating pressure) flows into adsorber bed B. During this step, air is not consumed nor is product gas generated. Therefore a nitrogen receiver is applied to allow for a constant flow, purity and pressure of the nitrogen product throughout the PSA cycle. Adsorber bed A then undergoes depressurisa-

tion and the oxygen enriched waste gas is vented to the atmosphere. Depressurisation permits the release of oxygen, carbon dioxide, and water vapor previously adsorbed during nitrogen production from adsorber bed A. At the same time, adsorber bed B is brought to operating pressure, and begins its nitrogen production portion of the cycle.

Following nitrogen production, adsorber bed B undergoes equalisation and subsequent depressurisation. The cycle continues at the point where adsorber bed A undergoes pressurisation and adsorber bed B is depressurised.

Plant control and turn down

The N₂-PSA plant is controlled by a programmable logic controller (PLC).

Its main control features include:

- Automatic operation of the entire N₂-PSA plant
- Supervision of process parameters with safety shut down and alarm in case of abnormal plant operation
- Control of the process values on a display
- Sophisticated plant diagnostics

The (im)purity of the product is being checked continuously by an automatic online O₂-analyzer.

Start-up and shut-down

The start-up of the plant is a simple push button operation. The product is being delivered within a short time from start-up.

At shut-down of the plant, a precisely defined programme cycle continues to run for a few minutes before complete shut-down is reached. The adsorbers are then in regenerated conditions and prepared for restart of operation. After restart product in accordance with specification can be produced within a few minutes.

Turndown operation

The plant flowrate can be reduced by inserting an "idle" step in the cycle thus saving plant power.

This is performed automatically by the PLC. The PLC program adjusts process parameters accordingly.

Typical A-series nitrogen PSA





Application of PSA generated Nitrogen

Operation and maintenance

The LINDE N₂-PSA plant is designed to run unattended during normal operation. The plant requires a minimum of operating and maintenance attention. The N₂-PSA will be designed and constructed to provide proper flexibility and easy accessibility for operation and maintenance of the machinery, valves and instrumentation.

Safety aspects

The plant operates at moderate temperatures and pressures. All necessary safety devices to avoid increased pressures, excessive or insufficient temperature or other failure functions are provided.

Safety, health, environment and quality (SHEQ)

Controls relating to safety, health, environment and quality are a pre-requisite for the Linde work processes.

Building/shelter

Due to the severe ambient conditions and in order to protect the PSA unit from driving rain and direct sunlight, it is strongly recommended to install the PSA unit in a closed shelter, at least a roof covering the valve skid and the compressor shall be supplied.

G-series nitrogen PSA.

The G-series comprises fully standardized nitrogen PSA generators with 26 plant sizes and hence providing optimal solution within its product range and purity.

Particular features of G-series nitrogen PSA

- Fully standardized
- Low investment
- Compact arrangement
- Existing standard documentation
- Short delivery, installation and commissioning time

The product ranges for the G-series plants are:

N ₂ -product range	50 - 1,500 Nm ³ /h
Nitrogen (N ₂ +Ar) purity	97 - 99.9 %
Oxygen impurity	3 - 0.1 %

Typical G-series nitrogen PSA plant for the generation of nitrogen, 310 Nm³/h, 0.5% O₂





A-series nitrogen PSA plant designed according to individual project specification

A-series Nitrogen PSA

The A-series comprise fully tailored nitrogen PSA generators. With its A-series PSA plants Linde is able to follow individual customers project specifications, standards and requirements. (e.g. for refineries etc.)

Particular features of A-series nitrogen PSA

- Tailor made according to individual project specifications and requirements
- High capacity and purity range
- Modular and prefabricated design

The product ranges for the A-series plants are:

N ₂ -product capacity	50 - 5,000 Nm ³ /h
Nitrogen (N ₂ +Ar) purity	97 - 99.9999 %
Oxygen impurity	3 % - 1 ppm

The advantages of Linde N₂-PSA

The Linde PSA process for the generation of nitrogen provides remarkable advantages:

First quality

- Only components are used which have proven highest durability.

Low nitrogen product cost

- The Linde PSA system produces high purity nitrogen at lowest cost compared to conventional cryogenic units or liquids supplied from outside.

Highest reliability

- The PSA system provides highest reliability. The control system allows for the production of nitrogen at the specified flow and purity within minutes of demand using simple push button.

Easy turn-down

- Excellent flexibility to match actual client needs are achieved with the PSA system as it provides a turn-down ratio between 0% and 100% at unchanged purity and at nearly proportional energy consumption.

Fully automatic operation

- The PLC based control system controls the purity and the flow by automatically adjusting the cycle time of the PSA system. A modbus port for the communication with a plantwide DCS and/or a communication board for the remote control by a modem can be supplied as an option.

Modular skid design

- The shop fabricated valve skid design reduces the on-site costs for erection and commissioning.

Easy maintenance

- Only routine maintenance is required. All components are easily accessible.

Typical G-series nitrogen PSA plant mounted in a container





A-series nitrogen PSA plant with high pressure nitrogen storage

The N₂-PSA layout

All components on the skid – including nitrogen product analyzer and control system – are completely piped and wired for quick assembly at the job site.

The Linde N₂-PSA nitrogen generators can be designed for indoor or outdoor installation.

The scope of supply

The scope of supply mainly comprises the following material and equipment:

- Air compressor, if required
- Adsorber vessels
- Specially selected adsorbent material
- PSA buffer drum
- Valve skid
- Control system
- Nitrogen product O₂-analyzer
- Nitrogen product compressor, if required



Heavy industrial standard for LINDE nitrogen PSA plants

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 adsorption plant team:

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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