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Evaluation of Nitrogen Systems for Fire Suppression in Northern British Columbia Wood Pellet Plants

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After multiple severe fire incidents in Northern BC wood pellet plants and long delivery time for Nitrogen (in some cases days of waiting), WorkSafeBC met with WPAC safety committee and evaluation of a Nitrogen suppression system became a priority. WPAC's safety committee asked me to evaluate the possible available options to ensure we can secure quick access to enough supply of nitrogen in case of any fire incidents.

Self-heating of wood pellets and silo fires is a major concern during storage of wood pellets. An effective approach to suppress silo fires is through nitrogen injection into the silo. However, access to large amount of nitrogen may take days should a silo smoldering/fire occur in some areas. The closest nitrogen storage for wood pellet plants located in northern BC is 10-15 hours away, in Edmonton and thus it may take hours to receive nitrogen. Or it might also be in use at the time it is requested and thus it may take days to get access to sufficient nitrogen. Moreover, some infrastructure is needed for nitrogen injection on-site such as piping, injection point location and its orientation that must be built into the silo.

The needs for quick access and application of nitrogen for wood pellet storages in a silo fire emergency was discussed and evaluated with four vendors. The discussion included identifying the required flowrate and infrastructure needed on-site for each option, evaluating mobile nitrogen vaporizer units as well as on-site nitrogen generation units through separation from air. Below is a summary of evaluated options. I have evaluated the four available options for on site nitrogen generations (either through separation of N_2 from air or vaporization of mobile liquid N_2 mounted on trailer) in response to developing a Suppression System for Northern British Columbia. This document provides a summary of the four evaluated nitrogen systems. The required design specification for the nitrogen systems, and all other infrastructure needed on-site to get connected to a central mobile nitrogen storage have also been considered.

Nitrogen Generation and Vaporization Systems Alternatives

- **<u>Atlas Copco Nitrogen Systems</u>**

Atlas Copco has two nitrogen generating system available. NGM (Membrane Nitrogen Generation) and NG (Pressure Swing Adsorption Nitrogen Generation) which are both systems that generate nitrogen from air through gas separation.

The NGM consists of several parallel membranes, each of which consists of a bundle of fibres. Gas separation takes place as the pressurized air flows through the fibres. When they enter into contact with the membranes, oxygen, carbon dioxide and water vapour quickly permeate

through the fibre walls and exit at atmospheric pressure through the vent port on the side of each module. Nitrogen, does not permeate through the fibre walls as quickly under flowing conditions. As a result, enriched nitrogen exits the product manifold on the end of the module housing at a slightly lower pressure than the air entering the housing. Water vapour is also separated through the membrane. As a result, the nitrogen will have a pressure dew point of -40°C as a minimum, which means in most of cases that no additional drying is required.

The NG unit consists of two vessels, both of which contain Carbon Molecular Sieves (CMS). While one tower is capturing the oxygen, the other one is regenerating. The CMS is a type of activated carbon with pores in which the oxygen molecules are captured, whereby the output flow has reduced oxygen content. The purity of the nitrogen at the outlet of the NG can be as high as 99.9999%. Since the CMS is very sensitive to humidity, the air has to be dried before entering the NG unit. This can be achieved either with a refrigerant dryer or an adsorption dryer, depending on the required pressure dew point of the nitrogen at the outlet of the unit. Nitrogen generation with PSA technology is a discontinuous process. To level out fluctuations in nitrogen flow, an air receiver is installed at the inlet of the unit and a nitrogen receiver at the outlet of the unit. The units are built according to the required customer specifications.

Although the final quote of this system is still to be received, it is in the range of close to 1 million dollar.

- **Compressed Gas Technologies Nitrogen System**

HNS PSA nitrogen generators use patented technology to produce an uninterrupted supply of gaseous nitrogen, on site. This compact system is ideally suited for high flow applications that presently employ liquid nitrogen bulk delivery systems. With the HNS, the inconvenience of daily, weekly or monthly deliveries is eliminated. Nitrogen is generated at your location, continuously and reliably, requiring only a supply of compressed air.

The HNS operates on the Pressure Swing Adsorption (PSA) principle to produce a continuous stream of nitrogen gas from compressed air. Two towers are filled with carbon molecular sieve (CMS). Pretreated compressed air enters the bottom of the 'on-line' tower and follows up through the CMS. Oxygen and other trace gases are preferentially adsorbed by the CMS, allowing nitrogen to pass through. After a pre-set time, the on-line tower automatically switches to regenerative mode, venting contaminants from the CMS. Carbon molecular sieve differs from ordinary activated carbons in that it has a much narrower range of pore openings. This allows

small molecules such as oxygen to penetrate the pores and be separated from nitrogen molecules which are too large to enter the CMS. The larger molecules of nitrogen by-pass the CMS and emerge as the product gas.

The customized system with the flowrate needed our application @ 98% purity nitrogen generator package would cost $750K US. The equipment would need to be installed indoors.

- **Linde group Nitrogen System**

Linde's nitrogen pressure swing adsorption (PSA) plants are designed for on-stream applications that require clean, dry, high-purity nitrogen for inerting, blanketing and purging processes. Linde can deliver nitrogen PSA plants with capacities ranging from several Nm^3/h to several thousand Nm^3/h. The PSA plants can produce nitrogen purities of all levels, with oxygen content ranging from a few percent down to the ppmv level. The nitrogen gas is normally provided at pressures between 4 bar(g) and 9 bar(g) (between 60 psig and 130 psig). A downstream nitrogen compressor can be used if higher pressures are required. Linde offers two different series of nitrogen PSA plants:

GX series: The GX series comprises fully standardized nitrogen PSA plants. Customers can choose from 20 different sizes. GX-series plants require low investment and have short delivery times, making them the ideal solution for capacities ranging from approximately 50 to 1,500 Nm^3/h and nitrogen purity levels from approximately 97 to 99.9 vol.-%.

A series: A series nitrogen PSA plants are tailored to individual project specifications, standards and requirements (for example, nitrogen PSA plants for refineries).

Capacities range from around 50 to 5,000 Nm^3/h and nitrogen purity levels from around 97 to 99.9999 vol.-%.

Although the final quote of this system is still to be received, it is in the range of close to 1 million dollar.

- **Praxair Nitrogen Systems**

The unit Praxair would provide is composed of individual components such as liquid N_2 pressure tank, vaporizer and steam bath vaporizer (to avoid freezing off at high flow volumes) all. What makes the unit unique is that all components are trailer-mounted together, to enable the mobility of the unit, and do not require external power supply. Praxair will review all plants silo drawings and designs and make recommendations to ensure the unit can be hooked up safely in case of any fire. This system can be parked somewhere close to the plants and be shared

between different plants. However, engagement of a third-party company who has the license to drive LG is required.

The mobile trailer mounted nitrogen system cost is around $850,000 CAD. Praxair would offer purchase or log-term lease for this system. Unit specifications, maintenance needed, and examples of payments can be found in Appendix D.

Table 1. Nitrogen systems comparison

	Atlas Copco	**Compressed Gas Technologies**	**Linde Group**	**Praxair**
Technology/ Equipment Used	Membrane and Pressure Swing Adsorption (separation of N_2 from air on site)	pressure swing adsorption (PSA) (separation of N_2 from air on site)	pressure swing adsorption (PSA) (separation of N_2 from air on site)	liquid N_2 pressure tank, vaporizer and steam bath vaporizer
Price	In the range of 1 million dollar (exact quote not received yet)	$750,000 USD per plant	In the range of 1 million dollar (exact quote not received yet)	$850,000 CAD Option #1 – Purchase (~$8,765/month) Option #2 – Long term lease (~$7,265/month for minimum 180-month lease)
Advantages	On site N_2 generation and thus no need for liquid N_2 storage	On site N_2 generation and thus no need for liquid N_2 storage	On site N_2 generation and thus no need for liquid N_2 storage	Can be shared between several plants
Disadvantages	Need to be set up at every plant, should be installed indoors	Need to be set up at every plant, should be installed indoors	Need to be set up at every plant	Continuously need N_2 refill, Third party needed to drive the trailer, continuous maintenance is needed
Mobile Unit?	No	No	No	Yes

Recommended Next Steps

- After evaluation of possible nitrogen systems and technologies available, due to very high cost of all three PSA systems and the need to set it up for each plant, the only viable economic option is the one offered by Praxair. The mobile nitrogen system can be shared between multiple plants to be used in fire incidents.
- The practical details for the proposed solution needs to be worked out including a location (parking spot) for the trailer, hauler with certifications needed to drive the trailer, operation training and maintenance, necessary fittings in the plant to hook up the nitrogen system, identify cost of maintenance and other associated monthly costs
- Identify all costs associated with operation of the unit in case of any fire incident
- Identify which plants want to contribute to it and how the cost share formula looks like
- Identify and evaluate any source of external funding if any

Appendix A
Atlas Copco Nitrogen Systems

www.atlascopco.com/nitrogen

Atlas Copco Group

Atlas Copco is an industrial group with world-leading positions in compressors, expanders and air & gas treatment systems, construction and mining equipment, power tools and assembly systems. With innovative products and services, Atlas Copco delivers solutions for sustainable productivity.

The company was founded in 1873, is based in Stockholm, Sweden, and has a global reach spanning more than 170 countries. in 2011, Atlas Copco had about 37,500 employees and revenues of BSEK 81(BEUR 9).
Learn more at www.atlascopco.com.

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Atlas Copco

www.atlascopco.com

Generate your own nitrogen supply for improved efficiency

Extract nitrogen from the air instead of buying it

Sustainable Productivity

Atlas Copco

Nitrogen is a colourless, tasteless and odourless gas ideal for reducing oxidation

What is Nitrogen?

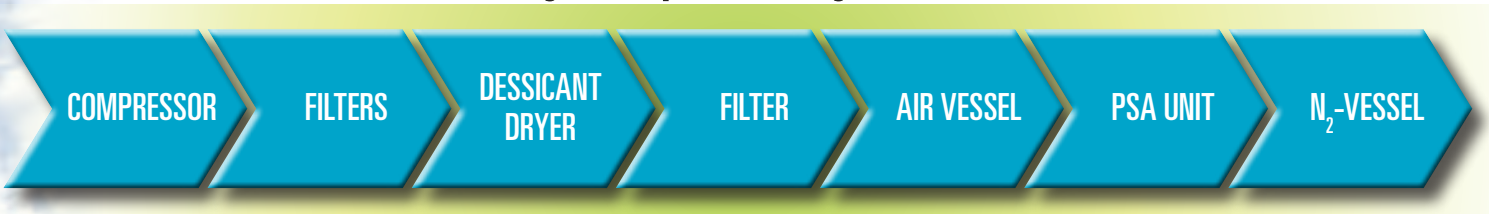
Nitrogen is an inert, odourless and colourless gas that doesn't sustain life. It is extremely useful in industry as it prevents fast and slow oxidation.

Fires or explosions are perfect examples of fast oxidation. If a vessel is flushed with nitrogen, the oxygen is removed, along with the risk of fire or explosion as these processes need to be fuelled by oxygen. Nitrogen is also used to prevent slow oxidation, i.e. the corrosion of non-organic products or the growth of bacteria in food products.

The level of purity needed for nitrogen depends upon its use. For most applications, high purity (over 95%) is necessary, a level easily achieved by both Atlas Copco's Membrane and PSA technologies. A purity of 99,9999% can even be reached.

Since the number of applications for nitrogen is increasing, there is a growing tendency for businesses to generate nitrogen on site, rather than using liquified nitrogen, particularly in view of the fact that the technology has significantly evolved, making it more competitive not to mention safer to handle.

NG (Pressure Swing Adsorption Nitrogen Generator)



NGM (Membrane Nitrogen Generation)

A reliable partner throughout the whole process of nitrogen generation

Atlas Copco is your reliable partner throughout the whole nitrogen generation process, supplying equipment all the way from compressors to our PSA or Membrane units. Together with our **proven track record** and our **worldwide presence**, having a **single point of contact** will set your mind at ease, saving costs and allowing you to work more efficiently.

On-site nitrogen generation eliminates transport costs

Our compact Nitrogen generators enable you to produce nitrogen on site, which eliminates all costs attached to transport and bottling, **thereby improving cost-efficiency in relation to other types of generation**.

Adjust the purity of the nitrogen to its purpose

For certain applications, nitrogen purity has to be close to 100%, whereas for others, a lower level is perfectly adequate. Atlas Copco generators can ensure that you reach **the exact required quality or purity** without any unnecessary expense, due for instance to the purchase of bottles of nitrogen, which are only available with N_2 in the purest form.

A complete concept for nitrogen generation, that's our offer!

Atlas Copco offers the whole range of machinery for nitrogen generation, from initial compression and filtering right through to the gas's storage. As a result, with just a simple phone call to your Atlas Copco contact person, any failure in the production process is handled promptly without you having to worry about who to contact.

NG (Pressure Swing Adsorption Nitrogen Generator)

COMPRESSOR → FILTERS → DESICCANT DRYER → FILTERS

Compressor: Atlas Copco's compressors guarantee a reliable and efficient supply of compressed air to the nitrogen system.

Filter: Our air filters ensure a proper filtration of the compressed air with a minimum of pressure drop and a long cartridge lifetime.

Desiccant dryer: Atlas Copco's desiccant dryers dry the compressed air using a minimum of energy and generating a minimum pressure drop.

Filter: Our air filters ensure a proper filtration of the compressed air with a minimum of pressure drop and a long cartridge lifetime.

NGM (Membrane Nitrogen Generation)

COMPRESSOR → FILTERS → ACTIVATED CARBON TOWER → MEMBRANE UNIT

Compressor: Atlas Copco's compressors guarantee a reliable and efficient supply of compressed air to the nitrogen generation system.

Filter: Our air filters ensure a proper filtration of the compressed air with a minimum of pressure drop and a long cartridge lifetime.

Activated carbon tower: To ensure a proper protection of the membrane unit and to remove all hydrocarbons and ozone from the compressed air, an activated carbon tower with a long stand time is installed in front of the membrane unit.

Membrane unit: Atlas Copco's NGM delivers the required nitrogen flow at the required purity.

AIR VESSEL

Air Vessel: The PSA process, which is inherently a fluctuating procedure, naturally requires a fluctuating inlet flow. To guarantee the smooth operation of the compressed air system, an air vessel is installed before the NG.

PSA UNIT

PSA unit: Atlas Copco's NG delivers the required nitrogen flow at the required purity with PSA technology.

N_2-VESSEL

Nitrogen vessel: Since nitrogen production is a discontinuous process, a nitrogen vessel is installed at the outlet of the NG to guarantee a continuous outlet flow of nitrogen.

The right solution for a whole range of applications

At Atlas Copco, we know your application and our solutions are a perfect match for your needs. Nitrogen is used in many industries, either in the production process itself or for the handling and storage of goods. This gas can be used either to protect the environment from the product or vice-versa. It is also utilised in applications such as soldering and moulding for increased effectiveness.

1. Blanketing

Tank Blanketing refers to applying a cover of nitrogen gas over the surface of a stocked commodity to protect or contain the stored product or prevent it from causing harm.

Blanketing:
- Prevents liquid from vaporizing into the atmosphere
- Reduces ignition potential
- Prevents oxidation or contamination of the product by reducing its exposure to atmospheric air
- Reduces the moisture content

Surface Equipment Inerting: By applying a cover of nitrogen, explosions in the environment can be prevented.

Transport: Nitrogen blanketing is used for protection during the transport of flammable and oxidising products.

Glass Industry: Blanketing with nitrogen prevents tin from oxidizing. It also prevents air infiltration during the process.

Pharmaceutical industry: Nitrogen is used for inerting flammable products, and on the other hand, to protect fragile products against oxidation and humidity.

Metal annealing: Nitrogen is used to purge heat treat furnaces and reflow solder baths.

Chemical industry: Applications include blanketing for storage, the regeneration of purification beds, the preparation of catalysts, and the transport of polymer powders. Nitrogen also serves as a medium for the exhaust of heat in fluid bed reactors and to control temperature in reactors.

2. Modified Atmosphere Packaging (MAP)

MAP is an increasingly popular technique used to easily and economically improve product quality and extend shelf-life.

Flushing packaged foods with inert high purity nitrogen delays aerobic spoilage and oxidative deterioration by typically reducing the oxygen level in packaged foods to below 1% so that food tastes as good as the day it was made.

Nitrogen is primarily used to reduce the oxygen content within food packaging and to avoid product deterioration. A secondary reason for using nitrogen is as a filler gas to provide a pressurised atmosphere that prevents package collapse.

3. Electronics

Electronic Packaging
The presence of moisture and oxides can lead to reductions in yields.

Nitrogen has become a key to preventing some of these problems by creating an inert area around the process that is free of moisture and other impurities.

Reflow soldering
In this process, nitrogen is used to drive out the oxygen from the soldering chamber. This prevents the solder pads and component terminals from oxidising during the reflow of the solder paste. Furthermore, improved soldering quality and less reoxidation increases the strength of the solder joints. The process window is also enlarged.

4. Gas Assist Injection Moulding

Nitrogen is used to reinforce ribbed parts, which eliminates sink marks and surface blemishes. The gas is injected with a uniform pressure distribution throughout the mould.

This means larger parts can be produced with less tonnage on smaller machines, which reduces capital investment when purchasing new equipment. Another benefit is weight reduction while rigidity is preserved, and it also makes it possible to produce piping with intricate shapes.

Gas-assist injection moulding is faster and uses less material, saving you time and money.

Two performing technologies to meet your specific demands

Whether you need nitrogen of the highest purity or of a lower purity for your specific application, Atlas Copco has the perfect technological solution for you.

In the case of membrane air separation, air is pumped through membrane fibres, a process whereby nitrogen is filtered out as it permeates more slowly through the membranes. In the case of Pressure Swing Adsorption, Carbon Molecular Sieves capture oxygen, as a result of which the concentration of nitrogen at the outlet increases (up to 99.9999%).

NGM (Membrane Nitrogen Generation)

The NGM

The NGM consists of several parallel membranes, each of which consists of a bundle of fibres. These fibres are polymer structures with the membrane as a thin layer at the outside.

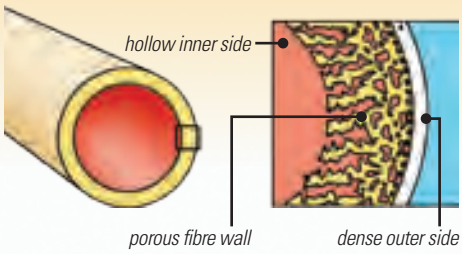
Gas separation takes place as the pressurized air flows through the fibres. When they enter into contact with the membranes, 'fast' gases such as oxygen, carbon dioxide and water vapour quickly permeate through the fibre walls and exit at atmospheric pressure through the vent port on the side of each module.

Nitrogen, a "slower" gas, does not permeate through the fibre walls as quickly under flowing conditions. As a result, enriched nitrogen exits the product manifold on the end of the module housing at a slightly lower pressure than the air entering the housing.

Water vapour is also separated through the membrane. As a result, the nitrogen will have a pressure dew point of -40°C as a minimum, which means in most of cases that no additional drying is required.

The membranes are sensitive to water droplets and other contaminations, so inlet filtration is required.

Hollow fibre with assymetric structure



NG (Pressure Swing Adsorption Nitrogen Generation)

The NG unit consists out of two vessels, both of which contain Carbon Molecular Sieves (CMS). While one tower is capturing the oxygen, the other one is regenerating.

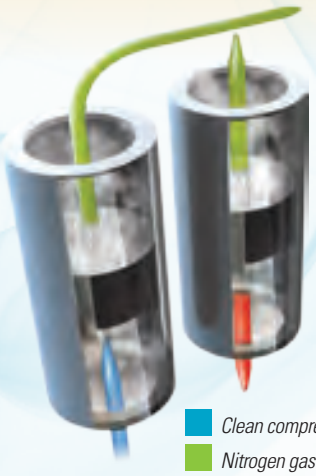
The CMS is a type of activated carbon with pores in which the oxygen molecules are captured, whereby the output flow has reduced oxygen content. The purity of the nitrogen at the outlet of the NG can be as high as 99.9999%.

Since the CMS is very sensitive to humidity, the air has to be dried before entering the NG unit. This can be achieved either with a refrigerant dryer or an adsorption dryer, depending on the required pressure dew point of the nitrogen at the outlet of the unit.

Nitrogen generation with PSA technology is a discontinuous process. To level out fluctuations in nitrogen flow, an air receiver is installed at the inlet of the unit and a nitrogen receiver at the outlet of the unit.

The units are built according to the required customer specifications.

The Carbon Molecular Sieve has a much narrower range of pore opening than the standard activated carbon which allows the NG to deliver a purity of up to 99,9999%.



- *Clean compressed air*
- *Nitrogen gas*
- *Oxygen exhaust*
- *Carbon Molecular Sieve*

The small oxygen molecules will penetrate the pores while the big nitrogen molecules will by-pass the Carbon Molecular Sieve.

A complete and reliable package

NGM (Membrane Nitrogen Generation)

The NGM nitrogen generator is supplied as a package containing the inlet air treatment equipment, the regulating valves, the membranes, the nitrogen outlet package and the controls. The range is available for purities of 95% up to 99,5% and Nitrogen flows from 100 Nm³/hr up to 1000 Nm³/hr. This is the standard range and is called NGM.

Higher purities and flows can be provided on request. Furthermore, higher customer specs can be met by our NGME units, which are the engineered products.

Application range

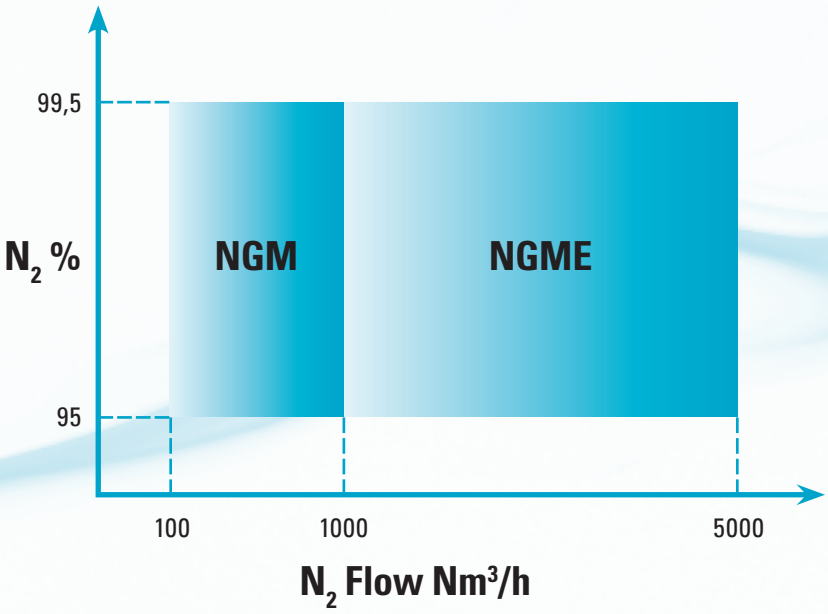
NGM's can operate in a much wider range of conditions:

- From -10°C to 75°C inlet temperature
- From 4-25 bar inlet pressure
- For purities of 95-99,5%

Benefits

Advantages of an NGM unit:

- The most efficient system for working at lower purities
- Light and easy to transport
- Not sensitive to vibrations
- No moving parts means less maintenance
- No need for extra dryer
- Constant flow
- Modular, i.e. a membrane can be removed while the unit can keep on working



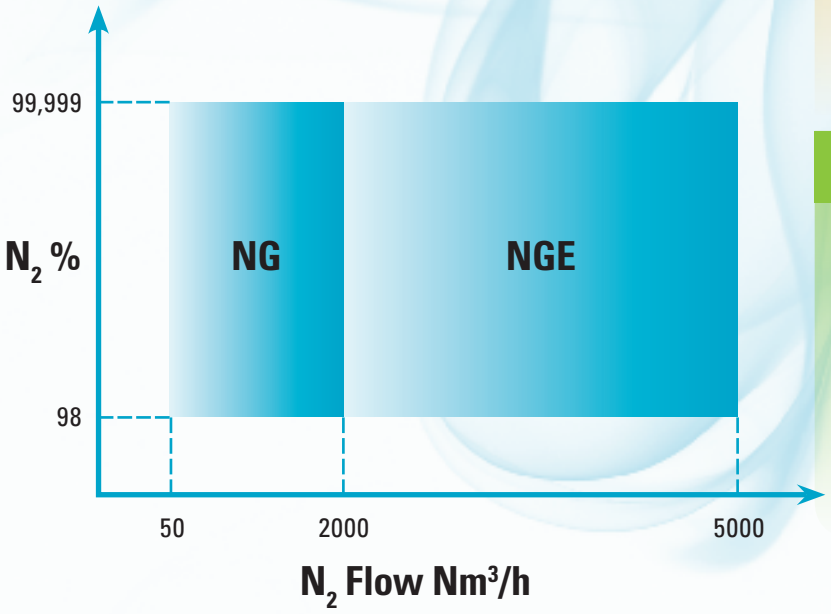
NG (Pressure Swing Adsorption Nitrogen Generation)

The NG nitrogen generator is supplied as a package containing the inlet air piping, controls and valves.

The unit consists of two pressure vessels both filled with carbon molecular sieves.

The range is available for purities of 98% up to 99,9999% and Nitrogen flows from 50 Nm³/hr up to 2000 Nm³/hr. This is the standard range and is referred to as NG.

Higher purities and flows can be provided on request, and higher customer specs can be met by our NGE units, which are the engineered products.



Application range

The NG operates effectively in a limited range:

- From 10-25°C inlet temperature
- From 4-13 bar pressure
- For purities of 98-99,9999%

Benefits

Advantages of a NG unit:

- More efficient at higher purity levels
- Cost-efficient
- Easily customizable
- Compact unit for bigger flows
- The exact nitrogen purity to meet your application demands

Appendix B
Compressed Gas Technologies Nitrogen System

CGT

COMPRESSED GAS TECHNOLOGIES INC.

The Gas Generation Specialists

APPLICATIONS

Food Packaging & Processing:

Modified Atmospheric Packaging is a proven method for extending shelf life without using chemical food preservatives. Almost every type of snack food can be packaged with nitrogen. These include potato chips, dried meat snacks, pre-cut fruits and vegetables, nuts, crackers, and cookies. The use of extremely dry nitrogen inside food packages eliminated moisture problems. Reduced oxygen content also diminishes the oxidation and discoloration of food.

Food Preservation (Controlled Atmospheric Storage):

When fruits and vegetables are stored at their optimum temperature, their respiration rate is reduced. A nitrogen purge lowers the oxygen levels inside the storage facilities down to 2-5%, further reducing the fruit's respiration rate. When apples are stored at their optimal temperature, they can last for 2-3 months. But, by reducing the oxygen level inside the storage warehouses with nitrogen, these same apples can be stored for over a year. For many perishable fruits, particularly apples, bananas, pears, berries, and kiwis, the quality of freshness can be significantly prolonged by storage in refrigerated warehouses filled with a balanced atmosphere of nitrogen, oxygen, and carbon dioxide.

Chemical Processing & Blanketing:

Production, storage, handling, and blanketing of chemicals will sometimes require the use of chemically inert nitrogen. Nitrogen is used by the chemical industry to protect against the danger of fire, moisture contamination, and discoloration or product degradation that result from atmospheric moisture and oxygen.

Laboratory Nitrogen:

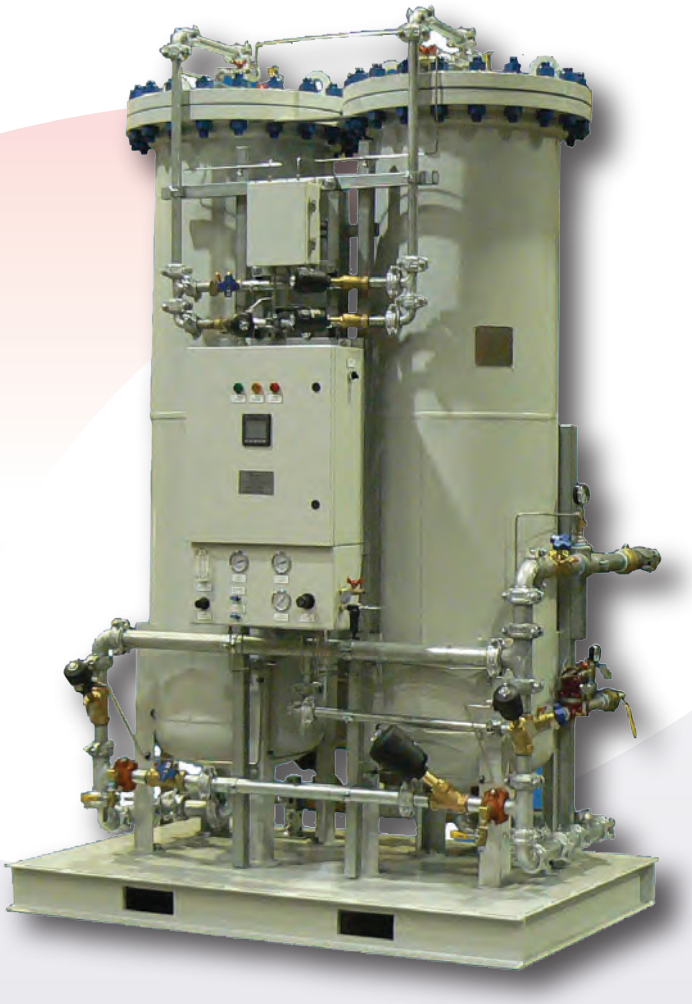
Nitrogen is used within the laboratory in a wide range of applications because of its relative inertness, chemical inactivity and non-combustibility. Nitrogen is used as a carrier or make-up gas for gas chromatographs; as an inert atmosphere within glove boxes and fume cupboards and for instrument purging of mass spectrometers and inductively coupled plasma applications.

Tire Filling:

The aircraft industry, racing teams, and US Military have been using nitrogen to inflate their tires for years now. Nitrogen has been proven as the best choice for maintaining proper pressure in tires, therefore adding to the life of the tires, improving gas mileage, and ensuring the rims are not damaged due to corrosion. Nitrogen, being a significantly larger molecule than oxygen, will not permeate through the tire wall, thus nitrogen does not have the tendency to leak out of the tire, causing low tire pressure. Nitrogen filled tires will increase safety, improve gas mileage, and reduce operating costs, while improving the performance of the vehicle.

HNS PSA SERIES NITROGEN GENERATOR

HNS PSA nitrogen generators use patented technology to produce an uninterrupted supply of gaseous nitrogen, on site. This compact system is ideally suited for high flow applications that presently employ liquid nitrogen bulk delivery systems. With the HNS, the inconvenience of daily, weekly or monthly deliveries is eliminated. Nitrogen is generated at your location, continuously and reliably, requiring only a supply of compressed air.



HOW IT WORKS

The HNS operates on the Pressure Swing Adsorption (PSA) principle to produce a continuous stream of nitrogen gas from compressed air. Two towers are filled with carbon molecular sieve (CMS). Pretreated compressed air enters the bottom of the 'on-line' tower and follows up through the CMS. Oxygen and other trace gases are preferentially adsorbed by the CMS, allowing nitrogen to pass through. After a pre-set time, the on-line tower automatically switches to regenerative mode, venting contaminants from the CMS. Carbon molecular sieve differs from ordinary activated carbons in that it has a much narrower range of pore openings. This allows small molecules such as oxygen to penetrate the pores and be separated from nitrogen molecules which are too large to enter the CMS. The larger molecules of nitrogen by-pass the CMS and emerge as the product gas.

Features:

- Nitrogen flows from 300 scfh to 30, 000 scfh
- Nitrogen purity adjustable from 95% to 99.999%
- High flow design
- Oxygen analyzer with alarm capabilities
- Energy saving mode - Auto-shutdown during periods of low demand
- High efficiency CMS
- High efficiency compressed air and extractment
- Custom designed systems to meet your exact requirments

Technical Specifications

Delivery Types	• Skid mounted PSA nitrogen generator. • Skid mounted PSA nitrogen generator plant - complete with feed air compressor; air dryer; nitrogen buffer tank.
Purity	• Matching your specific requirements from 95% - 99.999%
Capacity	• Flow capacities to meet any requirement
Pressure	• Low pressure: 0-100 psig.
Electrical	• 115/1/60 - nitrogen generator only.
Temperature	• Working environment: From 32˚F to 95˚F
Separation Technology	• Pressure Swing Adsorption (PSA) using Carbon Molecular Sieves (CMS)
Codes	• ASME • CRN • UL & CUL
Options	• Containerized units. • High pressure option. • Cylinder filling stations. • Low and high ambient conditions.

U.S Mailing Address:

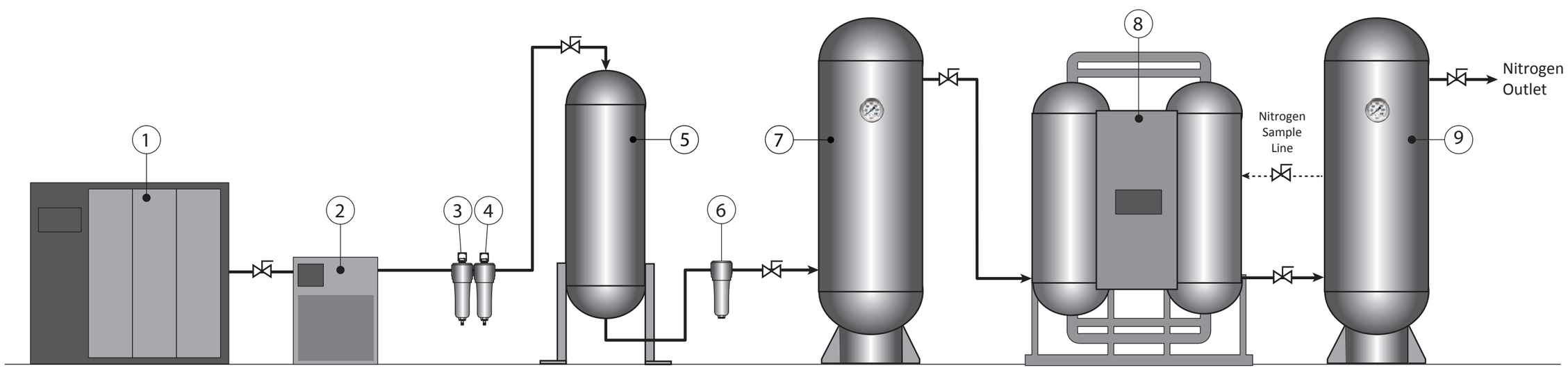
Compressed Gas Technologies
P.O. Box 1953 • Troy, Michigan, USA • 48099-1953

E-Mail: **sales@nitrogen-generators.com**
Website: **www.nitrogen-generators.com**

Canadian Mailing Address:

Compressed Gas Technologies
P.O. Box 61, Station "A" • Windsor, Ontario, Canada • N9A 6J5

Toll Free: **1-877-737-7760**
Phone: **1-519-737-7760** • Fax: **1-519-737-6944**



Proposed equipment:

1. Air Compressor
2. Refrigerated Air Dryer
3. 0.1 micron General Purpose Coalescing Filter
4. 0.01 micron High Effeciency Coalescing Filter
5. Activated Carbon Tower
6. 1 micron Particulate (Dust) Filter
7. Dry Air Receiver
8. CGT PSA Nitrogen Generator
9. Nitrogen Buffer Tank

CGT HNS PSA Nitrogen Generating System

REFERENCE NUMBER	DATE	REVISION

CGT
COMPRESSED GAS TECHNOLOGIES INC.
Nitrogen Generation Specialists

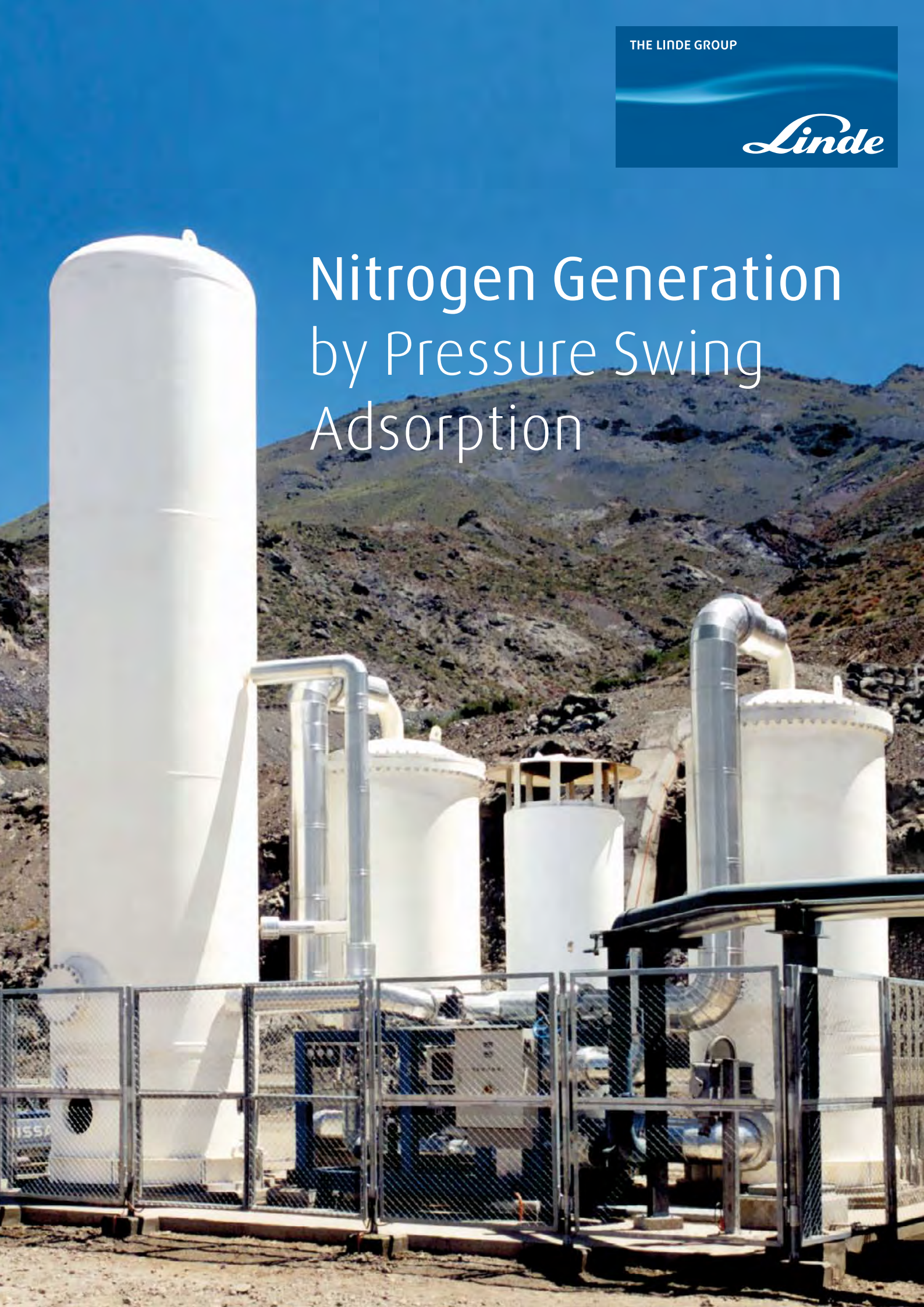
sales@nitrogen-generators.com
www.nitrogen-generators.com
1-877-737-7760

Appendix C
Linde group Nitrogen System

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 Nm^3/h, up to large-scale plants with several thousand Nm^3/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 N_2-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.

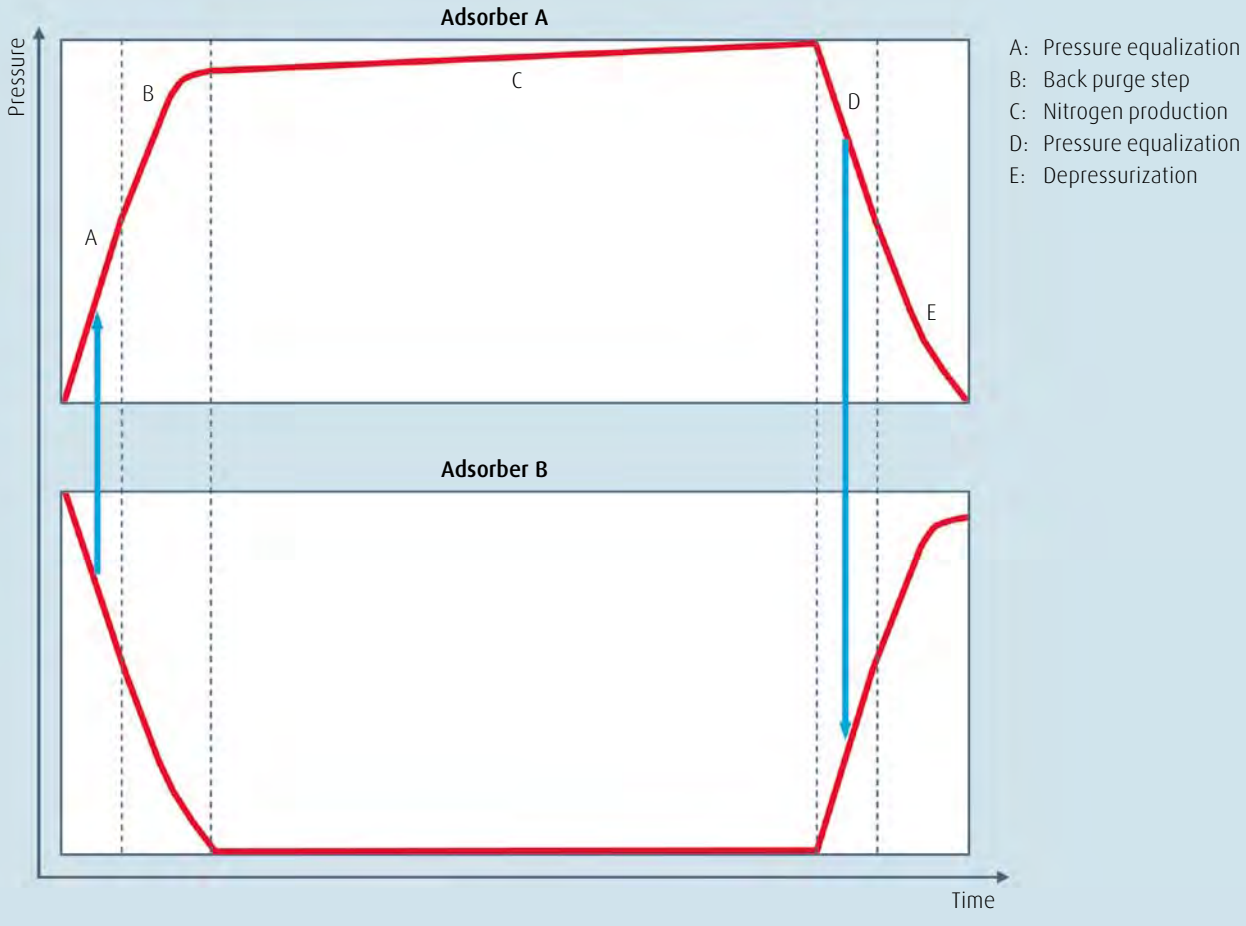
Linde´s PSA systems have proven to be successful in cases where performance, flexibility, availability and reliability are the determining factors. High quality and easy accessibility to all components minimize and facilitate maintenance to the maximum extent.

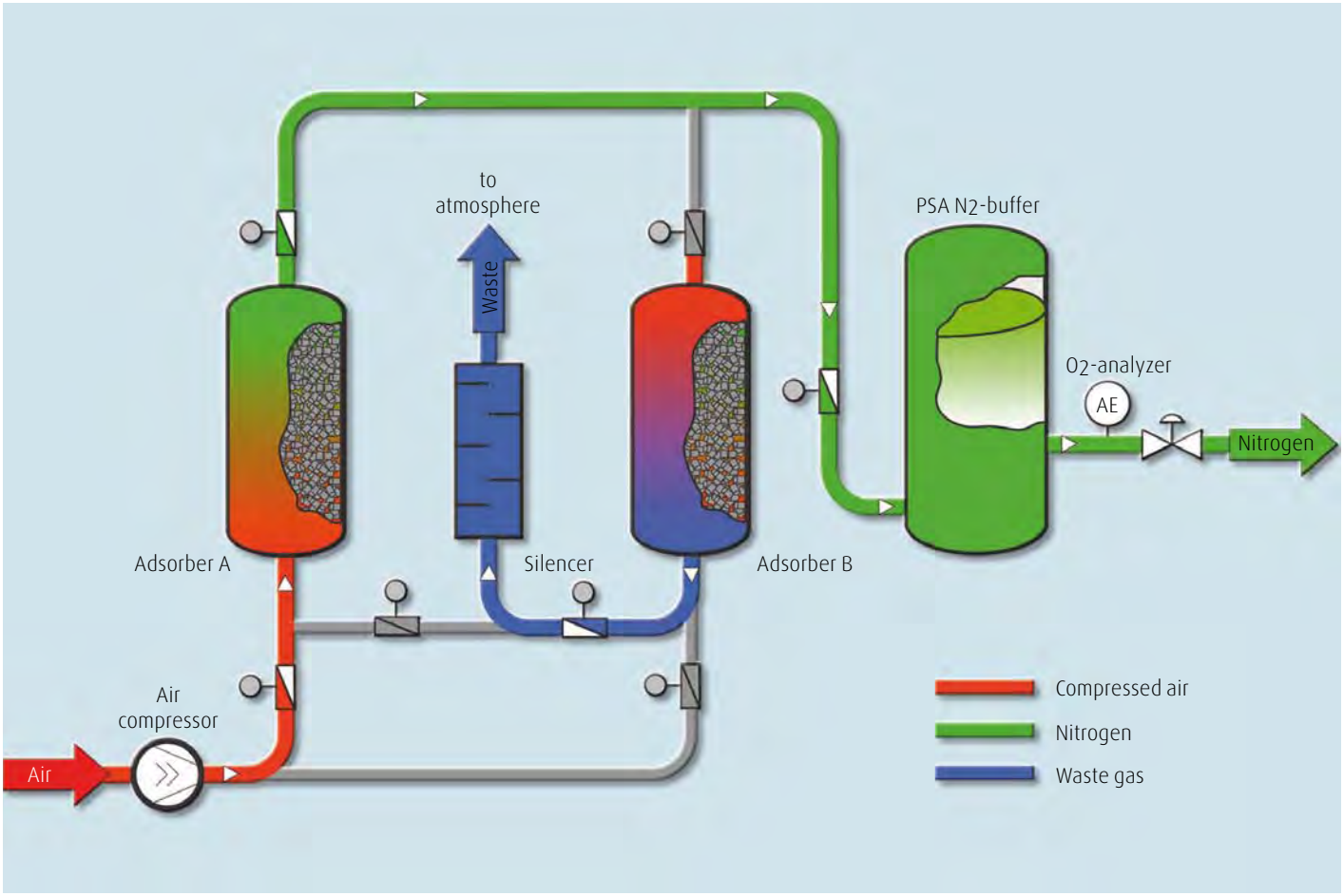
The process.

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.

Carbon molecular sieve

Pressure time diagram for nitrogen PSA process





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 depressurisation 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 N_2-PSA plant is controlled by a programmable logic controller (PLC).

Its main control features include:

- Automatic operation of the entire N_2-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 O_2-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

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 Nm^3/h, 0.5% O_2

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 Nm³/h
Nitrogen (N_2 +Ar) purity	97 - 99.9999 %
Oxygen impurity	3 % - 1 ppm

The advantages of Linde N_2-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 N_2-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 N_2-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 O_2-analyzer
- Nitrogen product compressor, if required

Heavy industrial standard for LINDE nitrogen PSA plants

Biomass Fire Suppression.

Customer presentation.

THE LINDE GROUP

Linde

Contents

1. **Preventing fires**
   - Auto-ignition: why scale is not your friend
   - Studies into the effect of reduced O_2
2. **Fighting fires**
   - The devastating impact of water
   - The gas solution
3. **Linde's solution**

Since December 2010…

… there have been over 24 major biomass combustion incidents world wide

Fire Prevention.

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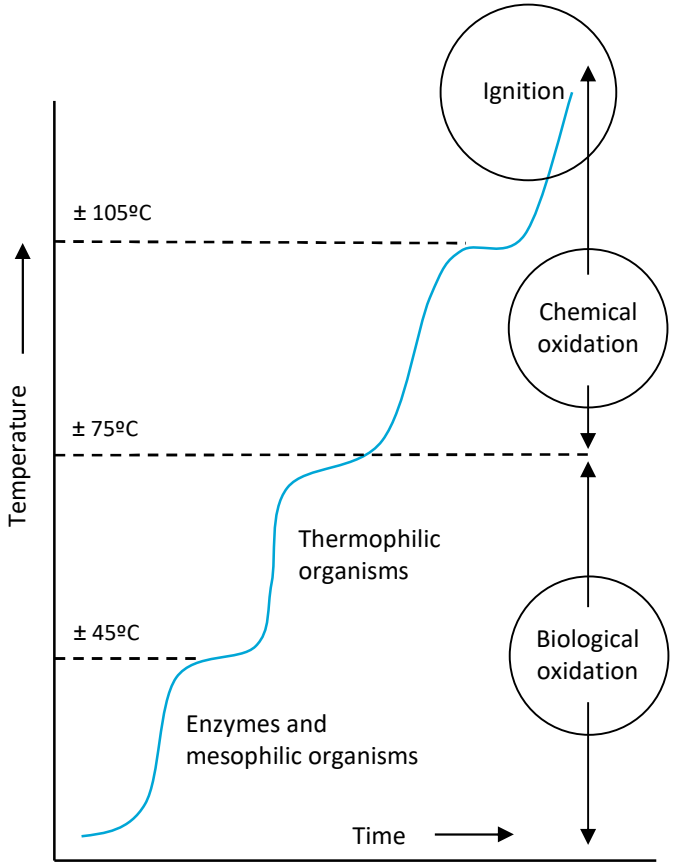
Why does Biomass Auto Ignite?

— Bacterial and fungal activity generate heat in the pile, along with toxic and combustible gases

— If not addressed, the insulating nature of the material causes the temperature to increase

— When the rate of heat generation exceeds the rate of heat loss, the path to ignition and combustion is set

— Runaway reaction (oxidation)



Example of self-heating temperature increase, Meijier, 2004

Challenges of Auto-Ignition

— The fire can occur at very low oxygen levels - levels as low as 3% oxygen can support a pyrolysis

Early indicators

— Carbon monoxide concentration rises

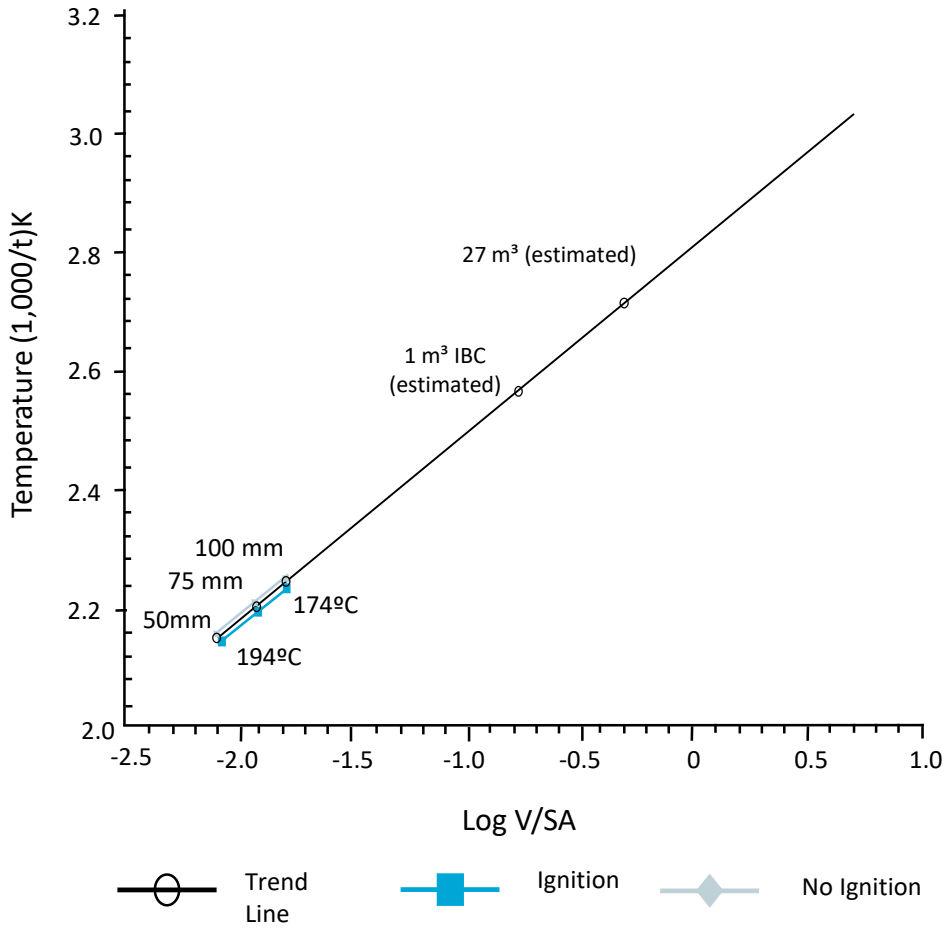
— Followed by temperature increase

— Auto ignition can occur very deep in the material – by the time it is apparent, you already have an issue

— The temperature increase leads to deterioration of fuel quality and loss of dry matter

Auto-Ignition – Geometry and Scale

- Auto-ignition is made worse by the scale and geometry of the storage silo
  - Affects rate of heat loss
- Very large silos can have a critical ignition temperature < 50° C
- These temperatures can be reached in a short space of time
  - Variable with age of material, type of material etc



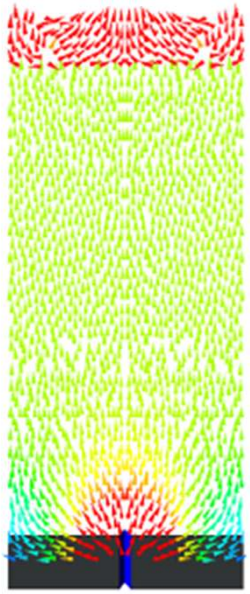
Auto-Ignition – Assessing the Risks

— The Fourier equation provides the basic understanding of combustion in these types of scenarios

$$\frac{\partial T}{\partial t} = \frac{\lambda}{\rho\, c}\ \nabla^2 T + \frac{1}{\rho\, c}\ \rho H_0 k_0 e^{-E/RT}$$

T = Temperature, t = Time, λ = Thermal Conductivity, ρ = Density, c = Specific Heat Capacity, ∇= Differential gradient, H_0 = Self Heating Calorific Value, k_0 = Arrhenius Pre-exponential Factor, E = Activation Energy, R = Universal Gas Constant

— Through investing in combustible testing and CFD modelling, Linde has progressed beyond the Fourier approach to gain a significant understanding of how these fires are generated and how to reduce the risk



Heat produced by oxidation warms up the material producing it and is lost by combustion

The Dangers of Dust

Dust and its hazards are well establishe within the biomass industry

Close confines of a biomass silo

+

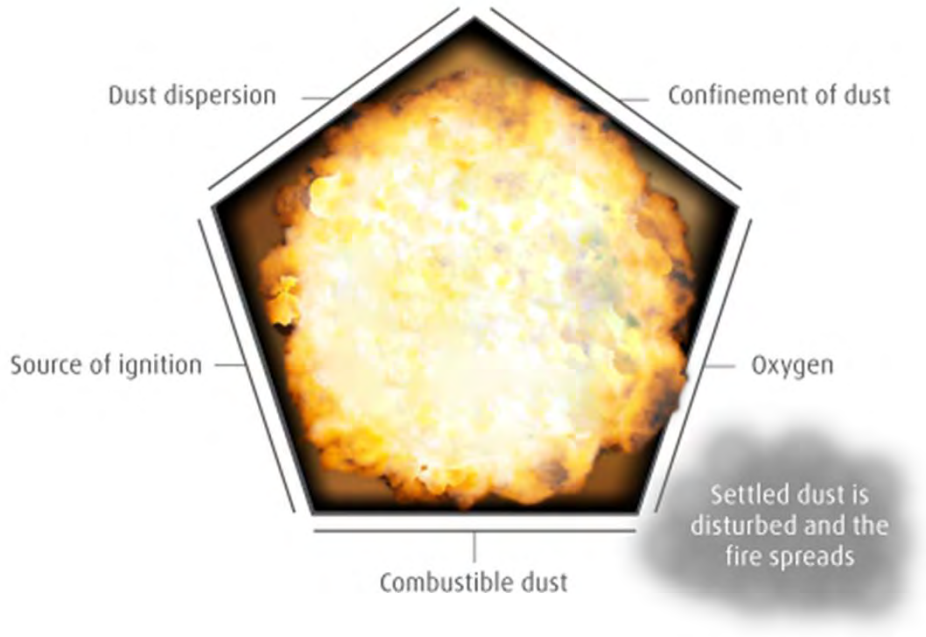
Presence of dust

+

Primary ignition of flammable gases

=

Secondary more powerful explosion



The Gas Solution

Nitrogen

— A constant nitrogen purge through biomass can reduce the rate of bacterial oxidation and assist in conditioning the biomass

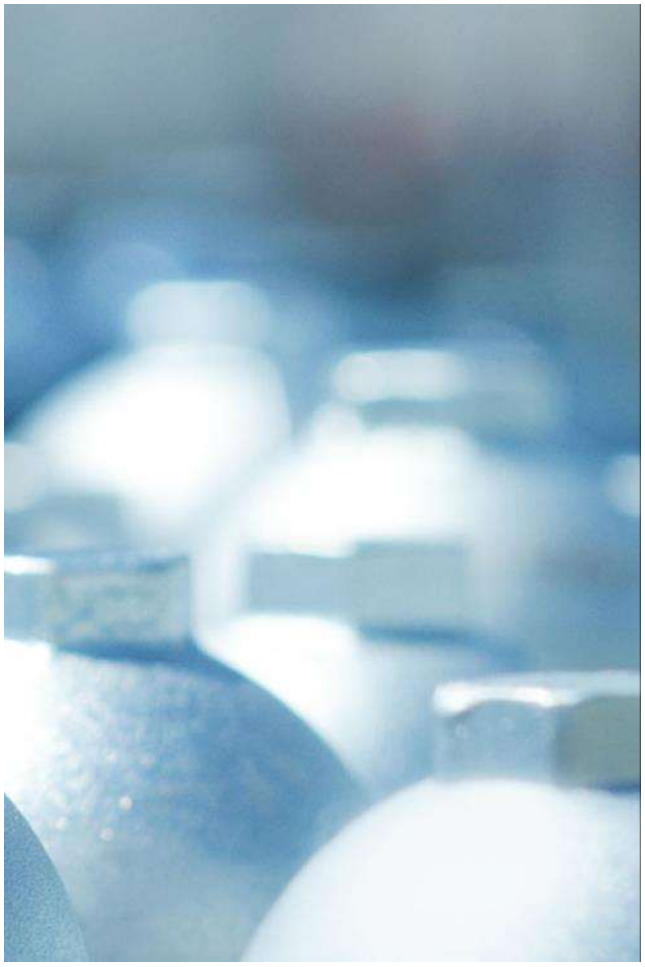
Inerting the silo can:

— Reduce the rate of production of flammable gases such as carbon monoxide

— Help detect a fire more quickly as the nitrogen gas will force combustion gases upwards to gas detection systems at the top of the silo

— Control the temperature of the biomass pile

— Control the oxygen concentration within the silo



Fire Fighting.

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Challenges of Tackling Biomass Silo Fires

- The onset of a fire is often not detected until it has grown to a substantial size
- The fire gives off H_2 and CO
  - Mix may be explosive at >5% O_2
  - CO causes death at 1500ppm
- A minor gas explosion can cause a major dust explosion
- The fire is hard to locate within the pile
  - Insulating nature means use of IR and thermocouples is limited
  - Location of smoke and location of fire is not necessarily correlated
- Water can cause serious complications and will not penetrate the pile
- The fire cannot be left to burn out due to the amount of heat and the insulating properties of the wood
- Re-ignition can occur if the fire is not completely extinguished
  - (1998 fire in Denmark burned for a year before it destroyed the silo)

It is not possible to tackle a biomass silo fire like an ordinary fire

The Issues with Water

- Water causes the pellets to swell
  - Can ‘hydraulic’ the silo
- This effect can make the surface of the biomass impermeable – preventing the effectiveness of extinguishing the fire with water
- Water can create hydrogen in the right circumstances – adding a flammable gas which could lead to an explosion
- Water run off that is not collected and recycled appropriately can cause serious pollution problems – classified as effluent
- Cost of clean up is substantial alongside the damage to the silo and ruination of all the material

The Gas Solution

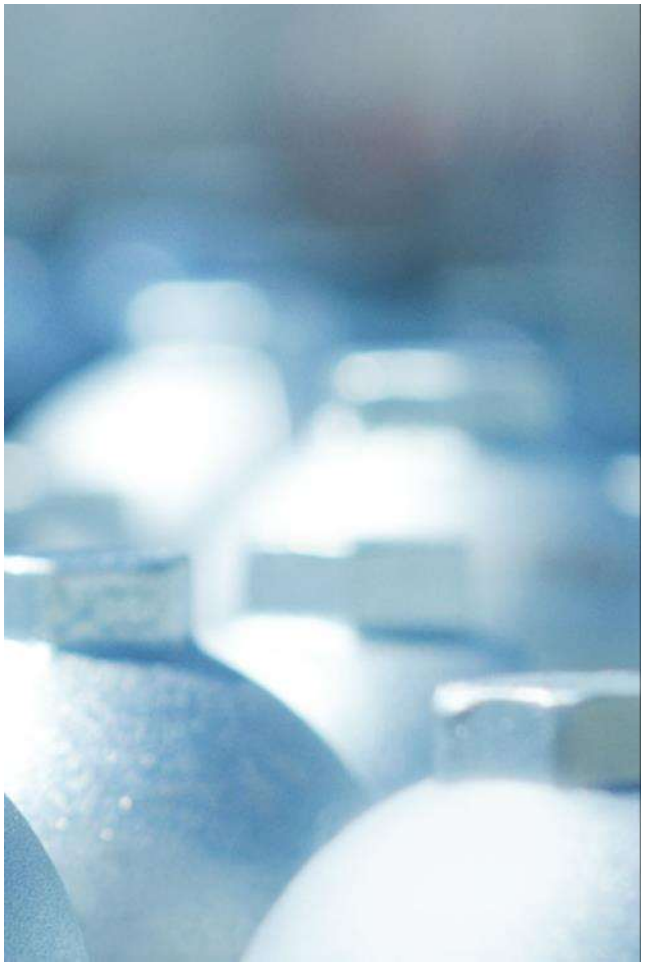
Carbon Dioxide

— Density of >1.5 times air, therefore sinks and forms an inert blanket

— Suppresses smoke production

The Gas Solution

- The removal of oxygen is relatively straightforward when compared to the removal of heat
- Linde can provide a solution that is designed to be the most efficient method of distributing gas appropriately through the silo to extinguish the fire
- Re-ignition is a big issue when extinguishing biomass fires
  - The temperature needs to be reduced to a critical point to prevent re-ignition when exposed to the air whilst removing material during the fire fighting process
- The specific heat capacity of gas is low compared to wood, and there is a lot of energy in the pyrolysis zone



Linde’s Solution.

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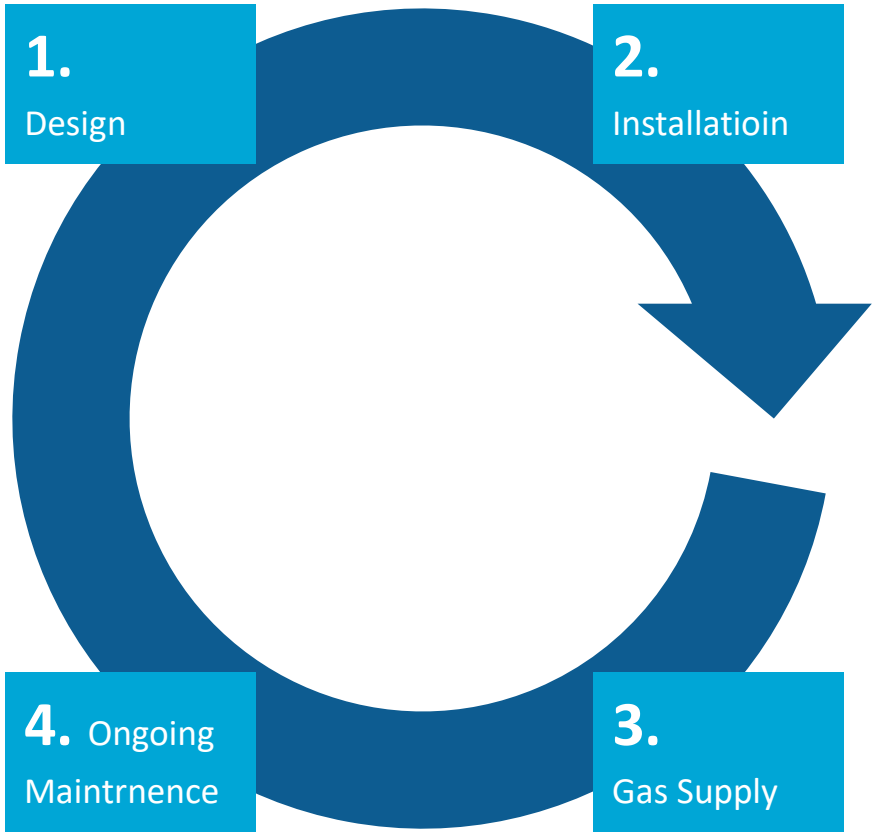
Linde's Service and Support

Linde works with you to design a gas supply system and its integration into the wider material handling and storage project



Once building begins, Linde can supply and install all gas-related equipment, working alongside other construction teams

Linde monitors and maintains the equipment throughout its running life, and provides gas awareness and safety training to ensure a safe working environment for personnel

Linde provides a reliable and secure gas supply solution that best meets your individual requirements

Linde's Design Service

- Assist in assessing customer risk
- Assist in developing a safe operating window for storage using:
  - Biomass testing
  - Silo heat/loss production modelling
- Calculate inert gas concentration and volumes required to allow safe storage for long periods
- Consideration of the off gases produced and inert gases required
  - Assessment of system / detection needed / safe working environments
- Calculate gas flow rate based on silo geometry
- Design a gas injection system
- Combat incipient and surface fires
- Provide operational instructions to deal with:
  - Incipient fires (auto-ignition)
  - Surface fires (external ignition source)
- Understand unique customer requirements
  - Tolerable time to extinguish – more gas = less time = more cost
    - A single large silo may have a higher criticality than several smaller ones
- Provide hazard assessment – expertise available to participate in HAZOP and LOPA studies

Installation and Maintenance

Utilising process knowledge acquired across The Linde Group over decades of bespoke installations, we:

— manage the installation of the fire suppression solution onsite

— ensure that all equipment is installed to industry standards

— provide installation engineers

— have service engineers available 24/7/365 ensuring systems are maintained to the highest standards

— provide gas safety awareness and operator training to ensure safe operating practices on site

Linde's Gas Supply

Bulk storage

— One of the largest supplier of Bulk gases in the world, with the largest dedicated delivery fleet

— The Delivery Planning Centre is committed to managing the delivery scheduling, using either a usage prediction algorithm or a dedicated telemetry system to provide direct access to current stock levels via a modem link

Onsite generation

— Linde has a range of onsite generation equipment to suit larger scale nitrogen supply requirements

— Onsite generation ensures a continuous, monitored and flexible gas supply

— A modular design, it is sized appropriately depending on volume requirements

— Linde's Remote Operating Centre* can be used to operate onsite equipment providing 24/7 support and monitoring of customer's onsite supply

* not available in all countries

Contact

Linde's team of experts have experience in designing a variety of fire suppression systems and practical experience in tackling biomass fires

We are here to help you manage your risk and design and install a system capable of meeting your needs.

If you have any questions or queries about Linde's expertise in this area:

Please contact:

Dipl.- Ing. Hans-Rudolf Himmen

Senior Expert Application Technology

Carl-von-Linde Straße 25

85716 Unterschleißheim

Germany

E-Mail: Hans-Rudolf.Himmen@linde-gas.com

Appendix D
Praxair Nitrogen Systems

Fahimeh Yazdan Panah, PhD, P.Eng, PMP
Director of Research and Technical Development
Wood Pellet Association of Canada
Tel/mob: +1 (778) 990-2656

Feb 10,2020

Praxair Services Canada, Inc
9020 - 24th Street NW
Edmonton, AB T6P 1X8

Hi Fahimeh,

As requested, I am providing further details to you and the Wood Pellet Association of Canada a solution to your Nitrogen needs for silo fire suppression. Your unique situation requires the equipment to be located on 'standby' in the Prince George area and dispatched to several locations, depending on the site of a potential fire concern. Having the unit closely located to your area businesses will increase response time and security of equipment availability. I have attached a spec sheet with an image to illustrate what this unit looks like.

The unit which we would provide is composed of individual components such as liquid N2 pressure tank, vaporizer and steam bath vaporizer (to avoid freezing off at high flow volumes). This is the unit we provided during the last incident. What makes our unit unique is all components are trailer-mounted together, to enable the mobility of the unit, and do not require external power supply. This is a unique offering of Praxair, which we have not sold to customers out right in the past. We would consider this option, with an information protection, or alternatively, offer you a long-term lease.

Option #1 - Purchase: The last time we had units manufactured was in 2008. We are currently working with the manufacturer and our design parameters to get a timeline and accurate estimate for other fleet units we are commissioning to build this year. I do not have this yet, but you can still use the previous estimate of $850,000 for budget numbers. We recommend exploring your own financing options first to capitalize on current interest rate options you may have. We would have to negotiate a settlement agreement based on your interest rate and the principle paid annually. My best estimate at a 7.78% interest would be a $50,000 annual payment on the principle amount.

Maintenance will be additional which I highly recommend you have us do, to ensure the equipment functions properly over time.

In addition to your monthly loan payment, a monthly service charge of $1500 for a technician to do a visual inspection of the unit plus mileage and travel time (mileage/TT can be confirmed when location of unit has been decided). Any actual repairs required would be additional. The unit will also lose approximately 5-10% of the N2 product due to off gassing. YOU MUST MAKE SURE THE UNIT IS NOT LEFT PRESSURIZED WHEN NOT IN USE OR YOU COULD LOSE THE WHOLE LOAD OVER TIME. A 10% N2 monthly top up would be about $1250 plus mileage. We could try to combine both services and only charge one mileage charge per month. A pumper per km will be more than a technician in a pickup but the savings would be substantial to combine the two.

Examples:

Monthly

- Monthly Inspection - Pick up truck and technician $60/hr travel time (*$960) + $0.95/km(**$1425) + $1500 inspection = $3,885
- Monthly N2 top up – Pumper truck and operator $60/hr travel time (*$1,140) + $3.25/km ($4,875) + $1,250 (depending on N2 pumped) = $7,265
- Monthly Combined Service for cost effectiveness – Pumper truck and technician $60/hr travel time ($1,140) +$3.25/km ($4,875) +$1,500 inspection + $1,250 (depending on N2 pumped) = $8,765

Annual

- Add $850 to the Monthly inspection fee or the Monthly Combined Service. Mileage and shop time are additional if required. $4,735 or $9,615

5 Year

- Tractor and operator $60/hr travel time x 2 ($2,280) + $3.25/km x 2 ($9,750) + shop time at $150/hr x number of hours to complete full service. $12,030 + shop time.

Rough estimate of *travel hours and **1500km Roundtrip from Edmonton to Prince George

Option #2 - Long term lease: We can offer a 180 month lease for $9,000/monthly which would include the monthly maintenance, annual and 5 year inspection fee. Travel time and mileage would be billed extra. Any damages or failures due to operator error would be the customers responsibility. N2 transport delivery for top ups and refills will be charged. Praxair still owns the asset, but you'll have sole control and use of the asset during the lease. We can also discuss a cancellation clause with notice and negotiate that into the agreement.

Examples:

Monthly

- Monthly inspection - Pickup truck and technician $60/hr travel time (*960) + $0.95/km ($1,425) =$2,385
- Monthly N2 top up – Pumper truck and operator $60/hr travel time (*1,140) + $3.25/km ($4,875) + $1,250 (depending on N2 pumped) = $7,265
- Monthly Combined Service for cost effectiveness – Pumper truck and technician $60/hr travel time +$3.25/km + $1250 (depending on N2 pumped) = $7,265

Rough estimate of *travel hours and **1500km Roundtrip from Edmonton to Prince George

Annual

- $850 (waived) to the Monthly inspection fee and the Monthly Combined Service. Mileage to the shop is additional if required (shop time waived).

5 Year

- Tractor and operator $60/hr travel time x 2 ($2,280) + $3.25/km x 2 ($9,750) + shop time (waived)

Monthly, Annual and 5 year Maintenance Intervals:

a) A monthly check will be a basic walk around and function test. A unit this size will need to have N2 topped up monthly due to normal evaporative losses. N2 will be billed separately as you require refills or top ups.
b) An annual full checkup done at your location, will take about 4 hours and entails a detailed checklist we use in our own fleet procedures. If any repairs are required, we would have to bring it in to our shop. If possible, we can schedule this in our slow time, so you have back up equipment available if necessary.
c) Every 5 years, the unit will come into our shop for a complete shop service.

Travel Time and Mileage to the unit location are additional and will be confirmed.

CVIP of the trailer for highway use can be conducted by any local shop certified to do so. Your choice.
Transport of the unit can be 3rd partied from someone in your area for convenience. We do not have a regular carrier in the area to recommend but any haul company that can transport LNG or the like should be fine. I can have an operations superintendent advise what he/she would recommend.
We will provide an operator training course for key personnel in your association for correct operation of the unit.

The Maintenace break outs are based on some assumptions and are to be used to illustrate the cost differences between the purchase and lease options and provide a general base to decide which works best for your organization.

I have also attached our rate schedule if you require more assistance with fire supression and need additional equipment to support your incident. Having a TMVU with trained local personel locally in this hard to service area will help to close the gap of response time to your needs.

Give me a call if you have any questions,

Sherry Dykes
Account Manager – Western Canada
Praxair Services Canada Inc.
Cell: (780) 667-1836

TRAILER MOUNTED VAPORIZING UNIT – TMVU-100
Confidential Equipment Specifications – (Please do not share)

SPECIFICATIONS

Type	*Vaporization Method*	*Max Flow w/ Steam Assist*	*Max Flow W/O Steam*	*Max Temp w/ Steam*	*Max Pressure (PSI)*	*LN2 Capacity (M3)*	*Length (M)*	*Width (M)*	*Height (M)*	*GVRW (Kg)*
100	Ambient & Steam	47 M^3/min	9 M^3/min	80˚ C	250	7000 M^3	12.5	2.6	3.8	25,000

STANDARD EQUIPMENT ON BOARD
(Please discuss if alternate fittings/hose lengths are required)

	½”, ¾”, 1”, 1½”, 2”
Customer Connections	(Female NPT)
Safeties (PSI)	250/300
Hose (Feet)	1.5" -100' GN2 /10' LN2

2020 Rate Sheet

Service Type	Quantity	Unit Rate
Minimum Service Charge (Each occurrence, per pumper)	Each	$3,375
Equipment Charges (Variable)		
N2 pumper, each, any size (pumping)	hr	$165.00
N2 pumper, each, any size (stand-by)	hr	$90.00
N2 bulker, each	hr	$130.00
N2 bulker, high capacity	hr	$185.00
Equipment Charges		
N2 Storage Tank – Queen or Whale Portable storage	day	$1,400.00
Service Vehicle	day	$150.00
Jumbo Tube Trailer (lesser of)	day week month	$750.00/day $3500.00/wk $8,000.00/mo
Fuel Support – Diesel for onsite pumping to be provided by customer	n/a	n/a
TMVU (lesser of)	day week month	$1,800.00/day $7,000.00/wk $22,000.00/mo
Transportation Charges (Mileage based on round trip basis)		
Nitrogen Pumper	km	$3.25
Nitrogen Bulker (<=20,000 m3)	km	$3.25
Nitrogen Bulker (>20,000 m3, B-Train or Tri-Tri)	km	$4.25
Service Vehicle	km	$0.95
TMVU, Jumbo Tube Trailer, Queen, Whale	km	$3.25
Labour – Man Hours		
Operator – Straight	hr	$90
Premium (1.5x)	hr	$135.00
Travel Time	hr	$60.00
Other Services		
Subsistence (living out allowance if not provided at Cenovus camps)	day	$240.00
3rd Party Expenses (Fuel trucks/Parts/Labour/etc.)	each	Cost+15%