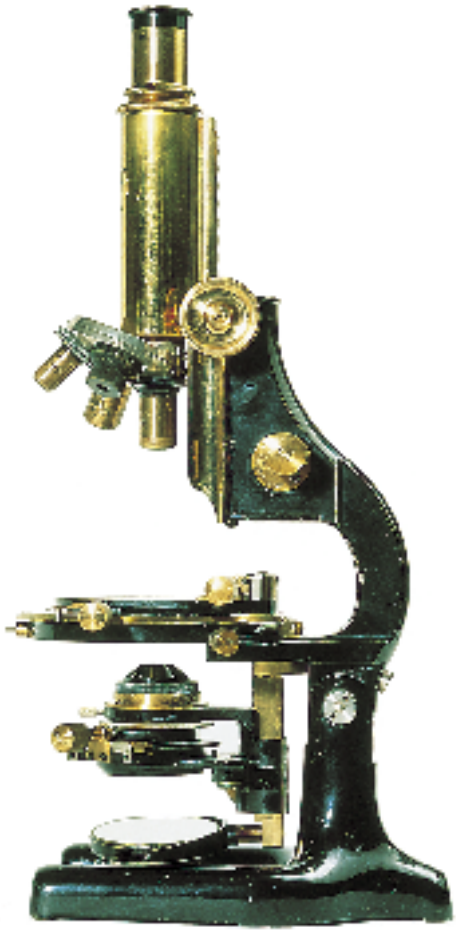
Gases for Medical Applications

Gases in the Service of Medicine

Gases have long been an established aid to the medical profession - and year after year, researchers and technicians continue to discover new, successful applications.

Gases assist with respiration and anaesthesia, allow specialists to study the functioning of the lungs and cardiovascular system, are essential tools in diagnosis and cryosurgery, and - when they meet the necessary specifications - can also be used to operate and calibrate medical measuring apparatus. Liquid nitrogen and helium have already proved their worth in the field of MR imaging.

In other words:
Gases are an essential part of modern medicine.



This brochure provides the reader with an overview of the many medical applications for gases of various kinds.

1. Gases for respiration
2. Heimox® (oxygen therapy)
3. Supplying gas in hospitals
4. Gases used in anaesthesiology
5. Supplying coolants for MR imaging
6. Gases for the clinical laboratory
7. Surgery, medicinal baths, cryomedicine and gases for medical lasers
8. Gases for diagnostics (e.g. for lung function tests, respiratory gas and blood gas analysis)
9. For general laboratory use: Gases in small containers and gas handling equipment

Gases for Respiration

Oxygen and various gas mixtures are used when the body's gas regime is disrupted. When the body is subjected to unusual stresses or respiration is weak as a result of inhaling anaesthetics or other substances that have a paralysing effect on the respiratory centre, the use of pure oxygen is indicated.

The Carbogen gas mixture (5% CO_2, balance O_2) is used to assist and stimulate respiratory activity.

Carbogen is just one example of the wide and varied range of gas mixtures that are available and can be supplied to support the respiratory function. Options range from simple mixtures such as "synthetic air" to complex mixtures that include stable isotopes. All gas mixtures are manufactured to very high standards of precision and reliability using state-of-the-art technology, and the entire production chain is subject to a stringent quality assurance process.

● **Oxygen** for medical purposes (DAB/Ph.Eur.)
Oxygen for medical purposes is supplied in specially prepared steel cylinders (from a separate cylinder store) with chromium-plated cylinder valves.

Containers: *steel cylinders*

Water-capacity (litres)	Exterior dia. (mm)	Length incl. cap (mm)	Total weight incl. contents (kg approx.)	Filling pressure at 15 °C (bar approx.)	Contents (m^3)
2	100	490	6	200	0.4
10	140	970	17	200	2
50	229	1640	79	200	10

Cylinder bundle consisting of 12 upright 50-litre cylinders

Water-capacity (litres)	Dimensions L x W x H (mm)	Total weight incl. contents (kg approx.)	Filling pressure at 15 °C (bar approx.)	Contents (m^3)
600	965 x 760 x 1842	1180	200	120

Oxygen can also be supplied as cryogenic liquid by road tanker for the production of oxygen for medical purposes (DAB/Ph.Eur.).

● **Carbogen** (5 % CO_2, balance O_2)

Containers: *steel cylinders*

Water-capacity (litres)	Exterior dia. (mm)	Length incl. cap (mm)	Total weight incl. contents (kg approx.)	Filling pressure at 15 °C (bar approx.)	Contents (m^3)
10	140	970	17	188	2
50	229	1640	79	188	10

● **e.g., helium-oxygen mixture** (20 % O_2, balance He)

Containers: *steel cylinders*

Water-capacity (litres)	Exterior dia. (mm)	Length incl. cap (mm)	Total weight incl. contents (kg approx.)	Filling pressure at 15 °C (bar approx.)	Contents (m^3)
10	140	970	17	200	2
50	229	1640	79	200	10

External circumstances may create an atmosphere that even represents a hazard to healthy people. With the help of breathing equipment – either supplied with gas from a central store or fitted with a portable supply of gas in cylinders – it can be ensured that each individual receives the right kind of "air".

See also our remarks in the chapter on HEIMOX®.

The composition of artificial respiratory gases can be adjusted to compensate for unusual circumstances or requirements. Normal respirators work with compressed air or "synthetic air", a mixture composed of 20 – 21% oxygen and 79 – 80% nitrogen.

Whenever artificial respiration is necessary under increased absolute pressure – consequently with the risk that the pressure might suddenly drop – the nitrogen in the respiratory air is replaced by helium (e.g. in deep-sea diving apparatus, undersea laboratories, decompression chambers).

Other gas mixture options are described in the section on *"Gases for Diagnostics"*.

● **Synthetic air** (20 % O_2, balance N_2)

Containers: *steel cylinders*

Water-capacity (litres)	Exterior dia. (mm)	Length incl. cap (mm)	Total weight incl. contents (kg approx.)	Filling pressure at 15 °C (bar approx.)	Contents (m^3)
10	140	970	17	200	2
50	229	1640	79	200	10

Cylinder bundle consisting of 12 upright 50-litre cylinders

Water-capacity (litres)	Dimensions L x W x H (mm)	Total weight incl. contents (kg approx.)	Filling pressure at 15 °C (bar approx.)	Contents (m^3)
600	965 x 760 x 1842	1180	200	120

● **Compressed air** according to DIN 3188

Containers: *steel cylinders*

Water-capacity (litres)	Exterior dia. (mm)	Length incl. cap (mm)	Total weight incl. contents (kg approx.)	Filling pressure at 15 °C (bar approx.)	Contents (m^3)
10	140	970	17	200	2
50	229	1640	79	200	10

● **Other respiratory gas mixtures** are produced to order, according to the requirements of the specific application. For example, the mixture of respiratory gases used by divers operating at great depths must be adjusted with care. In this case, the nitrogen is partially or completely replaced by helium.

Heimox®
All You Need for Oxygenation and Ventilation ❷

The HEIMOX®- mobil

The HEIMOX®- mobil liquid-oxygen system consists of two elements: a reservoir container that can also be used as a stationary supply, and a lightweight portable container, which is available in two versions with different capacities. Integrated tubular heat exchangers and control fittings convert the liquid oxygen into its gaseous state and warm it to approximately room temperature for inhalation by the patient. A flow regulator then dispenses it at a rate between 0.12 and 15 litres per minute, depending on the model.

HEIMOX® Ska

The HEIMOX® Ska oxygen concentrator is an electrically powered, electronically controlled device for producing oxygen from the ambient air. It employs the „pressure swing adsorption“ method to accomplish this, channelling the air alternately through two containers filled with nitrogen-selective molecular sieve material (zeolite). The oxygen concentration is continuously monitored, and a lamp lights up to alert the patient if it falls

below the required level of 85 % O_2. The built-in flow regulator provides the patient with oxygen at a stepless rate between 0 and 5 litres per minute.

Companion® 318

The Companion® 318 is designed to treat insomnia arising from obstructions of the airways. It uses the nasal continuous air-passage overpressure method (nCPAP) of respiration. This involves passing filtered ambient air through a two-stage fan to generate a pressure that can be regulated between 3 and 18 cm w.g. The system supplying air to the patient - which normally consists of an air hose with a nosepad fitting and nosepad (ADAM® system) or an air hose with mask – is connected to the front of the device. An optional humidifier can be used to humidify the air if required. The integrated delay mechanism means that the pressure can be lowered at predefined intervals, e.g. while the patient is going to sleep.

Please ask for our brochures on “Long-term oxygen therapy using the HEIMOX® SKa oxygen concentrator” and “An oxygen source for long-term therapy of in-patients and out-patients”.

Linde Supplying Gas in Hospitals ❸

In nearly all situations, it is just as vital for hospitals to have continuous availability of gases as it is for the medical personnel to be prepared and ready for action at all times. To make sure that gases are delivered where they are needed, we offer two distinct systems:

Central gas supply

Nowadays, almost every hospital has a central gas supply installation. Through a system of pipes that permeates the entire complex of buildings, almost every room can be supplied with essential gases:

- **Oxygen**
- **Nitrous oxide**
- **Compressed air**
- **Synthetic air**

The system of pipes is fed by a central unit in the basement (usually with some form of access for road tankers).

There are a number of variations on this type of supply:

- Individual cylinders (where the gas requirement is very low)
- Combinations of 624 single cylinders to form cylinder batteries
- Cylinder bundles (only available for oxygen and synthetic air)
- Storage tanks for oxygen (also for synthetic air if combined with nitrogen) and nitrous oxide

Benefits

- Centralisation, because installation is housed in hospital supply building
- Constant availability at point of consumption
- Takes the pressure off staff: No need to carry around steel cylinders, reduction of associated risks and sources of error
- Installation can be connected to the emergency power supply

Supply by individual cylinders

A central gas supply is only practicable in the case of the gases listed above, which are constantly required at various points of use.

Individual cylinders are always available for use where the relevant gases (e.g. gas mixtures, instrumentation gases) are required in small quantities. Also, it makes sense to have individual cylinders of oxygen, nitrous oxide, compressed air and synthetic air available for use at short notice, e.g. in emergency situations, or for use with mobile diagnostic, therapeutic or anaesthetic apparatus.

If a particular kind of gas is required at several points (e.g. in a central laboratory), then we recommend that you consider installing a central gas supply.

Gases Used in Anaestetics 4

The purpose of anaesthetic agents is to induce a condition in the patient whereby sensations of pain and consequently muscle contractions, and hence also defensive reactions, are massively attenuated or even neutralised altogether. If the patient also loses consciousness, this is termed general anaesthesia or narcosis.

Nitrous oxide (DAB/Ph.Eur.)

A gaseous anaesthetic is added to the respiratory gas (oxygen, air). Modern anaesthetic apparatus allows very precise and easily controllable metering of the anaesthetic gas or vapour. At the same time, the oxygen and carbon dioxide content of the respiratory gas is continuously monitored.

Of the various gases (or vapours from volatile liquids) once used for inhalation anaesthesia (including nitrous oxide, cyclopropane, chloroform, and ether), only nitrous oxide (also known as laughing gas, N_2O) is still in regular use.

● Nitrous oxide (DAB/Ph.Eur.)

Containers: *steel cylinders*

Water capacity (liters)	Exterior dia. (mm)	Length incl. cap mm)	Total weight incl. contents (kg approx.)	Vapour pressure at 20 °C (bar approx.)	Contents (kg)
2 **	100	420 **	4.3	50.8	1.5 *
3 **	100	580 **	6.1	50.8	2.25 *
10	140	970	21.5	50.8	7.5 *
40	204	1630	78	50.8	29.6

* The given contents relates to containers with a test pressure of 250 bar.
** Cylinder without foot or cap, only for nitrous oxide (DAB/Ph.Eur.) for medical applications; supplied in suitable packaging. The size of cylinder is appropriate for use in medical apparatus.

In the case of nitrous oxide, when larger volumes of gas are needed it is advisable to switch to a gas supply based on liquefied gases supplied from a tank facility.

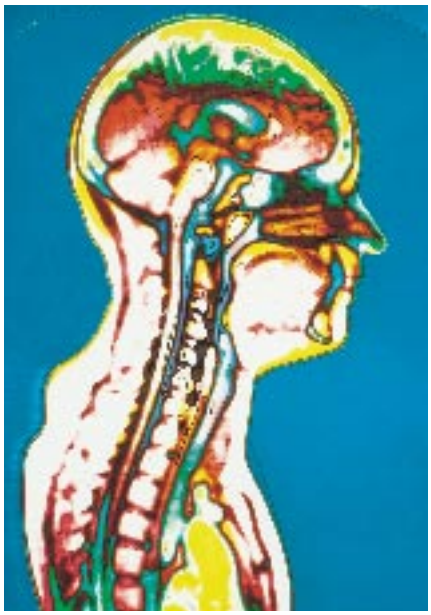
Nitrous oxide is a gas liquefied under pressure. A steel cylinder filled completely with nitrous oxide consequently always contains both liquid nitrous oxide and a gas cushion on top of the liquid. The pressure exerted by this cushion of gas (= the vapour pressure of nitrous oxide) can be measured, i.e. the pressure shown on a pressure gauge remains constant if the temperature of the cylinder does not change, even when gas is being withdrawn from the cylinder. (The withdrawn gas is replaced by gas evaporating from the liquid phase.)

● Xenon

This rare gas (Xe) both produces a more powerful anaesthetic effect and is more fat-soluble than nitrous oxide. Using modern closed-circuit anaesthetic apparatus, this expensive gas can be reclaimed and put back into circulation again. Xenon is currently undergoing clinical trials as an inhalable anaesthetic.

Properties
Xenon is a colourless, odourless rare gas that is present in the air in amounts of 0.08 vpm (= 0.000008 % by vol.). It is neither flammable nor toxic.

Liquid Helium for MR Imaging ❺



Principle of MR imaging

Alongside spectrometric applications in chemistry and solid-state physics, magnetic resonance imaging (MRI) has become a well-established tool for medical diagnosis.

It can be used to build up layered pictures of the human body, and also - by means of in vivo spectroscopy - to observe metabolic processes in living tissue. In order to generate the images or spectra, the signals emitted by specific chemical elements as a result of the magnetic behaviour of their atomic nuclei are analysed.

Unlike other imaging procedures used for diagnosis, MRI allows high-contrast images of soft tissue to be generated without the use of high-energy ionising rays. The primary tools used to generate the external stationary magnetic field are superconducting magnets. These are capable of generating very powerful homogeneous magnetic fields, a prerequisite for high-contrast images.

„Superconductivity“ is the complete disappearance of electrical resistance in a substance. This phenomenon only occurs below the transition temperature specific to each material. Niobium-titanium alloy, which is used for the coil of a superconducting magnet, has a transition temperature of -263.7 °C. The only cryogenic gas capable of generating such extremely low temperatures is liquid helium. The coil is immersed in a liquid helium bath at a temperature of -268.9 °C (4.22K), whereby a certain amount of liquid helium evaporates and has to be replaced.

Building design

During the early planning stages of a project, it is essential to take a very detailed look at the architectural and logistical aspects of supplying coolant to the MR installation. Experienced Linde gas specialists are always available to give appropriate expert advice. When planning the installation of an MRI unit, intensive discussion between the future operator, the supplier of the installation, the architect or contractor and the gas specialist are a sine qua non.

Talk to us - Linde has the liquid helium, the expertise and the service.

Gases for the Clinical Laboratory ⑥

Gases and gas mixtures are not just required for diagnosis and anaesthesia. They also provide essential assistance to clinical researchers and research laboratories.

Based on many years of experience in our own laboratory, from the outset Linde was able to take full account of the stringent requirements for gas analysis instrumentation. High-quality instrumentation gases and an appropriate gas supply are key prerequisites for undisrupted, reliable analysis using ultra-sensitive measuring apparatus.

The following applications are typical of gas usage in a clinical laboratory:

Flame photometry

This analytical procedure, popular in clinical sectors, is used to capture the quantity and quality of traces of alkali and alkaline earths such as sodium (Na), potassium (K), lithium (Li). Depending on what exactly needs to be measured, various flame temperatures are used to excite different atoms.

All the fuel gases required to produce the flame are available as part of Linde's specialty gas range:

- Methane 2.5, 2.7
- Hydrogen 3.8, 5.0
- Propane 2.5
- Acetylene for flame photometry
- Acetylene (solvent-free)
- Synthetic air (20% vol. O_2, balance N_2)
- Oxygen

Atomic absorption spectrometry (AAS)

AAS is a modified form of flame photometry. The radiation from an element-specific spectral light source is directed through the sample, which has been thermally dissociated into atoms. The weakening of the radiation as a result of the absorbing atoms is being measured. This is the method used for quantitative and qualitative analysis of a variety of metals, such as copper (Cu), zinc (Zn), magnesium (Mg), calcium (Ca), cadmium (C) and mercury (Hg).

A wide variety of fuel gas combinations can be used to produce the optimal flame temperature in these cases:

- Acetylene for flame photometry/ synthetic air
- Acetylene for flame photometry/ nitrous oxide 2.5 (not for medical purposes)
- Propane 2.5/synthetic air Argon for spectrometry/ hydrogen 5.0/oxygen
- Hydrogen 5.0/synthetic air

For "graphite-tube" AAS, argon is most widely used as an inert and purge gas to prevent combustion of the graphite tube. For this and all other applications, the required pure gases and gas mixtures gases can be supplied by Linde ex-stock, including:

● Carrier gases

These are used, for example, to transport the sample being analysed through the separation column of a gas chromatograph into the downstream detector system.

● Zero gases

These contain the calibration component to be measured in a concentration that is below the level of detection of the measuring systems being employed. They are used to set the zero point in gas analysers, and as a gas that is free of the component to be measured, for purging.

Surgery, Medicinal Baths, **Cryomedicine** and **Gases for Medical Lasers** 7

Carbon dioxide in surgery and medicinal baths

Minimally invasive surgery is an integral part of modern medicine. And insufflation with carbon dioxide makes endoscopic procedures substantially easier to perform.

In baths, carbon dioxide creates a sensation of warmth and acts as a vasodilator for the skin by stimulating its heat receptors.

● **Carbon dioxide (DAB/Ph.Eur.)** for medical purposes (CO_2 med.)
Carbon dioxide for medical purposes is supplied in specially prepared steel cylinders (from a separate cylinder stock) with chromium-plated cylinder valves.

Containers: *steel cylinders*

Water capacity (liters)	Exterior dia. (mm)	Length incl. cap mm)	Total weight incl. contents (kg approx.)	Vapour pressure at 20 °C (bar approx.)	Contents (kg)
2	100	490	6.8	57.29	1.5
8	140	805	16.5	57.29	6
13	204	720	28.0	57.29	10
27	204	1260	58.0	57.29	20
30	204	1700	80.0	57.29	30

Cryomedicine

Thanks to progress in low-temperature techniques, cryomedicine has become an established medical technique.

This technique exploits the effects of exposing cells and tissue to cryogenic liquid nitrogen at the extremely low temperature of -196 °C.

Application of very low temperatures performs two important tasks:
- Cryoconservation e.g. of cells and tissues
- Cryosurgery e.g. deliberate destruction of unhealthy tissue

Other applications are in cryotherapy. Here, a cold gas mixture produced from cryogenic liquid nitrogen is used as a therapeutic aid.

Supply

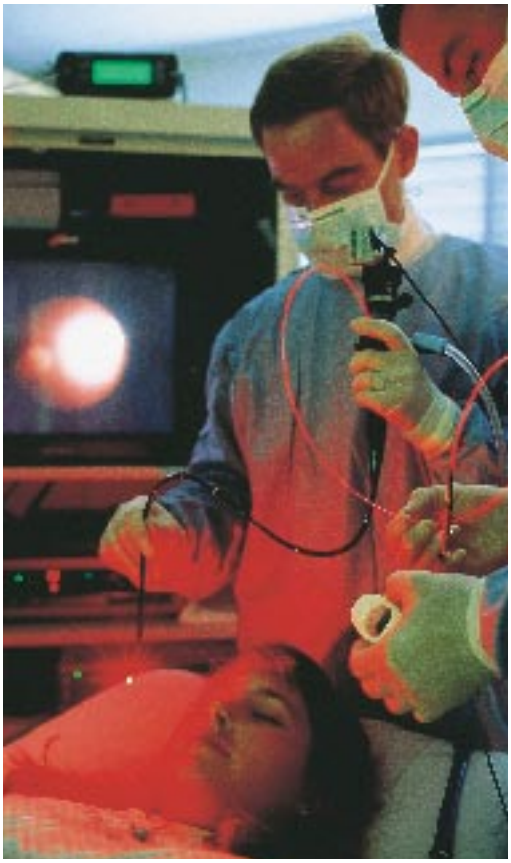
Consumers of liquid nitrogen need a cost-effective supply that is appropriate to their needs. Linde has the right system to meet every requirement. Small quantities (of between 5 and 300 litres) are delivered by nitrogen service vehicles. When larger quantities are required, Linde installs a vacuum-insulated storage tank at the customer's premises, which is filled with cryogenic liquid gas supplied by road tanker.

Gases for medical lasers

Various gas mixtures are used for medical lasers. CO_2 and excimer lasers have emerged as new surgical tools in modern medicine.

Pure gases and gas mixtures in standard and custom formulations can be supplied in LASPUR® purities.

If you have any questions relating to delivery options, gas supply systems, technical specifications, gas properties or safety procedures, Linde would be pleased to provide you with detailed information.



Liquid nitrogen delivery service

Gases for Diagnostics

● Calibration gas mixtures

Calibration gas mixtures are high-precision gas mixtures used to calibrate measuring equipment. They also play an important role in various processes and in experimental research, whenever mixtures with precisely defined and precisely measured compositions are required.

Linde now offers calibration gas mixtures containing any of over 150 different gases and vapours as calibration components. And we are continually extending the list based on ongoing development work and our efforts to satisfy our customers' requirements. Whether or not it is feasible to supply appropriate calibration gas mixtures has to be decided on the merits of each individual case. Here users can benefit from our many years of experience.

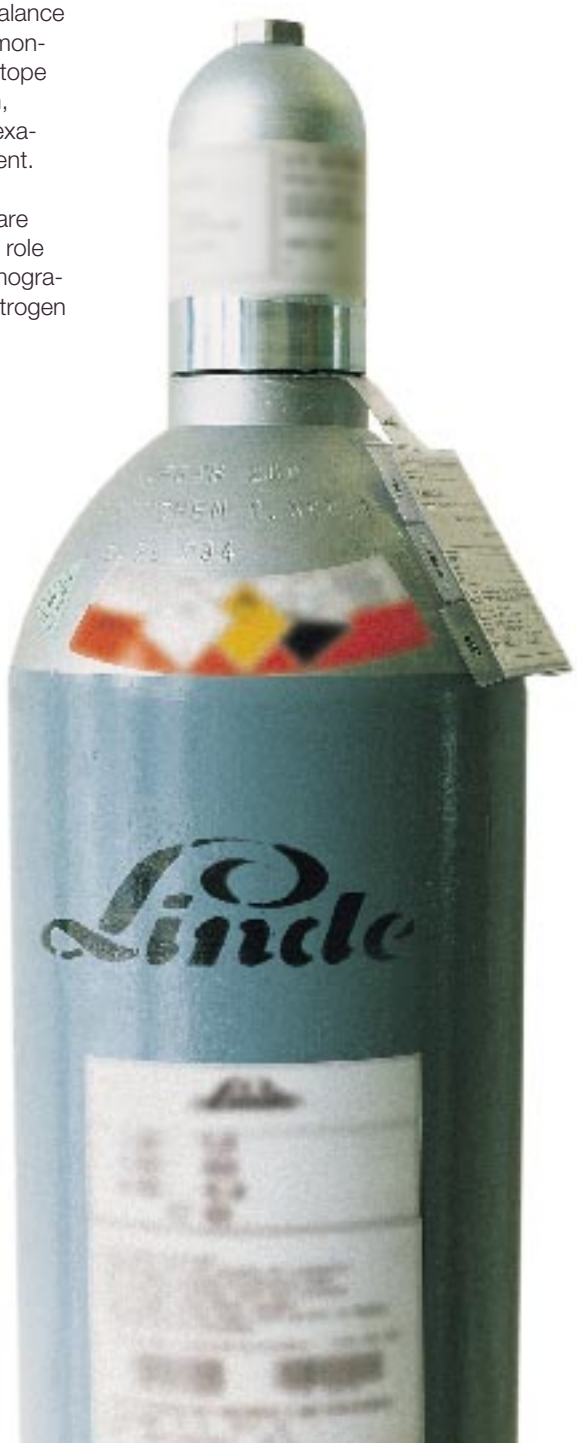
Calibration gas mixtures are used in medicine primarily for:

- Calibration of measuring apparatus in laboratories; for example, to calibrate gas analysers that run on various physical or physico-chemical principles.
- Creation of precisely defined atmospheres in order to test gas alarm systems.

Delivery of customised formulations

Gas mixtures consisting of oxygen, helium, xenon or nitrogen as the balance gas, plus carbon dioxide, carbon monoxide, stable carbon monoxide isotope ($C^{18}O$), nitrogen monoxide, oxygen, helium, argon, xenon or sulphur hexafluoride as the calibration component.

Examples of custom formulations are xenon/oxygen mixtures that play a role as contrast media in computer tomography, and the nitrogen monoxide/nitrogen mixtures used in NO therapy.



Typical Applications

● Blood gas/ respiratory gas analysis

High-precision gas mixtures are used to monitor the acid/base and blood gas status (pH value, partial pressure of O_2 and CO_2) and to measure the composition of inhaled and exhaled air. One of two methods is commonly used to take these measurements:

- Equilibration, that is, saturation of the blood sample with CO_2 gas mixtures, followed by a measurement
- Direct measurement of the sample in question

Examples of standardised gas mixtures
Available ex-stock

CO_2	O_2	N_2	Synth. air 20 % O_2, balance N_2	Description
2 %	2 %	Balance		„E 1 gas“
5 %	12 %	Balance		„Low gas“
5 %	20 %	Balance		
6 %	12 %	Balance		„E 2 gas“
4 %	Balance			
5 %			Balance	
10 %		Balance		„High gas“
15 %		Balance		

● Gases for lung function tests

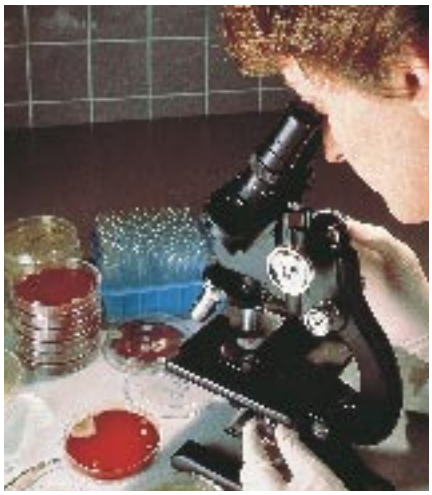
Lung functions tests are primarily used to measure static lung function values (functional capacity, ability to work) both in healthy individuals and in cases of respiratory infection or disease.

Gas mixtures are used in spirometry, usually with a proportion of some rare gas such as helium which the body cannot easily resorb. In order to measure static lung function values, e.g. diffusion capacity using the single-breath method, gas mixtures containing CO and He are predominantly used.

Other available standard mixtures
O_2/He, O_2/He/N_2 mixtures.

Examples of standardised gas mixtures
Available ex-stock

CO	He	CO_2	O_2	N_2	Synth. air (20 % O_2, balance N_2)
0,2 %	5 %				Balance
0,2 %	8 %				Balance
0,25 %	18 %				Balance
0,27 %	9,3 %				Balance
			20,9 %	Balance	
		5 %	15,9 %	Balance	
Synth. air (20 % O_2, balance N_2)					



For General Laboratory Use

Gases in small containers

For many applications, large gas cylinders are too cumbersome to handle. Other circumstances, such as low or merely sporadic gas requirement, safety considerations, technical requirements and so on, may also call for more convenient forms of gas supply.

Linde's range of "gases in small containers" is able to meet every kind of gas supply requirement whenever low container weight or very small quantities of gas are needed.

The following types are available:

Linde minican® pressure cans are made out of aluminium and have a test overpressure of 18 bar. Typical applications range from ambient air monitoring and process control to gas chromatography and medicine. For all the above applications, a wide variety of pure gases, calibration gas mixtures and standard gas mixtures are available in minican® pressure cans. For withdrawing the gas, a proprietary range of fittings is available that can be used on all minican® products.

Linde small steel cylinders are high-pressure steel containers for high-purity gases. As they have a test overpressure of 300 bar, the containers have a large contents. Gas is withdrawn using standard fittings of the type also used on high-pressure cylinders.

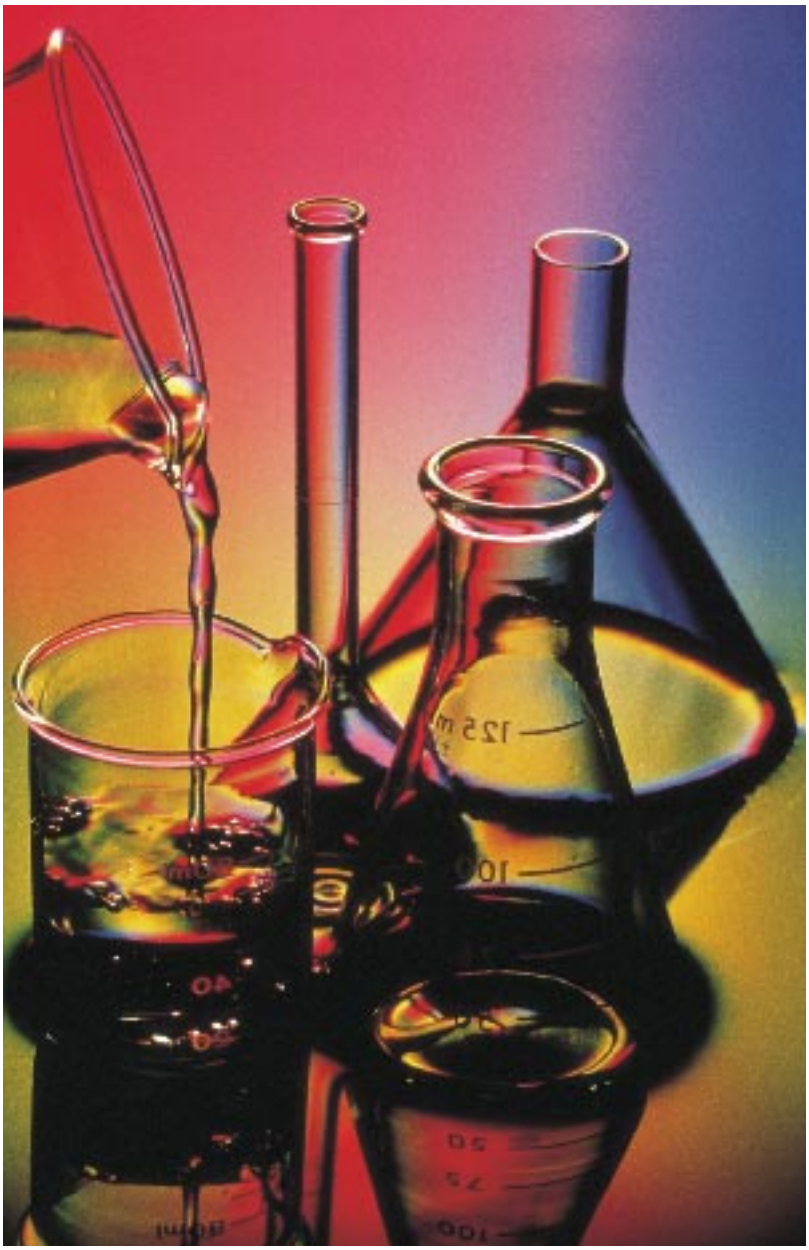
Gas handling equipment

When pure gases, precision calibration gas mixtures and other gas mixtures are transferred, it is much more important that their purity and composition be maintained when the gas is withdrawn from the cylinders and distributed to the actual point of use than in the case of industrial gases. That is why Linde offers the right equipment for each and every application, from standard regulating valves to specially customised supply systems.

Regulating valves are used to withdraw gases without pressure control. They can be set to maintain a given gas flow rate. In closed systems, they can be used to maintain a pressure up to the level of the cylinder pressure.

Pressure regulators are used to reduce the pressure of compressed gas from high pressure down to a constant, lower withdrawal pressure.

Gas supply systems for general laboratory use etc.: the required gas type and purity depend upon the application. This must also serve as the basis for specifying the gas supply system. Our engineers specify the type and quality of the equipment in such a way as to optimise safety and cost efficiency while satisfying the specific requirements of the application at hand.



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Subject to change

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