THE LINDE GROUP

Linde

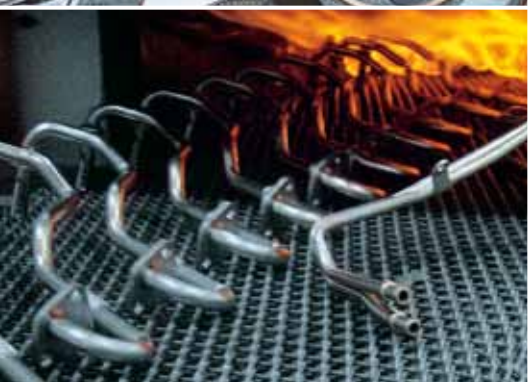
Achieving best results in heat treatment.

With our leading solutions for furnace atmosphere gas supply, generation, control and stirring as well as for sub-zero treatment.









Contents.

End-to-end portfolio of heat treatment process technologies, services and supply solutions

Increase productivity and reduce costs

Individual concepts for lasting success

Real added value. Built on in-depth expertise.

Whether you are a manufacturer, metal fabricator or heat treatment expert, you need a reliable partner at your side – a partner that can help ensure the stability and controllability of your processes. An optimised furnace atmosphere and efficient heat treatment applications are essential to meet the high quality standards expected of metals today. The extensive know-how and experience we have gained in the delivery of countless successful heat treatment projects means we are ideally positioned to add real value to your process. For example, we can provide advice on the most suitable protective and reactive gases, complementing our process technologies with services tailored to your particular needs.

An optimised furnace atmosphere translates into reduced rework effort and lower reject costs. Vast industry experience and close, long-standing collaboration with our customers equip our local experts with the insights they need to develop the best solution for your process challenges. Building on a relationship of trust, we develop the most efficient concept for your process, gas supply and hardware needs. Analysis and training services round off our offering.

Linde has been producing and selling industrial gases for over a hundred years. Customers value our state-of-the-art, comprehensive and reliable supply capabilities along with our ability to execute on time and in budget. You can rely on us to support your entire project lifecycle – from tank design and plant engineering to commissioning and follow-up maintenance.

Services supporting your heat treatment processes. Entire system designed down to the last detail.

Linde is the partner of choice for heat treatment in metallurgy. As well as tailored gas supply concepts and optimised hardware, we also offer a range of services to cover all stages in your production flow.

Our services

Analysis of your current process conditions
- → Our qualified engineers perform process audits to investigate the potential for process improvements.

Analysis of furnace atmosphere with calibrated and certified measurement instruments
- → Detection of flammable gases: hydrogen, residual methane (CH_4) and carbon monoxide (CO)
- → Detection of oxidising components: water, carbon dioxide (CO_2) and oxygen (O_2)
- → Detection of carbon potential using "shim stock analysis"

Identification of areas offering potential for improvement in close liaison with our customers
- → Overall view of entire process chain
- → Analysis of upstream and downstream processes
- → Analysis of furnace mechanical conditions, its gas supply skids and control equipment
- → Close liaison with customers
- → Customer tests and demonstrations in furnaces at our Technology Centre
- → Economic feasibility studies
- → Preparation of a final report

Our experience

All common furnace types, e.g.:
- → Multi-purpose chamber furnaces (integral or sealed quench furnaces)
- → Mesh belt furnaces
- → Cast link furnaces
- → Roller hearth furnaces
- → Pusher type furnaces
- → Bell type furnaces
- → Vacuum furnaces
- → Pit furnaces
- → Rotary retort furnaces

All typical protective atmospheres, e.g.:
- → Nitrogen-methanol/endothermic gas atmospheres
- → Nitrogen-propane atmospheres
- → Nitriding atmospheres
- → Pure nitrogen atmospheres
- → Pure hydrogen atmospheres
- → Forming gas atmospheres (nitrogen-hydrogen atmospheres)
- → Endothermic gas atmospheres
- → Exothermic gas and monogas atmospheres

Practical training to give you a head-start.
Put our process know-how to work for you.

You need highly qualified personnel to get the most out of your heat treatment processes. Your customers continue to raise the bar for quality, delivery flexibility, cost efficiency and documentation that complies with industry quality standards.

Mastering your processes

By taking advantage of our training programme, you can capitalise on decades of practical experience in furnace atmospheres for heat treatment. Generally tailored to your needs, our in-house training will give your staff the process-specific know-how required to completely master your workflow. Starting with the basics and moving on to the effects of various gases on parts, the training will then cover more advanced topics like carbon potential, carburisation and decarburisation or nitriding processes. Our experts will also discuss in detail the heat treatment processing of various materials, and explain the complex interactions between workpieces and protective atmospheres such as optimising the sintering furnace atmosphere for the metal injection moulding (MIM) process.

Protective atmosphere in focus

From experience, we know that residue on workpiece surfaces, regardless of the origin, often lead to unsatisfactory heat treatment results and can cause damage to the furnace. Our training can therefore also cover the effects of various substances on a particular process. Another possible topic could be the handling of protective gas supply systems with all the various supply options – for example hydrogen, nitrogen/methanol or ammonia as well as endothermic and exothermic gas. A training module on the measurement and control of protective atmospheres is another option.

Safety built on knowledge

Protective atmosphere furnaces are not dangerous in themselves. But failure to observe correct safety procedures can potentially cause a dangerous situation. Our mission is to help you get the most out of your plant without compromising on safety.

Best practice in gas handling and risk awareness can help to minimise risks – and we are committed to helping you achieve that. Our intensive safety course will give your staff all the theoretical and practical information they will need to do their job safely. In particular, they should be aware of the significant risk posed by the carbon monoxide-containing gases used in many heat treatment processes. Other gases like propane, hydrogen, methanol and nitrogen should always be handled with due care by qualified personnel. As an option, the training can incorporate demonstrations of things going wrong, for example explosions or suffocation.

Training tailored to your heat treatment processes

Since we try to keep group sizes to a maximum of ten people, our training courses can usually cater to individual needs and interests. Experience has shown us that greater interaction results in more effective learning. Different levels of coursework also provide a useful training tool. The participants receive a certificate when they successfully complete their course.

Please contact us if you would like us to tailor the training to your requirements.

Heat treatment laboratory and metallography. Consulting based on detailed data.

Targeted improvements through process simulations

Engineers at our Application Centres are responsible for developing new gas supply systems for heat treatment processes and improving the control systems of existing processes. For this purpose as well as testing and demonstrations, the following furnace types are available:

- Mesh belt furnace
- Multi-purpose chamber furnace
- Pit furnace
- High-temperature pusher type furnace operating at up to 1450°C for sintering processes
- Salt spray chamber for salt spray tests according to DIN EN ISO 9227

All furnaces are equipped with the latest control technology and universal gas inlets to simulate every conceivable furnace atmosphere with the utmost precision. We have installed a comprehensive metrology system for monitoring and analysis, and a plasma cleaning system is used to prepare samples. The facility's process control computers are also capable of simulating your heat treatment processes. We will gladly send you the log files detailing the optimal carburisation, nitriding or annealing conditions. The vast experience of our heat treatment experts is, however, our biggest success factor. They are the people who provide the application-specific advice to help you make your production more cost-effective.

Low-temperature laboratory

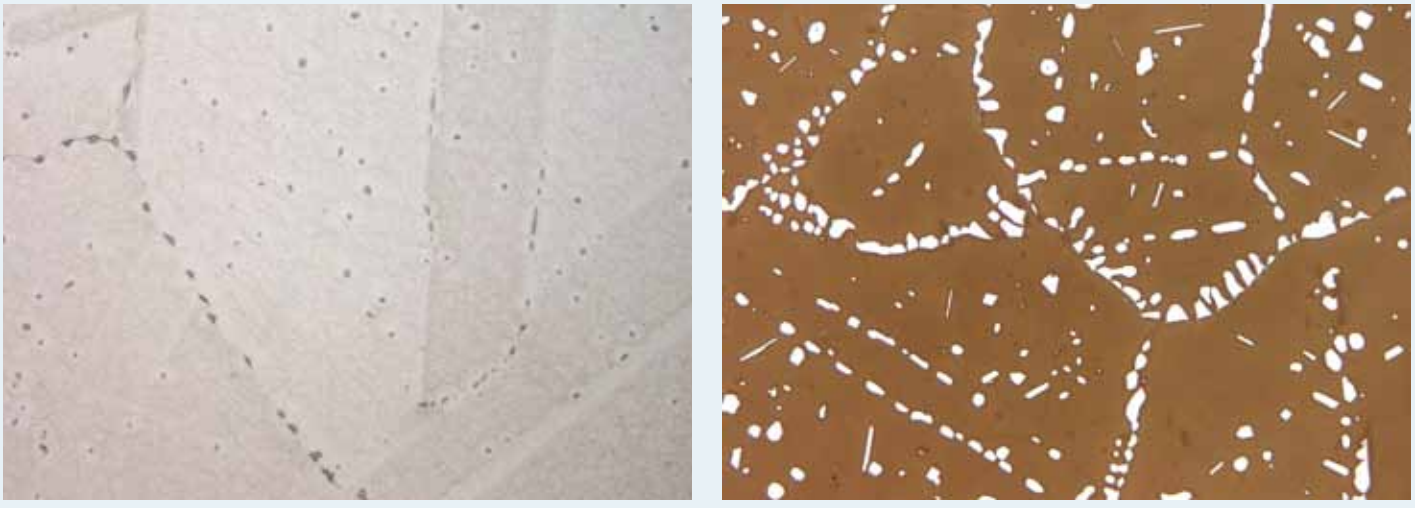
This special laboratory contains equipment for low-temperature treatments, for instance to transform retained austenite at temperatures of around –90°C or increase the wear resistance of tool steels at controlled cryogenic temperatures as low as –180°C, with subsequent tempering to +600°C.

Metallography

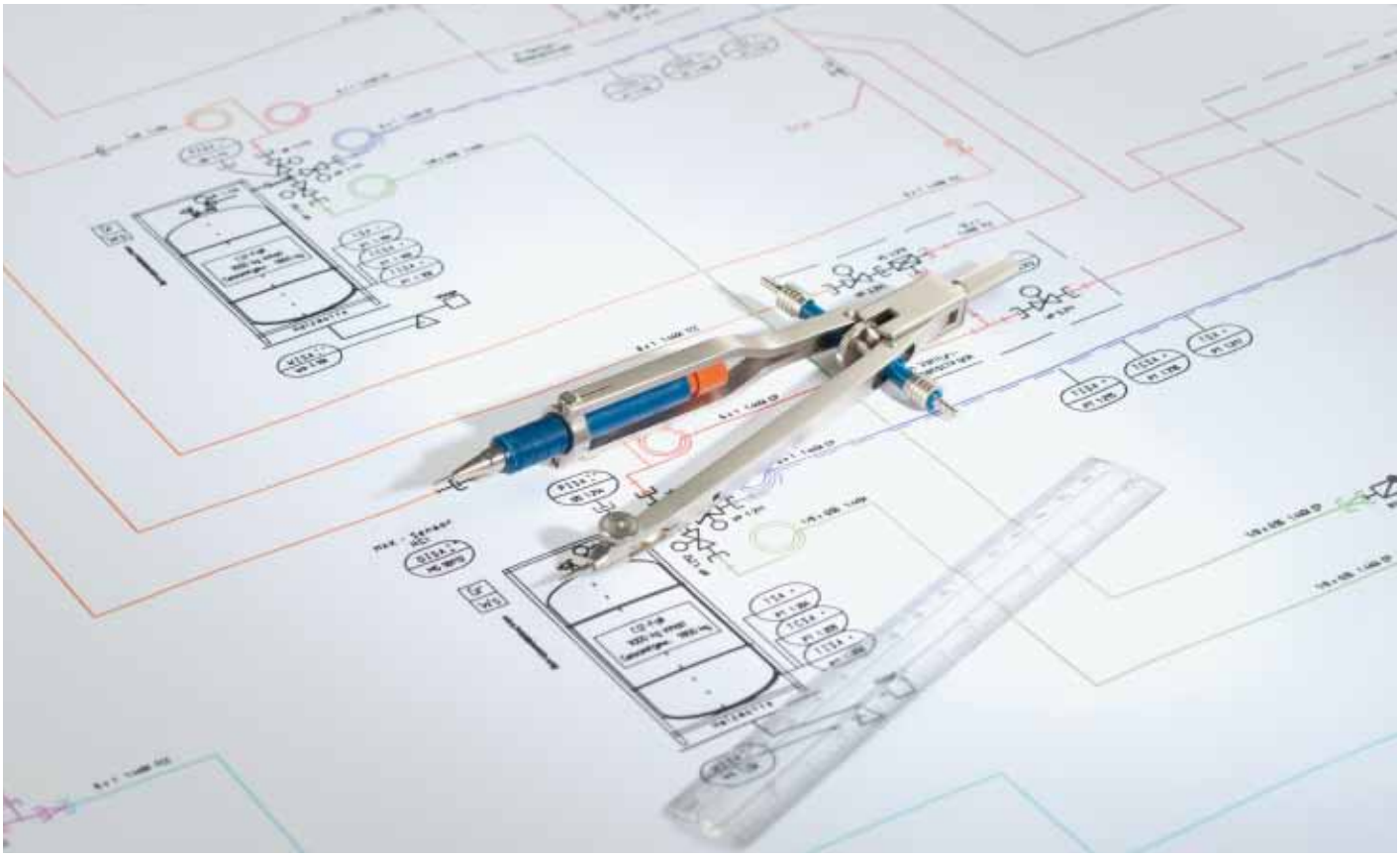
We have a fully equipped metallography lab to analyse the results of customer tests. The laboratory staff create and analyse macrosections and microsections and carry out a variety of hardness tests. Other services offered by the lab include scanning electron microscopy and material analyses.

On-site demonstration and commissioning

We offer a full service package covering tests, demonstrations and commissioning of Linde processes at your plant. These services are delivered by our dedicated application engineers, who draw on their practical experience and technical know-how to meet your individual needs.



Comparison of strip material 1.4841 from a continuous furnace with (left) and without (right) SINTERFLEX® atmosphere control



The efficient way to modernise your protective gas supply scheme. With our expert engineers.

If you need a partner to plan or update the protective gas supply system of your furnaces, our engineers can support you every step of the way. Our range of services includes advice on the most suitable industrial gases, concept development, professional project execution and hardware start-up at your site.

We can plan and build your system for generating, measuring and controlling the protective atmosphere for your furnace or cryogenic application. As well as standard solutions, we also provide custom designs adapted to your production facility.

The factors that need to be considered when planning a protective gas supply scheme include the dimensions of the pipes, the required components, the measurement and control systems, the PLC and, where required, the analysis tools. Other options include data logging and connection to master control systems for quality assurance. Furthermore, we can equip your new furnace with the latest in protective gas control technology or integrate it with existing production lines as part of a plant modernisation project.

It goes without saying that Linde technologies and equipment comply with all current standards and guidelines. We are the ideal partner if you are looking for the efficiency gains of an all-inclusive, industrial gas and engineering package.

Gas injection without a fan. More efficient gas mixing with CARBOJET®.

CARBOJET® provides a number of benefits for your heat treatment process depending on the application. This technology can make any furnace more efficient thanks to the ultra-high-speed injection of a gas or gas mixture through special lances. This ensures better mixing of the injected gases with the furnace atmosphere as well as better movement of the gas flows within the furnace.

Increase productivity and reduce costs

CARBOJET® offers a variety of benefits for different applications. In continuous furnaces, for example, the homogenisation effect results in more even carbon distribution around the workpiece being treated. Soot formation during enrichment is also kept to a minimum. If CARBOJET® is positioned at the inlet of a roller hearth furnace, the improved heat transfer can potentially increase the plant's productivity by 10%. The high-velocity method of injection also improves the reproducibility of your gas analysis. In the cooling zone, meanwhile, a productivity increase of up to 35% is possible. You can increase output by around 20% when handling bulk goods in a rotary retort type furnace. Since the gas flows generated can penetrate deeper into the bulk material, heating and carburisation occur at a faster rate.

This technology has particular benefits for pit furnaces. CARBOJET® technology will make the fans, guide cylinders and furnace lids redundant. Not only does this allow more even distribution of temperature and the carburisation effect, the space inside the furnace can also be used up to 20% more efficiently. Greater energy efficiency and higher output are the knock-on benefits here. In April 2013, the first nitriding furnace pre-fitted with CARBOJET® technology successfully commenced operations.

Customer benefits for pit furnaces

- Uniform carburising, annealing, nitriding, etc.
- Uniform heating
- No need to install, power or maintain an atmosphere circulation fan
- Guide cylinder and furnace lid are not needed; more efficient use of furnace space
- Cost saving thanks to simpler furnace lid design
- Less corrosion, therefore up to 3 times longer furnace lid life
- Elimination of vibration damage to batch, retort and heating elements
- Resource efficiency as no water cooling is required
- Better heat insulation thanks to improved lid insulation
- Reduced soot formation

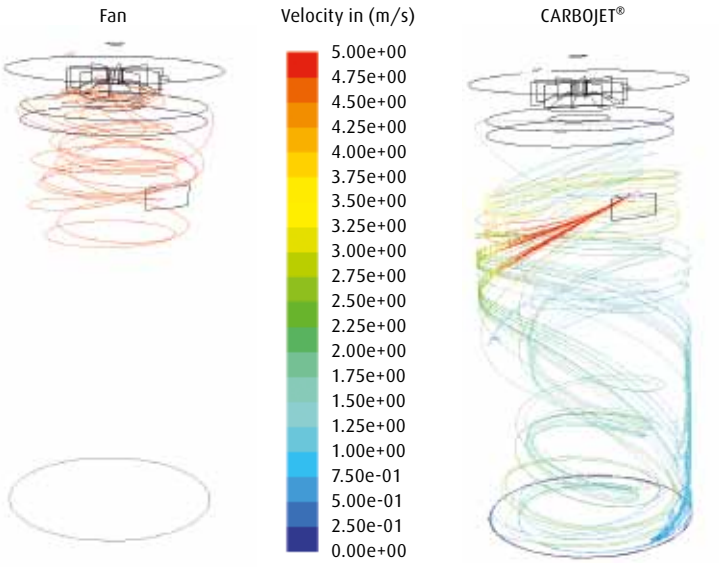
Customer benefits for continuous furnaces

- Quicker conditioning when atmosphere is switched
- Reduced soot formation
- Improved carbon transfer and homogenisation
- More intensive heat transfer with improved convection
- Better burn-off of mechanical oil and drawing lubricant residue at the front of the furnace
- Better cooling zone performance

Customer benefits for rotary retort type furnaces

- Better mixing of atmosphere
- Atmosphere is easier to control (O_2 probe)
- Soft spot formation minimised
- Increased throughput
- Longer retort life

CFD simulation empty pit furnace



CARBOFLEX®. Added control for brilliant results.

The requirements after annealing for semi-finished products, such as tubes and pipes, have become much more demanding in recent years. While in the past it was enough to deliver a standard bright annealed pipe, now customers specify strict tolerances for the surface quality, e.g. decarburisation values or grain size. As a result, your furnace atmosphere has to be able to meet these new challenges.

Aligned to perfection

Up until recently, a whole range of products could be treated using the same atmosphere. Today, however, flexibility is needed to meet specific customer requirements. To meet changing demands in this area, we developed the CARBOFLEX® system for flexible mixing of the input gas, whether it is nitrogen, endothermic gas or an enrichment gas. This allows you to precisely adjust the furnace atmosphere to suit the material being treated and its position in the furnace.

Tight process control for greater flexibility

The CARBOFLEX® control cabinet is equipped with a programmable logic controller (PLC) and a user-friendly touchscreen. Using the PC touchscreen, operators can view and modify key process parameters, such as atmosphere gas flow values, monitor the furnace data in real time, change the mixture or adjust the alarm settings. The set-points for the supply of gas to the furnace are defined in recipes, so CARBOFLEX® can automatically control the protective atmosphere in the furnace.

CARBOFLEX® is designed to monitor the protective atmosphere to the very latest safety standards. The system creates a data archive which you can view and analyse for continuous process monitoring and compliance with the relevant safety and quality standards.

Benefits

Optimised annealing

- Consistently high, reproducible quality standards for decarburisation and surface cleanness
- Minimised downstream cleaning through the integration of controlled oxidation for drawing lubricants or emulsion residues
- Cleaner pipe interiors and homogeneous distribution of carbon on surface thanks to CARBOJET® high-speed injection technology
- Optional integration of furnace hall draught monitoring to prevent oxidation in the cooling zone

- Endothermic gas production and handling with an external generator
- Optional integration of automatic detection of defective radiant tubes

Easy to operate

- Gas supply parameters are easily adjusted to meet product quality or dimensional requirements using recipes
- Process control with dynamic and closed loop measurement system
- Automatic, recipe-driven carbon potential control depending on pre-programmed parameters
- Alarm to signal deviation from set-points
- Complete documentation of atmosphere data for quality assurance
- Convenient access to process data history

Reduced costs

- Optimised gas consumption thanks to recipe system and draught control
- Easy upgrading of older furnaces
- Minimisation of rejects and reworking thanks to carbon potential control
- Less maintenance as systems have been tried and tested for several years

Improved safety

- Safety purging with N_2 from tank with sufficient volume of gas
- Low concentration of flammable gas (CO/H_2) in protective gas
- Draught control for protection against risk of explosions

CARBOTHAN®. Low-energy route to more flexibility.

Our CARBOTHAN® solution is a convenient and highly flexible nitrogen-methanol-based atmosphere system. Its main benefits are ease of operation, low investment costs and minimal maintenance. In addition, we have developed a wide selection of tailored injection systems to meet your heat treatment needs.

Cost-effective alternative to endothermic gas

As a flexible solution and a sound investment for the future, the use of nitrogen-methanol mixtures has many advantages over endothermic gas. The system uses special lances to disperse or dissociate a nitrogen-methanol mixture inside the furnace. Either the tried-and-tested CTL branded lances or our innovative new CARBOJET® lances can be used. The nitrogen to methanol ratio can be varied so that the CO composition can be adjusted between 0% and 33% at any time. This allows operators to achieve for instance the fastest carburisation with the minimum amount of internal oxidation at the substrate.

Optimised process flow

The methanol is stored in a tank and conveyed to the point of use via a powerful pump. Reliable gas supply means that sufficient quantities of nitrogen are always available. The flow rate can be easily and continuously regulated with mass flow controllers due to the high pressure. This supports various gas supply configurations. Immediately after charging, for instance, the oxygen in the furnace atmosphere can be very quickly purged with a large increase in the volume of injected gas. This results not only in quicker conditioning of the furnace, but also in less internal oxidation. For carburisation, the atmosphere – as with endothermic gas – has to be enriched with propane or another hydrocarbon gas.

For other applications such as quenching and tempering, CARBOTHAN® also provides an ideal alternative to endothermic gas. Since quenching and tempering require a controlled carbon potential in the furnace with only a minimum concentration of CO, a CARBOTHAN® atmosphere will enable a process with minimum soot formation, low rates of decarburisation or carburisation and very little internal oxidation. All the current possibilities in process regulation, such as β value regulation, are easier to achieve with nitrogen and methanol than with endothermic gas, since higher CO values can be attained.

No burn-off of excess gas

Even today, high and widely fluctuating CO_2 content of natural gas can pose a problem for some heat treatment operations. This is because it is very hard to crack CO_2 when used in endothermic gas generators or as an enrichment gas, and cracking requires a lot of energy. We can expect this problem to become more widespread in the future due to the increasing use of renewable energy sources and development of new sources of natural gas. With CARBOTHAN®, there is no excess gas to burn off because only the exact amount of gas needed is supplied to the furnace. During downtime, there is no need to keep part of the plant in operation. A plant which has been set up with a suitable supply scheme can be extended with just about any number of furnaces, without requiring more space or operation and maintenance costs, or investment for further endothermic gas generators.

Benefits of using nitrogen-methanol mixtures

- Cost-effective and proven gas supply system
- No endothermic gas generator with burn-off required
- Shorter atmosphere conditioning time
- No carcinogenic catalyst materials required for operation (REACH)
- Less maintenance and fewer spare parts needed
- Unlimited protective gas available practically 24/7
- Extremely flexible in terms of volume and composition
- Less soot formation in quenching and tempering processes
- Same carbon potential control as with endothermic gas (existing C potential regulators can still be used) → possibilities of β value regulation can be better exploited
- Flow regulation possible with mass flow controllers
- Flexible adjustment of carbon availability at the parts' surface
- Weekend idling operation with lower protective gas needs
- Nitrogen curtains are easy to implement in continuous furnaces
- Can be combined with CARBOJET® technology

HYDROFLEX®. Atmosphere control solution for oxide-free heat treatment.

HYDROFLEX® is a universal solution for oxide-free annealing of steel, stainless steel, copper, bronze or brass. Whatever the application, HYDROFLEX® determines the optimum ratio of hydrogen and nitrogen or argon to prevent oxidation in the heat treatment plant. While the inert gases N_2 or Ar as the carrier gas maintain the furnace pressure, the hydrogen serves to prevent oxidation. Many annealing tasks can be successfully completed with non-flammable H_2/N_2 mixtures containing less than 5% hydrogen. HYDROFLEX® can therefore often be the optimum solution for annealing with induction heating.

In many cases, HYDROFLEX® eliminates the need for a complex and high-maintenance gas mixer. Monitoring and safety mechanisms can be put in place to guarantee the safe handling of hydrogen and compliance with the relevant regulations.

The nitriding of gas-sensitive materials can be safely prevented by using pure hydrogen or an argon/hydrogen mixture. Our Furnace Atmosphere Zoning application optimises protective atmosphere costs in continuous conveyor or roller hearth furnaces. Special nozzles or curtains are used to inject an inert gas like nitrogen or argon at the entry and exit of the furnace. This increases the concentration of the thermochemically active hydrogen in the hotter zones of the furnace without the need to inject more hydrogen. Injected gas cost savings of up to 50% can be achieved in this way.

An oxygen probe at the exit of the cooling zone ensures early detection of air infiltration. The HYDROFLEX® control system counteracts this to prevent oxidation of the component. Further process optimisation can be achieved through additional intelligent measurement and control systems. These allow the ratio of hydrogen to inert gas to be adjusted at any time according to the atmosphere conditions in the furnace, rather than using fixed set values.

Regardless of whether you are annealing, sintering or brazing copper, steel, stainless steel, bronze or brass with pure hydrogen or an optimised mixture of hydrogen and nitrogen or argon, HYDROFLEX® provides a perfect – customisable – fit for your individual requirements.

Benefits

- → Precisely controlled atmosphere
- → Less reworking costs
- → Automatic safety purging with N_2
- → Storage of process data history
- → Improved heat transfer
- → Uniform heat distribution, faster cooling rate

Low-pressure carburising. Reliable supply of enrichment and quenching gas mediums.

In low-pressure carburising, process temperatures of up to 1070°C are reached. This significantly reduces process times. When combined with high-pressure gas quenching, distortion can also be reduced to a minimum. Significantly improved results compared to oil quenching, for instance, with regards to microstructure properties and component hardness can be achieved with the right quenching method.

The success of this heat treatment process is a consequence of the right protective gas and supply scheme. We can provide all the protective and process gases you need to optimise the operation of your plant. In addition, we offer comprehensive supply packages for helium, helium mixed gas, acetylene, nitrogen and hydrogen.

Our process gases

- Acetylene as carbon source and carburising medium
- Helium and helium mixed gas as quenching medium and for regeneration of catalysts in the helium recycling system
- Nitrogen as protective gas while the chamber is heating up and as quenching medium
- Hydrogen as process and injected gas and as quenching medium

Depending on the size of your plant, we will customise a gas supply system consisting of tanks or cylinder bundles. We will factor in all safety requirements at the planning stage and ensure that your entire supply scheme is engineered for the best possible results.

As an extra service, you can benefit from automatic delivery of all your required process gases. This service, enabled by our remote data monitoring system, saves you the hassle of ordering supplies and switching used with new cylinders.

Helium recycling

Faster quenching rates can be achieved with the use of helium, which is typically kept at a pressure of up to 20 bar. If required, we can also provide a turnkey supply and recycling system for new or existing plants.

NITROFLEX®. Optimised component performance.

Nitriding, like carburising, is a thermochemical diffusion process. The diffusion of nitrogen and/or carbon into the surface of the component forms a very hard nitride layer (ε and γ iron nitride), which, depending on treatment time, can become 2–30 µm thick and develop a porous layer of approximately 2–10 µm on the surface. This porous layer can act as a self-lubricating surface, improving the wear resistance of components. The approx. 0.1 to 0.7 mm-thick diffusion zone lies under the nitride layer. This is where the nitrogen is stored in the ferritic metal matrix. For the subsequent chemical or galvanic coating, however, nitriding without the nitride layer may also be desired.

Nitride layer with porous layer

Improving component properties

By combining nitrocarburising and oxidation, air, steam or nitrous oxide (N_2O) can be added at the end of the process to improve corrosion resistance and give an aesthetically pleasing black finish (oxy-nitrocarburising). For greater corrosion resistance, postoxidation treatment is used to create 1–2 µm Fe3O4 protective oxide layers. Piston rods treated in this way, e.g. those made from C45 steel, show much greater corrosion resistance in the salt spray test according to EN ISO 9227 compared with hard chrome-plated parts. Nitriding can optimise many other properties of a component apart from corrosion resistance. These include wear resistance and fatigue strength – especially in the case of plain or low-alloy steel components.

Because of the low treatment temperatures used, nitriding causes little distortion and is mostly used on finished components. With traditional nitriding, the treatment temperatures usually range between 500 and 540°C, and with nitrocarburising, between 550 and 590°C. As nitrogen and carbon donors, mixtures of NH_3 + N_2 + CO_2 are normally matched to the required treatment conditions. Modern atmosphere control systems (O_2 probe and H_2 nitriding sensor with mass flow control connected) support the best possible reproduction of defined treatment results.

Plasma nitriding

If even lower treatment temperatures are desired, plasma nitriding may be an option for high-alloy materials in particular. This process causes nitrogen to be diffused onto iron components, typically at temperatures of 480 to 560°C. This takes place in the vacuum on the material surface with the aid of plasma created with a glow discharge. In certain cases, treatment temperatures of between 350 and 480°C are possible. The process gases used are N_2, H_2, N_2O (nitrous oxide) and CO_2. Looking beyond gas nitriding, plasma nitriding is a particularly suitable process for rust- and acid-proof high-alloy components (>13% Cr). One thing to be aware of here is a possible diminishing of corrosion resistance, which can be counteracted with postoxidation treatment.

For reproducible results when subjecting materials to thermal gas and plasma nitriding, the composition, function and control of the furnace atmospheres are critical factors. We can provide solutions and gas control panels tailored to your heat treatment needs, regardless of your actual process.

SINTERFLEX® dynamic atmosphere control. Raising the bar for sintering quality.

Creating new opportunities for sintered parts through online carbon control

The powder metallurgy (PM) industry is challenged to increase the quality and consistency of sintered parts in order to open up new market opportunities. We have developed a technology to control the sintering process and improve the mechanical strength of sintered parts. A sophisticated, online carbon control system is at the heart of our SINTERFLEX® offering. It paves the way for exciting new market opportunities for sintered parts.

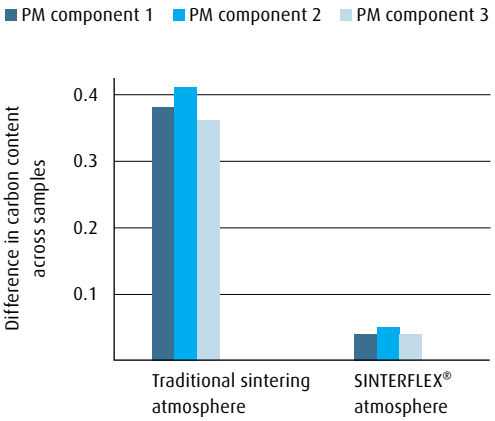
Creating a lean sintering atmosphere

Today, most furnace atmospheres in the PM industry are fed a mixture containing nitrogen (as the base gas) and various active gases such as hydrogen, and hydrocarbons. The aim of these active gases is to control the carbon content and the oxidation process.

These gases can be finely adjusted to create a leaner atmosphere which delivers the desired carbon potential. In other words, keeping all active gases to a minimum so the carburising process can be tightly controlled. The challenge lies in ensuring advanced monitoring and control functionality that allows operators to ensure carbon potential uniformity throughout the furnace.

We have resolved this challenge with our unique SINTERFLEX® offering. This innovative, automated and user-friendly solution gives operators real-time monitoring and dynamic adjustment capabilities over furnace atmospheres.

Range of carbon content in parts treated during a production day



Benefits at a glance

- Delivers real-time monitoring and dynamic adjustment capabilities over furnace atmospheres
- Allows faster start-up conditioning and reduced switching times between different alloys
- Reduces post-treatment costs for salvaging carbon content of components
- Enables operators to sinter highly alloyed powders (Cr)
- Enables controlled carburisation (up to 150 µm) for greater resistance to fatigue
- Enables consistently high quality of the sintering furnace atmosphere through closed loop control

Precision counts

Working with our partner Höganäs and selected key customers, our R&D team ran extensive tests to show that SINTERFLEX® helps you to deliver parts which do not vary in quality. These tests demonstrated that the carbon content deviation among parts treated in a base atmosphere and parts treated in a SINTERFLEX® atmosphere dropped by more than 80% (see illustration). The tests covered a significant number of parts and were extended over different shapes. The positive effect of SINTERFLEX® atmospheres can even be clearly seen with a metallographic examination.

CRYOFLEX® cryogenic treatment. For parts that last three times longer.

Sub-zero treatment

Many manufacturers in industries such as automotive, aerospace and machine tooling rely on heat treatment processes to improve material properties. In the constant search to optimise heat treatment results, more and more players are focusing on sub-zero treatment – a cryogenic step that follows a normal heat treatment process.

By transforming retained austenite into martensite and by precipitating fine carbides, sub-zero treatment delivers:

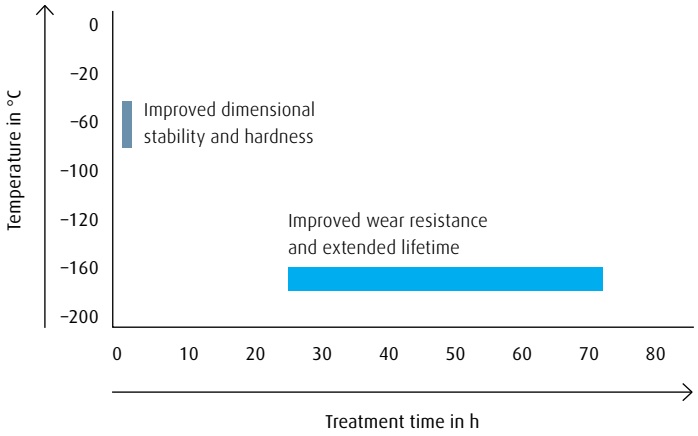
- Improved hardness
- Improved dimensional stability
- Increased wear resistance
- Extended lifetime

The physics in a nutshell

Wear resistance and the lifetime of high-alloy and tool steels can be significantly increased through the correct application of sub-zero treatments.

These cryogenic treatments are typically performed in the temperature range from –160 to –180°C and take 24 to 72 hours (see chart below). Beyond the transformation of retained austenite to martensite, cryogenic treatment has the added effect of precipitating fine carbides in the steel microstructure. This improves wear resistance and extends service life even further.

Benefits at different temperatures and treatment times



Improved dimensional stability and increased hardness

At room temperature, retained austenite is unstable and will slowly decompose over time. This decomposition can cause dimensional changes, resulting from rearrangement of the crystallographic structure.

Components that require a high degree of dimensional precision must be engineered to avoid this decomposition. This can typically be achieved with a cold treatment in the temperature range from –40 to –80°C over a period of 1–2 hours (see illustration). This cold treatment not only improves dimensional stability but also increases hardness. The increase in hardness is attributable to the transformation of the steel microstructure from austenite to martensite, which is stronger and harder.

Creating value with CRYOFLEX®

Investments in professional sub-zero application technologies and equipment generally deliver rapid payback. Here liquid nitrogen is the cooling agent of choice as it enables temperatures down to –180°C, and accelerates cycle times.

We deliver a range of sub-zero solutions designed for ease of operation and cost efficiency, meeting the highest standards of quality and safety. They also come with leading features enabling fully automatic temperature tracking and reporting capabilities that comply with the rigorous demands of the aerospace industry, for instance AMS 2750 E, NADCAP and CQI-9 – three standards widely demanded by the industry.

You can choose from our three off-the-shelf CRYOFLEX® freezers – our box, cabinet and tunnel models. Complementing this standard offering, we also design customised models and sizes for your specific needs.

Tailored tank supply solutions. Gas supply optimised to your requirements.

Our range of application engineering services is rounded off with gas supply solutions that can be tailored to your individual requirements. For low volumes, we supply compressed industrial gases in pressure vessels. For higher volume requirements, liquefied gases in a tank with an evaporator system are more suitable. We supply tanks in a range of sizes and configurations – all proven in the field and tailored to your requirements.

Nitrogen

Flexible supply of high-purity nitrogen

We can provide you with a turnkey system with all the required fittings on a rental basis. Regular functionality and safety checks are also part of our service. In addition, we can supply downstream heat exchangers (air-heated vaporisers) in a size that meets your requirements.

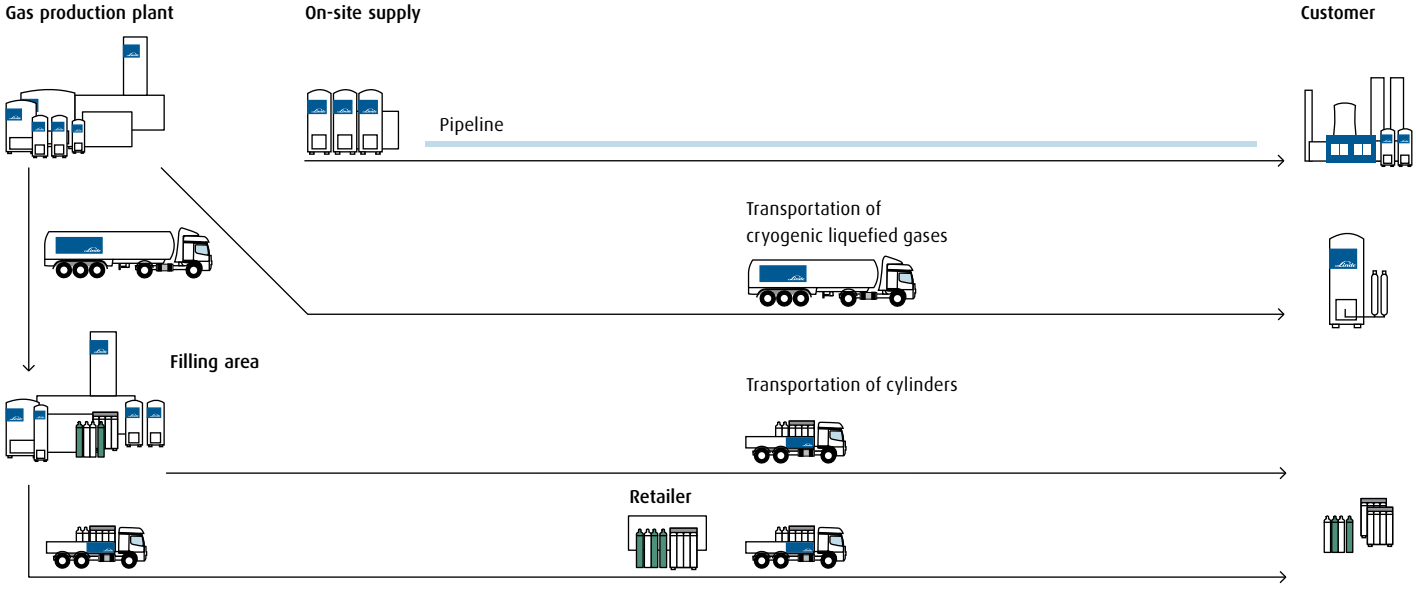
Securing a regular supply of nitrogen is very straightforward: the cryogenic liquefied gas is delivered in special tankers and pumped into the tank on site. The pressure in the tank remains constant so that gas can be withdrawn without any adverse effects, even when the tank is being filled. A downstream heat exchanger (e.g. an air-heated vaporiser) vaporises the liquid gas, which is delivered to your process via pipes.

The supply systems are usually installed outside, which saves space inside your furnace hall. As a rule, the nitrogen we supply complies with the high purity specification 5.0 (99.999% by volume) and it can be used in all heat treatment applications. If required, we can also supply purity grade 6.0 nitrogen.

ECOVAR® – on-site nitrogen supply

In recent years, customers are opting increasingly for on-site supply solutions instead of gas deliveries. This is being driven by the availability of new nitrogen generation technologies and innovations in cryogenic systems. With decades of experience as a manufacturer and operator of air separation plants, we have a strong lead in this area. ECOVAR® is the result of the continued evolution of our air separation processes, inspired by the desire to bring our customers the benefits of optimised costs and greater reliability. Customers with relatively continuous and uniform consumption patterns may find that the ECOVAR® on-site supply solutions are more cost-effective than nitrogen deliveries. To find the ideal supply solution for your business, we would need to perform an in-depth analysis of your consumption profile and purity requirements. Our application engineers can perform this service for you at any time.

Linde Gas supply modes



Hydrogen

Hydrogen is supplied in gaseous form in steel cylinders, cylinder bundles or trailers, and in cryogenic liquefied form in tankers. At the customer's site, it is stored in cylinders, special pressure vessels or a vacuum-insulated tank. We supply and service all of these gas containers.

Propane

Propane is stored in pressure tanks in liquid form and delivered in tankers. Customers who consume small volumes of propane can have the gas delivered in cylinders.

Acetylene

Acetylene is supplied in steel cylinders, cylinder bundles or trailers. Acetylene supply and storage requires special attention to detail. Our acetylene experts consider all of your requirements. By complying with the highest level of safety standards, we ensure the safest installation for supply and use for your process.

Carbon dioxide

For some processes, carbon dioxide is also delivered in cylinders, cylinder bundles or in tanks. Again, all are serviced by Linde experts.

Ammonia

Ammonia is also delivered in cylinders, or drums specifically designed for the heat treatment industry. These storage mediums are usually washed (purged with nitrogen) between each filling to dry accumulating contaminants such as water.

Helium

Depending on your volume requirements, we can supply helium in special insulated ISO containers, tube trailers, dewars, multi-cylinder packs (MCPs), regular cylinders or portable cylinders

Gas mixing and dosing solutions

We tailor our supply systems, safety features included, to the exact requirements of your heat treatment process. In addition, we can provide you with mixing systems to adjust the required gas mixture on site. We manufacture conveyor and charging systems, controllers, catalysts and measuring devices unique to the market at our own production facilities. In this way, we can guarantee fast and cost-effective delivery of all your gas supply needs.

Security of supply

With over 600 affiliated companies in more than 100 countries, The Linde Group complements its global production and delivery capabilities with local expertise to ensure timely deliveries and consistently high levels of service quality.

Getting ahead through innovation.

With its innovative concepts, Linde is playing a pioneering role in the global market. As a technology leader, it is our task to constantly raise the bar. Traditionally driven by entrepreneurship, we are working steadily on new high-quality products and innovative processes.

Linde offers more. We create added value, clearly discernible competitive advantages, and greater profitability. Each concept is tailored specifically to meet our customers' requirements – offering standardised as well as customised solutions. This applies to all industries and all companies regardless of their size.

If you want to keep pace with tomorrow's competition, you need a partner by your side for whom top quality, process optimisation, and enhanced productivity are part of daily business. However, we define partnership not merely as being there for you but being with you. After all, joint activities form the core of commercial success.

Linde – ideas become solutions.

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