
# Specialty Gases — Worth Their Weight in Gold

## A Special Report by Linde Gases

High purity specialty gases are frequently delivered to laboratories and research facilities, food and beverage plants, and medical facilities. It is not often that these gases are associated with the gold trade. Yet ultra high purity gases play a pivotal role across the spectrum of gold mining and the subsequent metallurgical processing, purification, and refining of ore into gold bars.

Sought after since history began, gold has myriad uses beyond the jewellery and monetary exchange of old. Owing to properties such as corrosion resistance, electrical conductivity, ductility and malleability, infrared reflectivity and thermal conductivity, today this precious metal has become a requisite in food and beverage production, automotive production, medicine, dentistry, industrial processes, electronics, space equipment, beauty products, and imaging.

China is currently the world's top gold producer, followed by Australia, the United States, Russia, and South Africa. These five producers account for more than half of the world's gold production. South Africa's drop in ranking over recent decades is not a result of resource depletion, but rather of high production costs, as lower priced global sources have come on stream — and deep South African ores are, in comparison, relatively expensive to extract. While gold prices had a rollercoaster ride in 2013 compared with the seemingly unstoppable rise in price in 2012, gold remains sought after by both end-users and investors, as it has throughout history.

### Safety

In the all-important arena of human safety, specialty gases come into play in the gold mining industry to operate and calibrate underground gas detection sensors. As essential as a miner's helmet and headlamp, underground gas sensors continuously "sniff" for naturally occurring toxic and flammable gases such as methane and carbon monoxide, both of which are colorless and odorless and therefore undetectable by humans.

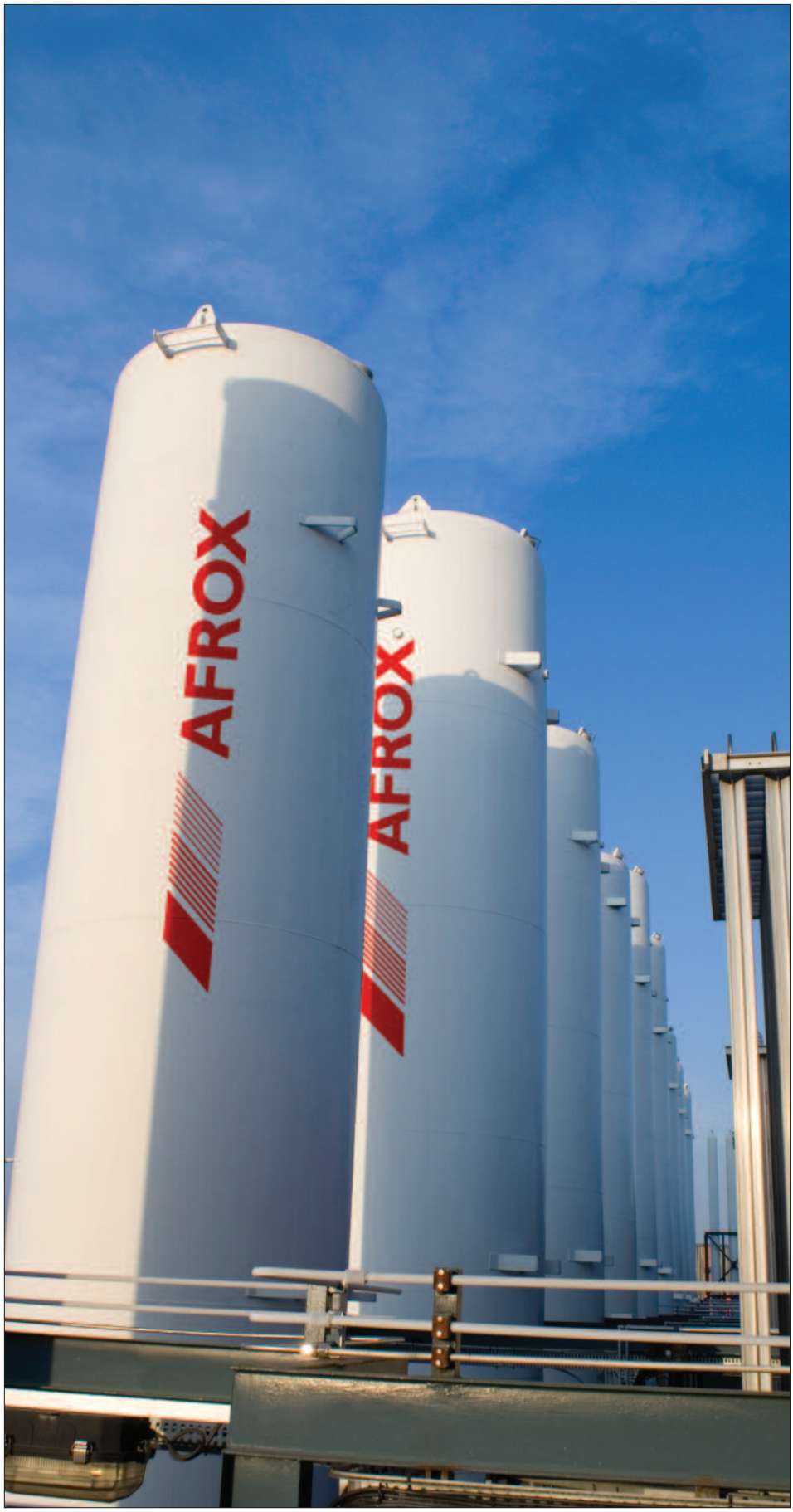
Precise calibration of the underground gas detectors is achieved with accurate specialty gas mixtures containing small known quantities of carbon monoxide and methane. The gas mixtures required to test and calibrate sensors located in key positions underground are transported in steel

cylinders, rather than the aluminium cylinders that are commonly used for these types of gas mixtures in surface applications. The steel cylinders reduce the risk of sparking in this hazardous underground environment.

## Emergency Oxygen Supply

In the event of toxic gas accumulation that renders the underground atmosphere unbreathable, hard rock miners are equipped with self-contained self-rescuers (SCSRs) that allow them to breathe while escaping to a safe area or returning to the surface. A SCSR is a portable oxygen source for providing breathable air that provides a comfortable margin of safety of about 30 minutes. A SCSR is usually a closed-circuit breathing apparatus with a chemical oxygen generator or a compressed oxygen cylinder and a carbon dioxide absorber. Some SCSRs use potassium superoxide as a chemical oxygen source.

A leading South African industrial gases company, Afrox, a subsidiary of the German Linde Group, has been a leader in the design of SCSRs and recently released the latest version of its award-winning design. The Afroxpac35i is a closed-circuit, self-contained oxygen breathing apparatus. It employs an efficient bi-directional re-breathing system in which exhaled gas makes two passes through the carbon dioxide removal/oxygen generation canister before the oxygen-rich gas returns to the user.

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## Metallurgy

In a laboratory servicing a gold mining operation, time is money and accuracy is of the utmost importance. These laboratories are analyzing ore samples to determine the gold content of the ore on a 24-hour turn-around. This information is fed back to the miners to determine future development to maximize gold yields from the ore. The consequences of a delay in this information feedback loop, or the implications of an inaccurate result might mean that the costly efforts of ore extraction are being done where the rock has a low gold yield. In these laboratories a broad range of analytical methods is used on a daily basis and many of these methods require a diversity of specialty gases.

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air, helium, hydrogen, or nitrogen are used to zero and purge analytical equipment. High purity gases are also used, for example, argon in inductively coupled plasma (ICP) analysis and acetylene in atomic absorption spectroscopy measurements (AAS). ICP mass spectroscopy is typically used to determine the purity of the refined metals being produced by the mine. Techniques like this require high purity specialty gases with very low levels of impurities, such as Linde's ICP grade argon from its HiQ specialty gases range. Ore structures are also assayed using X-ray crystallography, for which an instrumentation specialty gas mixture of methane in argon is typically required. Specialty gas equipment such as Linde's REDLINE® range is used in many areas to control gas cylinder pressures, while ensuring gas purity is not compromised.

Environmental measurements for air, water, and ground water pollution in and around a mine use a number of individual calibration gas mixture standards to calibrate instrumentation used to measure and control various organic and inorganic chemical emissions. The requirement here is for gas mixtures with low levels of reactive components, and many specialist techniques must be used to create these mixtures and achieve "flat-line" stability of the mixtures for the duration of their usable shelf-life. SPECTRA-SEAL® from Linde is one such technology that guarantees the stability, accuracy, and quality of these types of calibration gas mixtures.

These calibration gas mixture standards also must often be produced to meet the requirements of regulatory agencies around the world, because within many areas of environmental monitoring, local governments require that the instrument and sensor calibration gases used be certified to ISO 17025. This is to ensure data is traceable to a national standard and that overall uncertainties for pollution data are within specified limits and are therefore consistent around the world.

A wide range of gas mixtures is applied to calibrate the analytical equipment and to ensure its correct operation. Normally, these mixtures are supplied in high pressure or disposable gas cylinders. Depending on the type of instrumentation, consumption, and the required mobility required, the size of the cylinders varies from one to up to 50 liters.

## Ventilation

Underground mine ventilation provides a critical flow of air to the underground workings of a mine of sufficient volume to dilute and remove noxious gases, typically hydrogen sulphide, nitrogen oxides, methane, carbon dioxide, and carbon monoxide. The sources of these gases are: equipment that runs on diesel engines; blasting with explosives; and the virgin orebody itself.

In certain geographical regions, however, underground mines can be extremely cold places to work in, particularly during winter. These underground work zones need to be heated to provide a comfortable environment for mine personnel and to prevent equipment and water pipes from freezing.

Each country has specific regulations governing the volume of ventilation necessary to maintain safe working conditions for miners, and the air volumes needed to ventilate a mine are calculated to suit each mine.

Air temperature is another factor, since the deeper the mine goes, the hotter the rock and the

higher the underground working temperature for the miners. Some gold mines in South Africa have recorded underground temperatures in the region of 117°F (47°C). To keep the air at these deep levels at a safe temperature for physical work, chillers are installed underground, or used in overground locations and combined with extensive ventilation systems. Large quantities of refrigerant gases are required to operate these chillers. Since these chillers are permanently in use, maintenance is often carried out while they are in service. To support this in-service maintenance requirement and maximize chiller on-time, Linde offers a proprietary mobile technology to remove oils from the refrigerant. Oils can leak into the refrigerant gas circuit from the lubrication oil circuits and when mixed with the refrigerant gas, they diminish the efficacy of the refrigeration system. So, an "on-line" refrigerant gas clean-up can return the refrigeration system to its optimum efficiency and maximum chilling impact.

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## Gold Extraction

After removing the gold ore from underground, the metallic gold is recovered through a complex extraction processes. Gold ore is crushed, milled, and slurried. The slurry is thickened and pre-conditioned prior to leaching. The most common reagent is cyanide, which must be combined with oxygen in a process known as carbon-in-pulp. As the cyanide and oxygen react chemically, the gold is leached and absorbed onto activated carbon.

The next stage is stripping, where a hot caustic solution separates the gold from the carbon and finally the gold-bearing solution enters the electrowinning phase, which recovers gold from the leaching chemicals. In electrowinning, the gold-bearing solution is poured into cells where anode and cathode introduce a strong electric current to the solution that causes gold to deposit on the cathode. The recovered gold is then smelted in a furnace and, after a chemical mixture known as flux is added to the molten material, the gold separates from the metal terminals. The flux is later removed and the liquid gold is poured into molds to produce solid bars, which enter the market for further processing.

Several years ago Afrox innovated a new leach feed diagnostics system developed for in-the-field evaluation of oxygen demand characteristics. Goldox™ is a process developed for the use of oxygen in cyanide gold leaching. It was first introduced to South African gold mines in the mid-1980s and is now used by mines in North America, Australia, and Asia, establishing it as an internationally-proven technology. Benefits include capital savings on new plant, optimized cyanide usage, and potentially lower and stable residue grades. The technology can also be retrofitted unobtrusively to existing plants.

The Goldox™ process performs a dual function. Through the introduction of pure oxygen in the preconditioning stage to the ore slurry, the dissolved oxygen concentration is increased, reducing the ore reactivity, resulting in an increased gold leaching rate which improves gold recovery and profitability.

More recently, solvent extraction (SX), which uses sulfur dioxide as the solvent, has become popular as an efficient way to extract gold from certain pipes of gold, particularly where the purity of the gold is an important factor. This can be critical, for example, where the gold will be used in electronic applications. As an increased number of gases such as sulfur dioxide are used in the gold extraction and refining process, the partnership between gas companies such as Linde and the operators will deepen further.

## End-to-End Solutions

Linde differentiates itself in the mining market by offering customers an end-to-end solution that is fully integrated. Value is added to these processes, both from a financial and a productivity perspective, by sourcing the necessary consumables, equipment, and processing gases for ore enrichment, welding gases for maintenance, refrigerant gases for chilling systems, and specialty gases for ore assay and safety, as well as on-site customer-specific support and training, from a single supplier. Welding consumables for fabrication in the mining environment range from industry-leading general purpose and low hydrogen electrodes, to the more exotic nickel and chrome alloys for welding high corrosion resistant materials and duplex stainless steels.

This 360 degree solution is being recognized and exploited by the market, whether in combination as a fully-integrated bundle to complement clients' processes, or provided on a menu-type basis.

Linde's quality range of gas equipment extensively utilized within the gold mining industry conforms to relevant national and international safety standards. To further support the gas equipment products, the company offers dedicated training for the safe use of gases and gas equipment.