Helium Supply: Scarcity Prompts The Search For Alternatives

Helium is a finite resource and, along with fossil fuels such as coal, petroleum and natural gas, reserves of this noble gas are noticeably dwindling. Some experts believe it is quite possible that more than half of the world's helium supply has already been depleted. This poses a challenge to the new century's leading scientific minds — could helium be replaced in the myriad applications that presently rely on it, and if so, with which gases?

Worldwide demand for helium has been steadily increasing to meet the requirements of both conventional applications and the latest new-frontier uses. Helium is used in gaseous form in welding and cutting, fiber optics, electronics, in aerospace applications, in leak-testing, deep-sea diving, growing crystals to make silicon wafers, as well as inflation of balloons. Additionally, it is employed in liquid form for cooling superconductive magnets used in magnetic resonance imaging (MRI) scanners for medical diagnostics and nuclear magnetic resonance (NMR) laboratory instrumentation. Helium is also commonly used with a wide range of analytical instruments as a carrier gas or in calibration gas mixtures.

In terms of usage worldwide, the greatest demand for helium comes from the USA (36%), while Asia (28%) and Europe (22%) are the second and third largest markets, respectively. Twenty percent of global demand alone comes from the manufacture and operation of MRI scanners, which use liquid helium to cool the superconducting magnets that generate high resolution images of the human body. Rising demand for MRI, along with growth in the electronics, semiconductor, liquid crystal display and fiber optic industries is fueling increased requirement for the gas in China, India, Korea, Taiwan and in the Middle East.

The entire industrial gases industry may be facing one of the most prolonged shortages in the history of the global helium supply. Nevertheless issues around helium scarcity and temporary supply disruptions will continue into the future and unfortunately are a natural consequence of the fragile supply chain characteristic to the helium industry.

In 2009 the global economic crisis caused a downturn in the need for helium from a number of sectors, and gas suppliers expected a slow recovery from this downturn. Instead, these sectors made a strong recovery, including sectors that had suffered the most, coming back with a vengeance. In addition to this here was a rapid emergence of a number of processes that did not previously require helium, adding to the demand.

The supply of helium, which is largely governed by sources linked to fossil fuel reserves, has not kept pace. Some existing sources have experienced disruptions and have performed below expectations. Furthermore, a number of sources that were planned to come on stream a couple of years ago, have not yet done so.

The scientific world needs to navigate a safe transition from helium, and indeed other scarce gases we have traditionally used for their convenience, to other suitable and sustainable alternatives, wherever possible.

Supply Sources

The largest helium source that industrial gas suppliers take from is the Bureau of Land Management (BLM) complex in the United States that provides about 50% of worldwide demand. The system has physical constraints, however, that force the BLM to allocate the amount of crude available to refiners that in turn affect the entire supply chain. Reductions in volume—impacting the whole industry—have been in place for a year.

In addition to the BLM, suppliers also source a significant portion of helium from a number of other sources to ensure diversity and stability of supply. One such example is Qatar in the Middle East via the Qatar 1 Helium Project. One supplier now operates the first helium liquefaction plant in the southern hemisphere in Darwin, Australia.

Several new sources are expected to come on stream, including the Qatar 2 helium project, which might become the world's largest. Once these new sources are operational, there will be sufficient helium to satisfy existing demand and also to support claim some experts in the industry.

This will, however, only be a temporary respite. The supply from the BLM system is depleting and will be winding down over the next 4-7 years they predict. Replacing this supply will take time and multiple helium sources need to be identified and developed in the medium term. Furthermore, many of these new sources will be located in some challenging geographies like Siberia and North Africa, and on the back of very large and complex projects such as LNG trains and intercontinental pipelines. the experts caution that the complexity, cost and risk of helium extraction will increase significantly over time.

Another challenge to industrial gas companies, who are distributing helium to end user markets, is the lack of full visibility of all the new processes using helium. An example of this is in the electronics industry, where demand growth has been significant — almost exponential — and somewhat unexpected. Although this industry is typically guarded about exactly how the helium is being used, one process that is well known is the advent of the larger diameter silicon wafer. About six years ago, these wafers were being produced with a 150 mm diameter and the amount of helium required to cool down a wafer of this diameter was not significant. When the design progressed to a 300 mm diameter, it resulted in a doubling of the wafer rod surface area coupled with a quadrupling the wafer rod volume, thereby placing higher demands on the heat extraction capacity of the cooling gases surrounding the wafer rod. This caused a substantial increase in helium demand.

Now the 450 mm diameter wafer is on its way, and it is expected that the electronics industry will use considerably more helium to satisfy its cooling needs.

Recovery and Recycling

Linde is now working with customers to incorporate recovery and recy-

Helium containers

cling of the helium in their processes. The hope is that the amount of helium recovered, liquefied and put back into manufacturing facilities will provide a significant change. Some key MRI manufacturers have, for many years and with the support of suppliers managed to capture helium, re-liquefy it and put it back into their processes. Other manufacturers are likely to follow suit.

Linde Kryotechnik, a division of The Linde Group that specializes in helium liquefaction and refrigeration technology, has been installing these liquefiers at a number of manufacturing facilities throughout the world. So while the amount of liquid helium required to cool down an MRI unit after the manufacturing process will stay more or less the same, the amount of product recovered will increase through more intensive recovery efforts. As a result, the quantity of fresh helium required by these factories will decrease.

During operation, MRI scanners require liquid helium to cool down their superconductive magnet coils to 4.3 Kelvin. Where MRI scanners are used in the healthcare industry, there are two clear trends. One is the incremental growth of the number of scanners being used in the developing world, specifically India, China and Brazil, pushing up demand for helium. On the other hand, the scanners being manufactured today are considerably more efficient than they were only five years ago. Therefore, the average amount of helium required per scanner while in operation is decreasing, with the net result likely to be a constant level of demand for helium for the MRI scanners in operation.

One of the newer applications for helium is being driven by passenger safety considerations in the automotive industry. This is airbags. About 80% of automobile airbags harness a helium and argon gas mixture compressed in a steel cartridge at 600 bar. Helium has a number of advantages in this application, foremost of which is the fact that it does not generate heat during the inflation process. This means both driver and passengers are at far less risk of burns when airbags deploy, than they were with older technology which used other gases to inflate the airbags.

Economizing World Usage

Experts in the field agree that there are two approaches that will help economize on world helium usage. One is substitution through use of another gas and the other is recovery and recycling of helium. Some industrial sectors have come up with their own alternatives to helium. About five years ago, there was an understanding that cooling down photovoltaic panels required helium in the same way as is required for electronic wafers. When this technology first emerged, the solar industry believed helium was the only way to cool the glass substrate.

Gas suppliers eyed these developments with some concern, particularly the amount of helium that these manufacturers projected would be required in the following five to ten years. But the industry itself discovered that helium could be replaced with argon or, in some instances where less sophisticated photovoltaic panels were manufactured, even nitrogen.

Dan Baciu, Head of Global Helium Business Development at Linde, says the price of one cubic meter of argon is significantly less than the same quantity of helium and when you move to nitrogen, this gas costs significantly less than argon. So these industry players managed to save significantly on operating costs before any helium was even required, because all this took place during the forecasting phase."

Helium transportation containers

Helium is also used in leak testing and Baciu says Linde is working to move some of these users from high to low helium concentrations. Leak testing is typically carried out on an industrial scale with a mix of helium and nitrogen and sometimes, particularly in the USA where helium has been traditionally more abundant and less expensive, many manufacturers choose to use 100% helium.

Baciu points out, "Now we're trying to educate this industry—with the support of the manufacturers of leak testing equipment—that using a high percentage of helium is unnecessary, because a lot of that helium is simply being wasted. In fact, using 100% helium reduces the chances of finding the leak, because with so much helium in the surrounding environment, the highly sensitive leak test equipment might 'sniff' out some waste helium in the environment instead of the leak. For this type of application it's possible to go as low as about 5% helium in nitrogen."

Another alternative that has been identified for certain applications involving helium is the substitution of hydrogen for the helium. Like the helium atom, the hydrogen molecule has a very small size, making it a viable alternative. It is now believed that many users of helium, including those in the laboratory environment could actually employ hydrogen in certain instances. An initial obstacle to replacing helium with hydrogen is, of course, hydrogen's flammability. The flammability range for hydrogen in air is 4-75 % volume, but, operators will typically target the percentage level of hydrogen in the workplace environment to be below 50% of the lower explosion limit (LEL), so only 2% of hydrogen in the atmosphere is regarded as a safe working environment. However, good operating practices which avoid hydrogen gas leaks coupled with the added security of hydrogen gas sniffers or gas detectors can often mitigate the risks of these flammability concerns.

Laboratory Alternatives

In a laboratory environment, a carrier gas transports the samples to be analyzed in a gas chromatograph through a column into a detector, where the sample is then analyzed. Typically helium, hydrogen and nitrogen are used in this application. The choice of carrier gas is dependent on the type of detector, the specific application, which type of column is used for separating the sample and also the level of safety required.

Stephen Harrison, Global Head of Specialty Gases and Specialty Equipment at Linde says that often the main drivers for the transition from helium to hydrogen are the shortage of helium and its high cost relative to hydrogen. However hydrogen also has the analytical advantage of having a lower viscosity, which makes the analyzing time faster, increasing laboratory productivity. In addition, hydrogen has a broader range of separation performance as a result of this lower viscosity, and is therefore used specifically for capillary columns in a gas chromatograph, which are very narrow.

"This type of application is found in market sectors where environmental analysis is conducted to determine air quality or for emissions monitoring, as well as in laboratories undertaking analysis for the food, pharmaceutical and petrochemical industries, and along with universities," he explains. "The most commonly used detector for these carrier gases is the gas chromatograph flame ionization detector (FID), which is used for analyzing hydrocarbons and volatile organic compounds (VOCs) and is the workhorse of these types of laboratory.

Other types of detectors able to use either helium or hydrogen are the thermal conductivity detector (TCD) and the electron capture detector (ECD), which is used specifically for environmental testing and can detect to very low parts per million (ppm) or even to parts per billion (ppb).

In the petrochemical industry, the flame photometric detector (FPD) can use hydrogen as a carrier gas to analyze sulphur and sulphurous compounds to determine the sulphur content of fuels, for example.

There are some applications in which helium must be used and it cannot be substituted with hydrogen. For example, the helium ionization detector (HID) is a very specific type of detector that can analyze volatile inorganics in very low ppm levels and it relies on the specific properties of helium to function. Hydrogen also cannot be used when analyzing unsaturated or aromatic hydrocarbon solvents, because it is a reactive gas that could possibly hydrogenate these samples and thereby distort the analytical results.

Laboratories that opt to replace helium with hydrogen in suitable applications can employ as a source a hydrogen generator, hydrogen cylinders or a combination of both. In cases in which cylinders are used, switchover panel technology can also be used to monitor the pressure of a cylinder and automatically swap to an adjacent full cylinder of the same gas when the first one runs empty, thereby ensuring continuity of supply. This is critical because after starting a sequence of analysis and then running out of gas halfway through, effectively ruins the sample and results in having to abort the sequence. A switchover panel allows personnel the opportunity to change out the first cylinder while the second one is running, ensuring an uninterrupted and trouble-free flow of gas.

Another option for high supply integrity is a hydrogen cylinder switchover panel as a backup to a hydrogen gas generator. This option can automatically switch supply to a cylinder when the generator gas runs too low, for example, in the event of the hydrogen generator water reservoir running dry, or a power outage resulting in the gas generator no longer able to function.

Security of Supply

Due to its unique properties and the fact it is so vital to so many applications, the security of the helium supply is often the most critical factor. Because of a variety of factors contributing to great uncertainty to future availability, helium suppliers are carefully watching supply and demand and even diversifying their source portfolio. Simultaneously, customers are encouraged to incorporate recycling and reuse when viable or to find suitable alternative gases for their applications that can do the job of helium wherever possible.