CHALLENGES TO THE WORLDWIDE SUPPLY OF HELIUM IN THE NEXT DECADE

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ABSTRACT

As the world's economy recovers from its current slowdown, there is growing concern over the ability to meet future supply needs and maintain competitive economics for helium including those that make it an essential ingredient for many electronics, medical and industrial applications.

Because the world's helium supply is finite and irreplaceable, three options exist to increase its global availability – find new sources where extraction is economically feasible, develop more effective methods to recover and recycle helium and conserve it.

What is driving these challenges? And what is the industry doing to insure economical helium supply?

One of the most promising solution areas is the growing development of recovery and recycling of helium. Recovery techniques including cryogenic applications are on the forefront of development for such areas as superconductivity applications and research, magnetic resonance imaging, and traditional helium uses.

A clearer understanding of these global helium challenges will drive innovation and create technological and commercial opportunities in the decade ahead.

INTRODUCTION

Helium is a unique industrial gas. It exhibits characteristics both of a bulk, commodity gas and of a high-value "specialty" gas. Liquefied helium is distributed in bulk containers each carrying over 25,000 nm^3 (cubic meter at normal temperature and pressure, defined as 20ºC and 1 atmosphere). It is the only industrial gas distributed in such large quantities on a global basis. However, only a handful of sources in the world produce helium. The high cost of extraction restricts helium use to relatively few, generally high-technology, applications.

Helium's split personality is reflected in the various ways in which different industrial gas companies manage their helium businesses. Some group helium together with the other rare gases such as krypton, xenon and neon. Others manage helium as a bulk industrial gas alongside nitrogen, oxygen and argon. A few have dedicated teams with global responsibility focusing exclusively on this unique product. Why is this? What are the implications for the future?

The answers lie in understanding helium, its uses and their economic impact.

PROPERTIES AND APPLICATIONS OF HELIUM

Helium and hydrogen stand alone at the top of the periodic table, and they exhibit many similar properties. Hydrogen has one major advantage over helium in that it is freely available at relatively low cost. Hydrogen could serve equally well for many helium applications were it not for one fact: unlike helium, hydrogen is flammable and, therefore, explosive.

Because of its atomic configuration, helium exhibits a number of extreme physical and chemical properties that give it unique advantages in a number of industrial applications. TABLE 1 lists some of these properties and key applications derived from each. Some applications draw on more than one property. For most applications, non-flammability is an important consideration.

One of helium's most useful properties is its extremely low boiling point; at 4.2K, it is the lowest of any material. Helium is also the only material that, at atmospheric pressure at least, does not turn into a solid even at absolute zero temperature. These properties make helium ideal for a wide variety of industrial, commercial and research applications. The largest single use for helium is cooling low-temperature superconductors. Although hydrogen's boiling point is only a few degrees Kelvin higher than helium's, hydrogen is unlikely ever to be used as a cheaper substitute for cooling Magnetic Resonance Imaging (MRI) equipment in hospitals.

The fact that helium is the only material with a lower boiling point than hydrogen, coupled with the fact that helium is inert and non-flammable, makes helium a useful medium for purging liquid hydrogen systems before and after use. Although nitrogen is a more conventional purging medium, in these circumstances it would form solid nitrogen—an obvious problem. These unique properties of helium benefit the space agencies, such as NASA and Arianespace, that use liquid hydrogen-powered launch vehicles (FIGURE 1).

As a side note, the fact that all other materials solidify at liquid helium temperatures, means that the liquid helium distributed around the world is inherently extremely pure. (Separating hydrogen from helium is a relatively straightforward chemical process.)

TABLE 1. Properties and Applications of Helium.

Property	**Application**
Lowest boiling point; does not solidify at atmospheric pressure and 0K	Liquid cooling of LT Superconductors Purging liquid hydrogen systems
Second lightest element (after hydrogen)	Lifting medium for balloons, airships
Smallest molecular size	Leak detection
Chemically inert	Carrier gas – analytical, semiconductor
Very high specific heat and thermal conductivities	Gaseous cooling – fiber optics
Radiologically inert (no radioactive isotopes)	Heat transfer medium in fusion reactors
Highest ionization potential	Metal arc welding – aluminum, …. Plasma arc melting – titanium, ….
Extremely low solubility	Deep sea diving gases
Very high sonic velocity	Metal coating
Superfluid below 2.2K	Cooling of LT Superconductors

FIGURE 1. Helium is used for purging liquid hydrogen systems in space launch vehicles.

Hydrogen is the lightest of all gases. Helium is second, with a density double that of hydrogen, but still very much less than all other gases. Because they are both lighter than air, either hydrogen or helium can be used as a ‘lifting’ medium for blimps (airships), meteorological balloons and toy balloons. In the vast majority of cases helium is preferred, despite its cost and weight disadvantages, because it is non-flammable. The Hindenburg disaster silenced any debate about using hydrogen for blimps for the foreseeable future, although some parts of the world still use hydrogen to fill toy balloons.

Helium has the smallest atomic size of any element, and is also a monatomic molecule. This extremely small molecular size gives rise to another important use: leak detection. Helium passes easily through the smallest gaps, providing a very sensitive means of detecting leaks in various electronic devices, television tubes and heat exchangers and similar manufactured components. Helium is so small that it can even permeate through latex membranes with great ease. A helium-filled latex balloon will only float for a few hours. An air-filled balloon will stay inflated for considerably longer (although it won't float).

Helium is also a truly inert gas. Other gases, such as nitrogen, are widely referred to as inert, but in reality they will react to a greater or lesser degree under the right circumstances. Their stable chemical compounds—such as ammonia (NH_3), nitrous oxide (NO_2) and various metal nitrides in the case of nitrogen—testify to this. On the other hand, helium forms no stable compounds under almost any circumstances. Therefore, despite its higher cost, helium is the element of choice for applications such as gas chromatography and semiconductor manufacturing that require a truly inert gas.

Helium's very high specific heat and a high thermal conductivity make it one of the most efficient gaseous heat transfer agents. Helium's inertness gives it an advantage over some other efficient gaseous coolants, such as steam. One of the main applications for helium resulting from this property is the rapid cooling of glass fibers as they are drawn from a glass billet or ‘pre-form’ during optical fiber production. It is also used as a heat

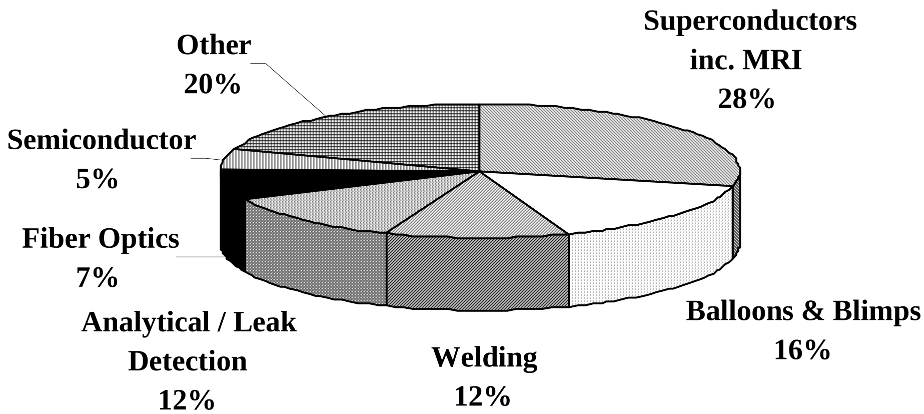

FIGURE 2. Worldwide Demand for Helium in 2002 was 140 million nm^3.

transfer medium in certain types of nuclear reactors. (Another attribute of helium is the absence of any radioactive isotopes.)

Helium has other extreme properties that result in significant commercial opportunities. Examples include:

- the highest ionization potential of any atom, which makes it useful for electric arc welding of exotic metals such as titanium, magnesium and aluminum alloys used in aerospace and shipbuilding;
- extremely low solubility in water (and therefore blood), has lead to substitution of helium/oxygen mixtures for nitrogen/oxygen breathing mixtures in order to avoid nitrogen narcosis when deep-sea diving;
- extremely high speed of sound has led to development of some very interesting alternative processes for producing metal coatings, which rely on spraying metal powders at great velocities through a high-pressure helium stream.

Finally, helium exhibits a curious property of superfluidity below 2.2K; its viscosity is reduced to zero and the liquid experiences no resistance to motion. However, to date no commercial applications have been identified that exploit this particular property.

MARKET SIZE AND GROWTH

The total worldwide demand for helium in 2002 has been estimated to be 140 million nm^3 (5.4 billion scf). FIGURE 2 shows the distribution among the principal applications.

Superconductors

By far the largest use of helium is as a liquid coolant for various superconductors. This use accounts for about 28 percent of global demand. MRIs (FIGURE 3) account for three quarters of this volume. The MRI market can be sub-divided into two key segments: the

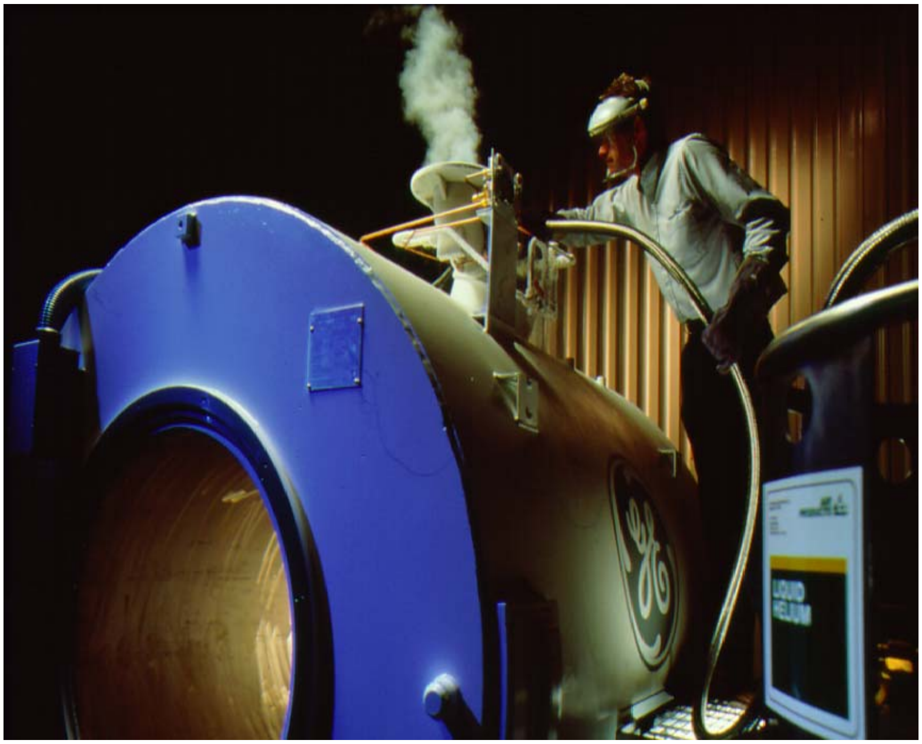

FIGURE 3. Liquid helium is used for cooling MRI machines in hospitals.

original equipment manufacturers (OEMs) who pre-cool and test the magnets prior to shipment; and hospitals and other field locations that need to replace helium lost through evaporation in service. The remaining helium in the superconductor sector is used for devices such as NMR's, SQUIDS, for particle accelerators and for myriad other, smaller applications.

The global market for new MRI installations continues to show a healthy growth, but advances in MRI design help reduce the need for increased liquid helium supply to field locations. Development of high-temperature superconductors (HTS) cooled by liquid nitrogen or other means is not expected to blunt helium demand significantly in existing low-temperature superconductor (LTS) markets. Instead, this technology is likely to extend the use of superconductors into new areas such as electrical energy storage and transmission, and magnetic levitation transport.

Lifting

The various "lifting" applications are the second-largest market for helium. Today, blimps represent a fairly small part of this use. The greatest volume in this sector, around 20 million nm^3/yr, is for party and promotional balloons, a market that is heavily concentrated on the United States.

This market, too, exhibits a healthy and sustained growth rate that is relatively recession-proof. In the long term, some interesting projects are underway to develop blimps for heavy lift transport of loads measured in 100's of tonnes and for telecommunications platforms in the upper atmosphere. Neither of these applications, however, is expected to have an appreciable impact on the demand for helium in the next decade.

Welding

Welding represents the next largest application for helium. It accounts for 12 percent of the total global market demand. This use is heavily concentrated in the United States, where helium historically has been somewhat less expensive and more freely available than in other parts of the world. Of all the major applications for helium, its use for welding is judged to be the most susceptible to substitution as helium costs rise. In fact, in parts of the world where helium has traditionally commanded a higher price, alternative more sophisticated shielding gas mixtures already fulfill many of the same needs that helium meets in the United States. Resistance to changing construction codes in aerospace, shipbuilding and other manufacturing industries, however, will slow the move away from helium in U.S. welding.

Instrumentation

Analytical applications (principally gas chromatography) and leak detection (mass spectrometry) each represent some 6 percent of global helium demand. The industries that use these applications are moving toward more rigorous quality control and compliance with more demanding environmental standards. As a result, helium demand in this sector is growing steadily.

Fiber Optics

Demand for helium in the fiber optics industry, principally for cooling, suffered a major setback in late 2001 when production levels collapsed by an estimated 50 percent. Nevertheless, this industry continues to be a significant user of helium and is expected to recover at a modest pace during the coming years.

Semiconductor

The semiconductor industry today accounts for some 7 million nm^3 of annual helium demand. However, researchers continue to find new ways to capitalize on helium's unique properties and inherent purity and so, despite recent stagnation, the semiconductor industry is expected to be a key growth market for helium in the next decade.

Other

Other applications for helium include the space program, deep-sea diving, plasma hearth furnaces, cryogenic research and many more. Together, they represent the remaining 28 million nm^3/yr or 20 percent of demand. This category also includes a number of developmental applications, some of which will undoubtedly emerge as significant markets for helium in future years.

Regional Market Size

FIGURE 4 shows the worldwide demand for helium split by geography. Due to the historic concentration of helium sourcing and the nature of the principal helium applications, the United States accounts for nearly 60 percent of global demand. The next largest market for helium is Europe (21 percent), followed by Japan (9 percent). Asia and

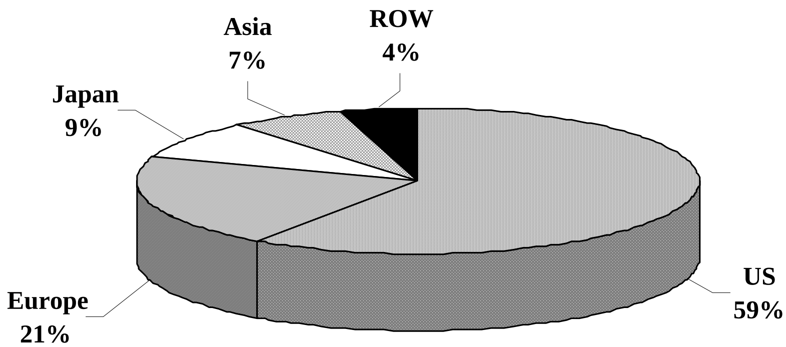

FIGURE 4. Worldwide Demand for Helium by Geography.

the rest of the world (ROW) account for 7 percent and 4 percent of helium demand respectively.

Market Growth Rate

Taking into account the growth rates of the individual helium markets and considering that new high technology applications for helium continue to be developed, the demand for helium is estimated to grow at 5 percent to 6 percent per year over the next decade. This compares with an average historic growth rate of more than 8 percent per year over the past 30 years.

HELIUM PRODUCTION AND AVAILABILITY

Although hydrogen is more abundant on earth, helium is the most common element in the universe. The radioactive decay of heavy metals continuously forms helium in the earth's crust. The vast majority of this helium gradually permeates through the earth's surface. Being much lighter than air, the helium rises through the atmosphere and eventually dissipates into outer space. The earth's atmosphere contains less than 0.001 percent helium. Given today's technology and today's value, it is not economical to extract atmospheric helium.

However, helium can be a constituent in some natural gas fields. This occurs when radioactive decay of heavy metals and natural gas formation take place in the same area and the resultant gases are trapped in the earth's crust by non-permeable rock formations. This can result in helium concentrations of up to 1 percent or higher. At today's economic conditions, any concentration of helium above approximately 0.2 percent is considered worthwhile examining as a potential helium source, providing the total natural gas field is large enough to justify long-term operation of a helium extraction plant.

Helium's existence was first established by examining a spectrograph of the sun's radiation; the name "helium" derives from "Helios", the Greek sun god. Helium was discovered on earth in 1905 as a high concentration in a natural gas field near Dexter, Kansas. Fields in this area of the United States were the first to be developed for

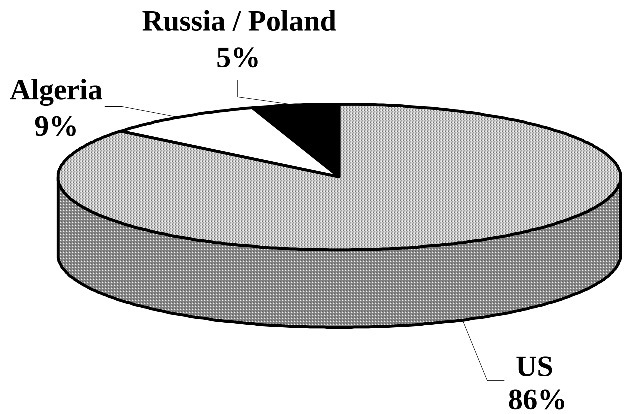

FIGURE 5. Production of Helium around the World in 2002.

commercial and military use. To this day, the United States remains the world's principal source of helium (FIGURE 5).

History of U.S. Helium Production

A look at the history of helium production in the United States sheds light on the challenges facing the worldwide helium industry and market today. In the 1920s, the U.S. Government recognized helium's commercial and military, and hence strategic value. (At the time, helium-filled blimps protected convoys in the North Atlantic.) Also noting that helium was a finite, non-renewable resource, the United States passed the 1925 Helium Act, nationalizing all existing helium production and making it the responsibility of the U.S. Bureau of Mines. In 1937 this Act was modified, and the U.S. government started selling limited quantities of helium to the commercial market for emerging applications in oil exploration (deep-sea diving) and in medicine.

By 1960, the U.S. government had become increasingly concerned about future availability of this precious resource, and so it passed the so-called Helium Act Amendments. Through the Amendments, the government made a commitment to purchase any helium that could be recovered from the large helium-bearing natural gas fields in the states of Texas, Oklahoma and Kansas at a predetermined price for the next 22 years. To facilitate collection and storage of this helium, the Bureau of Mines constructed a pipeline connecting the various gas fields. It terminated in a unused field at Cliffside near Amarillo, Texas, where the recovered helium was to be stored.

Stimulated by this opportunity to sell unlimited quantities of helium to a willing buyer, many private companies constructed helium extraction facilities during the 1960s and early 1970s. Before long, however, the U.S. government had nearly 1 billion nm^3 of helium in inventory and in 1973 it cancelled its purchase commitments. As a result, many private companies found themselves with significant helium production capacity but few buyers. This excess capacity drove much of the development of commercial helium applications in the United States in the mid-1970s. Through the Bureau of Land Management (BLM), which has superseded the Bureau of Mines, the U.S. government still owns approximately 1 billion nm^3 of helium inventory.

In 1996, U.S. Congress passed the 1996 Helium Privatization Act, which required the U.S. government to sell all the helium operations it had acquired since the 1925 Helium Act, except for the Cliffside storage facility and the associated pipeline. The act also required the BLM to offer its inventory for sale to private industry no later than 2005, with the objective of selling all but approximately 16 million nm^3 by 2015.

In the meantime the natural gas fields in and around Texas, Oklahoma and Kansas, which long were the principal sources of helium for the United States and the world, have begun to deplete. Production is now declining at the rate of about 10 percent to 15 percent each year. Therefore, the availability of the U.S. BLM reserves does not increase U.S. production capacity, but only stabilizes it at current levels for the next decade or so.

Future Sources of Supply

FIGURE 6 shows significant natural gas fields around the world that are known to contain helium in quantities that are potentially interesting as commercial sources. The solid arrows point to fields or plants that are already producing helium. The hollow arrows point to fields that are known to contain helium but which are not currently productive for one reason or another. If the fields have not been exploited for their natural gas content, it is not feasible to exploit them for helium alone. Other fields have low helium content. Still others have high concentrations of constituents such as carbon dioxide, the disposal of which creates environmental concerns, or they are remote from the principal helium markets.

Although many exploratory projects are underway across the world to develop new sources of helium supply, the best prospects appear to be in the Middle East and North Africa. This area has many very large, helium-rich (up to 0.5 percent) natural gas fields that are already producing natural gas for export, either as a gas by pipeline to Europe or as liquefied natural gas (LNG) by ship. It is estimated, for example, that the amount of helium

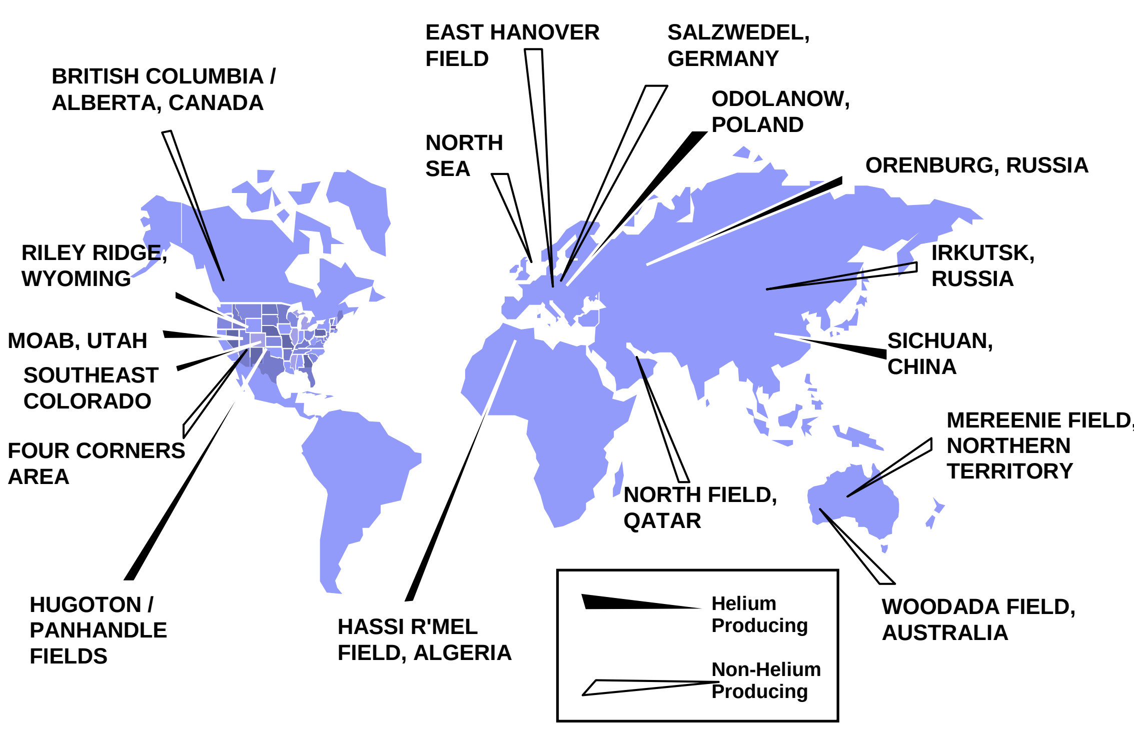

FIGURE 6. Natural Gas Fields Containing Helium.

in the natural gas that Algeria produces today exceeds 100 million nm^3 per year. In other words, Algeria alone has the capability of fulfilling nearly 70 percent of today's worldwide helium demand. However, the industry currently is recovering only 17 million nm^3 per year of this helium. The vast majority is lost forever as a waste stream from LNG production, or when industrial and domestic consumers burn the natural gas.

Given the Middle East's political instability, building plants in this region clearly carries political and financial risks. Typically it has taken longer to bring industrial projects to fruition in this region than within the United States. Nevertheless, the Middle East is becoming increasingly important as a source of the world's energy needs. Given the nature of sourcing helium, it is clearly no coincidence that the region also is becoming increasingly important to the world's helium supply. Two new plants for helium recovery and liquefaction have recently been announced in Algeria and Qatar, each with a capacity of 17 million nm^3 per year. Both expect to come on stream in 2005 or early 2006.

OUTLOOK FOR FUTURE HELIUM SUPPLY AND DEMAND

Currently, a total of just 14 plants produce helium at 12 locations around the world. Their total capacity to produce liquid pure helium is estimated at approximately 165 million nm^3 per year. This number does not represent the plants' accumulated nameplate capacity. The figure is adjusted for the amount of helium that is available from the associated natural gas fields with existing extraction equipment, including the available BLM reserves. By comparing this with the estimated current worldwide helium demand of approximately 140 million nm^3 per year, it would appear that the industry in 2002 operated at about 85 percent of capacity.

However natural gas production is seasonal and so, therefore, are helium extraction rates. Allowing for plant outages and other constraints on the global helium distribution system, the actual capacity available to be committed to the market should realistically be considered about 5 percent less than the theoretical maximum. That puts the effective

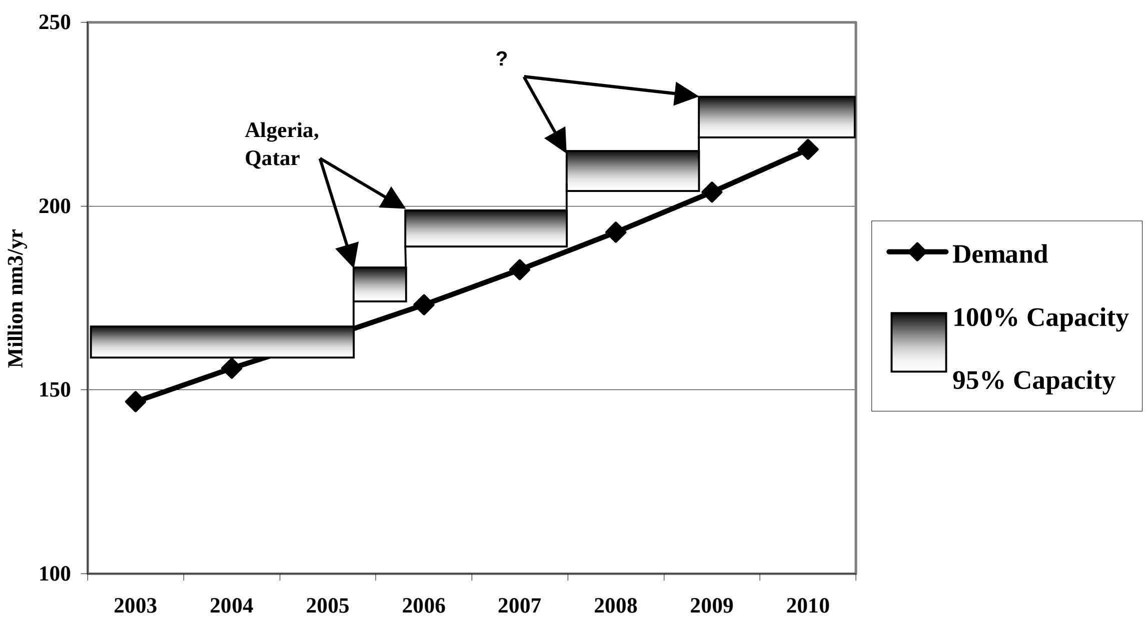

FIGURE 7. Future Worldwide Helium Supply-Demand Balance.

capacity utilization in 2002 nearer to 90 percent. Given that demand is estimated to grow at 5 percent to 6 percent per year, it is clear that helium supply and demand is finely poised in anticipation of the new capacity that will become available in Algeria and Qatar in 2005-2006 (FIGURE 7).

A typical new production plant has capacity of around 17 million nm^3 per year. The industry will need approximately six new production plants over the next 10 years to keep pace with the projected growth in demand. This is equivalent to one new plant approximately every 20 months. Development of further sourcing opportunities in the Middle East, North Africa or elsewhere in a timely fashion is required to maintain the balance of helium supply and demand in the future.

OUTLOOK FOR FUTURE HELIUM COSTS

There is another twist in the tale of the various U.S. government Helium Acts. The 1996 Helium Act committed the U.S. BLM to offer its helium reserves for sale and did not stipulate a price, but U.S. Treasury rules direct that the reserves must be sold at a price that recovers the accumulated debt of the Helium Conservation Program. Although the government originally bought the helium at fair market value, the costs of operating the Cliffside storage field and related facilities, coupled with the financial carrying cost of this inventory over the past 30 years, has resulted in a minimum price that is approaching double that of traditional sourcing costs in the United States.

Confronted with reducing output from existing sources, and with no new capacity due on stream until 2005, the industry has begun to purchase the government's reserves. Fortunately, only a fraction of current demand needs be met from this source today, but that proportion could increase over time if new helium sources cannot be developed in a timely fashion. Furthermore, the energy companies that control on-going recovery from natural gas fields have ramped prices to the industrial gas companies for access to their product. This effect has been observed outside the United States, too; costs from the new sources of supply in Algeria and Qatar are considerably higher than historical sourcing costs. The higher costs of distribution from these remote locations further drive helium costs. As helium costs rise, retail prices are ramping rapidly and are expected to continue to increase for several years to come.

SAFEGUARDING THE FUTURE

What can be done to mitigate future helium cost increases and to reduce reliance on new sources of supply in countries remote from today's markets? Aside from seeking alternatives to helium in its various applications, the answers lie in three possible areas of initiative:

Conservation: Maximizing the extraction of helium from all natural gas production facilities around the world, regardless of whether it is needed to satisfy current demand, and minimizing losses in the distribution and supply chain through to the final point of use.

Recovery: Capturing effluent helium from a given process and shipping it to a reprocessing plant for eventual resale to other customers.

Recycling: Capturing effluent helium from a given process and returning it to the same process at the same location (after reprocessing on site as necessary).

HELIUM CONSERVATION

The greatest example of conservation, as the name suggests, is the U.S. government-sponsored Helium Conservation Program of the 1960s and '70s. It resulted in more than 1 billion nm^3 of helium being stored for future use. The program's original intention was to preserve this helium for military and other government uses, but the reserve has recently become a lifeline for the whole helium-producing and consuming industries. Many people may think that the circumstances that enabled the U.S. Helium Conservation Program are unique to the gas fields in Texas, Oklahoma and Kansas. However, similar programs probably could be implemented in other parts of the world to capture helium that is currently left as an inert and unvalued constituent of natural gas, and to store it for future generations. This scenario would require considerable investment, resolve and foresight. It is unlikely to be practical for private industry; as before, it would best succeed as a government-sponsored initiative.

Opportunities for conservation extend throughout the supply chain. All helium production and distribution companies practice them to a greater or lesser extent. In production plants, they regularly check all seals for leak tightness. Where leaks are inevitable, such as from compressor bearings, they capture the leaks along with all other waste streams for reprocessing. In helium transfills around the world, suppliers allow no molecule to escape. When filling liquid dewars, they capture all vaporized gas for compression into high-pressure gaseous containers. When customers return residual product, suppliers ensure quality and reprocess it before filling it into containers for resale. Reducing losses to as near absolute zero as possible is the holy grail for all helium plant managers.

The containers used to distribute liquid helium from production source to customers and helium transfills are a prime example of the technology brought to bear in an effort to minimize losses in the supply chain. These special containers must shield liquid helium at just a few degrees Kelvin from the ambient temperature and prevent heat ingress from

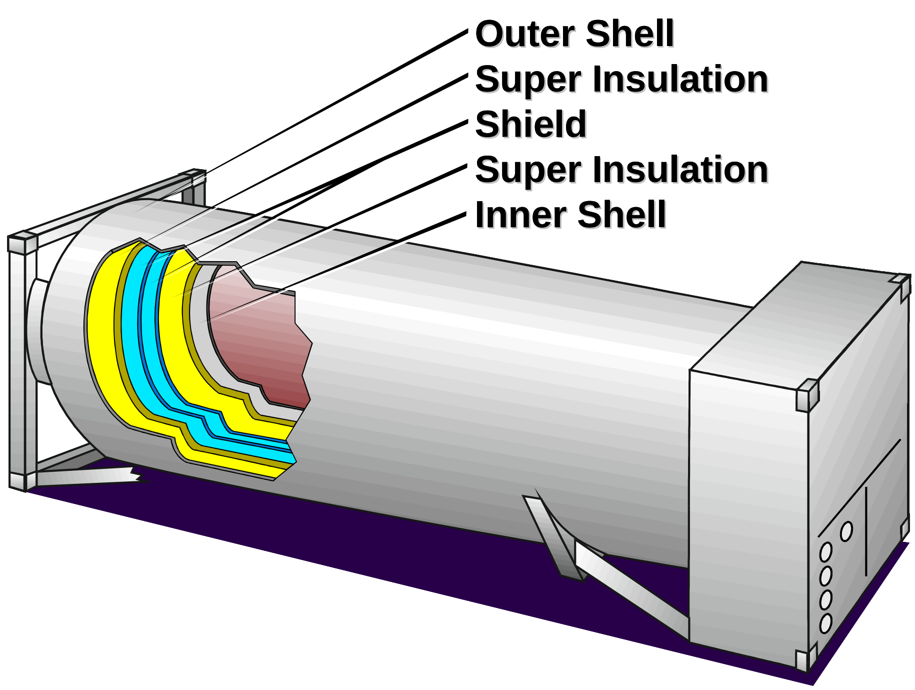

FIGURE 8. Schematic of a Liquid Helium Distribution Container.

boiling away this valuable cargo. Typical transit times from supply points in the United States to delivery locations in Asia can exceed 20 days. The technical challenge is significant, but the rewards for success are high.

Gardner Cryogenics, a division of Air Products and Chemicals Inc., manufactures nearly all liquid helium distribution containers in use today. They consist of inner and outer vessels separated by many layers of super-insulating material (FIGURE 8). Support points for the inner vessel are engineered to a bare minimum in order to limit this potential path for heat conduction into the inner vessel. In between the layers of super insulation, a liquid nitrogen "shield" consists of capillary tubes that carry liquid nitrogen from a small on-board storage vessel. As heat leaks into the outer insulation layers, the liquid nitrogen vaporizes, diverting heat away from the liquid helium. This is similar to using a sacrificial anode for corrosion protection, but in this case, the process sacrifices liquid nitrogen to conserve the more valuable liquid helium. By restricting the pressure buildup in the inner vessel this way, some versions of these containers can transport liquid helium at a temperature differential of about 300 degrees Kelvin from ambient for up to 45 days without any helium loss. This technology comes at a price, however; each container retails for more than $600,000 and typically makes only four or five deliveries a year to the Far East.

Efforts to conserve helium are not the exclusive preserve of governments and the helium supply industry. End users can also play a part by using helium more efficiently. This is particularly true for processes that use helium in its liquid state. In these cases, as is true with liquid distribution containers, heat is the enemy. Helium is lost through boiling. Although the vaporized gas can be captured for subsequent recycling, it is better to prevent boiling in the first place. Liquid-helium users should make every effort to improve insulation efficiency, reduce the length of pipe runs and reduce the mass of material that needs to be cooled to achieve a given result. Any responsible helium supplier should be prepared to help with this. For example, Air Products is currently working with a major superconductor manufacturer to replace an existing liquid helium distribution system in their production plant with a new, more efficiently designed and constructed system. The projected saving in helium is highly significant, and the financial payback will be measured in months, not years – music to any financial director's ears!

RECOVERY AND RECYCLING

Some of the common applications for helium are simply not conducive to recovery or recycling. For instance, it is clearly unrealistic to consider retrieving helium from party and promotional balloons after use. It would not make practical or economic sense, and most of the helium permeates quickly into the atmosphere anyway. This fact eliminates from consideration the second-largest helium-consuming application, which accounts for over one-seventh of the worldwide market.

In many other applications, consumption is scattered over so many points of use that the scale of operation does not lend itself readily to recovery or recycling. Consider, for example, the largest market for helium: magnetic resonance imaging. Leaving aside MRI manufacturing, which will be discussed later, it is estimated the 14,000 MRIs installed in hospitals and medical facilities around the world consume approximately 17 million nm^3 per year of liquid helium. This averages only 1200 nm^3 per year per machine. No one has yet developed a satisfactory model for wholesale collection and reprocessing of this vented product, so a further 12 percent of the market is out of reach of recovery or recycling.

The economics of recycling any product clearly improve with the scale of operation. Indeed the two industries where introduction of helium recovery and recycling technologies has achieved greatest penetration are MRI manufacturing and fiber optic production, both of which consume very large quantities of helium at relatively few locations around the world.

Gas Recycling in Optical Fiber Production

In the fiber optic industry, large quantities of gaseous helium are used to cool the fiber as it is drawn from a glass billet or "pre-form". In the drawing process, the fiber must pass continuously through an open-ended cooling chamber. Helium escapes from the chamber into the surrounding atmosphere. Several companies have introduced different technologies for capturing and reprocessing the helium before returning it to the cooling chamber. FIGURE 9 shows a simple diagram of the patented technology offered by Air Products. The system can recycle up to 95 percent of the helium, depending on the specific configuration of the fiber draw tower. The control system prevents gross contamination of the recovered helium, eliminating the need to purify it before reintroducing it into the process. Competitive systems do not do this, but will cite other advantages.

Most of the larger fiber optic manufacturing plants around the world adopted some form of helium recycling technology several years ago, but the recent slump in the industry has thwarted attempts to penetrate this market further.

Flash Gas Recovery from MRI Manufacturing

The challenge for the MRI manufacturing industry is quite different. Here, manufacturers use large quantities of liquid helium to cool and partially fill the magnets before shipment to the customer. The process of cooling the sizable magnets generates significant amounts of gaseous helium. These must be captured in order to control production costs. MRI manufacturers employ many productivity initiatives to improve efficiency, but the process inevitably produces large quantities of gaseous helium.

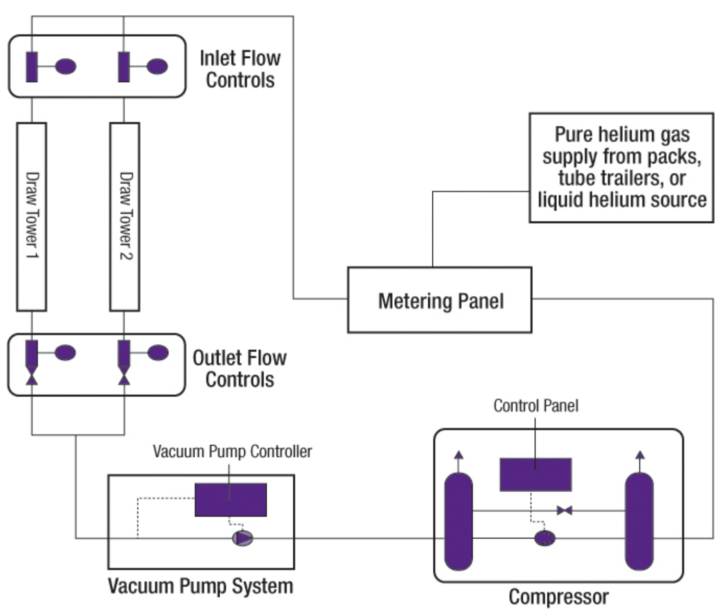

FIGURE 9. Recycle rates up to 95% can be achieved in Fiber Optics Manufacturing.

Compared to recovering helium from an open-ended fiber-optic draw tower, capturing the vaporized helium from vent stacks is generally relatively straightforward. However challenges arise when testing the magnets prior to shipment. This can occasionally lead to "quenching," the term used when the magnet loses its superconducting properties. In a quench, nearly the entire charge of liquid helium can be lost in a matter of minutes. Capturing this large quantity of extremely cold gas presents several materials management and other engineering issues, but several potential solutions can be employed, depending on local economic circumstances.

Having captured the vaporized helium, the question becomes, what to do with it? The basic options are to return it as a gas to the helium supply company for reprocessing, or to reliquefy it for reuse on the same site. Helium liquefiers tend to be multi-million-dollar investments that can be difficult to justify, even considering the large scales of MRI manufacturing sites. Again, the final solution depends on local economic circumstances, and both solutions are practiced in different parts of the world today.

Helium Purifier for Blimp Operations

Helium recovery and recycle solutions can be extremely diverse, as illustrated by FIGURE 10, which shows a portable helium purifier developed by Air Products for use by blimp operators. Helium is contained at minimal positive pressure inside the blimp envelope. Gradually the gas becomes contaminated with air from minor leaks and permeation through the envelope material. This contamination reduces lift and eventually compromises flight handling. The traditional solution has been to replace the contaminated helium wholly or partly with fresh product periodically, releasing the waste helium to atmosphere in a so-called "pump and dump" operation. This purifier allows the impure helium to be reused with greater than 99 percent recovery efficiency.

By making the unit mobile – it can be accommodated on a small trailer – it is possible for the operator to take the unit to the blimp rather than to fly the blimp to the purifier. This not only increases the available flying time, but also allows the blimp to be 'refreshed' frequently, keeping helium purity within tight tolerances and further improving the in-flight handling of the craft. This is therefore an example where recycling not only makes

FIGURE 10. Mobile Helium Purifier for Blimps.

direct economic sense, but also introduces other advantages to the operator.

Custom Solutions

The technology employed in the recycling unit for blimps is based on a simple membrane purifier manufactured by Permea, a division of Air Products and Chemicals, Inc. It is interesting to compare this recycling solution based on a purifier with the other examples previously mentioned. The solution developed for the fiber optics industry is based on a sophisticated control mechanism, but employs no purifier; the MRI manufacturing industry variously returns recovered helium to the supplier for reprocessing, or employs a reliquefier. These three industries employ four entirely different approaches to effect helium recycling.

Other helium-consuming industries face other challenges, requiring further innovation. Even within one application area, individual equipment configurations, scales of operation and local economic conditions may lead to totally different solutions. Helium recovery or recycling has been successful in deep-sea diving, plasma hearth furnaces for titanium production, leak detection in various industries, vacuum quench furnaces for metal heat treatment and several other applications. Each of these examples employs very different technologies to reach the desired end result.

In most cases the challenge can be separated into three broad categories. The first is how to capture the waste helium stream. Closed systems clearly lend themselves to efficient recovery. Applications that vent helium to the atmosphere, such as most welding operations, arguably present one of the greatest technical challenges in recycling - namely, how to capture vented helium without entraining excessive quantities of air that increase the cost of processing the captured helium for reuse.

The next issue is re-purification. In applications where purity is not critical, it may be possible to control the recovery process enough to avoid the need for any purification. Most likely, this principle only applies to a few situations. A number of standard purification technologies generally work very effectively for helium since it has properties quite different from other gases. The choice of technology depends on the process's purity requirements and the type of contamination in the waste stream.

The final challenge comes in returning the recovered and, if necessary, purified helium stream back into the process. This is potentially the greatest economic challenge. Gaseous helium applications will normally require recompression. Helium’s properties make it notoriously difficult — and expensive — to compress. Because liquid applications require very low temperatures, helium liquefiers are high capital and operating cost items. As a rule of thumb, compressing a gaseous stream back into the same process on-site is preferable to compressing the helium into very-high-pressure containers for transport to an offsite reprocessing plant. For liquid applications, it would be preferable to distribute the helium to other local customers than to operate an on-site liquefier.

It is clear that many factors need to be taken into account in deciding the most effective helium recycle solution for a given situation. At the heart of the analysis, however, are standard technologies, and any helium supply company should be able to assist in the evaluation of possible solutions.

Future directions in helium recovery and recycling

Rising helium supply costs will increase the impetus behind helium recovery and recycling, and the economics of installing systems will become increasingly attractive. To make a large-scale change in the acceptance of this practice, however, the industry must develop techniques for the more efficient collection of waste streams in applications open to the surrounding environment. The industry will also need to develop more cost-effective purifiers and compressors for low-flow situations, in order to make recycling practical for small use points.

CONCLUSION

The outlook for the helium industry is one of increasing pressure on costs and supply during the next few years. Despite this, demand for helium is expected to continue to rise, albeit at rates somewhat lower than in the past. Sufficient helium reserves exist in the world to satisfy demand for the foreseeable future and it is expected that new sources of supply will be developed at a rate necessary to keep pace with the increase in demand. The new sources of supply, however, are likely to be in more remote parts of the world.

As helium demand rises greater emphasis will be placed on helium conservation, recovery and recycling. Development of cost effective solutions tailored to each application will require close cooperation between the helium supply industry and its customers.