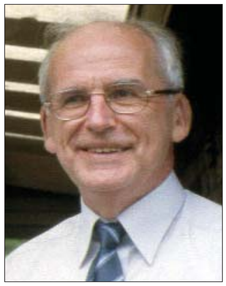
Helium — The Sun Gas

This is the fifth in our series of articles on **The History of Gases**. In this series Ebbe Almqvist, author of *History of Industrial Gases*, provides his keen insights on the origins, applications and uses of industrial gases and processes.



Helium, after hydrogen, is the next most abundant element in the universe but by volume, helium is barely 0.001 percent of the atmosphere. Helium applications continue to expand rapidly due to its unique physical properties: its inertness, low density, and very low liquefaction temperature.

In 1868 Pierre Janssen and William Lockyer independently noticed a bright yellow band in the solar spectrum, indicating an unknown, mysterious element in the chromosphere of the sun. He believed that it was produced by an element not present on earth and named it helium, from the Greek word "helios" for sun. About 20 years later, W. F. Hillebrand of the US Department of the Interior obtained an unidentified gas from the mineral uraninite. In 1895 the Swedish professor Per Teodor Cleve and his assistant Nils Abraham Langlet discovered helium in minerals. The same year William Ramsay isolated helium while searching for a better source of argon. He heated the uranium-containing mineral cleveite and purified the resulting gas. This residue, helium, proved that the solar element did indeed exist on earth. The work of the above three pioneers remained relatively unheralded until a method was developed to obtain and use helium in volume.

The key to this development came in 1905, when Hamilton P. Cady of the University of Kansas examined a sample of natural gas from a gas well in Dexter, KS. Cady found that the gas contained almost 2 percent by volume of helium. This was the first time helium was discovered in natural gas. Cady's student, Clifford Seibel, then analyzed samples from other natural gas wells for their helium content. When Seibel presented the results at an American Chemical Society meeting in 1917 he remarked, "unfortunately this study had no practical application."

But Richard Moore, Superintendent of the US Bureau of Mines Station in Golden, CO, and a former student of Sir William Ramsay, told the assembly that Ramsay was eagerly searching for a large volume source of helium in England. In a letter to Moore in 1915, Ramsay had pointed out the possibility of extracting helium from natural gas. The urgent need for large scale helium extraction came as a result of events during WWI. The British learned that their German enemy was seeking to switch to a non-flammable lifting gas to replace the hydrogen in their high flying dirigibles used for bombing London. The British had rocket-like projectiles to set the hydrogen gas on fire. Since the German airships flew higher than airplanes, helium filled airships were the only way to meet this new threat. And so the helium industry was born of the British effort to keep ahead of Germany. Experimental extraction of helium from natural gas by the British during WWI took place in Hamilton, Canada. The US Government started a helium development project in July of 1917 and by November of 1918, the first steps were taken for large scale helium production.

HELIUM PRODUCTION

50 years after its discovery, helium was being extracted in large quantities from natural gas. Three small plants were built in Texas by Linde Air Products and Airco at Fort Worth, and by Jefferies-Norton at Petrolia. The US Bureau of Mines chose a gas well near Fort Worth, TX, which contained 0.84 percent helium. The helium produced was about 90 percent pure. By the mid-1920s, the Fort Worth gas well was depleted and a new plant was built at the Cliffside field in Amarillo, Texas, where the natural gas contained 1.8 percent helium.

The quantities of helium produced before World War II were relatively small. Virtually all helium production in the period 1918–1961 was by the US Bureau of Mines and was used to meet the needs of

FIRST HELIUM RECOVERY IN NORTH AMERICA

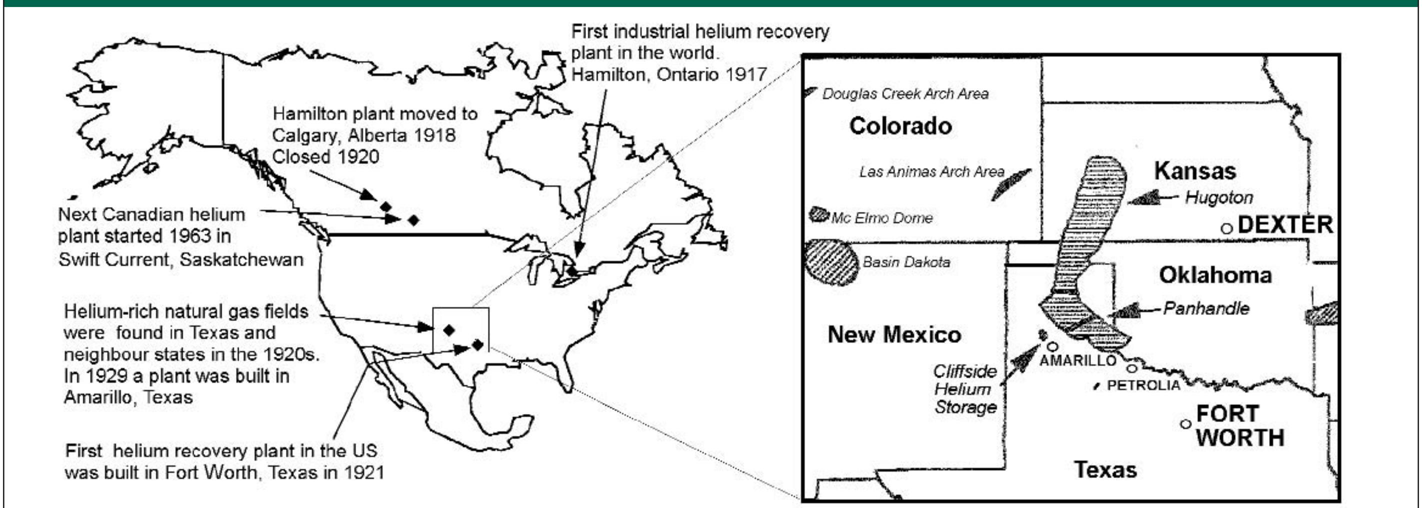


Figure 1 Map of early helium sources in North America.

federal agencies. For short periods during 1928–1937 one private company operated two small plants located in KS and CO. It was not until the early 1960s that private industry entered the helium production field. A large helium plant in operation in Saskatchewan, Canada, was started in 1963.

The production of helium from natural gas in Europe also began during the 1960s. In Europe small quantities have been produced as a by-product of air separation. The production of helium from natural gas started from wells in the North Sea off the coasts of England and the Netherlands and in Poland. Helium is also produced in Orenburg, Russia, which began exporting helium to the West in the early 1990s.

Generally, only natural gas containing more than 0.3 percent helium has been considered economic for helium extraction but the economics also depend on the other products in a natural gas stream. Since helium recovery from liquefied natural gas (LNG) can be profitable (See related article, "Early Helium Recovery Efforts Linked to Development of LNG Process Technology" on page 26), even from low-helium-concentration gas fields, there are potentially many new sources throughout the world today but the large natural gas fields in Algeria and Qatar will dominate on the European and Southeast Asian markets in the near future.

GASEOUS HELIUM APPLICATIONS

Medicine
- Breathing mixtures in medical therapies
- Breathing mixtures for deep sea diving

Protective Atmospheres
- Leak Detection
- Optical fiber manufacturing
- Semiconductor manufacturing
- Rare metal smelting
- Heat treatment of metals
- Shielding gas for cutting & welding

Heat Transfer Vacuum
- Heat exchange in gas-cooled nuclear reactors
- Cryopumps

Transportation
- Balloon and airship inflation
- Inert gas in space sensors

LIQUID HELIUM APPLICATIONS

Cooling Sensor Technology
- Infrared detectors
- Josephson junction devices
- NMR imaging
- Superconductivity
- Ultra low temperature material research

Energy Generation
- Superconductive cables
- Nuclear fusion research
- MHD generation
- Particle accelerators

Figure 2 Helium applications

HELIUM GAS APPLICATIONS

In the early years of production, helium was used almost exclusively for airships. Goodyear began building airships for helium in 1919, and the first military helium filled dirigibles appeared in 1921. According to the Treaty of Versailles, the Germans were only allowed to make smaller airships. The Allies divided the nine remaining larger airships (150-250 m in length) between them. Under the Treaty, the Germans were also to build a new large passenger airship for the USA as partial payment for war reparations. In 1923, an agreement of cooperation was signed between the German Zeppelin works and American Goodyear under which part of the Zeppelin technical staff and patent rights were taken over by Goodyear.

From 1925 on, Goodyear built a series of smaller airships for passenger transport (30-50 m long, requiring 2 million litres of helium [53.3mmscf]) of which the first, the "Pilgrim" became well known.

In 1925, helium began to replace nitrogen as the gas used for deep-sea diving to avoid decompression sickness (the bends). Helium is less soluble in the blood when under pressure than nitrogen and does not form bubbles that can block the smaller blood vessels.

About 99 percent of the annual helium production before 1946 was used in blimps, dirigibles, and balloons and non-government sales were small. The military produced most helium applications up until World War II. The Hindenburg disaster of 1937 demonstrated the dangers of hydrogen-filled airships and helium was increasingly used in military blimps for antisubmarine surveillance during World War II. At this time the demand for helium grew very fast. Toward the end of the war helium also found an important use in early nuclear energy investigations and developments.

In the late 1940s the purity of produced helium was raised, first to about 99.5 percent and then to nearly 100 percent. With higher purity levels new uses developed and grew rapidly. Large quantities of helium were used for shielded arc welding and nuclear energy development. At the same time, helium was finding a variety of uses in rapidly expanding research programs.

HELIUM CONSERVATION IN THE UNITED STATES

In 1932, there were about 600,000 equivalent liquid litres per year of helium (16mmscf) being produced in the United States. By 1937, it was down to about 200,000 litres (5.3mmscf) per year. That year, the US passed the Helium Act which allowed government plants to sell helium to non-government users for medical, scientific, and commercial use. Shortly thereafter, the use of helium in shielded-arc welding began. As discussed, large-scale helium production for helium-filled blimps occurred during WWII. Later, large volumes of helium were used in the development and operation of ballistic missiles and in the initial program for space exploration. By the mid-1950s, as natural gas demand increased, some helium-rich sources began to dwindle. At this time, there was a dramatic increase in the use of natural gas in the US and much of the nation's potential helium reserves were being vented to the air. To stem these losses the 1960 Helium Act was passed. This Act authorized the US Secretary of the Interior to enter into 25-year contracts for the purchase of crude helium for conservation. At that time, helium production was about 20 million litres per year (533mmscf), of which 70–80 percent was consumed by Government projects. The development of a private helium industry in the United States began. A deep gas well at Cliffside, TX was found to store the helium, and held enough helium to meet US Government needs for up to 100 years. (See related feature, "Helium from the Bureau of Land Management: Past History — Future Plans" on page 22.)

LIQUID HELIUM

First produced in Leiden, Holland in 1908, liquid helium is used in applications where it is necessary to achieve the lowest possible temperatures, such as in superconductors and sensitive detectors.

Crygogenics is one of the most interesting uses of helium because of its very low boiling point, 4.2 Kelvin (-452°F). Helium itself is scientifically interesting because of its transformation to helium II at 2.18 K and the absence of a triple point. (A triple point is the temperature and pressure at which a substance can exist in equilibrium in the liquid, solid, and gaseous states.) The unusual characteristics of helium II, such as super fluid creep, abnormal viscosity, and sound propagation, have been studied extensively by low-temperature physicists.

Several attempts to liquefy helium were made prior to 1908 by

Karol Olszewski in Krakow and James Dewar in London, but these were unsuccessful. Kamerlingh Onnes in Leiden made experiments to liquefy helium by cooling compressed helium gas with liquid hydrogen and then rapidly expanding it. He finally achieved success with a circulation technique in which compressed helium gas is cooled to near the triple-point temperature of hydrogen and then piped through a regenerative heat exchanger prior to expansion.

It was not until the early and middle 1920s that other laboratories reported success in liquefying helium. Franz Simon and Pjotr Kapitza found new methods to liquefy helium in the early 1930s. After World War II Samuel Collins of MIT developed a highly successful helium liquefier which made it possible for low-temperature research and development labs to liquefy helium on their own.

"HIGH-TECH" RESEARCH AND DEVELOPMENT APPLICATIONS

The extremely low boiling point makes helium useful as a coolant in magnetic resonance imaging, super conducting magnets, sensitive detectors, and for low termperature Tc superconductivity applications. Because of its high thermal conductivity and inertness, helium is also used as a coolant in nuclear reactors. Liquid helium was used in the world's first superconducting particle accelerator, at Fermi Labs and for a magneto hydrodynamic (MHD) water propulsion system without moving parts at Argonne National Labs. The use of liquid helium for magnetic resonance imaging (MRI) continues to increase in medical diagnostics.

Helium has also been used in several Strategic Defence Initiative (SDI) applications such as anti-satellite (ASAT) rockets, where liquid-helium-cooled infrared sensors are used for target location and guidance, and for cooling tracking telescopes. Gaseous helium is used in lasing gas mixtures of chemical lasers. Super conducting magnetic energy storage (SMES) has also been investigated as a means to provide power for defence laser systems.

HELIUM DISTRIBUTION

Traditionally, helium has been shipped in quantities of about 1000 cubic meters compressed to approximately 160 bars in high-pressure tubes mounted on truck trailers. Newer designs using longer trailers and tubes made of higher strength steels have increased the carrying capacity to nearly 3000 cubic meters. Rail cars have for many years carried about 9000 cubic meters of helium at 270 bars.

The commercial shipment of liquid helium to various consumers for research purposes, started in the late 1950s, was made possible by technological advances in cryogenic insulation and helium liquefaction. Theses advances made the transport of liquid helium practical even in cases where the end use was gaseous helium. In May 1966, Airco started transporting liquid helium in semi-trailers from a new helium separation and liquefaction facility to four distribution centers within the United States.

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To order Ebbe Almqvist's "History of Industrial Gases" (Kluwer Academic/Plenum Publishers, New York, 2003, pp.472, ISBN 0 306 472775) go to www.cryogas.com or call 781-862-0624. ❑