The Continuing U.S. Helium Saga

Edward F. Hammel, Milton C. Krupka, K. D. Williamson, Jr.

Summary. Helium, resident in relatively high concentrations in certain natural gas fields in the United States, can be lost to the atmosphere when the natural gas is burned as fuel. In 1960, Congress amended the Helium Act of 1925 to provide for stripping natural gas of its helium, for purchase of the separated helium by the government, and for its long-term storage. In 1971, after about 28 billion cubic feet had been stored, the purchase program was terminated by the government, an action that unleashed several lawsuits and not a little acrimony. After more than a decade of controversy, much of the litigation has been concluded, much of the helium that could have been saved has been wasted to the atmosphere, and the gas fields supplying the helium are almost depleted. A new rich source of helium has been discovered in southwestern Wyoming that could ensure adequate supplies for many decades if an appropriate new federal policy on helium is developed and implemented.

Shortly after the 86th Congress passed the Helium Act Amendments of 1960 (Public Law 86-777), the federal government began to purchase annually about 3.5 billion cubic feet (bcf) of helium that otherwise would have been lost to the atmosphere. This helium, originally resident in the helium-rich natural gas from the Hugoton-Panhandle field in Texas, Oklahoma, and Kansas, was extracted by private industry, sold under long-term contracts to the government, and stored by the latter in the national helium reserve (a partially depleted, federally owned gas field called Cliffside near Amarillo, Texas). In 1971 the government terminated its helium purchase program after only about 28 bcf (of the 60 bcf projected to be conserved) had been purchased. Since then about 20 bcf of produced or easily producible helium has been vented or otherwise lost to the atmosphere. The plants for separating this helium from natural gas streams have been idle for most of the past 12 years because there was neither a market for such large amounts of helium nor an economic incentive for the producers to store their excess production themselves. The contract terminations provoked several legal actions against the government.

Three recent developments make it an opportune time to reopen the question of the role of helium in the nation's future and to objectively evaluate federal policy on helium. The first of these is that substantial amounts of helium from the stockpile are now being sold. The U.S. Bureau of Mines (BOM) is selling federally owned helium to other federal agencies and, since the supply of helium from Hugoton-Panhandle natural gas is decreasing rapidly due to field depletion, the U.S. helium industry is supplementing production by drawing on its own stocks in the national reserve (*1*). These stocks will be consumed within a few years, and the shortfall could then be made up by the industry's purchase for resale of the remaining federally owned helium. The result of these actions will be the depletion of the national helium reserve within about 20 years.

The second recent development is that the lawsuits provoked primarily by the contract terminations are now either settled or in the final phases of settlement (*1*). Since the total damages and claims sought in these lawsuits approach $1 billion, their existence has influenced the actions of the parties involved for more than a decade. In particular, since the government's liability substantially exceeded that of the other defendants, all attempts to address the core problems of a helium conservation program have been thwarted by four national administrations, in large part through fear that, by doing otherwise, the government would compromise its position in its various court battles. With the litigation essentially over, it now becomes possible to reopen the matter without prejudice.

The third new development is a revision in the estimate of the amount of helium resident in a deep gas field in southwestern Wyoming. In 1960 a single deep exploratory well drilled by Mobil Oil Corporation led to an estimate of 3 to 15 bcf in the Tip Top drilling unit of that field (*2*). The Tip Top gas was found to be so energy-poor, however, that it was judged unsuitable for use as a fuel. Consequently, the borehole was cemented shut and the well abandoned.

Recently it was established by additional drilling that the amount of helium recoverable from the Wyoming field is at least 200 bcf (*3*). (This is the good news. The bad news is that this field, which had been a nondepleting, albeit poorly defined, helium reserve, will eventually become a depleting one.) Recent regulatory changes permitting substantial increases in the price of natural gas have resulted in plans to develop the field and market the gas. The development is now known as the Riley Ridge Natural Gas Project.

Since more than 90 percent of this gas field lies within federal land boundaries, title to most of the contained helium is reserved to the government by the Mineral Lands Leasing Act of 1920. But if the federal government decides to exercise its right to that helium, it is required to extract it expeditiously—that is, in such a way as to "cause no delay in the delivery of the natural gas to the owner, purchaser, or purchasers thereof, except that required by the extractive process" (*4*). A timely decision is therefore required on what to do and how to do it if this resource is not to be wasted.

Sources of Helium

In addition to the helium produced for the conservation program, helium has been extracted from the Hugoton-Panhandle gas streams and sold by privately owned plants for the past 20 years. By the year 2000, however, field depletion will have reduced the total production of helium by these plants to less than 20 percent of 1982 sales.

When the helium conservation purchase program was initiated in 1960, only about half of the helium-rich (> 0.3 percent by volume) natural gas streams

Edward F. Hammel is a consultant and a former assistant director for energy at Los Alamos National Laboratory, University of California, Los Alamos, New Mexico 87545. Milton C. Krupka is a staff member and K. D. Williamson, Jr., is group leader, Energy Technologies Group, Analysis and Assessment Division, Los Alamos National Laboratory.

were stripped of their helium. Some of the other helium-rich fields are still producing, and, in principle, new helium extraction plants could be built astride the trunk lines fed by these fields. In practically all cases, however, the remaining life of these fields would not justify the necessary investment in capital plant.

Still other natural gas reservoirs (discovered and undiscovered) less rich in helium (< 0.3 percent by volume) constitute another source. These are estimated to contain hundreds of billions of cubic feet of helium and are expected to continue producing well into the 21st century. The cost of extracting helium at such low concentrations has, however, been estimated to exceed present recovery costs by a factor of 5 to 10 (*5, 6*).

A further source is, of course, the Riley Ridge helium. This discovery suggests that privately owned natural gas reservoirs rich in helium may be found in other portions of the Overthrust Belt. However, the presence of high helium concentrations in natural gas reservoirs is an exceedingly rare phenomenon.

Other sources of helium exist at major liquefied natural gas (LNG) plants throughout the world. In the course of liquefaction, all the commingled helium as well as most of the other noncondensibles in the natural gas are separated from the LNG product and rejected to the atmosphere. However, the delivered cost in the United States of helium from LNG plants is presently estimated to exceed current U.S. prices, and consequently that helium continues to be vented to the atmosphere.

Helium is contained in the reject stream from air separation plants together with neon (a satisfactory substitute for helium in most inert gas applications) in the ratio 1/3.5. When further production of helium from natural gas becomes uneconomical, about 0.25 bcf of helium and almost 1 bcf of neon will probably be available annually from U.S. air separation plants at a cost of \$200 to \$400 (1982 dollars) per thousand cubic feet for the helium (*6*).

Since helium is an inert component of the atmosphere in the amount of about 5 parts per million and since the atmosphere contains about 50 trillion cubic feet of helium, there is no possibility of ever "running out" of helium. But to extract 1000 cubic feet of helium from the atmosphere in a plant designed only to produce helium would require an energy consumption of about 150,000 kilowatt-hours (kWh) and would cost \$10,000 to \$12,000 in 1982 dollars (including return on investment, taxes, profit, and so on). In comparison, the energy expended in extracting 1000 cubic feet of helium from the Riley Ridge natural gas has been estimated at less than 100 kWh and would cost \$10 to \$20 (*7*).

Advances in technology capable of significantly increasing the efficiency with which helium can be removed from the atmosphere are considered extremely unlikely by gas separation technologists. The basis for this conclusion is the physical fact that 1 million volumes of air have to be processed to obtain 5 volumes of helium. No way of eliminating or even reducing this requirement and the attendant energy and dollar costs for handling such large amounts of air appears to exist (*8, 9*).

In considering helium sources, it is important to recognize that large-scale production of helium has seldom been pursued for its own sake (*10*). Rather, since the helium resident in natural gases is concentrated, together with other inerts when that gas is liquefied, upgraded, or subjected to liquefied petroleum gas extraction processes, the helium-rich reject gas from such plants has served for decades as the nation's primary source of helium. Furthermore, since the primary objective of these processing plants is production of a natural gas product, the helium is a by-product. Finally, since the rate of by-product production is set by that of the primary product, helium production from such a plant may be greater, equal to, or less than its own market demand. Under these circumstances, the "cost" of producing the helium becomes an allocated cost ranging from zero (when no demand for it exists, in which case it is wasted) to some other amount determined by prevailing market conditions. Should the demand for (and hence the price) of the plant's primary product decline sufficiently to make its operation marginal, income from by-product sales may become essential for its survival. In this case, the installation becomes a multiproduct plant for which individual product outputs are adjusted to maximize profits. Industries involved in the further processing and marketing of helium must therefore contend with production rates that can (and do) change independently of demand considerations.

Future Uses of Helium

Numerous projections of future demand for helium were published in the 1970's (*8*, pp. 31–34 and 48–60). All have proved overly optimistic. For some current uses, substitutes not only exist but will be progressively employed should the price of helium escalate substantially. But for many technologies, helium is a sine qua non. Use of another gas (such as hydrogen in lifting applications) either involves unacceptably high hazards or is impossible because the technology exploits either the unique physical properties of helium (*11*) or its unique quantum fluid properties.

At present, the largest projected use of helium (in the sense that only helium is capable of doing the job) is in fusion energy. Two other uses of helium are in superconducting power transmission lines and in superconducting energy storage systems (*8*). Of these three technologies, the first is being developed to provide an additional energy source and the latter two are intended to make transport and storage of electrical energy more efficient, safer, and more environmentally acceptable.

When research and development was begun on these projects, U.S. electrical generating capacity was growing at 7 to 8 percent per year and had been growing at about that rate for the previous half-century. Although it was recognized that such growth could not continue indefinitely, nothing then seemed to indicate that a major decrease in the growth rate was imminent. Nevertheless, a sharp decrease did occur, and with it the urgency associated with development and deployment of the new technologies has decreased substantially, but not the eventual need for them or for the large amounts of helium they require.

Unexpected uses for helium continue to emerge. One of the more exciting is a ~ 49-m-diameter helium-filled sphere recently proposed as a lighter-than-air hoist capable of moving loads in excess of 90 tons (*12*). Another is in superconducting magnets for imaging with nuclear magnetic resonance (*13*). Finally, proposals for the use of large amounts of helium are constantly being made in the national security area.

Toward a New Federal Helium Policy

The recent developments discussed earlier, the possibility that source depletion may cause the cost of helium to rise precipitously, and the fact that new uses of helium continue to emerge make it a propitious time to formulate a new federal policy on helium (*14*). A key element in such an undertaking is the future demand for helium. In 1982 U.S. helium sales totaled 1.3 bcf, of which about 1 bcf was produced by private industry and the remainder by BOM, primarily for other federal agencies. Since 1961, nonfederal market sales of helium have increased by about 10 percent per year, and a least-squares fit projects 1990 sales to be about 3 bcf and those in the year 2000 to be in excess of 8 bcf. However, the price of helium in current dollars has remained almost constant for the past 20 years, so the 10 percent growth rate has been accompanied by a more than threefold decrease in the real price of helium over the period. The price decreases bottomed out in 1981, and prices are now rising and will continue to rise. BOM sales to federal agencies have been ranging between 0.2 and 0.3 bcf per year and are expected to continue more or less indefinitely at about the same level. In our judgment, maintenance of a 10 percent growth rate for the next two decades is most improbable. Furthermore, sales have been substantially below the fitted 10 percent curve for the past 4 years. It seems more reasonable to assume a 5 percent growth rate in helium sales for the next two decades. This would project annual sales of about 2 bcf in 1990 and 3 bcf in 2000 and a cumulative consumption by the end of the century of about 45 bcf (*15*).

Two questions central to formulation of a new federal policy on helium are what to do about helium in the national reserve and what to do about the Riley Ridge helium. Since practically all of this helium is government-owned, some of the issues to be considered in reaching answers to these questions are (i) current needs for helium, (ii) obligations to present and future generations, (iii) national security requirements, and (iv) facilitating the development of new sources of supply for the U.S. helium industry.

A Dwindling National Reserve

Depletion of the Hugoton-Panhandle natural gas fields, from which both crude helium produced for conservation and pure helium produced for sale are derived, has occurred as expected, with the result that, after about 1988, production from existing helium extraction (HELEX) plants will no longer be able to satisfy current, let alone any increased, demand (*8*). However, in part due to a reduction in storage charges made by BOM in 1974, the private helium industry has stored much of its surplus helium in the national reserve. At present, privately owned stocks in the reserve amount to about 3.5 bcf. If, therefore, by 1988 the total private production of pure helium diminishes, as expected, to the point at which it equals sales, any shortfall thereafter can be made up by withdrawing privately owned helium from the national reserve (*16*). A rough calculation indicates that this method of dealing with the problem of decreasing production of helium from fuel gas streams could continue until the early 1990's, at which point all privately owned helium in the reserve will have been withdrawn. At about the same time, practically all production from existing HELEX plants will have ceased due to field depletion. Finally, federally owned stocks in the reserve will then have been reduced by approximately 2 bcf because of BOM withdrawals to satisfy the demand by government agencies.

Whenever the situation described above is realized, nothing exists in federal law to prevent the U.S. helium industry from purchasing from the government whatever additional pure or crude helium it requires to meet domestic demand and the export market. All other things remaining equal, initiation of such a sales program will then result in a drawdown of federally owned stocks in the reserve at a rate of 2 to 3 bcf per year and its complete elimination within the next 15 years.

Since the stockpiled helium constitutes only about 20 percent of all known government-owned helium reserves, a case can be made for making federally owned helium in the reserve available for private as well as for public sector use. Indeed, the conservation purchase program was initiated in 1960 with the expectation that the accumulated returns from stockpile sales would, by 1982, be sufficient to repay the Treasury for borrowing authorized by Congress to cover the initial purchase price of the helium and the accumulated interest on the debt. Finally, private purchase and resale of the government-owned helium in Cliffside could provide the helium industry with the least traumatic transition to development of new sources of helium and simultaneously provide some additional revenue to the Treasury.

Managing the Riley Ridge Helium

The Riley Ridge well field is a 650-square-kilometer area in the southwestern part of Sublette County, Wyoming, just east of the Overthrust Belt (*3*). Approximately 20 trillion cubic feet of recoverable natural gas is estimated to exist in the project area, producible from the Madison formation at depths exceeding 4267 m. The average composition of this gas is (percent by volume) CO_2, 67; CH_4, 20; N_2, 8; H_2S, 4; and He, > 0.5.

Oil and gas development of the area began in the late 1940's and concentrated on relatively shallow (depth of about 2440 meters) wells producing nonacidic gas. Since 1980, increasing attention has been directed toward the economic feasibility of producing fuel gas from much deeper acidic gas reservoirs (containing appreciable quantities of CO_2 and H_2S).

It has been proposed that, after an initial separation of condensibles at the well sites, the acidic gas be piped to treatment plants at which the CH_4, N_2, and He would be separated from the CO_2 and H_2S. The resulting nonacidic gas stream would then be further processed to remove N_2 and He to produce pure CH_4. Pure sulfur would be recovered from the H_2S as a potentially marketable product and the CO_2 as well as the already separated N_2 and He would be vented to the atmosphere.

American Quasar Petroleum Company, Williams Exploration Company, Exxon Company, U.S.A., and Mobil Oil Corporation, together with Northwest Pipeline Corporation, are expected to independently carry out the Riley Ridge Natural Gas Project. Present plans call for drilling about 240 deep wells from which 2.8 bcf of acidic gas per day would be produced. Production is scheduled to begin between 1986 and 1990 and is expected to continue for 30 to 35 years.

With all four proposed treatment plants operating at capacity, about 5 bcf of helium would be vented to the atmosphere each year unless it was conserved or a market could be found for it. Conservation would be expensive. Crude helium production facilities (to increase the helium concentration), pipelines, compressor stations, and a storage reservoir (with associated injection, recovery, and monitoring wells, and eventually recovery and purification units) would have to be built, acquired, or drilled. Because the helium recovery operation would have to be capable of treating about 250 bcf of reject gas per year, the outlay for capital plant could reach $100 to $200 million.

It is unlikely that private industry could be persuaded to conserve any of the Riley Ridge helium for future sales, primarily because the costs of so doing could not be recovered in less than 10 to 20 years. Nor is it probable that private industry could be persuaded to participate with the government in a joint conservation program. Consequently, if anything is to be done about conserving the Riley Ridge helium, it will have to be done by the federal government. In view of projected budget deficits, however, the probability of obtaining new government funding for an even more costly replay of the 1960 Helium Act Amendments appears to us vanishingly small.

The remaining alternative for the Riley Ridge helium is its separation for sale by the producers themselves. The main problem with this approach is the apparent mismatch between production capability and the projected market: ~ 5 versus ~ 2 bcf per year, assuming no slippage in the field development and production schedule. Slippage does appear possible, however, in view of current conditions in the natural gas industry. Tight energy supplies in the late 1970's and the gas price deregulation provisions of the Natural Gas Policy Act of 1978 led to a boom in gas exploration and in development of deep (and expensive) gas reservoirs. The resulting increase in supply, energy conservation, a shift back to cheap oil in some cases, and the 1982–1983 recession have all led to a gas glut and falling prices. These developments, together with continued high interest rates, may result in suspension of the entire Riley Ridge enterprise until gas prices again rise sufficiently to justify the capital investment necessary to complete the project or until prospects of by-product sales become firm enough to ensure its economic feasibility.

Conclusions

The short-term answer to the question what to do about the Riley Ridge helium is simple: do nothing. The Bureau of Land Management and the Forest Service have issued a draft environmental impact statement (EIS), public hearings have been held, and a final EIS was just released (*17*). With these preliminaries completed, little more can be done with respect to the helium extraction problem until firm decisions on field development are made by the corporations involved. Furthermore, since helium demand appears to increase as a function of time, that demand will depend on the size of the market when the helium becomes available. Then, if the helium production rate is greater than the market (and is likely to remain so for many years), we urge that the excess be conserved and title to the fraction that can be marketed be sold by the government to those responsible for its separation, purification, and sale. Responsibility for conservation would remain with the government. If the helium production rate is less than market demand and if other sources have been exhausted or have become inaccessible, only the questions of title transfer to the appropriate private entities need be addressed.

Returning to the question of the disposition of the helium in the national reserve, the answer depends largely on what happens at Riley Ridge and when. If the Wyoming production is delayed beyond the early 1990's, consideration should be given to making the Cliffside helium available to the industry for resale. Since the Hugoton-Panhandle facilities are all in place and functioning (*18*), sale of the helium in the national reserve would seem to (i) make the best use of existing resources, (ii) constitute one method of returning to the Treasury a portion of the funds borrowed to create the reserve, and (iii) provide the least traumatic transition for the U.S. helium industry from present to new helium production facilities.

If the helium in the reserve is to be sold, some (5 to 10 bcf) ought to be reserved for national security purposes. Consideration should also be given to setting aside and earmarking some of the income from the Cliffside helium sales for the construction of new helium conservation facilities at Riley Ridge if they turn out to be necessary. Indeed, if such an investment could result in parlaying the 40 bcf of federally owned helium now in storage at Cliffside into a much larger amount in Wyoming, that action would seem to be well worth pursuing.

But if the Riley Ridge project, including helium production and sales (together with its partial conservation by the government if necessary) is well under way by 1990, the helium in Cliffside can continue to function as a national reserve. Without the Cliffside sales, obtaining funding for a Wyoming conservation project promises to be a problem, however.

Formulating and implementing a new federal policy on helium as outlined above could probably be done administratively with little or no new legislation, since extensive discretionary authority over management of the nation's helium resources has already been given to the Secretary of the Interior in Public Law 86-777 and earlier legislation. Nevertheless, the 1960 Helium Act Amendments assigning many of these authorities to the secretary were designed specifically to establish a conservation, purchase, and storage program for the helium in the Hugoton-Panhandle field. Today the situation is quite different: only federally owned helium is involved, substantial new reserves of helium have been confirmed, a private sector helium industry exists, a federally owned stockpile exists, present sources of helium are rapidly depleting, and, not least, much has been learned about how not to try to conserve helium. Under these circumstances, it appears to be a particularly appropriate time for Congress to reexamine national policy on helium.

References and Notes

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2. *Ibid.*, fiscal year 1965.
3. "Draft environmental impact statement, Riley Ridge Natural Gas Project" (Department of the Interior and Department of Agriculture, Washington, D.C., May 1983).
4. Public Law 86-777, Section 3(b). See also Mineral Lands Leasing Act of 1920 and U.S. Code, title 50, paragraph 161.
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8. E. F. Hammel and M. C. Krupka, *Los Alamos Natl. Lab. Rep. LA-8455 MS* (1980).
9. Future separation processes may be substantially different from those now in use, however. See, for example, J. M. S. Henis and M. K. Tripodi, *Science* **220**, 11 (1983).
10. C. W. Seibel, *Helium: Child of the Sun* (Univ. of Kansas Press, Lawrence, 1968).
11. Helium, with a critical point of 5.2 K, a boiling point of 4.2 K, and no triple point, is the only gas capable of functioning as a refrigerant in temperatures below 14 K.
12. M. T. Kaufman, *New York Times*, 24 May 1983, p. C3.
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14. E. Cook, *Science* **206**, 1141 (1979).
15. For a more optimistic forecast, see A. Francis, D. Keierleber, D. Swartz, *Proceedings of the 1983 Cryogenic Engineering Conference* (Plenum, New York, in press).
16. This situation actually occurred in 1982 when two of the nation's largest HELEX plants were shut down because market conditions for both natural gas and natural gas products extracted in the same plants did not justify their continued operation. It is hoped that these shutdowns will be temporary.
17. *Final Environmental Impact Statement, Riley Ridge Natural Gas Project* (Department of the Interior and Department of Agriculture, Washington, D.C., November 1983).
18. Facilities include purification and liquefaction plants, distribution centers, transport and maintenance facilities, administrative services, and experienced personnel.

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