Lithium: Will Short Supply Constrain Energy Technologies?

Many of the energy technologies now being developed will require specialized materials. These range from certain stainless steels needed for advanced types of nuclear reactors to such rare materials as the gallium used in one version of photovoltaic solar cells. Before large amounts of money are committed to develop these new energy sources, however, one should certainly ask whether the specialized materials are potentially available in quantities large enough to allow widespread use, should the technology in question turn out to be feasible. A case in point is lithium, an element that occurs in the earth's crust with an average concentration of only 20 parts per million but that may be essential not only as the fuel for nuclear fusion but also as a constituent in a new and promising type of battery that could make the electric automobile the car of the future.

At a recent conference on lithium supply,* it was clear that there are several points of view regarding the adequacy of present and potential resources of this rare metal. At one extreme is the assessment of James Vine of the U.S. Geological Survey. He believes that the potential demand will be nearly twice the expected supply by the end of the century and hence that the United States risks not only shortages but also the possibility of depleting lithium resources that may be needed later as fuel for fusion. Taking the opposite point of view are spokesmen for the lithium industry, such as Ihor Kunasz of the Foote Mineral Company, who dispute projections of scarcity, pointing out that known reserves are immense compared to present annual consumption. The industry contends that there will be no difficulty in meeting increased demand. Caught in between are energy technologists, such as the battery researchers whose prospects depend not only on the amount of lithium but also its cost.

The debate illustrates the confusion that often attends questions about the magnitude of known resources, probable but undiscovered deposits, and the extent to which ore in the ground is actually recoverable. In the case of lithium these questions are complicated by the nature of the lithium industry, which is small and guards information very closely.

Worldwide, about 5 million kilograms of lithium were produced in 1974. About 3.4 million kilograms of this came from the United States, which is not only the largest producer but also the largest exporter of lithium. Nearly all the U.S. production comes from two companies, the Foote Mineral Company and the Lithium Corporation of America, although other companies are involved in processing lithium metal and several dozen commercial products. These range from glasses and ceramics to lubricating greases to pharmaceutical chemicals. Lithium chemicals also find use in the production of aluminum and as catalysts for making synthetic rubber. Even though these conventional uses are projected to grow somewhat, there appears to be plenty of lithium to meet that demand. Known reserves in one mining area alone—the Kings Mountain region of North Carolina—amount to at least a 100-year supply at current U.S. production rates. Concern, then, is limited to the potential impact of new, energy-related uses for lithium that could drastically expand present consumption.

Lithium-Sulfur Batteries

Improved batteries are the key to widespread use of electric automobiles, which are thought to offer one of the best means to shift part of our transportation energy use from imported oil to indigenous coal and nuclear fuel. Batteries are also being considered by the utility industry to store electric power for periods of peak demand, thus smoothing the generating load and reducing the need to burn petroleum fuels in gas turbine peaking units. One of the most promising battery concepts is the so-called lithium-sulfur cell—actually a lithium-aluminum cathode and an iron sulfide anode in the design now being intensively investigated by government and industrial laboratories. According to W. J. Walsh of the Argonne National Laboratory in Chicago, recent developments have improved the storage capacity and lifetime of this battery significantly. Experimental units have shown the capacity to store as much as 150 watt-hours of electricity per kilogram of battery, compared to 25 watt-hours per kilogram for typical lead-acid batteries. In addition to low weight, lithium-sulfur batteries have the advantage that they are not damaged by being nearly completely discharged.

The Energy Research and Development Administration (ERDA) plans to test full-scale batteries for both automobile and electric utility applications in about two years. If, subsequently, the batteries prove commercially successful, then ERDA planners project that 20 million urban electric cars containing a total of 2.7×10^8 kilograms of lithium might be on the road by the end of the century. Utility electric storage—a projected 1000 units capable of delivering 100 megawatt-hours of power each—might require about twice that amount of lithium. If these estimates are correct, they portend a tenfold increase in lithium production rates by the year 2000. Moreover, the cumulative amount required by these projections—more than 1 billion kilograms when conventional uses are included—equals or exceeds Vine's estimate of the amount of lithium that is known and could be mined by that date.

Fusion will require more, possibly much more, lithium, although not in this century. All current thermonuclear power efforts are based on the deuterium-tritium reaction because the conditions for it to occur are far easier to achieve than those for the deuterium-deuterium reaction. But tritium is radioactive and decays with a half-life of 12.6 years. It is thus not found in nature in any significant quantity and must be bred from lithium by capture of a neutron—in a manner directly analogous to the breeding of plutonium from a nonfissionable isotope of uranium in a fission reactor. Lithium, despite its rarity, is thus the limiting fuel for thermonuclear reactors of the type now planned.

The amount of lithium required for fusion depends in part on the particular reactor design chosen. At one extreme, according to S. Locke Bogart of ERDA, is a design in which natural lithium (a mixture of the ^{6}Li and the ^{7}Li isotopes) is used both as a neutron-absorbing blanket around the core of the reactor and as a coolant. It may require about ten times as much lithium as designs in which it forms a blanket only. But in the latter designs, the ^{6}Li isotope must be enriched from its naturally occurring 7.4 percent to about 90 percent, and the breeding process must be enhanced through the generation of additional neutrons in ways that may require substantial quantities of beryllium, itself a scarce material. Bogart estimates the required lithium at between 100 and 1000 kilograms per megawatt of fusion capacity. A large fusion power industry sometime in the 21st century might thus require 10^8 to 10^9 kilograms of lithium. In view of this, some scientists have suggested that ^{6}Li be separated from the naturally occurring ores before they are used in other ways and stockpiled to preserve the fusion option. Others, however, point out that the energy value of lithium as a fuel is at least 3000 kilowatt-

*A symposium on U.S. lithium resources and requirements by the year 2000, 22 to 24 January 1976, Golden, Colorado, sponsored by the U.S. Geological Survey.

Fig. 1 (left). Lithium-carbonate plant, Kings Mountain, N.C. [Source: Foote Mineral Co.] Fig. 2 (right). Brine ponds in Clayton Valley, Nev. [Source: Foote Mineral Co.]

hours (electric) per gram. Hence fusion can in a sense afford to pay a high price for lithium and can make use of material extracted from lower-grade, more costly ores.

The expected demand for lithium, either for lithium-sulfur batteries or for fusion, may never materialize, of course. Sodium-sulfur batteries, for example, also look promising and are being developed. And there is considerable debate about whether lithium resources might not be large enough in any case.

At present two types of lithium raw materials are being mined in the United States. The largest, at Kings Mountain, is a belt of pegmatites, granite-like rocks. Two open-pit mines within the 30-mile-long belt extract ore that contains about 0.68 percent lithium in the form of spodumene ($LiAlSi_2O_6$). This mineral is used directly in the ceramic industry but is costly to reduce to lithium metal (Fig. 1). Lithium-bearing pegmatites are also mined in Rhodesia, Southwest Africa, the Soviet Union, and several other countries. The consensus of geologists familiar with lithium resources seems to be that most of the occurrences of pegmatites exposed on the earth's surface have probably been discovered, since they have long been exploited as a source of tin. Several of these occurrences—particularly in Canada and in a remote area of Zaire—are known to contain lithium in commercial quantities, although they are not now being mined.

The second, and historically newer, source of lithium is brines found in or beneath the surface of arid, desert valleys of the western United States. At Clayton Valley, Nevada, brines with a lithium content of about 300 parts per million are pumped to the surface, concentrated by evaporation in shallow solar ponds (Fig. 2), and precipitated as lithium carbonate. Lithium is recovered as a by-product from potash and borate production at Searles Lake, California, where its concentration is somewhat lower. Geothermal brines in Imperial Valley, California, and the Great Salt Lake, Utah, are also known to contain large quantities of lithium, although neither of these is considered to be commercially exploitable at present because of low concentrations or the presence of other chemicals that would make extraction difficult. Lithium-bearing brines have been discovered in Chile, and there are hundreds of dry lakes and desert basins throughout the western United States that have not been fully explored for their lithium potential.

Shortage or Abundance?

Lack of knowledge about the extent of lithium brine deposits and their characteristics has been behind the debate over lithium resources. Earlier estimates by Foote Mineral Company indicated that the Clayton Valley deposits were huge, but these have been revised downward on the basis of additional drilling and experience with how much of the lithium in the ground could actually be recovered. As a result, Vine believes, the country faces a serious shortage unless new deposits can be discovered, and he proposes exploration efforts by the Geological Survey. Vine estimates that known U.S. reserves comprise less than 1 billion kilograms, and also questions whether industry can expand production rapidly. Some other observers point out that it would be in industry's interest if a shortage of lithium, and higher prices, did develop.

Higher prices would certainly increase the amount of lithium that could be recovered, but they might also preclude some of the new uses. Walsh estimates that lithium-sulfur batteries for automotive use would still be feasible if the price of lithium were to double or triple, but that batteries would not be competitive with other means of storing off-peak electricity for utilities at prices for lithium much higher than those which now prevail—about $10 to $15 per pound in large lots. If a lithium shortage does indeed develop later in this century, at least one of the battery applications may fall by the wayside, thus considerably relieving the pressure on the resource.

But it is not at all certain that scarcity is the correct forecast. Kunasz, for example, disputes Vine's estimates of potential supply, pointing out that they include only already proved domestic deposits and, even then, are extremely conservative. Vine's estimate for Clayton Valley, for instance, is limited to the area currently being pumped. Kunasz says that the full extent of the pegmatite and brine deposits is not yet known, but that they are surely larger than the proved reserves. He points out that in the past the industry has expanded production very rapidly when necessary—more than fivefold within a few years during the early 1950's, when the Atomic Energy Commission was stockpiling ^6Li for thermonuclear weapons. Moreover, he believes that known reserves should not be compared with hypothetical future demand, since such an approach does not take into account future discoveries of resources. Other industry geologists point out that in the past year—in response to the debate over lithium supplies—the two major companies have increased their proved reserves dramatically. In drilling in the Kings Mountain pegmatite belt, which extends for some 30 kilometers, the Lithium Corporation of America increased its reserves by 50 percent and Foote increased its reserves by 20 percent. The industry spokesmen assert, in effect, that the Geological Survey, in publishing Vine's estimates, is being alarmist.

There remain other potential sources of lithium about which little is known but which could conceivably amount to a very large resource, although probably at higher prices. Some oil field brines, for example, have been found to have lithium contents of up to 500 parts per million. Many clays also contain lithium at concentrations considerably higher than those in ordinary rock. And ultimately there is the possibility of recovering lithium from seawater, although few geologists believe that it is a very realistic economic possibility.

The lithium debate, whatever else it may prove, would seem to show the need for an increased resource consciousness among energy researchers. As the lithium-fusion connection illustrates, not even fusion can accurately be considered an unlimited energy source, and as similar realizations dawn about other energy sources and other resources, perhaps a more realistic view of future options will emerge.

—Allen L. Hammond