LITHIUM

By Joyce A. Ober

The United States has been the largest producer and consumer of lithium and the two U.S. companies have been the leading lithium carbonate producers in the world for many years. Chile has become an increasingly important player in the lithium industry, and with the expected development of a second lithium operation in that country, it may become the world lithium leader by the end of this century.

Because lithium is electrochemically reactive and has other unique properties, there are many commercial lithium products. Producers sold lithium as mineral concentrate, brine, compound, or metal depending on the end use. Most lithium compounds were consumed in the production of ceramics, glass, and primary aluminum.

Legislation and Government Programs

During 1994, the Department of Energy (DOE) negotiated to sell portions of its 36 million kilogram stock of lithium hydroxide monohydrate. No sales were made. DOE had planned to offer the lithium hydroxide in 1989, but delayed the disposal until an environmental impact study was complete. Since that time, sales were made in 1993 only.

The stocks were excess from a weapons program that used the lithium to make tritium, a hydrogen isotope necessary for nuclear fission reactions. The stockpile originally contained about 42,000 metric tons of material, from which about 75% of the lithium 6 isotope had been removed. This material possibly contained 8 to 9 parts per million of mercury, which could present an environmental hazard.

Production

The U.S. Bureau of Mines collects domestic production data for lithium from a voluntary survey of U.S. operations. The two U.S. companies responded to the survey, representing 100% of total production. Production and stock data were withheld from publication to avoid disclosing company proprietary data. *(See table 1.)*

Cyprus Foote Mineral Co. produced lithium carbonate from its brine deposit in Silver Peak, NV. In addition to its Nevada operation, Cyprus Foote, a subsidiary of Cyprus Amax Minerals Co. and the world's largest lithium producer, owned a spodumene mine and lithium carbonate plant that have been inactive since 1991 in Kings Mountain, NC. The lithium carbonate plant was dismantled in 1994. Cyprus Foote moved most of its administration, research, and lithium metal processing facilities to Kings Mountain. A new lithium hydroxide production facility was under construction at Silver Peak; upon completion of the new plant, Cyprus Foote's lithium hydroxide plant in Sunbright, VA, will be closed. A project to increase the production capacity by 50% at the company's New Johnsonville, TN, butyllithium plant was completed during the year. Cyprus Foote owned a large lithium operation in Chile.[1]

FMC Corp., Lithium Div., mined spodumene, a lithium ore, from pegmatite dikes near Bessemer City, NC, and produced lithium carbonate and a full range of downstream compounds, including lithium metal and some organic lithium compounds, at a chemical plant near the mine. The company also operated a butyllithium plant in Bayport, TX.

Spodumene is the most common lithium ore, but petalite and lepidolite are other types of lithium ores that are mined in different parts of the world. These three types of ore are beneficiated to produce lithium ore concentrates that can be consumed directly in certain applications. Spodumene concentrates and brines are converted to lithium carbonate and then other compounds for consumption in other end uses.

Lithium carbonate is the most important lithium compound produced from brine and ore deposits. Spodumene was a major raw material for the production of lithium carbonate in North Carolina, and small amounts of spodumene concentrate were produced for sale. Extracting lithium from spodumene entails an energy-intensive chemical recovery process.

After mining, spodumene is crushed and undergoes a flotation beneficiation process to produce concentrate. Concentrate is heated to 1,075° C to 1,100° C, changing the molecular structure of the mineral, making it more reactive to sulfuric acid. A mixture of finely ground converted spodumene and sulfuric acid is heated to 250° C, forming lithium sulfate. Water is added to the mixture to dissolve the lithium sulfate. Insoluble portions are then removed by filtration. The purified lithium sulfate solution is treated with soda ash, forming insoluble lithium carbonate that precipitates from solution. The carbonate is separated and dried for sale or use by the producer as feedstock in the production of other lithium compounds.

Production of lithium carbonate from brine in Nevada is much less energy intensive than production from the spodumene. Brines enriched in lithium chloride—averaging about 300 parts per million when operation began in 1966—are pumped from the ground and progress through a series of evaporation ponds. Over the course of a year to 18 months, concentration of the brine increases to 6,000 parts per million lithium through solar evaporation. When the lithium chloride reaches optimum concentration, the liquid is pumped to a recovery plant and treated with soda ash, precipitating lithium carbonate. The carbonate is then removed through filtration, dried, and shipped.

Consumption and Uses

The aluminum, ceramics and glass, lubricating grease, and synthetic rubber industries consumed most of the lithium minerals and chemicals. These markets primarily were related to transportation; i.e., the aircraft and automotive industries. Industrial and consumer applications also used ceramics and glass. Estimated domestic consumption increased nearly 9% from 1993. Ceramics and glass production and aluminum smelters were the largest consumers of lithium carbonate and lithium concentrates in the United States, comprising an estimated 20% and 18% of the lithium market, respectively. Other consuming industries were synthetic rubber and pharmaceuticals, 13%; chemical manufacturing, 13%; miscellaneous chemicals, 12%; lubricants, 11%; batteries, 7%; and air treatment, 4%.[2]

Lithium carbonate and mineral concentrate additions in ceramics and glass manufacturing processes lower process melting points, reduce the coefficient of thermal expansion and the viscosity, and eliminate the use of more toxic chemicals. The manufacture of thermal-shock-resistant cookware (pyroceramics) consumed the majority of lithium used in the ceramics and glass industry domestically. The manufacture of black and white television picture tubes consumed significant amounts of lithium concentrates overseas. Low-iron spodumene and petalite were a source of lithium used to improve the physical properties of container and bottle glass and as a source of alumina, another important component of the glass. Glass manufacturers used lithium in container and bottle glass, enabling them to produce lighter weight, thinner walled products.

Aluminum producers added lithium carbonate to cryolite baths in aluminum potlines. The chemistry of the potline converts it to lithium fluoride, lowering the melting point of the bath, allowing a lower operating temperature for the potline, and increasing the electrical conductivity of the bath. Operators used these factors to increase production or reduce power consumption.

The third largest end use for lithium compounds is as catalysts in the production of synthetic rubbers and plastics and pharmaceuticals. N-butyllithium initiates the reactions between styrene and butadiene that form abrasion-resistant synthetic rubber and thermoplastic rubbers that require no vulcanization. Other organic lithium compounds are catalysts for the production of plastics like polyethylene. Lithium metal and compounds also are used by drug manufacturers in the production of a number of drugs including Vitamin A, some steroids, an anti-cholesterol drug, an analgesic, antihistamines, tranquilizers, sleep inducers, and contraceptives. Pharmaceutical-grade lithium carbonate is approved directly for the treatment for manic-depressive psychosis. This is the only treatment approved by the U.S. Food and Drug Administration in which lithium is consumed by the patient.

The multipurpose grease industry was another of the important end uses for lithium in 1994. Lithium hydroxide monohydrate was the compound used for the production of lithium lubricants. Lithium-base greases are favored for their retention of lubricating properties over a wide temperature range; good resistance to water, oxidation, and hardening; and formation of a stable grease on cooling after melting. These greases continued to be utilized in military, industrial, automotive, aircraft, and marine applications.

Almost all major battery manufacturers marketed some type of lithium batteries, and research and development continued for further substitution in applications that implement more conventional alkaline batteries. These batteries represent a growth area for lithium consumption, and new battery configurations continue to be developed. Continued interest in electrically powered vehicles spurred additional interest in battery research. New, more efficient types of rechargeable (secondary) lithium batteries have been developed and improved to meet the needs for this market and for electronic equipment such as portable telephones and video cameras. Work continued on lithium polymer and lithium ion batteries. These batteries are of particular interest because they take advantage of large power capacity available from lithium batteries without the safety problems encountered when these batteries contain lithium metal, a very reactive and volatile material when exposed to air and moisture.

Nonrechargeable (primary) lithium batteries offer improved performance over alkaline batteries at a slightly higher cost and have been commercially available for over 10 years. They were used in watches, microcomputers, and cameras, and, more recently, in small appliances, electronic games, and toys. The military purchased large and small lithium batteries for a variety of military applications. The Galileo spacecraft, launched in October of 1989 for its 6-year trip to explore the atmosphere of Jupiter, contained lithium sulfur dioxide batteries to power its scientific instruments when it reaches its destination. Recent modifications to the lithium sulfur dioxide battery have extended the life of the batteries to at least 10 years with little or no reduction of performance. The final disposition of lithium batteries has caused some concern in the past. Until recently, no technology had been developed for the safe and economic disposal of large lithium batteries, especially the military types. ToxCo, Inc., a hazardous waste remediation company based in Claremont, CA, developed a process for neutralization, disposal, and recycling of lithium batteries and built a commercial facility in Trail, British Columbia.[3]

Aircraft manufacturers in several countries have designed new aircraft using aluminum-lithium alloys for wing and fuselage skin or structural members. Use of aluminum-lithium alloys can reduce the weight of the aircraft by more than 10%, allowing significant fuel savings during the life of the aircraft. The alloys, which are 2% to 3% lithium by weight, are attractive to the aircraft and aerospace industry because of their reduced density and superior corrosion resistance compared to those of conventional aluminum alloys. These alloys face direct competition, however, from composite materials consisting of boron, graphite, or aramid fibers imbedded in polymers.

Small quantities of other lithium compounds were important to many industries. Lithium chloride and lithium bromide were used in industrial air-conditioning systems, commercial dehumidification systems, and in the production of sophisticated textiles. Sanitizers for swimming pools, commercial glassware, and public restrooms contained lithium hypochlorite, as did dry bleach for commercial laundries. Lithium metal was used as a scavenger to remove impurities from copper and bronze, and anhydrous lithium chloride was used as a component in fluxes for hard-to-weld metals such as steel alloys and aluminum.

Prices

The price for lithium carbonate, the largest volume lithium compound, increased 3% in 1994. Lithium hydroxide monohydrate remained about the same, and standard-grade lithium metal increased more than 7%. Price increases for other lithium products ranged from about 3% to nearly 9%. *(See table 2.)*

Foreign Trade

Total U.S. exports of lithium compounds were about 5% lower in 1994 than they were in 1993. More than 50% of all U.S. exports of lithium compounds were to Germany, Japan, and the United Kingdom.

Imports of lithium compounds increased 5%. Cyprus Foote Mineral Co. owns a lithium brine operation in Chile; 98% of all lithium imports were from this source. Lithium ore concentrates from Australia, Canada, and Zimbabwe were consumed in the United States, but no import statistics were available. *(See tables 3 and 4.)*

World Review

A small number of countries throughout the world produced lithium ore and brine. Chile and the United States were the leading producers of lithium carbonate; significant quantities of lithium compounds and ore concentrates also were produced in Australia, Canada, Chile, China, Portugal, Russia, and Zimbabwe. Argentina, Brazil, and Namibia produced smaller quantities; production primarily consisted of concentrates. Rwanda, the Republic of South Africa, and Zaire are past producers of concentrates. Pegmatites containing lithium minerals have been identified in Austria, France, India, Ireland, Mozambique, Spain, and Sweden, but economic conditions have not favored development of the deposits. Lithium has been identified in subsurface brines in Argentina, Bolivia, China, and Israel. Companies in France, Germany, Japan, and the United Kingdom produced downstream lithium compounds from imported lithium carbonate.

Argentina.—Construction of the

evaporation facilities neared completion at the Salar de Hombre Muerto in Catamarca Province. A lithium carbonate plant with the capacity to produce nearly 4,500 tons per year is expected to be started in 1995 with lithium carbonate production to begin in 1996 or 1997. If lithium carbonate demand expands as expected, production would be expanded to about 16,000 tons. Minera Antiplano, a wholly owned subsidiary of FMC, is investing about $45 million in the first phase of the project.[4]

Australia.—Gwalia Consolidated Ltd., the only lithium ore concentrate producer in Australia and the largest in the world, was building a lithium carbonate plant at its spodumene mine at Greenbushes, Western Australia. The plant was expected to be completed late in 1995 and will have the capacity to produce 5,000 tons of lithium carbonate per year. Initial production is planned to be 1,000 tons.[5]

The Gwalia lithium carbonate plant will use an unusual process in which calcined spodumene is leached directly with a slurry of soda ash at high temperature and pressure forming lithium carbonate. The lithium carbonate reacts with carbon dioxide to form lithium bicarbonate, a soluble compound that is separated from the silicate residue. The lithium carbonate is then reprecipitated. The process is believed to be less costly than the process used at other spodumene processing facilities, although not as low as recovering lithium carbonate from brines.[6]

Canada.—A feasibility study for construction of a spodumene mine and lithium carbonate plant in Quebec was underway. Lithos Corp., a new company formed through the merger of Wrightbar Mines Ltd. and Charlim Exploration Ltd., was examining the development of the Sirmac Lake spodumene deposit and other deposits in the Jonquiere region.[7]

Chile.—Sociedad Quimica y Minera de Chile (SQM), a Chilean fertilizer producer, was developing a second project on the Salar de Atacama for the potash that would be produced as a raw material for its potassium nitrate plant. Production of lithium carbonate is important to the economics of the project. Production of 9,000 tons per year of lithium carbonate, the second stage of the project, should begin by the end of the century.[8] Cyprus Foote has been recovering lithium carbonate from the same deposit since 1984.

Outlook

The health of the lithium industry is closely tied to the performance of the primary aluminum industry. Improved consumption of lithium in the aluminum industry has had a positive effect on lithium consumption. Demand for lithium compounds and minerals in the ceramics and glass industry continues to grow modestly. Similar increases are expected for the near future.

Demand for butyllithium is expected to continue to increase, and both domestic producers have increased production capacity to meet that demand. Demand for lithium metal for batteries and to some extent for alloys should increase, but total consumption of metal will remain small in comparison to the demand for lithium compounds for the short term. The fate of the lithium battery market will be largely dependant on the success of electric vehicles and whether the best type of battery for powering them finally is determined to be some form of lithium battery.

Other markets should remain relatively stable with slight growth. Lithium demand could increase dramatically if any of the new technology areas such as nuclear fusion were perfected. This is not expected to occur within the remainder of this century and probably not within the next 25 years.

The United States should remain the largest producer of lithium carbonate until production of lithium carbonate from the SQM project in Chile. At that time, Chile should become the leading producer of lithium compounds in the world.

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[1]Cyprus Amax Minerals Company 1994 10-K Report. 1995, p. 14.

[2]Cyprus Minerals Company 1992 Annual Report. 1993, p. 14.

[3]McLaughlin, W.J. Lithium Recycling and Disposal Techniques. Presented at the EV Battery Readiness Working Group, August 1994, Washington DC, 9 pp.

[4]Mining Magazine (London). FMC to Exploit Argentine Lithium. V. 171, No. 4, 1994, p. 230.

[5]F & S International Inc. press release. March 3, 1995. 1 page.

[6]Lithium Carbonate Project Description. Gwalia Consolidated Ltd. Sept. 1993, 4 pp.

[7]Industrial Minerals (London). Feasibility Study on Lithium Mine and Plant. No. 326, 1994, p. 8.

[8]Metals Week. FMC Testing, Weighing Options in South America. V. 64, No. 11, 1993, p. 9-10.

OTHER SOURCES OF INFORMATION

U.S. Bureau of Mines Publications

Lithium. Ch. in Mineral Commodity Summaries, annual.
Lithium Availability—Market Economy Countries.

Other Sources

Canadian Minerals Yearbook, annual.
Chemical Marketing Reporter, weekly.
Chemical Week, weekly.
Engineering and Mining Journal, monthly.
European Chemical News (London), monthly.
Industrial Minerals (London), monthly.

TABLE 1
SALIENT LITHIUM STATISTICS 1/

(Metric tons of contained lithium)

	1990	1991	1992	1993	1994
United States:					
Production 2/	W	W	W	W	W
Producers' stock changes 2/	W	W	W	W	W
Imports 3/	790	590	770	810	851
Exports 4/	2,600	2,400	2,100	1,700	1,700
Consumption:					
Apparent	W	W	W	W	W
Estimated	2,700	2,600	2,300	2,300	2,500
Rest of world: Production 2/	5,400 r/	5,000	5,700	5,900 r/	6,000 e/

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.
1/ Previously published and 1994 data rounded by U. S. Bureau of Mines to three significant digits.
2/ Mineral concentrate and carbonate.
3/ Compounds, concentrate, ores, and metal.
4/ Compounds.

TABLE 2
DOMESTIC YEAREND PRODUCERS' 1/ AVERAGE PRICES OF LITHIUM AND LITHIUM COMPOUNDS

	1993		1994	
	Dollars per pound	Dollars per kilogram	Dollars per pound	Dollars per kilogram
Lithium bromide, 54% brine: Truckload lots, delivered in drums	5.47	12.06	5.67	12.50
Lithium carbonate, technical: Truckload lots, delivered	1.91	4.21	2.00	4.41
Lithium chloride, anhydrous, purfied: Truckload lots, delivered	4.83	10.65	4.84	10.67
Lithium fluoride	6.87	15.14	7.14	15.74
Lithium hydroxide monohydrate: Truckload lots, delivered	2.59	5.71	2.55	5.62
Lithium metal ingot, standard grade: 1,000-pound lots, delivered	33.60	74.05	35.98	79.32
Lithium sulfate, anhydrous	4.16	9.17	4.45	9.81
N-butylithium in n-hexane (15%): Truckload lots, delivered	19.34	42.64	20.20	44.53

Source: U.S. lithium producers and Chemical Marketing Reporter, v. 245, No. 1, 1994, pp. 25 and 28.

TABLE 3

U. S. EXPORTS OF LITHIUM CHEMICALS, BY COMPOUND AND COUNTRY 1/

Compound and country	1993 Gross weight (metric tons)	1993 Value (thousands)	1994 Gross weight (metric tons)	1994 Value (thousands)
Lithium carbonate:				
Australia	38	$174	119	$454
Canada	892	3,490	875	3,230
Germany	1,440	4,610	906	3,010
India	42	183	77	264
Japan	1,650	6,570	1,020	3,610
Korea, Republic of	115	387	97	319
Mexico	120	479	121	470
Netherlands	789	2,670	300	1,010
Taiwan	73	267	90	321
United Kingdom	1,000	2,820	933	2,880
Venezuela	--	--	613	1,890
Other	91	450	(2/)	242
Total	6,250	22,100	5,200	17,700
Lithium carbonate U.S.P. 3/				
France	(2/)	(2/)	1	7
Germany	1	34	(2/)	(2/)
Korea, Republic of	--	--	1	7
Malaysia	1	15	1	15
Mexico	1	4	19	75
New Zealand	2	28	(2/)	12
United Kingdom	3	21	7	62
Venezuela	--	--	28	190
Other	(2/)	33	1	26
Total	8	135	58	393
Lithium hydroxide:				
Argentina	97	361	110	471
Australia	62	275	149	584
Canada	65	310	88	394
Germany	447	1,840	711	3,210
India	350	1,270	221	852
Japan	777	3,700	693	3,360
Korea, Republic of	161	629	308	1,280
Mexico	228	1,050	143	608
Netherlands	72	338	40	159
Saudia Arabia	69	309	50	150
Singapore	91	407	204	992
South Africa, Republic of	3	14	76	796
Thailand	111	505	83	373
United Kingdom	301	942	441	1,850
Other	226	1,250	283	1,521
Total	3,060	13,200	3,600	16,600

1/ Previously published and 1994 data are rounded by the U. S. Bureau of Mines to three significant digits; may not add to totals shown.

2/ Less than 1/2 unit.

3/ Pharmaceutical-grade lithium carbonate.

Source: Bureau of the Census.

TABLE 4
U. S. IMPORTS FOR CONSUMPTION OF LITHIUM CHEMICALS 1/

	Compounds			
	1993		1994	
	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)
Lithium carbonate:				
Chile	4,160	$11,700	4,450	$12,500
China	71	250	50	177
France	1	5	(3/)	(3/)
Hong Kong	52	188	(3/)	(3/)
Russia	1	4	(3/)	(3/)
Other	2	20	(3/)	14
Total 1/	4,290	12,100	4,500	12,700
Lithium hydroxide:				
China	2	18	(3/)	(3/)
Japan	21	198	25	253
Russia	(3/)	1	(3/)	21
Switzerland	--	--	3	19
Other	(3/)	21	1	37
Total	24	238	29	330

1/ Previously published and 1994 data are rounded by the U. S. Bureau of Mines to three significant digits; may not add to totals shown.
2/ Customs value.
3/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 5
LITHIUM MINERALS AND BRINE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1990	1991	1992	1993	1994 e/
Argentina, spodumene and amblygonite	69 r/	287 r/	620 r/	300 r/ e/	400
Australia, spodumene	40,000 e/	40,400 4/	42,500 4/	52,900 r/ e/	53,000
Brazil, concentrates	475	1,560	1,600 e/	1,600 e/	1,600
Canada, spodumene e/ 5/	12,000	12,000	18,500	18,900 r/	20,000
Chile, carbonate from subsurface brine	9,080	8,580	10,800	10,400 r/	10,500
China (minerals not specified) e/ 6/	15,000	15,500	15,500	15,500	16,000
Namibia:					
Amblygonite	54	20	5	5 r/	5
Lepidolite	80	33	93	88 r/	90
Petalite	1,130	1,140	1,060	649 r/	700
Portugal, lepidolite e/	10,600 r/ 7/	10,000	9,000	9,000 r/	9,000
Russia (minerals not specified) e/ 6/ 8/	XX	XX	45,000	40,000	40,000
U.S.S.R. e/ 9/	55,000	50,000	XX	XX	XX
United States, spodumene and subsurface brine	W	W	W	W	W
Zimbabwe (minerals not specified)	19,100	9,190	12,800	18,100 r/	19,000

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data. XX Not applicable.
1/ Previously published and 1994 data are rounded by the U.S. Bureau of Mines to three significant digits.
2/ Table includes data available through Apr. 3, 1995.
3/ In addition to the countries listed, other nations may produce small quantities of lithium minerals, but output is not reported and no valid basis is available for estimating production levels.
4/ Data are for year ending June 30 of that stated.
5/ Based on all of Canada's spodumene concentrates (Tantalum Mining Corp. of Canada Ltd.'s Tanco property).
6/ These estimates denote only an approximate order of magnitude; no basis for more exact estimates is available.
7/ Reported figure.
8/ All production in the U.S.S.R. for 1990-91 came from Russia.
9/ Dissolved in Dec. 1991.