BERYLLIUM

By Larry D. Cunningham

Beryllium (Be), silver in color and one of the lightest of all metals, has one of the highest melting points (about 1,280 °C) of all light metals. Beryllium has physical and chemical properties (such as its stiffness, high resistance to corrosion from acids, and high thermal conductivity) that make it useful for various applications in its alloy, oxide, and metallic forms. Only two beryllium minerals, beryl and bertrandite, are of commercial importance. Bertrandite is the principal beryllium mineral mined in the United States and beryl is the principal mineral produced in the rest of the world. Beryl contains about 4% Be. In 1997, U.S. production of beryllium ore increased from the 1996 level, and total ore consumption for the production of beryllium alloys, beryllium metal, and beryllium oxide also increased. (See table 1.) The Generalized System of Preferences (GSP), which expired on May 31, 1997, was extended to June 30, 1998. The Defense Logistics Agency (DLA) offered and sold beryl ore from the National Defense Stockpile (NDS).

Legislation and Government Programs

To ensure a supply of beryllium during an emergency, goals have been established for the NDS. As of September 30, 1997, the NDS goal for beryllium metal was 363 metric tons. (*See table 2.*)

According to the DLA Annual Materials Plan (AMP) for each of fiscal year (FY) 1997 (October 1, 1996, through September 30, 1997), and FY 1998 (October 1, 1997, through September 30, 1998), the maximum amount of beryl ore that could be sold from the NDS would be about 1,800 tons. However, there were no sales of beryl ore in calendar year 1997. The National Defense Authorization Act for FY 1998, Public Law 105-85, authorizes the Department of Defense (DOD) to dispose of all beryllium copper master alloy, about 6,700 tons (gross weight), from the NDS. The disposal would be contingent upon certification by the NDS Manager that any disposal of this material will not adversely affect the capacity of the stockpile to supply the strategic and critical material needs of the United States. In its AMP for FY 1998, the DOD is authorized to dispose of about 1,130 tons of beryllium copper master alloy. There were no sales of this material during 1997.

Under GSP, the United States grants duty free access to goods from qualifying developing countries and territories. In 1997, U.S. imports for selected beryllium materials ranged from duty free to 8.5% ad valorem for most-favored-nation (MFN) status and from duty free to 45% ad valorem for non-MFN status.

The GSP program expired on May 31, 1997. On August 5, 1997, the President signed the Budget Reconciliation Tax Bill of 1997, which contained provisions for the extension of duty-free treatment and the retroactive application for certain liquidations and reliquidations under the GSP. The provisions apply GSP

duty-free treatment to eligible articles from designated beneficiary countries that are entered, or withdrawn from warehouse, for consumption on or after August 5, 1997, through June 30, 1998, and for those entries made after May 31, 1997, through August 4, 1997, to which duty-free treatment would have applied, and to refund any duty paid with respect to such entry, provided that a request for liquidation or reliquidation is filed with the Customs Service by February 4, 1998 (U.S. Department of the Treasury, 1997).

On January 17, the International Trade Administration (ITA) made a final determination that beryllium metal and high-beryllium alloys from Kazakstan were being sold in the United States at less than fair value. The scope of this investigation covered beryllium metal and high-beryllium alloys in ingot, billet, powder, block, lump, chunk, blank, or other semifinished form. The materials are traded under the Harmonized Tariff Schedule of the United States (HTS) subheadings 8112.11.3000 and 8112.11.6000, and aluminum-beryllium alloys (containing greater than 30% beryllium by weight) are covered under HTS 7601.20.9075 and HTS 7601.20.9090. The ITA determined that the material would be subject retroactively to a 16.56% dumping margin for the period of investigation of July 1, 1995, through December 31, 1995 (U.S. Department of Commerce, 1997).

However, on March 5, the U.S. International Trade Commission (USITC) determined that an industry in the United States is not materially injured or threatened with material injury, and the establishment of an industry in the United States is not materially retarded, by reason of imports from Kazakstan of beryllium metal and high-beryllium alloys (U.S. International Trade Commission, 1997). Thus, the investigation was terminated and all securities posted were to be refunded or canceled. This investigation was instituted on March 14, 1996, in response to a petition filed with the Department of Commerce and the ITC by Brush Wellman Inc., Cleveland, OH.

In May, the Department of Energy (DOE) announced its intention to establish a Beryllium Rule Advisory Committee. The purpose of the committee is to provide the Secretary of Energy with advice, information, and recommendations on the development of a notice of proposed rulemaking for beryllium. The committee will provide an organized forum for a diverse background of individuals to conduct an in-depth assessment of beryllium-related issues. The committee will include DOE and contractor employees (with expertise in beryllium operations), representatives from health professions, physicians, other Federal agencies, private industry (national and international), and academic institutions which have expertise in the health effects, exposure monitoring, appropriate controls, and medical monitoring for beryllium (U.S. Department of Energy, 1997). Subsequently, committee meetings were held in Washington, DC, and in Arlington, VA.

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Production

Beryllium data are collected from two voluntary surveys of U.S. operations. In 1997, there were four responses to the "Beryllium Mineral Concentrate and Beryllium Ore" survey. These respondents produced 100% of total domestic mine shipments shown in tables 1 and 7. A small number of unidentified producers may have shipped insignificant quantities of byproduct beryl, which have not been included.

The United States is one of only three countries that process beryllium ore and concentrates into beryllium products and supplies most of the rest of the world with these products. Brush Wellman Inc. mines bertrandite and converts ore of this mineral, along with beryl, into beryllium hydroxide at its operations near Delta, UT. Beryllium hydroxide is shipped to the company's plant in Elmore, OH, where it is converted into beryllium alloys, oxide, and metal.

One other company in the United States has the capability to produce beryllium alloys. NGK Metals Corp., a subsidiary of NGK Insulators of Japan, produces beryllium alloys at a plant near Reading, PA. Because NGK Metals does not have facilities to process the raw materials, the company purchases beryllium oxide from Brush Wellman.

Brush Wellman's \$117 million expansion at its Elmore, OH, facility proceeded as scheduled. The expansion was approved by the company's Board of Directors in May 1996 with goals to increase capacity, reduce costs, improve service, and optimize working capital utilization. Advanced environmental, health, and safety technology would also be incorporated. The expansion includes the installation of a new cast shop, hot and cold rolling mills, and annealing, pickling, and finishing equipment. Casting began in November and the new capacity is anticipated to be fully operational in the fourth quarter 1998. Primary financing for the project includes an operating lease arrangement for the building, lease on the equipment, and cash outlays and debt (Brush Wellman Inc., 1997).

Environment

Beryllium dust and fumes have been recognized as the cause of beryllosis, a serious chronic lung disease. In the 1940's, the disease was diagnosed among beryllium industry employees and their relatives, who had handled dusty workclothes prior to the establishment of suitable hygienic procedures. Cases also were reported among residents of communities surrounding beryllium-processing plants. Although uncertainties related to the cause of the disease still exist, the problem appears to be controlled when established preventative measures are exercised. In beryllium-processing plants, harmful effects are prevented by maintaining clean workplaces; requiring the use of safety equipment such as personal respirators; collection of dust, fumes, and mists at the source of deposition in dust collectors; medical programs; and other procedures to provide safe working conditions. Control of potential health hazards adds significantly to the final cost of beryllium products.

Consumption

According to its annual report, Brush Wellman reported that its

worldwide sales in 1997 were a record \$433.8 million, a 15% increase in sales from the 1996 level. Primary markets for the company's products were telecommunications, automotive, and electronics. Sales of alloy products increased owing to high demand in electronics applications, and the company's success in developing new applications in automotive electronics, telecommunications, appliances, commercial aircraft, and plastic mold materials markets. Beryllium oxide ceramic sales to the telecommunications market also increased. International sales totaled \$88.7 million compared with \$74.8 million in 1996. The largest foreign customers were concentrated in Germany, Japan, Singapore, Switzerland, and the United Kingdom (Brush Wellman Inc., 1997).

Beryllium-Copper Alloys.—Beryllium-copper alloys are used in a wide variety of applications and average about 75% of annual U.S. consumption on a beryllium metal equivalent basis. These alloys, most of which contain approximately 2% beryllium, are used because of their high electrical and thermal conductivity, high strength and hardness, good corrosion and fatigue resistance, and nonmagnetic properties. Beryllium-copper strip is manufactured into springs, connectors, and switches for use in applications in automobiles, aerospace, radar and telecommunications, factory automation, computers, home appliances, and instrumentation and control systems. The principal use of large-diameter beryllium-copper tubing is in oil and gas drilling equipment and in bushings and bearings in aircraft landing gear and heavy machinery. Connectors in fiber-optic telecommunications systems are the main application for beryllium-copper rod. Small, pluggable sockets for joining integrated circuits to printed circuit boards are the main application for beryllium-copper wire. Beryllium-copper bar and plate are used in resistance-welding parts, components for machinery and materials-handling systems, and for molds to make metal, glass, and plastic components.

Beryllium also is used in small quantities in nickel- and aluminum-base alloys. Miniature electronic connector components that operate at high temperatures are the main use for beryllium-nickel alloys, and these alloys are used in automotive passive restraint systems (airbags). Beryllium-aluminum alloys are used as castings in the aerospace industry. Addition of small quantities of beryllium to magnesium alloys inhibits oxidation.

Beryllium Metal.—Beryllium metal, which averages about 10% of annual U.S. beryllium demand, is used principally in aerospace and defense applications. Its high stiffness, light weight, and dimensional stability over a wide temperature range make it useful in satellite and space vehicle structures, inertial guidance systems, military aircraft brakes, and space optical system components. Because beryllium is transparent to X-rays, it is used in X-ray windows. In nuclear reactors, beryllium also serves as a canning material, as a neutron moderator, in control rods, and as a reflector. In the past, the metal had been used as a triggering device in nuclear warheads. Other applications for metallic beryllium include high-speed computer components, audio components, and mirrors. In the U.S. space shuttles, several structural parts and brake components use beryllium.

Beryllium Oxide.—Beryllium oxide (beryllia) is an excellent heat conductor, with high hardness and strength. This material also acts as an electrical insulator in some applications. Beryllium oxide, averaging about 15% of domestic beryllium demand, serves

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mainly as a substrate for high-density electronic circuits for high-speed computers, automotive ignition systems, lasers, and radar electronic countermeasure systems. Because it is transparent to microwaves, microwave communications systems and microwave ovens may use beryllium oxide.

Because of its high cost compared to those of other materials, beryllium is used in applications in which its properties are crucial. Steel, titanium, or graphite composites substitute for beryllium metal in some applications, and phosphor bronze substitutes for beryllium-copper alloys, but these substitutions result in substantial loss in performance. In some cases, aluminum nitride may be substituted for beryllium oxide.

Prices

Yearend price quotes for beryllium products are shown in table 3. Prices for beryllium products at yearend 1997 were unchanged from those of yearend 1996.

Foreign Trade

Data for U.S. exports and imports are summarized in tables 4 and 5, respectively. Overall trade value for exports increased by about 20%, with total volume down by almost 30%. Canada, Germany, and Japan were the major recipients of the materials. For imports, overall trade value and volume were up substantially. Canada provided most of the beryl ore imports. China, Germany, Russia, and Switzerland accounted for about 75% of the metal imports.

The Bureau of the Census does not separately identify all imports and exports of beryllium-copper alloys. The Journal of Commerce Port Import/Export Reporting Service (PIERS) provides some data on materials that are transported by ship. According to PIERS, about 2,700 tons (gross weight) of beryllium-copper alloys (mostly in billet and strip form) were imported in 1997, primarily from Japan. Exports of beryllium-copper alloys totaled almost 100 tons (gross weight), with Japan (30%), Hong Kong (22%), and Sweden (20%) as the principal recipients.

The schedule of tariffs applied during 1997 to U.S. imports of selected beryllium materials is found in the USITC's 1997 HTS, USITC Publication 3001. Canada, Germany, Russia, and Switzerland were the major sources for U.S. beryllium imports (contained beryllium), accounting for almost 80% of the total.

World Review

Annual world beryl production capacity (metric tons, contained beryllium) is shown in table 6. Estimated world beryl production (metric tons, gross weight) is shown in table 7.

In Canada, Highwood Resources Ltd. filed an application with the Government to mine and process bulk samples from its Thor Lake beryllium property. Based on underground and surface exploration, metallurgical test work, and a feasibility study, a mineral inventory of about 500,000 tons of ore grading 1% beryllium oxide (BeO) has been established at the property. Upon approval of the application, the company plans to invest Canadian \$17 million to construct plants for the ultimate production of beryllium copper alloy for sale in North America (Metal Bulletin,

1997).

In Singapore, Brush Wellman formed a joint-venture service center with Semitron Materials. The venture, Brush Semitron Service Center Pte. Ltd., will supply beryllium copper strip products to Malaysia and Singapore, and eventually to Brunei, China, Indonesia, the Philippines, and Thailand. The venture will be managed by Semitron Materials, a Singapore metals processor (American Metal Market, 1997).

Outlook

Beryllium alloys are expected to remain the dominant form of consumption for beryllium. Consumption of these alloys will probably continue to increase in the United States. The development of new applications for beryllium-aluminum alloys in aerospace, commercial satellites, and automotive uses, is expected to aid in the steady growth of overall beryllium consumption. Demand for beryllium materials in the traditional applications such as ceramics, electronics, and telecommunications, will probably experience growth in line with economic trends.

The United States is expected to continue to be self-sufficient with respect to most of its beryllium requirements. In its annual report, Brush Wellman reports proven bertrandite reserves of about 6.28 million tons at yearend 1997, with an average grade of 0.249% beryllium (Brush Wellman Inc., 1997). This represents almost 16,000 tons of contained beryllium. In 1997, the United States consumed almost 260 tons of beryllium contained in beryllium-bearing ores.

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TABLE 1 SALIENT BERYLLIUM MINERAL STATISTICS

(Metric tons of beryllium metal equivalent unless otherwise specified)

	1993	1994	1995	1996	1997
United States:					
Beryllium-containing ores:					
Mine shipments	198	173	202	211	231
Imports for consumption, beryl 1/	2			1	9
Consumption, reported	196	174	227	234	259
Yearend stocks	114	113	162	139	110
World: Production 1/	243 r/	218 r/	247 r/	256 r/	276

r/ Revised.

TABLE 2 STOCKPILE STATUS, DECEMBER 31, 1997

(Metric tons, beryllium content)

		Uncommitted	Authorized
Material	Goal 1/	inventory	for disposal
Beryllium ore	-	469	469
Beryllium-copper master alloy		268	268
Beryllium metal	363	363	

^{1/} Goal as of September 30, 1997.

TABLE 3 YEAREND BERYLLIUM PRICES, 1997

(Dollars per pound unless otherwise specified)

Material		Price
Beryl ore	per short ton unit of contained BeO	\$75-\$80
Beryllium vacuum-cast ingot, 98.5% pure, in lots up to 1,000 pounds		327
Beryllium metal powder, in 1,000- to 4,999-pound lots and 99% pure		385
Beryllium-copper master alloy	per pound of contained Be	160
Beryllium-copper casting alloy		5.52-6.30
Beryllium-copper in rod, bar, wire		9.85
Beryllium-copper in strip		8.90
Beryllium-aluminum alloy, in lots up to 100 pounds; 62% Be, 38% Al		260
Beryllium oxide powder, in 10,000-pound lots		77.00

 $Sources:\ American\ Metal\ Market,\ Brush\ Wellman\ Inc.,\ Metal\ Bulletin,\ and\ Platt's\ Metals\ Week.$

^{1/}Based on a beryllium metal equivalent of 4% in beryl.

TABLE 4 U.S. EXPORTS OF BERYLLIUM ALLOYS, WROUGHT OR UNWROUGHT, AND WASTE AND SCRAP, BY COUNTRY 1/2/

	199	6	1997	7
	Quantity	Value	Quantity	Value
Country	(kilograms)	(thousands)	(kilograms)	(thousands)
Canada	25,200	\$683	11,700	\$373
France	3,530	749	3,130	1,370
Germany	5,490	792	6,120	1,150
Japan	4,380	905	7,020	1,070
Netherlands	5,760	247	1,710	166
Norway	5,970	51		
Philippines			2,530	8
United Kingdom	1,170	317	3,890	387
Other	5,220	762	4,250	873
Total	56,700	4,510	40,300	5,400

^{1/} Consisting of beryllium lumps, single crystals, powder; beryllium-base alloy powder; and beryllium rods, sheets, and wire.

Source: Bureau of the Census.

 ${\bf TABLE~5}$ U.S. IMPORTS FOR CONSUMPTION OF BERYLLIUM ORE, METAL, AND COMPOUNDS 1/

	199	1996		1997	
	Quantity	Value		Quantity	Value
Material	(kilograms)	(thousands)		(kilograms)	(thousands)
Beryl ore	19,400	\$9		224,000	\$3,680
Beryllium-copper master alloy	31,300	545	r/	62,800	708
Beryllium oxide and hydroxide	9090	58			
Beryllium, unwrought and waste and scrap	19,100	1,920		42,900	3,230

r/ Revised.

Source: Bureau of the Census.

TABLE 6 WORLD ANNUAL BERYL PRODUCTION CAPACITY, 1/ DECEMBER 31, 1997

(Metric tons, contained beryllium)

Continent and country	Capacity
North America: United States 2/	360
Africa:	
Madagascar	5
Mozambique	3
Rwanda	3
South Africa	3
Zimbabwe	
Total	19
Asia: China	75
Europe:	
Kazakstan	7
Portugal	3
Russia	70
Total	80
South America:	
Argentina	4
Brazil	
Total	9
World total	543

^{1/} Includes capacity at operating plants as well as at plants on standby basis.

^{2/} Data are rounded to three significant digits; may not add to totals shown.

^{1/} Data are rounded to three significant digits.

^{2/} Includes bertrandite ore.

 ${\bf TABLE~7} \\ {\bf BERYL:~ESTIMATED~WORLD~PRODUCTION,~BY~COUNTRY~1/~2/} \\$

(Metric tons, gross weight)

Country 3/	1993	1994	1995	1996	1997
Argentina	r/				
Brazil	9 r/	6 r/4/	6 r/4/	6 r/4/	6
Kazakstan	100	100	100	100	100
Madagascar 5/	3	3	32 r/	32 r/	30
Namibia	15	r/	r/		
Portugal	4	5 r/	5 r/	5 r/	5
Russia	1,000 r/	1,000 r/	1,000 r/	1,000 r/	1,000
United States 6/ (mine shipments)	4,940 4/	4,330 4/	5,040 4/	5,260 4/	5,770
Zambia	(7/) r/	1	1	1	1
Zimbabwe (concentrate, gross weight)	r/	r/	r/	r/	
Total	6,070 r/	5,440 r/	6,180 r/	6,400 r/	6,910

r/ Revised.

^{1/}W World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

^{2/} Table includes data available through June 11, 1998.

^{3/} In addition to the countries listed, China produced beryl and Bolivia may also have produced beryl, but available information is inadequate to formulate reliable estimates of production.

^{4/} Reported figure.

^{5/} Includes ornamental and industrial products.

^{6/} Includes bertrandite ore, calculated as equivalent to beryl containing 11% BeO.

^{7/} Less than 1/2 unit.