BERYLLIUM

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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. It 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 contains less than 1% Be, and beryl contains about 4% Be. Bertrandite is the principal beryllium mineral mined in the United States, and beryl is the principal mineral produced in the rest of the world.

In 1999, U.S. production of beryllium ore and total ore consumption for the production of beryllium alloys, beryllium metal, and beryllium oxide decreased from those of 1998 (table 1).

The Defense National Stockpile Center (DNSC), U.S. Department of Defense (DOD), offered and sold selected beryllium materials from the National Defense Stockpile (NDS). The Generalized System of Preferences (GSP), which expired on June 30, 1999, was renewed on December 17, 1999 (retroactive to July 1, 1999), and extended to September 30, 2001. Beryllium price quotations remained unchanged. Overall U.S. exports and imports of beryllium in 1999 were down significantly from those in 1998.

Legislation and Government Programs

To ensure a supply of beryllium during an emergency, various materials have been purchased for the NDS. The Stockpile goal, as of October 5, 1999, for beryllium metal was 45 metric tons (t), (table 2). For fiscal year (FY) 1999 (October 1, 1998, through September 30, 1999), the DNSC sold about 1,810 t of beryl ore valued at about $158,000, about 1,130 t of beryllium copper master alloy (BCMA) valued at about $6.32 million, and about 18 t of beryllium metal valued at about $2.42 million from the NDS (U.S. Department of Defense, 2000, p. 14-15, 38).

For FY 2000 (October 1, 1999, through September 30, 2000), the DNSC had authority under its revised Annual Materials Plan to sell about 3,630 t of beryl ore, about 1,360 t of BCMA, and about 36 t of beryllium metal (Defense National Stockpile Center, 2000a). The National Defense Authorization Act for FY 2000 (Public Law 106-65, October 5, 1999) authorizes the President of the United States to dispose of about 227 t of beryllium metal from the NDS. The President may not, however, dispose of the material to the extent that the disposal will result in "Beryllium undue disruption of the usual markets of producers, processors, and consumers of the materials proposed for disposal; or (2) avoidable loss to the United States" (U.S. Department of Defense, 2000, p. 28-29). In February 2000, the DNSC announced the sale of about 168 t of beryllium metal. The multiyear award was made to Brush Wellman, Inc., Cleveland, OH, and was valued at about $26 million (Defense National Stockpile Center, 2000d). In March and June 2000, the DNSC sold a total of about 222 t of BCMA valued at about $1.48 million to Brush Wellman and Freedom Alloys, Inc., Royersford, PA (Defense National Stockpile Center, 2000b, c).

For FY 2001 (October 1, 2000, through September 30, 2001), the DNSC proposed maximum disposal levels of about 3,630 t of beryl ore, about 1,360 t of BCMA, and about 36 t of beryllium metal (Bureau of Export Administration, 1999, p. 54864).

Under GSP, a renewable preferential trade program, the United States grants duty-free access to eligible products from designated developing countries. In 1999, U.S. import duties for selected beryllium materials ranged from duty free to 8.5% ad valorem for normal-trade-relations (NTR) status and from duty free to 45% ad valorem for non-NTR status (U.S. International Trade Commission, 1998). The GSP program expired on June 30, 1999, but was renewed through September 30, 2001, effective December 17, 1999, retroactive to July 1, 1999, by a provision in the Ticket To Work and Work Incentives Improvement Act of 1999. Importers were notified that Customs was again accepting claims for GSP duty-free treatment for merchandise entered or withdrawn from a warehouse for consumption, and that Customs was processing refunds on all duties paid, with interest from the date the duties were deposited, on GSP-eligible merchandise that was entered during the period that the GSP program was lapsed. Customs began processing refunds due to the renewal on January 7, 2000 (U.S. Customs Service, 2000, p. 11367).

In December, the U.S. Department of Energy (DOE) published a final rule to establish a chronic beryllium disease prevention program. The rule, effective January 7, 2000, was intended to "reduce the number of workers currently exposed to beryllium in the course of their work at DOE facilities managed by DOE or its contractors, minimize the levels of, and potential for, exposure to beryllium, and establish medical surveillance requirements to ensure early detection of the disease" (U.S. Department of Energy, 1999, p. 68854).

Production

The U.S. Geological Survey collects beryllium data from two voluntary surveys of U.S. operations. In 1999, five respondees

to the "Beryllium" and the "Mineral Concentrate and Beryllium Ore" surveys produced 100% of total domestic mine shipments presented 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, one of only three countries that process beryllium ores and concentrates into beryllium products, supplies most of the rest of the world with these products. Brush Wellman mined bertrandite and converted ore of this mineral, along with imported beryl, into beryllium hydroxide at its operations near Delta, UT. Beryllium hydroxide was shipped to the company's plant in Elmore, OH, where it was converted into beryllium alloys, oxide, and metal. In 1999, Brush Wellman proposed a reorganization of the company's capital and corporate structure. The proposal included the creation of Brush Engineered Materials Inc., as the publicly held parent of Brush's businesses. Existing shareholders would own all shares of Brush Engineered Materials and Brush Wellman, Inc. would be a wholly owned subsidiary of the new holding company (Brush Wellman, Inc., 2000, p. 8). On May 2, 2000, shareholders of Brush Wellman approved the reorganization, effective May 16, 2000 (Brush Engineered Materials Inc., 2000).

NGK Metals Corp., a subsidiary of NGK Insulators, Ltd. of Japan, produced beryllium alloys at a plant near Reading, PA, and beryllium rod and bar products at a facility in Sweetwater, TN. Because NGK Metals does not have facilities to process beryllium ores and concentrates, the company purchases beryllium oxide from Brush Wellman. In 2000, NGK plans to consolidate its U.S. beryllium production operations in Sweetwater.

Environment

Because of the toxic nature of beryllium, the industry must maintain careful control over the quantity of beryllium dust and fumes in the workplace. The EPA issues standards for certain hazardous air pollutants, including beryllium, under the Clean Air Act, and the Occupational Safety and Health Administration issues standards for airborne beryllium particles. To comply with these standards, plants are required to install and maintain pollution-control equipment. 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 (Petkof, 1985, p. 80; Rossman, Preuss, and Powers, 1991, p. 278-280; Kramer, 1998, p. 107-108). Control of potential health hazards adds to the final cost of beryllium products.

Consumption

Domestic mine shipments and beryllium ore consumption were down from that of 1998. According to its annual report, Brush Wellman's worldwide sales were about $456 million in 1999 compared with about $410 million in 1998. The domestic market accounted for 70% of the company's revenue compared with 69% in 1998. Telecommunications continued as the leading revenue market. The Metal Systems Group, which included Alloy Products, Beryllium Products, and Engineered Material Systems, represented 67% of total revenue compared with 72% in 1998. Alloy strip products (primarily copper-beryllium alloys) sales increased from the previous year owing to strong demand from the telecommunications, automotive electronics, and computer markets. Production of strip products remained at capacity. However, the company was limited in its ability to satisfy total demand for strip products, owing to operational issues that delayed the midyear startup of the $117 million alloy expansion project at Elmore. Beryllium Products sales decreased. Defense applications remained an important market for beryllium but at a level significantly lower than that of the 1970's and 1980's, as spending on various DOD programs was postponed. Company international sales totaled about $137 million (about $87 million from international operations, with facilities in England, Germany, Japan, and Singapore, and about $50 million from U.S. operations' exports) (Brush Wellman, Inc., 2000, p. 2, 4-5, 28-30).

Beryllium-Copper Alloys.—Beryllium-copper alloys, most of which contain approximately 2% beryllium, are used in a wide variety of applications. These alloys are used because of their 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. These alloys also are used in automotive passive restraint systems (airbags). Beryllium-aluminum alloys are used as castings in the aerospace industry. The addition of small quantities of beryllium to magnesium alloys inhibits oxidation.

Beryllium Metal.—Beryllium metal is used principally in aerospace and defense applications. Its high level of stiffness, light weight, and dimensional stability within 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, and in control rods. 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 levels of hardness and strength. This material also acts as an electrical insulator in some applications. Beryllium oxide serves 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 the cost of beryllium is high compared with that of other materials, it is used in applications in which its properties are crucial. Graphite, steel, and titanium may be substituted for beryllium metal in some applications, and phosphor bronze may be substituted for beryllium-copper alloys, but these substitutions can result in substantial loss in performance. In some applications, aluminum nitride may be substituted for beryllium oxide.

Prices

Yearend price quotes for beryllium materials and products are shown in table 3. Prices for beryllium materials and products at yearend 1999 were unchanged from those of yearend 1998. The Metal Bulletin published price for beryl ore, which ranged from $75 to $80 per short ton unit of contained BeO, was unchanged through the 1990's. The American Metal Market published prices for selected beryllium products were as follows: BCMA, $160 per pound of contained beryllium, unchanged since August 1987; beryllium metal (99% beryllium powder), $385 per pound, unchanged since January 1995; beryllium-copper strip, $8.90 per pound of contained beryllium, unchanged since January 1993; and beryllium oxide, $77 per pound, unchanged since April 1996.

The chapter for beryllium in the U.S. Geological Survey publication "Metal Prices in the United States Through 1998" includes a graph of annual current and 1992 constant dollar prices for 1959 through 1998; a list of significant events that affected prices; a brief discussion of the metal and its history; and a table that lists yearend average beryllium metal prices (Cunningham, 1999; U.S. Geological Survey, 2000). Individual chapters, including the 3-page beryllium chapter, may be accessed on the World Wide Web at URL http://minerals.usgs.gov/minerals/pubs/metals_prices.

Foreign Trade

Data for U.S. exports and imports are summarized in tables 4 and 5, respectively. Overall beryllium exports decreased significantly compared with those of 1998. Canada, Japan, the Netherlands, and the United Kingdom were the major recipients of the materials, with about 70% of the total. Overall beryllium imports were down significantly, owing mainly to the decline in beryl ore imports. However, BCMA imports were up significantly. Canada continued to provide all the beryl ore imports, and Russia accounted for more than 90% of alloy and metal imports (mostly BCMA).

The Bureau of the Census does not separately identify all imports and exports of beryllium-copper products. The Journal of Commerce Port Import/Export Reporting Service (PIERS) provides some data on materials that are transported by ship. According to PIERS, about 2,100 t (gross weight) of beryllium-copper products (mostly in strip form) was imported in 1999, primarily from Japan. Exports of beryllium-copper products totaled more than 1,000 t (gross weight); Japan received most of this material.

The schedule of tariffs applied during 1999 to U.S. imports of selected beryllium materials is found in the U.S. International Trade Commission's Publication 3138, 1999 Harmonized Tariff Schedule of the United States (U.S. International Trade Commission, 1998). Canada, Germany, Kazakhstan, Russia, and Sweden were the major sources for U.S. beryllium imports (contained beryllium), accounting for more than 80% of the total.

World Review

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

Japan.—Japanese demand for beryllium-copper alloys, which was down in 1998, recovered strongly since March 1999. In September, consumption was estimated at 2,500 to 3,000 metric tons per year (t/yr), with 1999 consumption forecast to rise by 15% to 20% for the year. However, supply of beryllium-copper alloys had not kept pace with demand, and, in response to increased consumption and tight supply, Nippon Gaishi Co., Ltd. made plans to expand its production capacity for beryllium-copper rolled products by 50% to 300 t/yr by March 2000. The company also planned to double production capacity for beryllium-copper cast and forged products at its Chita plant in Handa City, Aichi Prefecture, from October 2000 (Roskill's Letter from Japan, 1999).

Kazakhstan.—Early in the year, the Government of Kazakhstan was reviewing the terms of a 1995 agreement between the country's Ulba Metallurgical Works, a major beryllium producer, and Sweden's Scanburg AG, under which Scanburg would provide a $52 million line of credit and Ulba would put up 270 t of beryllium as collateral. Within 5 years, the credit was to be repaid and the beryllium returned to Kazakhstan. The Kazakhstan Government, however, deemed the deal to be uneconomical in 1997. Scanburg released some of the credit and about 26 t of beryllium was shipped to Sweden. Ulba treated the shipped beryllium as sold, not collateral, but the Kazakhstan Government did not sanction the sale and gave Scanburg until April 1, 1999, to return the beryllium (Interfax International, Ltd., 1999d).

Kazatomprom, Kazakhstan's national nuclear industry concern, owns 90% of the common stock in Ulba. In an agreement signed in June 1999, Kazatomprom planned to "swap" shares (34%) of Ulba with members of the Russian

TVEL nuclear fuel concern for shares in a Russian metallurgical plant during the first quarter 2000 (Interfax International, Ltd., 1999b, e).

In May, it was reported that Ulba was acting to preserve its beryllium production capacity. Annual profits of $9.4 million could be generated if Ulba could sustain beryllium production at about 200 t/yr and if the company could sell a similar amount from its beryllium stockpiles. Ulba was also setting up a carbothermy division to obtain beryllium alloying additives and to restore its chemicals and metallurgy complex. A new method had been developed for processing about 800 t of semifinished toxic materials stockpiled at Ulba, containing about 149 t of beryllium. In June, Ulba's beryllium production was reported to consist of beryllium alloying agents containing up to 10% beryllium. Production of beryllium bronze, an alloy containing less than 2% beryllium, was planned for the year (Interfax International, Ltd., 1999a, c).

Russia.—In February 1999, Russia imposed a 5% duty for a period of 6 months on nonferrous and rare metals exported to all countries outside the Commonwealth of Independent States (CIS). In September, the Russian Government extended export duties on nonferrous and rare metals for shipments to all countries except members of the CIS Customs Union. Resolution no. 978, September 7, 1999, stated that duties on metals (including beryllium) and waste and scrap would become effective 7 days from the document's official publication (Interfax International, Ltd., 1999f, g).

Outlook

Beryllium alloys are expected to remain the dominant form of consumption for beryllium. The demand for newly developed alloys targeted for automotive electronics, telecommunications, and computer applications is promising. New government programs such as the F-22 air superiority fighter and the Comanche helicopter may stimulate beryllium demand (Brush Wellman, Inc., 2000, p. 4-5).

The United States is expected to continue to be self-sufficient with respect to most of its beryllium requirements. Brush Wellman (2000, p. 33) reported proven bertrandite reserves of about 7.05 million metric tons at yearend 1999, with an average grade of 0.265% beryllium. This represents about 18,700 t of contained beryllium. In 1999, the United States consumed about 260 t of beryllium contained in beryllium-bearing ores, compared with about 270 t in 1998.

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TABLE 1
SALIENT BERYLLIUM MINERAL STATISTICS

(Metric tons, beryllium metal equivalent)

	1995	1996	1997	1998	1999
United States:					
Beryllium-containing ores:					
Mine shipments	202	211	231	243	200
Imports for consumption, beryl 1/	--	1	9	13	1
Consumption, reported	227	234	259	272	260
Yearend stocks	162	139	110	81	17
World: Production 1/	247	255	276	289	248

-- Zero.

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

TABLE 2
STOCKPILE STATUS, DECEMBER 31, 1999

(Metric tons, beryllium content)

Material	Goal 1/	Uncommitted inventory	Authorized for disposal
Beryllium ore	--	387	387
Beryllium-copper master alloy	--	166	166
Beryllium metal	45	345	299

-- Zero.

1/ Goal as of October 5, 1999.

TABLE 3
YEAREND BERYLLIUM PRICES, 1999

(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		8.9
Beryllium-aluminum alloy, in lots up to 100 pounds; 62% Be, 38% Al		260
Beryllium oxide powder, in 10,000-pound lots		77

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

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

Country	1998 Quantity (kilograms)	1998 Value (thousands)	1999 Quantity (kilograms)	1999 Value (thousands)
Canada	1,450	$39	6,630	$190
Costa Rica	192	6	3,170	55
Finland	541	71	602	71
France	17,700	1,470	2,010	1,020
Germany	6,460	1,000	3,320	617
Japan	14,200	3,750	7,110	1,360
Netherlands	2,540	128	3,760	220
United Kingdom	7,440	1,390	10,700	2,710
Other	7,160 r/	2,080 r/	2,290	530
Total	57,700	9,940	39,600	6,770

r/ Revised.
1/ Consisting of beryllium lumps, single crystals, powder; beryllium-base alloy powder; and beryllium rods, sheets, and wire.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: Bureau of the Census.

TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF BERYLLIUM ORE, METAL, AND COMPOUNDS 1/

Material	1998 Quantity (kilograms)	1998 Value (thousands)	1999 Quantity (kilograms)	1999 Value (thousands)
Beryl ore	321,000	$5,600	20,400	$13
Beryllium-copper master alloy	67,800	1,060	103,000	1,530
Beryllium oxide and hydroxide	7,100	75	1,020	14
Beryllium, unwrought and waste and scrap	40,100	4,280	11,900	1,060

1/ Data are rounded to no more than three significant digits.

Source: Bureau of the Census.

TABLE 6
WORLD ANNUAL BERYL PRODUCTION CAPACITY, DECEMBER 31, 1999 1/

(Metric tons, contained beryllium)

Continent and country	Capacity
North America: United States 2/	360
Africa:	
Madagascar	5
Mozambique	3
Rwanda	3
South Africa	3
Total	14
Asia: China	75
Europe:	
Kazakhstan	7
Portugal	3
Russia	70
Total	80
South America: Brazil	5
World total	534

1/ Includes capacity at operating plants as well as at plants on standby basis.
2/ Includes bertrandite ore.

TABLE 7
BERYL: ESTIMATED WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons, gross weight)

Country 3/	1995	1996	1997	1998	1999
Brazil	6 4/	6 4/	7 4/	7 4/	7
Kazakhstan	100	100	100	100	100
Madagascar 5/	32	11	28	30	30
Portugal	5	5	5	5	4
Russia	1,000	1,000	1,000	1,000	1,000
United States (mine shipments) 6/	5,040	5,260	5,770	6,080	5,070
Zambia 5/	2 r/	4 r/	4 r/	4 r/	4
Total	6,180	6,390 r/	6,910	7,220	6,220

r/ Revised.
1/ 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 9, 2000.
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.