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 1998, U.S. production of beryllium ore and total ore consumption for the production of beryllium alloys, beryllium metal, and beryllium oxide increased from those of 1997. (See table 1.) The Generalized System of Preferences (GSP), which expired on June 30, 1998, was extended to June 30, 1999. The Defense National Stockpile Center (DNSC) offered and sold beryllium-copper master alloy (BCMA) from the National Defense Stockpile (NDS).

Legislation and Government Programs

To ensure a supply of beryllium during an emergency, various materials have been purchased for the NDS. As of November 17, 1998, the NDS goal for beryllium metal was 272 metric tons (t), table 2; (U.S. Department of Defense, 1999, p. 37).

The National Defense Authorization Act for fiscal year (FY) 1998 (Public Law 105-85) authorizes the DNSC to dispose of all BCMA from the NDS, which was equivalent to about 211 t of beryllium contained in BCMA at yearend 1998. The disposal would be contingent upon certification by the NDS Manager that any disposal of this material will not adversely affect the capability of the stockpile to supply the strategic and critical material needs of the United States. According to the DNSC Annual Materials Plan (AMP) for each of FY 1998 (October 1, 1997, through September 30, 1998) and FY 1999 (October 1, 1998, through September 30, 1999), the maximum amount of BCMA that could be sold from the NDS would be about 1,130 t. In May 1998, the DNSC initiated the sale of BCMA from the NDS. From May through November, the DNSC sold about 1,190 t of BCMA valued at about $6.71 million. Awards were made to the following companies: Alloy Research, Inc., Chicago, IL, Brush Wellman, Inc., Cleveland, OH, and Freedom Alloys, Inc., Royersford, PA. In its AMP for FY 1999, the DNSC set maximum disposal levels of about 1,810 t of beryl ore and about 18 t of beryllium metal. No beryl ore or beryllium metal was, however, sold in calendar year 1998. The DNSC also proposed maximum disposal levels of about 1,130 t of BCMA, about 1,810 t of beryl ore, and about 36 t of beryllium metal in FY 2000 (Defense National Stockpile Center, 1999a, b, 1998a, b, c; U.S. Department of Defense, 1999).

Under the GSP, a renewable preferential trade program, the United States grants duty-free access to eligible products from designated developing countries. In 1998, U.S. import duties 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 expired on June 30, 1998, but was renewed effective October 21, 1998, by a provision in the Omnibus Consolidated and Emergency Supplemental Appropriations Act, 1999 (Public Law 105-277; the extension was retroactive to July 1, 1998, when the program was allowed to lapse. The provision "provides notice to importers that Customs will begin processing refunds on all duties paid, with interest from the date the duties were deposited, on GSP-eligible merchandise that was entered on July 1, 1998, through October 20, 1998, and that customs will accept claims for GSP duty-free treatment for merchandise entered, or withdrawn from a warehouse, for consumption on or after October 21, 1998, through June 30, 1999, the provision's current sunset date" (U.S. Department of the Treasury, Customs Service, 1998).

In December, the U.S. Environmental Protection Agency (EPA) published a compilation of its national recommended water-quality criteria for 157 pollutants. Under Section 304 (a) of the Clean Water Act (CWA) of 1972, as amended, the EPA is required to develop and publish criteria for water quality accurately reflecting the latest scientific knowledge. The recommended water-quality criteria provides guidance for States and Tribes in adopting water-quality standards under Section 303 (c). The water-quality criteria are not regulations, however, and do not impose legally binding requirements on the EPA, the States, the Tribes, or the public. The compilation is presented as a summary table containing the EPA's water-quality criteria, and for each set of criteria, the EPA lists a cited reference. For beryllium, Federal Register, v. 62, p. 42160, is the cited reference. The EPA has not calculated human health criterion for beryllium. Permit authorities should, however, address beryllium in National Pollutant Discharge Elimination System permit actions by using the State's existing narrative criteria for toxics (U.S. Environmental Protection Agency, 1998).

In December, the U.S. Department of Energy (DOE) announced proposed regulations to establish a chronic beryllium disease prevention program. Program goals are to reduce the number of workers currently exposed to beryllium in the course of their employment with DOE or its contractors, to minimize the levels of and potential for exposure to beryllium, and to establish medical surveillance requirements to ensure early detection and treatment of disease. The proposed regulations would codify the interim program requirements currently prescribed in DOE directives and protect the health and safety of workers. The comment period for the proposed rulemaking ends March 9, 1999. Public hearings were scheduled for February 1999 in Oak Ridge, TN, Golden, CO (Denver), and Washington, DC (U.S. Department of Energy, 1998).

Production

Beryllium data are collected from two voluntary surveys of U.S. operations. In 1998, five respondees to the "Beryllium" and the "Mineral Concentrate and Beryllium Ore" surveys produced 100% of total domestic mine shipments (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 mines bertrandite and converts ore of this mineral, along with imported 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. During 1998, the cast shop portion of Brush Wellman's $117 million expansion at Elmore was placed in service. The new strip mill portion of the project was anticipated to be in full production in the third quarter 1999 (Brush Wellman, Inc., 1998, p. 28-29).

One other company in the United States has the capability to produce beryllium alloys. NGK Metals Corp., a subsidiary of NGK Insulators, Ltd. 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.

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. Under the Clean Air Act, the EPA issues standards for certain hazardous air pollutants, including beryllium, 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; Rossman, Preuss, and Powers, 1991; Kramer, 1994). Control of potential health hazards adds to the final cost of beryllium products.

Consumption

Domestic mine shipments and beryllium ore consumption continued to rise, resulting from a 20% increase in overall domestic beryllium demand since 1994.

According to its annual report, Brush Wellman reported that its worldwide sales were about $410 million in 1998 compared with the record of about $434 million in 1997. The domestic market accounted for 69% of company sales. The Metal Systems Group, which included Alloy Products (primarily copper-beryllium), Beryllium Products, and Engineered Material Systems, represented 72% of total sales. Telecommunications was the leading market for company products. Alloy Products sales were down from the previous year owing to lower copper prices, a change in product mix, and the strength of the dollar. The quantity of material shipped, however, was a new company record. Beryllium Products sales continued to increase. Company international operations, with distribution centers in England, Germany, Japan, and Singapore, had sales totaling $82 million compared with $88.7 million in 1997 (Brush Wellman, Inc., 1998, p. 1-4, 29).

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, 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 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.

Although 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, or titanium 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 applications, 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 1998 were unchanged from those of yearend 1997. The Metal Bulletin published price for beryl ore ranged from $75 to $80 per short ton unit of contained BeO, which was unchanged through the 1990's. The American Metal Market published prices for some 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; and beryllium oxide, $77 per pound, unchanged since April 1996.

Foreign Trade

Data for U.S. exports and imports are summarized in tables 4 and 5, respectively. Overall beryllium exports increased substantially compared with those of 1997. France, Germany, Japan, and the United Kingdom were the major recipients of the materials, with almost 80% of the total. Beryllium imports continued to increase. Canada provided all the beryl ore imports, and China, Kazakhstan, Russia, and Sweden accounted for almost 90% of alloy and 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, almost 1,200 t (gross weight) of beryllium-copper alloys (mostly in strip form) was imported in 1998, primarily from Japan. Exports of beryllium-copper alloys totaled about 2,100 t (gross weight); with Japan the recipient of most of the material.

The schedule of tariffs applied during 1998 to U.S. imports of selected beryllium materials is found in the U.S. International Trade Commission's (USITC's) 1998 Harmonized Tariff Schedule of the United States, USITC Publication 3066. Canada, Kazakhstan, Russia, and Sweden were the major sources for U.S. beryllium imports (contained beryllium), accounting for about 75% 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.

Japanese demand for beryllium-copper mill products decreased from that of 1997 as a result of the economic recession. Shipments to the electronics sector were down by as much as 15%. Total shipments of beryllium-copper products however were down by only about 3% owing to continued growth in demand for less expensive low-beryllium products (Roskill's Letter from Japan, 1999).

In the first half of 1998, Kazakhstan's Ulba Metallurgical Works supplied about 69 t of beryllium alloying additives valued at about $941,000 to Germany's Tropag (Oscar H. Ritter Nachf. GmbH) and 10.3 t of metallic beryllium valued at about $981,000 to Nukem GmbH. For the year, Ulba planned to produce 162 t of beryllium products, consisting of 30 t of copper-beryllium additives containing 10% beryllium, 72 t of copper-beryllium additives containing 4% beryllium, and 60 t of aluminum-beryllium additives containing 4% beryllium, for Tropag. In 1998, Ulba's capacity utilization was expected to be about 27% for beryllium products (Interfax International, Ltd., 1998).

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. Development of some new alloys is being targeted for the appliance, automotive, computer, and telecommunications markets. The future growth in the usage of beryllium-aluminum alloys in satellite structures is also promising (Brush Wellman, Inc., 1998, p. 3-4).

The United States is expected to continue to be self-sufficient with respect to most of its beryllium requirements. Brush Wellman (1998, p. 33) report proven bertrandite reserves of about 7 million metric tons at yearend 1998, with an average grade of 0.259% beryllium. This represents about 18,000 t of contained beryllium. In 1998, the United States consumed about 270 t of beryllium contained in beryllium-bearing ores.

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[1] Prior to January 1996, published by the U.S. Bureau of Mines.

TABLE 1
SALIENT BERYLLIUM MINERAL STATISTICS

(Metric tons of beryllium metal equivalent unless otherwise specified)

	1994	1995	1996	1997	1998
United States:					
Beryllium-containing ores:					
Mine shipments	173	202	211	231	243
Imports for consumption, beryl 1/	--	--	1	9	13
Consumption, reported	174	227	234	259	272
Yearend stocks	113	162	139	110	81
World: Production 1/	218	247	255 r/	276	289

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

TABLE 2
STOCKPILE STATUS, DECEMBER 31, 1998

(Metric tons, beryllium content)

Material	Goal 1/	Uncommitted inventory	Authorized for disposal
Beryllium ore	--	469	469
Beryllium-copper master alloy	--	211	211
Beryllium metal	272	363	91

1/ Goal as of November 17, 1998.

TABLE 3
YEAREND BERYLLIUM PRICES, 1998

(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.

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

Country	1997 Quantity (kilograms)	1997 Value (thousands)	1998 Quantity (kilograms)	1998 Value (thousands)
Canada	11,700	$373	1,450	$39
France	3,130	1,370	17,700	1,470
Germany	6,120	1,150	6,460	1,000
Italy	555	359	2,750	381
Japan	7,020	1,070	14,200	3,750
Netherlands	1,710	166	2,540	128
Taiwan	10	19	1,050	71
United Kingdom	3,890	387	7,440	1,390
Other	6,210 3/	503 3/	4,100 4/	1,700 4/
Total	40,300	5,400	57,700	9,940

1/ Consisting of beryllium lumps, single crystals, powder; beryllium-base alloy powder; and beryllium rods, sheets, and wire.
2/ Data are rounded to three significant digits; may not add to totals shown.
3/ Revised; unspecified group of countries differs from that in the 1997 Annual Report.
4/ All or part of these data have been referred to the Bureau of the Census for verification.

Source: Bureau of the Census.

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

Material	1997 Quantity (kilograms)	1997 Value (thousands)	1998 Quantity (kilograms)	1998 Value (thousands)
Beryl ore	224,000	$3,680	321,000	$5,600
Beryllium-copper master alloy	62,800	708	67,800	1,060
Beryllium oxide and hydroxide	--	--	7,100	75
Beryllium, unwrought and waste and scrap	42,900	3,230	40,100	4,280

1/ Data are rounded to three significant digits.

Source: Bureau of the Census.

TABLE 6
WORLD ANNUAL BERYL PRODUCTION CAPACITY,
DECEMBER 31, 1998 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/	1994	1995	1996	1997	1998
Brazil	6 4/	6 4/	6 4/	7 r/ 4/	7
Kazakhstan	100	100	100	100	100
Madagascar 5/	3	32	11 r/	28 r/	30
Portugal	5	5	5	5	5
Russia	1,000	1,000	1,000	1,000	1,000
United States 6/ (mine shipments)	4,330 4/	5,040 4/	5,260 4/	5,770 4/	6,080 4/
Zambia	1	1	1	1	1
Total	5,440	6,180	6,380 r/	6,910	7,220

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 11, 1999.
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.