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, resistance to corrosion from acids, and electrical and thermal conductivity, that make it useful for various applications in its alloyed, oxide, and metallic forms. Only two beryllium minerals, beryl and bertrandite, are of commercial importance; beryl contains about 4% Be and bertrandite contains less than 1% 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 2001, 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 2000 (table 1). Computers and telecommunications were the major markets for beryllium.

The Defense National Stockpile Center (DNSC), U.S. Department of Defense, offered and sold selected beryllium materials from the National Defense Stockpile (NDS). The Generalized System of Preferences (GSP), a renewable preferential trade program, was allowed to expire after September 30, 2001. Most beryllium price quotations remained unchanged. Overall U.S. exports and imports of beryllium in 2001 were up significantly compared with those in 2000.

Legislation and Government Programs

To ensure a supply of beryllium during an emergency, various materials have been purchased for the NDS. The stockpile goal for beryllium metal, effective as of December 28, 2001, was about 45 metric tons (t), (table 2). For fiscal year (FY) 2001 (October 1, 2000, through September 30, 2001), the DNSC sold about 1,260 t of beryllium copper master alloy (BCMA) valued at about $7.62 million and about 23 t of beryllium metal valued at about $3.62 million from the NDS. There were no sales of beryl ore in FY 2001. As of September 30, 2001, beryllium inventory sold but not shipped from the NDS included about 836 t of beryl ore; about 388 t of BCMA; and about 33 t of beryllium metal (U.S. Department of Defense, 2002, p. 12-13, 49, 56).

In its revised Annual Materials Plan for FY 2002 (October 1, 2001, through September 30, 2002), the DNSC had authority to sell about 3,630 t of beryl ore, about 2,000 t of BCMA, and about 36 t of beryllium metal (Defense National Stockpile Center, 2002; U.S. Department of Defense, 2002, p. 9). The National Defense Authorization Act for FY 2000 (Public Law 106-65, October 5, 1999) authorized 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 "(1) 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, 2002, p. 34-35). For FY 2002, through March 31, 2002, there were no sales of beryllium materials from the NDS. The DNSC also proposed maximum disposal limits in FY 2003 of about 2,720 t of beryl ore (actual quantity limited to the remaining sales authority or inventory), about 907 t of BCMA (actual quantity limited to the remaining sales authority or inventory), and about 36 t of beryllium metal (Bureau of Export Administration, 2001).

Under the GSP, the United States grants duty-free access to eligible products from designated developing countries. In 2001, 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, 2000). The GSP program was allowed to expire after September 30, 2001, temporarily ending duty-free treatment for imports of selected goods from qualifying developing countries and territories. In October 2001, the U.S. Customs Service provided notice to importers that claims for duty-free treatment under GSP would not be processed by Customs for merchandise entered or withdrawn from a warehouse for consumption on or after October 1, 2001. The notice also set forth the mechanisms that would facilitate refunds, should the GSP be renewed with retroactive effect (U.S. Customs Service, 2001). Categories of U.S. imports from developing countries affected by the GSP included all beryllium tariff articles except BCMA NTR, beryllium ores and concentrates, and beryllium unwrought waste and scrap, for which the general rate of duty already was zero. The GSP program had not been renewed at yearend 2001.

Production

The U.S. Geological Survey collects beryllium data from two voluntary surveys of U.S. operations. In 2001, respondents 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 negligible quantities of byproduct beryl, which have not been included. In 2001, domestic mine shipments were down significantly compared with that of 2000, a decrease in overall beryllium demand and increased beryl ore imports contributed to the decline.

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 Inc., Cleveland, OH, 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, metal, and oxide.

NGK Metals Corp., headquartered in Reading, PA (a subsidiary of NGK Insulators, Ltd. of Japan) produced beryllium alloy products at a plant in Sweetwater, TN. Because NGK Metals does not have facilities to process beryllium ores and concentrates, the company purchases beryllium hydroxide 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. The U.S. Environmental Protection Agency 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; collecting dust, fumes, and mists at the source of deposition; establishing medical programs; and implementing other procedures to provide safe working conditions. Standards for exposure to beryllium were under review (Petkof, 1985, p. 80; Rossman, Preuss, and Powers, 1991, p. 278-280; Kramer, 1998, p. 107-108; Brush Engineered Materials Inc., 2002, p. 5, 6, 16). Control of potential health hazards adds to the final cost of beryllium products.

Consumption

In 2001, beryllium-containing ore consumption was down significantly compared with that of 2000. According to its annual report, Brush Engineered Materials Inc.'s worldwide sales were about $473 million in 2001 compared with about $564 million in 2000. The domestic market accounted for 72% of the company's revenue, with computer and telecommunications (42%) the leading revenue market. The Metal Systems Group (MSG), which included Brush Wellman Inc.'s Alloy Products and Beryllium Products business units, had sales of about $296 million compared with about $378 million in 2000 and accounted for 63% of total company revenues. Alloy Products, the company's largest business unit, accounted for more than 40% of company sales and assets, supplying strip and bulk products. Alloy strip products (primarily copper beryllium and nickel beryllium alloys) accounted for about 74% of total MSG sales. Strip product sales, in dollars, and the quantity of material sold were down by 23% and 29%, respectively, compared with that of 2000. Alloy bulk products (consisting of aluminum-, copper-, and nickel-based alloys) sales, in dollars, and quantity of material sold were down by 10% and 13%, respectively. Beryllium Products, the company's smallest business, supplies beryllium aluminum alloys and beryllium metal and accounts for more than 9% of MSG sales. Sales were up by 11% compared with sales in 2000, owing to improved defense-related demand and increased sales of acoustic components for high performance loudspeaker applications. Company international sales totaled about $134 million ($86.8 million from international operations and $47.5 million from U.S. operations' exports) compared with about $150 million in 2000. Company international sales were mostly to Asia, Canada, and Western Europe. In 2001, sales to Asia and Europe decreased, while sales to Canada increased compared with those of 2000. Automotive and computer electronics and telecommunications were the major markets served by the international operations (Brush Engineered Materials Inc., 2002, p. 1-3, 12-13, 15).

In response to overall declining company sales, Brush Engineered Materials initiated some cost reduction actions in the second quarter 2001. "Total manpower was reduced by 22% by yearend 2001 compared to the beginning of the year. In addition, various facilities operated at 32-hour work weeks for a large portion of the year. Other cost reduction efforts included changes to employee benefits, elimination or reduction of outside service contracts and use of various consultants, and the closing of a domestic service center and renegotiation of supply agreements" (Brush Engineered Materials Inc., 2002, p. 10).

U.S. apparent consumption of all beryllium materials was estimated to be about 230 t of contained beryllium in 2001 compared with about 300 t in 2000.

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 connectors, springs, and switches for use in applications in aerospace, automobiles, computers, factory automation, home appliances, instrumentation and control systems, and radar and telecommunications. 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 glass, metal, and plastic components.

Beryllium also is used in small quantities in aluminum- and nickel-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 by 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 inertial guidance systems, military aircraft brakes, satellite and space vehicle structures, 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 audio components, high-speed computer components, and mirrors. In the U.S. space shuttles, some brake components and structural parts use beryllium.

Beryllium Oxide.—Beryllium oxide (beryllia) is an excellent heat conductor, with a high level 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. Published prices for most beryllium materials remained unchanged throughout the year, with the exception of beryllium metal. In October, the price for 99% beryllium metal powder decreased to a range of $350 to $400 per pound from $492 per pound and beryllium vacuum-cast ingot decreased to a range of $325 to $350 per pound from $421 per pound. The American Metal Market published prices for other selected beryllium products were as follows: beryllium-aluminum alloy, $260 per pound, unchanged since January 1995; BCMA, $160 per pound of contained beryllium, unchanged since August 1987; and beryllium-copper strip, $8.90 per pound, unchanged since January 1993. The Metal Bulletin published price for beryl ore was discontinued in October at a range of $75 to $80 per short ton unit of contained BeO.

Significant events affecting beryllium prices since 1958 include the following: 1969, bertrandite mine established in the United States providing a significant raw materials source; 1977, effects of inflation, increased energy costs, and additional costs associated with complying with air emission standards resulted in increased prices; 1979, beryllium metal price set by one producer; 1988, purchase of beryllium metal for the NDS; 1990, conversion of NDS beryl ore to beryllium metal for the NDS; and 1991, recession and dissolution of the U.S.S.R. (Cunningham, 1999).

Foreign Trade

Data for U.S. exports and imports are summarized in tables 4 and 5, respectively. Overall beryllium exports were up by almost 80% compared with those of 2000. In descending order, Japan, Canada, Norway, the Netherlands, and Brazil were the major recipients of the materials, with more than 70% of the total. Overall beryllium imports increased significantly, owing to a rise in beryl ore imports from Brazil and a significant increase in BCMA from Russia. The schedule of tariffs applied during 2001 to U.S. imports of selected beryllium materials is found in the U.S. International Trade Commission's Publication 3378, 2001 Harmonized Tariff Schedule of the United States (U.S. International Trade Commission, 2000).

Net import reliance as a percent of apparent consumption is used to measure the adequacy of current domestic beryllium production to meet U.S. demand. For 2001, net import reliance as a percent of apparent consumption was estimated to be about 57% compared with about 37% in 2000. In descending order, Kazakhstan, Brazil, the Philippines, and Russia were the major sources for U.S. beryllium imports, on the basis of contained beryllium, accounting for more than 90% of the total. Other sources of imports were Canada, Estonia, Germany, South Africa, and the United Kingdom.

The U.S. Census Bureau does not separately identify all imports and exports of beryllium 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 1,400 t, gross weight, of beryllium products (mostly beryl ore from Brazil and beryllium-copper from Japan) was imported in 2001. Exports of beryllium products (mostly beryllium-copper) totaled about 560 t, gross weight; France, Hong Kong, and Japan received most of this material.

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. In 2001, estimated world beryl production (including bertrandite ore) decreased by more than 30% compared with that of 2000, because of a significant decline in production in the United States. The two major producers, Russia and the United States, accounted for more than 95% of total production.

In 2000, Japan's demand for beryllium-copper alloys rose by 10% to about 2,400 t, with consumption mostly by the computer and telecommunication industries. NGK Insulators, Nagoya, the only Japanese producer of beryllium-copper alloys and supplier to 90% of the domestic user market, recorded about a 15% increase in sales by its electronics business for the year ending March 2001. NGK produces beryllium-copper alloys at its Chita plant in Handa City, Aichi Prefecture. The plant's average production output was about 350 metric tons per month (t/mo) during the first half of 2001. NGK's worldwide production capacity (including plants in France, Japan, and the United States) was expected to be about 600 t/mo in 2001 (Metal Bulletin Monthly, 2001).

Outlook

Beryllium alloys, primarily beryllium-copper, are expected to remain the dominant form of consumption for beryllium. Beryllium demand from the telecommunications sector, which is the largest market, was declining. For the medium term, the decline in demand from the telecommunications sector was expected to be offset by increased demand for beryllium-copper in automotive electronics and computers. Demand for beryllium-copper products for undersea communications

equipment and pipe products for the oil and gas industry was also expected to increase. Beryllium-aluminum alloys containing up to about 65% beryllium, compared with beryllium-copper alloys containing about 2% beryllium, may stimulate demand in applications such as aerospace and computers. Beginning in 2003, annual world beryllium consumption was forecast to increase by about 2% per year (Roskill Information Services Ltd., 2001, p. 1-5, 120-123).

The United States is expected to remain self-sufficient with respect to most of its beryllium requirements. In 2001, the United States consumed about 170 t of beryllium contained in beryllium-bearing ores, compared with about 240 t in 2000. Brush Engineered Materials reported proven bertrandite reserves in Juab County, UT, of about 6.6 million metric tons at yearend 2001, with an average grade of 0.268% beryllium. This represents about 17,700 t of contained beryllium, compared with about 18,300 t in 2000. About 87% of the beryllium is recovered from the ore during the extraction process. In 2001, Brush Engineered Materials purchased land and mineral rights previously leased by the company's mining operations in Utah and land adjacent to its Utah extraction plant for $1.3 million. In lieu of leasing, the company now "owns approximately 95%" of its proven mineral reserves (Brush Engineered Materials Inc., 2002, p. 17-18).

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TABLE 1
SALIENT BERYLLIUM MINERAL STATISTICS

(Metric tons, beryllium metal equivalent)

	1997	1998	1999	2000	2001
United States:					
Beryllium-containing ores:					
Mine shipments	231	243	200	180	100
Imports for consumption, beryl 1/	9	13	1	--	19
Consumption, reported	259	270 r/	260	240	170
Yearend stocks	110	80 r/	20 r/	115 r/	100
World, production 1/	276	289	248	226	145

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

TABLE 2
BERYLLIUM IN GOVERNMENT INVENTORIES
AS OF DECEMBER 31, 2001

(Metric tons, beryllium content)

Material	Stockpile goal 1/	Disposal authority	National Defense Stockpile inventory	
			Uncommitted	Committed
Beryllium ore	--	281	281	54
Beryllium-copper master alloy	--	41	41	10
Beryllium metal	45	252	298	15

-- Zero.
1/ Goal effective as of December 28, 2001.

Source: Defense National Stockpile Center.

TABLE 3
YEAREND BERYLLIUM PRICES, 2001

(Dollars per pound unless otherwise specified)

Material		Price
Beryl ore	per short ton unit of contained BeO	(1/)
Beryllium vacuum-cast ingot, 98.5% pure, in lots up to 1,000 pounds		$325-$350
Beryllium metal powder, in 1,000- to 4,999-pound lots and 99% pure		350-400
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		100

1/ The published price for beryl ore was discontinued in October at a range of $75 to $80.

Sources: American Metal Market, Brush Wellman Inc., Metal Bulletin, and Platts Metals Week.

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

(Gross weight)

Country	2000		2001	
	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)
Brazil	582	$9	5,880	$76
Canada	1,670	40	11,800	319
Chile	1	7	4,340	844
France	5,880	1,270	3,180	609
Japan	6,440	1,470	13,600	2,880
Mexico	170	29	3,680	136
Netherlands	4,860	226	6,000	311
Norway	--	--	6,890	65
Other	14,300 r/	2,360 r/	5,190 3/	1,950 3/
Total	33,900	5,410	60,600	7,190

r/ Revised. -- Zero.
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.
3/ All or part of these data have been referred to the U.S. Census Bureau for verification.

Sources: U.S. Census Bureau and U.S. Geological Survey.

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

(Gross weight)

Material	2000		2001	
	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)
Beryl ore	--	--	482,000	$237
Beryllium-copper master alloy	149,000	$2,480	264,000	1,760
Beryllium oxide and hydroxide	4,790	31	5,400 2/	197 2/
Beryllium, unwrought and waste and scrap	10,400	753	86,800 2/	3,430 2/

-- Zero.
1/ Data are rounded to no more than three significant digits.
2/ All or part of these data have been referred to the U.S. Census Bureau for verification.

Sources: U.S. Census Bureau and U.S. Geological Survey.

TABLE 6
WORLD ANNUAL BERYL PRODUCTION CAPACITY,
DECEMBER 31, 2001 1/

(Metric tons, beryllium content)

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
Grand 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/	1997	1998	1999	2000	2001
Brazil	7 4/	5 4/	11 4/	13 r/ 4/	13
Kazakhstan	100	100	100	100	100
Madagascar 5/	28	30	20 r/	25	25
Portugal	5	5	4	4	5
Russia	1,000	1,000	1,000	1,000	1,000
United States (mine shipments) 6/	5,770	6,080	5,070	4,510	2,480
Zambia 5/	3 r/	3 r/	3 r/	3 r/	3
Total	6,910	7,220	6,210 r/	5,660 r/	3,630

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, 2002.
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.