BERYLLIUM

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The United States was the world's leading beryllium ore producer in 2004. U.S. mine shipments of beryllium ore increased from those of 2003; total ore consumption for the production of beryllium alloys, beryllium metal, and beryllium oxide, however, decreased (table 1). The Defense National Stockpile Center (DNSC), U.S. Department of Defense, offered and sold selected beryllium materials from the National Defense Stockpile (NDS). In 2004, total U.S. exports of beryllium decreased and total imports of beryllium increased compared with those in 2003.

Beryllium is gray in color and one of the lightest metals. Its other physical and chemical properties, such as outstanding stiffness-to-weight and strength-to-weight ratios, one of the highest melting points of all light metals, high specific heat, excellent thermal conductivity, outstanding dimensional stability over a wide range of temperatures, the lowest neutron absorption cross section of any metal and a high neutron-scattering cross section, and transparency to x rays, make it useful for many applications. Beryllium is used primarily as beryllium-copper alloys, beryllium oxide ceramics, and beryllium metal in a wide variety of products in aerospace, automotive electronics, computer, defense, electronics, heavy machinery, home appliance, industrial component, instrumentation and control system, medical, nuclear, oil and gas drilling, telecommunications, wireless, and other applications.

Only two beryllium minerals are of commercial importance for the production of beryllium. Bertrandite, which contains less than 1% beryllium, is the principal beryllium mineral mined in the United States. Beryl, which contains about 4% beryllium, is the principal mineral mined in the rest of the world. Aquamarine, bixbite, emerald, goshenite, heliodor, and morganite are gem forms of the mineral beryl. More information on gem-quality beryl and chrysoberyl can be found in the "Gemstones" chapter of the U.S. Geological Survey (USGS) Minerals Yearbook, volume I, Metals and Minerals.

Legislation and Government Programs

National Defense Stockpile.—The United States maintained a stockpile of strategic materials for use during a national emergency. As of December 31, 2004, the NDS goal for hot-pressed beryllium metal powder was 45 metric tons (t) (table 2). A goal of 155 t of hot-pressed beryllium metal powder, however, had been proposed in the 2003 "National Defense Stockpile Requirements Report to the Congress." The Annual Materials Plan (AMP) for fiscal year 2004, which represented the maximum quantities of beryllium materials that could be sold from October 1, 2003, through September 30, 2004, was as follows: 3,630 t of beryl ore (145 t of beryllium content; actual quantity limited to remaining sales authority or inventory), 1,090 t of beryllium-copper master alloy (BCMA) (44 t of beryllium content; actual quantity limited to remaining sales authority or inventory), and 36 t of beryllium metal. These quantities remained the same for fiscal year 2005 (October 1, 2004, through September 30, 2005) (U.S. Department of Defense, 2005, p. 6, 8, 50, 54).

During fiscal year 2004, the DNSC sold the following beryllium materials from the NDS: 1,700 t of beryl ore (68 t of beryllium content) valued at $148,000, 1,050 t of BCMA (42 t of beryllium content) valued at $6.48 million, and 27 t of beryllium metal valued at $4.55 million. The sales of BCMA depleted the NDS of this material. As of September 30, 2004, beryllium inventory sold but not shipped from the NDS included about 1,500 t of beryl ore (60 t of beryllium content), 913 t of BCMA (37 t of beryllium content), and 23 t of beryllium metal (U.S. Department of Defense, 2005, p. 10, 12, 49, 55).

During calendar year 2004, the DNSC sold the following beryllium materials: 1,700 t of beryl ore (68 t of beryllium content) valued at $148,000, 1,010 t of BCMA (40 t of beryllium content) valued at $6.25 million, and 27 t of beryllium metal valued at $4.55 million. NDS inventories of beryllium materials on December 31 are listed in table 2.

Research.—Engineers and scientists from the Air Force Research Laboratory in Dayton, OH, worked with material suppliers and spacecraft original equipment manufacturers to demonstrate the feasibility of using beryllium-aluminum alloys to make near-net-shape and net-shape component parts for spacecraft. The alloys, which contained 35% to 65% beryllium by weight, reduced the weight of vital spacecraft components while increasing payload and/or performance. This research increased the technology base and established cost-effective manufacturing capabilities for fabricating prototype components (Air Force Research Laboratory, 2004§[1]).

Production

Domestic production and consumption statistics for beryllium-containing ores, as listed in tables 1 and 4, are based on data collected by the USGS by means of two voluntary surveys of U.S. operations. A small number of unidentified producers may have shipped negligible quantities of byproduct beryl, but these have not been included. In 2004, domestic mine shipments were greater than those of 2003.

The United States is one of only three countries known to process beryllium ores and concentrates into beryllium products. Brush Resources Inc. [a subsidiary of leading beryllium producer Brush Engineered Materials Inc. (BEM)] extracted

[1]References that include a section mark (§) are found in the Internet References Cited section.

bertrandite from open pit mines in the Topaz-Spor Mountain region of Juab County, UT. Brush Resources converted the bertrandite, along with imported beryl and beryl from the NDS, into beryllium hydroxide at its operations near Delta, UT. Some of the beryllium hydroxide was shipped to Elmore, OH, where BEM subsidiary Brush Wellman Inc. converted it into beryllium alloys, metal, and oxide, and some was sold to other companies.

Environment

Because of the toxic nature of beryllium, various international, national, and State guidelines and regulations have been established regarding beryllium in air, water, and other media. Industry must maintain careful control over the quantity of beryllium dust, fumes, and mists in the workplace. Plants are required to install and maintain pollution-control equipment, and 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; establishing medical programs; and implementing other procedures to provide safe working conditions. Control of potential health hazards adds to the final cost of beryllium products (Petkof, 1985, p. 80; Rossman, Preuss, and Powers, 1991, p. 277-281; Kramer, 1998, p. 107-108; Agency for Toxic Substances and Disease Registry, 2002§).

Consumption

U.S. consumption of beryllium-containing ore decreased in 2004, even though BEM's worldwide sales increased by 24% in terms of dollar value. The increase in sales was attributed to a strong recovery in the telecommunications and computers market, improving domestic economic conditions, growing economic strength in Asia and Europe, and company initiatives to broaden its products and markets. Domestic sales accounted for 67% of BEM's revenue. Telecommunications and computers (41%), automotive electronics (12%), magnetic and optical data storage media (10%), aerospace and defense (10%), and industrial components (9%) were the leading revenue markets (Brush Engineered Materials Inc., 2005, p. 1-2).

BEM's Beryllium Products unit produced beryllium and two families of metal matrix composites, one made from aluminum and beryllium and the other made from beryllium and beryllium oxide. The products, in the form of rods, sheets, tubes, and a variety of customized shapes, were produced at plants in Elmore and in Fremont, CA. Sales by this unit were 12% higher than those of 2003 as a result of strong demand from the defense, other government, and medical sectors. In 2004, the unit began to supply beryllium blanks for the 6.5-meter diameter optical mirror for the National Aeronautics and Space Administration (NASA) James Webb space telescope. Shipments of beryllium blanks for this project are scheduled to continue through 2005 (Brush Engineered Materials Inc., 2005, p. 11, 17-18; Brush Wellman Inc., undated§).

BEM's Alloy Products unit produced copper- and nickel-base alloy products, the majority of which contained beryllium. Alloy strip products (which were used as connectors, contacts, switches, relays, and shielding) and alloy bulk products (including bar, plate, rod, tube, and customized forms) were produced at plants in Elmore and in Shoemakersville, PA. Alloy Products' sales were 25% higher than those of 2003 as a result of increased demand from the appliances, automotive electronics, industrial components, and telecommunications and computers markets and the introduction of new products and market share gains (Brush Engineered Materials Inc., 2005, p. 17).

Brush Ceramic Products Inc. (a subsidiary of BEM) produced beryllium oxide ceramic products for aerospace, automotive electronics, defense, medical, semiconductor, telecommunications, and wireless applications at its plant in Tucson, AZ. In 2004, sales of beryllium oxide ceramic products were approximately 14% higher than sales in 2003 as a result of improved demand from the telecommunications and computer market (Brush Engineered Materials Inc., 2005, p. 19; Brush Ceramic Products Inc., undated§).

BEM had agreements with the DNSC to purchase beryl ore, BCMA, and beryllium metal from the NDS. In 2004, BEM purchased beryllium materials valued at approximately $6.6 million to be used as raw material input for its operations. The agreements were scheduled to expire in 2007 (Brush Engineered Materials Inc., 2005, p. 48).

BEM also had a long-term supply arrangement with Ulba/Kazatomprom of Kazakhstan and its marketing representative RWE NUKEM, Inc., Danbury, CT, to purchase BCMA and beryllium vacuum-cast billet through 2012. In 2004, BEM purchased beryllium-containing materials valued at $5.9 million (Brush Engineered Materials Inc., 2005, p. 48).

Other domestic producers of beryllium alloy products included Applied Materials Science, Inc., Concord, MA; Freedom Alloys Inc., Royersford, PA; NGK Metals Corp. (a subsidiary of NGK Insulators, Ltd. of Japan), Sweetwater, TN; and Olin Corp.'s Brass Division, East Alton, IL. American Beryllia Inc. produced beryllium oxide ceramic products at its plant in Haskell, NJ.

U.S. apparent consumption of all beryllium materials was estimated to be about 69 t of contained beryllium in 2004. Apparent consumption for 2003, as calculated on the same basis, was 57 t. The increased demand in 2004 was met by higher shipments of beryllium materials from the NDS.

Recycling

Beryllium was recycled primarily from new scrap generated during the manufacture of beryllium-related components. Detailed data on the quantities of recycled beryllium are not available but may represent as much as 10% of U.S. apparent consumption (Cunningham, 2004, p. P1-P3).

Prices

Current prices for beryllium materials are no longer published in trade journals.

Foreign Trade

U.S. foreign trade in beryllium materials, as reported by the U.S. Census Bureau, is summarized in table 3. Beryllium exports decreased by 20% compared with those of 2003. Japan was the major recipient of these materials. Beryllium imports increased by 67% primarily because of increases in imports

of BCMA, beryllium oxide, and beryllium-copper alloy plate, sheet, and strip. Japan and Kazakhstan were the leading suppliers of these materials.

Net import reliance as a percentage of apparent consumption is used to measure the adequacy of current domestic beryllium production to meet U.S. demand. Net import reliance was defined as imports minus exports plus adjustments for Government and industry stock changes. Releases from stocks, including shipments from the NDS, were counted as part of import reliance regardless of whether they were imported or produced in the United States. In 2004, net import reliance as a percentage of apparent consumption indicated that the United States was a net exporter of beryllium.

Structure of the World Industry

In 2004, estimated world beryllium mine production increased by about 4% compared with that of 2003 (table 4). The United States accounted for nearly 80% of estimated world production.

World Review

China.—The Ningxia Non-ferrous Metals Smeltery (NNMS), its subsidiary Ningxia Orient Tantalum Industry Co., Ltd., and Shuikoushan Non-ferrous Metal Co., Ltd. (SNMC) produced beryllium products in various forms with an estimated combined production capacity of 20 metric tons per year (t/yr) of contained beryllium. SNMC and six other small metal producers from Hunan Province planned to join together to form a nonferrous metal conglomerate to improve their economies of scale and complement one another in resources, talent, and technology (McNeil, 2004; China Economic Information Network, 2004§).

Kazakhstan.—A 5-year investment program at Ulba Metallurgical Plant JSC (UMP) was scheduled for completion in 2005. The beryllium program had several components. One part of the program was to use carbothermic reaction technology to increase the production capacity for BCMA by 3,000 t/yr. A second part was to extend the beryllium-copper product range and increase the capacity to produce these products by up to 1,000 t/yr. Other parts of the program focused on introducing new techniques for converting beryllium concentrates using the existing 200-t/yr plant capacity and developing digestion and refining production methods to produce beryllium hydroxide to international standards. UMP's production reportedly is from stockpiled beryllium concentrate imported mainly from Russia (McNeil, 2004).

BerylliUM Ltd. (a joint venture between Moscow Non-Ferrous Metal Processing Works and UMP) began selling aluminum-beryllium master alloys produced by UMP. UMP opened an office in Shanghai, China, to improve access and increase sales to the Asian market (BerylliUM Ltd., 2004§; Ulba Metallurgical Plant JSC, 2004§).

Outlook

The United States is expected to remain self-sufficient with respect to most of its beryllium requirements. At yearend 2004, BEM reported proven bertrandite reserves in Juab County, UT, of about 6.02 million dry metric tons (6.64 million dry short tons) with an average grade of 0.268% beryllium. This represented about 16,100 t of contained beryllium, which would be sufficient for more than 100 years of operation based on average production levels in recent years. BEM owned approximately 95% of its proven mineral reserves and leased the remainder (Brush Engineered Materials Inc., 2005, p. 24).

BEM was scheduled to produce and deliver most of the blanks for the optical mirror for NASA's James Webb space telescope in 2005. The company forecast that its sales of beryllium products for defense applications could decrease in late 2005 and early 2006, depending on how Department of Defense spending is allocated (Brush Engineered Materials Inc., 2005, p. 11, 17-18, 27). Commercial demand for beryllium products will depend on the performance of the many diverse industries that use them. Industry sectors that use beryllium products include, but are not limited to, aerospace, automotive electronics, computers, electronics, heavy machinery, home appliances, industrial components, instrumentation and control systems, medical equipment, nuclear, oil and gas drilling, plastic processing, telecommunications, and wireless. BEM stated that the outlook in its key end-use markets was generally positive owing to the emergence of new wireless technologies, growth in information technology investment, increases in demand for heavy equipment, and expansion of exploration for oil and gas (Brush Engineered Materials Inc., 2005, p. 4).

World consumption of beryllium was forecast to increase by about 2% per year during the short to medium term. Production and stockpiles were expected to be sufficient to meet demand (McNeil, 2004).

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TABLE 1
SALIENT BERYLLIUM MINERAL STATISTICS

(Metric tons of beryllium content)

	2000	2001	2002	2003	2004
United States, beryllium-containing ores:					
Mine shipments	180	100	80	85	90
Imports for consumption, beryl[1]	--	19	11 r	9	--
Consumption, reported	240	170	120	140	130
Yearend stocks	115	100	90	45	40
World, production[e, 1]	202 r	120 r	102 r	108 r	112

[e]Estmated. [r]Revised. -- Zero.
[1]Based on a beryllium content of 4%.

TABLE 2
BERYLLIUM IN GOVERNMENT INVENTORIES AS OF DECEMBER 31, 2004

(Metric tons of beryllium content)

			National Defense Stockpile inventory	
Material	Stockpile goal[1]	Disposal authority	Uncommitted	Committed
Beryllium ore	--	149	149	60
Beryllium-copper master alloy	--	--	--	36
Beryllium metal:				
Vacuum-cast	--	67	67	(2)
Hot-pressed powder	45	110	155	(2)

-- Zero.
[1]Goal effective as of December 28, 2001.
[2]About 4 metric tons of beryllium metal committed for sale/pending shipment.

Source: Defense National Stockpile Center.

TABLE 3
U.S. FOREIGN TRADE OF BERYLLIUM MATERIALS, BY TYPE[1]

Type and material	2003 Gross weight (kilograms)	2003 Value (thousands)	2004 Gross weight (kilograms)	2004 Value (thousands)	Destinations and sources, 2004
Exports:					
Beryllium, unwrought[2]	174,000	$5,620	153,000	$7,320	Japan, 99%; other, 1%.
Beryllium waste and scrap	101	50	1,510	51	China, 55%; United Kingdom, 34%; Italy, 8%; Finland, 3%.
Beryllium, other[3]	94,800	13,100	62,500	12,200	Canada, 29%; Germany, 14%; Japan, 14%; France, 11%; United Kingdom, 10%; Netherlands, 6%; Republic of Korea, 4%; Singapore, 4%; other, 8%.
Total	269,000	18,800	217,000	19,600	Japan, 74%; Canada, 8%; Germany, 4%; France, 3%; United Kingdom, 3%; Netherlands, 2%; other, 6%.
Imports:					
Beryllium ores and concentrates	237,000	128	--	--	
Beryllium oxide and hydroxide	25	6	31,000	351	Ireland, 81%; United Kingdom, 11%; Germany, 6%; Brazil, 2%.
Beryllium, unwrought[2]	5,970	42	6,270	882	Kazakhstan, 100%.
Beryllium waste and scrap	101,000	670	17,200	51	Singapore, 99%; Germany, 1%.
Beryllium, other[3]	45,900	2,220	29,700	2,140	Kazakhstan, 97%; Japan, 2%; United Kingdom, 1%.
Beryllium-copper master alloy	20,000	200	511,000	5,630	Kazakhstan, 62%; Japan, 36%; Germany, 2%.
Beryllium copper plates, sheets, and strip	357,000	2,790	685,000	5,170	Japan, 99%; other, 1%.
Total	767,000	6,050	1,280,000	14,200	Japan, 68%; Kazakhstan, 28%; Ireland, 2%; other, 2%.

-- Zero.

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

[2]Includes powders.

[3]Includes articles not elsewhere specified.

Source: U.S. Census Bureau.

TABLE 4
BERYL: ESTIMATED WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons of gross weight)

Country[3]	2000	2001	2002	2003	2004
Brazil	13 [4]	-- [r]	7 [r]	6 [r]	6
China	500	500	500	500	500
Kazakhstan[5]	-- [r]	-- [r]	-- [r]	-- [r]	--
Madagascar[6]	2 [4]	1 [4]	1	1	1
Mozambique	19 [4]	1 [4]	54 [4]	78 [4]	78
Portugal	4	5	5	5	5
Russia[5]	-- [r]	-- [r]	-- [r]	-- [r]	--
United States, mine shipments[7]	4,510	2,480	1,970	2,100	2,210
Zambia	7	7	7	7	7
Total	5,060 [r]	2,990 [r]	2,540 [r]	2,700 [r]	2,810

[r]Revised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through June 11, 2005.

[3]In addition to the countries listed, Uganda produced beryl, and Nigeria may also have produced beryl, but information is inadequate to make reliable estimates of production. Other nations that produced gemstone beryl may also have produced some industrial beryl.

[4]Reported figure.

[5]Mine production is believed to have ceased in the 1990s.

[6]Includes ornamental and industrial products.

[7]Includes bertrandite ore, calculated as equivalent to beryl containing 11% beryllium oxide.