BERYLLIUM

By Deborah A. Kramer

Beryllium, a material valued for its light weight and stiffness, is used in a wide number of applications where these properties are important. In 1996, production of beryllium ore increased from the 1995 level, and total consumption of end products—beryllium alloys, beryllium metal, and beryllium oxide—also increased. *(See table 1.)* The introduction of new beryllium-aluminum alloys is opening new markets, in both the defense and commercial sectors, for beryllium products.

Legislation and Government Programs

On March 14, Brush Wellman Inc. filed a petition with the U.S. International Trade Commission alleging that the U.S. beryllium industry was threatened with material injury by imports of beryllium metal and high-beryllium alloys from Kazakstan. The imports covered under this investigation were beryllium metal in ingot, billet, powder or block form, which is traded under the Harmonized Tariff Schedule of the United States (HTS) subheadings 8112.11.30 and 8112.11.60, and beryllium alloys containing greater than 30% beryllium by weight, particularly aluminum-beryllium alloys covered under HTS 7601.20.90 (U.S. International Trade Commission, 1996). On August 28, the International Trade Administration made a preliminary determination that beryllium metal and high-beryllium alloys from Kazakstan would be subject to a dumping margin of 70.80% for the period of investigation of July 1, 1995, through December 31, 1995 (U.S. Department of Commerce, International Trade Administration, 1996). The final determination was scheduled for January 1997. The United States imported 23 metric tons of beryllium metal from Kazakstan in 1995.

In its Annual Materials Plan for fiscal year 1997, the Defense Logistics Agency (DLA) is authorized to dispose of a maximum of 1,800 metric tons of beryl ore. (This is the same quantity as was allowable in the 1995 and 1996 Annual Materials Plans, none of which has been sold.) On December 20, 1996, the Defense National Stockpile Center—DLA awarded the entire 1,800 tons to Muelege International for $400,000 (Defense National Stockpile Center, 1996). *(See table 2.)*

The Department of Energy (DOE) planned to hold two forums in January 1997 to collect scientific data and information to aid in developing occupational beryllium exposure standards for DOE employees and contractors. DOE was concerned that workers who were exposed to beryllium prior to 1989 were at risk for chronic beryllium disease, and the agency was concerned with potential exposure for workers participating in decontamination and decommissioning work in some of DOE's nuclear facilities in the future. Information gathered in the forums was expected be used in proposed rulemaking (U.S. Department of Energy, 1996).

Production

The United States is one of only three countries that can process beryllium ore and concentrates into beryllium products and supplies most of the rest of the world with these products. Brush Wellman mines bertrandite and converts this ore, along with beryl, into beryllium hydroxide at its facility in 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 announced plans to begin an expansion at its Elmore, OH, facility with new capacity to be operational by 1998. Additional equipment for melting, casting, rolling, and finishing beryllium-copper strip will constitute the bulk of the company's $110 million program. In conjunction with the capacity increase, the new equipment was expected to reduce production costs, reduce delivery times, and reduce work-in-process inventory requirements. No specific measure of increased capacity was announced (Metal Bulletin, 1996).

Beryllium data are collected from two voluntary surveys of U.S. operations. In 1996, there were four responses to the "Beryllium Mineral Concentrate and Beryllium Ore" survey, representing 100% of the total canvassed. 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.

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 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 1996 were $376.3 million, with international sales of $74.8 million. This was a 2% increase in sales from the 1995 level. Increases in sales of beryllium alloys more than offset declines in sales of beryllium metal and beryllium oxide ceramic material. Shipments of beryllium-copper alloys to the automotive electronics and telecommunications markets increased, and at the same time, beryllium oxide ceramic shipments to these same markets declined (Brush Wellman Inc, 1996).

Nuclear Metals Inc. (NMI) was awarded a trademark for its Beralcast® beryllium-aluminum alloy in 1996, which was expected to lead to new uses for the metal in investment castings in aerospace applications. Three military systems—the Army's RAH-66 Comanche helicopter, the Air Force's F-22 fighter plane, and the Army's PAC-3 missile system—already use Beralcast® investment castings. Beralcast® is 25% lighter and almost three times greater in stiffness than aluminum, which makes it suitable for aerospace and satellite applications.

NMI received several contracts for its Beralcast® components during 1996. The company received a $2.4 million add-on contract for prototype components for the Comanche helicopter from Lockheed Martin Inc., which required NMI to build an additional 23 prototype components over and 18-month period. This would bring the total number of NMI-produced prototypes to 36 (Nuclear Metals Inc., 1996c). NMI also was awarded a contract by Honeywell Satellite Systems for its Miniature Inertial Measurement Unit system. This guidance system will be used in some commercial satellites and represents the first use of Beralcast® investment castings for this type of application (Nuclear Metals Inc., 1996a). Lockheed Martin, through its subsidiary Sanders, awarded NMI a contract for Beralcast® components for use in its Advanced Threat Infrared CounterMeasures (ATIRCM) program. The ATIRCM program is the U.S. Department of Defense's next generation missile warning system, and systems are being designed for numerous Army, Navy, and Air Force aircraft. NMI anticipated that 200 systems per year will be constructed over the next 10 to 20 years, which have a sales potential of $20 million (Nuclear Metals Inc. 1996b).

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 (air bags). 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 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

Quoted prices for beryllium metal increased significantly from those at yearend 1995. The beryllium powder price

increased by 31%, and vacuum-cast beryllium ingot price increased by 6%. Published beryllium oxide price increased by 9%. *(See table 3.)*

Foreign Trade

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, 1,190 tons (gross weight) of beryllium-copper alloys in strip and billet form were imported in 1996, primarily from Japan. Exports of beryllium-copper alloys totaled 57 tons (gross weight), with Japan (44%) and Hong Kong (26%) as the principal recipients. *(See tables 4 and 5.)*

World Review

In Canada, interest was renewed in the Thor Lake beryllium property in the Northwest Territories. In May, Mountain Minerals Co. Ltd. purchased Conwest Exploration Co. Ltd.'s 34.7% interest in Highwood Resources Ltd., the largest owner of the Thor Lake property (North American Mineral News, 1996). In August, Mountain Minerals announced a plan to merge with Highwood Resources and planned to begin additional work on the Thor Lake property after the merger is complete. The company planned to conduct a feasibility study on the property to determine the economics of producing either beryllium oxide or beryllium metal (Platt's Metals Week, 1996). The project has been idle since 1990 when work on a pilot plant was halted because of insufficient sales commitments. Reserves at the property were estimated at 479,000 tons of ore grading 1.4% BeO and 1.3 million tons of ore, grading 0.66% BeO. *(See tables 6 and 7.)*

Outlook

Beryllium alloys are expected to remain the dominant form of consumption for beryllium. Consumption of alloys should continue to increase in the United States, particularly with the introduction of beryllium-aluminum alloys. Although applications using the new alloys are not as high-volume as traditional beryllium-copper alloy applications, each application contains more beryllium per use (greater than 60% vs. 0.5% to 2% for beryllium-copper).

The United States should be able to continue to supply its beryllium requirements with domestically mined ore. According to its annual report, Brush Wellman reports proven bertrandite reserves of 6.135 million tons at yearend 1996, with an average grade of 0.249% beryllium (Brush Wellman Inc., 1996). At an average annual U.S. consumption of 250 tons of beryllium, proven bertrandite reserves would last more than 60 years.

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TABLE 1
SALIENT BERYLLIUM MINERAL STATISTICS

(Metric tons of beryllium metal equivalent unless otherwise specified)

	1992	1993	1994	1995	1996
United States:					
Beryllium-containing ores:					
Mine shipments	193	198	173	202	211
Imports for consumption, beryl 1/	2	2	--	--	1
Consumption, reported	196	196	174	227	234
Yearend stocks	111	114	113	162	139
World: Production 1/	278	270	246 r/	274 r/	281 e/

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

TABLE 2
STOCKPILE STATUS, DECEMBER 31, 1996

(Metric tons, beryllium content)

Material	Goal	Uncommitted inventory	Authorized for disposal
Beryllium-copper master alloy	287	268	--
Beryllium metal	363	363	--
Beryllium ore	653	545	545

TABLE 3
YEAREND BERYLLIUM PRICES

(Dollars per pound unless otherwise specified)

Material		Price
Beryl ore	per short ton unit of contained BeO	$78- $85
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 98.5% 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 500-pound lots; 62% Be, 38% Al		260
Beryllium oxide powder, in 10,000-pound lots		77.00

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

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

	1995		1996	
Country	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)
Canada	6,640	$255	25,200	$683
France	10,700	2,270	3,530	749
Germany	16,500	338	5,490	792
Japan	19,000	1,620	4,380	905
Netherlands	341	104	5,760	247
Norway	--	--	5,970	51
United Kingdom	7,070	696	1,170	317
Other	1,000 r/	512 r/	5,220	762
Total	61,300	5,800	56,700	4,510

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 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/

	1995		1996	
Material	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)
Beryl ore	--	--	19,400	$9
Beryllium-copper master alloy	94,200	$880	31,300	549
Beryllium oxide and hydroxide	8,310	112	9,090	58
Beryllium, unwrought and waste and scrap	32,200	2,830	19,100	1,920

1/ Data are rounded to three significant digits.

Source: Bureau of the Census.

TABLE 6
WORLD ANNUAL BERYL PRODUCTION CAPACITY, 1/
DECEMBER 31, 1996

(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	5
Total	19
Asia: China	75
Europe:	
Kazakstan	7
Portugal	3
Russia	70
Total	80
South America:	
Argentina	4
Brazil	65
Total	69
Grand total	603

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)

Country 3/	1992	1993	1994	1995	1996
Argentina	34	35 4/	--	--	--
Brazil	850	850	900 r/	900 r/	850
Kazakstan	100	100	100	100	100
Madagascar 5/	3	3	3	3	3
Namibia	10	15 4/	15	15	--
Portugal	4	4	4	4	4
Russia	1,100	800	800	800	800
United States 6/ (mine shipments)	4,830 4/	4,940 4/	4,330 4/	5,040 4/	5,260 4/
Zambia	1	1	1	1	1
Zimbabwe (concentrate, gross weight)	23	(7/)	(7/)	(7/)	(7/)
Total	6,950	6,750	6,150 r/	6,860 r/	7,020

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 Apr. 8, 1997.

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.