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2017 Minerals Yearbook

BERYLLIUM [ADVANCE RELEASE]

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Beryllium

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On the basis of estimated beryllium content, U.S. mine shipments of beryllium ore in 2017 decreased by 3% to 150 metric tons (t) from 155 t in 2016, and reported consumption of ore for the production of beryllium hydroxide remained the same at 160 t (table 1). U.S. shipments and consumption of beryllium ore were at their lowest levels since 2009 (fig. 1). On the basis of estimated beryllium content, imports of beryllium materials decreased by 9% in 2017 from that of 2016, and exports of beryllium metal increased by 11% (table 3).

In 2017, estimated world beryllium ore production decreased by 4% compared with that of 2016 (table 4). The United States accounted for 71% of estimated world production, and China accounted for 23%. Beryl, a principal mineral of beryllium mined outside of the United States, is commonly stockpiled for later processing, and sales or exports may not accurately reflect current production. As a result, world production and the U.S. share of world production have a high degree of uncertainty.

Beryllium is gray in color and one of the lightest metals. Its physical and mechanical properties—outstanding stiffness-to-weight and strength-to-weight ratios, high melting point relative to other light metals, high specific heat, excellent thermal conductivity, outstanding dimensional stability over a wide range of temperatures, high reflectivity, lowest neutron absorption cross section of any metal and high neutron-scattering cross section, and transparency to X-rays—make it useful for many applications. Beryllium is used primarily in beryllium-copper alloys, beryllium oxide ceramics, and as beryllium metal in a wide variety of products, such as bearings and bushings, computer chip heat sinks, contacts and connectors, disc brakes, highly conductive and high-strength wire, mirrors, protective housings, switches and relays, and X-ray windows. Industries that use beryllium products include aerospace, automotive, computer, defense, electronics, energy, marine, medical, nuclear, and telecommunications.

The leading use for beryllium, accounting for about 75% of total world consumption, was in copper-base alloys containing from 0.2% to 2.0% beryllium. Beryllium enhances the strength, stiffness, and hardness of copper alloys while retaining relatively good ductility, machinability, and electrical and thermal conductivity. Beryllium-copper alloys are predominantly formed into strip products used as electrical connectors, contacts, relays, shielding, and switches, and as bulk products in the form of bars, plates, rods, and tubes. The second leading use of beryllium, consuming 20% of total world production, was as 99.5%-pure or greater beryllium metal and beryllium-base alloys containing greater than 60% beryllium (primarily alloyed with aluminum). Beryllium metal and alloys are typically used to produce components for high-technology equipment where low weight, low thermal distortion, and good machinability are critical factors. Beryllium oxide ceramics, which accounted for the remaining 5% of beryllium consumption, were used where electrical insulation and heat extraction are essential, such as automotive electrical systems, and heat sinks for radar and radio-frequency equipment (Trueman and Sabey, 2014, p. 101–103).

Only two beryllium minerals are of commercial importance for the production of beryllium. Bertrandite, which can contain as much as 15% beryllium, is the principal beryllium mineral mined in the United States; however, bertrandite ore mined in the United States contained about 0.25% beryllium by weight. Beryl, which can contain up to 5% beryllium, is the principal beryllium mineral mined in the rest of the world from ores typically grading 4% beryllium or less. Commercial beryl contains approximately 12% beryllium oxide, 19% aluminum oxide, 67% silicon dioxide, and 2% other oxides. Artisanal mining of the gemstone varieties of beryl, most notably aquamarine and emerald, is a primary source of byproduct beryl for beryllium extraction. 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

Because beryllium is toxic, various international, national, and State guidelines and regulations have been established to determine and monitor allowable beryllium content in air, water, and other media. Industry regulations require control of the quantity of beryllium dust, fumes, and mists in the workplace and effluent discharges.

Defense Production Act.—To ensure current and future availability of high-quality domestic beryllium to meet critical defense needs, in 2008, the U.S. Department of Defense (DOD), under the Defense Production Act Title III Program, invested in a public-private partnership with Materion Corp. (Mayfield Heights, OH) to build a primary beryllium facility in Elmore, OH. The facility was designed to produce high-purity beryllium metal from beryllium hydroxide sourced from Materion's Delta, UT, operation. Approximately two-thirds of the facility's output was to be allocated for defense and Government-related end uses; the remaining output was to go to the private sector. The plant, with a design capacity to produce 73 metric tons per year (t/yr) of beryllium metal, was placed into service in 2012 (Metal Bulletin, 2010; Materion Corp., 2018a, p. 53).

National Defense Stockpile.—The Defense Logistics Agency Strategic Materials, DOD, offered and sold selected beryllium materials from the National Defense Stockpile (NDS). At yearend 2017, the stockpile contained 74 t of beryllium metal, an excess to the NDS beryllium metal stockpile goal of 47 t. The Annual Materials Plan for fiscal year 2017, which represented the maximum quantities of beryllium metal that could be upgraded or disposed of from October 1, 2016,

through September 30, 2017, was 2 t, a decrease of 90% from that in fiscal year 2016. In calendar year 2017, the NDS sold approximately 2 t of beryllium metal. The NDS also upgraded beryllium hot-pressed metal powder into hot isostatic pressing structured metal powder to meet product specification for many modern DOD applications. This upgrading is most likely the reason for the large decrease in the fiscal year 2017 Annual Materials Plan. NDS calendar yearend inventories of beryllium materials are listed in table 2 (Defense Logistics Agency Strategic Materials, 2016).

Production

Domestic production and consumption data for beryllium-containing ores (tables 1, 4) were collected by the USGS from two voluntary surveys of U.S. operations. In 2017, 100% of the canvassed respondents replied to the survey. A small number of unidentified producers may have shipped minimal quantities of byproduct beryl, but these have not been included. In 2017, the only domestic beryllium mine shipped approximately 150 t of contained beryllium, 3% less than shipments in 2016.

The United States is one of only three countries known to process beryllium ores and concentrates into beryllium products. Materion converted bertrandite from open pit mines in the Topaz-Spor Mountain region of Juab County, UT, into beryllium hydroxide at its operations near Delta. Most of the beryllium hydroxide was shipped to Elmore, where Materion converted it into beryllium-copper master alloy (BCMA), metal, or oxide, and some was sold to NGK Insulators, Ltd. of Japan. In 2017, 96% of Materion's beryllium hydroxide was produced from bertrandite, and 4% was produced from imported beryl (Materion Corp., 2018a, p. 27). Very-high-purity beryllium is made exclusively from beryl, as beryl typically has fewer impurities (for example, fluorine and uranium) than bertrandite. Beryl-sourced high-purity beryllium is used in nuclear applications, where the absence of uranium in the beryllium allows for safe and timely disposal of nuclear waste containing beryllium, and in foil for use as X-ray windows for medical applications (Keith Smith, Vice President, Technology and Government Business Development, Materion Corp., oral commun., April 4, 2016).

Based on the expectation that worldwide stockpiles of beryllium concentrate were being depleted, Materion increased its capacity to produce beryllium hydroxide at its Delta plant in 2013 and, in 2015, invested $23 million to further develop its bertrandite pits in the Topaz-Spor Mountain region. In 2017, the capacity utilization of the Delta plant was 47%, up from 42% in 2016 (Materion Corp., 2014, p. 3; 2016, p. 2; 2018a, p. 27).

Consumption

In 2017, U.S. reported consumption of bertrandite ore and beryl for the production of beryllium hydroxide was approximately 160 t of contained beryllium, the same as that of 2016. U.S. apparent consumption of all beryllium materials in 2017, as calculated from mine shipments, net trade, and changes in Government and industry stocks, was estimated to be 181 t of contained beryllium, a slight decrease from that of 2016. Beryllium mine shipments and net imports decreased in 2017.

Materion produced beryllium hydroxide, beryllium products (including metal, metal-matrix composites, and ceramics), and beryllium strip and bulk products in its Performance Alloys and Composites segment. Materion produced two types of metal-matrix composites—one made from aluminum and beryllium, and the other made from beryllium and beryllium oxide (BeO or beryllia). Foil, rod, sheet, tube, and a variety of customized shapes were produced at plants in Elmore and in Fremont, CA. Beryllia ceramic products for aerospace, defense, electronics, medical, semiconductor, telecommunications, and wireless applications were produced at its plant in Tucson, AZ, and copper- and nickel-base alloy products, the majority of which contained beryllium, were produced at plants in Elmore and in Shoemakersville, PA. These included alloy strip products (which were used as connectors, contacts, relays, shielding, and switches) and alloy bulk products (including bar, plate, rod, tube, and customized forms).

In 2017, sales from the Performance Alloys and Composites segment increased by 18% from that of 2016, owing mostly to higher raw material sales of beryllium hydroxide and higher sales to the automotive electronics, consumer electronics, and industrial components markets. In 2017, consumer electronics and industrial component applications each accounted for 21% of the Performance Alloys and Composites value-added sales. The remaining sales were distributed as follows: automotive electronics, 14%; defense, 9%; telecommunications infrastructure, 7%; energy, 6%; medical, 2%; and other, 20% (Materion Corp., 2018a, p. 20; 2018c, p. 5).

IBC Advanced Alloys Corp. (Franklin, IN) manufactured beryllium-aluminum and beryllium-copper alloys and its proprietary Beralcast® alloys, which were castable beryllium-aluminum products, at plants located in Franklin, IN, New Madrid, MO, Royersford, PA, and Wilmington, MA. IBC had multiyear agreements to purchase beryllium metal and BCMA from the Ulba Metallurgical Plant (UMP) in Kazakhstan (IBC Advanced Alloys Corp., 2018, p. 1–7). The UMP is part of Kazatomprom JSC, the national operator for the nuclear industry in Kazakhstan.

Beryllium alloys were also manufactured domestically by Belmont Metals Inc. (Brooklyn, NY) and NGK Metals Corp. (Sweetwater, TN), a subsidiary of Japan's NGK Insulators, Ltd. American Beryllia Inc. (Haskell, NJ) manufactured beryllium oxide ceramic components and compound materials. American Elements (Los Angeles, CA) manufactured beryllium metal sheets and foil.

Recycling

Beryllium was recycled from new scrap generated during the manufacture of beryllium-containing components, as well as from old scrap collected from end users. Detailed data on the quantities of recycled beryllium were not available but may have represented as much as 20% to 25% of U.S. consumption. Beryllium products manufactured by Materion from recycled metal require only 20% of the full-cycle (mine through manufacture) energy as that of beryllium products manufactured from primary material. Materion established a comprehensive recycling program for its beryllium products and indicated a 40% beryllium recovery rate from processed new and old

beryllium scrap (Stephen Freeman, President, International Business Development, Materion Corp., oral commun., August 2, 2012).

Foreign Trade

U.S. foreign trade in beryllium materials, as reported by the U.S. Census Bureau, is summarized in table 3. On the basis of estimated beryllium content, total beryllium imports decreased by 9% compared with those of 2016. The leading suppliers of beryllium materials to the United States were, by beryllium content, Kazakhstan, Czechia, and Japan. By gross weight, the leading suppliers of beryllium materials to the United States were Japan, Kazakhstan, and Brazil.

On the basis of estimated contained beryllium, beryllium exports increased by 11% compared with those of 2016. Canada was the major recipient of exported beryllium metal, followed by Germany and France. The U.S. Census Bureau, however, only identifies exported beryllium metal; exported BCMA, and beryllium oxide and hydroxide, are not identified. According to Materion, BCMA typically accounts for about 85% of domestic beryllium exports, whereas beryllium metal typically accounts for less than 15% of exports (Stephen Freeman, President, International Business Development, Materion Corp., oral commun., January 10, 2013).

Net import reliance as a percentage of apparent consumption is one measure of the adequacy of current domestic beryllium production to meet U.S. demand. Net import reliance is defined as imports minus exports plus adjustments for Government and industry stock changes. Included among stock changes are acquisitions or shipments from the NDS, regardless of whether the materials were imported or produced in the United States. For 2017, net import reliance as a percentage of apparent consumption was 17%, an increase from 15% in 2016. Net import reliance as a percentage of apparent consumption decreased since its peak of 61% in 2010, owing mainly to increased U.S. beryllium metal production and a commensurate decrease in beryllium imports and Government stockpile shipments.

World Review

China.—Two facilities in China processed beryllium ores and concentrates into beryllium products—Hunan Shuikoushan Nonferrous Metals Group Co., Ltd. in Xinjiang Uygur Autonomous Region and Fuyun Hengsheng Beryllium Industry Co., Ltd. in Guangdong Province. In 2015, the last year with reported information, China produced approximately 100 t of beryllium, of which about 95 t was consumed in the production of beryllium-copper alloys, beryllium oxide ceramics, and beryllium metal. Approximately 50 t of the contained beryllium was sourced from domestic ore, and 50 t was obtained from Kazakhstan and other foreign sources (China Mining Association, 2016). In 2017, China was thought to have produced a similar amount of contained beryllium. China was thought to be the world's second leading beryllium-processing country (after the United States), surpassing Kazakhstan (Ron Gilerman, Managing Director, A&R Merchants, Inc., oral commun., August 10, 2017).

Kazakhstan.—The UMP produced about 95 t of beryllium contained in beryllium-copper alloys, beryllium oxide ceramics, and beryllium metal in 2017 (Kazatomprom JSC, 2018, p. 62), a 6% increase from that produced in 2016 (based on 2013 data—the last year with reported information until 2018) (Kazatomprom JSC, 2014, p. 33). Since the early 1990s, the UMP's production was sourced from beryllium concentrate stockpiled in Kazakhstan, which had accumulated prior to the breakup of the Soviet Union. The beryllium concentrate stockpile in Kazakhstan was still present but thought to be nearly depleted. The UMP's current primary source of beryllium concentrate was from a Soviet-era stockpile located in Russia. The Russian stockpile would support about 20 years of production, based on the UMP's current rate of consumption (Ron Gilerman, Managing Director, A&R Merchants, Inc., oral commun., August 10, 2017).

In 2017, Ulba-China Co., Ltd. (a subsidiary of the UMP based in Shanghai, China) accounted for 63% of Kazatomprom's sales of beryllium products by volume. The beryllium products were sold to customers in China, Japan, Malaysia, and the Republic of Korea. In addition, Tropag Oscar H. Ritter Nachf, GmbH in Germany, NGK Insulators, Ltd. in Japan, and IBC Advanced Alloys in the United States accounted for 18%, 10%, and 5%, respectively, of Kazatomprom's sales of beryllium products by volume (Kazatomprom JSC, 2018, p. 105).

Russia.—As of 2012, the last year with reported information, MBC Corp. (a subsidiary of Metropol Investment Group), Russia's state-owned Rusnano Corp., and technology specialists from a number of research institutions began work on reopening the Ermakovskoe bertrandite operation in the Siberian Republic of Buryatiya. Ermakovskoe was thought to be the largest identified beryllium deposit in Russia. The mining was to be carried out in two stages: open pit mining of 764,000 t of reserves followed by underground mining of the remaining 630,000 t of reserves (MBC Corp., 2009, 2011; Rusnano Corp., 2012). Recently, however, Russia's reopening of the Ermakovskoe operation has been reported to be on hold owing to a 2014 financial downturn in Russia. Kazakhstan's UMP was expected to continue supplying Russia with beryllium products (Ron Gilerman, Managing Director, A&R Merchants, Inc., oral commun., August 10, 2017).

In an effort to augment the beryllium metal imported by Russia, Russia's Industry and Trade Ministry financed research on beryllium metal production. At yearend 2015, Tomsk Polytechnic University and the Rare Metals of Siberia Research and Production Association jointly produced a total of 1 kilogram of beryllium metal. The Priargunsky Industrial Mining and Chemical Union in Krasnokamensk, Trans-Baikal Territory, was being considered for a concentrator, and the Siberian Chemical Combine in Seversk, Tomsk Region, was being considered for the beryllium hydrometallurgical plant. Commercial production of beryllium metal was expected to begin in 2019, with a planned production capacity of 30 t/yr of beryllium (Dragomanovich, 2015; Tass, 2015; Tomsk Polytechnic University, 2017).

Outlook

The United States is expected to remain self-sufficient with respect to most of its beryllium requirements. At yearend 2017, Materion reported proven reserves in Juab County, UT, of 7.37 million metric tons of bertrandite having an average grade of 0.248% beryllium and containing about 18,300 t of beryllium. Materion owned approximately 90% of its proven mineral reserves and leased the remainder from the State (Materion Corp., 2018a, p. 27).

In the first quarter of 2018, value-added sales for Materion's beryllium-rich Performance Alloys and Composites segment increased by 28% from those in the first quarter of 2017 owing to stronger demand in the commercial aerospace, consumer electronics, and industrial components markets (Materion Corp., 2018b, p. 23).

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TABLE 1
SALIENT BERYLLIUM STATISTICS[1]

(Metric tons, beryllium content)

	2013	2014	2015	2016	2017
United States, beryllium-containing ores:					
Mine shipments[2]	235	270	205	155	150
Imports for consumption, beryl[3]	8	9	18	12	5
Consumption, reported[4]	250	280	220	160	160
Stocks, December 31:					
Industry[2]	20	15	25	35	30
U.S. Government, beryl[3, 5]	(6)	(6)	(6)	(6)	(6)
World, production[e, 3]	296	338 [r]	265 [r]	221 [r]	212

[e]Estimated. [r]Revised.
[1]Table includes data available through July 27, 2018.
[2]Data are rounded to the nearest 5 metric tons.
[3]Based on a beryllium content of 4%.
[4]Data are rounded to the nearest 10 metric tons.
[5]Data from Defense Logistics Agency Strategic Materials.
[6]Less than ½ unit.

TABLE 2
U.S. GOVERNMENT NATIONAL DEFENSE STOCKPILE
BERYLLIUM STATISTICS IN 2017[1]

(Metric tons, beryllium content)

Material	Stockpile goal[2]	Annual Materials Plan[3]	Inventory, December 31
Beryl ore	--	--	(4)
Beryllium metal:			
Hot-pressed powder	(5)	(5)	60
Rods	--	--	(4)
Structured powder	--	--	7
Vacuum-cast	(5)	(5)	6
Total	47	2	74
Grand total	47	2	74

-- Zero.
[1]Table includes data available through July 27, 2018. Data were converted from gross weight reported in short tons; may not add to totals shown.
[2]Source: 2013 Biennial Report on Stockpile Requirements. Goal is for beryllium metal, excluding beryllium structured powder.
[3]Maximum quantity of material that can be upgraded or disposed during the 12-month period ending September 30, 2017.
[4]Less than ½ unit.
[5]Stockpile goal and Annual Materials Plan for beryllium metal included under "Total."

Source: Defense Logistics Agency Strategic Materials.

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

Type and material	2016 Gross weight (kilograms)	2016 Be content[2] (kilograms)	2016 Value (thousands)	2017 Gross weight (kilograms)	2017 Be content[2] (kilograms)	2017 Value (thousands)	Principal destinations or sources, based on gross weight, 2017
Exports:							
Beryllium, unwrought[3]	6,450	6,450	$272	1,920	1,920	$85	Argentina, 62%; Republic of Korea, 14%; Canada, 9%; Germany, 5%; United Kingdom, 5%; Lebanon, 4%.
Beryllium waste and scrap	--	--	--	3,290	3,290	191	Canada, 66%; Taiwan, 34%.
Beryllium, other[4]	28,000	28,000	20,700	33,000	33,000	21,400	Canada, 58%; Germany, 13%; France, 8%; Japan, 5%; United Kingdom, 4%.
Total	34,400	34,400	20,900	38,200	38,200	21,600	Canada, 56%; Germany, 11%; France, 7%; Japan, 4%; United Kingdom, 4%.
Imports for consumption:							
Beryllium ores and concentrates	292,000	11,700	837	120,000	4,780	197	Brazil, 67%; Canada, 33%.
Beryllium oxide and hydroxide	12,400	4,460	63	10,600	3,820	112	China, 45%; Republic of Korea, 45%; Japan, 10%.
Beryllium, unwrought[3]	69	69	21	2,340	2,340	38	Austria, 95%; Germany, 5%.
Beryllium waste and scrap	224	224	11	14,300	14,300	126	Czechia, 95%; Canada, 5%.
Beryllium, other[4]	39,600	39,600	2,140	23,500	23,500	1,960	Kazakhstan, 77%; Latvia, 12%; Canada, 7%.
Beryllium-copper master alloy	90,200	3,610	1,850	106,000	4,250	2,730	Kazakhstan, 89%; Germany, 8%.
Beryllium-copper plates, sheets, and strip	561,000	8,420	6,920	589,000	8,840	8,990	Japan, 98%.
Total	995,000	68,100	11,800	866,000	61,800	14,100	Japan, 67%; Kazakhstan, 13%; Brazil, 9%; Canada, 5%.

-- Zero.

[1]Table includes data available through July 27, 2018. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Estimated from gross weight.

[3]Includes powders.

[4]Includes articles not elsewhere specified.

Source: U.S. Census Bureau.

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

(Metric tons, gross weight)

Country or locality[3]	2013	2014	2015	2016	2017
Brazil[e]	110	160	100	120	80
China[e]	1,100	1,200	1,200	1,200	1,200
Madagascar[e, 4]	85	135	140	140	140
Mozambique	103	--	35 [r]	180 [r]	--
Nigeria	90 [e]	52 [r]	26 [r, e]	--	100 [e]
Rwanda	--	--	23 [r]	20 [r]	20 [e]
United States, mine shipments[5]	5,910	6,900	5,100	3,870	3,760
Total	7,400	8,440 [r]	6,630 [r]	5,530 [r]	5,300

[e]Estimated. [r]Revised. -- Zero.

[1]Table includes data available through May 31, 2018. All data are reported unless otherwise noted. Totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Unless otherwise noted, figures represent beryl ore for the production of beryllium and exclude gem-quality beryl.

[3]In addition to the countries and (or) localities listed, Kazakhstan, Portugal, Russia, and Uganda may also have produced beryl ore, but information was inadequate to make reliable estimates of production. Other nations that produced gemstone beryl ore may also have produced some industrial beryl ore.

[4]Beryl in quartz concentrates.

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

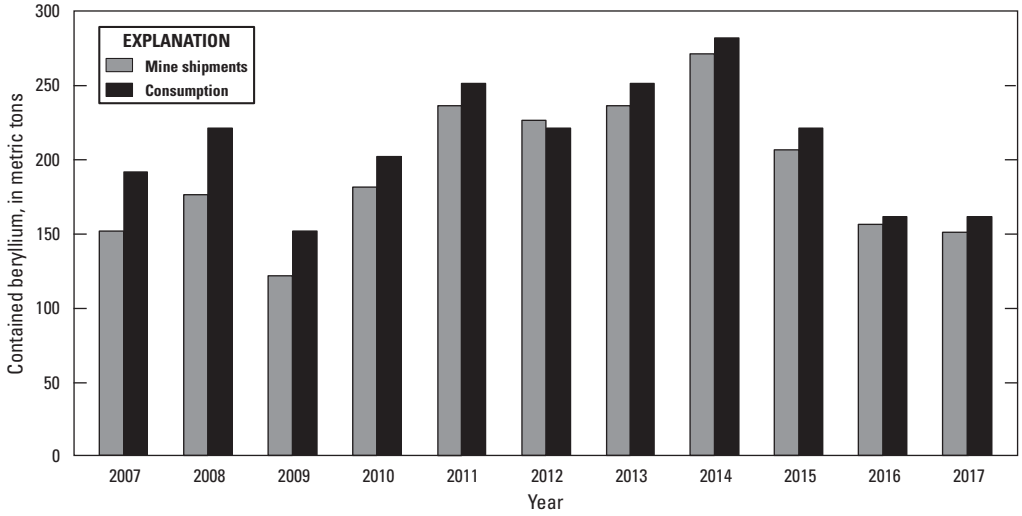

Figure 1. U.S. mine shipments and consumption of beryllium from 2007 through 2017.