BERYLLIUM

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Beryllium is a very light, strong metal with a high melting point of 1,280°C, which is resistant to acids and has a high thermal conductivity. These properties make it useful in a number of applications as a metal, as part of an alloy or as a ceramic. However, high processing costs restrict the use of beryllium to applications where there are no practical alternatives, or where performance is critical.

The majority of world beryllium ore production, around 80% in 2004, takes place in the US, as shown in Table 1. Most of the remaining output comes from China, Brazil and more recently Mozambique. Mining of beryllium minerals is also thought to have taken place in Madagascar, Portugal and Zambia but no official production statistics are available. Beryllium ore production in Russia and Kazakhstan stopped during the 1990s. Prior to 1997, beryllium mining was recorded in Argentina, Namibia and Zimbabwe.

Table 1: Production of beryllium ores by country, 1997 to 2004 (t gross weight)

	1997	1998	1999	2000	2001	2002	2003	e2004
Brazil	7	5	11	13	12	12	12	12
China[e]	500	500	500	500	500	500	500	500
Madagascar[e]	28	30	20	2	1	1	1	1
Mozambique	-	-	-	19	1	54	78	75
Portugal[e]	5	5	4	4	5	5	5	5
Russia[e]	70	-	-	-	-	-	-	-
USA[1]	5,770	6,080	5,070	4,510	2,480	1,970	2,100	2,250
Zambia[e]	3	7	7	7	7	7	7	7
World total	**6,383**	**7,145**	**5,612**	**5,036**	**3,005**	**2,495**	**2,525**	**2,850**

Note:e=estimated
1-Mine shipments including bertrandite ore calculated as equivalent to beryl containing 11% beryllium oxide

A possible new source of beryllium is the Etykinskoye rare metals operation in Russia owned by Zabailkalsky GOK. The plant, in operation since 2000, currently produces tantalum-niobium concentrate but there are future plans for the output of 20,000t/y of lithium and 30,000t/y of beryllium in concentrates. Zabailkalsky GOK is owned by JSC TVEL, part of the Ministry of the Russian Federation for Atomic Energy.

Brush Wellman is the sole US producer of beryllium ore and mines bertrandite in Utah. In China, the Ningxia Non-ferrous Metals Smeltery is reported to mine beryllium ores. In Brazil, Esmeralda de Conquista, part of the Mineração Badin Group, has reportedly stockpiled its production of beryl since the early 1990s but may have restarted exports in 2001. Piteiras Mineração of Minas Gerais produces beryllium concentrate based on industrial beryl and gems, which is further processed to produce emerald and industrial beryl.

Production by main companies

Brush Wellman of the US is the only known fully-integrated beryllium company in world. The Ningxia Non-ferrous Metals Smeltery (NNMS) of China produces beryllium from raw materials, possibly including imported material from Brazil. UMP of Kazakhstan uses stockpiled concentrates.

Brush Wellman is a wholly-owned subsidiary of a holding company, Brush Engineered Materials (BEM). Brush Wellman is part of the Metal Systems Division of BEM, which is further divided into Alloy Products, Technical Materials and Beryllium Products. The Microelectronics Division includes Brush Ceramics Products, which produces beryllium ceramics.

In 2004, reported sales by the Metal Systems Division were US$296 million compared with US$239.4 million in 2003 and US$378.2 million in 2000. Alloy Products accounted for 68.5% of sales, Technical Materials for 18.1% and Beryllium Products for 13.3%. By 2004, revenues from the Beryllium Products business had risen for five consecutive years, largely due to growing demand from the defence and medical sectors.

The amount of bertrandite ore processed by Brush Wellman fell from 113,000 t in 1998 to 41,000 t in 2003. Production of beryllium by the company is shown in Table 2. The company reports that the recovery rate of beryllium from the bertrandite is around 87%.

Table 2: Brush Wellman: estimated production of beryllium, 1999 to 2004

(tonnes Be content)[1]

	1999	2000	2001	2002	2003	2004
Bertrandite ore processed (t)	93,000	84,000	48,000	40,000	41,000	39,000
Beryllium grade (%)	0.215	0.217	0.219	0.232	0.232	0.248
Estimated beryllium output (100%)	199.95	182.28	105.12	92.80	95.12	96.72
Estimated beryllium output (87%)	173.96	158.58	91.45	80.74	82.75	84.15

Source: Brush Wellman and Roskill Information Services Ltd

Bertrandite is used to produce beryllium hydroxide concentrate at the company's Delta plant in Utah. The concentrate is then used to produce beryllium metal and alloys at Elmore in Ohio, ceramic grade powder at Lorain in Ohio and strip and wire products at Reading in Pennsylvania. The Elmore plant produces finished goods for the Alloy Products and Beryllium Products businesses, as well as materials for further processing by these units and Technical Materials. Ceramic powder from Lorain is also supplied to the company's plants in Tucson in Arizona and Newburyport in Massachusetts. The Electrofusion Products plant at Fremont California is a fully-integrated producer of beryllium windows.

In the US, NGK Metals, Starmet and Advanced Industries International produce beryllium products using raw materials supplied by Brush Wellman. Starmet,

formerly known as Nuclear Metals Inc, jointly developed beryllium-aluminium (BeAl) alloys with Lockheed. Starmet later developed a family of BeAl alloys under the trade name Beralcast®. In October 2000, Advanced Industries International purchased the National Beryllia Division of General Ceramics, which had been the second-largest US producer of beryllium oxide ceramics.

NGK Metals Corp, part of NGK Insulators of Japan, is one of the largest producers of beryllium-copper (BeCu) alloy castings, strip, rod, bar and plate products in the world from its plants in Japan, the US and France. The company is estimated to be capable of producing 600 t/mth of BeCu products. The Chita plant in Handa City, Aichi Prefecture in Japan can produce an estimated 400 t/mth following the installation of a mill-hardening furnace in 2000. The Chita plant melts and casts BeCu into billets. The Sweetwater plant in the US can produce an estimated 100 t/mth following the addition of the first BeCu alloy continuous caster in the world in 1998. Finally, the Coueron plant in France can produce an estimated 100 t/mth after a new pickling line was installed. NGK was also considering the addition of a new mill-hardening kiln to the Coueron plant but there have been no reports that this went ahead.

The Ulba Metallurgical Plant (UMP) in Kazakhstan was the largest beryllium product manufacturer in the former Soviet Union. The plant mainly used beryllium concentrate from mines in Russia but stopped imports in the mid 1990s, partly because it had accumulated considerable stocks of material. The lack of an export market eventually led to the end of Russian beryllium concentrate production during 1997. UMP reportedly holds sufficient stocks of beryllium concentrate to allow decades of production.

In August 2004, UMP set up Ulba-China in Shanghai to sell its beryllium and tantalum products in China and other Asian countries.

In September 2002, UMP and the Moscow Precious Metals Processing Plant (MZOTsM) established BerylliUM Ltd, a 50:50 joint venture. The joint venture was set up to increase sales of BeCu products in Russia. UMP supplies billets to MZOTsM for the production of BeCu and beryllium bronze products. In January 2003, BerylliUM started sales of BeCu products in Russia and Belarus. In June the company signed an agreement with Tropag Oscar H Ritter Nachf. GmbH of Germany for the sale of BeCu rolled products in Europe. In August, BerylliUM started sales of BeCu rod and wire and also rods, cast cylinder billet and plates made of CuCoBe alloy. In March 2004, the company started selling AlBe master alloy in ingot form produced by UMP.

In 2000, UMP restarted production of beryllium metal, followed in 2001 by technical grade beryllium hydroxide and BeCu. According to the National Statistical Agency of Kazakhstan, UMP produced 737 t of beryllium products in 2001, an increase of 71% on 2000 output. Production of unprocessed beryllium rose by 31% in the first half of 2002 compared with 2001. By 2005, beryllium production is forecast to be 900% higher than in 1999.

In 2000, UMP began a US$13 million five-year investment programme in its beryllium business that will include the following:

- BeCu master alloy (BCMA) capacity to be increased by 3,000 t/y using carbothermic reaction technology;

- development of digestion and refining production methods for beryllium hydroxide to international standards;

- Introduction of new techniques to convert beryllium concentrates using existing capacity of up to 200 t/y; and

- BeCu product range to be extended and capacity raised by up to 1,000 t/y.

In China, Ningxia Non-ferrous Metals Smeltery (NNMS) and its subsidiary Ningxia Tantalum Orient, both located in Inner Mongolia, produce BeCu strip, rods, wire and beryllium sheet and strip. NMMS is also reported to be the only domestic producer of beryllium raw materials. NNMS is currently looking to develop the 801 deposit in Eastern Inner Mongolia close to the border with Jilin Province. This contains estimated reserves of 21,500 t of Ta_2O_5, 370,000t of Nb_2O_5 and also beryllium, zirconium and rare earths. NNMS has reached an agreement with the relevant government departments to develop the deposit.

Shuikoushan Nonferrous Metal Co (SNMC) of Hunan Province reportedly operates a beryllium smelter and produces beryllium bronze cast alloy, beryllium oxide, beryllium beads and BeCu master alloy. In 2002, SNMC was reported to have significantly expanded its beryllium production capacity. The combined capacity of these two companies has been estimated at 500 t/y gross weight of beryl or about 20 t/y of beryllium, mainly in the form of beryllium copper alloys.

Applications

Alloys are the most common form of beryllium product, accounting for an estimated 75% of US consumption. In the US, ceramics (15%) incorporating beryllium oxide, also known as beryllia, are the next most important form of beryllium followed by metal (10%). Electronic and electrical components, aerospace and defence applications account for around 80% of US consumption.

Beryllium-copper alloys are the most commonly used beryllium products. These alloys are divided into high strength (typically containing 1.6-2% Be) and high conductivity (containing around 0.3% Be) types. High-strength alloys are used in telecommunications applications and high-conductivity alloys in automotive markets. Beryllium copper is also used in drilling equipment, aircraft landing gear and other heavy industrial machinery.

Beryllium-aluminium alloys are becoming increasingly important in terms of beryllium consumption because of their high beryllium content, up to 65% by weight. Applications include aerospace, hard disc drives and brakes.

Beryllium oxide ceramics have excellent electrical insulation properties and a high thermal conductivity. These characteristics, together with a high melting point of 2,570^{o}C and resistance to chemical attack, mean that beryllium oxide ceramics are used in a wide variety of applications in electronics. These include heat sinks for

electronic and microelectronic applications. Telecommunication and computer industries use beryllium oxide ceramics in substrates, where performance and the need for high levels of reliability and heat dissipation outweigh the cost.

Beryllium metal is used in military aircraft, spacecraft, inertial guidance systems, high performance brakes and space optical systems because of its strength, low weight and stability over a wide range of temperatures. Other uses for beryllium metal include in reflectors for research nuclear reactors and x-ray windows.

Trade

US trade in beryllium, either exporting beryllium products or importing raw or scrap materials for processing, is a major component of the world total. The US Government imposes import tariffs of 3.7% on beryllium oxide or hydroxide, 5.5% on wrought beryllium and 8.5% on beryllium waste and scrap on imports from countries with normal trade relations. All other forms of beryllium can be imported free of tariff.

The majority of reported world beryllium trade is in the form of waste, scrap, powder, wrought and unwrought material. The most commonly traded type of beryllium material is almost certainly beryllium-copper alloy but data are not generally available.

In 2000, Brush Wellman and UMP signed an agreement under which UMP would supply Brush Wellman with BeCu master alloys. This agreement was amended in 2001 and 2003 and the purchase commitments reduced. The 2003 amendment added beryllium vacuum cast billet and extended the agreement to 2012. UMP has also concluded supply agreements with Chinese organisations and in February 2003 exported an unreported amount of beryllium products to China. UMP was also reported to be planning to arrange “extremely large deliveries” of beryllium to China in the future and sees the Chinese market as “very important”. The opening of the Ulba China subsidiary in 2004 would seem to confirm this.

In 2001, 185 t of crude beryllium products were exported from Brazil, the first such exports since 1995. The majority, 89%, was exported to the US, almost certainly to Brush Wellman for use as feedstock. The material shipped was probably beryl from Esmeralda de Conquista. In 2002, a further 36 t of crude beryllium products were exported from Brazil to China. These exports continued in 2003 with 162 t sent to China.

The only known significant reported trade in beryllium oxide is between US and Chinese companies and consumers in Japan.

Stocks

The US Government has long held quantities of beryllium in the Defense National Stockpile Centre (DNSC) in order to guarantee supplies to the defence industry in times of conflict. These and stocks of other strategic metals and minerals have been progressively reduced over the past decade.

In Fiscal Year 2004, the NDSC sold 1,700 t of beryl ore and 1,048 t of beryllium copper master alloy. For Fiscal Year 2005, the DNSC has announced maximum

disposal limits of 3,630 t of beryl ore (around 145 t Be content), 1,090 t of BeCu master alloy (about 44 t Be content) and 36 t of beryllium metal. As of September 2004, the NDS held 3,681 t of beryl ore (11% Be), no beryllium copper master alloy, 67 t of vacuum cast beryllium metal and 155 t of high-purity beryllium metal.

Market trends

US consumption of beryllium is the largest of any country in the world and probably accounts for around half the global total. In the late 1990s and early 2000s, US consumption shrank sharply as demand from the domestic economy declined, particularly for BeCu products. This was offset to some degree by growth in the defence and aerospace sectors. Consumption began to recover in 2003 and seems to have continued to do so in 2004. Changes in US beryllium consumption are shown inTable 3.

Table 3: US apparent and reported consumption of beryllium, 1996 to 2004 (t)

	1996	1997	1998	1999	2000	2001	2002	2003	2004
Reported	234	259	270	260	240	170	120	140	…
Apparent	197	316	320	385	300	230	180	200	220

Source: USGS

World consumption of beryllium is forecast to rise slowly by perhaps 2% a year in the short to medium term. Production and stockpiles are sufficient to meet current and short/medium term demand. This is likely to discourage the development of new sources of beryllium raw materials apart from the Etykinskoye deposit in Russia and the 801 deposit in China.

BeCu alloys are the main form in which beryllium is used and this is expected to remain the case for the foreseeable future. The telecommunications and computer markets are expected to be the fastest growing in terms of consumption. Other markets where demand for BeCu alloys is also growing are in automotive electronics and industrial components.

Miniaturisation of electronic products requires the use of strong materials, such as BeCu alloys, able to cope with higher operating temperatures. The growth in the use of electrical components in automobiles and the use of higher voltages could lead to higher demand for BeCu alloys. The use of BeAl alloys in aerospace applications is growing, especially in defence projects, but from a low base. Demand for beryllium oxide ceramics for use as substrates is expected to rise, as ever more powerful computer chips generate larger amounts of heat that must be rapidly dissipated. Beryllium metal consumption remains concentrated in defence applications, such as refits of the F-16 and the new F22 fighter planes, and is unlikely to rise appreciably in the future outside of this market.