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Beryllium Recycling in the United States in 2000

By Larry D. Cunningham

U.S. GEOLOGICAL SURVEY CIRCULAR 1196–P

FLOW STUDIES FOR RECYCLING METAL COMMODITIES IN THE UNITED STATES

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FOREWORD

As world population increases and the world economy expands, so does the demand for natural resources. An accurate assessment of the Nation's mineral resources must include not only the resources available in the ground but also those that become available through recycling. Supplying this information to decisionmakers is an essential part of the USGS commitment to providing the science that society needs to meet natural resource and environmental challenges.

The U.S. Geological Survey is authorized by Congress to collect, analyze, and disseminate data on the domestic and international supply of and demand for minerals essential to the U.S. economy and national security. This information on mineral occurrence, production, use, and recycling helps policymakers manage resources wisely.

USGS Circular 1196, "Flow Studies for Recycling Metal Commodities in the United States," presents the results of flow studies for recycling 26 metal commodities, from aluminum to zinc. These metals are a key component of the U.S. economy. Overall, recycling accounts for more than half of the U.S. metal supply by weight and roughly 40 percent by value.

Charles G. Groat
Director

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Multiply	By	To obtain
metric ton (t, 1,000 kg)	1.102	short ton (2,000 pounds)
million metric tons (Mt)	1,102,000	short ton

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ABSTRACT

This report describes the flow of beryllium in the United States in 2000 with emphasis on the extent to which beryllium was either recycled or reused. Beryllium was recycled mostly from new scrap that was generated during the manufacture of beryllium-related components. In 2000, about 35 metric tons of beryllium was either recycled or reused, about 14 percent of which was derived from old scrap. The beryllium recycling rate was calculated to be about 10 percent, and beryllium scrap recycling efficiency, about 7 percent.

INTRODUCTION

This materials flow study of beryllium includes a description of beryllium supply and demand factors for the United States in 2000 to illustrate the extent of beryllium recycling[1] and to identify recycling trends. Figure 1 shows the beryllium recycling flow with domestic supply and distribution of domestic supply of primary and secondary beryllium in 2000.

Beryllium (Be) was discovered in 1797 as a constituent of the mineral beryl. The metallic form was isolated in 1828 and named beryllium. It was not until 1926, however, that the true value of beryllium was realized. Beryllium, which is 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, metallic, and oxide forms.

Salient beryllium statistics are based mostly on the beryllium content of beryllium-copper alloys and beryllium metal (table 1). In 2000, about 130 metric tons (t) of beryllium contained in old scrap was generated; about 5 t of beryllium valued at about $1.8 million was recycled or reused. The old scrap recycling efficiency was calculated to be about 7 percent, and the recycling rate, about 10 percent. Beryllium contained in new scrap consumed was about 30 t.

[1]Definitions for select words are found in the Appendix.

GLOBAL GEOLOGIC OCCURRENCE OF BERYLLIUM

The beryllium content of the Earth’s crust has been estimated to be 4 to 6 parts per million. Some 45 beryllium-containing minerals have been identified. Only two beryllium minerals, bertrandite and beryl, are of commercial importance; bertrandite contains less than 1 percent Be and beryl contains about 4 percent Be. Bertrandite is the principal beryllium mineral mined in the United States, and beryl is the principal mineral mined in the rest of the world. The only active U.S. beryllium mineral deposit (bertrandite) occurs in ore grades at Spor Mountain, northwest of Delta, Utah. The mountains are a tilted block of Paleozoic sediments overlain by a Tertiary volcanosedimentary sequence. The bertrandite occurs in water-lain Pliocene tuff, mainly in those parts that contain detrital Paleozoic carbonate pebbles. The tuff is overlain by a series of volcanic rocks, all of which are relatively impermeable compared with the tuff. Beryllium and fluorine-bearing hydrothermal solutions gained access to the tuff through numerous local faults and then spread laterally removing magnesium and calcium from the detrital carbonate fragments in the tuff and precipitating fluorite and bertrandite. Elsewhere, granite pegmatites are a significant source of the beryllium mineral beryl. Beryl has been mined from zones, fracture- filling units, and replacement bodies in heterogeneous pegmatites. The principal beryl deposits are zones. Most beryl-rich zones contain only a few thousand metric tons of ore, but a few may contain as much as 1 million metric tons (Mt). Beryl occurs in concentrations of approximately 2 percent in zones that contain muscovite mica, plagioclase, and quartz and also is as abundant in zones from which amblygonite, feldspar, and spodumene are recovered. Much of the fine- and medium-grained beryl of pegmatites in the Black Hills, South Dakota contains abundant inclusions of other minerals. Large masses of beryl that contain almost no inclusions have been found in inner zones and may extend across several zones. Beryl is evenly distributed in some deposits, but in others, it is irregularly distributed in rich aggregates in various parts of a zone. It has been found in quartz veins that contain cassiterite, molybdenite, wolframite, and other minerals. The concentration of beryl in the outer parts of these veins, just

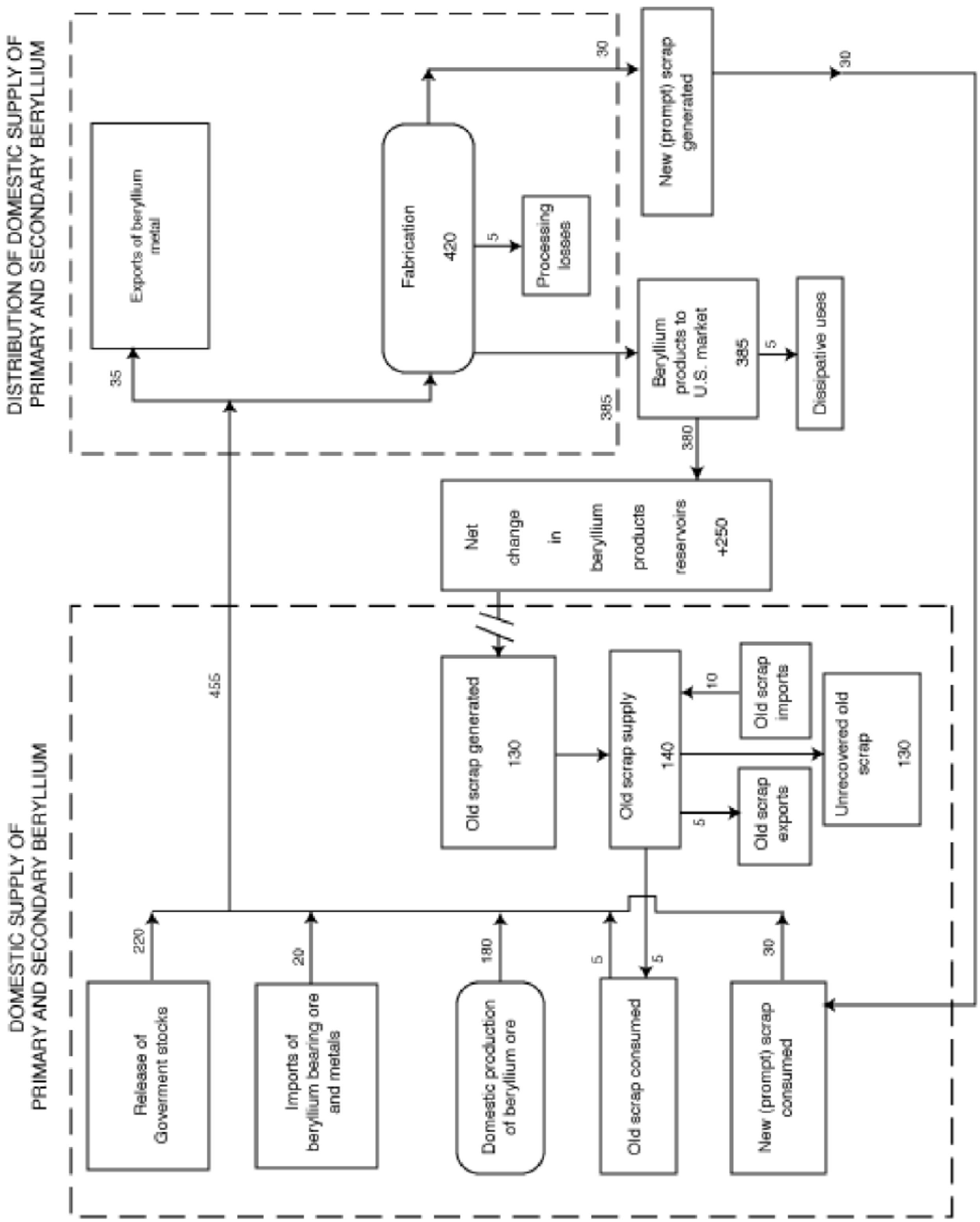

Figure 1. U.S. beryllium materials flow in 2000. Values are in metric tons of contained beryllium.

Table 1. Salient statistics for U.S. beryllium scrap in 2000.
[Values in metric tons of contained beryllium unless otherwise specified]

Old scrap:	
Generated[1]	130
Consumed[2]	5
Consumption value[3]	$1.8 million
Recycling efficiency[4]	7 percent
Supply[5]	140
Unrecovered[6]	130
New scrap consumed[7]	30
New-to-old-scrap ratio[8]	86:14
Recycling rate[9]	10 percent
U.S. net exports of scrap[10]	5
Value of U.S. net exports of scrap[11]	$700 thousand

[1]Beryllium content of products theoretically becoming obsolete in the United States in 2000; this excludes dissipative uses.

[2]Beryllium content of products that were recycled in 2000.

[3]Value of beryllium in materials used in calculating total value of contained metal in scrap.

[4](Old scrap consumed plus old scrap exported) divided by (old scrap generated plus old scrap imported).

[5]Old scrap generated plus old scrap imported.

[6]Old scrap generated plus old scrap imported minus old scrap consumed minus old scrap exported.

[7]Including prompt industrial scrap but excluding home scrap.

[8]Ratio of quantities consumed, in percent.

[9]Fraction of beryllium apparent supply that is scrap on an annual basis.

[10]Trade in scrap is assumed to be principally in old scrap.

[11]Value of U.S. net imports of scrap is the value of beryllium scrap imports minus value of exports as reported by the U.S. Census Bureau.

as beryl is concentrated in the outer part of quartz zones in some pegmatites, suggests that these quartz veins are genetically similar to pegmatite (Griffitts, 1973; Petkof, 1985; Soja and Sabin, 1986, p. 8–11; Stonehouse and others, 1992, p. 126; Kramer, 1993; Lindsey, 1998).

World resources of beryllium have been estimated to be more than 80,000 t (contained mostly in known nonpegmatite deposits). About 65 percent of the beryllium resources is concentrated in the United States; the Gold Hill and the Spor Mountain areas in Utah and the Seward Peninsula area in Alaska account for most of the total. The United States is expected to remain self-sufficient with respect to most of its beryllium requirements. At yearend 2000, reported proven bertrandite reserves in Juab County, Utah, totaled about 7 Mt with an average grade of 0.263 percent beryllium, or about 18,300 t of contained beryllium. About 87 percent of the beryllium is recovered from the ore mined at Spor Mountain during the extraction process (Griffitts, 1973; Cunningham, 2002, 2003).

PRODUCTION AND PRODUCTION PROCESSES

The United States is the world's largest producer of beryllium-containing ores and concentrates (bertrandite). Most of the beryllium-containing ores and concentrates (beryl) produced outside the United States are from Kazakhstan and Russia. Little is known, however, about the mining operations in Kazakhstan and Russia.

Beryl was essentially the only source of beryllium until the late 1960s when Brush Wellman Inc. (a subsidiary of the world's largest beryllium producer Brush Engineered Materials Inc., Cleveland, Ohio) began commercial extraction of bertrandite at Spor Mountain by open pit methods. Unlike beryl, in which the mineral can be identified by color and crystal structure, bertrandite mineralization cannot be recognized by the naked eye. Consequently, Brush Wellman conducts geologic and geochemical evaluations on a specific area followed by a drilling program to determine if an economic ore body exists. After delineating an ore body, overburden is removed during the winter and spring. Drill benches are constructed to take samples of the ore body to analyze for development of cross-sectional and contour maps. These maps are then used to plan the mining and processing operations. After the maps are prepared, the remainder of the overburden is removed, and the ore is mined typically by using a self-loading scraper. Because of the irregular ore-grade distribution in the ground, the ore is mined from predetermined areas and layered in a stockpile to obtain a homogeneous blend. Drilling, sampling, and assaying the stockpiled ore generates a map that identifies ore-grade distribution throughout the stockpile. Subsequently, the stockpiled ore is transported by truck from the mine site to Brush Wellman's beryllium processing facility near Delta, a trip of about 80 kilometers. Brush Wellman's plant is the only commercial facility in the United States that extracts beryllium from beryllium concentrates. To form a beryllium sulfate solution, bertrandite and imported beryl are crushed, leached with sulfuric acid, and heat treated to dissolve the contained beryllium. The solution undergoes solvent extraction and hydrolysis, which results in the formation of beryllium hydroxide. Brush Wellman uses the beryllium hydroxide at its plant in Elmore, OH, to produce beryllium alloys, metal, and oxide (Petkof, 1985; Soja and Sabin, 1986, p. 11–13; Roskill Information Services Ltd., 2001, p. 9–10).

Beryllium-copper master alloys are produced by combining beryllium hydroxide, carbon, and electrolytic copper in an electric arc furnace. The resultant melt, which contains about 4 percent beryllium, is cast into ingots. Remelting master alloy ingots with additional copper, other alloying elements, and new alloy scrap yields the desired beryllium-copper alloy, which is then cast into slabs or billets. Slabs of beryllium-copper alloys are processed further into plate or strip, and billets are extruded into bar, rod, tube, and wire products. Beryllium metal is produced by dissolving beryllium hydroxide in an ammonium bifluoride solution. The solution is concentrated in an evaporator to yield an ammonium beryllium fluoride salt. The salt is removed, and the cooled beryllium fluoride is reacted with magnesium in induction furnaces to produce metallic beryllium and magnesium fluoride. Cooling the mixture produces a solid cake that contains beryllium pebble, magnesium fluoride, and unreacted beryllium fluoride. Crushing this mixture followed by water leaching yields beryllium metal and magnesium fluoride. After separating the magnesium fluoride, the pebbles are vacuum melted to remove any slag trapped in them and cast into ingots. The ingots are further processed into a powder, which is produced by machining the ingots into chips followed by grinding. Beryllium oxide powder is produced by dissolving beryllium hydroxide in sulfuric acid. The resulting beryllium sulfate solution is concentrated by evaporation and then cooled producing beryllium sulfate crystals. Calcining the crystals at temperatures up to 1,430 °C produces beryllium oxide (Kramer, 1993).

USES

The use of beryllium as an alloy, metal, and oxide in electronic and electrical components and aerospace and defense applications accounts for an estimated 90 percent of total consumption. In 2000, estimated end uses for beryllium in the United States were electronic components, 60 percent; electrical components, 20 percent; aerospace, 10 percent; and other, 10 percent. U.S. beryllium consumption during the past 20 years is shown in figure 2. For most of the 1980s, primary uses for beryllium were for electrical components and in nuclear applications, such as nuclear reactors. In the late 1980s and early 1990s, beryllium demand was being influenced by the dissolution of the Soviet Union, a decline in Defense-related applications/procurement, and a downturn in the economy. By the end of the 1990s, the demand for beryllium was being driven by the emphasis on technology and miniaturization in telecommunications, automotive electronics, computers, and optical-media product applications.

Beryllium has physical and chemical properties, such as its stiffness, high resistance to corrosion from acids, and high thermal conductivity, that make it useful for various applications in its alloy, metallic, and oxide forms. Beryllium-copper alloys average about 70 percent of annual U.S. consumption on a beryllium metal equivalent basis. The alloys, most of which contain approximately 2 percent beryllium, are used in a wide variety of applications but mainly in electrical and electronic components, aerospace, and defense. These alloys are used because of their electrical and thermal conductivity, good corrosion and fatigue

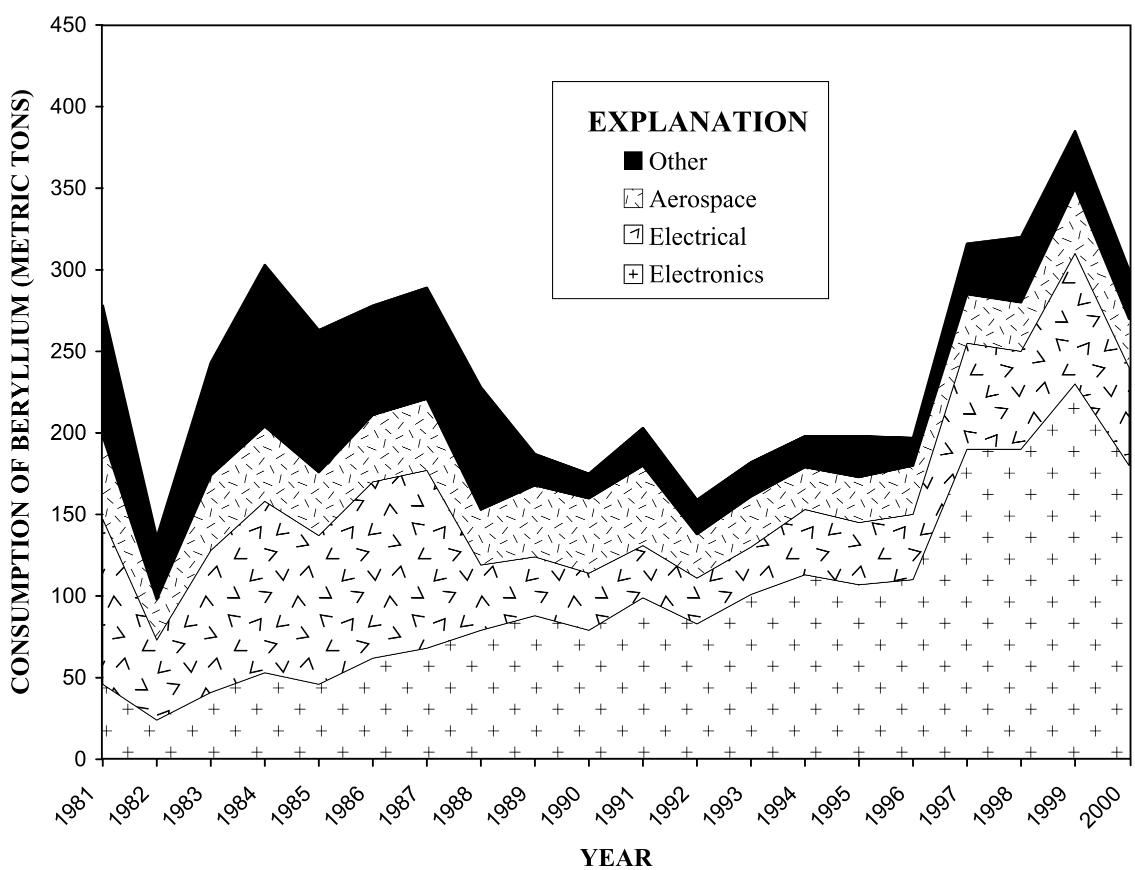

Figure 2. U.S. beryllium consumption by end-use sector, from 1981 through 2000.

resistance, high strength and hardness, 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 luggable 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 and components for machinery and materials-handling systems and for molds to make glass, metal, and plastic components.

Beryllium also is used 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. Brush Wellman's AlBeMet, which is a wrought powder metallurgy product that contains from 40 to 62 percent beryllium with at least 38 percent aluminum combines the high modulus and low density of beryllium with the ductility, fabrication, and strength characteristics of aluminum. AlBeMet is specified for components of the United States F15 and F16 fighter planes.

Beryllium metal, which averages more than 10 percent of annual U.S. beryllium demand, is used principally in aerospace and defense applications. Its dimensional stability within a wide temperature range, high level of stiffness, and light weight, 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 most X-rays, it is used for X-ray windows. In nuclear reactors, beryllium also serves as a canning material and 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 shuttle, beryllium is used for some brake components and structural parts.

Beryllium oxide (BeO, beryllia), which has a high level of hardness and strength, is an excellent heat conductor. This material also acts as an electrical insulator in some applications. Beryllium oxide, which averages more than 15 percent of annual U.S. beryllium demand, serves mainly as a substrate for high-density electronic circuits for automotive ignition systems, high-speed computers, lasers, and radar electronic countermeasure systems. Because it is transparent to microwaves, microwave communications systems and microwave ovens may use beryllium oxide.

PRICES

Figure 3 shows trends in the yearend average beryllium metal powder price from 1981 to 2000. During the 1980s through the 1990s, the effect of inflation rates and rising operating costs were reflected in increased beryllium prices. Energy requirements for producing beryllium metal are high. Processing requires the use of induction furnaces that consume large quantities of energy. Also, because of the toxic nature of beryllium, the industry must maintain careful control over the quantity of beryllium dust and fumes in the workplace. This control of potential health hazards adds to the cost of beryllium products. The additional costs are ultimately passed on to the consumer in the form of increased prices. Since 1979, when one of two domestic beryllium producers discontinued beryllium metal production, the price of the metal has been set by one company (Cunningham, 1999).

Yearend American Metal Market published prices for selected beryllium products were as follows: 99 percent beryllium metal powder, $492 per pound; beryllium vacuum-cast ingot, $421 per pound; beryllium-aluminum alloy, $260 per pound; beryllium-copper master alloy, $160 per pound of contained beryllium; beryllium oxide, $100 per pound; and beryllium-copper strip, $8.90 per pound. The Metal Bulletin published price for beryl ore ranged from $75 to $80 per short ton unit of contained BeO.

In 2000, no public price for beryllium scrap was published. For this report, the price for beryllium contained in beryllium-bearing scrap was estimated to be the published price for beryllium-copper master alloy.

SOURCES OF BERYLLIUM-BEARING SCRAP

About 75 percent of domestic beryllium consumption is in the form of beryllium-copper alloys that are used mostly in electrical and electronic components. Little beryllium, however, is recovered from used products (old scrap) owing to their small size, difficulty in separation, and the low beryllium content in the alloys; beryllium-copper alloys contain about 2 percent beryllium. Also, little beryllium metal old scrap is recycled; much of the metal is contained in nuclear reactors and nuclear weapons, which are difficult to recycle and may have been contaminated. These applications are rarely dismantled, and the beryllium may have been lost during testing (Roskill Information Services, 1989, p. 9). Most of the recycling of beryllium-copper alloy old scrap products is undertaken to reclaim the copper value; the contained beryllium units are lost to the beryllium industry. In 2000, the old scrap supply available to the beryllium industry was estimated to be about 140 t of contained beryllium with about 130 t generated from discarded or obsolete components/parts (estimated lifetime ranges from 10 to 15 years). About 5 t of this old scrap was recycled in the beryllium production process; most of the remaining scrap was unrecovered for its beryllium value.

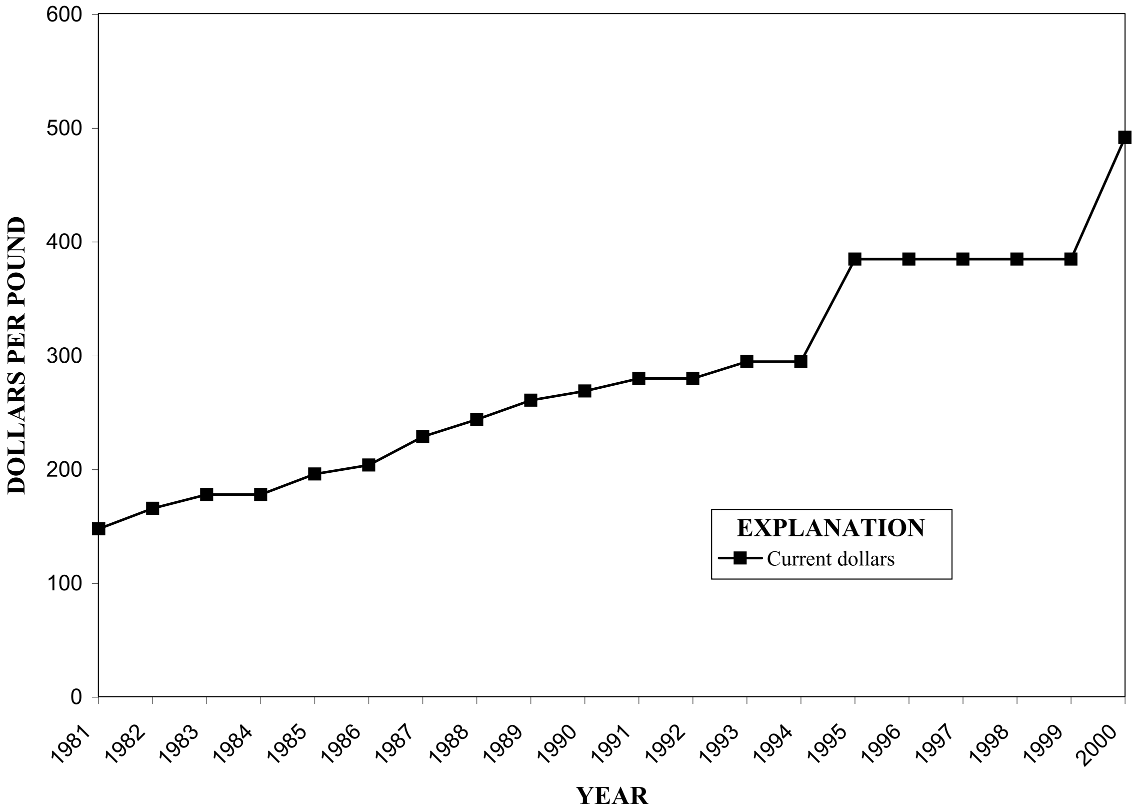

Figure 3. Year-end average beryllium metal powder price from 1981 through 2000. Values are in current dollars per pound beryllium (Source: American Metal Market and Bush Wellman Inc.).

Although little beryllium-bearing old scrap is recycled for its beryllium content, new scrap materials, such as beryllium alloys and beryllium metal, reclaimed at manufacturing plants that produce beryllium-related components are an important source of beryllium supply. The low beryllium content of beryllium-copper alloys is offset by the large amounts consumed. Beryllium-copper alloy is used in computers, which is one of the largest markets for beryllium, mainly in the form of connectors. In 1999, U.S. shipments of computers were about 20 million units with an estimated 2.11 grams of beryllium contained in each computer. Beryllium metal, which is available as billet, foil, ingot, powder, rod, sheet, and so forth, normally contains from about 98 to 99.5 percent beryllium. The majority of beryllium metal is consumed in defense applications where the high performance of the material outweighs the material cost. Beryllium metal used in nuclear missile applications includes structural components, electrical and guidance systems, and triggering devices. The use of beryllium metal in nuclear reactors is said to be concentrated in its use as a reflector in research reactors (Roskill Information Services, 2001, p. 77–119). New beryllium-bearing scrap generated by fabricators from their machining and stamping operations is returned to beryllium producers for reprocessing. In 2000, the United States consumed an estimated 30 t of beryllium contained in beryllium-related new scrap (alloys and metal) generated during the beryllium manufacturing process.

DISPOSITION OF BERYLLIUM-BEARING SCRAP

In 2000, the quantity of beryllium recycled or reused from old scrap represented less than 2 percent of domestic beryllium supply. Of the estimated 140 t of beryllium contained in old scrap that was available for recycling in 2000, more than 90 percent was unrecovered; about 4 percent used for domestic beryllium supply in the manufacture of new products; and the remainder, exported. Most of the unrecovered material was in the form of beryllium-related electrical and electronic equipment, some of which was abandoned in place, lost to the environment, recycled for the copper value (contained beryllium units lost to the beryllium industry), or shipped to landfills.

RECYCLING EFFICIENCY

Old scrap recycling efficiency shows the relation between what is theoretically available for recycling and what was recovered. Most scrap beryllium is either unrecovered or reused in the form of clean beryllium-bearing new scrap. The recycling or reuse of beryllium-bearing old scrap is minimal. A beryllium recycling efficiency of about 7 percent was estimated to have been reached in 2000. The recycling efficiency would have been higher if not for the lack of a concerted program to reuse beryllium from its major end use, beryllium-related electrical and electronic components manufactured from beryllium-copper alloys (containing about 2 percent beryllium).

INFRASTRUCTURE

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 imported beryl, into beryllium hydroxide at its facility near Delta. Beryllium hydroxide is shipped to the company's plant in Elmore where it is converted into beryllium alloys, metal, and oxide. NGK Metals Corp. (a subsidiary of NGK Insulators of Japan) produces beryllium alloys at a plant in Sweetwater, Tenn. Because NGK Metals does not have facilities to process beryllium ores and concentrates, the company purchases beryllium hydroxide from Brush Wellman. U.S. beryllium consumption was mainly in the form of alloys, metal, and oxide in the aerospace, electrical, and electronic sectors.

Processing methods, such as crushing, shredding, grinding, shot-blasting, welding, sparkling, melting, or casting beryllium products, used by scrap recyclers can produce potentially hazardous particles. "Handling beryllium or beryllium-containing materials in solid form posses no special health risks. Yet, as a dust or airborne particle, beryllium and beryllium-containing materials, like many other materials or substances, may require special handling to reduce potential health risks" (Scrap, 2003, p. 7). Since 1985, suppliers of scrap materials to scrap handlers or recyclers have been obligated under the Occupational Safety and Health Administration (OSHA) Hazard Communication regulations (29CFR 1910.1200) to inform the recipients of potential health risks (Scrap, 2002, 2003).

The U.S. International Trade Commission's Harmonized Tariff Schedule categorizes some selected beryllium materials. The United States imports a significant amount of its beryllium requirements. In 2000, imports of beryllium materials (alloys, metal, oxide, and waste and scrap) totaled about 20 t of contained beryllium valued at about $3.3 million. Beryl was not imported in 2000. In descending order, Estonia, Germany, and China were the major sources for U.S. beryllium imports on the basis of contained beryllium and accounted for more than 80 percent of the total. Other sources of imports were Belgium, Russia, and the United Kingdom. Imports that were categorized as "waste and scrap" contained an estimated 10 t of beryllium scrap; Estonia was the major supplier. Beryllium exports totaled about 35 t of contained beryllium valued at about $5.4 million. Canada, France, Germany, the Netherlands, the Republic of Korea, and the United Kingdom were the major recipients of beryllium exports. Exports that were categorized as "waste and scrap" contained an estimated 5 t of beryllium with most of the material going to China, France, the Republic of Korea, South Africa, and the United Kingdom.

PROCESSING OF BERYLLIUM-BEARING SCRAP

Although about 75 percent of the beryllium is consumed in the United States in the form of beryllium-copper alloys, the amount of beryllium recovered from obsolete beryllium-copper scrap is small. Beryllium-copper alloys, containing about 2 percent beryllium, manufactured into small articles, such as connectors, springs, and switches, are difficult to segregate and are mostly not recycled for their beryllium value. Most of the obsolete beryllium-copper alloy scrap that is recycled ends up being reclaimed for the copper value, with the beryllium units lost/unrecovered to the beryllium industry. A companion report on copper recycling in this series discusses the processing of copper scrap (Edelstein, in press). In contrast, clean segregated beryllium-bearing scrap generated by fabricators in machining and stamping operations is returned to producers, such as Brush Wellman and others, for reprocessing (see section "Production and Production Processes").

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 OSHA 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. Control of potential health hazards adds to the final cost of beryllium products (Cunningham, 2002).

Computers, which are a major end use for beryllium, have a life span, which includes reuse, of up to 7 years at which time their materials must be disposed of or recycled. By 2005, about 64 million computers will have reached the end of their usefulness. Recycling of computers, however, can be difficult because they contain a number of recyclable materials, some of which present environmental problems on disposal. Such materials as lead solder and mercury are common in most electronics. Computer and electronic equipment account for only about 1 percent of the total waste generated in the United States, but an estimated 70 percent of heavy metals that go to landfills results from this 1 percent (Resource Recycling, 2000a, b, 2001).

A small amount of workable used computers will be sold/reused through the resale market, and some will be donated to schools and nonprofit organizations. Demanufacturing, which is the disassembly of obsolete products, is one method to recycle electronic equipment, such as computers. In North America, more than 300 facilities harvest such computer components as hard drives and circuit boards for resale value. Demanufacturing can be profitable, but barriers, such as the lack of an adequate collection infrastructure, limited and cyclical markets for recovered materials, and products that are not designed to be disassembled and recycled, exist. A major source of material for demanufacturing is institutions that frequently update equipment owing to software updates and technology requirements. Shredding is another option that can be used to recycle computer equipment. Components, which range from laptops to mainframes, can be shredded, and the materials separated. This is an efficient way to recycle large volumes of computers, such as units formerly leased to businesses (Recycling Today, 2000; Resource Recycling, 2000a, b; Mossholder, 2001; U.S. Geological Survey, 2001).

OUTLOOK

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. At yearend 2001, Brush Engineered Materials reported proven bertrandite reserves in Juab County of about 6.6 Mt with an average grade of 0.268 percent beryllium. This represents about 17,700 t of contained beryllium compared with about 18,300 t in 2000. About 87 percent 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 percent” of its proven mineral reserves (Brush Engineered Materials Inc., 2002, p. 17–18).

A 20-year pattern of U.S. beryllium consumption is shown in figure 2. Beginning in 2003, annual world beryllium consumption was forecast to increase by about 2 percent per year. Beryllium alloys, primarily beryllium-copper, are expected to remain the dominant form of consumption for beryllium. Beryllium demand from the telecommunications sector 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 that contain up to about 65 percent beryllium compared with beryllium-copper alloys that contain about 2 percent beryllium may increase beryllium demand in such applications as aerospace and computers (Roskill Information Services Ltd., 2001, p. 1–5, 120–123).

Development of beryllium recycling (old scrap) in the electronics sector, however, is very limited and represents a potential for future beryllium recycling. Beryllium recycling in this area will have to be part of a total recycling concept for electronic equipment, which will require time and major effort/cooperation between the metals industry and the electronics equipment recyclers. Concerns, factors, and issues that relate to disposal of obsolete/discarded electronic equipment include State government initiatives that affect electronic equipment disposition; the logistics for the collection/transport of used equipment to scrap processors/recyclers; the loss of offshore processing/recycling capacity; and the need for a plan for the disposition of stored surplus equipment and the disposition of the increasing volume of equipment being sold (Resource Recycling, 2000a). Although the United States has no mandatory electronic take back/recycling program, certain U.S. computer manufacturers have voluntary internal recycling programs to handle some leased and purchased equipment. Legislation in the European Union (EU), however, set new standards for sale of electronic equipment in Europe; this includes equipment manufactured outside the region. EU directives require companies to take back and recycle their electronic equipment and to phase out the use of various heavy metals, such as lead, in new equipment by 2008 (Metal Bulletin Monthly, 2001; Recycling Today, 2001).

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APPENDIX—DEFINITIONS

apparent consumption. Primary plus secondary production (old scrap) plus imports minus exports plus adjustments for Government and industry stock changes.

apparent supply. Apparent consumption plus consumption of new scrap.

dissipative use. A use in which the metal is dispersed or scattered, such as paints or fertilizers, making it exceptionally difficult and costly to recycle.

downgraded scrap. Scrap intended for use in making a metal product of lower value than the metal product from which the scrap was derived.

home scrap. Scrap generated as process scrap and consumed in the same plant where generated.

new scrap. Scrap produced during the manufacture of metals and articles for both intermediate and ultimate consumption, including all defective finished or semifinished articles that must be reworked. Examples of new scrap are borings, castings, clippings, drosses, skims, and turnings. New scrap includes scrap generated at facilities that consume old scrap. Included as new scrap is prompt industrial scrap—scrap obtained from a facility separate from the recycling refiner, smelter, or processor. Excluded from new scrap is home scrap that is generated as process scrap and used in the same plant.

new-to-old-scrap ratio. New scrap consumption compared with old scrap consumption, measured in weight and expressed in percent of new plus old scrap consumed (for example, 40:60).

old scrap. Scrap including (but not limited to) metal articles that have been discarded after serving a useful purpose. Typical examples of old scrap are electrical wiring, lead-acid batteries, silver from photographic materials, metals from shredded cars and appliances, used aluminum beverage cans, spent catalysts, and tool bits. This is also referred to as postconsumer scrap and may originate from industry or the general public. Expended or obsolete materials used dissipatively, such as paints and fertilizers, are not included.

old scrap generated. Metal content of products theoretically becoming obsolete in the United States in the year of consideration, excluding dissipative uses.

old scrap recycling efficiency. Amount of old scrap recovered and reused relative to the amount available to be recovered and reused. Defined as (consumption of old scrap (COS) plus exports of old scrap (OSE)) divided by (old scrap generated (OSG) plus imports of old scrap (OSI) plus a decrease in old scrap stocks (OSS) or minus an increase in old scrap stocks), measured in weight and expressed as a percentage:

$$\frac{\text{COS} + \text{OSE}}{\text{OSG} + \text{OSI} + \text{decrease in OSS or} - \text{increase in OSS}} \times 100$$

old scrap supply. Old scrap generated plus old scrap imported plus old scrap stock decrease.

old scrap unrecovered. Old scrap supply minus old scrap consumed minus old scrap exported minus old scrap stock increase.

primary metal commodity. Metal commodity produced or coproduced from metallic ore.

recycling. Reclamation of a metal in usable form from scrap or waste. This includes recovery as the refined metal or as alloys, mixtures, or compounds that are useful. Examples of reclamation are recovery of alloying metals (or other base metals) in steel, recovery of antimony in battery lead, recovery of copper in copper sulfate, and even the recovery of a metal where it is not desired but can be tolerated—such as tin from tinplate scrap that is incorporated in small quantities (and accepted) in some steels, only because the cost of removing it from tinplate scrap is too high and (or) tin stripping plants are too few. In all cases, what is consumed is the recoverable metal content of scrap.

recycling rate. Fraction of the apparent metal supply that is scrap on an annual basis. It is defined as (consumption of old scrap (COS) plus consumption of new scrap (CNS)) divided by apparent supply (AS), measured in weight and expressed as a percentage:

$$\frac{\text{COS} + \text{CNS}}{\text{AS}} \times 100$$

scrap consumption. Scrap added to the production flow of a metal or metal product.

secondary metal commodity. Metal commodity derived from or contained in scrap.