UNITED STATES TARIFF COMMISSION

BERYLLIUM

Report to the Congress on Investigation No. 332-41
Under Section 332 of the Tariff Act of 1930
Made Pursuant to Senate Resolution 206,
87th Congress, Adopted September 23, 1961

TC Publication 66

Washington
August 1962

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(TC28946)

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Introduction

This report incorporates information obtained by the Commission in connection with its investigation of beryllium, conducted under section 332 of the Tariff Act of 1930, as amended (19 U.S.C. 1332), pursuant to Senate Resolution 206, 87th Congress, adopted September 23, 1961. A copy of the resolution appears in appendix A of this report.

The resolution directed the Commission to make an investigation "of conditions in the industries producing . . . beryllium and report to Congress not later than August 31, 1962." Accordingly, this report presents information on U.S. production, consumption, imports, exports, and foreign production, and other data pertinent to an understanding of the conditions of competition between domestically produced and imported beryllium ores and refined beryllium products.

The Commission instituted its investigation on October 5, 1961. Public notice of the investigation, and of the public hearing to be held in connection therewith, was given by posting a copy of the notice at the offices of the Tariff Commission in Washington, D.C., and New York City, and by publication of the notice in the Federal Register (26 F.R. 9610) and in the October 12, 1961, issue of Treasury Decisions. The public hearing was held on April 17, 1962, and all interested parties were given an opportunity to be present and to be heard.

In addition to the information obtained at the public hearing, data were obtained from other U.S. Government agencies, from questionnaires received from U.S. producers and refiners engaged in the production and importation of refined beryllium products and beryllium ores, from information in the Commission's files, and from fieldwork by members of the Commission's staff.

Description and Uses

Refined beryllium products are commonly classified in three broad categories--beryllium metal, beryllium alloys, and beryllium compounds. In terms of value, the leading products are beryllium metal and beryllium alloys. The production and sale of compounds are small relative to those of the other beryllium products.

In the United States virtually all of the refined beryllium products are presently processed from beryl ore, nearly all of which is imported. The great bulk of domestic output is accounted for by two concerns that produce a full line of products from purchased beryl ore exclusively. Beryllium ores other than beryl are used by one other concern to produce a small quantity of compounds.

Refined beryllium products

Beryllium metal.--Beryllium is a dark gray metal of particular importance in the space age because of its light weight, high strength-to-weight ratio, its high degree of stiffness, high melting point, excellent thermal and electrical conductivity, high capacity to absorb heat, and resistance to oxidation and to distortion under stress (see table 1 in appendix B for selected physical properties of beryllium and several competing metals). These characteristics have led to its use in heat sinks (devices to absorb and dissipate heat) and in precision instrumentation and guidance components in space vehicles and missiles. An application that illustrates the unique properties of beryllium has been its use as a heat sink in the project Mercury capsules to shield astronauts from the intense heat generated by the reentry of the capsules into the earth's atmosphere.

Inasmuch as beryllium metal is an excellent moderator of neutrons--capable of slowing them to the thermal state required for nuclear fission--it is also used in nuclear reactor cores. And since it has the lowest thermal neutron absorption rate of all metals, beryllium is used as a reflector to contain reactor cores and prevent the loss of neutrons, thus increasing efficiency and minimizing nuclear fuel requirements. Because of its light weight it is particularly suitable for use in portable reactors, such as those in submarines and other marine vessels. High permeability to X-rays makes the metal useful for windows in X-ray tubes.

Beryllium's high heat of combustion has led to considerable interest in the material as a solid fuel for rockets and space vehicles; its use for this purpose, however, is still in the development stage.

Beryllium metal is initially produced in the form of bead or pebble, or electrolytic flake, then converted to vacuum-cast ingot, powder, and hot-pressed block or billet. Virtually all semifabricated and fabricated beryllium metal products are produced from hot pressed billets. Notwithstanding the remarkable progress that has been made in the past few decades in beryllium metal processing techniques, many technical problems remain that have a significant bearing on the future use of the product. Some of the important problems relate to its high cost of fabrication, poor ductility, toxicity, and the tendency under certain conditions to become brittle and to corrode at high temperatures. 1/

1/ The experience of the United Kingdom Atomic Energy Authority in its use of beryllium metal in the Windscale gas-cooled reactor points up the problems of embrittlement and corrosion. When exposed to carbon dioxide containing water vapor at high temperatures, beryllium in the fuel element of the reactor corroded to an undesirable extent. When used for fuel cans in the reactor, beryllium failed by embrittlement upon being cooled from high temperatures. Although corrosion was reportedly stopped by the addition of a small quantity of calcium to the beryllium, the problem of embrittlement remained and led to suspension of the use of beryllium in the reactor.

Problems relating to high cost of fabrication and to corrosion at high temperature would presumably be ameliorated by the achievement of fine-grain crystallization in the vacuum-cast-ingot stage. As presently produced, cast beryllium metal has a coarse grain structure which makes it difficult to work. Chipping the ingot, grinding the chips to powder, and hot-pressing the powder into billet provides a fine grain structure which permits fabrication of the metal. Elimination of these operations would reduce costs substantially. And since corrosion in beryllium is thought to be related to beryllium oxide impurities introduced during chipping, grinding, recycling, and hot-pressing, the elimination of any of these procedures would tend to increase resistance to corrosion. In coping with the problem of producing ductile metal, the Franklin Institute of Philadelphia has reported that it achieved a high degree of ductility in beryllium by means of vertical zone refining. Nuclear Metals, Inc., of Cambridge, Mass., has also reported improvement in ductility when vacuum distillation methods were used in refining beryllium.

While beryllium is toxic only in the form of metal powder, dust, fume, mist, and some compounds, it produces acute lung and skin irritations in those who are allergic to the element. Safeguards in producing and handling the material, however, have resulted in a very low incidence of affliction in recent years. Nevertheless, toxicity probably has been a factor in retarding wider use of beryllium in certain industries; it has reportedly been an important factor bearing on the possible use of beryllium as a solid fuel for rockets.

Beryllium alloys.--Of the several beryllium alloys produced, beryllium-copper is by far the most important. Beryllium-copper alloys, which contain from 0.25 to 4.4 percent beryllium, are hard and stiff, exhibit good thermal and electrical conductivity, are highly resistant to wear, and are nonsparking and nonmagnetic. The higher the beryllium content of the alloy, the greater is its strength, hardness, and durability; the lower the beryllium content, the greater its conductivity. Beryllium-copper alloys are used widely in such products as welding electrodes, circuit breakers, switches, bearings, gears, valves, casting molds for plastics, various types of dies, and nonsparking tools.

Beryllium-copper is produced as a master alloy containing about 4 percent beryllium and the balance copper; this master alloy is added to a copper melt to formulate final alloy compositions which average about 1.9 percent beryllium. These alloys are processed into castings and semifabricated forms such as sheet, strip, rod, wire, and tubing, which in turn are fabricated into finished forms.

Beryllium-aluminum master alloy containing 5 percent beryllium is used to introduce beryllium in small quantities (0.01 to 0.1 percent) into aluminum alloys to improve their castability. Beryllium-aluminum is also added to magnesium to raise its ignition temperature.

Other beryllium alloys that have been produced--all in small quantities--are beryllium-nickel, beryllium-iron, and beryllium-magnesium-aluminum.

Beryllium compounds.--Of the several beryllium compounds produced, beryllium oxide (beryllia) is by far the most important. It is used principally as a source material for beryllium in making beryllium-copper

alloys. Beryllia, however, has several additional uses. When pressed and sintered, beryllia becomes a ceramic substance. In ceramic form, beryllia's high thermal conductivity, coupled with its stability at high temperatures and resistance to thermal shock, make it an effective heat transfer medium. Because of their high melting point, good electrical properties, and low vapor pressure, beryllia ceramics are well adapted for use in the production of crucibles. Beryllia also possesses properties similar to beryllium metal, and it is therefore useful for making fuel containers in nuclear high temperature thermal reactors. Beryllia ceramics also find important applications in the electronics and aircraft industries, where a ceramic with high electrical resistivity and high thermal conductivity is required.

Another beryllium compound, beryllium nitrate, is used in incandescent mantles, but handling difficulties have sharply restricted its use for this purpose. Beryllium nitride and beryllium carbide have limited uses in the nuclear energy field. A number of other beryllium compounds are derived and used in the processes involved in extracting beryllium from the ore; other applications of most such compounds have been confined to laboratory use on a small scale.

Beryllides, which have been developed only recently, are intermetallic compounds of beryllium and other metals in which the component metals are so combined as to form a substance with a new crystal structure. Beryllides are oxidation-resistant materials having great strength at high temperatures (up to 2900° F.), a high capacity to absorb heat, and good thermal conductivity. Of the beryllides that have been tested, seven are of the greatest promise--three of columbium, two of tantalum,

and two of zirconium. They probably will have their greatest use as structural members in space vehicles, missiles, and aircraft.

Substitute products.--Various materials may be used in lieu of refined beryllium products. Illustrative of these substitutes are the following: In situations where weight is not of extreme importance, titanium can be substituted for beryllium metal for various structural purposes. Stainless steel, although not as suitable as beryllium metal, may be substituted for it as a canning material for nuclear fuel. Copper-nickel-silicon alloy may be substituted for beryllium-copper alloys in making many types of springs and diaphragms. Phosphor bronze (a copper-tin alloy) is used to replace beryllium copper where extra strength and electrical resistivity are not required. Aluminum bronze may be used as a substitute in some bearings and nonsparking tools. Stainless steel may be used for diaphragms and springs where resistance to corrosion is of particular importance.

Beryllium ore

About 30 minerals are known to contain beryllium (Be) as an essential constituent; the element may also occur to some extent in about 50 other minerals. Beryl, bertrandite, chrysoberyl, phenakite, and helvite are the most common beryllium-bearing minerals known today. Table 2 indicates the principal minerals in which beryllium has been found.

As has been noted, all of the beryllium metal and beryllium alloys, and most of the beryllium compounds, are produced domestically from beryl ore, a mineral which is essentially a beryllium aluminum silicate. 1/

1/ $Be_3Al_2(SiO_3)_6$.

Beryl crystals are hexagonal prisms which vary in size from a fraction of an inch to several feet and which range in weight from a few ounces to several tons. The crystals appear in a variety of colors. In its translucent gem form, beryl is known as emerald when green, aquamarine when blue, morganite when pink, and heliodor when yellow. Because the crystals are usually separated from associated rock materials by hand, the ore in common use is called "hand cobbed" beryl ore.

The mineral beryl contains from 10 to 14 percent beryllium oxide (3.6 to 5 percent elemental beryllium); the exact percentage depends on whether alkali metals, such as lithium, sodium, and cesium, are present. As the alkali metal content of the mineral increases, the beryllium content decreases. Beryl ore 1/ may contain less than 10 percent BeO because of the presence of waste rock. In view of the limitations and high cost of present refining techniques, the minimum BeO content of the beryl ore currently refined by the two domestic producers of beryllium metal is 10 percent. The average grade of ore refined is closer to 12 percent BeO (4.3 percent of Be).

The only beryllium minerals other than beryl being mined and shipped commercially in the United States are in a mixed beryl-bertrandite-phenakite ore produced in Park County, Colo.; this ore is currently used exclusively in the production of beryllium compounds--chiefly beryllium oxide. The total quantity of beryllium oxide produced from such ore,

1/ An ore is a rock material containing economically minable quantities of a mineral. In common practice, the term "ore" is also used to describe deposits which contain fairly large concentrations of a mineral which may not be economically mined under prevailing conditions. Such deposits are often referred to as "off-grade" ores.

however, is small relative to the quantity produced from beryl. Like beryl, both bertrandite and phenakite are silicate minerals that resemble the quartz with which they are associated. Both have a much higher beryllium content than beryl. The mixed beryl-bertrandite-phenakite ore shipped in 1961, however, averaged less than 4 percent BeO because of the low concentration of the mineral in the ore.

U.S. Customs Treatment

Beryllium metal and other refined beryllium products

The various beryllium products covered by this report are dutiable under paragraphs 79, 397, 5, 214, and 1719 of the Tariff Act of 1930 (table 3). With the exception of ore, for which duty-free entry was provided, beryllium products were initially dutiable at rates ranging from 25 to 45 percent ad valorem. Since 1930, all duties on beryllium products have been reduced pursuant to concessions negotiated under the reciprocal trade-agreements program. In the discussion which follows, reference will be made primarily to the customs treatment currently applicable.

Metallic beryllium in primary forms and beryllium metal scrap are currently dutiable under paragraph 79 of the Tariff Act of 1930 at 19 percent ad valorem. 1/ Pursuant to a concession granted at the 1960/61 GATT tariff Conference, this rate will be reduced to 17 percent ad valorem effective July 1, 1963. Beryllium plate, rod, disk, and other fabricated

1/ The duty on certain metal scrap, including beryllium metal scrap and beryllium alloy scrap, was suspended during the period Mar. 14, 1942, to June 30, 1949, and since Oct. 1, 1950, by a series of public laws, the most recent of which (Public Law 87-514) continues the suspension through June 30, 1963.

items not specially provided for in the Tariff Act of 1930 are classifiable as manufactured articles in chief value of metal, not specially provided for, under paragraph 397; they are dutiable at 22-1/2 percent ad valorem.

There have been no definitive rulings by the U.S. Bureau of Customs regarding the classification of beryllium alloy products other than beryllium-copper scrap, in chief value of beryllium. Beryllium-copper scrap has been classified as a combination of chemical elements, not specially provided for, under paragraph 5, dutiable at 10-1/2 percent ad valorem. 1/ In addition, beryllium-copper scrap is subject to an import tax on its copper content under section 4541, Internal Revenue Code of 1954.

There have been no known imports of beryllium-copper alloy or other beryllium alloy products in primary form. If imported, they would probably be classified under paragraph 5 at the same rate of duty as beryllium-copper scrap--10-1/2 percent ad valorem. Fabricated and semifabricated beryllium alloy products, not specially provided for, would probably be dutiable under paragraph 397 at 22-1/2 percent ad valorem.

Beryllium compounds are dutiable under the provisions of paragraph 5. Beryllium oxide and beryllium carbonate are currently dutiable at 11 percent ad valorem; as the result of a concession at the aforementioned GATT Conference, this rate will be reduced to 10 percent ad valorem effective July 1, 1963. Other beryllium compounds are dutiable at 10-1/2 percent ad valorem.

1/ See footnote on p. 9.

Wrought forms of beryllium oxide, such as rods and tubes, have been classified as articles, wholly or in chief value of earthy or mineral substances, not specially provided for, under paragraph 214; they are dutiable at 15 percent ad valorem.

Beryllium ores and concentrates

Beryllium ores which have not been advanced in condition or value by grinding, refining, or other process of manufacture enter the United States free of duty under paragraph 1719 of the Tariff Act of 1930. Ores wholly or partly manufactured are dutiable under paragraph 214 at 15 percent ad valorem. The Bureau of Customs has ruled that ore which has been crushed merely to facilitate handling and transportation is classifiable as crude ore.

Treatment of beryllium products under the revised tariff schedules

The duty-free status of beryllium ores and the rates of duty applicable to beryllium products (except beryllium alloys) under the Tariff Act of 1930 will be continued in the new Tariff Schedules of the United States, the adoption of which is provided for in the Tariff Classification Act of 1962 (Public Law 87-456, approved May 24, 1962). It is anticipated that these schedules will become effective January 1, 1963. The amount of the change in the rates of duty for beryllium alloys will vary because, under the new schedules, the rate is that applicable to the metal in the alloy which is predominant by weight. Beryllium seldom contributes the bulk of the weight in beryllium alloys.

The pertinent item numbers in the revised schedules for beryllium products are as follows: 601.09, beryllium ore; 628.05, beryllium, unwrought, and waste and scrap; 628.10, beryllium, wrought; 417.90, beryllium oxide or carbonate; 417.92, other beryllium compounds.

The U.S. Industry

U.S. producers

Refined beryllium products.--Although the element beryllium was first isolated some 130 years ago in Europe, no practical commercial use of the product was developed before 1926, when the discovery in the United States of its hardening effect on copper led to the establishment of the domestic industry. In 1929, the Beryllium Corp., formerly the Beryllium Corp. of America, was founded. In 1931, the Brush Beryllium Co. was incorporated to continue the research and development work on beryllium that had been initiated by the Brush Laboratories Co. in 1921.

These two concerns are the only companies in the United States producing beryllium metal from ore. 1/ Both are integrated concerns which make metal, alloys, and compounds from purchased beryl; they also fabricate these items into finished or semifinished form for sale. Both also sell primary products to other concerns for processing.

The Beryllium Corp.'s main plant and headquarters are located near Reading, Pa., where it produces and fabricates beryllium alloys and compounds. Beryllium metal is made and fabricated at the company's Hazleton, Pa., plant.

Headquarters of the Brush Beryllium Co. are in Cleveland, Ohio, where its beryllium metal fabrication plant is located. The company's

1/ In 1939 Clifton Products, Inc., was organized in Painesville, Ohio, and by 1942 it was producing commercial high-purity beryllium oxide from ore for use in fluorescent lamps and refractories. The company initiated production of electrolytic beryllium flake in 1943 and also reclaimed Government stocks of beryllium-copper scrap until 1944. The fluorescent-tube industry discontinued its use of beryllium oxide in 1948 because of problems of toxicity. Clifton Products ceased production of beryllium oxide in that year but continued research on beryllium for a number of years before discontinuing operations.

ore refinery is located at Elmore, Ohio, where it produces beryllium metal, beryllium alloys, compounds, and ceramics. The Brush company also has a plant for fabricating beryllium alloy and other metal strip at Shoemakersville, Pa., and a machine shop at Hayward, Calif.

In addition to the foregoing companies, several other domestic concerns produce refined beryllium products. None of them, however, produce a full line of products. The Mineral Concentrates & Chemical Co., Inc. (Mincon), of Denver, Colo., produces beryllium compounds and beryllia ceramics from domestic beryl and beryl-bertrandite ores. It is the only company currently (July 1962) producing and selling a beryllium product made from ores other than beryl. The National Beryllia Corp. (Haskell, N.J.), is a comparatively large producer of beryllia ceramic products for electronic and electrical uses. Coors Porcelain Co. (Golden, Colo.), fabricates beryllia ceramic items, mainly for nuclear energy applications. Both companies produce the ceramic items from purchased beryllium oxide. The General Astrometals Corp., a small company which began operations in 1961 at Yonkers, N.Y., produces beryllium hot-pressed billet and other semifabricated and fabricated beryllium metal products from electrolytic beryllium flake and powder imported from the large French metals producer Pechiney et Cie. General Astrometals is also Pechiney's exclusive North American sales agent for beryllium metal products. When demand warrants, the company plans to produce electrolytic beryllium metal from ore. Four other companies produce specialized ceramic products but consume only minor quantities of beryl ore; they are the Beryl Ores Co., Arvada, Colo.; the Glass Coating Materials Division

of A. O. Smith Corp., Milwaukee, Wis.; the Lapp Insulator Co., Le Roy, N.Y.; and the Champion Spark Plug Co., Detroit, Mich.

Beryllium ores and concentrates.--In the United States, as well as abroad, the production of beryl ore has generally occurred on a very small scale and has been largely a hand operation. The output from individual mines has ranged from a few pounds to a few tons per year. Most of the beryl is produced jointly with other minerals. In most mines, the output is irregular; few of them have a consistent or sustained record of production from year to year. In 1960 more than 170 mine operators produced beryl ore in the United States, and in 1961 there were only about 100 such producers.

Beryllium ores other than beryl are mined by one domestic company, U.S. Beryllium Corp., on a commercial basis. This concern operates mines in Park County, Colo., which produce an ore containing a mixture of bertrandite, beryl, and phenakite. This ore has been sold exclusively to Mineral Concentrates & Chemical Co., Inc., which concentrates the material in a mill adjacent to U.S. Beryllium Corp.'s Boomer mine. Mincon is the only firm producing (July 1962) beryllium mineral concentrate on a commercial basis.

Production processes

In the United States the production of refined beryllium products involves the chemical treatment of beryllium ore to derive beryllium hydroxide. The hydroxide is either used directly to produce beryllium metal or converted to beryllium oxide for use in producing beryllium alloys and ceramics.

Three processes are used commercially in the United States to make beryllium hydroxide from ore. The Brush Beryllium Co. begins its process by melting coarse beryl ore and quenching the melt in water to make the ore amenable to treatment by sulfuric acid. The Beryllium Corp. applies heat to a mixture of ground beryl ore and fluorides. The Mineral Concentrates & Chemical Co. also uses a fluoride process to refine mixed bertrandite-beryl-phenakite ores. In all the foregoing processes, further chemical treatment ultimately yields beryllium hydroxide, which is converted to beryllium oxide by calcining to drive off contained moisture. The basic process used by The Beryllium Corp. may also be used to treat beryllium ores other than beryl. The process used by the Brush Beryllium Co., on the other hand, is suitable only for the treatment of beryl ore.

Beryllium metal.--Most beryllium metal produced in the United States is derived from beryllium hydroxide. The latter is converted to beryllium fluoride, which is then reduced in the presence of magnesium metal in a vacuum furnace to yield beryllium metal in the form of pebbles or beads. The pebbles or beads are vacuum melted to remove slag, magnesium, and other impurities, and then cast into ingots consisting of about 99 percent beryllium. Since the cast ingot metal has a coarse grain structure, it must be reduced to powder to achieve fine grain size. The cast ingots are machine-turned and the resultant chips are ground between two beryllium discs to a powder finer than 200 mesh. The powder thus obtained is then pressed into dense fine-grained shapes (billets or blocks), mainly by vacuum hot-pressing. In the latter process, the powder is placed in a steel or graphite die of a size and shape appropriate to the metal's end use, and then compacted in a vacuum furnace. The resultant beryllium

billet is fine grained, dense, uniform, possibly twice as strong as cast beryllium, and capable of being machined readily. Billets can be made in sizes ranging up to 65 inches in diameter and weighing up to 2,500 pounds. Shapes and forms may be made either by machining, extruding, rolling, or forging the billets.

Beryllium metal is also made electrolytically by converting beryllium oxide to beryllium chloride for use as the source of beryllium in the electrolyte. The extracted beryllium metal is deposited in flake form.

Beryllium alloys.--In the production of beryllium-copper master alloy, beryllium oxide is mixed with carbon powder and copper in batches and melted in electric arc furnaces. The alloy so produced is impure; it must therefore be refined to remove carbon and gases absorbed in the reduction process. Beryllium-copper master alloy usually contains between 4 and 4.25 percent beryllium; an alloy having a lower beryllium content would not be economical to produce, whereas an alloy having a higher beryllium content would be undesirable inasmuch as it would contain an excess of beryllium carbide. 1/

The beryllium-copper master alloy is subsequently remelted and diluted to specific alloy compositions, depending on the characteristics required. The alloy melt may be cast into foundry ingots or into ingots suitable for mechanical working into semifabricated and fabricated products--such as sheet, strip, rod, bar, wire, forgings, extrusions, and tubing. Most of the ingots used for mechanical working are consumed by the two alloy producers.

1/ A beryllium-copper master alloy containing as little as 3 percent beryllium, as well as a greater quantity of impurities, is also made, partially from scrap. This may be used, where feasible, at a cost saving.

Beryllium alloys other than beryllium-copper are made by melting beryllium directly with the alloying metal.

Beryllium compounds and ceramics.--Processes for recovery of beryllium oxide and hydroxide are indicated above. Most other beryllium compounds are derived in the process of making the hydroxide. Nuclear grade beryllium oxide is usually made by decomposition of pure beryllium sulfate.

Ceramic products are usually fabricated from high purity beryllium oxide powder by hot-pressing, cold-pressing, and extrusion. The purity and grain size of the powder largely determine the quality of the ceramic products.

Beryl ore.--Deposits of beryl are found principally in pegmatite, a coarse variety of granite occurring in veins or dikes. Some other sources of beryl have been quartz veins, granite, and schist. Usually beryl deposits are found in small pockets and are accompanied, often in commercial quantities, by such minerals as feldspar, mica, quartz, and various lithium minerals. Outside the United States, beryl is also found frequently with cassiterite, columbite, and tantalite.

In general the U.S. pegmatites are solid and separation of the beryl is difficult, whereas the foreign deposits are frequently highly weathered, permitting the beryl crystals to be separated fairly easily from the host rock.

In the United States, beryl is usually mined either from open pits and quarries or underground by open-stope methods. The ore is removed by picking, drilling, or blasting the rock wall. It is then crushed by hammer, after which the beryl crystals are separated by hand from the other materials--a process called hand-cobbing. Ordinarily, in the United States, crystals smaller than an inch in length are not recovered.

Ores other than beryl.--Bertrandite has been found associated with evidence of volcanic or subsurface igneous activity in the following types of occurrences: As a replacement deposit in limestone, as an epithermal solution deposit in a claylike rhyolite tuff, and as replacement veins and pipes in a griesen. Phenakite has been found along with bertrandite and some beryl in a limestone replacement deposit, in a pegmatite, and in quartz veins in granite.

In crystal form bertrandite is easily mistaken for quartz and therefore has been seldom recognized when found. Recent important discoveries of bertrandite have resulted largely from chance chemical analysis or the use of the recently invented berylometer, or beryllium analyzer. 1/

The mixed bertrandite-beryl-phenakite ores currently being produced in Colorado are mined both underground and from open cuts.

Beryllium concentrates.--Inasmuch as the specific gravity of beryl is close to that of other pegmatite minerals, it is difficult to separate beryl from other materials by gravity methods. Moreover, most individual deposits of beryl tend to be small, making the erection of mills at mine sites impracticable. Hand-cobbing the ore, however, is wasteful, since small crystals and fragments, composing probably a third to a half of the beryl in the average commercial deposit, are not recovered. Several companies are currently working on better processes for concentrating beryl and other beryllium ores. All such processes that have gone beyond the laboratory stage appear to be based on flotation methods.

1/ The berylometer, which was developed in 1958, reacts only to the presence of beryllium, causing neutrons in the element to be released, and then counting them.

To date only the Mineral Concentrates & Chemical Co. (Mincon) has established its concentration process commercially. Its mill was erected in 1961 to concentrate mixed beryl-bertrandite-phenakite ore at a site adjacent to U.S. Beryllium Corp.'s Boomer mine near Lake George, Colo. The process involves treating crushed and fine-ground off-grade ore with a conditioner and then sending it through flotation cells. Mincon has been concentrating mixed beryl, bertrandite, and phenakite ores that average about 4 percent BeO. The concentrate has averaged about 15 percent BeO and has ranged as high as 23 percent BeO; it is shipped to Mincon's plant at Loveland, Colo., for conversion to beryllium oxide. Mincon's mill has a capacity for 50 tons of ore per day; its capacity could be readily doubled by minor changes in equipment.

Northwest Beryllium Corp. (Rapid City, S. Dak.) is experimentally concentrating beryl ores in its mill in the Black Hills area of South Dakota; results have not yet been announced. Lithium Corp. (New York City) is erecting a mill to concentrate disseminated beryl near their Bessemer City, N.C., lithium operations.

Domestic Ore Reserves

Virtually all of the domestic production of refined beryllium is derived from imported beryl ore. Notwithstanding that the supply of imported beryl appears to be adequate to meet existing U.S. requirements, considerable effort is being directed to the development of domestic ore reserves. To an important extent these efforts reflect recognition of the fact that foreign sources of beryl might not be adequate to meet U.S. requirements at, or close to, existing prices should the demand

for beryllium increase substantially. An additional consideration is that the flow of ore to the United States might conceivably be restricted as a result of political changes or production and export controls, or both, in some foreign producing areas. 1/

Domestic ore reserves consist chiefly of off-grade deposits of beryl, bertrandite, and phenakite. Although the two major domestic consumers of ore indicate that it would be technically possible to extract beryllium from such ores, it will no doubt be more economic for some time to meet most domestic requirements from imported beryl. The ore-refining facilities of the domestic producers of beryllium metal are designed for the use of beryl and would not be converted to the use of domestic beryllium ores other than crystal beryl unless an adequate supply of such ore were assured and the requisite modification of production facilities could be achieved economically. Moreover, except where beryllium could be recovered as a coproduct, it does not appear likely that additional concerns would undertake the production of primary beryllium products from off-grade domestic ores in the near future.

The following estimates of domestic reserves are based on a review of available information on domestic reserves of beryl and known deposits of off-grade beryllium ores that might be utilized in the future as the demand for beryllium expands. The available information includes estimates of (1) known reserves in 1957, largely beryl, reported by geologists

1/ India imposed export controls on beryl ore in 1946. In 1950, Brazil and Argentina imposed similar controls. These controls are still in effect. Argentina also controls production of beryl through COCOMINE, a Government agency which has a monopoly on the purchase of beryl.

of the U.S. Geological Survey, 1/ and (2) off-grade reserves of other beryllium minerals reported by industry geologists. 2/

U.S. reserves of beryllium ore are estimated to contain from 44,000 to 53,000 tons of beryllium oxide. This amount is equivalent to 379,000 to 457,000 tons of cobbed beryl of the grade currently being used by the major consumers. Of the total, perhaps less than 2 percent--or ore containing less than 1,000 tons of beryllium oxide--is in known deposits of crystalline beryl economically suitable for hand cobbing. 3/ Estimated domestic reserves of ore consist of the following (in terms of BeO content): About 25,000 tons in disseminated beryl deposits in North and South Carolina; 15,000 to 22,500 tons in bertrandite deposits in Utah; about 1,250 to 2,500 tons in phenakite-bertrandite deposits in Nevada; and 2,500 to 3,000 tons in all other deposits, including those that contain from 0.2 to 1.0 percent of beryl.

The largest known domestic reserve of coarse crystalline beryl is in pegmatites in the Black Hills area of South Dakota near the towns of Keystone and Custer. Feldspar, mica, and quartz are usually present in these deposits. Reserves of coarse crystalline beryl are also found in New England (New Hampshire, Maine, and Connecticut), Colorado, New Mexico, Idaho, and Nevada.

1/ J. J. Norton, W. R. Griffitts, and V. R. Wilmarth, "Geology and Resources of Beryllium in the United States," Proceedings of the 2d United Nations International Conference on Peaceful Uses of Atomic Energy, vol. 2, Survey of Raw Materials Resources, Geneva, 1958, pp. 21-34.

2/ C. H. Smith, C. C. Woo, and B. F. Dickerson III, New Beryllium Ore Developments, paper to be presented at annual meeting of A.I.M.E., Feb. 18-22, 1962; Preprint No. 62H69, Society of Mining Engineers A.I.M.E.

3/ In deposits that contain more than 100 tons of beryl and wherein beryl comprises more than 1 percent of the rock.

Large reserves of disseminated fine-grained beryl are found in the so-called tin-spodumene pegmatites of North and South Carolina. The rock is mined for spodumene (a lithium mineral) by large-scale methods, but the beryl content is not currently (July 1962) being recovered because of the difficulty of separating it from the other minerals present. The minerals are evenly distributed through the deposits; beryllium oxide comprises about 0.05-0.06 percent of an estimated 50 million tons of rock.

The largest known nonberyl beryllium deposit is in the Spors Mountain area of Utah. The beryllium is contained in a fine-grained bertrandite that is distributed within volcanic rocks (largely an altered rhyolite tuff) that lie on the flanks of Spors Mountain. The claylike tuff requires chemical processing to remove the beryllium. A number of companies have staked claims in the area, but in May 1962 only three were actively engaged in geological exploration. Beryllium Resources, Inc., 1/ Vitro Minerals Corp., 2/ and Topaz Beryllium Corp. (jointly owned by the Anaconda Co. and Combined Metals Reduction Co.) have drilled and pitted in the area to delineate the ore horizons. The beryllium-bearing material is estimated to total from 3 to 4-1/2 million tons containing an average of 0.5 percent BeO. All three companies have been testing processes for treating the ores chemically. In addition, United Technical Industries (U.T.I.) of Salt Lake City, Utah, and the Beryllium Corp. have jointly tested processes for treating ore taken from U.T.I.'s claims in the area.

1/ Jointly owned by the Brush Beryllium Co. (29.5 percent); Hidden Splendor Corp., a subsidiary of Atlas Corp. (29.5 percent); Federal Resources Corp. (29.5 percent); and Mr. E. Van Dornick (11.5 percent).

2/ Jointly owned by Rochester & Pittsburgh Coal Co. and Vitro Corp.

Deposits in the Mt. Wheeler district, White Pine County, Nev., consist mainly of phenakite and bertrandite found in limestone. Largely as a result of exploratory work performed at the Mt. Wheeler mine (owned by Mt. Wheeler Mines, Inc.), potential reserves in the area have been estimated at 500,000 tons containing 0.5 to 1 percent BeO. The Mt. Wheeler ores have been tested by the U.S. Bureau of Mines and by private companies and have been found to be amenable to concentration, but indications are that mining would require high-cost underground operations. The Anaconda Co. currently (May 1962) is evaluating the potential of these deposits.

No information is available on the reserves of mixed beryl-bertrandite ores in Park County, Colo., which are currently being mined and concentrated. These ores occur chiefly in veinlike deposits in a mica-quartz rock (greisen).

Domestic reserves also include occurrences of helvite in New Mexico, chrysoberyl in Nevada, and disseminated beryl in Idaho.

It is estimated that during the last 3 years nearly $5 million in private capital has been invested in the United States in exploring for beryllium ores other than beryl and in development work and pilot plant facilities for extracting beryllium compounds from these ores. The U.S. Bureau of Mines is now engaged in an expanded beryllium ore exploration program. The increased activity, both by Government and industry, will doubtless add to the information now available on total ore reserves.

U.S. Government Procurement and Assistance Programs

All phases of the beryllium industry have been affected markedly by programs of the U.S. Government. Production of ores has been stimulated throughout the free world by Government purchases for the Atomic Energy Commission (AEC) and for stockpiling. For a period of 10 years, a domestic purchase program provided a guaranteed market for domestic beryl ore. AEC purchases and Commodity Credit Corporation (CCC) barter contracts which provide for the acquisition of beryllium metal and alloys have greatly stimulated beryllium refining. Government contracts have directly and indirectly accounted for a large share of the demand for refined beryllium products. These products are used in military, space, and nuclear programs.

Government purchases for stockpiling and other purposes

During World War II, the Government purchased beryl ore for stockpiling under the authority of the strategic material stockpiling act of 1939 (53 Stat. 811). At the end of the war, these stocks were transferred to the national stockpile (strategic stockpile) under the authority of the 1939 act as amended by Public Law 520, 79th Cong. (60 Stat. 596), which provided authority for the bulk of the postwar purchases of materials for stockpiling. Since the end of World War II, significant Government purchases for stockpiling have also been made under the provisions of the Defense Production Act of 1950 (64 Stat. 798), and the Commodity Credit Corporation Charter Act (approved June 29, 1948; 62 Stat. 1070), and the Agricultural Trade Development and Assistance Act of 1954 (68 Stat. 454).

As of December 31, 1961, the maximum objective of the national stockpile was 23,100 short tons of beryl ore, including the ore equivalent of

7 million pounds of beryllium-copper master alloy. On that date the total stocks of ore on hand were equivalent to 36,000 short tons of beryl containing 11 percent BeO. The estimated market value of these stocks at the end of 1961 was $35,200,000, whereas the acquisition cost had amounted to $33,500,000. Stocks of beryl ore on hand at that time exceeded the maximum objective by 12,900 short tons, valued at $23,300,000. 1/

Of the total inventory on hand on December 31, 1961, about 23,000 short tons (including the ore equivalent of 2,171,000 pounds of beryllium-copper master alloy) comprised materials in the national stockpile. About 2,000 short tons were in the DPA inventory, 2/ and 11,000 short tons (including the ore equivalent of 12,624,000 pounds of beryllium-copper master alloy) were in the CCC and supplemental stockpile.

Purchase programs for domestic ore.--A purchase program for domestic beryl, initiated by the General Services Administration (GSA), became effective on October 11, 1952, in accordance with the Defense Production Act of 1950. The purpose of the program was to "encourage expansion in the production of beryl ore by small producers by providing a uniform price scale . . ." The domestic purchase regulation, as amended, provided for the termination of the program on June 30, 1962, or when 4,500 short tons of beryl ore had been received, whichever was earlier. 3/

1/ The excess includes the ore equivalent of 7,795,000 pounds of beryllium-copper master alloy.

2/ Originally administered by the Defense Production Administration and now by the Office of Emergency Planning.

3/ Legislation (S. 1419 and H.R. 5769) was introduced in the 87th Congress "to extend the purchase program for beryl ore under the Defense Production Act of 1950 to include other forms of beryllium ore." Other bills (S. 2497, H.R. 9358, and H.R. 9921) were introduced "to extend the purchase programs for . . . beryl ores to June 30, 1965" and to increase the quantity limit by 1,000 tons.

The program provided for a price of $50 per short ton unit 1/ for ore containing 10 percent beryllium oxide or more; $45 per unit for ore having a BeO content of 9 to 9.9 percent, and $40 per unit for ore having a BeO content of 8 to 8.9 percent. The prices cited were for ore delivered to GSA purchase depots at Custer, S. Dak., Franklin, N.H., and Spruce Pine, N.C.

To be acceptable the ore had to contain a minimum of 8 percent beryllium oxide and had to be "in the form of clean crystals, cobbed free of waste." Thus, beryllium ore other than crystalline beryl cobbed free of waste was not eligible for purchase under the program. By December 31, 1961, a total of 3,030 tons of cobbed beryl ore, valued at $1,687,000, had been purchased and stockpiled. Of this quantity, 877 tons had been sold at $104,000 below the cost of acquisition.

Under the provisions of the Defense Production Act, the GSA also negotiated two individual contracts for the acquisition of beryl ore and beryl concentrate in 1952 and 1953, respectively. Under these contracts, 312 short tons of beryl ore mined in South Dakota were purchased for $111,000, and beryl concentrates containing 699 metric ton units of beryllium oxide (about 77 short tons of beryl) were purchased for $35,000 from a Brazilian firm.

Commodity Credit Corporation barter contracts.--Under the Commodity Credit Corporation Charter Act and the Agricultural Trade Development and Assistance Act of 1954, the CCC has implemented procurement for

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1/ Beryllium ore prices are quoted on the basis of short ton units of beryllium oxide contained in the ore. A short ton unit is defined as 1 percent of a short ton, or 20 pounds of BeO. Thus the price of a short ton of beryllium ore is determined by multiplying the percentage of BeO in the ore by the price of a unit of BeO. For example, assuming that the price of the BeO per short ton unit is $50, the value of a ton of beryllium ore having a BeO content of 10 percent would be $500.

stockpiling by bartering surplus agricultural commodities for foreign beryl and domestic beryllium-copper master alloy and beryllium metal produced from imported beryl.

Under the barter program imported beryl ore was first received in the fall of 1954. Aggregate receipts amounted to 4,406 short tons by December 31, 1961. No beryl ore has been received in 1962, and no CCC barter contracts were outstanding on July 31, 1962. Beryllium-copper master alloy was first received under the program in the fall of 1956. By December 31, 1961, receipts had totaled 12,623,963 pounds. No beryllium-copper master alloy was received during the period January-July 1962. There were no outstanding Government contracts as of July 1962.

In September 1961, beryllium metal was added to the list of commodities that would be accepted under the barter program in exchange for surplus agricultural commodities. The announced purpose of the program was to assist in "maintaining employment in domestic industry" and to "bring into the supplemental stockpile a strategic material." In January 1962, two barter contracts were announced for acquisition of beryllium metal, produced from imported beryl, valued at $17.4 million in exchange for surplus agricultural products. 1/

Atomic Energy Commission purchase contracts.--To provide metal for nuclear activities, the Atomic Energy Commission contracted in 1956 with

1/ Beryl ore to be used in the production of beryllium metal is expected to come from Latin America and Africa. The agricultural commodities involved--wheat, tobacco, feed grains, nonfat dry milk and butter--will go to Australia, Austria, Egypt, Hong Kong, Ireland, Israel, Jamaica, Japan, Portugal, the United Kingdom, and West Germany. The metal is to be received in the form of vacuum-cast ingot.

the two U.S. producers of beryllium metal for the annual delivery by each firm of 100,000 pounds of nuclear grade beryllium ingot over a 5-year period beginning in 1958. The contracts were amended in 1958 to provide for the annual delivery of 37,500 pounds by each firm. The final deliveries under these contracts were scheduled for 1962.

Other Government programs

Government loans.--Section 302 of the Defense Production Act of 1950 provides for Government loans to private business to stimulate production of materials essential to national defense. 1/

In 1951 the Reconstruction Finance Corporation (RFC) extended a loan of $800,000 to the Brush Beryllium Co. to construct a plant at Elmore, Ohio, for the production of beryllium-copper master alloy. In 1952 the RFC extended two loans to domestic producers of beryl ore to purchase equipment and to provide working capital. The loan to one concern amounted to $125,000; foreclosure resulted in a loss to the Government of about $94,000. The other loan amounted to $44,545; foreclosure in that instance resulted in a loss to the Government of about $35,000.

Accelerated tax amortization privileges.--The Revenue Act of 1950 (64 Stat. 906), provided that the cost of plants, or portions thereof, required for defense purposes might be written off for tax purposes over a 5-year period rather than over the economic life of the property, and

1/ Before such loans are granted, the Director of the Office of Emergency Planning must certify that the projects are essential to the defense effort and that funds are not available from private sources. Initially, the loans were administered by the Reconstruction Finance Corporation; after liquidation of that agency in 1953, the authority to administer the loans was transferred to the Secretary of the Treasury.

the writeoff provision was retained in the Internal Revenue Code of 1954. To be eligible for such accelerated depreciation, the facility must have been granted a "certificate of necessity" by the Office of Defense Mobilization, 1/ which was the certifying authority for the Department of Defense and the Atomic Energy Commission. After December 31, 1959, certificates of necessity were no longer available.

The privilege of rapid tax amortization has played an important role in the expansion of facilities of the two domestic producers of metal. In the period 1951-57, the Brush Beryllium Co. and the Beryllium Corp. were granted certificates of necessity covering $10.3 million of their cost of expanding and constructing new facilities. About $6.5 million, or 63 percent of the amount certified as essential for defense purposes, was declared eligible for rapid writeoff for tax purposes. 2/

Depletion allowances.--For income-tax purposes, the Internal Revenue Code permits producers engaged in the extraction of natural resources to deduct from their gross income an allowance for the depletion of reserves. The allowance may be computed either on the basis of the cost of the resource in question (including the cost of development and other specified charges) or on the basis of a fixed percentage of the gross income derived from it. If the latter method is used, the deduction may not exceed one-half of the owner's taxable income from the property. Special provisions of the Internal Revenue Code of 1954 (sec. 613), provide for a depletion deduction rate of 23 percent for certain domestically produced strategic

1/ Initially, certificates were issued by the National Security Resources Board, followed by the Defense Production Administration.

2/ Certificates of eligibility issued to the Brush Beryllium Co. amounted to $3,465,000 and one issued to the Beryllium Corp. amounted to $3,060,000.

minerals, including beryl. 1/ The deduction rate for other beryllium ores is 15 percent. A bill was introduced in the 87th Congress to make all beryllium ores subject to the deduction rate of 23 percent.

The depletion deduction rate for U.S. income-tax purposes on all beryllium ores produced by U.S. concerns in foreign countries is 15 percent.

Exploration assistance program.--To stimulate the search for ore, Government agencies have provided financial assistance for beryllium ore exploration under the authority of the Defense Production Act of 1950. The program was initiated in 1950 by the Defense Minerals Administration, the name of which was changed to the Defense Minerals Exploration Administration in 1951; its administration was assumed by the Office of Minerals Exploration in 1958. Initially, the Government was authorized to provide funds covering 90 percent of the total exploration cost; the authorization was changed to 75 percent in 1953 and to 50 percent in 1958. Also in 1958 a limit of $250,000 was set on the amount of Government participation permitted in any one contract.

The program initially specified beryl ores but was enlarged to include all beryllium ores after August 1960. One contract was negotiated for exploration for beryllium ores other than beryl. The contract, which involved properties located in Utah, was rescinded because of conflicting claims.

By January 31, 1962, 26 contracts had been negotiated. Actual expenditures by the Government amounted to $113,555, of which $2,335 had

1/ The depletion deduction is allowed to any person having a legal or contractual right to participate in the income derived from the property, and it continues even though the cost of the property has already been recovered by previous years' depletion allowances.

been repaid from royalties. Of the total number of contracts, 10 had been certified (indicating ore was found and royalty would be due the Government in the event of any production within a 10-year period). Most of the contract recipients were small miners, but at one time contracts were in force with the two beryllium metal producers. In July 1962 no contracts were in force.

Research and development programs.--For some time the U.S. Bureau of Mines has been actively engaged in the search for domestic sources of beryllium ore. In the fiscal year 1962 it greatly expanded its program, using advanced techniques and equipment. The U.S. Geological Survey, in its study of the geology of the United States, has examined and described many beryllium deposits.

The Bureau of Mines has also been testing various methods for concentrating beryllium ores of different types. In May 1962 its process for concentrating beryl and spodumene by flotation was patented and became available to the public without royalty. The method has been tested in a pilot plant at Kings Mountain, N.C., near the extensive disseminated beryl deposits in the area. At various experimental stations, the Bureau has conducted research on techniques for electrochemical production of high-purity beryllium metal, on the preparation of ingots for pure metal, and on problems relating to ductility. Research has also been undertaken on the production of beryllium castings directly from ingots.

In recent years a number of other Government agencies--particularly the Atomic Energy Commission, the Department of Defense, and the National Aeronautics and Space Administration--have engaged directly in research, or have sponsored projects by private organizations, relating to the purification, fabrication, and utilization of beryllium products.

Position of the United States in World Production and Consumption

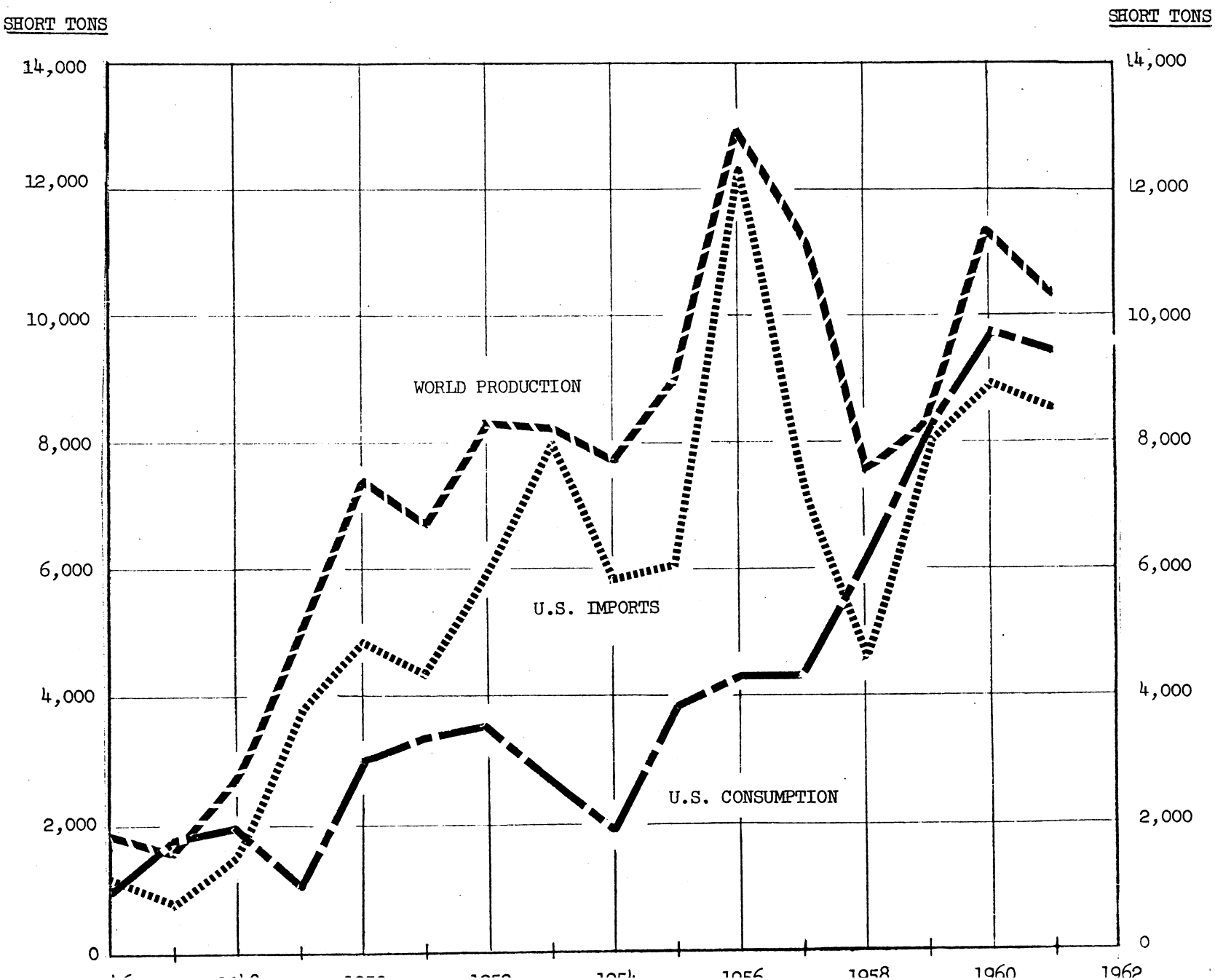
The United States is by far the world's largest producer and consumer of refined beryllium products. Other producers are France, Great Britain, West Germany, Japan, Italy, Argentina, and the Soviet Union. The combined output of these countries, however, is much smaller than that in the United States. The requirements for beryllium products in the Western European countries, the principal area of consumption outside the United States, appear to have been met largely by U.S. producers.

In keeping with its position as the world's largest producer of refined beryllium products, the United States also accounts for the bulk of the world's consumption of ore. U.S. output of ore is small, however, in relation to both world production and domestic consumption. In 1957-61 the United States accounted for about 6 percent of the average annual world output of ore. Most U.S. output was stockpiled. From the foregoing it is clear that virtually all of the beryl ores consumed in the United States have been supplied by imports. In the years in which the volume of imports exceeded the volume consumed, the excess has reflected chiefly additions to Government stockpiles (see chart on the following page).

Data on the quantity of refined beryllium products consumed in the United States are not available; however, the long-term trend is indicated by the trend in domestic consumption of beryllium ore (table 4). These data show that total domestic consumption averaged 2,105 short tons annually in 1941-45, 1,751 tons annually in 1946-50, and 3,067 tons in 1951-55. Thereafter consumption rose sharply; it reached a record high of 9,692 short tons in 1960 and 9,392 tons in 1961. 1/

1/ In addition to beryllium ore, both metal producers use substantial quantities of beryllium metal scrap and beryllium alloy scrap, which consist almost entirely of new scrap recovered during the production of fabricated and semifabricated products from primary metal and alloys. Data on the total quantity of scrap consumed are not available, but consumption is known to be substantial. It is estimated that about 70 to 80 percent of the hot-pressed beryllium billet put into processing is returned to the refineries as scrap for recycling; similarly, a substantial proportion of the beryllium alloy ingot put into processing is recycled as new scrap. Recovery of old scrap from used, discarded beryllium products, if any, is small.

BERYLLIUM ORES: WORLD PRODUCTION, U.S. IMPORTS, AND U.S. CONSUMPTION, 1946-61



U.S. Production, Capacity, and Sales

Much of the discussion in this section relating to refined beryllium products is based on data supplied to the Tariff Commission by the two U.S. concerns that produce beryllium metal from ore. Inasmuch as only two producers are involved, the publication of totals on production, capacity, sales, and related aspects of the domestic industry would disclose operations of one company to the other. Since consent to such disclosure has not been obtained, the Commission may not publish the aforementioned totals (18 U.S.C. 1905). Such quantitative data as are hereinafter reported were obtained from published sources.

Refined beryllium products

Production.--Data on production of refined beryllium products are not available from published sources. From the foregoing data on consumption of beryllium ore, however, it is clear that U.S. output was fairly stable during much of the period 1941-55 and increased rapidly thereafter. Assuming no change in the yield of beryllium recovered from ore, the data indicate that the beryllium content of primary products 1/ derived from ore more than doubled between 1957 and 1960, but was slightly smaller in 1961 than in 1960.

Data supplied to the Commission by domestic producers show that the annual output of beryllium metal in primary form increased without interruption between 1958 and 1961, when production was at a record level. Production of beryllium-copper alloy ingot increased substantially in the period 1958-60, but was smaller in 1961 than in 1960. Production

1/ Primary beryllium products include bead and pebble, flake, vacuum-cast ingot, master alloys, and compounds.

of most other primary beryllium products by these concerns increased during the period. Similarly, production of most semifabricated and fabricated products increased markedly.

Capacity.--Capacity for producing beryllium metal is reflected by the industry's rated annual capacity to produce vacuum-cast beryllium ingot from ore; the rated capacities reported are based on the assumption that plant facilities will be (1) fully utilized and (2) operated three shifts a day, 7 days a week, 50 weeks a year.

Available data indicate that capacity has risen sharply in the past few years. The total domestic capacity for producing beryllium metal from ore increased from 1,000 pounds in 1942 to 3,000 pounds in 1945, and then rose sharply to 24,000 pounds in 1948. During the 1942-48 period all of the U.S. output of beryllium metal was supplied by the Brush Beryllium Co. Near the end of 1948 the facility of the Brush Beryllium Co. was destroyed by fire. In 1950 the company opened a new plant having a rated annual capacity of 48,000 pounds. In 1958, the Beryllium Corp. completed its plant for producing beryllium metal; the capacity of both concerns increased rapidly thereafter. Late in 1961 the total estimated industry capacity amounted to 660,000 pounds annually. 1/ So far as is known, there has been no appreciable expansion in plant capacity since that time. Information presented to the Tariff Commission during its public hearing indicates that early in

1/ N. W. Bass, vice president of The Brush Beryllium Co., "Technology, Drive, Move Markets to Lower Cost of Beryllium," American Metal Market, Nov. 21, 1961.

1962, these concerns were operating at about 50 percent of capacity. 1/

Trends in sales.--The information reported by the two major domestic refiners on the value of their sales of specific refined beryllium products may not be published. Data on total sales of all products by these concerns, however, are regularly published in their annual reports to stockholders. Inasmuch as the bulk of their sales consist of beryllium products produced from ore, these data are indicative of long-term trends in their aggregate sales of the beryllium products produced by them.

The following tabulation shows the combined sales of all products by the two concerns during 1951-61, as reported by Standard and Poor's:

Year	Total net sales of all products by major domestic refiners of beryllium ore (million dollars)
1951	10.8
1952	12.6
1953	12.0
1954	9.5
1955	15.8
1956	23.2
1957	24.1
1958	27.4
1959	39.3
1960	53.0
1961	49.7

Aggregate annual sales increased almost without interruption from $10.8 million in 1951 to $53.0 million in 1960. In 1961, total sales amounted to $49.7 million, the second highest year on record. The annual increase in the value of sales in 1951-57 averaged about 20 percent, compared with an average of 27 percent in 1958-61.

1/ Transcript of U.S. Tariff Commission hearing on beryllium Apr. 17, 1962, testimony of James D. Williams, president, Mt. Wheeler Mines, Inc., p. 63.

Sales by kinds of products.--Information supplied to the Commission in response to its questionnaires indicates that the quantity of beryllium metal products sold by these concerns increased without interruption between 1958 and 1961. In terms of contained beryllium, sales of beryllium alloys rose between 1958 and 1960, but were substantially smaller in 1961 than in 1960; most of that decrease was attributable to the decline in sales of beryllium-copper ingot. Sales of most other beryllium products rose sharply between 1958 and 1961.

In 1960-61, sales of beryllium metal accounted for the major share of the value of sales of all beryllium products. Sales of beryllium-copper alloys accounted for all but a small part of remaining sales in those years. Sales of semifabricated and fabricated products (including metal, alloy, and ceramics) were equal to about three-fourths of the value of sales of all beryllium products by these two concerns in 1960-61.

Because of the inherent characteristics of beryllium, the production of semifabricated and fabricated products involves many technical problems and complex production processes. To a large extent both semifabricated and fabricated beryllium products are manufactured to rigid customer specifications and incorporate a large number of man-hours of highly skilled labor. As a result there is a wide spread between the unit values of the primary products sold and the unit values of fabricated products made therefrom.

Sales to the U.S. Government.--As noted, beryllium products are widely used in the nation's space, missile, and nuclear energy programs, and by the electronics industry. Many of the programs and industries

involved have been closely associated with the activities of the Government in these fields. Accordingly, a large part of total sales of the two producers of beryllium metal are made directly or indirectly to the U.S. Government. It is estimated that in 1961 at least 70 percent of the total sales of all refined beryllium products (in terms of their beryllium content) were either directly or indirectly connected with U.S. Government programs.

Beryllium ores and concentrates

Trends in mine shipments.--Total U.S. mine shipments of beryllium ore (gross weight basis) averaged 584 short tons annually in 1951-55 and about 481 in 1956-60. In 1961 they amounted to 1,122 short tons. Before 1958 most of the U.S. production consisted of cobbed beryl having an average BeO content of about 11 percent. Since 1958, production has consisted of both beryl ore and off-grade beryl-bertrandite mixtures. Shipments of these off-grade ores rose steadily from 42 short tons in 1958 to 805 tons in 1961, when they were equivalent to about 72 percent of aggregate U.S. shipments. The average BeO content of these off-grade ores amounted to 5.0 percent in 1960 and 3.4 percent in 1961.

Principal producing States.--South Dakota, which has been the leading producer of beryl ore in the United States since 1951, accounted for 75 percent of the total domestic output of such ore in 1961 (table 5); Colorado, New Mexico, and New Hampshire have supplied most of the remainder. Colorado has been the sole source of off-grade beryllium ores.

Value of mine shipments.--The total value of the beryl ore shipped by domestic mines, as reported by the Bureau of Mines, declined from

$238,000 in 1958 to $121,000 in 1960, whereas the value of other beryllium ores increased from $5,000 in 1958 to about $41,000 in 1960 (table 6). Published data on the value of shipments for 1961 are not available.

In 1958-61 nearly all of the domestically produced beryl ore was sold to the U.S. beryl purchase depots operated by the General Services Administration. The average value ranged between $46 and $48 per short ton unit in those years. The average value of the beryl-bertrandite ore sold to a producer of beryllium oxide in Colorado approximated $42 per short ton unit in 1958, $20 in 1959, and $31 in 1960.

Coproducts.--Most of the beryl ore produced in the United States is mined jointly with other minerals. In fact, few U.S. mines could be sustained by the production of beryl alone. Information supplied in response to the Commission's questionnaire by individual producers indicates that the combined value of other minerals shipped from mines that produced beryl in 1961 was about equal to the value of the beryl ore shipped. The following tabulation shows the composition, in terms of value, of the shipments of minerals from mines producing beryl in 1961: 1/

Products shipped	Percent of total value of shipments
Beryl	48
Mica	37
Feldspar	10
Quartz	5
Total	100

1/ Derived from data supplied by 29 mine operators that accounted for 80 percent of the total U.S. output of beryl in that year. No byproducts were shipped in 1961 by mines that produced mixed bertrandite-beryl-phenakite ores.

Stocks

Domestic metal producers' stocks

Refined beryllium products.--Data supplied to the Commission by the two domestic metal producers indicate that their stocks of beryllium metal rose without interruption from the end of 1957 to the end of 1961. Much of this increase is attributable to the rise in inventory of primary products. The ratio of year-end inventories of semifabricated and fabricated beryllium metal products to the annual sales of those products declined sharply between 1958 and 1961.

In terms of beryllium content, total inventories of beryllium alloys increased appreciably from the end of 1957 to the end of 1961. Nearly all of this increase was attributable to the rise in stocks of fabricated and semifabricated beryllium-copper alloys; the ratio of yearend inventories to sales of such products also increased.

Yearend inventories of beryllium compounds also rose substantially during this period. The ratio of inventories of beryllium compounds to sales, however, declined markedly in this period.

Beryllium ore and scrap.--In terms of contained beryllium, stocks of beryl ore in the hands of the two producers of metal declined sharply from the end of 1957 to the end of 1960. Although inventories of ore rose substantially in 1961, they were still materially below the 1957 level.

The beryllium content of the beryllium scrap in the hands of the two domestic metal producers also increased sharply between 1957 and 1961. The bulk of the increase was attributable to supplies generated

by the fabricating divisions of the two concerns, and thus reflects in part a rise in operating levels during that period.

Government stocks

Data on Government stocks of beryllium metal are not available. 1/ At the end of 1961, Government stocks of beryllium-copper ingot amounted to about 14.8 million pounds; the beryllium content of these stocks amounted to about 592,000 pounds.

Government stocks of beryl ore for the years 1942-61 are shown in table 7, along with total U.S. consumption and total U.S. industry stocks. The table shows that Government stocks were small prior to 1953, both in quantity and in relation to U.S. consumption. Since that time, they have been maintained at significantly higher levels. They rose rapidly from about 11,000 short tons in 1953 to a record of 32,000 tons in 1960. 2/ They were about 3,000 tons smaller in 1961 than in 1960, as a result of transfers to industry. During each of the years 1959-61, Government stocks of beryl ore were equivalent to a 3- to 4-year supply at the rate of U.S. consumption in those years.

1/ Data on AEC stocks of beryllium metal are classified information. There were no acquisitions of beryllium metal by the CCC under barter contract until 1962. There are no other Government stocks of beryllium metal.

2/ The data do not include the ore equivalent of beryllium-copper master alloy in Government stocks.

Employment and Wages

Producers of beryllium metal

Data submitted to the Tariff Commission on employment and man-hours worked by production and related workers at plants of the two domestic metal producers may not be published. It may be observed, however, that in the period 1958-61, total man-hours worked annually by production workers engaged in producing semifabricated and fabricated products more than doubled; man-hours of employment by workers engaged in refining ore and producing primary products increased rapidly between 1958 and 1960, but was considerably smaller in 1961 than in 1960. The number of man-hours worked by production and related workers engaged in refining ore in 1961 was many times greater than that in mining beryllium ore.

Average hourly wages paid to production and related workers increased somewhat more in 1958-61 than did the average hourly wages paid all workers in U.S. manufacturing industries, which rose about 10 percent in that period.

Producers of ore

As noted earlier production of some beryllium ore was reported from about 100 mines in 1961. Some of them produced only a few pounds of ore in that year. Usable data on employment were submitted to the Commission by 30 mine operators who accounted for about 94 percent of the total domestic production reported in that year. The average number of employees reported by these operators totaled 49, of whom 41 were production and related workers. The work performed at 19 of the mine operations was done entirely by the operators, who were not included in the number of workers reported.

Reported man-hours worked by the 41 production and related workers in 1961 totaled 89,156. Information supplied to the Commission indicates that somewhat more than half of the man-hours worked in 1961 were allocated to the production of beryllium ore and the rest to the production of coproducts. The hourly wage paid the 41 production and related workers in 1961 averaged $1.83.

U.S. Imports

Refined beryllium products

The value of imports of refined beryllium products are insignificant compared to the value of either domestic sales or U.S. exports.

It is estimated that imports of primary metal products, consisting chiefly of beryllium powder and flake from France, were valued at $27,000 in 1960, $75,000 in 1961, and $40,000 in the first 6 months of 1962. Imports were negligible or nil before 1960.

During 1957-61, imports of beryllium oxide and beryllium carbonate combined ranged between a high of $51,828 (in 1958) and a low of $3,234 (in 1959) and averaged about $31,000 annually. France was the principal supplier; the balance came from West Germany and the United Kingdom.

Both of the two domestic refiners of beryllium metal import beryllium metal and alloy scrap. Although imports of scrap were many times larger in 1961 than in 1958, they still were small in 1961.

Imports of fabricated and semifabricated beryllium metal and alloys have been negligible.

Beryllium ores and concentrates

Trend of imports.--U.S. imports of beryllium ores and concentrates consist entirely of cobbed beryl ore. The imports averaged 2,447 short tons annually in 1940-45 and then declined sharply to 767 short tons in 1947 (table 4). Thereafter they rose almost without interruption to a record of 12,371 short tons in 1956, reflecting increases both in the level of domestic consumption and in acquisitions for Government stockpile. Imports then declined to 4,599 short tons in 1958. In 1959-61 they averaged 8,499 tons annually, with little variation from year to year.

Principal sources of imports.--Entries from four countries, Brazil, Argentina, Mozambique, and India, accounted for about 78 percent of the average annual U.S. imports in 1959-61, and for about 74 percent of the average in 1956-58 (table 8). Four countries--British East Africa, the Republic of the Congo, the Union of South Africa (including South-West Africa), and the Malagasy Republic (Madagascar)--supplied most of the remaining imports in recent years. In 1959-61, entries from each of these four countries accounted for nearly 5 percent of average annual imports.

Grades of ore imported.--The average BeO content of imported ore consumed by the two domestic producers of beryllium metal ranged between 11 and 12 percent in the period 1960-61.

Channels of distribution.--The major portion of U.S. imports of beryl ore are handled by two importers whose main offices are in New York City. The balance are imported by firms, also located principally in New York City, which sell either directly to domestic consumers or to the two major importers. For the most part the importers make delivery to the domestic consumers under term contracts extending from 12 to 18 months. In addition to stipulating the quantity of ore to be delivered, the contracts specify the price of the ore per short ton unit of contained BeO, as determined by laboratory assay after arrival at the U.S. port of entry. In effect, the price specified in the contract reflects the judgment of the parties concerned regarding the amount that must be paid foreign producers to assure the delivery of the quantity of ore indicated in the contracts.

Most importers maintain ore collection stations in the principal foreign producing countries. The miners are generally paid cash for the ore upon delivery. Usually the price is based on the estimated BeO content of the ore as determined by visual assay. The ore may then be sorted and regraded by hand, after which it is packaged for shipment to the United States. A 50-ton lot is a typical shipment.

Nearly all of the imported ore enters the United States at the port of Philadelphia, where it is sampled for subsequent assaying to determine the BeO content. The cost of shipping the ore (including freight, insurance, and handling) from the foreign port to the

U.S. point of consumption ranges from 10 to 15 percent of its delivered value. 1/

Value of imports.--The reported foreign value of the imported beryl ore declined from about $4.5 million in 1956 to about $1.5 million in 1958. Thereafter it rose to $2.9 million in 1960 and then fell to $2.8 million in 1961.

In general, the foreign value of the ore reported by the importer to the U.S. Government for statistical purposes is based on its estimated value as determined by a visual assay abroad. Thus there may be a substantial difference between the reported foreign value of the ore and its value as determined by assay in the United States.

U.S. Exports

The two domestic producers of beryllium metal account for the bulk of the U.S. exports of refined beryllium products. 2/ In terms of contained beryllium, their exports of refined products rose sharply in 1958-61; in this period the ratio of exports to total sales by these firms increased from about 4 percent to about 14 percent. Although exports of all refined beryllium products rose in this period, most of the increase was accounted for by exports of beryllium compounds and

1/ Transportation and handling charges for shipments from the foreign port to the U.S. point of consumption are estimated at from $4 to $6 per short ton unit.

2/ Data on the total quantity and value of exports may not be published because they would reveal the operations of individual concerns. Export data published by the Department of Commerce separately reporting beryllium products do not include beryllium-copper alloys or beryllium compounds and thus understate the volume of total exports.

beryllium-copper alloys. About half of the value of exports in 1960-61 consisted of primary products, chiefly alloys and compounds. The bulk of the exports of semifabricated and fabricated products in those years consisted of beryllium-copper alloys and beryllium metal. Exports of beryllium ores and concentrates were insignificant.

In recent years most of the U.S. exports have gone to Western Europe; Canada has been the major export market outside Europe.

Prices

Refined beryllium products

Prices received by producers.--The Commission requested the two domestic producers of refined beryllium products to supply information on their net selling prices of the principal beryllium products (exclusive of sales directly to the U.S. Government) on selected dates in the years 1958-62. Over this period the prices of fabricated and semifabricated beryllium metal products declined steadily; between February 1958 and February 1962 the decline was about 57 percent. However, the prices of other beryllium products for which information was supplied remained virtually unchanged during this period; such changes as occurred in the prices of beryllium-copper and other alloys reflected principally changes in the price of the metal that was alloyed with beryllium.

Quoted market prices.--Quoted market prices for beryllium in various t forms, as reported by E & MJ Metal and Mineral Markets, the Bureau of Mines, and American Metal Market are shown in table 9. The prices shown for refined beryllium products represent the range in the prices quoted by domestic producers or their agents, f.o.b. plant or point of shipment, for each

of the years 1952-61 and January-May 1962. The quoted prices of beryllium metal (97 percent pure, in lump or bead form) rose from $65 to $71.50 per pound upon the termination of Government price controls in March 1953. The $71.50 price remained in effect until the current price of $62 per pound was announced in August 1960.

The quoted price of beryllium-copper master alloy increased from $32 per pound of contained beryllium in 1952 to $43 per pound in 1955, and has since remained at that level. (In addition to the price of the contained beryllium, the purchaser must pay the price of the contained copper on the date of shipment.)

Ore

Domestic.--Since the initiation of the domestic purchase program in 1952, the prices quoted for domestic ore have been related closely to the prices paid by the General Services Administration. 1/ In January 1952, domestic beryl ore containing 10-12 percent BeO was quoted at $34-$37 per short ton unit, f.o.b. mine, whereas in December 1952, following initiation of the domestic purchase program (October 1952) the price for this material was $45-$48 per short ton unit (table 9). The price of domestically produced beryl ore has not changed since 1954. The GSA prices for domestic beryl in the form of clean crystals, cobbed free of waste, f.o.b. depots at Custer, S.D.; Franklin, N.H.; and Spruce Pine, N.C., per short ton unit have been as follows since October 1952:
8-8.9 percent BeO, $40; 9-9.9 percent BeO, $45; 10 percent BeO and over, $50. Although efforts are being made to develop a commercial market for beryllium mill concentrates, none exists at this time; consequently,

1/ Prices quoted by E&MJ for beryl ore, both domestic and imported, represent the range of prices paid for the ore, as indicated by importers, consumers, and producers.

published price quotations are not available. All mill concentrates currently produced in the United States are held by the company concentrating the ore for further processing into more advanced products.

Imported.--Quoted market prices of imported beryl ore containing 10 to 12 percent BeO, c.i.f. Philadelphia, ranged between $34 and $48 per short ton unit in 1952 and between $45 and $48 per short ton unit in 1953 (table 9). During these two years, the price of imported beryl (c.i.f. U.S. port) and that of domestic beryl (f.o.b. mine) were about the same. Since 1953, prices of imported beryl have been substantially lower than those of domestic beryllium ore. Prices of imported beryl declined steadily until in 1959 they ranged between $28 and $34.50, compared with $46 to $48 for domestic beryllium ore. In 1960, 1961, and January-July 1962, prices for imported beryl ores ranged from $31.75 to $34.50. On August 9, 1962, the price for imported ore under term contract ranged from $34.00 to $34.50; whereas prices quoted for spot sales of imported beryl ranged from $32 to $33 per short ton unit.

Foreign Production

Refined beryllium products

Seven foreign countries--France, the United Kingdom, Japan, Argentina, West Germany, Italy, and the Soviet Union--are known to have facilities for producing refined beryllium products from ore.

Perhaps the leading foreign producer is Pechiney et Cie., of France, which uses beryl ore to make high-purity beryllium metal by chloride electrolysis. Capacity at Pechiney for the production of beryllium metal is estimated at about 40,000 pounds per year (compared with estimated U.S. capacity of 660,000 pounds). A substantial share of Pechiney's output is being sold in the United States. In the United Kingdom, Consolidated Beryllium, Ltd., an affiliate of the Beryllium Corporation, owns a former United Kingdom Atomic Energy Authority plant at Milford Haven capable of producing nuclear-grade beryllium metal, as well as a plant for producing beryllium-copper master alloy at Avonmouth. 1/

Three concerns in Japan--Nippon Gaishi Kaisha, Ltd., Yokozawa Kagaku Kogyo, and Santoku Kinzoku Kogyo--produce refined beryllium products on a small scale. After a period of government-subsidized experimental work, these three firms initiated commercial production in 1958. In 1961, their combined capacity was estimated to be 460 short tons of beryllium-copper master alloy (4 percent); 26 tons of beryllium-

1/ Consolidated Beryllium, Ltd., is jointly owned by the Beryllium Corp. and the Imperial Smelting Corp., Ltd.

aluminum master alloy (3-5 percent Be); 4 tons of beryllium oxide powder, and 265 pounds of beryllium metal. Japan's production of beryllium-copper master alloy in 1960 was reported to be about 60 short tons. In Argentina, Cia Argentina Berilio y Aleaciones initiated production of beryllium alloy in 1958. By mid-1961 this company was reportedly producing beryllium-copper alloy (4 percent Be) at a monthly rate of 1,320 pounds and beryllium-cobalt-copper alloys (0.5 percent Be) at a monthly rate of 1,100 pounds. In Italy, Montecatini (Societa Generale per l'Industria Mineraria e Chimica, Anonima) recently initiated production of beryllium oxide from ore on a small scale. Production of refined beryllium metal in Italy terminated during World War II. Germany, which conducted a considerable amount of development work on beryllium earlier in this century, now reportedly produces a small quantity of beryllium alloys and compounds.

No quantitative data are available on the production and consumption of refined beryllium products in the U.S.S.R. Recent reports indicate that beryllium is used in the products of a number of that country's industries. All of the Soviet Union's output is believed to be from native beryl ores, including flotation concentrates, which are refined by the same chemical processes used in the United States.

Beryllium ore

As far as is known, all foreign mine production consists of beryl ore. Most foreign ores are from small deposits scattered in pegmatites. Usually only crystals large enough to be separated easily (three-fourths of an inch in length or larger) are recovered. In some areas, however, notably Mozambique and the Congo, crystals as small as one-fourth of an

inch or less are cobbed. Few of the deposits are sufficiently large to be worked for beryl alone on the basis of present technology and prices. Thus, with rare exception, all of the current foreign output is supplied from mines that have been or are being worked for other minerals, such as mica, feldspar, columbite-tantalite, quartz, gem emeralds, or minerals of lithium and tin.

For the most part, the beryl is taken from soft eluvial surface deposits or from open cuts in weathered pegmatite bodies which are easily worked by hand. The use of mechanical equipment is rare and most deposits are worked solely with pick and shovel. At a few of the larger deposits, pneumatic drills and bulldozers are used.

As soon as the observable supply of crystals is exhausted, production usually ceases. Most of the known deposits appear to have been well worked over and available information indicates that no newly found deposits of significance were exploited in the past few years. Moreover, there has been little economic incentive to work such deposits since present prices are not sufficiently high to encourage the development and mining of deposits for beryl alone.

Trends in world output.--As indicated in table 4, total world output of beryllium ore rose from 2,391 short tons in 1940 to about 6,000 tons in 1943; thereafter, output declined to about 1,085 tons in 1945.

Following World War II, world production rose almost without interruption to a record high of 12,900 tons in 1956, primarily in response to U.S. Government requirements for stockpiling. Production declined to 7,500 tons in 1958 and then rose to 11,300 tons in 1960; the quantity produced in 1961 was 10,300 tons.

Principal producing countries.--Essentially continuous beryl production has been reported in the past decade in about 15 countries, chiefly in South America, Africa, and southeast Asia (table 10).

In recent years Brazil has been the leading producer. Estimated annual output in that country averaged 3,675 short tons in 1960-61 and was equivalent to nearly a third of world production in those years. Production in Mozambique, currently the second-ranking producer, averaged 1,337 short tons annually in 1960-61, or the equivalent of about 13 percent of the world total. Estimated production in India, the third-ranking country was about 9 percent of world output in that period. 1/ The combined output of these three countries was equal to about half of the world output in 1957-61 and to about 40 percent of the average in 1952-56.

Most of the rest of world production in recent years has been fairly evenly distributed among 12 other countries. For example, production in each of six countries--Argentina, the Malagasy Republic, Uganda, the Federation of Rhodesia and Nyasaland, the United States, and the Republic of the Congo (including Ruanda-Urundi)--was in the range of 5 to 9 percent of world output in 1960-61. The combined annual output of these six countries averaged about 40 percent of average annual world output in 1952-61.

In 1960-61, production in each of three countries--Australia, the U.S.S.R., and the Union of South Africa (including South-West Africa)--

1/ India's estimated share of world production is probably greater than indicated, since production for that country is reported by the U.S. Bureau of Mines as being equivalent to U.S. imports.

ranged from 2 to 5 percent of average world output. The relative position of these three countries as producers of beryl has not changed materially since 1952.

Foreign ore reserves 1/

Beryl.--Inasmuch as beryl deposits tend to be widely scattered and sporadic, there has been limited exploration abroad. For many of the foreign producing areas no quantitative data on reserves are available.

Brazilian beryl deposits are located in the States of Rio Grande do Norte, Ceará, and Paraíba in northeastern Brazil, in the States of Minas Gerais in the east, and the State of Baía to the south. Some 10 years ago, estimates indicated the possibility of 200,000 tons of beryl ore in eastern Brazil and possibly another 100,000 tons in the north and northeast. 2/

Canada has had no production, but the Montgary pegmatite located at Bernic Lake in southeastern Manitoba about 110 miles northeast of Winnipeg reportedly has large deposits of beryl, the average beryl content of which is 2.2 percent (0.26 percent BeO). Lithium and cesium minerals are also present.

1/ Except where otherwise noted, information in this section of the report is compiled largely from U.S. Foreign Service dispatches and from publications of the U.S. Geological Survey and the Bureau of Mines.

2/ U.S. Bureau of Mines, Minerals Yearbook, 1953, Vol. 1, pp. 242-243.

In India, the chief source of beryl ore is Kodarma in Bihar State. Beryl is also found in the States of Rajasthan and Andhra Pradesh. The Indian Department of Atomic Energy offers to buy at a fixed price all beryl ore that meets minimum specifications.

African reserves of beryl ore are probably extensive but, as elsewhere, the known easily mined ores have been depleted.

In Mozambique, the largest beryl-producing country in Africa, the Government system of granting concessions to explore and to mine ores has restricted beryl production to three major producing companies. Two of them, Montemines, Lda., and Sociedade Minera de Melela, Lda., that had jointly accounted for most of the country's output, ceased operations in late 1961 and early 1962; the principals decided to place their capital in other ventures. The third company, and the major single producer, is Empreso Mineira de Alto Ligonha, Lda. All beryl deposits in Mozambique are located in the Zambezia district.

The major sources of beryl in Southern Rhodesia, in descending order of importance, are the Bikita district east of Fort Victoria in the south; the Miami district near the Zambezi River in the north; the Mtoko district in the northeastern corner of the country; and the Mazoe district north of Salisbury.

Uganda's Ankole district is the major beryl source in the country and the Ishasha Mine on the Ishasha River north of Kayonza is the largest producer.

Namaqualand is the main beryl locality in the Union of South Africa. The ore is found on both sides of the Orange River, mainly on the south side. Another important source of beryl is Lataba in the northeast

Transvaal. The northwestern part of Cape Province, including Namaqualand, includes a vast area in which beryl occurrences have been found, the area extending to the Warmbad district of South-West Africa. Karibib in central South-West Africa is that country's most important source of beryl ores.

In Argentina beryl is often a byproduct of quartz and feldspar production. In Brazil, columbite-tantalite and lithium ores are the major products. The Indian output of beryl is largely a byproduct of mica production. Mozambique's major pegmatite product is columbite-tantalite. In the Congo the major product is cassiterite (a tin mineral); in Southern Rhodesia, mainly lithium ores, tantalite, and mica; in Uganda, columbite-tantalite; and in South-West Africa, mainly lithium ores, with some columbite-tantalite ores.

Other beryllium ore.--Information on foreign deposits of beryllium ore other than beryl is limited, but such ore is known to exist in substantial quantities in various parts of the world.

Deposits of bertrandite and fluorspar have been found in the Aguachile District, Coahuila, Mexico, about 80 miles below the U.S. border. The deposits are in limestone that has been altered by volcanic activity. Available data indicate an average grade of about 0.27 percent BeO. The bertrandite is generally coarse grained. 1/

Another apparently extensive deposit, which contains the beryllium mineral barylite, is located near Seal Lake about 100 miles northwest

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1/ Smith, Woo, and Dickerson, op. cit., pp. 3-4.

of Goose Bay, Labrador. The barylite and other as yet unidentified beryllium minerals are found in metamorphosed volcanic and sedimentary rocks, chiefly paragneisses and associated migmatites. These deposits have a potential of 3 million tons of ore containing 0.5 percent BeO. 1/

1/ Smith, Woo, and Dickerson, op. cit., p. 7.

Appendix A

Senate Resolution 206

87TH CONGRESS
1ST SESSION

S. RES. 206

[Report No. 1103]

IN THE SENATE OF THE UNITED STATES

SEPTEMBER 11, 1961

Mr. DIRKSEN (for himself, Mr. MANSFIELD, Mr. COOPER, Mr. MORTON, Mr. ALLOTT, and Mr. DWORSHAK) submitted the following resolution; which was referred to the Committee on Finance

SEPTEMBER 21, 1961

Reported by Mr. BYRD of Virginia, with amendments

SEPTEMBER 23, 1961

Considered, amended, and agreed to; preamble agreed to

RESOLUTION

Whereas, pursuant to a resolution of the Senate Committee on Finance, dated August 14, 1954, the United States Tariff Commission made an investigation under section 332 of the Tariff Act of 1930, of the domestic fluorspar industry and submitted a report of the results thereof to the said committee on June 6, 1955, and the Senate of the United States subsequently on August 21, 1959, by S. Res. 163, directed the United States Tariff Commission to bring up to date said report and to submit its findings not later than February 21, 1960; and

Whereas, pursuant to a resolution of the United States Senate adopted August 21, 1959, the United States Tariff Commission was directed to make a supplemental investigation of conditions in the lead and zinc industry and to bring up to date its report on lead and zinc which had previously been made on April 19, 1954; and

Whereas, pursuant to a resolution of the Senate Committee on Finance, dated March 17, 1958, the United States Tariff Commission made an investigation under section 332 of the Tariff Act of 1930, of the domestic mercury (quicksilver) industry and submitted a report of the results thereof to the said committee on December 1, 1958; and

Whereas the industries producing manganese, cobalt, and beryllium are becoming more and more distressed and such distress could have an effect on our national security: Now, therefore, be it

Resolved, That the United States Tariff Commission is hereby directed, pursuant to section 332 of the Tariff Act of 1930, to make further studies and bring up to date the reports on lead, zinc, mercury, and fluorspar and to report to the Congress on or before May 15, 1962, and to conduct investigations of conditions in the industries producing manganese, cobalt, and beryllium and report to Congress not later than August 31, 1962.

The supplemental reports and new reports shall include a summary of the facts obtained in the investigation, including a description of the domestic industry, domestic production, foreign production, imports, consumption, channels and methods of distribution, United States exports, and other factors affecting the competition between domestic and imported products. In the course of the investigations, the Commission shall hold hearings, giving adequate oppor-

tunity to interested parties to appear and be heard, except that in the case of lead, zinc, mercury, and fluorspar where reports are being brought up to date, the matter of further hearings shall be left to the discretion of the Tariff Commission.

Appendix B

Statistical Tables

Table 1.--Selected physical properties of beryllium and several competing metals.

Property 1/	Beryllium	Aluminum	Boron	Lithium	Magnesium	Titanium	Zirconium
Atomic number	4	13	5	3	12	22	40
Atomic weight	9.013	26.98	10.82	6.940	24.32	47.90	91.22
Density (specific gravity), 20°C (g/cm^3)	1.845	2.70	2.34	0.534	1.74	4.54	6.45
Melting point, °C	1284	660	2300	179	651	1668	1852
Melting point, °F	2345	1220	4172	354	1204	3035	3366
Boiling point, °C	2507	2450	2550	1317	1103	3260	3580
Heat of combustion (kg cal/g) 2/	17.2	7.4	13.0	10.3	6.0	-	-
Specific heat (cal/g/°C)	0.425	0.214	0.307	0.784	0.25	0.125	0.0659
Latent heat of fusion (cal/g)	250-275	96	489	158	82.2	104.5	60.3
Latent heat of vaporization (cal/g)	5917	3050	8300	4680	1337	2350	1360
Thermal conductivity (cal/cm/cm^2/sec/°C)	0.35	0.503	-	0.17	0.376	0.041	0.04
Electrical resistivity (microhm-cm)	4.2	2.66	650 x 10^9	8.55	4.46	42	44
Thermal neutron absorption cross section (barns/atom)	0.009	0.23	755	-	0.063	5.8	0.180

1/ Key to abbreviations: g--gram; cm--centimeter; kg--kilogram; cal--calorie; sec--second.

2/ Al Knoerr and Mike Eigo, "Beryllium Update 1961," Engineering and Mining Journal, vol. 162, No. 9, September 1961, p. 95.

Source: Clifford A. Hampel, ed., Rare Metals Handbook, 2d ed., London, 1961, except as noted.

Table 2.--Principal beryllium minerals

Mineral	Chemical composition	Percent BeO	Description 1/
Barylite	$BaBe_2Si_2O_7$	15.4-15.8	Orth., platy; greasy; white; H, 6-7; G, 4.0.
Bertrandite	$Be_4Si_2O_7(OH)_2$	39.6-42.6	Orth., tabular, prismatic; vitreous; colorless, yellow; H, 6; G, 2.6.
Beryl	$Be_3Al_2(SiO_3)_6$	10.0-14.0	Hex., prismatic, vitreous; green, blue, white, pink, yellow; H, 7.5-8; G, 2.6-2.8.
Beryllonite	$NaBePO_4$	19.8	Orth., short prismatic; vitreous; colorless, white, yellow; H, 5.5-6; G, 2.8; F, 5.
Bromellite	BeO	100.0	Hex., prismatic; white; H, 9; G, 3.0.
Chrysoberyl	$BeAl_2O_4$	16.9-19.7	Orth., tabular, twinned crystals; vitreous; green, yellow, brown, red; H, 8-9; G, 3.7.
Euclase	$BeAlSiO_4(OH)$	16.9	Mono., prismatic; vitreous; colorless, green, blue, white; H, 7.5; G, 3.0-4.0.
Eudidymite	$HNaBeSi_3O_8$	10.6-11.1	Mono., basal plates; vitreous; white; H, 6; G, 2.5.
Gadolinite	$Be_2Y_2FeSi_2O_{10}$	5.5-13.2	Mono., prismatic; vitreous; black, greenish, brown; H, 7; G, 4.0-4.6.
Hambergite	$Be_2(OH)BO_3$	36.7	Orth., prismatic; vitreous; gray-white; H, 7.5; G, 2.3.
Helvite group:			
Helvite	$Mn_4Be_3Si_3O_{12}S$	10.5-15.0	Isom., tetrahedrons, spherical masses; vitreous to resinous; yellow, red, brown; H, 6; G, 3.2-3.4.
Danalite	$Fe_4Be_3Si_3O_{12}S$	12.7-13.8	Isom., octahedrons, massive; red, brown; H, 6; G, 3.3-3.5.
Genthelvite	$Zn_4Be_3Si_3O_{12}S$	12.6	Isom., rose red, brown; H, 6; G, 3.6.
Leucophanite	$(Ca,Na)_2BeSi_2(O,OH,F)_7$	10.0-12.4	Orth., basal plates, massive, columnar; vitreous; white, green, yellow; H, 4; G, 3.
Meliphanite	$(Ca,Na)_2Be(Si,Al)_2(O,F)_7$	9.8-14.0	Tetr., obtuse pyramidal or platy; vitreous; yellow to reddish; H, 5-5.5; G, 3.
Phenakite	Be_2SiO_4	44.0-45.6	Trig., rhombohedral or prismatic; vitreous; colorless, yellow, rose, brown; H, 7.5-8; G, 3.0.
Trimerite	$Be_3Mn_2Ca(SiO_4)_3$	17.1	Mono., tubular prisms; pink; H, 6-7; G, 3.5.

1/ Key to abbreviations: G--specific gravity; H--hardness, Mohs scale; hex.--hexagonal; isom.--isometric; mono.--monoclinic; orth.--orthorhombic; tetr.--tetragonal; trig.--trigonal.

Source: Warner, Lawrence A., and others, Occurrence of Nonpegmatite Beryllium in the United States, U.S. Geological Survey Professional Paper 318, 1959.

Table 3.--Beryllium metal, manufactured articles, compounds and ores: U.S. rates of duty under pars. 79, 397, 5, 214, and 1719, Tariff Act of 1930, from June 18, 1930, to July 1, 1962

Tariff designation	Rate	Effective date and act or trade agreement
	Percent ad valorem	
Par. 79:		
Beryllium, caesium, potassium, and sodium (include beryllium metal in primary forms).	25 1/	June 18, 1930; Tariff Act of 1930.
	23-1/2	June 30, 1956; GATT.
	22-1/2	June 30, 1957; GATT.
	21	June 30, 1958; GATT.
	19 2/	July 1, 1962; GATT.
Par. 397:		
Articles n.s.p.f., 3/ partly or wholly manufactured, not plated with platinum, gold, or silver, and not colored with gold lacquer:		
* * *		
Wholly or in chief value of metal other than gold, lead, platinum, silver, tin, and tin plate:		
* * *		
Other than those in chief value of iron, steel, brass, bronze, zinc, or aluminum (include semifabricated and fabricated beryllium products, n.s.p.f.).	45 1/	June 18, 1930; Tariff Act of 1930.
	22-1/2	Jan. 1, 1948; GATT.
Par. 5:		
Chemical compounds, elements, and salts, medicinal preparations, and combinations and mixtures of any of the foregoing; all the foregoing obtained naturally or artificially and n.s.p.f.:		
* * *		
Beryllium oxide or carbonate	25 1/	June 18, 1930; Tariff Act of 1930.
	12-1/2 4/	Nov. 15, 1941; Argentina.
	12-1/2	June 6, 1951; GATT.
	11 5/	July 1, 1962; GATT.
* * *		
Other (include beryllium compounds other than oxide or carbonate).	25 1/	June 18, 1930; Tariff Act of 1930.
	12-1/2	June 6, 1951; GATT.
	11-1/2	June 30, 1956; GATT.
	11	June 30, 1957; GATT.
	10-1/2	June 30, 1958; GATT.
Par. 214:		
Earthy or mineral substances wholly or partly manufactured and articles (crude or advanced in condition) wholly or in chief value of earthy or mineral substances, n.s.p.f., whether susceptible of decoration or not:		
* * *		
Other:		
Not decorated in any manner:		
* * *		
Other (include refined beryllium ores and wrought forms of beryllium oxide).	30 1/	June 18, 1930; Tariff Act of 1930.
	15	Jan. 1, 1948; GATT.
Par. 1719:		
Minerals, crude or not advanced in condition or value by grinding, refining, or other process of manufacture, n.s.p.f.:		
Beryl or beryllium ore	Free	June 18, 1930; Tariff Act of 1930.
	Free 6/	Jan. 1, 1948; GATT.

1/ Currently applicable to the products of Communist-dominated nations or areas designated by the President pursuant to sec. 5 of the Trade Agreements Extension Act of 1951.

2/ The current rate will be reduced to 17 percent ad valorem effective July 1, 1963, pursuant to a concession granted at the 1960-61 GATT Conference.

3/ Not specially provided for.

4/ Concession subject to withdrawal or modification on 6 month's notice.

5/ The current rate will be reduced to 10 percent ad valorem effective July 1, 1963, pursuant to a concession granted at the 1960-61 GATT Conference.

6/ Bound.

Table 4.--Beryllium ore: U.S. consumption, shipments, and imports for consumption, and world production, 1940-61

(In short tons, gross weight)

Year	United States			World production
	Consumption	Shipments	Imports	
1940	600	121	810	2,391
1941	1,200	158	2,666	4,508
1942	2,352	269	2,050	3,311
1943	3,058	356	4,840	6,009
1944	2,176	388	3,115	3,262
1945	1,738	39	1,201	1,085
1946	1,013	100	1,188	1,872
1947	1,735	145	767	1,576
1948	1,970	99	1,720	2,721
1949	1,029	475	3,811	5,053
1950	3,007	559	4,860	7,400
1951	3,388	484	4,316	6,700
1952	3,476	515	5,978	8,300
1953	2,661	751	7,998	8,200
1954	1,948	669	5,816	7,700
1955	3,860	500	6,037	8,900
1956	4,341	445	12,371	12,900
1957	4,309	521	7,290	11,300
1958	6,002	505	4,599	7,500
1959	8,173	425	8,038	8,200
1960	9,692	509	1/ 8,943	11,300
1961	9,392	1,122	1/ 8,516	10,300

1/ Preliminary.

Source: Compiled from official statistics of the U.S. Bureau of Mines.

Table 5.--Cobbed beryl ore: Shipments from U.S. mines, by States, 1951-61

(In short tons, gross weight)

Year	Colorado	New Hampshire	New Mexico	South Dakota	All other	Total
1951	97	50	141	138	58	484
1952	54	1/	101	334	26	515
1953	75	57	89	392	138	751
1954	59	12	117	337	144	669
1955	46	20	106	294	34	500
1956	163	1/	31	195	56	445
1957	182	4	29	268	38	521
1958	2/ 134	14	27	240	48	2/ 463
1959	2/ 124	20	11	156	17	2/ 328
1960	2/ 39	14	-	167	24	2/ 244
1961	2/ 14	23	24	238	18	2/ 317

1/ Included with "All other" in order to avoid disclosing the operations of an individual concern.

2/ In addition to cobbed beryl ore, shipments of off-grade beryllium ore amounted to 42 tons in 1958, 97 tons in 1959, 265 tons in 1960, and 805 tons in 1961.

Source: Compiled from official statistics of the U.S. Bureau of Mines.

Table 6.--Beryllium ore: U.S. mine shipments, by kind of ore, 1958-61

Year	Beryl	Other beryllium ore	Total
	Quantity (short tons, gross weight)		
1958	463	42	505
1959	328	97	425
1960	244	265	509
1961	317	805	1,122
	Value		
1958	$238,017	$5,000	$243,017
1959	170,523	8,622	179,145
1960	121,105	41,250	162,355
1961	1/	1/	1/
	Approximate value per short ton unit of BeO		
1958	$47	$42	-
1959	48	20	-
1960	46	31	-
1961	1/	1/	-

1/ Publication of data for this year would reveal the operations of individual concerns.

Source: Compiled from official statistics of the U.S. Bureau of Mines.

Table 7.--U.S. consumption of beryl and yearend industry and Government stocks, 1941-61

(In short tons, gross weight)

Year	Consumption	Industry stocks	Government stocks 1/
1941	1,200	2,200	-
1942	2,353	1,400	725
1943	3,058	1,100	2,513
1944	2,176	131	4,669
1945	1,738	90	4,497
1946	1,013	879	4,118
1947	1,735	386	1,206
1948	1,970	1,042	198
1949	1,029	2,322	1,076
1950	3,007	2,621	3,196
1951	3,388	1,417	5,812
1952	3,476	2,492	7,754
1953	2,661	4,987	11,350
1954	1,948	4,101	16,673
1955	3,860	2,888	20,563
1956	4,341	4,643	27,283
1957	4,309	7,270	28,158
1958	6,002	4,529	29,959
1959	8,173	3,871	31,810
1960	9,692	2,740	32,336
1961	9,392	4,886	29,631

1/ Government stocks during the years 1950-61 were estimated by deducting U.S. consumption from the total of U.S. production and imports and adjusting the balance to account for changes in industry stocks.

Source: Compiled from official statistics of the U.S. Bureau of Mines.

Table 9.--Range in price quotations for specified beryllium products, 1952-61 and January-May 1962 1/

Period	Beryl ore 2/		Beryllium-copper 3/ master alloy (domestic)	Beryllium metal lump or beads 4/ (domestic)
	Domestic	Foreign		
	Per short ton unit BeO	Per short ton unit BeO	Per pound of beryllium content	Per pound
1952	$34.00-$48.00	$34.00-$48.00	$32.00	$65.00
1953	45.00- 48.00	45.00- 48.00	$32.00- 40.00	$65.00- 71.50
1954	46.00- 48.00	39.00- 46.00	40.00	71.50
1955	46.00- 48.00	36.00- 40.00	40.00- 43.00	71.50
1956	46.00- 48.00	36.00- 39.50	43.00	71.50
1957	46.00- 48.00	36.00- 39.00	43.00	71.50
1958	46.00- 48.00	28.00- 37.00	43.00	71.50
1959	46.00- 48.00	28.00- 34.50	43.00	71.50
1960	46.00- 48.00	31.75- 34.50	43.00	62.00- 71.50
1961	46.00- 48.00	31.75- 34.50	43.00	62.00
1962 (January-May)	46.00- 48.00	32.00- 34.50	43.00	62.00

1/ Price quotations for domestic ore are f.o.b. mine; for imported ore are c.i.f. U.S. port of entry (principally Philadelphia); prices for beryllium copper master alloy and beryllium metal lump or beads are f.o.b. producing plant.

2/ Containing 10-12 percent beryllium oxide.

3/ Containing approximately 4 percent beryllium.

4/ Containing 97 percent beryllium minimum.

Source: Ore prices, E & MJ Metal and Mineral Markets; beryllium-copper master alloy and beryllium metal lump or beads, U.S. Bureau of Mines, and American Metal Market.

Table 10.--Beryllium ore: World production, by country, average 1952-56, annual 1957-61 1/

(In short tons, gross weight)

Country	Average 1952-56	1957	1958	1959	1960	1961
Brazil	2,232	1,452	1,295	2,961	3,849	2/ 3,500
United States, total	576	521	505	425	509	1,122
Cobbed beryl	576	521	463	328	244	317
Other beryllium ore	-	-	42	97	265	805
Mozambique	682	1,870	1,161	1,559	1,649	2/ 1,025
India 3/	999	1,256	600	-	1,000	885
Argentina	1,058	1,571	1,004	645	739	2/ 770
Malagasy Republic 4/	418	299	181	468	701	2/ 660
Uganda	68	78	86	235	470	2/ 500
Republic of the Congo 5/	6/ 753	1,772	1,114	467	2/ 650	2/ 440
Federation of Rhodesia and Nyasaland	1,131	578	346	442	541	396
Australia	198	442	278	355	213	2/ 280
South-West Africa	535	386	247	170	413	252
U.S.S.R. 2/	110	110	160	220	220	220
Union of South Africa	283	711	464	203	325	192
Portugal	293	191	52	41	32	14
Swaziland	-	-	-	2	6	7
Kenya	1	6	4	2	1	1
Afghanistan	21	14	-	-	11	-
Sweden	-	-	28	3/ 41	-	-
Norway	-	-	3/ 3	3/ 4	-	-
Republic of Korea	3/ 3	7/	-	-	-	-
Morocco	40	-	-	-	-	-
British Somaliland	8/ 18	-	-	-	-	-
World total 9/	9,400	11,300	7,500	8,200	11,300	10,300

1/ Except for the United States, data on production of beryllium ores by kind of ore is not separately reported. Virtually all of the production outside the United States consists of hand-cobbed beryl.

2/ Estimated.

3/ Data represent U.S. imports.

4/ Became independent June 26, 1960; formerly Overseas Territory of Madagascar.

5/ Became independent June 26, 1960; formerly Belgian Congo. Data include production in Ruanda-Urundi.

6/ Represents the average for 1954-56 for the Belgian Congo and the average for 1953-56 for Ruanda-Urundi.

7/ Less than 1/2 short ton.

8/ 1955-56 average.

9/ Data do not add to totals shown because of rounding where estimated figures are included in the detail.

Source: Compiled from official statistics of the U.S. Bureau of Mines.