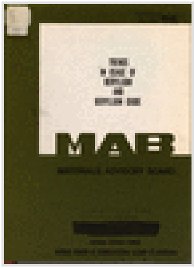

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TRENDS IN USAGE OF BERYLLIUM AND BERYLLIUM OXIDE

Prepared by

THE COMMITTEE ON TECHNICAL ASPECTS OF CRITICAL & STRATEGIC MATERIALS

MATERIALS ADVISORY BOARD

Division of Engineering - National Research Council

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FOREWORD

The intent of this report is to assess the changing applications of one of a group of materials (together with supply prospects), in a manner to be of assistance to a number of government agencies concerned with the adequacy of materials for critical military and civilian requirements. The focus is on changing technical requirements. From the conclusions reached, actions by the government such as the acquisition or disposal of government stockpiles might follow, but such decisions are necessarily influenced by other considerations, such as the economics of the situation. This report aims to answer the questions to only one part of the problem--prospective changes in use. Decisions on what to substitute for a scarce material are based on factors such as cost, production schedule, fabricability, and availability of property data as well as on purely technical considerations. Therefore, only limited comments could be made on substitutability.

Beyond the limitation noted above, a finite ability to predict the future should be appreciated. A worrysome aspect of materials management lies in the totally unexpected invention which generates a new requirement or renders an old one obsolete. Just as a committee cannot invent, neither can it foresee true invention. The best that can be hoped for are extrapolations based on recent discoveries and on technical and commercial trends. This is what is contained in the report that follows.

For the sources of data on material availability, principal credit is due the Bureau of Mines. These data have been augmented by input from metal producers who were asked to help, and from information available to the Committee members.

The report received the benefit of review by the entire Committee, by the sources of input from industry and by commodity specialists at the Bureau of Mines. Committee members were asked to serve as technical experts, and not as representatives of their company. This, together with the variety of inputs and reviews has made possible what are believed to be balanced presentations.

CONTENTS

Introduction

Beryllium is the first element in Group II of the periodic system of elements. Its atomic number is 4; its atomic weight is 9.0122. It was discovered in 1797 as a constituent of the mineral beryl; the first metallic beryllium was produced in 1828. Commercial development of beryllium in the United States was begun in 1916.

Beryllium metal has a low specific gravity of 1.848 at 20°C, and is known as the only such metal combining good physical strength with a high melting point, $1278 \pm 5^{\circ}C$. With a density only slightly greater than magnesium and a melting point nearly twice as high, a large and unique area of service would appear to be natural. This potential is unrealized primarily because of our present inability to produce beryllium with sufficient ductility for normal means of fabrication or sufficient resistance to brittle failure in service.

Beryllium's possibilities as a structural material for space and aircraft applications are very attractive. Its combined properties of low density, high modulus of elasticity, high heat capacity, and thermal conductivity make it a leading contender for airframe structures, aircraft brakes, and as a heat sink material.

Great interest in beryllium metal also exists because of its low atomic weight, low neutron-absorption cross section, and high neutron scatter cross section. These properties make it useful as a moderator in nuclear reactors.

Another possible use for beryllium would be as a high-energy fuel since it has the second highest heat yield rating among the elements (29,000 BTU/lb.), surpassed only by hydrogen (52,000 BTU/lb.).

The principal outlet for beryllium at present is in beryllium-copper because of its ability to precipitation-harden copper. Beryllium-copper alloys containing up to 2 percent beryllium have remarkable strength, wear and fatigue resistance, and electrical conductivity. They find applications in many consumer and industrial items, as well as in military uses for aircraft and electronic applications.

Beryllium oxide ceramics are finding increased technical applications because they exhibit the highest thermal conductivity of any ceramic material, combined with excellent dielectric properties and stability over a wide temperature range.

This report assesses present and projected technical advances, where beryllium and beryllium-containing materials may play an important role. It reviews the beryllium ore situation in the light of present and projected needs.

I. Raw Materials Availability

A. Sources and Consumption

Virtually all commercial world production to date has been obtained from the mineral beryl (3 $BeOAl_2O_3 6 SiO_2$). This mineral occurs characteristically in pegmatite dikes, and occasionally such occurrences may be considered commercial down to around 1 percent of beryl (about 3 pounds of BeO or 1 pound of beryllium per ton of ore mined). The beryl is cobbed out by hand, since no method for successful beneficiation has been developed and applied. Largely because of this high labor requirement, and the scarcity of crystal beryl, domestic deposits have supplied only minor amounts of U.S. consumption. Cobbed beryl contains an average of 10-12 percent BeO or 3.6-4.3 percent Be. Expressed differently, one ton of cobbed beryl contains 220 pounds of BeO or 79 pounds of Be, on the average. Allowing for yield losses, etc., it is generally estimated that a ton of cobbed beryl yields 50 pounds of beryllium metal.

Major world sources in recent years have been India, Brazil, U.S.S.R., Uganda, Mozambique, and Argentina. Table 1 shows U.S. mine shipments and world production of beryl, by countries, 1962-66. During the period 1935-1951, for each ton of beryl that the United States produced, the world produced 14 tons.

Table 1

World Production of Beryl by Countries[1]
(short tons)

Country	1962	1963	1964	1965	1966 p/4
Australia	250	123	125 r	44 r	28 e
Argentina	998 [2]	825 [2]	442 [2]	175 r,2	218 [3]
Brazil	3,319 [2]	2,170 [2]	1,566 [2]	1,227 r,2	877 [3]
Congo (Kinshasa)	304	235	136	21	21 e
India (U.S. Imports)	150	---	---	1,507	500
Kenya	---	---	---	---	---
Malagasy Republic	743	453	234	22	22 e
Mozambique	627	613	451	202 r	71 [3]
Portugal	19	2	20	44 r	44 e
Rhodesia, Southern	559	249	182	101 r,3	72 [3]
Rwanda	394	282	328	166 r,3	147
South Africa, Republic of	360	425	151	53	20 e
South-West Africa	159	61	8	57	25 e
Swaziland	---	2	---	---	---
Sweden (U.S. Imports)	26	---	49	---	---
Uganda	1,116	419	434	212	249 [3]
U.S.S.R. e,4	1,000	1,100	1,100	1,100	1,200
U.S. (Mine shipments):					
Cobbed beryl	218	1	W [5]	W [5]	W [5]
Other lower grade Be ore	760	750	---	---	---
World total (estimate)[1]	11,000	7,700	5,200	4,900 r	3,600

e Estimate. p Preliminary. r Revised. W Withheld to avoid disclosing individual company confidential data.

[1] Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[2] Exports.

[3] United States imports.

[4] Cobbed concentrates at about 11 percent BeO.

[5] U.S. output was very small, not included in world total.

Compiled by Bureau of Mines

During the 10-year period 1953-62, domestic production of beryl amounted to 4,456 tons, of which 3,276 tons (73 percent) was sold to the government at incentive prices for the stockpile program. Since then, production of domestic beryl has been small and the lower prevailing prices have discouraged production.

The relatively high world total of 1962-64 can be attributed to the building up of the government stockpile.

Beryl requirements, expressed in percentages for the three main products--metal, alloys, and oxide--are as follows:

	1962	1963	1964
Beryllium Metal	43.0	34.8	35.3
Beryllium Master Alloys	53.4	60.4	59.9
Beryllium Oxide (Ceramic)	3.6	4.8	4.8

Although no data are available for later years, there is no evidence that it has changed significantly.

A summary of salient statistics on beryl, 1957-61 (average) and 1962-1966 is given in Table 2.

Table 2

Salient Beryl Statistics

	1957-61 (avg)	1962	1963	1964	1965	1966
United States: Beryl, approx. 11% BeO unless otherwise stated:						
Domestic beryl shipped from mines - short tons	375	218	1	W	W	W
Other domestic low-grade Be ore - short tons	(1)	760	750	---	---	---
Imports - do	7,477	8,552	6,243	5,425	7,791	2,147
Consumption - do	7,514	7,758	7,934	4,435	5,845	6,026
Price, approx. per unit BeO imported, cobbed beryl at port of exportation	$30	$31	$24	$23	$26	$25
World: Production-short tons	11,080	11,000	7,700	5,200	4,900 r	3,600 p

W Withheld to avoid disclosing individual company confidential data.
p Preliminary
r Revised
(1)Material first available in 1958; 1958, 42 short tons; 1959, 97 short tons; 1960, 265 short tons; and 1961, 805 short tons.

B. Reserves

At the present levels of operation, or at any reasonable expanded level, such as 10-20 percent annual growth, reserves of foreign beryl ore are available, although price fluctuations can be expected along with changes in demand. Unlike many commodities, the price of beryl tends to rise as the amount utilized increases. Rather than lending itself to volume production economies, beryl mining normally expands into marginal areas as demand rises. Thus, although beryl reserves are believed adequate for a substantial volume increase, this will entail higher costs. For stabilization, a much larger assumed market than presently exists is required.

A great deal of effort has been spent by both industry and the government in searching for and appraising reserves of beryllium-bearing deposits in the United States, especially since 1958. Beryl reserves in pegmatites in the U.S. are fairly well known, but there are few data on world reserves.

A summary of beryllium-bearing reserves in the United States is shown in Table 3.

Table 3

Summary of Beryllium-Bearing Reserves in the United States[1]

	Short Tons	
	Beryl	Contained Be
A. In deposits containing at least 1% beryl and at least 100 tons of beryl (75% in N. England & South Dakota)	8,800	440
B. In deposits containing 0.2 to 1.0% beryl and at least 100 tons of beryl (90%+ in tin-spodumene belt in N.C.)	216,000	10,800
C. In deposits containing 0.4% beryl in tin-spodumene belt of pegmatites at Kings Mountain, N.C. - not yet economic for Be	823,000	41,000
D. Spor Mt. & Gold Hill, Utah (+15 million tons ore containing 0.5% BeO)		27,000

[1]Mineral Facts & Problems, 1965 Edition, U.S. Bureau of Mines, Bull. 630.

Table 3 (continued)

Summary of Beryllium-Bearing Reserves in the United States

	Short Tons	
	Beryl	Contained Be
E. Mt. Wheeler, Nevada (500,000 tons ore containing 0.5% BeO)		900

In the Kings Mountain deposit (item C in Table 3) the Be content is so low (0.4 pound per ton of rock or 0.02 percent) as to make its economic recovery dependent on production of lithium and possibly other co-products. Even so, the Be output would amount to only about 3 percent of the Li output. U.S. consumption of Li as metal and contained in compounds is estimated at around 3 million pounds per year. If all of this were derived from Kings Mountain, this would result in only 90,000 pounds of Be (less losses) or less than 45 tons of Be. This compares with about 240 tons of Be in beryl consumed in the U.S. in 1966.

Extensive experimental work done by companies with holdings in the Utah disseminated deposits shown in Table 3, Item D, indicates confidence in producing, extracting, and selling Be metal at prices well below present prices of Be powder of $54-66 per pound, if sufficiently high and steady demand can be developed.

The mineralized material is bertrandite ($4BeO2SiO_2H_2O$), containing 0.5 percent BeO on the average. The deposits can be mined by mechanized methods, and much of the area can be strip-mined. The two major parties (Brush & Anaconda) owning most of the known reserves have developed direct extraction processes. One party reported they are shooting at about $30 per pound if demand increases sufficiently (say to 1,000,000 pounds of Be annually). A valuable by-product of the Utah deposits would be aluminum oxide of high purity.

In December of 1967, The Brush Beryllium Company announced plans to develop its ore deposit in the Spor Mountain area of Utah and to build a processing plant near Delta, Utah. Construction will begin in the spring of 1968 with completion a year later. Cost is estimated at $8-10 million. Brush will also expand its processing and fabricating facilities in Ohio at a cost of $5 million.

C. Consumer Stocks

Consumer stocks of beryl in the U.S. have been maintained generally at around one-year's supply.

D. Government Stocks

At the end of November 1966, the government stockpiles amounted to 28,213[1] short tons of beryl containing about 11 percent BeO, 7,387 short tons of beryllium-copper master alloy, and 152 short tons of beryllium metal. During 1966 the Beryllium Corporation and Brush Beryllium Company each received a $4 million contract from Commodity Credit Corporation (U.S. Department of Agriculture) for supplying the government supplemental stockpile with 37.5 tons of Be metal ingot over an 18-month period. The beryl is to be acquired through the barter program, by the exchange of surplus agricultural commodities for beryl from India.

Details of government stocks of beryllium-bearing materials at the end of 1966 are shown in Table 4.

Table 4

Government Year-End Stocks of Beryllium-Bearing Materials - 1966
(short tons)

	National Stockpile	Defense Production Act (DPA) Stockpile	Supplemental Stockpile	Commodity Credit Corp. (CCC)	Total
Beryl (11% BeO):					
Objective	13,532	---	1,683	---	15,215
Excess	8,202	950	1,686	2,160	12,998
Total	21,734	950	3,369	2,160[1]	28,213[1]
Be-Cu master alloy:					
Objective	1,075	---	3,675	---	4,750
Excess	---	---	2,637	---	2,637
Total	1,075	---	6,312	---	7,387
Beryllium metal:					
Objective	---	---	150	---	150
Excess	---	---	3	---	3
Total	----	---	153	---	153

[1] Does not include 4,008 tons of stockpile grade beryl on order

E. Specifications

National Stockpile Purchase Specification P-6-R3, November 30, 1967, covers beryl concentrates suitable for the production of beryllium metal, beryllium chemicals (including BeO), and beryllium-bearing alloys. Chemical and physical requirements are:

1. Chemical requirements: Beryl shall contain not less than 10 percent, by weight, of beryllium oxide (BeO).

2. Physical Requirements: Beryl shall be either hand-sorted concentrates or flotation concentrates.

The specification for metallic beryllium, P-110, June 1, 1964, covers impurity limits for each billet, and a maximum level determined from a composite sample of ten billets. The latter levels are given below:

			Percent (by Weight)
Beryllium Oxide	(BeO)	Maximum	0.5 1/
Iron	(Fe)	Maximum	0.11 1/
Carbon	(C)	Maximum	0.10 1/
Aluminum	(Al)	Maximum	0.08 1/
Magnesium	(Mg)	Maximum	0.07 1/
Silicon	(Si)	Maximum	0.06
Nitrogen	(N)	Maximum	0.03
Calcium	(Ca)	Maximum	0.02
Zinc	(Zn)	Maximum	0.02
Copper	(Cu)	Maximum	0.015
Chlorine	(Cl)	Maximum	0.005
Fluorine	(F)	Maximum	0.005
Lead	(Pb)	Maximum	0.002
Molybdenum	(Mo)	Maximum	0.002
Silver	(Ag)	Maximum	0.001
Cobalt	(Co)	Maximum	0.0005

1/ The percentages for these elements may be computed as a weighted average of the results of the tests in Section a. I. above.

II. Consumption by Application

A. Metal

1. Present

Beryllium has a number of unusual properties including:

a. Low specific weight
b. High modulus/density
c. High strength/density
d. High heat capacity
e. Good dimensional stability
f. Low atomic weight
g. High atomic scattering cross section
h. Low absorption cross section

The unique combination of all these properties in one material makes it especially interesting to aerospace and nuclear designers faced with solving problems of conflicting design demands involving weight limitations, high temperatures, nuclear requirements, etc.

The bulk of beryllium metal applications is for nuclear and military requirements. It is estimated that over 95 percent of all metal applications are for government use.

The industry ships between 100,000-150,000 pounds of product a year. This is mostly in the form of rough machined hot-pressed blocks. As a rule of thumb, the finished weight of the various parts varied from 15-75 percent of the hot-pressed weight.

At present only a few thousand pounds of sheet are used. Powder use is presently about 10,000 pounds a year.

Nuclear applications consume a major portion of beryllium metal. The AEC weapons applications are classified, but it may be estimated that they use about one-half of beryllium nuclear consumption. The other portion of beryllium goes into noncommercial reactors as in the Nerva and Phoebus reactors, with small amounts for SNAP and HFIR (high flux isotope reactor).

Inertial guidance applications (gyros), gimbals, platforms, are the second largest class of uses. Virtually all the systems use some beryllium parts.

Space vehicles presently comprise a minor market. Beryllium as a structural material in aerospace and aircraft structures is still in the experimental stage, although it offers the greatest volume potential for the metal. Besides cost considerations, the biggest task facing the beryllium industry is the need to develop a higher degree of confidence in the metal on the part of the designer and the fabricator.

The beryllium industry has stated that the beryllium metal business has, so far, provided an unsatisfactory return on investment, to a degree, in fact, that discourages future capital investment. In contrast, beryllium-copper has yielded satisfactory rates of return. Several years ago, the largest producers enlarged plant capacity in reasonable expectation of an expanded market. Unfortunately, this did not materialize. For some time, the industry operated considerably below capacity (at times as low as 25%). In 1964 and 1965, the demand for beryllium products actually declined below the 1960-63 level. Fortunately, in 1968, future requirements are projected upwards again and may well involve additional expansion of capacity.

2. Projected

Projected uses of beryllium in the near future include increases in the present applications as well as new applications which are now in various stages of development.

Expansion of present uses includes proposed larger nuclear reactors for the Rover nuclear rocket system, broader applications of inertial guidance systems.

Typical examples of newly developing prospective volume uses of beryllium include rocket fuel powders, structural uses in supersonic aircraft, and aircraft brakes.

A vastly increased use of beryllium has been reported in connection with the ballistic missile programs. The exact use and quantity of beryllium in such programs is highly classified. If these new systems are built and incorporate beryllium parts, it is estimated that the demand for beryllium will increase 5-10 times of the quantities procured during recent years. Peak production is scheduled for 1969 and 1970.

In the rocket propellant field, beryllium metal powder has attracted interest as a replacement for aluminum in the propellant mix for certain missiles because of its greater specific impulse and, therefore, of improved missile range and/or payload capability. Implementation has generally floundered on questions of cost or toxicity.

A major program to utilize beryllium in jet engines is nearing conclusion by the Air Force. The low impact resistance of the metal available for the study made it apparent that this will be a possible, but unlikely application, at least in the near future. Beryllium shafts have performed successfully, but the benefit in their use is marginal. Improved performance is particularly necessary for V/TOL or V/STOL engines, and if beryllium were to be used, these would be the logical first applications. Several beryllium rocket nozzle designs have been qualified in NASA and Air Force programs, one of which has been placed into limited production.

The use of beryllium metal aircraft disc brakes in the Lockheed C-5A troop transport and other aircraft is now under engineering qualification and test. This proposed use of beryllium in the C-5A, for example, will save about 2000 pounds of weight per plane. If successful, this application can be expected to grow to important levels, and may find application in other types of aircraft. It is not only one of the most direct ways to reduce weight, but also promises more efficient, cooler running, brakes. It must be borne in mind, however, that while high cost is a deterrent to selection of beryllium brakes, corrosion resistance also needs to be demonstrated.

The foregoing examples are those involving potentially large levels of beryllium requirements. It is probable that some, but not all, will evolve into production items.

B. Alloys

1. Present

About 20 percent of beryllium alloys produced are for government end use. Beryllium, as an addition to other metals, produces alloys with a capacity for precipitation hardening. The predominant metal thus strengthened is copper. Most common Be-Cu alloys contain 1.9 to 2.05 Be and 0.25 Co. The unique properties of beryllium-copper alloys have resulted in a great variety of applications in industry. In the electrical field, beryllium-copper, because of high electrical and thermal conductivities, coupled with strength and resistance to fatigue at elevated temperatures, is used for applications such as high strength current carrying springs, fuse clips, connectors, contacts, and welding electrodes. In such specialized fields as precision instruments, beryllium-copper is preferred for springs, diaphragms, bellows, and Bourdon tubes because of its freedom from elastic drift, good thermal conductivity and mechanical strength. The computer industry is making extensive use of Be-Cu alloys. As castings, Be-Cu alloys are used for injection and blowing molds for molding plastics, as well as for electrodes and welding fixtures.

2. Projected

There are no foreseeable new applications which may account for any significant increase in demand, but the use has been on a steadily growing basis in the known fields of application.

C. Beryllia Ceramics

1. Present

BeO ceramics have a combination of outstanding chemical, physical, and nuclear characteristics which dictate their applications. Among these are: high melting point, high thermal conductivity, high specific heat, and high electrical insulation resistance over a wide temperature range. The major present applications are in electronics as substrates for integrated microcircuits, heat sinks, radome, and microwave windows. About 60 percent of BeO ceramics end up in government applications.

There are no Bureau of Census figures available for beryllia ceramic production, but estimated figures at manufacturers' level are:

Dollar Sales: 1963: 2.5 Mill. 1967: 3.5 Mill.

2. Projected

Use of beryllium oxide ceramics in electronics could undergo a large increase. The total consumption of BeO for ceramics in the U.S. is now in the order of 50 tons per annum. New military applications now in the planning stage could add hundreds of tons to the annual consumption of the oxide. These applications depend primarily upon the microwave transmission characteristics of beryllium oxide.

It is somewhat speculative as to whether these applications will develop, because development depends upon deployment decisions yet to be made by the Department of Defense. If anti-missile systems are deployed, the requirements for beryllium oxide could run to hundreds of thousands of pounds of BeO per year. This would be a large perturbation of the present supply situation.

Other potential applications which may require substantial quantities of BeO are for heat dissipation discs in aircraft brakes. Small quantities of BeO are presently being used as fillers in plastics to improve heat absorption and dissipation. At least 80 percent by weight is required to be effective. This application may become more important in the future.

D. Summary

The following estimated growth rates are educated guesses of the three major processors and suppliers.

1. Metal

It is difficult to estimate the growth rate on the demand of beryllium metal due to the dynamic nature of contemplated uses and the still unsolved problems of cost, sheet properties and fabrication, and designers' confidence in the use of the material as a structural member. If the expected applications in space optics, aircraft brakes, and missiles all materialize, it is possible that by 1972, the demand of beryllium metal could increase 175% over 1967 demand, indicating a growth rate of 25%. Another estimate mentions a growth rate of 50% per annum. Even this estimate would be substantially low if one of the projected missile applications mentioned goes into production. By 1977 the potentials might be as high as a 600% increase over the 1967 usage. All these estimates are highly conditional and only indicate what might be possible.

2. Alloys

The estimated growth rate is 5-15 percent per annum.

3. BeO Ceramics

The estimated normal growth rate is 10-15 percent. If new potential applications materialize, this could change to 25-50 percent.

III. Substitute Materials

Substitutes can be used for each of these materials, but such use would result in substantial downgrading of performance.

In the case of beryllium metal, steel or titanium (in structures) and graphite (in nuclear reactors) can be regarded as substitutes. In the future, the biggest competition for structural beryllium will be composites, such as those containing boron or graphite fibers.

For beryllium alloys (beryllium-copper), phosphor bronze substitution (with usually some loss of fatigue strength) is possible, with inferior conductivity and formability.

The most logical substitute material for BeO in ceramics is sintered alumina, where thermal conductivity is not the main consideration.

The superior microwave transmission characteristics of beryllium oxide make it unique for certain applications, such as radomes and microwave windows. There really are no possible substitutes for the potential large-scale military applications of such windows.

Beryllium metal and beryllium oxide ceramics are costly and difficult to handle. Just for these two reasons, it is evident that beryllium containing materials are being used only in applications where the payoff is in superior performance, particularly in military and aerospace programs.

IV. The Government Stockpile

The government stockpile contains the three items, beryl concentrates, metals, and master alloys based on past consumption. It holds at least a three-year supply of beryl. In addition, the two major producers maintain one-to-two years' inventories of beryl. Actually, the present U.S. stockpile has about 30,000 tons of beryl, as compared with the published stockpile objective of 15,215 tons. This excludes an additional 3,000 tons of beryl which is shortly coming, or has already come, into the stockpile from India.

The two largest producers feel that, while the overall beryllium content in the beryl stockpile objective is reasonable, some of the excess beryl should be converted to metallic beryllium (even though the metal objective has already been attained). The arguments for the conversion are almost entirely non-technical (a more usable form, capacity now exists for the conversion, temporarily alleviate spending abroad, assist a region with high unemployment, etc.), and, therefore, will not be gone into in this report. There is no presently known application for which the quality of metal acquired under the most recent specification is inadequate. No judgment is being passed on older stockpiled metal due to lack of knowledge concerning its quality.

One company, not now a primary refiner-producer, suggested the storage of BeO rather than beryl. Possible health or contamination hazards in storage of such a material have been pointed out by another.

V. Conclusions and Recommendations

Beryllium metal, beryllium alloys, and beryllium oxide are the three materials to be considered for assessing raw material demands and stockpiling requirements.

Of the three, beryllium-copper alloys consume presently about 60 percent of beryl requirements. The annual compound rate of growth, under foreseeable conditions is 10-15 percent. The bulk of applications for this alloy is in the civilian industrial field. In case of an emergency, some substitution can be made with phosphor bronze.

The future demand for beryllium metal, which consumes presently about 35 percent of beryl requirements, is much more difficult to predict. Beryllium is not employed in many potential applications because of its three shortcomings: cost, brittleness, and toxicity. The picture might change, however, with the increased demand on performance, improvements in manufacturing methods, and sophisticated educational efforts aimed at design engineers. It seems that use of beryllium metal for nuclear and aerospace demands is assured on an expanding basis. But the growth rate is rather uncertain, ranging from 10-25 percent annually over the next decade. This is too wide a spread to permit making meaningful recommendations.

At present, the only commercial source of beryllium is imported beryl. Domestic sources of ore (other than beryl) with low beryllium content are known. Exploitation of one of these deposits will soon begin. Until the situation with regard to beryllium applications can be seen more clearly, there is no technical basis for suggesting any change in the present stockpiles of beryl, master alloy, and metal in the various government stockpiles. A continuing monitoring of beryllium demand and technology is essential in order to assess the appropriate size of the stockpile. This is important principally to reflect increasing demand, but also to avoid possible obsolescence of the beryl stockpile as the domestic source of supply comes under stream. (The two largest producers currently utilize beryl as a starting material; the new plant of one of these will yield BeO as a product.)

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13. ABSTRACT

This report is one in a series of five (the others being molybdenum, platinum, silver, and tantalum), in which the influence on applications of changing technology is explored.

Forecasting consumption trends is difficult; many possible applications, each having an important impact on consumption, have been developed to the prototype stage, but further consumption of any one is problematical. Some large usages do appear certain, however, and the consumption trend is upward. The supply of beryllium is in reasonable balance with demand, but a close watch should be maintained on the situation.

Historically, about 60% of beryl goes into beryllium-copper alloys; ceramics about 5%. Present applications of beryllium metal, such as guidance and nuclear components are expected to increase. In addition, relatively new uses, such as aerospace components and aircraft brakes, are expected to consume very significant and rapidly growing quantities of metal.

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