

STATUS OF THE BERYLLIUM INDUSTRY IN THE UNITED STATES OF AMERICA

Bengt R. F. Kjellgren

THE first industrial production of metal beryllium in the United States dates back to 1939, when The Brush Beryllium Co. established a small plant. The earlier activities connected with beryllium industry were however confined only to the sales of beryllium nitrate and beryllium oxide in minor quantities. In the 1930's, alloys of beryllium copper became the industry's main product and have so remained almost up to the present time. Sales of beryllium metal started to grow slowly in the early 1940's. The increasing demand for the metal, which in the following ten years fluctuated greatly, has now become more steady and has, particularly during the last 3-4 years, grown so rapidly that the dollar value of sales of beryllium metal in primary or fabricated form now is exceeding the dollar sales volume of beryllium copper alloys and fabricated alloy products.

As frequently has been the case in other industries, the major expansions of the beryllium industry have resulted originally from military demands. The industrial production and fabrication of beryllium copper alloys was greatly expanded and became firmly established during the Second World War. This part of the beryllium industry, after some adjustment after the War, is now operating normally in a broad variety of commercial applications.

In regard to pure beryllium metal, The Brush Beryllium Company pioneered the industrial beryllium production in the United States by establishing a small plant in 1939. This plant was enlarged as new requirements of beryllium for atomic energy development programmes increased under the impetus of the Second World War. Presently, the ever-increasing demands for new materials are tending to create new and increasing demands on the beryllium industry, particularly in the fields of applications for pure beryllium metal and to a lesser extent for beryllium oxide.

The growth of the beryllium industry in the United States is well illustrated by the annual consumption of beryl ore. Fig. 1 shows the annual ore consumption which has increased from 3,000 tons of beryl in

1950 to an estimated amount of 9,500 tons of beryl in 1960. The annual ore production is also shown. The difference shown in the shaded area is the amount available for inventory. The cost of the ore per beryllium oxide unit may be seen from the third curve shown in the figure.

The mineral beryl, a beryllium aluminium silicate, occurs in nature mostly in pegmatite dikes. The beryl crystals found in the ore are usually green or bluish green and are often considered to be precious or semi-precious stones. Two well known varieties are emerald

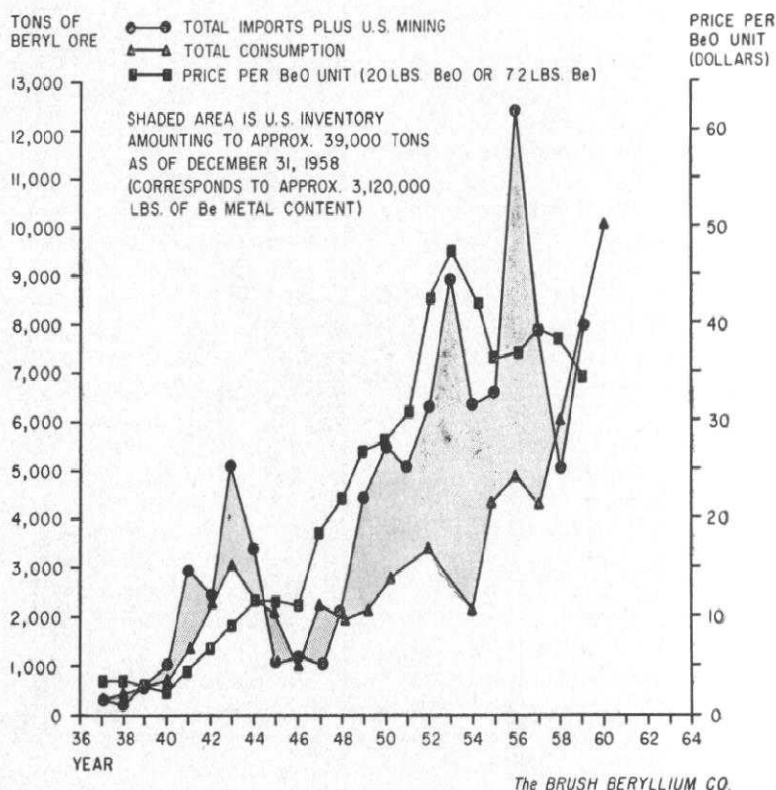


Fig. 1.
Beryl ore statistics.

Mr. Bengt R. F. Kjellgren, Chairman of the Board, The Brush Beryllium Company, Cleveland, Ohio, U.S.A.

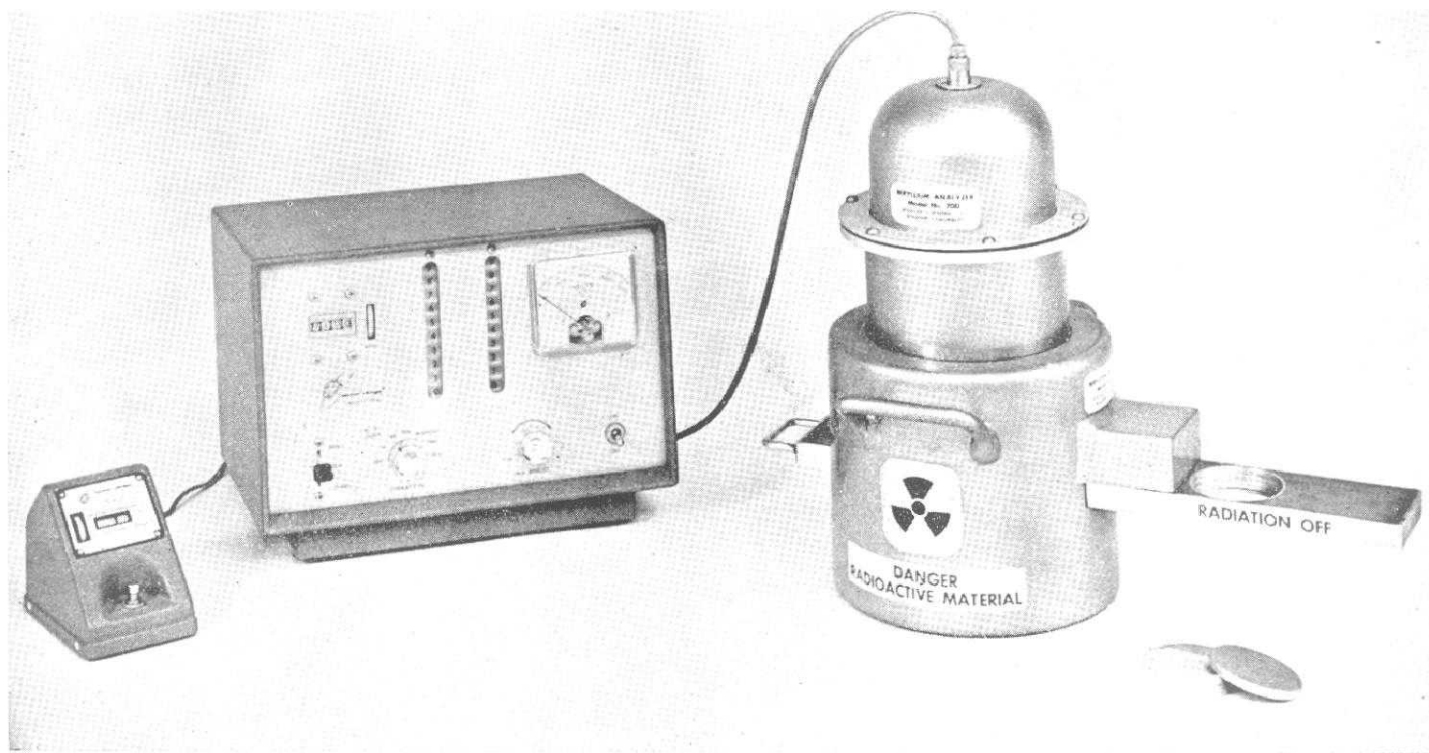


Fig. 2.
Beryllometer.

and aquamarine. In actual mining, some 100 to 300 tons of rock must be moved and examined together, by hand picking, one ton of beryl of commercial grade containing 10-12% BeO.

All industrially produced beryllium has to date been derived from beryl ore. During the period from 1936 through 1959 the United States received 98,060 short tons of beryl from 27 different countries. It is of interest to note at this point that The Brush Beryllium Company has recently, through the use of the new St. Lawrence Seaway, received in the nearby Port of Toledo, Ohio, on Lake Erie, several shipments of beryl ore directly from Bombay, India.

With the steadily increasing uses for beryllium, prudent and constructive planning for the future dictates that beryllium-bearing ore sources in the United States of America and in other countries should be developed. It has, therefore, been the policy of U.S. Government agencies. The Brush Beryllium Company and other private companies to try to develop adequate ore reserves on a long-range basis.

A new portable field instrument called a Beryllometer is now being used to help the beryllium prospector in his work. Fig. 2 shows a portable beryllometer with the radiation source removed. The source and impulse counter can be taken into the field on a litter-like frame carried by two men if it is desired to prospect for beryllium in situ. The instrument makes use of a well

known nuclear reaction to detect beryllium and to make a fast and fairly accurate determination of the amount of beryllium in rock. This instrument is actually a scintillation counter with a phosphor which has a high neutron-to-gamma ratio. Radioactive antimony 124 is the source of the gamma radiation. This radiation causes neutron emission from beryllium minerals. The neutrons are picked up and recorded with an impulse counter. Since beryllium minerals are the only ones that emit neutrons under this bombardment the instrument is a positive means of identification.

By the use of such nuclear devices, previously unrecognized beryllium mineral deposits have been found. Deposits that appear to be extensive show occurrences of high-content minerals including phenacite and bertrandite. By chemical formula, these minerals contain about three times as much beryllium as beryl. While the BeO content in a pegmatite dike containing beryl runs perhaps as high as 0.1% BeO, the content in these new beryllium-bearing deposits may run as high as 1% BeO. However, these beryllium-bearing minerals have so far been found only in very small particle sizes which cannot be separated by hand picking.

Some of the more important recent discoveries of beryllium-containing minerals in the United States of America have been in the Topaz Mountain area of Utah. It is of special interest because it is found in disseminated non-pegmatitic deposits, much of it lying

close to the surface where it can be mined by open-pit methods.

Other recent discoveries have been in Colorado where coarse crystals of beryl and some bertrandite have been found. Phenacite has also been identified in Nevada and Idaho.

The Brush Beryllium Company has co-operated, during the last year and a half, with The Beryllium Resources Company, Salt Lake City, Utah, in the fields of exploration for beryllium-bearing ore deposits and concentration methods of low grade beryllium ores. We have now acquired an interest in this company to promote these developments. The future raw material requirements for the beryllium industry may well be available from low grade ore deposits of non-pegmatitic nature and from low grade beryl ore not suitable for hand picking. We are confident that economic processes for the beneficiation of low grade beryl ore and other beryllium-bearing ores will be developed and that the industry's sources of raw materials are dependable and adequate.

Within the next few months, The Brush Beryllium Company will have completed an expansion of its beryllium production facilities in Elmore, Ohio. The enlarged plant's capacity for ore consumption will then be approximately 12,000 tons per year. Fig. 3 shows an aerial view of the Elmore, Ohio plant prior to the expansion just mentioned. In addition to the plant in Elmore, The Brush Beryllium Company has a plant in Shoemakersville, Pennsylvania where beryllium copper alloy is processed; a new machine shop in Hayward, California; Executive Headquarters, Research and Development and machine shop facilities in Cleveland, Ohio. Also in Cleveland a new two million dollars fabricating facility is nearing completion and will be ready for occupancy next month.

There are at the present time two basic producers of beryllium in the United States, The Beryllium Corporation, Reading, Pennsylvania and The Brush Beryllium Company, Cleveland, Ohio. The operations of both companies are fully integrated for producing beryllium metal, its alloys, compounds, fabricated products and parts.

The total sales of the Beryllium Industry has increased from a total of 12 million dollars in 1953 to a conservatively estimated total of 53 million dollars in 1960. During the same period the sales of The Brush Beryllium Company increased from approximately 3 million dollars in 1953 to an estimated total of 29 million dollars in 1960.

Both The Beryllium Corporation and The Brush Beryllium Company first extract beryllium in the form of hydroxide from beryl ore using, however, different processes.

The Beryllium Corporation's process for recovering beryllium oxide from beryl ore is based on the Copeaux-Kawecki process wherein beryllium ore is ground to a fine powder, mixed with soda ash and sodium silicofluoride and the mixture made into briquettes. These are subsequently sintered by heating, cooled, crushed and slurried in water to extract the water soluble beryllium fluoride. After separating the

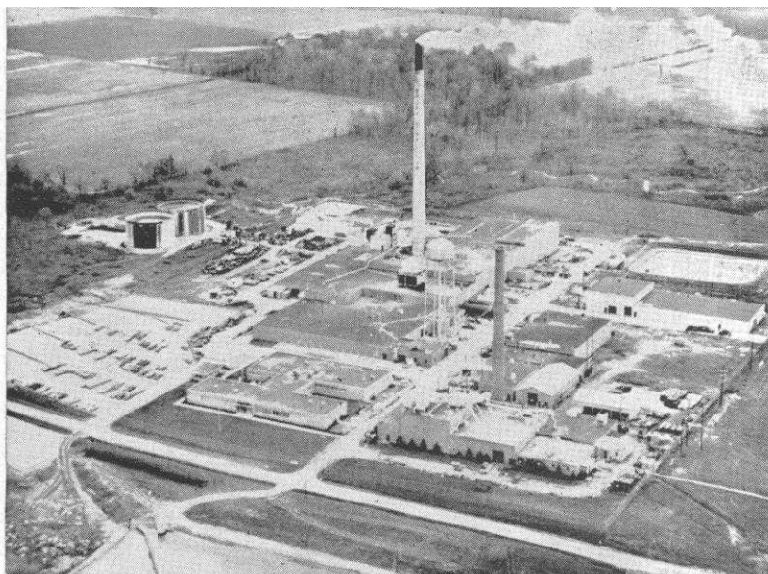


Fig. 3.
Brush Beryllium Plant, Elmore, Ohio.

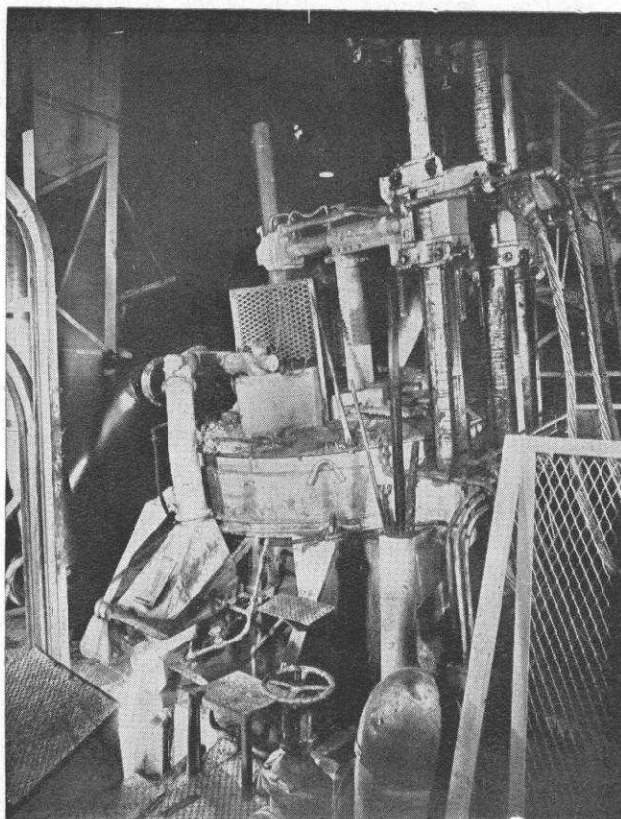


Fig. 4.
Beryl melting furnace.

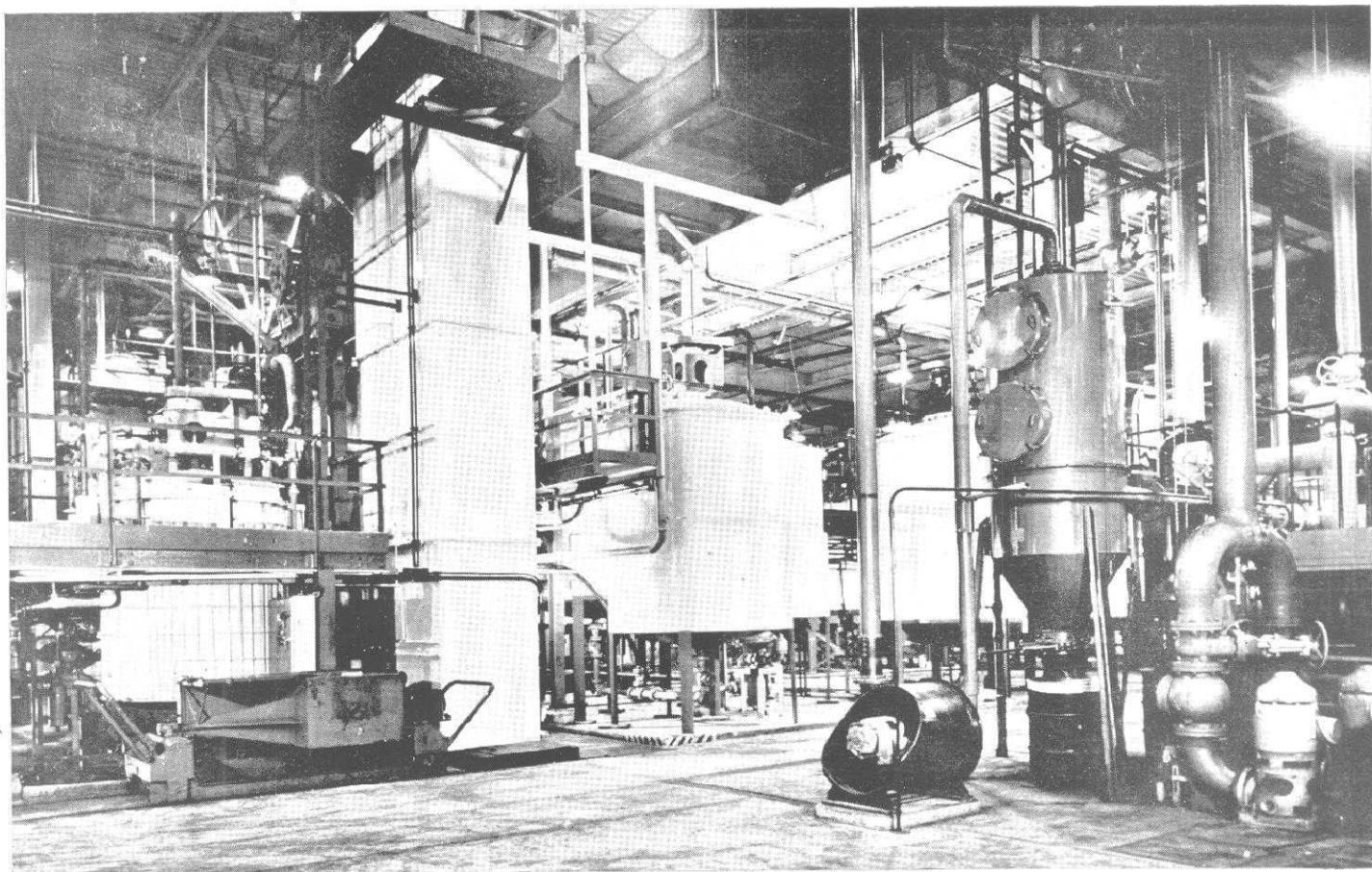


Fig. 5.
Ore processing tanks.

solids by filtration, caustic soda is added to precipitate beryllium hydroxide.

The Brush Beryllium Company's process for recovering beryllium oxide from beryl ore is based on the Sawyer-Kjellgren process in which melted beryl is quenched in cold water to produce a frit. Fig. 4 shows molten beryl ore being poured from an ore melting furnace and the stream of cold water impinging on the molten ore. After drying and grinding, the frit is reacted with a small excess of sulphuric acid. The sulphated ore is then leached with water to produce an acid solution of beryllium and aluminium sulphates which, after separation of the solids by settling and filtration, is neutralised with ammonium hydroxide. Fig. 5 shows a view of some of the tanks used in processing the ore. The ammonium sulphate so formed combines with the bulk of the aluminium sulphate present to form ammonium alum crystals which are separated continuously. The remaining impure solution of beryllium sulphate is then treated with a chelating agent to prevent the impurities from precipitating with the beryllium hydroxide upon the addition of sodium hydroxide. Except for the steps of melting and sulphating the ore, the Brush hydroxide process is con-

tinuous and automatically controlled.

The beryllium hydroxide produced by either the Copeaux-Kawecki or the Sawyer-Kjellgren process can be used as a raw material for producing beryllium metal, beryllium alloys and beryllium compounds.

In the metal process developed, patented, and used by The Brush Beryllium Company, the hydroxide made by the Sawyer-Kjellgren process, Fig. 6, is first converted to pure ammonium beryllium fluoride which is then decomposed by heating to beryllium fluoride and ammonium fluorides—the latter being recycled to the ammonium beryllium fluoride step. The beryllium fluoride is reacted with magnesium to yield beryllium which is recovered in the form of solid pebbles. The pebbles are freed from slag by melting and casting the metal in vacuum into billets. Fig. 7 shows a vacuum casting furnace used to melt the beryllium pebbles.

For alloying, beryllium metal is, as a rule, melted directly with the base metal, except in the production of beryllium copper which is produced by direct reduction of beryllium oxide in the presence of copper in an electric arc reduction furnace. This direct reduction process was a most important development for the growth of the industry because beryllium copper alloys

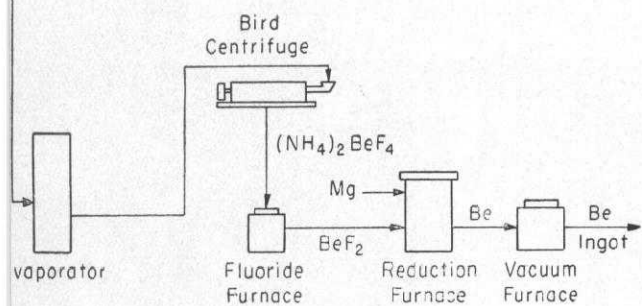
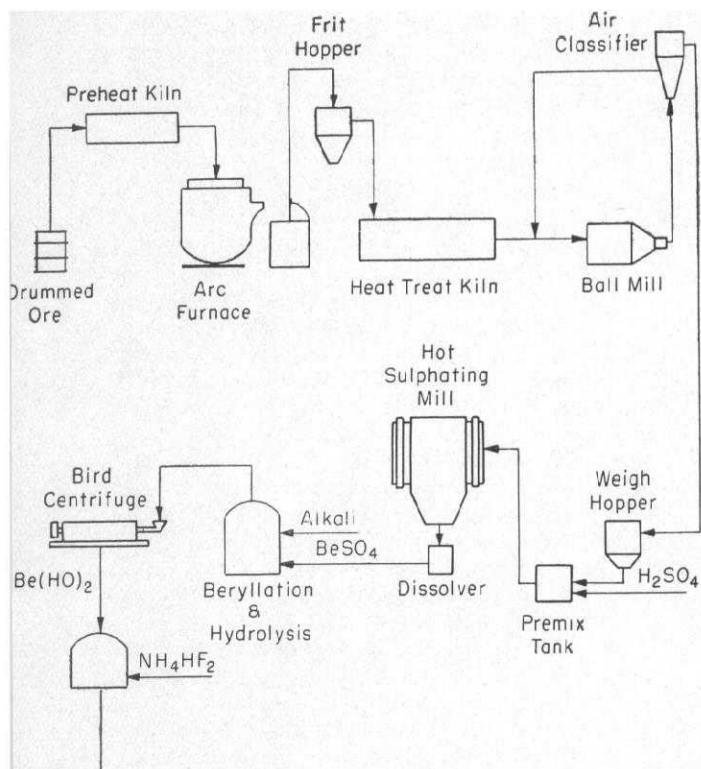


Fig. 6.

Sawyer-Kjellgren process.

could be produced at sufficiently low cost to be widely used industrially. Both companies use this basic process but with different patented techniques.

The beryllium oxide used in the beryllium copper process is made directly from the hydroxide by ignition. Fig. 8 shows a firing furnace used in producing beryllium oxide. Nuclear grade beryllium oxide is generally made by decomposition of pure beryllium sulphate. Power-metallurgy techniques developed by Brush are required for fabrication of beryllium because casting techniques thus far developed have resulted in coarse-grained metal.

In the Brush powder-metallurgy process the vacuum cast beryllium billets are first cut into small chips and then ground in an atmosphere of dry nitrogen to -200 mesh. The powder next, as a rule, is packed into graphite or steel moulds which are heated in vacuum

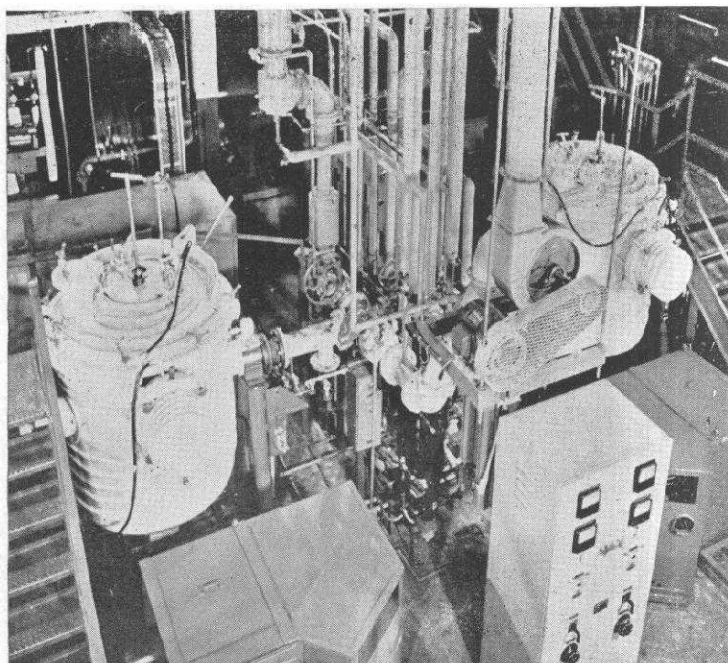


Fig. 7.

Vacuum casting furnace.

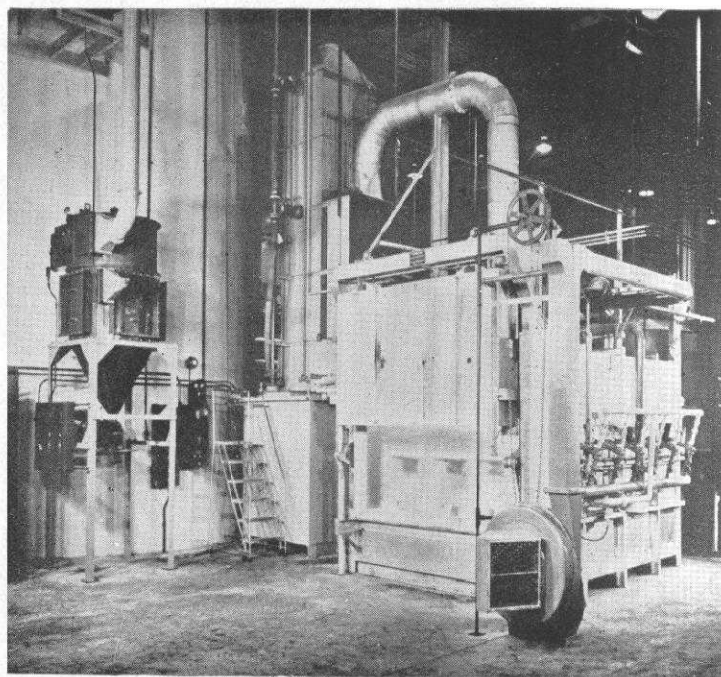


Fig. 8.

Oxide firing furnace.

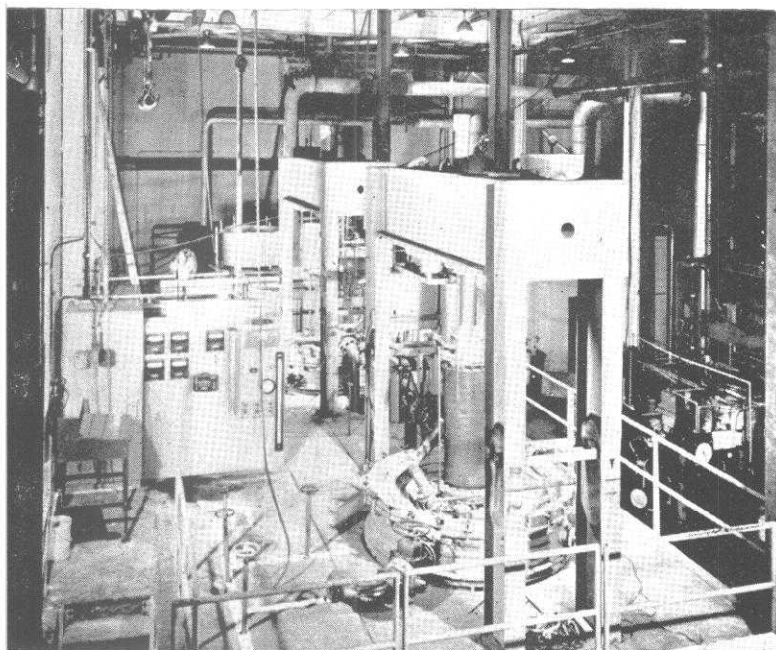


Fig. 9.
Vacuum pressing furnace.

with pressure applied to the powder. Fig. 9 shows a view of vacuum pressing furnace in which beryllium powder is pressed into blocks. A solid block with a density of 1.84–1.85 is formed. Fig. 10 shows a large beryllium block formed by pressing beryllium powder.

The unique properties of fabricated beryllium prepared by powder-metallurgy methods are now becoming well known. Its use in the atomic energy field as a moderator and a reflector is well established. It also has the property of absorbing fewer neutrons than any other known structural material. Its use in reactors which feature neutron economy and fuel conservation is now being tested both in the United Kingdom and in the United States.

Beryllium metal has many important properties of definite interest in structural applications for missiles, high speed aircraft, space vehicles, and instruments. Some of the properties which have led to applications in these fields are:

1. The density of beryllium, 1.85, is nearly as low as that of magnesium.
2. The melting point, 1278°C, is almost twice as high as the melting points of magnesium (650°C) and aluminium (660°C).
3. The heating capacity is 1.74 times higher than that of magnesium and about two times higher than that of aluminium.
4. The latent heat of fusion is about three times higher than those of magnesium and aluminium.
5. The heat conductivity although lower than that of aluminium is higher than that of magnesium.

6. Beryllium resists oxidation up to 825°C, i.e. to temperatures well above the melting points of magnesium and aluminium.
7. The coefficient of expansion is about the same as that of stainless steel—an important feature in design considerations.
8. The modulus of elasticity is about 40% higher than that of steel—a property of great importance where rigidity of structure is required at elevated temperatures.
9. The strength-weight ratio is greater than those of titanium, aluminium alloys and aircraft steels.

In addition, machined parts of beryllium have been found to have high dimensional stability. In instrument designs, it is also of interest that beryllium is non-magnetic.

Despite the low ductility of beryllium, the abovementioned properties in combination place it in a uniquely advantageous position for structural and nuclear applications in our rapidly expanding technology. We already have many structural and nuclear applications based on these properties and expect others to develop, particularly in applications where rigidity, light weight and heat resistance are more important than ductility.

The high density, fine-grained beryllium metal made by the powder-metallurgy methods developed by The Brush Beryllium Company is more uniform in physical properties, machineability and corrosion resistance than when vacuum cast and extruded. Extrusion into rods and flats produces a metal with substantial ductility

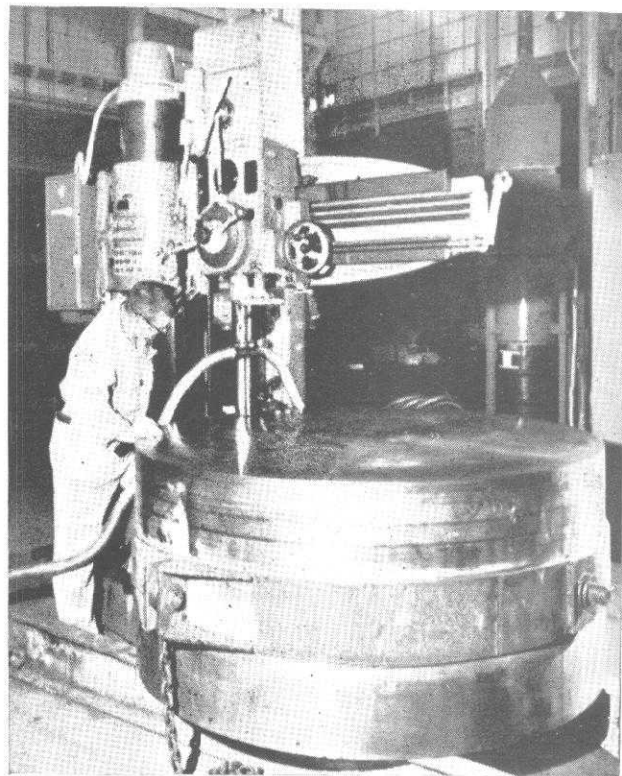


Fig. 10.
Vacuum hot-pressed beryllium billet.

(10–25%) in the extrusion direction, but only 1–3% in the transverse direction. The ductility of powder metallurgically fabricated beryllium which is closely related to grain size does not seem to be intimately related to purity, particularly with respect to beryllium oxide.

In comparing the cost of beryllium with other competing metals such as aluminium, titanium, zirconium and steels it is well to keep in mind that these metals are about 1.5 to 4 times heavier than beryllium while the cost of machining parts is about the same.

It is of interest to note that the successful development and growth of the beryllium industry was originally due mainly to the unique capacity for precipitation hardening imparted by the addition of beryllium to heavy metals and particularly to certain copper-base alloys.

Beryllium-copper is used in electrical contacts, springs, bellows, gears, bearings, precision castings and rollers in the automotive, electrical, refrigeration and electronic industries. It should be realised that the beryllium industry's earnings from selling these alloys have been a most important factor in reducing the costs of producing pure beryllium metal, particularly at the time when the demand for pure beryllium was very small.

Let us now consider some of the recent advances in research and development of other alloys of beryllium, beryllium-compounds as well as the technology of beryllium itself.

Two other beryllium alloys are beryllium-nickel which resembles stainless steel in corrosion resistance, and beryllium-aluminium which contributes to the thermal stability of aluminium. Many unusual combinations of metals requiring minor amounts of beryllium have been patented or are under investigation.

Of all beryllium compounds, beryllium oxide is the most important. Beryllium oxide has a high melting point (2585°C), strength, hardness, stability at high temperatures, resistance to thermal shock and exceptional thermal conductivity. In addition to nuclear applications which require very pure oxide, it is also used in crucibles, refractory supports in electrical heating equipment, linings in induction furnaces, thermal radiation shields, in special glasses and in electronics.

Brush is a leading supplier of high-purity, sinterable beryllium oxide and beryllia ceramics in commercial quantities. Fig. 11 shows a piece of extruded beryllium oxide.

The development by Brush of a sinterable grade of beryllium oxide of very high purity (called UOXR) was of great importance in the field of high-temperature ceramics. This grade of oxide, now being produced in the amount of several tons per month, permits the fabrication of high-density, high-purity beryllium oxide shapes by relatively low-cost conventional ceramic techniques, such as, dry pressing and firing. All operations are geared to the production of parts of high-purity and close dimensional tolerances. A beryllium oxide segment block is measured with a height gauge. The gauge is on a very smooth and level 12-inch surface plate. The laboratory in which the measurement is made is maintained at a constant 68 degrees Fahrenheit. If extremely close tolerances are required the sintered and

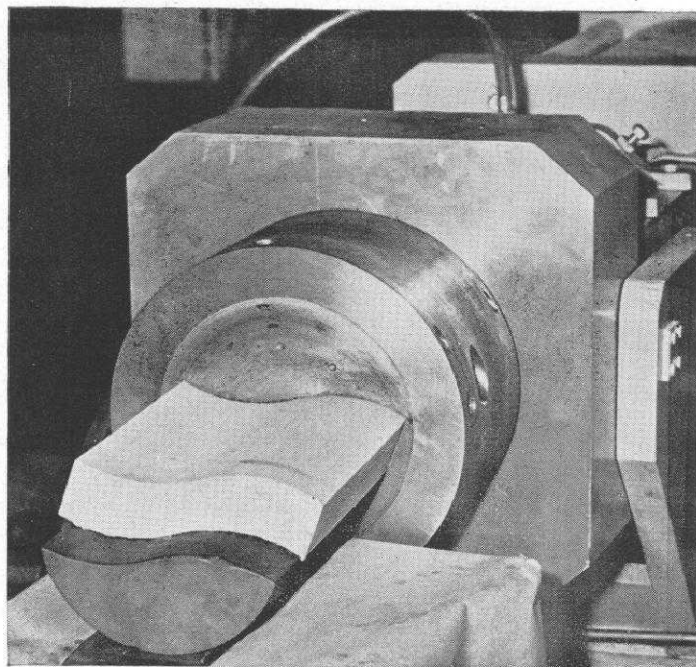


Fig. 11.
Extruded beryllium oxide.

very hard material can be ground to dimensional tolerances of 0.001 inch or less with diamond tools.

The Brush Beryllium Company has also established that a series of intermetallic compounds of beryllium and transition-element metals are potential high-temperature materials. These compounds, which have come to be known collectively as the beryllides, are oxidation resistant and show good mechanical strength at high temperatures coupled with favourable thermal properties. Intermetallic compounds from thirty-five binary metallic systems have been prepared, fabricated as test specimens, and tested for oxidation resistance. The study indicated that MoBe_{12} , NbBe_{12} , TaBe_{12} , TiBe_{12} and ZrBe_{13} were the most promising in the 1250°C to 1500°C temperature range. In addition to the MoBe_{12} compounds, $\text{Zr}_2\text{Be}_{17}$, $\text{Nb}_2\text{Be}_{17}$ and $\text{Ta}_2\text{Be}_{17}$ were also identified as materials with good high-temperature properties.

Intermetallic powders can be fabricated experimentally by usual ceramic techniques and sintered to densities in the order of 99% theoretical. However, much work remains to be done to bring these materials into commercial production.

The beryllium metal technology is advancing rapidly, spurred on by substantial research and development expenditures by both private industry and the Government.

The ductility of beryllium hot-pressed powder metallurgical shapes is more than adequate for many applications. Improvement in this area is desired, however, for certain special applications, such as, airfoils and wing structures.

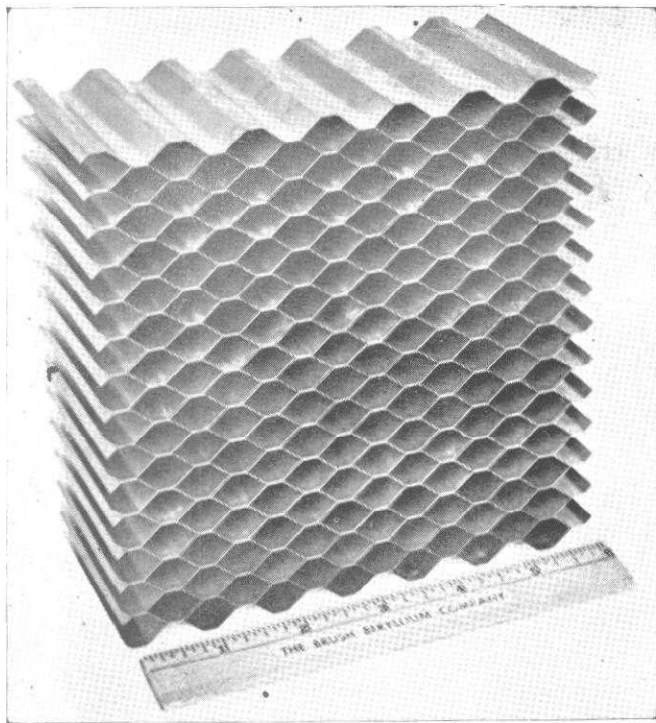


Fig. 12.
Beryllium honeycomb.

While machining of hot-pressed powder-metallurgy blocks is still the standard method of fabrication for most shapes being produced today, the production of rolled, forged, extruded or drawn products is increasing. Beryllium can now be produced in the form of sheet, strip, wire, honeycomb, extruded tubing and rod. Fig. 12 shows a section of fabricated honeycomb which has an outstanding strength to weight ratio.

The Brush Beryllium Company recently produced several 84 in. diameter discs of beryllium by forging (at the Aluminium Company of America) 50 in. diameter hot-pressed blanks. Fig. 13 shows the steel enclosed beryllium disc being prepared for forging. These discs, after machining, are to be tested as heat sinks on the Mercury Project Man-in-Space capsules. The forged beryllium discs are then machined. Production techniques have been developed for producing drawn beryllium metal wire down to 0.010" diameter. Fig. 14 shows some representative coils of beryllium wire. In the field of joining, methods have been developed for welding, brazing, riveting and otherwise joining beryllium both to itself and to other metals, with good results. Fig. 15 shows a typical part made by welding beryllium.

There is an extensive research effort in the beryllium industry in the United States at the present time. In addition to privately financed research and development programmes there are many unclassified research projects sponsored by the U.S. Government. Fig. 16 lists the titles of some unclassified research programmes

recently completed or presently in progress and sponsored by the Air Force, the Navy or the Atomic Energy Commission at The Brush Beryllium Company.

Beryllium metal is increasing in use as a construction material in high-speed aircraft, missiles, space vehicles, and airborne guidance and instrumentation, because of the unique properties previously enumerated. To illustrate the intricate parts that can be machined from beryllium, Fig. 17 shows some instrument parts made at The Brush Beryllium Company. Several major aircraft firms have indicated that they may soon use large quantities of beryllium in applications such as aircraft

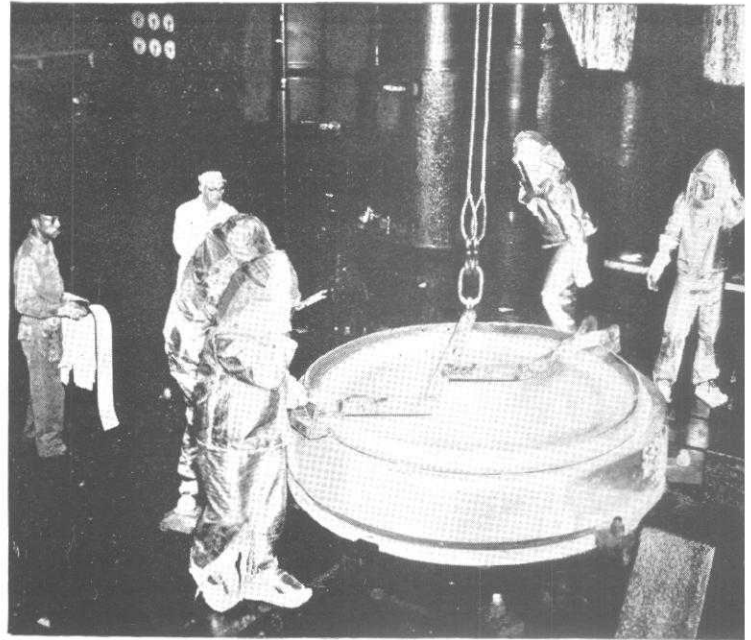


Fig. 13.
Forging beryllium disc.

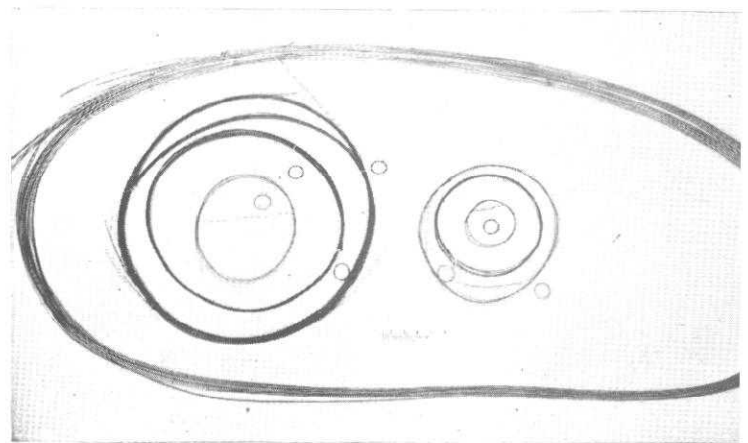


Fig. 14.
Beryllium wire coils.

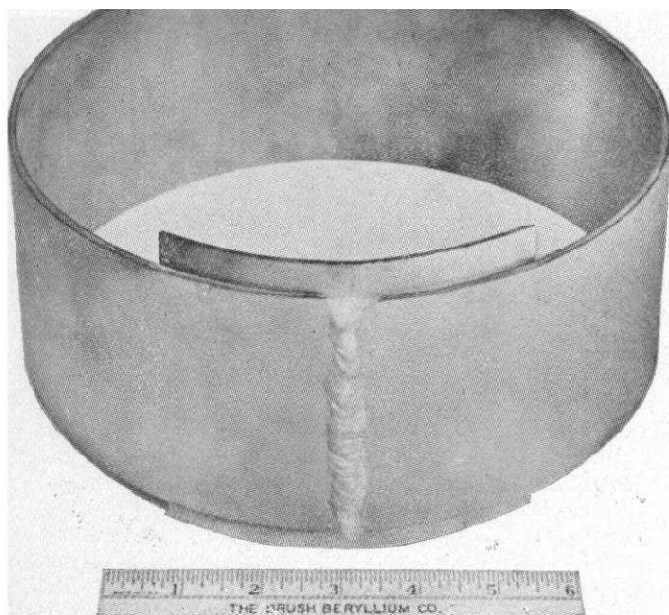


Fig. 15.
Beryllium weld.

Development of Beryllium Sheet Rolled Flat to Gauge.

Fusion Welding of Beryllium.

Brazing of Beryllium.

Welding of Beryllium.

Investigation of Refractory Metal Beryllised and Silicides at Very High Temperature.

Structural Material.

Investigation of Processing and Fabrication Techniques for Promising Intermetallic Compounds and Effects upon Thermal and Mechanical Properties.

Beryllium Wire Development.

Research and Development Programme for Development of Finned Beryllium Tubes.

Fig. 16.

Some Government sponsored research programmes.

brake discs, jet engine control doors, internal jet engine parts, primary and secondary structural parts for aircraft and guided missiles, control surfaces, and fuel pump shafts.

In the atomic energy field, there is continued development and use of beryllium oxide as mixtures with uranium fuel materials, fuel-element cladding, coolant flow liners, pressure tubes, moderator and reflector sections. Both beryllium metal and beryllium oxide are used or are being evaluated for use in reactors of practically all types. Beryllium and beryllium oxide are

particularly advantageous where weight saving and heat resistance are important.

The average price of beryllium metal fabricated shapes has decreased about 50 per cent in the last two or three years, and this downward trend is expected to continue as production and sales volume increase.

With regard to the occupational health hazards connected with producing beryllium this problem first appeared in the industry in the early 1940's. Prevention methods were immediately studied both from the medical and engineering standpoints with substantial assistance from the United States Atomic Energy Commission.

Special equipment to reduce the exposure to beryllium both inside and outside of our plant facilities was developed and training programme for employees introduced. A protective hood is installed to reduce the amount of beryllium containing material in the machine shop area. As a result, there has been no evidence to the present time of any new case of chronic beryllium-induced lung disease since the programme was instituted in 1948.

There has been no evidence that beryl ore can produce either lung or skin irritations due to its beryllium content.

Fabricated parts of beryllium metal, beryllium-copper and solid high density beryllium oxide can be handled as far as our experience has shown like any other relatively innocuous material. However, if dusts, mist or fumes are to be generated in fabrication, operations should be carefully controlled and monitored as recommended by health and safety experts. The health record of the beryllium industry is now excellent.

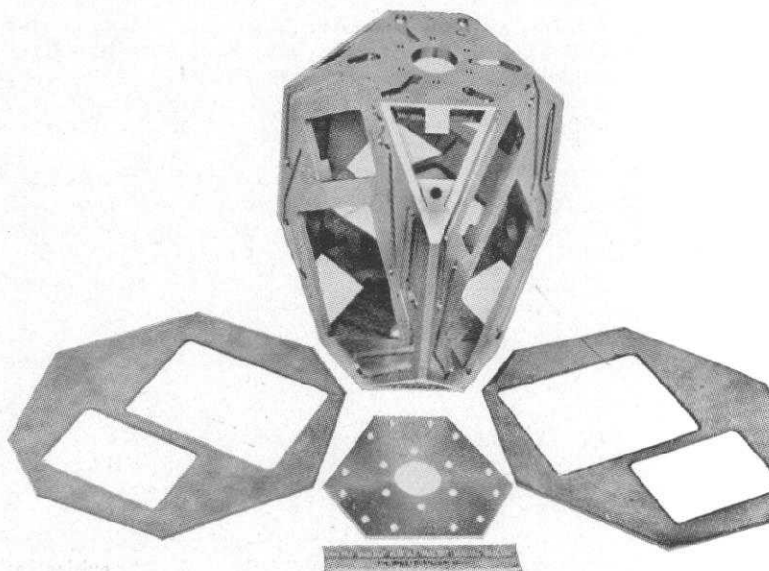


Fig. 17.
Machined beryllium parts.

Dr. T. Banerjee and Mr. P. B. Chakrabarti, NML: We have heard with great interest Dr. Kjellgren's very illuminating paper on beryllium. This paper has got added interest for us, as we worked on this problem for pretty long time in search of a suitable process for commercial production of beryllium oxide from beryl.

After a thorough search of the literature on the production of beryllium oxide from beryl and looking into the various processes in practice, viz. The Brush Beryllium Co. process (U.S.A.), Degussa process (Germany), Beryllium Corporation process (U.S.A.), Siemens process (Germany) and Sappi process (Italy), the fluoride process, as worked out by the Beryllium Corporation, was adopted by us with a slight modification.

The Beryllium Corporation process is based on the reaction of Copaux, as modified by Opatowski, wherein a part of the sodium silico-fluoride, used as the flux, is replaced by sodium carbonate. Our experience, while working with this method was that there was always considerable increase in the silica content of the product with the use of sodium carbonate in the flux. This is quite natural in view of the fact that beryl is a silicate mineral and is liable to attack by the alkali at the sintering temperature. Our further work in connection with our attempt to improve the process showed that it was possible to completely eliminate the use of sodium carbonate in the flux without any detriment to the recovery. Thus, we made use of the Copaux reaction only for the decomposition of the mineral, the difference lying in the fact that a lower sintering temperature was used namely 700°C instead of 750°C with a ratio of 1 : 1 between ore and flux.

The economics of the process have been worked out on the basis of a pilot plant capable of producing 2400 lb of beryllium oxide per annum. The cost of production by working one, two and three shifts per day worked out to Rs. 29, Rs. 25 and Rs. 24 per pound respectively on the pilot plant scale.

From the author's paper we find that beryllium oxide was sold at \$ 2½ round about the year 1950-52 when our scheme was prepared. This might be due to the fact that our scheme was projected on a very small scale—a scale that perhaps did not make the process competitive.

The process was then modified by producing clear filtrate of sodium beryllium fluoride and then subjecting the same to electrolysis as the catholyte in a diaphragm cell, using 10% solution of sodium chloride as the anolyte. The purity of the oxide produced at the

cathode was of the order of 95.3 to 97.7%, depending upon the operating conditions.

From data obtained in course of operating these two processes, some figures, which are, of course, tentative were arrived at. The cost of electric power and chemicals comes to Re. 0.87 per pound of oxide for electrolytic process whereas chemicals alone would cost Rs. 6.50 per lb of oxide by the chemical process. This wide difference is, of course, only apparent and would, in all probability, narrow down considerably in operation on bigger scale when other factors like capital and working expenditure for the whole process, depreciation, cost of by-products, purity of the end products, etc. are taken into consideration. It is, however, felt that there is sufficient margin of advantage left for the electrolytic process over the chemical one to warrant its adoption for an industrial operation. On point of purity of the product too, the electrolytic process is expected to give a product of higher purity than the other. The reason is that, in the chemical method, treatment with various chemicals in large amount is necessary, whereby impurities were introduced in small quantities at every step, whereas in the electrolytic process, no such possibility exists, provided materials, not attacked by fluoride solution, are used for preparing pure aqueous solution of sodium beryllium fluoride and also for electrolysis. Also, on point of ease and neatness of operation, the electrolytic process seems to be preferable.

Mr. Bengt R. F. Kjellgren (Author): Beryllium Corporation and The Brush Beryllium Company have now used their respective beryllium hydroxide extraction processes for about 30 years. During these many years of competition no significant difference in the extraction costs of beryllium hydroxide have appeared. Evidently both processes are sound, commercially speaking.

Since we at Brush have no practical experience in the use of the silico-fluoride process, I cannot judge the value of the elimination of the sodium carbonate. It would seem that if the same or higher extraction yields could be maintained, combined with lower silica content in the hydroxide, the elimination of sodium carbonate would be an improvement. However, since the present type of crude hydroxide produced by the silico-fluoride process is now used without purification for the production of beryllium-copper master alloy, and since it is unlikely that the extracted hydroxide can be made pure enough to be used directly for making nuclear grade beryllium oxide, the value of the lower silica content in the hydroxide as produced by the elimination of sodium carbonate may not be significant.

In regard to the electrolytic process for producing beryllium hydroxide from a solution of sodium beryllium fluoride after addition of sodium chloride, the difference in the cost of precipitating the hydroxide with sodium hydroxide (Rs. 6.50 per lb BeO) and the cost of electric power and chemicals in the electrolytic process (Rs. 0.87 per lb BeO) is difficult to understand. Perhaps the price of sodium hydroxide is unusually high in India, or much less sodium hydroxide is needed in the electrolysis.

The chemical precipitation method can be carried out continuously using comparatively simple, low cost equipment with low maintenance costs. Direct current generating equipment and electrolytic cells built to collect and withstand the corrosive action of chlorine,

although economical for large-scale production of sodium hydroxide and chlorine, may be too costly for the comparatively low electrolysis rates which would necessarily be involved in the production of beryllium hydroxide. Without knowing the details of the process, my offhand impression is that fixed, operational and maintenance costs of the electrolytic process would greatly reduce and perhaps eliminate the apparent gains in the cost of chemicals as compared with the chemical precipitation process.

As to the suggestion of using electrolysis instead of chemical precipitation, I feel that the idea is excellent, demonstrating what we are all looking for, i.e., individuals with original thoughts and initiative.

