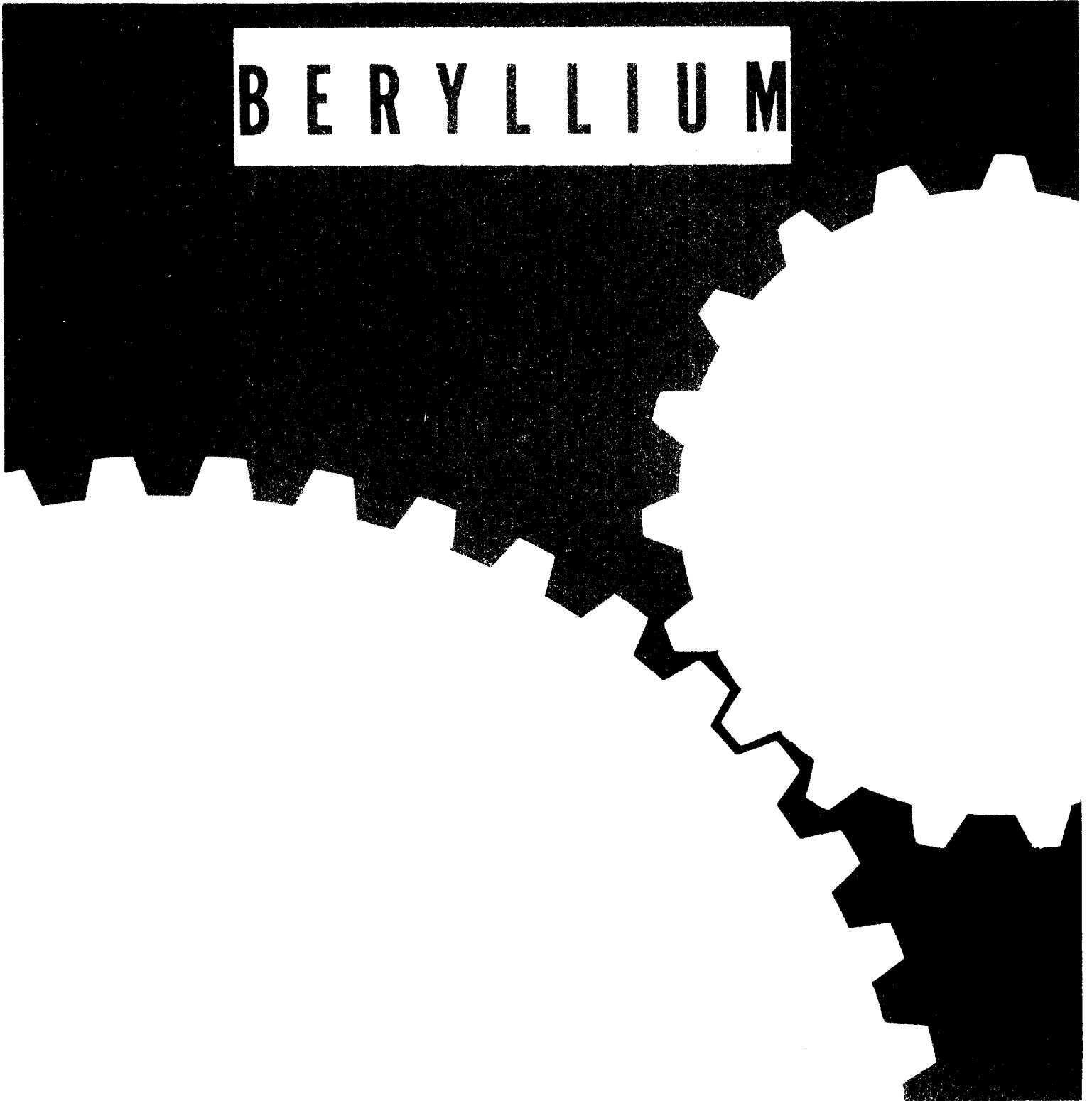


criteria for a recommended standard

OCCUPATIONAL EXPOSURE TO

B E R Y L L I U M



criteria for a recommended standard

**OCCUPATIONAL EXPOSURE
TO
BERYLLIUM**



**U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Health Services and Mental Health Administration
National Institute for Occupational Safety and Health**

1972

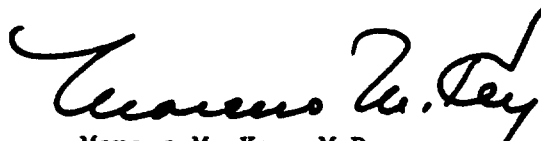
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PREFACE

The Occupational Safety and Health Act of 1970 emphasizes the need for standards to protect the health of workers exposed to an ever increasing number of potential hazards at their workplace. To provide relevant data from which valid criteria and effective standards can be deduced, the National Institute for Occupational Safety and Health has projected a formal system of research, with priorities determined on the basis of specified indices.

It is intended to present successive reports as research and epidemiologic studies are completed and sampling and analytic methods are developed. Criteria and standards will be reviewed periodically to ensure continuing protection of the worker.

I am pleased to acknowledge the contributions to this report on beryllium by members of my staff and the valuable constructive comments by the Review Consultants on Beryllium to NIOSH; the ad-hoc committees of the American Industrial Hygiene Association and the American Medical Association Committee on Occupational Toxicology; and Dr. Harriet L. Hardy, Dartmouth Medical School, and Mr. Harry F. Schulte, Atomic Energy Commission, as unusually qualified experts. The NIOSH recommendations for standards are not necessarily a consensus of all the consultants and professional societies that reviewed this criteria document on beryllium. A list of the Review Committee members and Review Consultants appears on pages iii and iv.



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The Office of Research and Standards Development, National Institute for Occupational Safety and Health, had primary responsibility for development of the criteria and the recommended standard for beryllium. Douglas L. Smith, Ph.D., served as criteria manager and had NIOSH program responsibility for development of the document; Mr. Andrew D. Hosey developed the basic information for consideration by NIOSH staff and consultants under contract No. 68-03-0008.

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**CRITERIA DOCUMENT: RECOMMENDATIONS FOR AN
OCCUPATIONAL EXPOSURE STANDARD FOR BERYLLIUM**

Table of Contents

PREFACE

REVIEW COMMITTEES

I. RECOMMENDATIONS FOR A BERYLLIUM STANDARD

- Section 1 - Environmental
- Section 2 - Medical
- Section 3 - Labeling
- Section 4 - Personal Protective Equipment and Clothing
- Section 5 - Appraisal of Employees of Hazards from Beryllium
- Section 6 - Work Practices
- Section 7 - Sanitation Practices
- Section 8 - Monitoring and Recordkeeping Requirements

II. INTRODUCTION

III. PROPERTIES AND SOURCES

IV. BIOLOGIC EFFECTS OF EXPOSURE

- Extent of Exposure
- Early Historical Reports
- Effects on Humans
- Animal Toxicity
- Beryllium Case Registry
- Neighborhood Cases
- Correlation of Exposure and Effect

V. ENVIRONMENTAL DATA

VI. DEVELOPMENT OF THE STANDARD

- Basis for Standard
- Other Beryllium Standards

VII. COMPATIBILITY WITH EMISSION STANDARDS

VIII. REFERENCES

IX. APPENDIX I - Sampling Practices for Beryllium

Table of Contents (continued)

X. APPENDIX II - Analytical Method for Beryllium

XI. APPENDIX III - Material Safety Data Sheet

TABLES AND FIGURES

I. RECOMMENDATIONS FOR A BERYLLIUM STANDARD

The National Institute for Occupational Safety and Health (NIOSH) recommends that worker exposure to beryllium and its compounds in the workplace be controlled by requiring compliance with the standard set forth in the following sections. Control of worker exposure by the techniques recommended should prevent the development of acute and chronic beryllium disease in workers exposed to beryllium.

The limits are attainable with existing technology and measurable by techniques that are valid and reproducible. The standard will be reviewed and revised as necessary.

Section 1 - Environmental (workplace air)

(a) Concentration

No worker shall be exposed at his place of employment to a concentration of beryllium more than two micrograms of total airborne particulate beryllium per cubic meter of air ($2 \mu\text{g Be}/\text{m}^3$) (determined by the breathing-zone and general air methods as described in Appendix I), determined as a time-weighted average (TWA) exposure for an 8-hour work day, and no peak concentration of beryllium to which workers are exposed shall exceed $25 \mu\text{g Be}/\text{m}^3$ as determined by a minimum sampling time of thirty minutes.

(b) Sampling and Analysis

Procedures for sampling, calibration of equipment, and analysis of beryllium samples shall be as provided in Appendices I and II.

Section 2 - Medical

(a) Medical surveillance as specified in this section is required for workers who are exposed to beryllium.

(b) A comprehensive pre-placement history and physical examination for all worker applicants shall be provided to include as a minimum a 14" by 17" chest roentgenogram, baseline pulmonary function [forced vital capacity (FVC) and forced expiratory volume at one second ($FEV_{1.0}$)], and a baseline weight.

(c) Each worker exposed to beryllium shall receive an annual* evaluation that includes:

(1) Spirometry, including FVC and $FEV_{1.0}$.

(2) A medical history questionnaire that includes presence and degree of respiratory symptoms, i.e., breathlessness, cough, sputum production, and wheezing.

(3) A 14" by 17" chest X-ray.

(d) Department of Health, Education, and Welfare (HEW) and Department of Labor (DOL) physicians and medical consultants and those physicians designated and authorized by the employees shall have access to medical records.

(e) Medical records shall be maintained for at least 20 years.

*Except where a variance has been granted, based on minimal exposure.

Section 3 - Labeling

(a) The following precautionary label shall be applied to all shipping and storage containers or packages containing beryllium and beryllium compounds where exposures to dusts, fumes, powders, or liquids are likely to occur.

BERYLLIUM

(Name of Compound)

Dust, Fume, Powder, or Liquid

DANGER

**Harmful If Inhaled and May Cause Immediate Or
Delayed Injury**

**Use Only With Adequate Local Exhaust Ventilation and
Approved Respiratory and Personal Protective Devices**

**May Cause Rash or External Ulcers
Wash Thoroughly After Handling**

(b) The following warning sign shall be affixed in a readily visible location on processing and other equipment, on storage bins and tanks, and at or near entrances and areas where exposure to dusts or fumes of beryllium and its compounds are likely to occur.

DANGER

Beryllium Dust (or Fume) Areas

UNAUTHORIZED PERSONS

KEEP OUT

Breathing Dust (Or Fumes) May Cause Immediate or Delayed Injury

Section 4 - Personal Protective Equipment and Clothing

(a) Respiratory Devices

(1) Respiratory protective devices shall be used any time the actual or projected level of beryllium will exceed an 8-hour time-weighted average concentration of $2 \mu\text{g}/\text{m}^3$. These devices shall not be used as a substitute for proper engineering controls, but are appropriate for necessary periods where excessive atmospheric concentrations result from emergencies or from maintenance or repair.

(2) If a variance order is granted under provisions of the Occupational Safety and Health Act of 1970 from the environmental limits set forth in Section 1, the provisions of this section shall still apply to safeguard workers.

(3) Standard procedures shall be established for respirator use to include the following:

(i) Procedures established for respirator usage shall insure that no worker is exposed to beryllium in excess of the standard because of improper respirator selection or facepiece fit.

(ii) Facepiece fit shall be checked by the wearer each time he puts on the respirator.

(iii) The respirator used shall be of the appropriate class as determined on the basis of the actual or projected atmospheric concentration of airborne beryllium at the worksite where the respirator is to be used as follows:

(A) Reusable half mask air purifying respirators equipped with high efficiency filters shall be used in atmospheres containing

not more than $25 \mu\text{g Be/m}^3$ for any period of time.

(B) Reusable full-facepiece air purifying respirators equipped with high efficiency filter shall be used in atmospheres containing not more than $100 \mu\text{g Be/m}^3$ for any period of time.

(C) Powered air purifying respirators equipped with high efficiency filters, operating with positive pressure during the inhalation phase of breathing shall be used in atmospheres containing not more than $1000 \mu\text{g Be/m}^3$. When equipped with a "fume filter," respirators shall be used in atmospheres containing not more than $40 \mu\text{g Be/m}^3$.

(D) Continuous flow air-line respirators or self-contained breathing units operating in the pressure-demand mode and providing positive pressure during the inhalation phase of breathing, shall be used in atmospheres that exceed $1000 \mu\text{g Be/m}^3$.

(iv) Only respirators approved by the U.S. Bureau of Mines and/or NIOSH under the provisions of 30 CFR Part 11 (37 F.R. 6244) shall be used.

(4) An effective respirator program to include selection, use, maintenance and care, special problems, and effective respirator program evaluation shall be established. Compliance with the requirements of the latest revision of the American National Standard Practices for Respiratory Protection Z88.2 shall be considered prima facie evidence of compliance with this subsection.

(b) Protective Clothing

(1) Beryllium Exposed Workers

(i) The employer shall provide each employee except those with minimal exposure with protective clothing, headgear, and shoes when the employee must work with and/or be exposed to beryllium, beryllium compounds, or beryllium containing products.

(A) Such clothing may be coveralls or similar full-body protective clothing.

(B) Protective shoe covers or work shoes shall be worn during the working hours in areas where there is exposure to beryllium.

(C) Resin-impregnated paper or similar protective clothing can be substituted for fabric-type clothing.

(ii) Protective clothing shall be changed at least each day at the end of each shift.

(iii) The employer shall provide for maintenance and laundering of soiled protective clothing, which shall be stored, transported, and disposed of in sealed, non-reusable containers and labeled with easy-to-read letters as outlined in Section 3.

(iv) Dust removal, by blowing or shaking of clothing, shall be prohibited; protective clothing shall be cleaned by power suction (vacuum) prior to removal; removal of contaminated clothing shall be allowed only in the change rooms.

(v) The employer shall provide laundering controls and inform the employee and any third party which launders contaminated clothing of the potentially harmful effects of exposure to beryllium dust and of safe practices required in the laundering of beryllium-soiled work clothing.

(2) Workers with Minimum Beryllium Exposure

(i) The employer shall provide laboratory coats or equivalent protective clothing to each such employee who works with or is exposed to beryllium, beryllium compounds, or beryllium containing products.

(ii) Clean protective clothing shall be supplied to each worker at least weekly.

Section 5 - Appraisal of Employees of Hazards from Beryllium

(a) Each employee exposed to beryllium shall be apprised of all hazards, adverse symptoms of overexposure, appropriate emergency procedures, and proper conditions and precautions for safe use or exposure, to include as a minimum, all information as set forth in Appendix III which is applicable to that specific product or material containing beryllium to which he is exposed.

(b) The information shall be maintained on file and readily accessible to the worker at all places of employment where beryllium is involved in unit processes and operations.

(c) Information as specified in Appendix III shall be recorded on U.S. Department of Labor Form OSHA-20, "Material Safety Data Sheet," or a similar form approved by the Occupational Safety and Health Administration, U.S. Department of Labor.

Section 6 - Work Practices

(a) Emergency Procedures

(1) Procedures, including fire fighting procedures, shall be established and implemented to meet foreseeable emergency events, including those involving massive release of beryllium contaminants.

(1) Where there is the possibility of massive beryllium contamination from accidents involving elevated temperature operations or large scale spills, a general alarm, drench-type showers, and cleansing facilities shall be installed in such a manner as to provide prompt, immediate access by any employee; respirators shall be available for wearing during evacuation procedures if long distances need to be traversed; and full-facepiece or supplied-air respirators shall be available for employee use where equipment or operations cannot be abandoned. If large scale spills occur, careful monitoring of beryllium air levels shall be instituted as soon as possible. Determinations shall be made as to when it is safe to reenter a contaminated area with respiratory protection and to resume operations without respiratory protection. Thoroughly supervised cleanup operations shall be instituted as soon as air levels recede to the point where operations may be conducted.

(ii) Full-facepiece or supplied-air respirators shall be kept ready for emergency use.

(A) They shall be inspected after each use and at least monthly to assure satisfactory working condition.

(B) Where used, air and oxygen cylinders shall be fully charged according to the manufacturer's instructions.

(iii) Sand, soda ash, or commercial metal fire extinguishment powder shall be available for use as an extinguishing agent for beryllium; water and carbon dioxide shall not be used.

(b) Exhaust Systems

Procedures shall be established to reduce exposure to airborne beryllium through implementation of adequate ventilation methods. Local exhaust and collection shall be designed and maintained to prevent the accumulation of beryllium dust and fumes.

(c) General Housekeeping

(1) No dry sweeping shall be performed.

(2) Emphasis shall be placed upon cleanup of spills, periodic repair of equipment and leaks, and proper storage of materials to prevent breakage.

(d) Disposal

Beryllium waste and scrap shall be collected and disposed of in sealed bags or other sealed containers. Scrap shall be recycled or shall be disposed of by burial.

(e) Non-Worker Access to Beryllium Areas

Entry to any area where there is the possibility of exposure to beryllium shall be permitted only on the basis of need and all persons so entering shall be provided with the same protective clothing as required for employees regularly assigned to that area.

(f) Educational Program

An educational program shall be instituted for all workers to include proper instruction in maintenance procedures, cleanup methods, and use of respiratory protective devices and protective clothing.

Section 7 - Sanitation Practices

(a) Food Facilities

Food preparation and eating should be prohibited in beryllium work areas.

(b) Locker and Toilet Facilities*

(1) Separate locker facilities shall be provided for work clothes and street clothes.

(2) Showers for exposed workers shall be required following a work shift and prior to putting on street clothes.

(3) Locker-shower facilities shall be so arranged that the showers can serve to demarcate between potentially "clean" and "contaminated" areas.

(4) Suitable provisions shall be made for the control of contaminated dust in workshoe storage and clothing hamper locations.

(5) Handwashing and toilet facilities shall be arranged so that following use, workers need not re-enter a potentially contaminated area.

*Except where a variance has been granted, based on minimal exposure.

Section 8 - Monitoring and Recordkeeping Requirements

(a) Employers shall maintain records of environmental exposures to beryllium based upon the following sampling and recording schedule:

(1) Quarterly Requirements*

(i) Breathing-zone samples shall be collected from employees at least quarterly for specific work operations. The first sampling period shall be completed within 180 days of the effective date of this standard.

(ii) Samples shall be collected and evaluated as both time-weighted and peak concentration values.

(2) Thirty-Day Requirements

The sampling regime shall be every 30 days for work areas under the following conditions:

(i) The environmental time-weighted average or peak concentrations are in excess of the standard.

(ii) Sampling, monitoring, and recordkeeping requirements of a 30-day schedule shall be required only until two consecutive 30-day sampling periods have resulted in environmental levels which meet the standard.

(b) Records shall be maintained for all sampling schedules to include the type of personal protective devices, if any, in use.

(c) Workers shall be informed of the periodic results of samplings.

*Except where a variance has been granted, based on minimal exposure, as determined by selected sampling of representative or minimal exposed workers. It is recognized that sampling frequency is dependent upon the process and emissions; the quarterly sampling frequency is primarily for production operations.

II. INTRODUCTION

This report presents the criteria and the standard based thereon which were prepared to meet the need for preventing occupational diseases arising from exposure to beryllium and its compounds. The necessary relevant data are made available for use by the Secretary, Department of Health, Education, and Welfare in accordance with the provision of the Occupational Safety and Health Act of 1970 requiring the development of criteria by "The Secretary, Department of Health, Education, and Welfare... on the basis of such research, demonstrations, and experiments and any other information available to him...to effectuate the purposes of this Act."..."...by providing medical criteria which will assure insofar as practicable that no employee will suffer diminished health, functional capacity, or life expectancy as a result of his work experience...".

The National Institute for Occupational Safety and Health (NIOSH), after a review of data and consultation with others, formalized a system for the development of criteria upon which standards can be established to protect the health of workers from exposure to hazardous chemical and physical agents. It should be pointed out that any recommended criteria for a standard should result in development of better engineering controls, resulting in more healthful work practices, and should not be used as a final goal.

These criteria for a standard for beryllium and its compounds are in a continuing series of criteria developed by NIOSH. The criteria and standard apply only to the processing, manufacture, and use of beryllium products as applicable under the Occupational Safety and Health Act of 1970.

These criteria were not designed for the population-at-large, and any extrapolation beyond general occupational exposures is not warranted. They are intended to assure that the standard based thereon will (1) protect against development of acute and chronic beryllium disease, (2) be measurable by techniques that are valid; reproducible, and available to industry and official agencies, and (3) be attainable with existing technology.

III. PROPERTIES AND SOURCES

Beryllium is one of the lightest of metals, is widely distributed geographically, and has found wide application in industry. It has many unique properties: it is the only stable, lightweight metal with a high melting point; it has an especially high strength-to-weight ratio; its alloying property confers to metals specific properties of resistance to corrosion, vibration, and shock; and it possesses extreme hardness yet excellent ductility. A condensed list of its physical properties is presented in Table I.¹

Beryl ($3\text{BeO}\cdot\text{Al}_2\text{O}_3\cdot 6\text{SiO}_2$) is presently the chief source of beryllium, although bertrandite [$\text{Be}_4\text{Si}_2\text{O}_7(\text{OH})_2$], chrysoberyl (BeAl_2O_4), and phenacite (BeSiO_4) are also important beryllium-containing minerals.

Domestic production of beryl, the principal beryllium-containing ore of commercial importance, was approximately 500 tons in 1950. Domestic production has remained relatively constant as contrasted with domestic consumption which, in 1969, reached 8500 tons and is forecast to reach 20,000 tons by the year 2000.^{2,3} The bulk of our beryllium ore supply is imported^{3,4} and is processed primarily in Ohio and Pennsylvania. Products from the initial processing either are utilized locally or shipped to a variety of sources for incorporation into finished products. Beryllium-copper alloys have high tensile strength, excellent casting and machining characteristics, high electrical and thermal conductivity, and resistance to corrosion and fatigue. Heat-treated beryllium-nickel alloys have many properties comparable or superior to heat-treated stainless steel. Beryllium oxide is unusual in that it is both a good conductor of heat and an electrical insulator. It is used in the manufacture of ceramic parts, crucibles,

thermal coatings, and also has application in nuclear reactors. Aerospace applications include structural materials, inertial guidance systems, rocket motor parts, heat shields, rotor blades, and airplane brakes.

Further products which may contain beryllium include jewelry, fishing rods, bicycle spokes, dental plates, furnace bricks, and spark plugs.

The major industrial uses and industries which process and manufacture beryllium products are listed in Tables II and III.
3,5,6