OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR BERYLLIUM AND ITS COMPOUNDS POTENTIAL HUMAN CARCINOGEN

INTRODUCTION

This guideline summarizes pertinent information about beryllium and its compounds for workers, employers, and occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments in these fields; therefore, readers are advised to regard these recommendations as general guidelines.

SUBSTANCE IDENTIFICATION

- **Formula:** Be
- **Synonyms:** Synonyms vary depending upon specific compound
- **Identifiers:** CAS 7440-41-7; RTECS DS1750000; DOT 1567, label required: "Poison, Flammable Solid"
- **Appearance:** Silvery gray metal

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 9.01
2. Boiling point (at 760 mmHg): 2,970°C (5,378°F)
3. Specific gravity (water = 1): 1.85
4. Melting point: 1,283°C (2,341°F)
5. Insoluble in water

- **Reactivity**

1.Incompatibilities: Acids, alkalies, chlorinated hydrocarbons, and oxidizable agents

2. Hazardous decomposition products: Beryllium reacts with strong acids to evolve hydrogen.

- **Flammability**

1. Extinguishant: Sand, soda ash, or commercial metal fire extinguishant powder may be used. Do not use water or carbon dioxide.
2. Flammability Rating 1 (NFPA)
3. Caution: Powdered beryllium is flammable in air. Hazard increases as fineness of powder increases.

- **Warning properties**

Evaluation of warning properties for respirator selection: Warning properties are not considered in recommending respirators for use with carcinogens.

EXPOSURE LIMITS

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for beryllium and its compounds is 2 micrograms of beryllium per cubic meter of air ($\mu g/m^3$) as a time-weighted average (TWA) concentration over an 8-hour workshift; the acceptable ceiling concentration is 5 $\mu g/m^3$; and the maximum peak concentration above the acceptable ceiling concentration (maximum duration of 30 minutes) is 25 $\mu g/m^3$. The National Institute for Occupational Safety and Health (NIOSH) recommends that beryllium be controlled and handled as a potential human carcinogen in the workplace and that exposure be minimized to the lowest feasible level. The NIOSH recommended exposure limit (REL) is that occupational exposure to beryllium be controlled so that no worker will be exposed in excess of 0.5 $\mu g/m^3$. The NIOSH REL is the lowest concentration reliably detectable by current NIOSH-validated sampling and analytical methods. The American Conference of Governmental Industrial Hygienists (ACGIH) has designated beryllium as an A2 substance (suspected human carcinogen) having an assigned threshold limit value (TLV®) of 2 $\mu g/m^3$ as a TWA for a normal 8-hour workday and a 40-hour workweek (Table 1).

Table 1.—Occupational exposure limits for beryllium

	Exposure limits $\mu g/m^3$
OSHA PEL TWA	2
Acceptable ceiling	5
Maximum peak above ceiling (30 min)	25
NIOSH REL (Ca)*	
No exposure in excess of	0.5
ACGIH TLV® TWA (A2)†	2

* (Ca): NIOSH recommends treating as a potential human carcinogen.
† (A2): Suspected human carcinogen.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Beryllium may cause adverse health effects following exposure via inhalation, ingestion, or dermal or eye contact.

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

• **Summary of toxicology**

1. *Effects on animals:* Chronic inhalation or intratracheal injection of beryllium metal or its compounds produced lung cancer in rats. Single intrabronchial implantations of beryllium oxide or chronic inhalation of beryllium sulfate produced lung cancer in monkeys. In rabbits, intraosseous administration of beryllium metal or its compounds produced bone cancer.

2. *Effects on humans:* Acute or chronic inhalation of beryllium has caused rhinitis (inflammation of the mucous membranes of the nose), tracheobronchitis (inflammation of the trachea and bronchi), pneumonitis (inflammation of the lungs), and death due to pulmonary edema or heart failure. Chronic inhalation of beryllium has been associated with kidney stones; enlargement of the liver, spleen, and heart; multiple granulomas of the lung, spleen, liver, and lymph nodes; and an increased incidence of lung cancer.

• **Signs and symptoms of exposure**

1. *Short-term (acute):* Exposure to beryllium can cause pain below the sternum, weight loss, nonproductive cough, shortness of breath, and irritation of the eyes, respiratory system, and skin.

2. *Long-term (chronic):* Exposure to beryllium can cause cough, pain in the joints, general weakness, weight loss, clubbing of fingers, shortness of breath, cyanosis, and allergic contact dermatitis. Accidental implantation of beryllium metal or crystals into the skin can cause tissue necrosis and ulceration.

RECOMMENDED MEDICAL PRACTICES

• **Medical surveillance program**

Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control occupational injury and disease. The program should include education of employers and workers about work-related hazards, placement of workers in jobs that do not jeopardize their safety and health, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive values of biologic monitoring and medical screening tests should be evaluated on an industry-wide basis prior to application in any given worker group. Intrinsic to a surveillance program is the dissemination of summary data to those who need to know, including employers, occupational health professionals, potentially exposed workers, and regulatory and public health agencies.

• **Preplacement medical evaluation**

Prior to placing a worker in a job with a potential for exposure to beryllium, the physician should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the eyes, skin, liver, kidneys, spleen, and cardiovascular and respiratory systems. Medical surveillance for respiratory disease should be conducted by using the principles and methods recommended by NIOSH and the American Thoracic Society (ATS).

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to beryllium at or below the NIOSH REL. The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such a worker. Such conditions, which should not be regarded as absolute contraindications to job placement, include a history of chronic skin disease or concurrent dermatitis and significant breathing impairment due to preexisting chronic lung disease. Skin patch testing with soluble beryllium compounds is *not* recommended because of the risk of sensitization.

• **Periodic medical screening and/or biologic monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals. Additional examinations may be necessary should a worker develop symptoms that may be attributed to exposure to beryllium. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an excessive decrease or adverse trend in the physiologic function of the skin, liver, kidneys, spleen, and cardiovascular and respiratory systems as compared to the baseline status of the individual worker or to expected values for a suitable reference population. The following tests should be used and interpreted according to standardized procedures and evaluation criteria recommended by NIOSH and the ATS: standardized questionnaires, tests of lung function, and chest X-rays. In the event of the occurrence of a chronic respiratory disease, diagnostic tests such as the lymphocyte transformation test may be useful in determining the role of beryllium sensitization.

• **Medical practices recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic and laboratory tests which were conducted at the time of placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared to those expected for a suitable reference population. Because occupational exposure to beryllium may cause diseases of prolonged induction-latency, the need for medical surveillance may extend well beyond termination of employment.

• **Sentinel health events**

1. Acute SHE's include: Contact and/or allergic dermatitis.

2. Delayed-onset SHE's include: Chronic beryllium disease of the lungs.

MONITORING AND MEASUREMENT PROCEDURES

• **Method**

Sampling and analysis may be performed by collecting beryllium with cellulose membrane filters followed by digestion with acid and analysis by flameless atomic absorption with a graphite furnace. A detailed sampling and analytical method for beryllium may be found in the *NIOSH Manual of Analytical Methods* (method number 7102).

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the manufacturer, and then evaluating the clothing under actual use conditions.

Workers should be provided with and required to use CPC, gloves, and other appropriate protective clothing necessary to prevent skin contact with beryllium.

SANITATION

Clothing which is contaminated with beryllium should be removed immediately and placed in sealed containers for storage until it can be discarded or until provision is made for the removal of beryllium from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of beryllium's hazardous properties. Reusable clothing and equipment should be checked for residual contamination before reuse or storage.

A change room with showers, washing facilities, and lockers that permit separation of street and work clothes should be provided.

Workers should be required to shower following a workshift and prior to putting on street clothes. Clean work clothes should be provided daily.

Skin that becomes contaminated with beryllium should be promptly washed with soap and water.

The storage, preparation, dispensing, or consumption of food or beverages, the storage or application of cosmetics, the storage or smoking of tobacco or other materials, or the storage or use of products for chewing should be prohibited in work areas.

Workers who handle beryllium should wash their faces, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

Common operations in which exposure to beryllium may occur and control methods which may be effective in each case are listed in Table 2.

Table 2.—Operations and methods of control for beryllium

Operations	Controls
During use in the manufacture of electrical components and ceramics	Process enclosure, local exhaust ventilation, personal protective equipment
During use in the production of beryllium metal from ore	Process enclosure, local exhaust ventilation, personal protective equipment
During use in the production of alloy	Process enclosure, local exhaust ventilation, personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, remove the victim from further exposure, send for medical assistance, and initiate emergency procedures.

• **Eye exposure**

Where there is any possibility of a worker's eyes being exposed to beryllium, an eye-wash fountain should be provided within the immediate work area for emergency use.

If beryllium gets into the eyes, flush them immediately with large amounts of water for 15 minutes, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

• **Skin exposure**

Where there is any possibility of a worker's body being exposed to beryllium, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If beryllium gets on the skin, wash it immediately with soap and water. If beryllium penetrates the clothing, remove the clothing immediately and wash the skin with soap and water. Get medical attention promptly.

• **Rescue**

If a worker has been incapacitated, move the affected worker from the hazardous exposure. Put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILLS AND LEAKS

Workers not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

If beryllium is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak.

3. For small quantities of liquids containing beryllium or beryllium compounds, absorb on paper towels and place in an appropriate container.
4. Large quantities of liquids containing beryllium or beryllium compounds may be absorbed in vermiculite, dry sand, earth, or a similar material and placed in an appropriate container.
5. Beryllium dust may be collected by vacuuming with an appropriate high-efficiency filtration system. If a vacuum system is used, there should be no sources of ignition in the vicinity of the spill, and flashback prevention devices should be provided.

WASTE REMOVAL AND DISPOSAL

U.S. Environmental Protection Agency, Department of Transportation, and/or state and local regulations shall be followed to assure that removal, transport, and disposal are in accordance with existing regulations.

RESPIRATORY PROTECTION

It must be stressed that the use of respirators is the least preferred method of controlling worker exposure and should not normally be used as the only means of preventing or minimizing exposure during routine operations. However, there are some exceptions for which respirators may be used to control exposure: when engineering and work practice controls are not technically feasible, when engineering controls are in the process of being installed, or during emergencies and certain maintenance operations, including those requiring confined-space entry (Table 3).

In addition to respirator selection, a complete respiratory protection program should be instituted which as a minimum complies with the requirements found in the OSHA Safety and Health Standards, 29 CFR 1910.134. A respiratory protection program should include as a minimum an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic environmental monitoring, maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program, including selection of the correct respirators, requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly.

Only respirators that have been approved by the Mine Safety and Health Administration (MSHA, formerly Mining Enforcement and Safety Administration) and by NIOSH should be used. **Remember! Air-purifying respirators will not protect from oxygen-deficient atmospheres.**

BIBLIOGRAPHY

• American Conference of Governmental Industrial Hygienists: "Beryllium and Compounds," *Documentation of the Threshold Limit Values and Biological Exposure Indices* (5th ed.), Cincinnati, 1986.

• American Conference of Governmental Industrial Hygienists: *TLVs® Threshold Limit Values and Biological Exposure Indices for 1987-88*, Cincinnati, 1987.

• American Industrial Hygiene Association: "Beryllium and its Compounds" (revised 1964), *Hygienic Guide Series*, Detroit, 1964.

• American Lung Association of San Diego and Imperial Counties: "Taking the Occupational History," *Annals of Internal Medicine*, 99:641-651, November 1983.

• Baier, E.J., Deputy Director, National Institute for Occupational Safety and Health, Center for Disease Control, Public Health Service, Department of Health, Education, and Welfare: Statement before the Department of Labor, Occupational Safety and Health, Public Hearing on the Occupational Standard for Beryllium, August 19, 1977.

• Clayton, G.D., and Clayton, F.E. (eds.): *Toxicology*, Vol. IIA of *Patty's Industrial Hygiene and Toxicology* (3rd rev. ed.), John Wiley & Sons, Inc., New York, 1981.

• *Code of Federal Regulations*, U.S. Department of Labor, Occupational Safety and Health Administration, 29 CFR 1910.134, 1910.1000, OSHA 2206, revised July 1, 1986.

• *Code of Federal Regulations*, U.S. Department of Transportation, 49 CFR 172.101, Transportation 49, revised October 1, 1982.

• Dean, J.A. (ed.): *Lange's Handbook of Chemistry* (12th ed.), McGraw-Hill, Inc., New York, 1979

• Finkel, A.J. (ed.): *Hamilton and Hardy's Industrial Toxicology* (4th ed.), John Wright—PSG Inc., Boston, 1983.

• Goldman, R.H., and Peters, J.M.: "The Occupational and Environmental Health History," *Journal of the American Medical Association*, 246:2831-2836, 1981.

• Halperin, W.E., Ratcliffe, J., Frazier, T.M., Wilson, L., Becker, S.P., and Shulte, P.A.: "Medical Screening in the Workplace: Proposed Principles," *Journal of Occupational Medicine*, 28(8): 547-552, 1986.

• Hample, C.A., and Hawley, G.G. (eds.): *The Encyclopedia of Chemistry* (3rd ed.), Van Nostrand Reinhold Company, New York, 1973.

• Hankinson, J.L.: "Pulmonary Function Testing in the Screening of Workers: Guidelines for Instrumentation, Performance, and Interpretation," *Journal of Occupational Medicine*, 28(10):1081-1092, 1986.

• Hankinson, J.L.: *Pulmonary Function Testing in the Screening of Workers: Guidelines for Instrumentation, Performance, and Interpretation*, U.S. Department of Health and Human Services, Centers for Disease Control, National Institute for Occupational Safety and Health, Division of Respiratory Disease Studies, Clinical Investigations Branch, Morgantown, West Virginia, 1985.

• Hawley, G.G.: *The Condensed Chemical Dictionary* (10th ed.), Litton Educational Publishing, Inc., New York, 1981.

• International Agency for Research on Cancer: *IARC Monographs on the Carcinogenic Risk of Chemicals to Humans, Some Metals and Metallic Compounds*, Vol. 23, Lyon, France, 1980.

• Leidel, N.A., Busch, K.A., and Lynch, J.R.: *Occupational Exposure Sampling Strategy Manual*, U.S. Department of Health, Education, and Welfare, Public Health Service, Center

for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 77-173, Cincinnati, 1977.
• Levy, B.S., and Wegman, D.H. (eds.): *Occupational Health: Recognizing and Preventing Work-Related Disease*, Little, Brown and Company, Boston, 1983.
• Mark, H.F., Othmer, D.F., Overberger, C.G., Seaborg, G.T., Grayson, M., and Eckroth, D. (eds.): *Kirk-Othmer Encyclopedia of Chemical Technology* (3rd ed.), John Wiley & Sons, Inc., New York, 1978.
• National Fire Protection Association: *National Fire Codes®* (Vol. 13), Quincy, Massachusetts, 1983.
• National Institute for Occupational Safety and Health, U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control: *Criteria for a Recommended Standard. . . .Occupational Exposure to Beryllium*, HSM Publication No. 72-10268, 1972.
• National Institute for Occupational Safety and Health, U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control: *Occupational Diseases—A Guide to Their Recognition* (rev. ed., 2nd printing), DHEW (NIOSH) Publication No. 77-181, 1978.
• National Institute for Occupational Safety and Health, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control: *NIOSH Manual of Analytical Methods* (3rd ed., Vol. 1), Eller, P.M. (ed.), DHHS (NIOSH) Publication No. 84-100, Cincinnati, 1984.
• National Institute for Occupational Safety and Health, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control: *Registry of Toxic Effects of Chemical Substances* (Microfiche Edition), Sweet, D.V., and Lewis, R.J. (eds.), Cincinnati, April 1985.
• Parmeggiani, L. (ed.): *Encyclopedia of Occupational Health and Safety* (3rd ed.), International Labour Office, Geneva, Switzerland, 1983.
• Proctor, N.H., and Hughes, J.P.: *Chemical Hazards of the Workplace*, J.B. Lippincott Company, Philadelphia, 1978.
• Rom, W.N. (ed.): *Environmental and Occupational Medicine*, Little, Brown and Company, Boston, 1983.
• Rothstein, M.A.: *Medical Screening of Workers*, Bureau of National Affairs, Washington, DC, 1984.
• Rutstein, D.D., Mullan, R.J., Frazier, T.M., Halperin, W.E., Melius, J.M., and Sestito, J.P.: "Sentinel Health Events (Occupational): A Basis for Physician Recognition and Public Health Surveillance," *American Journal of Public Health*, 73:1054-1062, 1983.
• Scientific Assembly on Environmental and Occupational Health: "Evaluation of Impairment/Disability Secondary to Respiratory Disease," *American Review of Respiratory Diseases*, 126:945-951, 1982.
• Scientific Assembly on Environmental and Occupational Health: "Surveillance for Respiratory Hazards in the Occupational Setting," *American Review of Respiratory Diseases*, 126:952-956, 1982.
• Weast, R.C. (ed.): *CRC Handbook of Chemistry and Physics* (64th ed.), CRC Press, Inc., Boca Raton, Florida, 1983.

Table 3.—Respiratory protection for beryllium

Condition	Minimum respiratory protection*
Any detectable concentration	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Planned or emergency entry into environments containing unknown or any detectable concentration	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
	Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying full facepiece respirator with a high-efficiency particulate filter
	Any appropriate escape-type self-contained breathing apparatus

* Only NIOSH/MSHA-approved equipment should be used.