

LLEINST 6706E
24 February 2006

LLE INSTRUCTION 6706E

SUBJECT: BERYLLIUM SAFETY PROCEDURES

REFERENCE:

- a. 10 CFR Part 850 Chronic Beryllium Disease Prevention Program (CBDPP); Final Rule
- b. 29 CFR 1910.1450 the OSHA Laboratory Standard
- c. University of Rochester/LLE Chemical Hygiene Plan
- d. LLE PPE Job Hazard Assessment Form

1. **Purpose:** To promulgate procedures and protocols to ensure that beryllium is handled, processed and used safely, whether it is used in the form of a solid “article” (e.g., a foil, film, stalk, or other shape) or integrated as a component of a piece of experimental equipment or diagnostic instrument. The procedures and protocols specified herein shall ensure that the concentration of both airborne and surface (“removable”) beryllium particulate contamination remains below accepted safe occupational exposure levels.

2. **Background:**

a. Beryllium is a silver-gray metal with a density of 1.85 g/cm³ and a high stiffness. Beryllium in the form of a powder or dust can cause a granulomatous respiratory disorder called chronic beryllium disease (CBD) when the concentration of respirable beryllium particles (dust or fumes) in the workplace environment exceeds established safe exposure limits. The degree of hazard is a function of the different toxicity of the various forms of beryllium and of the type, magnitude, and duration of exposure to insoluble beryllium particulates. The chemical form, physical form, and morphology of beryllium are all important in determining its toxicity. Researchers believe that beryllium oxide may be the primary chemical form of beryllium that causes CBD. Particles initially generated as metallic beryllium develop a coating of beryllium oxide because small beryllium metal particles readily oxidize in ambient air. The oxide coating on respirable-size beryllium metal particles makes up 25% to 30% of the particle by weight. Beryllium and beryllium compounds are also classified as known human carcinogens by the National Toxicology Program’s Board of Scientific Counselors. Beryllium is ubiquitous in the

environment and can be detected virtually anywhere if a sufficiently large air sample is taken. According to the Environmental Protection Agency's (EPA) Integrated Risk Information System, the United States population is being exposed to detectable background levels of beryllium without any appreciable risk of contracting CBD in their lifetime.

- b. At LLE, beryllium is frequently used as a blast shield for x-ray optics, a filter material for x-ray diagnostics, a vacuum window for KB microscopes and pinhole cameras, and for specialized targets shot on the OMEGA laser. The beryllium used for blast shields, filters, vacuum windows, and targets is normally purchased pre-cut to size and is classified in accordance with 10 CFR 850.3 as a "beryllium article" [defined in Sec. 3(d)] that neither releases beryllium dust nor will produce airborne particulate concentrations of beryllium under normal handling conditions prior to being exposed to an OMEGA target shot. Although it is believed that these beryllium articles in their as-purchased form present an insignificant health and safety risk and require no special handling or personnel protective equipment (PPE) beyond that dictated by prudent laboratory safety practices (safety glasses and gloves), there are certain activities in which there may exist a finite risk to personnel of exposure to beryllium dust. These activities are subject to the provisions of this instruction and include:
- cutting or shaping of beryllium articles,
 - servicing diagnostic nose cones and film packs that may contain beryllium residues,
 - handling of diagnostic equipment containing beryllium windows or filters that are under a substantial pressure differential, and
 - entry into either the OMEGA or OMEGA EP target chamber(s).

3. **Definitions:**

Reference (a) describes the Chronic Beryllium Disease Prevention Program (CBDPP) enacted by the Department of Energy (DOE) that is applicable to DOE and contractor employees who may be exposed or potentially exposed to insoluble beryllium particulates. The CBDPP defines "beryllium" as elemental beryllium and any insoluble beryllium compound or alloy containing $\geq 0.1\%$ beryllium that may be released as an airborne particulate. The handling and use of soluble forms of beryllium (e.g., salts other than oxides) that do not cause CBD are not specified in the DOE CBDPP program, and in the absence of specific DOE guidelines are instead covered under existing OSHA regulations {OSHA Laboratory Standard 29 CFR 1910.1450 and the UR/LLE Chemical Hygiene Plan [Refs. (b) and (c), respectively]}.

Based on the DOE CBDPP, the following terms are defined in the scope and context of the LLE Beryllium Safety Program outlined in this document:

- a. **DOE contractor:** any entity under contract with DOE with responsibility to perform beryllium activities. Because LLE is not contracted to perform beryllium activities, the proposed DOE program is not applicable per se to LLE. However, LLE will ensure that beryllium levels are consistently maintained well below the acceptable exposure limits established in Ref. (a).
- b. **Action level:** the level of airborne concentration of beryllium particles that, if met or exceeded, requires implementation of contamination mitigation and personnel protection procedures. Such procedures include decontamination protocols, periodic exposure monitoring, regulated areas, change rooms, protective clothing and equipment, and medical surveillance of exposed personnel. **The action level currently defined by Ref. (a) is $0.2 \mu\text{g}/\text{m}^3$.**
- c. **Beryllium:** elemental beryllium and any insoluble beryllium compound or alloy containing $\geq 0.1\%$ beryllium that may be released as an airborne particulate.
- d. **Beryllium article:** a pre-cut or pre-manufactured foil, film, stalk, or other shape made from beryllium that neither releases beryllium dust nor will produce airborne particulate concentrations of beryllium under normal handling conditions.
- e. **Beryllium-associated laboratory worker:** any current LLE laboratory personnel who work with beryllium and thus potentially could be exposed to airborne concentrations of beryllium.
- f. **Removable contamination:** beryllium contamination on surfaces in the form of dust or particulates that can be removed by casual contact, wiping, brushing, or washing.
- g. **Permissible exposure limit (PEL):** the maximum concentration of particulate beryllium that a beryllium-associated worker can be exposed to over a specified work interval, generally expressed as an 8-h, time/weighted average (TWA). **The PEL (8-h TWA) currently defined by Ref. (a) is $2 \mu\text{g}/\text{m}^3$.**
- h. **Removable contamination level:** the acceptable level of residual beryllium contamination on routine working surfaces in operational areas (exclusive of interior surfaces of systems such as enclosures, glove boxes, chambers, or ventilation systems) during non-operational periods. **The**

current acceptable removable contamination level on working surfaces defined by Ref. (a) is 3 $\mu\text{g}/100 \text{ cm}^2$.

- i. **Acceptable surface contamination limit (ASCL):** the acceptable level of residual beryllium surface contamination that is acceptable for releasing equipment or other items exposed to beryllium to the general public or for use in an uncontrolled area. **The ASCL currently defined by Ref. (a) is 0.2 $\mu\text{g}/100 \text{ cm}^2$.**
 - j. **Operational area:** areas where workers are routinely in the presence of beryllium as a part of their normal work activities.
 - k. **Regulated area:** areas in which the airborne concentration of beryllium either exceeds or can be reasonably expected to exceed the action level.
- 4 **Procedures and Protocols:**
- a. **Beryllium limits:** Table 1 below establishes the exposure limits for beryllium particulates at LLE to preclude unsafe occupational exposure.

Table 1: Exposure limits for beryllium particulates established at the LLE facility.

Area	Contamination type	DOE CBDPP	LLE
<i>General Areas:</i>	Airborne	<0.2 $\mu\text{g}/\text{m}^3$	<0.1 $\mu\text{g}/\text{m}^3$
	Removable	<0.3 $\mu\text{g}/100 \text{ cm}^2$	<0.3 $\mu\text{g}/100 \text{ cm}^2$
<i>Operational Areas:</i>	Airborne	<0.2 $\mu\text{g}/\text{m}^3$	< 0.2 $\mu\text{g}/\text{m}^3$
	Removable	<3 $\mu\text{g}/100 \text{ cm}^2$	<3 $\mu\text{g}/100 \text{ cm}^2$
<i>Regulated areas:</i> (Target Chamber-internal)	Airborne	< 0.2 $\mu\text{g}/\text{m}^3$	<0.2 $\mu\text{g}/\text{m}^3$
	Removable	<3 $\mu\text{g}/100 \text{ cm}^2$	<3 $\mu\text{g}/100 \text{ cm}^2$

- b. **Training:** Reference (a) requires a separate training program on beryllium hazards be established for both those individuals working directly with beryllium and all other individuals that work at a site where beryllium

activities are conducted. All individuals who purchase, store, shape, process, or otherwise use or handle beryllium, whether in the form of a beryllium article or incorporated into experimental equipment or diagnostics, must attend a Beryllium Safety Training session prior to their first assignment handling or using beryllium or beryllium-containing equipment. These individuals shall be identified through the LLE PPE Job Hazard Assessment form [Ref. (d)]. This training shall include the following elements:

- Explanation of the potential health risks resulting from uncontrolled contact with beryllium particulates.
- An overview of the goals, objectives, and requirements of the DOE CBDPP as it applies to beryllium activities at LLE.
- General awareness about beryllium hazards and controls.
- Specific training on the procedures and protocols for beryllium handling at LLE in accordance with this instruction.

General refresher training on beryllium safety is to be conducted on a yearly basis. To maintain a high level of facility awareness, all laboratory personnel will receive general awareness training of the adverse health effects of uncontrolled exposure to beryllium particulates as a part of the standard LLE Chemical Hygiene Plan training.

The LLE Chemical Hygiene Officer functions as the Facility Beryllium Safety Officer and is responsible for conducting the Beryllium Safety Training sessions and maintaining a personnel training database for beryllium safety training as a functional subset of the LLE Chemical Hygiene Plan

- c. **Purchasing:** All beryllium will be purchased by the Mechanical Engineering Production Control Specialist.
- d. **Storage and inventory:** Beryllium shall be stored in sealed containers (particle-impermeable plastic bags or other particle-impermeable containers) that are labeled in accordance with paragraph 3.e. The Mechanical Engineering Production Control Specialist will maintain the master storage area for bulk quantities of beryllium in a labeled, secure cabinet and keep a running log of beryllium article distribution. Users shall only store quantities of beryllium in their laboratories or work areas that are sufficient for operational needs. Beryllium must be stored in sealed bags or containers as described above that are properly labeled, and the storage location in the laboratory or work area must be clearly labeled in accordance with paragraph 3.e. Normal locations where storage of beryllium is required to support operations are in the Target Fabrication laboratory (foil in Room 2828, mounted targets in Room 2839), the X-Ray Laboratory (Room 1228), the Target Bay (Room 247), and LaCave

(Room 146). All locations in the LLE facility where beryllium is stored and the quantities stored in these locations shall be included in the LLE Chemical Inventory as required under the OSHA Laboratory Standard and the UR/LLE Chemical Hygiene Plan [Refs. (c) and (d), respectively].

- e. **Baseline monitoring and hazard assessment:** An initial, one-time baseline monitoring of these areas shall be performed by a Certified Industrial Hygienist from the University's Environmental Health and Safety (EHS) group to ensure that the levels of beryllium particulates are below the limits shown in Table 1, Sec. 4 (a).
- f. **Labeling:** Warning labels shall be affixed to all beryllium storage areas, beryllium storage containers, equipment and diagnostics containing beryllium windows or filters, equipment that is contaminated with beryllium debris, and beryllium waste containers. The following labels shall be used:

- **For beryllium storage areas and containers:**

**BERYLLIUM
DANGER!
DO NOT REMOVE DUST BY BLOWING OR SHAKING
CANCER AND LUNG DISEASE HAZARD**

- **For contaminated equipment and beryllium waste containers:**

**DANGER
CONTAMINATED WITH BERYLLIUM
DO NOT REMOVE DUST BY BLOWING OR SHAKING
CANCER AND LUNG DISEASE HAZARD**

- **For experimental and diagnostic equipment containing beryllium windows or filters**

**CONTAINS BERYLLIUM OPTICAL ELEMENT
*EXTREMELY BRITTLE-DO NOT TOUCH, CLEAN, OR CONTACT
WITH ANY OBJECT WHILE UNDER VACUUM***

Thickness: _____

Diameter: _____

The above label must contain information on the dimensions of the beryllium window and the maximum allowable pressure differential. The minimum allowable window thickness for safe operation under vacuum in standard configurations is 1 mil (25 μm). In cases where a thinner window is required to meet experimental objectives, the principal investigator must ensure that both the beryllium window diameter and the mount design and construction are appropriate for safe operation under vacuum by having the window mounting configuration reviewed and approved by senior personnel with extensive experience in deploying beryllium optical element in vacuum environments.

- g. **Waste disposal:** All beryllium-contaminated waste shall be collected in sealed, impermeable bags or containers that are labeled in accordance with both paragraph 3.e. and EPA hazardous waste disposable requirements. The labeled containers are then delivered to the hazardous waste locker on the shipping and receiving dock for collection by the University's Hazardous Waste Unit. If the waste is also potentially contaminated with tritium, the waste must be disposed of as radioactive waste by sending it to the University of Rochester Radiation Safety Unit. Waste containing beryllium should be segregated from other tritium waste and be specifically labeled.
- h. **Cutting or otherwise processing beryllium foil:** To the maximum extent possible, beryllium should be purchased pre-cut to size to preclude the necessity of cutting it at LLE. Should this not be possible, the only processing to be done at LLE is crimp cutting. **Under no circumstances is beryllium to be sawed, drilled, machined, or otherwise abraded.**

Crimp cutting should be performed in such a manner so as to preclude beryllium splinters or chips from being spread. A recommended manner for doing this is to place the beryllium sheet on a tissue soaked with ethanol prior to cutting. After crimping, the tissue is used to wipe the beryllium pieces clean. The tissue must then be disposed of in accordance with paragraph 3.f. Rubber gloves and a face shield or mask shall be worn when performing this operation.

- i. **Handling procedures for diagnostics and other equipment incorporating beryllium filters or windows:** Thin beryllium windows (usually around 1 mil, or 25 μm thick), such as those found on x-ray cameras, are extremely brittle and can be shattered with a seemingly insignificant amount of touch pressure (e.g., lightly wiping with a tissue). In a system either above or below ambient pressure, there can be a substantial risk to personnel from beryllium fragments and particulates that would be generated in the event of a window rupture. For systems

under vacuum, a stressed beryllium window will implode and any flying fragments will be contained within the apparatus and vacuum system, causing damage to sensitive components and requiring decontamination of the system from beryllium fragments and particulates. A greater danger to personnel from flying beryllium shards and particulates exists if the window was to rupture outward due, for instance, to a pressure buildup in a cryostat, which can occur if the cryostat develops a vacuum leak while at low temperature and is then allowed to warm up.

- (1) **Under no circumstances are beryllium windows under vacuum or pressure ever to be wiped, cleaned, or contacted in any way. If it is determined that cleaning the window is necessary, the apparatus containing the window must be vented to room pressure before such operations can proceed.**
 - (2) Cryostats used with equipment containing beryllium windows must have a pressure relief valve to prevent an outward rupture of the window in the event of an intended or unintended warm-up of the cryostat. As a secondary precaution, the window should be covered with a plastic or metal cap when the apparatus is not in use to confine beryllium debris in the event of an unexpected window failure.
- i. **Decontamination of diagnostics and other equipment exposed to beryllium debris:** Diagnostic nose cones that employ beryllium blast shields or filters during target shots on OMEGA will become contaminated with beryllium debris. The servicing of these nose cones must be accomplished in a manner that contains and collects the beryllium debris and prevents collateral contamination. Rubber gloves and a facemask must be used when servicing these diagnostics, and all debris must be collected in impermeable bags and then sealed and disposed of in accordance with paragraph 3.f. Before removing the diagnostic nose cone from the servicing area, it must be cleaned to remove beryllium particulates. This is best accomplished by using tissue and ethanol. The tissue must then be disposed of in accordance with paragraph 3.f.
- j. **Decontamination of diagnostics and other equipment before leaving the LLE facility:** Because of collaborative research efforts with other laboratories, it will be necessary to ship diagnostics by common carrier. The procedure below outlines a protocol that has been established with LLNL for transfer of diagnostics directly from LLE to LLNL.
1. *Diagnostics can be shipped directly from LLE to LLNL provided that they have first gone through the usual LLE cleaning process and have been tested and cleared for tritium contamination. Part of this cleaning involves disposing of any large beryllium shards that may be found in the detector head due to a broken filter. If a*

beryllium filter has been broken within the diagnostic, this information must be conveyed to the receiver of the instrument in the form of hard-copy attached documentation followed up with an e-mail notice.

2. *With regard to containment failure during transport for instruments with potential beryllium contamination, the US Department of Transportation has verified that as long as the beryllium contamination is in the form of large pieces that are non-dispersible, no regulation is necessary. Since the instrument is wiped down during the cleaning process prior to shipment it is reasonable to assume that no dispersible particulates are present, thus it presents no hazard. Additionally, air samples at LLE, where these instruments are used have only shown airborne contamination levels well below the action level of $0.2 \mu\text{g}/\text{m}^3$.*
- k. **Beryllium airborne monitoring:** The target chamber shall be monitored semiannually for airborne beryllium to verify that levels remain below the limit of Table 1, Sec. 4(a). With the exception of the one-time baseline monitoring described in paragraph 4d, general areas need not be monitored so long as the procedures of this instruction are followed.
- l. **Beryllium surface contamination monitoring:** The target chamber (internal surfaces), general areas where diagnostics are serviced, and general areas where beryllium is cut should be monitored semiannually for removable beryllium surface contamination. If beryllium is detected at levels above those established in Table 1, Sec. 4(a), these areas must be cleaned (decontaminated).
- m. **Respiratory protection:** Technically, respiratory protection for airborne particulates should not be required as long as the level of beryllium particulate contamination remains below the action level of $0.2 \mu\text{g}/\text{m}^3$. Because of the potential for exposure levels in the target chamber to exceed the action level due laser ablation of beryllium contained in the chamber, LLE treats the inside of the target chamber as a “regulated” area as defined by Ref. (a) and in Sec. 3(a) of this instruction and requires respiratory protection for all personnel who enter the target chamber. LLE will also provide respiratory protection to individuals who are performing tasks for which analyses indicate the potential for exposures at or above the action level. All such personnel described above must be enrolled in the University’s Respiratory Protection Program through LLE, receive medical clearance as a respirator wearer, and have their respirator fit-tested by the University Health Service at yearly intervals in accordance with the OSHA Personal Protective Equipment (PPE) Standard and the University of Rochester Respiratory Protection Program.

- n. **Records and reports:** Records of all monitoring results will be forwarded to the Laboratory Safety Officer for retention. In the event the limits of Table 1, Sec. 4(a) are exceeded, the Laboratory Safety Officer and Chemical Hygiene Officer will be informed.

5. Responsibilities:

a. **Personnel who use, process, or could potentially be exposed to beryllium**

- (1) Receive training prior to handling beryllium and/or beryllium-containing equipment or diagnostics.
- (2) Forward all requests to purchase beryllium to the Mechanical Engineering Production Control Specialist.
- (3) Comply with the procedures of this instruction for handling, labeling, and disposing of beryllium, beryllium-contaminated items, beryllium waste, and any equipment or diagnostic that contains beryllium optical elements.

b. **Experimental Operations Group Leader**

- (1) Manage the airborne and surface monitoring for the target chamber and general areas.
- (2) Train and supervise the Experimental Operations personnel on these procedures.
- (3) Ensure that all equipment under vacuum that contains beryllium windows that are >1 mil (25 μm) thick has been reviewed and approved for safe operation.

c. **Scientists, Research Engineers, and Supervisors**

- (1) Ensure that all individuals they supervise have received training from the Chemical Hygiene Officer, have been made aware of the hazards of working with beryllium and beryllium-containing experimental equipment, and have reviewed and understand this Instruction.
- (2) Ensure that any experimental configurations operating under vacuum that require beryllium windows to be thinner than 1 mil (25 μm) have been reviewed and approved by senior personnel with extensive experience in deploying beryllium optical element in vacuum environments

d. **Mechanical Engineering Production Control Specialist**

- (1) Order all beryllium;
- (2) Ensure operational supplies are given only to trained personnel;

- (3) Maintain a record of all beryllium ordered and distributed including the names of requestors/recipients, date, and quantity.

e. **Departmental Chemical Hygiene Officer**

- (1) Train all users of beryllium on the health risks and the requirements of this instruction and keeps a record of this training;
- (2) Maintain quantity and location information on beryllium in the facility Chemical Inventory.
- (3) Ensure that beryllium is disposed of in accordance with this instruction and all University, State, and Federal requirements

f. **Laboratory Safety Officer**

- (1) Provide overall direction to ensure an effective beryllium safety program.

5. Approval:

Robert L. McCrory
Director