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# LAWRENCE LIVERMORE LABORATORY'S BERYLLIUM CONTROL PROGRAM FOR HIGH-EXPLOSIVE TEST FIRING BUNKERS AND TABLES

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## ABSTRACT

This detailed report on Lawrence Livermore Laboratory's control program to minimize beryllium levels in Laboratory workplaces includes an outline of beryllium surface, soil, and air levels and an 11-y summary of sampling results from two high-use, high-explosive test firing bunkers. These sampling data and other studies demonstrate that the beryllium control program is functioning effectively.

## INTRODUCTION

Beryllium components have been an integral part of nuclear weapons systems since their inception. And, beryllium operations for weapons development have typically included machining, powder pressing, plasma sputtering, and high-explosive test firing, all of which produce large amounts of airborne beryllium. Although the mechanism that causes beryllium to be toxic is not completely understood, Lawrence Livermore Laboratory (LLL) has always treated beryllium as a toxic material and has long recognized that inhalation of beryllium dust is the major risk in working with beryllium. To achieve a more complete measure of the airborne dust potential in Laboratory workplaces, LLL supplements air monitoring with surface-swipe and gravel monitoring of test-assembly firing tables. This additional monitoring helps identify potential sources of beryllium contamination before they create an airborne problem. The Laboratory's beryllium control program for high-explosive test firing bunkers and tables is outlined in this report.

## BERYLLIUM STANDARDS

### ATOMIC ENERGY COMMISSION

In 1949, the Atomic Energy Commission (AEC) established the following standards for permissible airborne concentrations of beryllium in in-plant air[1]:

- The in-plant atmospheric concentration of beryllium should not exceed an average of 2 $\mu g/m^3$ over an 8-h work day.
- No person should be exposed to atmospheric concentrations of beryllium greater than 25 $\mu g/m^3$ at any time, however short, even though the average daily concentration may be less than 2 $\mu g/m^3$.
- Average monthly concentrations of beryllium at the breathing level *should not exceed 0.01* $\mu g/m^3$ *in neighborhoods where plants handling* beryllium compounds are located.

When the Workshop on Beryllium[2] reviewed these standards in 1961, they were unanimously agreed that berylliosis will disappear with strict adherence to the airborne beryllium levels set in the AEC standards.

### LAWRENCE LIVERMORE LABORATORY

Since the 1950's, the Laboratory has followed a more conservative workplace standard for beryllium to better control employee exposure. This standard was prepared by Kusian[3] and is outlined below. The workplace beryllium levels set in this standard are still followed by LLL any place beryllium is handled.

#### Normal Operating Levels

When the average atmospheric concentration of beryllium is consistently less than 0.2 $\mu g/m^3$ during an 8-h working day, the control measures are considered adequate.

#### Warning Levels

When the average atmospheric concentration of beryllium exceeds 0.2 $\mu g/m^3$ but is not over 2 $\mu g/m^3$ for three consecutive working days, the operation involved will be studied to determine the cause and correct the condition. In most cases, the study will begin as soon as the condition is noticed.

If average beryllium concentrations of 1 to 2 μg/$m^3$ persist for three consecutive weeks, the operation will be stopped until corrective measures have been completed.

Emergency Action Levels

When the average atmospheric concentration of beryllium exceeds 2 μg/$m^3$ but is not over 5 μg/$m^3$ for two consecutive 8-h working days, the operation involved will be stopped until corrective measures have been completed.

If any air sample shows a beryllium concentration exceeding 5 μg/$m^3$, the operation involved will be stopped until corrective measures have been completed.

SITE 300

In 1961, Campbell[4] outlined the beryllium monitoring program followed by high-explosive test facilities at the Laboratory's Site 300. This program supplemented air sampling with surface and soil sampling. The following soil and surface levels for beryllium were set to maintain a minimum airborne beryllium level at Site 300 facilities.

Soil Levels

A level of 500 μg of beryllium per gram of soil is permissible in areas where beryllium operations are in progress provided average airborne concentrations of beryllium do not exceed 2.0 μg/$m^3$ and short-term (30-min) concentrations do not exceed 25 μg/$m^3$.

A level of 100 μg of beryllium per gram of soil is permissible in areas where no beryllium operations are in progress provided average airborne concentrations of beryllium do not exceed 0.2 μg/$m^3$ and short-term concentrations do not exceed 25 μg/$m^3$.

## Surface Levels

Beryllium surface levels are limited to 0.05 $\mu g/cm^2$ for floors and walls and to 0.01 $\mu g/cm^2$ for unenclosed equipment.

## NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

In 1972, the National Institute for Occupational Safety and Health (NIOSH) published criteria for a recommended standard on occupational exposure to beryllium.[5] These criteria supported the existing AEC standard of 1949.

## OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION

The Occupational Safety and Health Administration (OSHA) published a proposed standard for beryllium[6] in 1975. This proposed standard lowered the 8-h, time-weighted average airborne level for beryllium from 2 $\mu g/m^3$ to 1 $\mu g/m^3$ and the ceiling beryllium level from 25 $\mu g/m^3$ to 5 $\mu g/m^3$. OSHA also mentioned that beryllium could pose a carcinogenic threat to man.

In 1977, OSHA revised its proposed beryllium standard[7] to include a requirement for beryllium and beryllium work areas to be identified as "cancer hazards." OSHA hopes to have this revised beryllium standard in effect by the end of 1981. Its only impacts on LLL operations will be to change beryllium labels so they include the cancer hazard and to expand the medical surveillance program.

## BERYLLIUM CONTROL PROGRAM

The purpose of LLL's strict beryllium control program is to minimize beryllium levels in Laboratory workplaces. This philosophy enables LLL to use beryllium routinely without creating a hazard to LLL employees or to the environment. To minimize beryllium levels in high-explosive test firing bunkers and on firing tables, the Laboratory uses the following administrative controls.[8] Hazards Control is responsible for monitoring the effectiveness of these controls to ensure that beryllium contamination levels do not present a health hazard and to inform the facility supervisor when protective measures other than those given below are needed.

### HOUSEKEEPING

All facilities must be kept free of accumulated dust through good housekeeping. A vacuum cleaner, not compressed air, shall be used to clean the interior of facility boxes, flash x-ray houses, bunkerettes, and the mechanical equipment room when they are dusty.

When debris is present after a shot, exterior bunker walls, docks, stairs, and bottle racks must be washed down. The firing table must also be washed down each time a shot contains toxic material or disturbs the table gravel.

The exterior of all facility vehicles shall be hosed off, and the floors and seats shall be vacuumed before vehicles are sent in for maintenance or repair or are transfered out of the area.

All instrumentation and miscellaneous cable should be pulled from the firing table. When this is not possible, some other acceptable means of removing them shall be used to avoid bringing dust and contamination into the bunker.

All openings into the bunker should be closed to keep dust from entering the bunker after a detonation. Any dust "blow-in" shall be reported to Hazards Control Department.

### BUNKER DESIGN

Firing bunkers for high-explosive test assembly should be designed so they are positive to their environment (i.e., so air flows from the inside out). This can be done by supplying the interior of the bunker with excess air that has been filtered through high-efficiency, particulate-air (HEPA) filters. HEPA filters are 99.97% efficient for 0.3-μm monodisperse dioctyl phthalate aerosol and should be inspected annually to ensure they function properly. At blast time, the bunker's large isolation valves should be closed to protect the HEPA filters from overpressure rupture.

## CONTAMINATION AND EQUIPMENT TRANSFER

All firing tables should be considered contaminated areas except during the time between a gravel change and the first detonation containing such toxic materials as beryllium. And, because only parts of the table may be changed after a detonation, facility supervisors should be aware of where personnel will be on the firing table so they can prescribe appropriate protection.

Equipment that has become contaminated with firing table material must be washed down before it can be moved from the firing area. Any transfer of contaminated material must be approved by Hazards Control Department. Procedure 109 of the *Site 300 Manual*, "Transferring Explosives and Other Hazardous Materials," outlines the procedures to be followed when contaminated materials are transferred.

## GRAVEL CHANGES

Firing-table gravel must be changed whenever the gravel contamination level reaches the "derived working limit," which has been established as 500 μg of beryllium per gram of gravel. Hazards Control Department will regularly collect and analyze firing-table soil and inform the facility supervisor whenever the working limit is exceeded.

Before any work involving the movement of gravel may be done, the firing table must be thoroughly watered down. When firing-table gravel is being moved, personnel on the table must wear respirators and full protective clothing (protective footwear, underwear, socks, and coveralls). No visitors or unnecessary personnel should be allowed on the firing table when gravel is being moved.

## PROTECTIVE CLOTHING

All personnel working on a contaminated firing table must wear contamination-control protective footwear. A supply of plastic booties shall be maintained at all firing facilities to accomodate persons not wearing LLL-issued protective footwear.

When significant amounts of gravel are being moved or distributed, all personnel on a contaminated firing table must wear protective clothing. Gloves are also required when personnel are handling debris that could cut their hands. Hazards Control Department will provide guidance on the need for respirators.

Whenever a person must come in contact with the table soil or perform an operation that raises visible dust, protective clothing and respirators are required. This is because the principal hazard on firing tables is from radioactive or beryllium dust left by a shot.

Plant Engineering crafts and maintenance personnel called to perform work on firing tables must stop at Bldg. 820 to obtain protective clothing. When they have completed work in the contaminated area, they must return to Bldg. 820 to shower and change into their regular working clothes.

## POSTFIRING CONTROLS

There will be a delay after every firing or attempted firing to allow the dust cloud to dissipate. The command post will keep the facility supervisor informed about the movement of the dust cloud. During this time, all key switches to the firing units shall be turned off. Detonators, cables, flash lamps, and miscellaneous power-supply cables shall be reconnected to the grounding panel, and necessary postshot camera procedures will be completed.

No personnel will be allowed outside the bunker until the dust cloud has dissipated. The facility supervisor may require all personnel going to the firing table to wear respirators. If any significant movement of gravel is anticipated, respirators must be worn by all personnel.

## EVIDENCE TO SUPPORT PROGRAM EFFECTIVENESS

In 1970, Yamamoto[9] attempted to correlate beryllium soil levels with airborne beryllium levels by deliberately throwing contaminated firing-table gravel into the air. Although the data from Yamamoto's tests were inconclusive, they support established Laboratory controls requiring protective clothing and footwear for entry onto a firing table after a beryllium/radioactive shot has been fired. Yamamoto also recommended that half-mask respirators and gloves be worn when the firing-table soil is disturbed by any means other than walking.

In a Laboratory study tc determine the effectiveness of beryllium program controls, two high-use bunkers--Bunkers 850 and 851--were selected for evaluation. Both bunkers are used for hydrostatic testing of weapon components and weapon-like assemblies that contain toxic materials such as beryllium. Figures 1 and 2 are photographs of Bunkers 850 and 851; they show the firing table location and typical bunker construction.

The key plans of Bunkers 850 and 851 shown in Figs. 3 and 4 identify where air and gravel samples are taken for beryllium analysis. Surface-swipe samples for beryllium analysis are composites of many interior surface locations that are varied regularly.

Table 1 is an 11-y summary of beryllium monitoring results from Bunkers 850 and 851. As the data show, the beryllium levels inside the bunkers have remained well below conservative LLL standards. And observed airborne beryllium levels within the bunkers are normally at least one order of magnitude less than LLL's standards, demonstrating that the Laboratory's beryllium control program for high-explosive test firing bunkers and tables is functioning effectively.

FIG. 1. (a) Bunker 850 (aerial view). (b) Bunker 851 (ground view, showing firing table).

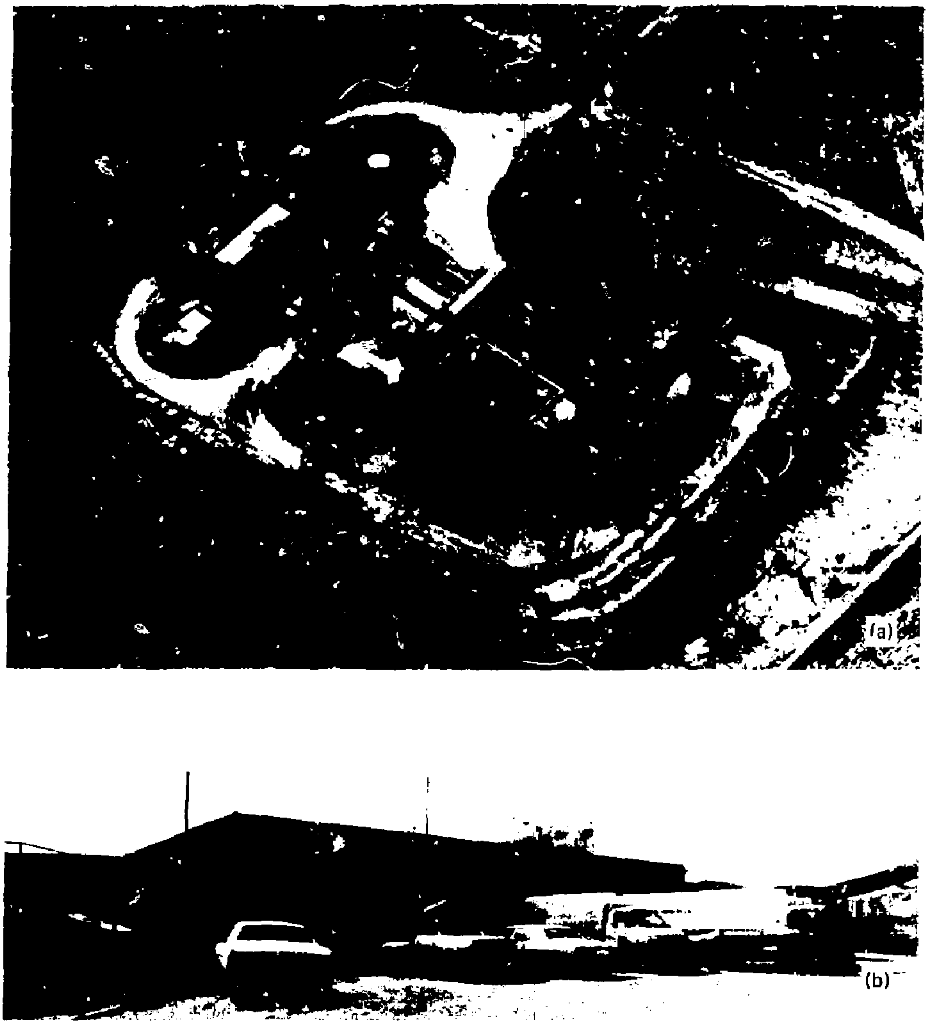


FIG. 2. Bunker 851. (a) Aerial view and (b) ground view, showing bunker entrance and loading dock.

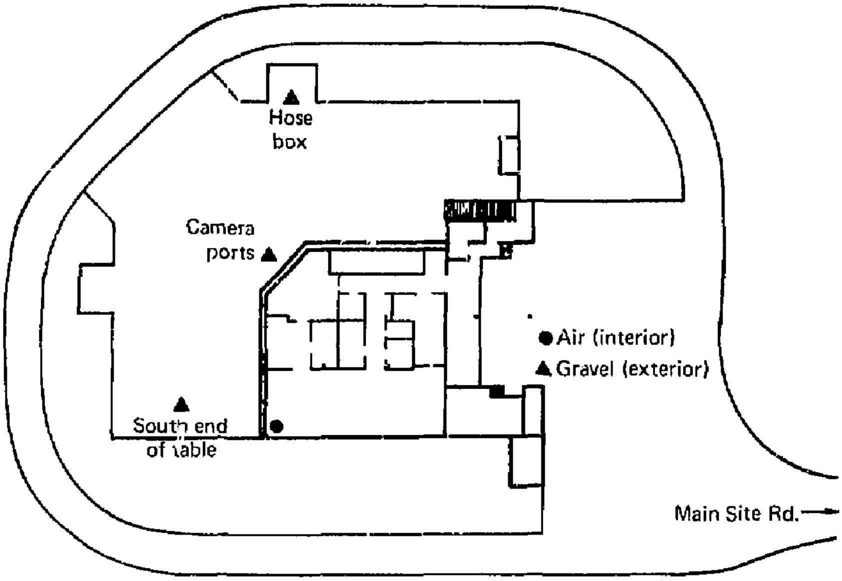


FIG. 3. Key plan of Bunker 850, showing beryllium air and gravel sampling locations.

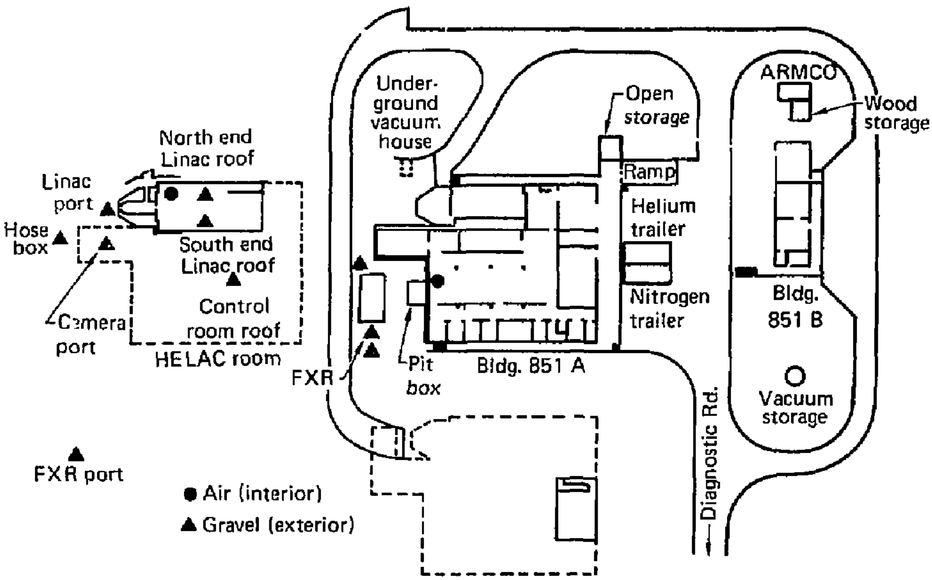


FIG. 4. Key plan of Bunker 851, showing beryllium air and gravel sampling locations.

TABLE 1. Summary of beryllium monitoring for Bunkers 850 and 851.[a,b]

| Bunker, sample, and beryllium expended | Sampling period 1968 | 1969 | 1970[c] | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Bunker 850 | | | | | | | | | | | |
| Interior air ($\mu g/m^3$) | (50) 0.000-0.001 | (15) 0.000-0.001 | (15) 0.000-0.000 | (11) 0.000-0.000 | (83) 0.000-0.000 | (48) 0.000-0.000 | (47) 0.000-0.000 | (48) 0.000-0.000 | (42) 0.000-0.000 | (33) 0.000-0.000 | (57) 0.000-0.002 |
| Interior swipe ($\mu g/cm^2$) | (25) 0.000-0.000 | (7) 0.000-0.000 | (7) 0.000-0.000 | (2) 0.000-0.000 | (33) 0.000-0.001 | (15) 0.000-0.005 | (13) 0.000-0.000 | (6) 0.000-0.001 | (23) 0.000-0.000 | (29) 0.000-0.001 | (23) 0.000-0.000 |
| Firing table soil ($\mu g/g$) | (30) 0.000-22.50 | (15) 0.000-4.00 | (12) 1.75-4.00 | (6) 2.50-300.00 | (68) 1.75-231.25 | (37) 0.000-356.25 | (36) 0.000-35.00 | (43) 0.250-200.00 | (30) 0.250-13.25 | (18) 0.250-6.75 | (19) 0.600-262.50 |
| Expended Be (kg) | 0.0 | 0.0 | 0.4 | 1.2 | 1.2 | 2.0 | 46.6 | 0.9 | 0.2 | 0.4 | 0.4 |
| Bunker 851 | | | | | | | | | | | |
| Interior air ($\mu g/m^3$) | (104) 0.000-0.022 | (103) 0.000-0.003 | (103) 0.000-0.000 | (37) 0.000-0.000 | (186) 0.000-0.000 | (108) 0.000-0.000 | (71) 0.000-0.000 | (98) 0.000-0.000 | (114) 0.000-0.000 | (119) 0.000-0.037 | (101) 0.000-0.010 |
| Interior swipe ($\mu g/cm^2$) | (38) 0.000-0.003 | (43) 0.000-0.004 | (43) 0.000-0.005 | (22) 0.000-0.007 | (72) 0.000-0.001 | (33) 0.000-0.005 | (18) 0.000-0.000 | (12) 0.000-0.001 | (46) 0.000-0.002 | (45) 0.000-0.002 | (28) 0.000-0.002 |
| Firing table soil ($\mu g/g$) | (58) 0.000-375.00 | (64) 0.000-290.00 | (73) 2.50-556.25 | (16) 2.75-206.25 | (31) 2.50-462.50 | (63) 2.00-1250.00[d] | (73) 0.000-990.00[d] | (80) 5.00-1075.00[d] | (46) 1.5-475.00 | (61) 4.00-425.00 | (27) 24.75-656.25 |
| Expended Be (kg) | 14.5 | 20.8 | 12.8 | 18.2 | 16.1 | 27.5 | 71.3 | 89.7 | 30.3 | 62.6 | 28.2 |

[a] Samples were analyzed by atomic absorption spectroscopy, which has a sensitivity of 0.05 μg. Prior to May of 1975, analyses were done with the Morin Dye procedure, which has the same sensitivity.

[b] Items in parentheses indicate the number of samples taken each year.

[c] Both bunkers were closed from the middle of 1970 to late 1971.

[d] If an unrepresentative sample is collected, the area is immediately resampled. Gravel is changed if the high results are confirmed.

## REFERENCES


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