U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES ■ Public Health Service
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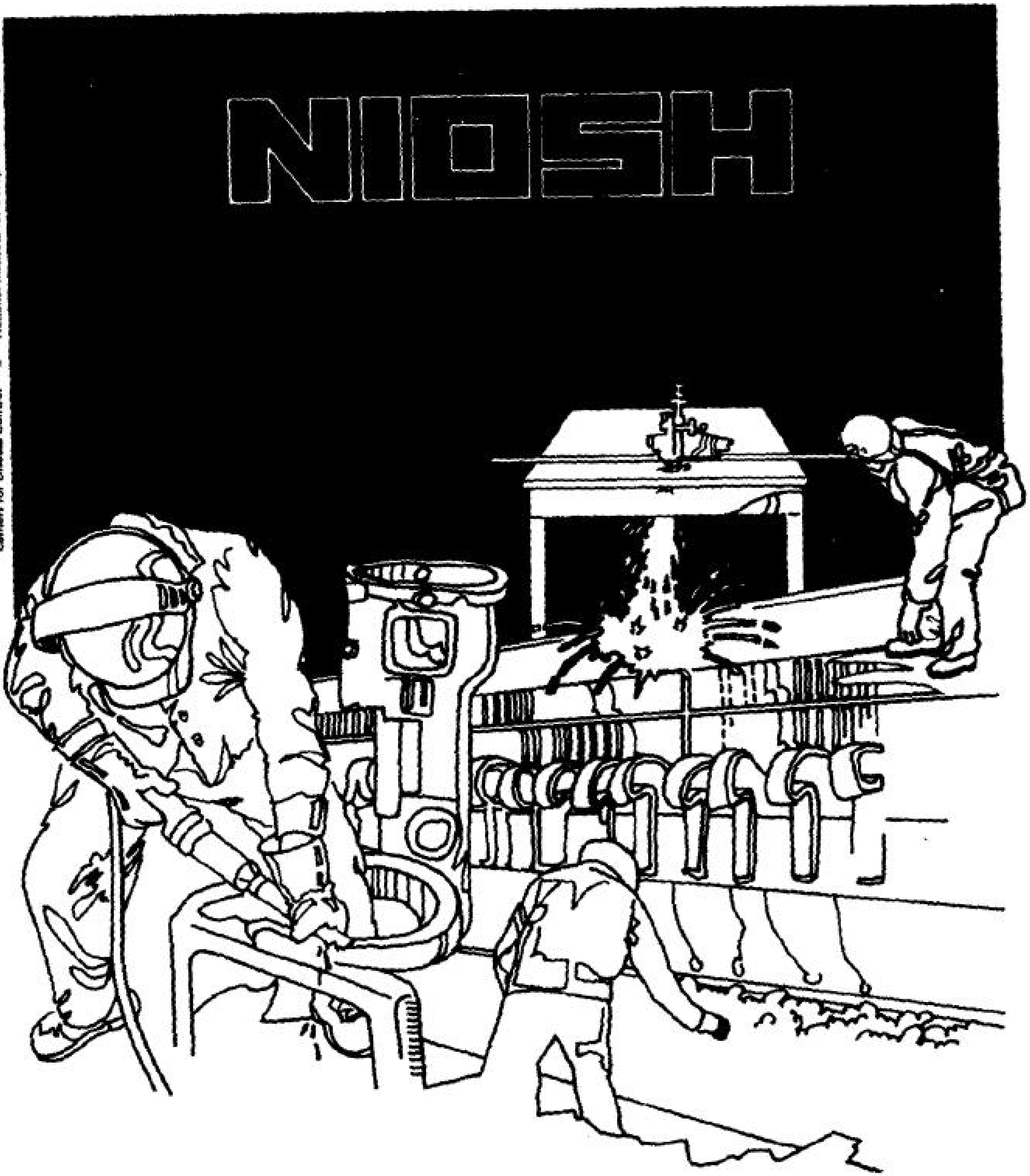

Health Hazard Evaluation Report

HETA 89-213-1992
BLUE RANGE ENGINEERING CO.
BUTTE, MONTANA

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

HETA 89-213-1992
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BLUE RANGE ENGINEERING CO.
BUTTE, MONTANA

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I. SUMMARY

On February 13, 1989, the National Institute for Occupational Safety and Health (NIOSH) received a request to evaluate employee exposures to lead at Blue Range Engineering, Butte, Montana. The company uses lead oxide to extract precious metals from mining samples in a process known as "fire assaying."

In March 1989, NIOSH investigators conducted an environmental and medical survey at the facility. Personal breathing zone (PBZ) and area air samples were collected in the fire assay laboratory to determine concentrations of airborne lead, trace metals, and crystalline silica. Selected employees completed a self-administered questionnaire, a medical and occupational history, a limited physical examination, and a blood analysis for blood lead and free erythrocyte protoporphyrin (FEP).

An 8-hour time weighted average (TWA) concentration of 170 micrograms lead per cubic meter of air (ug/M^3) was found in the PBZ sample for the assayist. This concentration is above the Occupational Safety and Health Administrations (OSHA) Permissible Exposure Limit (PEL) of 50 ug/M^3 as an 8-hour TWA. The employee was wearing respiratory protection, and therefore, the actual exposure may have been less than this value provided that the respirator was properly fitted and maintained. The results of short-term PBZ samples showed that flux dispensing contributed significantly to the employee exposure. The results of area air samples analyzed for trace metals revealed that no other metals were present in significant amounts when compared to their environmental criteria. Concentrations of respirable crystalline silica were below the limit of quantitation of 0.02 milligrams/sample.

The assay lab employees reported an increased frequency and intensity of symptoms consistent with lead poisoning compared to non-assay lab employees; however, none of these frequencies were statistically significant. The mean blood lead levels were significantly higher among the assay lab employees compared to the non-assay lab employees. One of the two assay lab workers had a blood lead level above 50 up/deciliter (dl) (the OSHA standard requires removal from the area where the employee lead exposure exceeds the action level of 30 ug/M^3).[15] The mean FEP levels were significantly higher among the assay lab employees compared to the non-assay lab employees. One of the two assay lab workers had an FEP level above 50 ug/dl (normal range <50 ug/dl).[15]

On the basis of the data collected, the investigators concluded that a potential health hazard existed at the time of this survey from employee exposure to lead in the fire assay operations at Blue Range Engineering Company. Recommendations designed to reduce exposures are included in this report.

KEY WORDS: SIC 1041 (Gold Ores), Fire Assay, Gold Assay, Lead, Blood Lead, FEP, Litharge, Ventilation

II. INTRODUCTION

On February 13, 1989, NIOSH received a request from Blue Range Engineering, Butte, Montana, to evaluate employee exposures to lead in the company's fire assay operations.

On March 15, 1989, an environmental/medical survey was conducted at the facility. The environmental survey consisted of: 1) obtaining background information on operations in the fire assay laboratory, and 2) collecting personal breathing zone and area air samples for lead, trace metals, and crystalline silica. The medical component of this study consisted of: 1) a self-administered questionnaire, 2) a medical and occupational history, 3) a limited physical examination, and 4) a blood analysis for blood lead and free erythrocyte protoporphyrin (FEP). The environmental results were provided to company representatives by letter on April 21, 1989. The blood lead and FEP results were reported to participating employees by telephone and mail on April 3, 1989.

III. BACKGROUND

A. General Description of Fire Assaying

The fire assaying process separates noble metals, such as gold and silver, from their ores using dry reagents and heat. The process can be traced back to 2600 B.C., however fire assaying is still used today due to its ability to concentrate minute amounts of precious metals from relatively large ore samples. Despite its long history, the exact chemical reactions involved in the process are not completely understood.[1]

The first step in the fire assay process is "sample preparation." During this step the various ore samples are ground, milled, and crushed to approximately 5 mesh size. The second step is "charge" preparation. "Charges" are prepared in a fireclay crucible by adding dry reagents (flux) to a finely crushed sample of the ore. The dominant reagents used in this operation are lead oxide and wheat flour. Other flux reagents include sodium carbonate, silica, borax, and potassium nitrate in varying concentrations.[1] To extract all the precious metals from each ore sample, the flux's composition needs to be "adjusted" to accommodate the ore's oxidizing, reducing, or neutral characteristics. This delicate process of "adjusting" the flux to accommodate the ore's characteristics makes assaying as much of an art as a science.

The third step is called crucible fusion. In this process approximately 24 of the "charged" fire clay crucibles are placed in a furnace. As the temperature reaches approximately 1600°F, the carbon contained in the flour reduces a portion of the lead oxide to lead droplets. These droplets then alloy with the noble metals released from the decomposed ore. The remaining litharge forms silicates and other compounds which mix with the slag produced from the ore. After 44 to 55 minutes, the crucibles are removed from the oven and the molten contents are quickly poured into iron molds. The lead droplets then settle through the slag to form a "button" at the bottom of each mold. After cooling, the slag is broken away from the molds using a small hammer, and the lead buttons containing the noble metals are collected.[1]

The third stage involves separating the noble metals from the lead in a process called "cupellation." The lead buttons obtained from the crucible fusion are hammered into squares and placed in small containers made from compressed bone ash (cupels). The cupels are reintroduced into the furnace at approximately 1500°F for 60-75 minutes. The lead button oxidizes into molten lead oxide, of which 98.5% is absorbed into the porous cupel, and 1.5% is volatilized.[1] The bone ash cupel absorbs the molten lead oxide, but is impermeable to the noble metals. Thus, when the cupels are removed from the oven, small beads of the noble metals remain in the center of each cupel. These beads are then weighed and further analyzed for their gold and silver content.[1]

B. Description of Company Operations

Blue Range Engineering Co., located in Butte, Montana, provides commercial fire assay services for determination of gold and silver content in ore samples. The assay lab analyzes an average of 72 samples per day, with the actual numbers ranging from 24 to 100 per day. On the average, two 50 pound cans of litharge are used each week. Two employees work in the fire assay laboratory: one assayist and one sample preparation employee. The assayist performs the fire assays, and works 5 eight-hour work shifts per week with occasional overtime. The sample preparation employee grinds, mills, and crushes the ore samples to be used in the assaying process. This person also works 5 eight-hour work shifts per week with occasional overtime; however, at the time of our investigation this operation was not being conducted.

The fire assay operations are conducted in a laboratory which consists of three rooms. The "furnace room" contains the furnaces used for crucible fusion and cupellation. In addition, this is the area where the ore samples are mixed with the flux and added to the crucibles. The "scale room" is where the precious metals samples are weighed following the cupellation process, and is connected to the furnace room. The scale room is attached to the main office where the other company employees are located. A maintenance shop is located directly behind the furnace room and contains the sample preparation equipment.

C. Personal Protection and Engineering Controls

Personal protective equipment worn by the assayist included a NIOSH certified half-face piece respirator with high efficiency particulate filters. The respirator was worn during the process of mixing flux and adding it to crucibles as well as when placing and removing crucibles and cupels from the furnaces. Gloves and a helmet with a face shield were also worn when working with the hot crucibles and cupels.

Smoking and eating were not allowed in the assay laboratory. Hand washing facilities were located in the lab. Dry sweeping was used during laboratory cleaning. Local exhaust ventilation present in the oven room included exhaust vents on the two furnaces, and a canopy hood on the table where the crucibles were poured into the molds.

Monitoring of the employees blood lead levels was performed through a local physician's office every six months. An environmental survey had been conducted by a private consultant; however, no written results had been received to date.

IV. MATERIALS AND METHODS

A. Environmental

On March 15, 1989, an environmental survey was conducted to determine employee exposures to lead, trace metals, and crystalline silica. During this survey, personal breathing zone (PBZ) air samples were collected near the workers' breathing zone, and general area air samples were collected at locations throughout the assay laboratory. Samples were obtained using battery-powered sampling pumps operating at 1.85 and 4.0 liters of air per minute. The pumps were attached by Tygon tubing to the collection medium (37-millimeter (mm), 0.8 micron pore size, mixed-cellulose ester membrane filters contained in 3-piece plastic cassettes). The sampling media for the personal sample collected on the assayist was replaced approximately halfway through the work-shift.

The samples were analyzed for lead by atomic absorption spectroscopy according to NIOSH method 7082.[2] In addition, two of the samples were analyzed for 30 trace metals using inductively coupled plasma - atomic emission spectroscopy in accordance with NIOSH Method 7300.[2]

Samples were also collected for crystalline silica in the area in which the ore samples were mixed with the flux. Area samples for respirable crystalline silica were collected using battery-powered pumps operating at 1.7 lpm with preweighed 37-mm, 5 micron pore size polyvinyl chloride (PVC) membrane filters contained in a 10-mm nylon cyclone. A bulk sample of the dust which was settled on a light fixture was also collected for analysis for crystalline silica content. The samples were analyzed for free crystalline silica using x-ray diffraction according to NIOSH method 7500.[2]

B. Medical

The two assay lab employees (one assayist and one sample preparation employee) and two randomly selected non-assay lab employees working in the company's adjacent room were invited to participate in the study. To allow statistical analysis, the questionnaire data from this plant was combined with the data from this company's other assay lab located in Lewistown, Montana (HETA 89-136). The assay process, the study design, and the data collection for the Lewistown assay lab was performed in the same manner. The four assay lab employees working in the Lewistown lab (two assayists and two sample preparation employees) and three randomly selected non-assay lab employees working in the adjacent building were invited to participate in the study. The study consisted of: 1) a medical and occupational history, 2) a limited physical examination, 3) a blood sample analyzed for lead and free erythrocyte protoporphyrin (FEP), and 4) a self-administered questionnaire. The questionnaire was designed to gather demographic information and symptoms associated with lead poisoning. Each of the 20 symptom questions was scored on a 4-point scale: "not at all" (score = 1), "a little" (score = 2), "moderately" (score = 3), and "quite a lot" (score = 4). Four symptoms were combined into one of five symptom clusters: constitutional, cognitive, gastrointestinal (GI), emotional, and peripheral nervous system (PNS) (Table 2). Cluster scores could range from 4 to 16, reflecting the frequency and intensity of the individual's symptoms within that cluster. Mean symptom cluster scores were calculated for the assay lab employees and the non-assay lab employees. We defined a case of symptomatic lead poisoning as any symptom cluster with a score of 8 or more, and analyzed the prevalence of cases between the assay lab employees and the non-assay lab employees.

Statistical analyses were performed using EPIINFO and SPSS/PC.[3,4] The mean symptom cluster scores were analyzed using parametric (student's t-test) and non-parametric (Kruskal-Wallis) statistical procedures. Only the parametric results are reported unless there was discrepancy between the two tests rendering an association "statisically significant" in which cases we report both results. Statistical significance was defined as p less than 0.05.

The blood leads and FEPs were analyzed in one of the OSHA-CDC (Occupational Safety and Health Administration-Centers for Disease Control) approved laboratories for blood lead analysis based on proficiency testing.[5] The blood leads were determined utilizing anodic stripping voltimmetry, and FEPs were determined by photofluormetric techniques.[6]

The medical and occupational history, and limited physical examination was performed by a NIOSH physician trained in internal and occupational medicine. The limited physical examination consisted an inspection of the employee's gums for signs of lead exposure (Burtonian lead line)[7].

V. EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week, for a working lifetime, without experiencing adverse health effects. It is important, however, to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a preexisting medical condition, and/or a hypersensitivity (allergy).

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the evaluation criterion. These combined effects often are not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes and, thus, potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent becomes available.

The primary sources of environmental evaluation criteria for the workplace are: 1) NIOSH Criteria Documents and recommendations, 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs), and 3) the U.S. Department of Labor/Occupational Safety and Health Administration (OSHA) occupational health standards [Permissible Exposure Limits (PELs)]. Often, the NIOSH recommendations and ACGIH TLVs are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLVs usually are based on more recent information than are the OSHA standards. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that the company is required by the Occupational Safety and Health Administration to meet those levels specified in an OSHA standard.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday.

A brief discussion of the toxicity and evaluation criteria for inorganic lead and crystalline silica is presented as follows.

A. Inorganic Lead

1. Toxicological

Inhalation (breathing) of lead dust and fume is the major route of lead exposure in the industrial setting. A secondary source of exposure may be from ingestion (swallowing) of lead dust deposited on food, cigarettes, or other objects. Once absorbed, lead is excreted from the body very slowly. Absorbed lead can damage the kidneys, peripheral and central nervous systems, and blood forming organs (bone marrow). These effects may be felt as weakness, tiredness, irritability, digestive disturbances, high blood pressure, kidney damage, mental deficiency, or slowed reaction times. Chronic lead exposure is associated with infertility and with fetal damage in pregnant women. There is some evidence that lead can also impair fertility in occupationally exposed men.[8] A summary of the lowest observable effect levels of lead in adults are listed in Table 3.

The blood lead test is one measure of the amount of lead in the body and is the best available measure of recent lead absorption. Adults not exposed to lead at work usually have a blood lead concentration less than 30 ug/dl; the average is less than 15 ug/dl.[9,10] In 1985, the Centers for Disease Control (CDC) recommended 25 ug/dl as the highest acceptable blood level for young children.[11] Since the blood lead concentration of a fetus is similar to that of its mother, and since the fetus's brain is presumed to be at least as sensitive to the effect of lead as a child's, the CDC advised that a pregnant woman's blood lead level be below 25 ug/dl.[11] Recent evidence suggests that the fetus may be adversely affected at blood lead concentrations well below 25 ug/dl.[12] Furthermore, there is evidence to suggest that levels as low as 10.4 ug/dl affect the performance of children on educational attainment tests, and that there is a dose-response relationship with no evidence of threshold or safe level.[13] Lead levels between 40-60 ug/dl in lead-exposed workers indicate excessive absorption of lead and may result in some adverse health effects. Levels of 60-100 ug/dl represent unacceptable elevations which may cause serious adverse health effects. Levels over 100 ug/dl are dangerous and require medical treatment.

Free erythrocyte protoporphyrin (FEP) levels measure the effect of lead on heme synthetase, the last enzyme in heme synthesis. FEP levels increase abruptly when blood lead levels reach about 40 ug/dl, and they tend to stay elevated for several months. A normal FEP level is less than 50 ug/dl.[14]

2. Occupational Exposure Criteria

The current OSHA PEL for airborne lead is 50 ug/m^3 calculated as an 8-hour TWA for daily exposure.[15] In addition, the OSHA lead standard establishes an "action level" of 30 ug/m^3 TWA which initiates several requirements of the standard, including periodic exposure monitoring, medical surveillance, and training and education. For example, if an employer's initial determination shows that any employee may be exposed to over 30 ug/m^3, air monitoring must be performed every six months until the results show two consecutive levels of less than 30 ug/m^3 (measured at least seven days apart). The standard also dictates that workers with blood lead levels greater than 50 ug/dl must be removed from further lead exposure. The affected employee must be removed from further lead exposure until the blood lead concentration is at or below 40 ug/dl. Removed workers have protection for wage, benefits, and seniority for up to 18 months until their blood levels decline to below 40 ug/dl and they can return to lead exposure areas.[15]

B. Crystalline Silica

Crystalline silica or quartz dust causes silicosis, a form of disabling, progressive, and sometimes fatal pulmonary fibrosis characterized by the presence of typical nodulation in the lungs. The earliest lesions are seen in the respiratory bronchioles.

Symptoms of silicosis include cough, dyspnea, wheezing and repeated nonspecific chest illnesses.[16]

The NIOSH REL for crystalline silica is 50 ug/M^3 for respirable free silica. The OSHA PEL and the ACGIH TLV are 100 ug/M^3 for respirable quartz.

VI. RESULTS AND DISCUSSION

A. Air Samples

The results of the environmental survey are contained in Table 1. As evidenced by these data, an 8-hour TWA concentration of 170 ug/M^3 was found in the PBZ samples collected for the assayist. This concentration is above the OSHA PEL of 50 ug/M^3 as an 8-hour TWA. It should be noted that this employee was wearing respiratory protection during the handling of litharge, crucibles, and cupels. Provided the respirator was properly fitted and maintained, the actual exposure would be expected to be substantially lower than the measured values.

Table 1 also contains the results of short-term PBZ samples which were collected to define exposures which occurred during specific tasks in the fire assay process. The highest concentration (12,000 ug/M^3) was found in a 2.5 minute personal sample collected during the dispensing of flux into the crucibles, an activity which was carried out without the use of local exhaust ventilation. This process was carried out in the vicinity of the cupel oven, and may help explain the higher reading obtained in that area sample. Two other short-term samples which were obtained during the unloading of crucibles from the furnace and pouring into the molds were found to be below the LOQ of 8.5 ug/filter. This operation was carried out under a local exhaust ventilation hood. It should be noted that these sample concentrations are calculated for short-term durations of exposure, and as such, should not be compared to evaluation criterion based on 8-hour TWAs.

Table 1 also shows the results of area air samples collected in each of the rooms comprising the facility. As evidenced by these data, the highest TWA concentration of lead was found in the furnace room by the cupel oven (170 ug/M^3), and the ore mixing table (40 ug/M^3). A sample collected in the adjacent scale room was below the limit of quantitation (LOQ) of 8.5 (ug), and the sample collected in the office area was less than the limit of detection (LOD) of 3.0 micrograms per filter. It should be noted that the air samples discussed in this paragraph are "general area" air samples, and as such, do not relate directly to the OSHA standards which address "personal" exposures. However, these data do provide useful information in assessing the relative degree of airborne lead exposure which would be present in each of the work areas.

Two area air samples collected in the furnace room, one located next to the crucible oven and the second located on the cupel cooling table, were analyzed for trace metal content. The results of the analysis revealed the primary metallic component on the filter to be lead. In addition, trace quantities of iron, manganese, magnesium, and tin were found. However, the concentrations of these contaminants were far below their respective evaluation criteria.

A concentration of 9.8% quartz was found in the bulk sample of the settled dust collected in the area where the ore samples were added to the crucibles. Analysis of the general area air samples revealed the concentration of respirable quartz to be below the limit of quantitation of 0.02 milligrams per sample.

B. Medical

All four selected employees of the Butte lab and seven selected employees of the Lewistown lab participated in the study. These 11 employees were composed of 6 assay lab employees, and 5 non-assay lab employees. No statistically significant differences were found for age, sex, and race between assay and non-assay lab employees (Table 4).

The assay lab employees reported an increased mean score of constitutional, cognitive, emotional, and peripheral nervous system symptom complexes compared to the non-assay lab employees; however, none of these were statistically significant (Table 5).

Two of the six (33%) assay lab employees satisfied our case definition for symptomatic lead poisoning. Two of the six (33%) assay lab employees (one assayist and one sample preparation employee) satisfied our case definition for symptomatic lead poisoning (any symptom cluster score of 8 or more). The Lewistown assayist had a constitutional symptom cluster score of 8 and a blood lead level of 50 ug/dl, while the Butte sample preparation employee had a cognitive symptom cluster score of 12 and a blood lead level of 65 ug/dl. None of the non-assay lab employees met our case definition and none had a blood lead level over 36 ug/dl.

The mean blood lead levels were significantly higher among the assay lab employees compared to the non-assay lab employees (Table 6). Three of the six (50%) of the assay lab workers were above 40 ug/dl (the OSHA standard for monitoring the blood lead every 2 months) and two of the six (33%) of the assay lab workers were above 50 ug/dl (the OSHA standard for removal from the area where the lead exceeds the action level (30 ug/M^3).[15] None of the five non-assay lab employees were above 40 ug/dl.

The mean FEP levels were significantly higher among the assay lab employees compared to the non-assay lab employees (Table 6). Three of the six assay lab workers (50%) were above the normal range (<50 ug/dl), while none of the five non-assay lab employees were above the normal range.

None of the 11 employees had signs of lead exposure on their gums (Burtonian lead line).

C. Personal Protection, Hygiene, and General Housekeeping

Based on observations and information obtained during the course of the survey, several shortcoming were identified related to respirator use, housekeeping, and hygiene. Examples included the lack of a written respiratory protection program. A most obvious deficiency of the program was the use of a negative pressure respirator by an employee who had a full beard. Facial hair that lies along the sealing area of the respirator will interfere with the seal and allow contaminated air to enter the respirator. Therefore, employees with beards should not be permitted to wear respirators in a contaminated work area.[17] The assayist was not wearing coveralls or protective clothing. In addition, the employee did not shower or change clothes at the end of the work shift. Such circumstances provide a potential for lead to be spread to other areas of the workplace or the home where secondary lead exposure can occur. It was noted that the assayist stored his coat in the lab area, which would further contribute to this potential problem. In order to avoid the spread of lead to other parts of the facility and to employees' homes, street clothing should not be permitted in lead-contaminated areas.

VII. CONCLUSIONS

The environmental survey revealed lead exposures above the OSHA PEL for the assayist. The medical study revealed one assayist having constitutional symptoms consistent with lead poisoning, and a blood lead level of 50 ug/dl. A substantial portion of the exposure occurred during the flux dispensing operation which did not have local exhaust ventilation. At the time of the survey, recommendations were made to add ventilation to this operations. In addition, although it was not carried out during the survey, the flux mixing operation appeared to be another area where a potential for high lead exposures could take place. In both these areas, the addition of local exhaust ventilation could substantially reduce employee exposures.

Although levels of crystalline silica were not above the evaluation criteria in the furnace room where the ore samples were handled, the activities carried out in the adjacent sample preparation area would be expected to generate higher dust levels. Since this operation was not being carried out at the time of this survey, no assessment of exposures could be made. However, due to the presence of a substantial amount of crystalline silica in the dust sample which was analyzed (approximately 10%), monitoring should be conducted to ensure exposures are properly controlled in this area.

The medical study revealed one Lewistown assayist having constitutional symptoms consistent with lead poisoning and a blood lead level of 50 ug/dl, and one Butte sample preparation employee having cognitive symptoms consistent with lead poisoning and a blood lead level of 65 ug/dl.

VIII. RECOMMENDATIONS

To ensure that workers are adequately protected from the adverse effects of lead, a comprehensive program of surveillance and prevention is needed. The guidelines for such a program are clearly presented in the OSHA lead standard.[15] In addition to specifying PELs for airborne exposure, the OSHA lead standard also contains specific provisions dealing with mechanical ventilation, respirator usage, protective clothing, housekeeping, hygiene facilities, employee training, and medical monitoring.[15] The implementation of the provisions of this standard will help to ensure that the employees are protected against any potential adverse health effects of lead exposure.

A copy of the OSHA lead standard was provided to the employer and will not be repeated in detail in this report. However, to assist the employer in implementing the standard's key provisions, a brief overview of these provisions as they relate to the findings of this survey follow.

A. Mechanical Ventilation

The short-term samples identified the flux dispensing operation as contributing significantly to the airborne lead concentrations. Installation of local exhaust ventilation for this operation should greatly reduce the lead exposure to the assayist. A slot exhaust hood with side enclosures would be one form of exhaust hood which might be suitable for this operation. The ACGIH recommends that capture velocities for substances released at low velocity into moderately still air be at least 100 to 200 fpm, and that the upper end of this range be used for contaminants of high toxicity (e.g., lead).[17] Additional design specifications for exhaust hoods are contained in Appendix 1.

Improvement in capture efficiency of the hood used for crucible cooling could be gained through the use of side and back enclosure panels. This would reduce the required amount of air for the capture of the air contaminants and improve the efficiency of this hood.

Periodic testing of all local exhaust ventilation systems is necessary to ensure their continued efficiency. Such systems should be tested every three months, or following any major modification.[15] A complete discussion of specific details regarding ventilation system testing, as well as information regarding the design, construction, and operation of local exhaust ventilation systems, is contained in the ACGIH Industrial Ventilation, A Manual of Recommended Practice.[17]

B. Air Monitoring

Despite the presence of engineering controls, periodic monitoring for airborne lead is needed to ensure that these controls operate effectively. Air monitoring can also be used to pinpoint the need for further employee protection (i.e., respirators) in certain areas or during certain procedures. When airborne exposures are found to be above the OSHA action level of 30 ug/M^3, as was the case in this survey, the standard calls for repeat monitoring every six months. This monitoring should be continued until such time as concentrations are found to be below this level in two consecutive measurements conducted at least one week apart.[15] Employees should be informed of the monitoring results.

C. Respiratory Protection

Due to their inherent limitations, respirators should not be considered a primary means of employee protection. A more appropriate means of exposure control in this instance would be properly designed engineering controls; i.e., local exhaust ventilation. However, the use of respiratory protection is a suitable means of exposure control in the event that engineering controls can not feasibly reduce the exposure levels. Respirators may also be used as a backup to existing engineering controls when substances of high toxicity are present. In order to ensure the effective use and function of the respirators, a comprehensive respiratory protection plan should be put in place. Such a program is outlined by the American National Standard Institute in the ANSI Standard Z88.6-1984.[18] The program should include a written standard operating procedure which addresses respirator selection, training, fitting, testing, inspection, cleaning, maintenance, storage, and medical examinations. A detailed discussion of these key program elements is provided in the NIOSH Guide to Industrial Respiratory Protection, a copy of which has been provided to the employer.[19]

Assuming proper maintenance and fitting, the respirators worn by the employees during the survey should have significantly reduced their actual exposures. However, the effectiveness of the respirator on an employee with a beard is questionable. In lieu of removal of the beard, a powered air-purifying respirator with a loose fitting hood or helmet might provide an alternative form of respiratory protection, which would provide an adequate protection factor at these exposure levels.[18]

D. Personal Protective Clothing

Wherever lead dust is present, there is a possibility that the employee's skin and clothing may become contaminated. This can lead to subsequent inhalation or ingestion of the lead, which can substantially increase the employee's overall absorption of lead. In addition, lead contamination on skin or clothing may be transported to other areas of the facility, and possibly to the worker's homes where secondary exposure of co-workers or family members can occur. In one recent study, blood lead levels were found to be markedly higher in household members residing in homes of workers with occupational lead exposure compared to members of homes of people not occupationally exposed to lead.[20] In order to prevent this secondary source of lead exposure, the appropriate use of personal protective clothing is required.

E. Hygiene Facilities and Practices

A separate change room, free from lead contamination, should be provided to the employees to store their "street" clothing. Street clothing should be stored separately from clothing worn during work. If available, showers should be taken at the completion of the work shift to remove any lead that may have reached the employee's skin. Clothing worn at work, should not be worn home. Employees should carry necessary personal clothing and shoes home separately, and clean them carefully so as not to contaminate the home.[15]

Food, beverages, or tobacco should not be used or stored in lead contaminated areas. These items can become contaminated with lead and cause subsequent absorption of lead through ingestion or inhalation during eating, drinking, or smoking. Employees should also continue to eat their lunch in a lunchroom separate from the assay lab. All protective clothing should be removed prior to entering the lunchroom, and hands and face should be thoroughly washed.

F. Housekeeping

Housekeeping plays an important role in controlling lead exposures. Dust which has accumulated on surfaces can be reintroduced into the air thereby increasing airborne lead exposures. Also, dust accumulated on chairs or work surfaces can cause unnecessary contamination of the employees protective clothing. Therefore, all surfaces in the assay lab should be kept as free as practicable of the accumulation of lead dust. Vacuuming is the preferred means of removing lead dust. Dry or wet sweeping should not be used except in areas where vacuuming is not feasible. A regular housekeeping program should be established to ensure that all areas are periodically cleaned.

G. Medical Monitoring

While the previously discussed NIOSH recommendations have been aimed at preventing or minimizing lead exposure, NIOSH believes that medical monitoring plays a supplemental role in that it ensures that the other provisions of the program have effectively protected the individual. The OSHA standard for inorganic lead places significant emphasis on the medical surveillance of all workers exposed to levels of inorganic lead above the action level of 30 ug/M^3 TWA. Even with adequate worker education on the adverse health effects of lead and appropriate training in work practices, personal hygiene and other control measures, the physician has a primary responsibility for evaluating potential lead toxicity in the worker. It is only through a careful and detailed medical and work history, physical examinations to rule out other potential causes of symptoms, and appropriate laboratory testing that an accurate assessment can be made. Many of the adverse health effects of lead toxicity are either irreversible or only partially reversible and therefore early detection of disease is very important.[15]

The OSHA lead standard provides detailed guidelines on the frequency of medical monitoring, the important elements in medical histories and physical examinations as they relate to lead, and the appropriate laboratory testing for evaluating lead exposure and toxicity. This standard should be consulted by plant management and the local physician for guidance in carrying out an ongoing medical monitoring program.[15]

In summary, a comprehensive program is necessary for controlling lead exposures during the assay operations. While the company has put into place several key elements of an exposure prevention program, ongoing attention is needed in all of the areas previously discussed in order to effectively reduce the risk of adverse health effects.

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XI. DISTRIBUTION AND AVAILABILITY OF DETERMINATION REPORT

Copies of this Determination Report are currently available upon request from NIOSH, Hazard Evaluations and Technical Assistance Branch, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days the report will be available through the National Technical Information Services (NTIS), 5285 Port Royal Road, Springfield, Virginia 22161. Information regarding its availability through NTIS can be obtained from the NIOSH publications office at the Cincinnati, address. Copies of this report have been sent to:

A. Blue Range Engineering, Butte, Montana
B. Occupational Safety and Health Administration - Region VIII
C. Montana Department of Health
D. NIOSH Regional Offices/Divisions

For the purposes of informing the affected employees, copies of the report should be posted in a prominent place accessible to the employees, for a period of 30 calendar days.

TABLE 1

RESULTS OF ENVIRONMENTAL SAMPLES COLLECTED FOR
AIRBORNE INORGANIC LEAD DURING FIRE ASSAY OPERATIONS
Blue Range Engineering Co., Butte, Montana

SAMPLE TYPE	SAMPLE DESCRIPTION	MINUTES SAMPLED	LITERS SAMPLED	TWA CONCENTRATION LEAD (ug/M3)
Long-Term Samples				
Personal	Assayist - Morning	136	252	300
	Assayist - Afternoon	292	540	140
	(Cumulative 8-hour TWA Exposure)			170*
Area	Furnace Room On sample preparation table	396	733	40
Area	Furnace Room Near cupel oven	401	742	170
Area	Lab/Scale Room Above weighing scale	395	731	< LOQ (8.2)
Area	Administrative Office On shelf inside doorway	389	720	< LOD
Short-term Samples				
Personal	Assayist - Short-Term (Removing crucibles and pouring into molds)	18	68	< LOQ (74)
Personal	Assayist - Short-Term (Removing crucibles and pouring into molds)	14	53	< LOQ (110)
Personal	Assayist - Short-Term (Dispensing flux - no local exhaust ventilation)	2.5	9.5	12,000

Evaluation Criteria - Inorganic Lead - OSHA - 50 ug/M^3, 8-hour TWA

Abbreviations and Key
TWA - Time-weighted average
ug/M^3 - micrograms per cubic meter of air
< LOD - less than the limit of detection of 3.0 micrograms/ filter
< LOQ - less than the limit of quantitation of 8.5 micrograms/filter. (Values in parenthesis are estimates of the actual concentration.)
* - Indicates a calculated 8-hour TWA with "zero" exposure assumed for the remainder of the work shift. All other values are expressed as TWAs for the period of sample collection.

Table 2

List of Symptoms Comprising the Five Symptom Clusters
Blue Range Engineering Co., Butte, MT

CONSTITUTIONAL	COGNITIVE
Tired	Trouble remembering things
Weak	Difficulty concentrating
Headaches	Make notes to remember things
Dizzy	Confused

GASTROINTESTINAL	EMOTIONAL
Decreased Appetite	Depressed
Diarrhea	Irritable
Nausea	Excitable
Indigestion	Changing Moods

PERIPHERAL NERVOUS SYSTEM
Decrease in upper extremity strength
Decrease in lower extremity strength
Upper extremity paresthesias
Lower extremity paresthesias

TABLE 3

Lowest Blood Lead Levels Reported To Cause Health Effects In Adults

Blood Lead Level	Health Effect
100-120 ug/dl	Cental Nervous System Toxicity (Encephalopathy)
100 ug/dl	Chronic Renal Damage
80 ug/dl	Low Blood Count (Anemia)
60 ug/dl	Pregnancy Complications
50 ug/dl	Decrease Hemoglobin Production Mild Central Nervous System symptoms
40 ug/dl	Decrease Peripheral Nerve Conduction Pre-term Delivery
30 ug/dl	High Blood Pressure

Table 4

Demographic Characteristics by Assay Lab Employment
Blue Range Engineering Co., Butte, MT
Blue Range Mining Co., Lewistown, MT

	Assay Lab Employees N=6 # (%)	Non-Assay Lab Employees N=5 # (%)	Significance
Sex (female)	2 (33%)	3 (60%)	p = 0.39*
Race (White)	6 (100%)	5 (100%)	p = Undefined*
Age (mean)	37 yrs	41 yrs	p = 0.68**

* - p-values were calculated using 1-tailed Fisher's exact test.
** - p-values were calculated using a student's t-test for a parametric distribution.

Table 5

Mean Symptom Cluster Scores by Assay Lab Employment[1]
Blue Range Engineering Co., Butte, MT
Blue Range Mining Co., Lewistown, MT

	Assay Lab Employees N=6	Non-Assay Lab Employees N=5	Significance[2]
Constitutional	5.83	4.60	p = 0.08
Cognitive	6.50	5.40	p = 0.51
GI	4.33	4.60	p = 0.56
Emotional	5.83	4.80	p = 0.13
PNS	5.00	4.00	p = 0.11

1 - Definition of Symptom Cluster Score located in Methods Section.
2 - p-values were calculated using a student's t-test for a parametric distribution.

Table 6

Blood Lead Levels and FEPs by Assay Lab Employment[1]
Blue Range Engineering Co., Butte, MT
Blue Range Mining Co., Lewistown, MT

	Assay Lab Employees N=6			Non-Assay Lab Employees N=5			Significance[2]
	mean	median	(range)	mean	median	(range)	
Blood Lead (ug/dl)	42	40	(23-65)	18	14	(7-36)	p = 0.017*
FEP (ug/dl)	40	41	(20-68)	19	20	(15-24)	p= 0.046* p= 0.065**

1 - FEPs = Free Erythrocyte Protoporphyrin
2 - Comparing the mean blood lead and FEP among the assay lab employees to the non-assay lab employees
* - p-value calculated using the student's t test for parametric distributions.
**- p-value calculated using the Kruskal-Wallis one-way analysis of variance for non-parametric distributions.

APPENDIX I

RECOMMENDED SHEET METAL SPECIFICATIONS FOR LOCAL EXHAUST VENTILATION SYSTEMS[21]

1. Ducts should be made of galvanized sheet steel of the following thicknesses:

   3" to 12" diameter ---------------------24 gauge
   13" to 18" diameter ---------------------22 gauge
   19" to 28" diameter ---------------------20 gauge
   29" to 36" diameter ---------------------18 gauge

2. Ducts should be constructed so that they are leaktight with soldered or tapered joints.

3. All lap joints should be constructed so the the outlet of one length of pipe enters the inlet of the next in the direction of air flow.

4. Hoods should be made of metal at least two gauges heavier than the pipes to which they are connected.

5. 90° elbows should have a centerline radius that is two times the diameter of the pipes joined.

6. 90° elbows six inches or less in diameter should be made of five pieces. Elbows of larger diameter should be made of seven pieces. Angles different than 90° should be made of proportionate numbers of pieces. They should be made of sheet metal that is two gauges heavier than the straight pipes.

7. Every branch pipe should be connected to the main pipe at an angle of 45°.

8. Main pipes should be sized so as to be at least equal in area to all the branch pipes connected to them.