

IN-DEPTH SURVEY REPORT
CONTROL TECHNOLOGY FOR MINE ASSAY LABORATORIES

AT

Pinson Mine
Winnemucca, Nevada

REPORT WRITTEN BY
John W Sheehy
Ronald M Hall

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U S DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health
Division of Physical Sciences and Engineering
4676 Columbia Parkway - R5
Cincinnati, Ohio 45226

PLANT SURVEYED Pinson Mine
P O Box 129
Winnemucca, Nevada 89445

SIC CODE 8734

SURVEY DATE March 9-11, 1993

SURVEY CONDUCTED BY John Sheehy
Ronald Hall
Don Murdock

EMPLOYER REPRESENTATIVES CONTACTED Keith Belingheri, General Manager
Ralph Erquiaga, Lab Supervisor
James Frei

EMPLOYEE REPRESENTATIVES CONTACTED No Union

MANUSCRIPT PREPARED BY Debra A Lipps

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INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH), a Federal agency located in the Centers for Disease Control and Prevention under the Department of Health and Human Services, was established by the Occupational Safety and Health Act of 1970. This legislation mandated NIOSH to conduct research and education programs separate from the standard setting and enforcement functions conducted by the Occupational Safety and Health Administration (OSHA) in the Department of Labor. An important area of NIOSH research deals with methods for controlling occupational exposure to potential chemical and physical hazards.

The Engineering Control Technology Branch (ECTB) of the Division of Physical Sciences and Engineering has been given the lead within NIOSH to study and develop engineering controls and assess their impact on reducing occupational illness. Since 1976, ECTB has conducted a large number of studies to evaluate engineering control technology based upon industry, process, or control technique. The objective of each of these studies has been to document and evaluate control techniques and to determine their effectiveness in reducing potential health hazards in an industry or at specific processes.

This study of mine assay laboratories is being undertaken by ECTB to provide control technology information for preventing occupational disease in this industry. This project is part of a NIOSH special initiative on small business and will be accomplished by developing and evaluating control strategies and disseminating control technology information to assay laboratories, nationwide.

The goal of this research study is to identify, evaluate, and disseminate practical and cost effective control methods which reduce exposures to arsenic, cobalt, lead, mercury, and respirable crystalline silica to below their respective NIOSH-recommended exposure limits (RELs) and OSHA/MSHA permissible exposure limits (PELs) for workers in mine assay laboratories. The study will be accomplished by identifying and evaluating existing control methods used in mine assay laboratories. The results of these field evaluations will be presented in in-depth survey reports for each laboratory. These reports will be summarized in a scientific journal article, trade journal articles, and in handbooks which will be disseminated to the workers, owners, and operators of mine assay laboratories, to the OSHA/MSHA consultation program, and to other safety and health professionals.

As part of this overall study, an in-depth survey was conducted at the mine assay laboratory located on the Pinson Mines site. The purpose of this survey was to evaluate and document potentially effective control systems including work practices.

PLANT AND PROCESS DESCRIPTION

Pinson Mine is a gold and silver mining operation. The entire mining operation employs 110 workers. A total of ten workers are employed in the assay laboratory operation on two shifts. Day shift is seven days per week and swing-shift is five days per week. The assay laboratory performs

approximately 10,000 determinations per month. Of these, 2,500 to 3,000 are fire assay analysis. Samples analyzed in the mine assay laboratory are obtained from exploration holes and blast holes as well as from the mineral ore recovery processes. Exploration samples are taken at 5-foot intervals down to a depth of 500 feet. Rayrock Yellow Knife is the operating company for the Pinson Mine site. The mine assay laboratory is located at 4900 feet above sea level. Outdoor temperatures at the mine site range from -40°F to 100°F during the year.

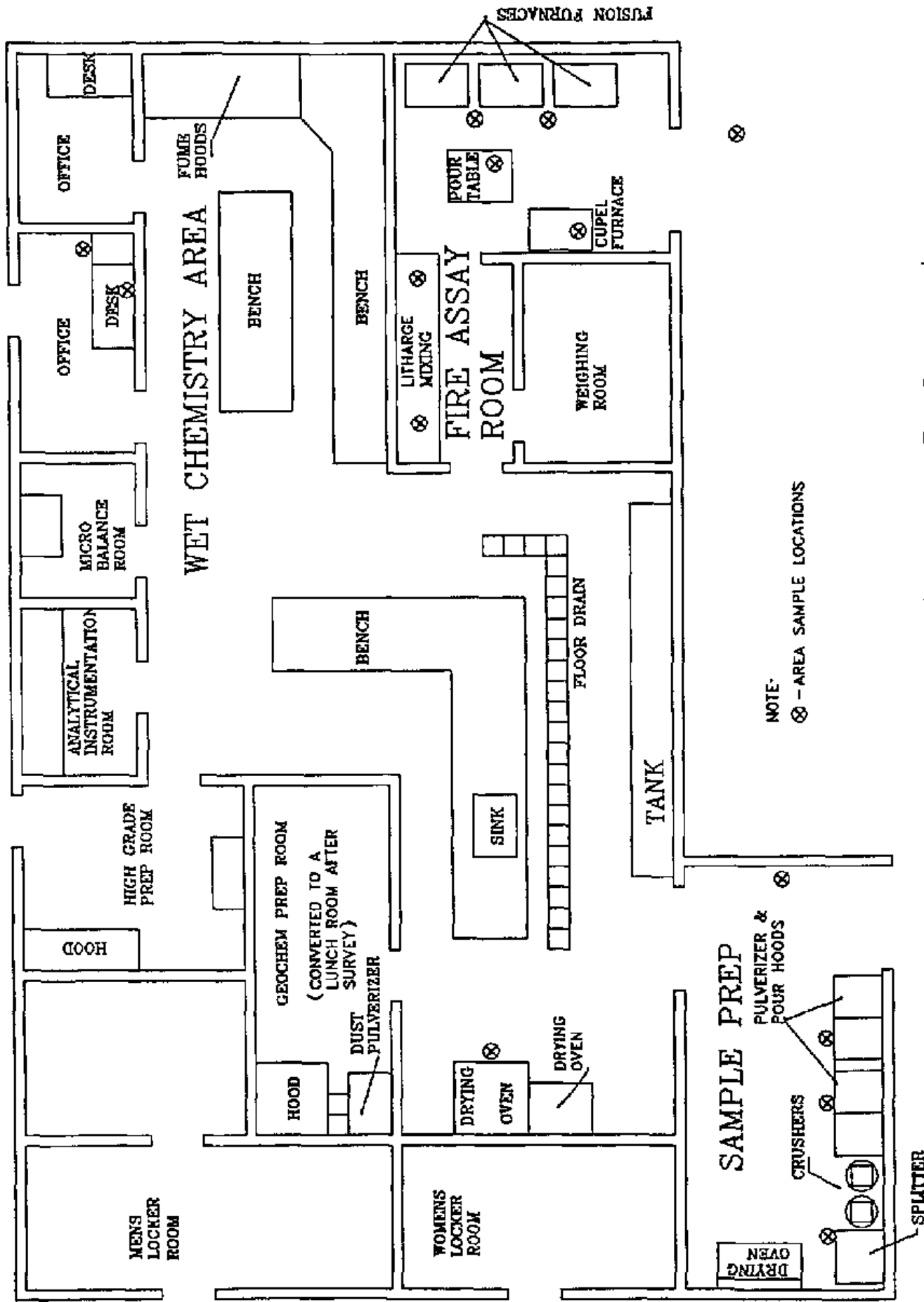
PROCESS DESCRIPTION

Rock, ore, dirt, and core samples are brought to the sample receiving area of the assay laboratory in individual bags weighing 5 to 10 pounds. Samples that are too wet are dried in an oven operated at 350 degrees Fahrenheit (°F). In the sample prep operation (see Figure 1), samples are crushed, split, and pulverized. Samples are crushed in either a jaw crusher or a cone crusher and then ground to 85 percent less than 200 mesh size in one of two identical pulverizers. This crushed material is then poured into envelopes. Each sample from the pulverizer weighs 200 grams.

The sample splitter is located in an enclosed ventilated hood with an exhaust opening in the back of the hood and a downdraft opening located near the splitter. Each pulverizer is located in a ventilated hood with a glass door. There is a 4-inch high opening between the sash of the glass door and the table to allow supply air into the hood. To prevent cross contamination between assay samples, the pulverizer is cleaned off with compressed air after each sample is ground. Fixed nozzle compressed air jets for cleaning the pulverizer are located in the hood above the pulverizer. Next to each pulverizer hood is another ventilated hood where the crushed samples are poured into envelopes. Using a compressed air gun, the worker cleans off the table after each sample is poured. The worker spends about one hour per shift at the splitter and half the shift at the pulverizer. The current sample preparation operation was installed in 1986.

Three 200- to 300-pound mill feed samples are brought to the assay laboratory for analysis each day. These samples, contained in 55-gallon drums, are fed by overhead cranes to a crusher and a large sample splitter. This operation is performed outside because of the bulk of the samples. The moisture content of the dust is generally sufficient to minimize dust levels. Several slurry samples from the mill stream also are analyzed. These samples, containing 30 to 40 percent solids (60 to 70 percent moisture), are separated in a filter press, which is located inside the laboratory, and the liquid and solid portions are analyzed separately.

The samples are then mixed with lead oxide, borax, flour, silica sand, and soda ash in a process called fluxing. Mixing is done by hand or with an automated mixer. In the fire assay room, the fluxed samples are placed into an oven that operates at a temperature of approximately 2000°F. The carbon contained in the flour reduces part of the lead oxide to lead which combines with the precious metals released from the ore⁽¹⁾. The samples are then removed from the oven and the lead is separated from the slag by pouring the samples into metal cone molds. A lead button is formed in the bottom of the



NOTE:
 ⊗ - AREA SAMPLE LOCATIONS

Layout Of Mine Assay Laboratory

Figure 1

metal cone After cooling, the material in the metal cone is removed and the worker breaks excess slag away which frees up the lead button

The lead buttons, which contain the precious metals, are placed into a bone ash or magnesium oxide cupel The cupel is placed in another oven where the different melting points of lead and the precious metals are exploited for extraction of the metals The lead is absorbed by the cupel, leaving the precious metals at the bottom of the cupel Sometimes, controlled amounts of silver are added to the samples in order to obtain a visual amount of precious metals in the bottom of the cupel The remaining material is taken to the balance room and weighed to determine the amount of precious metal Pinson has three gas-fired fusion furnaces, each with a ventilated hood, and one electric cupellation furnace with an exhaust hood in the fire assay room The laboratory also has a process room called the high grade prep area This room contains a pulverizer and is used only a few times per month

Alternate recovery techniques involve wet chemistry with acidic or cyanide digestion These procedures are performed in the wet chemistry laboratory

POTENTIAL HEALTH HAZARDS AND EVALUATION CRITERIA

POTENTIAL HAZARDS

Workers in this mine assay laboratory are potentially exposed to lead, crystalline silica, respirable dust, mercury, and arsenic Because mining is presently done in an oxide pit, arsenic and mercury exposures are generally low Oxide ore bodies tend to be low in arsenic and mercury while refractory ore bodies can be much higher in these metals

Lead

Lead adversely affects a number of organs and systems The four major target organs and systems are the central nervous system, the peripheral nervous system, kidney, and hematopoietic (blood-forming) system ⁽²⁾ Inhalation or ingestion of inorganic lead can cause a range of symptoms and signs including loss of appetite, metallic taste in the mouth, constipation, nausea, colic, pallor, a blue line on the gums, malaise, weakness, insomnia, headache, irritability, muscle and joint pains, fine tremors, and encephalopathy Lead exposure can result in a weakness in the muscles known as "wrist drop," anemia (due to shorter red blood cell life and interference with the heme synthesis), proximal kidney tubule damage, and chronic kidney disease ⁽³⁻⁴⁾ Lead exposure is associated with fetal damage in pregnant women ⁽²⁻⁴⁾ Finally, elevated blood pressure has been positively related to blood lead levels ⁽⁵⁻⁶⁾

Crystalline Silica

Crystalline silica causes silicosis, a form of disabling, progressive, and sometimes fatal pulmonary fibrosis characterized by the presence of typical nodulation in the lungs or chest x-ray ⁽⁴⁾ Historically, many silicotic workers had tuberculosis In some mines, up to 60 percent of the workers with silicosis had tuberculosis ⁽⁷⁾ Evidence indicates that crystalline silica is a

potential occupational carcinogen and NIOSH is in the process of reviewing the data on carcinogenicity ⁽⁸⁻¹¹⁾

Inorganic Arsenic

Inorganic arsenic is strongly implicated in respiratory tract and skin cancer and has been determined to be a potential occupational carcinogen by NIOSH ⁽¹²⁻¹⁴⁾ Inorganic arsenic has caused peripheral nerve inflammation (neuritis) and degeneration (neuropathy), anemia, reduced peripheral circulation, and increased mortality due to cardiovascular failure in workers who have been exposed to inorganic arsenic through inhalation, ingestion, or dermal exposure ⁽⁴⁾

Inorganic Mercury

Acute effects of overexposure to inorganic mercury include chest pain, cough, chemical pneumonitis, and bronchitis. Chronic exposures can produce symptoms of weakness, loss of appetite, loss of weight, insomnia, diarrhea, nausea, headache, and excessive salivation. It may also cause metallic taste in the mouth, loose teeth, soreness of the mouth, a black gum line, irritability, loss of memory, and tremors of the hands, eyelids, lips, tongue, or jaw. Three historical manifestations of mercury poisoning are gingivitis, increased irritability, and muscular tremors. Mercury can cause allergic skin rash and is a primary irritant of the skin and mucous membranes ^(4, 15)

EVALUATION CRITERIA¹

The occupational exposure criterion for inorganic lead in air is the current OSHA permissible exposure limit (PEL) of 50 $\mu\text{g}/\text{m}^3$, the OSHA Action Level is 30 $\mu\text{g}/\text{m}^3$ ⁽¹⁷⁾ If the action level is exceeded, blood lead testing must be conducted at least every 6 months for workers. The OSHA standard also prescribes that workers with blood lead concentrations higher than 60 $\mu\text{g}/\text{dl}$ of whole blood must be immediately removed from further lead exposure and workers with average blood lead levels of 50 $\mu\text{g}/\text{dl}$ or greater also must be removed. The affected employee may not return to a lead exposure job until the blood lead level drops below 40 $\mu\text{g}/\text{dl}$. The OSHA lead standard should be consulted for details of blood lead monitoring.

If air sampling shows lead levels exceed 30 $\mu\text{g}/\text{m}^3$, air monitoring for lead must be conducted every 6 months. Finally, if results show lead levels between 50 and 150 $\mu\text{g}/\text{m}^3$, air sampling must be repeated every 3 months, and the employer is required to provide showers, a separate lunchroom, and clean clothing at least weekly. In addition, workers are not permitted to eat, drink, or smoke in the work areas and are required to wash their hands before

¹Assay laboratories located at mine sites fall under the jurisdiction of the Mine Safety and Health Administration (MSHA) and the PELs for MSHA apply ⁽¹⁶⁾ Mine assay laboratories are legally required to meet only those levels specified by the MSHA PELs. Some current MSHA PELs are 150 $\mu\text{g}/\text{m}^3$ for lead, 10 mg/m^3 /(% respirable quartz+2) for silica, 500 $\mu\text{g}/\text{m}^3$ for inorganic arsenic, and 0.05 mg/m^3 for mercury.

eating and smoking. Workers should also change out of work clothes before leaving work so that lead will not be taken home and affect their families. Additional air sampling for lead is not required if airborne lead levels are below $30 \mu\text{g}/\text{m}^3$.

The occupational exposure criteria for respirable crystalline silica^(18, 19) are the NIOSH REL of $0.05 \text{ mg}/\text{m}^3$ and the OSHA PEL of $0.1 \text{ mg}/\text{m}^3$.

Arsenic requires stringent controls to minimize exposures to the current OSHA PEL of $10 \mu\text{g}/\text{m}^3$, the OSHA Action Level of $5 \mu\text{g}/\text{m}^3$, and the NIOSH recommended exposure limit (REL) of $2 \mu\text{g}/\text{m}^3$ (15-minute ceiling)^(12, 20). The NIOSH REL and the OSHA PEL for mercury are $0.05 \text{ mg}/\text{m}^3$.

METHODOLOGY

AIR SAMPLING AND ANALYSIS

Personal and area samples for lead and other metals were collected on 37-mm diameter cellulose ester, $0.8\text{-}\mu\text{m}$ pore size filters using SKC (Model #224) pumps at 3.0 liters per minute (Lpm). Pump flow rates were checked every 2 hours using a mini-Buck calibrator. Samples were analyzed for lead and other metals by inductively coupled plasma-atomic emission spectrometry (ICP) in accordance with NIOSH Method 7300⁽²¹⁾. Eight additional area samples were analyzed for lead by graphite furnace atomic absorption spectroscopy using NIOSH Method 7105⁽²²⁾.

Area samples for arsenic were collected on 37-mm diameter cellulose ester filters with an $0.8\text{-}\mu\text{m}$ pore size, followed by a 600-mg coconut charcoal tube, with a Gilian pump (Model LFS-113) operating at a flow rate of 0.3 Lpm. A backup charcoal tube was employed in areas with heated arsenic sources because of the possible presence of volatilized arsenic. These vapors may pass through conventional sampling filters, hence, monitoring with only a filter could underestimate total arsenic exposures. All filter samples for arsenic were analyzed by graphite furnace atomic absorption spectrophotometry in accordance with NIOSH Method 7901⁽²³⁾. Charcoal tubes were analyzed for arsenic by NIOSH Method 6001⁽²⁴⁾ using graphite furnace AA.

Air samples for respirable crystalline silica (quartz) and respirable dust were collected on preweighed $5\text{-}\mu\text{m}$ (pore size) PVC membrane filters, mounted in series with 10-mm nylon cyclones using SKC (Model #224) pumps at a flow rate of 1.7 Lpm. Quartz samples were analyzed according to NIOSH Method 7500 using x-ray diffraction⁽²⁵⁾. Respirable dust samples were analyzed for weight by NIOSH Method 0500 gravimetric analysis⁽²⁶⁾.

Ventilation measurements were made using the Kurz (Model #1440-4) digital and the TSI (Model #1650) analog hot-wire anemometers. A smoke tube was used to qualitatively evaluate air movement in front of and in the enclosure. The capacity and dimensions of the local exhaust ventilation control were obtained.

During the sampling survey, work practices and use of personal protective equipment were documented. Personal hygiene practices, such as furnishing clean uniforms, were also observed and documented.

RESULTS/DISCUSSION

AIR SAMPLING RESULTS

Individual sample results for lead, arsenic, respirable crystalline silica, and respirable dust are shown in Appendix A.

Lead

Personal samples for lead were taken on the fire assayists working in the litharge mixing and fire assay furnace room. Personal sample results for lead, as 8-hour time-weighted-averages (TWA), are shown in Table 1. The lead exposures, ranging from 8 to 41 $\mu\text{g}/\text{m}^3$, were all less than the OSHA PEL for lead, however, three of the four samples were above the OSHA Action Level of 30 $\mu\text{g}/\text{m}^3$, which triggers a number of requirements under the OSHA lead standard. The fire assay workers in the litharge/furnace room always wore respiratory protection during our survey.

Area lead concentrations measured in the litharge mixing and fire assay room are presented in Table 2. Average area sample lead concentrations measured at the flux mixing hood, the fusion and cupellation furnaces, and while pouring into the cone molds were highly consistent ranging from 18 $\mu\text{g}/\text{m}^3$ at the cupellation furnace to 24 $\mu\text{g}/\text{m}^3$ during pouring. The maximum area lead concentration of 55 $\mu\text{g}/\text{m}^3$ in the fire assay room indicates that there is the potential for lead levels to exceed the OSHA PEL for lead on occasion. The area sample results along with the personal sample results indicate that the ventilation system satisfactorily controls lead exposures in the litharge/furnace room to below the OSHA PEL of 50 $\mu\text{g}/\text{m}^3$. One half-day personal sample exceeded 50 $\mu\text{g}/\text{m}^3$ which suggests that the use of respiratory protection should continue. Area lead concentrations collected above the drying ovens in the sample prep area and wet chemistry laboratory averaged 6 and 4 $\mu\text{g}/\text{m}^3$, respectively, indicating the drying ovens were not a source of lead.

Full-shift indoor (background) samples for lead, collected in an office adjacent to the wet laboratory, averaged 2 $\mu\text{g}/\text{m}^3$. These indoor ambient lead concentrations indicate little buildup of lead in the laboratory building and represents less than one-tenth the fire assay workers' average lead exposure. Full-shift outdoor ambient area samples for lead averaged 1 $\mu\text{g}/\text{m}^3$. The outdoor ambient lead samples were collected outside about 10 feet from the door to the fire assay room at about 4 feet above the ground. These outdoor lead concentrations indicate outdoor lead levels contributed little or nothing to lead levels in the mine assay laboratory and that lead emissions from the local exhaust system had little effect on the outdoor environment.

Table 1
Lead Exposures for Workers in Furnace and Litharge Room

Date	Worker	Sample Time (min)	Sample Volume (liters)	Lead Concentration ($\mu\text{g}/\text{m}^3$)
3/9/93	A	412	1236	41
3/10/93	B	411	1233	33
3/11/93	B	190	570	30
3/22/93	C*	300	900	8

OSHA PEL 50 $\mu\text{g}/\text{m}^3$

OSHA Action Level 30 $\mu\text{g}/\text{m}^3$

* Collected by company hygienist

Table 2
Area Lead Concentrations

Location	Number of Samples	Arithmetic Mean ($\mu\text{g}/\text{m}^3$)	Range ($\mu\text{g}/\text{m}^3$)
Flux mixing hood	8	9	5-14
Fusion Furnaces	7	19	6-55
Cupel Furnace	3	18	16-22
Pouring Station	4	13	8-20
Drying Oven in Sample Prep	8	6	1-13
Drying Oven in Wet Lab	3	4	2-6
Indoor Background	3	2	2
Outdoor Background	3	1	0.5-2

OSHA PEL - 50 $\mu\text{g}/\text{m}^3$

OSHA Action Level - 30 $\mu\text{g}/\text{m}^3$

Respirable Dust and Respirable Quartz

Respirable dust and respirable quartz exposures were well controlled in the sample preparation area (Table 3). Respirable dust exposures averaged 0.2 mg/m³ which is much less than the OSHA PEL for respirable dust of 5 mg/m³. Respirable quartz exposures averaged 0.03 mg/m³ which is less than the NIOSH REL of 0.05 mg/m³ and the OSHA PEL of 0.1 mg/m³ for respirable quartz.

Area samples were collected in front of the splitter hood, pulverizer hood, and pouring hood at about head height. Area respirable dust concentrations shown in Table 4 averaged 0.2 mg/m³, while area respirable quartz concentrations averaged 0.02 mg/m³. These personal and area sample results show that the enclosed, ventilated hoods and work practices used in the sample prep operation were effective in controlling respirable dust and quartz exposures. In particular, the dust generated by the use of compressed air to clean off the equipment and work surfaces inside the enclosures was well controlled. Full-day background samples collected inside in the laboratory office and outdoor ambient samples collected near the doors to the sample preparation area (4 feet above the ground) showed respirable quartz levels of less than 0.01 mg/m³. These data indicate that respirable quartz did not escape from the sample prep area into other rooms inside the building and that outside respirable quartz levels were negligible.

Table 3
Respirable Dust and Quartz Exposures in Sample Prep

Date	Worker	Sample Duration (min)	Sample Volume (liters)	Respirable Dust Concentration (mg/m ³)	Respirable Quartz Concentration (mg/m ³)
3/9/93	A	409	695	0.03	<0.014
3/9/93 ^(a)	B	287	488	0.31	0.04
3/10/93	C	460	782	0.09	<0.013
3/11/93	C	396	673	0.19	0.045
OSHA PEL				5 mg/m ³	0.1 mg/m ³
NIOSH REL					0.05 mg/m ³

^(a) second shift

Table 4
Area and Background Respirable Dust and Quartz Concentrations

Location	Number of Samples	Arithmetic Mean Respirable Dust Concentration (mg/m ³)	Arithmetic Mean Respirable Quartz Concentration (mg/m ³)
Splitter Hood	4	0.1	0.02
Pulverizer Hood	4	0.2	0.03
Pour Hood	4	0.1	0.02
Indoor Background	3	0.03	<0.01
Outdoor Background	3	0.03	<0.01
NIOSH REL		--	0.05 mg/m ³
OSHA PEL		5 mg/m ³	0.10 mg/m ³

Mercury

A company Jerome Model 411 Mercury Vapor Analyzer was calibrated and used to measure mercury levels during the survey. Spot mercury measurements were made in the wet chemistry lab, by the drying oven in the sample preparation area (with door open and closed), next to the furnaces in the fire assay room, and while pouring molten sample into the metal cone molds. All mercury levels were less than the sensitivity of the instrument which was 0.003 mg/m³. The NIOSH REL and the OSHA PEL for mercury is 0.05 mg/m³.

Arsenic and Other Metals

Personal samples for arsenic (filter only) were collected on workers in the fire assay area and showed arsenic exposures were all less than 0.2 µg/m³. This is well below the OSHA PEL for arsenic of 10 µg/m³. Area samples for arsenic (filter only), collected in the sample preparation area, wet chemistry laboratory, and by the fire assay furnaces, were 0.2 µg/m³ or less. Background samples for arsenic taken both inside and outside were all less than 0.1 µg/m³.

An earlier NIOSH engineering control study⁽²⁷⁾ of arsenic exposures in gallium arsenide processing showed that a high percentage of arsenic passed through the sample filter and was collected on a charcoal tube, therefore, additional area samples for arsenic were taken using a sampling train consisting of a filter followed by a charcoal tube in order to capture any arsine or vapor arsenic that might pass through the filter. These samples were taken by the furnaces and during pouring in the fire assay room and on top of the drying oven in the sample prep area. The drying ovens were operated at a temperature of 350°F. The arsenic results collected using the filter/charcoal tube combination are presented in Appendix A, Table A-3. Arsenic on the filters were all less than the limit of detection while arsenic was measured on only one charcoal tube (which resulted in an arsenic concentration of 0.2 µg/m³).

These data demonstrate that both particulate and vapor phase arsenic were at low levels during our survey

The maximum personal sample concentration for various metals collected on workers in the fire assay room is presented in Appendix B, Table B-1. Exposures to these metals were all less than their respective NIOSH REL and OSHA PEL. Nevertheless, there is the potential for increased exposure to hazardous metals for the mine assay laboratory workers when the mining operation moves to a different ore body, because the specific level of exposure varies with the composition of the ore body. For example, oxide ore bodies tend to be low in arsenic and mercury while refractory ore bodies can be much higher. Additional air sampling should be conducted whenever a different ore body is encountered or evidence from laboratory analytical data indicates increased levels of hazardous metals such as cobalt or arsenic.

CONTROL TECHNOLOGY

PRINCIPLES OF CONTROL

Occupational exposures can be controlled by the application of a number of well-known principles including engineering measures, work practices, and personal protection. Engineering measures are the preferred and most effective means of control. These include material substitution, process and equipment modification, isolation and automation, and local and general ventilation. Control measures also may include good work practices and personal hygiene, housekeeping, administrative controls, and use of personal protective equipment such as respirators, gloves, goggles, and aprons.

ENGINEERING CONTROLS

Sample Preparation

Pinson Mine employs local exhaust ventilation and partial enclosures in the sample preparation area, flux mixing, and fire assay areas. In the sample preparation laboratory, the sample splitter hood, cone crusher, and jaw crusher are equipped with downdraft local exhaust ventilation. Flexible hoses from these three units connect into a distribution box which is tied into a single exhaust fan. The average face velocity and air flow into the sample splitter hood face opening (80" wide by 40" high) and the face velocity at the mouth of the jaw crusher are shown in Table 5.

Each pulverizer has its own ventilated hood (32" wide by 41" high) with a glass door in front. The sash of the glass door is positioned 4 inches above the bench so that makeup air flows under the door into the hood. The glass door prevents dust from being blown into the room while the pulverizer is being cleaned with compressed air. Next to each pulverizer hood is a pouring station with a ventilated hood (31" wide by 41" high). The face velocity and exhaust air volumes for the pulverizer and pour hoods are shown in Table 5. Ventilation measurements for the pulverizer hoods were taken with the glass doors closed. Air flows into the pulverizer hoods through 4-inch wide openings between the table and the bottom of the glass door. (Air flow volumes for the hoods in the sample prep area measured during this survey were

nearly the same as those measured during the walk-through survey in March 1992) Exhaust ventilation for the splitter hood, crushers, pulverizers, and pour hoods is provided by two 2-HP fans and one 1-HP fan, each with a 1725 rpm motor

Table 5
Ventilation Measurements in Sample Prep Area

Location	Average Face Velocity ^(*) (fpm)	Air Volume (cfm)	Notes
Splitter Hood	120	2600	All fans running in sample prep
Crusher	830	70	Measurements from walk-through survey (3/19/92)
Right Pulverizer Hood	1060	840	Glass door closed
Right Pour Hood	270	2500	
Left Pulverizer Hood	1730	1540	Glass door closed
Left Pour Hood	300	2600	
Total Air Volume of Hoods		10,150	

^(*) The ACGIH Industrial Ventilation Manual recommends capture velocities from 100 to 500 fpm for these operations ⁽²⁸⁾

Fire Assay

Premixed flux including lead oxide (litharge), silica sand, and other ingredients are mixed in an exhaust hood made of transparent plastic with the exhaust opening in the table. The premixed flux contains a mineral oil which helps control dust levels - especially lead - during mixing. The face opening of the hood is 14 inches high by 94 inches wide and the downward exhaust opening in the table is 48 by 3½ inches. The average face velocity and the total air flow into the hood are shown in Table 6. The face velocity to the flux mixing hood was low at only 30 fpm. (Shortly after this survey, the company modified the flux mixing hood by lowering the transparent plastic to reduce the front opening of the hood and replacing the existing exhaust fan with one having greater capacity.) There is also an automatic mixer that is sometimes used to mix the flux with the samples which helps reduce the workers exposure compared to hand mixing.

Each of the three fusion furnaces has an exhaust hood above the furnace door extending out 4 to 5 5 inches from the front of the furnace. The cupellation furnace has a large hood above the furnace door that extends 17 inches in front of the furnace as well as along both sides. The primary purpose of these hoods is to exhaust fumes when the doors are open. Ventilation

measurements to the fusion and cupellation furnace hoods are presented in Table 6. Exhaust air flow for the left fusion furnace hood was nearly twice that for the right fusion hood. This is not surprising since the hood for the left furnace was nearest to the exhaust fan and the right hood was farthest away. During the survey, the operating temperatures for fusion furnaces #1, #2, and #3 were 1950, 1950, and 1770°F, respectively. The cupellation exhaust hood had its own fan. Exhaust air from all the furnaces is discharged directly outside.

Table 6
Ventilation Measurements in Fire Assay Room

Location	Average Face Velocity (fpm)	Air Volume (cfm)	Notes
Flux Mixing Hood	30	290	
Fusion Furnace (left)	1340	430	
Fusion Furnace (center)	740	320	
Fusion Furnace (right)	480	240	
Cupellation Furnace	270	1050	
Total Air Volume into Hoods		2330	

The local exhaust ventilation hoods were fabricated by an outside contractor but were installed by company staff. Ventilation ducts were installed by a contractor. The sample prep hoods are 1/8-inch rolled sheet metal that are painted for appearance. The current sample prep operation was built in 1986. A glass company was hired to put in the glass doors in the sample prep hoods. Hoods over the furnaces in fire assay are made of 1/16-inch stainless steel and are in good condition after 12 years.

Weather Conditions

During our survey, daily maximum outside air temperatures ranged from 49 to 55°F and minimum temperatures from 29 to 39°F. Average daily wind speed ranged from 2 to 8 mph. Inside the shop, temperatures ranged from 57 to 70°F and the dew point was about 50°F. Average annual rainfall for this mine site is about 8 inches.

WORK PRACTICES

Workers in the sample preparation area use a screw driver and a paint brush to clean off the pulverizer. The glass door is opened about one foot when performing this task. The paint brush is also used to sweep dust from the lip of the pulverizer bench (i.e., table) into a pan or onto the floor. In addition, compressed air at 50 psi is used to clean dust off the equipment and

work surfaces. The glass doors to the pulverizers are usually, but not always, closed when cleaning with compressed air. Operators are able to do a good job of cleaning at this reduced air pressure. However, this air hose pressure is still above the OSHA standard which is 30 psi for cleaning purposes.⁽²⁹⁾ It is recommended that the air hose pressure for cleaning be reduced to 30 psi.

MONITORING

The company air monitoring program consists of personal sampling for lead and total dust along with periodic sampling for mercury using a Jerome Mercury Vapor Analyzer. Biological monitoring consists of weekly collection and analysis of urine for mercury, and quarterly analysis of blood for lead and mercury. Company records show the highest blood lead level among assay laboratory workers from April 1990 through 1991 was 28 $\mu\text{g}/\text{dl}$. The maximum blood lead level from January 1992 to January 1993 was 19 $\mu\text{g}/\text{dl}$. The blood mercury levels from January 1992 to January 1993, for the one assay worker sampled, were all less than the detection limit of 20 $\mu\text{g}/\text{liter}$.

PERSONAL PROTECTIVE EQUIPMENT

HEPA-filtered, half-mask respirators for dusts, fumes, mists, radionuclides, radon daughters, and asbestos (Glendale Model #C50A) were worn in the sample preparation area, fire assay room, and at the flux mixing station. Occasionally, a Dustfoe 66 respirator for dust and mists is worn in the sample preparation area. The fire assayer wore either welding, aluminum backed, or Xetex gloves (rated to 2000°F) and coveralls and wore a face shield with a gold film to reflect heat when opening the furnaces.

Ear plugs or ear muffs must be worn in the sample prep room. The fire assayer wore ear pugs while hammering the lead buttons. The company provides each worker five sets of coveralls and there is a laundry service to take care of the coveralls.

HYGIENE

The laboratory includes shower and locker room facilities. Workers in the fire assay area must take showers after work, others can if they want. No eating, drinking, or smoking is permitted in the fire assay area. Since the survey, the company has converted the Geochem Prep room into a lunchroom.

DISCUSSION AND CONCLUSIONS

Engineering controls in the mine assay laboratory consist of local exhaust ventilation and enclosures in the sample preparation area, a local exhaust ventilation hood over the flux mixing table, and local exhaust hoods over the furnace doors in the fire assay room. The exhaust hood and ducts appeared to be in good condition. The premixed flux contains a mineral oil which helps control lead dust during flux mixing. In addition, HEPA-filtered half-mask respirators are worn in the fire assay area and during flux mixing operations. Either a HEPA-filtered half-mask or a dust-and-mist respirator is worn in the sample preparation area. The shop also rotates employees through the fire

assay and sample preparation areas to help minimize exposures. Assay laboratory workers are provided with clean uniforms daily and have shower facilities available. Production (i.e., the number of fire assay analysis performed by workers in the sample preparation area and the fire assay room) was average to slightly below average for the laboratory during our survey.

In the sample preparation area, the combination of partial enclosures and local exhaust ventilation effectively controlled respirable dust and crystalline silica levels. For example, all respirable crystalline silica exposures were less than the NIOSH REL of 0.05 mg/m^3 as well as the OSHA PEL of 0.1 mg/m^3 . Area samples taken in the sample preparation area on top of the drying oven showed lead and arsenic levels to be much below their respective NIOSH RELs and OSHA PELs.

The fire assayists' lead exposures were controlled to less than the OSHA PEL by the use of (1) premixed flux containing a mineral oil which helps control dust levels, (2) a partial enclosure and exhaust ventilation for the litharge mixing table, and (3) local exhaust ventilation hoods over the fusion and cupellation furnace doors. Nonetheless, three of four personal samples for lead were above the OSHA Action Level of $30 \text{ } \mu\text{g/m}^3$, which triggers a number of requirements under the OSHA lead standard. With lead exposures above the action level, it would be prudent practice for the fire assayists to continue to wear respiratory protection while working in the litharge/furnace room.

The arsenic exposures (filter only) of the fire assayists were all less than one-fiftieth the OSHA PEL for arsenic of $10 \text{ } \mu\text{g/m}^3$. In addition, the fire assayists' exposures to a variety of metals including cadmium, chromium, cobalt, nickel, selenium, and zinc were all less than their respective NIOSH REL and OSHA PEL. However, there is the potential for increased exposure to hazardous metals for the mine assay laboratory workers when the mining operation moves to a different ore body, the specific level of exposures varies with the composition of the ore body. For example, oxide ore bodies tend to be low in arsenic and mercury while refractory ore bodies can be much higher. Additional air sampling should be conducted whenever a different ore body is encountered or evidence from laboratory analytical data indicates increased levels of hazardous metals such as arsenic or cobalt.

Spot mercury measurements were made with a mercury vapor analyzer by the drying oven in the sample preparation area, by the furnaces in the fire assay room, in the wet chemistry lab, and while pouring molten samples into the metal cone molds. All mercury levels were less than the NIOSH REL and the OSHA PEL for mercury.

Compressed air at 50 psi is used to clean dust off the equipment and work surfaces. Operators are able to do a good job of cleaning at this reduced air pressure and our sampling results show that respirable dust and respirable crystalline dust exposures were satisfactorily controlled. Nevertheless, the OSHA standard requires that the air hose pressure for cleaning purposes be reduced to 30 psi.

Smoking and eating in the laboratory work areas should not be permitted even during downtime. Workers exposed to lead, arsenic, or other toxic metals

should shower and change from work clothes to street clothes after their tour of duty (Workers in the fire assay area presently must take showers after work) HEPA-filtered vacuums should be available and used for cleaning dust from the interior of automobiles that may become contaminated from lead or other hazardous contaminants Such measures should help reduce the possibility of taking lead home to the family

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APPENDIX A TABLE A 1 LEAD CONCENTRATIONS

DATE	DAY	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE LOCATION	LOCATION DETAILS	SAMPLE TIME (min)	FLOW RATE (LPM)	VOLUME (liters)	LEAD DET LIMIT	LEAD MASS (ug)	LEAD CONC (ug/m3)
03/09/93	MAR_9	365	PERS	FIREASSAY		227	3.0	881	0.5	30	44.1
03/09/93	MAR_9	348	PERS	FIREASSAY		185	3.0	555	0.5	21	37.8
03/09/93	MAR_9	354	AREA	FLUXMIX	LEFT	193	3.0	579	0.02	4	6.9
03/09/93	MAR_9	366	AREA	FLUXMIX	RIGHT	193	3.0	579	0.02	7.9	13.8
03/09/93	MAR_9	349	AREA	FLUXMIX	LEFT	192	3.0	575	0.02	3.6	6.3
03/09/93	MAR_9	350	AREA	FLUXMIX	RIGHT	191	3.0	573	0.02	4.7	8.2
03/09/93	MAR_9	361	AREA	FUSNFURN	BETWEEN1&2	353	3.0	1059	0.5	16	14.2
03/09/93	MAR_9	353	AREA	FUSNFURN	BETWEEN2&3	353	3.0	1059	0.5	7.2	6.8
03/09/93	MAR_9	360	AREA	FIREASSAY	POURING	353	3.0	1059	0.5	21	19.8
03/09/93	MAR_9	355	AREA	CUPELFURN		322	3.0	996	0.5	17	17.1
03/09/93	MAR_9	368	AREA	FIREASSAY	FUSNFURN	167	0.3	50	0.5	1.2	24.0
03/09/93	MAR_9	369	AREA	SAMPLEPREP	DRYOVEN	280	3.0	840	0.5	0.6	0.7
03/09/93	MAR_9	363	AREA	SAMPLEPREP	DRYOVEN	159	0.3	48	0.5	0.6	12.6
03/09/93	MAR_9	357	AREA	SAMPLEPREP	DRYOVEN	279	0.3	84	0.5	0.35	4.2
03/09/93	MAR_9	370	AREA	SAMPLEPREP	POURSTA	276	3.0	825	0.5	0.35	0.4
03/09/93	MAR_9	362	AREA	WETLAB	DRYOVEN	348	3.0	1044	0.5	6.1	5.8
03/09/93	MAR_9	359	AREA	INSIDE	OFFICE	642	3.0	1926	0.5	3.2	1.7
03/09/93	MAR_9	367	AREA	OUTSIDE	SW	639	3.0	1917	0.5	2	1.0
03/10/93	MAR10	364	PERS	FIREASSAY		212	3.0	636	0.5	21	33.0
03/10/93	MAR10	385	PERS	FIREASSAY		199	3.0	597	0.5	20	33.5
03/10/93	MAR10	367	AREA	FLUXMIX	LEFT	377	3.0	1131	0.02	11	9.7
03/10/93	MAR10	388	AREA	FLUXMIX	RIGHT	379	3.0	1137	0.02	11	9.7
03/10/93	MAR10	375	AREA	FUSNFURN	BETWEEN1&2	385	3.0	1155	0.5	19	18.5
03/10/93	MAR10	362	AREA	FUSNFURN	BETWEEN2&3	385	3.0	1155	0.5	6.5	5.6
03/10/93	MAR10	374	AREA	FIREASSAY	POURING	383	3.0	1149	0.5	17	14.8
03/10/93	MAR10	381	AREA	CUPELFURN		384	3.0	1152	0.5	25	21.7
03/10/93	MAR10	386	AREA	SAMPLEPREP	DRYOVEN	436	3.0	1308	0.5	3.4	2.8
03/10/93	MAR10	380	AREA	SAMPLEPREP	DRYOVEN	192	0.3	58	0.5	0.7	12.2
03/10/93	MAR10	384	AREA	SAMPLEPREP	DRYOVEN	209	0.3	63	0.5	0.6	9.6
03/10/93	MAR10	378	AREA	WETLAB	DRYOVEN	408	3.0	1218	0.5	5.1	4.2
03/10/93	MAR10	382	AREA	INSIDE	OFFICE	447	3.0	1341	0.5	2.1	1.6
03/10/93	MAR10	356	AREA	OUTSIDE	SW	475	3.0	1425	0.5	2.6	1.8
03/11/93	MAR11	320	PERS	FIREASSAY		190	3.0	570	0.5	17	29.8
03/11/93	MAR11	382	AREA	FLUXMIX	LEFT	352	3.0	1056	0.02	10	9.5
03/11/93	MAR11	372	AREA	FLUXMIX	RIGHT	352	3.0	1056	0.02	6.2	4.9
03/11/93	MAR11	390	AREA	FUSNFURN	BETWEEN1&2	352	3.0	1056	0.5	25	23.7
03/11/93	MAR11	377	AREA	FUSNFURN	BETWEEN2&3	352	3.0	1056	0.5	9.2	8.7
03/11/93	MAR11	305	AREA	FUSNFURN		282	0.3	78	0.5	4.3	54.7
03/11/93	MAR11	391	AREA	FIREASSAY	POURING	352	3.0	1056	0.5	12	11.4
03/11/93	MAR11	317	AREA	FIREASSAY	POURING	262	0.3	79	0.5	0.6	7.6
03/11/93	MAR11	306	AREA	CUPELFURN		352	3.0	1056	0.5	17	16.1
03/11/93	MAR11	393	AREA	SAMPLEPREP	DRYOVEN	235	0.3	71	0.5	0.35	5.0
03/11/93	MAR11	383	AREA	SAMPLEPREP	DRYOVEN	393	3.0	1149	0.5	0.7	0.6
03/11/93	MAR11	312	AREA	WETLAB	DRYOVEN	368	3.0	1104	0.5	1.8	1.6
03/11/93	MAR11	389	AREA	INSIDE	OFFICE	401	3.0	1203	0.5	1.9	1.6
03/11/93	MAR11	384	AREA	OUTSIDE	SW	429	3.0	1287	0.5	0.6	0.5
03/22/93	MAR11	308	PERS	FIREASSAY		300	3.0	800	0.5	8	8.8
03/09/93	MAR_9	358	BLANK					0	0.5		
03/10/93	MAR10	373	BLANK					0	0.5		
03/11/93	MAR11	315	BLANK					0	0.5		
03/11/93	MAR11	318	BLANK					0	0.5		
03/11/93	MAR11	314	BLANK					0	0.5		
03/11/93	MAR11	319	BLANK					0	0.5		

APPENDIX A TABLE A-2 RESPIRABLE QUARTZ AND WEIGHT

DATE	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE LOCATION	LOCATION DETAILS	SAMPLE TIME (min)	VOLUME (liters)	TOTAL WEIGHT		QUARTZ DETECTED	QUARTZ MASS (mg)	QUARTZ CONC (mg/m ³)
							WEIGHT (mg)	CONC (mg/m ³)			
03/09/93	2127	PERS	SAMPLEPREP		409	695	0.02	0.03	ND	0.01	0.014
03/09/93	2134	PERS	SAMPLEPREP		287	488	0.15	0.31		0.02	0.041
03/09/93	2124	AREA	SAMPLEPREP	SPLITTERHOOD	289	491	0.05	0.10	ND	0.01	0.020
03/09/93	2126	AREA	SAMPLEPREP	PULVERHOOD	289	491	0.18	0.37		0.03	0.061
03/09/93	5324	AREA	SAMPLEPREP	POURHOOD	290	493	0.19	0.39		0.02	0.041
03/09/93	2131	AREA	SAMPLEPREP	SPLITTERHOOD	384	653	0.08	0.12		0.02	0.031
03/09/93	2130	AREA	SAMPLEPREP	PULVERHOOD	383	651	0.07	0.11		0.01	0.015
03/09/93	2123	AREA	SAMPLEPREP	POURHOOD	381	648	0.01	0.02	ND	0.01	0.015
03/09/93	5331	AREA	INSIDE	OFFICE	648	1102	0.05	0.05	ND	0.01	0.009
03/09/93	2132	AREA	OUTSIDE	SW	673	1144	0.04	0.03	ND	0.01	0.009
03/10/93	2049	PERS	SAMPLEPREP		460	782	0.07	0.09	ND	0.01	0.013
03/10/93	2061	AREA	SAMPLEPREP	SPLITTERHOOD	440	748	0	0.00	ND	0.01	0.013
03/10/93	2060	AREA	SAMPLEPREP	PULVERHOOD	436	741	0.03	0.04	ND	0.01	0.013
03/10/93	1974	AREA	SAMPLEPREP	POURHOOD	436	741	0.05	0.07	ND	0.01	0.013
03/10/93	2040	AREA	INSIDE	OFFICE	475	808	0.01	0.01	ND	0.01	0.012
03/10/93	2121	AREA	OUTSIDE	SW	447	760	0.01	0.01	ND	0.01	0.013
03/11/93	5335	PERS	SAMPLEPREP		398	673	0.13	0.19		0.03	0.045
03/11/93	2047	AREA	SAMPLEPREP	SPLITTERHOOD	386	556	0.03	0.05	ND	0.01	0.015
03/11/93	2043	AREA	SAMPLEPREP	PULVERHOOD	386	556	0.11	0.17		0.01	0.015
03/11/93	2058	AREA	SAMPLEPREP	POURHOOD	385	555	0.02	0.03	ND	0.01	0.015
03/11/93	2044	AREA	INSIDE	OFFICE	401	682	0.03	0.04	ND	0.01	0.015
03/11/93	2041	AREA	OUTSIDE	SW	429	729	0.02	0.03	ND	0.01	0.014
03/09/93	1968	BLANK			0		0.01		ND		
03/10/93	2051	BLANK			0		-0.01		ND		
03/11/93	2126	BLANK			0		-0.01		ND		
03/11/93	2045	BLANK			0		0.04		ND		
03/11/93	5336	BLANK			0		-0.02		ND		
03/11/93	2120	BLANK			0		0		ND		

APPENDIX A TABLE A-3 ARSENIC CONCENTRATIONS

DATE	SAMPLE NUMBER	TYPE	SAMPLE LOCATION	LOCATION DETAILS	SAMPLE TIME (min)	FLOW RATE (LPM)	VOLUME DETECTED (liters)	ARSENIC DETECTED	ARSENIC MASS (ug)	ARSENIC CONC (ug/m3)
03/09/93	365	PERS	FIREASSAY		227	3.0	891	ND	0.09	0.13
03/09/93	348	PERS	FIREASSAY		185	3.0	555	ND	0.09	0.16
03/09/93	361	AREA	FUSNFURN	1&2	353	3.0	1059	ND	0.09	0.08
03/09/93	353	AREA	FUSNFURN	2&3	353	3.0	1059	ND	0.09	0.08
03/09/93	360	AREA	FIREASSAY	POURING	353	3.0	1059	ND	0.09	0.08
03/09/93	355	AREA	CUPELFURN		332	3.0	996	ND	0.09	0.09
03/09/93	368	AREA	FIREASSAY	FUSNFURN	187	0.3	50	ND	0.09	1.80
03/09/93	369	AREA	SAMPLEPREP	DRYOVEN	280	3.0	840		0.2	0.24
03/09/93	363	AREA	SAMPLEPREP	DRYOVEN	159	0.3	48	ND	0.09	1.89
03/09/93	367	AREA	SAMPLEPREP	DRYOVEN	279	0.3	84	ND	0.09	1.08
03/09/93	370	AREA	SAMPLEPREP	POURSTA	278	3.0	825		0.1	0.12
03/09/93	362	AREA	WETLAB	DRYOVEN	348	3.0	1044	ND	0.09	0.08
03/09/93	359	AREA	INSIDE	OFFICE	642	3.0	1926	ND	0.09	0.05
03/09/93	367	AREA	OUTSIDE	SW	639	3.0	1917	ND	0.09	0.05
03/10/93	364	PERS	FIREASSAY		212	3.0	636	ND	0.09	0.14
03/10/93	385	PERS	FIREASSAY		199	3.0	597	ND	0.09	0.16
03/10/93	375	AREA	FUSNFURN	1&2	385	3.0	1155	ND	0.09	0.08
03/10/93	362	AREA	FUSNFURN	2&3	385	3.0	1155	ND	0.09	0.08
03/10/93	374	AREA	FIREASSAY	POURING	383	3.0	1149	ND	0.09	0.08
03/10/93	361	AREA	CUPELFURN		384	3.0	1152	ND	0.09	0.08
03/10/93	368	AREA	SAMPLEPREP	DRYOVEN	436	3.0	1308	ND	0.09	0.07
03/10/93	380	AREA	SAMPLEPREP	DRYOVEN	192	0.3	58	ND	0.09	1.58
03/10/93	384	AREA	SAMPLEPREP	DRYOVEN	209	0.3	63	ND	0.09	1.44
03/10/93	378	AREA	WETLAB	DRYOVEN	406	3.0	1218	ND	0.09	0.07
03/10/93	382	AREA	INSIDE	OFFICE	447	3.0	1341	ND	0.09	0.07
03/10/93	358	AREA	OUTSIDE	SW	475	3.0	1425	ND	0.09	0.06
03/11/93	320	PERS	FIREASSAY		190	3.0	570	ND	0.09	0.16
03/11/93	390	AREA	FUSNFURN	1&2	352	3.0	1056	ND	0.09	0.09
03/11/93	377	AREA	FUSNFURN	2&3	352	3.0	1056	ND	0.09	0.09
03/11/93	305	AREA	FUSNFURN		262	0.3	79	ND	0.09	1.16
03/11/93	391	AREA	FIREASSAY	POURING	352	3.0	1056	ND	0.09	0.09
03/11/93	317	AREA	FIREASSAY	POURING	262	0.3	79	ND	0.09	1.16
03/11/93	306	AREA	CUPELFURN		352	3.0	1056	ND	0.09	0.09
03/11/93	393	AREA	SAMPLEPREP	DRYOVEN	235	0.3	71	ND	0.09	1.28
03/11/93	383	AREA	SAMPLEPREP	DRYOVEN	383	3.0	1149	ND	0.09	0.08
03/11/93	312	AREA	WETLAB	DRYOVEN	388	3.0	1164	ND	0.09	0.08
03/11/93	388	AREA	INSIDE	OFFICE	401	3.0	1203	ND	0.09	0.07
03/11/93	394	AREA	OUTSIDE	SW	429	3.0	1287	ND	0.09	0.07
03/22/93	308	PERS	FIREASSAY		300	3.0	900	ND	0.09	0.10
03/09/93	356	BLANK					0	ND		
03/10/93	373	BLANK					0	ND		
03/11/93	315	BLANK					0	ND		
03/11/93	318	BLANK					0	ND		
03/11/93	314	BLANK					0	ND		
03/11/93	319	BLANK					0	ND		

APPENDIX A TABLE A 3 ARSENIC CONCENTRATIONS

ARSENIC FILTER PLUS TUBE SAMPLES												
DATE	SAMPLE NUMBER	TYPE	SAMPLE LOCATION	LOCATION DETAILS	SAMPLE TIME (min)	FLOW RATE (LPM)	VOLUME (liters)	ARSENIC DETECTED (filter)	ARSENIC MASS (filter)	ARSENIC MASS (tube-blank)	ARSENIC MASS (total)	ARSENIC CONC. (ug/m3)
03/09/93	368/672	AREA	FIREASSAY	FUSNFURN	167	0.3	60	ND	0.09	0	0.09	1.8
03/09/93	363/663	AREA	SAMPLEPREP	DRYOVEN1	158	0.3	48	ND	0.09	0	0.09	1.9
03/09/93	367/671	AREA	SAMPLEPREP	DRYOVEN	279	0.3	84	ND	0.09	0	0.09	1.1
03/10/93	390/411	AREA	SAMPLEPREP	DRYOVEN	192	0.3	58	ND	0.09	0.01	0.10	1.7
03/10/93	384/669	AREA	SAMPLEPREP	DRYOVEN	209	0.3	63	ND	0.09	0	0.09	1.4
03/11/93	393/708	AREA	SAMPLEPREP	DRYOVEN	235	0.3	71	ND	0.09	0	0.09	1.3
03/11/93	306/702	AREA	FIREASSAY	FUSNFURN	262	0.3	79	ND	0.09	0	0.09	1.1
03/11/93	317/704	AREA	FIREASSAY	POURING	262	0.3	79	ND	0.09	0	0.09	1.1

APPENDIX B

TABLE B-2

Average Personal Sample Concentrations for Metals and Minerals in Fire Assay Area

Analyte	OSHA PEL (mg/m ³)	NIOSH REL (mg/m ³)	Concentration (mg/m ³)
Beryllium	0.002	0.0005	0.0002
Cadmium	0.1	0.01	0.0003
Chromium	1	0.5	0.0008
Cobalt	0.05	0.05	0.0003
Copper	0.1	0.1	0.0008
Manganese	5(C)	1	<0.001
Molybdenum	5	--	0.0003
Nickel	0.1	0.015	<0.002
Selenium	0.2	0.2	<0.002
Silver	0.01	0.01	<0.0002
Tellurium	0.1	0.1	<0.002
Thallium	0.1	0.1	<0.004
Tin	2	2	<0.004
Vanadium	0.05	0.05	0.0003 0.0003
Zirconium	5	5	