

IN-DEPTH SURVEY REPORT  
CONTROL TECHNOLOGY FOR MINE ASSAY LABORATORIES  
AT  
Skyline Laboratories, Inc  
Wheat Ridge, Colorado

REPORT WRITTEN BY  
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## ABBREVIATIONS AND DEFINITIONS

'	feet
"	inches
capture velocity	minimum hood-induced air velocity necessary to capture and convey the contaminant into the hood
face velocity	air velocity at the hood opening
fpm	feet per minute
ft <sup>2</sup>	feet squared
mg/m <sup>3</sup>	milligrams per meter cubed
mm	millimeters (1 X 10 <sup>-3</sup> m)
lpm	liters per minute
rpm	revolutions per minute
μm	micrometers (1 X 10 <sup>-6</sup> m)

## 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 the control and prevention of 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 mine 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, and respirable crystalline silica to below the respective NIOSH recommended exposure limits (RELs) and OSHA/MSHA permissible exposure limits (PELs) for workers in mine assay laboratories. This 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 Skyline Laboratories, Inc. (a commercial mine assay laboratory). The purpose of this survey was to evaluate potentially effective control systems including work practices.

## PLANT AND PROCESS DESCRIPTION

Skyline Laboratories is a commercial mine assay laboratory which analyzes samples from various mines throughout the world. Skyline Laboratories operates one shift a day and presently has a work force consisting of 15 employees.

## PROCESS DESCRIPTION

Assay samples from various mines are delivered to the sample receiving area of the laboratory in individual bags weighing 10 to 12 pounds. Wet samples are dried in an oven at approximately 200° Fahrenheit. The samples are crushed in one of two ventilated jaw crushers to approximately 1/4" granules. The crushed samples are reduced to a finer texture in a ventilated roll crusher. The crushed samples are passed through a splitter box to obtain a small, representative sample (approximately 200 grams). This sample is pulverized to approximately 200 mesh (0.0003") in a puck and ring pulverizer. Both the splitter and the ring and puck mills are cleaned using a paint brush and compressed air. Ore samples are then taken to the fire assay area where they are mixed with fluxing agents.

Large batches of fluxing agents consisting of borax, flour, silica sand, and soda ash are prepared in a barrel mixer. The barrel is placed in a ventilated hood and 50 pounds of litharge (lead oxide) is added to the fluxing material. The barrel is sealed, removed from the ventilated hood, then placed on a roller and mixed for approximately 30 minutes until the flux and litharge are thoroughly mixed. The fluxing material is approximately 60 percent litharge. The barrel is placed back under the ventilated hood where the seal is removed. Part of the fluxing material is removed from the barrel and placed in a container located inside the hood. The barrel is then resealed, removed from the hood, and placed in storage. Fluxing material and pulverized assay samples are added to crucibles and thoroughly hand mixed in the ventilated hood. The crucibles (containing the sample and fluxing material) are then placed in one of two fusion furnaces that operate at approximately 2000° Fahrenheit.

The carbon contained in the flour reduces part of the lead oxide to lead which combines with the precious metals released from the ore <sup>(1)</sup>. The samples are then removed from the oven and the lead is separated from the slag by pouring the samples into metal button molds. A lead button is formed in the bottom of the metal mold. After cooling, the lead button is removed.

Lead buttons, which contain the precious metals, are placed into a bone ash cupel. The cupel is placed in a cupellation furnace where the lead is oxidized and absorbed by the cupel, leaving the precious metals at the bottom of the cupel. In some cases, a controlled amount of silver is added to the samples in order to obtain a visible amount of precious metals in the bottom of the cupel. The precious metals are then collected and weighed in a balance room.

## POTENTIAL HEALTH HAZARDS

### Inorganic Lead

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 peripheral and central nervous systems,

gastrointestinal system, kidneys, reproductive system, hematopoietic system (blood-forming organs), and virtually all other systems of the body <sup>(2)</sup> The acute effects may manifest as weakness, tiredness, irritability, reduced intelligence, slowed reaction times, abdominal pain, or high blood pressure <sup>(3)</sup> Chronic lead exposure can cause infertility, kidney damage, and, in pregnant women, fetal damage manifested as prematurity, reduced birth weight, reduced red blood cell production, and reduced intelligence <sup>(4-8)</sup> The Blood Lead Level (BLL) test is one measure of the amount of lead in the body and is the best available measure of recent lead absorption. The mean serum lead level for U.S. men between 1976 and 1980 was 16  $\mu\text{g}/\text{dl}$ , <sup>(9,10)</sup> however, with the implementation of lead-free gasoline and reduced lead in food, the 1991 average serum lead level of U.S. men will probably drop below 9  $\mu\text{g}/\text{dl}$  <sup>(2)</sup> A summary of the lowest observable effect levels of lead are listed in Table 1.

### Inorganic Arsenic

Compounds of inorganic arsenic produce the following health effects: dermatitis (skin inflammation), keratoses (horny growths on skin), peripheral neuropathies (diseases of the nerves of the extremities), peripheral vascular diseases (diseases of the arteries and veins of the extremities), and cancer of the skin, liver, and lungs <sup>(12)</sup> Arsenic compounds are mainly absorbed via the respiratory and gastrointestinal routes. Over 90 percent of the ingested amount of water soluble compounds in humans and animals is absorbed. Oral ingestion from contaminated hands may result in absorption of toxicologically significant amounts of arsenic <sup>(13)</sup> In addition, experiments on rats have shown that arsenic in aqueous solutions can penetrate through intact skin <sup>(14)</sup>

The major elimination pathways of inorganic arsenic are metabolism and urinary excretion. The total amount excreted in urine accounts for about 60 percent of the absorbed amount <sup>(15,16)</sup> Inorganic arsenic metabolites appear in urine shortly after the start of exposure. The concentration rises slowly during the first days of the exposure, and then levels off <sup>(16)</sup> If a worker's exposure on the following days is similar, the arsenic concentration in urine remains more or less the same.

Arsenic is present in water, food, and polluted air <sup>(17)</sup> Smoking is also a source of exposure to arsenic (12 to 42  $\mu\text{g}$  per cigarette) <sup>(18)</sup> Therefore, it is found in the urine of people who have no occupational exposure to arsenic. Concentrations of inorganic arsenic and its metabolites in the urine of the general population are usually below 10  $\mu\text{g}/\text{g}$  of creatinine\* <sup>(19)</sup>

### Crystalline Silica

Crystalline silica is a potential constituent of an assay sample. Assay samples processed in the sample preparation area are crushed and pulverized to a fine powder. These operations can create an airborne dust which contains crystalline silica. The severity of this hazard depends, in part, upon the

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\* Since arsenic concentrations in urine are dependant on urine output, creatinine determination in the same specimen is necessary because creatinine is usually excreted at a constant rate <sup>(12)</sup>





amount of crystalline silica present in the sample, work practices, duration of exposure, effectiveness of the general/local ventilation system, and proper use of personal protective equipment

Crystalline silica can cause silicosis, a form of disabling, progressive, and sometimes fatal pulmonary fibrosis characterized by silicotic nodules in the lungs. Silicosis usually occurs after years of exposure, but may appear in a shorter time if exposure concentrations are high. Symptoms of silicosis include shortness of breath, fever, and cyanosis (bluish skin). The amount of dust inhaled, the percentage of free or uncombined silica in the dust, the size of the dust particles, and the length of exposure all affect the onset of silicosis <sup>(20)</sup>

#### OCCUPATIONAL EVALUATION CRITERIA

As a guide to the evaluation of the hazards resulting in 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, however, important 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 criteria. These combined effects are often 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 become available.

The primary sources of environmental evaluation criteria in the United States that can be used for the workplace are (1) the U.S. Department of Labor (OSHA) Permissible Exposure Limits (PELs), and (2) NIOSH Recommended Exposure Limits (RELs) <sup>(21,22)</sup>. In establishing PELs, OSHA is required to consider the feasibility of controlling exposures in various industries where the agents are used, the NIOSH RELs, by contrast, are based primarily on concerns relating to the prevention of occupational disease. It should be noted that industry is legally required to meet only those levels specified by OSHA PELs.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limits or ceiling values, which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures.

Under the OSHA Lead Standard, the PEL for lead in air was established at  $50 \mu\text{g}/\text{m}^3$  averaged over an 8-hour workday. Under the requirements of the standard, employers must first determine if workplace air lead levels exceed the PEL. When air lead levels exceed the PEL, the employer must notify employees and provide a description of corrective action that will be taken to reduce exposure. Exposure must be rechecked every 6 months if levels exceed the action level ( $30 \mu\text{g}/\text{m}^3$ ) but are below the PEL. If air lead levels drop below the action level, the employer may discontinue monitoring individuals if two consecutive measurements, taken at least 2 weeks apart, are below the action level. However, when there is a production, process, control, or personnel change at the workplace which may result in new or additional exposure to lead, or whenever there is any other reason to suspect a change which may result in new or additional exposure to lead, the employer must perform additional monitoring. <sup>(23)</sup>

The requirements specified under the standard for medical monitoring of workers exposed to lead are specified in Section 8, Paragraph J, in the Code of Federal Regulations Section 1910.1025.

The medical surveillance program is part of the standard's comprehensive approach to the prevention of lead-related disease. Its purpose is to supplement the main thrust of the standard which is aimed at minimizing airborne concentrations of lead and sources of ingestion. Medical surveillance requirements help determine if the other provisions of the standard have effectively protected the individual worker.

In addition, all medical surveillance required by the standard must be performed by or under the supervision of a licensed physician. The employer must provide required medical surveillance without cost to employees and at a reasonable time and place. The standard's medical surveillance program has two parts, periodic biological monitoring and medical examinations.

The employer's obligation to offer medical surveillance is triggered by the results of the air monitoring program. Medical surveillance must be made available to all employees who are exposed to lead in excess of the action level for more than 30 days a year. The initial phase of the medical surveillance program, which includes blood lead level tests and medical examinations, must be completed for all covered employees. Biological monitoring under the standard consists of BLL tests at least every 6 months after the initial test. If a worker's BLL exceeds  $40 \mu\text{g}/\text{dl}$ , the monitoring frequency must be increased from every 6 months to at least every 2 months and not reduced until two consecutive BLL determinations indicate a BLL below  $40 \mu\text{g}/\text{dl}$ . Employers must notify employees when their BLL are over  $40 \mu\text{g}/\text{dl}$ , in writing, 5 working days of his/her receipt of the test results. The employer must also inform the employee that the standard requires medical removal with economic protection when the BLL exceeds certain criteria. Medical examinations beyond the initial one must be made available on an annual basis if the BLL exceeds  $40 \mu\text{g}/\text{dl}$  at any time during the preceding year. The initial exam provides information to establish a baseline to which subsequent data can be compared. <sup>(23)</sup>

NIOSH recommends that arsenic and all its inorganic compounds be controlled and handled as potential human carcinogens in the workplace, and that exposure be reduced to the lowest feasible limit. The NIOSH REL for arsenic and all its inorganic compounds is  $2 \mu\text{g}/\text{m}^3$  as a ceiling concentration determined in any 15-minute sampling period <sup>(24)</sup>. The current OSHA PEL for inorganic arsenic is  $10 \mu\text{g}/\text{m}^3$  as a TWA over an 8-hour work shift <sup>(21)</sup>.

The occupational exposure criteria for respirable crystalline silica is the NIOSH REL of  $0.05 \text{ mg}/\text{m}^3$ . The NIOSH REL for crystalline silica is intended to prevent silicosis. However, evidence indicates that crystalline silica is a potential occupational carcinogen, and NIOSH is currently reviewing the data on carcinogenicity <sup>(25)</sup>. The OSHA PEL for respirable crystalline silica is  $0.1 \text{ mg}/\text{m}^3$ .

## 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

Skyline Laboratories, Inc. employs local exhaust ventilation and partial enclosures in the sample preparation area, flux mixing, and fire assay areas. In addition, HEPA-filtered, half-mask respirators are worn during hazardous tasks.

#### Sample Preparation Area

Figures 1 and 2 are ventilation system diagrams for the crusher and pulverizer rooms. Three local exhaust ventilation systems serve the sample preparation area. The collection system in the crusher room is a Torit Dust Collection System, rated at 3450 rpm. The jaw crusher and two splitter hoods located in the north side of the pulverizer room is served by a separate Torit Dust Collection System. Air from both systems is filtered prior to being recirculated into a storage room located between these rooms. Twenty high efficiency bag filters are used per system. According to the manufacturer's specifications, these filters are 99.9 percent efficient in removing particles  $\geq 1 \mu\text{m}$  and 98 percent efficient in removing particles  $\geq 0.5 \mu\text{m}$ . Manual shakedown of the accumulated particulate occurs on a monthly basis. The puck and ring mill hood located in the east side of the pulverizing room is served by the third collection system (DCE Volks Unimaster). Air from this system is exhausted directly outside of the building.

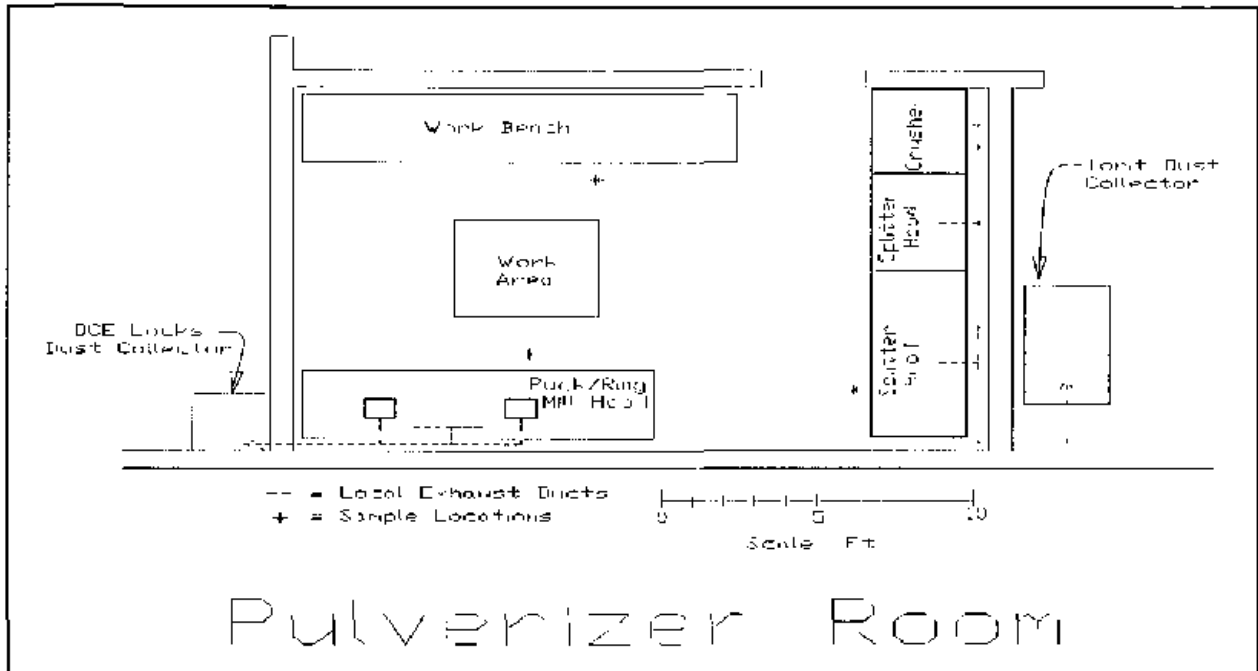


Figure 1 Ventilation systems located in pulverizer room

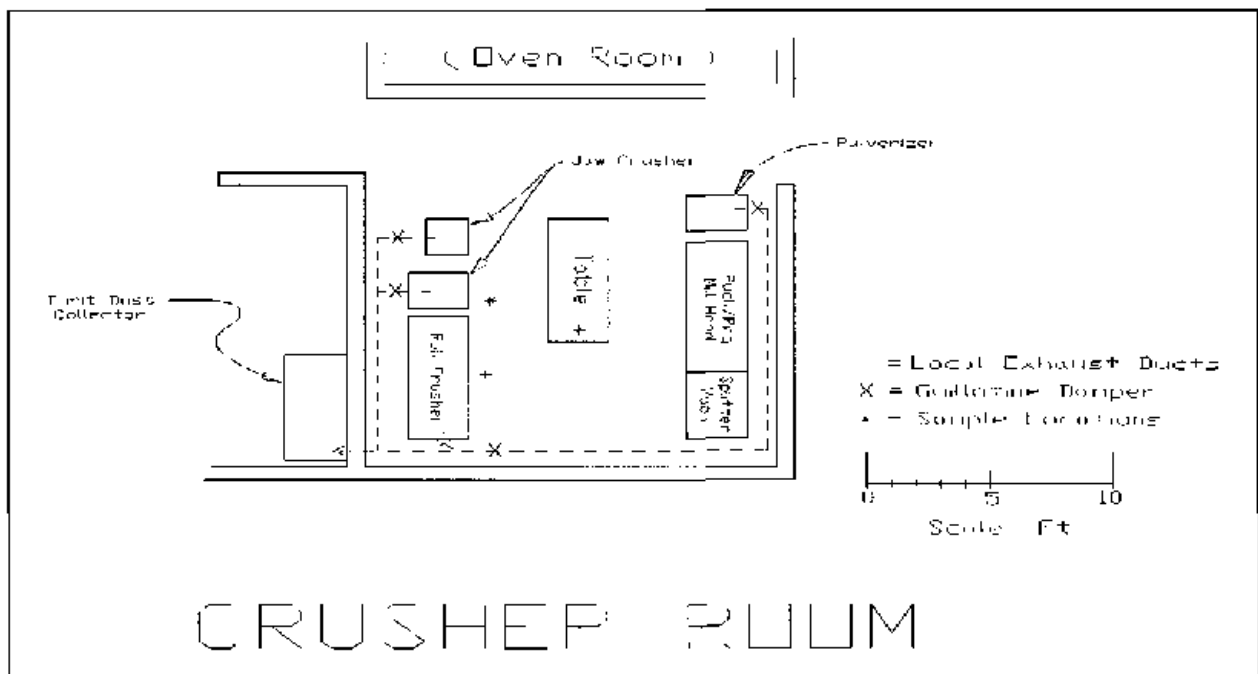


Figure 2 Ventilation systems located in the crusher room

Smoke tube observations in the sample preparation area revealed no unusual findings. Face velocities were measured using a hot wire anemometer at the openings to the crusher equipment and the face of the splitter and puck and ring pulverizer hoods. All measurements were taken such that the ventilation system configuration mirrored the conditions in which the employees used them (i.e., maximum capture velocities). The face velocities of the crusher equipment hood ranged from 350 to 460 fpm and is within the ACGIH Industrial Ventilation Manual recommendations (see Figure 3) <sup>(26)</sup>. However, the face velocities at the hood opening for both the splitter and puck and ring mill hoods ranged from 20 to 54 fpm. These velocities are less than recommended capture velocities (200 to 500 fpm). Capture Velocities of 200 to 500 fpm are needed because use of compressed air can create significant turbulence within the hood.

Range of Capture Velocities <sup>(1)(2)(3)</sup>		
Condition of Dispersion of Contaminant	Example	Capture Velocity, fpm
Released with practically no velocity into quiet air	Evaporation from tanks, degreasing, etc	50-100
Released at low velocity into moderately still air	Spray booths, intermittent container filling, low speed conveyor transfers, welding plating pickling	100-200
Active generation into zone of rapid air motion	Spray painting in shallow booths barrel filling conveyor loading crushers	200-500
Released at high initial velocity into zone of very rapid air motion	Grinding abrasive blasting, tumbling	500-2000

In each category above, a range of capture velocity is shown. The proper choice of values depends on several factors.

<i>Lower End of Range</i>	<i>Upper End of Range</i>
1 Room air currents minimal or favorable to capture	1 Disturbing room air currents
2 Contaminants of low toxicity or of nuisance value only	2 Contaminants of high toxicity
3 Intermittent low production	3 High production heavy use
4 Large hood large air mass in motion	4 Small hood local control only

Figure 3 Range of capture velocities

#### Fire Assay Area

The ventilation systems in the fire assay area consisted of a downdraft ventilated hood controlling litharge mixing operations, a large canopy hood located over the two cupel furnaces, and a canopy hood located over the crucible furnace.

See Figure 4 for a schematic drawing of the downdraft ventilated hood that controls the litharge mixing operations. The litharge, fluxing agents, and assay sample are added to the crucible under the downdraft ventilated hood. The litharge mixing hood has a face opening of 4.5' x 1.3', with a face area of 5.9 square feet (sq/ft). The face velocity at the litharge hood averaged 160 fpm, with an average air volume of 950 cfm. ACGIH Ventilation Manual

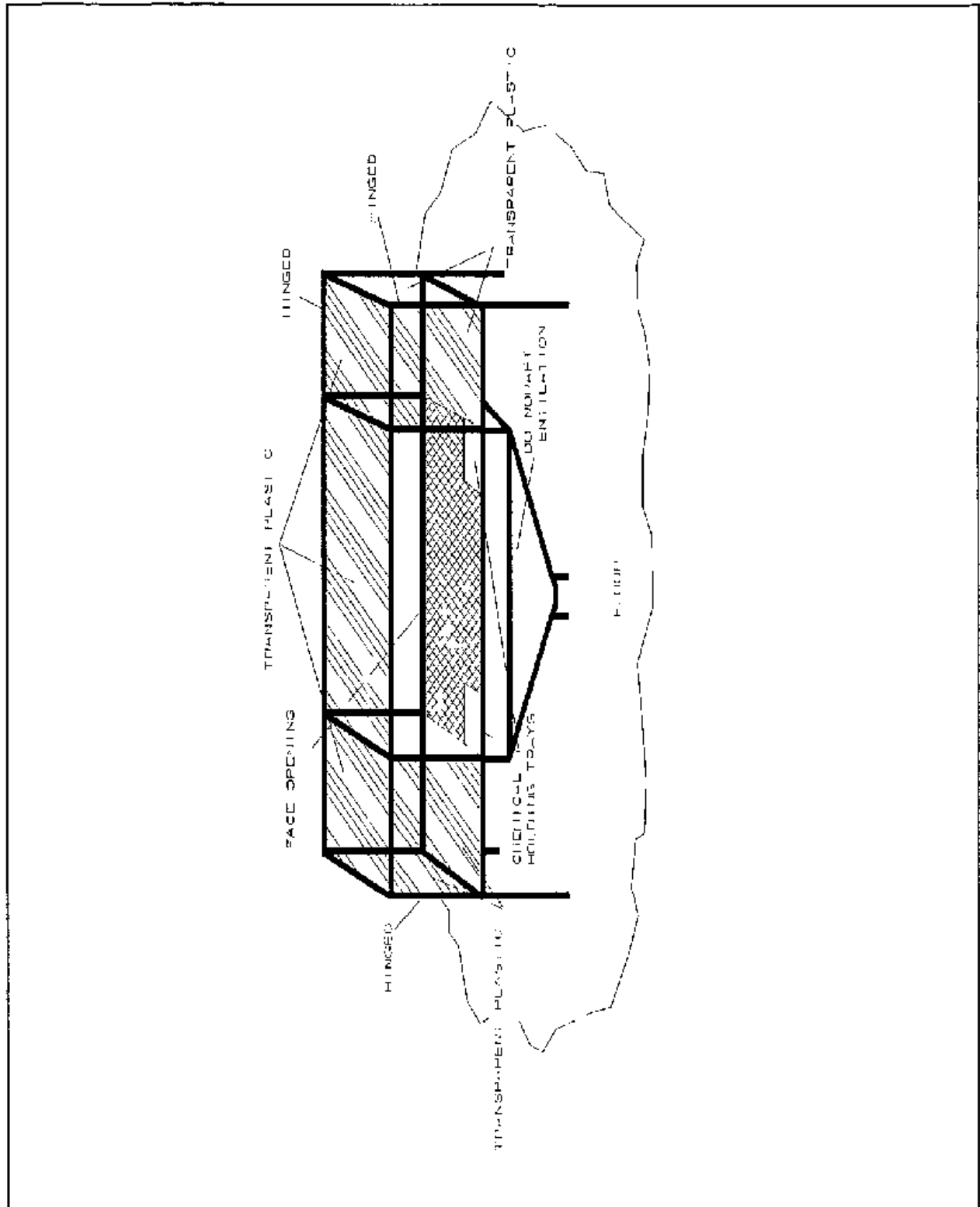


Figure 4 Litharge mixing down draft ventilated hood

recommends 100 to 200 fpm capture velocity (Table 3-1) for intermittent container filling operations <sup>(26)</sup> This is within the guidelines set in the ACGIH Ventilation Manual

Smoke tubes were used to visualize the air currents in the fire assay area. Smoke tube results indicated that the canopy hoods located over the furnaces in the fire assay area did not extend out far enough in front of the furnaces or have adequate air volume to capture the smoke. Smoke escaped the capture of the canopy hoods and rose to the ceiling where it exited through an opening located around the exhaust ventilation duct.

The canopy hood located over the two cupel furnaces has an opening of 8' 6" x 3' 5". The canopy hood extends down over the top of the two cupel furnaces. The area under the canopy hood is 30.4 square feet, however, the opening is blocked by the two furnaces (21 square feet). Therefore, the actual opening is 9.4 square feet. The canopy hood had an average face velocity of 110 fpm with an air volume of 1034 cfm. The hood exhaust volume of 1034 cfm was less than the convection currents of approximately 2000 cfm generated by the two furnaces. The convection currents were calculated using the formula  $q_o = 29[(H')(Ap^2)(m)]^{1/3}$  <sup>(27)</sup>

where  $q_o$  = air induction rate at upper limits of hot source (cfm)  
 $Ap$  = cross-sectional area of airstream  
 $m$  = height of column receiving heat  
 $H'$  = convection heat transfer rate, BTU per minute

The canopy hood extends out in front of the two furnace doors 3". The hood should extend out approximately 6" to 8" in front of the furnaces to capture the plume given off at a 5-degree angle from the heat source <sup>(27)</sup>

The canopy hood located over the crucible furnace has an opening of 3' 3" x 3' 8" with an area of 12.5 square feet. The average face velocity into the hood was 60 fpm with an air exhaust volume of 750 cfm. This exhaust volume was less than the convection currents of approximately 1100 cfm calculated to be generated by this furnace <sup>(27)</sup>. The canopy hood on the crucible furnace should also extend 6" to 8" over all sides of the furnace <sup>(27)</sup>

## ENVIRONMENTAL MONITORING

### SAMPLE PREPARATION AREA

An environmental evaluation was conducted in the sample preparation area to determine the potential for exposure to crystalline silica. Bulk samples were taken to determine the percent silica in the assay sample material. Air sampling was conducted over a 3-day period. Personal air samples were taken on the two employees who work in this area. Area air samples were taken throughout the sample preparation area and outside of the building to characterize exposures at select locations. See Figures 1 and 2 for area sample locations.

Air samples for crystalline silica were collected and analyzed according to NIOSH analytical method 7500 (28). This method was modified as follows: (1) filters were dissolved in tetrahydrofuran rather than being ashed in a furnace and (2) standards and samples were run concurrently and an external calibration curve was prepared from the integrated intensities rather than using the suggested normalization procedure.

Samples were collected using battery-operated sampling pumps. The pumps were used to draw air through 37-mm (diameter), 5- $\mu$ m (pore size) PVC membrane filters, mounted in series with 10-mm nylon cyclones at an approximate flow rate of 1.7 lpm. Nylon cyclones were used to determine the respirable portion of crystalline silica in the airborne dust. The sampling pumps were calibrated before and after sampling. The PVC membrane filters were analyzed using x-ray powder diffraction.

#### FIRE ASSAY AREA

An environmental evaluation was conducted in the fire assay area to determine the potential for exposure to lead, arsenic, and other elements. Air sampling was conducted over a 3-day period. Each of the two workers in the fire assay area wore two sampling pumps, one personal air sample was collected and analyzed for lead and the other personal air sample was collected and analyzed for elements. Area air samples collected for lead, elements, and arsenic were taken throughout the fire assay area. Area samples were placed around the ventilation controls to assess the effectiveness of the controls. Area samples were also collected at the pouring station to characterize exposures at this location. See Figure 5 for fire assay area sample locations.

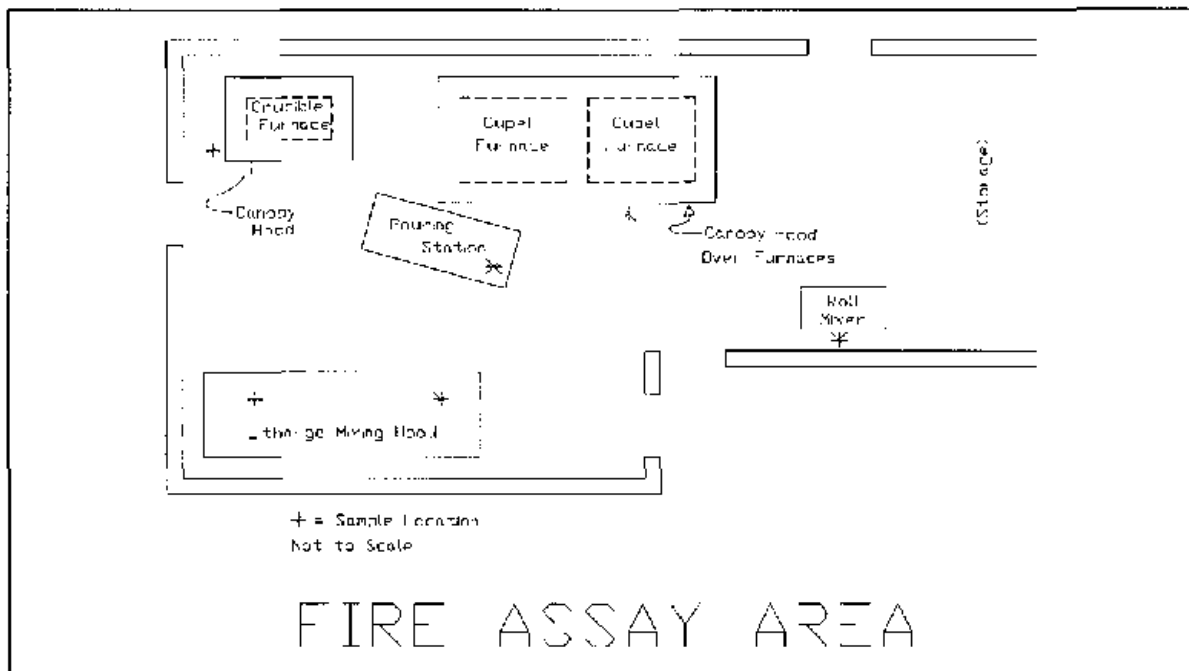


Figure 5 Sample Locations in the Fire Assay Area



Air samples for lead were collected and analyzed according to NIOSH analytical sampling method 7105 <sup>(29)</sup>. Air samples were collected using battery-operated sampling pumps to draw air through 37-mm (diameter), 0.8- $\mu$ m (pore size) membrane filters, at an approximate flow rate of 3 lpm. The sampling pumps were calibrated before and after sampling. The membrane filters were analyzed using a Graphite Furnace Spectrometer.

Air samples for arsenic were collected and analyzed according to NIOSH analytical methods 6001 and 7901 <sup>(30,31)</sup>. Air samples were collected on a 37-mm (diameter), 0.8- $\mu$ m (pore size) membrane filter followed by a 600-mg coconut charcoal tube, with a Gilian low flow pump (model LFS-113) operating at a flow rate of 0.2 lpm. The charcoal tube was used because of the possible presence of volatilized arsenic given off during furnace and lead button pouring operations. The sampling pumps were calibrated before and after sampling. The samples were analyzed using a Graphite Furnace AA Spectrometer.

Air samples for elements were collected and analyzed according to NIOSH analytical method 7300 <sup>(32)</sup>. Samples were collected using battery-operated sampling pumps to draw air through 37-mm (diameter), 0.8- $\mu$ m (pore size) membrane filters, at an approximate flow rate of 3 lpm. The sampling pumps were calibrated before and after sampling.

## RESULTS AND DISCUSSION

### SAMPLE PREPARATION AREA

Approximately 130 assay samples were processed in the sample preparation area over the 3 days of this survey. The majority of the assay samples were core samples from the same mine. One random bulk sample was taken to represent these assay samples (grey, slate-like appearance). This sample contained 26 percent quartz (most common form of crystalline silica) and no cristobalite (octahedral form of crystalline silica). Another bulk sample was taken of an assay sample representing approximately 5 percent of the samples processed over this period (pure white appearance). This sample contained 91 percent quartz and no cristobalite.

All airborne silica concentrations were below applicable evaluation criteria. Eighteen area samples and five personal breathing zone (PBZ) samples were taken. The employees who work in this area characterized the work activities as normal. The collection times for the area and PBZ samples ranged from 400 to 465 minutes. One anomaly was a PBZ sample that ran only 301 minutes because the worker left early. All area and PBZ results were below the analytical limit of detection (LOD) for crystalline silica. The LOD is defined as the smallest amount of analyte which can be distinguished from the background <sup>(33)</sup>. In terms of weight on the filter, the crystalline silica was less than 0.01 mg per filter for quartz and less than 0.015 mg per filter for cristobalite. All airborne silica concentrations (respirable fraction) were less than 0.02 mg/m<sup>3</sup> for the area samples and 0.03 mg/m<sup>3</sup> for the PBZ samples based on the minimum collection volumes.

## FIRE ASSAY AREA

### Lead

#### Personal Breathing Zone Samples--

The results of the PBZ sampling for lead are summarized in Table 2, individual sampling data for lead are listed in Appendix A. According to the workers in the area, work activities during the survey were normal. Twenty PBZ samples were collected on two workers in the fire assay area and analyzed for lead (NIOSH method 7150) and elements (NIOSH method 7300). Samples collected for elements had detectable levels of lead reported. Results of lead from element samples were combined with results from the lead samples to determine average lead exposures. The collection times for the PBZ samples ranged from 200 to 250 minutes. During the first day, Worker A had an arithmetic mean of  $4 \mu\text{g}/\text{m}^3$ . Worker B was absent this first day. On the second day, Worker A had an arithmetic mean of  $9 \mu\text{g}/\text{m}^3$  and Worker B had an arithmetic mean of  $23 \mu\text{g}/\text{m}^3$ . The third day of the sampling period Worker A had an arithmetic mean of  $8 \mu\text{g}/\text{m}^3$  and Worker B had a arithmetic mean of  $47 \mu\text{g}/\text{m}^3$ .

Table 2 Personal Sample Concentrations of Lead  
in Fire Assay Area ( $\mu\text{g}/\text{m}^3$ )

Worker	Day	Average Sample Time (min)	Arithmetic Mean	Standard Deviation	Range
A	12/14/93	240	4	2	2 - 7
A	12/15/93	230	9	7	2 - 20
A	12/16/93	210	8	4	4 - 14
B	12/15/93	220	23	21	2 - 49
B	12/16/93	160	47	7	40 - 59

Time weighted averages (TWA), over the sampling period, are shown in Table 3. The lead (TWA) exposures ranged from 4 to  $49 \mu\text{g}/\text{m}^3$ , which are less than the OSHA PEL. However, the potential to exceed the OSHA PEL of  $50 \mu\text{g}/\text{m}^3$  and action level of  $30 \mu\text{g}/\text{m}^3$  does exist. Exceeding the action level triggers a number of requirements under the OSHA Lead Standard previously mentioned. Worker A and B performed the same type of operations throughout the survey. Worker A had TWAs that were considerably less than Worker B. This indicates that work practices may contribute to worker exposures in the fire assay area.

Two short term PBZ samples were collected when Worker A mixed a large batch of fluxing agents under the downdraft ventilated litharge hood. During this mixing operation, 50 pounds of litharge were added to the fluxing agents inside the hood. The short-term samples were also collected during hand mixing operations where fluxing agents were mixed with ore samples in a crucible inside the ventilated hood. The two short-term samples collected

Table 3 Time-Weighted Average (TWA) Exposures  
Over the Sampling Period

Worker	Day	Sample Period (min)	TWA Concentration ( $\mu\text{g}/\text{m}^3$ )
A	12/14/93	484	4
A	12/15/93	465	7
A	12/16/93	419	8
B	12/15/93	430	20
B	12/16/93	317	49

during these operations indicated lead exposure to be less than  $2 \mu\text{g}/\text{m}^3$ . This indicates that the litharge hood does control worker exposures during litharge mixing operations.

Area Samples--

A summary of area and background (ambient) lead concentrations measured during the survey are presented in Table 4. Forty-nine area samples were collected in the fire assay area. Figure 5 shows area sample locations in this area.

Table 4 Summary of Lead Area Sample  
Concentrations in Fire Assay Area ( $\mu\text{g}/\text{m}^3$ )

Area	Number of Samples	Average Sample Time (min)	Arithmetic Mean	Standard Deviation	Range
Litharge Hood (left)	6	220	5	3	1 - 10
Litharge Hood (right)	6	220	5	3	1 - 10
Cupel Furnace*	4	230	122	76	1 - 200
Crucible Furnace	6	230	19	9	8 - 30
Pouring Station	12	230	15	11	1 - 34
Background (indoor)	6	420	0.1	0.1	0 - 0.2
Background (outdoor)	6	420	0.1	0.1	0 - 0.3

\* Area samples taken on the second day of survey when the cupel furnace was not in operation were omitted in this summary.

Area samples collected on the right side of the litharge hood had an arithmetic mean of  $3 \mu\text{g}/\text{m}^3$  for the first day,  $6 \mu\text{g}/\text{m}^3$  for the second day, and  $5 \mu\text{g}/\text{m}^3$  for the third day of the sampling period. Area samples collected on the left side of the litharge hood had an arithmetic mean of  $3 \mu\text{g}/\text{m}^3$  for the first day,  $6 \mu\text{g}/\text{m}^3$  for the second day, and  $7 \mu\text{g}/\text{m}^3$  for the third day of the sampling period. These results verify that the enclosed litharge mixing hood does control lead exposures during litharge mixing operations.

Area samples collected at the large canopy hood covering the two cupel furnaces had an arithmetic mean of  $62 \mu\text{g}/\text{m}^3$  for the first day,  $8 \mu\text{g}/\text{m}^3$  for the second day, and  $183 \mu\text{g}/\text{m}^3$  for the third day of the sampling period. The cupel furnaces were not operated on the second day. These results verify that the large canopy hood over the two cupel furnaces is not controlling lead exposures adequately. This control should be modified according to specifications given in the engineering control section of this report.

Area samples collected at the small canopy hood covering the crucible furnace had an arithmetic mean of  $12 \mu\text{g}/\text{m}^3$  for the first day,  $19 \mu\text{g}/\text{m}^3$  for the second day, and  $25 \mu\text{g}/\text{m}^3$  for the third day.

Area samples collected at the pouring station had an arithmetic mean of  $10 \mu\text{g}/\text{m}^3$  for the first day,  $14 \mu\text{g}/\text{m}^3$  for the second day, and  $23 \mu\text{g}/\text{m}^3$  for the third day.

#### Arsenic

##### Personal Samples--

The ore bodies analyzed in this lab are from various mine sites through-out the world. Some of the ore analyzed is high in arsenic. Six personal air samples were collected and analyzed for elements over the 3-day sampling period. The results of some of these samples did show personal arsenic exposures in the fire assay area. The results of the personal air sampling for arsenic are summarized in Table 5. Air sampling data for arsenic are listed in Appendix B.

Time-weighted averages (TWA), over the sampling period, are shown in Table 6. The arsenic (TWA) exposures ranged from 0.2 to  $8 \mu\text{g}/\text{m}^3$ , which are less than the OSHA PEL. However, the NIOSH REL of  $2 \mu\text{g}/\text{m}^3$  (ceiling limit) was exceeded and potential to exceed the OSHA PEL of  $10 \mu\text{g}/\text{m}^3$  does exist.

##### Area Samples--

An earlier NIOSH engineering control study<sup>(34)</sup> 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, area samples at the pouring station for arsenic were taken using a sampling train consisting of a filter followed by a charcoal tube in order to capture any arsine or arsenic vapor that might pass through the filter. The arsenic results collected using the filter/charcoal tube combination are also presented in Appendix B. All of these arsenic samples were at or below  $3.2 \mu\text{g}/\text{m}^3$  for this method. Area samples for arsenic were also collected at the drying ovens using the filter/tube combination, although the drying ovens were not used during our survey. All samples for arsenic collected in the

Table 5 Personal Sample Concentrations  
of Arsenic in Fire Assay Area ( $\mu\text{g}/\text{m}^3$ )

Worker	Day	Average Sample Time (min)	Arithmetic Mean	Standard Deviation	Range
A	Dec 14	243	8	8	0.1 - 15
A	Dec 15	234	0.3	0.1	0.2 - 0.5
A	Dec 16	212	0.2	0.1	0.2 - 0.3
B	Dec 15	215	3	3	0.2 - 5.6
B	Dec 16	160	0.4	0.1	0.3 - 0.5

Table 6 Time-Weighted Averages (TWA)  
of Arsenic Exposures Over the Sampling Period

Worker	Day	Sample Period (min)	TWA Concentration ( $\mu\text{g}/\text{m}^3$ )
A	12/14/93	485	8
A	12/15/93	468	0.4
A	12/16/93	424	0.2
B	12/15/93	430	3
B	12/16/93	321	0.4

drying area were below the limit of detection which resulted in arsenic concentrations less than  $1.1 \mu\text{g}/\text{m}^3$ . Area samples collected for elements at the furnaces in the fire assay area all had arsenic concentrations less than  $1.3 \mu\text{g}/\text{m}^3$ .

#### Other Elements

The average personal sample concentration to various metals and minerals are presented in Appendix C. The concentration of each of the metals including cobalt and chromium were all at low levels and were well controlled during the survey. Nevertheless, an increase in metal content of the mine assay ore (e.g., different ore bodies) may result in higher airborne concentrations in the mine assay laboratory.

## WORK PRACTICES AND PERSONAL PROTECTIVE EQUIPMENT

### Sample Preparation Area

The two employees who work in this area have both been employed over 7 years. These employees were conscientious regarding proper use of the sample preparation equipment and their personal protective equipment. NIOSH/MSHA-approved, half-face, powered, air-purifying respirators are used by personnel while performing crushing operations. NIOSH/MSHA-approved, disposable dust masks were used during the splitting and pulverizing operations (North, Model 7175). Ear plugs or ear muffs are worn by workers in the sample preparation areas.

Several work practices appear to reduce potential exposures. Guillotine gates are installed throughout the local exhaust ventilation system. Employees configure the ventilation system (by opening and closing the guillotine gates) to maximize capture velocities associated with the equipment in use. Paint brushes and compressed air are utilized to clean out the ring and puck pulverizers. Employees are careful to sparingly use the compressed air because they don't want to dirty the room and cross-contaminate the assay samples. According to the employees, this is sometimes a problem with temporary employees who infrequently use this area.

### Fire Assay Area

In the fire assay area, aluminum-lined gloves, lab coats, aprons, safety glasses, and safety shoes are utilized by workers. HEPA-filtered half mask respirators are worn during litharge mixing operations.

### HYGIENE

A shower facility and a separate break area are available for employees at the laboratory. No eating, drinking, or smoking is permitted in the laboratory areas.

## CONCLUSIONS AND RECOMMENDATIONS

### SAMPLE PREPARATION AREA

As demonstrated by the air sampling results, the local ventilation systems in the sample preparation area appear to control exposures. Results for the bulk samples revealed 26 to 91 percent crystalline silica. No area or personal air samples were above applicable evaluation criteria. These results appear related to several factors, including (1) small quantities of material

processed, (2) good ventilation of the crusher equipment, (3) enclosure of the puck and ring mills, and (4) conscientious work practices. However, several recommendations are presented to improve the current setup and reduce potential crystalline silica exposures.

- 1 The risk of exposure to crystalline silica is greatly increased through the use of compressed air. Conscientious efforts to minimize the use of compressed air have helped to reduce what could have been significant exposures. A portable high efficiency particulate air (HEPA) filter vacuum system or a vacuum system connected to the local ventilation system is recommended to prevent unnecessary silica exposures and to reduce the risk of cross contamination between assay samples.
- 2 The face velocities on all of the ventilation hoods ranged from 20-54 fpm. These measurements were below design recommendations of 200 to 500 fpm<sup>(26)</sup>. These capture velocities were chosen due to the use of compressed air which creates significant turbulence within the hoods. If vacuuming was used, reduced capture velocities could be used to effectively control exposures.
- 3 The face velocities for all of the hoods could be economically increased by decreasing the hood areas. This could be accomplished by adding transparent plastic to the existing hoods to decrease the face area, yet still maintain visibility so that the employees could effectively perform their duties. A 25 percent decrease in the hood face area could result in a 25 percent increase in face velocities.
- 4 The dust collection systems used in the crusher room and the north side of the pulverizer room recirculates filtered air back into the sample preparation area. The problem associated with this practice is that the exhausts from these systems could potentially add to the respirable silica concentrations within this area if the system is not operating effectively. Recirculation of filtered air can be safely accomplished if the current control systems are modified to those recommended by the ACGIH Ventilation Manual<sup>5</sup> (see Figure 6)<sup>(26)</sup>.

#### FIRE ASSAY AREA

As demonstrated by air sampling results, the enclosed downdraft ventilation hood does appear to be effective in controlling worker exposures during litharge mixing operations. Smoke tube test and air sampling results in the fire assay area indicated that the ventilation systems on the furnaces are not working effectively. Personal exposures in the fire assay area could be a result from the ventilation systems (located over the furnaces) not functioning properly. Several recommendations are presented to improve the ventilation controls over the furnaces and reduce potential lead and arsenic exposures.

- 1 The hood exhaust volume of the large canopy hood located over the two cupel furnaces should be increased to 2000 cfm to control the convection currents generated by the two furnaces<sup>(27)</sup>. The small canopy hood

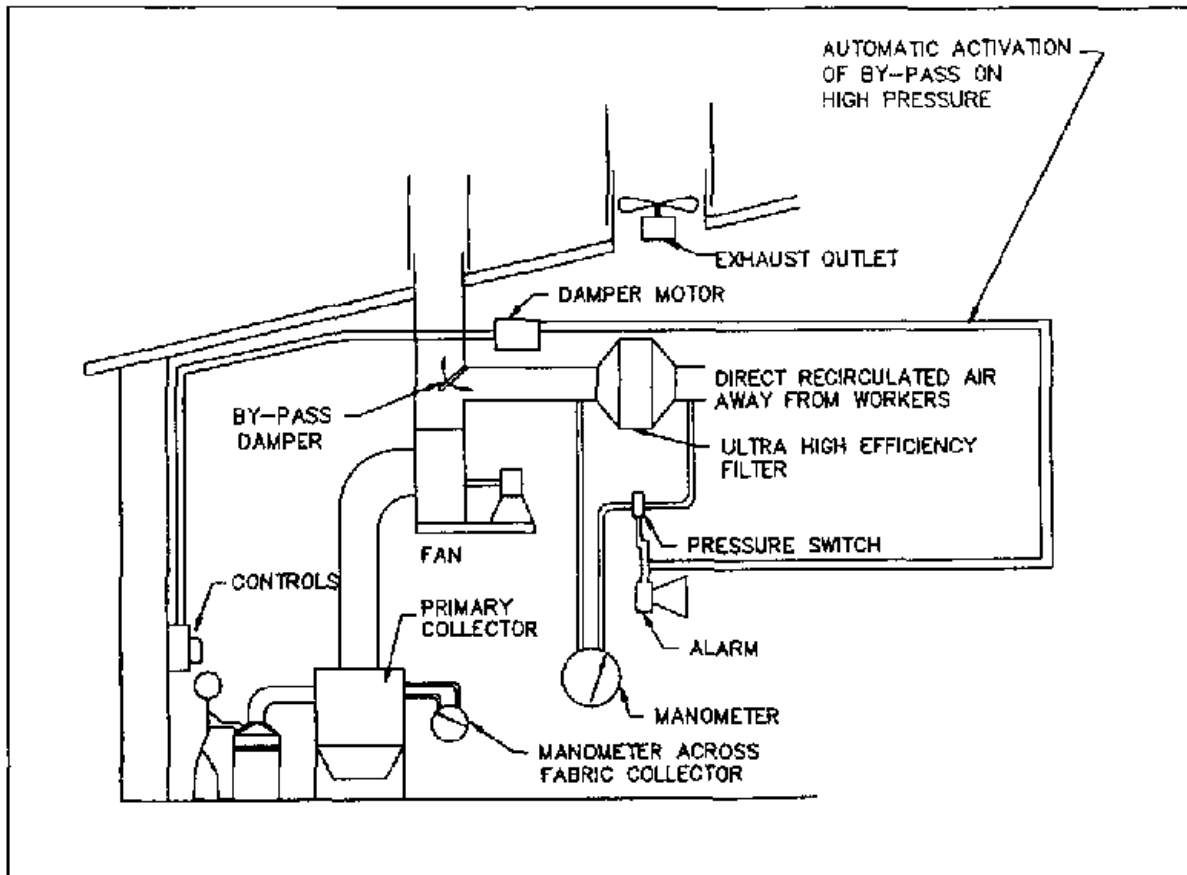


Figure 6 Recirculation of filtered air

located over the crucible furnace should have the hood exhaust volume increased to 1100 cfm to control convection currents generated by this furnace <sup>(27)</sup>

- 2 The large canopy hood extends out in front of the two furnace doors 3" It is recommended that the hood be modified to extend out in front of the furnace doors and around the furnace approximately 6" to 8" to capture the 5-degree plume given off by the heat source <sup>(27)</sup> The canopy hood on the crucible furnace should also extend 6" to 8" over all sides of the furnace
- 3 It is recommended that a respiratory protection program be set up in accordance with the OSHA lead standard <sup>(23)</sup> It is also recommended that workers in the fire assay area wear HEPA-filtered respirators during furnace and pouring operations
- 4 During pouring operations, it is recommended that workers place the pouring table as close as possible to the ventilation hoods and that workers do not stand between the pouring operation and the exhaust air flow



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APPENDIX A

SKYLINE LABS-LEAD SAMPLES

DATE	DAY	SAMPLE NUMBER	TYPE	MEN CODE	SAMPLE LOCATION	LOCATION DETAILS	SAMPLE TIME (min)	FLOW RATE (LPM)	VOLUME (liters)	LEAD DET LIMIT	LEAD MASS (ug)	LEAD CONC (ug/m3)
12/14/93	DEC_14	103	PERS	A	FIREASSAY		242	30	7260	0.4	21	28
12/14/93	DEC_14	106	PERS	A	FIREASSAY		243	30	7290	0.4	43	58
12/14/93	DEC_14	203	PERS	A	FIREASSAY		246	30	7380	0.1	13	18
12/14/93	DEC_14	207	PERS	A	FIREASSAY		237	30	7110	0.1	48	68
12/14/93	DEC_14	100	AREA		POURING ST		247	30	7410	0.4	9	121
12/14/93	DEC_14	102	AREA		Furnace2cr		249	30	7470	0.4	93	124
12/14/93	DEC_14	209	AREA		LITHARGH	LEFT	174	30	5220	0.1	22	42
12/14/93	DEC_14	208	AREA		LITHARGH	RIGHT	173	30	5190	0.1	18	25
12/14/93	DEC_14	115	AREA		POURING ST		240	30	7200	0.4	42	58
12/14/93	DEC_14	206	AREA		POURING ST		235	30	7050	0.1	41	58
12/14/93	DEC_14	110	AREA		Furnace1cu		252	30	7560	0.4	82	121.7
12/14/93	DEC_14	201	AREA		LITHARGH	LEFT	249	30	7470	0.1	0.73	10
12/14/93	DEC_14	101	AREA		Furnace1cu		245	30	7350	0.4	1	14
12/14/93	DEC_14	202	AREA		LITHARGH	RIGHT	250	30	7500	0.1	19	25
12/14/93	DEC_14	111	AREA		Furnace2cr		182	30	5460	0.4	64	117
12/14/93	DEC_14	200	AREA		POURING ST		246	30	7380	0.1	11	149
12/15/93	DEC_15	219	PERS	B	FIREASSAY		237	30	7110	0.1	13	18
12/15/93	DEC_15	124	PERS	A	FIREASSAY		186	30	5580	0.4	6	10.8
12/15/93	DEC_15	225	PERS	B	FIREASSAY		192	30	5760	0.1	28	48.6
12/15/93	DEC_15	224	PERS	A	FIREASSAY		180	30	5400	0.1	11	20.4
12/15/93	DEC_15	116	PERS	A	FIREASSAY		282	30	8460	0.4	16	19
12/15/93	DEC_15	119	PERS	B	FIREASSAY		238	30	7140	0.4	15	21
12/15/93	DEC_15	120	PERS	B	FIREASSAY		192	30	5760	0.4	23.00	39.9
12/15/93	DEC_15	216	PERS	A	FIREASSAY		282	30	8460	0.1	170	20
12/15/93	DEC_15	121	AREA		POURING ST		216	30	6540	0.4	16	24.5
12/15/93	DEC_15	222	AREA		LITHARGH	RIGHT	203	30	5090	0.1	59	97
12/15/93	DEC_15	213	AREA		LITHARGH	LEFT	281	30	8430	0.1	1.5	1.8
12/15/93	DEC_15	116	AREA		POURING ST		278	30	8340	0.4	11	13
12/15/93	DEC_15	212	AREA		POURING ST		281	30	8400	0.1	0.96	11
12/15/93	DEC_15	117	AREA		Furnace1cu	NOT ON	280	30	8400	0.4	0.49	0.6
12/15/93	DEC_15	122	AREA		Furnace2cr		212	30	6360	0.4	19	29.9
12/15/93	DEC_15	114	AREA		Furnace2cr		281	30	8430	0.4	6.5	7.8
12/15/93	DEC_15	223	AREA		POURING ST		210	30	6300	0.1	17	27.0
12/15/93	DEC_15	221	AREA		ROLL MIXER		154	30	4620	0.1	0.78	1.7
12/15/93	DEC_15	123	AREA		Furnace1cu	NOT ON	205	30	6150	0.4	9.5	15.4
12/15/93	DEC_15	214	AREA		LITHARGH	RIGHT	281	30	8430	0.1	1.2	1.4
12/15/93	DEC_15	220	AREA		LITHARGH	LEFT	203	30	6090	0.1	5.8	9.5
12/16/93	DEC_16	232	PERS	A	FIREASSAY	LT	224	30	6720	0.03	29	43
12/16/93	DEC_16	239	PERS	A	FIREASSAY	ST	18	30	540	0.03	0.06	1.1
12/16/93	DEC_16	243	PERS	A	FIREASSAY	LT	190	30	5700	0.03	4.1	7.2
12/16/93	DEC_16	234	PERS	B	FIREASSAY		203	30	6090	0.03	36	59.1
12/16/93	DEC_16	133	PERS	B	FIREASSAY		117	30	3510	0.4	15	42.7
12/16/93	DEC_16	228	PERS	B	FIREASSAY		109	30	3270	0.03	13	39.8
12/16/93	DEC_16	134	PERS	A	FIREASSAY	LT	210	30	5300	0.4	9	14.3
12/16/93	DEC_16	144	PERS	B	FIREASSAY		204	30	6120	0.4	28	45.8
12/16/93	DEC_16	128	PERS	A	FIREASSAY	LT	214	30	6420	0.4	4.4	6.9
12/16/93	DEC_16	233	PERS	A	FIREASSAY	ST	20	30	600	0.03	0.098	1.6
12/16/93	DEC_16	236	AREA		LITHARGH	RIGHT	224	30	6720	0.03	3.2	4.8
12/16/93	DEC_16	230	AREA		LITHARGH	LEFT	225	30	6750	0.03	3.8	5.6
12/16/93	DEC_16	130	AREA		POURING ST		214	30	6420	0.4	7.2	11.2

SKYLINE LABS - LEAD SAMPLES

DATE	DAY	SAMPLE NUMBER	TYPE	MEN CODE	SAMPLE LOCATION	LOCATION DETAILS	SAMPLE TIME (min)	FLOW RATE (LPM)	VOLUME (liters)	LEAD DET LIMIT	LEAD MASS (ug)	LEAD CONC (ug/m3)
12/16/93	DEC_16	135	AREA		POURING ST		208	3.0	609.0	0.4	20	32.8
12/16/93	DEC_16	131	AREA		Furnace2cr		216	3.0	648.0	0.4	13	20.1
12/16/93	DEC_16	139	AREA		Furnace1cu		201	3.0	603.0	0.4	97	160.9
12/16/93	DEC_16	132	AREA		Furnace1cu		212	3.0	636.0	0.4	139	204.4
12/16/93	DEC_16	246	AREA		POURING ST	RIGHT	185	3.0	555.0	0.03	19	34.2
12/16/93	DEC_16	242	AREA		LITHARGH		179	3.0	537.0	0.03	3.2	6.0
12/16/93	DEC_16	129	AREA		Furnace2cr		205	3.0	615.0	0.4	18	29.3
12/16/93	DEC_16	247	AREA		LITHARGH	LEFT	180	3.0	540.0	0.03	4.1	7.6
12/16/93	DEC_16	235	AREA		POURING ST		225	3.0	675.0	0.03	7.8	11.6

BACKGROUND SAMPLES (LEAD)

12/14/93	DEC_14	205	BKGR		OUTDOOR		409	3.0	1227.0	0.1	0.4	0.3
12/14/93	DEC_14	204	BKGR		INDOOR		413	3.0	1239.0	0.1	0.3	0.2
12/14/93	DEC_14	104	BKGR		INDOOR		413	3.0	1239.0	0.03	0.26	0.2
12/14/93	DEC_14	105	BKGR		OUTDOOR		409	3.0	1227.0	0.03	0.39	0.3
12/15/93	DEC_15	217	BKGR		OUTDOOR		442	3.0	1326.0	0.1	0.1	0.1
12/15/93	DEC_15	218	BKGR		INDOOR		444	3.0	1332.0	0.1	0.1	0.1
12/15/93	DEC_15	108	BKGR		INDOOR		444	3.0	1332.0	0.03	0.04	0.0
12/15/93	DEC_15	109	BKGR		OUTDOOR		442	3.0	1326.0	0.03	0.03	0.0
12/16/93	DEC_16	241	BKGR		INDOOR		407	3.0	1221.0	0.03	0.037	0.1
12/16/93	DEC_16	237	BKGR		OUTDOOR		410	3.0	1230.0	0.03	0.11	0.1
12/16/93	DEC_16	138	BKGR		INDOOR		407	3.0	1221.0	0.03	0.04	0.0
12/16/93	DEC_16	136	BKGR		OUTDOOR		409	3.0	1227.0	0.03	0.08	0.1

FIELD BLANKS (LEAD)

12/14/93	DEC_14	210	BLANK		BLANK		0	3.0	0.0	0.1	0.1	
12/14/93	DEC_14	211	BLANK		BLANK		0	3.0	0.0	0.1	0.1	
12/14/93	DEC_14	107	BLANK		BLANK		0	3.0	0.0	0.03	0.03	
12/14/93	DEC_14	112	BLANK		BLANK		0	3.0	0.0	0.03	0.03	
12/15/93	DEC_15	227	BLANK		BLANK		0	3.0	0.0	0.1	0.1	
12/15/93	DEC_15	228	BLANK		BLANK		0	3.0	0.0	0.1	0.1	
12/15/93	DEC_15	231	BLANK		BLANK		0	3.0	0.0	0.1	0.1	
12/15/93	DEC_15	127	BLANK		BLANK		0	3.0	0.0	0.03	0.03	
12/15/93	DEC_15	126	BLANK		BLANK		0	3.0	0.0	0.03	0.03	
12/15/93	DEC_15	125	BLANK		BLANK		0	3.0	0.0	0.03	0.03	
12/16/93	DEC_16	229	BLANK		BLANK		0	3.0	0.0	0.03	0.03	
12/16/93	DEC_16	240	BLANK		BLANK		0	3.0	0.0	0.03	0.03	
12/16/93	DEC_16	141	BLANK		BLANK		0	3.0	0.0	0.03	0.03	
12/16/93	DEC_16	137	BLANK		BLANK		0	3.0	0.0	0.03	0.03	

APPENDIX B

ARSENIC FILTER PLUS TUBE SAMPLES										ARSENIC MASS (filter)			ARSENIC MASS (tube)			ARSENIC MASS (total)			ARSENIC CONC (ug/m3)		
DATE	DAY	SAMPLE NUMBER	TYPE	MEN CODE	SAMPLE LOCATION	LOCATION DETAILS	SAMPLE TIME (min)	FLOW RATE (LPM)	VOLUME (liters)	FILTER	ARSENIC MASS (filter)	ARSENIC MASS (tube)	ARSENIC MASS (total)	ARSENIC CONC (ug/m3)	ARSENIC CONC (ug/m3)	ARSENIC CONC (ug/m3)	ARSENIC CONC (ug/m3)	ARSENIC CONC (ug/m3)	ARSENIC CONC (ug/m3)		
12/14/93	DEC_14	251/531	AREA		POURING ST	POURING ST	123	0.2	24.6	NQ	0.06	0.01	0.07	0.07	2.9						
12/14/93	DEC_14	256/534	AREA		DRYOVEN	RIGHT	120	0.2	24.0	ND	0.021	0.008	0.03	0.03	1.1						
12/14/93	DEC_14	258/533	AREA		POURING ST	POURING ST	123	0.2	24.8	ND	0.021	0.008	0.03	0.03	1.2						
12/14/93	DEC_14	259/537	AREA		POURING ST	POURING ST	121	0.2	24.2	ND	0.021	0.006	0.03	0.03	1.1						
12/14/93	DEC_14	261/530	AREA		DRYOVEN	LEFT	120	0.2	24.0	ND	0.021	0.006	0.03	0.03	1.1						
12/14/93	DEC_14	100	AREA		POURING ST		247	3.0	741.0	0.1	1.1		1.1	1.5							
12/14/93	DEC_14	101	AREA		Furnace1cu		245	3.0	735.0	0.1	0.1		0.1	0.1							
12/14/93	DEC_14	102	AREA		Furnace2cr		248	3.0	747.0	0.1	0.99		0.99	1.3							
12/14/93	DEC_14	110	AREA		Furnace1cu		252	3.0	756.0	0.1	0.1		0.1	0.1							
12/14/93	DEC_14	111	AREA		Furnace2cr		182	3.0	546.0	0.1	0.1		0.1	0.2							
12/14/93	DEC_14	115	AREA		POURING ST		240	3.0	720.0	0.1	0.1		0.1	0.1							
12/14/93	DEC_14	103	PERS	A	FIREASSAY		242	3.0	726.0	1	1.1		1.1	15.2							
12/14/93	DEC_14	106	PERS	A	FIREASSAY		243	3.0	729.0	0.1	0.1		0.1	0.1							
12/15/93	DEC_15	252/523	AREA		POURING ST	POURING ST	239	0.2	47.6	ND	0.021	0.008	0.03	0.03	0.6						
12/15/93	DEC_15	262/527	AREA		POURING ST	POURING ST	49	0.2	9.8	ND	0.021	0.01	0.03	0.03	3.19						
12/15/93	DEC_15	263/529	AREA		POURING ST	POURING ST	184	0.2	36.8	ND	0.021	0.008	0.03	0.03	0.8						
12/15/93	DEC_15	114	AREA		Furnace2cr		281	3.0	843.0		0.1		0.1	0.1	0.1						
12/15/93	DEC_15	116	AREA		POURING ST		278	3.0	834.0		0.1		0.1	0.1	0.1						
12/15/93	DEC_15	117	AREA		Furnace1cu	NOT ON	280	3.0	840.0		0.1		0.1	0.1	0.1						
12/15/93	DEC_15	121	AREA		POURING ST		218	3.0	654.0		0.1		0.1	0.1	0.2						
12/15/93	DEC_15	122	AREA		Furnace2cr		212	3.0	636.0		0.1		0.1	0.1	0.2						
12/15/93	DEC_15	123	AREA		Furnace1cu	NOT ON	205	3.0	615.0		0.1		0.1	0.1	0.2						
12/15/93	DEC_15	118	PERS	A	FIREASSAY		282	3.0	840.0		0.4		0.4	0.5							
12/15/93	DEC_15	119	PERS	B	FIREASSAY		238	3.0	714.0		4		4	5.8							
12/15/93	DEC_15	120	PERS	B	FIREASSAY		192	3.0	576.0		0.1		0.1	0.2	0.2						
12/15/93	DEC_15	124	PERS	A	FIREASSAY		186	3.0	558.0		0.1		0.1	0.2	0.2						
12/16/93	DEC_16	239/535	AREA		POURING ST	POURING ST	191	0.2	38.2	ND	0.021	0.02	0.04	0.04	1.08						
12/16/93	DEC_16	255/520	AREA		POURING ST	POURING ST	206	0.2	41.6	ND	0.021	0.006	0.03	0.03	0.65						
12/16/93	DEC_16	129	AREA		Furnace2cr		205	3.0	615.0		0.1		0.1	0.2	0.2						
12/16/93	DEC_16	130	AREA		POURING ST		214	3.0	642.0		0.1		0.1	0.2	0.2						
12/16/93	DEC_16	131	AREA		Furnace2cr		216	3.0	648.0		0.1		0.1	0.2	0.2						
12/16/93	DEC_16	132	AREA		Furnace1cu		212	3.0	636.0		0.1		0.1	0.2	0.2						
12/16/93	DEC_16	135	AREA		POURING ST		203	3.0	609.0		0.1		0.1	0.2	0.2						
12/16/93	DEC_16	138	AREA		Furnace1cu		201	3.0	603.0		0.1		0.1	0.2	0.2						
12/16/93	DEC_16	128	PERS	A	FIREASSAY		214	3.0	642.0		0.1		0.1	0.2	0.2						
12/16/93	DEC_16	133	PERS	B	FIREASSAY		117	3.0	351.0		0.1		0.1	0.3	0.3						
12/16/93	DEC_16	134	PERS	A	FIREASSAY		210	3.0	630.0		0.2		0.2	0.3	0.3						
12/16/93	DEC_16	144	PERS	B	FIREASSAY		204	3.0	612.0		0.3		0.3	0.5	0.5						
BACKGROUND ARSENIC LEVELS FILTER AND TUBE																					
12/14/93	DEC_14	253/528	AREA		BKGR	OUTDOOR	216	0.2	43.2	ND	0.021	0.008	0.03	0.03	0.65						
12/14/93	DEC_14	260/524	AREA		BKGR	INDOOR	219	0.2	43.8	ND	0.021	0.007	0.03	0.03	0.65						
12/15/93	DEC_15	250/521	AREA		BKGR	OUTDOOR	245	0.2	49.0	ND	0.021	0.008	0.03	0.03	0.56						
12/15/93	DEC_15	215/522	AREA		BKGR	INDOOR	245	0.2	49.0	ND	0.021	0.010	0.03	0.03	0.64						
12/16/93	DEC_16	264/536	AREA		BKGR	OUTDOOR	210	0.2	42.0	ND	0.021	0.007	0.03	0.03	0.67						
12/16/93	DEC_16	245/538	AREA		BKGR	INDOOR	203	0.2	40.6	ND	0.021	0.006	0.03	0.03	0.67						



ARSENIC FILTER PLUS TUBE SAMPLES													
DATE	DAY	SAMPLE NUMBER	TYPE	MEN CODE	SAMPLE LOCATION	LOCATION DETAILS	SAMPLE TIME (min)	FLOW RATE (LPM)	VOLUME (liters)	ARSENIC MASS (filter)	ARSENIC MASS (tube)	ARSENIC MASS (total) (ug)	ARSENIC CONC (ug/m3)

BKGRD SAMPLES (filter element samples)

12/14/93	DEC_14	104	AREA	BKGR	INDOOR	413	3.0	1239.0	0.1	0.1	0.1	0.1
12/14/93	DEC_14	105	AREA	BKGR	OUTDOOR	409	3.0	1227.0	0.1	0.1	0.1	0.1
12/15/93	DEC_15	108	AREA	BKGR	INDOOR	444	3.0	1332.0	0.1	0.1	0.1	0.1
12/15/93	DEC_15	109	AREA	BKGR	OUTDOOR	442	3.0	1326.0	0.1	0.1	0.1	0.1
12/16/93	DEC_16	138	AREA	BKGR	INDOOR	407	3.0	1221.0	0.1	0.1	0.1	0.1
12/16/93	DEC_16	136	AREA	BKGR	OUTDOOR	409	3.0	1227.0	0.1	0.1	0.1	0.1

Blank filters/tubes

12/14/93	DEC_14	254/525	BLANK	BLANK	BLANK	0	0.2	0.0 ND	0.03	0.008	0.008	
12/15/93	DEC_15	257/528	BLANK	BLANK	BLANK	0	0.2	0.0 ND	0.03	0.008	0.008	
12/16/93	DEC_16	244/511	BLANK	BLANK	BLANK	0	0.2	0.0 ND	0.03	0.006	0.006	

Blank filter element samples

12/14/93	DEC_14	107	AREA	BLANK	BLANK	0	3.0	0.0	0.1	0.1	0.1	0.1
12/14/93	DEC_14	112	AREA	BLANK	BLANK	0	3.0	0.0	0.1	0.1	0.1	0.1
12/15/93	DEC_15	127	AREA	BLANK	BLANK	0	3.0	0.0	0.1	0.1	0.1	0.1
12/15/93	DEC_15	128	AREA	BLANK	BLANK	0	3.0	0.0	0.1	0.1	0.1	0.1
12/15/93	DEC_15	125	AREA	BLANK	BLANK	0	3.0	0.0	0.1	0.1	0.1	0.1
12/16/93	DEC_16	141	AREA	BLANK	BLANK	0	3.0	0.0	0.1	0.1	0.1	0.1
12/16/93	DEC_16	137	AREA	BLANK	BLANK	0	3.0	0.0	0.1	0.1	0.1	0.1

APPENDIX C

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

Analyte	Concentration ( $\mu\text{g}/\text{m}^3$ )
Beryllium	<0.03
Cadmium	<0.2
Cobalt	<0.5
Chromium	0.6
Copper	<0.6
Magnesium	7
Manganese	<1.2
Molybdenum	<0.6
Nickel	<3
Selenium	<6
Silver	0.7
Tellurium	<3
Thallium	<6
Titanium	0.7
Vanadium	<0.6
Zinc	<2
Zirconium	<0.3