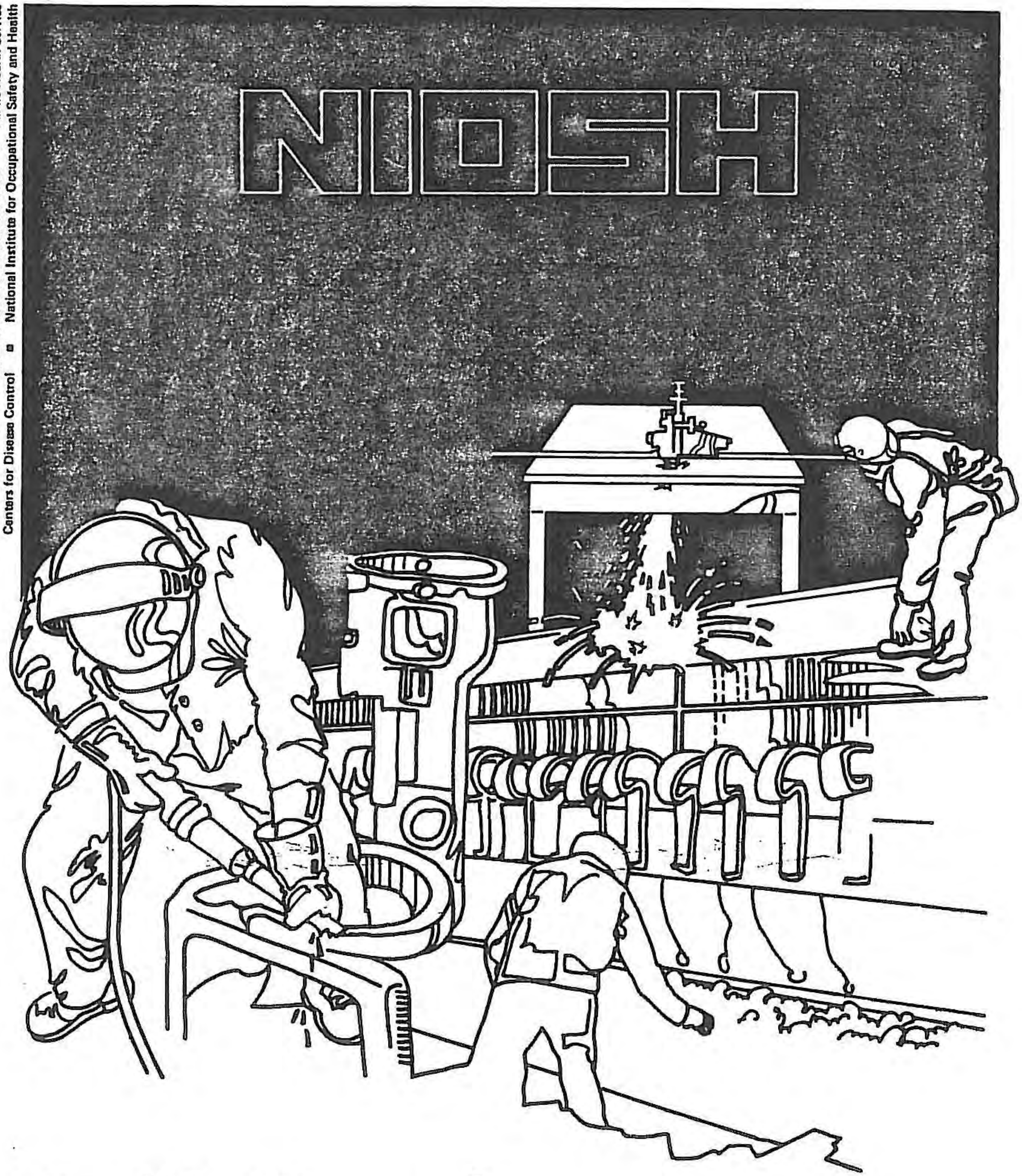
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES ■ Public Health Service
Centers for Disease Control ■ National Institute for Occupational Safety and Health



Health Hazard Evaluation Report

HHE 78-034-930
HOMESTAKE MINING COMPANY
LEAD, SOUTH DAKOTA

PREFACE

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

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

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Homestake Mining Co.
Lead, South Dakota

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I. SUMMARY

In December 1977, a health hazard evaluation by the National Institute for Occupational Safety and Health (NIOSH) was requested by United Steelworkers of America, Local 7084, Homestake Mining Co., Lead, So. Dakota to evaluate exposure to dust and toxic fumes during gold and silver refining. On February 28, and May 15, 1978, NIOSH investigators obtained area and personal air samples to evaluate exposures to lead, mercury, silica, total and respirable particulate dust, asbestos, hydrogen chloride, manganese, iron oxide, chromium, total welding fumes, toluene, and xylene. Medical testing included blood lead and urine mercury determinations, neurological evaluation, pulmonary function testing, sputum cytology and administration of a standardized personal interview.

All personal air samples for lead in the refinery contained concentrations above the present OSHA standard of 50 µg/M^3 (range: 70 - 12,300 µg/M^3). All 11 refinery workers had blood lead values above 40 µg/dl, (the upper limit of normal), and 82 percent had values above 60 µg/dl (mean: 68 µg/dl). In the assay office all 3 personal air lead values in the furnace area exceeded the OSHA standard. The mean blood lead value of 17 assay office workers was 37 µg/dl. Two of 3 air mercury samples in the refinery and the mill exceeded the NIOSH-recommended standard of 0.050 mg/M^3 (range 0.048 - 0.070 mg/M^3). The mean urine mercury concentration of 4 regularly exposed workers was 108 µg/l (unexposed: less than 14 µg/l). There was no evidence of heavy metal-related neurological or kidney damage or of excessive exposure to arsenic, manganese, iron oxide, chromium, total welding fumes, toluene or xylene.

In the assay office all 6 air samples obtained during the first survey for respirable silica exceeded the NIOSH-recommended standard of 0.05 mg/M^3 (range: 0.15 - 1.33 mg/M^3). Three of 9 samples for respirable particulate dust exceeded the ACGIH standard of 5.00 mg/M^3, (range: 0.36 - 22.28 mg/M^3). Levels were substantially less in the second survey due to the partial implementation of engineering recommendations, but all 4 respirable silica values still exceeded the recommended standard. Asbestos air levels were less than the NIOSH-recommended standard of 0.1 fibers/cc. Pulmonary function testing revealed no evidence of restrictive lung disease. Sputum cytology testing disclosed no evidence of asbestos-related pulmonary cytopathology. In the refinery all 6 air samples for hydrogen chloride were less than the OSHA standard of 7.0 mg/M^3 but acute respiratory symptoms reported by 2 exposed workers suggested the possibility of episodic exposure. In the furnace charging operation total and respirable particulate dust levels were twice the respective standards.

On the basis of medical and/or environmental data obtained in this evaluation, NIOSH determined that a health hazard existed in the refinery, assay office and mill at Homestake Mining Co. from exposures to lead, mercury, silica, and total and respirable particulate dust. A potential hazard also existed from episodic exposure to hydrogen chloride. There was no evidence of a health hazard from asbestos, arsenic, manganese, iron oxide, chromium, total welding fumes, toluene, or xylene. Recommendations for improved ventilation, engineering controls, housekeeping practices, and medical surveillance are included in this report.

keywords: SIC-3330, gold, silver, lead, mercury, silica, total particulate dust, respirable particulate dust, hydrogen chloride, asbestos, arsenic, manganese, iron oxide, chromium, total welding fumes, toluene, xylene.

II. INTRODUCTION

In December 1977 United Steelworkers of America, Local 7084, Lead, South Dakota requested a health hazard evaluation at Homestake Mining Co. to evaluate worker exposure to mercury, manganese, iron oxide, chromium, toluene, and xylene in the milling operation; to dust, silica, lead, mercury, and hydrogen chloride in the refinery operation; and to dust, silica, asbestos, lead and arsenic in the assay office. An initial survey was conducted February 28-March 3, 1978 focusing primarily on the assay and milling operations. A follow-up survey of the refinery was conducted May 15-19, 1978 when all processes of concern were in operation. Preliminary reports were sent to the employer and the union with recommen- dations to date on April 5, 1978 and July 12, 1978.

III. BACKGROUND

Homestake Mining Co. recovers gold and silver from raw ore and processes about 56,000 tons of rock per day. There are approximately 10-15 employees in the Mill, 11 employees in the Refinery, and 17 in the Assay Office. Workers receive complete physical examinations every other year including chest x-ray and spirometry. Assay office and refinery workers have blood drawn monthly for lead determinations. Work clothes are washed by the company in the refinery but not in the assay office or mill.

A. Mill Operation:

In the milling operation raw ore is crushed, ground, and pulverized. The primary removal process is a series of settling tanks (sand, carbon, and pulp) where precipitating agents attract the precious metals.

Mercury is used to separate the gold from the ore. In the amalgam room two operators load a large tumbler each day with ore from the settling tanks, tumbling rocks, and mercury. After eight hours the operators unload the amalgamated product into a wheelbarrow. The amalgam, (mercury and gold), is transferred into several small pots which are placed in a water bath to reduce mercury vapors. The operator separates the gold from the mercury by hand as he pours a pot of amalgam down a trough. Water flows over the trough which reduces mercury exposure. The operator then transfers the mercury into a recovery compressor which forces the mercury into blocks for easier handling and storage.

B. Refinery Operation:

The gold amalgam is heated in a retort furnace to remove any remaining mercury prior to electrolysis. The electrolytic operation involves the application of electric energy to melt, recover and refine gold to 99.999 percent pure. The operation is performed daily by one operator who sets up the operation on Monday and breaks down on Friday The oxidized gold is purified by the electrolysis of gold chloride solutions containing hydrogen chloride. Eight electrolytic tanks are used. Each contain anode plates of a gold and silver alloy, and cathodes plates. Gold deposits on the cathode, and silver forms a chloride salt which remains as a deposit on the anode.

Recycled materials (crucibles, bricks etc.) containing minute amounts of gold are crushed and smelted in a blast furnace and then refined in the electrolytic operation to recover all traces of gold.

C. Assay Office Operation:

The assay office is a smaller scale operation of the milling and refinery processes where the gold content of ore samples is determined. Samples of ore (Diamond Drill cores) from rock containing silica, amosite asbestos (cummington-grunerite series), and arsenic, are crushed, ground, milled, mixed with lead oxide, and placed in crucibles to go through a retort furnace process. Two samples are assayed for each core. The final product, gold, is analyzed for its purity. The assay operation is repeated daily.

D. Miscellaneous Mill Operations

1. Rubber Repair: The rubber repair operator repairs and relines rubber parts on various pieces of equipment (e.g., impellers, suction and backside liners from ash pumps, rubber pipes, valves, etc.). All worn rubber material is removed from the parts, either by cutting, grinding, or air hose. The surfaces are cleaned with a rag and a 99 percent toluene-base solution. The operator cuts the new rubber part needed and glues it to the cleaned surface with a toluene/xylene based glue.

2. Welding Operation: The welder works primarily in the main welding room although welding may be performed throughout the mill. The majority of the welding rods are a composition of carbon, manganese, chromium, and other trace components. Half of the welding is done on walking/shifting screens with the remainder on miscellaneous materials.

IV. METHODS AND MATERIALS

A. Environmental

Personal and area samples were collected in the assay office, the refinery and the milling operations. A ventilation survey was performed in each of these areas and measurements of several exhaust hoods were reviewed. Personal sampling and a ventilation survey were repeated in the sample preparation room of the assay office during the second survey. Sampling analytic techniques for suspected contaminants are listed below:

Substance	Sampling Equipment	Flow Rate	Analysis
Lead, Manganese Iron Oxide, Arsenic	Breathing zone samples on 37 mm diameter cellulose ester, 0.8 um pore size filters	1.5 lpm 360 min	Atomic Absorption
Chromium	Polyvinyl chloride filters with 5 u pore size	1.5 lpm	Atomic Absorption
Total Welding Fumes	Breathing zone samples on 37 mm diameter cellulose ester, 0.8 um pore size filters	1.5 lpm 360 min	Weighing
Particulate Dusts:			
Total	Pre-weighed vinyl membrane in closed face cassette	1.5 lpm	Weighing
Respirable	Size-selective 10 mm nylon cyclone with pre-weighed vinyl membrane	1.7 lpm	Gravimetric
Asbestos	37 mm diameter 0.8 um pore size membrane in open face cassette	2.0 lpm 130 min.	Fiber counts 400-500 magnification by phase contrast optical microscopy
Hydrogen Chloride	Impingers containing sodium acetate solution	1 lpm 120 min.	Chloride in specific electrodes
Toluene, Xylene	Activated charcoal tubes using a battery powered pump	50 and/or 200 cc/min. 360 min.	Gas Chromatography charcoal by CS_2
Mercury	3M Brand mercury vapor monitor badges	-	Binary diffusion system

B. Medical

After informed consent had been obtained from each participant, workers were offered medical testing appropriate to their individual exposures; not every worker was exposed to every substance.

Medical Tests:	Exposure:
Questionnaire for Heavy Metal Exposure and Neurological Examination	Lead, Mercury
Respiratory Tests:	
Spirometry, Respiratory Questionnaire (BMRC)	Silica, Asbestos, Total and Respirable Particulate Dust
Sputum Cytology	Asbestos
Urine Tests:	
Mercury, Beta-2-microglobulin, Creatinine	Mercury
Arsenic	Arsenic
Protein	Lead, Mercury
Blood Tests:	
Lead, ZPP, Hematocrit	Lead
BUN, Creatinine	Mercury
SGOT, SGPT, CBC	Toluene, Xylene

Trained interviewers administered a standardized questionnaire for heavy metal exposure and the British Medical Research Council (BMRC) Respiratory Questionnaire (Medical Research Council, 1965, 1966). Using responses from the BMRC respiratory questionnaire, all workers receiving respiratory testing were classified as smokers, nonsmokers, or ex-smokers (i.e., having smoked at least 100 cigarettes but not current smokers). Workers were classified as normal, borderline or abnormal for chronic respiratory disease (CRD) using criteria recommended by the American Thoracic Society (Committee on Standards, ATS).

Three trials of pulmonary function testing were administered by a trained health technician for FVC and FEV 1.0 measurements. A predicted value for FVC and FEV 1.0 was computed using each individual's age, height and sex and compared with the best of three trials. FVC was used as an indicator of restrictive respiratory disease and the ratio of FEV 1.0 to FVC as an indicator of obstructive respiratory disease. An individual was classified as abnormal if his test result was less than that predicted for the lower 1 percent of a normal population for his specific age, height and sex. An individual was classified as borderline if his test result fell between the lower 1-5 percent of a normal population (Discher 1972). The test results of any individual who had an upper respiratory infection on the day of testing were considered invalid.

Sputum cytology samples were collected by trained health technicians using aerosol induction on two consecutive days to increase the likelihood of detecting any cytopathology present. The criteria used to classify sputum cytology slides was that established by the NIOSH contract laboratory (Saccomano). The more severe of the two cytology readings was used as an individual's test result.

Blood was drawn by venipuncture. ZPP testing (using a portable ESA hematofluorometer) and hematocrit determinations were made on site. Blood lead, CBC, SGOT, SGPT, BUN and creatinine testing were performed by a NIOSH contract laboratory.

Urine samples were collected during shift time from workers exposed to arsenic in the assay office. Twelve-hour overnight samples were collected from workers exposed to mercury in the refinery and mill and from a group of unexposed workers in the assay office. Specific gravity measurements and dipstick testing for urine protein were performed on site. Urine arsenic and mercury testing were performed by a NIOSH contract laboratory and were corrected to a specific gravity of 1.024. Beta-2-microglobulin measurements, corrected for urine creatinine, were made by the NIOSH laboratory.

A neurological examination for reflexes, muscular strength, tremor and coordination was performed. A history of alcohol consumption and thyroid disease was collected as part of these examination.

V. EVALUATION CRITERIA

A. Environmental

Several criteria used to evaluate the potential toxicity of air contaminants: (1) NIOSH Criteria Documents for Recommended Occupational Health Standards; (2) American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLV's); and (3) Federal Occupational Health Standards promulgated by the U. S. Department of Labor.

The values are designed to allow an occupational exposure for an 8-hour work day up to a 10-hour work day, 40-hour work week. The Time Weighted Average (TWA) is that exposure an employee recieves over a normal lifetime, without the worker experiencing undue discomfort. In some instances, a few employees may experience discomfort at or below the criteria. For some airborne contaminants a Ceiling Value for an interval of 15 minutes or less is given; this ceiling concentration should never be exceeded, even momentarily.

The NIOSH recommended standard for lead was 100 $\mu g/M^3$ at the time of this survey. The OSHA standard of 50 $\mu g/M^3$ which was proposed in November, 1978 is used for evaluation purposes throughout this report however.

Substance		Evaluation Criteria 8-Hour Weighted Average (TLV-TWA) (mg/M^3)	(ppm)	Ceiling Value
Lead	OSHA 80	0.05 (50 μg/M^3)		
Mercury	NIOSH 79	0.05		0.1 mg/M^3 (15 min., OSHA)
Arsenic	OSHA 80	0.05		
Respirable Particulates	ACGIH 79	5.0		
Total Particulates	"	10.0		
Respirable Silica	NIOSH 79	0.05		
Asbestos	NIOSH 79	0.1 fibers/cc		0.5 fibers/cc (15 min.)
Hydrogen Chloride	OSHA 80	7.0	56	5 ppm (15 min.)
Manganese	ACGIH 79	5.0		
Iron oxide	ACGIH 79	10.0		
Chromium	OSHA 80	1.0		
Total Welding Fumes	ACGIH 79	5.0		
Toluene	NIOSH 79	375.0	100	200 ppm (10 min.)
Xylene	"	435.0	100	200 ppm (10 min.)

B. Toxicological

1. Lead: Lead poisoning, one of the oldest known occupational hazards, is often unrecognized since early symptoms (fatigue, headache, irritability, aching bones and muscles, digestive disturbances, abdominal pain and decreased appetite) may resemble many common illnesses. For this reason blood lead testing is essential for detecting increased lead absorption. Continued exposure may affect the kidneys, the peripheral nervous system (wrist-drop), and the central nervous system (convulsions), and eventually cause permanent, irreversible damage (DHEW, NIOSH 1977). Lead is also known to cause reproductive effects in both males and females (Rom 1980). Elevated blood lead levels have been found in family members of lead exposed workers (Baker 1977). The OSHA lead standard requires that a blood lead value of 60 μg/dl whole blood be the maximum tolerated occupational blood lead level. A blood lead of 40 μg/dl is considered the upper limit in unexposed adults. A ZPP value greater than 60 μg/dl whole blood is considered outside the normal range (DHEW/PHS 1975). A range of 40-54 percent was considered normal for hematocrit (Wintrobe 1976).

2. Mercury: Mercury, like lead, may cause permanent neurological and kidney damage. Fine tremors of the hands and difficulty in walking may occur and eventually brain damage may result from exposure to mercury. For urine mercury, removal from exposure is recommended at 200 μg/l (Calif. Bur. Occ. Hlth. 1967). The normal range for beta-2-microglobulin is 4-370 μg/l (Phadebas) and 0-150 μg/g for creatinine-corrected values (Lowry 1978). A range of 90-139 ml/min is considered normal for creatinine clearance rate (Wallach 1978).

3. Arsenic: Arsenic may also cause neurological damage and skin lesions. Both skin lung and liver cancer have been associated with arsenic exposure. Arsenic exposure may also be linked to the occurrence of lymphoma although further research is needed to clarify this relationship. Urine arsenic concentrations have been reported to be less than 60 µg/l in an unexposed population (Webster 1941).

4. Particulate Dust, Silica, Asbestos, Hydrogen Chloride: Exposure to particulate dust may cause industrial bronchitis (increased cough and phlegm in the absence of localized destructive disease of the lungs). Exposure to silica in particular may cause a restrictive lung disease, silicosis, with shortness of breath. In silicosis, permanent lung damage has occurred and may continue to worsen even after an individual is removed from exposure. Asbestos may cause a similar restrictive lung disease, asbestosis. Asbestos is also a well known cause of both lung cancer and of mesothelioma. Hydrochloric acid may cause irritation to the eyes, skin and lungs (DHEW, NIOSH 1977).

5. Toluene, Xylene and Benzene: Toluene may irritate the eyes, skin, and lungs and cause liver damage. Central nervous system symptoms of headache, dizziness, fatigue, muscular weakness, drowsiness and incoordination may also be seen. Xylene and benzene have the same acute effects as toluene, and xylene may cause transient kidney effects. Normal values for CBC were taken from a standard hematopoietic text (Wallach 1978). The NIOSH contract laboratory provided normal values for SGOT (7-40 mu/ml), SGPT (3-18 IU), and BUN (5-26 mg/dl. Benzene may also affect the production of red and white blood cells and exposure to benzene has been associated with leukemia (DHEW, NIOSH 1977).

VI. RESULTS AND DISCUSSION

Of 33 workers offered medical testing, one declined to participate and the remainder were distributed as follows: assay office-17, refinery-11, mill-4. All except one were male. The number of workers from each work area receiving medical testing for specific toxic agents are listed below; frequently workers were exposed to more than one substance.

	Assay	Refinery	Mill	Total
Lead	17	11	-	28
Arsenic	17	-	-	17
Mercury	-	3	2	5
Silica, Asbestos	7	-	-	7
Toluene, Xylene	-	-	2	2

Almost all workers had more than 5 exposure years in their present work area. In the assay office and refinery almost two-thirds of the workers had been employed in their present work area 10 years or more.

A. Assay Office

1. Lead:

a. Environmental: All three personal air samples for lead in the sample preparation room were nondetectable (Table 1). Lead was detected in both personal samples in mixing operation (range: 10 - 20 μg/M3) but both were below the OSHA standard of 50 μg/M3. All three personal air samples in the furnace area exceeded the OSHA standard (range: 67 - 89 μg/M3).

b. Medical: The mean blood lead concentration was 37 μg/dl with individual results ranging from 17 to 73 μg/dl (Table 2). Almost one third (29 percent) of the 17 workers had blood lead levels above 40 μg/dl. The mean blood lead concentration of four workers in non-assaying jobs (three samplers and one technician) with minimal exposure to the furnace was 22 μg/dl. The mean blood lead concentration of 6 individuals who indicated they worked in the furnace area was 41 μg/dl. This difference was statistically significant ($t = 5.03$, $df = 8$, $p < 0.01$).

Six workers (35 percent) had ZPP values greater than or equal to 60 μg/dl, the limit for normal (Table 3). The mean value was 52 μg/dl (range: 10 - 146 μg/dl). One worker had a hematocrit value of 37 percent; however, neither his blood lead value (29 μg/dl) nor his ZPP value (49 μg/dl) was elevated. All other workers were within the normal range for hematocrit determinations although over one-third had elevated ZPP values. Hematopoietic effects were thus detectable by ZPP screening even in the absence of anemia. One worker showed trace urine protein; all others had none.

All workers reported one or more constitutional symptoms: 50 percent, one or more gastrointestinal symptoms; 29 percent, one or more skeletal-muscular symptoms; and 18 percent, one or more symptoms associated with peripheral neuropathy (Table 4). Two workers (18 percent) reported an unusual metallic or sweet taste in the mouth. No worker showed clear evidence of clinical neurological effects which could be attributed to heavy metal exposure.

One worker reported previous chelation therapy. This worker and two others were diagnosed by a physician as having anemia. One other worker reported being hospitalized for seizures and severe headaches for which lead poisoning was considered as a diagnosis. The reporting of 3 past cases of anemia among 17 adults exposed to lead suggests this exposure as a likely cause.

2. Arsenic: The range of values for six air samples for arsenic was nondetectable to 0.006 mg/M^3. All values were well below the OSHA standard of 0.050 mg/M^3. The mean urine arsenic concentration was 11 µg/l with individual values ranging from 4 to 36 µg/l. All values were less than the maximum of 60 µg/l reported for an unexposed population.

3. Silica, Total and Respirable Particulate Dust, Asbestos:

a. Environmental: In the first survey none of six samples for total particulate dust in the sample preparation room (range: 0.36 - 5.54 mg/M^3) exceeded the ACGIH TLV of 10.00 mg/M^3 (Table 1). Three of nine samples for respirable particulate dust (range: 0.36 - 22.28 mg/M^3) were above the ACGIH TLV of 5.00 mg/M^3 (Tables 1 and 5). The highest value (22.28 mg/M^3 in the mixing area) was over four times the TLV. In the second survey, after implementation of engineering controls, all four samples for respirable particulate dust (range: 0.13-0.67 mg/M^3) were 15 percent or less than the ACGIH TLV. (Table 5).

In the first survey all values for respirable silica (range: 0.15 - 1.33 mg/M^3) exceeded the NIOSH-recommended standard of 0.05 mg/M^3 (Table 5). The highest value (1.33 mg/M^3) was more than 25 times greater than the recommended standard. In the second survey, all four respirable silica samples (range: 0.07 - 0.24 mg/M^3) were still above the NIOSH-recommended standard, however values were markedly reduced from the initial values.

The five personal samples taken for asbestos ranged from nondetectable to 0.01 fibers/cc, only one-tenth of the NIOSH recommended standard of 0.10 fibers/cc.

b. Medical:

All workers evaluated for respiratory effects were either smokers or ex-smokers. Seven workers were interviewed concerning acute respiratory symptoms on the job or soon after work. Five reported coughing, three reported wheezing and two reported shortness of breath. Six of these were evaluated for chronic respiratory effects. Using symptoms from the BMRC respiratory questionnaire three workers (all smokers) were classified as abnormal for chronic respiratory disease and three (all ex-smokers) were classified as normal. The three classified as abnormal all reported chronic bronchitis (increased phlegm for three months or more each year). Since all of these workers were smokers it is difficult to determine the individual (and potentially synergistic) contributions of both occupational exposure and smoking to their bronchitis.

Pulmonary function testing results showed one worker, an exsmoker, was abnormal for obstructive lung disease and two, both smokers, were borderline. No worker showed evidence of restrictive lung disease such as is seen in silicosis or asbestosis.

Sputum cytology testing results were: normal, two workers; regular metaplasia, two; and mild atypia, three. All of these cytology classifications are commonly seen in smokers and ex-smokers.

No direct evidence of silicosis was seen. Nevertheless, the presence of acute respiratory effects, and of air levels exceeding the respective standards for both respirable particulate dust and for silica, indicate the presence of a health hazard. The low levels of asbestos found and the lack of restrictive lung disease or of more severe cytopathology suggest that a hazard does not exist from asbestos.

4. Ventilation Survey: The canopy hoods used in the receiving/drying room (where the ore samples are brought initially) were not operating effectively. In the sample preparation room the jay crushers, grinders, and ripple boxes had circular ducts extending down to the operation. However the distance between the ducts and the actual process ranged from 18 to 20 inches, resulting in a large amount of dust not being collected.

A. Refinery:

1. Lead:

a. Environmental: All 16 air lead levels taken in the refinery (Table 6) were above the OSHA standard of 50 $\mu g/M^3$. The range of values was from 70 to 12,300 $\mu g/M^3$. The four highest values, (4,100 - 12,300 $\mu g/M^3$), were seen in the furnace charging operation. The maximum value was almost 250 times the OSHA standard.

b. Medical: All 11 refinery workers had blood lead concentrations greater than 40 µg/dl with 82 percent of the workers having values above 60 µg/dl (Table 2). The mean value was 68 µg/dl (range: 53 - 86 µg/dl). The mean blood lead of the two foremen was 54 µg/dl. The mean blood lead of four less senior positions (millman, refiner helper and two assistant refiners) was 65 µg/dl. The mean blood lead of five more senior positions (three refiners and two master refiners) was 75 µg/dl.

Eight workers had ZPP values greater than or equal to 60 µg/dl, the limit for normal (Table 3). The mean value was 135 µg/dl (range: 15 - 365 µg/dl). All hematocrit values were within the normal range even though almost three-fourths of the workers had elevated ZPP values. Hematopoietic effects were therefore detectable by ZPP screening even in the absence of anemia.

Almost one half (45 percent) of the workers reported one or more constitutional symptoms; 18 percent, one or more gastrointestinal symptoms, 45 percent, a muscular-skeletal symptom; and 9 percent, one or more symptoms of peripheral neuropathy (Table 6). Almost half (46 percent) reported an unusual metallic or sweet taste in the mouth. No worker showed clear evidence of clinical neurological effects which could be attributed to heavy metal exposure.

2. Mercury:

a: Environmental: Personal air sampling for mercury showed a value of 0.070 mg/M^3 for the retort operator which exceeded the NIOSH recommended standard of 0.050 mg/M^3.

b. Medical: The three exposed workers in the refinery had urine mercury concentrations of 75 µg/l, 104 µg/l and 114 µg/l. All unexposed workers from the assay office had concentrations less than 14 µg/l. The three refinery workers had beta-2-microgloblin values, (both corrected and uncorrected for creatinine), within the normal range. None showed clear evidence of clinical neurological effects which could be attributed to heavy metal exposure. Although none of the workers had evidence of kidney or neurological damage, the effects of low level mercury absorption are not well defined. The elevated urine mercury concentrations, while less than the hazardous level of 200 µg/l, clearly indicate the occurrence of exposure when compared with unexposed workers.

3. Total and Respirable Particulates, Hydrogen Chloride:

a. Environmental: All 16 air samples were taken when both the retort and the blast furnace were operating. Both samples obtained for the furnace charging operation exceeded the criteria for total and respirable particulate dust (Table 6). The highest values seen were 20.0 mg/M^3 for respirable dust (four times the standard) and 19.2 mg/M^3 for total dust (almost two times the standard). Although the range of values in other jobs was below the ACGIH TLV's for total particulate dust and for respirable particulate dust, a major portion of this dust consisted of lead, for which a different OSHA standard applies. In five of eight samples for total particulate dust, and six of eight samples for respirable particulate dust, over half of the sample was composed of lead. As has been noted earlier, all air samples for lead in the refinery exceeded the OSHA standard.

The range of values for six air samples for hydrogen chloride was from 0.27 to 1.24 mg/M^3, all well below the OSHA standard of 7.00 mg/M^3. The last phase of the electrolytic operation, at the end of the week when the plates are removed from the tank and hung up to dry, was not evaluated however. This portion of the process may produce higher levels of hydrogen chloride. With the inadequate exhaust ventilation it is likely that exposure would occur.

b. Medical: Both electrolytic operators with exposures to hydrogen chloride reported coughing and sudden, unexplained shortness of breath on the job or soon after work. One of these workers also reported wheezing. Although air levels for hydrogen chloride were less than the OSHA standard, the presence of acute respiratory symptoms among exposed workers suggests the possibility of episodic exposures to hydrogen chloride exceeding the ceiling value.

4. Ventilation Survey: The ventilation systems for the electrolytic operation (the local exhaust system and the lab hood) were both inadequate. Flow rates of the local exhaust system, which draws aerosols from behind each tank through slot-type ducts, ranged from 50-100 foot per minute (fpm) at the face of the slots and from 10-30 fpm across the surface of the tanks. These rates are far below the 1000-3000 fpm required. This exhaust system was also inadequate when the cathodes and anodes were hung above the tanks to drip dry during the breakdown process. The lab hood used to clean various parts and materials did not allow adequate exhausting due to a sliding cover window which could not be opened or closed properly.

Ventilation problems were also noted in the blast furnace exhaust system used to collect fumes from the lead vat. During a blow-out a large amount of smoke lingers in the work area, due to the poor exhaust ventilation.

C. Milling Operation:

1. Mercury:

a. Environmental: Values from the mercury badges worn by the amalgum operator were 0.048 and 0.055 mg/M^3, just under and just over the NIOSH recommended standard of 0.050 mg/M^3.

b. Medical: The two individuals evaluated for urine mercury in the mill had concentrations of 20 µg/l and 138 µg/l. The individual with the lower value only worked in the amalgam room approximately one day per month and was not evaluated for environmental exposure. Both individuals had beta-2-microglobulin values, (both corrected and uncorrected for creatinine), within the normal range. The individual with the highest urine mercury concentration had a normal BUN value of (17 mg/dl) and a normal creatinine clearance rate (111 ml/min). Neither individual showed clear evidence of clinical neurological effects which could be attributed to heavy metal exposure.

Although the urine mercury concentrations were less than the hazardous level of 200 µg/l, both values exceed the maximum level seen in unexposed workers in the assay office (less than 14 µg/l). As has been previously noted, the health effects of low level mercury absorption are not well defined.

2. Manganese, Iron Oxide, Chromium, Total Welding Fumes: Three personal samples on the welding operator showed non-detectable levels of chromium. All values for manganese, iron oxide and total welding fumes were below the evaluation criteria. Results for manganese ranged from 0.02 - 0.14 mg/M^3 (ACGIH TLV: 5.0 mg/M^3). Iron oxide levels ranged from 0.35 - 1.31 mg/M^3 (ACGIH TLV: 10.0 mg/M^3), and total welding fumes ranged from 1.74 - 3.54 mg/M^3 (ACGIH TLV: 5.0 mg/M^3).

3. Toluene, Xylene:

a. Environmental: Benzene was initially suspected as a contaminent of both toluene and xylene. Analysis of bulk samples however did not reveal the presence of any benzene. Four personal samples for toluene ranged from 0.1 to 14.8 mg/M^3, well below the NIOSH-recommended standard of 750 mg/M^3. Three of four personal samples for xylene were nondetectable and the fourth was 0.02 mg/M^3, far below the NIOSH-recommended standard of 435 mg/M^3.

Medical: Both workers exposed to toluene and xylene had liver function tests (SGOT and SGPT) within the normal range and neither showed any abnormality on the neurological examination. Both individuals had slightly decreased white blood cell counts (4200 and 3700) on CBC testing. The lack of any benzene present (as revealed by the bulk sample analysis) however, suggests other explanations for these results such as minor viral infection.

4. Ventilation Survey:

The only ventilation in the amalgam room was industrial window-type fans and windows. Water is used during the transfer process but frequently the worker is unable to fill the water bucket resulting in exposure to mercury vapor. In the rubber repair area, the operator wore a dust particulate type respirator which was not sufficient for organic vapors. In the welding room there was no local exhaust or general room ventilation system.

Excessive noise levels were noted in the pulverizing area of the mill. It was frequently impossible for individuals standing next to one another to hear each other.

VI. CONCLUSIONS:

There was environmental and/or biological evidence of excessive exposure to lead and respirable particulate dust in the assay office and refinery; to mercury in the refinery and the mill; to silica in the assay office; and to total particulate dust in the refinery. A potential hazard existed for episodic exposure to hydrogen chloride in the refinery. There was no evidence of excessive exposure to asbestos or arsenic in the assay office or to manganese, iron oxide, chromium, total welding fumes, toluene or xylene in the mill.

VIII. RECOMMENDATIONS

Most of the following recommendations were previously made in Interim Reports No. 1 and No. 2.

1. Respirator Program: An official respirator program needs to be developed for individuals working in the assay office, the refinery and welding operators in the mill. This program should be similar to that described in the OSHA requirements outlined in 29 CFR part 1910.34 standard. This standard emphasizes education in the proper use, maintenance and storage of respirators. The publication "A Guide to Industrial Respiratory Protection" was enclosed with the second interim report.

Until proper local exhaust ventilation can be installed the electrolytic operator should wear a chemical cartridge type respirator which affords protection against irritants such as hydrogen chloride and ammonia. Consideration should be given to supplying the welder, (especially while welding in the welding room) with a combination mechanical/chemical filter respirator. A respirator with a back-mounted filter element is especially well suited for welding operations where the air contaminant is concentrated in front of the worker.

2. Industrial Hygiene-Assay Office:

a. The canopy hood in the receiving/drying room, requires maintenance (restoring the motor, axial fan, and/or barometric damper to original design specifications). An alternative would be replacement of the fan and/or motor with ones which will increase the capture velocity at the source.

b. In the sample preparation room, the overall exhaust system needs modification. Hoods should be used on the jay crushers, grinders and ripple boxes. A perforated table-top exhaust system should be used in the pulverizer areas similar to that being used in the mixing rooms.

The process of discarding samples into the barrel creates a large amount of dust. Therefore, a top cover, spring-loaded.trap door type should be placed on the barrel. Or, as an alternative, the operation should be moved next to the drying table where the dust would be captured by the canopy/exhaust hood.

c. The cutting down process area needs improved exhaust ventilation. The use of the perforated table-top mentioned above would be the most functional design. The use of high pressure air hoses to clean off the pulvizers should eliminated altogether. Sweeping or vacuuming should replace this method of removing excess dust.

3. Industrial Hygiene-Refinery:

a. The exhaust systems for the electrolytic tanks and the lab hood system need maintenance to restore the motor and/or ducting to the original condition so as to increase capture velocity. The best alternative would be to replace the equipment. Each tank cover should fully cover the top of the tank. An additional piece of plastic could be added to extend approximately three-fourths of the way down the front face of the cover.

An exhaust system should be designed which would exhaust the hydrogen chloride vapors between the drying and rinsing phase. One example would be a multiple slot type exhaust system which draws the contaminant off the surface of the tank as well as at various heights above the tank. The guide cables on the lab hood need to be replaced. Until more effective engineering controls can be developed, barrier or protective creams should be made available, as well as respiratory protection.

b. A mercury cleaning compound should be used in the retort furnace area.

c. In the blast furnace (lower floor) area the slot exhaust system should have the valve open to its maximum during the blast furnace operation. The smoke created during a blow-out could be more effectively controlled by moving the window exhaust fan over to the next window or installing a local exhaust system which removes the smoke at the source.

4. Industrial Hygiene-Mill Operation:

a. In the amalgam room the exhaust ventilation needs to be improved. An effective alternative would be a localized ventilation system which captures the contaminant at the source. This would be far more efficient in the long run. A system should be designed to automatically feed water when the amalgam is separated from the mercury to minimize exposure. A mercury cleaning compound should be used on various surfaces in this area.

b. An industrial hygiene survey for noise should be conducted and appropriate engineering controls implemented where levels exceed the OSHA standard.

5. Industrial Hygiene--Re-evaluation: Following the implementation of industrial hygiene recommendations and any engineering changes, air sampling should be conducted to determine if such changes have been effective. Air sampling should be repeated periodically to assure that any exposures are within recommended standards.

6. Medical Surveillance:

a. Any worker with a blood lead level greater than 60 µg/dl should be transferred to another job until his/her level decreases to less than 40 µg/dl in accordance with the criteria established in the OSHA Lead Standard.

b. The monthly blood lead surveillance program should be continued. Laboratory analysis should be done by a laboratory which performs satisfactorily in the Centers for Disease Control Blood Lead Proficiency Testing Program.

c. Work clothes of workers in the assay office and of mercury exposed workers in the mill should be laundered at the work site, to prevent contamination of the home environment.

d. Routine screening for respiratory effects with chest X-ray and spirometry should be continued. Audiometry should be included in the pre-employment and biennial physical examination.

e. Since mercury vaporizes more easily at higher temperatures, urine mercury testing should be repeated during the summer. Air sampling should also be conducted at this time.

f. Each worker's medical file should include an occupational history including job title, department, beginning and end dates, job description, and specific exposures for each job held. A sample format is attached (Appendix A). One mechanism for keeping the occupational history current would be to routinely provide the medical department with a carbon copy of all personnel actions (excluding salary increases).

7. Worker Education Program:

a. An education program should be conducted for workers exposed to lead, mercury, silica and hydrogen chloride to explain the health hazards associated with these compounds and the appropriate medical surveillance. Information covered should include: specific medical tests performed, possible results for each of these tests, medical implications and appropriate follow-up for each result.

b. Workers should be routinely informed in writing of their individual medical test results, the interpretation (in layman's language), and what action should be taken concerning abnormal or suspicious test results.

IX. ACKNOWLEDGMENTS

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X. DISTRIBUTION AND AVAILABILITY

Copies of this report are currently available upon request from NIOSH, Division of Technical Service, Information Resources and Dissemination Section, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days the report will be available through the National Technical Information Service (NTIS), Springfield, Virginia 22216.

Copies of this report have been sent to:

1. United Steelworkers of America, Local 7084
2. Homestake Mining Company
3. U.S. Department of Labor/OSHA - Region VIII.
4. NIOSH - Region VIII.

For the purpose of informing all employees, a copy of this report shall be posted in a prominent place accessible to the employees for a period of 30 calendar days.

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APPENDIX A

HOMESTAKE MINING COMPANY
LEAD, SOUTH DAKOTA

OCCUPATIONAL AND EXPOSURE HISTORY

Full Name: ____

Current Address: ____
(street)

____
(city) (state) (zip)

Soc. Sec. No.: ____________________ Birthdate: ____________________

	JOB TITLE	DEPT.	START (mo/da/yr)	STOP (mo/da/yr)	JOB DESCRIPTION	CHEMICAL EXPOSURES
1.						
2.						
3.						
4.						

Table 1

PERSONAL/AREA SAMPLING CONCENTRATION DATA
FOR
LEAD, RESPIRABLE AND TOTAL PARTICULATE DUST
ASSAY OFFICE
HOMESTAKE MINING COMPANY
LEAD, SOUTH DAKOTA
MARCH, 1978
HE 78-34

Area and/or Job Activity	Sample Time(Hrs.)	Sample Volume(M^3)	Atmospheric Concentration		
			Lead $\mu g/M^3$	Particulate Dust (mg/M^3) Total	Respirable
Personal Samples					
Sample Preparation:					
Assayer Helper	6.0	.61	ND	.31	-
Crushing	6.0	.61	ND	4.43	-
Cutting Down	6.0	.54	ND	-	6.17
Mixing:	6.0	.54	10	-	.98
	6.0	.54	20	-	22.28
Furnace:	5.5	.50	67	-	-
	5.5	.50	78	-	-
	5.5	.50	89	-	-
Area Samples					
Sample Preparation (Cutting Down)	6.0	.61	ND	2.26	-
Mixing	6.0	.61	ND	ND	-
Furnace	5.5	.50	10	-	-
Environmental Criteria			50 $\mu g/M^3$ (OSHA)	10.00 mg/M^3 (ACGIH)	5.00 mg/M^3 (ACGIH)
Limits of Detection			5 μg	.01 mg	.01 mg

Table 2

DISTRIBUTION OF BLOOD LEAD VALUES BY WORK AREA
HOMESTAKE MINING COMPANY
LEAD, SOUTH DAKOTA
MARCH, 1978
HE 78-34

	µg/dl whole blood	Assay Office	Refinery
Normal Values in Unexposed Population:	< 20	2	-
	20 - 29	4	-
	30 - 39	6	-
	40 - 49	2	-
	50 - 59	2	2
Values Requiring Medical Removal by OSHA Standard:	60 - 69	-	4
	70 - 79	1	4
	80 - 89	-	1
Total		17	11
Range		17-73	53-86
Mean (S.D.)		37 (14)	68 (9)

Table 3

DISTRIBUTION OF ZINC PROTOPORPHYRIN VALUES BY WORK AREA
HOMESTAKE MINING COMPANY
LEAD, SOUTH DAKOTA
MAY 1978
HE 78-34

	µg/dl whole blood	Assay Office	Refinery
Values Seen in Normal Population:	< 20	3	1
	20 - 39	5	1
	40 - 59	3	1
Medical Evaluation Indicated:	60 - 79	2	1
	80 - 99	1	1
	100 - 149	3	2
	150 - 400	-	4
Total		17	11
Range		10-146	15-365
Mean (S.D.)		52 (40)	135 (116)

TABLE 4

DISTRIBUTION OF SYMPTOMS ASSOCIATED WITH LEAD EXPOSURE BY WORK AREA
HOMESTAKE MINING COMPANY
LEAD, SOUTH DAKOTA
MAY 1978
HE 78-34

	Assay Office (N = 17)		Refinery (N = 11)		Total (N = 28)	
	No.	Percent	No.	Percent	No.	Percent
I. Gastrointestinal:						
nausea	6	35	4	36	10	36
crampy abdominal pain	1	6	2	18	3	11
poor appetite	2	12	1	9	3	11
constipation	0	0	2	18	2	7
diarrhea	0	0	0	0	0	0
Any Gastrointestinal Symptom	7	5	2	18	9	32
II. Constitutional:						
fatique	9	53	3	27	12	43
irritability	6	35	2	18	8	29
frequent headaches (2/wk)	6	35	1	9	7	25
dizziness	1	6	3	27	4	14
insomnia	1	6	1	9	2	7
decreased interest in sex	2	12	1	9	3	11
Any Constitutional Symptom	14	100	5	46	19	68
III. Muscular-skeletal:						
muscle pain in legs	0	0	4	36	4	14
aching in bones	5	29	3	27	8	29
Any Muscular-skeletal Symptom	5	29	5	45	10	36
IV. Peripheral neurological: unexplained tingling or diminished sense of touch in fingers	3	18	1	9	4	18
V. Unusual metallic or sweet taste	2	12	5	46	7	25

Table 5

PERSONAL AIR SAMPLING CONCENTRATIONS
FOR
RESPIRABLE SILICA AND RESPIRABLE PARTICULATE DUST
SAMPLE PREPARATION ROOM, ASSAY OFFICE
HOMESTAKE MINING COMPANY
LEAD, SOUTH DAKOTA
MARCH/MAY 1978
HE 78-34

	Job Classification	Sample Time (Hrs.)	Sample Volume (M^3)	Atmospheric Concentrations (mg/M^3) Respirable Silica	Respirable Particulate Dust
First Survey March 1978	Assay Helper	6.0	.61	.15	.57
	Sizer	6.0	.61	.16	.36
	Assistant Assayer	6.0	.61	.25	.57
	Sampler 3rd Grade	6.0	.61	1.00	4.13
	Assay Helper	6.0	.61	1.05	3.75
	Sampler 1st Grade	6.0	.61	1.33	5.54
Second Survey May 1978	Assay Helper	4.5	.45	.07	.13
	Sizer	4.5	.45	.07	.18
	Sample 1st Grade	4.5	.45	.22	.44
	Assay Helper	4.5	.45	.24	.67
Enivironmental Criteria				(NIOSH) 0.05 mg/M^3	(ACGIH) 5.00 mg/M^3
Limits of Detection				0.03 mg	0.01 mg

Table 6

PERSONAL SAMPLING DATA FOR LEAD AND
TOTAL AND RESPIRABLE PARTICULATE DUST IN THE REFINERY DEPARTMENT
HOMESTAKE MINING COMPANY
LEAD, SOUTH DAKOTA
MAY 1978
HE 78-34

Blast Furnace - Job Activity or Area	Sample Time(min)	Sample Volume(M^3)	Lead ($\mu g/M^3$)	Particulate Dust (mg/M^3) Respirable	Total
Furnace Opr. (preparation)	360	.54	130	-	2.0
	360	.61	80	1.1	-
Furnace Opr. (preparation)	360	.54	2,710	-	2.9
	420	.71	1,200	2.2	-
Furnace Opr.	360	.54	2,070	-	2.1
	420	.71	1,760	3.0	
Furnace Area(top fl)	360	.54	1,960	-	2.2
	420	.71	320	0.6	-
Furnace Area(bot.fl)	360	.54	250	-	2.0
	360	.61	290	2.1	-
Furnace Area(bot.fl)	360	.54	70	-	1.9
	360	.61	110	0.2	-
Furnace Charging Opr.	360	.54	10,740	-	17.0
	360	.61	12,300	22.6	-
Furnace Charging Opr.	360	.54	4,260	-	7.3
	360	.61	4,100	7.1	-
Environmental Criteria			50 $\mu g/M^3$ (OSHA)	5.00 mg/M^3 (ACGIH)	10.00 mg/M^3 (ACGIH)
Limit of Detection			3 µg	0.01 mg	0.01 mg