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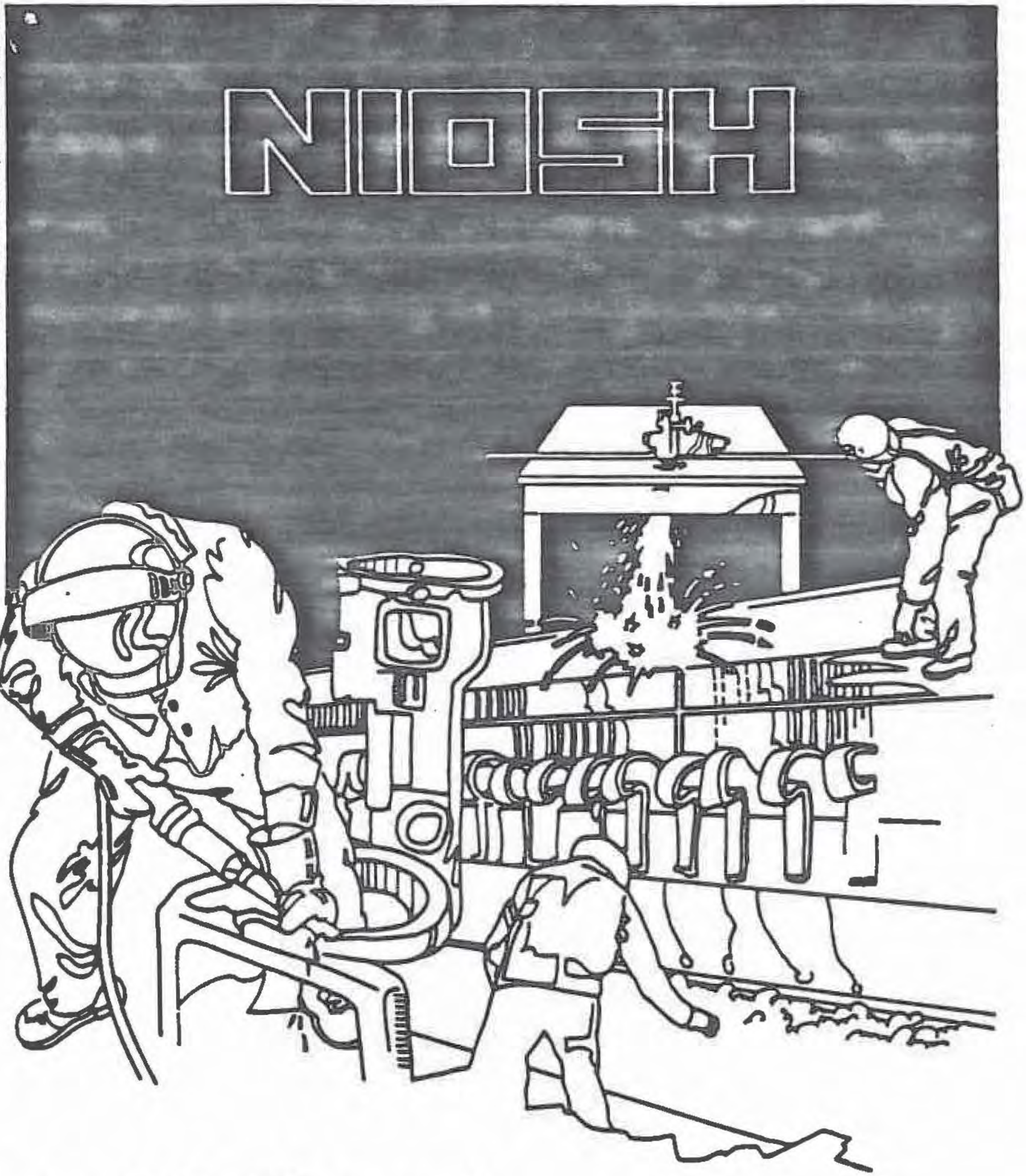

Health Hazard Evaluation Report

HETA 83-162-1746
HANDY AND HARMAN, INC.
FAIRFIELD, CONNECTICUT

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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HANDY AND HARMAN, INC.
FAIRFIELD, CONNECTICUT

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I. SUMMARY

In February 1983, the National Institute for Occupational Safety and Health (NIOSH) was requested to evaluate health concerns relating to beryllium and other metal exposures by employees at Handy and Harman (a precious metals refinery) in Fairfield, Connecticut. A major concern was the occurrence of granulomatous lung disease (GLD) in four male workers aged 27 to 31. An environmental-medical survey was conducted in July 1983 and a follow-up environmental survey was conducted in November 1983. Personal air samples were obtained in the refinery and manufacturing melt areas to measure arsenic, beryllium, cadmium, lead, nickel and silver. Medical records for the four workers (and a subsequent fifth worker) with GLD were reviewed. A questionnaire designed to identify other cases of GLD was administered to 45 of 70 current refinery workers. Company medical records, spirometry, chest x-rays, and urinary cadmium levels were reviewed.

Of the 121 personal air samples obtained in the refinery, 114 (92%, range 4.8-543, mean 309 $\mu g/m^3$) exceeded the OSHA permissible exposure limit (PEL) for silver of 10 $\mu g/m^3$; 62 (51%, range $\leq$ 0.22-42, mean 1.4 $\mu g/m^3$) exceeded the NIOSH recommended exposure limit (REL) for beryllium of 0.5 $\mu g/m^3$; 55 (46%, range 1.2-925, mean 86 $\mu g/m^3$) exceeded the OSHA PEL for lead of 50 $\mu g/m^3$; 54 (45%, range 1.8-161, mean 20 $\mu g/m^3$) exceeded the NIOSH REL for nickel of 15 $\mu g/m^3$; and 6 (5%, range $\leq$ 1.0-5.8, mean 1.4 $\mu g/m^3$) exceeded the NIOSH REL for arsenic of 2.0 $\mu g/m^3$. The cadmium levels ranged from 1.7-1150 $\mu g/m^3$; NIOSH recommends that cadmium be regarded as a potential carcinogen and that exposures be controlled to the lowest feasible limit. The 39 personal air samples obtained in the manufacturing melt area showed exposure concentrations to cadmium ranging from 9.3-115 $\mu g/m^3$ (mean 47 $\mu g/m^3$) and concentrations of silver ranging from 11-104 $\mu g/m^3$ (mean 32 $\mu g/m^3$); 100% of silver concentrations exceeded the OSHA PEL.

Four of the five cases of GLD should be diagnosed as chronic beryllium disease. Each has histologically confirmed granulomatous disease, documented beryllium exposure and marked *in vitro* proliferation of lung lymphocytes to beryllium salts. The fifth case is more problematic in view of coexistent gastrointestinal schisotsomiasis, predominant losinophilia on bronchoaloeolar lavage, negative peripheral blood testing and failure to obtain viable lavage lymphocytes. Clinical

assessment of the questionnaires and review of prior x-rays and spirometry showed that 18 current refinery workers had lower respiratory tract complaints (cough, dyspnea or wheezing) believed to have occurred since onset of employment. Of these, seven had either abnormal spirometry or nonspecific radiographic abnormalities. Urinary cadmium levels measured over a 17-year period for employees in manufacturing melt indicated that the mean concentrations (range of means 22-49 µg/l) exceeded the recommended limit of 10 µg/l necessary to prevent damage to the kidneys.

Based on environmental results and clinical evidence, it was concluded that a health hazard from beryllium exposure has existed and may still exist at this facility. Four and possibly five cases of chronic beryllium disease have resulted from work in the refinery. Current refinery workers are exposed to potentially toxic concentrations of arsenic, beryllium, cadmium, lead, nickel and silver. Manufacturing melt workers are exposed to potentially toxic concentrations of cadmium and silver. Recommendations to control these exposures are offered in Section VII of this report.

KEYWORDS: SIC 3341 (Secondary Smelting and Refinery of Nonferrous Metals), beryllium disease, sarcoidosis, granulomatous disease, beryllium, lead, arsenic, nickel, cadmium and silver.

II. INTRODUCTION

On February 22, 1983, the National Institute for Occupational Safety and Health (NIOSH) was requested by the United Steel Workers of America on behalf of Local 7201 to evaluate health concerns relating to employee exposures to beryllium, arsenic, lead, nickel, cadmium and silver at Handy and Harman, Inc., in Fairfield, Connecticut. A major concern was the occurrence of granulomatous lung disease in four male workers aged 27 to 31 who had previously worked in the furnace area of the refinery.

NIOSH investigators conducted an environmental-medical survey on July 5-8, 1983, and a followup environmental survey on November 1-4, 1983. The environmental sample results were reported to the company in letters dated September 22, 1983, and February 7, 1984. The company was notified by NIOSH of a fifth case of granulomatous lung disease, diagnosed as chronic beryllium disease, in a letter dated June 26, 1985. This letter was accompanied by a copy of the recommendations to reduce employee exposure to beryllium and other metals, which were presented to the company on November 4, 1983.

III. BACKGROUND

The Fairfield facility of Handy and Harman is engaged in the refining of precious metals from industrial scrap, and the fabrication of silver and gold alloys in various mill forms. The facility consists of two primary production areas - (a) refinery and (b) manufacturing melt.

A. Refinery Process

The refinery operation involves the processing of precious metals bearing scrap to yield homogeneous metal ingots and powders of varying purities of gold and silver. The precious metals are reclaimed from industrial scrap using waste materials culled from the electronics, computer, photographic, chemical and decorative industries.

The process is diagrammed in Figure 1. The materials are physically described and weighed in the receiving department and classified according to the flow process best suited for refining. Wet materials and those with organic constituents (e.g. circuit boards) are first incinerated for drying and elimination of carbonaceous material. The residue then goes through mechanical processing including crushing, ball milling and screening to reduce the material to a homogeneous mixture. Screening or volumetric sizing separates the milled material into two fractions with respect to particle size of the material. The undersize fraction

(-40 mesh) is assayed and either mixed with powders of similar purity, or blended with other powders to achieve a desired purity level. The oversize fraction (+40 mesh) is melted in direct arc induction furnaces and cast as 1000 ounce ingots. Input materials of high purity (e.g., bullion and silverware) are melted directly and cast as 1000 ounce ingots. These powders and ingots are then shipped to other facilities for further refining to yield gold and silver of the desired purity level.

The refinery work force of approximately 70 is divided into eight distinct job groupings: Samplers, crusher-screen operators, ball mill operators, floor sweepers, furnace tenders, dry pan operators, incinerator operators, and silver powder operators. With the exception of some utility workers who rotate jobs, assignments tend to be stable with infrequent switching from category to category.

The process and ventilation had been largely unchanged for decades. Beginning in 1981 all refinery workers were required to wear air purifying respirators. No respiratory protective devices had been routinely used prior to that date.

B. Manufacturing Melt Process

The manufacturing melt area produces gold and silver, primarily as alloys, in various mill forms. The refined precious metal ingots and alloying elements (e.g., cadmium and nickel) are melted in electric arc furnaces and cast as wire, tubing, sheet, strip or bars.

The manufacturing melt work force of approximately 25 is divided into five distinct job groupings: furnace operators, furnace helpers, saw operators, mold-man, and utility operators.

IV. EVALUATION DESIGN AND METHODS

A. Environmental

The evaluation consisted of collecting and analyzing 121 personal air samples in the refinery, 39 personal air samples in the manufacturing melt area, and bulk settled dust samples from the refinery. Sampling was roughly evenly distributed over job categories as well as over all work shifts. Multiple samples were obtained to characterize the range of exposures in an inherently variable "batch" process. Each air sample was collected for 7-8 hours to define an 8-hour time weighted average exposure to beryllium, arsenic, cadmium, lead, nickel, and silver. The samples were collected on 37-mm diameter mixed cellulose ester filters (0.8 µ nominal pore size) contained in a 3-piece closed-faced cassette using calibrated constant flow sampling pumps operating at 2.0 L/min. The filters were analyzed in the laboratory of the National Institute for Occupational Safety and Health (NIOSH) using inductively coupled plasma-atomic emission spectroscopy (ICP-AES)[1].

Eleven samples of settled dust were obtained from the crusher-screen, dry pan and furnace areas of the refinery and were analyzed for arsenic, beryllium, cadmium, nickel, lead and silver by ICP-AES (1). These samples also were analyzed for one polymorph of crystalline silica (quartz) by x-ray diffraction [1]. The settled dust samples were obtained from surfaces, selected to represent the accumulation of dust over an extended period of time.

B. Medical

Medical records for the four workers (and a subsequent fifth worker) with granulomatous lung disease were collected and reviewed. Established criteria for diagnosis of chronic beryllium disease (CBD) specify that there must be a documented exposure to beryllium and three or more of the following (2,3):

1. Establishment of significant beryllium exposure based on sound epidemiologic history.

2. Objective evidence of lower respiratory tract disease and a clinical course consistent with beryllium disease.

3. Chest x-ray films with radiologic evidence of interstitial fibronodular disease.

4. Evidence of restrictive or obstructive defect with diminished carbon monoxide diffusing capacity by physiologic studies of lung function.

5. Pathologic changes consistent with beryllium disease on examination of lung tissue and/or lymph nodes; presence of beryllium in lung tissue or thoracic lymph nodes.

Forty-five of 70 current refinery workers were administered a questionnaire reviewing demographic information, work history and respiratory symptoms. The questionnaire was designed to identify any other cases of granulomatous lung disease and to identify workers for further evaluation of possible atypical CBD.

Medical records, spirometry and chest x-rays obtained routinely by the company within the past 5 years were reviewed. Unfortunately, data on laid-off, terminated or retired workers were not available nor were the numbers of workers in the latter categories readily ascertainable.

Urinary cadmium records for the previous seventeen years (1976-1983) on employees in the manufacturing melt area were reviewed.

V. EVALUATION CRITERIA

A. Environmental Criteria

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers my 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 snall percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy).

In addition, some hazardous substances my act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the evaluation criterion. These combined effects 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 for the workplace are: 1) NIOSH Criteria Documents and recommendations, 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs), and 3) the U.S. Department of Labor (OSHA) occupational health standards. Often, the NIOSH recommendations and ACGIH TLVs are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLVs usually are based on more recent information than are the OSHA standards. The OSHA standards also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH-recommended standards, by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that industry is legally required to meet those levels specified by an OSHA standard.

Substances evaluated in this study and corresponding environmental criteria are shown below:

	Environmental Criteria µg/m^3 8-Hour Time-Weighted Average		
	NIOSH	OSHA	ACGIH
Arsenic	2c	10	200
Beryllium	0.5	2	2
Cadmium	LFL	200	50
Lead	50	50	150
Nickel	15	1000	100
Silver	-	10	10

c - Ceiling concentration and should never be exceeded.
LFL - Lowest feasible limit.

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.

B. Health Effects

1. Arsenic [4-6]

The major route of exposure to arsenic is normally through inhalation, although skin absorption and ingestion are other important modes. Since arsenic's toxic effect is at the specific site of absorption, as well as systemic, the chemical form of the exposure -- metal, salt, chloride, oxide -- combined with the exposure site can produce very different etiologies of disease.

Irritant and Sensitization Effects. Arsenic compounds are irritants of the skin, mucous membranes, and eyes. Hyperpigmentation and hyperkeratoses are also associated with occupational exposure to arsenic compounds. The dermatitis associated with arsenic may involve either primary irritation or allergic sensitization. Ulceration and a sometimes painless perforation of the nasal septum are classical stigmata of arsenic trioxide exposure.

Neurological Effects. Peripheral neuropathies have been described with environmental exposure to arsenic compounds. Some organic arsenicals have a selective effect on the optic nerve, including blindness.

Systemic Effects. Arsenic's notoriety as a cumulative systemic poison is expressed in its wide range of adverse symptoms, which include weakness, anorexia, and gastrointestinal disorders. There are selective actions on the liver, the other blood forming organs, and on the cardiovascular system. Impairment of peripheral circulation has lead to gangrenous conditions of the extremities ("blackfoot disease"), although this has not been reported to be a consequence of occupational exposure.

Cancer. Arsenic has been related to skin cancers at the site of exposure. Much more serious is a reported elevated rate of lung cancer. Several studies of smelter workers have shown a three to five fold increase in lung cancer mortality among smelter workers.

2. Beryllium [7-11]

The main route of exposure of beryllium and beryllium compounds is through the lung. Local contact has produced a granulomatous and scarring skin reaction and can produce a systemic sensitization, aggravating the effects of inhalation.

Under current conditions of exposure, skin reactions are no longer seen in the United States among workers exposed to beryllium. The most serious effect is a granulomatous lung disease, which can produce symptoms of shortness of breath, weight loss, anorexia, and cough. The disease is associated with alterations in immunity and clinical anergy. Before the advent of steriods, and when exposures were higher, one-third of all cases died from the chronic form of the disease. In the classical presentation of the disease, there is no remission and steriod dependency is lifelong. There is an acute form of beryllium disease, a chemical pneumonitis, which was common before industrial regulations. There have been no reported cases of the acute disease in the United States in more than 20 years.

Although beryllium disease is generally regarded as an intrathoracic process, liver granulomata are common and there is at least one case report in the NIOSH Beryllium Case Registry (BCR) of an exclusively neurological manifestation of the disease.

Beryllium is a potent animal carcinogen. Its status as a human carcinogen is still undetermined although several studies have associated its occupational use with increased rates of lung cancer.

3. Lead [12]

Inhalation of lead dust and fumes is the major route of lead exposure in industry. A secondary source of exposure may be from lead dust contamination on food, cigarettes, or other objects. Once absorbed, lead is excreted from the body very slowly. The absorbed lead can damage the kidneys, peripheral and central nervous systems, and the blood forming organs (bone marrow). These effects may be felt as weakness, tiredness, irritability, digestive disturbances, high blood pressure, kidney damage, mental deficiency, or slowed reaction times. Chronic lead exposure has been associated with infertility and with fetal damage in pregnant women.

Blood lead levels below 40 µg/100 ml whole blood are considered to be normal levels which may result from daily environmental exposure. However, fetal damage in pregnant women may occur at blood lead levels as low as 30 µg/100 ml. Lead levels between 40-60 µg/100 ml in lead exposed workers indicate excessive absorption of lead which may result in some adverse health effects. Levels of 60 to 100 µg/100 ml represent unacceptable elevations which may cause serious adverse health effects. Levels over 100 µg/100 ml are considered dangerous and often require hospitalization and medical treatment.

The Occupational Safety and Health Administration (OSHA) standard for lead in air is 50 µg/m^3 calculated as an 8-hour time-weighted average for daily exposure.[12] The standard also dictates that workers with blood lead levels greater than 50 µg/100 ml must be immediately removed from further lead exposure and, in some circumstances, workers with lead levels of less than 50 µg/100 ml must also be removed. At present according to the OSHA Standard medical removal of workers is necessary at blood lead levels of 60 µg/100 ml or greater. Removed workers have protection for wage, benefits, and seniority for up to 18 months until their blood levels decline to below 50 µg/deciliter and they can return to lead exposure areas.

4. <u>Cadmium</u> [13-15, 21]

Cadmium is an irritant to the respiratory tract. Prolonged exposure can cause anosmia (loss of sense of smell) and a yellow stain that gradually appears on the necks of the teeth. Cadmium compounds are poorly absorbed by the intestinal tract, but relatively well absorbed by inhalation. Skin absorption appears negligible. Once absorbed, cadmium has a very long half-life and is retained in the kidney and liver.

Systemic effects have been reported as a result of cadmium exposure at concentrations which did not provide warning symptoms of irritation. If enough is inhaled, after a delay of several hours, a person may develop cough, shortness of breath (emphysema), chest pain, sweating, chills, headache, muscle aches, weakness, and nausea. Exposure to cadmium has also been reported to cause kidney damage and an increased incidence of prostrate cancer in man.

In animal studies, cadmium has produced damage to the liver and central nervous system, testicular atrophy, testicular neoplasms, hypertension, and teratogenic effects. None of these conditions have yet been reported resulting from occupational exposure to cadmium.

A NIOSH epidemiological study has demonstrated a statistically significant excess of lung cancer mortality among workers exposed to cadmium oxide. A chronic inhalation exposure study with rats provides toxicological evidence that exposure to cadmium chloride aerosol can cause a dose dependent incidence of malignant lung cancer.

5. <u>Nickel</u> [16-17]

The most toxic route of entry for nickel is by inhalation. Nickel is an irritant, sensitizer, and carcinogen. Signs and symptoms of nickel overexposures include gingivitis, stomatitis, and metallic taste. Acute symptoms include metal fume fever and nickel itch. Dermatitis with eczema may occur later. Carcinoma of the nasal sinuses and lungs may result from chronic exposure.

6. Silver [20]

The only local effect from metallic silver derives from the implant of small particles in the skin of the workmen (usually hands and fingers) which causes a permanent discoloration equivalent to the process of tatooing (local argyria). All forms of silver are cumulative once they enter body tissues, and very little is excreted. Although silver produces argyria, the condition produces no constitutional symptoms. The dust may be deposited in the lungs and may be regarded as a form of pneumoconiosis, but it carries no hazard of fibrosis. The existence of kidney lesions of consequence to renal function is improbably from occupational exposure.

VI. RESULTS AND DISCUSSION

A. Environmental

1. Refining Area

Metal assays were completed on 11 settled dust samples obtained from elevated horizontal surfaces in the crusher-screen, dry pan, and furnace areas (Table 1). The samples contained by weight (mean $\pm$ 1SD) 0.008 $\pm$ 0.017% arsenic, 0.037 $\pm$ 0.019% beryllium, 1.88 $\pm$ 2.28% cadmium, 1.54 $\pm$ 0.877% lead, 0.418 $\pm$ 0.284% nickel and 1.27 $\pm$ 1.06% silver.

Personal 8-hour time-weighted average (TWA) exposures to arsenic, beryllium, cadmium, lead, nickel and silver were measured for each of the eight job classifications in the refining area (Tables 2-7). The mean exposure concentrations for 121 personal samples by job classifications are presented in Table 8. The exposure concentrations exceeded the environmental criteria for all of the metals, except arsenic (mean 0.82 $\mu g/m^3$, 2.0 $\mu g/m^3$ NIOSH REL). Table 9 presents these data as percent of the 8-hour TWA exposure concentrations that exceed the environmental criteria. The highest percentage of exposures exceeded the silver criteria (94%), followed by beryllium (53%), lead (46%), nickel (45%), cadmium (20%), and arsenic (5%).

The percentage distribution of personal 8-hour TWA exposures that exceed the environmental criteria by job classification are presented in Table 10. The exposures by the ball mill operators most frequently exceeded the environmental criteria

(70%), followed by the crusher-screen operators (57%), sampler-mixers (49%), floor-sweepers (40%), dry pan operators (34%) and furnace tenders (28%).

The personal 8-hour TWA concentrations of beryllium measured in the refining area (Table 11) revealed a wide range of values from 0.22 $\mu g/m^3$ to 42.3 $\mu g/m^3$ (mean 1.2 $\pm$ 0.96 $\mu g/m^3$). These values closely fit a log normal distribution ($R > 0.9$). Approximately 50% (57 of 114 values) of the exposure concentrations exceeded the NIOSH REL of 0.5 $\mu g/m^3$; and 10% (14 of 114) of the exposure concentrations were in excess of the OSHA PEL of 2.0 $\mu g/m^3$.

Analysis of the beryllium air concentrations by job classification revealed some striking differences (Figure 2). Beryllium exposure levels for furnace tenders, sweepers and dry pan operators were uniformly below the OSHA PEL with means of 0.52 $\pm$ 0.44, 0.63 $\pm$ 0.32 and 0.46 $\pm$ 0.48 $\mu g/m^3$, respectively, while those for the crushers and ball mill operators were much higher (means 2.7 $\pm$ 7.2 and 2.1 $\pm$ 1.6 $\mu g/m^3$); samplers were intermediate, mean 0.72 $\pm$ 0.95.

A crystalline silica (quartz polymorph) analysis was completed on 11 settled dust samples obtained from elevated horizontal surfaces in the crusher-screen, dry pan, and furnace areas of the refinery (Table 12). The crystalline silica (quartz) content of the samples (percent by weight) ranged from 4 to 12% (mean 8.7 $\pm$ 3%). Although no air samples were collected for crystalline silica, these settled dust samples demonstrate that the workers in the refining area also may be exposed to crystalline silica.

2. <u>Manufacturing Melt</u>

The data in Tables 13 and 14 indicate that exposures in the manufacturing - melt area were below the established criteria for arsenic, beryllium, lead and nickel. However, 35 of the 39 sample results (90%) exceeded the criteria for silver exposure. The exposure levels (mean $\pm$ standard deviation) for cadmium and silver in the manufacturing area were 46.5 $\pm$ 29.6 and 32.3 $\pm$ 20.8 respectively.

These results are consistent with the fact that the metals used in the manufacturing area have already been refined to a high degree of purity. Most of the alloys used during the NIOSH sampling visits were silver/cadmium, again consistent with the sampling results.

B. Medical

1. Refining Area

Forty-five of 70 current refinery workers were available for the survey; others were unavailable because of temporary lay-off, transfer or illness. The mean age was 44.5. Average duration of employment at the facility was 14.4 years with an average of 12.6 years in the refinery. Ethnic composition was 31% Northern European, 33% Portuguese, 16% Hispanic and 20% Black.

Review of specific job assignments within the refinery revealed that 29% of the workers were currently assigned to jobs which involved some work around the furnaces (including utility workers and repairman). Workers had changed jobs on the average of once every 4 years, although most changes were within, rather than between, groupings. Overall, 38% of the group had had at least one assignment around the furnaces.

The clinical histories of the four workers with granulomatous lung disease have been reviewed by the NIOSH investigators. The patient's physician has summarized the case histories [7].

"Case 1 (Index)

This 40-year old nonsmoking man referred himself to the Yale Occupation Medicine Clinic in 1980 for suspected "berylliosis". In 1964, he had moved to Connecticut and taken employment at the refinery; he was stationed at the furnace. In 1972, he developed chronic respiratory symptoms.

Despite transfer out of the refinery, symptoms progressed. In 1976, he was hospitalized for evaluation. Chest x-ray showed hilar adenopathy and diffuse parenchymal infiltrates bilaterally. Lung function studies revealed a restrictive defect with a decreased diffusing capacity for carbon monoxide. Open lung biopsy revealed non-caseating granulomata and pulmonary-fibrosis. He was begun on corticosteroids for presumed sarcoidosis.

Between 1976 and 1980, the patient independently investigated a possible relationship between exposure at the furnace and his lung disease, prompted by the occurrence of "sarcoidosis" in several co-workers. He maintained a list of raw materials delivered to the receiving room of the plant; many contained beryllium alloys.

Re-evaluation in 1980 showed diffuse dry crackles over the chest and moderate digital clubbing; he was slightly tachypneic at rest. Dermatologic and general physical examination was otherwise unrevealing. Chest x-ray and lung function tests were unchanged from 1976 despite discontinuing steriods after 1 year. Complete blood count, differential, routine serum chemistries and angiotensin converting enzyme were all normal. Ashing of his prior lung specimen for beryllium content demonstrated 0.016 ng/gm dry wt, a high normal level [18].

<u>Case 2</u>

This 31-year old man had worked near case #1 beginning in 1971 when he came to Connecticut. He smoked less than 1/2 pack of cigarettes daily. In 1975, he developed respiratory and constitutional symptoms. Evaluation in 1976 revealed an abnormal chest x-ray with hilar adenopathy and reticulonodular infiltrates. Lung function showed mild restriction and obstruction with a diffusing capacity for carbon monoxide that was 50% of predicted. A percutaneous liver biopsy showed non-caseating granulomas. Sarcoidosis was diagnosed. No therapy was begun. Because of symptoms, the patient was transferred out of the refinery area.

Re-evaluation in 1980 showed little progression clinically. Crackles were ausculated over the lungfields; the remainder of the physical exam was normal. Routine bloodwork and serum angiotensin converting enzyme were also normal. Radiographs and lung function studies were unchanged.

<u>Case 3</u>

This 35-year old man had been in good health prior to starting work as a furnace operator in 1972; he was a nonsmoker. He had been told of possible hilar enlargement while in military service 10 years earlier. In 1977, he developed a respiratory illness with persistent fevers and anthralgias. Radiographs showed moderate hilar enlargement and diffuse bilateral parenchymal infiltration. He had reduced lung volumes and marked impairment of diffusing capacity. A diagnosis of sarcoidosis was established by transbronchial biopsy. Steroids were begun and he was transferred out of the refinery area.

In 1980 he was stable functionally and radiographically although he remained steroid-dependent. Physical examination, routine bloodwork and serum angiotensin converting enzyme were normal.

Case 4

This 41-year old nonsmoker had moved to Connecticut in 1968 where he began work in the furnace area of the refinery. In 1972, he developed an illness characterized by fevers, cough and dyspnea. During hospital evaluation, he was noted to have eosinophilia and abnormal liver function as well as hilar lymphadenopathy and advanced pulmonary parenchymal infiltration with fibrocystic changes. Liver biopsy revealed non-caseating granulomas and ovae of schistosoma mansoni. Open lung biopsy revealed diffuse non-caseating granuloma, Schauman bodies and fibrosis. Ova, eosinophils and vascular involvement often seen in association with granulomas in pulmonary schistosomiasis were notably absent on the lung specimen. He was discharged with the diagnosis of gastrointestinal Schistosomiasis and probably sarcoidosis. Corticosteroids were begun and the patient shortly thereafter returned to Puerto Rico.

Re-evaluation in 1980 revealed a chronically ill, cushingoid man in moderate respiratory distress. Physical examination was remarkable only for diffuse wheezing and an enlarged liver. Fingers were moderately clubbed. Liver function studies showed slight elevations of hepato-cellular enzymes and alkaline phosphatase. Peripheral blood smear and angiotensin converting enzyme were normal. Chest x-ray was unchanged since 1972. Pulmonary function tests showed moderately severe restriction and obstruction with severely impaired diffusing capacity for carbon monoxide."

Neither the company nor union officials were aware of any other cases of sarcoidosis among workers at the plant or among workers who had left.

Clinical assessment by questionnaire and review of prior x-rays and spirometry was undertaken for evidence of granulomatous lung disease. Eighteen current workers had lower respiratory complaints (cough, dyspnea or wheezing) believed to have occurred since onset of employment. Of these, 7 had either abnormal spirometry or non-specific radiographic abnormalities. No current refinery worker, however, had either an x-ray or spirometry suggestive of sarcoidosis or chronic beryllium disease.

In June 1985, NIOSH investigators were notified of a fifth case of a worker with granulomatous lung disease. This worker with granulomatous lung disease had completed a questionnaire at the time of the November 1983 survey:

Case 5

This 38-year old male began work at the magnetic separator machine in 1961. Between 1972 and 1985 he worked in the crushing area and at the separator and as a mixer/sampler. Notably, he did not work in the furnace area (unlike all four other cases).

In December 1984, he noted respiratory and constitutional symptoms. A chest x-ray and CT scan were compatible with pulmonary interstitial fibrosis and demonstrated hilar and mediastinal lymphadenopathy. His diffusion capacity for carbon monoxide was 32% of normal, and there was elevation of serum hepatocellular enzymes and alkaline phosphatase. He had a polyclonal gammopathy. A trans-bronchial biopsy in May 1985 demonstrated non-caseating granulomas.

An independent investigation by researchers at Yale University and University of Pennsylvania demonstrated proliferation of lavage lymphocytes in response to incubation with mitogens or with beryllium salts in three workers with granulomatous disease in whom adequate lavage samples were obtained [7]. These results were in marked contrast to the absence of a lavaged cellular proliferative response to beryllium salts in a group of ten patients with sarcoidosis (and no history of exposure to beryllium) who were used as controls. Unfortunately, viable lung lymphocytes for the study were not available to the university researchers for cases #3 and #4.

2. Manufacturing Melt Area

Mean urinary cadmium was computed for all measurements for every fifth year of available data:

Year	Mean Urinary Cadmium (µg/l)
1967	27
1972	49
1977	38
1983*	22

All mean concentrations exceed 10 µg/l; a level considered necessary to prevent damage to the kidneys [19].

*This includes results for the year up until the time of NIOSH visit to the plant in November 1983.

C. Observations Pertaining to Safety Program

Employees who will be required to wear respirators receive pre-employment training in their use and limitations. Periodic training seminars are held for the different work groups. Examples of films, video-tapes and other safety presentations include "Way to Live" - dealing with respirator safety, "Wrong Time, Wrong Place, Wrong Shoes" - dealing with safety shoes, "Survival in the 70's" - dealing with security, "Practical Lighting Workshop", "Bearing Maintenance", "Work Measurement and Methods", "Preventive Maintenance", "Applied Sampling Techniques", "Industrial Noise Measurement", "Conservation and Audiometric Testing". In addition, the safety officer has attended OSHA training for Voluntary Compliance, and "OSHA-Up-To-Date". The fire brigade receives periodic training in the use of fire fighting equipment.

There is a hearing conservation program in effect, with annual audiometric testing. For the past year the company has been establishing base line levels on all new employees, and initial monitoring for all present employees.

There is also a medical monitoring program in effect for employees potentially exposed to cadmium and lead. Urine cadmium levels are determined in the manufacturing melt area and blood lead levels are determined in the refinery. Only a representative sample of employees are selected for each round of medical monitoring. There did not appear to be a logical mechanism for selecting employees to be monitored. However, most employees indicated that they have been monitored at some time in the past. Not all employees were aware of the results of their individual monitoring. Employees indicated that results were communicated to them as "OK", or "too high". Relatively few employees have been removed from exposure due to the results of the medical monitoring program.

The company has a written respirator program, which was reviewed on-site. The program essentially identifies the training required and the areas where respirator use is mandatory (mostly in the refinery). Medical certification is part of the pre-employment physical process. The selection of respirators was made by the company based on previous environmental monitoring results. At present, qualitative fit testing is the norm.

VII. CONCLUSIONS

The environmental sampling results and clinical evidence demonstrate that a health hazard from beryllium exposure has existed at this facility. Four of the five cases of granulomatous lung disease at this refinery (cases #1-3 and #5) should be diagnosed as CBD based on histopathology and beryllium exposure. The diagnosis is less certain in case #4, because schistosomiasis could also have caused the pathology seen in the lung biopsy. Three cases are (in addition) reported to have shown remarkable in vitro proliferation of lavaged lymphocytes to beryllium salts which distinguished them from cases of sarcoidosis without beryllium exposure [7]. Bronchoalveolar lavage appears promising as a diagnostic tool for differentiating sarcoidosis from CBD.

In addition, the results of the environmental evaluation indicate that the current refinery workers are exposed to potentially toxic concentrations of arsenic, beryllium, cadmium, lead, nickel and silver; and current manufacturing melt workers are exposed to potentially toxic concentrations of cadmium and silver. These conclusions do not consider the protection afforded through the use of respirators. However, the use of respirators is not a substitute for engineering controls where exposure levels are in excess of established criteria.

Elevations of urinary cadmium suggests that the cadmium-exposed workers are at increased risk for kidney disease and for other diseases, including lung cancer, associated with overexposure to cadmium.

VIII. RECOMMENDATIONS

1. Unloading Crushers: The process of dumping material from the third floor crushers into 55 gallon drums on the second floor was extremely dusty. Material travels down a length of ductwork to a metal lid which fits over the drum opening. There is a two-inch vacuum exhaust duct attached to the metal lid which is very ineffective in controlling the fugitive dust emissions. Updraft air currents created by dust dropping into the drum causes the lid to lift off, and dust to escape. At times, the dust filled the entire second floor.

   Recommended improvements: Since the rims on the drums are often irregular (dented), a rubber gasket could be installed on the lid to overcome these irregularities. In addition, a weight could be applied to the tops of the lid to prevent it from lifting off the drum during dumping. The exhaust ventilation would then be able to compensate for air displacement within the drums during dumping. A second alternative could be to enclose the drums in a booth that is kept under negative pressure by means of exhaust ventilation.

2. Blender Unloading: Unloading the blender into 55 gallon drums creates essentially the same condition as mentioned above with the crushers. There are canvas skirts attached to the lids, but they do not create an effective seal. The back pressure puffs right out through the sides.

   Recommended improvements: Same as #1 above.

3. Blender Loading: The dumping of powders from drums on the second floor into the blender on the first floor created a considerable contribution to employees overall exposure. Simple redesign of the loading hood could eliminate the majority of this dust - again caused by back pressure puffs due to air displacement within the blender. The ventilation on the sides of the booth is totally ineffective. The exhaust on the back is good.

   Recommended improvements: The side flanges should be extended forward, well beyond the floor opening. Exhaust slots should be attached to the sides drawing sufficient velocity to capture the dust as it puffs back. It is much easier to capture the dust at its point source than after it disperses. It is a good practice to store the drums upside down after emptying, and this should be continued.

4. Patterson Mill: The Patterson Mill or ball mill appeared to be the most dusty operation in the refinery. Several reasons were noted. (1) The ventilation hood on top of the unit provided essentially no capture. Dust generated while loading and unloading went right past the hood. (2) Over-pulverization occurs when the mill is left on too long, resulting in very fine powder. (3) The conveyor on the bottom of the unit, in the pit, allows too much dust to fall off, necessitating employees to constantly sweep and shovel fine dust, creating additional exposure. (4) Drum and lid seals are ineffective at the end of this screening operation.

   Recommended improvements: Maintain sufficient capture velocity at the hood above the mill. If the ductwork is plugged up there is a need for more routine cleaning and maintenance. If this is not possible, a new system is indicated. It is essential to capture the dust generated at this point. Secondly, minimize pulverization time to the least amount necessary to do the job. This may require more stringent supervision to ensure that employees are not allowing the mill to run too long. This problem was pointed out by several employees and a supervisor during the NIOSH visits. Thirdly, the lower conveyor belt should be examined closely to determine how better to transport the material to the screen. One possibility would be to install a totally enclosed screw type conveyor. Finally, the drum and lid seal problem should be corrected as described in #1 above.

5. Manual Picking: There are several areas where drums are emptied on the floor and manually picked over by employees to remove large pieces of scrap. The dust created by dumping on the floor adds to the overall exposure, and could be eliminated.

   Recommended improvement: Dumping on the floor should be limited to designated areas. These areas should be enclosed in a three sided booth with ventilation drawing dust away from the employee, toward the back and sides. This will also help reduce worker exposure while shoveling.

6. Smoking and Eating: Smoking and eating should only be allowed in designated areas, and enforced. These areas should be free from dust contamination. Eating at the work station should be strictly prohibited in the refinery and melt room.

7. Cafeteria: There should be some means of removing loose dust from employees clothes prior to entering the lunch room, i.e., a down draft room. There should not be any source of exposure in the cafeteria. Ingestion of metals adds to the total body burden, and strict control measures are indicated.

8. First Floor Crush and Screen Area: The use of pressurized air to blow down employee's clothing should be prohibited. In addition to creating additional dust exposure, it is a serious safety hazard. The potential for getting foreign objects in the eyes is greatly increased. Also, the risk of embedding pieces of metal under the skin and the possibility of injecting metal into open wounds demands that this practice be stopped.

9. Melt Room: The use of respirators was very lax in this area. The respirator program should be improved to require their use in the melt room. All areas have potential overexposure to silver and cadmium, which mandates the use of respirators while trying to eliminate the exposures. There is a need to increase the exhaust ventilation at the fume generation source of all machines.

10. Based on past and current exposures, refinery workers are at risk for chronic beryllium disease, as well as silver-, lead-, nickel-, cadmium-, and arsenic-associated disease. Systematic medical examinations should be available to workers at timely intervals to identify early disease and to prevent progression. Such examinations of healthy workers might reasonably include (as a minimum) yearly chest x-ray, spirometric examination, liver function tests, hematocrit, and urinalysis. Lead-exposure workers

should be monitored according to legally required OSHA standards (C.F.R. 1910.1025, Appendices A-C). A careful history and physical examination by a physician familiar with the pathology associated with plant exposures should focus on the respiratory, dermatologic, hepatic, neurologic and renal organ systems. Employment records of former workers should be maintained in the event that early detection and successful preventive intervention for CBD might become available in the future. In this way, former workers could be notified and further disease prevented.

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XI. DISTRIBUTION AND AVAILABILITY OF REPORT

Copies of this report are currently available upon request from NIOSH, Division of Standards Development and Technology Transfer, Publications Dissemination Section, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through the National Technical Information Service (NTIS), 5285 Port Royal, Springfield, Virginia 22161. Information regarding its availability through NTIS can be obtained from NIOSH Publications Office at the Cincinnati address. Copies of this report have been sent to:

1. Handy and Harman, Inc., Fairfield, Connecticut
2. United Steel Workers of America, Local 7201, Wallingford, Connecticut
3. United Steel Workers of America, Pittsburgh, Pennsylvania
4. NIOSH, Region I
5. OSHA, Region I

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

Figure 1

Schematic flow chart of the refinery process

Handy and Harman, Inc.
Fairfield, Connecticut
July and November 1983

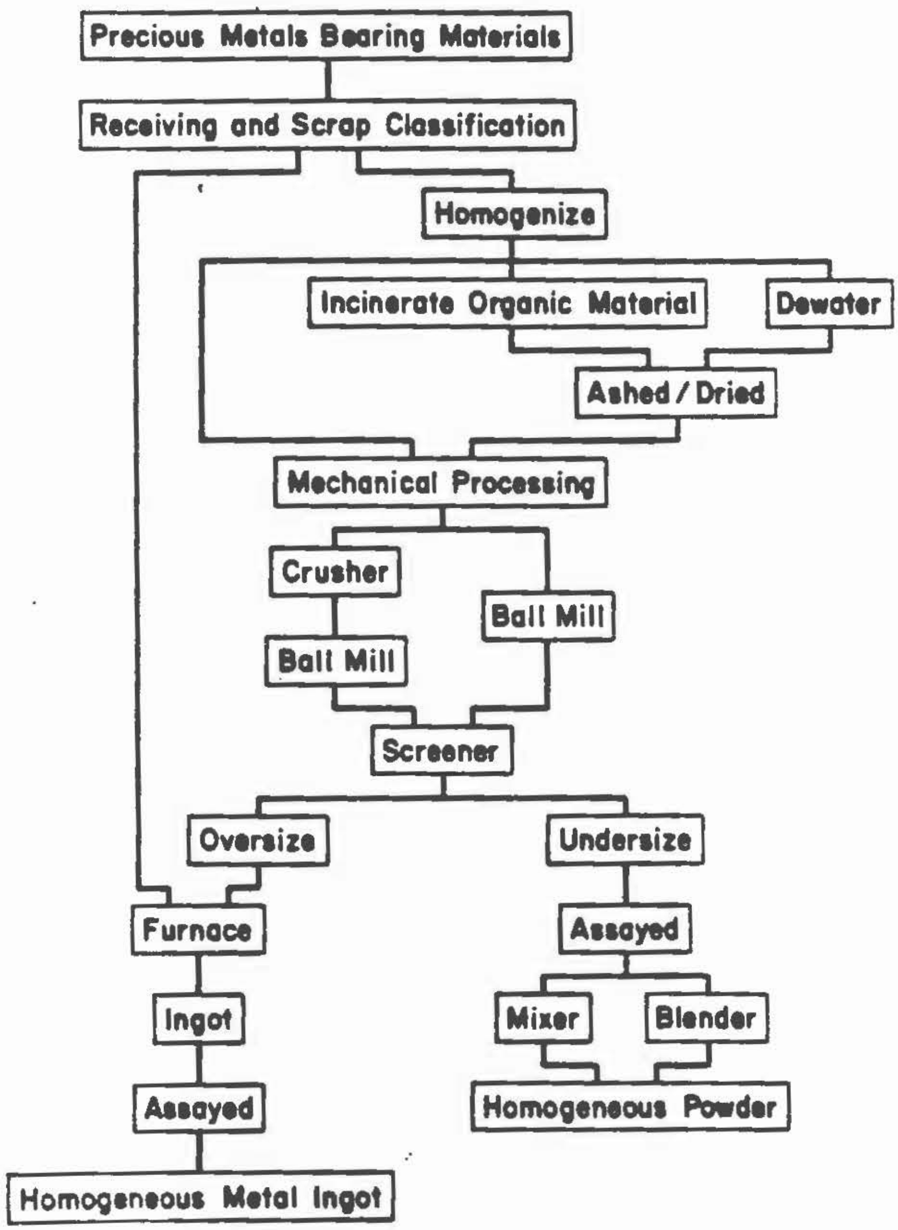

Figure 2

Mean and Maximum 8-hour TWA Exposures to Beryllium by Job Classification

Handy and Harman, Inc.
Fairfield, Connecticut
July 6-8 and November 1-4, 1983

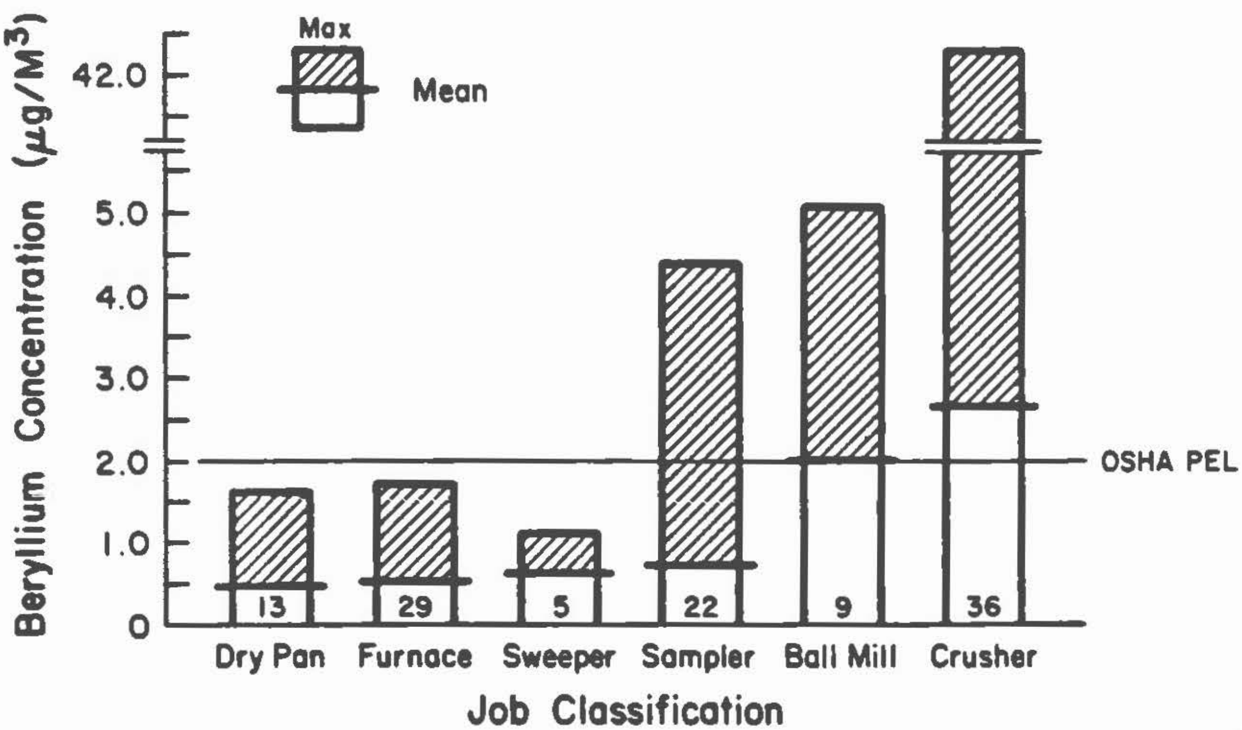

TABLE 1
Metals Assay of Settled Dust Samples Obtained in the Refinery
Handy and Harman
Fairfield, Connecticut
November 1-2, 1983

Sample Description	Concentration - % by Weight					
	Arsenic	Beryllium	Cadmium	Lead	Nickel	Silver
1st level crush screen - surface of panel box at blender 4	(0.006)*	0.039	0.277	1.51	0.256	3.04
1st level crush screen - surface of panel box at mixer	(0.004)	0.065	0.506	1.75	0.283	0.688
2nd level crush screen - surface of light luminaire	0.059	0.021	0.380	0.995	0.443	2.47
3rd level crush screen - surface of light luminaire	(0.004)	0.033	0.498	1.19	0.358	1.02
Small fires - surface of light luminaire	(0.006)	0.030	2.70	0.506	0.329	0.748
Electric furnace shop - surface of light luminaire	(0.009)	0.062	3.70	2.67	0.933	3.03
Electric furnace shop - surface fires filling unit	(0.007)	0.029	6.89	3.41	1.01	1.09
Electric furnace shop - surface of panel box at Fischer	(0.006)	0.041	4.57	0.916	0.219	0.774
Surface of Morse-Bolyer incinerator	(0.006)	0.064	0.080	2.08	0.188	0.289
Surface of clear air incinerator	(0.005)	0.015	0.552	1.09	0.222	0.610
Surface of dry pan #10	(0.004)	0.010	0.507	0.831	0.358	0.180
MEAN**	0.008	0.037	1.88	1.54	0.418	1.27
± S.D.	0.017	0.019	2.28	0.877	0.284	1.06

* None detected. The detection limit is enclosed in the parenthesis.

** In calculating the mean concentration, the none detected values were treated using the L/2 approximation method. This approach assumes that the none-detected value is equal to half the detection limit, L, i.e. ND=L/2.

TABLE 2
Personal Exposure Concentrations to Airborne Inorganic Metals - Refining
Handy and Harman
Fairfield, Connecticut
July 6-8, November 1-4, 1983

Date	Sample Description	Sampling Period	Sample Volume Liters	Airborne Concentration - ug/M3 Arsenic	Beryllium	Cadmium	Lead	Nickel	Silver
7/6	Patterson Mill Opera.	0700 - 1413	866	(1.2)*	1.4	12.2	148	48.7	60.4
7/7	Patterson Mill Opera.	1510 - 2230	880	(1.1)	0.31	53.4	126	12.1	115
7/7	Patterson Mill Opera.	0710 - 1410	840	5.6	0.90	34.3	125	21.1	113
7/8	Patterson Mill Opera.	0701 - 1416	870	(1.2)	4.0	9.7	53.1	69.1	84.7
11/1	Patterson Mill Opera.	0703 - 1410	854	(1.2)	5.1	24.2	331	72.7	706
11/1	Patterson Mill Opera.	1450 - 2225	910	(1.1)	2.2	8.6	187	29.1	166
11/2	Patterson Mill Opera.	0709 - 1414	850	(1.2)	1.7	95.1	328	46.7	285
11/2	Patterson Mill Opera.	1500 - 2215	870	(1.2)	1.2	35.1	210	19.5	28.6
11/4	Patterson Mill Opera.	0713 - 1415	844	(1.2)	1.2	49.5	275	45.7	95.1
Environmental Criteria				2	0.5	LFL**	50	15.0	10

* Value in parenthesis is the volume adjusted lower limit of quantitation. LOQ's for arsenic and beryllium are 1.0 and 0.5 ug per filter, respectively.

** Lowest feasible limit.

TABLE 3
Personal Exposure Concentrations to Airborne Inorganic Metals - Refining
Handy and Harman
Fairfield, Connecticut
July 6-8, November 1-4, 1983

Date	Sample Description	Sampling Period	Sample Volume Liters	Airborne Concentration - ug/M3					
				Arsenic	Beryllium	Cadmium	Lead	Nickel	Silver
7/6	1st floor Crush Screen Opera.	0707 - 1412	850	(1.2)*	0.94	10.5	127	14.6	57.3
7/6	1st floor Crush Screen Opera.	0700 - 1414	868	(1.2)	2.2	39.8	121	16.5	108
7/7	1st floor Crush Screen Opera.	1510 - 2215	850	(1.2)	0.71	6.1	101	49.2	54.6
7/7	1st floor Crush Screen Opera.	0708 - 1410	844	1.3	4.2	56.2	212	32.8	101
7/7	1st floor Crush Screen Opera.	0705 - 1402	834	1.3	1.4	34.5	127	33.8	309
7/8	1st floor Crush Screen Opera.	0702 - 1415	866	(1.2)	42.3	34.2	64.0	80.1	61.3
7/8	1st floor Crush Screen Opera.	0703 - 1411	856	(1.2)	5.1	17.6	42.6	161.0	520
11/1	1st floor Crush Screen Opera.	0700 - 1410	860	(1.2)	0.70	34.1	189	96.1	2279
11/1	1st floor Crush Screen Opera.	0707 - 1410	846	(1.2)	1.2	140	82.0	23.3	834
11/1	1st floor Crush Screen Opera.	0711 - 1413	844	(1.2)	(0.59)	8.9	42.7	62.3	5413
11/1	1st floor Crush Screen Opera.	1450 - 2225	910	(1.1)	(0.55)	10.4	146	46.0	944
11/2	1st floor Crush Screen Opera.	0704 - 1402	836	(1.2)	1.5	365	206	26.9	350
11/2	1st floor Crush Screen Opera.	0707 - 1414	854	(1.2)	1.8	1150	78.3	27.3	516
11/2	1st floor Crush Screen Opera.	0701 - 1420	878	(1.1)	1.0	45.1	101	20.2	1765
11/2	1st floor Crush Screen Opera.	1459 - 2230	902	(1.1)	1.3	23.2	195	22.5	273
7/6	2nd floor Crush Screen Opera.	0706 - 1415	858	(1.2)	0.68	11.7	33.7	10.4	167
7/7	2nd floor Crush Screen Opera.	1508 - 2230	884	4.6	0.97	26.4	71.7	16.5	214
7/7	2nd floor Crush Screen Opera.	1505 - 2222	874	1.4	12.8	8.8	31.1	25.9	330
7/7	2nd floor Crush Screen Opera.	0706 - 1411	850	5.3	0.69	10.9	33.8	9.5	179
7/8	2nd floor Crush Screen Opera.	0705 - 1415	860	(1.2)	5.0	4.0	23.5	13.3	65.8
7/8	2nd floor Crush Screen Opera.	0715 - 1409	828	(1.2)	2.8	7.1	22.7	36.0	38.1
11/1	2nd floor Crush Screen Opera.	0702 - 1415	866	(1.2)	(0.58)	8.4	64.4	35.6	1425
11/1	2nd floor Crush Screen Opera.	1505 - 2231	892	1.9	(0.56)	40.1	241	86.4	3892
11/2	2nd floor Crush Screen Opera.	0703 - 1409	852	(1.2)	0.70	86.5	85.6	22.5	379
11/2	2nd floor Crush Screen Opera.	1506 - 2230	888	(1.1)	(0.56)	158	228	39.7	284
7/6	3rd floor Crush Screen Opera.	0704 - 1414	860	(1.2)	0.58	16.5	25.6	6.9	67.8
7/6	3rd floor Crush Screen Opera.	0710 - 1416	852	(1.2)	0.29	3.8	11.6	1.8	17.8
7/7	3rd floor Crush Screen Opera.	1508 - 2230	884	1.2	0.28	12.3	30.2	26.4	80.2

TABLE 3
Continued

Date	Sample Description	Sampling Period	Sample Volume Liters	Airborne Concentration - ug/M3					
				Arsenic	Beryllium	Cadmium	Lead	Nickel	Silver
7/7	3rd floor Crush Screen Opera.	1505 - 2222	874	(1.1)	0.78	10.8	95.6	18.8	116
7/7	3rd floor Crush Screen Opera.	0706 - 1411	850	(1.2)	0.93	4.7	17.8	6.9	37.5
7/8	3rd floor Crush Screen Opera.	0705 - 1416	862	(1.2)	0.64	2.4	10.7	6.3	30.7
7/8	3rd floor Crush Screen Opera.	0711 - 1416	850	(1.2)	0.51	1.7	9.1	6.9	15.10
11/1	3rd floor Crush Screen Opera.	0714 - 1414	840	1.2	(0.60)	6.7	407	29.6	265
11/1	3rd floor Crush Screen Opera.	1505 - 2231	892	1.1	1.0	8.1	925	89.8	198
11/2	3rd floor Crush Screen Opera.	0706 - 1415	858	4.2	(0.58)	10.0	193	29.6	47.8
11/2	3rd floor Crush Screen Opera.	1504 - 2230	892	1.1	(0.58)	5.4	731	73.8	60.2
Environmental Criteria				2.	0.5	LFL**	50	15.0	10

* Value in parenthesis is the volume adjusted lower limit of quantitation. LOQ's for arsenic and beryllium are 1.0 and 0.5 ug per filter, respectively.

** Lowest feasible limit.

TABLE 4
Personal Exposure Concentrations to Airborne Inorganic Metals - Refining
Handy and Harman
Fairfield, Connecticut
July 6-8, November 1-4, 1983

Date	Sample Description	Sampling Period	Sample Volume Liters	Airborne Concentration - ug/M3					
				Arsenic	Beryllium	Cadmium	Lead	Nickel	Silver
7/6	Dry Pan Operator	0720 - 1327	734	(1.4)*	(0.22)	5.5	19.2	3.0	17.4
7/6	Dry Pan Operator	0707 - 1410	846	(1.2)	(0.24)	5.6	15.6	2.4	31.9
7/7	Dry Pan Operator	0703 - 1411	856	(1.2)	(0.23)	11.9	27.0	5.6	25.9
7/7	Dry Pan Operator	0701 - 1412	862	(1.2)	(0.23)	8.0	27.2	6.4	51.5
7/8	Dry Pan Operator	0704 - 1417	866	(1.2)	1.1	21.3	26.4	8.4	162
7/8	Dry Pan Operator	0704 - 1419	820	(1.2)	1.6	13.0	31.5	13.9	51.6
11/1	Dry Pan Operator	0706 - 1417	862	(1.2)	(0.58)	21.8	54.8	23.3	508
11/1	Dry Pan Operator	0708 - 1414	852	(1.2)	(0.60)	21.7	45.4	16.7	407
11/1	Dry Pan Operator	1506 - 2226	880	(1.1)	(0.57)	6.3	79.2	18.3	88.9
11/1	Dry Pan Operator	1500 - 2231	902	(1.1)	(0.55)	13.5	32.8	4.9	47.3
11/2	Dry Pan Operator	0709 - 1420	862	(1.2)	1.1	43.6	103	12.5	142
11/2	Dry Pan Operator	0700 - 1420	880	(1.1)	(0.57)	53.8	61.5	5.2	171
11/2	Dry Pan Operator	1506 - 2223	874	(1.1)	(0.57)	23.1	88.2	17.9	130
Environmental Criteria				2	0.5	LFL**	50	15	10

* Value in parenthesis is the volume adjusted lower limit of quantitation. LOQ's for arsenic and beryllium are 1.0 and 0.5 ug per filter, respectively.

** Lowest feasible limit.

TABLE 5
Personal Exposure Concentrations to Airborne Inorganic Metals - Refining
Handy and Harman
Fairfield, Connecticut
July 6-8, November 1-4, 1983

Date	Sample Description	Sampling Period	Sample Volume Liters	Airborne Concentration - ug/M3					
				Arsenic	Beryllium	Cadmium	Lead	Nickel	Silver
7/7	Sampler Mixer	1512 - 2230	876	(1.1)*	0.65	9.0	79.5	24.5	26.9
7/7	Sampler Mixer	1508 - 2215	854	(1.2)	(0.23)	2.5	13.9	3.9	219
7/7	Sampler Mixer	1509 - 2220	862	(1.2)	0.43	3.5	36.7	10.1	41.7
7/7	Sampler Mixer	1510 - 2215	850	(1.2)	0.66	7.2	46.4	16.4	66.9
7/7	Sampler Mixer	0705 - 1421	872	(1.2)	0.52	6.4	78.6	10.0	15.0
7/7	Sampler Mixer	0708 - 1410	844	(1.2)	0.52	5.5	64.9	14.7	27.7
7/7	Sampler Mixer	0704 - 1421	874	1.7	0.56	7.8	60.8	11.1	46.7
7/8	Sampler Mixer	0703 - 1412	858	(1.2)	1.5	6.2	24.2	8.2	35.3
7/8	Sampler Mixer	0701 - 1415	868	(1.2)	4.4	6.9	28.8	29.9	241
7/8	Sampler Mixer	0706 - 1416	860	(1.2)	2.1	8.0	36.1	11.5	46.4
11/1	Sampler Mixer	0704 - 1415	861	(1.2)	(0.58)	7.6	187	17.3	207
11/1	Sampler Mixer	0705 - 1415	860	(1.2)	(0.58)	11.3	167	19.8	485
11/1	Sampler Mixer	0713 - 1410	834	1.3	(0.60)	16.6	68.1	33.3	3253
11/1	Sampler Mixer	1505 - 2227	888	(1.1)	(0.56)	10.6	144	22.4	139
11/1	Sampler Mixer	1453 - 2225	904	(1.1)	(0.55)	11.9	149	22.5	169
11/1	Sampler Mixer	1502 - 2227	890	(1.1)	(0.59)	8.3	86.1	27.8	751
11/2	Sampler Mixer	0710 - 1415	850	(1.2)	(0.60)	54.4	76.0	15.2	153
11/2	Sampler Mixer	0708 - 1407	838	(1.2)	(0.60)	71.9	60.9	13.7	212
11/2	Sampler Mixer	0707 - 1402	830	(1.2)	1.1	54.3	155	27.6	203
11/2	Sampler Mixer	1500 - 2220	880	(1.1)	(0.57)	15.4	137	22.3	253
11/2	Sampler Mixer	1503 - 2220	874	(1.1)	(0.60)	33.3	161	31.3	205
11/2	Sampler Mixer	1507 - 2225	876	(1.1)	(0.60)	33.1	197	40.0	196
Environmental Criteria				2	0.5	LFL**	50	15	10

* Value in parenthesis is the volume adjusted lower limit of quantitation. LOQ's for arsenic and beryllium are 1.0 and 0.5 ug per filter, respectively.
** Lowest feasible limit.

TABLE 6
Personal Exposure Concentrations to Airborne Inorganic Metals - Refining
Handy and Harman
Fairfield, Connecticut
July 6-8, November 1-4, 1983

Date	Sample Description	Sampling Period	Sample Volume Liters	Airborne Concentration - ug/M3					
				Arsenic	Beryllium	Cadmium	Lead	Nickel	Silver
7/6	Vac. Sweeper	0657 - 1415	876	(1.1)*	0.34	10.3	23.7	3.7	39.5
7/7	Vac. Sweeper	0701 - 1415	868	(1.2)	0.35	6.2	22.2	4.8	23.2
7/8	Vac. Sweeper	0700 - 1415	870	(1.2)	1.1	7.2	30.2	7.0	55.9
11/1	Vac. Sweeper	0701 - 1416	870	(1.2)	0.80	21.2	92.6	28.7	664
11/2	Vac. Sweeper	0700 - 1416	872	(1.1)	0.57	33.4	97.0	14.5	391.1
7/6	Incinerator	0717 - 1420	846	(1.2)	(0.24)	0.95	3.6	1.2	7.8
7/6	Incinerator	0718 - 1415	834	(1.2)	(0.24)	2.2	4.3	1.2	4.8
7/8	Incinerator	0705 - 1417	864	(1.1)	(0.22)	7.1	22.6	1.6	36.1
7/8	Incinerator	0715 - 1417	844	(1.2)	(0.23)	13.0	7.7	1.4	56.9
7/6	Incinerator	0712 - 1414	844	(1.2)	(0.24)	3.4	28.0	1.8	8.5
7/8	Incinerator	0712 - 1418	852	(1.2)	(0.23)	2.6	26.7	3.6	10.8
7/6	Silver Powders	0722 - 1410	816	(1.2)	(0.22)	0.74	1.2	1.2	3063
Environmental Criteria				2	0.5	LFL**	50	15	10

* Value in parenthesis is the volume adjusted lower limit of quantitation. LOQ's for arsenic and beryllium are 1.0 and 0.5 ug per filter, respectively.
** Lowest feasible limit.

TABLE 7
Personal Exposure Concentrations to Airborne Inorganic Metals - Refining
Handy and Harman
Fairfield, Connecticut
July 6-8, November 1-4, 1983

Date	Sample Description	Sampling Period	Sample Volume Liters	Airborne Concentration - ug/M3					
				Arsenic	Beryllium	Cadmium	Lead	Nickel	Silver
7/6	Small Fires Furnace Opera.	0602 - 1330	896	(1.1)*	(0.22)	20.4	10.7	4.4	29.0
7/7	Small Fires Furnace Opera.	0605 - 1325	880	(1.1)	0.45	32.7	9.6	2.3	37.7
7/8	Small Fires Furnace Opera.	0605 - 1330	890	(1.1)	0.25	25.4	11.9	2.6	69.1
7/6	Small Fires Furnace Helper	0602 - 1330	896	1.2	(0.22)	6.4	6.4	(1.2)	8.5
7/7	Small Fires Furnace Helper	0604 - 1324	880	(1.1)	(0.23)	22.2	8.9	1.5	16.5
7/8	Small Fires Furnace Helper	0604 - 1330	892	(1.1)	(0.21)	12.4	8.0	1.4	36.8
7/6	Electric Furnace Opera.	0600 - 1326	892	(1.1)	0.24	6.7	3.8	(1.0)	7.3
7/7	Electric Furnace Opera.	0600 - 1320	880	(1.1)	(0.23)	5.1	11.0	1.3	9.0
7/7	Electric Furnace Opera.	1404 - 2140	904	(1.1)	0.51	10.2	7.41	2.0	13.4
7/8	Electric Furnace Opera.	0601 - 1327	892	(1.1)	(0.22)	3.9	7.5	1.2	9.0
7/6	Electric Furnace Helper	0605 - 1331	892	(1.1)	(0.22)	6.1	16.3	1.8	10.4
7/7	Electric Furnace Helper	0557 - 1326	898	(1.1)	0.30	14.4	10.7	1.7	11.1
7/7	Electric Furnace Helper	1406 - 2140	908	(1.1)	(0.22)	4.9	4.5	2.6	15.8
7/8	Electric Furnace Helper	0602 - 1325	886	(1.1)	(0.23)	5.8	17.2	1.9	13.4
7/6	Fischer Furnace Opera.	0600 - 1331	898	4.8	0.40	14.6	21.4	3.2	28.7
7/7	Fischer Furnace Opera.	0558 - 1326	896	(1.0)	0.55	21.1	13.2	2.7	21.6
7/8	Fischer Furnace Opera.	0600 - 1325	890	(1.1)	0.69	28.3	23.0	4.0	96.5
11/1	Small Fires Furnace Opera.	0600 - 1313	866	(1.2)	(0.58)	40.0	23.1	3.2	34.2
11/2	Small Fires Furnace Opera.	0557 - 1325	896	(1.1)	1.7	376	23.9	2.9	159
11/1	Small Fires Furnace Helper	0615 - 1315	840	(1.2)	(0.60)	32.9	16.1	2.7	29.4
11/2	Small Fires Furnace Helper	0605 - 1321	872	(1.2)	1.5	196	13.4	2.2	38.9
11/1	Electric Furnace Opera.	0610 - 1332	884	(1.1)	(0.57)	21.2	22.3	3.2	51.7
11/2	Electric Furnace Opera.	0606 - 1335	898	(1.1)	0.78	69.9	28.4	2.5	45.4
11/2	Electric Furnace Opera.	1425 - 2121	832	(1.2)	1.2	705	37.7	6.6	27.9
11/1	Electric Furnace Helper	0605 - 1335	900	(1.1)	0.56	10.9	24.2	1.6	12.7
11/2	Electric Furnace Helper	0604 - 1335	902	(1.1)	1.2	61.5	21.6	1.4	27.3
11/2	Electric Furnace Helper	1425 - 2135	820	(1.2)	0.70	94.5	18.7	3.1	20.3
11/1	Fischer Furnace Opera.	0604 - 1334	900	5.7	0.89	53.4	46.7	7.0	165
11/2	Fischer Furnace Opera.	1425 - 2135	820	(1.2)	0.85	354	35.4	1.8	24.7
Environmental Criteria				2	0.5	LFL**	50	15	10

* Value in parenthesis is the volume adjusted lower limit of quantitation. LOQ's for arsenic and beryllium are 1.0 and 0.5 ug per filter, respectively.

** Lowest feasible limit.

TABLE 8
Mean Personal 8-Hour TWA Exposures to Metals by Job Classification - Refining
Handy and Harman
Fairfield, Connecticut
July 6-8, November 1-4, 1983

Job Classification	N	Air Concentration - ug/m3 Arsenic	Beryllium	Cadmium	Lead	Nickel	Silver
Crusher-Screen	36	1.1	2.7	67	142	36	597
Ball Mill	9	1.1	2.1	36	198	41	184
Sampler-Mixer	22	0.67	0.72	18	94	20	318
Floor Sweeper	5	1.1	0.63	16	53	12	235
Furnace Tender	29	0.92	0.52	78	17	3	37
Dry Pan	13	1.1	0.46	19	47	11	141
Incinerator	6	1.2	0.22	4.8	16	2	21
Silver Powder	1	1.2	0.22	0.74	1.2	1.2	3063
	121	0.82	1.4	48	86	20	309
NIOSH Criteria		2.0	0.5	LFL**	50	15	10*

* OSHA PEL
** Lowest feasible limit.

TABLE 9
Percent of Personal 8-hour TWA Exposures
Exceeding the NIOSH REL by Job Classification
Handy and Harman
Fairfield, Connecticut
July 6-8, November 1-4, 1983

Job Classification	N	% 8-hour TWA Exposures above NIOSH REL					
		As	Be	Cd	Ni	Pb	Ag*
Crusher-Screen	36	87	75	100	75	64	100
Ball Mill	9	11	89	100	89	100	100
Sampler-Mixer	22	0	41	100	64	73	100
Floor Sweeper	5	0	60	100	20	60	100
Furnace Tender	29	7	41	100	0	0	86
Dry Pan	13	0	23	100	31	31	100
Incinerator	6	0	0	100	0	0	50
Silver Powders	1	0	0	100	0	0	100
Total	121						
Mean		5	53	100	45	46	94

* OSHA PEL

TABLE 10
Percentage Distribution of Exposures
Exceeding the Environmental Criteria by Job Classification
Handy and Harman
Fairfield, Connecticut
July 6-8, November 1-4, 1983

	% Exposures Exceeding Environmental Criteria					
Substance	Crusher-Screen	Ball Mill	Sampler-Mixer	Sweeper	Furnace Tender	Dry Pan
Arsenic	8	11	0	0	7	0
Beryllium	75	89	41	60	41	23
Cadmium	100	100	100	100	100	100
Lead	64	100	73	60	0	38
Silver	100	100	100	100	86	100
Nickel	75	89	64	20	0	31
Mean	57	70	49	40	28	34

TABLE 11
Personal 8-hour TWA Exposures to Beryllium
By Job Classification - Refining Area
Handy and Harman
Fairfield, Connecticut
July 6-8, November 1-4, 1983

Job Classification	N	Be Concentration - ug/m3		
		Range	Mean	± S.D.
Crusher	36	0.28 - 42.3	2.7	7.2
Ball Mill	9	0.31 - 5.1	2.1	1.6
Sampler	22	(0.23)* - 4.4	0.72	0.95
Floor Sweeper	5	0.34 - 1.1	0.63	0.32
Furnace Tender	29	(0.22) - 1.7	0.52	0.44
Dry Pan	13	(0.22) - 1.6	0.46	0.48
Total Mean ± S.D.	114	(0.22) - 42.3	1.2	0.96

* Value in parenthesis is the volume adjusted limit of quantitation.

TABLE 12
Results of Semi-Quantitative Analysis of Settled Dust Samples For Crystalline Silica - Refining
Handy and Harman
Fairfield, Connecticut
July 6-8, 1983

SAMPLE DESCRIPTION	% QUARTZ*
3rd level of crush-screen area - surface of light luminaire	11
2nd level of crush-screen area - surface of light luminaire	10
1st level of crush-screen area - surface of power panel box next to blender #4	8
1st level of crush-screen area - surface of power panel for large blender	12
Small fires area - surface of light luminaire	4
New induction furnace area - surface of light luminaire	12
Electric furnace shop - surface of light luminaire	5
Electric furnace shop - power panel next to Fischer Furnace	6
Surface of Morse-Bolger Incinerator	11
Surface of clean air incinerator	11
Surface of No. 10 dry pan	6

* The lower limit of quantitation is estimated to be 2% based on a two-milligram portion of the settled dust collected. (Cristobalite was not detected in any sample). The reported values are expressed as a range of ± 5% of the calculated value.

TABLE 13
Personal Exposure Concentrations to Airborne Inorganic Metals - Manufacturing-Melt
Handy and Harman
Fairfield, Connecticut
July 6-8, November 1-4, 1983

Date	Sample Description	Sampling Period	Sample Volume Liters	Airborne Concentration - ug/M3					
				Arsenic	Beryllium	Cadmium	Lead	Nickel	Silver
7/8	DC#6 Furnace Operator	0606 - 1320	868	(1.2)*	(0.23)	62.3	4.3	*1.2	50.1
11/2	Operator direct cast	1405 - 2059	828	(1.2)	(0.60)	89.6	5.1	*0.6	36.0
11/2	Operator direct cast	0603 - 1402	960	(1.0)	(0.52)	29.6	3.9	3.9	30.2
11/3	Operator direct cast	0603 - 1356	946	(1.0)	(0.51)	50.9	1.8	0.6	15.7
11/4	Operator direct cast	0611 - 1322	862	(1.2)	(0.58)	13.9	3.4	1.3	36.2
11/2	Helper direct cast	0602 - 1402	960	(1.0)	(0.52)	29.0	3.6	3.0	23.8
11/3	Helper direct cast	0605 - 1401	952	(1.0)	(0.50)	67.0	2.6	0.5	14.6
11/4	Helper direct cast	0617 - 1321	848	(1.2)	(0.59)	11.2	2.6	0.6	53.3
11/2	Operator vertical cast	0608 - 1424	872	(1.0)	(0.50)	9.3	2.0	1.6	59.9
11/3	Operator vertical cast	0610 - 1402	944	(1.0)	(0.53)	24.9	(1.1)	0.74	27.0
11/4	Operator vertical cast	0604 - 1323	878	(1.1)	(0.57)	47.2	3.0	1.9	75.9
11/2	Operator vertical cont. cast	0618 - 1404	932	(1.0)	(0.50)	31.3	2.5	1.0	31.1
11/3	Operator vertical cont. cast	0604 - 1334	900	(1.1)	(0.51)	45.0	(1.1)	0.56	24.4
11/4	Operator vertical cont. cast	0615 - 1324	858	1.6	(0.58)	45.4	2.1	2.7	64.7
11/2	Helper vertical cont. cast	0618 - 1446	986	(1.0)	(0.51)	9.5	2.0	1.5	44.8
11/3	Helper vertical cont. cast	0605 - 1355	940	(1.0)	(0.50)	23.0	(1.0)	2.8	74.8
11/4	Helper vertical cont. cast	0615 - 1321	852	2.1	(0.59)	15.4	1.9	5.5	104
Environmental Criteria				2	0.5	LFL**	50	15	10

* Value in parenthesis is the volume adjusted lower limit of quantitation. LOQ's for arsenic, beryllium, lead and nickel are: 1.0, 0.5, 1.0, 0.5 ug per filter, respectively.

** Lowest feasible limit.

TABLE 14
Personal Exposure Concentrations to Airborne Inorganic Metals - Manufacturing-Melt
Handy and Harman
Fairfield, Connecticut
July 6-8, November 1-4, 1983

Date	Sample Description	Sampling Period	Sample Volume Liters	Airborne Concentration - ug/M3					
				Arsenic	Beryllium	Cadmium	Lead	Nickel	Silver
11/2	Operator Inresa	0612 - 1423	982	(1.0)*	(0.50)	41.0	12.0	2.2	50.4
11/3	Operator Inresa	0559 - 1359	960	(1.0)	(0.52)	111	4.2	0.96	15.8
11/4	Operator Inresa	0605 - 1320	870	(1.2)	(0.57)	24.4	13.9	2.5	20.5
11/2	Helper Inresa	0612 - 1412	960	(1.0)	(0.52)	25.8	8.2	1.5	25.3
11/3	Helper Inresa	0558 - 1358	960	(1.0)	(0.52)	77.9	3.9	0.84	15.2
11/4	Helper Inresa	0600 - 1325	890	(1.1)	(0.56)	31.1	11.5	2.7	25.8
7/8	Operator horiz. cont. cast	0608 - 1321	866	(1.2)	(0.23)	43.7	1.6	(1.2)	32.0
11/2	Operator horiz. cont. cast	0556 - 1410	1000	(1.0)	(0.50)	25.2	8.3	2.1	46.8
11/3	Operator horiz. cont. cast	0555 - 1355	960	(1.0)	(0.52)	77.9	3.9	0.84	15.2
11/4	Operator horiz. cont. cast	0600 - 1323	886	(1.1)	(0.56)	10.9	5.8	1.5	11.2
11/2	Helper horiz. cont. cast	0556 - 1416	1000	(1.0)	(0.50)	24.6	7.4	2.5	22.1
11/4	Helper horiz. cont. cast	0600 - 1323	886	(1.1)	(0.56)	9.4	5.4	1.0	10.1
7/8	Operator - Electric	0603 - 1320	874	(1.1)	(0.22)	83.8	1.1	1.4	21.8
11/2	Operator - Electric	0605 - 1415	980	(1.0)	(0.50)	70.9	4.4	5.2	27.5
11/3	Operator - Electric	0604 - 1400	952	(1.1)	(0.53)	76.3	2.3	0.53	11.0
11/4	Operator - Electric	0604 - 1325	882	(1.1)	(0.57)	60.6	2.0	0.60	24.7
11/2	Helper - Electric	0608 - 1402	948	(1.0)	(0.51)	111	2.1	0.51	12.8
11/3	Helper - Electric	0612 - 1412	960	(1.0)	(0.50)	60.8	4.0	6.0	22.5
11/4	Helper - Electric	0610 - 1320	860	(1.2)	(0.58)	115	1.8	0.58	31.1
11/2	Feeder - Electric	0606 - 1416	980	(1.0)	(0.51)	31.8	5.2	6.0	17.2
11/3	Feeder - Electric	0602 - 1400	956	(1.0)	(0.52)	63.3	2.6	0.52	11.0
11/4	Feeder - Electric	0610 - 1320	860	(1.2)	(0.58)	30.5	2.4	0.70	23.4
Environmental Criteria				2	0.5	LFL**	50	15	10 +

* Value in parenthesis is the volume adjusted lower limit of quantitation. LOQ's for arsenic, beryllium, lead and nickel are: 1.0, 0.5, 1.0, 0.5 ug per filter, respectively.

** Lowest feasible limit.

DEPARTMENT OF HEALTH AND HUMAN SERVICES
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