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FINAL REPORT

MERCURY CONTROL TECHNOLOGY ASSESSMENT STUDY

McDermitt Mine
McDermitt, Nevada

Indepth Survey Report
for the Site Visit of
February 9-10, 1982

Contract No. 210-81-7101

August 4, 1982

Submitted to:

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FOREWORD

A Control Technology Assessment (CTA) team consisting of members of Dynamac Corporation, Enviro Control Division, met with representatives of McDermitt Mine in McDermitt, Nevada, on February 9 and 10, 1982, to conduct an indepth survey on the techniques to control worker exposure to mercury. Participants in the survey were:

Dynamac Corporation

Donato Telesca, Manager, Engineering Department
Robert Reisdorf, Industrial Hygienist
David D'Orlando, Environmental Engineer

McDermitt Mine

Jerald Hepworth, Safety Coordinator
Francis Schultz, General Superintendent
Randy Powell, Mill Superintendent

The indepth CTA survey was completed in 2 days. The study included personal and area air monitoring and detailed inspections of mercury controls.

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INTRODUCTION

CONTRACT BACKGROUND

The Mercury Control Technology Assessment Study has been initiated to assess the current technology used to protect workers from exposure to mercury. The objective is to identify the methods employed by industries in controlling worker exposure to elemental mercury and mercury compounds. A result of the study will be the publication of a comprehensive document describing the most effective means to control emissions and exposures. This report will be available to companies that handle mercury in order to transfer technology within the major mercury-using industries. The study will also identify areas where additional research is necessary.

JUSTIFICATION FOR SURVEY

McDermitt Mine was selected for a survey because it is the largest producer of elemental mercury in the country. It has implemented several unique mercury controls in the mill section of the facility, and it is experimenting with process substitutions which will eliminate the need for the mercury furnace. The facility has achieved low urine-mercury levels despite the large amount of mercury produced.

SUMMARY OF INFORMATION OBTAINED

An opening conference was held during which the objectives of the program were discussed with mine representatives. A tour of the mill was made, and information on mercury controls was obtained from the plant safety coordinator. Area and personal monitoring was conducted in the mill and change rooms. Detailed historical information on control implementation and urine-mercury levels was obtained.

DESCRIPTION OF FACILITY

McDermitt Mine is located in Humbolt County, Nevada, approximately 11 miles southwest of the town of McDermitt. The mine and mill, constructed in 1974, occupy approximately 135 acres. Mercury-containing minerals in the McDermitt ore body consist of 70 percent cinnabar (containing mercuric sulfide), 30 percent Corderoite (containing $Hg_3S_2CL_2$), and traces of other mercury-containing minerals. The ore body is a nearly horizontal bed with an average thickness of 20 feet. The ore body is mined as an open pit, and mercury vapor concentrations are therefore not a concern in the mining area. The average grade of mine ore is 10 pounds/ton (i.e., 0.5 percent mercury). The estimated total mercury content of the ore body is 400,000 flasks (30.4 million pounds). To date, over 100,000 flasks have been mined.

Mercury vapor concentrations are a concern in the plant site where the ore is processed into elemental mercury. The plant site is in a fenced-in compound consisting of a mill (concentrator and furnace), maintenance shop and warehouse, mine office, change room, and assay lab (Figure 1). The concentrator consists of the milling and flotation processes. Mill buildings are constructed of steel beams with corrugated steel siding and concrete floors. The plant was designed with mercury control as a prime consideration. Major renovations for mercury vapor control have included the construction of a ventilated enclosure for the disc filter, a ventilated break area, and a change room. Plant representatives are continuously experimenting with new control techniques, and several major process modifications for mercury control are currently being investigated.

There are presently 62 people employed at the mine in the following job categories:

Administration	7
Engineering	5
Purchasing	1
Mine	14
Mill	14
Maintenance (including custodians)	16
Assaying	4
Safety	1

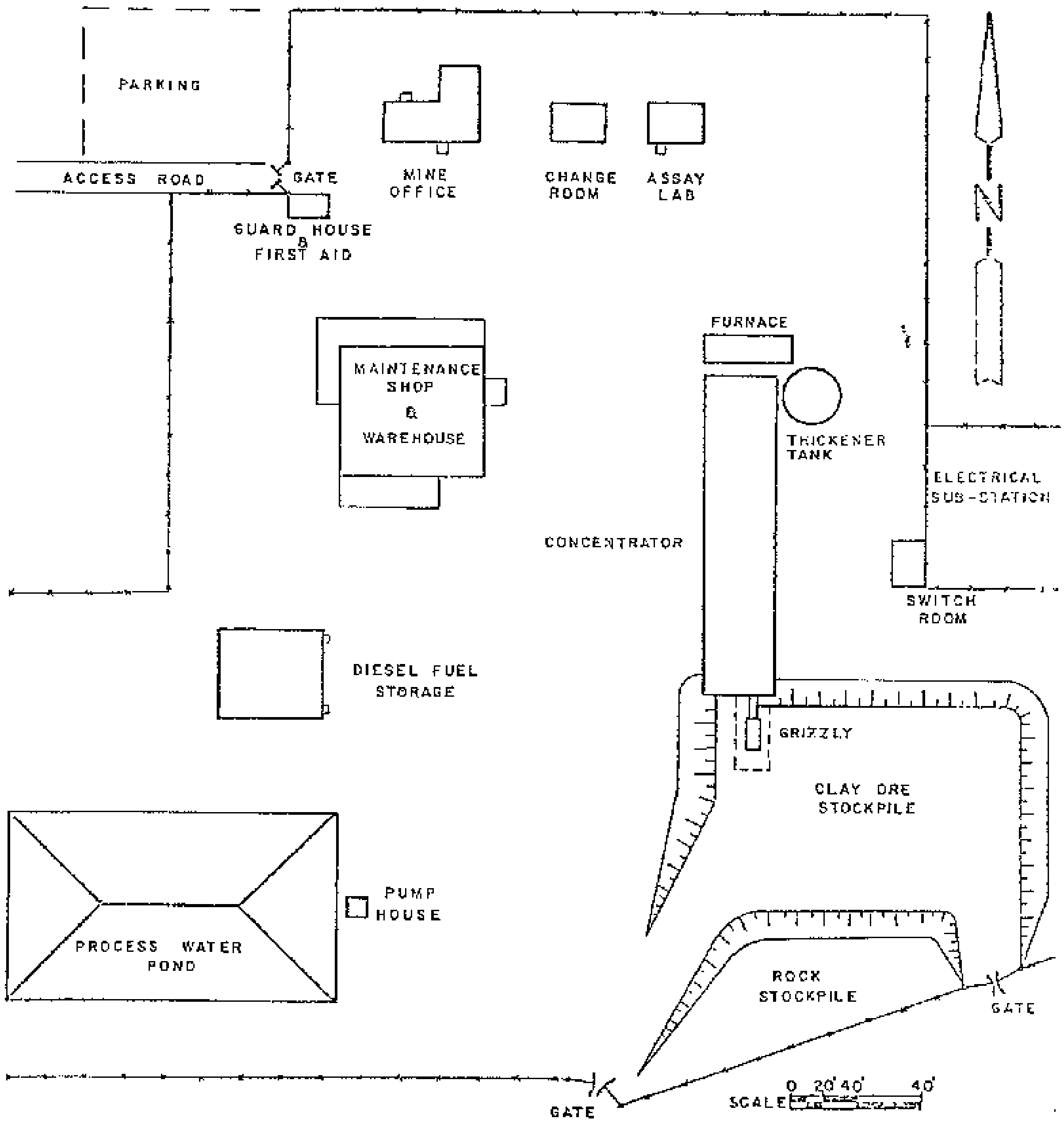

Figure 1. McDermitt Mine Site Plan.
Reference: McDermitt Mine Description of Operations.

Of these employees approximately 28 are potentially exposed to mercury on a regular basis.

The milling operation is conducted intermittently. The furnace is operated 24 hours/day for 15-day periods.

PROCESS DESCRIPTION
(Figure 2)

Clay ore is mined in the open pit, adjacent to the plant site, using Caterpillar scrapers. The scrapers carry the material to a stockpile inside the plant site where it is moved by a front-end loader through a "grizzly" (a 19-inch grating) and into a 50-ton hopper. From the hopper, the ore falls into a pan-feed conveyor that discharges into a semiautogenous grinding mill. The grinding mill uses the abrasive action of large rocks (added to the system along with the clay ore) and 3.5-inch steel balls to grind the ore.

The grinding produces particles that are fine enough to permit separation of the mercury-containing minerals into a concentrate by flotation. The particles pass through a cyclone separator. Oversized particles are returned to the grinder, and the remainder flow as a slurry to a series of flotation cells. Agitation of the slurry, after the addition of methyl isobutyl carbinol as a frothing agent and Cyanamid A-242 as a collector, causes the mercury-containing minerals to float and concentrate. The concentrate flows over the sides of the flotation units and into launders that lead to a thickening tank. The underflow (waste slurry or "tailings") from the flotation process flows to a series of four settling ponds located adjacent to the plant site. The tailings are dewatered, first by decantation and then through solar evaporation in the ponds. The concentrate is dewatered to 60 percent solids in the thickener, and it is pumped to a concentrate storage tank. Thickened concentrate is slurried and pumped to a 6-foot-diameter, two-disc, multileaf filter, where it is dewatered to 85 percent solids. It is then gravity fed to an enclosed screw conveyor that feeds the top of a furnace. Calcium oxide and sodium sulfide are added to aid in the chemical reduction of the mercury-containing minerals.

The furnace has six hearths and operates at temperatures between 649 C and 871 C (1,200 and 1,600 F). The furnace discharge consists of dust, mercury

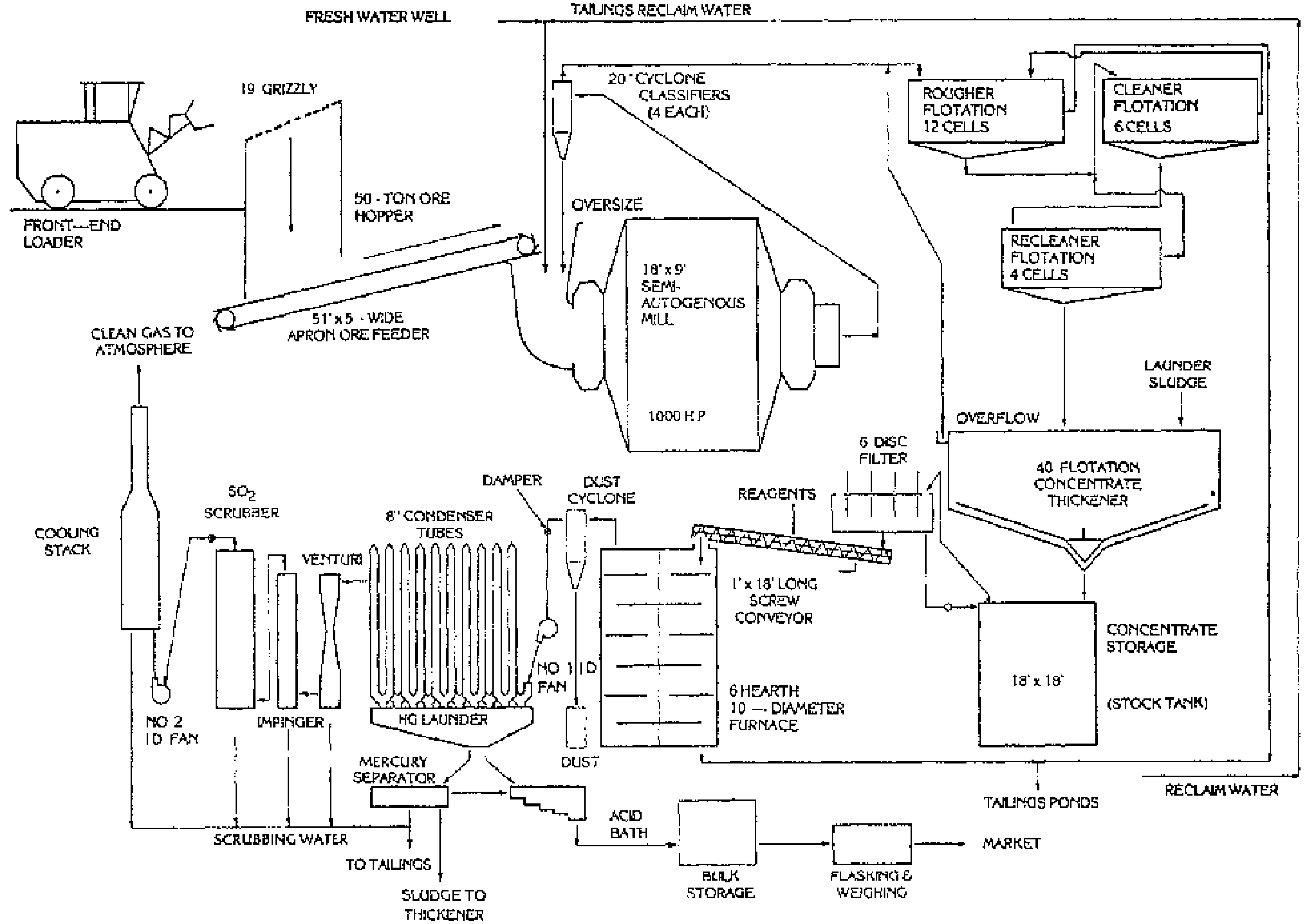

Figure 2. Flow Chart Showing Processing of Mercury Ore from Grinding Production of Prime Virgin Mercury.

Reference: McDermitt Mine Information Brochure.

vapor, water vapor, sulfur dioxide, chlorine compounds, and other produc of combustion. Dust is removed from the discharge using a cyclone separator. Mercury is condensed from the gas stream in a series of 12 condensing tubes, and it is collected in Fiberglas line launders. The remainder of the gas stream is scrubbed to remove potential pollutants before release into the ambient air. The furnace meets all State of Nev EPS Emission Standards.

The mercury flows through a cleaning bath and is pumped to bulk storage tanks. It is then double filtered and bottled in 76-pound metal flasks metal metric ton containers.

MERCURY CONTROL TECHNIQUES

PROCESS DESIGN AND MODIFICATIONS

Induced Draft Furnace

The furnace is operated at a negative pressure for improved mercury recovery and for mercury vapor control. The induced draft system that creates this pressure (see Figure 2) consists of a dust cyclone, condensers, a scrubbing system, and two 1,030 cubic feet per minute (cfm) induced draft fans that operate at suction pressures of 26 inches of water. When this system is operating properly, a draft is created that draws mercury vapor from the feed conveyor through to the condensers. This reduces mercury vapor concentrations in the furnace building and allows the operators to inspect the burning in the furnace levels without being exposed to hot mercury vapor when opening inspection ports. One problem the plant experiences with this system is plume flattening at the stack discharge as a result of variable prevailing winds. This may affect the air intake for the newly installed breakroom ventilation system, since furnace discharge may be drawn in as supply air. The plant safety coordinator is currently designing an accelerator cone to be added to the stack. By increasing the static pressure and decreasing the velocity pressure at the point of discharge, the stack discharge velocity is calculated to increase from 1,600 feet per minute (fpm) to 3,000 fpm, thereby reducing the plume flattening.

DILUTION VENTILATION

The concentrator has a dilution ventilation system consisting of seven roof exhaust fans and three wall intake louvers. The exhaust fans, manufactured by Chicago Blowers, are rated at 16,150 cfm each (locations are illustrated in Figure 3). The wall louvers are Robertson industrial operating louvers located on the first floor of the building. The exhaust fans pull the air through the wall louvers, through the grating between the first and

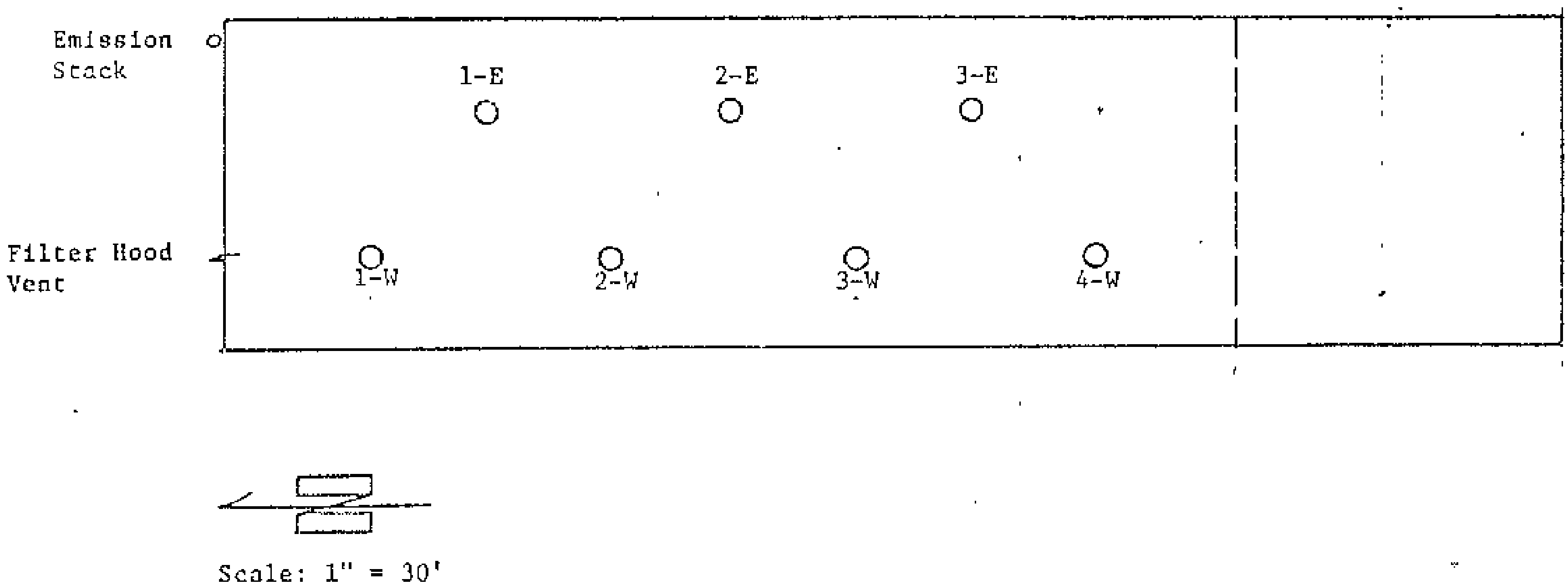

Figure 3. Concentrator Ventilation Layout.

Reference: McDermitt Mine Drawing by J.N. Hepworth - 9/25/75.

second floors, and out through the roof, thus creating an air flow up past the flotation cells. One potential problem associated with this airflow is that mercury vaporizing from materials on the first floor may be carried up through worker breathing zones on the second floor. Plant representatives believe that the dilution ventilation is not the most significant control in reducing mercury vapor concentrations. Efforts to control mercury are being made by concentrating on the removal of mercury vapor at its source.

LOCAL EXHAUST VENTILATION

Exhausted Equipment Enclosure

The 6-foot disc filter at the furnace feed is enclosed and ventilated. The enclosure is constructed of Fiberglas and Fiberglas-coated wood. The exhaust duct is polyvinyl cloride (PVC) piping. These materials are used instead of metal because of the corrosive sulfur dioxide gas present in the gas train. The enclosure is exhausted by a 3,500 cfm fan located on the roof. This control is also important in reducing mercury vapor levels because furnace operation occasionally fluctuates between negative and positive pressure, allowing hot mercury vapor to travel back through the feed screw conveyor and into the filter. The plant safety coordinator is currently exploring the use of flexible gasketing material at the upper end of the screw auger, which may further reduce mercury vapor release due to furnace back pressure. This concept of controlling the release of mercury vapor at operations that may experience pressure fluctuations can be applied to mercury stills, retorts, and reactors.

The concentrate storage tank (stock tank) is also enclosed and ventilated to control mercury vapor. The tank is exhausted through PVC pipe that leads to the same 3,500 cfm exhaust fan used for the filter hood.

CHEMICAL CONTROL

At the grinding mill feed, ore from the feed conveyor combines with over-sized milled ore returned from the cyclone separator. Plant representatives have found that the addition of aqueous Na_2S helps to suppress the generation of mercury vapor at this point. Experiments conducted by the safety engineer have shown that mercury vapor concentrations are indirectly proportional to the Na_2S addition rate (Figure 4). The problem, as can be seen on the graph, is that increasing the addition of Na_2S reduces mercuric sulfide flotation and therefore increases the tailings losses. There is a tradeoff between the handling costs of tailings and mercury vapor control, and the plant has found the equilibrium point to be an addition of Na_2S at a rate of 150 cubic centimeters/ore ton. This corresponds to an addition rate of 0.04 pounds/ore ton (or 0.004 pounds Na_2S/pound of mercury in the ore, based on a yield of 10 pounds of mercury/ore ton).

PROCESS SUBSTITUTION

McDermitt Mine, along with the Bureau of Mines, is currently investigating a hydrometallurgical method for treating concentrate to eliminate problems associated with emission of mercury vapor in the furnace. This process involves the leaching of the concentrate with chlorine and oxygen at 100 C (212 F). Mercury goes into solution as mercuric chloride, which is then decomposed through aqueous electrolysis into elemental mercury and chlorine.

PROTECTIVE EQUIPMENT AND FACILITIES

Protective Equipment

Plant representatives have identified locations where there is an increased potential for worker exposure to mercury. These locations are the mill (concentrator and furnace areas) and the maintenance shop. The mill and maintenance workers must wear the following personal protective equipment:

- rubber boots
- rubber gloves
- cloth coveralls (company supplied - laundry service on premises)
- respirators.

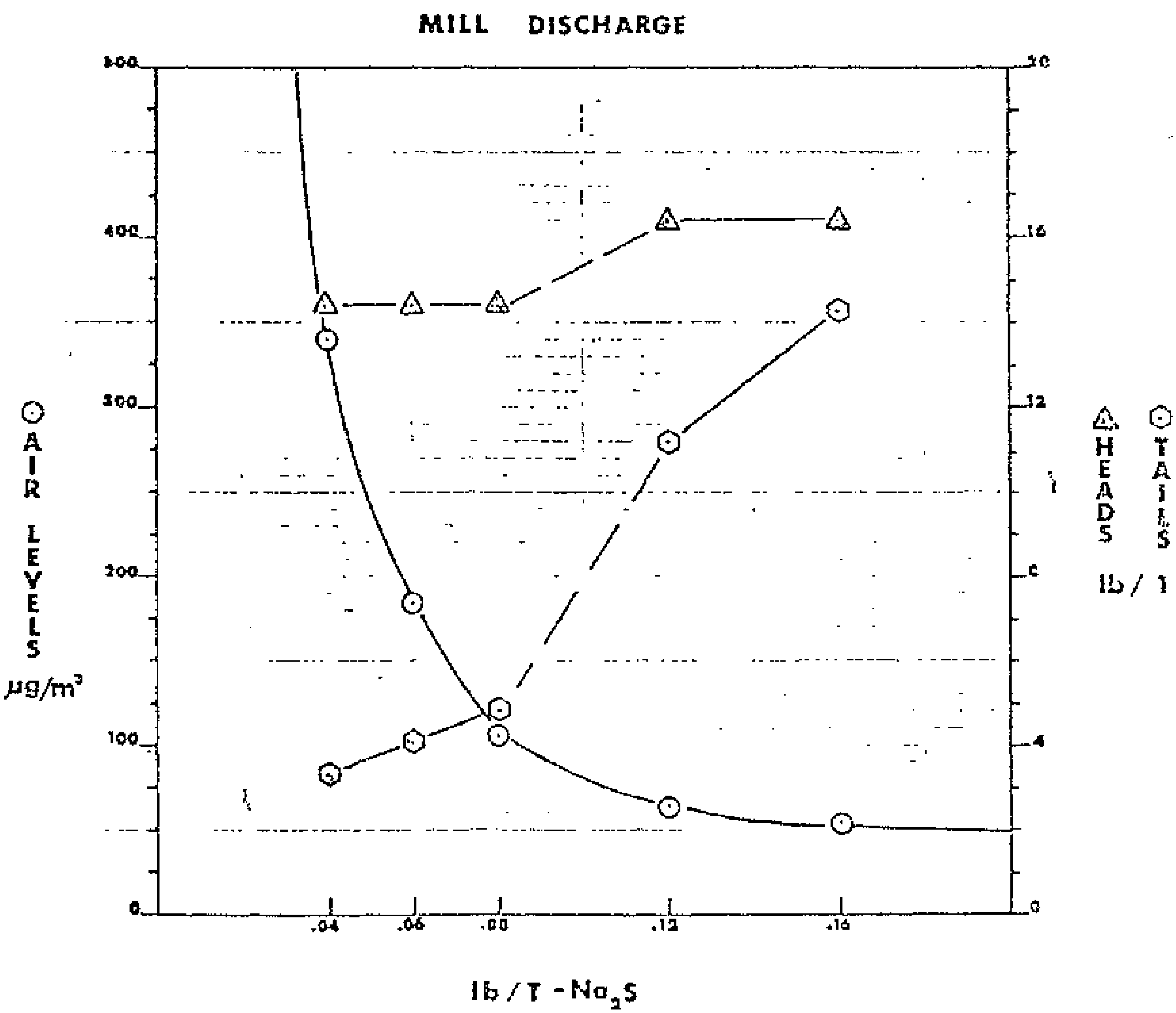

Figure 4. Mercury Vapor Levels, Heads (Concentrate) Production, and Tailings Production as a Function of Na_2S Addition.

Reference: McDermitt Mine Drawing by J.N. Hepworth.

Resipirators used at the facility are either the 3M #8707 Mercury Vapor Respirator (half-face, air-purifying, containing iodine impregnated charcoal as the primary adsorption medium) or the MSA Mersorb Respirator (Comfo-II, half-facepiece, dual chemical-indicator cartridge, #463532). The latter respirator has a color indicator on the cartridge that changes from orange to brown when the filter media has absorbed a specified amount of mercury (before saturation occurs). The advantage of the respirator is that a worker can easily monitor the color indicator on another worker's respirator. At this facility the respirator cartridges generally last several weeks before color change, at which time they are replaced. The 3M respirator is used only for transient exposures and is usually disposed of after 1 day of use. The MSA respirator facepieces are cleaned on a daily basis using a solution of potassium iodine (to remove inorganic mercury) and iodine (as a bactericide).

Mill workers wear MSA Mersorb respirators whenever they are working inside the mill areas; respirators are not worn in the break room. In other areas of the plant, 3M #8707 respirators are worn for short-term tasks in which there is potential for exposure to mercury vapor. The respirators are worn for a maximum of 8 hours. Plant representatives feel that respirators are currently the most effective control in reducing worker exposure to mercury vapor at this facility.

Change House

To prevent the possibility of spreading mercury contamination to the worker's home, a new change house was constructed. The facility includes a "clean" and a "dirty" side. Each section of the building is well ventilated and designed with a separate air supply. Upon arrival at work, all street clothing is removed on the "clean" side and work clothing is put on in the "dirty" side. When the shift is completed, the employee returns to the "dirty" side. There, work clothing is removed and laundered; the employee showers and then passes through to the "clean" side to don street clothes. Plant representatives feel that this concept has worked reasonably well, and the possibility of spreading mercury contamination has been considerably reduced, if not eliminated.

WORK PRACTICES

Work practices (including housekeeping procedures) have been instituted to reduce exposure to mercury vapor, solid particulate mercury, and liquid mercury. These work practices are summarized as follows:

- Mill or maintenance personnel who create a spill are required to clean it up.
- Workers are encouraged to wash their hands at every opportunity and are required to wash before breaks and lunch. Barrier cream is available for use on hands.
- Smoking and eating are not permitted in process areas. In mid-1981 the mill break room facility was completed. This facility, located within the Mill Building, offers operators a controlled, fresh (outside) air-supplied, positive-pressure, low mercury exposure environment for breaks, lunch, and visual monitoring of process equipment during large portions of the shift. Smoking and eating are allowed in this room.
- Tobacco products should remain in the low exposure areas (break room, locker room) due to the potential absorption of mercury onto tobacco.
- Change room procedures (described earlier) must be followed.
- Workers' gloves and boots should be cleaned (using water) and inspected daily.

Good housekeeping is an important part of the plant's mercury control program. The program involves the containment and cleanup of liquid mercury, mercury-containing dusts, sludges, and solid concentrates. Complete control is difficult to achieve at the facility because the mineral processing operation from ore (containing approximately 0.5 percent mercury by weight) to liquid mercury has numerous emission sources, including spillage from flotation tanks and solids and sludges agitated during maintenance operations. The housekeeping practices program is summarized as follows:

- All liquid mercury, sludge, or concentrate should be contained and removed as soon as is practically possible. Cleanup usually involves washdown with water.
- Floor and work surfaces are treated periodically with polysulfide mercury suppressants. A 5 percent solution of Na_2S has been found to work well in reducing mercury contamination in the mill.

HgX^R mercury vapor suppressant was used at the mill for about 1 year; however, plant representatives feel that Na_2S is more effective and is less expensive than HgX^R. Sodium sulfide is also used throughout the process for metallurgical purposes and, as a result, is less expensive to use than HgX^R. Caution should be used in applying Na_2S due to its corrosive characteristics.

- Floors, work surfaces, and handrails are washed down using a high-pressure water spray.
- Contaminated tools must be cleaned daily.
- Contaminated mill or furnace components must be cleaned prior to any maintenance or storage.
- Flotation cells and concentrate sumps must be washed down if shutdown periods exceed 24 hours.
- The use of boot wash units is encouraged when leaving the concentrator/furnace complex.

MONITORING PROGRAMS

Physiological Monitoring

Physiological monitoring at this facility consists of biological monitoring (urinalyses and blood-mercury analyses) and physical examinations.

Spot urine-mercury samples, adjusted for specific gravity, are collected and analyzed weekly at the plant's laboratory for all individuals exhibiting levels exceeding 200 micrograms per liter (ug/L). All other exposed personnel are sampled bimonthly. Blood-mercury samples are collected monthly for all personnel exhibiting urine-mercury levels in excess of 200 ug/L. All other exposed personnel (mill and maintenance workers) are sampled at least once per quarter.

Trend analysis is very important when considering reassignment of exposed personnel due to elevated biological mercury values. Biological levels that warrant removal to a low-exposure work assignment are 300 ug/L urine-mercury and 10-15 ug/100 ml blood-mercury levels. Some individuals at this facility exhibit urine-mercury levels in excess of 300 ug/L without developing elevated blood-mercury values. Since, in the opinion of the consulting physician, urine-mercury levels only depict an individual's exposure and/or the efficiency of mercury excretion, blood-mercury data may be a more reliable index of body burden.

Physical examinations are conducted semiannually for all exposed personnel. All other employees are examined annually. Preemployment examinations are required for all new employees. Biannual mercury exposure examinations are conducted by a medical doctor specializing in neurology. Plant biological monitoring data are summarized in the histogram in Figure 5. The histogram incorporates all monitoring data collected for active employees since plant startup in June 1975 to the present. Results of urinalyses for mercury range from none detected to greater than 1,000 ug/L, with most samples below approximately 200 ug/L. Results of blood analyses range from none detected to greater than 24 ug/100 ml; most samples were below 5 ug/100 ml.

Air Monitoring

Air monitoring to determine the concentration of mercury vapor is routinely performed at this facility to identify problem areas and determine exposure levels. Air monitoring is conducted weekly at specified locations throughout the plant site using a direct reading instrument. Currently, a Mercometer, Model No. 2006-1-P (Anti-Pollution Technology Corp., Holland, Michigan) portable mercury vapor detector, is used for this purpose. This instrument works on the principle of ultraviolet atomic absorption of mercury vapor.

Monitoring to determine time-weighted average (TWA) exposure to mercury vapor is also performed. Currently, Gold Coil Mercury Vapor Dosimeters (Jerome Corp.) are used for this purpose. Prior to April 1981, a sampling method incorporating Hopcalite as the adsorption medium was used. Plant data show that personal exposure concentrations are generally higher than area concentrations.

A summary of plant air monitoring data collected with the Mercometer is presented in Figure 6. Results have been averaged for each location indicated. For ease of interpretation of trends, dotted horizontal lines

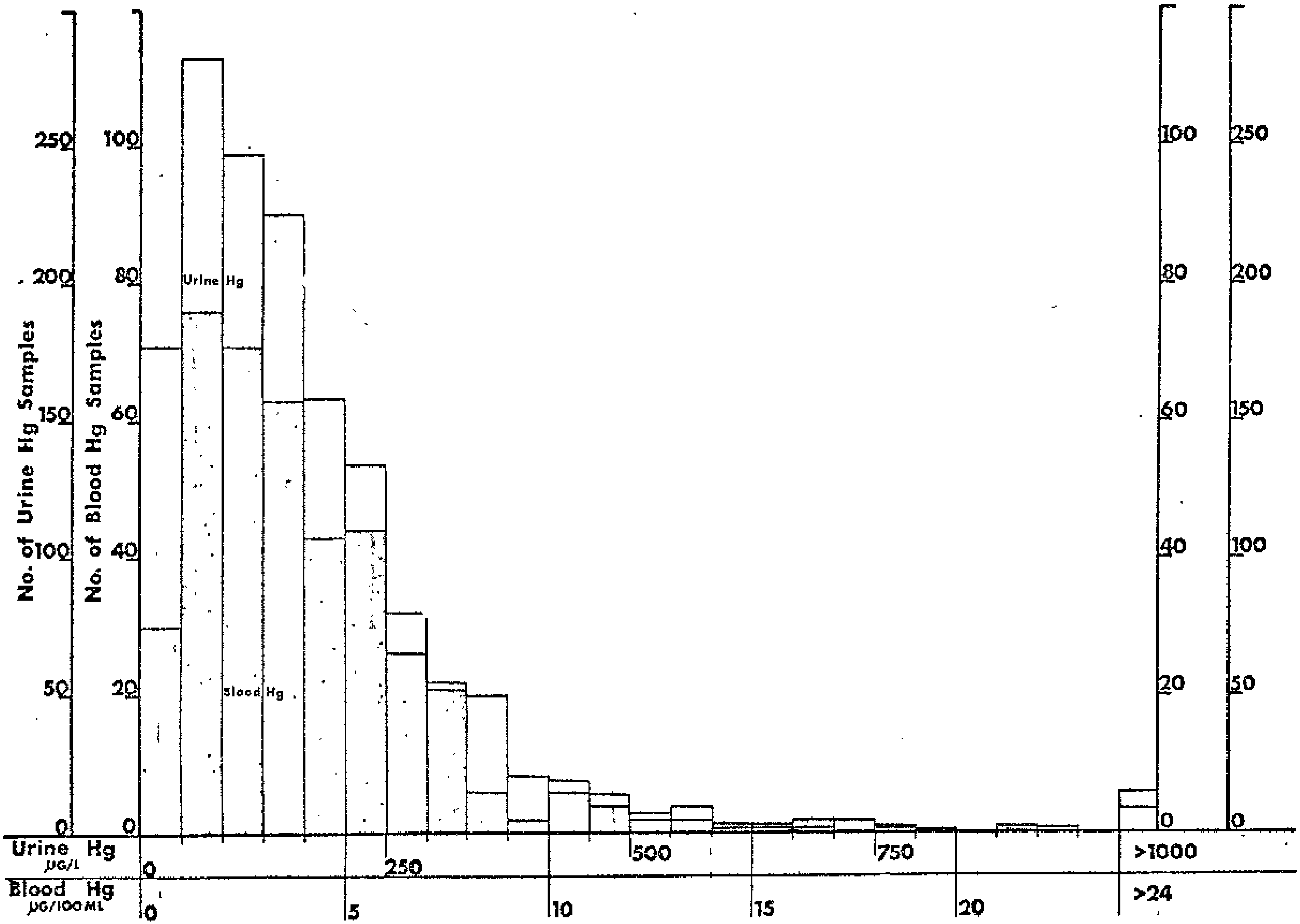

Figure 5. Plant Biological Monitoring Data Urine/Blood-Mercury Historgram as of 2/29/80 (Total Samples = 1,901).

Reference: McDermitt Mine by J.N. Hepworth

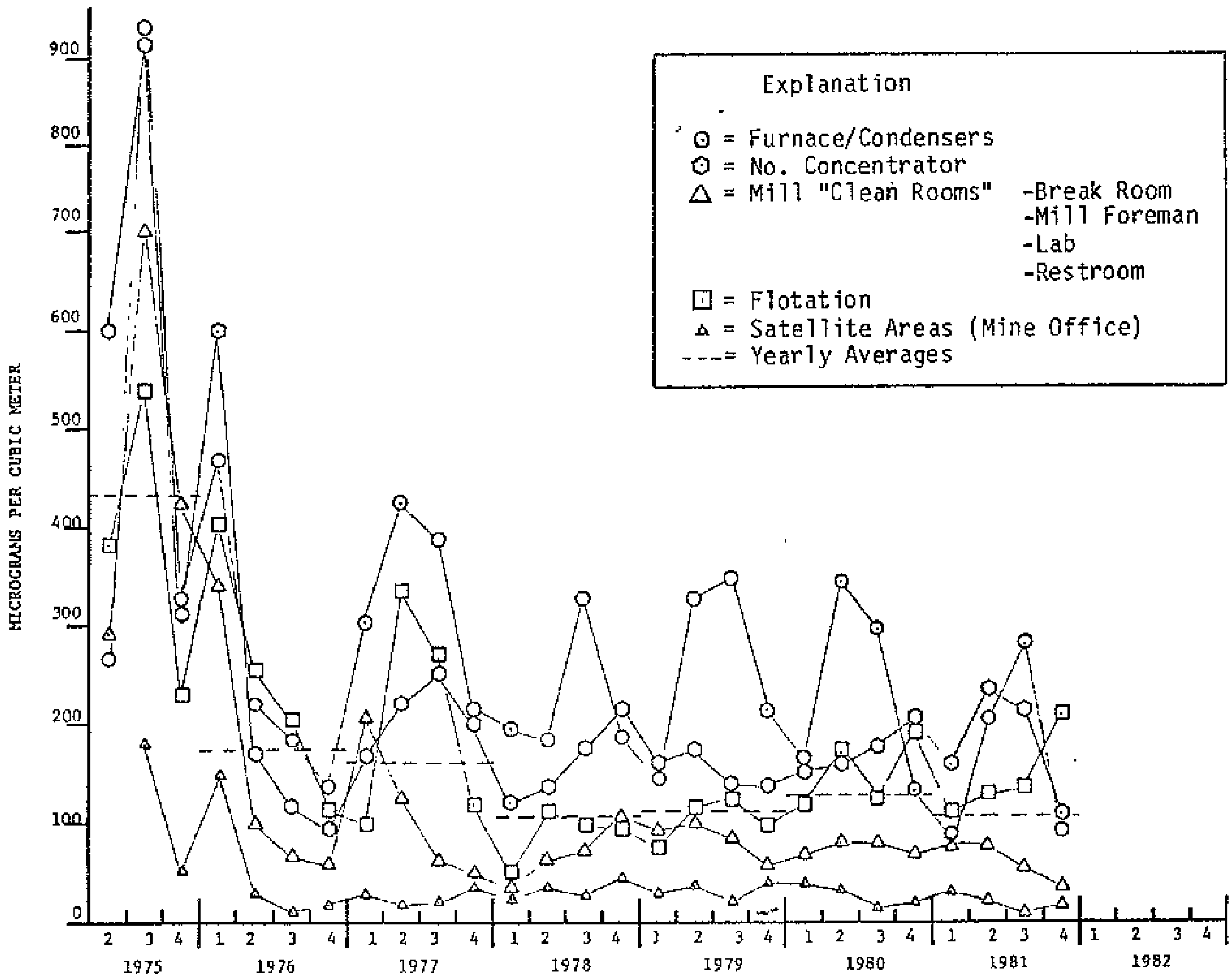

Figure 6. Mercury Vapor Day-Weighted Average by Areas per Quarter.
Reference: McDermitt Mine by J.N. Hepworth.

have been plotted to represent the average yearly mercury concentrations of all areas. Mercury concentrations were relatively high (average of 0.44 mg/m^3) during the first year of operation in 1975. Aware of a potential problem, plant representatives introduced steps to reduce mercury concentrations by improving housekeeping practices and optimizing process parameters. The result of those improvements was the achievement of an average concentration of 0.18 mg/m^3 in 1976. In the last quarter of 1976, the mine was moving towards achieving higher production rates, and it became evident to plant representatives that mercury concentrations were rising as a result of this step-up. Therefore, additional engineering controls had to be implemented to maintain mercury vapor control. In mid-1977, Na_2S addition was initiated and the disc filter and stock tank ventilated enclosures were implemented. A corresponding decline in mercury vapor concentrations occurred during the last two quarters of 1977 and the first quarter of 1978, resulting in a 0.02 mg/m^3 drop in the yearly average mercury level despite increased production. The 1978 average mercury vapor concentration shows further reduction (down to 0.10 mg/m^3). Average area concentrations since 1978 have ranged between 0.11 and 0.13 mg/m^3.

SURVEY DATA

During the survey, personal and area samples were taken in various locations throughout the facility to determine TWA concentrations of mercury vapor. Samples were obtained by using sampling pumps to draw air through a Hopcalite solid sorbent tube. Analysis of the samples was done by flameless atomic absorption. Results are shown in Table 1.

Sample results show that employee personal exposure to mercury vapor was significantly higher than the corresponding area samples. Personal exposure to mercury vapor was 0.260 mg/m^3 for the mill worker in the Furnace Building, and 0.200 mg/m^3 for the mill worker in the Concentrator Building. The Mine Safety and Health Administration (MSHA) standard of 0.05 mg/m^3 as a TWA was exceeded.

Disparity between personal sample concentrations and concurrent area sample concentrations is not uncommon in industries that use inorganic mercury. The differences may reflect a "microenvironmental" exposure to mercury vapor, presumably from contaminated clothing or hands.*

The area locations selected for sampling purposes correspond to some of those selected for routine monitoring by plant representatives. For comparison purposes some plant data have been summarized and included in Table 2. In most cases, area TWA concentrations determined by plant representatives averaged slightly higher than TWA concentrations determined during the site visit. Sample results from two areas, Furnace Filter and Flotation Walkway, were significantly lower during the survey than historical sampling results.

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* Stopford, Woodhall M.D., S. Bundy, L. Goldwater, J. Bittikofer. Microenvironmental Exposure to Mercury Vapor. American Industrial Hygiene Association Journal (39) May, 1978.

Table 1

Personal and Area Sample Results
(2/9/82 - 2/10/82)

Location	Full Shift TWA Concentration mg/m^3
Furnace Bldg. - Top Floor	0.023 - 0.036 (2)
Furnace Bldg. - 2nd Floor	0.025 - 0.030 (2)
Furnace Filter Area	0.066 - 0.067 (2)
Flotation Walkway	0.015
Above Ball Mill	0.040
New Mill Break Room	0.001
Flotation Basement	0.007
Change Room - Clean Side	0.002
Change Room - Dirty Side	0.080
Mill Worker A - Furnace	0.260
Mill Worker B - Concentrator	0.200

*Number in parentheses indicates number of samples taken at that location.

Table 2

Summary of Historical Area Sampling Data
Collected by Plant Representatives
(4/81 - 12/81)

Location	TWA* Concentration of Mercury Vapor** (mg/m^3) Range	Average
Furnace Bldg. - Top Floor	0.018-0.147 (3)***	0.096
Furnace Bldg.- 2nd Floor	0.045-0.160 (3)	0.084
Furnace Filter Area	0.079-0.483 (7)	0.229
Flotation Walkway	0.058-0.243 (7)	0.130
Above Ball Mill	0.006-0.182 (5)	0.095
New Mill Break Room	0.004-0.156 (11)	0.044
Flotation Basement	0.023-0.950 (3)*	0.048

* Sampling times are 8-24 hours' duration.

** Sampling method involved the use of the Gold Coil Mercury Vapor Dosimeter (Jerome Corp.).

*** Number in parentheses indicates number of samples taken at that location.

CONCLUSIONS

The high volume and omnipresence of mercury-containing materials throughout this facility makes it difficult to maintain mercury vapor concentrations below the MSHA standard of 0.05 mg/m^3. The chief objective of mercury control in the concentrator and furnace areas is to reduce the concentrations to as low as possible and use respirators for further reducing worker exposure. Plant representatives have found that the best way to achieve this is to add a mercury vapor suppressant to the stock and to provide negative pressures (induced draft and local exhaust ventilation) to the process points that emit the highest concentrations of mercury vapor. Unlike many other mercury-using industries, dilution ventilation is not exclusively relied upon as a major control to reduce mercury vapor concentrations at this facility.

Based on sampling results and historical records of worker urine-mercury levels, this facility is successfully controlling worker exposure to high levels of mercury vapor through the use of respirators. The respirators appear to be the single most important control, since they result in acceptable urine-mercury levels despite ambient mercury vapor concentrations in excess of the MSHA standard.

This company is engaged in a continous effort to develop, install, and evaluate new controls for protecting workers from exposure to mercury. The stack accelerator currently being designed is an example of this effort. It illustrates the importance of considering exhauster velocities and locations with respect to air intakes. Poorly situated exhausters can negate the benefits of even the most effective and efficient ventilation systems. Emphasis is also on control through the use of process modifications (such as the furnace-feed conveyor gasket currently being developed). Historical records enable the safety coordinator to detect trends in exposures and thus determine the effectiveness of the measures taken.