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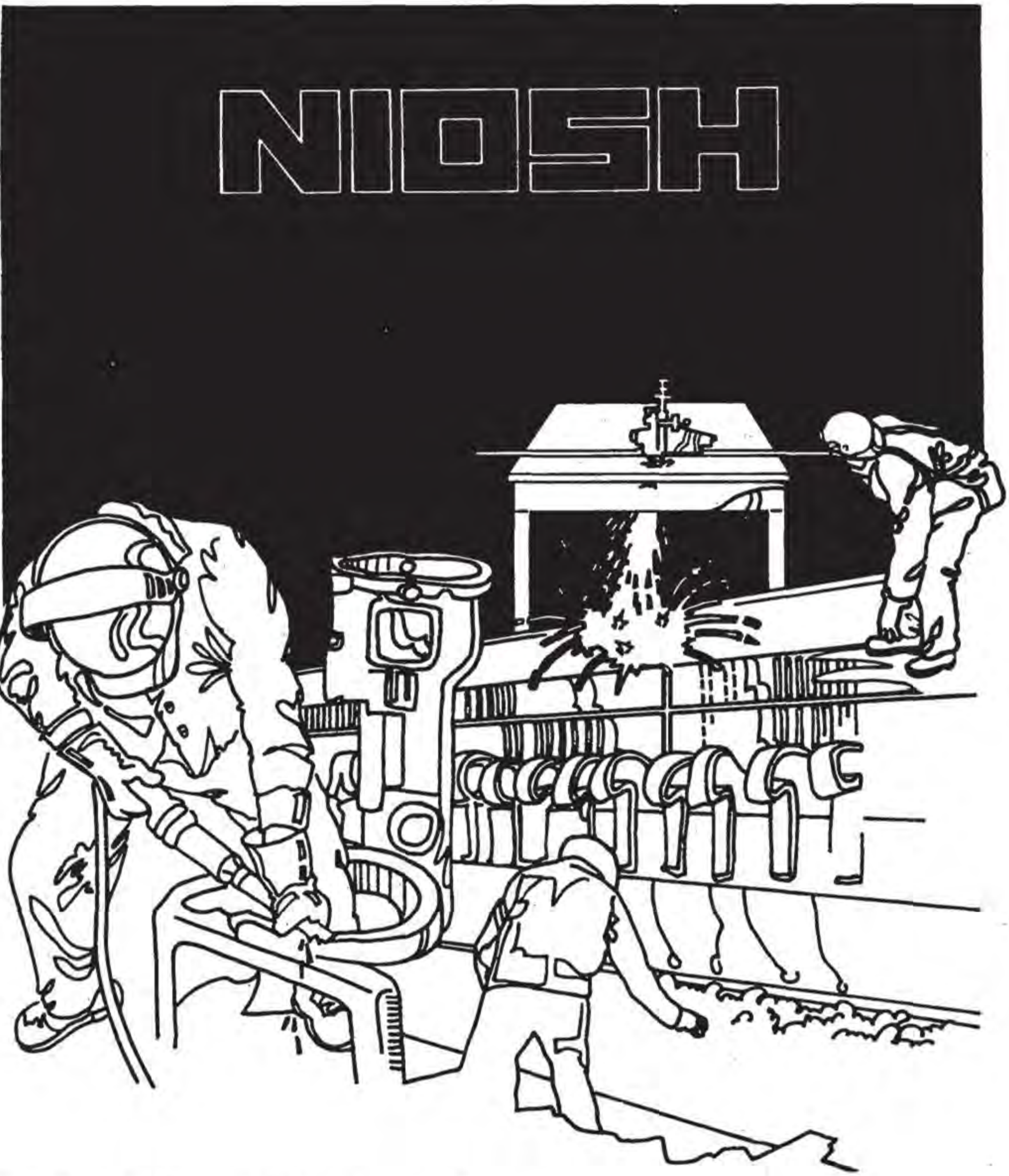

Health Hazard Evaluation Report

HETA 81-009-1052
GLOBE BATTERY PLANT CORPORATION
BENNINGTON, VERMONT

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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I. SUMMARY

On September 25, 1980, the National Institute for Occupational Safety and Health (NIOSH) was requested by the United Auto Workers International Union to conduct a follow-up evaluation of arsenic exposure in lead-acid battery production workers at the Globe Battery Plant, Bennington, Vermont. In a previous NIOSH investigation at this plant, the arsenic content in 5 (1.5%) of 344 personal (breathing zone) air samples had equalled or exceeded the OSHA standard of 10 ug/M^3, and 13 (3.8%) had equalled or exceeded the NIOSH recommended limit of 2 ug/M^3. Also 53 (43%) of 122 workers had urine arsenic concentrations of 50 ug/liter or above, indicating increased absorption of arsenic.

From November 10 to 13, 1980, NIOSH conducted environmental and medical evaluations at the Globe Battery Plant. The investigation was designed (1) to measure workers' personal (breathing zone) exposures to each of two forms of airborne arsenic which might be encountered in battery manufacture - particulate arsenic and arsine; (2) to correlate those exposures with urine arsenic excretion; and (3) to estimate arsenic trioxide vapor concentrations at 6 fixed locations within the plant.

Particulate arsenic concentrations in 177 breathing zone air samples were found to range from non-detectable to 5.1 ug/M^3. Nine values (5.1%) were greater than 2 ug/M^3. Highest average exposures were found in the Assembly Line (Post Burn) (0.9 ug/M^3), Element Battery Repair (0.87 ug/M^3), and Salvage and Remelt (0.69 ug/M^3) areas.

Arsine concentrations in 179 breathing zone air samples ranged from non-detectable to 49 ug/M^3. Highest average exposures were found in Process Attendants (20.6 ug/M^3), Power Spin Operators (14.5 ug/M^3), and Conveyor Formation Handlers (14.2 ug/M^3). The OSHA standard for occupational exposure to arsine is 200 ug/M^3, a level intended to prevent acute toxicity, and the NIOSH recommended exposure standard for arsine is 2 ug/M^3.

Arsenic trioxide vapor concentrations in 49 area samples ranged from non-detectable to 0.44 ug/M^3 (expressed as arsenic). Highest average arsenic trioxide vapor concentrations were found in the Element Battery Repair and Post Burn areas and appeared to be generated by torching.

Medical testing showed that 8 (20.5%) of 39 production workers had urine arsenic concentrations of 50 ug/liter or above. Highest urine arsenic concentrations were found in Process Attendants and Conveyor Formation Handlers. Correlation of urine arsenic levels with airborne exposures showed little correlation with particulate arsenic, but a close correlation with exposure to arsine ($r = 0.84$; $p < 0.0001$). Arsine exposures above 15.6 ug/M^3 were associated with urine arsenic concentrations of 50 ug/l or above.

Based on the medical and industrial hygiene data collected in this investigation, NIOSH has determined that workers at the Globe Battery Plant Bennington have exposures to airborne particulate arsenic and to arsenic trioxide vapor. Workers are exposed to arsine gas at levels below the OSHA standard, but above the NIOSH recommended standard. These occupational exposures to arsine are sufficient to cause increased absorption and urinary excretion of arsenic. Because all species of arsenic are carcinogens, exposures to all three species, especially to arsine, should be reduced through ventilation to the lowest levels feasible. Evidence of chronic intravascular hemolysis should be sought in workers exposed to arsine. Detailed recommendations are presented in Section VII of this report.

KEYWORDS: SIC 3691, Arsenic, Arsine, Arsenic Trioxide, (Storage Batteries).

II. INTRODUCTION AND BACKGROUND

Following a previous Health Hazard Evaluation (HE 78-98-710), the National Institute for Occupational Safety and Health (NIOSH) reported in July 1980 that excessive occupational exposure to arsenic existed at the Globe Lead-acid Battery Plant, Bennington, Vermont.[1]

Airborne arsenic exposures in 5 (1.5%) of 344 personal (breathing zone) air samples obtained at the Globe Battery Plant in the previous evaluation equalled or exceeded the arsenic standard of the Occupational Safety and Health Administration (OSHA) of 10 ug/M^3 air; arsenic concentrations in 13 (3.8%) air samples equalled or exceeded the NIOSH recommended limit of 2 ug/M^3. Also urine arsenic concentrations of 50 ug/liter or above were found in 53 (43%) of 122 workers tested; 11 workers had urine arsenic concentrations of 100 ug/liter or above. A positive correlation was found between air and urine arsenic concentrations ($r = 0.25$; $p = 0.01$; $n = 86$). Most of the workers with elevated urine arsenic levels worked in or near either the acid handling or battery forming areas of the plant, areas in which arsine might be expected to be the predominant species of arsenic exposure. NIOSH recommended that further study be undertaken to define the sources and magnitude of the arsenic exposure hazard at the Globe Battery Plant.

On September 25, 1980, the United Auto Workers (UAW) International Union requested that NIOSH conduct a follow-up Health Hazard Evaluation at the Globe Battery Plant to evaluate the possible hazard of occupational exposure to arsenic. The evaluation was undertaken in close coordination with the State of Vermont Department of Health and the Vermont Occupational Safety and Health Administration (VOSHA).

On September 10, 1980 representatives of labor and management met with NIOSH investigators in Cincinnati to discuss protocol and procedures for the follow-up study. There was no formal opening conference at the plant. A closing conference was held on November 13, 1980. A letter, dated January 6, 1981, reported the exposure data available on that date to management and to the Globe Battery Plant employees sampled.

The Plant

The Bennington Plant has been in operation since 1965 and has approximately 140,000 square feet of production area. In November 1980, the plant employed approximately 40 production workers over three shifts in the areas with potential for exposure to arsenic. There had been extensive changes in plant layout since the previous NIOSH visit, including changes in the location of the forming and power spin areas. However, the manufacturing process was substantially unchanged, except that the amount of arsenic used had decreased. The process description is as follows (Figure 1):

Grid Casting - In this area, purchased lead is fed into six melt melting pots. This area is isolated from the general plant area by swinging doors. The molten lead is poured into grid molds in a localized non-oxidizing atmosphere. The grids are fed out and are transferred to the pasting area.

Salvage and Remelt - Scrap lead is gathered throughout the plant (SCRAP COORDINATOR)* and fed into a melt furnace (SALVAGE AND REMELT OPERATOR). The lead is poured into pigs to be used in grid casting. The furnace is drossed to remove impurities. Also present in the scrap area is a scrap plate reprocessor into which scrap containing lead and lead oxide is fed. The lead and lead oxide are separated and recovered.

Small Parts Casting - Purchased lead and reclaimed lead are fed into a small furnace. Molten lead is manually poured via ladles into molds for production of lead pieces to be used in the Tiegel burn area for specific applications.

Ball Mill - Purchased lead pigs are fed into a rotating mill. The pigs tumble and break apart from continued impact. The heat generated by friction and the breaking of the lead into smaller and smaller pieces enhances the production of lead oxide. After oxide is produced, it is transported to a classifier where the large particles are separated and returned for further milling. The remaining oxide is transported by conveyor to storage.

Paste Mixing - Lead oxide is conveyed from storage to two paste mixing machines which are located directly above the pasting lines. The lead oxide is mixed with water, sulfuric acid, carbon black and other constituents to form a paste.

Panel Pasting - Lead grids are fed into one of two feed conveyors and are passed under a hopper containing paste which has dropped from the paste mixer. The pasted panels are conveyed through a drying oven. They are subsequently split and stored to cure.

Element Assembly - Cured plates may go to either the Cast-On-Strap Area for high production batteries or to the Tiegel burn area for specialized batteries. In the Cast-On-Strap area the plates are blocked on a tamping box and placed in a plate stacking machine. The plates are mechanically stacked, interleaved with separators and then assembled into groups. These groups are conveyed to the cast-on-strap lead station and are loaded into the Cast-On-Strap machine. If the groups of plates are being produced faster than the Cast-On-Strap machine can handle them, they are stored on a surge table. The Cast-On-Strap machine takes six plate groups at a time and dips them in molten lead to form them into battery elements. The Tiegel burn area operates in much the same manner except that the plate groups are stacked in the surge area until a sufficient number have accumulated. The operator then places the groups into the Tiegel machine

*The job categories in each process area are named in (PARENTHESES).

and forms elements by burning on small parts. Finished elements from the Cast-On-Strap and Tiegel areas are dropped into battery containers.

Welding Elements - The battery containers are conveyed to an intercell welding machine and the elements welded together. The battery is then checked for electrical continuity.

Heat Seal - The battery container and the battery cover are heated and sealed together. The battery is pressure checked. Those batteries which do not have side mounted connections have molds placed in the top and molten lead is poured to form posts (POST BURNING). The batteries are then filled with sulfuric acid (IMMERSION FILLER).

Formation - After batteries are filled with acid they are electrically formed (BATTERY STACKER, CONVEYOR FORMATION HANDLER, PROCESS ATTENDANT). Those which are to be shipped dry have the acid dumped and are then spun in a centrifuge to remove the remaining acid (POWER SPIN). Those batteries which are to be shipped wet are electrically boosted (BOOSTED STOCK). All batteries are then washed and dried, processed by the exterior finishing department, if necessary, and shipped.

Batteries with correctable defects are refurbished in ELEMENT BATTERY REPAIR.

Arsenic Exposure in Battery Production

In recent years alloying elements such as arsenic, antimony, calcium, selenium, cobalt, strontium and tin have been used in increasing quantities in lead-acid battery production. Arsenic is used in concentrations of up to 0.5 to 0.7 percent in lead to increase breakage resistance ("harden" the lead) and to increase resistance to electrochemical corrosion.[2]

The introduction of arsenic to the battery industry poses a hazard of occupational exposure to several forms (species) of airborne arsenic. Arsine gas (AsH_3) may be generated, particularly in battery forming and charging areas, where lead-arsenic alloys may come into contact with acids which can generate nascent hydrogen. Arsine may also be formed in lead recovery operations whenever alloys containing arsenic are combined in the molten state with alloys containing calcium or strontium. Particulate arsenic can be released into the air whenever lead-arsenic alloys are cut or fragmented and when drosses from lead containing arsenic are handled. Finally, arsenic trioxide (As_2O_3) may be generated by high-temperature operations such as welding and burning.

In the previous NIOSH survey at the Globe Battery Plant Bennington, particulate arsenic exposure had been demonstrated in Element Battery Repair, Post Burning, Salvage and Remelt and Tiegel areas. Torching conducted in the Element Battery Repair and Tiegel areas was a suspected source of both particulate arsenic and arsenic trioxide. The forming process has been demonstrated to generate arsine. Element Battery Repair, which included a torching operation, was located immediately adjacent to the forming area and thus had potential for exposure to all three species of arsenic. Arsine generation was also suspected to occur during the charging of Boosted Stock.

III. METHODS

A. Environmental

1. Goal

The environmental sampling undertaken in this investigation was intended (1) to measure workers' personal (breathing zone) exposures to two forms (species) of airborne arsenic which might be encountered in lead-acid battery manufacture - particulate arsenic and arsine, and (2) to measure airborne concentrations of arsenic trioxide (As_2O_3) vapor in the plant. Arsenic trioxide concentrations were measured in area air samples obtained at six fixed locations.

2. Sampling Techniques

To simplify assessment of personal (breathing zone) exposures to particulate arsenic and arsine (which previously would have required the use of two separate sampling trains), NIOSH developed a two-component sampling train comprised of a 13-mm AAWP filter followed by a 150-mg charcoal tube operated at a flow rate of 0.2 liters per minute. The filter inlet of this sampling train was restricted to provide a velocity equivalent to that of an open-face 37-mm filter cassette operated at a flow rate of 2 liters per minute after the method of Hill and Arnold[3]. Laboratory measurements demonstrated that the collection characteristics of this system were comparable to those of standard methods.[4]

To improve the accuracy of measurement of exposures to total particulate arsenic plus arsenic trioxide vapor, NIOSH developed a sodium carbonate-glycerol (CARB) filter system. Arsenic trioxide can co-exist in both particulate and vapor states at normal plant temperatures. Earlier laboratory studies had demonstrated that 25 to 90% of arsenic trioxide vapor passed through an AAWP filter and that 4 to 40% passed through both the filter and its backup pad. For that reason, 37-mm AAWP filters which had been pre-treated with sodium carbonate and glycerol were used for collection of arsenic trioxide. In the laboratory these filters were shown to be more than 90% efficient as collectors of arsenic trioxide.[5]

To compare these sampling methods with conventional techniques and to calculate their efficiencies in the field for the collection of various arsenic species, four replicate full-shift samples were collected each shift in each of six plant locations. The four sampling devices compared were: (1) the 13-mm AAWP filter and charcoal tube sampling train operated at a flow rate of 0.2 liters per minute, (2) a standard 37-mm open-face filter operated at a flow rate of 2 liters per minute, (3) a charcoal tube with a 37-mm prefilter operated at a flow rate of 0.2 liters per minute, and (4) the sodium carbonate and glycerol treated (CARB) filter operated at a flow rate of 1.5 liters per minute.

All samples, both personal and area, were collected using personal sampling pumps equipped with automatic flow rate controllers. Both the personal and area samples were analyzed for arsenic content by Utah Biomedical Test Laboratories (UBTL), the same laboratory employed for environmental arsenic analysis in the earlier NIOSH study at the Globe Battery Plant Bennington. The front and back sections of each charcoal tube were analyzed separately. The filter and filter pad of each 37-mm filter were analyzed using ultrasonication and the modified digestion procedure specified by Eller and Hull.[6,7]

3. Personal Samples

Full-shift personal (breathing zone) air samples were collected on all individuals on all shifts in the job categories with potential exposures to arsenic who were willing to participate in the study. The job categories identified for study on the basis of the workers having experienced either elevated exposures to arsenic or elevated urine arsenic concentrations in the previous NIOSH survey included: Assembly Line (Post Burn), Battery Stacker, Boosted Stock, Conveyor Formation Handler, Element Battery Repair, Gravity Check Acid Leveler, High Rate Tester (W.O. 15), Immersion Filler, Power Spin Operator, Process Attendant, Salvage and Remelt Operator, Scrap Coordinator, and Tiegel Operator. Office Workers were sampled as controls. Procedures for collection and analysis of personal air samples are described above (Sections III A.2 and III A.3).

4. Area Samples

Area air samplers were positioned in plant locations that offered a wide range of potential exposures to airborne arsenic species. These selected areas were Boosted Stock, Element Battery Repair, Forming, Post Burn, Salvage and Remelt, and Tiegel. Procedures for collection and analysis of area air samples are described above (Sections III A.2 and III A.3).

Additional area air samples were collected on Nuclepore filters and were analyzed in the NIOSH Cincinnati laboratories by electron microscopy and single particle X-ray fluorescence to determine the mean size of airborne particulates and the elemental composition of individual particles.

5. Ventilation Assessment

Because migration of arsenic species from their sources to other plant areas was suspected to occur at the Globe Battery Plant, air flow patterns were observed using artificial smoke generated by smoke candles. Observations were made in the Boosted Stock, Forming/Element Battery Repair, and Tiegel/Assembly Line areas.

6. Water Samples

To evaluate the possibility that plant workers had exposure to arsenic in drinking water, six random tap water samples were collected from sinks and drinking fountains at the Globe Battery Plant plant. These samples were collected in acid-washed Nalgene bottles, to which 0.5 gram of sodium EDTA was added as a preservative. The samples were refrigerated and shipped to UBTL for arsenic analysis by atomic absorption spectrophotometry using a hydride evolution technique.[8]

B. Medical

The medical component of this evaluation was intended to measure workers' absorption of arsenic and to correlate absorption with exposure to airborne arsenic species.

To measure arsenic absorption, 24-hour urine samples were collected on the second and third days of the workweek (Tuesday and Wednesday) from all production and office workers who had agreed to participate in the air sampling survey. (Make-up samples were collected on Thursday and Friday from workers who had missed the previous collections.) Workers were given arsenic-free plastic collection bottles with written instructions for collection of complete 24-hour urine output and for sanitary precautions to be observed during urine collection. At the conclusion of each 24-hour period, the samples were collected at the plant by NIOSH staff and shaken by hand until they appeared homogenous. The volume was measured, and the specific gravity was determined by means of a refractometer. An aliquot of 125 ml was taken from each sample and placed in an acid-washed Nalgene bottle, to which was added 0.5 gram of sodium EDTA as a preservative. These aliquots were held for the duration of the study at 4°C and were then shipped refrigerated to UBTL for arsenic analysis.

At the time of the collection of urine samples, each worker was asked whether he/she had eaten any salt water fish, shell fish, or crabs in the preceeding week. This procedure was designed to assess the major possible dietary source of arsenic.

As a quality control measure, two separate aliquots were taken from each of 12 urine samples. These duplicate aliquots were separately numbered, and were sent to UBTL with no indication that they represented duplicates. Also, as a further control, four sample collection bottles were washed in the field with distilled water and the washings sent to UBTL with EDTA preservative for arsenic analysis.

After extraction with nitric, perchloric, and sulfuric acids, urine samples were analyzed at UBTL for total arsenic content by atomic absorption spectroscopy using an automated hydride evolution technique. This technique does not distinguish among species of arsenic, but only measures the total urinary excretion of arsenic of any species which has been absorbed into the body. The results of analyses were corrected to the specific gravity of "standard" urine (S.G., 1.024). The lower limit of detection for arsenic in urine samples was 1 ug arsenic/liter.

IV. EVALUATION CRITERIA

A. Inorganic Arsenic (including Arsenic Trioxide)

Occupational exposure to inorganic arsenic occurs primarily through inhalation of arsenic-containing airborne particulates. Inhalation of arsenic trioxide vapor can also occur. Non-occupational arsenic absorption results almost entirely from eating food which contains traces of arsenic, seafood in particular, or from drinking contaminated water.

Excretion of arsenic occurs mainly via the urine. Most of a dose of arsenic is excreted within 30 hours; arsenic does not accumulate in the body as do lead and cadmium. Human absorption of arsenic has been assessed through measurement of arsenic concentrations in blood, hair, and urine. Of these, the urine arsenic concentration appears to be the best measure of recent absorption (past 1-3 days).[9] In virtually all persons without occupational or other unusual exposures to arsenic, urine arsenic concentrations are below 50 micrograms (ug) per liter. Thus a urine arsenic concentration of 50 ug per liter or above reflects increased absorption of inorganic arsenic.[10]

Arsenic toxicity among workers is almost always caused by chronic inhalation of arsenic or arsenic trioxide. Dermatitis (skin rash) is the most common sign of occupational arsenic toxicity and may be associated with development of areas of increased skin pigmentation or skin thickening ("arsenical warts"). Chronic exposure to arsenic has been shown to cause skin cancer.[10]

Chronic exposure to arsenic in high doses can also cause damage to the nerves of the arms and legs (peripheral neuropathy). This neuropathy primarily affects the sensory nerves and has been associated with slowed sensory nerve conduction velocity.[11,12] Symptoms of tingling (paresthesias) and numbness have been reported.

Chronic absorption of arsenic in high doses can cause toxicity to the liver and occasionally cirrhosis. Arsenic has been shown to cause a rare form of liver cancer, angiosarcoma of the liver.[13] Inorganic arsenic, and especially arsenic trioxide, is a potent irritant of the respiratory tract. Chronic exposure results in inflammation of the eyes and nose, nosebleeds, and occasionally perforation of the nasal septum. Chronic exposure to arsenic in the smelting and pesticide formulating industries has been shown to cause excessive deaths from cancer of the lungs and bronchi.[14,15] The lung cancer mortality rate in workers chronically exposed to arsenic has been shown to increase with the duration and intensity of exposure.[16]

The NIOSH recommended standard for occupational exposure to inorganic arsenic in air is 2 ug/M^3 based on a 15-minute ceiling measurement.[17] The OSHA standard is 10 ug/M^3 measured as an eight-hour time-weighted average.[18] No specific exposure standard exists for arsenic trioxide, but in view of its ability to cause cancer, exposure to arsenic trioxide (in both vapor and particulate forms) should be reduced to the lowest level feasible.

B. Arsine Gas

Arsine is a rapidly acting poison with toxicologic properties very different from those of other species of inorganic arsenic. It is therefore considered separately.

Arsine (AsH_3) is a colorless, non-irritating gas which is odor-free in low concentrations and at higher concentrations has an odor like garlic. Arsine is formed when arsenic comes into contact with hydrogen, for example when metals containing arsenic as an alloy come into contact with water or acid.

Symptoms of arsine poisoning begin 2 to 24 hours after inhalation exposure. Early symptoms consist of headache, muscle aches, weakness, difficulty in breathing, and vomiting. Those symptoms are followed in more severe cases by the appearance of abdominal pain, bloody urine, and jaundice. The liver may be enlarged and painful to touch.

All of the signs and symptoms of arsine poisoning are caused by the rapid destruction of circulating red blood cells (intravascular hemolysis). The most serious complication of arsine poisoning is kidney failure, which apparently results from the accumulation of hemoglobin in the kidney tubules.[19,20]

The OSHA standard for occupational exposure to arsine is 200 ug/M^3 measured as an eight-hour time-weighted average.[20] That standard is intended to protect workers against the acute toxic consequences of exposure to arsine. It does not consider the possibility that workers with chronic arsine exposure may absorb excessive amounts of inorganic trivalent arsenic as a result of their inhalation of arsine. Once absorbed into the body, arsine can react with oxygen to produce the reactive trivalent arsenous ion plus water, or it can react with water to produce arsenous acid. In either event, carcinogenic trivalent arsenic is released into the blood stream. The NIOSH recommended standard for occupational exposure to arsine is 2 ug/M^3.[17] That recommended standard is intended to minimize the possible occurrence of cancer resulting from chronic inhalation of arsine.

V. RESULTS

A. Industrial Hygiene

1. Personal Samples

a. Particulate Arsenic

A total of 177 breathing zone air samples were collected for particulate arsenic analysis. Particulate arsenic concentrations ranged from less than the limit of detection to 5.1 ug/M^3. Nine values (5.1%) were greater than 2 ug/M^3 (Table 1). Highest average exposures to airborne arsenic were found on the Assembly Line in Post Burn (0.9 ug/M^3), Element Battery Repair (0.87 ug/M^3), and Salvage and Remelt (0.69 ug/M^3) (Table 2). There were no differences in particulate arsenic exposures between days ($F_{3,164} = 0.89$; $p = 0.45$) and shifts ($F_{2,164} = 1.49$; $p = 0.23$) (Appendix I).

The general procedure used in handling samples below the limit of detection was to divide the detection limit for the specific sample set by 2 and then dividing that number by the modal sample volume. The resulting values were used in determining mean concentrations. The detection limit for the NIOSH samples was 10-25 nanograms per sample.

b. Arsine

A total of 179 breathing zone air samples were collected for arsine analysis. Arsine concentrations ranged from less than the limit of detection to 49 ug/M^3 (Table 3). Highest average exposures to airborne arsine were found in Process Attendants (20.6 ug/M^3), Power Spin Operators (14.5 ug/M^3), and Conveyor Formation Handlers (13.7 ug/M^3) (Table 2). There were no differences in arsine concentrations between days. The second shift had higher arsine exposures than the other two shifts when log transformed values were analyzed ($F_{2,166} = 3.44$; $p = 0.04$) (Appendix II).

2. Area Air Samples

a. Arsenic Trioxide

Area air samples for arsenic trioxide vapor were collected at six plant locations (Table 4). The highest mean concentrations of arsenic trioxide were found in the Element Battery Repair (0.36 ugAs/M^3) and Post Burning (0.18 ugAs/M^3) areas.

The concentration of arsenic trioxide vapor in these area samples was calculated using an algorithm in which the measured arsenic concentration on the backup pad of each 37-mm filter was divided by the collection efficiency (0.39) of that pad for arsenic trioxide vapor (Figure 2).[5]

The collection efficiency assumes that 1.0 units of AS_2O_3 enters the sampling device. For the AA37 filter 0.42 units are collected on the filter, 0.39 on the backup pad, and 0.19 units escape. The collection efficiency of the backup pad is equal to 0.39 divided by 0.58, the sum of 0.39 and 0.19, or 0.67. The corresponding fractions for the CARB filter are 0.93, 0.05, and 0.02. The weight of arsenic trioxide vapor collected on the FWAA37 filter and the FWCARB filter was averaged because each type of filter has its individual collection characteristics that have been measured separately. When there are two independent estimates, a better estimate of the true value can be obtained by averaging the two independent estimates.

There were three observations indicating that arsenic trioxide vapor was present: the AA37 results were higher than the calculated values for particulate arsenic (P) (Table 4); significant amounts of arsenic were found on the AA37 backup pads in the Element Battery Repair, Forming, Post Burn, and Tiegel areas; and only small quantities of arsenic were found on the CARB backup pads.

The calculated values of V by plant area are shown in Table 4. The ratio of V to CARB is also shown, and may be taken as an estimate of the contribution of arsenic trioxide vapor to total non-arsine arsenic. The results suggest that the proportion of arsenic trioxide vapor ranges from about 25% in Salvage and Remelt to more than 50% in Element Battery Repair, Forming, and Tiegel. This is reasonable because of the torching operations in Tiegel and Element Battery Repair and the proximity of the Forming Area to the latter. The highest concentration of arsenic trioxide vapor found, 0.36 ug/m^3, was in Element Battery Repair. This concentration is close to the equilibrium vapor concentration of arsenic trioxide.

b. Collection of Particulate Arsenic and Arsenic Trioxide

The filter samplers performed as anticipated. The particulate collection efficiencies of the three samplers are identical (Figure 2). However, the AA13 filter collected less than the corresponding AA37 filter, which in turn collected less arsenic than the corresponding CARB filter (Figure 3). These relationships may be seen in the data tabulated in Table 4.

This result is not surprising when the effect of arsenic trioxide vapor is considered. The CARB filter has the highest arsenic trioxide vapor collection efficiency (98% for FWCARB + BWCARB). The AA37 filter has a backup pad, and the weight of arsenic it collects is the sum of the weight of arsenic and arsenic trioxide particulate on the filter plus the weight of arsenic trioxide vapor that passes through the filter and is collected on the backup pad. There is no backup pad for the AA-13 filter and its collection efficiency for arsenic trioxide vapor is less than that of the AA37 filter-backup pad combination.

Additional evidence of the presence of arsenic trioxide vapor is seen in the ratio of mass of arsenic collected on the filter to the total mass collected on filter plus backup pad. Since the AA37 and CARB filters are 100% efficient collectors of particulate arsenic, any arsenic found on the backup pad is assumed to have been present as arsenic trioxide vapor. The ratios were calculated for both filters and appear in Table 4. In each case where a ratio of less than 1.0 is observed, arsenic trioxide vapor is judged to be present. The CARB filters, as expected by their higher collection efficiency for arsenic trioxide vapor of FWCARB, appear to give ratios closer to 1.0.

The arsenic trioxide collection efficiency of the AA13 filter (E) was not measured in the laboratory. It is 0.42 for AA37 filters[5]; and should be similar for AA13 filters, since the filter face velocity and composition are identical. E was calculated from field study results using equation (3) and a value of 0.35 ± 0.07 was obtained in Element Battery Repair where the highest levels of arsenic trioxide vapor were found. In three areas, Boosted Stock, Forming, and Tiegel, the filter loadings were too low to estimate E. Negative E values were calculated using data from the Post Burn and Salvage and Remelt, where relatively little arsenic trioxide vapor and high particulate arsenic concentrations were found.

The value $E = 0.35$ was used in calculating the effect of arsenic trioxide penetration of the charcoal tube (CT) which was in series with the AA13 filter. This was greatest, about 10%, in the Salvage and Remelt area (Table 4).

Good agreement was seen, as expected, between results of the two charcoal tubes, CT and PCT, which were in series behind the 13-mm and 37-mm filters ($r = 0.76$, $p < 0.00001$). The calculated true values of arsine [i.e. after correction of charcoal tube results for the arsenic trioxide vapor contribution (Equation 4)] are quite close to the measured values because of the relatively high concentrations of arsine compared to the arsenic trioxide vapor concentrations (Table 4).

c. Segregation of Particulate Arsenic from Arsine

Particulate arsenic was quantitatively separated from arsine. The arsenic trioxide that penetrated the prefilter was collected on the charcoal tube. An estimated collection efficiency of 35% for arsenic trioxide by the 13-mm filter was used to calculate the effect of arsenic trioxide penetration of the charcoal tube (CT) which was in series with the AA13 filter. This effect was greatest, about 10%, in the Salvage and Remelt area (Table 4).

d. Description of Airborne Particulates

Individual particles collected on Nuclepore filters in area air samples were analyzed for elemental composition and size. The particles were examined by scanning electron microscopy. Many were spherical and their median circular area equivalent diameter was less than 1 micron. The spherical shape of the particles is indicative of a fume.

The dust was examined by single particle X-ray fluorescence. The major elements found, in order to decreasing frequency of occurrence, were lead, silicon, sodium, iron, and antimony. Lead and antimony are constituents of battery grids. Iron is frequently detected in the air near moving machinery. Silicon may be due to abrasion of the concrete floor in the plant. Sodium compounds are ubiquitous, but may be due to the use of Na_2CO_3 to neutralize acid spills or NaCl for ice control in winter.

Arsenic was not detectable, but it should be noted that single particle X-ray fluorescence is much less sensitive for detection of arsenic than the graphite furnace atomic absorption technique used in the analysis of the filters. The failure to find arsenic in individual dust particles by x-ray fluorescence indicates that the arsenic concentration in the particles analyzed was less than 1% and that the arsenic present on the filter samples occurs as a trace component of the individual particles and not as discrete particles of arsenic trioxide. These results are consistent with the small percentage of arsenic used in the process materials and the extensive use of lead.[22]

3. Ventilation

The airflow patterns observed in the southern half of the plant indicated that air moved from the Boosted Stock area through the Element Battery Repair and Formation Areas in a generally west to east direction (Figure 4). Upon encountering the eastern plant wall, the main air stream appeared to divide. One branch moved north for a short distance and then turned westward. This countercurrent flow was most pronounced in the Maintenance/Battery Washer area and at the plant/warehouse juncture. A second smaller current turned south and then turned towards the west and flowed along the southern plant wall. Arsine is generated in the Forming process and to a much lesser extent in the Boosted Stock area.

These airflow patterns suggest that arsine is transported to other areas by in-plant air movements (Figure 4, Table 4). These findings suggest also that particulate arsenic is transported from Element Battery Repair to the Forming Area, where there is no known source of particulate arsenic. It is also possible that atmospheric transport of particulate arsenic accounts for the single elevated particulate arsenic exposure in the immersion fill area where there is no particulate arsenic used directly in the unit operation. The consistently high particulate arsenic sample results obtained at one work station in the Element Battery Repair Area suggest the need to investigate and improve the contaminant control with engineering techniques.

4. Water Samples

Six random tap water samples collected from various sinks and drinking fountains in the Globe Battery Plant contained no arsenic.

B. MEDICAL

Thirty-nine (93%) of 42 production workers in plant areas with potential exposure to arsenic participated in the medical component of this investigation. Eight office workers participated as a comparison group. One of these office workers had an elevated urine arsenic concentration. This following analysis was performed with and without this value included in the data set and no difference resulted.

Forty-three of the participating workers provided two 24-hour urine samples, and four provided only a single sample. The mean urine arsenic concentration (corrected for specific gravity) in the samples from the first day of collection was 31.5 ug/l, and on the second day was 24.9 ug/l. The difference between those two mean values was not great, and therefore for those workers who had provided two samples, the results were averaged, and the arithmetic mean of the two corrected values was employed in subsequent calculations. For those workers who had provided only a single urine specimen, the corrected arsenic concentration of that sample was used.

Duplicate aliquots were prepared at the plant from 12 urine samples and were sent separately to the laboratory under separate identification numbers and with no indication that they represented paired specimens. Excellent agreement was seen in the blind analysis of those duplicate specimens; the correlation coefficient (r) between the 12 pairs of results was 0.99.

Distilled water washings of four sample bottles of the types used in this study for urine collection and shipment were sent to the laboratory for arsenic analysis. No arsenic was detected in any of those samples.

Eight (11.0%) of the workers evaluated had corrected urine arsenic concentrations (mean of 2 values, when available) of 50 ug/l or above. Urine arsenic concentrations of 50 ug/l or above indicate increased absorption of one or more species of inorganic arsenic.[10] All workers with urine arsenic concentrations of 50 ug/l or above were employed in production areas. The greatest number of elevated urine arsenic values was found in Process Attendants, where all three workers had concentrations above 50 ug/l.

The highest mean urine arsenic concentration (69.0 ug/l) was found among Process Attendants in the Battery Formation area (Table 2). The next highest values were found in Conveyor Formation Handlers (mean, 46.3 ug/l), and in Battery Stackers (mean, 42.0 ug/l), both of which groups also work in Battery Formation. The mean urine arsenic concentration in the Office workers was 14.4 ug/l.

Six workers who participated in the medical survey reported that they had eaten seafood or shellfish in the week prior to the investigation. Urine arsenic concentrations in these six ranged from 4.25 to 53.5 ug/l; the one value over 50 ug/l was found in a Process Attendant. The mean urine arsenic concentration in the six workers who ate seafood was 20.8 ug/l, and the mean in the remaining 41 study participants was 28.7 ug/l. These data indicate that seafood was not a major source of absorbed arsenic for workers at the Globe Battery Plant.

Correlation of workers' urine arsenic concentrations with their personal (breathing zone) exposures to airborne arsenic species showed little correlation with exposure to particulate arsenic ($n = 47$; $r = 0.075$; $p = 0.62$). However, a close correlation was found between urine arsenic concentration and exposure to arsine in air ($n = 47$; $r = 0.84$; $p < 0.0001$) (Figure 5). The highest urine arsenic concentrations were found in that area of the plant, Battery Formation, in which workers were most heavily exposed to arsine. Exposure to arsine in personal (breathing zone) air samples in concentrations of 15.6 ug/M^3 or greater was found to be associated with urinary arsenic concentrations of 50 ug/l and higher (Figure 5).

VI. DISCUSSION AND CONCLUSIONS

The results of this investigation corroborate two major findings of the previous NIOSH evaluation at the Globe Battery Plant Bennington: (1) that arsenic species are present in air samples, and (2) that arsenic in concentrations of 50 micrograms/liter (ug/l) or above is present in samples of workers' urine.

However, the concentrations of arsenic in air and in urine in this investigation were lower than those found in the previous NIOSH study at the Globe Battery Plant-Bennington. These reductions appear to have resulted from improvements in ventilation and from the reduced use of arsenic in lead-acid battery manufacture at this plant.

Three species of inorganic arsenic were found in the air samples collected during this investigation - particulate arsenic, arsenic trioxide vapor, and arsine. Particulate arsenic and arsine have been noted previously in battery plants. Arsenic trioxide vapor has not, however, to our knowledge, been detected previously in lead-acid battery manufacture. Highest concentrations of the trioxide were found in those areas of the plant where lead arsenic alloy was torched in an oxidizing atmosphere, namely, in the Element Battery Repair and Post Burn areas. Although the concentrations of arsenic trioxide in air were not great, the detection of the trioxide is noteworthy, because of the particularly potent carcinogenic properties of this species of arsenic. Workers' exposure to arsenic trioxide must be reduced to the lowest level feasible.

It is important to realize that arsenic trioxide can exist both as an airborne particulate (fume) and as a vapor at the ambient temperature of a battery plant. Failure to recognize that property will result not only in failure to detect arsenic trioxide vapor in air samples, but also in serious underestimation of the total content of airborne arsenic; in those areas of the plant in which arsenic trioxide vapor was present in air, it comprised up to 50% of total non-arsine arsenic (Table 4).

As a result of the air sampling data on arsenic trioxide vapor which were gathered in this investigation, NIOSH has revised its recommended methods for collection of arsenic in air samples (Method P&CAM 346[28]).

Arsine was the predominant species of arsenic found in air samples at the Globe Battery Plant Bennington. Highest concentrations of arsine were found in the Battery Formation area, where freshly formed hydrogen comes into contact with lead-arsenic alloy during overcharging conditions. Because arsine is a gas, workers' exposure to arsine is entirely through inhalation.

A strong dose-response relationship was observed in this investigation between exposure to arsine gas and workers' excretion of arsenic in urine (Figure 5). No such relationship was seen in regard to either particulate arsenic or to arsenic trioxide, presumably because exposures to those species of arsenic were so much lower than the exposures to arsine.

An anomaly becomes apparent on examination of the dose-response relationship between arsine exposure and urinary excretion of arsenic. On the one hand, the current OSHA standard for exposure to airborne arsine is 200 ug/M^3, expressed as an eight-hour, time-weighted average (TWA). That standard is intended to prevent the well recognized acute toxic effects of arsine.[29] However, the upper limit of normal for the concentration of arsenic in urine is 50 ug/l; urine arsenic concentrations of 50 ug/l or greater reflect increased absorption of arsenic.[10] Examination of the dose-response relationship for arsine exposure which was developed in this investigation shows that a urinary arsenic excretion of 50 ug/l is exceeded when workers are exposed to arsine concentrations in personal (breathing zone) air samples of 15.6 ug/M^3 or above, an exposure level which is considerably below the standard. That finding takes on considerable importance in view of the fact that trivalent arsenic is a proven carcinogen and that inhaled arsine is metabolized to inorganic trivalent arsenic. In view of that observation, all species of arsenic (including arsine) ought to be regulated equally stringently as carcinogens, and exposures to arsine should be controlled to at least the NIOSH recommended standard for inorganic arsenic of 2 ug/M^3.

Finally, the observation that arsine exposure at the Globe Battery Plant Bennington is associated with excessive urinary excretion of arsenic raises the possibility that those workers most heavily exposed to arsine may be undergoing chronic low-grade intravascular hemolysis. It is recommended that a hematocrit determination, reticulocyte count or other appropriate tests for hemolysis be conducted during the next medical screening of workers in the Battery Formation area at the Globe Battery Plant Bennington, and that those tests be repeated periodically for as long as exposure to arsine exists at the plant.

VII. RECOMMENDATIONS

A. Environmental

Arsine exposure should be reduced to the NIOSH recommended standard of 2 ug/M^3 by engineering control in the Formation and Boosted Stock Area. In the battery charging area it may be possible to eliminate arsine generation by controlling the voltage applied during charge.[30]

Because arsine originating in the formation area is transported throughout the facility by the in-plant air currents it would be prudent to isolate the forming area from the production floor and to ventilate the enclosure to remove hydrogen and toxic gases (arsine and stibine). This procedure would also tend to minimize the reported acute episodes of sensory irritation attributed to sulfuric acid mist.

Because arsenic trioxide was not monitored by personal breathing zone samples, personal exposure to total particulate As and arsenic trioxide vapor should be conducted on employees working near the forming, Element Battery Repair, Tiegel and Post Burn areas using the new collection method specified in P&CAM 346.[28]

B. Medical

1. Workers at the Globe Battery Plant should be informed by management of the acute toxic effects and potential chronic toxic effects of exposure to arsine gas. A program should be instituted by management for the education and training of new employees.

2. Management should consider instituting a program for the periodic medical screening of those workers at the Bennington plant who are exposed to arsine. We suggest that such screening should take place twice each year. Such a program would most logically be directed toward workers in the Battery Formation area, and might include at a minimum the following two evaluations: (a) determination of urine arsenic concentration, as an index of arsenic

(including arsine) absorption; and (b) determination of hematocrit and/or of the percentage of reticulocytes on the peripheral blood smear, as an index of any arsine-induced hemolysis.

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X. DISTRIBUTION AND AVAILABILITY OF REPORT

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Copies of this report have been sent to:

1. International Representative, United Auto Workers International Union 179, Allyn Street, Hartford, Connecticut 06103.

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9. OSHA, Region I.

TABLE 1

EXPOSURE TO AIRBORNE PARTICULATE ARSENIC (PERSONAL BREATHING ZONE SAMPLES)
HE 81-009
GLOBE BATTERY PLANT
BENNINGTON, VERMONT
NOVEMBER 10-13, 1980

			DISTRIBUTION OF CONCENTRATIONS									
Job Categories	No. of Workers	No. of Samples	≤ 2.0 ug/M^3		2.01-3.00 ug/M^3		3.01-4.00 ug/M^3		4.01-5.00 ug/M^3		≥ 5.01 ug/M^3	
			n	%	n	%	n	%	n	%	n	%
Assembly Line (Post Burn)	4	16	13	81.3	2	12.5	0	0.0	0	0.0	1	6.3
Battery Stacker	2	8	8	100.0	0	0.0	0	0.0	0	0.0	0	0.0
Boosted Stock	2	8	8	100	0	0.0	0	0.0	0	0.0	0	0.0
Conveyor Formation Handler	6	23	23	100	0	0.0	0	0.0	0	0.0	0	0.0
Element Battery Repair	5	19	15	78.9	2	10.5	1	5.3	0	0.0	1	5.3
Gravity Check Acid Leveler	4	12	12	100.0	0	0.0	0	0.0	0	0.0	0	0.0
High Rate Tester (W.O. 15)	2	8	8	100.0	0	0.0	0	0.0	0	0.0	0	0.0
Immersion Filler	2	8	7	87.5	0	0.0	0	0.0	1	12.5	0	0.0
Power Spin Operator	2	6	6	100.0	0	0.0	0	0.0	0	0.0	0	0.0
Process Attendant	3	12	12	100.0	0	0.0	0	0.0	0	0.0	0	0.0
Salvage and Remelt Operator	3	12	11	91.7	0	0.0	0	0.0	1	8.3	0	0.0
Scrap Coordinator	3	11	11	100.0	0	0.0	0	0.0	0	0.0	0	0.0
Tiegel Operator	2	6	6	100.0	0	0.0	0	0.0	0	0.0	0	0.0
Office	8	28	28	100.0	0	0.0	0	0.0	0	0.0	0	0.0

TABLE 2

MEAN EXPOSURE TO AIRBORNE PARTICULATE ARSENIC AND ARSINE (BREATHING ZONE SAMPLES) AND MEAN URINE ARSENIC CONCENTRATIONS (24-HOUR SAMPLES) BY JOB CATEGORY

HE 81-009
GLOBE BATTERY PLANT
BENNINGTON, VERMONT
NOVEMBER 10-13, 1980

	AIR ARSENIC (ug/M^3)			AIR ARSINE (ug/M^3)			URINE ARSENIC (ug/l)		
Job Category	No. of Samples	Mean	S.D.	No. of Samples	Mean	S.D.	No. of Samples	Mean	S.D.
Assembly Line (Post Burn)	16	0.93	1.38	16	1.92	1.09	4	16.9	3.8
Battery Stacker	8	0.08	0.0	8	8.12	3.98	2	42.0	21.9
Boosted Stock	8	0.08	0.0	8	4.42	1.67	2	13.6	9.0
Conveyor Formation Handler	23	0.09	0.02	24	13.74	10.89	6	46.3	28.2
Element Battery Repair	19	0.87	1.53	20	10.82	8.64	5	38.4	18.5
Gravity Check Acid Leveler	12	0.08	0.0	12	2.78	1.95	3	17.6	10.3
High Rate Tester (W.O. 15)	8	0.08	0.01	8	11.63	3.94	2	33.2	12.4
Immersion Filler	8	0.66	1.64	8	2.00	1.20	2	34.2	6.7
Power Spin Operator	6	0.08	0.01	7	14.48	7.15	2	36.4	5.4
Process Attendant	12	0.11	0.08	12	20.57	8.56	3	69.0	14.1
Salvage and Remelt Operator	12	0.69	1.15	12	0.15	0.19	3	8.3	4.0
Scrap Coordinator	11	0.09	0.04	11	0.95	0.52	3	9.7	1.2
Tiegel Operator	6	0.32	0.43	6	0.51	0.34	2	7.9	3.7
Office	28	0.08	0.00	27	0.06	0.11	8	14.4	14.9

TABLE 3

AIRBORNE ARSINE EXPOSURES
(PERSONAL BREATHING ZONE SAMPLES)
HE 81-009
GLOBE BATTERY PLANT
BENNINGTON, VERMONT
NOVEMBER 10-13, 1980

			DISTRIBUTION OF CONCENTRATIONS					
Job Categories	No. of Workers	No. of Samples	Less than or equal to 10.0 ug/M^3		10.01-25.00 ug/M^3		25.01-50.00 ug/M^3	
			n	%	n	%	n	%
Assembly Line (Post Burn)	4	16	16	100.0	0	0.0	0	0.0
Battery Stacker	2	8	7	87.5	1	12.5	0	0.0
Boosted Stock	2	8	8	100.0	0	0.0	0	0.0
Conveyor Formation Handler	6	24	10	41.7	12	50.0	2	8.33
Element Battery Repair	5	20	12	60.0	7	35.0	1	5.0
Gravity Check Acid Leveler	4	12	12	100.0	0	0.0	0	0.0
High Rate Tester (W.O. 15)	2	8	3	37.5	5	62.5	0	0.0
Immersion Filler	2	8	8	100.0	0	0.0	0	0.0
Power Spin Operator	2	7	3	42.9	4	57.1	0	0.0
Process Attendant	3	12	1	8.3	8	66.7	3	25.0
Salvage and Remelt Operator	3	12	12	100.0	0	0.0	0	0.0
Scrap Coordinator	3	11	11	100.0	0	0.0	0	0.0
Tiegel Operator	2	6	6	100.0	0	0.0	0	0.0
Office	8	27	27	100.0	0	0.0	0	0.0

Table 4

Arsenic Species by Plant Area

All Values, Except Ratios, are in ug/m^3 of Arsenic. Standard Deviations are in Parentheses.

Parameter	Determined By	Boosted Stock	Element Battery Repair	Forming	Post Burn	Salvage and Remelt	Tiegel
		N = 10	N = 3	N= 11	N = 7	N = 11	N = 7
<u>Arsenic Trioxide Vapor</u>							
V	Calculation	<0.02	0.36 (0.06)	0.11 (0.07)	0.18 (0.14)	0.07 (0.12)	0.06 (0.07)
V/CARB	Ratio	----	0.52 (0.07)	0.76 (0.40)	0.33 (0.40)	0.25 (0.29)	0.91 (0.88)
<u>Particulate Arsenic</u>							
AA37	Measurement	0.02 (0.02)	0.57 (0.13)	0.13 (0.16)	0.57 (0.46)	0.39 (0.35)	0.06 (0.06)
AA13	Measurement	<0.08	0.42 (0.10)	0.06 (0.08)	0.47 (0.32)	0.15 (0.19)	<0.08
CARB	Measurement	0.03 (0.03)	0.69 (0.06)	0.14 (0.08)	1.25 (1.32)	0.48 (0.64)	0.07 (0.07)
P	Calculation	0.03 (0.02)	0.30 (0.07)	0.07 (0.10)	0.60 (0.52)	0.37 (0.32)	0.04 (0.06)
AA37CORR	Calculation	0.01 (0.02)	0.28 (0.13)	0.06 (0.15)	0.37 (0.44)	0.28 (0.30)	0.02 (0.04)
AA13CORR	Calculation	<0.04	0.29 (0.10)	0.04 (0.07)	0.41 (0.30)	0.14 (0.19)	<0.04
CARBCORR	Calculation	0.02 (0.02)	0.32 (0.09)	0.05 (0.06)	1.07 (1.32)	0.41 (0.63)	0.04 (0.05)
FWAA37/(FW+BW)AA37	Ratio	1.0 (0.0)	0.75 (0.04)	0.70 (0.19)	0.84 (0.11)	0.97 (0.05)	0.76 (0.28)
FWCARB/(FW+BW)CARB	Ratio	1.0 (0.0)	0.93 (0.02)	1.0 (0.0)	0.95 (0.05)	0.99 (0.02)	1.0 (0.0)
<u>Arsine</u>							
CT	Measurement	6.3 (3.4)	40 (4)	41 (33)	2.1 (1.1)	0.33 (0.62)	0.69 (0.52)
A	Calculation	6.3 (3.4)	40 (4)	41 (33)	2.0 (1.0)	0.32 (0.62)	0.58 (0.57)

NOTE: When the weight of arsenic trioxide vapor was subtracted from the total weight of arsenic collected on the filters using the following equations:

AA37CORR = AA37 - 0.81 V

AA13CORR = AA13 - 0.35 V

CARBCORR = CARB - 0.98 V

better agreement was seen among the corrected filter results

APPENDIX I ARSENIC

SUMMARY OF DESCRIPTIVE STATISTICS
COMBINED ENVIRONMENTAL DATA
HE 81-009
GLOBE BATTERY PLANT CORPORATION
NOVEMBER 10-13, 1980

Day/Shift	No. of Samples	Mean	Standard Deviation	MIN	MAX
TOTAL	177 177	0.323 -0.909	0.847 0.424	<0.08 <-1.097	5.14 0.711
11/10/80	42 42	0.49 -0.857	1.2 0.516	<0.08 <-1.097	5.1 0.711
11/11/80	45 45	0.31 -0.941	0.90 0.422	<0.08 <-1.097	4.7 0.675
11/12/80	44 44	0.30 -0.868	0.62 0.423	<0.08 <-1.097	3.0 0.476
11/13/80	46 46	0.21 -0.965	0.46 0.339	<0.08 <-1.097	2.4 0.377
Shift 1	106 106	0.41 -0.899	1.06 0.475	<0.08 <-1.097	5.1 0.711
Shift 2	52 52	0.19 -0.923	0.29 0.349	<0.08 <-1.097	1.4 0.146
Shift 3	19 19	0.17 -0.922	0.24 0.311	<0.08 <-1.097	1.1 0.053

Notes:

1. The particulate arsenic concentration is reported on the 1st line and the Log (Arsenic) concentration on the 2nd Line.
2. Concentrations are expressed in ug/M^3.

APPENDIX II ARSINE
SUMMARY OF DESCRIPTIVE STATISTICS
COMBINED ENVIRONMENTAL DATA
HE 81-009
GLOBE UNION CORPORATION
Nov 10 - Nov 13, 1980

Day/Shift	No. of Samples	Mean	Standard Deviation	MIN	MAX
TOTAL	179	6.6	8.6	<0.02	49.4
	179	0.186	1.025	<-1.699	1.694
11/10/80	44	4.7	6.2	<0.02	22.9
	44	0.012	1.027	<-1.699	1.356
11/11/80	44	8.6	10.7	<0.02	49.4
	44	0.301	1.085	<-1.699	1.694
11/12/80	45	6.6	9.1	<0.02	36.2
	45	0.143	1.068	<-1.699	1.559
11/13/80	46	6.6	7.6	<0.02	26.6
	46	0.287	0.923	<-1.699	1.425
Shift 1	108	6.1	7.5	<0.02	29.6
	108	0.047	1.127	<-1.699	1.471
Shift 2	52	7.6	9.5	<0.02	49.4
	52	0.501	0.704	<-1.699	1.694
Shift 3	19	6.9	11.5	<0.02	36.2
	19	0.116	1.009	<-1.699	1.559

Note: The arsine concentration is reported on the 1st line and the Log (Arsine) concentration on the 2nd Line. Concentrations are expressed in ug/M^3.