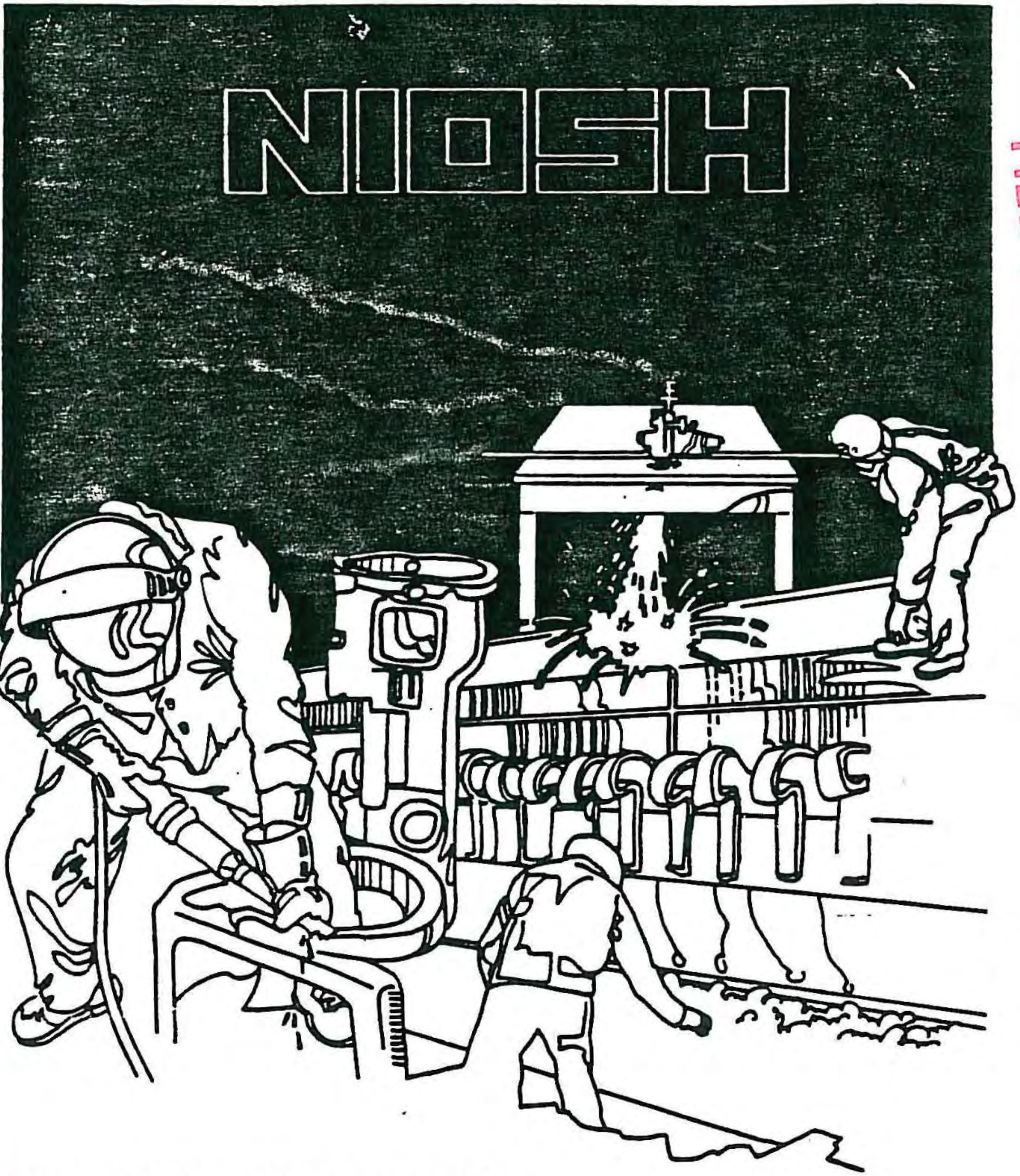
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES ■ Public Health Service
Centers for Disease Control ■ National Institute for Occupational Safety and Health



Health Hazard Evaluation Report

HETA 84-041-1592
JOHNSON CONTROLS, INC.
OWOSSO, MICHIGAN

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.

HETA 84-041-1592
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JOHNSON CONTROLS, INC.
OWOSSO, MICHIGAN

NIOSH Investigators:
Mitchell Singal, M.D.
John N. Zey, I.H.
Sara J. Arnold, M.D.

I. SUMMARY

On October 31, 1983, the National Institute for Occupational Safety and Health (NIOSH) received a request from the United Auto Workers International Union to evaluate exposures to lead and other substances at Johnson Controls, Inc.'s Battery Division (formerly Globe Battery) plant in Owosso, Michigan. The union was particularly concerned about what they perceived as physiologic discrepancies between blood lead and zinc protoporphyrin (ZPP) concentrations in certain workers. NIOSH personnel conducted environmental and medical investigations at the plant on November 30, 1983 and April 2-5, 1984.

Lead concentrations in 675 personal air samples collected by the company over the year preceding the first NIOSH visit ranged from 1 ug/m^3 to greater than 1600 ug/m^3. Two percent of the values were $\geq$ 100 ug/m^3, 9% were $\geq$ 50 ug/m^3, and 20% were $\geq$30 ug/m^3. Twenty-six (46%) of the 57 values exceeding 50 ug/m^3, and 10 (67%) of the 15 exceeding 100 ug/dl, were obtained in four departments (oxide mill, janitorial, maintenance, inspectors) that accounted for only 24% of the 675 samples. The technical aspects of the company's written respirator program were sound, but we observed instances in which respirators were not being used properly.

NIOSH personnel collected 49 personal breathing zone and 17 general area air samples for inorganic arsenic, including arsenic trioxide and arsine, and for stibene and particulate antimony, in the casting, pasting, cast-on-strap (COS), post burn and battery forming areas. One or more species of arsenic were detected in 10 (20%) of the personal samples and in 1 (6%) of the area samples. One air concentration, 3.3 micrograms per cubic meter (ug/m^3) in a personal sample from a post burn worker, exceeded the NIOSH recommended standard of 2 ug/m^3. [The Occupational Safety and Health Administration (OSHA) standard is 10 ug/m^3.] Antimony concentrations ranged from less than 0.23 to 4.6 ug/m^3, and stibene concentrations from less than 0.04 to 0.54 ug/m^3, all well within the NIOSH and OSHA exposure limits of 500 ug/m^3. Ten sulfuric acid samples were collected in and around the battery forming area. No sulfuric acid was detected; the limit of detection was 8 ug/sample, equivalent to concentrations ranging from 0.15 to 0.19 ug/m^3 for these samples.

NIOSH medical personnel analyzed the company's blood lead/ZPP data for 1982 and 1983. Using the most recent test results from each of the workers, ZPP was exponentially related to blood lead, a blood lead of 30 ug/dl corresponding to a ZPP of 44 ug/dl for men and 70 ug/dl for women, and a blood lead of 40 corresponding to a ZPP of 57 for men and 96 for women. All departments had a mean blood lead of less than 40 ug/dl; the plant-wide mean blood lead decreased from 36 ug/dl in January 1982 to 31 ug/dl in November 1983, with an unexplained peak of 46 ug/dl in November 1982. At the time of their most recent blood tests, 16 (4%) of 371 workers had blood lead concentrations of less than 40 micrograms per deciliter (ug/dl) and blood ZPP concentrations of 100 ug/dl or more. In thirteen (81%) of the sixteen, as of March 1984, the ZPP was within the range expected for the corresponding blood lead. In the remaining three cases, our interviews suggested the possibility that other medical conditions (unrelated to occupational lead exposure) might be contributing to a persistently elevated ZPP.

Urine arsenic concentrations ranged up to 52 ug/g creatinine (upper limit of "normal": 100), with a median of 7; when multiple determinations (on different days) for a worker were averaged, the median urine arsenic concentration for the 30 workers was 8 ug/g creatinine.

Based on the results of our review of company data, we conclude that (a) maintenance and janitorial jobs have the greatest potential for excessive lead exposure, but (b) there is no pattern of medically unexplained discrepancies between workers' blood lead and ZPP results. Attempts to keep workers ZPP levels, as well as their blood lead levels, from rising excessively are appropriate because an elevated ZPP may be a marker of a biologically significant adverse effect of lead. The use of respirators may be necessary for the immediate control of exposure, but engineering controls and good work practices should be the primary means of achieving a permanent reduction of exposure. Except for one elevated air arsenic concentration in a post burn worker, we did not document excessive exposures to inorganic arsenic, sulfuric acid, or stibine. Recommendations to reduce exposure to lead, to improve the implementation of the respirator program, and to reduce the potential for arsenic exposure in the post burn area, are presented in section VIII of this report.

KEYWORDS: SIC 3691 (Manufacturing of storage batteries), lead, blood lead, zinc protoporphyrin, arsenic, arsine, sulfuric acid, antimony, stibine

II. INTRODUCTION

On October 31, 1983, the National Institute for Occupational Safety and Health (NIOSH) received a request from the United Auto Workers International Union to evaluate exposures to lead and other substances at Johnson Controls, Inc.'s Battery Division (formerly Globe Battery) plant in Owosso, Michigan. The union was particularly concerned about what they perceived as physiologic discrepancies between blood lead and zinc protoporphyrin (ZPP) concentrations in certain workers. Subsequent discussions with union representatives revealed concerns about what they perceived as inconsistencies in respirator use requirements (for example, requiring only some of the workers with apparently similar jobs to use respirators) and about the potential increased exposure to lead resulting from the reduction in the number of janitorial positions in December 1982.

On November 30, 1983, NIOSH personnel conducted a walk-through inspection of the plant, interviewed company and union representatives, and reviewed available environmental and medical monitoring records. On April 2 - 5, 1984, NIOSH personnel conducted a survey of arsenic exposure which included both air sampling and urine analysis. Letters dated December 12, 1983, and May 14, September 7, November 8, and November 14, 1984, informed the company and union of the progress of the investigation. We notified individuals of their urine arsenic results on September 7, 1984.

III. BACKGROUND

A. Process Description

The Battery Division plant manufactures LSI (lighting, starting, and ignition) lead-acid storage batteries, primarily for automobile manufacturers. The plant began production in 1937 as a carburetor factory and converted to battery production in 1946. Globe Battery purchased the facility in 1972. The plant size is approximately 220,000 square feet. At the time of our investigation it employed approximately 370 people. About 335 of them, including 15 supervisory personnel, worked in the production area. Approximately 11% of the employees were women. The plant has a capacity for two million batteries per year; the production rate at the time of our investigation was 1.6 million per year.

The battery production process is broken down into divisions according to the principal operation conducted in the area.

<u>Shipping and Receiving</u> - In this area raw materials are received and batteries shipped by truck and/or rail. Approximately 17,000 tons of lead ingots are received each year.

Grid Casting - In this department lead-calcium ingots are melted and then maintained at approximately 1000° F. The molten lead is piped into molds where thin perforated grids are produced. This area contains 10 banks of three casting machines each, with one operator per bank. Once per shift the operator uses a ladle to skim dross (waste material) from the lead pots.

Ball Mill Area - Lead ingots are melted and then formed into small plugs. The plugs are transferred via a conveyor into rotating mills. Oxygen and water are mixed in with the lead at a temperature of 400°F to form lead oxide powder. The temperature is a product of the friction of the lead slugs with one another as they rotate. One operator and one assistant operator monitor this operation.

Plate Pasting - Lead oxide, water, sulfuric acid (H_2SO_4), and expanders are combined in mixers on the second floor to produce positive and negative pastes. One employee is responsible for this operation. The paste is then automatically applied, filling and coating each grid. There are four pasting lines with one operator per line. The grids then proceed through a flash oven for drying and then through a transfer point onto the parting line. This operation separates each grid into two plates. The plates are manually loaded onto carts at an operation called off-bearing. Two employees work at off-bearing on each of the four lines. Subsequently, plates are transferred to the cast-on-strap (COS) department.

Cast-on-strap - An operator (one for each of the five COS lines) loads the grids and items called separators onto a machine which automatically wraps each grid with a separator and seals the sides of the separator, forming an envelope. Subsequently the plate-envelope units are combined into groups (or books) consisting of six positive and six negative plates. An employee called a loader or sticker then manually loads the books into the COS machine, which automatically dips the lugs (an extension on each plate) into flux and then molds a lead-antimony strap onto the lugs of each book. The straps for a battery are identical except that the strap on each end has a small projecting cone which eventually forms the inner component of the battery post. This operation is called strap casting. The antimonial lead which forms the straps is heated to 850° F. Subsequently, an employee called a sinker manually loads the books into a polypropylene container. The container forms the bottom, sides, and individual cells of a battery. The number of books per container depends on the type of battery being produced. Next, an employee called the HV assembler insures that the straps are aligned properly. The units are automatically tested for tensile strength, welded with an HV welder, then tested for continuity. The HV assembler is responsible for monitoring the test and weld operations. Next, an employee applies hot glue to the straps, and then the battery proceeds to the cover operation, where a polypropylene cover and the top of the polypropylene container are heated and subsequently stuck together. The batteries are pressure checked, stacked on pallets, and eventually transferred to the developing and boosting (D & B) department.

D & B Department - Initially the batteries go through one of two post burning lines. Molten antimonial lead is dipped from a lead pot using a small ladle. The molten lead is poured into the top of each battery post. The projecting cone forms a seal with the post bushing of the battery cover. The addition of the molten lead fills in and completes the battery post. Next, batteries are automatically submerged into a tank of forming acid (sulfuric acid). The batteries are manually capped and then conveyed through a series of tunnels while a current is applied. After 12 hours the batteries are automatically emptied and subsequently submerged in a tank containing booster acid (also H_2SO_4). The batteries are then capped again, washed, and forwarded to storage or shipping.

B. Exposure Controls, Engineering and Personal Protective Equipment

The plant has an extensive engineering control system to the extent that most of the anticipated emission points are equipped with local exhaust ventilation and are enclosed. Other engineering controls include clear plexiglass or safety glass shields over emission points such as post burn and plate parting . Vacuum cleaners with high efficiency filters are located at the entrance to the locker/bathrooms, and powered floor sweepers are used.

The plant provides the employees with protective equipment including hard hats, safety glasses, safety shoes, work clothes, and half-face cartridge respirators. The respiratory protection program includes (a) quantitative fit testing (QNFT) of all employees who wear respirators, (b) various sizes and brands of respirators, (c) machine or mechanical cleaning of respirators, and (d) a separate storage compartment for each individual's respirators. QNFT facilities, respirator and filter media storage, as well as the cleaning and maintenance areas, are located in a central room. Two people (one per shift) have full-time responsibility for the cleaning, maintenance, and storage of respirators and fit testing of employees. The respirator technicians are under the supervision of the plant industrial hygienist.

In addition to the medical removal requirements of the Michigan Department of Labor's lead standard, company policy requires any employee with a blood lead level of 40 ug/dl or more, or a ZPP level of 100 ug/dl or more, to use a respirator for the entire shift (except in offices, locker rooms, and the cafeteria). This requirement is in addition to any respirator use legally required as a result of elevated air lead levels.

At the beginning of each workshift, a clean respirator is given to every worker requiring respiratory protection. At the end of the shift, the worker returns the used respirator for inspection, maintenance, and cleaning. Also, at this time, the high efficiency particulate (HEPA) filter cartridges are removed from the respirator, their pressure drops are measured, and they are vacuum cleaned to remove loose particulates. In this way, HEPA filter media are re-used for up to one year's service life.

All plant employees use one central plant entrance. They are provided with a change of clothing each day. They enter the clean area of the locker room, change into work clothes, and then enter the production area of the plant. At the end of the shift employees vacuum their clothing at the entrance to the locker room, enter the dirty area of the locker room, remove their work clothes, and throw the clothing through small wall openings into containers located in a small enclosed storage room. A shower is located between the clean and dirty areas of the locker room. Additionally, employees must walk through the locker area when going from the plant to the cafeteria.

IV. METHODS

A. Environmental

1. Lead

We reviewed (a) the company's air lead monitoring data for the year (October 1982 - September 1983) preceding our initial visit, and (b) results of personal air lead samples collected by the Michigan Department of Labor during surveys in 1977/78, 1979, and 1982. The company routinely samples primary jobs every three months. Sampling and analytical techniques appeared to be consistent with currently accepted methods. The union is involved in selecting employees to be sampled, the actual sampling is done by bargaining unit employees (under the supervision of the company's industrial hygienist), and all employees receive their air sampling results. Thus, there did not seem to be a need for NIOSH to collect additional air samples for lead.

2. Arsenic and Antimony

Although company air sampling had detected particulate arsenic in 59 (31%) of 190 personal samples from various locations in the plant, there had been no air sampling for arsine. (Concentrations of arsine greater than 20 ug/m^3 have been measured at other lead battery plants, even in areas where particulate arsenic levels were less than 1 ug/m^3.)[1,2] Additionally, one Material Safety Data Sheet (MSDS), reported by the company to be a generic MSDS for several of its plants, listed the arsenic content as ranging from 0 to 21%. Thus, even though the lead used at the plant reportedly contained less than 0.05% arsenic, air sampling for both particulate arsenic and arsine seemed warranted.

Airborne arsenic species were collected using a sampling train consisting of a sodium carbonate-impregnated filter followed in line by a charcoal tube. The sampling train was connected to a portable battery-operated pump. For the first day of sampling, the pumps were calibrated at one liter per minute (Lpm). On subsequent days, because of concern about the strain of a high pressure drop, the flow rates were reduced to as low as 0.5 Lpm. The calibration was checked at mid-shift and/or post-shift. If flow rates deviated by more than 0.05 Lpm, the volume calculations were modified. If flow rates deviated by more than 0.2 Lpm, the sample was voided.

The filters were analyzed by graphite furnace atomic absorption spectroscopy according to NIOSH method 346.[3] The charcoal tubes were analyzed by graphite furnace atomic absorption spectroscopy according to NIOSH method 265.[4] The sampling train enabled us to have the samples analyzed for antimony species (particulate antimony and stibine) as well as arsenic species.

3. Sulfuric Acid

Airborne samples for sulfuric acid were collected on silica gel tubes attached to battery-operated pumps calibrated at approximately 0.1 Lpm. The tubes were analyzed by ion chromatography; NIOSH method 339 was used for preparing the samples.[3]

B. Medical

1. Lead

At our request, the company provided a computer tape of the plant's blood lead and ZPP test results for 1982 and 1983. (ZPP concentration is determined by the plant nurse using a direct reading hematofluorometer. Blood is analyzed for lead by a commercial laboratory approved by the Occupational Safety and Health Administration pursuant to the standard for occupational lead exposure.[5]) We analyzed these data for temporal trends in blood lead and ZPP concentrations, for relationships between these variables and indicators of exposure (department, job), and for the relationship between lead and ZPP. We also evaluated the test results of individual workers who appeared to have a discrepancy between the results of their most recent blood lead and ZPP tests. In cases where the apparent discrepancy was still present at the time of our April 1984 survey, we interviewed those workers to determine possible causes, including whether there might be a non-occupational etiology of the elevated ZPP.

2. Arsenic

From each worker who had an arsenic air sample, we collected a urine specimen at the end of the shift; if the worker had air samples on more than one day, we collected a urine sample each day. Participants were given collection bottles and produced the urine specimens after they had changed out of their work clothes and showered. The urine was transferred to a 125 ml plastic bottle containing 5N ammonium chloride and refrigerated in an ice chest.

Six arbitrarily selected urine specimens were used to provide duplicate samples; each was sent to the laboratory with a different specimen identification number so that the laboratory knew neither how many nor which specimens were duplicates. Each urine sample was digested with nitric, perchloric, and sulfuric acids and analyzed for total arsenic content by atomic absorption spectrophotometry utilizing hydride generation (NIOSH method 139).[6] The urine was also analyzed for creatinine utilyzing the Jaffe reaction[7] on a GEMSAEC centrifugal analyzer, and the urine arsenic content was expressed as micrograms (ug) arsenic per gram (g) creatinine.

To each person who agreed to provide a urine specimen, we administered a questionnaire to determine recent non-occupational sources of potential arsenic exposure, current occupational information, and current respirator use. To each person who provided a urine specimen on subsequent days, we administered a brief questionnaire each day to update the information on the initial questionnaire.

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 may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy).

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the evaluation 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 (TLV's), and 3) the U.S. Department of Labor (OSHA) occupational health standards. The OSHA standards may be required to take into account the feasibility of controlling exposures in various industries where the agents are used, whereas the NIOSH recommended standards are based primarily on concerns relating to the prevention of occupational disease. In reviewing the exposure levels and the recommendations for reducing those levels found in this report, it should be noted that industry is required by the Occupational Safety and Health Act of 1970 to meet those levels specified by OSHA standards.

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. Inorganic Lead[8-11]

The general public is exposed to small amounts of lead in air, food and water.[12] Occupational exposure occurs primarily by inhalation, and to a lesser extent by ingestion (contamination of hands, food, and smoking materials). The OSHA standard for inorganic lead limits exposure to an eight-hour TWA of 50 micrograms per cubic meter of air (ug/m^3).[5]

Lead accumulates in the body, primarily in the bones, and is excreted slowly. Inorganic lead poisoning is a chronic process, although symptoms may develop suddenly after sufficient exposure. Manifestations of inorganic lead toxicity in adults include decreased appetite, weight loss, nausea, constipation, and abdominal cramps; fatigue, insomnia, memory impairment, and irritability; headache, muscle pain, and joint pain; pallor; anemia; impaired kidney function; increased blood pressure;[13,14] and impaired nerve function, resulting in muscle weakness, notably in the muscles that extend the wrists and ankles. It has long been known that women exposed to high lead levels have an increased risk of miscarriage and stillbirth. There is some evidence that lead can impair fertility in occupationally exposed men.[15]

The blood lead test is one measure of the amount of lead in the body and is the best available measure of recent lead absorption. Adults not exposed to lead at work usually have a blood lead concentration less than 30 ug/dl; the average is less than 15 ug/dl.[16,17] Blood lead levels higher than 30 ug/dl have harmful effects on the mental development of young children. The Centers for Disease Control (CDC) now considers a blood lead concentration of 25 ug/dl or more in a young child to be "elevated".[12] Since the blood lead concentration of a fetus is similar to that of its mother, and since the fetus's brain is presumed to be at least as sensitive to the effects of lead as a child's, the CDC advises that a pregnant woman's blood lead be below 25 ug/dl.[12] For purposes of compliance with the OSHA lead standard, a blood lead concentration averaging 50 ug/dl or more represents excessive lead exposure, and the affected employee must be removed from further lead exposure until the blood lead concentration is below 40 ug/dl. (The standard protects the earnings, seniority, and other benefits of employees who, because of excessive lead absorption, are removed from jobs involving lead exposure.) A World Health Organization (WHO) study group recommended (in 1980) that blood lead concentrations not exceed 30 ug/dl in occupationally exposed women of childbearing age and not exceed 40 ug/dl in other workers.[18]

One of the earliest adverse health effects of lead is interference with the production of hemoglobin, the oxygen-carrying molecule in red blood cells. One of the steps in hemoglobin synthesis that is blocked by lead causes zinc protoporphyrin to accumulate in red blood cells before they are released from the bone marrow (where they are made) into the blood. Although one of lead's effects is a shortening of the lifespan of red blood cells, they normally last about 120 days in the blood. Therefore, red blood cells containing elevated amounts of ZPP can still be circulating three to four months after lead has exerted its adverse effects in them. Initially after lead exposure begins, affected red blood cells will be in the minority, but with continued lead exposure the proportion of red blood cells with increased amounts of ZPP increases. Therefore, blood lead and ZPP levels will not rise and fall at the same time or rate.[19] Furthermore, people who have been exposed to different levels of lead for different periods of time may have different "body burdens" of lead stored in their bones and other tissues; this can affect their ZPP levels.[20,21] Finally, certain medical conditions can affect protoporphyrin metabolism; iron deficiency is the most common cause of an elevated ZPP in people without occupational lead exposure.

The blood lead level at which ZPP becomes elevated varies from person to person. At a blood lead level of 35-40 ug/dl about half of adult males will have an elevated ZPP, and at a blood lead level of 25-30 ug/dl about half of adult women will have an elevated ZPP.[18]

The OSHA lead standard requires exposed workers to have periodic ZPP determinations, but it specifies no level at which any action should be taken. The previously mentioned WHO study group recognized that in countries where blood lead monitoring is impractical, it may be necessary to use ZPP to assess lead exposure. The group recommended that if ZPP is used for this purpose, a worker's ZPP should not exceed the upper limit of the laboratory's "normal" range by more than 50%.

C. Inorganic Arsenic[22,23] and Arsine[24]

Inorganic arsenic can cause a variety of adverse health effects, depending on the amount, duration, and route of exposure. Some arsenic compounds, including arsenic trioxide (which is formed by the heating of arsenic-containing materials in the presence of air), irritate the eyes, nose, throat, lungs, and skin. Dermatitis and other skin lesions can occur as a result of direct contact with arsenic compounds or as a result of inhalation or ingestion.

Gastrointestinal effects, neuropathy (impaired nerve function), liver damage, blood vessel disease, and anemia have generally been associated with acute or chronic ingestion of arsenic, rather than with chronic inhalation (the more typical route of exposure in industrial settings). Occupational arsenic exposure is associated with an increased risk of lung cancer and skin cancer; angiosarcoma of the liver (a rare type of cancer) has been associated with ingestion of arsenic.

Arsine is generated by hydrogen reacting with arsenic or by hydrolysis of metallic arsenides. Acute arsine exposure causes hemolysis (destruction) of circulating red blood cells; symptoms of arsine poisoning include dark urine, nausea, and abdominal cramps. Little is known about the effects of chronic arsine exposure.

Arsenic is present in varying, usually small, amounts in soil and water. Seafood contains relatively large amounts of organic arsenic compounds, which do not have the toxicity of either inorganic arsenic or the organic arsenic compounds used as pesticides. People unexposed to arsenic at work, and who have not recently eaten seafood, have urine arsenic concentrations of less than 100 ug/g creatinine.[25] Data from most published studies have suggested that people without unusual exposure to arsenic have urine arsenic concentrations of less than 50 ug/liter (ug/L).[23] Even when standardized to a common specific gravity (1.018 or 1.024, for example), ug/L is not directly convertible to ug/g creatinine, but 50 ug/L would generally be closer to 50 than to 100 ug/g creatinine.

NIOSH recommends that occupational exposure to inorganic arsenic, including arsine, not exceed 2 ug/m^3 for any 15-minute period.[26] The OSHA standard for arsenic is an 8-hour TWA of 10 ug/m^3;[27] for arsine it is an 8-hour TWA of 200 ug/m^3 (0.05 ppm).[28]

D. Inorganic Antimony and Stibine [29,30]

Antimony irritates the eyes, nose, and throat. Symptoms of excessive exposure include nasal congestion, skin rash, respiratory symptoms, headache, dizziness, sleeplessness, loss of appetite, nausea, and vomiting. Effects on the heart have also been reported. Stibine, which is formed by the reaction of antimony with acid, has health effects similar to those of arsine. NIOSH recommends that occupational exposure to antimony and its compounds (excluding stibine) not exceed a full-shift (up to 10 hours) TWA of 500 ug/m^3.[31] The OSHA standards for both antimony and stibine are 8-hour TWA's of 500 ug/m^3.[28]

E. Sulfuric Acid[30,32]

Sulfuric acid is a strong tissue irritant; contact with it can result in severe chemical burns. Inhalation of its vapor can cause nose and throat irritation, cough, bronchitis, pulmonary edemea (accumulation of fluid in the lungs), and bleeding from the nose, lungs, and stomach. It also erodes the teeth. NIOSH recommends that occupational exposure to sulfuric acid not exceed an 8-hour TWA of 1 milligram per cubic meter of air (mg/m^3).[33] The OSHA standard is also 1 mg/m^3.[28]

VI. RESULTS AND DISCUSSION

A. ENVIRONMENTAL

1. Lead

Analysis of the company's air lead data for the previous year revealed that 98% of the sample results were below 100 ug/m^3, and 92% were below 50 ug/m^3 (Table 1). Although the majority of sample results were below the corresponding OSHA permissible exposure limit (PEL), certain departments had a high percentage of values exceeding 50 ug/m^3. Twenty-six (46%) of the 57 samples whose air lead values were above 50 ug/m^3 were from four departments, oxide mill, janitorial, maintenance, and inspectors, yet only 24% of the 675 samples were collected in these four departments. Furthermore, the four departments had 10 (67%) of the 15 values exceeding 100 ug/m^3 and four of the five highest mean departmental values (oxide mill - 173 ug/m^3, janitorial - 54, maintenance - 30, inspectors - 50) (Table 2). Pasting had the other high mean, 31 ug/m^3.

Results of personal air lead samples collected by the Michigan Department of Labor from 1977 to 1983 are summarized in Table 3. These data indicate that airborne lead values have been decreasing, and the data for 1982 are similar to those reported by the company (Table 1).

2. Arsenic and Antimony

Results of sampling for airborne arsenic and antimony species are presented in Table 4. Of 49 personal and 17 area samples analyzed, arsine and/or particulate arsenic was detected in 10 (20%) personal and 1 (6%) area sample. All of these were in the post burn and battery forming areas. Five personal samples collected in the post burn area had arsenic air concentrations ranging from 0.21 to 3.3 ug/m^3. Five personal samples, collected in the battery forming area, had arsine air concentrations ranging from 0.21 to 0.34 ug/m^3. None of the workers from whom these ten samples were collected was wearing a respirator. One area sample collected on the battery forming loading platform had an air concentration of 0.34 ug/m^3.

One of the personal sample results exceeded the NIOSH recommended standard of 2 ug/m^3 for elemental arsenic and all of its inorganic compounds. All sample results were under the OSHA PEL's of 10 ug/m^3 for arsenic and 200 ug/m^3 for arsine.

Concentrations for antimony ranged from less than 0.23 to 4.6 ug/m^3, and for stibine from less than 0.04 to 0.54 ug/m^3. These values are well below all current environmental criteria (500 ug/m^3 - OSHA and NIOSH). The arsenic species and antimony species were collected and analyzed using the same techniques. These were developed for arsenic species and have not been validated for antimony species. Thus, the values reported for antimony species should be considered estimates.

3. Sulfuric Acid

No sulfuric acid was detected in any of the 10 samples collected (Table 5). The laboratory limit of detection was 8 ug/sample, so the sulfuric acid concentration in all samples was less than 0.10 mg/m^3. As a comparison, the OSHA PEL is 1 mg/m^3.

4. Respiratory Protection Program

We thought that the basic elements of the respiratory protection program were sound, with quantitative fit testing, maintenance, cleaning, and provision of respirators and supplies being well-administered. QNFT was performed twice a year for each worker. For each fitted worker there were two to five respirators that were supposed to be placed in clean plastic bags, but we observed a few instances in which this was not done.

The program requires workers to perform a positive- and negative-pressure fit test each time a respirator is used. We observed that this was not always done and that supervisors were not enforcing this requirement. The program also mandated that workers who wore respirators have no facial hair. We observed several bearded employees wearing respirators.

5. Engineering Controls

The engineering controls, in general, seemed well-maintained and appeared to be functioning properly. In many locations, airflow patterns were visible due to particulates arising from specific process points, such as conveyor transfer points immediately after the ovens in pasting. In a few locations, Plexiglas shields were cracked or broken; for example, there was a damaged shield in the COS department just prior to the sticker operation on machine number 5.

One location where engineering controls did not appear very effective was the post burn area. We observed particulates escaping the partial enclosures as torches were applied to molten lead in the battery posts. Furthermore, there were visible deposits on the smocks of employees working at post burn.

6. Work Practices

We observed employees in the pasting area banging dropout trays against trash receptacles as they emptied the trays. This resulted in some material, which includes lead oxide, falling on the floor. This potentially increases lead contamination of the air, as well as the floor.

B. MEDICAL

1. Lead

The computer file supplied by the company contained results of 3045 blood lead determinations (most of which have a corresponding ZPP determination) from 374 workers, 345 of whom had at least one blood lead/ZPP determination in each of 1982 and 1983. The file contained blood lead/ZPP data from January 1982 through December 5, 1983; there were no ZPP results for November or December 1982. Some of the analyses below refer to "first" and "last" blood leads; these are, respectively, an individual's first blood lead/ZPP determination (in 1982 in all cases) and his or her most recent blood lead/ZPP determination (in 1983 in all cases).

Using each worker's last blood lead/ZPP, we identified 16 people whose blood lead levels were less than 40 ug/dl and whose ZPP's were 100 ug/dl or more. By March 1984, the time of the most recent blood lead/ZPP results available during our April 1984 survey, the lead and ZPP results had become "consistent" in six cases; that is, the blood lead had risen above 40 ug/dl or the ZPP had fallen below 100 ug/dl. In two other cases, the apparent lead/ZPP discrepancy was minimal and due to the arbitrary cut-offs of 100 and 40 ug/dl (e.g. a ZPP of 105 with a lead of 39). We interviewed the remaining eight workers. Two had a history of relatively high blood leads (multiple instances of blood lead greater than 40 ug/dl during the previous 12 months), and their ZPP's were decreasing as their blood leads remained below 40 in more recent months. In three other cases the ZPP's seemed high in comparison to other workers at the plant who had similar blood lead levels. The ZPP responses of these three workers followed their blood lead levels, however, and were within the range of ZPP values documented in other studies for workers with similar blood lead levels.[34,35] Therefore, in 13 of the 16 cases we thought that there was probably no medical discrepancy between the blood lead and ZPP levels. [An elevated ZPP, however, as discussed later in Section VII, may be an indicator of adverse health effects of lead.] In the three remaining cases we thought, based on our interviews, that there might be medical conditions (unrelated to occupational lead exposure) contributing to persistently elevated ZPP levels.

Forty-six (12%) of 371 last blood determinations were ≥40 ug/dl. The sensitivity* of ZPP as an indicator of elevated blood lead (using 100 and 40 ug/dl, respectively, as cut-off values) was 41%, and the specificity* was 95% (Figure 1). For this set of data, then, the predictive value* of ZPP <100 for estimating blood lead <40 was 92%, but the predictive value of ZPP ≥100 for estimating blood lead ≥40 was only 54%. The predictive value of an elevated ZPP using higher cut-offs was only slightly better for indicating a blood lead of 40 ug/dl or more; ZPP cut-offs of 125 and 150 ug/dl yielded predictive values of 68% and 64%, respectively.

The mean first and last blood lead levels were both 28 ug/dl, 29 if only production area employees are considered. Mean ZPP increased from 49 to 55 ug/dl, a statistically significant (n = 335, s.d. = 29, t = 3.74, p = 0.0002) but physiologically inconsequential amount. If only production area employees are considered, mean ZPP increased from 49 to 53 (n = 321, s.d. = 29, t = 2.79, p = 0.006). Based on each employee's last blood lead, all departments had a mean blood lead of less than 40 ug/dl. Nine departments had means in the 30-39 range (Table 4). Because the "departments" used in this analysis were administrative categories that did not always correspond to a specific area of the plant, or were not inclusive of everyone in the area, we reanalyzed the data according to actual location (as determined by job codes) rather than by department. For example, the department code for pasting includes mixers, pasters and parters (30 workers altogether), but not janitors, inspectors, truck drivers, set-up persons, or supervisors assigned to pasting (an additional 12 workers). This reanalysis yielded no difference in mean blood lead of more than 2 ug/dl (Table 8).

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* The sensitivity of a test is the percentage of times that the condition of interest (in this case, blood lead ≥40 ug/dl) is identified by a "positive" test (in this case, ZPP ≥100 ug/dl). The specificity of a test is the percentage of times that the absence of that condition is identified by a "negative" test. The predictive value of a negative test is the percentage of negative tests that correspond to the absence of the condition. The predictive value of a positive test is the percentage of positive tests that correspond to the presence of the condition. Predictive values of a test are dependent on the prevalence of the condition of interest.

Within departments, differences in mean blood lead levels between different job codes were generally either relatively small or consistent with differences in exposure (Table 8). Three notable exceptions were (a) millwrights, whose mean blood lead was substantially higher than the mean of other maintenance department workers and who had a significantly higher prevalence of ZPP > 100 ug/dl [6 (55%) of 11] than other workers [29 (8%) of 360] (X^2 = 21.8, $p < 0.001$); (b) the janitors in pasting, whose mean blood lead was substantially lower than both the mean of other janitors and the mean of other pasting area workers; and (c) COS set-up workers, whose mean blood lead level was higher than the means of other COS area jobs. Interestingly, although supervisors in COS and D & B had mean blood leads similar to the area means, those in pasting and grid casting had higher mean blood lead levels (44 and 36 ug/dl respectively) than others in their areas (32 and 25 ug/dl, respectively).

Mean blood lead showed a slight downward trend from January 1982 to November 1983 (the last full month in the data set), with a definite peak in November 1982 and a lesser peak in May 1983 (Figure 2). Although mean ZPP's were slightly higher in the latter months of 1983 than in the early months of 1982, they were more notably higher between September 1982 and August 1983. There were no data for November and December 1982 and no ZPP peak early in 1983 that would correspond to the November 1982 blood lead peak. Analysis of monthly mean blood lead by department showed that most exhibited the November 1982 (plus or minus one month) peak period. Some exhibited the May 1983 peak, which was typically not as pronounced as the November 1982 peak. No other noteworthy peaks were apparent in 1983, but because some departments had few employees tested in some months, departmental temporal trends tended to appear more erratic than the plant-wide temporal trend. This was also true for mean ZPP's, where there were no apparent temporal patterns except for a suggestion, based on relatively few employees, of the peak in May-June 1983 in a few departments.

As found in other studies,[35-41] ZPP was exponentially related to blood lead. Using the most recent test results from each worker, a blood lead of 30 corresponded to a ZPP of 44 for men (Figure 3) and 70 for women (Figure 4), and a blood lead of 40 corresponded to a ZPP of 57 for men and 96 for women. (Regression analysis showed the ZPP/lead curves for men and women to be significantly different.)

2. Arsenic

Thirty of the thirty-one persons on whom arsenic air samples were obtained submitted a urine specimen each day an air sample was taken. Fifteen were sampled only one day, six on two days and nine on three days. Results of five of the six pairs of split samples were in close agreement, differing by 4 ug/g creatinine or less. In the sixth case, there was a marked disagreement, 52 ug/g creatinine vs none detected, but this was apparently due to the imprecision of the analytical method at the relatively low concentration of arsenic (15 and <5 ug/L) in the relatively dilute urine specimen (0.29 and 0.33 g creatinine/L).

Urine arsenic concentrations ranged from non-detectable to 52 ug/g creatinine, with a median of 7 ug/g creatinine. (For this and other calculations involving split samples, we used the average of a pair of results, counting a non-detectable as 0.) Only four (7%) of the 54 specimens exceeded 20 ug/g creatinine. The highest urine arsenic concentration, 52 ug/g creatinine (not the worker with the split sample noted above), was in a parter who was sampled only one day. He had no detectable airborne arsenic exposure. [He had eaten fish (unknown type from a package of frozen fish) the day before.] The next highest urine arsenic concentration, in a D & B loader sampled only one day, was 33 ug/g creatinine. He, too, had no detectable airborne arsenic exposure. Averaging the results of the multiple specimens from each worker who had them, the median concentration for the 30 participants was 8 ug/g creatinine; three (10%) exceeded 20 ug/g creatinine.

VII. CONCLUSIONS

A. Lead

The available air lead data indicate that maintenance and janitorial personnel have had the greatest potential for excessive lead exposure. Overall, though, exposures to lead and arsenic were less than those measured by NIOSH at other lead battery plants. In a report of studies at five plants, lead exposures averaged 72 ug/m^3 (standard deviation 110), arsine 42 ug/m^3, and particulate arsenic 0.83 ug/m^3.[1] A study at another plant found an average lead concentration of 90 ug/m^3 (standard deviation 100) among 3442 samples and an average arsenic concentration of 0.75 ug/m^3.[42] In a later study at the same plant, mean particulate arsenic and arsine concentrations among 179 samples were 0.3 ug/m^3 (standard deviation 0.85) and 6.6 ug/m^3 (standard deviation 8.6), respectively.[43]

Our review of company data revealed no pattern of substantial discrepancies between workers' blood lead and ZPP results. Although an elevated blood ZPP not accompanied by anemia probably does not, in itself, constitute an adverse health effect, there is some evidence that an elevated ZPP might be an indicator of the non-hematological adverse health effects of lead. For example, altered red blood cell protoporphyrin metabolism might mean that nervous system protoporphyrin metabolism is also affected.[44] A study of workers with episodic lead exposure, most of whom had blood lead concentrations of less than 30 ug/dl, found an association between the presence of central nervous system and/or gastrointestinal symptoms and ZPP levels, and the absence of an association between symptoms and blood lead levels.[45] Another study,[46] of secondary lead smelter workers, 82% of whom had blood lead concentrations in the 40-80 ug/dl range, found impaired performance on neurobehavioral tests to be more highly correlated with ZPP than with blood lead. This association was seen in workers both with and without central nervous system symptoms. Furthermore, it occurred even though ZPP, unlike blood lead, was not associated with the current job's estimated relative level of lead exposure.

On the basis of our current, incomplete understanding of the health implications of chronic, relatively low lead exposure, it seems to be a reasonable health protection measure to take action to reduce lead exposure solely on the basis of an otherwise unexplained, persistently elevated ZPP. As in other circumstances that indicate a need to reduce exposure, engineering methods are preferable to personal protective equipment to achieve the reduction. Personal protective equipment should be used only as (a) an interim control measure while engineering changes are being implemented; (b) a control measure for episodic, non-routine exposures; (c) a control measure for routine short-term exposures where engineering controls are not feasible; and (d) an additional measure to further reduce exposures that are already controlled, by other means, to a level that meets current occupational health standards.

Individuals with similar lead exposures, and even similar blood lead concentrations, may have different ZPP levels. Therefore, a policy to keep ZPP levels below a specified concentration might result in corrective measures (such as use of a respirator) applied to some workers, but not others with similar exposures. Even though this might appear inconsistent to someone observing only the result of the policy, it does not necessarily mean that the policy is medically illogical or inconsistently applied.

B. Arsenic

Except for one elevated air arsenic concentration in a post burn worker, neither the air sampling nor urine analyses suggested excessive exposure to inorganic arsenic. The air sampling data does, however, document the potential for arsenic exposure in the post burn area and for arsine exposure in the battery forming area.

C. Sulfuric Acid, Inorganic Antimony, and Stibine

This study found no measurable exposure to sulfuric acid, and all air concentrations of stibine and other inorganic antimony compounds were well within currently accepted occupational exposure limits.

VIII. RECOMMENDATIONS

A. Environmental

1. The post burn area should be evaluated to determine techniques to reduce the escape of particulates and/or gases during post burning.
2. Employees in the pasting area should be instructed to empty dropout trays without hitting the trays against the trash container being used.
3. Use of vacuum cleaners by employees entering the locker area should be emphasized, as most employees spent little, if any, time using the cleaners.
4. Modifications should be made to improve the overall respirator program, including providing supervisors with special training on respirators and special instructions about following the written program. Respirator use and wear rules must be uniformly enforced, specifically:
    a. Employees who are wearing respirators should not have facial hair that interferes with the respirator seal.[47-49] The lack of an adequate seal between a respirator and the employee's face due to facial hair has been documented for both negative- and positive-pressure respirators.[50-56]

    b. Employees should perform positive and negative fit tests each time they don respirators.

c. Both respirator straps should be used.

d. All respirators in storage should be in clean plastic bags.

e. Although the service life of the HEPA filter media can be increased by vacuuming, this may damage the filter, resulting in increased worker exposure. Therefore, this should not be done.

5. The environmental monitoring program should be modified to (a) better assess lead exposure among maintenance and janitorial personnel, and (b) periodically assess arsenic exposure in the post burn area and arsine exposure in the battery forming area.

6. Material Safety Data Sheets should be revised such that percentages of constituents are accurately reported.

B. Medical

1. The company should continue to take measures to keep employees' blood lead levels below 40 ug/dl. Ideally, the blood lead level of women who are, or might become, pregnant should be maintained below 25 ug/dl.

2. We have no data from which to determine whether the company's current ZPP action level of 100 ug/dl, in conjunction with a blood lead action level of 40 ug/dl, is adequate to prevent all of the chronic health effects of lead. Therefore, at this time, we have no basis for recommending any change in this ZPP action level.

3. An employee with a persistent, substantial elevation of ZPP (for example, greater than 100 ug/dl), despite blood lead levels consistently below 40 ug/dl, should have a medical evaluation to determine (a) whether there are any symptoms or other indications of lead toxicity, and (b) whether there is some other explanation (for example, iron deficiency) for the elevated ZPP.

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X. AUTHORSHIP AND ACKNOWLEDGEMENTS

Report Prepared by:	Mitchell Singal, M.D., M.P.H. Assistant Chief Medical Section
	John N. Zey, M.S. Industrial Hygienist Industrial Hygiene Section
	Sara J. Arnold, M.D. Medical Officer Medical Section
Originating Office:	Hazard Evaluations and Technical Assistance Branch Division of Surveillance, Hazard Evaluations, and Field Studies
Technical Assistance:	Laurence D. Reed Industrial Hygiene Engineer
	Raymond L. Ruhe Industrial Hygienist Industrial Hygiene Section Hazard Evaluations and Technical Assistance Branch Division of Surveillance, Hazard Evaluations and Field Studies
	Warren R. Meyers Chief Quality Assurance Section Testing and Certification Branch Division of Safety Research

G. Robert Schutte
Chief
Medical Services Section

Dorothy B. Lowe
Statistician
Statistical Services Section
Support Services Branch
Division of Surveillane, Hazard
Evaluations and Field Studies

Acknowledgment: Irving Davis and staff
Division of Occupational Health
Michigan Department of Labor

Report Typed By: Toni Frey

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1. United Automobile Workers International Union
2. Johnson Controls, Inc.
3. NIOSH, Region V
4. OSHA, Region V
5. Michigan Department of Labor

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.

TABLE 1

Summary of Results of Company-Collected Air Lead Samples
October 1982 - September 1983

Johnson Controls, Inc.
Battery Division
Owosso, Michigan

HETA 84-041

Department/number code	No. of Samples	Sample Concentrations No. Samples >30 ug/m^3	No. Samples >50 ug/m^3	No. Samples >100 ug/m^3	No. Samples >250 ug/m^3	No. Samples >500 ug/m^3
Grid casting/11	72	1	0	0	0	0
Pasting/13	104	37	14	0	0	0
COS/14, COS weld/16	184	29	10	2	0	0
D & B/15,18	74	14	4	3	2	1
Oxide mill/12	19	6	5	2	2	2
Janitorial/19	29	14	8	4	0	0
Maintenance/20	73	10	6	3	1	1
Inspectors/23	39	11	7	1	1	1
Store room attendant/27, respirator sanitizer/30, plant-wide utility/31, general labor/32, shipping-receiving/78	8	2	0	0	0	0
Truck-drivers/40	15	0	0	0	0	0
Set-up/41	34	10	3	0	0	0
Supervisors/55	24	1	0	0	0	0
Total	675	135	57	15	6	5
Percentage of total samples	100%	20%	8%	2%	1%	1%

TABLE 2
Statistical Summary of Air Lead Data
October 1982 - September 1983

Johnson Controls, Inc.
Battery Division
Owosso, Michigan

HETA 84-041

Department/code	No. of Samples	Range ($\mu g/m^3$)	Mean ($\mu g/m^3$)	Standard Deviation
Grid casting/11	72	2 - 49	11	7
Pasting/13	104	5 - 99	31	19
COS/14	145	1 - 100	22	19
D & B/15,18	74	1 - 520	24	76
COS weld/16	39	3 - 220	26	35
Oxide mill/17	19	10 - 1600	173	438
Janitorial/19	29	1 - 219	54	63
Maintenance/20	73	1 - 660	30	82
Inspectors/23	39	2 - 1100	50	174
Store room attendant/27, respirator sanitizer/30, plant-wide utility/31, general labor/32, shipping-receiving/78	8	3 - 38	13	11
Truck drivers/40	15	6 - 27	14	7
Set-up/41	34	4 - 88	25	18
Supervisors/55	24	2 - 44	13	11
Total	675	1 - 1600	30	96

TABLE 3

Summary of Michigan Deparment of Labor Air Lead Data

1977 - 1982

Johnson Controls, Inc.
Battery Division
Owosso, Michigan

HETA 84-041

Date	Number of Samples	Range (ug/m^3)	Mean(ug/m^3)	Standard Deviation
August 1977* and January 1978	89	3 - 1700	82	181
January 1979	30	30 - 280	99	56
September - October 1982	16	9 - 180	51	43

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* - Production in pasting department significantly curtailed in August 1977 due to production schedules.

TABLE 4

Air Concentrations for Arsine and Antimony Species

Johnson Controls, Inc., Battery Division
Owosso, Michigan

HETA 84-041

April 3-5, 1984

Job/Location	Date	Sample Time	Volume (liters)	Type	Airborne Concentration (ug/m³) Arsine	Arsenic	Stibine	Antimony
Wirtz casting operator Machines no. 1, 2, 3	4-3	822-1337	284	P	ND(<0.28)	ND(<0.35)	ND(<0.07)	1.4
Wirtz casting operator Machines no. 1, 2, 3	4-4	820-1456	297	P	ND(<0.27)	ND(<0.34)	ND(<0.07)	2.0
Wirtz casting operator Machines no. 1, 2, 3	4-5	806-1512	320	P	ND(<0.25)	ND(<0.31)	ND(<0.06)	1.9
Wirtz casting operator Machines no. 10, 11, 12	4-3	823-1511	395	P	ND(<0.20)	ND(<0.25)	ND(<0.05)	ND(<0.51)
Wirtz casting operator Machines no. 10, 11, 12	4-4	832-1502	293	P	ND(<0.27)	ND(<0.34)	ND(<0.07)	ND(<0.34)
Wirtz casting operator Machines no. 10, 11, 12	4-5	812-1514	317	P	ND(<0.25)	ND(<0.32)	ND(<0.06)	ND(<0.32)
Wirtz casting operator Machines no. 19, 20, 21	4-3	829-1452	383	P	ND(<0.21)	ND(<0.26)	0.13	ND(<0.52)
Wirtz casting operator Machines no. 19, 20, 21	4-4	822-1502	300	P	ND(<0.27)	ND(<0.33)	ND(<0.07)	ND(<0.67)
Wirtz casting operator Machines no. 19, 20, 21	4-5	809-1509	315	P	ND(<0.25)	ND(<0.32)	ND(<0.06)	ND(<0.32)

Table 4 (Continued)

Wirtz casting operator Machines no. 31, 32, 33	4-4	827-1510	302	P	ND(<0.26)	ND(<0.33)	ND(<0.07)	4.6
Wirtz casting operator Machines no. 31, 32, 33	4-5	814-1510	312	P	ND(<0.26)	ND(<0.32)	ND(<0.06)	ND(<0.32)
Pasting machine operator Line no. 1	4-3	710-1355	465	P	ND(<0.17)	ND(<0.22)	ND(<0.04)	ND(<0.43)
Pasting machine operator Line no. 1	4-4	554-1437	392	P	ND(<0.20)	ND(<0.26)	ND(<0.05)	ND(<0.51)
Pasting machine operator Line no. 2	4-5	718-1455	343	P	ND(<0.23)	ND(<0.29)	ND(<0.06)	ND(<0.29)
Pasting machine operator Line no. 3	4-5	616-1454	389	P	ND(<0.21)	ND(<0.26)	ND(<0.05)	0.26
Pasting machine operator Line no. 4	4-4	710-1517	360	P	ND(<0.22)	ND(<0.27)	ND(<0.05)	ND(<0.55)
Pasting off bear Line no. 1	4-3	714-1403	409	P	ND(<0.20)	ND(<0.24)	0.07	0.49
Pasting off bear Line no. 1	4-4	558-1453	401	P	ND(<0.20)	ND(<0.25)	ND(<0.05)	ND(<0.50)
Pasting off bear Line no. 2	4-4	550-1435	394	P	ND(<0.20)	ND(<0.25)	ND(<0.05)	ND(<0.50)
Pasting off bear Line no. 2	4-5	608-1506	441	P	ND(<0.18)	ND(<0.23)	ND(<0.05)	0.23
COS, Sticker machine no. 3	4-3	825-1544	439	P	ND(<0.18)	ND(<0.23)	0.09	ND(<0.46)
COS, sticker machine no. 3	4-4	819-1542	332	P	ND(<0.24)	ND(<0.30)	ND(<0.06)	ND(<0.30)

Table 4 (Continued)

COS, sticker machine no. 5	4-3	815-1436	369	P	ND(<0.22)	ND(<0.27)	0.05	ND(<0.54)
COS, sticker machine no. 5	4-5	803-1452	307	P	ND(<0.26)	ND(<0.33)	ND(<0.07)	0.33
COS, sticker machine no. 7	4-3	820-1545	445	P	ND(<0.18)	ND(<0.22)	ND(<0.04)	ND(<0.45)
COS, sticker machine no. 4	4-4	816-1537	331	P	ND(<0.24)	ND(<0.3)	ND(<0.06)	ND(<0.30)
COS, sticker machine no. 2	4-5	809-1530	331	P	ND(<0.33)	ND(<0.3)	ND(<0.06)	0.30
COS, sticker machine no. 6	4-5	801-1546	349	P	ND(<0.23)	ND(<0.29)	ND(<0.06)	0.29
COS, reed stacker machine no. 5	4-4	809-1520	323	P	ND(<0.25)	ND(<0.31)	ND(<0.06)	ND(<0.31)
Post burn	4-3	659-1454	475	P	ND(<0.17)	0.42	ND(<0.08)	ND(<0.42)
Post burn	4-3	700-1455	475	P	ND(<0.17)	0.21	ND(<0.08)	ND(<0.42)
Post burn	4-4	645-1443	359	P	ND(<0.22)	3.3	0.08	2.8
Post burn	4-4	650-1455	364	P	ND(<0.22)	0.27	0.05	0.55
Post burn	4-4	648-1443	356	P	ND(<0.22)	1.1	0.08	1.7
Post burn relief operator	4-5	605-1502	403	P	ND(<0.20)	ND(<0.25)	0.15	0.49
Post burn	4-5	635-1503	381	P	ND(<0.21)	ND(<0.26)	0.16	0.26
Post burn, relief oper. on fork lift after lunch	4-4	712-1447	341	P	ND(<0.23)	ND(<0.29)	0.12	2.3

Table 4 (Continued)

Battery forming, gravity reader east end 45 min., rest of day at post tightening	4-3	654-1500	486	P	ND(<0.16)	ND(<0.21)	0.16	ND(<0.41)
Battery forming, gravity reader east end 45 min., rest of day at deposting	4-4	649-1443	356	P	ND(<0.22)	ND(<0.28)	0.28	ND(<0.56)
Battery forming, gravity reader east end 45 min., rest of day at capping	4-5	608-1459	398	P	0.28	ND(<0.25)	0.33	0.25
Battery forming, gravity reader west end	4-3	712-1451	459	P	ND(<0.17)	ND(<0.22)	0.28	ND(<0.44)
Battery forming, gravity reader west end	4-4	706-1452	350	P	ND(<0.23)	ND(<0.29)	0.40	0.86
Battery forming, gravity reader west end	4-5	620-1453	385	P	0.34	ND(<0.26)	0.49	0.52
Battery forming, LSC no. 1 loader	4-3	659-1504	485	P	0.27	ND(<0.21)	0.54	ND(<0.41)
Battery forming, LSC no. 1 loader	4-4	652-1443	353	P	0.31	ND(<0.28)	0.40	ND(<0.57)
Battery forming, LSC no. 2 loader	4-3	717-1450	453	P	ND(<0.18)	ND(<0.22)	0.24	ND(<0.44)
Battery forming, LSC no. 2 loader	4-4	708-1443	341	P	ND(<0.23)	ND(<0.29)	0.21	ND(<0.59)
Battery forming, LSC no. 2 loader	4-5	622-1440	374	P	0.21	ND(<0.28)	0.27	0.28
Casting, janitor	4-5	1019-1535	237	P	ND(<0.34)	ND(<0.42)	ND(<0.08)	ND(<0.42)
Grid storage, directly below clock	4-3	915-1605	410	A	ND(<0.20)	ND(<0.24)	ND(<0.05)	ND(<0.49)

Table 4 (continued)

Grid storage, directly below clock	4-4	725-1557	384	A	ND(<0.21)	ND(<0.26)	ND(<0.05)	ND(<0.52)
Grid storage, directly below clock	4-5	722-1558	361	A	ND(<0.22)	ND(<0.2)8	ND(<0.06)	ND(<0.28)
Wirtz casting area, near bank no. 1	4-3	830-1603	453	A	ND(<0.2)1	ND(<0.22)	ND(<0.05)	0.44
Wirtz casting area, near bank no. 1	4-4	722-1555	385	A	ND(<0.21)	ND(<0.26)	ND(<0.05)	0.26
Between steam chambers on loading side	4-3	906-1600	415	A	ND(<0.19)	ND(<0.24)	ND(<0.05)	ND(<0.48)
Between steam chambers on loading side	4-4	720-1553	385	A	ND(<0.21)	ND(<0.26)	ND(<0.05)	ND(<0.52)
Near posting/off bear on beam C6	4-3	830-1558	448	A	ND(<0.18)	ND(<0.22)	ND(<0.09)	0.45
Near posting/off bear on beam C6	4-4	714-1552	389	A	ND(<0.21)	ND(<0.26)	ND(<0.05)	ND(<0.51
COS on machine no. 3	4-3	834-1555	441	A	ND(<0.18)	ND(<0.23)	0.14	0.45
COS on machine no. 3	4-4	730-1552	377	A	ND(<0.21)	ND(<0.28)	ND(<0.05)	ND(<0.27)
At aisle between COS and post burn, on beam E15	4-3	855-1552	417	A	ND(<0.19)	ND(<0.24)	ND(<0.12)	ND(<0.48
At aisle between COS and post burn, on beam E15	4-4	735-1550	379	A	ND(<0.21)	ND(<0.26)	ND(<0.08)	ND(<0.53)
At aisle between COS and post burn, on beam E15	4-5	705-1608	407	A	ND(<0.20)	ND(<0.25)	ND(<0.05)	0.25
Battery forming, edge of platform at entrance of tunnel, east end	4-4	835-1548	325	A	0.34	ND(<0.31)	0.28	0.31

Table 4 (continued)

Battery forming, edge of platform at entrance of tunnel, east end	4-5	849-1610	331	A	ND(<0.24)	ND(<0.30)	0.30	0.30
Cafeteria, on beam near lunch storage	4-4	740-1600	375	A	ND(<0.21)	ND(<0.27)	ND(<0.05)	ND(<0.27)

Laboratory limit of detection (ug/sample): arsine = 0.08, arsenic = 0.1, stibine = 0.02, antimony = 0.1

ND = Not detected in this sample.

< = Less than; this indicates that specific material (e.g., arsine) was below the laboratory limit of detection on this sample and that if the material was present, the air concentration was below the value indicated. This value changes depending on the amount of air sampled.

P = Personal sample

A = Area sample

Occupational Exposure Criteria (ug/m^3):

NIOSH = 2 (15 minute ceiling) for all inorganic arsenic compounds, including arsine; 500 for all inorganic antimony compounds except stibine

OSHA = 10 for all inorganic arsenic compounds except arsine; 200 for arsine; 500 for antimony and compounds, including stibine

TABLE 5

Results of Air Sampling for Sulfuric Acid

Johnson Controls, Inc., Battery Division
Owosso, Michigan

HETA 84-041

April 3-5, 1984

Job/Location	Date	Sample Time	Volume (liters)	Sample Type	Airborne Concentration (mg/m^3)
Gravity reader	4-3	709-1506	46	P	ND(<0.17)
Acid dip, capping	4-3	659-1501	47	P	ND(<0.17)
Acid dip, capping	4-4	658-1443	45	P	ND(<0.18)
Acid dip, capping	4-5	614-1458	54	P	ND(<0.15)
Battery load and connect	4-3	658-1456	46	P	ND(<0.17)
Battery load and connect	4-4	835-1548	45	P	ND(<0.18)
Battery load and connect	4-5	605-1446	53	P	ND(<0.15)
Thirty foot dump	4-4	645-1443	44	P	ND(<0.18)
Thirty foot dump	4-5	624-1448	50	P	ND(<0.16)
Area sample at edge of battery forming tunnel platform	4-5	824-1548	42	A	ND(<0.19)

Laboratory limit of detection = 8 ug/sample
ND = Not detected in this sample.
< = Less than; this indicates that *if* sulfuric acid was present, the air concentration was below the indicated value, which changes, depending on the volume of air sampled.
P = Personal sample
A = Area sample

Occupational Exposure Criterion: 1 mg/m^3 (NIOSH and OSHA)

TABLE 6

Blood lead* by department

Johnson Controls, Inc., Battery Division
Owosso, Michigan

HETA 84-041

Department**		Number of Workers	Blood lead (ug/dl)	
Code	Description		Mean	Range
11	Grid casting	25	24	11-36
13	Casting	30	34	17-50
14	COS/HV	52	29	13-45
15	D & B	24	25	7-42
16	COS weld	12	34	16-52
17	Oxide mill	6	33	18-47
18	Post burn	44	24	9-40
19	Janitors	13	31	16-46
20	Maintenance	38	33	12-54
23	Inspectors	15	29	8-50
27	Store room attendants	***	28	23-33
31	Plant-wide utility	***	30	7-53
32	General labor	***	39	23-56
40	Truck drivers	12	28	11-46
41	Set-up	16	35	11-58
55	Supervisors	15	30	10-51
56	Engineers	10	10	3-18
78	Shipping/receiving	5	24	8-41

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* Based on each employee's most recent blood lead as of December 5, 1983.
** Only production area departments with three or more workers listed.
***Fewer than five workers

TABLE 7

Mean blood lead as determined by specific department code and by including all workers in an area

Johnson Controls, Inc., Battery Division
Owosso, Michigan

HETA 84-041

Work Area	Department Code	Number of workers	Mean blood lead (ug/dl)	All workers in area Number	All workers in area Mean blood lead (ug/dl)
Grid casting	11	25	24	33	26
Pasting	13	30	34	42	33
COS WELD	16	12	34	12	34
COS	14	52	29	77 (89*)	31 (31*)
D & B	15	24	25	28	24
Post burn	18	44	24	44	24
Oxide mill	17	6	33	12	33
Maintenance	20	38	33	41	32

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* COS plus COS weld

TABLE 8

Blood and air lead concentrations according to work area and job

Johnson Controls, Inc., Battery Division
Owosso, Michigan

HETA 84-041

				Air lead samples[4]		
Area[1]	Job	Number of Workers[2]	Mean blood lead (ug/dl)[3]	Number	Median[5]	Range[5]
Pasting	paster	11	38	28	30	5-99
	parter	17	32	55	23	9-92
	janitor		24	8	29	9-100
	inspector		33	14	36	8-1100
	truck driver	1		4	10	9-24
	set-up		41	12	34	4-88
	supervisor		44	7	22	3-44
	mixer		26	13	22	11-46
	overall	42	33	141	25	3-1100
COS	envelope stacker	13	30	36	20	<2-52
	loader	9	32	37	23	<2-81
	case punch/hot melt		29	6	7	2-19
	sinker	14	25	37	14	<2-110
	utility	13	32	7	12	9-45
	janitor		32	14	23	<2-219
	truck driver		26	3	11	8-14
	set-up	9	40	10	18	5-44
	inspecto	6	36	16	11	3-35
	supervisor		33	7	11	2-19
	overall	77	31	173	15	<2-219
	COS weld	12	34	37	17	<2-220
	overall	89	31	210	16	<2-220
Grid casting	operator & utility	25	24	72	11	<2-49
	truck driver		33	3	11	9-23
	supervisor		36	6	27	<2-9
	inspector		24	7	5	2-11
	overall	33	26	88	9	<2-49

TABLE 8 (continued)

Post burn	code 15 jobs	44	24	56	11	2-420
D & [illegible]	code 15 jobs	24	25	14	4	<2-17
	truck driver		17	2	17	6-27
	supervisor		25	2	3-4	<2-6
	overall	28	24	18	5	<2-420
Janitors	power sweep		37	2	56	38-73
	pasting		24	8	29	9-100
	mill		35	3	63	<2-65
	COS		32	14	23	<2-219
	send-out charge	1		1	12	--
	overall	13	31	28	26	<2-219
Oxide mill	operator & assistant	6	33	21	29	10->1600
	janitor		35	3	63	<2-65
	truck driver		33	3	11	9-23
	overall	12	33	27	25	<2->1600
Maintenance	pipefitter	7	35	14	9	2-48
	machine repair		37	10	23	2-59
	electrician	8	27	3	12	1-100
	millwright	11	40	16	17	3-660
	painter		31	2	20	10-30
	lift truck repair		30	19	--	--
	tool maker		22	4	10	<2-19
	oiler		24	3	11	10-18
	carpenter	1		1	27	--
	supervisor		24	2	7-8	<2-14
	overall	41	32	74	19	<2-660
Respirator sanitizer		1		1	12	--
Store room attendant		4	28	2	21	3-38
Plant-wide utility			30	1	8	--
General labor			39			

TABLE 8 (continued)

Truck drivers	cast, mill		33	3	11	9-23
	west, COS		26	3	11	8-14
	barrell scrap	1		3	17	14-21
	D & B		17	2	17	6-27
	west, paste	1		4	10	9-24
	overall	12	28	15	11	6-27
Engineers		10	10	0	--	--
Shipping receiving		5	24	3	13	12-14

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1 - Non-production areas not listed.
2 - A blank in this column indicates 2-4 workers.
3 - Not listed for jobs with only one worker.
4 - Company data, October 1982 - September 1983; includes samples only for those jobs listed.
5 - Micrograms of lead per cubic meter of air.

FIGURE 1

CONTINGENCY TABLE OF ZPP VS. BLOOD LEAD CATEGORIES

LAST SAMPLE DRAWN, FOR ALL WORKERS

		ZPP (µG/DL) CATEGORIES		
		0-99	≥ 100	TOTAL
BLOOD LEAD (µG/DL) CATEGORIES	0-39	309	16	325
	≥ 40	27	19	46
	TOTAL	336	35	371

PREVALENCE OF BLOOD LEAD ≥ 40 µG/DL = 0.12

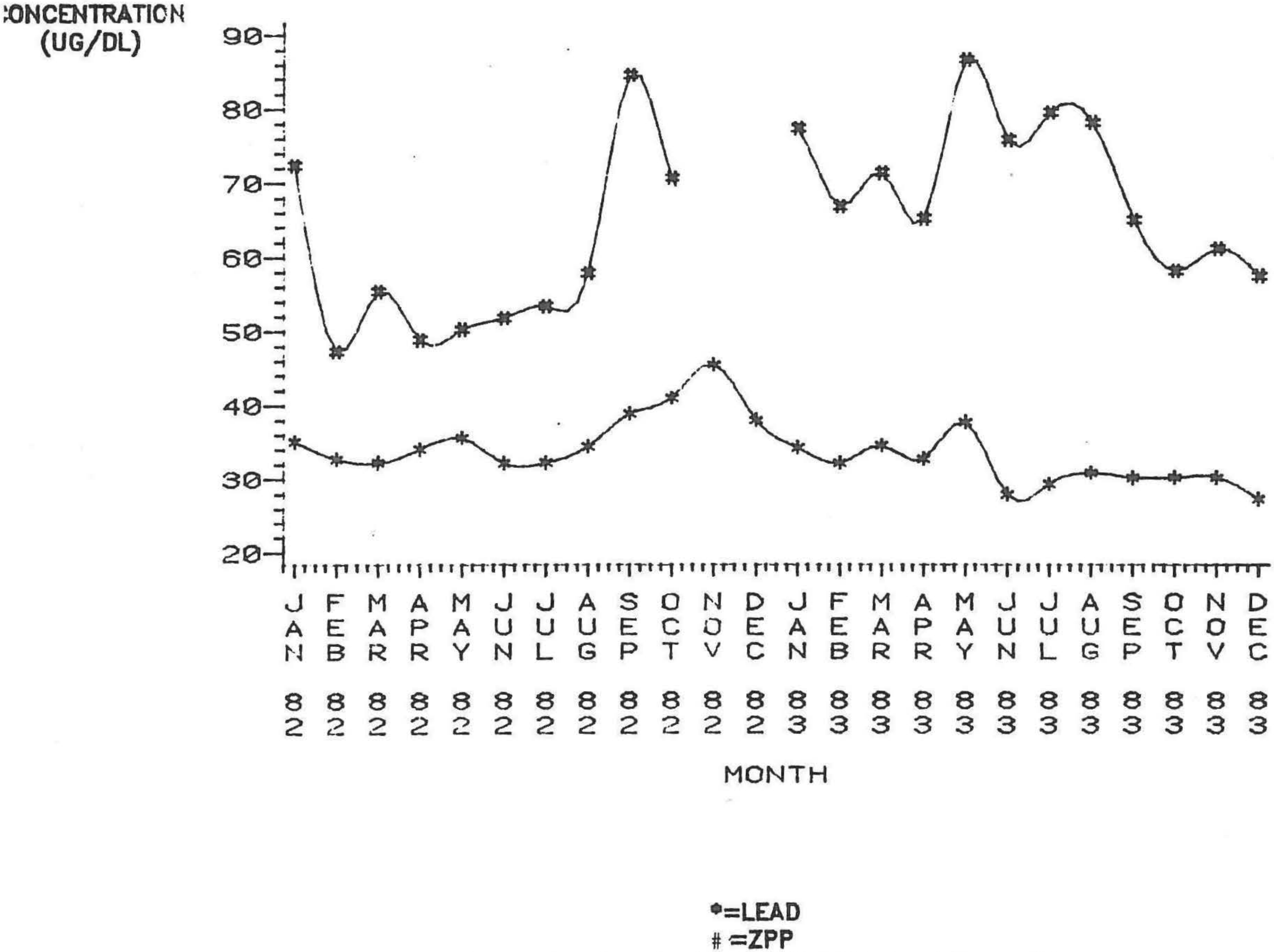
SENSITIVITY OF ZPP ≥ 100 µG/DL TO DETECT BLOOD LEAD ≥ 40 µG/DL = 0.41

SPECIFICITY OF ZPP < 100 µG/DL TO DETECT BLOOD LEAD < 40 µG/DL = 0.95

PREDICTIVE VALUE POSITIVE OF ZPP ≥ 100 = 0.54

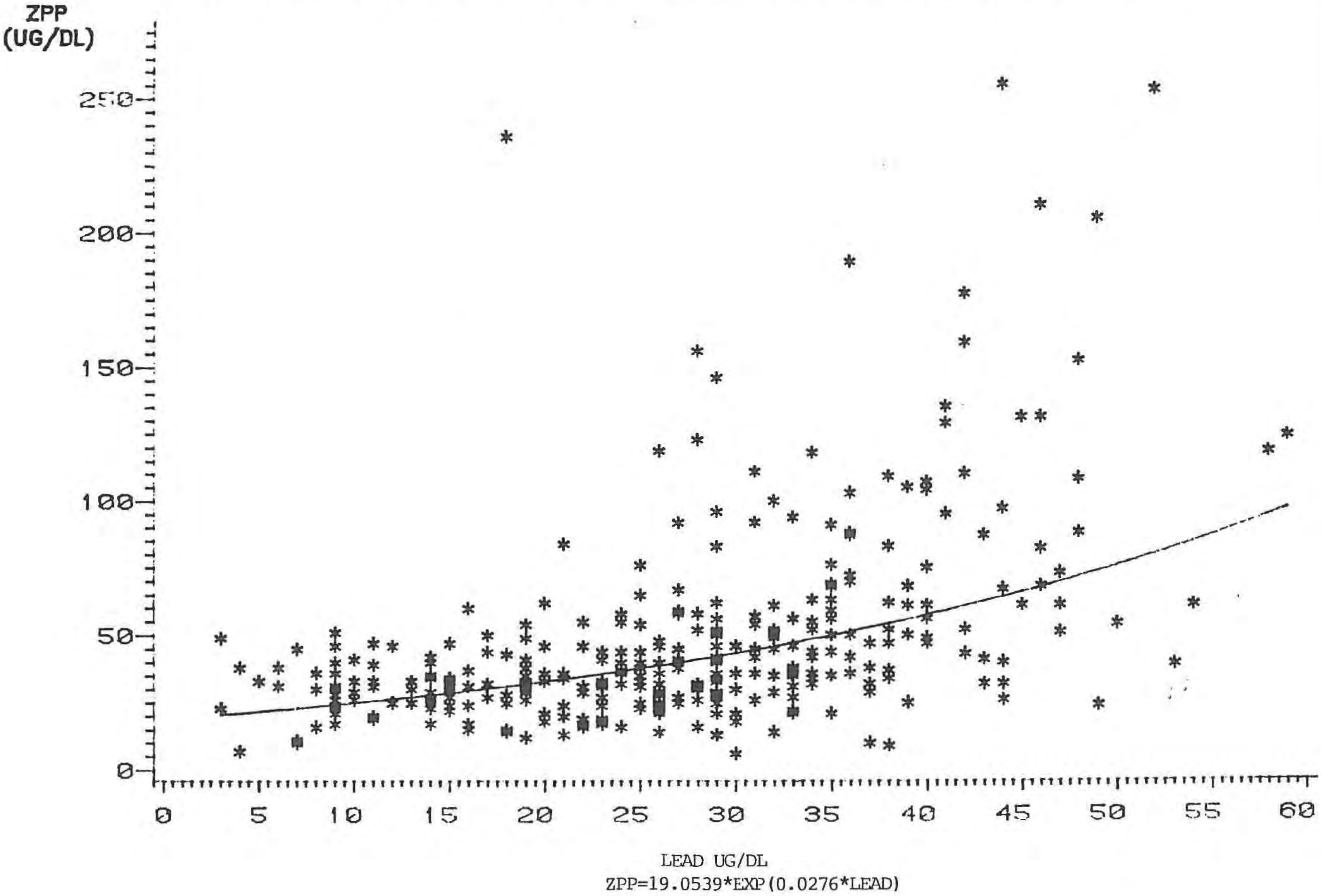
PREDICTIVE VALUE NEGATIVE OF ZPP < 100 = 0.92

FIGURE 2
MONTHLY MEAN BLOOD LEAD AND ZINC PROTOPORPHYRIN (ZPP) CONCENTRATIONS



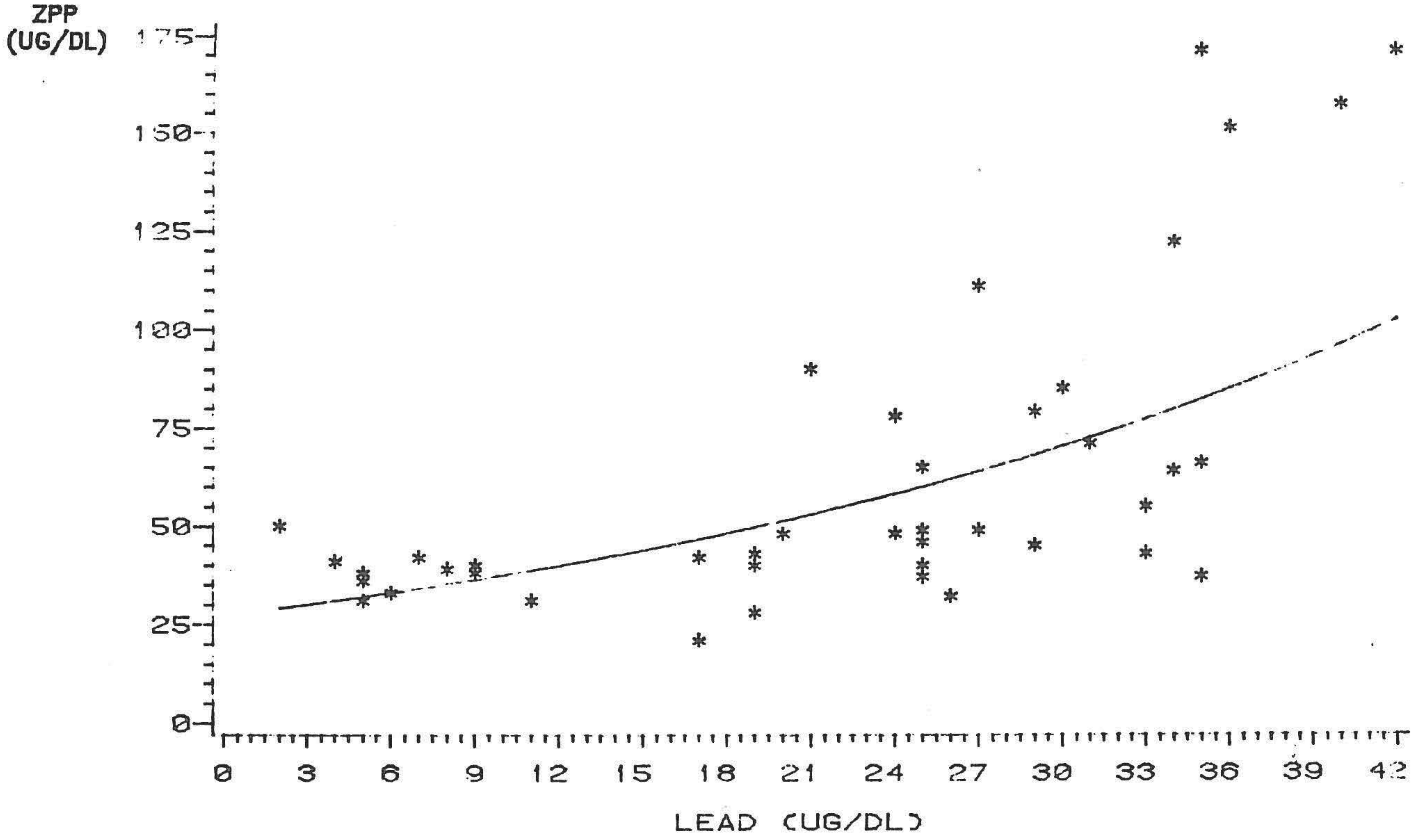
NO ZPP DATA AVAILABLE FOR NOV. OR DEC. 1982

FIGURE 3
ASSOCIATION BETWEEN BLOOD LEAD AND ZINC PROTOPORPHYRIN (ZPP), MALE WORKERS



ZPP=19.0539*EXP(0.0276*LEAD)

FIGURE 4
ASSOCIATION BETWEEN BLOOD LEAD AND ZINC PROTOPORPHYRIN (ZPP), FEMALE WORKERS



ZPP=27.3998*EXP(0.0314*LEAD)