U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
CENTER FOR DISEASE CONTROL
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
CINCINNATI, OHIO 45226

HEALTH HAZARD EVALUATION DETERMINATION
REPORT NO. HE 77-28-552

DELCO BATTERY PLANT
MUNCIE, INDIANA

DECEMBER 1978

I. TOXICITY DETERMINATION

A survey team from the National Institute for Occupational Safety and Health (NIOSH) performed a health hazard evaluation at Delco Battery Plant, Muncie, Indiana, on February 16-17, March 21-23, April 4-6, and August 25-27, 1977. The following determinations are based upon environmental measurements of airborne lead concentrations, medical screening, testing and evaluation, a review of pertinent literature, review of the company's lead monitoring data, observations of employees' work practices and engineering controls.

Environmental lead samples (personal and area) were collected during both a preliminary survey and a follow-up survey. Ninety-nine samples were collected on the follow-up survey from eight departments. Thirty-three of these samples exceeded the NIOSH recommended lead standard (1978) and the Occupational Safety and Health Administration (OSHA) proposed standard (1975) of 0.10 milligrams of lead per cubic meter of air (mg/m^3). Five of the eight departments are determined to have airborne lead concentrations which exceeded the NIOSH recommended standard. These departments are as follows: Department 901 - grid mold and small parts molding, Department 903 - plate pasting, Departments 905 and 912 - battery assembly, Department 994 - reclaim, old and new. Eight of the 33 samples collected from Departments 901, 905 and 994 exceeded the current OSHA standard of 0.20 mg/m^3.

Medical evaluation of the company's lead monitoring program showed that 85% of the workers' blood leads were below 60 microgram per 100 milliliters whole blood (60 ug/100 ml) during 1976. The NIOSH study found 88% below 60 ug/100 ml in a group of workers somewhat selected towards finding workers with high blood leads. Based on laboratory proficiency testing results and slightly higher average blood leads by department in the NIOSH study as compared to the 1976 company monitoring data, it appears that during 1976 the company blood leads may have been reported on the low side.

This difference was not great (about 5 ug/100 ml on the average.) and should not have made much difference in clinical interpretation. At the time of the NIOSH study the company's laboratory results were comparable to the NIOSH laboratory results. It is concluded that the company's biologic lead monitoring program was functioning well at the time of the NIOSH study.

No lead intoxication was found, nor were there many findings to distinguish one group from another on the basis of potential lead exposure. Workers in departments judged "high risk" based on the company's 1976 blood lead monitoring data showed higher mean blood lead levels and higher urinary lead levels than did workers from other departments. Workers with health complaints had higher mean blood lead levels than those without complaints, although no specific complaints emerged as characteristic of workers with high blood leads. Coughing smokers (presumably the heavy smokers) had higher mean blood leads than did the non-coughing smokers who in turn were higher than the non-smokers. This suggests that heavy smokers are at greater risk of increased lead absorption than others.

In about half of 20 workers with medical problems they considered might be due to lead exposure, their medical records supported the possibility.

Zinc protoporphyrin (ZPP) testing did not prove a good substitute for blood leads in biological monitoring programs, although it or a free erythrocyte protoporphyrin (FEP) determination should prove a valuable adjunet in interpreting blood lead status over time, and might be useful for monitoring in low exposure areas.

II. DISTRIBUTION AND AVAILABILITY OF DETERMINATION REPORT

Copies of this determination report are currently available upon request from NIOSH, Division of Technical Services, Information Resources and Dissemination Section, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days the report will be available through the National Technical Information Service (NTIS), Springfield, Virginia. Information regarding its availability through NTIS can be obtained from NIOSH, Publications Office at the Cincinnati address.

Copies of this report have been sent to:

a) Delco Battery Plant, Muncie, Indiana
b) Authorized representatives of Local 489, United Autoworkers of America
c) International Union of United Autoworkers, Detroit, Michigan
d) U. S. Department of Labor - Region V
e) NIOSH - Region V

For the purpose of informing the approximately 600 "affected employees" the employer shall promptly "post", for a period of thirty calendar days, this Determination Report in a prominent place(s) near where exposed employees work.

III. INTRODUCTION

Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S. Code 669(a)(6) authorizes the Secretary of Health, Education, and Welfare, following a written request by 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 National Institute for Occupational Safety and Health received such a request from an authorized representative of Local 489, United Autoworkers of America (U.A.W.). The health hazard evaluation was prompted by workers who believed the company's lead monitoring program was giving false low blood lead values. Several men who worked in the lead storage battery plant had felt ill with symptoms consistent with lead poisoning (plumbism). These employees visited their private physicians who obtained blood or urine lead levels, diagnosed them as having plumbism, and in some cases, treated them with a chelating agent.

In the last couple of years the union contract has included two provisions of note: (1) The worker has the right to know his individual blood lead levels. These are obtained by making an appointment with the company physician. (2) If the worker's private doctor and the company doctor disagree as to the worker's ability to return to work, the worker is sent to a third doctor chosen from a panel. The third doctor's decision is binding on the continuation of sickness benefits although it does not affect the worker's employment status. Because of these two provisions, the employees noted apparent discrepancies between the blood lead levels as measured by the laboratories used by the private physicians and the laboratory used by the company.

The company's lead monitoring and control program was reviewed prior to this study. Several points should be mentioned. First, the company had been conscious of laboratory error in lead determinations and had tried to assure accuracy. Second, it appeared to the NIOSH investigators that the company had tried to do more than enough to assure safety. Where the then generally accepted upper limit of safety was 80 ug lead per 100 grams whole blood, (80 ug/100 g) the company adopted 70 ug/100 g as an alert level and the level to which they wanted blood leads to return before considering an elevated blood lead has been properly handled. Whereas the the current Federal standard allowed a time weighted average (TWA) air concentration of lead of 200 ug/m^3, the company tried to keep their concentrations below 150 ug/m^3. Last, there was a consistency between the company's air leads and blood leads which suggested that both levels were, indeed, predominantly within the desired range. The company physician stated that the company had not had any confirmed cases of lead poisoning in the 22 years that he had been there and had only occasionally had to transfer men to low exposure departments because of elevated blood leads. He had not used chelation therapy or prophylaxis.

Because the company was preparing to move from their old plant to a new facility, the major question to be answered by this study was the adequacy of the company's lead monitoring program. Exposures in the new plant will be different from those in the old plant. This study was also designed to help assess the relationship between zinc protoporphyrin values and blood lead values.

A separate part of the NIOSH study not covered in this report concerns reproductive effects of exposure to lead.

IV. HEALTH HAZARD EVALUATION

A. Process Description

Delco Battery plant has a work force of approximately 660 employees. Although the company manufactures several types of batteries, all of these are of lead-acid type. The plant basically operates three eight-hour work shifts per day, five days per week. There are, however, a few employees who work up to ten hours per day, five days per week. A detailed description of the major production departments are listed below.

1. Department 901 (grid mold and small parts molding): This is an open, continuous, hot operation in which 13 operators and three relief men each operate 3 of the 54 grid mold machines.

Molten lead is supplied to each grid mold machine via insulated piping which is connected to a lead melting pot in the new reclaim department (994). The molten lead is directed to a water cooled jacket where the lead is cooled and solidified. Once the grids are formed, they are trimmed free of excess lead and stacked onto a skid. The excess

trimmings fall down a chute onto a conveyor belt which directs the excess material back to the melting pot in the new reclaim area.

The grid mold machines occasionally produce defective grids which are immediately obvious to the operator. Consequently, the grid mold machine water jacket is washed-out or sprayed-out. The operator uses hot water and a wire brush to perform this task. Once the water jacket has been cleaned, a mold coat is sprayed onto the jacket. This coat acts as a release agent and insulator for the water jacket.

2. Department 903 (Plate Pasting): This department incorporates several operations.

a) Lead oxide production - This is a continuous, closed, hot operation performed in a room adjacent to the pasting machines. Molten lead is supplied to Barton® or Linklator® pots* where oxidation and lead mixing occur. The pots are under negative pressure ventilation leading to bag collectors. The oxidized particles are sent through a closed screw conveyor system to the oxide grinders where the particles are ground to a uniform size of about 5.0 micrometers (μm). The particles are then blown to storage tanks on the third floor, or to the mixers on the second floor.

b) Paste forming - Paste production is a closed, cold, batch operation. The negative and positive paste consists of an oxide, water and sulfuric acid. The paste is prepared in one of several mixers. Each mixer has a local exhaust ventilation system which is connected to a wet scrubber system.

c) Grid pasting and plate breaking - This is a cold, continuous, open operation. Grid plates are hand fed to a conveyor system. A hopper directly above the conveyor line gravity feeds oxide paste onto the grids passing below the chute. The paste is mechanically smoothed onto the grids after which the grids are passed through drying ovens. As the plates exit the ovens, they are passed through a transparent enclosure where the double plates are cut in two. The cut plates are hand stacked onto skids and transported to the curing room. The entire line is two feet above a downdraft ventilation grate.

3. Department 905 (Dry battery line): This is an open, continuous operation. Plates are brought into the department on skids. Employees remove the plates from the skid and place them in the stacker machine. The stacker alternately places positive and negative plates into stacks

*Mention of company name or product does not constitute endorsement by the National Institute for Occupational Safety and Health.

on a conveyor belt. The stacks of plates are then inserted into a burning rack which is also on a movable conveyor belt. Small parts are set on the plates prior to the burning rack entering the burners where the plates are automatically welded together. This burning station has downdraft exhaust ventilation. After the automatic welds are made, a worker goes over the spot welds with a torch. This part of the operation has lateral feed local exhaust (fumes were visibly pulled into the exhaust slot.) The groups of plates are subsequently inspected for defects and inserted into plastic battery cases after which the battery is leak checked. If defects are noted, the battery repairman makes the necessary corrections thereby completing the battery cycle. No face velocity measurements were made, but the plant engineer reported the duct flow rate for this entire operation to be 40,000 cubic feet per minute (cfm).

4. Departments 911 and 912 (Wet battery line): Both departments are similar except that one department makes a battery that is marketed for a specific company. The production line is a continuous, open, "cast on strap" operation. Stacker operators place grids into the stacker machine. The stacker alternately places positive and negative plates into stacks on a conveyor belt. The group of plates are mechanically held together and dipped into molten lead to form a strap for assembly. The plates are finally placed in a plastic battery case and sent to an inspection station. The other battery hardware are mechanically applied. The battery is then heat sealed, air checked and filled with an electrolyte. Downdraft exhaust ventilation exists along the production line. Although no face velocities were measured, the plant engineer reported the duct flow rate as 78,000 cfm.

5. Department 945 (Mac wheel area): This battery assembly operation is for large batteries such as those used in buses or trucks. This five person operation is semi-automated. One person loads the stacker which automatically stacks the plates. Another employee loads the groups of plates into a burning rack. The third worker places hardware on the battery. The fourth operator stacks the finished product on the skid and the fifth employee serves as a relief man. This operation uses rubber battery cases.

6. Department 907 (Battery charging): The batteries are automatically filled with an electrolyte solution and conveyed to the charging area. Batteries are placed on a grate with downdraft exhaust ventilation. The batteries are connected to a power source and slowly charged for the prescribed time.

The gas and mist generated during charging are collected by a wet scrubber ventilation system. No face velocity measurements were made of the downdraft exhaust system; however, the plant engineer reported a duct flow rate of 30,000 CFM.

7. Department 994 (Reclaim - old and new):

a) Old - This reclaim area consists of a hot batch operation. The employee spends a maximum of three to four hours per day in this area, and he is required to wear a respirator. Scrap lead from the various operations and reclaimed lead oxide from the air pollution control device (i.e., oxide from the bag house and sludge from the Rotoclave® units) are used to charge the furnace. Once the molten lead has been checked for the correct metallic concentration, the molten metal is poured into large molds, called hogs, and cooled. The hogs are either transported to oxide manufacturing, the grid mold pot or the small parts pot. Local exhaust consisting of a side draft hood with baffles was used to capture hot mold fumes.

b) New - The operator spends a maximum of three to four hours per day in this department and he is required to wear a respirator. The operator is required to replace the plastic bags used by the air pollution control device to capture the oxide paste. In addition, the operator adds a "sweetening lead" to the melting pot furnace. A sweetening lead is simply a lead mold that is used to increase the lead concentration of the melting pot.

B. Evaluation Design and Methods

1. Environmental

Environmental monitoring for airborne lead was performed during the day shift since this work operation was characteristic of the other shifts. Personal samples were collected during a two day period for as much of an eight-hour work day as possible in order to evaluate the workers' time-weighted average exposure (TWA). Sampling was performed in the following eight Departments: Department 901 - grid mold and small parts molding, Department 903 - plate pasting, Departments 905, 911, 912 - battery assembly, Department 907 - battery charging, Department 945 - mac wheel area, Department 994 - reclaim - old and new.

The sampling method for inorganic lead consisted of using Mine Safety Appliance® (MSA) pumps operating at flow rates of 1.5 liters per minute (lpm) ±5 percent; 37-millimeter (mm) three-piece cassette filter holder, and a 37-mm 0.8µm mixed-cellulose-ester membrane filters supported by a cellulose back-up pad.[1]

The filter samples were wet ashed in distilled nitric acid and brought to a volume of 25.0 milliliters with deionized water. An alliquot of the sample was directly aspirated into an atomic absorption spectrophotometer.[2]

2. Medical

a. Study Protocol

The medical portion of this study was divided into three phases with a selective reduction of the number of workers included in each phase of the study. This is diagramed in Figure I.

Phase I - Initial Screening

This was offered to all workers and consisted of a brief questionnaire to identify them and their current department and job. A zinc protoporphyrin (ZPP) was performed on a venous blood specimen.

Phase II - Blood Lead Survey

This consisted of a self-administered questionnaire covering work history, questions concerning lead poisoning or transfer because of elevated blood lead levels, non-directed questions about health problems, and a question on treatment for kidney problems. Venous blood available from Phase I was tested for lead, free erythrocyte (FEP), ZPP, hemoglobin (Hgb) and hematocrit (Hct). Criteria for inclusion in Phase II were:

A. All workers in Departments 903, 911, 912, 945, and 994 ("high risk" areas as judged by the company's 1976 lead monitoring data.)
B. All workers with a ZPP of 40 ug zinc protoporphyrin per 100 ml (ug ZP/100 ml) whole blood or more.
C. A history of treatment or job transfer for an elevated blood lead.
D. A 1/4 random sample of workers in departments other than those listed in A without a history of treatment or job transfer for an elevated blood lead and with a ZPP of under 40 ug ZP/100 ml whole blood.
E. All those for whom duplicate bloods had been drawn for quality control of lead values.

Phase III - Inquiry for possible lead poisoning

This was done on a pre-selected sub-group of phase II. There was a more extensive medical history with some directed questioning, a brief examination for blood pressure (BP) and signs of muscle weakness and

additional blood tests for blood urea nitrogen (BUN), creatinine, and serum uric acid (as part of an SMA-12*). In addition a clean first-voiding urine specimen was obtained and tested for protein (by dip stick), lead, creatinine, and specific gravity. Instruction was given about obtaining a clean specimen. Criteria for inclusion in Phase III were:

A. All workers with a ZPP of 155 ug ZP/100 ml whole blood or more.
B. A 1/3 random sample of those with a history of treatment or job transfer for an elevated blood lead.
C. A 1/5 random sample of workers with a ZPP below 155 ug ZP/100 ml who were included in phase #2 categories A & B, but without a history of elevated blood lead.
D. Every worker included in phase #2 category D.

Twenty (20) blood samples were split to allow two samples to be sent to the laboratory doing the blood leads in this study with an additional sample to each of two other laboratories, one of which was the laboratory utilized by Delco. Six (6) blood specimens were obtained from NIOSH employees to serve as additional low level controls. All six had ZPP levels below 40 ug ZP/100 ml.

As the running of the ZPPs required opening a tube of blood on which it might be necessary to later run a blood lead determination, the tubes were only opened in a clean area and the air was monitored for lead in that area. All air lead levels were below the limit of detection.

Copies of the questionnaires and physical examination form are included as Appendix A.

b. Study Methods

Phase I (March 21-23, 1977)

All shifts were covered utilizing four or five blood drawing stations set up in inner offices at strategic locations within the plant. Workers to be included in Phase II of the study were selected daily on the basis of ZPP, current department and history of possible treatment for or transfer because of an elevated blood lead. A sample of those with a low ZPP and no history of problems were drawn utilizing a table of random numbers. Of 662 workers on a current active roll, 527 participated. All workers at the time of the study were men.

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*SMA-12 (Serum Multiphasic Analysis is an automated test on serum which includes: SGOT (Serum Glutamic Oxalacetic Transaminase); LDH (Lactic Dehydrogenase); Alkaline Phosphatase; Total Bilirubin; Albumin; Total Protein; Cholesterol; Uric Acid; BUN (Blood Urea Nitrogen); Glucose; Inorganic Phosphorous; Calcium.

Participants included a few men who came in from sick leave and two men not on the active roll supplied to us. Nonparticipants included men on leave and men declining to participate.

An attempt was made by NIOSH to talk to a number of workers not wishing to participate in the study to be sure they understood the scope of the study. One of the major reasons for nonparticipation involved a labor/management dispute over whether blood specimens could be drawn in the plant, or should only be drawn in the medical section. Because the NIOSH investigator felt that adequate specimens could be safely obtained at the five drawing stations, and because it was not feasible to bring all the men to a central location within the time constraints, the collection of blood specimens proceeded as planned. On the last day of the visit the few stragglers were drawn in the room in the office section where the ZPPs were being done.

ZPPs were done on an Environmental Sciences Associated Number 4000 Hematoflurometer calibrated in ug ZP (zinc protoporphyrin)/100 ml whole blood with an assumed hematocrit of 42%.

Phase II

The Phase II questionnaire was mailed to the men along with their ZPP results. A second mailing was made to those who had not already responded. In all 332 out of 390 questionnaires were returned, with partial questionnaires on an additional 14 from Phase III.

The bulk of the blood leads were done by Medical Diagnostic Services - Ohio Valley, Cincinnati (MDS) using a Delves cup and atomic absorption. The laboratory used by the company was Bio Industrial Laboratories, Gadsden, Alabama, who used a graphite furnace and atomic absorption. The third laboratory used was the Utah Biomedical Test Laboratory, Salt Lake City also using a Delves Cup and atomic Absorption procedure. The remaining laboratory work from Phase II was done by MDS.

Phase III (April 25-27, 1977)

Two examination stations were utilized at a time to cover all shifts. one examination station was in a NIOSH trailer set up in the plant yard. The other station was either in a conference room in the administrative section of the plant or in an office in the back section of the plant. Because the workers had not received their notification letters with the Phase II questionnaires at the time of this visit, the "non-directed" health questions from the Phase II questionnaires were asked at the onset of the Phase III questioning.

Blood and urine leads were done at the Utah Biomedical Test Laboratory. The other laboratory work was done by MDS.

C. Evaluation Criteria and Toxic Substances Medical Data

1. Environmental

Exposure limits for airborne inorganic lead have been recommended or promulgated by several sources. For this study the criteria used to assess the degree of health hazards were collected from three sources:

(1) NIOSH: Criteria for a Recommended Standard ... Occupational Exposure to Inorganic Lead, 1972, and Revised Recommendations (1978)

(2) Threshold Limit Values (TLV): Guidelines for Chemical Substances and Physical Agents recommended by the American Conference of Governmental Industrial Hygienists (ACGIH) for 1977.

(3) OSHA Standard: The standard for inorganic lead enforced by the Occupational Safety and Health Administration (OSHA) of the U.S. Department of Labor (DOL) found in the Federal Register, 29 CFR 1910.1000(b) (Table Z-2), and the 1975 proposal.

SOURCE	8-Hour Time Weighted Average Concentration (TWA)[1]	Acceptable Ceiling Concentration[2]
NIOSH Criteria Document - 1978[3]	100 ug/M^3 [4]	-
OSHA Standard	200 ug/M^3	-
OSHA Standard Proposed - 1975	100 ug/M^3	-
1977 TLV	150 ug/M^3	450 ug/M^3

[1]USDOL employee exposure standards are based on a computed time-weighted average occupational exposure for up to a 10-hour workday, 40-hour work week. This standard represents conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse effects. In some instances, however, a few employees may experience discomfort at or below the time-weighted average.

[2]This value should never be exceeded during a 15-minute sampling period.

[3]NIOSH recommends that workers shall not be exposed to inorganic lead at a concentration greater than 0.01 mg/m^3 determined as a time-weighted average exposure for a 10-hour work day, 40-hour work week.

[4]ug/M^3 = micrograms of lead per cubic meter of air (1 ug = .001 milligrams).

2. Toxic Substances Medical Data

Although capable of causing acute toxicity when absorbed in large amounts, lead is usually associated with chronic toxicity due to much smaller exposures repeated over a period of time. Lead and its inorganic compounds can be absorbed by inhalation of vapors, fumes or dust. Oral intake can also lead to poisoning, but absorption is not as complete. The three systems of most concern affected by lead are: the nervous system; the red blood cell forming tissue (the bone marrow); and the kidney. Classic symptoms of lead intoxication are wrist drop (a weakness of the muscles which cock the wrist caused by effects upon the nerves supplying these muscles), anemia (with small, hemoglobin poor red cells), colicky abdominal pain, and constipation. The muscles which raise the ankles may also be affected. In children, but rarely in adults, there can be an acute encephalopathy.

None of the symptoms due to lead poisoning are absolutely specific and any of the individual complaints can also be caused by a number of other conditions. Other symptoms referable to the nervous system might include peripheral neuritis with muscle weakness. Central nervous system symptoms might include convulsions, irritability, personality change, headaches, forgetfulness, or tiredness. Kidney problems might lead to decreased kidney function (including the ability of the kidney to excrete lead), protein in the urine, increased nitrogenous wastes in the blood, and increased blood uric acid with consequent gout.

3. Interpretation of Medical Results and Blood Pressure

a. Blood lead levels are important in helping to make the diagnosis of lead intoxication. Values of blood lead up to 40 ug/100 ml whole blood[3,4] are considered normal, 40 ug/100 ml to 60 ug/100 ml[4,5] are considered acceptable (not likely to be causing problems in male workers who are not anemic), 60 ug/100 ml to 100 ug/100 ml represents an unacceptable elevation which may be causing problems[4], and over 100 ug/100 ml is considered dangerous[4]. Until recently, lead levels up to 80 ug/100 ml were considered acceptable by most authorities. One problem with determination of blood lead levels is that values are subject to a laboratory error of up to 10 ug/100 ml, even in well-run laboratories.

b. Urine leads are done less frequently now because they are usually more variable than blood leads and are more likely to be contaminated during collection. It is usual to correct the specific gravity of the urine to 1.024 to allow better comparisons, and it is specified that the urine should have an initial specific gravity of over 1.010. Normal values are less than 65 ug/l[6], but men occupationally exposed to lead often show amounts greater than this. Urine leads in excess of 200 ug/l are considered excessive and require a blood lead follow-up[5].

c. Urine specific gravity is a measure of how much water the body is putting into the urine in relation to dissolved substances. The normal range is 1.001 to 1.035 (3). If the kidney is neither concentrating the urine (to save body water) nor diluting the urine (to get rid of excess body water), the specific gravity is 1.010. The first specimen on getting up is usually concentrated with a specific gravity greater than 1.010. Pure water has a specific gravity of 1.000.

d. Zinc Protoporphyrin (ZPP) accumulates in the red blood cell when lead interferes with the introduction of iron into the hemoglobin as the red cell is formed in the bone marrow. The same thing is also seen in anemias. Once formed, the red cell will carry however much hemoglobin and zinc protoporphyrin it obtained in formation until its destruction (normally in about 120 days). ZPP can be reported in ug zinc protoprophyrin 100 ml (ug ZP/100 ml) whole blood or ug free erythrocyte protoporphyrin 100 ml (ug EP/100 ml) whole blood. According to a letter dated September 28, 1977 from Environmental Sciences Associates, Inc., the manufacturer of the instrument used in this study, the proper conversion between ZP units and EP units is: 1 ug EP/100 ml equals 1.3 ug ZP/100 ml. Based on this and several other NIOSH studies[7,8] it appears that a ZPP of 40 ug ZP/100 ml whole blood corresponds to a blood lead of 40 ug/100 ml whole blood. The ZPP rises exponentially as the blood lead rises linearly. In other words, the ZPP rises much faster than does the blood lead. The relationship of ZPP with blood lead will be discussed in the Results and Discussion section of this report.

e. Free Erythrocyte Protoporphyrin (FEP) measures the same thing as ZPP using a different laboratory method. It can be elevated in lead exposures and in anemia. Normal levels at the laboratory used in this study are 374-622 ug/l red blood cells (RBC).

f. The Red Blood Cell Count (RBC Count), Hemoglobin (HGB), Hematocrit (HCT), Mean Corpuscular Volume (MCV), Mean Corpuscular Hemoglobin (MCH), Mean Corpuscular Hemoglobin Concentration (MCHC) are all measures of anemia and all refer to the red blood cells (corpuscles). Normal values for the laboratory where these were done are listed in Appendix B.

g. Serum Creatinine, Blood Urea Nitrogen (BUN), and Urine Protein are measures of how well the kidney is functioning. Increased levels show a decrease in kidney function. Normal values are listed in Appendix B.

h. Urine Creatinine is excreted at a fairly uniform rate over the day with the amount an individual excretes being dependent on his muscle mass rather than his food. This represents an alternative to using a standard specific gravity in correcting for differences between dilute and concentrated urine. No normals are listed as normals are expressed as the amount of creatinine excreted over 24 hours. It was not possible to collect sufficient urine to determine 24 hour excretion.

i. Uric Acid may be elevated in gout or with kidney damage. Normal values are in Appendix B.

j. Albumin and Total Protein reflect the state of nutrition, liver function, kidney function and antibody production. Normals are in Appendix B.

k. Blood Pressure normally measures two values, the Systolic pressure which is the pressure reached when the heart contracts to pump out the blood, and a lower pressure, the Diastolic pressure, which is the lowest pressure found in the main arteries between contractions. The systolic pressure is normally less than 140 mm Mercury (Hg) and the diastolic less than 90 mm Hg. This is usually expressed as 140/90. A repeated finding of a systolic pressure of 150 or more, or of a diastolic pressure of 95 or more is considered hypertension (high blood pressure). If either the systolic is 140-149 and/or the diastolic is 90-94 the patient is considered possibly hypertensive.

l. The remaining tests were done because they were included in the package of tests requested to obtain the desired tests. These included White Blood Cell Count (WBC), Serum Glutamic Oxalacetic Transaminase (SGOT), Lactic Dehydrogenase (LDH), Total Bilirubin, Alkaline Phosphatase, Inorganic Phosphorous, Calcium, Glucose, and Cholesterol. Normals are in Appendix B.

D. Evaluation Results and Discussion

1. Environmental

The environmental lead samples collected during the initial survey (Table I) were short term personal and area samples (approximately 3.0 hours per sample). This data was not used to determine a state of compliance or non compliance with the recommended standards, nor was it used to determine if a health hazard condition existed. This preliminary data was used to characterize the airborne lead concentrations throughout the various departments.

The environmental data collected during the follow-up survey (Table II) is arranged according to departments in order to more easily evaluate the data. Five of the eight departments monitored had airborne lead concentrations which exceeded the NIOSH recommended standard (1978) and OSHA proposed standard (1975) of 0.10 mg/m^3. Three of these departments had concentrations exceeding the current OSHA Standard of 0.20 mg/m^3. It should be noted that Department 994 is the only respirator required work area.

Four samples were collected in the conference room in order to assure the integrity of the blood samples which were tested for ZPP levels. No environmental lead was detected in this area.

Fifteen lead samples were collected from Department 901 (grid mold and small parts molding). The airborne lead concentrations ranged from 0.05 - 0.30 mg/m^3 with nine samples exceeding the revised NIOSH recommended standard. Furthermore, this department was not a respirator required area. Several employees did not follow the grid mold spray-out procedures. That is, the workers were dry-brushing the molds instead of wet brushing. Several men were observed smoking on the job. In one case, the employee was observed rolling his own cigarette. These last two actions potentiate the likelihood of lead exposure by ingestion.

Twenty personal samples were collected from Department 903 (plate pasting). The lead concentrations ranged from 0.06 - 0.20 mg/m^3. Thirteen of these samples exceeded the NIOSH recommended standard. It was reported that the bleed conveyor (second floor) to the grinders sometimes backs up resulting in spills which fill the air with a visible dust. The dust settles through the cracks on the wooden floors thereby contaminating the first floor. The No. 1 paste machine was alleged to be the most affected by the dust. A visible dust was observed on the second floor.

Twenty-two personal airborne lead samples were collected in Department 905 (battery assembly). The airborne lead concentrations ranged from 0.03 - 0.21 mg/m^3. Two samples exceeded the recommended standard. Both samples were from the group puller, and the concentrations were 0.21 and 0.20 mg/m^3. The stacker operators were observed tapping off excess paste from the plate onto the skid instead of tapping off the excess paste over the downdraft table. Additionally, several stackers were observed smoking on the job. Respirator protection was not required along this production line.

Four area samples were collected in Department 907 (charging area). The lead concentrations were 0.02, 0.04, 0.06, and not detected. All of these samples were well within the limits of the recommended standard. It was alleged by the supervisor that the wet scrubber system was intentionally shut off. Respirator protection was not required in this area.

Twelve personal lead samples were collected from Department 911 (battery assembly). None of these samples exceeded the NIOSH recommended concentration. The airborne lead concentrations ranged from 0.02 - 0.10 mg/m^3. Respirator protection was not required along the production line.

Eighteen personal samples were collected from Department 912 (battery assembly). Airborne lead concentrations ranged from 0.03 - 0.14 mg/m^3. Five samples exceeded the revised criteria. The "cast-on-strap" operators position was sampled six times, and four of these samples exceeded the value of 0.10 mg/m^3. Respirator protection was not required along this production line. One stacker operator was observed smoking on the job.

Nine personal lead samples were collected from Department 945 (mac wheel area). The five operators rotate job positions every 15 minutes; therefore, no specific position has been identified in Table II. No air lead levels exceeded the recommended standard. The lead concentrations ranged from 0.01 - 0.05 mg/m^3. Respirators were not required along this production line.

Six samples were collected from Department 994 (Reclaim - old and new). All of these samples exceeded the recommended standard. On the first day, separate samples were collected before and after lunch in order to determine if there was a period when exposure was greatest. On the second day, the sample was collected for as much of the shift as possible. The TWA concentrations for the old reclaim area for the first and second day were 0.15 and 0.24 mg/m^3 respectively. The TWA concentration for the new reclaim area for the first and second day are 0.14 and 0.23 mg/m^3 respectively. Respirator protection is required in both areas. The worker in new reclaim does not consistently wear his respirator. He only wears it when he is sludging.

2. Medical

a. Comparison of Blood Lead Determinations by Different Laboratories

Twenty (20) workers had multiple tubes of blood drawn through the same needle so that samples could be sent to three different laboratories for comparison and so that two samples could be sent to the MDS laboratory as a check on their internal consistency. In the case of duplicate samples to the same laboratory, different "case numbers" were used for the two specimens.

1) Nineteen duplicate specimens were analyzed by MDS. The mean difference between the two specimens was 10.4 ug lead/100 ml whole blood, with a standard deviation of 7.8 ug/100 ml and a range of 0 to 31 ug/100 ml.

2) Comparing the other two laboratories (Bio-Industrial and UBTL) with a random selection of one of the paired readings by MDS, the following two-way analysis of variance was obtained on the twenty specimens:

Laboratory	Mean ug lead/100 ml whole blood	Standard Error of Mean
MDS	38.7	2.9
UBTL	36.2	3.3
BIO-IND.	38.4	2.7

There was no clinically or statistically significant difference ($F = 1.83$, $p = 0.174$) between the laboratories.

3) The Center for Disease Control, Bureau of Laboratories, runs a proficiency testing program which includes quarterly tests for laboratories doing lead analyses. Both the MDS and Bio-Industrial laboratories participate in this testing program. As can be seen in Table III, both laboratories have had some unacceptably low values in the past, but both have done acceptably on the testing closest to the time of this study. It is also worth noting the wide range of acceptability which is necessary because of the problems with the analysis of lead in blood.

UBTL participates in the proficiency testing program for CDC's Childhood Lead Screening Program. In this program tests are run monthly. Results are again shown in Table III. All recent testing was in the acceptable range.

b. Relationship of ZPP to Blood Leads

Although ZPP levels appear to be related to blood lead levels and have proven to be of value in the Childhood Lead Program run by CDC, their use in occupationally exposed adults as a screening tool has been frought with difficulties. In the childhood program the question to be asked of the screening test is, "Has this child been exposed to lead in excess of the normal background amounts in soil and food?" As in most cases the answer is an unqualified "no", the screening level can be set low enough to virtually exclude false negatives (ZPP all right, lead too high). Further, it is unlikely that the child will have a rapidly changing exposure, giving the ZPP, which changes more slowly, a chance to adequately reflect the blood lead, which changes more rapidly.

In the occupational setting where we know the workers have been exposed to lead in excess of the normal background amounts, the question to be asked is, "Does this worker have an excessive blood lead level?" This difference in perspective is compounded with the possibility of fluctuating blood lead levels. From what experience NIOSH has had with ZPPs, (this study and references 7,8) if the screening level is set low enough to eliminate false negatives there will be so many false positives (ZPP higher than the screening level but blood lead within the acceptable range) requiring a blood lead, that it would have proved easier to simply do blood leads on everyone in the first place.

It appears, then, that the ZPP determination will be of greatest use in serving as an estimate of what the average blood lead level has been over the preceding three to four months. Based on ZPP and blood lead determinations on 669 male workers taken from this and several other studies[7,8], the relationship between ZPP (in ug/100 ml whole blood) is:

$$\text{Blood Lead} = 17.02 \times \log \text{ZPP} + 14.14 \quad (r = 0.86)$$

This assumes a hematocrit of 42%. In deriving this formula variability in the laboratory results, in the individual's recent lead exposure, and in the individual hematocrit levels was minimized by averaging the data down to 49 points.

In this current study the formula is:

$$\text{Blood Lead} = 15.94 \times \log \text{ZPP} + 16.39 \quad (r = 0.45)$$

Table IV compares these two formulas as well as one derived utilizing the company's 1976 lead monitoring data in conjunction with the NIOSH data. A formula for these same men utilizing only the NIOSH data is also given for comparison.

The formulas do not differ significantly, but is should be noted that the correlation (r) between ZPP and blood lead was better when compared to an average blood level for the individual than to a single reading.

In the remainder of this report the formula based on the 669 men will be used when deriving a predicted blood lead value from ZPPs.

c. ZPP and Blood Lead Findings

1) Company Data

Table V presents a summary of the company's lead monitoring data for 1974, 1975, and 1976 by department. Table VA gives the names to correspond to the department numbers. The departmental figures in Table V include 100 workers with dual department designations. These were coded to the first listed department. In all, there were 687 active workers 29 inactive workers who had lead monitoring during 1976. The average of their year's average blood lead was 38.3 ug/100 ml whole blood. The distribution in relation to an upper limit of acceptability of 60 ug/100 ml is given in Table VI. About 84% of individual's high values and about 96% of individual's average values were less than 60 ug/100 ml and so would be considered acceptable. This would point to an effective lead monitoring and control program.

Departments 903 - Plate Pasting, 912 - Battery Assembly - Semi-automatic, 925 - Battery Assembly (a part of 912 at the time of the NIOSH study), and 994 - Reclaim, all had average blood lead levels in excess of 45 ug/100 ml whole blood. Departments 911 - Battery Assembly, Private Brand, and 945 - Mac Wheel Area (bus batteries) were included with these departments as "high risk" areas because of the similarity in their process to that in 912.

2) NIOSH Study

a) ZPP screening

The results of the ZPP screening are presented in Table VII. As can be seen the "high risk" group has significantly more workers with ZPPs of 155 ug/100 ml or greater (corresponding to a blood lead of about 51.5 ug/100 ml) and significantly less workers with a ZPP of less than 40 ug/100 ml (corresponding to a blood lead of about 40 ug/100 ml). (Chi square = 52.89; p less than 0.005). The proportion of workers who gave a positive history of possible problems with an elevated blood lead on the initial questioning (either treatment or transfer) increases in the groups with the higher ZPPs. The differences in proportions between the "high risk" groups and the "low-moderate risk" groups with similar ZPP levels are not statistically significant, but the increasing proportion with increasing ZPP level is highly significant. (Chi square = 17.99; p less than 0.005).

On the Phase I screening about one quarter of the workers were eliminated from further study on the basis of a low ZPP. Although even at this low screening level a few workers with blood leads over 60 ug/100 ml (false negatives) could be missed, the company's monitoring program could reasonably be expected to pick them up. As a result of this selection it is not appropriate to directly compare NIOSH lead averages with company monitoring data averages except in those departments where blood leads were done on everyone (the "high risk" departments).

b) Findings by department

Table VIII presents the NIOSH ZPP and blood lead findings by department, along with predicted blood leads based on the ZPP and the number of workers found to have elevated blood lead levels. Because blood leads were not done on all individuals, and because the average exposure over the past few months is really of more interest when studying chronic effects than the exposure on any particular day, the predicted average blood leads probably give a better comparison between departments than will the actual average blood leads. In the case of the five "high risk" departments, the blood leads can be directly compared to each other and to the company's blood monitoring data. For these five departments the NIOSH average was always higher than the company's 1976 monitoring data. However, this difference only averaged about 5 ug lead/100 ml whole blood, a difference which although statistically significant, does not appear consequential considering the variation in blood lead determinations and possible changes in exposure over time. Considering this and the data on laboratory monitoring results presented earlier, it is likely that the laboratory used by the company was reading a little low during part of 1976, however this discrepancy was not sufficiently large to seriously compromise the interpretation of blood lead results if one bears in mind the inexactness of the test for blood lead, and the variability of individual response to accumulation of lead in the body. As mentioned before, the company used laboratory was giving acceptable readings at the time of this study.

With the exceptions of Department 904, which had only one value, and 945, where the value was only slightly higher than predicted, the average of actual blood leads was slightly to appreciably lower than the average of predicted blood leads on the same individuals. This strongly suggests that the exposure to lead had been relatively stable over the preceding 3 or 4 months or had improved somewhat.

The departments chosen as "high risk" based on 1976 company data were found on the NIOSH study to be the ones that had the highest average blood lead levels, both by actual measurement and predicted from the ZPPs. Exceptions are Department 904-Plastic Case Line - with only one worker and Department 901-Grid Molding and Small Parts Molding - which were high on the NIOSH study but not by 1976 company data.

c) Findings by study group

Because of the large number of department designations and the general lack of correlation between symptoms, physical findings, and laboratory results, most of the remaining data is presented by study groups. These groups are based on the three variables addressed in Phase I - ZPP level (low, moderate, high); department ("low-moderate risk", "high risk"); and history of a possible problem with an elevated blood lead in the past (no such history, or possibly such a history). The "comparison group" is a randomly selected sample of the group with a low ZPP from a "low-moderate risk" department, without a history of possible problems with an elevated blood lead. Table IX compares study groups by age, years of employment, log ZPP, and predicted blood lead. The statistically significant differences in mean log ZPP levels are to be expected because ZPP was a selection factor. It is of note that the workers in the "high risk" departments had statistically significantly lower ages and shorter lengths of employment. The differences were not, however, great.

Table X compares the groups by blood lead levels for both Phase II and for Phase III along with the associated predicted blood lead based on the ZPPs of the individuals included in each mean blood lead. In both Phase II and Phase III the "high risk" departments showed statistically significantly higher levels than did the "low-moderate risk" departments. In most groups the predicted mean blood lead level was within 5 ug/100 ml of the actual mean blood lead level. Exceptions were workers with a high ZPP working in a "low to moderate risk" department without a history of problems with elevated blood leads. Their predicted blood leads were higher than their actual levels. This probably represents a decreased exposure in the recent past. On the other hand, workers in "high risk" departments with a history of past problems with elevated blood lead levels had a higher mean level for the actual level than for the predicted level. As the mean lead level did not change greatly over the month between blood lead determinations, this may represent a variable exposure situation or one in which recent exposure had stabilized at a higher level than in the past.

Workers in "high risk"departments without a history of lead level problems who had low-level ZPPs in Phase II had higher actual lead levels than predicted levels. This undoubtably represents a lag between the rising blood lead level and the rising ZPP level. Unfortunately, this group was not represented in Phase III so no comparison can be made between phases. The increase in mean blood lead level between Phase II and Phase III seen in the combined "high risk"departments may represent the result of sampling as there is also a rise in the mean ZPP.

Thus, it appears that most groups were experiencing fairly stable exposures to lead. Exceptions were workers with high ZPPs who were currently in "moderate to low risk"departments who had probably decreased their exposure. Also, those workers with low ZPPs in "high risk" departments and those workers in high risk departments with a history of past problems with lead levels had not had time for their ZPPs to adjust to their current lead levels (which represented some increase over the past).

d) ZPP and lead level findings by history, physical examination, and other laboratory results will be discussed along with these latter categories of results.

c. Findings from the Questionnaires.

1) Phase II Questionnaires.

Phase II questionnaire allowed the workers to mention any health complaints they might have in either of two categories - "Possibly Job Related" or "Other Complaints". In correlating the data, no single complaint by an individual was included in both categories. If the workers indicated some uncertainty as to where it belonged, it was included in the "Possibly Job Related" category. Thus, for any specific complaint, the total number of workers giving the complaint was found by adding together the number of workers in each of the two categories of job relatedness giving the complaint. However, for the overall summaries this was not possible as workers could have some complaint(s) in each category. Table XI relates ZPP levels and blood lead levels to the presence or absence of complaints. The workers with complaints averaged higher ZPPs than those without complaints; at statistically significant levels for "Job Related" complaints or for any complaints. The difference was only possibly significant for other than "Job Related" complaints. The differences were too small to be clinically useful. Lead levels were only possibly statistically higher for any complaint, but insignificantly higher for "Job Related" or other complaints. Again, the difference too small for clinical use.

Table XII breaks out the 20 commonest complaints by study group. In all, there were 168 different complaints, most with only one or two individuals mentioning them. Eighty-three different complaints were mentioned as possibly job related. Of these "top twenty" only a history of being "leaded" or having had toxicity from lead was associated with a statistically significantly higher mean blood lead level. Complaints of muscle spasms or cramps, back pain, and headache had possibly statistically significantly higher mean lead levels.

Complaints associated with statistically significantly higher mean ZPP levels were (in descending order of ZPP level): muscle weakness, arthritis, numbness, stomach problems (except ulcers), and tiredness or fatigue. Back pain was possibly statistically significant.

None of the complaints related significantly to whether the worker was in a "high risk" or "low to moderate risk" department. Where numbers were sufficiently large for comparisons, there were either statistically significant or possibly statistically significant relationships between the grouping by ZPP level for those complaints which were associated with a statistically significant (or possibly significant) elevation of mean ZPP. In the case of arthritis, tiredness fatigue, and back pain the significance was low and moderate ZPP levels versus high levels. In the case of numbness it was low ZPP levels versus moderate or high levels. Headaches, which did not show a statistically significant elevation of mean ZPP levels, did show a statistically significant difference between the low ZPP level groups and the moderate and high level groups. A history of joint pains or pains in the limbs did relate to a history of past lead-level problems. Back pains, however, related to the absence of such a history.

2) Phase III Questionnaire

In the Phase III questionnaire all workers were asked about specific symptoms. Table XIII gives the percentage reporting each symptom by study group, mean ZPP levels and blood lead levels. The comparison group (low ZPPs, "low-moderate risk" department, no history of problems with elevated blood leads) had a statistically significantly lower incidence of irritability than did the rest of the workers. Also, those with a history of lead problems in the past had a statistically significantly higher incidence of constipation. When mean blood levels of ZPP and lead were examined in relation to the presence of symptoms, the complaint of muscle cramps was associated with an elevated mean ZPP and an elevated mean blood lead. In view of a possibly statistically significant relation between this as a spontaneous complaint in Phase II and an elevated blood lead, it would seem that this symptom is probably of some significance in helping to evaluate possible effects from lead exposure.

The other symptom of note associated with a statistically elevated mean ZPP and mean blood lead, was that of cough. As cough is not a symptom of known relationship to lead intoxication, other factors were considered. Coughing also strongly correlated with a history of smoking. Smoking was associated with a statistically significant elevation in mean ZPP. The mean blood lead level of smokers was elevated but not sufficiently to be statistically significant. Assuming that coughing smokers are probably the heavy smokers, it seemed reasonable to look at ZPP and blood lead levels in relation to smoking and coughing status.

The results are shown in Table XIV. The few non-smoking coughers were included with the other non-smokers as they did not appear to differ greatly in ZPP or blood lead level (actually they averaged a little lower in both). The coughing smokers had statistically significantly higher mean ZPPs and mean blood leads than did the non-smokers. Most of the smokers smoked at work (82%) and 79% of those smoking at work did not wash before smoking. Coughing smokers who did not smoke at work did not differ from non-coughing smokers who did not smoke at work in mean ZPP or mean blood lead.

Although most smokers did not wash before smoking (79% of those smoking at work), almost all workers, smokers and non-smokers, washed before eating. Eighty-five percent of the workers showered after work and 81% changed clothes after work (36% at work and 46% on getting home). Of those questioned in Phase III, only 22% were supposed to use respirators at least some of the time, and of these 36 workers (75%) said they did, in fact, use them when they were supposed to.

e. Findings on Physical Examination

Physical findings are presented in Tables XV and XVI. Overall, there was no correlation between findings and study group, mean ZPP or mean blood lead level, except for the slight elevation in mean blood lead level in workers found to have a tremor. This slight elevation was only possibly statistically significant. Combining physical findings and symptoms together failed to yield any combinations with statistically significantly elevated mean ZPPs or mean blood leads.

Only 5 workers were found to have a decrease in ankle strength -- 2 in the comparison group, 1 in another "low-moderate risk" department and 2 in "high risk" departments. This finding did not appear to relate to other physical findings or responses to the questionnaire.

f. Results of Laboratory Tests

Various measurements of red blood cells done in Phase II are presented by study group in Tables XVII and XVIII.

The low ZPP groups had statistically significantly higher mean hemoglobins, hematocrits, mean corpuscular hemoglobins and mean corpuscular hemoglobin concentrations than did the other groups. Conversely, the high ZPP groups had statistically significantly lower mean hemoglobins, mean corpuscular volumes and mean corpuscular hemoglobins.

When workers were grouped by ascending lead levels (Table XIX) there were slight statistically significant increases in red blood cell count and hematocrit with the higher lead levels and decreases in mean corpuscular hemoglobins and mean corpuscular hemoglobin concentrations. Although differences as slight as those shown probably do not have clinical significance by themselves, this does suggest that the lead is having a slight effect on the workers' blood-forming bone marrow. It even suggests that the first effect of interference with hemoglobin production is to increase the number of red cells so that the increased number of cells can compensate for the reduced hemoglobin in each cell to give approximately the same hemoglobin levels in the blood as a whole.

Table XX displays findings on pertinent laboratory tests done in Phase III. One statistically significant difference noted was an elevation of the mean BUN in workers with a history of possible problems with an elevated blood lead level along with a high ZPP. The mean BUN was still well within the range accepted as normal. There was only one urine positive for protein, and this was in a worker in the comparison group. Of the 149 normal urines, 30 showed a trace of protein.

The other statistically significant differences related to mean urine lead levels and both ZPP grouping and departmental "risk" grouping. Those workers in low ZPP groups had a lower mean urine lead than average and those workers in high ZPP groups had a higher mean urine lead. Also those workers in "high risk" departments had a higher mean urine lead than the rest. Table XXA gives additional figures for urine leads.

The urine lead findings help to validate both the ZPP grouping and the departmental "risk" grouping, as the major reason for higher lead excretion would be higher lead exposure.

White blood cell counts had a mean of 7.22 thousand/ul of whole blood and did not relate to study grouping, ZPP or blood lead levels. The standard deviation was 2.004 with a range of 1.6 to 18.0. The free erythrocyte protoporphyrins (FEP) show a mean of 3472 ug/l RBC with a standard deviation of 2663 and a range of 152 to 15652. FEP correlated well with ZPP ($r = 0.90$) with a $p = 0.001$. Because of the high degree of correlation between ZPP and FEP it was felt unnecessary to further present the FEP results.

g. Summary of Results and Discussion

1) The duplicate blood specimens showed only statistically insignificant differences in mean lead levels between the laboratory the company was using in their lead monitoring program and two laboratories NIOSH frequently uses for blood lead analyses. All three laboratories were functioning acceptably on CDC Proficiency Testing Programs at the time of the NIOSH study.

In comparing 1976 company blood lead monitoring data on 5 "high risk" departments to lead levels found on the NIOSH study, NIOSH mean levels for corresponding departments were consistently higher than the means of individual yearly averages from the company data. Although statistically significant, the differences averaged about 5 ug/100 ml whole blood. Further, proficiency testing results from the laboratory used by the company were at the lower limit of acceptability (either just above or just below) during 1976. This suggests the company data for 1976 may have been on the low side, but not sufficiently low to seriously hamper clinical interpretation.

2) The company's lead monitoring program in 1976 showed that about 85% of the workers' blood leads were below 60 ug/100 ml whole blood and about 96% of the individual's average blood lead level were below 60 ug/100 ml even though the target value was 70 ug/100 ml. NIOSH found about 88% below 60 ug/100 ml on blood lead determination in a group of workers somewhat selected towards finding workers with high blood leads.

Considering both points 1) and 2) one can conclude that the company's lead monitoring program was functioning well at the time of the NIOSH study.

3) Although ZPP levels were used in setting up the study groups and were found to give a general indication of expected lead levels, the correlation was not good enough to allow substitution of ZPP monitoring for blood lead monitoring for any department with appreciable lead exposure. It, or an FEP, may well be used in helping evaluate the significance of an individual blood lead reading. (above, at, or below average for recent past.) It could prove valuable (as it has in childhood lead screening) for screening workers in a "no exposure" setting who have had no recent problems with lead.

Utilizing ZPPs to predict blood leads, it would appear that findings at the time of the NIOSH study represented either a relatively stable exposure or a slightly decreased exposure over that of the previous few months.

4) By and large, no significant differences were found between study groups, nor were any frank lead intoxications found. There were some statistically significant findings which may have clinical significance, although this would be more in the nature of "risk factors" than diagnostic entities. However, there were a few specific findings which should be noted.

a) The "high risk" departments as judged by the mean of individual average yearly blood lead data from the company's 1976 data, showed higher mean blood leads by both actual measurement and prediction from ZPP, than did the other departments and also showed statistically significantly higher urinary lead levels.

b) The workers with complaints tended to have higher mean ZPP levels and blood lead levels than those without complaints. The finding was more striking with ZPP than with blood lead as the indicator. Combining significant results from both Phase II and Phase III data, more specific factors which may be associated with an increased ZPP level and/or increased blood lead level were: past history of being "leaded" or having lead toxicity;' muscle cramps; muscle weakness; arthritis; numbness; stomach problems (except ulcers); and tiredness or fatigue. In none of these could the complaint be considered diagnostic, nor could a combination of several of these be considered diagnostic.

c) Utilizing the symptom of cough (Phase III questionnaire) in conjunction with smoking status, it was possible to divide the group into three groups - coughing smokers (presumably the heavy smokers), non-coughing smokers, and non-smokers. The coughing smokers had statistically significantly higher ZPPs and blood lead levels than did the non-smokers. The non-coughing smokers fell in between. Although numbers were not sufficiently large to evaluate the effect of smoking at work as opposed to smoking only away from work, it would appear logical that smoking on the job or carrying smoking materials in lead contaminated areas increases the risk of excess lead absorption.

d) ZPP levels showed an inverse relation to red cell indices. The only relation between blood lead level and red cell measures were a slight increase in red blood cell count and hematocrit and slight decrease in mean corpuscular hemoglobin concentration. This possibly represents a compensatory change induced by lead allowing the hemoglobin to remain unchanged.

F. CONCLUSIONS

Because the body can eliminate absorbed lead only very slowly, and because lead dust can find its way into a worker's mouth and be absorbed from the gut, air monitoring alone has proved insufficient to assure safe working conditions. Thus, it is essential that the company provide an adequate lead monitoring program which includes both air lead determinations and biological monitoring, periodic blood leads being the most reliable method for inorganic lead exposure monitoring with our current knowledge.

In this plant the company was providing a functioning lead monitoring program including both air and blood lead determinations. Further, comparison with the results of our study showed the company results to be adequately reliable.

The only areas in need of improvement are 1) a lowering of acceptable air levels to the recommended standard of 0.10 mg/m^3 with appropriate engineering controls and, if necessary, respiratory protection in areas exceeding this level. 2) a lowering of the upper level of acceptability for blood leads from 80 ug/100 ml to 60 ug/100 ml. By history, it would seem that there is some increase in non-specific symptomatology with increasing ZPP and blood lead levels. Laboratory results showed some changes in red cell indices associated with an increase in blood lead level even in the 50-60 ug/100 ml range. 3) a prohibition of smoking in the work area; nor should smoking materials be allowed into areas where they might pick up lead dust. Lead dust inhaled through a cigarette is in a much more absorbable form than lead dust swallowed. There were increased mean blood lead levels in coughing (so presumably heavy) smokers. 4) a less rigid dependance on blood lead levels in evaluating individuals with clinical problems which might relate to their lead exposure (If the blood lead is not over 80 ug/100 ml, it cannot be due to lead). In about half of twenty workers with medical problems they considered might be due to lead exposure, their medical records supported the possibility.

V. RECOMMENDATIONS:

1) Smoking in lead exposure areas and carrying smoking material or food into lead exposure areas should be prohibited.

2) The air and blood action levels for lead should be brought into conformance with current NIOSH recommendations. (Air levels not over 100 ug/m^3 and blood leads 60 ug/100 ml or less).

3) Blood lead levels should be interpreted a little less rigidly than they have in the past when assessing the possible role of lead in individual worker's medical problems. Blood lead levels remain an important finding in assessing the role of lead as a factor in medical problems.

4) ZPP (or FEP) levels may prove useful in helping to assess the clinical significance of a worker's current blood lead level. Except in low exposure areas where knowledge of the average blood lead over the past 3-4 months is as desirable or more desirable than a single blood lead determination, ZPP is not recommended as a replacement for blood leads for routine screening.

5) Employees should be routinely instructed in correct use and inspection of respirators.

6) There was some confusion and conflict regarding the correct grid mold cleaning procedures. It is recommended that specific maintenance procedures be identified and disseminated to the appropriate employees.

7) The ventilation system in the charging department, in addition to the other areas, should have a lock-out device to prevent unauthorized personnel from turning off the system.

8) It is recommended that the stacker operators tap off excess grid plate paste over the downdraft table and not over the skid.

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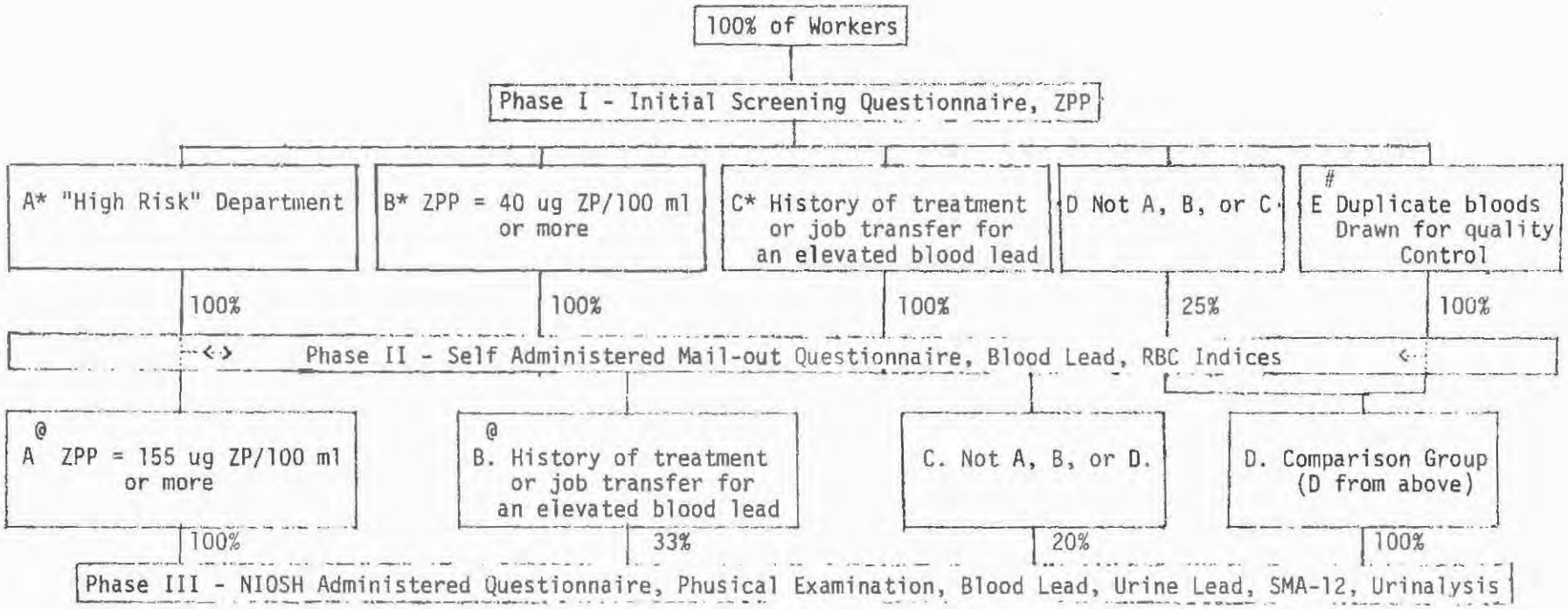
FIGURE I

Flow Diagram of Medical Study Protocol
HE 77-28
Delco Battery
Muncie, Indiana



* A, B, and C. are not mutually exclusive.
\# E is included in one or more of the other categories
@ B does not include any workers who were included in A. A includes some workers who also qualified for B.

TABLE I

Airborne Lead Concentrations

Delco Battery Plant
Muncie, Indiana
February 16-17, 1977

Field Number	Sampling Period	Volume (liters)	Type Sample	Location, Description	Comments	Concentration (mg/M^3) [3]
1	0805-1119	297	A[1]	Dept. 912 cast on machine	Pump fell off counter	0.24
2	0800-1105	270	A	Dept. 905 group inserters		0.10
3	0740-1125	342	A	Dept. 912 stacker operator		0.08
4	0825-1054	225	A	Dept. 903 paste machine at breathing zone of operator		0.23
5	0725-1030	279	P[2]	Dept. 994 old reclaim		0.13
6	0730-1025	270	P	Dept. 994 new reclaim	Pump left on and placed into locker for 10 min.	0.28
7	0831-1040	195	P	Dept. 903 oxide room operator		0.16
8	0837-1104	225	A	Dept. 903 oxide room #3 pot		0.14
9	0700-1125	396	A	Dept. 912 stacker operator		0.07
10	0748-1100	288	A	Dept. 905 stacker operator		0.08
11	1104-1403	270	A	Dept. 903 oxide room #3 pot		0.03
12	1107-1401	285	P	Dept. 903 oxide room operator		0.03
13	1130-1405	232	A	Dept. 912 group repair		0.05
14	-	185	blank	-		<0.03
15	-	195	blank	-		<0.03
16	1127-1415	254	A	Dept. 911 inserter area	Duct work in progress during sampling.	0.06
17	1125-1400	232	P	Dept. 994 new reclaim		0.38
18	1140-1358	202	P	Dept. 994 old reclaim		0.34
19	1145-1420	232	A	Dept. 945 mac wheel area		0.12
20	1057-1413	285	A	Dept. 903 paste machine @ breathing zone of operator @ end of line		0.24
21	1135-1405	225	A	Dept. 905 group pullers		0.08
22	1135-1410	232	A	Dept. 905 battery repair		0.06
23	-	200	blank	-		<0.03

1) A - Area Sample
2) P - Personal Sample
3) mg/M^3 - milligrams of lead per cubic meter of air.

TABLE II

Airborne Lead Concentrations

Delco Battery Plant
Muncie, Indiana

Date	Field Number	Sampling Period (Hrs.)	Sampling Volume (Liters)	Type Sample	Location, Description	Concentration (mg/M^3)[3]
3/21/77	21-1-A	10.0	900	A[1]	Conference Room (ZPP testing)	N.D.[2]
3/21/77	21-1-B	10.0	900	A	Conference Room (ZPP testing)	N.D.
3/21/77	22-1-A	7.0	630	A	Conference Room (ZPP testing)	N.D.
3/21/77	22-1-B	7.0	630	A	Conference Room (ZPP testing)	N.D.
3/21/77	A-51	-	-	Blank	-	N.D.
4/5/77	92	7.8	702	P[4]	Dept. 90. Grid Machine Operator	0.11
4/5/77	2	6.5	585	P	Dept. 90. Grid Machine Operator	0.08
4/5/77	3	6.9	621	P	Dept. 90. Grid Machine Operator	0.07
4/5/77	14	6.5	585	P	Dept. 90. Grid Machine Operator	0.06
4/5/77	5	4.5	405	P	Dept. 90. Grid Machine Operator	0.05
4/5/77	1	6.4	576	P	Dept. 90. Grid Machine Operator	0.11
4/5/77	15	6.4	576	P	Dept. 90. Grid Machine Operator	0.07
4/5/77	106	2.0	180	P	Dept. 90. Grid Machine Operator	0.07
4/6/77	74	6.7	603	P	Dept. 90. Grid Machine Operator	0.30
4/6/77	98	6.5	585	P	Dept. 90. Grid Machine Operator	0.17
4/6/77	104	6.6	594	P	Dept. 90. Grid Machine Operator	0.15
4/6/77	99	6.3	567	P	Dept. 90. Grid Machine Operator	0.30
4/6/77	83	6.5	585	P	Dept. 90. Grid Machine Operator	0.14
4/6/77	73	6.5	585	P	Dept. 90. Grid Machine Operator	0.26
4/6/77	109	6.4	576	P	Dept. 90. Grid Machine Operator	0.15

1) A - Area Sample
2) N.D. - Not Detected
3) mg/M^3 - Milligrams of lead per cubic meter of air.
4) P - Personal Sample

TABLE II (page 2)

Airborne Lead Concentrations

Delco Battery Plant
Muncie, Indiana

Date	Field Number	Sampling Period (Hrs.)	Sampling Volume (Liters)	Type Sample	Location, Description	Concentration (mg/M^3)[2]
4/5/77	35	7.7	693	P[1]	Dept. 903 Paste Machine Operator	0.14
4/5/77	36	7.7	693	P	Dept. 903 Oxide Pot Operator	0.11
4/5/77	37	6.7	603	P	Dept. 903 Mixer Operator	0.20
4/5/77	38	6.0	540	P	Dept. 903 Mixer Operator	0.19
4/5/77	72	-	-	Blank	-	N.D.[3]
4/5/77	33	7.2	648	P	Dept. 903 Brushing Grids	0.12
4/5/77	32	7.3	657	P	Dept. 903 Off Bearer (#1 Machine)	0.06
4/5/77	43	6.7	603	P	Dept. 903 Off Bearer (#4 Machine)	0.09
4/5/77	42	7.1	639	P	Dept. 903 Off Bearer (#8 Machine)	0.08
4/5/77	41	7.0	630	P	Dept. 903 Off Bearer (#8 Machine)	0.12
4/5/77	34	6.9	621	P	Dept. 903 Paste Machine Operator	0.15
4/6/77	60	-	-	Blank	-	N.D.
4/6/77	100	6.7	603	P	Dept. 903 Relief - Off Bearer	0.08
4/6/77	112	6.6	594	P	Dept. 903 Oxide Inspector	0.20
4/6/77	114	6.3	567	P	Dept. 903 Off Bearer (#4 Machine)	0.14
4/6/77	103	6.7	603	P	Dept. 903 Oxide Room Operator	0.07
4/6/77	110	6.2	558	P	Dept. 903 Paste Machine Operator	0.10
4/6/77	108	6.2	558	P	Dept. 903 Shoveling out Hopper	0.09
4/6/77	113	7.0	630	P	Dept. 903 Relief Oxide Operator	0.12
4/6/77	128	6.9	621	P	Dept. 903 Paste Machine Operator	0.12
4/6/77	126	6.8	612	P	Dept. 903 Mixer Operator	0.15
4/6/77	105	6.1	549	P	Dept. 903 Mixer Operator	0.20

1) P - Personal Sample
2) mg/M^3 - Milligrams of lead per cubic meter of air.
3) N.D. - Not Detected

TABLE II (page 3)

Airborne Lead Concentrations

Delco Battery Plant
Muncie, Indiana

Date	Field Number	Sampling Period (Hrs.)	Sampling Volume (Liters)	Type Sample	Location, Description	Concentration (mg/M^3)[2]
4/5/77	13	7.2	648	P[1]	Dept. 905 Stacker	0.03
4/5/77	39	6.7	603	P	Dept. 905 Stacker	0.04
4/5/77	48	7.1	639	P	Dept. 905 Stacker	0.05
4/5/77	45	6.9	621	P	Dept. 905 Inserter	0.04
4/5/77	12	6.8	612	P	Dept. 905 Inserter	0.04
4/5/77	40	7.0	630	P	Dept. 905 Parts Setter	0.03
4/5/77	44	6.5	585	P	Dept. 905 Group Puller	0.05
4/5/77	46	6.4	576	P	Dept. 905 Group Puller	0.05
4/5/77	19	6.5	585	P	Dept. 905 Inserter	0.04
4/5/77	11	6.8	612	P	Dept. 905 Utility Man	0.04
4/5/77	47	6.4	576	P	Dept. 905 Repair Man	0.03
4/6/77	122	5.1	459	P	Dept. 905 Repair Man	0.03
4/6/77	115	6.3	567	P	Dept. 905 Stacker	0.04
4/6/77	86	6.3	567	P	Dept. 905 Stacker	0.05
4/6/77	78	5.9	531	P	Dept. 905 Stacker	0.04
4/6/77	118	6.4	576	P	Dept. 905 Inserter	0.04
4/6/77	121	6.1	549	P	Dept. 905 Inserter	0.07
4/6/77	119	5.8	522	P	Dept. 905 Parts Setter	0.07
4/6/77	120	5.8	522	P	Dept. 905 Group Puller	0.21
4/6/77	85	5.0	450	P	Dept. 905 Group Puller	0.20
4/6/77	116	6.1	549	P	Dept. 905 Inserter	0.06
4/6/77	127	5.0	450	P	Dept. 905 Utility Man	0.06
4/6/77	63	-	-	Blank	-	N.D.[3]

1) P - Personal Sample
2) mg/M^3 - Milligrams of lead per cubic meter of air.
3) N.D. - Not Detected

TABLE II (page 4)

Airborne Lead Concentrations

Delco Battery Plant
Muncie, Indiana

Date	Field Number	Sampling Period (Hrs.)	Sampling Volume (Liters)	Type Sample	Location, Description	Concentration (mg/M^3)[2]
4/5/77	123	5.5	495	A[1]	Dept. 907 Charging	0.02
4/5/77	124	5.3	477	A	Dept. 907 Charging	0.04
4/6/77	107	3.3	297	A	Dept. 907 Charging	0.06
4/6/77	117	3.3	297	A	Dept. 907 Charging	N.D.[3]
4/5/77	27	5.6	504	P[4]	Dept. 911 Inspector	0.02
4/5/77	22	6.5	585	P	Dept. 911 Repairman	0.03
4/5/77	23	6.2	558	P	Dept. 911 Re-builder	0.04
4/5/77	17	6.4	576	P	Dept. 911 Inserter	0.10
4/5/77	20	6.1	549	P	Dept. 911 Stacker	0.05
4/5/77	125	4.2	378	P	Dept. 911 Re-builder	0.04
4/5/77	55	-	-	Blank	-	N.D.
4/6/77	53	5.5	495	P	Dept. 911 Stacker	0.04
4/6/77	81	5.9	531	P	Dept. 911 Inspector	0.02
4/6/77	76	5.9	531	P	Dept. 911 Extrusion/Fusion Repairman	0.02
4/6/77	82	6.0	540	P	Dept. 911 Re-builder	0.03
4/6/77	75	5.4	486	P	Dept. 911 Inserter	0.05
4/6/77	77	6.0	540	P	Dept. 911 Stacker	0.10
4/5/77	26	6.3	567	P	Dept. 912 Stacker	0.05
4/5/77	25	6.2	555	P	Dept. 912 Cast on Strap Operator	0.12
4/5/77	31	6.7	600	P	Dept. 912 Cast on Strap Operator	0.12
4/5/77	7	6.6	595	P	Dept. 912 Cast on Strap Operator	0.03

1) A - Area Sample
2) mg/M^3 - Milligrams of lead per cubic meter of air.
3) N.D. - Not Detected
4) P - Personal Sample

TABLE II (page 5)

Airborne Lead Concentrations

Delco Battery Plant
Muncie, Indiana

Date	Field Number	Sampling Period (Hrs.)	Sampling Volume (Liters)	Type Sample	Location, Description	Concentration (mg/M^3)[2]
4/5/77	9	6.2	561	P[1]	Dept. 912 Battery Repairman	0.04
4/5/77	30	6.3	568	P	Dept. 912 Battery Re-builder	0.04
4/5/77	68	-	-	Blank	-	N.D.[3]
4/5/77	66	-	-	Blank	-	N.D.
4/6/77	93	7.0	627	P	Dept. 912 Utility Man	0.06
4/6/77	96	5.7	513	P	Dept. 912 Truck Operator, Stocker	0.13
4/6/77	84	5.5	496	P	Dept. 912 Fast Stacker	0.06
4/6/77	95	6.2	555	P	Dept. 912 Cast on Strap Operator	0.11
4/6/77	94	6.0	541	P	Dept. 912 Battery Repair	0.03
4/6/77	88	5.5	498	P	Dept. 912 West Stacker	0.07
4/6/77	90	6.1	549	P	Dept. 912 Battery Re-builder	0.03
4/6/77	91	6.2	559	P	Dept. 912 Cast on Strap Operator	0.03
4/6/77	89	6.3	570	P	Dept. 912 Cast on Strap Operator	0.14
4/5/77	8	6.4	584	P	Dept. 912 Stacker/Utility Man	0.05
4/5/77	4	6.3	569	P	Dept. 912 Trucker/Stacker	0.07
4/5/77	6	6.2	562	P	Dept. 912 Stacker	0.07
4/5/77	28	7.1	639	P	Dept. 945 Rotational Position	0.05
4/5/77	24	6.7	603	P	Dept. 945 Rotational Position	0.03
4/5/77	18	7.4	666	P	Dept. 945 Rotational Position	0.03
4/5/77	16	7.3	657	P	Dept. 945 Rotational Position	0.05
4/5/77	21	7.4	666	P	Dept. 945 Rotational Position	0.04

1) P - Personal Sample
2) mg/M^3 - Milligrams of lead per cubic meter of air.
3) N.D. - Not Detected

TABLE II (page 6)

Airborne Lead Concentrations

Delco Battery Plant
Muncie, Indiana

Date	Field Number	Sampling Period (Hrs.)	Sampling Volume (Liters)	Type Sample	Location, Description	Concentration (mg/M^3)[2]
4/6/77	49	6.5	585	P[1]	Dept. 945 Rotational Position	0.01
4/6/77	80	5.9	531	P	Dept. 945 Rotational Position	0.02
4/6/77	87	6.4	576	P	Dept. 945 Rotational Position	0.02
4/6/77	54	6.2	558	P	Dept. 945 Rotational Position	0.02
4/5/77	97	3.6	324	P	Dept. 954 Truck Operator (Old Reclaim)	0.21
4/5/77	111	2.3	207	P	Dept. 954 Truck Operator (Old Reclaim)	0.10
4/5/77	101	2.4	216	P	Dept. 954 Truck Operator (Old Reclaim)	0.23
4/5/77	10	3.1	279	P	Dept. 954 Truck Operator (New Reclaim)	0.05
4/6/77	102	5.9	531	P	Dept. 954 Truck Operator (Old Reclaim)	0.24
4/6/77	79	6.7	603	P	Dept. 954 Truck Operator (New Reclaim	0.23

1) P - Personal Sample
2) mg/M^3 - Milligrams of lead per cubic meter of air.

TABLE III
Proficiency Testing for Laboratories
Doing Blood Leads
HHE 77-28
Delco Battery
Muncie, Indiana

Test Batch	Specimen Number	CDC Mean	Acceptable Range	Bio-Industrial	MDS	UBTL
	Bureau of Laboratories Proficiency Testing Program Center for Disease Control (CDC)					
'76-I	6.01	77.7	65.0-89.2	68.7	-	-
	6.05	61.1	51.9-70.3	52.0	-	-
	6.09	22.5	16.5-28.5	19.7	-	-
'76-II	6-10	96.0	81.6-110.4	82.3	-	-
	6-14	79.4	67.5-91.3	69.3	-	-
	6-18	65.9	56.0-75.8	50.3*	-	-
'76-III	6-19	98.7	83.9-113.5	-	95	-
	6-23	62.0	52.7-71.3	-	52*	-
	6-24	29.0	23.0-35.0	-	31	-
'76-IV	D76-41	50.1	42.6-57.6	37.0*	52	-
	D76-42	56.8	48.3-65.3	43.0*	55	-
	D76-43	58.7	49.8-67.4	48.7*	-	-
'77-I	DE7-A01	16.6	10.6-22.6	18.0	22	-
	DE7-A02	48.2	41.0-55.4	41.0	42	-
	DE7-A03	54.6	46.4-62.8	49.0	61	-
	Childhood Lead Screening Program Proficiency Testing Program (CDC)					
Dec., '76	6-28	35.0	--	-	-	36
	6-33	50.8	--	-	-	56
	6-34	23.2	--	-	-	26
Jan., '77	All three samples satisfactory (figures not available).					
Feb., '77	7-1	29.5	23.5-35.5	-	-	29
	7-3	47.3	40.2-54.4	-	-	46
	7-5	40.0	34.0-46.0	-	-	34

* Unacceptable values

Units: ug lead/100 ml whole blood

Bio-Industrial - Bio-Industrial Laboratories, Gadsden, Alabama
MDS - Medical Diagnostic Services-Ohio Valley, Cincinnati, Ohio
UBTL - Utah Biomedical Test Laboratory, Salt Lake City, Utah

TABLE IV
Comparison of ZPP-Blood Lead Regression Lines
HHE 77-28
Delco Battery
Muncie, Indiana
March 21-23, 1977

Study Group and Formula Blood Lead = b x logZPP + c b is the slope	Number	Mean LogZPP	Corresponding ZPP	Range	Mean Blood Lead	Range	Correlation Coefficient	Mean Square for Error	95% Confidence Limits of Slope
Men All Studies									
Blood Lead = 17.02 x logZPP + 14.14	49	1.8674	73.7	5.3-404.3	45.9	30.3-70.6	0.86	18.86	± 2.91
(Based on 669 individual values averaged to 49 points.)	669			-4 to +627		10 to 99			
Men - Delco Battery									
Results from NIOSH study on all men (workers and NIOSH controls.)									
Blood Lead = 15.94 x logZPP + 16.39	388	1.8114	64.8	-4 to +627	45.3	10 to 99	0.45	182.66	± 3.19
Average of 1976 company blood monitoring results plus results from NIOSH study.									
Blood Lead = 15.62 x logZPP + 14.26	249	1.8320	67.9	1-627	42.9	18.6-73.5	0.63	68.40	± 2.40
Results on these same workers from NIOSH Study only.									
Blood Lead = 16.31 x logZPP + 16.02	249	1.8320	67.9	1-627	45.9	10-99	0.47	177.35	± 3.87

Units: ZPP is in ug zinc protoporphyrin/100 ml whole blood with an assumed hematocrit of 42%
Blood lead is in ug/100 ml whole blood

TABLE V
Mean Blood Lead and Air Lead Levels by Department
Based on Company Monitoring Data
HHE 77-28
Delco Battery
Muncie, Indiana
March 21-23, 1977

Dept	Year	Blood Lead Measurements (Average of Individual Averages; ug/100 ml whole blood)								Air Lead Measurements* (Average for year; ug/m^3)		
		Males					Females					
		N #	MEAN	SD #	MIN	MAX	N #	MEAN	SD #	N#	MEAN	SD#
901	74	86	46.0	5.22	37.5	62.7				15	164.2	81.64
	75	81	41.2	4.79	29.5	54.1				9	126.8	37.63
	76	84	42.9	9.45	22.0	67.0				*21	136.2	80.75
902	74	20	42.4	7.48	30.0	55.0						
	75	34	35.7	5.96	28.0	50.5						
	76	34	26.1	9.06	14.0	47.6						
903	74	116	48.1	5.09	35.0	61.7	6	40.9	6.42	33	163.3	51.10
	75	98	44.7	4.86	33.0	56.2				17	163.3	47.24
	76	93	47.9	10.10	21.0	70.7				*33	147.9	75.77
904	74	1	42.3									
	75	1	44.3									
	76											
905	74	147	46.7	4.81	37.8	66.4	11	40.8	4.68	34	141.8	50.21
	75	88	42.4	5.53	28.0	54.0	1	35.0		15	88.5	40.93
	76	75	41.2	9.14	24.5	65.8				*58	87.4	52.15
906	74	3	43.3	5.34	37.5	48.0						
	75	2	37.8	4.60	34.5	61.0						
	75	2	26.8	5.89	22.7	31.0						
907	74	13	43.4	8.72	29.0	57.0						
	75	26	40.7	7.94	30.0	62.0						
	76	25	27.9	11.00	15.0	64.0						

TABLE V (cont.)

Dept.	Year	Blood Lead Measurements (Average of Individual Averages; ug/100 ml whole blood)								Air Lead Measurements* (Average for year; ug/m^3)		
		Males					Females					
		N #	MEAN	SD #	MIN	MAX	N#	MEAN	SD#	N#	MEAN	SD#
908	74	12	42.8	7.37	33.5	57.0				3	23.7	5.10
	75	11	38.7	3.80	33.7	45.0				3	41.2	12.05
	76	11	27.7	8.09	16.3	46.0				*10	48.9	19.73
909	74	15	41.2	4.87	33.8	54.5				6	46.6	46.23
	75	13	39.3	5.67	30.0	47.3				6	29.5	26.24
	76	15	29.7	7.74	21.0	53.0				*20	25.9	14.22
910	74	30	44.3	5.00	35.0	53.0	1	45.3				
	75	26	39.8	4.35	29.0	47.5						
	76	20	28.3	7.69	18.0	45.8						
911	74	7	47.3	3.21	43.4	52.6						
	75	8	42.1	4.27	36.8	49.3						
	76	11	40.6	9.47	25.7	56.5				*37	64.7	44.00
912	74	48	45.6	4.87	36.3	58.3	1	45.0		24	175.5	55.45
	75	54	41.5	4.35	33.0	52.2				25	131.9	54.84
	76	35	45.9	10.23	32.6	70.4				*45	72.2	49.66
920	74	1	38.0									
	75	1	39.0									
	76	1	14.5									
925	74	16	47.3	4.39	40.0	56.0						
	75	3	45.9	3.17	42.7	49.0						
	76	3	53.1	9.60	42.0	59.2						
935	74	1	55.5									
	75											
	76											

TABLE V (cont.)

Dept.	Year	Blood Lead Measurements (Average of Individual Averages; ug/100 ml whole blood)								Air Lead Measurements* (Average for year; ug/m^3)		
		Males					Females			N#	MEAN	SD#
		N #	MEAN	SD #	MIN	MAX	N #	MEAN	SD #			
945	74	22	44.9	4.86	36.0	58.0	2	45.6	1.66	8	70.0	32.46
	75	19	40;9	3.83	34.5	48.0				13	35.2	21.06
	76	20	39.6	6.96	28.0	50.0				*29	54.4	44.16
948	74	15	42.0	4.04	35.0	47.8						
	75	12	38.3	2.68	34.0	42.3						
	76	14	29.6	5.54	17.0	37.0						
974	74	52	45.1	5.84	31.0	58.0	3	38.7	1.15			
	75	49	38.9	5.00	29.0	55.0						
	76	49	37.2	11.14	17.0	60.8						
990	74	56	43.0	7.09	31.1	58.0	No Females					
	75	61	39.3	6.09	29.0	59.7	"					
	76	60	29.9	12.04	13.0	66.0	"					
991	74	4	47.0	4.80	41.0	51.7	"					
	75	4	38.2	5.66	31.0	43.0	"					
	76	4	24.0		18.0	32.0	"					
993	74	71	45.9	7.10	26.5	62.0	"					
	75	67	41.3	6.67	28.5	61.0	"					
	76	67	39.4	9.09	22.0	69.0	"					
994	74	19	50.9	3.63	41.7	57.7	"			4	338.0	41.24
	75	16	44.6	3.26	40.0	51.0	"			2	202.1	9.90
	76	14	47.7	7.30	34.0	56.1	"			*2	227.2	148.14
995	74	44	44.8	5.83	35.7	58.0	"					
	75	43	40.9	5.75	25.5	52.0	"					
	76	43	36.5	9.30	18.0	58.0	"			*2	39.2	18.74
998	74	29	43.9	5.13	34.5	55.0	"					
	75	37	40.8	4.86	32.0	54.5	"					
	76	36	32.4	9.73	18.0	64.0	"			*2	35.0	35.35

*NOTE: '74 and '75 are mobile area samples, '76 is back-pack personal
# N = number of workers (blood) or samples (air)
SD = standard deviation

TABLE VA
Departments
HHE 77-28
Delco Battery
Muncie, Indiana
March 21-23, 1977

Department Number	Department Name
901	Grid Mold and Small Parts Molding
902	Case and Cover Molding
903	Plate Pasting
904	Plastic Case Line (not operating in 1976)
905	Battery Assembly
906	Dynacast
907	Battery Charging
908	Battery Washer and Jet Dryers
909	Automatic Battery Assembly Line
910	Ordinance, p29 and Hand Line
911	Battery Assembly - Private Brand
912	Battery Assembly - Semi-automatic (Formerly Dept. 925) Plastic Cases
920	Process Engineering (Inactive now)
923	Engineering
925	Combined with Dept. 912
926	Engineering
935	Personnel
945	Mac Wheel Area (Bus batteries)
948	Permanizer, Charge Conveyor and Storage Conveyor Area
950	Plant Protection
974	Inspection
990	Process Shop and Tool Room
991	Tool Crib
993	Maintenance
994	Reclaim - New and Old
995	Laborers and Janitors
998	Material Handling

TABLE VI
Distribution of Lead Levels in 1976 Based on Company Monitoring Data
HHE 77-28
Delco Battery
Muncie, Indiana
March 21-23,1977

Blood Lead Level	All Tests	Values for Individual Workers	
		Individual High Values	Individual Year's Average Values
Number	2009	687	687
ug Lead/100 ml whole blood			
Under 60	89.2%	83.6%	95.6%
60-69	7.8	10.3	3.8
70-79	2.3	4.8	0.6
80-89	0.5	0.9	0
90+	0.2	0.4	0

TABLE VII
ZPP Screening Results
HHE 77-28
Delco Battery
Muncie, Indiana
March 21-23, 1977

ZPP Screening	Low to Moderate Risk Departments				High Risk Departments				Totals$	
µg ZP/100 ml whole blood	History of Possible Blood Lead Problem				History of Possible Blood Lead Problem					
	No		Yes @	Total @	No	Yes @	Total @			
	Blood Lead Not Done	Done								
Less than 40 "Low"	133#	44*	13 (6.8%)	190 (48.1%)	24	2 (7.6%)	26	(21.0%)	216	(41.6%)
Equal to or greater than 40, less than 155 "Moderate"	#	148	28 (15.9%)	176 (44.6%)	52	10 (16.1%)	62	(50.0%)	238	(45.9%)
Equal to or greater than 155 "High"	0	19	10 (34.4%)	29 (7.3%)	29	7 (19.4%)	36	(29.0%)	65	(12.5%)
Totals	133	211	51 (12.9%)	395 (100%)	105	19 (15.3%)	124	(100%)	519	(100%)

*These 44 workers were included in Phases II and III as a comparison group.
#For 8 workers the exact ZPP was not available, 5 were less than 40 µg/100 ml and 3 were in the 50-59 µg/100 ml range. 5 of these workers had subsequent blood leads, all less than 50 µg/100 ml. These 8 are not included in totals.

@% of Total in the same "risk" and ZPP category
$% of Total in study.

All workers were men. 94% were white, 5% non-white, 1% unstated.

TABLE VIII
Summary of NIOSH ZPP and Blood Lead By Department
HHE 77-28
Delco Battery
Muncie, Indiana
March 21-23, 1977

Dept.	Number	Average ZPP ug ZP/100 ml	Predicted Average Blood Lead ug/100 ml	Blood Lead Values Found 60-79 ug/100 ml		80+ ug/100 ml		Actual Average Blood Lead ug/100 ml	(n)	Predicted Average Blood Lead for These Individuals ug/100 ml
				Number	%	Number	%			
901	53	105.6	50.5	5	9	2	4	49.4	46	51.3
902	24	40.8	43.5	0	0	0	0	36.5	16	45.7
903*	50	155.3	53.4	9	18	0	0	49.5	47	53.4
904	1	92	49.5	1	100	0	0	65	1	49.5
905	55	84.5	48.9	5	9	3	5	47.6	46	50.0
906	1	39	43.2	0	0	0	0	23	1	43.2
907	28	51.4	45.2	3	11	0	0	43.7	15	48.9
908	10	30.0	41.2	0	0	0	0	31.2	4	44.4
909	14	29.9	41.2	0	0	0	0	39.7	7	42.3
910	13	34.9	42.3	1	8	0	0	47.2	4	48.4
911*	13	95.3	49.8	1	8	1	8	48.5	12	49.8
912*	37	100.3	50.2	7	19	3	8	48.5	35	50.2
945*	10	64.1	46.8	4	40	0	0	49.3	10	46.8
948	9	17.8	37.4	0	0	0	0	33.6	5	37.7
974	22	48.1	44.7	0	0	0	0	34.7	14	47.0
990	44	42.0	43.7	0	0	0	0	33.5	21	47.1
991	3	17.3	37.2	0	0	0	0	38	1	-
992	1	3	24.2	-	-	-	-	-	0	-
993	55	82.3	48.7	7	13	1	2	48.4	44	49.7
994*	7	221.1	56.0	1	14	0	0	52.1	7	56.0
995	34	70.6	47.6	1	3	0	0	41.2	24	48.8
998	25	45.5	44.3	0	0	0	0	37.1	14	46.8
Total Plant	519#	79.9	48.5	46	9	10	2	45.3	384#	49.4 (n= 383)

Totals include 10 workers with dual department designations

* Departments in which all workers were to be included in Phase II. Considered High Risk based on 1976 Company blood lead monitoring data.

TABLE IX
Comparison of Age, Length of Employment,
ZPP and Predicted Blood Lead by Study Groups
HHE 77-28
Delco Battery
Muncie, Indiana
March 21-23, 1977

Study Group	Number	Age			Years of Employment			Log ZPP (ug ZP/100 ml Whole Blood)			Antilog of Log ZPP		Predicted Blood Lead (ug/100 ml)
		Mean	St. Dev.	95% Conf. Limits	Mean	St. Dev.	95% Conf. Limits	Mean	St.Dev.	95% Conf. Limits	Mean	3 Confidence Limits	Mean
No History of Possible Lead Problem on Initial Interview													
Comparison	44	46.2	9.42	± 2.9	20.9	6.19	± 1.9	1.2410*	0.3202	± 0.0973	17.4	13.9 - 21.8	35.3
Other low ZPP, low-mod risk dept	133	46.4	8.26	± 1.4	21.4	7.26	± 1.2	1.2597*	0.2774	± 0.0476	18.2	16.3 - 20.3	35.6
Low ZPP, high risk dept.	24	42.4	9.05	± 3.8	19.1	5.08	± 2.1	1.3399*	0.1991	± 0.0840	21.9	18.0 - 26.5	36.9
Total low ZPP	201	45.8	8.67	± 1.2	21.0	6.82	± 0.9	1.2652	0.2797	± 0.0389	18.4	16.8 - 20.1	35.7
Mod. ZPP, low-mod risk dept.	148	44.5	8.90	± 1.4	21.3	7.55	± 1.2	1.8320*	0.1542	± 0.0251	67.9	64.1 - 72.0	45.3
Mod ZPP, high risk dept.	52	43.1*	6.27	± 1.8	20.0	4.90	± 1.4	1.8917*	0.1768	± 0.0493	77.9	69.6 - 87.3	46.3
Total mod. ZPP	200	44.1	8.30	± 1.2	20.9	6.96	± 1.0	1.8475*	0.1621	± 0.0226	70.4	66.8 - 74.1	45.6
High ZPP, low-mod risk dept.	19	46.7	9.01	± 4.3	22.2	6.71	± 3.2	2.4148*	0.1386	± 0.0668	259.9	222.8 -303.1	55.2
High ZPP, high risk dept.	29	44.2	7.52	± 2.9	20.6	5.01	± 1.9	2.4225*	0.1486	± 0.0565	264.5	232.3 -301.3	55.4
Total high ZPP	48	44.9	8.09	± 2.4	21.2	5.73	± 1.7	2.4195*	0.1433	± 0.0417	262.7	238.7 -289.2	55.3
History of Possible Lead Problem on Initial Interview													
Low-mod. ZPP, low-mod risk dept.	41	48.2*	8.33	± 2.6	22.6	5.83	± 1.8	1.6931	0.4162	± 0.1318	49.3	36.4 - 66.8	43.0
Low-mod. ZPP, high risk dept.	12	42.4	7.28	± 4.6	20.0	4.13	± 2.6	1.8152	0.2112	± 0.1347	65.3	47.9 - 89.1	45.0
Total low-mod ZPP	53	46.9	8.41	± 2.3	22.0	5.56	± 1.5	1.7207	0.3813	± 0.1053	52.6	41.2 - 67.0	43.4
High ZPP, low-mod risk dept.	10	50.6	7.55	± 5.4	22.8	5.45	± 3.9	2.4609*	0.0773	± 0.0553	289.0	254.4 -328.2	56.0
High ZPP, high risk dept.	7	43.9	3.29	± 3.0	22.9	2.12	± 2.0	2.4861*	0.1178	± 0.1090	306.3	238.3 -393.6	56.5
Total high ZPP	17	47.8	6.91	± 3.6	22.8	4.29	± 2.2	2.4713*	0.0934	± 0.0481	296.0	265.0 -330.7	56.2
Total	519	45.3	8.44	± 0.7	21.2	6.64	± 0.6	1.6824	0.4539	± 0.0391	48.1	44.0 - 52.7	42.8
Total low-mod risk dept.	395	45.8	9.03	± 0.9	21.4	7.16	± 0.7	1.5986*	0.4432	± 0.0439	39.7	35.9 - 43.9	41.7
Total high risk dept.	124	43.2*	7.05	± 1.3	20.1*	4.79	± 0.9	1.9352*	0.4179	± 0.0743	86.1	72.6 -102.2	47.1

*Statistically significantly different from mean of total study groups at a = 0.05

TABLE X ·
Comparison of Observed and Predicted Blood Leads
(ug/100 ml whole blood) by Study Groups
HHE 77-28
Delco Battery
Muncie, Indiana

Study Group	Blood Leads of 3/21-23/77 Number	Mean	Std. Dev.	95% Conf. Limits	Predicted@	Blood Leads of 4/25-27/77 Number	Mean	Std. Dev.	95% Conf. Limits	Predicted@
No History of Possible Lead Problem on Initial Interview										
Low ZPP										
Comparison low-moderate risk dept.	43	34.4*	9.25	± 2.8	35.2	44	31.4*	10.12	± 3.1	35.3
High risk dept.	22	44.8	15.21	± 6.7	36.9					
Total low ZPP	65	37.9*	12.51	± 3.1	35.8					
Moderate ZPP										
Low-moderate risk dept.	144	44.3	12.89	± 2.1	45.2	27	49.6	14.64	± 5.8	45.7
High risk dept.	50	47.6	12.75	± 3.7	46.7	12	44.7	10.19	± 6.5	45.7
Total moderate ZPP	194	45.2	13.11	± 1.8	45.6	39	48.1	13.48	± 4.4	45.7
High ZPP										
Low-moderate risk dept.	19	50.2	13.34	± 6.4	55.2	17	48.0	9.58	± 5.1	55.3
High risk dept.	28	51.6*	14.09	± 5.5	55.3	26	58.6*	13.38	± 5.4	55.1
Total high ZPP	47	51.0*	13.67	± 4.0	55.3	43	54.4*	13.07	± 4.0	55.2
History of Possible Lead Problem on Initial Interview										
Low-moderate ZPP										
Low-moderate risk dept.	41	44.7	16.06	± 5.1	43.0	16	38.2*	10.28	± 5.5	41.8
High risk dept	12	56.4	15.71	±10.0	45.1	3	72.3	14.14	±37.6	48.0
Total low-mod ZPP	53	47.4	16.59	± 4.6	43.4	19	43.6	16.65	± 8.0	42.8
High ZPP										
Low-moderate risk dept.	10	56.4	14.95	±10.7	56.0	9	58.9*	12.88	± 9.9	56.1
High risk dept.	7	69.1*	22.50	±20.8	56.5	7	71.4*	7.66	± 7.1	56.5
Total high ZPP	17	61.6*	18.90	± 9.7	56.2	16	64.4*	12.38	± 6.6	56.3
TOTAL	376	45.7	14.65	± 1.5	45.2	161	46.3	16.55	± 2.6	46.1
Total low-mod. risk dept.	257	43.5*	14.04	± 1.7	44.4	113	41.4*	14.73	± 2.7	43.4
Total high risk dept.	119	50.2*	15.52	± 2.8	47.1	48	57.9*	14.89	± 4.3	52.5

@ Based on ZPPs done 3/21-23/77
* Statistically significantly different from mean of total study groups at a=0.05

TABLE XI
Comparison of Complaints on Phase II Questionnaire
with Mean ZPP and Blood Lead Levels
HHE 77-28
Delco Battery
Muncie, Indiana
March 21-23, 1977

Category of Complaint	ZPP (ug ZP/100 ml whole blood)			Blood lead (ug/100 ml whole blood)		
	Number	Mean ZPP	Probability*	Number	Mean ZPP	Probability*
Total Workers	346	104.2	-	337	45.6	-
No "Job Related" Complaints	212	94.7	0.01	207	45.7	greater than 0.1
"Job Related" Complaints	134	119.4		130	45.6	
No Other Complaints	170	96.7	0.09	165	44.9	greater than 0.1
Any Other Complaints	176	111.5		172	46.3	
No Complaints	108	83.0	less than 0.005	106	43.8	0.06
Any Complaints	238	113.9		231	46.5	

*This column gives the statistical probability that the difference between the means is due to chance alone. A probability of greater than 0.1 is considered to show that the difference between the means is statistically insignificant. A probability between 0.1 and 0.05 is considered possibly significant and a probability of 0.05 or less is considered statistically significant.

TABLE XII
Complaints on Phase II Questionnaires Compared to Mean ZPP
mean blood lead levels, risk group, zpp level group,
and History of Problems with Lead on Phase I Questionnaires

HHE 77-28
Delco Battery
Muncie, Indiana
March 21-23, 1977

Complaint	Total Number with Complaint	%	% "Job Related" $$	Mean ZPP ug/100 ml	Mean Blood Lead ug/100 ml	Risk Group Low-Moderate	Risk Group High	ZPP Group Low	ZPP Group Moderate	ZPP Group High	History of Past Lead Problems Phase I None %	History of Past Lead Problems Phase I Yes %
Total Number of Workers in Group	346	100		104.2	45.6 (n=337)	237 (68.5%*)	109 (31.5%*)	76 (22.0%*)	205 (59.2%*)	65 (18.8%*)	287 (82.9%*)	59 (17.1%*)
"Job Related"	134	38.7		119.4#	45.6 (n=130)	38.0	40.4	25.0#¢	41.0#¢	47.7#¢	35.2#	55.9#
Other	176	50.9		111.5@	46.3 (n=172)	51.9	48.6	56.6#&	45.4#&	64.6#&	50.5	52.5
Any	238	68.8		113.9#	46.5@ (n=231)	68.4	69.7	65.8#&	65.9#&	84.6#&	66.2	81.4
Hypertension, Hypertensive Heart Disease, Elevated Blood Pressure	53	15.3	19	109.8	45.2	15.2	15.6	22.4@	12.2@	16.9@	14.3	20.3
Tired, Fatigued	45	13.0	80	150.2#	45.3	11.8	15.6	5.3#&	12.2#&	24.6#&	12.2	16.9
Joint Pains	44	12.7	93	119.1	44.2	12.2	13.8	6.6	13.7	16.9	11.1**	20.3**
Nervousness, Irritability	39	11.3	67	105.0	39.3	12.2	9.2	10.5	11.2	12.3	10.8	13.6
Arthritis	25	7.2	20	169.7#	46.7	6.3	9.2	1.3#&	5.9#&	18.5#&	6.6	10.2
Pain in Limbs	21	6.1	71	124.8	44.4	5.1	8.3	6.6	4.9	9.2	4.2#	15.3#
Back Pain	18	5.2	67	146.0@	45.4@	5.1	5.5	4.5@	4.4@	10.8@&	6.3@	0@

TABLE XII (cont.)

Complaint	Total Number with Complaint	%	% "Job Related" $$	Mean ZPP ug/100 ml	Mean Blood Lead ug/100 ml	Risk Group Low-Moderate %	Risk Group High %	ZPP Group Low %	ZPP Group Moderate %	ZPP Group High %	History of Past Lead Problems Phase I None-%	History of Past Lead Problems Phase I Yes-%
Headaches	18	5.2	78	132.3	41.4@	4.6	6.4	0#¢	4.6#¢	7.7#¢	4.5	8.5
Leaded, Lead Toxicity	15	4.3	100	85.1	55.5#	3.8	5.5	5.3	4.9	1.5	0.3#$	23.7#$
Muscle spasms and/or Cramps	15	4.3	100	144.0	52.9@	4.2	4.6	3.9	3.4	7.7	3.5	8.5
Numbness	14	4.0	86	167.4#	49.1	3.8	4.6	0@¢	3.9@¢	9.2@¢	3.8	5.1
Sinus Trouble	14	4.0	7	103.3	47.4	4.6	2.8	7.9	2.0	6.2	4.2	3.4
(For the following diagnoses the numbers are too small to make statistically meaningful comparisons between groups)												
Stomach Problems (except ulcers)	13	3.8	62	164.8#	49.5	3.4	4.6	0	3.4	9.2	3.5	5.1
Diabetes	11	3.2	0	61.3	44.3	3.8	1.8	2.6	4.4	0	3.1	3.4
Constipation	11	3.2	91	131.4	44.8	2.5	4.6	1.3	3.4	4.6	2.4	6.8
Stiff Joints	11	3.2	91	79.1	45.4	3.8	1.8	1.3	4.4	1.5	3.5	1.7
Back Trouble	11	3.2	27	86.5	51.6	3.8	1.8	2.6	3.9	1.5	3.1	3.4
Muscle Weakness	9	2.6	78	185.8#	49.0	2.1	3.7	0	2.4	6.2	2.1	5.1
Abdominal Cramps	9	2.6	100	133.4	44.1	1.3	5.5	1.3	2.4	4.6	2.1	5.1
Kidney Infections	9	2.6	22	114.8	48.9	3.4	0.9	2.6	2.4	3.1	2.1	5.1

TABLE XII (cont.)

* The % in parentheses represents the % that group of the total number of workers.

These differences are statistically significant (Probability of the differences being due to chance is 0.05 or less).

@ These differences are possibly statistically significant (probability 0.05 to 0.1). However, because 20 items are being considered in this table a few values should fall into this range by chance alone. Without other indications of significance these values would not be considered even possibly statistically significant.

& Low + Moderate ZPP vs. High ZPP.

¢ Low ZPP vs. Moderate + High ZPP

$ This response is related to the distinction between those with a history of problems with lead as reported on Phase I questioning. Theoretically the "No History" group should have had 0% mentioning this and the "History" group up to 100%.

** Although this difference is only possibly significant, if only the "Job Related" joint pains are considered (10.1% without history of past lead problems, 20.3% with such a history) the difference becomes statistically significant.

$$ The % of those with a particular complaint who felt it might be "Job Related."

TABLE XIII

Delco Battery
Muncie, Indiana
HE 77-28

April 25-27, 1978

Comparison of Percent of Workers Reporting Symptoms on Phase III Questionnaire by Study Group

Study Group	Number	Sleep Problems	Unusual Tiredness	Dizziness	Irritability*	Poor Memory	Headaches	Muscle Weakness	Muscle Cramps	Tremors
No History of Possible Lead Problem on Initial Interview										
Low ZPP Comparison	44	27	45	11	16#	21#	36	25	20	14
Moderate ZPP Low-moderate risk Department	27	26	44	19	48	22	33	7	30	15
High risk Department	12	25	67	8	33	8	17	17	33	8
Total	39	26	51	15	44	18	28	10	31	13
High ZPP Low-moderate risk Department	18	22	44	33	22	22	17	11	28	17
High risk Department	26	46	62	23	42	31	38	27	38	23
Total	44	36	55	27	34	27	30	20	34	20
History of Possible Lead Problem on Initial Interview										
Low-moderate ZPP	19	42	47	32	47	37	47	42	32	26
High ZPP Low moderate risk Department	9	33	88#	33	67	56	67	33	44	22
High risk Department	7	43	29	0	0	14	29	0	43	14
Total	16	31	60#	19	38	38	50	19	44	19
Total Numbers	162	31	51#	20	34#	25#	35	22	30	17
Total low-moderate risk Departments	114	28	47#	19	33#	26#	36	20	27	15
Total high risk Departments	48	40	60	21	35	25	33	25	38	23
Mean ZPP (ugZP/100 ml)	136.6	147.7	144.0	165.3¢	148.0	160.1	135.9	131.9	162.7$	140.1
Mean Blood Lead (Phase III) (ug/100 ml)	46.3	46.5	45.9	47.5	48.2	43.2¢	45.7	44.1	50.1$	50.0¢

TABLE XIII
(cont.)
Delco Battery
Muncie, Indiana
HE 77-26

April 25-27, 1978

Comparison of Percent of Workers Reporting Symptoms on Phase III Questionnaire by Study Group

Study Group	Joint Pains	Poor Appetite	Weight Loss	Abdominal Cramps	Nausea	Vomiting	Diarrhea	Constipation @	Metallic Taste	Cough
No History of Possible Lead Problem on Initial Interview										
Low ZPP Comparison	45	7	9	16	11	2	9	20	16	23
Moderate ZPP										
Low-moderate risk Department	56	11	7	11	11	4	11	4	30	41
High risk Department	50	8	17	17	8	0	17	17	8	0
Total	54	10	10	13	10	3	8	13	23	28
High ZPP										
Low-Moderate risk Department	44	11	0	11	6	0	11	17	28	39
High risk Department	50	12	8	15	15	12	15	19	27	38
Total	48	11	5	14	11	7	14	18	27	39
History of Possible Lead Problem on Initial Interview										
Low-moderate ZPP	68	11	32	21	32	16	5	37	22#	32
High ZPP										
Low-moderate risk Department	67	11	0	22	33	11	22	56	44	44
High risk Department	43	0	14	14	14	14	14	43	0	71
Total	56	6	6	19	25	12	19	50	25	56
Total Numbers	52	9	10	15	15	6	10	23	23#	33
Total low-moderate risk Departments	52	10	9	15	15	4	9	22	24#	32
Total High risk Departments	52	8	15	17	15	10	15	25	19	33
Mean ZPP (µgZP/100 ml)	137.2	141.3	90.7¢	154.5	153.3	198.7$	185.1$	151.4	151.3	166.9$
Mean Blood Lead (Phase III) (µg/100 ml)	45.7	44.1	42.5	43.9	44.3	48.1	47.5	45.7	49.3	51.2$

TABLE XIII
(cont.)

Delco Battery

One "don't know" or "missing" omitted completed.

* Comparison group statistically significantly lower than all others ($Chi^2 = 6.78$ $p = 0.006$)

@ Workers without history of lead problem statistically significantly lower than those with history ($Chi^2 = 8.73$ p less than 0.005)

$ Statistically significant (p = 0.05 or less)

¢ Possibly statistically significant (p between 0.1 and 0.05)

Table XIV

Delco Battery
Muncie, Indiana
HE 77-28

April 25-27, 1978

Comparison of Smoking History and ZPP and Blood Lead Levels

Smoking Category	Number	3/21-23/77 ZPP (ug ZP/100 ml whole blood)		4/25-27/78 Blood Lead (ug/100 ml whole blood)	
		Mean	95% Conf. Limits	Mean	95% Conf. Limits
Coughing Smokers	45	174.6	± 40.7	52.8	± 5.3
Smokers without Cough	47	134.8	± 37.4	45.0	± 4.8
Total Smokers	92	154.3	± 27.3	48.8	± 3.6
Non Smokers	69	109.9	± 25.9	43.0	± 3.6
Total Workers Studied	161	135.2	± 19.3	46.3	± 2.6

Using a single variable of classification, statistical analysis of variance showed both the increases in ZPP and increases in blood leads to be statistically significant,
F for ZPP =3.85 p=0.03
F for leads=5.23 p is less than 0.01

Using the L statistic for ZPP's the difference between coughing smokers and non-smokers is statistically significant at a=0.05. For blood leads the differences between coughing smokers and either 1) the non-smokers, or 2) the non-smokers and non-coughing smokers are statistically significant at a=0.05.

Table XV

Delco Battery
Muncie, Indiana
HE 77-28

April 25-27, 1978

Comparison of Physical Findings by Study Group

Study Group	Number	Blood Pressure						Bicepts Reflexes				Tremors	Weak Wrist(s)
		Systolic			Diastolic			Normal	Increased	Decreased			
		Mean	Std. Dev.	95% Conf. Limits	Mean	Std. Dev.	95% Conf. Limits			Both	One		
								%	%	%	%	%	%
No History of Possible Lead Problem on Initial Interview													
Low ZPP Comparison	44	127.6	15.5	± 4.7	78.4	9.0	± 2.7	75	9	7	9	25	11
Moderate ZPP Low-moderate risk Department	27	126.3	18.7	± 7.4	77.0	11.1	± 4.4	63	15	7	15	26	15
High risk Department	12	124.1	10.5	± 6.7	74.2	8.9	± 5.7	50	25	25	0	33	8
Total	39	125.6	16.5	± 5.4	76.1	10.4	± 3.4	59	18	13	10	28	13
High ZPP Low-moderate risk Department	18	120.5	14.7	± 7.3	75.1	12.2	± 6.1	67	6	11	17	28	17
High risk Department	26	129.2	17.0	± 6.9	77.1	9.3	± 5.5	65	0	15	19	23	12
Total	44	125.6	16.5	± 5.0	76.3	12.9	± 3.9	66	2	14	18	25	14
History of Possible Lead Problem on Initial Interview													
Low-moderate ZPP	19	134.7	19.3	± 9.3	83.9	12.9	± 6.2	53	11	16	21	6	37
High ZPP Low-moderate risk Department	9	124.4	8.6	± 6.6	79.2	8.9	± 6.8	67	11	22	0	33	11
High risk Department	7	125.4	21.1	±19.5	77.6	9.3	± 8.6	71	0	14	14	43	29

Table XV (con't)

Delco Battery
Muncie, Indiana
HE 77-28

April 25-27, 1978

Comparison of Physical Findings by Study Group

Study Group	Number	Blood Pressure						Bicepts Reflexes				Tremors	Weak Wrist(s)
		Systolic			Diastolic			Normal	Increased	Decreased			
		Mean	Std. Dev.	95% Conf. Limits	Mean	Std. Dev.	95% Conf. Limits			Both	One		
								%	%	%	%	%	%
History of Possible Lead Problem on Initial Interview													
Total	16	124.9	14.8	± 7.9	78.5	8.8	± 4.7	69	6	19	6	38	19
Total	162	127.2	16.5	± 2.6	77.9	11.1	± 1.7	65	9	12	13	26	16
Total low-moderate risk Departments	114	127.2	16.8	± 3.1	78.6	10.9	± 2.0	67	11	10	13	25	16
Total high risk Departments	48	127.0	15.8	± 4.6	76.4	11.6	± 3.4	62	6	19	12	29	17
Mean ZPP (ug ZP/100 ml)	136.6							141.1	71.7	160.2	137.4	147.4	123.2
Mean Blood Lead (ug/100 ml)	46.3 (n=161)							46.3	39.9	52.8	44.4	49.2@	46.6

@ Possibly statistically significantly elevated. (t=1.313 p=0.1)
Reflex findings were analysed by analysis-of-variance for a single variable of classification. They were not statistically significantly different.

Table XVI

Delco Battery
Muncie, Indiana
HE 77-28

April 25-27, 1978

Comparison of Blood Pressure to ZPP and Blood Leads

Blood Pressure Grouping (mm Hg)	Numbers	Mean ZPP (ug ZP/100 ml)	Mean Blood Lead (ug/100 ml)
Systolic Pressure			
Less than 140 (mean 120.9/74.9)	129	136.8	46.1 (n=128)
140 - 149 (mean 142.8/88.2)	18	139.3	47.1
150 + (mean 162.3/91.5)	15	131.7	46.9
Diastolic Pressure			
Less than 90 (mean 123.7/75.1)	140	138.7	46.0 (n=139)
90 - 94 (mean 145.1/90.7)	14	115.9	52.1
95 + (mean 155.5/104.4)	8	134.8	40.9
Combined Grouping*			
Normal Pressure (mean 120.6/74.4)	125	139.3	46.3 (n=124)
Possibly Hypertensive (mean 140.6/86.8)	19	124.8	46.6
Hypertensive (mean 158.8/92.8)	18	129.7	45.9
Total Workers	162	136.6	46.3 (n=161)

No statistically significant differences using analysis of variance.

* Normal pressure - Systolic less than 140, and Diastolic less than 90.

Hypertensive - Systolic 150 or more, or Diastolic 95 or more.

Possibly Hypertensive - the rest.

Table XVII

Delco Battery
Muncie, Indiana
HE 77-28

March 21-23, 1978

Comparison of Red Blood Cell Count, Hemoglobin, and Hematocrit by Study Group

Study Group	Number	Red Blood Cell Count (x1,000,000/ul blood)			Hemoglobin (g/100 ml blood)			Hematocrit (% Red Cells)		
		Mean	Std. Dev.	95% Conf. Limits	Mean	Std. Dev.	95% Conf. Limits	Mean	Std. Dev.	95% Conf. Limits
No History of Possible Lead Problem on Initial Interview										
Comparison	43	5.14	0.37	± 0.11	15.9*	0.90	± 0.3	47.7	1.12	± 1.0
Low ZPP, high risk Department	23	5.08	0.73	± 0.32	15.6	0.75	± 0.3	47.4	2.80	± 1.2
Total low ZPP	66	5.12	0.52	± 0.13	15.8*	0.85	± 0.2	47.6*	3.00	± 0.7
Moderate ZPP, low-moderate risk Department	146	5.12	0.33	± 0.05	15.5	0.97	± 0.2	46.8	2.79	± 0.5
Moderate ZPP, high risk Department	52	5.14	0.37	± 0.10	15.5	1.03	± 0.3	46.6	2.97	± 0.8
Total moderate ZPP	198	5.12	0.34	± 0.05	15.5	0.98	± 0.1	46.7	2.84	± 0.4
High ZPP, low-moderate risk Department	19	5.13	0.24	± 0.12	15.1	0.98	± 0.5	45.9	2.46	± 1.2
High ZPP, high risk Department	28	5.22	0.32	± 0.12	15.2	0.96	± 0.4	46.5	2.67	± 1.0
Total high ZPP	47	5.19	0.29	± 0.08	15.2	0.96	± 0.3	46.2	2.57	± 0.8
History of Possible Lead Problem on Initial Interview										
Low-moderate ZPP, low-moderate risk Department	41	5.13	0.41	± 0.13	15.5	1.19	± 0.4	47.0	3.34	± 1.1

Table XVII (con't)

Study Group	Number	Red Blood Cell Count (x1,000,000/ul blood)			Hemoglobin (g/100 ml blood)			Hematocrit (% Red Cells)		
		Mean	Std. Dev.	95% Conf. Limits	Mean	Std. Dev.	95% Conf. Limits	Mean	Std. Dev.	95% Conf. Limits
History of Possible Lead Problem on Initial Interview										
Low-moderate ZPP, high risk Department	12	5.03	0.43	± 0.28	15.4	0.83	± 0.5	47.0	3.44	± 2.2
Total low-moderate ZPP	53	5.11	0.41	± 0.11	15.5	1.11	± 0.3	47.0	3.33	± 0.9
High ZPP, low-moderate risk Department	10	4.94	0.31	± 0.22	15.1	1.03	± 0.7	45.8	3.39	+ 2.4
High ZPP, high risk Department	7	5.22	0.46	± 0.43	15.1	1.25	± 1.2	46.0	4.18	± 3.9
Total high ZPP	17	5.06	0.37	± 0.19	15.1	1.09	± 0.6	45.9	3.61	± 1.9
Total	381	5.13	0.38	± 0.04	15.5	1.00	± 0.1	46.8	2.96	± 0.3
Total Low ZPP	81	5.13	0.50	± 0.11	15.8*	0.96	± 0.2	47.8*	3.13	± 0.7
Total Moderate ZPP	236	5.12	0.35	± 0.04	15.4	0.98	± 0.1	46.7	2.86	± 0.4
Total High ZPP	64	5.15	0.32	± 0.08	15.2*	0.99	± 0.2	46.2	2.86	± 0.7

*Statistically significantly different from mean of total study group at $a = 0.05$.

Table XVIII

Delco Battery
Muncie, Indiana
HE 77-28

March 21-23, 1978

Comparison of Red Blood Cell Indeces by Study Group

Study Group	Number	Mean Corpuscular Volume (MCV) (cubic micrometers)			Mean Corpuscular Hemoglobin (MCH) (pg/red cell)			Mean Corpuscular Hematocrit Concentration (MCHC) (%)		
		Mean	Std. Dev.	95% Conf. Limits	Mean	Std. Dev.	95% Conf. Limits	Mean	Std. Dev.	95% Conf. Limits
No History of Possible Lead Problem on Initial Interview										
Low ZPP Comparison	43	92.5	5.36	± 1.6	31.4*	1.87	± 0.6	33.3	1.19	± 0.4
High risk Department	23	91.0	4.94	± 2.1	30.2	1.47	± 0.6	33.1	1.29	± 0.6
Total	66	92.0	5.23	± 1.3	31.0*	1.81	± 0.4	33.3	1.22	± 0.3
Moderate ZPP										
Low-moderate risk Department	146	91.8	4.04	± 0.7	30.5	1.24	± 0.2	33.0	0.70	± 0.1
High risk Department	52	90.8	3.58	± 1.0	30.3	1.17	± 0.3	33.0	0.71	± 0.2
Total	198	91.5	3.93	± 0.6	30.5	1.22	± 0.2	33.0	0.70	± 0.1
High ZPP										
Low-moderate risk Department	19	89.3	4.55	± 2.2	29.7	1.78	± 0.9	32.9	0.65	± 0.3
High risk Department	28	89.2*	4.80	± 1.9	29.4*	1.65	± 0.6	32.7*	0.64	± 0.2
Total	47	89.3*	4.65	± 1.4	29.6*	1.69	± 0.5	32.8	0.65	± 0.2
History of Possible Lead Problem on Initial Interview										
Low-moderate ZPP										
Low-moderate risk Department	41	91.8	5.31	± 1.7	30.5	1.74	± 0.5	32.9	0.72	± 0.2

Table XVIII (con't)

Delco Battery
Muncie, Indiana
HE 77-28

March 21-23, 1978

Study Group	Number	Mean Corpuscular Volume (MCV) (cubic micrometers)			Mean Corpuscular Hemoglobin (MCH) (pg/red cell)			Mean Corpuscular Hemoglobin Concentration (MCHC) (%)		
		Mean	Std. Dev.	95% Conf. Limits	Mean	Std. Dev.	95% Conf. Limits	Mean	Std. Dev.	95% Conf. Limits
History of Possible Lead Problem on Initial Interview										
High risk Department	12	93.9	8.39	± 5.4	31.0	1.95	± 1.2	33.3	2.04	± 1.2
Total	53	92.3	6.11	± 1.7	30.6	1.78	± 0.5	33.0	1.14	± 0.3
High ZPP Low-moderate risk Department	10	92.8	3.23	± 2.3	30.8	1.03	± 0.7	32.8	0.60	± 0.4
High risk Department	7	88.3*	2.75	± 2.5	29.2*	1.65	± 0.9	32.7	0.75	± 0.7
Total	17	90.9	3.73	± 1.9	30.1	1.26	± 0.6	32.8	0.65	± 0.3
Total	381	91.4	4.67	± 0.5	30.5	1.53	± 0.2	33.0	0.88	± 0.1
Total Low ZPP	81	92.5	5.15	± 1.1	31.1*	1.76	± 0.4	33.2#	1.16	± 0.3
Total Moderate ZPP	236	91.5	4.43	± 0.6	30.4	1.32	± 0.2	33.0#	0.81	± 0.1
Total High ZPP	64	89.7*	4.46	± 1.1	29.7*	1.60	± 0.4	32.8#	0.64	± 0.2

* Statistically significantly different from mean of total study group at a =0.05

Using analysis of variance Total Low ZPP is statistically significantly higher (at a = 0.05) than the Total High ZPP, and than the Total Moderate ZPP and Total High ZPP together.

Table XIX

Delco Battery
Muncie, Indiana
HE 77-28

April 25-27, 1978

Comparison of Red Blood Cell Indeces by Lead Level Intervals

Blood Lead Level ug/100 ml		Red Blood Cell Count (x1,000,000/ul		Hemoglobin g/100 ml		Hematocrit % red cells		Mean Corpuscular Volume (MCV) cubic micrometers		Mean Corpuscular Hemoglobin (MCH) pg/red cell		Mean Corpuscular Hemoglobin Concentrati (MCHC) %	
	Number	Mean	Standard Dev.	Mean	Standard Dev.	Mean	Std. Dev.	Mean	Standard Dev.	Mean	Standard Dev.	Mean	Standard Dev.
0 - 29	46	4.99	0.59	15.5	1.1	46.6	3.2	92.3	4.4	31.0	1.9	33.3	1.4
30 - 39	98	5.07	0.35	15.4	1.0	46.6	3.2	92.0	4.4	30.8	1.5	33.1	0.9
40 - 49	110	5.14	0.33	15.4	0.9	46.5	2.6	90.8	4.5	30.2	1.5	32.9	0.7
50 - 59	74	5.15	0.27	15.5	0.9	46.9	2.7	91.2	4.3	30.4	1.4	33.0	0.6
60 - 69	37	5.23	0.38	15.7	1.0	47.4	2.8	91.2	4.9	30.2	1.5	32.8	0.6
70 - 79	9	5.35	0.22	16.8	0.9	49.3	2.7	92.3	3.7	30.5	1.2	33.4	1.9
80 - 89	7	5.32	0.58	15.9	1.1	49.4	3.3	93.9	10.9	30.1	2.3	32.0	1.6
90 - 99	4	5.38	0.21	15.0	1.6	46.2	4.0	86.0	6.2	28.2	2.6	32.4	1.5
Total	385	5.12	0.38	15.5	1.0	46.8	2.9	91.4	4.7	30.5	1.6	33.0	0.9
F(7,377)		2.70*		1.61		2.23*		1.88#		3.54*		11.35*	

* Using Analysis of Variance this is statistically significant (p less than 0.05).

This is possibly statistically significant (p less than 0.1).

TABLE XX
Comparison of Blood Urea Nitrogen (BUN), Serum Creatinine, Serum Uric Acid, and Urine Lead by Study Groups
HHE 77-28
Delco Battery
Muncie, Indiana
April 25-27, 1977

Study Group	Number	BUN (mg/100 ml serum)			Serum Creatinine (mg/100 ml serum)			Serum Uric Acid (mg/100 ml serum)			Number	Urine Lead (ug/l corrected to sp. gr. 1.024)		
		Mean	St. Dev.	95% Conf. Limits	Mean	St. Dev.	95% Conf. Limits	Mean	St.Dev.	95% Conf. Limits		Mean	St. Dev.	95% Conf. Limits
No History of Possible Lead Problem on Initial Interview														
Low ZPP Comparison	44	14.7	3.4	± 1.0	1.02	0.22	± 0.07	6.23	1.00	± 0.30	39	40.9*	22.1	± 7.2
Moderate ZPP Low-mod risk dept.	27	15.8	4.8	± 1.9	1.03	0.24	± 0.09	6.46	1.62	± 0.64	26	84.9	46.8	±19.0
High risk dept.	12	15.9	2.2	± 1.4	1.03	0.33	± 0.21	6.05	0.78	± 0.50	1	72.0	11.4	± 7.7
Total	39	15.5	4.2	± 1.4	1.03	0.26	± 0.09	6.33	1.41	± 0.46	7	81.0	39.9	±13.4
High ZPP Low-mod risk dept.	18	14.4	4.0	± 2.0	0.98	0.16	± 0.08	5.93	1.19	± 0.59	18	80.0	28.7	±14.3
High risk dept.	26	14.5	4.2	± 1.7	1.07	0.18	± 0.07	6.52	0.98	± 0.40	24	113.5*	60.1	±25.4
Total	44	14.5	4.1	± 1.2	1.03	0.17	± 0.05	6.28	1.09	± 0.33	42	99.1*	51.5	±16.1
History of Possible Lead Problem on Initial Interview														
Low-mod ZPP	19	15.6	4.4	± 2.1	1.04	0.24	± 0.12	6.22	1.34	± 0.65	7	80.1	74.5	±38.4
High ZPP Low-mod risk dept.	9	16.8	3.1	± 2.4	1.07	0.28	± 0.22	6.68	1.35	± 1.04	9	98.6	49.1	±37.7
High risk dept.	7	16.9	2.5	± 2.4	1.10	0.21	± 0.19	6.43	0.94	± 0.87	6	142.7*	32.1	±33.7
Total	16	16.8*	2.8	± 1.5	1.08	0.25	± 0.13	6.20	1.43	± 0.76	15	116.2*	47.4	±26.3
Total	162	15.2	3.9	± 0.6	1.04	0.22	± 0.03	6.30	1.18	± 0.18	150	79.1	51.8	± 8.4

*Statistically significantly different from mean of total study group at $a = 0.05$

TABLE XXA
Urine Lead by Grouped Study Groups
HHE 77-28
Delco Battery
Muncie, Indiana
April 25-27, 1977

Study Groups	Number	Urine Lead (ug/l. corrected to sp. gr. 1.024)		
		Mean	St. Dev.	95% Conf. Limits
Total	150	79.1	51.8	± 8.4
Low ZPP	43	39.0*	22.3	± 6.9
Moderate ZPP	50	85.6	51.4	±14.7
High ZPP	57	103.6*	50.6	±13.4
Low-Moderate risk department	106	64.3	39.9	± 7.7
High risk department	44	114.6*	59.8	±18.2
No history of possible lead problem on initial interview	118	74.2	46.7	± 8.5
History of possible lead problem on initial interview	32	97.0	64.9	±23.4

*Statistically significantly different from mean of total study group at $\alpha = 0.05$

APPENDIX A

DELCO BATTERY PLANT
MUNCIE, INDIANA
HHE 77-28
PHASE I - QUESTIONNAIRE

INTERVIEWER: ☐☐

DATE OF INTERVIEW: ☐☐ — ☐☐ — ☐☐
MO DAY YR

SUBJECT IDENTIFICATION

CASE NO. ☐☐☐☐ ☐

LAST NAME:

FIRST NAME:

MIDDLE INITIAL: ☐

ADDRESS:

CITY:

STATE: ☐☐ ZIP CODE: ☐☐☐☐☐

PERSONAL DATA

1. TELEPHONE: ☐☐☐ - ☐☐☐ - ☐☐☐☐
AREA CODE

2. RACE/ETHNIC CODE: ☐
   1. White, not of Hispanic Origin
   2. Black, not of Hispanic Origin
   3. Hispanic
   4. American Indian or Alaskan Native
   5. Asian or Pacific Islander
   6. Other

3. SEX: 1. Male 2. Female ☐

4. What is your date of birth? (month/day/year) ☐☐-☐☐-☐☐

EMPLOYMENT HISTORY

DATE HIRED: MONTH ☐☐ YEAR 19 ☐☐

CURRENT DEPARTMENT: ______________________ HOW LONG? MONTHS ☐☐ YEARS ☐☐

CURRENT JOB: ______________________ HOW LONG? MONTHS ☐☐ YEARS ☐☐

Have you ever been treated for lead poisoning?.............. 1 ☐ YES 2 ☐ NO 8 ☐ DK

Have you ever been transferred to a different job because of a high blood lead?.. 1 ☐ YES 2 ☐ NO 8 ☐ DK

CDC/NIOSH(C) TF 2.15A
3-77 EXP. 6-77

DELCO BATTERY PLANT
MUNCIE, INDIANA
HHE 77-28

ID NUMBER ____-____

REPRODUCTIVE SCREENING QUESTIONS

1. Have you ever been married? 1 ☐ Yes 2 ☐ No

   IF NO: STOP

2. How many times have you been married? ☐☐

(ASK QUESTIONS 3 - 9 FOR EACH MARRIAGE. RECORD RESPONSES FROM LEFT TO RIGHT STARTING WITH MOST RECENT MARRIAGE AND WORKING BACK IN TIME. IF THE WOMAN IS DECEASED, NOTE THIS IN THE ADDRESS SPACE.)

	Most recent Marriage	Previous Marriage	Previous Marriage
3. In what year were you and your wife married?	19☐☐	19☐☐	19☐☐
Are you currently living together? IF NO: 4. In what year did you stop living together?	19☐☐	19☐☐	19☐☐
5. What is her first and maiden name?			
6. What is her present address? (Street, city, and State)			
7. How many live births have you and your wife had?	☐☐ live births	☐☐ live births	☐☐ live births
8. Did any of these children die before one year of age? IF YES: HOW MANY?	1 ☐ Yes → ☐ # 2 ☐ No	1 ☐ Yes → ☐ # 2 ☐ No	1 ☐ Yes → ☐ # 2 ☐ No
9. Did (has) your wife have (had) any miscarriages? IF YES: HOW MANY?	1 ☐ Yes → ☐ # 2 ☐ No 8 ☐ DK	1 ☐ Yes → ☐ # 2 ☐ No 8 ☐ DK	1 ☐ Yes → ☐ # 2 ☐ No 8 ☐ DK

CDC/NIOSH(C) TF 2.15B
3-77 EXP. 6-77

HHE 77-28

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
4676 Columbia Parkway
Cincinnati, Ohio 45226
Delco Battery, Muncie, Indiana
PHASE II QUESTIONNAIRE 0003

NAME _____ _____

You have been chosen to be a part of Phase II of the health hazard evaluation at Delco Battery, Muncie, Indiana, conducted by the National Institute for Occupational Safety and Health (NIOSH). This includes a lead determination on the blood we already obtained from you. Please complete this questionnaire and return it to us in the enclosed self-addressed, postage-free envelope.

1. Do you have any health problems which you think are related to your job?

   Yes _____ No _____

   If yes, describe what they are, how often you have the problem(s) and anything special which is likely to make the problem(s) better or worse.

   _____

   _____

   _____

   _____

   Have you seen a doctor for these problems? Yes _____ No _____

   Which ones? _____

2. Do you have any other health problems not necessarily related to your job?

   Yes _____ No _____

   If yes, describe: _____

   _____

   _____

   _____

   Have you seen a doctor for these problems? Yes _____ No _____

   Which ones? _____

3. Have you ever been treated for lead poisoning or anemia ("low blood")?

   Yes _____ No _____ If yes:

Date	Treating Doctor	Hospital (if hospitalized)	Type of Treatment and How Long (pills, shots, etc.)

4. Have you ever taken any pills to prevent lead poisoning or to treat "mild" or "slight" lead poisoning? Yes _____ No _____

   How many treatments? _____

   When was the last time? _____

   Who usually gave you the pills?

   The Company Doctor _____

   Another medical doctor _____

   Someone other than a medical doctor without you having seen a doctor first? _____

5. Have you ever been treated for kidney problems or been studied by a doctor for kidney problems? Yes _____ No _____

6. Please list the jobs you have held in this plant:

	Job Category	Dept.	Dates or number of months and years	Lead Exposure (check one) High	Intermediate	Low	None
Present Job							
Previous Job							
Other Jobs							

7. Please list any work you have done other than in this plant in the past three years:

Type of Work	Dates or number of Months	Lead Exposure (check one)			
		High	Intermediate	Low	None

8. If you were not working anywhere for more than a month in the past three years, please give the dates you were out of work.

_____

_____

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
4676 COLUMBIA PARKWAY
CINCINNATI, OHIO 45226

HHE 77-28

DELCO BATTERY, MUNCIE, INDIANA
PHASE III
QUESTIONNAIRE

1. In the past six months have you had any of the following symptoms;

Trouble sleeping	1	/ /	YES	2	/ /	NO	8 / / DK	7
Unusually tired	1	/ /	YES	2	/ /	NO	8 / / DK	8
Dizziness	1	/ /	YES	2	/ /	NO	8 / / DK	9
Irritability	1	/ /	YES	2	/ /	NO	8 / / DK	10
Poor memory or confusion	1	/ /	YES	2	/ /	NO	8 / / DK	11
Headache	1	/ /	YES	2	/ /	NO	8 / / DK	12
Muscle weakness	1	/ /	YES	2	/ /	NO	8 / / DK	13
Muscle cramps	1	/ /	YES	2	/ /	NO	8 / / DK	14
Tremors (shakes)	1	/ /	YES	2	/ /	NO	8 / / DK	15
Joint pains	1	/ /	YES	2	/ /	NO	8 / / DK	16
Poor appetite	1	/ /	YES	2	/ /	NO	8 / / DK	17
Weight loss	1	/ /	YES	2	/ /	NO	8 / / DK	18
Abdominal cramps	1	/ /	YES	2	/ /	NO	8 / / DK	19
Nausea	1	/ /	YES	2	/ /	NO	8 / / DK	20
Vomiting	1	/ /	YES	2	/ /	NO	8 / / DK	21
Diarrhea	1	/ /	YES	2	/ /	NO	8 / / DK	22
Constipation	1	/ /	YES	2	/ /	NO	8 / / DK	23
Metallic taste in mouth	1	/ /	YES	2	/ /	NO	8 / / DK	24
Cough	1	/ /	YES	2	/ /	NO	8 / / DK	25

2a. Do you smoke? 1 / / YES 2 / / NO 26

b. Do you ever smoke while you work? 1 / / YES 2 / / NO 27

3a. Do you usually wash your hands and and face before smoking at work? 1 / / YES 2 / / NO 28

QUESTIONNAIRE
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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
4676 COLUMBIA PARKWAY
CINCINNATI, OHIO 45226

NHE 77-23

DELCO BATTERY, MUNCIE, IN
PHASE III
QUESTIONNAIRE

3a.	Do you usually wash before eating or drinking at work?	1 /__/ YES 2 /__/ NO	29
4a.	Do you usually change your clothing before going home at the end of the shift?	1 /__/ YES 2 /__/ NO	30
b.	If no, do you change immediately after arriving at home?	1 /__/ YES 2 /__/ NO	31
5a.	Are you supposed to use a respirator?	1 /__/ YES 2 /__/ NO	32
b.	If yes, do you use it all the time you are supposed to?	1 /__/ YES 2 /__/ NO	33
6.	Do you usually shower after work (at the plant or at home)?	1 /__/ YES 2 /__/ NO	34
7.	Do you have any hobbies or other activities that would expose you to lead?	1 /__/ YES 2 /__/ NO	35

If yes, explain _____

_____

_____

_____

8.	Have you drunk "moonshine" in the past 6 months?	1 /__/ YES 2 /__/ NO	36
9.	Do you have any handmade or foreign-made pottery that you use for food or beverages?	1 /__/ YES 2 /__/ NO	37
10a.	Has anyone in your household other than you ever had lead poisoning?	1 /__/ YES 2 /__/ NO	38

b. If yes, give age at time of illness and date of illness.

Age (in yrs.)	Date (Mo.Day Yr.)	
/__/__/	/__/__/ - /__/__/ - /__/__/	39 - 46
/__/__/	/__/__/ - /__/__/ - /__/__/	47 - 54
/__/__/	/__/__/ - /__/__/ - /__/__/	55-62
/__/__/	/__/__/ - /__/__/ - /__/__/	63 - 70

11. How many children under 7 live in your household? /__/ 71

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
CENTER FOR DISEASE CONTROL
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
CINCINNATI, OHIO 45226

DELCO BATTERY, MUNCIE, INDIANA
PHASE III
PHYSICAL EXAM

Examiner_____

1. Biceps tendon and/or brachioradialis reflexes

1 /___/	normal	7
2 /___/	decreased, symmetrical	
3 /___/	increased, symmetrical	
4 /___/	decreased, asymmetrical	
5 /___/	increased, asymmetrical	

2. Tremor (outstretched hands)

1 /___/	absent	8
2 /___/	present	

3. Wrist strength

1 /___/	normal	9
2 /___/	one side weak	
3 /___/	both sides weak	

4. Ankle strength

1 /___/	normal	10
2 /___/	one side weak	
3 /___/	both sides weak	

5. Other abnormalities or comments:

_____

_____

_____

_____

CDC/NIOSH(C) TF 2.15E
4-77 EXP. 6-77

APPENDIX B
NORMAL LABORATORY VALUES

Test	Normal Value	Reference
Blood Lead	0 - 40 ug/100 ml whole blood Up to 60 ug/100 ml acceptable	1,2 2,3
Urine Lead	0 - 65 ug/l (corrected to specific gravity 1.024) Up to 200 ug/100 ml acceptable	4 3
Urine Specific Gravity (sp. gr.)	1.001 - 1.035	4
Free Erythrocyte Protoporphyrin (FEP)	374 - 622 ug/l RBC	*
White Blood Cell Count (WBC)	4.8 - 10.8 Thousand/ul whole blood (males)	*
Red Blood Cell Count (RBC Count)	4.7 - 6.1 Million/ul whole blood (males)	*
Hemoglobin (HGB)	14 - 18 g/100 ml whole blood (males)	*
Hematocrit (HCT)	42 - 52% of whole blood (males)	*
Mean Corpuscular Volume (MCV)	80 - 94 cubic micrometers (males)	*
Mean Corpuscular Hemoglobin (MCH)	27 - 31 pg/red cell (males)	*
Mean Corpuscular Hemoglobin Concentration (MCHC)	32 - 36% (males)	*
Urine Protein	Negative to Trace	*
Serum Creatinine	0.5 - 1.3 mg/100 ml serum	*
Blood Urea Nitrogen (BUN)	10 - 20 mg/100 ml serum	*
Uric Acid	2.5 - 8.0 mg/100 ml serum	*
Albumin	3.5 - 5.0 g/100 ml serum	*
Total Protein	6.0 - 8.0 g/100 ml serum	*
Serum Glutamic Oxalacetic Transaminase (SGOT)	7 - 40 mu/ml serum	*
Lactic Dehydrogenase (LDH)	100 - 225 mu/ml serum	*
Total Bilirubin	0.15 - 1.0 mg/100 ml serum	*
Alkaline Phoshpatase	30 - 85 mu/ml serum	*
Inorganic Phosphorus	2.5 - 4.5 mg/100 ml serum	*
Calcium (ionic)	8.5 - 10.5 mg/100 ml serum	*
Glucose	65 - 110 mg/100 ml serum	*
Cholesterol	150 - 300 mg/100ml serum	*

*Normal for laboratory doing the testing