HETA 2000-0077-2816
Delphi Automotive Systems - Flint East Operations
Flint, Michigan

Bradley S. King, MPH

PREFACE

The Hazard Evaluations and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (NIOSH) conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health (OSHA) Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Bradley S. King of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Calvin K. Cook and Gerlinde Astleithner. Analytical support was provided by DataChem Laboratories. Desktop publishing was performed by Robin Smith. Review and preparation for printing were performed by Penny Arthur.

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Highlights of the NIOSH Health Hazard Evaluation

Evaluation of Lead Exposures due to Wave Soldering Operations at a Circuit Board Production Facility

NIOSH conducted this Health Hazard Evaluation in department 75 of Delphi Automotive - Flint East Operations' facility, Flint, Michigan, in response to employee concerns of lead exposures. The concern is in regards to the use of a lead/tin solder during the production of automotive circuit boards.

What NIOSH Did

We collected personal breathing zone and area air samples for lead and tin.

We collected wipe samples for lead from numerous locations throughout the work area, including floors, equipment surfaces, and employees' hands.

We discussed with management their written lead compliance program, personal protective equipment program, and environmental monitoring and medical surveillance plans.

We talked to the employees who work in the area about their health and work practices.

What NIOSH Found

Employee exposures to airborne lead were very low.

Accumulated lead was present on a variety of work surfaces.

What Delphi - Flint East Managers Can Do

Maintain a housekeeping plan which calls for thorough cleaning of equipment surfaces on a regular basis.

Continue to provide training on personal hygiene practices, respiratory protection, and lead training.

What the Delphi - Flint East Employees Can Do

Wash hands thoroughly, especially before eating.

Maintain the validity of their Health and Safety Training Center identification cards to keep updated with safety training and proper respiratory protection.

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National Institute for Occupational Safety and Health
NIOSH

Health Hazard Evaluation Report 2000-0077-2816
Delphi Automotive Systems - Flint East Operations
Flint, Michigan
November 2000

Bradley S. King, MPH

SUMMARY

On January 3, 2000, the National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation (HHE) from employees at Delphi Automotive Systems - Flint East Operations in Flint, Michigan. The HHE request expressed concerns about possible exposure to lead resulting from the use of wave solder machines during the production of circuit boards.

In response to this request, a site visit was conducted on March 30 through April 1, 2000. During this site visit, two NIOSH industrial hygienists and a visiting researcher conducted a walk-through inspection of the area of concern and discussed the exposure issue with management and employees working in the area. Full-shift personal breathing zone (PBZ) and area air sampling was performed to measure the levels of potential exposure to lead and tin dust originating from the 60% tin / 40% lead solder used in the wave solder machines. Surface sampling was also conducted for lead dust on equipment surfaces, lunch room tables, floors, and hands of employees. Discussions were held with management regarding their written lead compliance program, personal protective equipment program, and their environmental monitoring and medical surveillance plans.

Results from the PBZ sampling ranged between nondetectable and 4.0 micrograms per cubic meter ($\mu g/m^3$) for lead and between nondetectable and 7.0 $\mu g/m^3$ for tin. The PBZ results were all well below the Occupational Safety and Health Administration (OSHA) permissible exposure limits (PEL) of 50 μg lead/m^3 and 2000 μg tin/m^3 averaged over an 8-hour work shift. None of the area air samples had detectable amounts of lead or tin. Wipe sampling did detect the presence of accumulated lead on a variety of work surfaces. These included the floor near wave solder machines, some equipment surfaces, and ceiling air supply ventilation registers. Results for the wipe sampling ranged from nondetectable to 1700 μg lead/wipe sample (each sample was collected over a 100 square centimeter [cm^2] area.)

Despite the fact that employee exposure to airborne lead does not appear to be excessive in the work areas evaluated, the presence of accumulated lead on work surfaces indicates a potential for occupational exposure to lead. Management needs to stress regular and thorough housekeeping procedures in these areas and employees need to recognize the importance of personal hygiene practices in the prevention of ingestion of this accumulated lead. Recommendations regarding the site's written lead compliance program, lead sampling, and housekeeping issues are provided in this report.

Keywords: SIC 5013 (motor vehicle supplies and new parts) lead, Pb, wave soldering, circuit board production, wipe sampling

TABLE OF CONTENTS

INTRODUCTION

On January 3, 2000, the National Institute for Occupational Safety and Health (NIOSH) received a confidential employee request for a Health Hazard Evaluation (HHE) at Delphi Automotive Systems - Flint East Operations, in Flint, Michigan. The requesters expressed concern regarding possible excessive lead exposures in the area of Plant 2, Division 75 due to wave soldering operations for electronic circuit boards using a 60% tin / 40% lead solder.

A site visit was conducted on March 30 - April 1, 2000. An opening conference was held with management and employee representatives. During the site visit, work practices and use of PPE were reviewed. Two NIOSH industrial hygienists and a visiting researcher monitored both PBZ and area air for airborne lead and tin dust. Surface wipe samples for lead were taken from equipment surfaces, break/lunch area tables, and other selected surfaces, as well as from the hands of workers before their lunch break. The respiratory protection, employee lead training, and medical monitoring programs were discussed. An overview of the ventilation system serving the area was also presented.

BACKGROUND

Delphi Automotive Systems manufactures automotive components, systems, and modules. The Flint East Operations' Division 75 contains 4 production lines for the assembly of circuit boards for automobile cruise controls. Lines 1, 3, and 4 are located together in a room approximately 150 feet in length by 100 feet wide. Across a hall is Line 5, located in a room measuring approximately 150 feet in length by 30 feet wide. One hundred and five active employees work in this area of the facility in three shifts: 47 employees during the 6:00 a.m. - 2:30 p.m. shift; 28 employees during the 2:30 p.m. to 10:30 p.m. shift; and 30 during the 10:30 p.m. to 6:00 a.m. shift.

The process of circuit board production includes a number of steps beginning with the insertion of components including a microprocessor, resistors, diodes, and capacitors into holes in a wafer board. These steps are followed by the insertion of transistors and resonators further down the production line. More capacitors, diodes, and resistors are mounted and glued to the surface of the board during the next step. The circuit board is then sent through a wave solder machine, during which the board rolls over a wave of solder. This results in the tips of the extensions of the inserted components being soldered onto the bottom of the board. As the soldered circuit boards proceed out of the wave solder machine, they pass under a number of small fans which blow cooling air onto the boards. The circuit board then continues on for completion, inspection, and shipping.

Usually once per shift, the solder pot in the wave solder machine must be pulled out in order to perform a dedrossing of the top of the liquid solder. In this procedure, a large, slotted spoon is used to skim the surface of the liquid solder to remove any dross, or impurities, that have risen to the surface of the liquid solder and which may interfere in the circuit board soldering process. A potential for the creation of airborne lead dust exists during this operation and thus a potential for exposure. The time required for this task is approximately one hour.

In addition to a once per shift dedrossing, a "deep cleaning" of the solder pot and wave solder machine occurs approximately once per week. This procedure entails a thorough cleaning of the internal parts of the wave solder machine, and also a much more thorough removal of dross from the solder pot. The completion of this task may take a number of hours, up to a full shift, to perform. The chance for exposure to lead increases during this task due to the close proximity of the worker to the lead source and the possibilities of dispersal of lead dust resulting from the disturbance that is required.

A dedicated exhaust system exists for each of the four wave solder machines. Each of these machines has a filterless exhaust stack leading from the top of the machine directly to the roof to exhaust lead dust produced during normal circuit board production processes. These exhaust stacks reach between 10 to 15 feet above the roof line. Two air handling units (AHUs) serve the large room holding three of the four production lines. Both of these AHUs have their own outdoor air intake on the roof, providing 40% outdoor air to the room during the summer season and 10% outdoor air during the winter season. The distances between the closest wave solder machine exhaust stack and the two outdoor air intakes are approximately 35 feet and 50 feet, respectively. The room in which production Line 5 is located is served by 5 AHUs which provide 100% recirculated air from other areas of the factory. There are no outdoor air intakes for these AHUs.

When a production line worker skims the top of the solder pot to remove dross, the dross is placed in a large barrel (with a hinged lid) off to the side of the wave solder machine. A flexible exhaust hose extends from the side of the dross barrel to the exhaust stack above the wave solder machine, providing a pathway for the airborne particulates in the barrel to be drawn out and exhausted. Additionally, a hose from a portable high-efficiency particulate air (HEPA)-filtered vacuum is placed in the opened barrel to capture additional lead dust which may rise up out of the barrel as this procedure is performed. In order to provide more local exhaust ventilation (LEV), a Coppus PFX-3000®, a portable HEPA filtration unit, can be rolled to the area. The fume arm of this LEV is pulled to position its 10"-diameter cone-shaped hood to within several inches of the solder pot during dedrossing operations, providing approximately 700 cubic feet per minute (cfm) airflow. This unit has been in use since approximately December 1999/January 2000.

According to Delphi sampling records, the Delphi Flint East Safety Department made 22 area air sampling measurements for lead in Department 75 from a period of January 1990 to March 2000. Of these, one (taken in April1997), returned a result of 180 micrograms per cubic meter ($\mu g/m^3$) of air, above the Permissible Exposure Limit (PEL) of 50 $\mu g/m^3$ of air. The remaining sample results ranged between 0.50 and 27.0 $\mu g/m^3$.

Additionally, medical monitoring records for the past two years were available to be reviewed. The recorded blood lead levels (BLL's) for the tested employees in this time frame ranged from 1 micrograms (μg) lead/100 grams (g) blood to 12 μg/100 g. These records were described as being retained for a period of approximately five years.

METHODS

On March 31, 2000, PBZ and area air samples were collected to measure airborne lead exposure (PbA) and airborne tin exposure. These samples were taken on workers at various stations of all four production lines (1, 3, 4, and 5) in the area of concern. Air samples were collected and analyzed using NIOSH Method 7300 (inductively coupled plasma spectrometry modified for microwave digestion).[1] The flow rate used for personal air sampling pumps was 2.0 liters per minute (LPM); pumps were calibrated in the field pre- and post-sampling. The analytical limit of detection (LOD) and limit of quantitation (LOQ) for lead in air samples for this method of analysis are 0.6 μg/sample and 2.0 μg/sample, respectively. For tin, the LOD is 1 μg/sample, and the LOQ is 4 μg/sample. The minimum detectable concentration (MDC) for lead, 0.66 $\mu g/m^3$, and for tin, 1.1 $\mu g/m^3$, in these samples are based on the analytical LODs and a sample volume of 900 liters. The minimum quantifiable concentration (MQC) for lead, 2.2 $\mu g/m^3$, and for tin, 4.4 $\mu g/m^3$, are based on the analytical LOQ and a sample volume of 900 liters. Results are reported in μg/m3.

A number of surface wipe samples were also collected to determine the extent of lead dust surface contamination (the amount of lead dust per unit surface area, referred to as lead loading) at various locations in the work area. Examples of sample collection locations include wave solder equipment surfaces, floors, break/lunch room table surfaces, and ceiling ventilation supply registers. The samples were collected with pre-moistened Wash n' Dry® towelettes according to NIOSH Method 9100. The procedure was as follows: (1) identify the area to be sampled; (2) put on pair of latex disposable gloves; (3) place wipe flat on surface as defined by the 10 cm by 10 cm template and wipe surface using 3 to 4 horizontal S-strokes, side to side so that entire surface is covered; (4) fold the exposed side of the wipe in and wipe the area with 3 to 4 vertical S-strokes; (5) fold the wipe once more and wipe the area with 3 to 4 horizontal s-strokes and; (6) fold the pad, exposed side in and place in a container. Between each sample, the template was thoroughly cleaned in preparation for the next wipe sample. The wipe samples were digested and analyzed for lead according to NIOSH Method 7082 (flame AA spectrophotometry).

Handwipe samples were taken from a number of production line workers to assess lead contamination on skin. Participants were instructed to perform their normal hand-washing practices prior to eating lunch. Following this, their hands (including between the fingers) were wiped for approximately 30 seconds using pre-moistened Wash n' Dry® towelettes, which were then placed into a sterile plastic container.

All lead wipe samples were sent to the NIOSH contract laboratory for analysis.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increases the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs),[2] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[3] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) PELs.[4] Employers are encouraged to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion.

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970, Public Law 95–596, sec. 5.(a)(1)]. Thus, employers should understand that not all hazardous chemicals have specific OSHA exposure limits such as PELs and short-term exposure limits (STELs). An employer is still required by OSHA to protect their employees from hazards, even in the absence of a specific OSHA PEL.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended STEL or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

Lead

Exposure to lead occurs via inhalation of lead-containing dust and fume, and ingestion from contact with lead-contaminated surfaces. Absorbed lead accumulates in the body in the soft tissues and bones. Lead is stored in bones for decades, and may cause health effects long after exposure as it is slowly released in the body. Symptoms of lead poisoning include weakness, excessive tiredness, irritability, constipation, anorexia, abdominal discomfort (colic), fine tremors, and "wrist drop."[5,6,7] Overexposure to lead may also result in damage to the kidneys, anemia, high blood pressure, infertility and reduced sex drive in both sexes, and impotence. Lead exposure is especially devastating to fetuses and young children due to potentially irreversible toxic effects on the developing brain and nervous system.[8] The adverse effects of lead on children and fetuses include decreases in intelligence and brain development, developmental delays, behavioral disturbances, decreased stature, anemia, decreased gestational weight and age, and miscarriage or stillbirth. Neurological toxicity is observed in children of exposed female workers due to lead's ability to cross the placental barrier and to cause neurological impairment in the fetus.[9]

An individual's BLL is a good indication of recent exposure to, and current absorption of, lead.[10] The zinc protoporphyrin (ZPP) level in blood reflects the toxic effect of lead on heme synthesis in the body. Persons without occupational exposure to lead usually have a ZPP level of less than 40 micrograms per deciliter (µg/dL).[11] Elevated ZPP levels due to lead exposure, which may remain months after the exposure, have been used as an indicator of chronic lead intoxication. Because other factors, such as iron deficiency, can cause an elevated ZPP level, the BLL is a more specific test in the evaluation of occupational exposure to lead.

In the OSHA lead standards for general industry and construction the PEL for airborne lead is 50 µg/m^3 (8-hour TWA), which is intended to maintain worker BLLs below 40 µg/dL; medical removal is required when an employee's BLL reaches 50 µg/dL.[12,13] NIOSH has concluded that the 1978 NIOSH REL of 100 µg/m^3 as an 8-hour TWA does not sufficiently protect workers from the adverse affects of exposure to inorganic lead.[14] NIOSH intends to analyze the feasibility of developing an REL that would provide better protection for workers. NIOSH has conducted a literature review of the health effects data on inorganic lead exposure and finds evidence that some of the adverse effects on the adult reproductive, cardiovascular, and hematologic systems, and on the development of children of exposed workers can occur at BLLs as low as 10 µg/dL.[15] For example, fetal exposure to lead is associated with reduced gestational age, birth weight, and early mental development with maternal BLLs as low as 10 to 15 µg/dL.[8] At BLLs below 40µg/dL, many of the health effects would not necessarily be evident by routine physical examinations, but represent early stages in the development of disease. In recognition of this, voluntary standards and public health goals have established lower exposure limits to protect workers and their children. The ACGIH TLV® for airborne lead is 50 µg/m^3 as an 8-hour TWA, with worker BLLs to be controlled to $\leq$30 µg/dL. A national health goal is to eliminate all occupational exposures which result in BLLs greater than 25 µg/dL.[16]

Lead-contaminated surfaces in the workplace represent a potential source of exposure for workers. In the workplace, generally there is little or no correlation between surface lead levels and employee exposures because ingestion exposures are highly dependent on personal hygiene practices and available facilities for maintaining personal hygiene. There is no federal standard which provides an exposure limit for lead contamination of surfaces in the workplace. The U.S. Environmental Protection Agency (EPA) and the U.S. Department of Housing and Urban Development currently recommend the following clearance levels for lead on surfaces after residential lead abatement or interim control activities: uncarpeted floors, 100 micrograms per square foot (µg/ft^2); interior window sills, 500 µg/ft^2, and window wells, 800 µg/ft^2.[17]

In homes with a family member occupationally exposed to lead, care must be taken to prevent "take home" of lead, that is, lead carried into the home on clothing, skin, and hair, and in vehicles. High BLLs in resident children, and elevated concentrations of lead in the house dust, have been found in the homes of workers employed in industries associated with high lead exposure.[18]

Tin

Inorganic tin compounds are irritants of the eyes, nose, throat, skin, and respiratory system. Certain inorganic tin compounds are primary skin irritants. Persons with pre-existing skin disorders may be more susceptible to these agents. In persons with impaired pulmonary function, particularly those with obstructive airway diseases, the breathing of certain inorganic tin compounds may cause exacerbation of symptoms due to their irritant properties.[19] Inhalation of fumes can also produce headaches, sore throats, and cough. Exposure limits include an OSHA PEL and a NIOSH REL of 2000 µg/m^3 (8-hour TWA) for airborne tin fumes or dust.[20]

RESULTS

Environmental Monitoring

Personal Breathing Zone Sampling

The results of PBZ sampling for lead and tin can be found in Table 1. A total of 18 samples were taken during the two shifts sampled. On March 30, 2000, two samples from personnel on Line one were taken, four from Line 3, four from Line 4, and two from Line 5. Additionally, on April 1, 2000, two samples from personnel on Line 1 were taken, two from Line 4, one from Line 5, and one from a person not stationed on any one specific line. Of these PBZ samples, only three samples showed detectable amounts of airborne lead and tin. Two of these three came from personnel working directly with the wave solder machine and pot. However, these two results, 2.1 µg lead/m^3 and 0.7 µg lead/m^3, are between the minimum MDC and the MQC. This means that, while lead is present, the numerical concentrations are imprecise. The third result is the only sample of the 18 which identified an amount of lead, 4.0 µg/m^3, above the MQC. This result is a five and a half hour TWA taken during the deep cleaning procedure of a solder pot. (The rest of the results are TWAs taken during approximately 8-hour shifts.) The results for tin correspond with these results for lead, with only one sample above the MQC, also taken during the deep cleaning procedure.

Area Air Sampling

Table 2 lists the results of area air sampling for lead and tin. All area air samples taken during the two shifts on March 30, 2000, and April 1, 2000, had results below the MDC of 0.66 µg lead/m^3 and 1.1 µg tin/m^3. These samples were taken at various positions along each of the four production lines, including near the access panels to the solder pots of the wave solder machines and the cooling conveyor line after the exit of the wave solder machine during normal production operations. Samples were also taken of the area in which a deep cleaning of the solder pot and wave solder machine were being performed.

Surface Sampling

During the two days of environmental sampling, a number of surface wipe samples for lead were taken throughout the facility. The results of this sampling can be found in Table 3. The surfaces sampled can be divided in four general areas: equipment/floor/handrail surfaces; lunch-area and smoking-break tabletops; ceiling supply ventilation registers; and employee hands.

For the equipment/floor/handrail surfaces, 7 wipe samples were collected. These included surfaces such as the floor by the entry panel of a wave solder machine, the glass entry panel of a wave solder machine, and the handrail of a bridge over one of the production lines. The results from these surfaces ranged from non-detectable (one sample on the glass entry panel) to 1300 µg lead/wipe (on the bridge handrail). Between these two extremes, the remaining results fell between 30 and 250 µg lead/wipe sample. The table top surfaces where Delphi workers eat their mid-shift meal and/or take their smoking breaks were sampled as well. Of three table top surfaces sampled, all three were below the limit of detection of 4 µg lead/wipe sample. An approximately 10 cm x 10 cm area of the surface of 4 ceiling supply ventilation registers were each wipe sampled. The results ranged from a low of 140 (the center conference room register) to a high of 1700 µg lead/wipe (a register above production Line 3).

Six hand wipes were obtained from employees. Of these 6, 3 had no detectable lead. Two of the 6 results, 5.0 and 8.0 µg lead/wipe, fell between the LOD and the LOQ. These 5 results came from employees stationed at various positions on the circuit board production lines. The 6th hand wipe, from an individual who performed the deep cleaning solder pot procedure, returned a result of 52 µg lead.

DISCUSSION

Every air sample collected in this study, both PBZ and area air samples, had very low lead and tin concentrations, all well below the OSHA PELs. However, evidence of lead was found on 6 of the 7 equipment/floor/handrail surfaces sampled, including levels of 230, 250, and 1300 µg lead/wipe sample. A possible explanation for these results is that airborne lead was produced in some amount previous to the added engineering controls such as the extra local exhaust ventilation and had settled onto these work surfaces. The length of time this contamination was present on these surfaces is impossible to ascertain. It is important to note that no OSHA standards exist for lead loading on work surfaces against which one can compare these results. The only standards that exist for lead on surfaces comes from the U.S. Department of Housing and Urban Development (HUD). These apply to lead on surfaces in public housing such as floors and window sills following lead abatement work. For example, HUD considers a lead hazard for children to exist in homes with a lead loading of 100 µg lead/ft^2 on the floor. (In comparison, when extrapolated from 100 cm^2 (the area of the floor wipe sampled) to ft^2, the results of this study indicate lead loadings of 2137 µg/ft^2 on the floor near the entry panel of the wave solder machine on Line 1, and 279 µg/ft^2 on the floor near the entry panel of the wave solder machine on Line 3.) However, because of the inherent differences between, and activities in, a home environment and a factory environment, the HUD guidelines do not apply to the latter. Although they can not be used to state a lead hazard exists at the work site, they suggest that a higher level of cleaning is warranted for the affected surfaces to prevent contamination of skin and clothes and decrease the opportunity for accidental ingestion. The handrail of the bridge over the production line particularly would benefit from this cleaning due to the higher levels of lead on it, as well as the increased chances of transfer of lead from the surface of the handrail to the hand of a worker who uses the bridge but who may not normally wear or need to wear gloves at his or her work station.

Of all the surfaces sampled, those which most likely would promote exposure resulting from hand to mouth activities are the smoking area table tops and lunch area table tops. These activities could bring any lead found on these surfaces to the mouth for accidental ingestion. However, none of the samples taken from these surfaces had detectable amounts of lead. The location of these tables outside the lead work area limits potential contamination. Also, better housekeeping in this area may be a possible factor in these results. Continued care should be taken to ensure that lead is not transferred to these surfaces by avoiding activities like wearing PPE, such as gloves, that have been in use in the work area, at these tables.

Lead was found to be present on ceiling supply ventilation registers located above production lines and the center conference room, in one case at 1700 µg/wipe. There are a variety of possible scenarios which could explain the presence of lead at these locations. One involves the adherence of airborne lead already present in the work areas to the surface of these registers. Another possibility is the deposition of lead particles present in the air supply flowing through the register into the work area. The presence of lead on the register in the center conference room suggests the latter possibility may be more likely due to the room being relatively isolated from the work area. If lead is currently, or previously had been, in the air supply, a source may be the re-entrainment of exhausted lead from the wave solder machine. Currently, no filters are present on the exhaust stacks leading from the wave solder machine to the roof. It may be possible that the outdoor air intakes on the roof are capturing some of this exhausted lead dust despite being located a good distance from these exhaust stacks. To counteract this possibility, an engineering control such as HEPA filters or scrubbers could be installed on the exhaust stacks to capture any lead particles prior to their release. It is impossible to tell how long the lead was actually present on the registers. If the accumulation of the lead occurred over a long period of time, the amount of lead in the air supply may actually be quite small and pose no significant hazard. Again, every result from personal breathing zone and area air samples showed the levels of exposure to airborne lead to be well below current occupational exposure limits during the days the sampling was performed.

Only one of the six hand wipe samples taken had lead above the level of quantitation. The task performed before this sample was collected was a "deep cleaning" of the wave solder machine and pot. It is possible that inherent to this procedure is an increased contact with lead particles. Despite the use of PPE such as gloves, an amount of lead was transferred to the skin of the hands, possibly through bare-handed contact with contaminated equipment surfaces or contaminated work clothing. Even after normal hand washing, this lead was still present. This result stresses the importance of practicing good personal hygiene. Not only applicable to this one individual but to everyone in the work area, thorough washing of hands before lunch, snack breaks, and end of shift, is a very important step in preventing ingestion of lead that may be present on the hands. Although perhaps greater during certain procedures, the chance of transferring lead to one's hands is still possible for all who work in the area due to the presence of lead found on a variety of surfaces.

Review of the records of past airborne lead sampling performed by the company indicate an agreement with the results found during our evaluation with one exception. A result of 180 µg lead/m^3 in the area two years ago should have prompted further evaluation and sampling to determine if it was, in fact, an error or atypical exposure as thought by Delphi management. Despite the low air levels in our evaluation, the company should continue to perform scheduled evaluations of airborne lead, particularly when changes are introduced in the normal procedures, and investigate any future results above the permissible limits.

CONCLUSIONS

During the two day site visit, none of the employees sampled were exposed to levels of airborne lead or tin above the OSHA PELs. The engineering controls, such as the portable HEPA-filtered local exhaust unit used, the addition of the hose from the HEPA-filtered vacuum into the dross barrel, and the exhaust hose entering the side of that barrel from the exhaust stack, most likely contributed to the low levels of airborne lead and should continue to be used during work procedures. Although exposure via inhalation of airborne lead appears to be low, the possibility of its ingestion exists due to the presence of lead on a variety of work surfaces. However, the exposure to this lead is highly dependent on the activities and precautions taken by the worker. Thorough housecleaning and personal hygiene procedures can help to decrease the chances that this will be a route of exposure for the workers in the area.

RECOMMENDATIONS

1. Review of the written lead compliance program provided by Delphi - Flint East Operations showed a comprehensive program directed towards the protection of workers exposed to lead during work involving the disturbance of surfaces with lead containing coatings. While the program contains all the important aspects of a lead compliance program, it does not sufficiently address the specific activities in which workers may be exposed to lead during the wave soldering operations. Aspects which should be considered for inclusion in the compliance program include: (1) a description of each operation in which lead is emitted (including the machinery used, the materials processed, the controls in place, etc.); (2) air monitoring data which documents the source of the emissions; and (3) a work practice program which includes protective work clothing, housekeeping and hygiene facilities.

2. A review of records of environmental monitoring showed the sampling results for airborne lead in the area of the four production lines in the area of concern since 1994. Although short descriptions of each sample were provided in the records, a more detailed, precise sampling record may be beneficial in the future. This includes the duration, location, and description of the sampling procedure used to determine representative employee exposure, as well as information about the employee and job classification of the individual monitored and of those jobs/tasks the measurement is intended to represent.

3. Two issues necessitate more focus on the OSHA lead standard 29 CFR 1910.1025. One is the maintenance of both medical surveillance and environmental monitoring records. This standard states that employers keep and maintain the employees' records for at least 40 years or for the duration of a person's employment plus 20 years, whichever is longer.

The second issue pertains to the fact that some individuals stated they had not received results from past environmental monitoring in a timely manner. According to the standard, within 5 working days after receipt of the monitoring results by an employer, the employer shall notify each employee in writing of the results which represent that employee's exposure, even if below the PEL. If and when the results should indicate employee exposure exceeds the PEL, the employer shall include in the written notice a statement that the PEL was exceeded and a description of the corrective action taken or to be taken to reduce the exposure to or below the PEL.

4. Discussions regarding the respiratory protection program in place for Delphi - Flint East Operations revealed the identification card system through which employees can receive respiratory protection for their particular work practices. This card is given to the employee only after the employee obtains medical clearance and passes respirator training; it expires 6 months after the

issue date. It is through this mechanism that employees can receive the proper protective equipment from a centralized respirator storage area. However, during discussions with employees in the area, we noted that some of these cards had been expired for several months. Thus it is possible that these employees were lacking the most up-to-date training information or adequate respirator protection. It is imperative that management stress to the employees the importance of and their responsibilities in following procedures for maintaining the validity of these cards, as well as to provide the time necessary for the employees to perform these responsibilities.

5. The practice of cleaning down the equipment with a commercial lead cleaning product has been a relatively recent instituted step. This procedure may increase the cleanliness of the equipment and work area and help to provide a work area as free of accumulated lead dust as possible. We strongly recommend that this practice continue on a regularly scheduled basis. Since there is no janitorial service for this area, the production line workers who work in the wave solder areas should continue to have access to such cleaning products and equipment, as well as the time necessary to perform this function. Brooms should not be used to dry sweep the floors or equipment surfaces, especially near the wave solder machine areas, in order to prevent any accumulated lead from becoming airborne. HEPA-filtered vacuums should be used in their place.

6. The PPE used such as the coveralls, gloves, eye protection and respirators should continue to be used, providing extra protection to the workers, especially in the case when or if conditions should change and lead become airborne.

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Table 1. Personal Breathing Zone Sampling Results: Lead and Tin
HETA 2000-0077-2816
Delphi - Flint East Operations, March 30 - April 1, 2000

Sample number	Location	Sample Time (minutes)	Lead (µg/m³)	Tin (µg/m³)
MCE 6 -3/31	Line 1 - Wave solder machine	474	(2.1)	(2.1)
MCE 7 - 3/31	Line 1 - Wave solder machine	422	ND	ND
MCE 29 - 4/1	Line 1 - Wave solder machine	397	ND	ND
MCE 31 - 4/1	Line 1 - Wave solder machine	459	ND	ND
MCE 2 - 3/31	Line 3 - HP	468	ND	ND
MCE 5 - 3/31	Line 3 - Wave solder machine	419	ND	ND
MCE 8 - 3/31	Line 3 - Radial	480	ND	ND
MCE 11 - 3/31	Line 3 - Pre-inspect	472	ND	ND
MCE 27 - 4/1	Line 3 - Deep clean solder pot	317	4.0	7.0
MCE 1 - 3/31	Line 4 - Wave solder machine	469	(0.7)	(1.0)
MCE 4 - 3/31	Line 4 - Packout inspection	362	ND	ND
MCE 10 - 3/31	Line 4 - Pre-inspect	436	ND	ND
MCE 12 - 3/31	Line 4 - Radial	482	ND	ND
MCE 30 - 4/1	Line 4 - Pre-inspect	449	ND	ND
MCE 3 - 3/31	Line 5 - Coaters	472	ND	ND
MCE 9 - 3/31	Line 5 - Multi-mod	480	ND	ND
MCE 26 - 4/1	Line 5 - Wave solder machine	453	ND	ND
MCE 28 - 4/1	no set station on specific line	363	ND	ND

$\mu g/m^3$: micrograms of contaminant per cubic meter of air sampled

OSHA PEL:	Lead: 50 $\mu g/m^3$	Tin: 2000 $\mu g/m^3$
Minimum detectable concentration (MDC):	Lead : 0.66 $\mu g/m^3$	Tin: 1.1 $\mu g/m^3$
Minimum quantifiable concentration (MQC):	Lead : 2.2 $\mu g/m^3$	Tin: 4.4 $\mu g/m^3$

MDC and MQC based on an average sample volume of 900 L.

ND : parameter not detected above the analytical limit of detection (LOD).
( ) : parameter between the analytical LOD and the analytical limit of quantitation (LOQ).

Table 2. Area Air Sampling Results for Lead and Tin
HETA 2000-0077-2816
Delphi - Flint East Operations, March 30 - April 1, 2000

Sample number	Location	Sampling Time (minutes)	Lead ($\mu g/m^3$)	Tin ($\mu g/m^3$)
MCE 16 - 3/31	Line 1 - Cooling conveyor after wave solder machine	475	ND	ND
MCE 17 - 3/31	Line 1 - Wave solder machine	473	ND	ND
MCE 33 - 4/1	Line 1 - Wave solder machine	495	ND	ND
MCE 14 - 3/31	Line 3 - Wave solder machine	464	ND	ND
MCE 25 - 4/1	Line 3 - Entry point of boards into wave solder machine during deep cleaning of solder pot	492	ND	ND
MCE 32 - 4/1	Line 3 - Down draft table during deep cleaning of solder pot	485	ND	ND
MCE 34 - 4/1	Line 3 - Exit point of boards from wave solder machine during deep cleaning of solder pot	491	ND	ND
MCE 35 - 4/1	Line 3 - Sequencer cabinet at beginning of production line	443	ND	ND
MCE 15 - 3/31	Line 4 - Cooling conveyor after wave solder machine	460	ND	ND
MCE 36 - 4/1	Line 4 - Wave solder machine	483	ND	ND
MCE 13 - 3/31	Line 5 - Wave solder machine	460	ND	ND

$\mu g/m^3$: micrograms of contaminant per cubic meter of air sampled

OSHA PEL:	Lead: 50 $\mu g/m^3$	Tin: 2000 $\mu g/m^3$
Minimum detectable concentration (MDC):	Lead : 0.66 $\mu g/m^3$	Tin: 1.1 $\mu g/m^3$
Minimum quantifiable concentration (MQC):	Lead : 2.2 $\mu g/m^3$	Tin: 4.4 $\mu g/m^3$

MDC and MQC based on an average sample volume of 900 L.

ND : parameter not detected above the analytical limit of detection (LOD).
( ) : parameter between the analytical LOD and the analytical limit of quantitation (LOQ).

Table 3. Wipe Sampling Results for Lead
HETA 2000-0077-2816
Delphi - Flint East Operations, March 30 - April 1, 2000

Sample number	Location	Lead (µg/wipe)	Lead (ug/ft^2)
Wipe 7 - 3/31	Line 1 - floor by entry panel of wave solder machine	230*	2137
Wipe 11 - 3/31	Line 1 - Hewlett Packard 3070 equipment surface, near exit point of boards from wave solder machine	43	399
Wipe 4 - 3/31	Line 3 - on handrail of bridge over production line	1300**	----
Wipe 9 - 3/31	Line 3 - floor by entry panel of wave solder machine	30	279
Wipe 21 - 4/1	Line 3 - entry panel of wave solder machine after deep clean of solder pot	41	381
Wipe 22 - 4/1	Line 3 - top of downdraft table after deep clean of solder pot	250*	2322
Wipe 5 - 3/31	Line 4 - glass entry panel of wave solder machine	ND	ND
Wipe 1 - 3/31	lunch area table top	ND	ND
Wipe 3 - 4/1	smoking area table top	ND	ND
Wipe 6 - 4/1	lunch area table top	ND	ND
Wipe 13 - 3/31	ceiling supply ventilation register above line 3	1700**	----
Wipe 12 - 4/1	ceiling supply ventilation register above line 4	150	----
Wipe 8 - 4/1	ceiling supply ventilation register above line 5	450**	----
Wipe 14 - 4/1	ceiling supply ventilation register in center conference room	140	----
Wipe 15 - 3/31	hand wipe	ND	----

Sample number	Location	Lead (µg/wipe)	Lead (ug/ft^2)
Wipe 16 - 3/31	hand wipe	ND	----
Wipe 17 - 3/31	hand wipe	(8.0)	----
Wipe 18 - 3/31	hand wipe	ND	----
Wipe 19 - 3/31	hand wipe	(5.0)	----
Wipe 10 - 4/1	hand wipe (after deep clean of solder pot)	52	----

µg/wipe : micrograms of lead per wipe; sample area of 10 centimeters by 10 centimeters
µg/ft^2 : micrograms of lead per square foot of flat surface area (extrapolated from 10 cm x 10 cm area)

Limit of detection (LOD): Lead : 4 µg/wipe
Limit of quantitation (LOQ): Lead : 10 µg/wipe

* Limit of detection (LOD): Lead : 20 µg/wipe
  Limit of quantitation (LOQ): Lead : 50 µg/wipe

** Limit of detection (LOD): Lead : 40 µg/wipe
   Limit of quantitation (LOQ): Lead : 100 µg/wipe

ND : parameter not detected above the LOD.
( ) : parameter between the LOD and the LOQ.

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