

Evaluation of EMPLOYEE EXPOSURES at a PCB Plant

A review of best-in-class controls for maintaining factory worker health.

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CARLOS ARISTEGUIETA, M.D., AND MAUREEN T. NIEMEIER

The National Institute for Occupational Safety and Health (NIOSH) received a confidential employee request for a Health Hazard Evaluation (HHE) at an electronics manufacturer specializing in printed circuit board fabrication, assembly, and testing for different end-user applications (sidebar). At the time of our evaluation, approximately 2,300 employees worked at the facility in either the medical section plant or the defense and aerospace section. Employees were primarily concerned about exposure to solder paste and fumes, as well as dust and noise. They reported coughs, burning eyes, nosebleeds, voice loss, headaches, sinus infections, bronchitis, and respiratory problems.

At the time of our evaluation, the medical section had four wave soldering lines and eight surface mount lines. Wave solder lines 1, 2, and 3 used Pb-free solder (96.5% tin), and wave solder line 4 used solder composed of 63% tin and 37% lead. The defense and aerospace section had five wave solder lines and six surface mount lines. It also had ruggedization, conformal coating and bonding operations, where the finished PCBs are fitted with additional structural supports and hand-brushed or sprayed with an acrylic copolymer to provide increased environmental and mechanical protection. Spraying during conformal coating was conducted in a ventilated, open-face, bench-top spray booth. Employees wore safety glasses and air-purifying, elastomeric, half facepiece respirators with organic vapor cartridges while spraying. At least once per shift, wave solder operators clean solder dross by using a ladle to remove dross floating on top of the molten solder (**FIGURE 1**). Residual molten solder inadvertently collected during this operation is separated with a sieve, and the remaining dross disposed of in a drum sealed with a lid. Employees are required to wear heat-resistant gloves over disposable nitrile gloves, a face shield, and an apron when performing dross cleaning. In addition to dross cleaning, employees periodically clean and maintain the wave solder machines. Finally, the facility has an auto insertion (AI) operation, which involves machine insertion of components onto a PCB by punching through it.

Assessment. During our first visit to the facility, we conducted confidential medical interviews with 40 employees, observed work processes and practices, collected general

area air samples for volatile organic compounds (VOCs), and collected surface wipe samples for lead and tin. We also reviewed air sampling records, the respiratory protection program, injury and illness records, and material safety data sheets. After sharing our findings with employee and management representatives in an interim letter, we returned to the facility to collect personal breathing zone and general area air samples for lead and specific VOCs. We also measured noise levels at the AI stations, evaluated room acoustics near the air rotation units (ARUs), collected hand wipe samples to assess lead contamination on skin, and evaluated the effectiveness of the local exhaust hoods for the wave solder and surface mount machines (**FIGURE 2**).

Occupational exposure limits. NIOSH investigators use both mandatory (legally enforceable) and recommended occupational exposure limits (OELs) for chemical, physical, and biological agents as a guide for making recommendations. OELs have been developed by Federal agencies and safety and health organizations to prevent the occurrence of adverse health effects from



FIGURE 1. Employee cleaning solder dross from a wave solder machine.

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The Health Hazard Evaluation Program

Based on a federal law, NIOSH conducts Health Hazard Evaluations (HHE) to investigate possible workplace health hazards. Employees, employers or union representatives can ask our comprehensive team of experts to investigate their health and safety concerns by requesting an HHE. Our team contacts the requestor and discusses the problems and how to solve them. This may result in sending the requestor information, referring the requestor to a more appropriate agency, or making a site visit, which may include environmental sampling and medical testing. If we make a site visit, we prepare a report of our investigation that includes recommendations specific to the problems found, as well as general guidance for following good occupational health practices. HHE reports are available on the Internet (<http://www.cdc.gov/niosh/hhe/>).

workplace exposures. They suggest levels of exposure to which most employees may be exposed up to 10 hr. per day, 40 hr. per week for a working lifetime without experiencing adverse health effects. However, a small percentage of employees may still experience health effects due to personal susceptibility, a preexisting medical condition, and/or hypersensitivity (allergy). In addition, some hazardous substances may act in combination with

other workplace exposures, the environment, or with medications or personal habits of the employee to produce health effects, even if occupational exposures are controlled at the level set by the exposure limit. Also, some substances can be absorbed by direct contact with the skin and mucous membranes in addition to being inhaled, which contributes to the individual's overall exposure.

Results and Discussion

One of six personal breathing zone air samples for lead exceeded the Occupational Safety and Health Administration action limit (OSHA AL) of 30 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$) and was close to the OSHA permissible exposure limit of 50 $\mu\text{g}/\text{m}^3$. This employee, a wave solder operator in the DAS, was cleaning the wave solder machines without wearing a respirator. The employee was exposed to an airborne lead concentration of 49 $\mu\text{g}/\text{m}^3$. However, with this one exception, wave solder operators had lead exposures well below the OSHA AL.

Our surface sampling showed the presence of lead and tin on work surfaces in both sections of the plant. Currently, there are no OELs for surface metal contamination in occupational settings. We also sampled tables in two of the break rooms and found detectable levels of lead and tin in one of the break rooms. This suggests that workplace contamination is being tracked into the break rooms by employees' footwear, clothing or hands, and that these areas should be kept cleaner.



FIGURE 2. Employee inspecting boards near local exhaust of a reflow oven.

Additionally, despite hand washing prior to sample collection, three of seven hand wipe samples tested positive for lead.

Full-shift noise exposures for the AI operators in the medical and defense and aerospace section were well below the NIOSH recommended exposure limit. Because telephone communication is not required in the production areas, and communication between employees is minimal, the louder noise levels experienced by employees with work stations near the ARUs were within the criteria specified by the balanced noise criteria (NCB) 55-70 curves. The NCB curves are a set of noise criteria for occupied interior spaces, devised to limit noise to levels at which speech can be reasonably understood. Refer to "Resources and Links" for more information on the NCB curves, as well as Appendix B of the HHE report (referenced in this section).

Our ventilation evaluation revealed that several local exhaust hoods were not effectively capturing process emissions. These included three hoods in the medical section and two hoods in the defense and aerospace section. This could have been due to local exhaust ventilation systems being imbalanced or improperly maintained. Air sampling results for specific VOCs indicated that employee exposures were well below all applicable OELs.

Although both the medical and defense and aerospace section share the main workspace and have similar tasks and equipment, the health concerns originated exclusively from employees in the medical section. Of the 40 medical section employees we interviewed, 23 did not report any work-related symptoms. The most commonly reported symptoms were upper

respiratory, including runny nose, cough, and sinusitis; fatigue (frequently related to overtime work), and voice loss. However, these symptoms are also common in the general population, and we could not attribute them to the exposures documented.

Last, we found inconsistencies between the facility's written respiratory protection program and employee practice. The written respiratory protection program required respirators to be worn when cleaning wave solder machines. However, it did not identify the appropriate type of respirator that should be worn for this task, and we did not observe employees wearing respirators when performing this activity. In addition, employees were voluntarily wearing respirators during spraying in the conformal coating area.

Recommendations

We made a number of recommendations to the facility to improve employee health and safety. Many of these recommendations may also apply to readers' facilities:

- Use engineering controls such as portable exhaust hoods when removing solder dross and cleaning wave solder machines. Periodically evaluate the local exhaust hoods to ensure they are performing per manufacturer's specifications. Evaluate their effectiveness at least every three months, and within five days of a production, process, or control change.
- Comply with all requirements of the OSHA lead standard (29 CFR 1910.1025). This includes instituting an industrial hygiene monitoring program to assess lead exposure for

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employees working with leaded solder, or for employees having the greatest potential for lead exposure. Additionally, institute a maintenance program for evaluating enclosed local exhaust hoods used to control lead exposure.

- Improve general housekeeping practices to ensure break rooms and work surfaces are clean. Use commercial cleaning wipes that are made for removing lead and other heavy metals every shift to keep work surfaces such as control consoles clean. Use high-efficiency particulate air vacuum cleaners in work areas to minimize dust in the air.
- Practice good personal hygiene. Thoroughly wash hands before eating, before and after using the restroom, and before leaving work. Eating, drinking, smoking, and applying cosmetics in work areas should be prohibited.
- Ensure that the respiratory protection program meets all applicable requirements of the OSHA Respiratory Standard (29 CFR 1910.134). The written respiratory protection program should identify job tasks requiring a respirator to be worn, the type of respirator needed, and the locations where respirator use is required. Evaluate respiratory hazards for job tasks currently requiring respiratory protection to ensure protection is adequate. The program should also note any job tasks for which employees voluntarily wear respirators.
- Encourage employees to report work-related health concerns. Consult a physician trained in occupational medicine (see "Resources and Links").
- Train employees about potential exposures and how to

protect themselves from hazards, and promptly communicate any health and safety changes to employees. **PCD&F**

RESOURCES AND LINKS

1. NIOSH HHE program information, cdc.gov/niosh/hhe/HHEprogram.html.
2. Link to this HHE report: cdc.gov/niosh/hhe/reports/pdfs/2007-0201-3086.pdf.
3. Code of Federal Regulations (CFR), 29 CFR 1910.95, US Government Printing Office, Office of the Federal Register.
4. L.L. Beranek, "Criteria for Noise and Vibration in Communities, Buildings, and Vehicles," Noise and Vibration Control, Rev. ed. Cambridge, MA: Institute of Noise Control Engineering; 1988:554-623.
5. L.L. Beranek, "Balanced Noise Criterion (NCB) Curves," J Acoust Soc Am., 1989; 86(2):650-664.
6. Acoustical Society of America, ANSI S12.2-1995, "Criteria for Evaluating Room Noise," 1995.
7. Association of Occupational and Environmental Clinics (aoec.org).
8. American College of Occupational and Environmental Medicine (acoem.org).

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by SRINIVAS DURGAM, CHANDRAN ACHUTAN, PH.D.,
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When layout and test take place under the same roof, determining the right strategy to increase test coverage for a given product becomes much easier, and ensures the end-product will be successfully tested.

by ZULKI KHAN

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Solder Paste Jetting: A Broadband Solution

Recent product miniaturization breakthroughs have pushed stencil printing solder paste to its current process limits. Many different approaches can be taken to address this issue. A just-published study takes a step approach to understand the challenges associated with noncontact dispensing, better known as jetting, associated with both large-volume jetting and ultra-fine dot jetting.

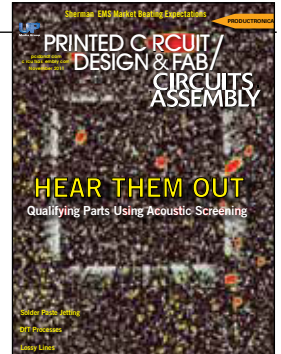
by RITA MOHANTY, PH.D.

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Acoustic Screening to Remove Suspect Plastic Components

Most gap-type anomalies make no difference in the proper functioning or lifespan of the component. Some, though, depending on size and location within the package, can expand until they break a connection. A new technique to image the bulk of the mold compound in many sequential slices reveals the real dangers.

by TOM ADAMS



ON THE COVER:
Acoustic image of
BGA showing voids in
the mold compound.
(Sonoscan)

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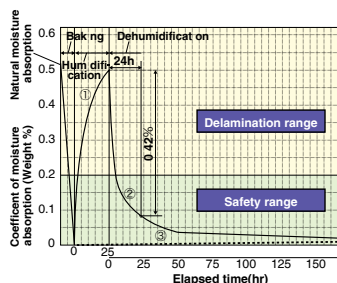


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