Evaluation of Metals, Solvents, Formaldehyde, Ventilation, and Ergonomic Risks during the Manufacture of Electrical Cable Accessories

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Contents

The employer is required to post a copy of this report for 30 days at or near the workplace(s) of affected employees. The employer must take steps to ensure that the posted report is not altered, defaced, or covered by other material.

The cover photo is a close-up image of sorbent tubes, which are used by the HHE Program to measure airborne exposures. This photo is an artistic representation that may not be related to this Health Hazard Evaluation. Photo by NIOSH.

Highlights of this Evaluation

The Health Hazard Evaluation Program received a request from employees at a manufacturer of underground electrical cable parts. They were concerned about developing respiratory disease or cancer from exposures during rubber molding, plastic extrusion, soldering, and painting. Employees were also concerned about poor ventilation and ergonomic risks in the workplace.

What We Did

- We visited the company and talked to 41 employees about their health and work.
- We reviewed safety data sheets and injury and illness logs.
- We looked at work practices and plant processes, and inspected the ventilation system.
- We collected air samples for metals and solvents.
- We collected surface wipe samples for metals.
- We evaluated workstations for ergonomic risk factors.

We evaluated employee health concerns, work practices, air and surface contaminants, ventilation, and ergonomic risks at a manufacturer of electrical cable accessories. Employees reported irritant, neurological, and musculoskeletal symptoms. We found the ventilation system needed many repairs, one painter was overexposed to toluene, and equipment and work practices in the paint department needed adjustments to reduce musculoskeletal injuries.

What We Found

- Some employees had eye, nose, throat or respiratory symptoms that may be due to workplace exposures.
- Some employees reported headache, dizziness, feeling lightheaded, and feeling “high.” These symptoms are consistent with exposure to solvents.
- The ventilation system had holes, disconnected ducts, and broken dampers.
- Air velocity at the opening of all the paint booths was good.
- One personal air sample result on a spray painter exceeded the 12-hour occupational exposure limit for toluene. All other personal air sample results were very low.
- Formaldehyde air samples were measured in the plastic extrusion area. The levels of formaldehyde, a known carcinogen, were below levels of concern.
- Some employees held the paint spray gun outside the spray booth.
- Employees used unventilated racks to hold freshly painted parts.
- Several employees reported hand, wrist, elbow, shoulder, and arm pain. They thought it was due to pulling, pushing, grasping, reaching, and forceful or repetitive job tasks.
- The height of the spray booths caused employees to hold the spray gun awkwardly.
- Some employees had to reach or bend awkwardly to remove or load parts.

What the Employer Can Do

- Repair the ventilation system.
- Provide exhaust ventilation on the drying racks used for painted parts.
- Improve communication with employees regarding how chemicals can affect their health and how to prevent exposures at work.
- Move the paint booths so that the elbow of the spray painter is at a 90º angle to the part being sprayed.
- Install a conveyor to help load parts, and use a tool to move parts into the collection bin.
- Rotate employees between job tasks that use different muscle groups.

What Employees Can Do

- Move parts and spray nozzle inside the spray booth.
- Wash your skin if you get chemicals on your skin.
- Wash your hands before you eat, drink, or smoke.
- Report all health and safety concerns to your supervisor.

Abbreviations

ACGIH®	American Conference of Governmental Industrial Hygienists
MDC	Minimum detectable concentration
mg/m^3	Milligrams per cubic meter
MQC	Minimum quantifiable concentration
ND	None detected
NIOSH	National Institute for Occupational Safety and Health
OEL	Occupational exposure limit
OSHA	Occupational Safety and Health Administration
PEL	Permissible exposure limit
ppm	Parts per million
REL	Recommended exposure limit
TLV®	Threshold limit value
TWA	Time-weighted average
VOC	Volatile organic compound
WEEL	Workplace environmental exposure level

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Introduction

The Health Hazard Evaluation Program received a request from employees at a plant that produced underground electrical power distribution cable accessories. The request concerned inadequate ventilation and potential chemical exposures during plastic and rubber injection molding, painting, manual soldering, and copper cable dipping. Employees were concerned that these exposures might cause respiratory illness or cancer. In May 2012, we met with employer and employee representatives to discuss the health hazard evaluation request. We observed work processes and workplace conditions and held confidential employee interviews. We also reviewed safety data sheets, preventive maintenance procedures for the paint booths, and Occupational Safety and Health Administration (OSHA) Form 300 Logs of Work-Related Injuries and Illnesses. We returned to the plant in October 2012 to evaluate the ventilation system and collect air samples for volatile organic compounds (VOCs), lead, tin, aldehydes, and formic acid. We also collected surface wipe samples for lead and tin and evaluated ergonomic risks associated with work tasks. We sent interim letters containing our preliminary findings to the employer and employee representatives in May 2012 and November 2012.

Background

The company began operations in 1972 manufacturing premolded cable accessories such as elbow connectors, cable joints, terminations, and surge arrestors for use in underground power distribution systems. Several changes had occurred in the year prior to our visit. Managers reported that the company health and safety coordinator had retired a few months prior to the HHE request and the company had been acquired by an international firm a few months prior to our first site visit. An environmental contractor was fulfilling the health and safety coordinator role until a new coordinator was hired. Managers also reported changes in the company's safety culture in the prior 5 years. A "zero accident culture" had been adopted that included daily safety observations and additional safety, ergonomics, and problem-solving training. The employee requestors reported an increase in the production of plastic and rubber parts and more painting of parts when compared to previous years, and managers reported adding jobs in the prior year.

At the time of our evaluation, the plant operated 24 hours a day, 7 days a week. The approximately 300 nonunion production employees worked 8-hour shifts, except for paint department employees who normally worked 12-hour shifts. All employees wore either chemical-resistant nitrile gloves or woven cotton gloves. The selection and use of the type of glove depended on the chemicals handled or work task. Employees could change their gloves as needed, and the company trained employees on how to identify gloves that needed replacement.

Ventilation Description

The single-story, 100,000-square-foot production area had general and local exhaust ventilation. The general exhaust ventilation system had seven radial exhaust fans (no specifications available) mounted on exterior walls approximately 20 feet above the floor. The exhaust fans were manually controlled by the maintenance supervisor and were used for climate control. Additional exhaust ventilation was provided by eight roof-mounted, tube-axial style fans. Outdoor air was drawn into the plant through seven louvered, manually operated vent openings on the exterior wall opposite the wall-mounted exhaust fans. The production area was cooled by 38 rooftop evaporative coolers.

A single, tube-axial style inline fan (no specifications available) attached to an exterior wall provided local exhaust to parts ovens and other machinery. Both rigid and flexible ductwork was used, and manually operated gate dampers in the ducts regulated the exhaust ventilation.

Process Descriptions

We evaluated rubber and plastic injection molding, painting, electrical testing, and small component assembly. Other processes evaluated included assembling and hand soldering printed circuit boards (called the Fisher-Pierce department), dipping copper cable into tin solder, and electrically testing and deflashing plastic parts.

Rubber Injection Molding

In the rubber insulation molding press area, coiled rubber strips were heated in a die molding machine to produce electrical connector parts.

Plastic Injection Molding

Plastic parts were injection molded using nylon or polybutylene terephthalate resins. Bulk resins were gravity-fed from a hopper to an electrically-heated extrusion screw. The melted resin was extruded under pressure into a die. The molded parts were ejected and carried by conveyor for further processing. In the past, extruders were purged (cleaned) between resin changes by increasing the temperature and pressure for approximately 30 minutes. This generated a substantial amount of smoke that was released to the plant atmosphere. However, the purge procedure was recently changed by lowering the temperature and pressure and shortening the purge time. The new purge process now takes about 10–15 minutes and produces much less smoke. In addition to the new purge cycle, a portable snorkel-type local exhaust ventilation unit equipped with a high efficiency particulate air filter and carbon sorbent material was available to capture smoke and organic compounds released if there was a need to run longer purge cycles. However, during our visit, routine operation of the extruders did not require the use of the portable local exhaust ventilation unit.

Paint Application

Four Spray Tech Inc. spray booths exhausted into the paint department. The booth openings were 42 inches square, and each spray booth was supported by four legs approximately 42 inches above the floor. Each booth had a paint-arresting prefilter, a pleated secondary filter, and an activated carbon final filter to absorb organic solvents. The company followed the spray booth manufacturer's recommendation of weighing the carbon filters monthly and replacing them when the weight of the carbon filter reached 12 pounds. Each booth had a manometer that indicated when the paint-arresting and pleated filters needed changing. Painters placed parts onto rotating spindles to spray a bonding paint containing carbon black pigment, toluene, xylene, and ethylbenzene.

Electrical Testing and Small Component Assembly

Employees used naphtha to lubricate plastic and rubber parts during assembly. The naphtha was applied onto the parts with a trigger-type spray bottle. Once assembled, the parts were electrically tested prior to packaging and shipping.

Cable Dipping and Hand Soldering

In cable dipping, employees manually dipped the end of bare copper cable into molten tin solder then placed it on a rack to cool. The ladle of molten tin was enclosed on three sides by a ventilated exhaust hood. A flexible metal duct connected the hood to an exhaust fan that discharged to the surrounding air after passing through a high efficiency particulate air filter. The company changed from a lead-based solder to a tin-based solder between our first and second site visits.

In the Fisher-Pierce department employees assembled printed circuit boards using a hand-held electric soldering iron to melt the solder (60% lead, 40% tin) and complete electrical connections. A fume extractor containing an activated carbon filter operating at a flow rate of 300 cubic feet per minute was positioned directly behind the circuit board being soldered to capture smoke generated during the process.

Deflashing

Deflashing removes excess plastic material from parts following molding. Employees manually loaded plastic parts into the top of the deflasher machine. The employees then removed, inspected, and sorted deflashed parts.

Methods

Our objectives for this evaluation were to:

1. Assess work-related health concerns of employees.
2. Evaluate the condition and function of the local exhaust ventilation system.
3. Evaluate employee’s exposures to volatile organic compounds, lead, tin, aldehydes, and formic acid.
4. Determine the extent and magnitude of lead and tin surface contamination in the cable dipping and Fisher-Pierce soldering areas and near the cafeteria.
5. Assess ergonomic risk factors associated with different jobs.

Employee Interviews and Records Review

We interviewed production employees working the 8-hour day and the two rotating 12-hour day shifts. Managers provided employee rosters for each of these shifts. We chose employees in job titles with greater potential for exposure to airborne contaminants from plastic and rubber injection molding and painting based on prior conversations with employees and managers. The job titles we selected included molders, assemblers, painters, material handlers, testers, maintenance staff, production operators, and quality assurance staff. We asked employees about demographics, work exposure history, medical history, and history of work-related health problems. We asked employees reporting a work-related health problem whether they had experienced any respiratory symptoms related to irritant (e.g., dust, smoke) or solvent (e.g., paint vapors, toluene) exposures during work hours in the month prior to our site visit. We also asked employees if they had any comments or concerns about their work. We reviewed OSHA Logs for years 2009, 2010, and 2011. We also reviewed safety data sheets of the substances used in the plastic and rubber injection molding processes and in the painting process to see if any were associated with causing respiratory illness or cancer.

Ventilation

We visually inspected the local exhaust ventilation system for damage and deficiencies. We used ventilation smoke to observe air flow patterns at machines connected to the local exhaust ventilation system and where painters stood in front of the spray booths. We measured the air velocity at the face of the spray booths with a TSI Velocicalc™ thermoanemometer.

Air and Surface Sampling

We collected area air samples with thermal desorption tubes using National Institute for Occupational Safety and Health (NIOSH) Method 2549 [NIOSH 2014] to identify VOCs in the paint department. On the basis of these results we collected personal and area air samples with charcoal tubes to measure specific VOCs using NIOSH Method 1500 [NIOSH 2014].

We collected personal and area air samples for tin and lead in the Fisher-Pierce and cable dipping departments using 37-millimeter diameter, 0.8-micrometer pore size, mixed cellulose ester filters connected to SKC Aircheck 2000™ air sampling pumps operating at 2 liters per minute. The sampling pumps were calibrated before and after sampling. Air samples were analyzed using NIOSH Method 7303 [NIOSH 2014].

We collected surface wipe samples for lead and tin in the Fisher-Pierce and cable dipping departments and the cafeteria using premoistened Palintest USA, Palintest® wipes following NIOSH Method 9100 [NIOSH 2014]. We also wiped the palm and back of both hands of a Fisher-Pierce department employee who had soldered for 4 hours. With the exception of the hand sample, we used a template to collect each wipe sample over an area of 100 square centimeters. The wipe samples were analyzed according to NIOSH Method 7303 [NIOSH 2014].

We measured petroleum naphtha in the electrical test department; and petroleum naphtha, dimethyl ether, and 1,1,1,2-trifluoroethane in the molding department using activated charcoal sorbent tubes connected to calibrated SKC Pocket Pumps™ operating at 50 cubic centimeters per minute. These samples were analyzed using NIOSH Method 1550 [NIOSH 2014].

Our review of safety data sheets for the resins used in the plastic molding department found that some rubber and plastic products, when heated, can form aldehydes, including formaldehyde which has been classified as a carcinogen. On the basis of this information, we collected full-shift personal and area air samples for aldehydes and formic acid using

2,4-dinitrophenylhydrazine-treated silica gel cartridges. We used two sampling pumps, operating side-by-side, to collect these samples. One pump operated at a flow rate of 50 milliliters per minute (for formic acid), and the cartridge was analyzed using NIOSH Method 2011 [NIOSH 2014]. The other pump operated at a flow rate of 200 milliliters per minute (for aldehydes), and was analyzed by a screening method (EPA TO-11A) to identify and quantify aldehydes, including formaldehyde [EPA 1999]. We also collected a short duration area air sample for formaldehyde during a material purge cycle.

Ergonomic Evaluation

We observed various tasks throughout the plant. We took digital photographs to document the tasks and measured workstation heights. The ergonomic evaluation criteria we used to determine risk factors for work-related musculoskeletal disorders are discussed in Appendix B.

Results

Employee Interviews and Records Review

Ninety-eight employees worked in the selected job titles on the day shifts. We interviewed 41 of the 98, including 11 of 22 from the two rotating 12-hour day shifts and 30 of 76 from the 8-hour day shift. Of the eleven 12-hour shift employees who were not interviewed, eight left work early because their machine was shut down, two were absent, and one declined. We chose 30 of the 76 employees on the 8-hour day shift to interview by selecting every third, then every fourth name from the employee roster. The roster grouped employees by shift, work area, and job title. The 41 interviewed employees included 20 molders, 6 assemblers, 5 material preparers in the paint department, 3 testers, 2 material handlers, 2 maintenance staff, 2 quality assurance staff, and 1 production operator.

Of the 41 interviewed employees, 14 were women. The average age was 46 years (range: 18 to 60 years), the average length of employment at the plant was 16 years (range: 1 to 35 years), and the average number of years in their current job position was 7 (range: 2 months to 32 years). We asked employees if they ever got chemicals on their skin when at work; 22 (54%) responded "yes."

We asked the interviewed employees if they had concerns about their work. Over half were concerned about the lack of ventilation in their workplace and smoke and odors from plastic molding. Some were concerned about the silicone mold release spray, plastic grinding dust, neoprene, lead and tin when soldering, and solvents in the paint department. Eleven employees reported having upper extremity (hand, wrist, elbow, shoulder, and arm) musculoskeletal pain related to work tasks. When asked what they thought might have caused their upper extremity pain, employees reported tasks such as hammering, using gate cutters, pushing, pulling, grasping, twisting, and repetitive work. Other symptoms occurring during work that were reported by employees included headache (8), lightheadedness (6), eye irritation (6), dizziness (5), nose irritation (3), throat irritation (3), cough (3), skin irritation or rash (2), feeling "high" (1), and asthma symptoms (1). Employees reporting work-related eye irritation reported that the purging of plastics from the molding machines and silicone mold release spray caused the irritation. Employees reporting work-related skin irritation thought that hot, dirty armguards and a component in the rubber caused their problem. Six employees felt stressed at work. Reasons given for this stress included feeling overworked, perceptions of a hostile work environment and favoritism, lack of training on hazards of their jobs, poor communication between managers and employees, and the perception that managers did not listen to or address employees' concerns.

Our review of SDSs and the scientific literature found that employees were potentially exposed to chemicals which could cause health effects. Appendix B provides potential health effects, including cancer, and occupational exposure limits for chemicals that employees may be exposed to at this workplace.

We reviewed plant OSHA Logs from 2009 through 2011. The most common entries were musculoskeletal injuries (12 upper extremity and 5 back injuries) followed by contusions and lacerations (10); slips, trips, and falls (5); and hearing loss (2).

Ventilation

In May 2012, the local exhaust ventilation system was not operating. When asked, the maintenance supervisor was unaware it had been turned off. In October 2012, the local exhaust system was operating but needed repairs. For example, foil tape used to seal duct joints was either peeling or missing. Sections of duct were uncapped (Figure 1). Duct damper handles used to control exhaust air flow were broken or missing which makes it difficult to determine whether the damper is open or closed (Figure 2). Ducts connecting multiple oven exhausts were loose and leaking. A fabric filter bag attached to a grinder had a hole that allowed particulate to escape (Figure 3). We also observed the use of personal cooling fans by some employees in the Fisher-Pierce area.

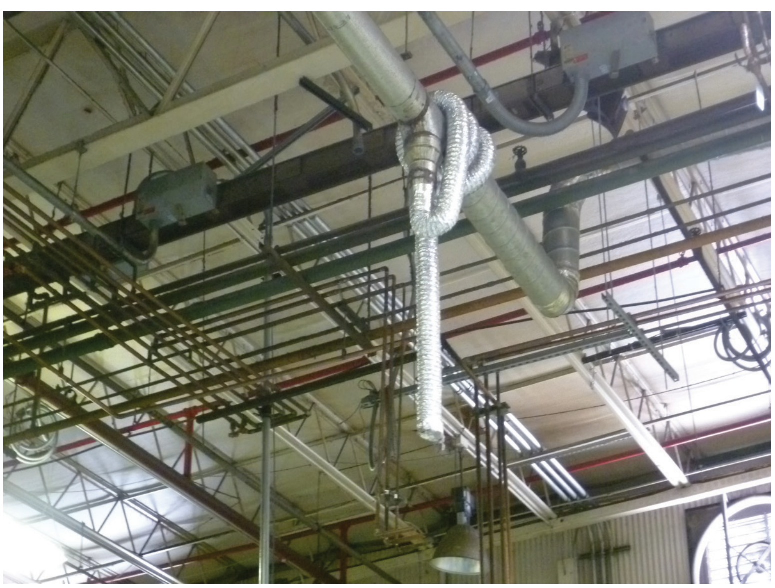

Figure 1. Example of uncapped, unused duct. Photo by NIOSH.

Figure 2. Damper handle broken/missing. Photo by NIOSH

Figure 3. A hole in a filter allowed particles to escape into the plant air. Photo by NIOSH.

Air and Surface Sampling

The predominant solvents in thermal desorption tube air samples collected in the paint department were toluene, ethylbenzene, and xylene. These VOCs were also found in all 14 personal air samples and an area air sample taken in the center of the paint department (Appendix A, Table A1). All but one result were well below their respective occupational exposure limits (OELs). One air sample collected on a painter exceeded the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV) of 10 parts per million (ppm) for toluene when adjusted for a 12-hour work shift. The painter held the spray nozzle outside the face of the spray booth, and freshly painted parts were placed on unventilated drying racks outside the booth (Figure 4). Because adjusted TLVs do not have the benefit of historical use and long-time observation, employees in this exposure category should be monitored more closely.

We measured the average air flow rates through the face of each spray booth. Results ranged from 110 feet per minute to 144 feet per minute, well within the OSHA minimum standard of 100–150 feet per minute [29 CFR 1910.94 (c)(6)(i)].

Figure 4. Spray painting parts inside ventilated booth. Spray released outside booth reduced contaminant control. Freshly painted parts are left on a table to air dry outside the spray booth, resulting in VOCs being released to air. Photo by NIOSH.

The results for five full-shift air samples (three personal; two area) collected for lead and tin in the Fisher-Pierce hand soldering area are shown in Appendix A, Table A2. No lead was detected (< 0.0002 milligrams per cubic meter [mg/m^3]), and very low levels of tin were found on one personal air sample (0.0034 mg/m^3) and one area air sample (0.0029 mg/m^3).

We collected five air samples (three personal; two area) in the cable dipping area and analyzed them for lead and tin (Appendix A, Table A2). No lead was detected on any air sample (< 0.0003 mg/m^3). Measureable levels of tin were found on personal and area air samples (range: 0.013–0.024 mg/m^3), but none exceeded the OELs for tin. The company had changed from the use of lead-based solder to tin-based solder in this area prior to our second site visit.

Nine surface wipe samples were collected and analyzed for lead and tin in the Fisher-Pierce area, the cable dipping area, and the cafeteria (Appendix A, Table A3). We also wiped the hand of an employee working in the Fisher-Pierce area after 4 hours of hand soldering circuit boards. All samples had measureable amounts of lead and tin (Appendix A, Table A3).

Employee's personal exposures to naphtha were very low. Exposures ranged from 16-44 mg/m^3 in the electrical test area and from 2.0–5.6 mg/m^3 in the molding department (Appendix A, Table A4). None of these results exceeded either the most protective OEL (Germany's maximum allowable concentration of 300 mg/m^3 [DFG 2012]) or the NIOSH recommended exposure limit (REL) of 350 mg/m^3 for refined petroleum products like naphtha. In the molding department, neither dimethyl ether nor 1,1,1,2-tetrafluoroethane were detected on any personal sample. The minimum detectable concentration (MDC) was 0.012 mg/m^3 for dimethyl ether and 0.12 mg/m^3 for 1,1,1,2-trifluoroethane.

Formic acid was not detected (< 0.1 ppm) in personal air samples collected in the plastic extrusion department (Appendix A, Table A5). Formaldehyde concentrations ranged from 0.0032–0.0058 ppm in personal air samples, below the NIOSH REL of 0.016 ppm. The highest formaldehyde concentration we measured (0.051 ppm) was from an area air sample collected near the extruder discharge point during purging. Local exhaust ventilation was available but not used during the purge cycle because the time needed to complete a purge (approximately 10 minutes) substantially reduced smoke generation, therefore the use of local exhaust ventilation was reportedly no longer necessary.

We observed employees wearing their lab coats into the cafeteria. These employees mentioned occasionally taking the lab coats home for laundering because onsite laundry services were not available. Wearing potentially contaminated clothing outside the immediate work area can result in contamination of these other areas.

Ergonomic Evaluation

Workstation heights in the Fisher-Pierce area varied from 35″–38″. Parts bins that supported the assembly and soldering process were in front of the employee and at the correct reach distance.

In the molding department, the use of assist devices to remove parts from the machines appeared helpful. The company was developing more assist devices for other parts that were hard to remove. Steps next to some of the molding machines allowed shorter employees to reach the top of the machine. However, taller employees who did not need to use steps had to extend their reach to access the top of the machine.

We saw some employees in the paint department using an awkward elbow posture during paint spraying (Figure 4). Some employees also had to reach overhead or bend at the waist to place painted parts on the drying racks. The racks had slots or pegs for parts that ranged from 7″–76″ above the floor (Figure 5).

Figure 5. Drying racks. Photo by NIOSH.

Employees loaded the deflasher machines by throwing parts into an overhead hopper (Figure 6). Employees also had to bend at the waist or kneel to retrieve parts collected in a bin on the floor.

Figure 6. Employee loading hopper of deflasher by tossing parts overhead. Photo by NIOSH.

We saw employees using pallets on the floor to stack parts and boxes. This practice required employees to bend at the waist to load the pallet. Two pallet loading stations had rotating platforms, but the employees reported they did not know how to use them (Figure 7). We saw gravity flow racks used for some parts. The retrieval and replenish heights for these racks were within the appropriate range (Figure 8).

Employees at workstations requiring prolonged standing did not use antifatigue mats. We were also informed that employees did not routinely rotate job duties.

Figure 7. Pallet rotation platform could be used to reduce unnecessary movements during loading/unloading. Photo by NIOSH.

Figure 8. Gravity-fed supply racks. Photo by NIOSH.

Discussion

We found several deficiencies in the plant's ventilation system including leaking ducts and filter bags and broken damper handles. These problems will decrease the effectiveness of the local exhaust ventilation system. Personal cooling fans were being used in the Fisher-Pierce area, which could diminish the effectiveness of the recirculating bench-top fume extractors used during hand soldering. Air sampling for the predominant chemicals used or produced in the rubber and plastic molding areas were all below the most conservative OELs. We did not account for skin absorption of chemicals.

One employee was overexposed to toluene in the paint department. This overexposure may have occurred because the painter held the spray nozzle outside the face of the spray booth, and freshly painted parts were placed on unventilated drying racks outside the booth. Another contributing factor might have been that the paint booth's carbon filter in the exhaust could have been nearing or exceeded its capacity to absorb solvents in the paint mixture. Because the paint booth was a recirculating exhaust type, once the carbon filter was saturated, solvents would be discharged into the plant atmosphere. This could result in solvent exposures for employees in and near the paint department. We do not recommend recirculating potentially contaminated exhaust air back into occupied spaces. OSHA discusses recirculation of exhaust air from spray painting operations in standard 29 CFR 1910.107, *Spray Finishing Using Flammable and Combustible Materials*, and standard interpretation letters [OSHA 2002, 2009].

No air samples we collected in the Fisher-Pierce area or the cable dipping area contained lead. However, all surface samples collected in the Fisher Pierce area contained lead and tin. Although lead-based solder was being used in the Fisher-Pierce area, proper housekeeping should remove surface contamination. We also found lead on surfaces in the cable dipping area despite the change from lead-based to lead-free solder in this area. These findings suggest that a thorough cleaning in the cable dipping area is needed to remove any previous lead contamination, and better housekeeping in the Fisher Pierce area is also needed until the lead-based solder can be replaced by an appropriate lead-free solder.

Employees were concerned about developing respiratory problems and cancer over time from workplace exposures. Exposure to dust, smoke, rubber components, plastic components, pigments and solvents can produce eye, nose, throat, and bronchial irritation, as well as skin irritation. Some rubber and plastic components and pigments may elicit an allergic reaction in susceptible individuals including allergic asthma and allergic contact dermatitis [Adams 1999]. Pre-existing lung conditions, such as asthma, may be aggravated by exposure to many of these substances. Some rubber and plastic products, when heated, can form formaldehyde, which has been classified as a carcinogen.

The International Agency for Research on Cancer (IARC) evaluates chemicals on their potential to cause cancer by looking at data from animal and human studies. IARC has determined that formaldehyde is a human carcinogen, ethylbenzene is possibly carcinogenic to humans, and toluene and xylene are not classifiable as to their carcinogenicity to humans

[IARC 1999, 2000, 2012]. Tin and naphtha have not been evaluated by IARC. We found personal air samples for formaldehyde and ethylbenzene to be well below their OELs. OELs are based on available toxicology and epidemiology data to protect nearly all workers over a working lifetime. On the basis of our findings, we would not expect an increased risk for cancer from these exposures. Assessing cancer risk among employees who are exposed to chemical mixtures is difficult since there is very little information on effects from chemical mixtures in the scientific literature and because there are so many non-work factors that contribute to developing cancer. These factors include dietary and other personal habits, genetic background, and non-work environmental exposures, among others. Minimizing or preventing these work exposures is the most effective way to avoid these types of health effects.

Employee reports of headache, dizziness, and feeling "high" during their work shifts are consistent with exposure to ingredients in paint used in this plant (e.g., toluene, ethylbenzene, and xylene). Although the chemicals we measured during our evaluation were below relevant OELs, levels at other times may have been higher depending on varying conditions. In addition, some employees may still experience symptoms when compounds are present at levels below the OELs. Employee symptoms despite low air levels of solvents could be explained by the skin absorption of certain chemicals (OELs do not take into account chemical exposure through skin absorption). The most common route of exposure to VOCs is through inhalation, but some solvents may contribute to systemic health effects through skin absorption [LaDou 1990; Klaassen 2008].

The findings from employee interviews and OSHA Logs suggest that musculoskeletal injuries and disorders from job tasks requiring repetitive, forceful motions using awkward postures are a concern (Appendix B). Some employee work stations had appropriate heights and several assist devices were provided that helped avoid awkward postures. The Fisher-Pierce area needed some additional help to accommodate people of varying heights. Hand-working height for standing assembly tasks should be 38″–47″ or fixed at 42″. The height of the product being handled should be considered when calculating the hand working height relative to the work surface (e.g., as a parts height increases, the height of the work surface should decrease). In the molding department, taller employees were reaching over steps that were provided for shorter employees. Steps that could fold up when not in use would reduce the reach distance for the taller employees. For employees in the paint department, the height of the parts in the booths should be such that employees can use their spray gun with their elbow bent at a 90° angle. Also, these employees should have drying racks where parts are stored at 27″–62″ to eliminate awkward postures and unnecessary bending and reaching overhead. In the deflashing area, employees had to throw parts into the overhead machine hopper and bend and kneel to pick up parts off of the floor. The department supervisor mentioned that a conveyor system was being considered to eliminate the need to throw parts into the overhead machine hopper or to climb a ladder to dump parts into the machine. It would also be helpful to provide employees with a retrieval device such as a rake to eliminate bending or kneeling when collecting parts. Shipping department employees did not know how to use the rotating platforms when loading pallets. Using rotating lift tables or load levelers to stack parts or boxes onto pallets eliminates the need for employees to bend and reach to place or retrieve parts. The use of antifatigue mats for jobs tasks requiring prolonged standing and routine rotation of job duties would help reduce muscle fatigue.

Conclusions

We found deficiencies in the plant's ventilation system. Air levels of chemicals in this worksite were low except for one toluene air sample above an OEL in the paint department. This may have resulted from inadequate exhaust ventilation or improper work practices. Despite our low measurements of chemicals, some employees working with irritants and solvents reported eye and upper respiratory symptoms, headaches, and lightheadedness. The air levels of chemicals we measured were below those that have resulted in long-term respiratory problems in other scientific studies; however, these current levels may not reflect those that existed in the plant in years past. Finally, we noted that many employees had a combination of forceful exertion, repetitive movements, twisting and bending, during paint spraying, rubber molding, and deflashing operations which puts them at risk for musculoskeletal disorders.

Recommendations

On the basis of our findings, we recommend the actions listed below. We encourage the company to use a labor-management health and safety committee or working group to discuss our recommendations and develop an action plan. Those involved in the work can best set priorities and assess the feasibility of our recommendations for the specific situation at this facility.

Our recommendations are based on an approach known as the hierarchy of controls (Appendix B). This approach groups actions by their likely effectiveness in reducing or removing hazards. In most cases, the preferred approach is to eliminate hazardous materials or processes and install engineering controls to reduce exposure or shield employees. Until such controls are in place, or if they are not effective or feasible, administrative measures and personal protective equipment may be needed.

Elimination and Substitution

Eliminating or substituting hazardous processes or materials reduces hazards and protects employees more effectively than other approaches. Prevention through design, considering elimination or substitution when designing or developing a project, reduces the need for additional controls in the future.

1. Substitute a lead-free solder for the lead-based solder used in the Fisher-Pierce department.

Engineering Controls

Engineering controls reduce employees' exposures by removing the hazard from the process or by placing a barrier between the hazard and the employee. Engineering controls protect employees effectively without placing primary responsibility of implementation on the employee.

1. Repair the local exhaust ventilation system. Ask a ventilation consultant to evaluate and balance the system to ensure proper operation and efficient control of air contaminants.
2. Provide adjustable workstations for assembly tasks. Parts bins that support the assembly process should be in front of the employee at a vertical height of 24″–70″ and a forward reach ≤ 16″.
3. Provide foldup steps on the platforms that support the molding machines.
4. Lower paint booths or provide a raised platform to allow employees to use the spray gun with their elbow at a 90° angle.
5. Locate the parts drying racks in the paint department at heights of 27″–62″ to eliminate reaching overhead or bending at the back.
6. Continue to evaluate ways to eliminate excessive reaching and bending when working on the deflasher. Provide employees with a retrieval tool such as a rake or hoe to pull parts from the machine into the bin.
7. Provide rotating lift tables or load levelers for stackable parts and boxes. Do not use pallets placed directly on the floor.
8. Provide antifatigue mats at all standing workstations.
9. Choose a tool (e.g., hammer) of the right size and shape for the task and the user. More information on this topic can be found at http://www.cdc.gov/niosh/docs/2004-164/pdfs/2004-164.pdf.

Administrative Controls

The term administrative control refers to employer-dictated work practices and policies to reduce or prevent hazardous exposures. Their effectiveness depends on employer commitment and employee acceptance. Regular monitoring and reinforcement are necessary to ensure that policies and procedures are followed consistently.

1. Conduct air sampling for VOCs in the exhaust air from each spray booth to ensure that the carbon filter changeout schedule is appropriate to maintain VOC exposures in recirculated air below applicable OELs. Otherwise, exhaust contaminated air to the outdoors.
2. Clean equipment and structures identified as having residual lead contamination to remove surface contamination and prevent unnecessary exposure.

3. Move parts to be painted further back into the spray booth.
4. Ensure that the nozzle of the spray gun is at the opening of the spray booth.
5. Dry freshly painted parts in ventilated booths.
6. Use local exhaust ventilation at the plastic extruder during longer than normal purge cycles.
7. Remove lab coats before leaving the work area during breaks or at the end of the work day.
8. Professionally launder lab coats to minimize potential take home exposure to metals and other contaminants.
9. Educate employees on how to recognize the hazards of workplace chemical exposure and to use work practices that prevent exposure to these chemicals. Employees should wear gloves when handling chemicals and, if chemicals touch the skin, to wash them off with soap and water as soon as possible. Review skin protection techniques, hand hygiene, and spill clean-up procedures with employees.
10. Rotate employees between job tasks that use different muscle groups.
11. Encourage all employees to report possible work-related health conditions to their supervisor. Employees with persistent symptoms should be evaluated by an occupational medicine physician or a medical provider specializing in workplace diseases and illnesses. You can locate these physicians in your area at http://www.aoec.org.
12. Look for trends in reported health problems or injuries that may be related to particular job duties, work materials, machines, or areas of the plant. Evaluate areas or jobs that show an increase in injuries or health problems and develop an intervention to reduce exposures.
13. Improve communication between the employer and employees regarding responses to employee safety and health concerns. A management or employee representative of the safety management team should communicate directly with employees who report health and safety concerns to let the employees know that their input has been received and what will be done to address the concern. If nothing will be done to address the concern, this should also be communicated and the rationale given to provide closure. Increasing employee involvement in identifying and mitigating safety and health issues may benefit the company if employees feel that their concerns and suggestions are heard and appreciated.
14. Encourage employees to learn about known cancer risk factors, measures to reduce risk for preventable cancers, and availability of cancer screening programs for certain types of cancer. The American Cancer Society posts information about cancer on its website at http://www.cancer.org/.
For general information, click on the "Learn About Cancer" tab at the top of

the webpage. For information about a specific type of cancer, click on "Show All Cancer Types," under the "Learn About Cancer Topics" sidebar. Additionally, NIOSH posts information about occupational cancer and cancer cluster evaluations on its website at http://www.cdc.gov/niosh/topics/cancer/. Employees can take an active role in changing personal risk factors that are associated with certain types of cancer. You can help them by encouraging use of the onsite fitness facility, providing healthy food in the cafeteria and vending machines, and banning smoking from the entire plant and grounds.

Personal Protective Equipment

Personal protective equipment is the least effective means for controlling hazardous exposures. Proper use of personal protective equipment requires a comprehensive program and a high level of employee involvement and commitment. The right personal protective equipment must be chosen for each hazard. Supporting programs such as training, change-out schedules, and medical assessment may be needed. Personal protective equipment should not be the sole method for controlling hazardous exposures. Rather, personal protective equipment should be used until effective engineering and administrative controls are in place.

1. Continue to offer gloves to employees as needed and train employees on proper wear. Train employees on visual signs that indicate glove material is worn out so that new gloves can be obtained.

Appendix A: Tables

Table A1. Personal air sampling results for toluene, ethylbenzene, and xylenes in the paint department

Job Title	Sample time (minutes)	Sample volume (m^3)	Toluene (ppm)	Ethylbenzene (ppm)	Xylenes (ppm)
Painter	428	0.086	3.4	0.25	1.2
	448	0.090	4.4	0.40	1.9
	450	0.090	2.3	0.16	0.8
	450	0.090	**13***	1.2	5.4
	374	0.075	3.2	0.28	1.4
	358	0.072	4.1	0.35	1.6
	439	0.088	4.5	0.44	2.2
	424	0.085	3.8	0.29	1.5
	410	0.082	2.9	0.28	1.3
	443	0.089	7.2	0.59	2.9
	421	0.084	3.2	0.25	1.3
	419	0.084	4.1	0.32	1.6
	444	0.089	5.7	0.51	2.6
	446	0.089	6.0	0.46	2.2
NIOSH REL			100	100	100
OSHA PEL			200	100	100
ACGIH TLV			20	20	100

*Concentration exceeds an adjusted ACGIH TLV of 10 ppm, on the basis of a 12-hour work shift.

Note: One full-shift general area sample (490 minutes) was collected in the center of the work area. The results were, toluene: 3.8 ppm, ethylbenzene: 0.3 ppm, xylenes: 1.4 ppm.

Table A2. Personal and area air sampling results for lead and tin

Department	Sample time (minutes)	Sample volume (m^3)	Lead (mg/m^3)	Tin (mg/m^3)
Personal air samples				
Fisher-Pierce	380	0.75	ND	[0.00034]*
	423	0.84	ND	0.0029
	387	0.76	ND	ND
Cable dip	453	0.90	ND	0.013
	448	0.89	ND	0.024
NIOSH REL			0.05	2
OSHA PEL			0.05	2
ACGIH TLV			0.05	2
Area air samples				
Fisher-Pierce	455	0.90	ND	[0.00082]
	455	0.90	ND	0.0028
	450	0.89	ND	[0.00074]
Cable dip	462	0.91	ND	0.0091
	490	0.96	ND	0.018
MDC		0.87	0.0002	0.0003
MQC		0.87	0.0007	0.001

ND = none detected; result was below the MDC.

MDC = minimum detectable concentration assuming a sample volume of 0.87 m^3

MQC = minimum quantifiable concentration assuming a sample volume of 0.87 m^3

*Values in brackets [ ] are between the MDC and the MQC; more uncertainty is associated with these concentrations.

Table A3. Surface wipe sample results for lead and tin

Department	Location	Lead*	Tin*
Cable dip	Top of vent enclosure covering heating ladle	7.2	1,300
	Shelf, 20 feet from workstation	0.96	14
	Light fixture above ladle	140	850
	Work table top	80	1,700
Fisher-Pierce	Work table top	62	150
	Shelf above soldering table	67	210
	Employee handwipe after soldering	69	110
Cafeteria	Floor, inside doorway	1.1	4.8
	Door handle	19†	48†

*Micrograms per surface area sampled (100 square centimeters unless otherwise noted).

†Door handle surface area was less than 100 square centimeters.

Note: There are no OELs for surface contamination.

Table A4. Personal and area air sampling results for naphthas* in the electrical test area

Sample type	Sample time (minutes)	Sample volume (cubic meter)	Concentration (mg/m^3)
Personal	436	0.087	44
	412	0.082	16
	276	0.055	29
	412	0.082	26
MAK (Germany)			300
NIOSH REL			350
OSHA PEL			2,000
Area	444	0.090	17
	470	0.094	25
	452	0.090	46
	432	0.086	15

*Reported as n-hexane

Table A5. Personal and area air sampling for formaldehyde in the plastic extrusion department*†

Sample Type	Sample time (minutes)	Sample volume (cubic meter)	Concentration (ppm)
Personal	458	0.092	0.0044
	393	0.078	0.0058
	418	0.082	0.0032
NIOSH REL			0.016
OSHA PEL			0.75
ACGIH TLV			0.3‡
Area	21	0.004	0.051§
	488	0.096	0.0011
	476	0.094	0.0063
	425	0.084	0.0063
	459	0.090	0.0015

*Other aldehydes detected but well below their applicable OELs were acetaldehyde, benzaldehyde, butyraldehyde, hexaldehyde, isovaleradehyde, methacrolein, o,m,p-tolualdehyde, valeraldehyde, propionaldehyde.

†Acrolein, crotonaldehyde, and glutaraldehyde were not detected on any sample (< 0.004 ppm).

‡Indicates a ceiling value that should not be exceeded during any part of the work shift.

§The short duration area air sample collected for 21 minutes was collected during a material purge cycle.

Appendix B: Occupational Exposure Limits and Health Effects

NIOSH investigators refer to mandatory (legally enforceable) and recommended OELs for chemical, physical, and biological agents when evaluating workplace hazards. OELs have been developed by federal agencies and safety and health organizations to prevent adverse health effects from workplace exposures. Generally, OELs suggest levels of exposure that most employees may be exposed to for up to 10 hours per day, 40 hours per week, for a working lifetime, without experiencing adverse health effects. However, not all employees will be protected if their exposures are maintained below these levels. Some may have adverse health effects because of individual susceptibility, a pre-existing medical condition, or a hypersensitivity (allergy). In addition, some hazardous substances act in combination with other exposures, with the general environment, or with medications or personal habits of the employee to produce adverse health effects. Most OELs address airborne exposures, but some substances can be absorbed directly through the skin and mucous membranes.

Most OELs are expressed as a time-weighted average (TWA) exposure. A TWA refers to the average exposure during a normal 8- to 10-hour workday. Some chemical substances and physical agents have recommended short term exposure limit or ceiling values. Unless otherwise noted, the short term exposure limit is a 15-minute TWA exposure. It should not be exceeded at any time during a workday. The ceiling limit should not be exceeded at any time.

In the United States, OELs have been established by federal agencies, professional organizations, state and local governments, and other entities. Some OELs are legally enforceable limits; others are recommendations.

- The U.S. Department of Labor OSHA PELs (29 CFR 1910 [general industry]; 29 CFR 1926 [construction industry]; and 29 CFR 1917 [maritime industry]) are legal limits. These limits are enforceable in workplaces covered under the Occupational Safety and Health Act of 1970.
- NIOSH RELs are recommendations based on a critical review of the scientific and technical information and the adequacy of methods to identify and control the hazard. NIOSH RELs are published in the *NIOSH Pocket Guide to Chemical Hazards* [NIOSH 2010]. NIOSH also recommends risk management practices (e.g., engineering controls, safe work practices, employee education/training, personal protective equipment, and exposure and medical monitoring) to minimize the risk of exposure and adverse health effects.
- Other OELs commonly used and cited in the United States include the TLVs, which are recommended by ACGIH, a professional organization, and the workplace environmental exposure level (WEELs), which are recommended by the American Industrial Hygiene Association, another professional organization. The TLVs and WEELs are developed by committee members of these associations from a review of the published, peer-reviewed literature. These OELs are not consensus standards. TLVs

are considered voluntary exposure guidelines for use by industrial hygienists and others trained in this discipline “to assist in the control of health hazards” [ACGIH 2014]. WEELs have been established for some chemicals “when no other legal or authoritative limits exist” [AIHA 2013].

Outside the United States, OELs have been established by various agencies and organizations and include legal and recommended limits. The Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (Institute for Occupational Safety and Health of the German Social Accident Insurance) maintains a database of international OELs from European Union member states, Canada (Québec), Japan, Switzerland, and the United States. The database, available at http://www.dguv.de/ifa/Gefahrstoffdatenbanken/GESTIS-Internationale-Grenzwerte-für-chemische-Substanzen-limit-values-for-chemical-agents/index-2.jsp, contains international limits for more than 1,500 hazardous substances and is updated periodically.

OSHA requires an employer to furnish employees a place of employment free from recognized hazards that cause or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970 (Public Law 91–596, sec. 5(a)(1))]. This is true in the absence of a specific OEL. It also is important to keep in mind that OELs may not reflect current health-based information.

When multiple OELs exist for a substance or agent, NIOSH investigators generally encourage employers to use the lowest OEL when making risk assessment and risk management decisions. NIOSH investigators also encourage use of the hierarchy of controls approach to eliminate or minimize workplace hazards. This includes, in order of preference, the use of (1) substitution or elimination of the hazardous agent, (2) engineering controls (e.g., local exhaust ventilation, process enclosure, dilution ventilation), (3) administrative controls (e.g., limiting time of exposure, employee training, work practice changes, medical surveillance), and (4) personal protective equipment (e.g., respiratory protection, gloves, eye protection, hearing protection). Control banding, a qualitative risk assessment and risk management tool, is a complementary approach to protecting employee health. Control banding focuses on how broad categories of risk should be managed. Information on control banding is available at http://www.cdc.gov/niosh/topics/ctrlbanding/. This approach can be applied in situations where OELs have not been established or can be used to supplement existing OELs.

Below we provide the OELs for most of the compounds we measured, as well as a discussion of the potential health effects from exposure to these compounds. The International Agency for Research on Cancer (IARC) evaluates chemicals on their potential to cause cancer by looking at data from animal and human studies (http://monographs.iarc.fr/ENG/Classification/index.php).

Toluene

Toluene causes central nervous system depression, and can cause acute irritation of the eyes, respiratory tract, and skin. It can also cause headache, dizziness, and a feeling of intoxication (narcosis) [ACGIH 2007, 2014]. The NIOSH REL is 100 ppm, and the OSHA PEL is 200 ppm. The ACGIH TLV is 20 ppm. IARC does not classify toluene as carcinogenic to humans due to inadequate human evidence. Animal studies looking at toluene suggest a lack of carcinogenicity [IARC 1999].

Ethylbenzene

Ethylbenzene is a respiratory tract irritant. It can also affect the kidneys, depress the central nervous system, and affect hearing [ACGIH 2007, 2014]. The NIOSH and OSHA occupational exposure limit is 100 ppm for an 8-hour TWA; the ACGIH TLV is 20 ppm. IARC classifies ethylbenzene as possibly carcinogenic to humans [IARC 2000].

Xylene

Xylene can irritate the skin, eyes, and respiratory tract. Acute xylene inhalation exposure may cause headache, dizziness, incoordination, drowsiness, and unconsciousness. At high concentrations, exposure to xylene has a narcotic effect on the central nervous system and minor reversible effects on the liver and kidneys. The current OSHA PEL, NIOSH REL, and ACGIH TLV for xylene are all 100 ppm over an 8-hour TWA. In addition, NIOSH and ACGIH have published a short-term exposure limit for xylene of 150 ppm averaged over 15 minutes. IARC designates xylene as an agent that is not classifiable as to carcinogenicity to humans due to inadequate animal and human evidence [IARC 1999].

Tin

In general, the toxicity of inorganic tin and its salts is relatively low. With the exception of the oxides, these compounds can cause irritation of the eyes, nose, throat, and skin. No systemic effects have been reported from industrial exposures. Inhalation of fumes can also produce headaches, sore throat, and cough. The OSHA PEL, NIOSH REL, and ACGIH TLVs for tin are all 2 mg/m^3 as an 8-hour TWA.

Naphtha

Petroleum naphtha is considered a refined petroleum product (petroleum distillate) and is comprised mainly of aliphatic hydrocarbons. Light and heavy paraffinic naphtha were the primary products used in the rubber molding and electrical test/assembly areas at this company. Effects from exposure to these organic solvents are primarily acute. Overexposure can cause dry throat; burning or tearing of the eyes; central nervous system depression; mild headaches; dizziness; respiratory irritation; dermatitis; and possible effects on the liver, kidney or other organs. Exposure to organic solvents such as naphtha can occur through inhalation of the vapors, skin contact with the liquid, or ingestion. Many industrial solvents are primary irritants and can cause defatting of the skin and dermatitis. The OSHA PEL for naphtha is 2,000 mg/m^3 for an 8-hour TWA. The NIOSH REL for petroleum distillates (naphtha) is 350 mg/m^3 of air as a TWA exposure while Germany's maximum allowable concentration is 300 mg/m^3. In addition, NIOSH recommends a ceiling concentration limit (15 minutes duration) not to exceed 1,800 mg/m^3.

Formaldehyde

Formaldehyde is a colorless gas with a strong odor. Exposure can occur through inhalation and skin absorption. The most commonly reported health complaints due to exposure to low concentrations of formaldehyde include irritation of the eyes, nose, and throat; nasal congestion; headaches; skin rash; and asthma [ACGIH 2007]. Under the OSHA general industry standard for airborne exposure to formaldehyde [29 CFR 1910.1048], the PEL is 0.75 ppm for an 8-hour TWA, the action level is 0.5 ppm for an 8-hour TWA, and the short-term exposure limit is 2 ppm for a 15-minute TWA. The standard requires medical surveillance for employees exposed to formaldehyde at or above the action level or short-term exposure limit. Formaldehyde is an OSHA-regulated carcinogen [29 CFR 1910.1048]. The NIOSH REL for formaldehyde is 0.016 ppm for up to an 8-hour TWA. NIOSH also has a 15-minute ceiling limit of 0.1 ppm that is not to be exceeded during a work shift [NIOSH 2010]. ACGIH lists formaldehyde as a sensitizer with a ceiling limit of 0.3 ppm [ACGIH 2007, 2014]. This limit is intended to minimize eye and respiratory tract irritation. IARC classifies formaldehyde as a human carcinogen [IARC 2012]. ACGIH and NIOSH have designated formaldehyde as a suspect human carcinogen [NIOSH 1977; ACGIH 2014].

Ergonomic Evaluation Criteria

Musculoskeletal disorders are those conditions that involve the nerves, tendons, muscles, and supporting structures of the body. They can be characterized by chronic pain and limited mobility. Work-related musculoskeletal disorder refers to (1) musculoskeletal disorders to which the work environment and the performance of work contribute significantly, or (2) musculoskeletal disorders that are made worse or longer lasting by work conditions. There is strong evidence of an association between musculoskeletal disorders and certain work-related factors (physical, work organizational, psychosocial, individual, and sociocultural). The complex nature of musculoskeletal disorders requires discussing individual factors and how they are associated with work-related musculoskeletal disorders. Strong evidence shows that working groups with high levels of static contraction, prolonged static loads, or extreme working postures involving the neck/shoulder muscles are at increased risk for neck/shoulder musculoskeletal disorders [NIOSH 1997]. Further evidence shows job tasks that require a combination of risk factors (highly repetitious, forceful hand/wrist exertions) increase risk for hand/wrist tendonitis [NIOSH 1997]. Finally, evidence shows that low-back disorders are associated with work-related lifting and forceful movements [NIOSH 1997]. A number of personal factors can also increase your risk for musculoskeletal disorders. These include age, sex, smoking, physical activity, strength, and body type. However, studies conducted in high-risk industries show that the risk to overexertion injuries/disorders resulting from personal factors is small compared to risks associated with occupational exposures [NIOSH 1997].
In all cases, the preferred method for preventing and controlling work-related musculoskeletal disorders is to design jobs, workstations, tools, and other equipment to match the physiological, anatomical, and psychological characteristics and capabilities of the

employee. Under these conditions, exposures to risk factors considered potentially hazardous are reduced or eliminated.

Workstation design should directly relate to the anatomical characteristics of the employee. Because a variety of employees may use a specific workstation, a range of work heights should be considered. On the basis of the size and shape of the human body, working heights should be within a range of 27″ to no higher than 62″ [Humantech 2009]. These heights correspond to a range of employees, between smallest (5th percentile female) and largest (95th percentile male).

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Availability of Report

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This report is available at http://www.cdc.gov/niosh/hhe/reports/pdfs/2012-0025-3207.pdf.

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