Air Contaminant, Noise, and Dermal Hazards during Aluminum Beverage Can Manufacturing – Texas

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The employer shall post a copy of this report for a period of 30 calendar days at or near the workplace(s) of affected employees. The employer shall take steps to insure that the posted determinations are not altered, defaced, or covered by other material during such period. [37 FR 23640, November 7, 1972, as amended at 45 FR 2653, January 14, 1980].

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Abbreviations

ACGIH®	American Conference of Governmental Industrial Hygienists
AL	Action level
CFR	Code of Federal Regulations
CFU/mL	Colony forming units per milliliter
dB	Decibels
dBA	Decibels, A-scale
°F	Degrees Fahrenheit
EU/m^3	Endotoxin unit per cubic meter
EU/mL	Endotoxin unit per milliliter
GA	General area
HHE	Health hazard evaluation
HTL	Hearing threshold level
Hz	Hertz
kHz	Kilohertz
Lpm	Liters per minute
MDC	Minimum detectable concentration
mg/m^3	Milligrams per cubic meter
MQC	Minimum quantifiable concentration
mL	Milliliter
MWF	Metalworking fluid
NAICS	North American Industry Classification System
ND	Not detected
NIHL	Noise-induced hearing loss
NIOSH	National Institute for Occupational Safety and Health
OEL	Occupational exposure limit
OSHA	Occupational Safety and Health Administration
PBZ	Personal breathing zone
PEL	Permissible exposure limit
PPE	Personal protective equipment
ppm	Parts per million
REL	Recommended exposure limit
SLM	Sound level meter
TLV®	Threshold limit value
STEL	Short-term exposure limit
STS	Standard threshold shift
TWA	Time-weighted average
WEEL™	Workplace environmental exposure level

Highlights of the NIOSH Health Hazard Evaluation

The National Institute for Occupational Safety and Health (NIOSH) received a confidential employee request for a health hazard evaluation at an aluminum beverage can manufacturer. Employees were concerned about exposures to metalworking fluids (MWFs), inorganic acids, printing inks, and noise. Employees reported having skin rashes, headaches, fatigue, and upper respiratory symptoms.

What NIOSH Did

- We evaluated the workplace in December 2008 and June 2009.
- We looked at job tasks, work processes, and the equipment used. We also looked at employees' use of personal protective equipment.
- We measured employees' exposures to noise and the frequencies of noise that employees were exposed to. We also analyzed their hearing tests.
- We took bulk samples of MWFs. These samples were analyzed for bacteria, fungi, and endotoxin.
- We took air samples for MWFs, inorganic acids, dibutylaminoethanol, formaldehyde, and endotoxin.
- We talked with employees about their work. We asked them if they had any health concerns that they thought might be related to their work.
- We asked employees to fill out a survey about health symptoms. We kept their answers to this survey confidential.

What NIOSH Found

- Employees were overexposed to noise.
- Some employees may have hearing loss from noise exposure at work.
- Some employees did not correctly insert their foam earplugs.
- Employees in the lacquer spray, necker, and printer areas need to wear ear plugs and ear muffs. Dual hearing protection will help protect employees from high noise levels in these areas.
- Employees were not overexposed to MWFs, inorganic acids, dibutylaminoethanol, or endotoxin.
- Printer operators were exposed to formaldehyde. They must be told about this exposure and trained about the hazards.
- A few employees exposed to MWF reported health symptoms. The most common symptom was eye irritation.
- No convincing evidence of a relationship between MWF exposure and respiratory symptoms was found. We found no convincing evidence of a relationship between MWF exposure and dermatitis either.
- Bulk samples of MWF had low levels of bacteria and endotoxin. No fungi were found in the samples.

What Managers Can Do

- Use engineering controls to reduce noise.
- Require employees to get baseline audiometric tests when they are hired. Repeat the audiometric tests every year.

- Make sure employees wear hearing protection properly.
- Require employees to wear ear plugs and ear muffs in the lacquer spray, necker, and printer areas.
- Inform printer operators about the low levels of formaldehyde in their work area. Educate them on the health hazards of formaldehyde.
- Encourage employees to use a skin moisturizer after they wash their hands. They should also use moisturizer before and after work to prevent skin problems from MWF and other chemicals.
- Use a can cleaner that is safer than hydrofluoric acid.
- Place a biocide dispenser at the MWF sump.
- Check exhaust ventilation systems regularly. Make repairs as soon as possible when problems are found.
- Install emergency eyewashes and showers where corrosive chemicals are stored or dispensed.
- Check existing emergency eyewash and showers weekly to make sure they work.
- Repair leaks as soon as they are identified. This will keep liquids from dripping or spilling onto walking surfaces.
- Encourage employees to report work-related health concerns, such as skin or breathing problems, to their supervisors.
- Train employees about health hazards from chemicals in the workplace.

What Employees Can Do

- Wear hearing protection properly to prevent hearing loss.
- Wear ear plugs and ear muffs when working in the lacquer spray, necker, and printer areas.
- Wear gloves to protect your skin from MWFs, biocides, inorganic acids, printing inks, and other chemicals.
- Use a skin moisturizer after you wash your hands. Also use moisturizer before and after work to prevent skin problems from MWF and other chemicals.
- Wear all personal protective equipment that your safety manager recommends.
- Report health symptoms that you think are work related to your supervisor and follow up with a healthcare provider who is familiar with occupational exposures.
- Report all health and safety concerns to your supervisor and the health and safety committee.
- Attend all training about safety and health.

Summary

In January 2008, NIOSH received a confidential employee request for an HHE at an aluminum beverage can manufacturer. The requestors were concerned about workplace exposures to MWFs, inorganic acids, printing inks, and noise. Health problems believed to be work related included skin rash, upper respiratory symptoms, headaches, and fatigue.

NIOSH investigators measured employee exposures to noise, MWFs, acids, dibutylaminoethanol, formaldehyde, and endotoxin at an aluminum beverage can manufacturer. Employees were overexposed to noise, and some may have noise-induced hearing loss. Employees were not overexposed to airborne chemicals, and those surveyed about exposure to MWFs reported minimal symptoms. Employees should avoid skin contact with chemicals, use PPE, and follow up with a doctor if symptoms occur.

During the initial site visit, investigators observed work processes, collected screening air samples for volatile organic compounds, and measured noise levels. We talked with employees about their work activities and their health. We also reviewed OSHA 300 Logs of Work-Related Illnesses and Injuries, material safety data sheets, and written health and safety procedures. During our second site visit we collected air samples for MWFs, inorganic acids, dibutylaminoethanol, formaldehyde, and endotoxin. We analyzed bulk samples of MWFs for bacteria, fungi, and endotoxin. We measured employees' noise exposures and took noise frequency measurements. We asked employees to complete a confidential symptom survey to look at possible associations between MWF exposure and dermatitis, respiratory symptoms, and PPE use.

During the second site visit, 128 out of 148 (86%) available plant employees completed the symptom survey. The survey data show that few employees who were exposed to MWF reported respiratory symptoms. We found no convincing evidence of a relationship between MWF exposure and work-related respiratory symptoms or dermatitis. Of the employees who completed the survey, 16% reported dermatitis since starting at the plant. Of 119 employees who completed the survey, four reported work-related dermatitis during the previous month.

Employees were not overexposed to MWFs, inorganic acids, dibutylaminoethanol, or endotoxin during this evaluation. Employees' exposures to formaldehyde were below the OSHA PEL-TWA of 0.75 ppm. Two printer operators were exposed to formaldehyde above 0.1 ppm, the OSHA level requiring employee notification and training. Bacteria and endotoxin levels in the bulk MWF samples were very low, and no fungi were detected in the samples. This finding indicated that the MWF system was well maintained.

All 26 of the monitored employees' TWA noise exposures exceeded the NIOSH REL of 85 dBA for an 8-hour work shift and 83.4 dBA for a 12-hour work shift. Printer operators and back

Summary (continued)

end operators who worked in the necker and lacquer spray areas had TWA noise exposures greater than 100 dBA. Because OSHA uses different noise measurement criteria than NIOSH, TWA noise exposures for material handlers, millwrights, palletizers, and front end maintenance and repair personnel did not exceed the PEL. However, employees' noise exposures in all of the job titles monitored exceeded the OSHA AL of 85 dBA for an 8-hour work shift and 82.1 dBA for a 12-hour work shift.

We recommended the company use engineering controls to reduce noise levels. We also recommended that employees working in the lacquer spray, necker, and printer areas wear dual hearing protection (ear plugs and ear muffs) because noise exposures exceeded 100 dBA. Additionally, we recommended that employees exposed to airborne MWF concentrations exceeding half of the REL (0.20 mg/m^3) receive annual medical monitoring. Other recommendations included wearing PPE, inspecting the ventilation systems, reducing slippery walking surfaces, and reporting all work-related health symptoms.

Keywords: NAICS 331316 (Aluminum Extruded Product Manufacturing), beverage can manufacturing, aluminum cans, metalworking fluids, MWFs, formaldehyde, noise, octave band analysis, hearing loss, audiogram, acids, dermatitis, rash.

Introduction

NIOSH received a confidential HHE request from employees at an aluminum beverage can manufacturer who were concerned about exposures to MWFs, inorganic acids, printing inks, and noise. The employees' health concerns included skin rash, headache, fatigue, and respiratory symptoms. NIOSH investigators visited the company in December 2008 and June 2009. We sent an interim report to the plant management and employee requestors with preliminary findings on September 1, 2009.

Process Description

The plant operated 24 hours per day with three production lines. At the time of the evaluation the plant had 148 production employees working 12-hour shifts and 19 non-production employees working 8-hour shifts.

The beverage can manufacturing process began by unwinding aluminum sheet metal coils. Aluminum sheets were lubricated with DTI M3 lubricating oil, stamped by the cupping press to produce shallow aluminum cups, then extruded by ironers to form can bodies. The tops of the cans were trimmed to a uniform height. Synthetic MWF (DTI Atoguard I-102B) was used for lubrication and to keep cans and machining tools from overheating during extrusion and trimming. This area of the plant was referred to as the front end. About 50 employees operated and maintained machinery and the MWF system in the front end.

After trimming, cans were cleaned with a heated sulfuric acid solution, etched with hydrofluoric acid, and then rinsed. Henkel Deoxylite 115 was added to the rinse water to help the cans flow smoothly throughout the subsequent printing operation. The rinsed cans were dried, and a thin ultraviolet-cured resin was applied to the can's base for abrasion resistance. The cans then traveled to one of four printers where an ink label and a varnish coating were applied to the exterior. Three rotary printers each had a maximum production capacity of 1,300 cans per minute, and another printer had a maximum production capacity of 1,800 cans per minute. Isopropyl alcohol was used to clean all the printers.

Following printing and coating, the cans passed through one of four gas-powered curing ovens. Curing oven emissions were captured and exhausted through an incinerator. After curing, a protective coating was sprayed inside the cans at the lacquer spray

Introduction (continued)

machines. The cans then went through one of three ovens heated to 485°F. Afterwards, a wax film was applied to the top of the cans prior to necking.

At necker machines, a flange was formed on the top rim of the cans. The flange was used to form the seal with the top of the cans during filling (a step not performed at this plant). The cans received a final check for damage and were then palletized and shipped to the customer. About 50 employees operated and maintained the printers, applicators, lacquer spray machines, and neckers. The area of the plant that includes the lacquer spray machines and neckers was referred to as the back end.

A 13,000-gallon central system supplied synthetic MWF for the ironer/trimmer lines. The Henkel DTI-I102B MWF (main ingredients included amine soaps, triethanolamine, and triazine) [Henkel 2007] was maintained under contract by Henkel Surface Technologies. The MWF sump had an automatic metering device to add coolant and water, and a fabric filter removed metal filings and other particulates. The biocide used at the plant, Rohm and Haas Kathon™ 886, contained 5-chloro-2-methyl-4-isothiazolin-3-one, 2-methyl-4-isothiazolin-3-one, magnesium nitrate, and magnesium chloride [Rohm and Haas 2009]. Biocide was manually added to the sump when necessary on the basis of level of bacteria in the MWF. The MWF system had been last emptied and cleaned on November 25, 2006.

Assessment

December 2008 Site Visit

We met with management and employee representatives to discuss the HHE. After the meeting, we toured the plant to observe work activities and the production process. We collected GA air samples on thermal desorption tubes to screen for volatile organic compounds and measured sound levels in production areas.

We selected for health interviews a convenience sample of three employees out of 20 employees from the printer area and all 14 front end and maintenance employees who were present on the day of the first NIOSH site visit. These areas had been identified as having employees with skin rashes and respiratory problems. We asked about employment history, exposures, health symptoms, PPE use, and workplace safety and health concerns. We focused on interviewing this small group to obtain an indication of the types of problems that were occurring and to help determine, along with other factors, where a larger survey was needed.

We reviewed OSHA 300 Logs of Injury and Illness from 2004–2008, first aid logs for 2008, and monthly accident reports for the last 3 years (2006–2008). We also reviewed the written respiratory protection and other safety programs, and we observed PPE use.

June 2009 Site Visit

We collected full-shift PBZ and GA air samples for MWFs at the front end, printer, and necker; sulfuric and hydrofluoric acids at the acid tank and can washer area; 2-dibutylaminoethanol at the printer; formaldehyde in all production areas; and endotoxin at the front end and printer. Formaldehyde and 2-dibutylaminoethanol were components of inks used for printing onto cans. Endotoxin can be a contaminant in used MWFs. We collected bulk samples of MWFs and submitted them for analyses for total bacteria, mycobacteria, fungi, and endotoxin. Air sampling methods are described further in Appendix A.

We measured full-shift personal noise exposures of 26 employees with Larson Davis (Provo, Utah) Spark™ Model 705P integrating noise dosimeters. We used a Larson Davis Model 824 integrating sound level meter and real time frequency analyzer equipped with a half-inch random incidence microphone (Type 1) for sound level and one-third octave band noise frequency measurement throughout production areas of the facility. Noise monitoring methods are further described in Appendix A.

We obtained an electronic database of 1,182 audiograms from 1988 to 2008 for 104 current production employees. We analyzed employee audiometric test history to determine hearing threshold shift using OSHA and NIOSH criteria. For analysis, a hearing threshold shift was considered persistent when a minimum of two consecutive audiograms confirmed the threshold shift. We calculated material hearing impairment using NIOSH criteria. We also calculated the length of time between hire date and baseline audiogram, and the length of time between consecutive employee audiograms.

Assessment (continued)

We asked all plant employees to complete a questionnaire to investigate possible associations between MWF exposure and dermatitis, respiratory symptoms, and PPE use. The questionnaires also asked about demographic information, pertinent medical history, and non-work exposures. We analyzed the questionnaire data using SAS Version 9.2. Details of the questionnaire analysis are described in Appendix A.

We classified our exposure groups on the basis of reported current job title of the participant. We classified the current job titles that were known to have exposures to MWF production work as the MWF-exposed group. This included all front end and back end employees in the production area who were known to have contact with MWF. We classified current job titles that were not exposed to MWF as the unexposed group. All administrative and office staff and employees involved in shipping and packaging (with minimal or no exposures to MWF) were included in the unexposed group.

We defined the following work-related symptoms: cough, wheezing or whistling in chest, unusual shortness of breath, chest tightness, nose irritation, eye irritation, sore throat, fever, and body aches by positive responses to both (1) having the symptom in the past month and (2) improvement on days away from work. We defined possible work-related asthma as a positive response to (1) ever had asthma, (2) still have asthma, and (3) does your asthma seem better when you are away from your current job. Symptoms suggestive of work-related asthma were defined as a positive response to work-related wheeze or two or more of the following symptoms: work-related cough, work-related chest tightness, or work-related shortness of breath in the past month as defined above. A personal history of allergic disease, or atopy, was defined as ever having a persistent itchy rash that affected skin creases (eczema or atopic dermatitis). We defined current work-related dermatitis as a positive response to (1) dermatitis on hands, wrists, or forearms in the last month; and (2) dermatitis is better when away from work.

Results

Air and Bulk Sampling

A summary of air sampling results for MWFs and formaldehyde is provided in Tables 1 and 2. All air sampling results for MWFs, inorganic acids, formaldehyde, and 2-dibutylaminoethanol are presented in Appendix B, Tables B1–B4.

The MWF concentrations, as total thoracic particulate mass, were below the NIOSH REL-TWA of 0.40 mg/m^3. Exposures to total thoracic particulates and extracted MWFs were similar in the front end and printer areas. In addition, extracted MWFs were not detected in seven of the twelve PBZ air samples collected on employees working in the front end, or in three of the four air samples collected on printer operators. NIOSH does not have an REL-TWA for extracted MWFs.

Table 1. PBZ air sampling results for MWF, collected on June 9–10, 2009

Location/Job	# Samples	Concentration (mg/m^3) Total thoracic particulates*§		Extracted MWFs†§	
		Mean	Range	Mean	Range
Front end	12	0.17	0.09–0.28	0.087	ND‡–0.19
Printer	4	0.15	0.09–0.27	0.098	ND‡–0.21
Necker	1	(0.070)	NA¶	ND‡	NA¶
MDC		0.03		0.06	
MQC		0.098		0.18	
NIOSH REL		0.40		NA	

*The total thoracic particulates value includes all dust and other aerosols in the air that are in the thoracic size range.
†The extractable fraction represents the portion of the sample that was MWF.
‡ND = not detected (below the MDC).
§Concentrations between the MDC and MQC are shown in parentheses to point out that there is more uncertainty associated with these values than with concentrations above the MQC.
¶NA = not applicable

We collected a full-shift PBZ air sample for hydrofluoric and sulfuric acid on an employee working near the can washer, hydrofluoric acid tank, and sulfuric acid tank. We also collected five GA air samples for hydrofluoric and sulfuric acids at these locations. One of the GA samples for hydrofluoric acid, collected near a hydrofluoric acid tank, had a TWA concentration of 0.24 mg/m^3, which was below the REL-TWA of 2.5 mg/m^3. The PBZ air sample and all the other GA air samples for hydrofluoric acid and sulfuric acid had measured concentrations that were either ND or below the MQC.

The results from the six PBZ samples for 2-dibutylaminoethanol collected on printer operators ranged from 0.20 to 0.26 mg/m^3, much lower than the NIOSH REL-TWA of 14 mg/m^3. The PBZ TWA concentrations for formaldehyde ranged from 0.020 to 0.13 ppm, below the OSHA PEL of 0.75 ppm for an 8-hour TWA exposure [29 CFR 1910.1048]. However, these PBZ sample results exceed the NIOSH REL for formaldehyde of 0.016 ppm [NIOSH 1977]. Printer operators had the highest exposure to formaldehyde. Two printer operators were exposed to formaldehyde concentrations greater than 0.1 ppm, the concentration at which OSHA requires employee notification and training.

Table 2. PBZ air sampling results for formaldehyde, collected on June 9–10, 2009

Location/Job	# Samples	Concentration (ppm)	
		Mean	Range
Front end	11	0.044	0.023–0.090
Printer	5	0.098	0.071–0.13
Chemical process operator	2	0.026	0.020–0.031
Millwright	1	0.040	NA*
Forklift operator	1	0.080	NA
Lacquer spray	1	0.042	NA
NIOSH REL-TWA		0.016	
OSHA PEL-TWA		0.75	

* NA = not applicable (one sample collected)

We collected 16 PBZ air samples for endotoxin. Concentrations ranged from 0.23 to 2.2 EU/m^3. The concentration in a background sample collected outdoors was 1.1 EU/m^3. No accepted occupational exposure limits have been developed in the United States because of the variability of sampling and analytical methods and because of a lack of data showing a consistent dose-response relationship between exposures and health effects. In 2010, the Dutch Expert Committee on Occupational Safety recommended a health-based occupational exposure limit for airborne endotoxin of 90 EU/m^3 [DECOS 2010]. Endotoxin air sampling results are presented in Appendix B, Table B5.

Endotoxin concentrations ranged from 46 to 74 EU/mL in the five bulk MWF samples collected, with a mean concentration of 62 EU/mL. Although there are no guidelines for acceptable levels of endotoxin in MWFs, these concentrations are lower than the average concentrations researchers have reported for endotoxin in MWFs at other companies [Simpson et al. 2003; Cyprowski et al. 2007]. Five MWF bulk samples were analyzed for bacteria and fungi. Neither mycobacteria nor fungi were detected in any of the samples. Total bacteria counts ranged from 1 to 100 CFU/mL for Bacillus species and 0 to 2 CFU/mL for aerobic actinomycetes. These are well below a concentration of one million CFU/mL of MWF, a level suggested by some researchers as appropriate for well-maintained MWFs [Rossmore and Rossmore 1994].

Noise

Table 3 summarizes personal noise exposure measurements. Employees in the job titles front end maintenance/repair and millwright worked 8-hour shifts. Employees in the other job titles worked 12-hour shifts. All 26 of the personal noise exposure measurements exceeded the NIOSH REL of 85 dBA for an 8-hour work shift and 83.2 dBA when adjusted for a 12-hour work shift. Four of five TWA noise exposure measurements for printer operators and three of four TWA measurements for back end operators (necker and lacquer spray areas) exceeded 100 dBA.

Because OSHA uses different noise measurement criteria than NIOSH, TWA noise exposures for employees in the job titles material handler, millwright, palletizer, and front end maintenance/repair did not exceed the PEL. However, employees' noise exposures in all of the job titles monitored exceeded the OSHA AL of 85 dBA for an 8-hour work shift and 82.1 dBA for a 12-hour work shift. Table B6 in Appendix B provides detailed personal noise monitoring results.

Table 3. Range of personal noise dosimetry measurements

Job title	Number of measures	TWA noise measurements (dBA)		
		OSHA AL	OSHA PEL	NIOSH REL
Back end operator (lacquer spray)	2	97.5 – 99.0	97.4 – 98.9	98.8 – 100.5
Back end operator (necker)	2	99.9 – 99.9	99.8 – 99.9	102.2 – 102.7
Baler room/forklift operator	2	94.9 – 95.6	94.6 – 95.4	95.6 – 97.0
Front end ironer/trimmer	8	91.3 – 97.7	90.6 – 97.6	93.4 – 99.9
Front end maintenance/repair*	1	86.3	88.6	91.0
Material handler	2	81.3 – 87.3	71.2 – 81.8	84.2 – 89.8
Millwright*	2	87.7 – 89.8	84.3 – 87.4	90.7 – 93.4
Palletizer	2	85.6 – 86.9	72.5 – 77.3	86.6 – 88.0
Printer operators	5	98.2 – 100.2	98.2 – 100.0	99.7 – 101.2
Noise exposure limits	12-hour work shift	82.1	90.0	83.2
	*8-hour work shift	85.0	90.0	85.0

* Employees in the job titles front end maintenance/repair and millwright worked 8-hour work shifts.

Results (continued)

We measured one-third octave band noise levels at the cupper presses, ironers, printers, neckers, lacquer spray machines, and balers. At the cupper presses and ironers the predominant noise frequencies were 315 to 500 Hz. We found multiple peaks in low and high frequencies at the necker and lacquer spray machine. Similarly, the baler had multiple frequency peaks, but all were below 1,000 Hz, with 125 Hz being the dominant frequency. The dominant frequency for the printer was 10,000 Hz. A separate and very distinct peak of approximately 800 Hz occurred at the printer when the printer alarm sounded. Octave band measurement results are shown in Figures B1–B6 in Appendix B.

An analysis of the audiometric history for the 104 production employees for whom we had historic audiometric test results indicated that 43 (41%) had experienced an STS since their baseline audiogram on the basis of OSHA STS criteria. Using NIOSH hearing threshold shift criteria, 51 employees (49%) had experienced a hearing threshold shift. Appendix C explains the difference between the OSHA and NIOSH threshold shift criteria. Audiograms for 15 employees (14%) showed they had material hearing impairment on the basis of the NIOSH definition, which is an average HTL for both ears of 25 dB at 1,000, 2,000, 3,000, and 4,000 Hz [NIOSH 1998b]. Six additional employees also had material hearing impairment. However, these employees had this hearing loss at the time of hire.

We analyzed the time between employees' hire date and the date of their first audiogram. Because the company started an audiometric testing program in 1988, only employees with a hire date of 1988 or later (N=70) were included in this analysis. Results are shown in Table 4. Of these 70 employees, 43% had audiometric tests within 6 months of hire, but 17% had their first audiometric test more than 1 year after hire.

Table 4. Time between employee's hire date and first audiometric test (only employees hired after 1988 included, N=70)

Time between hire date and first audiogram	Number of employees (%)
≤ 6 Months	30 (43)
> 6 Months and < 12 Months	28 (40)
≥ 12 Months	12 (17)
Average = 247 days (Range: 7–1569 days)	

We separately analyzed the time between consecutive audiograms (N=1182) for each employee in the dataset (Figure 1). Approximately 25% of audiometric tests were completed within 12 months of the previous test, as required by OSHA. More than 12 months elapsed between consecutive tests for about 75% of all audiometric tests. However, most of these were completed within 12 to 15 months of the previous audiometric test. For 4% of audiometric tests, more than 2 years elapsed between consecutive tests.

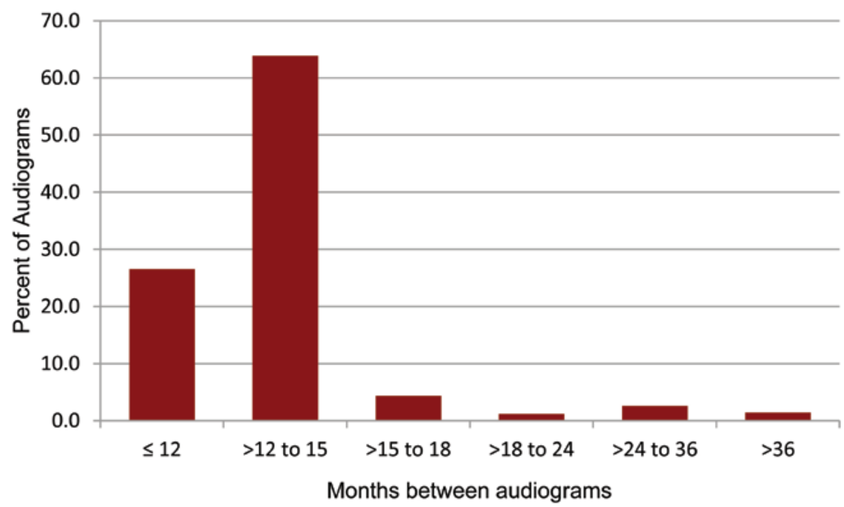

Figure 1. Months between consecutive audiograms (N=1,182).

Employee Interviews and Review of Injury and Illness Recordkeeping Logs

In December 2008, we interviewed a convenience sample of 17 employees (three employees from the printer area and all 14 front end and maintenance employees). These areas had been identified as having employees with skin rashes and respiratory problems. Six reported skin rash to the wrist, arms, and hands that improved when they were away from work; three reported acute upper respiratory symptoms that improved when they were away from work; three reported hearing loss symptoms; and one employee reported recurring headaches that improved when away from work. In addition to health symptoms, employees also reported lack of safety communication, inadequate training, need for improved housekeeping to minimize slips and trips in the front end area, and general safety issues.

An incident log maintained by the plant had 29 incidents recorded in 2006, 27 in 2007, and 31 in 2008 that resulted in injuries or were considered near misses. Each entry included a short-term and long-term action plan to prevent future incidents. We reviewed the incident log from 2008 for injuries or illnesses that required first aid from the safety staff; four entries were recorded for skin rash and six for falls, abrasions, and slips/trips.

Our review of the OSHA 300 Logs from 2004–2008 revealed two reports of skin rashes from front end employees and eight reports of STS. The employees with STS did not have a common occupation or work area. All other entries on the OSHA 300 Logs were injuries; specifically, 24 sprains/strains, 9 lacerations, 2 crushing/smashing injuries, 2 eye injuries, and 2 contusions. Employees in maintenance and machinists were the most frequently injured.

Written Safety and Health Programs

Respiratory Protection

Employees in the respiratory protection program were fitted to wear North (Cranston, Rhode Island) model 7700 half-mask elastomeric respirators. The written respiratory protection program lacked information on the chemical hazards present, anticipated concentrations, and specific type of respirator needed for these chemicals or hazardous conditions. The written program also did not include a cartridge or canister change-out schedule to ensure that employees replaced cartridges before the end of their service life.

Personal Protective Equipment

The company had a written personal protective equipment certification of hazard assessment, as required by OSHA. All employees were required to wear safety glasses, safety shoes, and hearing protection. The company provided work uniforms (short or long sleeve shirts and pants), which some employees wore. However, some employees told us that because they were required to pay for cleaning the work uniforms, they chose not to wear the uniforms and wore their own clothes, typically jeans and T-shirts.

Some employees voluntarily wore nitrile gloves (Flexshield®) while changing tools on the ironer/trimmers or when handling chemicals. A concern noted by employees was the limited selection of glove sizes. The employees maintaining the can washers wore polyvinyl chloride gloves, a Tychem® suit, and steel-toe rubber boots because they could contact hydrofluoric and sulfuric acid. Employees adding chemicals to the water treatment tank or adding biocide to the MWF sump wore a rubber apron and rubber or nitrile gloves. Durapro® barrier cream was available for employees at their workstations and from the storage room.

Hearing Conservation Program

The company had a written hearing conservation program that included information on noise monitoring, audiometric testing, hearing protection, and training. Employees were provided with Aearo (Indianapolis, Indiana) EAR Classic® and EAR Earsoft Superfit® foam insert type earplugs. The earplugs have a noise reduction rating of 29 dB and 33 dB, respectively. The company contracts a mobile audiometric testing provider to complete audiometric testing. The contractor provides the company with an audiometric test history report for each employee. The report notes individual trends, such as an OSHA STS. If the audiologist reviewing test results notes something unusual in an employee's audiogram, such as asymmetrical hearing loss, the company is provided with an "audiologist review report" for use during further evaluations. Follow-up testing, if necessary, was usually done at a local clinic. Basic hearing conservation training was provided by the audiometric testing contractor while site-specific training, including instructions on proper fitting of hearing protection, was provided by the company safety director.

Health Questionnaire

During the site visit in June 2009, 128 out of 148 (86%) available plant employees completed the questionnaire. Fewer than 10 employees were not at work because of vacation or sick leave.

Table 5 presents the characteristics of the MWF exposed and unexposed groups. Other than sex, demographics were similar between both groups.

Table 5. Demographic characteristics among MWF-exposed and unexposed employees

Characteristic	MWF-exposed (N = 101) Number (%)	Unexposed (N = 27) Number (%)
Male	92 (91)	17 (63)
Personal history of atopy*	7 (7)	1 (4)
Age – average	44 Years	48 Years
Total years at plant – average	13 Years	9 Years

*Positive responses to ever having a persistent itchy rash that affected skin creases (eczema or atopic dermatitis)

Work-Related Respiratory Symptoms Among Plant Employees

Table 6 compares the prevalence of work-related symptoms in MWF-exposed and unexposed groups. Employees exposed to MWF reported few symptoms. Of reported symptoms, eye irritation had the highest prevalence. We did not find statistically significant differences in the prevalence of work-related symptoms in employees exposed to MWF compared to those unexposed to MWF. Four employees exposed to MWF reported that they had current work-related dermatitis. We looked at the prevalence of current work-related dermatitis in those exposed to MWF compared to those unexposed to MWF. We did not find a statistically significant difference.

Table 6. Prevalence of work-related symptoms among MWF-exposed and unexposed employees

Work-related symptoms*	MWF-exposed (N = 92–101)† Number (%)	Unexposed (N=26–27)† Number (%)	Prevalence ratio¶ (*P* value)
Cough	8 (8)	4 (15)	0.26 (0.25)
Wheeze	1 (1)	3 (12)	0.02 (0.003)
Shortness of breath	5 (5)	2 (8)	0.63 (0.58)
Chest tightness	4 (4)	2 (8)	0.60 (0.42)
Nose irritation	14 (14)	6 (23)	0.24 (0.26)
Eye irritation	10 (10)	3 (12)	0.72 (0.81)
Sore throat	3 (3)	2 (8)	0.27 (0.27)
Fever	0	2 (8)	0.04 (0.005)
Body aches	6 (6)	4 (15)	0.21 (0.11)
Asthma‡	2 (2)	2 (7)	0.20 (0.15)
Symptoms suggestive of asthma§	3 (3)	3 (12)	0.10 (0.07)
Dermatitis	4 (4)	0	0.57 (0.27)

*Positive responses to both: (1) having the symptom in the past month and (2) did it improve on your days off.
†Range of denominators, i.e., the number of employees answering each question differed.
‡Positive responses to (1) ever had asthma, (2) still have asthma, and (3) does your asthma seem better when you are away from your current job.
§Positive responses to work-related wheeze, or two or more of the following symptoms: work-related cough, work-related chest tightness, or work-related shortness of breath in the past month.
¶The prevalence ratio is defined as the prevalence of a symptom reported by MWF-exposed employees divided by the prevalence of symptom reported by MWF-unexposed employees.

Dermatitis Among Plant Employees

Of 128 employee participants, 25 (16%) reported having had dermatitis on their hands, wrists, or forearms since they began working at the plant. Nine employees reported that they had seen a doctor for their dermatitis. Summer was the most common season when employees reported dermatitis. Employees reported what jobs they were working in when they first developed dermatitis. Of the 24 jobs reported, most were in the printer (8) and front end (7) areas. Eight employees reported that contact with oil residue on metal parts, coolants or machining fluids, and lubricants in their work made their dermatitis worse, and four employees reported solvents made their dermatitis worse. Of the 14 employees who reported using gloves at work before they developed dermatitis, five reported that they changed glove type or stopped using gloves because of their dermatitis. Table 7 describes PPE use and hygiene practices among the employees exposed to MWF.

Table 7. Describing PPE use and hygiene practices among MWF-exposed employees

Reported PPE use and hygiene practices	MWF-exposed employees (N =72–101)* Number (%)
Use gloves at work	87 (86)
Use double glove† (among glove users)	22 (26)
Reuse disposable gloves‡ (among glove users)	1 (1)
Use protective sleeves	9 (9)
Average number of times hands washed at work	14
Apply moisturizing skin lotion	20 (20)
Apply barrier creams	12 (12)
Wet hands 2 hours or more/shift	36 (36)

*Range of denominators, i.e., the number of employees answering each question differed
†Using two pairs of the same glove at the same time
‡Current reuse of black latex or blue neoprene gloves

Other Findings

Following our initial site visit, the plant installed drip gutters beneath the conveyor lines between the ironers and trimmers to catch excess MWF from cans. This was an excellent application of engineering controls. However, we did observe MWF leaking at some of the ironers during our return visit (Figures 2 and 3).


Figure 2. Leaking MWF at an ironer.


Figure 3. MWF overflowing from an ironer.


Figure 4. Metalworking fluid on floor in ironer area.

We observed walking surfaces that were slippery from MWF in the ironer area (Figure 4) and on the short metal grating platforms used for stepping over the can conveyor lines. The stair steps for the wastewater treatment platform (Figure 5) were slippery from chemical residue used for the wastewater treatment tanks. We observed water on the floor (Figure 6) near the water fountain between the Concord printers. The water dripping from the platform above appeared to be dripping onto an electrical panel box. We informed management of this water leak during the site visit.

During our second site visit, we observed that employees could reach into or enter the palletizer to retrieve stray cans while the machine was still operating. This potential safety hazard resulted from an incorrect location of the automatic shut-off light sensors. We also noted that the palletizer system could lose air pressure while it was locked out for repair, resulting in the top frame carriage potentially falling and trapping or injuring an employee. We informed management of this safety hazard during the site visit.

Some work areas where acids were located did not have emergency eyewash stations or showers. This was noted in the tank farm building and near the outdoor tanks of sulfuric acid and hydrochloric acid. The chemical storage room where 12 330-gallon totes of hydrofluoric acid were stored had an eyewash station, but did not have an emergency shower. We observed that the eyewash in the washer and dryer area was not working correctly. The left nozzle had low water flow unless the activation paddle was completely depressed. However, when the paddle was completely depressed the water flow appeared to be excessively strong through the left nozzle.

We observed that steam was not captured by the exhaust hood at some of the ironers. The effectiveness of the exhaust ventilation system at the ironers was decreased by the use of flexible duct, which has greater air flow resistance than smooth duct. Additionally, some ductwork had unnecessary bends that also reduced the overall effectiveness of the exhaust ventilation system (Figure 7). We also saw a hole in the bottom of the ventilation duct near the top of Cure Oven 1.

The labels on some storage tanks in the washer area did identify the contents as acids. Some containers in one of the quality control labs did not include hazard warning information, as is required

Results (continued)

by the OSHA hazard communication standard (Figure 8). We saw other tanks without hazard warning information, including the tramp oil tank in the bulk storage room.

We observed that some forklift drivers did not consistently wear seat belts.

Figure 5. Stairs at mezzanine of wastewater treatment area were noticeably slippery.

Figure 7. Flexible exhaust ventilation duct with too many bends at an ironer, which reduces effective ventilation.

Figure 6. Water on floor near Concord printers.

Figure 8. Labels on containers of alcohol in a quality control lab did not include hazard information to warn users of possible adverse health effects from the product.

Air Contaminants

Our sampling results indicated that employees were not overexposed to airborne MWFs, inorganic acids, dibutylaminoethanol, or endotoxin during this evaluation. However, even small amounts of these substances can irritate the skin and cause dermatitis [Blanc et al. 1991; Lee et al. 1997; Rosenberg et al. 1997; NIOSH 1998a; Godderis et al. 2008]. Information on the health hazards associated with MWF and formaldehyde is provided in Appendix C.

The MWF bulk samples we collected from the sump and the ironer/trimmer machines contained low levels of bacteria and endotoxin. Additionally, our review of the results from previous testing completed by Henkel Surface Technologies revealed that bacteria and fungi were not detected in samples collected between January 2007 and November 2008, on the basis of dipstick testing methods (limit of detection not specified in test reports). The pH ranged from 8.9 to 9.4, and tramp oils ranged from 1.3% to 3.6%. This suggests that the MWF system was well maintained. We noted that employees manually added Kathon 886™ biocide to the MWF sump if high levels of bacteria were detected. Installing a metered dispenser to add biocide to the sump would reduce the risk of employee exposure from manual application.

Formaldehyde concentrations were well below the OSHA PEL of 0.75 ppm, but did exceed the NIOSH REL of 0.016 ppm. This REL was established in 1981 when NIOSH recognized formaldehyde as a potential occupational carcinogen. On the basis of the carcinogen policy in existence at the time, NIOSH set the REL to the "lowest feasible concentration," which for formaldehyde was defined as the analytical limit of quantification of 0.016 ppm for up to a 10-hour TWA and a ceiling limit of 0.10 ppm that should not be exceeded [NIOSH 1981]. However, research has shown that concentrations of formaldehyde in ambient air can approach or exceed this level [Lemen 1987]. Additionally, the subsequent revision of the NIOSH carcinogen policy [NIOSH 1995], combined with better exposure characterization and advances in risk assessment and management strategies, support the need for NIOSH to reassess the formaldehyde REL.

Noise Exposures

OSHA and NIOSH use different criteria for measuring TWA noise exposures. Although not all employees were exposed to noise levels that exceeded the OSHA PEL of 90 dBA, all monitored employees' noise exposures exceeded the OSHA AL and NIOSH REL. The NIOSH REL for noise is not a legally enforceable noise exposure limit; however, it is more protective than the OSHA PEL in preventing hearing loss.

More than 57% of employees had their first, or baseline, audiogram more than 6 months after their hire date, and 17% had their baseline audiogram more than 1 year after they were hired. Completion of baseline audiograms before newly hired employees begin working allows identification of hearing loss prior to workplace noise exposures. If hearing loss is identified on an audiogram completed after a new employee has begun working, the source of the hearing loss cannot be determined because it may have been present prior to workplace exposure or have occurred after the employee began working.

Our analysis of employee audiograms showed that 15 employees (14%) had hearing loss that met the NIOSH definition of material hearing impairment. Previous NIOSH research has shown that employees with noise exposures greater than 85 dBA are at risk of hearing loss in as little as 5 to 10 years of exposure. Figures 9 and 10 present NIOSH research estimates for excess risk of material hearing impairment, on the basis of age and duration of exposure [NIOSH 1998b].

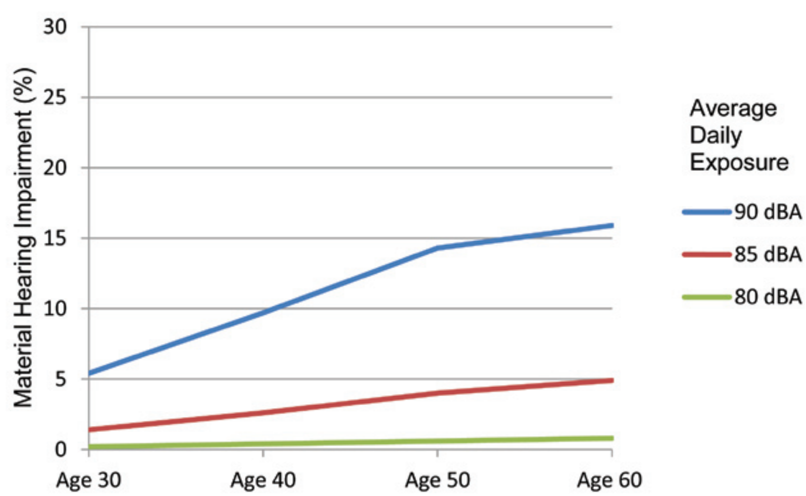

Figure 9. NIOSH excess risk estimates (%) for material hearing impairment, by age, after 5 to 10 years of noise exposure.

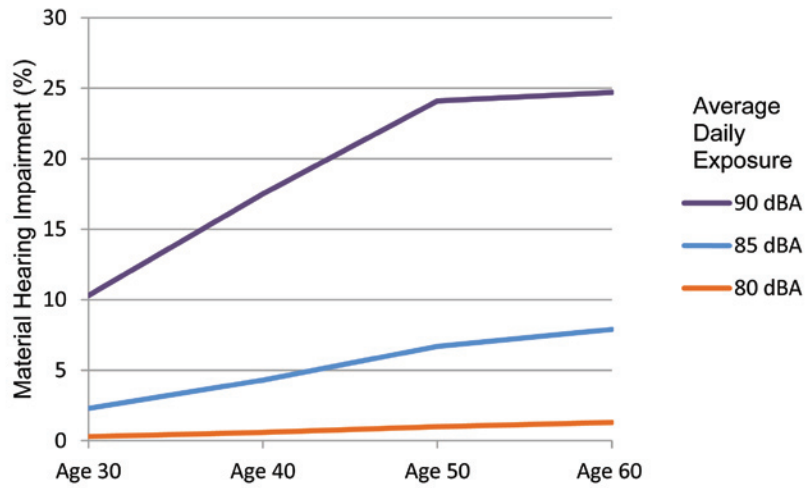

Figure 10. NIOSH excess risk estimates (%) for material hearing impairment, by age, after more than 10 years of noise exposure.

Our analysis of the audiometric history for 104 current production employees indicated that 41% had an OSHA-defined STS, and 49% had a NIOSH-defined hearing threshold shift since their baseline audiogram. The reason for this difference is that NIOSH includes hearing loss in all audiometric test frequencies, whereas OSHA only uses the frequencies 2, 3, and 4 kHz.

Figure 11 shows the audiometric history for one of the production employees. The figure shows a characteristic notch at 4 kHz representing a common NIHL audiogram pattern. Figure 12 also shows the audiometric history for a different production employee. However, the audiograms in this figure show substantial hearing loss at 6 kHz, rather than 4 kHz. Although NIHL is typically first observed in the 4 kHz and 6 kHz audiometric test frequencies, interpretation of the audiograms in Figure 13 is somewhat challenging because an audiogram showing progressively increasing HTLs with increasing audiometric test frequencies can also indicate presbycusis (age-related hearing loss). Inclusion of the 8 kHz frequency in audiometric testing would allow detection of a notch at 6 kHz and provide better information for audiologists or physicians reviewing audiograms to interpret hearing loss in audiometric test results. Additionally, if the audiometric testing program only uses OSHA STS criteria and does not track hearing levels at 6 kHz or 8 kHz, employees with progression of NIHL at 6 kHz may not be identified or their NIHL may not be detected until the hearing loss has also progressed substantially at 4 kHz. This could delay important intervention to prevent further hearing losses. Therefore using both OSHA and NIOSH criteria for evaluating threshold shifts among the employees is advisable.

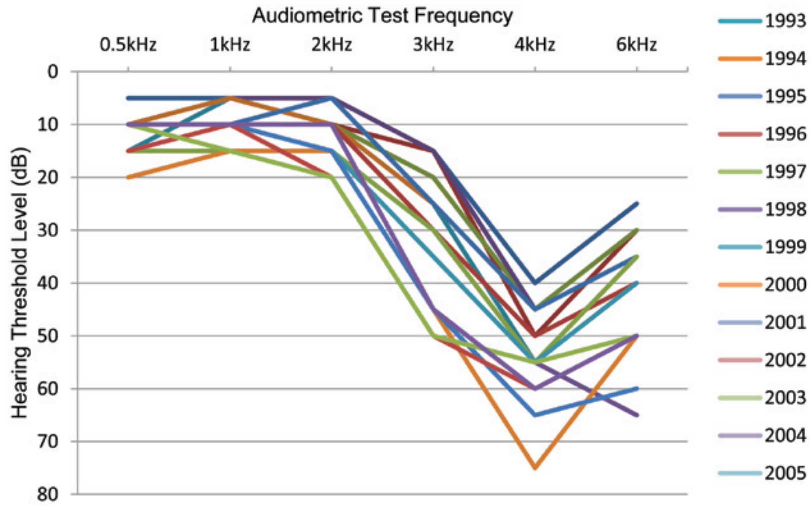

Figure 11. Audiometric history showing typical NIHL pattern at 4 kHz.

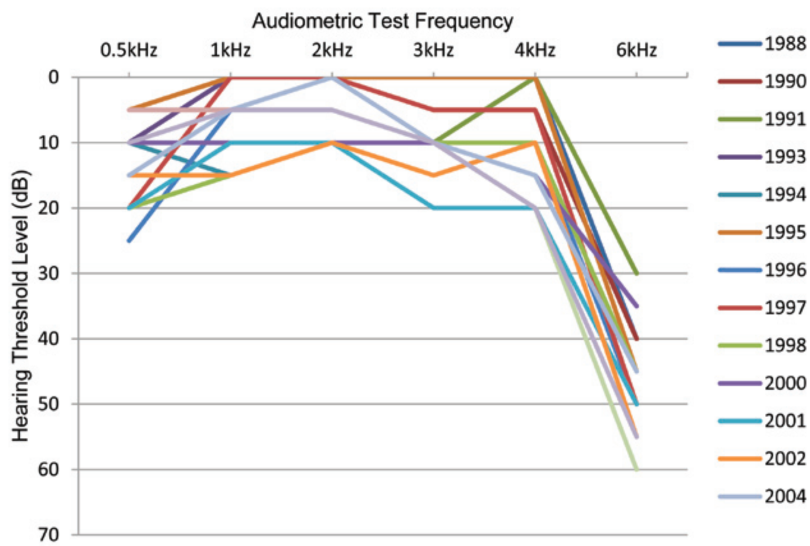

Figure 12. Audiometric history showing substantial hearing loss at 6 kHz.

Several employees' audiograms showed year-to-year variation in HTLs. Although variation of 5 to 10 dB in HTL from one year to the next is common, an improvement in HTL greater than 10 dB is not typical. There may be several reasons for this variability. Because audiograms were conducted during the work shift, some of the employees may have had a temporary threshold shift at the time of an audiogram, but did not have one for the next audiogram. A temporary threshold shift can occur if employees wear no hearing protection before the audiogram or their hearing protection was not properly worn and allowed substantial noise to reach the ear. OSHA requires that employees not be exposed to noise levels greater than 85 dBA for at least 14 hours before an audiogram. NIOSH recommends that employees have at least 12 hours of unprotected quiet before an audiometric test. Alternatively, any background noise during the employee's audiometric test could produce an artificially high HTL for that particular test. OSHA specifies the maximum noise limits inside the audiometric test booth during a test. Additionally, different audiometers used from one year to the next can yield different results.

Our analysis was limited to the 104 current production employees for whom we had audiometric records and did not include former employees from the period 1988 to 2008. Although the audiograms we evaluated show that some employees have experienced threshold shifts and hearing loss, our analysis does not reveal whether the rate of threshold shifts has changed over time. Additionally, we did not include age correction adjustments to the audiograms. Therefore, the number of threshold shifts we identified is likely higher than would be identified if OSHA age correction criteria were applied. NIOSH does not recommend that age correction be applied to an individual's audiogram for threshold shift calculations [NIOSH 1998b]. Some, but not all, people experience some decrease in hearing sensitivity with age. It is not possible to know who will and who will not have an age-related hearing loss. Thus, applying age corrections individually to calculate a significant hearing threshold shift tends to overestimate the expected hearing loss for some and underestimate it for others because the median hearing loss attributable to presbycusis for a given age group will not be generalizable to that experienced by an individual in that age group. However, some researchers support the practice of age correction because not all hearing loss experienced by employees is a result of noise exposures, and advocate an expert professional review of audiograms to avoid categorization that all hearing changes are work-related [Royster 2000].

Although all company employees wore foam insert hearing protection, some did not insert them deeply enough in the ear canal. Additionally, employees can appear to have hearing protection properly inserted but it may not fit effectively. Given these observations and the analysis of audiograms indicating hearing loss, it is important for the company to emphasize consistent and proper use of hearing protection. Methods for fit testing of hearing protection are also available from some manufacturers to help ensure proper selection and adequate fit of hearing protection.

Some or all of the monitored employees in the job titles lacquer spray operator, necker operator, and printer operator had TWA noise exposures greater than 100 dBA. No employees were observed wearing earmuffs during the HHE. Some employees expressed reluctance to use earmuffs, particularly during warm weather, because they sweat around their ears and the earmuffs become very uncomfortable.

Octave band noise frequency analysis revealed that some equipment had the highest noise levels at low frequencies. Noise reduction strategies for low frequency noise should focus on reducing equipment vibration. For example, installation of appropriately designed vibration isolation pads or springs can reduce vibration transmitted from operating equipment to surrounding surfaces (Figure 13). Replacing thin metal panels with thicker metal or dampened metal panels can also help reduce vibration.

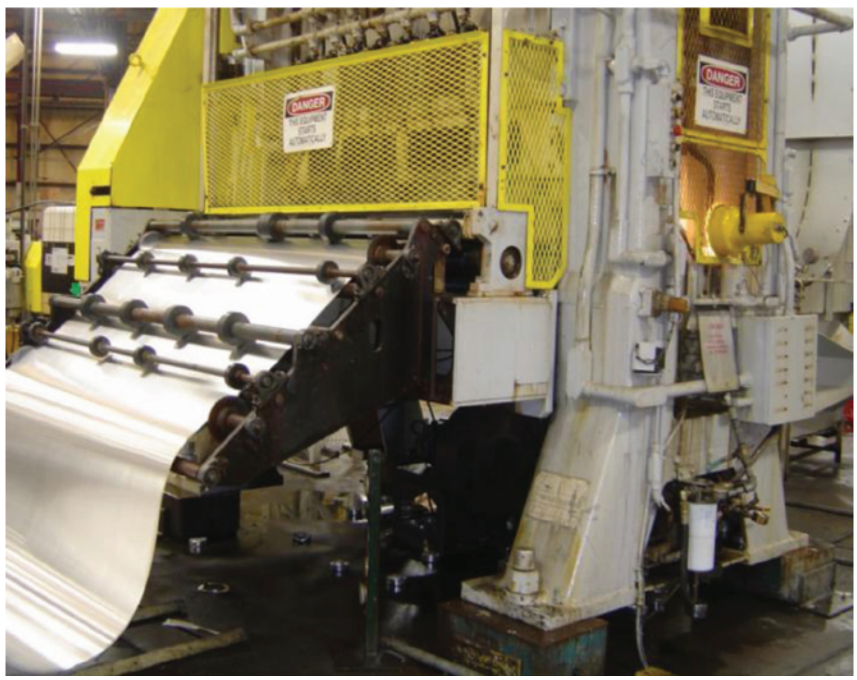

Figure 13. Large cupper press, without vibration damping, mounted to the concrete floor.

High frequency noise can be reduced by using acoustic equipment enclosures or noise barriers (Figures 14). For example, properly designed equipment enclosures may be suitable for the lacquer spray machine, printer, necker, and baler. If space and production logistics allow, it may be possible to construct operating booths for employees to use when they are not working directly at production equipment. Although most noise results from equipment operation, some noise could result from lack of timely maintenance. For example, high frequency squeaks noticeable near the backside of the some printers could be eliminated by lubrication of the equipment. We observed loose panels at the ironers that, if tightened, would eliminate unnecessary rattling.

Because effective noise engineering controls can be challenging to design and implement, noise reduction should be considered as part of an overall long-term strategy. For example, when equipment is replaced, the amount of noise generated by the new equipment should be considered as part of the purchasing decision. It may also be helpful to consult with an experienced noise control engineer to help design noise controls.

Figure 14. Motor and blower, without vibration isolation or noise enclosure, mounted directly to a metal platform above the necker line.

Health Questionnaires and Interviews

Because of the open layout of the manufacturing areas, many of the production and maintenance employees could be exposed to MWF. However, our analysis of the questionnaire and interview responses revealed few MWF-exposed employees who reported respiratory symptoms. We did not find a statistically significant relationship between MWF exposure and work-related respiratory symptoms. In addition, employees in work areas such as near the printer and lacquer spray machines areas could be exposed to paints, printing inks, and solvents that could be related to health outcomes of interest in this evaluation. Other employees such as those working in the shipping/receiving area and administrative area would not be exposed to MWF.

We found no statistically significant increase in current work-related dermatitis in employees exposed to MWF compared to those unexposed to MWF. Few employees reported current work-related dermatitis, and few reports of skin rash were reported in the interviews. Of the 16% of employees reporting dermatitis since starting employment at the plant, we were unable to determine if past symptoms were work-related. Of those with existing irritant and allergic contact dermatitis, symptoms can become worse when exposed to MWF or machining oils, formaldehyde, or solvents [NIOSH 1998a, Chew and Maibach 2003; Slodownik et al. 2008, Warshaw et al. 2007, 2008].

In addition to MWF exposure, some employees (36%) reported that they had wet hands for 2 hours or more, defined as exposure of skin to liquid for more than 2 hours per day. Wet hands, use of water resistant gloves for more than 2 hours per day, or frequent hand washing, are the most common causes for skin irritation [Chew and Maibach 2003; Slodownik et al. 2008]. Few employees used lotions or barrier creams or wore long sleeves, actions that are known to help prevent the irritant effects from MWF [NIOSH 1998a]. More information about exposures that contribute to contact dermatitis can be found in Appendix C. We found that most employees exposed to MWF used gloves, but a lower percentage of employees reported using protective sleeves and moisturizing lotions (Table 3).

The findings from these questionnaires and interviews should be carefully interpreted because the information may not be representative of all plant employees. Although we achieved a high participation rate of 86% and we randomly selected staff to interview, participation was voluntary and some employees declined to participate. Also, employees away from work on the day we offered the interviews or questionnaire are not represented in these results.

Other Findings

On the days of the June 2009 site visit the temperatures in the plant were above 90°F; therefore, during the summer, employees could be at risk for heat-related illness. In addition, summer was the season that employees reported the most problems with hand, wrist, or forearm dermatitis. Heat disorders and health effects in individuals exposed to hot working environments include (in increasing order of severity) skin disorders (heat rash, hives, etc.), fainting, heat cramps, heat exhaustion, and heat stroke. Fainting results from blood flow being directed to the skin for cooling, resulting in decreased supply to the brain. This most often happens to employees who stand in place for extended periods in hot environments. Heat cramps, caused by sodium depletion due to sweating, typically occur in the muscles during strenuous work. Heat exhaustion symptoms include weakness, fatigue, confusion, nausea, chills, and others. Heat cramps and fainting often accompany heat exhaustion. The level of heat stress at which health effects occur is highly individual and depends upon the heat tolerance capabilities of each individual [NIOSH 1986].

Age, weight, degree of physical fitness, degree of acclimatization, metabolism, alcohol or illicit drugs, over the counter and prescribed medications, and a variety of medical conditions, such as hypertension and diabetes, all affect a person's sensitivity to heat. At greatest risk are un-acclimatized employees, people performing physically strenuous work, those with previous heat illnesses, the elderly, people with cardiovascular or circulatory disorders (diabetes, atherosclerotic vascular disease), those taking medications that impair the body's cooling mechanisms, people who use alcohol or are recovering from recent use, people in poor physical condition, and those recovering from illness.

Conclusions

All production employees were overexposed to noise, and some employees may have noise-induced hearing loss. While all employees should be enrolled in a hearing conservation program, the printer, lacquer spray, and necker operators need to wear dual hearing protection (plugs and muffs) because of the extremely high noise levels present in their work areas. Employees were not overexposed to airborne MWFs, inorganic acids, dibutylaminoethanol, or endotoxin. However, two printer operators were exposed to formaldehyde above 0.1 ppm, the level at which OSHA requires employee notification and training. Few respiratory or skin symptoms were reported among employees exposed to MWF, and we did not find statistically significant increases in work-related respiratory or dermatitis symptoms in employees exposed to MWF.

Recommendations

On the basis of our findings, we recommend the actions listed below to create a more healthful workplace. We encourage the plant to use a labor-management health and safety committee or working group to discuss the recommendations in this report 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 the plant. Our recommendations are based on the hierarchy of controls approach (refer to Appendix C: Occupational Exposure Limits and Health Effects). 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/or personal protective equipment may be needed.

Engineering Controls

Engineering controls reduce exposures to employees by removing the hazard from the process or placing a barrier between the hazard and the employee. Engineering controls are very effective at protecting employees without placing primary responsibility of implementation on the employee. We recommend the following engineering controls:

1. Install engineering controls at noisy equipment to reduce noise exposures. We recommend consulting with an acoustic engineer for specific guidance on noise control strategies.
2. Reduce exposures to MWFs by the following methods:
   a. Reduce aerosolization of MWF from the ironer.
   b. Repair MWF leaks.
   c. Enclose the MWF operations as much as possible.
   d. Use smooth walled exhaust ventilation duct (instead of flexible duct) and minimize bends in the duct to improve the overall capture efficiency.
   e. Inspect the exhaust ventilation systems regularly to identify and repair corrosion, holes, and other problems.
3. Install a closed loop dispenser to add Kathon 886™ biocide to the MWF sump.
4. Replace hydrofluoric acid with a less hazardous chemical, if feasible. Hydrofluoric acid is extremely corrosive and can easily penetrate the skin and damage underlying tissue such as bone.
5. Ensure that emergency eye washes and showers are installed in areas where employees could have exposure to corrosive chemicals [29 CFR 1910.133(a)(1)].
6. Install leak detectors and audible alarms in areas where acids are stored.
7. Repair leaks to keep fluids from spilling onto walking surfaces or onto other surfaces. To prevent slipping, clean walking surfaces and steps promptly when leaks occur.
8. Adjust the automatic shut-off light sensors on the palletizer to prevent employees from entering the machine while it is still operating.
9. Secure the top frame carriage of the palletizer when making repairs.

Administrative Controls

Administrative controls are management-dictated work practices and policies to reduce or prevent exposures to workplace hazards. The effectiveness of administrative changes in work practices for controlling workplace hazards is dependent on management commitment and employee acceptance. Regular monitoring and reinforcement are necessary to ensure that control policies and procedures are not circumvented in the name of convenience or production. We recommend you implement the following administrative controls:

1. Complete baseline audiograms before employees begin working, and repeat audiometric tests annually.
2. Use NIOSH and OSHA criteria for identifying hearing threshold shifts.
3. Include the 8 kHz frequency in audiometric tests.
4. Include all employees exposed to MWF above half of the NIOSH REL in the medical monitoring program. Even employees with less exposure to MWF may benefit from medical monitoring. See Appendix C for more information.
5. Educate employees to recognize the hazards of MWF exposure and to use work practices that prevent skin exposure to MWFs (Appendix C, Contact Dermatitis section).
6. Instruct employees not to use cleaning solvents to wash their hands or other parts of their body. These solvents remove protective oils in the skin, increasing the potential for skin irritation when employees come in contact with MWFs and other chemicals.
7. Encourage employees to report all potential work-related skin problems and respiratory problems to their supervisors so they can be evaluated, preferably by a healthcare provider familiar with occupational conditions.
8. Train employees on the health hazards associated with exposures to hazardous chemicals (such as hydrofluoric and sulfuric acid, biocides, and MWFs), what PPE is required when handling the chemicals, and what to do in the event of a spill. Refer to OSHA standard 29 CFR 1910.1200, hazard communication, for more information.
9. Provide training for printer operators on the health hazards associated with exposure to formaldehyde and the contents of the OSHA formaldehyde standard 29 CFR 1910.1048.
10. Improve the quality of safety and health training by conducting monthly interactive and comprehensive safety training sessions that include a question and answer period for employees to discuss safety and health issues openly.
11. Include information in the written respiratory protection program about the chemical hazards present, anticipated concentrations, and specific type of respirator needed. A cartridge or canister change-out schedule must also be included.

12. Label all containers and pipes containing hazardous chemicals to identify the contents and potential hazards of exposure to the chemicals.
13. Check emergency eyewashes and showers weekly to ensure proper function.
14. Take prompt action to correct safety and health problems identified and reported by employees or the safety and health committee. Follow-up action should be reported back to employees and documented in the safety and health committee meeting minutes.

Personal Protective Equipment

PPE is the least effective means for controlling employee exposures. Proper use of PPE requires a comprehensive program and calls for a high level of employee involvement and commitment to be effective. The use of PPE requires the choice of the appropriate equipment to reduce the hazard and the development of supporting programs such as training, change-out schedules, and medical assessment if needed. PPE should not be relied upon as the sole method for limiting employee exposures. Rather, PPE should be used until engineering and administrative controls can be demonstrated to be effective in limiting exposures to acceptable levels. Until employees exposures are eliminated or reduced below applicable OELs we recommend the following guidelines for use of PPE:

1. Provide dual hearing protection (ear plugs and earmuffs) for the printer and back end operators (necker and lacquer spray areas) where noise exposures exceed 100 dBA.
2. Make sure employees properly insert ear plugs.
3. Ensure that employees wear required PPE such as chemical protective gloves when in contact with coolants and acids.
4. Encourage employees to use moisturizer after washing hands, as well as before and after work, to prevent skin problems from MWFs and other chemicals.
5. Inform employees that skin barrier creams have not shown to be as effective as claimed in preventing penetration of irritants and avoiding hand dermatitis.
6. Encourage employees to use protective sleeves to prevent dermal exposure to MWFs and other chemicals.

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Metalworking Fluid Air Samples

MWF air samples were collected using a 37-millimeter open-face three-piece cassette containing a tared 2-micron pore-size polytetrafluoroethylene filter and a supporting pad mounted on a BGI (Waltham, Massachusetts) GK2.69 thoracic cyclone. The cassette was connected by Tygon® tubing to an SKC (Eighty Four, Pennsylvania) AirCheck® pump set at a nominal sampling rate of 1.6 Lpm. The samples were analyzed by gravimetric analysis for the thoracic fraction of MWF particulates per NIOSH Method 5524 [NIOSH 2011].

Formaldehyde

Formaldehyde air samples were collected using SKC UMEX 100 passive badges (SKC #500-400, lot #5926) containing a sample strip and a reference strip impregnated with 2, 4-dinitrophenylhydrazine that forms dinitrophenylhydrazine-hydrazone when exposed to formaldehyde [SKC 2007]. The samples were analyzed for formaldehyde by OSHA Method 1007 [OSHA 2009]. The UMEX 100 badge has a measurement range of 0.005 to 5 ppm and a limit of detection of 0.002 ppm.

Inorganic Acids

Inorganic acid air samples were collected on silica gel tubes (SKC #226-10-03, lot #5727) connected by Tygon tubing to an SKC Pocket Pump® set at a nominal sampling rate of 0.20 Lpm. The samples were analyzed for sulfuric and hydrofluoric acid per NIOSH Method 7903 [NIOSH 2011].

Dibutylaminoethanol

Dibutylaminoethanol air samples were collected on 90-mg XAD-7 tubes (SKC #226-94, lot #4919) connected by Tygon tubing to an SKC Pocket Pump set at a nominal sampling rate of 0.050 Lpm. The samples were analyzed per NIOSH Method 2561 [NIOSH 2011].

Endotoxin in Air

Endotoxin (a component in the cell membrane of Gram-negative bacteria) air samples were collected on tared 5.0-micron pore-size, 37-millimeter polyvinyl chloride filters connected by Tygon tubing to an SKC AirCheck® pump set at a nominal sampling rate of 2.0 Lpm. The samples were weighed and analyzed for endotoxin content with the Kinetic-QCL instrumentation using the Limulus amebocyte lysate assay [Cambrex 2005]. For these analyses, 10 endotoxin units are equivalent to one nanogram of endotoxin. The limit of detection for this analysis was 0.005 endotoxin units per sample, which equates to a minimum detectable concentration of 0.02 EU/m^3 on the basis of a sample volume of 230 liters.

Noise

Larson-Davis (Provo, Utah) Spark® 705P noise dosimeters were attached to the wearers' belts, and small remote microphones were fastened to the wearers' shirts at a point midway between the ear and the outside of the shoulder. Windscreens provided by the dosimeter manufacturer were placed over the microphones during measurements to reduce or eliminate artifact noise, which can occur if objects bump against an unprotected microphone. The dosimeters were set up to collect data using different settings to allow comparison of noise measurement results with the three different noise exposure limits referenced in this HHE, the OSHA PEL and AL, and the NIOSH REL. OSHA uses a 90-dBA criterion and a 5-dB exchange rate. The difference between the OSHA PEL and AL is the threshold level used for each. The PEL has a 90 dBA threshold and the AL has an 80 dBA threshold. NIOSH has an 85 dBA criterion and uses an 80 dBA threshold. During noise dosimetry measurements, noise levels below the threshold level are not integrated by the dosimeter for accumulation of dose and calculation of TWA noise level.

The dosimeters averaged noise levels every second during monitoring. The noise measurement information stored in the dosimeters was downloaded to a personal computer for interpretation with Larson Davis Blaze® computer software. The dosimeters were calibrated before and after the measurement periods according to the manufacturer's instructions.

Area noise levels and octave band frequency spectrum analysis (measurement of noise in different frequencies) were measured with System 824 SLM and real-time frequency analyzers (Larson-Davis, Provo, Utah). The SLMs were equipped with 0.5-inch random incidence Type 1 electret microphones and the instruments measured noise levels between 16 and 150 dBA. The SLMs were calibrated before and after the measurement periods according to the manufacturer's instructions. SLMs were either handheld or mounted on a tripod at a height of approximately 5 feet.

Statistical Analysis

Descriptive statistics including means, frequencies, and percents were calculated to summarize the questionnaire data. To compare prevalences of dermatitis between those in the MWF-exposed and MWF-unexposed job categories, either the chi-square test or the Fisher's exact test was used, and the prevalence ratio was reported. The prevalence ratio is defined as the prevalence of cough reported by MWF-exposed employees divided by the prevalence of cough reported by MWF-unexposed employees. Therefore, a prevalence ratio > 1 would indicate that a MWF-exposed employee might be more likely to report cough. For the statistical tests, a *P* value was also reported. If the *P* value is 0.05 or less, the result is described as statistically significant and one can confidently state that the result is not likely due to chance.

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Table B1. Air sampling results for metalworking fluids, June 9–10, 2009

Sample Type	Location	Sample volume (liters)	Sample time (minutes)	Concentration mg/m^3	
				Total thoracic particulate mass*	Extracted MWF
Personal breathing zone	Front end	1006	679	0.17	ND†
	Front end	1045	657	0.28	(0.19)‡
	Front end	956	601	(0.10)	ND
	Front end	1022	647	0.19	(0.07)
	Front end	989	622	0.19	(0.08)
	Front end	1005	636	0.19	(0.12)
	Front end	1048	663	0.13	ND
	Front end	1006	649	0.17	ND
	Front end	1049	664	(0.090)	ND
	Front end	986	632	0.13	ND
	Front end	1030	644	0.22	(0.14)
	Front end	1029	651	0.12	ND
	Printer	938	590	0.13	ND
	Printer	1000	641	0.11	ND
	Printer	997	638	0.27	0.21
	Printer	1008	638	(0.090)	ND
	Necker	906	596	(0.070)	ND
General area	Front end	901	574	0.28	0.19
NIOSH REL-TWA				0.40	
MDC§				0.03	0.06
MQC¶				0.098	0.18

*The NIOSH REL-TWA for MWF aerosols of 0.4 mg/m^3 of air is based on the total thoracic particulates and not the extractable fraction of MWF. The total thoracic particulates include all dust and other aerosols in the air in addition to the MWFs that fall within that size range. The extractable fraction represents the portion of the sample that was MWFs.

†ND = not detected (below the minimum detectable concentration).

‡Concentrations between the MDC and MQC are shown in parentheses to point out that there is more uncertainty associated with these values than with concentrations above the MQC.

§The MDC was calculated by dividing the method limit of detection by the average sample volume collected (1.0 cubic meter).

¶The MQC was calculated by dividing the method limit of quantitation by the average sample volume collected (1.0 cubic meter).

Table B2. Air sampling results for inorganic acids, June 9–10, 2009

Sample type	Job title/location	Sample volume (liters)	Sample time (minutes)	Concentration (mg/m^3)	
				Hydrofluoric acid	Sulfuric acid
Personal breathing Zone	Chemical process operator	99.8	504	(0.0096)*	ND†
General area	HF acid tank	111	567	(0.007)	ND
	HF acid tank	86	426	0.24	(0.04)
	Can washer	85	420	(0.010)	(0.042)
	Can washer	114	572	(0.006)	(0.027)
	Sulfuric acid tank	83	425	(0.005)	ND
NIOSH REL-TWA				2.5	1
NIOSH REL-Ceiling				5	
OSHA PEL-TWA				2.5	1
MDC‡				0.001	0.03
MQC§				0.011	0.10

*Concentrations between the MDC and MQC are shown in parentheses to point out that there is more uncertainty associated with these values than with concentrations above the MQC.
†ND = not detected (below the minimum detectable concentration).
‡The MDC was calculated by dividing the method limit of detection by the average sample volume collected (0.096 cubic meter).
§The MQC was calculated by dividing the method limit of quantitation by the average sample volume collected (0.96 cubic meter).

Table B3. Air sampling results for formaldehyde, June 9–10, 2009

Sample type	Job title/Location	Sample time (minutes)	Sample volume* (liters)	Concentration (ppm)
	Front end	635	18.2	0.023
	Front end	618	17.7	0.040
	Front end	673	19.3	0.039
	Front end	650	18.6	0.048
	Front end	662	18.9	0.035
	Front end	650	18.6	0.066
	Front end	655	18.7	0.048
	Front end	666	19.1	0.047
	Front end	630	18.0	0.039
	Front end	636	18.2	0.058
Personal breathing zone	Front end	658	18.8	0.038
	Printer	612	17.5	0.090
	Printer	640	18.3	0.080
	Printer	640	18.3	0.071
	Printer	546	15.6	0.13
	Printer	625	17.9	0.12
	Chemical process operator	505	14.4	0.020
	Chemical process operator	650	18.6	0.031
	Millwright	602	17.2	0.040
	Forklift operator	651	18.8	0.080
	Lacquer spray	640	18.3	0.042
	Conference room	702	20.1	0.040
General area	Outdoor	703	20.1	0.0056)†
	Outdoor	667	19.1	(0.011)
NIOSH REL-TWA				0.016
NIOSH REL-Ceiling (15 minute sample)				0.1
OSHA PEL-TWA				0.75
ACGIH TLV-Ceiling				0.3
MDC‡				0.005
MQC§				0.016

*Because passive diffusion sampling badges were used, the volume of air sampled was calculated, in liters, using the following formula: time (min) X sampling rate (28.6 mL/min) ÷ 1000.

†Concentrations between the MDC and MQC are shown in parentheses to point out that there is more uncertainty associated with these values than with concentrations above the MQC.

‡The MDC was calculated by dividing the limit of detection by the average sample volume collected (18.3 liters).

§The MQC was calculated by dividing the limit of quantitation by the average sample volume collected (18.3 liters).

Table B4. Air sampling results for 2-dibutylaminoethanol, June 9–10, 2009

Sample Type	Job Title/Location	Sample Time (minutes)	Sample Volume (liters)	Concentration (mg/m^3)
Personal breathing zone	Printer	552	28	0.26
	Printer	613	30	0.25
	Printer	507	25	0.20
	Printer	643	32	0.24
	Printer	595	29	0.24
	Printer	640	32	0.21
General Area	Printer	579	29	0.28
	Printer	584	29	(0.11)*
NIOSH REL-TWA				14
OSHA PEL-TWA				None
ACGIH TLV-Ceiling				3.5
MDC†				0.03
MQC‡				0.13

*Concentrations between the MDC and MQC are shown in parentheses to point out that there is more uncertainty associated with these values than with concentrations above the MQC.
†The MDC was calculated by dividing the method limit of detection by the average sample volume collected (29 liters).
‡The MQC was calculated by dividing the method limit of quantitation by the average sample volume collected (29 liters).

Table B5. Air sampling results for endotoxin, June 9–10, 2009

Sample type	Job Title/Location	Sample Time (minutes)	Sample Volume (liters)	Endotoxin units per cubic meter of air
Personal breathing zone	Front end	635	18.2	0.023
	Front end	618	17.7	0.040
	Front end	673	19.3	0.039
	Front end	650	18.6	0.048
	Front end	662	18.9	0.035
	Front end	650	18.6	0.066
	Front end	655	18.7	0.048
	Front end	666	19.1	0.047
	Front end	630	18.0	0.039
	Front end	636	18.2	0.058
	Front end	658	18.8	0.038
	Printer	612	17.5	0.09
	Printer	640	18.3	0.080
	Printer	640	18.3	0.071
	Printer	546	15.6	0.13
	Printer	625	17.9	0.12
General area	Outdoors			1.1
NIOSH REL-TWA				None

Table B6. Personal noise dosimetry results, June 9–10, 2009

Job title	Start time	Stop time	Minutes	OSHA action level (dBA)	OSHA PEL (dBA)	NIOSH REL (dBA)
Back end operator (lacquer spray)	7:50	18:30	640	97.5	97.4	98.8
Back end operator (lacquer spray)	8:05	18:05	600	99.0	98.9	100.5
Back end operator (necker)	8:25	18:25	600	99.9	99.9	102.2
Back end operator (necker)	8:02	18:05	603	99.9	99.8	102.7
Baler room/forklift	7:20	18:43	683	94.9	94.6	95.6
Baler room/forklift	7:55	18:49	654	95.6	95.4	97.0
Front end ironer trimmer	7:18	18:20	662	93.4	92.9	95.4
Front end ironer trimmer	7:15	18:10	655	93.8	93.4	95.7
Front end ironer trimmer	7:25	18:15	650	96.5	96.4	97.8
Front end ironer trimmer/chemical process operator	7:39	15:30	471	91.3	90.6	93.4
Front end ironer trimmer leadman	7:43	18:10	627	95.0	94.8	96.5
Front end ironer trimmer leadman	7:20	18:26	666	95.2	95.0	96.5
Front end ironer trimmer line 3	7:29	18:42	673	97.7	97.6	99.0
Front end ironer trimmer lines 1 and 2	7:22	18:15	653	96.2	95.8	97.9
Front end maintenance/repair*	7:25	18:05	640	88.6	86.3	91.0
Material handler	8:16	15:29	433	81.3	71.2	84.2
Material handler	7:45	18:33	648	87.3	81.8	89.8
Millwright*	8:15	18:20	605	87.7	84.3	90.7
Millwright*	7:43	18:30	647	89.8	87.4	93.4
Palletizer	8:08	18:10	602	85.6	72.5	86.6
Palletizer	7:45	18:36	651	86.9	77.3	88.0
Printer	7:55	18:05	610	98.2	98.2	99.7
Printer	7:45	18:10	625	98.6	98.5	100.1
Printer	7:35	18:15	640	98.8	98.8	100.3
Printer	7:50	17:01	555	100.2	100.0	101.2
Printer leadman	7:30	18:10	640	98.9	98.8	100.4
Noise exposure limits		12-hour work shift		82.1	90.0	83.4
		*8-hour work shift		85.0	90.0	85.0

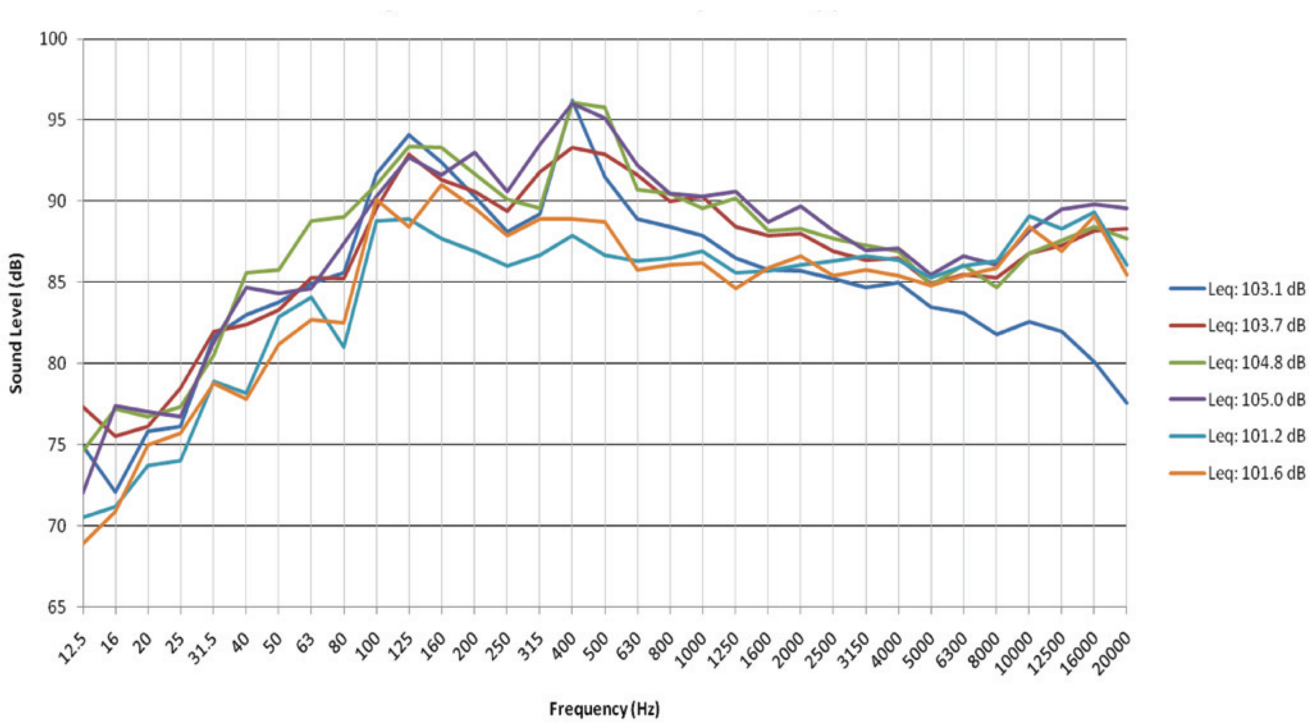

Figure B1. Octave band analysis for cupper band press.

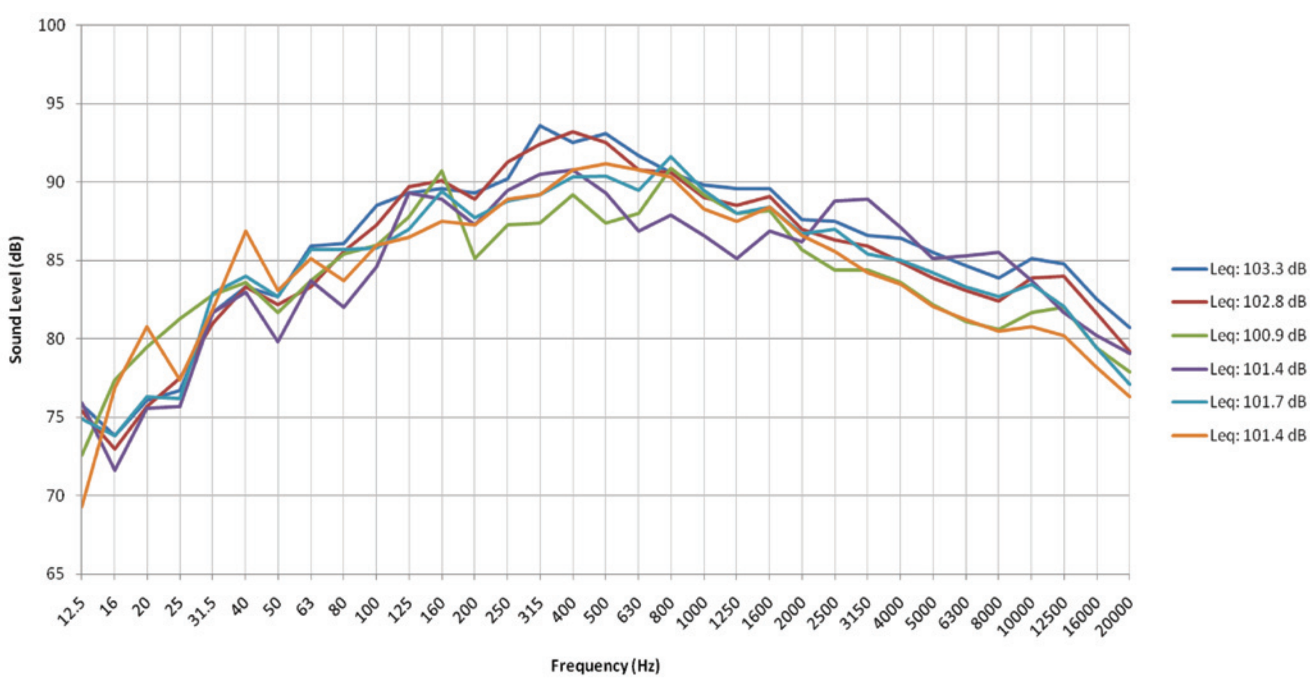

Figure B2. Octave band analysis for ironers.

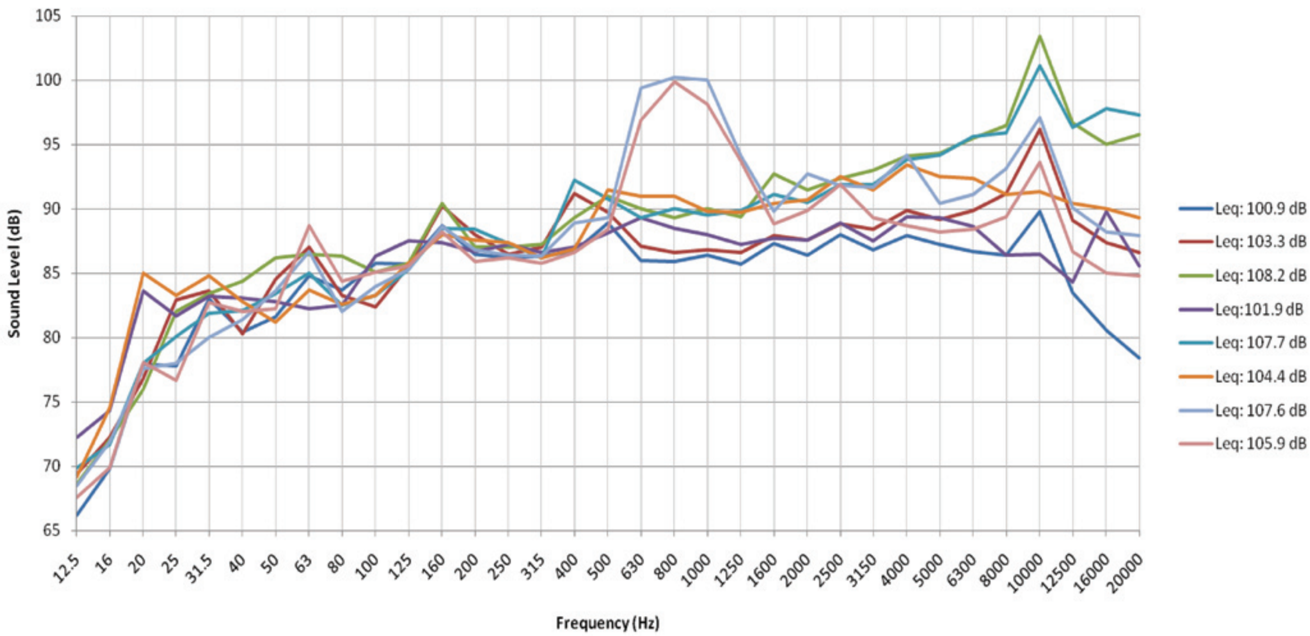

Figure B3. Octave band analysis for printers.

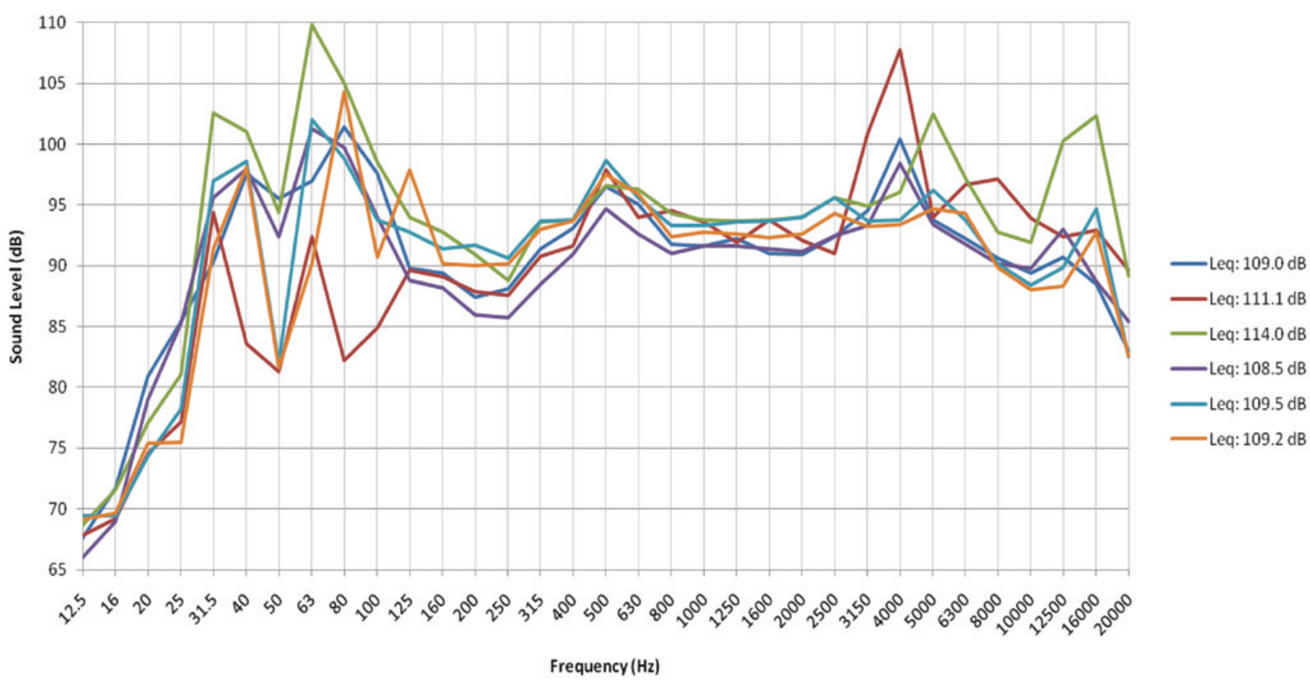

Figure B4. Octave band analysis for necker machines.

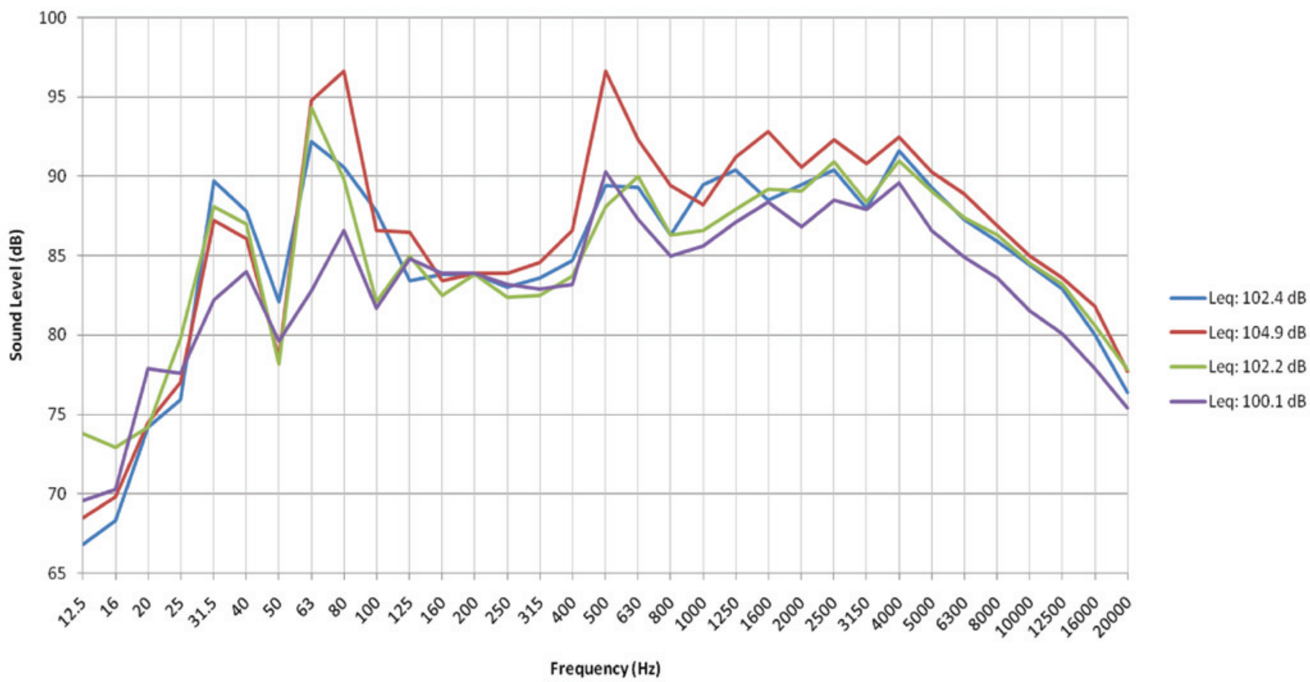

Figure B5. Octave band analysis for lacquer spray machines.

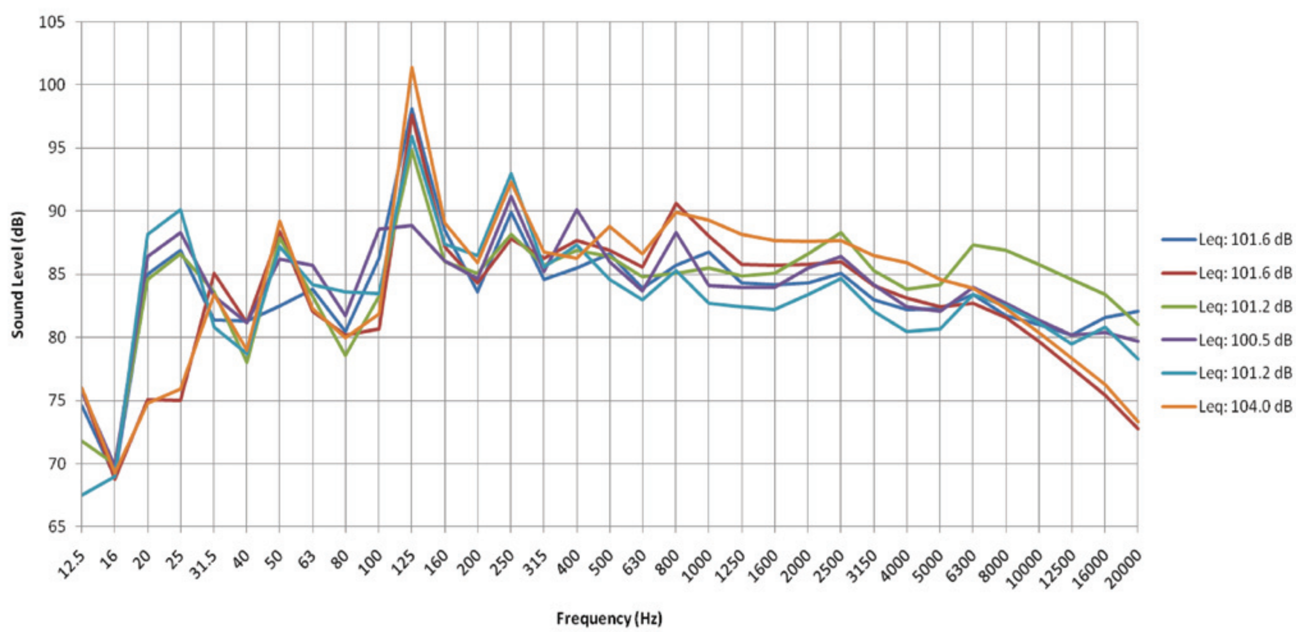

Figure B6. Octave band analysis for baler.

Appendix C: Occupational Exposure Limits and Health Effects

In evaluating the hazards posed by workplace exposures, NIOSH investigators use both mandatory (legally enforceable) and recommended 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 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 from adverse health effects even if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a preexisting medical condition, and/or 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 employee to produce health effects even if the 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.

Most OELs are expressed as a 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 STEL or ceiling values where health effects are caused by exposures over a short period. Unless otherwise noted, the STEL is a 15-minute TWA exposure that should not be exceeded at any time during a workday, and the ceiling limit is an exposure that 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, while 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 enforceable in workplaces covered under the Occupational Safety and Health Act. NIOSH RELs are recommendations based on a critical review of the scientific and technical information available on a given hazard and the adequacy of methods to identify and control the hazard. NIOSH RELs can be found in the NIOSH Pocket Guide to Chemical Hazards [NIOSH 2010]. NIOSH also recommends different types of 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 from these hazards. Other OELs that are commonly used and cited in the United States include the TLVs recommended by ACGIH, a professional organization, and the WEELs 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. They are not consensus standards. ACGIH 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 2011]. WEELs have been established for some chemicals "when no other legal or authoritative limits exist" [AIHA 2011].

Outside the United States, OELs have been established by various agencies and organizations and include both legal and recommended limits. The Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (IFA, 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/en/gestis/limit_values/index.jsp, contains international limits for over 1,500 hazardous substances and is updated periodically.

Employers should understand that not all hazardous chemicals have specific OSHA PELs, and for some agents the legally enforceable and recommended limits may not reflect current health-based information. However, an employer is still required by OSHA to protect its employees from hazards even in the absence of a specific OSHA PEL. 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))]. Thus, NIOSH investigators encourage employers to make use of other OELs when making risk assessment and risk management decisions to best protect the health of their employees. NIOSH investigators also encourage the use of the traditional hierarchy of controls approach to eliminate or minimize identified 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 that focuses resources on exposure controls by describing how a risk needs to 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 the OELs, when available.

Below we provide the OELs and surface contamination limits for the compounds we measured, as well as a discussion of the potential health effects from exposure to these compounds.

Metalworking Fluids

MWFs are complex mixtures used to cool, lubricate, and remove metal chips from tools and metal parts during machining of metal stock. The term MWF aerosol refers to the mist generated during machining. This mist may contain a variety of substances including any component of the MWF, additives to the MWF, contaminants of the MWF such as oils, metals, corrosion inhibitors, and biological contaminants.

Exposure to MWFs can result from inhalation of aerosols or from skin contact due to touching contaminated surfaces, handling of parts and equipment, splashing of fluids and settling of MWF aerosol on the skin [NIOSH 1998a]. Inhalation of MWF aerosols may cause irritation of the throat (e.g., sore, burning throat), nose (e.g., runny nose, congestion, and nosebleeds), and lungs (e.g., cough, wheezing, increased phlegm production, and shortness of breath). MWF aerosol exposure has been associated with chronic bronchitis, asthma, hypersensitivity pneumonitis, and worsening of pre-existing respiratory problems. Skin contact with MWFs may cause allergic contact dermatitis and/or irritant contact dermatitis depending on the chemical composition of the fluid, types of additives and contaminants contained in the MWFs, type of metal being machined (e.g., nickel or chromium), and the exposed individual's tendency for developing allergies. Petroleum-based products, certain chemical additives, and strong detergents and hand cleansers may also cause dermatitis or aggravate an existing condition.

Synthetic, semisynthetic, and soluble oil MWFs like the ones used at this company are diluted with water and hence can be a breeding ground for bacteria if an inadequate amount of biocide is added. High temperature and low pH, and the presence of metals can also favor bacterial growth. Levels of microbial contamination indicate the cleanliness or degree of maintenance of the MWF. Inhalation of MWF aerosols containing bacteria may result in respiratory problems. Employees with broken skin may develop skin infections if they have contact with MWF contaminated with bacteria.

At this time, there is insufficient health data for NIOSH to recommend a specific limit for bacterial or fungal contamination in MWF. However, some researchers have suggested that well-maintained MWFs should have bacterial concentrations below 106 CFU/mL of fluid [Rossmoore and Rossmoore 1994]. On the Web site "Management of the Metal Removal Fluid Environment." the Organization Resources Counselors, Inc. recommends maintaining bacterial levels < 105 CFU/mL and fungal levels < 100 CFU/mL [http://www.aware-services.com/orc].

NIOSH recommends that exposures to MWF aerosols be limited to 0.4 mg/m^3 for the thoracic particulate mass, as a TWA concentration for up to 10 hours per day during a 40-hour workweek [NIOSH 1998a]. The NIOSH REL is intended to prevent or greatly reduce respiratory disorders associated with MWF exposure. In addition, limiting dermal (skin) exposure is critical to preventing allergic and irritant disorders related to MWF exposure. NIOSH recommends that all employees exposed to MWFs at over half the REL receive medical monitoring, and all employees with exposure to MWF may benefit from medical monitoring [NIOSH 1998a]. Supervision of the medical monitoring program should be done by a physician or other health professional with expertise in the identification and management of MWF-related respiratory conditions and skin diseases. Employees should be encouraged to continue to report all potential work-related skin problems to the plant medical department.

Formaldehyde

The most commonly reported and best documented 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. NIOSH recognized formaldehyde as a potential occupational carcinogen in 1981 and, following the NIOSH carcinogen policy in existence at the time, set the REL to the "lowest feasible concentration," which for formaldehyde was defined as the analytical limit of quantification of 0.016 ppm for up to a 10-hour time-weighted average and a ceiling limit of 0.10 ppm that should not be exceeded [NIOSH 1981, 2010]. Since then, experience has shown that this REL is actually not the "lowest feasible concentration" because formaldehyde in the ambient air can exceed 0.016 ppm, a fact later acknowledged by NIOSH [Lemen 1987]. Additionally, the subsequent revision of the NIOSH carcinogen policy [NIOSH 1995], combined with better exposure characterization and advances in risk assessment and management strategies, support the need for NIOSH to reassess the formaldehyde REL that is in progress.

Noise

Noise-induced hearing loss is an irreversible, sensorineural condition that progresses with exposure. Although hearing ability declines with age (presbycusis), noise exposure produces more hearing loss than that resulting from aging alone. This NIHLis caused by damage to nerve cells of the inner ear (cochlea) and, unlike some conductive hearing disorders, cannot be treated medically [Berger et al. 2003]. In most cases, NIHL develops slowly and usually occurs before it is noticed. Hearing loss is often severe enough to permanently affect a person's ability to hear and understand speech. For example, people with hearing loss may not be able to distinguish words such as "fish" from "fist" [Suter 1978].

The dBA is the preferred unit for measuring sound levels to assess employee noise exposures. The dBA noise scale is weighted to approximate the sensory response of human ears to sound frequencies near the hearing threshold. Because the dBA scale is logarithmic, increases of 3 dBA, 10 dBA, and 20 dBA represent a doubling, tenfold increase, and hundredfold increase of sound energy, respectively. Noise exposures expressed in dBA cannot be averaged by taking the arithmetic mean.

The OSHA noise standard [29 CFR 1910.95] specifies a PEL of 90 dBA, as an 8-hour TWA. The OSHA PEL is calculated using a 5 dB exchange rate. This means that a person may be exposed to noise levels of 95 dBA for no more than 4 hours, 100 dBA for 2 hours, 105 dBA for 1 hour, etc. An employee's daily noise dose, based on the duration and intensity of noise exposure, can be calculated according to the formula

$$\text{Dose} = 100 \times (C1/T1 + C2/T2 + \ldots + Cn/Tn),$$

where Cn indicates the total time of exposure at a specific noise level and Tn indicates the reference duration for that level as given in Table G-16a of the OSHA noise regulation. Doses greater than 100% are in excess of the OSHA PEL.

When noise exposures exceed the PEL of 90 dBA, OSHA requires that employees wear hearing protection, and that an employer implement feasible engineering or administrative controls to reduce noise exposures. The OSHA noise standard also requires an employer to implement a hearing conservation program when 8-hour TWA noise exposures exceed the AL 85 dBA. The program must include noise monitoring, employee notification, observation, audiometric testing, hearing protectors, training, and record keeping.

NIOSH [NIOSH 1998b] and ACGIH [ACGIH 2011] recommend an exposure limit of 85 dBA, as an 8-hour TWA. A more conservative 3 dB exchange rate is used in calculating exposure these limits. Using NIOSH criteria, an employee can be exposed to 85 dBA for 8 hours, but to no more than 88 dBA for 4 hours, 91 dBA for 2 hours, 94 dBA for 1 hour, etc. Twelve-hour exposures have to be 83.2 dBA or less according to the NIOSH REL.

Audiometric evaluations of employees hearing thresholds must be conducted in quiet locations, preferably in a sound-attenuating booth, by presenting pure tones of varying frequencies at threshold levels (i.e., the level of a sound that the person can just barely hear). Zero dB hearing loss represents the hearing level of an average, young individual with good hearing. OSHA requires hearing thresholds to be measured at test frequencies of 500, 1,000, 2,000, 3,000, 4,000, and 6,000 Hz. Individual employee's annual audiograms are compared to their baseline audiogram to determine if an STS has occurred. OSHA states that an STS has occurred if the average threshold values at 2,000, 3,000, and 4,000 Hz have increased by 10 dB or more in either ear when comparing the annual audiogram to the baseline audiogram [29 CFR 1910.95]. The NIOSH-recommended hearing threshold shift criterion is a 15-dB shift at any frequency in either ear from 500–6,000 Hz measured twice in succession [NIOSH 1998b]. Both of these hearing threshold shift criteria require at least two audiometric tests.

The audiogram profile is a plot of the hearing test frequencies (x-axis) versus the hearing threshold levels (y-axis). For many employees, the audiogram profile tends to slope downward toward the high frequencies with an improvement at the audiogram's highest frequencies, forming a notch [Suter 2002]. A notch in the audiogram of an employee with otherwise normal hearing may indicate the early onset of hearing loss. The notch from occupational noise usually occurs at frequencies from 3,000 Hz to 6,000 Hz [ACOM 1989; Osguthorpe and Klein 2001]. However, it is generally accepted that a notch at 4,000 Hz indicates occupational hearing loss [Prince et al. 1997]. An individual may have notches at different frequencies in one or both ears [Suter 2002]. For this evaluation, a notch is defined as the frequency where the hearing level is preceded by an improvement of at least 10 dB and followed by an improvement of at least 5 dB.

Contact Dermatitis

Contact dermatitis makes up 90% to 95% of all occupational skin diseases [Ingber and Merims 2004; Lushniak 2004]. Contact dermatitis, both irritant and allergic, is an inflammatory skin condition caused by skin contact with agents such as chemical irritants (irritant contact dermatitis) or allergens (allergic contact dermatitis). Exposed areas of the skin, such as hands and forearms, have the greatest contact with irritants or allergens and are most commonly affected. In fact, more than 80% of occupational contact dermatitis involves the hands [Warshaw et al. 2003; Belsito 2005; Flyvholm et al. 2007]. More than 57,000 chemicals are reported to cause skin irritation, but only 3,700 chemicals are known skin allergens [Belsito 2005]. Usually only a small percentage of people are susceptible to skin allergens.

The cause of irritant contact dermatitis is often due to many factors. The most common skin irritant is wet work, defined as exposure of skin to liquid for more than 2 hours per day, use of occlusive gloves for more than 2 hours per day, or frequent hand washing [Chew and Maibach 2003; Slodownik et al. 2008]. Other common causes of irritant contact dermatitis include soaps and detergents, solvents, food products, cleaning agents, plastics and resins, petroleum products and lubricants, metals, and machine oils and coolants [Chew and Maibach 2003; Slodownik et al. 2008].

The first steps in dermatitis prevention are to avoid irritants, allergens, and wet work. Liberal use of skin moisturizers helps to prevent contact dermatitis by maintaining a healthy skin barrier, and also helps to repair this barrier if it has been compromised [Chew and Maibach 2003]. Proper handwashing methods, such as using lukewarm or cool water and mild cleansers, are also valuable in preventing contact dermatitis [Warshaw 2003].

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Acknowledgments and Availability of Report

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