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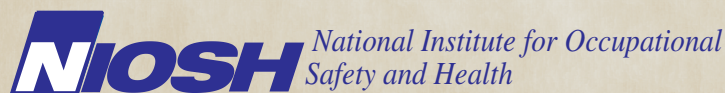


Evaluation of Potential Exposures during Composite Grinding at an Aircraft Manufacturing Plant

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ABBREVIATIONS

µm	Micrometer
ACGIH®	American Conference of Governmental Industrial Hygienists
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
BADGE	Diglycidyl ether of bisphenol-A
CFR	Code of Federal Regulations
CO	Carbon monoxide
CO ₂	Carbon dioxide
D039	Department 039
D133	Department 133
GA	General area
HHE	Health hazard evaluation
MDC	Minimum detectable concentration
mg/m ³	Milligrams per cubic meter
MQC	Minimum quantifiable concentration
mm	Millimeter
MSDS	Material safety data sheet
NAICS	North American Industry Classification System
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
RH	Relative humidity
SMA	Sheet metal assembler
STEL	Short term exposure limit
TLV®	Threshold limit value
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 Cessna Aircraft Company in Wichita, Kansas. The requestors were concerned about exposure to paint and sealants, carbon monoxide, and dust generated during grinding of composite and metal parts. Reported health effects included headaches, dizziness, fatigue, and abdominal pain.

What NIOSH Did

- We evaluated the facility on January 23–24, 2008.
- We looked at work processes and practices in Departments 039 and 133.
- We collected air samples for total dust, respirable dust, and carbon monoxide. We also analyzed the total dust air samples for metals.
- We determined the particle size distribution of the dust generated during grinding.
- We talked to employees about health symptoms related to work.
- We reviewed air sampling records, maintenance records for a downdraft table, material safety data sheets, and injury and illness records.

What NIOSH Found

- Air sampling results for total dust, respirable dust, metals, and carbon monoxide were below the applicable occupational exposure limits.
- Particles generated during grinding were mainly in the size range that can be inhaled deep into the lungs (below 5 micrometers).
- Exposure to paints and sealants was minimal and not likely to be a hazard.
- One employee reported being diagnosed with asthma since working at Cessna, and three of four employees with pre-existing asthma said their asthma was worse at work.
- Three employees reported skin problems related to work.
- Two employees reported headaches but none of the interviewed employees reported dizziness, fatigue, or abdominal pain.
- Some employees had facial hair that interfered with their respirator seal.

What Managers Can Do

- Require employees to use downdraft tables when grinding composite materials.
- Provide shrouded grinding and buffing tools to employees when tasks prevent the use of downdraft tables.
- Make sure that respirators are used correctly.
- Encourage employees to report all work-related health concerns to the onsite medical department.

What Employees Can Do

- Use a downdraft table when grinding composite materials. This will further reduce dust exposure.
- Wear respirators properly. Be clean shaven to ensure a good seal.
- Report all work-related health concerns to the onsite medical clinic.

NIOSH received a request to evaluate employee exposures in two departments at the Cessna Prospect facility. We found that employee exposures to total dust, respirable dust, metals, and CO were below the OELs. However, some employees noted either onset of asthma or worsening of pre-existing asthma at work. Despite low levels of total and respirable dust and metals, it is possible that the reported respiratory symptoms are work related. We recommend that employees use downdraft tables and shrouded grinding tools when grinding on composite materials to further reduce exposures. We also encourage employees to report all work-related health concerns to the onsite medical clinic.

NIOSH received a confidential request from employees for an HHE at the Prospect facility of Cessna Aircraft Company (Cessna) in Wichita, Kansas. The requestors were concerned about adverse health effects from exposure to paint and sealants, CO, and dust generated during grinding of composite and metal parts in D039 and D133. Health effects noted in the request were headaches, dizziness, fatigue, and abdominal pain.

We evaluated the facility on January 23–24, 2008, to learn more about the manufacturing process. We observed work practices; evaluated employee exposure to total dust, respirable dust, and CO; and interviewed employees in D039 and D133 about their health. We also interviewed Cessna's Health Services manager. We reviewed the OSHA Form 300 Log of Work-related Injuries and Illnesses from the years 2005–2007 and company air sampling reports for D039 and D133 from 2002–2007. We also looked at MSDSs and the maintenance chart for the downdraft table in D039.

Three of four employees in D039 and D133 with pre-existing asthma reported worsening of their asthma at work. One employee reported being diagnosed with asthma since beginning work at Cessna. Three employees reported skin rashes, and two employees reported headaches. None of the interviewed employees reported dizziness, fatigue, or abdominal pain. Our air sampling results indicated that employees' exposures to total dust, respirable dust, and metals were below the NIOSH RELs, OSHA PELs, and ACGIH TLVs. Air sampling results for CO indicated that the air concentrations were below all applicable OELs. However, dust generated from grinding composite materials can contain reactive components that can cause health effects at levels far below the applicable OELs. Despite low levels of total and respirable dust and metals, it is possible that the reported respiratory symptoms are work related.

To further reduce exposure to dust, we recommend that employees use downdraft tables when grinding on composite materials. Engineering controls such as shrouded grinding tools should also be provided to employees. Employees should wear respirators correctly, including being clean shaven to have a good seal. We also encourage employees to report all work-related health concerns to the onsite medical clinic.

Keywords: NAICS 336411 (Aircraft Manufacturing), composite material, grinding, epoxy, BADGE, asthma, carbon monoxide

In August 2007, NIOSH received a confidential request from employees for an HHE at the Prospect facility of Cessna Aircraft Company (Cessna) in Wichita, Kansas. The requestors were concerned about potential adverse health effects from exposure to paint and sealants, CO, and dust generated during grinding of composite and metal parts in D039 and D133. Health effects noted in the request were headaches, dizziness, fatigue, and abdominal pain. We visited the Cessna facility from January 23–24, 2008, to learn more about the manufacturing process; observe work practices; review pertinent records; evaluate employee exposure to total dust, respirable dust, metals, and CO; and interview employees in D039 and D133 about their health.

Facility and Process Description

Cessna manufactures a variety of commercial aircraft and employs around 15,000 people at its Wichita, Kansas, site. The site has numerous facilities that manufacture parts for different aircraft models. Various phases of the aircraft manufacturing operations are housed in different buildings on the site.

The Prospect facility has 348 employees, of whom 16 work in D039 and D133. These employees work 8-hour shifts. The composite parts used in D039 and D133 are manufactured in a different building and use a woven fiberglass material pre-impregnated with epoxy resins, filler, and other suitable hardening agents. The raw woven fiberglass material arrives at Cessna in rolled-up bundles that are laid out and cut to specification by an automated machine. The cut fiberglass mat is then laid out on premade molds for various aircraft parts and heated in large curing ovens. In the curing process, the epoxy resin in the woven material hardens into the shape of the aircraft part when heat is applied. The cured composite part is then removed from the mold, and the excess material is trimmed with hand held grinding machines. These parts are then painted with a spray gun, air dried, and sent to various departments, including D039 and D133, for machining. In D039 and D133, painted and cured composite parts are ground to the exact dimensions specified for the parts. Metal parts are riveted together, and employees use a paint brush to touch up the parts with paint and a corrosion inhibiting sealant such as alodine before sending them to a different department. Propane powered forklift trucks, which can generate CO, are used in the facility to move airplane parts.

INTRODUCTION (CONTINUED)

In D039, employees working with composite materials can perform grinding for 6–8 hours during their work shift. D039 has a downdraft table that employees use when they are grinding on larger composite material parts. We observed that employees grinding smaller composite parts conducted these tasks at their workstations or used a step stool instead of using the downdraft table. Exhaust ventilation was not available at employee workstations. Employees wore Tyvek® suits, elastomeric half mask air purifying respirators with P100 cartridges, safety glasses or face shields, ear muffs, and cotton gloves when grinding composite parts. Employees were medically cleared and fit tested for respirators, but the use of respiratory protection in these departments was voluntary.

Cessna has three onsite medical clinics with a full time physician, a nurse practitioner, and six registered nurses. The company has a health and safety committee that includes employee and management representatives.

ASSESSMENT

During our site visit, which took place from January 23–24, 2008, we met with employer and employee representatives to discuss the HHE request. We observed work processes, employee work practices, and workplace conditions. We privately interviewed most of the employees working in D039 and D133. The interviews focused on job history, overall health, and work-related symptoms. We also interviewed Cessna's Health Services manager. We reviewed the OSHA Logs for years 2005–2007, the company's air sampling reports pertaining to D039 and D133 from 2002–2007, MSDSs, and the D039 downdraft table maintenance chart.

The dust generated during grinding of composite materials was one of the requestors' primary concerns; therefore, we evaluated exposures of SMAs who worked with composite materials and metal parts in D039 and D133. We collected seven PBZ and three GA air samples for respirable dust and five PBZ and four GA air samples for total dust and metals during the last half of the work shift on January 23, 2008, and for the full work shift on January 24, 2008. Respirable dust and total dust air samples were analyzed gravimetrically. After gravimetric analysis, the total dust air samples were also analyzed for metals. In addition, we characterized the particle size of dust generated by grinding (Figure 1) with an ARTI HHPC-6 (ART Instruments, Inc., Grant Pass, Oregon), a handheld

ASSESSMENT (CONTINUED)



Figure 1. Employee using a handheld grinder to grind composite material.

optical particle counter that was held in the breathing zone of the employee during sample collection.

We noted the use of two propane gas powered forklifts and measured CO, a combustion product, in the high forklift traffic areas of D133 and outdoors with a direct reading instrument (TSI Q-Trak™, Shoreview, Minnesota). The instrument also provided temperature and relative humidity measurements.

Details on the methods used in this evaluation for total dust, respirable dust, and metals are explained in Appendix A. The OELs and potential health effects for exposure to total and respirable dust and CO are discussed in Appendix B.

RESULTS

PBZ and GA air sampling results for total dust along with the applicable OELs are presented in Tables 1 and 2. Although air samples were only collected for approximately half of the work shift on January 23, 2008, the TWA results are considered representative of full-shift exposures.

The total dust PBZ air sample concentrations obtained during our sampling ranged up to 0.28 mg/m³ (Table 1). All concentrations were below the OSHA PEL of 15 mg/m³ and ACGIH TLV of 10 mg/m³. The GA total dust concentrations ranged from 0.11–0.29 mg/m³ (Table 2). The five PBZ total dust air samples were also analyzed for individual elements and showed the presence of metals such as aluminum, cadmium, chromium, copper, and manganese. However, the concentrations of the metals were 0.001%–0.1% of their respective OELs.

Table 1. PBZ air sample results for total dust (January 23–24, 2008)

Date	Job Title	Department Number	Sampling Time (minutes)	Air Concentration (mg/m ³)
1/23/2008	SMA	D133	201	0.28
	SMA	D039	285	0.17
	SMA	D039	236	(0.17)*
1/24/2008	SMA	D133	500	0.26
	SMA	D039	469	0.25
OSHA PEL				15
ACGIH TLV				10†

*Values in parentheses indicate a concentration between the MDC and the MQC.

†Inhalable fraction

RESULTS

(CONTINUED)

Table 2. GA air sample results for total dust (January 23–24, 2008)

Date	Sample Location	Department Number	Sampling Time (minutes)	Air Concentration (mg/m ³)
1/23/2008	Post AX08 Downdraft table	D133	221	(0.18)*
		D039	266	0.29
1/24/2008	Workstation near post AQ01	D039	467	0.11
	Workstation near post BA01	D039	511	0.14
OSHA PEL				15
ACGIH TLV				10†

*Values in parentheses indicate a concentration between the MDC and the MQC.

†Inhalable fraction

The respirable dust PBZ air sample concentrations ranged up to 0.29 mg/m³ (Table 3) and were below the OSHA PEL of 5 mg/m³ and the ACGIH TLV of 3 mg/m³. The three GA respirable dust sample concentrations were below the MDCs.

Table 3. PBZ air sample results for respirable dust (January 23–24, 2008)

Date	Job Title	Department Number	Sampling Time (minutes)	Air Concentration (mg/m ³)
1/23/2008	SMA	D133	200	(0.26)*
	SMA	D039	246	0.29
	SMA	D039	282	(0.078)*
1/24/2008	SMA	D039	444	(0.10)*
	SMA	D039	508	(0.042)*
	SMA	D039	436	(0.075)*
OSHA PEL				5
ACGIH TLV				3

*Values in parentheses indicate a concentration between the MDC and the MQC.

The ARTI HHPC-6 particle counter counts particles in size ranges of 0.3, 0.5, 1, 3, 5, and > 10 µm. The particle count result showed that on average, 95% of the particles generated during grinding were less than 5 µm in diameter, which is in the respirable range.

The CO, temperature, and RH measurements in D133 are summarized in Table 4. The outdoor CO concentration was 0 ppm, and the indoor CO measurements ranged from 0–13 ppm on January 23, 2008, and from 0–2 ppm on January 24, 2008. These concentrations are well below the NIOSH recommended ceiling limit of 200 ppm [NIOSH 2005]. Additionally, the mean

RESULTS

(CONTINUED)

CO concentrations on both days of monitoring were also well below the applicable OELs [NIOSH 2005]. Temperature and relative humidity measurements were within recommended ASHRAE guidelines [ASHRAE 2007].

Table 4. Environmental air sampling results in D133

Date	Sampling Time	Air Concentration (ppm)	Mean	Mean RH (%)
		Mean (Min–Max) CO	Temperature (°F)	
01/23/2008	10:58 a.m.–02:11 p.m.	3 (0–13)	77.8	14.1
01/24/2008	08:16 a.m.–02:10 p.m.	0 (0–2)	71.9	10.5

Employee Interviews

We privately interviewed 16 employees, including eight men and eight women. Five employees worked in D133, and 11 employees worked in D039. These employees represented almost all of the employees working in these two locations. Most of the interviewed employees worked as SMAs. Their average length of employment at Cessna was 5.3 years, and the average length of employment in their current department was 1.7 years. Job duties included drilling holes, grinding composites, and riveting. Employees reported exposures to methyl propyl ketone, sealants, alcohol, alodine, and glue.

Of the interviewed employees, 43% (7/16) reported that they had no health symptoms related to their work. While 12% (2/16) of interviewed employees reported headaches, none reported dizziness, fatigue, or abdominal pain. Twenty-five percent (4/16) reported that they had pre-existing asthma, and three of the four reported that their asthma was worse at work. All four employees with asthma worked as SMAs, but only one reported grinding composites. One employee reported a new diagnosis of asthma but declined our request for a personal medical record review. Eighteen percent (3/16) of interviewed employees reported skin symptoms including hives, itchiness, and other rash, and two of them reported grinding composites.

Document Review

We reviewed three reports of air sampling conducted by Cessna's staff in D039 and/or D133. In September 2003, three full-shift

RESULTS

(CONTINUED)

PBZ air samples were collected with 3M organic vapor passive badges from D133 employees for total volatile organic compounds. The air samples were analyzed for methyl propyl ketone, n-hexane, toluene, and xylene. All the reported TWA air concentrations were below the applicable OELs. In September 2006, Cessna conducted air sampling in response to an employee complaint to OSHA about CO₂ exposures in D133. Spot measurements were taken with a direct reading instrument at three different locations in D133; the CO₂ concentrations ranged from 289–333 ppm. The outdoor CO₂ air concentration was not reported. In September 2007, one PBZ air sample for respirable dust was collected on an SMA, and one GA air sample for total dust was collected in D039. CO concentrations were also monitored in D039 with a direct reading instrument. The PBZ respirable dust concentration was 0.16 mg/m³, and the GA total dust concentration was 0.23 mg/m³. These results were similar to our air sampling results and were below the applicable OELs. The TWA CO concentration was 0.86 ppm and was below applicable OELs.

Review of the D039 downdraft table maintenance chart showed that filters were changed when the pressure drop across the filters reached 3.5–4 inches of water on the magnahelic® gauge, which is in accordance with the manufacturer's recommendation. During our site visit we were informed that the composite materials were made using isocyanates. However, our subsequent review of the MSDSs indicated that the composite materials used in these departments were made using epoxy novolac resin, BADGE (a building block for epoxy resin), and cyanoguanidine (an amine).

The Health Services manager provided us with a letter containing the details of incident reports from 2007, when four employees presented with work-related complaints. All four employees reported respiratory symptoms including chest pain, cough, and difficulty breathing; three also reported skin irritation, and two reported dizziness. The Health Services department concluded that the symptoms of two employees were not work related. One employee was thought to have symptoms consistent with personal tobacco use, and the other employee was found to have a pre-existing medical condition. The other two employees reporting symptoms reported skin irritation and breathing difficulty but had no objective findings on clinical exam. These two employees had no further complaints after the original visit to Health Services [Gilbert 2007]. The work locations of these four individuals within the facility were not included in this letter.

RESULTS

(CONTINUED)

Most cases recorded in the OSHA Logs were musculoskeletal. The 2005 OSHA Log contained an entry concerning a rash on the hands of an SMA and two entries concerning lung irritation in an administrator and in an assembler/sealer. The 2006 OSHA Log contained one entry concerning a rash in a paint preparation worker, and the 2007 OSHA Log contained an entry concerning a rash in an SMA. No entries concerning lung irritation were recorded in 2006 and 2007. It is not known in which departments the OSHA-recordable injured or ill employees were working.

Other Observations

In D039 and D133, Cessna employees use very small quantities of paint and sealants for touching up parts. We observed that paint was mostly stored in small cans, which had lids, and employees used a brush to touch up metal parts. Review of the MSDSs for paints and sealants used in these departments indicated the presence of solvents such as methyl propyl ketone, toluene, and xylene. The inhalation exposure potential to employees during the touch-up task is limited as the task duration is short, and employees close the cans after use. Also, excess paint and other sealants are stored separately, and some are stored in a locked refrigerator. Review of Cessna's air sampling report also indicated that employee exposures to these solvents were below the applicable OELs. Based on this information, we did not evaluate these potential exposures further.

DISCUSSION

Historically, dust generated from grinding cured composite materials has been considered to be inert [Boatman et al. 1987; Hathaway and Proctor 2004]. However, studies have shown that employees working with epoxy-containing composite materials are at risk of developing asthma. Case studies have shown that employees working with composite material ingredients such as bisphenol-A and BADGE can develop occupational asthma [Kanerva et al. 2000; Hannu et al. 2008]. Employees can also develop asthma when inhaling vapors generated during curing or when grinding cured epoxy resins [Asthma induced by epoxy resin systems 1977; Ward and Davies 1982; Hathaway and Proctor 2004]. Epoxies are sensitizing agents and can cause health effects at very low levels, far below the applicable OELs.

Three employees with pre-existing asthma reported worsening of their asthma at work. Only one of these employees worked grinding composite materials, but the other two worked in the vicinity of other employees grinding composites. Another reported new onset asthma since working at Cessna. While 9 (56%) out of 16 employees interviewed during our site visit reported various work-related health symptoms, these symptoms did not appear to be reported in the Health Services incident reports or the OSHA Logs.

Our air sampling results indicated that employees' exposures to total and respirable dust are below the OSHA PELs and ACGIH TLVs. It is possible, however, that the reported respiratory symptoms are work related. NIOSH does not have an REL for total and respirable dust but concluded in 1988 that the documentation cited by OSHA for a reduced PEL (8-hour TWA) of 10 mg/m³ for total dust was inadequate and may not protect employee health [NIOSH 2005]. Similarly, ACGIH TLVs for inhalable and respirable dust are applicable only when dust particles are insoluble or poorly soluble in water and have low toxicity [ACGIH 2009]. Dust generated from grinding of composite materials can contain reactive components; therefore, caution must be exercised when interpreting air sampling concentrations for total and respirable dust samples in this setting.

Current sampling methods for dusts containing composite material require sampling for total dust. Although NIOSH has a draft air sampling method for BADGE, one possible component in the dust, no OELs for specific components of composite dust have been established. In addition, there are no OELs for composite dust as a whole, unlike welding or metalworking fluids [NIOSH 2005]. Composite materials manufactured with different chemicals and additives can have other reactive components that can exacerbate respiratory symptoms in predisposed employees. In addition, dust generated during grinding of composites is mostly in the respirable size range, which allows these particles to deposit in the bronchial and alveolar regions of the lung.

Our air sampling results for CO indicated that the air concentrations were below all the applicable OELs. Cessna's air sampling reports showed that CO, total dust, and respirable dust concentrations were similar to our air sampling results. Temperature and relative humidity measurements collected during our visit were within the recommended ASHRAE guidelines [ASHRAE 2007].

DISCUSSION

(CONTINUED)

The capture efficiency of the D039 downdraft table can be affected by even moderate room air currents. Use of baffles on three sides of the table (i.e., back and side shields) will help increase the capture efficiency of the downdraft table by reducing interfering room air currents [ACGIH 2007]. If employees continue to grind at their work stations, use of local exhaust ventilated (shrouded) tools can help reduce employee exposure to composite dust [ACGIH 2007; 29 CFR 1910.94 (b)].

We observed that some employees wearing elastomeric respirators had facial hair in the sealing area. This prevents the respirator from creating a good seal around the face and substantially reduces the protection afforded by respirators.

CONCLUSIONS

Employee exposures to total and respirable dust in D039 and D133 were below the applicable OELs. However, dust generated from grinding of composite materials can contain reactive components that can cause health effects at levels far below the applicable OELs. Three employees reported worsening of their asthma at work, and one reported new onset asthma since working at Cessna. Despite low levels of total and respirable dust and metals, it is possible that these reported respiratory symptoms are work related. CO levels in both departments were below the applicable OELs and did not present a health hazard.

RECOMMENDATIONS

Based on our findings, we recommend the actions listed below to create a more healthful workplace. These recommendations apply not only to D039 and D133 but also to similar operations throughout the facility. We encourage Cessna to use its 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 Cessna. Our recommendations are based on the hierarchy of controls approach (Appendix B: 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.

1. Use downdraft tables when grinding on composite materials. Downdraft tables should have baffles on three sides to reduce interference from room air currents and increase the capture efficiency of the table. ACGIH recommends that a downdraft table or a hand grinding bench have a flow rate range of 150–250 cubic feet per minute per square foot of bench area and a minimum duct velocity of 3500 feet per minute. Please refer to the ACGIH publication *Industrial Ventilation: A Manual of Recommended Practice for Design* for further guidance on selecting local exhaust hoods appropriate to your processes [ACGIH 2007].
2. Provide shrouded grinding and buffing tools to employees when the task prevents the use of the downdraft tables. Please refer to the above mentioned ACGIH publication and OSHA ventilation standard (29 CFR 1910.94) for guidance on minimum exhaust flow rates required for shrouded tools [http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9734].

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.

RECOMMENDATIONS

(CONTINUED)

1. Encourage employees to report all work-related health concerns to Cessna's onsite medical clinic. These problems should be investigated on an individual basis by the company and contracted healthcare providers.
2. Reassign employees determined to have health effects resulting from work related exposures to areas with minimum or nonexistent exposures. Employees reassigned for work-related medical reasons should not lose seniority, wages, or other benefits to which they would be entitled had they not been reassigned.

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.

1. Provide a copy of Appendix D of 29 CFR 1910.134 to employees who continue to wear respirators voluntarily.
2. Encourage employees who voluntarily wear respirators to follow all aspects of proper respirator use including being clean shaven when using the respirator to ensure a good seal.

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Total Dust and Metals

Air samples were collected on tared 37-mm diameter, 5- μ m pore size polyvinyl chloride filters using SKC Air Check® 2000 air sampling pumps calibrated at a flow rate of 2 liters per minute. The inlet port of the sampling pump was connected to the sampling media with Tygon® tubing. All air sampling pumps were calibrated before and after use. For PBZ samples, the sampling media was attached to the employee's lapel within the breathing zone, roughly defined as an area in front of the shoulders with a radius of 6 to 9 inches. All samples were first analyzed gravimetrically according to NIOSH Method 0500 [NIOSH 2009]. These air samples were subsequently analyzed for metals by inductively coupled argon plasma-atomic emission spectroscopy according to NIOSH Method 7303 [NIOSH 2009].

For total dust samples, the limit of detection was 0.030 mg/sample, and the limit of quantitation was 0.093 mg/sample. The MDC and MQC were obtained by dividing the analytical limit of detection and the limit of quantitation, respectively, by the sample volume. Therefore, for a sample volume of 0.96 m³, the MDC was 0.031 mg/m³, and the MQC was 0.097 mg/m³.

Respirable Dust

Air samples were collected on tared 37-mm diameter, 5- μ m pore size polyvinyl chloride filters with SKC Air Check® 2000 air sampling pumps calibrated at a flow rate of 1.7 liters per minute. Nylon cyclones were used as preselectors for the respirable dust samples because they match the 4- μ m, 50% cut, respirable curve. All samples were analyzed gravimetrically according to NIOSH Method 0600 [NIOSH 2009].

For respirable dust samples the limit of detection was 0.030 mg/sample, and the limit of quantitation was 0.093 mg/sample. Therefore, for a sampling volume of 0.96 m³, the MDC was 0.031 mg/m³, and the MQC was 0.097 mg/m³.

Reference

NIOSH [2009]. NIOSH manual of analytical methods (NMAM®), 4th ed. Schlecht PC, O'Connor PF, eds. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication 94-113 (August, 1994); 1st Supplement Publication 96-135, 2nd Supplement Publication 98-119; 3rd Supplement 2003-154. [<http://www.cdc.gov/niosh/docs/2003-154/>].

APPENDIX B: OCCUPATIONAL EXPOSURE LIMITS & 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 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 a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the 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 2005]. 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 2009]. WEELs have been established for some chemicals “when no other legal or authoritative limits exist” [AIHA 2009].

Outside the United States, OELs have been established by various agencies and organizations and include both legal and recommended limits. Since 2006, the Berufsgenossenschaftliches Institut für Arbeitsschutz (German Institute for Occupational Safety and Health) has maintained a database of international

APPENDIX B: OCCUPATIONAL EXPOSURE LIMITS & HEALTH EFFECTS (CONTINUED)

OELs from European Union member states, Canada (Québec), Japan, Switzerland, and the United States available at http://www.dguv.de/bgia/en/gestis/limit_values/index.jsp. The database contains international limits for over 1250 hazardous substances and is updated annually.

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.

Total and Respirable Dust

Respirable particulates are those particles that when inhaled can be deposited in the gas exchange region [ACGIH 2009]. Total dust refers to particulates that may be deposited anywhere in the respiratory tract. Total dust includes respirable particulates. OSHA has 8-hour PEL-TWAs for respirable and total particulates (particulates not otherwise regulated) of 5 and 15 mg/m³ respectively. The ACGIH position is that all particles, even if they are biologically inert or not soluble, may have adverse health effects. Therefore, ACGIH therefore recommends that exposure to respirable particles not exceed 3 mg/m³ and exposure to inhalable particles not exceed 10 mg/m³. These recommendations are for particles that do not have a specific TLV, are of low toxicity, and are referred to by ACGIH as particles (insoluble or poorly soluble) not otherwise specified [ACGIH 2009].

Carbon Monoxide

Carbon monoxide is a colorless, odorless, tasteless gas that can be a product of the incomplete combustion of organic compounds. It is classified as a chemical asphyxiant because it combines with hemoglobin and interferes with the oxygen carrying capacity of blood. Symptoms of overexposure include headache,

APPENDIX B: OCCUPATIONAL EXPOSURE LIMITS & HEALTH EFFECTS (CONTINUED)

drowsiness, dizziness, nausea, and vomiting. Collapse, myocardial ischemia, and death can also result [LaDou 2004]. The NIOSH REL for CO is 35 ppm for an 8-hour TWA. NIOSH also recommends a ceiling limit of 200 ppm, which should not be exceeded at any time during the workday [NIOSH 2005]. The OSHA PEL for CO is 50 ppm for an 8-hour TWA. The ACGIH TLV for CO is 25 ppm as an 8-hour TWA. This value is intended to maintain blood carboxyhemoglobin levels below 3.5%, to minimize the potential for adverse neurological behavioral changes, and to maintain cardiovascular work and exercise capacities. The time to reach a carboxyhemoglobin level of 3.5% at a given CO concentration decreases as the workload increases [ACGIH 2001]. Carboxyhemoglobin levels are elevated in active smokers but usually do not exceed 10% (values range between 4%–7% for a two-pack-per-day cigarette smoker). Carboxyhemoglobin levels above 50% can be lethal [LaDou 2004].

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The Hazard Evaluations and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (NIOSH) conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found. HETAB also provides, upon request, technical and consultative assistance to federal, state, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

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Copies of this report have been sent to employee and management representatives at Cessna Aircraft Company, the state health department, and the Occupational Safety and Health Administration Regional Office. This report is not copyrighted and may be freely reproduced. The report may be viewed and printed at <http://www.cdc.gov/niosh/hhe/>. Copies may be purchased from the National Technical Information Service at 5825 Port Royal Road, Springfield, Virginia 22161.

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