Part 2. Case Studies

Case Study A. Manual Material Weighout

Introduction
At this operation, powdered acrylic copolymer was weighed into batch lots at a weigh-out booth, diagrammed in Figure A-1.[A1] A hinged segment of the work platform could be raised to allow a drum of raw material to be placed inside the booth. An exhaust plenum formed the back wall of the booth. At the booth, the worker emptied 22.7 kg (50 lb) bags of powder into a fiber drum measuring 84 cm (33 in.) high and 55 cm (21.5 in.) in diameter. Then, using a scoop, the worker transferred the powder from the drum to a small paper bag. The bag was placed on the scale and the weight of powder in the bag adjusted. Usually, two scoops of the powder were required to achieve the proper weight. Finally, the filled bag was closed and placed in a bin behind the worker. This process was repeated until the required number of batches were filled or the fiber drum was emptied.

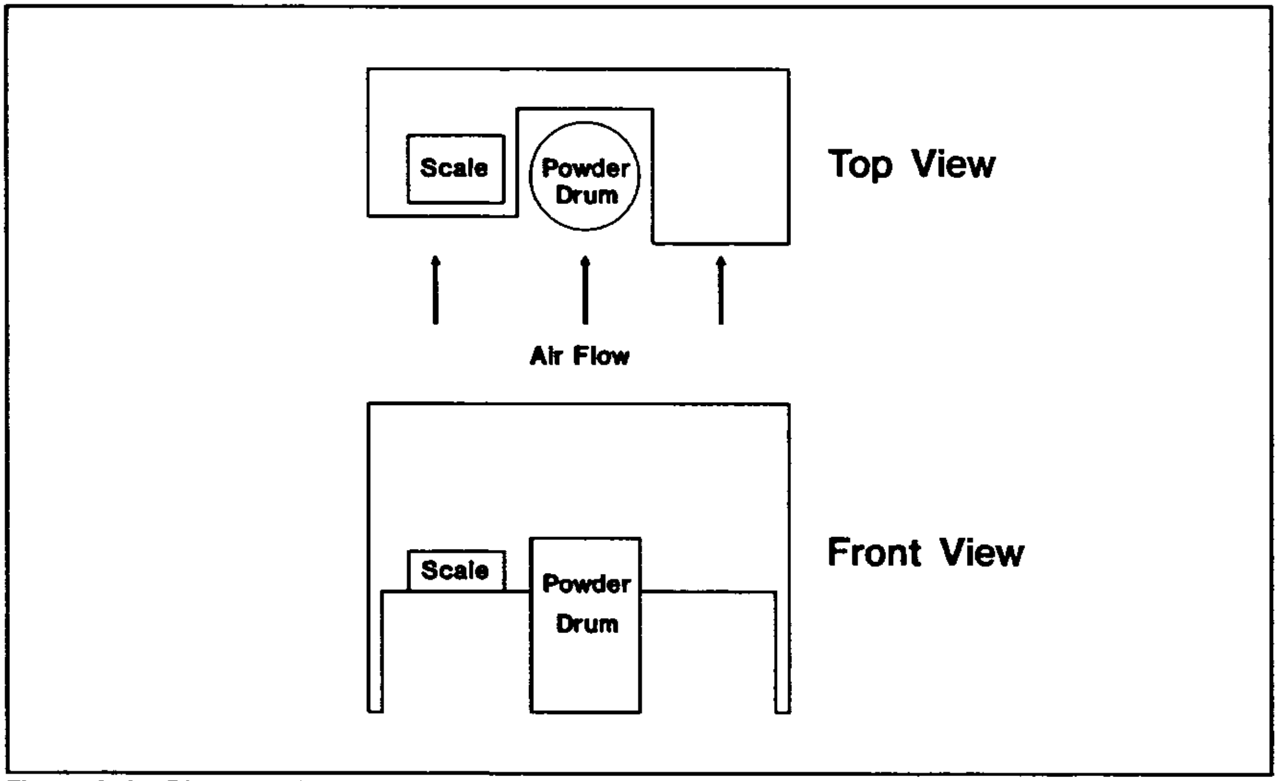

Figure A-1. Diagram of workstation. The drawing is not to scale nor is the exhaust plenum shown.

Methodology
Direct reading monitors were used to study the effect of depth of material in the drum and the elements of the job cycle on dust exposure. The worker began with a full drum and weighed the powder into paper bags. An aerosol photometer, the Hand-held Aerosol Monitor (HAM) (PPM Inc. Knoxville, TN), was used to monitor the dust concentration in the worker's breathing zone. Every 2 sec, the HAM's analog output was recorded by an Apple II Plus® computer equipped with an AI 13 analog-to-digital converter (Interactive Structures Inc., Bala Cynwyd, PA). The evaluation ended when the drum was nearly empty (about 22 min).

The voltage output was statistically analyzed to determine if the amount of powder in the drum affected worker dust exposure, and if it did, which activities contributed the most to this increase. The strategy for this analysis was to fit a regression model involving the relation of the variable, "worker," (a time-dependent measure of dust exposure) to the independent variables, "bagcount," "scooping," "weighing," and "turning." Worker was the voltage output of the direct reading monitor mounted on the worker. Bagcount was the cumulative number of bags that were weighed. Scooping was the cumulative time during each cycle spent scooping material from the drum and into the bag. Weighing was the cumulative time during each cycle spent weighing the bag on the scale and adjusting the amount of powder in the bag. Turning was the cumulative time during each cycle spent placing the bag in the bin. The worker's exposure was modeled closely enough to provide a fair representation of its relationship to the variables. There was no attempt to continue to add terms to the model until the lack of fit was not statistically significant.

A key assumption in the data analysis is the independence of measurements. Successive readings from the instrument are not independent. When a dust generating event occurs, dust concentrations do not increase immediately; time is needed for the air to transport the dust cloud from the point of generation to the inlet of the instrument. Also, the HAM was operated with a time constant of 1 sec and required some time to respond to fluctuating concentrations. The total instrument response time appeared to be 2 to 5 sec, meaning the instrument responded 2 to 5 sec after a dust generating activity occurred. As a result, autoregressive terms were used in the analysis.

The results of the regression analysis are shown in Figures A-2 and A-3. Figure A-2 shows that dust exposure during the scooping activity increased as the bag count increased. Bag count was a surrogate measure for the level of powder in the drum; a bag count of 0 corresponded to a full drum, and a bag count of 55 corresponded to an empty drum. During weighing and turning, the worker's dust exposure either remained constant or failed to increase as fast as the exposures during scooping.

Figure A-3 illustrates the effect of job cycle upon dust exposure. During the scooping activity, the dust exposure increased. During the weighing and turning activities, the dust exposure decreased. This suggests that most of the worker's dust exposure was caused when scooping the powder from the drum. Dust exposures caused by weighing and turning were much smaller than the dust exposures caused by scooping and may have been controlled by the ventilation system. The weighing activity appeared to be associated with higher dust exposure than did the turning activity. This difference, however, may be an artifact caused by the delay of the HAM's response to the high dust exposures during scooping.

Findings
Figure A-2 shows that dust exposure increased with bag count, which is a surrogate variable for depth of scooping. The data were collected over an approximately 20 min period. This same conclusion was reached with the use of conventional short-term measurement of dust concentrations with pumps and filters. The filter data, which required three full shifts to collect, did not however, provide any insight into the relationship between job cycle and the workers' dust exposure. Knowledge of the specific task that elevated the workers' dust exposure was crucial to the redesign of the weigh-out booth.

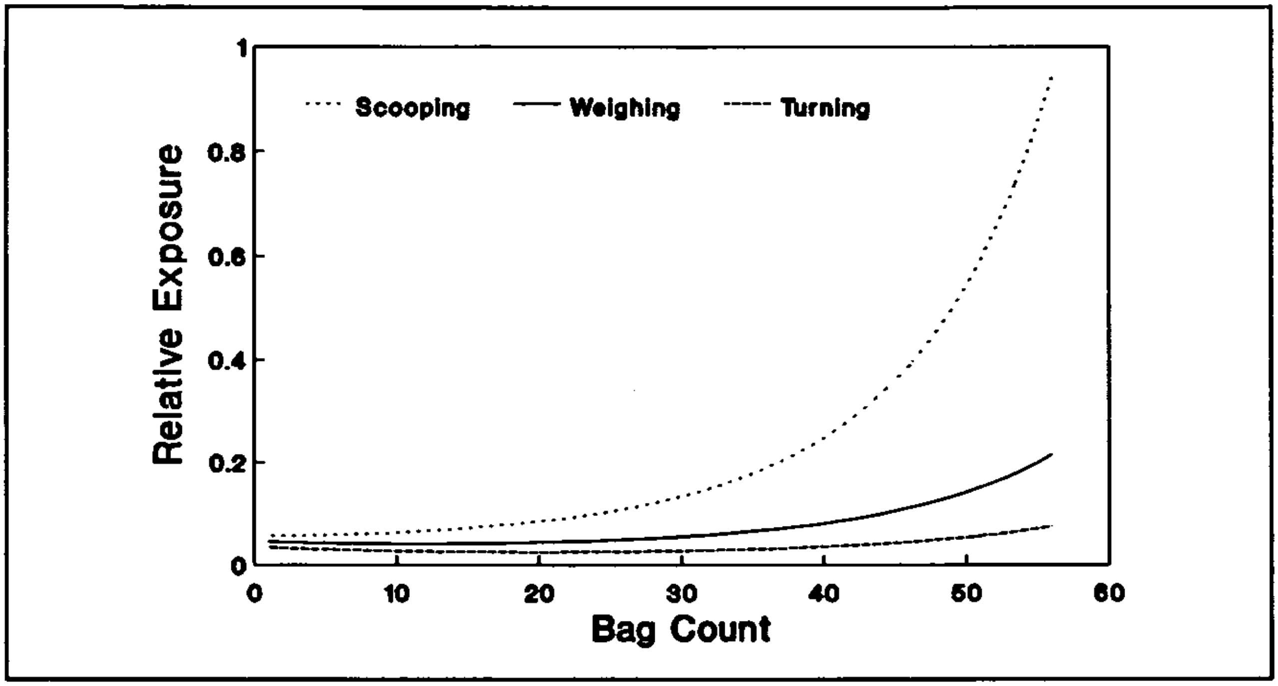

Figure A-2. Modeled dust exposure of a worker as a function of bag count for scooping, weighing, and turning.

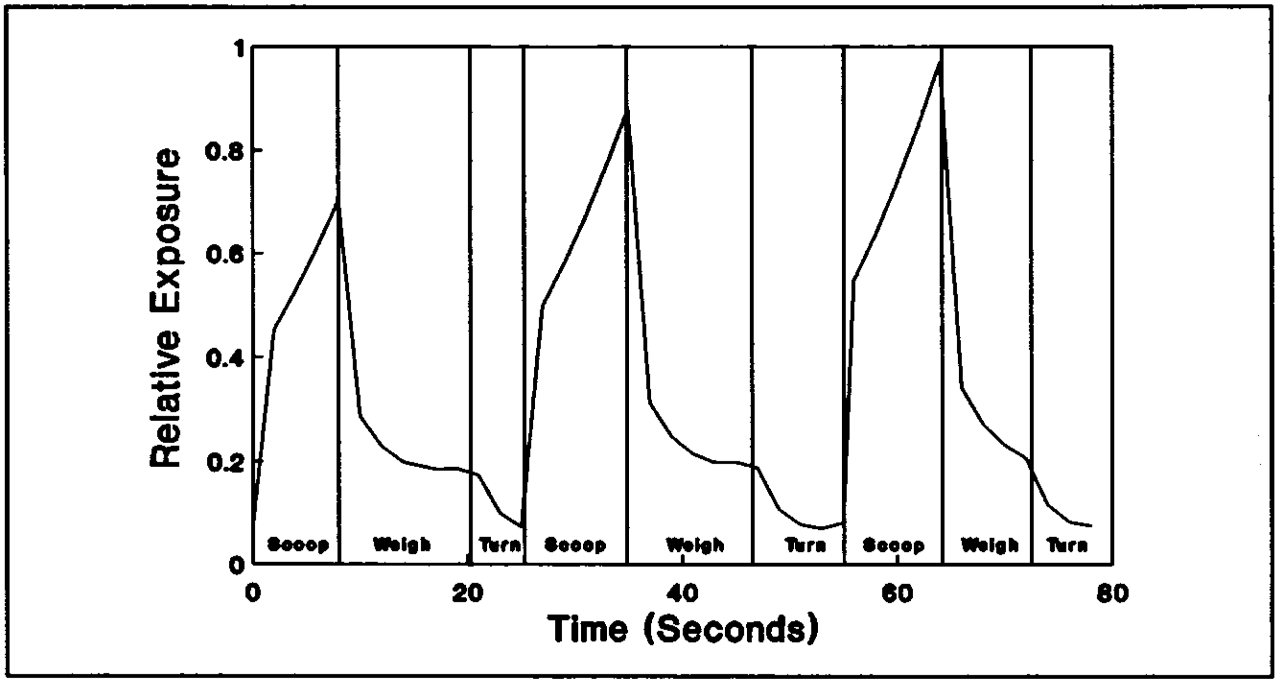

Figure A-3. Modeled dust exposure of worker for filling bags 51 thru 53.

Recommendations

A recommendation was made, based upon the results presented in Figures A-2 and A-3, to restrict the depth from which powders are scooped out of drums: use shorter drums for bulk storage. This case study clearly showed that direct reading monitors can be used to qualitatively and quantitatively study sources of dust exposure during the work cycle -- exposures too short to be studied with integrated air sampling methods.

Reference

A1. Gressel, M.; W. Heitbrink; J. McGlothlin; and T. Fischbach: Real-time, Integrated, and Ergonomic Analysis of Dust Exposure During Manual Materials Handling. Applied Industrial Hygiene 2(3):108-113, (1987).

Case Study B. Ceramic Casting Cleaning

Introduction

A casting operation in a ceramics manufacturing plant was studied to characterize occupational respirable silica exposures.[B1] This particular plant made sanitary fixtures such as sinks and toilets. Worker began the cleaning process by placing a casting on a rotating platform. They "scraped" the mold marks and other rough areas with a flat blade. After smoothing the rough areas, the workers "brushed" the dust from the casting and then "wiped" the casting with a wet sponge for final smoothing. Workers then turned the casting over and repeated the process for the other side of the casting.

The castings cleaned in this plant were in two different states. If made on the previous day, the casting was green. If made more than one day earlier, the casting was white. Green castings contain more water than white castings. The silica exposures resulting from cleaning white castings was compared with that from green castings. In addition, all elements of the job cycle were evaluated to determine their effect on exposures.

Methodology

Since no direct reading monitor is available for measuring silica, total dust was measured as a surrogate for the silica exposures. If the silica concentration in each casting remained constant, the silica exposure was assumed to be proportional to the total dust. The worker wore a portable aerosol monitor (HAM, PPM Inc., Knoxville, TN), and the output signal was recorded by a data logger (Rustrak® Ranger, Gulton, Inc., East Greenwich, RI). A video recording system documented the activities of the worker. The clock of the data logger was synchronized with the timer in the video camera. A worker cleaned four white castings and then four green castings. The data loggers were downloaded after data collection. The data logger software converted the data set to an ASCII file for import to a spreadsheet program. The casting cleaning process was broken down into four major activities: scraping, brushing, wiping (as earlier defined) and other (such as moving the castings and other activities not directly related to the cleaning operation). From viewing the video recording, the exposure measurements were coded with the corresponding activity by using the spreadsheet program. Data in the spreadsheet were analyzed to evaluate the effect of activity and the type of casting upon exposure.

Findings

The analysis results, summarized in Table B-1, show statistically significantly greater dust exposures when cleaning white castings. The brushing and wiping activities brought the highest instrument response. Since the brushing activity did not last for a long period of time, it did not result in a high dose (time × concentration). The brushing activity may, however, have increased the workers exposure for a period of time extending into the wiping activity, which did last for a long period of time. The wiping activity was responsible for more than half the dose during the cleaning of both white and green castings.

Table B-1. Relative exposures and doses for the cleaning of white and green castings.

	Air Concentration Index*		
Casting Type/Activity	A Relative Mean	B Operating Time (sec)	A x B Relative Dose
Green castings overall	0.10	923	92
Scraping	0.07	300	21
Brushing	0.07	69	5
Wiping	0.13	486	63
Other	0.06	68	4
White castings overall	0.45	1115	502
Scraping	0.16	380	61
Brushing	0.58	99	57
Wiping	0.69	530	366
Other	0.11	106	12

* Levels are reported as an "Index" since the instrument was not calibrated.

Recommendations

The major recommendation of this evaluation was to clean castings while they are still green. Modified brushing and wiping activities also were recommended. The use of a vacuum system for removing the dust on the castings may eliminate the brushing activity. Wetting the dust on the casting with a spray bottle also may help reduce exposures during the wiping activity. The graphical presentation of the data demonstrating activity results was most useful. In this case, the computer overlay system was used to place the raw exposure data onto the video recording of the activities. The resulting video recording illustrated how the workers' exposures changed as a result of the various work activities.

Reference

B1. Caplan, P.E.; Cooper, T.C.; Crouch, K.G.; Gideon, J.A.; Gressel, M.G.; and McGlothlin, J.D.: Sentinel Event Notification System for Occupational Risks (SENSOR): Recommendations for Control of Silica Exposures at Woodbridge Sanitary Pottery Corporation, Woodbridge, New Jersey. NTIS Pub. No. PB-89-227-847. National Technical Information Service, Springfield, VA (1989).

Case Study C. Dumping Bags of Powdered Material

Introduction
In this case study of a bag emptying operation,[C1] an operator emptied 50 lb bags of lead chromate into a ventilated hopper. This labor intensive operation had eight repetitive tasks, most requiring only a few seconds to complete. Video exposure monitoring made it possible to isolate the individual tasks contributing most to the operator's total exposure. By combining these data with a video recording of the operation, it was possible to view simultaneously the operator's activity and the resultant dust exposure. This combination proved to be a useful tool in identifying good and poor work practices, as well as effective and ineffective engineering controls in relation to the operator's movements.[C2]

Methodology
In a 24-min period, an operator emptied sixty-five 50-lb bags of lead chromate pigment into a ventilated dump station. This job was broken down into the following eight tasks:

1. Move a pallet load of bags to the dump station.
2. Remove the plastic wrap from the pallet.
3. Position the bag on pallet.
4. Cut open the bag.
5. Lift the bag to the dump shelf of the station.
6. Empty the bag into hopper.
7. Drop the empty bag into a barrel for disposal.
8. Manually compact the empty bags by pushing the bag into the barrel.

Tasks 3 thorough 8 were repeated at a rate of over a 160 times per hour, each task requiring from less than 1 to 8 sec to complete.

Four basic components were used to collect real-time data: a direct reading monitor, a data logger, a portable computer, and a video taping system. The direct reading monitor was a Hand-held Aerosol Monitor, (HAM manufactured by PPM, Inc., Knoxville, TN). This instrument was set to respond to respirable dust; however, it did not differentiate between different types of dust. Only relative concentrations -- estimates of the actual lead chromate dust concentration -- were given. Parallel filter samples were used to determine actual concentration of the lead chromate dust.

The HAM's analog output was connected to a data logger, Rustrak® Ranger (Gulton, Inc., East Greenwich, V). When the data collection was completed, the data logger was downloaded into a portable Compaq® Portable III computer (Compaq Computer Corporation, Houston, TX) for analysis. A database of exposure measurements was constructed with a 1-sec interval between the concentration measurements. The database was imported into a spreadsheet program, which was used to plot the real-time information and to provide a graphic display of the relative dust concentrations during the worker's activities.

The video recording system was a camcorder with an on-screen clock displaying hours, minutes, and seconds. The clocks in the camcorder and the data logger were synchronized at the start of the data collection. Identifying and coding worker tasks into the data set using a spreadsheet program permitting the dust contribution for each task to be calculated. From a graphical printout of the data shown in Figure C-1, activities resulting in elevated dust levels were identified.

The real-time exposure data were overlaid onto the video recording of the operator's activity to give a video recording of the worker activities and the resultant dust exposures. The exposure representation was in the form of a bar that increased or decreased with the worker's exposure. An example is shown in Figures C-2 and C-3.

Findings
The real-time data are summarized in Table C-1 and depicted in Figure C-1. Three tasks causing elevated dust levels were identified; cutting bag open, lifting opened bag, and pushing emptied bag into the barrel. The greatest exposure occurred when the bags were pushed into the barrel: 39% of the total exposure and only 15% of the worker's time. The other two tasks accounted for 14% of the total exposure and 15% of the worker's time. By reducing the average concentration of these three activities to near background levels, the worker's average exposure would be reduced by about 30%.

Recommendations
The existing bag emptying station should be altered to make it easier to use. As designed, it requires the worker to reach inside the hood to dispose of the empty bag, stretching at an awkward angle to compact the bags into the barrel. Most workers prefer placing the barrel outside the hooded enclosure, but when they compact the bags into the barrel, dust laden air is forced from the bags out of the barrel and directly into the worker's breathing zone. There are bag emptying machines that automatically open, empty, and compact the bags thus removing the worker from the main dust source. Another possibility is to install an air-operated ram inside the enclosure to compact the bags while the barrel remains inside the hood. The worker dust exposures could be reduced further by lifting the bag from the pallet and placing it on to the dump shelf before cutting it open.

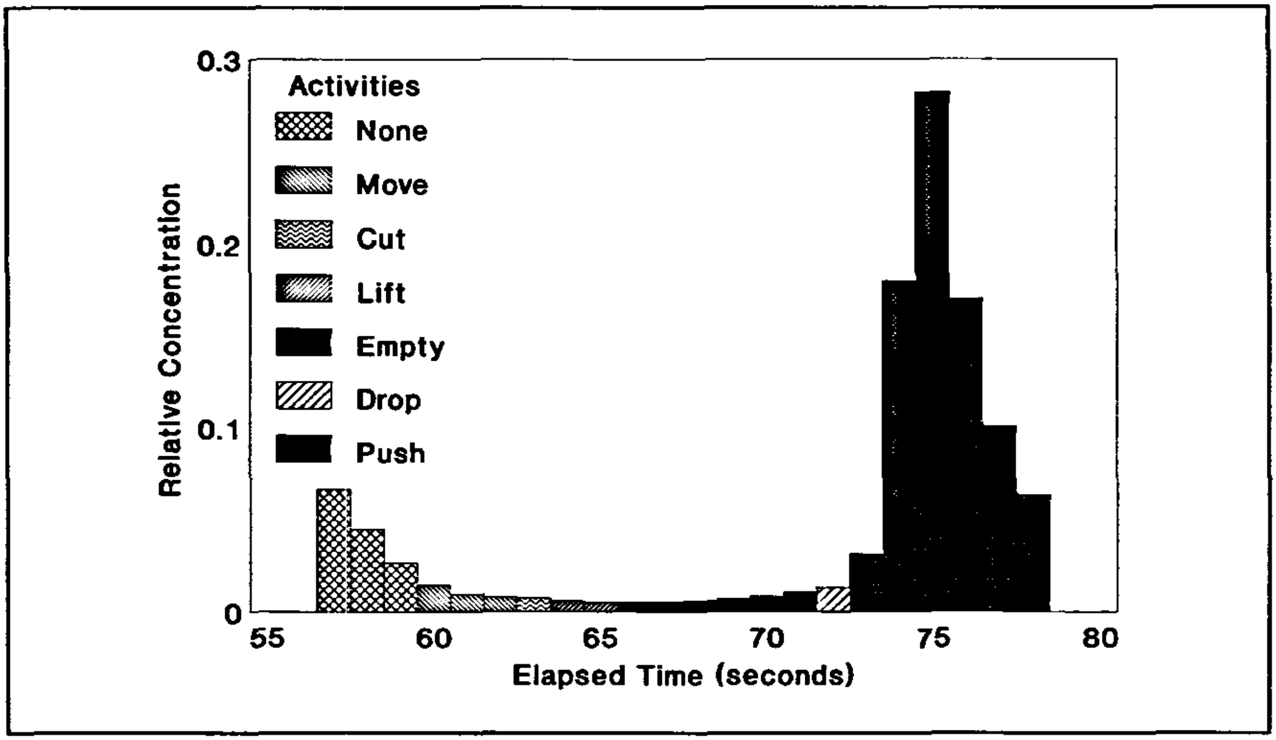

Figure C-1. Relative worker exposure to lead chromate dust from dumping a single bag (by activity).

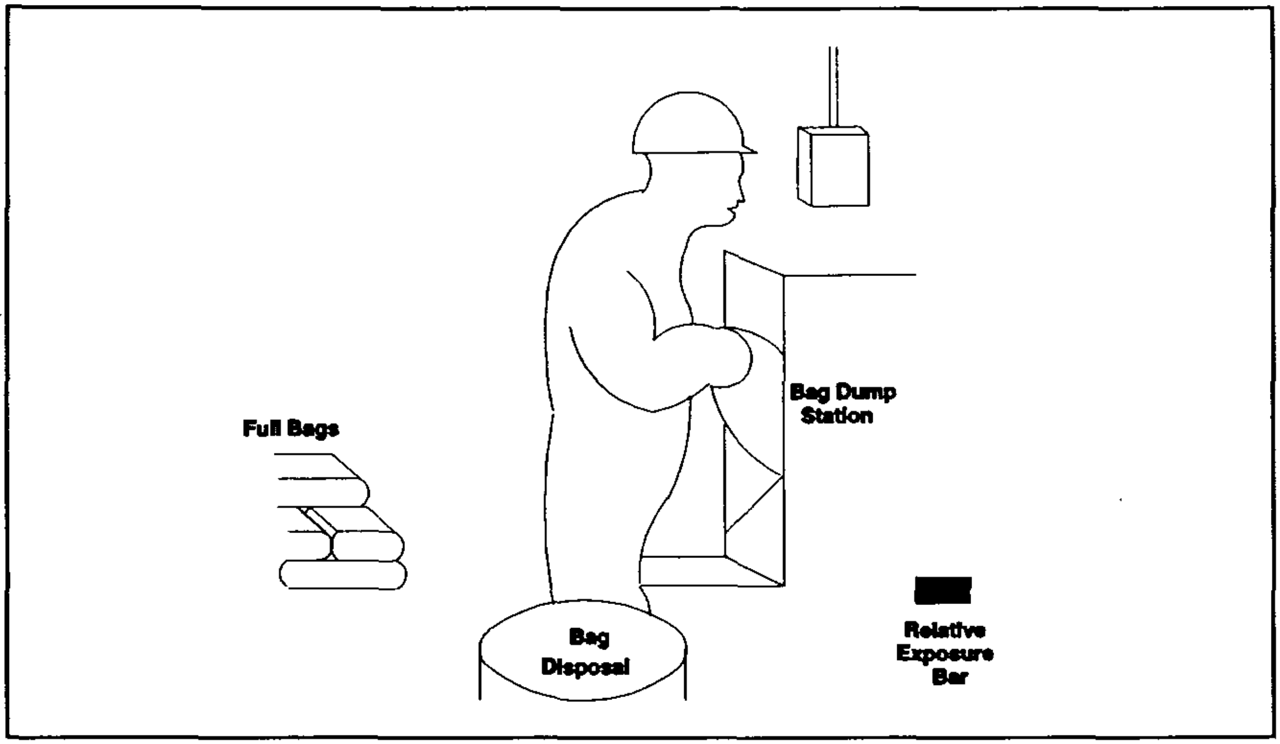

Figure C-2. Sketch of low dust exposure activity (dumping bag) with overlaid exposure measurement.

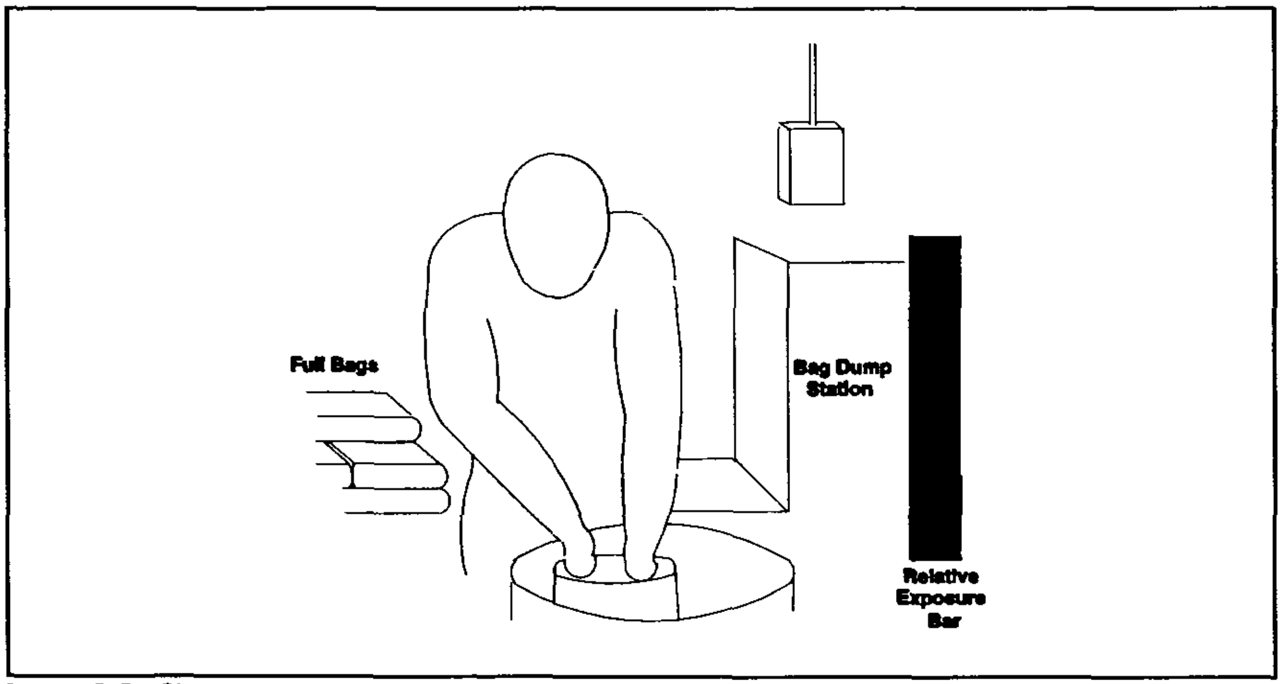

Figure C-3. Sketch of high dust exposure activity (bag disposal) with overlaid exposure measurement.

Table C-1. Worker dust exposure by activity.

Tasks: Emptying 65 Bags	Avg. Relative Concentration volts	Average Time seconds	Total Time, %	Total Dose, %
None*	0.007	2.2	10	6
Miscellaneous†	0.009	2.6	12	10
Moving bag on pallet	0.008	2.4	11	8
Cutting bag open	0.011	1.3	6	6
Lift bag to hood	0.010	2.0	9	8
Empty bag	0.007	7.8	36	22
Drop bag into barrel	0.003	0.2	>1	>1
Push bag into barrel	0.028	3.3	15	39
Total	0.011	21.8	100	100

* None - activities away from the dump station.

† Miscellaneous - activities such as removing the stretch wrap from pallet and placing the wrap in a barrel; using the forklift to raise the pallet load to waist height; replacing full bag-disposal barrel with an empty barrel.

References

C1. Cooper, T.C.; Heitbrink, W.A.; O'Brien, D.M.: Study Report: Evaluation of Dustiness Test Methods and Recommendations for Improved Dust Control at Heubach Inc., Newark, New Jersey. NTIS Pub. No. PB-89-187-876. National Technical Information Service, Springfield, VA (1989).

C2. Gressel, M.G.; Heitbrink, W.A.; McGlothlin, J.D.; and Fischbach, T.J.: Advantages of Real-time Data Acquisition for Exposure Assessment. Applied Industrial Hygiene 3(11):316-320 (1988).

Case Study D. Furniture Stripping

Introduction

Methylene chloride and methanol are commonly found in solutions used to strip paint, vanish and other finishes from furniture. The facility surveyed in this study used a Flow-Over® tank.[D1] A piece of furniture was placed in this shallow tank, recycled furniture stripping solution was pumped through a brush, and the solution was applied to the furniture. After allowing the solution to react with the finish, more recycled solution was applied and the old finish was brushed off. After the finish was removed, the residual solution was rinsed off the furniture with tap water and allowed to air dry.

Methodology

During the entire stripping process, TWA sorbent-tube samples (SKC 226-01 & SKC 226-10, SKC, Inc., Eighty-Four, PA) were collected in the worker's breathing zone. Concurrent with the sorbent-tube samples, a Photovac TIP II® (Photovac, Inc., Thornhill, Ontario, Canada) with a 10.6 eV ultraviolet lamp continuously monitored the relative methanol and methylene chloride concentrations. The analog output of the TIP II was recorded on a Rustrak® Ranger data logger (Gulton, Inc., East Greenwich, RI). The data logger was later downloaded to an IBM compatible computer. The following formula converts the TIP II output (volts) to contaminant concentration (mg/m^3):

$$C_i(t) = IR(t) \left[\frac{ST_i}{IR} \right] \qquad \text{(D-1)}$$

where:

$C_i(t)$	=	Concentration of contaminant at time t (mg/m^3)
$IR(t)$	=	Instrument response at time t (volts)
ST_i	=	TWA sorbent tube concentration (mg/m^3)
IR	=	TWA instrument response (volts)

The major assumption with this estimation method was that the relative vapor concentration ratio of methylene chloride to methanol remained constant throughout the stripping process. The limited sorbent tube data collected supported this assumption.

The real-time concentration measurements were used to evaluate the difference in vapor generation rate among the tasks of stripping, rinsing, and other duties performed by the worker. While stripping the furniture, the employee works in proximity to the evaporating furniture stripping solution and sprays additional solution on the furniture throughout the stripping process. During the rinsing procedure, the employee works in proximity to the furniture; however, only the evaporation of the residual stripping solution contributes to the generation of vapors. Finally, during the "other" category, only residual stripping solution in the room or on the furniture contributes to the generation rate. Because of these three different scenarios for generation rates, a material balance was applied independently to each task, assuming that each had a different generation rate. The "other" category of tasks included leaving the stripping area to answer the phone, talk to customers, and carry furniture outside to dry. Due to the room configuration, the mixing factor (K) was assumed to be six.[D2] Because each task lasted 3 to 5 minutes, the generation rate (G) for each task was estimated by rearranging equation (11) in section IX. The general ventilation rate for the room was multiplied by the TWA concentration of methylene chloride for each task, and divided by K:

$$G = \frac{Q\,C_{AVG}}{K} \qquad \text{(D-2)}$$

where:

G = Contaminant generation rate
Q = Exhaust flow rate
C_{AVG} = TWA concentration during each task
K = Room mixing factor

To explain the apparent difference in exposure among the various types of furniture stripped, the generation rates (G) were recalculated for each item stripped (i.e., chair, desk, roll top, and nothing). A least squares fit of the material balance (equation (9), section IX) to the data was performed.

Findings
As displayed in Figure D-1, the initial model using the material balance without considering the type of furniture followed the real-time data; however, a more refined model was needed to better define the apparent difference in generation rates throughout the sampling interval. A least squares curve fit was used to determine the room mixing factor and the generation rate of each specific type of furniture. This model, as in Figure D-2, followed the real-time concentration data. The generation rate estimates from the model are listed in Table D-1. The generation rates (G) for the second model appear reasonable, but the mixing factor (K) was less than one. This led to a relatively large effective ventilation rate. The normal range for K is between 3 and 10 for a room of this configuration.[D2]

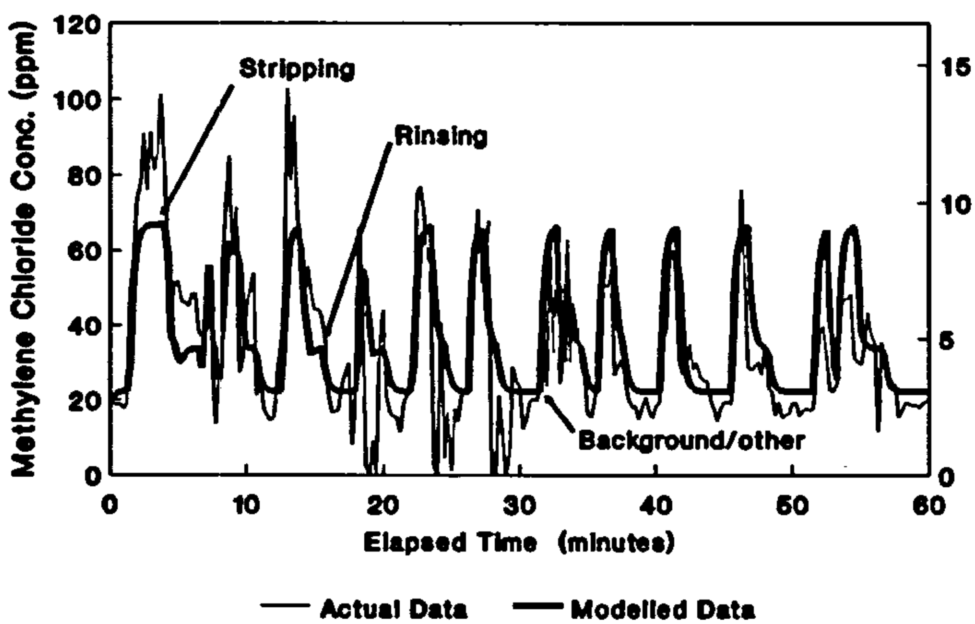

Figure D-1. Real-time and modeled methylene chloride and methanol exposure concentrations, by task only. Concentrations were measured with the PPM TIP II.

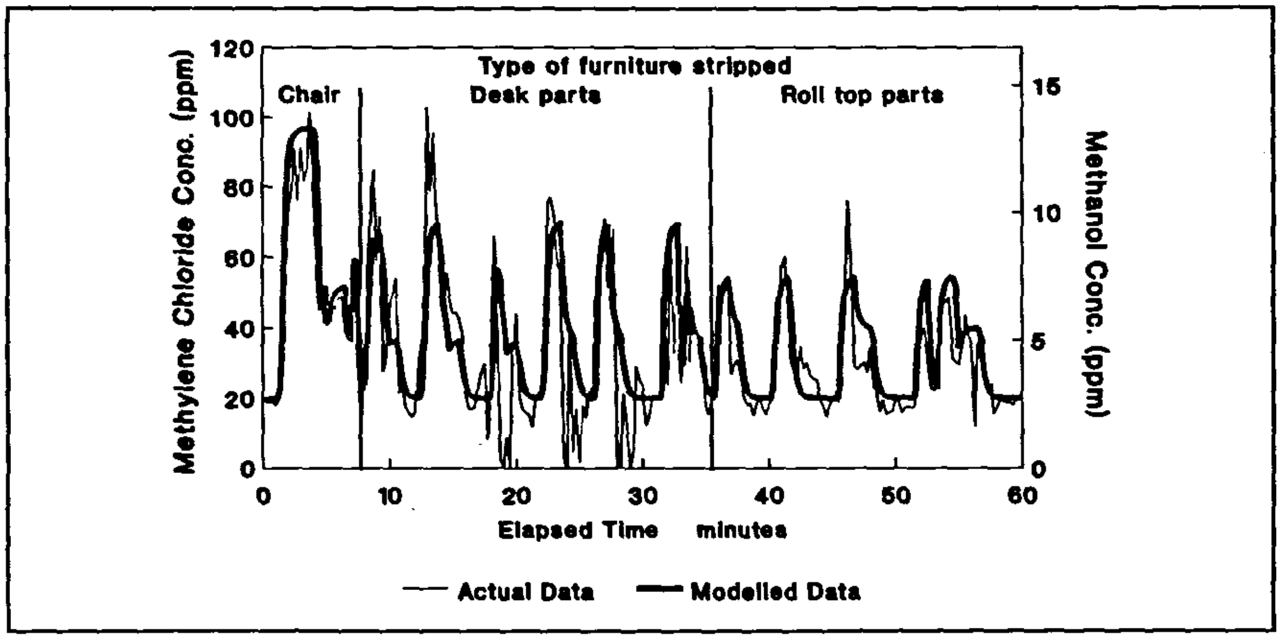

Figure D-2. Real-time and modeled methylene chloride and methanol exposure concentrations, by furniture type. Concentrations measured with PPM TIP II.

Table D-1. Methylene chloride generation rates

Task Performed	Furniture Category	Methylene Chloride Generation Rate, lpm
Stripping	All	0.27
	Chair	0.48
	Desk	0.32
	Roll Top	0.25
	Nothing	0.19
Rinsing	All	0.14
	Chair	0.23
	Desk	0.16
	Roll Top	0.18
	Nothing	0.11
Other	All	0.09

Obviously, the room ventilation rate was greater than that of the measured general exhaust. Additional ventilation flow of approximately 10,000 m^3/hr was assumed to be from a 2.2 m^2 open window and two large open double doors totalling 5.4 m^2. The worker was receiving far greater dilution air from to "natural ventilation" than from the installed general exhaust system of 1,500 m^3/hr.

The material balance clearly shows that the generation rate not only varies with the specific task (i.e., stripping, rinsing, or other tasks) but also with the physical characteristics of the furniture being stripped (i.e., chair, roll top, desk, or nothing). In addition, the generation rate of methylene chloride and methanol vapors during the rinsing process was approximately 60% of that during the stripping process. Another significant observation was that the baseline for the vapor concentration data while the worker was in the stripping area was not zero. The existing ventilation, at best, maintained a level of control of several hundred parts per million.

Recommendations
Solvent exposures at both the stripping and the rinsing areas must be controlled. Chairs and other tall pieces of furniture should be placed flat in the Flow-Over tank to increase the distance between the furniture and the breathing zone of the worker. The installation of a local ventilation system should be investigated to reduce solvent exposure.

References

D1. Jensen, P.A.; Todd, W.F.; and Fischbach, T.J.: Walk-through Survey Report: Control of Methylene Chloride in Furniture Striping at Ronald Alsip Furniture Refinishing, Cincinnati, OH. USDHHS(NIOSH) Report No. ECTB 170-12a. NIOSH, Cincinnati, OH (1990).

D2. American Conference of Governmental Industrial Hygienists: Industrial Ventilation: A manual of Recommended Practice, 20th ed. ACGIH, Cincinnati, OH (1988).

Case Study E. Dental Administration of Nitrous Oxide

Introduction

This study was conducted to evaluate how effectively scavenging systems reduce occupational exposure to waste nitrous oxide (N_2O).[E1] N_2O has used for more than 100 years in dentistry as a general anesthetic agent, an analgesic, and a sedative.[E2] Today, N_2O is used primarily for psychosedation, to reduce fear and anxiety in the conscious patient.[E2] N_2O scavenging systems typically have three principal components: a N_2O and oxygen (O_2) gas delivery system, a nasal cone for the patient from which to inhale the gases, and an exhaust system that carries the respired gas from the patient out of the building. A schematic of the nasal cone is shown in Figure E-1. Although studies show that scavenging systems significantly reduce N_2O concentrations, the systems do not reduce it to the NIOSH Recommended Exposure Limit (REL) of 25 ppm during the time of administration.[E3] In addition to evaluating the effectiveness of scavenging systems, this study was also conducted to determine why exposures exceeded 25 ppm.

Methodology

A dental facility that uses a market-available scavenging system during dental surgery was evaluated by NIOSH researchers. Ten dental operations (i.e., filling, extracting) were monitored by using a combination of sampling strategies: personal breathing zone sampling (dentist and dental assistant), general area sampling, and real-time sampling. A Miran® 1A (Foxboro Instruments, Foxboro, MA) was used to monitor the real-time N_2O concentrations. A sampling probe connected to the Miran 1A was

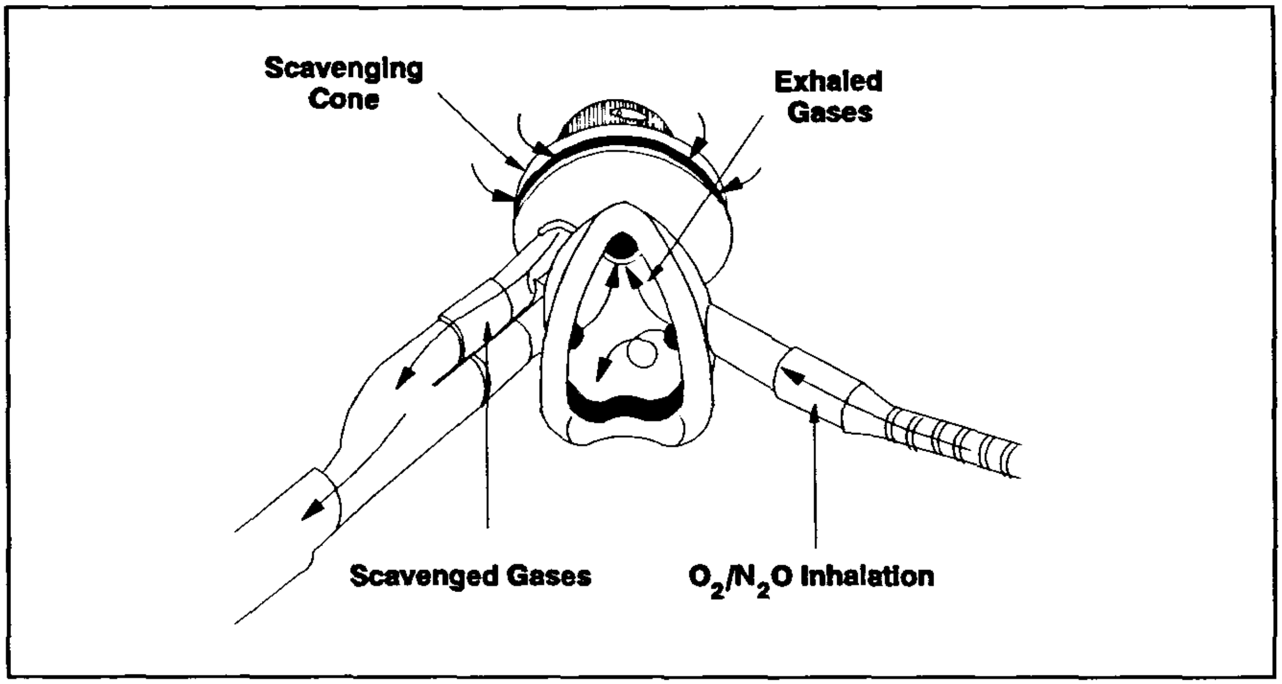

Figure E-1. Diagram of a typical dental N_2O scavenging system.

placed approximately 12 in. above the patient's head. In addition, video recordings using video and infrared scanning equipment monitored the dental practices (activities). Because N_2O is infrared absorbing, it can be "visualized" by using infrared thermography. Motion and time measurement techniques were used to document activities of the dentist, the dental assistant, and the patient during the operation.[E4] These activities, listed below, were coded into a computer spreadsheet along with the associated N_2O concentration data.

- local anesthetic injection
- extraction of tooth
- filling of tooth
- use of aspirator
- use of water and air syringe
- use of rubber dam (small rubber sheet used to isolate the operative site)
- use of curing light for restorative composite resin material
- patient talking, coughing, and yawning
- turning on N_2O
- turning off N_2O
- adjusting N_2O flow rate

Statistical analysis of the N_2O concentration and changes in concentration were modeled as a function of these work elements from the spreadsheet.[E5]

Findings

Average real-time N_2O concentrations for the 10 operations ranged from 206 ppm to 770 ppm. The average real-time concentration over all 10 operations was 442 ppm. The average personal breathing zone (integrated sample) concentration over all 10 operations for the dentists was 487 ppm. There was no significant difference ($p<0.68$) between the real-time and personal breathing zone concentrations for dentists. There was, however, a significant difference ($p<0.014$) between the overall average real-time sampling concentration and the average personal breathing zone concentrations among dental assistants (150 ppm). The differences in dental assistant breathing zone concentrations and the real-time concentrations may have been because the sampling probe was placed closer to the patient's and the dentist's breathing zone than to the breathing zone of the dental assistant. Thus, these real-time sampling results may be more representative of the dentist's exposure than that of the dental assistants. It also was determined that the dentists, by nature of the dental surgery, worked in closer to the patient's breathing zone than did the dental assistants.

Real-time sampling results and work activities were combined to determine if changes in N_2O concentrations were related to these activities. From the video recordings, several dental surgery activities were selected for analysis. To analyze the data, the real-time concentrations were matched with the identified dental activities. A plot of this relationship is shown in Figure E-2. Based on this analysis, the only activities that showed significant N_2O concentration changes were: (a) when the dentist turned the N_2O gas on, (b) when the dentist adjusted the N_2O concentration over the course of the operation, and (c) when the dentist turned the N_2O gas off at the end of the operation. Statistical analysis showed that 98% of the changes in N_2O exposure could be accounted for by the N_2O concentration of the gas delivered to the patient. Specific dental surgery activities had less effect on changes in N_2O concentration to which the dentist and dental assistant were exposed (note the "sawtooth" pattern in Figure E-2). Thus, the primary source of N_2O exposure was not from the work practices of the dentists but from N_2O delivery and the inadequacy of scavenging system exhaust.

During two of the 10 dental operations, an infrared video camera was used to qualitatively evaluate scavenging mask leakage. The infrared camera revealed N_2O leakage between the mask and face seal, indicating the scavenging mask did not fit the patient's face properly. However, the off gassing of N_2O

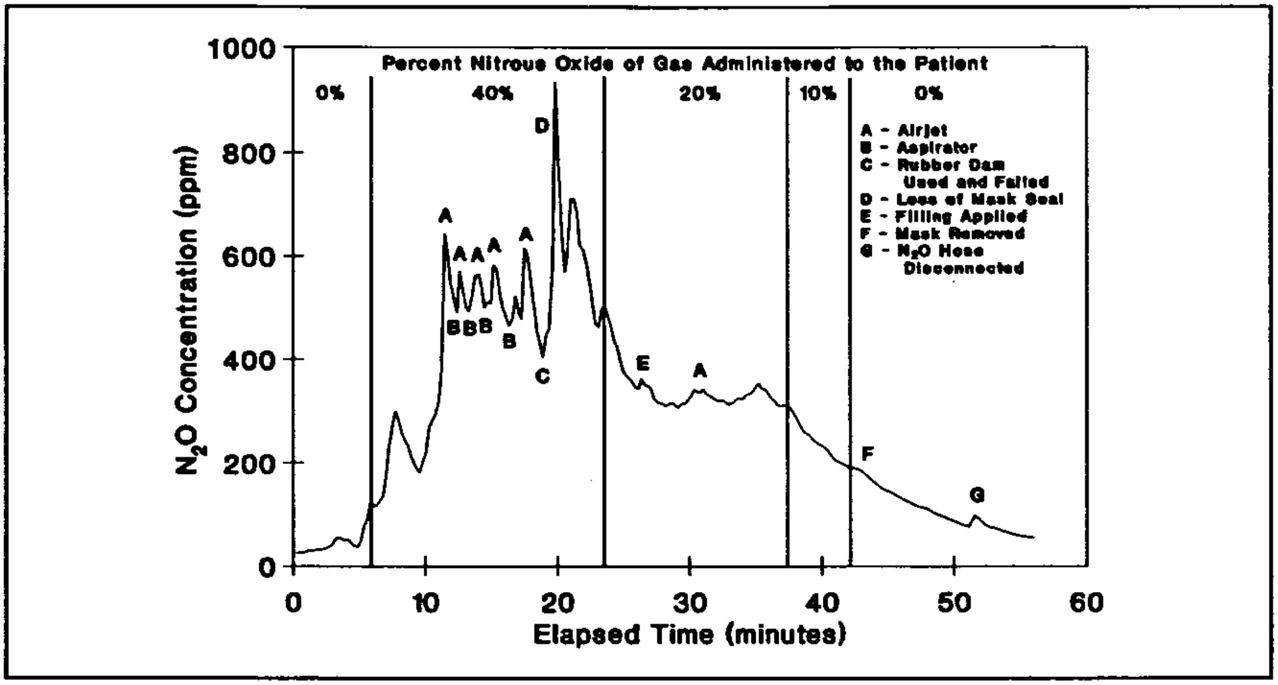

Figure E-2. Plot of real-time N_2O concentration with activities and supply concentrations. Real-time concentrations measured by the Miran 1A.

during patient mouth breathing also affected exposure during these two operations. The infrared video camera also revealed that a sudden increase in N_2O exposure could be traced to the patient's expired breath. This increase was also observed from the real-time data. When the patient inspired, the N_2O levels decreased. Synchronization of the real-time data with the infrared video camera helped to confirm that patient mouth breathing was also a source of N_2O exposure.

Recommendations

Scavenging mask leakage and inadequate scavenging system exhaust caused most of the N_2O exposure in the dental operatory evaluated in this study. Patient mouth breathing was a secondary source of exposure. If the scavenging system were more efficient, the work practices, such as use of the aspirator, air and water syringes, and patient mouth breathing may have had a greater impact on the N_2O exposures of dentists.

The infrared video camera proved to be a valuable tool for detecting N_2O leakage from the patient's mask as well as from patient mouth breathing. By following the real-time data patterns, NIOSH researchers discerned when there was a mask leak, when the patient was mouth breathing, or both. This ability to determine these exposure sources helped provide recommendations for scavenging system mask design, improving work practices, and reducing overall N_2O exposures.

References

E1. McGlothlin, J.D.; Jensen, P.A.; Todd, W.F.; Fischbach, T. J.; and Fairfield, C.L.: Control of Anesthetic Gases in Dental Operatories at Children's Hospital Medical Center, Dental Facility, Cincinnati, Ohio. NTIS Pub. No. PB-90-155-946. National Technical Information Service, Springfield, VA (1990).

E2. Eger, E.I. (Ed.): Nitrous Oxide/N_2O. Elsevier Science Publishing Co. Inc., New York (1985).

E3. National Institute for Occupational Safety and Health: Criteria for a Recommended Standard; Occupational Exposure to Waste Anesthetic Gases and Vapors. Pub. No. 77-140. NIOSH, Cincinnati, OH, (1977).

E4. Barnes, R.M.: Motion and Time Study, Design and Measurement of Work, 7th ed. John Wiley and Sons, New York (1980).

E5. McGlothlin, J.D.; Jensen, P.A.; Todd, W.F.; and Fischbach, T. J.: Study Protocol: Control of Anesthetic Gases in Dental Operatories. USDHHS(NIOSH) Report No. ECTB 166-03. NIOSH, Cincinnati, OH (1989).

Case Study F. Hand-held Sanding Operations

Introduction

This case study describes an evaluation of tool-mounted, high-velocity, low-volume (HVLV) exhaust hoods used on hand-held sanders.[F1] Exposures to sanding dust were determined for two workers, one using a sander with a hood, the other using a sander with none. Both workers were partners in a two-person team sanding a fiber-reinforced plastic truck hood and fender assembly. The equipment employed in this study included direct reading monitors to obtain a time history of exposure during a short (e.g., 20 minutes) sampling period and a stopwatch-equipped video camera to identify work activities. Exposure measurements of workers operating sanders with and without hoods were used to estimate potential exposure reductions.

Methodology

The dust exposure of each sander operator was measured with the use of a hand-held aerosol monitor (HAM, PPM, Inc., Knoxville, TN) connected to a data logger while his/her activities were recorded on videotape. The HAM is a device that indirectly determines the quantity of airborne dust from amount of light scattered by dust particles. To calibrate the instrument, the instrument output signal, integrated over a given period, was compared with a measurement obtained by conventional (filter) techniques over the same period. One instrument sampled a worker's dust exposure while using a hooded sander; a second sampled a worker using an uncontrolled sander. Dust exposure data from each worker were combined into a spreadsheet. Review of the video recording allowed worker activity variables (sanding, compressed air blowing, and other) to be coded with the associated real-time exposure measurements in the spreadsheet so the contribution of each activity to each worker's dose of dust could be calculated.

Findings

Regression analysis of the spreadsheet data indicated that the exposure difference between the two workers was statistically significant (probability $> t = 0.95$). When the activity variables were used as the sorting criteria, the contribution of the various work activities (sanding, using compressed air, and other) was easily determined. The relative importance of each activity was ascertained by calculating the dose (concentration $\times$ time). If the average dust concentration during "other" activities is subtracted from the average concentration during "sanding," then the contribution of that worker's own "sanding" activities can be measured and the results compared for the hood equipped and uncontrolled tools. The results of these calculations are presented in Tables F-1 and F-2. The estimated reduction in dust concentration as a result of using the hooded sander was 71%. Since the hood emission rate was not measured directly the degree of reduction may have considerable uncertainty, as it represents the ratio of numbers of great variability. "Other" sources represent about one half of the dust dose. Since none of the "other" activities involve dust generating operations, this dose must be due to cross-contamination from other workers sanding in the vicinity. Blowing dust off the truck hood assembly did not appear to result in an appreciable dust dose to the two workers studied; "blowing" represented from 2% to 8% of the total dose.

Table F-1. Real-time sampling results for the sanding operators. These result are based on sorted data from reduced (time independent) data set.

Task	Uncontrolled Sander				Hooded Sander			
	Time, sec	Dose, mg/m³•s	% of dose	Conc, mg/m³	Time, sec	Dose, mg/m³•s	% of dose	Conc, mg/m³
Sanding	381	1410	54	3.7 (3.1)*	306	551	31	1.8 (0.9)
Blowing	48	58	2	1.2 (1.0)	60	138	8	2.3 (0.7)
Other	912	1157	44	1.3 (1.0)	975	1073	61	1.1 (0.9)
Total	1341	2625	100		1341	1762	100	

*( ) indicates standard deviation

Table F-2. Average dust concentrations during sanding and "other' activities.

Concentration/Difference	Uncontrolled Sander	Hooded Sander
Average sanding concentration	3.7	1.8
Average "other" Concentration	1.3	1.1
Average difference between sanding and other	2.4	0.7

Recommendations

HVLV hoods for the sanding operations demonstrated a statistically significant exposure reduction. The real-time sampling results indicated potential reductions of about 71%. Integrated sampling results obtained at this plant indicated reductions of the same magnitude. These numbers are crude estimates; better estimates would require installing more hoods and studying the operations on an off-shift to avoid problems of cross contamination from other dust producing operations. The results are encouraging but not definitive.

Although use of compressed air in the blowing operation did not appreciably contribute to dust exposure, review of the videotapes indicates that visible clouds of dust are blown away from the workers. Thus, although the two workers took care not to blow dust at each other, these activities probably increased the exposure of others in the work area. Use of the compressed air nozzles not only removed dust from the hood assembly but re-entrained dust that had settled to the floor.

Reference

F1. O'Brien, D.M.; Fischbach, T.J.; Cooper, T.C.; Todd, W.F.; Gressel, M.G.; and Martinez, K.F.:Acquisition and Spreadsheet Analysis of Real-time Dust Exposure Data: A Case Study. Applied Industrial Hygiene. 4(9):238-243 (1989).

Case Study G. Methanol Exposures in Maintenance Garages

Introduction
A site visit was conducted at a public transit facility where ten methanol-powered buses were in service. The survey was done to determine the methanol vapor exposures associated with routine refueling, maintenance, and operation of methanol-powered buses.[G1]

Methodology
During each process of interest, TWA samples were collected on sorbent tubes (NIOSH Method 2000[G2]) placed in the breathing zone of a transit garage worker. Concurrent with the sorbent tube samples, the relative concentration of methanol was measured and recorded continuously, using a Photovac TIP II® (Photovac, Inc., Thornhill, Ontario, Canada) with a 10.6 eV ultraviolet lamp. The analog output of the TIP II was recorded on a Rustrak Ranger® data logger (Gulton, Inc., East Greenwich RI). The data logger was later downloaded to a Compaq Portable III computer (Compaq Computer Corp., Houston TX). The following formula was used to convert the output of the TIP II (volts) to concentration of contaminant (mg/m^3):

$$C(t) = IR(t)\frac{ST}{IR} \qquad \text{(G-1)}$$

where:

C(t)	=	concentration of methanol at time t (mg/m^3)
IR(t)	=	instrument response at time t (volts)
ST	=	TWA sorbent tube methanol concentration (mg/m^3)
IR	=	TWA instrument response (volts)

During all operations, methanol concentrations were measured and recorded continuously with a Miran® 1B2 infrared analyzer (Foxboro Instruments, Inc., Foxboro, MA) that was calibrated for methanol. The Miran 1B2 was used to measure "instantaneous" methanol levels. The sampling probe was placed in the vicinity of the breathing zone of the worker or was carried at a height approximating normal breathing zone height around the bus and general work area to detect other sources of methanol. The analog output of the Miran 1B2 was recorded on a Rustrak Ranger data logger, later down loaded to an IBM compatible computer, and then converted to concentration of methanol.

The transit workers performing the refueling and the maintenance tasks were videotaped to document work activities and sampling conditions.

Findings
By simply sorting the TWA sorbent tube data by task, exposures during the maintenance of fuel filters were found to be twice those measured during refueling. The 8-hr TWA exposure of the maintenance workers (n=6) was 3.5 ppm whereas the refueler's (n=4) 8-hr TWA exposure was <2 ppm. The exposures during refueling (Figure G-1) can be compared with those during fuel filter maintenance (Figure G-2). The total maintenance period (the time required to replace both fuel filters on a single bus) was approximately double that of the refueling period for a single bus. One TWA sample taken during refueling was significantly higher than the other refueling TWA samples. A review of the videotape indicated that the worker spent several minutes cleaning up after a minor "over-fill" of a fuel tank. The real-time data indicated a significantly higher exposure when the worker cleaned up the

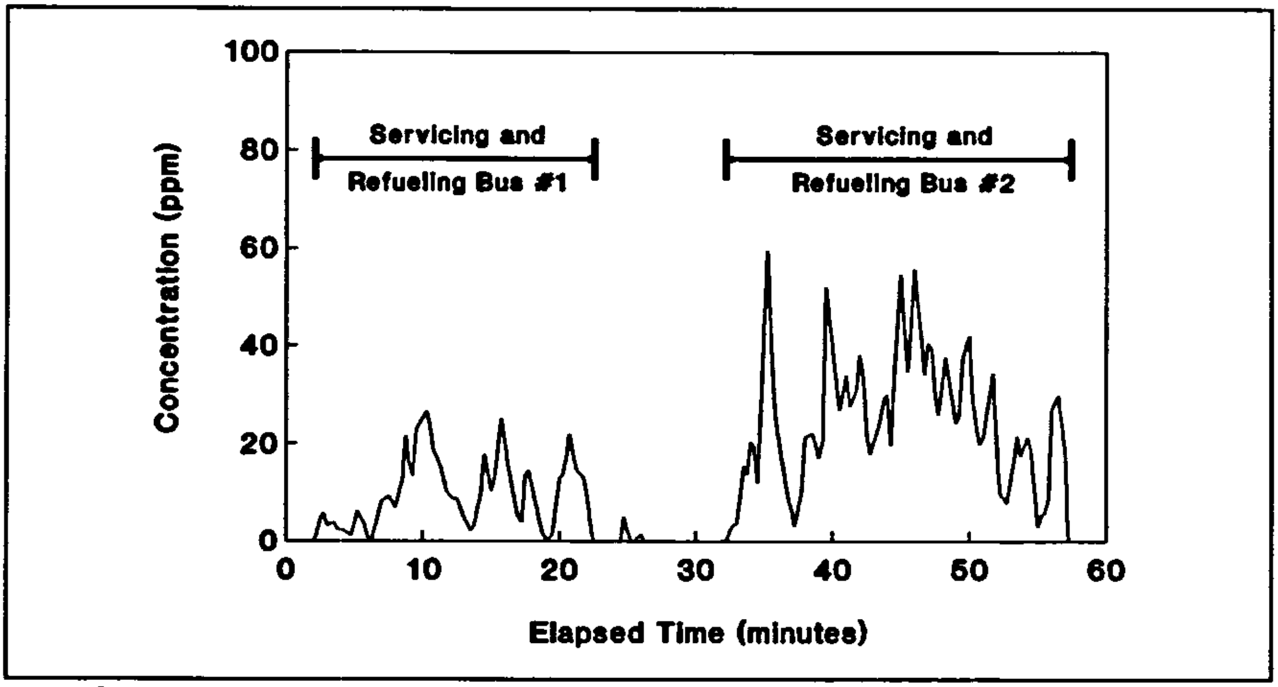

Figure G-1. Real-time plot of exposures during servicing and refueling operation.

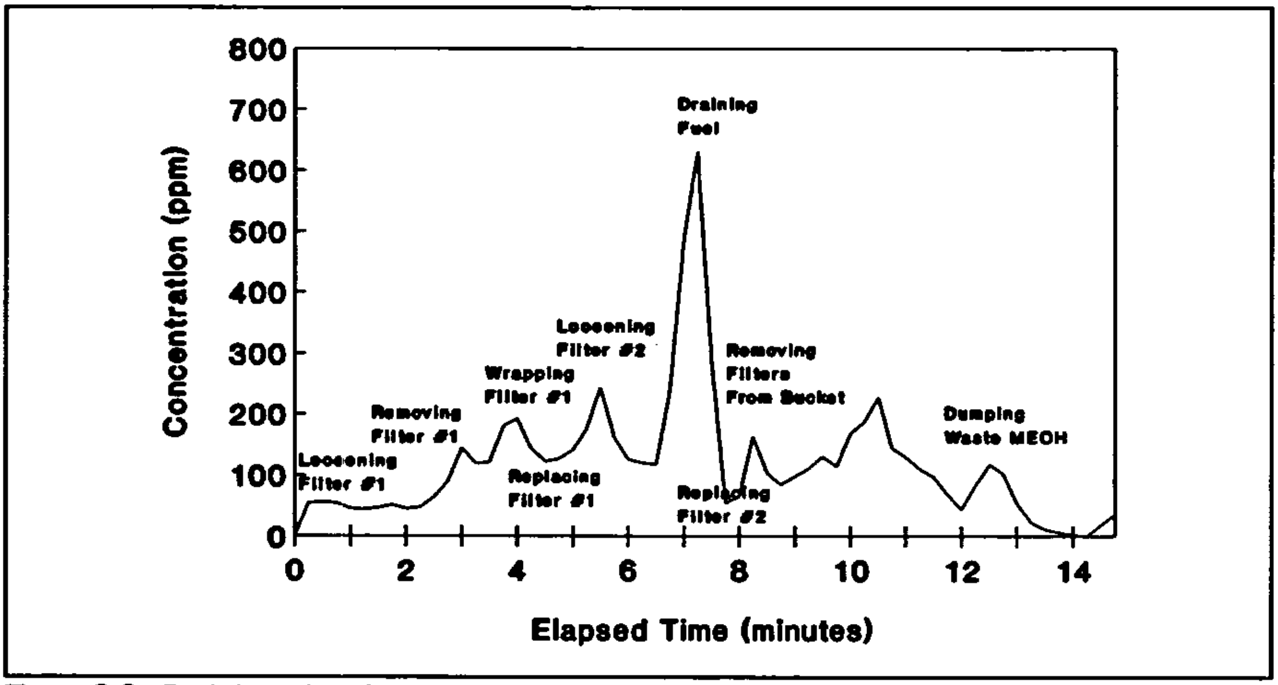

Figure G-2. Real-time plot of exposures during fuel filter maintenance.

spilled methanol. In addition, the real-time data indicated that a large portion of the exposure occurred directly after the refueling nozzle was disconnected.

Recommendations

Exposures to methanol during refueling operations were well below current occupational exposure limits. Good work practices can maintain workers exposures below the limit of detection for NIOSH method 2000.[G2] After refueling, the operator should wait a few minutes for the nozzle to drain to ensure that no fuel remains in the refueling nozzle. This will eliminate minor spills in the vicinity of the refueling nozzle. Management also must train personnel on proper response to minor and major releases of methanol to ensure the safety and health of its workers.

While changing fuel filters, workers were exposed to methanol concentration levels approaching the OSHA short term exposure limit (STEL) of 250 ppm. The 8-hr TWA exposure was well below current limits because the worker serviced only two methanol-powered buses per shift. To reduce the exposures during filter changes, the filter canister should be drained into a partially closed container. After the old fuel filters are removed, they should be placed in a closed container to reduce methanol vapors in the vicinity of the worker.

References

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G2. Eller, P. (Ed.): NIOSH Manual of Analytical Methods (NMAM), 3rd Ed. USDHHS (NIOSH) Pub. No. 84-100, (1984); 85-117 (1985); 87-117 (1987); 89-127 (1989); and 90-121 (1990). NIOSH, Cincinnati, OH

Case Study H. Brake Servicing

Introduction
Asbestos has been used as a component in motor vehicle brake materials and may be found in a large number of brakes. This case study was concerned with the control of asbestos exposures to workers at a maintenance shop that services brakes on over 1100 vehicles a year.[H1] Most of the these vehicles had 13- and 14-in. wheels, with 10-in. long brake shoes. A wet brake washer assembly, shown in Figure H-1, controlled potential asbestos exposure. The catch basin, raised to the work area, is used for holding small brake parts and catching the brake washing solution. The solution is recirculated through a nylon filter and pumped at a gentle flow through a flexible tube out through the bristles of the brush for cleaning the brake assembly.

Methodology
Video exposure monitoring was conducted to evaluate the brake maintenance operation. Two hand-held aerosol monitors (HAM, PPM, Knoxville, TN) and a personal computer (Apple II Plus®, Apple Computer Corp., Cupertino, CA) measured and recorded dust levels. The HAM, measuring respirable total dust levels, is a light scattering device; its response is dependent on the optical characteristics of the dust being measured. Because it does not differentiate between asbestos fibers and other dusts, dust concentrations were reported as relative levels (rather than absolute levels) and were used only to compare similar operations. At the start of the operation, the computer's clock was synchronized with the timer in the video camera that recorded the entire operation on videotape. Sampling pumps were connected by tubing to each HAM, and each HAM in turn was connected by

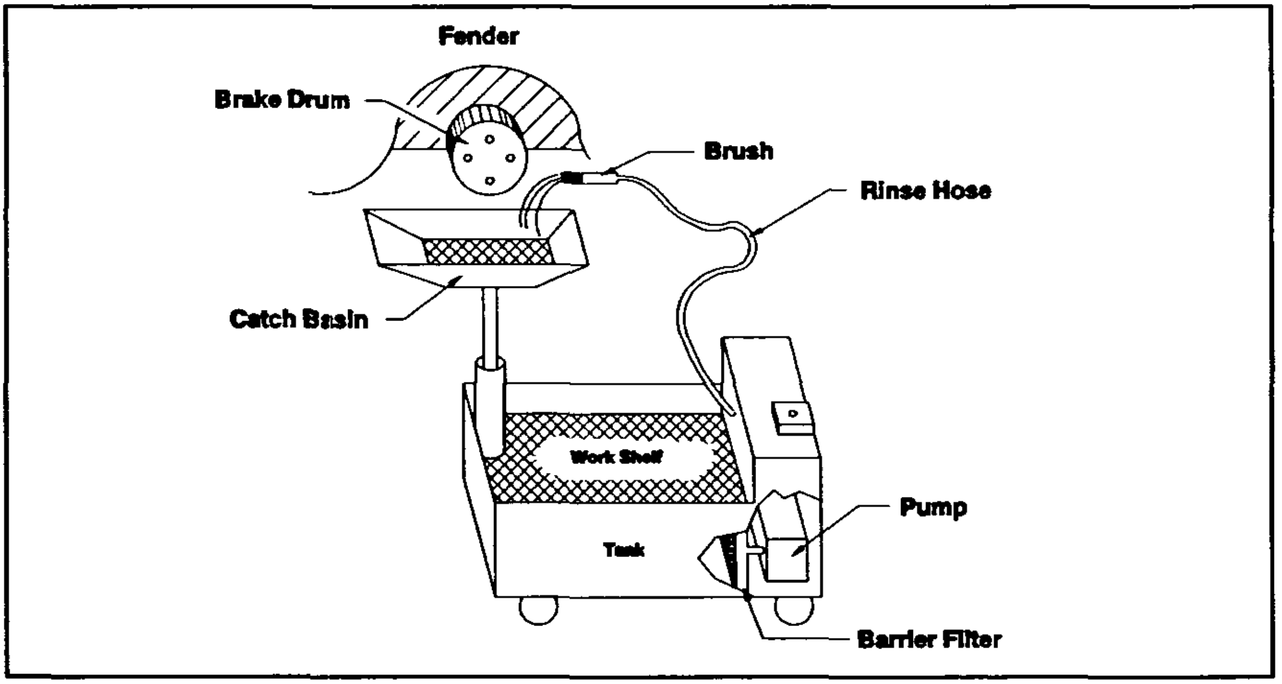

Figure H-1. Diagram of a brake washing unit.

a 25-ft electrical lead to the computer. The brake maintenance operator wore one HAM (personal sample) measuring dust levels in his breathing zone and the other HAM was set beneath the axle of the vehicle (source sample). The computer stored the data on a disk in a file that was later imported into a spreadsheet. The computer program recorded a maximum of 2,000 readings at a minimum of four second intervals before it had to be reset. Using a spreadsheet program (Lotus 1-2-3®, Lotus Development Corp., Cambridge, MA), a plot of the real-time dust levels was constructed. By comparing the plots with the video, the work practices producing changes in dust levels were identified.

Personal and area air samples for asbestos analysis (NIOSH Method 7400-B[H2]) were collected on filters. Personal exposures were taken during the entire brake servicing for each vehicle. Area samples near the axle and fender determined fiber concentrations at the source; general shop area samples determined background fiber levels inside the garage, and out-of-door samples determined the environmental level of asbestos.

Findings

Real-time data were collected on nine different operators performing brake maintenance on 10 vehicles. The general brake maintenance procedure was:

- remove the wheel's lug bolts and wheel;
- remove the brake drum;
- thoroughly wash the drum, brake shoes, and brake support plate;
- inspect the brake shoes; if they do not need replacing, reinstall the drum and wheel;
- remove brake shoes needing replacement, and
- install the new brake shoes and brake drum, remount the wheel, and tighten the lug bolts.

To interpret the real-time data, the instrument background level (the internal noise level of the Apple/HAM combination was 0.05 millivolts) was used as the reference level. Values above this level were used to identify dust sources and determine their magnitude. Brief elevations of dust were detected during the removal of the lug bolts and the drum, and during the reinstallation of the lug bolts.

As shown if Table H-1, the highest measured dust levels occurred during the removal of the brake drum. Since this dust contained ground-up brake shoe (which may or may not be asbestos), this activity was assumed to have the highest potential exposure for asbestos. The second and third highest measured dust levels occurred during the removal and remounting of the wheels and lug bolts. Since most of this dust came from accumulated road dirt on the wheel and probably contained little asbestos, this activity was assumed to have a low potential asbestos exposure. The measured dust levels for all other brake servicing activities were near background levels; these activities were a low potential source for asbestos exposure.

Table H-1. Average relative dust concentrations by brake activity.

Brake Activity	Average Relative Concentration
Remove lug bolts and wheels	0.094
Remove drums	0.173
Clean brake assemblies	0.005
Remove brake hardware	0.008
Install brake hardware	0.007
Remount wheels and lug bolts	0.040

Real-time data indicated that thorough washing of the brake support plate, brake shoes, and gear used to attach the brake shoes reduced dust levels. It appeared that the dust was either removed or wetted before the operator started to manually manipulate the brakes. As a result, dust levels were low or not measurable during 91% of the brake shoe service.

Air sample results further confirmed the real-time data indicating that the brake washer assembly effectively reduced the worker's potential exposure to asbestos during brake servicing. Nineteen of twenty personal samples were below the detectable limits of 0.004 fibers/cc and well below both the current OSHA PEL of 0.2 fibers/cc and the NIOSH REL of 0.1 fibers/cc. Source and area samples were less than 0.002 fibers/cc (source and area sample limit of detection was 0.002 fibers/cc). The axle source sample data showed that fibers were not being propelled by the brake washer assembly toward the other side of the vehicle. Background and ambient asbestos levels (0.002 fibers/cc) were also low, indicating that the asbestos in the personal and source samples were from brake servicing activities and not from outdoor sources or from resuspended dust in the garage.

Recommendations

Direct reading monitors used to measure dust levels, although not necessarily specific for asbestos fibers, can indicate activities where there is a potential asbestos exposure. Analysis of the video and real-time data indicates that some dust emissions may be reduced by altering work practices such as: (1) allowing the cleansing fluid to flow between the brake drum and brake support plate before the drum is removed, and (2) after removing the brake drum, thoroughly wetting contaminated surfaces before the operator starts to manually remove the old shoes. To determine actual asbestos exposures, air samples collected on the appropriate filters are still needed.

References

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H2. Eller, P. (Ed.): NIOSH Manual of Analytical Methods (NMAM), 3rd Ed. USDHHS (NIOSH) Pub. No. 84-100, (1984); 85-117 (1985); 87-117 (1987); 89-127 (1989); and 90-121 (1990). NIOSH, Cincinnati, OH

Case Study I. Bulk Loading of Railroad Cars and Trucks

Introduction

Loading whole grain sand into trucks and railroad cars can be a major dust generating operation. This case study was conducted to determine if a ventilated loading spout, as compared to a nonventilated spout, could significantly reduce dust emissions. Whole grain sand was being loaded into railroad cars from a nonventilated spout and into trucks from a ventilated spout at a sand mine.[I1] Exposure monitoring with note-taking was used to compare dust concentrations between the two types of spouts while filling different types of vehicles. Spreadsheet analysis of the data compared dust generation from each type of spout during filling operations.

The nonventilated loading spout used to fill railroad cars was a flexible hose from the silo connected to a metal pipe fitted with a manually operated slide gate. Sand flowed by gravity at approximately 4500 lb/min (45 ft^3/min). The spout was positioned over an open hatch, the flow gate opened to fill a portion of the car. The gate was closed while the car was moved forward, and filling was resumed through the next hatch until the car was filled. The types of railcar hopper openings are illustrated in Figure I-1.

The ventilated loading spout used to fill trucks was an enclosed-type retractable spout, operated from an isolated control room. An open-type ventilated spout, designed for filling open vehicles, is also available. These two ventilated spout designs are shown in Figure I-2. To fill the truck hopper openings illustrated in Figure I-3, sand flowed by gravity at approximately 10,000 lb/min (100 ft^3/min) from an overhead hopper through the spout and into the truck. The spout was lowered, the flow started, and as the sand rose, the operator retracted the spout keeping it within a few inches of the top of the sand. When a portion of the truck was filled, the flow was stopped, the truck was moved forward, the spout was lowered, and loading was resumed until the truck was filled. For hopper trucks, the spout remained a few inches above the open hatch during filling. For trucks with cross ribs but no longitudinal rib, the spout was lowered between the ribs. For trucks with a longitudinal rib, the spout was lowered to the longitudinal rib and the sand flowed over the rib into the truck.

Methodology

A combination of respirable area air samples and direct reading monitors determined dust emissions from a controlled and an uncontrolled loading spout. Several of the air samples collected were analyzed for respirable dust and respirable free silica.

Real-time measurements were taken near each spout using a hand-held aerosol monitor (HAM, PPM, Knoxville, TN) connected to a data logger (Rustrak® Ranger, Gulton, Inc., East Greenwich, RI). The response of the HAM, a light scattering device, is dependent on the optical characteristics of the dust monitored. It was used to measure respirable dust concentrations. Because the HAM cannot be calibrated to differentiate between crystalline silica and other dusts, dust levels were reported as relative levels (rather than absolute levels) and were only used to compare similar operations. When sampling was completed, the data logger was downloaded to a portable computer (Compaq® Portable III) for analysis.

Findings

A summary of the concentrations from the respirable dust samples and real-time samples for the ventilated and nonventilated spouts is shown in Table I-1. The real-time dust levels are summarized for the ventilated spout in Table I-2 and for the nonventilated spout, in Table I-3.

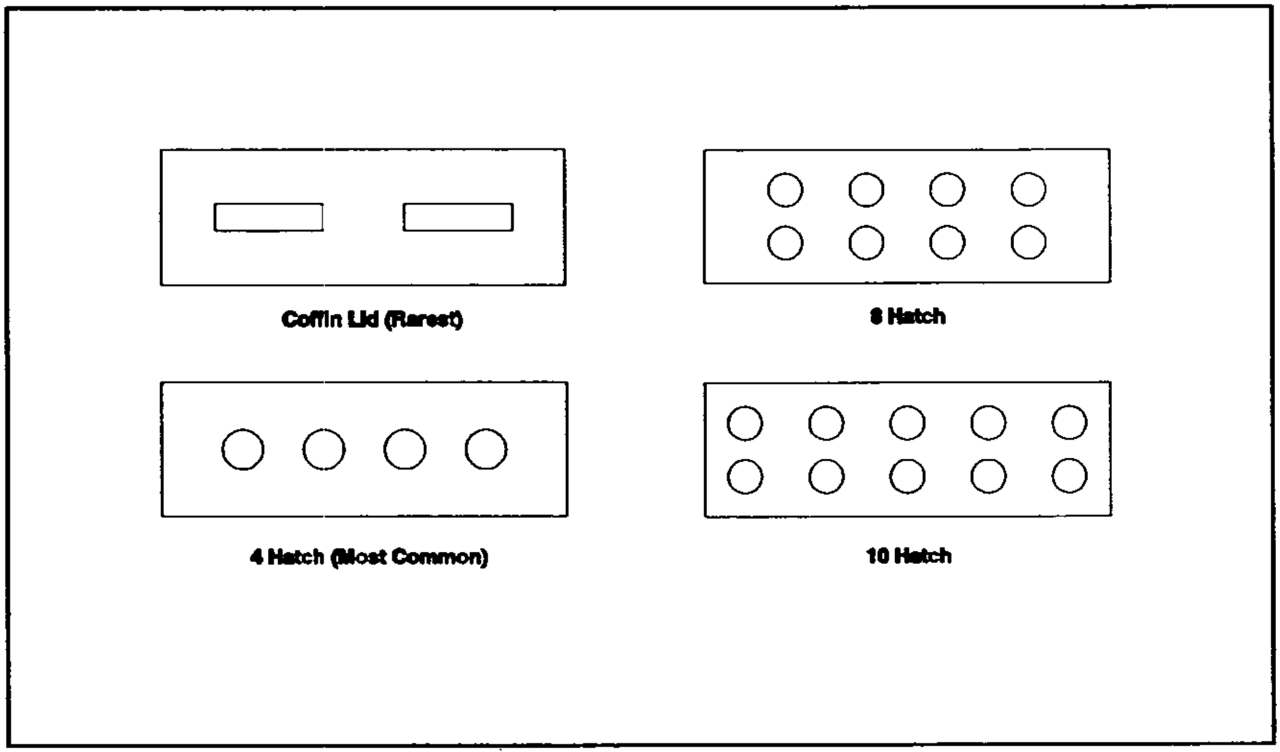

Figure I-1. Types of railcar hopper openings.

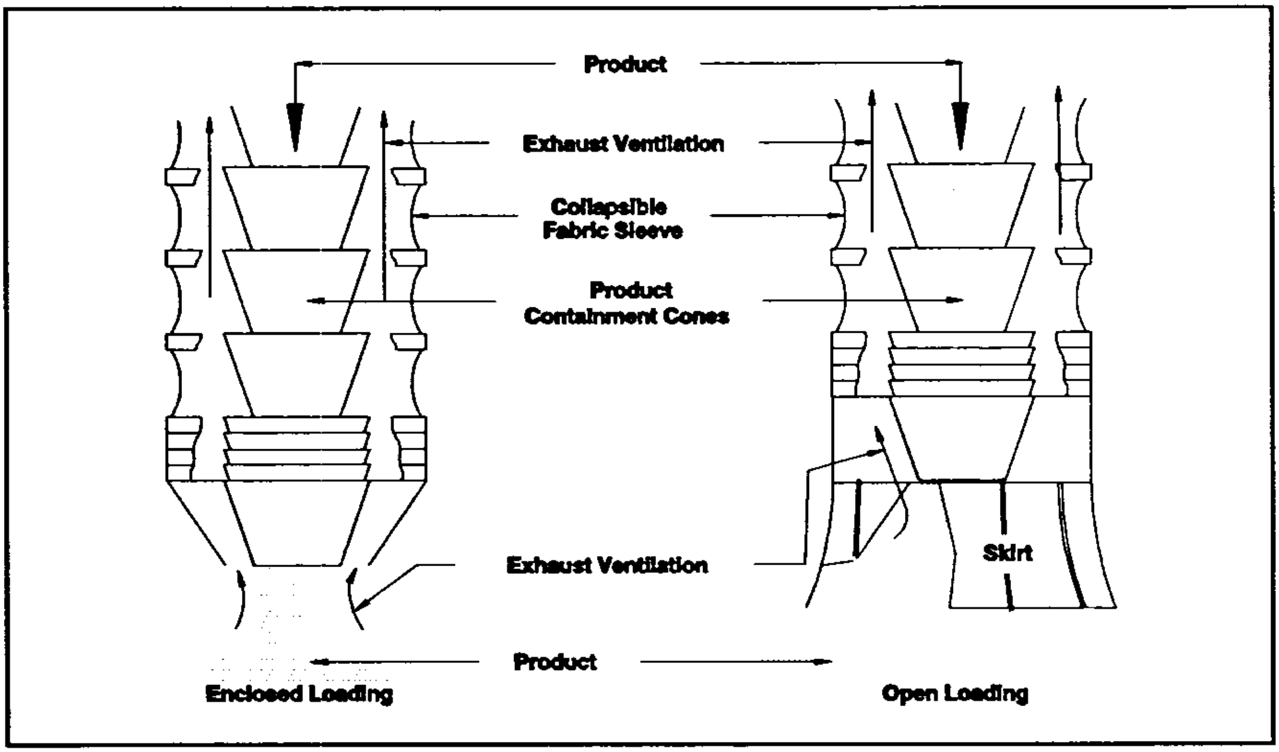

Figure I-2. Retractable, ventilated, loading spouts, enclosed-type and open-type.

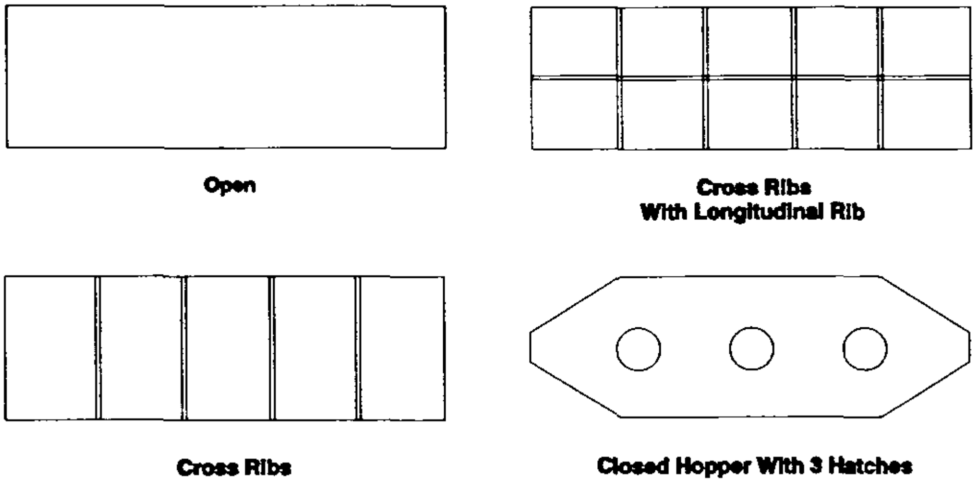

Figure I-3. Types of truck hopper openings.

Table I-1. Average area respirable dust concentrations (mg/m^3)

Spout	Filter Samples: Respirable Dust	Filter Samples: Quartz Dust	Real-time Samples: Respirable Dust	Real-time Samples: Maximum Reading	Number of Vehicles Filled
Ventilated	0.06	0.03	0.25	0.72	13
Ventilated*	-	-	0.72	1.65	1
Nonventilated	0.09	0.77	2.6	20	5
Background	0.03	<0.01	0.05	-	-

* Sand flowing over cross member.

Table I-2. Average real-time total dust concentrations at ventilated spout

Type of Truck	Total No. of Trucks	% of Trucks	% of Dust	Average Dust Level, mg/m^3
Background	-	-	-	0.03
All	13	100	100	0.25
Open	7	54	21	0.26
Cross ribs	3	23	14	0.18
Cross ribs with longitudinal	1	8	58	0.72
Hopper	2	15	7	0.08

Table I-3. Average real-time total dust concentrations at nonventilated spout

Type of Railroad Car	No. of Cars	Cars, %	Dust, %	Average Dust Level, mg/m^3
All cars	5	100	100	2.6
4 Hatch	2	40	30	3.2
8 Hatch	1	20	48	5.1
10 Hatch	1	20	17	1.8
2 Coffin lid	1	20	5	0.5

Dust levels were 10 (real-time data) to 15 (air samples) times higher near the nonventilated loading spout than near the ventilated spout. When the spout was not lowered to the bottom of the truck or when sand flowed over a rib, dust levels were up to 40 times higher than when the spout was kept near the top of the sand pile. This was a problem for trucks with longitudinal ribs. By keeping the spout near the top of the sand pile, the free fall distance of the sand, the amount of airflow entrained in the falling sand, and the amount of dust generated were greatly reduced. When loading enclosed hopper trucks, free falling sand generates dust inside the enclosed container. With sufficient exhaust ventilation at the spout, the dust was effectively contained. The controlled spout used in this case study operated at the designed ventilation rate, with a face velocity of 130 ft/min (400 ft^3/min) for a loading capacity of 100 ft^3/min of sand.

Recommendations
When a ventilated spout used to bulk fill vehicles with a dry, free flowing sand was compared with a nonventilated spout, the former reduced dust concentrations by approximately 97%. To accomplish this reduction in dust concentrations, sufficient ventilation at the spout was needed. The proper type of ventilated spout, open or closed, could possibly further reduce these concentrations during loading operations. This was shown when the enclosed-type loading spout was used to fill an open-type truck (Table I-2). No matter which controls are used, good work practices are needed. When using a ventilated spout, it is important to prevent the flow of sand over a rib and to keep the spout discharge near the top of the accumulating sand pile.

Reference
I1. Cooper, T.C.; O'Brien, D.M.; Sheehy, J.W.; Froehlich, P.A.; Valiante, D.; and Stephens, A.: Sentinel Event Notification System for Occupational Risks (SENSOR): Recommendations for Control of Silica Exposures at Uniman Dividing Creek Sand Plant, Millville, New Jersey. USDHHS(NIOSH) Report No. ECTB 171-12b. NIOSH, Cincinnati, OH (1990).

Case Study J. Grinding Operations

Introduction

This case study describes an evaluation of exposures to silica-containing dusts in the casting cleaning operation at a steel foundry.[J1] In the metal casting process, crystalline silica is contained in molding and coremaking sands, in clays used as bonding agents, in parting compounds, in some refractory materials, and as surface contamination on castings. Exposure can occur almost anywhere within the foundry. Castings are first cleaned by steel shot in an abrasive blasting machine or by sand blasting in a walk-in cabinet. Additional material is primarily removed from castings by various hand-held grinders on downdraft benches. Full-shift exposure measurements of the grinder operators demonstrated the potential for excessive exposure to silica.

Methodology

Because the greatest number of workers are potentially overexposed to silica in the casting cleaning operations, this area of the foundry received special attention. Real-time dust concentrations were measured with a hand-held aerosol monitor (HAM, PPM, Inc., Knoxville, TN). The HAM is a light scattering monitor; its response is dependent on the optical characteristics of the dust being measured. The HAM responds to respirable dust but does not differentiate between crystalline silica and other dusts. Measurements were made on two workers performing chipping and grinding operations to determine the relative exposure caused by different tools and operations. Each worker selected a casting that required the use of a variety of tools. One selected a pump housing; the other selected an impeller. Each worker used a 6-in. horizontal radial wheel grinder (6000 rpm), a 4-in. cutoff wheel (15,000 rpm), and a 3/8-in. diameter burr mounted on a 16-in. extension (18,000 rpm). The worker cleaning the impeller also used a cone wheel mounted to the same type of tool as the 4-in. cutoff wheel. Each tool was pneumatically operated with the exhaust unmuffled at the tool. Dust exposure measurements and video recordings were made for a nominal 30 min on each worker, and a data logger (Rustrak® Ranger, Gulton, Inc., East Greenwich, RI) electronically recorded dust exposures.

Dust exposure data were overlaid as a moving bar (proportional to the exposure) onto the video record and viewed to estimate activities that may affect exposure. This review indicated that the type of tool used, the direction of the grinding swarf (the stream of glowing metal particles), and the position of tool (inside or outside of the casting) caused noticeable exposure differences. To determine the extent to which these variables affected exposure, the real-time data were assembled into a commercial spreadsheet consisting of time, exposure, and activity for each 5-sec time period. The exposure measurements were "slipped" 5 sec with respect to the time and activities to allow for instrument and contaminant transportation lag. This lag was determined by viewing the video recordings of the work activities while tracking the real-time exposure measurements. The average exposure, the time, and the "dust-dose" (the product of dust concentration and time) were calculated for each of the activity variables with the use of the "database" functions of the spreadsheet.

Findings

The average dust concentration for each tool type and the percent of the time each tool was used are presented in Figure J-1. While cleaning the pump housing, dust concentrations were highest for the 6-in. grinder and the 4-in. cutoff wheel. While cleaning the impeller, dust concentrations were highest for the 6-in. grinder and the cone grinder. Tool usage times were similar, except that the cone grinder was not used on the impeller housing. The "dust-dose" is described graphically in Figure J-2 as a function of tool type, tool location, and swarf direction. The "dust-dose" was almost an order of

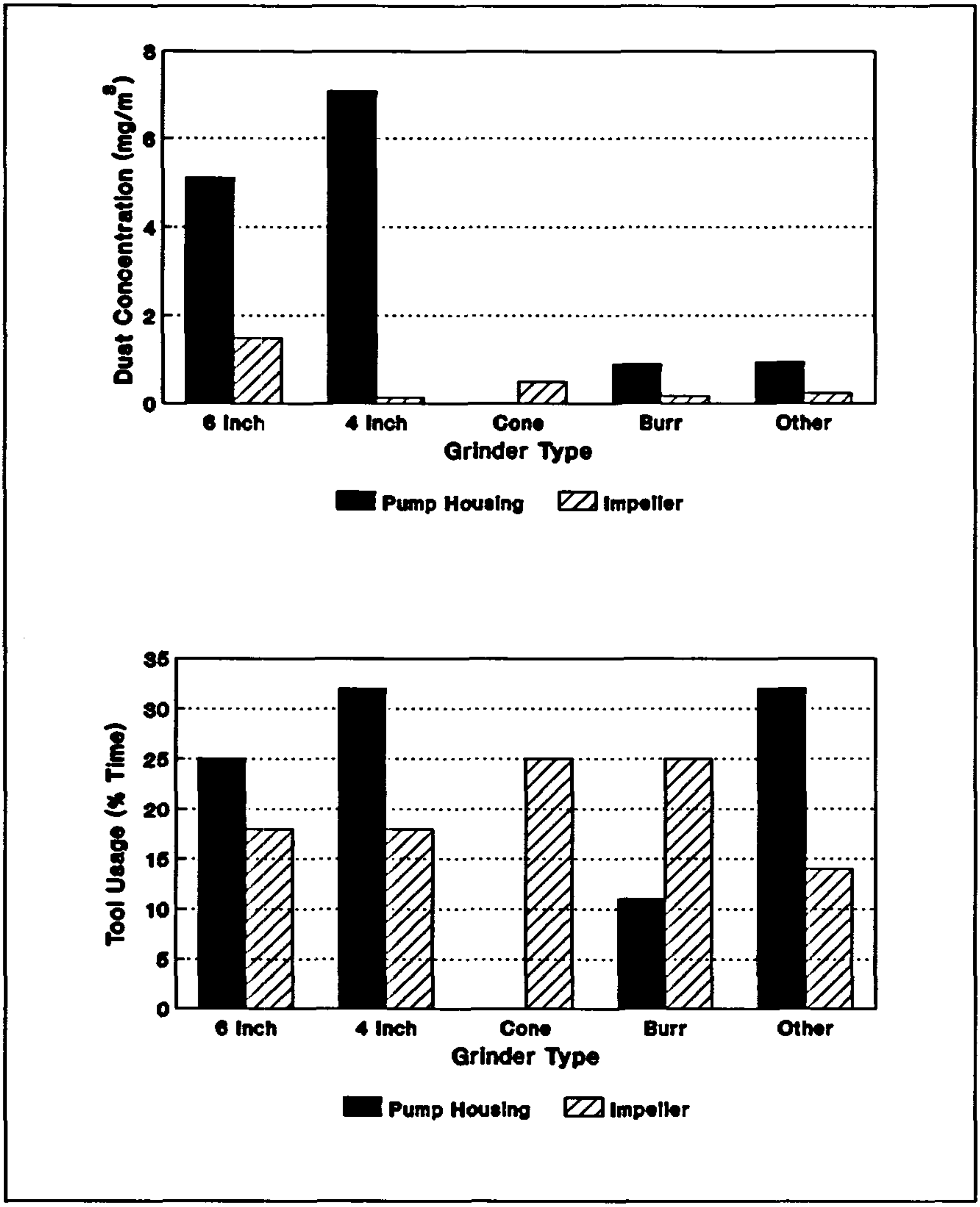

Figure J-1. Average dust concentration for each tool type and the percent of the time each tool was used in cleaning the castings.

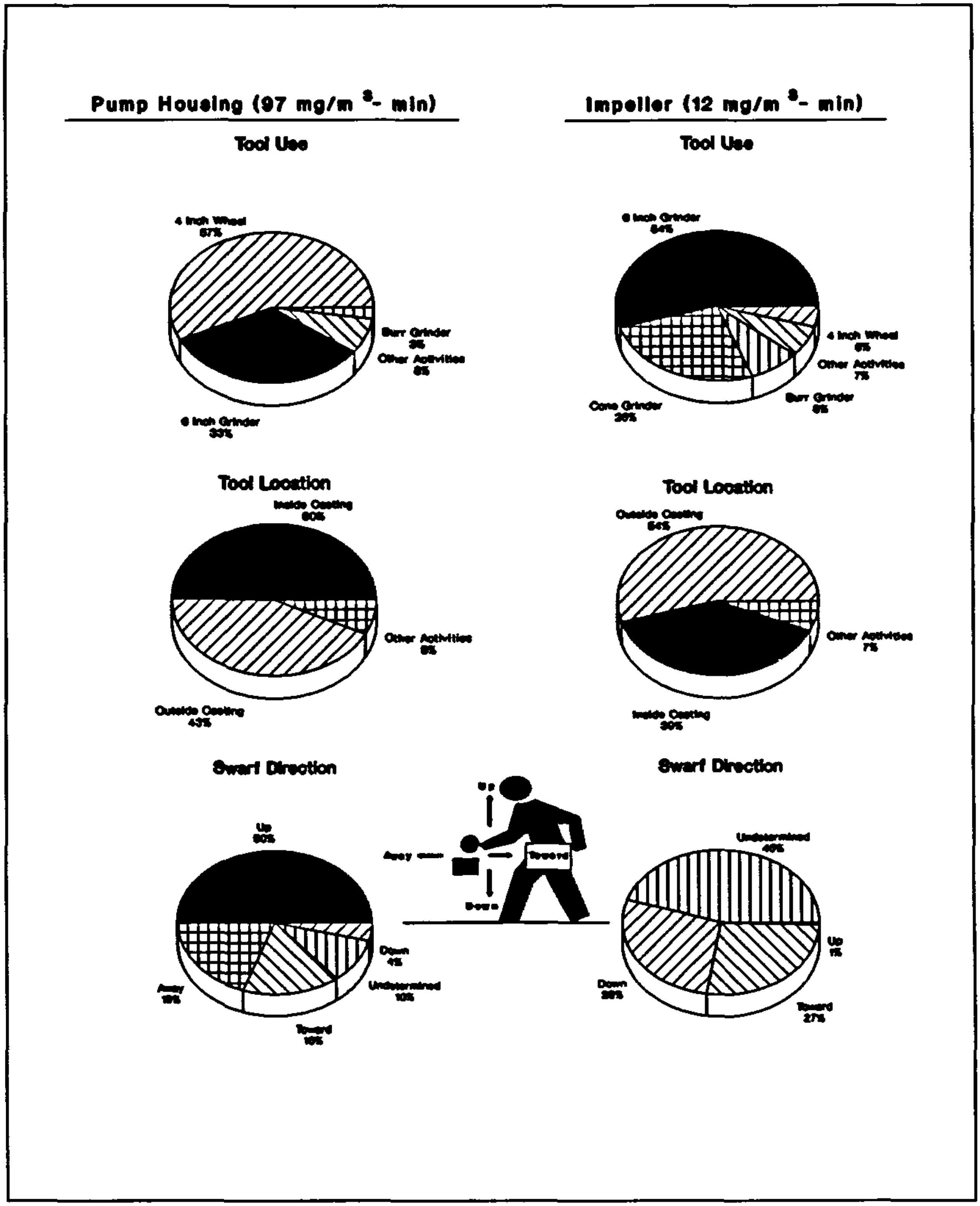

Figure J-2. Percentage of "dust-dose" as a function of tool type, tool location, and swarf direction when grinding castings.

magnitude greater for the pump housing than for the impeller. The 4-in. cutoff wheel was the greatest contributor (57%) to "dust-dose" for the worker cleaning the pump housing, and the 6-in. grinder was the greatest contributor (54%) to the "dust-dose" for the worker cleaning the impeller. When the inside of the impeller casting was cleaned, the dust dose was lessened; although the worker spent about five times as long cleaning the inside of the casting as the outside, cleaning the inside resulted in only about 39% of the total "dust-dose" for this worker. This reduced dose may be because the impeller diffused the grinding swarf. Swarf direction appeared to be a major exposure factor; for the pump housing, concentrations ranged from highest to lowest in the order of "toward," "up," "away," "down," and "undetermined." For the impeller, only short periods were observed where the swarf was directed "toward," "up," or "away."

Recommendations

Cleaning the large castings presents difficult problems. The size of the casting precludes working close enough to the grates of the downdraft booths for dust to be efficiently captured. Perhaps a sidedraft booth would be more effective -- one with the castings set on a rotating fixture so that the grinding swarf could be directed into the hood (the real-time data indicated that the swarf direction was an important exposure factor). Worker training and continued supervision would be required to encourage proper use of such a system. A better approach for cleaning large castings would be the installation of high-velocity, low-volume (HVLV) exhaust hoods to supplement the downdraft benches. The real-time monitoring indicates that the tools that are most easily controlled, the 6-in. grinder and the 4-in. cutoff wheel, are also the tools that contribute most heavily to dust exposure.[J2] The American Conference Governmental Industrial Hygienist has made detailed recommendations for HVLV hoods (VS-801 through VS-807).[J3]

References

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