

Mist Control at a Machining Center, Part 2: Mist Control Following Installation of Air Cleaners

John M. Yacher , William A. Heitbrink & G. Edward Burroughs

To cite this article: John M. Yacher , William A. Heitbrink & G. Edward Burroughs (2000) Mist Control at a Machining Center, Part 2: Mist Control Following Installation of Air Cleaners, AIHAJ - American Industrial Hygiene Association, 61:2, 282-289, DOI: [10.1080/15298660008984538](https://doi.org/10.1080/15298660008984538)

To link to this article: <https://doi.org/10.1080/15298660008984538>



Published online: 04 Jun 2010.



Submit your article to this journal [↗](#)



Article views: 42



View related articles [↗](#)



Citing articles: 5 View citing articles [↗](#)

AUTHORS

John M. Yacher^a
 William A. Heitbrink^b
 G. Edward Burroughs^b

^aRetired

^bU.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health 4676 Columbia Parkway—R5, Cincinnati, OH 45226

Mist Control at a Machining Center, Part 2: Mist Control Following Installation of Air Cleaners

At a machining center used to produce transaxle and transmission parts, aerosol instrumentation was used to quantitatively evaluate size-dependent mist generation of a synthetic metalworking fluid (MWF) consisting primarily of water and triethanolamine (TEA). This information was used to select an air cleaner for controlling the mist. During most machining operations, the MWF was flooded over the part. These machining operations were performed in a nearly complete enclosure that was exhausted to an air cleaner consisting of three sections: a fall-out chamber, a trifier section to capture metal chips and mist, and a 1.13 m³/sec (2400 ft³/min) blower. The partnering company requested that National Institute for Occupational Safety and Health (NIOSH) researchers perform an evaluation of the effectiveness of a commercially available air cleaner. After NIOSH researchers characterized mist generation at the machining centers and found that performance of a test air cleaner appeared to be suitable, the company installed more than 25 air cleaners on different machining centers in this plant and enclosed the corresponding fluid filtration unit. The facility also has implemented a maintenance program for the air cleaners that involves regularly scheduled filter changes; performance is ensured by monitoring static pressure. A NIOSH-conducted air sampling evaluation showed that area TEA concentrations were reduced from a geometric mean of 0.25 to 0.03 mg/m³. Personal total particulate concentrations were reduced from a geometric mean of 0.22 to 0.06 mg/m³. These results show the effectiveness of this combination of enclosure, ventilation, and filtration to greatly reduce the exposure to MWF mist generated in modern machining centers.

Keywords: machining operations, metalworking fluid, mist

Health concerns (as discussed in Part 1, the accompanying article, *AIHAJ* 61: 275–281) prompted the National Institute for Occupational Safety and Health (NIOSH) researchers to assist a company in an effort to reduce worker exposure to metalworking fluids (MWFs) by using air cleaners to control mist generated at machining centers.⁽¹⁾ The information derived from this study was incorporated into the NIOSH *Criteria for a Recommended Standard, Occupational Exposure to Metalworking Fluids*, which proposes a recommended exposure limit of 0.4 mg/m³ thoracic particulate

mass, which corresponds to 0.5 mg/m³ for total particulate mass as a time-weighted average concentration for up to 10 hours/day during a 40-hour workweek.⁽²⁾

FACILITY DESCRIPTION

This metalworking plant, located in the midwestern United States, employed approximately 300 production workers. The iron castings brought into the plant are preshaped for the transmissions used for off-the-road vehicles such as lawn mowers and agricultural equipment. At

Mention of company and/or product name does not constitute an endorsement by the Centers for Disease Control and Prevention.

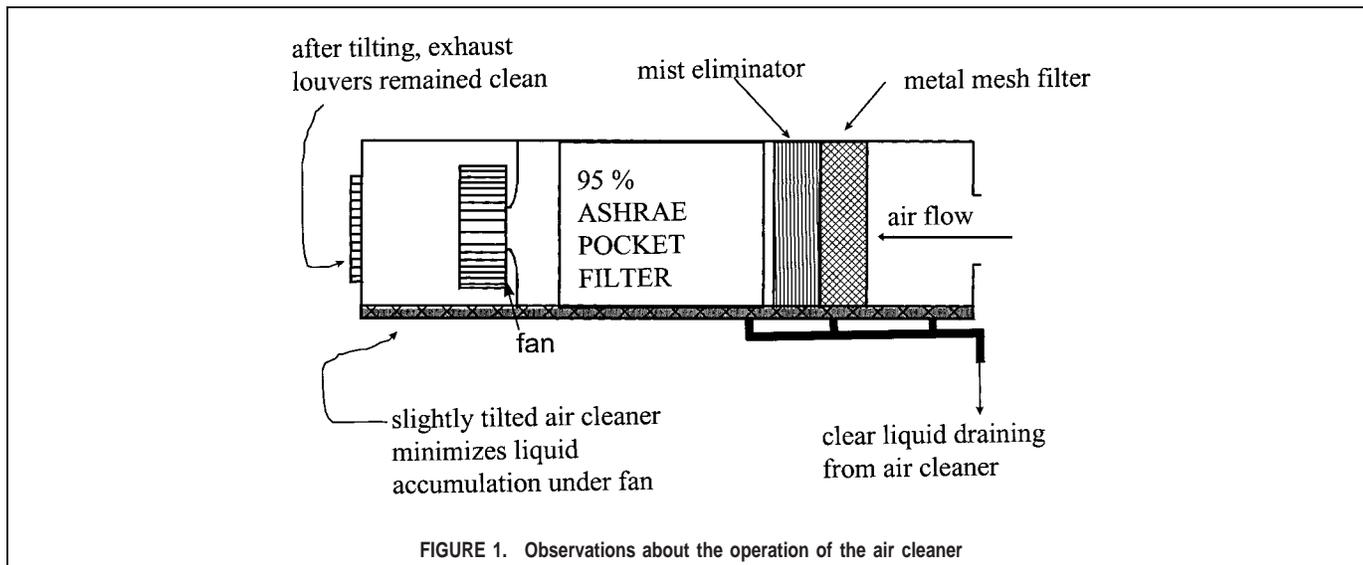


FIGURE 1. Observations about the operation of the air cleaner

12 automated machining centers, metalworking operations such as milling and drilling are performed on each piece. One operator programmed and tended several machines. The main source of the worker's exposure to MWF mists appeared to be the 12 automated machining centers.

At the machining centers, MWF is used to remove metal shavings and to serve as a coolant and lubricant. At the metalworking stations examined in this study, the MWF was flooded onto the parts at a pressure of 551 kPa or 80 psi during approximately 70% of the machining cycle. During some machining operations, the coolant was forced through small holes in the drills at higher pressures ranging between 4135 to 5857 kPa (600 to 850 psi). The high-pressure application of fluid was used during approximately 30% of the machining cycle. The machining center had a sloped bottom where the excess fluid and debris were removed via a screw feeder leading to the fluid recycle system. In the L-Shop, the area studied during this survey, fluid was recycled through the Hydromation unit, which was used to pump and filter the fluid, removing metal chips and other debris. The fluid used in the L-Shop at approximately 12 stations was Syntilo® 9902 (Castro Industrial, Inc., Downers Grove, Ill.), a synthetic product primarily composed of water and triethanolamine (TEA). The material safety data sheet for this product reports that it has a volatile organic compound content of 96.5 g/L. The vapor pressure of TEA is reported to be less than 0.01 mm of Hg.⁽³⁾ In the MWF the Syntilo concentration was maintained between 6 and 8%.

PRELIMINARY STUDIES

In studies described in the accompanying article,⁽¹⁾ the partnering company and NIOSH researchers collaborated to (1) characterize the aerosol produced during metalworking, (2) determine the effect of machining operations on the mist size distribution, and (3) evaluate whether the selected air cleaner was appropriate for controlling the generated mist. Mist size distribution did not vary significantly with MWF application pressure or changing machining operations such as grinding, drilling, and reaming. Although relatively unaffected by changing machining operations, mist generation appeared to depend on MWF application pressure. Mist generation started with MWF flow and increased with increased application pressure. The selected air cleaner, described below, was

effective in reducing the aerosol concentration, removing most of the material greater than 4 μm , accounting for 90% of the aerosol mass.

AIR CLEANER DESCRIPTION

The type of air cleaner installed is shown in Figure 1. It is a packaged air filter unit, Model F120, manufactured by Airflow Systems, Inc. (Dallas, Tex.) with an approximate cost of \$4000. The units were installed over the metalworking stations and pulled the air into the cleaning units. The air cleaner's fan moved approximately 1.13 m³/sec (2400 ft³/min) through the enclosure. The air cleaner is equipped with a metal mesh prefilter, followed by a pleated "mist eliminator." Next are the pocket filters, which are consistent with 95% efficient as defined by the American Society of Heating, Refrigeration, and Air Conditioning Engineers.⁽⁴⁾ The fluids captured by the filters drip to the floor of the cleaner and exit via three drainage holes. The coolant then drains to the Hydromation recycling system. At the outlet of the cleaner is a four-way adjustable grille for the exhaust air. When the initial single air cleaner was evaluated, the three air cleaner drains were found to be clogged, resulting in an accumulation of MWF in the bottom of the air cleaner and the emission of millimeter-size mist droplets from the air cleaner's discharge.⁽¹⁾ To correct this problem, subsequent horizontal installations were modified by slightly inclining the air cleaners so that they sloped toward the drains instead of the fans, and the three drains on each air cleaner were enlarged from 1.27 to 2.54 cm (0.5 to 1.0 inch) in diameter to allow proper drainage.

CONTROL STRATEGY

The control strategy adopted by the company included enclosing most of the Hydromation unit (Figure 2), which filtered and recycled the MWF; the floor flumes (Figure 3) that carried the used MWF to the Hydromation unit also were almost completely enclosed. The older machining stations (Figure 4) were not well enclosed; some were open at the top, back, and sides. The newer



FIGURE 2. Central cleaning (Hydro) unit



FIGURE 3. Covered floor flumes

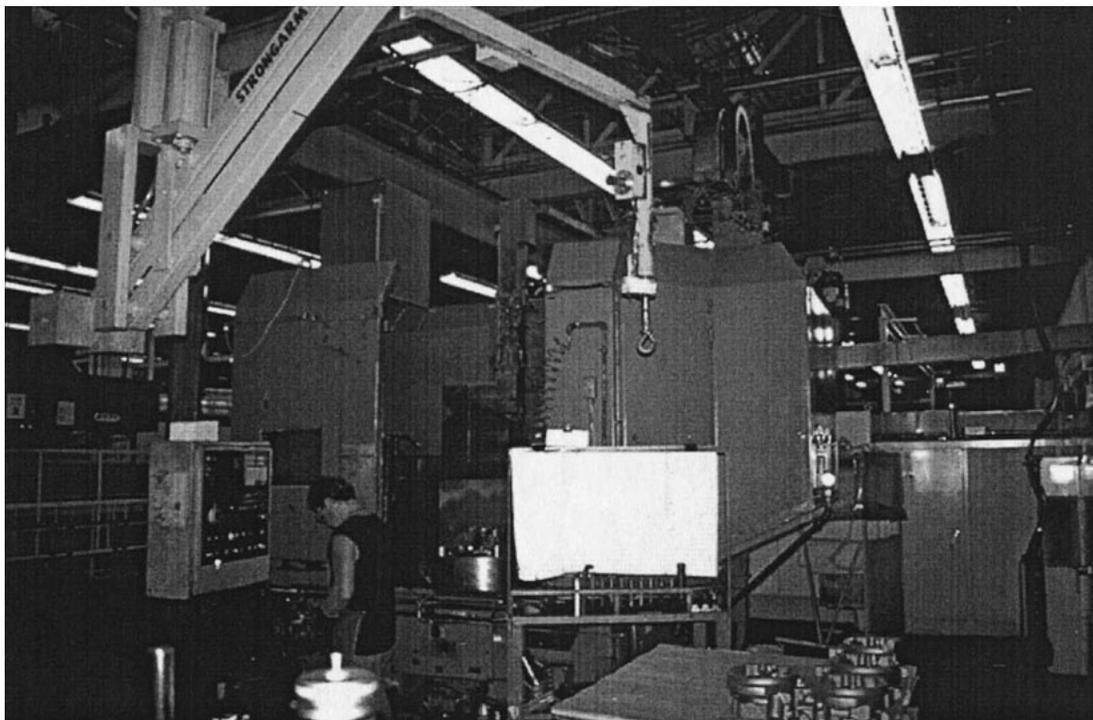


FIGURE 4. Older, unenclosed machining center

machining centers (Figure 5) were nearly completely enclosed, including weather stripping-type seals around the doors. The enclosures had windows to allow observation of the machining operations. Even with the nearly complete enclosures of the newer machining centers, openings for tool changes and other necessary operations allowed plant air to enter the enclosures at velocities of 0.762–1.778 m/sec (150–350 ft/min). The company also purchased more than 25 additional air cleaners and installed them on machining centers in the L-Shop and other plant areas. A comprehensive maintenance program was established for the installed air cleaners. Each air cleaner was fitted with an aneroid pressure gauge to indicate airflow through the system. The filters were changed at 30-day intervals and thoroughly cleaned or replaced. Because the MWF tends to accumulate in the filters and not fully drain when a machining center is run on a 24-hour per day cycle, the air cleaners on these machines are turned off, i.e., rested, for 1 hour out of each 24 hours. This step is not necessary for machining centers operated fewer than 24 hours per day. Maintenance personnel reported that the air cleaner exhaust grilles, which became coated with MWF in the original installation, now remain clean.

STUDY PURPOSE

The partnering company requested that NIOSH researchers conduct air sampling to evaluate the effectiveness of the company's control strategies. The main issues to be examined included the following.

- Measure airborne concentrations and worker air contaminant exposures of TEA and total particulate before and after installation of more than 25 air cleaners in and near the L-Shop area of the

plant. Identify specific operations that showed higher worker exposures by video exposure monitoring (with an aerosol photometer—handheld aerosol monitor [HAM]) and locate and identify major sources of MWF mists by use of a direct-reading instrument (an optical particle counter—Grimm).

- Determine size distribution of particulate in the plant atmosphere using an eight-stage inertial impactor.

NIOSH conducted air sampling to evaluate whether these air cleaners produced a significant reduction in air contaminant concentrations in this plant. The details of these evaluations are contained in two survey reports.^(5,6)

EXPERIMENTAL PROCEDURES

After the initial air cleaner was found to be acceptable, over 25 of these air cleaners were installed in the plant. The effect of these air cleaners on air contaminant concentrations was evaluated by measuring the concentration of total particulate and TEA before and after the control measures were implemented. Impinger samples were taken using NIOSH Method 3509 for TEA.⁽⁷⁾ Pump flow rates were increased from 0.5–1 to 2 L/min to improve impaction efficiency.

Impinger sampling was used only for area samples. Samples were taken for 4–8 hour periods (10-hour shifts) using spill-proof midget impingers at several locations, including “between machines,” which was a position between two of the enclosed machining centers near the center of L-Shop. Two other sites were chosen because they were at opposite boundaries of the L-Shop; the samples were denoted as “L-Shop Edge” and, near the Hydromat (Hydro) unit, “central cleaning.”

Personal and area samples for total weight particulate were



FIGURE 5. Newer, enclosed machining center

taken according to NIOSH Method 0500.⁽⁶⁾ Area samples were taken at the same locations as for impinger samples. In addition, personal samples were collected on several of the workers in the area.

To understand the workers' exposure sources, two operators were monitored by an aerosol photometer, HAM (ppm Inc., Knoxville, Tenn.). The HAM continuously sampled the air from each operator's breathing zone. The HAM was operated on the 0–2 mg/m³ range and at a time constant of 1 sec. In the instrument's sensing chamber, the HAM measures the quantity of light scattered by the entire cloud. The quantity of scattered light is a function of concentration and the aerosol's properties. Thus, this instrument's response is a measure of relative concentration. The analog output of this instrument was recorded using a datalogger (Metrasonics, Inc., Rochester, N.Y.). The unit was belt mounted, and the operators were simultaneously videotaped as they performed various tasks including machining center adjustment and cleaning, remounting castings on "tombstones" (parts holders), checking specifications of machined castings inside a plant floor enclosed room, and making adjustments on partially enclosed machining centers.

The Portable Dust Monitor (PDM), (Grimm, Ainring Germany) an eight-channel optical particle counter, was used to measure mist concentration at six locations inside the plant shop areas, the front office area on the first floor, and outside the main employee entrance. Total particulate concentration was recorded. The optical particle counter uses the quantity of light scattered by individual particles to determine particle size, and the aerosol photometer uses the quantity of light scattered from all the particles in the sensing volume to estimate the aerosol concentration.⁽⁸⁾ As a result, the response of these instruments will vary with particle size and particle optical properties. Thus, measurements from these instruments are reported as relative concentration.

A particle fractionating sampler/impactor (Anderson 2000), (Anderson Instruments, Inc., Atlanta, Ga.), an eight-stage cascade impactor, was used to determine the size distribution of particulate in the plant atmosphere. One cascade impactor was located between machines and another near central cleaning. They were operated at 28.3 L/min for 71.6 hours. The MWF mist was collected on 81-mm tared glass fiber filters; the filters were pre- and postweighed in a temperature and humidity controlled environment.

RESULTS

TEA and total particulate concentrations measured before and after the air cleaners were installed on the more than 25 machining centers are summarized in Tables I and II, respectively. For TEA, the limit of detection (LOD) was 9 µg/sample and the limit of quantitation (LOQ) was 29 µg/sample. There were no samples reported as undetectable. Samples that were found to be between the LOD and LOQ were estimated with the analytical laboratory reported result. For the total particulate samples, other than blanks, there was only one sample that resulted in an undetectable level. For statistical purposes, this sample was estimated to be LOD/2, or 0.01 mg/sample. Inspection of Tables I and II shows decreases in total particulate and TEA concentrations by factors of 2 to 10. After taking the logarithms of the concentrations, a one-way analysis of variance was used to evaluate whether the installation of the controls affected concentration.^(9,10) With the exception of the total particulate concentration measured at the L-Shop Edge (Table II), these differences are all statistically significant. Installation of controls reduced workers' personal total particulate geometric mean exposure from 0.22 to 0.06 mg/m³; however, this reduced value was higher than area concentrations

TABLE I. Summary Statistics for TEA Concentrations

Location	August 1995			August 1996			Significance of Concentration Reduction Probability > F
	N	GM (mg/m ³)	GSD	N	GM (mg/m ³)	GSD	
Between machines	5	0.25	1.34	6	0.03	1.21	0.0001
Central cleaning (Hydro unit)	6	0.43	1.38	6	0.04	1.23	0.0001
L-Shop edge	6	0.11	2.21	6	0.03	1.26	0.0024

Notes: Based on a one-way analysis of variance using log transformed data. N = number of samples.

measured at the L-Shop Edge and between machines, based on the Waller-Duncan k-ratio t-test. Thus, the worker engages in activities that provide some minor increase in his total particulate exposure as compared with measured area concentrations. The results of the HAM/video-exposure monitoring in Figure 6 provide some insight into the sources of worker exposure to particulate matter. Operator A had his highest relative concentration, 0.93 mg/m³, when he was inside a machining center (#4897) cleaning; his second highest, 0.46 mg/m³, occurred when he was inside the L-shop floor office checking specifications (tolerances); this may have resulted from dust in the office. Operator B had his highest concentration when he was at the open door, at times with his arm inside, of partially enclosed machining centers (#6922 and #6921). The relative concentrations were 0.45 to 0.63 mg/m³.

Mineral oils have a sufficient vapor pressure so that evaporation/condensation phenomena can occur.⁽¹¹⁾ This can lead to sample loss from filters and air samples.⁽¹²⁾ Based on the reported volatile organic compound content of the fluid, the total particulate concentrations could be low by 10–20%. However, the TEA and total particulate concentrations did not differ significantly (p = 0.5). This suggests that the mist in this facility was mostly TEA. However, others have reported TEA vapor concentrations that are 10 to 90% of the particulate TEA concentrations of 0.03 to 0.05 mg/m³.⁽¹³⁾

Figure 7 presents some short-term relative concentration measurements made with the PDM. The highest relative mist concentration levels were found in the flume near a machining center across the main aisle from the Hydromation (central cleaning) unit at 22.4 mg/m³; the lowest relative concentration was outside the plant at 0.018 mg/m³. Concentrations at an unventilated, partially enclosed machining center (#6902) were the next highest at 0.397 mg/m³, followed closely by 0.284 mg/m³ over a piece of plywood covering a floor flume where a machining center had been removed. Apparently, the motion of the fluid in the flume is a source of MWF mist. Throughout most of the plant, these flumes are covered and are enclosed (see Figure 3).

The results of the eight-stage (Anderson) impactor studies are shown in Figure 8. For the Anderson, the LOD = 0.1 mg/filter

and the LOQ = 0.3 mg/filter. The impactor located between machining centers yielded an overall concentration on 0.11 mg/m³ with 30% of the material deposited on the first filter or stage, indicating that there was a heavy concentration of large particles. Without the material on the first filter, the concentration was 0.078 mg/m³. The corresponding numbers for near the central cleaning (Hydro) unit are 0.14 mg/m³, 37%, and 0.087 mg/m³. Aerosols larger than 3–4 μm were present, indicating exposures are probably due to uncontrolled operations.

DISCUSSION

The preliminary work conducted with a single air cleaner showed that the mist aerosol had a particle size mode of about 8–10 μm. The use of high-pressure coolant appears to increase the mist emissions (see accompanying article). Installing the air cleaners on the machining centers and controlling the mist emissions from the Hydromation unit reduced TEA concentrations 4- to 10-fold. The total particulate concentrations were reduced 16-fold near the Hydromation unit, the location of highest concentration in the “before” study. The concentrations were significantly improved in the other area samples and in the personal samples. The area concentrations are typical of background air pollution.

As noted earlier, mist exposures for personal samples in this facility were reduced from a geometric mean of 0.22 to 0.06 mg/m³ for the total particulates. In fact, no individual sampled worker’s exposure exceeded 0.15 mg/m³ after the controls were implemented.

The most significant MWF emission sources included the machining centers, especially those unventilated and unenclosed, the flumes, and the fluid filtration unit. The mist concentrations measured by PDM, Figure 7, at floor level over a partially covered flume were nearly 0.3 mg/m³; near unventilated machining centers, nearly 0.4 mg/m³; and more than 22 mg/m³ in the flume below the floor level. Entry and even partial entry into a machining center can lead to higher operator exposures (see Figure 6). This data showed the need to develop a comprehensive control

TABLE II. Summary Statistics for Total Particulate Concentrations

Location	August 1995			August 1996			Significance of Concentration Reduction Probability > F
	N	GM (mg/m ³)	GSD	N	GM (mg/m ³)	GSD	
Between machines	6	0.25	1.72	5	0.02	1.77	0.0001
Central cleaning (Hydro unit)	6	0.48	1.59	6	0.03	1.33	0.0001
L-Shop edge	6	0.07	2.20	6	0.03	2.76	0.0960
Worker (personal)	18	0.22	1.59	16	0.06	1.50	0.0001

Notes: Based on a one-way analysis of variance using log transformed data. N = number of samples.

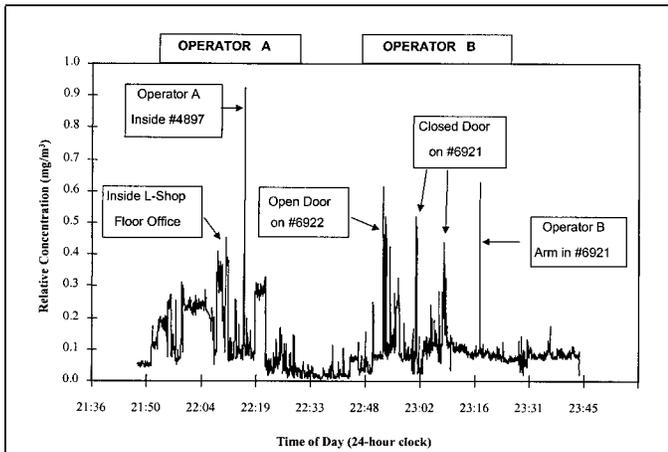


FIGURE 6. Effect of work activities on mist exposure after the air cleaners were installed. The worker's mist exposure was monitored with an aerosol photometer.

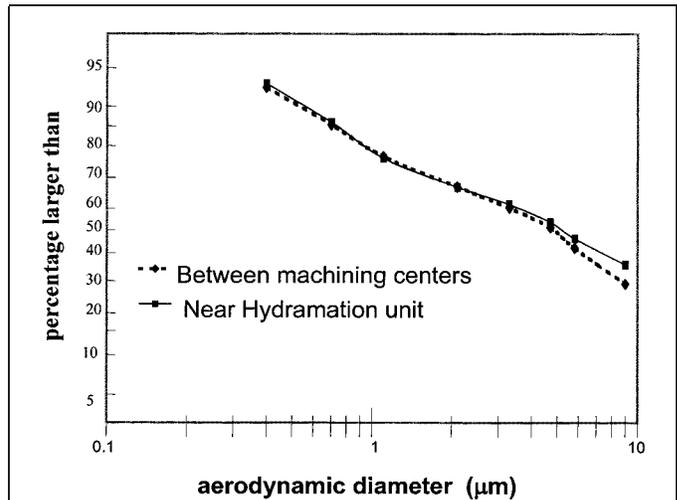


FIGURE 8. Cumulative distribution function for mass fraction of aerosol collected by Anderson Impactor. For each sample collected near the Hydramation unit, 17.7 mg of aerosol was collected during a 71.5-hour period. For the sample collected between the machining centers, 14.7 mg of aerosol was collected over a 71.6-hour period.

strategy and helped identify areas of concern. Effective mist control was obtained because the worker was separated from most of the mist generation sources. The automated machining centers isolated and separated the workers from much of the mist generation caused by the machining operations. The air cleaners installed on these machining centers prevented the mist from entering the workplace and eliminated much of the worker exposure to MWF. The MWF flumes were below floor level and mostly enclosed, and the fluid treatment unit was enclosed and ventilated to control mist generated by fluid movement. When these control measures were absent at unventilated machining centers, mist generation was observed using the optical particle counter. There remained, however, some uncontrolled sources as indicated by the large particles still measured, as shown in Figure 8.

As summarized in Table II, the geometric mean particulate exposures reported at this site were 0.06 mg/m³. These exposures are noticeably smaller than the median exposure of 0.21 mg/m³ reported for ventilated original equipment enclosures at Ford Motor Co. enclosures. The reason for this is unclear as there is little

discussion of facility design and operation, air cleaner selection and performance, and the degree to which the coolant handling system approaches a totally enclosed processing system.⁽¹⁴⁾ In contrast, at this site the coolant handling system was enclosed, the machining centers and filtration system were enclosed and ventilated, and the air cleaners were selected for their efficiency at removing mist from the air.

CONCLUSIONS

A comprehensive approach addressing mist generation by all the sources was used. To keep MWF mist exposures below 0.5 mg/m³. This entailed the nearly complete enclosure and ventilation of machining operations and fluid handling equipment and

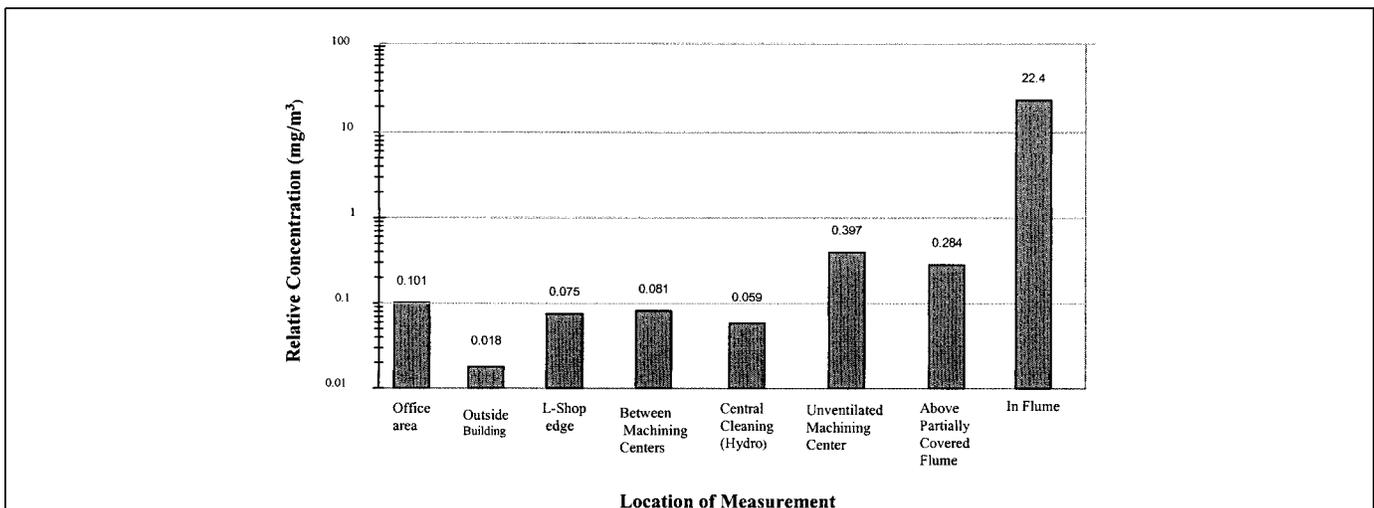


FIGURE 7. Total particulate concentrations as measured by the Grimm PDM at several locations. Apparently, unventilated machines and uncovered flumes can be noticeable sources of emissions.

the complete enclosure of the flumes. An air cleaner maintenance program, rigorously followed, was necessary to ensure proper operation and to produce the performance required to control exposures.

REFERENCES

1. Heitbrink, W.A., J.M. Yacher, G.J. Deye, and A.B. Spencer: Mist control at a machining center, part 1: Mist characterization. *AIHAJ* 61:275–281 (2000).
2. National Institute for Occupational Safety and Health (NIOSH): *NIOSH Criteria for a Recommended Standard, Occupational Exposure to Metalworking Fluids* (DHHS [NIOSH] Pub. no. 98–102). Cincinnati, OH: NIOSH, 1998.
3. Mellan, I.: *Industrial Solvents Handbook*. Park Ridge, N.J.: Noyes Data Corp., 1977. p. 478.
4. American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE): *1996 ASHRAE Handbook: Heating, Ventilating, and Air-Conditioning Systems and Equipment*. Atlanta, GA: ASHRAE, Inc., 1996. pp. 24.4–24.5.
5. Heitbrink, W.A., A.B. Spencer, and G.J. Deye: *In-Depth Survey Report: Characterization of Metalworking Mists During the Evaluation of a Commercial Air Cleaner, June 8–14 and August 1–3, 1995* (NTIS Pub. no. PB-96–191960). Springfield, VA: NTIS, 1996.
6. Yacher, J.M., W.A. Heitbrink, and G.E. Burroughs: *In-Depth Survey Report: Concentration of Metalworking Mists Before and After Installation of a Commercial Air Cleaner, June 8–14 and August 1–3, 1995 and August 19–22, 1996* (NTIS Pub. no. PB-106149). Springfield, VA: NTIS, 1997.
7. National Institute for Occupational Safety and Health (NIOSH): *NIOSH Manual of Analytical Methods* (Pub. no. 94–113), 4th ed. Cincinnati, OH: NIOSH, 1994.
8. National Institute for Occupational Safety and Health (NIOSH): *Analyzing Workplace Exposures Using Direct Reading Instruments and Video Exposure Monitoring Techniques* (DHHS [NIOSH] Pub. no. 92–104). Cincinnati, Ohio: NIOSH, 1992.
9. National Institute for Occupational Safety and Health (NIOSH): 1977. *NIOSH Occupational Exposure Sampling Strategy Manual* (DHEW [NIOSH] Pub. no. 77–173). Cincinnati, OH: NIOSH.
10. SAS Institute, Inc.: *SAS/STAT User's Guide*, rel. 6.03 ed. Cary, NC: SAS Institute, Inc., 1988. p. 570.
11. Raynor, P.C., S. Cooper, and D. Leith: Evaporation of polydisperse multicomponent oil droplets. *Am. Ind. Hyg. Assoc. J.* 57:1128–1136 (1996).
12. Leith, D., F. Leith, and M.G. Boundy: Laboratory measurements of oil mist concentrations using filters and electrostatic precipitation. *Am. Ind. Hyg. Assoc. J.* 57:1137–1141 (1996).
13. Ilgner, R.H., A. Palausky, R.A. Jenkins, A.M. Ball, and W.E. Lucke: Distribution of fatty acids and triethanolamine in synthetic metalworking fluid aerosols generated in the laboratory and field. In *Metalworking Fluids Symposium II—The Industrial Metalworking Environment: Assessment and Control of Metal Removal Fluids*. Detroit, MI: American Automobile Manufacturers Association, 1998. pp. 173–178.
14. Hands, D., M.J. Sheehan, B. Wong, and H.B. Lick: Comparison of metal working fluid mist exposures from machining with different levels of machine enclosure. *Am. Ind. Hyg. Assoc. J.* 57:1173–1178 (1996).