HETA 96-0232-2776
Met-Tech Industries, Inc.
Cambridge, OH

Chris Piacitelli, C.I.H.
Rita Washko, M.D.

PREFACE

Under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6), the National Institute for Occupational Safety and Health (NIOSH) conducts field investigations of possible health hazards in the workplace upon request. These investigations, which require a written request from any employer or authorized representative of employees, are undertaken to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found. NIOSH also provides, upon request, technical and consultative assistance to Federal, State, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease. Mention of company names or products does not constitute endorsement by NIOSH.

ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Chris Piacitelli, C.I.H. and Rita Washko, M.D. of the Respiratory Disease Hazard Evaluation and Technical Assistance Program, Clinical Investigations Branch (CIB), Division of Respiratory Disease Studies (DRDS). Other DRDS staff were involved: Environmental field assistance was provided by Joseph Burkhart, C.I.H. and Marilyn Velez (intern), and medical field assistance was received from Dee Cress, Marty Pflock, Jim Taylor, and Diana Freeland. Desktop publishing was performed by Terry Rooney.

Copies of this report have been sent to employee and management representatives at Met-Tech and the Occupational Safety and Health Administration (OSHA) Regional Office. This report is not copyrighted and may be freely reproduced. Single copies of this report will be available for a period of three years from the date of this report. To expedite your request, include a self-addressed mailing label along with your written request to:

NIOSH Publications Office
4676 Columbia Parkway
Cincinnati, Ohio 45226
800-356-4674

After this time, copies may be purchased from the National Technical Information Service (NTIS) at 5825 Port Royal Road, Springfield, Virginia 22161. Information regarding the NTIS stock number may be obtained from the NIOSH Publications Office at the Cincinnati address.

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Health Hazard Evaluation Report 96-0232
Met-Tech Industries, Inc.
Cambridge, OH
December 1999

Chris Piacitelli, C.I.H.
Rita Washko, M.D.

SUMMARY

On July 24, 1996, the National Institute for Occupational Safety and Health (NIOSH) received a confidential request for a health hazard evaluation at Met-Tech Industries, Inc. in Cambridge, Ohio. The company produces roof bolts for the underground coal mining industry. The request listed health problems of burning eyes, heartburn, coughing, sinus problems, sore throats, headaches, and shortness of breath among the workers. Workers attributed symptoms to a metalworking fluid (MWF) used at the automatic plate-stamping presses.

The NIOSH medical officer conducted telephone interviews of symptomatic employees during October and November 1996; and an on-site medical survey was performed January 26-28, 1997. Environmental sampling was performed November 13, 1996, and February 5-6, 1997.

Sampling in the facility to determine 8-hour time-weighted average (TWA) concentrations of airborne metalworking fluids found none to be in excess of the OSHA Permissible Exposure Limit (PEL) and American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV®) of 5 milligrams per cubic meter of air (mg/m^3); however all the sample concentrations (area and personal breathing zone) measured gravimetrically at two of the three presses were above the NIOSH Recommended Exposure Limit (REL) of $0.4 mg/m^3$ for thoracic aerosol. When the thoracic samples were analyzed subsequent to solvent extraction, both of the area and both of the personal breathing zone concentrations at one of the three presses were found to exceed the REL of $0.4 mg/m^3$. All other air samples analyzed by the same method for MWFs measured concentrations below the REL.

Area air sampling for endotoxin indicated most levels were lower than 2 endotoxin units per cubic meter of air (EU/m^3) and none exceeded $11.5 EU/m^3$. However, within the MWF supply systems for the presses, gram-negative bacteria, predominantly of the *Pseudomonas* genus, were present in concentrations ranging from 2.5×10^6 to 2.5×10^8 colony-forming units (CFU) per milliliter of fluid. Endotoxin contamination in these fluids ranged from about 68,000 to 537,000 endotoxin units (EU) per milliliter.

Our survey did not indicate that illness(es) such as hypersensitivity pneumonitis were occurring among this workforce. The symptom survey did, however, suggest that there was a high prevalence of chronic respiratory symptoms. Slightly more than one-third of participants met the definition for chronic bronchitis.

Respiratory symptoms and level of pulmonary function were not associated with work station or tenure, both indirect indicators of exposure to the implicated MWF. None of the participants in our survey had a significant (>10%) decline in FEV_1 over the work shift.

There was high prevalence of reported work-related skin and eye irritation among workers at the facility.

NIOSH investigators determined that a health hazard existed from occupational exposure to metalworking fluid at this facility. Personal breathing zone and area concentrations above the NIOSH REL for airborne MWFs were measured. Mists, from fluids contaminated with bacteria and endotoxin, were generated at the plate-stamping presses. Although hypersensitivity pneumonitis was not found among this workforce, a high prevalence of chronic respiratory symptoms was indicated. There was also high prevalence of reported work-related skin and eye irritation among workers. Methods to prevent exposure of workers to MWFs are provided in the recommendations section of this report.

Keywords: SIC 3469 Fabricated Metal Products (Metal Stampings, not elsewhere classified), roof bolts, oil mist, metalworking fluid, asthma, hypersensitivity pneumonitis.

TABLE OF CONTENTS

Preface ii

Acknowledgments and Availability of Report ii

Summary iii

Introduction 1

Background 1

Methods 1

Results 3

Discussion 7

Recommendations 10

References 11

Tables 13

Appendix I Consent Form and Questionnaire used at Met-Tech Industries, Inc.

Appendix II Evaluation Criteria

Appendix III NIOSH Pamphlet: *What you need to know about occupational exposure to metalworking fluids.*

INTRODUCTION

On July 24, 1996, the National Institute for Occupational Safety and Health (NIOSH) received a confidential request for a health hazard evaluation at Met-Tech Industries, Inc. in Cambridge, Ohio. The request listed health problems of burning eyes, heartburn, coughing, sinus problems, sore throats, headaches, and shortness of breath among the workers. Workers attributed symptoms to a metalworking fluid (MWF) used at the automatic plate-stamping presses.

On August 13, 1996, NIOSH industrial hygienists met with employer and employee representatives and independent safety consultants to the company and conducted a walk-through visit of the facility. The NIOSH medical officer made an initial site visit in October and conducted telephone interviews of symptomatic employees during October and November 1996; an on-site medical survey was performed January 26-28, 1997. Limited environmental sampling was performed November 13, 1996, and a more comprehensive survey was conducted February 5-6, 1997.

BACKGROUND

Met-Tech Industries produces roof bolts for the underground coal mining industry. Sections of long steel rods are cut to bolt length. If threads are required on a bolt, they are cut on one end at the threader machines. At the header machines the other end of the bolt is heated and pressed to form a head. Bolt plates are produced from coiled flat steel stock fed into any of the three automatic presses, known as N-2, N-3, and C-3, where immediately prior to being stamped by a die, the stock is sprayed from above and below with MWF. Depending on the design, the resultant plate is square or rectangular with one or more holes of bolt diameter. An operator collects and bundles the plates as they exit the machine and places them on pallets. The plugs, created as the press punches the holes, fall onto a conveyor that carries and then drops them into a waste bin. Alternatively, the plugs can be blown into the bin by blasts of compressed air synchronized with the stamping cycles. The remainder of the operation is dedicated to assembly and shipping of the bolt systems.

The plant employs 55 workers involved in the production of the roof bolts, 4 maintenance mechanics, and 7 administrative personnel. Production workers rotate among the different operations, though through job-trading some can avoid and others may spend most of their time at the plate-stamping presses.

Polar Draw 919®, the product used at the plate-stamping presses, has been used at the facility for over 10 years. It is a petroleum-based soluble oil to which the workers add approximately 12 parts (by volume) water in a 5-gallon bucket. The feed box reservoirs of each press are replenished from the bucket. Approximately 40 gallons of the mixture are used during each shift.

A consultant performed air sampling at the facility in September 1996. Total aerosol was collected on PVC filters in the breathing zones of two plate-stamping press operators for an 8-hour period, and the mass gain of the filters was measured. Concentrations of 0.14 and 1.39 milligrams per cubic meter of air (mg/m^3) were reported.

METHODS

ENVIRONMENTAL

During the NIOSH environmental evaluation of the facility, personal breathing zone (PBZ) and area air sampling were performed to measure the concentration of MWFs primarily at the plate-stamping presses. Sampling arrangements were prepared for collection of total aerosol, but because of proposed changes to the NIOSH

recommendation for exposure to MWFs, the thoracic fraction of aerosol was simultaneously collected. From the filters, a mass gain measurement was obtained prior to subjecting the filters to a solvent extraction and spectrophotometric analysis for MWFs. Area air samples were also collected to measure endotoxin. Bulk liquid samples were obtained and analyzed to determine endotoxin and gram-negative bacterial contamination of the MWFs. Details of the sampling and analytical methods are shown in Table 1.

MEDICAL

Prior to the medical survey, the medical project officer conducted interviews with Met-Tech employees by telephone. A list of names and telephone numbers of Met-Tech employees with any complaint felt to be related to work was provided by the local union representative. The purpose of this activity was to obtain a better understanding of the nature of health complaints and exposures among this work force to develop an appropriate questionnaire and medical testing protocol for the medical survey.

All current employees were invited to participate in the on-site medical survey conducted January 26 (11 PM to 7 AM shift) through January 28 (7 AM to 3 PM shift, followed by the 3 PM to 11 PM shift), 1997. The survey included an occupational and medical questionnaire, baseline spirometry, and cross-shift spirometry testing. Spirometry was performed on the first day of the work week.

1. Questionnaire

A modified version of the respiratory symptoms questionnaire developed by the Medical Research Council (MRC) of Great Britain [MRC 1960], and supplemented with questions concerning demographic information, occupational history, medical symptoms and history, and smoking habits, was used to collect information [Appendix I]. Definitions for chronic respiratory symptoms were as follows:

chronic cough (without phlegm): cough on most days for at least 3 months per year;
chronic phlegm: phlegm production on most days for at least 3 months per year;
chronic bronchitis: cough and phlegm on most days for as much as 3 months for 2 or more years;
chronic wheezing: wheezing on most days or nights each week; and
chest illness: chest illness with excess phlegm preventing usual activities (i.e., kept from work, indoors at home, or in bed) during the past 3 years.

Questions were asked about the severity of dyspnea and were defined as follows:

grade 2 dyspnea: shortness of breath when hurrying on level ground or walking up a slight hill;
grade 3 dyspnea: shortness of breath when walking with people of the same age on level ground; and
grade 4 dyspnea: shortness of breath when walking at one's own pace on level ground.

In addition to these chronic respiratory symptoms, questions concerning acute respiratory symptoms were asked. Wheezing was defined as wheezing or whistling in the chest other than that associated with a cold, and attacks of shortness of breath with wheezing were defined as any previous such attack.

Questions concerning eye and skin irritation were also asked. Eye irritation was determined to be work related if: a) participants reported red, itchy, or watery eyes at least a few days each month; b) they attributed these symptoms to exposure to metalworking fluids; and c) symptoms improved when away from work. Skin rash was considered to be related to work if participants reported both a rash involving exposed body parts, which they felt was related to their work, and that the rash improved when away from work.

Questionnaires were distributed to participants for self-administration upon receipt of a signed consent form. The medical project officer reviewed completed questionnaires on-site for accuracy and completeness.

2. Spirometry

Spirometry was performed using a dry rolling-seal spirometer interfaced to a dedicated computer. At least five maximal expiratory maneuvers were recorded for each person each time spirometry was performed. All values were corrected to BTPS (body temperature, ambient pressure, saturated with water vapor). The largest forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) were the parameters selected for analysis, regardless of the curves on which they occurred. Testing procedures conformed to the American Thoracic Society's recommendations for spirometry [American Thoracic Society 1995]. Predicted values were calculated using the Knudson reference equations [Knudson et al. 1983]. Predicted values for blacks were determined by multiplying the value predicted by the Knudson equation by 0.85 [Lanese et al. 1978]. Test results were compared to the 95th percentile lower limit of normal (LLN) values obtained from Knudson's reference equations to identify participants with abnormal spirometry patterns of obstruction and restriction [Knudson et al. 1983; American Thoracic Society 1991]. Five percent of the population will have predicted values that fall below the normal range, or LLN, while 95% will have predicted values above the lower limit.

Using this comparison, obstructive and restrictive patterns are defined as:

Obstruction: Observed ratio of FEV_1/FVC% below the LLN.
Restriction: Observed FVC below the LLN; and FEV_1/FVC% above the LLN.

The criteria for interpretation of the level of severity for obstruction and restriction, as assessed by spirometry, is based on the NIOSH classification scheme (available upon request from the Division of Respiratory Disease Studies). For those persons with values below the LLN, the criteria are:

Classification	*Obstruction FEV_1/FVC (x100)*	*Restriction Predicted FVC (%)*
Mild	>60	> 65
Moderate	45 to 60	51 to 65
Severe	< 45	< 51

Cross-shift spirometry was used to document acute airway response and was performed pre- and post-shift on the first day of the participant's work week. A decrement of 10% or greater in FEV_1 across a work shift on this first day of the work week was considered an acute response and suggestive of a relationship with work place exposures.

3. Statistical Analysis

Categorical variables were compared with the use of the Yates corrected chi-square or Fisher's exact test [Rosner 1982]. Continuous variables were compared with the use of Student's t-test [Dean et al. 1994]. Values of $p \leq 0.05$ were considered significant.

As a guide to the assessment of hazards associated with workplace exposures, certain criteria were employed. These are given in Appendix II.

RESULTS

ENVIRONMENTAL

NIOSH air sampling in November 1996 (results submitted to the company January 24, 1997) consisted of sampling for total aerosol for approximately 2.5 hours with subsequent gravimetric analysis of the filters. Two area

samples which were placed almost directly in the MWF spray at the presses measured 0.47 and 3.69 mg/m^3. Samplers worn on press operators measured 0.69 and 0.92 mg/m^3.

Results of the NIOSH full-shift air sampling of February 5-6, 1997, are presented in Table 2. Included are concentrations of MWFs measured through filters from sampling arrangements that collected total or thoracic fraction of the MWF aerosol in the environment. Each filter was weighed prior to being subjected to solvent extraction. Personal breathing zone (PBZ) and area samples were collected at each of the plate-stamping presses and at a header machine.

The filters which were measured for total mass gain indicated personal exposures ranging from 0.22 to 3.84 mg/m^3 and area concentrations in the range of 0.09 to 4.81 mg/m^3. The PBZ and area concentration ranges reported subsequent to solvent extraction were 0.13 to 3.54 mg/m^3 and 0.10 to 4.38 mg/m^3, respectively.

PBZ concentrations, as measured by mass gain in thoracic sampling arrangements, were in the range of 0.16 to 1.06 mg/m^3, while the area concentrations ranged from nearly nondetectable to 1.47 mg/m^3. After solvent extraction of the thoracic filters, concentrations ranging from 0.07 to 0.88 mg/m^3 were measured for personal exposures to MWFs. Area concentrations ranged from almost 0.01 to 1.27 mg/m^3.

Area air sampling for endotoxin indicated most levels were lower than 2 endotoxin units per cubic meter of air (EU/m^3) and none exceeded 11.5 EU/m^3. Table 2 also includes details of these results.

Table 3 presents results of bulk fluid analyses for endotoxin and gram-negative bacterial contamination. The samples from the threading machine, which used a different MWF than that used at the presses, showed little or no contamination. This was also true for the sample of the undiluted MWF used at the presses drawn from the bulk supply tank. However, fluid within the MWF supply systems of the presses showed contamination. Gram-negative bacteria, predominantly of the *Pseudomonas* genus, were present in concentrations ranging from 2.5×10^6 to 2.5×10^8 colony-forming units (CFU) per milliliter of fluid. Endotoxin contamination in these fluids ranged from about 68,000 to 537,000 EU/ml.

The Polar Draw 919® metalworking fluid was used exclusively at the stamping presses in the production of the plates. After the excess fluid at the C-3 Press dripped down to the recycle box, it was pumped back to the spray feed box for reuse. Purging of the systems to remove old and possibly contaminated MWF was not a routine operation at the plant. Biocides were not being used at the facility for treatment of the metalworking fluid.

The presses were at full production during the first day of sampling in February 1997. On this day, air blast plug discharge was utilized on the N-2 Press, and conveyors were used for plug removal at the other two presses. On the second day of sampling, the N-2 Press was being repaired throughout the shift and operated during only brief testing periods. The other two presses were fully operational throughout the second day of sampling. For approximately an hour after a clutch oil reservoir on the C-3 Press was filled, small bursts of oil mist were ejected from a hose fitting in synchrony with the cycle of the steel coil advancing to be stamped. A visible cloud of the mist formed in the vicinity. The same oil was used on the clutches of the other machines.

At times during the evaluation, smoke was seen rising from the header machines. At one of the header machines, the smoke was somewhat heavier when heads were being formed on a batch of bolts which held a remnant of threading oil from a threader machine.

No local exhaust ventilation was provided at the plate-stamping presses. Portable fans were directed at workers around many of the machines. There were a few ceiling exhaust fans above the

header machines. Personal protective equipment available at this plant included cotton gloves, rubber gloves, eye protection (safety glasses with side shields), hearing protection (ear plugs) and single-use respirators. Only the glasses and ear plugs were mandatory-use items. Workers were not observed wearing the respirators or the rubber gloves. Inspection of used cotton gloves in a laundry bin near a press revealed varying degrees of saturation of MWF: almost all were coated on the outside with fluid, and about 10% of them showed fluid had soaked through to the inside where it could contact the skin.

Cigarette smoking was permitted in the facility. Workers were observed smoking at their workstations.

MEDICAL

Telephone Interviews

Twenty (40%) of the 50 current workers were interviewed by telephone. Most of the interviewed workers complained of skin irritation and rashes, mucous membrane irritation, heartburn, and respiratory symptoms. None had constitutional symptoms (i.e., fever, sweats, unexplained weight loss, severe fatigue, malaise, or myalgia), had sought medical attention for their symptoms, or had been diagnosed with pneumonia since employment at the plant.

Questionnaire

Thirty-seven (74%) of 50 current workers participated in the survey. All completed both the questionnaire and baseline spirometry; 36 performed pre- and post-shift spirometry. All participants were Caucasian males and had a mean age of 33 years (range 21 to 61 years). Average tenure was 7.5 years (range 2.5 to 15 years); all worked eight hours daily, five days per week. Participation by shift worked was as follows: 15 (75%) of 20 workers from the 7 AM to 3 PM shift, 13 (87%) of 15 from the 3 PM to 11 PM shift, and 9 (60%) of 15 workers from the 11 PM to 7 AM shift participated. The prevalence of current smoking was 41% (15 of 37); current smokers had a mean and median of 14.5 and 7.0 pack years of smoking, respectively. Seven (19%) workers were former smokers; this group had a mean and median pack years of smoking of 13.1 and 2.0, respectively.

When asked which machine they were assigned to most often, slightly more than half (19/37, or 51%) stated that they usually worked at the headers, six (16%) worked at the presses, and three (8%) at the automatic cut-off. Two participants were unable to answer this question, stating that they could not determine where they spent most of their working hours because the assignments varied greatly from day to day. Among the remaining seven, each listed a different machine as their most frequent assignment. Participants were asked to estimate the number of days, or partial days, that they were assigned to work at the various machines during a typical work week. The most frequent assignment was to the headers; 35 (95%) participants work an average of 1.9 days (range 0.6 to 3.0) at the headers during a typical work week. Information on work assignments is presented in Table 4.

Three-fourths (27/37) of the workers have traded their work assignments for an alternate machine station. Most of those who traded, 16 or 59%, did so to avoid working at the presses. Reasons for avoiding the presses were as follows: nine (56%) of these 16 listed respiratory problems, four (25%) listed other problems (one each of headache, dry skin, offensive odor, physically demanding), and three (19%) did not give a reason.

Among 23 (62%) workers who have held other jobs before employment with Met-Tech, 6 (26%) have worked in a dusty trade. Fourteen (38%) participants stated that Met-Tech was their first job.

Respiratory Symptoms

Chronic cough (without phlegm) and chronic phlegm were reported by 3 (8%) and 4 (11%)

participants, respectively. Eight (22%) participants reported attacks of wheezing with shortness-of-breath (and normal breathing between attacks) and 13 (35%) met the definition for chronic bronchitis. The average number of days worked on the presses, and thus exposed to the MWF, was not significantly different between those who met the definition of chronic bronchitis compared to those who did not meet this definition (mean days worked on presses for those with chronic bronchitis = 1.4; mean days for those without chronic bronchitis = 1.6; p = 0.30). Three (8%) participants had grade 3 dyspnea (shortness-of-breath when walking with other people at an ordinary pace on level ground) and four (11%) reported grade 4 dyspnea (shortness-of-breath when walking at their own pace on level ground). Among these seven workers with higher grade dyspnea, five were either current or former smokers; four worked most often at the headers and three at the presses. Six of the seven were assigned to the presses an average of 1.6 days/week (range 1.1 to 2.0 days); the seventh worker did not work at any of the presses. The average tenure for these seven was 6.1 years (range 2.5 to 12.8 years).

Respiratory symptoms by smoking status are presented in Table 5. Smoking status was significantly associated with the prevalence of lower grade dyspnea (i.e., shortness of breath when hurrying on the level or walking up a slight hill) but was not associated with other chronic respiratory symptoms.

Participants were asked if, during the past three years, they have had any chest illnesses with excessive phlegm that have kept them from their usual activities and eight (22%) responded that they had. Within the past year, these eight reported an average of 1.6 (range 1 to 4) of such illnesses. Two of these eight have had no exposure to the presses; five were current smokers and one was a former smoker.

Past Respiratory Illnesses

Physician-confirmed bronchitis was reported by eight (22%) participants. Five of these eight workers were current smokers and three had never smoked. Among the three never smokers, one was diagnosed with bronchitis 5 years before coming to work at Met-Tech; the remaining two workers were diagnosed with bronchitis 5 and 2.7 years after starting work at Met-Tech, respectively. These latter two had been employed at Met-Tech for 11 and 3.7 years where they had worked at the presses an average of 0.5 days/week and 2.0 days/week, respectively. Neither one had worked in other dusty occupations. One of these two did not meet the questionnaire definition for chronic cough or chronic bronchitis; both had baseline and cross-shift spirometry results that were within normal limits.

Three (8%) participants had been diagnosed with asthma, however only one of the three still had asthma. In all three, asthma had been diagnosed when they were a child. Three participants had been diagnosed with pneumonia; however, in all cases the diagnoses were made before the participant worked at Met-Tech Industries. None of the participants had been diagnosed with emphysema.

Other Symptoms

Twenty-four (65%) workers reported eye irritation that occurred at least a few days each month and 17 (71%) of these 24 thought that these symptoms were due to exposures at work and that the symptoms improved when they were away from the work place. Thus, work-related eye irritation was reported by almost half (17 of 37, 46%) of the participants. Among 14 workers who reported a skin rash on exposed body areas, eight thought that it was due to exposure to metalworking fluid at work. All eight (22% of participants) stated that the rash improved when they were away from the work place. One of these eight had sought medical evaluation for his rash and was diagnosed as having a skin infection.

Spirometry

All thirty-seven participants performed baseline spirometry prior to their first shift of the work week. The mean FVC percent predicted was 101 (range 79 to 129); mean FEV_1 percent predicted was 97 (range 63 to 117); and mean FEV_1/FVC ratio was 80 (range 60 to 95). Four (11%) participants had abnormal results; three had an obstructive pattern and one, a restrictive pattern. Two of the four with abnormal spirometry results were current smokers (one had an obstructive pattern and one, a restrictive pattern); one was a former smoker, and one had never smoked. Lung function was not associated with smoking status (Table 6).

Lung function results were also analyzed by exposure to MWF (Table 7) and tenure at the plant (Table 8). Because of the small numbers involved, participants were grouped into either of two smoking categories, ever (current or former) smokers or never smokers; exposure to MWF was grouped into two categories, those who worked on the presses from 0.5 to 1.5 days per week and those who worked on the presses more than 1.5 days per week. There were no significant differences in lung function by exposure to MWF. Lung function by tenure and smoking status is presented in Table 8. Workers with tenures greater than 5 years were no more likely to have reduced lung function than those with tenures of 5 years or less (stratified by smoking status).

Lung function in workers without respiratory symptoms (N=11) was compared to those with respiratory symptoms (N=26). Respiratory function results were similar in both groups. Two participants without respiratory symptoms had abnormal lung function results (obstructive patterns in both).

Thirty-six of the 37 participants performed cross-shift spirometry. None of these 36 met the definition for a significant decrease in FEV_1 over the work shift. Change across shift in FEV_1 ranged from -7.6% to +5.7% (mean and median = -0.1%). Cross-shift changes in FEV_1 by work assignment on the survey day are presented in Table 9.

DISCUSSION

HEALTH RISKS

NIOSH has conducted more than 70 on-site Health Hazard Evaluations of industries with occupational exposures to MWFs or mineral oil aerosols. Exposed workers most often reported skin disorders (skin irritation, rashes, oil acne) followed by eye, nose, and throat irritation, and respiratory symptoms or disorders (breathing problems, cough, chest tightness, asthma). Occupational exposure to MWFs causes the following potential health risks [NIOSH 1998a]:

Dermatologic Conditions

Workers potentially exposed to MWFs suffer a high rate of skin diseases. In 1991, the list of industries with the highest incidence rates for skin disorders (e.g. fabricated, screw machine products, and general industrial machinery) all involved potential MWF exposure.

Several different skin diseases can result from skin contact with MWFs. In general, reports link straight MWFs to folliculitis, oil acne, and keratoses; and semisynthetic and synthetic MWFs with irritant contact dermatitis and less frequently with allergic contact dermatitis.

Contact dermatitis (either irritant contact dermatitis or allergic contact dermatitis) is the most commonly reported skin disease associated with MWFs. The high prevalence of dermatitis rates indicates the susceptibility of many workers to the irritating or sensitizing nature of MWFs and contaminants. Despite the high reporting rate, many workers continue to work even with skin lesions and considerable discomfort from burning

and itching. Some of these workers eventually are disabled as a result of their skin disorders.

Cancer

Substantial evidence indicates that some MWFs are associated with an increased risk of larynx, rectum, pancreas, skin, scrotum, and bladder cancer. Because the time between initial exposure to a carcinogen and the appearance of most types of cancer is often 20 or more years, these studies most likely reflect the cancer risk associated with exposure conditions in the mid-1970s and earlier. It should be noted that the studies results were not highly consistent with respect to the specific types of cancer which were associated with MWF. In addition, the specific MWF constituent(s) or contaminant(s) responsible for the various cancers remain to be determined. The inconsistencies in the results, and the inability to identify the MWF constituent(s) or contaminant are a likely result of the diverse nature of the MWF mixtures studied, and the absence of detailed exposure information.

Over the last several decades, the metalworking industry has made substantial changes including changes in MWF composition and reduction in MWF impurities and exposure concentrations. Efforts have been made to reduce potentially carcinogenic MWF additives and impurities with the removal of polynuclear aromatic hydrocarbons (PAHs) from MWFs beginning in the 1950s, and the EPA enacting regulations in the 1980s directed at reducing nitrosamine exposures. It is likely that the changes have reduced the cancer risks, but the data are insufficient to conclude that these changes have eliminated all cancer risks. Thus, the risk of cancer from MWF exposures later than the mid-1970s remains to be determined. However, both the substantial evidence which associates some MWFs used before the mid-1970s with cancer at several organ sites, and the potential for current MWFs to pose a similar carcinogenic hazard supports the NIOSH recommendation to reduce MWF aerosol exposures.

Lung Disease

The primary basis for the NIOSH recommendation is the risk that MWFs pose for nonmalignant respiratory disease. Occupational exposure to MWF aerosols may cause a variety of respiratory conditions, including lipid pneumonia, hypersensitivity pneumonitis, asthma, acute airways irritation, chronic bronchitis, and impaired lung function. While, most diseases of the deep lung (lipid pneumonia, hard metal disease, and legionellosis) are unusual in workers exposed to MWF aerosols, hypersensitivity pneumonitis is emerging as an important risk among workers exposed to MWF aerosol; and substantial evidence indicates that workers currently exposed to MWF aerosols have an elevated risk of airways disorders, including asthma.

MWF-Induced Asthma

Workers exposed to synthetic, soluble, and straight MWFs have an increased risk of work-related asthma. The risk of asthma exists but is likely to be lower with exposure to straight oil MWF aerosol than with exposure to aerosol from other classes of MWFs.

MWF-induced asthma appears to involve known sensitizers in some cases, but various other agents (possibly acting through irritant or inflammatory mechanisms) may cause a high proportion of cases. These sensitizers and irritants include ethanolamine and other amines, colophony, pine oil, tall oil, metals and metallic salts (e.g., chromium, nickel), castor oil, formaldehyde, chlorine, various acids, and microbial contaminants including Gram-negative bacterial endotoxin.

Studies of acute drops in lung function over a work shift also provide evidence that exposure to MWF aerosol is associated with asthma. In three of four pertinent studies, workers were more likely to experience acute loss of lung function as the level of exposure to MWF aerosol increased.

Respiratory Effects Other Than Asthma

Studies of lung function provide some evidence that MWF aerosol exposure can also cause an adverse chronic effect. Overall, this evidence provides limited support for associating MWF aerosol exposures above the NIOSH Recommended Exposure Limit (REL) with a chronic reduction in lung function. More convincing, all but one of ten studies of symptoms provide consistent and compelling evidence that occupational exposure to MWF aerosol, for each class of MWFs (straight, soluble, and synthetic) and at concentrations at or above the REL, causes chronic respiratory symptoms. Currently, no clear evidence identifies any component(s) of MWF aerosol as the predominant cause of these symptoms.

In addition to work-related asthma and chronic airway effects, recent outbreaks of hypersensitivity pneumonitis [HP] have been associated with exposure to aerosols of synthetic, semisynthetic, and soluble oil MWFs (all of which are water-based or diluted with large amounts of water) at concentrations both above and below the REL. Microbial contaminants in MWFs are postulated to be the most likely cause of these HP outbreaks. Some workers with HP have been able to return to jobs that involve no MWF exposure or to jobs that involve exposure to a different MWF. It is not clear whether reducing MWF aerosol exposure concentrations alone will effectively reduce the risk of HP.

Risks from Microbial Contamination of MWFs

Water-based MWFs are excellent nutritional sources for many kinds of microbes. The predominant microbial species routinely recovered from MWFs are usually similar to those found in natural water systems. The bacterial species most commonly isolated from MWFs is *Pseudomonas*. Endotoxin is a component of cell walls of gram-negative bacteria and exhibits inflammatory and irritant bioactivity. Generally, MWFs with high levels of gram-negative bacteria also have high endotoxin concentrations. When inhaled, endotoxin causes symptoms of upper and lower airway irritation, as well as systemic flu-like symptoms. Asthmatics are more sensitive to the airways effects of endotoxin than nonasthmatics.

FINDINGS AT MET-TECH

Sampling in the Met-Tech facility to determine 8-hour time-weighted average (TWA) concentrations of airborne metalworking fluids found none to be in excess of the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) and American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV®) of 5 mg/m^3 (Appendix II). However, all of the sample concentrations (area and personal breathing zone) measured gravimetrically at two of the three presses were above the NIOSH REL of 0.4 mg/m^3 for thoracic aerosol. When the thoracic samples were analyzed subsequent to solvent extraction, both of the area and both of the personal breathing zone concentrations at the C-3 Press were found to exceed the NIOSH REL.

The NIOSH REL stipulates that if no thoracic sampler is available, a total dust sampler can be used and the total particulate mass can be divided by 1.25 (or other factor experimentally measured for that operation) to estimate the thoracic fraction. A factor of about 3.00 was obtained from the side-by-side samples collected at the plate presses during this investigation. Overall, the thoracic sample concentrations obtained subsequent to solvent extraction were approximately 70% of those obtained using thoracic mass gain measurements. This suggests the presence of other particulate material in the environment around the presses.

It is the thoracic component of the aerosol that is specified in the REL. The availability of thoracic sampling devices makes its direct measurement possible, so determination of an appropriate conversion factor (as needed when sampling with total sampling devices) is not necessary. Although

solvent extraction of filters suggested non-MWF aerosol in the environment was contributing to the mass gain measurements at this facility, it seems that thoracic mass gain sampling provides acceptable and less costly estimates of employee exposures and adequacy of controls.

There are multiple sources of airborne MWFs at the facility. These include the intentional spraying of mist on the workpieces, the use of air blasts for plug removal, and leaks in fittings of high-pressure, oil-filled hoses at the presses.

Although airborne concentrations of endotoxin were low, the fluids at all the presses indicated bacterial and endotoxin contamination. Note that even the freshly mixed fluid in the bucket used to refill the C-3 press feed box showed contamination. Also, the fluid dripping near the die of the C-3 Press showed the highest bacterial and second highest endotoxin contamination levels. It is this fluid which would become airborne when the air blast plug discharge method is used in lieu of conveyor removal. Development of a fluid maintenance program could reduce contamination levels in the fluids.

Since complaints were heard from some workers in 1994, the company has tried to respond to the health concerns. Substitute MWF products have been tried with resulting performance that was not deemed satisfactory. Similar negative results were obtained during testing of a roller application for the MWF in an attempt to eliminate the need for spraying. The introduction of the conveyors to remove plugs at the presses has had positive results. When these are used at a press, the need for air blasts to remove the plugs is eliminated at that particular machine. However, at the time of the survey, there were not enough conveyors for all possible production configurations. In addition, during production of certain types of plates, conveyors were reported to perform unsatisfactorily. Thus, the air blast discharge method, which is a likely source of MWF aerosols, could not yet be entirely replaced.

The NIOSH survey did not indicate that illness(es) such as hypersensitivity pneumonitis were occurring among this workforce. Notably, none of the participants had been diagnosed with pneumonia during their tenure at the plant and, furthermore, their symptoms did not support this outcome. The symptom survey did however suggest that there was a high prevalence of chronic respiratory symptoms. Slightly more than one-third of participants met the definition for chronic bronchitis. As stated above, reports in the literature support an association between exposure to MWFs and respiratory symptoms.

Respiratory symptoms and level of pulmonary function were not associated with work station or tenure, both indirect indicators of exposure to the implicated MWF. None of the participants in the survey had a significant (>10%) decline in FEV_1 over the work shift. Had Kennedy's [1989] more conservative cut-off of 5% been used, two workers would have been classified as having an acute, or cross-shift, airway response. Neither worker worked at a machine where the implicated MWF was used on the day of the survey. It should be mentioned, that one machine was using air blasts for plug discharge on the day of the medical testing for about half of the shift.

The high prevalence of reported work-related skin and eye irritation among workers at Met-Tech Industries is consistent with that reported in other workplaces with occupational exposure to MWFs. It indicates a need to institute measures to reduce these exposures.

RECOMMENDATIONS

The comprehensive set of recommendations in the *NIOSH Criteria for a Recommended Standard: Occupational Exposure to Metalworking Fluids* [NIOSH 1998b] includes guidelines for exposure monitoring, engineering controls, work practices, personal protective equipment, sanitation and hygiene, medical monitoring, and hazard

communication. Attached as Appendix III is the NIOSH publication *What You Need to Know About Occupational Exposure to Metalworking Fluids* [NIOSH 1998a], an easy to read summary of that criteria document. In addition to the recommendations furnished in those documents, the following are provided:

- Avoid creating aerosols of MWF: Test additional methods of applying the MWF to the workpiece that would eliminate the need for spraying a mist. Continue efforts to get rid of the air blast discharge method of plug removal, and repair leaks in clutch oil hose systems.

- Clean press fluid systems regularly, including containers, reservoirs, and all surfaces of the presses that the fluids contact.

- Irritant and allergic contact dermatitis are associated with exposure to MWFs. Attempts should be made to reduce skin contact to the MWFs to the extent possible. Employees who work with MWFs should be required to wear goggles and impervious gloves, aprons and lab coats.

- Workers experiencing respiratory problems should be evaluated by their health care provider.

- To prevent unnecessary additional exposure to MWFs through ingestion and skin contact, a no-smoking policy in the work environment should be enforced. Additionally, cigarette smoke may exacerbate the respiratory effects of MWFs: the employer should support smoking cessation efforts.

REFERENCES

American Thoracic Society [1991]. Lung function testing: Selection of reference values and interpretative strategies. Am Rev Respir Dis 144:1202-1218.

American Thoracic Society [1995]. Standardization of spirometry: 1994 update. Am J Respir Crit Care Med 152:1107-1136.

Dean AG, Dean JA, Coulombier D, et al. [1994]. Epi Info, version 6: a word processing, database, and statistics program for epidemiology on microcomputers. Atlanta: Centers for Disease Control and Prevention.

Kennedy SM, Greaves IA, Kriebel D, et al. [1989]. Acute pulmonary responses among automobile workers exposed to aerosols of machining fluids. Am J Ind Med 15:627-641.

Knudson RJ, Lebowitz MD, Holberg CJ, Burrows B [1983]. Changes in the normal maximal expiratory flow-volume curve with growth and aging. Am Rev Respir Dis 127:725-734.

Lanese RR, Keller MD, Foley MF, Underwood EH [1978]. Differences in pulmonary function tests among Whites, Blacks, and American Indians in a textile company. J Occup Med 20:39-44.

MRC [1960]. Medical Research Council's Committee on the etiology of chronic bronchitis: Standardized questionnaire on respiratory symptoms. Br Med J 2:1665.

NIOSH [1998a]. What you need to know about occupational exposure to metalworking fluids. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 98-116.

NIOSH [1998b]. Criteria for a recommended standard: Occupational exposure to metalworking fluids. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 98-102.

Rosner B [1982]. Hypothesis testing: Categorical data. In Fundamentals of Biostatistics. Boston: Duxbury Press, pp. 288-343.

Table 1
Sampling and Analytical Methods

Met-Tech Industries, Inc.
February 5-6, 1997
HETA 96-0232

Analyte	Sample Type	Collection Medium	Flow	Analytical Method
Metalworking Fluid	Air - Total	37-mm tared PVC filter (Close-faced cassette)	2 L/min	1 - NIOSH 0500 Gravimetric (mass gain) measurement *followed by:* 2 - NIOSH 5026 Extraction with solvent (carbon tetrachloride) then analysis via infrared spectrophotometry
Metalworking Fluid	Air - Thoracic Fraction	37-mm tared PVC filter preceded by BGI® thoracic cyclone	1.8 L/min	1 - NIOSH 0500 Gravimetric (mass gain) measurement *followed by:* 2 - NIOSH 5026 Extraction with solvent (carbon tetrachloride) then analysis via infrared spectrophotometry
Endotoxin	Air	37-mm tared polycarbonate filter	2 L/min	Chromogenic limulus amebocyte lysate assay
Endotoxin	Bulk liquid	20 ml glass vial	----	Chromogenic limulus amebocyte lysate assay
Bacteria-Gram-negative	Bulk liquid	20 ml glass vial	----	Incubation on tryptic soy agar (TSA) followed by bacterial colony counts

Table 2
Air Sampling Results (8-hour Time-Weighted Average Concentrations)

Met-Tech Industries, Inc.
February 5-6, 1997
HETA 96-0232

Sample Date	Sample Location		Sample Type	Time (mins)	Metalworking Fluid (mg/m³)				Endotoxin (EU/m²)
					Thoracic Filters		Total Filters		
					Gravimetric	Solvent	Gravimetric	Solvent	
5-feb-97	C-3 Press	Operator	Personal	423	*0.62*	*0.43*	*2.77*	*2.40*	--
5-feb-97	C-3 Press	Operator Station	Area	455	*1.47*	*1.16*	*4.81*	*4.38*	9.37
6-feb-97	C-3 Press	Operator	Personal	408	*1.06*	*0.88*	*3.84*	*3.54*	--
6-feb-97	C-3 Press	Operator Station	Area	421	*1.34*	*1.27*	*2.88*	*2.60*	1.04
5-feb-97	N-2 Press	Operator	Personal	422	0.35	0.16	*0.69*	0.43	--
5-feb-97	N-2 Press	Operator	Personal	420	0.38	0.21	*0.73*	0.44	--
5-feb-97	N-2 Press	Operator Station	Area	447	0.29	0.16	*0.90*	*0.59*	2.29
6-feb-97	N-2 Press	Operator	Personal	404	0.16	0.07	0.22	0.13	--
6-feb-97	N-2 Press	Operator Station	Area	407	0.27	0.23	*0.77*	*0.61*	0.63
5-feb-97	N-2 Press	Plug Discharge (Air blast)	Area	423	--	--	*1.11*	*0.76*	--
5-feb-97	N-2 Press	Plug Discharge (Air blast)	Area	423	--	--	*1.10*	*0.75*	--
5-feb-97	N-2 Press	Plug Discharge (Air blast)	Area	401	--	--	*1.10*	*0.76*	1.56
5-feb-97	N-3 Press	Operator	Personal	426	*0.78*	0.25	*2.17*	0.47	--
5-feb-97	N-3 Press	Operator Station	Area	445	*0.96*	0.37	*2.41*	*0.57*	nd
6-feb-97	N-3 Press	Operator	Personal	407	*0.44*	0.20	*1.18*	0.32	--
6-feb-97	N-3 Press	Operator Station	Area	407	*0.52*	0.17	*0.88*	0.23	11.46
6-feb-97	N-3 Press	Operator Station	Area	void	--	--	void	void	--
5-feb-97	H-1 Header	Operator	Personal	398	0.20	0.23	0.26	0.21	--
5-feb-97	H-1 Header	Operator Station	Area	438	0.15	0.21	0.17	0.20	0.52
6-feb-97	H-1 Header	Operator Station	Area	400	<0.02	<0.01	0.09	0.10	0.83

PRODUCTION NOTES: 5-Feb-97: Full Production, N-2 Press using air blast plug discharge.
6-Feb-97: N-2 Press being repaired all day, others fully operational, only very brief air blast plug discharges.

mg/m3 = milligrams of contaminant per cubic meter of air
EU = endotoxin units
void = pump faulted
nd = none detected
Underlined Italic = results greater than 0.4 mg/m³ thoracic or 0.5 mg /m³ total

Table 3
Bulk Fluid Sampling Results

Met-Tech Industries, Inc.
February 5-6, 1997
HETA 96-0232

Sample Location		Fluid ID	Fluid Notes	Endotoxin (EU/ml)	Gram-neg Bacteria (CFU/ml)	ID
Bulk Tank	Spigot	Polar Draw 919®	Fluid only - not yet diluted with water	<.05	ND	---
C-3 Press	Spray Feed Box	Polar Draw 919®	Freshly diluted with water and mixed with some recycled fluid	172,000	45,000,000	Pseudomonas psuedoalcaligenes
C-3 Press	Feed Box Refill Bucket	Polar Draw 919®	Freshly diluted with water	68,000	2,500,000	Pseudomonas psuedoalcaligenes
C-3 Press	Recycle Box	Polar Draw 919®	Old - collection of drippings that are pumped back to feed box (only C-3 press recycles)	175,000	74,000,000 1,000,000	Pseudomonas psuedoalcaligenes Pseudomonas stutzeri
C-3 Press	Near Die (drippings)	Polar Draw 919®	Dripping near die onto and around conveyor prior to recycle box (gets air blasted)	176,000	250,000,000	Pseudomonas psuedoalcaligenes
N-2 Press	Spray Feed Box	Polar Draw 919®	---	115,000	40,000,000	Pseudomonas psuedoalcaligenes
N-2 Press	Waste Box	Polar Draw 919®	Does not get recycled	537,000	16,000,000 4,000,000 1,000,000	Pseudomonas psuedoalcaligenes Shewanella putrefaciens Citrobacter freundii
N-3 Press	Spray Feed Box	Polar Draw 919®	---	143,000	35,000,000	Pseudomonas psuedoalcaligenes
T-1 Threader	Recycle Channel	Cleartex D®	---	12	10	Xanthomonas maltophilia
T-2 Threader	Recycle Channel	Cleartex D®	---	<.05	ND	---

EU/ml = endotoxin units per milliliter of fluid
CFU/ml = colony-forming units per milliliter of fluid
ND = none detected

Table 4
Work Station (Machine) Assignments

Met-Tech Industries, Inc.
January 26-28, 1997
HETA 96-0232

Machine	No. of workers assigned at any time during work week*	Mean days per week assigned	Range of days/week assigned	Average worker-days assigned to machine per week
Headers	35	1.9	0.6 - 3.0	66.5
Presses	32	1.5	0.5 - 3.8	48.0
Assembly table	22	0.8	0.3 - 1.9	17.6
Automatic cut-off	20	0.9	0.4 - 2.0	18.0
Threaders	16	0.8	0.5 - 1.7	12.8
Manual cut-off	10	0.6	0.3 - 1.0	6.0
Lathes	5	0.6	0.6 - 0.7	3.0
Automatic mill	4	0.4	0.3 - 0.6	1.6
Other**	3	3.7	1.0 - 5.0	11.1
Total†				184.6

* Number of workers who stated that they had at least one assignment to this machine during a typical work week.
** Forklift and machine shop maintenance
† 37 workers x 5 days per week = 185 total worker days

Table 5
Prevalence of Respiratory Symptoms by Cigarette Smoking History

Met-Tech Industries, Inc.
January 26-28, 1997
HETA 96-0232

Symptom	Cigarette Smoking History			
	Current smoker N=15	Former smoker N=7	Never smoker N=15	p value
	N (%)	N (%)	N (%)	
Chronic cough (without phlegm)	2 (3)	0 (0)	1 (3)	NS
Chronic phlegm	2 (13)	0 (0)	2 (13)	NS
Bronchitis	7 (47)	3 (43)	3 (20)	NS
Chest illnesses	5 (33)	1 (14)	2 (13)	NS
Grade 2 dyspnea	8 (53)	2 (29)	2 (13)	0.03
Grade 3 or 4 dyspnea	3 (20)	2 (29)	2 (13)	NS
Attacks of shortness of breath with wheezing (with normal breathing between attacks)	3 (20)	2 (29)	3 (20)	NS

NS Prevalence of individual respiratory symptoms was not significantly different between smoking categories (ie.- $p > 0.05$).

Table 6
Summary Statistics of Spirometry Measurements
by Cigarette Smoking History

Met-Tech Industries, Inc.
January 26-28, 1997
HETA 96-0232

Lung Function	Cigarette Smoking History								
	Current Smoker N=15		Former Smoker N=7		Never Smoker N=15		Total N=37		p value
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Percent Predicted FVC	97	8.3	106	12.8	103	11.3	101	10.8	NS
Percent Predicted FEV_1	95	10.7	100	15.8	98	13.4	97	12.6	NS
FEV_1 / FVC Ratio	82	6.9	78	6.1	80	7.2	80	6.9	NS

SD Standard deviation
NS Average lung function measurement was not significantly different between smoking categories (ie.- $p > 0.05$)

Table 7
Lung Function* Among Workers Exposed to Metal Working Fluid (on the Presses) Stratified by Cigarette Smoking History

Met-Tech Industries, Inc.
January 26-28, 1997
HETA 96-0232

Smoking History	Exposure** (days/week)	No.† Workers	FVC	FEV_1	FEV_1/FVC	p value
Ever Smoker (N=18)	0.5 - 1.5	12	102 ± 10.6	99 ± 10.9	81 ± 4.6	NS
	>1.5	6	97 ± 10.4	98 ± 11.7	86 ± 7.9	
Never Smoker (N=14)	0.5 - 1.5	7	104 ± 14.9	99 ± 12.4	80 ± 3.3	NS
	>1.5	7	102 ± 8.5	96 ± 16.1	78 ± 10.3	

* Data are presented as means ± standard deviation.
** Exposed to metal working fluid, i.e., working on the presses
† Number of workers exposed (32 of 37 workers had exposures of ½ day or more)
NS Average lung function measurement was not significantly different between exposure groups (ie.- $p > 0.05$)

Table 8
Lung Function* Among Workers by Tenure and Cigarette Smoking History

Met-Tech Industries, Inc.
January 26-28, 1997
HETA 96-0232

Smoking History	Tenure (years)	No.† Workers	FVC	FEV_1	FEV_1/FVC	p-value
Ever Smoker (N=22)	≤ 5	8	103 ± 10.1	99 ± 14.6	83 ± 7.9	NS
	> 5	14	98 ± 10.7	95 ± 11.0	80 ± 6.1	
Never Smoker (N=15)	≤ 5	8	101 ± 7.2	97 ± 8.0	82 ± 3.8	NS
	> 5	7	105 ± 15.1	98 ± 18.6	77 ± 9.3	

* Data are presented as means ± standard deviation.
† Number of workers exposed
NS Average lung function measurement was not significantly different between tenure groups (ie.- $p > 0.05$)

Table 9
Work Station Assignments on day of Survey and Cross-Shift Change in FEV_1

Met-Tech Industries, Inc.
January 26-28, 1997
HETA 96-0232

Machine	No. Workers	Average cross-shift change (%) in FEV_1	Range
Headers	13	0.0	-3.3 to +5.7
Presses	8	+0.1	-2.6 to +3.4
Automatic and Manual Cut-off	7	+1.4	-3.8 to +3.4
Assembly	4	-0.1	-0.9 to +2.7
Other*	4	-3.9	-7.6 to +1.1

* Other = machine shop (1); forklift (2); and towmotor (1).

APPENDIX I

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH (NIOSH)
CENTERS FOR DISEASE CONTROL AND PREVENTION
U.S. PUBLIC HEALTH SERVICE
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
HETA 96-0232

CONSENT TO PARTICIPATE IN A HEALTH HAZARD EVALUATION

I. You are being asked to participate in a NIOSH health hazard evaluation of respiratory (lung) complaints, eye irritation, and skin rash among workers at Met-Tech Industries, Inc., Cambridge, Ohio. This health hazard evaluation was a confidential request. The purpose of this evaluation is to determine if the symptoms mentioned above are associated with exposure(s) at Met-Tech.

II. The study will include the following procedures:

1. A questionnaire about your work history, health history, symptoms, and health-related activities. You will be asked to complete the questionnaire yourself, but a NIOSH representative will be present to assist you and check it for completeness (when you return it). It should take from 10 to 15 minutes to complete.

2. Pulmonary function testing. You will be asked to breathe in as deeply as you can and forcefully blow out as quickly and completely as possible through a tube that you place in your mouth. You will be asked to do this at least five times, and possibly several more times. This test may be tiring, and you may feel momentary lightheadedness or chest discomfort. If, at any time, you feel unable to continue, the test will be terminated. The test typically takes five to ten minutes. You will be asked to perform this breathing test immediately before and after your work shift.

III. The benefits to you from participating in the study include the free medical test described above. Your participation may also benefit your co-workers, and possibly other people, as a result of what is learned from this study. NIOSH will provide you and your doctor (if you wish) with results of your medical test. We will do this when the study is finished, or sooner, if appropriate. The overall study results (without names or other personal identifying information) will be provided to the company and union (or other employee representative); the company is required to post a copy of the final report in a place accessible to employees for a period of 30 days. In addition, if you so request, NIOSH will send you a copy of the final report. The only disadvantage, besides the slight discomfort and inconvenience described above, is that a test result may be outside the range of "normal" even though nothing is wrong. This could result in a recommendation for further medical evaluation that, ultimately, may not have been necessary.

IV. All of the procedures described above are standard medical tests.

V. Injury from this project is unlikely. But if it results, medical care is not provided, other than emergency treatment. If you are injured through negligence of a NIOSH employee you may be able to obtain compensation under Federal Law. If you want to file a claim against the Federal government your contact point is: Public Health Service Claims Office: 301-443-1904. If you are injured through the negligence of a NIOSH contractor, your claim would be against the contractor, not the Federal government. If an injury should occur to you as the result of your participation, you should contact Dr. Rita Washko, Medical Project Officer, at (304) 285-5711.

VI. The National Institute for Occupational Safety and Health (NIOSH) of the Centers for Disease Control and Prevention (CDC), an agency of the Department of Health and Human Services, is authorized to collect this information under provisions of the Public Health Service Act, Section 301 (42 U.S.C. 241); Occupational Safety and Health Act, Section 20 (29 U.S.C. 669); and Federal Mine Safety and Health Act of 1977, Section 501 (30 U.S.C. 95). The information you supply is voluntary and there is no penalty for not providing it. The data will be used to evaluate the respiratory, eye, and skin symptoms among workers at Met-Tech. Data will become part of CDC Privacy Act system (09-20-0147), "Occupational Health Epidemiological Studies" and may be disclosed to: appropriate State or local health departments to report certain communicable diseases; the State Cancer Registry to report cases of cancer where the State has a legal reporting program providing for the information's confidentiality; private contractors assisting NIOSH; collaborating researchers under certain limited circumstances to conduct further investigations; one or more potential sources of vital statistics to make a determination of death; the Department of Justice in the event of litigation; and to a congressional office assisting individuals in obtaining their records. An accounting of the disclosures that have been made by NIOSH will be made available to you upon request. Except for these and other permissible disclosures expressly authorized by the Privacy Act, no other disclosure may be made without your written consent.

VII. If you have any reaction to the tests or procedures, you should contact Dr. Rita Washko, Medical Project Officer, at 304-285-5711. You should also contact Dr. Washko if you have any questions concerning this study or your participation.

VIII. Your participation is voluntary and you may withdraw your consent and your participation in this study at any time without penalty or loss of benefits to which you are otherwise entitled.

IX. SIGNATURES

I have read this consent form and I agree to participate in this study.

PARTICIPANT _____ Age __ Date _____
(signature)

I, the NIOSH representative, have accurately described this study to the participant.

NIOSH REPRESENTATIVE _____ Date _____
(signature)

ID number: _____

HETA 96-0232

Thank you for participating in this survey conducted by the National Institute for Occupational Safety and Health (NIOSH), Division of Respiratory Disease Studies, Morgantown, West Virginia. Please **answer all questions** and return the completed questionnaire to Rita Washko, MD, project medical officer. **This page must be completed at the time of your "pre-shift" breathing test (or, spirometry);** the remainder of the questionnaire will be completed during your "post-shift" spirometry session. In addition to these questions, spirometry will be performed as part of the medical survey at Met-Tech Industries, Inc. **Please print your answers.**

Before you begin, please let us know where your spirometry results should be sent:

Mail my results to (check the appropriate answer):

_____ 1=Myself

_____ 2=Both myself and my doctor (Please provide doctor's name and address):

Dr's name: _____

Street address: _____

City, state, zip: _____

---

1. What is your name? _____ _____ ___
(last name) (first name) (MI)

2. What is your address? _____
(street)

_____ _____ _____
(city) (state) (zipcode)

3. What is your telephone number? (_____) _____ - _____

4. What is your date of birth? _____/_____/_____ 5. How old are you? ____ years
Mo Day Yr

6. What is your gender? __ Male __ Female

7. What is your race? __ 1=White __ 2=Black __ 3=Asian/Pacific Islander
__ 4=American Indian/Alaska native
__ 5=Other

8. Are you of Hispanic origin? __ Yes __ No

ID number: _____

NIOSH TO RECORD: Participant's Height _____ inches; Weight _____ kg

WORK HISTORY
CURRENT POSITION AT THIS PLANT

The next few questions are about your job at this plant.

9.A. How many years have you worked at this plant? (If you have worked here less than one year, skip to 9B) _____ years

B. How many months have you worked at this plant? _____ months

10. How many hours per day do you usually work? _____ hours per day

11. How many days per week do you usually work? _____ days per week

12. What shift do you usually work? __ 11 to 7 __ 7 to 3 __ 3 to 11 __ Other

13.A. Which machine do you **usually** work at? (Refer to list in Question 14 and record the **one** machine that you work at most often; if none of these apply, please state why):

_____

B. Which machine did you work at **today**? _____

14. During a typical work week, how many days do you work at the following machines? *(Estimate the average number of days per week that you work at a particular machine; **record only half or full days**.* For example, if you work at Cleveland III an average of ½ day per week, record "½" in the space next to this machine. For those machines where you work less than ½ day per week, record a "0").

Cleveland III	_____	Assembly Table	_____
Niagra II	_____	Bolt Salvage Press	_____
Niagra III	_____		
Header I	_____	Lathe I	_____
Header II	_____	Lathe II	_____
Header III	_____		

ID number: _____

Threader I	_____	Automatic Cut-off	_____
Threader II	_____	Manual Cut-off	_____
		Automatic Mill	_____

Other (Explain) _____

15. Do you ever "trade-off" your work assignment?
    __ Yes (Answer the following questions)
    __ No (Skip to Question 16)

    Which machine(s) do you try to avoid? _____
    Why do you avoid this/these machine(s)?
    __1=Respiratory (lung) problems
    __2=Other health problem; please explain _____
    __3=Other reason; please explain: _____

16. Are the following personal protective equipment available at your work place?

Cotton gloves	__ Yes	__ No
Rubber or other impermeable gloves	__ Yes	__ No
Eye protection	__ Yes	__ No
Respiratory protection	__ Yes	__ No

    If yes, what kind of respiratory protection is available?
    __ Paper mask only __ Other respirator __ Both

17. Do you ever use the following personal protective equipment at work?

    Cotton gloves __ Yes __ No
    If yes, for which machines? _____

    Rubber/other impermeable gloves ? __ Yes __ No
    If yes, for which machines? _____

    Eye protection? __ Yes __ No
    If yes, for which machines? _____

    Respiratory protection __ Yes __ No
    If yes: For which machines? _____
    What kind of respiratory protection do you use?
    __ Paper mask only __ Other respirator __ Both

ID number: _____

PREVIOUS WORK HISTORY

The next few questions are about jobs you have had before you worked at this plant. We are interested in the previous two jobs that you had before working at Met-Tech. We will begin with the most recent job that you held before Met-Tech.

18.A. Did you work anywhere before Met-Tech? __ Yes __ No (If No, Skip to Question 19)

If YES:
Where did you work (what industry)? _____
Describe your duties: _____
How many years did you work at this job? (If less than 1 year, skip to next question) _____
If you worked less than 1 year at this job, how many months did you work? ____

Were you exposed to any hazardous substances or processes at this job?
__ Yes (Please list): _____
__ No

B. Did you work anywhere before the job listed in 18.A.?
__ Yes __ No (If No, Skip to Question 19)

If YES:
Where did you work (what industry)? _____
Describe your duties: _____
How many years did you work at this job? (If less than 1 year, skip to next question) _____
If you worked less than 1 year at this job, how many months did you work? ____

Were you exposed to any hazardous substances or processes at this job?
__ Yes (Please list): _____
__ No

C. Have you ever worked in a dusty trade/at a dusty job (for example, coal mining, sand blasting, or in a foundry)?
__ Yes (Please list industry, your job title, years worked) _____
_____
__ No

ID number: _____

SYMPTOMS

The next questions are about your chest. Please answer YES or NO if possible. If you are in doubt about whether your answer is YES or NO, record NO.

COUGH

19. Do you usually have a cough first thing (on getting up) in the morning in the winter? (Count a cough with first smoke or on first going out-of-doors. Exclude clearing of throat or a single cough. Usually means 4 or more days per week).
__Y __N

20. Do you usually cough during the day – or, at night, if you work nights – in the winter? (Ignore an occasional cough. Usually means 4 or more days per week)
__Y __N

IF YOU ANSWERED NO TO BOTH 19 and 20, SKIP TO QUESTION 21. IF YOU ANSWERED YES TO EITHER QUESTION 19 or 20, ANSWER THE FOLLOWING:

20.A. Do you cough like this on most days – or nights, for those who work nights – for as much as 3 months during the year?
__Y __N

20.B. How many years have you coughed like this? _____ years

PHLEGM

21. Do you usually bring up phlegm from your chest first thing (on getting up) in the morning in the winter? (Count phlegm with first smoke or on first going out-of-doors. Exclude phlegm from the nose. Count swallowed phlegm. Usually means 4 or more days per week.) __Y __N

22. Do you usually bring up phlegm from the chest during the day – or night, if you work nights – in the winter? (IF twice or more per day, mark Yes. Usually means 4 or more days per week).
__Y __N

IF YOU ANSWERED NO TO BOTH QUESTIONS 21 and 22, SKIP TO QUESTION 25. IF YOU ANSWERED YES TO EITHER QUESTION 21 or 22, PLEASE ANSWER THE FOLLOWING QUESTIONS.

ID number: _____

23. Do you bring up phlegm like this on most days -- or, most nights -- for as much as three months during the year?
__Y __N

24. How many years have you brought up phlegm like this? _____ years

---

WHEEZING

25. Does your chest ever sound wheezy or whistling?
__Y __N (If No, Skip to Question 26)

If YES, do you get this:
Only when you have a cold? __Y __N
Occasionally apart from colds? __Y __N
Most days or nights each week? __Y __N

For how many years has this been present? _____

26. Have you ever had an ATTACK of wheezing that has made you feel short of breath?
__Y __N (If No, Skip to Question 27)

If YES:
Was your breathing absolutely normal between attacks? __Y __N
How old were you when you had your first such attack? _____
Have you had 2 or more such episodes? __Y __N
Have you ever required medicine or treatment for the(se) attack(s)? __Y __N

BREATHLESSNESS

27. Are you troubled by shortness of breath when hurrying on the level or walking up a slight hill? __Y __N (If No, Skip to Question 30)

28. Do you ever have to walk slower than people of your own age on level ground because of breathlessness?
__Y __N

ID number: _____

29. Do you have to stop for breath when walking at your own pace on level ground?
__Y __N

CHEST COLDS AND CHEST ILLNESSES

30. During the past 3 years, have you had any chest illnesses that have kept you off work, indoors at home, or in bed? __Y __N (If No, Skip to Question 33)

31. Did you bring up more phlegm than usual with any of these illnesses?
__Y __N

32. In the last year, how many such illnesses, with (increased) phlegm, did you have which lasted a week or more? _____

MOST BOTHERSOME SYMPTOM

33. Of the following, which one has been the most troublesome chest symptom?
_____ wheezing or whistling in the chest
_____ attacks of shortness of breath
_____ chest tightness
_____ attacks of cough
_____ other (Specify): _____
_____ I have no chest symptoms (If you have no chest symptoms, Skip to Question 37)

34.A. How often do you have this most bothersome chest symptom? (Mark only one answer)
_____ only one time
_____ only a few days ever
_____ a few days each year
_____ a few days each month
_____ a few days each week
_____ usually at least once each day or night

B. Is it related to anything (If yes, please explain)? ___ Yes:_____
___ No

35. When you are off work on weekends or vacation, does this symptom get: (Mark only one)
_____ better
_____ worse
_____ no change

ID number: _____

36. **When you return** to work from weekends or vacation, does this symptom get: (Mark only one)
    _____ better
    _____ worse
    _____ no change

OTHER SYMPTOMS

37. During the past 12 months, have your eyes been red, itchy, or watery?
    __ Y __ N (If No, Skip to Question 38)

    If YES:
    How often has this occurred: (Check only one)
    _____ only one time
    _____ only a few days ever
    _____ a few days each year
    _____ a few days each month
    _____ a few days each week
    _____ usually at least once each day or night

    What were these eye symptoms due to? (Check all that apply)
    _____ contact lenses
    _____ cold or flu
    _____ hay fever
    _____ other allergies
    _____ liquids, fumes, or dust at work
    _____ something else (Specify): _____
    _____ I don't know

    Did/do the eye symptoms seem: (Check only one)
    _____ better when I was away from work
    _____ worse when I was away from work
    _____ no change, neither better nor worse away from work

ID number: _____

38. During the past 12 months, have you had a skin rash, dermatitis, or eczema?
__ Y __ N (If No, Skip to Question 39)

If YES:
What parts of your body were affected? (Check all that apply)
_____ scalp
_____ face and neck
_____ hands or arms
_____ trunk
_____ groin
_____ feet or legs
_____ other (Specify): _____

Do any of the following substances cause rashes on your skin? (Check all that apply)
_____ jewelry
_____ deodorant, after shave, cosmetics, perfumes
_____ soaps, detergents
_____ hair dyes/colorings
_____ clothing, shoes
_____ tapes, glues
_____ skin medicine
_____ poison ivy/oak
_____ substance(s) at work (Specify): _____

Did/do the skin symptoms seem: (Check only one)
_____ better when I was away from work
_____ worse when I was away from work
_____ no change, neither better nor worse away from work

Have you seen a health professional for your skin condition? __ Y __ N
If YES, what was the diagnosis? _____

ID number: _____

PAST ILLNESSES

39. Did you have any lung trouble before the age of 16? __Y __N

40. Have you ever had any of the following:

Attacks of Bronchitis?	__Y	__N
Was this confirmed by a doctor?	__Y	__N
At what age was your first attack?	_____	
Pneumonia (include bronchopneumonia)?	__Y	__N
Was this confirmed by a doctor?	__Y	__N
When was it first diagnosed?		_____
How many times have you been diagnosed with pneumonia?		_____
Hayfever?	__Y	__N
Was this confirmed by a doctor?	__Y	__N
At what age was your first attack?	_____	
Emphysema?	__Y	__N
Was this confirmed by a doctor?	__Y	__N
At what age was it diagnosed?	_____	
Do you still have it?	__Y	__N
Asthma?	__Y	__N
Was it confirmed by a doctor?	__Y	__N
Do you still have it?	__Y	__N
At what age did it start?	_____	
At what age did it stop?	_____	
Any other chest illnesses?	__Y	__N

If YES, Please list other illnesses:

_____

_____

ID number: _____

TOBACCO SMOKING

The last few questions are about tobacco use.

41. Do you currently (as of 1 month ago) smoke cigarettes? __Y __N
    If No, Go to next Question.
    If Yes, Skip to Question 43.

42. Have you ever smoked cigarettes? __Y __N
    If No, Skip to Question 46.
    If Yes, Go to next Question.

43. On average, how many cigarettes per day do you/did you smoke? _____

44. How many years did you smoke/have you smoked? _____ years

45. Do you/did you ever smoke while performing your job? __Y __N

46. Do you use any other kind of tobacco (such as cigars, snuff/chewing tobacco) regularly?
    __Y __N

This brings us to the end of the questionnaire. Thank you for participating in this study. If you have any questions, please contact Rita Washko, MD, medical project officer, at NIOSH 1-800-232-2114.

APPENDIX II

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs), (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®), and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs) [NIOSH 1992, ACGIH 1998, CFR 1998]. NIOSH encourages employers to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion.

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm [Public Law 91-596]. Thus, employers should understand that not all hazardous chemicals have specific OSHA exposure limits. An employer is still required by OSHA to protect employees from hazards, even in the absence of a specific PEL.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8-to-10-hour workday. Some substances have recommended short-term exposure limits (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

MWFs

The OSHA PEL and ACGIH TLV® for mineral oil mist are 5 mg/m^3 as an 8-hr TWA. The NIOSH REL was also 5 mg/m^3 until January 1998, when NIOSH recommended that exposures to MWF aerosols be limited to 0.4 mg/m^3 for thoracic particulate mass (or 0.5 mg/m^3 for total particulate mass) as a TWA concentration for up to 10 hours per day during a 40-hour workweek [NIOSH 1998]. NIOSH recommends sampling with a thoracic sampling device with gravimetric (mass gain) measurement of MWF aerosol using NIOSH Method 0500 [NIOSH 1994]. If no thoracic sampler is available, a total dust sampler can be used and the total particulate mass can be divided by 1.25 (or other factor experimentally measured for that operation) to estimate the thoracic fraction. If there are simultaneous exposures to particulate materials that might interfere in the mass measurements of the MWF, NIOSH Method 5026 or a similar method may be used to estimate the soluble component of the workroom aerosol.

Besides the health basis for the REL (as presented in the Discussion section of this report), the other considerations on which it was based included the availability of an index for measuring MWF exposures, the

universal applicability of the REL to all types of MWFs, and the evidence that controlling MWF exposures is technologically feasible.

It should be noted that the OSHA PEL was an adoption of the 1968 ACGIH TLV® which was based on limited animal studies [ACGIH 1971]. The NIOSH REL is based on a considerable amount of occupational health information that has become available since that time.

MICROBIAL CONTAMINANTS

There are no occupational exposure criteria for airborne bacteria or endotoxin. However, a recommended endotoxin exposure limit of 50 endotoxin units (EU)/m^3 based on inhalable dust sampling has recently been adopted in the Netherlands. This limit was established as about half of the 90 EU/m^3 level that induces measurable airways obstruction [Dutch Expert Committee 1998]. Insufficient health data exist to recommend specific limits for bacterial or endotoxin concentrations in MWFs [NIOSH 1998].

References:

ACGIH [1971]. Documentation of the threshold limit values for substances in workroom air. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

ACGIH [1998]. 1998 TLVs® and BEIs®: threshold limit values for chemical substances and physical agents. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

CFR [1998]. Code of Federal Regulations. 29 CFR 1910.1000. Washington, DC: U.S. Government Printing Office, Federal Register.

Dutch Expert Committee on Occupational Standards [1998]. Endotoxins: health-based recommended occupational exposure limit. Health Council of the Netherlands, Publication No. 1998/03WGD.

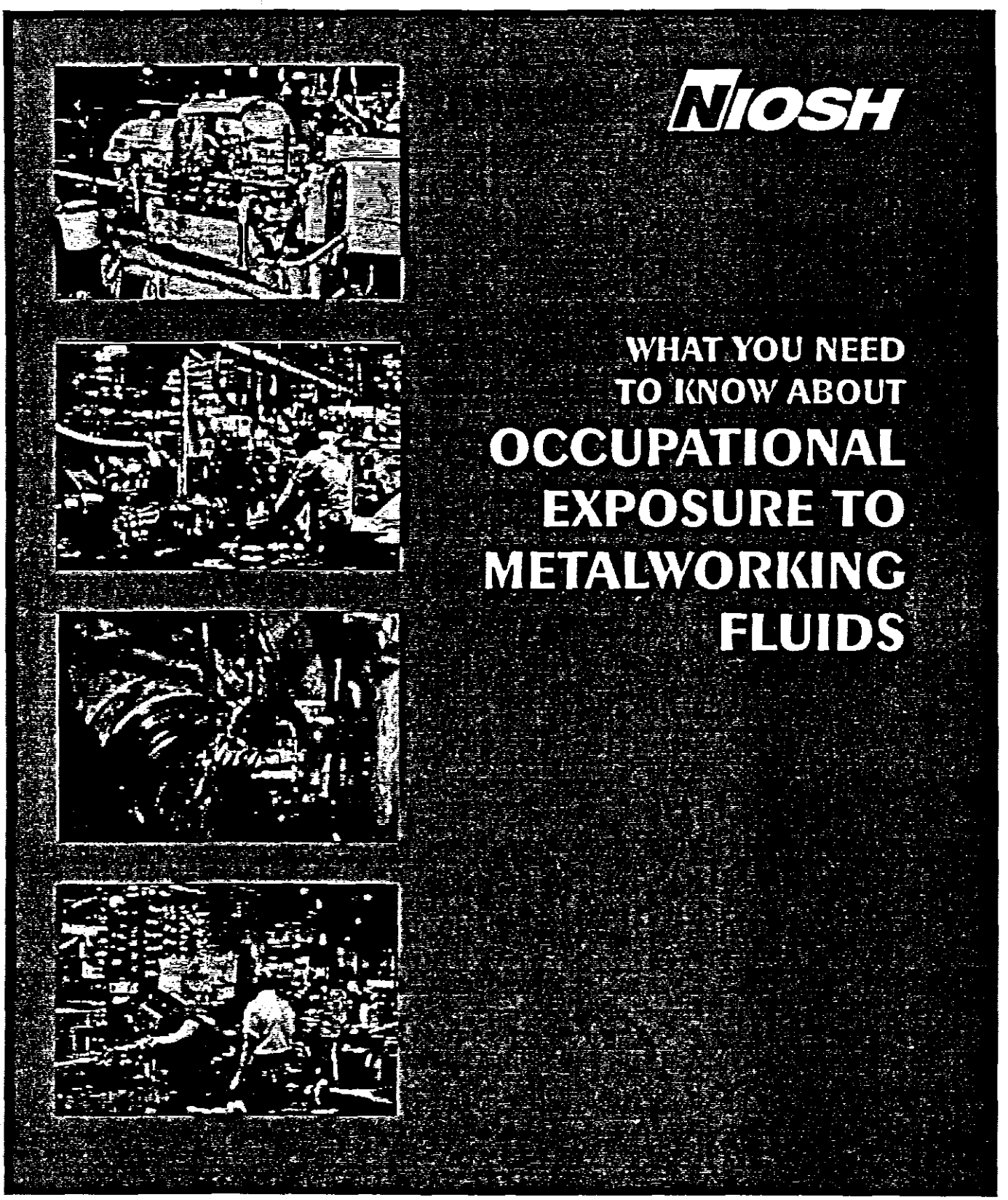
NIOSH [1992]. Recommendations for occupational safety and health: compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 92-100.

NIOSH [1994]. NIOSH manual of analytical methods. 4th ed. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94-113.

NIOSH [1998]. Criteria for a recommended standard: Occupational exposure to metalworking fluids. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 98-102.

Public Law 91-596. Occupational Safety ad Health Act of 1970, Sec 5(a)(1).

APPENDIX III



What you need to know about

OCCUPATIONAL EXPOSURE TO METALWORKING FLUIDS

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

March 1998

The National Institute for Occupational Safety and Health (NIOSH) is part of the Centers for Disease Control and Prevention (CDC) within the Department of Health and Human Services. NIOSH is the federal Institute responsible for conducting research and making recommendations for the prevention of work-related injuries and illnesses.

DHHS (NIOSH) Publication No. 98-116

Table of Contents

Foreword iii

Section 1 - Introduction 1

Section 2 - Occupational Exposures to Metalworking Fluids 3

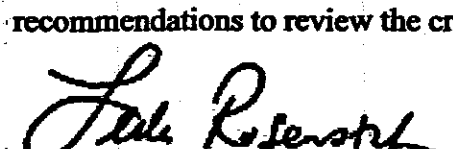
Section 3 - Recommendations for an Occupational Safety and Health Program 13

References 29

Foreword

This document summarizes the findings of the recently released NIOSH Criteria for a Recommend Standard Occupational Exposure to Metalworking Fluids. According to the Occupational Safety and Health Act of 1970 (Public Law 95-164), the National Institute for Occupational Safety and Health (NIOSH) is charged with recommending occupational safety and health standards and describing exposure concentrations that are safe for various periods of employment–including but not limited to concentrations at which no worker will suffer diminished health, functional capacity, or life expectancy as a result of his or her work experience. The metalworking fluids criteria document provides the scientific basis for NIOSH's recommended occupational health standard for occupational exposure to metalworking fluids. It contains a critical review of the scientific and technical information available on the extent and type of health hazards associated with metalworking fluids and the adequacy of control methods.

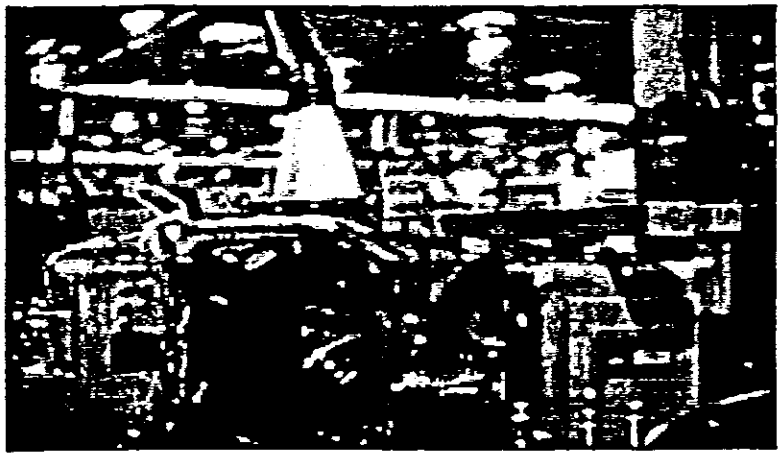
This document represents the first effort by NIOSH to develop simultaneously both a companion educational document and a criteria document. NIOSH uses criteria documents to communicate these recommended standards to regulatory agencies (including the Occupational Safety and Health Administration [OSHA]) and to others in the occupational safety and health community. The companion educational document is intended to communicate the basic information from the criteria document to health professionals, industry, organized labor, public interest groups, government agencies, and other interested groups or individuals. We encourage readers who are interested in examining in more detail the scientific evidence on the health effects of metalworking fluids and the basis of the NIOSH recommendations to review the criteria document.



Linda Rosenstock, M.D., M.P.H.
Director, National Institute for Occupational Safety Health
Centers for Disease Control and Prevention

Section 1 - Introduction

For purposes of this document, metalworking fluids (MWFs) are fluids used during machining and grinding to prolong the life of the tool, carry away debris, and protect the surfaces of work pieces. These fluids reduce friction between the cutting tool and the work surface, reduce wear and galling, protect surface characteristics, reduce surface adhesion or welding and carry away generated heat.



Gear Cutting

Workers can be exposed to MWFs by inhaling aerosols (mists) and by skin contact with the fluid. Skin contact occurs by dipping the hands into the fluid, splashes, or handling workpieces coated with the fluids. The amount of mist generated (and the resulting level of exposure) depends on many factors: the type of MWF and its application process; the MWF temperature; the specific machining or grinding operation; the presence of splash guarding; and the effectiveness of the ventilation system in capturing and removing the mist.

Substantial scientific evidence indicates that workers currently exposed to MWF aerosols have an increased risk of respiratory [lung] and skin diseases. These health effects vary based on the type of MWF, route of exposure, concentration, and length of exposure.

To reduce the potential health risks associated with occupational exposures to metalworking fluids (MWFs), NIOSH recommends an exposure limit (REL) for MWF aerosol of 0.4 mg/m^3 for thoracic particulate mass (the portion of the aerosol that penetrates below the larnyx in the respiratory system) as a time-weighted average (TWA) concentration for up to 10 hours per day during a 40-hour work week.[1] Because of the limited availability of thoracic samplers, measurement of total particulate mass is an acceptable substitute (see footnote 1 for details). The REL for total particulate mass is 0.5 mg/m^3.

The REL of 0.4 mg/m^3 is based on four major considerations:

- the adverse respiratory health effects of MWF exposure;
- the selection of an index for measuring MWF aerosol exposure;
- the universal applicability of the REL to all types of MWFs; and,
- the technological feasibility of the REL.

NIOSH also recommends the development and implementation of occupational safety and health programs, engineering controls, fluid management and medical monitoring to reduce MWF exposures.

These recommendations are intended to prevent or greatly reduce respiratory disorders causally associated with MWF exposure. Whenever possible, reduce MWF aerosol levels below 0.4 mg/m^3 (thoracic particulate mass) because some workers have developed work-related asthma or hypersensitivity pneumonitis at MWF exposures below the NIOSH recommended exposure level. It is also important to limit exposure levels based on the association between some past MWF exposures and various cancers and because the minimization of exposures by skin contact helps prevent allergic and irritant skin disorders.

---

[1] NIOSH recommends the use of NIOSH method #0500 for the sampling and analysis of MWF aerosols (mist). In order to convert the total particulate measurement into an equivalent thoracic particulate result, divide the total concentration by a correction factor of 1.25 (or other factor experimentally measured for that operation) [conversion factor adapted by Baron from the data of Woskie et al., 1994]. As a result, the REL of 0.4 mg/m^3 thoracic particulate mass is equivalent to a 0.5 mg/m^3 total particulate mass.

Section 2 - Occupational Exposures to MWFs

There are four different classes of metalworking fluids.

Metalworking fluids are grouped into four major classes:

1. ***Straight oil (neat oil) MWFs*** are severely solvent-refined petroleum oils (lubricant-base oils) or other animal, marine, vegetable, or synthetic oils used singly or in combination and with or without additives. Straight oils are not designed to be diluted with water.

2. ***Soluble oil (emulsifiable oil) MWFs*** are combinations of 30% to 85% severely refined lubricant-base oils and emulsifiers that may include other performance additives. Soluble oils are diluted with water at ratios of 1 part concentrate to 5B40 parts water.

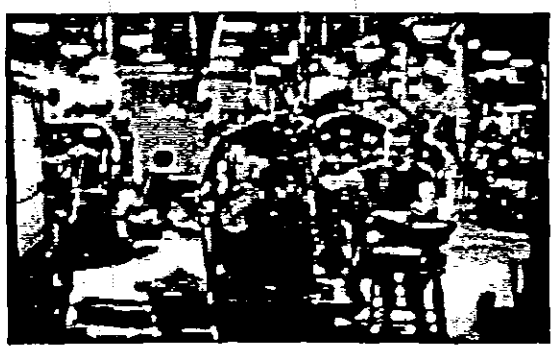
3. ***Semisynthetic MWFs*** contain a lower amount of severely refined lubricant-base oil in the concentrate (5% to 30%), a higher proportion of emulsifiers, and 30% to 50% water. The transparent concentrate is diluted with 10 to 40 parts water.

4. ***Synthetic MWFs*** contain no petroleum oils and may be water soluble or water dispersible. The synthetic concentrate is diluted with 10 to 40 parts water.

Occupational exposures to MWFs occur by inhalation and skin contact.

During machining operations, MWF exposures can occur by inhalation and skin contact.

- Skin contact usually occurs when the worker dips his/her hands into the fluid, floods the machine, tool, or work, or handles parts, tools, and equipment covered with fluid, without the use of personal protective equipment



Turning (Chucker)

such as gloves and aprons. Skin contact can also results from fluid splashing onto the worker from the machine if guarding is absent or inadequate.

- Inhalation exposures result from breathing MWF mist or aerosol. The severity of the exposure depends on a wide variety of factors. In general, the exposure will be higher if: the worker is in close proximity to the machine, the operation involves high tool speeds and deep cuts, the machine is not enclosed, or if ventilation equipment was improperly selected or poorly maintained. In addition, high-pressure and/or excessive fluid application, contamination of the fluid with tramp oils, and improper fluid selection and maintenance will tend to result in higher exposures.

MWFs may contain potentially hazardous chemical ingredients, additives, and contaminants.

Each MWF class consists of a wide variety of chemicals used in different combinations and the risk these chemicals pose to workers may vary because of different manufacturing processes, various degrees of refining, recycling, improperly reclaimed chemicals, different degrees of chemical purity, and potential chemical reactions between components.

Workers may be exposed to a variety of contaminants.

Exposure to hazardous contaminants in MWFs may present health risks to workers. Contamination may occur from (1) process chemicals and ancillary lubricants inadvertently introduced, (2) contaminants, metals, and alloys from parts being

machined, (3) water and cleaning agents used for routine housekeeping, and (4) contaminants from other environmental sources at the worksite. In addition, bacterial and fungal contaminants may metabolize and degrade the MWFs to hazardous end-products as well as produce endotoxins.

Workers may be exposed to microorganisms and hazardous end products.

Water-based MWFs are excellent nutritional sources for many kinds of bacteria and fungi. The predominant microbial species routinely recovered from MWFs are virtually identical to those routinely recovered from natural water systems. Anaerobic bacteria, specifically the sulfate reducers, may produce hydrogen sulfide and other disagreeable and toxic gases.

Research suggests that microorganisms and/or their products such as endotoxins may cause some of the respiratory health effects seen in exposed workers. However, this research has not determined the specific role that the contaminating microorganisms play in causing MWF associated respiratory effects.

At this time, insufficient health data exists to recommend a specific limit for bacterial or fungal concentrations in contaminated MWFs. However, their potential as health hazards for exposed workers must not be minimized. A total MWF system management program should be used to protect workers. This program should include:

- careful fluid monitoring, record keeping and maintenance;
- use of biocides only as a preventive measure and not for the cure of microbial overgrowth;
- a system of mist control including close-capture ventilation, and machine enclosures; and
- training for employees on the hazards and proper use of the MWFs.

The improper use of biocides to manage microbial growth may result in potential health risks.

Attempts to manage microbial growth solely by the incorporation or addition of biocides may result in the emergence of biocide-resistant strains from complex

interactions that may occur among different member species or groups within the population. For example, the growth of one species may result in conditions more (or less) favorable for the establishment of future species, or the elimination of one group of organisms may permit the overgrowth of another. Studies also suggest that exposure to certain biocides can cause either allergic or contact dermatitis.

Occupational exposures to MWFs cause potential health risks, including: dermatological (skin) disorders, and lung disease.

NIOSH has conducted more than 70 on site Health Hazard Evaluations (HHEs) of industries with occupational exposures to MWFs or mineral oil aerosols. Exposed workers most often reported skin disorders (skin irritation, rashes, oil acne) followed by eye, nose, and throat irritation, and respiratory symptoms or disorders (breathing problems, cough, chest tightness, asthma).

Dermatological Conditions:

Workers potentially exposed to MWFs suffer a high rate of skin diseases. In 1991, the list of industries with the highest incidence rates for skin disorders (e.g. fabricated, screw machine products, and general industrial machinery) all involved potential MWF exposure.

Several different skin diseases can result from skin contact with MWFs. In general, reports link straight MWFs to folliculitis, oil acne, and keratoses; and soluble, semisynthetic and synthetic MWFs with irritant contact dermatitis and less frequently with allergic contact dermatitis.

Contact dermatitis (either irritant contact dermatitis or allergic contact dermatitis) is the most commonly reported skin disease associated with MWFs. The high prevalence of dermatitis rates indicates the susceptibility of many workers to the irritating or sensitizing nature of MWFs and contaminants. Despite the high reporting rate, many workers continue to work even with skin lesions and considerable discomfort from burning and itching. Some of these workers eventually are disabled as a result of their skin disorders.

Many factors play a role in the development of contact dermatitis and other skin diseases in workers exposed to MWFs. These factors include:

- the MWF class and additives used;
- the amount of skin contact with MWFs (e.g., through splashing or repeated or prolonged immersion);
- skin abrasion or cuts;
- individual susceptibility to irritants or allergens present in MWFs;
- inadequate cleansing of the skin after skin contact;
- the irritant nature of some soaps/detergents and other cleansing materials used by the workers;
- reuse of MWF-soaked clothing and other materials;
- use of personal protective equipment such as face shields, clean and nonirritating/nonsensitizing gloves and aprons;
- the cleanliness of the general work environment;
- climate (high or low humidity and hot, warm, or cold temperatures);
- machine types and operations, and engineering control methods (e.g., especially tight fitting machine enclosures) in place and in use.

Dermatitis prevention is important because of the poor prognosis for workers with MWF dermatitis and because worker protection and engineering controls can achieve primary prevention by limiting dermal exposure to MWFs. Other preventive measures include:

- substitution of safe, less irritating or nonallergenic additives or MWF constituents;
- process modification and isolation to limit the dispersal of MWFs;
- work practice and administrative controls to assure the proper MWF maintenance and workplace cleanliness;
- the proper use of personal protective equipment such as protective gloves, aprons, and clothing; and
- the education of the workers regarding dermal effects due MWF contact, and the importance of workplace personal hygiene.

Cancer

Substantial evidence indicates that some MWFs are associated with an increased risk of larynx, rectum, pancreas, skin, scrotum, and bladder cancer. Because the time between initial exposure to a carcinogen and the appearance of most types of cancer is often 20 or more years, these studies most likely reflect the cancer risk associated with exposure conditions in the mid-1970s and earlier. It should be noted that the studies results were not highly consistent with respect to the specific types of cancer which were associated with MWF. In addition, the specific MWF constituent(s) or contaminant(s) responsible for the various cancers remain to be determined. The inconsistencies in the results, and the inability to identify the responsible MWF constituent(s) or contaminant are a likely result of the diverse nature of the MWF mixtures studied, and the absence of detailed exposure information.

Over the last several decades, the metalworking industry has made substantial changes including changes in MWF composition and reduction in MWF impurities and exposure concentrations. Efforts have been made to reduce potentially carcinogenic MWF additives and impurities with the removal of polynuclear aromatic hydrocarbons (PAHs) from MWFs beginning in the 1950s, and the EPA enacting regulations in the 1980s directed at reducing nitrosamine exposures. It is likely that the changes have reduced the cancer risks, but the data are insufficient to conclude that these changes have eliminated all cancer risks. Thus, the risk of cancer from MWF exposures later than the mid-1970s remains to be determined. However, both the substantial evidence which associates some MWFs used before the mid-1970s with cancer at several organ sites, and the potential for current MWFs to pose a similar carcinogenic hazard supports the NIOSH recommendation to reduce MWF aerosol exposures.

Lung Disease:

The primary basis for the NIOSH recommendation is the risk that MWFs pose for nonmalignant respiratory disease. Occupational exposure to MWF aerosols may cause a variety of respiratory conditions, including lipid pneumonia, hypersensitivity pneumonitis, asthma, acute airways irritation, chronic bronchitis, and impaired lung function. While, the most diseases of the deep lung–lipid pneumonia,

hard metal disease, and legionellosis–appear relatively unusual in workers exposed to MWF aerosols, hypersensitivity pneumonitis is recently emerging as an important risk among workers exposed to MWF aerosol; and substantial evidence indicates that workers currently exposed to MWF aerosols have an elevated risk of airways disorders, including asthma.

MWF-Induced Asthma

Workers exposed to synthetic, soluble and straight MWFs have an increased risk of work-related asthma, as seen below:

Synthetic MWFs - In one study the adjusted risk estimate for workers exposed to synthetic MWF aerosol was about three times the risk relative for unexposed workers. Risk estimates were elevated in all three studies of asthma and exposure to synthetic MWF aerosol, although the finding in one study was not statistically significant.

Soluble MWFs - The evidence associating asthma and exposure to soluble oil MWF aerosol is somewhat less consistent than that for synthetic MWFs, but more studies have investigated this relationship. Only two studies presented elevated risk estimates that were statistically significant, but five of the seven epidemiologic studies of soluble oil MWF exposures reported elevated risk estimates for asthma, with point estimates ranging upward from 1.7. Overall, the preponderance of evidence associated asthma with exposure to soluble oil MWF aerosol.

Straight MWFs - The epidemiologic evidence for an association between asthma and exposure to straight oil MWF aerosol is less convincing than that for synthetic and soluble oil MWFs. None of the five studies of straight oil MWFs documented a significantly increased risk, one did not include an unexposed group necessary to derive a risk estimate, and two of the other four studies did have a nonsignificant elevated risk. Some clinical case reports suggest that asthma is associated with exposure to straight oil MWF aerosol or to compounds commonly found in straight oil MWFs. Overall, the risk of asthma exists but is likely to be lower with exposure to straight oil MWF aerosol than with exposure to aerosol from other classes of MWFs.

MWF-induced asthma appears to involve known sensitizers in some cases but various other agents (possibly acting through irritant or inflammatory mechanisms) may cause a high proportion of cases. These sensitizers and irritants include ethanolamine and other amines, colophony, pine oil, tall oil, metals and metallic salts (e.g., chromium, nickel), castor oil, formaldehyde, chlorine, various acids, and microbial contaminants including Gram-negative bacterial endotoxin.

Studies of acute drops in lung function over a work shift also provide evidence that exposure to MWF aerosol is associated with asthma. In three of four pertinent studies, workers were more likely to experience acute loss of lung function as the level of exposure to MWF aerosol increased.

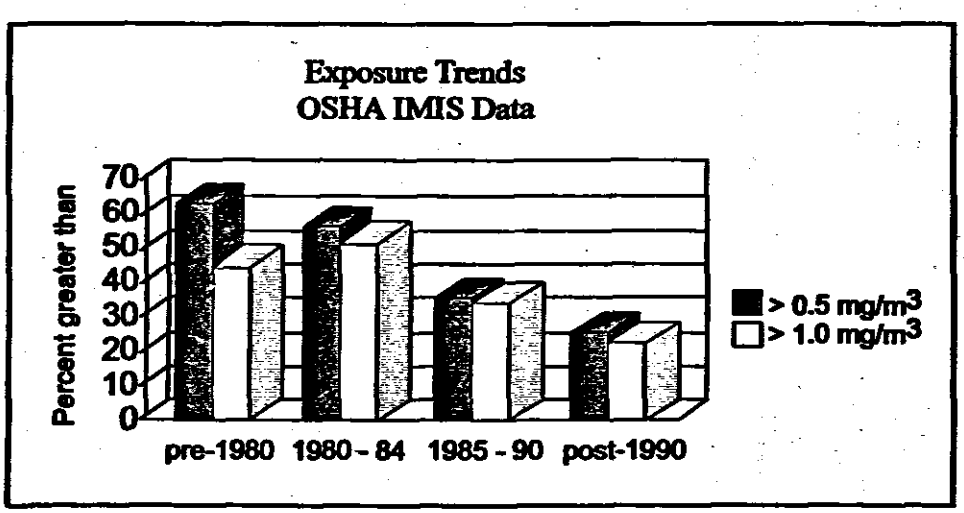
Respiratory Effects Other Than Asthma

Studies of lung function provide some evidence that MWF aerosol exposure can also cause an adverse chronic effect. Overall, this evidence provides limited support for associating MWF aerosol exposures above the REL with a chronic reduction in lung function. More convincing, all but one of the ten studies of symptoms provide consistent and compelling evidence that occupational exposure to MWF aerosol, for each class of MWFs (straight, soluble, and synthetic) and at concentrations at or above the REL, causes chronic respiratory symptoms. Currently, no clear evidence identifies any component(s) of MWF aerosol as the predominant cause of these symptoms.

In addition to work-related asthma and chronic airway effects, recent outbreaks of hypersensitivity pneumonitis [HP] have been associated with exposure to aerosols of synthetic, semisynthetic, and soluble oil MWFs (all of which are water-based or diluted with large amounts of water) at concentrations both above and below the REL. Microbial contaminants in MWFs are postulated to be the most likely cause of these HP outbreaks. Some workers with HP have been able to return to jobs that involve no MWF exposure or to jobs that involve exposure to a different MWF. It is not clear whether reducing MWF aerosol exposure concentrations alone will effectively reduce the risk of HP.

Reducing MWF exposures to concentrations below the REL, whenever feasible, should decrease the number of new cases of MWF-related asthma and the risk of chronic airways disease in exposed working populations.

Based on the evidence of increased asthma risk in some studies and the clearly increased risk of respiratory symptoms and acute lung function changes with exposures above the REL, reducing MWF exposures to concentrations below the REL, whenever feasible, should decrease the number of new cases of MWF-related asthma in exposed working populations. The prevention of asthma is an important priority because, although clinical asthma may be mild in many affected workers, it can sometimes be debilitating. Occupational asthma frequently persists as a chronic condition even after affected workers are removed from exposure. NIOSH is concerned that the same may be true for MWF-related asthma.



Reducing MWF exposures should also decrease the risk of chronic airways disease. Repeated, modest acute airways effects from chronic exposure to MWF aerosol–though apparently reversible when workers are removed from exposure–may ultimately lead to irreversible impairment and chronic pulmonary disability. Numerous studies link acute effects and chronic lung impairment for a variety of other occupational respiratory hazards. Although no studies have attempted to

relate acute decrements caused by MWF aerosols with chronic airways obstruction among exposed metalworkers, NIOSH is concerned that long-term exposure to MWFs may cause chronic lung impairment in workers who experience acute respiratory effects.

An opportunity exists to reduce respiratory conditions in the many thousands of metalworkers exposed to MWF aerosol concentrations greater than the REL by reducing exposures to below the REL. The onset or worsening of many symptoms over a work-shift, as well as reported substantial symptomatic improvement experienced by many affected workers when away from work, suggest opportunities not only for reversing early MWF-induced airways effects, but also for preventing chronic effects induced by occupational exposure to MWF aerosol, through control of worker exposure to MWF aerosols.

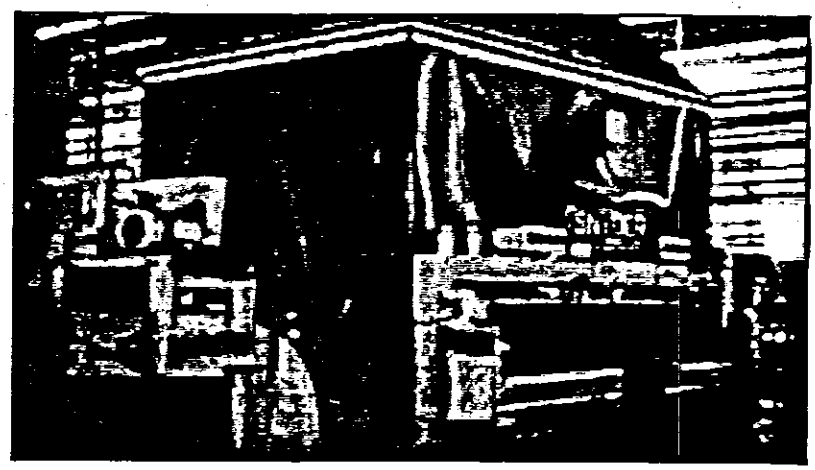
The recent decline in worker MWF exposure levels suggests that developed control technologies can significantly reduce exposure concentration levels.

Major changes introduced into the U.S. machine tool industry over the last several decades have increased the overall consumption of MWFs. Specifically, the use of synthetic MWFs increased as tool and cut speeds increased. At the same time, technological advances allowed the partial enclosure of machines and the application and use of local exhaust ventilation. During the 1970s and 1980s, many U.S. plants installed recirculating air cleaners, improved the recirculating air filtration systems, and renovated the factories.

In the automotive industry these changes resulted in a significant decline in worker exposures to airborne MWFs over a 30-year period (1958-1987). Since 1987, the exposures in the automotive industry have continued to decline. The NIOSH health hazard evaluation (HHE) program (1972-1993) and the Integrated Management Information System (IMIS) of OSHA have also reported decreases worker exposure to airborne MWFs. The trend of declining exposure concentrations suggests that developed control technologies can significantly reduce exposure concentration levels.

Section 3 - Recommendations for an Occupational Safety and Health Program

In addition to the REL, NIOSH recommends that employer's develop and implement a comprehensive safety and health program as part of their management system. This program must have strong management commitment, worker involvement, and include four major components: (1) safety and health training, (2) worksite analysis, (3) hazard prevention and control, and (4) medical monitoring of exposed workers.



Poor Enclosures

1. Safety and Health Training

Employers should establish a safety and health training program for all workers potentially exposed workers to MWFs. This training program should:

- enable workers to identify potential workplace hazards;
- inform employees and contract workers about any hazardous chemicals in their work areas and the adverse health effects associated with MWF exposures;

- provide information on material safety data sheets (MSDSs) and other information sources;
- teach workers how to detect hazardous situations (e.g., appearance of bacterial overgrowth and degradation of MWFs) and how they can protect themselves (e.g., the use of appropriate work practices, emergency procedures, and personal protective equipment); and,
- encourage workers to maintain good personal hygiene and housekeeping practices to help prevent environmental contamination of the MWFs.

2. Worksite Analysis

An effective workplace monitoring program should include routine environmental monitoring of dermal and inhalation exposures. Environmental monitoring and sampling can help assess the effectiveness of engineering controls, work practices, and personal protective equipment and help determine the likelihood that a workplace exposure caused the worker's symptoms.

The initial environmental sampling survey should use personal sampling techniques for the entire work shift, concentrating on work areas where airborne MWF exposures may occur. Each survey should evaluate the workers' potential skin exposures and all routine personal samples (including samples representative of the full-shift time-weighted average exposure to airborne MWFs) should be collected in the worker's breathing zone. Few full-shift samples, if any, should exceed the recommended exposure limit.

Each exposure measurement should represent actual worker exposure. Periodic sampling of all workers or worker groups will ensure that the targeted sampling includes all workers with exposure potentials above the REL. Conduct airborne exposure measurements at least every six months for workers with exposure levels at or above one-half of the REL, or more frequently as indicated by an industrial hygienist. Notify workers of the results of all sampling and increase monitoring of exposed workers until at least two samples indicate that the exposure no longer exceeds the REL. Notify workers of additional monitoring and explain control actions taken to reduce their exposures.

3. Hazard Prevention and Control

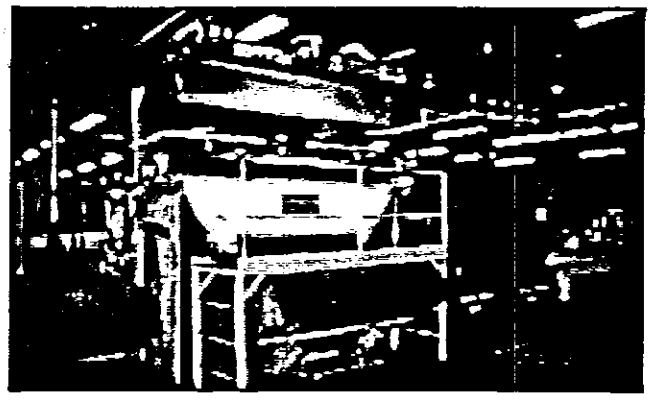
Proper MWF selection and application, fluid maintenance, isolation of the operation(s), ventilation, and other operational procedures can prevent or minimize inhalation of MWF aerosols. Dermal exposures may be reduced by the use of machine guarding and protective equipment such as gloves, face guards, aprons, or other protective work clothes.

Fluid Selection

The MWFs selected should be as nonirritating and nonsensitizing as possible while remaining consistent with operational requirements. Petroleum-containing MWFs should be evaluated for potential carcinogenicity using ASTM Standard D1687-95, *Determining Carcinogenic Potential of Virgin Base Oils in Metalworking Fluids*. If soluble oils or synthetic fluids are used, ASTM Standard E1497-94, *Safe Use of Water-Miscible Metalworking Fluids* should be consulted for safe-use guidelines, including product selection, storage, dispensing, and maintenance. To minimize the potential for nitrosamine formation, nitrate-containing materials should not be added to MWFs containing ethanolamines.

Fluid Use and Application

Many factors influence the generation of MWF mists, which can be minimized through the proper design and operation of the MWF delivery system. ANSI Technical Report B11 TR 2-1997 (*Mist Control Considerations for the Design, Installation and Use of Machine Tools Using Metalworking Fluids*) [ANSI 1997], provides directives for minimizing mist and vapor generation. These include



Fluid Filter

minimizing fluid delivery pressure, matching the fluid to the application, using MWF formulations with low oil concentrations, avoiding contamination with tramp oils, minimizing the MWF flow rate, covering fluid reservoirs and return systems where possible, and maintaining control of the MWF chemistry. Also, proper application of MWFs can minimize splashing and mist generation. Proper application includes:

- applying MWFs at the lowest possible pressure and flow volume consistent with provisions for adequate part cooling, chip removal, and lubrication;
- applying MWFs at the tool/work piece interface to minimize contact with other rotating equipment;
- ceasing fluid delivery when not performing machining;
- not allowing MWFs to flow over the unprotected hands of workers loading or unloading parts; and,
- using mist collectors engineered for the operation and specific machine enclosures.

Properly maintained filtration and delivery systems provide cleaner MWFs, reduce mist, and minimize splashing and emissions. Proper maintenance of the filtration and delivery systems includes:

- the selection of appropriate filters;
- ancillary equipment such as chip handling operations, dissolved air-flotation devices, belt skimmers, chillers or plate and frame heat exchangers, and decantation tanks;
- guard coolant return trenches to prevent dumping of floor wash water and other waste fluids;
- covering sumps or coolant tanks to prevent contamination with waste or garbage (e.g., cigarette butts, food, etc.); and
- keeping the machine(s) clean of debris.

Fluid Maintenance

A key element in controlling worker exposure to MWFs is the development of a written MWF management plan. Components of this plan should include maintenance of the fluid chemistry as well as the fluid filtration and delivery systems.

Temperature

Store the drums, tanks, or other containers of MWF concentrates in an area that will protect them from outdoor weather conditions and exposure to low or high temperatures. MWFs should be maintained at as low a temperature as is practical. Low temperatures slow the growth of microorganisms, reduce water losses and change in viscosity, and in the case of straight oils, reduce the fire hazard risks. Extreme temperature changes may destabilize the fluid concentrates, especially concentrate mixed with water, and cause water to seep into unopened drums encouraging bacterial growth in the fluids.

Concentration Levels

Routinely monitor MWFs and keep records of the fluid levels in the sump or coolant tank, the MWF concentration (maintain within the pH and concentration ranges recommended by the formulator or supplier), the fluid pH, and the degree of tramp oil contamination (by visual inspection). Increase testing during hot weather or increased work output, both of which may result in increased fluid losses.

To maintain proper MWF concentrations, do not top off with water or concentrate. Rather, prepare the MWF emulsion by first adding the concentrate to the clean water (in a clean container) and then adding the emulsion to the solution in the coolant tank. Mix the MWFs just before use and do not store large amounts because of potential deterioration.

Personal Protective Clothing

Always wear personal protective clothing and use protective equipment when removing concentrates from the original container, mixing and diluting MWF

concentrate, preparing additives (including biocides), and adding MWF emulsions, biocides or other potentially hazardous ingredients to the coolant reservoir. Personal protective clothing includes eye protection or face shields, gloves, and aprons which do not react with but rather shed MWF ingredients and additives.

Service

Regular service of coolant systems and maintenance of the machines will prevent contamination of the fluids by tramp oils (e.g., hydraulic oils, gear box oils, and machine lubricants leaking from the machines or total loss slideway lubrication). Tramp oils can destabilize emulsions, cause pumping problems and clog filters. Tramp oils can also float to the top of MWFs effectively sealing the fluids from the air, allowing metabolic products (such as volatile fatty acids, mercaptols, scatols, ammonia, and hydrogen sulfide) produced by the anaerobic and facultative anaerobic species growing within the biofilm to accumulate in the reduced state. A variety of methods can remove tramp oils, including: centrifugal liquid/liquid separators, coalesces, oleophilic belts and ropes, skimmers, and vacuum. In work situations that involve high lubrication losses, consider the use of continuous removal systems.

Thoroughly clean all parts of the system when replacing MWFs because microorganisms grow on surfaces whenever possible. Some bacteria, such as *Pseudomonas* and *Flavobacter* species secrete layers of slime and may grow in stringy configurations that resemble fungal growth. Many bacteria secrete polymers of polysaccharide and/or protein, forming a glycocalyx, which cements cells together much as mortar holds bricks. Fungi may grow as masses of hyphae, forming mycelial mats. This attached community of microorganisms appears as a biofilm and may be very difficult to remove by ordinary cleaning procedures. Cleaning methods include: steam, vacuum, disinfectant solutions, or commercial chemical cleaners. Use a cleaning method compatible with the type of MWF.

Biocide Treatment

Biocides maintain the functionality and efficacy of MWFs by preventing microbial overgrowth. Biocides with a wide spectrum of biocidal activity should be used to suppress the growth of the widely diverse contaminant population. Only

the concentration of biocide needed to meet fluid specifications should be used, since overdosing could lead to skin or respiratory irritation in workers, and under-dosing could lead to an inadequate level of microbial control.

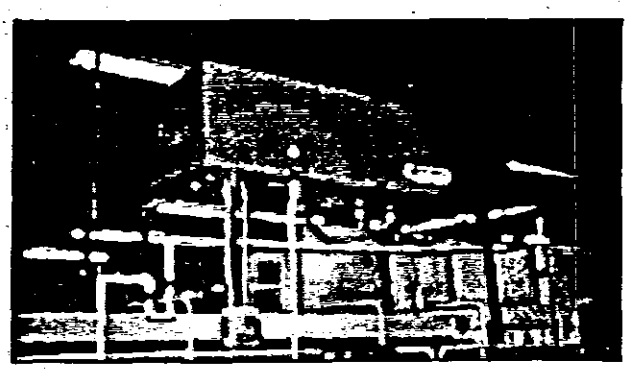
Isolation

Isolation of the worker through mechanical parts handling equipment and machine enclosures can minimize skin and inhalation exposure. Simple splash guarding may suffice for low production machines. While high production machines require complete enclosure (with ventilation). Locate transfer machines away from other operations and protect workers with isolation booths or fresh air showers.

Ventilation Systems

The ventilation system should be designed and operated to prevent the accumulation or recirculation of airborne contaminants in the workplace. The following publications present general principles for the design and operation of ventilation systems:

> *Industrial Ventilation: A Manual of Recommended Practice*;
> *American National Standard: Fundamentals Governing the Design and Operation of Local Exhaust Systems*; and
> *Recommended Industrial Ventilation Guidelines*.

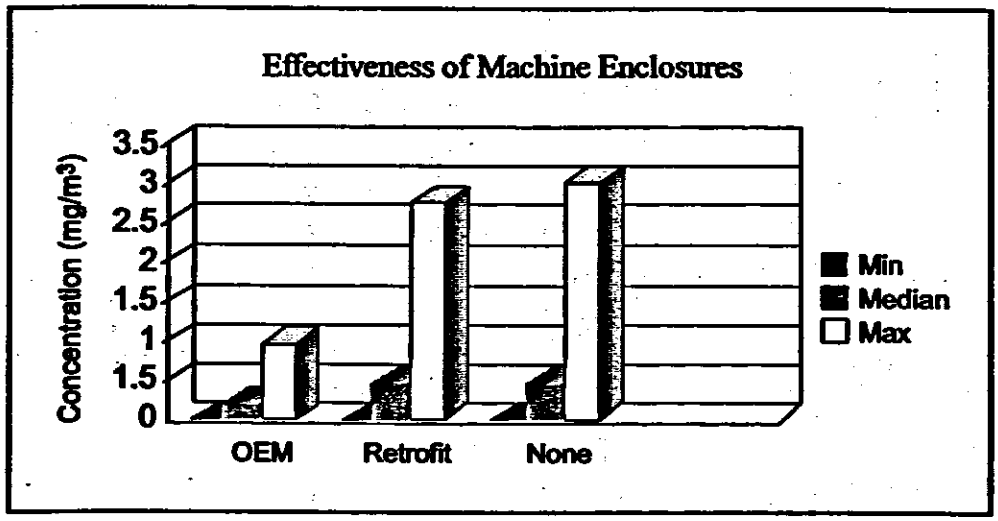


Exhaust Air Recirculation

OEM Enclosure

Exhaust ventilation systems function through suction openings placed near a source of contamination. The suction opening or exhaust hood creates an air motion sufficient to overcome room air currents and any airflow generated by the process. This airflow captures the contaminants and conveys them to a point where they can either be discharged or removed from the airstream. Exhaust hoods are classified by their position relative to the process as *canopy, side draft, down draft* or *enclosure*. ANSI Technical Report B11 TR 2-1997 [ANSI 1997] contains guidelines for exhaust ventilation of machining and grinding operations. Enclosures are the only type of exhaust hood recommended by the ANSI committee. They consist of physical barriers between the process and the worker's environment. Enclosures can be further classified by the extent of enclosure: close capture (enclosure of the point of operation), total enclosure (enclosure of the entire machine), or tunnel enclosure (continuous enclosure over several machines).

If no fresh make up air is introduced into the plant, air will enter the building through open doors and windows, potentially causing cross-contamination of all process areas. Ideally, all air exhausted from the building should be replaced by tempered air from an uncontaminated location. By providing a slight excess of make up air in relatively clean areas and a slight deficit of make up air in dirty areas, cross-contamination can be reduced. In addition, this air can be channeled directly to operator work areas, providing the cleanest possible work environment. Ideally, this fresh air should be supplied in the form of a low-velocity air shower (<100 ft/min to prevent interference with the exhaust hoods) directly above the worker.



Protective Clothing and Equipment

Engineering controls are used to reduce worker exposure to MWFs. But in some situations, the added protection of chemical protective clothing (CPC) and respirators should be provided in the event of dermal contact with the MWFs or airborne exposures that exceed the REL. Maintenance staff may also need CPC because the nature of the work requires contact with MWFs during certain operations. All workers should be trained in the proper use and care of CPC. After any item of CPC has been in routine use, it should be examined to ensure that its effectiveness has not been compromised.

If respiratory protection is needed, the employer should establish a comprehensive respiratory protection program as outlined in the *NIOSH Respirator Decision Logic* and the *NIOSH Guide to Industrial Respiratory Protection* and as required in the OSHA respiratory protection standard. Respirators should be selected by the person who is in charge of the program and knowledgeable about the workplace and the limitations associated with each type of respirator.

Selection of the appropriate respirator depends on the operation, MWF chemical components, and airborne concentrations of MWFs in the worker's breathing zone. Guidance on the selection of respirators can be found in the *NIOSH Respirator Decision Logic.*

Sanitation and Hygiene

Workers should keep personal items such as food, drink, cosmetics, and tobacco separate from the work environment to prevent any unnecessary additional exposures to MWFs. Employers should establish a "no smoking" policy because cigarette smoke may exacerbate the respiratory effects of MWF aerosols.

Training and instruction in personal hygiene will help reduce potential dermal MWF exposures. Workers should promptly clean exposed skin contaminated with MWFs with gentle soaps, clean water, and clean towels, and should change from contaminated work clothes into street clothes before leaving work. If possible, workers should shower and change into clean clothes at the end of the work shift.

Keep the floors, equipment and general work environment clean. Do not dump or sweep wastes, including floor wash water, into MWF sumps or coolant return trenches.

Labeling and Posting

Employers should train workers on OSHA Hazard Communication labeling standards. Labels must inform workers of chemical exposure hazards, potential adverse health effects, and appropriate methods for self-protection. Post labels and signs on, or near, hazardous metalworking processes to provide an initial warning to other workers who may not routinely work near the processes and transient nonproduction workers. Depending on the process and exposure concentration, warning signs should state a need to wear protective clothing or an appropriate respirator for regular exposure to MWF aerosol greater than the REL. Post all labels and warning signs in both English and the predominant language of workers who do not read English.

4. Medical Monitoring of Exposed Workers

As indicated by the research, the 0.4-mg/m^3 (thoracic particulate mass) REL for MWF aerosol does not remove all risk for the development of skin or respiratory disease among exposed workers. Medical monitoring is therefore needed for early identification of workers who develop symptoms of MWF-related conditions such as asthma, HP, and dermatitis. If identified early, affected workers can control their exposures and minimize their risks of acute or chronic effects. Another important objective of medical monitoring is to provide standardized data on exposed workers to identify work areas in need of additional primary prevention efforts.

All exposed workers should be included in an occupational medical monitoring program. However, priority should be given to those at highest risk. Medical monitoring should be conducted regardless of exposure concentration in work areas where one or more workers have recently developed asthma, HP, or other serious conditions apparently related to MWF exposure.

The medical monitoring program should provide all workers with information about the purposes of the program, the potential health-protection benefits of participation, and a description of the procedural aspects of the program. This information should include the use of routine test results, potential actions based on these results, who has access to individual results of routine medical monitoring and of more detailed medical evaluations, and how confidentiality is maintained.

A qualified physician (or other qualified health care provider as determined by appropriate state laws and regulations), informed and knowledgeable about the following, should direct and supervise the medical monitoring program:

- the respiratory protection program and types of personal respiratory protection devices available at the workplace,

- the identification and management of occupational asthma and other work-related respiratory effects or illnesses (including preexisting asthma exacerbated by occupational exposures), and

- the identification and management of occupational skin diseases.

Information Provided to Program Supervisor/Director

The employer should provide the supervisor/director with specific information for each worker covered by the medical monitoring program. This information should include current and previous job assignments/descriptions, potential hazardous exposures, actual exposure measurements, personal protective equipment provided/used, relevant material safety data sheets, and applicable occupational safety and health standards. If a worker is referred to others for either periodic examinations or detailed evaluations, the initial examiner should provide the appropriate information to all future examiners.

Initial or Preplacement Examination

Each worker included in the medical monitoring program should receive an initial medical examination. For newly hired workers and workers transferred from an unexposed work area, this examination should occur before assignment to a job associated with exposure to MWFs or MWF aerosols. At a minimum, the initial examination should consist of a standardized questionnaire to obtain information concerning medical history (of asthma, other serious respiratory conditions, and skin diseases) and an examination of the skin. Baseline spirometric testing may also prove useful for comparisons with subsequent tests in individual workers.

Periodic Examination

All workers included in the medical monitoring program should undergo periodic screening examinations based on the frequency and severity of health effects in the specific worker population. These examinations should include a brief standardized questionnaire that ascertains the presence or absence of symptoms indicative of possible respiratory conditions (e.g., episodic shortness of breath,

wheeze, chest tightness, or cough) and skin disorders, as well as their temporal relationship to work. Also determine the use of medications for these conditions.

If resources permit, routine periodic examinations should include examination of the skin and spirometric testing. The skin examination should emphasize dermatitis and nonmelanoma cancer. The addition of spirometric testing will improve the sensitivity and specificity of screening programs. The spirometric testing should emphasize measurement of forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC). Conduct spirometry both preshift (on the first day back to work after a weekend off) and postshift on the same day. Then, interpret each worker's preshift values with respect to predicted normal values, as well as in comparison to that same worker's previous test results, and evaluate cross-shift differences for indication of an acute adverse effect of work exposure. Such objective examination and testing complements information obtained from questionnaires.

Detailed Medical Examination for Selected Workers

Any worker should undergo more frequent medical evaluations if: (1) identified by periodic questionnaire, spirometry testing, or self-referral as having respiratory symptoms or physiologic effects suggesting asthma and/or other respiratory condition possibly related to MWF aerosol exposure; (2) identified by periodic questionnaire, skin examination, or self-referral as having recurrent or chronic dermatitis; or (3) judged by the program director/supervisor to have any medically significant reason for more detailed assessment.

Detailed pulmonary evaluations should include a careful history and the appropriate physiological testing. Use physiological testing to document/confirm hyperresponsive airways (e.g., a comparison of pre- and postbronchodilator spirometry, and/or methacholine challenge testing) and more specifically to document airway effects associated with workplace exposure to MWF aerosols (e.g., a comparison of pre- and postshift spirometry testing on the first day of the workweek and/or serial peak flow testing over several days). Allow highly specialized laboratories and experienced clinical investigators to perform laboratory-based specific inhalation challenge testing .

Dermatological evaluations should include a full medical and occupational history, a medical examination, a review of exposures, possibly diagnostic tests (such as skin patch tests to detect causes of allergic contact dermatitis), and complete follow-up to note the progress of the individual.

Physician's Reports to the Worker

Following the initial and each periodic or detailed examination, the physician should provide a written report to the worker. This report should include the following:

- the results of any medical tests performed on the worker,
- the physician's opinion about any medical conditions that would increase the worker's risk of impairment from exposure to MWF or MWF aerosols (or any other agents in the workplace),
- the physician's recommended limits on the worker's exposure to MWF or MWF aerosols (or any other agents in the workplace) and on the worker's use of respiratory protective devices and/or protective clothing, and
- the physician's recommendations about further evaluation and treatment of any detected medical conditions.

Physician's Reports to the Employer

Following the initial and each periodic or detailed examination, the physician should provide a written report to the employer. This report should include the following:

- the physician's recommended limits on the worker's exposure to MWF aerosols (or any other agents in the workplace) and on the worker's use of personal respiratory protective devices and/or protective clothing, and
- a statement that the worker has been informed of the results of the medical examination and of any medical condition(s) that should have further evaluation and/or treatment.

To protect confidentiality, the report provided to the employer should not reveal specific findings or diagnoses without a signed authorization from the worker.

Follow-Up Medical Evaluations

Reevaluate workers transferred as a result of the physician's opinion to document the achievement of the intended benefit (e.g., reduced symptoms and/or reduced physiologic effects). Continue to monitor transferred workers periodically until they have not shown symptoms for at least two years.

References

Section 1 - Introduction

ANSI [1997]. American national standard technical report: mist control considerations for the design, installation, and use of machine tools using metalworking fluids. New York, NY: American National Standards Institute, B11 Ventilation Subcommittee, TR 2-1997.

Nachtman ES, Kalpakjian S [1985]. Lubricants and lubrication in metalworking operations. New York, NY: Marcel Dekker, Inc.

NIOSH [1984]. Health hazard evaluation report: Torrington Company, Torrington, Connecticut. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, NIOSH Report No. HHE 82–107–1444.

Weindel HF [1982]. Elements of selecting and using metal-cutting fluids. In: Improving production with coolants and lubricants. Dearborn, MI: Society of Manufacturing Engineers, p. 34.

Woskie SR, Smith TJ, Hallock MF, Hammond SK, Rosenthal F, Eisen EA, et al. [1994]. Size-selective pulmonary dose indices for metal-working fluid aerosols in machining and grinding operations in the automobile manufacturing industry.

Section 2 - Occupational Exposures to Metalworking Fluids

There are four different classes of metalworking fluids

CRC [1985]. CRC handbook of lubrication; theory and practice tribology. Booser ER, ed. Vols. 1–2. Boca Raton, FL: CRC Press, Inc.

ILMA [1996]. Comments submitted to NIOSH, May 31, 1996. Arllington, WV: Independent Lubricant Manufacturers Association.

Occupational exposures to MWFs occur by inhalation and skin contact

Bennett EO, Bennett DL [1987]. Minimizing human exposure to chemicals in metalworking fluids. J Am Soc Lub Eng *43*(3):167–175.

MWFs may contain potentially hazardous chemical ingredients, additives, and contaminants.

ILMA [1996]. Comments submitted to NIOSH, May 31, 1996. Arllington, WV: Independent Lubricant Manufacturers Association.

Workers may be exposed to microorganisms and hazardous end products.

Hill EC [1983]. Microbial aspects of health hazards from water based metal working fluids. Tribology Intl *16*(3):136–140.

Kreiss K, Cox-Ganser J [1997]. Metalworking fluid-associated hypersensitivity pneumonitis: a workshop summary.

Mattsby-Baltzer I, Sandin M, Ahlström B, Allenmark S, Edebo M, Falsen E, et al. [1989]. Microbial growth and accumulation in industrial metal-working fluids. Appl Environ Microbiol *55*:2681–2689.

Mattsby-Baltzer I, Edebo JL, Järvholm B, Lavenius B, Söderström T, et al. [1990]. Subclass distribution of IgG and IgA antibody response to *Pseudomonas pseudoalcaligenes* in humans exposed to infected metal-working fluid. J Allergy Clin Immunol *86*(2):231–238.

Robins T, Seixas N, Franzblau A, Burge H, Abrams L, Minick S [1994]. Respiratory effects of machining fluid Aerosols. Final Report to the UAW-GM Occupational Health Advisory Board.

Salmeen I, Brown JA Jr., Foxall-Van Aken S, Olsen RH [1987]. Presence of *Acinetobacter* species among the predominant bacteria found in a contaminated metal-working fluid. Tribology Intl *20*:218–221.

The improper use of biocides to manage microbial growth may result in potential health risks.

Zugerman C [1986]. Cutting fluids. Their use and effects on the skin. Occup Med: State of the Art Rev *1*(2):245–258

Occupational exposures to MWFs cause potential health risks, including: dermatological (skin) disorders, and lung disorders.

<u>Dermatological Conditions</u>

DOL [1993]. Occupational injuries and illnesses in the United States by industry, 1991. Washington, DC: U.S. Department of Labor, Bureau of Labor Statistics. U.S. Government Printing Office, Bulletin 2424.

Fisher AA [1986]. Dermatitis due to cutting oils, solvents, petrolatum, and coal-tar products. In:
Fisher AA, ed. Contact Dermatitis 3rd ed. Philadelphia, PA: Lea and Febiger, pp. 531–545.

Mansdorf SZ, Lubs PL [1994]. Role of the industrial hygienist: evaluation and management of occupational skin disease.

Pryce DW, Irvine D, English JSC, Rycroft RJG [1989a]. Soluble oil dermatitis: a follow-up study. Contact Dermatitis *21*(1):28–35.

Tucker SB [1988]. Prevention of occupational skin disease. Dermatologic Clinics-Occupational Dermatoses *6*:87–96.

<u>Cancer</u>

Tolbert P, Eisen E, Pothier LJ, Monson RR, Hallock MF, Smith TJ [1992]. Mortality studies of machining-fluid exposure in the automobile industry. II. Risks associated with specific fluid types. Scand J Work Environ Health *18*(6):351–360.

Lung Disease

Forbes JD, Markham TN [1967]. Cutting and grinding fluids in chronic pulmonary airway disease. J Occup Med *9*(8):421–423.

Robertson AS, Weir DC, Burge PS [1988]. Occupational asthma due to oil mists. Thorax *43*(3):200–205.

Savonius B, Keskinen H, Tuppurainen M, Kanerva L [1994]. Occupational asthma caused by ethanolamines. Allergy *49*(10):877–81.

MWF-Induced Asthma

Ameille J, Wild P, Choudat D, Ohl G, Vaucouleur JF, Chanut JC, et al. [1995]. Respiratory symptoms, ventilatory impairment, and bronchial reactivity in oil mist-exposed automobile workers. Am J Ind Med *27*(2):247–256.

Chan-Yeung M, Malo J-L [1993]. Compendium I: table of the major inducers of occupational asthma. In: Bernstein IL, Chan-Yeung M, Malo J-L, Bernstein DI, eds. Asthma in the workplace. New York, NY: Marcel-Dekker, Inc., pp. 595–623.

Eisen EA, Holcroft CA, Greaves IA, Wegman DH, Woskie SR, Monson RR [1997]. A strategy to reduce healthy worker effect in a cross-sectional study of asthma and metalworking fluids. Am J Ind Med *31*(6):671–677.

Greaves IA, Eisen EA, Smith TJ, Pothier LJ, Kriebel D, Woskie SR, et al. [1995]. Respiratory health of automobile workers and exposures to metal-working fluid aerosols. III. Lung spirometry. Boston, MA: Harvard School of Public Health, Occupational Health Program. Final Draft.

Greaves IA, Eisen EA, Smith TJ, Pothier LJ, Kriebel D, Woskie SR, et al. [1997]. Respiratory health of automobile workers exposed to metal-working fluid aerosols. II. Respiratory Symptoms. Am J Ind Med *32*(5):450–459.

Hendy MS, Beattie BE, Burge PS [1985]. Occupational asthma due to an emulsified oil mist. Br J Ind Med *42*(1):51–54.

Kennedy SM, Greaves IA, Kriebel D, Eisen EA, Smith TJ, Woskie SR [1989]. Acute pulmonary responses among automobile workers exposed to aerosols of machining fluids. Am J Ind Med *15*(6):627–641.

Kriebel D, Eberiel D, Eisen EA, Eraso RM, Kumar S, Sama S, et al. [1994]. Field investigations of the acute respiratory effects of machining fluids. Final report to the UAW-GM National Joint Committee on Safety and Health, June 1, 1994.

Massin N, Bohadana AB, Wild P, Goutet P, Kirstetter H, Toamain JP [1996]. Airway responsiveness, respiratory symptoms, and exposures to soluble oil mist in mechanical workers Occup Environ Med *53*(11):748–752.

Michel O, Ginanni R, LeBon B, Content J, Duchateau J, Sergysels R [1992]. Inflammatory response to acute inhalation of endotoxin in asthmatic patients. Am Rev Respir Dis *146*(2):352–357.

Robins T, Seixas N, Franzblau A, Burge H, Abrams L, Minick S [1994]. Respiratory effects of machining fluid Aerosols. Final Report to the UAW-GM Occupational Health Advisory Board.

Rosenman KD, Reilly MJ, Kalinowski DJ [1997]. Work-related asthma and respiratory symptoms among workers exposed to metal-working fluids. Am J Ind Med *32*(4):325–331.

Wild P, Ameille J [1997]. Bronchial reactivity in oil-mist exposed automobile workers revisited [letter to the editor]. Am J Ind Med *32*(4):421–432.

Respiratory Effects other than Asthma

Ameille J, Wild P, Choudat D, Ohl G, Vaucouleur JF, Chanut JC, et al. [1995]. Respiratory symptoms, ventilatory impairment, and bronchial reactivity in oil mist-exposed automobile workers. Am J Ind Med *27*(2):247–256.

Bernstein DI, Lummus ZL, Santilli G, Siskosky J, Bernstein IL [1995]. Machine operator's lung: a hypersensitivity pneumonitis disorder associated with exposure to metalworking fluid aerosols. Chest *108*(3):636–641.

Greaves IA, Eisen EA, Smith TJ, Pothier LJ, Kriebel D, Woskie SR, et al. [1995]. Respiratory health of automobile workers and exposures to metal-working fluid aerosols. III. Lung spirometry. Boston, MA: Harvard School of Public Health, Occupational Health Program. Final Draft.

Greaves IA, Eisen EA, Smith TJ, Pothier LJ, Kriebel D, Woskie SR, et al. [1997]. Respiratory health of automobile workers exposed to metal-working fluid aerosols. II. Respiratory Symptoms. Am J Ind Med *32*(5):450–459.

Kennedy SM, Greaves IA, Kriebel D, Eisen EA, Smith TJ, Woskie SR [1989]. Acute pulmonary responses among automobile workers exposed to aerosols of machining fluids. Am J Ind Med *15*(6):627–641.

Kriebel D, Eberiel D, Eisen EA, Eraso RM, Kumar S, Sama S, et al. [1994]. Field investigations of the acute respiratory effects of machining fluids. Final report to the UAW-GM National Joint Committee on Safety and Health, June 1, 1994.

Kreiss K, Cox-Ganser J [1997]. Metalworking fluid-associated hypersensitivity pneumonitis: a workshop summary.

Krzesniak L, Kowalski J, Droszcz W, Piotrowska B [1981]. Respiratory abnormalities in workers exposed to oil mist. Eur J Respir Dis *62* (Suppl 113):88–89.
Massin N, Bohadana AB, Wild P, Goutet P, Kirstetter H, Toamain JP [1996]. Airway responsiveness, respiratory symptoms, and exposures to soluble oil mist in mechanical workers Occup Environ Med *53*(11):748–752.
Rose C, Robins T, Harkaway P, et al. [1996]. Biopsy-confirmed hypersensitivity pneumonitits in automobile production workers exposed to metalworking fluids—Michigan, 1994-1995. MMWR *45*:606-610.

Reducing MWF exposures to concentrations below the REL, whenever feasible, should decrease the number of new cases of MWF-related asthma and the risk of chronic airways disease in exposed working populations.

Becklake MR, Bourbeau J, Menzies R, Ernst P [1988]. The relationship between acute and chronic airway responses to occupational exposures. Curr Pulmonol *9*:25–66.

Chan-Yeung M, Malo J-L [1993]. Compendium I: table of the major inducers of occupational asthma. In: Bernstein IL, Chan-Yeung M, Malo J-L, Bernstein DI, eds. Asthma in the workplace. New York, NY: Marcel-Dekker, Inc., pp. 595–623.

Christiani DC, Ye TT, Wegman DH, Eisen EA, Dai HL, Lu PL [1994]. Cotton dust exposure, a cross-shift drop in FEV_1, and five-year change in lung function. Am J Respir Crit Care Med *150*(5):1250–1255.

Glindmeyer HW, Lefante JJ, Jones RN, Rando RJ, Weill H [1994]. Cotton dust and across-shift change in FEV_1 as predictors of annual change in FEV_1. Am J Respir Crit Care Med *149*(3):584–90.

Hankinson JL, Hodous TK [1983]. Short-term prospective spirometric study of new coal miners. Morgantown, WV: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Clinical Investigations Branch. NTIS PB83–237–446.

Rosenman KD, Reilly MJ, Kalinowski DJ [1997]. Work-related asthma and respiratory symptoms among workers exposed to metal-working fluids. Am J Ind Med *32*(4):325–331.

Tabona M, Chan-Yeung M, Enarson D, MacLean L, Dorken E, Schulzer M [1984]. Host factors affecting longitudinal decline in lung spirometry among grain workers. Chest *85*(6):782–786.

Wegman DH, Musk W, Main DM, Pagnotta LD [1982]. Accelerated loss of FEV-1 in polyurethane production workers: a four-year prospective study. Am J Ind Med *3*(2):209–215.

Weill H [1984]. Relations between acute and chronic occupational airway responses. In: Gee JBL, Morgan WKC, Brooks SM, eds. Occupational lung diseases. New York, NY: Raven Press, pp. 87–95.

The recent decline in worker MWF exposure level suggests that developed control technologies can significantly reduce exposure concentration levels.

Hallock MF, Smith TJ, Woskie SR, Hammond SK [1994]. Estimation of historical exposures to machining fluids in the automotive industry.

IMIS [1995]. Integrated Management Information System. Washington, D.C.: U.S. Department of Labor, Occupational Safety and Health Administration. Unpublished database.

Section 3 - Recommendations for an Occupational Health and Safety Program

2. Worksite Analysis

NIOSH [1995]. NIOSH criteria for a recommended standard: occupational exposure to respirable coal mine dust. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No. 95--106.

3. Hazard Prevention Control

Fluid Selection

ASTM [1997a]. ASTM Standard E1497-94: safe use of water-miscible metalworking fluids.
West Conshohocken, PA: American Society for Testing and Materials.

ASTM [1997b]. ASTM Standard E1687-95: determining carcinogenic potential of virgin base oils in metalworking fluids. West Conshohocken, PA: American Society for Testing and Materials.

Fluid Use and Application

ANSI [1997]. American national standard technical report: mist control considerations for the design, installation, and use of machine tools using metalworking

fluids. New York, NY: American National Standards Institute, B11 Ventilation Subcommittee, TR 2-1997.

Ball A [1997]. A survey of metalworking fluid mist in manufacturing plants. Lubrication Eng *53*(9):18–22.

Joseph J [1991]. Keeping fluids clean in GM-Spring Hill. Am Mach *Oct*:42–45.

Fluid Maintenance

HSE [1994]. Management of metalworking fluids. A guide to good practice for minimising risks to health. Health and Safety Executive.

Joseph J [1991]. Keeping fluids clean in GM-Spring Hill. Am Mach *Oct*:42–45.

ORC [1997]. Metal removal fluids: a guide to their management and control. Washington, DC: Organization Resources Counselors, Inc.

Ventilation Systems

ACGIH [1995]. Industrial ventilation: a manual of recommended practice. 22nd ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists, Committee on Industrial Ventilation.

ANSI [1979]. American national standard: fundamentals governing the design and operation of local exhaust systems. New York, NY: American National Standards Institute, ANSI 29.2–1979.

ANSI[1997]. American national standard technical report: mist control considerations for the design, installation, and use of machine tools using metalworking fluids. New York, NY: American National Standards Institute, B11 Ventilation Subcommittee, TR 2-1997.

Hagopian JH, Bastress EK [1976]. Recommended industrial ventilation guidelines. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 76–162.

Protective Clothing and Equipment

29 Fed Reg 1910.1016 (51) (138)

Forsberg K, Mansdorf SZ [1993]. Quick selection guide to chemical protective clothing. 2nd ed. New York, NY: Van Nostrand Reinhold.

NIOSH [1987]. NIOSH guide to industrial respiratory protection. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 87–116.

NIOSH [1987]. NIOSH respirator decision logic. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 87–108.

Sanitation and Hygiene

NIOSH [1987]. NIOSH respirator decision logic. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 87–108.

Labeling and Posting

29 Fed Reg 1910.1200; 29 Fed Reg 1926.59

4. Medical Monitoring of Exposed Workers

ACCP (American College of Chest Physicians) [1995]. ACCP consensus statement: assessment of asthma in the workplace. Chest *108*:1084-1117.

Balmes JR [1991]. Surveillance for occupational asthma. Occup Med: State of the Art Rev *6*(1):101–110.

Matte TD, Fine L, Meinhardt TJ, Baker EL [1990]. Guidelines for medical screening in the workplace. Occup Med: State of the Art Rev *5*(3):439–456.

For Information on Other Occupational Safety and Health Concerns

Call NIOSH at:
1-800-35-NIOSH (356-4674)
or visit the NIOSH Homepage at:
http://www.cdc.gov/niosh/homepage.html

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

NIOSH Publication 98-116

CDC
CENTERS FOR DISEASE CONTROL AND PREVENTION