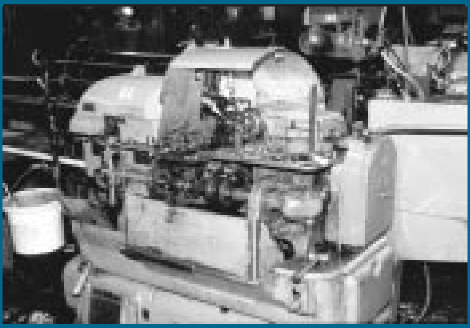
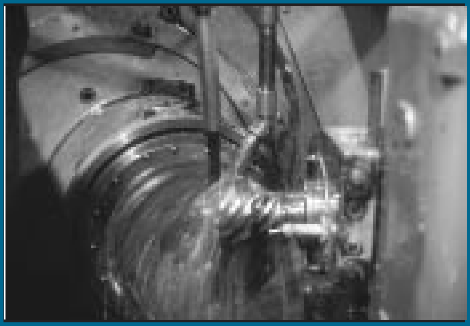




NIOSH

WHAT YOU NEED
TO KNOW ABOUT

OCCUPATIONAL EXPOSURE TO METALWORKING FLUIDS

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

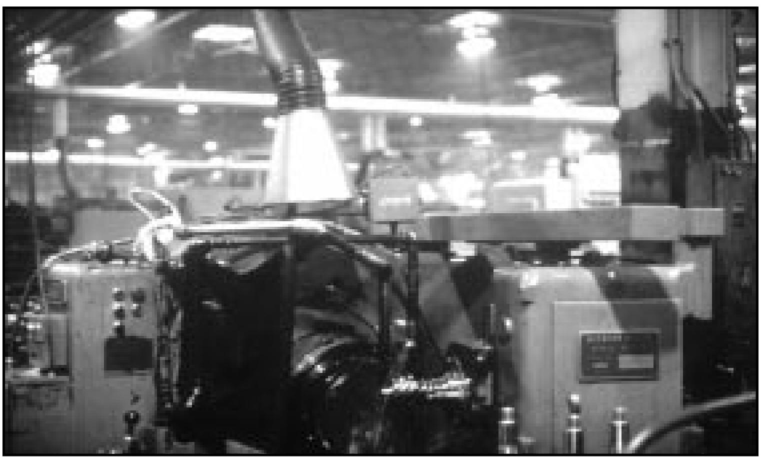
This document summarizes the findings of the recently released NIOSH Criteria for a Recommend Standard Occupational Exposure to Metalworking Fluids. According to the Occupational Safety and Health Act of 1970 (Public Law 95-164), the National Institute for Occupational Safety and Health (NIOSH) is charged 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

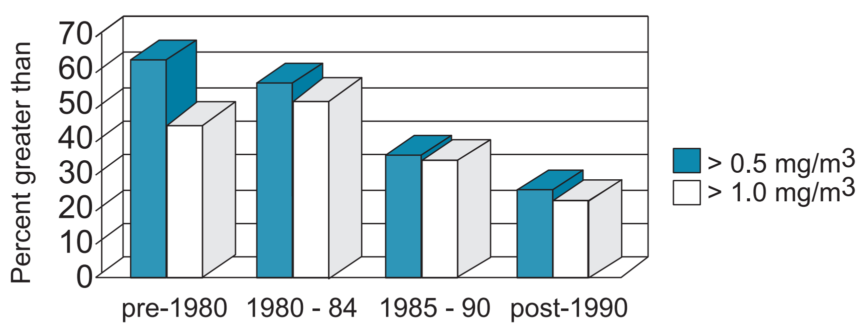
Studies of lung function provide some evidence that MWF aerosol exposure can also cause an adverse chronic effect. Overall, this evidence provides limited support for associating MWF aerosol exposures above the REL with a chronic reduction in lung function. More convincing, all but one of the ten studies 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.

Exposure Trends
OSHA IMIS Data



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

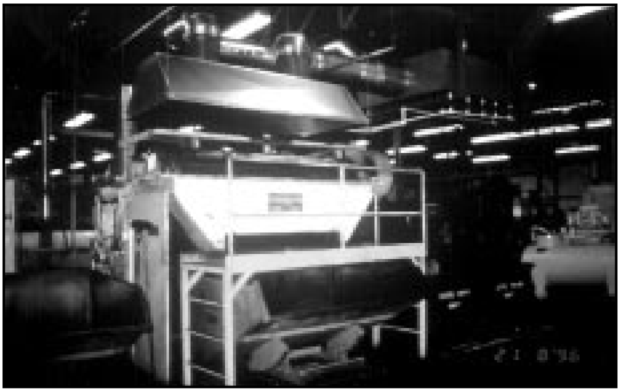
Proper MWF selection and application, fluid maintenance, isolation of the operation(s), ventilation, and other operational procedures can prevent or minimize inhalation of MWF aerosols. Dermal exposures may be reduced by the use of machine guarding and protective equipment such as gloves, face guards,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

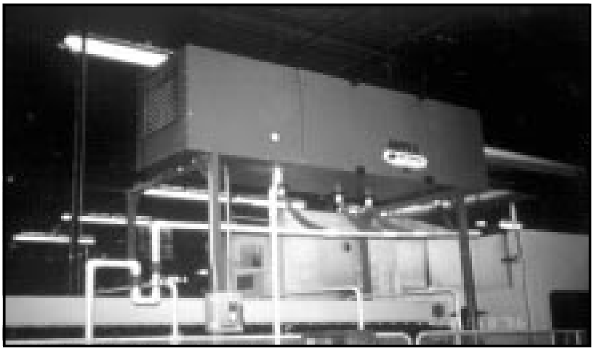
Isolation

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.

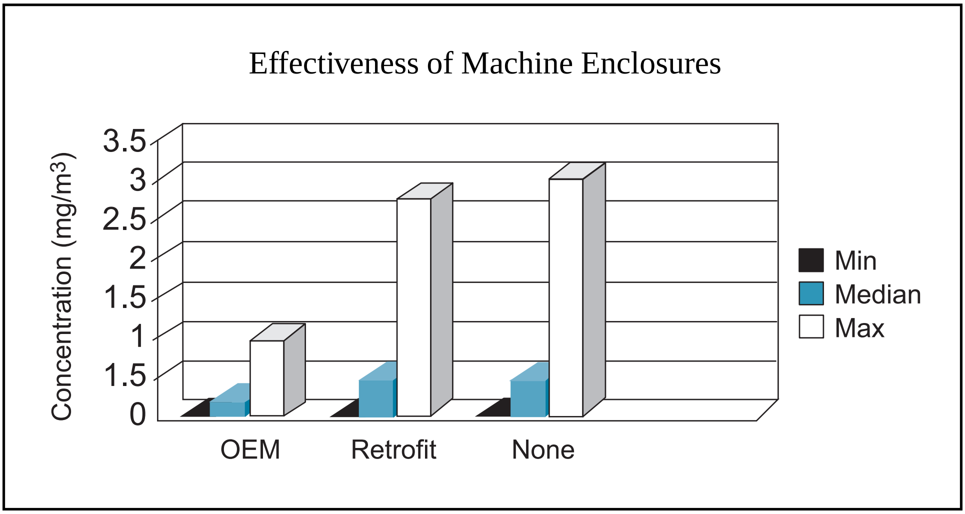


Exhaust Air Recirculation

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