*CHAPTER 9*

# Recommendations for an Occupational Safety and Health Program

NIOSH has long recognized the value of comprehensive occupational safety and health programs to prevent occupational deaths, injuries, and illnesses. To be effective, a safety and health program needs to be developed and implemented as part of the employer's management system. Such a program must have strong management commitment and worker involvement. The major elements for a comprehensive, effective safety and health program are: (1) safety and health training, (2) environmental monitoring, (3) hazard prevention and control, and (4) medical monitoring of exposed workers. These elements are described in the following sections.

## 9.1 Safety and Health Training

Employers should establish a safety and health training program for all workers with MWF exposures. One important goal of training is to enable workers to identify workplace hazards. Instruction should be provided when changes occur in job duties, when a new job is assigned, and when new MWFs or hazardous chemicals are introduced. Both employees and contract workers should be informed about hazardous chemicals in their work areas and the availability of information from MSDSs and other sources.

Workers should be trained to detect and report hazardous situations (e.g., the appearance of bacterial overgrowth and degradation of MWFs). Instruction should include information about how workers can protect themselves (e.g., the use of appropriate work practices, emergency procedures, and personal protective equipment). Workers should be encouraged to maintain good personal hygiene and housekeeping practices to prevent MWFs from contaminating the workplace. In addition, workers should be instructed about the adverse health effects associated with MWF exposures.

## 9.2 Environmental Monitoring

An occupational safety and health program designed to protect workers from the adverse health effects of exposures to MWF and MWF aerosol should include the

means for thoroughly identifying all hazards. An important part of this program is sufficient environmental monitoring to determine the effectiveness of work practices, engineering controls, and personal protective equipment.

The goal of environmental monitoring is to ensure a more healthful work environment where worker exposures (as measured by full-shift samples) do not exceed the REL. However, as indicated earlier in this document, adverse health effects can occur at the REL, and thus lower exposures are desirable where feasible.

In work areas where airborne MWF exposures may occur, the initial environmental sampling survey should collect representative personal samples for the entire work shift. Surveys should be repeated at least annually and whenever any major process change takes place. Surveys should also qualitatively evaluate the workers' potential skin exposures. All routine personal samples should be collected in the breathing zones of the workers. More frequent monitoring should be undertaken in workers with higher exposure. Airborne exposure measurements should be taken at least every 6 months for workers whose exposures to MWFs are one-half or more of the REL. For workers exposed to MWF aerosols at concentrations above the REL, more frequent monitoring should be maintained until at least two samples indicate that the worker's exposure no longer exceeds the REL. All workers should be notified of monitoring results and of any control actions being undertaken to reduce their exposures. Those who develop an environmental sampling strategy should consider variations in work and production schedules and the inherent variability in most environmental sampling [NIOSH 1995].

When the goal of sampling is to determine whether worker exposures are below the REL, random sampling (without a systematic bias excluding high or low exposures for workers or sampling periods) is usually not included in the sampling strategy. Instead, the strategies should focus sampling efforts on workers with the highest exposures (i.e., the maximum-risk worker, a concept discussed by Leidel and Busch [1994]). Such targeted strategies can most efficiently identify exposures above the REL if maximum-risk workers and time periods can be accurately identified. However, all workers or worker groups should be periodically sampled to ensure that the targeted sampling includes all workers with exposure potentials above the REL.

Source and area samples may be useful supplements to personal monitoring. Area sampling can help determine the source of MWF aerosol exposures and assess the effectiveness of engineering controls.

## 9.3 Hazard Prevention and Control

First and foremost, management should be knowledgeable about the proper selection, application, and maintenance of MWFs for each operation in the plant or shop; selected

workers should also be trained in these areas. Worker exposures during metalworking operations can occur through inhalation of MWF aerosols and through contamination of the skin by settled mists, splashes, dipping of hands and arms into MWFs, or handling of parts coated with MWF. Most airborne exposures can be controlled by a combination of proper MWF use and application, MWF maintenance, isolation of the operation(s), ventilation, and other operational procedures. 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. Workers should be encouraged to clean MWF-contaminated skin periodically with gentle soaps, clean water, and clean towels. Workers should not need to place their unprotected hands and arms repeatedly into MWFs. Barrier creams may be useful for some workers, but their protective effects are controversial. The use of nonbarrier cream moisturizers may also be protective.

## 9.3.1 Work Practices

### 9.3.1.1 Fluid Selection, Use, and Application

Factors to be considered in reducing MWF exposure include operation, fluid type, ventilation, fluid flow rates, machine speed, machine guarding, placement of machines with respect to flumes, and mist collection devices [Ball 1997]. Splashing and mist generation can be minimized by the proper application of the MWF. MWFs should be applied at the lowest possible pressure and flow volume consistent with adequate part cooling, chip removal, and lubrication. To avoid unnecessary mist generation, the fluid should be applied at the interface of the tool and workpiece, thereby minimizing contact with other rotating equipment. Properly maintained filtration and delivery systems can provide cleaner fluids for use, reduce misting, and minimize splashing and emissions. Fluid delivery should stop when machining stops. MWFs should not be allowed to flow over the unprotected hands of workers loading or unloading parts.

If petroleum-containing MWFs are used, the base oil should be evaluated for potential carcinogenicity using ASTM Standard E1687–95: *Determining Carcinogenic Potential of Virgin Base Oils in Metalworking Fluids* [ASTM 1997b]. If soluble oil or synthetic MWFs are used, ASTM Standard E1497–94: *Safe Use of Water-Miscible Metalworking Fluids* [ASTM 1997a] should be consulted for safe use guidelines, including those for product selection, storage, dispensing, and maintenance. To minimize the potential for the formation of nitrosamines, nitrate-containing materials should not be added to MWFs containing ethanolamines. The use of antimisting additives may be considered to minimize the mist production.

The MWFs selected should be as nonirritating and nonsensitizing as possible and remain consistent with operational requirements. MWFs should be maintained by a careful management program and should be compatible with machines, tools, and workpieces. The National Center for Manufacturing Sciences (NCMS) has developed a

draft document *(Metalworking Fluid Evaluation Guide)* that presents MWF compatibility (including in-process compatibility) and performance issues to be considered during fluid selection [NCMS 1996]. Components of the MWF management program should include diligent maintenance of filtration and delivery systems. This maintenance includes the selection of appropriate filters and the consideration of ancillary equipment such as chip-handling equipment, dissolved-air flotation devices, belt skimmers, chillers or plate and frame heat exchangers, and decantation tanks. Coolant return trenches should be guarded to prevent the dumping of floor wash water and other waste fluids. Sumps or coolant tanks should be covered to prevent contamination with waste or garbage. Machines should be kept clean and free of debris. Parts washing before machining can be an important part of maintaining cleaner MWFs [Joseph 1991].

Since all additives will be depleted with time, the MWF and additives concentrations should be monitored frequently so that components and additives can be made up as needed. The MWF should be maintained within the pH and concentration ranges recommended by the formulator or supplier. MWF temperature should be maintained at the lowest practical level to slow the growth of microorganisms, reduce water losses and changes in viscosity, and—in the case of straight oils—reduce fire hazards.

#### 9.3.1.2 Fluid Maintenance

Drums, tanks, or other containers of MWF concentrates should be stored appropriately to protect them from outdoor weather conditions and extremes of temperature, which may cause the fluid concentrates to be unstable because of chemical changes (especially in the case of concentrates mixed with water).

MWFs should be routinely monitored and a record should be kept of the fluid level in the sump or coolant tank, the MWF concentration (measured by refractometer or titration), the fluid pH, and the degree of tramp oil contamination (inspected visually). Monitoring may be more frequent during periods of hot weather or increased work output—both of which may result in increased fluid losses [HSE 1994]. The draft *Metalworking Fluid Evaluation Guide* developed by NCMS presents a list of MWF "symptoms" with possible causes, fixes, and fluid tests [NCMS 1996]. In addition, the guide presents test methods for determining the disposability of spent MWFs.

Insufficient data exist to determine what constitutes a "safe" level of microbial contamination in MWF—either in terms of species present or of absolute numbers of CFUs. Commercial tests are available to determine dissolved oxygen in MWFs (for an indirect measurement of biological activity). Routine microbiological plate counts or dipslides can be used to estimate the number of viable microorganisms. Neither the undiluted fluid concentrates nor the water used for making up the fluids is free of bacteria. However, because of concerns about safety and health as well as fluid

performance, the working solutions should be made with water of drinking quality and correct hardness. To maintain proper MWF concentrations, neither water nor concentrate should be used to top off the system. The MWF mixture should be prepared first by adding the concentrate to the clean water (in a clean container) and then adding the emulsion to that mixture in the coolant tank [HSE 1994]. MWFs should be mixed just before use; large amounts should not be stored, as they may deteriorate before use. Personal protective clothing and equipment should always be worn when removing MWF concentrates from the original container, mixing and diluting concentrate and preparing additives (including biocides), and adding MWF mixture, biocides, or other potentially hazardous ingredients to the coolant reservoir. Personal protective clothing should include eye protection or faceshields, gloves, and aprons that do not react with but shed MWF ingredients and additives.

Coolant systems should be regularly serviced, and the machines should be rigorously maintained to prevent contamination of the fluids by tramp oils (e.g., hydraulic oils, gear box oils, and machine lubricants leaking from the machines). Tramp oils can destabilize emulsions, cause pumping problems, and clog filters [HSE 1994]. Tramp oils may float to the top of MWFs, effectively sealing the fluids from the air and changing the bacterial flora of the fluids. The metabolic products such as volatile fatty acids, mercaptols, scatols, ammonia, and hydrogen sulfide are produced by the anaerobic and facultative anaerobic species growing in MWF with low levels of oxygen. A variety of methods may be used to remove tramp oils: centrifugal liquid or liquid separators, coalescers, oleophilic belts and ropes, skimmers, and vacuums [HSE 1994]. Continuous removal systems should be considered for work situations involving high lubrication losses.

When the fluids are not being agitated and circulated, oxygenation of the fluids can occur only by diffusion. If this process is restricted by a layer of oil, there may be little or no oxidation of the reduced molecules. When the pumps are restarted, malodorous and irritating gases may be suddenly released, causing the characteristic "Monday morning smell," so named because some operations are turned off over the weekend or other prolonged periods of inactivity. This smell generally does not occur in fluid systems that are in good condition. Leaving coolant circulation pumps running over the weekend or during downtime may not be practical, but it may be feasible to pump air through the fluid to produce movement and reduce anaerobic bacterial growth [HSE 1994].

MWFs are usually replaced over time as emulsion and additives are added to make up fluid losses. If it becomes necessary to replace the fluids, care should be taken that all parts of the system are thoroughly cleaned because microorganisms tend to grown on surfaces. 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 or protein, which form a glycocalyx and cement cells together much as mortar holds bricks. Fungi may grow as masses of hyphae that form

mycelial mats. The attached community of microorganisms is called a biofilm and may be very difficult to remove by ordinary cleaning procedures. Cleaning methods include the use of steam, vacuums, disinfectant solutions, or commercial chemical cleaners. The cleaning method selected should be compatible with the MWFs [HSE 1994]. Special cleaning precautions are needed for entry into confined spaces [29 CFR 1910.146].

Biocides are used to maintain the efficacy of MWFs by preventing microbial overgrowth. These compounds are often added to the stock fluids as they are formulated. Over time, chemical and biological demands may consume the biocides and cause the concentrations to fall below those needed to inhibit microbial growth. However, biocide concentration should not exceed that needed to meet fluid specifications, as overdosing could cause workers to experience dermal effects, respiratory irritation, or other adverse health effects. Treatment with biocides may eliminate the predominant bacterial species and permit the emergence of previously subordinate, slower-growing species. Therefore the spectrum of biocidal activity should be broad enough to suppress the growth of a highly diverse contaminant population. A single-dose shock treatment may kill the fluid phase (planktonic) organisms without reaching the cells buried within the biofilm. Rapid regrowth from the undisturbed biofilm may be incorrectly interpreted as biocide failure.

Biocides should be added judiciously to *prevent* microbial growth and not as a remedy for grossly contaminated fluids—particularly if large numbers of gram-negative bacteria are present. Even though the numbers of viable cells might be reduced, killed bacterial cells can release large amounts of endotoxins and other microbial products. Currently, no feasible way exists to remove endotoxins, which are soluble and heat-stable. Conscientious monitoring and prevention of microbial proliferation is the best approach for preventing the buildup of endotoxins and other hazardous biological substances and for preserving fluid quality and function.

#### 9.3.1.3 Sanitation and Hygiene

Workers should keep personal items such as food and cosmetics away from the work environment. Eating and applying make-up should not be permitted in work areas. A no-smoking policy should be established, since cigarette smoke may exacerbate the respiratory effects of MWF aerosols for all workers. Employers should support smoking cessation efforts [NIOSH 1991].

Workers should be instructed in personal hygiene to reduce potential dermal exposures to MWFs. Workers should be encouraged to clean MWF-contaminated skin promptly and should be allowed time during the work shift to do so. Workers should change from contaminated work clothes into street clothes before leaving work. If onsite shower facilities are available, workers should be encouraged to shower and change into clean clothes at the end of the work shift.

Good housekeeping includes keeping the floors, equipment, and general work environ- ment clean. Wastes (including floor wash water) should not be dumped or swept into MWF sumps or coolant return trenches.

## 9.3.2 Labeling and Posting

Workers should be trained to be aware of labeling practices in accordance with the OSHA hazard communication standards [29 CFR 1910.1200 and 29 CFR 1926.59]. Warning labels and signs should be posted on or near hazardous metalworking processes. Depending on the process and MWF exposure concentration, warning signs should state the need to wear protective clothing or an appropriate respirator for exposure to MWF aerosol concentrations exceeding the REL. If respiratory protection is required, the following statement should be posted:

**RESPIRATORY PROTECTION REQUIRED IN THIS AREA**

All labels and warning signs should be printed in both English and the predominant language of workers who do not read English. Workers unable to read the labels and signs should be informed verbally about the hazards and instructions printed on the labels and signs.

## 9.3.3 Engineering Controls

### 9.3.3.1 Isolation

Skin and inhalation exposures to MWF and MWF aerosol can be minimized by using mechanical parts handling equipment and machine enclosures to isolate the workers. Simple splash-guarding may suffice for low-production machines, but complete enclosure (with ventilation) is required for high-production machines. Plant layouts should be such that transfer machines are isolated from other operations. Workers should be provided with isolation booths or fresh air showers.

Machine enclosures are an effective method of reducing worker exposures. Johnston and White [1995] have described the features that are important in designing effective enclosures. ANSI B11 [1997] contains detailed enclosure and mist control designs as well as considerations for installation and use. Hands [1995] examined exposure data collected at an automobile parts manufacturing plant to determine the effect of enclosures on MWF aerosol exposures. This study suggests that enclosures (particularly manufacturer's enclosures that are original equipment) effectively reduce MWF exposures. Retrofitting enclosure structures may also reduce exposures.

#### 9.3.3.2 Ventilation

The ventilation system should be designed and operated to prevent the accumulation or recirculation of airborne contaminants in the workplace. The ventilation system should include a positive means of bringing in at least an equal volume of air from the outside, conditioning it, and evenly distributing it throughout the exhausted area. Principles for the design and operation of ventilation systems are presented in the following publications:

*Industrial Ventilation: A Manual of Recommended Practice* [ACGIH 1995]

*American National Standard: Fundamentals Governing the Design and Operation of Local Exhaust Systems* [ANSI 1979]

*Recommended Industrial Ventilation Guidelines* [Hagopian and Bastress 1976]

Ventilation of operations that produce MWF aerosols is most readily achieved if the machine tool and machining operation are enclosed. The ventilation rate should be selected based on the size of the enclosure openings and the overall size of the enclosure. Air velocity through all openings must be sufficient to prevent the escape of mist. The air velocity depends on the proximity of the opening to the point of mist generation, the energy of the generated mist, and any airflow induced by the rotating machinery or elevated temperature. Guidelines for the selection of this indraft or capture velocity can be found in *Industrial Ventilation: A Manual of Recommended Practice* [ACGIH 1995]. The total exhaust flow rate must also be adequate to purge the enclosure after machining has ceased and before the enclosure is opened. Exhaust duct takeoffs should be located near the point of mist generation and away from enclosure openings to ensure complete purging of the enclosure. Appropriate ventilation rates for purging can be determined by using the procedures outlined in *Industrial Ventilation: A Manual of Recommended Practice* [ACGIH 1995].

Local exhaust ventilation may be used where the machining operations do not permit the use of an enclosure. Design criteria for exhaust hoods are found in *Industrial Ventilation: A Manual of Recommended Practice* [ACGIH 1995].

Air exhausted from machine tool enclosures is often cleaned and recirculated in the workplace. Criteria to ensure the safe recirculation of exhaust air are discussed in *The Recirculation of Industrial Exhaust Air* [NIOSH 1978], and general guidelines for recirculating exhaust air are presented in *Industrial Ventilation: A Manual of Recommended Practice* [ACGIH 1995]. Current industrial practice employs either filtration or precipitation to remove mist particles from the recirculated exhaust air. Selection of appropriate air cleaning equipment (either filtration or electrostatic precipitation) for exhaust from metalworking operations is based on the concentration and size distribution of the particles present in the exhaust stream. Vapors may also be produced in the process, but they are not removed by the filters and precipators typically

employed in metalworking operations. The NIOSH REL is directed at reducing MWF aerosols; researchers have not studied the role MWF vapors play in causing adverse health effects. If unfiltered exhaust air is vented outside the work environment, local air pollution authorities should be contacted regarding the relevant regulations.

In addition to local ventilation of machining operations, general ventilation systems inside plants, manufacturing or processing enclosures, or buildings may be used to control worker exposures to aerosols, vapors, mists, and dust. General ventilation systems are designed to maintain either heated or cooled airflow throughout the plant or building, and airborne hazards are controlled by dilution or removed by exhaust. Air quality is maintained by designing a general ventilation system that minimizes air stagnation and excess humidity, prevents short-circuiting of the fresh air supply to the exhaust, and directs clean air across the workers to carry airborne contaminants to the exhaust.

### 9.3.4 Protective Clothing and Equipment

Engineering controls are used to reduce exposure to MWF aerosols. But in the event of airborne exposures that exceed the NIOSH REL or dermal contact with the MWFs, the added protection of CPC and equipment such as respirators should be provided. Maintenance staff may also need CPC because their 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. The following recommendations should be used as a guide to selecting CPC.

#### 9.3.4.1 Protective Clothing

Protective clothing for workers exposed to MWFs should protect wearers from chemicals as well as punctures, cuts, and abrasions. Workers should wear faceshields or goggles, protective sleeves, aprons, trousers, and caps as needed to protect their skin from contact with MWFs. The use of gloves may increase the risk of injury from entanglement with moving tools or workpiece parts. If gloves are required, special attention should be given to guarding the equipment and ensuring that the gloves will tear easily if entangled. Workers should also wear safety shoes with slip-resistant soles.

Types of dermal protection should be determined by assessing the identity, concentration, and toxicity of the chemicals to which workers are exposed, the state of these chemicals (solid, liquid, or gas), and the body parts potentially affected. Three interactive parameters must be evaluated to determine the performance of protective materials and their properties:

- Chemical resistance of the materials

- Physical properties of the materials
- Human factors

### *Chemical resistance*

CPC is constructed from plastic and elastomeric materials and functions as a protective barrier to the skin. This clothing is conveniently categorized by body part to be protected (type of dermal protection) and by the performance (properties) of the garment materials. Selecting CPC involves choosing both the type of dermal protection needed (e.g., gloves to protect hands) and the material from which the clothing should be constructed (e.g., butyl rubber for gloves).

Chemical resistance testing evaluates the interaction between challenge chemicals and the garment material. Three interactions are possible: (1) chemical degradation—a breakdown of the garment's physical structure as a result of garment/chemical incompatibility, (2) chemical penetration—the bulk chemical flow through garment imperfections or through discontinuities such as seams and closures, and (3) chemical permeation—the molecular flow of chemicals through garment material.

Where feasible, selection of CPC should be based on permeation data. Furthermore, the permeation properties of chemical mixtures must be determined by testing, not inferred from the permeation properties of the components.

### *Physical properties*

Physical properties of CPC are important to barrier performance. Key physical properties for gloves are resistance to flexing, tearing, abrasions, cuts, and punctures. Ergonomic evaluations such as dexterity and grip involve physical properties that are governed by glove thickness. Surface texture is another important property, since grip is enhanced by a rough surface. The physical requirements of the task must be balanced against the chemical resistance requirements and human factors. Although CPC should protect the worker, it must not unduly restrict worker performance.

### *Selection criteria*

The physical and chemical properties of CPC should be determined from tables, charts, and general references used to select appropriate CPC. Chemical resistance data for a brand of CPC and its physical properties may be available from the manufacturer. Since only a few studies have been published on CPC for MWFs, material selection is based on limited data for one cutting oil and one emulsifiable cutting fluid.

Data indicate that nitrile affords the most chemical resistance of chemical protective materials [Forsberg and Mansdorf 1993]. The physical properties of nitrile are also rated as excellent for flexibility and resistance to abrasion, tears, and punctures. In

addition, Silvershield™ and 4H™ material are believed to afford protection similar to that of nitrile. Approximate service life is 4 hr for these materials.

#### 9.3.4.2 Respiratory Protection

Respirators should not be used as the primary means of controlling worker exposures. Instead, effective engineering controls (such as machine enclosures or local exhaust ventilation) should be implemented to minimize routine exposures to MWF aerosol. However, workers may use respirators when engineering controls are being implemented and when intermittent tasks expose them to concentrations that cannot be kept below REL by engineering controls alone.

The primary goal of a respiratory protection program is to reduce MWF aerosol exposures to concentrations below the REL. The secondary goal is to reduce these exposures further to protect workers who may experience adverse respiratory effects at concentrations below the REL. Depending on the nature and severity of their conditions, some workers with asthma or HP will develop clinical symptoms even when exposures to MWF aerosols are substantially below the REL. In these workers, personal respiratory protection may not prevent adverse health effects. Respiratory protection for these workers should be based on the individual recommendation of a qualified physician or health care provider. A possible (but unevaluated) use of personal respiratory protection might be to protect unaffected workers who are not exposed at concentrations above the REL, but who work in a facility with recent disease outbreak (e.g., HP) associated with MWF aerosol.

When respirators are used, the employer should establish a comprehensive respiratory protection program as outlined in the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a] and as required in the OSHA respiratory protection standard [ 29 CFR 1910.134]. Important elements of the OSHA respiratory protection standard are (1) an evaluation of the worker's ability to perform the work while wearing a respirator, (2) regular training of personnel, (3) periodic environmental monitoring, (4) respirator fit-testing, and (5) respirator maintenance, inspection, cleaning, and storage. The program should be evaluated regularly by the employer. 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. Without a complete respiratory protection program, workers will not receive the protection anticipated.

Selection of the appropriate respirator depends on the operation, chemical components, and airborne concentrations in the worker's breathing zone. Table 9–1 lists the NIOSH-recommended respiratory protection for workers exposed to MWF aerosol. Guidance on the selection of appropriate respirator filters is presented in the *NIOSH Guide to the Selection and Use of Particulate Respirators Certified Under 42 CFR 84* [NIOSH 1996].

**Table 9–1. NIOSH-recommended respiratory protection for workers exposed to MWF aerosols***

| Concentration of MWF aerosol ($mg/m^3$) | Minimum respiratory protection† |
|---|---|
| ≤0.5 $mg/m^3$ (1 × REL)‡ | No respiratory protection required for healthy workers§ |
| ≤5.0 $mg/m^3$ (10 × REL) | Any air-purifying, half-mask respirator including a disposable respirator**,†† equipped with any P- or R-series particulate filter (P95, P99, P100, R95, R99, or R100) number |
| ≤12.5 $mg/m^3$ (25 × REL) | Any powered, air-purifying respirator equipped with a hood or helmet and a HEPA filter‡‡ |

*Only NIOSH/MSHA-approved or NIOSH-approved (effective date July 10, 1995) respiratory equipment should be used.

†Respirators with higher assigned protection factors (APFs) may be substituted for those with lower APFs [NIOSH 1987a].

‡APF times the NIOSH REL for total particulate mass. The APF [NIOSH 1987b] is the minimum anticipated level of protection provided by each type of respirator.

§See text for recommendations regarding workers with asthma and for other workers affected by MWF aerosols.

**A respirator that should be discarded after the end of the manufacturer's recommended period of use, or after a noticeable increase in breathing resistance, or when physical damage, hygiene considerations, or other warning indicators render the respirator unsuitable for further use.

††An APF of 10 is assigned to disposable particulate respirators if they have been properly fitted.

‡‡High-efficiency particulate air filter. When organic vapors are a potential hazard during metalworking operations, a combination particulate and organic vapor filter is necessary.

Additional guidance on the selection of more protective respirators is presented in the *NIOSH Respirator Decision Logic* [NIOSH 1987b]. The REL is directed at reducing exposure to MWF aerosol—not to vapors from MWFs and MWF aerosols. Thus the recommended respirators were selected for their ability to reduce particulate exposure—not MWF vapor exposure.

## 9.4 Medical Monitoring of Exposed Workers

Medical monitoring (together with any intervention based on the results of medical monitoring) represents secondary prevention and should not supplant primary prevention efforts to control inhalation and skin exposures to MWF aerosol. However, as indicated by evidence reviewed in this document, the 0.4 $mg/m^3$ REL for thoracic particulate mass does not remove all risk for the development of skin or respiratory disease among exposed workers. A major objective of the medical monitoring recommended here is the early identification of workers who develop symptoms of MWF-related conditions such as asthma, HP, and dermatitis. If identified early, affected workers can have their exposures controlled to minimize their risk of recurring conditions (such as acute asthma and irritant contact dermatitis) and chronic effects (such as significant, irreversible impairment of lung function and allergic contact dermatitis).

Another important objective of medical monitoring is to provide standardized data that can be used to identify work areas that need additional primary prevention efforts.

All workers who are exposed to MWF aerosol or have skin contact with MWF may benefit from inclusion in an occupational medical monitoring program. However, priority should be given to workers at highest risk. For example, all workers exposed to MWF aerosol above a designated concentration (e.g., half the REL) should be included. Medical monitoring should be conducted in work areas where (regardless of exposure concentration) one or more workers have recently developed asthma, HP, or another serious condition apparently related to MWF exposure. Medical monitoring should be more intense in work areas with high exposures or with severe adverse health effects among workers. HP is infrequent but often severe.

All exposed workers should be provided with appropriate education and training—particularly with respect to self-referral for further medical evaluation if they develop symptoms suggestive of asthma, HP, other respiratory conditions, or dermatitis. All workers in the medical monitoring program should be provided with information about the program purposes, potential health benefits of participation, and program procedures (how routine test results are used, what actions may be taken on the basis of these results, who has access to individual results from routine medical monitoring and from more detailed medical evaluations, and how confidentiality is maintained [Matte et al. 1990]).

The employer should assign responsibility for medical direction and supervision of the program to a qualified physician or other qualified health care provider (as determined by appropriate State laws and regulations) who is informed and knowledgeable about the following:

- The respiratory protection program and types of respiratory protection devices available at the workplace
- The identification and management of occupational asthma, HP, and other work-related respiratory effects or illnesses (including pre-existing asthma exacerbated by occupational exposures)
- The identification and management of occupational skin diseases

Anyone who administers spirometric tests as part of an occupational medical monitoring program should have completed a NIOSH-approved training course in spirometry or other equivalent training. Spirometry equipment and procedures should comply with American Thoracic Society guidelines [ATS 1979, 1987, 1995, and future updates] that are current at the time of the testing.

### 9.4.1 Information Provided to Program Director

The employer should provide the program director with the following specific information for each worker covered by the medical monitoring program: a list and description of current and previous job assignments, hazardous exposures, exposure measurements, personal protective equipment provided or used, relevant MSDSs, and applicable occupational safety and health standards [Matte et al. 1990]. If a worker is referred to others for periodic examinations or detailed evaluations, the examiners should be provided with the appropriate information.

### 9.4.2 Initial or Preplacement Examination

The employer should provide an initial medical examination for each worker included in the medical monitoring program. For newly hired workers and for workers transferred from work areas where they were not exposed to MWFs, this examination should be provided before assignment to a job associated with such exposures. At a minimum, the initial examination should consist of (1) administration of a standardized questionnaire about symptoms and medical history of asthma, other serious respiratory conditions, and skin diseases, and (2) an examination of the skin. Baseline spirometric testing may also be useful for comparisons with subsequent tests of individual workers.

### 9.4.3 Periodic Examination

All workers included in the medical monitoring program should be provided with periodic health examinations. These should include a brief standardized questionnaire to determine the presence or absence of respiratory symptoms (e.g., shortness of breath, wheezing, chest tightness, or cough) and skin disorders as well as their temporal relationship to work. In addition, the questionnaire should determine the use of medications for these conditions. The frequency of periodic examinations (e.g., semiannual, annual, or biannual) for a given worksite should be dictated by the frequency or severity of health effects in that worker population. In the absence of a case of likely disease associated with MWF or MWF aerosol at a particular metalworking facility, annual examinations would be reasonable.

If an employer's resources permit, routine periodic examinations should include examination of the skin and spirometric testing. The addition of spirometric testing will improve the sensitivity and specificity of screening programs, but it will increase the cost. The skin examination should emphasize screening for dermatitis and skin cancer. The spirometric testing should emphasize measurement of $FEV_1$ and FVC. Spirometry should be performed preshift on the first day back to work after a weekend off and postshift on the same day. Each worker's preshift values should be interpreted with respect to predicted normal values and in comparison with each worker's previous test results. Cross-shift differences should also be evaluated to indicate any acute adverse effect of

work exposure [NIOSH 1974; Robins et al. 1994]. Such objective examination and testing complement information obtained from questionnaires. As observed in workers exposed to cotton dust [Imbus and Suh 1973], acute symptoms correlated with cross-shift lung function decline in individual workers. In one study of workers exposed to MWF aerosol, only 13 of 28 cross-shift $FEV_1$ declines exceeding 10% were accompanied by work-related symptoms [Robins et al. 1994].

### 9.4.4 Detailed Medical Examinations for Selected Workers

Any worker should undergo additional or more frequent medical evaluations if the worker

- — is identified by periodic questionnaire (or spirometry testing) or by self-referral as having respiratory symptoms (or physiologic effects) suggestive of asthma or other respiratory conditions possibly related to MWF aerosol exposure, or
- — is identified by periodic questionnaire, skin examination, or self-referral as having recurrent or chronic dermatitis, or
- — is judged by the program director to have any medically significant reason for more detailed assessment.

Robins et al. [1994] have proposed more specific guidance about medical monitoring for respiratory effects of MWFs.

Detailed pulmonary evaluations should include a careful history and appropriate physiologic testing. Physiologic testing may be used to document (1) hyperresponsive airways (e.g., a comparison of pre- and post-bronchodilator spirometry or methacholine challenge testing) and (2) airway effects associated with workplace exposure to MWF aerosols (e.g., a comparison of pre-and post-shift spirometry testing on the first day of the workweek or serial peak flow testing over several days) [Balmes 1991]. Laboratory-based specific inhalation challenge testing should be left to highly specialized laboratories and experienced clinical investigators [ACCP 1995]. Chest radiography, measurements of pulmonary gas transfer (e.g., diffusing capacity tests and blood gases before and during exercise), or other clinical testing may be indicated in workers with symptoms or findings that suggest lung parenchymal involvement (e.g., HP).

Dermatological evaluations should include a full medical and occupational history, a medical examination, a review of exposures, and complete followup to note the clinical course of the individual's skin condition. The work-relatedness of skin diseases may be difficult to prove. The accuracy of the diagnosis is related to the skill level, experience, and knowledge of the medical professional who makes the diagnosis and confirms the relationship with a workplace exposure. Guidelines are available for assessing the work-relatedness of dermatitis [Mathias 1989], but the diagnosis may be difficult

nonetheless. The diagnosis should be based on the medical and occupational histories and physical findings. In some situations, diagnostic tests are useful—for example, skin patch tests to detect causes of allergic contact dermatitis. In irritant contact dermatitis, patch tests or provocation tests are discouraged because of a high false-positive rate. In many instances, allergic contact dermatitis can be confirmed by skin patch tests using standardized allergens or, in some circumstances, by provocation tests with nonirritating dilutions of industrial substances [Fisher 1986]. False-positive and -negative patch tests occur even with allergic contact dermatitis [Nethercott 1990]. The lack of a standard case definition and the difficulty of diagnosis can lead to misclassification of occupational contact dermatitis, and incorrect estimates of disease frequency.

### 9.4.5 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 aerosol (or any other agents in the workplace)
- The physician's recommended restriction of the worker's exposure to MWF or MWF aerosol (or any other agents in the workplace) and of the worker's use of respiratory protective devices or protective clothing
- The physician's recommendations about further evaluation and treatment of medical conditions detected

### 9.4.6 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 restrictions of the worker's exposure to MWF aerosols (or any other agents in the workplace) and of the worker's use of respiratory protective devices or protective clothing.
- A statement that the worker has been informed about the results of the medical examination and about medical condition(s) that should have further evaluation 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.

### 9.4.7 Employer Actions

The employer should assure that the physician's recommended restrictions of a worker's exposure to MWF or MWF aerosol or to other workplace hazards are not exceeded without the use of personal protective equipment. Workers are likely to delay self-referral or deny symptoms on periodic questionnaires if the reporting of symptoms leads to involuntary transfers or loss of income. Thus efforts to encourage worker participation and prompt, accurate reporting of symptoms are important to the program's success. Medical monitoring and followup medical evaluations should be provided without cost to the participating workers.

The employer should ensure that the program director regularly collaborates with the employer's safety and health personnel (e.g., industrial hygienists) to identify and control work exposures and activities that pose a risk of adverse health effects. Aggregate analyses of medical monitoring data can be useful for identifying risks while maintaining the confidentiality of the results for individual workers.

### 9.4.8 Followup Medical Evaluations

Workers who are transferred as a result of the physician's opinion should be reevaluated later to document that the intended benefit (e.g., reduced symptoms or reduced physiologic effects) has been achieved. Transferred workers should continue to be monitored periodically until they have been asymptomatic for at least 2 years. If symptoms persist, the responsible physician should carefully consider any continuing exposures (e.g., irritants or allergens) that may be exacerbating the worker's condition.

In addition, workers who have negative physiologic test results despite symptoms suggestive of asthma should be carefully followed with repeat medical evaluation during an episode of acute symptoms.

*CHAPTER 10*

# Research Needs

Substantial research has been conducted on the health effects of acute and chronic exposures to MWFs and to MWF aerosol, but additional information about current exposure risks would be very useful. NIOSH recommends the following research to determine the magnitude of potential health effects, to improve our understanding of their etiology, and to evaluate the effectiveness of prevention strategies:

- Provide additional epidemiologic and industrial hygiene evaluations for workers exposed to MWFs in current use. Include HP, asthma, and chronic obstructive airways disease in these studies.
- Investigate and evaluate potential worker exposures and health effects from bacterial and fungal contamination, endotoxins, and other metabolic products in MWFs.
- Develop methods of biomonitoring exposed workers and using biomarkers to measure worker exposures to MWF contaminants and hazardous ingredients and additives.
- Accurately assess dermal exposures to MWFs and their absorption through normal or damaged skin.
- Determine whether contaminants are concentrated or removed during the refining and recycling of used MWFs. Examine the health risks of using recycled or reprocessed MWFs.
- Examine and evaluate worker protection and engineering controls in various work situations to determine better ways to eliminate or reduce exposures to MWFs and to MWF aerosols. Document effective control strategies.
- Test representative mixtures of MWF components to evaluate the potential synergy of typical MWF mixtures.
- Develop bioassays or other methods to measure respiratory or dermatologic irritation.
- Investigate possible substitutes for hazardous MWF ingredients and additives to identify those that are the safest.

- Conduct research on acute and chronic exposures that lead to irritation, sensitization, and lung or skin injury. Models should be developed for assessment of exposure to multiple agents.
- Develop sensitization and irritation bioassays for biocides in MWFs.
- Develop sampling and analytical methods to detect and monitor MWFs contaminated with N-nitrosamines. Investigate current conditions on the worksite that lead to nitrosamine formation.
- Conduct further research to determine concentrations of MEA, DEA, and TEA exposures during metalworking operations and their adverse health effects.