Metalworking Fluids:

A Resource for Employers and Health & Safety Personnel in Washington State

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Introduction

Metalworking fluids (MWFs) are also known as coolants, cutting oils, lubricants, and machining fluids. These fluids lubricate and cool metalworking operations by reducing friction and carrying away heat. MWFs are also used to wash away waste metal chips. According to the National Institute for Occupational Safety and Health (NIOSH), over 1 million workers in the United States are exposed to MWFs. Here at the Safety & Health Assessment & Research for Prevention (SHARP) program, we have estimated that approximately 20,000 workers in Washington State use MWFs. Machinists, machinery mechanics, metalworkers, and other machine operators and setters have the greatest contact with these fluids. However, workers performing assembly operations can also be exposed if MWFs remain on the machined product. Workers other than machinists may also be exposed to MWF mists if ventilation systems are poorly designed or inadequate. Workers may be exposed by skin contact, inhaling (breathing in), or ingesting (swallowing) particles, mists, and aerosols.

Although recent changes in MWF formulations have resulted in safer products, it is important to realize that MWFs may cause a variety of health problems. Skin exposure to MWFs can result in conditions like dermatitis or folliculitis. Repeated inhalation of MWF mists has been shown to decrease lung function over the course of a work-shift. MWF mists may also cause several respiratory diseases, including asthma, bronchitis, and hypersensitivity pneumonitis. Exposure to some MWFs and/or their additives may cause cancer. The health hazards of MWFs depend upon the type of fluid used, as well as the additives and contaminants that may be present in the fluid.

MWFs have received increased attention recently because NIOSH has reviewed the scientific literature and concluded that workers may be suffering from asthma and possibly other lung diseases at the current occupational exposure limits. Consequently, NIOSH and OSHA (the Occupational Safety and Health Administration) are considering lowering the occupational exposure limit. NIOSH recommends that occupational safety and health programs that include medical monitoring should be established at MWF-using workplaces. As of fall 1997, NIOSH is finalizing its “Criteria Document” and OSHA has convened a committee of national experts to develop a proposal for a new standard to lower workplace exposures and increase worker protection.

The purpose of this booklet is to help health & safety personnel and employers reduce the toxicity of MWFs and minimize workers’ exposures to these potentially toxic substances. Please contact SHARP if you need more information. (Contact phone numbers are provided on page 23.)

Contents

What Types of MWFs Are Used?

MWFs fall into four main classes: insoluble (straight), soluble, synthetic, and semisynthetic. The table on page 3 summarizes the features of each type.

Insoluble oils

These formulations contain no water and are comprised of neat oil. Frequently referred to as cutting oils, insoluble oils are used as lubricants, improve the finish on the metal cut, and prevent rusting. The petroleum oils used in insoluble MWFs are usually refined mineral oils. However, animal, marine, or vegetable oils may be used singly or in combination with mineral oils to increase wetting action and lubricity. Insoluble oils are used for moderate- to heavy-duty machining and require fewer additives than the soluble types. However "extreme-pressure agents" are often added to enhance performance under high temperatures and pressures, including sulfur, chlorine, or phosphorous.

Insoluble oils are used much less frequently today than in the past because they cost more and are more difficult to clean than the soluble types. Prior to the 1950s, relatively unrefined mineral oils were used in MWF formulations. The high levels of polycyclic aromatic hydrocarbons (PAHs) present in older insoluble oils may be at least partially responsible for some of the excess cancers observed amongst machinists in epidemiological studies.

Soluble MWFs

These emulsions and water-soluble oils are designed to cool and lubricate. These fluids prevent welding of the cutting tool and the work surface, reduce abrasive wear of the tool at high temperatures, and prevent distortion caused by residual heat. The highly refined mineral oils of soluble MWFs are blended from higher viscosity oil bases than are insoluble oils. Soluble MWF concentrates are diluted 60% to 85% with water before use and contain a surface-active emulsifying agent to maintain the oil-water mix in an emulsified oil and water phase. Superfatted emulsions of soluble MWFs are produced by adding fatty oils, fatty acids, or esters. Extreme-pressure emulsions for very heavy-duty operations are produced by adding sulfur, chlorine, or phosphorous.

Synthetic MWFs

Synthetic MWFs do not contain oil; the simplest synthetics are composed of organic and inorganic salts dissolved in water. Also functioning as coolants and lubricants, synthetic MWFs eliminate smoking, reduce misting, provide detergent action, and reduce oxidation. Consequently, the simple synthetics offer rust protection and good heat removal, but usually have very low lubricating ability. Other synthetic MWFs may be formulated with synthesized hydrocarbons, organic esters, polyglycols, phosphate esters, and other synthetic lubricating fluids.

Synthetics are stable, can be supplemented with biocides to discourage the growth of microorganisms, and provide effective cooling capacity at high machining speeds and feed rates.

The same extreme-pressure agents that are added to insoluble oils may also be added to water-soluble oils. Coupling agents are used to maintain emulsification. Antifoaming agents, dyes, perfumes, and water softeners may also be added. Biocides may be added to reduce the growth of bacteria and fungi in water-based fluids.

The presence of water in the soluble fluids can cause machine tools and parts to corrode. Consequently, nitrites, amines, and certain oils may be added to inhibit corrosion.

Semisynthetic MWFs

This class of MWFs contain small amounts of oil (5% to 30% in the concentrate) and may be formulated with fatty acids, sulfur, chlorine, and phosphorous to provide lubrication for higher speed and feed operations to medium and heavy operations.

Other MWFs

For operations on certain metals, some machine shops use other fluids, such as perchloroethylene for molybdenum. If you are using a fluid that is not a standard type of formulation, your machinists may be at risk for health effects other than those covered in this booklet.

Independent machinists often formulate their own MWFs. When a health professional is faced with a blend of unknown or exotic ingredients, it is nearly impossible to determine if a specific health effect is related to exposure. It is safer to use a standard MWF with known ingredients in known amounts than to mix components that were never intended to be used in machining operations. Using such mixtures may put workers at risk for serious or unexpected health problems.

Types of metalworking fluids

Type	*Description*	*Commonly found additives*
Insoluble (waterless, oil-based material)	oily, amber-to-brown	extreme-pressure agents
Soluble (oil-based, with emulsifiers)	milky white	emulsifiers high-pressure additives corrosion inhibitors anti-foaming agents lubrication aids pH stabilizers coupling agents biocides
Semisynthetic Soluble (oil emulsion with large amounts of water)	translucent (light passes through), often tinted	lubricating aids emulsifiers corrosion inhibitors coupling agents biocides anti-foaming agents
Synthetic (water-based, contains no hydrocarbons)	transparent, often tinted green or other colors	lubrication aids corrosion inhibitors biocides anti-foaming agents dyes extreme-pressure agents water softeners perfumes

Source: Adapted from “A HESIS Guide to Metalworking Fluids”

Toxic Properties of MWFs

Although recent changes in many MWF formulations have resulted in safer products, it is important to realize that MWFs can still contain substances that are harmful to workers' health. Worker exposure to MWFs of all types has been associated with certain cancers, changes in lung function, lung disease, and skin problems.

What toxic substances are in MWFs?

Because the usage patterns, chemistry, and toxicology of MWFs are extremely complex, it has proven difficult to determine precise links between specific MWF formulations or ingredients with specific health effects in exposed workers. However, several components of MWFs are known or suspected carcinogens and/or have the potential to cause other health problems:

Mineral oil

Mineral oils (lubricant base oils) are complex mixtures of hydrocarbons that are refined from petroleum crude oils. The use of poorly- or non-refined mineral oils before the 1950s may have been responsible for skin cancer in machinists who were in extensive contact with insoluble oils. These older MWFs contained relatively high concentrations of polycyclic aromatic hydrocarbons (PAHs), some of which have been shown to cause cancer in laboratory animals and humans. Although the industry now manufactures MWFs using severely refined oils with relatively low PAH concentrations, contamination of MWFs with greases and oils from machinery (so called "tramp oils") and chemical reactions at high temperatures can increase PAH levels.

Nitrosamines

Several nitrosamines have been detected in commercial MWFs, including the potent animal carcinogen, *N*-nitrosodiethanolamine (NDELA). Nitrosamines are formed in MWFs from a reaction between amines (mostly alkanolamines) and nitrites (usually sodium nitrite). Recognizing this problem, the MWF industry now manufactures preparations that are "nitrite-free"; however, several recent MWF formulations have been shown to contain NDELA. Nitrosamines may be formed in MWFs if the source water is high in nitrites, if nitrate-containing biocides are used, or the recirculating system is contaminated with nitrite-containing corrosion-inhibitors, cleaners, and other products.

Triethanolamine (TEA)

Alkanolamines and ethanolamines are used to stabilize pH and act as surfactants or corrosion inhibitors. Relatively high airborne TEA concentrations have been found in transfer operations, which involve large, complex machines. There is some evidence to suggest that TEA causes

cancer in laboratory animals and may be responsible for occupational asthma.

Biocides

Biocides are used to prevent the growth of bacteria and fungi in MWFs. Biocides are classified into two groups: formaldehyde-releasing agents (containing condensates of formaldehyde), and others. Formaldehyde has been shown to cause cancer in laboratory animals and the human data are equivocal. This compound is also a well-know irritant and can cause either allergic or contact dermatitis. There is additional concern that nitrated biocides may release nitrites, which are precursors for nitrosamine formation.

Chlorinated paraffins

Used as extreme-pressure additives, chlorinated paraffins are activated by the heat generated during metalworking to form a film at the tool/workpiece interface to prevent destructive welding, excessive metal transfer, and surface breakdown. Long- and short-chain chlorinated paraffins have been shown to be carcinogenic in laboratory animals. The toxicity of mid-chain chlorinated paraffins has not been adequately characterized.

Contaminants

The composition of MWFs changes a great deal over time. Apart from the changes in PAH and nitrosamine concentrations discussed above, bacteria and fungi can grow to relatively high levels in water-containing MWFs. Practically all large-scale recirculating MWF systems contain bacteria that have no obvious effects on workers’ health. However, there have been reports of infectious disease caused by contaminated MWFs (Pontiac fever, from the same type of bacteria that causes Legionnaires' disease). Bacteria and the toxins they produce may also be responsible for hypersensitivity diseases and sensitization of the immune system. Fungi may be responsible for incidents of hypersensitivity pneumonitis seen in machinists.

Concentrations of toxicologically important metals, such as arsenic, cadmium, and lead, can also increase with use, as they are introduced into the MWFs during machining. A lung disease called “hard metal disease” has been seen in machinists who work with cobalt and tungsten carbide.

What are MWFs’ health effects?

Workers are most commonly exposed to MWFs and their additives through dermal (skin) contact. MWFs may affect workers’ skin following prolonged or frequent contact. Some of the fluid or additives may penetrate the skin, enter the bloodstream, and cause effects elsewhere in the body.

While machining, MWFs may also form a mist of small droplets suspended in air that are inhaled (breathed in). The larger droplets are trapped in the nose or trachea (windpipe), but smaller

droplets can be deposited in the lungs. The droplets that remain in the nose and trachea can later be swallowed, along with any MWF that may have contaminated foods or beverages at work.

Overexposure to MWFs most commonly affects the skin. However, depending upon the type of fluid and additive, there may be other health effects, including asthma and increased risk for cancer. The potential health effects associated with MWF additives are presented in Appendix A.

The most commonly observed illnesses associated with MWF use are:

Skin problems

Skin contact with MWFs is very common, since they are often applied to the machine tool in large volumes. Workers' skin can be covered with mist or spray while machining, or handling parts and tools covered with residual fluid. NIOSH has observed that 14% to 67% of workers in workplaces using MWFs have dermatitis.

Insoluble oils have been shown to cause a condition called "oil folliculitis", also known as "oil acne", in which the pores of the skin become plugged and the glands cannot drain. These blocked glands often look like pimples, and may fill with pus, become red, and cause itching and pain. The skin over the swollen glands may eventually become dark. People with large pores and much hair on their skin are more susceptible to folliculitis. Wearing oil-soaked clothing and using oily rags can cause oil folliculitis where the cloth comes into contact with the skin. Treatment consists of keeping the affected skin clean and free from further contact with oil.

The soluble oils, semisynthetic soluble oils, and synthetic fluids can cause dermatitis (skin rash) by removing the natural protective fats and oils from the skin. The skin may become dry, cracked, itchy, painful, and/or reddened. Skin affected by dermatitis is more susceptible to infections, and to penetration by chemicals. Changing MWF formulations or using gloves or barrier creams may reduce exposure. Treatment consists of using skin creams to replace the skin's natural oils (i.e., emollients).

Many of the additives used in water-soluble fluids may also cause allergic contact dermatitis, seen as redness and itching where even a small amount of the material has contacted the skin. Machining tools and metal stock may contain nickel, cobalt, and chromium metals that can also cause allergic dermatitis. These metals may accumulate in MWFs and wipe rags as small metal slivers and finely ground metal.

Cancer

The link between MWF exposure and cancer is controversial, since the epidemiological studies were performed on workers who were exposed to MWFs as long as 20-30 years ago. Before the 1950s, some MWFs contained relatively high concentrations of substances suspected to cause cancer (mostly polycyclic aromatic hydrocarbons and nitrosamines). Since then, industry actions have resulted in substantially reduced concentrations of these substances in MWFs. However, it is unclear whether these changes have eliminated the cancer risk because it is not known if the cancer-causing substances are present in the MWFs themselves, or whether they are present in

the additives or contaminants.

Repeated skin exposure to insoluble MWFs containing mineral oil may cause skin cancer and/or changes in the skin that may later develop into skin cancer. The affected areas frequently include the forearms and the backs of the hands. Workers who used insoluble MWFs were found to be at an increased risk of developing skin cancer of the scrotum. However, the risk of scrotal cancer appeared to have decreased greatly following the introduction of effective protective clothing and strict personal hygiene practices. Although skin cancer is typically associated with insoluble fluids, it is not known whether other types of MWF may increase a worker’s cancer risk.

Although the epidemiological data are inconsistent, NIOSH suggests that MWF exposures prior to the 1980s are associated with cancer of the stomach, pancreas, larynx, rectum, skin, and bladder. However, the evidence is equivocal for an association between MWF exposure and cancer at several other sites, including the esophagus, lung, prostate, brain, colon, and hematopoietic system.

Lung disease

Inhaling the aerosols, particles, and mists generated by MWFs while machining is a common source of exposure. Reductions in lung function have been seen in machinists who routinely inhale MWF mists. Several lung diseases are associated with inhaling MWFs, including asthma, acute airway irritation, hypersensitivity pneumonitis, lipid pneumonia, chronic bronchitis, and possibly lung cancer. NIOSH researchers suggest that machinists face an increased risk of asthma at concentrations below the current permissible exposure limits (PELs).

Other health effects

Many components of MWFs, like formaldehyde, are known irritants to the eyes, nose, and throat. Workers may experience burning sensations, sneezing, coughing, or teary and itchy eyes. Some MWF constituents, such as glycol ethers and pentachlorophenol, have the potential to cause birth defects or decrease a worker's ability to have children.

Occupational Standards for MWFs

In Washington State, workplace exposure limits are set and enforced by the Washington Industrial Safety and Health Act (WISHA). In addition to WISHA's legal standards, this section also describes non-enforceable exposure limits that may be used as guidelines to supplement health and safety programs.

Examples of the standards appropriate for regulating MWF exposures in the workplace are summarized in Appendix B (Occupational Exposure Limits for Selected MWF Constituents).

WISHA's permissible exposure limits

The two most important occupational standards that apply to MWFs are those for "particulates not otherwise regulated" and "mineral oil mists." Both standards are appropriate for oil-containing MWFs. The sampling for particulates captures both the aqueous (water-soluble) and oil-based fractions of the MWF aerosol; a solvent extraction is then performed on the filter used to collect the aerosol to determine the oil mist concentrations. For oil-free MWFs (i.e., synthetics), only the "particulates not otherwise regulated" standard is appropriate. (Washington State Department of Labor and Industries' sampling methods are provided in Appendix C.)

The WISHA permissible exposure limit (PEL) for "total" particulates is 10 milligrams of total particulate per cubic meter of air (10 mg/m^3), based on an 8-hour time weighted average (TWA). This means that exposures to total particulates can legally exceed 10 mg/m^3 at times, but only if concentrations are below 10 mg/m^3 at other times, so that the *average* exposure for any 8-hour workshift is 10 mg/m^3 or less. The PEL for oil mists is an 8-hour TWA of 5 mg/m^3.

NIOSH has recently reviewed the scientific literature and concluded that workers may experience adverse respiratory effects if they are exposed to MWFs at the current PELs for particulates and oil mists. Consequently, a revised occupational standard for MWFs is currently under consideration by NIOSH and OSHA. NIOSH recommends that occupational safety and health programs should be established at MWF-using workplaces (see below). NIOSH is finalizing its "Criteria Document" and OSHA is convening a committee of national experts to develop a proposal for a new standard to lower workplace exposures and increase worker protection.

Many of the additives and contaminants found in MWFs, such as formaldehyde, phosphorus, and various metals, also have their own PELs. The exposure limits for some selected additives are given in Appendix B. Some additives are readily absorbed through the skin and require special protective measures (these exposure limits are followed by an "S" in Appendix B).

WISHA also enforces short-term exposure limits (STELs) and ceiling limit values. The STEL is the employee's 15-minute time-weighted average exposure that must not be exceeded at any time during a working day. The ceiling limit value must not be exceeded during any part of the working day.

ACGIH’s threshold limit values

The American Conference of Governmental Industrial Hygienists (ACGIH) recommends three categories of threshold limit values (TLVs) - TWAs, STELs, and ceiling values. TLVs are based on available information from industrial experience; from experimental human and animal studies; and, when possible, from a combination of the three. ACGIH's TWAs for total particulates and mineral oil mists are identical to WISHA's. However, ACGIH does not provide a STEL or ceiling value for total particulates and the STEL for mineral oil mist (10 mg/m^3) is currently under review.

TLVs are recommendations of the ACGIH and are not enforceable by WISHA.

NIOSH’s recommended exposure limits

The National Institute for Occupational Safety and Health (NIOSH) develops and recommends criteria for identifying and controlling potentially hazardous exposures in the workplace. NIOSH’s recommended exposure limits (RELs) also include TWAs, STELs, and ceiling values, but are not enforceable by WISHA.

According to the draft Criteria Document, NIOSH is considering a REL for MWFs of 0.5 mg/m^3 as an 8-hour TWA for total particulate. This REL is based on the following considerations:

- MWF exposure at levels below the current PEL has been demonstrated to cause adverse respiratory health effects;
- A reliable sampling method for measuring MWF aerosol exposure is widely available;
- The REL is applicable to all types of MWFs; and
- The REL is technologically feasible.

NIOSH considers that health and safety programs are equally important and suggests that preventing dermal exposures to MWFs is critical to prevent MWF-related skin disorders.

Other Health & Safety Considerations

What are WISHA's requirements?

In addition to the numerical exposure limits described in the previous section (provided in WAC 296-62: General Occupational Health Standards), WISHA specifies General Safety and Health Standards (WAC 296-24), which must also be adhered to by Washington State employers. This subsection summarizes the most relevant portions of the General Safety and Health Standards and is not a complete review of all appropriate WISHA standards. The reader is encouraged to contact their nearest L&I service location with questions about these standards (see Appendix D for contact information).

Under WISHA, employers must:

- Provide a safe and healthful workplace and comply with safety and health standards.

- Establish an active safety committee and maintain a written accident-prevention program. The safety committee must include both employer and worker representatives and be tailored to the particular needs of the workplace. At a minimum, the accident prevention program should consist of a safety orientation program describing the employer's safety program and a designated safety and health committee consisting of management and employee representatives. The employee representatives are elected or appointed by fellow employees. (Note: employers with 10 or fewer employees or larger employers whose employees are segregated on different shifts or in widely dispersed locations in crews of 10 or less may elect to have crew meetings in lieu of a formal safety & health committee.)

- Prominently post a notice of employer responsibility and employee rights (L&I has produced a poster that contains all the required notices.)

- Provide training about job health and safety.

- Keep records of all job-related accidents. Recordkeeping systems must meet state requirements.

Washington State also has a Hazard Communication standard (WAC 296-62-054 through 05429), also know as "Right to Know." This rule requires chemical manufacturers or importers to assess the hazards of chemicals they produce or import. Employers then provide employees with information concerning the hazardous chemicals to which they are exposed. The elements

of a hazard communication program are:

- Inventory all chemical products in the workplace;
- Label hazardous chemical containers;
- Maintain a file of Material Safety Data Sheets (MSDSs) for each hazardous chemical that is packaged, handled, or transferred;
- Inform all employees about the hazard communication program. Identify and train employees who could be exposed to hazardous chemicals that are present in off-the-shelf MWF formulations and possible contaminants; and
- Develop and maintain a written program that explains how employees are informed and trained about the hazardous chemicals in their workplace.

WISHA requires that employers determine what personal protective equipment (PPE) employees need while doing their work (specified in WAC 296-24, Part A-2). WISHA requires that, when necessary, employers must provide PPE for eyes, face, head, and extremities, protective clothing, respiratory devices, and protective shields and barriers. If respirators are necessary, WISHA requires that employers develop a respiratory protection program, as specified in WAC 296-62-071. The main respiratory protection program requirements focus on respirator selection, wearer medical eligibility, fit-testing, training, and maintenance/storage.

PPE must be used and maintained in a sanitary and reliable condition. Where employees provide their own PPE, the employer must assure its adequacy, including proper maintenance, and sanitation. PPE must be of safe design and construction for the work to be performed. PPE must be durable, fit properly and must not unduly interfere with the movements of the wearer.

The employer must assess workplace operations to determine if hazards are present, or are likely to be present, which necessitate the use of PPE. If such hazards are present, or likely to be present, the employer must:

- Select, and have each affected employee use, the types of PPE that will protect the affected employee from the hazards identified in the hazard assessment;
- Communicate selection decisions to each affected employee; and
- Select PPE that properly fits each affected employee.

The employer is also responsible for providing training to each employee who is required to wear PPE.

NIOSH's recommendations

The following subsections provide excerpts from the "Recommendations for an Occupational Safety and Health Program" presented in NIOSH's draft Criteria Document. Contact NIOSH at *1-800-35-NIOSH* to request a copy of the Criteria Document if you are interested in adopting any of their recommendations. Although these recommendations are not enforceable by WISHA, employers may wish to supplement their health and safety programs with NIOSH's recommendations on a voluntary basis. Note that these recommendations refer to NIOSH's proposed REL of 0.5 mg/m^3 (8-hour TWA for total particulate). Although this value is 20-fold lower than WISHA's PEL for total particulates (10 mg/m^3), employers are encouraged to consider using NIOSH's REL, given the compelling evidence for lung disease below the current legal standards.

NIOSH emphasizes the need for comprehensive occupational safety and health programs to prevent occupational deaths, injuries, and illnesses. NIOSH recommends that safety and health programs should 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 and effective safety and health program should include:

- Safety and health training,
- Worksite analysis,
- Hazard prevention and control, and
- Medical monitoring of exposed workers.

These elements are described in the following subsections.

Safety and health training

Employers should establish a training program for all workers with MWF exposures. One of the important goals of training is to enable workers to identify potential workplace hazards. Instruction should be provided when changes occur in job duties, a new job is assigned, and when new MWFs or potentially hazardous chemicals are introduced. Workers, as well as contract workers employed to maintain the facility, should be informed about any hazardous chemicals in the work areas and the availability of information in the material safety data sheets (MSDSs), and other available information sources.

Workers should be trained how to detect the presence or potential release of hazardous chemicals (e.g., appearance of bacterial overgrowth and degradation of MWFs). Instruction should include information about how workers can protect themselves from potentially hazardous exposures (e.g., the use of appropriate work practices, emergency procedures, and personal protective equipment). Workers should be encouraged to maintain good housekeeping practices to help prevent environmental contamination of the MWFs. In addition, workers should be instructed on

the adverse health effects associated with MWF exposures, and the possible occurrence of respiratory and dermal effects below NIOSH's REL.

Worksite analysis

An occupational safety and health program designed to protect workers from adverse health effects associated with MWFs exposures should include the means for thoroughly identifying all hazards. An important part of this program is routine environmental monitoring of dermal and inhalation exposures. Such monitoring provides a means of assessing the effectiveness of engineering controls, work practices, and personal protective equipment.

Hazard prevention and control

Worker exposures during metalworking operations can occur by inhalation of MWF aerosols and mists. Exposure can also occur by contamination of the skin by settled mists, splashes, or dipping of hands and arms into MWFs. Most airborne exposures can be controlled by a combination of proper MWF use and application, maintenance, isolation of the operation, ventilation, and other operational procedures. Machine guarding, gloves, face guards, aprons, or other protective work clothes may reduce dermal exposures. Employees should be allowed the time and encouraged to periodically clean MWF contaminated skin with gentle soaps and clean towels. Barrier creams may be useful for some individuals, although their protective effects are controversial. The use of non-barrier cream emollients may also be protective.

Fluid use and application

Splashing and mist generation can be minimized by proper application of the MWF. MWFs should be applied at the lowest possible pressure and flow volume consistent with provision for adequate part cooling, chip removal, and lubrication. To avoid unnecessary mist generation, the fluid should be applied at the tool/workpiece interface, minimizing contact with other rotating equipment. Fluid delivery should cease when machining is not being performed.

[Although not specifically mentioned in NIOSH's recommendations, the practice of using compressed air to remove MWFs from the workpiece after machining should be discouraged.]

If petroleum-containing MWFs are used, PAHs in the mineral oil fraction of the MWFs should be < 1%, a level achieved by severe refining of the base oil stock used in the MWFs. To minimize the potential for the formation of nitrosamines, nitrate-containing materials should not be added to MWFs that contain ethanolamines. The use of anti-misting additives may be considered to minimize mist production.

Since all additives will be depleted with time, the MWF and additive concentrations should be monitored continually so that components and additives may be added and concentrations adjusted as needed. The MWF should be maintained within the pH and concentration range recommended by the supplier, and the MWF temperature should be maintained as low as practical to slow the growth of microorganisms. In all cases, the MWF should be selected to be

as non-irritating or sensitizing as possible, consistent with its operational requirements, and maintained in that condition by a careful MWF management program.

Fluid maintenance

Water-based or water-contaminated MWFs are contaminated by and support the growth of bacteria and fungi, which may be considered the "normal flora" of the MWFs. However, insufficient data are available to determine what constitutes a "safe" normal flora (i.e., bacterial or fungal genera, numbers of viable organisms, "safe" concentrations of endotoxin or other potentially hazardous by-products) and exactly what conditions lead to the degradation of MWFs. Biocides should be used to control microbial overgrowth. Judicious addition of biocides may be used to maintain the functionality and efficacy of, and prevent the degradation of the MWFs. Wearing of personal protective equipment during the process of reconstituting or adding bulk biocides to the MWFs may prevent or reduce skin or mucosal irritation in sensitive workers.

MWFs should be managed to prevent growth of bacteria and accumulation of their biological contaminants (e.g., endotoxins, exotoxins, and other potentially toxic metabolites). The organisms most commonly isolated from circulating fluids are aerobic bacteria. However, during a shutdown there may be no circulation or aeration of the MWFs and the aerobic population in the MWFs decreases as the oxygen in the fluids are consumed. This can result in MWF overgrowth with anaerobic bacteria, which may produce noxious odors and gases. The use of biocides to reduce the anaerobic bacterial concentrations may also lead to fungi proliferation. Overgrowth of bacteria or fungi may result in clogged filters and ports and may interfere with the metalworking operation. Toxic microbial metabolites may accumulate in MWFs or be released as irritant gases, such as ammonia and hydrogen sulfide.

One of the disadvantages of treating heavily contaminated MWFs with biocides is that while the concentration of viable microorganisms will be reduced, soluble toxins (e.g., endotoxins) may be released from the dead organisms. Currently there are no effective methods to remove or inactivate heat-stable, soluble microbial toxins or metabolites; the MWFs should be replaced and care should be taken to prevent succeeding overgrowths. When it is necessary to replace MWFs because of microbial overgrowth, it is usually necessary to remove the degraded MWF and clean the entire circulating system and sump before replacement with clean MWFs. If the cleaning is not thorough, overgrowth may rapidly reoccur.

Isolation

Skin and inhalation exposure to MWF can be minimized by isolation of the worker through the use of mechanical parts handling equipment, and through use of machine enclosures. Simple splash guarding may suffice for low production machines. Complete enclosure (with ventilation) will be required for high production machines. Transfer machines should be isolated from other operations through plant layout, worker isolation booths or fresh air showers, and separate heating, ventilating, and air conditioning systems.

Ventilation systems

The ventilation system should be designed and operated to prevent the accumulation or recirculation of airborne contaminants in the workplace. A positive means of bringing in at least an equal volume of air from the outside, conditioning, and evenly distributing it throughout the exhausted area is the essential function of an air-exhaust system.

Ventilation of MWF mist and aerosol producing operations is most readily achieved if the machine tool is 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 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 generation, and away from enclosure openings to ensure complete purging of the enclosure. Selection of appropriate air cleaning equipment for metalworking operations exhaust that is recirculated to the work environment is based on the concentration and size distribution of the exhaust stream. If 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 airborne 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 and/or removed by exhaust. Air quality is maintained by designing a general ventilation system that minimizes air stagnation, 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.

Containment enclosure

Machine enclosures are one of the most effective methods of reducing worker exposures. Retrofitting containment structures may also reduce exposures.

Protective clothing and equipment

Engineering controls are used to reduce the airborne concentration of MWFs. However, in some situations, the added protection of chemical protective clothing and equipment (e.g., respirators) should be provided in the event of excessive airborne exposure concentrations over the NIOSH REL of 0.5 mg/m^3 or dermal contact with the MWFs. The operator and maintenance staff may also need chemical protective clothing because the nature of the work requires coming in contact with the MWFs during specific operations. All workers should be trained in the proper use and care of the chemical protective clothing. After all chemical protective clothing has been in routine use, it should be examined periodically along with the work environment to ensure that nothing has occurred to compromise the effectiveness of these materials. The following recommendations should be used as a guide in the selection of specific chemical protective clothing.

Protective clothing. Workers should wear protective sleeves, aprons, trousers, and caps as needed to protect skin from work clothes soiled or wetted with MWFs. The use of gloves may increase the risk of injury due to possible entanglement by moving tool or workpiece parts. If gloves are required, special attention should be given to guarding the equipment and ensuring that the glove will tear easily if entangled. Workers should also wear chemical-impervious protective shoes.

Respiratory protection. Effective source control measures (such as containment or local exhaust ventilation) should be implemented to minimize routine worker exposure to MWF mists before consideration is given to the routine use of respiratory protection. Nevertheless, some intermittent job tasks may regularly expose the worker to concentrations above the REL, where engineering controls are not feasible. Respiratory protection should be considered for this type of job assignment.

When respirators are used, the employer should establish a comprehensive respiratory protection program. Important elements of a 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, and (4) respirator fit testing, 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, employees will not receive the protection anticipated.

Sanitation and hygiene

Workers should be trained to keep personal items such as food, drink, cosmetics, and tobacco separate from the work environment. Smoking, eating, drinking, and applying make-up should be discouraged in metalworking areas to prevent unnecessary additional exposures to MWFs. A no-smoking policy should be established, since cigarette smoking may exacerbate the respiratory effects of MWFs.

Instruction in personal hygiene will reduce potential dermal MWF exposures. Workers should be encouraged and allowed the time during the workshift to clean exposed skin contaminated with MWFs. If onsite shower facilities are available, workers should be encouraged to shower and change into clean clothes at the end of the workshift. If not, workers should change from contaminated work clothes into street clothes prior to leaving work.

[Although not specifically mentioned in NIOSH’s recommendations, machinists should be discouraged from introducing “foreign substances” into the MWF circulation system. Cigarette butts, food, spit, and other contaminants degrade MWF performance and encourage the growth of bacteria and fungi.]

Labeling and posting

Workers should be trained to be aware of labeling practices; they must be informed of chemical exposure hazards, of their potentially adverse health effects, and of the appropriate methods for self-protection. Labels and signs posted on or near hazardous metalworking processes provide an

initial warning to other workers who may not routinely work near processes. 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 in excess of the REL. Warning signs may be needed at the worksite to inform transient nonproduction workers of hazards. All labels and warning signs should be printed in both English and the predominant language of workers who do not read English.

Medical monitoring of exposed workers

Because asthma and other adverse nonmalignant respiratory health effects are associated with MWF aerosol exposure, NIOSH recommends that employers should provide preplacement examinations and medical monitoring for all workers exposed to MWF aerosols. NIOSH also suggests that employers should also provide appropriate evaluation and management of workers with signs or symptoms suggesting respiratory effects associated with MWF exposure.

Medical monitoring represents secondary prevention and should not supplant primary prevention efforts aimed at controlling MWF aerosol exposures. One objective of the recommended medical monitoring is to enable early identification of workers who develop symptoms of MWF-related conditions such as asthma and dermatitis. Those with asthmatic symptoms must have their exposure controlled in a timely manner in order to minimize the risks of recurrences of acute asthmatic episodes and of chronic impairment of lung function.

Workers involved in the medical monitoring program should include all those exposed to MWF aerosol concentrations above half of NIOSH's REL (i.e., 0.25 mg/m^3), or those who work in areas where there may be lower MWF aerosol concentration, but one or more workers have developed respiratory effects probably related to MWF exposure. 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.

The essential components of NIOSH's recommended medical monitoring program include:

- *Initial or preplacement examination.* The employer should provide an initial medical examination for each worker included in the medical monitoring program.

- *Periodic examination.* All workers included in the medical monitoring program should be provided with at least annual screening examinations.

- *Detailed medical examination for selected workers.* Any worker should undergo further/more frequent medical evaluations if (1) he or she is identified by periodic questionnaire (or by self-referral at any interval between periodic questionnaires) as having episodic respiratory symptoms suggestive of asthma or any other respiratory condition possibly related to MWF exposure, or (2) he or she is judged by the supervising physician to have a medically significant reduction in lung function or any other lung condition warranting more detailed

assessment.

- *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.

- *Physician's report to the employer.* Following the initial and each periodic or detailed examination, the physician should provide a written report to the employer.

- *Employer actions.* The employer should assure that the worker's exposure does not exceed either the physician's recommended limits on exposure to MWF aerosols or other workplace hazards. Also, the employer should assure that the physician's recommended limits on the use of respirators have not been exceeded for any individual worker.

- *Follow-up 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) has been achieved. In addition, workers with symptoms suggestive of asthma but who have negative physiologic test results should be carefully followed with repeat examination during an episode of acute symptoms.

How Safe Is Your Machine Shop?

When toxicologists and industrial hygienists characterize the risks associated with workplace or environmental chemicals, they consider two key features that contribute to the potential for adverse health effects:

- "Toxicity" – the inherent chemical, physical, and biological properties of a substance that influence its potential to cause adverse effects. For example, the toxicity of MWFs may be influenced by the presence of bacterial toxins, formaldehyde, nitrosamines, PAHs, etc.

- "Exposure" – the set of circumstances by which a substance reaches sites in the body at a concentration and for a length of time sufficient to cause an adverse effect. In the workplace, exposure is influenced by factors such as engineering controls, personal protective equipment, and other mechanisms that influence worker contact with occupational chemicals.

Whether or not adverse effects are seen in workers is dependent, therefore, on the intrinsic properties of the substance, the exposure situation, and the susceptibility of an individual worker.

Based on the "Toxicity-Exposure" model described above, the following check list is designed to help you determine whether machinists and other workers are at risk from developing MWF-related health problems. You should aim to circle as many of the **bold** answers as possible

How toxic are your MWFs?

1	Do you monitor the pH and temperature of your MWFs on a regular basis to maintain them in the manufacturer-recommended ranges?	**Yes**	~~No~~
2	Do your MWFs contain formaldehyde-based biocides?	~~Yes~~	**No**
3	If you use oil-based MWFs, do you use well-refined or pure mineral oils?	**Yes**	~~No~~
4	Do any of your additives used in the MWFs contain nitrites or ethanolamine-type chemicals?	~~Yes~~	**No**
5	Do you shut down the MWF circulation system during the weekend or at any other time when the machine is not in use?	~~Yes~~	**No**
6a	Do you routinely replace the MWFs?	**Yes**	~~No~~
6b	Do you clean and flush out the MWF circulation system when changing MWFs?	**Yes**	~~No~~
7	Are the metal workpieces coated or treated with nitrite-containing rust inhibitors?	~~Yes~~	**No**
8	Does "tramp oil" contaminate your MWFs?	~~Yes~~	**No**
9	If you machine compounds that contain tungsten carbide, do you change out MWFs frequently (i.e., less than once a month)?	**Yes**	~~No~~
10	Does the color of your MWF change after a few weeks of use?	~~Yes~~	**No**
11	Do unpleasant odors often result from MWF use or storage?	~~Yes~~	**No**
12	Are machinists instructed that they should not introduce foreign substances into the MWFs (e.g., food, tobacco products, etc.)?	**Yes**	~~No~~

Are machinists over-exposed to MWFs?

13	Are oil mist and/or particulate levels monitored routinely?	**Yes**	~~No~~
	Do levels of oil mist or total particulates ever exceed:		
14a	NIOSH's REL (0.5 mg/m^3 total particulate)	~~Yes~~	**No**
14b	WISHA's PEL (10 mg/m^3 total particulate)	~~Yes~~	**No**
14c	WISHA's PEL (5 mg/m^3 oil mist)	~~Yes~~	**No**
15	Are MWFs applied at the lowest possible pressures and flow volumes to reduce mists and droplet production?	**Yes**	~~No~~
16	When working with MWFs, do machinists wear gloves, protective clothing (coveralls, aprons, etc.), and safety glasses?	**Yes**	~~No~~
17	Are your machining operations that use high volumes of MWF enclosed?	**Yes**	~~No~~
18	Do you use splashguards on tools that use MWFs?	**Yes**	~~No~~
19	Are your local exhaust ventilation systems installed directly on the machines (as opposed to the ceiling)?	**Yes**	~~No~~
20	Are workers trained to keep personal items such as food, drink, cosmetics and tobacco separate from the work environment?	**Yes**	~~No~~
21	Is there a no-smoking policy at your workplace?	**Yes**	~~No~~
22	Are workers able to change from contaminated work clothes into street clothes prior to leaving work?	**Yes**	~~No~~
23	Are shower facilities available at your workplace?	**Yes**	~~No~~
24	Are workers informed of MWF labeling practices and are warning signs in place, which warn workers that PPE should be used with MWFs?	**Yes**	~~No~~
25	Do you have a medical monitoring program in place for workers exposed to MWFs?	**Yes**	~~No~~
26	Do machinists routinely get MWFs on their skin?	~~Yes~~	**No**
27	Are machinists encouraged to take care of their skin by using moisturizers, barrier creams, and mild soaps?	**Yes**	~~No~~
28	Do machinists keep MWF-soaked rags in their pockets?	~~Yes~~	**No**
29	Do machinists use compressed air to clean off their machined parts?	~~Yes~~	**No**

Please contact SHARP to request assistance in reducing the toxicity of your MWFs or preventing worker exposures.

For More Information

Safety and Health Assessment and Research for Prevention (SHARP) Program

If you would like additional information about MWFs in Washington State, please contact SHARP at:

Safety & Health Assessment & Research for Prevention (SHARP) Program
Washington State Department of Labor & Industries
P.O. Box 44330
Olympia, WA 98504-4330
Ph: 1-888-66-SHARP (toll-free)
Fax: 1-360-902-5672
E-mail: moor235@lni.wa.gov

Several SHARP publications, including this booklet, are available at SHARP's World Wide Web site: *http://www.wa.gov/lni/sharp*. You may be interested in reading SHARP's publication: *"Metalworking Fluids: A Fact Sheet for Workers."*

Washington State Industrial Safety and Health Act (WISHA)

For more detailed information about WISHA standards, please contact your nearest L&I service location. Addresses, telephone and fax numbers are provided in Appendix D.

Several relevant publications, including *"A Guide to WISHA,"* are available at L&I's World Wide Web Site: *http://www.wa.gov/lni*. Other useful documents include *"Understanding Right to Know"* and *"How to Write an Accident Prevention Program."*

L&I presents 25-30 no-fee workshops a year across the state, many of which help employers understand and implement WISHA standards. For more information, call 1-360-902-5590.

National Institute for Occupational Safety and Health (NIOSH)

To request a free copy of *"Criteria for a Recommended Standard: Occupational Exposures to Metalworking Fluids,"* call 1-800-35-NIOSH.

NIOSH's World Wide Web site (*http://www.cdc.gov/niosh/homepage.html*) contains a great deal of useful information, including downloadable portions of "Criteria Documents."

Appendix A: Additives and Their Potential Health Effects

ENT = eye, nose, and throat
CNS (Central Nervous System) depression = headache, dizziness, drowsiness, nausea (similar to intoxication)

Additive	*Potential health effects*	*Use*
alcohols	CNS depression	coupling agent
alkyl-phenol-ethylene oxide	none expected	lubricant
aromatic oils	oil folliculitis skin and scrotal cancer	lubricant
borates	ENT irritation dermatitis	corrosion inhibitor
chlorinated paraffins	cancer in animals	extreme-pressure agent
chlorophenols	ENT irritation dermatitis reproductive toxicity	biocide
cresol	dermatitis CNS depression liver and kidney damage	biocide
diethanolamines	ENT irritation dermatitis	corrosion inhibitor
esters	dermatitis ENT irritation	lubricant
fluorescein (resorcinol phthalein)	ENT irritation	dye

Additive	*Potential health effects*	*Use*
formaldehyde formalin	ENT irritation irritant dermatitis asthma cancer in animals	biocide
glycol ethers	CNS depression anemia reproductive effects	coupling agent
glycols	ENT irritation	coupling agent
hexahydrobenzoic acid	ENT irritation dermatitis	emulsifier
iodine	ENT irritation dermatitis	biocide
naphthenates	CNS depression	emulsifier
naphthenic oils	oil folliculitis skin and scrotal cancer	lubricant
nitrites	none expected	corrosion inhibitor
organic mercurials	ENT irritation nervous system dysfunction dermatitis allergic dermatitis	biocide
oxammonium	inadequate information	corrosion inhibitor
paraffinic oils	oil folliculitis skin and scrotal cancer	lubricant

Additive	*Potential health effects*	*Use*
phenols	ENT irritation dermatitis liver and kidney damage	biocide
phosphates	dermatitis ENT irritation	corrosion inhibitor
phosphorus	ENT irritation dermatitis	extreme-pressure agent
polyether glycols	none expected	lubricant
quarternary ammonia compounds	ENT irritation dermatitis allergic dermatitis	biocide
sodium, amine, and rosin soaps	inadequate information	emulsifier
sodium sulfonates	inadequate information	emulsifier
S-triazine compounds	allergic dermatitis suspected carcinogen	biocide
sulfur	ENT irritation	extreme pressure agent
triethanolamines	ENT irritation dermatitis	corrosion inhibitor
tris-hydroxymethylnitromethane	ENT irritation liver damage dermatitis	biocide

Source: Adapted from "A HESIS Guide to Metalworking Fluids"

Appendix B: Occupational Exposure Limits for Selected MWF Constituents*

Constituent	***WISHA PELs***		***ACGIH TLVs***		***NIOSH RELs***	
	TWA	***STEL/CEIL(C)***	***TWA***	***STEL/CEIL(C)***	***TWA***	***STEL/CEIL(C)***
particulates - total	10 mg/m^3	none	10 mg/m^3	none	0.5 mg/m^{3a}	none
Mineral oil mist	5 mg/m^3	none	5 mg/m^3	10 mg/m^{3b}	5 mg/m^3	10 mg/m^3
cresol	5 ppm (22 mg/m^3)-S	none	5 ppm (22 mg/m^3)-S	none	2.3 ppm (10 mg/m^3)	none
formaldehyde	1 ppm	2 ppm	None	0.3 ppm (0.37 mg/m^3) (C)[c]	0.016 ppm[d]	0.1 ppm[e]
2-ethoxyethanol	5 ppm (19 mg/m^3)-S	none	5 ppm (18 mg/m^3)-S	none	0.5 ppm (1.8 mg/m^3)-S	none
2-methoxyethanol	5 ppm (16 mg/m^3)-S	none	5 ppm (16 mg/m^3)-S	none	0.1 ppm (0.3 mg/m^3)-S	none
pentachlorophenol	0.5 mg/m^3-S	none	0.5 mg/m^3-S	none	0.5 mg/m^3-S	none
phosphorous	0.1 mg/m^3	none	0.02 ppm (0.1 mg/m^3)	none	0.1 mg/m^3	none
ethanolamine	3 ppm (8 mg/m^3)	6 ppm (15 mg/m^3)	3 ppm (7.5 mg/m^3)	6 ppm (15 mg/m^3)	3 ppm (8 mg/m^3)	6 ppm (15 mg/m^3)
diethanolamine	3 ppm (15 mg/m^3)	none	0.46 ppm (2 mg/m^3)-S	none	3 ppm (15 mg/m^3)	none
triethanolamine	none	none	5 mg/m^3	none	none	none
iodine	none	0.1 ppm (1 mg/m^3) (C)	None	0.1 ppm (1 mg/m^3) (C)	none	0.1 ppm (1 mg/m^3) (C)
acetaldehyde	100 ppm (180 mg/m^3)	150 ppm (270 mg/m^3)	None	25 ppm (45-mg/m^3) (C)[f]	lowest feasible conc.[g]	lowest feasible conc.[g]
ammonia	25 ppm (18 mg/m^3)	35 ppm (27 mg/m^3)	25 ppm (17 mg/m^3)	35 ppm (24 mg/m^3)	25 ppm (18 mg/m^3)	35 ppm (27 mg/m^3)
chlorine	0.5 ppm (1.5 mg/m^3)	1 ppm (3 mg/m^3) 1 ppm (3 mg/m^3) (C)	0.5 ppm (1.5 mg/m^3)	1 ppm (2.9 mg/m^3)	none	0.5 ppm (1.45 mg/m^3) (C)
hydrogen sulfide	10 ppm (14 mg/m^3)	15 ppm (21 mg/m^3)	10 ppm (14 mg/m^3)	15 mg/m^3 (21 mg/m^3)	none	10 ppm (15 mg/m^3)[h]
sulfur monochloride	none	1 ppm (6 mg/m^3) (C)	None	1 ppm (5.5 mg/m^3) (C)	none	1 ppm (6 mg/m^3) (C)

*This listing is not inclusive; standards also exist for metals, in addition to other contaminants and additives.

See over for legend

[a] Proposed in NIOSH's "Criteria Document". This REL for total particulate would apply only to MWFs
[b] Adopted value for which changes are proposed
[c] Class A2 carcinogen
[d] Carcinogen
[e] Carcinogen; 15-min. TWA ceiling
[f] Class A3 carcinogen
[g] Carcinogen; limit of quantitation 18 ppm
[h] 10-min. TWA ceiling

WISHA = Washington Industrial Safety and Health Act
PEL = Permissible exposure limit
ACGIH = American Conference of Government Industrial Hygienists
TLV = Threshold limit value
NIOSH = National Institute for Occupational Safety and Health
REL = Recommended exposure limit
TWA = Time-weighted average
STEL = Short term exposure limit
CEIL = Ceiling
mg/m^3 = milligrams per cubic meter
ppm = parts per million
S = readily absorbed by skin

Sources:
WISHA PELs - WAC 296-62-07515 (Part H, Air Contaminants, Control of Chemical Agents)
ACGIH TLVs and NIOSH RELs - ACGIH Guide to Occupational Exposure Values - 1996

Appendix C

L&I's Sampling Methods

Oil Mist, Vegetable & Mineral

FORMULA:	C_nH_{2n+2} where n ≥ 16	Method:	L&I0004
		Issued:	05/03/95
MW:	not pertinent	Revised:	06/21/95
CAS #:	8012-95-1	L&I Implementation:	01/01/90
RTECS:	PY8030000		

OSHA:	5mg/m^3	PROPERTIES:	liquid; d = 0.8 to 0.9 g/ml @ 20° C;
NIOSH:	no REL		BP 360 ° C
ACGIH:	5mg/m^3: (as sampled by a method which does not collect vapor)		vapor pressure negligible
WISHA:	5mg/m^3; particulate		

SYNONYMS: airborne mist of white mineral oil or the following water-insoluble petroleum-based cutting oils; cable oil; cutting oil; engine oil; heat-treating oils; hydraulic oils; transformer oils.

SAMPLING		MEASUREMENT	
SAMPLER:	Preweight PVC filter (preweighed 25mm or 37mm, 0.8mmPVC Omega filter)	TECHNIQUE:	GRAVIMETRIC extraction
		ANALYTE:	mineral oil
FLOW RATE:	1 to 3 L/min		
VOL -MIN:	20L @ 5 mg/m^3	BALANCE:	0.001 mg sensitivity or better; use same
-MAX:	500L		balance before and after sample collection
SHIPMENT:	routine		
		CALIBRATION:	ANSI/ASTM
SAMPLE STABILITY:	stable		Class 1 weights
BLANKS:	2 - 10 field blanks per set, minimum of 10%	RANGE:	0.050 to 2 mg per sample [1,2]
BULK SAMPLE:	none		
		ESTIMATED LOD:	0.050 mg per sample [1,2]
ACCURACY			
RANGE STUDIED:	2.5 to 11.7 mg/m3 (100 L sample) [1]	PRECISION:	<10 ug with 0.001 mg sensitivity balance [1]
			<68 mm with 0.01 mg sensitivity balance [1]
BIAS:	note determined		
OVERALL PRECISION (s_t):	not determined		
ACCURACY:	not determined		

APPLICABILITY: The working range is 1 to 20 mg/m^3 for a 100 L air sample. This method is applicable to all components soluble in petroleum ether or petroleum naphtha, but not to (nor does OSHA's standard cover) semi-synthetic or synthetic cutting fluids.

INTERFERENCES: Any organics not covered by standard which are soluble in petroleum ether.

OTHER METHODS: This method is based on NIOSH 5026, Issue 2, 15 August 1994 which is an IR Spectrophotometry method.

REAGENTS:

1. Petroleum ether or Petroleum Naphtha.
2. Mineral Oil, Alfa Products, CAS #: 08020-83-5.

EQUIPMENT:

1. Sampler: Preweighed 25 mm or 37 mm PVC 0.8 µm to 5 µm hydrophobic, polyvinyl chloride (PVC) filter and cellulose supporting pad in 25 mm or 37mm cassette filter holder. Omega Brand filters. Preweigh filter and seal with gel band.
2. Personal sampling pump, calibrated at 1 to 3 L/min ±5% , with flexible connecting tubing. Note: Pulsation in the pump flow must be within ±20% of the mean flow.
3. Microbalance, capable of weighing to 0.001 mg.
4. Static neutralizer: e.g., Po-210; replace nine months after the production date.
5. Tweezers for handling filter.
6. Glycine paper.
7. Flat blade screw driver to open cassettes.
8. Filtering apparatus capable of holding filter.
9. Watch glasses for drying filters.

Special Precautions: Use Petroleum ether in fume hood. Wear protective eye wear, gloves and lab coat.

PROCEDURES FOR PREWEIGHING FILTERS:

1. Lay out open, clean cassettes
2. Mark the backup pads using a permanent ink pen with consecutive filter codes and the appropriate expiration date . Place backup pads in clean, bottom cassettes with markings down.
3. Calibrate the balance and complete the first check weight. Record results. Handle the filter with forceps.
4. Place a filter on the static bar for at least 30 seconds.
5. Place the filter on balance pan and close the door.
6. After the weight has stabilized, record the filter preweight with the corresponding filter code.
7. Measure the check weight (20 mg) every ten filters. Measure the check weight after the last filter is weighed. Record all check weights and other measurements as completed.
8. Remove the filter from the balance and place it in the cassette on top of the backup pad with the correct filter code, on the bottom of the backpad.
9. Place the top cassette over the filters. To seal the cassettes tightly, place a large rubber stopper under and another rubber stopper on top of the cassette, then hit the rubber stopper very **firmly** three to four times with a hammer.
10. Check the seal in the cassettes by opening one out of every twenty cassettes. Properly sealed cassettes have filters with an indentation around the entire circumference of the filter. Document quality control check in the Laboratory notebook.
11. Place appropriately colored wet gel band around the sealed cassette and allow them to air dry. A small fan may be used in speed drying.
12. When dry, write the filter code as on the backpad on the outside of the cassette with a permanent ink pen.

SAMPLING:

13. Calibrate each personal sampling pump with a representative sampler in line.
14. Sample at 1 to 3 L/min. Do not exceed total filter loading of approximately 2 mg total dust.

SAMPLE PREPARATION:

15. Wipe exterior of cassette with a moist towel to minimize contamination.
16. Allow the samples to equilibrate in the gravimetric section of Laboratory at least 2 hours.
17. Check to make sure that the filter code and the Laboratory number assigned on the paperwork match the filter cassettes.
18. Calibrate the balance.
19. Open the cassettes. A knife or tweezers may be used to cut the gel band, and a short flat blade screw driver to pry open tightly seal cassettes. **Be careful not to spill particulate or contaminate the sample.**

NOTES: Insert tweezers through outlet hole of the filter cassette bottom to raise the filter so that filter can be grasped, with forceps. If filter sticks to cassette top, very gently remove with tweezers. This must be done carefully or the filter will tear.

20. Carefully remove the sample filter and place it on a static bar. Onto glycine paper, brush and tap out
any sample remaining in the cassette. Carefully transfer onto the sample filter. Allow it to sit on the static bar for at least 30 seconds.

CALIBRATION AND QUALITY CONTROL:

21. Use the same microbalance for weighing filters before and after sampling.
22. Carefully brush off the pan and inside of the Cahn.
23. Brush off the 20 mg and 200 mg calibration weights and set them on a static bar .
24. Zero the balance before weighing.
25. Follow the instructions in the Instrument Manual. Operate the scale with the door closed at all times.
26. Calibrate with the 200 mg weight.
27. Measure the weight of the 20 mg calibration weight. Record the date, weight measurement, temperature, humidity and your initials in the Laboratory notebook provided. This is the first check weight. **Complete check weights every 10 measurements and after the last sample.**
28. Recalibrate the balance whenever the check weight varies more than $\pm$0.005 mg.

FIRST POST SAMPLING MEASUREMENT:

29. Weigh each filter, including field blanks before extraction.
30. Carefully move the sample filter onto the balance pan. Close the door and allow balance to stabilize. Record any sample loss if you have a problem.
31. Record the sample post-weight with the corresponding filter code and preweight. Record any comments regarding load or problems with samples. Record anything remarkable about a filter (e.g., overload, leakage, wet, torn, etc.).
32. Remove the sample filter from the balance and place it back into the cassette. Place cassette top on and lightly seal.
33. Measure the check weight (20 mg) every ten filters and after the last sample filter. Record all check weights in the Laboratory Notebook.
34. Date and initial each days entries.

EXTRACTION PROCEDURES:

35. Using filtering apparatus mount each filter. Rinse filters with three times with approximately 20 ml in each rinse with petroleum ether for approximately 50 ml total.
36. Remove filters and place on clean, dry watch glasses or petri dishes that are clearly labeled.
37. Dry filters.

SECOND POST SAMPLING MEASUREMENT:

38. Following steps 29 through 34 and weigh each filter after extraction process.

CALCULATIONS:

39. Calculate the concentration of total particulate concentration, C (mg/m^3), in the air volume sampled, V (L):

$$C = \frac{(W_2 - W_1) - B_1}{V}, \ mg/m^3$$

Where: W_1 = Preweight of filter before sampling (µg)
W_2 = First Post-sampling weight of sample-containing filter (µg)
B_1 = Mean change in field blank filter weights between preweight and post sampling weight (µg) (+ or -)

40. Calculate the concentration of Oil Mist, C (mg/m^3), in the air volume sampled, V (L):

$$C = \frac{(W_2 - W_3) - B_2}{V}, \ mg/m^3$$

Where:

W_2 = First Post-sampling weight of sample-containing filter (µg)
W_3 = Second Post-sampling weight of sample-containing filter (µg)
B^2 = Mean change in field blank filter weights between first and second post sampling weight (µg) (+ or -)

EVALUATION OF METHOD: See NIOSH 5026, Issue 2: 15 August 1994. These procedures have been used in L&I Laboratory for the past 5 years.

REFERENCES:

[1] NIOSH Manual of Analytical Methods, 4th ed., U.S. Department of Health and Human Services, August 1994, Method 5026 and 0500.
[2] Washington State Department of Labor and Industries Method L&I 0026, Particulates Otherwise Not Regulated (based on NIOSH 0500).
[3] Documentation of the NIOSH Validation Tests, S272.
[4] NIOSH Manual of Analytical Methods, 3rd ed., 1611, U.S. Department of Health, Education, and Welfare, Publ. (NIOSH) (1985), Method 5026

Method Written By: Elisa Weiland and Christy Wood, Washington State, Department of Labor & Industries WISHA Laboratory.

Particulates Not Otherwise Regulated, Total

DEFINITION: Total aerosol mass

Method: L&I0026
Issued: 12/07/96
Revised: 04/17/95
L&I Implementation: 09/01/94

OSHA: 15mg/m^3
NIOSH: 10 mg/m^3
ACGIH: 10mg/m^3: total dust less than 1% quartz
WISHA: 10 mg/m^3; particulates not otherwise regulated

PROPERTIES: quartz less than 1%

SYNONYMS: Nuisance dusts, total; Particulates not otherwise regulated.

SAMPLING

SAMPLER: FILTER (preweighed 25mm or 37mm, 0.8µ PVC Omega filter)

FLOW RATE: 1.0 to 2 L/min

VOL -MIN: 120L
-MAX: 1000L

SHIPMENT: routine

SAMPLE STABILITY: indefinitely

BLANKS: 1 field blanks per 10 samples or 10% of sample set

BULK SAMPLE: none

MEASUREMENT

TECHNIQUE: GRAVIMETRIC (FILTER WEIGHT)

ANALYTE: airborne particulate material

BALANCE: 0.001 mg sensitivity or better; use same balance before and after sample collection

CALIBRATION: ANSI/ASTM Class 1 weights

RANGE: 0.050 to 2 mg per sample [2,5]

ESTIMATED LOD: 0.050 mg per sample [2]

PRECISION: 0.08 mg per sample [2]

ACCURACY

RANGE STUDIED: 0.25 to 10 mg/m3 (based on 200 L)

BIAS: not significant

OVERALL PRECISION (s_r): 0.056 [6]

APPLICABILITY: This method is nonspecific and determines the total dust concentration to which a worker is exposed. It may be applied, e.g., to gravimetric determination of fibrous glass [4] in addition to the other ADGIH nuisance dusts [1]. See NIOSH 0500 Issue 2 for additional information.

INTERFERENCES: Organic and volatile particulate matter may be removed by dry ashing [4].

OTHER METHODS: This method is based on and replaces NIOSH 0500.

EQUIPMENT:

1. Sampler: 25mm or 37-mm PVC .8 µ to 5 µ hydrophobic, filter and cellulose supporting pad in 25-mm or 37mm cassette filter holder. Omega Brand filters. Preweigh filters and seal cassettes with gel bands.
2. Personal sampling pump, 1.0 to 2 L/min, with flexible connecting tubing.
3. Microbalance, capable of weighing to 0.001 mg.
4. Static neutralizer: e.g., P©-210; replace nine months after the production date.
5. Tweezers for handing filters.
6. Gel bands.
7. Glycine paper
8. Flat blade screw driver.

Special Precautions: NONE.

PROCEDURES FOR PREWEIGHING FILTERS:

1. Lay out open, clean cassettes
2. Mark the backup pads using a permanent ink pen with consecutive filter codes and the appropriate expiration date . Place backup pads in clean, bottom cassettes with markings down.
3. Calibrate the balance and complete the first check weight. Record results. Handle the filter with forceps.
4. Place a filter on the static bar for at least 30 seconds.
5. Place the filter on balance pan and close the door.
6. After the weight has stabilized, record the filter preweight with the corresponding filter code.
7. Measure the check weight (20 mg) every ten filters. Measure the check weight after the last filter is weighed. Record all check weights and other measurements as completed.
8. Remove the filter from the balance and place it in the cassette on top of the backup pad with the correct filter code, on the bottom of the backpad.
9. Place the top cassette over the filters. To seal the cassettes tightly, place a large rubber stopper under and another rubber stopper on top of the cassette, then hit the rubber stopper very **firmly** three to four times with a hammer.
10. Check the seal in the cassettes by opening one out of every twenty cassettes. Properly sealed cassettes have filters with an indentation around the entire circumference of the filter. Document quality control check in the Laboratory notebook.
11. Place appropriately colored wet gel band around the sealed cassette and allow them to air dry. A small fan may be used in speed drying.
12. When dry, write the filter code as on the backpad on the outside of the cassette with a permanent ink pen.

SAMPLING:

13. Calibrate each personal sampling pump with a representative sampler in line.
14. Sample at 1.0 to 2.0 L/min. Do not exceed total filter loading of approximately 2 mg total dust.

SAMPLE PREPARATION:

15. Wipe exterior of cassette with a moist towel to minimize contamination.
16. Allow the samples to equilibrate in the gravimetric at least 2 hours.
17. Check to make sure that the filter code and the Laboratory number assigned on the paperwork match the filter cassettes.
18. Calibrate the balance.
19. Open the cassettes. A knife or tweezers may be used to cut the gel band, and a short flat blade screw driver to pry open tightly seal cassettes. **Be careful not to spill particulate or contaminate the sample.**

NOTES: Insert tweezers through outlet hole of the filter cassette bottom to raise the filter so that filter can be grasped, with forceps. If filter sticks to cassette top, very gently remove with tweezers.
This must be done carefully or the filter will tear.

20. Carefully remove the sample filter and place it on a static bar. Onto glycine paper, brush and tap out any sample remaining in the cassette. Carefully transfer onto the sample filter. Allow it to sit on the static bar for at least 30 seconds.

CALIBRATION AND QUALITY CONTROL

21. Use the same microbalance for weighing filters before and after sampling.
22. Carefully brush off the pan and inside of the Cahn.
23. Brush off the 20 mg and 200 mg calibration weights and set them on a static bar .
24. Zero the balance before weighing.
25. Follow the instructions in the Instrument Manual. Operate the scale with the door closed at all times.
26. Calibrate with the 200 mg weight.
27. Measure the weight of the 20 mg calibration weight. Record the date, weight measurement, temperature, humidity and your initials in the Laboratory notebook provided. This is the first check weight. **Complete check weights every 10 measurements and after the last sample.**
28. Recalibrate the balance whenever the check weight varies more than $\pm$0.005 mg.

MEASUREMENT

29. Weigh each filter, including field blanks.
30. Carefully move the sample filter onto the balance pan. Close the door and allow balance to stabilize. Record any sample loss if you have a problem.
31. Record the sample post-weight with the corresponding filter code and preweight. Record anycomments regarding load or problems with samples. Record anything remarkable about a filter (e.g., overload, leakage, wet, torn, etc.).
32. Remove the sample filter from the balance and place it back into the cassette. Place cassette top on and lightly seal.
33. Measure the check weight (20 mg) every ten filters and after the last sample filter. Record all check weights in the Laboratory Notebook.
34. Date and initial each days entries.

CALCULATIONS

35. Calculate the concentration of total nuisance dust, C (mg/m^3), in the air volume sampled, V (L):

$$C = \frac{(W_2 - W_1) + B}{V}, \ mg/m^3$$

Where: W_1 = Preweight of filter before sampling (□g)
W_2 = Post-sampling weight of sample-containing filter (□g)
B^2 = Mean change in field blank filter weights between preweight and post sampling weight (µg) (+ or -)

EVALUTAION OF METHOD: See NIOSH 0500, Issue 2: 15 August 1994.

REFERENCES [1] are taken from NIOSH 0500, Issue 2 [2]:

[1] Bartley, D.L., C.C. Chen, R. Song, and T.J. Fischback. Respirable Aerosol Sampler Performance Testing. Am. Ind. Hyg. Assoc. J. (In press, 1994)
[2] NIOSH Manual of Analytical Methods, 4th ed., U.S. Department of Health and Human Services, August 1994, Method 0500.
[3] Documentation of the NIOSH Validation Tests, S262 and S349, U.S. Department of Health, Education, and Welfare, Publ. (NIOSH) 77-185 (1977).
[4] NIOSH Manual of Analytical Methods, 3rd ed., 1611, U.S. Department of Health, Education, and Welfare, Publ. (NIOSH) (1985), Method 5000
[5] L&I Quality Assurance Control Charts and files.

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Appendix D

L&I Service Locations

Aberdeen (360) 533-9300 FAX: (360) 533-9325 TDD: (360) 533-9336 415 West Wishkah, Suite 1B Aberdeen, WA 98520-0013	**Longview** (360) 577-2200 FAX: (360) 577-5461 TDD: (360) 577-5428 900 Ocean Beach Hwy Longview, WA 98632-4013	**Tacoma** (253) 596-3800 FAX: (253) 596-3956 TDD: (253) 596-3887 1305 Tacoma Avenue S, Suite 305 Tacoma, WA 98402-1988
Bellevue (425) 990-1400 FAX: (425) 990-1446 TDD: (425) 637-5450 616 120th Avenue NE, Suite C201 Bellevue, WA 98005-3037	**Moses Lake** (509) 764-6900 TDD: (509) 754-6030 3001 W. Broadway Moses Lake, WA 98837-2907	**Tukwila** (206) 248-8240 FAX: (206) 248-8296 TDD: (206) 248-8245 PO Box 69050 12806 Gateway Drive Seattle, WA 98168-1050
Bellingham (360) 647-7300 FAX: 647-7310 TDD: (360) 647-7299 1720 Ellis Street, Suite 200 Bellingham, WA 98225-4600	**Mount Vernon** (360) 416-3000 FAX: (360) 416-3030 TDD: (360) 416-3006 525 E College Way, Suite H Mount Vernon, WA 98273-5500	**Tumwater** (360) 902-5799 FAX: (360) 902-5792 TDD: (360) 902-4637 1st Floor, Lobby PO Box 44851 7273 Linderson Way SW Olympia, WA 98504-4851
Bremerton (360) 415-4000 FAX: (360) 415-4047 TDD: (360) 415-4014 500 Pacific Avenue, Suite 400 Bremerton, WA 98337-1904	**Okanogan** (509) 826-7345 FAX: (509) 826-7349 TDD: (509) 826-7370 1234 2nd Avenue S PO Box 632 Okanogan, WA 98840-0632	**Vancouver** (360) 896-2300 FAX: (360) 896-2345 TDD: (360) 896-2304 312 SE Stonemill Dr, Suite 120 Vancouver, WA 98684-6982
Colville (509) 684-7417 Toll-free 1-800-509-9174 FAX (509) 684-7416 298 South Main, Suite 203 Colville, WA 99114-2416	**Port Angeles** (360) 417-2700 FAX: (360) 417-2733 TDD: (360) 417-2752 1605 East Front Street, Suite C Port Angeles, WA 98362-4628	**Walla Walla** (509) 527-4437 FAX: (509) 527-4486 TDD: (509) 527-4172 1815 Portland Avenue, Suite 2 Walla Walla, WA 99362-2246
East Wenatchee (509) 886-6500 or 1-800-292-5920 FAX: (509) 886-6510 TDD: (509) 886-6512 519 Grant Road East Wenatchee, WA 98802-5459	**Pullman** (509)334-5296 Toll-free 1-800-509-0025 FAX: (509) 334-3417 1250 Bishop Blvd SE, Suite G PO Box 847 Pullman, WA 99163-0847	**Yakima** (509) 454-3700 Toll-free 1-800-354-5423 FAX: (509) 454-3710 TDD: (509) 454-3741 15 W. Yakima Avenue, Suite 100 Yakima, WA 98902-3401
Everett (425) 290-1300 FAX: (425) 290-1399 TDD: (425) 290-1407 Evergreen Way Business Center 8625 Evergreen Way, Suite 250 Everett, WA 98208-2620	**Seattle** (206) 281-5400 FAX: (206) 281-5529 TDD: (206) 281-5528 300 W Harrison Street Seattle, WA 98119-4081	
Kennewick (509) 735-0100 FAX: (509) 735-0120 TDD: (509) 735-0146 500 N Morain, Suite 1110 Kennewick, WA 99336-2683	**Spokane** (509) 324-2600 Toll-free: 1-800-509-8847 FAX: (509) 324-2636 TDD: (509) 324-2635 901 N Monroe Street, Suite 100 Spokane, WA 99201-2149	