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An American National Standard

Standard Practice for Control of Respiratory Hazards in the Metal Removal Fluid Environment[1]

This standard is issued under the fixed designation E2889; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice sets forth guidelines to control respiratory hazards in the metal removal environment.

1.2 This practice does not include prevention of dermatitis which is the subject of Practice E2693 but it does adopt a similar systems management approach with many control elements in common.

1.3 This practice focuses on employee exposure via inhalation of metal removal fluids and associated airborne agents.

1.4 Metal removal fluids used for wet machining operations (such as cutting, drilling, milling or grinding) that remove metal to produce the finished part are a subset of metalworking fluids. This practice does not apply to other operations (such as stamping, rolling, forging or casting) that use metalworking fluids other than metal removal fluids. These other types of metalworking fluid operations are not included in this document because of limited information on health effects, including epidemiology studies, and on control technologies. Nonetheless, some of the exposure control approaches and guidance contained in this document may be useful for managing respiratory hazards associated with other types of metalworking fluids.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1356 Terminology Relating to Sampling and Analysis of Atmospheres

D2881 Classification for Metalworking Fluids and Related Materials

D7049 Test Method for Metal Removal Fluid Aerosol in Workplace Atmospheres

E1302 Guide for Acute Animal Toxicity Testing of Water-Miscible Metalworking Fluids

E1370 Guide for Air Sampling Strategies for Worker and Workplace Protection

E1497 Practice for Selection and Safe Use of Water-Miscible and Straight Oil Metal Removal Fluids

E1542 Terminology Relating to Occupational Health and Safety

E1972 Practice for Minimizing Effects of Aerosols in the Wet Metal Removal Environment

E2144 Practice for Personal Sampling and Analysis of Endotoxin in Metalworking Fluid Aerosols in Workplace Atmospheres

E2148 Guide for Using Documents Related to Metalworking or Metal Removal Fluid Health and Safety

E2169 Practice for Selecting Antimicrobial Pesticides for Use in Water-Miscible Metalworking Fluids

E2275 Practice for Evaluating Water-Miscible Metalworking Fluid Bioresistance and Antimicrobial Pesticide Performance

E2523 Terminology for Metalworking Fluids and Operations

E2563 Practice for Enumeration of Non-Tuberculosis *Mycobacteria* in Aqueous Metalworking Fluids by Plate Count Method

E2564 Practice for Enumeration of *Mycobacteria* in Metalworking Fluids by Direct Microscopic Counting (DMC) Method

E2657 Test Method for Determination of Endotoxin Concentrations in Water-Miscible Metalworking Fluids

E2693 Practice for Prevention of Dermatitis in the Wet Metal Removal Fluid Environment

E2694 Test Method for Measurement of Adenosine Triphosphate in Water-Miscible Metalworking Fluids

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[1] This test method is under the jurisdiction of ASTM Committee E34 on Occupational Health and Safety and is the direct responsibility of Subcommittee E34.50 on Health and Safety Standards for Metal Working Fluids.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

2.2 *OSHA (US Occupational Safety and Health Administration) Standards:*[3]

29 CFR 1910.132 Personal Protective Equipment

29 CFR 1910.134 Use of Respiratory Protection in the Workplace

29 CFR 1010.1020 Access to Employee Exposure and Medical Records

29 CFR 1910.1048 Formaldehyde

29 CFR 1910.1200 Hazard Communication

2.3 *EPA (US Environmental Protection Agency) Standards:*[4]

40 CFR 156 Labeling Requirements for Pesticides and Devices

2.4 *Other Documents:*

ANSI Technical Report B11 TR 2-1997, Mist Control Considerations for the Design, Installation and Use of Machine Tools Using Metalworking Fluids[5]

Metal Working Fluid Optimization Guide, National Center for Manufacturing Sciences[6]

Metal Removal Fluids, A Guide To Their Management and Control, Organization Resources Counselors, Inc.[7]

Industrial Ventilation: A Manual of Recommended Practice[8]

Criteria for a Recommended Standard: Occupational Exposure to Metalworking Fluids[9]

Metalworking Fluids: Safety and Health Best Practices Manual[10]

Method 0500: Particulates Not Otherwise Regulated, Total[11]

3. Terminology

3.1 For definitions and terms relating to this guide, refer to Terminologies D1356, E1542 and E2523.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *dilution ventilation, n*—referring to the supply and exhaust of air with respect to an area, room, or building, the dilution of contaminated air with uncontaminated air for the purpose of controlling potential health hazards, fire and explosion conditions, odors, and nuisance type contaminants, from Industrial Ventilation: A Manual of Recommended Practice.

3.2.2 *extractable mass, n*—the material removed by liquid extraction of the sampling filter using a mixed-polarity solvent mixture as described in Method D7049.

3.2.2.1 *Discussion*—This mass is an approximation of the metal removal fluid portion of the workplace aerosol.

3.2.3 *metal removal fluid (MRF), n*—any fluid in the subclass of metalworking fluids used to cut, or otherwise take away material or piece of stock. **E2148**

3.2.3.1 *Discussion*—Metal removal fluids include straight or neat oils (D2881), not intended for further dilution with water, and water miscible soluble oils, semisynthetics and synthetics, which are intended to be diluted with water before use. Metal removal fluids become contaminated during use in the workplace with a variety of workplace substances including, but not limited to, abrasive particles, tramp oils, cleaners, dirt, metal fines and shavings, dissolved metal and hard water salts, bacteria, fungi, microbiological decay products, and waste. These contaminants can cause changes in the lubricity and cooling ability of the metal removal fluid as well as have the potential to adversely affect the health and welfare of employees in contact with the contaminated metal removal fluid. **E2148**

3.2.4 *metal removal fluid aerosol, n*—aerosol generated by operation of the machine tool itself as well as from circulation and filtration systems associated with wet metal removal operations and may include airborne contaminants of microbial origin.

3.2.4.1 *Discussion*—Metal removal aerosol does not include background aerosol in the workplace atmosphere, which may include suspended insoluble particulates.

3.2.5 *total particulate matter, n*—the mass of material sampled through the 4-mm inlet of a standard 37-mm filter cassette when operated at 2.0 L/min, as described in Method D7049.

3.2.5.1 *Discussion*—As defined in Method D7049, total particulate matter is not a measure of the inhalable or thoracic particulate mass.

3.3 *Acronyms:*

3.3.1 *GHS, n*—globally harmonized system

3.3.1.1 *Discussion*—GHS is an acronym for the Globally Harmonized System of Classification and Labeling of Chemicals.

4. Significance and Use

4.1 Exposure to aerosols in the industrial metal removal environment has been associated with adverse respiratory effects.

4.2 Use of this practice will mitigate occupational exposure and effects of exposure to aerosols in the metal removal environment.

4.3 Through implementation of this practice users should be able to reduce instances and severity of respiratory irritation and disease through the effective use of a metal removal fluid management program, appropriate product selection, appropriate machine tool design, proper air handling mechanisms, and control of microorganisms.

[3] Code of Federal Regulations available from United States Government Printing Office, Washington, DC 20402.

[4] Code of Federal Regulations available from United States Government Printing Office, Washington, DC 20402.

[5] Available from Association for Manufacturing Technology, 7901 Westpark Drive, McLean VA 22102.

[6] Available from National Center for Manufacturing Sciences, Report 0274RE95, 3025 Boardwalk, Ann Arbor, MI 48018.

[7] Available from Organization Resources Counselors, 1910 Sunderland Place, NW., Washington, DC 20036 or from members of the Metal Working Fluid Product Stewardship Group (MWFPSG^{SM}). Contact Independent Lubricant Manufacturers Association, 651 S. Washington Street, Alexandria, VA 22314, for a list of members of the MWFPSG^{SM}.

[8] Available from American Conference of Governmental Industrial Hygienists, 1330 Kemper Meadow Drive, Cincinnati, OH 45240-1634.

[9] Available from U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Cincinnati, OH 45226.

[10] Available from US Occupational Health and Safety Administration, 200 Constitution Avenue NW, Washington, DC 20210 or at http://www.osha.gov/SLTC/metalworkingfluids/metalworkingfluids_manual.html

[11] Available from U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Cincinnati, OH 45226 or at. http://www.cdc.gov/niosh/docs/2003-154/pdfs/0500.pdf

5. Respiratory Health Hazards Associated with Metal Removal Fluids

5.1 *General:*

5.1.1 Metal removal fluids (MRF) can cause adverse health effects through skin contact with contaminated materials, spray, or mist and through inhalation from breathing MWF mist or aerosol.

5.1.2 Skin and airborne exposures to MRF have been implicated in health problems including irritation of the skin, lungs, eyes, nose and throat. Conditions such as dermatitis, acne, asthma, hypersensitivity pneumonitis, irritation of the upper respiratory tract, and a variety of cancers have been associated with exposure to MRF (NIOSH 1998a). The severity of health problems is dependent on a variety of factors such as the kind of fluid, the degree and type of contamination, and the level and duration of the exposure.

5.2 *Skin Disorders:*

5.2.1 Skin contact occurs when the worker dips his/her hands into the fluid or handles parts, tools, and equipment covered with fluid without the use of personal protective equipment, such as gloves and aprons. Skin contact may also result from fluid splashing onto the employee from the machine if guarding is absent or inadequate. For further information refer to E2693 Practice for Prevention of Dermatitis in the Wet Metal Removal Fluid Environment.

5.3 *Respiratory Diseases:*

5.3.1 Inhalation of MRF mist or aerosol may cause irritation of the lungs, throat, and nose. In general, respiratory irritation involves some type of chemical interaction between the MRF and the human respiratory system. Irritation may affect one or more the following areas: nose, throat (pharynx, larynx), the various conducting airways or tubes of the lungs (trachea, bronchi, bronchioles), and the lung air sacks (alveoli) where the air passes from the lungs into the body. Exposure to MRF mist or aerosol may also aggravate the effects of existing lung disease.

5.3.2 Some of the symptoms reported include sore throat, red, watery, itchy eyes, runny nose, nosebleeds, cough, wheezing, increased phlegm production, shortness of breath, and other cold like symptoms. These symptoms may indicate a variety of respiratory conditions, including acute airway irritation, asthma (reversible airway obstruction), chronic bronchitis, chronically impaired lung function, and hypersensitivity pneumonitis (HP). When symptoms of respiratory irritation occur, in many cases it is unclear whether the disease was caused by specific fluid components, contamination of the in-use fluid, products of microbial growth or degradation, or a combination of factors.

5.3.3 Exposure to MRF has been associated with asthma. In asthma, airways of the lung become inflamed, causing a reduction of the flow of air into and out of the lungs. During an asthmatic attack, the airways become swollen, go into spasms and fill with mucous, reducing airflow and producing shortness of breath and a wheezing sound. A variety of components, additives, and contaminants of MRF can induce new-onset asthma, aggravate pre-existing asthma, and irritate the airways of non-asthmatic employees.

5.3.4 Chronic bronchitis is a condition involving inflammation of the main airways of the lungs that occurs over a long period of time. Chronic bronchitis is characterized by a chronic cough and by coughing up phlegm. The phlegm can interfere with air passage into and out of the lungs. This condition may also cause accelerated decline in lung function, which can ultimately result in heart and lung function damage.

5.3.5 Hypersensitivity pneumonitis (HP) is a serious lung disease. Recent outbreaks of HP have been associated with exposure to aerosols of synthetic, semi-synthetic, and soluble oil MRF. In particular, contaminants and additives in MRF have been associated with outbreaks of HP (NIOSH 1998a). In the short term, HP is characterized by coughing, shortness of breath, and flu-like symptoms (fevers, chills, muscle aches, and fatigue). The chronic phase (following repeated exposures) is characterized by lung scarring associated with permanent lung disease.

5.3.6 Other factors, such as smoking, increase the possibility of respiratory diseases. Cigarette smoke may worsen the respiratory effects of MRF aerosols for all employees.

5.3.7 Respiratory effects have been observed among workers with exposures below 1.0 mg/M^3 to diverse fluids,[12] with water reduced fluids generally appearing more potent. Poorly controlled fluids have generally been more likely to be associated with adverse effects.

5.4 *Cancer:*

5.4.1 A number of studies have found an association between working with MRF and a variety of cancers, including cancer of the rectum, pancreas, larynx, skin, scrotum, and bladder (NIOSH 1998a). No authoritative review of studies of workers exposed to MRF has been conducted since 1999, although additional data have been published. Studies of MRF and cancer reflect the health experiences of workers exposed decades earlier. This is because the effects of cancers associated with MRF may not become evident until many years after the exposure. Airborne concentrations of MWF were known to be much higher in the 1970s–80s than those today. The composition of MRF has also changed dramatically over the years. The fluids in use prior to 1985 may have contained nitrite, mildly refined petroleum oils, and other chemicals that were removed after 1985 for health concerns. Based on the substantial changes that have been made in the metalworking industry over the last decades, the cancer risks have likely been reduced, but there is not enough data to prove this.

6. Fluid Properties Associated with Adverse Health Effects

6.1 *Aerosol Physical Properties:*

6.1.1 Metal removal fluid aerosols consist of a broad range of particle sizes. Airborne particles shrink as water and other volatiles evaporate; particles farther from point of generation are smaller. The "inhalable" fraction includes very large particles excluded by the closed face filter used by NIOSH 0500 for "total particulate." "Total" particulate includes particles larger than those in the "thoracic" fraction. Smaller

[12] Gauther, S.L., Metal Working Fluids: Oil Mist and Beyond, *Applied Occupational & Environmental Hygiene*, Volume 18: 818-824, 2003.

particles are more easily captured by machine tool ventilation exhaust, but may pass through an air cleaner. Particles may be generated by evaporation and condensation from air cleaner filter media. Larger aerosol particles are more likely to be controlled by enclosures. Controlling metal removal fluid emissions on one machine will not affect background aerosol or other aerosol generated by other work stations; all machine tools need to be considered together. Air sampling using filter methods captures no measurable water. Oil evaporates when captured on a filter, while non-oil additives to water soluble fluids do not.

6.2 *Bioaerosols:*

6.2.1 Bioaerosols include:

6.2.1.1 Whole microbes (archaeal, bacterial and fungal) cells and viruses;

6.2.1.2 Microbial cell fragments: segments of cell wall material;

6.2.1.3 Biomolecules: predominantly carbohydrates, endotoxins, lipids, nucleic acids and proteins;

6.2.1.4 Metabolites: innumerable microbial waste products (predominantly carbohydrates, organic acids, complex polymers (biofilm matrix), exotoxins and microbial volatile organic chemicals–MVOC)

6.2.2 Factors affecting bioaerosol generation include:

6.2.2.1 Bioburden in recirculating, bulk MRF: the bioaerosol component of the total aerosol generated from MRF comes directly from the microbes and microbially produced molecules present in the bulk fluid. Except MVOC, the introduction of which into the airspace is dictated by the physical-chemical properties of individual MVOC molecules, bioaerosol generation is proportional to bulk fluid bioburden.

6.2.2.2 Biofilm communities growing on MRF system surfaces are in dynamic equilibrium. Once they have formed, biofilms tend to slough off portions of the mass that are at the fluid-biofilm interface as new biofilm material is generated. The details of this equilibrium vary widely among systems.

(1) Biofilms that exist in high turbulent-flow conditions tend to be thinner than those growing in stagnant or slow laminar-flow environments.

(2) Biofilms growing in high turbulent-flow conditions tend to be more tenacious (more difficult to remove) than those growing in stagnant or low flow-rate environments.

(3) Biofilm communities are typically comprised of microbial consortia; complex communities of diverse species, which function in ways that resemble multi-cellular organisms; excreting and secreting the full range of bioaerosol constituent molecules listed in 6.2.1.

(4) The factors described in 6.1 and 6.3 can affect the persistence and distribution of microbes and biomolecules in MRF. Consequently, these factors will also affect bioaerosol generation.

6.3 *Chemicals:*

6.3.1 *Formulating Considerations:*

6.3.1.1 Aerosols in the metal removal environment may differ significantly from the components of virgin metal removal fluid dilutions. In addition to avoiding the use of possible irritants in the original design, formulators must account for possible changes in chemistry, microbiology, levels of contamination, and alterations in physical misting when developing a metal removal fluid.

6.3.1.2 The pH of a metal removal fluid dilution impacts corrosion, materials compatibility, microbial resistance, and emulsion stability in addition to acting as a possible source of operator irritation. It is important that the pH of a working fluid avoid extremes, generally between 5 and 10. The fluid should also be buffered within the target range of the fluid such that small amounts of contaminants do not create wide shifts in pH.

6.3.1.3 Even at a stable and buffered pH, metal removal fluid formulations should limit or eliminate chemicals that pose irritation threats. These chemicals include volatile amines, aldehydes, ketones, alcohols, ethers, and multifunctional organics. Some of these materials may only be present as contaminant byproducts of primary components, or may only be generated within an in-use fluid through contact with machining components. An awareness of possible secondary reactions between the fluid and machine/work piece substrates is key.

6.3.1.4 A recognized source of respiratory irritation in the metal removal fluid environment is microbiological contamination. A fluid formulated with materials that inhibit microbial growth and eradicate microbial contamination is necessary to mediate irritating worker mist contact. Unfortunately, many of the chemicals that are effective fluid preservatives can also contribute to irritating aerosols. Therefore, an effective formulation utilizes these preservatives within their well-defined inhibitory concentrations and within a product chemical matrix that does not magnify their irritation potential.

6.3.1.5 While mist is a physical phenomenon, metal removal fluid chemistry can play a role in enhancing or reducing mist generation in equivalent situations. Unfortunately, the dynamics of fluid chemistry and mist are not well understood. However, there exist effective chemical additives that increase droplet size and, as a result, reduce mist. These materials are generally unstable and must be added to a system continually over the life of a fluid system.

6.3.2 *Contamination Considerations:*

6.3.2.1 Diluted metal removal fluids quickly become contaminated in use. Some contaminants, such as alkaline materials, pH boosters and similar materials, can increase the respiratory hazard.

6.3.2.2 Minimize tramp oil contamination, such as leaking hydraulic fluids, way lubricants and gear box lubricants. Of all potential contaminants, tramp oil has the most significant effect on increasing airborne concentrations of metal removal fluids.

6.3.3 *Tankside Additive Considerations:*

6.3.3.1 As supplied, antimicrobial pesticides and other additives for tank side addition can present greater health and safety risks than the metal removal fluid. Further, additives and antimicrobials are less likely to be handled automatically, or with special delivery equipment, than metal removal fluid concentrate so greater care and attention are required to reduce risks of exposure.

6.3.3.2 Antimicrobial pesticides are designed to kill microorganisms and therefore have significant biological activity. To avoid potential for harm by mishandling or misapplication, antimicrobial pesticides must be handled with care. The user shall read, understand, and follow all appropriate instructions for handling, storage, and use of each antimicrobial pesticide as specified by the antimicrobial pesticide manufacturer on the material safety data sheet.

7. Metal Removal Fluid Management Practices

7.1 Management of metal removal processes is the most important step in minimizing exposure to metal removal fluid aerosols. As factors affecting aerosol generation are interdependent, a systems approach to metal removal process management will be the most effective approach.

7.2 Aerosolization of metal removal fluids may result in airborne exposure not only to the formulated components of the fluid, but also to contaminants introduced into the fluid systems while in use, including microbial contaminants.

7.3 Establish a metal removal fluid control program (see Section 12). Additional detailed guidance may be found in Practice E1497 and in Metal Removal Fluids, A Guide To Their Management and Control. Consult with your metal removal fluid suppliers.

8. Product Selection

8.1 Fluids vary in their misting characteristics. Select fluids with an understanding of their misting characteristics, bearing in mind available engineering control measures. Some fluids mist less, other factors being equal. Misting characteristics may change significantly with contamination. Some fluids retain entrained air, causing a significant increase in mist generation, possibly in areas away from the metal removal fluid operation. Polymeric additives may be useful in reducing aerosol from straight or neat oils and some water-miscible metal removal fluids. Components or contaminants may be more concentrated in the aerosol phase relative to their concentrations in the bulk fluid.

8.2 Practice E1497 and Metal Removal Fluids, A Guide to Their Management and Control describe product selection criteria. While specifically directed towards water-miscible metalworking fluids, the same principles generally apply to selection of neat or straight metal removal fluids.

8.3 Select fluids with an understanding of their acute and chronic toxicity characteristics. Guide E1302 references procedures to assess the acute toxicity of water-miscible metalworking fluids as manufactured. Review the material safety data sheet, required by 29 CFR 1910.1200, for health and safety information for the metal removal fluids being considered for the operation.

8.4 Select fluids that minimize components that can be irritating or can produce noxious odors.

8.5 Select fluids that are appropriate for the machining process, are cost-effective, can be safely disposed when they are no longer economically feasible to re-use, have supplier support, and are used with a fluid management program.

8.6 As the concentration of metal removal fluid in the machining system sump or reservoir increases, the level of chemicals in the metal removal fluid aerosol increases and the net exposure is greater. Maintaining proper metal removal fluid concentration while in use enhances machining performance and minimizes exposure potential.

9. Methods for Metal Removal Fluid Mist Minimization

9.1 *Minimizing Insoluble Particulate Matter:*

9.1.1 The difference between total particulate matter and extractable mass, as measured by Method D7049, is an estimate of the insoluble particulate matter in the machining environment. Minimize insoluble particulate matter such as may be generated by dry machining, welding operations, and so forth.

9.1.2 Estimate the background level of insoluble particulate by evaluating exposures in the workplace away from metal removal fluid operations.

9.1.3 Keep the metal removal fluid clean. Minimize accumulation of grinding swarf from cast iron grinding operations or aluminum and silicon from aluminum machining operations through proper design, selection, and maintenance of metal removal fluid filtration systems.

9.2 *Minimizing Extractable Mass Concentration:*

9.2.1 Minimize extractable mass concentration. The amount and average particle size of aerosol generated is dependent on the amount of energy imparted to the fluid. Energy may be imparted to the fluid through high pressure spray application, high speed tools, parts or machines, and any other activity that causes the bulk fluid to generate a mist of liquid droplets. The transfer of energy from the machine to the fluid can be reduced by several means. Combined means may also be required.

9.2.2 In addition to product selection, proper maintenance of metal removal fluid sump concentration, and the design, selection, and maintenance characteristics noted earlier in this section, excessive generation of metal removal fluid aerosol can be affected by parameters, such as compressed air blowoffs and higher than optimum fluid flow rates, pressures, and tool feeds and speeds.

9.2.3 Optimize machine tool feeds and speeds consistent with part finish, dimension, and productivity requirements. Excessively high speeds and feeds increase the amount of aerosol generated.

9.2.4 Minimize fluid flow rates consistent with desired part finish and dimension and movement of generated chips or swarf. If feasible, reduce or temporarily interrupt fluid flow when the metal removal operation is not occurring. Higher-than-required flow rates increase aerosol generation.

9.2.5 Reduce fluid pressure consistent with machine tool design and chip removal requirements. Use flooding instead of spray application, whenever possible.

9.2.6 Consider the geometry of fluid application. Minimize the number of directional changes the fluid must make before reaching the cutting zone.

9.2.7 Control sources of nonmetal removal fluid mists, such as from parts washers or mist lube systems.

10. Machine Tool Design & Maintenance—Engineering Control Methods

10.1 ANSI B-11 TR 2-1997 provides guidance concerning consideration for the design of metalworking fluid delivery systems, of machine tools, of machine enclosures for the control of airborne contaminants, of exhaust ductwork from machine tool enclosures, and of mist collectors, and guidelines for testing collection systems. Users of this practice should be well-versed in these considerations and implement them when practical where occupational exposures to metal removal fluids is expected to occur.

10.2 Design metal removal fluid delivery systems to minimize generation of metal removal fluid aerosols. For transfer line machines, as the earliest operation in the line is often the heaviest cut, early operations may contribute most to metal removal fluid aerosol generation.

10.3 Maintain metalworking fluid delivery system components, including pumps. Leaking seal packing, leaking mechanical seals, and leaking ports in delivery pumps entrain air in the metal removal fluid, significantly increasing aerosol generation.

10.4 Cover flumes and other sources of aerosol generation. Vent them to the metal removal fluid reservoir, if feasible, to minimize release of aerosol or to maintain negative pressure.

10.5 Select new machining and grinding equipment with enclosures and appropriate ventilation that minimizes generation of metal removal fluid aerosols in the workplace atmosphere.

10.6 Maintain existing equipment enclosures and guarding to minimize release of aerosol. Restore missing equipment and enclosures. If enclosures are not maintained or guarding is removed, larger particles may escape through openings in the enclosure.

10.7 Retrofitting existing equipment should be considered using ANSI B11 TR 2-1997 as a guide. Unless properly designed and constructed, retrofits may not significantly capture metal removal fluid aerosols.

10.8 Properly design and maintain exhaust ductwork from machine tool enclosures. ANSI B11 TR 2-1997 may be used as a guide. Inspect and clean ductwork regularly, and repair ductwork not in good working order.

10.9 Properly design and maintain mist collectors, ANSI B11 TR 2-1997 may be used as a guide. Other technologies may be appropriate. Poorly maintained mist collectors may increase metal removal fluid aerosol concentrations in workplace atmospheres. Check air cleaner filters and clean or replace as appropriate. Do not allow collected aerosol to drain back into the fluid system.

10.10 Measure exhaust airflow and compare to design specification. Make adjustments or repairs as appropriate.

10.11 Evaluate each workplace location in terms of the number of machine tools in a given area, the types of operations performed, existing ventilation patterns, ceiling height, and ultimate disposition of the collected mist.

10.12 Introduce a sufficient amount of make-up air into the plant ventilation system, particularly where machine enclosures are not present or local exhaust is ineffective. In colder weather, when doors and windows are shut, or in hotter weather in facilities with air conditioning, the amount of plant make-up air affects both the amount of insoluble particulate and extractable mass from metal removal fluid aerosol in workplace atmospheres. See Industrial Ventilation: A Manual of Recommended Practice for guidance on principles of ventilation.

11. Bioaerosol Control (Microbial Aerosols in the Metal Removal Environment)

11.1 Microorganisms can grow in all water-miscible metal removal fluid systems, producing offensive odors and potentially other adverse health effects as well as accelerating depletion of functional components of the metal removal fluid. Metal removal fluid aerosols may contain microbial contaminants, both viable and nonviable.

11.2 Monitor and control water-miscible metal removal fluid system microbiology on a routine basis. Methods E2657, E2563, E2564 and E2694 provide protocols for quantifying specific microbes and biomolecules likely to be found in metal removal fluids and metal removal fluid aerosols.

11.3 Practices E1497 and E2169 provide guidance regarding microbicides selection, storage, and use. Even if extractable mass and total particulate matter concentrations are low, uncontrolled fluid microbiology can potentially cause adverse respiratory health effects.

11.4 If unusual respiratory complaints are reported or if respiratory diseases are suspected, additional microbiological testing may be needed. Consult with your metal removal fluid or biocide supplier for their recommendations.

11.5 *Antimicrobial Pesticides and Control of Microorganisms in Metal Removal Fluids:*

11.5.1 Microorganisms can grow in all metal removal fluids, sometimes producing odors, irritation, and reducing product performance. Antimicrobial pesticides are often incorporated into water-miscible metal removal fluid formulations and are commonly added to machine sumps and to centralized water-miscible metal removal fluid systems to control microbial growth. Straight oils that become contaminated with water can also support the growth of bacteria.

11.5.2 Only antimicrobial pesticides that are registered for use in metalworking fluids by the applicable regulatory agency (the Environmental Protection Agency (EPA) in the United States) shall be used in metal removal fluids. Antimicrobial pesticide labels state approved uses.

11.5.3 Antimicrobial pesticides and combinations of antimicrobial pesticides should be evaluated for stability and efficacy in the specific fluid being used or under consideration prior to use. The use of ineffective antimicrobial pesticides may add to the toxicological burden of the metal removal fluid. See Practices E2275 and E2169.

11.5.4 Certain antimicrobial pesticides may release formaldehyde in use. Review fluid and antimicrobial pesticide MSDS information, and consult your antimicrobial pesticide and/or metal fluid supplier. See 29 CFR 1910.1048.

11.5.4.1 As discussed in Practice E2169, no individual antimicrobial pesticide is appropriate for all applications. Antimicrobial pesticides differ in their spectra of activities, speeds of kill, persistence in the treated fluid, and compatibilities with other MWF constituents. All antimicrobial pesticides should be used with an understanding of how these variables will affect their performance in a given system.

11.5.5 Endotoxin in metal removal fluids and their aerosols may present potential respiratory health hazards to workers who inhale them.

11.5.5.1 Endotoxin is sometimes the most biologically active component of an MRF environment, especially a poorly managed one.

11.5.5.2 Endotoxins are toxic heat-stable substances present in the outer membrane of gram-negative bacteria that remain active even when the bacteria dies.

11.5.5.3 See Practice E2144 and Method E2657 and consult your metal removal fluid supplier, chemical manager, and corporate health and safety personnel for further information.

11.5.6 Develop procedures for antimicrobial pesticide additions to individual machine sumps and to central metal removal fluid systems that are suited to the location's specific needs. Request the biocide manufacturer or distributor and metal removal fluid manufacturer to assist in the development of these procedures. Antimicrobial pesticides are to be added judiciously—in conformance with the manufacturer's recommendations and all applicable laws and regulations (for example, the Federal Insecticide, Fungicide and Rodenticide Act in the United States) as specified on the container label—and only when needed as determined by those developed procedures. Loss of apparent antimicrobial activity may be due to development of chemical incompatibility or development of resistant populations, or both.

11.5.7 Antimicrobial pesticides should be stored in their original containers and stored in secured areas to prevent unauthorized use.

11.5.8 Antimicrobial pesticides shall be added to the metal removal fluid system at a location that will ensure rapid and complete mixing so as to avoid excessive localized concentrations. Add antimicrobial pesticides slowly to ensure mixing and avoid splashing. Mechanical transfer equipment may be used to make antimicrobial pesticide additions to reduce the likelihood of skin or eye contact.

11.5.9 Some antimicrobial pesticides have a limited shelf life. Rotate stock regularly and use antimicrobial pesticides before the expiration data (if any). Contact the antimicrobial pesticide supplier for additional information on use, handling, or disposal.

12. Metal Removal Fluid Testing and Maintenance

12.1 Establish a metal removal fluid control program to collect data, monitor and evaluate the results, and maintain the metal removal fluid system within the prescribed limits set by the fluid manufacturer. Health risks and economic losses are enormous when large, centralized metal removal fluid systems get out of control compared to the effort required to maintain control and chemical stability.

12.1.1 Metal removal fluid management programs can be easily integrated with process control requirements of quality systems such as ISO 9001 or QS-9000.

12.1.2 Analyze treated water supplies for anion concentration, because anions may contribute to loss of product stability. In those operations performed on heat-treated, pickled, or surface-treated materials, test regularly for dissolved sulfate and chloride, which can increase rust and corrosion.

12.1.3 Metal removal fluid management procedures might include one or more of the following tests: fluid concentration, pH, microbial level, dissolved oxygen, antimicrobial concentration, tramp oil level, corrosion protection, and specific tests for critical components or suspected contamination such as suspended particulate matter. Appropriate field test procedures should be supplemented and confirmed by more exact laboratory tests. The metal removal fluid manufacturer can supply an accurate means of determining the fluid concentration and help with selection of parameters to test.

12.1.4 Test results should be evaluated to determine the amounts of additional metal removal fluid concentrate and additives required to maintain the system at the appropriate concentrations.

12.1.5 Certain tests, such as concentration, suspended particulate matter, or pH, may be performed every day. Other tests may be performed once or twice weekly, monthly, or even less frequently. The metal removal fluid manufacturer can help determine how frequently each test should be performed.

12.1.6 The evaluation of accumulated test data is critical to maintaining successful metal removal fluid management. Operating a metal removal fluid system as close to steady-state (minimum fluctuations of all parameters) as possible will consistently provide the most trouble-free operation with the greatest control of all risks, including health risks. The user, chemical manager, and the metal removal fluid manufacturer should work together to maintain system control.

12.2 Chemical additions, maintenance, volume control, and other actions that maintain metal removal fluid system control shall be performed as planned. Timely and deliberate activities should result from evaluation of test data. All additions or changes to a system shall be directed to maintain or restore previously determined chemical, biological, and physical system parameters.

12.3 Test periodically for metal contaminants. Suspended or dissolved metals, or both may contribute to health hazards or fluid degradation, or both. Test for metals present in the materials that are being processed. These include, but are not limited to, aluminum, barium, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, nickel, selenium, tellurium, tin, and zinc. Compare metal contaminant levels in the metal removal fluid shortly after a fresh start up with levels after several months.

12.3.1 Suspended or dissolved metal contaminants may also pose airborne contamination hazards.

12.3.2 Chloride concentrations greater than 50 ppm and sulfate concentrations greater than 100 ppm markedly decrease rust control in many metal removal fluids.

12.3.3 Exposures can be affected by type of alloy and metal removal operation.

12.4 Do not drain fluid from mist collectors, mop water, rain water, or liquid waste of any kind into metal removal fluid systems. Do not allow metal removal fluid systems to be used as trash conveyor for cigarettes, food, bodily fluids, or beverages.

12.5 Keep the fluid aerated; avoid extended periods of non-movement by circulating on weekends and during shutdowns to prevent stagnation.

13. Personal Protective Equipment

13.1 Requirements concerning use of respirators in the workplace can be found in 29 CFR 1910.134 should permissible exposure levels for the metal removal fluid or included components be exceeded and engineering controls not reduce airborne component concentrations to specified levels. (See Section 17, Communication and Training.)

14. Occupational Exposure Guidelines

14.1 The hazards associated with metal removal fluid environments are associated with fluids, additives and contaminants.

14.1.1 A key to effective management of the MRF environment is selection of appropriate occupational exposure guidelines to gauge the need for additional management of corrective action.

14.1.2 No single exposure guideline is able to assure the health or predict the toxicity of the complex metal removal fluid environment. Instead, review materials and processes to determine which guidelines should apply.

14.1.3 See Appendix X1, Occupational Exposure Guidelines, for further non-mandatory information.

14.2 Additional considerations include the following:

14.2.1 Straight oil mist.

14.2.1.1 Straight oils are less subject to deterioration or contamination by microorganisms than soluble oils.

14.2.1.2 However such straight oil mists can contain additives and metal particles.

14.2.2 Water-miscible fluid mist.

14.2.2.1 Soluble oils often contain more additives than do straight oils, and are more likely subject to deterioration and contamination by microorganisms.

14.2.2.2 Greater hazards are associated with water-miscible oil that has been in service for a long time than with new and clean oils.

14.2.2.3 Exposures above the OEG should trigger a review of MRF system management practices.

14.2.3 Metal contaminants.

14.2.3.1 One function of metal removal fluids is to reduce airborne generation of metal fines and particles from machining operations.

14.2.3.2 Some fines and particles may still become airborne and these metals may also be dissolved or suspended in the oil mist.

14.2.3.3 The oil mist OEG is a good indicator of control for most common metals but several metals, if present in the machined stock, should also be assessed individually because of their toxicity.

14.2.3.4 The risk of respiratory disease increases substantially when occupational exposure to the metals listed in Appendix X1 exceed their OEG.

14.3 Other potential exposures:

14.3.1 Certain other compounds are associated with MRF environments.

14.3.2 The presence of formaldehyde and ammonia at levels approaching their OEG usually indicate problems with the MRF management practices that require immediate correction.

15. Aerosol Monitoring and Testing Methods

15.1 Method D7049 covers a procedure for the determination of both total particulate matter and extractable mass metal removal fluid aerosol concentrations in a range from 0.05 to 5 mg/m^3 in workplace atmospheres. Guidance on workplace sampling strategies can be found in Guide E1370.

15.2 NIOSH 0500 is a non-specific method for analysis of total particulate matter. The working range is 1 to 20 mg/m^3 for a 100-L air sample. This method is nonspecific and determines the total dust concentration to which a worker is exposed.

15.3 Bioaerosol monitoring. See Practice E2144.

NOTE 1—Much historical air sampling data in the MRF environment has been obtained using NIOSH Method 0500. More recently, Method D7049 has been utilized to determine both total particulate matter and extractable mass metal fluid aerosol concentrations.

16. Medical Monitoring and Management

16.1 *Initial or Preplacement Examination*—All employees who will be directly exposed to MRF aerosols should receive medical monitoring before assignment to the job. At a minimum the initial examination should consist of the following:

16.1.1 Administration of a standardized questionnaire about symptoms and medical history of asthma, other serious respiratory conditions, and skin diseases;

16.1.2 Examination of the skin;

16.1.3 Baseline spirometric testing may be useful for comparisons with subsequent tests of individual workers.

16.2 *Periodic Medical Monitoring*—All workers exposed to airborne MRF concentrations of one-half the OEG or greater should receive a periodic medical examination at least biennially (once every two years). The examination should consist of the following:

16.2.1 A standardized questionnaire to determine the presence or absence of respiratory symptoms, including the following:

(1) treatment by a physician for a respiratory illness;

(2) wheezing or shortness of breath, especially if it occurs at work and improves when away from work;

(3) chest tightness;

(4) cough that produces phlegm;

(5) chills, fever and unusual weight loss;

(6) unusual fatigue;

(7) eyes burning or nasal congestion while at work;

(8) skin irritation.

16.2.2 Periodic monitoring should be done more frequently if MRF related health effects have occurred.

16.3 *Medical Management*—Health problems associated with MRF exposures require a medical management approach with some or all of the following elements:

16.3.1 The employer should investigate the area to determine if there is a correctable condition that caused or contributed to the condition.

16.3.2 In some situations it may be necessary to relocate a worker in order to manage the health condition.

16.3.3 Additional or more frequent medical evaluations may be necessary as directed by the responsible physician.

16.4 Refer to 29 CFR 1910.1020 for requirements and regulations pertaining to medical record retention and access.

17. Communication and Training

17.1 *Hazard Communication*—OSHA 29 CFR 1910.1200.

17.1.1 The training program should be conducted in such a way that the employee is able to understand the information. The employer should provide information and training to employees working in the metal removal fluid environment so each employee may perform his or her job safely.

17.1.2 Identify and communicate the nature of the hazard(s), in particular any respiratory hazards, as well as a distinction between the dilute and neat MRF fluids, and chemical additives.

17.1.3 Identify and communicate safe work practices including use of PPE when necessary.

17.1.4 Communicate the location of the MSDSs, and written hazard communication program.

17.1.5 Create and make available to employees, a written list of all the hazardous chemicals in the location.

17.1.6 Identify and communicate emergency procedures including first aid, spills, and evacuation procedures.

17.1.7 Identify and communicate specific information about the potential health hazards associated with exposure to metalworking fluids, the signs and symptoms of overexposure, the action an employee should take if he or she suspects the symptoms are related to exposure, and to whom they should report the symptoms.

NOTE 2—The GHS is a system for standardizing and harmonizing the classification and labeling of chemicals. It is an approach to defining health, physical and environmental hazards of chemicals; creating classification processes that use available data on chemicals for comparison with the defined hazard criteria; and communicating hazard information, as well as protective measures, on labels and Safety Data Sheets (SDS). Many countries already have regulatory systems in place for these types of requirements. The GHS itself is not a regulation or a standard. Regulatory authorities in countries adopting the GHS will thus take the agreed criteria and provisions, and implement them through their own regulatory process and procedures rather than simply incorporating the text of the GHS into their national requirements.

17.2 *General Requirements*—Personal Protective Equipment (PPE), OSHA 29 CFR 1910.132; Respiratory Protection, OSHA 29 CFR 1910.134.

17.2.1 Conduct and communicate a written a hazard assessment and equipment selection procedure to protect employees from injury or illness from occupational hazards. The program documents steps taken to protect workers through the use of PPE when the hazards cannot be eliminated or reduced below action levels.

17.2.2 Engineering and administration controls, such as ventilation and substitution of less toxic materials, are the first line of defense to control respiratory hazards. When engineering controls are not feasible, or cannot adequately control the identified hazards, respirators must be used.

17.3 *Formaldehyde*—OSHA 29 CFR 1910.1048.

17.3.1 To achieve compliance with this standard, administrative or engineering controls must first be determined and implemented whenever feasible. When these controls are not feasible to achieve full compliance, protective equipment or any other protective measures must be used to keep the exposure of employees to air contaminants within the limits prescribed in the regulation. Any equipment and/or technical measures used for this purpose must be approved for each particular use by a competent industrial hygienist or other technically qualified person.

17.3.2 The employer must assure that all employees who are exposed to formaldehyde participate in a training program, except when the employer can demonstrate, using objective data, that employees are not exposed to formaldehyde at or above 0.1 ppm.

17.4 *Labeling Requirements for Pesticides and Devices*—EPA 40 CFR 156.

17.4.1 Every pesticide product label must include information specified in this regulation including directions for use.

17.5 *Machine Safety:*

17.5.1 Employees should be trained in the presence and use of machine guarding, ventilation units, and other protective measures to ensure employee safety when using mechanical equipment during the machining process. Specifically, engineering controls designed to reduce or eliminate respiratory hazards should be reviewed.

17.6 *Metal Removal Fluid Management Program:*

17.6.1 Management of metal removal fluids is the essential in improving fluid life and ensuring employee health. The management program involves coordination with a number of employees, often across multiple shifts. It is advisable to have a program identifying specific functions. The MRF system can address MRF fluid testing, using additives in the system, replacing fluids, system filtration and delivery system, mist collection devices, and more. See Sections 7 and 12 of this standard.

17.6.2 Establish the metal removal fluid control program to collect data, monitor and evaluate the results, and maintain the metal removal fluid system within the prescribed limits set by the fluid manufacturer. Train each worker to correctly fulfill the criteria of the program.

17.7 *Communication:*

17.7.1 Communicating the requirements of MRF management program and each individual's role and responsibility for the program is essential for program success.

17.7.2 Periodic meetings concerning test results, MRF control and adjustments needed, etc. is recommended.

17.8 Results from testing of the occupational environment for contaminants (see Section 14, Occupational Exposure Guidelines; and Section 15, Aerosol Monitoring and Testing) should be communicated to the individuals tested and/or to workers in the areas tested. Reporting results to the safety committee (if one is present) is recommended.

17.9 Medical monitoring, the process that periodically examines a worker's health by collecting health information from the worker, conducting a physical examination, and/or appropriate medical tests can help to reduce occupational health risks. (See Section 16, Medical Monitoring and Management.)

Periodic communication of the status of medical monitoring results to both management and employees (safety committee) is recommended.

17.10 Prompt reporting of occupational health effects problems that any worker develops should be encouraged. More severe occupational health problems can averted if problems are detected, investigated, and resolved at an early stage.

17.11 During an outbreak of an adverse health effect event, it is essential to have good communication, cooperation, and coordination with the plant management, EHS department, occupational health, suppliers, contractors, and workers.

18. Keywords

18.1 aerosol sampling; bacteria; exposure; management; metal removal fluid aerosols; microbiology; workplace atmospheres

APPENDIX

(Nonmandatory Information)

X1. OCCUPATIONAL EXPOSURE GUIDELINES

X1.1 Governmental and non-governmental organizations have developed occupational exposure guidelines (OEG) for the several respiratory hazards that may be encountered in the metal removal fluid environment. The OEG recommendations listed below are provided along with the toxicological basis for them.

X1.1.1 Note that some of the materials for which OEGs are recommended are associated with additional regulatory requirements. For example, OSHA has established detailed requirements for cadmium, lead, and formaldehyde that need to be consulted.

X1.2 Straight oil metal removal fluid mist: 0.5 mg/m^3 TWA.

X1.2.1 The NIOSH recommended exposure level of 0.5 mg/m^3 is the basis of the OEG in consideration of reported adverse respiratory effects associated with exposure levels below the OSHA PEL for straight oil mist of 5 mg/m^3.

X1.3 Water miscible metal removal fluid mist: 0.5 mg/m^3 TWA.

X1.3.1 The NIOSH recommended exposure level of 0.5 mg/m^3 to prevent or greatly reduce respiratory disorders associated with the metal removal fluid environment is the basis of the OEG.

X1.4 Barium: 0.5 mg/m^3 TWA.

X1.4.1 The OSHA PEL has been established to prevent irritation, abdominal and nervous system effects and serves as the basis for the OEG.

X1.5 Beryllium: 0.002 mg/m^3 TWA.

X1.5.1 Beryllium is a highly toxic metal that may cause skin and respiratory disease.

X1.5.2 The OSHA PEL serves as the basis for the OEG.

X1.6 Cadmium: 0.005 mg/m^3 TWA.

X1.6.1 The OSHA PEL has been established on the basis of carcinogenic effects and serves as the basis for the OEG.

X1.7 Chromium III: 0.5 mg/m^3 TWA.

X1.7.1 The OSHA PEL has been established on the basis of skin, liver and kidney effects and serves as the basis for the OEG.

X1.8 Cobalt: 0.1 mg/m^3 TWA.

X1.8.1 The OSHA PEL has been established on the basis of skin and respiratory effects and serves as the basis for the OEG.

X1.9 Lead: 0.05 mg/m^3 TWA.

X1.9.1 The OSHA PEL has been established on the basis of blood, nervous system and reproductive effects and serves as the basis for the OEG.

X1.10 Manganese: 1.0 mg/m^3 TWA.

X1.10.1 The NIOSH REL has been established on the basis of potential neurological effects and serves as the basis for the OEG.

X1.10.2 These adverse neurological effects have been detected after the OSHA PEL was established and have been reported at levels below the PEL.

X1.11 Selenium: 0.2 mg/m^3 TWA.

X1.11.1 The OSHA PEL has been established on the basis of irritation, respiratory and systemic effects and serves as the basis for the OEG.

X1.12 Tellurium: 0.1 mg/m^3 TWA.

X1.12.1 The OSHA PEL has been established on the basis of skin and nervous system effects, unpleasant breath and metallic taste and serves as the basis for the OEG.

X1.13 Endotoxin: 50 EU/m^3 TWA.

X1.13.1 The Dutch Expert Committee on Occupational Standards (DECOS) of the National Health Council recommended limit value for endotoxin was established on the basis of respiratory effects similar to bronchitis and asthma and serves as the basis for the OEG.

X1.13.2 No endotoxin exposure guideline has been established by governmental agencies in the USA.

X1.14 Formaldehyde: 0.75 ppm TWA.

X1.14.1 The OSHA PEL has been established on the basis of carcinogenic effects and serves as the basis for the OEG.

X1.15 Ammonia: 25 ppm. TWA.

X1.15.1 The NIOSH REL serves as the basis for the OEG in consideration of irritation reported at levels below the OSHA PEL of 50 ppm.