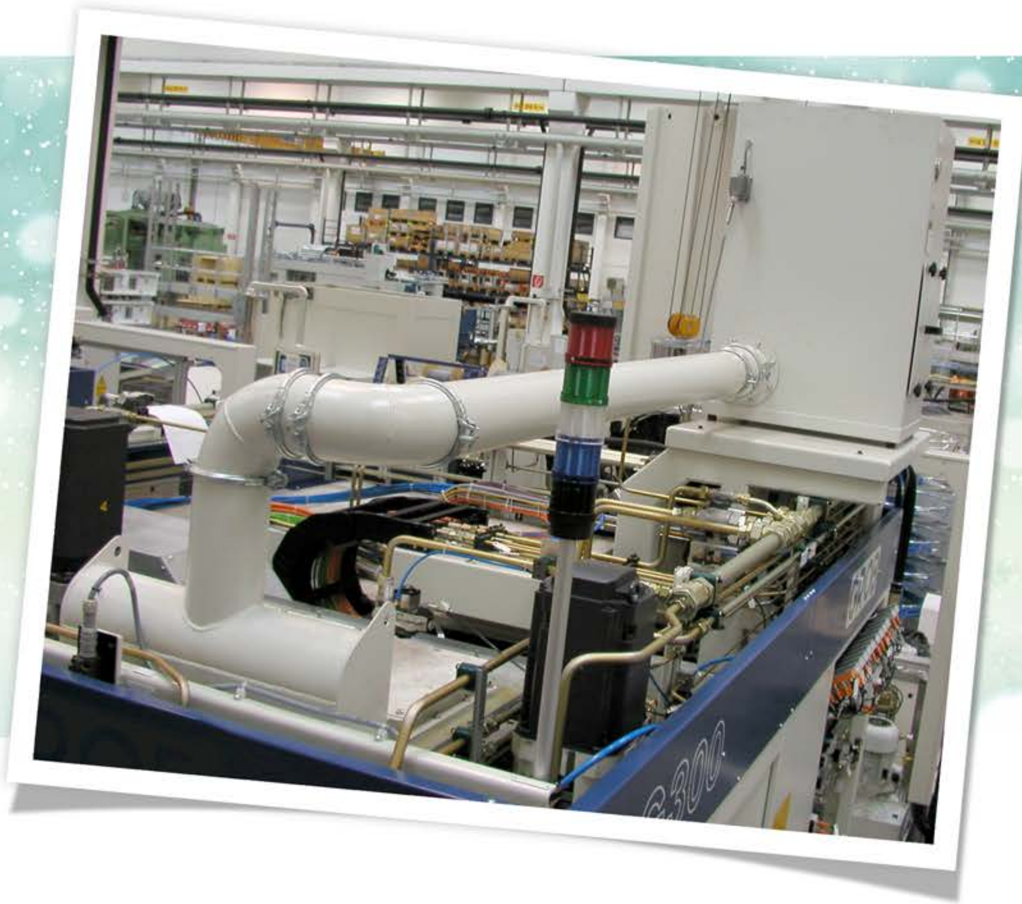
WHITE PAPER

The Importance of Proper Mist Collection for Worker Health and Safety



Airborne mists emitted during machining processes pose numerous risks to human health and safety. It is important to understand the regulations that limit these emissions as well as the various technologies available to achieve compliance with OSHA and other regulatory agencies. This white paper will help you to learn what you can do about mist collection issues in your facility; how to evaluate which type of collection system is most suitable for your application; and how to establish an overall safety program that will best protect employees and equipment.

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AIR POLLUTION CONTROL

By John Dauber and Kevin Tucker

The Importance of Proper Mist Collection for Worker Health and Safety

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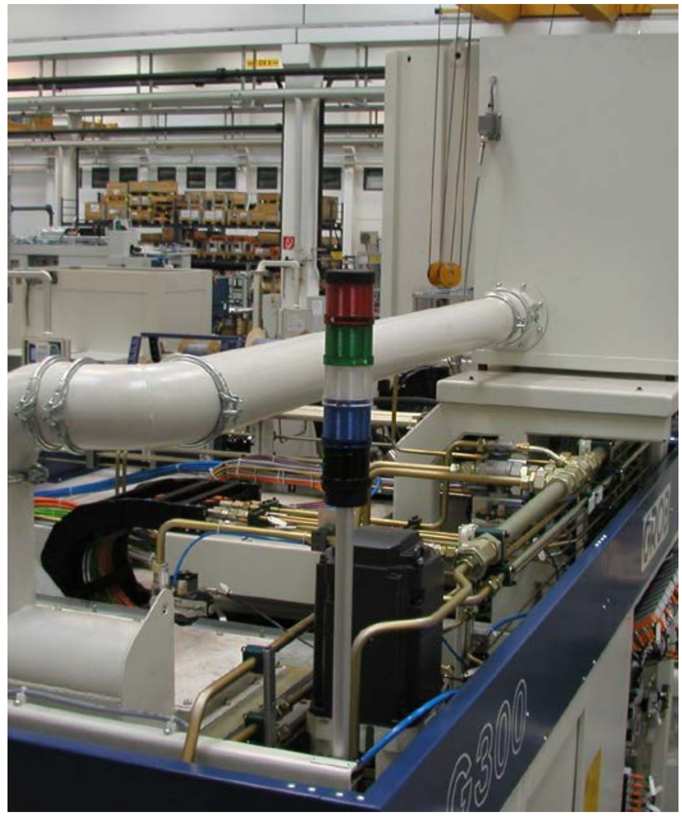
The metalworking fluids (MWFs) commonly used during machining processes generate airborne contaminant mists that must be carefully controlled: Otherwise, they pose a variety of health risks to workers, while also creating a dirty and unsafe work environment. It is important to understand the hazards associated with oil mists as well as exposure limits set by OSHA and other entities. This white paper will review these issues and will describe the role of proper mist collection in keeping machining centers clean. Proper mist collector maintenance and general housekeeping best practices will also be reviewed.



This machining center is equipped with high efficiency collection equipment designed for removal of emulsion coolant mist.

MWF Emissions – Laws, Regulations and Guidelines

The emissions generated by machining processes are formed due to a combination of mechanical and thermal effects and fall into three general categories:

- Coolant-mist liquid aerosols which are formed via cooling of condensation or mechanical processes.
- Coolant-vapor, i.e., substances which are turned into gaseous phase from liquid phase via heating, a colloquial term for hydrocarbons present in gas phase.
- Coolant-fume, the finest solid particles in the air, which are generally formed during combustion processes.

Occupational Safety & Health Administration (OSHA) presently uses two air contaminant permissible exposure limits (PELs) that apply to MWFs. They are:

- 5 mg/m3 for an 8-hour time-weighted average (TWA) for mineral oil mist
- 15 mg/m3 for an 8-hour TWA for Particulates Not Otherwise Classified

MWF hazards are addressed in specific OSHA standards for general industry, shipyard employment, and the construction industry. The applicable standard for General Industry is *29 CFR 1910, Subpart Z; Toxic and hazardous substances; 1910.1000, Air contaminants; Table Z-1, Limits for air contaminants.*

OSHA has also published a *Metalworking Fluids: Safety and Health Best Practices Manual.* This manual incorporates recommendations from the OSHA Metalworking Fluids Standards Advisory Committee Final Report (1999); the NIOSH Criteria Document on Occupational Exposure to Metalworking Fluids (1998); and the Organization Resources Counselors' *Management of the Metal Removal Fluid Environment: A Guide to the Safe and Efficient Use of Metal Removal Fluids* (1999). It does not carry the force of law or regulation, but is meant to be advisory and informational, and it contains a wealth of useful information. The goal is to help employers develop prevention programs that will create safer workplaces for employees exposed to MWFs.

Table 1: Exposure Limits for MWF Contaminants

Regulatory Organization	Exposure Limit	Applicable to:
OSHA	5 mg/m3 for an 8-hour time-weighted average (TWA)	Mineral oil mist
	15 mg/m3 for an 8-hour TWA	Particulates Not Otherwise Classified
NIOSH	0.4 mg/m3 for a 10-hour TWA for a 40-hour work week concentration for thoracic particulate mass	MWF aerosols and thoracic particulate
ACGIH	5 mg/m3 for an 8-hour TWA	Mineral oil mist
	10 mg/m3 for a 15-minute short-term exposure limit (STEL)	

Other groups besides OSHA have weighed in on exposure limits applicable to MWFs. The National Institute for Occupational Safety and Health (NIOSH) has set a much stricter recommended exposure limit (REL) for MWF aerosols of 0.4 mg/m3 for a 10-hour TWA for a 40-hour work week concentration for thoracic particulate mass. Thoracic particulate mass is defined as the fraction of inhaled particles capable of passing beyond the larynx during inhalation.

This REL is intended to prevent or greatly reduce respiratory disorders causally associated with MWF exposure. It is NIOSH's belief that in most metal removal operations, it is technologically feasible to limit MWF aerosol exposures to 0.4 mg/m3 or less (NIOSH 1998b).

The American Conference of Governmental Hygienists (ACGIH) has also set two threshold limit values (TLVs) for mineral oils:

- 5 mg/m3 for an 8-hour TWA.
- 10 mg/m3 for a 15-minute short-term exposure limit (STEL).

The various threshold limits above are summarized in **Table 1.**

Also, in 2003 the American Society for Testing and Materials (ASTM) published the *ASTM International Metalworking Industry Standards: Environmental Quality and Safety, Fluid Performance and Condition Monitoring.* This publication provides standard test methods, practices and guides for proper selection and use of MWFs to ensure optimal performance and reduced worker health risk.

ASTM also has a wide range of standards relating to MWFs. Some of the most pertinent ones include:

- ASTM Standard E 1687-98, *Determining Carcinogenic Potential of Virgin Base Oils in Metalworking Fluids.*
- ASTM Standard E 1302-00, *Standard Guide for Acute Animal Toxicity Testing of Water-Miscible Metalworking Fluids.*
- ASTM Standard E 1497-00, *Standard Practice for Safe Use of Water-Miscible Metalworking Fluids*
- ASTM E2889 – 12, *Standard Practice for Control of Respiratory Hazards in the Metal Removal Fluid Environment*

Health Risks

As noted, a number of adverse health effects are associated with MWFs. Harmful effects due to emissions include the following:

- **Respiratory system:** Aerosols and particles of <100 microns can be inhaled. Aerosols of <5 microns can reach the lower respiratory tract. Aerosols of <2.5 microns can penetrate into the pulmonary alveoli. Resulting complications include asthma, chronic bronchitis, and hypersensitivity pneumonitis.

- **Digestive tract:** Larger particles are deposited in the nose, trachea and bronchi, and can also be swallowed. Contaminants entering through the digestive tract have been linked with some forms of cancer.

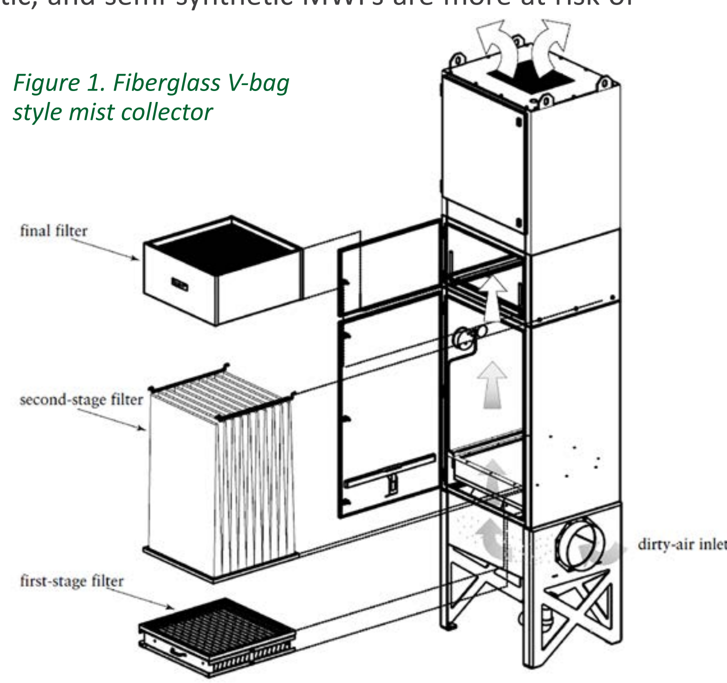
- **Skin:** Mineral oils have a degreasing and dehydration effect on the skin and often cause acne-like disorders. People working with water-based, synthetic, and semi-synthetic MWFs are more at risk of developing contact dermatitis.

- **Irritative effects:** Irritation to the skin, respiratory tract and mucous membranes are common. Vapors of low-viscosity hydrocarbons even have narcotic properties.

- **Allergenic effects:** Prolonged contact may cause allergic contact eczema. Coolant allergens that are inhaled can cause bronchial asthma for sensitive individuals.

- **Toxic effects:** These include changes in organs, as well as potential nerve damage.

Figure 1. Fiberglass V-bag style mist collector



- **Carcinogenic reactions:** Pancreatic, colon, bladder and liver cancer, tumors of the brain and respiratory organs.

- **Mutagenic effects:** Damages to genetic material.

- **Immune disorders:** The absorption of microorganisms into aerosols (emulsions) can cause other health hazards. Bacteria and fungi can lead to weakening of the body's immune system, increasing the risk of illness or disease.

The personal exposure limits (PELs) defined in the previous section have been developed to protect workers against many of these adverse health effects. If your facility is meeting the PEL requirements but workers are still experiencing symptoms, it may be necessary to set lower goals.

Coolants/Emulsions vs. Straight Oil: Understanding the Differences

There are two general categories of MWFs used in machining processes:

Emulsion coolants: Water-soluble and water-mixed coolants are cooling lubricant concentrates that are diluted with water up to their usage concentration prior to their use. They are generally made of oil/ lubricant/water-mixture and additives such as emulsifiers, esters and sulfur compounds, rapeseed oil, polymeric alcohols, defoamers, biocides and anti-corrosion additives. The oil or lubrication proportion is typically about 5–11 percent.

The main feature of emulsion mist coolants is very good heat dissipation. They are used primarily for their cooling function, as the lubricating effect is lower than that of undiluted oil. Emulsion coolants are used in a variety of applications including milling, drilling, tapping, turning, grinding and other machining processes.

Pure or "straight oil" coolants: Non-water-soluble coolants are not mixed with water and are used according to the composition provided by the manufacturer. These oils are usually composed of liquid hydrocarbon compounds (e.g. mineral oils, natural/synthetic oils) and additives (e.g. phosphorus, sulfur, chlorine compounds). Chlorine-containing oils are very hazardous. Other additives provide rust protection, the reduction of foaming and oil mist, and also reduction of the viscosity.

Straight oil coolants are generally used for their excellent lubricating properties – unlike the water-mixed emulsion compounds which provide some lubrication but are used primarily for cooling. Applications for straight oils include turning, drilling, milling, roughing, grinding, broaching, honing, rolling, deep-drawing and pressing.

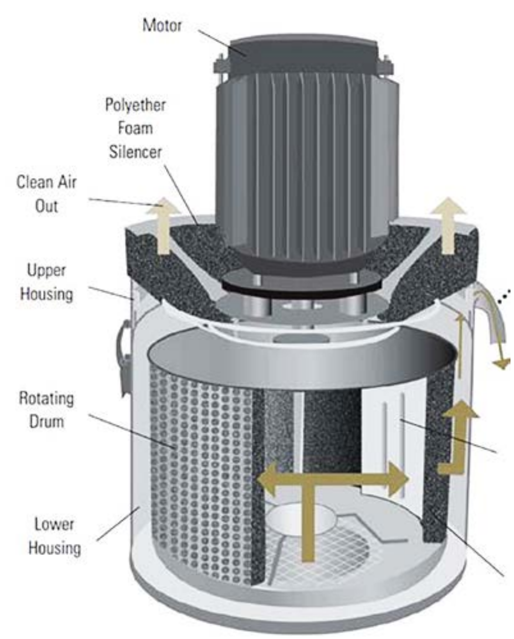


Figure 2 – Centrifugal-type mist collector

There is a variety of equipment used to capture mists generated when these coolants and lubricants are used. The most common type are fiberglass V-bag mist collectors offered by a wide range of manufacturers. These collectors use a first-stage Chevron metal filter, a second-stage aluminum mesh filter, and a third-stage fiberglass V-bag with a 95 percent ASHRAE efficiency rating. The efficiency rating is a bit misleading in that it has nothing to do with oil removal: The ASHRAE rating system is used to measure efficiency in removing dry particulates. Most units also offer an optional fourth-stage HEPA final filter for added protection and cleanliness.

Figure 3 – High efficiency mist collector for emulsion/coolant oils

Fiberglass V-bag style collectors like the one in **Figure 1** *(page 4)* are usually designed for double duty, i.e., they can be used on both straight oil and emulsion coolants. The units lose efficiency as the primary filter bags become saturated with fluid, so filters must be changed regularly to prevent harmful emissions from escaping into the workplace. V-bag collectors work well on lighter-duty applications but are not as effective for heavy-duty use and long production runs.

Centrifugal-type mist collectors **Figure 2** *(page 5)* use a rotating drum to spin out the oil. Typically, there is a pad inside the unit that functions as a final filter, but most contaminants are removed by the rotating action of the drum. If chips collect in too high a volume, the unit can go out of balance and malfunction, creating a health hazard as well as a maintenance headache.

Like V-bag collectors, centrifugal collectors may also be used for straight oil and emulsion coolants; and again, they are best suited for lighter-duty use such as machining centers that operate a few hours a day or change out parts only occasionally. Frequent opening of the door for parts change-out adds to the mist in the air if equipment is not properly vented. V-bag and centrifugal collectors offer relatively low initial cost but are limited in terms of run time, filter service life and filtration efficiencies.

Because of these limitations, many machining center operators recognize that one collector size and type does not fit all. Straight oils and emulsion coolants have very different properties and characteristics. As a result, a number of equipment manufacturers offer highly engineered collection systems that are specifically designed for use with one type or the other.

Figure 3 *(page 6)* shows a high efficiency mist collector designed especially for removal of water-based coolants/emulsions. It uses two stages of long-life coarse and fine filter demisters followed by a final-stage HEPA filter with combined efficiencies of 99.9 percent on particles of 0.3 micron and larger. This

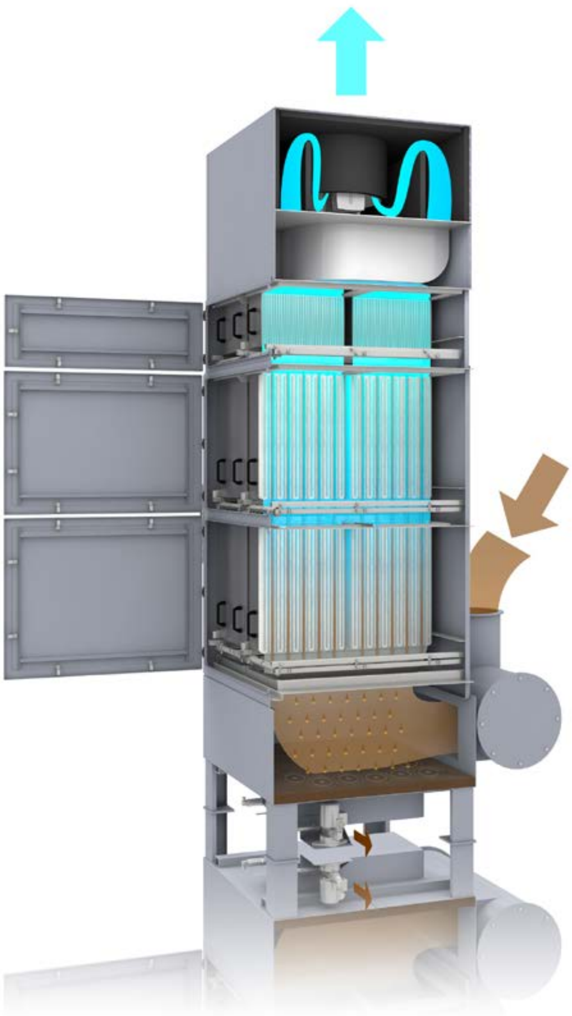


Figure 4 – High efficiency mist collector for "straight" (pure) lubricant oils

is much higher than capture efficiencies achieved with fiberglass V-bag filters. The HEPA filter stage is optional and is typically used where a process is generating smoke or very fine particulate.

This unit also has a patented integrated spraying system that performs two functions: It counteracts emulsion "clumping" in the system by maintaining the correct balance of water to oil, and it cleans the demister filters. In a typical emulsion mist collection system, the emulsion tends to thicken to a honey-like consistency which can gum up filters and other internal components, requiring downtime for periodic maintenance. The integrated spraying system eliminates this problem, performing a self-cleaning function that results in greatly reduced maintenance and an unprecedented filter life of up to 6 years for the primary demister filter.

Figure 4 shows a mist collector designed for use with pure or straight lubricant oils. The filtration stages employed are quite different from those in **Figure 3.** A first-stage coarse mesh filter separates out large particles and chips, followed by two stages of diffusion filters: a pre-filter and fine filter that are the heart of the collector. Media separators in the filter packs allow optimum airflow while providing maximum usable media area within a compact space.

This design combines high efficiency separation performance with self-cleaning capability via drainage of the separated cooling lubricant. Benefits include reduced energy consumption, extended filter life of three years on average, and enhanced protection of the optional HEPA final filter, which may be used for removal of ultra-fine mists and/or clean air recirculation. Achieving separation efficiencies up to 99.97 percent on 0.3 micron and larger particles, it is built to operate "24/7" and to withstand the most challenging applications.

Design Considerations

When designing equipment for mist removal, the best solution is a source capture collection system that will contain mist at the machine. Ceiling units that provide ambient ventilation are sometimes used: These will remove some of the mist but are not as effective as source capture. By contrast, ambient collection works well in welding shops, where the warm weld fumes rise to the ceiling and can be removed with a properly sized system and the correct number of air changes. But this approach does not translate well to mist removal, with mist-laden air and slippery floors inevitably resulting. Source capture requires less air, and is safer and more efficient with just about any type of wet or dry collection system.

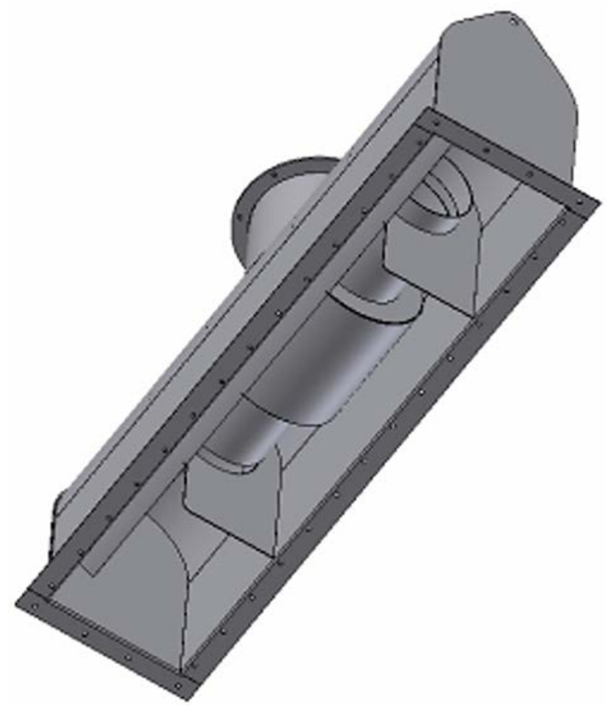


Figure 5 – Chip gate for pre-separation of metal chips

The design challenges will be greater when retrofitting equipment into an older machining center. Equipment built 20 or 25 years ago was often not designed for mist collection. Newer machines utilize better ductwork designs and better airflow patterns to pull air out of the machine at the recommended cfm airflow.

A good general rule is to maintain a slight negative pressure when doing machining. This will allow you to capture the fine mist without pulling chips, emulsion or oil into the collector.

One recommended option is to equip the oil or emulsion mist collector with a variable frequency drive (VFD). During machining, the VFD speed should be reduced to a level just adequate to contain the mist in the machine. In a newer machining center that is fairly airtight, you may be able to ramp down to 25 percent of full airflow while the doors are shut. Maximum airflow when doors are shut can pull mist and chips into the collector and shorten filter life.

When it comes time to change parts and the doors are opened up, the fan can be ramped up to full airflow. It is advisable to keep airflow to 50-75 fpm through the door opening while changing parts to keep the mist inside the cabinet. The best designed systems leave most of the oil and all of the chips in the machining center.

If compressed air is being used to clean parts, that must also be taken into consideration. Again, make sure there is enough air to contain the mist in the cabinet in order to protect workers during part change-out.

Another strategy is to use a special hood or chip gate **(Figure 5)** to separate out metal chips and pre-clean the oil. Basically it acts like a horizontal cyclone designed for the airflow you need in the machining center. It works by spreading out the airflow to prevent creating a high velocity suction area that will pick up a lot of chips. Ductwork is generally about 6" and the area pulling the air is about six times that size. With that ratio, you will not pull excessive air into one place in the cabinet. Chip gates can sometimes be retrofitted onto older equipment.

Figure 6 – Clogged ductwork conditions caused by inadequate filtration

Any time you can reduce the load on a collector, it's a good thing. As noted, lots of metal chips can drastically shorten filter life. Oil or emulsion can run for a very long time, if pickup hoods and airflow in the machines are optimally designed.

It is also important to equip ductwork with proper fittings and seals that are specifically made for oil. There is a misconception in the field that mist collectors and ductwork always leak, and unsuitable fittings and seals can often be the cause. Also, make sure the cabinet is leak-proof and won't seep oil: Otherwise employees are at risk of slipping and falling on oily floors. Even very small cracks will allow oil to seep out. Using equipment that has been dye-tested and certified as leak-proof by the manufacturer is a good way to make sure such leaks and cracks don't occur.

In addition to a guarantee that the collector and its components won't leak, a reputable manufacturer should also guarantee filter emissions efficiency, to ensure that you keep below required exposure limits. Some manufacturers will also provide written guarantees on filter life and run time to fit your operation.

Special design considerations are involved for applications utilizing Minimum Quantity Lubrication (MQL). MQL, or near-dry machining, replaces the coolant commonly used in machining operations with a very small amount of high-quality lubricant that is precisely metered and applied to the interface of the cutting tool and workpiece. The amount of lubricant used, often a pure vegetable-based or ester oil, is defined as less than 40 milliliters per hour (ml/h) lubricant. MQL is becoming increasingly popular because of its environmental and sustainable benefits.

In MQL applications, unless you design the ductwork correctly and have adequate filtration in place, ducts will become plugged. A special pre-filter in the oil mist collector is usually required to handle MQL. Otherwise, the near-dry material generated in the process will cake up and plug ductwork. **Figure 6** shows examples of ductwork conditions that can occur with improper designs.

General Work Practices and Controls for Reducing Exposure

You can tell when you walk into a machine shop whether good work practices are being observed. When they are not, you can literally smell, feel and taste the oil in the air. There are many factors involved in keeping machine shops as safe and clean as possible. Your approach to safety should be multi-faceted and should incorporate the following items:

Equipment considerations

- Make sure your machining centers and mist-producing processes use best practice mist collection. As noted, it is often preferable to use a collector designed specifically for either oil or emulsion coolant mist removal, as opposed to a "general purpose" collector. This is particularly important for centers with heavy duty applications and long production runs. Require the supplier to provide a written guarantee on filter life, emissions performance and leak-testing, as noted earlier.

- Inspect equipment regularly to make sure it's working as it's supposed to. Sometimes, emissions will be fine at startup, but that may change after the collector has been operating over time.

- Conduct frequent air sampling to make sure you are well within the required personal exposure limits. Monitors that measure emissions and show milligrams per cubic meter being emitted can be used for testing within the facility. If you suspect a problem or need independent verification of emission levels within the facility, it is best to hire a company that specializes in air quality testing.

- If you see oil on the floor, be sure not only to clean it up but also to find and address the source of where it's coming from.

- Monitor trends in the differential pressure across the filters and make sure pressure is within the manufacturer's recommended operating range. If you are seeing high differential pressures, chances are you are not pulling the required airflow. Pressure monitoring should be done daily. There are a number of monitoring devices available that will measure differential pressure and other critical functions and send alarms at critical set points. Some systems can provide web-based monitoring, can hook into your smart phone and/or your building maintenance system software.

Employee considerations

- Train and educate employees on the health risks associated with overexposure, on good work practices, and on the importance of good housekeeping.

- Require employees to wash hands several times during the day if they are not wearing gloves.

- Do not allow workers to wear fluid-soaked clothes.

- Prohibit food, beverages, any other personal items in the workspace that may become contaminated.

# # #

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