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Guidelines for the Control of Exposure to Metalworking Fluids

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Based on data from the National Occupational Hazard Survey, the National Institute for Occupational Safety and Health (NIOSH) estimates that 1.2 million people in the United States are exposed to metalworking fluids. A review, published in 1962 by Hendricks et al., of oils of all types used in industry found a striking lack of reported cases of illnesses related to "oil" mist inhalation at average exposure concentration of 3.7-mg/m^3, nor an increase in respiratory symptoms at an average concentration of 5.2-mg/m^3. The 5-mg/m^3 environmental limit for petroleum based oils is recommended by the American Conference of Governmental Industrial Hygienists as an index of good industrial practice. No such limit exists for synthetic metalworking fluids. Subsequently, control measures have been instituted as a means to control a nuisance material, but neither measurement of the actual concentrations of oil mist in the air nor documentation of the specific techniques used have been documented.

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GUIDELINES FOR THE CONTROL OF EXPOSURE TO METALWORKING FLUIDS

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ABSTRACT

Guidelines for the control of exposures to metalworking (cutting) fluids and mists are presented. Applications of the basic control principles of substitution, isolation, and ventilation are documented for seventeen machine tool types, including presentation of attained environmental levels, a critique of the application, and identification of research needs.

INTRODUCTION

Based on data from the National Occupational Hazard Survey, the National Institute for Occupational Safety and Health (NIOSH) estimates that 1.2 million people in the United States are exposed to metalworking fluids. A review, published in 1962 by Hendricks et al. (1), of oils of all types used in industry found a striking lack of reported cases of illnesses related to "oil" mist inhalation at average exposure concentrations below 15-mg/m^3. A more recent study, published in 1970 by Ely et al. (2), reported no excess mortality due to oil mist exposures at an average concentration of 3.7-mg/m^3, nor an increase in respiratory symptoms at an average concentration of 5.2-mg/m^3. The 5-mg/m^3 environmental limit for petroleum based oils is recommended by the American Conference of Governmental Industrial Hygienists as an index of good industrial practice (3). No such limit exists for synthetic metalworking fluids. Subsequently, control measures have been instituted as a means to control a nuisance material, but neither measurement of the actual concentrations of oil mist in the air nor documentation of the specific techniques used have been documented (4).

This study reviews the basic principles of control, substitution, isolation, and ventilation as applied to cutting fluid mists from machining operations, and presents case histories of control techniques used with seventeen types of machine tools.

INDUSTRY OVERVIEW

MACHINING OPERATIONS

Metal is cut in order to finish rough parts formed by other processes, such as casting and forging, to specified dimensions. It is accomplished by driving an edged tool through material to remove chips and leave geometrically true surfaces. The surface generated depends on the shape of the tool and the path it traverses through the material. Machine tools have evolved from handtools to provide rapid metal cutting with consistent precision. Table 1 lists the basic categories of machine tools. Table 2 lists some of the more frequently encountered speciality machines which have been developed to meet the demands for production of specific items in large quantities.

METALWORKING FLUIDS AND MISTS

More than ninety-seven percent of the work involving metal cutting appears as heat. The basic functions of a cutting fluid are to reduce friction, carry away generated heat, and flush away metal chips. Chemical (water) solutions and cutting oils are commonly used metalworking fluids. Cutting oils include both straight mineral oils and soluble oils. Soluble oils are emulsions of mineral oil in water. Mixtures vary from five to over 100 parts water to one part oil. As a general rule, the straight oils are employed for more difficult operations where heavy cuts are taken or fine finishes are required. Water based metalworking fluids (synthetics) are used in higher speed cutting operations due to the greater rate of heat generation and the higher specific heat of water. The composition of various classes of metalworking fluids is outlined in Table 3. Springborn (5) lists recommended fluids and application methods for selected operations work piece metals.

Cutting fluids may be applied to the tool manually, by an air carried mist, or by a continuous flood. Manual application of metalworking fluids is the easiest and least costly of the various methods in use (it consists of an oil can filled with fluid, or a container and paint brush for applying the fluid). In the mist application of metalworking fluids a small quantity of liquid coolant is introduced into a high velocity stream of air to form a mist. This stream is directed at the cutting zone with much of it evaporating on contact with the hot tool, workpiece or chip. Flooding is the most common method of metalworking fluid application. A low pressure pump delivers the fluid through pipes and valves to a nozzle, situated over the cutting zone, through which it flows down and floods the tool, work, and chip. The fluid is then collected in the chip pan and returned by gravity to the pump sump.

Metalworking fluid mist can be generated in three ways: 1) mechanically, by the centripetal forces generated by a rapidly spinning workpiece or tool, 2) thermally, by the vaporization and subsequent condensation of a fluid and 3) intentionally, by the application of a metalworking fluid as an atomized mist.

HAZARD ANALYSIS

As noted previously, the 5 mg/m^3 environmental limit recommended for petroleum based oils by the ACGIH is intended as an index of good industrial practice rather than as a mandate for prevention of injury. Hamilton and Hardy (6) indicate that exposure to mists of insoluble oils used in machining operations are not harmful to the respiratory tract, but add that metalworking fluids may be the most common cause of industrial dermatitis. They include the following as causative factors:

Synthetic fluids are potent defatting agents.

Soluble oil emulsions provide a breeding ground for bacteria. Bactericides are added primarily to prevent decomposition and odor formation and not for the prevention of skin infections.

Fluid additives can be a cause of either primary irritative or hypersensitive dermatitis.

Hamilton and Hardy (6) cite the carcinogenic constitutents of certain petroleum oils, especially shale oils (not manufactured and used in the United States). Skin cancer is not known to occur in numbers significantly above those that occur in a control population.

Re-refined straight oil was used in one plant surveyed. An analysis of this oil in the "as received" condition for polynuclear aromatic hydrocarbons was attempted, and perylene and chrysene tentatively identified but not quantified (7). Further research is needed to compare carcinogenic constitutents in petroleum oils, new and re-refined, both as received from the manufacturer and after normal machine use. As the price of oil continues to soar and environmental restrictions increase, the use of re-refined oils and synthetic fluids will grow.

The use of synthetic cutting fluids has recently become questionable, due to the discovery of diethanol nitrosamine, a suspected carcinogen, as a product from the reaction of amines with nitrites, both of which are common in commercially available fluids (8). No environmental limit exists for airborne concentrations of synthetic fluids, although standards may exist for specific additives or components.

ENGINEERING CONTROLS

The basic principles of control, substitution, isolation, and ventilation are all applicable to the control of metalworking fluid mist. More specifically, these principles involve techniques and evaluations concerning fluid selection, fluid additives, machine type, splash guarding, and ventilation.

Springborn (5) offers useful guidelines for the selection of metalworking fluids for machining operations. Factors entering into selection of a fluid include machining conditions, performance requirements, tool design, and fluid cost as well as working conditions. The synthetic and soluble oil metalworking fluids are less prone to fuming and misting than the straight mineral oils but carry a greater risk of dermatitis. The potential skin cancer hazard from the use of mineral oil based cutting fluids can be reduced by the use of oils from which the carcinogens have been removed by solvent extraction.

Straight oils incorporating anti-misting polymer additives have been introduced into the marketplace; one manufacturer claims reduction of mechanically produced mist in excess of ninety percent when compared to conventional oils (9, 10). Use of anti-misting oils is discussed in the case histories.

Substitute synthetic fluids are available which eliminate the potential of nitrosamine formation by removing nitrites from the formulation; however, the user contemplating any change in cutting fluids should give full consideration to the potential hazards of the substitute.

In order to protect the machine operator from cutting fluid splash and moving machine parts, Cookson (11) offers the following guidelines for the construction of machine guards:

> Guards must be as robust as possible and rigidly supported where possible.
>
> Guards which are not permanently fixed will be easily removed and, what is very important, just as easily replaced. This often leads to the use of sliding guards.
>
> If the guard obscures the view of the working area, shatter-proof windows will avoid the temptation to leave the guard off.
>
> Guards designed on an overlapping drip-proof principle have advantages over sealed, abutting types.
>
> The cutting of apertures to allow for the passage of pipes or conduit should be avoided.

Other methods of reducing operator fluid contact by machine modification which are also cited by Cookson include: automation (particularly in loading and unloading of the machine), improved swarf handling, pre-set tooling, and numerical control. Schulte (4) states that the most effective method of controlling mist from machining operations is a combination of enclosure and local exhaust ventilation. In most cases, the exhaust air is passed through an electrostatic precipitator and returned to the workroom. Filters (12) and centrifugal mist collectors (13) are also utilized. While the use of these unit collectors (individual air cleaners mounted directly on a given machine) is wide spread, their use should be limited to relatively small facilities since large numbers of air cleaners distributed throughout the workroom can present significant maintenance problems. Plenum type exhaust systems with large, centrally located air cleaners are ideally suited for metalworking fluid mist collection systems because of the ease with which branch ducts can be added, removed, or relocated. Care must be taken in the design of such systems to allow condensed mist and droplets to drain and to provide for adequate fire protection. Guidance for proper design can be found in Industrial Ventilation - A Manual of Recommended Practice (14), and in Fundamentals Governing the Design and Operation of Local Exhaust Systems, ANSI Z9.2-1971 (15).

Exhaust hoods should be designed so that the machine can be easily serviced and the operation observed when required. Hood sides should act as splash guards since an indraft of air will not stop oil thrown from the operation. Many machine tools are supplied by the manufacturer with windowed enclosures designed so that the operation can be observed and the hood readily opened or moved for placing and removing of parts machined. Suitable enclosures can usually be constructed if such hooding has been overlooked by the manufacturer. Kane (16) suggests an exhaust volume of 400 - 600 cfm in order to provide 100 fpm indraft, and to prevent vapor and mist from dispersing if care is exercised in the hood construction. He suggests that volumes of 1000 to 1500 cfm may be required when considerable heat is generated in the operation or where the degree of enclosure is compromised.

When a large number of sources are distributed in a workroom, and the total amount of metalworking fluid mist generated is small, general (dilution) ventilation can provide effective control if the worker is far enough away from the mist source. As general ventilation refers to the dilution of contaminated air with uncontaminated air, the rate of contaminant generation must be known to determine the required dilution air volume. In the case of metalworking fluid mist, this information is neither readily available nor experimentally obtainable. The best source of general ventilation data is from comparable operations rather than from ventilation "rules of thumb."

The widespread use of air conditioning in machining operations has been accompanied by the recirculation of exhaust air, both from local exhaust systems and general workroom air. Case history number 18 evaluates the performance of such a general ventilation scheme in a small production machine shop.

WORK PRACTICES

The risk of dermatitis can be reduced by proper work practices. Cleansing of soiled skin at work breaks followed by thorough drying and the application of an emollient cream is a hygienic procedure appropriate to all metalworking fluid applications. The use of petroleum solvents and abrasive cleansers as skin cleaners should be avoided. Work clothing should be changed daily. The practice of keeping oil soaked wipe rags in trouser pockets should be discouraged.

Dermatitis can occur with certain types of chlorinated sulfurized cutting oils when they get into a water miscible fluid. The water will gradually breakdown the chlorine in such oils and release hydrochloric acid. Almost anyone could experience an adverse reaction from such a situation (5). Care must be taken that oils are not mixed; machines must be thoroughly cleaned between fluid changes.

Soluble oil emulsions are breeding gi unds for bacteria. Cookson (11) recommends effective draining, cleaning (both flushing with a chemical cleanser and physical cleaning), and sterilizing between changes as the most beneficial steps in controlling infection of coolant systems.

PERSONAL PROTECTIVE EQUIPMENT

Oil resistant gloves provide protection from both direct metalworking fluid contact and nicks and scratches from parts or swarf handling. Gloves should be cuffed to avoid exposure to the arms.

Protective creams are of limited value. Germicides present in some protective creams can be skin irritants (6). Water soluble (oil insoluble) creams are required to protect against oil attack on the skin. There are no protective creams which can hold up in a diversified work environment where the hands will be exposed to a mixture of oil, solvents, and water-based fluids (5).

As an interim measure, oil resistant aprons should be used for protection against splashes until proper enclosures or splash guards can be installed.

METHODOLOGY

A literature search was conducted to determine the nature and use of metal-working fluids, the extent of exposure, and applicable control techniques. Machine tool manufacturers, metalworking fluid producers, control equipment fabricators, and others were solicited for their recommendations as to plants which offered a variety of well controlled machining operations. Three plants were selected for study to represent state-of-the-art control technology for the widest possible variety of operations within the allotted resources. Emphasis was given to those machining operations which utilized straight cutting oils, operated at high rotational speeds, machined common metals (mild steel, cast iron, brass), or could be classified as severe for high speed tools. The severity of the machining conditions is a relative index of the load on the tool and the amount of heat generated. It, thus, serves as an estimate of the relative tendency to thermally generate mist.

Control effectiveness was determined by compliance with an eight-hour time weighted average of 5 mg/m^3 mineral oil mist where straight and soluble metal-working oils were used. Due to the lack of an environmental standard for synthetic metalworking fluid mists, the airborne concentrations of nitrite was measured as an index of the control achieved.

Area air samples were taken at locations approximating the breathing zone at the machine operator's work station. Sampling was performed at several identical machines performing similar operations. All samples were collected on 37 mm membrane filters using a cassette filter holder.

Analyses were performed by either fluorescence of a chloroform extract or infrared absorbance of a carbon tetrachloride extract. The analytical procedure is outlined in NIOSH P+CAM #159 (17). Airborne levels of nitrites (where synthetic nitrite-amine formulations were used) were determined using the identical sampling technique and the spectrophotometric analytical technique of NIOSH P+CAM 231 (17).

CASE HISTORIES

Examples of the application of the basic principles of control, isolation, substitution, and ventilation are presented for seventeen machining operations. Because of the wide variety of machine tools and machining operations, the examples are intended to illustrate the general principles of control rather than provide the strict dictums of an engineering manual.

Each case history identifies the machine tool and manufacturer, the operation performed, the metalworking fluid in use, the control approach in use, and the environmental levels attained, followed by a brief commentary on the control method selected.

The majority of machining operations might well fall into a class which requires no elaborate means of control, other than simple splash guarding and general ventilation. A description and evaluation of an entire small plant general ventilation system is included as case history No. 18.

CASE HISTORY #1 - AUTOMATIC SCREW MACHINE

Operation:

Production of finished and semi-finished carburetor parts from brass and leaded steel. Brass constitutes 75% of production. Turning speed for brass is 3000 rpm; for steel, 2400 rpm. Machine operator's duties include: machine set up, loading of stock into the machines, checking of product dimensions, and machine adjustments.

Machine:

Davenport Model B 3/4" Screw Machine
National ACME Model RA-6 Screw Machine

Metalworking Fluid:

Straight Oil (Mobilmet 406)
Flood application

Control Method:

Primary control method is the use of a cutting oil with anti-misting additives. Limited splash guarding is in use. There is no local exhaust present, but control is aided by a high degree of general ventilation, high ceilings (26 feet), and a low density of machine tools.

Environmental Levels:

Location	Number of Samples	Average Concentration	Standard Deviation
3/4" screw machine	10	1.2 mg/m^3	0.42
1¼" screw machine	2	0.7 mg/m^3	-

Comment:

The use of an anti-misting cutting oil for automatic screw machines is an effective means for controlling of airborne oil mists. Partial enclosure of machines is desirable to contain mist generation and to protect from splashes and flying metal chips.

CASE HISTORY #2 - CHUCKER

Operation:

Production of finished brass carburetor parts from semi-finished parts. Turning speed is 3000 rpm. Machine operator's duties include: machine set up, manually loading individual small parts into the machine, checking of product dimensions, and machine adjustments.

Machine:

3/4" Chucker

Metalworking Fluid:

Straight Oil (Mobilmet 406)
Flood application

Control Method:

Primary control method is the use of a cutting oil with anti-misting additives. Limited splash guarding is used (including machine wipes used as drapes).

Environmental Levels:

Location	Number of Samples	Average Concentration	Standard Deviation
3/4" chucker	4	2.9 mg/m^3	3.29

Comment:

Because each part is hand-fed into the machine, splash guarding is minimal and the operator's breathing zone is near the zone of mist generation. Due to the variation in the sampling data it can not be concluded that the use of an anti-mist oil alone is an effective means of control. As it is the manual feeding operation that keeps the operator tied to the machine as well as providing substantial skin contact with the oil, automated feeding devices would provide a substantial reduction in both skin and inhalation exposure.

CASE HISTORY #3 - CHUCKER

Operation:

Turning of cast iron cylinder liners. The machine is equipped with an automatic loading/unloading device.

Machine:

Acme-Gridley Model RPA 6

Metalworking Fluid:

Synthetic, diluted 30:1 (Vantrol 31-228A)

Control Method:

The machine is equipped with a sheet metal enclosure, exhausted at two pickup points at a total rate of 1000 cfm, providing an indraft through the feed door of 60 - 125 fpm. Chuckers are vented to a plenum type exhaust system with exhaust air cleaned by metal mesh/fabric filter combination units and are then recirculated.

Environmental Levels:

Location	Number of Samples	Average Concentration	Standard Deviation
Chucker	4	$<10 \mu g\ NO_2^-/m^3$	-

Comments:

The cutting fluid in use has the potential for the formation of nitrosamines. As no health standards exist for these substances, environmental levels of nitrite were determined as an index of the level of control.

The automatic loading/unloading device greatly reduces the operator's skin exposure to the cutting fluids.

CASE HISTORY #4 - MULTI STATION DRILL PRESS

Operation:

Drilling oil hole in rocker arms of malleable iron. Operator loads and unloads rocker arms in each of four independent drill stations. Carbide tipped drills are used.

Machine:

Cincinnati Lathe and Tool Four Station Drill Press

Metalworking Fluid:

Semi-Synthetic Diluted 15:1 (Vantrol 31-237c)
Flood Application

Control Method:

None required.

Environmental Levels:

Location	Number of Samples	Average Concentration	Standard Deviation
Drill Press	4	0.2 mg/m^3	0.05

Comments:

As semi-synthetic fluids contain a substantial fraction of non "oil" constituents, environmental levels are reported as an index of control only. The user is cautioned to give full consideration to the potential hazards of any product in use or planned for future use.

CASE HISTORY #5 - MULTI-SPINDLE DRILL PRESS

Operation:

Boring, facing, and chamfering of malleable iron rocker arms for use in internal combustion engines. The operator loads and unloads parts.

Machine:

Kingsbury Multi-spindle Drill Press

Metalworking Fluid:

Semi-synthetic Diluted 15:1 (Vantrol 31-237c)
Flood application

Control Method:

Removable splash guards are provided which surround the drill heads.

Environmental Levels:

Location	Number of Samples	Average Concentration	Standard Deviation
Multi-spindle Drill (operator's station)	4	0.9 mg/m^3	0.54

Comments:

As semi-synthetic fluids contain a substantial fraction of non "oil" constituents, environmental levels are reported as an index of control only. The user is cautioned to give full consideration to the potential hazards of any product in use or planned for future use.

CASE HISTORY #6 - GUN DRILL

Operation:

Drilling of ¼" x 9" oil passage in steel connecting rods used in internal combustion engines. Each machine has two independent enclosed sections containing four drill heads each. Operator opens access door, loads connecting rods, closes door, activates drilling, then removes drilled rods.

Machine:

Snyder Gundrill

Metalworking Fluid:

Straight Oil (Transultex 240)
Flood application

Control Method:

Each half of the machine is surrounded by separate sheet metal enclosures which telescope with the movement of the drill heads. The machine is exhausted at seven pickup points at a rate of 2500 cfm. A canopy hood over the back half of the machine (drill heads, slideways, motors) is exhausted at 1000 cfm. A second gundrill, of the same manufacturer and performing the same operation, utilized a four by eight foot canopy hood covering the entire machine, with heavy rubber side curtains to effect an enclosure. The canopy was exhausted at a rate of 2500 cfm. Exhaust air from both machines is cleaned by a single fabric filter unit and recirculated.

Both machines have mist lubricated bearings using Trabon mist lubrication and mist collection systems.

Environmental Levels:

Location	Number of Samples	Average Concentration	Standard Deviation
Gundrill	4	0.4 mg/m^3	0.06

Comments:

Both control approaches illustrate that utilization of local exhaust and enclosure can reduce mist levels substantially below the current recommended level of 5 mg/m^3.

CASE HISTORY #7 - BROACHING MACHINE

Operation:

Surface broaching of steel connecting rods used in internal combustion engines. High speed steel broaches operate at 32 fpm. Operator manually loads connecting rods in fixture and removes broached product.

Machine:

Colonial Vertical Broaching Machine
Detroit Vertical Broaching Machine

Metalworking Fluid:

Soluble Oil Diluted 15:1 (Vantrol 711)
Flood Application

Control Method:

A soluble oil (less prone to fuming) is used in place of a straight oil, also commonly used in broaching operations. A high standard of general ventilation and well spaced machines aided in control.

Environmental Levels:

Location	Number of Samples	Average Concentration	Standard Deviation
Broaching machine	6	0.5 mg/m^3	0.15

Comments:

Proper metalworking fluid selection achieved low airborne mist levels without the aid of local exhaust. Careful fluid application techniques minimized skin contact via splashes.

CASE HISTORY #8 - CIRCULAR SAW

Operation:

Sawing off bearing cap of a malleable iron connecting rod. Actual cutting operation is dry; metalworking fluid used to wash swarf from saw blade.

Machine:

Snyder Circular Saw

Metalworking Fluid:

Soluble Oil Diluted 15:1 (Vantrol 711)
Flood Application

Control Method:

The saw blade is partially enclosed. No local exhaust is utilized.

Environmental Levels:

Location	Number of Samples	Average Concentration	Standard Deviation
Circular saw	2	0.7 mg/m^3	0.07

Comments:

Swarf from this operation is red hot. A water based coolant provides rapid cooling of the swarf with minimal misting. This and other operations which might utilize straight oils may require ventilation of the swarf collection area to prevent workplace contamination.

CASE HISTORY #9 - BORING

Operation:

Boring of piston end of steel internal combustion engine connecting rods. The operator loads and unloads rods from machine fixtures.

Machine:

Michigan Boring Machine

Metalworking Fluid:

Soluble Oil, Diluted 15:1 (Vantrol 711)
Flood Application

Control Method:

Removable sheet metal splash guards are provided. No local exhaust is utilized.

Environmental Levels:

Location	Number of Samples	Average Concentration	Standard Deviation
Boring Machine	4	0.5 mg/m^3	.08

Comments:

None

CASE HISTORY #10 - BORING

Operation:

Boring of cast iron cylinder liners. The operator loads feeder which automatically transfers liners to boring fixture.

Machine:

Moline Boring Machine

Metalworking Fluid:

Semi-synthetic, Diluted 30:1 (Vantrol 31-228A)
Flood Application

Control Method:

Partial enclosure is provided by drapes of rubber sheeting. Local exhaust is provided at four pickup points on each machine for a machine total of 1600 cfm design capacity. Machines are vented to a plenum type exhaust system with exhaust air cleaned by metal mesh/fabric filter combination units and recirculated.

Environmental Levels:

Location	Number of Samples	Average Concentration	Standard Deviation
Boring Machine (at feeder)	4	<10 $g\mu NO_2^-/m^3$	-

Comments:

The metalworking fluid in use has the potential for the formation of nitrosamines. As no health standards exist for these substances, environmental levels of nitrite were determined as an index of the level of control. Low airborne nitrite concentrations in this operation are more a function of the relative isolation provided the operator's station by the feeder rather than a function of the ventilation employed. Of two machines studied, one had no operating exhaust, and the other was 600 cfm less than design. In either case, the capture distance of the exhaust hoods was too great to produce any effect.

CASE HISTORY #11 - CYLINDRICAL CENTER TYPE CRINDER

Operation:

Grinding of external surfaces of steel gears and malleable iron differential housings for use in truck rear axle assemblies. Grinders operate at 5600 rpm. Operator is responsible for machine adjustments, loading rough machined parts and removing finished parts.

Machine:

Cincinnati Angle Grinder (gears)
Norton Angle Crinder (housings)

Metalworking Fluid:

Soluble Oil, Diluted 30 - 40:1 (Sunseco)
Flood Application

Control Method:

Each grinder is equipped with a free standing, 12" diameter side draft hood mounted 18" from the grinding wheel/workpiece contact point, and splash guarding of the wheel. Each hood was connected to the main duct by a flexible hose, and could be positioned by the operator. Each hood was exhausted at the rate of 1200 cfm. All grinders are connected to a 6000 cfm fabric filter and the cleaned exhaust returned to the workplace at ceiling level.

Environmental Levels:

Location	Number of Samples	Average Concentration	Standard Deviation
Grinder (gears)	3	1.3 mg/m^3	.42
Grinder (housings)	2	1.9 mg/m^3	.85

Comments:

Control of airborne mist is satisfactory in this application; however, the rapid rotation of the grinding wheel creates a considerable spray which, although it does not remain long in the air, does present a skin and clothing contact problem. The existing hood configuration produces a control velocity in the range of 50 fpm at the wheel/workpiece contact point. The spray is generated with such velocity that control by local exhaust alone is not practical, but rather local exhaust coupled with more complete enclosure of the operation.

CASE HISTORY #12 - SURFACE GRINDER

Operation:

Multi-wheel grinders machine flat surfaces of connecting rods (steel) for internal combustion engines. The operator loads and unloads the connecting rods from a carousel which brings the workpiece to each of the grinding wheels.

Machine:

Mattisson 3 Wheel Grinder
Mattisson 5 Wheel Grinder

Metalworking Fluid:

Synthetic Fluid Diluted 25:1 (Vantrol 31-223C)
Flood Application

Control Method:

Both inhalation and skin exposures are controlled by the enclosure of the grinding wheel portion of the carousel. Openings to admit the workpiece are baffled by rubber sheeting to reduce open area. Access openings a provided for maintenance and inspection with doors that latch securely. Both grinders are exhausted at the rate of 750 cfm with exhaust takeoffs located at both enclosure entrances and exits to guarantee good air distribution. All machines exhaust to a plenum serving the production line. Exhaust air from the plenum is cleaned in a number of fabric filter units and recirculated.

The potential for nitrosamine formation associated with synthetic fluids is eliminated by the substitution of a synthetic fluid which does not contain nitrites.

Environmental Levels:

Location	Number of Samples	Average Concentration	Standard Deviation
3 wheel grinder	2	0.5 mg/m^3	0.07
5 wheel grinder	2	0.4 mg/m^3	0.00

Comments:

The concentration of airborne synthetic fluid concentrate is reported as an index of the level of control, as no health standards exist for these substances as a class. The user is cautioned to give full consideration to the potential hazards of any product in use or planned for future use.

CASE HISTORY #13 - PLAIN INTERNAL GRINDER

Operation:

Grinding internal surfaces of various size gears used in truck rear axle assemblies. Grinder operates at 20,000 rpm. Machine operator is responsible for loading and unloading parts to be machined and checking/maintaining proper tolerances of product.

Machine:

Heald Internal Grinder

Metalworking Fluid:

Soluble Oil, Diluted 30 - 40:1 (Sunseco)
Flood Application

Control Method:

Partial enclosure of workpiece and grinding wheel is used. No local exhaust is present.

Environmental Levels:

Location	Number of Samples	Average Concentration	Standard Deviation
Grinder (small gear)	2	0.7 mg/m^3	0.0
Grinder (large ring gear)	2	0.6 mg/m^3	.07

Comments:

Although the high rotational speed of the grinder can generate a considerable spray, the operation is inherently clean as the workpiece itself contains much of the spray. The partial enclosure with no exhaust is all that was required in this case to achieve low mist levels.

CASE HISTORY #14 - CENTERLESS GRINDER

Operation:

Grinding of bearing surfaces on truck axle housings. The operator loads and unloads housings by means of a hoist. The grinding wheel operates at 5600 rpm.

Machine:

Cincinnati Centerless Grinder

Metalworking Fluid:

Synthetic, Diluted 45 - 50:1 (Cimcool Five Star)
Flood Application

Control Method:

Partial enclosure of the grinding and regulating wheels is provided. No local exhaust ventilation is used.

Environmental Levels:

Location	Number of Samples	Average Concentration	Standard Deviation
Centerless Grinder	5	22.5$\mu g NO_2^-/m^3$	10.4

Comments:

The metalworking fluid in use has the potential for the formation of nitrosamines. As no health standards exist for these substances, environmental levels of nitrite were determined as an index of the level of control.

For the purpose of estimating potential environmental levels of both nitrosamines and metalworking fluid "mist," bulk sample of fluid concentrate was subjected to analysis with the following results:

diethanol-N-nitrosamine	0.52 mg/ml
NO_2^-	7.9 mg/ml

Assuming identical composition of an airborne mist, total mist concentration would be approximately 3 mg/m^3, and nitrosamine would be approximately 1-2 $\mu g/m^3$.

The obvious control method for nitrosamines is material substitution, however, the user should give full consideration to the potential hazards of any substitute.

CASE HISTORY #15 - GEAR CUTTING

Operation:

Production of several sizes of straight bevel and hypoid gears from steel forgings, for use in truck rear axle assemblies. Large bevel and hypoid gears are rough cut in one operation, and manually transferred to a second machine for finishing cuts. Small bevel gears are cut in one operation. Operator's duty is primarily to load and unload work from the machine.

Machine:

Gleason No. 608 (large bevel gear - rough cut)
Gleason No. 609 (large bevel gear - finish cut)
Gleason No. 726 Straight Bevel Revacycle Machine (small bevel gear)
Gleason No. 116 Hypoid Generator (rough and finish cuts)

Metalworking Fluid:

Straight Oil (re-refined used oil, sulfurized and chlorinated)
Flood Application

Control Method:

Local exhaust is utilized on all machines except those making finish cuts. Rubber drapes are present on all machines as splash guards. The hypoid generators employ free standing cone shaped receiving hoods on machines making rough cuts. The large bevel gear cutter utilized a partial enclosure effected by sheet metal and coated cloth drapes, with an indraft of 50 - 150 fpm through open areas. The small bevel gear cutter was enclosed with minimum openings, through which an air flow of 500 fpm was maintained. All local exhaust ducts are connected to 6000 cfm fabric collectors servicing six to twelve machines, and returning the exhaust to the workplace at ceiling level.

Environmental Levels:

Location	Number of Samples	Average Concentration	Standard Deviation
Small bevel gear	4	0.5 mg/m^3	.10
Large bevel gear - rough cut	1	0.6 mg/m^3	-
Large bevel gear - finish cut*	2	0.5 mg/m^3	.14
Hypoid gear - rough cut	2	2.2 mg/m^3	.28
Hypoid gear - finish cut*	2	1.4 mg/m^3	.14

*No local exhaust ventilation

Comments:

Local exhaust coupled with some degree of enclosure is an effective means of control of airborne oil mist. While within acceptable levels, the higher mist levels at the hypoid gear generators (rough cut) are due to the use of free standing exhaust hoods with a capture distance in excess of two hood diameters. The configuration is such that the hood acts as a receiving (canopy) hood to a limited extent. Partial enclosure could provide better mist and splash control with existing exhaust volume.

CASE HISTORY #16 - HOBBING MACHINES

Operation:

Hobbing of teeth and splines on steel gear blanks for helical gears used in truck rear axle assemblies. Depth of cut is .003 inches. Machine operator is responsible for loading gear blanks and removing finished gear.

Machine:

Barber Colman Hobbing Machine
Pfauter Hobbing Machine

Metalworking Fluid:

Straight Oil (re-refined used oil, sulfurized and chlorinated)
Flood Application

Control Method:

The Barber Colman Hobbing Machines are equipped with a close fitting canopy hood with side drapes of a plastic coated cloth. Exhaust volume of 500 cfm produced control velocities in the range of 2000 fpm at the workpiece despite a one foot capture distance due to the baffling effect of the drapes and the tool. Unlike the older Barber Colman Hobbing Machines a new Pfauter Hobbing Machine is equipped with a factory installed windowed enclosure with an electrical interlock system to stop the operation once the enclosure is opened. The enclosure is exhausted by the plant at a rate of 500 cfm. Exhaust from twelve machines is connected to a 6000 cfm fabric collector and returned to the workplace at the ceiling level.

Environmental Levels:

Location	Number of Samples	Average Concentration	Standard Deviation
Hobbing machine (canopy hood)	5	0.7 mg/m^3	0.47
Hobbing Machine (enclosure)	2	0.5 mg/m^3	0.07

Comments:

While keeping airborne oil mist levels to an acceptable level, the total enclosure of the hobbing operation on the Pfauter machine is clearly superior as oil splashes on skin and clothing are effectively eliminated.

CASE HISTORY #17 - TRANSFER MACHINE

Operation:

Multi-station machine tool performs the following sequence of operations on malleable iron gear carriers for truck axle assemblies: mill, rough bore, drill, chamfer, finish bore, chase threads. Operator monitors control panel, loads and unload parts, and troubleshoots machine.

Machine:

Custom-made Transfer Machine

Metalworking Fluid:

Soluble Oil, Diluted 15:1 (Sunseco)
Flood Application

Control Method:

Each machining station was exhausted by various size slot hoods, varying from 500 - 1200 cfm in capacity, capable of producing a capture velocity of approximately 100 fpm at the point of generation. (Capture velocity estimated from Q = 3.7 LVX.) Each hood was connected to one of two 6000 cfm fabric filters and exhaust recirculated at the ceiling level.

Environmental Levels:

Location	Number of Samples	Average Concentration	Standard Deviation
Operator's station	1	0.6 mg/m^3	-
Face (mill)	1	0.7 mg/m^3	-
Chamfer	1	0.7 mg/m^3	-
Drill	1	1.8 mg/m^3	-
Mill	1	0.9 mg/m^3	-
Drill	1	0.5 mg/m^3	-

Comments:

The local exhaust system maintains satisfactory mist levels around the machine area. The operator's exposure is also limited by the location of the control module away from the points of mist generation. As splash guards and/or enclosure is not utilized, and coolant copiously applied, inspection operations could produce substantial contact of skin and clothing with metalworking fluid. Exposure could be reduced or eliminated by the partial enclosure of machining operations.

CASE HISTORY #18 - MACHINE SHOP GENERAL VENTILATION/RECIRCULATION

Operation:

A one shift operation producing small parts (chiefly carburetor parts) from brass and leaded steel. Production equipment includes forty-two screw machines, seven chuckers, and one centerless grinder, occupying a 45,000 square foot manufacturing space. All machines use a straight cutting oil, except for the centerless grinder, which was not operated during the series of tests.

Control Method:

Oil mist reduction is achieved through general ventilation, the use of a non-misting cutting oil, and building design. Plant design characteristics which contribute to low mist concentration include high ceilings (26 feet) and low density of machines (approximately 300 square feet per machine).

General ventilation is accomplished with six 13,500 CFM (nominal) air conditioning packages providing 4.15 air changes per hour for the manufacturing area. Shop air enters a metal mesh filter, is cleaned in an electrostatic precipitator of the Penney type, mixed with outside air, filtered through secondary filters, cooled, and returned. See Figure I for equipment arrangement. During the heating season (six months per year) outside air varies from 10 - 100% of the return air. During the cooling season, 100% of the return air is recirculated from the shop. Disposable fiberglass filters are replaced twice a year.

This survey was conducted during the cooling season with two week old filters. The electrostatic precipitator is a Trion model 30, rated at an efficiency of 90% by the National Bureau of Standards dust-spot test method at a flow of 14,000 CFM. The secondary filtration consists of Farr JP15 pleated fiberglass filters, with a 50 - 55% average dust spot efficiency per ASHRAE Standard 52 - 68. Total filtration area is 500 square feet corresponding to a filtration velocity of 27 FPM.

Oil mist is controlled at the source by the use of an anti-mist oil, Mobilmet 406. It contains additives which minimize the formation of a stable mist or fog in air. Mobil Oil Corporation claims a reduction of mist by 90 percent compared to conventional oils.

Control Achieved:

To evaluate the effectiveness of the control measures in reducing oil mist levels, twenty-three area and machine samples were taken over a two-day period. Thirteen samples were taken directly above machines at an elevation of approximately six feet to approximate worst case exposures.

Average concentration recorded for this sample group was 1.9 mg/m^3, indicated the effectiveness on the anti-mist oil in controlling the misting at its source. Five samples were taken from tripods placed to simulate average worker positions. Average concentration of these samples was 1.2 mg/m^3. Five general area samples had an average oil mist concentration of 0.8 mg/m^3.

Inlet and outlet air flows of the general ventilation units were measured with a hot wire anemometer to determine isokinetic sampling rates and overall system functioning. Inlet flows varied from 450 - 600 fpm with a weighted average of 550 fpm. Outlet flows varied across the louvers from 1500 - 2200 fpm due to poor air distribution, with an average velocity of 1620 fpm by calculation from the inlet air volume and the outlet open area. Roof top air intakes and exhaust were checked to be zero flow.

Inlet concentrations were measured by four one hour sets of four millipore cassettes at 2.2 lpm each. Flows were set using critical orifices. Average inlet concentration was 1.9 mg/m^3. Outlet concentrations were measured using two 1/8" sample nozzles and millipore cassettes at 4.0 lpm each. Flows were set using critical orifices. Sample times varied from one to three hours. Average oil mist concentration in the return air was < 0.2 mg/m^3, or < 4% of the current TLV of 5 mg/m^3. Oil mist removal efficiency was determined to be >89% on a mass basis.

CONCLUSIONS AND RECOMMENDATIONS

The current environmental limit of 5 mg/m^3 mineral oil mist can easily be met for the operations studied by a combination of proper fluid selection, enclosure, and ventilation. Because it is an inherently foolproof and inexpensive means of control, selection of a metalworking fluid with low misting characteristics is of prime importance. Where straight oils must be used, operations which produce mechanical generated oil mists (i.e., automatic screw machines), can be effectively controlled with a cutting oil which incorporates anti-misting additives. Severe machining operations require a combination of enclosure and local exhaust. The more complete the enclosure, the greater the control will be, and the greater the exhaust requirements will be reduced. In all cases, a constant supply of clean tempered air must be maintained to dilute any stray mist and provide heat relief.

No data exists on safe airborne concentrations of synthetic metalworking fluids. Epidemiological and toxicological studies need to be performed in order to identify safe levels to this class of substances to which over one million American workers are exposed.

As perylene and chrysene were tentatively identified in a bulk sample of a reprocessed straight oil collected in this study, further work is necessary to identify and quantify the presence of these and other polynuclear aromatic hydrocarbons in other oils in new, reprocessed, and used conditions.

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TABLE 1. Machine Tools

I. Turning Machines

1) Lathes
2) Automatic bar and chucking machines

II. Drilling Machines

1) Drill Presses
2) Gundrills

III. Shapers/Planers

1) Horizontal and vertical shapers
2) Planers

IV. Milling Machines

1) Knee and column milling machine
2) Bed-type milling machine
3) Planer-type
4) Special purpose

V. Broaching Machines

1) Broach press
2) Pull broach machine
3) Continuous broaching
4) Surface broaching

VI. Boring Machines

1) Horizontal boring mill
2) Vertical boring and turning machines
3) Jig boring

VII. Sawing and Filing Machines

1) Power hacksaw
2) Circular saw
3) [illegible]dsaw

VIII. Grinding

1) External cylindrical grinders
2) Internal cylindrical grinders
3) Surface grinder (horizontal/vertical)

IX. Finishing Machines

1) Horizontal honing machine
2) Vertical spindle honing machine

TABLE 2. Specialty Machines

I. Screw Manufacture

1) Universal threading machine
2) Universal thread miller
3) Thread rolling machines

II. Gear Cutting Machines

1) Gear shapers (form cutting)
2) Hobbing machines (gear generation)
3) Gearshavers (finishing)

III. Automated Machines

1) Fixed programming
2) Transfer machines

TABLE 3. Cutting Fluid Composition

I. Mineral Oil

1) Base 60 - 100%, paraffinic or naphthenic
2) Polar additives
   a) Animal and vegetable oils, fats, and waxes to wet and penetrate the chip/tool interface
   b) Synthetic boundary lubricants: esters, fatty oils and acids, poly or complex alcohols
3) Extreme pressure (EP) lubricants
   a) Sulfur - free, or combined as sulfurized mineral oil or sulfurized fat
   b) Chlorine - as long chain chlorinated wax or chlorinated ester
   c) Combination - sulfo-chlorinated mineral oil or sulfo-chlorinated fatty oil
   d) Phosphorous - as organic phosphate or metallic phosphate
4) Germicides

II. Emulsified Oil (Soluble Oil) - opaque, milky appearance

1) Base - mineral oil, comprising 50-90% of the concentrate; in use the concentrate is diluted with water in ratios of 1:5 to 1:50.
2) Emulsifiers: petroleum sulfonates, amine soaps, rosin soaps, naphthenic acids
3) Polar additives - sperm oil, lard oil, and esters
4) Extreme pressure (EP) lubricants
5) Corrosion inhibitors: polar organics, example: hydroxyl amines
6) Germicides
7) Dyes

III. Synthetics (transparent)

1) Base - water, comprising 50-80% of the concentrate; in use the concentrate is diluted with water in ratios of 1:10 to 1:200. True synthetics contain no oil. Semi-synthetics are available which contain mineral oil present in amounts of 5-25% of the concentrate.
2) Corrosion inhibitors
   a) Inorganics - borates, nitrites, nitrates, phosphates
   b) Organics - amines, nitrites (amines and nitrites are typical and cheap)
3) Surfactants
4) Lubricants - esters
5) Dyes
6) Germicides

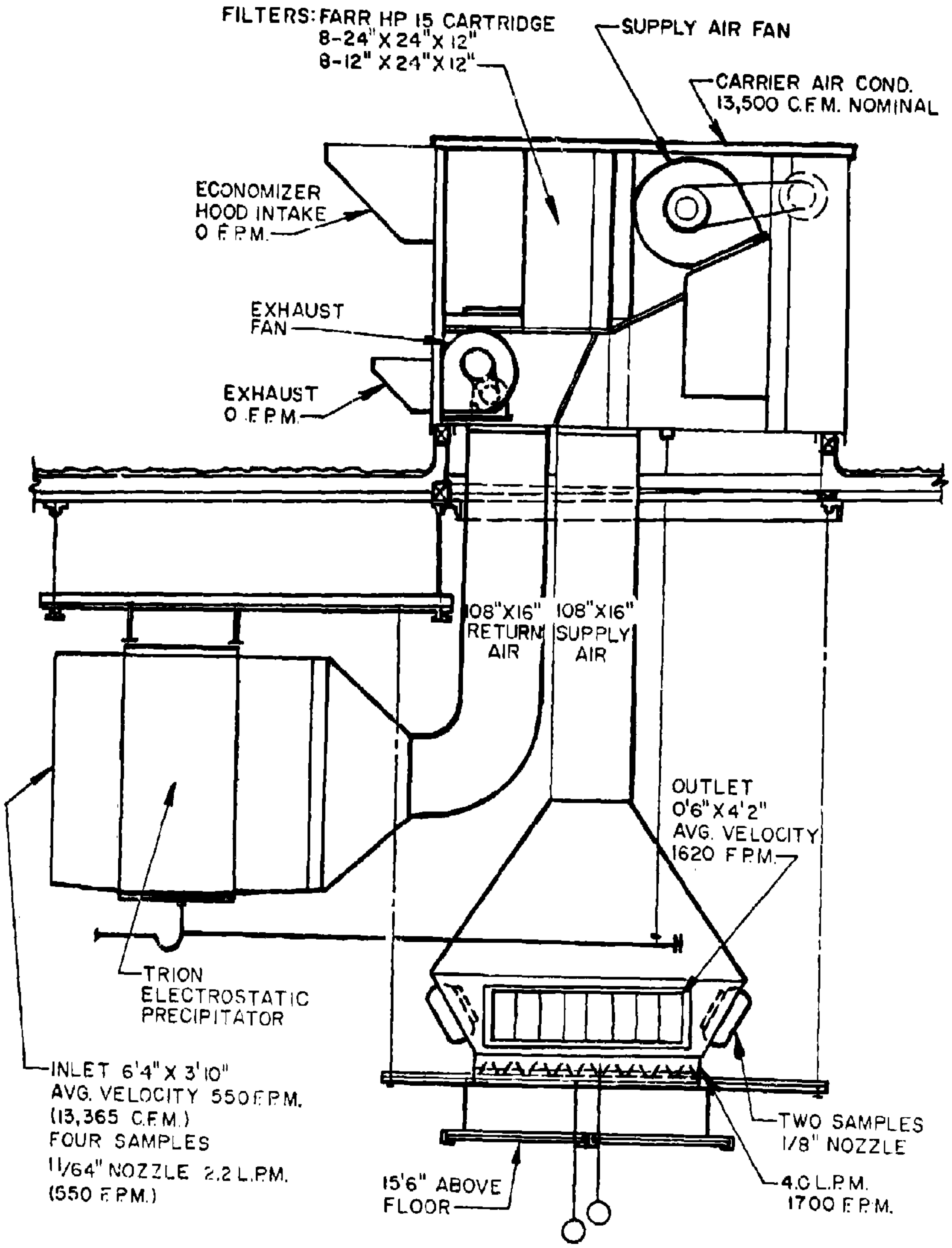

FIGURE ᵀ

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