

# SAFETY BRIEF

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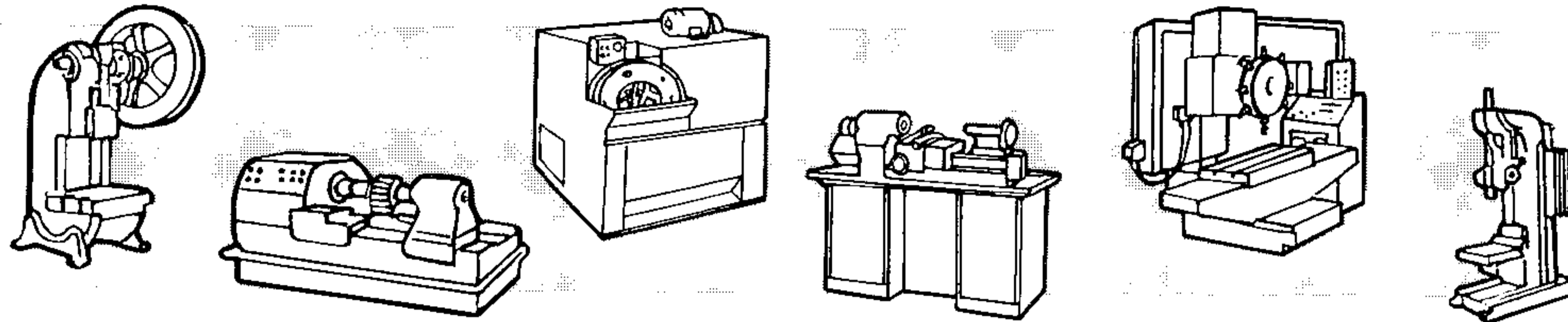


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## Airborne Contaminants in the Machine Tool Industry

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### I. INTRODUCTION

The machine tool industry consists of a broad spectrum of industrial facilities associated with the cutting, shaping, forming and related processing of primarily metallic materials with stationary powered equipment. This industry makes a broad assortment of products, including such diverse items as gears, cans, automobile fenders, fasteners and door hinges via such operations as cutting, slitting, milling, grinding, drilling, press operations and cold forming. Many of these machine tools are described in the ANSI B11 series of standards (See Table 1).

Throughout the years, significant attention has been focused on the traumatic injuries to workers in this industry. In comparison, it has been only recently that the specific health effects have been investigated and evaluated of exposures to the oils, metals and other airborne contaminants associated with this industry.

This paper addresses some basic aspects of occupational exposure to toxic and hazardous substances in the machine tool industry. It covers definitions of contaminants, measurement terminologies and strategies, routes of entry to the human body, regulations for controlling exposure, some interpretation of these regulations, and engineering and administrative controls.

**Table 1**

### Typical Machine Tools

Coil slitters	Iron workers
Alligator shears	Gear cutting machines
Metal saws	Drilling, milling and boring machines operations
Mechanical power presses	Roll forming and bending machines
Hydraulic power presses	Automatic screw/bar and chucking machines
Metal powder compacting presses	Grinding machines
Horizontal hydraulic extrusion presses	Lathes
Power press brakes	Cold headers and cold forming machines
Coil, sheet and plate machines	

### Accompanying Equipment/Processes

Forklift trucks for materials handling	Heat treating and furnace operations
Welding	Vapor degreasing
Torching/burning equipment	Coating, plating and painting operations

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## II. AIRBORNE CONTAMINANTS

On first view, airborne contaminants in machine tool operations would appear rather benign and limited when compared to those in the chemical, petroleum and mining industries. In reality, the combined operations of materials handling, materials processing, assembling and cleaning produce a potential soup of airborne contaminants. (See Table 2 for some common air contaminants from machine tool operations). These gases, vapors, fumes and dusts are generated by both primary manufacturing operations and accompanying processes.

In the manufacturing of automobile wheels, for example, the primary operations might include metal stamping, grinding, welding and drilling. Accompanying operations involve the use of forklift trucks for materials handling, vapor degreasing prior to welding or painting, and cutting tool sharpening as part of production equipment maintenance.

This collection of operations may release oil mists, potentially hazardous airborne particulates, products of combustion, solvent vapors and aerosols. Their individual sources and contributions vary considerably, based on manufacturing operation, building design, process rate, forced and natural ventilation and the season of the year.

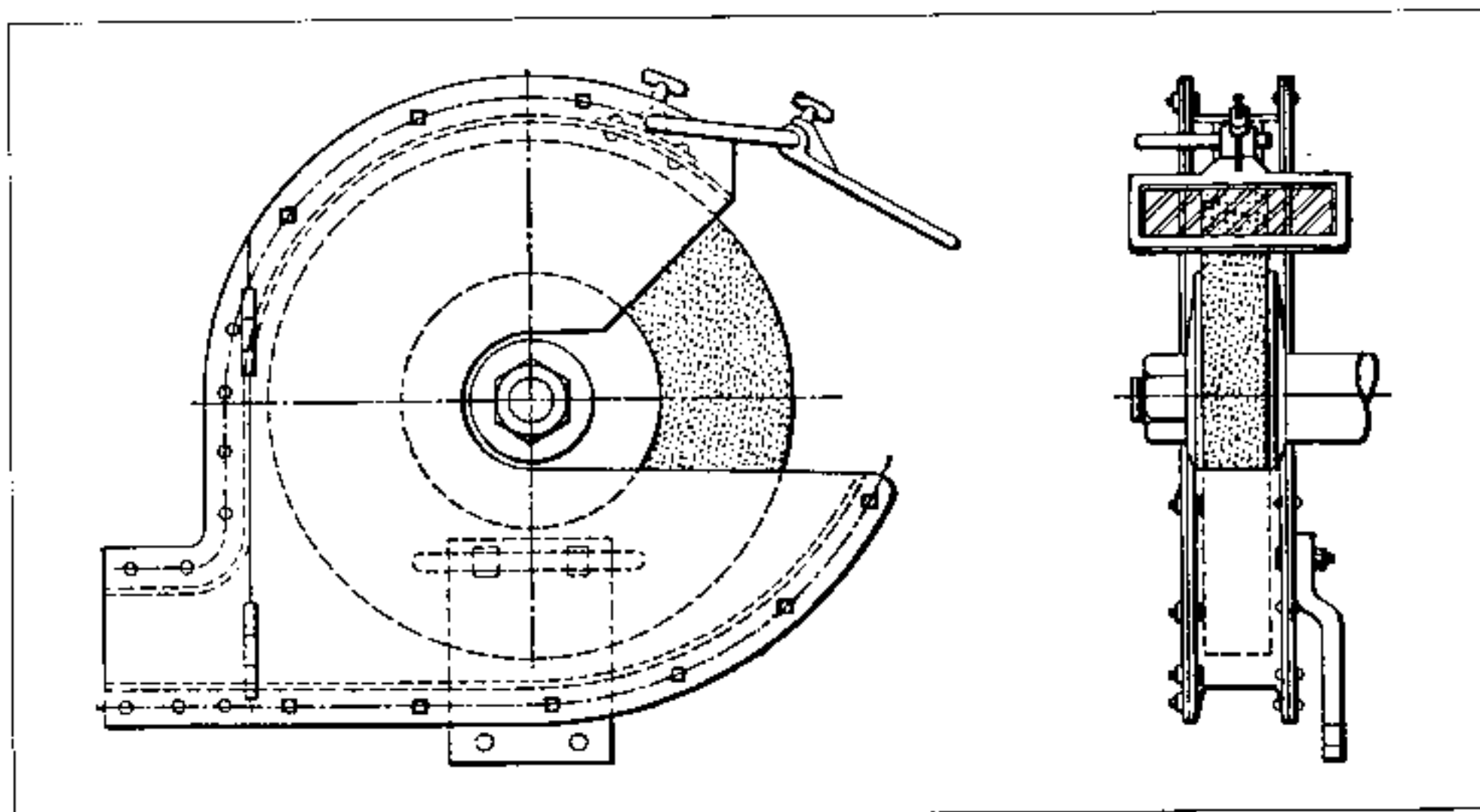
**Table 2**  
**Air Contaminants**  
**Commonly Associated with**  
**Machine Tool Operations**

### From Machine Tools

- Oil Mists
- Coolant Mists
- Metal Particles (e.g., Tungsten-Carbide, Cobalt, Beryllium; Lead, Chromium, Cadmium, Tin, Vanadium, Nickel)
- Fibers (e.g., fiberglass, asbestos)
- Bioaerosols

### From Accompanying Operations

- Carbon monoxide
- Carbon dioxide
- Hydrocarbons
- Nitrogen oxides
- VOCs (i.e., volatile organic chemicals such as trichloroethylene, toluene, etc.)
- Welding fumes
- Nuisance dust (respirable)



**Figure 1 Riveted steel hood with exhaust connection and shield.**

Typical sources of mists are: exhausted air-containing lubricant on pneumatic systems of mechanical power presses; coolant and lubricant spray patterns on grinding and drilling equipment; high-speed rotating machines such as lathes; and volatilization and recondensed micro-droplets from coolants coming into contact with heat-producing operations.

These mists consist of very fine droplets of oil or coolant which often remain suspended in the air due to a combination of Brownian motion, air currents and electrostatic forces. Their appearance in the manufacturing environment is characterized by a bluish haze in the air.

The chemical and physical character of oil and coolant mists may change based on their volatility, solubility, collisions with other suspended particles, and biological activity within the individual oil droplets. These changes may make the mist more or less hazardous to exposed workers. For example, epidemic level outbreaks of influenza-like respiratory illnesses have been reported in this industry due to biologically contaminated oil and coolant mists.

Sources of airborne particulate matter include the cutting, grinding and other operations from the machining elements of the machine tool itself, as well as from the workpiece. (Fig. 1) Hardened and strengthened industrial cutting and grinding tools often contain tungsten carbide and cobalt. Both materials are associated with various lung and respiratory system problems. The processed workpiece may contain lead, chromium or beryllium as a metallurgical component, plating agent or as a base material. These metals can become more harmful when transformed into respirable dust by certain machining operations.

Related equipment such as process furnaces, forklift trucks, and welders or torches may release combustion products and decomposition products of high-temperature pyrolysis. Parts-cleaning operations can release solvent vapor and other chemically active ingredients into the work atmosphere.

To identify, monitor and control these varied materials successfully, it is important to understand some of the basic units of measurement and exposure level terminologies. These are discussed in the following section.

## III. MEASUREMENT TERMINOLOGY

Airborne contaminants are generally measured in terms of:

1. parts per million (ppm)
2. parts per billion (ppb)
3. milligrams per cubic meter (mg/m<sup>3</sup>)
4. fiber-like structures per cubic centimeters (fibers/cc)

Parts per million and parts per billion are terms often associated with gaseous air contaminants and are based on a ratio of volumes of contaminant gas to the total combined volume of air and contaminant. One ppm of carbon monoxide, for example, translates into one volume unit of carbon monoxide gas mixed evenly into enough air to make a mixture of one million volume units of ambient air. Therefore, one cubic meter of carbon monoxide released into a room with a volume of one million cubic meters would result in an air concentration of one ppm carbon monoxide. Similarly, 0.5 m<sup>3</sup> of carbon monoxide released into a room with a volume of 500,000 m<sup>3</sup> would also have an air concentration of 1 ppm carbon monoxide. The term, parts per billion, follows similar logic but is a smaller

unit of concentration by a factor of one thousand. Over the normal range of temperatures and pressures encountered in most workplaces, no adjustments are needed for concentrations measured in ppm with variations in ambient temperatures or pressures.

A ppm or ppb can be considered similar to a percentage term. Ten thousand ppm is one percent based on volume.

Milligrams/cubic meter can be used to represent both a gas concentration (like ppm) or an airborne particle or aerosol concentration. When used in reference to a gas concentration, measurements of the weight of the contaminant gas in a known volume of air are necessary for this reporting unit. Conversion of ppm into mg/m<sup>3</sup> for gaseous contaminants is possible by the simple adjustment of a known volume of contaminant gas into its mass (weight) equivalent.

Milligrams/cubic meter has no ppm equivalent when it is used to indicate aerosols or a particulate air concentration. This unit of measure should also be accompanied by a temperature and pressure reading or assumed to be at standard pressure and temperature, as the numeric value changes as a function of these two variables.

The term, fibers/cubic centimeter, is used when the air contaminant is in a fiber form such as asbestos or fiberglass. This unit is an actual count of fibers or fiber-like structures removed from a known volume of ambient air which has passed through a filter media and observed by optical or electron microscope. The ratio of the observed number of fibers divided by the volume of filtered gas provides the measurement of fibers/cubic centimeter.

Due to the increased concern about bio-aerosols in the indoor environment, terms such as spores/cubic meter or colonies/square centimeter have appeared in the literature. Spores/cubic meter is a measurement similar to fibers/cubic centimeter and colonies/square meter is based on culture samples of a known cross-sectional area.

Liquid contaminants are often reported in ppm or ppb by mass units (as opposed to gas ppm measurements in volume units). For example, one gram of alcohol mixed with water to form a million gram solution would have a final concentration level of one ppm. Similarly, one milligram of alcohol mixed into one liter of water would yield a concentration of 1 mg/liter.

#### IV. EXPOSURE LEVEL TERMINOLOGY

When discussing exposure levels and conditions, several acronyms and abbreviations are commonly encountered. Many are based on the concept of a threshold level below which exposures are generally considered safe for the healthy adult worker. The various numerical boundaries which distinguish a safe exposure from a potentially hazardous exposure include safety factors and often represent some time-averaging element. Table 3 defines six of the most common exposure level and time-averaging terms in use in the United States.

Permissible Exposure Limits (OSHA terminology), Threshold Limit Values (ACGIH terminology) and Recommended Exposure Limits (NIOSH terminology) are all specific levels of exposure ordinarily accompanied by a time period as defined by Time-Weighted-Averages (TWAs), Short-Term Exposure Limits (STELs) or Ceiling Limits. TWAs are usually for eight hours of exposure for forty hours a week; Short-Term Exposure Limits are usually elevated excursion levels of fifteen-minute durations for as many as four times a day; and Ceiling Limits are, in effect, maximum exposures of nearly infinitesimal duration, not to be repeated during any part of a work shift. Most chemicals listed by OSHA are reported in terms of Time-Weighted-Averages and a much smaller number also have Short-Term Exposure Limits and Ceiling Limit values.

Two basic and important concepts embodied within these definitions are dosage and dosage rate. The use of the term "dosage" is most familiar within the context of dispensing pharmaceuticals and is usually related to the body weight of the individual receiving the medicine. Children's dosages are usually smaller in quantity of active ingredient when compared to adult dosages. An example is the dosage of children's versus adults' aspirin. The dosage rate for pharmaceuticals has to do with the distribution in time of a particular amount of medication. Taking six aspirin once a day or two aspirin every eight hours would be the same daily dosage, but significantly different dosage rates.

Chemical exposures defined in terms of short exposure time (STELs and Ceiling Limits) often indicate that the dosage rate is an important factor. Chemical exposures defined in terms of longer time periods (i.e., PEL-8-hour TWAs) indicate that, based on existing knowledge, the overall dosage is more critical than is a particular short-term dosage rate. When a PEL for an 8-hour TWA is 100 ppm without a STEL or ceiling limit, this means in theory that it is equally acceptable to be exposed to a concentration of 100 ppm for eight hours, or the combination of 200 ppm for four hours and 0 ppm for four hours. (Note: NIOSH and ACGIH do give guidance on these peak exposures in terms of multipliers of a PEL TWA when a STEL or a Ceiling Limit are not provided).

**Table 3**  
**Generalized Definitions of Exposures**

<b>PEL</b>	Permissible Exposure Limits are the maximum average concentration levels of chemicals and dusts to which employees can be exposed in the workplace, (usually for an eight-hour day, forty-hour week, based on the requirements of OSHA.)
<b>REL</b>	Recommended Exposure Limits, as proposed by NIOSH, are very similar to the PELs as defined by OSHA. RELs are often more conservative values than OSHA PELs.
<b>TLV</b>	Threshold Limit Values are the recommended maximum average concentration levels of chemicals and dusts to which employees can be exposed in the workplace for a specified time period, based on the requirements used by ACGIH.
<b>STEL</b>	Short-term exposure limits, when used with a PEL, REL or TLV, are the concentration levels to which workers can be exposed, usually for a fifteen-minute time period without suffering from (1) irritation; (2) chronic or irreversible tissue damage; or (3) narcosis.
<b>TWA</b>	A Time-Weighted Average when used with a PEL, REL, or TLV, is the employee's average airborne exposure concentrations during a normal eight-hour work shift of a forty-hour work week, to which nearly all workers may be repeatedly exposed, day after day, without adverse effects.
<b>Ceiling Limits</b>	The maximum concentration levels never to be exceeded and are established by OSHA, NIOSH, AND ACGIH.

This concludes an introductory discussion of exposure terminology used by the profession and regulatory bodies, as well as the hazards of airborne contaminants. The following section discusses the role of selected regulatory bodies and professional associations in controlling exposures to contaminants.

## V. GOVERNMENT REGULATIONS

Two federal agencies establish workplace exposure limits and environmental controls for chemicals normally encountered in the machine tool industry: the Occupational Safety and Health Administration (OSHA) and the Environmental Protection Agency (EPA). These administrative agencies establish exposure levels and controls considered to be safe; monitor and/or regulate workplaces for compliance; and as necessary, enforce these regulations. OSHA primarily uses a series of Permissible Exposure Limits to define exposure limits, whereas the EPA regulates the use of environmentally sensitive substances in this industry.

Other federal agencies which establish chemical exposure and use criteria are the Food and Drug Administration and the Consumer Product Safety Commission. These agencies, however, are not normally involved in the activities of the machine tool industry.

### V.(A). Occupational Safety and Health Administration

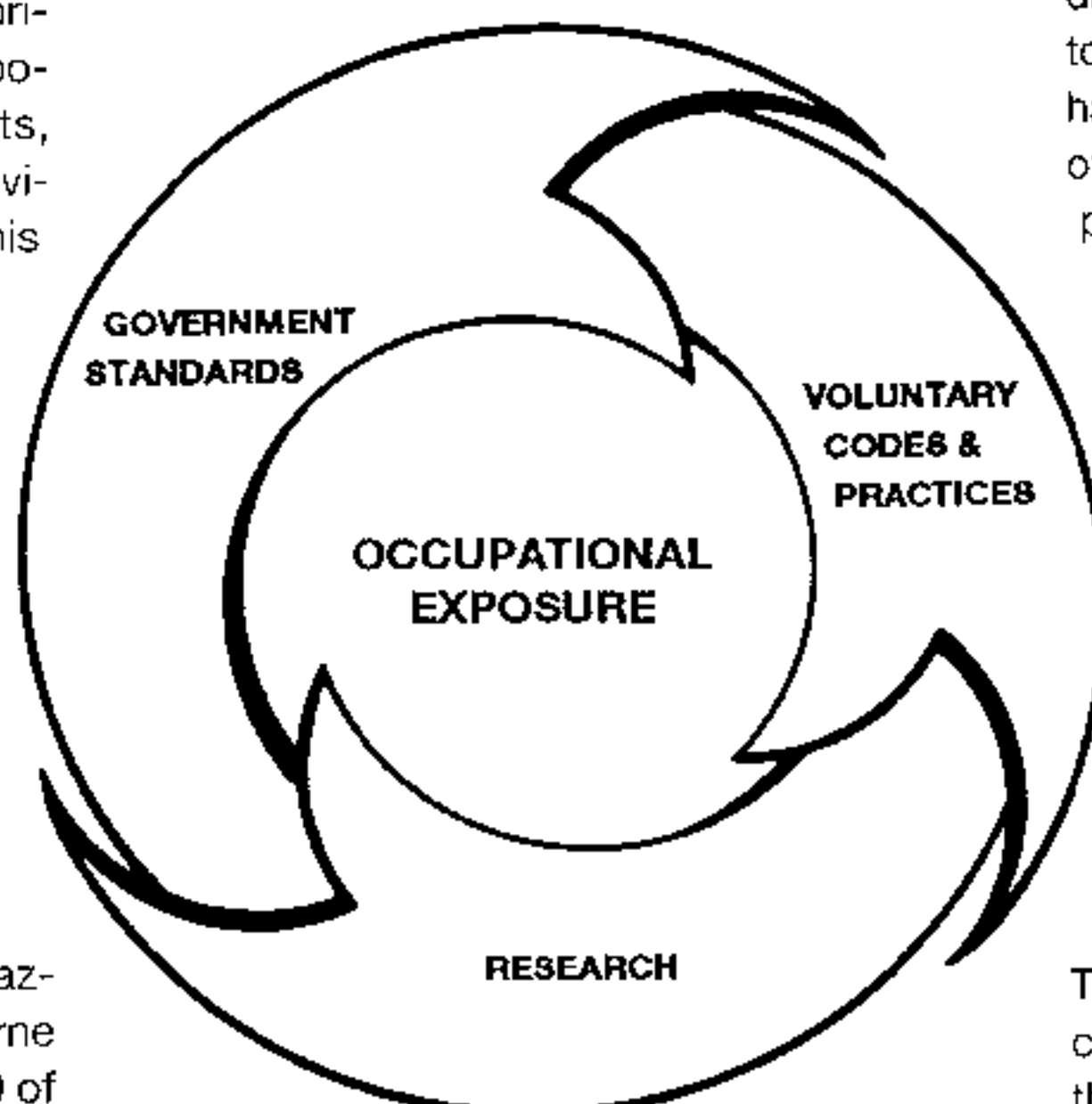
OSHA regulates exposure to toxic and hazardous substances which become airborne by publishing exposure limits in Title 29 of the Code of Federal Regulations (29 CFR 1910.1000) (2). Other parts of the OSHA Code address respirators, workplace ventilation, communication of environmental hazards, training, the handling of specific chemicals thought to be carcinogens, and the application of engineering controls to reduce occupational exposures. OSHA does not presently have regulations for occupational exposure to biological contaminants.

Subpart Z Tables Z.1-A, Z.2 and Z.3 list allowable human exposure levels in terms of Permissible Exposure Limits for (1) eight-hour TWA; (2) STEL and Ceiling Limits as applicable. Other voluntary guidelines often cite lower exposure levels. Examples of OSHA PEL 8-hour TWA for contaminants associated with the machine tool industry are:

Oil mists, mineral	5 mg/m <sup>3</sup>
Cobalt metal, dust, fume	0.05 mg/m <sup>3</sup>
Nickel metal and insoluble	1 mg/m <sup>3</sup>
Tin, inorganic compounds	2 mg/m <sup>3</sup>
Toluene	100 mg/m <sup>3</sup>
Nuisance dust (respirable)	5 mg/m <sup>3</sup>

The regulation states in paragraph (e): "To achieve compliance with ...this section, administrative or engineering controls must first be determined and implemented whenever feasible." Engineering controls would include control by means such as ventilation or substitution of a less hazardous material. Administrative control would be measures such as scheduling a person to be in a particular area only four hours during a work shift.

The newest OSHA regulation which includes workplace protection in the machine tool industry is "Hazard Communication," 29



CFR 1910.1200 (3). Often referred to as the Right-to-Know regulation, it ensures that all chemicals produced in, and imported into the United States, are evaluated to identify their possible health and physical hazards. It also requires that this information be provided to employers and employees through labeling, employee training, distribution of Material Safety Data Sheets (MSDS), and other warning methods. Materials covered by these regulations and commonly found in the machine tool industry include metalworking fluids, cleaners, solvents, all oils and any other specialty chemical or substance used or processed.

### V. (B). Environmental Protection Agency

The EPA was originally authorized to assure that the quality of the outdoor environment was acceptable. The emphasis was on "out-of-doors" conditions. The legislative acts which are the foundation of the EPA's activities are the Clean Water Act, the Clean Air Act, and various hazardous waste and conservation acts (i.e., Federal Environmental Pesticide Control Act, Toxic Substance Control Act, Resource Conservation and Recovery Act, and the Comprehensive Environmental Response, Compensation and Liability Act).

In the past decade, due to concerns for indoor air pollution and worker exposures to environmental contaminants, the EPA promulgated regulations which affect occupational exposure to certain materials. For example, 40 CFR 747 Subpart B addresses the addition of nitrosating agents to metalworking fluids (4). These materials had been added to increase the useful life of some metalworking fluids but are suspected carcinogens. This rule cites the occupational exposure problem through the Toxic Substance Control Act. Although this regulation does not establish allowable exposure limits to nitrosating agents in metalworking fluids for workers, it does affect the chemical composition and labeling of such fluids.

Risk assessments have been used by both OSHA and the EPA in the last ten years to promulgate new environmental and occupational exposure regulations. This concept establishes a risk of one excess death in 1,000 working lifetimes as a threshold. Its basis is in the U.S. Supreme Court's *IUD v API* decision on the regulation of benzene (53).

### V. (C). National Institute for Occupation Safety and Health

NIOSH, an agency administratively separate from OSHA, was originally formed under the U.S. Department of Health, Education and Welfare. It is now under the U.S. Department of Health and Human Services and acts as a research arm for OSHA's efforts to assure workplace safety. Established in 1974, NIOSH has made recommendations on approximately 400 workplace chemicals and, until adopted by OSHA, these levels are referred to as Recommended Exposure Limits (RELs). If adopted by OSHA, these exposure levels become known as Permissible Exposure Limits and are enforceable. While in the

REL status, they are non-enforceable. Numerous RELs have been rejected by OSHA due to a lack of sufficient supportive information.

NIOSH often publishes its research findings in: Criteria Documents, Current Intelligence Bulletins, Special Hazard Reviews, Occupational Hazard Assessments, the Pocket Guide to Chemical Hazards, and RTECS Registry of Toxic Effects of Chemical Substances. These publications provide detailed information on current literature and research into occupational exposure to workplace and chemical hazards. For example, the Pocket Guide lists symptoms of exposure, target organs, appropriate personal protective equipment, exposure measurement methods, and chemical and physical properties of over four hundred chemicals. Recommended Exposure Levels (RELs) are often lower and may represent more conservative exposure levels. For comparison purposes, in 1989 NIOSH's REL for toluene was 100 ppm (eight-hour TWA), whereas OSHA's PEL-TWA for toluene was 200 ppm.

## **VI. INDUSTRIAL CONSENSUS STANDARDS AND GUIDELINES**

Any exhaustive coverage of voluntary or consensus standards is beyond the scope of this paper; however, a brief summary is needed for several organizations which develop and publish voluntary standards and studies on occupational exposure. This summary is only intended to provide guidance and structure for those unfamiliar with the voluntary codes and standards which concern exposure to toxic and hazardous substances in the machine tool industry.

### **VI. (A). American Conference of Governmental Industrial Hygienists**

Founded in 1938 as a professional society of persons employed by official governmental units responsible for full-time programs of industrial hygiene, the ACGIH has promoted a forum for research on industrial health problems. It regularly publishes *Threshold Limit Values and Biological Exposure Indices*, commonly known as the TLV List (19-20).

Many of the new PEL values used by OSHA in its recently revised regulations (2) were based on the ACGIH 1987-1988 TLV List. Some were not adopted by OSHA. For comparison of the differences that may exist between the ACGIH and OSHA stan-

dards, the 1986-87 ACGIH TWA for cadmium fume exposure was 0.05 mg/m<sup>3</sup>, whereas the corresponding OSHA PEL-TWA was 0.1mg/m<sup>3</sup>.

It should be noted that ACGIH also publishes biological exposure indices. These indices are used to measure and monitor workers' exposure, using body fluids as well as hair and nail clippings.

### **VI. (B). American National Standards Institute**

ANSI and its predecessor organizations have been in existence for over eighty years. ANSI has published selected standards concerning toxic and hazardous materials in the workplace. Many of these standards deal with test methods, characteristics and labeling. A few older standards directly address recommended exposure levels.

The "American National Standard for Hazardous Industrial Chemicals - Precautionary Labeling," *ANSI Z129.1-1988* (26), presents guidance in the design of labels for chemicals (which could include solvents, coolants and other metalworking materials). This standard incorporates the legal terminology of "reasonably foreseeable use and misuse," but never defines these concepts in specific technical terms.

ANSI also has issued standards on ventilation configuration for grinding (*ANSI B11.9-1975*) (25), working in confined spaces (*ANSI Z117.1-1989*) (23) and respiratory protection equipment (*ANSI Z88.2-1980*) (22). All of these standards could affect worker exposure to airborne contaminants in machine tool operations.

### **VI. (C). American Society for Testing and Materials**

The world's largest source of voluntary standards is the American Society for Testing and Materials (ASTM), founded in 1898. ASTM's concentration is on the testing of characteristics and performance of materials, products, systems and services. Numerous ASTM standards have been adopted by ANSI. A few such standards pertinent to the machine tool industry are: "Standard Test Method for the Misting Properties of Lubricating Oils," *ASTM D3705-1986* (34); "Standard Test Method for Active Sulfur in Cutting," *ASTM D1662-1986* (33); and "Standard Test Method for Evaluating the Bioresistance of Water-Soluble Metal-Working Fluids," *ASTM D3946-80 (R1986)* (35).

### **VI. (D). National Fire Protection Association**

The NFPA, a voluntary standards-setting organization founded in 1896, is primarily concerned with fire prevention and fire fighting and has published the National Fire Codes since 1938. *NFPA 325M-1984*, "Fire Hazard Properties of Flammable Liquids, Gases, Volatile Solids," (27) recommends a diamond-shaped hazard identification system which numerically rates the health, flammability and hazardous nature of materials. Although control of airborne contaminants does not appear to be the goal of the NFPA standards, compliance with these codes may indirectly affect occupational exposures to many substances found in the machine tool industry.

### **VI. (E). General Literature**

Peer-reviewed journals and monographs often publish the most recent findings in health hazard research. Their importance must be weighed in the light of the type of research represented. The publications may be anecdotal (simply an observation), a case-control epidemiological study (a review of events which looks for relationships between exposures and outcomes), or clinical trials and cohort studies that identify significant patterns of outcomes as being statistically significant. These last two types of studies usually require large numbers of participants. In an attempt to bring research results to public attention quickly, not all necessary controls have always been implemented nor all causal associations evaluated. The results, therefore, must be carefully examined.

Such literature does play an important role in determining the direction of additional research. An example in this area are recent works on bacterial-related health problems associated with contaminated metalworking fluids (46). Although these problems have been acknowledged, regulatory agencies have not as yet provided regulations. The implications of this research are the need for continued evaluation of metalworking fluid formulations, the accumulation of more information on the aging characteristics of these fluids, and the measurement of occupational exposures to airborne biological contaminants.

Although many of the governmental regulations and industrial standards, codes and guidelines discussed up to this point are directly or indirectly concerned with chemicals and hazardous materials that may be-

come airborne, they also often include information about the multiple pathways for absorption into the body. The following section discusses these various routes of entry for toxic substances into the human body.

## VII. ROUTES OF ENTRY

There are three primary routes by which chemical substances can gain entry into a worker's body. In order of importance, they are inhalation, skin contact and ingestion. It is obvious that some substances may have multiple routes of entry. Stokinger notes in the NIOSH publication, *Occupational Diseases* (13), the following concepts concerning entry routes of contaminants.



### VII. (A). Inhalation

The lungs of an adult have an enormous gas-tissue interface (ninety square meters total surface, seventy square meters alveolar surface). These large surfaces, together with the capillary blood network surface of 140 square meters, enables an extremely quick rate of absorption of many substances from the air in the alveolar portion of the lungs into the blood stream.

Highly water-soluble substances and soluble chromates may pass through the lungs and quickly dissipate after cessation of their inhalation. In contrast, there are many industrial chemicals that remain in the lungs for extended periods of time.

Many of the highly reactive industrial gases and vapors of low solubility can produce an immediate irritation and inflammation of the respiratory tract and may produce pulmonary edema. Prolonged or continued exposure to these gases and vapors may lead to chronic inflammatory or neoplastic changes or to fibrosis of the lung (13).

#### VII. (A1). Gases, Fumes and Vapors

Basic oxide fume particulates and acid gases are examples of substances which are direct and fast-acting in the upper airway passages. Irritation of these passages occurs from concentrations of acid gases and particulates only slightly above the industrial air standards. Many of the submicron-size particles (metal oxide fumes) produce both immediate and long-term ef-

fects. For example, inhaled cadmium oxide fumes may cause acute or immediate pulmonary edema that can be fatal, while chronic inhalation over many years can result in eventual renal injury and pulmonary emphysema.

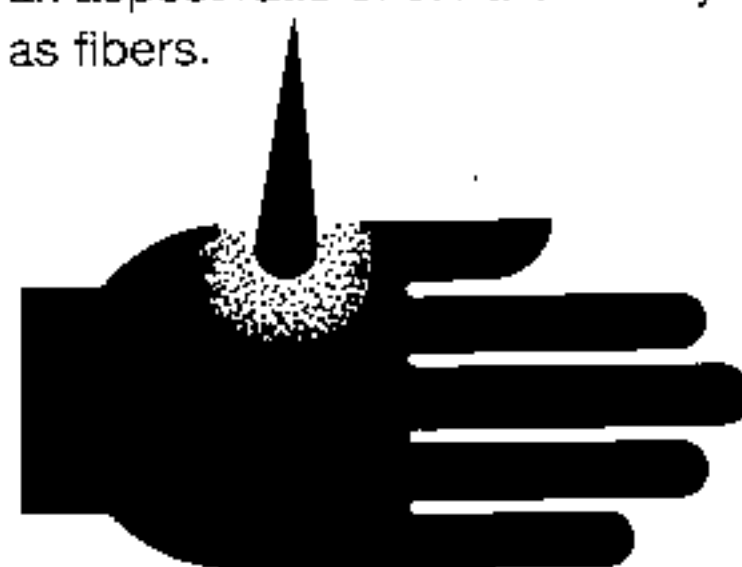
Some gases and vapors pass through the lungs into the blood to be distributed to liver, kidney and bone for which they have affinity. Industrial solvents are typical of those materials that exert their principal effects after absorption into the lung. The vapors of certain halogenated hydrocarbon solvents produce quick narcosis after brief exposures above the threshold limit value. Long, repeated exposures, well above the TLV, may injure the liver or the kidneys. Single, massive exposures to some of these substances can produce pulmonary edema.

It should be recognized and accepted as a general rule that exposure to chemicals can affect a variety of bodily functions, depending upon the nature and degree of exposure (13).

#### VII. (A2). Particulates

The parameter controlling the sites of deposition, retention, distribution, and resulting health effects of particulates obviously differ from those for gases and vapors. The aerodynamic diameter of the particulate determines if a particulate will deeply invade the respiratory system and may give some indication of the degree of injury on the various compartments of the respiratory system.

Respirable dust is often considered to be in the 5 to 0.5 micron diameter range. For fibers, the size and shape is also important in their ability to initiate certain toxicologic responses: for example, in the induction of mesotheliomas. The shape of a fiber appears to increase its ability to move and its potential for inflicting harm. Materials with an aspect ratio of 3:1 are usually classified as fibers.



### VII. (B). Skin Contact

When a substance comes into contact with the skin, at least four outcomes are possible:

1. the skin and its associated film or lipid can act as an effective barrier against penetration or adsorption;

2. delayed or immediate primary irritation (dermatitis) may occur when the substance reacts with the skin;

3. the substance can pass through the skin and interact with tissue protein, resulting in skin sensitization; and

4. the substance can pass through penetrate the skin and enter into the bloodstream and act as a potential systemic poison.

Although the skin functions as a protective barrier against entry of foreign substances, serious and even fatal poisonings have occurred from brief dermal exposures to highly toxic substances such as parathion and related organic phosphates, the organometallics, the alkyl leads and tins, aniline, phenol, and hydrocyanic acid.

In addition, abrasions, lacerations and cuts may greatly enhance the penetration of these compounds through the skin. Of the approximately 600 items presently on the PEL and TLV Lists, almost one-third are noted as being absorbed via the skin. Temperature elevation may be expected to increase skin absorption both by increasing the rate of diffusions and by increasing vasodilation and thus increasing the rate of transport away from the skin.

Human skin shows great differences in absorption at different anatomic regions. If the skin of the forearm is used as a frame of reference, the palm of the hand shows approximately the same penetration as the forearm, whereas the back of the hand and the skin of the abdomen have twice the penetration potential.



### VII. (C). Ingestion

Accidental ingestion of hazardous substances presents less of a hazard to workers in comparison with those from the inhalation and skin contact routes. Some of the reasons for this are: (1) there are fewer chemicals that can be ingested as it is virtually impossible to ingest a vapor or gas; (2) the frequency and degree of contact are very limited; mouth contact with substances on hands, in food, in drink, and on cigarettes is far less frequent, of shorter duration and lesser in amount during the work shift than other routes of entry; and (3) most importantly, toxicity by mouth is generally

**Table 4**  
**Exemplar Equipment For Sample Collection in NIOSH Test Procedures**

Equipment	Contaminant	Results
Detector Tubes/Badges	Gases	Colorimetric change with concentration levels, exposure duration and sample volume
Adsorption Tubes	Gases	Material passes through an adsorption column Vapors at known flow rate; the material is desorbed and evaluated by laboratory analysis
Gas Collection Bags	Gases	Sealed and non-reactive bags are filled with gas for removal to instrumentation for evaluation
Direct Reading Devices	Gases	Gas passes through a cell or across a specific electrode for combined sample collection and analysis
Midget Impingers	Gases	Uses calibrated pump to draw gas through a solution where it is then collected for analysis
Dosimeter Badges	Gases	Material diffuses through badge material and is collected; subsequent analysis allows calculation for concentration. Exposure times are critical values; results are averaged over time
Filter Cassettes	Solid Airborne Aerosols	Material is drawn across filter media with calibrated pumps and filter is evaluated by optical or chemical analysis

of a lower order than that by inhalation, because of poor absorption, acidity of the stomach, and the alkaline conditions of the small intestine.

Even with these considerations in mind, it is important that workers be aware of the oral ingestion hazards associated with substances in the workplace. The ingestion route contributes secondarily to the intake of particulates or soluble gases by inhalation. That portion of the inhaled material lodges in the upper respiratory tract, then is swept up the tract by ciliary action and is subsequently swallowed (13).

In the machine tool industry, a variety of airborne contaminants are candidates for entry into the human body via inhalation, skin absorption, and ingestion. For example, oil mists can cause adverse health effects through the respiratory tract and skin contact; cemented carbides, cobalt and other metals may enter the body by inhalation and oral ingestion.

Regardless of the exposure mechanism or absorption route, proper methods must be followed to measure and monitor the exposure levels. These methods may require simple or sophisticated equipment depending on the material to be measured, the contaminant concentration and form,

and interfering materials. Section VIII discusses some of the considerations involved in methods of measuring airborne contaminants.

## VIII. METHODS OF MEASUREMENT

Quantification of exposure levels requires sample collection and analysis. The most elementary methods of detection are based on sight and smell. The smell of an airborne contaminant, however, may not be sufficient to determine the presence of a contaminant at unacceptable levels (although it may be sufficient to indicate the presence of an elevated amount of a contaminant). With oil mists, a heavy, visual haze may prompt, for example, the question of whether the permissible exposure limit has been exceeded. Oil mists often produce a visually perceptible haze near to the OSHA PEL 8-hour TLV of 5 mg/m<sup>3</sup>.

For a quantifiable measure of exposure, personnel sampling may sometimes be performed by simply pinning a dosimeter (See Table 4) onto a worker for a known exposure time. A more difficult and more accurate procedure requires the worker to wear a calibrated sampling pump and corresponding collection device.

Sample collection devices include adsorption tubes, filter cassettes and cyclone separators. It is important when using these devices that a proper combination of flow and sampling times are used to provide an adequate mass quantity sample for analysis. Too small a collected mass will produce below-detection-limit results and too large a flow rate and sampling time can cause oversaturated collection media and passthrough.

Variations in the monitoring equipment, procedures, volume sampled, and analytical methods must be considered to provide the necessary information about the area concentration, actual exposure levels for given time periods, and the collective effect of the exposure. Each site is unique in its contamination sources and therefore in its specific testing and information requirements.

In addition to the measurement of airborne contaminants, the worker may be monitored at specific times by the collection and analysis of biological specimens. The American Conference of Governmental Industrial Hygienists describes the specimens (often urine, blood or exhaled air) and the corresponding Biological Exposure Indices. (19) One example of this measurement is the testing of exhaled air of a worker at the end of a shift for exposure to trichloroethylene. Another is the analysis of blood for lead or cadmium exposure (5).

There are numerous references in the literature to analytical methods for the measurement of airborne contaminants. Perhaps the most comprehensive and accepted methods are those available from the National Institute for Occupational Safety and Health (NIOSH)(10). NIOSH provides a short discussion of the principle underlying the methods, their apparatus and procedures and their limitations, accuracy, advantages and disadvantages.

The quantified level of airborne contaminants in the workplace is obviously an important measurement when compliance with permissible occupational exposure levels is determined. Other unexpected airborne materials or processes must be considered, monitored and their influences understood. For example, heating and ventilation changes from season to season may change air dilution characteristics throughout the year; increased hours of production may alter exposure levels by causing multiple simultaneous sources to be in operation. Therefore, selection of the correct equipment, design of sampling

methodology and analysis of data can truly become a multifaceted process which lends meaning to quantified results. Specially trained individuals are often needed to measure and interpret the results of workplace sampling.

The work environments of the machine tool industry are not necessarily amenable to, nor are their problems automatically resolved by, simple ventilation control techniques and universally standardized sample collection methods. Each workplace is site specific in contaminant, dispersion mechanisms and testing requirements; this means it is essential to evaluate exposures to assist in controlling them. (Fig. 2)

## IX. METHODS TO EVALUATE AND CONTROL WORKPLACE EXPOSURES

Before methods to control exposure can be established, certain steps must be taken to identify and evaluate the hazardous materials in use, the exposure levels and forms, the duration of exposure and effects on the work force. Many of these issues have been introduced earlier in this paper.

Methods to identify and evaluate exposures can follow many formats. Using cobalt, which is contained in many machining tools, as an example, one finds from the Material Safety Data Sheet that its respirable dust can cause asthma, cardiac effects, eye irritation and allergic skin rash. It

is also apparent that the PEL and TLV for an eight-hour TWA is  $0.05\text{mg}/\text{m}^3$ . Neither of these two guidelines and accompanying documents, however, provide sufficient detail to implement a specific control method. The selection of the appropriate control technology requires additional analysis. This analysis often follows the hierarchy shown in Table 5.

### IX. (A). Material Selection, Removal or Substitution

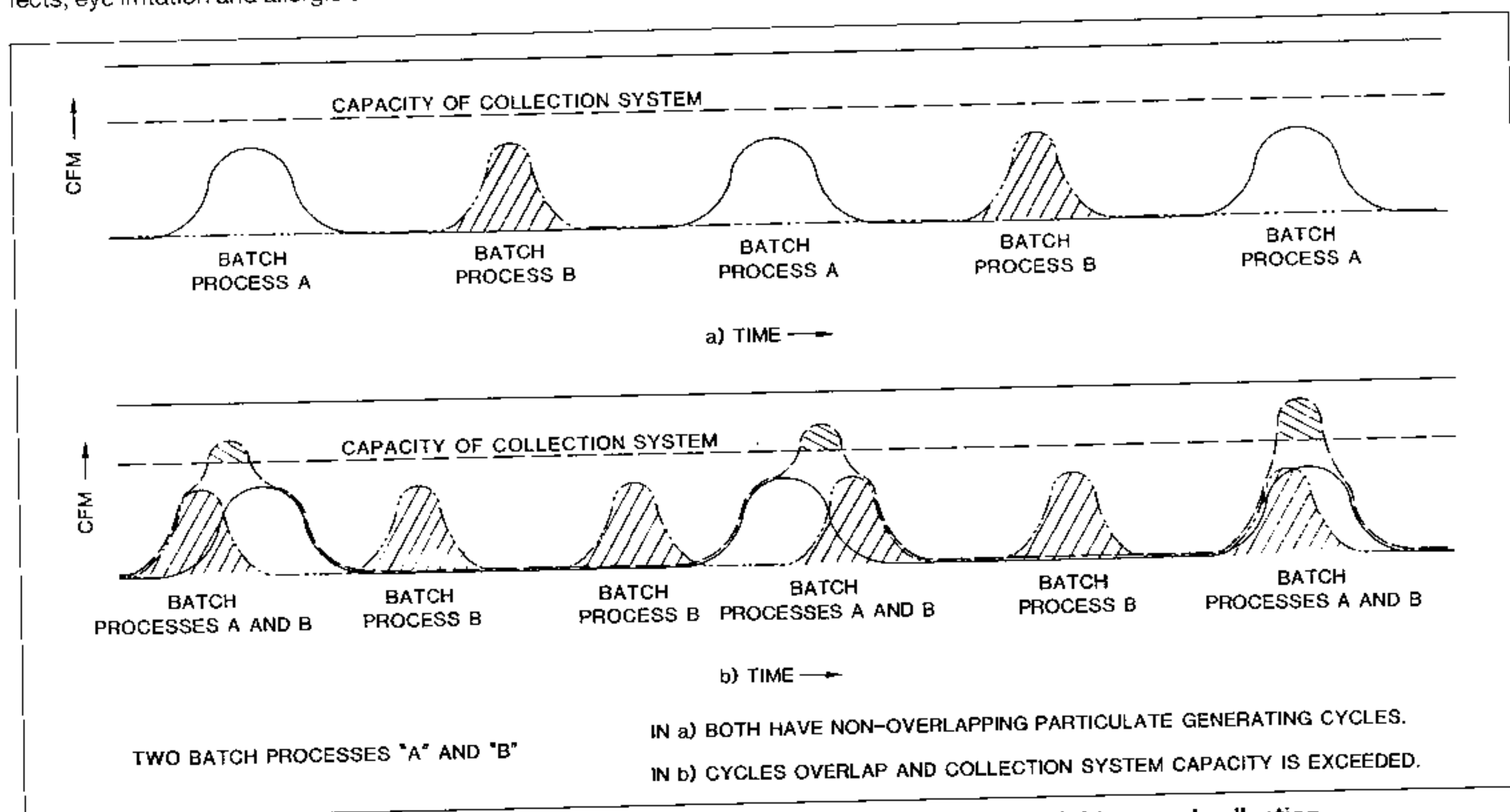
One of the rudimentary methods to reduce occupational exposure is to remove the offending material. The material of choice for many cutting tools, for example, is tungsten carbide. No other material has its unique combination of physical characteristics, rendering its replacement by another material almost an impossibility.

Substitution, the method of second choice for control, is thus not available and other exposure control means are necessary (see Table 5). Alternatively, the selection or use of an alternative cutting fluid may be quite possible. In the selection process, the chemical composition of the cutting fluid may be adjusted or substituted with less hazardous materials. Such a selection, however, may also require input and evaluation concerning the form and generation method by which the material becomes airborne.

**Table 5**  
**Exposure Control Techniques**

1. Eliminate the harmful material associated with the exposure.
2. Reduce the form contributing to the concentration by changing to a different physical form (i.e., from gas to liquid, from fumes to larger particulates, etc.).
3. Reduce the exposure by (a) reducing the exposure concentration by ventilation; or (b) reducing the exposure duration.
4. Separate workers from the exposure by (a) use of personal protective equipment; (b) worker rotation; (c) enclosure of equipment.
5. Provide worker-related activities such as (a) training on exposure effects; (b) training on personal hygiene/care; and (c) worker screening and surveillance.

Several categories of liquids and soluble materials are used in the machine tool industry. These include lubricants, greases, coolants, drawing compounds, waxes, degreasers, anti-oxidant and anti-fouling agents, and protective coatings. If, for example, the cutting fluid or coolant has been identified as the most important component of an airborne mist, several formulations may be available as a selection technique for exposure control.



**Figure 2** Changes in sequencing of operations which can produce emissions which might exceed collection capacity of hooding system

## IX. (B). Form and Formation of Contaminant

Other considerations including the form or formation of the contaminant should also be evaluated (see Table 6). If the exposure results in a dermatitis problem, it may be that a certain machining operation is causing liquids to splash onto the exposed worker. Alternative speed conditions, re-direction of the flow or the use of splash shields may be adequate remedies. If misting is the problem, source control may be achieved by lowering operating temperatures, equipment speeds or flow rates to reduce the formation of condensing gases, the formation of mist size droplets or the excess availability of the coolant, respectively.

In 1986, Foxall-Van Aken reported that the individual components of industrial metalworking fluids have a substantial influence on the amount and form of carbon available to support biological contamination of some metalworking fluids. Such conditions can increase the concentration of opportunistic bacteria in the fluids which then can cause skin infections. Under conditions of elevated biological contamination, the formation of biologically active constituents might be reduced by the addition of antibacterial agents (46).

In the case of vapor degreasing operations, the use of enclosures appropriate to the material process flow rates and ambient conditions may reduce the release of these vapors by providing a balance between vapor generation and surface area condensation. Again, control through process changes may influence the formation of the offending materials.

Generally, the above three examples relate to the specifics of the machine operation, local conditions, and to the equipment itself. That is: (1) the selection of an alternative lubricant or lubrication method may decrease exposure but may profoundly influence the performance of the equipment and the quality of the end products; (2) biological inoculation and contamination is heavily influenced by local conditions and additives may therefore be needed; (3) ambient air patterns may cause escape of solvent vapors from degreasing operations requiring additional barriers. Control and formation of these emissions are often beyond simple machine-based design configurations and often require more in-depth analysis.

**Table 6**  
**Definition of Forms of Airborne Contaminants**

### Particulates

Solid particles often produced by material handling, crushing and abrasion impacts, grinding, and chipping. To remain airborne particulates range in size from 0.1 to 25 microns (1 micron = 1/25,000 inch). Larger size particles will quickly settle under the influence of gravity. As a general rule, particulates do not flocculate except in electrostatic fields and they will not diffuse in air but rather tend to settle. Particulate matter between 0.5 and 5 microns are often classified as respirable.

### Fumes

Solid particles formed by condensation from the gaseous state. The originating gases are often volatilized from the molten state as would occur from a surface of molten metal. The condensed particle size is most likely very small in diameter and includes the 1 to 0.05 micron size. If the fumes originate from a metal, they often chemically react to form metal oxides.

### Smoke

Carbon or soot-like particle matter resulting from incomplete combustion usually in the micron range. Although mostly solid material, it may also contain some liquid or semi-liquid components.

### Fibers

Solid materials of organic and inorganic nature from both man-made and natural sources. They are characterized by a length to width ratio greater than 3:1. Part of their respiratory hazard is due to their geometry. Fibers may flocculate and attract other airborne materials. Fibers do not diffuse in air and tend to settle under the forces of gravity. Fibers are often found grouped together or imbedded in other materials and are then referred to as "fiber-like structures".

### Aerosols

Liquid droplets or solid materials generated by condensing vapors or from liquid streams that have been fractionated into droplets by physical means. Aerosols may grow or decrease in size due to continued condensation or evaporation. Aerosols may be a means for biological contaminants to become airborne and thrive.

### Mists

Large accumulation of airborne liquid droplets formed by condensing vapors or from liquid streams that are fractionated into droplets. Mists often occupy high moisture operations and processes where liquids are used to quench and cool, or are atomized. These processes include dip tank operations, high speed rotating equipment, and spray applications.

### Gases

The gas phase of any material is characterized by conforming to the shape of the container or space they fill. Gases generally follow the laws of diffusion and may be positively or negatively buoyant.

### Vapors

The gaseous state of materials that normally are liquid or solid at room temperatures. Materials become vapors by such processes as evaporation. Materials with high vapor pressures are more likely to become vapors. Vapors generally follow the laws of diffusion, but may also recondense and act as aerosols or mists.

## IX. (C). Control By Reduced Concentration and Exposure Duration

Ventilation is one of the most common methods of reducing the contaminant concentration level and the worker's exposure duration to airborne contaminants. Ventilation systems are broadly categorized into general dilution ventilation and dedicated capture and exhaust systems. These systems are covered broadly in the literature, including specific requirements in the American National Standard, "Fundamentals Governing the Design and Operation of Local Exhaust Systems," *ANSI Z9.2-1979* (21).

The application of ventilation or exhaust systems to machine tool processes is not an elementary task. A large number of air changes per hour (one form of control through general ventilation) is costly from an air conditioning, heating, and air han-

dling perspective; but generally provides a good uniform reduction in concentration levels if sufficient air mixing is achieved.

Dedicated exhaust systems remove smaller quantities of air from the specific area of generation of the airborne contaminant. As such, they are more energy efficient, but rely on "capturing" the higher-concentration contaminants. The effectiveness of these devices can be influenced by local air movement conditions, rates of release of the contaminant and competing air handling equipment. It becomes obvious that collecting and exhausting a buoyant gas may be easier for a dedicated vertical canopy exhaust than to collect and exhaust a heavier dust or fume particulate.

In addition, machining fluid aerosols in a metalworking environment have been reported as polydispersed and are generally bimodally distributed by size (42). Since

capture and collection efficiencies vary with droplet size, specific knowledge about the aerosol size is necessary if exhaust collection methods are to be used. Hence, air measurements may be necessary to define particle or droplet size distribution before a high capture efficiency can be achieved.

Due to the diversity of machine tool use, it is difficult to provide an all-encompassing dedicated exhaust system on most machines. Recent design advances have seen the incorporation of some ducting or enclosures to assist in the collection and exhaust on some machine types; however, total systems to collect and exhaust water and oil-based mists, fumes and particulates may not all be interchangeable. Similarly, high versus low liquid coolant or lubrication use rates may cause the excessive generation of emissions beyond the capacity of the exhaust systems. The positioning of a dedicated exhaust and the resulting capture velocity distribution may not collect materials under high speed equipment operations, whereas its performance may be adequate under lower speed operation. In addition, the effects of multiple exhaust locations must be considered as they compete to move common sources of ambient air.

Where multiple exhausts are necessary, generally, the physical layout of the production area will be designed with a single exhaust air handler servicing multiple collection points. Such configurations may be repeated for each production line or plant area. Availability and balancing of these multiple exhausts influence their application to various installations. This approach necessitates coordination between the facility engineers and equipment providers. Similarly, exposures are not constant in time throughout the workday or from season to season. Background concentrations throughout a workplace may start out near zero after a weekend shutdown and may increase toward the end of a shift or after prolonged work periods. An understanding of these issues again requires information particular to a specific workplace.

#### **IX. (D). Separation of Workers From Exposure Sources**

The means of separating workers from exposures traverse the spectrum and include isolated containment rooms, physical barriers, splash shields, worker rotation and the use of personal protective equipment (i.e., gloves, respirators, barrier creams, etc.).

Rarely in the past has it been the practice in the machine tool industry to isolate workers from the process, except in the processing of highly toxic materials. Many operations require human involvement at or near the point of operation. Increasingly, the application of remote equipment, robotics and computer-operated equipment have placed equipment operators at safer distances from the points of operation. This approach has been used mostly on new or high-production operations. The retrofit application of these techniques becomes increasingly difficult due to the geometry of equipment and placement of adjacent components.

The use of various barriers to assist in minimizing cross drafts and in enhancing dedicated capture and exhaust systems is a more common approach by equipment users. The spacing, location and utility of such barriers requires the talents and evaluation by those familiar with air handling and environmental control.

On the other end of the spectrum of methods to isolate workers from exposure is the application of: (1) dedicated air supply systems which engulf the worker with clean air; (2) the use of respirators to separate airborne contaminants from breathing air; and (3) the use of barrier creams (or gloves) on exposed hands and skin to prevent contaminant contact. Several manufacturers provide both water and oil-compatible barrier creams as alternatives to the use of gloves, for some operations. These options rely on various forms of personal protective equipment which are considered inferior to engineering control measures and are sometimes used in conjunction with other control measures to provide a redundancy in mitigation control.

#### **IX. (E). Worker-Related Activities**

Simply informing potentially exposed workers about symptoms and health effects of contaminant exposures is a means of reducing them and their adverse effects. Of course, this method relies on the human elements of skill and vigilance, but it plays an important role in exposure control. Similarly, training on the function, use and care of personal protective equipment and on personal hygiene methods is also an important means of reducing exposure.

Finally, the use of pre-employment or work-related screening techniques and medical surveillance can be used in many cases to identify those predisposed to adverse responses or those at risk from previous exposures. The ACGIH lists several measures of biological exposure determinants.

#### **SUMMARY**

The machine tool industry presents a number of opportunities for adverse occupational exposure conditions. The availability of materials used and processed in the industry and our increasing knowledge has resulted in newer and more stringent environmental requirements. Compliance with these criteria often is not an easy task.

It is important that the equipment manufacturer, chemical supplier, and owners of industrial facilities composing the machine tool industry remain aware of our new understanding of these problems and solutions that are available to them.

## SELECTED REFERENCES

### FEDERAL REGULATIONS

1. "Air Contaminants," 29 *CFR* 1910.93. Washington, Occupational Safety and Health Administration, effective February 15, 1972 (as published in 36 FR #105 [May 29, 1971]: 10503-6).
2. "Air Contaminants," 29 *CFR* 1910.1000. Washington, OSHA, effective dates vary from March 1, 1989 to August 31, 1989; effective dates of transitional provisions vary from December 30, 1992 to December 30, 1993, (as published in 29 CFR Part 1910.1000 to End, Revised as of July 1, 1990, pp. 6-32).
3. "Hazard Communication," 29 *CFR* 1910.1200. Washington, OSHA, originally effective November 25, 1985 (as amended and published in 29 CFR Part 1910.1000 to End, Revised as of July 1, 1990, pp. 357-373).
4. "Part 747 - Metalworking Fluids," 40 *CFR* 747. Washington, Environmental Protection Agency, effective September 20, 1984 (as published in 49 CFR Part 700 to End, Revised as of July 1, 1988, pp. 170-76).
5. "Occupational Exposure to Cadmium: Proposed Rule and Notice of Hearing," 29 *CFR* 1910.1000. Washington, OSHA, deadline for notification June 10, 1990 (55 FR #23 [Feb. 6, 1990]: 4052-4147).

### National Institute For Occupational Safety and Health

6. "Health Hazard Evaluation/Toxicity Determination. Modern Metals Products, Loves Park, Illinois," PB-229-127. Rockville, MD, NIOSH, July 1973.
7. "Health Hazard Evaluation/Toxicity Determination Report Number 76-23-319 Western Gear Corporation, Jamestown, ND," PB-264-803. Cincinnati, NIOSH, August 1976.
8. "Health Hazard Evaluation/Toxicity Determination Report 75-124-382, Franklin Electric Co., Bluffton, Indiana," PB-273-924. Cincinnati, NIOSH, April 1977.
9. "Nitrosoamines in Cutting Fluids," *Current Intelligence Bulletin* 15. Cincinnati, NIOSH, Oct. 6, 1976.
10. *NIOSH Manual of Analytical Methods*, 2nd edition. Cincinnati, NIOSH, April 1988.
11. O'Brien, Dennis and John C. Frede, "Guidelines for the Control of Exposure to Metalworking Fluids," *DHEW (NIOSH) Publication No. 78-165*. Cincinnati, NIOSH, February 1978.
12. "Pocket Guide to Chemical Hazards," (*NIOSH 85-114*). Cincinnati, NIOSH, September 1985.
13. Stokinger, Herbert E., "Routes of Entry and Modes of Action," in *Occupational Diseases, A Guide to Their Recognition (NIOSH 85-114)* 77-181, rev. ed. Washington, NIOSH, June 1977, pp. 11-42.
14. "Survey for N-Nitroso Compounds at Chevrolet Warren Manufacturing Plant, Warren, Michigan," PB 83-110544. Cincinnati, NIOSH, 20 June 1978.
15. "Survey for N-Nitroso Compounds at Ford Tool and Die Plant, Dearborn, Michigan," PB 83-110312. Cincinnati, NIOSH, 20 June 1978.

### Environmental Protection Agency

16. "Guides to Pollution Prevention: The Fabricated Metal Products Industry," EPA/625/7-90/006. Washington, EPA Office of Research and Development, July 1990.
17. "Meeting Hazardous Waste Requirements for Metal Finishers," EPA/625/4-87/018 Seminar Publication. Washington, EPA Office of Research and Development, September 1987.

### INDUSTRY STANDARDS AND CODES

#### American Conference of Governmental Industrial Hygienists

18. *Guidelines for the Assessment of Bioaerosols in the Indoor Environment*. Cincinnati, ACGIH, 1989.
19. *Threshold Limit Values and Biological Exposure Indices for 1986-1987*. Cincinnati, ACGIH, 1986.
20. *Threshold Limit Values and Biological Exposure Indices for 1989-1990*. Cincinnati, ACGIH, 1989.

## **American National Standards Institute**

21. "American National Standard Fundamentals Governing the Design and Operation of Local Exhaust Systems," *ANSI Z9.2-1979*. New York, approved March 29, 1979.
22. "American National Standard Practices for Respiratory Protection," *ANSI Z88.2-1980*. New York, approved May 22, 1980.
23. "American National Standard Safety Requirements for Confined Spaces," *ANSI Z117.1-1989*. New York, approved Oct. 5, 1989.
24. "American National Standard for Exhaust Systems - Spray Finishing Operations - Safety Code for Design, Construction, and Ventilation," *ANSI/ASC Z9.3-1985*. New York, approved Feb. 20, 1985.
25. "American National Standard Safety Requirements for the Construction, Care, and Use of Grinding Machines," *ANSI B11.9-1975*. New York, approved March 25, 1975.
26. "American National Standard for Hazardous Industrial Chemicals - Precautionary Labeling," *ANSI Z129.1-1988*. New York, ANSI, approved March 3, 1988.

## **National Fire Protection Association**

27. "Fire Hazard Properties of Flammable Liquids, Gases and Volatile Solids," *NFPA 325M-1984*. Quincy, MA, NFPA, effective July 5, 1984.
28. "Standard for the Storage, Handling and Processing of Magnesium," *NFPA 480*. Quincy, MA, NFPA, effective Dec. 30, 1986.
29. "Standard for the Production, Processing, Handling and Storage of Titanium," *NFPA 481*. Quincy, MA, NFPA, effective Dec. 30, 1986.
30. "Standard for the Production, Processing, Handling and Storage of Zirconium," *NFPA 482*. Quincy, MA, NFPA, effective Dec. 30, 1986.
31. "Standard for the Manufacture of Aluminum and Magnesium Powder," *NFPA 651*. Quincy, MA, NFPA, effective Dec. 30, 1986.

## **American Society For Testing and Materials**

32. "Standard Practices for Sampling Atmospheres for Analysis of Gases and Vapors," *ASTM D 1605-60 (Reapproved 1990)*. Philadelphia, ASTM, this edition approved Sept. 19, 1960.
33. "Standard Test Method for Active Sulfur in Cutting," *ASTM D1662-86*. Philadelphia, ASTM, this edition approved Oct. 31, 1986.
34. "Standard Test Method for Misting Properties of Lubricating Fluids," *ASTM D3705-86*. Philadelphia, ASTM, this edition approved Oct. 31, 1986.
35. "Standard Test Method for Evaluating the Bioresistance of Water-Soluble Metal-Working Fluids," *ASTM D3946-80 (Reapproved 1986)*. Philadelphia, ASTM, this edition approved Aug. 29, 1980.

## **Technical Articles**

36. Atherley, Gordon, "A Critical Review of Time-Weighted Average as an Index of Exposure and Dose, and of Its Key Elements," *American Industrial Hygiene Association Journal* v. 46 #9 (Sept. 1985): 481-87.
37. Barten, Axel E., "A New System for Separation and Recycling of Mineral Oils from Process Fumes," *Lubrication Engineering* v. 38 #122 (December 1982): 754-7.
38. Bech, A.O., "Hard Metal Disease and Tool Room Grinding," *Journal of the Society of Occupational Medicine* v. 24 #1 (January 1974): 11-6.
39. Bennett, E.O. and D.L. Bennett, "Minimizing Human Exposure to Chemicals in Metalworking Fluids," *Lubricating Engineering* v. 43 #3 (March 1987): 167-75.
40. Brautbar, Nachman, "Heavy Metal Toxicity at the Workplace; Symptomology and Perspective for the Trial Attorney," *Experts-at-Law* (September-October 1990): 43-5.
41. *Casarett and Doull's Toxicology: The Basic Science of Poisons*, 2nd ed. New York, Macmillan Publishing Co., 1980.
42. Chan, T.L. et al., "Size Characteristics of Metalworking Fluid Aerosols in an Industrial Metalworking Environment," *Applied Occupational Environmental Hygiene* v. 5 #3 (March 1990): 162-70.
43. Cheremisinoff, Paul N. and Richard A. Young, eds. *Pollution Engineering Practice Handbook*. Ann Arbor, Ann Arbor Science, 1981.
44. "Cutting Oils, Emulsions, and Drawing Compounds," *NSC Data Sheet 1-719-86*. Chicago, National Safety Council, 1986.
45. DeBodes, Leo J., "Health Risks in the Machine Shop," *National Safety News* v. 132 #2 (August 1985): 60-3.

46. Foxall-Van Aken, S. et al., "Common Components of Industrial Metal-Working Fluids as Sources of Carbon for Bacterial Growth," *Applied and Environmental Microbiology* v. 51 #6 (June 1986): 1165-69.
47. Glass, D.C., "Conference on the Health Hazards of Cutting Oils and Their Controls," *Institute of Occupational Health Proceedings 1989 No. 1*. Birmingham, UK, University of Birmingham, 1989.
48. Hallenbeck, W.H. and K. M. Cunningham, *Quantitative Risk Assessment for Environmental and Occupational Health*. Chelsae, MI, Lewis Publishers Inc., 1986.
49. Hedberg, Donald D. and Joyce A. Kilby, "Revised ANSI Labeling Standard includes More OSHA Requirements," *Occupational Health & Safety* v. 56 #10 (September 1987): 44-7, 111.
50. Herwaldt, Loreen A. et al., "A New Legionella species, Legionella Feeleii Species Nova, Causes Pontiac Fever in Automobile Plant," *Annals of Internal Medicine* v. 100 #3 (March 1984): 333-38.
51. Hombach, Wilhelm, "Skin Protection in the Factory: A Working Program," *National Safety News* v. 129 #2 (February 1984): 26-9.
52. "In-Die Lubrication," *Metal Forming* v. 24 #9 (September 1990): 51-5.
53. "Industrial Union Department. AFL-CIO v. American Petroleum Institute et al., 448 S. Ct. 607 (1979).
54. *Industrial Hygiene Technical Manual (OSHA 3058)*. Washington, Occupational Safety and Health Administration, 1980.
55. Keith, Lawrence H., ed. *Compilation of EPA's Sampling and Analysis Methods*. Boca Raton, FL, CRC Press, Inc., 1991.
56. Kennedy, A., J.D. Dornan and R. King, "Fatal Myocardial Disease Associated with Industrial Exposure to Cobalt," *Lancet* #8217 (February 1981): 412-4.
57. Kipling, M.D., "Health Hazard from Cutting Fluids," *Tribology International* v. 10 #1 (February 1977): 41-6.
58. Lockwood, F.E., J.P. Faunce and W. Boswell, "Application of Low-Polluting Lubricants to Aluminum Forging on Hydraulic Presses," *Lubrication Engineering* v. 39 #12 (December 1983): 753-60.
59. Ng, R.K., R.J. Schlager and T.A. Lowe, "New Sampling Methodology for Rolling Mill Mists and Vapors," *Lubrication Engineering* v. 38 #4 (April 1982): 304-7.
60. Oates, P.D., "Metalworking Fluid Formulations and Their Significance," in *Monitoring and Maintenance of Aqueous Metal-Working Fluids; Proceedings of an International Meeting by the Institute of Petroleum* (April 1983): 1-9.
61. *Occupational Diseases*. Richmond, BC, Workers' Compensation Board of British Columbia, October 1987.
62. Park, Robert M., Michael A. Silverstein and Franklin E. Mirer, "Characteristics of Worker Populations: Exposure Considerations in the Selection of Study Populations and Their Analysis," *Applied Occupational and Environmental Hygiene* v. 6 #6 (June 1991): 436-40.
63. Pilletteri, Carl, "The Control of Mineral Cutting-Oil Systems," *Lubrication Engineering* v. 38 #10 (October 1982): 622-5.
64. Pinkelton, Brenda, "The OSHA Hazard Communication Standard: How it Affects Metalworking Fluid and Grinding Wheel Users and Manufacturers," *Lubrication Engineering* v. 43 #4 (April 1987): 236-42.
65. Rossmore, H.W., "Antimicrobial Agents for Water-Based Metalworking Fluids," *Journal of Occupational Medicine* v. 23 #4 (April 1981): 247-54.
66. Salvador, Christopher P., "Cleaning, Pretreating, and Machining in the 80's," *Metal Progress* v. 117 #7 (June 1980): 40-2.
67. Shennan, J.L., "Selection and Evaluation of Biocides for Aqueous Metal-Working Fluids," *Tribology International* v. 16 #6 (December 1983): 317-30.
68. Silverstein, Michael et al., "Mortality among Bearing Plant Workers Exposed to Metalworking Fluids and Abrasives," *Journal of Occupational Medicine* v. 30 #9 (September 1988): 706-14.
69. Towne, C.A., "Practical Experience with Oil Mist Lubrication," *Lubrication Engineering* v. 39 #8 (August 1983): 496-502.
70. Warne, Thomas M. and Clive A. Halder, "Toxicity of Lubricating Oils," *Lubrication Engineering* v. 42 #3 (February 1986): 97-103.
71. Winship, John T., "Forming Lubrication and the Environment," *Metal Forming* v. 24 #6 (June 1990): 23, 25-8, 30, 32.
72. Zenz, Carl, *Occupational Medicine: Principles and Practical Applications*. Chicago, Year Book Medical Publishers, 1975.

## What is a Defect?

*The definition of a defective product in a state may be found in the case law of that state. In each issue we explore leading product liability case law for one or more states. Triodyne Inc. relies on the trial bar for selection of the cases cited.*

### MISSISSIPPI LAW

Mississippi has adopted the doctrine of strict liability as contained in *Restatement of Torts, 2nd Edition*, Section 402-A (1985), which states:

- (1) One who sells any product in a defective condition unreasonably dangerous to the user or consumer or to his property is subject to liability for physical harm thereby caused to the ultimate user or consumer or his property. *State Stove Mfg. Co. v. Hodges*, 189 So.2d 113 (Miss. 1966).

The Mississippi Supreme Court went on to define defective condition as follows:

Ordinarily the phrase "defective condition" means that the article has something wrong with it, that it did not function as expected. However, where the article was made as intended and yet proves to be not reasonably safe, the phrase "defective condition" has no independent meaning. The issue is whether the product is "unreasonably dangerous" or not reasonably safe. *State Stove v. Hodges*, 189 So.2d at 121.

Nearly twenty years after *State Stove*, the Mississippi Supreme Court made a substantial change in Mississippi products liability law when it overruled *Walton v. Chrysler Motor Corporation*, 229 S.2d 568 (Miss. 1969), and eliminated the previous bar to liability in "second impact" type cases. In *Toliver v. General Motors Corp.*, 482 So.2d 213 (Miss. 1985), the Mississippi Supreme Court reversed and remanded the trial court's dismissal of Edward Toliver's claim for injuries suffered when his 1973 Vega was struck from the rear by another vehicle; and upon impact Toliver's gas tank erupted, leaking gasoline into the passenger compartment. The gasoline ignited, causing extensive and severe burn injuries to Toliver. In addition to eliminating the "second impact" defense, the Court exten-

sively discussed the scope of strict liability in Mississippi.

An essential component of a successful products liability claim is proof that the injury resulted from a defect in the product which rendered it unreasonably dangerous and defective as stated in *State Stove*, 189 So.2d at 129:

Ordinarily the phrase "defective condition" means that the article has something wrong with it and that it did not function as expected.

The Court in *Toliver* cited comment (i) to Section 402-A which states:

The rule stated in this section applies only where the defective condition of the product makes it unreasonably dangerous to the user or consumer.

The Mississippi Court held that:

Thus the terms "defective condition" and "unreasonably dangerous" must be used in conjunction with each other. There must be a defect causing the product to malfunction and that defect must create the unreasonably dangerous condition. *Toliver v. General Motors*, 482 So.2d at 216.

Even though the manufacturer may have constructed the product as intended and even though the product may function as designed by the manufacturer, the issue is whether the product is "unreasonably dangerous" or not reasonably safe.

In *Toliver*, the Court reaffirmed its adherence to the doctrine of strict liability. It noted that problems may arise as a result of an application of strict liability. The Court has noted that the terms "defective condition" and "unreasonably dangerous" cannot be separated from each other. "The plaintiff must show that the product was defective and that its defective condition made the product unreasonably dangerous to him." *Toliver*, 482 So.2d at 218. The Court went on to comment (g) to Section 402-A in the *Restatement of Torts* and state that a defective condition is defined as "A condition not contemplated by the ultimate consumer, which will be unreasonably dangerous to him." As applied to the factual situation in *Toliver* where the plaintiff

was injured by a gas tank which allowed gasoline to spray into the passenger compartment and ignite. The plaintiff to make out a prima facie case must "show that the placement of the tank on the car that injured him was defective: that it fell below the standard of automotive design contemplated by the user, and thus became unreasonably dangerous to him."

The Mississippi Court recently addressed the question of "defective condition" in *Hall v. Mississippi Chemical Express, Inc.*, 528 So.2d 796 (Miss. 1988). The Court cited with approval both *State Stove*, supra, and *Toliver v. General Motors*, supra, in a case filed against Mack Trucks based upon a claim made by James Hall, an oil refinery worker, who suffered severe injuries in a fire at an oil refinery. Plaintiff claimed that the fire was ignited by a Mack diesel truck that was idling shortly before the fire started. Plaintiff claimed that the truck was defective because it was not equipped with an emergency device which would automatically shut down the engine before igniting hydrocarbons. The Supreme Court affirmed the trial judge's dismissal of the Plaintiff's case against Mack, noting that plaintiff "has utterly failed to prove that the Mack truck was defective in the sense that it was not reasonably fit for its intended uses." *Hall*, 528 So.2d at 799. It is an essential element of plaintiff's strict liability claim to show that the product was "defective and thus not reasonably safe." Performance with industry standards is a relevant consideration in determining whether or not a product is reasonably fit or unreasonably dangerous; however, industry standards are never conclusive on their point. However, Mississippi law does not require a manufacturer to incorporate every innovation which hindsight would suggest might render the product more safe. The standard is products that are reasonably fit, not perfectly fit.

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# SAFETY BRIEF

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